Risks in Rushing COVID-19 Vaccines | Sparrows Sing a New Tune

ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ AUGUST 1, 2020

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COVER These mussels got a lot of help to grow large enough to move from a laboratory to a Virginia riverbed. *Gary Peeples/USFWS*

FROM TOP: PHOTOTREAT/GETTY IMAGES PLUS; NICOLLE R. FULLER/SCIENCE SOURCE; SCOTT M. RAMSAY

What it takes to save species, locally and globally

The banks of the Potomac River upstream from Washington, D.C., are often mounded with drifts of tiny shells bleached white by the sun. That invertebrate abundance startles me every time I walk the riverbank, a clue to an invisible city of bivalves under the water.

In this issue, freelance writer Stephen Ornes takes us to Appalachia, where he chronicles scientists' dogged work to restore an endangered species of mussel, the golden riffleshell (Page 22). Freshwater mussels used to be incredibly common in the United States, but dams and pollution have taken a toll. It's a clear loss, because the humble creatures play an outsize role in riparian ecosystems, and in public health: More than two-thirds of U.S. homes get their drinking water from rivers, and mussels excel at cleaning water.

Ornes, who lives in Nashville, was looking forward to wading streams with the researchers doing the work, but the pandemic scotched those plans. Instead, multiple phone interviews helped him re-create the painstaking work of finding the rare mussels. "Tell me what it's like being in the river," he asked. "What does it feel like when you've been in the river for three hours and haven't found one?" A video tour of Kentucky's Center for Mollusk Conservation in Frankfort, led by director Monte McGregor, also helped. "Between his descriptions and the real-time tour, I felt like I could get a sense of what these people are doing every day," Ornes says.

This summer Ornes, like many parents, found himself with children at loose ends. The family ended up spending a lot of time kayaking the Tennessee River, blending work and play in a particularly satisfying way. "We've learned so much about the biodiversity," Ornes says. "It's like the Amazon of America right now in our backyard."

In this issue, we also examine the global challenges of protecting that biodiversity (Page 18). Staff writer Jonathan Lambert digs into goals being drafted by the U.N. Convention on Biological Diversity to protect 30 percent of the planet's land and sea by 2030 — and 50 percent by 2050. But even those ambitious targets may not be enough to slow extinction rates, with up to a million species at risk of disappearing in the next few decades.

"A lot of what's been written about these targets gets less into the science behind them," Lambert told me. "I thought it was useful to touch, in more detail, on how these numbers are arrived at, and the limitations of them, too." Those limitations include the difficulty of agreeing on what protection actually means, given that countries vary greatly in their needs, resources and priorities for preserving biodiversity. And once again, the pandemic intrudes. A conference to hammer out the details was supposed to convene in China this October; it's been delayed until 2021.

Longtime readers of *Science News* know that in-depth coverage of big issues in science is central to our mission. I recently asked those subscribers why they subscribe; their answers were wonderful. We'd love to hear from newer readers, too. What do you value in the magazine? Write to me at editors@sciencenews.org and share your story. — *Nancy Shute, Editor in Chief*

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Excerpt from the August 1, 1970 issue of *Science News*

50 YEARS AGO

Mauna Kea opened

The new Mauna Kea Observatory of the University of Hawaii has been completed and dedication ceremonies have been held. Standing at an altitude of 13,780 feet on the island of Hawaii, the new observatory is the highest in the world. Its major instrument is an 88-inch reflecting telescope that cost $3 million to build.

UPDATE: More than a dozen large telescopes now dot Mauna Kea, operated by a variety of organizations. Those telescopes have revolutionized astronomy, helping to reveal the accelerating expansion of the universe and evidence for the black hole at the center of the Milky Way. But the telescopes have long sparked controversy, as the dormant volcano is sacred to Native Hawaiians. Since 2014, protests have flared in response to the attempted construction of the Thirty Meter Telescope. Opponents have kept progress stalled by blocking the only access road to the site. Some scientists have spoken out against the telescope's location. The Thirty Meter Telescope collaboration is considering the Canary Islands as a backup site.

A pollen-rich bubble rests on a peach-leaved bellflower. Drones that blow such bubbles could help pollinate crops as bee populations dwindle.

TEASER

Bubble-blowing drones floated as future pollinators

Drones that blow pollen-laden bubbles onto blossoms could someday help farmers pollinate their crops.

Materials chemist Eijiro Miyako of the Japan Advanced Institute of Science and Technology in Nomi imagines outsourcing pollination from bees and other pollinating insects — whose numbers are dropping worldwide — to drones (*SN: 3/18/17, p. 4*). While blowing bubbles with his son, Miyako realized that bubbles might be a gentle delivery method.

Miyako and JAIST colleague Xi Yang devised a pollen-containing solution that a drone toting a bubble gun could blow onto crops. The researchers used the solution to pollinate by hand three pear trees in an orchard. On average, 95 percent of the 50 pollinated blossoms on each tree formed fruits. That was comparable to trees pollinated by hand with a standard pollen brush, the team reports in the June 26 *iScience*. On trees that relied on insects to deliver pollen, an average of about 58 percent of flowers bore fruit.

Miyako and Yang then armed a drone with a bubble gun that blew bubbles at fake lilies. More than 90 percent of the lilies were hit, but many bubbles missed the blooms. Future flying robots will have to deftly target specific blossoms, the team says. — *Maria Temming*

THE SCIENCE LIFE

Scientists inspire kids with STEM comics

Jaye Gardiner loves comic books, and she loves science. Sensing an opportunity, she decided to combine the two.

In 2015, Gardiner and two friends, Khoa Tran and Kelly Montgomery, founded an online publishing platform called JKX Comics. The three were pursuing Ph.D.s at the University of Wisconsin–Madison at the time. Knowing how tough it can be to explain research or engage students in the nuances of science, the group decided to use the easy-to-digest cartoon format and light humor to boost scientific literacy.

The three published their first comic book, *EBV and the Replication Dance*, in 2016. It describes how the common Epstein-Barr virus replicates by telling a story about the virus clubbing with friends inside a human cell.

It's not always easy to translate complex science into a comic. The creators have to balance accuracy and an engaging story. "It's never going to be perfect," says Tran, now an epigeneticist at the University of Pennsylvania. "But we really want to instill that curiosity in people to then learn more and further investigate the topic."

The trio is not alone in seeing a

JKX Comics illustrated astrophysicist Aomawa Shields (left), who studies climates of exoplanets (one at far left).

FROM TOP: E. MIYAKO; K. TRAN

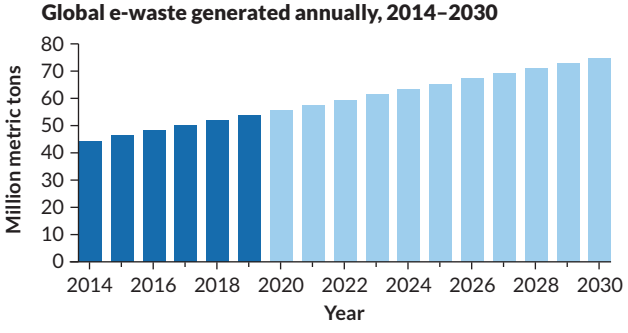
SCIENCE STATS

Earth's e-waste stash is bulking up

The planet's hefty pile of discarded electronics is getting a lot heavier, a new report finds.

In 2014, the world tossed about 44.4 million metric tons of "e-waste," devices such as laptops, smartphones and televisions. By 2030, that number is projected to grow to about 74.7 million tons, according to the Global E-waste Monitor 2020. (Dark blue in the graph below shows actual data; light blue shows projected data.)

High consumption rates and short device life cycles contribute to the pileup. And most people are not recycling their devices, the report states. Just 17.4 percent of the 53.6 million tons of e-waste generated in 2019 was recycled. Not recycling e-waste can contribute to global warming, the report notes, because new materials are mined and processed. Discarded electronics also can leach hazardous materials into the environment. — *Carolyn Gramling*



SOURCE: GLOBAL E-WASTE MONITOR 2020

Satellites can keep tabs on lightning that crackles around the globe, like this bolt over Finland.

THE –EST

A pair of lightning flashes zap the competition for lengthiest bolts

Two extreme bolts of lightning have smashed previous records for lightning duration and distance.

A bolt that lit up the sky over Argentina on March 4, 2019, lasted 16.73 seconds, more than twice as long as the previous record holder, the World Meteorological Organization announced June 25. And a bolt on October 31, 2018, set the new record for distance. It stretched for 709 kilometers from the Atlantic Ocean, across Brazil and into Argentina, a length more than twice that of the previous record.

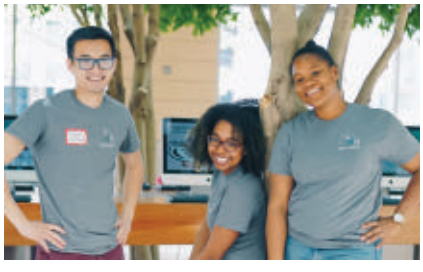
Until now, the records were held by a 2007 flash in Oklahoma that stretched 321 kilometers horizontally and a 2012 flash in France that lasted almost eight seconds (*SN: 10/29/16, p. 5*). Those bolts were assessed by ground-based sensors. The recent "megaflashes," by contrast, were verified using satellite images. Satellite data can detect extremes outside the limits of ground-based arrays, according to the WMO. — *Carolyn Gramling*

place for science in the comic universe. Many studies have suggested that comics can engage a wide and diverse audience with science, according to a 2018 review in the *Journal of Science Communication*. And comics can make information more accessible.

In 2018, JKX Comics partnered with seven scientists at UW–Madison, adding expertise in fields such as psychology, astronomy and microbiology. Local artists were drafted to help illustrate these scientists' research.

For the volunteer crew, the comics also have given scientists a friendlier face. They are "not all geniuses with Einstein-like hair," says Gardiner, now a cancer biologist at the Fox Chase Cancer Center in Philadelphia. "Using comics is a nice way to tell their story."

The latest comic, *Gilbert's Switch*



From left, Khoa Tran, Jaye Gardiner and Kelly Montgomery founded JKX Comics while studying at the University of Wisconsin–Madison.

Glitch, released in February, features a biochemist who gets sucked into a video game where he has to test amino acid combinations to get proteins to communicate. The panels are drawn in the style of the classic video game *Super Mario Bros.*, and the story line explains fundamental concepts in biochemistry, says its author, Montgomery, now a chemical biologist at the University of California, San Francisco. By understanding how proteins communicate, "you can modify a protein to be able to communicate to its neighbor better," she says. "This can help us with [stopping] diseases," such as Alzheimer's.

Though the comics are geared toward middle school students, the team hopes people of all ages can enjoy them. Ten comics are offered online for free, and the team is working on two new series. One is about women in science, technology, engineering and math, or STEM, fields. Another is about investigating diseased organs. JKX Comics also is planning to raise funds through Kickstarter to print comics for the Madison Reading Project, which will distribute them to underserved children. — *Kyle Plantz*

FROM TOP: NILLO ISOTALO/UNSPLASH; E. OTWELL; JKX COMICS

Read STEM comics at **jkxcomics.com**

BODY & BRAIN

A COVID-19 vaccine may come soon

But in the rush to find a shot, any misstep could erode public trust

Engineers at Sinovac Biotech in Beijing work on an experimental vaccine against the coronavirus that causes COVID-19.

NICOLAS ASFOURI/AFP/GETTY IMAGES

BY TINA HESMAN SAEY

In January, researchers lined up on the starting blocks, waiting to hear a pistol. The shot came on January 10, when scientists in China announced the genetic makeup of SARS-CoV-2, the coronavirus that causes COVID-19. With that information, the race toward a vaccine began.

Over six months later, with about 120 vaccine candidates now being tested in lab dishes, animals and even humans, the finish line may be in sight. Some experts predict that a vaccine may be available for emergency use for the general public by the end of the year, even before it receives expedited U.S. Food and Drug Administration approval.

But speed may come at the expense of safety and efficacy, some experts worry. And that could stymie efforts to convince enough people to get the vaccine to build the herd immunity needed to end the pandemic.

"We're calling for transparency of data," says Esther Krofah, executive director of FasterCures, a Washington, D.C.–based nonprofit. "We want things to accelerate meaningfully in a way that does not compromise safety or the science, but we need to see the data."

Having the genetic makeup of the coronavirus allowed scientists to make copies of a crucial piece of the virus that is now the basis of the experimental vaccines. That piece, the spike protein that studs the virus' surface, allows the virus to latch onto and enter human cells. Being on the virus's exterior makes the protein an easy target for antibodies.

Researchers have copied the virus's instructions for making that protein into RNA or DNA, or synthesized the protein itself, to create various vaccines (*SN: 3/14/20, p. 6*). Once a vaccine is delivered into the body, the immune system makes antibodies that recognize the virus and block it from getting into cells, preventing either infection or serious illness.

Drugmakers have set speed records in devising these vaccines and beginning clinical trials. As of July 14, FasterCures, part of the Milken Institute think tank, was tracking 121 vaccine candidates. A dozen are already being tested in people.

Going to trial

Some front-runners have emerged, including some propelled by Operation Warp Speed, a U.S. government effort that has picked a handful of vaccine candidates to fast-track.

One of those vaccines was developed by Moderna, a Cambridge, Mass.–based biotech company. Moderna inoculated the first volunteer with its vaccine candidate on March 16, a little more than two months after the virus's genetic makeup was revealed. Moderna has since reported preliminary safety data and some evidence that its vaccine stimulates the immune system to produce antibodies against the coronavirus.

As part of a Phase III clinical trial, Moderna and the National Institute of Allergy and Infectious Diseases in Bethesda, Md., planned to begin inoculating 30,000 volunteers in July with either the vaccine or a placebo to test the vaccine's efficacy in large numbers of people.

It will take "weeks and months" to get all of those people vaccinated, NIAID director Anthony Fauci said June 26 during a Milken Institute webinar. Results on whether more people in the placebo group get COVID-19 than those in the vaccine group, a sign the vaccine works, are expected in late fall or early winter.

