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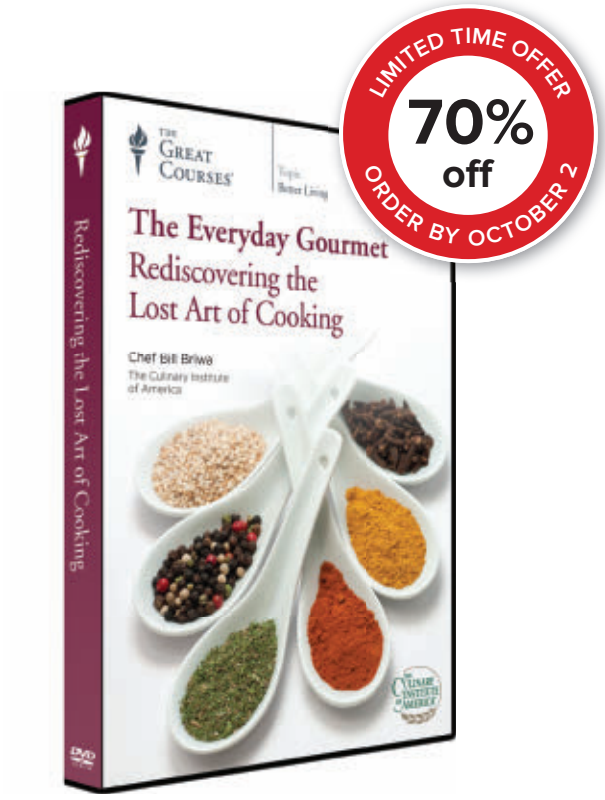

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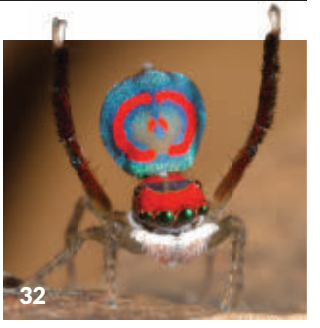
ScienceNews

Features

News



Departments

COVER An illustration shows the view from a newly discovered planet orbiting the nearby star Proxima Centauri. *M. Kornmesser/ESO*

CLOCKWISE FROM TOP: ASHLEY MACKENZIE; JÜRGEN C. OTTO; M. KORNMESSER/ESO

Proxima b deserves buzz, even if some didn't notice

Call it exoplanet fatigue. The historic detection of an exoplanet just 4.2 light-years from Earth, featured on our cover, was big news. It attracted a lot of media buzz. But outside the office, I heard little about it. No questions from other parents at the playground, including those who had been eager to chat about gravitational waves and the Zika virus. Even my significant other, a science fiction fan, didn't probe for any details or wonder aloud about the chances for alien life on Proxima b.

I was a bit surprised. Because, as astronomy reporter Christopher Crockett writes on Page 6, this nearby world might well be the one we've been searching for. Proxima b orbits its star within a zone where temperatures permit liquid water to exist on its surface. In terms of intriguing exoplanets that could possibly harbor life, this one seems to be in the sweet spot (*SN: 4/30/16, p. 32*). Proxima b may be just a tad bigger than Earth and it's also just next door, astronomically speaking. It orbits Proxima Centauri, the closest star to the sun and a member of the triple-star Alpha Centauri system.

There's plenty we still don't know. Proxima Centauri is quite different from the sun: A dim red dwarf, its planet is huddled up close, leaving the world vulnerable to stellar outbursts. And although the artist illustrated Proxima b with a rocky surface (and a news release announcing the discovery called it "rocky" as well), no one yet knows what the planet is really like. And, in this case, close-by is still dreadfully far — a trip there would take 80,000 to 90,000 years with current spacecraft technology. (In a post on his Context blog on the *Science News* website, managing editor Tom Siegfried discusses alternate technologies, such as a proposed scheme to use alpha radiation decay to power a ship that might cut the journey down to something like a mere 5,000 years.) Superfast, nano-sized spacecraft sent to investigate might make it in just 20 years, but development of that idea is just beginning.

Even with these caveats, though, this is a story that appeals to the imagination. The star system where the exoplanet was found has a long history as a potential destination in science fiction, from *Avatar* and *Doctor Who* to an Isaac Asimov short story and a Robert Heinlein novella. The TV show *Babylon 5* even featured an Earth colony orbiting Proxima Centauri. So why so little chatter among the people I know?

I have a few hypotheses, pretty much all untestable. One is that Donald Trump and Hillary Clinton are hogging all of the news-related conversations. Another is that it was back-to-school week. Maybe, after the thousands of exoplanets already found, folks have become blasé about exoplanets, even one that is so close. Perhaps some were so disappointed by the false alarm in 2012, when another group claimed to have found an exoplanet in the Alpha Centauri system, no one wanted to get their hopes up. Or, it could be that my acquaintances have taken the mature and reasonable approach that, while intriguing, more evidence is needed before we can say anything definitive about Proxima b.

I, for one, was excited about Proxima b. Now we know of at least one destination suitable for our first interstellar voyage. — *Eva Emerson, Editor in Chief*

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Lindell has been featured on numerous talk shows, including *Fox Business News* and *Imus in the Morning*. Lindell and MyPillow have also appeared in feature stories in major magazines and newspapers across the country. MyPillow has received the coveted "Q Star Award" for *Product Concept of the Year* from QVC, and has been selected as the Official Pillow of the National Sleep Foundation.

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Excerpt from the September 24, 1966 issue of *Science News*

50 YEARS AGO

Genetic surgery is far away for humans

Optimism concerning application of genetic experiments to improve mankind is unwarranted now, a Canadian pediatrician told the Third International Congress of Human Genetics meeting in Chicago.... Although striking and sometimes controversial experiments in genetic surgery have in fact been performed in multicellular systems, he explained, public demand seems likely to outstrip scientific resources for the treatment of many forms of genetic disease.

UPDATE: Things are looking up for "genetic surgery." Gene therapy has been around since the 1980s, but researchers have recently developed more precise gene-editing tools, including one that sent a child's leukemia into remission in 2015. Scientists are most excited about a molecular scalpel known as CRISPR/Cas9 that cuts and manipulates DNA (*SN: 9/3/16, p. 22*). Researchers are optimistic about the tool's potential to treat several diseases, but it may be a while before CRISPR is widely used.

Despite living in the tropics, fat-tailed dwarf lemurs (shown at the Duke Lemur Center) are truer to physiologists' sense of hibernation than bears are.

INTRODUCING

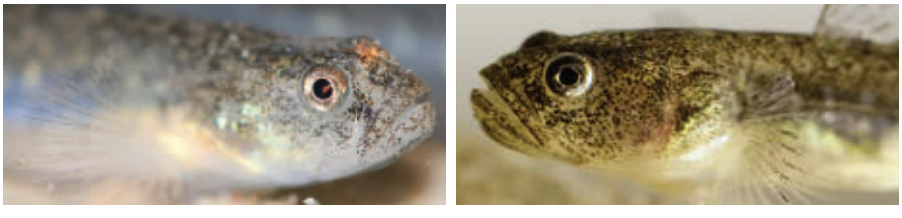
California's goby is two different fish

It's official: The southern tidewater goby is a thing. And it's chubbier and nubbier than its northern cousin.

Endangered tidewater gobies live in California's seaside lagoons. Ranging roughly the entire length of the state, the fish used to be considered one species. But a new study confirms that gobies living in Northern and Southern California are physically different, and now the southern swimmer has its own name: *Eucyclogobius kristinae*.

The northern goby, *E. newberryi*, is sleeker and longer than its southern counterpart. The southern fish has more girth and more nubby sensory organs exposed atop its head, researchers report July 27 in *PLOS ONE*.

Differences in DNA, found in earlier studies, suggest that the fish separated over a million years ago, probably because of geology. Tidewater gobies can dart from pool to pool in the rainy season but can become isolated by outcrops of rock or kelp. Today, the southern goby is found only in three coastal pools in San Diego's Camp Pendleton. The fish used to range north from San Diego County about 200 kilometers, says geobiologist David Jacobs of UCLA, who codiscovered the new species. As coastal cities grew, the goby lost habitat. Now that the southern species has its own name, Jacobs says, California is more likely to give it extra protection. —*Amy McDermott*



Northern (left) and southern (right) tidewater gobies have several physical and genetic differences that distinguish them as separate species. Both are endangered.

LEMURS: DAVID HARING/DUKE LEMUR CENTER; GOBIES: BRENT SPIES

IT'S ALIVE

Dwarf lemurs don't agree on sleep

Contrary to many adorable children's stories, hibernation is so not sleeping. And most animals can't do both at the same time.

So what's with Madagascar's dwarf lemurs? The fat-tailed dwarf lemur slows its metabolism into true hibernation, and stays there even when brain monitoring shows it's also sleeping. But two lemur cousins, scientists have just learned, don't multitask. Like other animals, they have to rev their metabolisms out of hibernation if they want a nap.

Hibernating animals, in the strictest sense, stop regulating body temperature, says Peter Klopfer, cofounder of the Duke Lemur Center in Durham, N.C. "They become totally cold-blooded, like snakes." By this definition, bears don't hibernate; they downregulate, dropping their body temperatures only modestly, even when winter den temperatures sink lower. And real hibernation lasts months, disqualifying short-termers such as subtropical hummingbirds. The darting fliers cease temperature regulation and go truly torpid at night. "You can pick them out of the trees," Klopfer says.

The fat-tailed dwarf lemur, *Cheirogaleus medius*, was the first primate hibernator discovered, snuggling deep into the softly rotting wood of dead trees. "You'd think they'd suffocate," he says. But their oxygen demands plunge to somewhere around 1 percent of usual. As trees warm during the day and cool at night, so do these lemurs. When both a tree and its inner lemur heat up, the lemur's brain activity reflects mammalian REM sleep.

Klopfer expected much the same from two other dwarf lemurs from an upland forest with cold, wet winters. There, *C. crossleyi* and *C. sibreei* spend three to seven months curled up underground, below a thick cushion of fallen leaves. "If you didn't know better, you might think they were dead because they're cold to the touch," Klopfer says.

Unlike the tree-hibernators, the upland lemurs take periodic breaks from hibernating to sleep, Klopfer, the Lemur Center's Marina Blanco and colleagues report in the August *Royal Society Open Science*. The lemurs generated some body heat of their own about once a week, which is when their brains showed signs of sleep (REM-like and slow-wave). "My suspicion is that sleep during torpor is only possible at relatively high temperatures, above 20° Celsius," Klopfer says. Sleep may be important enough for cold-winter lemurs to come out of the storybook "long winter's nap." *—Susan Milius*

SAY WHAT?

Blue whirl \bloo werl\ n.

A swirling flame that appears in fuel floating on the surface of water and glows blue

An unfortunate mix of electricity and bourbon has led to a new discovery. When lightning hit a Jim Beam warehouse in 2003, a nearby lake was set ablaze as the distilled spirit spilled into the water and ignited. Spiraling tornadoes of fire leapt from the surface. In a laboratory experiment inspired by the conflagration, researchers produced a new, efficiently burning fire tornado, which they named a blue whirl.

To re-create the bourbon-fire conditions, the researchers, led by Elaine Oran of the University of Maryland in College Park, ignited liquid fuel floating on a water bath. They surrounded the blaze with a cylindrical structure that funneled air into the flame, which began spinning and grew higher than 60 centimeters. The scientists were surprised when the chaotic fire calmed into a blue, cone-shaped flame just a few centimeters tall, which they report in the Aug. 23 *Proceedings of the National Academy of Sciences*.

A swirling flame is produced in the lab by igniting fuel floating on top of water (left). The flame transitions into a fire tornado (center) then settles into an efficiently burning blue whirl (right).

H. XIO, M.J. GOLLNER AND E.S. ORAN/*PNAS* 2016

"Firenadoes" are known to appear in wildfires, when swirling winds and flames combine to form a rotating inferno. They burn more efficiently than typical fires, as the whipping winds mix in extra oxygen to feed the flames. The blue whirl is even more efficient; its azure glow indicates complete combustion, which releases little soot, or uncombusted carbon, into the air.

Blue whirls could be a way to burn off oil spills on water without releasing much pollution, the researchers say, if they can find a way to control the flame in the wild. *—Emily Conover*

Watch a blue whirl in action at **bit.ly/SN_bluewhirl**

Proxima Centauri casts a reddish glow over Proxima b, the closest exoplanet to Earth, in this artist's illustration.

M. KORNMESSER/ESO

ATOM & COSMOS

Planet orbits sun's nearest neighbor

Potentially habitable world detected around Proxima Centauri

BY CHRISTOPHER CROCKETT

Earth might have a kindred planet orbiting the star next door. A world at least 1.3 times as massive as Earth appears to orbit the closest star to the sun: Proxima Centauri, a dim red orb about 4.2 light-years away.

Dubbed Proxima b, the planet is cozied up to its star, needing just 11.2 days to complete one orbit. But despite the proximity — just 5 percent of the distance from Earth to the sun — Proxima b is potentially habitable. Its temperature is just right for liquid water to flow on its surface, astronomer Guillem Anglada-Escudé of Queen Mary University of London and colleagues report in the Aug. 25 *Nature*. That makes Proxima b the closest known world outside our solar system where life might exist.

"It's an incredible discovery — it's almost a gift," says David Kipping, an astronomer at Columbia University. With Proxima b, researchers might now have their best chance at characterizing the atmosphere of an Earthlike world in another solar system and probing for hints of life elsewhere in the galaxy.

Proxima Centauri, which lies in the southern constellation Centaurus, is a runt of a star. Temperatures at the surface run about 2,800 degrees Celsius cooler than our sun, giving Proxima a feeble, ruddy glow. The star is much closer in size to Jupiter than the sun, and even though it's relatively close to Earth, Proxima is invisible to the naked eye — it wasn't discovered until 1915. Part of a triple star system known as Alpha Centauri, it's not clear whether Proxima is gravitationally bound to its brighter companions (taking hundreds of thousands of years to complete one orbit around both) or just passing by.

