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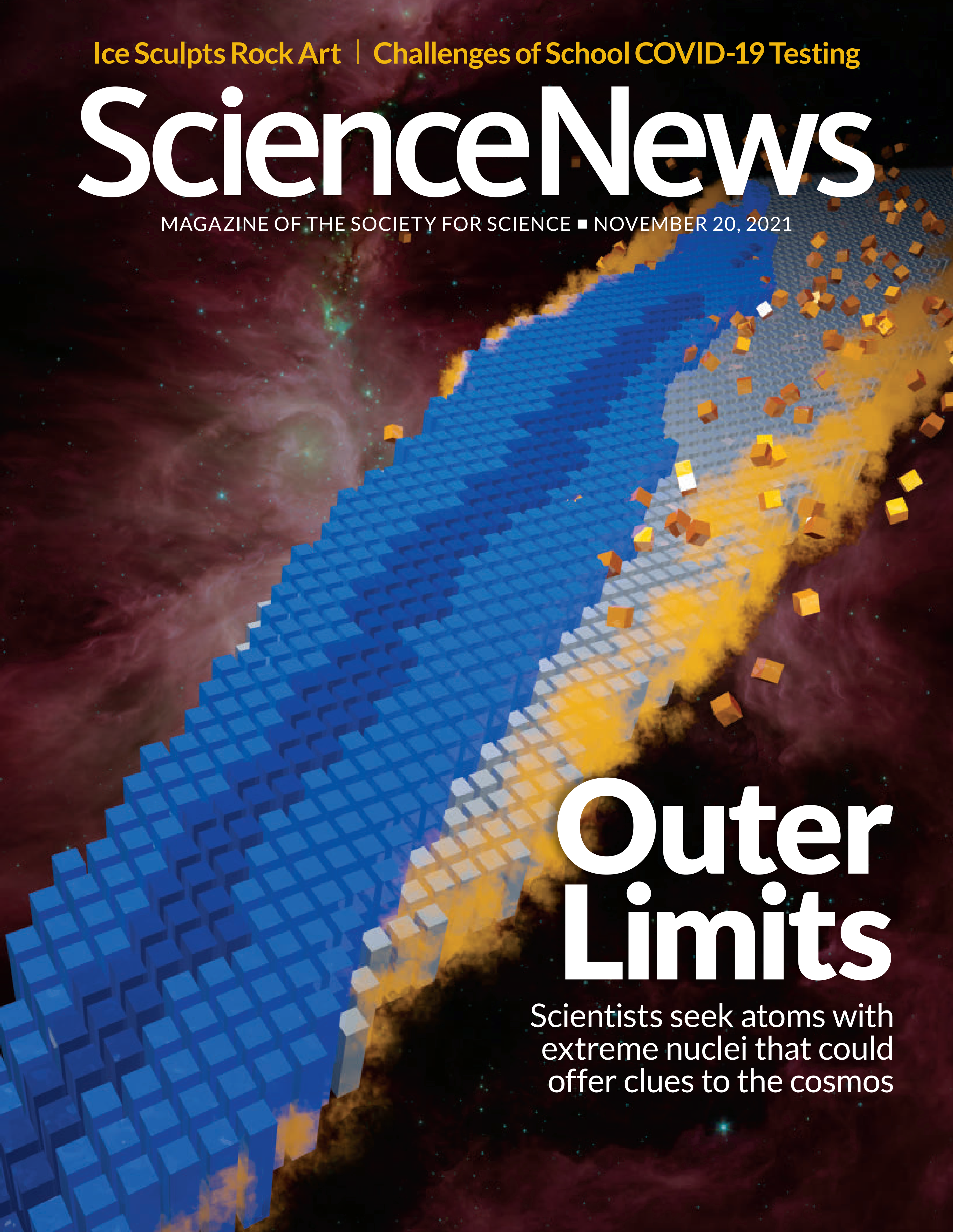
Science News

MAGAZINE OF THE SOCIETY FOR SCIENCE ■ NOVEMBER 20, 2021



Outer Limits

Scientists seek atoms with extreme nuclei that could offer clues to the cosmos

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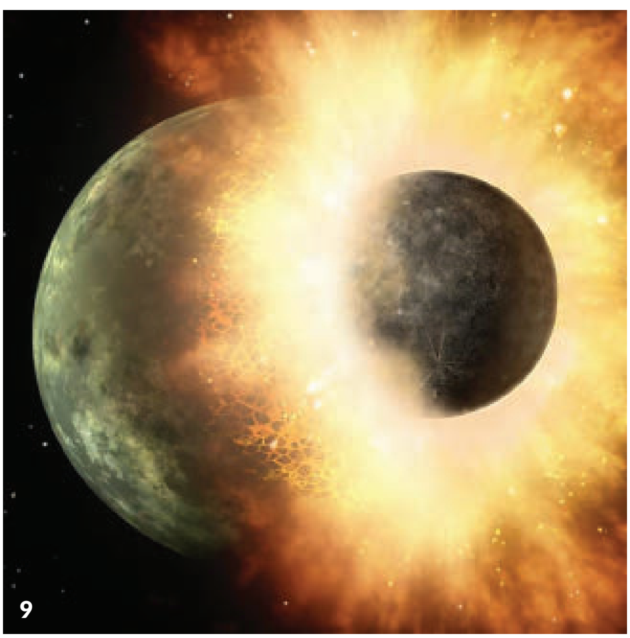
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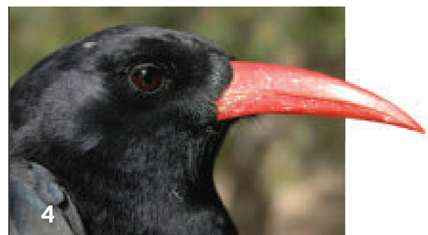
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Departments

COVER Physicists are probing the extreme edge of the chart of isotopes, where atomic nuclei are least stable. *Erin O'Donnell/National Superconducting Cyclotron Laboratory, Andy Sproles/Oak Ridge National Laboratory*

FROM TOP: JON CHERRY/GETTY IMAGES; GUILLERMO BLANCO; JPL-CALTECH/NASA

How analogies can make complex science clear

Many writers and editors at *Science News* have advanced degrees in the sciences. I am not one of them. So when I read an article on a subject like epigenetics or quantum physics, I expect that I've got my work cut out for me.

Fortunately, our journalists are adept at explaining complex concepts in ways that are clear and engaging without dumbing them down. This issue's cover story, "In search of extreme nuclei" (Page 20), is a prime example. It's about physicists building a new particle accelerator in a quest to find rare isotopes of elements — a fascinating tale but one that I'm guessing many of us are hearing for the first time.

As I read the story, I was struck by how physics writer Emily Conover, one of our senior writers, used metaphors to guide me through this alien territory. I never felt lost, and the journey was a delight. For instance, when describing the neutron drip line, a boundary beyond which an atom's nucleus has more neutrons than it can contain, Conover writes: "Imagine a greedy chipmunk with its cheeks so full of nuts that when it tries to shove in one more, another nut pops right back out."

I asked Conover how she came up with this delightful analogy, and she said it just popped into her head. "I had recently watched a YouTube video of a chipmunk greedily stuffing nuts into its mouth," she said. "But then there are other times when you have to sit down and think of something to compare, because you have such a complex topic you really need an analogy for people to grasp what you're talking about."

Sometimes the scientists help out. The simile comparing the difficulty of accelerating ions to herding cats came from Thomas Glasmacher, the laboratory director for the new particle accelerator, the Facility for Rare Isotope Beams at Michigan State University. "They also have to explain their very complicated research to the public," Conover said. "I'll take their tricks when they give them to me." Conover had fun with the concept, carrying the notion even further by adding that "rather than cat food, electromagnetic forces get [the ions] moving en masse."

Conover is trained as a particle physicist, and she takes care to remember that most of our readers don't share her level of expertise. "I try to step back all the time when I'm writing to keep in mind the perspective of someone who doesn't know anything about this topic. I have to be like, 'Oh yeah, a normal person does not know this.' "

And she makes sure any analogy she uses passes muster with the scientists too. "It can't be something that a physicist would read and say, 'No, it's not like that.' You're making it clear for the reader while also making it correct."

I'll end with a vexing logistical update. Global supply chain disruptions have made it difficult for us to get the usual paper stock for *Science News*. Thus the pages in this issue are a bit glossier than usual. Paper shortages and postal delays may also hold up the magazine's arrival. We're doing our best to get it to you ASAP. In the meantime, please visit our website at www.sciencenews.org to keep up on the latest discoveries. *— Nancy Shute, Editor in Chief*

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Sacred Stone of the Southwest is on the Brink of Extinction

Centuries ago, Persians, Tibetans and Mayans considered turquoise a gemstone of the heavens, believing the striking blue stones were sacred pieces of sky. Today, the rarest and most valuable turquoise is found in the American Southwest— but the future of the blue beauty is unclear.

On a recent trip to Tucson, we spoke with fourth generation turquoise traders who explained that less than five percent of turquoise mined worldwide can be set into jewelry and only about twenty mines in the Southwest supply gem-quality turquoise. Once a thriving industry, many Southwest mines have run dry and are now closed.

C.

We found a limited supply of turquoise from Arizona and snatched it up for our ***Sedona Turquoise Collection***. Inspired by the work of those ancient craftsmen and designed to showcase the exceptional blue stone, each stabilized vibrant cabochon features a unique, one-of-a-kind matrix surrounded in Bali metalwork. You could drop over $1,200 on a turquoise pendant, or you could secure 26 carats of genuine Arizona turquoise for **just $99**.

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Excerpt from the November 27, 1971 issue of *Science News*

50 YEARS AGO

Environmental advertising

A new report published by the Council on Economic Priorities clearly outlines facts showing that much corporate advertising on environmental themes is irrelevant or even deceptive.... A large percentage of the environmental advertising comes from companies that are the worst polluters.

UPDATE: Concerns about "greenwashing," a term coined in the 1980s to describe the practice of organizations marketing their products as environmentally friendly when they are not, have persisted into the current climate crisis. As more consumers have become environmentally conscious, corporations' greenwashing tactics have evolved. For instance, some energy companies in the United States have claimed that natural gas is a "clean" energy source because the power plants emit less carbon dioxide than coal plants. But natural gas plants can emit large amounts of methane, a potent greenhouse gas. In 2022, the U.S. Federal Trade Commission plans to review its "Green Guides," rules for companies that make environmental claims.

The red-billed chough is hard to hunt during the day. But the bird's roosting habits might have made it easy prey for Neandertals to catch bare-handed.

THE SCIENCE LIFE

Neandertal role-play hints at ancient hunting tactics

Juan Negro crouched in the shadows just outside a cave. For a moment, he wasn't an ornithologist at the Spanish National Research Council's Doñana Biological Station in Seville. He was a Neandertal intent on catching dinner. As Negro waited in the cold, dark hours of the night, crow-like birds called choughs entered the cave. The head lamp–wearing "Neandertal" then snuck in and began the hunt.

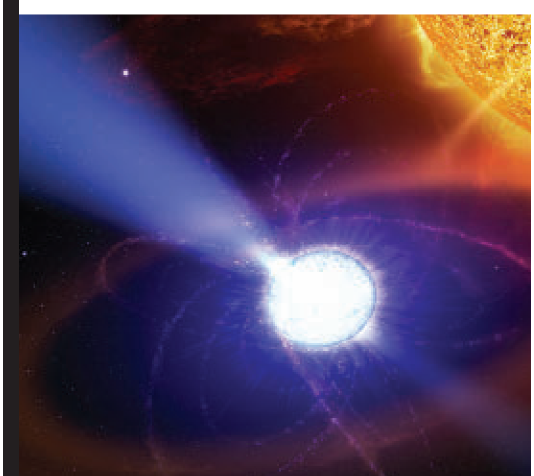
This idea to role-play started with butchered bird bones. Piles of ancient tool- and tooth-nicked chough bones have been found in the same caves that Neandertals frequented, suggesting that the ancient hominids chowed down on the birds. But catching choughs is tricky. During the day, they fly far to feed on invertebrates, seeds and fruit. At night though, the birds are practically sitting

THE –EST

A star twirls ultrafast with a little help from a friend

A white dwarf 2,000 light-years from Earth spins every 25 seconds, making it the fastest-spinning star ever seen — unless you consider such exotic objects as neutron stars and black holes, some of which spin even faster, to be stars (*SN: 3/17/07, p. 173*). The typical white dwarf takes hours or days to spin.

The fast-spinning white dwarf, part of a binary named LAMOST J024048.51+195226.9 in the constellation Aries, gets its whirl from a red dwarf star that revolves around it. Just as falling water makes a waterwheel turn, gas falling from the red companion star makes the white dwarf twirl.



Some white dwarf stars (one illustrated, center) twirl thanks to companion stars (upper right) dumping gas onto them, including the fastest-spinning white dwarf ever seen.

Astronomer Ingrid Pelisoli of the University of Warwick in Coventry, England, and colleagues detected a periodic blip of light from the duo. The blip repeated every 24.93 seconds, revealing the white dwarf star's record-breaking rotation period, the researchers report August 26 at arXiv.org.

The star's only known rival is an even faster-spinning object that may be a white dwarf in orbit with the blue star HD 49798. But that rapid rotator's nature is unclear: Some recent studies suggest it is probably a neutron star instead. — *Ken Croswell*

FROM TOP: GUILLERMO BLANCO; CASEY REED/NASA ducks: Choughs roost in groups and often return to the same spot, even if they've been disturbed or preyed on there before.

So the question was, how might Neandertals have managed to catch these avian prey?

To find out, Negro and colleagues decided to act like, well, Neandertals. Wielding bare hands along with butterfly nets and lamps — proxies for nets and fire that Neandertals may have had at hand (*SN: 5/9/20 & 5/23/20, p. 5*) — teams of two to 10 researchers silently entered into caves and other spots across Spain where the birds roost to see how many choughs they could catch.

Using flashes of light to resemble fire, the "Neandertals" dazzled and confused the choughs. The birds typically fled into dead-end areas of the caves where they were easily caught, often bare-handed. Hunting expeditions at 70 sites snared more than 5,500 birds in all, the researchers report September 9 in *Frontiers in Ecology and Evolution*. The birds were then released unharmed. It was "the most exciting piece of research" Negro says he's ever done.

Red-billed choughs, captured in experiments to see how Neandertals might have hunted, sit in a sack. The birds were released unharmed.

The findings not only demonstrate that people can nab choughs without fancy tools at night, but they also offer an approach that Neandertals may have used to capture the birds. Actual Neandertal bird-catching behavior, however, remains unknown. If this is in fact how Neandertals hunted, it adds to claims that their behavior and ability to think strategically was more sophisticated than they are often given credit for.

Previous studies have suggested that Neandertals may have been adept at foraging for seafood (*SN: 4/25/20, p. 12*) and could have hurled spears to hunt prey at a distance (*SN: 3/2/19, p. 14*).

Negro and his chough-hunting colleagues used butterfly nets to catch birds fleeing sites with narrow entrances, as well as bigger nets partially covering larger openings. But "the easiest thing was to grab the birds by hand," he says.