Three other global companies have announced plans to launch similarly large trials this summer: Johnson & Johnson; AstraZeneca, working with the University of Oxford; and Pfizer Inc., which has teamed with the German company BioNTech. All are part of Operation Warp Speed or will be joining it.

Eye on safety

Phase III trials are usually about determining efficacy. But the rush to get through earlier stages designed to make sure a vaccine doesn't cause harm means that scientists also will be keeping an eye on safety, Fauci said. Researchers will be watching, in particular, for any suggestion that antibodies generated by the

vaccine might enhance infection.

That can happen when antibodies don't fully neutralize the virus and can aid it getting into cells and replicating, or when the vaccine alters immune cell responses in unhelpful ways.

Enhanced infections may be more of a concern for some vaccine candidates than others, says Peter Pitts, president of the Center for Medicine in the Public Interest, a nonprofit research and education organization in New York City. China-based CanSino Biologics Inc., for instance, has a hybrid virus vaccine: The coronavirus spike protein is put into a common cold virus, adenovirus 5. That virus can infect humans but has been altered so that it can no longer replicate.

In a small study, reported June 13 in the *Lancet*, CanSino's vaccine triggered antibody production against the spike protein. But many volunteers already had preexisting antibodies to the adenovirus, raising concerns of a weakened response to the vaccine. A weakened response may make an infection worse when people encounter the real coronavirus, Pitts says.

That's of particular concern because CanSino announced June 29 that its vaccine was approved by the Chinese government for temporary use by the Chinese military. That's essentially turning soldiers into guinea pigs, Pitts says.

The type of antibodies stimulated by a vaccine will be important in determining whether the vaccine is protective or makes things worse, immunologists from Yale University warned in the June *Nature Reviews Immunology*. Some types of antibodies have been associated with more severe cases of COVID-19.

Side effects will also be tracked closely. "As big as the vaccine trials may be, we can't be sure that there aren't rare side effects," Anne Schuchat, principal deputy director of the U.S. Centers for Disease Control and Prevention, said June 29 during a question-and-answer session with *JAMA*. "That's why even when we get enough to vaccinate large numbers, we're going to need to be following" those who get vaccinated.

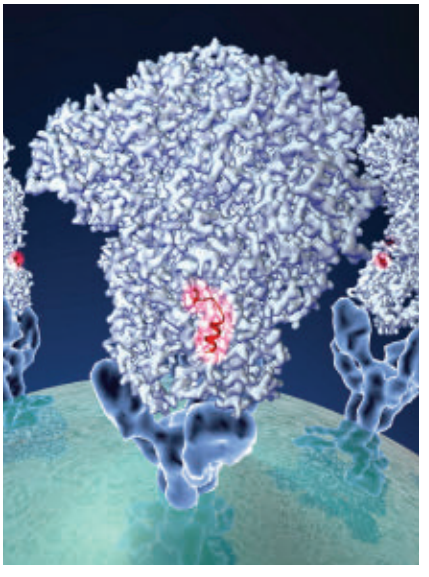
In 1976 for instance, Guillain-Barré syndrome, a rare condition in which the immune system attacks parts of the nervous system, turned out to be a rare side effect of the "swine flu" influenza vaccine. That didn't become obvious until the vaccine had already been rolled out to 45 million people in the United States.

Building trust

Some researchers have expressed concern that rushing clinical trials might lead regulators to approve a vaccine based on its ability to trigger antibody production alone. But it's unclear how well antibodies protect against reinfection with the coronavirus and how long any such immunity may last (*SN: 6/6/20, p. 22*). The measure of whether the vaccine works should instead be its ability to protect against illness, Fauci said.

So far, though, companies are measuring success by antibodies. For instance, on June 30, INOVIO, a biotechnology company in Plymouth Meeting, Pa., announced that 94 percent of volunteers in a small safety trial made antibodies against the virus. The data, delivered via news release as is much of the data from companies rushing to show progress, had not been peer-reviewed, and other details about the vaccine were sparse.

Despite still having much to prove, companies are gearing up manufacturing without knowing if their product will ever reach the market. For instance, if everything goes right, a vaccine in testing from Pfizer might be available as soon as October, Pfizer chairman and CEO Albert Bourla said during the Milken Institute session. The company expects to be able to make 1 billion doses by early next year.



DAVID VEESLER/UNIV. OF WASHINGTON

To infect cells, coronaviruses use their spike proteins (illustrated). Certain spots on the protein (red) may be vulnerable to antibodies.

Pfizer released preliminary data on the safety of one of its four vaccine candidates July 1 at medRxiv.org. In the study of 45 people, no severe side effects were noted. Vaccination produced neutralizing antibodies at 1.8 to 2.8 times the levels found in blood plasma from people who had recovered from COVID-19.

Biotech company Novavax Inc., in Gaithersburg, Md., announced July 7 that it won a $1.6 billion award from Operation Warp Speed to conduct Phase III trials and to deliver 100 million vaccine doses as early as the end of the year.

Even if companies deliver, there could be another hurdle: There's no guarantee people will line up for shots. About a quarter of Americans in recent polls said they would "definitely not" or "probably not" get a vaccine if one were available.

"We need to ... start building that public trust now," Krofah says. Tackling issues of vaccine hesitancy shouldn't be left until a vaccine is available.

Pitts agrees: "There's a perception that therapeutics or vaccines will be approved willy-nilly because of politics, and that's a dangerous misperception." The FDA laid out guidelines, including an accelerated approval process, on June 30 that should ensure any approved vaccines work.

There is good news for those awaiting vaccines. There will likely be many to choose from and that may be a necessity to protect different segments of the population, Krofah says. For instance, elderly people may need a vaccine that prods the immune system harder to make antibodies, and children may need different vaccines than adults do.

In the long term, investments in development will need to continue so that vaccines can be altered if the virus mutates, Krofah says. "We need to stay [at] the front and not declare victory once a vaccine has been approved for emergency use." ■

ATOM & COSMOS

Black hole collides with mystery object

Measured mass doesn't match a black hole or a neutron star

BY MARIA TEMMING

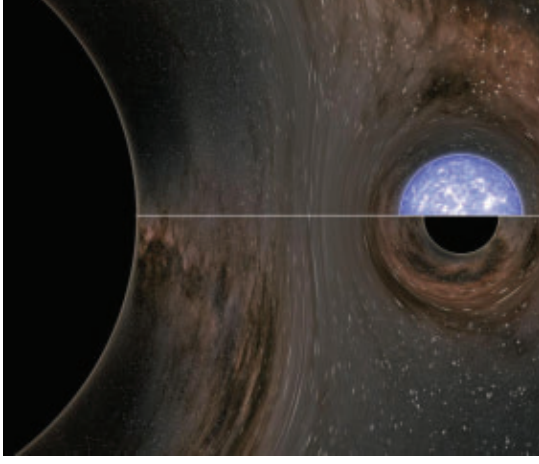
Ripples in spacetime have revealed a distant collision between a black hole and a mystery object, which appears too massive to be a neutron star but not massive enough to be a black hole.

At first glance, the event — detected by the LIGO and Virgo gravitational wave detectors on August 14, 2019 — looked like a collision between a black hole and a neutron star (*SN: 9/14/19, p. 14*). But a new analysis of the gravitational waves emanating from the merger tells a different story: A black hole about 23 times as massive as the sun crashed into a compact object of about 2.6 solar masses, researchers report in the June 20 *Astrophysical Journal Letters*.

That object is heavier than the presumed 2.5-solar-mass cap on neutron stars. But it's smaller than the most lightweight black hole ever observed, which is about five solar masses. "We have either the heaviest known neutron star ... or we have the lightest known black hole," says Cole Miller, an astrophysicist at the University of Maryland in College Park not involved in the work.

Neutron stars, which are dense remnants left behind by stellar explosions, are thought to max out at about 2.5 solar masses because any larger star is liable to crumple under its own weight, says study coauthor Vicky Kalogera, an astrophysicist at Northwestern University in Evanston, Ill. Black holes less than about five solar masses are theoretically possible, "we just have had no observational evidence of such low-mass black holes," she says. That could mean such objects are rare or that they're just so difficult to spot that they've been overlooked.

Unfortunately, this lone merger didn't leave behind enough clues for astronomers to figure out the object's identity.



Gravitational wave detectors spotted a crash between a black hole (illustrated, left) and an unknown object (right), either a heavy neutron star or a lightweight black hole.

After the U.S.-based Advanced Laser Interferometer Gravitational-Wave Observatory, or LIGO, and its sister experiment in Italy, Advanced Virgo, detected the merger, dozens of telescopes scoured the sky for light radiating from the crash site. But they found nothing.

That lack of observations fits with the idea that the mystery object is a black hole, because black hole collisions are generally not thought to give off any light. But it could also fit with the neutron star explanation. Although smashups involving neutron stars can throw off a lot

ATOM & COSMOS

Black hole crash spawns a surprise

Merger may have let off light along with gravitational waves

BY EMILY CONOVER

In spite of their dark reputations, two black holes may have set off a light show.

Subtle gravitational rumbles from a collision of two black holes may have been accompanied by a flare of light about a month later, physicists report in the June 26 *Physical Review Letters*. It's a surprising conclusion given black holes' propensity to swallow up light and matter. "The normal expectation has been they just merge and all you would detect is gravitational waves," says astrophysicist Matthew Graham of Caltech.

But scientists, not ones to rest on assumptions, wanted to check if that expectation was right. To look for a flare, Graham and colleagues combed through data from the Zwicky Transient Facility at the Palomar Observatory in California, which repeatedly images the sky, searching for short-lived changes. About 34 days after the gravitational waves were detected in May 2019, a blaze of light appeared in the vicinity of sky that the gravitational waves had pinpointed. This outburst was associated with a known quasar, a glowing object made up of a disk of gas and the supermassive black hole within. The black hole in question boasts a mass 100 million times that of the sun.

The researchers suggest that the flare could have been produced if two smaller black holes met up in the vicinity of that supermassive black hole, coalescing within the swirling gas disk. That unification could have flung the resulting merged black hole through the disk, creating a shock wave that heated the gas, producing a temporary burst of light.

If the theory is correct, the two smaller black holes had a total mass about 100 times that of the sun, the scientists calculate. After the merger, the resulting black hole would have plowed through the gas at about 700,000 kilometers per hour before leaving the disk. In the future, that black hole should swing back thanks to the gravitational pull of the disk, causing another flare in late 2020 or early 2021. Spotting that predicted flare would help confirm the explanation.

The connection between the flare and the gravitational waves isn't certain, says astrophysicist Daniel Holz of the University of Chicago, a member of the U.S.-based Advanced Laser Interferometer Gravitational-Wave Observatory, or LIGO, one of two observatories that detected the gravitational waves.

"The problem is that the sky is incredibly dynamic and lively. There are stars exploding and black holes burping and stars being ripped apart," Holz says. So

R. HURT, MIT, CALTECH, LIGO, IPAC

of light (*SN: 11/11/17, p. 6*), it's possible that this collision — nearly 800 million light-years away — was simply too far away for telescopes to see its radiation. Or perhaps the black hole swallowed its little neutron star companion in a single gulp, causing it to vanish without a trace.

Observations of similar events in the future might offer evidence in favor of either the small black hole or big neutron star theory, Kalogera says. If midsize objects in future collisions all tend to be between about 2.5 and three solar masses, she suspects that would mean astronomers are uncovering a heavier variety of neutron star. If, on the other hand, astronomers detect many objects whose masses run the gamut from about 2.5 to five solar masses, that may point to a population of previously overlooked petite black holes.

Kalogera and Miller both lean more toward the idea that the mystery object is a lightweight black hole. If it is, that raises another question: how such a pint-size black hole got paired up with a much bigger partner. Black holes usually team up with partners of similar heft. ■

the flare may just be a coincidence. But if it is real, he says, "it would provide a whole new window on how black holes are made and live and die."

Scientists don't know how merging black holes find one another. Previous work has focused on black holes meeting within a star cluster, for example. That they might pair up within an accretion disk is a newer hypothesis. "It started out as kind of a fringe idea," says astrophysicist Jillian Bellovary of Queensborough Community College in New York City. But it "has been gaining traction."

If correct, the result suggests that gravitational wave detections could help unravel the messy, poorly understood physics of such disks, says astrophysicist Richard O'Shaughnessy of Rochester Institute of Technology in New York. That in turn could help scientists understand how galaxies with quasars evolve as energy churned up by a supermassive black hole feeds back into the galaxy. ■

ATOM & COSMOS

Dense planet may be a leftover core

Orb is the innards of a former gas giant, scientists suggest

BY LISA GROSSMAN

A dense, scorched planet around a distant star may be the naked core of a gas giant.

The exoplanet has a radius nearly 3.5 times Earth's and a mass about 39 times Earth's. Those figures point to an Earthlike density, suggesting that the planet is mostly rock. Unlike other massive planets, this world, called TOI 849b, has a barely there atmosphere, making up 4 percent of the planet's mass at most, astronomer David Armstrong and colleagues report in the July 2 *Nature*.

That atmosphere is "absolutely minuscule for a planet of its size," says Armstrong, of the University of Warwick in Coventry, England.

The mass and near lack of an atmosphere suggest that TOI 849b may be the remnant core of a gas giant. It might be the first exposed gas giant core found.