The Alpha Centauri system is no stranger to claims of exoplanets. In 2012, astronomers reported in *Nature* that the star Alpha Centauri B hosts a planet roughly as massive as Earth, though too warm to be habitable (*SN: 11/3/12, p. 5*). Other researchers are skeptical; a 2015 report in *Monthly Notices of the Royal Astronomical Society Letters*, for example, found no evidence for the planet. The claim for Proxima b appears to be much stronger.

Anglada-Escudé and colleagues found their quarry by looking for a minute wobble in the speed of Proxima Centauri, the sign of a gravitational tug from the orbiting planet. An intensive two-month observing campaign in early 2016 using several telescopes — including the European Southern Observatory's 3.6-meter and Very Large telescopes in Chile — confirmed earlier suspicions of a planet.

"It's not clear if the planet will be Earth-like," Anglada-Escudé says. Not much is known about Proxima b, such as its size or what its atmosphere is like or whether it has a surface. Even its mass is just a minimum estimate. Without knowing how the planet's orbit is tilted relative to us, the researchers can say only that Proxima b is no lighter than 1.3 Earths — it could be heavier and have more in common with Neptune than Earth.

Even though it's just one star away, "we will likely have to wait a long time in order to learn anything more about the planet," says Heather Knutson, a planetary scientist at Caltech.

The best bet, Knutson says, is to hope that the planet, when viewed from Earth, passes in front of Proxima Centauri, allowing starlight to filter through the planet's atmosphere. Molecules in the atmosphere would betray their presence by absorbing specific wavelengths of light. Substances such as oxygen, methane and carbon dioxide are widely considered to be chemical markers of life.

If the planet does cross in front of the star, NASA's James Webb Space Telescope, scheduled to launch in late 2018, should be able to characterize its atmosphere, says Mark Clampin, an astrophysicist at NASA's Goddard Space Flight Center in Greenbelt, Md. Hundreds of hours of telescope time would need to be dedicated to the task. "It will be an extremely challenging observation, but not impossible," he says.

Scientists also could estimate the planet's size by measuring how much light the planet blocks. The size combined with the mass would let researchers determine the density of Proxima b and figure out if the planet is puffy like Jupiter or rocky like Earth.

Kipping has already been monitoring Proxima Centauri with the Canadian MOST satellite, looking for a periodic

dip in light caused by the planet partially blocking its sun. There's only a 1.5 percent chance, however, that the planet lines up just-so with the star. And if it does line up, the inherent variability in Proxima Centauri's light will make any drop in brightness from the planet hard to detect.

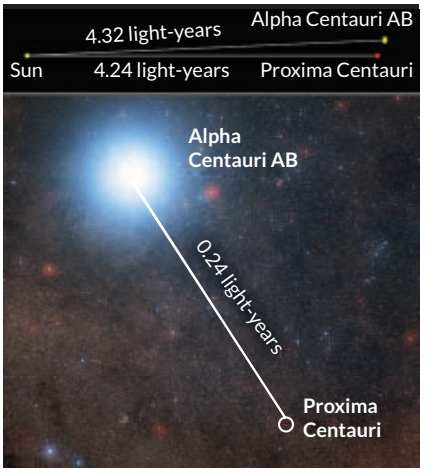
Without a fortuitous alignment, "things get much more difficult," says Knutson. Astronomers would have to rely on light coming from the planet — either an intrinsic infrared glow or visible light reflected from its sun. James Webb might be able to barely sense infrared light emanating from Proxima b, but it could be a decade or more before any other observatory is up to the challenge (*SN: 4/30/16, p. 32*). And even then, there are no guarantees. "It's going to be very difficult to characterize the planet without sending a probe there," Kipping says.

Breakthrough Starshot, a group funded by Russian entrepreneur Yuri Milner, wants to do just that. In April, the group announced a plan to put $100 million toward developing technology that would send a fleet of nanocraft — robotic probes weighing just a few grams — toward Alpha Centauri, nudging them along with an Earth-based 100-gigawatt laser. Accelerating to roughly 20 percent the speed of light, the armada would arrive at Alpha Centauri about 20 years after launch. In comparison, the fastest spacecraft ever to leave Earth — the New Horizons mission to Pluto — would need roughly 90,000 years to complete the journey, traveling at its current speed of about 52,000 kilometers per hour.

"The discovery is likely to energize the project," says Harvard University astrophysicist Avi Loeb, chairman of Breakthrough's advisory committee. "A spacecraft equipped with a camera and various filters could take color images of the planet and infer whether it is green (harboring life as we know it), blue (with water oceans on its surface) or just brown (dry rock)."

If anything is alive on Proxima b, it's probably quite different from anything on Earth. Photosynthesizing organisms would have to deal with a faint, cool star that emits mostly infrared light. Proxima Centauri is also known for exuberant flares, which would buffet any orbiting planets with bursts of ultraviolet radiation and X-rays. "Conditions on such a planet would be very interesting for life," says Lisa Kaltenegger, an astrophysicist at Cornell University.

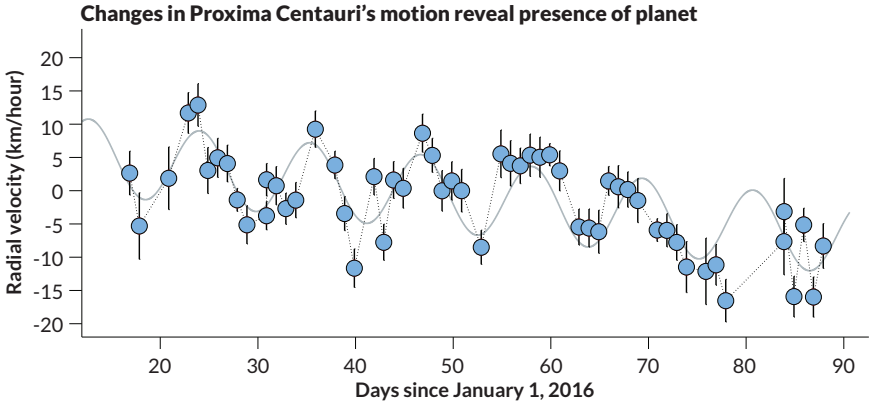
Given such an alien environment, life might show its presence in unusual ways. Kaltenegger, along with Cornell astronomer Jack O'Malley-James, proposes looking for biofluorescence, a glow from organisms triggered by UV light, in the wake of stellar flares. Critters on Proxima b could have evolved biofluorescence as protection, taking harmful UV radiation and transforming it into more benign visible light — a flicker that might be detectable from an Earth-based telescope. "The idea that we could spot a glow seems to be right out of a [science fiction] novel," says Kaltenegger, whose proposal appeared online August 24 at arXiv.org.



Proxima Centauri is part of a triple star system just over four light-years from the sun (distances shown to scale). Its two companions, Alpha Centauri AB, lie about 0.24 light-years from their dim neighbor.

That's assuming anything could survive on the planet. If Earth were placed in the same orbit as Proxima b, it would be stripped of its protective ozone roughly three times per Earth year, Kipping says. "That's kind of bad." That rate doesn't give the atmosphere time to recover, "but it's not a showstopper," he adds. A strong planetary magnetic field or a dense atmosphere might be able to withstand the blows. And if life has taken shelter underground or underwater — or is impervious to a lack of oxygen — it might still survive.

Whether or not critters crawl on Proxima b, the planet's discovery "could really usher new energy into the search for other nearby worlds," says Margaret Turnbull, an astronomer with the SETI Institute who is based in Madison, Wis. Most exoplanets found so far are hundreds to thousands of light-years away. But little is known about the possible planet families huddled up to the stars nearest to us. "I'd love to see interstellar travel," says Turnbull. "To really inspire that kind of effort, we need interesting destinations like this." ■



Telltale tug Proxima Centauri's speed relative to the sun oscillates by a few kilometers per hour, which indicates that a planet at least 1.3 times as massive as Earth is orbiting and tugging on the star. Blue dots are measured velocities; the gray curve is a fit of orbital motion to the data.
SOURCE: G. ANGLADA-ESCUDÉ/ESO

FROM TOP: DIGITIZED SKY SURVEY 2 (ACKNOWLEDGMENT: DAVIDE DE MARTIN, MAHDI ZAMANI), C. CROCKETT; ADAPTED BY T. TIBBITTS

GENES & CELLS

DNA diversity data offer disease clues

Exome studies give insights into schizophrenia, heart conditions

BY TINA HESMAN SAEY

A large study of human genetic variation finds more than 7 million spots where one person's DNA can differ from another's. Analyses of such variants, compiled from cataloging the genes of more than 60,000 people, are already offering doctors insights into diseases such as schizophrenia and some heart conditions.

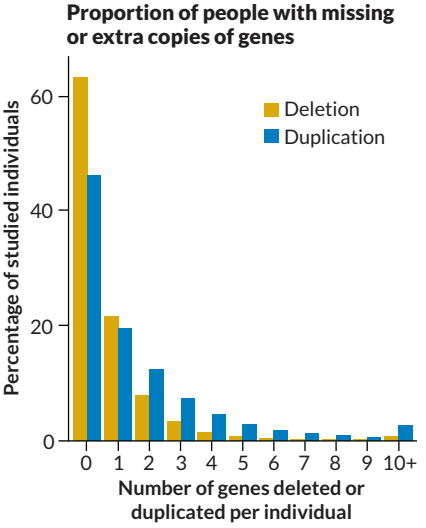
Researchers from the Exome Aggregation Consortium first presented their analysis of the ExAC database online at bioRxiv.org last year (*SN: 12/12/15, p. 8*). Now, the project is getting its official debut in the Aug. 18 *Nature*.

An exome consists of only the protein-producing genes in a person's genetic instruction book, or genome. Scientists pooled exome data from 60,706 people from nearly two dozen studies around the world, nearly 10 times as much data as any previous study of human genetic variation. The people were far more racially and ethnically diverse than those in any previous study and included people with various diseases as well as healthy people.

Any one person carries tens of thousands of DNA variants, geneticist Daniel MacArthur of Massachusetts General Hospital in Boston said in a news briefing. The ExAC team found that, on average, one in every eight DNA bases (the chemical building blocks of DNA) differs among people. In total, the team recorded over 7.4 million variants, most of them changes in single DNA bases.

Even before they presented their own analysis, ExAC researchers released the data in 2014 for other scientists to use. Already, these data have contributed to the day-to-day interpretation of genetic information in the clinic, says Eliezer Van Allen, a medical oncologist at Harvard Medical School. "It gives a new look into the drivers of human genetic diversity."

A companion study reported August 17 in *Nature Genetics*, for instance, found that, on average, people have 0.81 missing genes and 1.75 extra copies of genes. The analysis echoed previous studies in showing that people with schizophrenia are more likely to have deleted or duplicated genes, often genes important in the brain.



Copy count A genetic analysis of more than 60,000 people found that, on average, each person has 0.81 deleted genes (yellow) and 1.75 duplicated genes (blue). But some people may be missing or have extra copies of up to 10 or more genes, which may put them at risk for diseases such as schizophrenia.
SOURCE: D. RUDERFER *ET AL/NATURE GENETICS* 2016

Now, the challenge is to figure out what all of the variations mean.

Two separate studies suggest that ExAC data could give a clearer picture of the gene changes that contribute to heart conditions known as cardiomyopathies.

Scientists over the last 10 years have amassed a number of rare variants linked to heart diseases. "There was always a lot of doubt cast about whether these [variants] were real or not," says geneticist Roddy Walsh of Imperial College London.

Walsh and colleagues used ExAC data and data from 7,855 cardiomyopathy patients to reevaluate the likelihood that a particular variant would cause a heart problem. Finding a variant in patients that is rarely seen in people without the disease suggests the variant could be the cause. But if the variant appears just as often in people that don't have cardiomyopathies, it is unlikely to cause disease.

Of the people in ExAC, 11.7 percent carry variants linked to hypertrophic cardiomyopathy, Walsh's team reports August 17 in *Genetics in Medicine*. That's far more people than expected for a rare inherited condition, which strikes about one in 500 people. Those data and other evidence suggest that many of the variants implicated in the disease are benign.

ExAC data alone can't rule out a potentially disease-causing variant, says Benjamin Meder, a cardiologist at Heidelberg University Hospital in Germany. Researchers don't know the full medical history of ExAC volunteers. Some may have undetected cardiomyopathy; others may have been misdiagnosed as having the disease, he says. It's important to clearly define who has a disease and who doesn't before conducting genetic studies. "This paper does it the wrong way around," Meder says. Still, he says, ExAC offers some valuable insights into the genetics of heart problems.

Misdiagnosing a genetic disease can affect entire families, says Isaac Kohane, a biomedical informaticist at Harvard Medical School. For instance, people related to a youngster who collapses on the basketball court and is found to carry a rare variant associated with a heart condition may also be screened for the variant. Relatives carrying the variant may be treated for a condition they don't have.

Misdiagnosis is more likely for African-Americans, Kohane and colleagues report in the Aug. 18 *New England Journal of Medicine*. Five variants previously associated with hypertrophic cardiomyopathy are too common to cause a rare genetic disorder, Kohane's team found. Of black Americans, 2.9 to 27.1 percent carried at least one copy of the variants; 0.02 to 2.9 percent of white Americans had one.

Kohane's team now says these variants are benign. The mistake could have been avoided if researchers had included even a few black Americans in their studies. Kohane's team calculates that the ExAC data, with its genetic diversity, could rule out many benign variants, including ones carried by as little as 0.1 percent of the population. ■

HUMANS & SOCIETY

Details of Ötzi's clothes unveiled

Iceman wore hides from wild and domesticated animals

BY BRUCE BOWER

Ötzi had Copper Age style.

The 5,300-year-old Tyrolean Iceman, whose body was found in the Italian Alps in 1991, incorporated hides from at least five domesticated and wild animal species into his apparel, a new study finds. Comparing mitochondrial DNA from nine ancient leather fragments with DNA of living animals revealed the makeup of the clothes and a key accessory, says a team led by paleogeneticist Niall O'Sullivan.

