SN
SCIENCE NEWS MAGAZINE
SOCIETY FOR SCIENCE & THE PUBLIC
NOVEMBER 16, 2013

Comet ISON's Approach

Saharan Dust Once Fertilized Florida

Breath Diagnosis

Junk Flush: Why We Sleep

Brain CONTROL

Noninvasive technology gets paralyzed people walking

Moon Lands on Man!

The skeptics said it couldn't be done… but our ***Moon Phase*** *proves that one small step for Stauer is one giant leap for watch lovers!*

It has always taken scientific skill and artistic wizardry to discover the Moon's secrets. When Galileo Galilei turned his telescope towards the Moon in 1609, he relied on his knowledge of light and shadow learned as a painter to understand the movements of the heavenly orb. We relied on that same pairing of art and science to create one of our most complicated and beautiful movements yet… for an unbelievable price!

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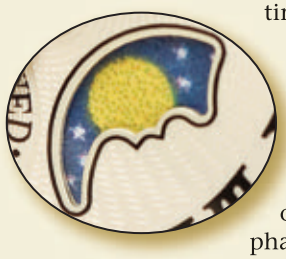

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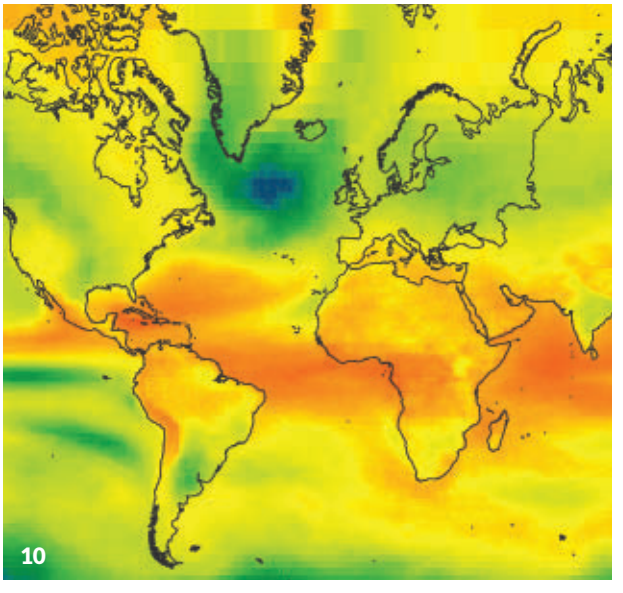
ScienceNews

Features

News



Departments

COVER Spinal-injury patient Gene Alford wears an electrode-studded cap that picks up his brain activity, letting him mentally direct the motion of a walking robot exoskeleton. *Felix Sanchez*

CLOCKWISE FROM TOP: FELIX SANCHEZ; M. SUPERINA; C. MORA *ET AL*/*NATURE* 2013

Medicine's future inspired by science fiction

We don't yet have a *Star Trek* tricorder or an *Iron Man* suit. But considering the stories in this issue and other recent news, that's not for a lack of trying.

As contributing correspondent Laura Beil reports on Page 18, scientists are making progress in mimicking the abilities of Dr. McCoy's handy medical sensor-computer by analyzing exhalations for signs of disease. A diagnostic Breathalyzer could give doctors a quick, noninvasive way to screen patients. The FDA has already approved breath tests for asthma and *H. pylori* infection, among others. And while measuring and cataloging the minute chemical changes that go along with different diseases poses a difficult challenge, scientists are now testing methods to identify people with heart failure, liver failure, tuberculosis and certain cancers. We may never get something quite as versatile as the medical tricorder (although there is now a $10 million tricorder XPRIZE competition focused on the development of a *Star Trek*–like diagnostic device). But we could end up with tools that will help people in the 21st century, not the 23rd.

Similarly, it sounded like a futuristic fantasy when staff writer Meghan Rosen invoked the exoskeleton worn in the *Iron Man* movies to pitch her story on brain-controlled robotic walkers. The U.S. Army has since announced a serious effort to build a prototype of the superhero's armored suit that can repel bullets and offer a bionic assist so a soldier can run and jump while carrying 100 or more pounds of equipment. Rosen ended up telling a quieter if equally astounding story about exoskeletons that may help paralyzed people walk again. On Page 22, she describes how scientists are able to tap into patients' brain waves using electrodes placed on the scalp. The patients are learning to command the robotic walker with only their thoughts. While the technology is not yet ready for widespread use, its potential is great. It would offer a noninvasive, and so less risky, alternative to the implanted brain-computer devices that have already shown great promise in helping the paralyzed.

More on what brain implants can do appears on Page 12. One study used implanted electrodes to restore mobility in rats with spinal injuries. The other hints at a way to build "smart" prosthetics enabled with the sensation of touch.

To me, none of these are quite examples of science fiction becoming real. But they do reveal how science fiction can inspire scientists and engineers to try things that sound outlandish or impractical — and that may well lead to radically new ways of doing things. — *Eva Emerson, Editor in Chief*

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SANDY SCHAEFFER

FOUND! American Coin Classics Collection

Hurry to secure yours before they disappear again!

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Excerpt from the November 9, 1963, issue of *Science News Letter*

50 YEARS AGO

Seek Meningitis Vaccine

A vaccine that will prevent meningitis is being sought. When found, it would solve the problem of meningitis outbreaks among military recruits.... After 24 years of successful prevention against meningococcal disease ... specific strains of *Neisseria meningitidis* have become resistant to the sulfonamides usually used for treatment or prevention.... Although meningococcal bacteria were handled easily until after World War II, resistance to sulfadiazine is showing up and could lead to serious conditions, even epidemics in public schools.

UPDATE: The first vaccine for bacterial meningitis was approved in 1974, and more effective conjugate vaccines came out in 2005 and 2010. The U.S. Centers for Disease Control and Prevention reported about 4,100 cases of bacterial meningitis per year, including 500 deaths, between 2003 and 2007.

Pink fairy armadillos have claws so specialized for digging that they struggle to walk on hard surfaces.

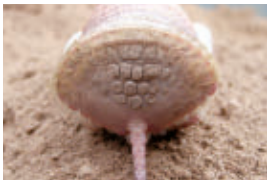
IT'S ALIVE

Pink armadillos ain't your Texas critters

Here's an Internet bizarrity that you can believe in: the pink fairy armadillo.

It's a real animal, the smallest armadillo species in the world. At about 100 grams, it would fit in your hands. It's covered with "very fine, silky white hair," says Mariella Superina of the CONICET research center in Mendoza, Argentina. And its hard outer covering, rich in blood vessels, can blush pink.

Full details of *Chlamyphorus truncatus* biology, though, might as well be a fairy tale. It's known only from a dry, sandy swath of Argentina and spends most of its time underground. The pink fairy is so hard to spot that Superina and her colleagues are struggling to determine whether it's endangered or not. She heads an international group of specialists now trying to assess the risk of extinction for the world's 21 known armadillo species, plus their close relatives, the sloths and anteaters.



In 10 years of field work, she has never caught sight of the pink species in the wild. She has seen tracks made by digging claws and the diamond-shaped tip of its tail. After several meters, the tracks just stop where, she presumes, the armadillo disappeared underground. Locals, she says, "can track down any animal — except the pink fairy armadillo." Occasionally someone captures one and soon panics about keeping it alive. These rare captives, she reports, usually live no more than about eight days.

Superina struggled to care for one such stray that couldn't be returned to the wild. In 2011, she published a *Zoo Biology* paper largely about what it wouldn't eat. In desperation, she discovered that it would slurp up a goop (consisting of milk, cat food and exactly half a banana) that had been mixed for a different species. The next stray fairy, though, wouldn't touch the stuff. (Don't even think of getting one as a pet, she says.)

During the eight months the goop-tolerant fairy lived in Superina's home terrarium, infrared cameras recorded it moving below the sand surface. Biologists had thought the species "swims" through sand. No, Superina now says. "It was very funny — it digs and then it backs up and compacts the sand with its butt plate." The video shows a pale, furry body digging and butting, digging and butting. The flattened round rear plate used in compaction (shown above) is unique to fairy armadillos. This rare glimpse may have solved a paleontological mystery, too: Previously found rows of compacted earth discs that look like slumping sliced bread may actually be the work of ancient fairy armadillos' butt plates. — *Susan Milius*

FROM TOP: NICHOLAS SMYTHE/GETTY IMAGES; M. SUPERINA

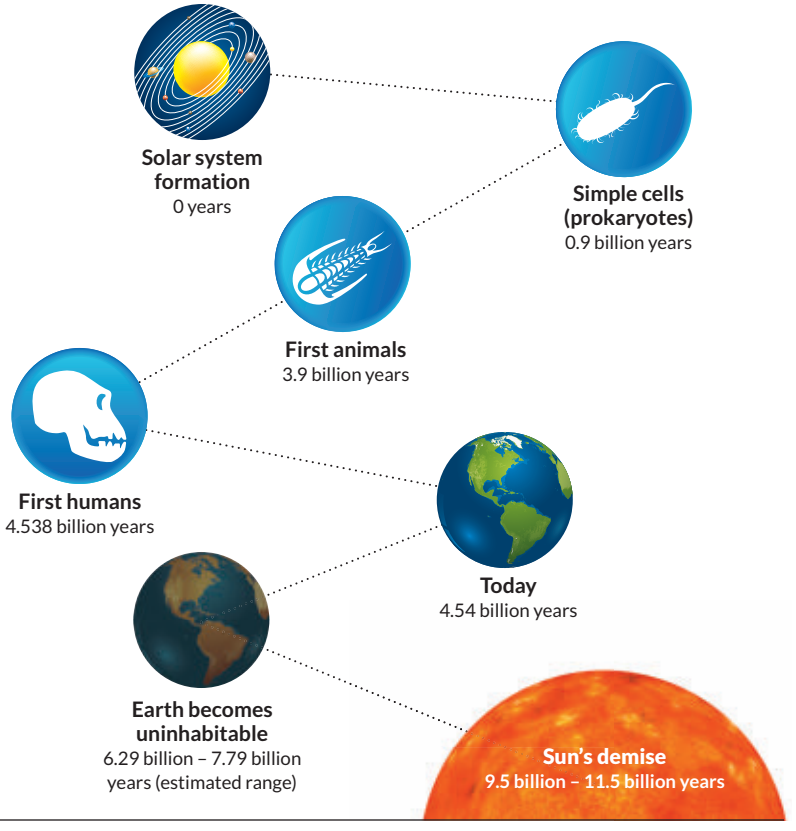
SCIENCE STATS

Uninhabitable Earth

To determine whether a planet could support life, astronomers first look at whether it falls within its star's habitability zone, the Goldilocks distance that is not too hot or too cold. But that range can change as a star evolves. A recent estimate of the lifetimes of the habitability zones of Earth and various exoplanets suggests Earth could become unable to support life as soon as 1.75 billion years from now, when the sun brightens before dying out.

SOURCE: A.J. RUSHBY *ET AL/ASTROBIOLOGY* 2013

Solar system's life cycle



SAY WHAT?

Qingsongite *CHING-sohng-ite*\ n.

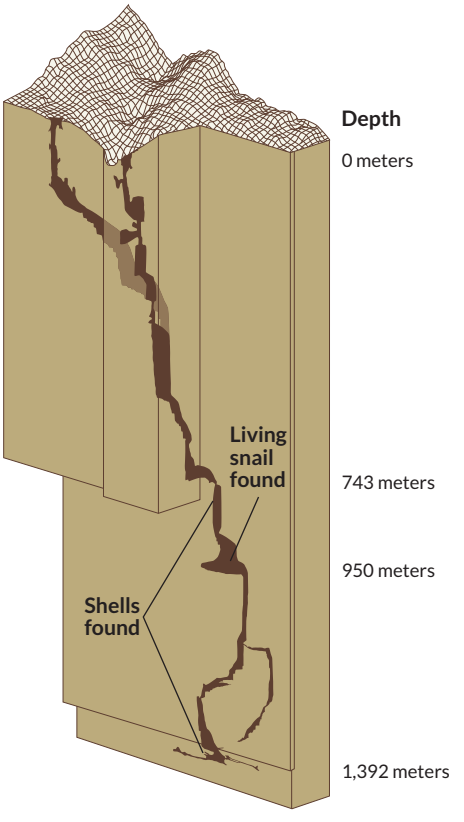
A newly christened mineral has an atomic structure that's similar to diamond and nearly as hard. Qingsongite (below) was first created in the laboratory in 1957, and geologists first found natural qingsongite, which is a cubic boron nitride, in chromium-rich rocks in Tibet in 2009. The mineral is named after deceased Chinese geologist Qingsong Fang, who discovered diamond in similar Tibetan rocks in the late 1970s. Cubic boron nitride is the only boron mineral formed deep within the Earth. About 180 million years ago, the collision of the Indian and Eurasian tectonic plates brought qingsongite near the planet's surface. An international team announced the discovery and new mineral name, now officially sanctioned by the International Mineralogical Association, in August. — *Sarah Zielinski*

INTRODUCING

Clearly new snail

Croatia's deepest cave system is home to a tiny, translucent resident. The newly named *Zospeum tholussum* belongs to a group of terrestrial snails found in wet subterranean habitats. Alexander Weigand of Goethe University Frankfurt in Germany retrieved a living specimen from one chamber and a handful of empty shells from others more than 800 meters deep inside the Lukina jama–Trojama cave system. At that depth, air temperature drops to a chilly 3.3° Celsius. The delicate shells averaged just 1.55 millimeters tall, or about the thickness of a penny. Unoccupied shells are nearly clear but turn milky white as they age, Weigand reported in August in *Subterranean Biology*. — *Allison Bohac*

Snail finds



STATS: PENFOLD/ISTOCKPHOTO, BANDERLOG/ISTOCKPHOTO, ENJOYNZ/ISTOCKPHOTO, BIKERBOY82/ISTOCKPHOTO, S. EGTS; INTRODUCING, FROM TOP: D. BAKŠIĆ, CROATIAN SPELEOLOGICAL SERVER 2010; JANA BEDEK, HBSD. ADAPTED BY S. EGTS; *SAY WHAT*: LARISSA DOBRZHINETSKAYA

HUMANS & SOCIETY

Fossil could prune human family tree

Early members of *Homo* line may have belonged to one species

A 1.8-million-year-old skull (far right) and other hominid fossils unearthed at a site in western Asia indicate that a single species of early *Homo* lived in Africa and Asia at that time.