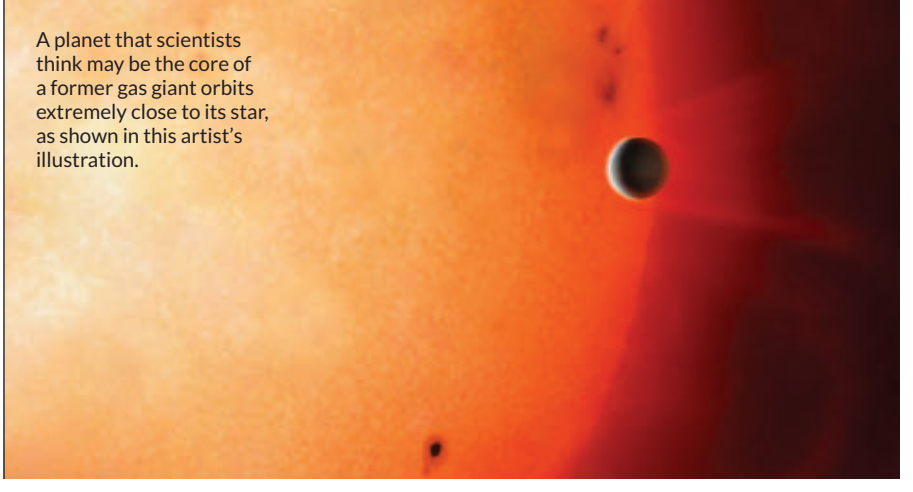
Using NASA's Transiting Exoplanet Survey Satellite, or TESS, the team spotted TOI 849b as it passed in front of a star 734 light-years away. Observations with the La Silla Observatory in Chile revealed the planet is more than twice as massive as Neptune. Those observations plus TOI 849b's inferred volume indicate that the planet is the densest known of its size.

The planet whips around its star about once every 18 hours, orbiting so close that the surface sizzles at about 1500° Celsius. Most planets that close to their stars are Jupiter-sized and larger, or Earth-sized and smaller. Only a handful of "hot Neptunes" have been seen before.

In the standard theory of planet formation, a ball of rock that reaches about 10 Earth masses should eat gas insatiably from the disk of gas and dust in which it formed. "Beyond that mass, it's very hard to stop it turning into a gas giant," says Armstrong. "You get this huge infall of gas that overwhelms the formation process."

There are two main possibilities for why TOI 849b doesn't have a thick atmosphere, the researchers say. The planet could have opened a gap in the protoplanetary disk as it was forming, and so had a more meager buffet to eat from, stalling growth. Or TOI 849b was a gas giant that lost its atmosphere. Energy from the planet's star could have heated the atmosphere enough that it blew or boiled away, or collisions with other planets could have tossed out the gas but left the core.

It's "a little premature" to say TOI 849b is a gas giant remnant, says astronomer Elisabeth Adams of the Planetary Science Institute, who is based in Somerville, Mass. But if it is, studying the planet and others like it will help scientists learn about Jupiter and other gas giants, whose cores are hidden in thick, gassy cocoons. "We don't even know how big Jupiter's core is," Adams says, "and we've sent spacecraft to Jupiter." ■



A planet that scientists think may be the core of a former gas giant orbits extremely close to its star, as shown in this artist's illustration.

UNIV. OF WARWICK, MARK GARLICK

BODY & BRAIN

Cancer immune therapy gets a boost

In mice, drugs that stymie suppressor cells helped fight tumors

BY ESTHER LANDHUIS

Drugs that release the brakes on the immune system have helped thousands of people with cancers that were previously untreatable. Yet these therapies, known as checkpoint blockers, fail in many patients and work poorly for some cancers. That's because the body's defense system can stall in more than one way.

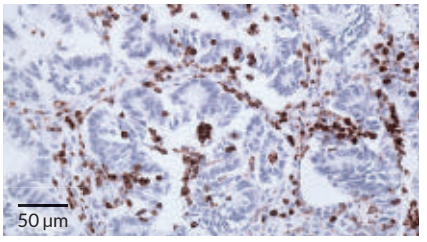
Checkpoint blockers traditionally target a particular set of brakes: protein interactions that disarm the body's T cells, allowing cancer to grow unchecked. But an additional brake may be at work — an immune cell population called myeloid-derived suppressor cells, or MDSCs. These cells reach unusually high levels in people with cancer.

Now, experiments in mice offer early hints that immune checkpoint therapies could get a boost if paired with drugs targeting MDSCs. Researchers reported their initial findings at a meeting of the American Association for Cancer Research, held virtually in late June.

MDSCs are a mix of immature cells from the same family as neutrophils and macrophages, which act as general first responders in the immune system. MDSCs' "normal function is to slow things down," says surgical oncologist William Carson III of Ohio State University in Columbus.

In a 2016 study of people who received checkpoint blockers for advanced melanoma, patients with lower levels of MDSCs in the blood responded better to the immune therapy and lived longer. That made Carson and colleagues wonder if getting rid of the suppressor cells could create an environment for checkpoint blockers to work better. There was already a class of drugs that could potentially achieve this: Brd4 inhibitors.

In tumor cells, Brd4 protein regulates the activity of various genes, including some that promote MDSCs. So perhaps a Brd4-inhibiting drug would give checkpoint blockers free rein to do their job.



Drugs that target immune suppressor cells (brown cells shown infiltrating the colon of a mouse with colorectal cancer) could help the body's defense system fight cancer.

Andrew Stiff, a physician-researcher in Carson's lab, studied mice with implanted breast tumors, a human cancer that responds poorly to checkpoint blockers. Among mice treated with the checkpoint blocker anti-PDL1, tumor growth slowed in three of 11 animals. Mice treated with a placebo or Brd4 inhibitor alone fared worse. A third group of mice got a combination therapy, anti-PDL1 and a Brd4 inhibitor. That combo aimed to release the brakes on T cells and curb the suppressor cells. Tumors shrank in seven of 11 mice, Stiff reported June 24 at the meeting.

Treated mice had fewer MDSCs in circulation and at the tumor site. Other tests suggested Brd4 inhibitors can influence MDSCs in several ways, including killing the cells or suppressing a molecule that drives their growth and expansion.

The team got similar results with several different Brd4 inhibitors and in mice with breast, colon or lung tumors. Though preliminary and unpublished, the findings suggest that Brd4 inhibitors "can get rid of these immune suppressor cells that are an additional brake on the immune system, and allow immune-stimulating drugs to work better," Carson says.

There are other ways to target those suppressor cells. Timothy Wang, a gastroenterologist at Columbia University Irving Medical Center, and colleagues used an anti-inflammatory peptide called trefoil factor 2, or TFF2. Previously, Wang and colleagues showed that some T cells release TFF2 to tone down inflammatory responses and that giving mice TFF2 can boost the immune system and slow tumor growth.

In a new study reported June 22 at the meeting, a team led by Wang and Columbia cancer biologist Woosook Kim chemically stimulated mice to form colorectal tumors. Some animals had genetic manipulations that led them to produce a lot of MDSCs and grow tumors quickly. Like human patients, these mice responded poorly to anti-PD1 immune therapy. However, combining TFF2 and anti-PD1 shrank tumors in all five animals with aggressive cancer.

Synthesizing TFF2 for this pilot study was expensive, Wang says, so his team could test only a single dose on a small number of animals. "The fact that we could get any responses here, and that we showed some degree of synergy with anti-PD1, is very encouraging," Wang says.

Li Peng, chief scientific officer at Palleon Pharmaceuticals, a Boston-area company developing cancer immunotherapies (*SN: 4/1/17, p. 24*), notes that chemically induced tumor models like the mice Wang's team used tend to mimic human cancer better than the implanted tumor models more commonly used for immune therapy studies.

But a drug's effectiveness in mice has often shown little correlation with its impact in humans. For example, anti-PD1 and anti-PDL1 therapies slowed tumor growth only modestly in mice, yet today they're "the cornerstone for immuno-oncology therapy in humans," Peng says. Another case in point: STING agonists. These drugs, cancer immunotherapies that activate a slew of host defense genes, worked like gangbusters in mice yet have floundered in clinical trials.

Over a thousand other trials are testing checkpoint blockers, alone or in combination with other drugs, and some, like one for people with advanced non-small cell lung cancer, are showing some promise. Yet the immune system is so sophisticated, with layers upon layers of brakes, that existing approaches may be "just scratching the surface," Peng says. ■

W. KIM

ATOM & COSMOS

Elusive class of neutrinos spotted

The particles could help assess the sun's chemical makeup

BY EMILY CONOVER

Neutrinos spit out by the main processes that power the sun are finally accounted for, physicists report.

Two sets of nuclear fusion reactions predominate in the sun's core and produce the lightweight subatomic particles in abundance. Scientists had previously detected neutrinos from the most prevalent process. Now, for the first time, neutrinos from the second set of reactions have been spotted, researchers with the Borexino experiment said June 23 at the Neutrino 2020 virtual meeting.

"With this outcome, Borexino has completely unraveled the two processes powering the sun," reported physicist Gioacchino Ranucci of Italy's National Institute for Nuclear Physics in Milan.

Before it's official, the result must still clear the hurdle of peer review in a scientific journal.

In the sun's core, hydrogen fuses into helium in two ways. One, known as the proton-proton chain, is the source of about 99 percent of the star's energy. The other is the CNO cycle, for carbon, nitrogen and oxygen — the elements that allow the reactions to proceed. Previously, Borexino had spotted neutrinos from the proton-proton chain (*SN: 9/20/14, p. 32*). But neutrinos from the CNO cycle had been MIA.

> "Borexino has completely unraveled the two processes powering the sun."
>
> GIOACCHINO RANUCCI

"They're top of everybody's list to try and identify," says physicist Malcolm Fairbairn of King's College London. "Now they think they've spotted them, which is a major achievement, really an extremely difficult measurement to make."

Located deep underground at the Gran Sasso National Laboratory in Italy, Borexino searches for flashes of light produced as neutrinos knock into electrons in a vat of liquid. Researchers have spent years fine-tuning the experiment to detect the elusive neutrinos that herald the CNO cycle. Although difficult to observe, the particles are plentiful, Borexino confirmed. On Earth, about 700 million neutrinos from the CNO cycle pass through a square centimeter each second, the researchers report.

Studying these particles could help reveal how much of the sun is composed of elements heavier than hydrogen and helium, a property known as metallicity. That's because the rate at which CNO cycle neutrinos are produced depends on the sun's content of carbon, nitrogen and oxygen. Different types of measurements currently disagree about the sun's metallicity. In the future, more sensitive measurements of CNO neutrinos could help scientists disentangle the problem. ■

LIFE & EVOLUTION

Watch out for caecilian bites

The snakelike amphibians may have oral venom glands

BY CHRISTIE WILCOX

The ringed caecilian, which grows to be about 45 centimeters long as an adult, may be the first amphibian known to have a venomous bite.

Caecilians are amphibians like frogs and salamanders, but the long, legless creatures are often mistaken for snakes. Now, scientists think that the similarities between the two are more than skin deep.

New microscope and chemical analyses suggest that, like venomous snakes, caecilians have glands near their teeth that secrete toxins. The discovery raises the possibility that caecilians may be the first amphibians found capable of delivering a venomous bite.

Pedro Mailho-Fontana, an evolutionary biologist at the Butantan Institute in São Paulo, has been studying caecilians for several years, and in particular, the glands in the skin. He helped show that the animals have separate glands for secreting mucus on the head and poison on the tail.

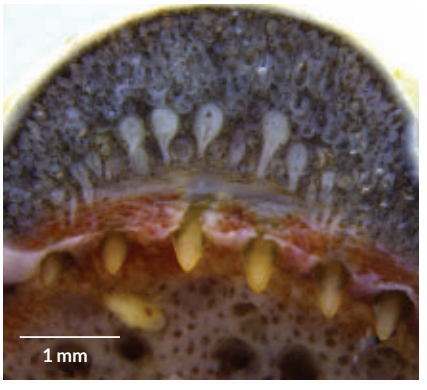
But one day in early 2018, as he was slowly eroding the skin on the skull of a dead ringed caecilian (*Siphonops annulatus*) to get a closer look at the mucus glands, Mailho-Fontana saw something that made his hair stand on end: large glands in the animal's upper and lower jaws that had ducts going to the teeth.

Mailho-Fontana, along with evolutionary biologists Marta Antoniazzi and Carlos Jared, also of the Butantan Institute, set about characterizing these unexpected oral glands in several caecilian species using standard and electron microscopes. Perhaps the most striking finding is that the glands arise from dental tissue. That's just like venom glands of snakes, but it's a first for amphibians, the researchers report online July 3 in *iScience*.

The team also performed preliminary biochemical tests on the fluid in the newfound glands and discovered that it contains phospholipase A2 enzymes, fat-chopping proteins that are frequent components in animal venoms. But the work stopped short of conclusively showing that the animals are venomous.

Venoms aren't entirely unknown in amphibians; some of these animals use bony protrusions to create wounds in their attackers and deliver skin-derived toxins. Jared and colleagues previously discovered the only known venomous frogs (*SN: 9/5/15, p. 4*). But Jared notes that these amphibians cannot inject their venom and instead rely on an attacker pressing on their pointy bits.

The caecilian oral glands don't quite work like the venom glands of snakes, though. The team didn't find any tubes or grooves in the teeth that could facilitate the delivery of the fluid. Instead, it appears the glands work more like the venom systems of Gila monsters or other venomous lizards: The glands simply ooze secretions onto the teeth, which then enter the victim as they tear into flesh.



In the jaws of caecilians, scientists discovered upside-down teardrop-shaped glands (white, above the yellow teeth) filled with fluid containing enzymes found in animal venoms.

That these snakelike animals seem to possess a venomous bite even somewhat akin to snakes' isn't likely to be a coincidence, Antoniazzi says. "We think it has to do with this fact that they have similar bodies," she says. Without limbs to subdue prey, both caecilians and venomous snakes benefit from having oral chemical weapons.

The caecilians' teeth and associated glands are "extremely fascinating," says Kartik Sunagar, an evolutionary biologist at the Indian Institute of Science in Bangalore, comparing them to "something out of an alien movie." But it's still unclear if the gland secretions are indeed toxic and play a functional role in feeding or defense, he says.

Tracking which genes are turned on or off in the oral glands compared with the tail poison glands or other tissues could give a better sense of what the oral secretions contain and whether they are unique to those glands, Sunagar says.