Little is known about what people wore during Ötzi's time. The findings provide a glimpse into how ancient Europeans exploited animals to make clothes and other items.

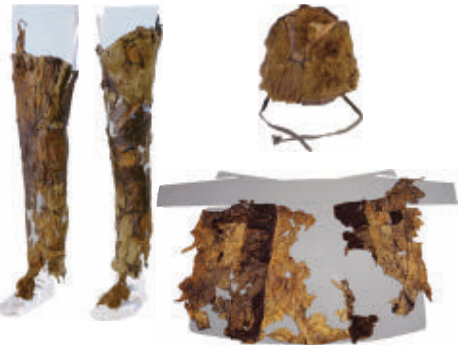
Ötzi's coat consisted of hides from at least three sheep and one goat, the scientists report August 18 in *Scientific Reports*. This garment may have been periodically patched with leather from whatever animals were available. Goats also provided skin for Ötzi's leggings.

A sheepskin loincloth and a shoelace derived from cattle round out Ötzi's attire made from domesticated animals.

As for wild animals, Ötzi wore a brown-bear cap and toted a quiver made from roe deer. The Iceman "may have been an opportunistic hunter or a scavenger," says O'Sullivan, of University College Dublin and EURAC Research in Bolzano, Italy.

A 2012 analysis of proteins from fur taken from Ötzi's clothing identified sheep and a goatlike animal called a chamois as sources for the coat. A team led by biochemist Klaus Hollemeyer of Saarland University in Saarbrücken, Germany, pegged goats and dogs or wolves as sources of skin for the leggings.

Disparities between the two studies may stem from the fact that they sampled different parts of patchwork garments.



Genetic evidence indicates that Ötzi the Iceman wore goatskin leggings (left), a brown-bear cap (top right) and a coat made of goat and sheep hides (bottom right).

The new report also used advanced techniques for extracting and analyzing ancient DNA. That enabled O'Sullivan's team to retrieve six complete mitochondrial genomes from Ötzi's belongings. Mitochondrial DNA typically gets passed from mothers to their offspring.

O'Sullivan's investigation "opens a new field of potential identification procedures for mammalian species in ancient leathers and furs," Hollemeyer says. ■

LIFE & EVOLUTION

Virus helps plant attract pollinators

Pathogen's effects ensure stable supply of hosts, study suggests

BY LAUREL HAMERS

Instead of destroying its leafy hosts, one common plant virus takes a more backhanded approach to domination. It makes infected plants more attractive to pollinators, ensuring a supply of virus-susceptible hosts for generations to come.

The strategy might discourage resistance from building up in the plant population, University of Cambridge biologist John Carr and colleagues report August 11 in *PLOS Pathogens*.

"It looks like the pathogen is cheating a little bit — but in a way that helps its host," Carr says.

Plants give off cocktails of volatile chemicals that send signals to pollinators, predators and other plants. Carr's team found that tomato plants infected with cucumber mosaic virus gave off a different chemical cocktail than noninfected plants — and that bumblebees preferred the infected plants' brew.

When infected tomato plants didn't get pollination assistance, they produced fewer seeds on their own than their healthy counterparts. But when bumblebees helped out, infected plants' seed production was similar to that of healthy ones.

The virus benefits, too. By ensuring that sick plants can still reproduce, "those genes enabling susceptibility to the virus will stay in the population," Carr says.

The team found that cucumber mosaic virus changes plants' chemicals by disrupting the plants' natural defenses against disease.

Plants can identify when bits of foreign genetic material (like those from a virus) have worked their way inside. Specialized silencing enzymes snap into action and chop up the invaders. But a cucumber mosaic virus protein called 2b disrupts this process by binding to the silencing molecules so that they can't do their job.

That lets the virus infect the plant more easily — and it changes the way the plant turns its genes on and off. When the researchers tested a virus that didn't have the gene for the 2b protein, infected plants didn't shift their chemical cocktails the way the plants infected with the fully functioning virus did.

The link between the 2b protein and volatile production is a major finding that could help scientists better understand how viruses manipulate their hosts, says Penn State biologist Andrew Stephenson.

But further work is needed to convincingly show that the increased pollination is really a benefit for the plant, he says. Although infected plants produced more seeds, those seeds could be less likely to germinate, he says. And the shift in chemicals could lure aphids (which transmit the virus from plant to plant) just as much as bumblebees. ■

INSTITUTE FOR MUMMIES AND THE ICEMAN

GENES & CELLS

Wildlife hosts antimicrobial resistance

Bacterial genes that thwart drugs turn up in all sorts of animals

BY SUSAN MILIUS

It's time to go wild studying antimicrobial resistance, a research team says.

Most analyses of how microbes come to laugh off the drugs and disinfectants that should kill them have focused on people in hospitals or livestock on farms, says Kathryn Arnold, a behavioral ecologist at the University of York in England. Yet a growing number of studies — in crows, elephant seals, voles and other wild animals — are raising big questions about where wildlife fits into the increasing threat of antimicrobial resistance. Genes for resistance are showing up in microbes flourishing in the guts and other parts of wild animals. How those genes get there and where they might now go needs serious attention, Arnold and colleagues argue in the August *Biology Letters* in a review of wildlife-related papers.

So far, scientists have not described a clear-cut case of genes for antimicrobial resistance traveling from wildlife microbial flora back to humans' microbes, but that scenario is "biologically logical," says Barry McMahon of University College Dublin. McMahon, who has examined gulls for antimicrobial resistance genes, endorses the new paper's case that overlooking wildlife and environmental factors leaves a big gap in understanding resistance.

So does Kathleen Alexander of Virginia Tech in Blacksburg. Monitoring what's circulating in wild animals might serve as an early warning for what's ahead. Focusing solely on hospitals, she says, is "monitoring the barn after the horse has left."

Genes for resistance can readily spread as bacteria multiply and carry their toolkits with them. And bacteria are "promiscuous," Arnold explains. They commingle genes with their own kind or with fairly strange strangers, widely distributing resistance genes. In this loose networking, a benign bacterium can pass along resistance genes to a pathogen, especially as resistance turns up in microbes in a wide diversity of animals.

One overview Arnold and her colleagues looked at tallied 210 papers (up through May 2015) that have reported some form of antimicrobial resistance in free-ranging animals.

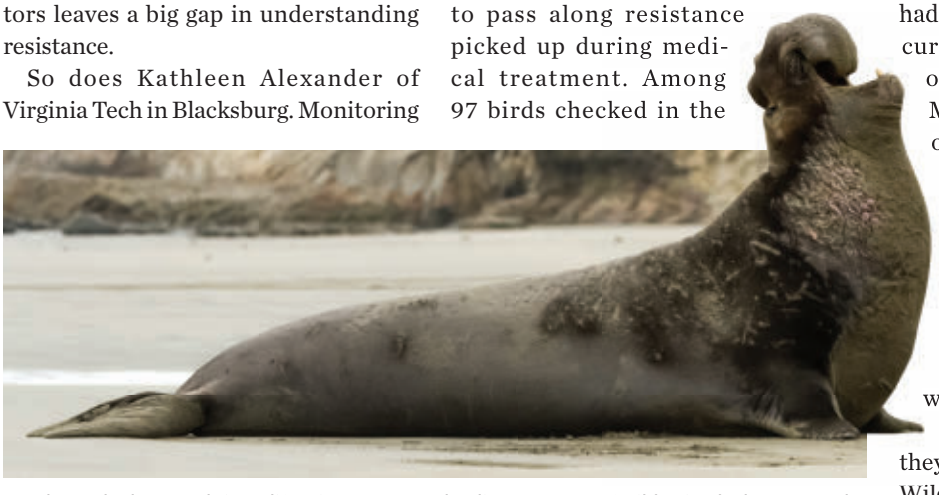
Known carriers include vertebrates (mostly North American birds and mammals) and a few invertebrates. For example, 15 of 590 fecal samples from American crows in three states carried *Enterococcus* bacteria with genes for resisting vancomycin, a drug of last resort for treating serious infections, a paper reported in 2014.

More puzzling reports come from places with few local people or livestock to pass along resistance picked up during medical treatment. Among 97 birds checked in the Arctic (Siberia, Alaska and Greenland), researchers in 2008 reported *Escherichia coli* bacteria resistant to 14 of the 17 antibiotics tested. Admittedly birds fly, but monkeys (outside of Oz) don't. In the Uxpanapa forests of Mexico, however, howler monkeys had *E. coli* resistance to ciprofloxacin, a synthetic antibiotic. That suggests some connection, however roundabout, between human medicine and faraway monkeys.

Maybe the answer is birds flying and roosting in trees. But for any resistance transfer involving wildlife, "the forensic trail isn't well understood," Arnold says. She hopes for tight chains of evidence showing how resistance moves among species and over distances. To date, researchers have only circumstantial evidence, much of it involving runoff from human wastes. A 2008 study of stranded northern elephant seals along the California coast, for instance, found that the nearer the animals were to outflow of freshwater from land, the more likely they were to test positive for antimicrobial-resistant *E. coli*.

Simple proximity to waste isn't the whole story, Arnold points out. Small differences in lifestyle matter, even among similar animals. Bank voles and wood mice living in the same British woodland both carried *E. coli* resistant to multiple antibiotics. But despite living in small rodents in the same habitat, *E. coli* populations in the animals ran a bit out of sync in amount and seasonal surge (mice had more and peaked earlier). Arnold's current coauthors — Nicola Williams of the University of Liverpool and Malcolm Bennett of the University of Nottingham — were among the researchers reporting these results in 2011.

Comparing levels of resistance among species offers clues to what's important in spreading the worrisome genes, says Alexander. In northern Botswana where she works, warthogs have extra antimicrobial resistance, she suspects because they eat human waste while cattle don't. Wildlife is already doing natural experiments, if researchers pay attention. ■



Northern elephant seals in California are among the diverse group of wild animals that researchers have found with microbes carrying genes for resisting drugs and disinfectants.

FRANK SCHULENBURG/WIKIMEDIA COMMONS (CC BY-SA 3.0)

BODY & BRAIN

Sleep loss hits some brain areas hard

Scanning study reveals varied effects of lack of shut-eye

BY RACHEL EHRENBERG

Pulling consecutive all-nighters makes some brain areas groggier than others. Regions involved with problem solving and concentration become especially sluggish, a new study reveals.

The results may lead to a better understanding of the rhythmic nature of symptoms in certain psychiatric or neurodegenerative disorders, says Derk-Jan Dijk. People with dementia, for instance, can experience "sundowning," or worsening symptoms at the end of the day. More broadly, the findings, published in the Aug. 12 *Science*, document the brain's response to too little shut-eye.

"We've shown what shift workers already know," says Dijk, of the University of Surrey in England. "Being awake at 6 a.m. after a night of no sleep, it isn't easy. But what wasn't known was the remarkably different response of these brain areas."

The research reveals the differing effects of the two major factors that influence when you conk out: the body's roughly 24-hour circadian clock, which helps keep you awake in the daytime and put you to sleep when it's dark, and the body's drive to sleep, which steadily increases the longer you're awake.

Dijk, along with Surrey colleagues and collaborators at the University of Liege in Belgium, studied 33 young adults who went without sleep for 42 hours. During this time, participants performed simple tasks testing reaction time and memory, and underwent 12 brain scans. Participants had another scan after 12 hours of recovery sleep. The researchers also measured participants' levels of the sleep hormone melatonin, which served as a way to track the hands of their master circadian clocks.

Activity in some brain areas, such as the thalamus, a hub that connects many other structures, waxed and waned in sync with the circadian clock. But in other areas, especially those in the brain's outer layer, the body's drive to sleep overrode the effects of this master clock. Brain activity diminished in these regions as sleep debt mounted, the scans showed.

Sleep deprivation also meddled with performance on simple tasks, effects influenced both by the sleep debt and the cycles of the master clock. Performance suffered at night but improved somewhat during the second day, even after no sleep.

The brain's circadian clock signal originates in a cluster of nerve cells known as the suprachiasmatic nucleus. But it isn't clear where the drive to sleep comes from, says Charles Czeisler, a sleep expert at Harvard Medical School. The need to sleep may grow as toxic metabolites build up after a day's worth of brain activity or when certain regions run out of fuel. ■

ATOM & COSMOS

Fading star still baffles astronomers

Slow dimming, sharp drops in light cannot yet be explained

BY CHRISTOPHER CROCKETT

A star that made headlines for its bizarre behavior has got one more mystery for astronomers to ponder.

Tabby's star, also known as KIC 8462852, has been inexplicably flickering and fading. The Kepler Space Telescope has caught two dramatic drops in light — by up to 22 percent — spaced about two years apart. Photographs from other telescopes dating back to 1890 showed that the star also faded by about 20 percent over much of the last century. Explanations for the behavior range from mundane comet swarms to fantastical alien engineering projects.

A new analysis of data from Kepler, NASA's premier planet hunter, shows that Tabby's star steadily darkened throughout the telescope's primary four-year mission from 2009 to 2013. That's in addition to the abrupt flickers already seen during the same time period. Over the first 1,100 days, the star dimmed by nearly 1 percent. The light dropped another 2.5 percent over the next six months before leveling off during the mission's final 200 days.

Astronomers Benjamin Montet of Caltech and Josh Simon of the Observatories of the Carnegie Institution of Washington in Pasadena, Calif., report the findings online August 4 at arXiv.org.

The slow fading hadn't been noticed before because Kepler data are processed to remove long-term trends that might confuse planet-finding algorithms. Montet and Simon analyzed images that are typically used only to calibrate data.

"Their analysis is very thorough," says Tabetha Boyajian, an astronomer at Louisiana State University in Baton Rouge who in 2015 reported the two precipitous drops in light (and for whom the star is nicknamed).