"You have to be intelligent to capture these animals, to process them, to roast and eat them," Negro notes. "We tend to think that [Neandertals] were brutes with no intelligence, but in fact, the evidence is accumulating that they were very close to *Homo sapiens*." — *Trishla Ostwal*

THE EVERYDAY EXPLAINED

Why baby ducks swim in a line

There's physics to having your ducklings in a row. By paddling in an orderly line behind their mother, baby ducks can take a ride on the waves in her wake. That boost saves the ducklings energy, researchers report in the Dec. 10 *Journal of Fluid Mechanics*.

Earlier measurements of duckling metabolism showed that the youngsters saved energy when swimming behind a leader, but the physics behind that savings wasn't known. Using computer simulations of waterfowl waves, naval architect Zhiming Yuan of the University of Strathclyde in Glasgow, Scotland, and colleagues calculated how a duckling cruising in just the right spot behind its mother gets an assist.

When a duckling swims on its own, it kicks up waves in its wake, using up some energy that would otherwise send it surging ahead — what's known as wave drag. But a duckling in the sweet spot behind mom experiences 158 percent less wave drag than when swimming alone, the researchers calculated, meaning the duckling gets a push instead.

Like good siblings, the ducklings share with one another. Each duckling in the line passes along waves to those behind, so the whole brood gets an easy ride. But to reap the benefits, the youngsters need to keep up with their mom. If they fall out of position, swimming gets harder. That's fair punishment for ducklings that dawdle. — *Emily Conover*

Scientists named an agile gecko found in the Western Ghats of India after martial arts legend Jackie Chan.

THE NAME GAME

This gecko moves like Jackie Chan

Martial arts legend Jackie Chan may not be aware of this yet but some of his biggest fans are a group of adoring herpetologists in India. These scientists have named a newly identified gecko species the Jackie's day gecko (*Cnemaspis jackieii*) after they observed the reptile springing from rock to rock, which reminded them of the nimble-footed martial artist. "Naming a species in this manner helps people connect with it, especially when it is a less popular class of animals like reptiles," says herpetologist Zeeshan Mirza of the National Centre for Biological Sciences in Bangalore. Jackie's day gecko is one of 12 newfound gecko species in India's Western Ghats mountain range, Mirza and colleagues report September 23 in *Zoological Research*. Unique skin patterns inspired names for some of the other species, including the golden-crowned day gecko (*C. regalis*), the galaxy day gecko (*C. galaxia*) and the clouded forest gecko (*C. nimbus*). — *Anne Pinto-Rodrigues*

FROM TOP: GUILLERMO BLANCO; SAUNAK PAL

News

BODY & BRAIN

Pig kidney tested in a human

Novel transplant is a step toward solving organ shortages

Surgeons at New York University's Langone Health attached a pig kidney to a human patient. Here, the team examines the kidney for signs of rejection.

JOE CARROTTA FOR NYU LANGONE HEALTH

BY JONATHAN LAMBERT

Surgeons in New York City successfully attached a pig kidney to a human patient and watched the organ function normally for 54 hours. It's the first time that a pig kidney has been transplanted to a human body and not been immediately rejected.

The procedure, announced in a news conference October 21, marks progress toward the goal of expanding the supply of lifesaving organs. Millions of people globally could benefit from donated organs, many of which never come.

While the details of the procedure have not yet been peer-reviewed or published in a journal, "it's a significant step," says immunologist Megan Sykes of Columbia University, who wasn't involved in the research. But there are many more steps before patients waiting for a kidney can get one from a pig, she says.

Scientists have long sought to solve a shortage in donor organs by using animal organs, a field called xenotransplantation. Pigs are the primary focus, in part, because their organs are anatomically similar to human organs. But simply transplanting the organ of another species into a person causes the immune system to revolt. When such transplants using nonhuman primates were tried in the early 20th century, the transplanted organ would quickly turn black.

"You could visibly see the organs fail in those days because there's an immediate reaction," says John Scandling, a nephrologist at Stanford University who wasn't involved in the new transplant. That immediate reaction, called a hyperacute rejection, is the first big obstacle for a xenotransplant to overcome.

In pig-to-human transplants, that immune response is spurred by antibodies that detect a specific sugar molecule called alpha-gal that dots pig blood vessels. In the early 2000s, scientists turned to genetic engineering to devise ways of disabling the gene responsible for the sugar. Organs from pigs with this gene disabled have been successfully transplanted to nonhuman primates.

So the success of the recent transplant wasn't a big surprise to experts. "This is completely as expected, but nevertheless it is an important piece of evidence to support moving to clinical trials," says immunologist Peter Cowan of the University of Melbourne in Australia.

Over two hours in September, surgeon Robert Montgomery of New York University's Langone Health and colleagues attached the kidney, from a pig engineered to lack alpha-gal, to blood vessels in the upper leg of a brain-dead patient who was kept alive on a ventilator. The woman was an organ donor, but her organs were not suitable for donation so her family agreed to the experiment.

The kidney was kept outside of the body so the team could assess its function in real time. The pig's thymus gland, which can help educate the immune system to recognize the kidney as part of the body, was also transplanted, Montgomery said at the news briefing. Drugs that suppress the immune system were also given.

Within minutes, the kidney started producing large amounts of urine and showed other signs of normal functioning. The team saw no signs of rejection, stopping the monitoring at 54 hours per guidance from ethics reviewers.

Before pig-grown organs can go mainstream, researchers will have to show that the organs can survive attacks from other immune system players. For example, over time, T cells can come to recognize the transplanted organ as foreign and attack. Immunosuppressing drugs can mitigate the response, but the drugs' side effects, such as susceptibility to infectious diseases, can be a burden.

Including the thymus may help lessen this longer-term rejection, says Kazuhiko Yamada, a surgeon at Columbia University who has worked on this method in nonhuman primates. "It's like a teacher that can educate [the immune system] to not attack the kidney."

Researchers will also have to show that such transplants are safe in the long term, Yamada says. For example, pig organs can have viruses that lie dormant in genes. Some researchers are using the gene-editing tool CRISPR to remove viruses as a way to improve safety (*SN: 9/2/17, p. 15*).

Another potential roadblock is the question of whether it's ethical to raise pigs for organ harvesting. Advocates for xenotransplantation argue the potential benefits of vastly expanding the organ supply are worth harms to pigs.

"Nearly half of the patients waiting for a transplant become too sick or die before receiving one," Montgomery said. "The traditional paradigm that someone has to die for someone else to live is never going to keep up with the ever increasing incidence of organ failure." ■

X-rays hint at first extragalactic planet

A mystery object may orbit a stellar duo outside the Milky Way

BY LISA GROSSMAN

Astronomers may have spotted the first known planet in another galaxy.

Called M51-ULS-1b, the potential world seems to orbit both a massive star and a dead star in the Whirlpool galaxy, about 28 million light-years from Earth. The object's existence, if confirmed, suggests that there could be many other extragalactic exoplanets waiting to be discovered, astronomers report October 25 in *Nature Astronomy*.

"We probably always assumed there would be planets" in other galaxies, says astrophysicist Rosanne Di Stefano of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass. "But to actually find something, it's a beautiful thing. It's a humbling experience."

More than 4,800 planets have been discovered orbiting stars other than the sun, all of them inside the Milky Way. There's no reason to think that other galaxies don't also host planets. But the most popular exoplanet-hunting techniques are difficult to do with such faraway stars. The stars blend together too much to observe them one by one.

In 2018, Di Stefano and astrophysicist Nia Imara of the University of California, Santa Cruz suggested searching for planets around extragalactic X-ray binaries.

X-ray binaries usually consist of a massive star and the remains of a second massive star that has collapsed into a neutron star or a black hole. The dead star steals material from the living star and heats that material to such high temperatures that it emits bright X-rays that stand out from the crowd of other stars.

That X-ray region can be smaller than a giant planet, meaning if a planet crosses, or transits, in front of such a system from astronomers' perspective on Earth, the planet could temporarily block all the X-rays, revealing its presence.

Di Stefano and colleagues searched archived data from NASA's Chandra X-ray telescope for signs of blinking X-ray sources. The team looked at a total of 2,624 possible transits in three galaxies: the Whirlpool galaxy (M51), the Pinwheel galaxy (M101) and the Sombrero galaxy (M104).

Only one transit turned up a clear planetlike signal. On September 20, 2012, an object had blocked all of the X-rays from the X-ray binary M51-ULS-1 for about three hours. "We said, 'Wow. Could this be it?' " Di Stefano says.

After ruling out gas clouds passing in front of the binary, fluctuations in the X-ray source itself or other explanations for the dip in light, Di Stefano and colleagues concluded that the object is most likely a Saturn-sized planet orbiting the X-ray binary at tens of times the distance between Earth and the sun.

Despite the planet's distance from the X-ray binary, this isn't a comfortable environment. "You don't want to be there," Di Stefano says. The region receives as much energy in X-rays and ultraviolet radiation as a hot Jupiter exoplanet that orbits an ordinary star at a small fraction of the distance between Earth and the sun (*SN: 7/8/17 & 7/22/17, p. 4*).

"The possibility that the team discovered the transit of an extragalactic planet is quite intriguing and would be a great discovery," says astrophysicist Ignazio Pillitteri of the Italian National Institute for Astrophysics in Palermo. He would like to see the transit happen again to confirm that the object is a planet.

Not everyone is as excited by the result. "I find the paper very speculative," says astrophysicist Matthew Bailes of Swinburne University of Technology in Melbourne, Australia. If the planet is real, finding it relied on a lot of coincidences: The planet's orbit needed to be perfectly aligned with the point of view from Earth, and the planet needed to pass in front of the X-ray binary while Chandra was looking.

Di Stefano counters that the fact that her team saw a signal within such a small number of observations suggests there are lots of extragalactic planets out there. "Maybe we were lucky," she says. "But I think it's very likely that we were not special. We looked and we found something because there was something to find."

Di Stefano doesn't expect to see this particular planet again in her lifetime. It could take several decades or more for it to pass in front of its host stars again. "The real test," she says, "is finding more planets." ■

The Whirlpool galaxy, shown in this image from the Hubble Space Telescope, may host the first planet spotted outside of the Milky Way.

S. BECKWITH/STSCI, THE HUBBLE HERITAGE TEAM/STSCI/AURA, NASA, ESA

The MicroBooNE detector (shown under construction) observes particles produced when neutrinos interact with argon. It has found no sign of hypothetical particles called sterile neutrinos, despite hints from earlier experiments.

ATOM & COSMOS

Doubt cast on hypothesized particle

A new experiment weakens the case for the 'sterile' neutrino

BY EMILY CONOVER

For decades, physicists have suspected an interloper. A reclusive, hypothetical subatomic particle might be creeping into studies of neutrinos, nearly massless particles with no electric charge. A new study casts doubt on the idea that the interloper exists, but leaves unsolved the mystery of what caused peculiar results in certain previous neutrino experiments.

"We still don't have the answer," says physicist Kate Scholberg of Duke University, who was not involved in the new research. "It's simultaneously satisfying and unsatisfying."

Neutrinos, which come in three known varieties, have shown up in greater numbers than expected in some experiments. That strange behavior raised the tantalizing prospect that a stealthier fourth type of neutrino, called a sterile neutrino, might be awaiting discovery. But new data from the Micro Booster Neutrino Experiment, or MicroBooNE, located at Fermilab in Batavia, Ill., favor the canonical neutrino trio.

An earlier experiment called MiniBooNE, also at Fermilab, had for years found more neutrinos than expected, a hint strengthened with more data in 2018 (*SN: 6/23/18, p. 7*). An even earlier neutrino experiment, performed in the 1990s, had also seen a similar signal.

With MiniBooNE, scientists studied a phenomenon called neutrino oscillation. The three known varieties of neutrinos — electron neutrinos, muon neutrinos and tau neutrinos — can transform, or oscillate, from one type to another as they travel. MiniBooNE looked for electron neutrinos produced when muon neutrinos oscillated. The apparent glut of electron neutrinos seen by MiniBooNE could indicate that the switch seemed to happen more often than expected, potentially due to sterile neutrinos muddling up the oscillations.

But there was a catch. Particle detectors can't directly spot neutrinos, instead identifying them by observing other particles that get spit out when neutrinos interact with material inside a detector. MiniBooNE tended to confuse electrons — a signature of electron neutrinos — with photons. These particles of light could indicate something other than an electron neutrino. That left scientists unsure whether they were really seeing excess neutrinos. The sterile neutrino remained a question mark.

Enter MicroBooNE. The experiment uses an advanced type of detector that can tell electrons from photons. So scientists set out to learn whether the excess detections involved electrons or photons. But MicroBooNE, confusingly, found no excess at all. In an October 1 seminar and a study posted at arXiv.org, scientists reported that MicroBooNE had mostly eliminated the possibility of extra events involving photons. And then in an October 27 virtual seminar, scientists also ruled out many of the possible types of extra events involving electrons, making the sterile neutrino idea less plausible.

It's not clear why one experiment saw an excess while the other didn't. The difference between the two measurements, Scholberg says, may come down to the materials used in the detectors: carbon in MiniBooNE, argon in MicroBooNE.

Other possible explanations for MiniBooNE's excess detections, some of which might be explained only by going beyond standard physics, remain to be investigated. The detections, for example, might involve electrons paired with their antimatter partners, positrons. That pair could point to different hypothetical subatomic stuff, such as axionlike particles.

The researchers "have eliminated a lot of possibilities of what this excess could be, so I found the results pretty compelling," says physicist Mayly Sanchez of Iowa State University in Ames. "You're giving fewer and fewer places to hide to these sterile neutrinos."

But all hope for sterile neutrinos is not lost: A more complicated scenario involving a sterile neutrino combined with other theorized new phenomena could still explain the excess.

"There's still a mystery afoot," says Yale physicist Bonnie Fleming, a spokesperson of the MicroBooNE experiment. "We have more work to do. There's no doubt about that." ■

REIDAR HAHN/FERMILAB

Hit-and-runs may have shaped Venus

Long-ago crashes may account for differences with Earth

BY LISA GROSSMAN

Space rocks the size of baby planets struck both the newborn Earth and Venus during the solar system's early days. But many of the rocks that only grazed Earth went on to hit — and stick to — Venus, new simulations suggest. That difference in early impacts may help explain why Earth and Venus are such different worlds today, researchers report in the October *Planetary Science Journal*.

"The pronounced differences between Earth and Venus, in spite of their similar orbits and masses, has been one of the biggest puzzles in our solar system," says planetary scientist Shigeru Ida of the Tokyo Institute of Technology, who was not involved in the work. This study introduces "a new point that has not been raised before."

Scientists have typically thought that collisions between baby planets can go one of two ways. The objects could graze each other and each continue on its way, in a hit-and-run collision. Or two protoplanets could stick together, or accrete, making one larger planet. Planetary scientists often assume that every hit-and-run eventually leads to accretion. Objects that collide must have orbits that cross each other's, so they're bound to collide again and again, and eventually should stick.

