SN
SCIENCE NEWS MAGAZINE
SOCIETY FOR SCIENCE & THE PUBLIC
FEBRUARY 16, 2019

Particle Colliders of the Future

Zapping Severe Depression

Early Tetrapod, Modern Moves

Curbing Low-Income Students' Test Anxiety

ROBOTS IN CLASS

Mechanical mentors try to make the grade

I'M FIGURING OUT BETTER WAYS TO HARNESS IT."

Anna Braun
Senior
Chemistry & Chemical Engineering

I've been working with Professor Rebecca DeVasher focusing on the degradation of perovskite photovoltaic cells. It's a material that could make solar panels a lot more affordable, which would be better for everyone. My hard work at Rose-Hulman landed me an internship at the Department of Energy in Colorado (two years in a row!) and scored me one of the best national academic awards out there—the Goldwater Scholarship.

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SOCIETY UPDATE
The latest stories from *Science News for Students*

COVER Tega is one of several robots being tested to help children become engaged learners. *Bruce Peterson*

FROM TOP: UCSF; BARBARA RIES FOR UCSF; STEFANO MAZZOLA/AWAKENING/ALAMY STOCK PHOTO; VINCENT MUNIER

Brain discoveries open doors to new treatments

For centuries, scientists have strived to figure out the workings of the human brain, but that blob of matter tucked inside a bony shell long resisted efforts to divine its secrets.

Techniques invented in the early 1900s, including angiography and electroencephalography, made it possible to examine some characteristics of the brain without invading the skull. But it wasn't until the 1970s, with the development of functional PET and MRI scanning, that it became possible to see the brain in action.

Two stories in this issue illuminate just how far we've come in being able to explore and influence the brain in this extraordinary era of neuroscience innovation. "Mood changer," by neuroscience writer Laura Sanders (Page 22), examines efforts to treat depression with electrical stimulation. Rather than deliver a whole-brain zap, which is used in electroconvulsive therapy for severe depression, these experiments are testing whether nudging parts of the brain with electrodes could work better than current treatments.

"It's one of those things that sounds a little bit like science fiction, but they're actually doing it," Sanders told me. "What if we could have this really precise, gentler, kinder approach that worked?"

A second story by Sanders looks at recent discoveries about the cerebellum (Page 10), a brain structure that had been thought to be involved only in movement. Now scientists say that the cerebellum plays a role in many of the things that make us human, including memory, language and social relationships.

Improved technology, such as the tiny electrodes used in the brain-zapping therapy, drives most of these discoveries. And often the innovation comes from combining methods.

In January, Sanders wrote about researchers affiliated with Howard Hughes Medical Institute's Janelia Research Campus who managed to zoom in on the structure of just one nerve cell at a time by combining a laser lattice light-sheet microscope with a technique called expansion microscopy, which enlarges tiny tissue samples to reveal individual structures. And a group of Stanford University scientists created an advanced form of optogenetics that uses laser light to control individual nerve cells. The researchers used the technique to switch nerve cells on and off in mouse brains, controlling the animals' behavior (*SN Online: 1/17/19*).

Sanders appreciates the difficulty of these achievements. She has a Ph.D. in molecular biology, which she earned by spending many, many hours tweaking nerve cells in fruit fly brains to see how various regions are involved in the flies' mating dance. "But I got really tired of watching videos of fruit flies mating," she says. Plus doing all those dissections of tiny fruit fly brains meant she needed glasses by the time she finished her degree.

Ultimately, Sanders realized, she's much more interested in the brains of people, and she decided to become a science journalist. "That's part of what I love," she says. "Thinking about how complicated human behavior is, and how we're actually getting clues now that were previously impossible." We're glad she decided to use her deep understanding of neuroscience to explain it to the public. The fruit flies' loss is our gain. — *Nancy Shute, Editor in Chief*

Science News
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Editorial/Letters: editors@sciencenews.org
***Science News* in High Schools:** snhs@societyforscience.org
Advertising/Sponsor content: ads@societyforscience.org
Science News (ISSN 0036-8423) is published 22 times a year with double issues in May, July, October and December by the Society for Science and the Public, 1719 N Street, NW, Washington, DC 20036.
Print, online and tablet access: Activate your subscribing member account, including digital access, at www.sciencenews.org/activate
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Excerpt from the February 22, 1969 issue of *Science News*

50 YEARS AGO

DDT killing off falcons

Fierce and swift, steel blue in color and called the world's most perfect flying machine, the peregrine falcon is heading toward extinction in North America. The reason: DDT. Perilously high levels of the pesticide and related chemicals have been found in the eggs, fat and tissues of the birds.... [The falcons] are not picking up the DDT directly, but get it by eating other birds which, in their southern migrations, ingest DDT-contaminated insects.

UPDATE: Two years after the American peregrine falcon (*Falco peregrinus anatum*) was declared endangered, the United States banned DDT in 1972. The pesticide lingered in the environment, however, and by 1975, North America's population of peregrine falcons hit a low of 324 nesting pairs. State and federal agencies worked with conservation groups to breed the species in captivity, with some 6,000 birds released into the wild since 1974. The species was removed from the U.S. endangered species list in 1999.

Wood-eating termites, such as the *Macrotermes* shown here, improve leaf decomposition, soil moisture and seedling survival during rainforest drought, a new study finds.

THE SCIENCE LIFE

Termites help rainforests withstand a drought

With tea bags and toilet paper rolls, tropical ecologist Kate Parr and colleagues showed how termites help tropical rainforests resist drought. Forests with more termites have more leaf litter decomposition, soil moisture and seedling survival during a drought than forests with fewer termites.

Termites play an important role in tropical ecosystems, but "nobody knows exactly how important," says Parr, of the University of Liverpool in England. To isolate the effects of termites from other soil critters, the researchers exploited termites' cellulose diet.

In 2014, Parr's team buried insecticide-soaked rolls of toilet paper and tea bags in four forest plots, each with an area of about five Olympic swimming pools, in the Maliau Basin Conservation Area of northern Borneo. Toilet rolls are like cotton candy for termites — "this really amazing, easy-to-digest food," Parr says. The tea bags were used in case some termites "were fussy and didn't eat the toilet paper."

Toilet paper rolls were sliced in half and dunked in liquid insecticide, offering an attractive meal for cellulose-munching termites. Thousands of poisoned rolls reduced termite populations in forest plots, without harming other animals.

Termites died after eating the poisoned baits, while the 14 other most commonly found invertebrates, including ants and beetles, were unaffected. Few of the other critters nosh on hard-to-digest cellulose.

For nearly three years, the team destroyed any termite mounds that appeared, while replenishing the poisoned baits every six months. The researchers went through about 3,500 rolls, including some without poison so the team could check how much termites were chomping. This helped in gauging an area's termite activity — a proxy for termite numbers. Termite activity fell by 45 percent in treated plots, compared with four untreated plots.

The project, described in the Jan. 11 *Science*, was part of a larger effort led by the University of Liverpool and the Natural History Museum in London to examine how ants and termites affect both decomposition and consumption in rainforests.

When drought hit a year into the study, Parr's team worried the insect-activity research would be compromised. Instead, the halt in rain offered a "wonderful opportunity," Parr says.

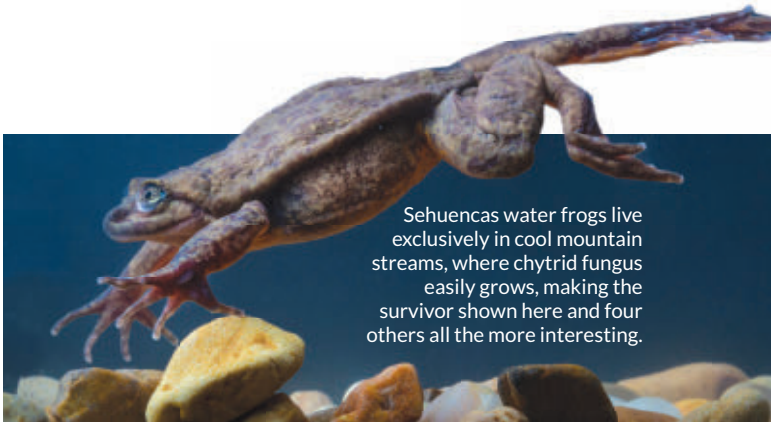
During the drought, termite numbers doubled and leaf litter decomposed faster in untreated plots than in treated plots. Untreated plots also had more soil moisture and nutrient mixing, as well as better seedling survival rates. These effects were not observed during nondrought periods.

The researchers aren't sure why termites kicked into high gear during drought, but the insects might have benefited from easier tunneling in drier soil or from fewer predators. — *Yao-Hua Law*

FROM TOP: Y.-H. LAW; LOUISE ASHTON

RETHINK

Newfound frogs may aid fungus fight



Sehuencas water frogs live exclusively in cool mountain streams, where chytrid fungus easily grows, making the survivor shown here and four others all the more interesting.

Save for one lonely survivor in captivity, the Sehuencas water frog hadn't been seen in the wild since 2008. That's when its numbers collapsed amid an outbreak of the fungal disease chytridiomycosis, which has devastated frog populations worldwide. Fearing the species might be extinct, a group of scientists searched Bolivia's mountain forests for 10 years, and just recently found a tiny population of five.

"It's just incredible," says herpetologist Robin Moore, communications director at the nonprofit Global Wildlife Conservation in Austin, Texas. He was among the scientists who announced the discovery on January 15.

With no safe way to get rid of the lethal chytrid fungus in the wild, scientists are keen to study the survivors. The five Sehuencas water frogs (*Telmatobius yuracare*) were found in their native cloud forest habitat, where the air is moist and cool — ideal for chytrid growth. Maybe this small population has immunity or genetic resistance to the fungus, Moore says. Maybe the environment, such as an unusually warm microclimate, is at play. Or the frogs' survival could just be luck.

"Many species of frogs that disappeared for years — decades in some cases — have been seen again later," says ecologist Karen Lips of the University of Maryland in College Park. "Once most of the frogs are gone, the fungus declines" from having fewer hosts to infect. Then the frogs slowly rebound.

These newly found frogs raise hopes that more populations exist in the wild and also offer researchers a chance to help the species recover. — *Jeremy Rehm*

In Italy, vineyards of high-quality prosecco are losing 400 million kilograms of soil every year, researchers calculate.

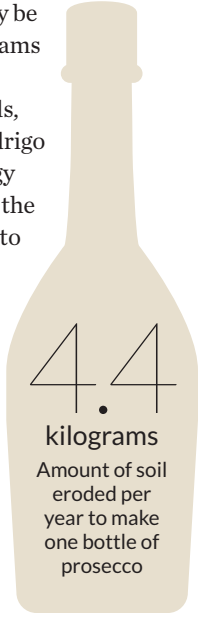
SCIENCE STATS

Prosecco production takes a toll on Italy's soil

Sorry to burst your bubbly, but demand for high-end prosecco may be sapping northeastern Italy's vineyards of soil — 400 million kilograms of it per year, scientists report online January 10 at bioRxiv.org.

That's a lot of soil, but not an anomaly. Some German vineyards, for example, have higher soil loss rates, says geographer Jesús Rodrigo Comino of the University of Málaga's Institute of Geomorphology and Soils in Spain, who was not involved in the study. But, he says, the amount eroding from vineyards in Italy's Veneto region — home to prosecco with the highest quality designation, DOCG — is not sustainable.

A team led by researchers from the University of Padua in Italy calculated the sparkling wine's "soil footprint." The group determined the industry was responsible for about 74 percent of the region's total soil erosion, by studying 10 years of data on rainfall, land use and soil characteristics, as well as high-resolution topographic maps. The team then compared the result with average sales of DOCG prosecco to estimate the annual soil footprint per bottle: 4.4 kilograms, roughly the mass of a house cat. — *Cassie Martin*



TEASER

This app detects an opioid overdose

A new smartphone app can detect breathing troubles that foreshadow an opioid overdose. The app, called Second Chance, works by emitting high-frequency sound waves and monitoring the echoes that bounce back from a user's chest.

Computer scientist Rajalakshmi Nandakumar and colleagues at the University of Washington in Seattle tested the app at a Vancouver facility where people self-inject opioids such as heroin under medical supervision.

The system, described in the Jan. 9 *Science Translational Medicine*, observed 94 users for five minutes after injection, when an overdose is likely to occur. The app flagged 47 of 49 cases where a user stopped breathing and raised one false alarm. It also caught 41 of 47 cases where a patient was breathing fewer than eight times per minute.

More than 130 people die of opioid overdoses daily in the United States. The team still needs to ensure the app can send alerts in time to resuscitate a person. — *Maria Temming*

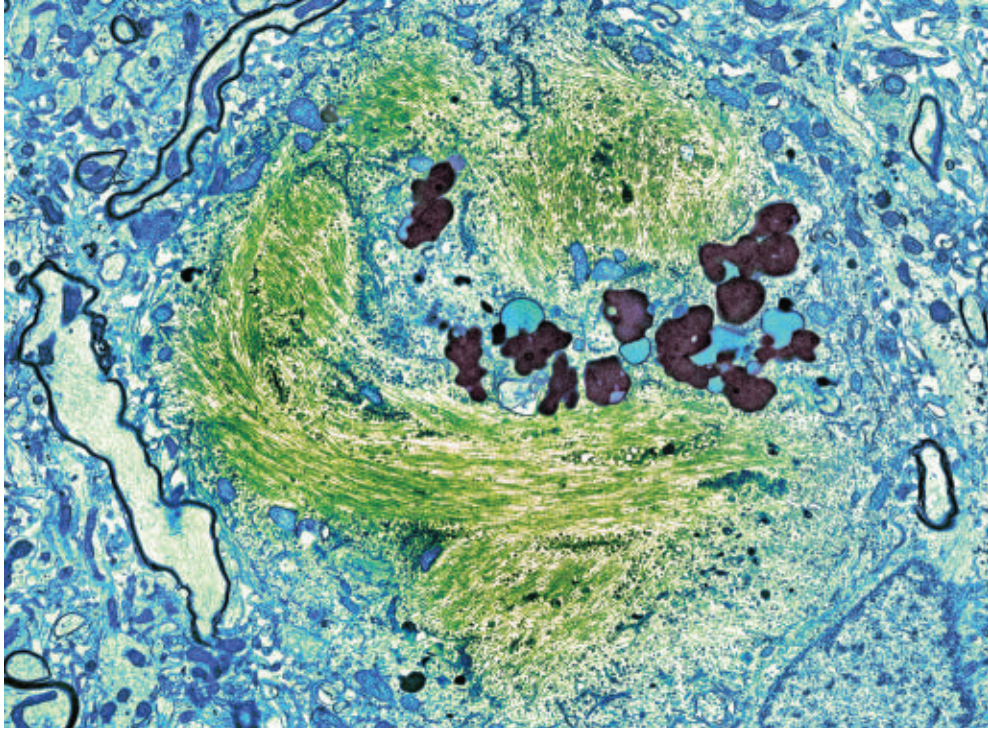
FROM TOP: R. MOORE; STEFANO MAZZOLA/AWAKENING/ALAMY STOCK PHOTO

BODY & BRAIN

Lack of sleep again tied to Alzheimer's

Levels of tau protein go up in people deprived of shut-eye

BY AIMEE CUNNINGHAM



Tangles of tau protein (green in this colorized micrograph) muck up a nerve cell from a patient with Alzheimer's disease. Sleep may affect the release of tau to the cerebrospinal fluid.