The team hopes to provide additional evidence for these amphibians being venomous soon, including a more detailed work-up of the oral gland components, which would shed new light on these enigmatic and poorly studied animals. Caecilians are "perhaps the most unknown vertebrate," Jared says. "This project has opened the door for future studies." ■

BOTH: C. JARED

LIFE & EVOLUTION

Fish eggs survive a trip through a duck

Birds eating, then pooping eggs may spread species to new places

BY CAROLYN WILKE

For fish eggs, getting gobbled by a duck kicks off a harrowing journey that includes a pummeling in the gizzard and an attack by stomach acids. But a few eggs can exit unscathed in a duck's excrement, possibly helping to spread those fish, including invasive species, to different places, a study finds.

It's been an "open question for centuries how these isolated water bodies can be populated by fish," says Patricia Burkhardt-Holm, a fish biologist at the University of Basel in Switzerland who was not involved with the new research. This study shows one way that water birds may disperse fish, she says.

Birds' feathers, feet and feces can spread hardy plant seeds and invertebrates. But researchers didn't expect that soft fish eggs could survive being in a bird's gut, says Orsolya Vincze, an evolutionary biologist at the Centre for Ecological Research in Debrecen, Hungary.

In the lab, Vincze and colleagues fed thousands of eggs from two invasive carp species to eight mallard ducks. About 0.2 percent of ingested eggs, 18 out of roughly 8,000, were intact after defecation, the team found. Some of those eggs contained wriggling embryos and a few eggs later hatched, the team reports in the July 7 *Proceedings of the National Academy of Sciences*. It's not clear yet whether eggs survive in this way in the wild.

Most of the viable eggs were pooped out within an hour of being eaten, while one took at least four hours to pass. Migratory ducks could travel dozens or possibly hundreds of kilometers before excreting those eggs, the scientists suggest.

Though the surviving egg count is low, their numbers may add up, making bird poop a possibly important vehicle for spreading fish. A single carp can release hundreds of thousands of eggs at a time, Vincze says. And there are huge numbers of mallards and other water birds throughout the world that may gorge themselves on those eggs. ■

LIFE & EVOLUTION

A new sparrow song went viral

Species's altered tune quickly spread across North America

BY JACK J. LEE

Some North American birds are changing their tune. The traditional song of the white-throated sparrow (*Zonotrichia albicollis*) ends with a repeated triplet of notes. By 2000, however, some birds in western Canada were whistling a variation with a two-note pattern. That new song has since spread widely across North America, researchers report online July 2 in *Current Biology*.

The findings fly in the face of hypotheses that birdsong dialects don't change much within local regions. The rapid spread of the new song is akin to someone moving from Kentucky to Vancouver and many people in Vancouver suddenly picking up a Kentucky accent, says Ken Otter, an avian behavioral ecologist at the University of Northern British Columbia in Prince George.

Otter and colleagues documented the adoption of the western song at a research station in eastern Canada. In 2005, only one male out of 76 surveyed sang the doublet-ending song. In 2014, nearly 22 percent of 101 males surveyed sang the new song. And in 2017, nearly half of 92 males recorded had adopted the variation.

"You can actually see the [transition] unfolding in real time," says Jeff Podos, a biologist who studies animal communication at the University of Massachusetts Amherst and was not involved with the new study.

The researchers confirmed the spread of the song with the double-noted ending across the continent — as far east as Quebec and Vermont — via recordings from citizen scientists and other researchers.

Eastern sparrows probably picked up the new song at common wintering grounds, the researchers say. By tracking birds from central British Columbia with backpacklike geolocators, the team found that the birds migrated to the southern U.S. Great Plains, which overlap with known wintering grounds of birds that breed east of the Rockies.

One explanation for this shift, Otter says, may be a female preference for novel songs, a focus for future study. ■

The white-throated sparrow traditionally sings a song with a three-note ending, but across North America, these birds have recently adopted a version ending with a repeated pattern of two notes.

SCOTT M. RAMSAY

Listen to the old and new sparrow songs at **bit.ly/SN_sparrow**

ATOM & COSMOS

New particle is very charming

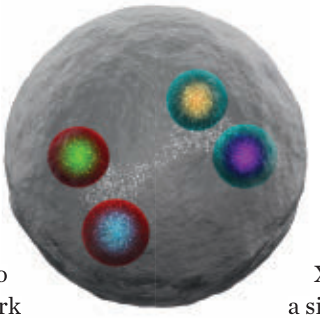
Tetraquark could be a testing ground for how quarks interact

BY MARIA TEMMING

In a never-before-seen particle, four quarks of a feather flock together.

Physicists think they have detected the first conglomerate of four quarks that includes more than two of the same kind. This tetraquark contains two charm quarks and their antimatter counterparts, anticharm quarks, researchers report online June 30 at arXiv.org.

Quarks, fundamental building blocks of matter, typically make up three-quark particles, like protons and neutrons, or quark-antiquark pairs, like pions and kaons. Physicists have observed some more exotic quark quartets (*SN: 5/17/14, p. 12*). But the new particle, dubbed X(6900), is the first four-quark particle with all of the same type. Charm quarks and anticharm quarks are among the heaviest types of quarks, so it is also the first tetraquark to have more than two heavy quarks.



A newfound particle (illustrated) is made up of two charm quarks and their antimatter partners, called anticharm quarks.

Quarks are bound together by the strong force. Discovering new, exotic quark arrangements "tells us something about the types of patterns of quarks that the strong interaction generates, which tells us something about the strong interaction," says physicist Matthew Shepherd of Indiana University Bloomington, who wasn't involved in the work. A deeper knowledge of that fundamental force could give insight into common quark-based particles, like the protons in atoms.

Evidence of the new tetraquark comes from the Large Hadron Collider, or LHC, near Geneva. Proton collision data collected from 2009 to 2018 contain signatures of a particle with the mass expected for a quartet of charm quarks: about 6,900 million electron volts. That particle decayed into two particles that each had a charm and an anticharm quark, suggesting it was originally a tetraquark with two charm and two anticharm quarks. X(6900) could be either a single entity, composed of four quarks bundled together, or a pair of two-quark particles that are more loosely bound — like a set of atoms in a molecule.

Assuming that the evidence holds, the new particle offers "a sort of stress tester" for ideas about how quarks construct matter, says study coauthor Chris Parkes, a physicist at the University of Manchester in England. He compares using this tetraquark for studying particle physics to looking at extremophile creatures like tardigrades to understand the limits of biology.

It may be easier to study quark interactions in X(6900) than in tetraquarks containing lighter quarks, Shepherd says. It's notoriously challenging to accurately predict the complex, fast-moving behavior of light quarks. With X(6900), physicists could potentially build simpler models to predict quark behavior. ■

BODY & BRAIN

How exercise keeps old brains fit

Liver enzyme helps boost memory, mouse study hints

BY LAURA SANDERS

Exercise's power to boost the brain might require a little help from the liver.

A chemical signal from the liver, triggered by exercise, helps elderly mice keep their brains sharp, suggests a study published in the July 10 *Science*. Understanding this liver-to-brain signal may help scientists develop a drug that benefits the brain the way exercise does.

Scientists have long sought an "exercise pill" that could slow the memory decline that comes with old age like exercise does. Such a pill could be useful for elderly people too frail to work out or for whom exercise is otherwise risky, says Saul Villeda, a neuroscientist at the University of California, San Francisco.

Villeda and colleagues injected sedentary elderly mice with blood plasma from elderly mice that had run on wheels over the course of six weeks. After eight injections over 24 days, those mice did better on memory tasks, such as remembering where a hidden platform was in a pool of water, than elderly mice that received injections from sedentary mice.

Other tests showed that mice that exercise have an abundance of proteins produced by the liver in their plasma compared with sedentary mice.

The researchers closely studied one of those liver proteins: an enzyme called GPLD1 that snips other proteins off the outsides of cells, releasing those proteins to go do other jobs. Targeting these biological jobs with a molecule that behaves like GPLD1 might be a way to mimic the brain benefits of exercise, the researchers suspect.

Old mice genetically engineered to make more GPLD1 in their livers performed better on the memory tasks than other old sedentary mice and about as well as old, exercised mice.

Blood samples from elderly people also hint that exercise raises GPLD1 levels. Compared with elderly sedentary people, elderly people who walked over 7,100 steps a day had more of the protein.

But the role of GPLD1 is far from settled, cautions Irina Conboy, a researcher who studies aging at the University of California, Berkeley. There's evidence that GPLD1 levels are higher in people with diabetes, she points out, hinting that the protein may have negative effects. And some experiments suggest that GPLD1 levels might actually fall in response to certain kinds of exercise in rats with markers of diabetes.

Whether GPLD1 is good or bad, or whether it goes up or down with exercise, Conboy says, "we don't know yet." ■

CERN

Early Polynesians had surprise visitors

DNA hints at an ancient encounter with South Americans

BY BRUCE BOWER

More than 800 years ago, people in South America traversed more than 7,000 kilometers of open sea to reach eastern Polynesia, a new study suggests.

There, South Americans mated with inhabitants who were just discovering and settling those remote islands, researchers say. Genetic analyses suggest that DNA swaps between the voyagers and people on a still-undetermined eastern Polynesian island were followed by the spread of the South American ancestry to other islands.

Eventually that ancestry spread as far east as Easter Island, also known as Rapa Nui, a team led by computational biologist Alexander Ioannidis and population geneticist Andrés Moreno-Estrada reports online July 8 in *Nature*.

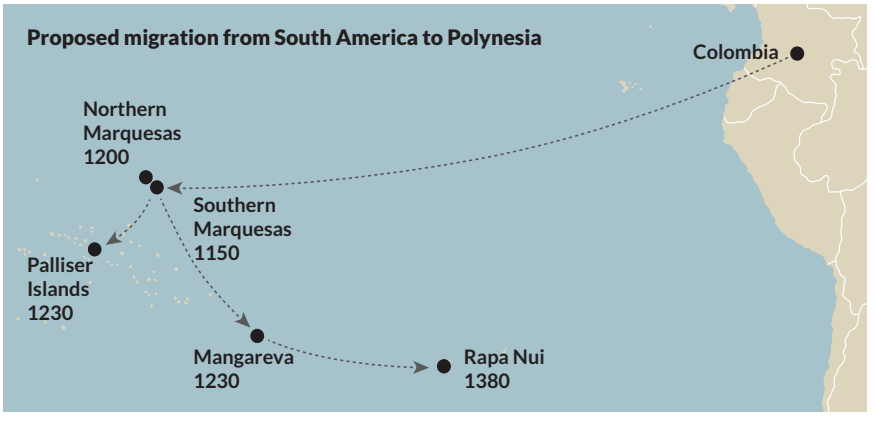
The study offers a genetic glimpse of "a prehistoric event that left no conclusive trace, except for the one recorded in the DNA of those who had contact 800 years ago in one of the most remote places on Earth," says Moreno-Estrada, of the National Laboratory of Genomics for Biodiversity in Irapuato, Mexico.

Ideas about how Polynesia came to be populated have long inspired debate. Norwegian explorer Thor Heyerdahl's 1947 *Kon-Tiki* expedition tested his idea that South Americans settled the Pacific islands by showing that it was possible to drift by wooden raft from about 129 kilometers off Peru's coast to Polynesia. But most scholars assumed Asians colonized relatively close-by western Polynesia as early as about 3,500 years ago, eventually populating eastern Polynesia by about 1,000 years ago without having any contact with South Americans.

Computer simulations have indicated that winds and currents would carry a vessel from northern South America to Polynesia. But the idea of seafaring South Americans having a role in the peopling of Polynesia hasn't been widely accepted.

It's unknown, for example, whether groups in the Americas had seagoing vessels or the navigational skills needed to reach Polynesia, says anthropologist and population geneticist John Lindo of Emory University in Atlanta.

Ioannidis, of Stanford University, and Moreno-Estrada's group searched for molecular markers of shared ancestry in DNA of 807 people from 17 island populations in or near Polynesia and 15 Indigenous groups in Central and South America. All DNA came from present-day people except for samples from four people who lived in the Americas between about 500 and 7,400 years ago.



Gene flow South Americans, perhaps from what's now Colombia, sailed across the Pacific and mated with people in eastern Polynesia over 800 years ago, a genetic study suggests. Exactly where the mating occurred is unknown, but South American DNA may have reached the southern Marquesas Islands by 1150, then spread as far east as Rapa Nui by 1380. SOURCE: P. WALLIN/*NATURE* 2020

DIKOBRAZIY/ISTOCK/GETTY IMAGES PLUS, ADAPTED BY E. OTWELL

Comparisons of the length of DNA segments shared by Polynesians and Indigenous Americans enabled calculations of when Indigenous American DNA was introduced to Polynesians. Smaller DNA segments are assumed to represent older instances of mating across populations than longer segments due to the breakdown of shared segments in later generations.

DNA resembling that of Indigenous people now living in Colombia appeared on an island called Fatu Hiva in the southern Marquesas Islands by about 1150, probably the result of a single ancient contact, the researchers estimate. South American DNA reached three nearby sets of islands between roughly 1200 and 1230, followed by Rapa Nui in about 1380. The genetic data can't establish which Polynesian islanders mated with the South Americans before spreading that ancestry elsewhere, only that evidence so far points to the southern Marquesas.

But other contact scenarios are possible. The study provides support for a scenario in which ancestors of Rapa Nui settlers traveled to South America and possibly returned with sweet potatoes, says archaeologist Carl Lipo of Binghamton University in New York. Those ancestors could have carried that crop and South American DNA to Polynesia, he says. Some scientists have argued that Polynesians went to and from South America, bringing the sweet potato to Polynesia more than 800 years ago and possibly chickens to the Americas more than 600 years ago (*SN: 6/9/07, p. 356*).

Ancient Polynesians' "tremendous navigation skills" would have made these trips possible, Lindo agrees.

Radiocarbon dating of archaeological remains and linguistic studies together suggest that people reached Rapa Nui by about 1200, nearly 200 years before the newly estimated arrival of Polynesians with South American ancestry, archaeologist Paul Wallin of Uppsala University in Sweden writes in a commentary published with the study. Trade and cultural exchanges may have connected Rapa Nui to South America before DNA did, he suggests. ■

BODY & BRAIN

Strokes, mental state changes hint at how COVID-19 harms the brain

COVID-19 cases described by U.K. doctors offer a sharper view of the illness's possible effects on the brain. Strokes, confusion and psychosis were found among a group of 125 people hospitalized with infections of SARS-CoV-2, the coronavirus behind the pandemic.

