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Muscles Controlled by Light

Ancient DNA Reveals Europe's First Culture Clash

Earth's Distant Cousin

Quartet of Quarks

# CRACKING EUROPA'S SHELL

Innovators test ways to penetrate the Jupiter moon's frozen surface

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# ScienceNews

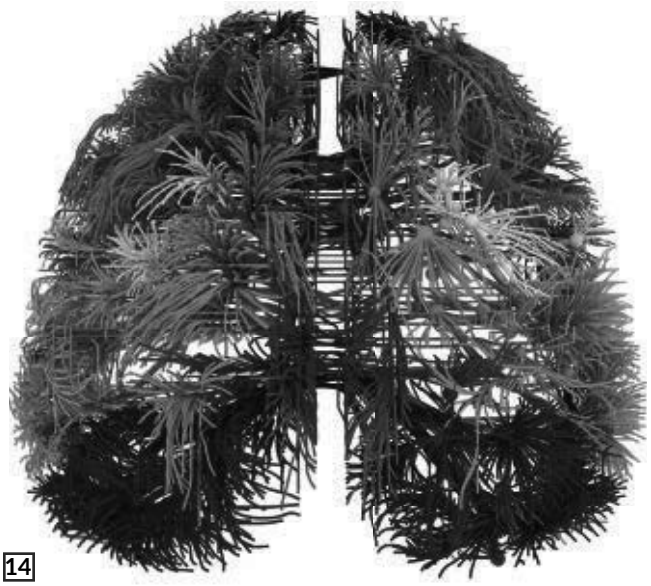
26

## Features



## News





14

CLOCKWISE FROM TOP: T. HARTMANN/PALEOGENETICS LABORATORY, MAINZ, GERMANY; EXACTOSTOCK/SUPERSTOCK; ALLEN INSTITUTE FOR BRAIN SCIENCE

4

## Departments



**COVER** One proposal for penetrating Europa's frozen surface would deploy a robot to melt its way through the ice. *Stone Aerospace © 2014*

# Prying tales from ancient DNA and a far-away moon

Farming didn't originate in Europe. It was an import. But over thousands of years, it steadily took hold and transformed the landscape of the continent. Along with it came a transformation of Europe's population.

Since the 1970s, genetics has been used to shed light on the spread of agriculture from the Middle East, as well as to look into the ancestry of modern Europeans. But only in the last decade has it become possible to study the genes of prehistoric people themselves. As molecular biology writer Tina Hesman Saey recounts on Page 26, DNA painstakingly recovered from the skeletons of dozens of ancient Europeans is providing new details about the region's prehistory. So far, the tale told by analyses of mitochondrial DNA and, increasingly, the entire genomes of early humans is a complicated one. It looks like migrants brought farming technology with them, but there's little evidence of local hunter-gatherers taking it up and changing their ways. Some studies point to groups of farmers and foragers living near each other for a thousand years. The farmers' DNA showed some signs of having mixed with hunter-gatherers', but the mixing was only one way: The hunter-gatherers had no farmer DNA.

What's most intriguing about these studies is the questions they raise about what life might have been like 5,000 years ago. How did these two groups of people think about and interact with each other? With fear, indifference, curiosity? Was hunting actually a more (or at least equally) successful living than farming, despite our modern bias that farming is superior? How do you explain the eventual demise of hunter-gatherers in much of Europe — was it violence, disease or something else entirely?

Answering some of these questions could shift our views of Western civilization itself. On Page 20, another story addresses an equally profound question: Is Earth the only outpost for life in the solar system? Jupiter's moon Europa is considered by many to be the other local spot most likely to host life. The problem, and hope, is its ice-capped ocean. Staff writer Meghan Rosen reports on efforts to build devices to pierce the thick ice and probe the waters below. Imagine the tales that await. — *Eva Emerson, Editor in Chief*



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SANDY SCHAEFFER


Excerpt from the May 16, 1964, issue of *Science News Letter*

50 YEARS AGO

## Anti-Leukemia Vaccine Reported Hope of Future

An anti-leukemia vaccine to prevent cancer of the blood-forming organs was reported as a possibility if, as experiments indicate, virus-like particles are proved to cause malignancy. The development of such a vaccine is not foreseeable in the immediate future, Dr. W. H. Murphy of the University of Michigan, Ann Arbor, said, but there is basis for "cautious optimism, rather than the stark pessimism which has been the feeling to date." A leukemia-like disease has been produced in mice by virus-like particles taken from children with leukemia.

**UPDATE:** While no preventive vaccine has come to pass, research on using leukemia vaccines as treatments has yielded some promising results. In 2013, researchers reported using personalized vaccines containing patients' own cancer cells, irradiated to inactivate them, to stimulate the immune system to mop up remaining cancer cells after chemotherapy for chronic lymphocytic leukemia.

IT'S ALIVE

## How to milk a naked mole-rat

Most naked mole-rats never have babies, but a queen can have three litters a year with a dozen pups each.

For the sake of science, Olav Oftedal has milked bats, bears and a lot of other mammals. But a naked mole-rat was something new.

"The thin, hairless skin is so translucent that you can see the milk accumulating in the mammary glands," says Oftedal, of the Smithsonian Environmental Research Center in Edgewater, Md. For once he could tell exactly

THE –EST

## Loblolly sets record for biggest genome

A giant among trees, the loblolly pine boasts the largest set of genetic blueprints published to date. Even though it's big on DNA letters, the pine's instruction book lacks originality: About 82 percent is made of repeating DNA elements. Researchers first reported deciphering loblolly's roughly 22 billion letters, or bases, at a conference in 2013 (*SN Online: 5/16/13*). Now, the team has provided analysis of the loblolly genome in three papers, two in the March issue of *GENETICS* and one in *Genome Biology*. Loblolly (*Pinus taeda*) took the title of largest genome away from wheat, which has 17 billion base pairs. The conifer can grow to 30 meters tall and is the source of most paper products in the United States. The new results reveal several spots in the pine's genome that are linked to resistance to pathogens. Continuing to study those regions could help scientists understand how loblollies and other pines battle disease. —*Ashley Yeager*

FROM TOP: EXACTOSTOCK/SUPERSTOCK; DAVID STEPHENS/BUGWOOD.ORG

which glands were full.

"In most small mammals," he says, "the big problem is you have hair that can wick the milk away. You have a capillary tube, and you're trying to catch the milk so it can't touch any hair." Naked mole-rats, though, are helpfully hairless.

Oftedal collected milk from the queens of *Heterocephalus glaber* colonies at the Smithsonian's National Zoo. In colonies of dozens or hundreds of mole-rats, only the queen reproduces.

The species is one of very few mammals that live in large, extremely social groups, much like honeybees, with a queen producing and nursing all the young. A colony's top female can have more than 900 offspring in a lifetime and meets their nursing needs by producing about half of her body weight in milk each day.

Just what's in that milk intrigued Oftedal and Wendy Hood of Auburn University in Alabama, who studies milk in all its variety. (Rhinos have virtually fat-free milk, and some seal milks top 60 percent in fat content. That means the milk is something like four times richer than Ben & Jerry's ice cream, she says.)

**Average percent fat content in milk**

| | | |
|---|---|---|
| 0.2 Rhino | 3–5 Human | 4.2 Naked mole-rat |
| 27 House mouse | 41 Blue whale | 61 Hooded seal |

When Hood got the milk samples, no, she didn't take a sip out of curiosity. "If I were to taste it, that would be that much less we'd have to analyze," she says.

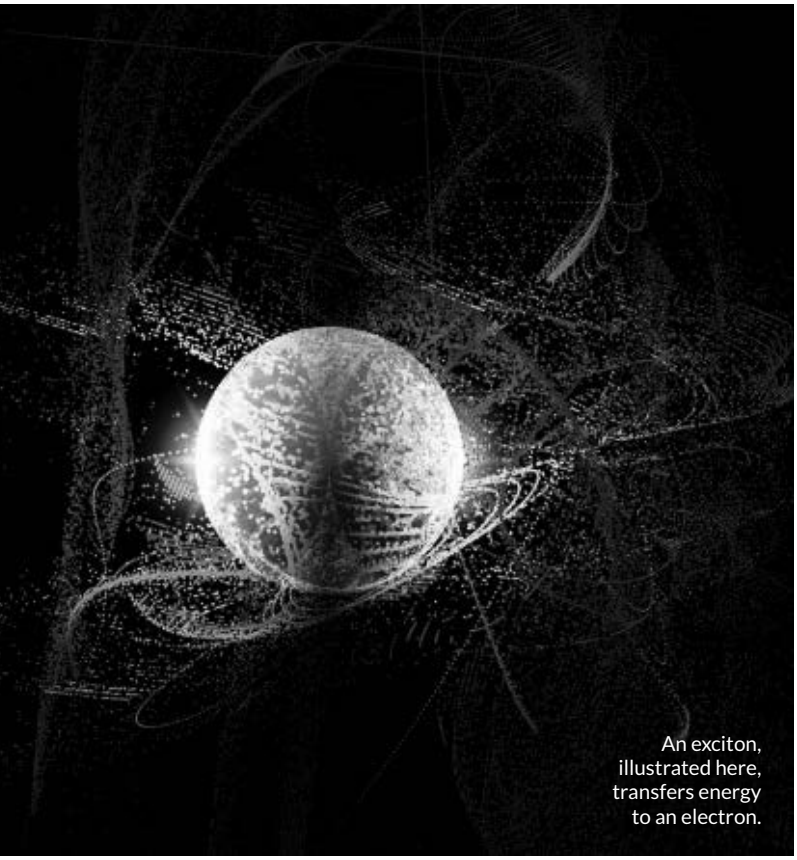
The milk turned out to be remarkably watery for a rodent: 83 percent water versus 59 percent for the house mouse, the team reported March 13 in the *Journal of Zoology*. It was also low in fat content: about 4.2 percent, far skinnier than house mouse milk at 27 percent fat.

Naked mole-rats live in hot arid places, so Hood proposes that the extra water may be needed to keep young hydrated. As unusual as naked mole-rat milk is for a rodent, in both fat and water content it's close to cow's milk and human breast milk. —*Susan Milius*

SAY WHAT?

## Exciton *EHK-seh-tahn*\ *n.*

Getting excited can kick a person's energy to a higher level. At the nanoscale, strange almost-particles called excitons do the same trick. In a crystal, thin film or even some liquids, an incoming particle of light can slam into an electron, bumping it to a higher energy level and leaving a hole at the energy level where the particle had been. The exciton is the excited electron paired with the resulting hole and can move energy in two ways: by physically hopping to a new molecule or transferring energy almost like an antenna transmitting a signal. Either way, the movement is quick, with the longest-lasting exciton existing for just a few milliseconds. Even though excitons don't last long, scientists were recently able to make images of how the quasiparticles moved (*SN Online: 4/16/14*). Investigating excitons' ability to kick around nanoscale energy could improve scientists' understanding of photosynthesis and lead to better solar cells, LEDs and semiconductor circuits. —*Ashley Yeager*



An exciton, illustrated here, transfers energy to an electron.

STEF SIMMONS, UCL MATHEMATICAL AND PHYSICAL SCIENCES/FLICKR (CC-BY 2.0)

# News

ATOM & COSMOS

## Earth-sized planet may host water

### Alien world is smallest yet found in a star's habitable zone

A planet similar in size to Earth on which liquid water could exist and four other worlds orbit the cool red star Kepler-186, as seen in an artist's illustration.

**BY CHRISTOPHER CROCKETT**

Earth, meet your distant cousin. The Kepler space telescope has turned up a potentially water-bearing world nearly the size of our planet. The exoplanet is the smallest one found in any star's habitable zone, a temperate region surrounding a star that is suitable for liquid water.

About 10 percent larger than Earth, the planet, Kepler-186f, orbits an M dwarf, a red star that is smaller, cooler and fainter than the sun. The planet circles the star, Kepler-186, once every 130 days in an orbit slightly smaller than Mercury's, astronomer Elisa Quintana of the NASA Ames Research Center in Moffett Field, Calif., and colleagues report in the April 18 *Science*.

The star, which is 490 light-years away in the Cygnus constellation, also hosts four other roughly Earth-sized planets. Previously discovered by Kepler, the other planets are much closer to the star, whipping around in as little as 3.9 days. Each planet was found using the tiny dips in starlight it creates when it passes in front of, or transits, Kepler-186.

"M dwarfs are now becoming everybody's darlings," says Jill Tarter, former director of the Center for SETI Research in Mountain View, Calif. Potentially habitable planets are easier to find around M stars because the habitable zones are relatively close to the cool stars. Close planets are more likely to transit their stars than more distant ones.

M stars are also the most common in the Milky Way, making up roughly three-quarters of known stars. "If we find that Earth-sized planets around habitable zones of M stars are common," says coauthor Thomas Barclay, also a NASA Ames astronomer, "that means they're common throughout the galaxy."

But, he adds, "Just because it's in the habitable zone doesn't mean it's habitable." Since the planet orbits a distant, faint star, follow-up observations will be difficult. Without examining the planet's atmosphere — or even knowing whether it has one — researchers can't be certain whether or not liquid water exists on the surface.

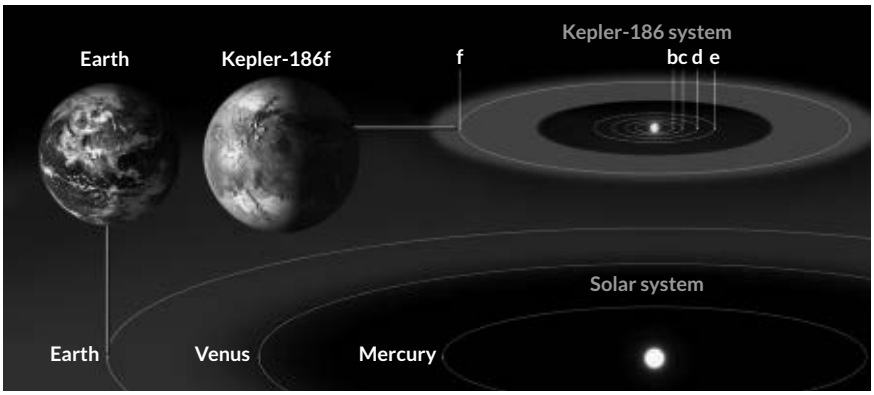
Even if the planet has liquid water, it may not be suitable for life. Some M stars are prone to violent flares of ultraviolet and X-ray radiation. And planets orbiting within an M star's habitable zone may orbit so closely that one side eternally faces its star, generating climate extremes. But Kepler-186f has some advantages, Barclay says. Its sun is relatively quiet for an M star, and the planet orbits far enough away that it may escape the brunt of flares. That farther distance might also allow the planet to rotate, which would help circulate heat.

While a flare might wipe out life or strip a planet of its atmosphere, the fluctuating environment around an M star could actually provide some benefits. "Change can be catastrophic," says astrobiologist Margaret Turnbull of the Global Science Institute in Antigo, Wis., but it can also be "inspirational for life." Earth's cataclysmic collisions with asteroids, for instance, not only triggered mass extinctions but also opened up new niches in which life could flourish.

If Kepler-186f is home to life, it would live in an environment completely foreign to Earth. M dwarfs emit mostly red and infrared light. On Earth, plants harvest higher-energy wavelengths of light for photosynthesis. Some cyanobacteria, however, perform photosynthesis with light slightly redder than visible light.

Although further observations of the distant planets found by Kepler are tough, Barclay says, Kepler data will help engineers design next-generation space telescopes and know where to point them. The Transiting Exoplanet Survey Satellite, scheduled to launch in 2017, will look for planets around M stars closest to Earth. The James Webb Space Telescope, due to launch in 2018, will examine those planets' atmospheres. "There's no reason that we couldn't be surrounded," Turnbull says, by planet-bearing stars. ■

Kepler-186f, a roughly Earth-sized planet shown in an artist's illustration, orbits within its star's habitable zone (green), a region where liquid water can exist. Because the star Kepler-186 is much cooler and fainter than the sun, its habitable zone is more compact than the solar system's.




BOTH: NASA AMES, SETI INSTITUTE, JPL-CALTECH

GENES & CELLS

# Activity in bone-growth genes may set humans apart from Neandertals

## Methylation differs between people and extinct hominids

**BY TINA HESMAN SAEY**

Extinct human cousins may have used some of the same genes differently than modern people do, a genetic analysis reveals.

Compared with living people, Neandertals and ancient Siberians known as Denisovans had slightly different patterns of DNA methylation — a chemical modification of DNA that doesn't change the information in genes but helps control gene activity. Liran Carmel, an evolutionary geneticist at the Hebrew University of Jerusalem, and colleagues found that the extinct hominids had lower activity in a group of genes called the *HOXD* cluster, which governs limb growth. Low *HOXD* activity could account for Neandertals' stocky build, the team reports April 17 in *Science*.