THOMAS DEERINCK, NCMIR/SCIENCE SOURCE

A sleep-deprived brain is awash in excess amounts of not one but two proteins whose bad behavior is implicated in Alzheimer's disease.

In extremely sleep-deprived adults, researchers found excessive amounts of a protein called tau in the fluid that bathes the brain and spinal cord. Tau tangles and spreads throughout the brain during Alzheimer's and is tied to nerve cell death. An earlier report on these sleepy adults found that the protein amyloid-beta — globs of which dot the brains of Alzheimer's patients — also increased with a lack of sleep.

Samples of cerebrospinal fluid collected from eight adults, monitored during a night of normal sleep and over the course of 36 hours of sleep deprivation, revealed a 51.5 percent increase in tau in participants robbed of shut-eye. And sleep-deprived mice had twice the amount of tau as well-rested mice, researchers report online January 24 in *Science*. Earlier work by this group had suggested that the quality of sleep might affect tau levels; this time, they were linked to duration of sleep.

With both A-beta and tau increasing with a lack of sleep, "it certainly argues that treating sleep disorders during midlife as well as getting appropriate levels of sleep is likely to decrease risk for Alzheimer's disease," says coauthor David Holtzman, a neurologist and neuroscientist at Washington University School of Medicine in St. Louis. During sleep, the brain appears to flush out excess protein and other debris (*SN: 7/21/18, p. 22*), so perhaps less sleep means that wash cycle is curtailed.

An estimated 5.7 million people in the United States have Alzheimer's disease, according to the Alzheimer's Association. Alzheimer's leads to problems with thinking, memory and behavior that eventually interfere with a person's ability to function day to day. Plaques of A-beta and twisted bits of tau litter the brains of those with the disease, producing damage that appears to play a role in the development of Alzheimer's symptoms.

In 2017, Holtzman and colleagues reported that a night of poor-quality sleep raised levels of A-beta in the cerebrospinal fluid, and if that night had been preceded by a week of less-than-sound snoozing, the amount of tau also increased (*SN Online: 7/10/17*). In that study, volunteers were monitored on a night of sound sleep and a night in which they got the same amount but their deep sleep was disrupted.

When brain nerve cells are highly active — that is, busily firing away electrical messages to other neurons — they release more tau, evidence suggests. Because being awake appears to result in more nerve cell activity, Holtzman says, "we wondered whether the release of tau from nerve cells might also be accelerated during wakefulness versus during sleep." In fact, when mice were awake, tau levels were 90 percent higher in the fluid between neurons than when the animals were slumbering, the researchers found.

And sleep deprivation seems to impact tau more than A-beta. In the samples of cerebrospinal fluid from the sleep-starved adults, the 51.5 percent increase in tau surpassed the 30 percent increase in A-beta. The excessive amounts of these two proteins in the fluid may set the stage for later problems. The more A-beta released from cells, the more likely the protein is to clump and accumulate over time, Holtzman says. Similarly, chronic increases of tau — driven by sleep deprivation or other means — may push the spread of its tangled, destructive form throughout the brain.

The findings show that just as the sleep-wake cycle regulates the release of A-beta from neurons, it also affects the amount of tau those cells release, says Bess Frost, a tau biologist at the University of Texas Health San Antonio who was not involved in the study. "The two main pathological hallmarks of Alzheimer's disease are both affected by sleep."

Frost says that the effect of the sleep-wake cycle on tau is also important to know for chronic traumatic encephalopathy, or CTE (*SN: 8/19/17, p. 15*), and other neurodegenerative diseases that feature tau tangles. ■

Robot re-creates a tetrapod's moves

Early four-limbed animal had a relatively modern style of walking

BY CAROLYN GRAMLING

Orobates pabsti lived between 280 million and 290 million years ago, but it was pretty advanced at doing the locomotion.

Using computer simulations, fossil footprints, a re-created skeleton and a walking robot, scientists found that this ancient four-footed creature had a surprisingly efficient gait. That result suggests that evolving a more advanced way of walking may not have been as closely linked to the later diversification of tetrapods as once thought, the researchers report in the Jan. 17 *Nature*.

O. pabsti was an early amniote, a group that arose about 350 million years ago and includes reptiles and mammals. Unlike amphibians, amniotes can live entirely on land. Protective membranes surrounding embryos allow amniotes to bypass a tadpole-type life stage: Reptile and bird eggs can be laid on land; mammal embryos stay within the mother.

The amniotic membrane "is regarded as a key evolutionary innovation, to be able to colonize different habitats," says John Nyakatura, an evolutionary biologist at Humboldt University of Berlin who led the new study. Understanding how early amniotes walked on land could help scientists better understand the origins of amniotes themselves, and how they diversified across the continents, he says.

Researchers first described *O. pabsti* in 2004, following the discovery of beautifully preserved fossils at a site in Germany known as the Bromacker locality. A few years later, researchers linked the creature to a series of footprints, called a trackway, found at the same place.

There's more to visualizing walking than knowing where an animal put its feet. Scientists use various approaches to study the locomotion of extinct animals, including studying trackways, examining anatomy or even building robots, says study coauthor and bioroboticist Kamilo Melo of École Polytechnique Fédérale de Lausanne in Switzerland. What's different about the new work, Melo says, is that it combines several tactics to get the best possible approximation of the gait.

The researchers first re-created the skeleton to constrain the possible ranges of motion of the legs. "You create a marionette and see what amount of angle each joint can move," Melo says. The scientists also created a simulation that included factors such as gravity, friction and balance to examine how the animal might have walked.

The team also looked to modern four-footed species, including salamanders, skinks, caimans and iguanas, to study possible ranges of motion for tetrapods. Skinks and salamanders, for example, hold their bodies lower with their limbs more sprawled out to the side, while caimans tend to have more erect limbs.

Finally, the scientists created a tetrapod robot, dubbed the OroBOT, to act out potential gaits and match the prints they created to known fossil tracks. The researchers ultimately considered 512 possible types of movement, scoring them on energy consumption, balance and precision to see how well the gaits reproduced the fossil tracks without slipping or sliding.

The data suggest that *O. pabsti* had a relatively advanced style of walking, one that many researchers previously thought would have been possible only in later tetrapods. *O. pabsti* probably held its belly off the ground and had a stable, efficient gait without a lot of side-to-side, salamander-like undulations. That style of walking would have helped the animal conserve energy.

Stuart Sumida, a vertebrate paleontologist at California State University, San Bernardino, praises the multipronged design of the study. The biomechanical analysis, he notes, has confirmed something that previously was strongly suspected only by the fossil's finders: that *O. pabsti* was indeed a fully terrestrial animal with a relatively modern gait.

Sumida and others have demonstrated that amniotes from the Bromacker locality had a range of walking styles. Some had erect limbs like *O. pabsti*, some sprawled, and at least one animal walked on two legs. "What these studies are showing is that when amniotes first showed up, they were doing lots of things more quickly than we ever realized," he says.

The new findings are just a start, Nyakatura says. His group hopes its approach will be a jumping-off point to better understand *O. pabsti* and to examine other puzzles, such as the evolution of active flight, bipedal locomotion in human ancestors and the transition from terrestrial to aquatic in marine mammals. "We have a whole bag of interesting things to study," he says. ■

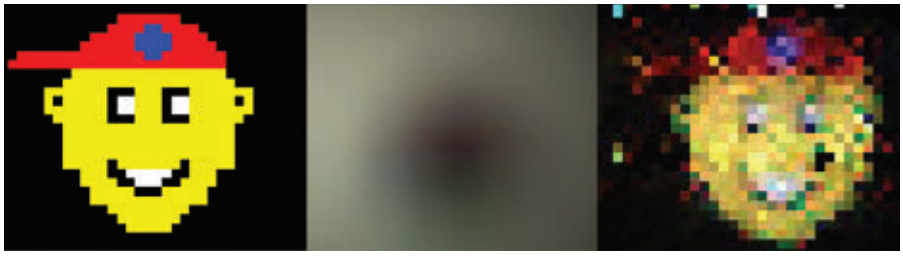
TOMISLAV HORVAT AND K. MELO/EPFL LAUSANNE

A robot called OroBOT helped researchers analyze different gaits that *Orobates pabsti*, a four-legged animal that lived about 290 million years ago, might have used.

MATH & TECHNOLOGY

Camera captures hidden objects

New imaging system works like a periscope mirror



By analyzing a multicolored jumble of light and shadow on a wall (middle), a computer program can create a rough reconstruction (right) of an image displayed on an out-of-frame LCD screen (left).

BY MARIA TEMMING

With a new computer program, a photographer can take a picture of something that's not even in frame.

The system analyzes light reflected off matte surfaces, such as walls, to discern out-of-sight images, similar to the way a periscope mirror reveals what's around a corner. Whereas other techniques for spotting out-of-sight objects require expensive, specialist optical equipment (*SN: 1/9/16, p. 15*), the new program can render a rough, full-color reconstruction of a hidden scene using a single snapshot from an ordinary digital camera.

"Looking way beyond what the camera can see could be very, very useful" for self-driving cars monitoring surrounding traffic or doctors using endoscopes to probe patients' bodies, says Aswin Sankaranarayanan, a computational photography researcher at Carnegie Mellon University in Pittsburgh who was not involved in the work. This technology, described in the Jan. 24 *Nature*, may also help police monitor buildings from the outside during hostage situations or first responders scout out collapsed buildings after disasters.

Electrical engineer Vivek Goyal and colleagues at Boston University tested the system by displaying images on an LCD monitor facing a wall. In between the two, the team placed an object that blocked some of the light emanating from the monitor, casting shadows on the wall. (The team used a rectangular panel, but an object of any size or shape would do.)

Both the light that reaches the wall and the shadows created by the intervening object contain clues about the LCD display. To picture why, imagine a screen displaying two white circles side by side against a black backdrop. Someone looking at the smear of light that these circles

ATOM & COSMOS

Japan will join gravitational wave hunt

Underground detector will look for cosmic ripples in a new way

BY EMILY CONOVER

In the quest for better gravitational wave detectors, scientists are going cold.

An up-and-coming detector called KAGRA aims to spot spacetime ripples by harnessing advanced technological twists: chilling key components to temperatures hovering just above absolute zero and placing the ultrasensitive setup in an enormous underground cavern.

Scientists with KAGRA, located in Kamioka, Japan, now have results from their first ultrafrigid tests. Those experiments suggest that the detector should be operational later this year, the team reports January 14 at arXiv.org.

KAGRA will join similar observatories in the search for gravitational waves, minute undulations stirred up by violent events like the collisions of black holes. The Advanced Laser Interferometer Gravitational-Wave Observatory, LIGO, has two detectors located in Hanford, Wash., and Livingston, La. Another observatory, Virgo, is located near Pisa, Italy. Those detectors sit above ground and don't use the cooling technique, making KAGRA the first of its kind.

KAGRA consists of two 3-kilometer-long arms arranged in an "L" shape. Within each arm, laser light bounces back and forth between two mirrors located at both ends. The light acts like a measuring stick, capturing tiny changes in the length of each arm, which can be caused by a passing gravitational wave stretching and squeezing spacetime.

Because gravitational wave detectors measure length changes tinier than a proton's diameter, minuscule effects like the jiggling of molecules on the mirrors' surfaces can interfere with measurements. Cooling the mirrors to about 20 kelvins (–253° Celsius) limits that jiggling.

In the new tests, performed in spring 2018, researchers cooled only one of the four mirrors in KAGRA's arms, says KAGRA leader Takaaki Kajita of the University of Tokyo. When the detector starts up for real, the others will be chilled too.

Having the detector underground also helps keep the mirrors from vibrating due to activity on Earth's surface. LIGO is so sensitive that it can be affected by rumbling trucks, a stiff breeze or even wildlife (*SN Online: 4/18/18*).

Building underground and going cold required years of effort from KAGRA's researchers. "They've taken on these two great challenges, which are both important to the long-term future of the field," says LIGO spokesperson David Shoemaker of MIT. In the future, even more advanced gravitational wave detectors could build on KAGRA's techniques.

For now, adding KAGRA to the existing observatories should help scientists improve studies of where gravitational wiggles come from. Once scientists detect a gravitational wave signal, they

C. SAUNDERS, J. MURRAY-BRUCE AND V.K. GOYAL/*NATURE* 2019

collectively cast on the opposite wall may not be able to tell whether the screen displays one or several bright spots. But put a chair between the monitor and wall, and that chair will cast two distinct shadows, making it clear that the screen has two distinct sources of illumination.

Using this kind of analysis, the program scrutinized the pattern of light in a photo of the wall to roughly reconstruct the image displayed on-screen. The system's re-creations of cartoon faces, letters and striped patterns "are really quite impressive," says Genevieve Gariepy, an engineering physicist at Heriot-Watt University in Edinburgh.

The technique's reliance on having an object in between the scene of interest and photographed surface may limit the system's use, says Gariepy, who has developed technology to track objects around corners. But many cluttered environments are likely to have obscuring objects aplenty, she says, so "I don't think that's a showstopper" for the imaging scheme. ■

ROHAN MEHRA/ICRR, UNIV. OF TOKYO

KAGRA's mirrors (one shown) are cooled to very low temperatures to prevent jiggling that could hinder the search for gravitational waves.

alert astronomers, who search for light from the cataclysm that generated the waves in the hope of better understanding the event (*SN: 11/11/17, p. 6*). Having an additional gravitational wave detector in a different part of the world will help better triangulate wave sources. "This feature is very important," Kajita says, "because telescopes can only see a small part of the sky at a time." ■

LIFE & EVOLUTION

Songs may not advertise brainpower

Female birds can't rely on tunes to discern a male's smarts

BY SUSAN MILIUS

After some 20 years of work, a scientist is publicly renouncing his own "beautiful hypothesis" that male birds' sexy songs could indicate the quality of their brains.

Behavioral ecologist Steve Nowicki of Duke University called birdsong "unreliable" as a clue for choosy females seeking a smart mate in a talk on January 4 in Tampa, Fla., at the annual meeting of the Society for Integrative and Comparative Biology. He presented results published in the March 2018 *Animal Behaviour*, plus an unpublished critique based on male songbirds that failed to score consistently on learning tests.

"This was a beautiful hypothesis that got beaten up by data," he says.

Knowing that something about male singing matters to females, Nowicki and others previously proposed that the quality of singing might indicate a bird's brainpower. The idea was that, because songbirds need to learn their songs, females could select males with the best brain development by selecting those singing the most precisely copied songs. A brainier male might be better at hunting baby food or spotting predators, thus helping chicks to survive. Or braininess might signal an indirect benefit, such as contributing good genes to chicks.

The first evidence for the notion that birdsong indicates bird smarts came from Neeltje Boogert of the University of Exeter in England, whose research suggested that female zebra finches preferred smarter males with more complex songs. But subsequent studies have found evidence both supporting and contradicting the idea. To try to settle the matter, Nowicki and collaborators hand-raised 19 male song sparrows in the lab, controlling which songs the birds heard as examples to copy so that it was clear how well each youngster learned each song.

