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The Robot Touch

Intelligent machines will need to sense the world around them

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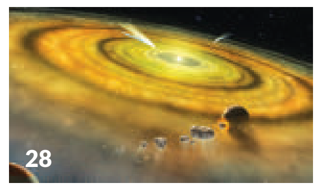

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COVER By giving robots physical intelligence, researchers hope to build machines that can work alongside humans. *Photo: Joanne Leung, UCLA Engineering; Products from SynTouch, LLC and Barrett Technology Inc.*

CLOCKWISE FROM TOP LEFT: HUMAN: CHEREZOFF/SHUTTERSTOCK; ROBOT: WILLYAM BRADBERRY/SHUTTERSTOCK; NASA; HARVEY BARRISON/FLICKR (CC BY-SA 2.0)

Artificial intelligence needs smart senses to be useful

True intelligence, Meghan Rosen notes in this issue's cover story (Page 18), lies in the body as well as the brain. And building machines with the physical intelligence that even the clumsiest human takes for granted — the ability to sense, respond to and move through the world — has long been a stumbling block for artificial intelligence research. While more sophisticated software and ultrafast computers have led to machine "brains" that can beat a person at chess or Go, building a robot that can move the pieces, fetch an iced tea or notice if the chessboard has turned into Candy Land has been difficult.

Rosen explores several examples of how roboticists are embodying smarts in their creations, crucial steps in creating the autonomous machines most of us imagine when we hear "robot." Of course, we are already, if unwittingly, living in a world of robots. As AI researcher Richard Vaughan of Simon Fraser University in Burnaby, Canada, pointed out to me recently, once a machine becomes part of everyday life, most people stop thinking of it as a robot. "Driverless cars are robots. Your dishwasher is a robot. Drones are extremely cheap flying robots."

In fact, Vaughan says, in the last few decades, robots' intelligence and skills have grown dramatically. Those advances were made possible by major developments in probabilistic state estimation — which allows robots to figure out where they are and what's going on around them — and machine learning software.

Probabilistic state estimation has enabled better integration of information from a robot's sensors. Using the math of Bayesian reasoning, robots can compare sensor data against a model of the world, and interpret their likelihood of being right. For example, a robot in a building can use its laser sensors to assess the space around it, compare that with its inner map of the building and determine that it's not in Hall A but has equal chances of being in Hall B or C.

Robots could do that in the 1990s. Scientists then asked a tougher question: How do you know where you are if you have no map? In two dimensions, researchers solved that by integrating sensory information with a set of all possible maps. But only recently was the problem solved in three dimensions, and challenges still remain for robots in less-structured or harsh environments.

Machine learning advances have aided aspects of AI such as computer vision, much improved by work done on boosting search engines' ability to identify images (so you can search "birthday party" to find images of candled cakes, for example). This research has helped to make robot senses smarter.

Progress is swift, as Rosen makes clear in her story, but many challenges remain. Roboticists still struggle with hardware, especially for humanoid robots, which remain rather clunky. Walking, climbing stairs, picking things up and getting back up after a fall are still hard. Providing independent power sources is also a big deal — batteries aren't yet good enough. But to build the robots that can do all that people want them to do, whether that's driving us to work, helping the elderly up from a chair or collaborating safely with human workers in factories or warehouses, will take even better senses. Intelligence is not simply processing information or even learning new information. It's also about noticing what's going on around you and how to best respond. — *Eva Emerson, Editor in Chief*

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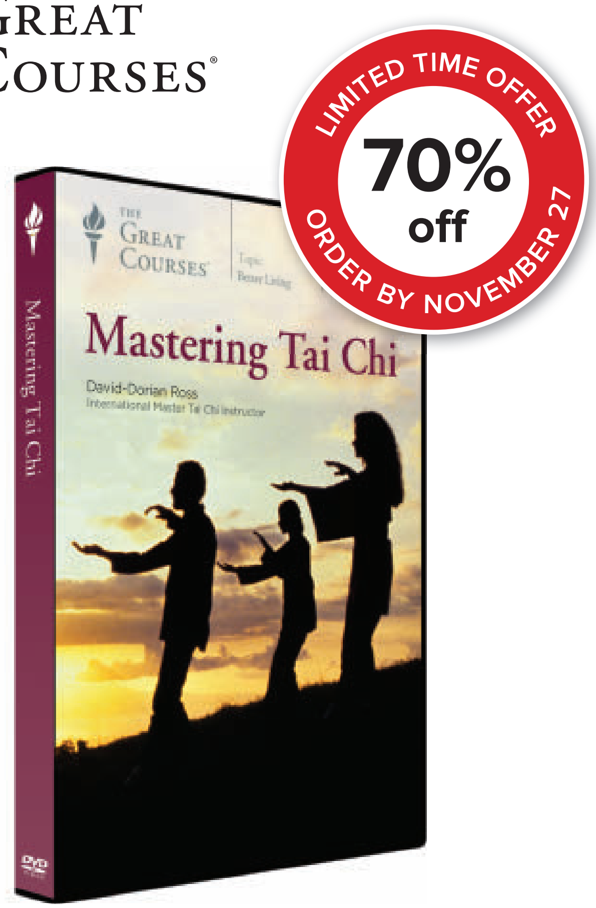

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Excerpt from the November 12, 1966 issue of *Science News*

50 YEARS AGO

More vaccines promised

"The decline of poliomyelitis among more than 350 million people of the world ... [offers] a promise of vaccines that will soon be used against other diseases considered hopeless or untreatable until recently. Vaccines against some of the many viruses causing the common cold, as well as those causing rubella, mumps and other diseases are on the way."

UPDATE: In 1971, vaccines against mumps and rubella were combined with the measles vaccine into one MMR shot. All three diseases are now very rare in the United States. But persistent pockets of lower vaccination rates (spurred in part by the repeatedly debunked belief that vaccines cause autism) have allowed sporadic outbreaks of all three illnesses. A vaccine against the common cold has not yet materialized. Creating one vaccine that protects against the hundred or so strains of rhinoviruses that can cause colds is not easy. But some scientists are giving it a shot, along with vaccines against HIV, Ebola and Zika.

Coasters with more jiggle and less speed may offer a ride that dislodges kidney stones.

THE SCIENCE LIFE

Roller coaster knocks out stones in kidney model

Passing a kidney stone is not exactly rocket science, but it could get a boost from Space Mountain.

It seems that shaking, twisting and diving from on high could help small stones dislodge themselves from the kidney's inner maze of tubules. Or so say two researchers who rode the Big Thunder Mountain Railroad roller coaster at Disney's Magic Kingdom in Orlando, Fla., 20 times with a fake kidney tucked inside a backpack.

The researchers, from Michigan State University College of Osteopathic

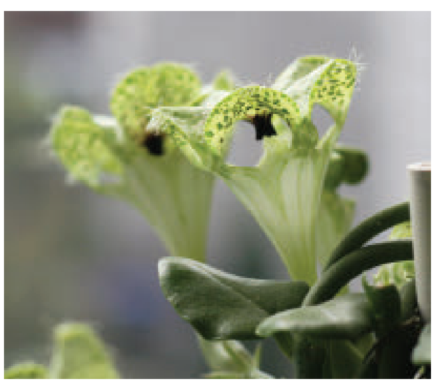
HOW BIZARRE

Flower lures flies with smell of honeybee fear

A flower in South Africa catches flies with honey, or in this case, the smell of honeybees.

Certain plant species lure potential pollinators with false promises of sweet nectar, sex or even rotting flesh. But *Ceropegia sandersonii* attracts its primary pollinator, *Desmometopa* flies, with the scent of fear. The flower mimics the chemical signals, or pheromones, released by alarmed western honeybees (*Apis mellifera*) during a predator attack. For flies that feast on the bees' guts, it's the perfect bait, Stefan Dötterl, a chemical ecologist at the University of Salzburg in Austria, and colleagues report October 24 in *Current Biology*.

The team compared the compounds that make up the flower's scent with pheromones released by the bees during simulated attacks. Not only did the two odors have several compounds in common, but the flies were strongly attracted to a mixture of a few of the shared compounds. That chemical cocktail has been observed only in the bees and *C. sandersonii*, the researchers say.



The *Ceropegia sandersonii* flower (shown) tricks carnivorous flies into pollinating it with false promises of a honeybee meal.

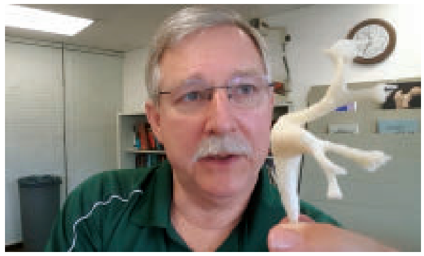
Before flies have a chance to wise up to the trickery, they become trapped inside the flower. The flies eventually escape about a day later, once the flower wilts, only to be duped by other flowers to finish the fertilizing task, Dötterl says. *— Cassie Martin*

FROM TOP: LOWE LLAGUNO/SHUTTERSTOCK; MAJA DUMAT/FLICKR (CC BY 2.0)

Medicine in East Lansing, planned the study after several of their patients returned from the theme park announcing they had passed a kidney stone. Finally, one patient reported passing three stones, each one after a ride on a roller coaster.

"Three consecutive rides, three stones — that was too much to ignore," says David Wartinger, a kidney specialist who conducted the study with Marc Mitchell, his chief resident at the time.

Since neither of the two had kidney stones themselves, the pair 3-D printed a life-size plastic replica of the branching interior of a human kidney. Then they inserted three stones and human urine into the model. The stones were of the size that usually pass on their own, generally smaller in diameter than a grain of rice. After arriving at the park, Wartinger and Mitchell sought permission from guest services to do the research, fearing that two men with a backpack boarding the same ride over and over might strike workers as suspect.



David Wartinger holds up a 3-D printed kidney cast from a patient known to form stones.

"Luckily, the first person we talked to in an official capacity had just passed a kidney stone," Wartinger says. "He told us he would help however we needed."

Even when a stone is small, its journey through the urinary tract can be excruciating. In the United States alone, more than 1.6 million people each year experience kidney stones painful enough to send them to the emergency room. Larger stones — say, the size of a Tic Tac — can be treated with sound waves that break the stones into smaller pieces that can pass.

For the backpack kidney, the rear of the train was the place to be. About 64 percent of the stones in the model kidney cleared out after a spin in the rear car. Only about 17 percent passed after a single ride in the front car, the researchers report in the October *Journal of the American Osteopathic Association*.

Wartinger thinks that a coaster with more vibration and less heart-pounding speed would be better at coaxing a stone on its way.

The preliminary study doesn't show whether real kidneys would yield their stones to Disney magic. Wartinger says a human study would be easy and inexpensive, but for now, it's probably wise to check with a doctor before taking the plunge. *— Laura Beil*

New 3-D printed bone scaffolds, such as this one of human vertebrae, may speed up tissue healing, researchers say.

SAY WHAT?

Hyperelastic bone \Hī-per-ə-LAS-tik bōn\ n.

A flexible 3-D printed scaffold designed to repair broken or damaged bone

"Hyperelastic bones" don't impart Stretch Armstrong abilities, but they could give surgeons a quick, less expensive way to repair bone breaks. Created by Ramille Shah, a materials science engineer at Northwestern University's medical campus in Chicago, and colleagues, the new, superflexible scaffold can be 3-D printed into femurs, skullcaps and other bone shapes.

The durable material is a mix of an elastic polymer plus hydroxyapatite, a calcium mineral found in human bones and teeth. Once implanted, the material's mineral makeup encourages real bone to start growing within a month to replace the scaffold, the team reports in the Sept. 28 *Science Translational Medicine*.

So far, the "bones" have been tested only in animals. In rats, spinal implants stimulated tissue and bone growth just as well as natural grafts.

In a macaque with skull damage, an implant almost seamlessly integrated with the monkey's natural skull tissue within a month. The material is malleable, so surgeons can fix it in place without glue or sutures, Shah says. *— Cassie Martin*

FROM TOP: J. AM. OSTEOPATH. ASSOC.; A.E. JAKUS

INTRODUCING

San Andreas has neighbor

Meet the San Andreas Fault's newfound neighbor. Mapping deformations deep underground along the shoreline of a Southern California lake called the Salton Sea, seismologists discovered a fault that runs parallel to San Andreas' southern end.

The newly identified fault, dubbed the Salton Trough Fault, shakes up assessments of the potential for damaging earthquakes in the region, according to Valerie Sahakian, a seismologist at the U.S. Geological Survey in Menlo Park, Calif. She and colleagues report the discovery of the fault in the October *Bulletin of the Seismological Society of America*.

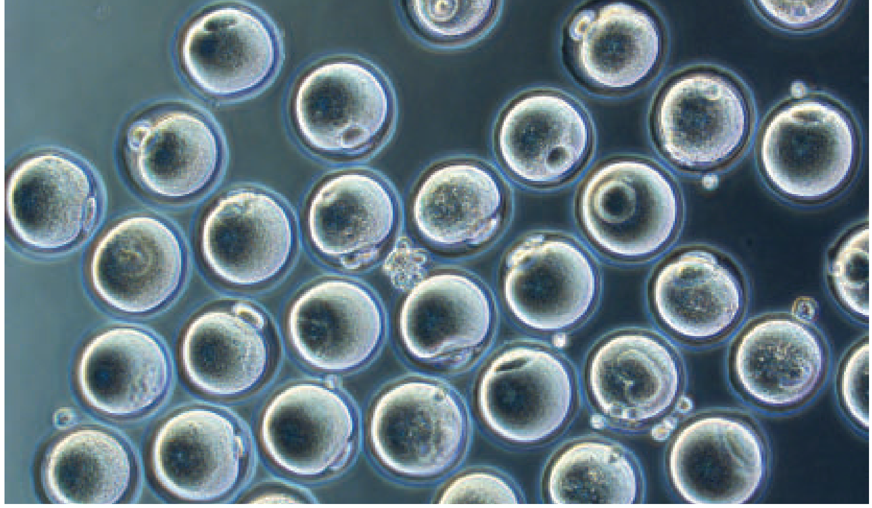
The Salton Trough Fault may accommodate some of the strain from the larger San Andreas system to the east, which has gone about 300 years without a major temblor. But the fault could also trigger, or be triggered by, a quake along the San Andreas, the researchers say. It could also amplify the effects of a San Andreas quake by causing its seismic waves to reverberate. Future assessments of the region's vulnerability, the researchers write, should consider these possibilities. *— Thomas Sumner*

News

GENES & CELLS

Eggs grown from mouse skin cells

New technique re-creates ovary conditions in lab dish



Skin cells from the tip of a mouse's tail were reprogrammed into viable eggs (shown) made entirely in a lab dish. The research could one day lead to new infertility treatments.

BY TINA HESMAN SAEY

For the first time, researchers have grown eggs entirely in a lab dish.

Skin-producing cells called fibroblasts from the tip of an adult mouse's tail have been reprogrammed to make eggs, Japanese researchers report online October 17 in *Nature*. Those eggs were fertilized, and when implanted in female mice, grew into six healthy mice. The accomplishment could make it possible to study the formation of eggs — a mysterious process that takes place inside fetuses. If the feat can be repeated with human cells, it could make eggs easily available for research and may eventually lead to infertility treatments.

"This is very solid work and an important step in the field," says developmental biologist Diana Laird of the University of California, San Francisco, who was not involved in the study. But, she cautions, "I wouldn't want patients who have infertility to think this can be done in humans next year," or even in the near future.

In a new experiment, reprogrammed skin cells developed into eggs, some of which went on to produce healthy mice (shown).

Stem cells reprogrammed from adult body cells have been coaxed into becoming a wide variety of cells. But producing eggs, the fundamental cells of life, is far trickier. Egg cells are the ultimate in flexibility, able to create all the bits and parts of an organism from raw genetic instructions. They are far more flexible, or potent, than even the embryonic-like stem cells from which they were created.

Making eggs in a dish is such a difficult task that it required a little help from ovary cells that support egg growth, stem cell researcher Katsuhiko Hayashi and colleagues found. The team had previously reprogrammed stem cells to produce primordial germ cells, the cells that give rise to eggs. But they had to put those cells into mice's ovaries to finish developing into eggs (*SN: 11/3/12, p. 14*).

It's unclear how support cells in ovaries foster egg development, says Hayashi, of Kyushu University in Fukuoka, Japan. Something made by support cells or physical contact with them, or both, may be necessary for an egg to fully mature. Researchers can't yet reproduce the supporting cells in the lab and so need to get those cells from embryos, Hayashi says. That could be a problem when trying to replicate the experiments in humans.