When and how strongly genes are turned on or off plays a big role in determining how an organism looks and behaves. To figure out whether modern humans use their genes differently from extinct human groups, the researchers had to find a record of gene activity in Neandertal and Denisovan DNA. The team combed previously sequenced ancient DNA for signs of methylation.

DNA methylation influences gene activity, usually by turning genes off. It is one of the most likely chemical marks to be preserved in the DNA record because it involves tacking a methyl group — a carbon atom surrounded by three hydrogen atoms — directly onto the DNA base cytosine. Over time, unmethylated cytosine spontaneously degrades into another base, uracil. But if the cytosine carries a methyl group, it instead transforms into thymine.

Carmel's group looked for places in the ancient DNA where cytosines had morphed into thymines. The researchers then compared methylation patterns from the Neandertal and the Denisovan DNA with that of modern humans.

Overall, the three groups had similar DNA methylation patterns, the researchers found. But there were a few notable exceptions, including heavier methylation of genes in the *HOXD* cluster in the extinct hominids than in present-day people. Heavier methylation means those genes likely had lower activity. Low activity of some genes in this cluster has been previously linked in humans or mice to bigger bones, shorter limbs, broader elbows and knees and more robust hands and fingers — all traits that distinguish Neandertals from modern humans.

> Comparing methylation patterns may help scientists learn what made modern humans successful.

Denisovans had *HOXD* methylation patterns more similar to Neandertals' than to modern humans'. That finding, along with Denisovans' unique methylation characteristics, may help reveal something about what Denisovans looked like. Scientists have never found a complete Denisovan skeleton.

In addition, the technique for comparing methylation patterns may help scientists learn what made modern humans successful while the other groups died out, says Sarah Tishkoff, an evolutionary geneticist at the University of Pennsylvania in Philadelphia.

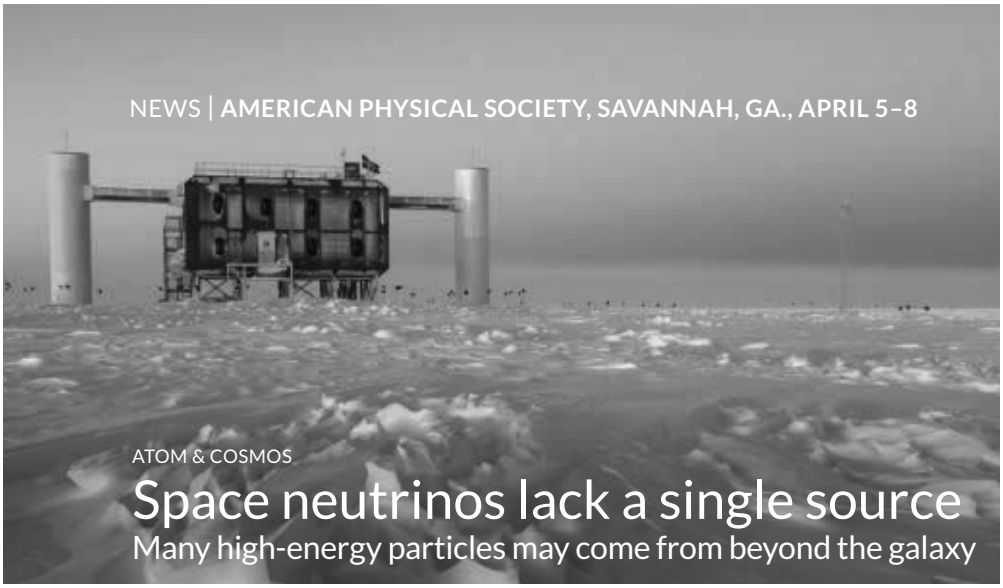
"It's an amazing technical feat," she says. "I'm impressed."

Tishkoff would also like to know whether Neandertal versions of genes carried by some modern humans are methylated differently than other human versions of those genes are. If so, those changes may influence susceptibility to diseases.

Other researchers say the work falls short of demonstrating biological relevance of the methylation patterns. "They haven't really proven anything," says Andrew Sharp, a genomics researcher at the Icahn School of Medicine at Mount Sinai in New York City. Scientists are still learning how chemical modifications, including DNA methylation, influence an organism's development. It may be too soon to draw firm conclusions about how ancient hominids' methylation affected their physiology, he says.

Environmental factors, such as nutrition and exercise, can also influence how genes are methylated, says molecular biologist Adrian Briggs of AbVitro, Inc., a biotechnology company in Boston. The gene activity difference the researchers uncovered may reflect the different lifestyles of Neandertals and Denisovans compared with that of present-day people. To determine whether there is a meaningful biological difference encoded in the DNA methylation patterns, he says, scientists should conduct similar analyses on humans who lived at the same time as the Neandertals and Denisovans, some 50,000 years ago. ■

Chemical modifications of DNA that may have dialed down the activity of genes related to limb growth may help explain why Neandertals (front) had stockier frames than modern humans (back) do.



The IceCube Laboratory near the South Pole collects data from underground sensors and picks out the detections most likely to have been triggered by neutrinos from deep space.

ATOM & COSMOS

# Space neutrinos lack a single source

## Many high-energy particles may come from beyond the galaxy

**BY ANDREW GRANT**

High-energy neutrinos from as far as the edge of the observable universe are pelting Earth from all directions, researchers announced April 7. The conclusion is based on data from IceCube, the enormous underground experiment near the South Pole that detected the first high-energy spaceborne neutrinos in 2013.

"It's a very important step," said astrophysicist Keith Bechtol of the University of Chicago. "IceCube neutrinos open a window into the very distant and high-energy universe that is extremely difficult to access by any other means."

Neutrinos, unlike every other subatomic particle, provide that window because they are electrically neutral and rarely interact with matter. By detecting these particles and charting the directions they come from, IceCube scientists aim to identify the sources of neutrinos: star-forming galaxies, supermassive black holes or perhaps some unknown violent objects. These sources can accelerate neutrinos and other subatomic particles to energies far greater than any human-made machine could achieve.

For three years, IceCube's strings of sensors stretching as deep as 2.5 kilometers below the surface of Antarctica have detected subtle flashes of light created when neutrinos and other particles collide with atoms. Last year, IceCube researchers identified 28 high-energy neutrinos from all directions that are almost certainly from outside the solar system (*SN: 12/28/13, p. 6*). The researchers have since found nine more, including the highest-energy neutrino ever detected (*SN Online: 4/7/14*).

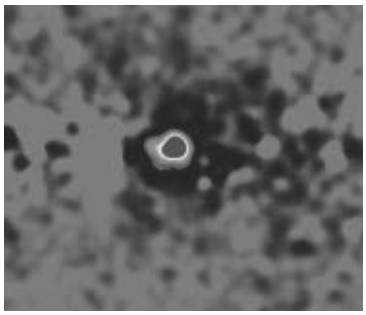
To complement this painstaking search, Christopher Weaver, a physicist at the University of Wisconsin–Madison, cast a wider net for the larger population of slightly lower-energy astronomical neutrinos. His approach relied on selecting particles that fell from the skies of the Northern Hemisphere, whizzed through Earth's interior and arrived at IceCube from below. Only neutrinos, and not other particles that often trigger IceCube's sensors from above, can make it through Earth's dense crust and core.

Weaver also limited his search to detections at a specific energy — about 100 trillion electron volts — so that the number of space neutrinos wouldn't be dwarfed by neutrinos produced in the atmosphere. (IceCube's sensors can't distinguish between the two.)

That left Weaver with about 35,000 neutrinos, at least some of which began their journeys beyond the solar system. He tracked the directions they came from and found no clustering in any particular part of the sky, which confirms previous analyses and suggests that no local source is primarily responsible for the neutrinos whizzing by Earth. "Most likely a lot of them are from beyond the galaxy," said Nathan Whitehorn, a Wisconsin astrophysicist who worked with Weaver. "It's quite possible they come from the edge of the universe." ■

ATOM & COSMOS

## Galaxy's gamma-ray glow may expose elusive dark matter



An unexpectedly bright glow of gamma rays at the center of the Milky Way may be the signature of suicidal dark matter, according to an analysis reported April 6.

Dark matter dominates the mass of galaxies, including our own, but its composition remains a mystery. Many theorists think that dark matter comes in the form of particles that annihilate each other and release energy when they collide. If that's the case, then galaxies should emit large amounts of high-energy gamma radiation, particularly at their centers where the density of dark matter is greatest.

That's what a team led by Dan Hooper of Fermilab in Batavia, Ill., found in data from NASA's Fermi Gamma-ray Space Telescope. After subtracting known sources of gamma rays, such as rapidly spinning dead stars called pulsars, the team was left with radiation (nonpurple colors, left) that is brightest at the galaxy's center and extends outward at least 5,000 light-years.

Hooper's team is not claiming a discovery of dark matter: Unidentified pulsars and other mundane objects could have produced the gamma rays. But the study offers a rare clue in the quest to understand dark matter. — *Andrew Grant*

FROM TOP: SVEN LIDSTROM, ICECUBE/NSF; T. LINDEN/UNIV. OF CHICAGO


# EVERY DAY, *I am a Red Raider*

*Andrew Alleman has long been intrigued by science. His passion for environmental sciences and engineering led him to Texas Tech, where he is majoring in environmental engineering. He's studied in Brazil and held an internship with the Environmental Protection Agency in Oregon. After finishing his education he plans to work on restoring coastal systems around the world.*

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BODY & BRAIN

# Light helps move paralyzed legs

## Blue flash activates neurons in damaged mouse muscles

**BY LAURA SANDERS**

Scientists can now control muscles with light. By combining advances from several fields, researchers created neurons that could be activated with light and implanted the cells onto damaged nerves in mice. A brief flash of blue light spurred formerly dormant mouse muscles to life, the team reports in the April 4 *Science*.

The results demonstrate how the disparate fields of stem cell biology and optogenetics, which uses light to activate specially engineered cells, might form the basis of therapies for people with movement problems. One near-term goal is to help people with nerve damage regain the ability to control breathing muscles, says study coauthor Linda Greensmith of University College London. Light-triggered motor neurons might, for instance, reinstate the ability to breathe or swallow in people with amyotrophic lateral sclerosis, also known as Lou Gehrig's disease, who lose control of their muscles.

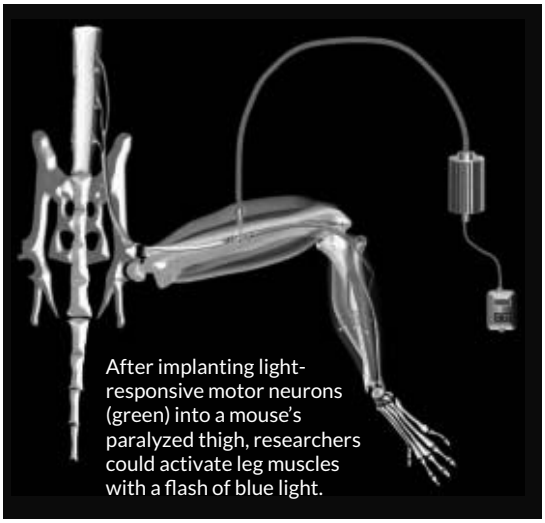
Greensmith and colleagues engineered stem cells to respond to blue light. Next, the team coaxed these cells to form motor neurons, which convey movement signals from the brain and spinal cord to muscles. The team implanted these light-responsive motor neurons into the paralyzed thighs of mice. The scientists had previously squeezed a section of the nerve that shuttles information between the spinal cord and leg muscles, called the sciatic nerve, to cut off neural signals.

The implanted neurons grew long tendrils called axons that reached muscles normally controlled by the nerve. Then the neurons were turned on. "They were completely silent, and then we shine a blue light on them and they spark to life," Greensmith says. (The light entered through an incision on the thigh.)

Different light signals caused different movements. Short, single pulses of light induced twitches; longer, repeated pulses caused sustained muscle contractions.

The ability to selectively control implanted neurons is important, says neurosurgeon Robert Brownstone of Dalhousie University in Halifax, Canada. "When you think about stem cells, everybody thinks that they're magic," he says. But those cells are unlikely to form the correct connections. Failing to make the right connections to neurons higher up in the chain of signals from the brain would leave motor neurons deaf to the instructions that say which muscles to activate.

Other research has relied on electrical signals to activate implanted neurons. But electrical stimulation isn't specific: It activates every neuron around, including those that carry information back to the nervous system, creating a side effect



After implanting light-responsive motor neurons (green) into a mouse's paralyzed thigh, researchers could activate leg muscles with a flash of blue light.

BARNEY BRYSON

BODY & BRAIN

# Potential measles drug tests well

## Enzyme-blocking compound saves ferrets from related virus

**BY NATHAN SEPPA**

There's no treatment for measles, but an experimental compound might do the trick by bogging down a key viral enzyme, a study of ferrets finds. When given to animals infected by a virus similar to the one that causes measles, the compound prevented illness.

"This is still a ways away from human testing," says Alan Hinman, a physician at the Task Force for Global Health, a nonprofit organization in Decatur, Ga. "But it's exciting to see this. I think it has potential to be really useful."

Measles is caused by a pathogen in the genus *Morbillivirus*. The virus relies on an enzyme called RNA polymerase to infect and spread in a host. Because mammals don't have the same enzyme, researchers are developing experimental compounds that target that RNA polymerase. Scientists report in the April 16 *Science Translational Medicine* that one such compound, called ERDRP-0519, inhibits measles virus in lab tests.

Another morbillivirus causes distemper in dogs. Since that disease is lethal to ferrets, the researchers developed an oral version of ERDRP-0519 and tested it in the animals. The team exposed three ferrets to the distemper virus and, three days later, started giving them two doses daily for two weeks. All three survived.

The compound thwarted viral replication, allowing the animals to launch a prompt immune assault on the virus. The animals' immune systems may even retain some "memory" that would prevent distemper in the future, but this isn't yet established, says study coauthor Richard Plemper, a virologist at Georgia State University in Atlanta.

All other ferrets exposed to the virus died within a few weeks, including nine that received ERDRP-0519 starting a few days before being infected. The timing is significant. Plemper says the effectiveness of the compound rests in its ability to stimulate an immune response in the ferrets when the virus is already present and replicating. If the drug attenuates the virus before it gets a foothold in the body, as was the case for animals receiving the compound before infection, he says, "potentially there may never be an initial strong trigger for the immune system."

Targeting viral enzymes is common, says virologist Diane Griffin of Johns Hopkins School of Public Health. "A lot

that may cause discomfort. "The advantage of using light over electrical stimulation is that you can be much more specific," Brownstone says. "You're stimulating only the neurons that you put in."

Many questions remain before the method might be useful in people, Brownstone cautions. In the experiments, cells were implanted three days after injury. In contrast, surgeons would probably want to wait between three and six months to see whether a person with a nerve injury recovers, he says.

New technology also needs to be developed, including a reliable light source that consistently delivers the right type and duration of light. Greensmith's team is also exploring ways to ensure that the implanted motor neurons stay put.

Some diseases, like Lou Gehrig's, might be particularly amenable to light-controlled treatments, Greensmith says. But, she adds, "We're not saying we're going to get people up and walking again." Walking relies on complex patterns of muscle activity. "Breathing, respiration, is a relatively simple function," she says, "and I think it's reasonable to say we could target it using this approach." ■

of antiviral drugs are polymerase inhibitors, but we don't have any for measles."

Plemper says that if ERDRP-0519 succeeds in further testing against the measles virus and is safe in humans, it could work in concert with vaccination to eradicate the disease. In a measles outbreak, health officials try to identify the "index case," the person who introduced measles to an area, Plemper says. Officials then can locate other people exposed to the index case. Those who aren't vaccinated could benefit from treatment with a drug that works like ERDRP-0519 does against canine distemper, he says, limiting new cases and lessening transmission. Measles vaccination typically doesn't work once a person is infected.

Measles kills about 1 in 1,000 infected people. ERDRP-0519 might protect immune-compromised people who are unable to clear an infection, Griffin says, or infants too young to vaccinate. ■

EARTH & ENVIRONMENT

# Carbon dioxide makes fish act drunk

## Wild animals in acid-rich water lose fear of predators' scent

**BY MEGHAN ROSEN**

Carbon dioxide can really mess with fishes' heads. Dissolved in ocean water, the acidic chemical turns timid young reef fish into tipsy little daredevils, researchers report April 13 in *Nature Climate Change*.

The findings are the first to show that carbon dioxide makes wild fish act just as crazy as fish dosed with the greenhouse gas in the lab, says marine biologist Astrid Wittmann of the Alfred Wegener Institute in Bremerhaven, Germany.

"These are pretty major behavioral changes," she says. "They're absolutely surprising."

As $CO_2$ enters the atmosphere, the gas dissolves into the oceans, slowly but steadily dialing up the waters' acidity. In lab tests, fish exposed to $CO_2$–infused waters have hearing and learning problems and odd behavior issues: They seek out predators' odors (*SN Online: 7/6/10*).