COURTESY OF M.S. PONCE DE LEÓN AND C.P.E. ZOLLIKOFER/UNIV. OF ZURICH

BY BRUCE BOWER

A remarkably complete, roughly 1.8-million-year-old fossil skull with surprising features adds key evidence to the controversial idea that early members of the *Homo* genus evolved as one species living in both western Asia and Africa.

The new find and the remains of four other skulls previously unearthed at a site called Dmanisi, in the nation of Georgia, belonged to *Homo erectus* despite big differences in shape and size, say paleoanthropologist David Lordkipanidze of the Georgian National Museum in Tbilisi and his colleagues. The magnitude of skull diversity at Dmanisi indicates that African *Homo* fossils dating to shortly before and after 1.8 million years ago can be folded into a single, intercontinental *H. erectus* population, the researchers conclude in the Oct. 18 *Science*.

Scientists usually sort the African fossils into four species: *H. habilis*, *H. rudolfensis*, *H. ergaster* and *H. erectus*.

"After finding these five fossil skulls from a snapshot of time at Dmanisi, we're reconsidering what we know about *Homo erectus*," Lordkipanidze says. African sites have yielded individual *Homo* fossils from around 2 million years ago, he adds, but those finds reveal nothing about physical differences in populations at that time.

Working at Dmanisi in 2000, Lordkipanidze's team found a lower jaw from a member of the *Homo* genus, the set of related species that includes people today. Five years later, the researchers uncovered the rest of the skull from the same ancient individual. Unlike any previously discovered *Homo* skull, the new find combines a relatively small brain case with a long face, projecting jaws and large teeth. The five Dmanisi skulls come from a regional branch of *H. erectus* that featured small-faced, straight-jawed youngsters and adult females along with large-faced, jut-jawed adult males, the investigators say.

Shape and size differences among the Dmanisi skulls don't exceed those found in modern populations of people and chimpanzees, they add, supporting the idea that all five represent a single species.

Early *Homo* fossils from East Africa — including a 2.3-million-year-old upper jaw, a nearly 2-million-year-old partial skull classified by some researchers as *H. rudolfensis* (*SN: 9/8/12, p. 8*) and a 1.8-million-year-old upper jaw often assigned to *H. habilis* — display enough similarities to the Dmanisi crowd to qualify as *H. erectus*, his group concludes.

"Whatever you call them, the Dmanisi hominids provide an amazing window into what our ancestors looked like when they left Africa for the first time," remarks paleoanthropologist Tim White of the University of California, Berkeley.

White finds it plausible that a single early *Homo* species spread from Africa to Georgia. More fossil discoveries are needed to establish whether additional African *Homo* species existed alongside *H. erectus*, he says.

But some paleoanthropologists don't see the Dmanisi finds as reason to put all early *Homo* fossils in one species.

"I'm prepared to think that we're witnessing *H. erectus* in the making at Dmanisi," says Fred Spoor of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany. *H. rudolfensis*, however, evolved distinct facial features in East Africa that don't appear on any Dmanisi skulls, Spoor holds.

Bernard Wood of George Washington University in Washington, D.C., agrees. The Dmanisi fossils may be examples of a hominid species that evolved in western Asia, he says, but "a raft of evidence" from the brain case, teeth, limbs, hands and feet suggest that *H. erectus* and *H. habilis* were different species. ■

BODY & BRAIN

Sleep allows brain to wash out junk

Finding may lead to improved Alzheimer's disease therapies

BY TINA HESMAN SAEY

Sleep hoses garbage out of the brain, a study of mice finds.

The trash, including pieces of proteins that cause Alzheimer's disease, piles up while the rodents are awake. Sleep opens spigots that bathe the brain in fluids and wash away the potentially toxic buildup, researchers report in the Oct. 18 *Science*.

The discovery may reveal why sleep seems mandatory for animals (*SN: 10/24/09, p. 16*). It may also shed new light on the causes of neurodegenerative disorders such as Alzheimer's and Parkinson's diseases.

"It's really an eye-opening and intriguing finding," says Chiara Cirelli, a sleep researcher at the University of Wisconsin–Madison. The results have already led her and other sleep scientists to rethink some of their own findings.

Although sleep requirements vary from individual to individual and across species, a complete lack of it is deadly. No one knows why.

One popular idea is that sleep severs weak connections between brain cells and strengthens more robust connections to solidify memories (*SN Online: 4/2/09*; *6/23/11*).

But a good memory is not a biological imperative. "You don't die from forgetting what you learned yesterday," says Maiken Nedergaard, a neuroscientist at the University of Rochester Medical Center in New York who led the study.

Researchers in Nedergaard's lab stumbled upon sleep's role in garbage clearance while studying a brain drainage system they described last year (*SN: 9/22/12, p. 15*). This service, called the glymphatic system, flushes brain and spinal cord fluid into the space between brain cells. Ultimately, the fluid and any debris it carries washes into the liver for disposal.

> "It was almost like you opened a faucet."
>
> MAIKEN NEDERGAARD

Studying fluid flow in the brain isn't easy. Lulu Xie in Nedergaard's lab trained mice to sit quietly on a microscope stage while researchers probed their brains. The mice were so relaxed that they sometimes fell asleep.

When that happened, Nedergaard says, "it was almost like you opened a faucet." While the mice slept, cerebrospinal fluid rushed into channels between brain cells and washed away debris. When the mice woke up, the faucet dried up and only a trickle of fluid got in or out of the brain.

Further experiments revealed that brain cells known as glial cells swell and shrink to control fluid flow. When mice are awake, glial cells expand, reducing the space between brain cells and shutting off fluid flow. During sleep, the cells contract and the faucet opens. The region between brain cells changes in volume by at least 60 percent between wake and sleep, the researchers found.

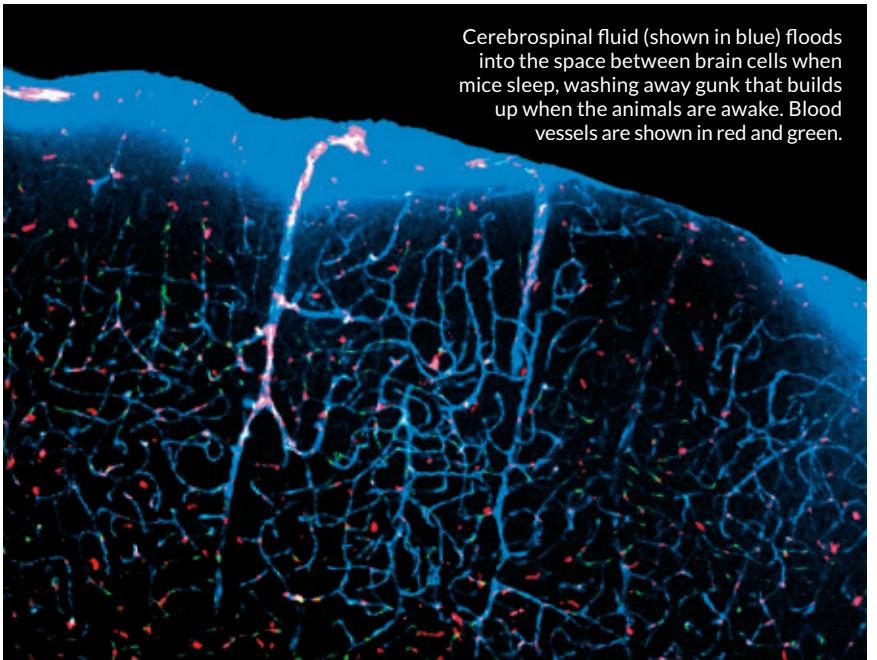
The fluid flow's on-off switch comes as a surprise because scientists have paid little attention to the area between cells, says Suzana Herculano-Houzel, a neuroscientist at the Federal University of Rio de Janeiro. "It's usually disregarded. It's considered just space."

Researchers including Randall Bateman, a neurologist at Washington University in St. Louis, have previously found that some biomolecules build up in the brain during waking hours. He and others have evidence that brain cells just keep pumping out more and more of the stuff the longer a person or animal is awake, and scientists thought that was the reason garbage piled up. One substance that follows this pattern is amyloid-beta, or A-beta, a protein fragment that forms plaques in the brains of people with Alzheimer's disease.

Levels of A-beta decrease with sleep, but researchers thought that was mostly due to enzymes and brain cells eating away the gunk, and that too little sleep means the brain's clean-up crew doesn't have time to clear away all the mess. Scientists never considered that brain tissue could expand and contract enough to open flood gates and flush away toxic by-products, Bateman says. Now he's rethinking some of his experiments.

"I'd be a fool not to pay attention to this," he says. If the results are confirmed in people, it could mean that doctors should time Alzheimer's treatment to when patients sleep. Increasing the brain's ability to rinse itself off may also prevent or combat Alzheimer's and similar diseases, he suggests.

But Bateman doubts that the mechanical flushing of the brain is the end of the sleep story. Even if garbage disposal is sleep's primary task, he says, "sleep has become such an integral part of life on this planet that it serves additional functions besides clearing substances out of the brain." ■



Cerebrospinal fluid (shown in blue) floods into the space between brain cells when mice sleep, washing away gunk that builds up when the animals are awake. Blood vessels are shown in red and green.

J. ILIFF AND M. NEDERGAARD

BODY & BRAIN

Hopes raised for Ebola treatment

Monkeys given dual therapy survive lethal viral infection

BY NATHAN SEPPA

A new treatment has protected monkeys exposed to live Ebola virus, one of the world's most fearsome pathogens. The dual therapy being tested for the first time, a combination of three antibodies and the antiviral protein interferon alpha, rescued nine of 12 animals even after they showed symptoms of disease.

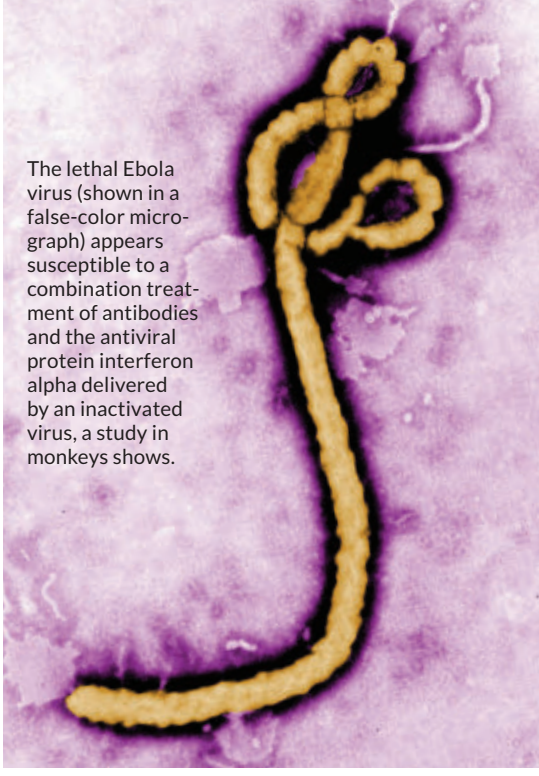
"This is a harbinger of the approach to come," says Daniel Bausch, an infectious disease physician at Tulane University in New Orleans who wasn't involved with the research. Scientists will probably go with a cocktail of drugs against Ebola in future testing, he says. "But it's too early to say precisely what the cocktail should be."

Ebola is a rare but lethal virus that has spawned human outbreaks across Central Africa since 1976. It apparently crosses from wild animals to people via exposure to wild game carcasses, causing hemorrhagic fever and high death rates. Neither a vaccine nor a treatment is available.

But 2012 was a promising year in the fight against Ebola. Researchers mainly at U.S. and Canadian government labs reported partial success in saving lab monkeys from Ebola using antibody-based treatments as late as two days after exposure to the virus.

The Canadian team, at the National Microbiology Laboratory in Winnipeg, now reports that combining the antibodies with interferon alpha allowed seven of eight monkeys to survive even when treatment came three days after exposure. Two of four other monkeys survived after getting a combination in which the antibodies were given four days after exposure.

By the time the monkeys got treated, all were experiencing fever, lethargy or loss of appetite, says study coauthor Gary Kobinger, a virologist. These symptoms might be more directly relevant to humans than the number of days post-exposure. "Now we know that we can wait until seeing fever and other clinical signs," he says, and potentially still rescue a person. But Kobinger acknowl-



The lethal Ebola virus (shown in a false-color micrograph) appears susceptible to a combination treatment of antibodies and the antiviral protein interferon alpha delivered by an inactivated virus, a study in monkeys shows.

FREDERICK MURPHY/CDC

LIFE & EVOLUTION

Amphibian killer forces immune cells to commit suicide

Fungal menace shuts down important parts of defenses in frogs and their kin

BY SUSAN MILIUS

A skin fungus that has swept around the globe killing frogs and their relatives can make key players in amphibian immune systems kill themselves.

The fungus nicknamed *Bd* (for *Batrachochytrium dendrobatidis*) has flummoxed biologists because the skin infection it causes in susceptible amphibians looks inconsequential. Yet this member of the chytrid fungi can kill a wide range of animals, some within days.

Part of *Bd*'s power comes from compounds in its cell walls that disable immune cells called lymphocytes and trigger these cells to self-destruct, says Louise Rollins-Smith of Vanderbilt University in Nashville. These fungal substances can withstand heat, acid and a protein-smashing enzyme, Rollins-Smith and her colleagues report in the Oct. 18 *Science*.

Cells of many kinds carry built-in systems for do-it-yourself breakdown, known as apoptosis. *Bd*'s fungal walls "seem to be especially effective at asking the lymphocytes to commit suicide," Rollins-Smith says.

> "*Bd* is an elegant pathogen."
>
> RICK SPEARE

This discovery starts to clarify how *Bd* creates its unexpected dangers. "Amphibians have a great immune system," she says. "They've evolved with fungi and should be able to recognize it and clear it." Yet descriptions of fungal attacks have noted that even severe *Bd* skin infections often trigger little or no inflammation.

The normally responsive amphibian immune system, much like the human one, has layers of defenses. Specialized cells pick up signs of trouble and signal the lymphocytes. Receiving the alarm, lymphocytes recognize the menace and call in a range of other cells that actually kill the invaders. It's this lymphocyte calling-in-soldiers step that *Bd* foils.

"*Bd* is an elegant pathogen in so many ways," says veterinarian Rick Speare of James Cook University in Townsville, Australia, who in 1993 was one of the first researchers to observe a massive frog die-off caused by the fungus in the wild. The new paper may not immediately lead to new therapies for amphibians, he says, but it's "highly significant" for understanding how the disease progresses.

