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SCIENCE NEWS MAGAZINE
SOCIETY FOR SCIENCE & THE PUBLIC
JUNE 14, 2014

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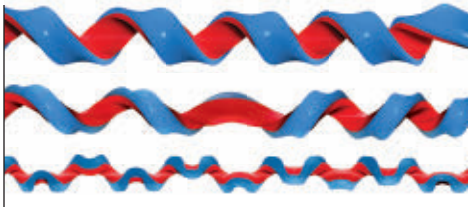

Departments

COVER By reprogramming T cells (pink), scientists are fighting cancer and other diseases. *Steve Gschmeissner/ Science Source*

CLOCKWISE FROM TOP: TANG YAU HOONG; MALUCHI ENYI; IMAGE COURTESY OF PAUL NICKLEN/NATIONAL GEOGRAPHIC

Your brain on marijuana: two views

Neuroscience writer Laura Sanders had little idea what she was walking into when she wrote a short news story about marijuana earlier this year. The finding was interesting if not Earth-shattering: A hormone blocks some of the intoxicating effects of marijuana in rats and mice (*SN: 2/8/14, p. 12*). The work, she wrote, "may lead to drugs that help people curb cannabis dependence."

The scolding began as soon as the story went up on the *Science News* website. Marijuana, many online commenters said, is simply not addictive. One wrote: "Cannabis was proven to be nonaddictive quite a long time ago.... I am sad to see a respected publication like *Science News*, which I read and appreciate, spreading this misinformation."

Yet, in her reporting, Sanders had heard something quite different. Most scientists believe that marijuana can be classified as addictive (though less so than tobacco and alcohol), with about 10 percent of users becoming hooked. With recent moves toward legalization and decriminalization of marijuana, it seemed well worth a deeper look at what the evidence actually shows, or doesn't show, about marijuana's dangers and how it affects the brain.

As revealed on Page 16 of this issue, many of the "facts" that people believe to be true about marijuana are not supported by science. And while the pro-pot lobby cherry-picks data to support its arguments (denying marijuana's addictiveness, for example), so too do anti-marijuana groups, which play up pot's dangers. Studies do show that marijuana may harm the developing brains of adolescents, but there's little science to support the idea that occasional use by an adult causes lasting damage.

What strikes Sanders is that the fierce debate over whether to legalize marijuana is largely fought by people with personalized "facts." The disagreement seems rooted in conflicting world views. "Science can help clarify some of these issues," she says, "but for research to have an effect on policy, people must first shed their biases and actually examine the evidence. And that seems a tall order." But, for those of us interested in truth, it's also an especially worthy one.
— Eva Emerson, Editor in Chief

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Excerpt from the June 13, 1964, issue of *Science News Letter*

50 YEARS AGO

No Pockets of Polio

The pockets of polio left in this country can be wiped out if every newborn baby is immunized. "We need a door-bell ringing campaign in the poorer sections where vaccination is ignored," Dr. Donald A. Henderson, surveillance chief of the U.S. Public Health Service's Communicable Disease Center, Atlanta, Ga., told SCIENCE SERVICE.... Dr. Albert B. Sabin, University of Cincinnati Medical Center scientist who developed the Sabin oral live-virus polio vaccine that in three years has been used for more than 250 million persons, ... says that "systematic ongoing programs" with oral vaccines must be kept in operation for the new generations of children if polio is to be eliminated.

UPDATE: Polio was considered eliminated in the United States by 1979, but since then vaccination rates have slipped, prompting concerns about reemergence. On May 5, the World Health Organization declared polio a global emergency. At least 10 countries are reporting polio cases this year, with potential for spread via international travel.

THE -EST

Longest year

THE SCIENCE LIFE

Outgoing Congressman Rush Holt calls scientists to action

Rush Holt, central New Jersey's "rocket scientist" representative, thinks Capitol Hill needs more scientists. He's leaving Congress at the end of this year, but his eight terms in office have taught him that scientists need to help craft the nation's laws now more than ever.

Holt joined Congress in 1999, and at one point was one of three physicists there. Fifteen years later he'll leave the House with just one, Rep. Bill Foster of Illinois. A microbiologist, six engineers and about two dozen medical professionals also hold seats in the House or Senate.

"We need more scientists, more people with training as scientists, in Congress, on town councils, on county commissions until that golden age when everyone can think intelligently about science," says Holt, a Ph.D. physicist and former assistant director of the Princeton Plasma Physics Laboratory. He says it's not just about explicitly scientific issues like climate change and energy sources, either. Even voting laws can benefit when legislators think like scientists.

When electronic voting machines first appeared, for example, Holt and other scientists in Congress immediately saw what other politicians didn't. Without a paper trail, results would not meet a basic standard of science: verifiability. Holt introduced a bill in 2008 to address the problem, and though it never passed nationally, states including California and Ohio did begin requiring paper records.

During his time in office, Holt got a $22 billion investment in new research into the 2009 stimulus package, helped write the College Cost Reduction Act and has been a vocal opponent of climate change denial. He has said that he's leaving Congress not because of frustrations with its dysfunction, but because there are so many other things he can do — though he isn't saying yet what his next steps will be.

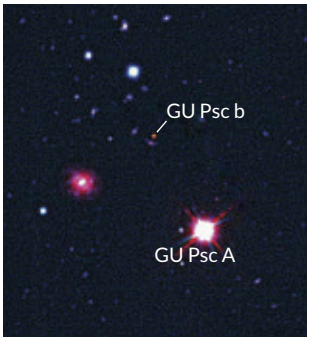
"People interested in politics should learn science, and people involved in science should learn politics," Holt says. For now, he puts the onus on scientists. "Scientists probably have greater responsibility than the average citizen to be involved in politics and policy," he says, because they often have a deep understanding of complex topics. "That responsibility involves more than just voting." — *Sam Lemonick*

THE -EST: LUCAS GRANITO, OBSERVATOIRE DU MONT-MÉGANTIC; THE SCIENCE LIFE: RUSHDHOLT/YOUTUBE

Watch a video of Rush Holt discussing physics, climate and Congress at **bit.ly/SNholt**

Nearly 156 light-years from Earth, the planet GU Psc b likes to keep its distance — at least from its sun. The planet orbits 2,000 times farther from its cool, red star than Earth does around the sun, making it possibly the longest planetary orbit known. One year on GU Psc b, which sits in the constellation Pisces, lasts nearly 163,000 Earth years.

Astronomers spotted the planet as a speck of infrared light following its sun across the sky, as described in the May 20 *Astrophysical Journal*. The planet glows in infrared because it's young — just 100 million years old — and still cooling. The escaping heat warms the planet to roughly 800° Celsius. Based on its age and brightness, astronomers estimate that the body is nine to 13 times as massive as Jupiter. While the star's companion is most likely a very massive planet, there's a chance it may actually be a very dim, lightweight star. *— Christopher Crockett*



Going the distance Compared with the distance from GU Psc b to its star GU Psc A, a trip from the sun to its farthest planet, Neptune, looks like a walk down the street. Light from the sun takes about four hours to reach Neptune. But to reach GU Psc b, light from its star would need nearly 12 days.

Neptune to sun = 30.1 astronomical units

GU Psc b to its star = 2,000 astronomical units

Some male frogs warn off rivals by stretching out their hind legs and spreading their toes, as shown here by *Micrixalus kottigeharensis*.

INTRODUCING

Indian frogs kick up their heels

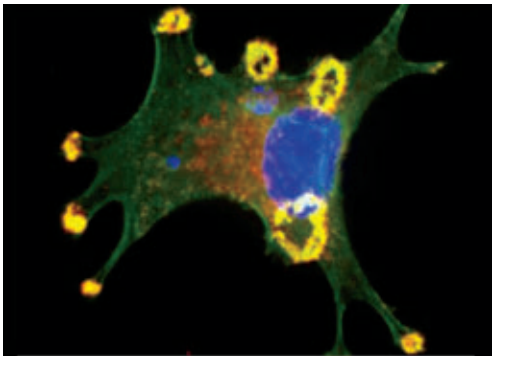
Some frogs use a little fancy footwork to get attention during mating season. A 12-year search of a 1,600-kilometer-long mountain range on India's west coast has turned up 14 new frog species, including at least four "dancing frogs," Indian researchers report May 8 in the *Ceylon Journal of Science (Biological Sciences)*. This finding more than doubles the number of species in the genus *Micrixalus*, a group of frogs known for their dance moves. The amphibian boogie starts off with *Micrixalus* males calling to females, showing off their bright white throats. Then males tap their feet and finish off by stretching out a hind leg and whipping it around behind them. Called foot-flagging, this pretty maneuver isn't just for show. Should a rival male intrude on the display, he may get kicked. *— Allison Bohac*

A male *Micrixalus* frog announces his presence with a call (1) then lifts his legs (2) and kicks any male rivals that crowd his space. When a female (gray) approaches, he climbs on her back and hangs on until eggs are laid and buried in the streambed.

SAY WHAT?

Invadopodia *in-vayd-uh-POH-dee-uh*\ *n.*

Tiny footlike protrusions that enable a cell to invade neighboring tissues. Scientists first discovered these "invasive feet" popping up on highly metastatic cancer cells grown in the laboratory (shown, yellow). It was thought that invadopodia might help cancer cells burrow into other tissues and eventually spread throughout the body. Despite more than a decade of research on these structures, only recently have invadopodia been found in live animals. A study in *C. elegans* worms published last year in the *Journal of Cell Biology* showed that invadopodia form on the uterus of the developing worm and push through to the neighboring vulva, connecting the two reproductive parts. More recent studies have begun to explore how these structures break down the scaffolding between cells to help tumors metastasize. *— Marla Vacek Broadfoot*

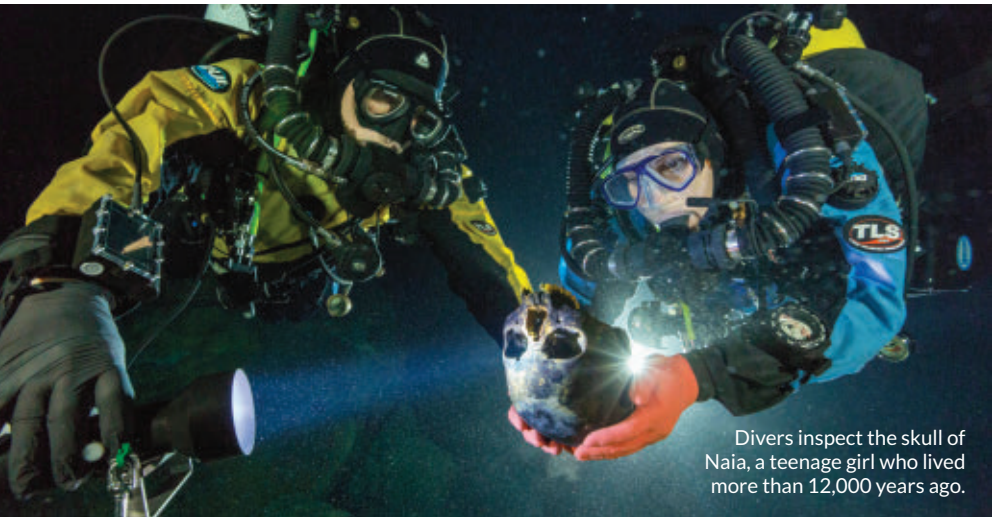


INTRODUCING: S.D. BIJU ET AL/CEYLON J. OF SCIENCE (BIOL. SCI.) 2014; SAY WHAT: P.S. SMITH-PEARSON ET AL/J. BIOL. CHEM. 2010

HUMANS & SOCIETY

DNA clarifies early Americans' heritage

Girl's skeleton ties New World settlers to today's native peoples



Divers inspect the skull of Naia, a teenage girl who lived more than 12,000 years ago.

BY BRUCE BOWER

Support for a genetic connection between the first Americans and modern Native Americans has come from the submerged remains of a teenage girl who lived between 12,000 and 13,000 years ago in what's now Mexico.

Divers discovered the youth's partial skeleton, along with bones of more than two dozen large mammals, while exploring an underwater cave on the Yucatán Peninsula in 2007.

As was true of previously unearthed skulls of early Americans, the girl's facial features differ sharply from those of current Native Americans, reports a team led by archaeologist James Chatters of Applied Paleoscience, a consulting firm in Bothell, Wash., in the May 16 *Science*. Yet the ancient youth shares with Native Americans a genetic profile that probably evolved among people who, between 26,000 and 18,000 years ago, occupied a land bridge connecting Asia to North America, say Chatters and colleagues.

Recent genetic findings, including DNA from an ancient baby's skeleton found in Montana (*SN: 3/22/14, p. 6*), have pointed to a common genetic origin in Asia for Native Americans. DNA from the Mexican skeleton "confirms that there has been genetic continuity from ancient Americans to modern Native Americans," says archaeologist and geologist Michael Waters of Texas A&M University in College Station, who studied the Montana baby's remains.

