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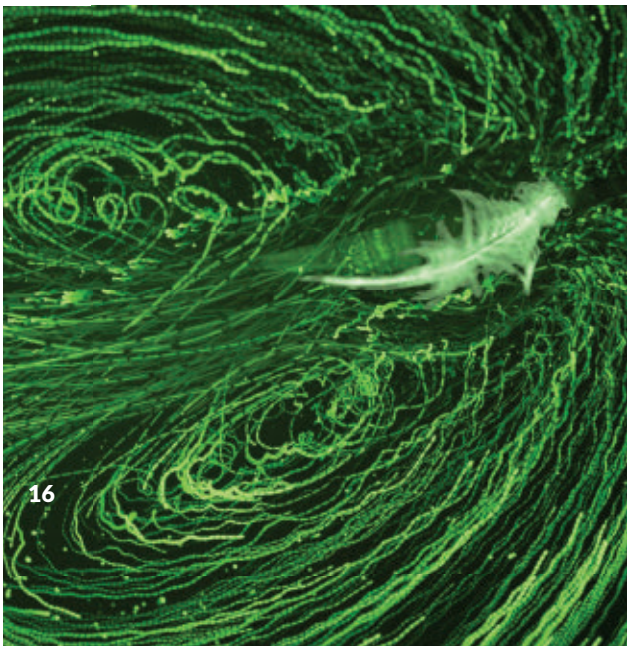
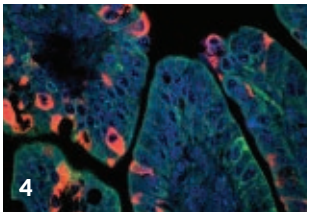
ScienceNews

Features

News





Departments

COVER In battles, some beetles use big horns to signal dominance, not to kill. But for some unassuming creatures, duels are deadly. *Ron Kurniawan*

FROM TOP: JOHAN SWANEPOEL/SHUTTERSTOCK; P. ZHOU *ET AL*/*NATURE* 2018; ISABEL HOUGHTON

Does this magazine look fat? If so, that's a good thing

Subscribers to *Science News* may note that this special double issue is a lot heftier than the usual magazine, boasting more than 20 pages of advertisements. That's up from 13 pages in last spring's expanded issue.

Indeed, our ace marketing department sold so many ads that we had to include more articles, which, as anyone in print publishing will tell you, is a very nice problem to have. Thus, you'll see not our usual two enterprise features, but three.

We have astronomy writer Lisa Grossman's beguiling look at how to cook up an exoplanet (Page 28). Since no one knows the exact recipes for planets outside our solar system, scientists are making educated guesses on exoplanet composition and literally cooking up samples in the lab.

In "Making the cut," behavioral sciences writer Bruce Bower tells the tale of an archaeologist who, thanks to high school summer jobs working construction for his dad, was able to reverse engineer a pendulum saw, build it in his dad's backyard and use it to slice stone (Page 32). This MacGyver-esque effort was undertaken to buttress the scientist's contention that ancient Mycenaeans used similar contraptions to build majestic Bronze Age palaces.

And if you were a critter, what armaments would increase your odds of surviving conflict with other members of your species? That's the question life sciences writer Susan Milius asks on Page 36, and the answer may surprise you. Giant stag antlers may look dangerous, but they're used largely to intimidate, not for lethal attack. If you must defend your turf and survive to mate, Milius notes, you might want to have the diminutive jaws of the female fig wasp. She annihilates potential competitors by pinching off their heads.

These stories dig deep into how scientists do their work and what the scientific process reveals, and I'm delighted that many of the top young scientific minds in the world will receive this special issue at the Intel International Science and Engineering Fair, ISEF, being held May 13 to 18 in Pittsburgh. It's the world's largest precollege science competition and is a flagship program of Society for Science & the Public, the nonprofit organization that publishes *Science News*. Intel ISEF draws 1,800 competitors from almost 80 countries, more than 1,000 volunteer judges and thousands of other students, volunteers and members of the public — about 10,000 people all told.

If you're encountering *Science News* for the first time at Intel ISEF, welcome! It's great to have you join us in exploring what's new, essential or just plain cool. You're joining our print subscribers, as well as students and teachers at more than 4,300 high schools who stay up to speed on innovations and advances with *Science News*.

This publication has been a force for independent, accurate science journalism for almost 100 years. We believe in the power of science to transform lives and advance civilization. Our mission is to empower people to critically evaluate the news and the world around them.

We also think that science can be a heck of a lot of fun, whether it involves animal armaments or cooking up a planet. — *Nancy Shute, Editor in Chief*

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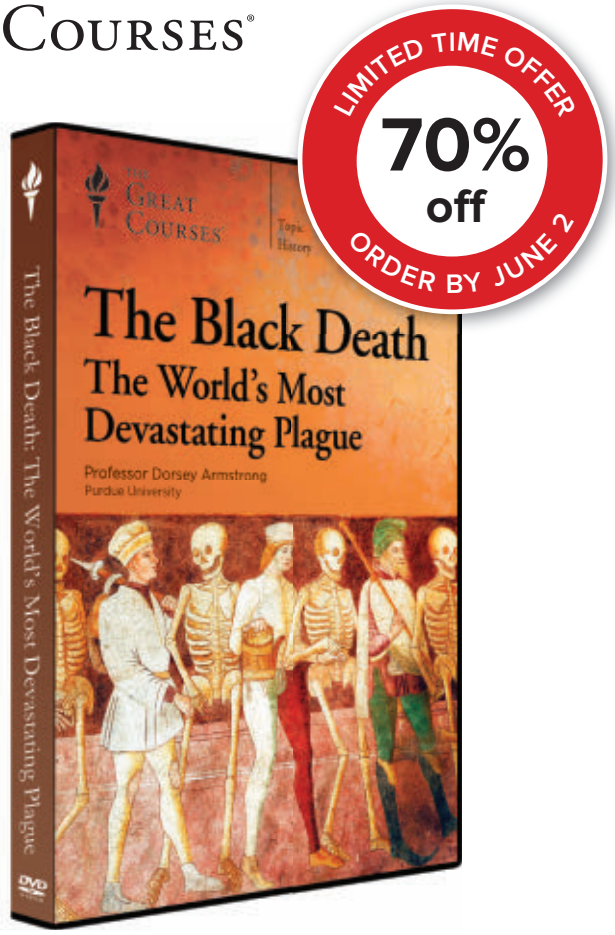

How Did the Black Death Change History?

In the late 1340s, a cataclysmic plague—known to us as the Black Death—left up to 75 million dead across Europe.

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Excerpt from the May 4, 1968 issue of *Science News*

50 YEARS AGO

Starve the tumor, not the cell

Animal experiments demonstrate for the first time that transplanted tumors release a chemical into the host's bloodstream that causes the host to produce blood vessels to supply the tumor.... If such a factor can be identified in human cancers ... it might be possible to prevent the vascularization of tumors. Since tumors above a certain small size require a blood supply to live, they might by this method be starved to death.

UPDATE: By the 1990s, starving tumors had become a focus of cancer research. Several drugs available today limit a tumor's blood supply. But the approach can actually drive some cancer cells to proliferate, researchers have found. For those cancers, scientists have proposed treatments that open up tumors' gnarled blood vessels, letting more oxygen through. Boosting oxygen may thwart some cancer cell defenses and promote blood flow — allowing chemotherapy drugs and immune cells deeper access to tumors (*SN: 3/4/17, p. 24*).

Tying your shoes with this bootlace worm might leave you with tingling fingers.

IT'S ALIVE

World's longest animal has a slimy, toxic trick

Bad news, cockroaches. Humans have discovered a new family of insect-killing toxins in the slightly milky ooze that coats the longest animal in the world.

Bootlace worms (*Lineus longissimus*) can stretch 50 meters, as long as an Olympic-sized swimming pool. This champion marine worm makes mucus that smells a bit like iron or sewage. The goo holds small toxic proteins, now dubbed nemertides, with a variation on knotty structures that chemists have

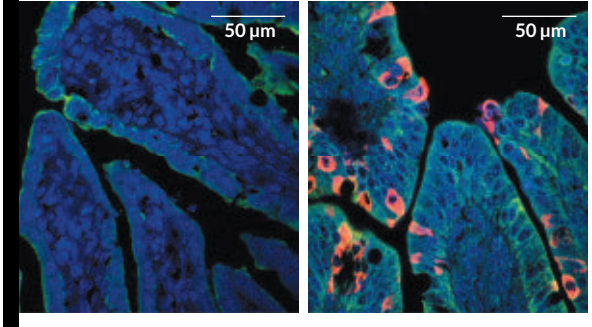
INTRODUCING

New coronavirus jumped from bats to pigs in China

A new kind of coronavirus is preying on pigs in China. And like the deadly SARS virus, which killed almost 800 people in 2002 and 2003, this one also got its start in bats.

In late 2016, pigs on a farm in southeastern China's Guangdong province came down with intense diarrhea and vomiting. By May 2017, the disease, dubbed swine acute diarrhea syndrome, or SADS, had killed 24,693 piglets on four farms (older pigs recover). The outbreak, which has waned, wasn't caused by any common pig viruses.

By analyzing samples from sick piglets, researchers pieced together the genetic blueprint of the virus causing SADS. The virus shares 95 percent of its genome with another coronavirus, HKU2, detected in cave-dwelling horseshoe bats in 2007. Evidence suggests that these two coronaviruses share a recent common ancestor and that SADS jumped from bats to pigs, researchers report online April 4 in *Nature*.



When six healthy piglets were infected with SADS virus taken from sick piglets, three died. Compared with healthy piglets' intestinal tissue (left), sick piglets' tissue showed signs of SADS (virus proteins shown red).

The disease doesn't appear to infect humans today. But the first reported human cases of SARS, short for severe acute respiratory syndrome, emerged in 2002 about 100 kilometers from the pig farms hit by SADS. The study adds to evidence that keeping an eye on bat viruses could reduce future viral outbreaks in pigs and in humans. — *Helen Thompson*

FROM TOP: FOSILETE/FLICKR (CC BY-NC-SA 2.0); P. ZHOU *ET AL*/*NATURE* 2018

not seen before, says Ulf Göransson of Uppsala University in Sweden. He studies chemicals derived from natural sources.

The nemertides attack tiny channels in cell membranes that control the amount of sodium flowing in and out of the cell, Göransson and colleagues report March 22 in *Scientific Reports*. Much vital cell business, such as communications between nerves, depends on the right flux through these so-called voltage-gated sodium channels.

Injections of small amounts of one of these nemertides permanently paralyzed or killed invasive *Carcinus maenas* crabs and *Blaptica dubia* cockroaches. These compounds might inspire novel ways to attack such pests.

Unlike earthworms, the 1,300 or so species of bootlace, or ribbon, worms have no segments. Scientists give these animals their own phylum, Nemertea. Bootlace worms have a brain but no lungs, and, like many other slender marine creatures, they breathe directly through the skin. The worms are carnivorous, supping on crustaceans, mollusks and other worms.

Bootlace worms are marvels of body expansion and contraction. An *L. longissimus* "of about 10 meters can be held in your hand as a slimy heap," says study coauthor Malin Strand, a marine biologist and molecular systematist at the Swedish University of Agricultural Sciences in Uppsala. She estimates the worms can live for about 10 years "or maybe much longer."

The stringy worms can be tricky to feed in captivity. In Strand's lab, some deigned to eat only once in three to four years.

Mucus toxins might help with feeding if, say, the bootlace squeezes under the shell of a limpet and flexes its mouth, a slit on the underside of its body, around the soft lump of mollusk. The mouth can stretch wide, says Strand, "a bit like a snake eating a dead deer." Researchers don't know if the toxins act on mollusks, but if so, there's plenty of slime to sneak under a shell.

The bootlace worm swallows its prey through a hole on the underside of the body.

Göransson proposes that toxic mucus may be useful for defense. He has seen video of Nemertean worms stretched out on the seafloor. "If you're a crab or a fish, it must be tempting to take a nip," he says, but nothing nibbles those worms.

Göransson once tried bare-handed contact with a small lab specimen, skinny from fasting, and didn't feel much of anything. Yet based on tales of other worm touchers experiencing "tingling" and hands going temporarily numb, Göransson prefers to wear gloves. — *Susan Milius*

SCIENCE STATS

Earth's oceans are sweltering

In 2011, a marine heat wave devastated the towering kelp forests of Australia's Great Southern Reef.

Over the last century, marine heat waves have become more common and longer-lasting. More than just a hot afternoon, a marine heat wave is defined as at least five consecutive days of unusually high temperatures. From 1925 to 2016, the number of heat waves seen each year in some part of the ocean rose by 34 percent — and most of that change occurred in the last few decades, researchers report April 10 in *Nature Communications*. Because the events lasted longer, the average number of marine heat wave days each year rose from 26 to 40, an increase of 54 percent.

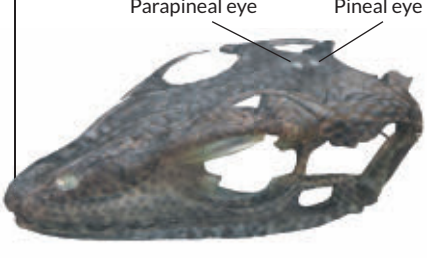
That trend is mostly influenced by climate change causing surface waters to warm, rather than changes in large atmosphere-ocean climate patterns, such as the El Niño–Southern Oscillation. The researchers predict even more frequent marine heat waves in coming decades. Extreme temperatures can be lethal for corals (see Page 20), kelp and other marine species, and can wreak havoc on fisheries and aquaculture (*SN: 2/3/18, p. 16*). — *Carolyn Gramling*

HOW BIZARRE

Ancient lizard had four 'eyes'

About 49 million years ago, a monitor lizard in what is now Wyoming perceived the world through four eyes. *Saniwa ensidens* is the only known jawed vertebrate to have had two eyelike photosensory structures at the top of its head, in addition to the organs we commonly think of as eyes, researchers report in the April 2 *Current Biology*.

CT scans of fossils collected 147 years ago revealed spaces in the skull for third and fourth eyes, known as the parapineal and pineal glands. What the ancient lizard did with these organs is unknown, but some modern vertebrates navigate using a pineal gland that amplifies photosensitivity. *S. ensidens* may have perceived polarized light and used the angle of the sun like a compass. Or it may have navigated using Earth's magnetic field, as do some amphibians and migratory birds (*SN Online: 4/3/18*). — *Carolyn Gramling*



With two extra eyes, the ancient monitor lizard *Saniwa ensidens* may have had some extra options for navigating.

FROM TOP: JAMES SOWERBY; EMMA FLUKES; ANDREAS LACHMANN, SENCKENBERG GESELLSCHAFT FÜR NATURFORSCHUNG, DIGIMORPH.ORG

EARTH & ENVIRONMENT

More CO_2 doesn't always help plants

The gas didn't boost growth as expected in a 20-year study

BY ERIKA ENGELHAUPT

Two major groups of plants have shown a surprising reversal of fortunes in the face of rising levels of carbon dioxide in the atmosphere.

During a 20-year field experiment in Minnesota, a widespread group of plants that initially grew faster when fed more CO_2 stopped doing so after 12 years, researchers report in the April 20 *Science*. Meanwhile, the extra CO_2 began to stimulate growth of a less common plant group that includes many grasses. The switcheroo, if it holds true elsewhere, suggests that in the future the majority of Earth's plants might not soak up as much of the greenhouse gas as expected, while some grasslands might take up more.

With such unexpected results, perhaps we shouldn't be so certain that we know what ecosystems will do in the future, says study leader Peter Reich, an ecosystem ecologist at the University of Minnesota in St. Paul. Today, land plants scrub about a third of the CO_2 that humans emit. "We need to be more worried," he says, about whether that trend will continue.

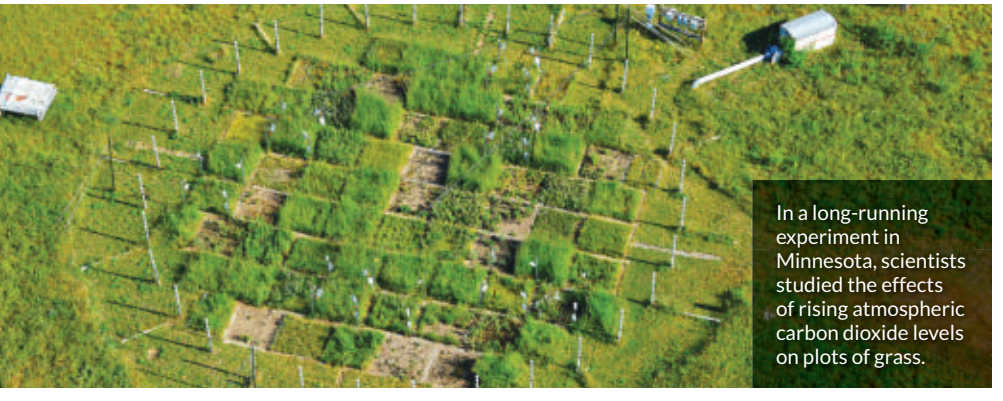
The two kinds of plants in the study react differently to CO_2 because they use different types of photosynthesis. About 97 percent of plant species, including all trees and some grasses, use a method called C3. Most plants using the other method, C4, are grasses.

Both processes feed plants by pulling CO_2 from the air. But C4 plants use CO_2 more efficiently, so they're less hungry for it. As a result, it has long been dogma that when CO_2 increases in the air, C3 plants gobble up more of it — and thus grow faster — while C4 plants ignore it.

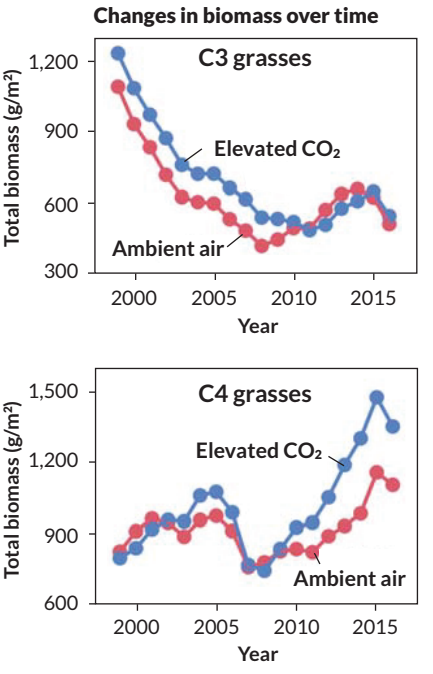
And that's what experiments on plants grown in elevated CO_2 have always shown — until now. For 20 years, scientists at the Cedar Creek Ecosystem Science Reserve grew both C3 and C4 grasses in 88 plots, pumping extra CO_2 into half of them to increase concentrations by 180 parts per million. That amounts to about 50 percent more CO_2 than was in ambient air at the experiment's beginning, and double preindustrial levels.

For the first 12 years, the plants hummed along as expected: C3 grasses responded more strongly to extra CO_2 — a 20 percent boost in growth compared with grasses grown in ambient air — and C4 grasses largely ignored the difference. But then the pattern reversed. Over the next eight years, C3 grasses grew on average 2 percent less plant material if they received extra CO_2, while C4 grasses grew 24 percent more.

"I'm not at all surprised that an experiment like this would produce the unexpected," says forest ecologist Rich Norby of Oak Ridge National Laboratory in Tennessee. Norby led a project that tested a forest's response to elevated CO_2 for 12 years, and says the new results highlight the importance of such long-term experiments. In particular, Norby says, soil fertility can affect how plants respond to CO_2 in the long run.