But previous work from planetary scientist Erik Asphaug of the University of Arizona in Tucson and others suggests hit-and-sticks were rare. It takes special conditions for two planets to merge, Asphaug says, like relatively slow impact speeds, so grazing hit-and-runs were probably much more common in the young solar system.

Asphaug and colleagues wondered what that might have meant for Earth and Venus, two apparently similar planets with vastly different climates today. Both worlds are about the same size and mass, but Earth is wet and clement while Venus is a searing, acidic hellscape.

"If they started out on similar pathways, somehow Venus took a wrong turn," Asphaug says.

The team ran about 4,000 computer simulations in which Mars-sized protoplanets crashed into a young Earth or Venus, assuming the two planets were at their current distances from the sun. About half of the time, incoming protoplanets grazed Earth without accreting. Of the objects that grazed Earth, about half went on to collide with Venus.

Unlike Earth, Venus ended up accreting most of the objects that hit it in the simulations. Hitting Earth first slowed down incoming objects enough to let them stick to Venus later, the study suggests. "You have this imbalance where things that hit the Earth, but don't stick, tend to end up on Venus," Asphaug says. "We have a fundamental explanation for why Venus ended up accreting differently from the Earth."

If that's really what happened, it would have had a significant effect on the composition of the two worlds. Earth would have ended up with more of the crust and outer mantle material from the incoming protoplanets, while Venus would have gotten more of their iron-rich cores.

The impact imbalance could even explain some major Venusian mysteries, like why the planet doesn't have a moon, why it spins so slowly and why it lacks a magnetic field — though "these are hand-waving kind of conjectures," Asphaug says.

The new findings fit into a growing debate among planetary scientists about how the solar system grew up, says planetary scientist Seth Jacobson of Michigan State University in East Lansing. Was it built violently, with lots of giant collisions, or calmly, with planets growing smoothly via pebbles sticking together?

"This paper falls on the end of lots of giant impacts," Jacobson says.

Each rocky planet in the solar system should have very different chemistry and structure depending on which scenario is true. But scientists know the interior chemistry and structure of only one planet with any confidence: Earth. And Earth's early history has been overwritten by plate tectonics and other geologic activity. "Venus is the missing link," Jacobson says. "Learning more about Venus' chemistry and interior structure is going to tell us more about whether it had [suffered] a giant impact or not."

Getting these answers will require sending a long-lived lander to Venus, or a sample-return mission, both of which would be extremely difficult on such a hot, hostile planet. "I wish there was an easier way to test it," Jacobson says. "I think that's where we should concentrate our energy as terrestrial planet formation scientists going forward." ■

Collisions between baby planets, as illustrated here, may have been common during the early solar system. But more of the fragments from those collisions may have stuck to Venus than to Earth.

JPL-CALTECH/NASA

MATTER & ENERGY

Gravity warps time on tiny scale

Atomic clock spots gravity's influence across a millimeter

BY EMILY CONOVER

A millimeter might not seem like much. But even a distance that small can alter the flow of time.

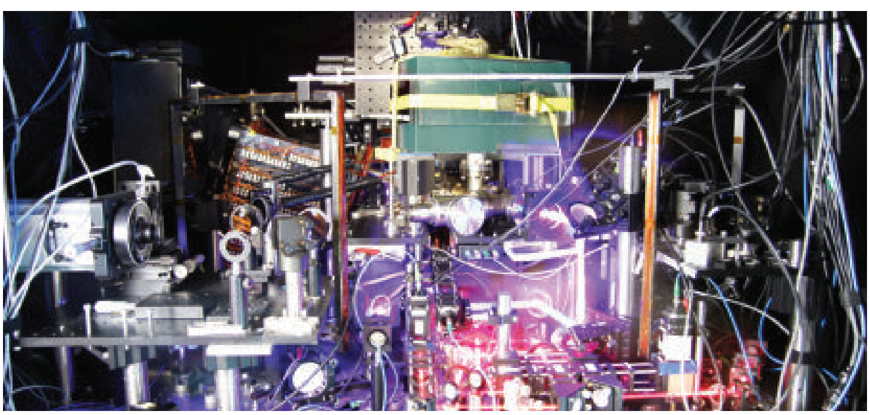
According to Einstein's theory of gravity, general relativity, clocks tick faster the farther they are from Earth or another massive object (*SN: 10/17/15, p. 16*). Theoretically, that should hold true even for very small differences in the heights of clocks. Now an incredibly sensitive atomic clock has spotted that speedup within its millimeter-sized sample of atoms, revealing the effect over a smaller height difference than ever before. Time moved slightly faster at the top of that sample than at the bottom, researchers report September 24 at arXiv.org.

"This is fantastic," says theoretical physicist Marianna Safronova of the University of Delaware in Newark, who was not involved with the research. "I thought it would take much longer to get to this point." The extreme precision of the atomic clock's measurement suggests the potential to use the sensitive timepieces to test other fundamental concepts in physics.

An inherent property of atoms allows scientists to use them as timepieces. Atoms exist at different energy levels, and a specific frequency of light makes them jump from one level to another. That frequency — the light waves' rate of wiggling — acts like a clock's regularly ticking second hand. For atoms farther from the ground, time runs faster, so a greater frequency of light will be needed to make the energy jump. Previously, scientists have measured this frequency shift, known as gravitational redshift, across a height difference of 33 centimeters (*SN: 10/23/10, p. 10*).

In the new study, physicist Jun Ye of the research institute JILA in Boulder, Colo., and colleagues used a clock made up of roughly 100,000 ultracold strontium atoms. Those atoms were arranged in a lattice, meaning that the atoms sat at a series of different heights as if standing on the rungs of a ladder. Mapping out how the required frequency differed over those heights revealed a shift. After correcting for non-gravitational effects that could alter the frequency, the clock's frequency shifted by about a hundredth of a quadrillionth of a percent over a millimeter, just the amount expected according to general relativity.

What's more, after taking data for about 90 hours, comparing the ticking of upper and lower sections of the clock, the scientists determined their technique could measure the relative ticking rates to a precision of 0.76 millionths of a trillionth of a percent. That sets a record for the most precise frequency comparison ever performed.



Atomic clocks keep time by measuring the frequency of light that initiates a jump between energy levels in atoms. An atomic clock (similar one shown in a composite image) located in Colorado revealed that a key feature of the general theory of relativity holds on a scale of a millimeter.

In a related study, also reported September 24 at arXiv.org, another team of researchers loaded strontium atoms into specific portions of a lattice to create six clocks in one. "It's very exciting what they did, as well," Safronova says.

Physicist Shimon Kolkowitz of the University of Wisconsin–Madison and colleagues measured the relative ticking rates of two of the clocks, separated by about six millimeters, to a precision of 8.9 millionths of a trillionth of a percent, which itself would have been a new record had it not been beat by Ye's group. With that sensitivity, scientists could detect a difference between two clocks ticking at a rate so slightly different that they'd disagree by just one second after about 300 billion years. Ye's team's clock could detect an even smaller discrepancy between the two halves of the clock — one second amassed over roughly 4 trillion years. Although Kolkowitz's team didn't measure gravitational redshift, the setup could be used for that in the future.

Authors of both studies declined to comment, as the papers have not yet been through the peer-review process.

The measurements' precisions hint at future possibilities in physics. For example, "atomic clocks are now so precise that they may be used to search for dark matter," says theoretical physicist Victor Flambaum of the University of New South Wales in Sydney. This unidentified substance lurks invisibly in the cosmos; certain hypothesized types of dark matter could alter clocks' ticktocks. Scientists could also compare atomic clocks made of different isotopes — atoms with varied numbers of neutrons in their nuclei — which might hint at new particles. And atomic clocks can be used to study whether fundamental constants of nature might vary (*SN: 11/12/16, p. 24*).

The ability to precisely compare different clocks is also important for a major goal of timekeeping: updating the definition of a second. The length of a second is currently defined using an earlier generation of atomic clocks that are not as precise as newer ones.

"There is a very bright future for the clocks," Safronova says. ■

YE GROUP AND BAXLEY/JILA

EARTH & ENVIRONMENT

Stranded red mangroves thrive inland

Ancient sea level rise displaced a group of normally coastal trees

BY TRISHLA OSTWAL

Nearly 200 kilometers from the sea, red mangroves thrive in the rainforests along the San Pedro Mártir River on the Yucatán Peninsula. But how did these tangled trees that typically grow in salty water along coasts end up trapped so far inland and in freshwater?

Carlos Burelo has been mulling a version of that question ever since he visited the river on a fishing trip with his father 35 years ago. As a kid, he saw how the mangroves with their twisted aboveground roots were different from other trees in the area, an observation that has stuck with him. He is a biologist at the Universidad Juárez Autónoma de Tabasco in Villahermosa, Mexico.

Now, genetic analyses, surveys of vegetation and sediments, and simulations of shifts in sea levels show that the red mangroves (*Rhizophora mangle*) are part of a "relict ecosystem" that has existed for more than 100,000 years. During the last interglacial period, which peaked about 130,000 years ago, warming raised sea levels about nine meters above current levels, and the lowlands of what's now the Yucatán Peninsula flooded. As a result, the mangrove forest was displaced and transplanted inland by today's standards, Burelo and colleagues report in the Oct. 12 *Proceedings of the National Academy of Sciences*. When sea levels dropped as the world cooled again, the trees were left far from the coast.

Aquatic life finds refuge in the submerged roots of a red mangrove forest on the Yucatán Peninsula. It's part of a "relict ecosystem."

"The remarkable resilience of these trees, in particular, is striking — that although they're normally adapted to seawater, they've survived all this time inland is incredible," says Holly Jones, a conservation biologist at Northern Illinois University in DeKalb who wasn't involved in the study.

To estimate where the mangroves may have been displaced from, the team collected leaves from the trees and from other mangrove forests along the coasts of the Caribbean Sea and Gulf of Mexico. Comparisons of the plants' DNA pinpointed the origins of the inland mangroves to about 170 kilometers away along the Gulf of Mexico.

By comparing the number of DNA mutations in the inland population with that in other mangroves and by estimating the ages of the trees using tree cores, "we were able to infer [that the inland mangroves] have been isolated for 120,000 years," says Felipe Zapata, an evolutionary biologist at UCLA. The calcium-rich river water and riverbed have buttressed the survival of these red mangroves over the years, Zapata says.

Red mangroves grow in the San Pedro Mártir River on the Yucatán Peninsula. Calcium in the water helps the trees survive farther inland than where mangroves typically grow.

In addition to the mangroves, other plants in the inland area have a coastal heritage, the team found. More than 30 percent, or 112 species, of the total flora growing along the river, including orchids and legumes, are typically found in coastal lagoons or along shorelines.

With those findings in hand, the team looked at the soil too. A geologic survey of sediments near the mangroves revealed coastal gravels, shells of marine gastropods, large oyster shells and clay sediments rich in shell fragments.

Those finds, along with simulations of past sea levels, confirm that at some point during the last interglacial period, the ocean must have merged with the lower basin of the San Pedro River, pushing the red mangroves and other coastal species inland, the researchers conclude.

Discovering this relict ecosystem highlights the widespread impact past climate change has had on the world's coastlines, says study coauthor Exequiel Ezcurra, an ecologist at the University of California, Riverside, and it provides a chance to better understand how future sea level rise may affect these ecosystems. ■

FROM TOP: BEN MEISSNER; OCTAVIO ABURTO

LIFE & EVOLUTION

Turtle barnacles travel with intention

Wandering may help the crustaceans find better feeding spots

BY JAKE BUEHLER

Barnacles aren't exactly known for their athleticism, staying glued in place for much of their lives. But turtle-riding barnacles can be fidgety travelers.

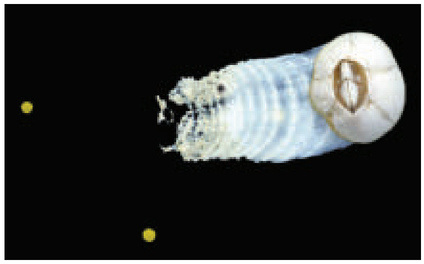
Adult turtle barnacles (*Chelonibia testudinaria*) can move about 1.4 millimeters a week across turtle shells, scientists report in the Oct. 13 *Proceedings of the Royal Society B*. Previous observations of barnacles stuck on green sea turtles suggested that the creatures were somehow mobile, propelled by either outside forces or their own actions. But this is the first experimental confirmation that they embark on self-directed treks.

Barnacles start life as free-swimming larvae, eventually settling and adhering to rocks, ship hulls or even other marine creatures. Some species have been known to rotate on their base or even scooch a smidge when nudged by a too-close neighbor. But once settled in, barnacles live and grow, eating particles of food drifting by what was long considered their permanent residence.

Now it turns out some may need forwarding addresses. Marine ecologist Benny K.K. Chan of Academia Sinica in Taipei, Taiwan, decided to test barnacles' mobility when one of his students successfully transferred turtle barnacles from crabs to an acrylic plate. The researchers followed 15 barnacles with time series photography over a year.

The team also collaborated with researchers in Spain to track barnacles on the shells of five captive loggerhead sea turtles over a few months, and worked with citizen-scientist divers to track barnacles' positions on the backs of wild green sea turtles in Taiwan over 16 weeks.

On loggerhead sea turtles, barnacles moved as much as 54 millimeters — a little less than the length of an adult human's thumb — during this time. Barnacles on plates moved too, leaving trails of pale cement in layered, crescent-shaped patterns. "We were amazed," Chan says.



A turtle barnacle leaves a white cement trail as it treks across an acrylic plate. The yellow dots are spatial reference points that researchers use to measure how far the barnacle moves.

How the barnacles move is still a mystery, but scientists think the crustaceans may partially dissolve their own cement and lift themselves slightly off the surface. "Then the barnacle can secrete a new cement layer and probably surf on the cement," Chan says.

The barnacles mostly traveled against currents, showing that they weren't just moving from the pressure of flowing water. Barnacles also didn't get closer together, suggesting that they sought better locations to filter food from the water rather than mating opportunities.

"This is rock-solid proof of something that is otherwise anecdotal," says marine biologist Henrik Glenner of the University of Bergen in Norway. Barnacles typically exemplify biological competition for space and resources. After settling, they must compete from that spot for the rest of their lives, Glenner says. But being mobile upends this dynamic.

The behavior also raises new questions. Marine ecologist Tara Essock-Burns of the University of Hawaii at Manoa wonders whether "turtle barnacle cement has a very different biochemistry than other barnacles that permanently adhere to [surfaces]." This is precisely what Chan and colleagues plan to study next.

"There is a reason that Darwin was so captivated by barnacles," Essock-Burns says. "They never cease to amaze us." ■

LIFE & EVOLUTION

Flamingo dye fights sun damage

Rouge keeps feathers pretty in pink during mating season

BY REBECCA DZOMBAK

Greater flamingos aren't fans of a sun-faded look for their neck feathers.