Fish in the wild behave the same way, says study coauthor Danielle Dixson, a marine ecologist at Georgia Tech in Atlanta. Damselfish and cardinal fish living in $CO_2$–rich waters ventured farther from home and hid out less in their coral shelters than did fish from low-gas waters, she and colleagues found.

"The fish behave kind of like they're drunk," she says. "They're extra bold and extra aggressive, and they make bad decisions."

If oceans continue soaking up $CO_2$, she adds, by the end of this century, reef fish all over may act more addled than their ancestors.

D. DIXSON

Young damselfish living in carbon dioxide–rich waters act oddly around predator odors compared with fish in areas with less $CO_2$ dissolved in the water.

Dixson, coauthor Philip Munday of Australia's James Cook University and colleagues wondered whether fish used to living in $CO_2$–rich water might acclimate to the extra acidity, just as humans can acclimate to high elevations.

The team boated out to Milne Bay in Papua New Guinea to study fish living near $CO_2$ seeps, or bubble reefs — natural spots where the gas leaks from the seafloor. The water in these bubbly zones holds about 1,000 parts per million of $CO_2$, more than twice as much as the water in nearby reefs without seeps. That level matches the average amount of $CO_2$ scientists predict oceans will hold by 2100, Dixson says.

The researchers placed fish one by one in a shallow chamber and gently pumped in side-by-side streams of water seasoned with different smells to create two areas in the chamber with distinct scents. Fish from the bubble reefs basked in water laced with predator odor, Dixson says, while fish from less acidic waters steered clear of the scary scent.

"If fish can't tell the difference between predators and nonpredators," she says, "there's a serious problem."

Fish use odors to glean clues about potential mates, nearby danger and what's for lunch. So fish with a distorted sense of smell are blinded to the everyday cues of their watery worlds.

But researchers don't think the $CO_2$–exposed fish have anything wrong with their noses. In previous studies, the team has traced laboratory animals' odd behaviors to problems in the brain.

"We were hoping that the fish would be able to cope with high levels of carbon dioxide," says study coauthor and reef ecologist Katharina Fabricius of the Australian Institute of Marine Science in Townsville. "But that was not the case. These fish are mad — they lose their ability to think straight." ■

ATOM & COSMOS

# Exotic particle packs a foursome of quarks

Tetraquarks could help physicists understand the universe's first generations of matter

**BY ANDREW GRANT**

The rediscovery of an exotic particle provides the best evidence yet that quartets of quarks exist in a universe dominated by two- and three-quark matter.

By validating the particle's existence, says lead author Tomasz Skwarnicki, a physicist at Syracuse University in New York, "we are automatically proving that four-quark states exist."

Quarks, one of the fundamental constituents of matter, never exist alone. Held together by particles called gluons, quarks and their antimatter counterparts, antiquarks, cluster in threes to form baryons (including protons and neutrons) and in pairs to produce mesons (including pions and kaons).

But in 2003, physicists discovered a bizarre particle called X(3872) that didn't seem to fit in either category. Based on its mass (3,872 million electron volts) and the particles it decayed into, X(3872) appeared to consist of a charm quark, an anticharm and at least two other quarks.

Since then, scientists trying to investigate the particle have inadvertently discovered other potential tetraquarks. One controversial example is Z(4430). Its discovery in 2008 made a splash because unlike X(3872), it has an electric charge. Because the charges of its charm and anticharm quarks cancel each other out, and because researchers had ruled out that Z(4430) was a three-quark particle, many physicists concluded Z(4430) must contain four quarks. However, some people disputed Z(4430)'s existence.

Now an experiment has confirmed the particle exists, says Indiana University Bloomington physicist Matthew Shepherd. Analyzing the subatomic shrapnel that led to the discovery of the Higgs boson (*SN: 7/28/12, p. 5*), Skwarnicki and others at the Large Hadron Collider sifted through more than 25,000 meson decays and found overwhelming evidence for a negatively charged particle with a mass of 4,430 million electron volts. The results appeared April 7 at arXiv.org.

Skwarnicki and colleagues are confident that Z(4430) is a single particle made up of four quarks – most likely a charm, anticharm, down and antiup. A few other four-quark candidates have emerged within the last year, but those particles came with more question marks. For instance, some theorists think that $Z_c(3900)$, announced last June (*SN: 7/27/13, p. 9*), is a pair of interacting particles, not a single particle.

Physicists still want to determine Z(4430)'s internal structure: It could be a union of two mesons or a true tetraquark — four quarks bound together by gluons. "There's so much activity going on right now," Shepherd says. "The prospects for resolving this soon are good."

Skwarnicki adds that even though these particles don't exist freely in nature, they may have played a role in the very early universe, when a hot, dense soup of quarks and gluons cooled and condensed into nature's first multiquark matter. ■

BODY & BRAIN

# Triclosan aids nasal invasions by staph

Antimicrobial compound may help bacteria stick around

**BY BETH MOLE**

Sneezing out antimicrobial snot may sound like a superpower, but it could be a handicap.

Triclosan, an omnipresent antimicrobial compound found in products ranging from soaps and toothpaste to medical equipment, is already known to show up in people's urine, serum and breast milk. It seeps in through ingestion or skin exposure.

Now researchers have found that it gets into snot, too. And in the schnoz, triclosan seems to help the disease-causing bacteria *Staphylococcus aureus* instead of killing the microbe.

64
percent
Fraction of people with high nasal triclosan levels who had staph in their nostrils

Microbiologist Blaise Boles, of the University of Michigan in Ann Arbor, and colleagues swabbed the noses of 90 adults and found that having triclosan-containing snot could double a person's likelihood of carrying staph. The microbes may have adapted to triclosan. The results appear April 8 in *mBio*.

Because triclosan usually kills bacteria, the finding was a surprise, says Boles. A person carrying the microbe in his or her nose, he says, has a much higher risk of getting a staph infection.

In the study, 37 people had detectable triclosan in their nasal secretions, and 64 percent of them carried staph. Of the people who had little or no antimicrobial compound in their snot, 27 to 32 percent had staph in their nostrils.

In the lab, staph cells grown with nonlethal doses of triclosan were more "sticky," attaching better to human proteins, as well as to glass and plastic surfaces. Triclosan in snot could help staph hunker down in the nose, Boles says.

Microbiologist Hanne Ingmer of the University of Copenhagen says the finding has troubling implications for public health. Triclosan, she says, could provide footholds for the most worrisome forms of staph, such as methicillin-resistant *Staphylococcus aureus* or MRSA. ■

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EARTH & ENVIRONMENT

# Wee minerals may have shaped plates

## Damaged rock may explain origin of Earth's tectonics

**BY NAOMI LUBICK**

The first ruptures in early Earth's skin formed because of the weakness of minerals a millimeter wide, two scientists propose. The small minerals' behavior created boundaries defining Earth's first crustal plates and set the stage for plate tectonics, according to a new computer simulation appearing in the April 24 *Nature*.

Earth's crust is divided into giant, mobile plates. A plate can bump up against another plate at a fault zone, or dive beneath another at a subduction zone. The outcome can be an earthquake or volcano. Where plates split apart, new crust forms. Venus, Earth's near twin in size and composition, may once have had the conditions to start plate tectonic processes, but it didn't.

Scientists have long wanted to know how plate tectonics began. After Earth formed 4.5 billion years ago, its innards settled into a dense iron core surrounded by a mantle of slowly flowing rock. That mantle was enveloped by a harder skin on top, called the lithosphere. Hot magma rises, while cold crust sinks, and scientists think that early on, cold chunks of rock from the lithosphere periodically sank or "dripped" into the warm, churning mantle below.

"This intermittent dripping would have caused damage in the lithosphere," says David Bercovici, a geophysicist at Yale University, who created the new simulation with geophysicist Yanick Ricard of the University of Lyon in France. The recurring mechanical damage would have made the minerals that compose the rocks ever smaller and ever easier to grind. The scientists used lab observations of millimeter- and submillimeter-sized crystals to model the behavior of common lithospheric minerals. The results suggest that the tiny crystals deform more with decreasing size. The tinier the mineral grains that make up rocks, the more easily deformed the rocks are at a larger scale.

Because of the increasing damage, a narrow corridor of weakness in the lithosphere would get still weaker.

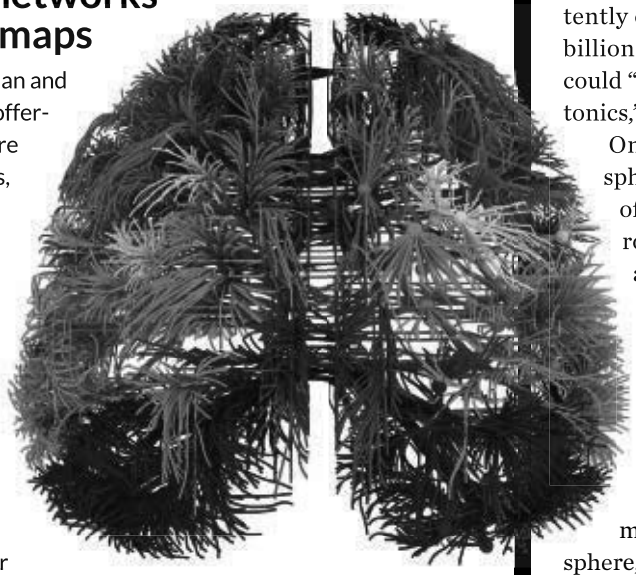
Stresses of the convecting mantle would have started to tear at these lithospheric weak spots, and movement would create proto-subduction, the researchers think. Repeated intermittently over a very long time, perhaps a billion years, the dripping and tearing could "build up enough to get plate tectonics," Bercovici suggests.

On Earth, the minerals in lithospheric rocks were damaged instead of "healing" — merging with other rocks to form larger grains. But in a simulation of Venus, which has always had a lithosphere that is 200 to 400 degrees Celsius warmer than Earth's, the minerals heal and grow.

The model shows one possible scenario for the origins of plate tectonics, but it lacks a mechanism for creating new lithosphere, says geochemist Kent Condie of New Mexico Tech in Socorro. "Nobody has come up with a satisfying answer yet on how plate tectonics started," he says. One problem is the lack of physical records from the era: Aside from a handful of ancient deposits, most of the rocks that were around 4 billion to 3 billion years ago have long since dived deep into the Earth, thanks to plate tectonics. ■

BODY & BRAIN

## Brain's growth, networks unveiled in new maps



ALLEN INSTITUTE FOR BRAIN SCIENCE

Two new maps illustrate human and mouse brains in sharp relief, offering insights into how brains are built and operate. The studies, led by scientists at the Allen Institute for Brain Science in Seattle and published in the April 10 *Nature*, join other recent large-scale descriptions of the brain (*SN: 5/3/14, p. 6; SN Online: 2/17/14*).

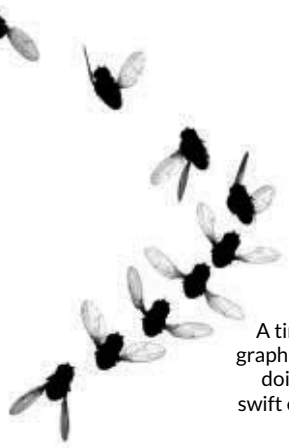
The new human map covers territory still in development. By studying levels of gene activity in four postmortem fetal brains, researchers were able to describe how genes in different regions orchestrate the growth of the human brain. Having a detailed map of when and where these genes are active might provide clues to complex neural disorders.

The mouse map (shown) traces multitudes of spidery neural connections in an adult brain. The resulting grid is based on about 15 to 20 percent of neurons situated in 295 distinct brain locales. The map will help scientists intent on figuring out how brains handle information, the authors write. — *Laura Sanders*

LIFE & EVOLUTION

# In a crisis, fruit flies do stunt turns

## Sophisticated tracking equipment reveals insects' deft moves



A time-lapse photograph shows a fruit fly doing a remarkably swift emergency turn.

**BY SUSAN MILIUS**

With a brain the size of a salt grain, a fruit fly can do *Top Gun* maneuvers in about one-fiftieth of the time it takes to blink a human eye.

That a fruit fly manages to do fighter-jet banked turns in midair contradicts some earlier ideas about how tiny insects maneuver, says Michael Dickinson of the University of Washington in Seattle. Other researchers had suggested that turning flies "use their wings almost like paddles to sort of row themselves around," he says. Yet an elaborate fly-filming arena that he and his students created reveals deft and quick banking, they report in the April 11 *Science*.

The *Drosophila hydei* flies studied by Dickinson have neither a lot of mental processing power nor fancy muscles for flying. But they still pull off sophisticated moves with minimal equipment.

To film fruit fly flight required years of refining a 3-D video monitoring setup. Filming flies at high speed means each exposure lasts only one thirty-thousandth of a second and needs brilliant light. Powerful illumination in the visible spectrum would blind the flies and end meaningful behavior, so Dickinson and his colleagues used infrared cameras with wavelengths flies can't see.

To startle the fruit flies into panicky moves, a lab version of a stadium Jumbotron showed a shape looming at the fly. Then came computing challenges. "You have just ridiculous amounts of data because you're capturing images at 7,500 frames per second," Dickinson says.

Emergency turns were much faster than the ones that flies make when no menace appears. Also, an alarmed fly doesn't reorient in the same plane like a rowboat turning on a lake surface. Instead, the fly abruptly rolls its whole body to one side like a plane, raising one wing as it banks. The fly then rolls back and zooms off in its new direction.

"When you look at what they're doing with their wings, it's remarkably subtle," Dickinson says. Wing-motion shifts, some barely detectable, are very precise.

"Exciting work," says Robert Wood of Harvard University, whose lab has developed beelike robots. Information on the speed and motions of the extreme turns will be "quite useful," he says, for designing fliers inspired by nature. ■

COURTESY OF FLORIAN MUJRES

BODY & BRAIN

# Poor slumber is bad for young fruit flies' brains

If same holds true in humans, children's sleep deprivation could alter adult behavior

**BY LAURA SANDERS**

Busy people like to say that the best time to sleep is when you're dead. But the best time to sleep is actually when you're young, a study of fruit flies suggests.

Young fruit flies deprived of sleep end up with brain and behavior problems later in life, scientists report in the April 18 *Science*. "This study is a really important advance in our understanding of how sleep and brain maturation are related," says neuroscientist Salome Kurth of the University of Colorado Boulder.

It's not clear whether sleep trouble early in life has similar effects in people. If so, the implications are provocative, says neuroscientist Megan Hagenauer of the University of Michigan in Ann Arbor. "They suggest that the consequences of chronic sleep deprivation in human children may go beyond temporary impairment and actually produce permanently altered brain development," she says.

Researchers have previously linked poor sleep in young children to negative outcomes such as anxiety and diminished academic performance, but those results come from observational studies that can't say whether disrupted sleep actually causes deficits. The new study in flies, however, makes a causal connection.

Like human infants, rat pups and many other immature animals, young fruit flies sleep more than older ones. Amita Sehgal, a neuroscientist at the University of Pennsylvania in Philadelphia, and colleagues found that sleep during early life is particularly important.

**20**
**percent**
Reduction in size in a particular brain area in sleep-deprived flies compared with flies that slept well early in life

The team studied the sleep of flies on their first day out of their pupal cases. These young flies slept about four hours longer per day than older flies, fell asleep earlier and were harder to wake up.

Sehgal and her colleagues found the signal in the brain that sends young flies to sleep. A brain structure called the dorsal fan-shaped body produces more sleepiness in young flies than in older flies, the team found. These sleep signals are held in check by a group of neurons that produce the neural chemical dopamine. Young flies have less dopamine in their brains than do older flies. This dearth of dopamine allows the fan-shaped body to send its sleepy message.

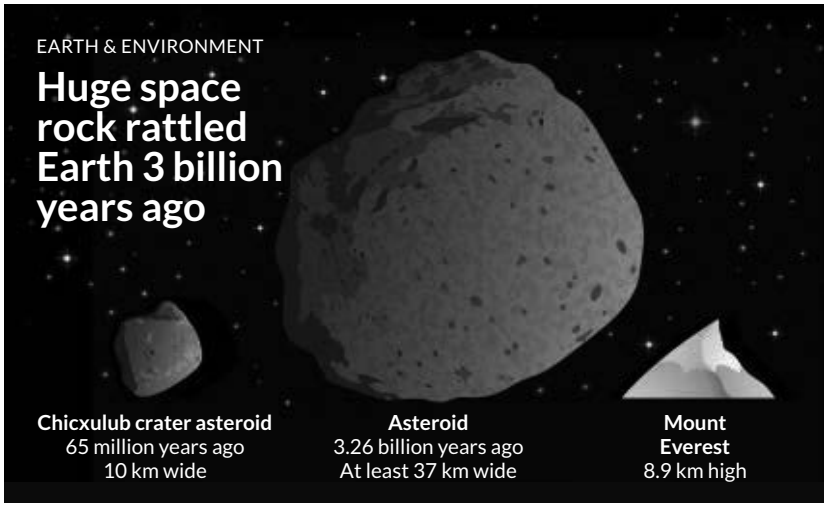
When the researchers disrupted youngsters' early sleep by genetically altering these dopamine neurons in the brain, male fruit flies' behavior at the ripe old age of 5 days suffered: Males spent less time courting females and were less likely to mate compared with males that slept well early in life. The researchers haven't studied how early sleep deprivation affects females.