To study the early phase of infection, Rollins-Smith and her colleagues

edges the clock is ticking after Ebola exposure: "Virus replication is exponential, so it's clear that at some point we will reach a point of no return."

The interferon alpha shots stimulated a robust immune cell response in the animals, and the antibodies, delivered intravenously, blocked virus entry into cells. All monkeys exposed to the virus but not treated died. The report appears in the Oct. 16 *Science Translational Medicine*.

Kobinger and his team plan to test the safety of the antibodies in people in late 2014 or early 2015. Because of the virus's lethality, the drug will never be tested in people who have been intentionally infected, he says. So he and other researchers are talking with the World Health Organization about using a combination of experimental drugs in an Ebola outbreak after a safety trial is complete. "We're telling WHO that everybody has to think very hard about this," he says. "We are getting into a zone where it could be unethical to not try something" in an outbreak. ■

exposed cells from two frog species to fungi and their fluids. The initial infection-spreading cells of the fungus, called zoospores, swim by lashing a hair-like flagellum and don't have a cell wall. And they don't have much effect on frog lymphocytes, the researchers found.

But once these mobile cells settle onto skin, they give rise to structures covered with complex cell walls. Alive or dead, these walled fungal cells (and even their fluids) can kill lymphocytes that would normally proliferate when mixed with an invader.

Exactly what's in the disabling brew remains a puzzle. And so does the biology that allows some amphibian species to thrive despite fungal attacks. African clawed frogs, the source of some of the lymphocytes that died in the lab tests, usually survive the fungus in the wild. Rollins-Smith speculates that their success may come from a different kind of defense: peptide molecules in frog skin mucus known to have antimicrobial effects. ■

ED LIM

GENES & CELLS

Flashy drug spotlights infection

Doctors could look for microbes with a fluorescent antibiotic

BY BETH MOLE

Glowing antibiotics may dim the chances of severe bacterial infections, according to a study published October 15 in *Nature Communications*.

Researchers made the experimental drug by fusing a fluorescent tag to vancomycin, an antibiotic that embeds itself in the outer walls of certain disease-causing microbes. The tag allowed scientists to see bacterial invaders in live mice and human cadavers. The method could help doctors thwart serious infections by spying them during early, treatable stages.

"It's a pretty smart approach," says biochemist Jianghong Rao of Stanford University, who was not involved in the study. Most important, he says, vancomycin and the fluorescent tag are already individually approved for human use, so the modified drug should sail through safety tests.

Study author Marleen van Oosten of the University of Groningen in the Netherlands says the method may help doctors monitor infections around surgically implanted materials, such as plates that fix broken bones and stents in arteries.

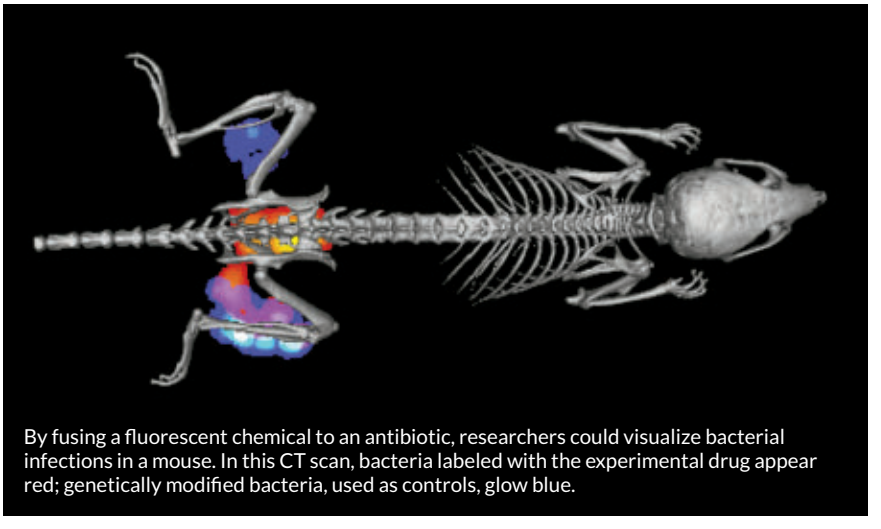
Bacteria often contaminate such materials during surgery. By the time standard methods detect such infections, it's often too late to treat them. At that point, the patient may have to undergo more surgery to replace the implant, van Oosten says.

She and colleagues injected mice with a mild dose of the glowing drug and minimal quantities of bacteria. Then, the team placed the animals under infrared light to see the early infection glow through the skin.

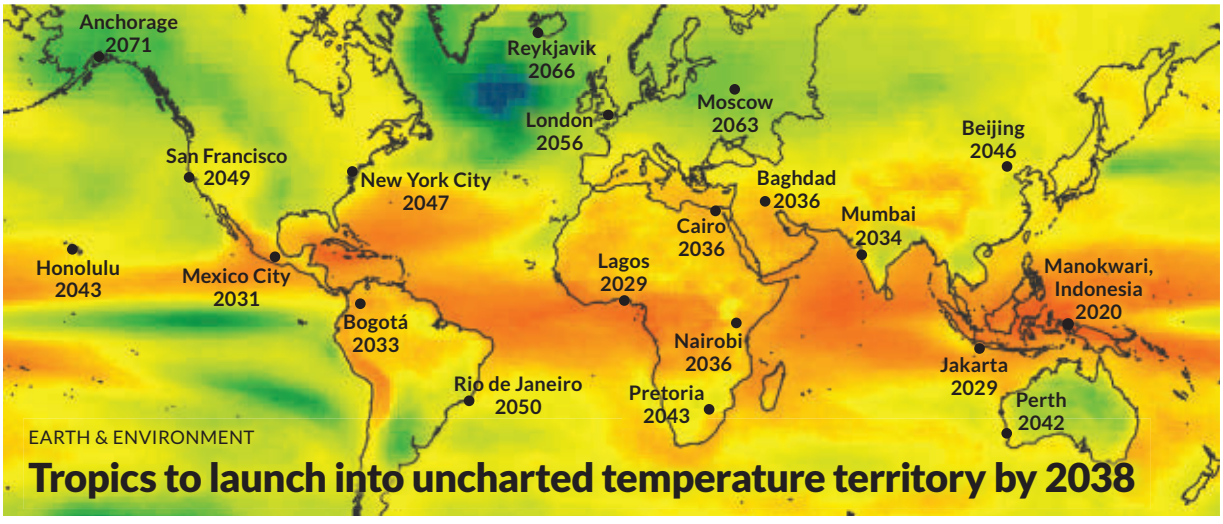
Surgeons already use infrared light with patients, and it has fewer health risks than some other imaging techniques, such as X-rays.

To test the method in humans, the researchers implanted plates in the ankles of two cadavers. Before surgery, the team coated the plates with bacteria and with the experimental drug. Using infrared light, the team could see the drug, embedded in bacteria on the plate, glow through the skin of the cadavers.

Bioengineer Niren Murthy of the University of California, Berkeley says it's still unclear whether the imaging will work for implants deeper in the body, such as in the hip. But, he says, it's a good step forward: "Being able to image bacteria with sensitivity in a clinical setting will be very, very useful." ■



By fusing a fluorescent chemical to an antibiotic, researchers could visualize bacterial infections in a mouse. In this CT scan, bacteria labeled with the experimental drug appear red; genetically modified bacteria, used as controls, glow blue.



EARTH & ENVIRONMENT

Tropics to launch into uncharted temperature territory by 2038

Global average temperature will surpass historical bounds by 2047 if greenhouse gas emissions continue unabated, a simulation suggests. In the tropics, the projected departure will occur by 2038, Camilo Mora of the University of Hawaii at Manoa and colleagues report in the Oct. 10 *Nature*. Drawing on data from 39 climate simulations, the team projected when average annual temperatures in different regions will permanently become higher than historical variability measured from 1860 to 2005 (years of projected temperature departures shown, ranging from 2020, orange, to 2100, blue). Because temperatures fluctuate more widely near the poles, these regions will take longer and require more of a temperature boost to depart from historical ranges than tropical regions will. — *Jessica Shugart*

EARTH & ENVIRONMENT

African dust fertilized Everglades

Wind change thousands of years ago transformed wetlands

BY BETH MOLE

Numerous water lilies and other aquatic flowers once dotted the grass carpets of Florida's Everglades thanks to nutrient-bearing dust from Africa.

Windblown sediment from the Sahara Desert landed in Florida around 4,600 years ago and enriched its nutrient-poor wetlands, scientists report October 7 in the *Proceedings of the National Academy of Sciences*. But an abrupt shift in winds around 2,800 years ago downsized the dust dump and stifled the nutrient flow, the authors suggest. That shift brought in the sawgrass-dominated ecosystem that exists today.

The discovery of airborne fertilizer revises scientists' understanding of the Everglades' history. Previously, most scientists thought the Everglades had been undernourished until nutrient-rich runoff from human development and agriculture began to seep in over the last century. Lead author and earth scientist Paul Glaser of the University of Minnesota in Minneapolis says the finding highlights the importance of traveling dust in distant nutrient cycles.

Glaser and colleagues pieced together the Everglades' history by dating layers of a 99-centimeter-long mud core from a swamp in the northeastern Everglades and then correlating the core's composition with other climate records.

"The biggest surprise was when I started to look at the cores in the lab, and I started to see these large quartz grains," Glaser says. He and his colleagues determined that the quartz didn't originate in the region or even on the continent. Instead, the quartz closely resembled windblown sand from the Sahara.

The quartz-rich sand, which Glaser and his colleagues say started landing in Florida roughly 4,600 years ago, contained relatively high levels of phosphorus and nitrogen. The sand also showed up in the core at the same time as pollen from aquatic plants such as water lilies.

At the time, Florida was much wetter and Africa was undergoing a dry spell, making it perfect for dust dispersal.

Joseph Prospero, an atmospheric chemist at the University of Miami in Florida, agrees that the core's data match other climate records. Based solely on previous climate records, you could almost expect the burst of dust that the researchers discovered, he says.

Sediment layers younger than 2,800 years lacked African dust and its nutrients. That timing coincides with a change in wind patterns that reduced Africa's dust stream, climate scientists say. Pollen in the core also changed at this time, indicating a shift from aquatic flowers to sawgrass, the plant that now dominates the Everglades' nutrient-poor marshes. When looking at all of the evidence, Glaser says, "everything seemed to fit together." ■

C. MORA ET AL/*NATURE* 2013

MATTER & ENERGY

Physics constant gets new limit

Analysis checks variability of quantum mechanics value

BY GABRIEL POPKIN

One of physics' most fundamental constants just got a little more constant.

Physicists have placed the strictest limit yet on how much the fine structure constant — which determines how strongly electrically charged objects interact — could change with the density of nearby matter. The team's method may help scientists probe whether the value has remained steady over the lifetime of the universe.

The fine structure constant, also known as alpha, has been both essential and confounding to physicists. It was introduced in 1916 to describe the strength of the electromagnetic force, which governs how charged objects interact and how molecules form. From there, the constant worked its way into important quantum mechanical equations. "It pops up all of the time in all of our theories," says Michael Tarbutt, a physicist at Imperial College London.

But alpha may not be a true constant. Some recent theories about the origins of dark energy — the repulsive energy field that seems to pervade the universe — suggest that alpha's value might vary depending on how much matter is nearby.

To probe this possibility, Tarbutt and his team measured alpha on Earth and in interstellar space, where the density of matter is far lower. To do this, they measured the frequency of light needed to change an electron's energy in a particular way in a molecule called CH, which is composed of one carbon atom and one hydrogen atom. The researchers chose to measure this frequency because it should vary sensitively with any change in alpha.

Data on interstellar gas clouds in the Milky Way, where CH is abundant, provided the frequency in deep space. For the earthbound measurement, the scientists produced the normally unstable CH in the lab at ultracold temperatures. They then put the CH molecules in a cavity and bombarded them with microwave pulses to force some of the molecules' electrons to jump to a higher energy state. The scientists measured the frequency of light emitted as the electrons returned to a lower energy state.

The scientists report October 15 in *Nature Communications* that alpha cannot vary between Earth and interstellar space by more than 1.4 parts in 10 million. Though not proof that alpha is the same everywhere, the result is the most stringent limit yet on the constant's dependence on local matter density.

Tarbutt's team has achieved a "remarkable result," says physicist Wim Ubachs of Vrije Universiteit Amsterdam. However, he says, to probe whether alpha has changed since the universe's early days, which some theories suggest, researchers need similar data from gas molecules far outside Earth's own galaxy. ■

BODY & BRAIN

Implants dupe brain into feeling touch

Experiments in monkeys could lead to sensitive prosthetics

BY LAURA SANDERS

Tickling the brain in just the right spot can create the sensation of touch. By zapping monkeys' brains with electrodes, scientists tricked the animals into feeling a poke.

The feat, described October 14 in the *Proceedings of the National Academy of Sciences*, offers a blueprint for creating advanced prosthetics that meld with the brain (see Page 22). Restoring touch to people who have lost limbs or are paralyzed is one of the biggest goals in prosthetic design, says study coauthor Sliman Bensmaia of the University of Chicago.

Without the sense of touch, everyday tasks like cracking an egg, holding a coffee cup or folding a newspaper are nearly impossible. Touch is also important for forging emotional connections and for the sensation of body ownership.

Touch-sensitive prosthetics like the one shown may one day restore the sense of touch in people who have lost limbs or are paralyzed.

Bensmaia and his team first trained rhesus macaques to report by looking in a certain direction which of their fingers was being touched. Electrodes implanted in an animal's somatosensory cortex — a brain area that handles tactile feedback from the body — simultaneously detected which neurons were active when an animal felt a precisely placed touch.

Then the scientists bypassed the finger and instead went straight to the brain. By zapping the finger-sensing neurons, the scientists tricked the monkeys into thinking they were being touched. "We are trying to mimic natural signals in the brain," Bensmaia says.

The animals couldn't describe the quality of the sensation, but the directions they looked in suggested that they experienced the electrode-induced artificial touch in the same way as the real thing. "That's really important," says neuroscientist Paul Marasco of the Department of Biomedical Engineering at the Cleveland Clinic. "There's a nice clear pathway for implementation with the amputee or the spinal cord–injured population in mind."

In another experiment, a prosthetic finger equipped with pressure sensors delivered these touch signals to the brain. The monkeys could not see the prosthetic; it was not attached to their bodies except through the electrodes. Monkeys were equally good at detecting pressures with a prosthetic finger and one of their real fingers, the team found.