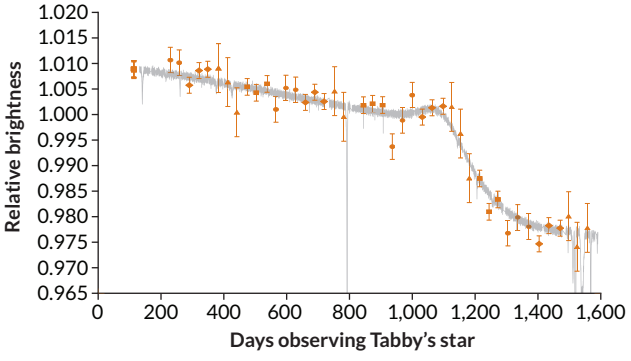
But the work doesn't yet explain the star's erratic behavior.

An object moving in front of the star and blocking light is the favored

Not-so-bright light

During the first four years of the Kepler Space Telescope mission, the brightness of Tabby's star faded. A gradual dimming in the first 1,100 days was followed by a relatively steep six-month decline that then leveled off. Around days 800 and 1,550, the brightness also plummeted and rebounded by roughly 20 percent.

Kepler telescope's recorded dimming of Tabby's star



B.T. MONTET AND J.D. SIMON/ARXIV.ORG 2016. ADAPTED BY J. HIRSHFELD

EARTH & ENVIRONMENT

Age of Americas' hookup debated

Latest analysis dates land bridge to 3 million years ago

BY THOMAS SUMNER

A debate over when the gap between North and South America closed has opened a rift in the scientific community.

Analyzing data from rocks, fossils and genetic studies, researchers have assembled a defense of the conventional view that the Isthmus of Panama formed about 3 million years ago. The work rebuts papers published last year that concluded that the continental connection began millions of years earlier (*SN: 5/2/15, p. 10*). The authors of the new paper, published August 17 in *Science Advances*, caution against the "uncritical acceptance" of the older formation date.

"Those of us who are advocating the traditional view are in danger of being seen as old fuddy-duddy conservatives," says molecular evolutionist Harilaos Lessios of the Smithsonian Tropical Research Institute in Panama City. "But sometimes the traditional view is the correct one."

The American continents drifted apart after the breakup of the Pangaea supercontinent some 200 million years ago. Eventually, the landmasses slid back together. As they reconnected, a volcanic mound on the Caribbean tectonic plate collided with South America and rose above the ocean, closing a seaway between the Pacific and Atlantic oceans.

Aaron O'Dea, a paleontologist at the Smithsonian institute, Lessios and colleagues revisited several lines of evidence to date the seaway closure. Fossils reveal that land animals began migrating more frequently between the Americas about 2.7 million years ago, possible evidence of a new land route, O'Dea's team concludes. Critics counter that those migrations were driven by climate and ecosystem changes that allowed animals to migrate.

In the ocean, the closed seaway divided populations of marine organisms such as sand dollars. Over time, these populations' genetic makeups diverged. Based on the degree of genetic change between groups, O'Dea's team estimates that the seaway closed about 3 million years ago.

Christine Bacon, an evolutionary biologist at the University of Gothenburg in Sweden, and colleagues analyzed similar evidence last year but came to a different conclusion. The seaway closed between 23 million and 7 million years ago, Bacon's team estimated in the *Proceedings of the National Academy of Sciences*. That study assumed a different rate of genetic divergence and looked at more species, Bacon says.

Rocks also trace the isthmus's rise. Last year, geologists described volcanically

explanation. The dimming is reminiscent of a planet crossing in front of a star, says Montet. But given how slowly the light dropped, such a planet would have to be on an orbit over 60 light-years across. "We figure that's pretty unlikely," he says.

An interstellar cloud between Earth and Tabby's star is also unlikely, says Penn State astronomer Jason Wright. "If the interstellar medium had these sorts of clumps and knots, it should be a ubiquitous phenomenon." While some quasars and pulsars appear to flicker because of intervening material, the variations are nothing like those seen in Tabby's star.

A clump of gas and dust orbiting the star — possibly produced by a collision between comets — is a more likely candidate, although that doesn't explain the century-long dimming.

Given the star's unpredictable nature, astronomers need constant vigilance to solve this mystery. Boyajian and colleagues have just started monitoring the star with the Las Cumbres Observatory Global Telescope Network, a worldwide web of telescopes that can keep an incessant eye on the star. ■

forged crystals found in South America that date back 13 million to 15 million years. The only possible source of those crystals was in Panama, suggesting that a river washed the crystals down a connection between Panama and South America, Camilo Montes of the Universidad de los Andes in Bogotá, Colombia, and colleagues concluded in *Science*.

Those South American crystals may have formed closer to home, O'Dea and colleagues argue. Similar crystals have been found elsewhere in South America, so those reported by Montes' team may have originated in South America, not Panama, O'Dea says.

Some of the disagreement stems from the fact that the seaway would have closed in stages, says Carlos Jaramillo of the Smithsonian institute, who coauthored both Montes' and Bacon's studies. "You can't just use one date for everything; it depends on what you're looking at," he says. ■

LIFE & EVOLUTION

Shark takes aim at longevity record

Radiocarbon dating suggests Greenland fish lived 392 years

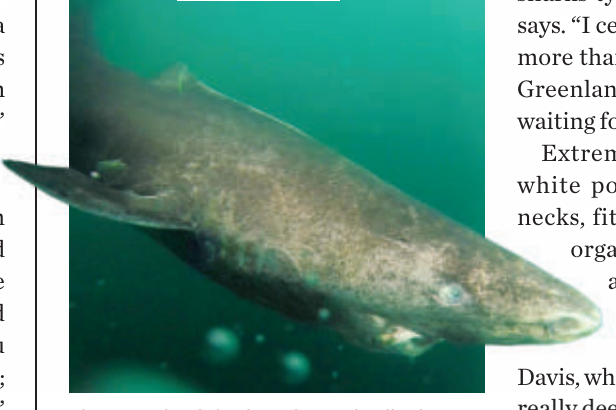
BY SUSAN MILIUS

The latest in birthday science proposes that the vertebrate with the longest life span yet measured is the mysterious Greenland shark.

Dating based on forms of carbon found in sharks' eye lenses suggests that a large female *Somniosus microcephalus* was about 392 years old (give or take 120 years) when she died, says marine biologist Julius Nielsen of the University of Copenhagen. Even with the uncertainty, the shark outdoes what Nielsen considers the previous record holder: a bowhead whale estimated to have lived 211 years.

The age comes from the first use of eye-lens dating for a fish, Nielsen says. The analysis that produced the date, involving 27 other Greenland sharks, suggests that females don't reach sexual maturity until they're about 156 years old, Nielsen and colleagues report in the Aug. 12 *Science*.

Figuring out the age of these sharks has "stymied all solution attempts," says Steven Campana of the University of Iceland in Reykjavik. "Given that the Greenland shark is one of the largest carnivores in the world and the king of the food chain in the Arctic Ocean, it is almost unbelievable that we don't know if this shark lives to 20 years or to 1,000," says Campana, who studies shark aging. Both extremes have been suggested. Little basic biology is known for the shark.



The Greenland shark might outdo all other vertebrates in longevity, a new study says.

J. NIELSEN

Unlike bony fish, such as salmon and cod, sharks don't have ear bones that build up calcified rings that reveal age. Some sharks, such as great whites, have some calcified vertebrae, but the Greenland species is "a soft shark," Nielsen says.

Working with 28 Greenland sharks of different sizes, Nielsen and colleagues examined eye lenses. The highly specialized clear proteins in lenses start with a nugget formed in utero, and studies in mammals have scrutinized that small bit for clues to a creature's birth date.

Nielsen's team looked for anomalies in carbon created by the pulse of radioactivity from the 1950s bomb testing in the Pacific Ocean. Radiocarbon worked its way into, and lingered in, all the food webs on the planet. The pulse first reached the sharks' realms in the North Atlantic in the 1960s, the scientific literature indicates. Only three specimens in the collection had the carbon anomalies — and they were the smaller sharks.

Nielsen and colleagues used the size of a shark that appeared to have been born just as the bomb pulse was arriving in the ocean food system as a kind of calibration marker. Then, in an elaborate statistical analysis, they used size and growth rates to work out ages for the rest.

Campana is skeptical that a Greenland shark can live nearly 400 years. Other sharks typically live 10 to 80 years, he says. "I certainly accept that it grows for more than a century." But to crown the Greenland shark a record holder, he is waiting for future research.

Extreme life spans evolve just like white polar bear fur or long giraffe necks, fitting into the sum of ways an organism feeds, dodges predators and reproduces in its environment, says James R. Carey of the University of California, Davis, who studies biodemography. "The really deeper question is once you identify a species that's long-lived — why?" ■

MATTER & ENERGY

Quantum data locking demonstrated

Long encrypted message can be sent with short decoding key

BY LAUREL HAMERS

Researchers have built a modern-day Enigma machine that relies on the quirky laws of quantum mechanics instead of the rotors and levers of the famous World War II–era code machines. It's the first experiment to show that it's possible to send large amounts of secure quantum data protected by a much shorter secret key, the team reports August 12 in *Physical Review A*.

Encryption usually relies on a secret key shared between two parties. The sender uses the key to scramble the message so it looks random to an outsider; the receiver uses the key to unscramble it. An eavesdropper who doesn't have the key can't read the garbled message.

Spies can use quantum mechanics to generate secure keys that can't be cracked by even the most powerful computers. Instead of 1s and 0s, quantum keys use the spins of photons, tiny packages of light. But those keys must be at least as long as the message they're protecting.

"It's very powerful, but it's very impractical if you're trying to transmit a dictionary or a volume of information," says Daniel Lum, a quantum physicist at the University of Rochester in New York.

By encoding the message itself (and not just the key) in a quantum system, it's theoretically possible to protect a long string of data using a much shorter key. The idea, called quantum data locking, was first proposed about 10 years ago. But nobody had experimentally tested it until now because of the challenges of actually sending inherently unstable quantum information.

Lum and colleagues built a setup that shoots a photon at a detector. To disguise the message encoded inside the photon, the sender scrambles the wave pattern of the photon so that it can't be focused onto a single point on the detector. The receiver knows the equation that the sender has used to disguise the wave and can therefore use the inverse function to cast off that disguise. Then the photon will land at the spot on the detector where it was intended to, and the receiver can read the message.

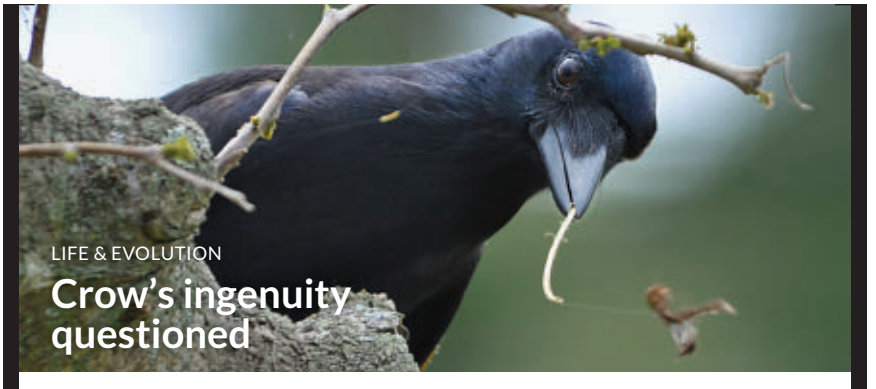
The eavesdropper doesn't know the equation, which acts like a key. Testing different keys to find the right one won't work; one wrong guess messes up the message because measuring a quantum system changes it. And there are so many different ways the message could be scrambled that the odds of guessing correctly with one try are practically zero.

The sender still needs a secure method to get the first key to the receiver. But once that ball is rolling, the sender can embed a new, shorter key in each quantum message, which the receiver can then use to unlock the next missive.

Quantum data locking has potential drawbacks. The experiment assumes that the eavesdropper has infinite computing power but limited quantum memory and so can't collect lots of information over time about the messages and put it all together to crack the code.

"In terms of people's technical capabilities, this is a very reasonable assumption," says study coauthor Seth Lloyd, a quantum mechanical engineer at MIT. But it's not fail-safe.

Applying this kind of data locking in the real world might be difficult. "What's really neat about data locking is that it does allow you to encrypt at essentially zero cost," says Stanford University quantum physicist Patrick Hayden. "But there are caveats to it. And in reality, the type of security that you achieve this way is delicate." Hayden thinks most people wanting to be certain that their messages remain private would probably pick a different quantum protocol. ■



LIFE & EVOLUTION

Crow's ingenuity questioned

Betty, a New Caledonian crow heralded as a toolmaking prodigy, may not have been such a whiz bird after all. Her apparently spontaneous wire bending is getting a closer look based on new information about wild birds.

As a lab resident, Betty astounded researchers over a decade ago by bending a wire into a hook — with no obvious design cues or known experience — and then using the hook to get a treat from a tube. The wire bending became "one of the most compelling demonstrations of insightful behavior in nonhumans," says Christian Rutz of the University of St. Andrews in Scotland. But tests of wild New Caledonian crows temporarily held in a field aviary raise the possibility that Betty may have bent twigs before coming into the lab, Rutz and colleagues say in the August *Royal Society Open Science*.

Of 18 wild *Corvus moneduloides* crows, 10 bent a pliable stick to use as a tool. (A wild crow using a hook to snag an insect is shown above.) Betty had also been caught in the wild and may have had some experience with bending pliable tools. The observations don't disprove that she invented wire bending spontaneously but raise an alternative explanation, Rutz says. — *Susan Milius*

JAMES ST CLAIR

Watch a toolmaking crow bend a twig at **bit.ly/SN_crow**

LIFE & EVOLUTION

Staying cool has hidden costs for birds

Simple strategies for beating the heat can impair foraging

BY SUSAN MILIUS

In the short-term, ways to beat the heat are cool. But for desert birds, even simple panting or flying into the shade can have some sneaky long-term costs.

When male southern yellow-billed hornbills pant, they're less able to snap up food, Susan Cunningham reported August 18. The hornbills are one of several bird species that Cunningham, of the University of Cape Town in South Africa, and various colleagues have shown face hidden costs of trying not to overheat.

Determining the full consequences of all the small ways birds ease the immediate dangers of heat becomes more urgent as the climate changes.