Early sleep deprivation also made its mark in the brain. A brain structure thought to be involved in courtship behavior was about 20 percent smaller in the flies that didn't get enough sleep early in life than in flies that slept well. This region, the VA1v glomerulus, does a lot of growing when flies are young, the researchers found. Disrupted sleep seemed to impair its growth.

The results highlight the importance of both sleep and dopamine, Sehgal says. Because the neurotransmitter also promotes wakefulness in people, drugs that affect dopamine levels, including some stimulants given to kids for attention deficit disorders, might interfere with children's sleep, she says. ■

EARTH & ENVIRONMENT

## Huge space rock rattled Earth 3 billion years ago




An asteroid almost as wide as Rhode Island may have plowed into Earth 3.26 billion years ago, leaving a trace in South Africa's Barberton greenstone belt. Hitting the planet at a speed of 20 kilometers per second, the 37- to 58-kilometer-wide space rock could have jolted Earth with at least the force of a magnitude 10.8 earthquake and set off tsunamis thousands of meters high, researchers report April 14 in *Geochemistry, Geophysics, Geosystems*. It is the first time scientists have calculated the scale of the impact and its effects on Earth. — *Ashley Yeager*

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ATOM & COSMOS

## Mountains on Saturn moon may have come from space

A mysterious mountain ridge ringing the equator of Saturn's moon Iapetus may be a load of space rubble. Ever since the Cassini spacecraft spied the jagged belt wrapped around Iapetus' middle in 2004, scientists have debated the ridge's origin. Some think volcanoes shoved it up from beneath the moon's surface or that tectonic activity created the range. Others think that the towering mountains, which may reach more than twice the height of Mount Everest, could be remnants of rings that once orbited the moon. The ring theory got a boost from an analysis of Cassini images by Erika Lopez Garcia of Brown University in Providence, R.I., and colleagues. Iapetus' ridge has steep slopes, a clue that the mountains may have formed as debris rained down on the moon and piled high on the surface, the team reports April 9 at arXiv.org. *— Meghan Rosen*

GENES & CELLS

## Five mutations could make bird flu spread easily through the air

Just five mutations could turn the deadly H5N1 avian influenza into a pandemic virus, controversial research on ferrets suggests. Since it first appeared widely in humans in 2003, the H5N1 virus has infected more than 650 people in 15 countries, killing nearly 60 percent of those infected. So far, it doesn't pass easily from human to human. A minimum of five genetic alterations are needed to make the bird flu into a virus that can infect ferrets — lab stand-ins for people — through the air, report Ron Fouchier of the Erasmus Medical Center in Rotterdam, the Netherlands, and colleagues in the April 10 *Cell*. The new study shows that to spread via air between ferrets, the virus requires changes to both its replication machinery and to the protein it uses to latch onto cells in the respiratory tract. These five changes aren't the only ones that could turn H5N1 into a pandemic virus, but may tell researchers the types of mutations they should look out for. *—Tina Hesman Saey*

BODY & BRAIN

## Celiac disease linked to cardiovascular problems

**WASHINGTON —** People with celiac disease appear to have an increased risk of heart disease. Rama Gajulapalli and Deepak Pattanshetty of the Cleveland Clinic analyzed a database of more than 22 million people and identified 24,530 with celiac disease. Probing the records further, they found that 9.5 percent of the celiac patients had coronary artery disease compared with 5.6 percent of those without celiac. In people over age 65, 28.6 percent of celiac patients, but only 13.2 percent of the others, had coronary artery disease. Celiac disease is an aberrant immune reaction to consumed gluten, which is found in wheat, rye and barley. Celiac is marked by inflammation of the small intestine, poor nutrient absorption and tissue damage. Inflammation, which also contributes to cardiovascular disease, might underlie the nearly doubled risk, Gajulapalli reported March 29 at a meeting of the American College of Cardiology. *— Nathan Seppa*

LIFE & EVOLUTION

## Tar pits yield Ice Age bee nest

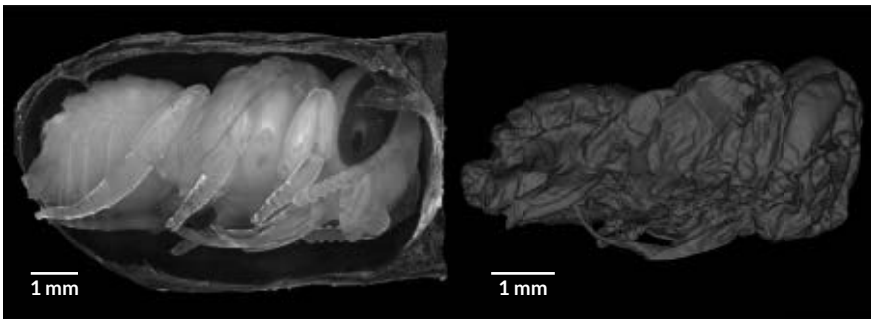
It's not all mammoths and saber-toothed tigers. The first preserved leafcutter bees from the Pleistocene epoch have turned up in the La Brea Tar Pits in Los Angeles. Exquisitely preserved as pupae undergoing their transformation to adulthood, a male and a female are still wrapped in their leafy nest. Micro-CT scans let researchers identify the bees as *Megachile gentilis*, a species still alive today. These bees line burrows with bits of leaves to protect developing offspring. The preserved pupae probably lived between 35,000 and 40,000 years ago, says Anna Holden of the Natural History Museum of Los Angeles County. The bees' presence suggests that the tar pit was near woods or riverbanks with pollen-rich plants in a relatively cool and moist climate, the team reports April 9 in *PLOS ONE*. *— Susan Milius*

MATTER & ENERGY

## Blender whips up graphene

With the whirl of a blender, researchers can serve up big batches of graphene. Graphene sheets are single-atom-thick layers of carbon. Individual sheets are sturdy, transparent and excellent conductors, giving them enormous potential for use in plastics, superconductors and other materials. But making large amounts is tricky. Recipes that rely on chemicals to peel wafer-thin layers off graphite, a form of carbon, run the risk of creating chinks in graphene's chicken wire arrangement of atoms. Ultrasonic waves can shimmy the layers apart but work only for small batches. Researchers led by Jonathan Coleman of Trinity College Dublin found that blenders can form graphene sheets from a graphite slurry without disturbing the atomic latticework. As some of the slurry is sucked into the blender's blades, it rushes past slower-moving slurry, creating a shearing force that strips off 100- to 2,000-nanometer-long graphene sheets from graphite flakes. The researchers used the graphene to reinforce plastics and as conductive elements, demonstrating that the graphene could work in batteries and solar cells. The findings appear April 20 in *Nature Materials*. *— Beth Mole*

A pupa of a modern female leafcutter *Megachile* bee (left) has the same basic look as a *Megachile* male (right, CT scan) that dates to the Pleistocene, having been preserved in the La Brea Tar Pits.

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FEATURE

# THE ICE OF A DISTANT MOON

## Piercing Europa's frigid shell to search for life below

**By Meghan Rosen**

On an unusually hot summer day in Wales, Sanjay Vijendran and colleagues aimed a rocket sled at an elephant-sized ice cube.

The sled rested on a raised metal track and carried what looked like a cartoon bundle of TNT to propel the contraption at the speed of sound. In front of it, a second sled held a bullet-shaped canister packed with scientific instruments.

Vijendran, a physicist at the European Space Agency, was ready to hurl the canister into a 6,200-kilogram block of ice, at the U.K.'s Ministry of Defense site in Pendine.

With chain saws on hand in case the canister got stuck, researchers watched the sleds hurtle down the track, launching the canister into the air at more than 340 meters per second. It flew the length of a school bus and then punched almost clear through the 3-meter-long frozen block, spraying geysers of snowy ice chips.

"It was all over in less than two seconds," Vijendran says of the July 2013 test. "If you blinked, you missed it."

Vijendran and his colleagues want to take this pyrotechnic spectacle to a place where no one will see it. They're trying to design a device strong enough to pierce Jupiter's fourth-largest moon, survive the impact and grab samples of ice.

The moon, named Europa, looks just as desolate and uninviting as any other place in the outer solar system. Its frozen façade is colder than the most frigid spot on Earth by more than 100 degrees Celsius. Blasts of radiation sweep the surface. But underneath Europa's inhospitable exterior, scientists think a vast ocean of liquid water flows. The moon's seafloor might also bustle with activity from volcanoes and hydrothermal vents. If chemicals from the surface trickle down through the ice, as some scientists suspect, Europa could hold all the necessary ingredients for life.

Hydrothermal vents on Earth's seafloor teem with life, says astrobiologist Kevin Hand of NASA's Jet Propulsion Laboratory in Pasadena, Calif. "You've got incredible ecosystems of tube worms and crabs and fish and microbes," he says. "It's anybody's guess whether or not you'd find tube worms on Europa."

If they exist, scientists will have to peel away the moon's frosty husk to find out. Research teams

Beneath the icy layer cloaking Jupiter's fourth-largest moon, Europa, scientists believe a vast ocean and a geologically active seafloor could potentially hold habitats for life. Several groups have begun devising ways to burrow beneath Europa's frozen surface.

JPL-CALTECH/NASA

around the world are trying to figure out how to pierce, melt or drill through the ice. It's not simple. Even if they could send a drill rig's engineers and hulking machinery to Europa, the moon's ice may be four times thicker than any ice found on Earth. Estimates vary, but the icy hull might reach more than 20 kilometers deep — about the height of 53 Empire State Buildings stacked one on top of another.

A mission to burrow down into the moon's ocean could still be decades away. But if scientists found microbes in the ice or water, the implications would be Copernican.

"If we found life twice in the same solar system," says physicist Dale Winebrenner of the University of Washington in Seattle, "it would tell us that when you look up at night, you're seeing lots of places where there might be microbes."

> "It's anybody's guess whether or not you'd find tube worms on Europa."
>
> KEVIN HAND

## Breaching the shell

More than four centuries ago, Galileo Galilei pointed his telescope into the night sky and gazed upon Europa. He was aiming at Jupiter, but caught sight of four moons circling the gas giant. Scientists later named the littlest of these Europa, after one of Jupiter's mythical lovers.

Modern astronomers got a good look at the icy moon in 1979 when the Voyager 2 spacecraft cruised past Jupiter. What they saw surprised them: Europa's surface didn't bear the typical marks of old age. Unlike Jupiter's other moons, Europa's ice was mostly unblemished by pockmarks from impact craters.

"That's where it all started," says planetary scientist Britney Schmidt of Georgia Tech in Atlanta. "That's when people got really excited."

Scientists suspected that Europa's fresh, young skin might signal geologic activity underneath. As the moon travels around Jupiter, the giant planet's gravity stretches and pulls Europa like a ball of taffy, NASA's Hand says. This tug and pull may generate heat in the moon's interior, which could help churn up the icy crust, erasing evidence of past craters. A roiling interior might also mean energy for life to tap into, he says.

Later data from the Jupiter-orbiting spacecraft Galileo suggested that the shell cloaks a salty ocean that may hold more than twice the volume of liquid water on Earth. The idea of exploring this vast ocean has launched a number of scientists on a quest for a space-ready ice drill.

Somehow, such a device has to breach the moon's icy shell — perhaps with blazing hot metal or the jagged teeth of a drill bit — and carry enough power for the job. The device has to be simpler and more reliable than anything used to bore through ice on Earth, and it will have to take care of itself. There's no way to send a team of engineers to the far edges of the solar system. And the entire ice-tunneling, power-toting, problem-free package needs to be light enough to launch beyond Earth's gravitational grip.

It's a tall order. So Vijendran's team is taking a more moderate approach. The researchers just want to puncture Europa's skin. Their "ice penetrator" would crash into the moon's surface, and like a splinter buried in flesh, lodge within the ice shell itself. Sheltered inside the device, a microscope, mass spectrometer and electrodes could then analyze frozen slivers pulled from the crash site. "This very basic set of instruments would still give us quite an interesting picture of the astrobiology potential of the icy surface," Vijendran says.

"It's very different from a rover mission on Mars, where you're taking your time, spending months and years doing experiments," he says. "This would be a quick, one-shot thing."

It may be enough even to tap into Europa's water. Pockets of water may linger within the icy surface itself, Schmidt and colleagues reported in *Nature* in 2011 (*SN: 12/17/11, p. 5*). And plumes of water vapor may erupt from the shell, researchers suggested in January in *Science* (*SN: 1/25/14, p. 6*). If these pockets or plumes carry tiny microbes, the ice penetrator may be able to detect them, which could hint at more complex organisms living far below.

"We might not have to get all the way down to the ocean to look at whether anything is living in Europa's water," Schmidt says.

What's more, at around 150 total kilograms

**Water world**
About the size of Earth's moon, Europa may hold two to three times the volume of liquid water found in Earth's oceans.

**Europa**

**Average ocean depth**
100 km

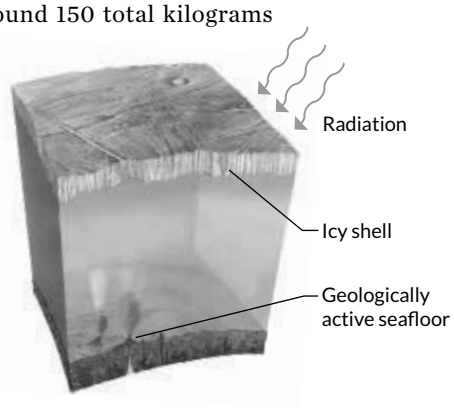
**Volume of water**
2.7 billion to 4.0 billion cubic km

**Earth**

**Average ocean depth**
3.7 km

**Volume of water**
1.3 billion cubic km

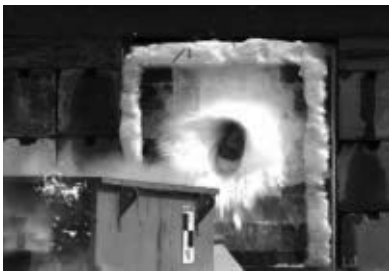
**Ingredients for life**
Blasts of radiation bombarding Europa's surface could generate chemicals that trickle down through the ice into the ocean. These chemicals could help power life on Europa, along with energy from an active seafloor that could be bursting with volcanoes and hydrothermal vents.




FROM TOP: NASA; GARY HINCKS/SCIENCE SOURCE

— about the weight of a football lineman — the team's penetrator system is small enough to send into space. It's too big, however, to ride along on the European Space Agency's upcoming mission, called JUICE for JUpiter ICy moons Explorer. That spacecraft is set to launch in 2022 and reach the Jovian system in 2030.

Vijendran hefts his team's prototype from the window ledge of his office, and cradles the canister in his arms. About the size of a 2-liter soda bottle, but heavier, it's in remarkably good shape after last year's trial run. A few tiny scuffs in the blue paint expose glimpses of shiny steel.



In a test, a prototype for a Europa ice penetrator crashed into a thick block of ice, sending frozen chips flying. The penetrator was only scratched.

The test in Wales proved that the design could take a beating while still protecting equipment stashed inside. This summer, the team hopes to create a battery and a communication system that can withstand impact with the ice.

Compared with devices that tunnel beneath the ice, "a penetrator project is going to be cheaper, and there's a better chance of everything going right," says Victoria Siegel, a researcher at Stone Aerospace near Austin, Texas.

## Melting down

Siegel and others, however, are still aiming for the ocean. "That's where the big stuff is going to be happening," she says. Getting to that big stuff is much more complicated than scratching the moon's surface.

Siegel and colleagues at Stone Aerospace have been working since 2011 on a device that would melt its way through Europa's ice, shooting jets of heated meltwater to clear the way ahead and to steer. Once through the ice, the device, called a cryobot, would launch a miniature submarine from its belly into the ocean.

"It's the equivalent of a Mars rover, but in an underwater vehicle form," Siegel says.

The plan is ambitious, but scientists and engineers at the company have already created a prototype of the cryobot and are in the early phases of building the underwater vehicle. It's part of a NASA-funded project Schmidt leads called SIMPLE, which could help calibrate ice-penetrating radar technology so spacecraft could one day form a clearer picture of Europa's ice. Together, the cryobot and the vehicle will weigh about 180 kilograms.

The cryobot, a tube about as long as a compact car, holds wires coiled within a sleek aluminum frame and five jets arranged in a domed head. By heating aluminum blocks within the head, the cryobot can melt ice, and then suck in the water and shoot out hot streams. To thaw the ultracold ice of Europa, the bot will need to carry some sort of onboard nuclear reactor. Siegel and colleagues are testing their device on Earth using laser light pumped down a fiber optics wire connected to the machine.