The details about how the brain senses location, pressure and timing of touch could help create supersensitive, realistic prosthetic systems that convey touch information. "I think the foundation is laid for human trials," Bensmaia says.

But work remains before the system is fully ready for people. The method requires surgery to implant electrodes into the brain, and it's not clear how long the electrodes would last. ■

BODY & BRAIN

Brain stimulation restores movement in paralyzed rats

Implanted electrodes might one day help humans with spinal cord injuries walk again

BY LAURA SANDERS

With the help of electrodes implanted in the brain stem, rats with spinal cord injuries can regain the ability to walk with ease, scientists report in the Oct. 23 *Science Translational Medicine*.

It's not yet clear whether the technique would work in people with paralysis, but the research represents a new lead in the search for badly needed therapies, says study coauthor Lukas Bachmann of the University of Zurich.

The results complement recent work that restored movement to paralyzed rats by stimulating neurons in the spinal cord. Instead of targeting the spine, the new study focuses on the brain.

Most spinal cord injuries leave some nerve fibers unscathed. The brain stimulation technique relies on this small population of fibers to carry an amplified "move" message from the brain to formerly paralyzed legs and paws.

Bachmann and his team studied rats with partially severed spinal cords that caused them to walk with difficulty. When electrodes stimulated a part of the brain stem called the mesencephalic locomotor region, the rats began walking almost normally.

A group of more severely injured rats, akin to people with completely paralyzed limbs, showed modest improvements. In these rats, electrical stimulation elicited twitches in formerly nonresponsive limbs. Though minor, such twitches might be refined into more useful movement with physical therapy, says Bachmann.

At moderate power levels, the stimulation enabled seemingly voluntary walking in animals with less severe spinal cord damage. This level of stimulation allowed but did not force movements. With the highest stimulation, the rats' movements became involuntary.

Brain stem stimulation therapy might be useful for temporary rehabilitation and as a permanent fix, much like a pacemaker, says Armin Curt of the University of Zurich's Balgrist University Hospital, who was not involved in the research. He cautions, though, that the therapy might not translate from rats to humans. ■

PNAS 2013

Ancient farmers, foragers kept genes to themselves

Central European groups lived as neighbors for thousands of years but didn't intermingle

BY BRUCE BOWER

Europeans' genetic roots took a surprising turn after farming's introduction to the continent around 7,500 years ago, two studies suggest.

Farmers and hunter-gatherers lived alongside each other in Central Europe for 2,000 years without mating outside their own groups, according to one of the studies. Until now, researchers have primarily thought that farmers entering Europe from the east either drove out hunter-gatherers or quickly drew nomadic groups into a lifestyle of crop growing and animal raising.

Instead, at least one group of hunter-gatherers clung to its culture for a surprisingly long time despite regularly crossing paths with farmers, paleogeneticist Ruth Bollongino of Johannes Gutenberg University of Mainz in Germany and her colleagues report October 10 in *Science*. It's not known whether these hunter-gatherers eventually took up farming, left Central Europe or died out.

Her team analyzed mitochondrial DNA from 25 individuals buried in a German cave: five who died a few thousand years before agriculture's onset and 20 from between about 6,000 and 4,900 years ago. Mitochondrial DNA is inherited only from mothers. Chemical compositions of the later skeletons revealed that 11 individuals had eaten primarily animals typical of early farmers, whereas nine had subsisted largely on freshwater fish.

Unlike the farmers, the fish eaters shared some of their mitochondrial DNA profile with the earlier hunter-gatherers excavated in the cave. That suggested to Bollongino's team that hunter-gatherers had continuously lived in the area since farmers had arrived but had not mated with them.

"The surprise is that foragers and farmers had separate ways of life for 2,000 years even though they clearly interacted with one another, as their use of the same burial cave shows," remarks Stephen Shennan, an archaeologist at University College London.

An extended, side-by-side coexistence of Central European farmers and hunter-gatherers fits with mitochondrial DNA evidence from the second study, published in the Oct. 11 *Science*. It analyzed DNA from 364 bodies of individuals who lived in what's now Germany between 7,500 and 3,550 years ago.

A team led by Johannes Gutenberg University of Mainz anthropologist Guido Brandt — working independently of Bollongino — concludes that Central European farmers remained genetically distinct until about 5,000 years ago.

Starting around 5,000 years ago, several farming populations influenced modern Central Europeans' genetic makeup, a new study finds. One of those populations, the Corded Ware culture, is represented by this woman's shell-covered skeleton excavated in Germany.

Groups from other cultures and regions, including hunter-gatherers from southern Scandinavia, altered Central Europeans' mitochondrial DNA profiles over the next 1,000 years, the researchers say.

Members of different Central European cultures from that time, previously identified by pottery styles and other material remains, possessed distinct mitochondrial DNA profiles, the researchers find. Farmers coming into Central Europe between 5,000 and 4,000 years ago, including early bronze-working cultures, contributed substantially to the mitochondrial DNA of Europeans today, Brandt's group proposes.

It's not yet clear whether mitochondrial DNA patterns uncovered in Brandt's study are consistent with those of ancient farmers and hunter-gatherers who lived elsewhere in Europe, says evolutionary biologist Mattias Jakobsson of Uppsala University in Sweden. Mitochondrial DNA results also need to be compared with as-yet-unrecovered ancient DNA from cells' nuclei, Jakobsson says, which makes up "the overwhelming part of the human genome." ■

JUST THE FACTS

Scorpion genome

32,016

Genes in a Chinese golden scorpion

22,333

Genes in a human

SOURCE: Z. CAO *ET AL/NAT. COMMUN.* 2013

FROM TOP: JURAJ LIPTÁK; WENXIN LI

ATOM & COSMOS

Oort cloud tosses astronomers a cometary curveball

After traveling millions of years, ISON delivers debris from the dawn of the solar system

BY GABRIEL POPKIN

Pretty much every major telescope in the world is gearing up to witness a meeting that has been scheduled since long before humans walked the Earth. Around Thanksgiving, Comet ISON, a mountain-sized chunk of primordial solar system, will approach within 2 million kilometers of the sun and either fall apart or slingshot back into deep space. Astronomers aren't yet sure how much of a spectacle ISON will be for earthbound observers, but from scientists' vantage point the comet is already providing a brief, unprecedented glimpse into what the solar system was like in its infancy.

"It's the sort of thing I've been waiting for my whole career," says Matthew Knight, a comet researcher with the Lowell Observatory in Flagstaff, Ariz.

ISON, officially known as Comet C/2012 S1, was discovered by amateur astronomers Vitali Nevski and Artyom Novichonok. The pair spotted the comet as part of a sky survey program known as the International Science Optical Network. Using a telescope near Kislovodsk, Russia, the astronomers first found ISON just outside Jupiter's orbit on September 21, 2012. Within days, researchers had combed through previously unnoticed images of the comet and calculated its trajectory from the outskirts of the solar system. They determined that the comet had traveled over millions of years to its present location, and projected its future path as well.

From those efforts, astronomers learned that the comet is most likely a refugee from the Oort cloud, a loose collection of frozen objects that scientists think cluster in the solar system's outer reaches about a thousand times as far from the sun as Neptune. Astronomers believe the Oort cloud objects were tossed out of the inner solar system when the planets formed and have barely changed since then (*SN: 10/19/13, p. 19*); Knight calls the cloud the "freezer of the solar system." Occasionally the gravitational tug of a passing star will nudge one of these frozen bodies out of the cloud and start it on a multimillion-year journey into the inner solar system. Unlike comets that originate in the solar system and make regular swings through Earth's neighborhood, Oort cloud comets like ISON are thought to come around only once.

In late November, the comet known as ISON will whiz by the sun, carrying dust and gas left behind from the birth of the solar system. The event will give scientists an opportunity to learn more about the early days of the sun and planets.

Looking ahead, astronomers found that ISON will pass within a cosmic whisker of the sun, close enough to potentially be ripped apart by the star's intense gravity. The first known object from the Oort cloud to approach so close to the sun, the comet promises researchers a spectacle of dust, gas and ice brilliantly illuminated by the sun's light.

And because ISON has probably spent nearly its whole existence in cold storage, astronomers believe it has preserved a record of the conditions that prevailed in the ancient solar system. "It gives us a chance to understand what the composition was and what the environment was when the solar system formed 4 ½ billion years ago," Knight says.

Reports on ISON's makeup have already started to come out. In April, a team led by Jian-Yang Li of the Planetary Science Institute in Tucson, Ariz., directed one of the Hubble Space Telescope's cameras toward ISON and snapped sharp photos of the comet. The researchers found that ISON is average-sized as comets go, with a nucleus no more than 4 kilometers across.

NASA, ESA, J.-Y. LI (PLANETARY SCIENCE INSTITUTE) AND THE HUBBLE COMET ISON IMAGING SCIENCE TEAM

Based on images taken in different wavelengths of light, Li and his team also discovered a large amount of water ice in the region around the nucleus. That probably indicates large amounts of ice near the comet's surface. The sun can easily drive off surface ice, so the finding confirmed that ISON has never passed through the inner solar system, Li says. Periodic visitors like Halley's comet have lost much of their superficial ice during repeated trips around the sun.

The Hubble observations also suggested that ISON presents only one face to the sun. Li thinks ISON's dark side could bear scars from bombardment by extremely high-energy particles called cosmic rays that whiz around in deep space. Relatively few of these particles make it to the inner solar system because they are deflected by a steady stream of particles known as solar wind and by the sun's powerful magnetic field; both of these shields stop short of the Oort cloud. ISON could thus provide a rare glimpse of the perilous environment beyond the sun's protective reach.

Unlike previous sun-grazing comets, ISON was detected more than a year out, giving researchers at the world's major ground-based telescopes plenty of time to watch its approach to the sun. Scientists led by Karen Meech of the University of Hawaii's Institute for Astronomy observed the comet using seven research telescopes and a network of amateur telescopes. The researchers report in the Oct. 20 *Astrophysical Journal Letters* that ISON shed large quantities of dust, as well as water vapor, carbon dioxide and carbon monoxide — all gases that scientists believe were present when the Oort cloud formed.

The researchers also investigated why ISON seemed to initially brighten faster than most comets but then slowed. Because sunlight interacts with gas and dust to make comets light up, Meech thinks the best explanation for her team's data is that ISON's nucleus contained a buried layer of solid carbon monoxide, a featherweight molecule that rapidly turns to gas when exposed to sunlight. When this layer vaporized, as Meech believes it did beginning in late 2011, it also kicked up a large amount of water ice and dust, causing further brightening. After the carbon monoxide had blown off, the comet no longer brightened as quickly.

Meech hopes her team's results can help end a debate that has exasperated scientists even as it has captivated the public. Early reports suggested that ISON could become as bright as the full moon. Then, when the comet didn't continue brightening as expected, some scientists began predicting the comet's demise. The most prominent of the doomsayers is the astronomer Ignacio Ferrin of the University of Antioquia in Medellín, Colombia, who makes such a prediction in a paper posted October 2 at arXiv.org.

Meech thinks both predictions were misinterpretations of the data; ISON's behavior so far, she says, suggests it will neither outshine the moon nor fizzle out.

Knight and colleague Kevin Walsh of the Southwest Research Institute's campus in Boulder, Colo., have also sought to temper speculation about ISON's impending doom. In the Oct. 10 *Astrophysical Journal Letters*, they analyze how likely ISON is to survive the sun's intense gravity. The scientists simulate the comet's fate while giving it a variety of rotation rates; in most cases it should survive. However, if ISON rotates rapidly in the same direction as its orbit, like a tennis ball with topspin, the comet could break apart.

Because scientists have no data on the comet's rotation, Knight and Walsh conclude that ISON will probably survive. However, Knight acknowledges that other comets have disintegrated for no known reason, and he is prepared for surprises.

Whether the comet breaks up or not, late November is when it will put on the best show, both visually and scientifically. Li thinks the comet could release a lot of ice in the bright sunlight just before brushing past the sun; he and others hope the gases coming off the comet will reveal the chemicals present when ISON formed billions of years ago. The comet will continue shedding material in the days after it rounds the sun; even if it breaks into fragments, scientists will be able to study the individual pieces.

Earthbound stargazers won't notice these details, but motivated observers may be able to spot a new object in the predawn sky. ISON could glow as brightly as Venus does, and those willing to wake up early and find a dark spot with an unobstructed view of the eastern sky could get a nice show.

As for the more detailed views that matter to astronomers, those can be found only at a few powerful observatories. As a result, Knight says, "many of us will not be spending Thanksgiving with our families."