Ancient American skulls feature long, narrow brain cases and small, short faces, unlike those of modern Native Americans. Those traits raised the possibility that the first Americans and ancestors of Native Americans came from different Asian homelands and arrived in the New World separately.

One of Naia's teeth provided DNA and radiocarbon dates for the 12,000- to 13,000-year-old find.

An opportunity to test that hypothesis occurred in a submerged cavern that divers dubbed Hoyo Negro, or black hole. More than 40 meters below sea level, divers found 46 parts of a human skeleton, including a skull, a pelvis, spinal bones and ribs. Bones of saber-toothed cats, giant ground sloths and other animals, many of which had died out in the area by 13,000 years ago, lay nearby.

Divers named the human skeleton Naia. She stood about 4 feet, 10 inches tall and died at age 15 or 16.

Naia and the animals probably fell to their deaths through a sinkhole into Hoyo Negro at a time when the cave was mostly dry. Reconstructions of ancient climate suggest that rising seas submerged the coastal cave around 10,000 years ago.

Divers returned to Hoyo Negro to measure and digitally photograph its bone collection. A series of dives also retrieved Naia's skull and other bones, as well as a tooth from an extinct mastodon-like creature. Radiocarbon dating of tooth enamel and analyses of mineral deposits on bones indicated that Naia lived between 12,000 and 13,000 years ago. The extinct animals may have roamed much earlier, about 40,000 years ago.

One of Naia's teeth yielded mitochondrial DNA, which is inherited solely from the mother. That DNA contained an Asian-derived set of gene variants previously found only in North and South America. The study suggests for the first time that members of this early maternal lineage reached Central America.

To pin down links between early New World settlers and modern Native Americans will take DNA from additional ancient Americans, remarks archaeologist David Meltzer of Southern Methodist University in Dallas. Differences in skull shape between ancient and modern Americans with common genetic origins could have developed after a founding population split up and random genetic changes accumulated in separate groups, Meltzer says.

Naia's ancient mitochondrial DNA lineage appears infrequently in native Mexican groups today, a sign that shifting and mixing of populations have occurred since Naia's time, says biological anthropologist Theodore Schurr of the University of Pennsylvania in Philadelphia. Recurring migrations within the Americas, including forced resettlements of conquered peoples by pre-Columbian civilizations, helped to shape regional genetic profiles, he says. ■

FROM TOP: PAUL NICKLEN/NATIONAL GEOGRAPHIC; J. CHATTERS

Watch a video of divers exploring Hoyo Negro at **bit.ly/SN_naia**

BODY & BRAIN

New brain cells might erase memories

Neuron birth may explain why infants can't remember

BY MEGHAN ROSEN

Unlike the proverbial elephants, babies always forget. Infants' memories may be wiped clean by the genesis of new brain cells, a study in rodents suggests. The findings offer an explanation for why people can't recall memories from early childhood, a century-old mystery.

The study's authors "make a very interesting and compelling case," says neuroscientist and psychiatrist Thomas Insel, director of the National Institute of Mental Health in Bethesda, Md. "It's just truly fascinating," he says. "Nobody has actually looked at this very carefully before."

More than 100 years ago, Sigmund Freud speculated that humans' tendency to forget their early years, dubbed infantile amnesia, might have a psychosexual origin. Scientists later thought memories might be rooted in language, because kids typically start making long-term memories around the time they start speaking, says study coauthor Sheena Josselyn of the Hospital for Sick Children in Toronto.

> "Maybe it's good to clear away some memories and forget some things that are not so important."
>
> SHEENA JOSSELYN

"But the really weird thing is that most animals show infantile amnesia too," she says. "So the development of language can't be the whole explanation."

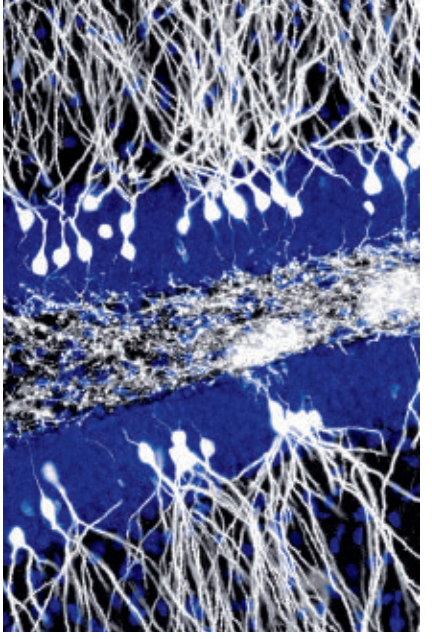
Inspired by observations of their own toddler, Josselyn and her husband, study coauthor Paul Frankland, wondered why young children couldn't retain memories of situations or events. These memories — such as what a person ate for dinner — involve the hippocampus, a skinny seahorse-shaped belt of tissue that houses a cell-making factory about the size of a few blueberries. This little factory is one of the only parts of the brain that normally cranks out new neurons, which scientists believe help make memories.

Josselyn and Frankland, also of Toronto's Hospital for Sick Children, knew that such cell production tapers off in childhood. "That's exactly when we start to be able to form long-term memories," Josselyn says. She and colleagues wanted to find out whether youngsters' recollections were somehow tied to brain cell formation. So the team turned to mice, animals that — like humans — harbor blank spots in their early memories. As mice age, the birthrate of neurons slows down. This dropoff matches up temporally with the rodents' ability to remember scary situations, the researchers report in the May 9 *Science*.

For their tests, the researchers placed adult mice in a chamber noticeably different from their usual homes — stripes on the walls and a vinegary smell — and buzzed the animals with mild foot shocks. The mice learned to fear the room, and even 28 days later would freeze up when put in the chamber. Infant mice were more forgetful. A day after being shocked, their fear began to fade. The animals' behavior hinted that making new brain cells might be mucking up memory retention.

Next, the researchers boosted neuron production, or neurogenesis, in adult mice. The team shocked adult mice in the striped room and then let them exercise at will on running wheels for days or weeks. Running naturally triggers the growth of new brain cells in the hippocampus, Josselyn says. Just a few weeks of racing on the wheel helped mice forget their fear of the scary room.

Other tricks to turn up the number of new neurons also cleared adult animals' memories. And the reverse worked too: Dialing down the birth of new neurons in infant mice kept the fear memory alive.



During infancy, in humans and some animals, a memory center of the brain called the hippocampus (blue, mouse brain shown) churns out new neurons (white). These cells may mess up early memories and could explain why adults can't remember their experiences as babies.

COURTESY OF JASON SNYDER

"It was really amazing to us that we could make a memory last much longer in these infant mice just by decreasing neurogenesis," Josselyn says.

The findings give a new twist to the role of neurogenesis in the hippocampus: Instead of merely making memories, as scientists currently believe, spawning brain cells may also help animals forget. The notion is "contradictory to where everyone else in the field has been," Insel says. "That's going to be very provocative."

Josselyn thinks that the new cells could be messing up brain circuits laid down by preexisting neurons. These cells reach out spindly fingers and link up with neighbors. Memories made using older links may be hard to call to mind when new links take over, she suggests.

"Maybe forgetting is not a bad thing," Josselyn says. "Maybe it's good to clear away some memories and forget some things that are not so important."

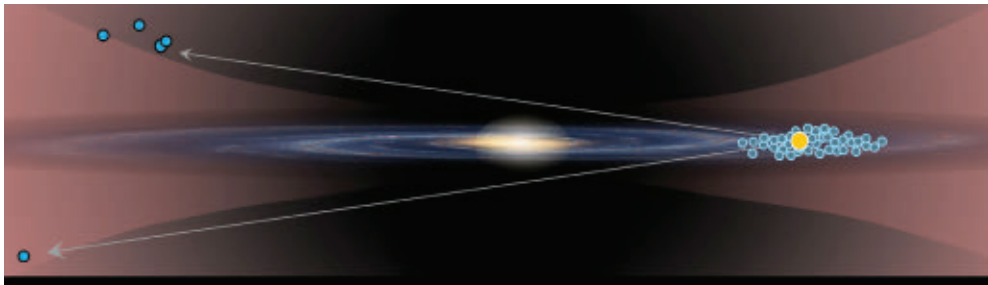
The hippocampus might be something like a computer cluttered with files, says neuroscientist Richard Morris of the University of Edinburgh. "Every so often we all sit down and do a little tidy-up," he says. "Maybe that's what neurogenesis is all about. It's the hippocampus's very own spring cleaning system." ■

ATOM & COSMOS

Light shed on galaxy's far side

'Variable stars' could help map Milky Way's dark matter

BY CHRISTOPHER CROCKETT



Far far away Five Cepheid stars (blue circles, left) sit on the opposite side of the Milky Way's center from Earth (yellow). The cluster of pale blue dots (right) marks previously known Cepheids. Pink areas show the Milky Way's hydrogen gas, which flares out toward the edge of the galaxy.

Beyond the galaxy's center lie mostly uncharted swaths of space. But now astronomers have found some landmarks: five stars roughly 75,000 light-years from Earth. The discovery should help astronomers map the largely unexplored far side of the Milky Way and understand the nature of the enigmatic dark matter thought to hold galaxies together.

The five stars are Cepheid variables, whose brightness fluctuates regularly. Astronomers use Cepheids as distance markers because the brighter the star, the slower it pulsates. By measuring a Cepheid's period and how bright it appears, astronomers can calculate its distance; if the star is in another galaxy, then researchers know how far away the galaxy is as well.

Michael Feast, an astronomer at the University of Cape Town in South Africa, and colleagues found the stars in data from the Optical Gravitational Lensing Experiment, a telescope in Chile. The instrument records visible light from various patches of sky, including the view to the center of the galaxy. The telescope, he says, was "not looking for these stars at all, but happened to find them."

Feast's team honed the stars' locations, reported in the May 15 *Nature*, by observing the stars in infrared light with a telescope at the South African Astronomical Observatory. Infrared light cuts through intervening interstellar dust more effectively than visible light does. Until now, all known galactic Cepheids were no farther than 28,000 light-years away; these five are almost three times as far.

"This is a beautiful piece of classical astronomy," says Leo Blitz, an astronomer at the University of California, Berkeley, "where you find some stars, get some distances to them and try to infer something." The stars, which are scattered well above and below the plane of the galaxy, confirm what earlier observations of hydrogen gas had suggested: The outer disk of the galaxy flares like a skirt.

In this region, astronomers think dark matter provides much of the gravity needed to hold the galaxy together. Without the dark matter, Feast says, the stars and gas would flare even more. Stars at the outer edge of the Milky Way are hard to come by, so mapping the Cepheids' locations and tracking their motions could help pinpoint how much

MATTER & ENERGY

Accidental chemistry leads to new superplastics

Self-healing or nearly unbreakable polymers can be easily recycled

BY BETH MOLE

With an accidental tweak to a classic chemical reaction, scientists have created the first easily recyclable forms of mighty plastics. The discovery could lower costs and reduce waste of everyday products, researchers say.

The two nitrogen-containing polymers, a superstrong plastic and a self-healing gel, represent new types of thermoset materials, which are heat resistant and highly stable. Thermosets are widely used, from automobiles to electronic devices, and are difficult or impossible to recycle. But the new polymers easily break down into their original components, ready to reassemble. "This is a completely different paradigm for recycling," says polymer chemist Jeannette García of IBM Almaden Research Center in San Jose, Calif.

Recycling methods for standard plastics like those in water bottles often involve melting the polymers at very high temperatures, which tends to damage the materials. With the new plastics, García says, researchers completely destroy and rebuild the material.

The new materials were created by serendipity. While testing a chemical recipe, García missed a step. A hard chunk of plastic appeared in her flask. After smashing the glassware to retrieve the material, García found a nearly unbreakable rock of thermoset that was stable up to around 300° to 350° Celsius.

García's team reports in the May 16 *Science* that the chemistry is a revision of an old reaction. For years, chemists have known that combining nitrogen-containing molecules called amines with formaldehyde creates hexagon-shaped rings of carbon and nitrogen, called triazines. But by fortuitously adding a double amine — one with two nitrogens — García's team created triazines that linked together into a 3-D network, forming a polymer with unusual powers.

R.M. CATCHPOLE/INSTITUTE OF ASTRONOMY/UNIV. OF CAMBRIDGE, JPL-CALTECH/NASA

dark matter is out there.

Studying the edge of the galaxy is difficult, Blitz says, because the thick screen of dust in the plane of the Milky Way blocks a lot of the light from distant stars. Blitz likens it to trying to get a picture of the back of a house while standing in the front yard: "You just can't do it."

Most of what astronomers know about the far side of the galaxy comes from radio observations of hydrogen gas. Researchers use the velocities of the gas to infer distances; those inferences depend on complex calculations of how the galaxy rotates. The key advantage of Cepheids, says Giuseppe Bono, an astronomer at the University of Tor Vergata in Rome, is that they provide distances without relying on such calculations.