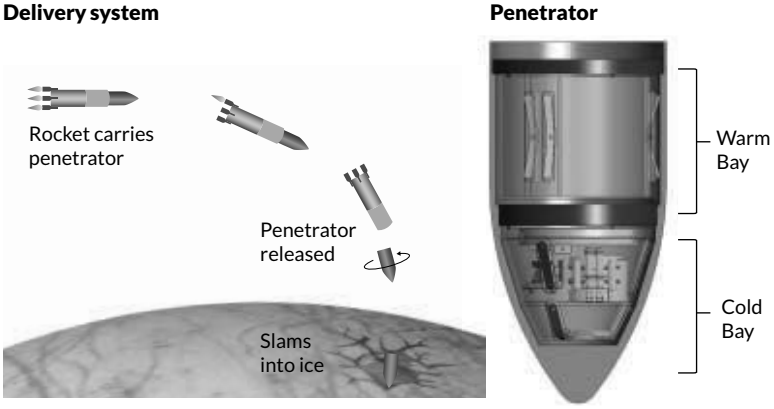
When the team ran the idea by fiber optics and laser manufacturers, "they all said, 'You're going to burn the fiber and everything's going to go up in a big poof of smoke,'" Siegel says.

But the power source worked, and last October the team used it to send the cryobot through a 2-meter-tall block of ice.

At the company's large warehouse-style workshop, half a dozen people gathered around the cryobot. A nearby desk held computer monitors displaying the bot's temperature readings, and team members watched closely to make sure the machine didn't overheat. If something went wrong, they could reach over and press a button. "It's like a big red Wile E. Coyote emergency stop button," Siegel says. "It knocks the laser off right away."

The team hoisted the robot on top of the ice block with a crane and then fired up the laser. Orange safety lights flashed and the laser's chiller

**Scratching the surface** To embed instruments in Europa's ice, a rocket-powered delivery system orbiting the moon would slow down and release the European Space Agency's ice penetrator, sending the capsule into the surface (left). Inside the device (right), a cold bay would sample the ice and a warm bay would house instruments needed to transmit data. SOURCE: S. VIJENDRAN/ESA



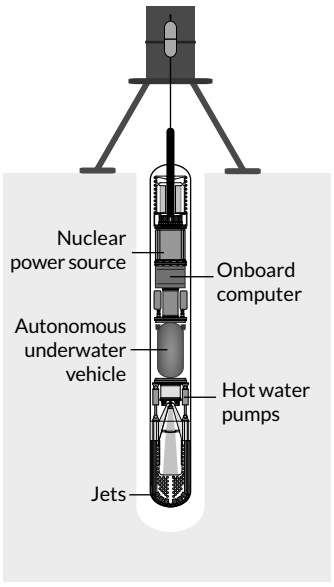

CLOCKWISE FROM TOP: ESA; ESA; M. ATAROD

system kicked into gear, rumbling like a loud refrigerator.

Light flowed through the fiber to the cryobot, and then, Siegel says, "Lo and behold, it actually started to descend."

The machine melted through the block at about 1 meter per hour — an impressive feat considering that one of the two pumps running the jets malfunctioned. Siegel reported the success in December in San Francisco at a meeting of the American Geophysical Union.

Now, the team is working on the bot's steering jets, and trying to incorporate sensing tools into the machine's body. This June, the group will travel to Alaska's Matanuska glacier and attempt to melt through about 30 meters of ice. On the way down, the team will test the bot's tools and collect data about organisms living within the ice, Siegel says.




**Burrowing down** Someday, a lander sitting on Europa's surface could launch a cryobot to melt through the ice (artist's illustration, left). The cryobot (right) would carry a nuclear power source and an onboard computer and heat its way though the ice with jets that shoot hot water. After reaching the ocean, the bot would release an underwater vehicle to explore and sample the water.

## A dangling drill

Kris Zacny, an engineer at Honeybee Robotics in Pasadena, Calif., says drilling is an easier way to go — and it won't require as much power as the cryobot.

For the last century, the oil and gas industry has used segmented drills to reach deep beneath the Earth's surface. As engineers tunnel deeper and deeper, they add segments to extend the length of the drill, and pump in fluids to clear the hole.

These rigs aren't the obvious choice for a mission to Europa: Lots of segments would make the drill heavy, and drilling fluids could freeze. So Zacny and colleagues teamed up with Jet Propulsion Laboratory scientists to design something different.

They came up with a wireline drill called the Auto-Gopher, a 22-kilogram, 2-meter-long tube about the diameter of a soda can, that's suspended from a wire tether.

"It's like a fishing rod," Zacny says, "and at the end of the fishing line, you have a drill."

The team's rig takes ice fishing to the extreme: It would rest on Europa's surface, dangle the drill from a slim tether and lower it into the shell as the bit chewed through ice.

At the tip of the Auto-Gopher, eight sharp, pointy teeth jut out from the bit. They're made of tungsten carbide — a material that scientists can design into nearly unbreakable barbs to bite through rock and ice. When researchers switch on the motors, a rotary system cranks the bit around, drilling the teeth downward.

Tungsten carbide is tough, but gnawing through kilometers of ice may dull the drill's teeth, or the drill could run into a particularly hard patch. So Zacny's team packed a percussive system into the Auto-Gopher's body that can pound the bit into the rock like a hammer.

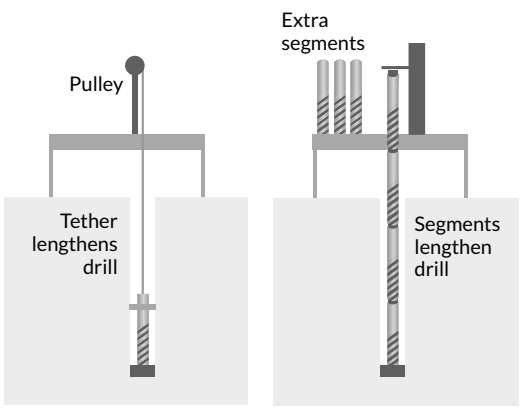
Researchers don't need a lot of power to chip away at ice, Zacny says. Even with the drill bit spinning and the hammer system thumping full time, the Auto-Gopher runs on about 350 watts, less energy than a typical hair dryer uses. Rovers like Curiosity can carry plenty of juice to run such a drill plus scientific instruments, Zacny says.

Using the Auto-Gopher, he and colleagues drilled about 3 meters into a gypsum quarry in Southern California. The rock is similar in strength and uniformity to ice, he says. At top speed, the drill moved a bit faster than Stone Aerospace's cryobot — about 1.6 meters per hour, the team reported last March at the 2013 IEEE Aerospace Conference in Big Sky, Mont. But the researchers ran into one big stumbling block: They had to stop periodically to clear out rock cores from the borehole.

"You'd think the core would always be a nice cylinder that you can capture and pull out," Zacny says. Not so. "Sometimes the core gets broken up into pieces."

Now the team is working on a new and improved drill, the AMNH Deep Drill, named

**Digging in** The Auto-Gopher, a long skinny drill (left), has made it through 3 meters of gypsum rock. Using a wireline approach, the drill hangs from a tether (middle), as opposed to a conventional approach (right), which uses heavy drill segments to lengthen its reach. A wireline approach could reduce weight for drills sent into space.
SOURCE: K. ZACNY/HONEYBEE ROBOTICS




after its funding source, the American Museum of Natural History. This drill will shuttle rock or ice cuttings to a container inside the tube instead of creating cores that have to be pulled from the borehole. And researchers plan to pack electronics and equipment, such as a microscope and sensors, inside the tube.

Zacny sees two big advantages for using his team's drill system to explore Europa. First, by capturing ice chips as the drill breaks through the shell, "you can systematically get data on every single foot of ice as you go all the way down," he says.

Second, by suspending the drill from a wire, the team avoids the bulk of added drill segments that weigh down earthly equipment.

But even at a dainty 10 grams or so per meter, 10 kilometers of tether (Kevlar cable wrapped around fiber optics wire) would weigh 100 kilograms. Using lighter materials, such as carbon nanotubes, could trim the tether's weight, Zacny says.

He and colleagues plan to test the AMNH Deep Drill at the gypsum quarry in the fall. This time, they're aiming for a depth of 30 meters.

Zacny is optimistic about the team's invention: "It's feasible to deploy this drill in the next decade," he says.

"We think geologic activity is a really big part of what makes a planet habitable. That's why Europa is so exciting."
**BRITNEY SCHMIDT**

## Getting there

Even if some kind of technology to puncture Europa's ice is ready to go in 10 years, prospects for a U.S. trip to the Jovian moon are far from certain.

Schmidt has helped devise a $2 billion mission concept for a spacecraft called the Europa Clipper. The Clipper would orbit Jupiter and send back data about Europa from a series of flybys to try and figure out whether the moon is habitable. "It's a gangbuster concept that gets the science done and is as cost-constrained as you can be," she says.

In March, President Obama proposed funding studies for a Europa mission — the first time the distant moon has made it into the President's budget. But NASA wants a mission for half the cost of the Clipper.

"It's kind of a slap in the face," Schmidt says.

She's thrilled that the President's budget now includes Europa, but frustrated by less-than-ideal funding. Scientists have been studying possible Europa missions for 15 years, Schmidt says, and NASA keeps bouncing back and forth between high and low price tags.

NASA astrobiologist Christopher McKay thinks the new budget is plenty for an exciting mission to Europa — just one that's small and focused.

"It makes so much sense to start small and build up," he says. "I see all sorts of opportunities in $1 billion." He'd like to land a camera and microphone on Europa's surface and take pictures of the landscape and listen to the ice.

"Ice talks," he says. "It's always creaking and groaning and cracking and chatting. The ice is telling a story — all we have to do is put our ear to the ground and listen."

Plus, he adds, less expensive missions may help build support for a more expensive ride later. "Imagine what pictures of Europa from the ground could do to motivate interest."

Surface-piercing technologies — whenever they are eventually used — could also be useful elsewhere in the solar system. Scientists have flagged other potentially habitable spots, such as Saturn's hydrocarbon-rich moon Titan and its watery moon Enceladus (*SN: 5/3/14, p. 11*).

But to Schmidt and other scientists, Europa is the top target: It's got water, a supply of potential nutrients and a possible source of energy bubbling beneath the surface.

"We think geologic activity is a really big part of what makes a planet habitable," she says. "That's why Europa is so exciting."

Discovering whether creatures live within or beneath the moon's ice strikes at "some of the biggest scientific questions that we have," says University of Washington's Winebrenner. "Is anybody out there? And if so, how widespread might life be?" ■

## Explore more

- NASA's Europa website: http://bit.ly/SNEuropa

FROM LEFT: HONEYBEE ROBOTICS; M. ATAROD

When studying ancient specimens, researchers work in ultraclean rooms to avoid contaminating samples with DNA from modern people or the environment.

T. HARTMANN/PALEOGENETICS LABORATORY, MAINZ, GERMANY

# Written in BONE

## Genetic data from ancient Europeans are rewriting the prehistory of the continent

**By Tina Hesman Saey**

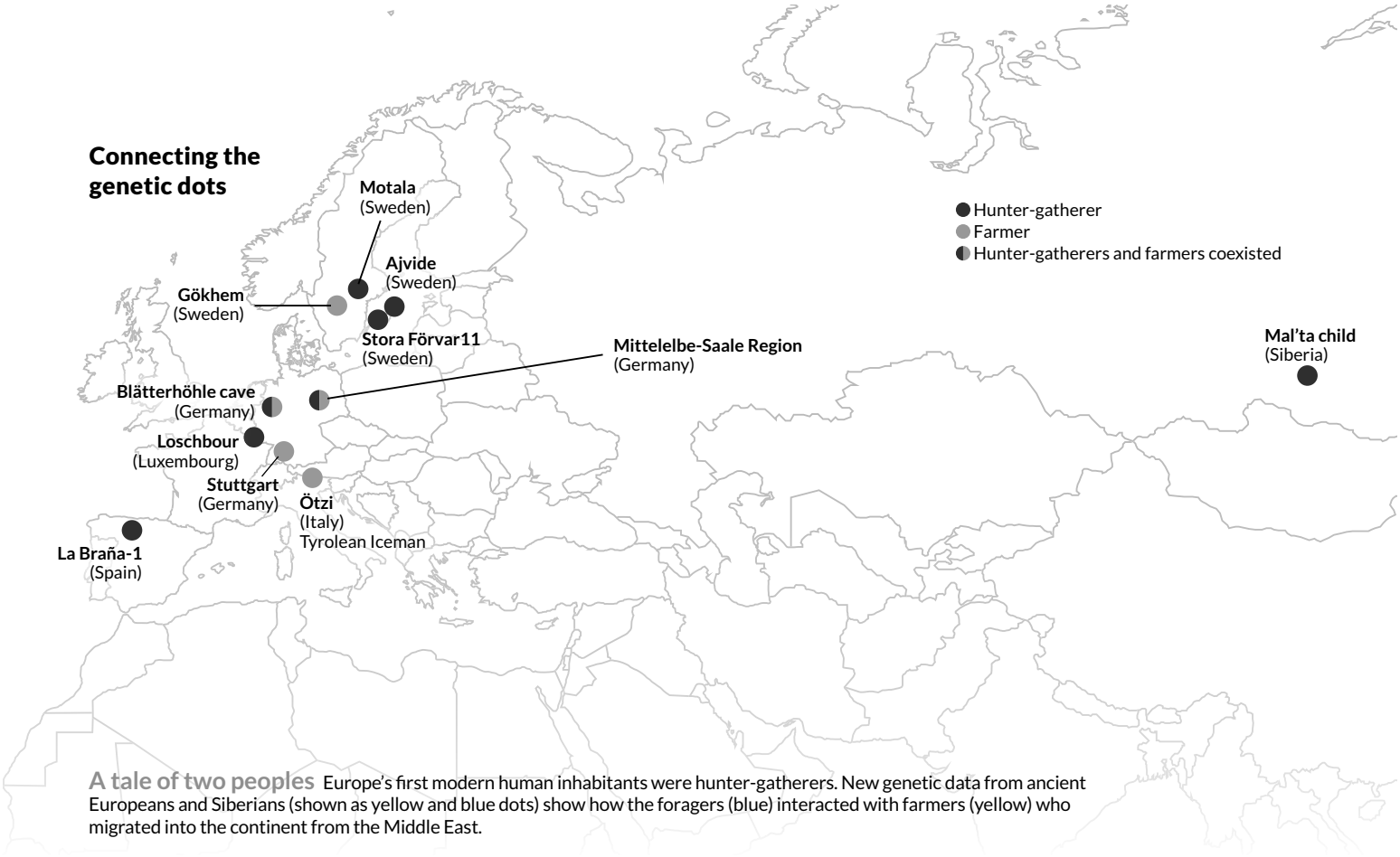
Carles Lalueza-Fox nearly missed an opportunity to paint the genetic portrait of a 7,000-year-old Spaniard.

In 2006, spelunkers stumbled across the ancient remains of two men in a cave in Spain's Cantabrian mountain range. Lalueza-Fox, an evolutionary geneticist at the Institute of Evolutionary Biology in Barcelona, got a call inviting him to examine the skeletons' DNA.

"I told them I wasn't interested," he recalls. Most of the genetic material in the bones had probably long since crumbled into tiny, unreadable fragments, he assumed. Plus, the technology to piece together nearly disintegrated genetic information wasn't up to the task. Even if it had been, the skeletons' DNA had probably become so contaminated with present-day people's DNA that it would be nearly impossible to tell the old from the new. "There was nothing I could do with it." He turned down the offer and didn't think much about it again until 2010, when an international group of researchers announced that it had compiled the genetic instruction book of Neandertals from bones dating back at least 40,000 years (*SN: 6/5/10, p. 5*), many times older than the Spaniards' bones.

"I started panicking," Lalueza-Fox says. He realized he'd passed up a golden opportunity to explore his country's distant history. He scrambled to find the skeletons, tracing them to a museum basement.

The two men had been about 30 to 40 years old when they died. They were covered in red ochre, a mineral commonly used in ancient burials. One of the men, called La Braña-1 for the archaeological site where his remains were found, was resting on a bed of broken stalagmites. The other, La Braña-2, had fallen into a neighboring pit. The only items found nearby were 24 red deer teeth that had probably been embroidered into cloth worn by La Braña-2. The skeletons' extreme age pegged them as hunter-gatherers, but beyond that there was




**A tale of two peoples** Europe's first modern human inhabitants were hunter-gatherers. New genetic data from ancient Europeans and Siberians (shown as yellow and blue dots) show how the foragers (blue) interacted with farmers (yellow) who migrated into the continent from the Middle East.

little to reveal who these men were and how they might be connected to the people who now inhabit northern Spain.

Little, that is, until Lalueza-Fox and his colleagues drilled into one of La Braña-1's teeth and pulled out relatively well-preserved DNA. In January, the researchers presented the complete genome of the ancient Iberian in *Nature*. That genetic portrait showed startling aspects of the hunter-gatherer that researchers never could have deduced from the bones alone.