Whatever ISON's fate, the combination of its unusual source, its early discovery and today's powerful telescopes will make it one of the most studied comets to date. "This is a very special comet," says Li. ■

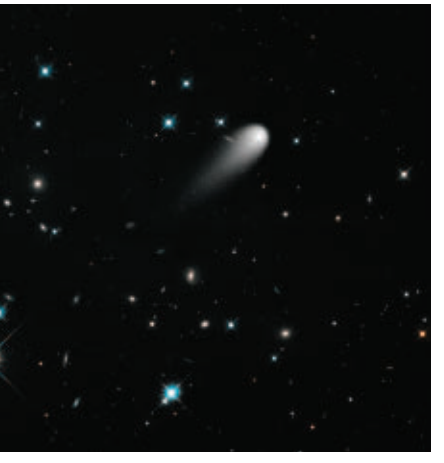
ISON events

September 21, 2012
ISON discovered

October 1, 2013
Closest approach to Mars

November 28, 2013
Closest approach to the sun

December 26, 2013
Closest approach to Earth
(if it survives solar encounter)



NASA, ESA, AND THE HUBBLE HERITAGE TEAM (STSCI/AURA)

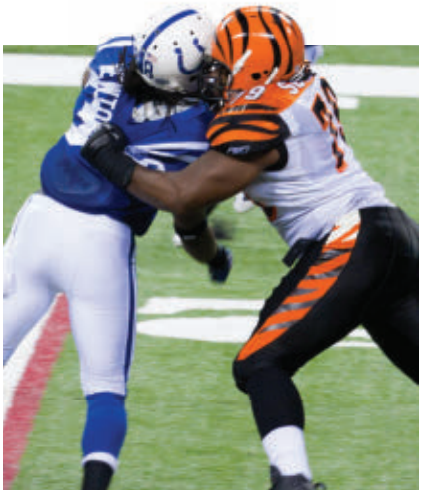
EARTH & ENVIRONMENT

Trees mark the spot of buried gold

Traces of treasure in eucalyptus tree leaves may signal a hidden trove of gold under the surface. Scientists have previously noticed small amounts of the precious metal in and around eucalyptus trees, but they didn't know if the plants were soaking up gold from the ground or from windblown dust. Researchers in Australia used X-ray imaging to tally the tiny bits of gold in eucalyptus trees growing near and on top of a gold deposit. Only trees growing directly over the 35-meter-deep deposit tapped into the gold with their deep-growing roots, the team reports October 22 in *Nature Communications*. Because gold may be toxic to plants at high concentrations, the researchers think the trees push the shiny cargo from their roots to their extremities, such as leaves and bark, which amass the metal and eventually fall to the ground. The team suggests that eucalyptus trees may offer a new way to locate hidden treasure. *— Beth Mole*

Fertilizer has staying power

Fertilizer applied today could still be there in 2093, scientists report October 21 in the *Proceedings of the National Academy of Sciences*. The study is the first to measure how long nitrogen-based fertilizers persist in the field. In 1982, scientists in France infused soil with fertilizer containing nitrogen-15, a form of the element uncommon in nature. By the next year, crops had absorbed around half of the fertilizer, with most of the rest taken up by microorganisms and released back into the soil. For the next 30 years, the scientists grew crops and fertilized them with compounds containing the more common nitrogen-14. Over time, nitrogen-15 in the soil decreased slowly, with small amounts taken up by plants or leached into groundwater each year. In 2010, 12 to 15 percent of the original nitrogen-15 remained in the soil; the researchers calculate that it will take at least another 50 years for it to disappear entirely. The finding helps explain why nitrogen pollution can continue in rivers even when farmers reduce their fertilizer use. *— Gabriel Popkin*



BODY & BRAIN

NFL players' brains take a hit

A punishing football career leaves a legacy in the brain. By revealing signs of brain damage in 13 retired NFL players, a brain-scanning study is the latest to show the effects of repeated hits to the head. The former NFL players performed almost normally on a tricky logic problem that relies on spatial perception and planning. But functional MRI brain scans uncovered changes that the behavioral test missed. Compared with people who didn't suffer blows to the head, retired NFL players doing the logic problem had abnormally high brain activity in the dorsolateral prefrontal cortex, an area involved in planning and control. And the timing of activity in other brain regions was off, suggesting that these regions failed to work in concert as they should. The more often a player had been pulled from a game for head injuries, the more pronounced these differences were. Hits on the field can cause repeated mild traumatic brain injury, which puts players at risk for neurological problems later in life, Adrian Owen of the University of Western Ontario in Canada and colleagues write October 17 in *Scientific Reports*. *— Laura Sanders*

Norovirus vaccine shows progress

SAN FRANCISCO — A vaccine in early testing partially protects against diarrhea-causing norovirus, a group of viral strains that includes the infamous Norwalk virus that plagues some cruise ships. Most people have experienced norovirus, but the infection can be lethal in elderly and immune-compromised people, said David Bernstein, a physician at the University of Cincinnati. He and his colleagues enrolled 98 healthy adults in a clinical trial, with 50 receiving two shots of the vaccine and 48 getting placebo shots. A month later, all drank water contaminated with norovirus. Slightly more than half of each group became infected, but the vaccinated people were less likely to feel sick. Among those receiving the vaccine, only one-fifth had vomiting or diarrhea or both, and no case was severe. Of the unvaccinated people, two-fifths had such illness and four cases were severe, Bernstein reported October 4 at IDWeek, a meeting of infectious disease specialists. The vaccine contains viral particles from strains that cause up to 80 percent of norovirus infections, Bernstein estimated. The particles elicit immunity but cannot cause infection. *— Nathan Seppa*

MATTER & ENERGY

Radar picks out electronics

The metal detector has received a dolphin-inspired upgrade. A new technique distinguishes electronic gadgets from other metals, potentially aiding first responders and law enforcement agents. Inspired by the way dolphins hunt fish by lassoing them with strings of bubbles, Timothy Leighton of the University of Southampton in England builds sonar devices that differentiate between underwater bubbles and objects such as naval mines (*SN: 8/25/12, p. 12*). The key is emitting two nearly identical sound pulses; by comparing pulses that return, Leighton can separate bubbles, which scatter sound, from objects that reflect it. Now Leighton has applied the same concept to radio waves, or radar, which detect metal. He emitted dual pulses at an aluminum plate, a rusted clamp and an electric circuit. The circuit scattered radio waves in a predictable way, so Leighton could easily identify pulses that had struck the circuit, he and his team report October 22 in the *Proceedings of the Royal Society A*. Similar circuits appear in cell phones, Leighton says, so the technique could be used to locate survivors of an avalanche or building collapse by targeting their phones. *— Andrew Grant*

ALEXEY STIOP/SHUTTERSTOCK

An Affordable Option ●

Perfect Choice HD™ is easy to use, hard to see and costs far less… it's like reading glasses for your ears™!

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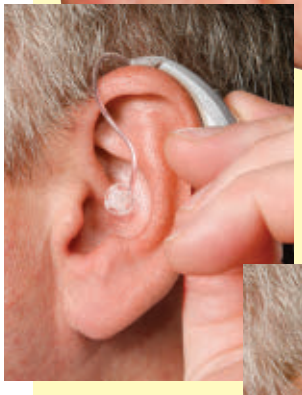

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Waiting to EXHALE

Scientists sift the chemical potpourri that escapes our lungs for new ways to diagnose disease

By Laura Beil

The 800 or so breaths you release each hour contain more than just spent air. Along with familiar gases like carbon dioxide, nitrogen and oxygen, each breath holds a vaporized record of the foods you've eaten, the places you've been, the drugs you've taken, the pollutants you've encountered and the general operation of your internal organs. It's a chronicle of daily living that doctors have been largely unable to read.

But a handful of researchers are getting better at deciphering these gaseous clues, bringing us closer to the day when a kind of disease Breathalyzer could be part of a routine checkup or maybe even a cell phone app.

The idea of medical diagnosis through exhaled odor is as old as the practice of medicine itself. Hippocrates wrote a treatise on "fetor hepaticus," or the fishy aroma of liver failure, and noted the sour-scented breath of those with failing kidneys. Only recently, however, has the mainstream medical establishment come to view the idea of breath analysis as anything more than, as one researcher described it, a bizarre curiosity. "When I go and talk to a bunch of doctors, they don't laugh at me any more," says internist Michael Phillips, who founded Menssana Research in Fort Lee, N.J., to develop breath tests for disease.

While the experimental technology still tends to be cumbersome — some breath-reading devices are the size of small refrigerators — it has progressed far enough in recent years that scientists have moved beyond theoretical scenarios. Doctors already have a few breath tests at their disposal, and researchers are making headway on the breath detection of tuberculosis, heart failure, environmental exposures, liver disease and even some cancers.

"The really good thing about breath is, you can measure it anywhere, in any time frame you want. You don't run out of it," says Joachim Pleil, an analytical chemist at the U.S. Environmental Protection Agency. "You can collect a breath sample from a guy standing on a street corner, and you can collect five samples or more in 10 minutes." Breath testing is as convenient and painless as medical tests come, even for the most vulnerable newborn or the frailest centenarian. The patient doesn't even have to be conscious.

For the idea to work, researchers have to mine breath samples to find airborne nuggets of disease, then build machines that detect those molecules

with the kind of sensitivity (the ability to correctly identify people who are sick) and specificity (the ability to rule out people who are not) necessary for a medical diagnosis.

Scientists know of more than 3,000 chemical compounds that can come out of the lungs, but often in infinitesimally small concentrations. Some signs of disease waft out at concentrations of parts per billion. The challenge is not just finding a needle in a haystack, but a needle in a haystack the size of a townhouse. And doing it cheaply enough to be practical. "We have to come up with a test that is useful, not just show-and-tell," says Raed Dweik, a pulmonologist at Cleveland Clinic.

Nonetheless, recent experiments provide reason for optimism. One of Dweik's research interests is heart failure, which affects more than 5 million Americans and is one of the most common reasons that older adults are admitted to the hospital. The disease develops when the heart muscle becomes damaged and unable to properly pump blood. The body's tissues are gradually starved of fuel. Among the chemical calling cards of heart failure is excess production of acetone and pentane by cells that are running on too little oxygen.

Writing in the *Journal of the American College of Cardiology* in April, Dweik and his colleagues described a study of 41 patients, two-thirds of whom had been hospitalized with heart failure. Based on a single exhalation, Dweik's breath test could separate the people with heart failure from the rest of the patients based on their acetone and pentane levels. He says his heart failure breath test has so far been accurate every time. Proof-of-principle experiments like these are important, he says, because researchers have to demonstrate that the technology can identify patients who are known to be sick before moving on to testing in those whose health is unknown.

Dweik is also using acetone, pentane and another compound, trimethylamine, as the foundation of an experimental breath test for liver disease. Trimethylamine levels rise in people with diseased livers because the enzyme that usually removes the compound from the body has dwindled. Dweik and colleagues reported in the Sept. 10 *Clinical Gastroenterology and Hepatology* that among patients with alcoholic hepatitis, a precursor to liver failure, the three compounds exceeded a certain threshold level about 90 percent of the time. (For comparison, mammography for breast cancer screening has an overall sensitivity of about 79 percent.)

79%

Typical sensitivity of a mammogram

90%

Sensitivity of experimental liver failure breath test

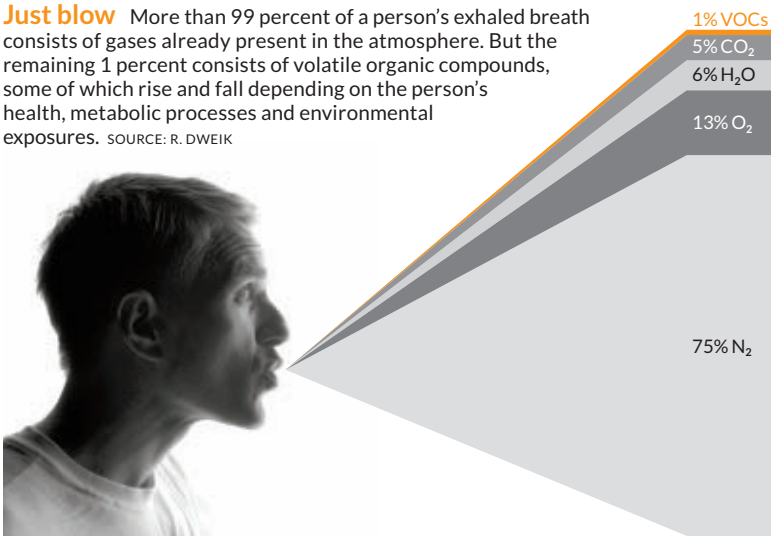
Rapid TB test

A breath test for tuberculosis has amassed a similarly encouraging track record. TB is second only to HIV as a cause of death from infection, and most of those affected live in countries with poor health care and scant resources. Rapid identification of those who are ill could help control outbreaks and lower mortality by getting treatment started sooner.

Definitive diagnosis of infection requires a chest X-ray or microscopic examination of lung sputum, both of which are time consuming and require access to a hospital and laboratories.

"One of the biggest problems, especially in developing countries, is they don't have much money to go out and find people with tuberculosis," says Menssana's Phillips, who is also on the clinical faculty of the New York Medical College.

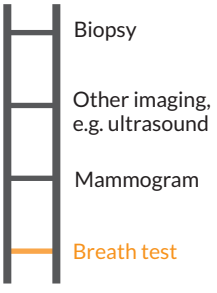
He set out to develop a TB breath test that provides almost immediate results. His device measures compounds like cyclohexane, an emission of TB-causing bacteria. Last year in the journal *Tuberculosis*, Phillips and his colleagues reported the results of a trial involving more than 250 patients in three countries. Six minutes after collecting a breath sample, the device detected



Just blow More than 99 percent of a person's exhaled breath consists of gases already present in the atmosphere. But the remaining 1 percent consists of volatile organic compounds, some of which rise and fall depending on the person's health, metabolic processes and environmental exposures. SOURCE: R. DWEIK

PESKY MONKEY/ISTOCKPHOTO, ADAPTED BY M. ATAROD

Diagnostic ladder
A breath test for a disease such as breast cancer would not be the final say in diagnosis. Researchers generally think of it as a first step to determine the need for more expensive and invasive tests.



tuberculosis with 80 percent accuracy.

Phillips is also one among a number of researchers in the United States and internationally who are trying to develop a breath test for cancer, notably lung cancer. Heavy smokers are now offered CT scans, but the method is costly and produces many false alarms. A cheap, widely available breath test could help decide who needs a CT screening, says Anton Amann of Innsbruck Medical University in Austria. He is developing a breath test based on the levels of compounds that are found in the lungs of cancer patients but not healthy volunteers, regardless of whether they are smokers or nonsmokers. That's an important distinction, because a breath test would need to tell the difference between cancer and general lung damage from tobacco. Around half of lung cancer patients are smokers at the time of diagnosis.

In 2009 in the journal *BMC Cancer*, Amann reported that testing for 15 different compounds allowed his research team to identify the breath of lung cancer patients 71 percent of the time. When they expanded to test for 21 compounds, sensitivity rose to 80 percent.

While promising, the results are still far from an actual test. For one thing, researchers must establish that a breath test could identify the malignancy at an early stage. Any test would also have to take into account the metabolic signatures of other tobacco-driven diseases, like emphysema, which could confuse the results of a breath screen.

Lung cancer is not the only malignancy under investigation. Scientists from Technion–Israel Institute of Technology in Haifa are developing a stomach cancer test with colleagues from China and Latvia. Writing this spring in the *British Journal of Cancer*, the researchers found that a prototype breath test could single out stomach cancer 89 percent of the time by searching for five particular compounds.