Scientists have known that the leggy birds touch up their color by smearing their necks with a serum produced by glands near their tails. But greater flamingos (*Phoenicopterus roseus*) aren't simply enhancing color that's already there; they're also fighting the bleaching effect of the sun, researchers report in the October *Ecology and Evolution*. Feathers with a thicker coating of this serum held their color better than those with less serum, an analysis shows.

Feathers help flamingos fly, keep their bodies dry and attract mates. The red hue of the plumage comes from carotenoids, molecules responsible for many natural pigments, found in the birds' diet of shrimp and algae.

When flamingos preen, they care for their feathers a bit like how we care for our hair, cleaning out dirt and parasites. And like some of us, they add color. To apply their DIY feather dye, flamingos rub their cheeks on a gland above their tail called the uropygial gland, which generates a color-carrying serum. The birds then rub their serum-coated cheeks on their neck feathers. All that effort, paired with some slick dance moves, is aimed at attracting potential mates.

But the sun's ultraviolet radiation can break down carotenoids. That got biologist Maria Cecilia Chiale wondering if flamingos lose their color without constant reapplication of the serum. If so, that might help explain their instinct to constantly "touch up" their plumage.

Chiale, of Universidad Nacional de La Plata in Argentina, and colleagues collected dozens of neck feathers from flamingos in France that died in a cold snap. The team scanned the feathers and used Adobe Photoshop to analyze their

B.K.K. CHAN AND JR-CHI LIN

color before extracting carotenoids from the feathers' surfaces. More carotenoids stuck to feathers meant that more serum had been applied.

The team took another set of neck feathers from the same birds and placed half on a roof exposed to sunlight. The other half were kept in darkness. Forty days later, scans showed that the feathers exposed to sunlight were faded and paler than those kept in the dark.

When the team compared sun-exposed feathers with each other, those assumed to have high concentrations of carotenoids kept more color. That suggests that the birds had applied more serum to those feathers, letting them withstand fading better than feathers with a thinner coating.

Male and female flamingos actively work to maintain their blushed necks throughout their display season as they prepare to mate, the research suggests.

Preening behaviors "have great social importance for flamingos because they live in large flocks and have synchronized behavior," says ecologist Henrique Delfino of Universidade Federal do Rio Grande do Sul in Brazil. Dye touch-ups are no exception. Without flashy feathers to advertise their health, flamingos probably struggle to find a partner, he says.

All that work to prevent feather fade doesn't continue forever, though. Once flamingos have snagged a mate and successfully hatched a chick, Chiale says, the serum's carotenoid concentration drops and the flamingos apply the serum far less often. "They don't need to have makeup on while they're raising the kids," she says. They need that energy to take care of their chicks. ■

EARTH & ENVIRONMENT

'Ice needles' sculpt natural works of art

The ice gradually pushes rocks into clusters that form patterns

BY BETH GEIGER

Neat rings, stripes and swirls embellish many cold, rocky landscapes. Although these beautiful stone patterns look like human-made artwork, they're all natural. Scientists have long known that such rocky patterns result from freezing and thawing. But precisely how some develop has been a mystery — until now.

Experiments reveal that "ice needles" can sort and organize rocks into many patterns, geologist Anyuan Li of the University of Tsukuba in Japan and colleagues report in the Oct. 5 *Proceedings of the National Academy of Sciences*.

"The beauty of [our] experiments is that you can actually see direct information on how the patterns form," says study coauthor Bernard Hallet, a geologist at the University of Washington in Seattle.

The researchers spread pebbles atop a pan holding moist, fine-grain soil, then froze and thawed this mini landscape over and over. When the moist soil had not yet frozen but the air temperature dropped below freezing, tiny, needle-like columns of ice sprouted up from the soil. These ice needles, each up to a few centimeters high, lifted any stones atop them. When temperatures rose, the ice collapsed and the stones tumbled off. Because the ice needles curved as they grew, the stones tended to fall off their icy pedestals to one side.

Over many freeze-thaw cycles, the ice needles cleared patches of exposed soil. Since needles could more easily form in spots where there were fewer rocks in the way, the needles efficiently cleared out any remaining pebbles. Stones were gradually shuffled into clusters between stone-free areas to form larger patterns. The pattern that develops on a landscape depends on the landscape's stone concentration, says study coauthor Quan-Xing Liu, a theoretical ecologist at East China Normal University in Shanghai.

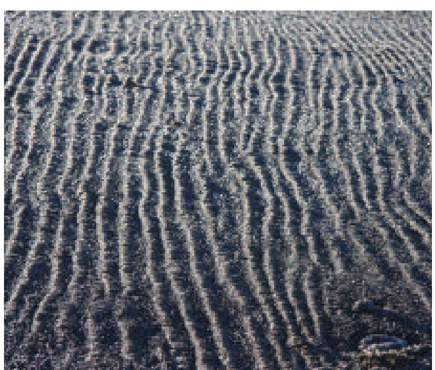
In the lab experiments, patterns formed after 30 freeze cycles, Hallet says. That could equate to 30 cold nights — or 30 years, if each freeze lasted a whole winter. In the real world, some patterns might take "thousands, if not tens of thousands, of years to form," Hallet says.

Using observations from the soil experiments, the team built a computer simulation of ice-needle landscaping that predicted stone movement under a range of conditions. The simulation confirmed that pattern formation rate depends in part on how dense stone cover is. Formation rate and pattern shapes also depend on soil moisture, ground slope and ice-needle height.

"We see identical patterns in different systems, such as fluids," Hallet says of the rock formations. Materials with different characteristics often start mixed together but don't stay that way (*SN: 6/5/21, p. 4*). Phase separation is the process that morphs these mixes into patterns. The new study is among the first to show how phase separation applies to landscapes.

Combining experiments and simulations provides a new way to connect how natural landscapes form and how their materials behave, says geologist Rachel Glade of the University of Rochester in New York. The approach could help scientists understand how landscapes may evolve in a changing climate, she says. ■

Freeze-thaw cycles form ice needles (left) that separate stones from soil and create intricate patterns seen across a variety of cold, rocky landscapes, a new study confirms. Such ice needles formed a ridge pattern (right) along a volcanic crater on the Hawaiian island of Maui.

FROM LEFT: MICHAEL BURZNYSKI; B. HALLET

HUMANS & SOCIETY

Blueprint links Mesoamerican cultures

Maya and Olmec societies shared ceremonial structure designs

BY BRUCE BOWER

An unexpected architectural tradition connected many Olmec and Maya societies of Mesoamerica, an ancient cultural area that included central Mexico and much of Central America.

Starting as early as around 3,400 years ago and for roughly the next two millennia, those communities constructed ceremonial centers based on a common blueprint. That plan was grounded in ideas about the use of space, the calendar and possibly beliefs about the universe, researchers report October 25 in *Nature Human Behaviour*.

An airborne remote-sensing technique called light detection and ranging, or lidar, revealed 478 rectangular and square ceremonial centers across Mexico's southern Gulf Coast, over an area roughly the size of Ireland. Lidar maps detected remnants of these ceremonial centers dotting the landscape in an Olmec homeland area and stretching about 500 kilometers eastward to the Maya lowlands, say archaeologist Takeshi Inomata of the University of Arizona in Tucson and his colleagues.

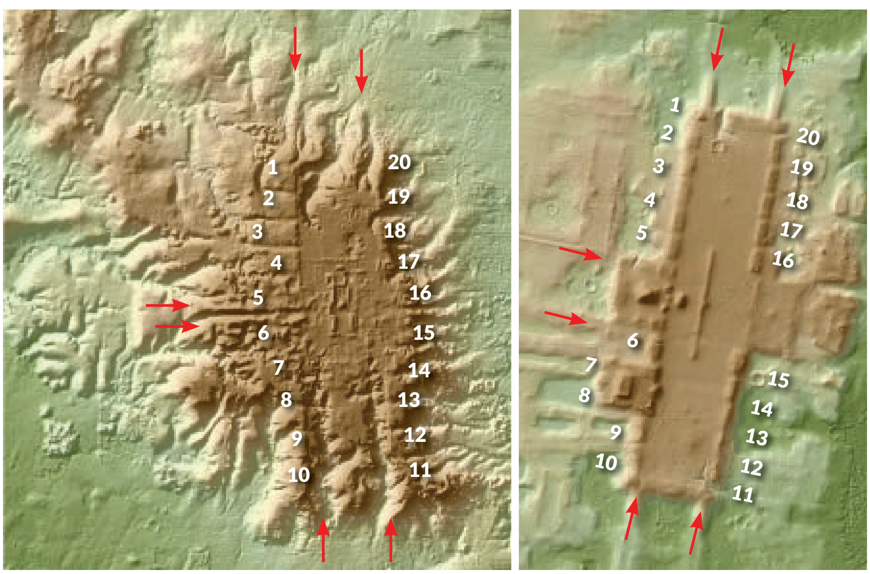
Olmec society dates from around 3,500 to 2,400 years ago. Its relation to later Classic Maya culture is unclear, although Maya and Olmec people may have influenced each other's cultures between 3,000 and 2,800 years ago, Inomata says.

A continuous 2,000-year tradition of ceremonial complex construction now appears to have characterized Mesoamerican settlements of various sizes and political arrangements. The discovery "forces us to rethink what was happening during this period," Inomata says.

New lidar data from so many Mesoamerican sites "reveals an astonishing reality — the sheer vastness of what we didn't know about the emergence of urbanism in this part of the world," says archaeologist Francisco Estrada-Belli of Tulane University in New Orleans.

Ground surveys and excavations of the lidar-detected sites are still in the early stages, but many probably date to between 1050 B.C. and 400 B.C. Inomata and colleagues have surveyed 62 sites in an eastern portion of the lidar-mapped area and excavated five of them.

In a major revelation, lidar detected a ceremonial space at an early Olmec settlement called San Lorenzo. Dating to between 1400 B.C. and 1150 B.C., this area consisted of 20 rectangular earthen mounds bordering a rectangular plaza.



Remote-sensing data show that the design of a ceremonial center at the Olmec site of San Lorenzo (left), which included a plaza surrounded by 20 earthen mounds, was later adopted at Aguada Fénix (right), located about 400 kilometers to the east. Arrows denote avenues that led into the plazas.

T. INOMATA ET AL/NATURE HUMAN BEHAVIOUR 2021

San Lorenzo's ceremonial center provided the framework for corresponding constructions at later sites, the team says. Later complexes also included rectangular or square plazas surrounded by 20 mounds. That number probably represented the base unit of Mesoamerican calendars, which were used to organize ritual activities, the scientists say. Some centers were built along an east-to-west axis that aligned with the sunrise on ritually important days of the year.

A site previously excavated by Inomata and colleagues contains the largest rectangular ceremonial complex discovered in Mesoamerica so far. Aguada Fénix, in the western Maya lowlands, dates to around 1,000 B.C. and features a rectangular plateau measuring about 1,400 meters long and nearly 400 meters wide (*SN: 7/4/20 & 7/18/20, p. 6*).

Frequent contacts among diverse societies across the region resulted in the initial spread of the San Lorenzo ceremonial blueprint and the adoption of a sequence of four variations on that theme over the next 2,000 years, the team suggests. Shared configurations appeared despite differences in Mesoamerican political systems. For instance, colossal head sculptures at San Lorenzo and another Olmec center, La Venta, reflect the presence there of class systems. But other sites with similar centers, including Aguada Fénix, show no signs of ruling classes or marked social inequality.

So many commonalities link the complexes that it's hard to sort their builders into different cultures, says archaeologist Robert Rosenswig of the University at Albany in New York, who wrote a commentary on the study in *Nature Human Behaviour*. "It would be realistic to refer to them all as Olmec," he says, especially as the later architecture of Maya in Guatemala and Belize seems to be quite different. Lidar surveys are uncovering shared architectural designs and layouts across other Mesoamerican regions. ■

LIFE & EVOLUTION

Tuskless elephants are evolving in response to poaching

During the Mozambican Civil War, from 1977 to 1992, armies hunted elephants and other wildlife for food and ivory, and the number of all large herbivores dropped more than 90 percent in the country's Gorongosa National Park.

Video footage and photographic records show that as elephant numbers plummeted, the proportion of female African savanna elephants (*Loxodonta africana*) without tusks rose from about 18.5 percent to 51 percent, researchers report in the Oct. 22 *Science*.

Fifteen years of poaching appears to have made tusklessness more advantageous from an evolutionary standpoint, encouraging the proliferation of tuskless females, the team says.

A genetic analysis of 18 tusked and tuskless females zeroed in on two genes rife with mutations in tuskless females. In humans, the disruption of one of those genes can cause the absence of a pair of upper incisors that are the "anatomical equivalent of tusks," says evolutionary biologist Shane Campbell-Staton of Princeton University. (If a male elephant inherits the mutated gene, he dies, probably early in development, which is why tusklessness is seen only in females.) Abnormalities in the other gene's protein product can cause tooth root malformations and tooth loss. *— Jake Buehler*

In Mozambique's Gorongosa National Park, poaching pressure resulted in an increase in naturally tuskless elephants.

JOYCE POOLE

LIFE & EVOLUTION

Domesticated horses' homeland traced to southwestern Russia

Researchers have pinpointed where and when horse and human history became intertwined. Ancient DNA shows that the modern domestic horse originated in what is now Russia over 4,200 years ago, researchers report in the Oct. 28 *Nature*.

Hypotheses abound for where modern horses were domesticated, ranging from Iberia to modern-day Kazakhstan, says Ludovic Orlando, a molecular archaeologist at the Centre for Anthropobiology and Genomics of Toulouse in France. He and colleagues analyzed DNA from 273 horse bones from across Eurasia, spanning 50,000 years. For most of that time, genetically varied wild horse populations were scattered across the region. But starting around 2000 B.C., that variation vanished. By 1500 to 1000 B.C., all domestic horses from Spain to Mongolia descended from the same population, which the researchers traced back to more than 4,200-year-old specimens dug up on the Pontic-Caspian steppe, north of the Caucasus region and the Caspian Sea.

Compared with other horse populations present at the time, these modern horse progenitors had two genes that were distinctly different. In humans and mice, those genes influence endurance, weight-bearing ability and docility. Selective breeding by humans could have "recombined two really good factors not [previously] present in any horse," Orlando says. "That created an animal that was both easier to interact [with] and move with." *— Jonathan Lambert*

HUMANS & SOCIETY

Vikings inhabited North America exactly 1,000 years ago

Wooden objects previously found at a Viking archaeological site in Newfoundland, Canada, were made from trees felled in the year 1021. Based on counting tree rings, that's the oldest precise date for Europeans in the Americas and the only precise date from before 1492, scientists report October 20 in *Nature*.

Researchers have assumed that Norse Vikings lived at the site, called L'Anse aux Meadows, about 1,000 years ago. But earlier attempts to more precisely date the settlement were inconclusive.

The new study focused on four wooden objects found at L'Anse aux Meadows, which was first excavated in the 1960s. It's not clear how the objects were used, but each had been cut with metal tools. On three of the finds, the team identified an annual tree growth ring that displayed a signature spike in radiocarbon levels. Other researchers have dated that spike to the year 993, when a surge of cosmic rays from solar activity bombarded Earth and increased atmospheric levels of radioactive carbon.