Hayashi and colleagues made artificial ovaries to incubate the lab-grown eggs by extracting ovarian support cells from albino mouse embryos. The researchers then mixed in primordial germ cell–like cells created from tail-tip skin cells from a normally pigmented mouse. After maturing for over a week in a lab dish, the eggs were ready for fertilization. That's about the same time it takes for eggs to mature in a mouse ovary, Laird says. That means researchers may need patience to make human eggs in lab dishes. "It could be a nine- to 12-month differentiation process in humans," she says.

Researchers fertilized the eggs and transplanted the embryos into the uteruses of female mice. Eight pups with dark eyes were born, indicating that they came from the tail-tip eggs and not eggs accidently extracted from the albino mice along with the support cells. Two of the pups were eaten by their mothers; the rest grew up apparently healthy and have produced offspring of their own.

Growing quality eggs in the lab may be an all-or-nothing exercise. In another experiment using eggs made from embryonic stem cells, the researchers found that some genes weren't turned on or off as in normal eggs. And only 11 of 316 embryos made from those lab-grown eggs grew into mouse pups. Some of the embryos didn't make it because they had abnormal numbers of chromosomes, indicating that the eggs weren't divvying up DNA properly.

The low success rate implies that only one in every 20 lab-grown eggs, or oocytes, is viable, Hayashi says. "This means that it is too preliminary to use artificial oocytes for clinical purposes. We cannot exclude a risk of having a baby with a serious disease. We still need to do basic research to refine the culture conditions." ■

BOTH: K. HAYASHI/KYUSHU UNIV.

LIFE & EVOLUTION

Ancient avian voice box unearthed

Oldest known syrinx fossil suggests bird honked like a duck

BY MEGHAN ROSEN

Some ancient birds may have sounded like honking ducks.

For the first time, scientists have discovered the fossilized remains of a voice box from the age of the dinosaurs. The structure, called a syrinx, belonged to *Vegavis iaai*, a bird that lived 68 million to 66 million years ago, researchers report online October 12 in *Nature*.

"It may be a once-in-a-lifetime discovery," says evolutionary biologist Patrick O'Connor of Ohio University in Athens, who wrote a commentary in *Nature* about the fossil.

The new work helps fill in the soundscape of the Late Cretaceous Epoch. It could also offer hints about sounds made by all sorts of dinosaurs, says study coauthor Julia Clarke of the University of Texas at Austin.

Unlike in humans, where the larynx lies in the neck, birds' voice boxes rest inside the chest at the base of the windpipe. Stacked rings of cartilage anchor vibrating membranes that make sound when air whooshes through.

This delicate structure doesn't typically fossilize. In fact, scientists have spotted just a few of these vocal organs in the fossil record. The previously oldest known, from a water bird, dates to about 50 million years ago. Clarke's team examined that syrinx, which hadn't been studied before, and the one from *V. iaai*.

The *V. iaai* fossil, a partial skeleton discovered on an island off Antarctica, was removed from a rock about the size of a cantaloupe, Clarke says. CT scans revealed the telltale rings of the voice box, a structure about half the size of a multivitamin pill. "It was one of the biggest, happiest days of my career," Clarke says.

A ducklike bird (*Vegavis iaai*, illustrated) that lived some 68 million to 66 million years ago left behind fossilized remains of a voice box, or syrinx, on an Antarctic island.

Comparing the fossil with living birds helped Clarke and her team determine that the ancient bird probably squawked like ducks and geese.

The find also proves that voice boxes from dinosaurs' time can indeed fossilize. No one has found the structures in nonavian dinosaurs, Clarke says. "That suggests that most dinosaurs may not have had a syrinx." Instead, she proposes, dinosaurs like *T. rex* might have made noises like crocodiles: deep "booming" sounds generated in the back of the mouth. ■

GENES & CELLS

Amoeba gives clues to animal origins

Single-celled life had molecular tools for going multicellular

BY LAUREL HAMERS

Scaling up from one cell to many may have been a small step rather than a giant leap for early life. A single-celled organism closely related to animals controls its life cycle using a molecular toolkit much like the one animals use to give their cells different roles, scientists report online October 13 in *Developmental Cell*.

"Animals are regarded as this very special branch, as in, there had to be so many innovations to be an animal," says David Booth, a biologist at the University of California, Berkeley. But this research shows "a lot of the machinery was there millions of years before animals evolved."

Multicellular organisms send messages between their cells and direct the cells to particular roles. The *Capsaspora owczarzaki* amoeba uses many of the same tricks to switch its single-celled body between different life stages. The earliest animals were probably "recycling mechanisms that were already present before," says Iñaki Ruiz-Trillo of the Institute of Evolutionary Biology in Barcelona.

C. owczarzaki has three life stages, acting independently in some stages and aggregating with other amoebas in others. Ruiz-Trillo and colleagues analyzed *C. owczarzaki*'s proteome — its complete set of proteins — during each life stage.

The amoeba made different amounts of proteins in each stage, suggesting that it was responding to new demands. It also shifted the way its proteins behaved.

Proteins can change behavior by grabbing on to a molecular fragment called a phosphate ion. The phosphate ion's effect depends on where it sticks to the protein and whether other phosphate ions are stuck on nearby. *C. owczarzaki* showed differences in the pattern of these add-ons between its life stages. In animals, proteins in different organs in the same individual show similar modifications.

The researchers also found changes in the molecules that control the protein modification process. Certain enzymes in a cell act like molecular concierges, helping phosphate ions latch on to proteins. The enzyme often determines where the ion sticks — and thus its effect. For instance, enzymes called tyrosine kinases often guide modifications that help send messages between cells. Those enzymes aren't thought to be widely used by single-celled species, says study coauthor Eduard Sabidó of the Centre for Genomic Regulation in Barcelona. But *C. owczarzaki* uses these enzymes across its life stages, generating them in different quantities depending on the stage.

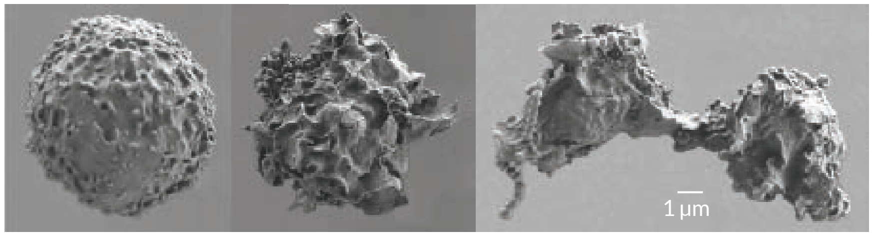
The shared molecular mechanisms suggest that the unicellular common ancestor of animals and *C. owczarzaki* probably used these same tricks, too, paving the way for multicellular life. ■

NICOLLE RAGER FULLER/SAYO ART FOR UT AUSTIN

BODY & BRAIN

Strep B pigment attacks placenta

Bacterial weapon pokes holes in immune cells, study shows



In a study of pregnant monkeys, toxic pigment made by Strep B bacteria destroyed infection-fighting cells called neutrophils (healthy neutrophil, left; one exposed to a pigmented strain of Strep B, middle; one exposed to a hyperpigmented strain, right).

BY RACHEL EHRENBERG

A type of bacteria that can cause stillbirth and fatal illness in newborns attacks with an unlikely weapon: an orange pigment made of fat.

This pigment mutilates infection-fighting immune system cells, enabling the bacteria — Group B *Streptococcus* — to quickly cross the placenta and invade the amniotic sac, a new study in monkeys shows. In one case, it took as little as 15 minutes for the bacteria to cross the protective membrane, researchers report October 14 in *Science Immunology*.

"That's shocking," says Kristina Adams Waldorf, a coauthor and an obstetrics and gynecology specialist at the University of Washington in Seattle. "The poor placenta has no time to control the invasion."

Strep B bacteria are an often harmless part of the gastrointestinal tract and vaginal flora. But during pregnancy, the bacteria can cause preterm labor, stillbirth and life-threatening infections.

Previous work conducted by study coauthor Lakshmi Rajagopal, a microbiologist at Seattle Children's Research Institute, found that strains of Strep B isolated from the amniotic fluid of women who went into preterm labor made an orange pigment. Experiments in lab dishes revealed that these pigmented strains were especially good at invading the placenta. But experiments with placental tissue in the lab are often muddied by antibiotics the mother takes during labor to prevent passing an infection to her baby. And researchers don't want to conduct invasive tests on pregnant women. So it was unclear how Strep B infections progressed or how neutrophils, the mother's immune system cells, responded to the bacteria.

"Neutrophils are the first line of defense," says Adams Waldorf. "If a placenta can't rely on its neutrophils to get rid of infection, it's really in trouble."

The researchers studied the progression of infection in macaques. Ten pregnant monkeys got a strain of Strep B that either made the pigment or didn't. (Five other monkeys got saline solution.)

Two monkeys exposed to pigment-free Strep B had a problematic pregnancy. But all of the monkeys exposed

HUMANS & SOCIETY

Apes recognize others' false beliefs

Animals anticipate person's thoughts and actions, scientists say

BY BRUCE BOWER

Apes understand what others believe to be true. What's more, they realize that those beliefs can be wrong, researchers say. To make this discovery, the researchers devised experiments involving a gorilla-suited person or a squirreled-away rock that had been moved from their original hiding places — something the apes knew, but a person called in to look for King Kong or the stone didn't.

"Apes anticipated that an individual would search for an object where he last saw it, even though the apes knew that the object was no longer there," says study coauthor Christopher Krupenye.

If this first-of-its-kind finding holds up, it means that apes can understand that others' actions sometimes reflect mistaken assumptions about reality. The ability of apes to grasp others' false beliefs roughly equals that of human 2-year-olds tested in much the same way, say Krupenye, of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, and colleagues.

Based on their targeted gazes during brief experiments, apes must rapidly assess others' beliefs about the world in wild and captive communities, the researchers propose in the Oct. 7 *Science*. Understanding the concept of false beliefs may help chimpanzees, for instance, deceive their comrades by hiding food from those who don't share, Krupenye suggests.

Experiments included 41 apes (chimps, bonobos and orangutans) born in captivity and living in open enclosures in Germany and Japan. Apes watched two videos. In one, a person in a King Kong suit hides in one of two haystacks while a man watches. After the man leaves, King Kong runs away. Then the man returns to look for King Kong. In a second video, a man returns for a stone that King Kong stole and hid in one of two boxes while the man watched. During the man's absence, King Kong runs off with the stone or moves it from one box to the other.

A camera equipped with an eye-tracking sensor revealed that, when the man in the videos returned, apes usually looked first at where King Kong or the stone had initially been hidden. They also spent more time looking at those initial locations than at other spots. Those behaviors indicate that the apes assumed the man would return to where he had last seen what he was looking for. Of 29 animals that viewed both videos, gazes of 23 indicated that they expected the man in one or both scenarios to hold a false belief, the researchers say.

E. BOLDENOW *ET AL*/*SCIENCE IMMUNOLOGY* 2016

Watch apes track others' false beliefs at **bit.ly/SN_ape** to the pigmented Strep B had problems. Four went into preterm labor; the fifth had an emergency C-section after researchers found discolored amniotic fluid indicating an infection.

Neutrophils flooded the sites of infection, but to no avail. Strep B's pigment, a chain of fat attracted to cell membranes, poked holes in the neutrophils. The pigment "inserts in random places, disfiguring the membrane," Rajagopal says. Neutrophils normally expel their innards, ensnaring invaders in a mess of DNA and chromatin, but the traps were ineffective against the pigmented bacteria.

Maria Gloria Dominguez-Bello of the New York University School of Medicine says that this "beautiful, elegant study" raises a lot of questions, such as how Strep B can go from harmless to dangerous.

Other recent work found that some Strep B strains emit toxic sacs that are associated with stillbirth in mice (*SN: 10/1/16, p. 11*). But the pigment seems to be the bacteria's primary weapon, the authors of the new paper argue. ■

Krupenye's team shows for the first time that a nonhuman animal can track others' false beliefs, says psychologist Amanda Seed of the University of St. Andrews in Fife, Scotland. But it has yet to be demonstrated that apes, like humans, can act on such knowledge, say, by hiding food from others, she says.

Laurie Santos, a psychologist at Yale University, isn't so sure apes track false beliefs. Previous research has consistently indicated that no nonhuman animals monitor others' beliefs, even on tasks similar to those used by Krupenye's team, Santos says. In the new study, she adds, apes may have realized that an observer was ignorant about an object's new location but not that he had false expectations about where to find it.

Krupenye disagrees: "The apes specifically anticipated that the actor in the video would search for an object where we humans know the actor falsely believed the object to be." ■

LIFE & EVOLUTION

Jumping spider hears distant sounds

Arachnid can detect airborne noise from across a room

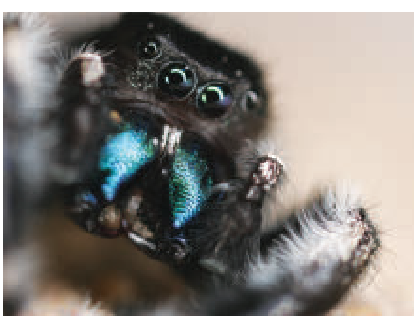
BY SUSAN MILIUS

Accidental chair squeaks in a lab have tipped off researchers to a new world of eavesdroppers.

Spiders don't have eardrums, though their exquisitely sensitive leg hairs pick up vibrations humming through solids like web silk. Biologists thought airborne sounds more than a few centimeters away would be inaudible. But the first recordings of auditory nerve cells firing inside a spider brain suggest that the *Phidippus audax* jumping spider picks up airborne sounds from at least three meters away, says Ronald Hoy of Cornell University.

During early sessions of spider brain recordings, Hoy's colleagues saw bursts of nerve cell, or neuron, activity when a chair moved. Systematic experiments then showed that from several meters away, the spiders detected relatively quiet tones at levels comparable to human conversation. In a hearing test based on behavior, the spiders also clearly noticed when researchers broadcast a low droning like the wing sound of a predatory wasp. In an instant, the spiders hunkered down motionless, the researchers report online October 13 in *Current Biology*.

Jumping spiders have brains about the size of a poppy seed. Hoy credits the success of probing even tinier spots inside these (anesthetized) brains to coauthor Gil Menda, also of Cornell. When Menda realized the spider brain reacted to a chair squeak, he and Paul Shamble, a



G. MENDA/HOY LAB AT CORNELL

Jumping spiders (*Phidippus audax*, shown) can hear airborne sounds from several meters away, new experiments suggest.

coauthor now at Harvard, started clapping hands, backing away from the spider and clapping again. The claps didn't seem earthshaking, but the spider's brain registered clapping even when the researchers had backed out into the hallway.

Clapping or other test sounds might confound the experiment by sending vibrations through equipment holding the spider. So the researchers did their neuron observations on a table protected from vibrations. They also took the setup to an echo-dampened chamber in the lab of coauthor Ronald Miles at Binghamton University in New York.

Tests revealed a narrow, low-pitched range of special sensitivity for the spiders. They pick up rumbly tones pitched around 70 to 200 hertz, Hoy says; people hear best between 500 and 1,000 hertz.

Spiders may hear low rumbles much as they do web vibes: with specialized leg hairs, Hoy and colleagues propose. They found that making a hair twitch could cause a sound-responsive neuron to fire.

"There seems to be no physical reason why a hair could not listen," says Jérôme Casas of the University of Tours in France. When monitoring nerve response from hairs on cricket legs, he's tracked airplanes flying overhead. Hoy's team calculates that an 80 hertz tone the spiders responded to would cause air velocities of only 0.13 millimeters a second if broadcast at 65 decibels three meters away. That's hardly a sigh of a breeze. Yet it's above the threshold for leg hair response, says Friedrich Barth of the University of Vienna, who studies spider senses.