To judge the birds' mental capacity separately from their song learning, the researchers administered five learning challenges, such as learning which colored container lids to flip open for food. We "found a hodgepodge" of results, Nowicki says. A bird might have done well on some tests and flubbed others, and the puzzle-solving results didn't match a bird's song learning ability.

"Maybe they weren't cognitively good at stuff because they lived their life in a cage," Nowicki wondered. So, he and colleagues turned to wild swamp sparrows.

It's trickier to judge the precision of birds' mimicry in the wild, where young hear multiple songs to copy. So a coauthor had a computer sort recordings from the marsh into a few "typical" song types. The closer a newly musical sparrow's songs came to the typical forms, the higher the scientists ranked the bird's learning. The team also put the new singers through the cognitive tests. Again, the results were a hodgepodge, Nowicki says, finally beating to pieces his hypothesis about birdsong.

Songbirds may not have a general "IQ" in the sense that people use the term, says Rindy Anderson of Florida Atlantic University in Davie, who has worked with Nowicki. Instead, bird intelligence may be modular, she says, with the birds good at some mental tasks but not others.

Even if male songbirds don't betray their smarts through song, some scientists are testing a different group of birds to see if females prefer smarter mates. Among flirting budgerigars, a kind of parrot, females preferred males that had learned to perform food-finding tricks over uneducated males, as reported in the Jan. 11 *Science*. A parrot researcher who wasn't involved in that study, Tim Wright of New Mexico State University in Las Cruces, and a former student are finishing a paper on a different way of testing whether budgerigars' sex appeal is tied to smarts. "There is evidence out there and there will be more coming shortly," Wright says. ■

BODY & BRAIN

Cerebellum shows it has a social side

The brain structure does more than coordinate movement

BY LAURA SANDERS

Its name means "little brain" in Latin, but the cerebellum is anything but. The fist-sized orb at the back of the brain has an outsize role in social interactions, a study in mice suggests.

Once thought to be a relatively simple brain structure that had only one job, coordinating movement, the cerebellum is gaining recognition for being an important mover and shaker in the brain.

The "cerebellum has more than half of the neurons in your entire brain," says neuroscientist Kamran Khodakhah of Albert Einstein College of Medicine in New York City. "It never made sense that the only thing it confines itself to do is motor coordination."

Khodakhah's results on social behavior, described in the Jan. 18 *Science*, expand that view. And by finding a connection between the cerebellum and a part of the brain involved in social behavior, he and his colleagues "solve an important gap in our understanding of the circuitry underlying disorders such as autism and schizophrenia," says pediatric neurologist Mustafa Sahin of Boston Children's Hospital. "We've known for a while that the cerebellum is involved in these disorders, but we really haven't been able to connect it to other regions directly."

Khodakhah's group went looking for connections to one such region — the ventral tegmental area, or VTA, which is heavily involved in feeling the thrill of reward. Using molecular tools that light up certain cells with fluorescent proteins, the team saw that some of the cerebellum's nerve cells, or neurons, connect directly to cells in the VTA in mice.

And those connections are important. The team used a method called optogenetics to control the cerebellar neurons that send messages to the VTA. The mice seemed to like when the neurons were activated, spending more time in a part of a square chamber where cells were turned on.

The cells, which were also active when mice were in contact with a companion, seem to send a feel-good signal that comes from social interactions. When the team turned the cells off with lasers, mice no longer preferred to hang out with a fellow mouse instead of an empty room. That social deficit suggests that this particular neural highway is involved in social behavior, Khodakhah says.

Tying the cerebellum to social behavior might explain connections to autism. Damage to the cerebellum ups the risk of autism, which comes with social deficits. Sahin has found some deficits in the cerebellar cells of people with a certain form of autism. The newfound neural highway "adds to our understanding of the circuitry of social behavior and reward behavior in a very important way," he says.

The cerebellum has other jobs, too, says neurologist Jeremy Schmahmann of Massachusetts General Hospital in Boston. People with damage to the cerebellum can have trouble with memory, planning, multitasking, creativity and language. That constellation of symptoms shows that the cerebellum has wide-ranging jobs, Schmahmann says.

An example comes from experiments with people reported in 2018 in *NeuroImage*. When scientists temporarily interfered with the cerebellum using strong magnets, people grew worse at seeing emotions on other people's faces. Those results add to the growing realization that the cerebellum might have its hands in many aspects of the brain. These expanded roles for the cerebellum are "not unexpected, but almost required," Schmahmann says. ■

VINCENT MUNIER

LIFE & EVOLUTION

Plucky young penguins navigate the high seas

Only months after their first ocean swim, young emperor penguins brave Antarctica's dangerous winter seas. GPS trackers attached to 15 young penguins revealed the birds go north to warmer waters beyond Antarctic pack ice in the Southern Hemisphere's summer, returning a few months later as the waters chill.

Some scientists had thought inexperienced juveniles (like those shown above) would stick to the sea ice's edge rather than risk freezing in the ice-strewn sea. But 5-month-old emperor penguins were already diving to depths of about 100 meters, as adults do, Sara Labrousse and colleagues report in the Jan. 17 *Marine Ecology Progress Series*. These birds also headed more than 1,000 kilometers north to open, ice-free waters. There, the youngsters made mostly shallow dives, probably hunting fish and krill that feast on floating algae, the authors say. After a few months, the fattened youngsters returned to the sea ice for winter.

Why the birds return to Antarctica in winter is unclear. Perhaps they go to feed on krill that eat the algae growing on the ice, says Labrousse, of Woods Hole Oceanographic Institution in Massachusetts. — *Jeremy Rehm*

LIFE & EVOLUTION

Animal remains found in Antarctic lake

Tiny carcasses raise questions about what lives beneath the ice

BY MARIA TEMMING

Much to their surprise, scientists in Antarctica have uncovered what appear to be remnants of tiny animals in mud dredged from a lake that has been covered by a thick mantle of ice for thousands of years.

The researchers on this expedition — known as the Subglacial Antarctic Lakes Scientific Access, or SALSA — are the first to sample Lake Mercer, about 600 kilometers from the South Pole. After drilling about a kilometer through the ice in late December, the researchers lowered instruments that brought water and sediment up to the surface.

Looking at these samples under a microscope, the team found creatures "that looked like squished spiders and crustacean-type things with legs [and] ... some other things that looked like they could be worms," says expedition member David Harwood, a micropaleontologist at the University of Nebraska–Lincoln. The researchers also spotted what appeared to be the vestige of a famously durable microscopic critter called a water bear, or tardigrade. Examining the DNA of these remnants will help researchers ID them more precisely.

The find, first reported January 18 by a reporter with *Nature*, "is really intriguing," says Slawek Tulaczyk, a glaciologist at the University of California, Santa Cruz who is not part of the SALSA team. Until now, scientists hadn't thought Antarctic lakes would be suitable environments for organisms larger than microbes.

When researchers in 2013 sampled another ice-lidded lake in Antarctica, Lake Whillans (*SN: 9/20/14, p. 10*), "we didn't uncover any evidence of anything more complex than a microbe," says SALSA team member Brent Christner, a microbiologist at the University of Florida in Gainesville. "We had a similar expectation here."

It's still unclear if the carcasses were left behind by creatures that actually lived in Lake Mercer, Tulaczyk says. Ice or water may have carried these fragments in from the ocean or lakes farther upstream in the Transantarctic Mountains. Carbon dating could help pinpoint the critters' age, which may provide a clue as to how and when these minuscule animal remains arrived in the lake, he says.

If any of the animals were Lake Mercer inhabitants, it's possible that some of them may still be kicking around down there, Harwood says. "It's interesting to think that life can exist in really extreme environments," such as an Antarctic lake that has been cut off from both the ocean and atmosphere for thousands of years, he says. "If life is still persisting there, that's important for our thoughts about what we might find out in space." ■

BODY & BRAIN

Benzodiazepines fuel overdose deaths

Prescriptions of these antianxiety drugs are also on the rise

BY AIMEE CUNNINGHAM

As public health officials tackle opioid addiction and overdoses, another class of prescription drugs has been contributing to a growing number of U.S. deaths.

Prescribed for anxiety and insomnia, benzodiazepines such as Valium and Xanax are highly addictive and can be fatal. In the latest sign of the drugs' impact, overdose deaths involving "benzos" rose from 0.54 per 100,000 in 1999 to 5.02 per 100,000 in 2017 among women ages 30 to 64, researchers report in the Jan. 11 *Morbidity and Mortality Weekly Report*. Among all overdose deaths, that 830 percent increase is surpassed only by rises in those involving synthetic opioids or heroin.

Overall, there were 10,684 U.S. overdose deaths involving benzos in 2016, according to the National Institute on Drug Abuse. In 1999, the total was 1,135.

Benzodiazepines are especially dangerous when used with other drugs that slow breathing, such as opioids. In combination, the substances can "cause people to fall asleep and essentially never wake up again," says addiction psychiatrist Anna Lembke of Stanford University School of Medicine. Benzos and opioids are often prescribed together.

830
percent
Rise in benzodiazepine-related overdose deaths from 1999 to 2017 in U.S. women ages 30 to 64

The rise in deaths hasn't stopped the flow of benzodiazepine prescriptions. The number of U.S. adults who filled such a prescription rose from 8.1 million in 1996 to 13.5 million in 2013, a 67 percent jump, a study in the *American Journal of Public Health* in 2016 found.

Benzos enhance the activity of gamma-aminobutyric acid, a chemical messenger in the brain that has a calming effect. With daily, long-term use the brain adapts, and the drugs become less effective. A person "needs more and more to get the same effect," Lembke says. Many people who take the drugs don't use them properly, according to a study reported last year in *Psychiatric Services*. Of 30.6 million adults who reported using benzos, 5.3 million acknowledged misuse, such as taking them without a prescription.

Safer anxiety and insomnia treatments are available, including antidepressants called selective serotonin reuptake inhibitors and therapies to learn coping strategies. Lembke says that benzos are more appropriate for short-duration, low-dose treatment in severe circumstances, such as for seizures. ■

HUMANS & SOCIETY

Easing test anxiety boosts bio grades

Psychological interventions helped low-income students

BY SUJATA GUPTA

At a large Midwestern high school, almost 40 percent of low-income students were poised to fail biology. Thanks to simple measures aimed at reducing test anxiety, that failure rate was halved.

Psychological interventions that improve grades could help keep more low-income students in the sciences, says Christopher Rozek, a Stanford University psychologist who led the study, reported online January 14 in the *Proceedings of the National Academy of Sciences*.

Low-income students are less likely than high-income students to take advanced science classes. In turn, those students are less likely, or unable, to major in science and math in college or to pursue related, often lucrative, careers. One factor underlying this achievement gap is low-income students' internalized feelings of inadequacy in such fields, Rozek says. Those feelings often translate to pretest anxiety and poor grades.

Previous small studies have shown that reducing performance anxiety improves test scores. To scale up that work, Rozek and colleagues recruited 1,175 freshman biology students at an Illinois public high school; 285 of the kids came from a low socioeconomic background. At the school, slightly over half of low-income students typically fail their final biology exams; 6 percent of high-income students do.

Rozek's group investigated whether reading and writing prompts before an exam could improve test performance. Students were placed in one of four groups. A control group was told to ignore anxiety. Another group of students wrote about their fears, a method intended to clear up the headspace needed to focus on a test. A third group read a statement explaining that the physiological responses to stress, such as a racing pulse, can actually be beneficial and help with attention. Students in a fourth group did both activities.

Of 205 low-income students in the three experimental groups, 168, or 82 percent, passed their exams, compared with 49 of 80 students, or 61 percent, in the control group. The three types of interventions worked equally well.

High-income students experienced no benefit from these activities. Rozek suspects that these students were already more adept at emotional regulation.

Robert Tai, a science education expert at the University of Virginia in Charlottesville, questions the study's emphasis on passing exams. "Improving a student's test scores will not improve the rate of them pursuing the sciences," says Tai, whose research has shown that interest in science matters more than grades when it comes to career trajectories.

But Rozek notes that tipping scores even slightly does have real-world implications. "You can imagine students who are failing science courses maybe can't even register for additional science courses," he says. ■

HUMANS & SOCIETY

Early dogs helped hunt small game

Bones found in Jordan offer new clues to domestication

BY BRUCE BOWER

Dogs that lived alongside Middle Eastern villagers roughly 11,500 years ago may have helped to transform how those humans hunted, researchers say.

Fragmentary canine bones unearthed at Shubayqa 6, an ancient site in northeastern Jordan, date to a time when remains of hares and other small prey at the outpost sharply increased, say zooarchaeologist Lisa Yeomans of the University of Copenhagen and colleagues. Many animal bones from Shubayqa 6 also display damage caused by having been swallowed by dogs and then passed through their digestive tracts, the scientists report in the March *Journal of Anthropological Archaeology*.

"The use of dogs for hunting small, fast prey such as hares and foxes, perhaps by driving them into enclosures, could explain the evidence at Shubayqa 6," Yeomans says.

The bone fragments challenge a longstanding idea that, in the early stages of domestication, dogs were first used to hunt large animals that yielded lots of meat per kill, she says. In that scenario, population growth and climate fluctuations later led to food shortages for foraging groups. People seeking a wider array of plants and animals in their diet then incorporated dogs into small-game hunts, too. That dietary shift heralded the rise of farming, researchers have suggested.

But no signs of food shortages have been found at Shubayqa 6. People who lived there starting about 11,500 years ago must have enjoyed a consistent supply of gazelles, hares, foxes and game birds, the researchers say. Dogs may have enabled humans at the site to devise new ways to hunt small game effectively enough to forgo large-animal hunts altogether, Yeomans' team argues.

Clues to that diet, and to the site's year-round occupation by those humans, include numerous structures built over roughly 1,000 years and located near garbage deposits containing a variety of animal bones. The researchers identified 55 dog bones among a total of more than 3,800 mammal bones excavated at Shubayqa 6. Recovered canine remains are too fragmentary to assign them to a species.

The investigators suspect that people allowed their four-legged hunting assistants to scarf bony scraps at butchery spots. Dogs would then have left behind digested bone chunks in their poop.

The findings offer new insight into dog domestication in the Middle East. Scientists commonly assume that dogs were domesticated in the region by Natufians, the first known society to inhabit settlements year-round, between about 15,000 and 11,500 years ago (*SN: 9/25/10, p. 14*). But archaeological support for Natufian dog taming is scant.

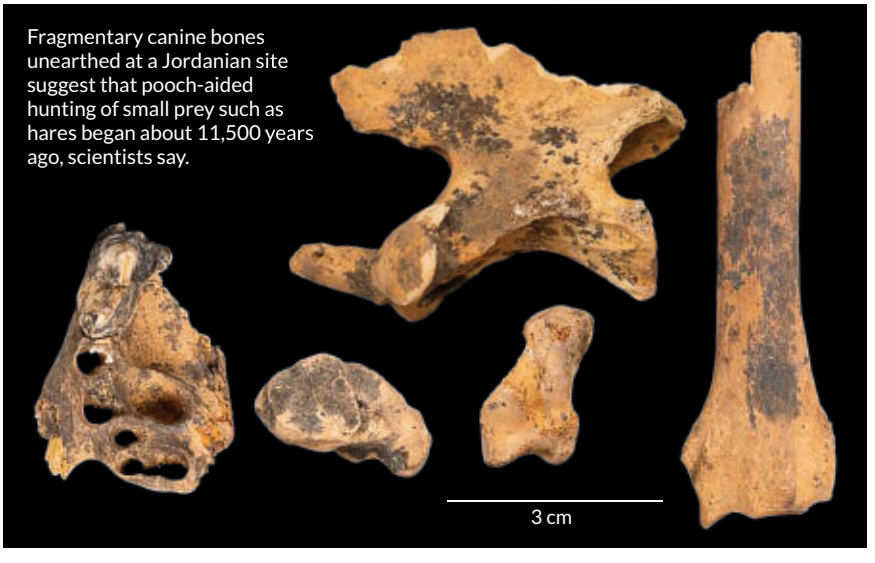
The new research "provides the best early evidence" of dog domestication in Mediterranean parts of the Middle East, shortly after Natufian society disappeared, says zooarchaeologist Natalie Munro of the University of Connecticut in Storrs.