Yellow-billed hornbills (*Tockus leucomelas*) could be especially vulnerable to hidden costs of heat because males become the sole provisioners of their families during the breeding season. A female walls herself and her eggs into a cavity (or a research nest box), leaving open a hole only big enough for her mate to poke food through. In southern Africa's Kalahari region, a female may stay walled up for a month or more, leaving the male to scour hot, dry land for food for her, himself and eventually the chicks.

Males caught less food during bouts of panting than they did in the minutes before or after, Tanja van de Ven, Cunningham's student, has found. A specially rigged perch on nest boxes registered a male's weight every time he landed on it. When the temperature rose above 36.5° Celsius, males typically failed to maintain weight, raising concerns about their ability to care not only for themselves but for dependents, too.

Cunningham had already seen costs of panting in another Kalahari species, the southern pied babbler (*Turdoides bicolor*). Cunningham, Amanda Ridley of the University of Western Australia in Crawley and other babbler chroniclers found that on hot days, the birds persevered in foraging but caught less for their effort. As temperatures rose above 35.5°, birds struggled to maintain body weight. Typically, they lost more weight overnight than they could make up during a day, the team reported in 2012.

Even a strategy as simple as taking shelter in the shade can cut into a bird's ability to collect resources. Southern fiscals (*Lanius collaris*), chunky predators with fierce bills, prefer high, sunny perches from which to scan for rodents and insects. As the Kalahari's temperatures rose, fiscals spent more and more time on shady perches, where vegetation often narrows the view. The birds didn't catch as much from such spots, the researchers found, and growth slowed among younger chicks when parents had to hunt from substandard posts. Each day with a temperature above 35° kept chicks in the nests a half day longer. That's perilous, Cunningham and colleagues argued in 2013. A bird nest is a high-value target for predators and faces about a 4 percent risk of catastrophe each day.

Uncovering the downsides of such simple behaviors "is pretty cool," said Blair Wolf of the University of New Mexico in Albuquerque. Birds can't sweat, he said, and the many species that pant have to compensate for water lost in the process. Birds let their body temperatures rise to heights that would cook a human, and Wolf's work has shown that this tolerance lessens water loss. Whether there are hidden costs to this heat-fighting measure remains to be seen. ■

MEETING NOTES

Warm-up benefit could explain morning birdsong

Vocally warming up puts more dazzle into a bird's singing for the day, a new test shows, perhaps helping to explain outbursts of birdsong at dawn.

Males of Puerto Rico's Adelaide's warblers (*Setophaga adelaidae*) start trilling through their repertoires of 30 or so songs while it's still pitch black. Tracking the songs of individual males showed that the order of performance had a strong effect on performance quality, behavioral ecologist David Logue of the University of Lethbridge in Canada said August 17. In the early versions of particular songs, males didn't quickly change pitch as well as they did later, Logue and colleagues found.

Time of day alone didn't explain the improvement. So Logue doesn't think factors like increasing light or rising temperatures help to refine singing. Logue proposes what may be a new explanation for dawn choruses: Males warming up sooner would fare better in mate competition. Over time, an arms race could have broken out as earlier warm-ups were beaten by even earlier ones. —*Susan Milius*

Bird nest riddle: Which shape came first?

Songbird nests seem to have evolved backward: The most distant ancestor probably built complex, roofed structures, researchers say. Simple open-top cup nests came later.

Most songbird species build some form of open cup, evolutionary biologist Jordan Price said August 18. Yet looking at patterns of nest style across bird family trees convinced him that the cup isn't a leftover from deepest bird origins.

Lineages thought to have branched out near the base of the avian family tree tend to have plentiful roof builders. Price, of St. Mary's College of Maryland, and Simon Griffith of Macquarie University in Sydney reconstructed nest styles for various branching points in the tree. That reconstruction suggests that open cups showed up independently four times among songbirds. —*Susan Milius*

HUMANS & SOCIETY

Lucy fell from tree, study claims

Disputed analysis says tumble killed famed early hominid

BY BRUCE BOWER

In a macabre twist, the hominid evolutionary tree's most famous fossil star, Lucy, tumbled to her death from high up in a tree, a controversial new study suggests.

Some of the damage to Lucy's 3.2-million-year-old partial skeleton most likely occurred when she fell from a height of 13 meters or more, say paleoanthropologist John Kappelman of the University of Texas at Austin and colleagues. Lucy, an ambassador of a prehuman species called *Australopithecus afarensis*, must have accidentally plunged from a tree while climbing or sleeping, the scientists propose online August 29 in *Nature*.

Bone breaks from head to ankle fit a scenario in which Lucy dropped the equivalent of at least four stories, landing feet first before thrusting her arms out in an attempt to break her fall, Kappelman says. Tellingly, the ancient female's right shoulder blade slammed into the top of her upper arm bone, Kappelman says. The shoulder end of Lucy's arm bone displays sharp breaks, as well as bone fragments and slivers forcibly driven into the shaft.

Such damage often appears in present-day people who fall from great heights or are in serious car accidents, Kappelman says. Massive internal bleeding typically follows a body slam as hard as Lucy's, he adds. "Lucy probably bled out pretty fast after falling."

Nonsense, responds paleoanthropologist Tim White of the University of California, Berkeley. He calls the new paper "a classic example of paleoanthropological storytelling being used as clickbait for a commercial journal eager for media coverage."

Cracks and breaks throughout Lucy's skeleton occurred after her death, White asserts. Bone cracking was caused by fossilization and by pressure on fossils embedded in eroding sandstone. Fossilization-related breakage much like Lucy's — including extensive shoulder-joint damage — appears in the bones of a variety of nonclimbing animals, including gazelles, hippos and rhinos, White says.

CT scans of the hominid Lucy's partial skeleton (lower arm bone shown, left) provide evidence of a fatal fall, scientists report. But Lucy's right upper arm bone (right, held in a person's hand) has breakage similar to that of a fossilized limb bone from a horse found in the same part of Africa. Such damage resulted from fossilization, not a fall, a critic of the new research contends.

When people accidentally fall from heights between two and 21 meters, he adds, physicians have documented frequent fractures of the spine, head, elbows, wrists, ankles and feet — but not the shoulders.

Scientists have been unable to decipher how Lucy died since her 1974 discovery in Ethiopia by anthropologist Donald Johanson, now of Arizona State University in Tempe, and his graduate student at that time, Tom Gray. In a 1982 report, a Johanson-led team, which included White, attributed Lucy's bone damage primarily to fossilization.

Intrigued by crushing and breakage at Lucy's right shoulder joint, Kappelman consulted orthopedic surgeon and study coauthor Stephen Pearce of the Austin Bone and Joint Clinic. When shown a 3-D model of Lucy's skeleton enlarged to the size of a modern human adult (Lucy stood about 107 centimeters tall, or 3 feet, 6 inches), Pearce said the damage resembled that caused by an individual extending an arm to break a steep fall.

Kappelman and colleagues then scoured high-resolution CT scans of Lucy's bones obtained in 2008, when the skeleton was brought to the University of Texas during a U.S. museum tour.

Along with the right upper arm bone and shoulder blade, damage consistent with hitting the ground after a long fall appeared in bones from an ankle, legs, pelvis, lower back, ribs, jaw and braincase, the researchers say. Fossilization and geologic forces caused additional cracking and breaks on Lucy's remains, as described in the 1982 report, they add.

Although initially skeptical that cause of death could be discerned in a fossil individual as old as Lucy, paleoanthropologist William Jungers of the Stony Brook University School of Medicine in New York says the evidence points to a fatal fall. No other explanation can account for Lucy's pattern of bone damage, he says.

If Lucy toppled out of a tree while climbing or snoozing in a nest, her kind must have split time between life on the ground and in trees, Kappelman says. Some researchers have long argued that *A. afarensis* was built mainly for walking.

Even today, Jungers says, deaths from accidental falls out of trees occur among some African hunter-gatherers, especially when raiding bees' nests for honey, and in wild chimps, animals more adept at tree climbing than Lucy was. ■

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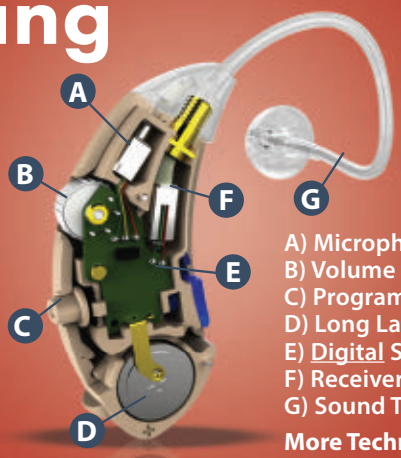

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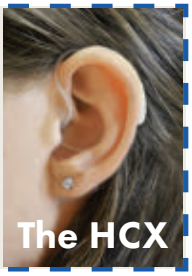

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Out of the DARK

Scientists identify bacteria lurking in the shadows

By Laura Beil

Few people today could recite the scientific accomplishments of 19th century physician Julius Petri. But almost everybody has heard of his dish.

For more than a century, microbiologists have studied bacteria by isolating, growing and observing them in a petri dish. That palm-sized plate has revealed the microbial universe — but only a fraction, the easy stuff, the scientific equivalent of looking for keys under the lamppost.

But in the light — that is, the greenhouse-like conditions of a laboratory — most bacteria won't grow. By one estimate, a staggering 99 percent of all microbial species on Earth have yet to be discovered, remaining in the shadows. They're known as "microbial dark matter," a reference to astronomers' description of the vast invisible matter in space that makes up most of the mass in the cosmos.

99 percent
of all microbial species on Earth have yet to be discovered

In the last decade or so, though, scientists have developed new tools for growing bacteria and collecting genetic data, allowing faster and better identifications of microbes without ever removing them from natural conditions. A device called the iChip, for instance, encourages bacteria to grow in their home turf. (That device led to the discovery of a potential new antibiotic, in a time when infections are fast outwitting all the old drugs.) Recent genetic explorations of land, water and the human body have raised the prospect of finding hundreds of thousands of new bacterial species.

Already, the detection of these newfound organisms is challenging what scientists thought they knew about the chemical processes of biology, the tree of life and the manner in which microbes live and grow. The secrets of microbial dark matter may redefine how life evolved and exists, and even improve the understanding of, and treatments, for many diseases.

"Everything is changing," says Kelly Wrighton, a microbiologist at Ohio State University in Columbus. "The whole field is full of enthusiasm and discovery."

Counter culture

Microbiologists have in the past discovered new organisms without petri dishes, but those experiments were slow going. In one of her first projects, Tanja Woyke analyzed the bacterial community huddled inside a worm that lives in the Mediterranean Sea. Woyke, a microbiologist at the U.S. Department of Energy's Joint Genome Institute in Walnut Creek, Calif., and colleagues published the report in *Nature* in 2006. It was two years in the making.

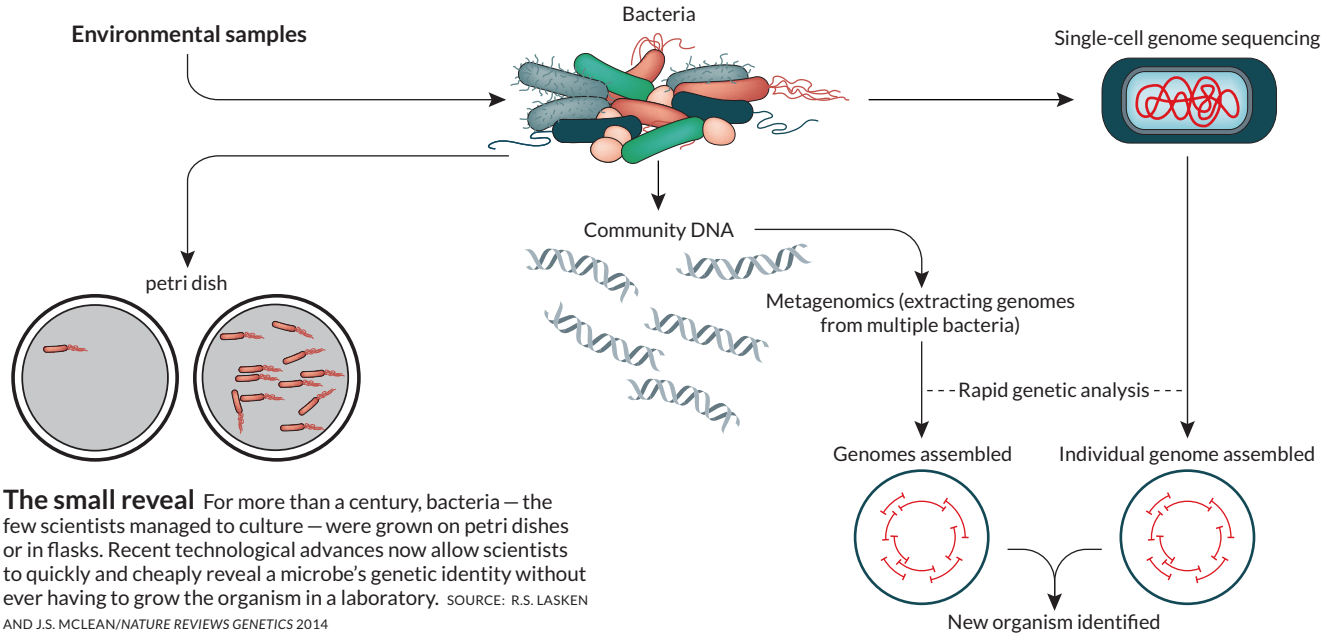
They relied on metagenomics, which involves gathering a sample of DNA from the environment — in soil, water or, in this case, worm insides. After extracting the genetic material of every microbe the worm contained, Woyke and colleagues determined the order, or sequences, of all the DNA units, or bases. Analyzing that sequence data allowed the researchers to infer the existence of four previously unknown microbes. It was a bit like obtaining boxes of jigsaw puzzle pieces that need assembly without knowing what the pictures look like or how many different puzzles they belong to, she says. The project involved 300 million bases and cost more than $100,000, using the time-consuming methods available at the time.