Eons of attacks from wasps might have been an evolutionary pressure favoring such sensitivity, Hoy says. If detecting wasp wing drone turns out to have been important in the evolution of hearing, other spiders vulnerable to wasps might do long-distance eavesdropping, too, says Ximena Nelson of the University of Canterbury in Christchurch, New Zealand. ■

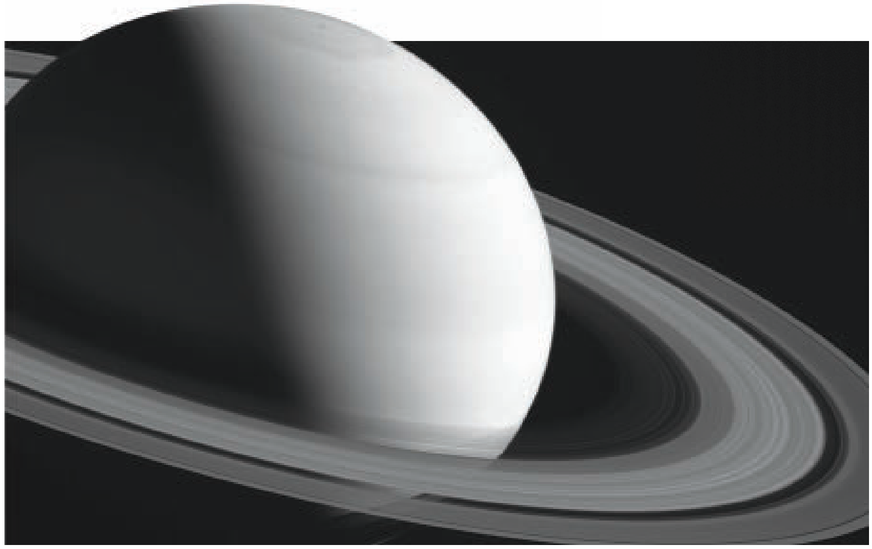
Watch a spider respond to threatening sounds at **bit.ly/SN_jumpingspider**

ATOM & COSMOS

Age of Saturn's rings debated

Data from Cassini spacecraft may help resolve argument

BY CHRISTOPHER CROCKETT



Saturn's rings, seen in this March 19 image from the Cassini spacecraft, could be as old as the planet itself or a more recent addition that formed in the last 100 million years.

JPL-CALTECH/NASA, SSI

Saturn's rings have maintained a youthful look, while still possibly being almost as old as the solar system itself. The dazzling belts of ice and debris continue to keep their age a secret, but researchers hope to get answers from a spacecraft orbiting the ringed planet.

Data from the Cassini spacecraft, in orbit since 2004, may help resolve a decades-long debate over the age of Saturn's rings. They may be primordial, dating back to roughly 4.6 billion years ago, or a recent addition in the last 100 million years or so. Evidence for both scenarios was presented October 17.

There's not enough pollution in the rings for them to have been around for a long time, argued planetary scientist Paul Estrada of the SETI Institute in Mountain View, Calif. Cassini data show that about 25 times as much debris — mostly from the Kuiper belt beyond Neptune — rains down on the rings than previously thought. All that interplanetary rain should not just darken the rings, but each impact should redistribute material as well. Sharp contrasts in composition seen at the inner edge of the main ring could not have been sustained for more than a few hundred million years, Estrada said.

The trouble with making rings so recently is how to do it. "It's hard to make rings in the last 100 million years," said Larry Esposito, a planetary scientist at the University of Colorado Boulder. "This is not an exciting time." Saturn's rings were probably created after a moon or some passing icy body got torn apart in a collision or wandered too close to the planet. But there hasn't been much stuff flying around Saturn or the solar system in the last several billion years.

Esposito argued that despite some youthful appearances, the rings are ancient and recycle material lurking beneath their top layers, keeping the pollution levels lower than expected. Also, some lightweight rings could have formed quite recently and still look pristine, he said, while the most massive part of the rings endured for billions of years.

Part of the solution to the age question is knowing how massive the rings are. Some observations from spacecraft suggest that the rings are relatively hefty — possibly comparable in mass to Saturn's moon Mimas (although those observations are not definitive). "It's a lot easier to make a massive ring if you make it early," said Glen Stewart, also at Colorado Boulder. Billions of years ago, more material was available to make a heavy ring than in recent times.

A lightweight ring could have formed more recently, however. Computer simulations suggest that the orbits of moons around Saturn could have changed a lot in the last several hundred million years or so, Estrada said. Those shifting orbits could lead to several different scenarios in which moons destroy one another, creating icy debris that spreads out and forms the rings.

In the coming year, this debate could be moot. Leading up to the end of Cassini's mission next September, the spacecraft is going to start some daring maneuvers to try and measure how much mass is in the rings. Cassini will dive between the planet and the rings several times, skimming Saturn's atmosphere. "This is kamikaze stuff," Stewart said. "For the first few orbits, they're putting the antenna forward as an impact shield."

By getting inside the rings, researchers can measure the gravitational tug on the spacecraft from the planet and compare that with earlier orbits where both the planet and the rings tugged on the probe. And more than scientific curiosity is on the line. "On the Cassini mission, there's a betting pool about the mass of the rings," Esposito said.

Figuring out the mass and age of Saturn's rings isn't just about solving one mystery about one aspect of one planet. Understanding how Saturn became bejeweled might offer insight into why other planets differ from one another, which in turn could reveal more details about their origins. "Why does Saturn have big rings but Jupiter doesn't?" asked Esposito. "Is it just a matter of luck, or a matter of time?"

And rings aren't unique to planets; they form around stars as well. Belts of ice and dust encircling young stars are thought to be where planets form throughout the universe. The disk that formed our solar system is long gone, Esposito said, but the physics underlying both that disk and the one around Saturn are largely the same. Understanding one can help researchers understand the other. ■

MEETING NOTES

Possibly cloudy forecast for Pluto

The forecast on Pluto is clear with less than a 1 percent chance of clouds. Images from the New Horizons spacecraft show hints of what could be a few isolated clouds scattered around the dwarf planet, the first seen in otherwise clear skies.

Seven cloud candidates appear to hug the ground in images taken shortly after the probe buzzed by the planet in July 2015. Along the line where day turns to night, several isolated bright patches appear. These are consistent with clouds forming at sunset and sunrise, mission head Alan Stern said in an October 18 news conference.

If they are clouds, they're probably made of ethane, acetylene or hydrogen cyanide, based on what researchers have learned about Pluto's atmosphere. But they might not be clouds, just reflective splotches on the surface, said Stern, of the Southwest Research Institute in Boulder, Colo. Without stereo imaging, it's impossible to tell how high off the ground the patches are, or whether they're in the sky at all.

Since New Horizons isn't returning to Pluto — it's hurtling deep into the Kuiper belt — the spacecraft won't be able to take another look at the cloud candidates and answer these questions. That will have to wait until another spacecraft goes to Pluto, Stern said.

— Christopher Crockett

Lava may flow from Venus volcano

Venus hosts a hellish landscape with stifling temperature and suffocating pressure — and, a new study hints, possibly rivers of lava oozing out of a volcano.

Several lava flows appear to be recently or currently active on a Venusian volcano known as Idunn Mons, planetary scientist Piero D'Incecco reported October 17. Hot spots first detected by the Venus Express spacecraft, which orbited the planet from 2006 to 2015, had already hinted that the volcano might be active. But Venus guards its secrets tightly. Orbiters have trouble peering through the thick clouds that blanket the planet, and landers don't last long because of the extreme environment.

Since Venus Express couldn't see the source of the heat, the researchers combined its data with maps from the Magellan spacecraft, which orbited from 1990 to 1994, and computer simulations to figure out how Idunn Mons could create the hot spots. D'Incecco, of the German Aerospace Center Institute of Planetary Research in Berlin, and colleagues deduced that five lava flows are responsible for the heat.

Future spacecraft could collect direct evidence of whether Idunn Mons, or anywhere else on Venus, is belching lava. Both NASA and the European Space Agency are considering proposals for several Venus orbiters that could visit sometime in the next decade.

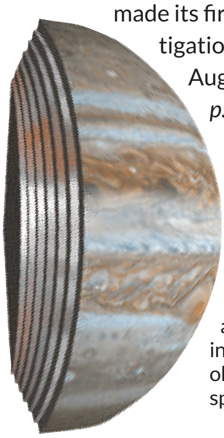
— Christopher Crockett

First peek under clouds reveals Jupiter's surprising depths

Jupiter's clouds have deep roots. The multicolored bands that wrap around the planet reach hundreds of kilometers down into the atmosphere, NASA's Juno spacecraft reveals, providing an unprecedented peek into the planet's interior.

"Whatever's making those colors and stripes still exists pretty far down," Scott Bolton, head of the Juno mission, said in a news conference October 19. "That came as a surprise." Until now, researchers weren't sure if Jupiter's stripes were just blemishes atop the clouds or extended farther inward. The bands reach at least 350 to 400 kilometers beneath the cloud deck, Bolton reported.

Juno arrived at Jupiter on July 4, then made its first up-close investigation of the planet on August 27 (*SN: 10/1/16, p. 13*). Coming within 5,000 kilometers of the cloud tops, Juno recorded the intensity of radio waves emanating from the planet. Different frequencies come from different depths; low frequencies originate from deep in the atmosphere while high frequencies originate higher up.



Cloud bands seen on Jupiter extend hundreds of kilometers down into the atmosphere, as seen in this depiction of data obtained by the Juno spacecraft.

JPL-CALTECH/NASA, SWRI, GSFC/NASA

"Deep down, Jupiter is similar but also very different than what we see on the surface," said Bolton, of the Southwest Research Institute in San Antonio. Some bands broaden while others vanish. "We can't tell what all of it means yet, but it's telling us hints about the deep dynamics and chemistry of Jupiter's atmosphere."

— Christopher Crockett

Comet 67P cracking under pressure

It's hard being a comet sometimes.

Comet 67P/Churyumov–Gerasimenko is developing stress fractures and might completely crack in the next several hundred years.

Comet 67P is famous for its oddball shape. With two lobes joined together at a neck, it vaguely resembles an interplanetary peanut. The Rosetta spacecraft, which ended its 26-month visit to the comet in September (*SN Online: 9/29/16*), noticed a large crack in the neck in 2014. After the comet made its closest approach to the sun in August 2015, the fissure grew by several hundred meters and new cracks appeared.

The fractures appear to be developing as forces subtly bend the comet to and fro, Stubbe Hviid, a planetary scientist at the German Aerospace Center Institute of Planetary Research in Berlin, reported October 17 in a news conference.

Hviid and colleagues combined maps from Rosetta with computer simulations of all the forces at work within the comet to determine how the cracks develop. They found that the two bulbous ends rock in opposite directions as the comet spins, flexing the neck and creating severe stress. Because the comet isn't held together strongly — it's a conglomeration of dust and ice not much stickier than snow, Hviid said — the neck is starting to break. After a few hundred more years, he said, the comet could fold itself in half as the two lobes snap apart and smoosh together. *— Christopher Crockett*

EARTH & ENVIRONMENT

Deep earthquakes surprise scientists

New type of weak temblor in upper mantle detected

BY THOMAS SUMNER

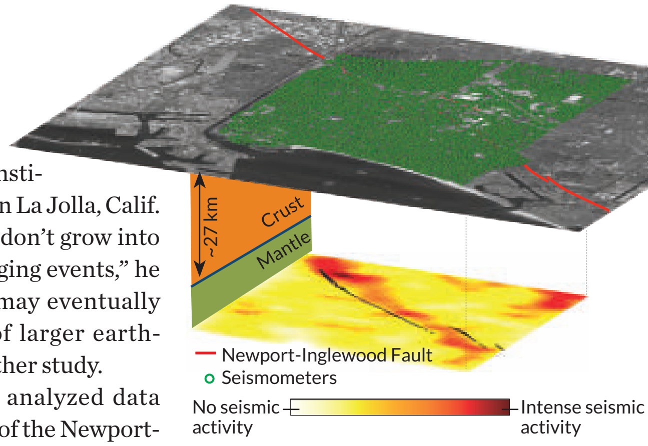
Mysterious earthquakes rattle deep beneath Southern California.

The tiny quakes originate from tens of kilometers below ground along the Newport-Inglewood Fault near Long Beach, seismologists report in the Oct. 7 *Science*. Rocks at that depth should be too hot and malleable to snag and break — a key mechanism behind earthquakes. Some unknown process must be at play, says study coauthor Asaf Inbal of Caltech.

The quakes don't pose a direct threat, says Yuri Fialko, a geophysicist at the Scripps Institution of Oceanography in La Jolla, Calif. "They remain small and don't grow into bigger, potentially damaging events," he says. Still, the quakes "may eventually lead to the triggering of larger earthquakes" and warrant further study.

Inbal and colleagues analyzed data from a six-month survey of the Newport-Inglewood Fault in 2011 that deployed about 5,300 seismometers in the area. Combining data from another, smaller survey in 2013 amplified faint quake signals above background noise, such as passing trucks and landing planes. The deepest newfound quakes, no bigger than magnitude 2, come from Earth's upper mantle at depths of about 30 kilometers — far below the conventional seismically active zone. At these depths, rocks should flow when under stress, rather than accumulating strain and breaking.

The researchers propose that upper mantle fluids flow into the fault and provide a source of high pressure that extends the depth of seismic activity. ■



Deep rumbling A dense network of seismometers around Long Beach, Calif., picked up small, unusually deep earthquakes along the Newport-Inglewood Fault, at a depth of about 27 to 32 kilometers.

MATTER & ENERGY

Physicists make 'time crystal' in lab

Flipped ions demonstrate new form of symmetry breaking

BY EMILY CONOVER

It may sound like science fiction, but it's not: Scientists have created the first time crystal, using a chain of ions. Just as a standard crystal repeats in a regular spatial pattern, a time crystal repeats in time, returning to a similar configuration at regular intervals.

"This is a remarkable experiment," says physicist Chetan Nayak of Microsoft's Station Q Santa Barbara in California.

Scientists at the University of Maryland and the University of California, Berkeley created a chain of 10 ytterbium ions, each with a spin (the quantum version of angular momentum) pointing up or down. A laser flipped the spins halfway around, from up to down; the ions then interacted so each spin influenced the others.

At regular intervals, the researchers repeated this sequence, flipping the ions halfway each time and letting them interact. When the scientists measured the ions' spins, on average the ions went full circle, returning to their original states, in twice the time interval at which they were flipped halfway.

This behavior is sensible: If each flip turns something halfway around, it takes two flips to return to the original position. But the ions' spins returned to their initial orientation at that rate even if they weren't flipped perfectly halfway. That indicates that the ion system responds at a certain regular period, the hallmark of a time crystal, just as atoms in a crystal prefer regular spacing. These time crystals are "one of the first examples of a new phase of matter," says UC Berkeley's Norman Yao, a coauthor of the study, posted online September 27 at arXiv.org.

Time crystals take an important unifying concept in physics — the idea of symmetry breaking — and extend it to time. Physical laws typically treat all points in space equally. In a liquid, atoms are equally likely to be found at any point in space. This is a continuous symmetry, as the conditions are the same at any point along the spatial continuum. If the liquid solidifies into a crystal, that symmetry is broken: Atoms are found only at certain regularly spaced positions, with voids in between. If you rotate a crystal, on a microscopic level it would look different from different angles. But liquid will look the same however it's rotated.

In 2012, MIT theoretical physicist Frank Wilczek proposed that symmetry breaking in time might produce time crystals (*SN: 3/24/12, p. 8*). Follow-up work indicated that time crystals couldn't emerge in a system in a state of equilibrium. But driven systems, which are periodically perturbed by an external force — like the laser flipping the ions — could create such crystals.

Unlike the continuous symmetry that is broken in the transition from a liquid to a solid crystal, in the driven systems of the time crystals, the symmetry is discrete, appearing at time intervals corresponding to the time between perturbations. If the system repeats at a longer time interval than the one it's driven at, as the time crystal does, that symmetry is broken.

Physicists don't yet have a handle on time crystals' potential applications. But, Wilczek says, "I don't think we've heard the last of this by a long shot." ■

Editor's note: Frank Wilczek is on the Board of Trustees of Society for Science & the Public, which publishes Science News.

A. INBAL

GENES & CELLS

DNA data point to unknown hominid

Melanesians carry clues to ancestor not revealed by fossils

BY TINA HESMAN SAEY

Traces of long-lost human cousins may be hiding in modern people's DNA, a new computer analysis suggests.

People from Melanesia, a South Pacific region encompassing Papua New Guinea and surrounding islands, may carry genetic evidence of a previously unknown extinct hominid, Ryan Bohlender reported October 20. That species is probably not Neandertal or Denisovan, but a different, related hominid group, said Bohlender, a statistical geneticist at the University of Texas MD Anderson Cancer Center in Houston. "We're missing a population or we're misunderstanding something about the relationships."

This mysterious relative was probably from a third branch of the hominid family tree that produced Neandertals and Denisovans, a distant cousin of Neandertals. While many Neandertal fossils have been found in Europe and Asia, Denisovans are known only from DNA from a finger bone and teeth found in a Siberian cave (*SN: 12/12/15, p. 14*).