Dogs and perhaps some other aids for catching small game, such as nets and snares, may have emerged after ancient Middle Easterners started hunting and eating those animals, rather than causing that shift in diet, Munro says. At Shubayqa 6, for instance, the new report indicates that Natufians hunted hares and foxes for perhaps 1,000 years before dogs appeared at the site.

Natufians probably used nets to trap hares, reflected in a high proportion of young, easier-to-catch animals found in Natufian-era sediment at Shubayqa 6, Yeomans says. But after 11,500 years ago, remains of harder-to-catch adult hares became common at the site, which by then was inhabited by the presumed descendants of the Natufians. Dogs probably aided in the capture of adult hares that had the meatiest payoffs for hunters, she contends.

Two present-day foraging groups in Nicaragua may offer insights into how ancient Middle Easterners used dogs to capture small prey. Mayangna and Miskito people, who now inhabit rainforest, hunt rodents called pacas that stay in underground burrows during the day. Dogs sniff out pacas' homes and alert hunters to the locations, says Jeremy Koster, an anthropologist at the University of Cincinnati who has studied these foragers.

Because hares live in aboveground nests, "there may have been a similar dynamic in ancient Jordan where dogs were valuable primarily for locating hares, not chasing them down," Koster says. ■



Fragmentary canine bones unearthed at a Jordanian site suggest that pooch-aided hunting of small prey such as hares began about 11,500 years ago, scientists say.

L. YEOMANS

ATOM & COSMOS

Future colliders will target the Higgs

Potential new accelerators plan to study the particle in detail

BY EMILY CONOVER

If particle physicists get their way, new accelerators could one day scrutinize the most tantalizing subatomic particle in physics — the Higgs boson. More than six years after discovering that particle at the Large Hadron Collider, scientists are planning enormous new machines that would stretch for tens of kilometers across Europe, Japan or China.

The 2012 discovery of the Higgs, which reveals the origins of mass, put the finishing touch on the standard model, the overarching theory of particle physics (*SN: 7/28/12, p. 5*). And it was a landmark achievement for the LHC, the world's biggest accelerator, located at the CERN laboratory near Geneva.

Physicists hope that delving further into the mysteries of the Higgs will be key to solving lingering puzzles of particle physics. "The Higgs is a very special particle," says physicist Yifang Wang, director of the Institute of High Energy Physics in Beijing. "We believe the Higgs is the window to the future."

The LHC — a ring 27 kilometers in circumference, where protons are accelerated to nearly the speed of light and smashed together a billion times a second — was great for discovering the Higgs. But the accelerator is not ideal for studying the particle in detail.

Physicists are clamoring for a collider that can crank out oodles of Higgs bosons. Blueprints for such machines have been put forth, and researchers hope these "Higgs factories" will reveal solutions to glaring weak spots in the standard model.

"The standard model is not a complete theory of the universe," says experimental particle physicist Halina Abramowicz of Tel Aviv University. For example, the theory can't explain dark matter, an unidentified substance whose mass is necessary to explain cosmic observations such as the motions of stars in galaxies. Nor can the theory explain why the universe is made up of matter, while antimatter is exceedingly rare.

Carefully scrutinizing the Higgs might point scientists toward the answers to those questions, proponents of the new colliders claim. But among scientists, the desire for new, costly accelerators is not universal, especially because it's unclear what exactly the machines will find.

Next in line

Closest to inception is the International Linear Collider in northern Japan. Unlike the LHC, in which particles zip around a ring, the ILC would accelerate two beams of particles along a straight line, directly at one another over the ILC's 20-kilometer length. And instead of crashing protons together, the accelerator would collide electrons and their antimatter partners, positrons.

But last December, a multidisciplinary committee of the Science Council of Japan came down against the project in a report, urging the government to be cautious with its support and questioning whether the expected scientific achievements justify the estimated cost of about $5 billion.

Supporters argue that the ILC's plan to smash together electrons and positrons, rather than protons, has some big advantages. Electrons and positrons are elementary particles — they have no smaller constituents — while protons are made up of smaller particles called quarks. So proton collisions have more useless particle debris to sift through.

Additionally, in proton smashups, only a fraction of each proton's energy goes into the collision. In electron-positron colliders, particles bring the full brunt of the accelerator's energy to bear, allowing scientists to tune the energy of collisions to maximize the number of Higgs bosons produced. Likewise, because of the electrons' and positrons' elementary nature, the ILC would require only 250 billion electron volts to produce Higgs bosons; the LHC needs 13 trillion electron volts.

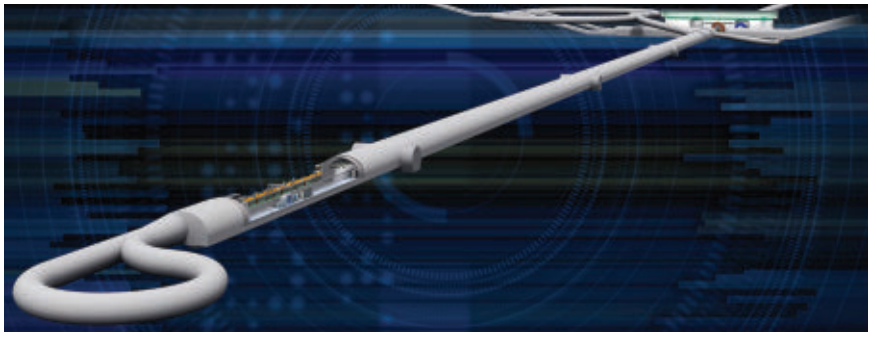
For the ILC, "the quality of the data coming out will be much higher, and there will be much more of it on the Higgs," says particle physicist Lyn Evans of CERN. One in every 100 ILC collisions would pump out a Higgs. That happens once in 10 billion collisions at the LHC.

The Japanese government is expected to decide about the collider in March. If approved, the ILC should take about 12 years to build, Evans says. It could also be upgraded later to increase its length and the energy it can reach.

CERN has plans for a similar machine, the Compact Linear Collider. It would also collide electrons and positrons but at higher energies than the ILC. The energy would start at 380 billion electron volts and increase to 3 trillion electron volts in a series of upgrades. To reach those higher energies, the Compact Linear Collider will rely on a new type of accelerator.

Running in circles

Two other planned colliders, in China and in Europe, would be circular like the LHC. But at 100 kilometers around, both



A 20-kilometer-long accelerator planned for Japan, the International Linear Collider (design illustrated), would slam together electrons and positrons to better understand the Higgs boson.

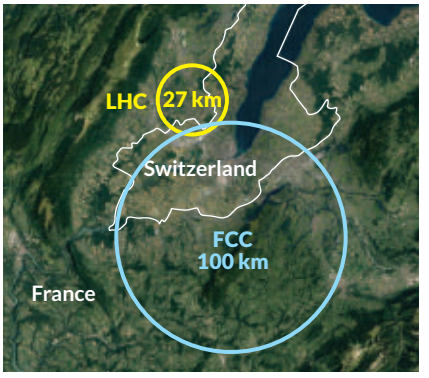
REY. HORI

would dwarf that already giant machine. Each collider would be so big that the country of Liechtenstein could easily fit inside — twice.

At a location yet to be determined in China, the Circular Electron Positron Collider would collide electrons and positrons at 240 billion electron volts, according to a plan released in November and championed by Wang and the Institute of High Energy Physics. The accelerator could later be upgraded to collide protons at higher energies. Scientists say they could begin building the $5 billion to $6 billion machine by 2022 and have it ready to go by 2030.

And at CERN, the proposed Future Circular Collider would likewise operate in stages, colliding electrons and positrons before moving on to protons. The ultimate goal would be to reach proton collisions with 100 trillion electron volts, more than seven times the LHC's energy, according to a January report from an international group of researchers.

Meanwhile, scientists have shut down the LHC for two years while they upgrade the machine to function at a slightly higher energy. Further down the line, a souped-up version known as the High-Luminosity LHC could come online in 2026 and would increase the proton collision rate by at least a factor of five while maintaining the same energy (*SN Online: 6/15/18*).



Scientists at CERN are planning a particle accelerator called the Future Circular Collider that would have a circumference nearly four times as large as the Large Hadron Collider's.
SOURCE: CERN

Portrait of the Higgs

When the LHC was built, scientists were fairly confident they'd find the Higgs boson. But with the new facilities, there's no promise of new particles. Instead, the machines will aim to catalog how strongly the Higgs interacts with other known particles; in physicist lingo, these are known as its "couplings."

Measurements of the Higgs' couplings may simply confirm expectations of the standard model. But if the observations differ from expectations, the discrepancy could indirectly hint at the presence of something new, such as the particles that make up dark matter.

Some scientists are hopeful that something unexpected might arise. That's because the Higgs is an enigma. The particles condense into a molasses-like fluid. As for why that happens, "we have no clue," says theoretical particle physicist Michael Peskin of Stanford University. But that fluid pervades the universe, slowing particles down and giving them heft.

Another puzzle is that the Higgs' mass is a million billion times smaller than expected (*SN Online: 10/22/13*). Certain numbers in the standard model must be fine-tuned to extreme precision to make the Higgs this small, a situation physicists find unnatural.

The weirdness of the Higgs suggests that other particles might be out there. Scientists previously thought they had an answer to the Higgs quandaries, via a theory called supersymmetry, which posits that each known particle has a heavier partner (*SN: 10/1/16, p. 12*). "Before the LHC started, there were huge expectations," Abramowicz says. Some scientists claimed the LHC would quickly find supersymmetric particles. "Well, it didn't happen," she says.

The upcoming colliders may yet find evidence of supersymmetry or otherwise hint at new particles, but this time around, scientists aren't making promises. "In the past, some people have clearly oversold what the LHC was expected to deliver," says theoretical particle physicist Juan Rojo of Vrije University Amsterdam. When it comes to any new colliders, "we should avoid making the same mistake if we want to keep our field alive for decades to come."

Researchers around the world are now hashing out priorities, making a case for new colliders and other particle physics experiments. European physicists, for example, will meet in May to work on a document, the European Particle Physics Strategy Update, to guide research there in 2020 and beyond.

One thing is certain: The proposed accelerators would explore unknown territory, with unpredictable results. The unanswered questions surrounding the Higgs boson make it the most obvious place to look for hints of new physics, Peskin says. "It's the place that we haven't looked yet, so it's really compelling." ■

Leveling up Potential new accelerators that would study the Higgs boson are compared with the Large Hadron Collider, which discovered the particle. SOURCES: CERN, L. EVANS, IHEP, Y. WANG

Accelerator	Style	Location	Particles collided	Energy (electron volts)
Large Hadron Collider	27 km circular	Europe	Protons	13 trillion
International Linear Collider	20 km linear	Japan	Electrons and positrons	250 billion
Compact Linear Collider	11 to 50 km linear	Europe	Electrons and positrons	380 billion to 3 trillion
Circular Electron Positron Collider	100 km circular	China	Electrons and positrons	240 billion
			Protons	TBD
Future Circular Collider	100 km circular	Europe	Electrons and positrons	90 billion to 365 billion
			Protons	100 trillion

GOOGLE EARTH

Study Buddies

They're cute, but will robots actually help kids?

By Maria Temming

Pondering a tablet screen displaying a town scene, a pre-K student tilts her head to the side and taps her lip thoughtfully.

"What are we trying to find?" asks the plush, red and blue robot called Tega that's perched on the desk beside the girl. The bot resembles a teddy bear–sized Furby.

"We are trying to find lavender-colored stuff," the girl explains. Lavender is a new vocabulary word. "OK!" Tega chirps.

The girl uses her forefinger to pan around the scene. She eventually selects an image of a girl — not wearing purple. The game puts a red mark through her choice: wrong.

The girl slumps down in her chair, head dropped to her chest as Tega says, "I'm sure you will do better next time. I believe in you."

The robot, which MIT researchers are testing with students in a Boston-area public school, tilts toward the girl, who leans in close so that her cheek is right next to Tega's.

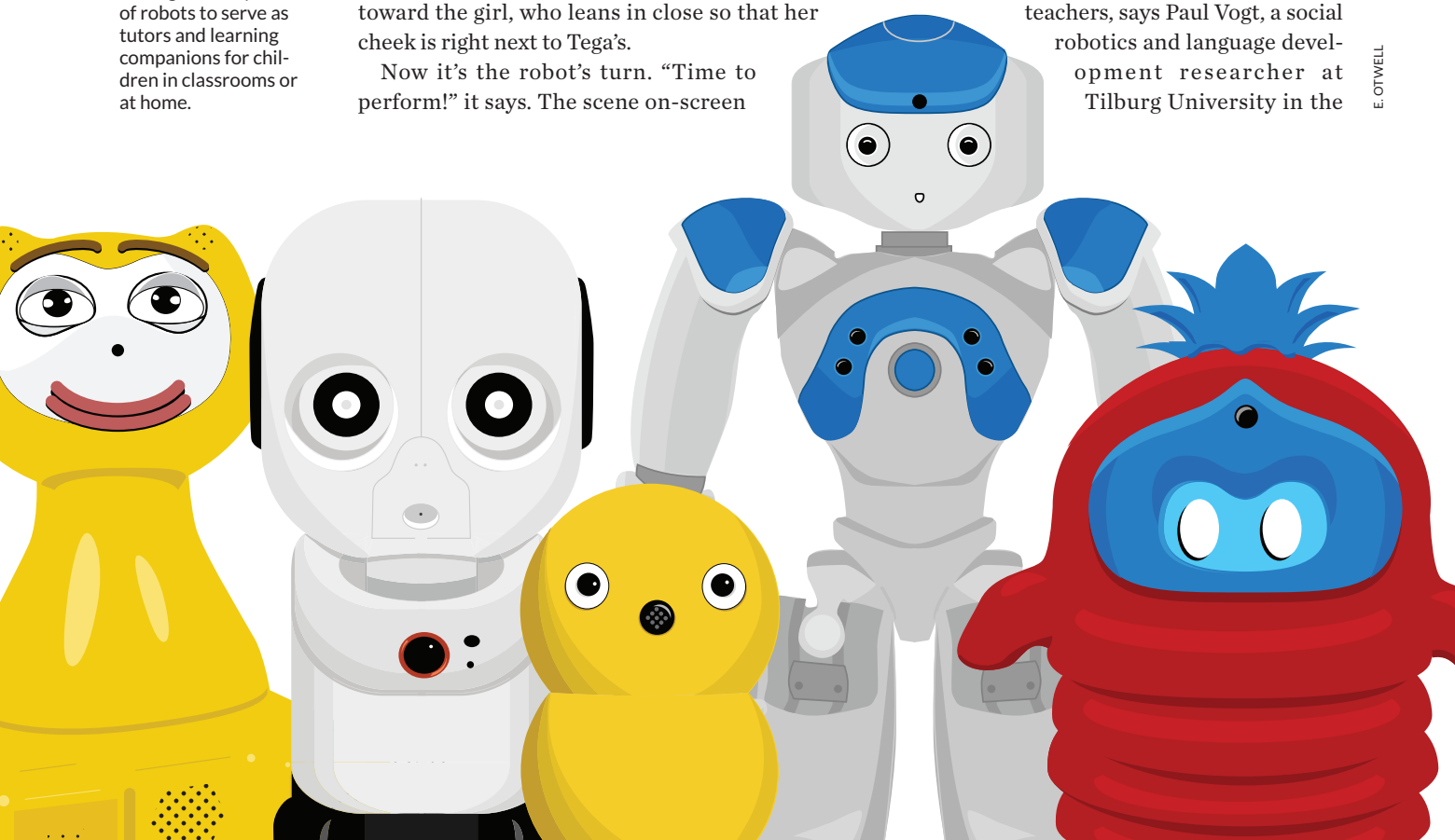
Now it's the robot's turn. "Time to perform!" it says. The scene on-screen shifts, as though the bot is telepathically controlling the tablet. "Hmm ..."