For one thing, the man's pigment genes indicated he had blue eyes and dark skin, an unusual combination among modern-day Europeans. Immune system genes revealed that he was probably already resistant to some diseases carried by domestic animals, even though agriculture didn't reach the Iberian Peninsula until centuries after his death.

Ancient DNA teased from skeletons like La Braña-1 is like a scrap of faded papyrus. Scientists can read in it details of human history and evolution that are invisible to researchers who rely on bones, pottery shards or threads of living people's DNA.

"Groups all over the world are filling up the past with genetic data," says Mark Thomas, an evolutionary geneticist at University College London. Scientists have examined a few pages from the genomes of hundreds of ancient people from around Europe and have fully deciphered the genetic instruction books of a handful of individuals. Genetic data from prehistoric Europeans are helping scientists write a new story of life on the continent. It's a saga that illustrates how people interacted with each other and their rapidly changing environment. The latest chapters detail the spread of agriculture and the origin stories of many modern Europeans.

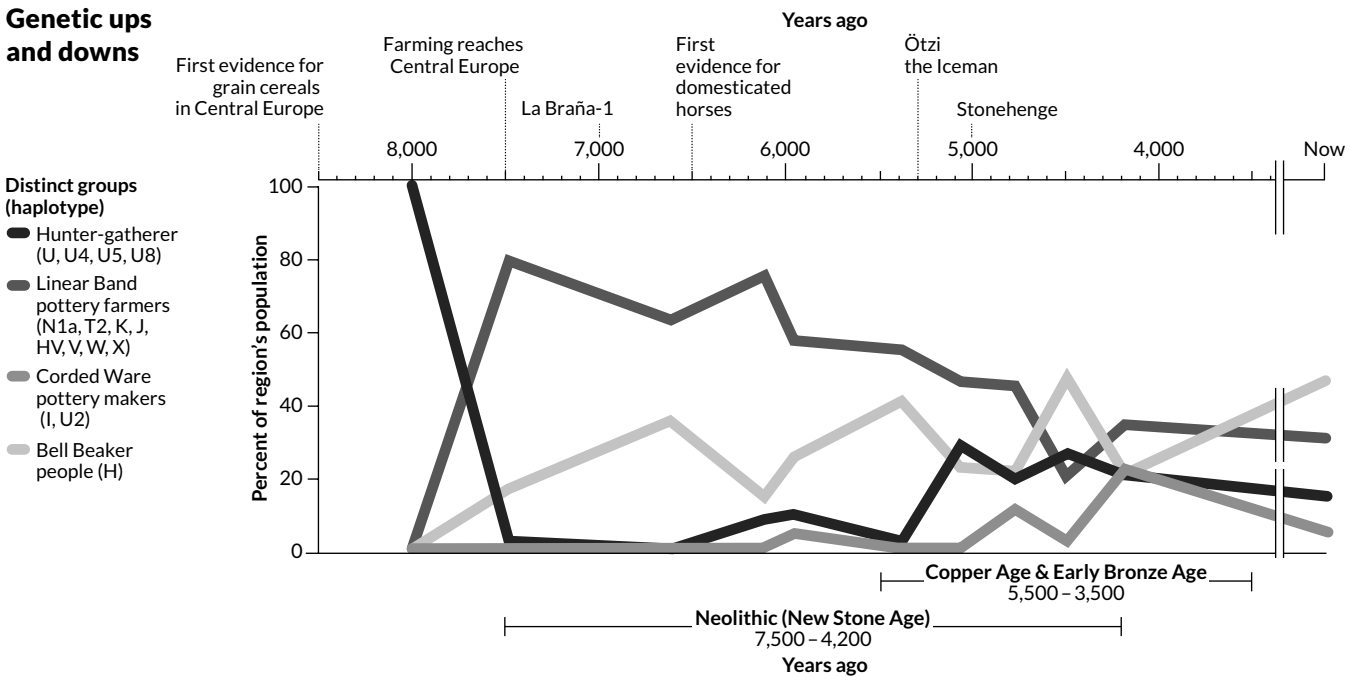
## Foragers and farmers

Archaeologists and anthropologists have used tools, bones, pottery and other artifacts to piece together a story of how the species of hominids known as *Homo sapiens* left Africa and spread around the globe. The European portion of the tale begins more than 40,000 years ago with the arrival of these anatomically modern humans to the continent. By about 30,000 years ago, humans had supplanted Europe's previous residents, Neandertals.

A major ice age that peaked about 25,000 years ago drove early Europeans to the southern and eastern parts of the continent. When the massive glaciers that had once crushed Scandinavia and much of the British Isles finally receded around 11,700 years ago, humans once again invaded the north.

DNA from the tooth of a 7,000-year-old Spanish hunter-gatherer revealed that he had blue eyes and dark skin (left), details that couldn't be discerned by looking at his skeleton (above).

CLOCKWISE FROM TOP: REDMAL/ISTOCKPHOTO, ADAPTED BY S. EGTS; J.M. VIDAL ENCINA; CSIC




**Culture clash** Mitochondrial DNA collected from people who inhabited central Germany shows that the spread of ideas was tied to the movement of people. Hunter-gatherers were once the region's only inhabitants, but their genetic stock plummeted when three different groups of farmers, each producing a unique type of pottery, moved in.
SOURCE: G. BRANDT *ET AL*/*SCIENCE* 2013

As early Europeans were reclaiming the thawing north about 11,000 years ago, agriculture took hold in the Middle East and began spreading.

The prominent view has been that agriculture was an idea that went viral, infecting people who already lived in Europe. When European hunter-gatherers heard about this great new idea from the East, they gave up their nomadic existence to embrace the farming life and settled down to raise grain and domesticated animals. Once the nomads-turned-farmers were comfortably ensconced in villages, population sizes boomed, eventually giving rise to the modern cities and towns of Europe. In that view, the idea spread but the people who adopted it were the same ones who had always been in Europe.

"There was a widespread assumption that technology changes, but the people don't," says John Hawks, an anthropologist at the University of Wisconsin–Madison.

Some archaeologists told a very different version of agriculture's spread. They suggested that migrant farmers carried their technology into Europe and jealously guarded it from hunter-gatherers. Either by violence, strength of numbers or hogging of resources, the farmers overwhelmed and pushed aside the hunter-gatherers.

Many people are uncomfortable with that version of events, Lalueza-Fox says. "It's unfashionable, that movement of people. It looks aggressive."

Analysis of ancient DNA suggests multiple story lines were playing out at once during agriculture's formative years in Europe. Farmers may have guarded their intellectual property, even though they lived side by side with hunter-gatherers for thousands of years. As hunter-gatherer populations declined, some members adopted agriculture and interbred with farmers. Toss in multiple migrations and the rise and fall of various pottery cultures within Europe and the story gets complicated.

Wolfgang Haak, a molecular archaeologist at the University of Adelaide in Australia, has been poring over the ancient DNA manuscripts, concentrating on DNA found in mitochondria, cells' power-producing organelles. Mitochondria are inherited from the mother, allowing researchers to use mitochondrial DNA signatures called haplotypes to trace maternal ancestry.

In 2005, Haak, then a graduate student at Johannes Gutenberg University Mainz in Germany, and his colleagues analyzed DNA from 24 Stone Age farmers who lived about 7,000 to 7,500 years ago in Germany, Austria and Hungary.

The researchers wanted to know if these early farmers were really the direct ancestors of present-day Europeans, as had long been suspected. Turns

S. EGTS

out they weren't. The difference appeared in a mitochondrial haplotype known as N1a. About 0.2 percent of modern Europeans carry haplotype N1a.

"But when we dug up those farmers, it was 25 percent," Haak says. "There was a real wow factor." Today's Central Europeans, according to the finding reported in *Science*, are not direct descendants of the people who tilled their land 7,500 years ago.

A few years after that discovery, in 2008, researchers read the mitochondrial DNA records of perhaps the most famous prehistoric European, a frozen mummy known as Ötzi, the Tyrolean Iceman. Ötzi was discovered half-buried in a melting glacier on the border between Austria and Italy in 1991. He carried a copper ax and was clad in a coat, loincloth and leggings made of domestic goatskins. His age — 5,300 years old — and implements marked him as a Copper Age farmer.

Studying Ötzi's mitochondrial DNA, researchers discovered that he shares no maternal ancestry with modern Europeans (*SN Online: 10/30/08*). At first, it looked like Ötzi's people might have died out, but a 2012 report of the Iceman's full genetic instruction book revealed he has living relatives on his father's side (*SN: 3/24/12, p. 5*). Although he was found in the ice high in the Alps between Austria and Italy, his modern relatives live more than 500 kilometers to the southwest, in Sardinia and Corsica.

The results were confusing, because modern Europeans have strong genetic ties to the region of their birth, says Lalueza-Fox. "But maybe that's only from the Middle Ages," he says. For several hundreds of years, people have stayed in the same place, not only the same country, but the same village, producing long, unbroken family lines. Genetic maps of modern Europe look very much like geographical maps. Less so for ancient Europeans, who were far more mobile, according to these ancient DNA studies.

> "There was a widespread assumption that technology changes, but the people don't."
>
> **JOHN HAWKS**

Haak and his colleagues more recently collected mitochondrial DNA from hundreds of ancient skeletons from central Germany where the Saale River feeds into the Elbe. That part of Germany has been continuously inhabited for more than 10,000 years; archaeologists have uncovered remains of numerous prehistoric cultures, distinguished by their pottery styles or distinctive tools.

The team chose skeletons from the Stone Age to the Bronze Age — between 7,500 and 3,500 years old. By tracing mitochondrial haplotypes in the skeletons from different time periods, Haak's team uncovered at least four major population shifts, which they described last October in *Science (SN: 11/16/13, p. 13)*.

The data clearly show that early farmers were different people from the foragers who hunted wild animals and gathered plants for millennia.

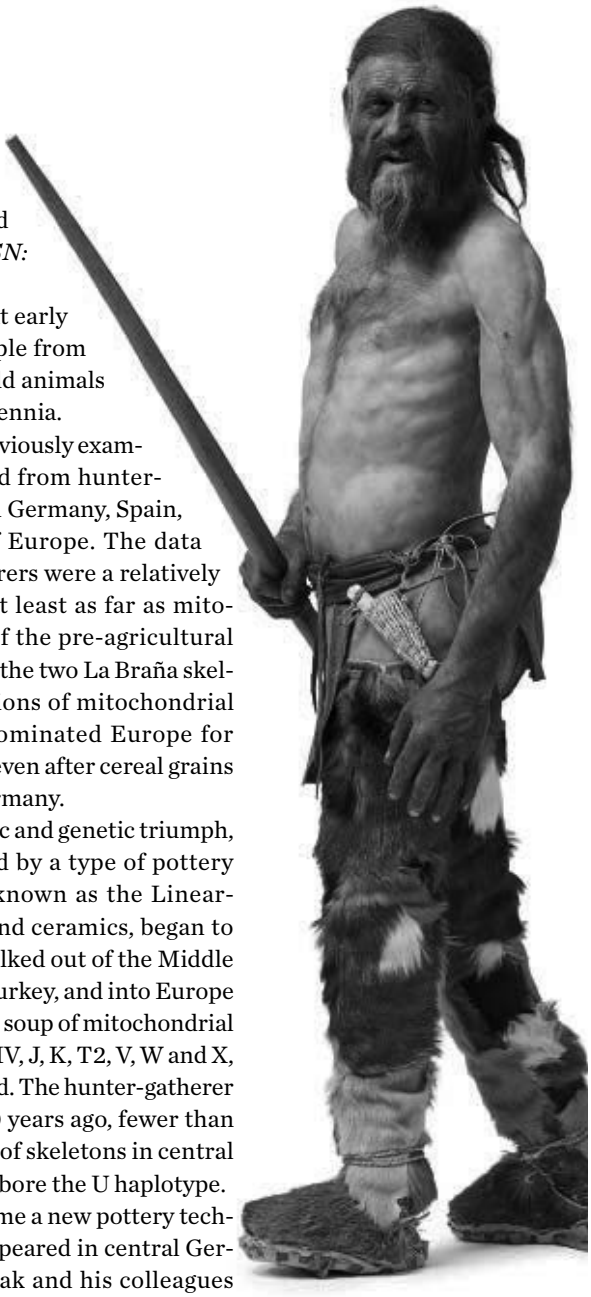
Other researchers had previously examined ancient DNA extracted from hunter-gatherer skeletal remains in Germany, Spain, Sweden and other parts of Europe. The data show that the hunter-gatherers were a relatively homogenous population, at least as far as mitochondrial types go. Many of the pre-agricultural people of Europe, including the two La Braña skeletons, carried various versions of mitochondrial DNA haplotype U. They dominated Europe for more than two millennia — even after cereal grains first appeared in central Germany.

But then, in a demographic and genetic triumph, early farmers distinguished by a type of pottery decorated with lines and known as the Linearbandkeramik, or Linear Band ceramics, began to take over. Those farmers walked out of the Middle East, through what is now Turkey, and into Europe carrying a veritable alphabet soup of mitochondrial haplotypes, including N1a, HV, J, K, T2, V, W and X, Haak and colleagues reported. The hunter-gatherer lines dwindled and by 7,500 years ago, fewer than 3 percent of skeletons in central Germany bore the U haplotype.

Each time a new pottery technology appeared in central Germany, Haak and his colleagues found a new mitochondrial haplotype, suggesting that people were migrating and bringing their pottery and ideas with them. A type of bell-shaped pottery called Bell Beaker came to central Germany, for example, with ancient farmers carrying haplotype H, a genetic signature new to that region. Another farming group with haplotypes I and U2 brought Corded Ware pottery into Germany from the east about 4,800 years ago. Those groups didn't seem to mingle with the people who were there before them.

## Living side by side

A similar population separation was going on at what is now known as the Blätterhöhle archaeological site in Hagen, Germany, researchers reported last October in *Science*. Ruth Bollongino of the Johannes Gutenberg University in Mainz and her



The frozen mummy of a person known as Ötzi, the Tyrolean Iceman (reconstructed here), provided some of the first evidence that ancient Europeans were genetically distinct from their modern counterparts.

RECONSTRUCTION BY KENNIS © SOUTH TYROL MUSEUM OF ARCHAEOLOGY, AUGUSTIN OCHSENREITER

**Pottery changes seen in the genes**
People who made different types of pottery in ancient Europe also tended to be genetically different from each other. Pottery technologies spread as people migrated around the continent, DNA data suggest.

**First farmers**
**Linear Band Pottery**
Central Europe
7,500–6,500 years ago

**Farmers**
**Funnel Beaker**
Sweden
6,300–4,800 ya

**Hunter-gatherers**
**Pitted Ware**
Southern Scandinavia
5,200–4,300 ya

**Farmers**
**Corded Ware**
Central Europe
4,900–4,350 ya

**Farmers**
**Bell Beaker**
Iberia, Central Europe, Britain
4,800–3,800 ya

colleagues examined mitochondrial DNA from the teeth and bones of 25 ancient people buried in a narrow cave. To find out what the people ate, Bollongino's group analyzed ratios of sulfur, nitrogen and carbon isotopes in the remains.

People bearing the mitochondrial signature of early hunter-gatherers were the first to bury their dead in the cave between 11,200 and 10,600 years ago, the researchers found. Those people had a diet composed primarily of wild animals.

About 5,000 years later, other genetically similar hunter-gatherers used the cave, but they were freshwater fish eaters, isotope ratios revealed. At the same time that those fish-eating foragers inhabited the region, people bearing a different genetic signature, mitochondrial type H, as well as a chemical mark associated with eating domestic herbivores — such as cows and goats — were also using the cave as a burial site.

The results suggest that the hunter-gatherers and farmers led parallel lives for roughly 2,000 years, probably interacting with each other culturally. However, each group maintained its own genetic identity and diet.

That separation didn't last forever, according to two studies — one published this April — by Mattias Jakobsson of Uppsala University in Sweden and his colleagues. The researchers examined complete genomes, not just mitochondrial DNA, of seven Stone Age hunter-gatherers and four farmers from Sweden. If the two groups had interbred, the scientists should have seen traces in this comprehensive picture of their DNA.

Remains of six seal hunters who used pottery known as Pitted Ware ceramics were excavated from burial grounds on the island of Gotland. Skeletons from those burial grounds range from about 4,400 years old to 5,300 years old. An even older hunter-gatherer, Stora Förvar11, was interred between 7,250 and 7,500 years ago in a cave on the nearby island of Stora Karlsö. The four farmers, known as Gökhem2, 4, 5 and 7, were buried less than 400 kilometers away under a large stone structure between 5,280 and 4,750 years ago. Chemical analysis showed that they had spent their lives within 100 kilometers of the structure.

The groups had probably lived side by side for at least 1,000 years, or about 40 generations. The farmers appear to have embraced the hunter-gatherers and interbred with them, Jakobsson's group reported April 24 in *Science* after examining the ancient Swedes' genomes. The Gökhem farmers had more forager ancestry than Ötzi did. The Iceman's more meager hunter-gatherer heritage reflects the fact that his people hadn't migrated as far as the Swedish farmers had, so probably encountered and interbred with fewer hunter-gatherers, researchers say.