In a long-running experiment in Minnesota, scientists studied the effects of rising atmospheric carbon dioxide levels on plots of grass.



Trading places Grasses using the C3 form of photosynthesis (top) initially showed a stronger response to extra CO_2 relative to ambient air than grasses using the C4 form (bottom). But this pattern reversed after about 12 years.

In fact, soil nutrients may have been key to the flip-flop in Minnesota. Without nitrogen, plants can't take advantage of extra CO_2. Over the course of the experiment, soil nitrogen became limited for C3 plants, but in greater supply for C4 plants. The team suspects that differences in decomposing plant material might have led to changes in the community of microbes that process nitrogen in the soil and make it available to plants.

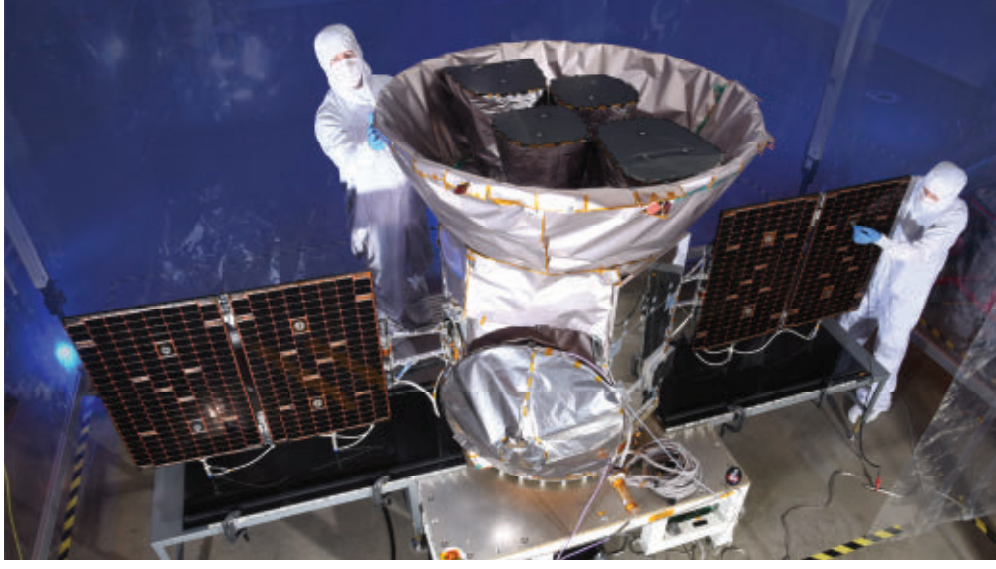
Grasslands cover 30 to 40 percent of Earth's land area, so it's important to learn how they could store carbon in the future, Reich says. If grasslands worldwide behave as in the study, C4 grasslands — found in warm, dry regions — may absorb more CO_2 than thought, while more abundant C3 plants could soak up less. As for crops, which can be either C3 like wheat or C4 like corn, the future is even less clear since farms often fertilize with nitrogen. ■

ATOM & COSMOS

Search for planets enters new phase

TESS could find 20,000 new worlds in the next 2 years

BY LISA GROSSMAN



NASA's new exoplanet-hunting satellite, TESS, will seek out worlds orbiting nearby, bright stars.

NASA is stepping up its search for planets outside our solar system. Following the Kepler space telescope's discovery of more than 5,000 possible exoplanets since 2009, the Transiting Exoplanet Survey Satellite, or TESS, will continue the galactic census — flagging more planetary candidates for further study.

Astronomers expect TESS, which launched April 18, to find about 20,000 planets in its first two years in operation, focusing on nearby, bright stars that will be easy for other telescopes to further investigate later. About 500 of those expected exoplanets would be less than twice the size of Earth — and therefore may be good places to look for life.

The TESS mission is "a whole new opening for exoplanet studies," MIT astronomer Sara Seager, TESS' deputy science director, said during a news conference on January 9.

TESS is tracing an unusual, elliptical orbital path between Earth and the moon that will enable the satellite to observe at least 85 percent of the sky — 350 times as much sky as Kepler saw during its main mission.

Most of the planets that Kepler found orbit stars 1,000 light-years away or farther. TESS will focus on 200,000 stars that are a few hundred light-years away at most and shine 30 to 100 times brighter on average than Kepler's stars.

The brighter the star, the easier it is for other telescopes to follow up and determine the characteristics of the star's planets, such as mass and the presence of an atmosphere, Seager says. "Photons are our currency — the more, the better."

Such follow-up will help TESS avoid some of Kepler's pitfalls. Because Kepler's stars were so far and dim, some of its planetary candidates were confirmed only by statistics, not by other telescopes. Not all of those confirmations may stick. A paper posted March 30 on arXiv.org showed that Kepler 452b, a roughly Earth-sized planet that orbits a sunlike star at the same distance Earth orbits the sun (*SN: 8/22/15, p. 16*), may be a mirage. Many of TESS' planets won't face that uncertainty.

But TESS will search for exoplanets in the same way as Kepler, by watching stars for signs of dimming, which can indicate that a planet is crossing in front of the star. Measuring how much starlight is blocked can tell astronomers the size of the planet.

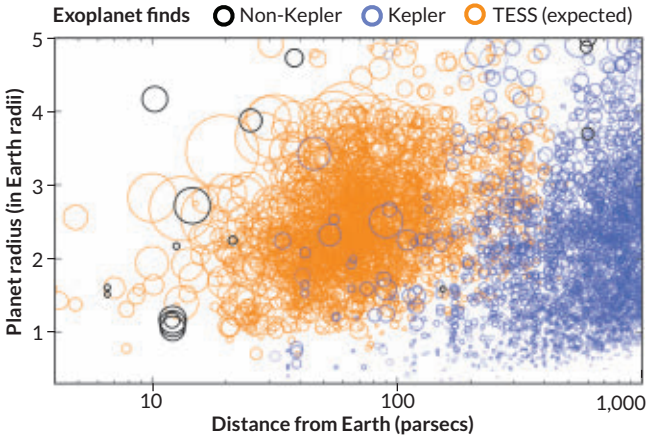
Once TESS finds a planet, ground-based telescopes will measure the gravitational tug of the planet on its host star to learn the planet's mass, which is a clue to its composition (see Page 28 for more on exoplanet diversity). Astronomers plan to measure masses for at least 50 TESS planets smaller than Neptune in the hopes that many will have rocky, and therefore potentially habitable, surfaces.

NASA's James Webb Space Telescope, set to launch in 2020, will then check some of those planets for signs of life.

"This is one of the major questions that TESS is intended to answer: Where will we be pointing Webb?" MIT astronomer George Ricker, TESS' principal investigator, said at the January 9 news conference. Webb will peer at the starlight filtering through planetary atmospheres to try to detect molecules that could be produced by something living on the surface.

It will be a few months before TESS swings into its regular orbit and begins collecting data. The satellite will then use the moon's gravity to stabilize itself for decades in orbit without using extra fuel. The mission is set to last two years but could continue almost indefinitely.

"TESS is not going to be limited by any expendable or other aspects," Ricker said. "It will be basically limited by how long NASA has the patience to fund the mission." ■



TESS' scope Most known planets (black and blue circles) are over 300 parsecs (about 1,000 light-years) away, with only a few closer than roughly 10 parsecs (about 30 light-years). TESS' expected discoveries (orange) will fill in the gap. Larger circles represent easier planets to find.

FROM TOP: ORBITAL ATK; ZACH BERTA-THOMPSON

SCIENCE & SOCIETY

Should missile defense stay grounded?

Physicists warn space-based systems could shoot down satellites

BY EMILY CONOVER

COLUMBUS, OHIO — A beefed-up missile defense system might seem like a good idea in a time of heightened nuclear tensions. But such enhancements could have dangerous consequences.

The current U.S. missile defense system isn't all it was cracked up to be, performing unreliably in tests, physicist and missile defense expert Laura Grego argued April 14 at a meeting of the American Physical Society. Enhancing the system's power might put the world on a slippery slope to space warfare, she warned. Missile defense systems can already strike down satellites, and an upgraded system would expand that power, especially if politicians decide to build a missile defense system in space.

The worries come against the backdrop of North Korea's nuclear weapons and missile tests (*SN: 8/5/17, p. 18*) and a missile defense review from the U.S. Department of Defense expected in May. That review could accelerate efforts to revamp the current system.

"Missile defense is once again having its day," Grego said at a news conference. Grego is a senior scientist at the Union of Concerned Scientists, a nonprofit science advocacy organization in Cambridge, Mass., which opposes the weaponization of space.

Boosted by a rocket engine, an intercontinental ballistic missile sails into space before releasing a warhead that plummets to its target under the force of gravity. Missile defense systems are designed to shoot down such missiles or their warheads in flight. But today's technology doesn't fully protect the United States. Tests of the U.S. system have been hit or miss, sometimes succeeding and sometimes failing to intercept the target.

Although not specifically designed for it, a system capable of stopping intercontinental ballistic missiles can also be used to destroy satellites, since some satellites travel at altitudes and speeds comparable with those of missiles. There's some precedent for this: In 2008, the United States shot down one of its malfunctioning satellites. Likewise, China demolished one of its fleet in 2007. So if countries around the world start ramping up their missile defenses in response to the United States bolstering its system, that could have the world tiptoeing closer to space warfare.

Using such antisatellite weapons could have major repercussions, including creating long-lasting space debris that could damage spacecraft. "If you ever expect to use space again, you don't start blowing things up in space," Grego said.

Even if countries refrain from using ground-based missile defense systems for antisatellite capabilities, there's another push to bring weapons into orbit. U.S. politicians have repeatedly floated the idea of taking missile defense to space as a way to get around limitations of ground-based systems. In a real-world scenario, ground-based missile defense systems have to cope with difficult conditions: For instance, in addition to releasing a weapon-carrying warhead, a missile might deploy a cloud of decoys that look similar to a real warhead, confounding the defense system's attempts to take out the real thing. Unlike land-based systems, space-based missile defense could intercept a missile before it has a chance to release its decoys and warhead.

The U.S. ground-based missile defense system, shown here in a test conducted at Vandenberg Air Force Base in California, aims to protect the United States from ballistic missiles.

U.S. MISSILE DEFENSE AGENCY

But putting missile defense in space would have additional antisatellite implications. While enhancing existing systems would strengthen the current U.S. capability to reach satellites orbiting at relatively low altitudes, creating a space-based missile defense system could also threaten satellites in higher orbits, Grego said. That's where GPS satellites are located, along with other equipment that provides essential services.

Many scientists have panned the idea of a missile defense system in space for various reasons. A 2012 report from the National Research Council, for example, noted that the system would be prohibitively expensive and impractical. Still, the political push for such a project persists.

Putting weapons in space has generally been a taboo that the world has been hesitant to break. But in a March 13 speech to military personnel in San Diego, President Donald Trump said that his national strategy recognizes that "space is a war-fighting domain, just like the land, air and sea." He then suggested creating a new military branch dubbed the "Space Force."

MIT physicist and missile defense researcher Theodore Postol has a different idea for defending the United States, at least from North Korea. A drone, flying above the waters off of North Korea, could carry an interceptor that could shoot down a missile in the early stage of flight, he said at the news conference.

Such a system would intercept a missile before it had a chance to release any decoys. And the project could be accomplished with proven technology, Postol said, abandoning the "preoccupation with science fiction" that he argues underlies some enhanced missile defense schemes. ■

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BODY & BRAIN

Elderly brains can still make nerve cells

In humans, the birth of new neurons doesn't end in childhood

BY LAUREL HAMERS

Your brain might make new nerve cells well into old age after all.

Healthy people in their 70s have just as many young nerve cells, or neurons, in a memory-related part of the brain as do teenagers and young adults, researchers report in the April 5 *Cell Stem Cell*. The discovery suggests that the hippocampus keeps generating new neurons throughout a person's life.

The finding contradicts a recent study in *Nature* that suggested neurogenesis in the hippocampus stops in childhood (*SN Online: 3/8/18*; *SN: 12/9/17, p. 10*). But the new research fits with a larger pile of evidence showing that adult human brains can, to some extent, make new neurons. While those studies indicated that the process tapers off over time, the new study proposes almost no decline at all.

Understanding how healthy brains change over time is important for untangling the ways that conditions like depression and memory loss affect older brains.

When it comes to studying neurogenesis in humans, "the devil is in the details," says neuroscientist Jonas Frisén of the Karolinska Institute in Stockholm, who wasn't involved in the new study. Small differences in methods — such as how neurons are counted — can have a big impact on results, which could explain the conflicting findings. The new paper "is the most rigorous study yet," he says.

Researchers studied hippocampi from the autopsied brains of 17 men and 11 women ranging in age from 14 to 79. In contrast to past studies that relied on donations from patients without a detailed medical history, the researchers knew that none of the donors had a history of psychiatric illness or chronic illness. Maura Boldrini, a psychiatrist at Columbia University, and colleagues also had access to whole hippocampi, rather than just a few slices, allowing the team to make more accurate estimates of the number of neurons, she says.

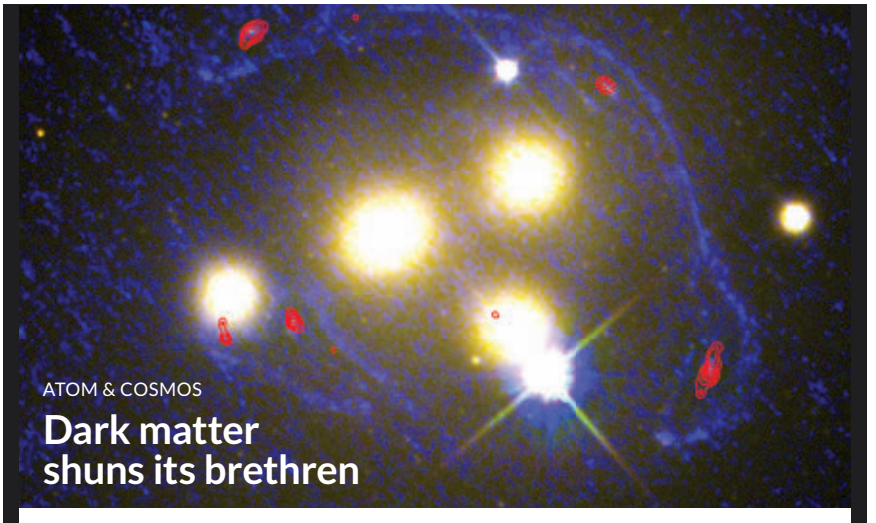
To look for signs of neurogenesis, the team hunted for proteins produced by neurons at particular stages of development. Proteins such as GFAP and SOX2, for example, are made in abundance by stem cells that eventually turn into neurons, while newborn neurons make more of proteins such as Ki-67. In all of the brains, the researchers found evidence of newborn neurons in the hippocampus.

Though the number of neural stem cells was a bit lower in people in their 70s compared with people in their 20s, the older brains still had thousands of the cells. The number of young neurons in intermediate to advanced stages of development was the same across age groups.

Still, older brains did show some signs of decline. The team found less evidence for the formation of new blood vessels and fewer protein markers that signal neuroplasticity, the brain's ability to make new connections between neurons. But it's too soon to say what these findings mean for brain function, Boldrini says.

Not all neuroscientists are convinced by the results. "We don't think that what they are identifying as young neurons actually are," says Arturo Alvarez-Buylla of the University of California, San Francisco, who coauthored the paper that found no neurogenesis in adult brains. In that study, some of the cells initially flagged as young neurons turned out to be mature cells upon further investigation.

But others say the new findings are sound. "They use very sophisticated methodology," Frisén says, and control for factors that the study Alvarez-Buylla coauthored didn't, such as the type of preservative used on the brains. ■



ATOM & COSMOS

Dark matter shuns its brethren

Dark matter is still the shiest stuff in physics. New observations show that dark matter in galaxy cluster Abell 3827 stubbornly ignores all other kinds of matter — including itself, an international team of astronomers reported April 6 in Liverpool, England, at the European Week of Astronomy and Space Science.

Previous observations of Abell 3827, a cluster including four colliding galaxies (shown above), had suggested that stars were separated from their dark matter (*SN: 5/16/15, p. 10*). Researchers proposed that the separation was the result of the dark matter interacting with another clump of dark matter via a new, unknown force. Dark matter, which makes up most of the mass of the universe, is known to interact only with ordinary, visible matter and only via gravity.

But new data collected in infrared and millimeter wavelengths indicate that the dark matter (highlighted as red contour lines) actually sticks with its stars as expected. — *Lisa Grossman*

RICHARD MASSEY/DURHAM UNIV., ESO, ESA, NASA

DEGREES OF IMPACT

Gage Dutkin
CEO of C-Safe
Senior, Business Management

Kimberly Gramm
Senior Managing Director of the
Innovation Hub at Research Park

GAGE DUTKIN IS A SENIOR AND THE CEO OF HIS OWN START-UP COMPANY, thanks to help from the Innovation Hub at Texas Tech. Dutkin's company, C-Safe, is developing a weighted pad that detects when a child is left in a car seat after an adult leaves the vehicle. After winning two innovation competitions, C-Safe is now part of the TTU Accelerator program which awarded a grant to C-Safe and allows the company to be surrounded by entrepreneurial resources.

Dutkin is grateful for the opportunities and continued guidance provided by the Innovation Hub. "Texas Tech is becoming a big leader in entrepreneurship. There are so many opportunities here that are not provided by other universities in an entrepreneurial sense."

TEXAS TECH UNIVERSITY.

DEGREES OF IMPACT

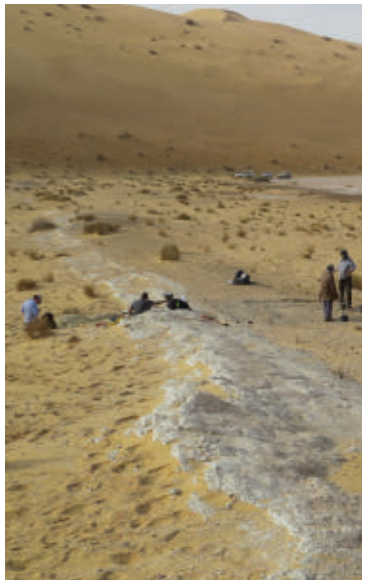
HUMANS & SOCIETY

When people reached Arabia

Fossil puts humans on the peninsula by 86,000 years ago

BY BRUCE BOWER

This finger bone, shown from different angles, is evidence of early human forays out of Africa. The fossil was found at Saudi Arabia's Al Wusta site (right).



A single human finger bone from at least 86,000 years ago points to Arabia as a key destination for Stone Age excursions out of Africa that allowed people to rapidly spread across Asia.

Excavations at Al Wusta in Saudi Arabia's Nefud desert produced this diminutive discovery. It's the oldest known *Homo sapiens* fossil outside of Africa and the narrow strip of the Middle East that joins Africa with Asia, based on dating of the bone itself, says a team led by archaeologists Huw Groucutt and Michael Petraglia. The find strengthens the idea that early human dispersals out of Africa began well before the traditional estimated departure time of 60,000 years ago and extended deep into Arabia, the scientists report in the May *Nature Ecology & Evolution*.