Tega looks up at its partner, as though seeking confirmation that it's doing this right, and the girl cups the bot's cheeks encouragingly. The robot looks back at the screen. The girl rests her hand in the robot's soft fur and murmurs, "I believe in you."

This kind of tight connection is typical of child-robot interactions, says MIT social robotics and human-robot interaction researcher Cynthia Breazeal. Her team is investigating how this turn-taking robot can help students learn. Kids have a "special kind of affinity" with robots, she says.

Although adults might quickly become disenchanted with machines that aren't very perceptive or don't speak more than scripted sentences, children are liable to chat with, listen to and otherwise treat even basic robots as sentient, social beings, says Tony Belpaeme, a social roboticist at Ghent University in Belgium. Researchers like Breazeal and Belpaeme are trying to leverage that connection to create robots that engage with kids as tutors and peer learners.

These robots aren't meant to replace human teachers, says Paul Vogt, a social robotics and language development researcher at Tilburg University in the



E. OTWELL

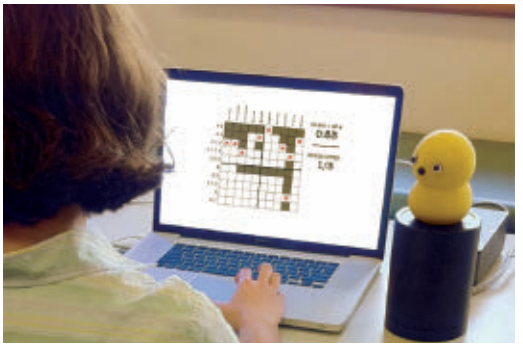
Cast of characters
Researchers are testing a motley crew of robots to serve as tutors and learning companions for children in classrooms or at home.

Netherlands. But customizable, endlessly patient automatons could provide students with one-on-one attention in crowded classrooms. That extra support may be especially helpful for children with special needs or for students who are learning in a different language than they're used to, says Belpaeme, who is studying how robots can help immigrant children in Europe pick up a second language.

Robots might also help homeschooled students, proponents say, or teach in areas where human experts are in short supply. English-speaking robots are slated to enter some 500 Japanese classrooms this year for exactly that purpose. Hundreds of Chinese kindergarten classes also have adopted educational robots. But in Western countries, these devices have yet to invade classrooms.

Just like any expensive educational technology, however, classroom robots may never make it to every classroom. Computer and cognitive scientist Brian Scassellati of Yale University and colleagues have had success with a device named Keepon that looks like two stacked yellow tennis balls with eyes and a nose. "When we produce them in the lab, they're probably costing us about $200 total," he says. But many researchers use the humanoid Nao robot, which costs several thousand dollars a pop, raising the question of how many schools will be able to afford the classroom helpers.

"There's a lot of hype about robots," says Goren Gordon, a natural and artificial curiosity researcher at Tel Aviv University. At this point, most testing has been short-term in small groups of children. So little is known about the potential risks involved when young kids keep close company with automatons. Yet early testing suggests that robots could help students learn new skills and promote good study habits and positive attitudes toward learning. Researchers still have a lot to figure out about best practices and potential impacts if educational robots are going to achieve tenure.



Relatively inexpensive robots such as Keepon, which costs researchers about $200 to produce, may be an affordable option for schools on tight budgets.

When working with social robots, like this furry Tega, kids will chat with, hug, pet and otherwise treat the machines like living beings.

FROM TOP: H.W. PARK *ET AL/PROCEEDINGS OF THE 2017 ACM/IEEE INTERNATIONAL CONFERENCE ON HUMAN-ROBOT INTERACTION*; D. LEYZBERG *ET AL/PROCEEDINGS OF THE ANNUAL MEETING OF THE COGNITIVE SCIENCE SOCIETY 2012*

Here to help

Before grading robots on their teaching abilities, consider why automated educators might work better as physical rather than virtual entities. It turns out that a robot's body may be just as important as its brain. A review of 33 studies that examined how adults and children respond to physically present robots, videos of the robots and animated versions of those same robots revealed that people generally view physical robots more positively and find them more persuasive than videotaped and animated robots. Jamy Li of the University of Twente in the Netherlands reported these results in 2015 in the *International Journal of Human-Computer Studies*.

"There's something about robots that sets them apart from a computer," Belpaeme says. "The exact same content delivered by a robot somehow makes our brains sit up and pay attention.... We don't yet know why that is." Still, roboticists have exploited that attention-grabbing edge to build machines that relay information on everything from math to nutrition and sign language.

Of course, a well-rounded education is about far more than learning facts. It's also about developing good study habits and attitudes toward education that will make students lifelong learners. In this area, robots have proved useful.

On a very basic level, robots can make schoolwork more fun, proponents assert. "If kids enjoy learning, they're going to learn more," Belpaeme says. "It's really as simple as that." Researchers at the University of Wisconsin–Madison witnessed robots' power to make schoolwork fun when they designed a bot named Minnie to support children's reading at home. Minnie, described last August in *Science Robotics*, comments on a book as the child reads aloud, shows emotional responses

to stories and summarizes plot points to support reading comprehension.

Roboticist Bilge Mutlu and learning researcher Joseph Michaelis randomly assigned 24 students ages 10 to 12 to either two weeks of reading aloud alone or with Minnie. Afterward, the solo readers gave the activity more mixed reviews, reporting, for example, "I didn't not like it, but I didn't, like, really enjoy it." Only four said the activity motivated them to read more. Kids in the robot group said reading to Minnie was "fun" and "a cool experience." Seven students said they felt more motivated to read.

Robots can also encourage specific reasoning strategies, such as thinking aloud, which is supposed to help students craft more deliberate, organized plans for multistep problem-solving. Computer scientist Chien-Ming Huang of Johns Hopkins University and colleagues programmed a Nao robot to nod along with a child's speech and remind students who lapse into silence to keep going.

To test whether this supportive robot helped students learn, researchers randomly assigned 26 kids who were about 11 years old to solve math word problems while thinking aloud with or without the robot's encouragement. From a pretest to a posttest taken about one week later, the robot-trained children increased their own scores an average of 52 percent; solo students self-improved by an average of 39 percent, the researchers reported last March in Chicago at the International Conference on Human-Robot Interaction, or HRI 2018.

For a more deep-rooted effect on students' educational experiences, robots can model certain beliefs about learning, like a growth mind-set: the idea that success comes from effort and perseverance, rather than inherent ability.

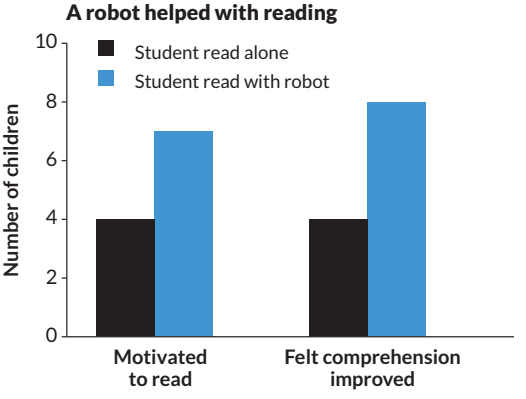
In one experiment, 33 children ages 5 to 9 solved geometric puzzles called tangrams with a Tega. Half the kids partnered with a robot that made growth mind-set comments, such as, "You are not afraid of a challenge. I like that!" Other students worked with a bot that stated facts only: "You solved the puzzle." Before and after working with the robot, each child completed an assessment that rated growth mind-set from 0 to 10. The growth mind-set cohort's scores, on average, increased a small amount, 7.63 to 8.06, but the neutral bot group's scores dropped from 6.94 to 6.59, Breazeal and colleagues reported in Vienna at HRI 2017.

Personalization problems

Although robots show the potential to positively influence students, tailoring a bot's behavior to an individual is still a major challenge. Roboticists have created machines that can make some simple decisions, like choosing when to encourage a student to take a break. In a study presented at HRI 2017, Scassellati's team found that when robots offered breaks as a reward for good work, or an opportunity to refocus if a student was struggling, children learned more than if the robot called time-outs at regular intervals.

Designing robots that track student performance to adjust pacing and choose what to teach next is trickier. Some robots have been programmed to adjust activity difficulty based on student proficiency, but researchers have had trouble showing that these bots help students learn more than generic robots do.

Educational robots have been designed to help students learn a wide range of topics, from handwriting to mathematics. This robot, named Minnie, supports children on reading assignments.



Going solo More students who read aloud with a robot companion said that the activity motivated them to read and increased their reading comprehension than students who read aloud alone. SOURCE: J. MICHAELIS AND B. MUTLU/*SCIENCE ROBOTICS* 2018

SARAH MAUGHAN (2018)

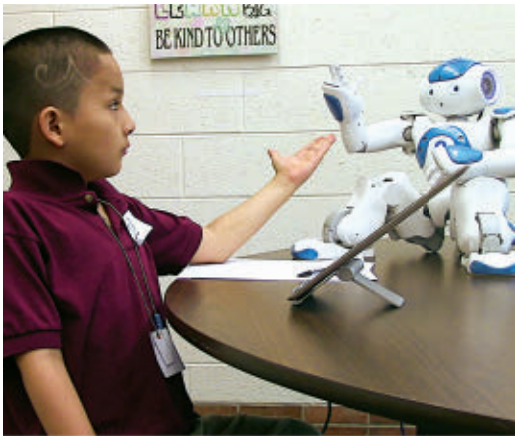
What if robots could go beyond responding to performance by keeping tabs on how a student is feeling? Gordon and colleagues at MIT explored this idea by creating a Tega robot that analyzed facial expressions for levels of engagement and valence, which is basically "the goodness of the emotion," Gordon says. For instance, happiness has positive valence and anger has negative. While working with students on a Spanish-language learning game that involved packing for a trip to Spain, the robot offered various types of feedback, from an excited "Woo-hoo, you're trying so hard!" to game-related comments like, "The suitcase looks heavy."

"The robot slowly learns which ... behaviors result in high valence and high engagement," and becomes more likely to use those behaviors at the right time, Gordon says. In three to seven sessions over two months, two groups of nine preschoolers worked with either this adaptable Tega or a nonadaptive Tega. From the first to final session, kids in the personalized group generally became more positive about the interaction, with their valence increasing an average of seven points on a scale of −100 to 100. In the impersonal group, valence dropped an average of 18 points, researchers reported in Phoenix in 2016 at an Association for the Advancement of Artificial Intelligence conference.

Robots attuned to students' thoughts and feelings may make better tutors and learning companions if they can offer the right level of personalization without becoming predictable. But some educators are concerned about the amount of data machines would have to collect and store to do that job right. Human teachers may be able to get a general read on a student's state of mind. But a robot designed to exhaustively analyze every facial expression or game move a child makes may be able to gather such detailed information on kids that it would constitute an invasion of privacy.

This concern was raised in a series of focus groups with certified and student teachers discussing educational robots. Some participants worried that companies might try to buy that student data from schools, Sofia Serholt, a child-robot interaction researcher at Chalmers University of Technology in Sweden, and colleagues reported in November 2017 in *AI & Society*.

Robotics ethicist Amanda Sharkey also notes that kids might feel compelled to share private information with a robot peer that acts like a friend. One remedy might include requiring robots to continually divulge what information is being collected and who the robots share it with, says Sharkey, of the University of Sheffield in England.



"As soon as you put a robot in the classroom, everything changes," says Brian Scassellati of Yale University. "The kids are excited, they're engaged." The trick is getting devices like this Nao robot to hold students' attention after the novelty is gone.

COURTESY OF B. SCASSELLATI/YALE UNIV.

Social savvy

If privacy concerns about oversharing with robots could be addressed, kids' comfort with robotic companions could be a strong force for good in the classroom. Scassellati recalls one first-grade boy who worked on English language skills with a robot. "He was so afraid to talk in class, he was so worried about making mistakes," Scassellati says. But when the student worked one-on-one with a nonjudgmental, patient robot peer, "the first time he made a mistake ... and the robot corrected him, he paused for a second, and then he went on, and it was OK."

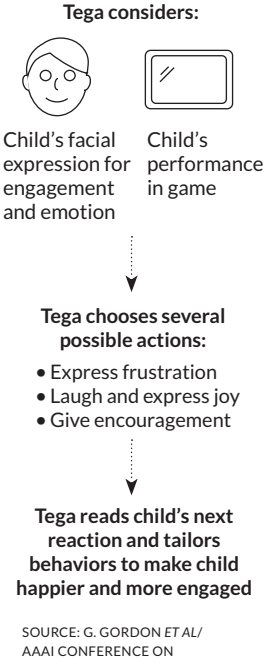
Gordon similarly recalls an especially shy student, who "only whispered in your ear; he didn't talk at all," he says. But "after the fourth or fifth interaction [with a robot], he started hugging the robot. Every three or four minutes, just stopped and started hugging the robot."

Capitalizing on this potential for child-robot kinship could help keep students invested even after the novelty effect wears off, so that educational robots don't end up collecting dust in a corner, Michaelis says. To that end, researchers have begun investigating how robots programmed to be more convivial can better hold students' attention and improve learning.

Social robotics researcher Ginevra Castellano of Uppsala University in Sweden and colleagues programmed iCat, a yellow robot with a feline face, to express empathy to test if that would

Read the room

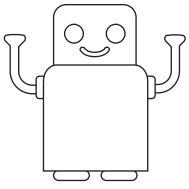
One Tega robot watched students' facial expressions after giving feedback on an educational activity and learned to offer comments that made kids happier.



SOURCE: G. GORDON *ET AL*/ AAAI CONFERENCE ON ARTIFICIAL INTELLIGENCE 2016

Machine learning

People tend to think that educational robots are ready to replace teachers, says learning researcher Joseph Michaelis. Not close. Even if robots are good at helping kids learn specific skills through highly structured exercises, the machines still need more work to handle many activities.