Just as Woyke was wrapping up the worm endeavor, new technology came online that gave genetic analysis a turbo boost. Sequencing a genome — the entirety of an organism's DNA — became faster and cheaper than most scientists ever predicted. With next-generation sequencing, Woyke can analyze more than 100 *billion* bases in the time it takes to turn around an Amazon order, she says, and for just a few thousand dollars. By scooping up random environmental samples and searching for DNA with next-generation sequencing, scientists have turned up entirely new phyla of bacteria in practically every place they look. In 2013 in *Nature*, Woyke and her colleagues described more than 200 members of almost 30 previously unknown phyla. Finding so many phyla, the first big groupings within a kingdom, tells biologists that there's a mind-boggling amount of uncharted diversity.

Woyke has shifted from these broad genetic fishing expeditions to working on individual bacterial cells. Gently breaking them open, she catalogs the DNA inside. Many of the organisms she has found defy previous rules of biological chemistry. Two genomes taken from a hydrothermal vent in the Pacific Ocean, for example, contained the code UGA, which stands for the bases uracil, guanine and adenine in a strand of RNA.

Using a device they named the iChip, researchers at Northeastern University and colleagues have found 50,000 new strains of soil bacteria. One new bacterium yielded a potential new class of antibiotics in 2015.

OPPOSITE: ASHLEY MACKENZIE; THIS PAGE: SLAVA EPSTEIN/NORTHEASTERN UNIV.

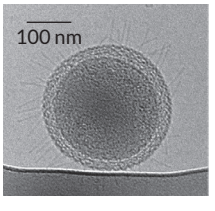


The small reveal For more than a century, bacteria — the few scientists managed to culture — were grown on petri dishes or in flasks. Recent technological advances now allow scientists to quickly and cheaply reveal a microbe's genetic identity without ever having to grow the organism in a laboratory. SOURCE: R.S. LASKEN AND J.S. MCLEAN/*NATURE REVIEWS GENETICS* 2014

UGA normally separates the genes that code for different proteins, acting like a period at the end of a sentence. In most other known species of animal or microbe, UGA means "stop." But in these organisms, and one found about the same time in a human mouth, instead of "stop," the sequence codes for the amino acid glycine. "That was something we had never seen before," Woyke says. "The genetic code is not as rigid as we thought."

Other recent finds also defy long-held notions of how life works. This year in the *ISME Journal*, Ohio State's Wrighton reported a study of the enzyme RubisCO taken from a new microbial species that had never been grown in a laboratory. RubisCO, considered the most abundant protein on Earth, is key to photosynthesis; it helps convert carbon from the atmosphere into a form useful to living things. Because the majority of life on the planet would not exist without it, RubisCO is a familiar molecule — so familiar that most scientists thought they had found all the forms it could take. Yet, Wrighton says, "we found so many new versions of this protein that were entirely different from anything we had seen before."

The list of oddities goes on. Some newly discovered organisms are so small that they barely qualify as bacteria at all. Jillian Banfield, a microbiologist at the University of California, Berkeley, has long studied the microorganisms in the groundwater pumped out of an aquifer in Rifle, Colo. To filter this water, she and her colleagues used a mesh with openings 0.2 micrometers wide — tiny enough that the water coming out the other side is considered bacteria-free. Out of curiosity, Banfield's team decided to use next-generation sequencing to identify cells that might have slipped through. Sure enough, the water contained extremely minuscule sets of genes.



This tiny groundwater bacterium can slip through filters.

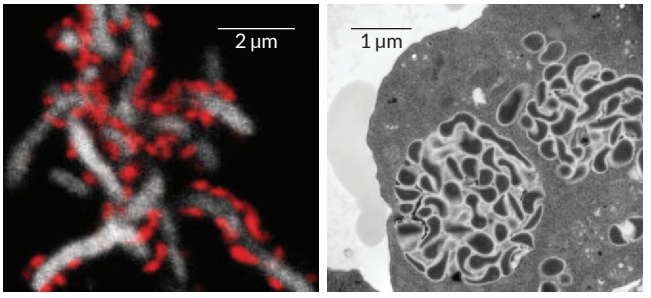
"We realized these genomes were really, really tiny," Banfield says. "So we speculated if something has a tiny genome, the cells are probably pretty tiny, too." And she has pictures to prove it. Last year in *Nature Communications*, she and her team published the first images (taken with an electron microscope) and detailed description of these ultrasmall microbes. They are probably difficult to isolate in a petri dish, Banfield says, because they are slow-growing and must scavenge many of the essential nutrients they need from the environment around them. Part of the price of a minigenome is that you don't have room for the DNA to make everything you need to live.

Relationship status: It's complicated

Banfield predicts that an "unimaginably large number" of species await in every cranny of the globe — soil, rocks, air, water, plants and animals. The human microbiome alone is probably teeming with unfamiliar microbial swarms. As a collection of organisms that live on and in the body, the human microbiome affects health in ways that science is just beginning to comprehend (*SN: 2/6/16, p. 6*).

Scientists from UCLA, the University of Washington in Seattle and colleagues recently offered the most detailed descriptions yet of a human mouth bacterium belonging to a new phylum: TM7. (TM stands for "Torf, mittlere Schicht," German for a middle layer of peat; organisms in this phylum were first detected in the mid-1990s in a bog in northern Germany.) German scientists found TM7 by sifting through soil samples, using a test that's specific for the genetic information in bacteria. In the last decade, TM7 species have been found throughout the human body. An overabundance of TM7 appears to be correlated with inflammatory bowel disease and gum disease, plus other conditions.

FROM TOP: ADAPTED BY J. HIRSHFELD; B. LUEF *ET AL*/*NATURE COMMUNICATIONS* 2015



Some bacteria live in untraditional ways. One, from a newly discovered phylum called TM7 (left, red dots), lives parasitically on another bacterium. Another, from phylum TM6 (right, dark blobs), lives in an amoeba.

FROM LEFT: BATBILEG BOR AND XUESONG HE/UCLA; V. DELAFONT *ET AL/ENVIRONMENTAL MICROBIAL REPORTS* 2015

Until recently, members of TM7 have stubbornly resisted scientists' efforts to study them. In 2015, Jeff McLean, a microbiologist at the University of Washington, and his collaborators finally isolated a TM7 species in a lab and deciphered its full genome. To do so, the team combined the best of old and new technology: First the researchers figured out how to grow most known oral bacteria together, and then they gradually thinned down the population until only two species remained: TM7 and a larger organism.

"The really remarkable thing is we finally found out how it lives," McLean says, and why it wouldn't grow in the lab. They discovered that this species of TM7, like the miniature bacteria in Colorado groundwater, doesn't have the cellular machinery to get by on its own. Even more unusual, these bacteria pilfer missing amino acids and whatever else they need by latching on, like parasites, to a larger bacterium. Eventually they can kill their host. "We think this is the first example of a bacterium that lives in this manner," McLean says.

He expects to see more unusual relationships among microbes as the dark matter comes to light. Many have evaded detection, he suspects, because of their small size (sometimes perhaps mistaken for bacterial debris) and dependence on other organisms for survival. In 2013 in the *Proceedings of the National Academy of Sciences*, McLean and colleagues were the first to describe a member of another uncultivated phylum, TM6. They found this group growing in the slime in a hospital sink drain. Later studies determined that the organism lives by tucking itself inside an amoeba.

One of the greatest hopes for microbial dark matter exploration is that newly found microbes might provide desperately needed antibiotics. From the 1940s to the 1960s, scientists discovered 10 new classes of drugs by testing chemicals found in soil and elsewhere for action against common infections. But only two classes of medically important antibiotics have been discovered in the last 30 years, and none since 1997. Some major infections are at the brink of being unstoppable because they've become resistant to most existing drugs (*SN Online: 5/27/16*). Many experts think that natural sources of antibiotics have been exhausted.

Maybe not. In 2015, a research team led by scientists from Northeastern University in Boston captured headlines after describing in *Nature* a new chemical extracted from a ground-dwelling bacterium in Maine. The scientists isolated the organism using the iChip, a thumb-sized tool that contains almost 400 separate wells, each large enough to hold only an individual bacterial cell plus a smidgen of its home dirt. The bacteria grow on this scaffold in part because they never leave their natural surroundings. In lauding the discovery, Francis Collins, director of the National Institutes of Health, called the iChip "an ingenious approach that enhances our ability to search one of nature's richest sources of potential antibiotics: soil." So far, the research team has discovered about 50,000 new strains of bacteria.

One strain held an antibiotic, named teixobactin (*SN: 2/7/15, p. 10*). In laboratory experiments, it killed two major pathogens in a way that did not appear easily vulnerable to the development of resistance. Most antibiotics work by disrupting a microbe's survival mechanism. Over time, the bacteria genetically adapt, find a work-around and overcome the threat. This new antibiotic, however, prevents a microbe from assembling the molecules it needs to form an outer wall. Since the antibiotic interrupts a mechanical process and not just a specific chemical reaction, "there's no obvious molecular target" for resistance, says Kim Lewis, a microbiologist at Northeastern.

Everything is illuminated

Some microbiologists feel like astronomers who, after years of staring up into the dark, were just handed the Hubble Space Telescope. Billions of galaxies are coming into view. Banfield expects this new microbial universe to be mapped over the next few years. Then, she says, an even more exciting era begins, as science explores how these dark matter bacteria make a living. "They are doing a lot of things, and we have no idea what," she says.

Part of the excitement comes from knowing that microbes have a history of granting unexpected solutions to problems that scientists never expected to solve. Consider that the enzyme that makes the laboratory technique PCR possible came from organisms that live inside the thermal vents at Yellowstone National Park. PCR, which works like a photocopier to make multiple copies of DNA segments, is now used across a range of situations, from diagnosing cancer to paternity testing. CRISPR, a powerful gene-editing technology, relies on "molecular scissors" that were found in bacteria (*SN: 9/3/16, p. 22*).

Banfield estimates that 30 to 50 percent of newly discovered organisms contain proteins that never met a petri dish. Their function in the chemistry of life is an obscure mystery. Since microbes are the world's most abundant organism, Banfield says, "the vast majority of life consists of biochemistry we don't understand." But once we do, the future could be very bright. ■

Explore more

■ Leonard Katz and Richard H. Baltz. "Natural product discovery: past, present and future." *Journal of Industrial Microbiology & Biotechnology*. March 2016.

Runaway Fish

Escapes from marine farms raise concerns about native wildlife

By Roberta Kwok

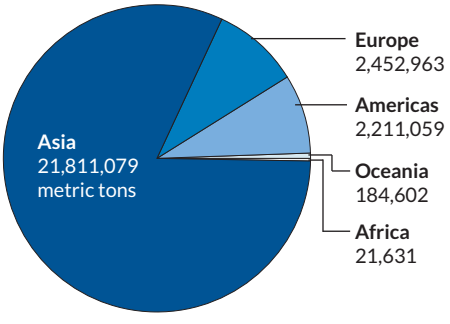
On the dock in Buenaventura, Colombia, the fisherman needed help identifying his catch. "I don't have any clue what this is," he said, holding a roughly 50-centimeter-long, grayish-brown fish. Gustavo Castellanos-Galindo, a fish ecologist, recalls the conversation from last October. "I said, 'Well, this is a cobia, and it shouldn't be here.' "

The juvenile cobia had probably escaped from a farm off the coast of Ecuador that began operating earlier in 2015, Castellanos-Galindo and colleagues at the World Wildlife Fund in Cali, Colombia, reported in March in *BioInvasions Records*. Intruders had probably cut a net cage, perhaps intending to catch and sell the fish. Roughly 1,500 cobia fled, according to the aquaculture company Ocean Farm in Manta, Ecuador, which runs the farm. Cobia are fast-swimming predators that can migrate long distances and grow to about 2 meters long. The species is not native to the eastern Pacific, but since the escape, the fugitives have been spotted from Panama to Peru.

The cobia getaway is not an isolated incident. Aquaculture, the farming of fish and other aquatic species, is rapidly expanding — both in marine and inland farms. It has begun to overtake wild-catch fishing as the main source of seafood for the dinner table. Fish farmed in the ocean, such as salmon, sea bass, sea bream and other species, are raised in giant offshore pens that can be breached by storms, predators, fish that nibble the nets, employee error and thieves. Global numbers for escapes are hard

Farming the ocean About one-third of the world's farmed fish, mollusks, crustaceans and other aquatic animals are raised in the sea and coastal areas, mainly in Asia. Underwater cages must withstand storms, predator attacks and other threats. SOURCE: FAO 2016

Tonnage of aquatic animals raised for human consumption in marine and coastal farms in 2014, by region



In Chile, fish are farmed mostly in coastal marine environments (sea cages, above). The South American country is the second largest producer of farmed salmon, after Norway.

FROM TOP: RENÉ LORENZ/ISTOCKPHOTO; T. TIBBITTS

E. OTWELL

to come by, but one study of six European countries over three years found that nearly 9 million fish escaped from sea cages, according to a report published in *Aquaculture* in 2015.

Researchers worry that these releases could harm wildlife, but they don't have a lot of data to measure long-term effects. Many questions remain. A study out of Norway published in July suggests that some domesticated escapees have mated extensively with wild fish of the same species, which could weaken the wild population. Scientists also are investigating whether escaped fish could gobble up or displace native fish.

Worst-case scenario: Escaped fish spread over large areas and wreak havoc on other species. From toxic toads overrunning Australia and Madagascar (*SN Online: 2/22/16*) to red imported fire ants in the United States, invasive species are one of the planet's biggest threats to biodiversity, and they cost billions of dollars in damage and management expenses. Not every introduced species has such drastic effects, but invasives can be tough to eliminate.

While researchers try to get a handle on the impact of farm escapes, farmers are working to better contain the fish and reduce the ecological impact of the runaways. Some countries have tightened their aquaculture regulations. Researchers are proposing strategies ranging from new farm designs to altering fish genetics. As aquaculture becomes a widespread means to feed the planet's protein-hungry people, the ecological effects are getting more attention.