The findings, described online June 25 in *Lancet Psychiatry*, come from a group of severely sick people, and so can't answer how common these neurological symptoms may be in a more general population. Still, the details bring scientists closer to better understanding COVID-19.

In April, neurologists, stroke physicians, psychiatrists and other doctors across the United Kingdom entered COVID-19 patient details into a centralized database as part of a survey to uncover the disease's brain-related symptoms. Of the 125 patients described fully, 77 had an interruption of blood flow in the brain, most often caused by a blood clot. Blood clots are a well-known COVID-19 complication, and strokes have been seen in younger people with COVID-19.

About a third of the 125 patients had a shift in mental state, including confusion, personality change or depression. Of 37 patients with altered mental states, 18 were younger than 60. For now, it's unclear exactly how SARS-CoV-2 might cause these symptoms. — *Laura Sanders*

LIFE & EVOLUTION

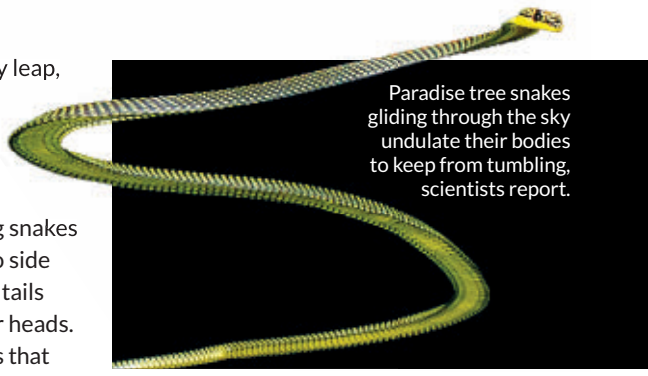
How flying snakes stay aloft

Certain species of tree snakes glide through the air, undulating their bodies as they soar from tree to tree. That wriggling isn't a useless attempt to replicate how the reptiles slither across land or swim through water. The contortions are essential for stable gliding, a group of engineers reports June 29 in *Nature Physics*.

Paradise tree snakes (*Chrysopelea paradisi*) fling themselves from branches, leaping 10 meters or more. To record the snakes' twists and turns, the team affixed reflective tape on snakes and used high-speed cameras to capture the motion.

Scientists already knew that the snakes flatten their bodies as they leap, which generates lift (*SN: 3/8/14, p. 4*). The new experiment reveals that the snakes also exert a complex combination of movements while soaring. Gliding snakes undulate their bodies both side to side and up and down, and move their tails above and below the level of their heads.

In computer simulations, snakes that undulated flew similarly to real-life snakes. But those that didn't wriggle failed spectacularly, rotating to the side or falling head over tail, rather than maintaining a graceful, stable glide. — *Emily Conover*



Paradise tree snakes gliding through the sky undulate their bodies to keep from tumbling, scientists report.

HUMANS & SOCIETY

Divers discover the oldest known red ochre mines in the Americas

Ancient Americans ventured deep into caves along Mexico's Yucatán Peninsula to mine a red pigment that may have had practical and ritual uses, researchers say.

Discoveries of mining-related artifacts and digging areas by divers in three now-submerged cave systems indicate people there removed red ochre, the investigators report July 3 in *Science Advances*. Radiocarbon dates of burned wood from fires used to illuminate mines put humans at these sites between about 12,000 and 10,000 years ago, making it the oldest evidence of ochre mining in the Americas.

Ancient Americans may have used red ochre in many ways, including as an antiseptic, sunscreen, hide-tanning agent and for symbolic purposes.

The new discoveries raise the possibility that some miners may have died and been left where they perished. Divers previously found at least 10 human skeletons in Yucatán caves dating to as early as about 12,000 years ago, before rising seas inundated the chambers.

In one cave system, a roughly 900-meter-long series of tunnels dubbed La Mina had extensive evidence of ochre extraction. Several narrow passages leading into La Mina had piles of stones and broken pieces of rocky cave growths that miners apparently used as navigation guides. Other broken-off cave growths were wielded as digging tools. — *Bruce Bower*

ATOM & COSMOS

Some exoplanets may be covered in a strange form of water

Exoplanets bigger than Earth but smaller than Neptune may come in more than two varieties.

Based on density, astronomers have largely sorted these planets into two categories: denser, rocky super-Earths and larger, puffy mini-Neptunes. Mini-Neptunes are generally thought to be padded in thick layers of hydrogen and helium gas, like the giant planets in our solar system. But astronomers have detected clear evidence of hydrogen on only some mini-Neptunes — and, curiously, seen traces of water on others.

Now, simulations indicate that some mini-Neptunes could actually be rocky planets covered in superheated oceans, where the water is in an exotic state between liquid and gas. Such extreme saunalike worlds could bridge the divide between rocky and gaseous planets, researchers report in the June 20 *Astrophysical Journal Letters*.

The researchers ran simulations of ocean-covered worlds in close orbits around their stars, where mini-Neptunes are often found. Intense stellar radiation would cause water on the planets to puff up into a diffuse layer of "supercritical" water between liquid and gas, topped by a steamy water vapor atmosphere.

Each simulated planet's puffiness depended on factors like water content. The team simulated water worlds with a range of sizes and densities that match nearly all of the hundreds of mini-Neptunes found so far. The results hint that some watery mini-Neptunes may be better explained by supercritical oceans than by hydrogen and helium gas layers. — *Maria Temming*

JAKE SOCHA

Actual size is 30.6 mm

ALL-NEW LIMITED RELEASE 2020

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Teamwork. Sportsmanship. Fitness. Leadership. Integrity. Respect. Perseverance. These are the "Naismith values," created by Dr. James Naismith, the inventor of basketball. 2020 marks the 60th anniversary of the Naismith Memorial Basketball Hall of Fame, and the United States Mint is celebrating with a very special limited release: the U.S. Mint's first-ever curved Basketball Half Dollar!

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The inwardly-curved obverse of the coin displays three athletes reaching for the same ball—symbolizing how basketball brings together people from all walks of life. The outwardly-curved reverse depicts a basketball as it's about to drop through the hoop. And just look at the detail on that ball!

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The 2020 Basketball Hall of Fame Clad Half Dollar has a limited mintage of just 750,000 coins. Meanwhile, CNN reports that as many as 30 million Americans tune in to the NBA Finals each year! That's one coin for every 40 fans!

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Official U.S. Half Dollar

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Habitat loss and human encroachment, such as clear-cutting in the Amazon (shown), are a major threat to biodiversity worldwide. The United Nations is drafting an ambitious new set of conservation targets to safeguard species and prevent further losses.

How much nature needs protecting?

Scientists and governments are discussing ways to stop the extinction crisis

By Jonathan Lambert

Goals under discussion

30 percent of land and sea protected by 2030

50 percent of land and sea protected by 2050

For millions of years, giants graced the murky depths of China's Yangtze River. The Chinese paddlefish (*Psephurus gladius*), which could reach 7 meters in length, used its swordlike snout to sense the electrical perturbations made by smaller prey, snatching them in the dark. But no more.

The fish was declared extinct in 2019, a victim of overfishing and habitat loss.

Its story is being played out across the world. From winding rivers to the windswept tundra to the tropical forests of Borneo, nature is in trouble.

Plants and animals are increasingly threatened by human activities and habitat encroachment. A million species face extinction, many within decades, one study estimates (*SN: 6/8/19, p. 5*). That means 1 million distinct, idiosyncratic answers to the basic question of how to live on planet Earth, gone.

The scale of this potential loss has many countries worried. Aside from its inherent value, the natural world makes the planet livable by cleaning the air, filtering water, cycling carbon dioxide and pollinating crops. So to stem this biodiversity loss, governments are drafting ambitious plans to set aside more space for natural habitats. Nature, after all, needs room to flourish.

A global plan under negotiation envisions designating 30 percent of land and sea as protected by 2030 in an effort to revive ecosystems and safeguard the diversity of species on Earth, according to a draft of the agreement under the U.N. Convention on Biological Diversity. The goal for 2050 is 50 percent protected in some form, for example through parks that restrict human use, or less restrictive but still sustainably managed protected areas.

But is 30 percent, or even 50 percent, enough? And enough for what exactly — to slow extinction rates, or to protect everything that's possible to protect, or something else entirely?

One basic goal is to preserve what's left. Humans have altered more than three-fourths of Earth's surface, and of the 14 terrestrial biomes — such as tropical rainforest, tundra or desert — eight have less than 10 percent of undeveloped wilderness remaining, researchers reported in 2016 in *Current Biology*. Many species have already vanished, including the Chinese paddlefish and the brilliantly blue Spix's macaw (*Cyanopsitta spixii*), not seen in Brazil's forests since 2000.

At least for marine ecosystems, there's research that says tangible benefits can come from the 30 percent target as a starting point. There's less

PHOTOTREAT/GETTY IMAGES PLUS

firm evidence for land. "The scientific consensus is telling us that we need [even] more ambitious targets," says Oscar Venter, a conservation scientist at the University of Northern British Columbia in Prince George. Targeting 30 percent of Earth's terrestrial regions for protection by 2030, he says, is "more a reflection of what's politically feasible, rather than what the best science says."

Eyeing ambitious targets

An idea like this is not unprecedented. In 2010, more than 190 countries agreed to 20 conservation goals, referred to as the Aichi Biodiversity Targets, as part of the U.N. Convention on Biological Diversity.

Those targets include increasing awareness about biodiversity and incorporating the traditional knowledge of Indigenous groups into conservation plans. More directly, governments agreed under the convention to each set aside 17 percent of their land and, for coastal countries, 10 percent of their seas, as protected areas by 2020. (The United States is the only country in the world that has not ratified the agreement.)

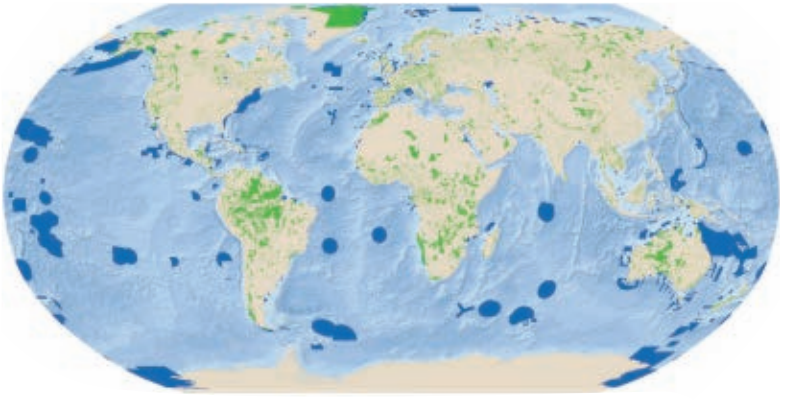
The Aichi Targets acknowledged two key reasons for preserving the planet. "We have a responsibility to be stewards of the planet, because nature is important in and of itself," says Jane Lubchenco, a marine ecologist at Oregon State University in Corvallis and former director of the National Oceanic and Atmospheric Administration. "But also because people benefit directly from healthy, productive and resilient ecosystems and abundant biodiversity."

The targets, while useful for motivating conservation efforts, were "not sufficient," Lubchenco says. Setting targets "often doesn't translate into actually achieving those targets," she says, thanks to uneven coordination between scientists, government officials and other key actors such as the agriculture or fishing industries. And while the agreement required countries to publish action plans, it did not demand reports on actual progress toward achieving the Aichi Targets.

It's close to 10 years since the Aichi agreement, and many targets remain unmet. Currently, about 15 percent of land and 7.4 percent of seas are in some way protected, or in line for protection, according to the U.N. Environment Programme World Conservation Monitoring Centre. Even so, current extinction rates are estimated to be 1,000 times higher than historical levels.

Even common animals, such as American sparrows, have seen their numbers drop in recent decades (*SN: 10/12/19 & 10/26/19, p. 7*). That's led scientists and governments to conclude that the targets set in 2010 didn't go far enough.

Areas under some form of protection in 2020



Protected areas

- Terrestrial
- Marine and coastal

Safe spaces As of May 2020, about 15 percent of land and about 7 percent of the seas were under some level of protection.

SOURCES: U.N. ENVIRONMENT PROGRAMME WORLD CONSERVATION MONITORING CENTRE AND THE INTERNATIONAL UNION FOR CONSERVATION OF NATURE

How much is enough?

Deciding how much of nature should be protected depends on the goal, whether it's keeping a specific animal from going extinct, preserving a unique ecosystem or ensuring the future of commercial fishing stocks. Different goals necessitate different kinds of protected areas.

The size of a protected area "is important, but it's not the only thing that matters," says Samantha Murray, an ocean law and policy expert at Scripps Institution of Oceanography in La Jolla, Calif.

When trying to prevent a specific animal from going extinct, biologists first try to figure out the minimum amount of habitat the species needs to persist. Wide-ranging species like North American caribou need about 10 percent of their natural range to be protected. Rarer species in microhabitats like a single valley or a specific island "typically need much more," Venter says, "potentially all the way up to 100" percent of their range. Figuring out those numbers is tricky, especially for understudied species. Additionally, it can be difficult to design a protected area that meets the diverse range requirements of all the species within it.

Another conservation approach focuses on protecting the rare slices of land and sea brimming with exceptional numbers of species, places like Australia's Great Barrier Reef, the Amazon River Basin and parts of the U.S. Great Smoky Mountains. Protecting these areas means protecting many different animals and plants all at once.

Finally, some conservation biologists argue for preserving vast tracts of wilderness not yet altered by human activity. The expansive boreal forests of Canada and Russia don't harbor as many species as the Amazon, but they do hold up to a third of

WWW.PROTECTEDPLANET.NET/UNEP-WCMC, 2020

the globe's terrestrial carbon and so they play a key role in pulling climate-warming carbon dioxide out of the atmosphere. Protecting these areas, along with other large tracts of wild land, is crucial for solving both the climate crisis and the biodiversity crisis, says Eric Dinerstein, a conservation biologist at RESOLVE, a sustainability nonprofit based in Washington, D.C.