Since the discovery of their variable nature in 1908, Cepheids have helped astronomers map the universe. "They are a jack-of-all-trades," Bono says. In the 1920s, Edwin Hubble used Cepheids to show that what was then called the Andromeda Nebula was not a nebula but rather another galaxy. Hubble also relied on Cepheids to reveal that the universe is expanding uniformly in all directions, which provided the foundations for the Big Bang theory. ■

"The formaldehyde-amine reaction is one of the oldest used in polymer engineering," says organic chemist Bert Meijer of Eindhoven University of Technology in the Netherlands. By using it to create unique materials, the research "catches the eye of every materials chemist," he adds.

Combining the formaldehyde and double amine at around 50° C created a gel that, when cut apart and placed back together, reformed into a seamless whole. The self-healing gel was shelf stable, but when researchers washed it with a liquid of neutral pH, it disassembled.

When heated to about 200° C, the reaction formed the hard plastic that García first discovered. That plastic breaks down in strong acid, at pH 2, regenerating the starting materials. ■

EARTH & ENVIRONMENT

Groundwater loss sets off tiny quakes

Draining California's aquifers may stress San Andreas Fault

BY MEGHAN ROSEN

Sucking out groundwater could be moving and shaking California. As humans drain aquifers in the state's Central Valley, the land flexes upward, lifting the surrounding mountain ranges and possibly triggering tiny earthquakes, researchers suggest May 14 in *Nature*.

It's the first link between the region's groundwater pumping and mountain uplift and seismic activity, says geophysicist Kristy Tiampo of the University of Western Ontario in London, Canada.

Researchers have known for years that, compared with wet months, dry times see more earthquakes in some spots near Parkfield, Calif., a tiny town in the middle of one of the state's biggest seismic hazards, the San Andreas Fault. Scientists weren't sure how to explain the uptick of quakes, most of which aren't strong enough to rattle a teacup. But researchers have now tied the region's seasonal shakes with another observation: The neighboring mountains are creeping slowly skyward.

"Everybody thought the uplift was due to tectonics — we thought it was all related to plate motion," Tiampo says.

Instead, Colin Amos, a geologist at Western Washington University in Bellingham, and colleagues looked to the vast amounts of water people have pumped out of the Central Valley. Over 150 years, the region has lost nearly 160 cubic kilometers of groundwater — more than the volume of Lake Tahoe.

The researchers analyzed years of data from 566 GPS stations at sites from the Pacific Ocean into Nevada that cross a southern portion of the Central Valley. On average, Amos says, stations in the Coast Ranges next to the San Andreas Fault are rising 1 to 3 millimeters per year, or up to about half the width of a paper clip.

That uplift matched the team's prediction of how much mountains would grow if unburdened by groundwater, a value Amos and colleagues calculated using the elastic properties of Earth's upper crust.

The results suggest that groundwater loss helps explain the mountains' rise. "I was surprised," Amos says. "I've got to confess: I study tectonics — I look at the mountains and want tectonic answers."

Although the movement doesn't sound like much, it could be just enough to unsettle the fault. As the ground expands upward, it pulls away from the fault, no longer clamping the plates tightly together. That makes it a bit easier for the plates to slide, which might set off subtle shudders. Because groundwater levels are especially low in summer, the idea could account for Parkfield's boost in earthquakes during dry months.

Caltech geologist Jason Saleeby says Amos' team is on to something, but he thinks tectonic activity is important too. "You've got two things going on," he says. "The next step is to figure out which is dominant." ■

A GPS station in California's eastern Sierra Nevada inches up and down slightly as the mountains rise and fall. The mountains' tiny movements may be influenced by groundwater pumping in the state's Central Valley. The water loss may also set off little earthquakes along the San Andreas Fault.

UNAVCO

LIFE & EVOLUTION

Electronics may upset birds' compass

Weak electromagnetic waves can impede robins' migratory orientation

The European robin, a different species from the North American kind, can lose its compass sense when exposed to a background of human-generated electromagnetic noise.

BY SUSAN MILIUS

A background buzz of electromagnetic waves from such ordinary sources as electronic equipment can interfere with a bird's magnetic compass, according to a particularly careful set of experiments.

Normally, migratory birds held in captivity during their travel season tend to hop, face and fidget in the direction they would fly. But caged in huts at a German university, European robins (*Erithacus rubecula*) failed to orient in their usual migratory direction unless researchers screened out the campus's background electromagnetic frequencies, says Henrik Mouritsen of the University of Oldenburg in Germany. Yet the robins oriented normally in a rural area with less electromagnetic background, he and colleagues report in the May 15 *Nature*.

Previous claims that background levels of electromagnetic emissions affect biological processes have been questioned or debunked. But this set of experiments was unusual in its protocol, says Joseph Kirschvink of Caltech, who also studies the magnetic sense in animals and has criticized other papers for lack of rigor.

Kirschvink wants to see other researchers repeat the experiments, but, he says, Mouritsen's team "did the best job so far, enough so that I think it needs to be considered seriously."

The electromagnetic background Mouritsen measured was not strong: Signals ranging in frequency up to 5 megahertz occurred at intensities well below the World Health Organization's limits for human exposure. Kirschvink compares the exposure to standing five kilometers away from a 50-kilowatt AM radio station.

But just being within listening range of AM stations isn't a problem for bird orientation, Mouritsen found. Nor do cell phones or power lines explain the effect. He speculates it's the sum total of the electronic equipment in use on his university's campus that affected birds.

The effects disappeared when Mouritsen's team moved the experiments to the countryside, which has much less intense electromagnetic background noise.

Asked whether these experiments have any implications for human health — a notoriously controversial question with a history of hard-to-replicate claims — Mouritsen just laughs. "I study birds," he says.

He acknowledges that conventional sensory processes in living cells would not be expected to jam at such weak levels of electromagnetic noise. "It's not the first time it's been claimed," he says, "but I hope it's the first time it holds up."

The results are "exciting and scary," says John B. Phillips of Virginia Tech in Blacksburg. They suggest that experiments in labs all over the world may have missed finding animals' magnetic compasses because background electromagnetic noise interfered. He recently demonstrated that mice could learn to navigate a maze using magnetic fields when he shielded the experiment's apparatus from background frequencies.

Mouritsen's work on background interference began with an experimental disaster. As a graduate student in Denmark, he had studied bird navigation using the standard test of looking at the direction of captive migratory birds' fidgeting. But when he set up the experiments at Oldenburg in 2004, they didn't work. He kept trying for three years, but the birds couldn't orient themselves. "We were desperate," he says.

Normal orientation behavior returned only when he shielded the birds from electromagnetic noise with aluminum screens grounded by connection to the equivalent of a lightning rod. "I didn't want to study this," he remembers, because he was well aware of the zany claims and iffy experimental protocols that have littered research on electromagnetic effects on biological processes.

Over seven years, however, he and collaborating research teams tweaked and repeated the experiments. To eliminate possible bias among students collecting data, he kept them from seeing whether the shielding device was actually connected to the grounding device. The effect still showed up.

Researchers also found they could create the disorienting effect by sending artificial "background" electromagnetic interference into shielded huts.

Animals have more than one way to sense magnetic information that can be used for orientation, Phillips says. Many have particles of magnetite in their bodies, but he suspects animals may use something else for orienting to compass directions. That could be a quantum compass, one that depends on weird subatomic effects such as temporary differences between entangled electrons in a molecule such as cryptochrome (*SN Online: 1/7/11*).

Mouritsen says the low energies involved in his results suggest to him that something subtle, such as the proposed quantum compass, could be at work. Yet he found that a broad range of frequencies disrupted his birds, in contrast to a previous study and some theoretical predictions about bird quantum compasses. If his results hold up, the avian version of quantum weirdness may have gotten even weirder. ■

H. MOURITSEN

HUMANS & SOCIETY

Farming shaped thinking modes

In China, cultural differences arose from growing rice or wheat

BY BRUCE BOWER

Differing thinking styles between Chinese people and Westerners, as well between northern and southern Chinese people, can trace their roots to rice paddies and wheat fields, one study suggests.

Rice farming cultivates a holistic focus on discerning relationships among people and objects, and valuing others as much as or more than oneself, say psychologist Thomas Talhelm of the University of Virginia in Charlottesville and his colleagues. Holistic thinking among many modern Chinese people partly reflects regional histories of building communal irrigation systems and cooperatively planting and harvesting rice paddy fields over thousands of years, the scientists propose in the May 9 *Science*.

They draw that conclusion using studies of college students from regions with different agricultural practices. Students from southern and central China's rice-growing provinces think holistically, even though they have probably never farmed rice, Talhelm's group reports.

In contrast, students from northern and central Chinese provinces that have specialized in wheat growing think more like Western students, exhibiting a preference for abstract analysis and self over others, the scientists find. Wheat is less labor-intensive to grow than rice, so farmers can plant and harvest crops without much help from neighbors.

Analytical, individualistic thinking is not more common among students from richer provinces, contrary to the argument that this outlook springs from modernization and capitalism.

Talhelm's "rice theory" posits that people have absorbed and held onto the outlook of their farming ancestors even in modernized societies. "Rice theory might explain why East Asia is so much less individualistic than expected based on its wealth," Talhelm says.

The study shows for the first time that thinking styles differ between people from rice- and wheat-farming regions, says psychologist Richard Nisbett of the University of Michigan in Ann Arbor. "I wish I had thought of [researching] that," adds Nisbett.

Talhelm's team tested 1,162 Chinese students, who viewed lists of three items, such as a rabbit, a dog and a carrot. For each trio, students chose two items that belonged together. Earlier research found that analytical thinkers often group items according to categories, so rabbits and dogs go together. Holistic thinkers tend to look for relationships, such as rabbits eating carrots.

Students from predominantly rice-growing areas made an average of around seven to nine holistic matches of 10 possible matches, compared with roughly five to seven holistic matches for those from wheat-growing areas. That pattern held for students from adjacent rice- and wheat-intensive provinces, suggesting that contrasting climates in southern and northern China didn't produce distinctive thinking styles.

Talhelm's team also analyzed national statistics in China from 1996, 2000 and 2010 and found a higher divorce rate and a greater number of successful patents for new inventions in wheat-growing provinces than in rice-growing provinces. That trend is consistent with the idea that analytical thinking fosters both individualism and creativity.

Talhelm's results suggest that a wheat-based culture encouraged technological innovations that underlay the rise of Western societies, writes psychologist Joseph Henrich of the University of British Columbia in Vancouver, also in *Science*. Contacts with people in individualistic herding cultures and proximity to rivers that served as trade routes may also have shaped China's regional thinking styles, Talhelm says. ■

EARTH & ENVIRONMENT

Antarctic glacier melt may be unstoppable

NASA

Some West Antarctic glaciers have entered terminal melt, two new studies suggest, threatening to raise global sea levels by around 4 meters in coming centuries. Satellite observations of six glaciers recorded over two decades indicate unstoppable liquefying that will probably accelerate, researchers report May 12 in *Geophysical Research Letters*. Another research team, reporting in the May 16 *Science*, used simulations to show that two of the six, the Thwaites (shown at left) and Haynes glaciers, may collapse rapidly sometime in the next 200 to 900 years. Disintegration of the six glaciers could raise sea level by 1.2 meters and eventually spur the melting of the rest of the continent's ice sheet. In that case the oceans could rise by another 3 meters or more. Both studies link climate change and warming ocean waters to the glaciers' irreversible demise. *—Beth Mole*

BODY & BRAIN

Football linked to brain changes

College players have smaller hippocampi than nonplayers

BY NATHAN SEPPA

A college football player who has been diagnosed with a concussion is likely to have a smaller hippocampus, the memory center of the brain, than a player who hasn't been so diagnosed, a new study finds. And regardless of whether they've had concussions, players have smaller hippocampi than men their age who don't play football and who have no history of brain trauma, the study suggests.

"This is one of the first papers to draw a direct link from concussion to specific tissue changes," says Dennis Molfese, a neuropsychologist at the University of Nebraska–Lincoln.

Sports-related trauma studies have focused on the hippocampus because some memory deficits are linked to head injuries. But much of that work has investigated people who were middle-aged or older, says Patrick Bellgowan, an experimental psychologist at the Laureate Institute for Brain Research in Tulsa, Okla., and the University of Tulsa.

He and his colleagues measured the hippocampus size of 50 Division I college football players and 25 male volunteers of similar age who don't play football or soccer. MRI scans revealed that 25 players with previous concussions had hippocampi that averaged just three-quarters the size of those of men who hadn't played football or soccer. The hippocampi in the 25 football players who hadn't suffered a concussion were about five-sixths as large as in the control group, the researchers report in the May 14 *JAMA*.

Having more years of football experience was also associated with slower reaction time on tests.

25 percent
Average decline in hippocampus size in football players with concussions compared with nonplayers

Bellgowan says the difference in hippocampus volume between the nonplayers and the football players who hadn't had a concussion suggests cumulative damage to the hippocampus could come from injuries that fall short of diagnosed concussions. "It was a bit of a surprise to find that both groups [of players] were smaller," he says.