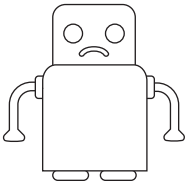
Robots are good at:

Playing structured games like chess or Snakes and Ladders

Teaching basic math skills or foreign language vocabulary

Offering scripted responses to books read aloud

Telling prerecorded stories



Robots struggle with:

Open-ended conversations

Adapting their behavior and lesson plans to individual students

Dexterity for physical activities, such as science lab experiments

Being engaging without distracting from the lesson

Keeping students' attention over the long term

help keep kids engaged with the robot for the long term. Over five weeks, iCat played weekly chess exercises with 16 children in Portugal, ages 8 and 9. The robot, described in 2014 in the *International Journal of Social Robotics*, monitored the game status and students' facial expressions and offered advice or emotional support when students looked unhappy. After the first and final interactions, kids filled out questionnaires that rated their feelings of social presence with the robot — that is, how much working with iCat felt like interacting with an intelligent, emotional being — from 1 to 5.

In an earlier study with a similar setup but a nonempathetic iCat robot, kids generally rated their sense of social presence between 2 and 4, and these scores declined between the first and fifth interactions. The empathetic iCat kept the kids at a high level of social presence — between 4 and 5 — from the first through the final session.

But robots' sociability can be a double-edged, distracting sword, as Belpaeme's team discovered when using a sociable Nao robot to teach 7- and 8-year-olds in the United Kingdom a strategy for identifying prime numbers. Twelve kids worked with this robot, which used social behaviors, calling the child by name and making eye contact. Another 11 students worked with an asocial bot. From a pretest to a posttest, kids who worked with the asocial bot improved their scores on a 12-point test an average of 2.18 points; the social robot group improved an average of 1.34 points, researchers reported in Portland, Ore., at HRI 2015.

The socially adept bot may have diverted attention away from the lesson; children spent about 45 percent more time looking at the social robot than the asocial one.

There are other reasons not to make the robots too engaging. Huang likens the dilemma to concerns about excessive screen time, which may put young children at risk for speech delay (*SN Online: 5/12/17*). "Obviously we have good intentions for these educational robots," he says, "but the long-term side effects ... are unclear." Some teachers in Serholt's focus groups expressed similar concerns that kids who spend too much time chatting with robots may lose some ability to decode human facial expressions or the youngsters may adopt more robotic mannerisms.

For Sharkey, "the main concern would be that [kids] come to prefer interacting with the robot." A robot that's always encouraging and never disagrees would probably be easier company than other kids. A child who spends more time hanging around agreeable machines than with peers may not develop the social skills necessary to navigate interpersonal conflict, Sharkey says.

Students who played chess with an iCat robot designed to express empathy reported feeling as if they were having a real social interaction.

PHOTO: I. LEITE/*INT. J. OF SOC. ROBOTICS* 2014; ROBOTS: E. OTWELL

Bridges left to cross

So far, investigations of student-robot interactions have typically lasted a couple of weeks or months at most. "What we would want to get up to is a full academic year," Breazeal says. Roboticists also need to test their technology with children from more diverse backgrounds. Belpaeme and colleagues recently ran an experiment with tutoring robots that helped about 200 children learn a second language. Compared with most educational robot studies, 200 students is a staggering number, says Huang, but "in the real world, this is like nothing."

Amid questions about how they should or shouldn't behave, today's robots are still pretty limited in what they can do. Educational robots are typically designed to work on very specific tasks. The robots still have trouble understanding the high-pitched and grammatically spotty speech of little kids and don't have the dexterity to participate in many physical learning activities such as science lab experiments.

"We are still a long way" from educational robots that can interact with students like real people, says Ana Paiva, an artificial intelligence researcher at the University of Lisbon in Portugal. Still, it's difficult to watch a kid doting on a fluffy Tega or making small talk with a seemingly interested Nao and not imagine a future where robots might join teachers and students in class photos. ■

Explore more

- T. Belpaeme *et al*. "Social robots for education: A review." *Science Robotics*. August 15, 2018.
- A. Sharkey. "Should we welcome robot teachers?" *Ethics and Information Technology*. December 2016.

DISCOVER THE ROBOT REVOLUTION

SPACE ROBOT

R5 VALKYRIE

The closest robotics has come to a modern-day superhero is NASA's hotshot humanoid robot R5 Valkyrie. This battery-powered bipedal bot can work alone in extreme environments without human assistance. Valkyrie is named after supernatural characters from Norse mythology who decided which warriors were rewarded in the afterlife. The robot builds on many years of NASA tests and feedback of previous robotic humanoids and features numerous sensors and actuators (moving parts) designed to help it carry out complex tasks. Its next mission is to Mars, with Valkyrie expected to take its first steps on the Red Planet before human visitors.

The dark visor covers a 3-D vision system and camera.

The bot's head can tilt and swivel around like a human head.

Each arm has seven joints and a group of actuators for motion.

The padded chest provides protection should the humanoid fall on its front.

The limbs are removable and can be replaced quickly.

The actuators in the bot's legs ensure easy movement.

The plastic shell covering on the leg includes fans to keep the robot cool.

The fabric-wrapped foam armor encases the robot's body for added protection.

The bot's heavyset legs and wide feet ensure balance when the robot is walking.

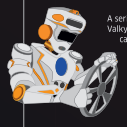
MOON MACHINE

One of the robot world's latest lunar exploration rovers is *ATHLETE* (All-Terrain Hex-Legged Extra-Terrestrial Explorer). Like a futuristic, super-sized, six-limbed insect, this rover can walk or roll over bumpy moonlike surfaces. Complete with a releasable grappling hook and a range of excavation instruments, *ATHLETE* is designed to move 100 times faster than existing exploration rovers.

"A **robust**, **rugged**, entirely electric humanoid robot capable of **operating in degraded... environments.**"
NASA

PREPPING FOR FUTURE

The Valkyrie team is constantly working to improve the bot's dexterity to enable it to work alongside astronauts in preparation for future exploration.



A series of tests have pushed Valkyrie to its limits. The robot can drive, climb a ladder, use power tools, and walk through unstable terrain without stumbling. This intensive preparation will prove beneficial when Valkyrie makes it to Mars.

Valkyrie's upgraded version includes modified humanoid hands to improve performance on the job. Each hand has three fingers and a thumb to grasp, manipulate, and work a variety of objects and instruments with precision and care. The actuators allow the wrists to roll easily, bringing further freedom of movement.

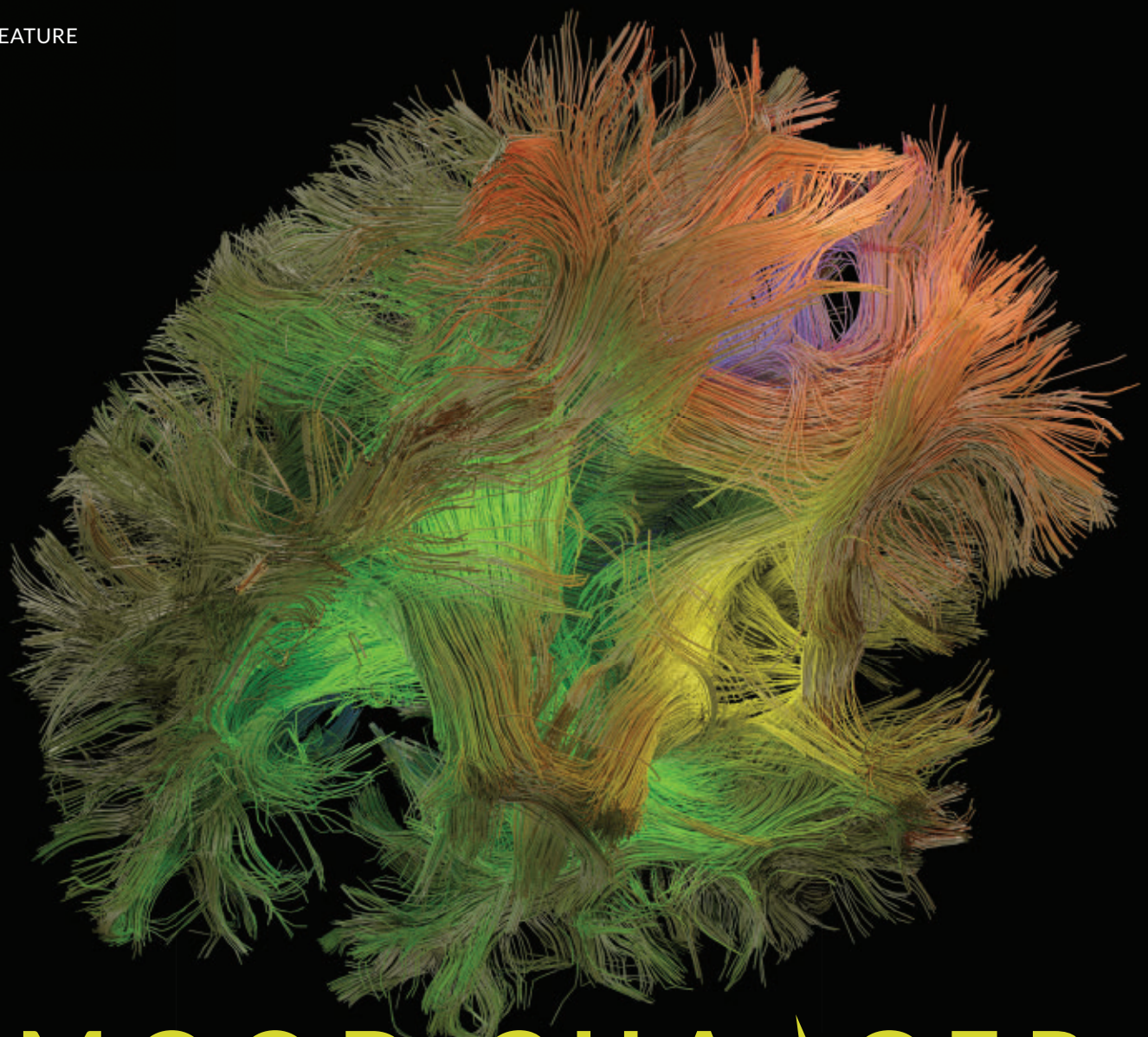
150 SPECIFICATIONS

MANUFACTURER NASA
ORIGIN US
DEVELOPED 2013
HEIGHT 6.2 ft (1.8 m)
WEIGHT 300 lb (136 kg)
POWER Battery

151

ALSO AVAILABLE

AVAILABLE WHEREVER BOOKS ARE SOLD



MOOD CHANGER

Is electrical stimulation a way out of depression?

By Laura Sanders

Neural activity in certain areas of the brain (brightly colored strands show connections emanating from those regions) can be measured to decode mood.

O.G. SANI AND M.M. SHANECHI/SHANECHI LAB

Like seismic sensors planted in quiet ground, hundreds of tiny electrodes rested in the outer layer of the 44-year-old woman's brain. These sensors, each slightly larger than a sesame seed, had been implanted under her skull to listen for the first rumblings of epileptic seizures.

The electrodes gave researchers unprecedented access to the patient's brain. With the woman's permission, scientists at the University of California, San Francisco began using those electrodes to do more than listen; they kicked off tiny electrical earthquakes at different spots in her brain.

Most of the electrical pulses went completely unnoticed by the patient. But researchers finally got the effect they were hunting for by targeting the brain area just behind her eyes. Asked how she felt, the woman answered: "Calmer in my nerves."

Zapping the same spot in other participants' brains evoked similar responses: "I feel positive, relaxed," said a 53-year-old woman. A 60-year-old man described "starting to feel a little more alive,

a little more energy." With stimulation to that one part of the brain, "participants would sit up a little straighter and seem a little bit more alert," says UCSF neuroscientist Kristin Sellers.

Such positive mood changes in response to light neural jolts, described in the Dec. 17 *Current Biology*, bring researchers closer to an audacious goal: a device implanted into the brains of severely depressed people to detect a looming crisis coming on and zap the brain out of it.

It sounds farfetched, and it is. The project is "fundamental, pioneering, discovery neuroscience," says Mark George, a psychiatrist and neurologist at the Medical University of South Carolina in Charleston. George has been studying depression for 30 years. "It's like sending a spacecraft to the moon."

Still, in the last several years, teams of scientists have made startling amounts of progress, both in their ability to spot the neural signatures that come with a low mood and to change a person's feelings.

With powerful computational methods, scientists have recently zeroed in on some key features of depressed brains. Those hallmarks include certain types of brain waves in specific locations, like the one just behind and slightly above the eyes. Other researchers are focused on how to correct the faulty brain activity that underlies depression.

A small, implantable device capable of both learning the brain's language and then tweaking the script when the story gets dark would be an immensely important clinical tool. Of the 16.2 million U.S. adults with severe depression, about a third don't respond to conventional treatments. "That's a huge number of people with a very disabling and probably underdiagnosed and underappreciated illness," says neurologist Vikram Rao, who is working on the UCSF project with Sellers.

A disease of circuits

When George began studying depression decades ago, the field was still haunted by the echoes of Sigmund Freud, who blamed the disorder on bad parenting and repressed anger. Soon after came the chemical imbalance concept, which held that the brain just needs a dash of the right chemical signal to fix itself. "It was the 'brain is soup' model," George says. Toss in more of the crucial ingredient — serotonin, for instance — and the recipe would sing.

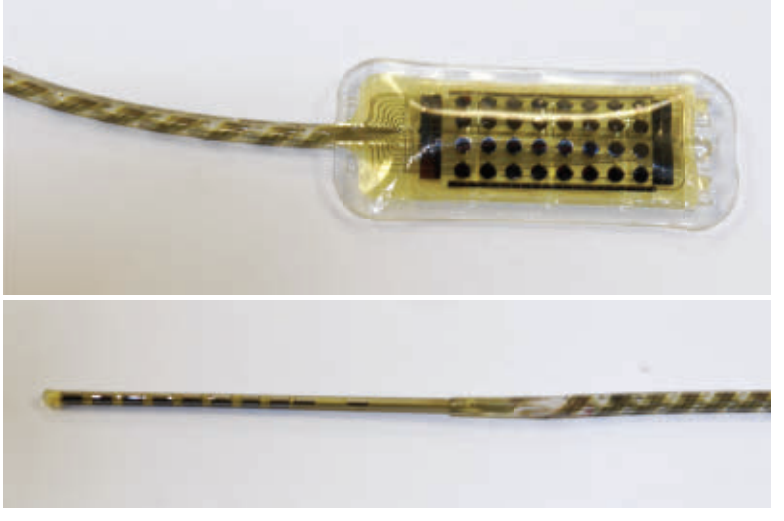
"We have a very different view now," George says. Thanks to advances in brain imaging, scientists see depression as a disorder of neural circuits — altered connections between important brain regions can tip a person into a depressed state. "We've started to define the road map of depression," George says.

Depression is a disorder, but one that's tightly linked to emotion. It turns out that emotions span much of the brain. "Emotions are more widespread than we thought," says cognitive neuroscientist Kevin LaBar. With his colleagues at Duke University, LaBar has used functional MRI scans to find signatures of certain emotions throughout the brain as people are feeling those emotions. He found the wide neural reach of sorrow, for instance, by prompting the emotion with gloomy songs and films.