If escapees weaken native wildlife, "we're solving a food issue globally and creating another problem," says population geneticist Kevin Glover of Norway's Institute of Marine Research in Bergen. Norway, a top producer of marine fish, has done much of the research on farm escapes.

Not born to be wild

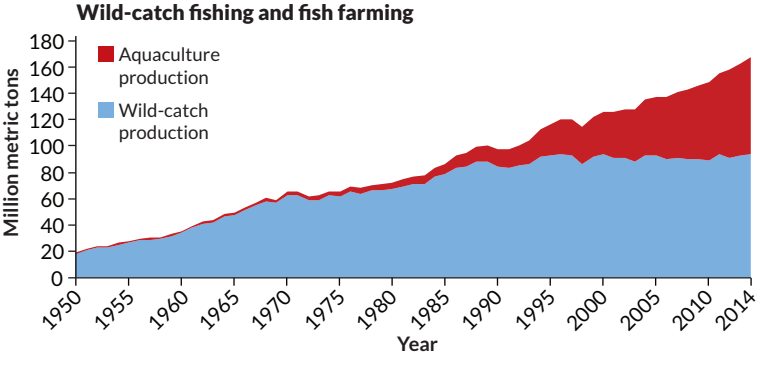
Fish farming is big business. In 2014, the industry churned out 73.8 million metric tons of aquatic animals worth about $160 billion, according to a report in July from the Food and Agriculture Organization of the United Nations in Rome.

Nearly two-thirds of this food comes from inland freshwater farms such as ponds, used in Asia for thousands of years. The rest is grown on marine and coastal farms, where farmed fish live in brackish ponds, lagoons or cages in the ocean.

Freshwater fish can escape from pond farms during events such as floods. Some escapees, such as tilapia, have hurt native species by competing with and eating wild fish. But sea farming has its own set of problems. The physical environment is harsh and cages are exposed to damaging ocean waves and wind, plus boats and predator attacks.

Salmon is one of the most heavily farmed marine fish. In some areas, the number of farmed salmon dwarfs wild populations. Norway's marine farms hold about 380 million Atlantic salmon, while the country's rivers are home to only about 500,000 wild spawning Atlantic salmon.

Aquaculture boom The fish farming industry is in growth mode, while wild-catch fishing has plateaued. In 2014, aquaculture harvests made up 44 percent of aquatic animal production worldwide and more than half of production intended for human food. SOURCE: FAO 2016



Top 10 producers of finfish in marine/coastal aquaculture, 2014

Country	Production (thousand metric tons)
Norway	1,330.4
China	1,189.7
Chile	899.4
Indonesia	782.3
Philippines	373.0
Japan	238.7
Vietnam	208.5
United Kingdom	167.3
Turkey	126.1
Taiwan	97.8

SOURCE: FAO 2016

In the four decades that farmers have been cultivating Atlantic salmon, farmed strains have diverged from their wild cousins. When both are raised in standard hatchery conditions, farm-raised salmon can grow about three to five times heavier than wild salmon in the first year of life.

Salmon raised in farms also tend to be less careful; for instance, after being exposed to an artificial predator, they emerge more quickly from hiding places than wild fish. This risky behavior may have arisen partly because the fish haven't faced the harsh challenges of nature. "The whole idea of a hatchery is that everything gets to survive," says Philip McGinnity, a molecular ecologist at University College Cork in Ireland. Farmed fish don't know better.

These differences are bad news for hybrid offspring and wild fish. In early experiments, hybrid offspring of farmed and wild salmon tended to fare poorly in the wild. In the 1990s, McGinnity's team measured these fish's "lifetime success" in spawning rivers and the ocean. Compared with wild salmon, hybrid offspring had a lifetime success rate about a fourth to a half as high. Around the same time, a team in Norway found that when wild fish swam with farmed fish in their midst, the number of wild offspring that survived long enough to leave the river to head to the ocean was about one-third lower than expected, perhaps because the fast-growing farmed offspring gobbled a lot of food or claimed territory.

"There was truly reason to be concerned," says Ian Fleming, an evolutionary ecologist at Memorial University of Newfoundland in St. John's, Canada, who was part of the Norway team.

Recent work supports the idea that farmed fish could crowd out wild fish by hogging territory in a river. In a study published last year in the *Journal of Fish Biology*, researchers found that the survival rate of young wild salmon dropped from 74 to 53 percent when the fish were raised in the same confined stream channels as young farmed salmon rather than on their own. When the channels had an exit, more wild fish departed the stream when raised with farmed salmon than when raised alone.

"These are fish that give up the territory and have to leave," says study coauthor Kjetil Hindar, a salmon biologist at the Norwegian Institute for Nature Research in Trondheim.

A weaker mix

To find out how much escaped fish had genetically mingled with wild fish, Glover's team obtained historical samples of salmon scales collected from 20 rivers in Norway before aquaculture became common. The researchers compared the DNA in the scales with that of wild salmon caught from 2001 to 2010 in those rivers.

Wild salmon in five of the 20 rivers had become more genetically similar to farmed fish over about one to four decades, the team reported in 2013 in *BMC Genetics*. In the most affected population, 47 percent of the wild fish's genome originated from farmed strains. "We're talking about more or less a complete swamping of the natural gene pool," Glover says. Imagine buckets of paint — red, blue, green — representing each river, he says, and pouring gray paint into each one.

380
million
Number of Atlantic salmon in Norway's marine farms

500
thousand
Number of spawning Atlantic salmon in Norway's rivers

Interbreeding was less of an issue where wild fish were plentiful. The farmed fish aren't good at spawning, so they won't mate much if a lot of wild competitors are present. But in sparse populations, the farm-raised salmon may be able to "muscle in," Glover says.

A larger study by Hindar's team, published in July in the *ICES Journal of Marine Science*, showed that genetic mixing between wild and farmed salmon is happening on a large scale in Norway. Among 109 wild salmon populations, about half had significant amounts of genetic material from farmed strains that had escaped. In 27 populations, more than 10 percent of the fish's DNA came from farmed fish.

What does that mean for the offspring? Each salmon population has adapted to survive in its habitat — a certain river, at a specific temperature range or acidity level. When farmed fish mate with wild fish, the resulting offspring may not be as well-suited to live in that environment. Over generations, as the wild population becomes more similar to farmed salmon, scientists worry that the fish's survival could drop.

Scientists at several institutions in Norway are exploring whether genetic mixing changes the wild salmon's survival rates, growth and other traits. Making a definitive link will be difficult. Other threats such as climate change and pollution also are putting stress on the fish.

If escapes can be stopped, wild salmon may rebound. Natural selection will weed out the

weakest fish and leave the strongest, fish that got a lucky combination of hardy traits from their parents. But Glover worries that, just as a beach can't recover if oil is spilled every year, the wild population can't rally if farmed fish are continually pumped in: "Mother Nature cannot clean up if you constantly pollute."

Uncertain consequences

In places where the species being farmed is not naturally abundant, researchers are taking a look at whether escapes could upset native ecosystems. For instance, European sea bass sometimes slip away from farms in the Canary Islands, where (except for a few small populations on the eastern end) the species doesn't normally live.

In February 2010, storms battered cages at the island of La Palma, "like a giant tore up all the nets," says Kilian Toledo-Guedes, a marine ecologist at the University of Alicante in Spain. About 1.5 million fish — mostly sea bass — reportedly swam free.

A couple of weeks later, the number of sea bass in nearby waters was "astounding," he says. "I couldn't see the bottom." Sea bass density in waters near the farm was 162 times higher than it had been at the same time the previous year, his team reported in 2014 in *Fisheries Management and Ecology*. Fisheries data showing a spike in catches of sea bass by local fishermen that January also suggested that large unreported escapes had occurred before the storm.

Despite being raised in captivity, where they are fed pellets, some of the farmed fish learn to hunt. The researchers found that escaped sea bass caught four months after the 2010 farm breakdown had eaten mostly crabs. Sea bass from earlier escapes that had been living in the wild for several years had eaten plenty of fish as well. The results, reported in 2014 in *Marine Environmental Research*, suggest that escapees start by catching easy targets such as crustaceans and then learn to nab faster-moving fish.

So far, though, scientists have not seen clear signs that the escapees damaged the ecosystem. The density of sea bass around La Palma had fallen drastically by October 2010 and continued to decline the next year, probably because some fish couldn't find enough to eat, while others were caught by fishermen or predators, according to a 2015 study by another team in the *Journal of Aquaculture Research & Development*.

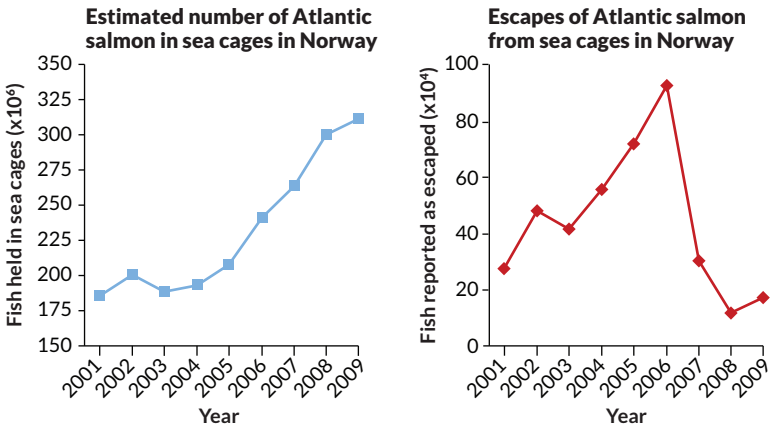
Catches of small fish that sea bass eat, such as parrot fish, did not drop significantly after the 2010 escape or after a similar large escape in 1999, says study coauthor Ricardo Haroun, a marine conservation researcher at the University of Las Palmas de Gran Canaria in Spain. While he agrees that the industry should try to prevent escapes, he sees no evidence that the runaways are suppressing wild species.

If the escaped fish can breed and multiply, the risk of harming native species rises. In a study published in *Marine Ecology* in 2012, Toledo-Guedes and colleagues reported finding sexually mature sea bass around the central island of Tenerife. But Haroun says the water is too warm and salty for the fish to reproduce, and his team did not see any juveniles during their surveys of La Palma, nor have they heard any reports of juveniles in the area. Toledo-Guedes says that more extensive studies, such as efforts to catch larvae, are needed before reproduction can be ruled out.

Similarly, researchers can't predict the consequences of the cobia escape in Ecuador. The water is the right temperature for reproduction, and these predators eat everything from crabs to squid. Castellanos-Galindo believes that farming cobia in the area is a mistake because escapes will probably continue, and the fish may eventually form a stable population in the wild that could have unpredictable effects on native prey and other parts of the ecosystem. He points to invasive lionfish as a cautionary tale: These predators, probably released from personal aquariums in Florida, have exploded across the Caribbean, Gulf of

After a 2010 escape of sea bass from a marine farm in Spain's Canary Islands, fishermen captured about one-quarter of the escapees (left). Escaped sea bass swam free (below) after a 2013 breach off Gran Canaria island.

FROM TOP: FELICIANO GONZÁLEZ; FERNANDO ROS; BOTH COURTESY OF K. TOLEDO-GUEDES



Reeling in escapes Norway made major improvements to its fish farms after a new aquaculture standard was rolled out in 2004. The number of reported Atlantic salmon escapees plunged within a few years (right), even as the number of salmon raised in sea cages grew (left). SOURCE: Ø. JENSEN *ET AL*/*AQUACULTURE ENVIRONMENT INTERACTIONS* 2010

Mexico and western Atlantic and are devouring small reef fish.

The situation for cobia may be different. Local sharks and other predators will probably eat the escapees, whereas lionfish have few natural predators in their new territory, argues Diego Ardila, production manager at Ocean Farm. Milton Love, a marine fish ecologist at the University of California, Santa Barbara, also notes that lionfish settle in one small area, but cobia keep moving, so prey populations might recover after the cobia have moved on.

Not all introduced species become established or invasive, and it can take decades for the effects to become apparent. "Time will tell what happens," says Andrew Sellers, a marine ecologist at the Smithsonian Tropical Research Institute in Panama City. "Basically, it's just up to the fish."

A slippery problem

Once fish have fled, farmers sometimes enlist fishermen to help capture the escapees. Professional fishermen caught nearly one-quarter of the sea bass and sea bream that escaped after the Canary Islands breach. On average, though, only 8 percent of fish are recaptured after an escape, according to a study published in June in *Reviews in Aquaculture*. Given the recapture failures, farmers and policy makers should focus on preventing escapes and maintaining no-fishing zones around farms to create a "wall of mouths," local predators that can eat runaway fish, says coauthor Tim Dempster, a sustainable aquaculture researcher at the University of Melbourne in Australia.

Technical improvements could help. The Norwegian government rolled out a marine aquaculture standard in 2004 that required improvements, such as engineering nets, moorings and other equipment to withstand unusually strong storms. Compared with the period 2001–2006, the average number of Atlantic salmon escaping annually from 2007–2009 dropped by more than half. Ocean Farm in Ecuador has tightened security, increased cage inspections and switched to stronger net materials; no cobia have escaped since last year's break-in, says Samir Kuri, the company's operations manager.

Some companies raise fish in contained tanks on land to avoid polluting marine waters, reduce exposure to diseases and control growth conditions. But the industry is largely reluctant to adopt this option until costs come down. The money saved from reducing escapes probably wouldn't make up for the current start-up expense of moving to land. The 242 escape events analyzed in the 2015 *Aquaculture* study cost farmers about $160 million. By one estimate, establishing a land-based closed-containment farm producing about 4,000 metric tons of salmon annually — a small haul by industry standards — would cost $54 million; setting up a similar-sized sea-cage farm costs $30 million.

Another solution is to raise fish that have three sets of chromosomes. These triploid fish, produced by subjecting fertilized eggs to a pressure shock, can't reproduce and therefore wouldn't proliferate or pollute the wild gene pool.