The mechanisms underlying this volume loss are unknown. An inflammatory reaction might cause cells in the hippocampus to rev into an excited state and eventually die. "That's the operating thesis," Bellgowan says. A contact sport that damages the blood-brain barrier and triggers such inflammation might disrupt normal hippocampal processes, he says.

Damage seemed limited to the hippocampus. The amygdala, which is near the hippocampus and shares some emotion and memory chores with it, "showed absolutely no difference between groups," Bellgowan says. ■

MATTER & ENERGY

Just two photons for teleportation

Quantum information passed without third particle

BY ANDREW GRANT

Quantum teleportation just got simpler and more reliable.

Despite its sci-fi connotation, quantum teleportation doesn't magically move objects but instead transmits fragile information. Unlike normal information, quantum information can exist in multiple states at once, as long as the particles encoding the data are not disturbed or measured. Teleportation enables the transfer of a particle's quantum state to another particle.

The standard procedure for quantum teleportation, proposed in 1993, requires three particles: the particle to be teleported, dubbed C, plus a pair of particles, A and B, that are entangled, meaning that they are linked in such a way that measuring a property of one instantly reveals the value of that property for the other. The sender measures the desired property of particles A and C, thus ruining their quantum states. The sender calls (or e-mails or faxes) the receiver with the measurements. Then the receiver can modify B so that the desired property perfectly matches that of C before it was measured. In effect, B becomes C.

Using this method, scientists have teleported particles up to 143 kilometers (*SN: 6/30/12, p. 10*), but physicists including Ebrahim Karimi of the University of Ottawa had reservations. The sender's simultaneous measurement of two photons requires expensive and complicated equipment. And teleportation often fails. So Karimi and his colleagues designed an experiment that uses less sophisticated equipment and would theoretically transfer quantum information with 100 percent success.

Karimi's demonstration used two photons. The researchers entangled the particles using a property called orbital angular momentum, a measure of how much a particle orbits around the axis of its forward motion. Karimi's team then encoded quantum information into a second property — polarization — of the sender's entangled photon, A. The sender then measured both properties of the particle and sent the results to the receiver. The researchers could teleport the quantum information held in the polarization of A to the orbital angular momentum of B more than 99 percent of the time, they report in a paper posted April 30 at arXiv.org.

"It's a beautiful experiment," says Seth Lloyd, a mechanical engineer at MIT. "They're actually doing teleportation in unconditional fashion — no ifs, ands or buts." He adds that the technique has potential for quantum cryptography and communication, as well as in linking future quantum computers. ■

EARTH & ENVIRONMENT

‘Rock snot’ came with river changes

Controversial idea suggests alga not an invasive species

BY BETH MOLE

Environmental change could be triggering “rock snot” algal blooms that harm fish and leave pristine riverbeds looking like tattered mats of soggy toilet paper.

Since the mid-2000s, the blooms, which look mucuslike up close, have cropped up in rivers worldwide. Researchers assumed that the responsible alga, *Didymosphenia geminata*, was a foreigner or mutant invading watersheds. But a new analysis suggests that the alga, nicknamed didymo, is instead native to much of the globe, and that changes in water conditions are to blame for a recent boom in blooms. The controversial suggestion could upend strategies for preventing cases of rock snot.

When they’re not blooming, the soda bottle–shaped algae are about the width of a human hair and live under river rocks. Researchers might scrub six to eight basketball-sized rocks to find one cell, says freshwater ecologist Brad Taylor of Dartmouth College. Didymo blooms, on the other hand, are dramatic. The algae grow whitish stalks that can extend 2 to 3 inches in just days. Cells clump at the top and form snotlike blobs. When blobs merge, they form mats that look like shredded paper.

“It’s amazing that a little creature like that can produce three inches of stuff on the stream bottoms that can cover miles of a riverbed,” Taylor says.

The mats look slimy, but they actually feel like wet cotton. Their forest of watery fibers creates a refuge for worms that carry a fish parasite. The mats are also a deadly snare for large insects that fish eat. The combination may devastate salmon and other fish populations.

Researchers and policy makers are anxious to stem what they assume is a biological blitz. But Taylor and aquatic ecologist Max Bothwell of Environment Canada in Nanaimo aren’t convinced that didymo is invading. The pair examined the alga’s fossil records, genetics and ecology. “None of it added up that [didymo] was spreading around,” Taylor says. The analysis appears May 7 in *BioScience*.

Explosions of rock snot, an algal bloom in rivers around the world, may be due to changes in the environment.

The invasion explanation arose in the wake of blooms that appeared in the 1990s around Vancouver Island, where blooms hadn’t been seen before. Starting in the mid-2000s, scientists had spotted didymo blooms in Europe, North America, South America, Asia and New Zealand. In many countries, policy makers hastily developed strategies to control the spread of the alga, assuming it was an invasive species.

But Taylor and Bothwell say that fossil records place the alga on multiple continents 10,000 years ago. In historical records, the researchers found didymo had been in most of the bloom locations for decades, if not centuries, Taylor says.

So something else must have changed. Genetic analyses haven’t found a mutation linked to the snot formation. But researchers including Bothwell have discovered that blooms occur only when a river’s phosphorus levels drop extremely low. Taylor and others think that when didymo is starved for phosphorus, it morphs into its long, stalked form to reach higher into the water.

The surge in blooms does seem linked to river conditions, says R. Jan Stevenson, an algal ecologist at Michigan State University in East Lansing. Stevenson and Taylor believe that pollution and climate changes are behind altered river conditions, which in turn caused the synchronized blooms during the 2000s. Emissions from power stations contain nitrogen, which falls to Earth in rain. When plants get more nitrogen, their metabolisms speed up, requiring them to take up more of other nutrients including phosphorus. Less phosphorus may then wash into streams where the algae live, the researchers hypothesize.

Taylor also speculates that increased snowmelt due to global warming may have lowered rivers’ phosphorus levels. Like increased nitrogen, extra water can speed plants’ growth, leading them to take up more phosphorus. Speedy snowmelt can reduce nutrient input to rivers and lakes, he says. “It’s just a question of whether this is occurring at all of these places.”

At least one place doesn’t fit the phosphorus pattern: New Zealand. Didymo has run rampant on the country’s South Island since 2004. However, says ecologist Cathy Kilroy of the National Institute of Water and Atmospheric Research in Christchurch, “good records of dissolved phosphorus in many rivers show fluctuations over time, but no sign of a general decline.” The New Zealand rivers hit by didymo had low phosphorus long before the 2004 blooms, so most researchers think that didymo is an invader there. Officials have instituted restrictions to keep the algae from contaminating pristine streams and rivers.

Kilroy does agree, however, that environmental changes probably contributed to other cases. ■

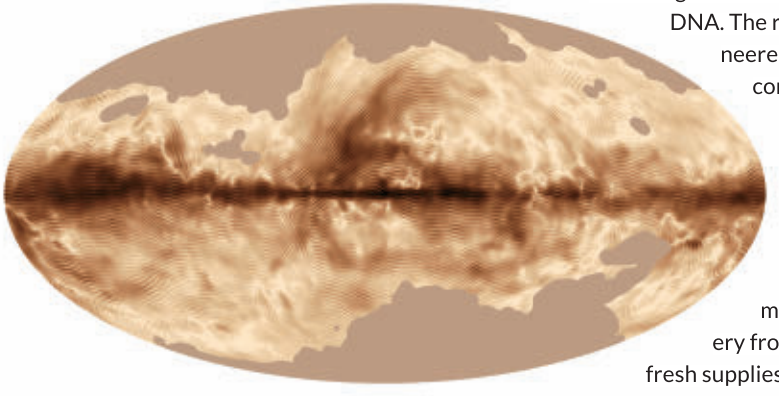
When *Didymosphenia geminata* blooms, the tiny, normally soda bottle–shaped alga transforms into a stalked, branching form (shown) that clings to rocks.

BOTH: B. TAYLOR

ATOM & COSMOS

Spin of an exoplanet calculated for the first time

Astronomers have measured the rotation of an exoplanet for the first time. A day on the planet Beta Pictoris b is roughly eight hours long — shorter than on any planet in the solar system, the team reports in the May 1 *Nature*. Beta Pictoris b orbits a star 63 light-years away in the constellation Pictor. Ignas Snellen of Leiden Observatory in the Netherlands and colleagues analyzed the planet's spectrum. The spectrum reveals certain wavelengths of light that are absorbed by carbon monoxide in the planet's atmosphere. By measuring how much the absorbed wavelengths are Doppler shifted by the rotating atmosphere, the researchers determined the planet spins at 25 kilometers per second. *— Christopher Crockett*



Milky Way's magnetic field mapped

If the Milky Way were one giant magnet, sprinkling iron filings around it would trace the galaxy's magnetic field. Scientists have found a more practical way to map the field using the Planck satellite. The galactic magnetic field is about 100-millionth the strength of a refrigerator magnet, and yet it may be crucial to star formation. The map took advantage of the magnetic field aligning interstellar dust grains, which then polarize light reflecting off them. Planck measured the polarization of the microwave radiation that permeates space. Planck's map (above), reported in four papers posted May 5 at arXiv.org, shows the entire sky with a dark band through the center representing the plane of the galaxy. Darker shading reveals more-polarized light. The brown lines mark the magnetic field's direction. *— Christopher Crockett*

GENES & CELLS

Organism with artificial DNA alphabet makes its debut

Synthetic biologists have created the first organism with a genetic code containing two artificial DNA bases in addition to the standard four: A, C, G and T. These four DNA bases link together (A's with T's and C's with G's) to encode genetic information. Bases, which form the rungs in a twisted DNA ladder, are components of nucleotides. Floyd Romesberg of the Scripps Research Institute in La Jolla, Calif., and colleagues expanded the genetic language using a pair of synthetic nucleotides, called d5SICS and dNaM, which together make up a new rung of DNA. The researchers engineered *E. coli* bacteria to contain the artificial nucleotides and process them like normal DNA. The team also equipped the bacteria with molecular machinery from algae to import fresh supplies of the foreign nucleotides for DNA copying and repair. If given synthetic nucleotides in food, the bacteria could survive and replicate, the researchers report in the May 15 *Nature*. The authors say the extended genetic vocabulary has potential for creating DNA-based nanomaterials and proteins with exotic abilities. *— Beth Mole*

LIFE & EVOLUTION

Lizards may scale back head bobbing to avoid predators

Predators can really mess up a lizard's mojo. When threatening foes come along, male brown anoles, *Anolis sagrei*, tone down the swaggering head bob that says "come hither" to females and "get lost" to other males, reports David Steinberg of Duke University and colleagues May 19 in the *Proceedings of the National Academy of Sciences*. The team measured the height of anoles' head bobs, sharp up-and-down jerks, on nine Bahamian islands. On five of the islands, the researchers introduced carnivorous curly-tailed lizards, *Leiocephalus carinatus*. On these islands, the anoles bobbed their heads less emphatically: a hearty nod became a timid wobble. These lizards' biggest bobs were as little as 40 percent of those of males on non-threatened islands. Showing off less than usual may help anoles avoid attracting unwanted attention, the team suggests. Researchers knew that other prey animals could change these types of mating and territorial signals over generations. But the idea that individual animals could tweak movement-based signals to cope with threats from predators hadn't been well documented. *— Meghan Rosen*

MATTER & ENERGY

A proposal to create matter from light

A proposed experiment may soon transform particles of light into matter. Oliver Pike, a plasma physicist at Imperial College London, typically works on nuclear fusion — a process that converts matter into energy and not vice versa. But he and colleagues laid out plans for a device that would use a key piece of fusion equipment to convert light, a form of energy, into particles with mass. It would do so by smashing photons together to create electrons and their antimatter counterparts, positrons. Physicists have never observed this process. Detailed May 18 in *Nature Photonics*, the design relies on a hohlraum, a small metal cylinder that holds hydrogen fuel in laser fusion experiments (*SN: 4/20/13, p. 26*). Heating a hohlraum with a laser produces a dense field of X-ray photons inside. The team estimates that passing a jet of high-energy gamma-ray photons through the laser-excited hohlraum would make enough photons collide to produce up to 100,000 pairs of electrons and positrons. The experiment requires two powerful lasers and vacuum conditions. Pike says several scientists are interested in trying it out. He hopes someone will start colliding photons within a year. *— Andrew Grant*

ESA AND THE PLANCK COLLABORATION

Watch a video of a head-bobbing lizard at **bit.ly/SN_anole**

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High TIMES

Legalization trend forces consideration of pot's dangers

By Laura Sanders

Some people think marijuana is nature's gift to humankind: a nonaddictive drug, safe at any dose, that opens the mind, lifts the spirit and transports the user to a more profound reality.

"The illegality of cannabis is outrageous, an impediment to full utilization of a drug which helps produce the serenity and insight, sensitivity and fellowship so desperately needed in this increasingly mad and dangerous world," a user named Mr. X wrote in the 1971 book *Marihuana Reconsidered*.