Dinerstein and others argue that the situation is now so dire that all approaches are needed to save what's left. "There are no immutable laws of conservation biology, nothing that says this paradigm for saving nature is better than that paradigm. We need to do it all."

That urgency is reflected in a recent flurry of proposals and analyses by scientists. Biologist E.O. Wilson says in his 2016 book *Half-Earth* that about 80 percent of the planet's biodiversity can be saved by protecting half of the planet. Dinerstein and colleagues laid out a plan in the June 2017 *BioScience* for preserving half the land on Earth in a way that covers a diversity of ecosystems.

Venter and colleagues estimate that targeting a little less than that — about 44 percent — can safeguard biodiversity. The team arrived at that number, in a study posted online at bioRxiv.org in November 2019, by tweaking boundaries around existing protected areas. The result is a protected global patchwork encompassing some of the world's richest areas of biodiversity. The expanded areas contain enough space for the 28,594 species of mammals, birds, amphibians, reptiles, dragonflies and crustaceans the researchers had data for.

Broad and ambitious goals, like preserving 30 percent by 2030, are important for galvanizing international action. "But ambitious targets are only good if countries are strategic in where they place protected areas," Venter says.

Problems with big targets

Indeed, not all biologists agree that setting such targets is the best strategy. "A big single number ... misses what we need to do to protect biodiversity," says conservation biologist Stuart Pimm of Duke University. The key is to focus on saving the places rich in biodiversity that are under imminent threat.

Much of Pimm's work focuses on connecting forest fragments with natural corridors, which can functionally increase an animal's habitat even when protecting more land area isn't feasible. Recent research shows that connecting fragmented habitats can boost biodiversity for both animals and plants (*SN Online: 9/26/19*).

Biodiversity also is not evenly distributed around the globe: Coral reefs, for example, account for less than 1 percent of the ocean floor, but house more than 25 percent of marine life. So having all countries aiming for the same targets might be counterproductive. Some countries may need to protect more than 30 percent of their territory, others less.

"If you're looking at the Amazon, for instance, recent research has shown that we probably need 80 to 90 percent of the Amazon intact," Pimm says. Otherwise, the rainforest may begin a rapid transformation into drier savanna, compromising the water cycle for the whole continent.

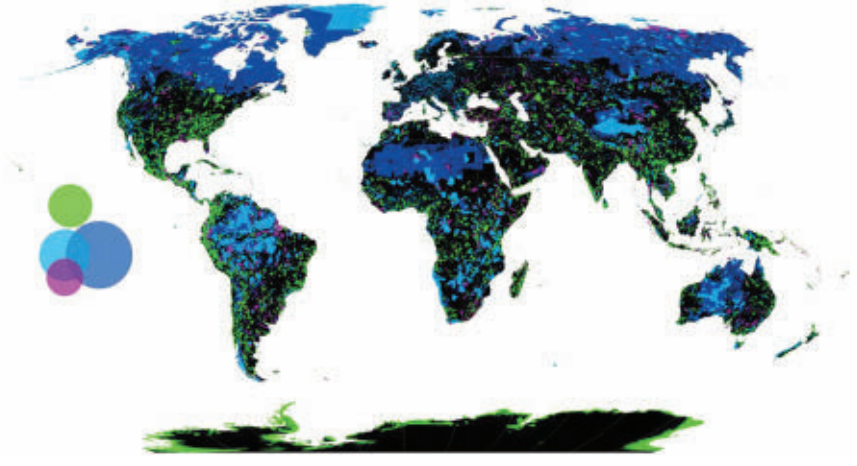
Additionally, countries rushing to meet their goals might only go for the low-hanging fruit. "Areas that are too cold, too hot or too remote" to hold any agricultural or commercial promise are easy targets, but not necessarily the areas most in need of protection, Pimm says.

The United States could get to 30 percent relatively quickly by preserving sparsely populated Western tracts of desert or high plains. Most of the country's biodiversity, however, is in the Southeast. For instance, more endemic salamander species are crawling around Appalachian streams and forests than anywhere else in the world, yet much of the animals' range remains underprotected. Similarly, protecting most of icy Greenland would effectively meet the European Union's 30 percent obligation.

"Large area targets may just encourage countries to protect areas that aren't going to do much for biodiversity," Pimm says. "Do we need to protect more of the planet? Of course, but we should do so in a smart, targeted way."

Expanded map
At least 44 percent of land must be protected or soundly managed to stem the biodiversity crisis, says one research team. To reach that goal would require protecting wilderness (dark blue on map), key biodiversity areas (pink) and new conservation priorities (green), while continuing to maintain existing protected areas (light blue). The Venn diagram shows the degree of overlap between categories.

Where protections exist and where they are needed



J.R. ALLAN *ET AL*/BIORXIV.ORG 2019

What does protection mean, anyway?

Designating a protected area is just the beginning. Protections need to be enforced through policing and prosecuting for illegal fishing, tree felling, hunting or pollution. Otherwise, protections don't work — and conservation efforts fall flat. A 2014 report by the U.N. Environment Programme found that only 22 percent of protected areas investigated were being soundly managed.

Places designated as protected only on paper "can give the illusion of protection where none really exists," says Murray, the Scripps ocean law and policy expert. "We could create the largest marine protected area in the world, but if we just walk away, it doesn't do anyone any good."

Having fully protected national parks across 30 percent of the globe is probably not feasible, conservationists say. But there are other ways of managing land and sea to meet conservation goals.

"Indigenous lands in Canada are a great example," Venter says. Hunting and gathering activities are allowed on these protected lands, but not large-scale habitat clearing. And there is evidence that such an approach works. Indigenous lands in Canada, Brazil and Australia had similar, or slightly higher, levels of vertebrate diversity than non-Indigenous protected areas in the same countries, researchers reported in November 2019 in *Environmental Science & Policy*.

The quarter of Earth's land now owned, used or occupied by Indigenous communities holds about 80 percent of Earth's biodiversity, according to a 2008 World Bank report. So supporting these groups in their efforts to manage their lands could help countries achieve their targets, Venter says.

Moving toward consensus

Still, many biologists say that percentage targets, even if clumsy, are important. Some "countries have taken great pride in getting close or meeting [Aichi] goals," says Hugh Possingham, chief scientist at The Nature Conservancy, who is based in Brisbane, Australia. That work can be a sign of how well countries are preserving nature, but it's not the whole story.

"Relying solely on targets is a bit like relying only on blood pressure to indicate health," Possingham says. He hopes that an eventual agreement incorporates more simple but meaningful metrics, for example, an estimate of how much a country's biodiversity is captured by existing protected areas. "That would give a fuller picture of how well we're doing."

Countries are still months away from finalizing a new agreement. A broad outline of the framework was released in January for months of discussions before the next meeting on the U.N. Convention on Biological Diversity. The timeline for those discussions has been extended due to the ongoing coronavirus pandemic. The meeting, originally scheduled for October in Kunming, China, has been delayed, possibly to 2021.

Parts of the outline suggest the agreement will address some of the failings of the Aichi Targets, says Aleksandar Rankovic, a senior research fellow at the Institute for Sustainable Development and International Relations in Paris. "There has been a strong cooperative spirit," he says. "Most delegations seem intent on improving the agreement."

For example, the outline stipulates that 60 percent of a country's protected areas be "of particular importance for biodiversity." What counts as a site of particular importance remains to be determined, but Rankovic says baking this kind of language into the document is a key step toward ensuring countries protect what needs protecting.

Rankovic hopes the COVID-19 pandemic serves as a wake-up call about the importance of keeping wild environments intact, as recent research links deforestation to the emergence of zoonotic diseases, like COVID-19, in humans.

"The fact that we have a biodiversity-related global pandemic that started where we're supposed to gather to propose ways to solve the biodiversity crisis is quite powerful as a symbol," he says. Reaching a deal "could be a big moment" in preventing a global extinction crisis. "But if we come out more divided, it will be harder to lay the groundwork for solving this crisis." ■

Greenland has the world's largest national park (the mountains at Ofjord in Northeast Greenland National Park shown), protecting nearly 1 million square kilometers of mountainous coast and icy interior. But the country has less biodiversity in need of protecting than other regions.

PETER PROKOSCH/RESOURCES/3977 (CC BY-NC-SA 2.0)

Explore more

- James R. Allan *et al.* "Conservation attention necessary across at least 44% of Earth's terrestrial area to safeguard biodiversity." bioRxiv.org. November 12, 2019.

GARY PEEPLES/USFWS

The Golden Riffleshell's Appalachian Road Trip

Saving an endangered mussel

By Stephen Ornes

The survival of mussel 6420 and thousands of its siblings started with an interstate rescue plan hatched by biologist Tim Lane (shown left).

G. PEEPLES/USFWS

The emergency surgery took place in the back of a modified pickup truck in a McDonald's parking lot in Pikeville, Ky. This scrappy plan to rescue a species of mussel on the edge of extinction made perfect sense: Meet somewhere between Indian Creek in Virginia, where the last known wild golden riffleshells lived, and Kentucky's Center for Mollusk Conservation in Frankfort, where they would be saved.

The strategy was a malacologist's version of a Hail Mary pass. One scientist would gingerly pry open three golden riffleshells and remove their larvae to be nurtured in his lab. The other would return the three mussels to Indian Creek, and wait for the day he could introduce their grown offspring to the same habitat. If the plan didn't produce enough offspring to sustain a new population, the mussels would probably vanish.

Five years ago, Indian Creek was the only known remaining habitat for the golden riffleshell (*Epioblasma florentina aureola*). And like many other mussels, this bivalve's future looked bleak. Biologists estimated that only about 100 remained in the wild. "They were the next species on the list for disappearing from the face of the Earth," says biologist Tim Lane, who leads mussel recovery efforts at the Virginia Department of Wildlife Resources' Aquatic Wildlife Conservation Center, near Marion. "We were literally watching the last of them."

> "They were the next species on the list for disappearing from the face of the Earth."
>
> TIM LANE

Seeing a species vanish in real time is difficult, he says, and is in some ways worsened by the mussels' near-invisibility beneath the surface. "They're not charismatic like, say, the northern white rhino," he says. When mussels go extinct, almost no one knows — or mourns them.

An avid amateur photographer who takes pictures of mollusks, snails, fish and various other small critters in the wild, Lane spends much of his time floating facedown in Appalachian waterways, suspended over rocky riverbeds like a float in the Macy's Thanksgiving Day Parade. He came up with the plan and carried out phase one: delicately prying the bivalves from the Indian Creek riverbed and laying them in a cooler filled with pebbles, dirt and river water for the 90-minute trip to Kentucky.

A full-grown golden riffleshell is about the size of a small biscuit, with a yellowy, fan-shaped case. Like other mussels, it anchors itself in gravel with a fleshy foot and rarely moves more than a few meters during its lifetime, which could last 15 years or more. The sedentary creatures have been listed as a federally endangered species since 1977.

Malacologists, like Lane and others who study mollusks, are accustomed to championing underdogs. More than two-thirds of all identified North American freshwater mussel species are extinct or endangered. North America has the greatest diversity of freshwater mussels — with a heavy concentration in the Southeast. Tennessee's Clinch River hosts about twice as many species as all of Europe.

In every locale, the mussels' problems arise from a mix of factors. Until about a century ago, enormous mussel populations thrived in the Midwest and Southeast, and mussels were often harvested to make shell buttons. But the construction of dams in major rivers divided these populations and separated the creatures from the fish that carry their larvae. "The dams suffocated the huge mussel beds in the most productive habitats," says Paul Johnson, who runs Alabama's Aquatic Biodiversity Center, in Perry County.

Adding insult to injury, rampant pollution from industrial dumping and chemical spills led to massive die-offs before the 1972 Clean Water Act led to cleaner waterways. The animals have faced other threats, too, including microbial pathogens and predators.

Just last December, more than 150 kilometers downstream of the confluence of Indian Creek and the Clinch, biologists with the U.S. Fish and Wildlife Service reported a massive die-off of pheasantshells (*Actinonaias pectorosa*) where the river passes through the town of Kyles Ford, Tenn. The researchers suspect some pathogenic fungi, bacteria or parasites are to blame. Myriad species in Europe and the Pacific Northwest, including the freshwater pearl mussel (*Margaritifera margaritifera*) and the depressed river mussel (*Pseudanodonta complanata*), have experienced similar die-offs.

Against that backdrop of known and unknown hazards, researchers around the world are combining in vitro propagation, months of tedious observation and exhaustive laboratory trial and error to save these animals. But none of these evolving methods offer a quick fix.

"It took us 100 years to get into this mess," Johnson says. "It's not going to take 10 to get out of it."

River cleaners

Those who study and try to save mussels feel an irresistible calling, says Jessi DeMartini, a biologist in Illinois who works on mussel conservation in the Forest Preserve District of DuPage County. "It's an addiction ... that becomes a passion." They see mollusks as the uncelebrated heroes of the world's rivers.

Mollusk shells stabilize riverbeds and create habitats for other creatures. The bivalves provide food to raccoons, muskrats and other critters. Most importantly, mollusks are nature's water filters, able to clean up big messes.

What looks like a tasty, spotted minnow is actually part of a *Lampsilis* mussel. When a fish goes in for a bite of this lure, it inhales a mouthful of mussel larvae that attach to the fish's gills and grow into juveniles.

M. CHRISTOPHER BARNHART

A single mussel can filter more than 50 liters of water per day, removing algae and pollution, including toxic substances dumped into rivers as industrial waste. Some researchers suspect that the ability to sop up toxic metals is contributing to the animals' decline. Like canaries in coal mines, if a mussel population suddenly plummets, it's a sign that something's gone foul in the water. (Malacologists describe the smell of a living mussel as rich and sweet, like the river it comes from. But find a dead mussel and the stench is so bad you'd wish you had been born without a sense of smell.)