Bohlender isn't the first to suggest that remnants of archaic human relatives may have been preserved in human DNA even though no fossil remains have been found. In 2012, another group suggested some people in Africa carry DNA heirlooms from an unknown extinct hominid species (*SN: 9/8/12, p. 9*).

Less than a decade ago, scientists discovered that human ancestors mixed with Neandertals. People of non-African descent still carry a small amount of Neandertal DNA: Bohlender's team calculates that European and Chinese people carry about 2.8 percent. Europeans have no hint of Denisovan ancestry, and people in China have a tiny amount — 0.1 percent, according to Bohlender. But 2.74 percent of the DNA in people in Papua New Guinea comes from Neandertals. And Melanesians have about 1.11 percent Denisovan DNA, Bohlender estimates, not the 3 to 6 percent estimated by other researchers. While investigating the Denisovan discrepancy, Bohlender and colleagues came to the conclusion that a third group of hominids may have bred with the ancestors of Melanesians.

Another group of researchers, led by Eske Willerslev, an evolutionary geneticist at the Natural History Museum of Denmark in Copenhagen, recently came to a similar conclusion. The group examined DNA from 83 aboriginal Australians and 25 people from native populations in the Papua New Guinea highlands (*SN: 10/15/16, p. 6*). Denisovan-like DNA was found in the study volunteers, the researchers reported in the Oct. 13 *Nature*. But the DNA is distinct from Denisovans and may be from another extinct hominid. That hominid could be *Homo erectus* or the extinct hominids found in Indonesia known as hobbits (*SN: 4/30/16, p. 7*), Willerslev speculates.

But researchers don't know how genetically diverse Denisovans were, says Mattias Jakobsson, an evolutionary geneticist at Uppsala University in Sweden. A different branch of Denisovans could be the group that mated with ancestors of Australians and Papuans.

Statistical geneticist Elizabeth Blue of the University of Washington in Seattle agrees that so little is known about the genetic makeup of extinct groups that it's hard to say whether the extinct hominid DNA actually came from an undiscovered species. DNA has been examined from few Neandertal fossils, and Denisovan remains have been found only in that single cave in Siberia. Denisovans may have been widespread and genetically diverse. If so, Blue says, the Papuans' DNA could have come from a Denisovan population that had been separated from the Siberian Denisovans for long enough that they looked like distinct groups, much as Europeans and Asians today are genetically different from each other. ■

MEETING NOTE

Zika disrupts cellular processes to impair brain development

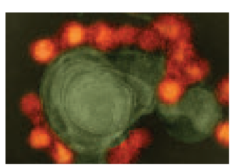
Zika virus's tricks for interfering with human brain cell development may also be the virus's undoing.

Zika infection interferes with DNA replication and repair machinery and also prevents production of some proteins needed for proper brain growth, geneticist Feiran Zhang of Emory University in Atlanta reported October 19.

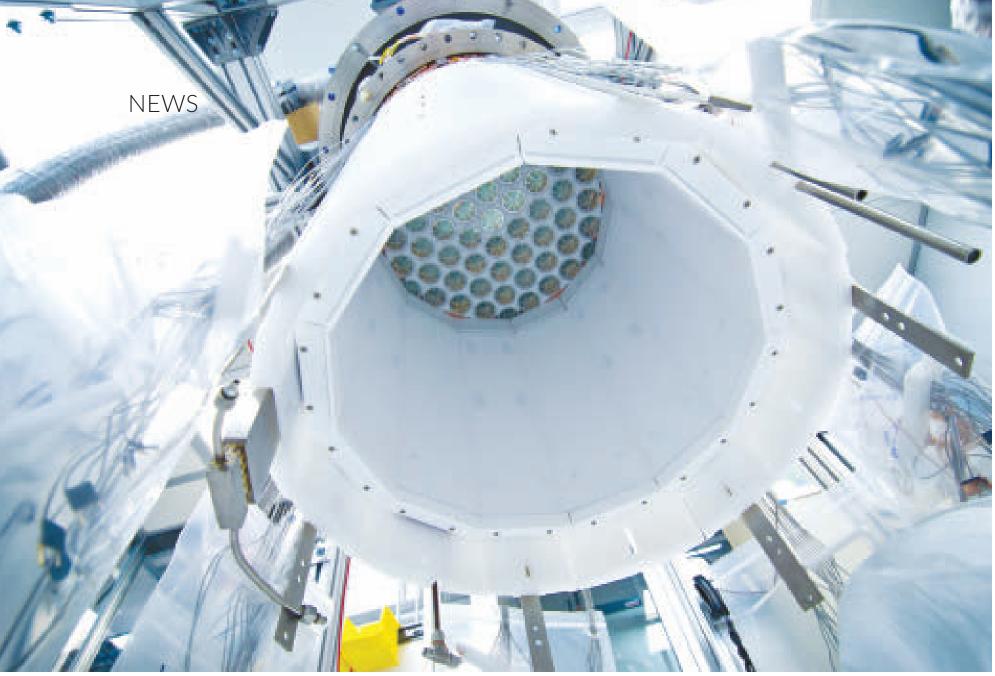
Levels of a protein called p53, which helps control cell growth and death, shot up by 80 percent in human brain cells infected with the viral strain responsible for the Zika epidemic in the Americas, Zhang said. The lab dish results are also reported in the Oct. 14 *Nucleic Acids Research*. Increased p53 levels stop developing brain cells from growing and may cause them to commit suicide.

A drug that inactivates p53 stopped brain cells from dying, Zhang said. Such inhibitors could help protect brains in babies infected with Zika. But researchers would need to be careful: Too little p53 can lead to cancer.

Zika also makes small RNA molecules that interfere with production of proteins needed for DNA replication, cell growth and brain development, Zhang said. A small viral RNA, *vsRNA-21*, reduced the amount of microcephalin 1 protein made in human brain cells in lab dishes. The researchers confirmed the results in mouse experiments. A lack of that protein causes the small heads seen in babies with microcephaly. Inhibitors of the viral RNAs might also be used in therapies, Zhang suggested. — *Tina Hesman Saey*



New research on the Zika virus (red) may lead to ways to stop its effects on developing brains.



C.H. FAHAM

The LUX detector in South Dakota has failed to detect dark matter through interactions with liquid xenon. A souped-up version of the experiment, known as LZ, is scheduled to continue the search in 2020.

ATOM & COSMOS

Dark matter searches come up empty

Physicists broaden efforts to identify bulk of universe's mass

BY EMILY CONOVER

Scientists have lost their latest round of hide-and-seek with dark matter, but they're not out of the game.

Despite overwhelming evidence that an exotic form of matter lurks unseen in the cosmos, decades of searches have failed to definitively detect a single particle of dark matter. While some scientists continue down the road of increasingly larger detectors designed to catch the particles, others are beginning to consider a broader landscape of possibilities for what dark matter might be.

"We've been looking where our best guess told us to look for all these years, and we're starting to wonder if we maybe guessed wrong," says theoretical astrophysicist Dan Hooper of Fermilab in Batavia, Ill. "People are just opening their minds to a wider range of options."

Dark matter permeates the cosmos: The material keeps galaxies from flying apart and has left its imprints in the universe's oldest light, the cosmic microwave background, which dates back to just 380,000 years after the Big Bang. Indirect evidence from dark matter's gravitational influences shows that it makes up the bulk of the universe's mass. But scientists can't pin down what dark matter is without detecting it directly.

In new results published in August and September, three teams of scientists came up empty-handed, finding no hints of dark matter. The trio of experiments searched for one particular variety of dark matter — hypothetical particles known as WIMPs, or weakly interacting massive particles, with a range of possible masses that starts at several times that of a proton. WIMPs, despite their name, are dark matter bigwigs — they have long been the favorite explanation for the universe's missing mass. WIMPs are thought to interact with normal matter only via the weak nuclear force and gravity.

Part of WIMPs' appeal comes from a prominent but unverified theory, supersymmetry, which independently predicts such particles. Supersymmetry posits that each known elementary particle has a heavier partner; the lightest partner particle could be a dark matter WIMP. But evidence for supersymmetry hasn't materialized in particle collisions at the Large Hadron Collider in Geneva, so supersymmetry's favored status is eroding (*SN: 10/1/16, p. 12*). Supersymmetry arguments for WIMPs are thus becoming shakier — especially since WIMPs aren't showing up in detectors.

Scientists typically search for WIMPs by looking for interactions with normal matter inside a detector. Several current experiments use tanks of liquefied xenon, an element found in trace amounts in Earth's atmosphere, in hopes of detecting the tiny amounts of light and electric charge that would be released when a WIMP strikes a xenon nucleus and causes it to recoil.

The three xenon experiments are the Large Underground Xenon, or LUX, experiment, located in the Sanford Underground Research Facility in Lead, S.D.; the PandaX-II experiment at China's JinPing underground laboratory in Sichuan; and the XENON100 experiment, located in the Gran Sasso National Laboratory in Italy. All three teams of scientists have reported no signs of dark matter particles. The experiments are most sensitive to particles with masses around 40 or 50 times that of a proton. Scientists can't completely rule out WIMPs of these masses, but the interactions would have to be exceedingly rare.

In initial searches, proponents of WIMPs expected that the particles would be easy to find. "It was thought to be like, 'OK, we'll run the detector for five minutes, discover dark matter, and we're all done,'" says LUX team member Matthew Szydagis, a physicist at the University at Albany in New York. That has turned into decades of hard work. As WIMPs keep failing to turn up, some scientists are beginning to become less enamored with the particles and are considering other possibilities more closely.

One alternative contender now attracting more attention is the axion. This particle was originally proposed decades ago as part of the solution to a particle physics quandary known as the strong CP problem — the question of why the strong nuclear force, which holds particles together inside the nucleus, treats matter and antimatter equally. If dark matter consists of axions, the particle could therefore solve two problems at once.

Axions are small fry as dark matter goes — they can be as tiny as a millionth of a billionth the proposed mass of a WIMP. The particles interact so feebly that they are extremely difficult to detect. If axions are dark matter, "you're sitting in an enormous, dense sea of axions, and you don't even notice them," says physicist Leslie Rosenberg of the University of Washington in Seattle, the leader of ADMX, for Axion Dark Matter eXperiment. After a recent upgrade to the experiment, ADMX scientists are searching for dark matter axions using a magnetic field and special equipment to coax the particles to convert into photons, which can then be detected.

Although WIMPs and axions remain the front-runners, scientists are beginning to move beyond these two possibilities. In between the featherweight axions and hulking WIMPs lies a broad range of masses that hasn't been well explored. Scientists' favorite theories don't predict dark matter particles with such intermediate masses, says theoretical physicist Kathryn Zurek of Lawrence Berkeley National Laboratory in California, but that doesn't mean that dark matter couldn't be found there. Zurek advocates a diverse search over a broad range of masses, instead of focusing on one particular theory. "Dark matter direct detection is not one size fits all," she says.

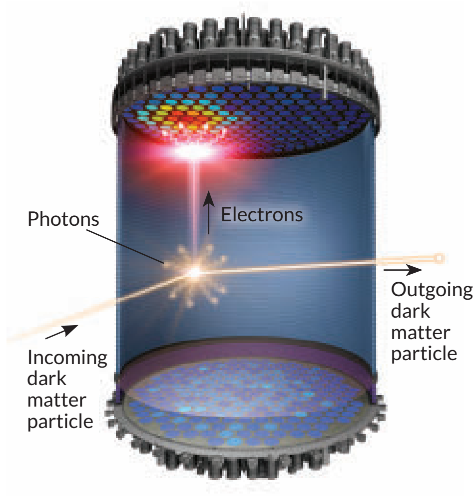
In two papers published in *Physical Review Letters* on January 7 and September 14, Zurek and colleagues proposed using superconductors — materials that allow electricity to flow without resistance — and superfluids, which allow fluids to flow without friction, to detect low-mass dark matter particles. "We are trying to broaden as much as possible the tools to search for dark matter," Zurek says. Likewise, scientists with the upcoming Super Cryogenic Dark Matter Search SNOLAB experiment, to be located in an underground lab in Sudbury, Canada, will use detectors made of germanium and silicon to search for dark matter with smaller masses than the xenon experiments can.

Scientists have not given up on xenon WIMP experiments. Soon some of those experiments will be scaling up — going from hundreds of kilograms of liquid xenon to tons — to improve their chances of catching a dark matter particle on the fly. The next version of XENON100, the XENON1T experiment (pronounced "XENON one ton") is nearly ready to begin taking data. LUX's next-generation experiment, known as LUX-ZEPLIN or LZ, is scheduled to begin in 2020. PandaX-II scientists are also planning a sequel. Physicists are still optimistic that these detectors will finally find the elusive particles. "Maybe we will have some opportunity to see something nobody has seen," says PandaX-II leader Xiangdong Ji of Shanghai Jiao Tong University. "That's what's so exciting."

Scientists have indirectly detected dark matter (depicted by blue in this cluster of galaxies) through its gravitational influence, which can bend and distort the light of galaxies.

In the sea of non-detections of dark matter, there is one glaring exception. For years, scientists with the DAMA/LIBRA experiment at Gran Sasso have claimed to see signs of dark matter, using crystals of sodium iodide. But other experiments have found no signs of DAMA's dark matter. Many scientists believe that DAMA has been debunked. "I don't know what generates the weird signal that DAMA sees," Hooper says. "That being said, I don't think it's likely that it's dark matter."

But other experiments have not used the same technology as DAMA, says theoretical astrophysicist Katherine Freese of the University of Michigan in Ann Arbor. "There is no alternative explanation that anybody can think of, so that is why it is actually still very interesting."



Nuclear recoil Xenon dark matter experiments watch for dark matter interactions that cause xenon nuclei to recoil. Such interactions would theoretically release photons and electrons, creating two consecutive bursts of light. That light would be observed by photomultiplier tubes (circles) at the top and bottom of the detector, as seen in this schematic of the LZ experiment.

Three upcoming experiments should soon close the door on the mystery, by searching for dark matter using sodium iodide, as DAMA does: the ANAIS experiment in the Canfranc Underground Laboratory in Spain, the COSINE-100 experiment at YangYang Underground Laboratory in South Korea and the SABRE experiment, planned for the Stawell Underground Physics Laboratory in Australia.

Scientists' efforts could still end up being for naught; dark matter may not be directly detectable at all. "It's possible that gravity is the only lens with which we can view dark matter," Szydagis says. Dark matter could interact only via gravity, not via the weak force or any other force. Or it could live in its own "hidden sector" of particles that interact among themselves, but mostly shun normal matter.

Even if no particles are detected anytime soon, most scientists remain convinced that an unseen form of matter exists. No alternative theory can explain all of scientists' cosmological observations. "The human being is not going to give up for a long, long time to try to search for dark matter, because it's such a big problem for us," Ji says. ■

FROM TOP: SLAC NATIONAL ACCELERATOR LAB.; NASA, ESA, D. HARVEY/EPFL, R. MASSEY/DURHAM UNIV. HST FRONTIER FIELDS

HUMANS & SOCIETY

Big Viking families nurtured murder

Killers tended to have more relatives than their victims

BY BRUCE BOWER

Murder was a calculated family affair among Iceland's early Viking settlers. And the bigger the family, the more bloodthirsty.

Data from three family histories spanning six generations support the idea that disparities in family size have long influenced who killed whom in small-scale societies. The analysis of these epic sagas, written between the years 900 and 1100, suggests that a tendency to gang up on outnumbered foes has long depended on having a surplus of relatives back home.

Iceland's Viking killers had on average nearly three times as many biological relatives and in-laws as their victims did, says a team led by evolutionary psychologist Robin Dunbar of the University of Oxford. Prolific killers responsible for five or more murders had the greatest advantage in kin numbers, the scientists report online September 20 in *Evolution and Human Behavior*.

Particularly successful killers chose victims carefully, knowing that their large families would deter revenge attacks by smaller families of the slain, the researchers contend. Land grabs may have motivated those killings. One-time killers tended to have only slightly bigger families than those of their victims; insults or goading may have led to those murders.

Strikingly, around 18 percent of all men mentioned in the sagas were murdered. Similarly high homicide rates, mainly due to cycles of revenge killing between feuding families, have been reported for some modern hunter-gatherer and village-based societies (*SN Online: 9/27/12*). Lethal raids by competing groups may go back 10,000 years or more (*SN: 2/20/16, p. 9*).