"Although long considered to be far from the main stage of human evolution, Arabia was a stepping stone from Africa into Asia," says Petraglia, of the Max Planck Institute for the Science of Human History in Jena, Germany.

Don't be misled by the vast deserts that dominate the Arabian Peninsula today. Geologic evidence indicates that Al Wusta lay within a well-watered, human-friendly area from about 95,000 to 86,000 years ago, the estimated age range for the finger fossil, Groucutt and Petraglia's team says. Dating relied on measures of the decay of a radioactive form of uranium in the human fossil and a nearby hippo tooth. Those results were combined with a measure of exposure to natural doses of radiation in the tooth. Another technique estimated the time since the finger bone and adjacent finds were buried by sediment.

The 2016 Al Wusta find is probably the middle bone from an adult's middle finger, suspects Groucutt, of the University of Oxford. It's unclear whether the bone came from a man or a woman, or from a right or left hand.

It's definitely human, though. To establish the fossil's identity, the researchers compared a 3-D image of the ancient finger bone with corresponding bones of present-day people, apes and monkeys, as well as Neandertals and other ancient hominids.

The newly discovered fossil fits into a rough timeline of Stone Age human departures from Africa. *H. sapiens* reached what's now Israel as early as 194,000 years ago (*SN: 2/17/18, p. 6*) and East Asia by at least 80,000 years ago (*SN: 11/14/15, p. 15*). Humans arrived in Indonesia (*SN Online: 8/9/17*) and Australia (*SN: 8/19/17, p. 10*) shortly before 60,000 years ago.

How humans moved into Arabia is uncertain. Along with the finger, Al Wusta yielded 380 stone tools and 860 nonhuman animal fossils from the same time. Some of those animals, including hippos and gazelles, originated in Africa and no longer inhabit the Arabian Peninsula. Ancient groups of hunter-gatherers followed these grazing animals from North Africa into Arabia as climate fluctuations periodically turned deserts into grasslands with lakes and rivers, Petraglia proposes. When those landscapes dried out every 20,000 years or so, people could have returned to Africa or headed farther into Asia.

Al Wusta's ancient human fossil — combined with comparably ancient stone tools found at other Arabian Peninsula sites (*SN: 4/4/15, p. 16*) — challenges the view that humans left Africa in only one or a few major migrations, says paleoanthropologist María Martinón-Torres. Instead, small groups of African *H. sapiens* continually traveled into Arabia and beyond starting nearly 100,000 years ago or earlier, suggests Martinón-Torres, who directs the National Research Center on Human Evolution in Burgos, Spain. Periods of increased rainfall may have provided "windows of opportunity" for human movements into Arabia, she adds.

Al Wusta stone tools differ in some ways from those at slightly older sites in Israel. Donald Henry, a paleoanthropologist at the University of Tulsa in Oklahoma, interprets those differences to mean that the people who ended up in Al Wusta took a southern route to Arabia and were culturally distinct from the people who went to Israel. To reach Al Wusta, East African travelers could have crossed a narrow sea channel from the Horn of Africa to Arabia's southwestern corner before heading up to Al Wusta, Henry suggests in a commentary published with the new report.

Petraglia doubts that scenario. Ancient humans could easily have followed grazing animals up the Nile River Valley into the Middle East and then south into Arabia, he says, adjusting tools to new settings along the way. ■

FROM LEFT: IAN CARTWRIGHT; M. PETRAGLIA

GEOLOGIC ROAD TRIP OF THE MONTH

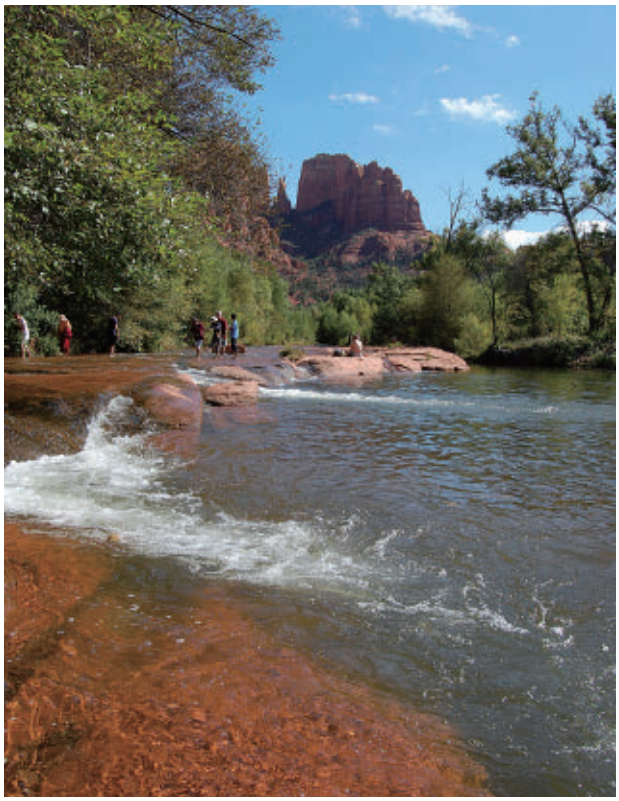
SEDONA'S RED ROCK CLIFFS

Remnants of a Rising Sea

Towering cliffs of rich red Schnebly Hill Formation, a mixed sequence of sandstone, siltstone, and limestone, surround Sedona. The Hermit Formation, directly below the Schnebly Hill Formation, and the Coconino Sandstone, directly above it, can be seen in many places throughout the greater Four Corners region, but the Schnebly Hill is exposed only within 20 miles of Sedona. The Schnebly Hill rocks are red because a tiny bit of iron in the sediments oxidized during the original erosion, transportation, and deposition of the sediment.

The Schnebly Hill Formation was deposited during a single rise and fall in sea level during Permian time about 275 million years ago. As sea level rose, a finger of ocean called the Pedregosa Sea invaded the area from the southeast, never reaching much farther than Sedona before retreating back to the southeast. Much of Permian Arizona was a desert environment. Rivers, flowing from mountains in what is now Colorado, carried and deposited silt, sand, and gravel onto floodplains and alluvial fans, now the Hermit Shale. Sedona is built on this soft and easily eroded rock, and it forms the rounded slopes below the colorful cliffs.

The spectacular scenery near Sedona is dominated by the red Schnebly Hill Formation, with light-colored Coconino Sandstone capping the higher mesas.



One of Sedona's most famous vistas is of Cathedral Rock soaring above Oak Creek at the Red Rock Crossing Recreation Area.

The Schnebly Hill Formation was deposited as the invading ocean replaced the floodplains with sandy beaches, silty lagoons, and salty tidal flats. The lower part of the formation, looking like a series of stair steps, is known as the Bell Rock Member. A thorough but brief deepening of the sea laid down a thin hard layer of limestone, the Fort Apache Member, on top of the Bell Rock. Then, as sea level began to fall, beach and lagoon conditions returned, creating the Sycamore Pass Member. Once the ocean had thoroughly retreated from the region, extensive windblown sand dunes covered everything with the Coconino Sandstone. This light-colored formation crowns the higher bluffs north of Sedona. This entire sequence of rocks is especially visible along AZ 179, the Red Rock Scenic Byway, where several roadside pullouts provide outstanding views.

BODY & BRAIN

Norovirus attacks rare type of gut cell

Discovery in mice also gives clues to inflammatory bowel disease

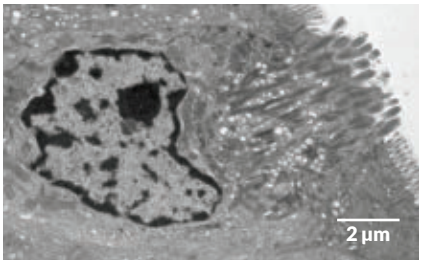
BY AIMEE CUNNINGHAM

How a nasty, contagious stomach virus lays claim to the digestive system just got a little less mysterious.

In mice, norovirus infects rare cells in the lining of the gut called tuft cells. Like beacons in a dark sea, these cells glowed with evidence of a norovirus infection in fluorescent microscopy images, researchers report in the April 13 *Science*.

If norovirus targets these cells in people, "maybe that's the cell type we need to be treating," says Craig Wilen, a physician scientist at Washington University School of Medicine in St. Louis.

Worldwide, norovirus causes about 1 in 5 cases of acute gastroenteritis, an illness of vomiting and diarrhea accompanied by rapid dehydration. But little is known about how norovirus does its dirty work in the body — including which cells the virus targets. Identifying a role for tuft cells in the interactions between virus and host "is a significant step forward," says immunologist David Artis of Weill Cornell Medicine in New York City, who was not involved in the study.



Tuft cells, like the one outlined in black with tubules protruding from the right side, may be key to treating norovirus infections.

Wilen and colleagues had previously discovered the protein that norovirus requires to enter cells in mice. The team used that clue to uncover the role of the tuft cells, which have recently been tied to a certain type of immune response. The cells get their name from a cluster of tube structures sticking off of one end.

The new study fits with previous research on norovirus and other pathogens. Intestinal parasitic worms can make a norovirus infection worse in mice, and tuft cells are known to increase in number during these parasite infections.

Killing off gut bacteria has also stopped mice's norovirus infections. In the new study, knocking out gut bacteria with antibiotics decreased the genetic activity of tuft cells in the colon and curbed mice's infections. Having more tuft cells seems to be "good for the virus," Wilen says.

The tuft cells–norovirus connection may prove fruitful for research into inflammatory bowel disease as well. Variants of certain genes slightly increase the risk of developing Crohn's disease or ulcerative colitis, but an outside trigger might be what ultimately unleashes these diseases. Wilen notes that research has shown that mice genetically predisposed to have Crohn's disease developed symptoms after a norovirus infection. ■

EARTH & ENVIRONMENT

Compost spreads microplastics

Effects of fertilizer's pollution need further investigation

BY RACHEL EHRENBERG

Composting waste is heralded as good for the environment. But compost made from home and grocery store waste is a previously unknown source of microplastic pollution, finds a new study published April 4 in *Science Advances*.

This plastic gets spread over farm fields, where it may be eaten by worms and enter the food web, make its way into waterways or break down further and become airborne, says ecologist Christian Laforsch of the University of Bayreuth in Germany. Once the plastic is spread on fields, he says, "we don't know its fate."

That fate and the effects of plastic pollution on land and in freshwater have gotten little research attention compared with marine plastic pollution, says ecologist Chelsea Rochman of the University of Toronto, who wasn't involved in the study. But evidence suggests plastic pollution is as prevalent in land and freshwater ecosystems as it is in the oceans.

Laforsch and colleagues looked at several kinds of biowaste that's composted and spread on farmland in Germany, including household compost and grass clippings, supermarket waste and grain silage left over from biogas production.

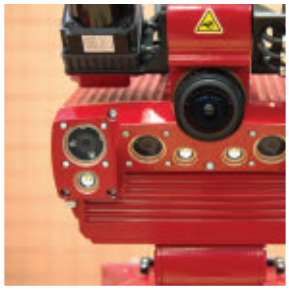
Compost from supermarket waste contained the most plastic particles: 895 pieces larger than 1 millimeter per kilogram of dry weight. Household compost contained 20 and 24 particles per kilogram of dry weight, depending on the size of the sieves used to sift the compost. The detritus included polyester and a lot of styrene-based polymers used in food packaging. Almost no particles were found in samples of silage from biogas production.

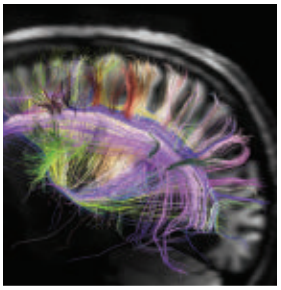
"I never thought about plastic in compost ending up as fertilizer. But when you think about it, it makes sense," says environmental scientist Ad Ragas of Radboud University in Nijmegen, the Netherlands. A crate of rotting cucumbers wrapped in plastic that gets chucked, those stickers on every tomato in a bunch — that packaging doesn't disappear.

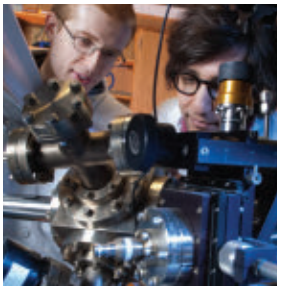
Ragas says compost probably doesn't contribute as much plastic to the environment as other sources, such as sewage treatment plant sludge, which contains polyester debris from clothes washers, and runoff from streets, which can be loaded with particles of synthetic rubber used in tires. But the compost contribution deserves investigation, Ragas says.

Scientists should examine possible effects on organisms, from plants to worms to birds to people, Rochman adds. Effects probably differ by plastic, which varies depending on the starter material and the additives used to impart qualities such as flexibility or sturdiness. ■

WANDY BEATTY/WASHINGTON UNIV. SCHOOL OF MEDICINE





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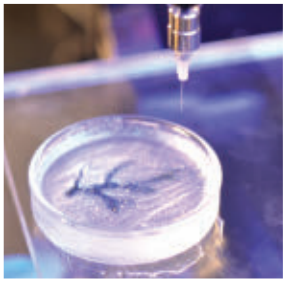








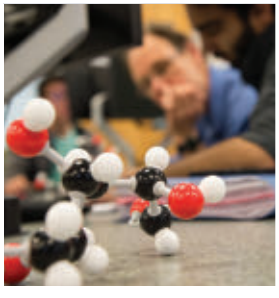
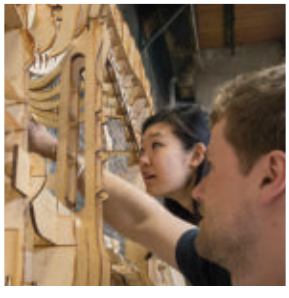


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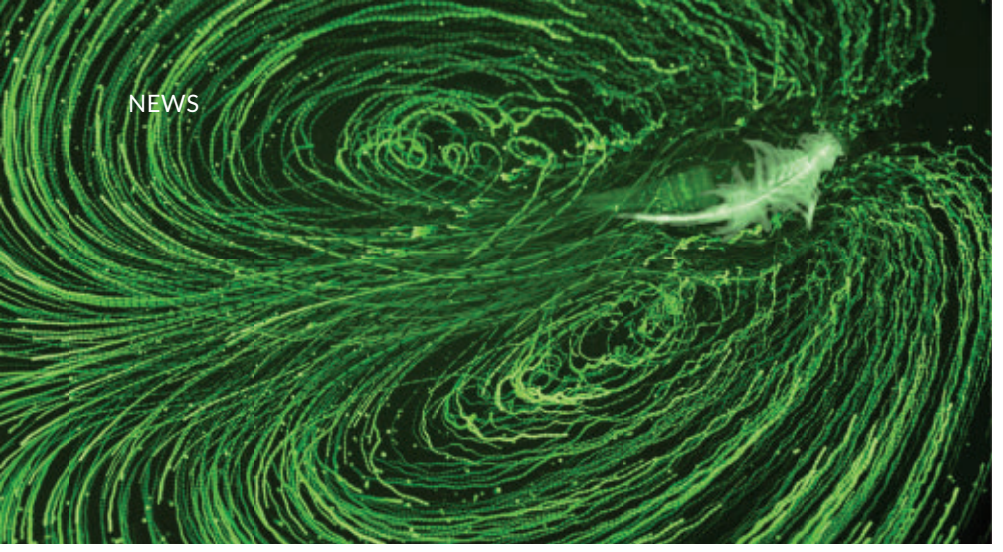


One swimming brine shrimp generates small-scale turbulence (suspended particles shown in green). But large numbers of the animals together may create currents that help mix the ocean.

EARTH & ENVIRONMENT

Tiny swimmers may stir the ocean

Turbulence from animals could redistribute nutrients

BY CAROLYN GRAMLING

When it comes to tiny ocean swimmers, the whole may be much greater than the sum of its parts. Ocean turbulence stirred up by multitudes of creatures such as krill can be powerful enough to extend hundreds of meters down into the deep, a new study suggests.

Brine shrimps moving vertically in two different laboratory tanks created small eddies that aggregated into a jet roughly the size of the whole migrating group, researchers report online April 18 in *Nature*. With a fluid velocity of about 1 to 2 centimeters per second, the jet was also powerful enough to mix shallow waters with deeper, saltier waters. Without mixing, these waters of different densities would remain isolated in layers.

The shrimps represent swarms of centimeter-sized swimmers, including krill (see Page 42) and shrimplike copepods, found throughout the world's oceans. Such swarms may be capable of mixing ocean layers — and delivering nutrient-rich deep waters to phytoplankton, or microscopic marine plants, near the surface, the researchers suggest.

"The original thinking is that these animals would flap their appendages and create little eddies about the same size as their bodies," says John Dabiri, an expert in fluid dynamics at Stanford University. But previous work, including acoustic measurements of krill migrations in the ocean (*SN: 10/7/06, p. 238*) and theoretical simulations of fluid flow around swimmers such as jellyfish (*SN: 8/29/09, p. 14*), had suggested that tiny animals may be stirring up more turbulence than thought.

In 2014, Dabiri coauthored a study that debuted the laboratory tank setup also used in the new research. That paper noted that migrating brine shrimps created jets and eddies much larger than themselves. "But there was skepticism about whether those lab results were relevant to the ocean," Dabiri says. The 2014 study didn't account for how ocean water stratifies into layers that don't easily mix due to differences in salinity or temperature. It wasn't clear if shrimp-generated turbulence could be strong enough and extend deep enough to overcome the physical barriers and mix the layers.

The new research used a 1.2-meter-deep tank and a 2-meter-deep tank. Each held tens of thousands of wiggly brine shrimps in two layers of water of different densities. The researchers used LED lights to prompt the shrimps to migrate upward or downward, mimicking the massive daily vertical migrations of krill, copepods and other ocean denizens. The shrimps migrated in close proximity to one another — and that helped to magnify their individual efforts, the scientists found.

Brine shrimps undergo a daily vertical migration of hundreds of meters, rising up at night to find food and diving down in the day to hide.

"As one animal swims upward, it's kicking backward," Dabiri says. That parcel of water then gets kicked downward by another nearby animal, and then another. The result is a downward rush that gets stronger as the migration continues and eventually extends about as deep as the entire migrating group. In the ocean, that could be as much as hundreds of meters.

"At the heart of the investigation is the question about whether life in the ocean, as it moves about the environment, does any important 'mixing,' " says William Dewar, an oceanographer at Florida State University in Tallahassee. "These results argue quite compellingly that they do, and strongly counter the concern that most marine life is simply too small in size to matter."

The team's finding opens the door to a host of interesting questions, Dewar adds. Ocean mixing is an important part of the global climate cycle: It churns up nutrients that feed phytoplankton blooms and aids the exchange of gases with the atmosphere. Adding biologically driven mixing to physical processes in the ocean makes the equation even more complex, he says.

The next step will be to try to observe the effect at sea, using shipboard measurements, Dabiri says. "Previous studies looked for turbulence or eddies on the scale of the animals' size," he says, instead of large downward jets. "This paper tells us for the first time what to look for." ■

BOTH: ISABEL HOUGHTON

Watch brine shrimp whip up eddies at **bit.ly/SN_shrimp**

"The more time I spent studying engineering in college, the more I realized I would never be bored in my career."

BY ARCONIC FOUNDATION

Meet Chelsea Cummings, an Additive Manufacturing Engineer focused on new product introduction of metal 3D printed aerospace parts at Arconic, in Austin, Texas. Early on, she knew that STEM education was a pathway for her to solve complex engineering challenges. Having earned her engineering degree from Arizona State University, she's now helping develop and build high-performance aerospace parts that will one day fly people around the world and into deep space.