Functional MRI allows scientists to see the entire scope of a working brain, but that wide view comes with the trade-off of lower resolution. And resolution is what's needed to precisely and quickly sense — and change — brain activity. Implanting electrodes, like those used in the UCSF project, gives a more nuanced look into select brain areas. Those detailed recordings, taken from people undergoing epilepsy treatment, are what allowed neural engineer Maryam Shanechi to decode the brain's emotions with precision.

As seven patients spent time in the hospital with electrodes monitoring brain activity, their emotions naturally changed. Every so often, the participants would answer mood-related questions on a tablet computer so that researchers could measure when the patients shifted between emotions. Then Shanechi, of the University of Southern California in Los Angeles, and her colleagues matched the brain activity data to the moods.

The task wasn't simple. The implanted electrodes



Some electrical arrays that researchers at the University of California, San Francisco are testing sit on the surface of the brain (top); others penetrate deep into brain tissue (bottom).

BOTH: K. SELLERS/UCSF

In one small study, electrodes in key brain areas measured activity related to a person's mood. These regions differed slightly for each person, but the orbitofrontal cortex (red, just behind the eyes) and a few other areas (green, yellow and blue) seemed to be important to mood.

recorded an enormous pile of data, much of it irrelevant to mood. Shanechi and her team developed an algorithm to distill all that data into a few key predictive brain regions for each person. The resulting decoder could tell what mood a person was in based on brain activity alone, the team reported in the October *Nature Biotechnology*. "In every single individual, we can show how their mood changes in real time," Shanechi says.

It's possible that the brains of people with epilepsy might handle emotions differently, but researchers still think that the results will hold more generally. In the seven people tested, each brain had its own hot spots that predicted mood. But there were commonalities, too. In four patients, one of the most predictive spots was the orbitofrontal cortex — that spot just behind the eyes that the UCSF scientists stimulated to boost mood. "We were excited because we had arrived at those results independently," Shanechi says. "They seem to all point to the important role of the orbitofrontal cortex."

Among brain regions, the orbitofrontal cortex may be one of the top networkers. It has links to diverse brain systems, many of which may be important for mood. "We're not saying that this is necessarily the best location to stimulate, but it's definitely a way to tap into that network," Sellers says. "There may be multiple different on-ramps to get on to this interstate."

Other work at UCSF, led by neurosurgeon Edward Chang and psychiatrist Vikaas Sohal, turned up different changes thought to be involved in depression: brain waves that carry messages between the hippocampus and the amygdala. Those two brain structures "tend to be quiet, then have a whole bunch of brief bursts of activity," Sohal says. For 13 of 21 patients with epilepsy, those bursts signaled lower moods, the researchers reported in the Nov. 29 *Cell*.

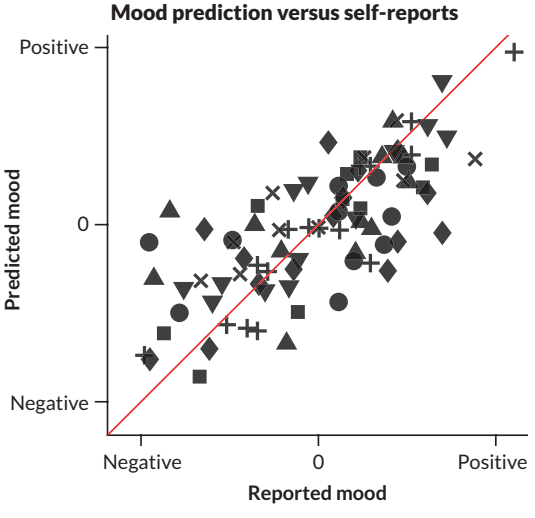
These studies add exquisite details to the brain map of depression, but on their own, these depression signatures are not enough, Shanechi says. "Let's say I know somebody's mood perfectly," she says. "I still don't know how to stimulate their brain to change their mood."

Electrical nudges

Doctors and scientists have been using electricity to jolt brains out of depression for decades. Electroconvulsive therapy, first used in the 1930s, had become a common depression treatment by the 1950s. The modern form of the therapy, which somehow resets the brain by sparking seizures, is still one of the more effective treatments for people whose severe depression hasn't responded to other interventions.

Other brain stimulation methods used for depression include transcranial direct current stimulation (tDCS), which relies on electrodes that rest on the surface of the scalp. Although still under study, tDCS is a favorite among home brain hackers eager to lift their moods or improve their minds (*SN: 11/15/14, p. 22*). Even deep-brain stimulation, which curbs some symptoms of Parkinson's disease, has been tried. But the technique requires surgery, and the implanted stimulators have to be adjusted manually.

Initial clinical attempts to treat depression with deep-brain stimulation were almost brute force sorts of stimulation. "We stuck the wire in and we turned it on all the time at high frequency," George says. That constant, full-blast stimulation created



Reading moods
Data from electrodes monitoring brain activity helped researchers predict the moods of seven people over time (each icon shape represents one person). The closer an icon is to the diagonal line, the better the prediction matched self-reported mood.
SOURCE: O.G. SANI *ET AL/NATURE BIOTECHNOLOGY* 2018

FROM TOP: O.G. SANI *ET AL/NATURE BIOTECHNOLOGY* 2018; C. CHANG

a sort of jamming signal — with mixed results. It helped some people tremendously but not others. After some success in lifting depression in a handful of people, a larger clinical trial, reported in 2017 in the *Lancet Psychiatry*, showed no positive effect. (Some researchers who study deep-brain stimulation have argued the trial was flawed.)

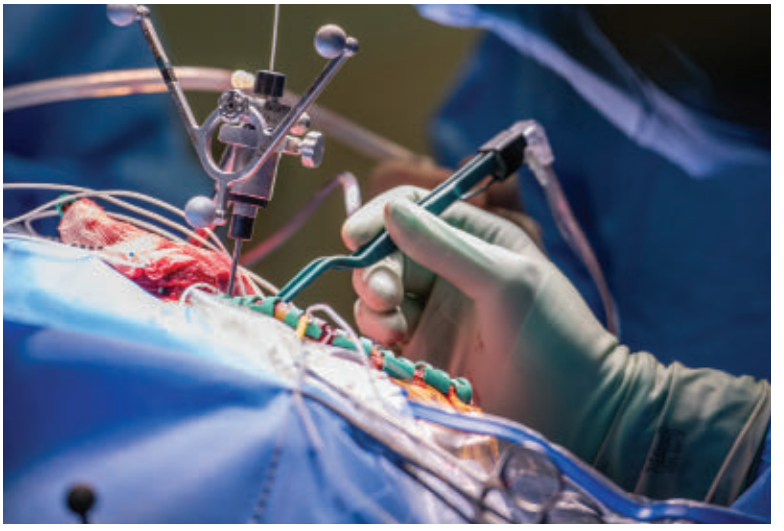
"We need to have a smarter approach, rather than, 'Put it in, turn it on and leave it on,'" says Darin Dougherty, a psychiatrist at Massachusetts General Hospital in Boston who is working on new stimulation methods. A system that can change its behavior depending on the patient's needs would ultimately enable better levels of control, he says, by "driving the system in real time and steering it."

Dougherty's collaborator Alik Widge is working on the steering. He and colleagues are studying how to inject the right dose of electrical medicine, at the right time and in the right spot, to skillfully drive these complicated brain circuits. In unpublished work in people with epilepsy, Widge, Dougherty and colleagues were able to stimulate brains in a way that slightly changed their neural state, and as a consequence, people's behavior, Widge says.

DARPA, a Department of Defense research agency, is funding this project plus work at UCLA on targeted brain stimulation. Now in its fifth and final year, the project, called SUBNETS, aims to help veterans with major depression, post-traumatic stress, anxiety and other psychiatric problems. "It is extremely frustrating for patients to not know why they feel the way they do and to not be able to correct it," Justin Sanchez, the director of DARPA's Biological Technologies Office, said in a Nov. 30 statement. "We owe them and their families better options."

These next-generation systems, primarily being developed at UCSF and Massachusetts General Hospital, might ultimately deliver. After detecting altered brain activity that signals a looming problem, these devices, called closed-loop stimulators, would intervene electrically with what their inventors hope is surgical precision.

In contrast to the UCSF group, Widge, who is at the University of Minnesota in Minneapolis, and his collaborators don't focus explicitly on mood. The researchers want to avoid categorical diagnoses such as depression, which they argue can be imprecise. Major depression is not the same disease for everyone. Causes and symptoms can differ greatly from person to person. Instead of grouping people by diagnosis, Widge and his team are going after brain circuits that are involved in traits that can be measured in the lab, such as cognitive flexibility (the ability to quickly shift strategies) and emotional regulation. These brain traits can then ultimately be tied to certain brain disorders, the researchers think.



To determine where seizures begin, surgeons at the University of California, San Francisco place electrodes into and on the brain of a person with epilepsy. Data from those electrodes can also help reveal how the brain creates moods.

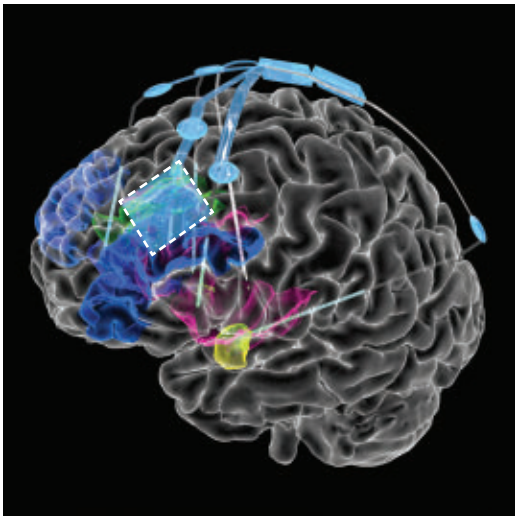
UCSF, BARBARA RIES FOR UCSF

In their trials, Widge, Dougherty and colleagues enlisted people who, like those in the UCSF trials, already had electrodes implanted for epilepsy treatment. Certain kinds of stimulation delivered to specific spots made participants slightly more likely to behave a certain way on computer tasks — emphasis on "slightly," Widge cautions. "One of the fascinating things that we keep running into is that the brain really has some pretty hard ceilings on this," he says. "You can move someone 5 percent or 10 percent, but you can't totally change them." A depressed person might begin to venture outside, take a short walk, visit a café, but a bigger shift is unlikely.

This type of influence might be able to nudge someone to choose chocolate ice cream over vanilla, for instance. "But if you hate nuts, there's no way I'll be able to make you choose butter pecan," Widge says.

Brain aikido

Animal studies and computer simulations by Widge take aim at characterizing the best ways to nudge neural circuits. Stimulation might be most effective when it works with the timing of the brain's existing brain waves, he and colleagues reported December 5 in *PLOS ONE*. "It's almost like trying to do aikido with the brain," Widge says. "You're trying to find this point at which the activity is perfectly poised so that all you have to do is give it a little bit of a push." Deliver the right nudge at the right time to the right spot, and the hope is



Researchers want to create a device like this schematic that can monitor and change neural activity. Electrode arrays that sit on the surface of the brain (white-framed rectangle) and others that penetrate deeper (thin implants shown) could allow access to brain regions involved in mood, addiction or other processes.

ANGELIQUE PAULK

that "the whole thing will cascade in exactly the direction you want it to," Widge says.

Shanechi's group is also trying to learn how best to stimulate the brain. Using computational models, she and colleagues recently predicted how certain kinds of stimulation would change depression-related brain activity in controlled ways, keeping the relevant circuit behavior tightly within a healthy range. Shanechi has been testing those mathematical predictions, published in the December *Journal of Neural Engineering*, in people with implanted electrodes. She is delivering the sorts of electrical stimulation that her models pointed to and monitoring the effects.

Clues about how best to stimulate also emerged from the study in *Current Biology*, which described the 44-year-old woman's calm mood during stimulation. Single and continuous electrical stimulation in the orbitofrontal cortex had different effects in neural tissue both near and far, the researchers found. This sort of neural tinkering — delivering certain kinds and doses of electrical current and seeing how the signals reverberate — is a crucial part of devising closed-loop systems.

The future isn't now

It may seem unsettling for someone to go about daily life with a device that dwells in the brain and has the power to influence emotions. But researchers point out that lots of things change our moods, such as meditation, exercise and alcohol. Don't forget the antidepressants, taken by nearly 13 percent of people over the age of 12 in the United States. "We think nothing of taking a pill to change our mood and improve our emotions," George says. "I don't think it's much different with a device."

Of course, that device doesn't exist yet. Scientists still aren't certain where to stimulate and how — questions that probably have different answers for everyone, the data suggest. And even if the protocols were clear, the hardware that does the work still isn't ready. In the recent mood-altering studies, wires emerging from under people's skulls were attached to large external computers, not ideal for moving around.

To succeed, all of the hardware needs to fit under the skull, where it would perform lightning-quick assessments and figure out how to tweak neural behavior when needed. That goal is a long way off, Widge says. The whole system — including the electrodes, the processor and the power source — needs more refinement to be nimble enough to handle complex algorithms, durable enough to reside permanently inside a living person and powerful enough to avoid the need for frequent battery replacements.

Researchers imagine one day using such a device, and the theories that drive it, for problems other than depression. "If you find it works for mood, why not use it for other problems, like addictions?" asks George, who dreams of an implant that could detect an opioid craving and instantly counter it.

In fact, some of the brain circuits that Widge, Dougherty and colleagues are trying to influence are involved in a person's predilection to seek new experiences. And that trait, called novelty-seeking, tracks closely with drug use. The ability to monitor and control that particular tangle of brain circuitry could ultimately lead to the device of George's dreams.

For now, the possibilities are wide open, experts say. Chances are good that in the coming years scientists will gain the ability to tap into the brain and influence it in precise ways. After all, perhaps more than any other part of the body, the brain is designed to continuously transform.

"Evolution spent billions of years giving us a brain that's fully capable of changing itself," Widge says. The brain can get itself into a depressed state, but it is also capable of getting itself out of one. "The machinery is all there," he says. "We just need to figure out how to work it." ■

Explore more

- Vikram R. Rao *et al.* "Direct electrical stimulation of lateral orbitofrontal cortex acutely improves mood in individuals with symptoms of depression." *Current Biology*. December 17, 2018.

GEOLOGIC ROAD TRIP OF THE MONTH

CAVE OF THE MOUNDS

Erosion has scoured away most of the Silurian dolomite that once lay over all of Wisconsin. Its remnants exist in the Niagara Escarpment on the eastern side of the state and on the tops of several mounds in the southwest corner, which are outliers of the more widespread Silurian strata now eroding to the south in Illinois and Iowa. Two of these mounds, called the Blue Mounds, are located about 20 miles west of Madison on US 151. The western mound is the higher of the two, standing 415 feet above the surrounding plain, the highest point in southern Wisconsin and the site of Blue Mound State Park. The eastern mound is 230 feet shorter.

Cave of the Mounds, a few miles east of the state park on the south face of the eastern mound, was discovered in 1939 when a routine dynamite blast at a quarry uncovered a 20-foot-high room with passages to other chambers. The landowner immediately halted the quarrying and, within a year, opened a commercial cave. Lying in Galena Dolomite deposited about 460 million years ago, the cave is 70 feet deep and about a half mile long. Groundwater, made weakly acidic by carbon dioxide absorbed from the environment, dissolved calcium carbonate along fissures and bedding planes in the dolomite, creating crevices and caverns. Percolating water combined with the sulfur in lead and other minerals deep underground to form sulfuric acid, which also dissolves calcium carbonate.