Murder rates rise in the absence of central authorities that enforce social order, Dunbar proposes. "The real issue is not that there were so many murders among Icelandic Vikings, but that murders were carefully calculated based on knowing whether one had a sufficient family advantage to take the risk."

That idea relates to mathematical formulas of fighting strength developed during World War I by British engineer Frederick Lanchester. One of these laws calculates that the fighting advantage of a larger group over a smaller one grows disproportionately as the disparity in the size of war parties increases. That rule also holds for family-size differences in small-scale societies, such as Icelandic Vikings, Dunbar's group concludes.

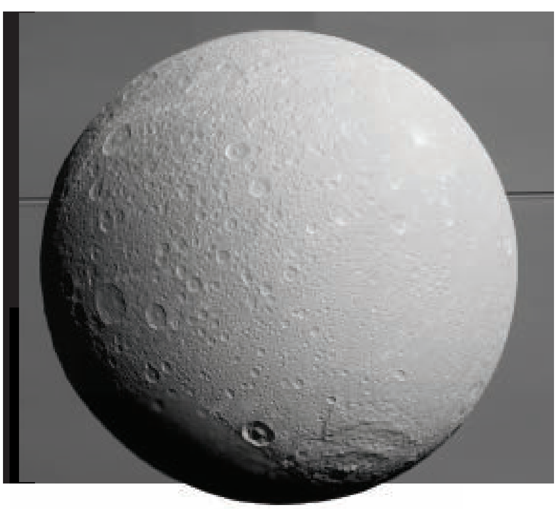
Tests of the possibility that greater kin numbers encourage lethal attacks in preindustrial groups, such as the Vikings, are rare, says Oxford evolutionary biologist and political scientist Dominic Johnson, who was not part of the new study. He has reviewed evidence suggesting that humans, chimps and social hunters such as wolves have evolved ways to monitor group sizes and launch attacks when they can gang up on a few opponents.

Dunbar's team studied three Icelandic family sagas that record everything from births and marriages to deals and feuds. For the 1,020 people mentioned in these sagas, the team identified a network of biological and in-law relationships.

Under Norse law, a murder entitled a victim's relatives to compensation, either via a revenge murder or blood money. Icelandic sagas describe the importance of avenging murdered relatives to save face and prevent further attacks, regardless of family size.

In the three sagas, a total of 66 individuals caused 153 deaths; two or more attackers sometimes participated in the same killing. No killers were biologically related to their victims (such as cousins or closer), but one victim was a sister-in-law of her killer. About two-thirds or more of killers had more biological kin on both sides of their families, and more in-laws, than their victims did.

Six men accounted for about 45 percent of all murders, each killing between five and 19 people. Another 23 individuals killed two to four people. The rest killed once. Frequent killers had many more social relationships, through biological descent and marriage, than their victims did, suggesting that they targeted members of families in vulnerable situations, the researchers say. ■



JPL-CALTECH/NASA, SSI

ATOM & COSMOS

Saturnian moon may host buried sea

A satellite of Saturn joins the club of moons with possible oceans. A subsurface sea of water might hide beneath the icy crust of Dione (shown), one of Saturn's moons, researchers report online October 9 in *Geophysical Research Letters*. That puts Dione in good company alongside Enceladus (another moon of Saturn) and several moons of Jupiter, as well as possibly Pluto (*SN Online: 9/23/16*).

Dione's ocean is about 100 kilometers below the surface and roughly 65 kilometers deep, Mikael Beuthe, a planetary scientist at the Royal Observatory of Belgium in Brussels, and colleagues report. They inferred the ocean's presence from measurements of Dione's gravity made by the Cassini spacecraft. *—Christopher Crockett*

ATOM & COSMOS

Cosmic census of galaxies updated to 2 trillion

Two trillion galaxies. That's the latest estimate for the number of galaxies that live — or have lived — in the observable universe, scientists report online October 10 at arXiv.org. This updated head count is roughly 10 times greater than previous estimates and suggests that there are a lot more galaxies out there for future telescopes to explore.

Hordes of relatively tiny galaxies, weighing as little as 1 million suns, are responsible for most of this tweak to the cosmic census. Astronomers haven't directly seen these galaxies yet. Christopher Conselice of the University of Nottingham in England and colleagues combined data from many ground- and space-based telescopes to look at how the number of galaxies in a typical volume of the universe has changed over much of cosmic history. They then calculated how many galaxies have come and gone.

The galactic population has dwindled over time, as most of those 2 trillion galaxies collided and merged to build larger galaxies such as the Milky Way, the researchers suggest. That's in line with prevailing ideas about how massive galaxies have been assembled. Looking for extremely distant galaxies, those whose light has taken most of the age of the universe to get here, could let astronomers see what these tiny galaxies were like before they merged. But that's beyond the ability of even the next generation of telescopes. "We will have to wait at least several decades before even the majority of galaxies have basic imaging," the researchers write. — *Christopher Crockett*

LIFE & EVOLUTION

Elephants walk on their tippy-toes

Elephants don't wear high heels, but they certainly walk like they do.

Foot problems plague pachyderms in captivity. But it hasn't been clear what about captivity drives these problems.

Olga Panagiotopoulou of the University of Queensland in Australia and colleagues tested walking in nearly wild elephants. The team trained five free-ranging elephants at a park in South Africa to walk over pressure-sensing platforms to map the distribution of weight on their feet. The team compared the data with similar tests of Asian elephants in a zoo in England.

Regardless of species or setting, a trend emerged: Elephants put the most pressure on the outside toes of their front feet and the least pressure on their heels, the team reports October 5 in *Royal Society Open Science*. Thus, elephants naturally walk on their tiptoes. The harder surfaces of captive environments must cramp a natural walking style, the researchers conclude. — *Helen Thompson*

Elephants develop foot problems in captivity when they tiptoe across hard surfaces, new research suggests.

BODY & BRAIN

Hot and spicy pain signals get blocked in naked mole-rats

Like Marvel's surly superhero Luke Cage, naked mole-rats are seemingly indestructible, nearly hairless creatures that are impervious to certain kinds of pain. This last power has puzzled researchers, because like other mammals, mole-rats have functional versions of a protein called TRPV1, which responds to painfully hot stimuli.

It turns out that a different protein, TrkA, is the key to the missing pain signals, Gary Lewin of the Max Delbrück Center for Molecular Medicine in Berlin and colleagues report in the Oct. 11 *Cell Reports*. Usually, TrkA detects inflammation and kicks off a molecular reaction that produces pain sensation by activating TRPV1. But naked mole-rats produce a version of TrkA that doesn't trigger this pain cascade.

That means that certain nerve cells don't become more sensitive after encountering something hot, such as capsaicin, a molecule that puts the burn in spicy peppers. Because naked mole-rats spend their time in hot African climates, the rodents might have evolved to not need the pain signals that come from heat, the authors speculate. — *Laura Sanders*

MATH & TECHNOLOGY

AI system learns like a human, stores info like a computer

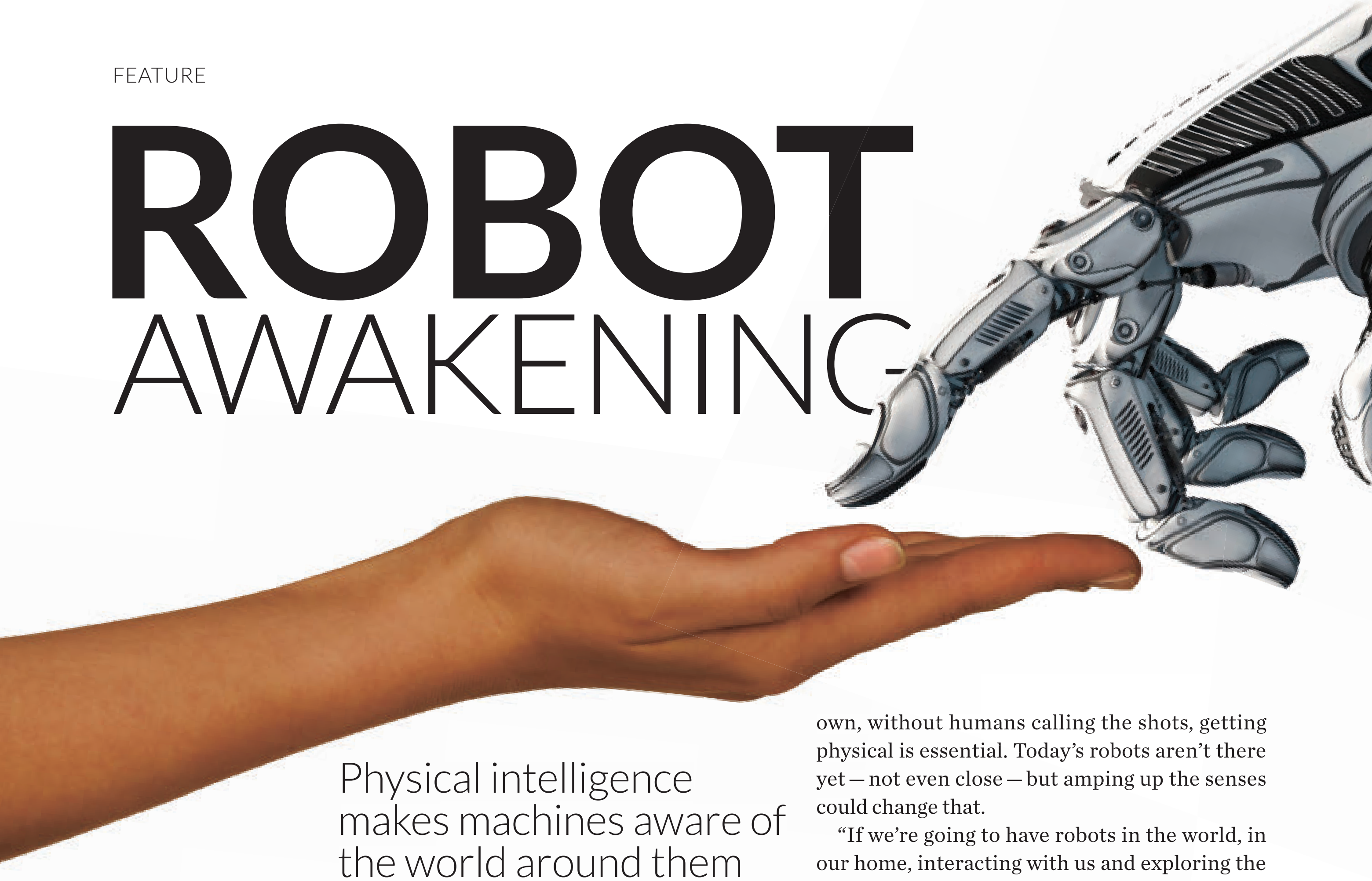
A GPS app can plan the best route between two subway stops if it has been specifically programmed for the task. But a new artificial intelligence system can figure out how to do so on the fly by learning general rules from specific examples, researchers report online October 12 in *Nature*.

Artificial neural networks, computer programs that mimic the human brain, are great at learning patterns and sequences, but so far they've been limited in their ability to solve complex reasoning problems that require storing and manipulating lots of data. The new hybrid computer links a neural network to an external memory source that works somewhat like RAM in a regular computer.

Scientists trained the computer by giving it solved examples of reasoning problems, like finding the shortest distance between two points on a randomly generated map. Then, the computer generalized that knowledge to solve new problems, like planning the shortest route between stops on the London Underground. Rather than being programmed, the neural network, like the human brain, responded to training: It can continually integrate new information and change its response accordingly.

The development comes from Google DeepMind, the same team behind the AlphaGo computer program that beat a world champion at the logic-based game of Go (*SN Online: 3/15/16*). — *Laurel Hamers*

ROBOT AWAKENING



Physical intelligence makes machines aware of the world around them

By Meghan Rosen

In a high-ceilinged laboratory at Children's National Health System in Washington, D.C., a gleaming white robot stitches up pig intestines.

The thin pink tissue dangles like a deflated balloon from a sturdy plastic loop. Two bulky cameras watch from above as the bot weaves green thread in and out, slowly sewing together two sections. Like an experienced human surgeon, the robot places each suture deftly, precisely — and with intelligence.

Or something close to it.

For robots, artificial intelligence means more than just "brains." Sure, computers can learn how to recognize faces or beat humans in strategy games. But the body matters too. In humans, eyes and ears and skin pick up cues from the environment, like the glow of a campfire or the patter of falling raindrops. People use these cues to take action: to dodge a wayward spark or huddle close under an umbrella.

Part of intelligence is "walking around and picking things up and opening doors and stuff," says Cornell computer scientist Bart Selman. It "has to do with our perception and our physical being." For machines to function fully on their own, without humans calling the shots, getting physical is essential. Today's robots aren't there yet — not even close — but amping up the senses could change that.

"If we're going to have robots in the world, in our home, interacting with us and exploring the environment, they absolutely have to have sensing," says Stanford roboticist Mark Cutkosky. He and a group of like-minded scientists are making sensors for robotic feet and fingers and skin — and are even helping robots learn how to use their bodies, like babies first grasping how to squeeze a parent's finger.

The goal is to build robots that can make decisions based on what they're sensing around them — robots that can gauge the force needed to push open a door or figure out how to step carefully on a slick sidewalk. Eventually, such robots could work like humans, perhaps even caring for the elderly.

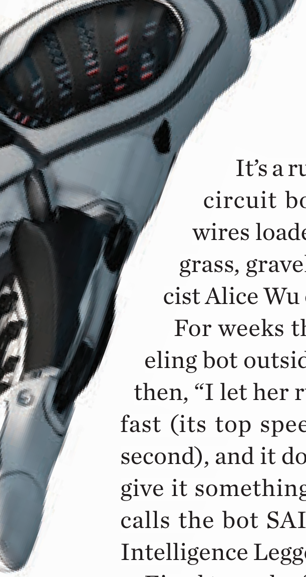
Such machines of the future are a far cry from that shiny white surgery robot in the D.C. lab, essentially an arm atop a cart. But today's fledgling sensing robots mark the slow awakening of machines to the world around them, and themselves.

"By adding just a little bit of awareness to the machine," says pediatric surgeon Peter Kim of the children's hospital, "there's a huge amount of benefit to gain."

Born to run

The pint-size machine running around Stanford's campus doesn't look especially self-aware.

HUMAN: CHEREZOFF/SHUTTERSTOCK; ROBOT: WILLYAM BRADBERRY/SHUTTERSTOCK



It's a rugged sort of robot, with stacked circuit boards and bundles of colorful wires loaded on its back. It scampers over grass, gravel, asphalt — any surface roboticist Alice Wu can find.

For weeks this summer, Wu took the traveling bot outside, placed it on the ground, and then, "I let her run," she says. The bot isn't that fast (its top speed is about a half a meter per second), and it doesn't go far, but Wu is trying to give it something special: a sense of touch. Wu calls the bot SAIL-R, for Sensorized Adaptive Intelligence Legged Robot.

Fixed to each of its six C-shaped legs are tactile sensors that can tell how hard the robot hits the ground. Most robots don't have tactile sensing on their feet, Wu says. "When I first got into this, I thought that was crazy. So much effort is focused on hands and arms." But feet make contact with the world too.

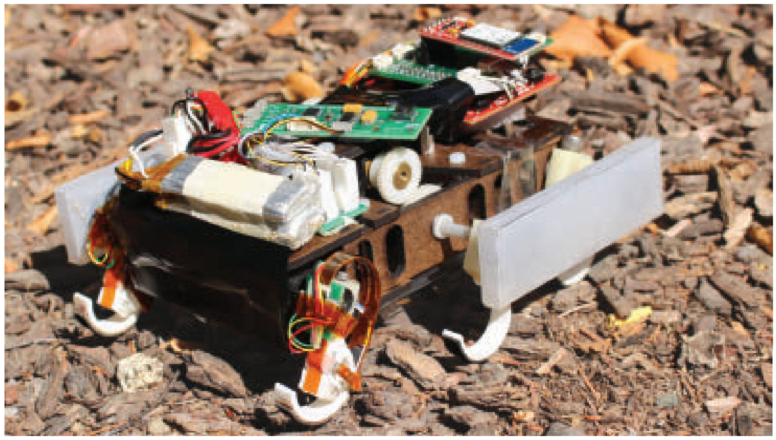
Feeling the ground, in fact, is crucial for walking. Most people tailor their gait to different surfaces without even thinking, feet pounding the ground on a run over grass, or slowing down on a street glazed with ice. Wu wants to make robots that, like humans, sense the surface they're on and adjust their walk accordingly.