But the mingling went only one way; the seal hunters, who had no farmer DNA, appear to have kept their genetic distance from their agricultural neighbors.

Today, there's no one in Europe quite like the Swedish hunter-gatherers or La Braña-1. But, says Jakobsson, "parts of their genomes live on all across Europe." Eventually, pure foragers died off or assimilated into farming families. Those who had interbred with the farmers passed along the hunter-gatherer genetic legacy. The amount of hunter-gatherer heritage in modern Europeans varies geographically, with people in the north claiming much more forager ancestry. People in Southern Europe have more farmer and fewer hunter-gatherer ancestors, Jakobsson's group found.

## Three ancient groups

That's a pattern also found by a large international group of researchers, including David Reich of Harvard University and Svante Pääbo of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany.

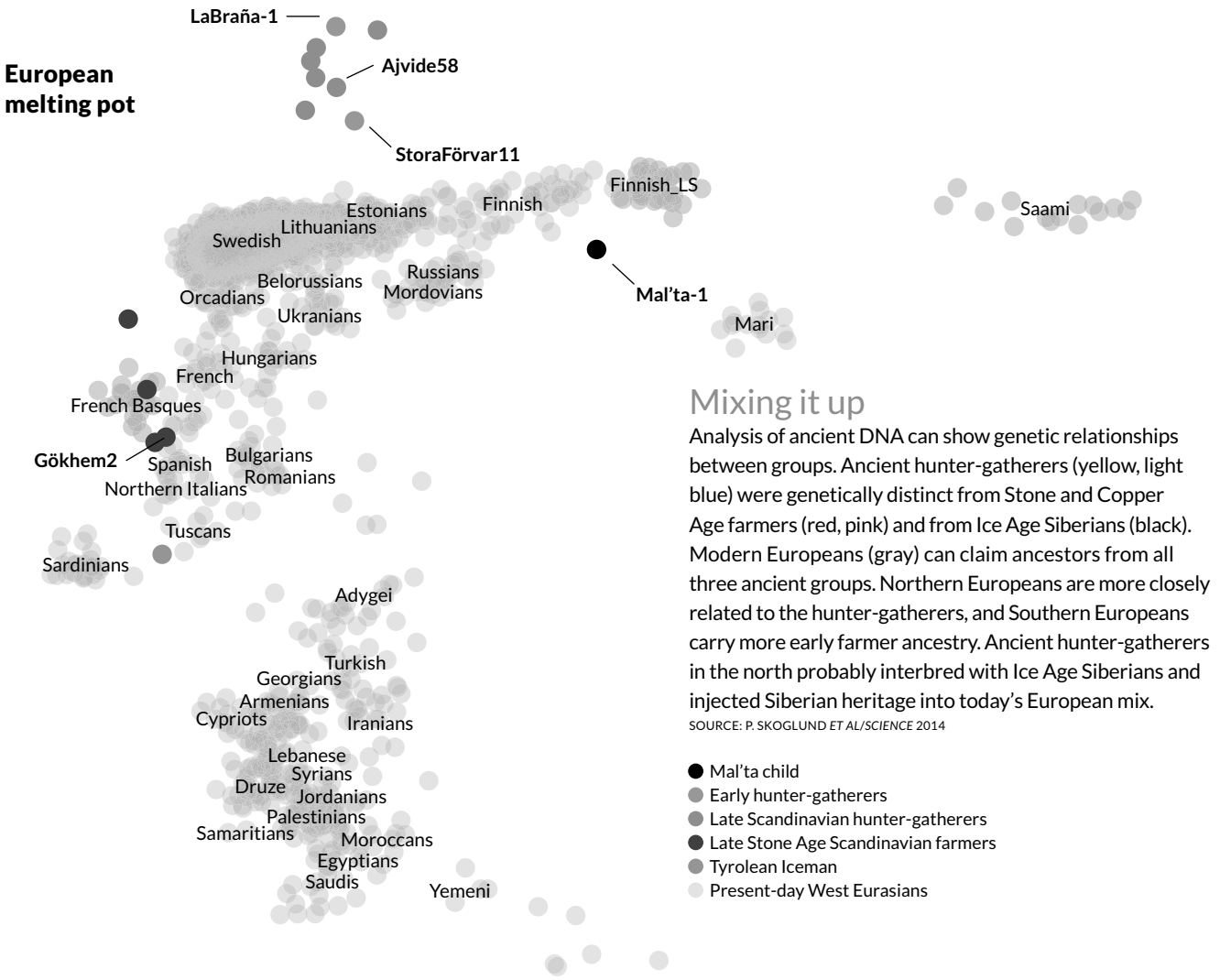
Just two days before Christmas, the researchers delivered a gift for those interested in prehistoric genetics to the bioRxiv.org preprint server: descriptions of the full genetic makeups of nine ancient Europeans and their links to modern people. The ancient specimens were the 7,500-year-old remains of a farmer woman from Stuttgart, Germany, an 8,000-year-old hunter-gatherer skeleton discovered in the Loschbour rock-shelter in Luxembourg and the skulls of seven hunter-gatherers that had been mounted on stakes and sunk into a lake 8,000 years ago at the Motala site in southern Sweden.

The researchers had compared those old genomes, as well as DNA from Ötzi, Gökhem4 and his hunter-gatherer contemporaries and La Braña-1, with new data collected from 2,196 living people representing 185 populations from around the world.

Modern-day Europeans, the team concludes, are a complex mix of at least three ancient groups: the early European farmers, Western European hunter-gatherers (like La Braña-1) and a third group the researchers call the ancient north Eurasians.

Eske Willerslev, an evolutionary geneticist at the University of Copenhagen, and his colleagues revealed that mysterious third group in

FROM TOP: *NORDISK FAMILJEBOK* (1917), VOL.26 *TILL ART. STENÅLDER. II*; WILLOW/WIKIMEDIA COMMONS (CC BY-SA 3.0); DRENTS MUSEUM/WIKIMEDIA COMMONS; EINSAMER SCHÜTZE/WIKIMEDIA COMMONS (CC BY-SA 3.0); JOSÉ MANUEL BENITO ÁLVAREZ/WIKIMEDIA COMMONS (CC BY-SA 2.5)




January via the genomes of two Ice Age Siberians (*SN: 12/28/13, p. 16*).

One of the Siberians was a young boy buried 24,000 years ago near Lake Baikal. The child, known as Mal'ta-1, is genetically unlike any living group of people today. His genetic profile lies somewhere between that of western Eurasians and Native Americans, Willerslev and colleagues reported in *Nature*. That finding helps explain why some Native Americans have similar genetic signatures to Europeans; both groups got DNA from the Mal'ta child's people.

Native Americans can trace up to a third of their genetic makeup to the ancient Siberians. Reich and his colleagues say Europeans may get up to 20 percent of their genetic heritage from those northern people.

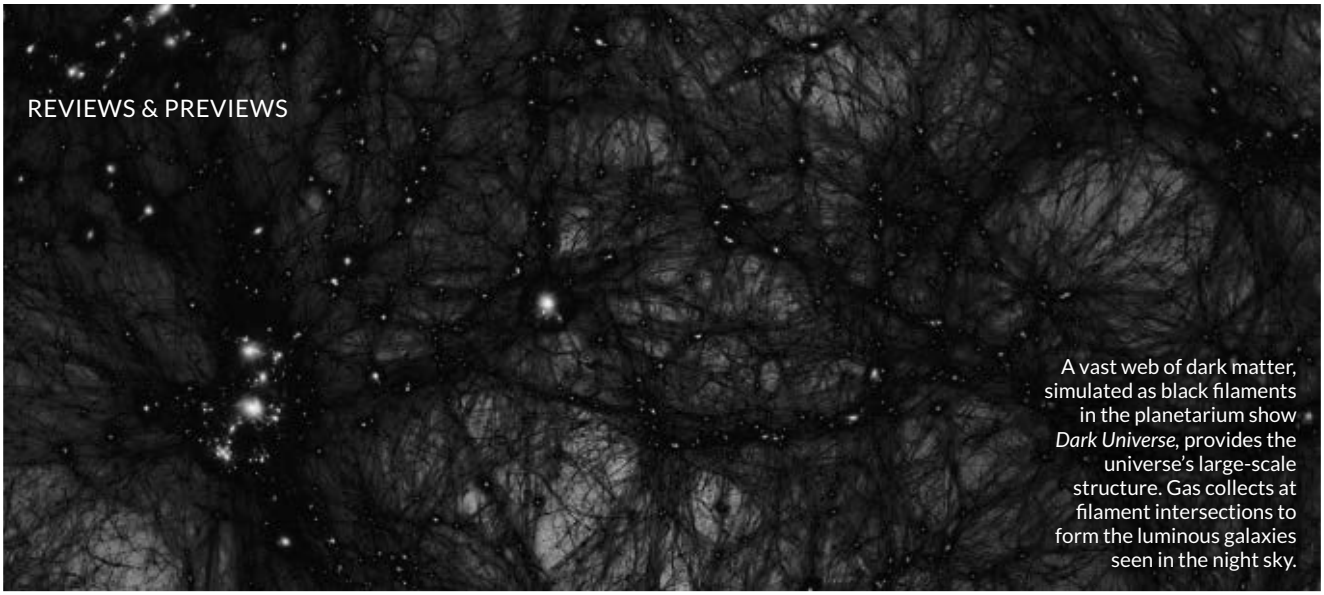
The Siberians came later to the party than other groups. Neither the Stuttgart woman nor the Loschbour man were genetically linked to the Siberians, but the Swedish foragers whose heads were mounted on spikes did bear a slight genetic resemblance to the Mal'ta child.

One of the seal hunters from Gotland, called Ajvide58, got about 15 percent of his DNA from the Mal'ta people, Jakobsson's team found. The Scandinavian hunter-gatherers probably passed on that Siberian ancestry to other Europeans via the farmers, but can't have been the only group to do so.

The complete account of European prehistory and its present-day legacy is still being written. Some chapters are sure to be revised or rewritten entirely as ancient DNA adds additional dramatic details. And unexpected new plot twists also await researchers as they uncover more founding European foragers and farmers, each with his or her own genetic tale to tell about what may be the Western world's first culture clash. ■

## Explore more


- P. Skoglund *et al.* "Genomic diversity and admixture differs for Stone-Age Scandinavian foragers and farmers." *Science.* Published online April 24, 2014. doi: 10.1126/science.1253448



A vast web of dark matter, simulated as black filaments in the planetarium show *Dark Universe*, provides the universe's large-scale structure. Gas collects at filament intersections to form the luminous galaxies seen in the night sky.

FILM

## Illuminating a dark universe

Space show brings the unseen to light

A hundred years ago, astronomers knew of just one galaxy: our own. Today they know the universe hosts billions. What's more, the visible stuff of galaxies is dwarfed by dark matter, and each galaxy is racing away from the others due to an even more mysterious entity: dark energy. *Dark Universe*, developed by the American Museum of Natural History's Hayden Planetarium in New York City, compresses a century of discovery into a crisp, comprehensible half hour. Now showing in spots across the country, the film merges spectacular scientific results with breathtaking computer simulations. The Big Bang bangs, the speckled Cosmic Microwave Background is written onto the sky and a vast cosmic web expands to fill space. From there the story launches itself into the unknown: Scientists don't yet understand dark matter or dark energy; large parts of the sky remain unmapped. "We stand on the threshold of great discoveries, and always will, as long as we keep exploring," says narrator and Hayden director Neil deGrasse Tyson. In an era of dwindling research budgets, it's a timely message. — *Gabriel Popkin*

### Now showing

**Einstein Planetarium at National Air & Space Museum**
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**Hayden Planetarium at American Museum of Natural History**
NEW YORK CITY

**Morrison Planetarium at California Academy of Sciences**
SAN FRANCISCO

**Stardome Observatory & Planetarium**
AUCKLAND, NEW ZEALAND (coming soon)

**Sir Thomas Brisbane Planetarium**
BRISBANE, AUSTRALIA (coming soon)

*Check your local planetarium for other showings*

SCREENTIME

## See the sky in a different light

An interactive map lets you explore the galaxy with infrared light

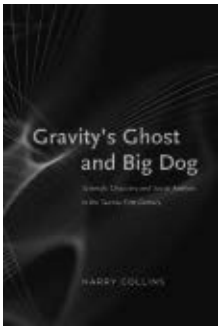
Gazing at the vast sky on a dark, clear night is humbling. But what if your eyes could see infrared light? The view might look something like NASA's new interactive map of the galaxy. GLIMPSE360 is a night-sky atlas assembled from over 2 million images taken by the Spitzer Space Telescope. Because interstellar clouds block visible light, the infrared maps allow you to peer through galactic dust lanes and into the hearts of stellar nurseries. Familiar pan-and-zoom tools allow users to explore the sky. But the most powerful feature is a slider bar that switches the view between visible and infrared light. Suddenly, the power of observing the universe at different wavelengths becomes evident as dark clouds give way to nebulae, star clusters and supernova remnants. A separate viewer lets you jump right to specific objects, in case browsing aimlessly isn't your thing. Be sure to check out the galactic center, the Cygnus-X star formation complex and the vast Eta Carina Nebula. — *Christopher Crockett*

The Seagull Nebula, seen in this Spitzer Space Telescope image from the GLIMPSE360 atlas, sits over 3,600 light-years from Earth along the border of the constellations Canis Major and Monoceros.

FROM TOP: AMNH; GLIMPSE TEAM/JPL-CALTECH/NASA



See NASA's infrared galaxy map at **bit.ly/SNglimpse360**




BOOKSHELF

## Gravity's Ghost and Big Dog

Scientific Discovery and Social Analysis in the Twenty-First Century

*Harry Collins*

Roughly 50 kilometers east of Baton Rouge, La., lasers ricochet off mirrors that dangle at the ends of a 4-kilometer-long, L-shaped vacuum tube. A nearly identical facility sits almost 3,000 kilometers away in Washington state. The research stations — part of the Laser Interferometer Gravitational-Wave Observatory, or LIGO — are designed to sense gravitational waves, minuscule ripples in the fabric of space. Unlike the recently detected waves from the Big Bang (*SN: 4/5/14, p. 6*), the waves LIGO picks up will most likely come from black hole or neutron star collisions.

In 2007, and again in 2010, the mirrors at both sites appeared to tremble in unison. Was this the first direct detection of gravitational waves? Was it a fake signal inserted to test project scientists? And if it was genuine, how would the researchers announce their Nobel-worthy finding?

In this update to his previous book *Gravity's Ghost*, sociologist Harry Collins chronicles the occasionally heated (and often arcane) debates among LIGO researchers as they wrestle with how best to analyze, interpret and publish their data. They argue over whether the detection (code-named "big dog") of gravity waves near the Canis Major constellation is real, and what to tell the world about it. While gravitational waves are at the heart of the book, Collins' main targets are the philosophies and social dynamics that drive modern science. His interest is less in the physics — though he does get caught up in the excitement and even dabbles in some hypothesizing of his own — and more in its sociological underpinnings.

As an embedded journalist, Collins had nearly unfettered access to years of internal deliberations among the LIGO scientists. This is as close as a layperson could come to actually being there. Unfortunately, this strength can also be the book's greatest downfall. At times, the reader drowns in detail, becoming mired in the minutiae of how to title a research paper or the subtleties of a statistical calculation. The casual reader might want to give this one a pass; the physics junkie or philosophy of science enthusiast, however, will find lots to mull over. — *Christopher Crockett*
*Univ. of Chicago, $30*

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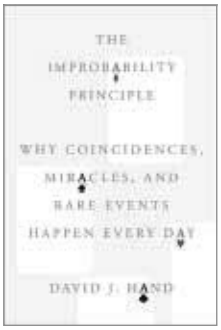


BOOKSHELF

## The Improbability Principle

Why Coincidences, Miracles, and Rare Events Happen Every Day

*David J. Hand*

Incredible things happen routinely. People win the lottery — twice. Golfers hit holes-in-one several days in a row. Basketball players appear to get a "hot hand" (*SN: 2/12/11, p. 26*; *SN Online: 10/29/13*).

Do these chance events validate superstition or suggest a hidden influence in our world — a higher power, perhaps? Absolutely not, argues Imperial College London statistician David J. Hand. The laws of mathematics and physics suffice to explain a world of coincidences.

Hand weaves his principle from several strands dubbed the "law of inevitability," the "law of truly large numbers" and others. Essentially, he argues that because so many things happen, and because we are biased toward noticing unusual events, we should not be surprised when an occasional startling coincidence emerges from a sea of ordinariness. Instead, we should be surprised if one doesn't.

In making his case, Hand devotes much space to debunking fallacies such as ESP-proving experiments and Carl Jung's "synchronicities." He also really likes dice. But if you're not a gambler and already assume a rational universe, you may wonder how the improbability principle might apply to more pressing societal problems.