50+
liters
Amount of water a single mussel can filter in a day

By observing the health of juvenile mussels and analyzing tissue samples, researchers can effectively monitor water quality and acute die-offs, Monte McGregor, director of Kentucky's Center for Mollusk Conservation, and others reported in December 2019 in *Freshwater Science*.

The effort to save mussels has implications far beyond the rural and rugged riverways of Appalachia. More than two-thirds of U.S. homes get their drinking water from rivers, Johnson notes. Mussels provide an inexpensive way to safeguard that resource and do some of the work of water treatment plants. "Mussels allow us to provide cleaner water on a less per-cost basis," he says.

For all these reasons, conservation biologists keep returning to the rivers and take hope where they can find it. The golden riffleshell has been particularly vexing. To even begin the process of mussel propagation, which has a high rate of failure, biologists typically need to start with larvae, also known as glochidia. The golden riffleshell's dwindling numbers mean

that finding a gravid female — one filled with glochidia — is a rare occasion. But on an April morning in 2016, hope came with a find by Sarah Colletti, a mussel-loving biologist also at Virginia's Aquatic Wildlife Conservation Center. Colletti had joined a small squad of biologists who donned tall rubber waders and spent hours hunched over viewscopes, which look like toy telescopes, pointed down into water to make it easy to tell rocks from mussels. Colletti was scanning the bottom of Indian Creek as part of what's become an annual ritual, the search for the last remaining golden riffleshells.

It's a monotonous pursuit, she says, and "you're second-guessing every rock." When a mussel comes into view, "it's kind of shocking."

Through her viewscope, Colletti spotted three golden riffleshells nestled among the rocks and silt. All were females displaying their lure, a section of tissue that resembles a tasty meal. Those exposed lures meant the mussels were gravid, ready to release millions of glochidia. Finding three gravid females was unusual. The biologists saw an opportunity — maybe one of the last — to help.

Alluring display

Just getting to the larval stage is an accomplishment for these bivalves. Eggs become fertilized only when females filter sperm released into the water by upstream males.

Glochidia, each the size of a grain of salt, can't survive on their own. They have to clamp onto the gills of a host fish and become parasitic passengers, embedding themselves in the gill tissue and thriving on a mix of nutrients in the water and in fish blood until undergoing a kind of metamorphosis.

As mussels grow their first shells and become juveniles, they swell to the size of a well-fed deer tick, then drop from the fish. For each species of mussel, there's often only one — or at most, a few — species of fish that can ferry larvae to the next stage of life.

Mussels have evolved a staggering array of methods for infesting fish; almost all involve deception. Some mussels disguise their glochidia in alluring packages that look like minnows; others unspool wormlike appendages tipped with packets holding millions of larvae. The rainbow mussel (*Villosa iris*) has a lure that looks like a crawfish skittering along the river floor. When a fish tries to eat the minnow or worm or crawfish, the fish gets a mouthful of glochidia, released like dandelion seeds. With the fish's next gulp of water, the glochidia wash over the gills and stick.

Members of the genus *Epioblasma*, including the golden riffleshell, have perfected a tactic that earned them the nickname "fish snapper." The ritual begins when a mother mussel sends out a short thread, the end of which looks like a bug. When a hungry fish swims in for a bite, the shell snaps shut around the fish's head and holds tight with short, sharp teeth just inside the shell's rim. As the fish chokes, it inhales the glochidia, which install themselves in the gills. After a few minutes, the mussel relaxes and releases its captive. The fish that survive are stunned; smaller fish (which aren't good hosts anyway) may die, their heads crushed by the mollusk's snap.

The handoff

All the pieces of this choreographed sequence — fertilization to glochidia formation to infestation of a host — have to happen in just the right way, says McGregor, who with fellow Kentucky biologist Leroy Koch was waiting at the McDonald's for Lane to arrive. "There are lots of strikes against these mussels," he says. "The glochidia have to hit the right fish at the right time."

Ideally, mussels would reproduce on their own and people wouldn't have to intervene. Malacologists step in when a species looks like it's on the brink of extinction.

BOTH: M. CHRISTOPHER BARNHART

A snuffbox mussel snaps shut on the head of a rainbow darter (shown left), giving the snuffbox larvae, or glochidia, enough time to attach to the fish's gills. A closeup photo (right) shows nearly clear glochidia of an oyster mussel attached to the pink gills of a logperch.

That morning in April, Colletti marked the location of the mussels in the stream with three large stones and a bright orange flag. She phoned Lane, who had spent much of graduate school studying the diversity of life in Appalachian rivers. The golden riffleshell always seemed to be foundering. In previous years, when they found gravid females in Indian Creek, Lane and colleagues had attempted streamside infestations: catching host fish and manually transferring glochidia from the mussel into the fish gills. But the approach didn't work.

Lane called McGregor, who was well-known in the close-knit malacology community for having pioneered in vitro approaches to bring bivalves back. Biologists have sent him glochidia in test tubes via UPS and FedEx; he's also been known to drive for hours to secure the larvae. At Kentucky's Center for Mollusk Conservation, he closely monitors the temperature and quality of the water that flows through the lab, and he makes his own food for the mussels — often customizing a recipe to fit the needs of a species. After Lane called and proposed the plan, McGregor agreed to meet in Pikeville and carry out the glochidia-removing procedure in what he calls his "mobile lab" (the topped bed of his Ford F-250 super duty crew cab).

Biologists have developed methods of propagating endangered mussel species in the lab, even without the host fish. To remove glochidia, scientists pry open the shell (top), then hold it open with a silicone wedge (bottom) to flush out the larvae with sterile water.

BOTH: T. LANE

Surgery took no more than 30 minutes per mussel. McGregor pried open the shell about five millimeters with his fingers, and used a silicone wedge to keep it open. Then, he filled a syringe with sterile water and flushed out the glochidia from the mussels into a lab dish. All the while, he had to pay attention to the patient and keep it cool.

"You have to handle the mussel properly," McGregor says. If the animal gets too warm, that could imperil both the larvae and the mother.

Once the procedure was over, Lane replaced the mussels in the cooler and drove east to return them to Indian Creek. McGregor drove west, escorting thousands of golden riffleshell larvae over 260 kilometers of twisting mountain roads, to the mussel recovery operation with the longest track record for propagating mussels in the lab without host fish. This would be the golden riffleshell's best chance at survival.

Take me to the river

For nearly 20 years, researchers at the Kentucky facility have worked on bringing mussels back from the brink of extinction. The small collection of buildings sits near Elkhorn Creek, but McGregor says the water is often too polluted to use for the tanks that hold mussels during the most sensitive part of their development. The pollutants include raw sewage. "We can't grow mussels in raw sewage," he says.

If such a thing as "artisanal algae" exists, it's surely the stuff grown in this lab. Researchers grow algal cultures in giant incubators. McGregor has grown many algal varieties and has spent years matching the right algal slime to the right mussel.

McGregor learned the basics of in vitro propagation in 2004 from Robert Hudson, a malacologist at Presbyterian College in Clinton, S.C. By 2016, McGregor had spent more than a decade improving his recipe, finding the right mix of algae, nutrients and rabbit serum to feed glochidia. Although he prefers to use host fish to grow mussels — and the lab contains dozens of tanks that hold fish as hosts for some other species — scientists have so far been unable to identify the fish that can carry golden riffleshell larvae (which is why streamside infestation doesn't work).

So McGregor had to grow the larvae without a host. After 18 days in an incubator with McGregor's custom-made mussel-growing cocktail, about 1,600 larvae survived to become juveniles. They were transferred to silt-lined raceways with cool flowing water to simulate a river. Within a few months, the glochidia had grown to the size of nickels — large enough to survive in the wild.

McGregor divided the spoils. "It was too risky for me to keep them all," he says. He sent groups of mussels back over the mountains to two facilities in Virginia. One is the Aquatic Wildlife Conservation Center, where Colletti and colleagues have been studying and cultivating the bivalves. In a typical year, researchers there release up to 10,000 lab-grown mussels into the wild, representing up to 10 species.

Colletti says she sees signs of hope for the golden riffleshell. Today, the progeny of those three mussels she found in 2016 are producing their own glochidia in the lab. "They were able to become gravid in captivity," she says. Lane recently sent photos of those larval grandchildren to McGregor. Colletti and Lane hope the young mussels released into the river will do as well.

There are other, scattered success stories emerging from recent mussel projects. Johnson, in Alabama, has spent years studying the pale lilliput (*Toxolasma cylindrellus*).

After more than two years of work, Johnson pegged the northern studfish (*Fundulus catenatus*), which looks like a larger, prettier version of a minnow, as the pale lilliput's host. Once he made that connection, Johnson began to infest a host fish to cultivate new populations of the endangered species.

There are also big risks. Last year, Johnson propagated about 5,000 juveniles of the rare Louisiana pearshell mussel (*Margaritifera hembeli*). But just before he was going to release juveniles into a Louisiana river, disaster struck. On an unusually hot spring morning, the temperature of the water streaming into his facility's raceways soared, killing thousands of the mussels before a researcher could close the valve. "One bad day can literally wreck several years of work," Johnson says.

He was left with only about 100 animals to return to nature. But those animals have been thriving in the lab. Johnson has grown new batches and plans to restore them to their natural habitat next year. It's too soon to declare victory, he says, but he's hopeful.

The ultimate goal in mussel conservation, Johnson says, is to propagate animals that can complete an entire life cycle. That means glochidia get to the host fish, survive the tumultuous juvenile years and mature enough to reproduce. In the wild, the whole process takes a few weeks to a few months. In the lab, the timescale is bigger. "It's a decadeslong effort," he says.

This gravid golden riffleshell began as a larva in Indian Creek, grew up in a Kentucky lab and is now in a Virginia lab. Its parted shell reveals pouches containing tiny larvae ready to infest an unwitting host fish.

FROM TOP: G. PEEPLES/USFWS; T. LANE

Biologist Sarah Colletti found three gravid golden riffleshell females in Virginia's Indian Creek in 2016, setting off a chain of events that might give the endangered species a chance at survival.

Hundreds of the next generation of golden riffleshells are now back at home, with two populations in the Clinch River and one in Indian Creek since 2017. These mussels now measure about the size of a quarter, though some are bigger. Of the 700 that Lane, Colletti and others installed in the wild, many have died and some are unaccounted for, but the researchers estimate that about 300 are still alive.

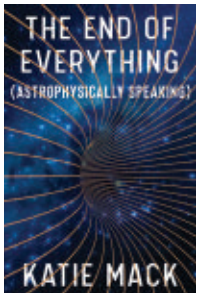
The scientists placed transponders on about 100 of the mussels, and every year Lane and Colletti return for a census, waving a device that looks like a metal detector over the water surface and waiting for the satisfying chirp that indicates a lab-grown riffleshell is found.

For now, the rescue of the golden riffleshell remains a good news story, but Lane says malacologists have to remain vigilant. "This gives us some time, but it's not like we can pat ourselves on the back and stop." To ensure the survival of the species, biologists will need to continue harvesting glochidia, shepherding mussels to the juvenile stage and returning them to the wild, year after year. The ultimate goal is to build a population that can sustain itself and reproduce without human intervention, rabbit serum or emergency surgery outside a rural McDonald's. ■

Explore more

- USFWS. "America's mussels: silent sentinels." www.fws.gov/midwest/endangered/clams/mussels.html

Stephen Ornes is a freelance science writer based in Nashville.



The End of Everything
Katie Mack
SCRIBNER, $26

BOOKSHELF

What to expect from the universe's demise

Eventually, the universe will end. And it won't be pretty.

The universe is expanding at an accelerating clip, and that evolution, physicists expect, will lead the cosmos to a conclusion. Scientists don't know quite what that end will look like, but they have plenty of ideas. In *The End of Everything*, theoretical astrophysicist Katie Mack provides a tour of the admittedly bleak possibilities. But far from being depressing, Mack's account mixes a sense of reverence for the wonders of physics with an irreverent sense of humor and a disarming dose of candor.

Some potential finales are violent: If the universe's expansion were to reverse, the cosmos collapsing inward in a Big Crunch, extremely energetic swells of radiation would ignite the surfaces of stars, exploding them. Another version of the end is quieter but no less terrifying: The universe's expansion could continue forever. That end, Mack writes, "like immortality, only sounds good until you really think about it." Endless expansion would beget a state known as "heat death" — a barren universe that has reached a uniform temperature throughout. Stars will have burned out, and black holes will have evaporated until no organized structures exist. Nothing meaningful will happen anymore because energy can no longer flow from one place to another. In such a universe, time ceases to have meaning.

Perhaps more merciful than the purgatory of heat death is the possibility of a Big Rip, in which the universe's expansion accelerates faster and faster, until stars and planets are torn apart, molecules are shredded and the very fabric of space is ripped apart.

If the universe culminates in a Big Rip, galaxies, stars, planets and spacetime itself would be torn apart, as illustrated. That's just one of several possible end times discussed in *The End of Everything*.

NICOLLE R. FULLER/SCIENCE SOURCE

These potential endings are all many billions of years into the future — or perhaps much further off. But there's also the possibility that the universe could end abruptly at any moment. That demise would not be a result of expansion or contraction, but due to a phenomenon called vacuum decay. If the universe turns out to be fundamentally unstable, a tiny bubble of the cosmos could convert to a more stable state. Then, the edge of that bubble would expand across the cosmos at the speed of light, obliterating anything in its path with no warning. In a passage a bit reminiscent of a Kurt Vonnegut story, Mack writes, "Maybe it's for the best that you don't see it coming."

Already known for her engaging Twitter personality, public lectures and popular science writing, Mack has well-honed scientific communication chops. Her evocative writing about some of the most violent processes in the universe, mixed with her obvious glee at the unfathomable grandness of it all, should both satisfy longtime physics fans and inspire younger generations of physicists.