Counting growth rings out to the edge of each object starting at the 993 ring yielded the same origin date: 1021. But that date leaves unanswered exactly when Vikings first set foot in the Americas. *— Bruce Bower*

HUMANS & SOCIETY

Earliest evidence of tobacco use dates back more than 12,000 years

Ancient North Americans started using tobacco around 12,500 to 12,000 years ago, roughly 9,000 years before the oldest indications that they smoked the plant in pipes, a new study finds. The discovery is the oldest direct evidence for the human use of tobacco anywhere in the world.

Excavations at the Wishbone site in Utah uncovered four charred seeds of wild tobacco plants in a fireplace. Those seeds, dated based on radiocarbon dates of burned wood in the fireplace, probably came from plants gathered at least 13 kilometers away, researchers report October 11 in *Nature Human Behaviour*.

It's unclear how people used the tobacco, says archaeologist Daron Duke of the Far Western Anthropological Research Group in Henderson, Nev. One possibility is that wads of tobacco leaves, stems and other bits may have been twisted into balls and chewed or sucked, with attached seeds spit out or discarded.

The earliest evidence of domesticated tobacco, from South America, dates to about 8,000 years ago. Duke suspects various ancient American populations independently tamed the plant at different times. *— Bruce Bower*

Test Results

COVID-19 testing in schools works, but hurdles include logistics, public health decisions and community buy-in **By Betsy Ladyzhets**

Routine COVID-19 testing at K–12 schools can identify cases in students who might not have symptoms or a known exposure. Rapid antigen tests, like the one used here to test a fourth-grader at Brandeis Elementary School in Louisville, Ky., are easy to administer in a school setting.

JON CHERRY/GETTY IMAGES

In August 2020, the school superintendent in Omaha, Neb., approached a microbiologist at the local university's medical center. School districts across the country were designing pilot programs for routine COVID-19 testing in the coming fall semester, and Omaha Public Schools wanted to do the same.

The result? During Omaha's pilot of frequent testing in students with no symptoms, the rate of cases detected was nearly six times as high as the case rate reported by standard testing for symptomatic students only. The pilot program detected 70 cases per 1,000 students, compared with 12 per 1,000 in the official tally from the local public health department, researchers reported September 22 in *JAMA Network Open*.

"Asymptomatic screening dramatically increases case detection among students and staff in the K–12 setting," says M. Jana Broadhurst, a microbiologist at the University of Nebraska Medical Center who led the team that designed and implemented the pilot program for the school district. In other words, regular testing of all students and staff can detect far more COVID-19 cases than simply testing those who demonstrate COVID-19 symptoms or have a known exposure to the coronavirus. Uncovering those cases is crucial to curtailing outbreaks and keeping kids in school and healthy, data show.

But this fall, Omaha Public Schools has no COVID-19 testing program at all. Why? "The absence of public health guidance on how to utilize and act upon those test results," Broadhurst says.

Omaha isn't alone. Throughout the United States, numerous K–12 schools have struggled to implement routine COVID-19 testing, despite expansive funding from the federal government and a recent surge in cases, fueled by the delta variant. This surge has taken a huge toll on children, demonstrating for many experts the need to deploy testing as a safety measure. Many school districts have seen more cases among students — and more classrooms shut down for quarantines — this fall than they did in the fall of 2020, before vaccines were authorized and widely available for people 12 years and older.

But major hurdles to testing include a lack of clear guidance on how testing programs should work, obtaining tests, gaining consent from parents and communicating the value of testing to families and staff in increasingly polarized environments.

Putting testing to the test

In the last year, both real-world testing pilots like Omaha's and simulations of different testing scenarios have shown that by routinely testing students and staff, school leaders can identify cases and quickly pull infected people out of the classroom, preventing widespread outbreaks.

"Testing has been widely used at institutions ranging from colleges and universities to the NBA," says Alyssa Bilinski, a biostatistician at Brown University School of Public Health in Providence, R.I. Testing programs "find people who are currently infectious and isolate them so they don't spread COVID-19 further."

At the same time, Bilinski says, testing can provide school leaders with valuable insights into coronavirus transmission in the classroom — information that can inform decisions about increasing or pulling back on other safety measures (*SN Online: 8/9/21*).

"Routine testing really has the potential to greatly reduce within-school COVID-19 transmission, and in some cases, even completely eliminate it," says Divya Vohra, an epidemiologist at Mathematica, a research organization with headquarters in Princeton, N.J. Vohra studies COVID-19 testing programs run by the New York City–based Rockefeller Foundation and develops models to compare different strategies. "We think that [testing] really is a very powerful tool when you layer it on top of all of the other mitigation strategies that schools are implementing, like masking and distancing," she says.

Some testing strategies can eliminate in-school coronavirus transmission, Vohra and colleagues reported July 26 in a study posted on Mathematica's website. Pool testing, a method in which samples from an entire classroom are combined and tested together using PCR, or polymerase chain reaction, is particularly effective at cutting down on transmission when case numbers in the community around the school are high, the models of testing scenarios suggest. This testing method is highly accurate because PCR tests identify coronavirus genetic material in samples, and it provides results more quickly than if each student's test was processed one by one.

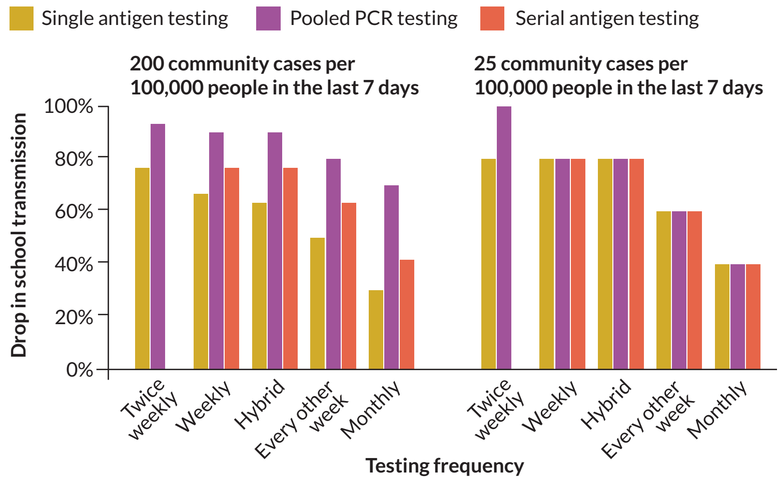
"You're more likely to catch an infection that an antigen test might miss," Vohra says. Antigen tests, which detect proteins on the surface of the coronavirus, provide results in just 15 minutes and are easy to administer in a school setting. While these tests are less accurate than PCR tests, they are almost as capable of reducing transmission when used once a week or more, especially when community transmission is lower, Vohra says. Testing is most effective when all students and staff are routinely swabbed. But even testing a subset of the school population will identify cases. Some testing is better than none.

Start-up challenges

Despite the value of routine COVID-19 testing, any school administrator aiming to test their students faces abundant challenges. Setting up such a program is "like taking the whole entire school on a field trip to somewhere nobody's ever been," says Leah Perkinson, a lead coordinator of K–12 testing pilot programs run by Rockefeller.

The first test, she says, is the most difficult. To

Estimated drop in COVID-19 transmission in schools under different testing scenarios and community incidence rates



Testing strategies

According to computer simulations, routine COVID-19 testing may reduce in-school virus transmission by up to 100 percent. In the left scenario, the community around this school faces high case rates, while in the right scenario, the community has low rates. Pooled testing, in which an entire classroom is PCR-tested at once, is the most successful at reducing transmission. Serial antigen testing (antigen tests two days in a row) is more successful than single antigen testing if community cases are high. The hybrid testing frequency means adults are tested twice weekly and students once weekly. All scenarios assume that all students and school staff participate.

SOURCE: D. VOHRA *ET AL*/ MATHEMATICA 2021

C. CHANG

make that test happen, school leaders have many decisions to make. They have to determine which testing strategy to use: standard PCR, pooled PCR or antigen. They must choose between nasal swabs and saliva tests, which have similar effectiveness but call for different staff and supply needs. Once enough tests are procured for hundreds of students and staff, school leaders need to determine who will conduct the tests, when and where testing will occur, how to report test results and how to collect consent from parents and guardians. And, crucially, school officials need to map out what will happen when a test result is positive.

> "Asymptomatic screening dramatically increases case detection among students and staff in the K–12 setting."
>
> M. JANA BROADHURST

Many of these decisions are, in essence, public health decisions. Yet school leaders are not trained in public health. As a result, schools need "coordination and support coming from experts, particularly at the state and federal level" to set up routine testing, Vohra says.

Like many other aspects of the pandemic, coordination and support for school testing varies greatly across states. Some, including Utah, Delaware, Rhode Island and California, have taken advantage of funding from last spring's federal stimulus package to buy tests for their public school districts and devote staff to developing and disseminating guidelines on how those tests should be used. But in other places, state-level leaders have refused funding entirely, leaving school districts on their own.

At the federal level, the U.S. Centers for Disease Control and Prevention recommends that schools set up regular COVID-19 testing but offers very limited guidance on specifics. Instead, the agency recommends that school leaders coordinate with their local public health departments.

To help fill the testing information gap, the National Institutes of Health, the Rockefeller Foundation and others have created detailed online resources that let school and public health leaders compare testing strategies and connect with test providers. Still, Perkinson says, these resources may be challenging for school administrators to find and use because the information is "not all in one centralized place."

Quarantine choices

What happens when a student or staff member tests positive in a routine testing program is the school's next tough call, Vohra says. "If you're identifying more cases, then that's going to mean that more students are going to be isolating or quarantining," she says.

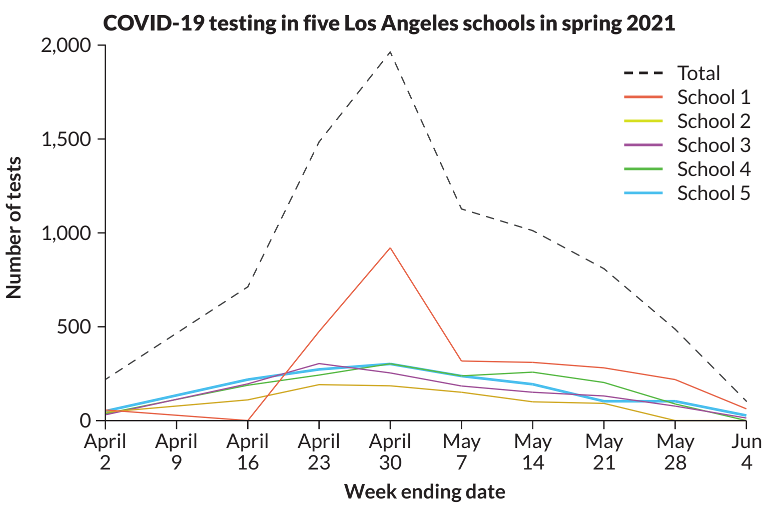
Some schools have adjusted their quarantine policies to minimize the number of students missing out on in-person learning. Instead of sending an entire classroom home, for example, a school may require only those students who sit within six feet of an infected student to quarantine. Policies may also differ for students who are and are not vaccinated. And there is no right answer when it comes to the best strategy, Vohra says.

To help local leaders understand different test and quarantine combinations, Vohra and colleagues built a dashboard based on the results from their modeling study. Users can plug in their testing goals, quarantine policies, community transmission rates and more; the tool offers comparisons of how well different testing strategies fare in reaching those goals.

Another strategy — one not included in the dashboard — is called "test to stay." Instead of sending students who are exposed to the coronavirus into quarantine, officials may require those students to get tested more often, such as one test a day for a week, with the aim of saving in-person school days. A study of secondary schools in the United Kingdom, reported September 14 in the *Lancet*, shows that schools where close-contact students were tested daily had similar success in identifying and isolating COVID-19 cases as schools where all contacts were required to isolate immediately.

In Utah, public schools are required by state law to conduct a test-to-stay event when they face

Real-world testing Five schools in Los Angeles took part in a pilot COVID-19 testing program. From late March to late May, the group of schools administered over 200 tests a week — peaking at almost 2,000 tests a week in late April. During this time, the overall test positivity rate in these schools (0.01 percent) was much lower than the positivity rate for Los Angeles County (ranging between 0.5 percent and 1 percent). This suggests that coronavirus transmission was lower in the schools that regularly tested their students and staff than in the wider community. (No tests were administered the week of April 9 during spring break.) SOURCE: D. VOHRA *ET AL*/MATHEMATICA 2021



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an outbreak. In these events, schools host mass testing days; all students must test negative to continue attending classes. A pilot version of the program saved over 100,000 days of in-person instruction for nearly 14,000 students, according to a CDC report published in May (*SN: 9/11/21, p. 6*).

Since expanding statewide this fall, the program has faced new challenges, says Maggie Graul, an epidemiologist with Utah's state public health department who manages K–12 school testing.

The state defines a school outbreak as 2 percent of the student body in large schools or 30 students in small schools testing positive within two weeks — a slightly higher threshold than was used in the pilot program. Schools and other local institutions that support test-to-stay events are often hesitant to set up mass testing until they hit that outbreak threshold, as they may face community pushback for testing before it is required, Graul says. As a result, she says, the school outbreaks "are actually larger, and we're not able to contain them as well as last year," during the pilot program.

Opt out versus opt in

A routine school testing program is most effective when all students and staff participate. If testing is voluntary, the families who opt in are likely to be the same families who also follow other COVID-19 precautions, such as wearing masks in public spaces.

Even when families and school staff expressed support for testing in the abstract, Rockefeller's pilot programs found it was much harder to get people on board for a specific testing regimen. Schools that institute these programs have struggled with everything from collecting consent forms, which are notoriously easy for students to misplace, to gaining consent in the first place from some parents. Staff opt-in rates, for example, at the foundation's six pilot sites ranged from 25 percent in Tulsa, Okla., to 100 percent in Los Angeles.

To increase the share of students who get tested, some schools use an opt-out strategy. Rather than students needing a consent form to get tested, they're automatically enrolled in testing and need a permission form to get out of the program. Baltimore has used this strategy, Perkinson says.

New York City also piloted an opt-out strategy in the 2020–2021 school year, requiring all students who attended class in person to participate in weekly random testing — essentially guaranteeing a participation rate of 100 percent for in-person students. In fall 2021, however, testing became opt-in rather than opt-out. As of October 6, less than a quarter of students had opted in.

In parts of the country where COVID-19 safety measures in schools have become intensely political, convincing people to opt in can be especially challenging. Fall 2021 has seen numerous parent protests over these measures — ranging from angry crowds at school board meetings to individual families pulling their children out of public schools.

Routine testing programs have not faced the same degree of scrutiny as mask mandates or vaccination requirements. But "testing has been politicized as much as every other aspect of the response to this pandemic," Broadhurst says. Some of Rockefeller's pilot programs faced some "families and community members who didn't really see the value of testing and didn't really think that schools should be in the business of testing," Vohra says.