How did you get interested in a STEM career?

Chelsea: I think I realized pretty early on that I was more interested in problem solving than anything else. Many career paths involve memorizing and executing certain strategies, but STEM encourages me to explore how many ways a problem can be solved, and it seems more is gained by solving problems differently every time. I was unsure exactly which field I wanted to end up in at first, but the more time I spent studying engineering in college, the more I realized I would never be bored in my career. I felt my professional excitement really took off when I discovered metal 3D printing for the first time. Now, metal 3D printing, or additive manufacturing, is offered at most universities in some form or another, so students can get involved even earlier.

Who was/is a role model for you?

Chelsea: Dr. Linda Chattin, an engineering professor I had for several classes was very inspirational to me. She had forged a path in industry when it was even less common for women to pursue engineering, and was one of the very best professors I had in college. She truly believed engineering was for anyone who was willing to work for it and led her classes as such. She also was anything but dull, breaking the much exhausted (in my opinion) stereotype that some still have about engineers. Her knowledge, motivation, and humor left a lasting impression on me.

What it is about what you do that excites you?

Chelsea: I am a visual, hands-on person, so the exciting part of work for me is that it's tangible. I get to build things from metal powder with lasers, and perform experiments to yield results that I can then directly apply back into what I am creating. I also get to work with highly sophisticated machines and software that enable me to visually analyze builds and data. It is hard not to be excited about going to work in the morning when a build has been running overnight. I love starting the day by seeing a real aerospace part that I modeled, programmed and 3D printed.

ATOM & COSMOS

Diamonds hint at long-gone planet

Gems inside meteorites offer clues to how the rocks formed

BY LISA GROSSMAN

Meteorites found in Africa may have been forged inside a long-lost planet from the early solar system. Pockets of iron and sulfur embedded in diamonds within the space rocks probably formed under high pressures found only inside planets the size of Mercury or Mars, scientists report April 17 in *Nature Communications*.

The parent planet no longer exists — it would have been smashed to smithereens in the solar system's violent infancy.

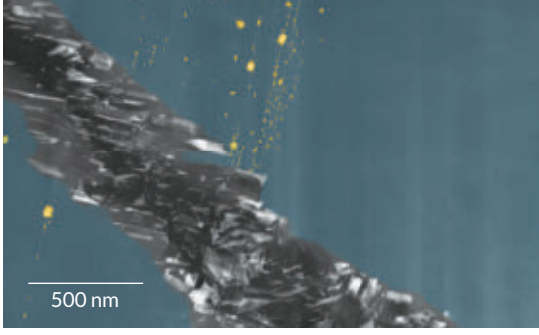
"We probably have in our hands a piece of one of these first planets that have disappeared," says mineralogist Philippe Gillet of École Polytechnique Fédérale de Lausanne, or EPFL, in Switzerland.

EPFL physicist Farhang Nabiei, Gillet and colleagues analyzed minuscule fragments of meteorites that came from the first-ever asteroid tracked from orbit to ground as it streaked to the Nubian desert in Sudan in 2008 (*SN: 4/25/09, p. 13*).

The meteorites' composition differs from the makeup of any of the solar system's rocky planets. But clues to the meteorites' origins come from diamonds in the rocks. The diamonds, estimated to be about 100 micrometers wide, are too big to have formed in the shock of two asteroids colliding, but could have formed inside asteroids at least 1,000 kilometers wide, where pressures would be high enough to compress carbon.

But the researchers discovered an oddity that made them question whether the gems came from an asteroid at all: The diamonds had grown around smaller crystals of iron and sulfur, which normally would repel each other like oil and water, says EPFL physicist Cécile Hébert.

Those crystals would be stable only at pressures above 20 gigapascals, almost 200,000 times atmospheric pressure at sea level on Earth. Such conditions are found only in the center of a Mercury-sized planet or in the core-mantle boundary of a Mars-sized planet, Hébert says.



Sulfur and iron (both yellow in this colorized image) within a meteorite's diamond (blue background, gray is graphite) suggest that the meteorite was once part of a now-dead planet.

Many planets that size probably roamed the solar system some 4.5 billion years ago. But only a few survived to become the four rocky planets that exist today. Simulations of the early solar system suggest that most of these planets crashed into each other and broke apart in the first 100 million years. "We are confirming the existence of such former planets," Gillet says.

But cosmochemist Martin Bizzarro of the Natural History Museum of Denmark in Copenhagen is not yet convinced. "They've done very careful work," he says, but more is needed. Testing for remnant magnetic fields in the meteorites could reveal if the rocks had once been within a large planet's molten core, for instance. ■

F. NABIEI, E. OVEISI AND C. HÉBERT/EPFL, SWITZERLAND

GENES & CELLS

Polynesian sailings to America doubted

DNA challenges theory of how the sweet potato crossed the sea

BY DAN GARISTO

Sweet potatoes were domesticated thousands of years ago in the Americas. So 18th century European explorers were surprised to find Polynesians had been growing the crop for centuries. Scientists later hypothesized that Polynesian seafarers had brought the tuber back from expeditions to South America.

Genetic data now suggest that wild precursors to sweet potatoes reached Polynesia by 100,000 years ago — long before humans inhabited the region, scientists say in the April 23 *Current Biology*. The plants or their seeds must have crossed the ocean on their own, perhaps via wind, water or birds.

The idea that Polynesians sailed to the New World rests heavily on the sweet potato evidence. So if correct, the study would cast doubt on whether early Polynesians traveled to the Americas at all.

To uncover the sweet potato's origins, plant geneticist Tom Carruthers of the University of Oxford and colleagues analyzed DNA from 199 specimens of sweet potato (*Ipomoea batatas*) and 38 species of its wild relatives.

The team confirmed the sweet potato's closest relative is *Ipomoea trifida*, similar to a morning glory. The analysis also showed that sweet potatoes originated from *I. trifida* at least 800,000 years ago. By 100,000 years ago, the Polynesian sweet potato diverged from its South American cousin. And indeed, a specimen preserved from Captain James Cook's 1769 expedition to the South Pacific is genetically different from South American sweet potatoes.

"It could be true," says biological anthropologist Lisa Matisoo-Smith of the University of Otago in New Zealand. But with just one historical sweet potato from Polynesia (the Captain Cook specimen), there's not "enough data to reject the argument of human-mediated transport," she says. And it's unlikely that *I. batata* would have been domesticated independently in different places and still look the same, adds evolutionary biologist Caroline Roullier of CNRS in Montpellier, France.

Other types of data also need to be considered, Roullier says. For example, the Polynesian word for sweet potato, *kuumala*, is similar to the Andean people's Quechuan word, *kumara*. That linguistic link is evidence that people introduced the tuber to the South Pacific, says anthropologist Seth Quintus of the University of Hawaii at Manoa. ■

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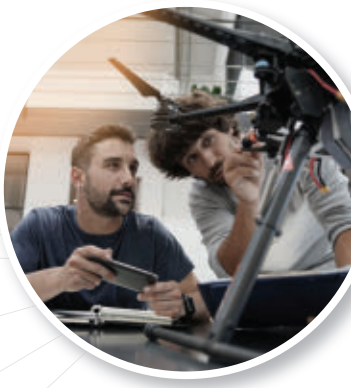

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LIFE & EVOLUTION

Some seals eat like their land ancestors

Clawed species hold and tear apart their prey at the sea surface

BY LAUREL HAMERS

Some seals still eat like landlubbers.

Just like lions, tigers and bears, northern true seals have claws that help the animals grasp prey and tear it apart. X-rays show that the bones in these seals' forelimbs look like those found in one of the earliest seals, a study finds.

Seal ancestors transitioned from land to sea at some point, preserving clawed limbs useful for hunting on land. But claws in modern seals seem to be more than just a holdover, says David Hocking, a marine zoologist at Monash University in Melbourne, Australia. Retaining claws probably helps these seals catch a larger meal than they could with the stiff, slippery fins of other pinnipeds such as sea lions, Hocking and colleagues report in the April *Royal Society Open Science*.

Hocking's group spent 670 hours observing two types of northern true seals, harbor and gray seals, hunting salmon in the wild. Tests with three captive clawed seals let the team observe eating behaviors at closer range.

Claws and flexible joints enable this harbor seal to grasp and dig into a salmon.

Wild and captive animals often used their claws to hold prey and rip off bites, much as a bear does. Seals tended to catch prey underwater, but ripped it apart at the surface. Surface eating probably lets the seals breathe while feasting without inhaling seawater — a challenge when devouring a large meal below the surface.

Northern true seals have flexible joints that allow the animals to curl their claws to grasp prey. Such joints are also seen in the early pinniped *Enaliarctos mealsi*, a seal that lived about 23 million years ago, Hocking and colleagues report. Fur seals and sea lions, however, "have inflexible fingers that help them to maintain a stiff flipper," Hocking says.

Flipperlike forelimbs help some pinnipeds propel themselves through the water more efficiently. Slippery flippers aren't as useful for grasping, so that may explain why fur seals and sea lions tend to target smaller fish that they can swallow whole underwater, Hocking says.

The researchers suspect that the earliest pinnipeds probably used their claws similarly to today's northern true seals. Catching prey underwater and eating at the surface was probably a smaller behavioral leap from full-on land feeding than were other aquatic hunting strategies.

Without knowing what early seals ate, though, it's hard to know whether they actively used their claws to grip large prey, says biologist Frank Fish of West Chester University in Pennsylvania. ■

EARTH & ENVIRONMENT

There's still hope for coral reefs

Staghorn species may survive another century of warming

BY DAN GARISTO

It's no secret that warming has devastated many of the world's coral reefs. For instance, a 2016 marine heat wave killed 30 percent of the Great Barrier Reef's coral, scientists report online April 18 in *Nature*. But some coral species may be able to keep up with warming waters for another century, or even two, a second team reports April 19 in *PLOS Genetics*. And that offers a glimmer of hope.

"What we've just experienced [in the Great Barrier Reef] is one hell of a natural selection experiment," says coral reef expert Terry Hughes of James Cook University in Townsville, Australia, who coauthored the study in *Nature*. A bright side, maybe: "The ones that are left are tougher."

While the marine heat wave particularly damaged staghorn corals, at least one species, *Acropora millepora*, may prove to be resilient, Mikhail Matz, a biologist at the University of Texas at Austin, and colleagues report in *PLOS Genetics*. The fast-growing coral — a key reef builder — is genetically diverse enough to survive for another 100 to 250 years, depending on how quickly the planet warms, Matz's group reports. Other studies have suggested that coral reefs may not last this century.

What happens to reefs affects vast underwater ecosystems and the hundreds of millions of people who depend on them. So scientists want to understand how corals might fare as climate change brings longer and stronger marine heat waves (see Page 5) and higher average ocean temperatures.

Though staghorn corals were particularly vulnerable to the 2016 heat wave, Matz and colleagues' study suggests that, extreme events aside, these corals may adapt quickly enough to keep pace with warming — at least for now.

A. millepora corals live throughout the Great Barrier Reef. The northern portion of the reef, closest to the equator, can be more than 5 degrees Celsius warmer than in the south. So the species already carries genetic variants that allow the corals to cope with a range of temperatures, Matz says. As the climate changes, some heat-resistant staghorn corals could send their larvae into areas that have become too hot for other staghorn corals, simulations by Matz's group show.

If corals need to move to survive, humans should focus on connecting reefs to encourage migration, says William Cheung, a marine biologist at the University of British Columbia at Vancouver. ■

D.P. HOCKING *ET AL*/*ROYAL SOCIETY OPEN SCIENCE* 2018

HUMANS & SOCIETY

Earliest known New World dogs ID'd

Domestic canines arrived in the Americas by 10,000 years ago

BY BRUCE BOWER

WASHINGTON — A trio of dogs buried at two ancient human sites in Illinois lived around 10,000 years ago, making the dogs the oldest known domesticated canines in the Americas.

Radiocarbon dating of the dogs' bones shows they are 1,500 years older than previously thought, zooarchaeologist Angela Perri said April 13 at the annual meeting of the Society for American Archaeology. The previous age estimate was based on a radiocarbon analysis of burned wood found in one of the animals' graves. Until now, nearly 9,300-year-old remains of dogs eaten by humans at a Texas site were the oldest physical evidence of domesticated American canines.

Ancient dogs at the Midwestern locations also represent the oldest known burials of individual dogs in the world, said Perri, of Durham University in England. A dog buried at Germany's Bonn-Oberkassel site around 14,000 years ago was included in a two-person grave. Placement of the Illinois dogs in their own graves indicates that these animals were held in high regard by ancient people, Perri argued.

An absence of tool incisions on the three ancient dogs' skeletons indicates that the animals were not killed by people but died of natural causes before being buried, Perri said.

Some researchers have proposed that whoever made the first excursions into the Americas from Asia arrived on dog-powered sleds. People reached the New World by at least 15,000 years ago, well before ancient people buried dogs at Illinois' Koster and Stilwell II sites. It's unclear whether humans spread into North and South America via coastal or inland routes. But no dog remains have been found in northwestern North America, where the earliest settlers crossing a land bridge from Asia would have entered the continent. Either those people had no dogs, or they and their furry companions stayed on the land bridge, possibly blocked by two massive ice sheets, until rapidly moving inland sometime before 10,000 years ago (*SN: 2/16/08, p. 102*), Perri said.

"As much as we want to believe that dogs initially pulled us into the New World, that may not have been the case," Perri said.

New radiocarbon evidence indicates that three dogs whose bones were excavated in Illinois, including this one, lived about 10,000 years ago, some 1,500 years earlier than originally thought.

DEL BASTON, CENTER FOR AMERICAN ARCHAEOLOGY

Genetic evidence has suggested that a second human migration from Asia to North America occurred around 11,500 years ago, with people trekking south through an ice-free corridor into the northern Great Plains. Those people probably brought dogs to the Americas, Perri proposed.

She and colleagues studied two of three dogs excavated at the Koster site in the 1970s and a dog unearthed at Stilwell II in 1960. These sites lie about 30 kilometers apart in west-central Illinois.

The lower jaws and teeth of the Stilwell II dog and one of the Koster dogs display some similarities to those of modern wolves, the team found. Another Koster dog's jaw shares some traits with present-day coyotes, possibly reflecting some ancient interbreeding.

A new genetic analysis positions the 10,000-year-old Illinois dogs in a single lineage that initially populated North America. Dog origins are controversial, but dogs may date to more than 20,000 years ago (*SN Online: 7/18/17*). Ancient American dogs shared a common genetic ancestor that originated roughly 15,000 years ago after diverging from a closely related Siberian dog population about 1,000 years earlier, cell biologist Kelsey Witt Dillon of the University of California, Merced reported April 13 at the meeting.

Dillon's team, which includes Perri, studied 71 complete mitochondrial genomes and seven nuclear genomes of dogs from more than 20 sites in the Americas, ranging in age from 10,000 to 800 years ago. Mitochondrial DNA is typically inherited only from the mother; nuclear DNA comes from both parents.

Much of the genetic blueprints of those ancient dogs is absent in modern dogs, Dillon said. Only a small number of modern U.S. dogs share maternal ancestry with ancient American dogs, suggesting that the arrival of European breeds starting at least several hundred years ago reshaped dog DNA in the Americas, she proposed. ■

BODY & BRAIN

'Sea nomads' have big spleens

The Bajau people of Southeast Asia are known for holding their breath for long periods while diving to spear fish and gather other seafood. The long dives may be possible because these "sea nomads" have unusually large spleens, which provide a big supply of oxygen-rich red blood cells, researchers report in the April 19 *Cell*.

When a mammal holds its breath and dives, one of the ways the body responds is by contracting the spleen to release oxygenated red blood cells. Certain seal species have enlarged spleens. Evolutionary geneticist Melissa Ilardo of the University of Utah in Salt Lake City wondered if the same was true for the Bajau.

While a researcher at the University of Copenhagen, Ilardo, along with colleagues, compared ultrasound measurements of the spleens of over 40 Bajau from a village in Indonesia with measurements from a nearby ethnic group that doesn't spend much time in the water. The Bajau's spleens were about 50 percent larger, and DNA tests showed that the Bajau had genetic variations associated with spleen size. — *Aimee Cunningham*

MATTER & ENERGY

Using laser tweezers, chemists nudge two atoms to bond

For the first time, chemists have played matchmaker between two specific atoms, joining them together to form a molecule.

Typically, chemists make molecules by mixing up many constituent atoms, some of which stick to each other to form desired compounds. In the new reaction, researchers trapped a sodium atom in one optical tweezer — which snares small particles in a laser beam — and a cesium atom in another tweezer. Both atoms were cooled to less than a ten-thousandth of a degree above absolute zero.

The researchers moved the tweezers closer together until the laser beams overlapped, allowing the sodium and cesium atoms to collide. A third laser shot a pulse of light at the atoms to provide an energy boost that helped the atoms bond into a sodium-cesium molecule, the team reports online April 12 in *Science*.

Fashioning individual molecules atom by atom could let scientists better study atomic collisions and observe how molecules behave in isolation. Researchers could also use optical tweezers to make molecules with specific quantum properties for use in quantum computers, says study coauthor Kang-Kuen Ni, a chemist at Harvard University. — *Maria Temming*

MATH & TECHNOLOGY

Light turns on bacteria killer

PHOENIX — A new material that harnesses the power of ambient light to produce bacteria-killing molecules could help stem the spread of hospital infections, including drug-resistant ones.

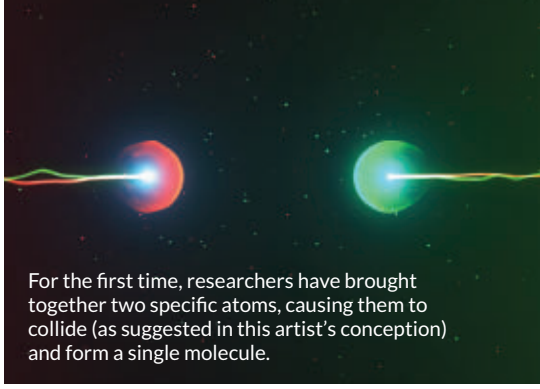
About 1 in 10 patients globally get an infection while receiving treatment at a health care facility, according to the World Health Organization. "Contaminated hospital surfaces play a key role in spreading those infections," chemist Ethel Koranteng of University College London said April 5 at the Materials Research Society spring meeting.

Koranteng and colleagues developed a polymer-based material to make hospital surfaces self-disinfecting. The material could be fashioned into a flexible film that covers computer keyboards, or molded into rigid, plasticlike casings that enclose phone handles, bedrails and other surfaces prone to contamination.

Unlike other polymer-based antimicrobial coatings that rely on water to release bug-killing particles, the new material is activated by overhead lighting.

The covering is made of polyurethane embedded with semiconducting nanoparticles called quantum dots and particles of a purple dye called crystal violet (*SN: 7/11/15, p. 22*). When the quantum dots absorb ambient light, they transfer some of that energy to the dye particles, which release a high-energy oxygen molecule that kills microbes.

In lab tests, the material killed 99.97 percent of MRSA, the strain of *Staphylococcus aureus* that is resistant to methicillin and other antibiotics, and 99.85 percent of a multidrug-resistant strain of *E. coli*. — *Maria Temming*



For the first time, researchers have brought together two specific atoms, causing them to collide (as suggested in this artist's conception) and form a single molecule.