Close to 30 years later, Mr. X was revealed to be the legendary science communicator and astronomer Carl Sagan. His message still reverberates with many Americans, whose support for legalizing marijuana has tripled since 1989 — from 16 percent to 54 percent today. In Colorado and Washington state, voters legalized recreational marijuana use in November 2012. That formal embrace of marijuana may signal a growing shift in acceptance. Today, 21 states and the District of Columbia sanction medical use (up from 16 in 2010) and 17 have curbed punishments for possession of small amounts of recreational cannabis.

Marijuana as medicine is gaining support in studies, both to tamp down nausea and pain and to directly counter insidious diseases such as epilepsy, cancer and multiple sclerosis (*SN: 6/19/10, p. 16*). But what about for healthy people? Is marijuana really a safe way to rise above the tumult and distress of daily life?

Michele Leonhart, the head of the U.S. Drug Enforcement Administration, says no. In congressional testimony in 2012, she portrayed marijuana as a dangerous addictive drug on par with methamphetamines or heroin. Like other drugs cordoned off by her agency to a list called Schedule I, she said, marijuana has no medical use and a high potential for abuse.

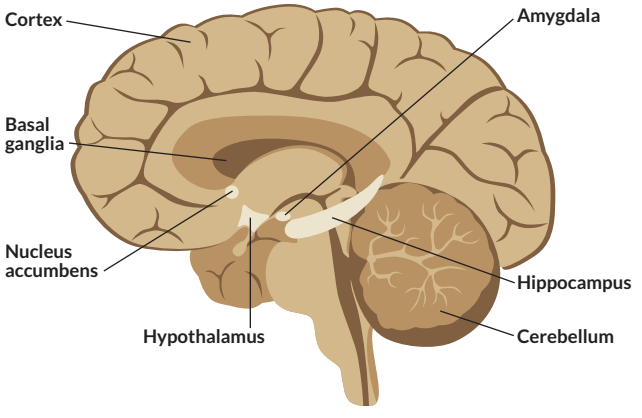
Convinced of marijuana's dangers, the DEA and vocal groups of police officers, educators and public health officials remain steadfastly opposed to the growing legalization movement. Legalization poses significant health and safety risks to Americans, they argue. This addictive drug wipes out memories, steals IQ points and triggers psychosis, leaving behind a zombie nation of slackers vegetating in their parents' basements, opponents say. The consequences may be especially damaging for teens.

Who is right? The people who contend that marijuana is a misunderstood salve for the soul or those who claim it's a dangerous narcotic that turns people into dimwitted potheads?

Turns out it's neither. Though the research is far from definitive, the scientific evidence that does exist suggests that marijuana is far less dangerous than highly addictive drugs like heroin, methamphetamines and alcohol. But it is not harmless. Pot can probably cause permanent changes in the developing brains of adolescents. And though marijuana is not highly addictive, about 10 percent of users become dependent.

It's unlikely that existing research will be able to provide a clear-cut answer about whether legalization is a good idea. But in a way, that debate is already over. As popular sentiment shifts and laws become more lenient, marijuana becomes a bigger piece of the social fabric.

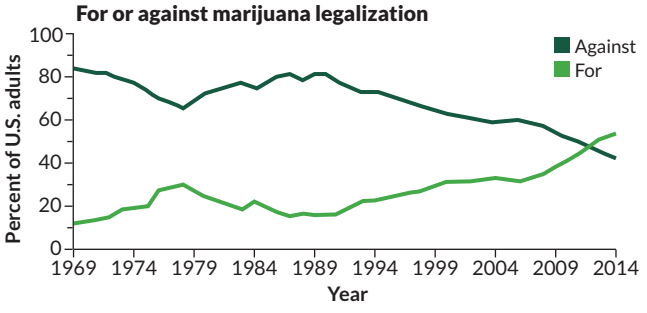
Altered states Marijuana can speed up the heart, expand blood vessels in the eye and make the mouth feel cottony. It also has several targets in the brain.



Brain structure	Effect of marijuana on brain region
Amygdala	Can alter emotional states
Basal ganglia	Reduces motor activity; users may move less
Cerebellum	Can impair coordination
Cortex	May alter complex thinking, making it hard to pay attention or switch quickly between two tasks
Hippocampus	Memory center becomes less efficient, making it harder to learn and remember new information
Hypothalamus	Stimulates appetite, giving marijuana users the well-known "munchies" effect
Nucleus accumbens	Can make users want to use again by targeting this area, which is part of the brain's reward system

SOURCE: K. FRANSON

OPPOSITE PAGE: TANG YAU HOONG; THIS PAGE: ALILA MEDICAL MEDIA/SHUTTERSTOCK



Leaning green From the 1960s until about four years ago, the majority of Americans thought pot should be illegal. Today, views have shifted, with 54 percent supporting the legalization of marijuana.
SOURCE: PEW RESEARCH CENTER 2014

"We're at this point, whether we like it or not, where things are changing, and they're changing fast," says Susan Weiss, associate director for scientific affairs at the National Institute on Drug Abuse (NIDA) at the National Institutes of Health. Her agency is funding studies to better understand the effects of marijuana, she says, so that the science can better inform public policy.

Your brain on pot

When a person tokes, eats or vapes cannabis, a wave of THC, or tetrahydrocannabinol, washes into the brain. Thought to be the major psychoactive ingredient in marijuana, THC latches on to a protein in the brain called cannabinoid receptor type 1, or CB1. These receptors are sprinkled liberally throughout the brain, especially in the cortex, where thinking takes place; the basal ganglia, which helps control movement; the appetite-regulating hypothalamus; and the hippocampus, a structure involved in forming memories.

CB1 receptors are an important part of how the brain works, says neuroscientist Valerie Curran of University College London. "They're not put there by God so we can all enjoy cannabis," she says. "They're put there because we have our own cannabis in our brains."

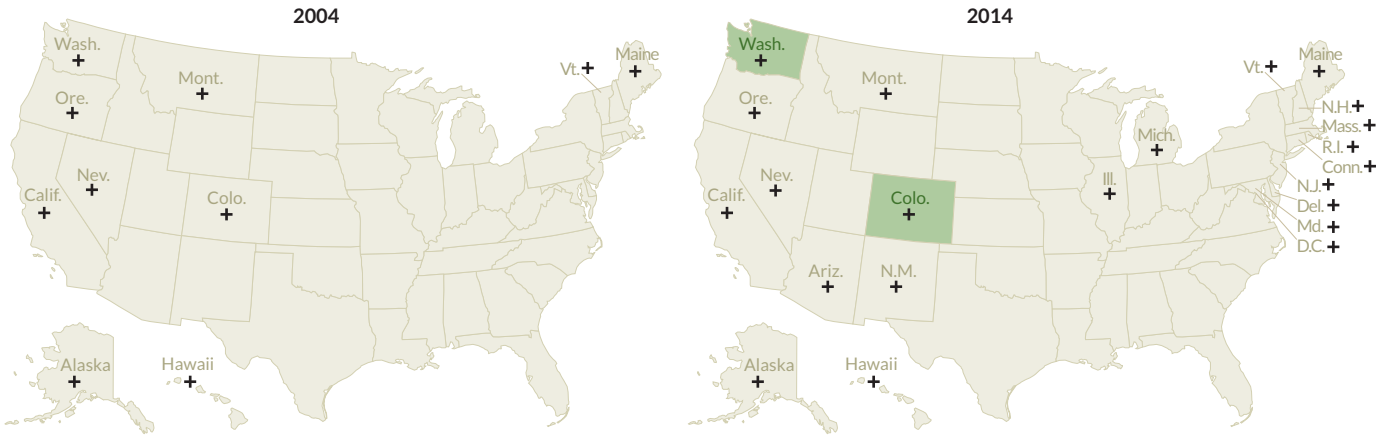
The brain's self-made cannabis consists of molecules called endocannabinoids, which hit the targets that cannabis hijacks. One of the primary endocannabinoids is named anandamide, after the Sanskrit word for bliss. The brain's endocannabinoid system influences pain, memory, mood and appetite, and plays a role in helping the brain grow.

So when foreign THC taps into this system, the effects can feel profound, says psychologist Mitch Earleywine of the University at Albany in New York. "It's got a novelty," he says. "It's got its own receptor system and its own set of effects. The fact is that not a lot of other substances hit that CB1 receptor." That's how cannabis elicits its particular brand of euphoria and cognitive flexibility, says Earleywine, who also serves on the board of NORML, the National Organization for the Reform of Marijuana Laws, which pushes to legalize the drug.

Unlike some other reality-altering drugs, cannabis doesn't seem to be lethal, even in high doses. "Can you die from alcohol just by drinking yourself to death? Yes, you can," says pharmacologist Kari Franson of the University of Colorado Denver. "Can you die from marijuana just from ingesting too much or smoking too much? Well, not really. You pretty much have to fall down and hit your head to die from it." (A paper published in the April *Forensic Science International* does describe the deaths of two presumably healthy young men from heart trouble under the acute effects of cannabis. But overall, deaths seem to be rare.)

Marijuana may not be deadly, but there are some clear downsides. A mental juggling act called working memory, the ability to hold pieces of information in mind, is diminished in someone who's high, 40 years' worth of studies show. Marijuana use has been linked to cardiovascular problems, most recently in a paper in the April *Journal of the American Heart Association* that describes heart problems in young cannabis users. Cannabis intoxication may double a driver's risk of a car crash, scientists reported in 2012 in *BMJ*. And heavy smokers

Coast-to-coast In the last decade, a growing number of states have passed laws legalizing marijuana, both for medical and recreational use. The numbers are expected to rise. In April, Maryland became the 18th state to ease punishment for marijuana possession and the 21st to allow medical marijuana. SOURCE: NATIONAL CONFERENCE OF STATE LEGISLATURES, NORML



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can show more signs of lung damage compared with nonsmokers, though whether that actually leads to more disease is unclear, according to a 2013 review published in the *Annals of the American Thoracic Society*.

"We're worried about having another drug that's highly prevalent and very accepted by society," says Weiss of NIDA. The burden of problems will only get worse, she says, including altered brain development, poorer school and work performance and higher numbers of people who are addicted. Between 2009 and 2011, as use rates went up, the rate of emergency room visits for cannabis intoxication rose by 19 percent, according to the Drug Abuse Warning Network.

Addiction

The concept of addiction plays front and center in the debate. Marijuana proponents are fond of pointing out that the drug is less addicting than tobacco and alcohol, substances that are legal for adults. And that is correct. On a relative scale, marijuana just isn't as addictive as other substances, says Franson.

"Think about those poor little rats pushing levers to get cocaine. They forgo eating, forgo sex, forgo everything because they just want to hit that lever," she says. Marijuana's addictive allure doesn't compete with opiates, or even alcohol or tobacco. But that doesn't let marijuana off the hook, she says. "It's not the worst offender, but it still does have some of those addictive components," Franson says.

It's not clear what goes on in the brain to cause pot addiction, or why so many people escape it. Marijuana somehow reduces the number of CB1 receptors in the brains of people who smoke regularly, an effect that might contribute to addiction, scientists reported in *Molecular Psychiatry* in 2012. But after a month of abstinence, the receptors bounced back to normal levels everywhere except the memory-forming hippocampus. Regular marijuana use might also influence an addiction-linked pathway that involves the neurochemical dopamine, though the details of that interaction aren't clear. Studies, mainly on animals, suggest that over time, cannabis might change the feel-good parts of the brain, including the neurons that produce dopamine, in ways that prompt people to keep using it.

Those changes might explain why some people struggle to stop using marijuana. About one user in 10 becomes dependent, defined by criteria described in the *Diagnostic and Statistical Manual of Mental Disorders*. Those criteria include two key features: tolerance and withdrawal. Experienced marijuana users need to up their dose as they become tolerant. "You need more of the drug to have the same effect," says Franson. Animal studies bear that out: Mice exposed habitually to THC need more and more of the drug to show the same motor deficits.

Marijuana withdrawal is even more contentious than tolerance. After stopping heavy marijuana use, some people — but not everyone — experience irritability, anxiety and loss of appetite. Still, those symptoms are mild compared with an opiate or alcohol withdrawal, Earleywine says. "If you tell an opiate addict you're 'addicted' to marijuana, you're probably going to get kicked in the crotch," he says.

But if cannabis isn't lethal and doesn't cause debilitating withdrawal, then is habitual use really such a bad thing? The answer, it turns out, probably depends on the age of the smoker.

Trouble for teens

Scientists can't say with confidence what marijuana does to the body and brain long-term, for several reasons. It would be unethical to randomly assign study participants to use an illicit drug for months, so the best scientists can do is look for associations — particular traits, abilities or limitations that appear more frequently in people who use cannabis. This approach leaves open all sorts of variables: People are from different backgrounds and smoke marijuana from different sources, for starters. The most these studies can offer is possible links.