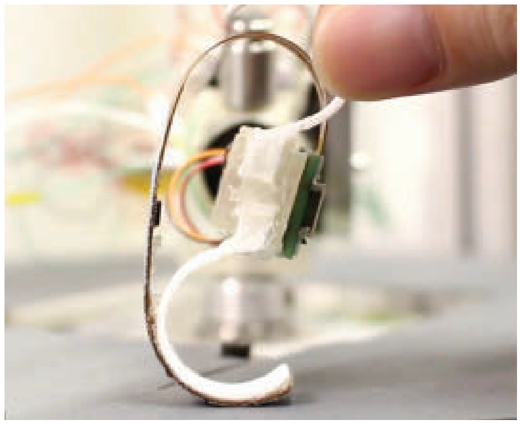
Walking robots have already ventured out into the world: Last year, a competition sponsored by DARPA, the Department of Defense agency that funds advanced research, showcased a lineup of semiautonomous robots that walked over rubble and even climbed stairs (*SN: 12/13/14, p. 16*). But they didn't do it on their own; hidden away in control rooms, human operators pulled the strings.

One day, Wu says, machines could feel the ground and learn for themselves the most efficient way to walk. But that's a tall order. For one, researchers can't simply glue the delicate sensors designed for a robot's hands onto its feet. "The feet are literally whacking the sensor against the ground very, very hard," Wu says. "It's unforgiving contact."

That's the challenge with tactile sensing in general, says Cutkosky, Wu's adviser at Stanford. Scientists have to build sensors that are tough, that can survive impact and abrasion and bending and water. It's one reason physical intelligence has advanced so slowly, he says.

"You can't just feed a supercomputer thousands of training examples," Cutkosky says, the way AlphaGo learned how to play Go (*SN Online: 3/15/16*). "You actually have to build things that interact with the world."





A small running robot named SAIL-R (top) has tactile sensors attached to six C-shaped legs (left). When the legs whirl around and smack the ground, the sensors detect the impact forces, which could help the machine choose an appropriate walking gait.

BOTH: A. WU/STANFORD UNIV.

Cutkosky would know. His lab is famous for building such machines: tiny "microTugs" that can team up, antlike, to pull a car, and a gecko-inspired "Stickybot" that climbs walls. Tactile sensing could make these and other robots smarter.

Wu and colleagues presented a new sensor at IROS 2015, a meeting on intelligent robots and systems in Hamburg, Germany. The sensor, a sandwich of rubber and circuit boards, can measure adhesion forces — what a climbing robot uses to stick to walls. Theoretically, such a device could tell a bot if its feet were slipping so it could adjust its grip to hang on. And because the postage stamp–sized sensor is tough, it might actually survive life on little robot feet.

Wu has used a similar sort of sensor on an indoor, two-legged bot, the predecessor to the six-legged SAIL-R. The indoor bot can successfully distinguish between hard, slippery, grassy and sandy surfaces more than 90 percent of the time, Wu reported in *IEEE Robotics and Automation Letters* in July.

That could be enough to keep a bot from falling. On a patch of ice, for example, "it would say, 'Uh-oh, this feels kind of slippery. I need to slow down to a walk,' " Wu says.

Ideally, Cutkosky says, robots should be covered with tactile sensors — just like human skin. But scientists are still figuring out how a machine would deal with the resulting deluge of information.

Smart skin

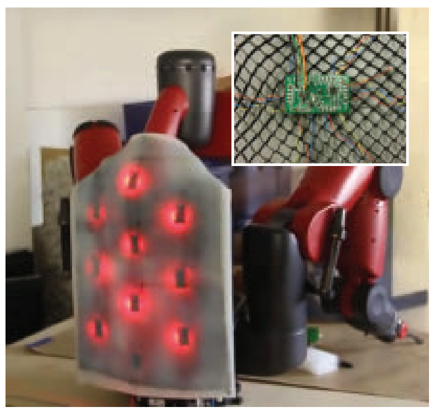
Even someone sitting (nearly) motionless at a desk in a quiet, temperature-controlled office is bombarded with information from the senses.

Fluorescent lights flutter, air conditioning units hum and the tactile signals are too numerous to count. Fingertips touch computer keys, feet press the floor, forearms rest on the desk. If people couldn't tune out some of the "noise" picked up by their skin, it would be total sensory overload.

"You have millions of tactile sensors, but you don't sit there and say, 'OK, what's going on with my millions of tactile sensors,' " says Nikolaus Correll, a roboticist at the University of Colorado Boulder. Rather, the brain gets a filtered message, more of a big-picture view.

That simplified strategy may be a winner for robotic skin, too. Instead of sending every last bit of sensing data to a centralized robotic brain, the skin should do some of the computing itself, says Correll, who made the case for such "smart" materials in *Science* in 2015.

"When something interesting happens, [the skin] could report to the brain," Correll says. Like human skin, artificial skin could take all the vibration info received from a nudge, or a tap to the shoulder, and translate it into a simpler message for the brain: "The skin could say, 'I was tapped or rubbed or patted at this position,' " he says. That way, the robot's brain doesn't have to constantly process a flood of vibration data from the skin's sensors.



A rubbery, artificial skin covers the back of a robot named Baxter. The skin contains 10 sensor nodes — vibration sensors coupled with tiny computers (inset) that let the skin detect different textures.

D. HUGHES AND N. CORRELL/*BIOINSP. & BIOMIMETICS* 2015

It's called distributed information processing. Correll and Colorado colleague Dana Hughes tested the idea with a stretchy square of rubbery skin mounted on the back of an industrial robot named Baxter. Throughout the skin, they placed 10 vibration sensors paired with 10 tiny computers. Then the team trained the computers to recognize different textures by rubbing patches of cotton, cardboard, sandpaper and other materials on the skin.

Their sensor/computer duo was able to distinguish between 15 textures about 70 percent of the time, Hughes and Correll reported in *Bioinspiration & Biomimetics* in 2015. And that's with no centralized "brain" at all. That kind of touch discrimination brings the robotic skin a step closer to human skin. Making robotic parts with such sensing abilities "will make it much easier to build a dexterous, capable robot," Correll says.

And with smart skin, robots could invest more brainpower in the big stuff, what humans begin learning at birth — how to use their own bodies.

Zip it

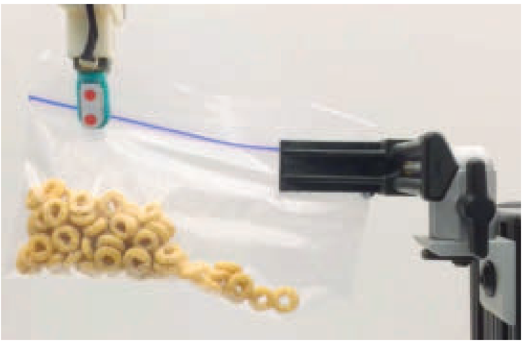
In UCLA's Biomechatronics Lab, a green-fingered robot just figured out how to use its body for one seemingly simple task: closing a plastic bag.

Two deformable finger pads pinch the blue seal with steady pressure (the enclosed Cheerios barely tremble) as the robot slides its hand slowly along the plastic zipper. After about two minutes, the fingers reach the end, closing the bag. It's deceptively difficult. The bag's shape changes as it's manipulated — tough for robotic fingers to grasp. It's also transparent — not easily detectable by computer vision.

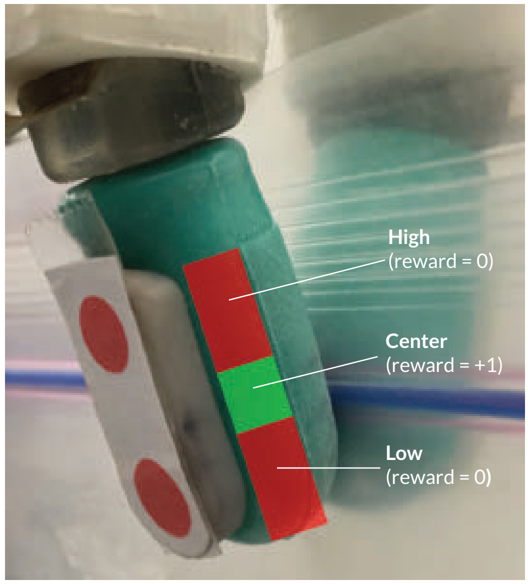
You can't just tell the robot to move its fingertips horizontally along the zipper, says Veronica Santos, a roboticist at UCLA. She and colleague

Robot reality Humans navigate the world through a suite of senses (some below). Robot tools can pick up sights and sounds (and more) from their environment. Some robot senses go beyond human abilities.

Sense	Human sensor	Robot sensor
Sight	Eyes	Cameras
Hearing	Ears	Microphones
Touch	Skin	Tactile sensors
Balance	Eyes, inner ear, feet	Gyroscope, accelerometer, tilt switch
Additional abilities	Requires gear (night vision goggles, sonar)	Night vision camera, ultrasound



Deformable, sensing finger pads (green, above) help a robot figure out how to seal a plastic bag. Researchers at UCLA designed a learning algorithm that gives the robot points for keeping the seal in the center of the finger pad (green square, right).



BOTH: V. SANTOS/UCLA

Randall Hellman, a mechanical engineer, tried that. It's too hard to predict how the bag will bend and flex. "It's a constant moving target," Santos says.

So the researchers let the robot learn how to close the bag itself.

First they had the bot randomly move its fingers along the zipper, while collecting data from sensors in the fingertips — how the skin deforms, what vibrations it picks up, how fluid pressure in the fingertips changes. Santos and Hellman also taught the robot where the zipper was in relation to the finger pads. The sweet spot is smack dab in the middle, Santos says.

Then the team used a type of algorithm called reinforcement learning to teach the robot how to close the bag. "This is the exciting part," Santos says. The program gives the robot "points" for keeping the zipper in the fingers' sweet spot while moving along the bag.

"If good stuff happens, it gets rewarded," Santos says. When the bot holds the zipper near the center of the finger pads, she explains, "it says, 'Hey, I get points for that, so those are good things to do.' "

She and Hellman reported successful bag closing in April at the IEEE Haptics Symposium in Philadelphia. "The robot actually learned!" Santos says. And in a way that would have been hard to program.

The crux is embodiment, or the robot's awareness that each of its actions brings an ever-shifting kaleidoscope of sensations.

It's like teaching someone how to swing a tennis racket, she says. "I can tell you what you're supposed to do, and I can tell you what it might feel like." But to smash a ball across a net, "you're going to have to do it and feel it yourself."

Learning by doing may be the way to get robots to tackle all sorts of complicated tasks, or simple tasks in complicated situations. The crux is embodiment, Santos says, or the robot's awareness that each of its actions brings an ever-shifting kaleidoscope of sensations.

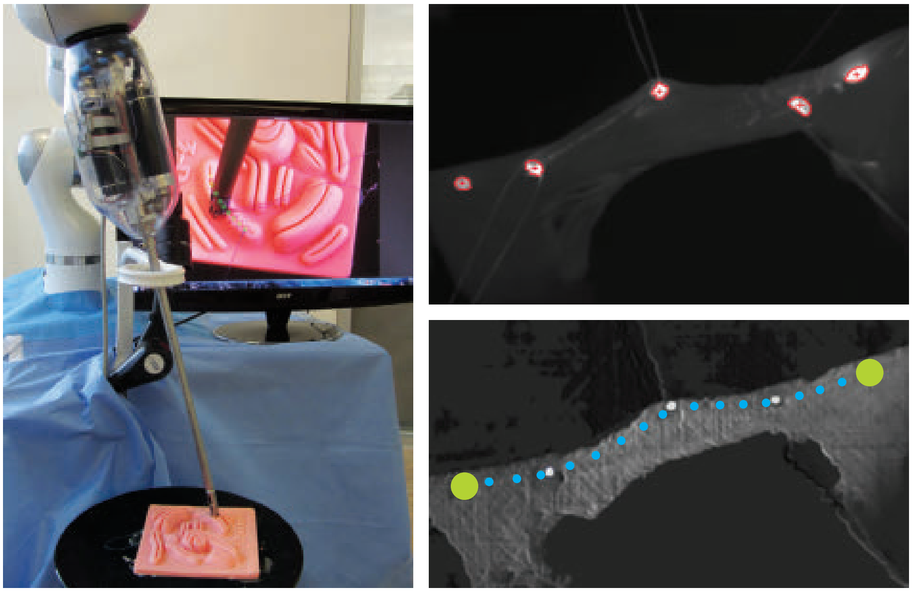
Smooth operator

Awareness of the sights of surgery, and what to make of them, is instrumental for a human or machine trying to stitch up soft tissue.

Skin, muscle and organs are difficult to work with, says Kim, the surgeon at Children's National Health System. "You're trying to operate on shiny, glistening, blood-covered tissues," he says. "They're different shades of pink and they're moving around all the time."

Surgeons adjust their actions in response to what they see: a twisting bit of tissue, for example, or a spurt of fluid. Machines typically can't gauge their location amid slippery organs or act fast when soft tissues tear. Robots needed an easier place to start. So, in 1992, surgery bots began working on bones: rigid material that tends to stay in one place.

In 2000, the U.S. Food and Drug Administration approved the first surgery robot for soft tissue: the da Vinci Surgical System, which looks like a prehistoric version of Kim's surgery machine. Da Vinci is about as wide as a king-sized mattress and reaches 6 feet tall in places, with three mechanical arms tipped with disposable tools. Nearby, a bulky gray cart holds two silver hand controls for human surgeons.



A surgical robot (left, shown practicing on a silicone pad with the texture of human tissue) is guided by fluorescent dots marked by a researcher (top right). The bot uses a 3-D camera and near-infrared imaging plus preprogrammed surgical knowledge to map out its suturing plan (bottom right — blue dots show stitches, green dots are knots and white dots are the researcher's fluorescent marks).

LEFT: RYAN DECKER/CHILDREN'S NATL. HEALTH SYST.; BOTH ON RIGHT: AZAD SHADEMAN *ET AL*/*SCIENCE TRANSL. MED.* 2016

In the cart's backless seat, a surgeon would lean forward into a partially enclosed pod, hands gripping controls, feet working pipe organ–like pedals. To move da Vinci's surgical tools, the surgeon would manipulate the controls, like those claw cranes kids use to pick up stuffed animals at arcades. "It's what we call master/slave," Kim says. "Essentially, the robot does exactly what the surgeon does."

Da Vinci can manipulate tiny tools and keep incisions small, but it's basically a power tool. "It has no awareness," Kim says, "no intelligence." The visual inputs of surgery are processed by human brains, not a computer.

Kim's robot is a more enlightened beast. Named STAR, for Smart Tissue Autonomous Robot, the bot has preprogrammed surgical knowledge and hefty cameras that let it see and react to the environment. Recently, STAR stitched up soft tissue in a living animal — a first for a machine. The bot even outperformed human surgeons on some measures, Kim and colleagues reported in May in *Science Translational Medicine*.

Severed pig intestines sewed up in the lab by STAR tended to leak less than did intestines fixed by humans using da Vinci, laparoscopic tools or sewing by hand. When researchers held the intestines under water and inflated them with air, it took nearly double the pressure for the STAR-repaired tissue to spring a leak compared with intestines patched up by humans.

Kim credits STAR's even stitches for the win. "It's more consistent," he says. "That's the secret sauce."

To keep track of its position on tissue, STAR uses near-infrared fluorescent imaging (like night vision goggles) to follow glowing dots marked by a person. To orient itself in space, STAR uses a 3-D camera with multiple lenses.

Then the robot taps into its surgical knowledge to figure out where to place a stitch. In the experiment reported in May, humans were still in the loop: STAR would await an OK if firing a stitch in a tricky spot, and an assistant helped keep the thread from tangling (a task commonly required in human-led surgeries too). Soon, STAR may be more self-sufficient. In late November, Kim plans to test a version of his machine with two robotic arms to replace the human assistant; he would also like to give STAR a few more superhuman senses, like gauging blood flow and detecting subsurface structures, like a submarine pinging an underwater shipwreck.

One day, Kim says, such technology could essentially put a world-class surgeon in every hospital, "available anyplace, anytime."