MATTER & ENERGY

Measurement of physics constant hints that dark photons don't exist

An ultraprecise measurement has given some weird physics theories a black eye.

By measuring one of nature's most fundamental constants more precisely than before, scientists have tested proposed tweaks to the standard model, the theory governing fundamental particles. The result, reported in the April 13 *Science*, casts doubt on hypothetical particles called dark photons and other potential oddities.

The quantity in question is the fine-structure constant, a number that governs the strength of electromagnetic interactions (*SN: 11/12/16, p. 24*), such as those that confine electrons within atoms. Previously, the most precise estimate of the constant was indirect, relying on a measurement of the electron's magnetic properties and using theoretical calculations to infer the constant's value.

Physicist Holger Müller of the University of California, Berkeley and colleagues have measured the constant more directly. The team fired lasers at cesium atoms to create a quantum superposition — a bizarre state in which each atom is in two places at once — and watched how the atoms interfered with themselves as they recombined. This interference revealed how fast the atom moved when hit by the laser, which scientists then used to calculate that the fine-structure constant is roughly 1/137.035999046.

That measurement agrees reasonably well with the previous measurement and therefore confirms that the electron is probably not composed of smaller particles and disfavors the possibility of dark photons. These hypothetical particles are similar to normal photons, or particles of light, but unlike normal photons, they would have mass and interact very weakly with known particles. — *Emily Conover*

FLASHMOVIE/SHUTTERSTOCK

Final Stop: Low-Earth Orbit

What does it take to launch a nanosatellite into space? Six years of development, 100+ crazy smart students, and one visionary professor. "When we see the exhaust plume coming out of the back-end of the SpaceX Falcon Heavy, we can say, 'Yeah, we did that.'"

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مؤسسة الملك عبدالعزيز ورجاله للموهبة والإبداع
King Abdulaziz & his Companions Foundation for Giftedness & Creativity

موهبة

Promoting Passion for Science & Knowledge for the Gifted

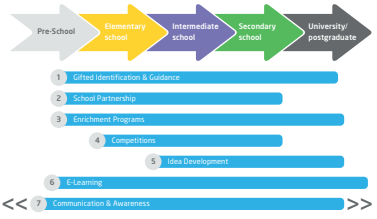
King Abdulaziz and his Companions Foundation for Giftedness & Creativity (known as "Mawhiba" meaning Giftedness) was established in 1999 as a non-profit foundation to support the long term vision of the Kingdom of Saudi Arabia (KSA) for developing giftedness and creativity in KSA. The foundation contributes in building a National Framework for Giftedness & Creativity by identifying and nurturing gifted students by a variety and array of programs and initiatives in STEM domains.

"We will bring together creative and talented people from all over the world to create something different"

HRH Mohammed Bin Salman Al-Saud,
Crown Prince, Deputy Prime Minister
The launch of NEOM project - October 24,2017

Our Mission
We contribute to building a national framework for giftedness and creativity, we provide distinguished care to the gifted, and we promote passion for science and knowledge.

Our Vision
For the Gifted and Creative to Become the Most Important Contributors to the Nation and its Prosperity.



1) Gifted Identification & Guidance:
The "National program for gifted identification" is one of the main gates for gifted students to access Mawhiba programs. It is a joint project between Mawhiba, Ministry of Education, and National Center for Assessment. It ensures sound, fair and unbiased selection procedures of gifted students and contributes in building a national database for gifted students in all regions and cities of KSA. Mawhiba's tests are yearly administered in grade 6 ,3, and 9 in the entire kingdom. This initiative also guides gifted students academically and professionally through the Guidance Program, which helps gifted students who wish to study abroad, and support them in developing a clear academic and professional career.

2) School Partnerships:
An initiative developed to create high-quality educational environment for primary and secondary gifted students to help them reach their full potential. Following identification the gifted students would be offered scholarships to join distinct Mawhiba partnership schools, which are carefully selected and encouraged to develop and to raise their standards in order to qualify. In return, these schools would commit to deliver the Mawhiba enhanced curriculum to Mawhiba students with the option to provide the same acceleration to their own students as well. Support is provided to the schools in the form of continuous teacher professional development, regular assessments, annual tests in the supplemental curriculum, as well as conducting parent orientation workshops. After school STEM programs are also conducted to expand and serve larger number of students and increase opportunities for early identification.

3) Enrichment programs:
An initiative intended to offer enrichment-type programs to supplement the regular school program. Enrichment programs consist of:

a) **Local summer programs**: A range of residential and non-residential three week summer programs that are designed for students entering grade 3 through to grade 11. The programs are offered on the campus of Saudi universities, research centers, leading companies and distinguished schools. They consist of challenging STEM-related academic subjects and advanced activities and skills which promote all personal aspects: intellectual, psychological, social or physical to help students explore and develop their full potential.

b) **International summer programs**: Mawhiba provides a challenging learning experience to optimize academic potential, for 10th and 11th grade students who are English proficient to take part in one of a number of international "off-the-shelf" summer programs for gifted individuals offered at top-tier universities in the US, Canada, UK and Ireland. To complement the conventional international summer programs and make them available to a greater number of students, Mawhiba international summer programs developed a joint venture project with international partners to conduct equivalent international programs in KSA.

4) Competitions
A) **National Olympiad for Scientific Creativity** (**Ibdaa**): The National Olympiad for Scientific Creativity "Ibdaa" is a science competition organized by Mawhiba in collaboration with the Ministry of Education.
The idea is based on a pre-college science competition targeted for the age group: 12-7th grade students and complies with ISEF 22 scientific categories. It is considered as the Kingdom's largest pre-college science competition that empowers the next generation of scientists, engineers, and entrepreneurs. This competition develops students' abilities in science research and encourages learning and self-development through science fairs and provides a competitive environment which challenges students' interests and abilities.

b) **Science International Olympiads**: These competitions are worldwide annual international high-quality competitions, held for more than 50 years and are considered an arena for identifying future scientists. Mawhiba selects and trains students (grade 7-12) to enter and participate in international Olympiads in Math, Physics and Chemistry and Science. The students benefit from after school support and residential seasonal training during school holidays. Over time, the training concentrates on the most promising students who will be selected to represent KSA in international competitions. This is a multi-year commitment to help students reach their full academic potential and increases their chances to being accepted in top universities.

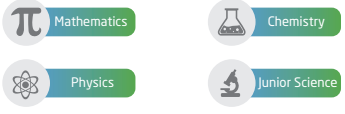
5) E Learning:
E-learning aims to support distance learning, acceleration, enrichment, outreach and interactive e-content for students from 4th to 12th grade. The intention is to develop an integrated eLearning system to provide effective learning experiences that engage and inspire the learner. Mawhiba is in the process of adapting its existing enhanced curriculum and teacher guidebooks into open courseware, adding some interactivity, for the benefit of any student or teacher.

6) Idea Development:
Mawhiba developed an on-line service to support would-be young inventors with scientific curiosity and innovative thinking skills. Inventors would pose ideas on-line which are evaluated by a panel of experts. Mawhiba also offers advice and support in how to apply for patents.

7) Awareness and Communications:
An initiative designed to create awareness for Giftedness & Creativity and engage stakeholders. It also aims to create awareness and excitement in participation in Mawhiba programs. Mawhiba developed its web presence and launched its portal as an online gateway to reach a wide audience (www.mawhiba.org) and developed a scientific content for giftedness & creativity targeting students, parents and educators. The portal provides a tool for student and teacher registration to sign-up for Mawhiba programs. The portal features a number of interactive services such as a consultation service named "Shawer" that provides personalized Q&A responses for any psychological, educational or social issues related to giftedness or creativity.

8) Translation and Research
In recognition of its responsibility to spread and promote the culture of giftedness and creativity in the society, Mawhiba established a "Translation Project" with the aim of supporting the movement of translation into Arab world for books of internationally renowned experts in the field of giftedness and creativity.
Mawhiba launched this project under the name of ". Mawhiba launched this project under the name of " Mawhiba Scientific Publications", where the 35 translated books are published in series form and are provided in an electronic version through its portal. Mawhiba also conducts scientific research and policy development in the field of gifted education. Mawhiba has carried out many important research, such as Proposed National Policy for Giftedness and Creativity in KSA, Gifted and Creativity Index, Needs of Gifted Students in Saudi Arabia, and Nurturing giftedness in Higher Education. In addition, Mawhiba provides its advisory services to researchers in the field of Giftedness and creativity.

Achievements:
a) The International Olympiad



Since 2010, KSA has awarded the following international Olympiad medals:

204 International Medals
44 Honorable Mentions

In the Mathematics Olympiad, KSA ranked first in the Arab world and in the top third internationally.

Chemistry International Olympiads 2017
Thailand
2 Silver Medals
2 Bronze Medals

Mathematical International Olympiads 2017
Brazil
2 Silver Medals
2 Bronze Medals
Honourable mentions

Physics International Olympiads 2017

Indonesia

- 2 Silver Medals
- 1 Bronze Medals
- Honourable mentions

International Junior Science Olympiad 2017

Netherlands

- 3 Bronze Medals

b) The National Olympiad for Scientific Creativity "Ibdaa"
Intel ISEF Participation from

Intel ISEF Participation from
2007 - 2017
No. of Awards

Total

36 Grand Awards

18 Special Awards

Categories

- Molecular and cell biology
- Material and Bioengineering.
- Chemistry and Biochemistry
- Medicine and Health Sciences
- Plant Sciences
- Environmental Sciences
- Energy and transportation
- Environmental Management
- Materials science
- Social and Behavioral Sciences

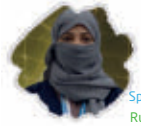
Intel ISEF 2017

Grand Award
Nadia Almutlak
Materials Science
Enhancing LiFi and Lighting: CsPbBr3 Zero-Dimensional Perovskite and Quantum Dot Based Color Converters

Grand Award
Dana Alkhaldi
Chemical Energy
A Novel Approach for the Preparation of High Efficiency Water Splitting Photocatalysts
Special Award

Grand Award
Amaar Amir
Animal Science
The Effect of Expression Patterns of Ammonium Transporters on the Interaction between Corals and Their Symbiotic Din flagellates

Top Award
Sara Alrabiah
Materials Science
Improving Resistive RAMs' Performance by Using Single Crystal MAPbBr3 Perovskite



Special Award
Ruba Alsulami
Environmental Engineering
Green Nanotechnology

NASA names asteroids after Saudi students

The NASA-funded LINEAR Program at MIT Lincoln Laboratory Names Minor Plants after these Saudi Students:
The asteroid (Al-Sheikh 33535) was named after Saudi talented student Fatima Abdel-Moneim Al-Sheikh in recognition of her efforts and excellence in her research in Botany for which she won the second place at Intel International Science and Engineering. Fair (Intel ISEF) 2016.
The asteroid (alhamood 31926) was named after Saudi student Abdul Jabbar Al-Hamood who had received 2 awards and ranked "The best of category and first place in Plant Sciences" at Intel International Science and Engineering Fair (Intel ISEF 2015).

Fatima Abdel-Moneim Al-Sheikh
ISEF 2017

Abdul Jabbar Al-Hamood
ISEF 2016

JOSEPH ALESSIO

Recipes for solar system formation are getting a rewrite

By Lisa Grossman

With a mortar and pestle, Christy Till blends together the makings of a distant planet. In her geology lab at Arizona State University in Tempe, Till carefully measures out powdered minerals, tips them into a metal capsule and bakes them in a high-pressure furnace that can reach close to 35,000 times Earth's atmospheric pressure and 2,000° Celsius.

In this interplanetary test kitchen, Till and colleagues are figuring out what might go into a planet outside of our solar system.

"We're mixing together high-purity powders of silica and iron and magnesium in the right proportions to make the composition we want to study," Till says. She's starting with the makings of what might resemble a rocky planet that's much different from Earth. "We literally make a recipe."

Scientists have a few good ideas for how to concoct our own solar system. One method: Mix up a cloud of hydrogen and helium, season generously with oxygen and carbon, and sprinkle lightly with magnesium, iron and silicon. Condense and spin until the cloud forms a star surrounded by a disk. Let rest about 10 million years, until a few large lumps appear. After about 600 million years, shake gently.

But that's only one recipe in the solar systems cookbook. Many of the planets orbiting other stars are wildly different from anything seen close to home. As the number of known exoplanets has climbed — 3,717 confirmed as of April 12 — scientists are creating new recipes.

Seven of those exoplanets are in the TRAPPIST-1 system, one of the most exciting families of planets astronomers have discovered to date. At least three TRAPPIST-1 planets might host liquid water on their surface, making them top spots to look for signs of life (*SN: 12/23/17, p. 25*).

Yet those planets shouldn't exist. Astronomers calculated that the small star's preplanet disk shouldn't have contained enough rocky material to make even one Earth-sized orb, says astrophysicist Elisa Quintana of NASA's Goddard Space Flight Center in Greenbelt, Md. Yet the disk whipped up seven.

TRAPPIST-1 is just one of the latest in a long line of rule breakers. Other systems host odd characters not seen in our solar system: super-Earths, mini-Neptunes, hot Jupiters and more. Many exoplanets must have had chaotic beginnings to exist where we find them.

These oddballs raise exciting questions about how solar systems form. Scientists want to know how much of a planet's ultimate fate depends on its parent star, which ingredients are essential for planet building and which are just frosting on the planetary cake.

NASA's Transiting Exoplanet Survey Satellite, or TESS, which launched April 18, should bring in some answers.

TESS is expected to find thousands more exoplanets in the next two years (see Page 7). That crowd will help illuminate which planetary processes are the most common — and will help scientists zero in on the best planets to check for signs of life.

Beyond the bare necessities

All solar system recipes share some basic elements. The star and its planets form from the same cloud of gas and dust. The densest region of the cloud collapses to form the star, and the remaining material spreads itself into a rotating disk, parts of which will eventually coalesce into planets. That similarity between the star and its progeny tells Till and other scientists what to toss into the planetary stand mixer.

"If you know the composition of the star, you can know the composition of the planets," says astronomer Johanna Teske of the Carnegie Observatories in Pasadena, Calif. A star's composition is revealed in the wavelengths of light the star emits and absorbs.

When a planet is born can affect its final makeup, too. A gas giant like Jupiter first needs a rocky core about 10 times Earth's mass before it can begin gobbling up gas. That much growth probably happens well before the disk's gas disappears, around 10 million years after the star forms. Small, rocky planets like Earth probably form later.

Geologist Christy Till mixes up a mock exoplanet from powdered minerals in her Arizona lab.

ABIGAIL WEIBEL PHOTOGRAPHY

Finally, location matters. Close to the hot star, most elements are gas, which is no help for building planets from scratch. Where the disk cools toward its outer edge, more elements freeze to solid crystals or condense onto dust grains. The boundary where water freezes is called the snow line. Scientists thought that water-rich planets must either form beyond their star's snow line, where water is abundant, or must have water delivered to them later (*SN: 5/16/15, p. 8*). Giant planets are also thought to form beyond the snow line, where there's more material available.

But the material in the disk might not stay where it began, Teske says. "There's a lot of transport of material, both toward and away from the star," she says. "Where that material ends up is going to impact whether it goes into planets and what types of planets form." The amount of mixing and turbulence in the disk could contribute to which page of the cookbook astronomers turn to: Is this system making a rocky terrestrial planet, a relatively small but gaseous Neptune or a massive Jupiter?

Some like it hot

Like that roiling disk material, a full-grown planet can also travel far from where it formed.

Consider "Hoptunes" (or hot Neptunes), a new class of planets first named in December in *Proceedings of the National Academy of Sciences*. Hoptunes are between two and six times Earth's size (as measured by the planet's radius) and sidled up close to their stars, orbiting in less than 10 days. That close in, there shouldn't have been enough rocky material in the disk to form such big planets. The star's heat should mean no solids, just gases.

Hoptunes share certain characteristics — and unanswered questions — with hot Jupiters, the first type of exoplanet discovered, in the mid-1990s.

"Because we've known about hot Jupiters for so long, some people kind of think they're old hat," says astronomer Rebekah Dawson of Penn State, who coauthored a review about hot Jupiters posted in January at arXiv.org. "But we still by no means have a consensus about how they got so close to their star."

Since the first known hot Jupiter, 51 Pegasi b, was confirmed in 1995, two explanations for that proximity have emerged. A Jupiter that formed past the star's snow line could migrate in smoothly through the disk by trading orbital positions with the disk material itself in a sort of gravitational do-si-do. Or interactions with other planets or a nearby star could knock the planet onto an extremely elliptical or even backward orbit (*SN Online: 11/1/13*). Over time, the star's gravity would steal energy from the orbit, shrinking it into a tight, close circle. Dawson thinks both processes probably happen.

Hot Jupiters are more common around stars that contain a lot of elements heavier than hydrogen and helium, which astronomers call metals, astronomer Erik Petigura of Caltech and colleagues reported in February in the *Astronomical Journal*. High-metal stars probably form more planets because their disks have more solids to work with. Once a Jupiter-sized planet forms, a game of gravitational billiards could send it onto an eccentric orbit — and send smaller worlds out into space. That fits the data, too; hot Jupiters tend to lack companion worlds.

Hoptunes follow the same pattern: They prefer metal-rich stars and have few sibling planets. But Hoptunes probably arrived at their hot orbits later in the star's life. Getting close to a young star, a Hoptune would risk having its atmosphere stripped away. "They're sort of in the danger zone," Dawson says. Since Hoptunes do, in fact, have atmospheres, they were probably knocked onto an elliptical, and eventually close-in, orbit later.

One striking exception to the hot loner rule is WASP-47b, a hot Jupiter with two nearby siblings between the sizes of Earth and Neptune. That planet is one reason Dawson thinks there's more than one way to cook up a hot Jupiter.

Rock or gas

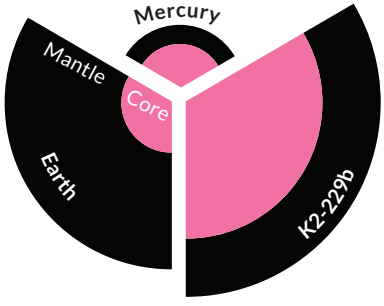
Hot Jupiters are so large that astronomers assume these exoplanets have thick atmospheres. But it's harder to tell if a smaller planet is gassy like Neptune or rocky like Earth.

To make a first guess at a planet's composition, astronomers need to know the planet's size and mass. Together, those numbers yield the planet's density, which gives a sense of how much of the planet is solid like rock or diffuse like an atmosphere.

The most popular planet detection strategies each measure one of those factors. The transit method, used by the Kepler space telescope, watches a star wink as the planet passes in front. Comparing the star's light before and during the transit reveals the planet's size. The radial velocity method, used with telescopes on the ground, watches the star wobble in response to a planet's gravity, which reveals the planet's mass.

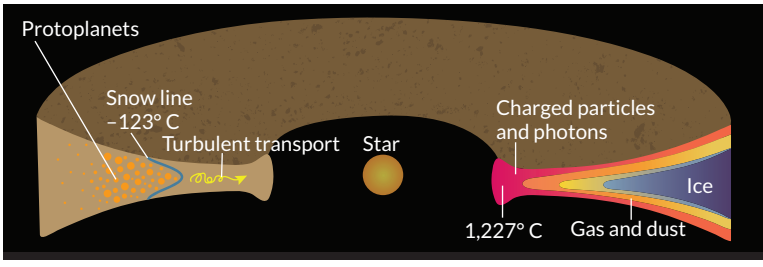
Most of the stars observed by Kepler are too far away and too dim for direct, accurate measures of planet masses. But astronomers have inferred a size cutoff for rocky planets. Last June, researchers analyzing the full Kepler dataset noticed a surprising lack of planets between 1.5 and two times Earth's size and suggested those 1.5 times Earth's radius or smaller are probably rocky; two to 3.5 times Earth's radius are probably gassy (*SN Online: 6/19/17*).