Average number of daily U.S. emergency room visits for drug use in teens ages 12–17

197
Alcohol, alone or with other drugs

165
Marijuana

74
Pain relievers

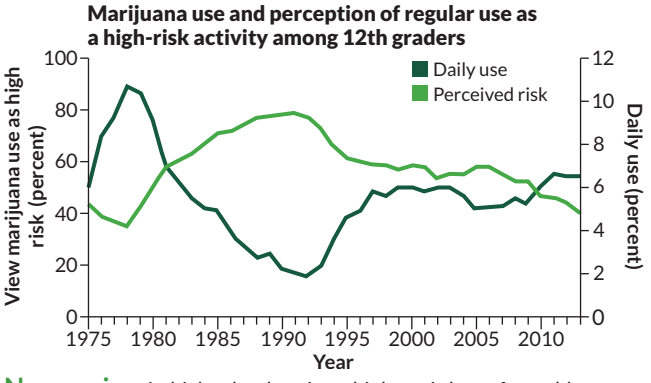
SOURCE: 2011 SAMHSA DRUG ABUSE WARNING NETWORK

One of the strongest links found so far comes from studies of young people. The teenage brain is still growing and refining its neural connections — a process that's regulated in part by the brain's natural endocannabinoid system. Marijuana use when the brain is vulnerable may interfere with its normal development. "The developing brain is at risk," Franson says.

Young adults, ages 18-25, who used marijuana at least once a week were more likely than nonsmokers to have structural differences in two brain areas thought to be involved in addiction, the nucleus accumbens and the amygdala. The differences were more pronounced with increased use, researchers reported April 16 in the *Journal of Neuroscience*. Scientists don't know whether these brain differences track with any behavioral deficits.

Adolescents who heavily use marijuana are more likely to perform poorly in school and drop out, though the effects of cannabis can't be easily separated from other social factors. New Zealanders in one study who used marijuana heavily during their teens showed an IQ drop of about eight points by the time they'd reached age 38. Because the study began before the participants started using marijuana and ran for decades, the results offer some of the strongest evidence yet that marijuana contributes to an IQ decline. But even these results come with caveats and methodological limitations.

Marijuana's long-term effects on people who start using the drug as adults are even less understood, but the hints provided from some studies suggest that it's not as harmful as adolescent use. That same IQ study, for instance, found no decline in people who began using cannabis as adults.



No worries As high school seniors think pot is less of a problem, mirroring adult attitudes, their use of the drug is going up. Marijuana use might be particularly risky for young brains, studies suggest.
SOURCE: MONITORING THE FUTURE STUDY, 2013, UNIV. OF MICHIGAN

A different study, published in the May *Addictive Behaviors*, looked at whether the cognitive effects of marijuana in adults go away when people stop using. "It's generally known that the acute effects are there," says study author April Thames of UCLA. "The question is, do these reverse over time?"

Most of the negative effects of marijuana — poorer attention, working memory and mental nimbleness — were absent in adults who had not used the drug for a month, Thames and her colleagues found. However, a person's ability to plan and make complicated decisions was still impaired a month out.

The results offer just a "snapshot at the time we did the testing," Thames says. They describe an association, not causation. "The question down the road is, what kind of implications does that have for everyday functioning?"

Scientists have largely failed to turn up compelling evidence that adult pot smokers risk permanent brain problems, Earleywine says. "Being stoned all the time is a strange way to live your life," he says, but data just aren't there to argue that a cannabis-fueled lifestyle is permanently harmful to the adult body and brain.

The new reality

As researchers try to make sense of study results, the nascent marijuana industry is charging ahead in a Wild West capitalistic society. That's worrisome, many scientists say. Policies should regulate the quality and strength of marijuana, and keep it away from children, Franson says.

In Colorado, where drug laws have been loosened, first for medical marijuana and then for recreational use, a growing number of children under 12 have been admitted to emergency rooms for acute marijuana intoxication, according to a study in the July 2013 *JAMA Pediatrics*. There ought to be tighter controls over shops, particularly those that sell marijuana-infused products like chocolates and cookies that entice children. Many marijuana retailers "look like sweets shops," Curran says.

NIDA is keeping tabs on ER visits as well as the increasing levels of THC in cannabis seized by law enforcement agencies, and how marijuana legalization has affected the health of people in Colorado and Washington State.

Some researchers see the growing availability of marijuana as inevitable and are advocating ways to keep the drug out of the hands of young people.

"Kids are growing up on a much more toxic form of marijuana than they would have done years ago," Curran says. Today's plants are very high in THC and low in a compound thought to counter its effects called cannabidiol, or CBD. THC levels in marijuana have increased from 3.4 percent in 1993 to 8.8 percent in 2008, according to a marijuana potency-monitoring project at the University of Mississippi. A more regulated market might keep the most potent marijuana out of the hands of young people, Curran says.

More accurate testing and labeling of marijuana products would help, many researchers believe. THC concentrations can vary from seller to seller and even batch to batch. "People need to know what they're getting," Franson says. "It's just named these weird names." Purple Urkel, Girl Scout Cookies and Super Silver Sour Diesel Haze are some of the options available in stores. Colorado is trying to improve labeling to describe important differences, which is particularly urgent for people who rely on certain doses of THC or CBD to treat medical conditions.

When marijuana is eaten, THC takes longer to reach the bloodstream, and its absorption rates can vary greatly. This imprecise delivery system can cause people to take much more than they intended. Proper labeling might help people better titrate their dose, Franson says.

Even Earleywine, who supports legalization, says he's concerned about commercialization of marijuana. "America is so free market and wild that it's going to take some reining in to make sure that no one is penalized for it and medical users have access, but it's not sponsoring every sport event or on TV every five seconds," he says. Current restrictions on cigarettes might be a good model for the burgeoning marijuana industry, he says.

Imperfect science leaves people on both sides of the marijuana debate wanting more. But in a way, the good-or-bad, yes-or-no argument is over: Marijuana is creeping across the country. That's probably not catastrophic for adults, but for young people, the implications are more worrisome. Just how worrisome is something scientists are still figuring out. That knowledge may help ease the transition to an ever-greener world. ■

Explore more

- Drugs Facts: Marijuana. National Institute on Drug Abuse. http://bit.ly/SNpotNIDA
- National Organization for the Reform of Marijuana Laws. www.NORML.org
- DrugScience: Independent Scientific Committee on Drugs. www.drugscience.org.uk

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Reported by J. Page

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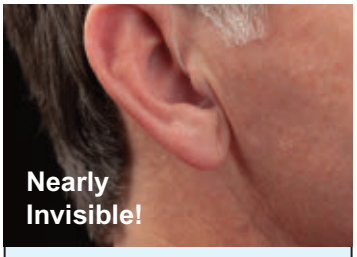

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T-FORCE

Reprogrammed immune cells emerge as weapons in the body's disease-fighting arsenal

By Susan Gaidos

Two T cells (orange) attack a cancer cell (blue), using special receptors to zero in on the cancer. Immunotherapies are boosting the potency of T cells.

STEVE GSCHMEISSNER/SCIENCE SOURCE

Doug Olson had all but lost his 14-year battle with leukemia. Exhausted and weakened by chemotherapy, his body no longer responded to any of the handful of drug treatments he had been given over the years. In 2010, his doctors suggested a different strategy: beefing up the disease-fighting immune cells in his body.

Researchers picked out certain immune cells from Olson's blood, then inserted a virus into the cells. The virus provided new genes that prompt the cells, known as T cells, to attack leukemia cells. When the altered T cells were delivered back into Olson's veins, his immune system became a cancer-seeking weapon.

One month after treatment, Olson was in complete remission. His doctors could find no sign of cancer in his blood or bone marrow. Today, at age 67, he remains cancer-free. Recently retired, Olson says he no longer worries about how long his remission will last; he's taken up sailing and running half-marathons.

Other cancer patients — children and adults — have seen similar results with reprogrammed immune cells. At least six research groups have treated more than 100 patients with leukemia and other blood cancers by using the patients' own enhanced T cells.

"It won't be long, I think, before the first line of therapy for some types of cancer won't be chemotherapy, it will be immunotherapy," says Carl June of the University of Pennsylvania School of Medicine in Philadelphia, one of the developers of T cell–boosting therapies.

These treatments are part of a medical strategy that researchers have been working on for decades, and their efforts are finally beginning to pay off. There are now dozens of early human trials around the world using engineered immune cells, and the pharmaceutical industry is beginning to invest.

Researchers are using refurbished T cells with two main goals: to encourage the immune system to attack bad players — cancers or viruses — or to tamp down the immune system so it will stop attacking the body's healthy tissues, as it does in some autoimmune diseases such as type 1 diabetes and rheumatoid arthritis. Though several obstacles remain, scientists are cautiously hopeful.

"Though there's still work to be done to make these treatments safe and effective, I'm optimistic now that there will be a role for cells as drugs," says immunologist Jeff Bluestone of the University of California, San Francisco.

Finding ways to intervene in the immune system has not

been easy. The human immune system is a busy network of organs and cells that attempt to keep harmful bacteria, viruses and parasites out of the body, and to destroy agents that manage to invade. This system includes an army of white blood cells that patrol the body, looking for trouble.

Certain white blood cells called macrophages are constantly on guard, tasked with destroying any germs they encounter. If an infection sets in, a more powerful force of white cells, namely B cells and T cells, joins the assault. B cells secrete substances to identify and neutralize invaders. Some T cells fight pathogens directly and some activate other cells to fight.

Killer T cells, one of several T cell types, are one of the immune system's most powerful weapons. They connect directly to infected cells and tumors, secreting chemicals to kill them. To identify its target, a T cell relies on receptors that sit poised on its surface. These receptors recognize and bind to surface structures, called antigens, found on pathogens.

Enhanced recognition

When all goes well, this recognition system allows T cells to remove infected cells and tumors. But occasionally, a cell develops traits that stymie immune surveillance. Some cancers, for example, have mutations that cloak them from patrolling immune cells. HIV and other viruses evolve to evade normal immune responses as well.

Scientists reasoned that adding certain genes to T cells might help them fight those evaders. The right gene added could instruct a T cell to make a receptor that zeroes in on an antigen found only on cancer cells, for example.

Although early attempts succeeded in getting genes into cells, the T cells soon exhausted themselves when placed inside a living host. In many cases, the engineered cells couldn't divide to make new cells.

June and his colleagues found a way to transform the T cells into more viable weapons, using a disabled form of HIV to deliver the genes into the T cells' DNA. Once inside, the genes produce a protein called chimeric antigen receptor, or CAR, which enables the T cell to recognize and specifically kill certain cancer cells.

June designed his CAR T cells to carry receptors for an antigen called CD-19, found on the surface of some leukemia cells. Once altered, the T cells seek and destroy cells that carry CD-19. Those altered cells continue to divide for several weeks, boosting the CAR T cell population. What's more, CAR Ts live longer than normal killer T cells — they can attack again and again.

"Essentially, they become serial killer cells," June says. "The cells kill a target and then go kill another one."

In 2011, June's group showed that after treatment, some CAR T cells become memory T cells, remaining primed to initiate attacks if the cancer tries to recur. "That's very different from standard drugs, which exert an effect and then are eliminated from the body," June says.

June's team has used CAR T cells to treat 62 patients with late-stage leukemia, including 32 with chronic lymphocytic leukemia, or CLL, and 30 — five adults and 25 children — with acute lymphoblastic leukemia. Of the 30 patients with ALL, 27 had complete remissions, all signs of cancer disappeared, he says.

CLL mainly affects adults and is not curable without a bone marrow transplant (BMT). Instead of getting a BMT, Olson chose to be one of the first three patients to receive CAR T treatment for CLL in 2010. For Olson and one other patient, the cancer disappeared, June's group reported in 2011 in *Science Translational Medicine*.

June's team has had recent success engineering T cells against HIV as well. They programmed the T cells of 12 HIV-infected patients to make their bodies resistant to the virus. In one patient, blood levels of HIV became undetectable. That study, in collaboration with scientists at the Albert Einstein College of Medicine in New York City and California-based Sangamo BioSciences, was published in the *New England Journal of Medicine* in March.

CAR Ts in the fast lane

June and other researchers have begun early-stage pilot trials using CAR T cells against pancreatic, breast and brain cancers and melanoma at centers across the country, including Memorial Sloan-Kettering Cancer Center in New York City, the Fred Hutchinson Cancer Research Center in Seattle, and Baylor College of Medicine in Houston.

Large-scale studies have not yet happened, but pharmaceutical companies already are making plans to take immune-cell therapies to market. Novartis is working with June to develop his CAR T cells. "I've told the team that resources are not an issue. Speed is the issue," Novartis Chief Executive

Cast of characters The human immune system contains several players. Researchers are trying to make them better at their jobs.

Macrophage White blood cells in the bloodstream that gobble up bacteria, viruses or pathogens.

T cell The human body has about 1 trillion T cells, each with a protective role.

Memory T cell T cells that remember an invader so the body can effectively respond to subsequent attacks.