Santos sees a future, 10 to 20 years from now perhaps, where humans and robots collaborate seamlessly — more like coworkers than master and slave. Robots will need all of their senses to take part, she says. They might not be the artificially intelligent androids of the movies, like *Ex Machina*'s cunning humanoid Ava. But like humans, intelligent, autonomous machines will have to learn the limits and capabilities of their bodies. They'll have to learn how to move through the world on their own. ■

Explore more

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- M.A. McEvoy and Nikolaus Correll. "Materials that couple sensing, actuation, computation and communication." *Science.* March 20, 2015.
- X. Alice Wu *et al.* "Integrated ground reaction force sensing and terrain classification for small legged robots." *IEEE Robotics and Automation Letters.* July 2016.

Constant Connections

New units based on fundamental properties of the universe will make measurements more precise

By Emily Conover

If scientists had sacred objects, this would be one of them: a single, closely guarded 137-year-old cylinder of metal, housed in a vault outside of Paris. It is a prototype that precisely defines a kilogram of mass everywhere in the universe.

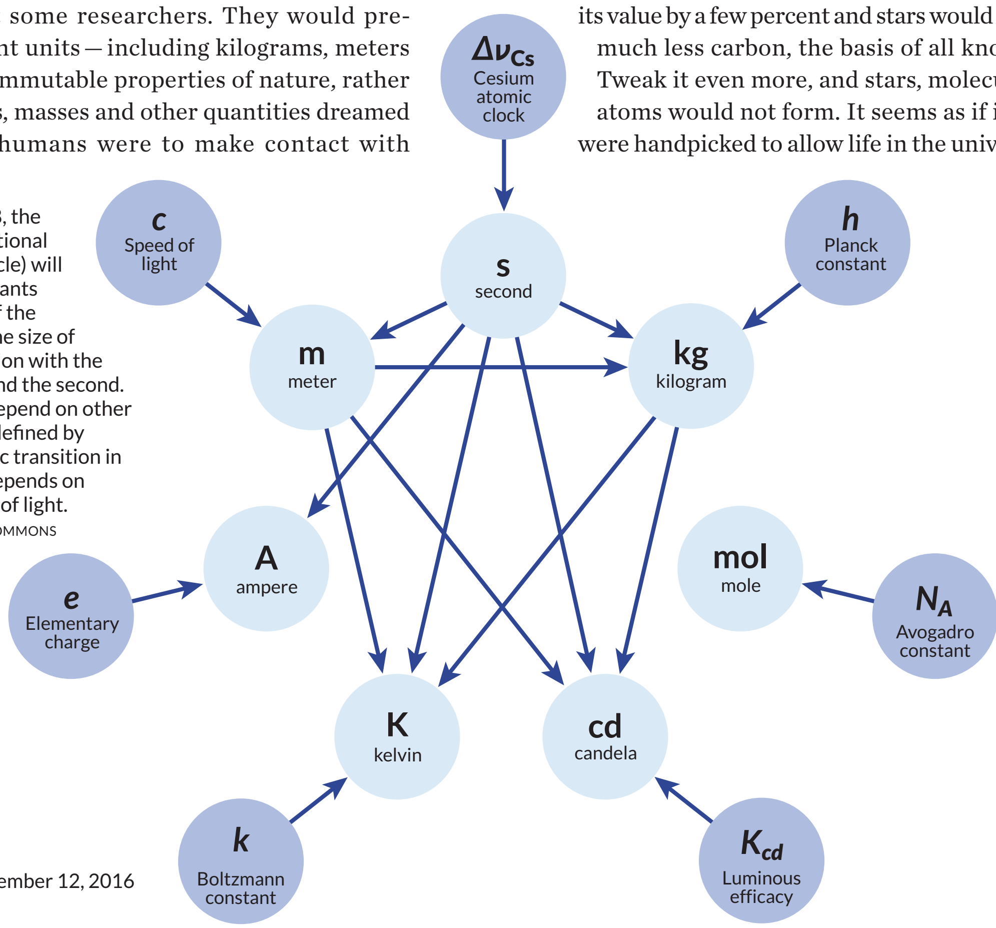
A kilogram of ground beef at the grocery store has the same mass as this one special hunk of metal, an alloy of platinum and iridium. A 60-kilogram woman has a mass 60 times as much. Even far-flung astronomical objects such as comets are measured relative to this all-important cylinder: Comet 67P/Churyumov–Gerasimenko, which was recently visited by the European Space Agency's Rosetta spacecraft (*SN: 2/21/15, p. 6*), has a mass of about 10 trillion such cylinders.

But there's nothing special about that piece of metal, and its mass isn't even perfectly constant — scratches or gunk collecting on its surface could change its size subtly (*SN: 11/20/10, p. 12*). And then a kilogram of beef would be slightly more or less meat than it was before. That difference would be too small to matter when flipping burgers, but for precise scientific measurements, a tiny shift in the definition of the kilogram could cause big problems.

That issue nags at some researchers. They would prefer to define important units — including kilograms, meters and seconds — using immutable properties of nature, rather than arbitrary lengths, masses and other quantities dreamed up by scientists. If humans were to make contact with aliens and compare systems of units, says physicist Stephan Schlamminger, "we'd be the laughingstock of the galaxy."

To set things right, metrologists — a rare breed of scientist obsessed with precise measurements — are revamping the system. Soon, they will use fundamental constants of nature — unchanging numbers such as the speed of light, the charge of an electron and the quantum mechanical Planck constant — to calibrate their rulers, scales and thermometers. They've already gotten rid of an artificial standard that used to define the meter — an engraved platinum-iridium bar. In 2018, they plan to jettison the Parisian kilogram cylinder, too.

Fundamental constants are among the most precisely measured quantities known and so seem ideal for defining the units. But the constants remain enigmatic. The fine-structure constant, in particular, has mystified physicists since it first emerged as an important quantity in scientists' equations 100 years ago. Every time electrically charged particles attract or repel — anywhere in the universe — the fine-structure constant comes into play. Its value sets the strength of the charged particles' push and pull. Nudge its value by a few percent and stars would produce much less carbon, the basis of all known life. Tweak it even more, and stars, molecules and atoms would not form. It seems as if its value were handpicked to allow life in the universe.



Unit upgrade In 2018, the seven units in the International System of Units (inner circle) will be defined by seven constants (outer circle). The value of the Planck constant will set the size of the kilogram, in combination with the definitions of the meter and the second. Those units themselves depend on other constants. The second is defined by the frequency of an atomic transition in cesium-133. The meter depends on the second and the speed of light.

SOURCE E. PISANTY/WIKIMEDIA COMMONS

E. OTWELL

The values of other fundamental constants are likewise unexplainable — all scientists can do is measure them. "Nobody has any idea why these quantities have the numerical values they do," says theoretical physicist John Barrow of the University of Cambridge.

This uncertainty swirling around the constants could cause headaches for metrologists. No law of physics prohibits the constants from changing ever so slightly in time or space — though scientists haven't found conclusive evidence that they do. Some controversial measurements suggest, however, that the fine-structure constant may be different in different parts of the universe. That could mean that the constants used to define the units vary, too, which could muck up the orderly system that metrologists are preparing to adopt.

A hairline crack

The kilogram isn't the only unit that gives scientists indigestion. A second culprit is the kelvin, the unit of temperature.

"It's bonkers," says physicist Michael de Podesta of the National Physical Laboratory in Teddington, England. "Humanity's standard for temperature is the level of molecular jiggling at a mystical point." That point — which much like the sacrosanct kilogram prototype is an arbitrary quantity chosen by humans — is the triple point of water, a particular temperature and pressure at which liquid, gas and solid phases of water coexist. This temperature is set to 273.16 kelvins (0.01° Celsius).

Then there's the ampere, or amp, which quantifies the flow of electrical current that juices up laptops and lightbulbs. "We've agonized over the years on the definition of an ampere," says Barry Inglis, president of the International Committee for Weights and Measures. The present definition is wonky: It is the current that, when flowing through two infinitely long, infinitely thin wires, placed one meter apart, would produce a certain amount of force between them. Such wires are impossible to produce, of course, so it is impractical to create a current that is precisely one amp in this way. This problem makes current-measuring equipment difficult to calibrate well. It's not a problem for household wiring jobs, but it's no good when the highest level of precision is needed.

These examples explain the discomfort that surrounds the units that are so fundamental to science. "There's this hairline crack in the foundation, and you cannot build your building of physics on that foundation," says Schlamminger, of the National Institute of Standards and Technology in Gaithersburg, Md.

To seal the crack, scientists are preparing to update the International System of Units, or SI, in 2018. The kilogram, kelvin, ampere and mole (the unit that quantifies an amount of material) will all be redefined using related constants. These include the Planck constant, which describes the scale of the quantum realm; the Boltzmann constant, which relates temperature and energy; the Avogadro constant, which sets the number of atoms or molecules that make up a mole; and the magnitude of the charge of an electron or proton, also known as the elementary charge. The new units will be based on the modern understanding of physics, including the laws of quantum mechanics and Einstein's theory of special relativity.

BOTH: NIST

A kilogram cylinder replica (left) is safeguarded under bell jars. Ultra-smooth silicon spheres (right) will soon be used to redefine the kilogram using the Planck constant — making the kilogram prototype obsolete.

Scientists went through similar unit acrobatics when they redefined the meter in terms of a fundamental constant — the speed of light, a speed that is always the same.

In 1983, the meter became the distance light travels in a vacuum in 1/299,792,458th of a second (*SN: 10/22/83, p. 263*). This long string of digits came from the increasingly precise measurements of the speed of light made over centuries. Scientists settled on a value of exactly 299,792,458 meters per second, which then defined the meter. The other units will now undergo similar redefinitions.

The shakeup of so many units is a "once in a lifetime" change, says NIST physicist David Newell. But most people won't notice. Definitions will flip, but the changes will be orchestrated so that the size of a kilogram or a kelvin won't change — you won't have to worry about overpaying at the salad bar.

Although the changes are mostly under the hood, their advantages are more than philosophical. In the current system, masses much larger or smaller than a kilogram are difficult to measure precisely. Pharmaceutical companies, for example, need to measure tiny fractions of grams to dole out minute drug doses. Those masses can be a millionth the size of the kilogram prototype cylinder, increasing the uncertainty in the measurement. The new system will tie masses to the Planck constant instead, allowing for more precise measurements of masses both large and small.

In 2018, at a meeting of the General Conference on Weights and Measures, metrologists will vote on the SI revision and will likely put it into practice. The new system is expected to be a welcome change. "Obviously, a system where you take a lump of metal and say, 'this is a kilogram,' is not very fundamental," says physicist Richard Davis of the International Bureau of Weights and Measures in Sèvres, France. "Why would anyone spend their life trying to measure an atom in terms of that?"

The new kilogram

To retire the Paris-based prototype, scientists must agree on a number for the Planck constant. Its value is about 6.62607×10^{-34} kilograms times meters squared per second. But scientists need to measure it with extreme precision —

within 2 millionths of a percent, out to about seven decimal places — and several independent measurements need to agree. Once that's done, scientists will fix the value of the Planck constant. Since the meter is already defined (by the speed of light) and the second is defined (using a cesium atomic clock), fixing the value of the Planck constant will define what a kilogram is.

Several teams are using different techniques to zero in on the Planck constant (*SN: 9/5/15, p. 15*). The first compares electromagnetic forces to the force imposed by gravity, using a tool called a watt balance. Schlamminger's group and others are in the final stages of refining such measurements. Thanks to precise quantum mechanical methods of producing voltages, an object's mass can be directly related to the Planck constant.

In a complementary effort, scientists are measuring the Planck constant using carefully formed and stunningly shiny spheres of pure silicon. "The principle is quite easy," says metrologist Horst Bettin of the German national metrology institute, Physikalisch-Technische Bundesanstalt in Braunschweig. "We are just counting the number of atoms."

Atoms in the sphere are perfectly spaced in a 3-D crystal grid, so the number of atoms can be deduced from the volume of the sphere. The result, a measurement of the Avogadro constant, can then be used to calculate the Planck constant, using precise measurements of other fundamental constants — including the Rydberg constant, which is related to the energy needed to ionize a hydrogen atom. To make this measurement, the spheres must be impressively round so that the number of atoms inside can be calculated. "The Earth would be as round as our spheres if the highest mountain [was] a few meters high," Bettin says.

Questioning the constants

Imagine a universe where the speed of light changes drastically from day to day. If metrologists' new system of units were in use there, "today's meter would be different than tomorrow's meter," says Schlamminger — clearly not an ideal situation. In our universe, however, no one has found solid evidence of variation, so if variation exists, it would be too small to have a practical impact on the units.

But if the constants weren't constant, physics would be in trouble. The whole of physics is founded on laws that are assumed to be unchanging, says physicist Paul Davies of Arizona State University in Tempe.

Physicists have found possible signs of fickleness in the fine-structure constant (*SN: 11/16/13, p. 11*). If true, such measurements suggest that charged particles tug differently in far-flung parts of the universe.

The fine-structure constant is an amalgamation of several other constants, including the charge of the electron, the speed of light and the Planck constant, all smooshed together into one fraction, with a value of about 1/137. Its value is the same regardless of the system of measurement because the fraction is a pure number, with no units.

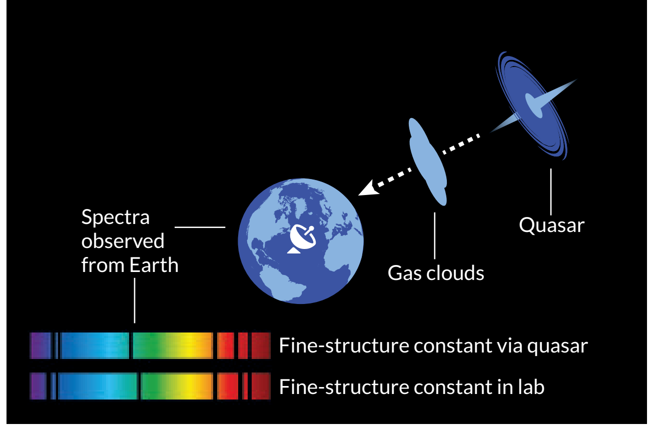
Scientists keep track of the fine-structure constant using quasars — brilliant cosmic beacons produced by distant supermassive black holes. On its way toward Earth, a quasar's light passes through gas clouds, which absorb light of particular frequencies, producing gaps in the otherwise smooth spectrum of light. The locations of these gaps depend on the fine-structure constant. Variations in the spacing of the gaps in space or time could indicate that the fine-structure constant has changed.

In 2011, scientists reported tantalizing hints that the fine-structure constant changes. In *Physical Review Letters*, astrophysicist John Webb of the University of New South Wales in Sydney and colleagues reported that the fine-structure constant increases in one direction on the sky, and decreases in the opposite direction, as if there were a special axis running through the universe (*SN Online: 9/3/10*). The claim is

Constant collection New definitions of basic units will depend on precisely measured constants. Fixing the value of constants that contain units defines those units. The fine-structure constant is in another category; it has no units and is a combination of other constants, including elementary charge, Planck constant and speed of light. SOURCES: P. J. MOHR, D.B. NEWELL AND B.N. TAYLOR/*REV. MOD. PHYS.* 2016; J. FISHER AND J. ULLRICH/*NAT. PHYSICS* 2016

Constants and their roles in the universe

Constant	Symbol	Role	Value	Needed to define what unit?
Planck constant	h	Denotes scale of quantum mechanics	$6.626070040 \times 10^{-34}$ kg m²/s	kilogram
Speed of light in a vacuum	c	Maximum speed of objects in the universe	299,792,458 m/s	meter
Elementary charge	e	Electrical charge of the electron and the proton	$1.6021766208 \times 10^{-19}$ ampere seconds	ampere
Boltzmann constant	k	Converts from energy to temperature	$1.38064852 \times 10^{-23}$ kg $m^2/(s^2$ kelvin)	kelvin
Avogadro constant	N_A	Indicates number of particles in one mole of a substance	$6.022140857 \times 10^{23}$/mole	mole; used with R_∞ to measure h, then define kg
Rydberg constant	R_∞	Determines the wavelengths of light emitted from a hydrogen atom	10,973,731.568508/m	used with N_A to measure h, then define kg
Hyperfine splitting of cesium	$\Delta\nu_{Cs}$	Frequency from a cesium atomic clock	9,192,631,770/s	second
Luminous efficacy	K_{cd}	Converts from luminous intensity (brightness) to power (energy per time)	683 candela steradian $s^3/(kg\ m^2)$	candela
Fine-structure constant	α	Indicates the strength of electromagnetic interactions between charged particles	1/137.035999139	none, but its value is related to the other constants



Quasars waver Light from quasars passes through gas clouds, creating absorption lines in light spectra observed from Earth (top color bar). The spacing of lines shifts depending on the fine-structure constant. If the constant changes, the spectrum will be different from one measured in the lab (bottom color bar). SOURCE: JULIAN BERENGUT/UNIV. NSW

controversial and Webb counts himself as one of the skeptics. "This is radical, obviously, and when you come out with a discovery like that, of course you don't believe it." But, he says, despite his best efforts to disprove it, the variation remains.