Reading Mack's prose feels like learning physics from a brilliant, quirky friend. The book is sprinkled with plenty of informal quips: "I'm not going to sugarcoat this. The universe is *frickin' weird*." Readers will find themselves good-naturedly rolling their eyes at some of the goofy footnotes and nerdy pop-culture references. At the same time, the book delves deep into gritty physics details, thoroughly explaining important concepts like the cosmic microwave background — the oldest light in the universe — and tackling esoteric topics in theoretical physics. Throughout, Mack does an excellent job of recognizing where points of confusion might trip up a reader and offers clarity instead.

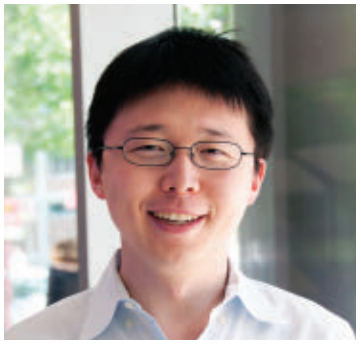
Mack continues a long-standing tradition of playfulness among physicists. That's how we got stuck with somewhat cheesy names for certain fundamental particles, such as "charm" and "strange" quarks, for example. But she also brings an emotional openness that is uncommon among scientists. Sometimes this is conveyed by declarations in all caps about how amazing the universe is. But other times, it comes when Mack makes herself vulnerable by leveling with the reader about how unnerving this topic is: "I'm trying not to get hung up on it ... the end of this great experiment of existence. *It's the journey*, I repeat to myself. It's the journey."

Yes, this is a dark subject. Yes, the universe will end, and everything that has ever happened, from the tiniest of human kindnesses to the grandest of cosmic explosions, will one day be erased from the record. Mack struggles with what the inevitable demise of everything means for humankind. By contemplating the end times, we can refine our understanding of the universe, but we can't change its fate.
— *Emily Conover*

STEM Leaders

Lara Glass | ISEF 2006

Divya Nag | ISEF 2007, 2009



Feng Zhang | ISEF 1998, 1999; STS 2000

Adam Bly | ISEF 2006

Alumni Offer Optimism at Society's First Virtual Regeneron ISEF

Every year at Society for Science & the Public's International Science and Engineering Fair (ISEF), alumni play vital roles, including volunteering, speaking on panels, judging finalist projects and supporting the fair as partners.

And in keeping with their enthusiasm for the fair, Society alumni adapted with us at the first Virtual Regeneron ISEF, sharing their experiences and advice on virtual panels and on social media as well as by engaging finalists from across the world about their research.

Early in the week, in an unexpected marriage of ISEF and health policy, **Lara Glass** (ISEF 2006), Student Program Fellow at Harvard University's Memorial Church, shared how she developed a social distancing model at her high school for her ISEF project. The model ultimately helped shape social distancing guidelines established during the COVID-19 pandemic.

In an age of uncertainty due to COVID-19, Society alumni in entrepreneurship weighed in across panels on how finalists and others with a product can scale and commercialize their research. They also addressed the shifting investor mind-set and how entrepreneurship is evolving. Panelists spoke on the need for people to remain resilient and resourceful in response to the pandemic. **Divya Nag** (ISEF 2007, 2009), Director of Health at Apple, summed up this sentiment: "Necessity is the mother of innovation. I see this moment as one of those crucial inflection points."

The week also featured Nobel laureates, MacArthur Fellows and **Feng Zhang** (ISEF 1998, 1999; STS 2000), who is known for his breakthrough work on CRISPR/Cas9. Zhang discussed how gene editing could be an effective way to combat COVID-19. He also reflected on the optimism he has witnessed in response to the pandemic within the scientific community, likening the current collegiality between companies to that of his student science competition days at ISEF and the Science Talent Search.

Audiences were even treated to a one-on-one interview between **Adam Bly** (ISEF 2006), Founder & CEO of System and Former Vice President of Data at Spotify, and Vint Cerf, internet pioneer and Google Vice President and Chief Internet Evangelist. They discussed misinformation dissemination across the Web and how to prevent it from happening.

Virtual Regeneron ISEF offered a unique and unprecedented opportunity for the Society community to come together and for alumni to connect on a world stage. In that vein, the Society's alumni program is excited to bring content to its global alumni constituency more regularly as we look to models that will allow for broader audience participation in Society alumni events.

JUNE 6, 2020

Antibody mysteries

Antibody tests can help reveal who has been infected with the coronavirus, but the tests don't say whether the antibodies protect against future infections, ***Erin Garcia de Jesus*** *reported in "So many questions on antibody testing"* (SN: 6/6/20, p. 22).

Reader **Bob Reckers** asked if antibodies for cold-causing coronaviruses, which are detectable by the coronavirus antibody tests, could bind to the coronavirus. "This could explain the wide variations in severity of COVID-19 infections," he wrote. "People who recently had a [cold] ... might have some level of protection."

Antibodies produced in reaction to some colds certainly could bind to the coronavirus that causes COVID-19, says **Garcia de Jesus**. But those antibodies don't appear to last long. It's unclear whether antibodies from a recent cold would offer protection or worsen COVID-19 symptoms, she says. For dengue viruses, antibodies sometimes can lead to severe symptoms. When people who have had dengue are infected with a different strain, antibodies from the previous infection help the new virus invade cells, putting those people at higher risk for severe symptoms. "There's no evidence in people either way for COVID-19, and not enough time has passed for researchers to fully study this question," **Garcia de Jesus** says.

Public health and privacy

Cell phone apps that have helped South Korea and China get a grip on the coronavirus' spread could help public health workers in the United States, ***Jonathan Lambert*** *reported in "A sprint to contact tracing"* (SN: 6/6/20, p. 19).

To comply with contact tracing apps, people in the United States must know that their privacy is protected, reader **Cielo DeCastro** noted. "It must be made explicit that identification between devices is anonymized and securely stored in encrypted form to prevent violation of privacy. The application should not gather any other information or track one's geolocation," he wrote. **DeCastro** acknowledged that phone tracking may be necessary for public health, "but the people's right to privacy must not be overlooked."

Lambert agrees that privacy around contact tracing apps is a major issue. The TraceTogether app mentioned in the story uses anonymized data gained through proximity tracking, whereby a phone exchanges encrypted data via Bluetooth with nearby phones. This method is considered less invasive than the geolocation tracking used by many apps on our phones (*SN: 2/3/18, p. 18*).

In June, U.S. legislators introduced the Exposure Notification Privacy Act. This bill would require anyone who operates a contact tracing app to collaborate with public health officials, make app use voluntary and prevent commercial use of data collected by the apps.

Chimera concerns

Scientists coaxed human stem cells into populating various organs and blood of growing mouse embryos, ***Laura Sanders*** *reported in "Mouse embryos host human cells"* (SN: 6/6/20, p. 7).

The story "made my skin crawl," reader **Jerome Knies** wrote. "What kind of moral supervision governs such experimentation?" he asked.

Little clarity exists, **Sanders** says. "Individual countries have an array of guidelines for conducting human chimera experiments, and individual research institutions often have their own approval committees," she says. For what it's worth, the International Society for Stem Cell Research highlights two potential concerns: chimeras with humanlike brains and chimeras that can pass human genes to offspring. "The organization flagged those scenarios as ones that require careful ethical considerations," **Sanders** says.

Correction

"Quantum computing's error problem" (*SN: 6/20/20, p. 18*) explained how two photons within a superconducting microwave cavity might represent a value of 0, with four qubits representing 1. This is incorrect. Four photons would represent 1.

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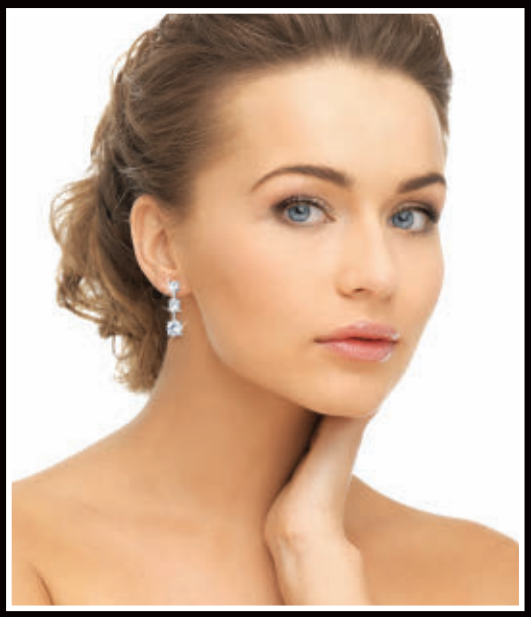

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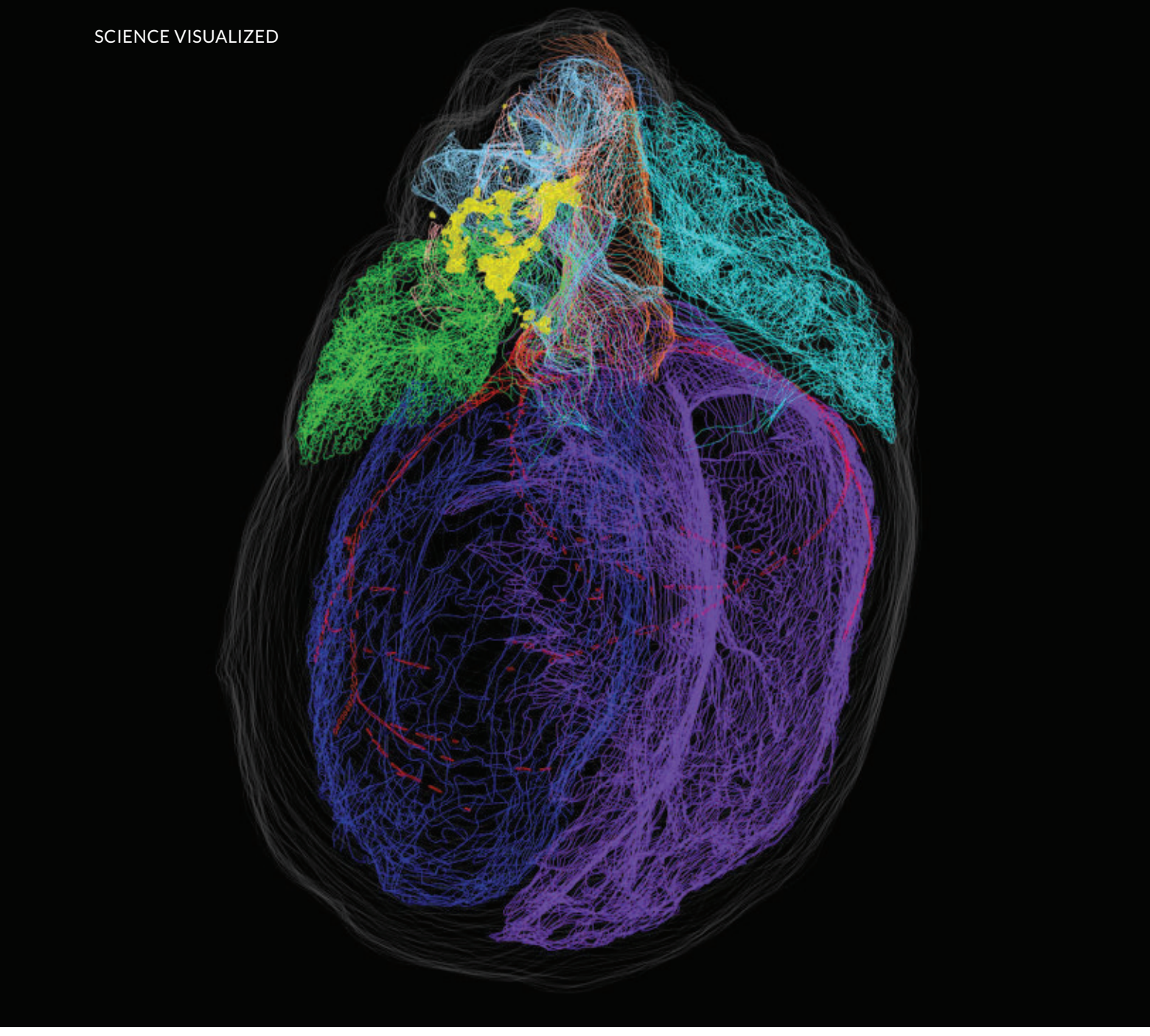

See the 'little brain' of the heart

The heart has its own "brain," a group of nerve cells known as the intracardiac nervous system. Now, scientists have drawn a detailed 3-D map of this nervous system in rat hearts.

The heart's big boss is still the brain, but nerve cells in the heart have a say, too. These neurons are thought to play a crucial role in heart health, helping to fine-tune heart rhythms and perhaps protecting people against certain kinds of heart disease. But this local control system hadn't been described in great detail, until now.

Systems biologist James Schwaber of Thomas Jefferson University in Philadelphia and colleagues used knife-edge scanning microscopy and genetic analyses to map the nerve cells in 3-D. In a reconstructed rat heart (shown from the back, above), nerve cells (yellow) that make up a heart's "brain" cluster around the top of the heart, near where blood vessels enter and exit. These clusters are abundant on the heart's left side and down the back of the left atrium (green). Other colors show the contours of other heart areas, including the right atrium (teal), left ventricle (blue) and right ventricle (purple).

The new map could ultimately lead to targeted therapies that could treat or prevent heart diseases, Schwaber and colleagues write in the June 26 *iScience*. — *Laura Sanders*

S. ACHANTA *ET AL*/*ISCIENCE* 2020

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Disinfect frequently touched objects.

Wash up after being in public spaces.

Stay about six feet away from others.

If you're sick, stay home and away from others.

If you have symptoms of fever, dry cough and shortness of breath, call your health care provider before going to their office.

We are all at risk, and some more than others. In challenging times, the choices you make are critical. And their impact is significant. Help slow the spread of coronavirus.

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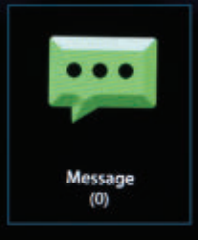

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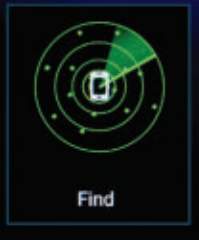

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