Dozens more planets have had their masses inferred indirectly, mostly those in multiplanet systems where astronomers can observe how planets tug on one another. From what astronomers can tell, super-Earths — planets between one and about 10 times Earth's mass — come in a wide range of compositions.



Hints from the star Based on its mass and radius, an exoplanet named K2-229b is about Earth's size but more similar to Mercury in composition, astronomers suggest.

SOURCE: A. SANTERNE *ET AL*/*NATURE ASTRONOMY* 2018



Birthplace In the disk around a star, giant planets form beyond the "snow line," where water freezes and more solids are available. Turbulence closer in knocks things around.

SOURCE: T. HENNING AND D. SEMENOV/*CHEMICAL REVIEWS* 2013

The Kepler mission is about to end, as the spacecraft's fuel is running out. TESS will pick up where Kepler leaves off. The new planet-hunting space telescope will revolutionize the study of super-Earth densities. It will scan 85 percent of the sky for bright, nearby stars to pick out the best planets for follow-up study. As part of its primary mission, TESS will find at least 50 planets smaller than Neptune that can have their masses measured precisely, too. "Having masses ... will help us understand the compositions," says Quintana, a TESS team member. "We can see: Is there a true transition line where planets go rocky to gaseous? Or is it totally random? Or does it depend on the star?"

Star power

All kinds of planets' fates do, in fact, depend on the stars, Petigura's recent work suggests. In a February report in the *Astronomical Journal*, he and colleagues measured the metal contents of 1,305 planet-hosting stars in Kepler's field of view.

The researchers learned that large planets and close-in planets — with orbital periods of 10 days or less — are more common around metal-rich stars. But the team was surprised to find that small planets and planets that orbit far from their stars show up around stars of all sorts of compositions. "They form efficiently everywhere," Petigura says.

That could mean that metal-rich stars had disks that extended closer to the stars. With enough material close to the star, hot super-Earths could have formed where they currently spin. The existence of hot super-Earths might even suggest that hot Jupiters can form close to the star after all. A super-Earth or mini-Neptune could represent the core of what was once a hot Jupiter that didn't quite gather enough gas before the disk dissipated, or whose atmosphere was blown off by the star (*SN Online: 10/31/17*).

Weird water

Some scientists are looking to stars to reveal what's inside a planet. The help is welcome because density is a crude measure for understanding what a planet is made of. Planets with the same mass and radius can have very different compositions and natures — look at hellish Venus and livable Earth.

BOTH: T. TIBBITTS

Take the case of TRAPPIST-1, which has seven Earth-sized worlds and is 39 light-years away. Astronomers are anxious to check at least three of the planets for signs of life (*SN: 12/23/17, p. 25*). But those planets might be so waterlogged that any signs of life would be hard to detect, says exogeologist Cayman Unterborn of Arizona State. So much water would change a planet's chemistry in a way that makes it hard to tell life from nonlife. Based on the planets' radii (measured by their transits) and their masses (measured by their gravitational influence on one another), Unterborn and colleagues used density to calculate a bizarre set of interiors for the worlds, which the team reported March 19 in *Nature Astronomy*.

The TRAPPIST-1 planets have low densities for their size, Unterborn says, suggesting that their masses are mostly light material like water ice. TRAPPIST-1b, the innermost planet, seems to be 15 percent water by mass (Earth is less than 0.1 percent water). The fifth planet out, TRAPPIST-1f, may be at least half water by mass. If the planet formed with all that water already in it, it would have had 1,000 Earth oceans' worth of water. That amount of water would compress into exotic phases of ice not found at normal pressures on Earth. "That is so much water that the chemistry of how that planet crystallized is not something we have ever imagined," Unterborn says.

But there's a glitch. Unterborn's analysis was based on the most accurate published masses for the TRAPPIST-1 worlds at the time. But on February 5, the same day his paper was accepted in *Nature Astronomy*, a group led by astronomer Simon Grimm of the University of Bern in Switzerland posted more precise mass measurements at arXiv.org. Those masses make the soggiest planets look merely damp.

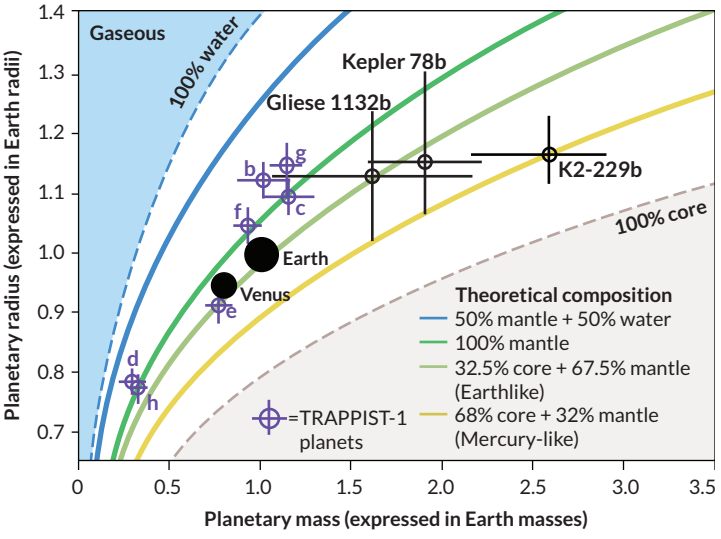
Clearly, Unterborn says, density is not destiny. Studying a planet based on its mass and radius has its limits.

Looking deeper

As a next step, Unterborn and colleagues have published a series of papers suggesting how stellar compositions can tell the likelihood that a group of planets have plate tectonics, or how much oxygen the planet atmospheres may have. Better geologic models may ultimately help reveal if a single planet is habitable.

But Unterborn is wary of translating composition from a star to any individual planet — existing geochemical models aren't good enough. The recent case of K2-229b makes that clear. Astronomer Alexandre Santerne of the Laboratory of Astrophysics of Marseille in France and colleagues recently tried to see if a star's composition could describe the interior of its newly discovered exoplanet, K2-229b. The team reported online March 26 in *Nature Astronomy* that the planet has a size similar to Earth's but a makeup more like Mercury's: 70 percent metallic core, 30 percent silicate mantle by mass. (The researchers nicknamed the planet Freddy, for Queen front man Freddie Mercury, Santerne wrote on Twitter.) That composition is not what they'd expect from the star alone.

Geologic models need to catch up quickly. After TESS finds the best worlds for follow-up observations, the James Webb Space Telescope, due to launch in 2020, will search some of those planets' atmospheres for signs of life (*SN: 4/30/16, p. 32*). For that strategy to work, Unterborn says, scientists need a better read on the exoplanet cookbook.



Size it up Measuring a planet's mass and radius gives astronomers a sense of planetary makeup. This plot compares the TRAPPIST-1 planets (purple) with Earth, Venus, an exoplanet named K2-229b and a couple of other worlds. SOURCE: A. SANTERNE *ET AL/NATURE ASTRONOMY* 2018

Christy Till's pressure-packed test kitchen may help. Till is primarily a volcanologist who studies how magma erupting onto Earth's surface can reveal conditions in Earth's interior. "The goal is to start doing that for exoplanets," she says.

Till and colleagues are redoing some foundational experiments conducted for Earth 50 years ago but not yet done for exoplanets. The experiments predict which elements can go into planets' mantles and cores, and which will form solid crusts. (Early results that Till presented in December in New Orleans at the American Geophysical Union meeting suggest that multiplying the sun's magnesium-to-silicon ratio by 1.33 still bakes a rocky planet, but with a different flavored crust than Earth's.)

Till uses three piston cylinders to squash and singe synthetic exoplanets for 24 hours to see what minerals form and melt at different pressures and temperatures. The results may help answer questions like what kind of lava would erupt on a planet's surface, what would the crust be made of and what gases might end up in the planet's atmosphere.

It's early days, but Till's recipe testing may mean scientists won't have to wait decades for telescopes to get a close enough look at an exoplanet to judge how much like home it really is. With new cookbook chapters, Unterborn says, "we can figure out which stars are the best places to build an Earth." ■

Explore more

- Erik Petigura *et al*. "The California-Kepler Survey. IV. Metal-rich stars host a greater diversity of planets." *Astronomical Journal*. February 2018.

T. TIBBITTS

MAKING THE CUT

Swinging blade slices into Bronze Age mystery

By Bruce Bower

Nicholas Blackwell and his father went to a hardware store about three years ago seeking parts for a mystery device from the past. They carefully selected wood and other materials to assemble a stonecutting pendulum that, if Blackwell is right, resembles contraptions once used to build majestic Bronze Age palaces.

With no ancient drawings or blueprints of the tool for guidance, the two men relied on their combined knowledge of archaeology and construction.

Blackwell, an archaeologist at Indiana University Bloomington, had the necessary Bronze Age background. His father, George, brought construction cred to the project. Blackwell grew up watching George, a plumber who owned his own business, fix and build stuff around the house. By high school, the younger Blackwell worked summers helping his dad install heating systems and plumbing at construction sites. The menial tasks Nicholas took on, such as measuring and cutting pipes, were not his idea of fun.

But that earlier work paid off as the two put together their version of a Bronze Age pendulum saw — a stonecutting tool from around 3,300 years ago that has long intrigued researchers. Power drills, ratchets and other tools that George regularly used around the house made the project, built in George's Virginia backyard, possible.

"My father enjoyed working on the pendulum saw, although he and my mother were a bit concerned about what the neighbors would think when they saw this big wooden thing in their backyard," Blackwell says. Anyone walking by the fenceless yard had a prime view of a 2.5-meter-tall, blade-swinging apparatus reminiscent of Edgar Allan Poe's literary torture device.

No one alive today has seen an actual Bronze Age pendulum saw. No frameworks or blades have been excavated. Yet archaeologists have suspected for nearly 30 years that a contraption capable of swinging a sharp piece of metal back and forth with human guidance must have created curved incisions on large pieces of stonework from Greece's Mycenaean civilization. These distinctive cuts appeared during a century of palace construction, from nearly 3,300 years ago until the ancient Greek society collapsed along with a handful of other Bronze Age civilizations. Mycenaeans built palaces for kings and administrative centers for a centralized government. These ancient people spoke a precursor language to that of Classical Greek civilization, which emerged around 2,600 years ago.

In Blackwell's view, only one tool — a pendulum saw — could have harnessed enough speed and power to slice through the especially tough type of rock that Mycenaeans used for pillars, gateways and thresholds in palaces and some large tombs.

Kings at the time valued this especially hard rock, known as conglomerate, for the look of its mineral and rock fragments, which form colorful circular and angled shapes.

In the early 20th century, archaeologists excavating a Mycenaean hill fort called Tiryns first

An ancient sculpture known as the Lion Gate relief contains marks in a column (center of image) that may have been made by a pendulum saw. The lions, now headless, stood above the main entrance to the citadel of Mycenae, in what is now Greece.

LULU AND ISABELLE/SHUTTERSTOCK

noticed curved cut marks on the sides of pillar bases and other parts of a royal palace. The researchers assumed that ancient workers sliced through conglomerate blocks with curved, handheld saws and a lot of elbow grease.

Some investigators still suspect that handheld saws make more sense than a swinging pendulum blade. But scholarly opinions began to change as similar marks were found on stonework at other Mycenaean sites, including the fortified town and citadel of Mycenae. Separate reports in the 1990s by German archaeologists proposed that a pendulum device produced curved Mycenaean masonry marks. One of the researchers estimated that a pendulum saw would have needed to swing from a massive arm, between 3 meters and 8 meters high, to create the observed curved cuts. His calculations rested on an assumption that the curved saw marks represented segments of perfect, geometric circles, which in some cases would have required the wide arc of an especially tall pendulum.

Blackwell doubted that Mycenaeans used pendulum saws as tall as 8 meters, the equivalent of about 2½ stories. But there was only one way to find out. His experiments, described in the February *Antiquity*, indicate that a wooden contraption supporting a blade-tipped swinging arm had to reach only about 2½ meters high to create stone marks like those at Tiryns and Mycenae.

The Indiana researcher's homemade pendulum saw "is the most persuasive reconstruction of a Mycenaean sawing machine that was used to cut hard stones, especially conglomerate," says archaeologist Joseph Maran of the University of Heidelberg in Germany. Only one other life-size model of a pendulum saw exists.

Swing time

Blackwell's experimental cutting device swung into action in December 2015 right where it was built, in his parents' Virginia backyard.

Positioned on opposite sides of the apparatus, Blackwell and his brother-in-law, Brandon Synan, pulled the sawing arm back and forth with a rope. A metal blade bolted to the bottom of the arm sliced into a limestone block. Unlike the type of conglomerate used in the Mediterranean region, limestone was readily available. The two tested four types of saw blades in the initial trials and again in February 2017.

Blackwell reviewed seven previously published designs and the one actual model of a pendulum saw that may have been used by a nearby Bronze Age society; they offered little encouragement. No consensus existed on the best shape for the blade or the most effective framework option. Designers were most notably stumped by how to build a pendulum that adjusted downward as the blade cut deeper into the stone.

Blackwell decided to build a device with two side posts, each studded with five holes drilled along its upper half, supported by a base and diagonal struts. A removable steel bar ran through opposite holes on the posts and could be set at different heights. In between the posts, the bar passed through an oval notch in the upper half of a long piece of wood — the pendulum. The notch is slightly longer than a dollar bill, giving the steel bar some leeway so the pendulum could move up and down freely while sawing.

Archaeologist Nicholas Blackwell (top, left) and brother-in-law Brandon Synan operate Blackwell's reconstructed pendulum saw, using a rope to pull a blade-tipped wooden arm back and forth across a piece of limestone. An experimental bronze blade appears in action (left).

FROM TOP: N. BLACKWELL; N. BLACKWELL/*ANTIQUITY* 2018

Finally, the apparatus needed a tough, sharp business end. A Greek archaeologist that Blackwell met while working at the American School of Classical Studies at Athens from 2012 to 2015 put him in touch with a metalsmith from Crete. The craftsman fashioned four bronze blades with different shapes for testing on the pendulum saw: a long, curved blade; a triangular blade with a rounded tip; a short, straight-edged saw and a long, straight-edged saw with rounded corners. During tests with each blade, Blackwell added water and sand to the limestone surface every two minutes for lubrication and to enhance the saw's grinding power.

Blackwell suspected the triangular blade would penetrate the limestone enough to produce the best replicas of Mycenaeans' arced cuts. He was wrong. Putting that blade through its paces, he found that only the tip creased the stone as the pendulum swung. The triangular blade yielded a shallow, wobbly groove that would have sorely disappointed status-conscious Mycenaean elites.

The short, straight blade did even worse. It repeatedly got stuck in the stone block during trials.

But in a dramatic showing, the long, curved blade left three concave incisions that looked much like saw marks at Tiryns. It took 45 minutes of sawing to reach a depth of 25.5 millimeters, a partial cut by Mycenaean standards. Blackwell and his brother-in-law took short breaks after every 12 minutes of pendulum pulling. "It takes a lot of physical effort to use a pendulum saw," Blackwell says.

The elongated, straight blade with rounded corners proved easiest to use. It made one Mycenaean-like cut after only 24 minutes of sawing. Either the straight or the curved blade could have fit the bill for Mycenaean stoneworkers.

Close inspection of successful experimental cuts showed that Blackwell's pendulum saw created curved incisions that were not segments of perfect circles. So an actual Mycenaean pendulum saw need not have been as tall as those earlier calculations had called for.

Blackwell suspects that Mycenaean masons tied or glued blades to one side of a pendulum's arm. After sawing deep enough so that the pendulum's wooden end hit rock, a worker chiseled and hammered off stone on one side of the incision so that the blade could be lowered for deeper sawing. Repeating those steps several times eventually left a flat face at the incision.

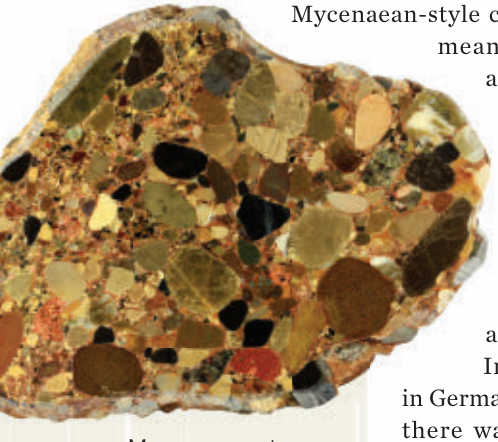
A half-finished pillar base from Mycenae preserves evidence of this procedure, Blackwell says. The stone displays a long, curved cut on a flat, vertical surface near one of its sides. The cut abruptly stops partway down. At that level, stone abutting the incision shows signs of having been pounded off.

Stonecutting experiments with a model of a pendulum saw tested four bronze blades crafted in Crete for the studies. Blades on the top left and bottom right produced Mycenaean-style curved incisions in rock. A triangular blade, top right, created a wobbly groove. A short, straight blade, bottom left, repeatedly became stuck as it swung into a rock's surface.

Ghost saw

Even after Blackwell's hands-on experiments, the Mycenaean pendulum saw remains an archaeological apparition. Some researchers believe it existed. Others don't.

"Pendulum saws could have been a solution to Mycenaeans' specific problem of having to work with conglomerate," says archaeologist James Wright of Bryn Mawr College in Pennsylvania. Mycenaean conglomerate is considerably harder and more resistant to cutting than other types of rock that were available to the Mycenaeans and neighboring societies. Blackwell's successful experimental incisions in limestone "conform with cut marks on Mycenaean stones," Wright adds. The next step is to see how Blackwell's pendulum saw performs on the tougher challenge of slicing through conglomerate.



Mycenaeans cut into a type of rock with colorful mineral fragments, known as conglomerate, to build gateways and pillars for palaces and tombs.

While Blackwell's experimental device produces Mycenaean-style curved cuts, that doesn't mean Mycenaeans invented and used pendulum saws, contends archaeologist Jürgen Seeher of the German Archaeological Institute's branch in Istanbul. Seeher built and tested the only other reconstruction of a pendulum saw.

In a 2007 paper published in German, Seeher concluded that there was a better option than his pendulum saw: a long, curved saw attached to a wooden bar and pulled back and forth by two people, like a loggers' saw. A loggers' saw could have produced curved marks on palace stones of ancient Hittite society, which existed at the same time as the Mycenaeans in what is now Turkey.

Unlike their Greek neighbors, Hittites did not construct pillars and gateways out of conglomerate. But a handheld, two-man saw would have enabled something a pendulum saw could not: precise cutting of conglomerate blocks from different angles, Seeher says.

"A handheld saw moved by two men is much more under control than a free-hanging pendulum," he says.

Seeher has archaeological evidence on his side. Double-handled loggers' saws have been excavated at sites from the Late Bronze Age Minoan society on Crete. Hittites and Mycenaeans, contemporaries of the Minoans, could easily have modified that design to cut stone instead of wood, Seeher proposes. They would have had to substitute rock-grinding straight edges for wood-cutting serrated edges.