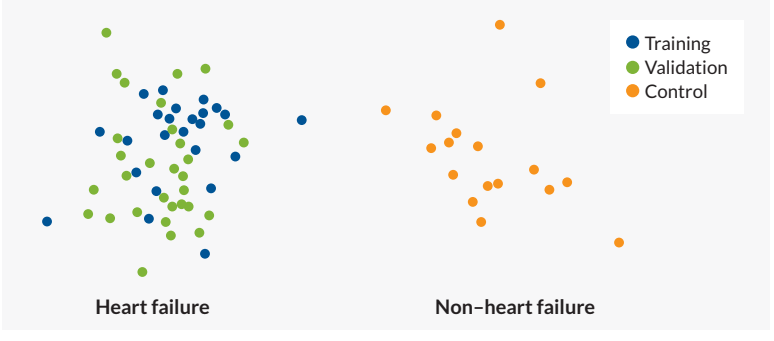
Aside from the obvious targets, breath tests are opening the door to other kinds of early detection. The EPA's Pleil is hoping to see screening for exposures to environmental pollutants that would produce instant results by measuring inflammatory reactions in the lungs — and with greater ease than urine or blood tests. He is also working with researchers from the University of North Carolina at Chapel Hill to develop a way to detect early lung infections among patients with cystic fibrosis. The disease causes mucus to build up in a patient's lungs, and this warm, moist environment offers an inviting home for microbes. "It behooves the medical community to be able to diagnose a ramping infection before the person actually gets sick," Pleil says, to give the right antibiotic as soon as possible. He expects to publish data soon.

Easier said than done

Although encouraged by the progress, researchers concede that breath testing is more challenging than it may seem. Clinicians have come to appreciate the complex interplay between body and breath. Breath testing is possible because the lungs catch molecules that escape from the bloodstream through small capillaries nestled against air sacs deep in the lungs. Some of these molecules come from substances that have been taken in and made their way into the blood, which is why an alcohol breath test works. Other chemicals are the natural remnants of metabolism. Then there are the bystander molecules that have been inhaled and re-released. "If you put gas in your car, you'll be breathing out gas the rest of the day," says Terence Risby, an environmental health scientist at Johns Hopkins School of Public Health. And not all of it came from fumes; substances absorbed through the hands and into the blood can also exit by air.

Bacteria, which outnumber the body's human cells by 10 to 1, add to the mix as well as they constantly belch waste products that make their way into the airways of their hosts. The bacteria within might also have surprising influences on health. In April, researchers from Cedars-Sinai Medical Center in Los Angeles reported in the *Journal of Clinical Endocrinology & Metabolism* that a breath heavy with hydrogen and methane was associated with a higher body mass index and more body fat, possibly because certain bacteria living in the intestine are affecting metabolism.

Breathprint Trace levels of organic chemicals in the breath can reliably distinguish heart failure from other cardiac conditions. Based on statistical profiles of breath constituents, researchers developed a "breathprint" that can be illustrated on a two-dimensional plot. After plotting 25 known cases of heart failure (blue dots) against controls (orange dots), they validated the method by correctly flagging 36 cases (green dots) from unknown samples. SOURCE: M. SAMARA *ET AL/J. AM. COLL. CARDIOL.* 2013



M. ATAROD

With this vast chemical potpourri traveling through the lungs, breath tests won't work unless scientists can tease out molecules that are biologically significant from those that aren't. One more problem: Collecting a pure breath sample is not as easy as puffing into a police officer's roadside Breathalyzer. The signals of illness are far too diffuse, and too easily drowned out by background noise. Even the act of breathing into a machine — a person tends to hyperventilate from trying too hard — or being in a hospital alters the composition of the breath. "If you don't control how you're sampling, you're analyzing garbage," says Risby, of Johns Hopkins.

His point: Breath analysis is not just about detecting the presence or absence of molecules. The breath changes when the body becomes ill, but usually it doesn't produce anything new or as obviously abundant as the steamy cloud of ethanol exhaled by a drunk driver. Instead, chemicals that occur naturally become more or less common, just as the same ingredients can produce a cupcake or a muffin depending on their proportions. The balance of chemicals, not their presence or absence, is what usually gives an illness a distinctive breath.

"I can smell an orange, but can't tell you what about it makes it an orange," Dweik says. So it is for the molecular composition of your breath. Changes occur, but the precise recipes for "cancer breath" or "kidney disease breath" are still being worked out. (Which is one of the limitations of a similar line of work, Dweik says: training dogs to detect disease in a whiff of a person's breath. A canine nose may be able to sniff cancer, but scientists still can't say what exactly the dogs are smelling, which may limit the future of dog detection.)

To better define the aerosol signature of disease, researchers are stepping back and examining dynamic shifts in breath not only from person to person, but even in the same individual over time. In April, scientists from Zurich reported in *PLOS ONE* the analysis of breaths sampled from 11 volunteers over nine days. Using technology that separates chemicals based on mass, the researchers found that although a person's breath changed slightly depending on the time and day the sample was taken, each volunteer had a unique "breathprint," or chemical composition, that remained distinct and relatively stable.

This seems like basic information, yet establishing what a healthy breath is supposed to be is necessary before doctors can single out an unhealthy one. No one in the field doubts they will eventually succeed. In some cases, they already have. A breath test is now used to detect infection with the bacterium *H. pylori*, the cause of stomach ulcers, and to help measure the odds that a heart transplant recipient will reject a donor organ within the first year after transplantation. The nitric oxide concentration in a person's breath is measured for managing asthma.

Once researchers know what a device needs to measure, and how, the next step will be to make the technology as compact and inexpensive as possible. There are precedents: Nitric oxide monitors are small enough now for children to hold. The first alcohol breath test, the Drunkometer, was introduced in 1938 and was bigger than a shoebox. Today, alcohol detectors that plug into a smartphone sell for as little as $30.

If medical breath testing follows a similar pattern of shrinking size and price, the next generation of texters may be able to blow into a thumb-sized device attached to a smartphone to learn about their health. "I don't think you're going to have one in your cell phone next week. But it's possible you could have one in a few years," Phillips says. "It's just a matter of ramping up the sensitivity." ■

Breath test pipeline Some tests that use breath to detect disease are already on the market, with more under development. SOURCE: K. PASCHKE *ET AL/F1000 MEDICINE REPORTS* 2010

Approved tests

Condition	Molecules detected	Year approved
Lactose malabsorption	Hydrogen	1997
H. pylori infection	Carbon dioxide	2001
Asthma/airway inflammation	Nitric oxide	2003
Heart transplant rejection	Methylated alkanes	2004

In development

Condition	Molecules detected
Cancers, including lung, breast and stomach	Multiple compounds, depending on type of cancer
Heart failure	Acetone, pentane
Liver disease	Acetone, pentane, trimethylamine
Tuberculosis	Cyclohexane
Obesity risk	Methane, hydrogen

Explore more

- Terence Risby and Joachim Pleil. "Breath analysis — past, present and future: a special issue in honour of Michael Phillips' 70th birthday." *Journal of Breath Research*. March 2013.

Smell phone An inexpensive cell phone–mounted device already exists to measure blood alcohol level by analyzing breath. In the future, similar devices may turn smartphones into medical diagnostic devices.

COURTESY ALCOHOOT, ISTOCKPHOTO

Mind to Motion

Brain-computer interfaces promise new freedom for the paralyzed and immobile

By Meghan Rosen

Thick Velcro straps cinched the robot's legs to Steve Holbert's calves and thighs. The straps were snug — they helped secure his body to the machine. But they had to be fastened just right. Too loose and Holbert might slip around. Too tight and the straps could cause pressure sores. Not that Holbert could tell the difference: He hadn't felt his legs since 2009.

Holbert was testing out a brain-controlled walking device for people who are paralyzed. He had tried the machine before, but couldn't quite get it to sync up with his thoughts. This afternoon, he was giving it another shot. Already, researchers in José "Pepe" Contreras-Vidal's lab at the University of Houston had stretched an electrode-studded cap over Holbert's head and strapped him into the robot, an 80-pound hulk of high-tech machinery and electronics named the NeuroRex. "It reminds me of the cargo-loader Sigourney Weaver drives in *Aliens*," Holbert says.

He grabbed the robot's armrests, scrolled through the LCD menu and selected "stand." The robot's motors whirred, and scientists hovered nearby in case the machine tipped over. At Contreras-Vidal's cue, the bustling lab hushed and Holbert cleared his brain. Then he mentally commanded the NeuroRex to move.

"I'm thinking, 'Go, go, go,' and it started walking!" he says. "It took off at exactly the same time I was trying to make it move." As Holbert marched slowly across the lab, he smiled. "Pepe, it feels like these legs are mine." The whole room started clapping. "It was an emotional moment," Contreras-Vidal says. Holbert remembers the scientist looking calm. "Pepe knew it was going to work," he says. "He's been optimistic the whole time."

Spinal cord–injury patient Gene Alford takes a supported step in NeuroRex, a thought-controlled robotic walking device. An electrode cap detects electrical signals from his brain that, decoded by a computer, tell the device to move.

FELIX SANCHEZ

For years, Contreras-Vidal has been working to decode brain signals collected from the scalp. Because skin and bone distort these electroencephalography, or EEG, signals, deciphering messages from the brain can be challenging. But Contreras-Vidal and a pack of scientists around the world have been finding creative ways around the problem. The researchers are gleaning new information from EEG and creating hybrid systems that merge brain signals with intelligent robotics, or draw upon several types of signals. Together, the new work is clearing a path for practical-use brain-computer interfaces, or BCIs.

Robotic gadgets guided by peoples' thoughts aren't a new idea: Quadriplegics with brain-implanted electrodes can use their minds to move prosthetic arms, scientists reported in 2012 and February of this year. Volunteers could reach, grasp and even sip coffee from a bottle. But those BCIs require neurosurgery — an expensive operation that carries significant risks. "You get a hole drilled in your head, you risk infection and you have scarring for the rest of your life," says Brendan Allison, a neuroscientist at the University of California, San Diego.

For some disabled people, the benefits of invasive techniques might outweigh the potential hazards. Implants can plug directly into neurons, tapping into detailed movement data. And patients don't have to fiddle with an electrode cap every time they want to use their device. But for other users, paralyzed or healthy, noninvasive BCIs may be a better fit.

Though the technology is still a little clunky for everyday use, Contreras-Vidal hopes patients could one day easily integrate noninvasive BCIs into their lives. "This is the beginning of a dream where we can restore walking capabilities to patients," he says. "We don't want this technology to stay in the lab."

Listening in

After a motocross crash paralyzed him from the chest down, Holbert tried anything that might help him use his legs again. "I lived over 50 years with a fully functioning body," he says. "To have that suddenly ripped away was extremely traumatic."

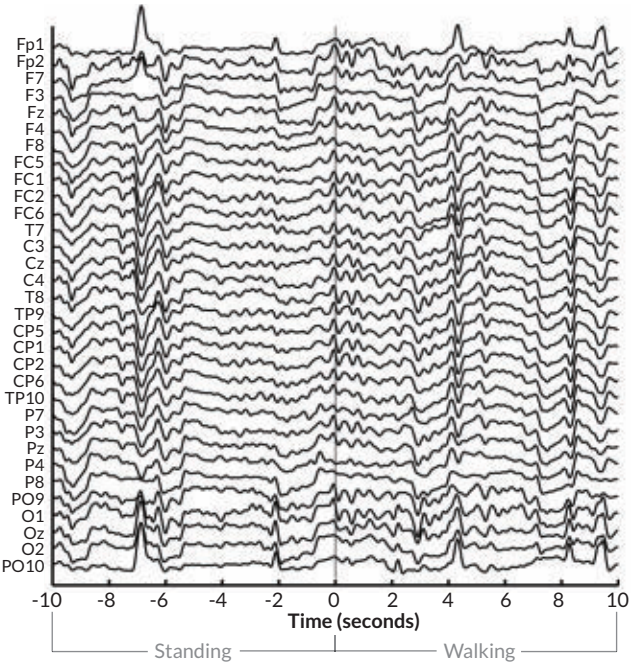
In 2012, after trying physical therapy and experimental treatments, Holbert met Contreras-Vidal, a neuroengineer who was working on fusing a robotic walking machine with a new type of BCI. But getting users to control machines with their minds is tricky. For the system to work, an electrode cap fitted over the skull has to pick up brain signals and send them to a computer. Then, the computer has to translate the signals into commands and deliver them to the robot. And it all has to happen fast.

With some BCIs, electrodes resting above the motor cortex, the brain area responsible for movement, pick up electrical signals when users imagine moving their hands and feet. Thinking about moving different body parts sparks different brain signals. Using computer programs, researchers can link these signals to specific commands. When patients imagine moving their left arms, for example, their robotic devices could turn left.

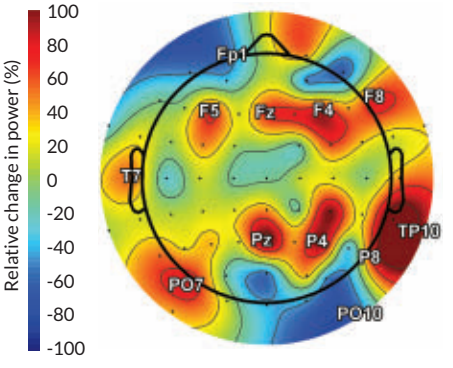
In other systems, electrodes sit above the occipital lobes, visual brain regions bundled in the back of the skull. By flashing lights at different speeds, researchers can make people's brains send out specific signals. As in the imagined movement system, researchers can tie different brain signals to commands. In this BCI, volunteers could look at a quickly blinking light to move a device in one direction, and a slowly blinking one to move in another.

Scientists have been studying EEG for decades, but decoding brain signals can be complicated and time-consuming. Volunteers often need weeks of training just to move a cursor in a virtual three-dimensional space, a feat accomplished only recently, in 2010. Even for simpler systems, the mental focus needed for control can be exhausting. So Contreras-Vidal's team wanted to tap into the neural wiring of walking itself. "Our patients used to walk, so that memory is still there," he

From thought to action To use brain waves to control a robotic walker like NeuroRex, a person thinks about walking. Electrodes (labeled Fp1, Fp2, etc.) placed against the scalp pick up electrical signals from different parts of the brain. An electroencephalogram, below, reveals changes in brain activity as a patient shifts from standing to walking, as shown in low-frequency, information-rich brain signals called delta waves. By analyzing fluctuations in the signals' amplitude, a computer program can be trained to decode the patient's intention to move.



A scalp map (with nose on top and ears on the sides) reveals brain areas that become more or less active (red or blue) when a person starts to walk in the NeuroRex. In active areas, electrodes such as Pz and P4 pick up delta waves that have higher amplitudes, or more power, during walking than standing.



BOTH: J. CONTRERAS-VIDAL

says. He just had to find a way to pluck the information from the brain.

Like a radio tower, the brain broadcasts information at different wavelengths. Scientists can tune into these brain waves with EEG. For most BCIs, researchers have zeroed in on FM, or frequency modulated, signals, which encode information in the waves' frequency, or how tightly packed they travel over time. But as talk radio fans know, there's another source of information. Contreras-Vidal's group flipped the receiver to AM, or amplitude modulation, and tuned into a low-frequency station called the delta band.