Killer T cell T cells that recognize and kill infected cells. A T cell that homes in on a flu virus will maintain its specificity for that virus each time the T cell divides.

B cell Immune cells that tag invaders with antibodies so that other immune cells can find and engulf them.

CAR T cell Genetically engineered T cells with surface receptors (called chimeric antigen receptors or CARs) that bind to a specific antigen on tumor cells.

Treg cell Peacekeepers that keep the body from attacking its own healthy tissues.

Cytokines Chemical messages released by immune cells to orchestrate an attack.

NICOLLE RAGER FULLER

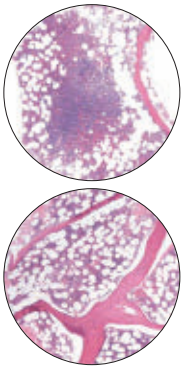
Joseph Jimenez told *Forbes* magazine in May. And researchers from Fred Hutchinson, Memorial Sloan-Kettering and Seattle Children's Research Institute launched Juno Therapeutics in Seattle to bring their CAR Ts to market.

Although studies to date suggest that CAR T cells are safe for most patients, some patients experience dangerously high fevers, nausea and chills, caused by chemicals called cytokines that pour out of T cells when the immune system becomes highly activated. And CAR T cells can kill unintended cells, such as B cells, which also carry the CD-19 antigen. This side effect continues long after the treatment has been stopped. Olson, for instance, visits his doctor several times a year to get an injection of immune globulin, to replace the proteins that B cells make.

To counteract such side effects, future versions of CAR T cells may be equipped with control circuits so that doctors can activate or deactivate them as needed, June says.

Other researchers are devising ways to focus the immune system on tumors with difficult-to-recognize antigens. Steven A. Rosenberg of the National Cancer Institute, an early developer of immunotherapies for cancer, is directing immune cells to zero in on other targets found in cancer cells but not on normal cells.

When normal cells become cancerous they acquire a number of mutations, and those mutations are unique to each patient. In a paper published May 9 in *Science*, Rosenberg's team describes how they sequenced the genome of a patient's cancer cells, then identified immune cells that could target a specific mutation on that patient's tumor, which had spread from the bile duct to the liver and lungs. Extracting these immune cells from the patient's tumor and growing armies of them in the lab, the scientists infused the cells back into the patient, and her tumors shrank. Though the treatment didn't eliminate the tumor, Rosenberg says it's a "proof of principle" that you can identify unique mutations in a tumor and then direct immune cells to recognize and destroy the cancer.



Bone marrow specimens show cancer (top, purple mass) that disappeared six months after CAR T cell infusion (bottom).

"It's a blueprint for identifying and targeting a single amino acid change among all of the proteins present in that cancer," he says.

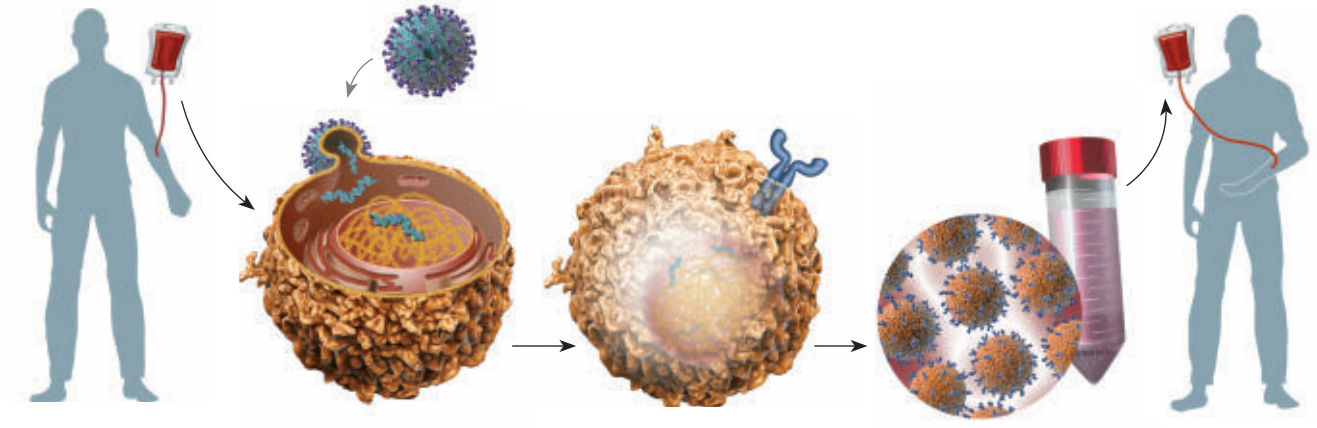
While still in early development, Rosenberg's findings open up possibilities of targeting many common cancers with patients' own immune cells. These cancers originate in epithelial cells that line the body's organs. Rosenberg says such cancers frequently occur in the breast, colon, liver, pancreas and esophagus, and often spread to other parts of the body.

Immunotherapy against cancer and viruses is about stimulating the right T cells to act. But sometimes the immune system gets overstimulated and attacks the body, or in the case of organ transplants, the body attacks the donated organ. Scientists are designing ways to steer the immune cells to fight only enemies and ignore the body's own tissues. Special T cells called regulatory T cells, or Tregs, help police the immune response, keeping overzealous killer T cells in check.

Autoimmune diseases too

Tregs suppress excessive immune responses. Finding ways to alter Tregs would be helpful in treating autoimmune diseases such as rheumatoid arthritis or type 1 diabetes. It would also be useful in cases of organ transplant, says UC San Francisco's Bluestone. His lab is developing ways to use specific Tregs

Engine of change Custom-made for each patient, CAR T cells are genetically engineered to target proteins called antigens on the surface of cancer cells. Grown in the lab for days to create an army of cancer-fighters, the altered T cells are delivered to the patient. If successful, the T cells multiply further in the patient and, with guidance from their engineered receptor, recognize and kill cancer cells. SOURCE: C. JUNE/UNIV. OF PENNSYLVANIA



1. T cells are collected from the patient. A machine removes the desired cells from the blood, then returns the rest back to the patient.

2. A modified virus (blue) is used to transfer DNA to the patient's T cells so they will produce CAR proteins.

3. CARs have two ends: a binding site (blue) specific to the tumor cells, and a signaling engine that activates the T cell to kill the tumor it binds to.

4. Once designed, millions of engineered CAR T cells are grown in the laboratory.

5. The expanded population of CAR T cells is infused into the patient through a standard blood transfusion.

FROM TOP: D.L. PORTER *ET AL*./*NEJM* 2011; NICOLLE RAGER FULLER

in transplant settings so that the cells recognize the transplanted organ and "educate" the immune system to see the organ as part of its own tissue. Such treatments may eventually eliminate the need for ongoing treatment with immunosuppressive drugs.

Current drugs used to suppress the immune system may work for years, but many transplanted organs are ultimately rejected by the patient's body.

To retrain the body's peacekeeping force, Bluestone's group focuses on a population of cells called Foxp3–expressing Tregs. These cells are master regulators of the immune system, Bluestone says.

Foxp3 Tregs squelch the action of other T cells directly, but are also appealing because of a two-pronged trait called bystander suppression. First, the cells create an overall suppressive environment in areas where they do their work. As a result, immune cells that recognize a foreign antigen such as a transplanted organ learn to make peace with the foreigner. Second, the Foxp3 Tregs convert other cells in the area into peacekeepers.

"You end up with this situation where you not only suppress locally, but you turn other cells into regulatory cells that perpetuate and amplify the effect of the Tregs," Bluestone says.

Still, he says, it's unlikely that a simple infusion of Tregs will work as a stand-alone therapy in transplants, at least for now. For starters, Tregs are often outnumbered by other cell types. After a transplant, a mix of several T cell types, called effector cells, attack and kill new organs and expand into armies of millions, making it harder for the Tregs to suppress.

Bluestone's group has found ways to combine the Foxp3 Tregs with drugs to temporarily deplete a large number of effector cells. That gives the Tregs a chance to take over. It's that combination, Bluestone says, that will make Tregs a useful therapeutic tool.

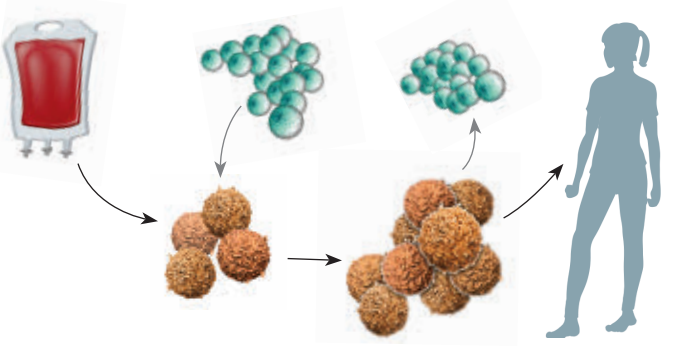
"It's a balancing act," he says. "The more effector cells you have, the more Tregs you need to suppress them. Anything we can do to reduce the number of effector cells allows the Tregs to be more effective."

University of Minnesota oncologist Bruce Blazar uses an approach similar to June's and Rosenberg's to increase Treg numbers: Pull the cells out of blood and expand their numbers before putting them into patients. The replication process ups the number of Treg cells by tens of millions in several weeks. Blazar is using this approach to give patients a better chance for a successful bone marrow or organ transplant.

The technique has shown promise in treating graft-versus-host disease, a complication of some bone marrow transplants in which T cells from donor bone marrow perceive a recipient's body as foreign and attack it. An early trial suggests that the technique can ameliorate some damaging effects of the disease. Blazar reported his results in February at the American Association for the Advancement of Science annual meeting.

Clinical trials also are under way to test Treg cells against autoimmune disorders. Bluestone's group is treating patients

Peacekeepers Regulatory T cells, or Tregs, can inhibit an immune response so the body won't attack healthy tissues. Researchers are using these cells to prevent the immune-system attacks that often occur after organ transplants. SOURCE: J.L. RILEY *ET AL/IMMUNITY* 2009



with type 1 diabetes with infusions of Tregs and plans to test the treatment in patients with lupus next year. Scientists at Dana-Farber Cancer Institute in Boston showed in 2013 that infusions of Tregs successfully blocked the development of a rheumatoid arthritis-like condition in mice.

Still, challenges remain. Not all patients respond to treatment with engineered T cells. Bluestone says scientists also have not yet found ways to control the enhanced T cells should they become overly active or overly suppressive. Researchers are still working on genetic and biochemical approaches to eliminate the engineered cells if they cause unwanted side effects, or find ways to adjust them if they begin working in ways they should not.

In most cases, the goal is to direct Tregs to sites where they're needed, rather than having them working systemically, Bluestone says.

Eventually, he adds, researchers might find ways to genetically modify the cells, following the example of engineered T cells for cancer. Though it will probably take years to get to that point, he says the field of immunotherapy is now exploding, and trials are moving rapidly in many areas.

"It's no longer early days for cell therapy," Bluestone says.

June agrees: "The issue now is not does cell therapy work, but how can it become available everywhere, and not just at boutique cancer centers."

He suggests taking a cue from manufacturing methods used by the automotive industry.

"Cars in Detroit are now made mostly by robots," he says. "We need to find ways to make our CARs — our T cell cultures — in an automated way, or else it won't happen on a large scale." ■

Explore more

- B.R. Blazar *et al*. "Advances in graft-versus-host disease biology and therapy." *Nature Reviews Immunology*. June 2012.
- D.W. Lee *et al*. "The future is now: Chimeric antigen receptors as new targeted therapies for childhood cancer." *Clinical Cancer Research*. May 2012.

NICOLLE RAGER FULLER

Intel ISEF 2014 top winners (left to right) Shannon Lee, Lennart Kleinwort and Nathan Han.

Cancer research scores big at Intel ISEF

LOS ANGELES — An innovative statistical analysis of cancer-promoting genes earned a 15-year-old the top prize — and $75,000 — last month at the world's premier high school science and engineering competition. Nathan Han of Boston claimed first prize at the Intel International Science and Engineering Fair 2014.

"Intel believes that young people are the key to innovation. And we hope that these winners inspire more students to get involved in science, technology, engineering and math," says Wendy Hawkins, executive director of the Intel Foundation.

Han earned his award for studying mutations in a gene associated with breast cancer. He surveyed public health databases, gathering data on mutations that affect the structure of a protein that normally repairs cell damage and stifles tumor growth. By analyzing how different mutations change the protein's structure, Han identified which ones are most likely to boost cancer risk.

Two other young researchers each received Intel Foundation Young Scientist Awards of $50,000. Lennart Kleinwort, 15, of Würzburg, Germany, won for developing a mathematics app for smartphones and electronic tablets. App users can draw and move shapes around, changing sizes and proportions. Or users can enter data and instruct the app to plot the most accurate fit. The software can handle everything from simple algebra to more complex math, such as calculus.