Blackwell disagrees. He is convinced that Mycenaean craft workers trained for years to operate pendulum saws, just as skilled artisans like his dad go through a long apprenticeship to learn their trade. Mycenaeans may have worked in teams that took turns using pendulum saws to cut conglomerate into palace structures, he speculates. Those workers probably used highly abrasive emery sand from the Greek island of Naxos to amplify the grinding power of their swinging saws, Wright adds.

Blackwell worked with his own family team to create a rough approximation of what a Mycenaean pendulum saw may have looked like and how it was handled. His father's construction expertise was crucial to the project. But those teenage summers doing scut work at building sites probably didn't hurt, either. ■

Explore more

■ Nicholas Blackwell. "Experimental stone-cutting with the Mycenaean pendulum saw." *Antiquity*. February 2018.

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Fight Like an Animal

Conflict resolution is not what it seems

By Susan Milius

Extravagant headgear on male animals like these gemsbok in Namibia's Etosha National Park can give species a ferocious look. But bulked-up adversaries may be far from nature's most routinely lethal fighters.

Pick an animal.

Choose wisely because in this fantasy you'll transform into the creature and duel against one of your own. If you care about survival, go for the muscular, multispiked stag roaring at a rival. Never, ever pick the wingless male fig wasp. Way too dangerous.

This advice sounds exactly wrong. But that's because many stereotypes of animal conflict get the real biology backward. All-out fighting to the death is the rule only for certain specialized creatures. Whether a species is bigger than a breadbox has little to do with lethal ferocity.

Many creatures that routinely kill their own kind would be terrifying, if they were larger than a jelly bean. Certain male fig wasps unable to leave the fruit they hatch in have become textbook examples, says Mark Briffa, who studies animal combat. Stranded for life in one fig, these males grow "big mouthparts like a pair of scissors," he says, and "decapitate as many other males as they possibly can." The last he-wasp crawling has no competition to mate with all the females in his own private fruit palace.

In contrast, big mammals that inspire sports-team mascots mostly use antlers, horns and other outsize male weaponry for posing, feinting and strength testing. Duels to the death are rare.

"In the vast majority of cases, what we think of as fights are solved without any injuries at all," says Briffa, of Plymouth University in England.

Evolution has produced a full rainbow of conflict styles, from the routine killers to animals that never touch an adversary. Working out how various species in that spectrum assess when it's worth their while to go head-to-head has become a challenging research puzzle.

To untangle the rules of engagement, researchers are turning to animals that live large in small bodies but don't have sports teams named after them. At least not yet.

Deadliest matches

It's hard to imagine nematodes fighting at all. There's little, if any, weaponry visible on the see-through, micronoodle body of the species called *Steinernema longicaudum*. Yet in Christine Griffin's lab at Maynooth University in Ireland, a graduate student offered a rare hermaphrodite to a male as a possible mate. Instead of mating, the male went in for the kill.

"We thought, well, poor hermaphrodite, she's not used to mating, so maybe it's just some kind of accident," says Griffin, whose lab specializes in nematodes as pest control for insects. When the grad student, Kathryn O'Callaghan, offered females of another species, males killed some of those females too. When given a chance, males also readily killed each other. That's how nematodes, in 2014, joined the list of kill-your-own-kind animals, Griffin says.

Killing another nematode is an accomplishment for a skinny thread of an animal with just two thin, protruding prongs. The male *S. longicaudum* slays by repurposing his mating moves.

When he encounters a female of his own species, the male coils his tail around her and positions the prongs, known as spicules, to hold open the entrance to her reproductive tract. To kill, a male just coils his tail around another male, or a female of a different species, and squeezes extra hard. Pressure ruptures internal organs; sometimes spicules even punch a hole during the fatal embrace. The grip lasts from a few seconds to several minutes. Of those worms paralyzed by the attack, most are dead the next day.

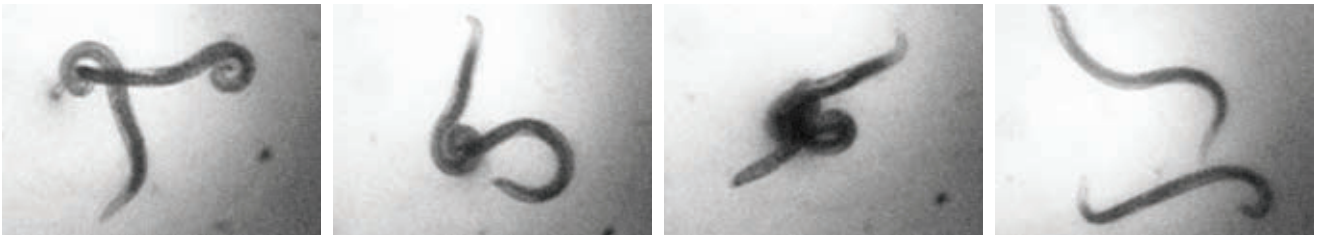
Other nematodes live in labs around the world without murdering each other. So why does *S. longicaudum*, for one, lean toward extreme violence? Its lifestyle of colonizing the innards of an insect inclines it to kill, Griffin suggests. An insect larva is a prize one male worm can monopolize, not to mention the only place he can have sex.

These nematodes lurk in soil without reproducing or even feeding until they find a promising target, such as the pale fat larva of a black vine weevil. Nematodes wriggle in through any opening: the larva's mouth, breathing pores, anus. If a male kills all rivals inside his new home, he becomes the nematode Adam for generations of offspring perhaps totaling in the hundreds of thousands, Griffin says.

Territorial female slayers

A defendable bonanza like a weevil larva, or a fig, has become a theme in the evolution of lethal fighting. Biologists have studied violence in certain male fig wasps for decades, but more recent research has revealed that some females kill each other too.

When a female *Pegoscapus* wasp, a bit longer than a poppy seed, chooses one particular pea-sized sac of flowers, a fig-to-be, she's deciding her destiny. That sac is most likely her only chance at laying eggs, and will probably be the fruit she will die in, says evolutionary ecologist Charlotte Jandér of Harvard University.



In a fight between nematodes, the male *Steinernema longicaudum* attacker (vertical, first panel) curls his body around one of his own kind and squeezes, rupturing the enemy's internal organs (middle panels). The victor (top, last panel) nudges the loser as if checking for any remaining resistance.

OPPOSITE PAGE: JOHAN SWANEPOEL/SHUTTERSTOCK; THIS PAGE: C. GRIFFIN

Dramatic fights rage inside the green, flower-filled sacs that will mature into figs (left, *Ficus citrifolia*). Certain male fig wasps are famous for lethal brawls, but research shows females also go at it. Two females (right) grapple jaw-to-jaw beside a wasp that may have died in earlier combat.

Shortleaf fig trees (*Ficus citrifolia*) have "a delicate flowery smell," Jandér says, but the blooms are hidden inside the little green-skinned sacs. To reach these inner riches and lay one egg per flower in as many flowers as she can, the wasp must push through a tight tunnel. The squeeze can take roughly half an hour and rip her wings and antennae. Reaching the inner cavity carpeted in whitish flowers, "there is plenty of space for one wasp to move around," Jandér says. But more than one gets cramped, and conflicts get desperate.

In a Panamanian wasp species that Jandér has watched, females "can lock on to each other's jaws for hours and push back and forth," she says. In a Brazilian species, 31 females were found decapitated among 84 wasps, reported Jandér, Rodrigo A.S. Pereira of the University of São Paulo and colleagues in 2015. That was the first documented female-to-female killing in fig wasps.

Walk away

From bellowing red deer stags to confrontational male stalk-eyed flies, many animal species have ways to back off rather than fight to the death. Searching for dynamics of less-than-deadly discord, Briffa studies sea anemones. And yes, anemones fight.

Beadlet sea anemones (*Actinia equina*) release sperm and eggs into open seawater, so the animals don't need to argue over mates. For a prime bit of tide pool rock, however, tensions rise.

Below a beadlet's pinkish, swaying food-catcher tentacles are what often look like "little blue beads," Briffa says. These are fighting tentacles, or acrorhagi. When combat looms, the anemone inflates them. "Imagine someone pulling out their bottom lip to make a funny face," he says.

It's no joke for an impertinent neighbor. Anemones, distant relatives of stinging jellies, carry harpoon-shooting, toxin-injecting capsules in the acrorhagi. Combatants rake stinger acrorhagi down each other's soft flesh. "It almost looks like they're punching each other," Briffa says. "When one of the anemones decides it's had enough and wants to quit the contest, it actually actively walks away."

"Walk" is used loosely here, says Sarah Lane, a postdoc in Briffa's lab, as she alternately arches her hand and flattens it in a measured trip across the Skype screen. "Like a cartoon caterpillar?" she says, trying to describe the gait. "A concertina?"

When placed side by side in the lab for fighting tests, anemones concertina away or otherwise resolve the tension without any acrorhagi swipes about a third of the time. De-escalating makes sense considering that a full exchange "looks quite vicious," Lane says. Strikes leave behind bluish fragments of acrorhagi full of stinging capsules, which kill tissue on the recipient. The attacker isn't unscathed either; close-ups show open wounds where acrorhagi tissue was pulled out. An anemone "literally can't hurt an opponent without ripping parts of itself off," she says.

Injuries to an attacker from swiping, biting or other acts of aggression get overlooked in theorizing over how animals weigh the costs and benefits of dueling, Lane and Briffa argued in the April 2017 *Animal Behaviour*. The sea anemones may be an extreme example of self-harm from a strike, but they're not the only one.

Humans can hurt themselves when they attack, and decision making around fighting has had some unintended consequences, Lane points out. In a bare-handed punch at somebody's head, little bones in the hand crack — called boxer's fractures — before the skull does. With the introduction of gloves around 1897, boxer's fractures basically disappeared from match records, Lane says. Before gloves, however, records show no reported deaths in professional matches. Once gloves lessened the costs of delivering high-impact punches, deaths began appearing in the records.

Worth the fight?

Sea anemones don't have a brain or centralized nervous system, yet costs and benefits of fighting somehow still matter. The animals clearly pick their fights, escalating some blobby sting matches and creeping away from others.

Just how anemones choose, or how any animal chooses when to fight and when to back down, turns out to be a rich vein for research. Theorists have proposed versions of two basic approaches. One, called mutual assessment, "is sussing out when you're weaker and giving up as soon as you know — that's the smart way," Briffa says. Yet the evidence Briffa has so far, he says with perhaps a touch of wistfulness, suggests anemones use "the dumb way of giving up."

Animals resort to this "dumb" option, called self-assessment, when they can't compare their opponent's odds of winning with their own. Maybe they fight in shadowy, murky places. Maybe they don't have the neural capacity for that kind of comparison. For whatever reason, they're stuck with "keep going until you can't keep going anymore," he says. Never mind if the fight is hopeless from the beginning.

BOTH: C. JANDÉR

The odds of fighting "smart" look better for the animals that Patrick Green of Duke University studies. Those creatures have a brainlike ganglion and come close to fighting with superpowers. He's working with, of course, mantis shrimp.

The high-powered smashers among these small crustaceans flick out a club that can accelerate as fast as a bullet shooting out of a .22 caliber pistol. When the clubs wham a tasty snail, the bounce back creates a low-pressure zone that vaporizes water. "I always feel weird saying this because it seems just goofy, but that does release heat equivalent to the surface of the sun," Green says. But only for a fraction of a microsecond.

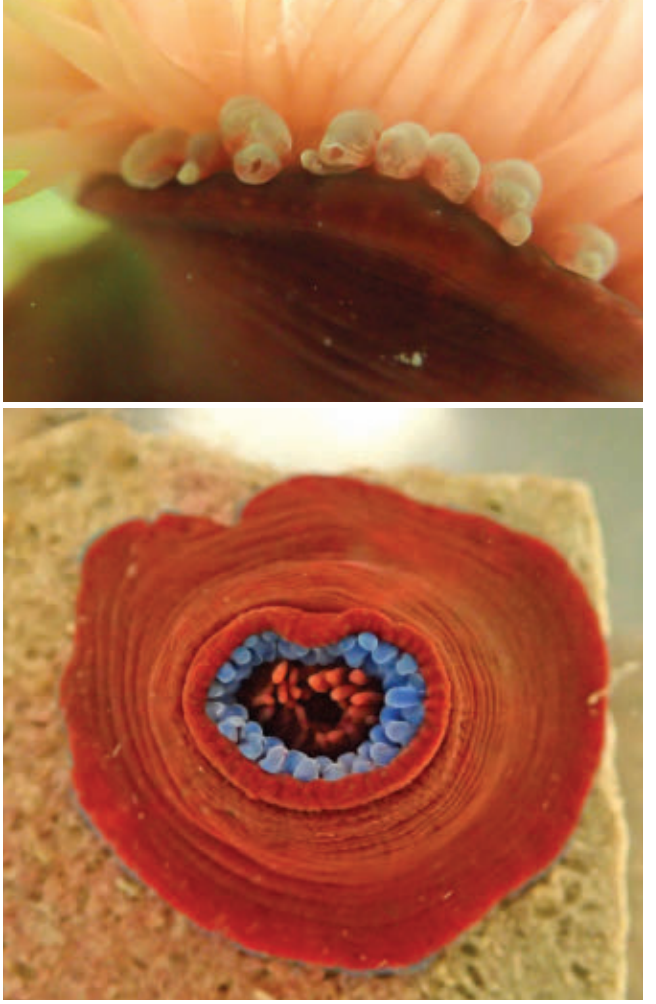
When smasher mantis shrimp — male or female — fight each other, they don't supernova rivals into oblivion. The reality, arguably stranger, is that they superpunch each other. But the blows land on an area that can withstand the force: the telson, a bumpy shield covering the rump (*SN: 7/11/15, p. 13*).

In Caribbean rock mantis shrimp (*Neogonodactylus bredini*), the battle is often over after just one to five blows too fast for the human eye to see. With combatants of equal size, the winner is not the animal that lands the most forceful blow, but the one that gets in the most punches. Then, with no visible gore, one dueler just gives up.

Now Green and Sheila Patek, also of Duke, propose that telson sparring, as they call it, permits genuine mutual assessment, the smart way of losing a fight. It's difficult to figure out what lurks in the neural circuits of an arthropod, but the researchers presented multiple lines of evidence in the Jan. 31 *Proceedings of the Royal Society B*.

One strong clue came from matches Green staged between mantis shrimp of different sizes. He didn't see a trend of smaller ones pointlessly pounding telsons as the lightweights fought bigger animals. Those bigger animals were going to win anyway, and it seemed as if the smaller ones got it, suggesting something more than self-assessment is going on, Green and Patek propose.

Researchers think they have seen mutual assessment in other animals too, among wrestling male New Zealand giraffe weevils (*SN: 10/4/14, p. 4*) and male jumping spiders that flip up banded legs in "Goal!" position to intimidate rivals. Analyzing assessment gets tricky. Game theorists have weighed in, but there's debate over what kind of biological evidence truly distinguishes one form of assessment from another. And research in new directions is bringing more biological realism to the discussion of conflicts. Human scientists, dazzled by the sights and sounds that our own sensory world emphasizes, may be underestimating chemical cues. Among crawfish, "part of their fight is squirting urine in one another's faces," Briffa says.



Sea anemones escalate some battles and "walk away" from others. After a fight, an anemone's stinging tentacles, called acrorhagi, show holes (top, center) after losing tissue to an opponent. When not battling, an anemone's fighting equipment (sometimes blue) is pulled in (bottom).

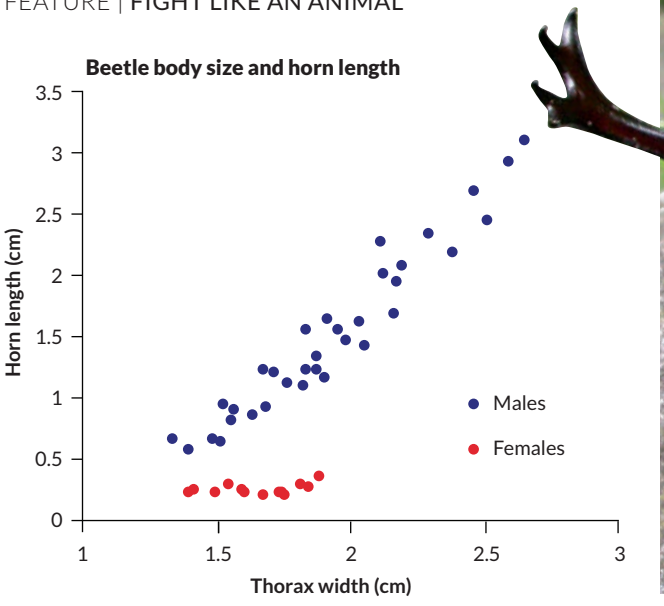
Power-punching Caribbean rock mantis shrimp can settle disputes without deadly blows. Here, the shrimp at right lifts its telson, or rump shield, which takes the hits.

ANEMONES: S. LANE; SHRIMP: ROY CALDWELL

Paradoxically peaceful

Many of the scariest-looking weapons end up causing little bodily harm. Some are specialized for combat that's more strategic than gory. Other weapons look so scary they hardly ever get used.

Among the tools for odd but not life-threatening combat are the horns of the male Asian rhinoceros beetles studied by Erin McCullough, now at the University of Western Australia in Perth. Male *Trypoxylus dichotomus* compete furiously with each other and grow forked horns on their heads that stretch nearly two-thirds the beetle's body length. The horns are surprisingly lightweight, but look cumbersome. "Like a Styrofoam leg sticking out of your forehead," she says.



Domination A male Asian rhinoceros beetle (right) uses his pronged horn as a pry bar to flick rivals away from females. The largest males grow the longest horns (graph), which gives those males an advantage in monopolizing a mate. SOURCE: I.A. WARREN *ET AL/PLOS ONE* 2014

She watched the beetles in action on a muggy summer night lurking around ash trees at a university in Taiwan. Hardly blending in with the students, she decked out in leather gloves and a head lamp, making sure her shirts had the collars pulled way up. "You shouldn't wear mosquito repellant when you're working with insects," she says.

The scene was "really messy and chaotic," she recalls. Beetles flying out of the dark fought to dominate cracks in ash tree bark that oozed sap and attracted females. A dominant beetle would grip the bark and use his horn to flick incoming challengers off the branch left and right — until he was usurped. Getting thrown off the limb doesn't kill losers; often they buzz right back for another try.

Yet evolutionarily speaking, a male prevented from mating might as well be dead, so the tactic was consequential. Males with longer horns are better at flicking off other males, but longer horns are more likely to snap, McCullough concluded. A broken horn doesn't grow back, so the extravagant tool needs to be a pry bar of the right length, lightness and strength. Pristine horns on male beetles just starting their fighting careers have about four times the strength the horns need to resist cracking, about the safety factor that engineers build into bridges but less than the standard for elevator cables, she says.

Horns or antlers on male mammals often can kill, yet fatal fights may be rare. One of his favorite studies from decades-old literature, says Douglas Emlen of the University of Montana in Missoula, looked at about 1,308 sparring matches between male caribou in Alaska. With all this glaring, snorting and rushing, only six matches escalated into violent, bloody fights.

The caribou fit one of the paradoxical phases of the evolution of animal weaponry that Emlen studies. Usually evolution doesn't favor extremes in teeth, horns or other such fighting body parts. Certain forms of sexual rivalry, however, can escape such stabilizing forces and expand extravagantly in a body-part arms race. There are common patterns to such arms races, he says, including some cheating.