AM signals carry information in their waves' power, or amplitude, which varies over time. "So many groups have focused on frequency," says Contreras-Vidal. But AM signals carry a lot of information, he says. Picking up only FM stations means researchers miss out on other useful signals.

His team tuned the BCI to AM and trained a computer program to recognize the brain signals that urge legs to walk. To teach the program to spot these signals, Contreras-Vidal's team strapped Holbert into the NeuroRex and switched on the robot's remote controls. Then they told Holbert to think about walking, while researchers stepped the machine forward. As the robot walked, stopped and walked again, the team collected EEG signals from Holbert's electrode cap.

Feeding these signals to the computer program teaches it how to recognize brain patterns for movement. The signals act like the computer's cheat sheet. When volunteers control the NeuroRex mentally, the BCI decodes their thoughts by checking for the brain patterns it learned during training sessions.

In July, Contreras-Vidal's team reported preliminary findings at the Engineering in Medicine and Biology Society Conference in Osaka, Japan. In training sessions, their system could recognize the brain patterns for movement about 98 percent of the time. And when Holbert took control of the NeuroRex, he could stop and start the machine with his mind. The system may even skirt the lengthy training sessions that plague other BCIs: The team's training takes less than five minutes.

"This is good, original, helpful work," says Allison, "and it seems to be leading to something real."

This fall, Contreras-Vidal's team is partnering with Houston Methodist Hospital in a phase I clinical trial to test the system in a larger group of paraplegic patients. The researchers suspect that the robot may offer patients more than mobility. The act of standing and walking could help them regain strength, as well as improve their cardiovascular health, bone density and bladder and bowel function, Contreras-Vidal says.

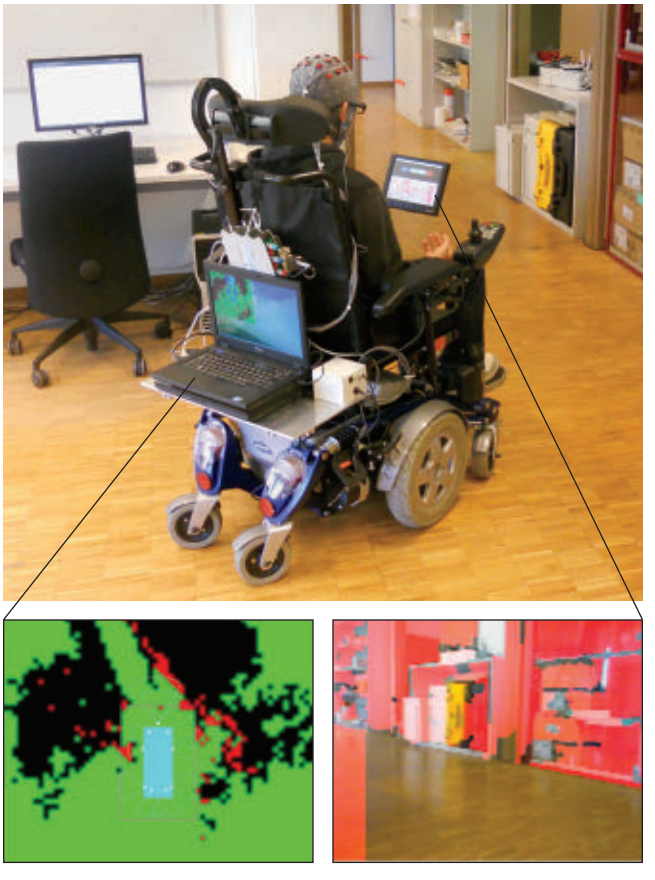
But the researchers still have to iron out some kinks. Two of the first patients the team has worked with, Holbert and Gene Alford, can't always control the robot with their thoughts. Getting the machine to walk outside of a controlled lab setting could make things even harder. "This has to work on the streets where you are bombarded with information," says Contreras-Vidal. Even a system that works 90 percent of the time isn't good enough, he says. Contreras-Vidal thinks pairing EEG signals with others, such as nerve signals in the muscles, could make the NeuroRex even more reliable, and that could give Holbert and other paralyzed people more options for movement.

Sharing control

To get around today, Holbert rides in a manual or an electric wheelchair. His accident wiped out muscular control from the nipples down, so he can still use his arms and shoulders but not his abs. Still, he has enough upper body strength to roll a wheelchair, and can almost hoist himself into the NeuroRex on his own.

Many paralyzed people have far less muscular control. Some have to rely on more limited movements to drive electric wheelchairs, such as lifting a finger, blowing a poof of air or twitching a cheek — the method Stephen Hawking uses. "Imagine that you need to 'poof' all day long," says bioengineer José del R. Millán of the Swiss Federal Institute of Technology in Lausanne. "It's hard. Your muscles will get very, very tired."

In recent years, several research groups have experimented



Mind-controlled chair An electric wheelchair outfitted with a computer, sensors and cameras integrates information about the immediate environment with a user's brain signals to control the wheelchair's movement. Sonar sensors (white dots, bottom left) help map nearby objects, with black and red spots showing potential obstacles. Webcams on the chair's front wheels highlight obstacles in red (bottom right).

T. CARLSON, J. MILLÁN/ *IEEE ROBOTICS AND AUTOMATION MAGAZINE* 2013

with electric wheelchairs coupled to EEG caps. In some of these chairs, cap-wearing users focus their eyes on specific commands such as "far right" or familiar household locations flashing on a screen. Focusing on these images spikes EEG activity, letting the BCI know which command to deliver to the wheelchair.

But Millán wanted to free patients from looking at a screen, and he wanted to ease the mental burden of constantly giving commands. So his team built a brain-controlled wheelchair with two key changes. It uses an imagined-movement mental task, and perhaps most important, it's intelligent: The chair works with its operator to decide where to drive, by nabbing information about the environment from an army of sensors.

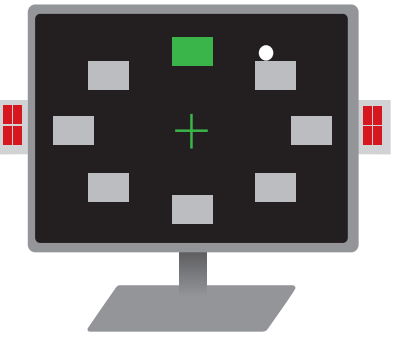
Two webcams perch above the chair's tiny front wheels, a laptop sits on a shelf in the back, gadgets called wheel-encoders gauge speed and 10 sonar sensors collect data about the chair's perimeter. Together, the extra hardware continuously maps out the chair's surroundings. When an operator decides to turn left or right, the computer program refers to the map before responding. This "shared control" system is kind of like a friendly GPS: Rather than spouting directions, it takes the wheel occasionally to give drivers a chance to rest.

As in Contreras-Vidal's system, Millán's volunteers wear an EEG cap. But instead of trying to walk, they imagine moving their right or left hands to turn different directions. Usually, such a system would require people to constantly direct the chair's movement. That's where shared control comes in, Millán says. If a user is driving across a room toward a desk, "The wheelchair can say, 'Aha, it seems that you want to reach that object, so I will help you.' " Then the chair can roll forward, avoiding obstacles automatically. This cuts down a user's mental workload, Millán says. "At that moment, they can relax a bit."

In March, Millán and a colleague reported that four healthy volunteers could sustain mental control of the wheelchair while steering it through an obstacle course. And because the system gave users a smooth ride and continuous control, it may outperform other brain-controlled wheelchairs, Millán suggests in *IEEE Robotics and Automation Magazine*. He and his colleagues have since tested their chair with two disabled people. The team hasn't published its results yet, but Millán says the volunteers can drive the chair as well as healthy people do.

Still, training to use the system takes hours. And though "there will always be some people who are natural whizzes with imagined-movement BCIs," says Allison, others may have trouble getting the hang of it. Millán thinks his wheelchair could work with other types of BCI, such as Contreras-Vidal's system, or those that draw upon signals from the brain and body. In 2011, Millán and colleagues reported a BCI that fused EEG signals with signals picked up from the muscles. Hybrids like this, or others that combine different types of EEG signals, could open up BCIs for a wider range of people.

And it's not just for patients. Healthy people can tap into the technology too, Allison says. Hybrid systems could one day help users explore virtual environments, remotely control robotics or even enhance prosthetics so that wounded soldiers can return to duty.



Mind game A hybrid system lets users move a white dot towards a green box without a mouse or keyboard. With EEG caps on, volunteers looked at LED lights on either side of the monitor to move the dot left or right. The LEDs flicker differently, creating a distinct signal for each direction. To move the dot up or down, volunteers imagined moving their left hand or both feet.

Practical BCIs

Though many people could likely use BCIs for simple tasks, such as moving a cursor across a screen, even slightly more complicated maneuvers are much more difficult. After scientists figured out how to master 1-D cursor movement with noninvasive BCIs in 1991, it took more than a decade to upgrade the technique to accurate 2-D control and six more years to achieve 3-D movement. "It's harder than it sounds," says Allison. With an imagined-movement BCI, as few as 5 percent of the population may be able to control a cursor in two dimensions.

But there might be another way to simultaneously move a cursor in 2-D, Allison thought. He wanted to combine the imagined-movement task with flickering lights, which can be used to control cursor movement in a different dimension.

"Maybe it's too overwhelming to think about moving your hand while also looking at a flickering light," Allison says, "but I didn't think so." This summer, as he watched a friend's toddler dash over rocks, he was reminded of just how simple it is to combine movement and visual attention tasks. "It's very basic," he says. "Even a 3-year-old kid can do it."

He and colleagues designed a BCI system where users imagined different movements to move a cursor up and down on a screen and looked at different flickering lights to move the cursor left or right. Using this hybrid system, some users were able to steadily move the cursor in two directions, such as up and right, at the same time, Allison's team reported last year in the *Journal of Neuroscience Methods*. The team estimates that its hybrid BCI could work for up to 20 percent of the population.

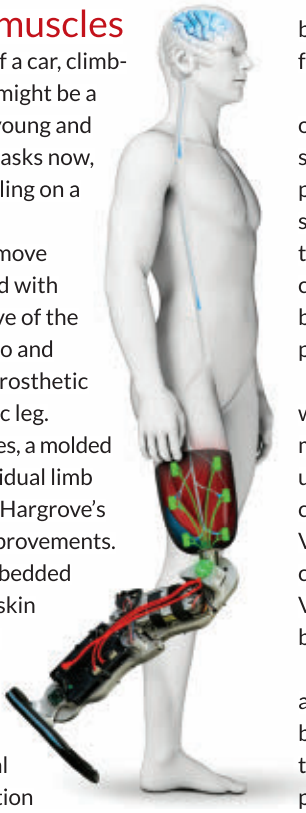
Allison can envision his system, or hybrids like it, helping disabled people communicate. Using a combination of BCI technologies could make tasks like checking e-mail or surfing the Web easier. "It's like having a keyboard and a mouse," he says. People can get by using only one or the other, but it's far less efficient. Allison's volunteers didn't find the dual BCI system annoying or even especially difficult. That's crucial if the technology is ever going to find a place in people's homes, says BCI researcher Theresa Vaughan of the Wadsworth

B. ALLISON *ET AL. / JOURNAL OF NEUROSCIENCE METHODS* 2012; ADAPTED BY E. OTWELL

Bionic leg listens to muscles

In just a few years, stepping out of a car, climbing up stairs and getting dressed might be a little easier for Zac Vawter. He's young and strong enough to conquer these tasks now, but with a prosthetic leg even pulling on a pair of jeans can be challenging.

After a 2009 amputation to remove his lower right leg, Vawter worked with biomedical engineer Levi Hargrove of the Rehabilitation Institute of Chicago and colleagues to test a new type of prosthetic limb — a thought-controlled bionic leg.



As with other types of prostheses, a molded plastic socket suctioned to his residual limb holds the robotic leg in place. But Hargrove's team added in a few high-tech improvements. Inside the socket, researchers embedded 10 electrodes that lie against the skin and pick up electrical signals from the muscles. These electromyographic, or EMG, signals travel to an onboard computer that also pulls data from 13 mechanical sensors that measure speed, position and pressure, among other variables.

A computer algorithm fuses information from all the sensors to figure out how a patient is trying to move the bionic leg — whether Vawter wants to point his foot, walk up a hill or stretch out his knee. "We're really going after what the person is thinking about," says Hargrove.

Thinking about walking sparks signals in the brain that zip down the spinal cord to the nerves in the legs. These nerves instruct muscles to contract, forcing joints to move. Researchers can eavesdrop on these instructions with the bionic leg's EMG sensors, rather than capturing EEG signals from the scalp.

Scientists can even gather information from nerves that once plugged into muscles in the amputated limb. The brain signals that command legs to walk are healthy up until the point where the nerves have been cut, Hargrove says. By surgically rewiring these nerves to hook up to muscles in the thigh, his team can tap into commands that would have once controlled Vawter's ankle. The surgery also offers a medical bonus: Rerouting snipped nerve fibers onto muscle tissue prevents painful scars called neuromas.

Hargrove's team tested the bionic leg by having Vawter walk on flat surfaces, slopes and stairs. Using only the mechanical sensors, the leg's movements failed to match up to Vawter's intentions about 13 percent of the time. But combining data from the mechanical sensors with that from Vawter's muscles dropped the error rate to less than 2 percent. And none of the errors were big enough to make Vawter stumble, Hargrove and colleagues reported September 26 in the *New England Journal of Medicine*.

Vawter was able to switch smoothly between walking and climbing stairs. "He said, 'This is how I used to do stairs before my amputation,' " Hargrove recalls. But for Vawter, the bionic leg especially outshone other prosthetics in simple joint movements. "Being able to reposition the knee and ankle just by thinking about it — that's something he's never been able to do before," Hargrove says.

Vawter has been coming to the lab a few times a year to try out the leg's latest enhancements. It's good for cruising around indoors and venturing outside a bit, but Hargrove wants to make it rugged enough for everyday use. He thinks Vawter will be able to take home a model in three to five years. As Vawter continues to test the device, Hargrove says, "I suspect it will get more and more difficult to leave it here each time he comes." — *Meghan Rosen*

Center, a research institute at the New York State Department of Health. "The technology has to be reliable, it has to be simple to operate and it has to be useful," she says.