It's not just politics, either. "Testing can't happen in a vacuum," Broadhurst says. If a student tests positive, not only is this student out of school for up to two weeks, but a whole family may be out of work to quarantine and care for that child, losing crucial income. This creates tension between public health measures and economic security, Broadhurst says. Integrating testing programs with other services — such as free meals and a space to isolate — for socioeconomically vulnerable families may boost participation in testing programs.

Despite the many challenges of routine testing, school leaders and researchers who work on K–12 COVID-19 testing programs are optimistic about this strategy's potential in the current school year and beyond.

"This is public health; it is not public perfect," Perkinson says. Even if a school is not able to meet an ideal testing benchmark for lowering transmission, every individual test is still a win, she says. Every positive result may identify a case before it turns into an outbreak. ■

Explore more

- D. Vohra *et al*. "Implementing COVID-19 routine testing in K–12 schools: lessons and recommendations from pilot sites." Mathematica. July 26, 2021.

Betsy Ladyzhets is a freelance science writer and data journalist based in Brooklyn, N.Y.

Five lessons from COVID-19 testing in U.S. schools

When acceptable and feasible, using opt-out approaches removes barriers to participation in testing.

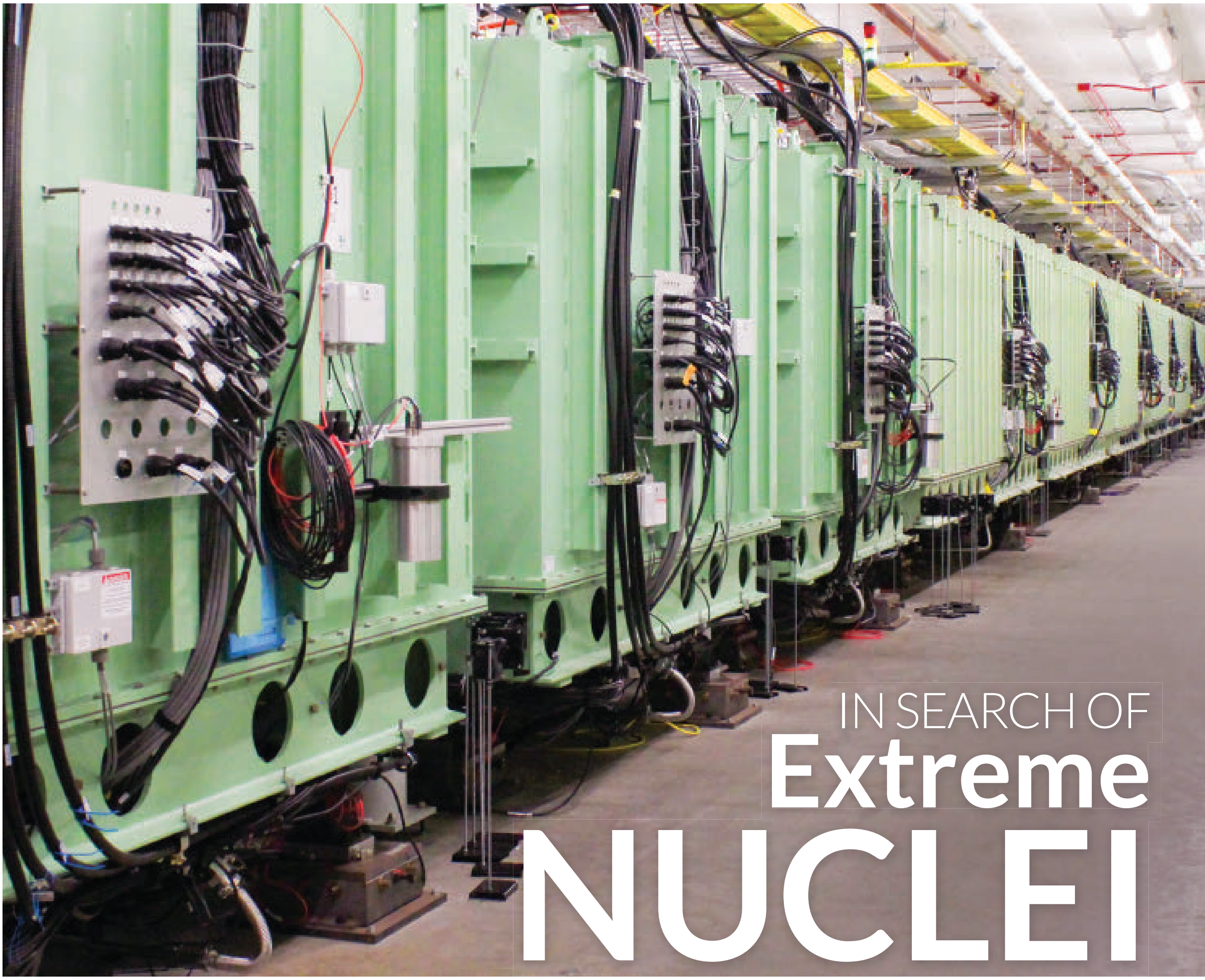
A clear and streamlined informed consent process helps parents better understand testing and makes it easier to opt in.

Offering in-classroom testing and promoting vaccination and testing simultaneously can help maintain enthusiasm for testing.

Keeping the testing program as stable as possible helps build trust in and comfort with testing as a routine part of the school experience.

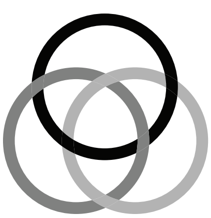
Using respected leaders to communicate about the testing program continues to be an important way to combat misinformation and retain support for testing.

SOURCE: D. VOHRA *ET AL*/MATHEMATICA 2021



IN SEARCH OF Extreme NUCLEI

With a new particle accelerator, scientists set their sights on unexplored atomic territory **By Emily Conover**



Remove one of the three Borromean rings and the whole structure falls apart. Some atomic nuclei have the same property.

Inscribed on an Italian family's 15th century coat of arms and decorating an ancient Japanese shrine, the Borromean rings are symbolically potent. Remove one ring from the trio of linked circles and the other two fall apart. It's only when all three are entwined that the structure holds. The rings have represented the concepts of unity, the Christian Holy Trinity and even certain exotic atomic nuclei.

A rare variety, or isotope, of lithium has a nucleus that is made of three conjoined parts. Lithium-11's nucleus is separated into a main cluster of protons and neutrons flanked by two neutrons, which form a halo around the core. Remove any one piece and the trio disbands, much like the Borromean rings.

Not only that, lithium-11's nucleus is enormous. With its wide halo, it is the same size as a lead nucleus, despite having nearly 200 fewer protons and neutrons. The discovery of lithium-11's expansive halo in the mid-1980s shocked scientists (*SN: 8/20/88, p. 124*), as did its Borromean nature. "There wasn't a prediction of this," says nuclear theorist Filomena Nunes of Michigan State University in East Lansing. "This was one of those discoveries that was like, 'What? What's going on?' "

FROM TOP: FRIB; T. TIBBITTS

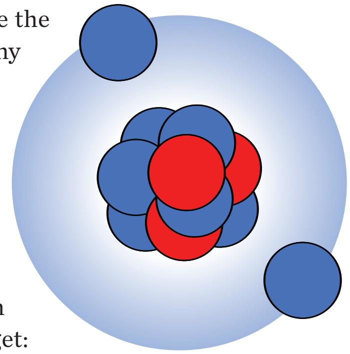
When it switches on in early 2022, the Facility for Rare Isotope Beams' particle accelerator (shown) will accelerate beams of ions to about half the speed of light.

T. TIBBITTS

Lithium-11 is just one example of what happens when nuclei get weird. Such nuclei, Nunes says, "have properties that are mind-blowing." They can become distorted into unusual shapes, such as a pear (*SN: 6/15/13, p. 14*). Or they can be sheathed in a skin of neutrons — like a peel on an inedible nuclear fruit (*SN: 6/5/21, p. 5*).

A new tool will soon help scientists pluck these peculiar fruits from the atomic vine. Researchers are queuing up to use a particle accelerator at Michigan State to study some of the rarest atomic nuclei. When it opens in early 2022, the Facility for Rare Isotope Beams, or FRIB (pronounced "eff-rib"), will strip electrons off of atoms to make ions, rev them up to high speeds and then send them crashing into a target to make the special nuclei that scientists want to study.

Experiments at FRIB will probe the limits of nuclei, examining how many neutrons can be crammed into a given nucleus, and studying what happens when nuclei stray far from the stable configurations found in everyday matter. With FRIB data, scientists aim to piece together a theory that explains the properties of all nuclei, even the oddballs. Another central target: pinning down the origin story for chemical elements birthed in the extreme environments of space.



Curious halo
Lithium-11's nucleus has a center packed with protons and neutrons, surrounded by two neutrons in a broad halo. If one of those three components is removed, the nucleus can't stay bound, what's known as a Borromean nucleus.

And if scientists are lucky, new mind-blowing nuclear enigmas, perhaps even weirder than lithium-11, will emerge. "We're going to have a new look into an unexplored territory," says nuclear physicist Brad Sherrill, scientific director of FRIB. "We think we know what we'll find, but it's unlikely that things are going to be as we expect."

Exploring instability

Atomic nuclei come in a dizzying number of varieties. Scientists have discovered 118 chemical elements, distinguished by the number of protons in their nuclei (*SN: 1/19/19, p. 18*). Each of those elements has a variety of isotopes, different versions of the element formed by switching up the number of neutrons inside the nucleus. Scientists have predicted the existence of about 8,000 isotopes of known elements, but only about 3,300 have made an appearance in detectors. Researchers expect FRIB will make a sizable dent in the missing isotopes. It may identify 80 percent of possible isotopes for all the elements up through uranium, including many never seen before.

The most familiar nuclei are those of the roughly 250 isotopes that are stable: They don't decay to other types of atoms. The ranks of stable isotopes include the nitrogen-14 and oxygen-16 in the air we breathe and the carbon-12 found in all known living things. The number following the element's name indicates the total number of protons and neutrons in the nucleus.

Stable nuclei have just the right combination of protons and neutrons. Too many or too few neutrons causes a nucleus to decay, sometimes slowly over billions of years, other times in mere fractions of a second (*SN: 3/2/19, p. 32*). To understand what goes on inside these unstable nuclei, scientists study them before they decay. In general, as the proton-neutron balance gets more and more off-kilter, a nucleus gets further from stability, and its properties tend to get stranger.

Such exotic specimens test the limits of scientists' theories of the atomic nucleus. While a given theory might correctly explain nuclei that are near stability, it may fail for more unusual nuclei. But physicists want a theory that can explain the most unusual to the most banal.

"We would like to understand how the atomic nucleus is built, how it works," says theoretical nuclear physicist Witold Nazarewicz, FRIB's chief scientist.

A fast clip

Accelerating beams of ions in FRIB is like herding cats.

In the beginning, "it's just a gaggle of cats," says Thomas Glasmacher, FRIB's laboratory director. The cats meander this way or that, but if you can nudge the unruly bunch in a particular direction — maybe you open a can of cat food — then the cats start moving together, despite their natural tendency to wander. "Pretty soon, it's a stream of cats," he says.

In FRIB's case, the cats are ions — atoms with some or all of their electrons stripped off. And rather than cat food, electromagnetic forces get them moving en masse.

The journey starts in one of FRIB's two ion sources, where elements are vaporized and ionized. After some initial acceleration to get the ions moving, the beam enters the linear accelerator, which is what sets the particles really cruising. The linear accelerator looks like a scaled-down freight train — a line of 46 boxes the color of pistachio ice cream, each about 2.5 meters tall, of varying lengths. But the accelerator sends the beam moving much faster than a cargo-filled train — up to about half the speed of light.

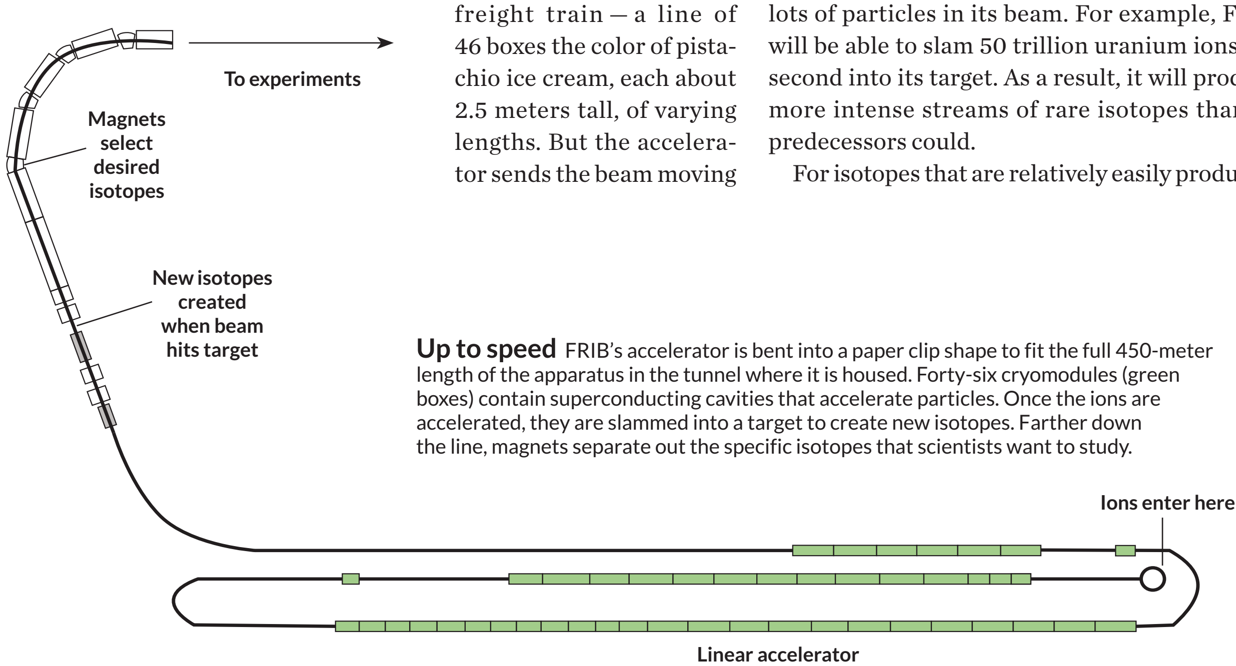
Within the green boxes, called cryomodules, superconducting cavities are cooled to just a few kelvins, a smidge above absolute zero. At those temperatures, the cavities can accelerate the ions using rapidly oscillating electromagnetic fields. The chain of pistachio modules wends around the facility in the shape of a paper clip, a contortion necessary so that the approximately 450-meter-long accelerator fits in the 150-meter-long tunnel that houses it.

When the beam is fully accelerated, it's slammed into a graphite target. That hard hit knocks protons and neutrons off the nuclei of the incoming ions, forming new, rarer isotopes. Then, the specific one that a scientist wants to study is separated from the riffraff by magnets that redirect particles based on their mass and electric charge. The particles of interest are then sent to the experimental area, where scientists can use various detectors to study how the particles decay, measure their properties or determine what reactions they undergo.