If confirmed, the result would have enormous consequences. "It's a tiny effect," says Davies, but "I think it would come as a great shock, because people really do want to think that the laws of physics are absolutely immutable. The idea that they could somehow vary makes most physicists feel seriously uneasy."

Some scientists have come up with a more comforting explanation for the hints of variation in the constant. Michael Murphy of Swinburne University of Technology in Melbourne, Australia, suggests that telescope calibration issues could be to blame for the changing fine-structure constant. (Murphy knows the ins and outs of the measurement — he was a coauthor on the 2011 paper reporting fine-structure constant changes.) Using measurements free from calibration issues, the fine-structure constant stays put, Murphy and colleagues reported in September in *Monthly Notices of the Royal Astronomical Society*. The quasars studied for the September paper, however, don't rule out variation in the part of the sky observed in 2011.

Other puzzles in physics might be connected to possible variation in the constants. Scientists believe that most of the matter in the universe is of an unseen form known as dark matter (see Page 14). In a paper published in *Physical Review Letters* in 2015, physicists Victor Flambaum and Yevgeny Stadnik of the University of New South Wales showed that dark matter could cause the fundamental constants to change, via its interactions with normal matter.

And a shifting speed of light could revise current views about the evolution of the infant universe. Scientists think that a period of inflation caused the newborn cosmos to expand extremely rapidly, creating a universe that is uniform across vast distances. That uniformity is in line with observations: The cosmic microwave background, light that emerged about 380,000 years after the Big Bang, is nearly the same temperature everywhere scientists look. But cosmologist João Magueijo of Imperial College London has a radical alternative to inflation: If light were speedier in the early universe, it could account for the universe's homogeneity.

"As soon as you raise the speed limit in the early universe," Magueijo says, "you start being able to work on explanations for why the universe is the way it is."

A finely tuned universe

To the consternation of many physicists, whose equations are riddled with fundamental constants, these quantities cannot be calculated directly from physical principles. Scientists don't know why electrons pull charged particles with the strength they do and can only measure the strength of the force and plug that number into formulas. Such black boxes detract from the elegance of scientists' theories, which attempt to explain the universe from the bottom up.

Particularly troubling is the fact that the precise values of these constants are essential to the formation of stars and galaxies. If, during the birth of the universe, certain constants — in particular the fine-structure constant — had been just slightly different, they would set the cosmos on a path to being empty and barren.

As a result, many scientists believe that there must be some deeper theory that constrains their values. But recent attempts to come up with such a theory have been stymied, says theoretical physicist Frank Wilczek of MIT. "Progress has been pretty limited in the last few decades."

Some scientists have begun turning to an alternative explanation: These constants may not be fine-tuned, but randomly chosen, with a roll of the dice that occurred many times in many universes, or different parts of the universe. "We've really changed our view of fundamental constants. They're less rigidly defined and ultimate," says Barrow.

There may be other universes, or faraway pockets of our own universe, that have very different constants. In those places, life might not be able to survive. Just as diverse life sprung up on Earth, with its favorable climate, and not Mars, we may just live in a universe that has constants amenable to life because that's the only place where life could gain a foothold.

There's also an increasing mismatch between what's known experimentally and theoretically about the constants. Although scientists are measuring them to painstaking precision, with experimental errors measured in parts per billion, the origins of the constants remain completely unexplained.

As metrologists attempt to build their system on stronger foundations by pinning the units to the constants, those very foundations may yet shift. Shifting constants would make the system of units less appealingly neat and tidy. The system of units will have to evolve as knowledge of physics advances, says Newell. "Then, you can turn around and use that measurement system to explore further the world around us." ■

Explore more

- International Bureau of Weights and Measures. "On the future revision of the SI." bit.ly/SIrevision.

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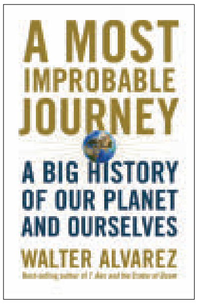


A Most Improbable Journey
Walter Alvarez
W.W. NORTON & CO., $26.95

BOOKSHELF

4.5 billion years of human history

Most people do not marvel much at sand. We may enjoy how it feels under our bare feet, or get annoyed when someone tracks it into the house. But few of us see those quartz grains the way geologist Walter Alvarez does — as the product of 4.5 billion years of improbable cosmic and geologic events that defined the course of human history.

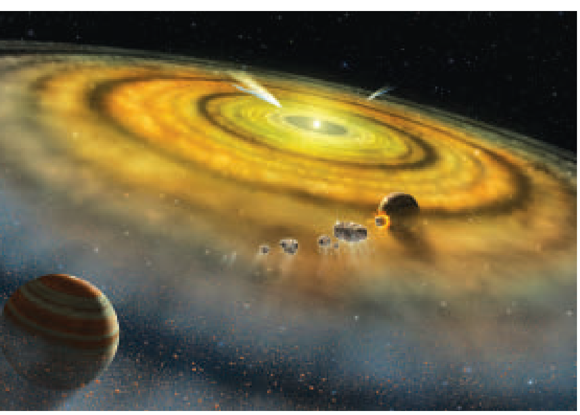
Sandy beaches exist because silicon — a relatively rare element in the solar system — happened to become concentrated on Earth during the solar system's early days, Alvarez, of the University of California, Berkeley, writes in *A Most Improbable Journey*. While powerful solar particles swept lighter, gaseous elements toward the outer planets, more massive, mineral-forming elements such as silicon, magnesium and iron were left behind for Earth. Later on, in the molten crucibles between Earth's colliding tectonic plates, these elements formed the raw materials for pivotal human inventions, including stone tools, glass and computer chips.

The 4.5 billion years of history that led to a computer chip is just one of many stories of scientific happenstance that Alvarez presents. Best known for proposing that an asteroid impact killed off the dinosaurs, Alvarez argues that rare, unpredictable cosmic, geologic and biological events — what he calls "contingencies" — are key to understanding the human condition.

Fans of Bill Bryson's *A Short History of Nearly Everything* will appreciate Alvarez's enthusiastic, clearly written tour of contingencies that have shaped our world, starting with the origins of life on Earth. No matter how distant the event, Alvarez quickly zeroes in on its eventual impact on people: For instance, the formation of oceanic crust helped expose rich deposits of copper ore on Cyprus, later an epicenter of the Bronze Age. A catastrophic Ice Age flood formed the English Channel in which the Spanish Armada would later sink. And ancient rivers in North America smoothed the terrain of the westward trail for American pioneers in covered wagons.

Not all of Alvarez's arguments are convincing — his claim in the final chapter that every individual is a "contingency" in his or her own right, given how many other people *could* have been born instead, feels more flattering than important. Still, it's hard to argue with his observation that impulsive human actions can transform the planet just as much as earthquakes, asteroids and other difficult-to-predict, occasionally world-changing phenomena.

Critics of this macro view, described in academia as "Big History," say that the approach sacrifices important nuance and detail. At roughly 200 pages of text, however, *A Most Improbable Journey* does not claim to be a comprehensive account of history or a replacement for more detailed, focused examinations of the past. Instead, it makes a compelling case for Big History as a fun, perspective-stretching exercise — a way to dust off familiar topics and make them sparkle. *— Emily Underwood*



A new book explores how cosmic and geologic events — such as the particular details of the solar system's formation — have shaped human history.

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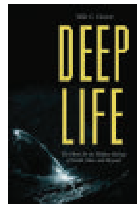
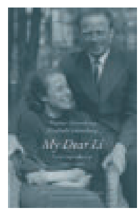
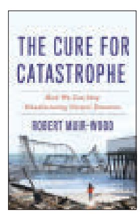


Deep Life
Tullis C. Onstott
A geomicrobiologist takes readers on a journey around the world, and deep underground, to discover the diverse collection of microbes that reside in some of the most extreme environments on Earth. *Princeton Univ., $35*

Strangers in a New Land
J.M. Adovasio and David Pedler
A few dozen pre-Columbian archaeological sites are profiled in this coffee table book, which examines how and when people colonized the Americas. *Firefly Books, $49.95*



My Dear Li
Anna Maria Hirsch-Heisenberg (ed.)
This collection of over 300 letters between physicist Werner Heisenberg and his wife, Elisabeth, offers a new perspective on the Nobel laureate's atomic research and everyday life in Nazi Germany. *Yale Univ., $40*



The Cure for Catastrophe
Robert Muir-Wood
In reviewing natural disasters from the last few centuries, a global risk expert dissects the role that humans play in turning earthquakes, hurricanes and other natural events into true catastrophes. *Basic Books, $29.99*

Buy Books Reviews on the *Science News* website include Amazon.com links that generate funds for Society for Science & the Public programs.

Building a 'community of geeks'

Two hundred science teachers gathered in Washington, D.C., in early October for the Society for Science & the Public's Research Teachers Conference. Attendees discussed best practices and shared advice for encouraging students to complete science fair projects.

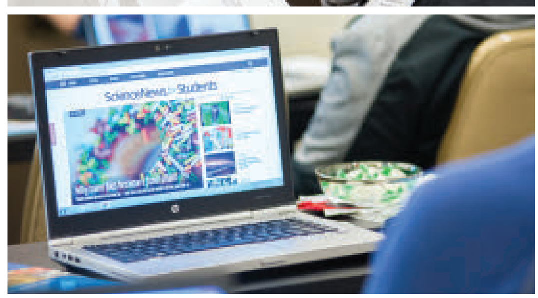
"You've got to have a community of geeks to build a successful science program," Lisa Scott, a science teacher in Florida, explained during the conference, which was sponsored by Regeneron. Scott, who counts herself as a geek, discussed her "geeky" classroom and the methods she uses for creating a community, including offering after-school programs, picnics and award ceremonies. Scott's principal writes award letters to high-achieving science students, just like letters athletes receive.

As part of the same panel, New York high school teacher Stephen Sullivan shared one key best practice: He decorates the walls of his classroom with newspaper clippings of former students who have won awards in science fair competitions. "When new students enter my classroom, it's already a goal for them to end up on that wall," Sullivan said.

Sharing articles from publications like *Science News* also helps engage students by showing them how the science they learn in the classroom can be applied in the real world, Phyllis Serfaty, a teacher from New York, said during a separate panel discussion. "I love *Science News* because it covers so many different STEM fields. It's all here," Serfaty explained. "I use it as a way of generating ideas."

Keynote speaker Rebecca Nyquist, a Ph.D. candidate at the University of Pennsylvania encouraged teachers to help their students gain grit and mindfulness. "We can will ourselves to do a lot of things," Nyquist said. "But having something that drives you to get up every day is grit. People aren't born with a set amount of grit. We can cultivate it in ourselves and in our students."

Read more about this year's Research Teachers Conference at **student.societyforscience.org/blog/doing-science**



From top: Educators discussed best practices for helping students complete science fair projects; keynote speaker Rebecca Nyquist defined grit and why educators should help students cultivate it; Lisa Scott (left) emphasized the importance of community for building a successful science program; teachers took the newly redesigned *Science News for Students* website for a test drive.

JESSICA YURINKO

SEPTEMBER 17, 2016

A dog-eat-wildlife world

Science News' Wild Things blog covers the weird and wonderful in the natural world. "Nature has a dog problem" (*SN Online: 9/30/16*) recently got readers buzzing online and on Facebook. Feral cats may wreak havoc on wildlife, but so do roaming dogs, **Sarah Zielinski** reports. Researchers have yet to fully assess dogs' environmental impact. Join the discussion at **bit.ly/SN_wilddogs**

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Buzzkill

Astronomers confirmed the existence of an exoplanet, Proxima b, only 4.2 light-years from Earth, ***Christopher Crockett*** *reported in "Planet orbits sun's nearest neighbor"* (SN: 9/17/16, p. 6).

Some readers thought there was too much excitement over the new potentially habitable planet.

Christina Gullion believes keeping Earth habitable in the face of a changing climate is more important than searching for other planets. "Off-planet exploration seems to me to be a counterproductive diversion of funds and scientific knowledge," she wrote. "I think it is self-indulgently romantic to invest scarce resources in curiosity about life out there in the universe when we could be protecting and enhancing life here on Earth." Although Proxima b is relatively close to Earth, **Gullion** correctly noted that it is still too far away to reach anytime soon.

Even if humans could travel to Proxima b, reader **Steve Moore** pointed out, scientists don't know much about the planet. It could be tidally locked with its star and vulnerable to solar flares, he said, which would make it hard, if not impossible, for humans to live on.

Crockett agrees that enthusiasm for Proxima b should be tempered by the little we know about the planet — so far, only its minimum mass, orbit and a few details about its star. Tidal locking is possible, **Crockett** says, "though there's an active debate about whether that would be OK for habitability or not." And though solar flares also pose a threat to habitability, "a denser atmosphere might be able to withstand Proxima's flares," he says. "We just won't know until we get better data on the planet."

Despite all of the unknowns, **Crockett** still thinks it's an exciting discovery. "The proximity of the planet means it's probably going to come under a lot of scrutiny in the years and decades to come," he says. "And knowing that there's a planet right next door is pretty neat. I can't wait to see what we learn about it."

Pavlov's fish

Researchers worry that escapes of farmed salmon, cobia and other fish into the ocean could weaken or harm native wildlife, ***Roberta Kwok*** *reported in "Runaway fish"* (SN: 9/17/16, p. 22).

"I wondered if anyone had considered training farm-raised fish to associate a sound or some other stimulus with food," **Rick Gelbmann** asked. "Then when fish escape, the sound could be used to attract the fish, making it easier to recapture them."

Scientists have successfully trained species such as Atlantic salmon to swim to a food source in response to a tone. But for runaways, this strategy "is basically impractical," says **Tim Dempster**, a sustainable aquaculture researcher. Fish often escape during storms when it's tough to deploy equipment. Escapees tend to flee quickly, so the sounds might not reach them. And farmers would have to train a huge number of fish just to potentially recapture a small fraction.

Bioacoustician **Frédéric Bertucci** notes that adding another source of human-made noise to the ocean could also affect nearby wild animals.

Star struck

Despite a new analysis of data from the Kepler Space Telescope, the slow-dimming and sporadic flickering of Tabby's star remains a mystery, ***Christopher Crockett*** *reported in "Fading star still baffles astronomers"* (SN: 9/17/16, p. 12).

Walt Davis wondered if the dimming could be caused by the star orbiting a black hole. "As the star moves closer to alignment behind [the black hole] ... the star's light rays are being more and more bent away from us," he wrote.

"As weird as this star is, a black hole is probably not the culprit," **Crockett** says. Astronomers would be able to detect the star's orbital motion if it were orbiting a black hole, but the star appears to stay put. "And if gravity of a companion black hole was occasionally bending the starlight directed toward Earth, it would make the star appear brighter, not darker," he says.

How to make a (zebra)fish face

This forlorn-looking face of a 4-day-old zebrafish embryo represents "a whole new avenue of research" for geneticist Oscar Ruiz, who studies how faces and facial abnormalities develop at the cellular level.

The research is possible thanks to a new method, developed by Ruiz and colleagues at the University of Texas MD Anderson Cancer Center in Houston, for mounting embryos in a gel that allows for clear, head-on pictures. A technique called confocal microscopy then captures images like the one above, the first-place winner of this year's Nikon Small World photography contest.

The embryo was euthanized before having its picture taken. But Ruiz is experimenting with taking time-lapse images of live zebrafish embryos. So far, the team has looked at embryos ranging from 1 to 6 days old. "We're able to watch the development happening," Ruiz says. The work could one day be used to help scientists understand how a cleft lip or cleft palate develops in humans and possibly how to treat it.

In the image above, shown at 10x magnification, basal cells (green) in the bottom layer of skin give rise to more developed surface skin cells (red). Cell nuclei appear in blue.

"Everyone's first impression is that those two holes in the center are its developing eyes," Ruiz says. But they're not. Those deceptive hollows are nascent olfactory tissue, used to smell. The eyes are actually the big bulges on either side of the face. *— Emily DeMarco*

O. RUIZ/UNIV. OF TEXAS MD ANDERSON CANCER CENTER

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