Vaughan and colleagues have spent years investigating how to translate BCIs for practical use. In 2005, her group teamed up with Helen Hayes Hospital in West Haverstraw, N.Y., to supply BCIs to people with amyotrophic lateral sclerosis, or ALS. In 2009, the researchers joined with the Veterans Administration to deliver 25 systems to vets with ALS. The collaborations are the first effort to track long-term use of BCIs in patients' homes.

These BCIs help patients communicate: The system lets them spell out words by focusing on letters flashing on a screen. Vaughan says the study is revealing how people fit the technology into their lives, and could one day help researchers make improvements. For new BCI technologies, she says, "These kinds of translational experiments are going to be key." Getting these technologies into real-life situations could hasten the delivery of a new toolbox to help people walk, move and talk.

"I'm ready for it right now," Holbert says. After walking in the mind-controlled robot, he and Contreras-Vidal's other volunteers are eager to try again. "They call me and say, 'Pepe, can we come back?' " Contreras-Vidal says. The NeuroRex isn't quite ready for its debut in people's homes: Its bulk can be unwieldy, and its slow, preprogrammed steps aren't exactly agile. But Holbert says even regaining a bit of walking ability could make a huge difference in his life. "Just being able to take a step closer to the sink or to grab something out of a cabinet," he says. "That would be tremendous." ■

Explore more

■ J.J. Shih *et al.* "Brain-computer interfaces in medicine." *Mayo Clinic Proceedings*. March 2012.

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Family takes on progeria in *Life According to Sam*

Documentary portrays an extraordinary search for a cure

At the beginning of *Life According to Sam*, Sam Berns is 13. He builds elaborate Lego structures and loves the Dave Matthews Band. And Sam desperately wants a place in his high school marching band's drum line. He's a straight-A student with ambitions to be an inventor, he says, "kind of like Albert Einstein and Steve Jobs combined."

"I didn't put myself in front of you to have you feel bad for me. I put myself in front of you to let you know that you don't need to feel bad for me."
SAM BERNS

Sam is like other smart kids his age in every way but one. He is one of an estimated 200 to 250 children in the world with a premature aging disease called progeria. Kids with the disease have an average life expectancy of 13 years, so Sam is already living on borrowed time.

The documentary follows Sam and his parents, Leslie Gordon and Scott Berns (left), over three years as Gordon, a medical researcher, leads a clinical trial of a drug that could improve some of the symptoms of progeria (*SN: 2/23/13, p. 32*). It's hard to imagine another portrayal of the scientific process as passionate, visceral and emotionally wrenching as this one. The film includes an elegantly illustrated scientific explanation of progeria, but it is the depiction of the trial itself and Gordon's efforts to get the research published that shows science as an entirely human and personal endeavor.

Sam's family started the Progeria Research Foundation shortly after he was diagnosed. The group raised $1.25 million for progeria research and was instrumental in identifying the gene defect that accelerates aging in people with the condition. New England Patriots owner Robert Kraft was so inspired by the story that he pledged to match donations to the foundation up to $500,000.

Early in the film, directed and produced by Sean Fine and Andrea Nix Fine, Sam's mother and her research collaborators enroll 28 children from 16 countries in the two-year clinical trial. The stories of these children and their parents show just how high the stakes of this research are.

As the film unfolds, Sam and the other children periodically undergo rounds of testing that include at least 100 procedures over five-day periods. Sam endures needle sticks, breath tests and other poking and prodding, but it is the least invasive test that tries his soul. Medical photography makes him feel like a bug under a magnifying glass and robs him of his humanity, he says.

But as Sam, who turned 17 on October 23, says, "I didn't put myself in front of you to have you feel bad for me. I put myself in front of you to let you know that you don't need to feel bad for me. I want you to get to know me. This is my life, and this progeria is part of it. It's not a major part of it, but it is part of it."

The documentary is available on HBO GO, HBO On Demand and is being screened at film festivals. A DVD release date has not yet been set. Learn more at bit.ly/SNsamslife. — *Tina Hesman Saey*

BOTH: HBO

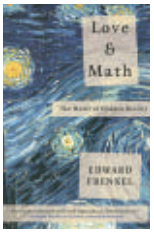
BOOKSHELF

Love and Math

The Heart of Hidden Reality

Edward Frenkel

Early in his career, mathematician Edward Frenkel had a secret love. He worked diligently on applied mathematics but would sneak away to indulge in the seductive problems of pure mathematics.



Frenkel recounts his maturation from a young boy plagued by anti-Semitism in the USSR to a leader in his field. Along the way, readers experience complex mathematical concepts as Frenkel did while developing his love affair with math. He admits that he was not always captivated by the subject. Like other teenagers, he assumed math was what he learned in school: quadratic equations, some calculus, geometry and trigonometry. He found the work easy, but pointless and irrelevant, he writes. Instead, quantum physics, and quarks in particular, first sparked his passion for numbers.

His path into this universe was not easy. In fact, part of his love affair with math stemmed from the discrimination he faced in the early 1980s. Frenkel was denied matriculation to Moscow State University despite acing the entrance exams, so he scaled the fence to attend lectures. Readers celebrate to learn that he later received a fellowship from Harvard that changed his fate forever.

These anecdotes are carefully mixed with small doses of increasingly more difficult mathematical concepts, such as symmetries and groups. Frenkel's descriptions do not magically make these easy to understand. But his passion inspires readers to be as dogged in working through the complexities as Frenkel was in climbing to the top of the field. —*Ashley Yeager*
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Peter Doherty
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OCTOBER 5, 2013

41%

Americans who say that news reports exaggerate global warming's seriousness. The rest say news underestimates (33%) or correctly reports (24%) the subject or have no opinion (2%).

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Solving soot

In "Cool idea" (*SN: 10/5/13, p. 26*), **Erin Wayman** explored the potential climate benefits of cutting back on emissions of black carbon, a component of soot, and other lesser-known climate warmers.

Reader **Ellis Johnson** e-mailed that U.S. EPA regulations have greatly reduced particulate matter emissions from diesel vehicles in recent years. "When was the last time you saw black smoke coming from a highway truck?" he asks. **Wayman** responds: "The United States has made great strides in reducing pollution from diesel vehicles, but in many parts of the world, diesel trucks and cars are still a major source of black carbon." A related climate-changing problem is pointed out by reader **Natasha Aristov**. "I can imagine that some powerful people will, instead of implementing climate-warming prevention measures at home, point their fingers at developing countries implying that the soot problem is 'mostly their (or their cookstoves') fault,' " Aristov says in an e-mail. But she has noticed a problem in developed countries: old or inefficient cooling fans that waste energy on vibration. "Replacing these fans does not require any changes in lifestyle (such as riding a bus instead of driving a car), does not require massive reforms of infrastructure, does not even require years of research in technology or materials science — the knowledge is there."

She-sheep success

Jessica Shugart reported on the trade-offs of horn size for male Soay sheep seeking mates in "For sheep horns, biggest is not best" (*SN: 10/5/13, p. 8*). Big-horned males mate more often, but small-horned males live longer.

Tim Cliffe e-mailed to say that we left out part of the story: female choice in mating. "Females, like males, must have successful mating strategies if their genes are to persist in the population," he writes, suggesting that females might sometimes prefer short-horned males. "Evolutionary logic suggests that females should mate with the small-horned males only if doing so would tend to enhance the females' own fitness," he says. **Shugart** replies: "According to study leader Susan Johnston of the University of Edinburgh, female Soay sheep don't appear to have much of a say in the matter. Rather, females will mate with any mature male that wins access to them through fighting (or in the case of smaller-horned males, seizing an opportunity to sneak in)."

Oldest clarification

In our 50 Years Ago section (*SN: 10/5/13, p. 4*), *Science News* ran an excerpt of "Huge galactic explosion" from the October 5, 1963, issue (then called *Science News Letter*) about astronomers detecting an event in the M-82 galaxy.

Some readers found it odd that the 1963 article mentioned that an explosion started 1.5 million years ago, but that the light had just reached Earth, 10 million light-years away. "The way it is stated certainly makes it sound like the light traveled 10 million light-years in 1.5 million years," **Doc Dougherty** says in an e-mail. Apparently readers in 1963 found it strange too. Upon further research, we discovered that the December 21, 1963, edition of *Science News Letter* addressed the issue. "When astronomers are dating events believed to have occurred in a celestial object, such as the explosion of a galaxy, they measure the time backward from the present when it could have been seen from the Earth," the editors wrote. "If there had been intelligent life on Earth one and a half million years ago and if sufficiently sensitive instruments had been used, the gigantic blast could have been detected then instead of the year 1963 A.D." In other words, the event began 11.5 million years ago and would first have been detectable from Earth 1.5 million years ago, after traveling 10 million light-years to reach Earth.

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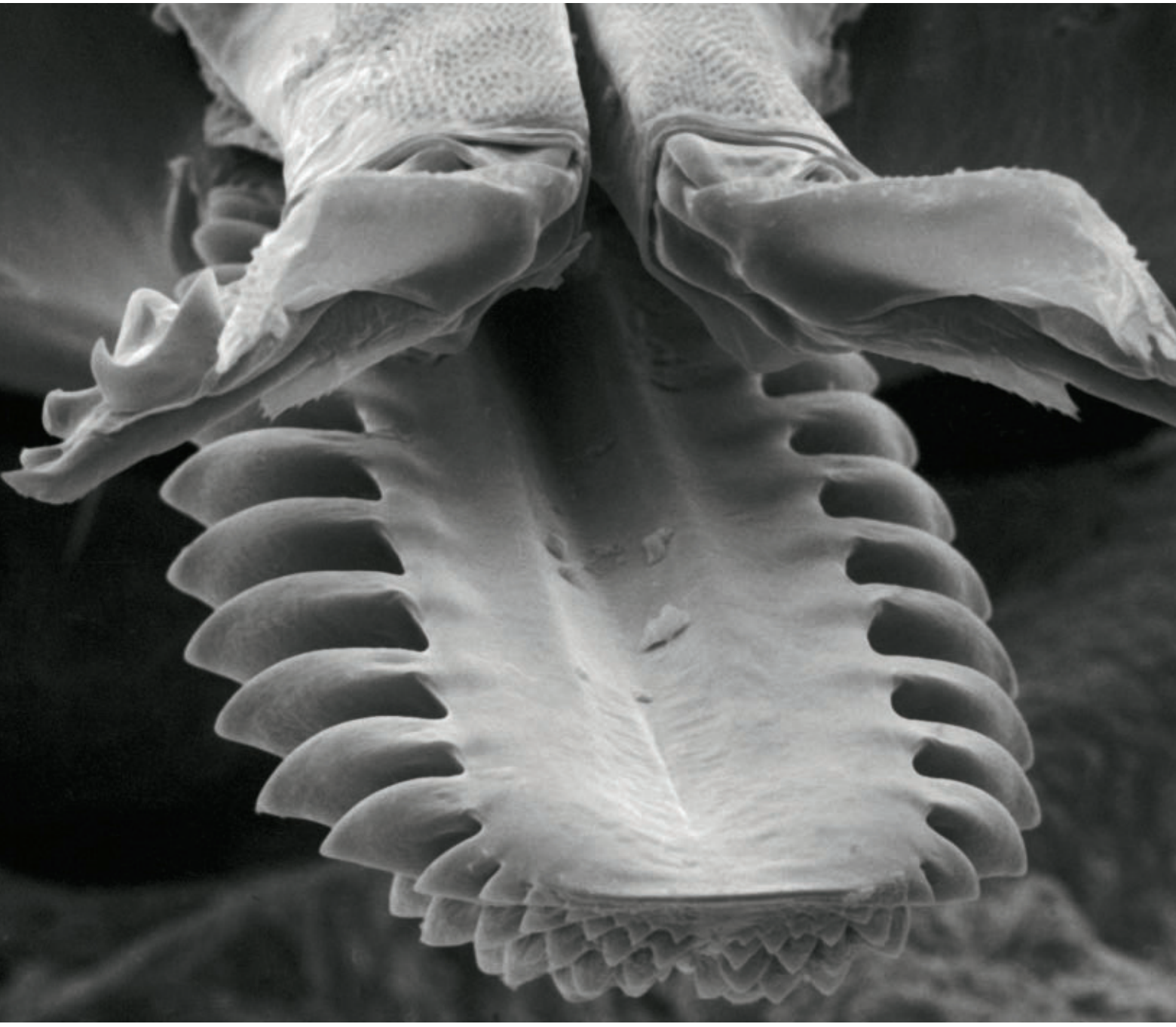

How ticks get under your skin

A new look at a tick's mouthparts shows how the arachnid saws its way through skin and hangs on for up to a week. The castor bean tick *Ixodes ricinus,* a European species that carries Lyme disease, faces an engineering problem: Its needlelike mouthparts are good at piercing but useless for hanging on during long periods of feeding. And unlike some ticks, this species does not make a cement to anchor itself to its host. Using a scanning electron microscope and videos to magnify their subjects thousands of times, German and U.S. researchers found that the ticks use a two-step process to ratchet their way in. First a pair of chelicerae (the wing-like structures at top) telescope out to pierce the skin, pumping alternately like engine pistons to gain a foothold. Then the chelicerae switch to a breaststroke motion that draws in the barbed tonguelike needle, or hypostome (center). The tick's method may inspire engineers to mimic it, the team reports October 29 in the *Proceedings of the Royal Society B.* — *Erika Engelhaupt*

See video of a tick attaching to skin **bit.ly/SNticks**

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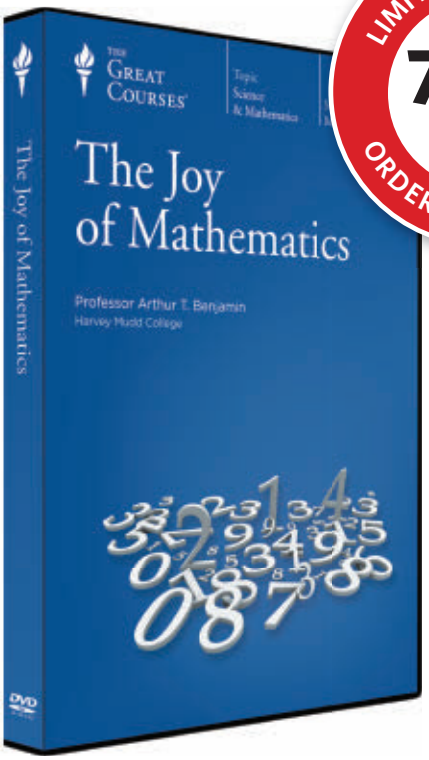

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