"The only ultimate solution is sterility," Norway's Glover says. "Accidents happen." Escaped triploid salmon are less likely to disrupt mating by distracting females from wild males, the researchers wrote in *Biological Invasions* in May. But triploid fish don't grow as well when the water is warmer than about 15° Celsius, and consumers might be reluctant to accept these altered salmon.

Although the ecological effects of fish farm escapes may take a long time to play out, most researchers agree that we shouldn't take chances with the health of the oceans, which already face threats such as climate change, pollution and overfishing. With the aquaculture industry expanding at about 6 percent per year, farmers will have to keep improving their practices if they are to stay ahead of the runaway fish. ■

Explore more

■ Dave Jackson *et al.* "A pan-European valuation of the extent, causes and cost of escape events from sea cage fish farming." *Aquaculture.* January 2015.

E. OTWELL

Congratulations Broadcom MASTERS!

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SCREENTIME

Black hole game lets you blow up stars

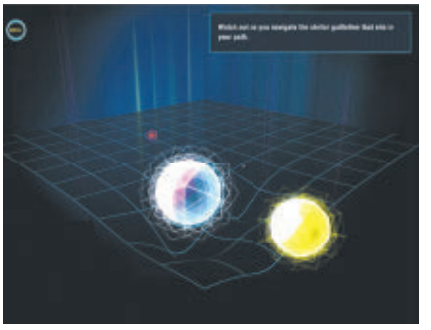
If you have an appetite for cosmic destruction, there's an app for that.

NOVA Black Holes, a free iPad game developed by the PBS series *NOVA*, lets you hurl a star at other celestial objects while navigating an increasingly complex minefield of stars, planets and black holes. Each level presents a new target and a fresh landscape of obstacles. And unlike real stars — whose fates are determined by the weight they're born with — your star grows bigger and brighter as the game progresses until it collapses under its own gravity to form a black hole. That's the goal.

The game is addictive — there's something surprisingly satisfying about blowing up a star. As it hooks you, the game sneaks in tidbits about astronomy and physics along the way.

Early levels are easy: Set the angle and speed of your star, then let it fly toward its mark. As the levels progress, so does the difficulty. A nearby black hole threatens to consume your target before your star gets there. The gravity from a passing star grabs your sun and throws it off course (or possibly ushers it in the right direction). You must get the lay of the gravitational landscape and decide how to aim your star. Sometimes the right strategy is not intuitive: It might be best to swing around the backside of a neighboring star and get a gravity assist to send your star on its way.

Interacting with the game is simple (even if some missions are not). To aim, just touch your finger to your star and pull back, much like drawing a bow and arrow. Numbers showing the speed and angle help you refine your aim on the often inevitable next try. A grid shows how gravity warps the space near each star, helping you plot your trajectory.



The objective of a new iPad game is to collide celestial objects together to grow a star so large that it collapses to form a black hole.

Underlying the simple, attractive graphics is a simulator that realistically captures the physics of gravity and orbital motion. Success requires thinking through the implications of how all the stars on the field interact and devising creative ways to use gravity to steer your star. Aiming randomly and hoping for the best works, too.

— Christopher Crockett

What the F
Benjamin K. Bergen
BASIC BOOKS, $27.99

BOOKSHELF

Cognitive scientist puts profanity in its place

Few of the expletives discussed in cognitive scientist Benjamin Bergen's new book can be spelled out in this review. But Bergen argues, in a bluntly engaging way, that the largely secret science of swearing reveals much about who we are.

Based on surveys of what people in several Western nations regard as unacceptable, the author divides profanity into four categories: praying (using names of religious figures and religious words, such as holy and damn, in secular ways), fornicating (the F-word and other terms for the sex act and genitals), excreting (everything related to bodily functions, from feces to vomit) and slurring (offensive words for groups based on ethnicity, religion, sexual orientation and so on).

Taboo words not only sound obscene, they have an obscene feel when spoken. A big part of that effect stems from the fact that the words are short and usually start and end with consonants, not softer-sounding vowels, Bergen says. In a study Bergen conducted, participants rated the made-up word "skoom" as more profane than "skoo."

Profanity often plays by its own grammatical rules, the author explains. If every sentence has to have a subject, for instance, then just try to find the subject of that all-purpose epithet "F-you." Perhaps different grammar variants exist for particular purposes, including swearing, he speculates.

Bergen concludes by critiquing studies that have allegedly shown that the more children hear profanity, the more aggressive and potty-mouthed they become. Children are more resilient to profanity than they're often given credit for, he says. Hearing a parent mutter a swear word falls far short of the reported harm to young children caused by exposure to violent images or verbal abuse, the author contends.

Slurs are an exception, Bergen writes. In experiments, people who overhear profane words for African-Americans or gay people tend to regard members of those groups as less human and keep their distance from them. Children who were called antigay slurs by middle-school peers also report high levels of anxiety and depression.

Banning slurs would only increase their power to hurt and offend, Bergen predicts. For that reason, adults should resist knee-jerk impulses to suppress any mention of words deemed especially vile. Instead, he advises, focus on addressing people with words they prefer and judging others more by their actions and intentions than their word choices.

Some prospective readers may avoid this book because of its subject matter. That would be a gosh-darned shame.

— Bruce Bower

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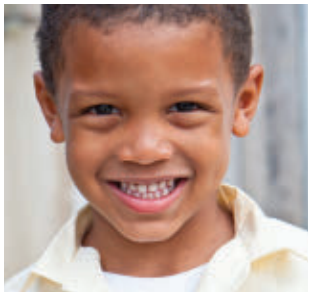
***Science News for Students* (sciencenewsforstudents.org)** is an award-winning, free online magazine that reports on research and new developments across scientific disciplines for inquiring minds of every age from middle school on up.

Even some Olympic athletes cheat with drugs

Athletes have been trying to improve their performance with various illegal substances since at least the time of the ancient Greeks (who used things such as strychnine to run faster and fight better). Called doping, this type of cheating "is a constant battle," notes Malene Lindholm of Sweden's Karolinska Institute, "especially in elite sports." Doping with amphetamines after World War II has given way to steroids and now, possibly, "gene doping." This last tactic could help the body make more of an endurance-enhancing protein call EPO. But scientists have been escalating their own war on doping and are now scouting out signs of such cheating — including genetic tweaks. — *Sarah Zielinski*

Read more: sciencenewsforstudents.org/olympics



Something in plastics may be weakening kids' teeth

Over the last two decades, the share of children with defective tooth enamel has been rising. It "now affects 15 to 20 percent of children 6 to 9 years old," says Sylvie Babajko of the French National Institute of Health and Medical Research in Paris. A chemical used to make many plastics could be partly to blame, her team now concludes. The researchers showed that the chemical, BPA, can trigger the same problem in lab rats that had been showing up in children. BPA is present in many foods (from packaging), rubs off of many store receipts and is an ingredient in some sealants applied to kids' teeth. — *Elizabeth Grossman*

Read more: sciencenewsforstudents.org/bpa-teeth

Got milk? Roach milk could be a new superfood

Cows, buffalo, goats and sheep provide most of the world's milk today. But one day, people could be sipping milk from cockroaches, if some scientists get their way. Pacific beetle cockroach moms (molted shell of one of these roaches shown below) feed their developing young a milklike nutrient. Using crystallography on its proteins, chemists have shown that the roach milk is "three times more nutritious than cow's milk and four times more nutritious than buffalo's milk," says biologist Barbara Stay of the University of Iowa in Iowa City. The researchers would like to see cockroach milk turned into a protein supplement to feed hungry people. — *Dinsa Sachan*

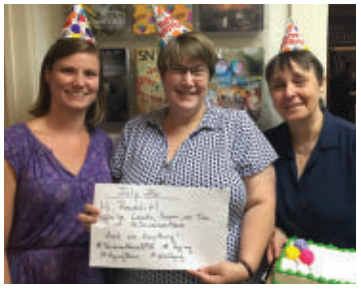
Read more: sciencenewsforstudents.org/roach-milk

CLOCKWISE FROM TOP: JACOB AMMENTORP LUND/ISTOCKPHOTO; KEN-ICHI UEDA/FLICKR (CC BY-NC 2.0); BLACQBOOK/ISTOCKPHOTO

JULY 23, 2016

Age-old questions

What is aging, exactly, and when does it start? Has the first person who will live to age 150 already been born? *Science News* writers **Laura Sanders**, **Tina Hesman Saey** and **Susan Milius** (below) answered these aging questions and others online in a Reddit Ask Me Anything. Read more at bit.ly/SN_Aging



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Live long and prosper

In Science News' *special report on aging* (SN: 7/23/16, p. 16), *writers* ***Laura Sanders***, ***Tina Hesman Saey*** *and* ***Susan Milius*** *explored the latest research — from the evolution of aging in the animal kingdom to scientists' quest to delay the process in humans' bodies and minds.*

"I would very much like to know how research into aging may benefit people who are middle-aged or elderly now?" asked **leftysrule200** in a Reddit Ask Me Anything about the special report. "Is there any research that can result in treatments in the very near future, or are the real-world applications only going to be visible in the distant future?"

Middle-aged and elderly people will be the first to benefit from aging research, **Saey** says. "A clinical trial using the diabetes drug metformin as an antiaging therapy will begin soon. That drug will be tested on healthy people aged 60 and older," she says.

Sanders cautions that most antiaging treatments are still a long way off. But various studies in rodents and humans provide potential clues to aging's secrets. Blood from young rats, for instance, has been shown to rejuvenate the bodies and brains of old rats. Based on those findings, a clinical study in humans is now under way that is looking at the effects of plasma from young donors on the brains of people with Alzheimer's. "If scientists could pinpoint the compounds that give young blood its power, then they could presumably develop drugs that mimic that process," **Sanders** says.

In the meantime, people may be able to slow the effects of aging by leading a healthy lifestyle. **Sanders** points to a long-term study of middle-aged women in Australia. Women who were more physically active had sharper memories 20 years later, the researchers found. Until proven antiaging treatments are available, "it seems that keeping the body physically active and strong is one of the best ways to keep your brain sharp as you age," she says.

Dino spills its guts

Tiny tracks discovered in the blackened stomach contents of a 77-million-year-old duck-billed dinosaur fossil suggest gut parasites infected dinosaurs, ***Meghan Rosen*** *reported in "Parasites wormed way into dino's gut"* (SN: 7/23/16, p. 14).

Online reader **Jim Stangle Dvm** thought the worms may not have been parasites at all. "It is more likely that the tunnels were formed by a scavenger worm [after the dino had died]. Still I think the findings are way cool!" he wrote.

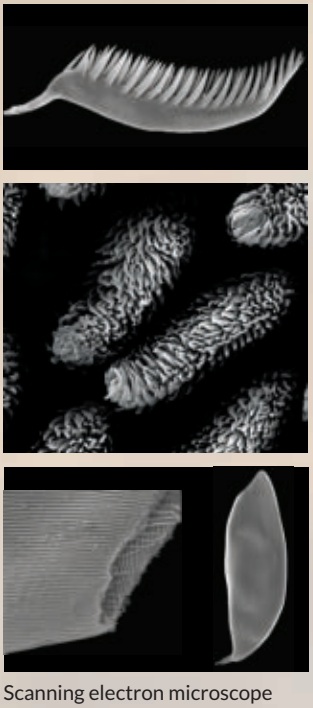
It's hard to say definitively whether the burrows were made by parasites or not, says paleontologist **Justin Tweet**. Scavenger worms could have tunneled through the gut after the dino's death, but his team found only one type of worm burrow "which suggests that either only one kind of scavenger had access to the carcass," or "that these burrows were an inside job," **Tweet** says.

That's no moon!

A recently discovered asteroid appears to orbit Earth, but that's just an illusion. The asteroid orbits the sun, but its constant proximity to Earth makes it the planet's only known quasisatellite, ***Christopher Crockett*** *reported in "Say What? Quasisatellite"* (SN: 7/23/16, p. 5).

Reader **Mike Lieber** wondered if the moon could also be a quasisatellite. "The gravitational attraction of the sun on the moon is twice that of the Earth," he wrote. "It seems that the apparent looping of the moon around the Earth is also illusory."

The moon is a true satellite, **Crockett** says. If the sun were to disappear, the moon would continue orbiting Earth. "The moon is within Earth's 'Hill sphere,' the volume of space in which Earth's gravity is the dominant influence," he says. "The strength of the gravitational force isn't as important as by how much it changes from one place to another." Given the moon's proximity to our planet, Earth prevails. "The moon orbits Earth and the Earth-moon system orbits the sun," he says.



Scanning electron microscope images reveal the miniature scales that produce white (top), red or yellow (middle) and blue (bottom; whole structure at right, detail at left) colors in the hairlike scales that adorn a peacock spider's rear end.

Tiny structures give a peacock spider its radiant rump

Male peacock spiders know how to work their angles and find their light.

The arachnids, native to Australia, raise their derriere — or, more accurately, a flap on their hind end — skyward and shake it to attract females. Hairlike scales cover their bodies and produce the vibrant colorations that make peacock spiders so striking.

Doekele Stavenga of the University of Groningen in the Netherlands and his colleagues collected *Maratus splendens* peacock spiders from a park outside Sydney and zoomed in on those scales.

Using microscopy, spectrometry and other techniques, the team found that the spiders' red, yellow and cream scales rely on two pigments, 3-OH-kynurenine and xanthommatin, to reflect their colors. Even white scales contain low levels of pigment. Spines lining these scales (inset, top and middle) scatter light randomly, giving them slightly different hues from different angles.

Blue scales are an entirely different story. They're transparent and pigment-free. Instead, the scales' architecture reflects iridescent blue and purple hues. Each peapodlike scale (inset, bottom) is lined with tiny ridges on the outside and a layer of threadlike fibers on the inside. Fiber spacing may determine whether scales appear more blue or more purple.

Whether peacock spiders' eyes can actually see these posterior patterns is an open question, Stavenga and his colleagues write in the August *Journal of the Royal Society Interface*. Given that other jumping spiders see at least three color ranges, it seems unlikely that such vivid come-hither choreography plays out in black and white. — *Helen Thompson*

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