Here Hand offers a few tantalizing examples: a mother exonerated by statistics after being convicted of double infanticide; CEOs whose swiftly appreciating stock options were found to have been postdated to just before a dramatic price increase; the unsettling frequency of stock market crashes. But more would have been welcome.

Hand also seems forever worried that his reader will forget the previous chapter's exposition, leading to much repetition. Still, his informal style, wide-ranging curiosity and knack for elucidating complicated mathematics make the book an enjoyable — and mostly convincing — read.
— *Gabriel Popkin*
*Scientific American/Farrar, Straus and Giroux, $27*

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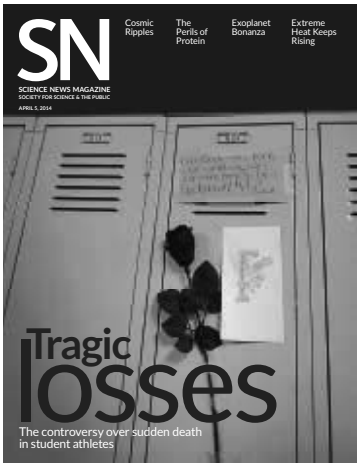


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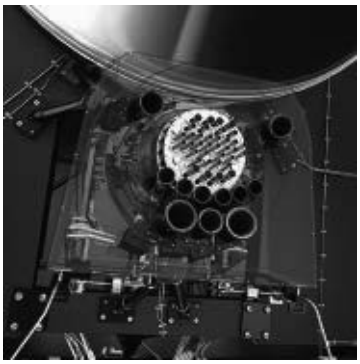

The Planck satellite's two instruments, shown in this artist's illustration, gather microwaves to map radiation left over from the Big Bang.

The **High Frequency Instrument** (shown in gold) converts higher-energy microwaves to heat to detect tiny amounts of diffuse radiation.

The **Low Frequency Instrument** (gray tubes) converts lower-energy microwaves to electricity to measure the intensity of radiation at each frequency.

## Clocking the universe's expansion

*Conflicting estimates of the Hubble constant — a measure of the speed of the universe's expansion — have sparked debate among cosmologists. The discrepancy in data from the Planck satellite with data from other methods may be just a mistake, or it may require adjusting the cosmological model of the universe, as* ***Tom Siegfried*** *explained in "Cosmic question mark" (*SN: 4/5/14, p. 18*).*

"I think I'm missing something," reader **Michael Herzog** wrote in an e-mail. "If dark energy is causing the expansion of the universe to accelerate, wouldn't we expect the value of the Hubble constant derived from the early universe (the Planck results) to be smaller than the current value?"

**Siegfried** replies: "The Planck satellite does not measure the Hubble constant directly, but collects data that can be used, in conjunction with other properties of the universe, to calculate the present day Hubble constant. Incidentally, at early times the universe's expansion was decelerating; it did not begin to accelerate until the universe was several billion years old."

## Temperature highs and lows

*While the average global surface temperature has hit a plateau in the last 15 years, high temperatures continue to climb on land, as* ***Beth Mole*** *reported in "Extreme heat still on the rise" (*SN: 4/5/14, p. 12*).*

Several readers wanted to know if this finding meant that climate scientists were seeing an increase in colder-than-normal temperatures, too. "I found **Beth Mole**'s article very interesting, but I was left wondering about cold extremes," wrote **Alexander Sabatino**. "I mention this in light of the recent harsh U.S. winter, especially in the Northeast. If global surface temperature is overall level, shouldn't heat extremes be balanced by cold extremes?"

In the study, says **Mole**, "climate scientist Sonia Seneviratne and colleagues focused on land temperature records because cooling ocean surface temperatures are the prime suspect behind the planet's recent flat-lined average surface temperature. While scientists are still trying to understand why ocean surface temperatures are staying cool, it's clear that some of the missing heat is being dunked deep underwater, possibly by unusually strong trade winds (*SN: 3/22/14, p. 12*). In the meantime, the authors reported ongoing rising heat trends on land. While some research has linked climate change to extreme weather besides heat, in this study the authors report no clear trend in cold temperature dips over land."

## To screen or not to screen

*In "Sudden death" (*SN: 4/5/14, p. 22*),* ***Laura Beil*** *described the issue of using electrocardiograms to identify young athletes at risk for fatal heart problems. But a misdiagnosis could bench a healthy player for no reason, leaving cardiologists divided on whether to require large-scale screening.*

Readers weighed in on the debate with their own experiences. "Mandatory EKG screening should not be proposed for just athletes but for all young people," e-mailed **Elizabeth McDowell**. "EKGs can identify other heart conditions in addition to heart attack risks, some of which don't become obvious until later in life. I am one person who could have benefited from EKG screening. When I was 40 and in the eighth month of my first pregnancy, I was diagnosed with Wolff-Parkinson-White syndrome, which causes bouts of rapid heartbeat. The complications during and after childbirth were life-threatening for me. My family and I would have been grateful for advance warning of the condition."

But other readers pointed out that the risk of needlessly pulling a healthy athlete off the field is high. As **Craig Finseth** noted, "with 8 million people participating in athletics in any given year, a false-positive rate of 0.1 percent — which is an incredibly good rate — would 'identify' 8,000 people, which is 7,900 people more than the death rate of 100 per year."

ESA

### Join the conversation

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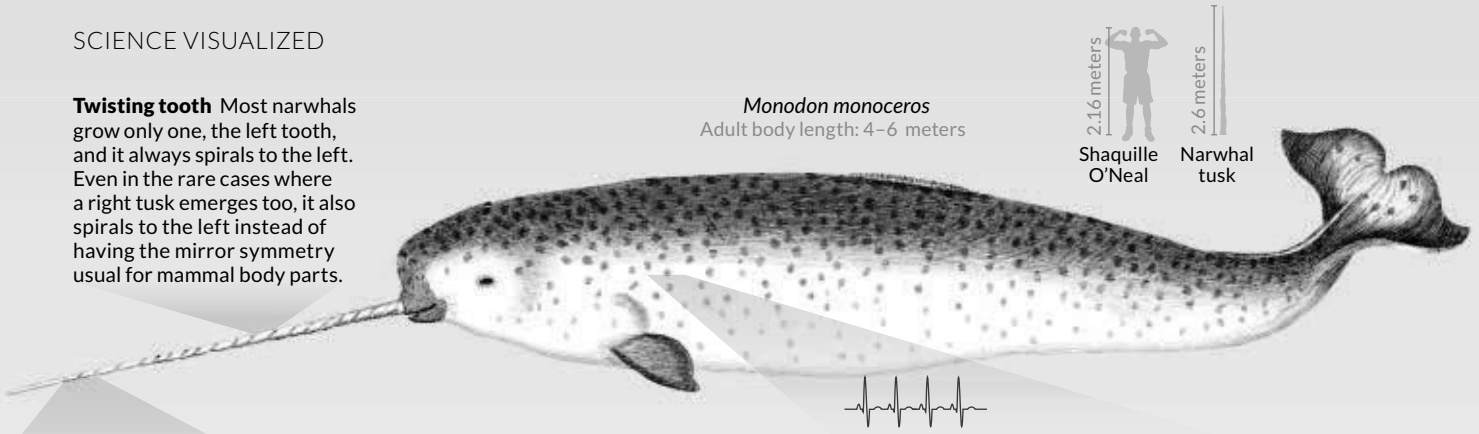
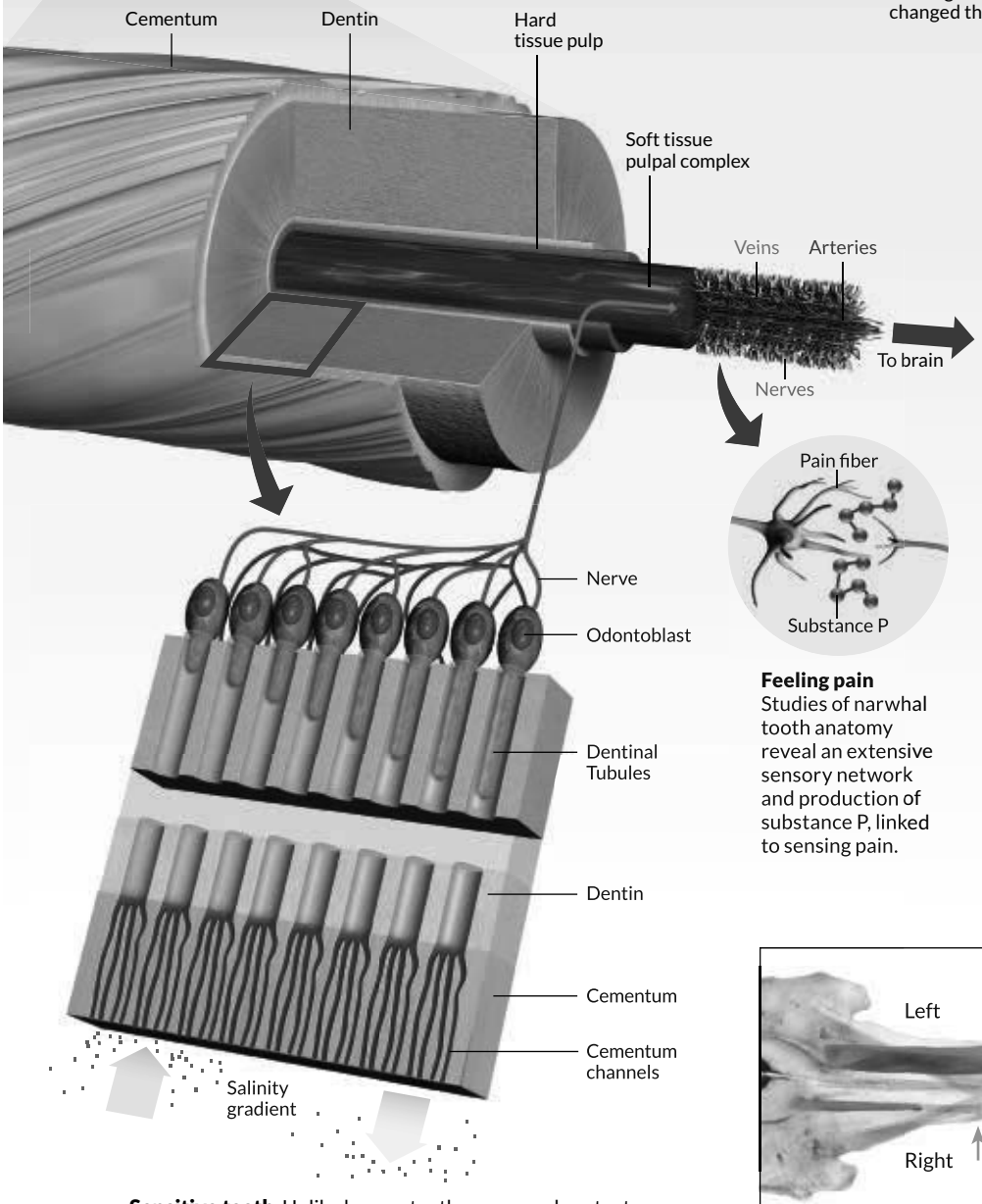
**Twisting tooth** Most narwhals grow only one, the left tooth, and it always spirals to the left. Even in the rare cases where a right tusk emerges too, it also spirals to the left instead of having the mirror symmetry usual for mammal body parts.




**Detecting salinity** Heart rates increased in living narwhals when researchers changed the water salinity around the tooth.

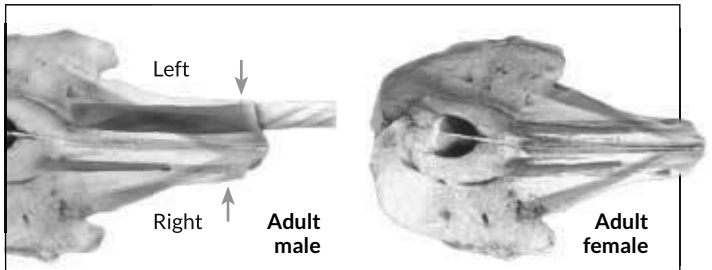



**Feeling pain** Studies of narwhal tooth anatomy reveal an extensive sensory network and production of substance P, linked to sensing pain.

**Sensitive teeth** Unlike human teeth, no enamel protects the outside of a narwhal tusk. Abundant pores in the outer layer (cementum) allow the salinity of surrounding water to trigger special cells called odontoblasts that connect to nerves in the tusk's inner pulp.

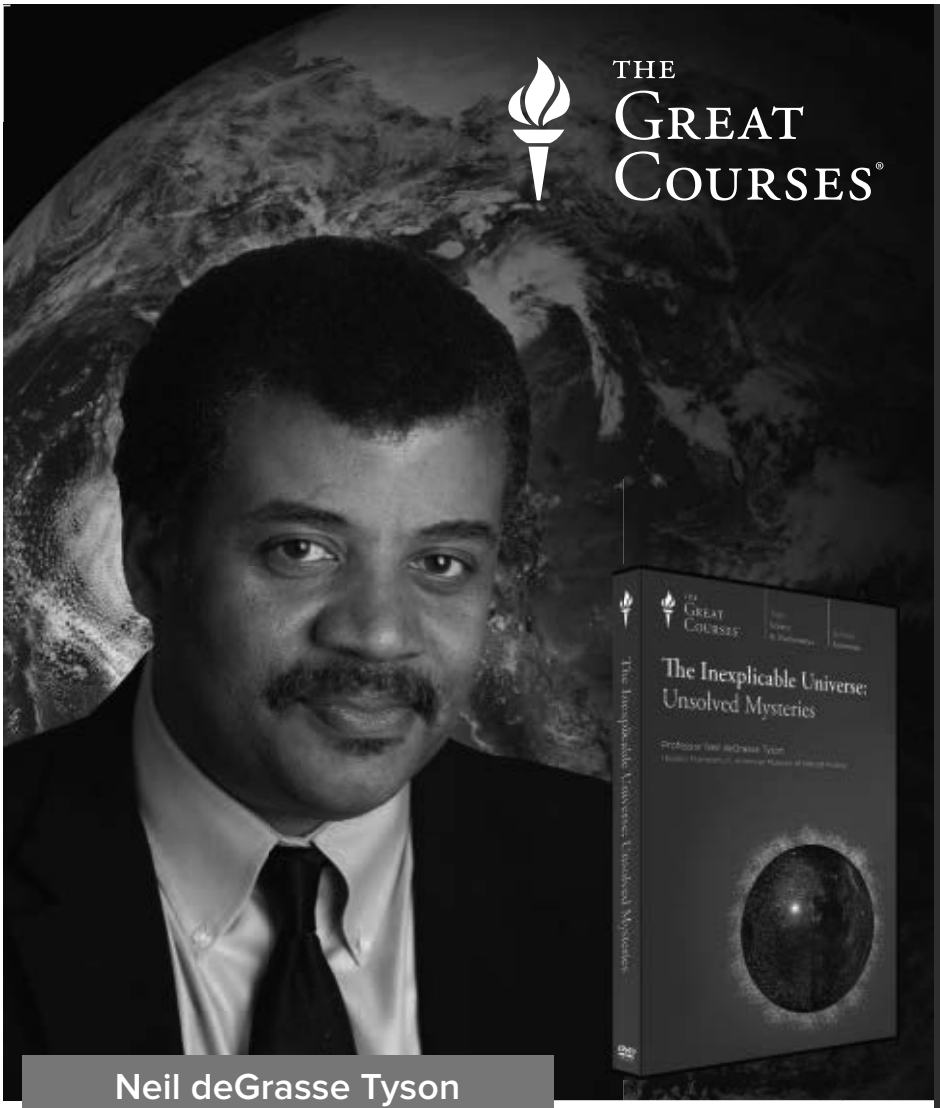
## Strangest tooth in the sea

Sometimes called the unicorn of the sea, the male narwhal's tusk is actually a tooth, and it grows directly through the whale's upper lip instead of pushing the lip aside. It's an exuberantly large version of a canine tooth that grows in a spiral; the only tooth known to do so. Otherwise narwhals are practically toothless, with only vestigial stubs that stop growing during development and rarely emerge into the mouth. This extreme anatomy has captivated dentist Martin Nweeia, who practices in Connecticut and teaches at Harvard University. For more than a decade, he has pioneered ways to study these difficult-to-reach Arctic whales, and he and his colleagues now describe in the April *Anatomical Record* that narwhals can detect changes in water salinity using only their tusks. The animals "don't have a good sense of humor," though, about being temporarily restrained for the testing, Nweeia says. —*Susan Milius*




**Female teeth** Only 15 percent of female narwhals have a tusk (blue) that emerges from the skull. Both sexes also have tiny vestigial teeth (green), not useful for eating.

FROM TOP: W. SCORESBY/WIKIMEDIA COMMONS; KEVIN HAND, M.T. NWEEIA *ET AL/ANATOMICAL RECORD* 2014; ETHAN TAYLOR, M.T. NWEEIA *ET AL/ANATOMICAL RECORD* 2012

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