Among the conditions that favor an arms race are rivalries playing out in one-on-one duels, he says. Imagine a magnificently endowed dung beetle in a tunnel, a female in the depths behind him, as he fends off rivals one by one for her attention. Growing bigger and bigger horns for an arms race becomes biologically expensive. Eventually, only an animal with the best nutrition, genes and luck can spare the resources to grow a truly commanding horn. At that point, horn size honestly signals a male that can overpower just about all rivals. Only if he confronts another supermale will he need to fight all out. The rest of the time, the signal value of his prodigious weaponry keeps the peace with barely a bump or a bruise.

Yet this is "a very unstable situation," Emlen says. "It creates incentives for males to cheat." Or maybe the word is "innovate." He found that big-horned male dung beetles defending their tunnels could be outmaneuvered by small rivals who dug bypass tunnels around the guard zone and mated with the supposedly defended female. Beetle horns may not be the best analogy for human nuclear arsenals, but, Emlen notes, the innovations of cyberattacks have certainly bypassed hugely expensive national defense systems.

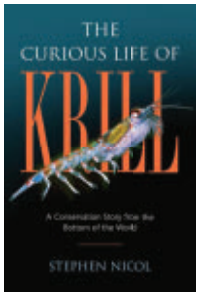
At the far extreme of animal rivalries are some species that blur the meaning of fights. Some butterflies, such as the speckled wood butterfly, "fight" without physical contact. Males compete for a little sunlit dapple on the forest floor by flying furious circles around each other until one gives up and scrams. No gore, but probably really exhausting. ■

Explore more

■ Douglas Emlen. *Animal Weapons.* Picador, 2014.

BEETLE: FRANTISEK BACOVSKY

Watch creature clashes at **bit.ly/SN_animalweapons**



The Curious Life of Krill
Stephen Nicol
ISLAND PRESS, $30

BOOKSHELF

Underappreciated krill deserve your attention

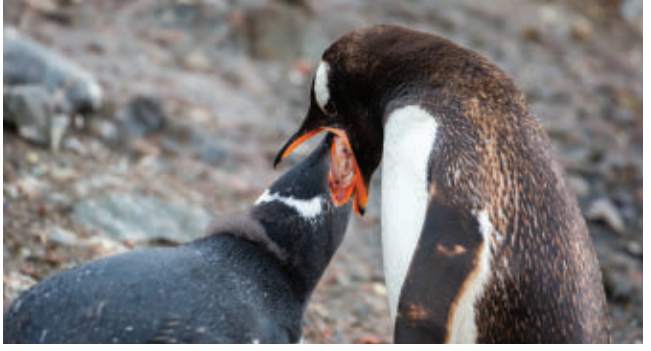
Stephen Nicol is here to change your mind about krill: They're not microscopic and they're far from boring. The biologist is so sick of people misunderstanding his study subjects that he's even gotten a (slightly botched) krill tattooed on his arm to help enlighten strangers.

In *The Curious Life of Krill*, Nicol is taking his mission to an even bigger audience. The book is an ode to Antarctic krill (*Euphausia superba*), which are among the most abundant animals in the world by mass. Each several centimeters long, krill cloud the ocean in swarms that can span 20 kilometers (see Page 16). They're a linchpin of ocean ecosystems — a key food source for whales, penguins and other marine life. And yet, Nicol points out, few people would be able to identify these translucent, red-and-green-speckled creatures with feathery appendages.

Anyone who has ever nurtured an affection for a species that others find odd or distasteful or unremarkable will understand Nicol's devotion. His wry and earnest way of describing krill and their ecology will probably draw in those interested in biology or environmental science.

As one of the world's leading experts on krill, Nicol offers an insider's view of the political negotiations over krill fishing in the Southern Ocean. And yet the book's conversational (sometimes slightly rambling) style makes you feel as if you're part of an engaging dinnertime conversation. Nicol chronicles the challenges of estimating krill populations and of studying the complex behavior of an animal too small to tag or track. And he shares plenty of delightful anecdotes. At one point, for instance, his lab amassed the world's largest collection of whale poop to study whether the cetaceans could fertilize the surface ocean by recycling the nutrient iron picked up through the krill they ate. The answer: probably yes.

The book tackles tougher subjects, too. Nicol delves into the threats that Antarctic krill face from fishing — the animals are gathered up for aquaculture feed and also ground into extracts and powders for dietary supplements and medical research — and describes efforts to regulate the industry. He ponders how krill may fare in warming oceans. The critters are resilient, he says, but it's not clear how quickly these animals, which are known to live as long as about a decade, will adapt to rapidly changing sea temperatures. — *Laurel Hamers*



A Gentoo penguin in Antarctica feeds its young regurgitated krill. The crustaceans are a dietary staple for many marine animals.

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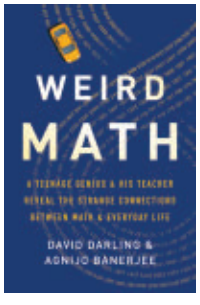

Weird Math
David Darling and Agnijo Banerjee
BASIC BOOKS, $27

BOOKSHELF

Connecting complex math to the real world

Weird Math sets out to "reveal the strange connections between math and everyday life." The book fulfills that laudable goal, in part. At times, teenage math prodigy Agnijo Banerjee and his tutor, science writer David Darling, find ways to make complex math relatable, like linking chaos theory to weather forecasting and virtual reality. But there's a tension between precision and accessibility, and the authors don't always find the sweet spot.

The book offers an in-depth exploration of the history of a number of mathematical concepts that Banerjee and Darling find intriguing. Some of their choices — including the mathematics of music, higher dimensions and chaos theory — are written in clear, accessible language that many science-interested readers will connect with.

The chapter on higher dimensions, for example, illustrates the utility of math for "seeing" dimensions beyond the three familiar ones. Because most people can't visualize dimensions beyond height, width and depth, other dimensions may seem "mysterious or alien to anything we know," the two write. Yet, ordinary math like algebra and calculus let researchers probe the properties of extra dimensions without first having to imagine what they might look like.

But a few of the topics — such as large numbers and infinity — get bogged down in the type of mathematical notation that the authors promise to minimize. Even with these hurdles, readers will still come away with a greater appreciation of how mathematics, as the authors write, "permeates every aspect of the reality in which we're embedded."

Although only 13 chapters, the book is wide-ranging, and readers can dip in and out without having to read from front to back. Many math newbies will probably find something to whet their appetites, with, say, the history of computation, the future of quantum computing or the role of prime numbers in cryptography. And serious math aficionados might find Banerjee and Darling's meditations on unsolved problems in mathematics intriguing.

But check the table of contents before reading. Anyone looking for a more comprehensive popular mathematics book might instead want to turn to *The Joy of Mathematics* by Alfred Posamentier and colleagues or *The Mathematics Lover's Companion* by Edward Scheinerman. — *Diana Steele*

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Cockroaches and the Society's *Science News* in High Schools program inspire students

Not every high school student acknowledges the brilliance of a cockroach. But Evains Francois, a junior at Baltimore Polytechnic Institute, designs robots based on the roaches' movements, a field of research known as biomimetics.

Evains is fully immersed in science research, inspired by articles he read through the *Science News* in High Schools program, which provides students with digital access to *Science News*' archive of articles going back to 1924. Teachers receive 10 print copies of each issue of the magazine during the academic year and an online Educator Guide.

"I'm really excited about *Science News* because here I have something that is at [the students'] reading level and can expose them to anything and everything that they could ever imagine," says Lisa Fridman, Evains' teacher.

In his research class, Evains read a *Science News* article about prototype watercraft modeled after how animals swim, and was hooked. Evains made the leap to another animal — roaches. "They're the ideal machine when we're talking about maneuvering and circumnavigating obstacles."

He plans to enter his research into STEM competitions like the Regeneron Science Talent Search and the Intel International Science and Engineering Fair, both programs of Society for Science & the Public.

Evains is one of millions of students participating in the *Science News* in High Schools program. "I knew nothing about biomimetics until I read the *Science News* article," Evains says. "*Science News* makes it very easy for me to understand what the latest research is saying. I still look at *Science News* for fun and to keep up with science."

Highlights from the 2017–2018 *Science News* in High Schools academic year:

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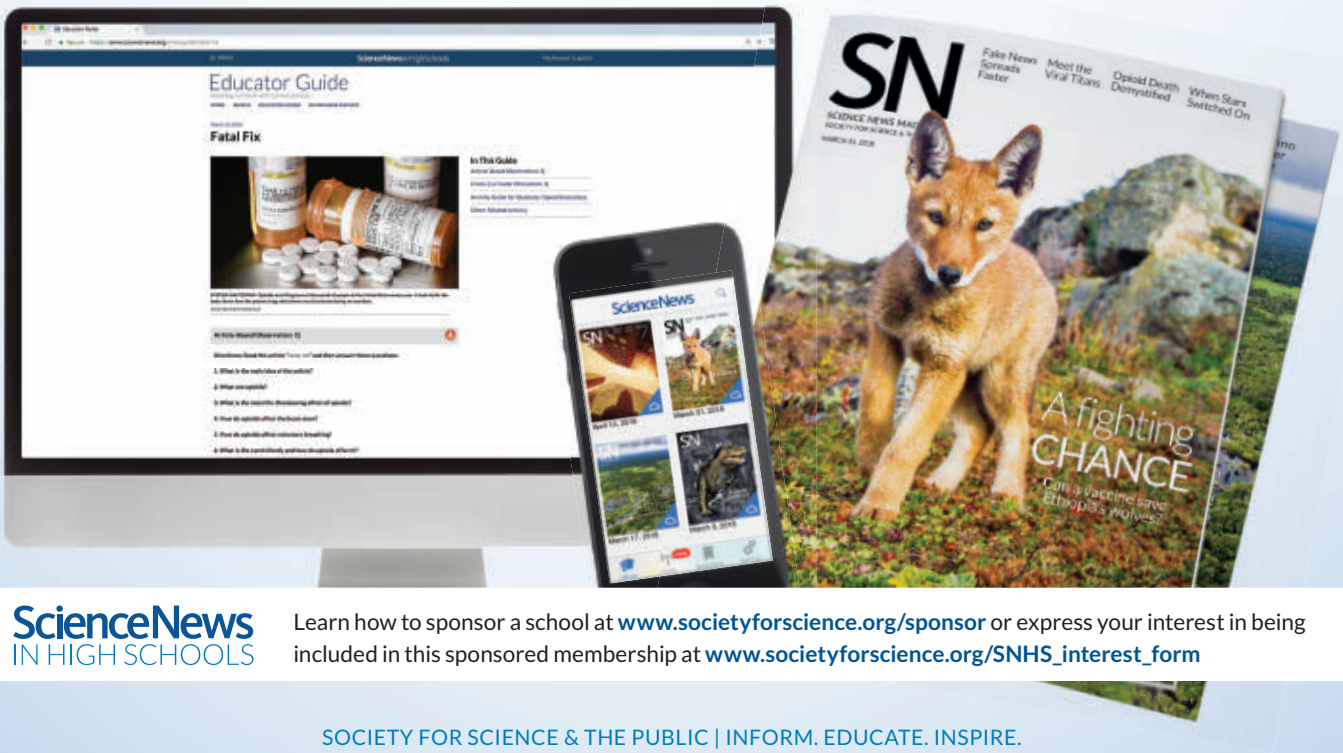

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Particle particulars

Physicists are ramping up their search for neutrinoless double beta decay, which could help explain why there is more matter in the universe than antimatter, ***Emily Conover*** *reported in "Striving to solve antimatter mystery"* (SN: 3/17/18, p. 14).

Reader **F L Stiles** wondered how this decay could explain a surplus of matter. "It seems to me that the neutrinoless double beta decay ... presumes an excess of matter to begin with," he wrote.

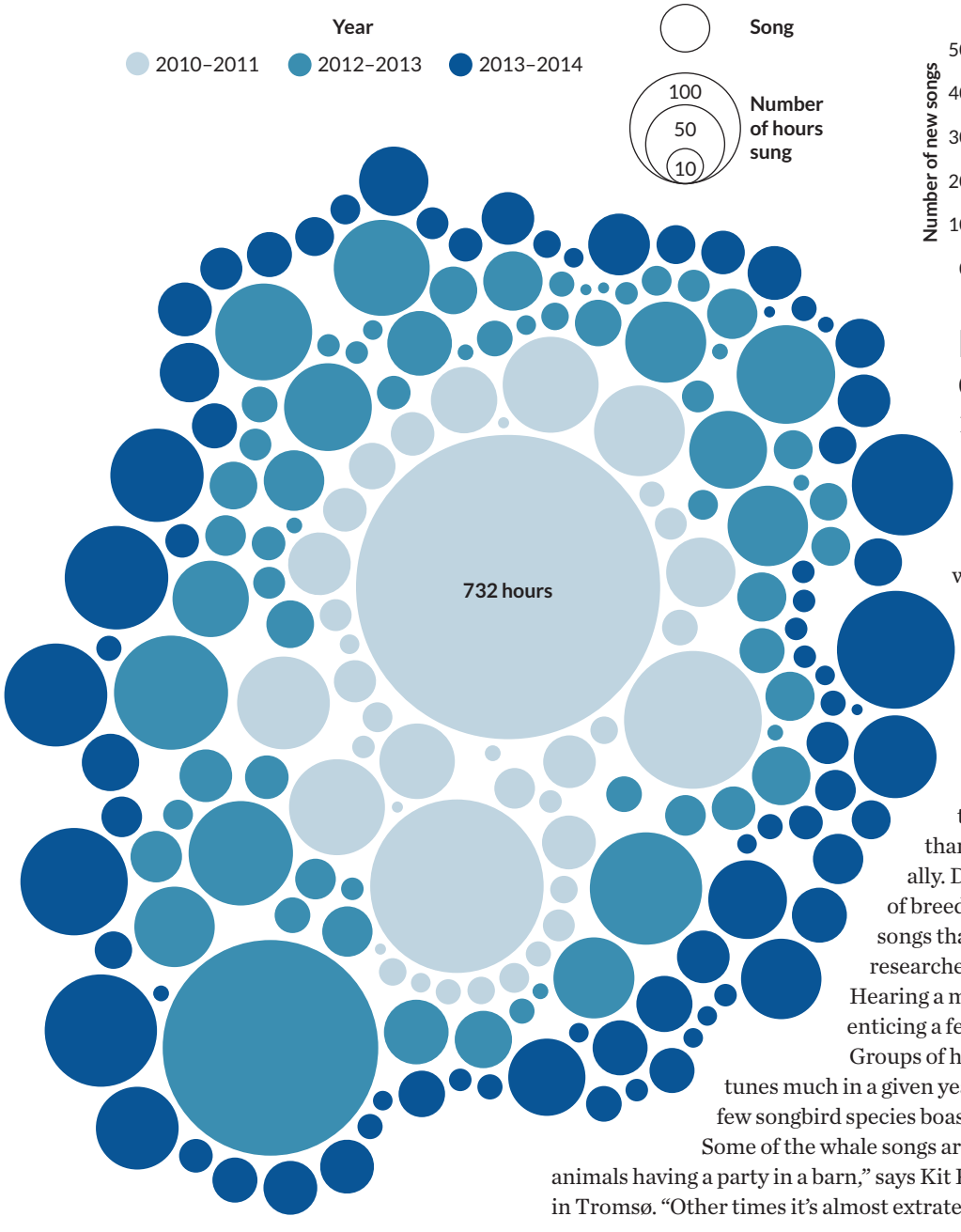
Neutrinoless double beta decay doesn't explain the matter-antimatter asymmetry on its own, **Conover** says. "Instead, the process indicates that neutrinos are their own antiparticles, which would open the door for the existence of another process that could create such an asymmetry," she says. "Early in the universe, there might have been superheavy neutrinos that decayed mostly to matter particles. Because this heavy neutrino would be its own antiparticle, it wouldn't have had a partner that would balance things out by decaying to antimatter."

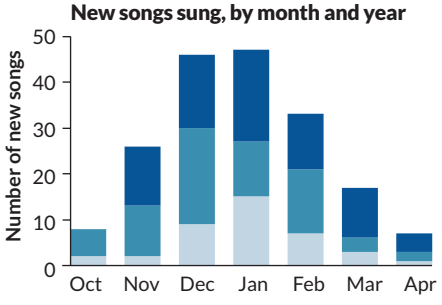
Hare-y details

Archaeologists found evidence that rabbits were not domesticated because of a papal decree, ***Tina Hesman Saey*** *reported in "Fishy rabbit tale debunked for Lent"* (SN: 3/17/18, p. 5)*. The decree supposedly classified the furry mammals as fish so rabbit meat could be eaten during Lent.*

Ron Pauluh joked that he can sleep well now that he knows rabbits aren't fish. "The only other thing that keeps me up is that rabbits lay colored chicken eggs once a year. That should be checked into with as much gusto," he wrote.

"Thank you for giving me a chuckle," **Saey** says. Some of the researchers who debunked this rabbit tale are indeed investigating the origins of Easter traditions, she says. By combining history and science, the team hopes to determine when modern traditions first emerged in Britain; how animals such as brown hares, rabbits and chickens became associated with the holiday; and why certain customs — including hunting for eggs hidden by the Easter Bunny — arose.





Bowhead whales sing a diverse array of songs

In the pitch-black waters beneath Arctic ice, a small population of endangered bowhead whales belt an unusually varied song repertoire. Underwater recorders captured the whales singing 184 acoustically distinct songs (represented with bubbles at left) from October to April in 2010 through 2014.

On the bowhead charts, a song's popularity is fleeting. Most songs were heard for less than 100 hours total, but one song registered over 730 hours total. Some songs appeared in more than one month, but none repeated annually. December and January, likely the height of breeding season, saw a wider array of new songs than other months (bar graph, above), researchers report in the April *Biology Letters*. Hearing a more distinct mixtape may play a role in enticing a female to mate.

Groups of humpback whales don't change their tunes much in a given year, compared with bowheads. Only a few songbird species boast similar diversity.

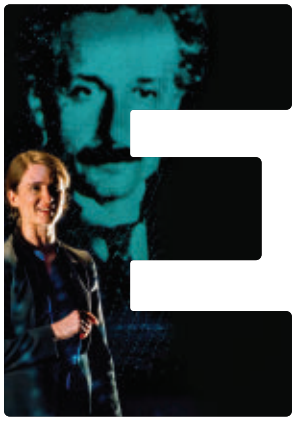
Some of the whale songs are just weird. "Sometimes it sounds like animals having a party in a barn," says Kit Kovacs of the Norwegian Polar Institute in Tromsø. "Other times it's almost extraterrestrial." —*Helen Thompson*

IMAGE: KIT KOVACS/NORWEGIAN POLAR INSTITUTE; GRAPHICS: E. OTWELL, T. TIBBITTS; DATA: K.M. STAFFORD *ET AL/BIOLOGY LETTERS* 2018

Hear whales' songs at **bit.ly/SN_BowheadWhaleSong**

RETHINK SCIENCE

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Visit www.sos-vo.org to see details about the 2017 winning paper **"You Get Where You're Looking For: The Impact of Information Sources on Code Security"** and other outstanding examples of Scientific Cybersecurity research from past winners of NSA's Best Scientific Cybersecurity Paper Award and NSA's Research Awards at ISEF.

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