At Cave of the Mounds, this dissolution process began between 1 and 2 million years ago when the dolomite was below the water table. As the local streams carved their valleys deeper, the water table dropped and underground erosion continued at deeper levels. Eventually, groundwater rivulets and then streams flowed through the cave, enlarging the passageways, and water dripped into the spacious caverns. Upon interacting with the air, the water's carbon dioxide escaped, triggering the deposition of calcium carbonate (the mineral calcite). Cave of the Mounds is famous for its spectacular dripstone formations, collectively called *speleothems*, that grew slowly as the calcite was deposited, crystal by crystal. One cubic inch of growth can take one hundred years or more. It is important to never touch any of the formations to avoid accidentally damaging them. Also, oil from our skin can interfere with the deposition of calcite and stop the growth of the speleothems.

The Gem Room in Cave of the Mounds displays three aspects of speleothem formation: prominent stalactites and stalagmites (center), flowstone (lower center to lower left), and color—red showing the presence of iron oxides in the calcite and blues and grays showing the presence of manganese oxides. —Courtesy Cave of the Mounds

South Cavern shows a variety of speleothems, including flowstone, where water, flowing in sheets, deposits layer upon layer of calcite on the walls or inclined floor of a cave. —Courtesy Cave of the Mounds

Cave of the Mounds, designated a National Natural Landmark in 1988, is open for touring throughout the year. Many caves close during winter to allow resident bats to hibernate undisturbed. However, this cave was a closed underground system until it was discovered and quickly sealed in 1939, and there is no evidence that bats have ever lived in it. Thus, the cave remains open in winter when its temperature is an even 50 degrees, just as in summer.

FILM

The Human Element makes the impacts of climate change feel real

Photographer James Balog (shown here next to a California wildfire) documents how people's lives are being affected by climate change.

Climate change, extreme weather events and debates over climate mitigation strategies dominated the news for much of the last year. Yet climate scientists continually wrestle with how best to talk about these issues: Should discussions of climate change appeal directly to people's emotions, whether fear or anger or even hope? Or are data-driven discussions the way to go?

There is no one answer, of course. But *The Human Element*, a documentary starring photographer James Balog, aims directly for the gut by putting a human face on the impacts. The movie, now streaming online, shows how human-caused climate change is intersecting with people's lives. For instance, we see flooded homes in Florida in the wake of Hurricane Irma in 2017. Global warming probably increased Irma's intense rainfall, researchers have found. We also see firefighters battling wildfires in the American West (the movie is almost entirely shot in the United States). "I felt a great sense of urgency to bear witness," Balog says in the film.

That collision of people and planet is something that Balog, also the subject of the 2012 documentary *Chasing Ice*, has been capturing in photographs for decades. In *The Human Element*, his work is framed through the four ancient elements: earth, air, fire and water.

People, Balog suggests, are a fifth element — a force of nature, too. People are driving climate change, and their lives are being altered by it.

The Human Element
NOW AVAILABLE
EARTH VISION FILM

It is in showing the faces of those directly affected by our tampering with nature that the movie packs its most powerful punches. After capturing the desolation of a family standing in knee-deep water inside their home in Irma's aftermath, the film shows other water-related impacts, particularly the plight of the residents of Tangier Island in Virginia, which is being rapidly and inexorably swallowed by the rising waters of the Chesapeake Bay.

The air segment focuses on how humans are altering the atmosphere, specifically with such pollution as volatile organic compounds emitted by planes, cars, trucks and facilities that process oil and gas. One heart-wrenching scene takes Balog to a school in Denver that specializes in treating kids with asthma, a condition often triggered by pollution. The kids are trained to treat themselves during an asthma attack; many do so several times a day.

In the fire segment, Balog photographs firefighters as they wearily but valiantly tackle the 2016 Soberanes Fire near Big Sur, Calif. With a price tag of $260 million, the blaze is among the most expensive ever battled in the United States. In the film, geographer Tania Schoennagel of the University of Colorado Boulder notes that climate change, as well as the increasing encroachment of human communities into former wilderness (*SN: 12/22/18 & 1/5/19, p. 8*), is already transforming the wildfire season. Since the 1970s, she says, there has been a 1,000 percent increase in the frequency of megafires — fires burning at least 40,000 hectares — in parts of the western United States.

Finally, the earth segment brings Balog to the coal-mining country of Kentucky and Pennsylvania — where, he says, "what we've dug from the Earth and burned has changed the other 'elements.'" Balog, whose grandfather died while mining coal, paints a grim picture of how a fading industry with dwindling jobs has left former miners in dire straits. But the segment ends on a rare note of hope — and offers the film's only nod at climate mitigation efforts. Balog follows a pair of developers who are planning to build a massive solar energy farm on reclaimed coal-mining land in hopes of bringing new jobs to the impoverished area.

The Human Element also doesn't dwell for long on actual climate science, though the scientists who appear throughout provide helpful context for each of the movie's segments.

What the film does do, and does well, is tell a series of human stories, accompanied by Balog's haunting photos. The combination of stories and images is indeed an effective, powerful way to communicate the impacts of climate change. — *Carolyn Gramling*

To find out where to watch the film, go to **thehumanelementmovie.com**

Science News for Students

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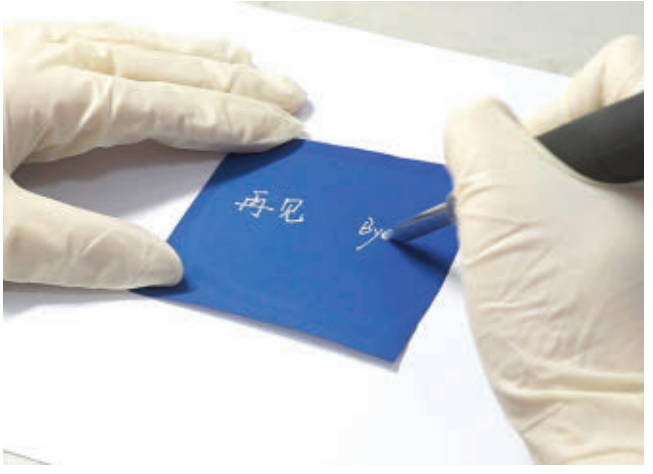

This rewritable paper depends on disappearing ink

Have you ever made a mistake on something you printed from a computer? That paper probably went right into the recycling bin. Now you can erase your mistake and reuse that first sheet of paper. Scientists at Fujian Normal University in Fuzhou, China, coated one side of a regular sheet of printer paper with a heat-sensitive ink. A heated pen or printer makes the ink's blue color disappear, revealing the white paper below. To fix any errors, put the paper in the freezer and the ink will turn blue again. Words and pictures can remain visible on the paper for at least six months. — *Alexandra Taylor*

Read more: **www.sciencenewsforstudents.org/ink**

Welcome to the Arctic's all-night undersea party

Light feeds life. To scientists, the high Arctic's months-long darkness would seem like a prescription for ecosystem hibernation. New data instead show that Arctic sea life, such as plankton, whales and fish, remains surprisingly active and mobile during this time, with some creatures timing their movements and eating cycles to the rising and setting of the moon or the northern lights. The challenge: figuring out how to study these creatures without turning on lights. — *Bethany Brookshire*

Read more: **www.sciencenewsforstudents.org/arctic**

Bacteria and bugs will save us from the zombie apocalypse

Don't fear the walking dead. An entomologist and forensic archaeologist explain why people have little to fear from zombies. After death, electrical impulses from the brain stop and muscle cells don't get oxygen, which causes the body to stiffen. No muscle movement, no shambling zombie hordes. As the body breaks down, enzymes that are normally stored in cells to process waste start to destroy organ tissue. Bacteria and maggots join the party, slurping up the remaining cells except hair, tendons, skin and bones. So no need to break out the machete or chainsaw. — *Bethany Brookshire*

Read more: **www.sciencenewsforstudents.org/zombie**

FROM TOP: LUZHUO CHEN; BESTDESIGNS/ISTOCK.COM; LEOLINTANG/ISTOCK.COM

DECEMBER 22, 2018 & JANUARY 5, 2019

SOCIAL MEDIA

Surf's up

Adult female mosquitoes may be surfing air currents above West Africa, **Susan Milius** reported in "Mosquitoes surf high above Africa" (*SN: 12/22/18 & 1/5/19, p. 13*). For reader **Keith Graham**, the story brought to mind Toto's 1982 hit song "Africa." On Facebook he wrote: "They surf the winds doooowwwnn in Aaaaafriiica."

Join the conversation

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Defining intelligence

Artificial intelligence followed fauna, diagnosed disease, mapped the moon and more in 2018, ***Maria Temming*** *reported in "AI gets a liberal arts education"* (SN: 12/22/18 & 1/5/19, p. 25). Online reader **greg** found the term "artificial intelligence" misleading. "In reality what we call AI are merely classification algorithms," **greg** wrote. "True AI may well never exist, we don't have the first clue how to do it."

Temming acknowledges that the term might give people the wrong idea about what computers are actually doing. "Certainly AI algorithms don't think like humans do," she says. "But you also might be conflating two different levels of artificial intelligence."

Artificial narrow intelligence is the AI that exists now. These systems are designed to mimic specific feats of human intelligence such as image recognition and game strategizing. "An A-list AI example would be AlphaGo, which is extremely good at the hardest board game ever, but nothing else," **Temming** says. The second kind of AI is artificial general intelligence. "That AI would be able to solve any problem with human-level intelligence. We're not there yet."

2019: A space odyssey

In "A year of launches and farewells in space" (SN: 12/22/18 & 1/5/19, p. 32), ***Lisa Grossman*** *reported on missions that started exploring the cosmos in 2018 and others that were winding down.* Reader **Leslie Hruby** suggested that *Science News*' 2019 space missions recap include coverage of New Horizons' flyby of the Kuiper Belt object nicknamed Ultima Thule. "So excited to learn more about these small worlds orbiting in our solar system (and how to pronounce them). Asteroids, dwarf planet, distant object, Oh my!" **Hruby** wrote.

We have it covered, **Grossman** says. She reported on New Horizons' New Year's Day flyby of Ultima Thule (pronounced TOO-lee, or THOO-lee, depending on whom you ask). "One exciting finding is that the space rock is shaped like a snowman," she says. The shape is the result of small rocks glomming together to form larger rocks (*SN: 2/2/19, p. 7*). If *Science News* does a 2019 mission recap, New Horizons will surely make the list.

Pooetry

Wombats' elastic intestines help the marsupials form cubelike scat, ***Laurel Hamers*** *reported in "Here's how wombats poop in cubes"* (SN: 12/22/18 & 1/5/19, p. 4). The story got readers' creativity flowing. Many sent in poems about the research.

Reader **Tom Torkildson** wrote: "Of all the many dainty species / only wombats shape their feces / Six-sided solids are what they pass / I wonder, can they sculpt their gas?"

On Twitter, **@cuttlefishpoet** penned a limerick: "So you're saying that wombats poop cubes / 'Cos their guts are elasticized tubes / Which take fiber-filled diet / And process and dry it / For stacking? C'mon — are we rubes?"

Science News alumni even got in on the fun. Former intern **Leah Rosenbaum** wrote: "They've never heard of Picasso / Braque, Léger or Cézanne / They don't sit at cafés drinking espresso / And they find canvases quite bland / If you gave them a paintbrush or palette / They wouldn't even need to use it / For them it's innate, it's a habit / Wombats are the original cubists."

A honeybee parasite is less vampire, more werewolf

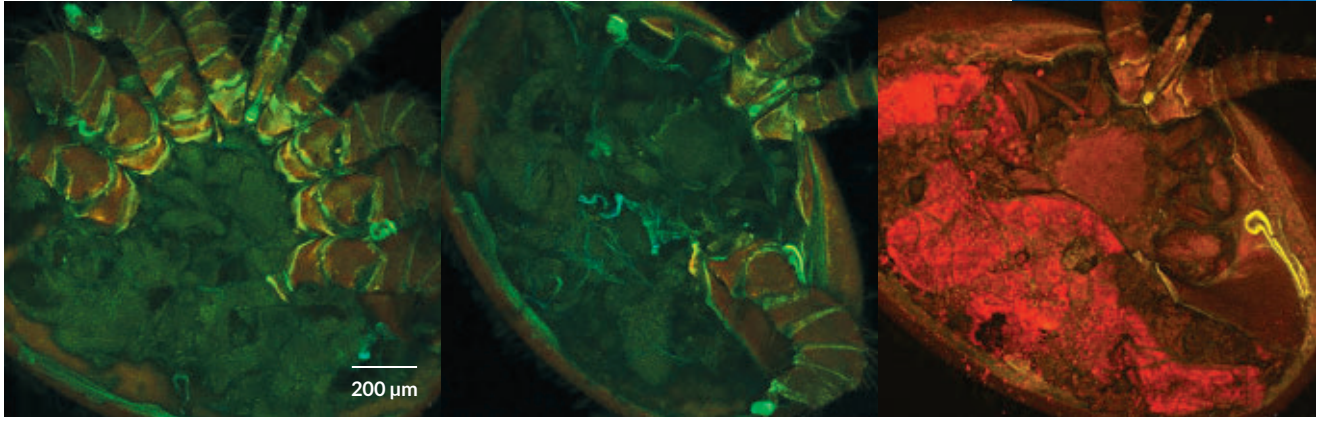
Detailed images and tests with fake bee larvae reveal that a "vampire" mite that attacks honeybees may not be so much a bloodsucker as a fat slurper.

The scanning electron microscopy image above shows a cross section of a mite ominously named *Varroa destructor* (colored pink) wedged under a protective plate on an adult honeybee's abdominal region. About 95 percent of mites surveyed in a new study were attached in this area, within reach of an organ called the fat body, researchers report.

V. destructor invaded North America in the 1980s and has become one of the biggest threats to honeybees. Scientists thought the mites harm bees by feeding on hemolymph, the bee version of blood. But tests using artificial bee larvae made from gelatin capsules (shown at right inside mock beehive cells) found that mites lived for only about 1.8 days on average when fed pure hemolymph. The only mites to survive the seven-day tests were fed 50 or 100 percent fat body tissue, entomologist Samuel Ramsey and colleagues report online January 15 in the *Proceedings of the National Academy of Sciences*.

Feeding adult bees dyes that stain hemolymph yellow and fat red also showed that the parasites target fat, says Ramsey, who completed the research while at the University of Maryland in College Park. Microscope images revealed that mites that fed on bees with only their hemolymph stained had ghostly dim guts (bottom left), similar to starved mites used as a control (middle). But mites that fed on fat-stained bees had glowing guts full of red fat (right).

Rather than sucking blood, the mite "is feeding on flesh, more like a werewolf," Ramsey says. That insight might aid the largely failed efforts to develop antimite compounds to feed to bees, says toxicologist Aaron Gross of Virginia Tech in Blacksburg. — *Susan Milius*



TOP: UMD, USDA, S.D. RAMSEY *ET AL/PNAS* 2019; ALL OTHERS: S.D. RAMSEY *ET AL/PNAS* 2019

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