The energy of FRIB's beam is carefully selected for producing rare isotopes. Too much energy would blow the nuclei apart when they collide with the target. So FRIB is designed to reach less than a hundredth the energy of the Large Hadron Collider at CERN near Geneva, the world's most energetic accelerator.

Instead, the new accelerator's potential rests on its juiced-up intensity: Essentially, it has lots and lots of particles in its beam. For example, FRIB will be able to slam 50 trillion uranium ions per second into its target. As a result, it will produce more intense streams of rare isotopes than its predecessors could.

For isotopes that are relatively easily produced,



Up to speed FRIB's accelerator is bent into a paper clip shape to fit the full 450-meter length of the apparatus in the tunnel where it is housed. Forty-six cryomodules (green boxes) contain superconducting cavities that accelerate particles. Once the ions are accelerated, they are slammed into a target to create new isotopes. Farther down the line, magnets separate out the specific isotopes that scientists want to study.

T. TIBBITTS

FRIB will churn out about a trillion per second; plenty to study. That opens prospects for scrutinizing isotopes that are more difficult to make. Those isotopes might pop up once a week in FRIB, but that's still much more often than in a weaker beam. It's like a case of low water pressure in the bathroom: "You can't have a shower if it's just trickling," says Nunes, who is one of the leaders of a coalition of theoretical physicists supporting research at FRIB. Now, "FRIB is going to come in with a fire hose."

Dripping with neutrons

That fire hose will also come in handy for pinpointing a crucial boundary known as the neutron drip line.

Try to stuff too many neutrons in a nucleus, and it will decay almost immediately by spitting out a neutron. Imagine a greedy chipmunk with its cheeks so full of nuts that when it tries to shove in one more, another nut pops right back out. The threshold at which nuclei decay in this way marks the ultimate limits for bound nuclei. On a chart of the known elements and their isotopes, this boundary traces out a line, the neutron drip line. So far, scientists know the location of this crucial demarcation up through, at most, the 10th element on the periodic table, neon.

"FRIB is going to be the only way to go heavier and far enough out to define that drip line," says nuclear physicist Heather Crawford of Lawrence Berkeley National Laboratory in California. FRIB is expected to determine the neutron drip line up to the 30th element, zinc, and maybe even farther.

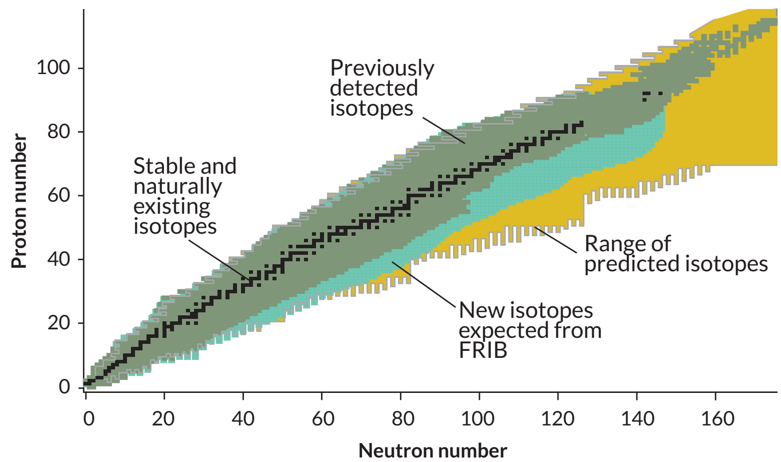
Near that drip line, where neutrons greatly outnumber protons, is where nuclei get especially strange. Lithium-11, with its capacious halo, sits right next to the drip line. Crawford focuses on magnesium isotopes that are close to the drip line. The most common stable magnesium isotope has 12 protons and 12 neutrons. Crawford's main target, magnesium-40, has 12 protons and more than double that number of neutrons — 28 — in its nucleus.

"That's right out at the limits of existence," Crawford says. Out there, theories that predict the properties of nuclei are no longer reliable. Theoretical physicists can't always be sure what size and shape a given nucleus in this realm might be, or even whether it qualifies as a bound nucleus. A given theory might also fall short when predicting how much energy is needed to bump the nucleus into its various energized states. The spacing of these energy levels acts as a kind of fingerprint of an atomic nucleus, one that's highly sensitive to the details of the nucleus' shape and other properties.

Sure enough, magnesium-40 behaves unexpectedly, Crawford and colleagues reported in 2019 in *Physical Review Letters*. While theories predicted its energy levels would match those of magnesium isotopes with slightly fewer neutrons, magnesium-40's energy levels were significantly lower than its neighbors'.

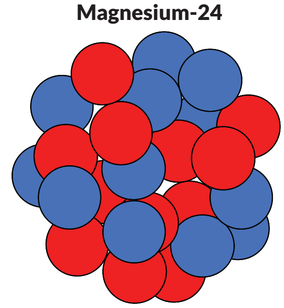
In August, Crawford learned that she will be one of the first scientists to use FRIB. Two experiments she and colleagues proposed were selected for the first round of about 30 experiments to take place over FRIB's first two years. She'll take a closer

Landscapes of isotopes

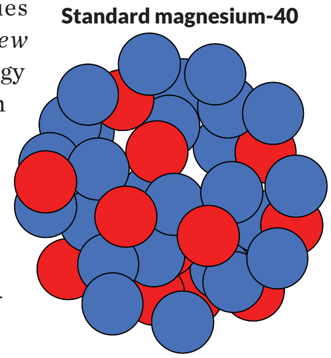


Nuclear limits Scientists have discovered a slew of isotopes of chemical elements (green). FRIB is expected to find new ones (turquoise) within the full range of predicted isotopes (gold). The neutron drip line, the bottom edge of the colored region, marks the limits of nuclei, but scientists don't know exactly where it lies.

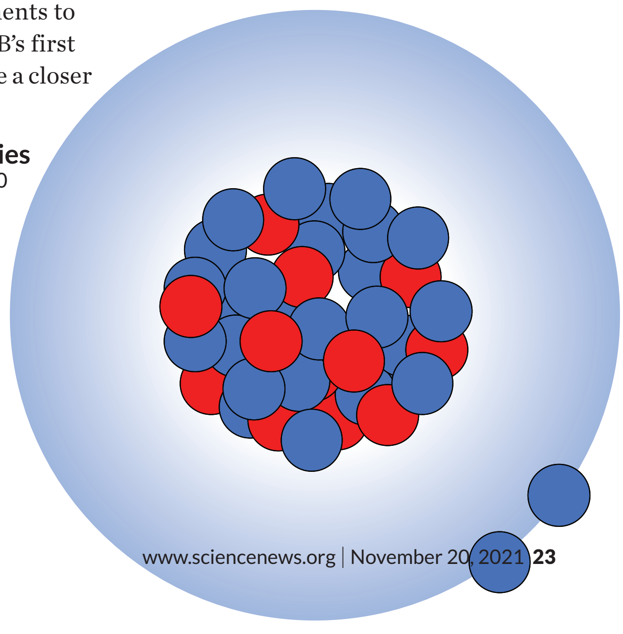
Magnesium-24



Standard magnesium-40



Magnesium-40 with halo



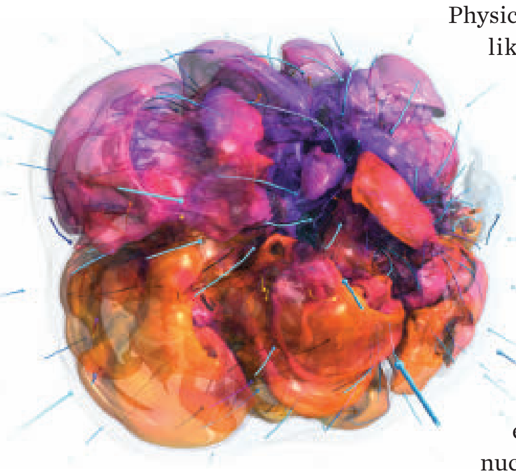
Nucleus possibilities
Unstable magnesium-40 has a nucleus packed with many more neutrons (blue) than the more common, stable magnesium-24 (top), although both have the same number of protons (red). Scientists want to know if magnesium-40 has a typical nucleus (center) or one with a large neutron halo (bottom).

CHART: FRIB; NUCLEI: T. TIBBITTS

The FRIB cryogenic plant makes liquid helium to cool components of FRIB's accelerator that rely on superconductors, which conduct electricity without resistance at temperatures just above absolute zero.

look at magnesium-40, which, like lithium-11, has a Borromean nucleus. Crawford now aims to determine if her chosen isotope also has a haloed nucleus. That's one possible explanation for magnesium-40's oddness. Despite the fact that nuclei with halos have been known for decades, theories still can't reliably predict which nuclei will be festooned with them. Understanding magnesium-40 could help scientists firm up their accounting of nuclei's neutron adornments.

Nuclear physics goes extreme in supernovas (computer simulation shown below) and similar environments. New elements and exotic isotopes may be formed in the tumult.



Elemental origins

Physicists want to be able to poke around, like mechanics under the hood, to understand the cosmic nuclear reactions that make the universe go. "Nuclear physics is like the engine of a sports car. It's what happens in the engine that determines how well the car performs," says nuclear physicist Ani Aprahamian of the University of Notre Dame in Indiana.

The cosmos powered by that engine can be a violent place for nuclei, punctuated with dramatic stellar explosions and extreme conditions, including matter crammed into ultratight quarters by crushing gravity. These environments beget wonders of nuclear physics unlike those normally seen on Earth. FRIB will let scientists get a glimpse at some of those processes.

For example, physicists think that certain neutron-rich environments are the cauldron where many of the universe's chemical elements are cooked. This cosmic connection allowed nuclear physicist Jolie Cizewski to make good on a childhood dream.

When Cizewski was a little girl, she caught the astronomy bug, she says. "I decided I was going to become an astronomer so I could go into space." It might seem that she took a left turn from her childhood obsession. She never made it to orbit and she didn't become an astronomer.

But echoes of that childhood dream now anchor her research. Instead of peering at the stars with a telescope, she'll soon be using FRIB to reveal secrets of the cosmos.

Cizewski, of Rutgers University in New Brunswick, N.J., is working to unveil details of the cosmic nuclear reactions responsible for the nuclei that surround us. "I'm trying to understand how the elements, in particular those heavier than

FROM TOP: MICHIGAN STATE UNIV.; ADAM BURROWS/PRINCETON UNIV., JOE INSLEY AND SILVIO RIZZI/ARGONNE NATIONAL LAB iron, have been synthesized," she says.

Many of the elements around us — and in us — formed within stars. As large stars age, they fuse progressively larger atomic nuclei together in their cores, creating elements farther along the periodic table — oxygen, carbon, neon and others. But the process halts at iron. The rest of the elements must be born another way.

A process called the rapid neutron capture process, or r-process, is responsible for many of those other elements found in nature. In the r-process, atomic nuclei quickly soak up neutrons and bulk up to large masses. The neutronfest is interspersed with radioactive decays that form new elements. The sighting of two neutron stars merging in 2017 revealed that such collisions are one place where the r-process occurs (*SN: 11/11/17, p. 6*). But scientists suspect it might happen in other cosmic locales as well (*SN: 6/8/19, p. 10*).

Cizewski and colleagues are studying an abbreviated form of the r-process that might thrive in supernovas, which may not have enough oomph for the full r-process. The team has zeroed in on germanium-80, which plays a pivotal role in the weak r-process. Physicists want to know how likely this nucleus is to capture another neutron to become germanium-81. At FRIB, Cizewski will slam a beam of germanium-80 into deuterium, which has one proton and one neutron in its nucleus. Knowing how often germanium-80 captures the neutron will help scientists nail down the neutron-slurping chain of the weak r-process, wherever it might crop up.

A Borromean bent

Like the interlinked Borromean rings, different facets of nuclear physics are closely entwined, from mysteries of the cosmos to the inner workings of nuclei. The exotic nuclei that FRIB cooks up could also allow physicists to tap into the very bedrock of physics by testing certain fundamental laws of nature. And there's a practical side to the facility as well. Scientists could collect some of the isotopes FRIB produces for use in medical procedures, for example.

Physicists are ready for surprises. "Every time we build such a facility, new discoveries come and breakthroughs in science come," Nazarewicz says. Like the 1980s discovery of lithium-11's Borromean nucleus, scientists may find something totally unexpected. ■

Explore more

■ Facility for Rare Isotope Beams. frib.msu.edu/

Icing on the cake

Along with studying atomic nuclei at extremes and exploring nuclear physics of the stars, scientists hope to use FRIB to make progress in two other key areas.

65
Tb
terbium

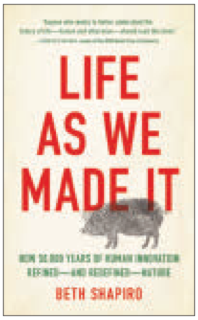
Harvesting useful nuclei
Scientists plan to collect isotopes produced in FRIB for societal applications. In medicine, for example, certain isotopes, such as terbium-149, can be used for radiation treatment or medical imaging.

When this isotope of the rare earth metal terbium decays, it can emit alpha particles (helium nuclei) that can kill cancer cells. Its half-life of 4.1 hours is in a sweet spot: fast enough to have an effect — it doesn't take hundreds of years to decay — but not so fast that it's gone within seconds, before it can do its work.

88
Ra
radium

Testing laws of nature
Scientists plan to check certain physics rules, for example, the idea that matter and antimatter behave as mirror images. Certain hypothetical physics effects could cause particles to flout this rule, and that could help explain why there's more matter than antimatter in the universe.

Effects that could make matter and antimatter behave differently might also cause electric charge in atoms to separate, with slightly more positive charge on one side of the atom and more negative on the other. In most atoms, this separation may be too tiny to measure. But in radium-225, which has a pear-shaped nucleus, the effect would be stronger, as the nucleus' asymmetry should enhance the asymmetry of the atom's charge. *— Emily Conover*



Life as We Made It
Beth Shapiro
BASIC BOOKS, $30

BOOKSHELF

Human innovation has long molded nature

With genetic engineering, humans have recently unleashed a surreal fantasia: pigs that excrete less environment-polluting phosphorus, ducklings hatched from chicken eggs, beagles that glow ruby red under ultraviolet light. Biotechnology poses unprecedented power and potential — but also follows a course thousands of years in the making.

In *Life as We Made It*, evolutionary biologist Beth Shapiro pieces together a palimpsest of human tinkering. From domesticating dogs to hybridizing endangered Florida panthers, people have been bending evolutionary trajectories for millennia. Modern-day technologies capable of swapping, altering and switching genes on and off inspire understandable unease, Shapiro writes. But they also offer opportunities to accelerate adaptation for the better — creating plague-resistant ferrets, for instance, or rendering disease-carrying mosquitoes sterile to reduce their numbers.

For anyone curious about the past, present and future of human interference in nature, *Life as We Made It* offers a compelling survey of the possibilities and pitfalls. Shapiro is an engaging, clear-eyed guide, leading readers through the technical tangles and ethical thickets of this not-so-new frontier. Along the way, the book glitters with lively, humorous vignettes from Shapiro's career in ancient DNA research. Her tales are often rife with awe (and ripe with the stench of thawing mammoths and other Ice Age matter).

The book's first half punctures the misconception that we "have only just begun to meddle with nature." Humans have meddled for 50,000 years: hunting, domesticating and conserving. The second half chronicles the advent of recent biotechnologies and their often bumpy rollouts, leading to squeamishness about genetically modified food and a blunder that resulted in accidentally transgenic cattle.

As we teeter on a technological precipice, Shapiro contends we have a choice to make. We can learn to meddle with greater precision, wielding the sharpest tools at our disposal. Or, she writes, "we can reject our new biotechnologies" and continue directing evolutionary fates anyway, "just more slowly and with less success."

Shapiro speculates about what the future may hold if we embrace our role as tinkerers: plastic-gobbling microbes, saber-toothed house cats, agricultural crops optimized for sequestering carbon. Whether these visions will come true is anyone's guess. But one thing is clear. No matter which route we choose, humans will continue to stir the evolutionary soup. There's no backing out now. *— Jaime Chambers*

APPLYING A CULTURAL LENS TO SCIENCE

"Who we are, our culture, our experiences, our identities, our background—all of those things—influence our interest and approaches to science," Mónica Feliú-Mójer shared during her keynote address during the Society for Science's 2021 Middle School Research Teachers Conference. Feliú-Mójer, a scientist-turned-educator who grew up in rural Puerto Rico, has focused her career on applying a cultural lens to science communication and storytelling as a means to make science more equitable and inclusive.

"Too often science, and more broadly STEM, is decontextualized and disconnected from our realities, cultures and experiences. This is particularly true when it comes to students and communities that have been historically marginalized in science," she noted. "Of course, this is problematic because it contributes to the underrepresentation and the continued marginalization of some of these groups in science."

Feliú-Mójer urged educators to find diverse role models for their students, recommending that they reach out to local universities that may have groups interested in community outreach. "If we're intentional about what role models we're presenting, we can diversify the idea of who a scientist is and really give kids role models who are more relevant to their realities and experiences," she said.

Feliú-Mójer has produced a series of short films available on YouTube called *Background to Breakthrough* that feature three scientists who are bringing their culture and experiences to their innovations. She also works with the nonprofit organization Ciencia Puerto Rico on an initiative to create more than 160 profiles of Latinas in STEM, which can be found on the organization's website.

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But for many collectors, his strongest legacy is having created one of the most fascinating and unique bronze coins in the history of the Roman Empire: the "Gladiator's Paycheck".

THE GLADIATORS PAYCHECK

Roman bronze coins were the "silver dollars" of their day. They were the coins used for daily purchases, as well as for the payment of wages. Elite Roman Gladiators—paid to do battle before cheering crowds in the Colosseum—often received their monthly 'paycheck' in the form of Roman bronze coins.

But this particular Roman bronze has a gladiator pedigree like no other! Minted between 348 to 361 AD, the Emperor's portrait appears on one side of this coin. The other side depicts a literal clash of the gladiators. One warrior raises his spear menacingly at a second warrior on horseback. Frozen in bronze for over 1,600 years, the drama of this moment can still be felt when you hold the coin. Surrounding this dramatic scene is a Latin inscription—a phrase you would never expect in a million years!

HAPPY DAYS ARE HERE AGAIN

The Latin inscription surrounding the gladiators reads: "Happy Days are Here Again" (*Fel Temp Reparatio*). You see, at the time these coins were designed, the Emperor had just won several important military battles against the foes of Rome. At the same time, Romans were preparing to celebrate the 1100th anniversary of the founding of Rome. To mark these momentous occasions, this new motto was added and the joyful inscription makes complete sense.

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Birds of poetry

Unusually bright plumage (shown, left) on some female white-necked jacobin hummingbirds may help them avoid harassment, **Carolyn Wilke** reported in "Female hummingbirds go undercover" (*SN: 9/25/21, p. 11*). While the story doesn't evoke romance, it reminded Twitter user **@vekerim** of Raymond Carver's poem "Hummingbird," which he wrote for his wife, Tess Gallagher, a fellow poet:

Suppose I say *summer*, / write the word "hummingbird," / put it in an envelope, / take it down the hill / to the box. When you open / my letter you will recall / those days and how much, / just how much, I love you.

Join the conversation

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Surf's up

A laser experiment suggests that protons in outer space can accelerate by surfing shock waves within plasma, ***Emily Conover*** *reported in "Shock waves give protons a boost" (*SN: 9/25/21, p. 7*).*

Reader **Norma Frank** wanted to know why the protons surf shock waves at all.

Protons in the presence of such cosmic shock waves don't have much choice, **Conover** says. "The electric and magnetic fields in the vicinity of the shock wave create forces that push and pull the protons, according to the laws of physics," she says. "That's what causes the particles to surf."

Mind the map

Humans tend to arrange abstract ideas such as numbers or time spatially, but we don't all use the same directions, ***Sujata Gupta*** *reported in "Culture shapes humans' mental maps" (*SN: 9/25/21, p. 8*).*

Reader **John Strand** asked whether native languages influence the direction in which people map objects.

Written language may influence directionality, **Gupta** says. A study published in 2005 in the *Journal of Cognition and Culture* examined how Arabic speakers, who read from right to left, arrange numbers in a line. That study revealed that people who read only in Arabic tend to place lower magnitude items on the right — the opposite of native English speakers. This tendency was weaker for people who could read in both Arabic and English, and was not observed in Arabic speakers who couldn't read, the researchers found.

Reckoning with racism in science

Some everyday names for animals and plants contain racist or offensive connotations. A movement to change those monikers is growing within the scientific community, ***Jaime Chambers*** *reported in "Racist legacies lurk in common names" (*SN: 9/25/21, p. 12*).*

"Bravo to this initiative!" wrote reader **Fatimah L.C. Jackson**, a biologist at Howard University in Washington, D.C. "This is an important step to making the world a better place."

Bidding brows adieu

The last century of paleoanthropology has sketched out a rough timeline of how human evolution played out, centering its early roots in Africa, ***Erin Wayman*** *reported in "Tracing the origins of humans" (*SN: 9/25/21, p. 20*).*

Reader **Elizabeth Hatcher** wondered when and why humans lost the prominent brow ridges sported by many early human ancestors.

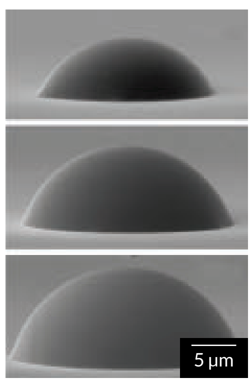
"No one knows for sure why humans lost big, heavy brow ridges," **Wayman** says. One recent idea is that the loss was a consequence of human "self-domestication" (*SN: 1/18/20, p. 16*). Sometime over the last few hundred thousand years, the theory goes, humans became more cooperative and peaceful, favoring the friendly over the aggressive. Selecting for "tameness" among each other also resulted in genetic changes that affected our appearance, leading to small, flatter faces — akin to how selecting for tame wolves as our companions tens of thousands of years ago led to the floppy-eared, curly-tailed dogs we know today.

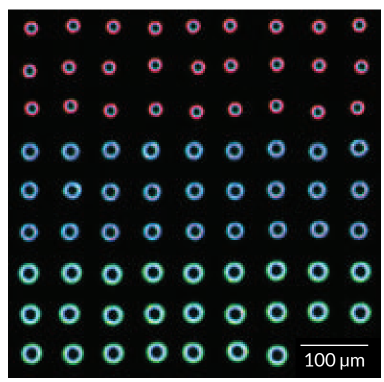
An offshoot of this idea suggests that smaller brow ridges allowed for the development of mobile eyebrows that could express a range of emotions, **Wayman** says. Being able to communicate even subtle feelings and intentions may have been advantageous at a time when human social relationships were becoming increasingly complex. "Of course, like many things in human evolution, these ideas are controversial," she says.

Reader **Rick Doughty** praised how **Wayman's** story put into perspective the last century of efforts to understand human origins. "I remember reading in *Science News* about the 'latest news and findings' that were coming to light in the 1960s and 1970s," **Doughty** wrote. "I now have a better understanding of the field and also an appreciation for how far we have come in 100 years (and also how much still remains unresolved)."

GERALD CORSI/ISTOCK/GETTY IMAGES PLUS

Tiny domes of see-through ink create these colorful butterflies





You've heard of disappearing ink. Now get ready for suddenly appearing ink. Using a clear liquid, researchers can print a full rainbow of colors on transparent surfaces. The trick is printing the liquid in precise, microscale patterns that create structural color, researchers report September 22 in *Science Advances*.

Structural color arises from the way different wavelengths of light bounce off microscopic imperfections on surfaces (*SN: 6/11/16, p. 32*). "In nature, there are many beautiful structure colors, such as the wings of butterflies, the feathers of peacocks, the skin of chameleons and so on," says Yanlin Song, a materials chemist at the Chinese Academy of Sciences in Beijing.

Song and colleagues printed structural colors on transparent silicone sheets using an ordinary ink-jet printer and clear polymer ink. The printer studded the silicone sheets with millions of microscopic ink domes. Each dome served as a single pixel in the resulting images, including of butterflies (top) and celebrities such as Marilyn Monroe.

Adjusting a microdome's size changed the wavelengths of light that the dome reflected and therefore its color. (Scanning electron micographs show domes with different diameters, above left, and dark-field optical micrographs show the corresponding colors created by those domes, right).

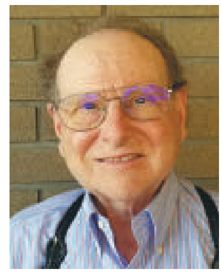
The denser the domes were packed, the brighter the image. And printing a medley of differently colored ink pixels across a single area created blended shades, such as brown and gray.

"I was excited to see that somebody had used [structural color] for this purpose," says Lauren Zarzar, a materials chemist at Penn State. The new images "illustrated the versatility of this mechanism." She imagines using structural colors to create complex optical signatures for anti-counterfeiting features on ID cards or currency. Such shimmery, colorfast hues could also be used in cosmetics, clothing or architecture, she says. — *Maria Temming*

ALL: K. LI *ET AL*/*SCIENCE ADVANCES* 2021

MAKE A DIFFERENCE
JON GRAFF DID

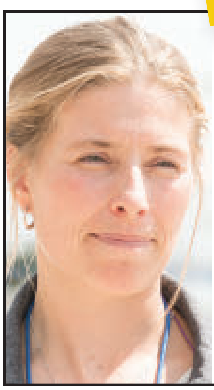
Jon Graff was a lifelong *Science News* reader who greatly admired the communications skills of its writers and editors. During his life, Jon helped devise the secure methods we use every day to make online credit card transactions. He also loved taking long trips in the Southwest on his beloved green bike.



When Jon looked back over his life as he grew older, he thought about the things that mattered to him most—his biking friends, his seminal work as a cryptographic architect and decades of reading *Science News*.

Sadly, Jon died in January 2021 at the age of 77. Before he died, Jon made a bequest intention to create an endowment—The Jon C. Graff Fund for *Science News*—whose income will benefit both the Society for Science and *Science News* journalism in perpetuity.

Bequest gifts are the right kind of gift for many of us, enabling us to support the organizations we most admire after our lifetimes.



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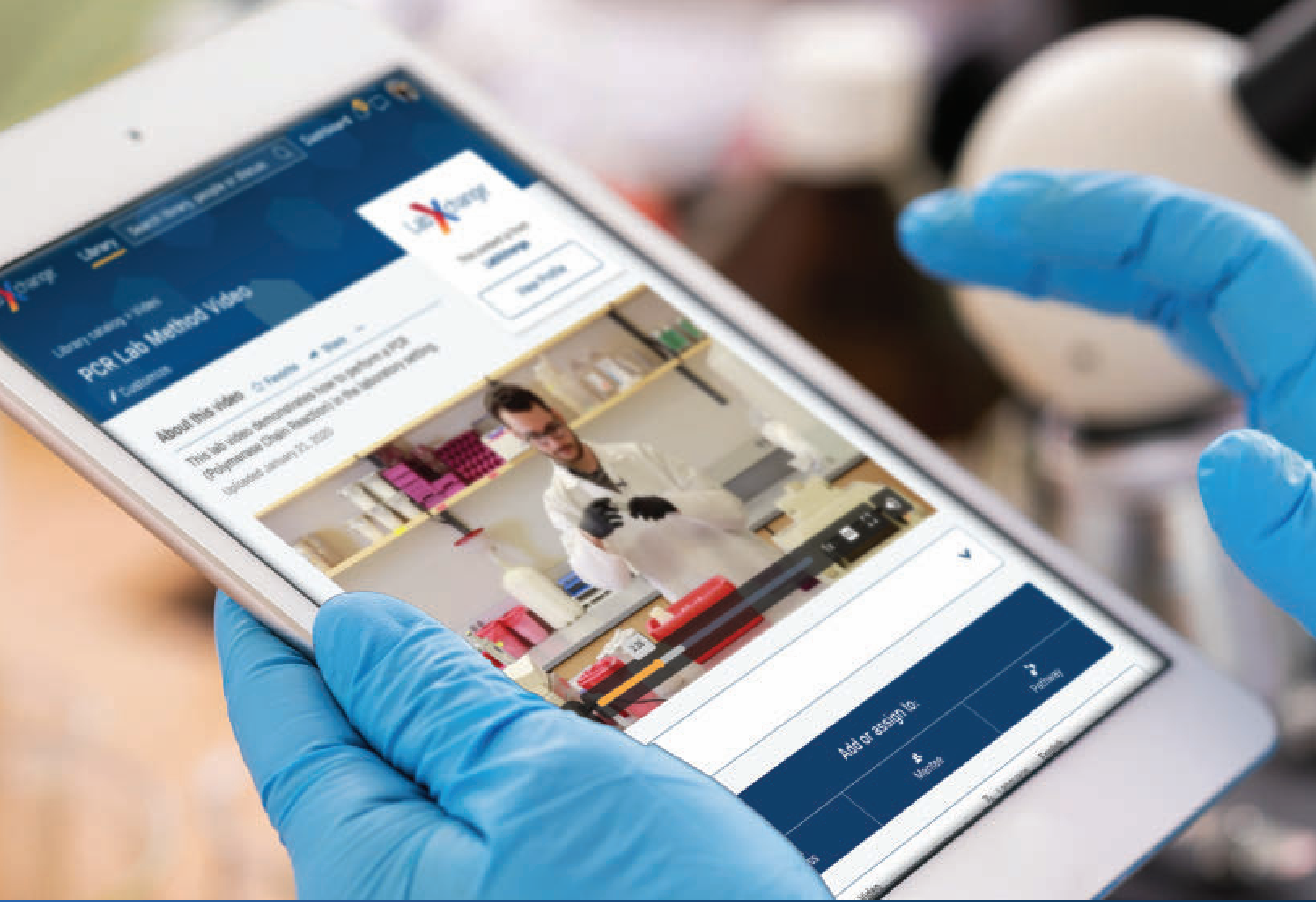

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