Shannon Lee, 17, of Singapore claimed the other $50,000 prize for developing an inexpensive electrode material for some types of batteries. Those batteries now typically include an electrode made from a costly mix of platinum and carbon. Lee made the material by heating an eggplant at a high temperature until it turned into charcoal. Then she soaked the highly porous carbon in potassium hydroxide to increase the surface area of the material. That provided more places for chemical reactions to occur, she explains. The change could allow engineers to get the same performance found in today's batteries from a smaller and lower-voltage device.

Seventeen "best of category" awards were given, including to Han, Kleinwort and Lee in each of their fields. The winners were chosen from more than 1,780 finalists.

"In congratulating Nathan, Lennart and Shannon, we join with Intel in seeing great hope in their research and that of all of our Intel ISEF finalists," says Rick Bates, the interim CEO of Society for Science & the Public, which manages the competition and publishes *Science News*. — *Sid Perkins*

Category winners

In addition to the top three winners, 14 other Intel ISEF finalists received "best of category" awards, each worth $5,000.

ANIMAL SCIENCES **Abhishek Verma**, 15, and **Daksh Dua,** 16, of Delhi, India, for showing that an extract from a common shrub helps treat giardiasis.

BEHAVIORAL AND SOCIAL SCIENCES **Michelle Marquez**, 15, of Midlothian, Va., for finding that listening to simple music and sounds triggers positive emotions.

BIOCHEMISTRY **Ken Aizawa**, 17, of Jericho, N.Y., for analyzing the role of two proteins in the growth of cancer cells.

CELLULAR AND MOLECULAR BIOLOGY **Joshua Meier**, 18, of Teaneck, N.J., for identifying genes linked with early aging of stem cells.

CHEMISTRY **Tai Hei Chan**, 18, and **Er Hai Fang**, 17, of Hong Kong, for a fast, cheap test for chronic renal failure.

COMPUTER SCIENCE **Yue Yao**, 17, of Shanghai, for using three colors of light transmitted over fiber-optic cables as the basis for new computing techniques.

EARTH SCIENCE **Yu-Hsin Chen**, 17, of Taipei, Taiwan, for finding that typhoons in the western North Pacific have increased in intensity by about 10 percent in the last 20 years.

ENGINEERING: ELECTRICAL AND MECHANICAL **Sarah Galvin**, 18, of Tempe, Ariz., for improving the performance of certain types of electronic components.

ENGINEERING: MATERIALS AND BIOENGINEERING **Harry Paul**, 17, of Port Washington, N.Y., for developing a device to treat children with scoliosis.

ENVIRONMENTAL MANAGEMENT **Faye Jong**, 15, of Kuching, Malaysia, for working out how to use biowastes as replacements for synthetic fabric dyes.

ENVIRONMENTAL SCIENCES **Perry Alagappan**, 17, of Houston, for inventing a filter that uses carbon nanotubes to remove toxic metals from water.

MICROBIOLOGY **Logan Collins**, 17, of Boulder, Colo., for delivering genes into bacteria that stunt the microbes' growth.

PHYSICS AND ASTRONOMY **J. Chapman Caddell**, 16, of Pebble Beach, Calif., for showing that lopsided grooves in a pipe act as a pump for boiling fluids.

PLANT SCIENCES **Yi-Hsuan Huang**, 17, of Taipei, Taiwan, for finding a protein's new function in the plant *Arabidopsis*.

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TO DO

Your Brain
OPENS JUNE 14
Clamber through a two-story neural network (right), explore brain images and learn how scientists study the brain in the Franklin Institute's newest, and largest, permanent exhibit.
FRANKLIN INSTITUTE, PHILADELPHIA

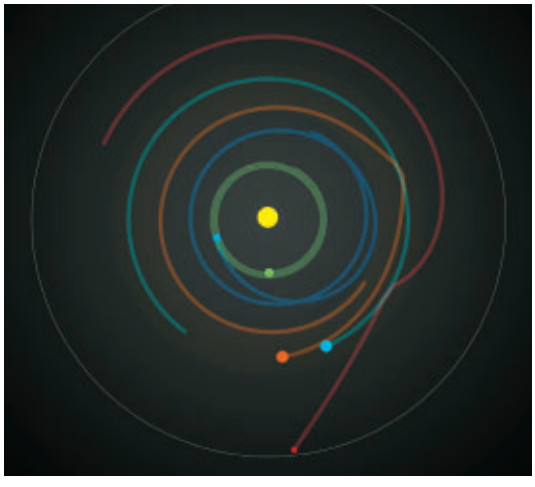
Museum at Prairiefire
OPENED MAY 12
This new museum, located in a retail development, offers a selection of exhibits created by the American Museum of Natural History.
OVERLAND PARK, KAN.

Inside Rodin's Hands: Art, Technology and Surgery
THROUGH AUGUST 3
Augmented-reality views of Auguste Rodin's sculptures reveal medical conditions in the sculpted hands.
STANFORD UNIVERSITY PALO ALTO, CALIF.

SCREENTIME

Do-it-yourself solar system

Online game challenges players with orbital physics



If you've always wanted to build your own solar system, roll up your sleeves — it's time to see what you've got. SuperPlanetCrash is an online solar system simulator, set up as a game. The goal is to plop planets around a star and keep them orbiting for 500 years. Seems simple enough, but gravity is a formidable opponent. Each planet or star adds to the gravitational tug-of-war with every other body. Get the balance wrong, and planets crash together or are flung into interstellar space.

The game, created by astronomer Stefano Meschiari of the University of Texas at Austin, simulates the movements of planets and stars using the same computer code that researchers use to find exoplanets. Points are awarded for how numerous, how massive and how crowded players make their planetary fiefdoms. Earn bonus points for keeping things stable in the central star's habitable zone, the temperate region suitable for liquid water.

Coming up with bizarre arrangements can be a lot of fun. Wonder how long an ice giant would last between two dwarf stars? Or if 11 super-Earths can squeeze into one habitable zone? For an extra challenge, see if you can get a planet to go counterclockwise. Win or lose, SuperPlanetCrash is the planetary sandbox you've been waiting for.
— Christopher Crockett

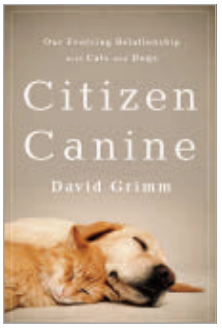
TOP: THE FRANKLIN INSTITUTE; SUPERPLANETCRASH

BOOKSHELF

Citizen Canine

Our Evolving Relationship with Cats and Dogs

By David Grimm



Cats and dogs have become furry little children in the eyes of many Americans. Pet owners call themselves "mom" or "dad." Some celebrate their animals' birthdays and spend thousands of dollars on toys, food and veterinary care. Others even risk their lives for pets, as when owners refused to enter shelters that wouldn't take in animals before Hurricane Katrina.

And now pets appear to be on the path to full citizenship, writes Grimm, a science journalist. "Dogs and cats have reached a critical juncture in their social evolution: As they inch towards personhood, we must decide whether to embrace them as fellow members of society or limit them to being mere pets."

Grimm spends much of his book tracing the history of dogs and cats from wild animals to humans' tools and on to beloved pets. This was not an easy path — cats, for instance, may have been heralded as gods in ancient Egypt, but they were also stoned, drowned and burned at the stake as witches' familiars in medieval times. More recently, owners have struggled for courts to recognize pets as something more than property, as beings with rights of their own.

But it's unclear exactly how that "more" will take shape. Grimm focuses on rights in America, visiting lawyers, a military base where dogs become soldiers and a farmer who practices "respectful use" of animals. Each situation gives a different view of pets' futures. Even veterinarians see a downside to the shifting pet-owner relationship: skyrocketing malpractice costs.

Other potential consequences of expanding recognition of animal rights, such as in medical research, get little more than a mention. And the book can get a bit bogged down in legal minutiae. But Grimm does an excellent job of documenting how Fido became family and how that relationship may be changing. Americans may have set pets on the path to citizenship, Grimm notes. But what happens next depends on the choices society makes regarding the animals that have wormed their way into hearts and homes. — *Sarah Zielinski*
PublicAffairs, $26.99

BOOKSHELF

Quantum Mechanics

The Theoretical Minimum

Leonard Susskind and Art Friedman

If you're ever banished to a desert island and allowed to take just one book, here it is. Given enough time, with no distractions, you could use it to eventually master quantum mechanics.

Susskind's latest book, this one with coauthor Friedman, is the second in a series on the "theoretical minimum" you'd need to know to actually be able to do physics. The first focused on the basics of classical physics. This one takes you deep into the weird realm of quantum theory.

There's no popularization here. Just clear, straightforward exposition of basic quantum principles and their mystifying implications. Susskind starts with qubits, the quantum units of information typically associated with the spins of subatomic particles. How such spins are measured, and the mathematical apparatus needed to account for the results of those measurements, form the core of the quantum theoretical toolkit.

Eventually you'll encounter quantum entanglement, the puzzling connection between some quantum particles that so disturbed Einstein. Further on comes the Heisenberg Uncertainty Principle, which Susskind is able to explain thanks to the preceding foundation, rather than just stating it, as most popular books do. Ultimately the Schrödinger equation itself emerges, the key mathematical tool for the bulk of quantum research. By then, you'd be ready to attempt quantum mechanical calculations at home, if you weren't trapped on that island.

But don't think it will be easy. Without a solid background in relatively high-level math, it's a formidable challenge to master all the symbolic notation and complex concepts like vector spaces and tensor products. Just reading this book won't produce quantum competence. You would have to work through it thoroughly, several times, and you'd probably need to reread the first volume, on classical physics, as well.

Still, even without mastering all the calculational complexities, a careful read at the very least offers deeper insight into the logic and mathematical substance of quantum physics than you'll get from any popular account. It may still be true, as Feynman said, that "nobody understands quantum mechanics." But by carefully studying Susskind's presentation of it, you might at least be able to come close. — *Tom Siegfried*
Basic Books, $26.99

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APRIL 19, 2014

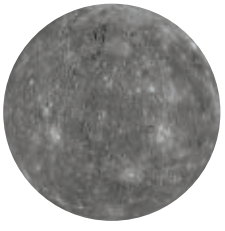
MAY 3, 2014

To be a planet

Size is a starting point for establishing planethood, but in 2006 the International Astronomical Union set additional criteria for planets in Earth's solar system. Chariklo orbits the sun but doesn't meet the other standards, while dwarf planet Pluto hasn't cleared its orbit of space debris. SOURCE: IAU

Pluto
Dwarf planet
Diameter:
2,320 km

Chariklo
Small solar system body
Diameter:
250 km



Mercury
Planet
Diameter:
4,878 km

Current IAU definition of a planet (in our solar system):

- Orbits the sun
- Big enough that its gravity pulls it into a nearly round shape
- Has cleared its orbital path by kicking out all other objects

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Planetary identity crisis

*Astronomers spotted icy rings encircling the planetoid Chariklo, a 250-kilometer-wide hunk of ice and rock that orbits the sun between Saturn and Uranus. In "Icy rings found around tiny space rock" (SN: 5/3/14, p. 10), **Christopher Crockett** added that Chariklo may also have unseen orbiting moons keeping the rings in place.*

These characteristics make Chariklo sound awfully planetlike, as some readers pointed out. "This 'planetoid' has its own orbit around the sun, so what criterion does it fail, preventing it from being called a 'planet'?" asked online commenter **Anthony Giarratano**.

Orbiting a sun is one characteristic of a planet, says **Crockett**, but astronomers look at other features, such as size and shape, when making the distinction (see sidebar). "There are many types and subtypes of little things out there, and some objects seem to straddle traditional boundaries. Chariklo is a centaur, a family of objects between Jupiter and Neptune that split their personalities between asteroids and comets. Historically the terms planetoid, minor planet and asteroid were interchangeable, but as astronomers learn more about the solar system, they've had to adapt their definitions (see also: Pluto). These days, they prefer the slightly unwieldy 'small solar system bodies' when referring to anything smaller than a dwarf planet." And what counts as an exoplanet is even murkier.

Taking molecules for a spin

*In "Fastest-spinning molecules" (SN: 5/3/14, p. 5), **Andrew Grant** reported that a powerful laser set some molecules of oxygen and nitrogen whirling, ramping up their speed to 600 trillion rotations per minute. Tires spinning at the same rate could carry a car to the nearest star in half an hour, he noted.*

Some readers had trouble wrapping their minds around that analogy. If the molecules were traveling as fast as the hypothetical car's tires, they would be violating an important tenet of physics. "It seems to me that the outer bits of the oxygen and nitrogen molecules would be moving faster than light. I must be missing something, since I haven't heard anything about anyone having figured out how to exceed that particular speed limit," wrote **Bill Robertson** in an e-mail. "What gives?"

The comparison isn't perfect, admits **Grant**, because physics-wise, car tires don't behave like individual molecules. "Obviously, nothing can travel faster than the speed of light. The point is that nothing we encounter in our everyday, macroscopic lives comes even close to spinning 10 trillion times a second. And since a molecule is far smaller than a car tire, its rotational velocity does not approach the speed of light."

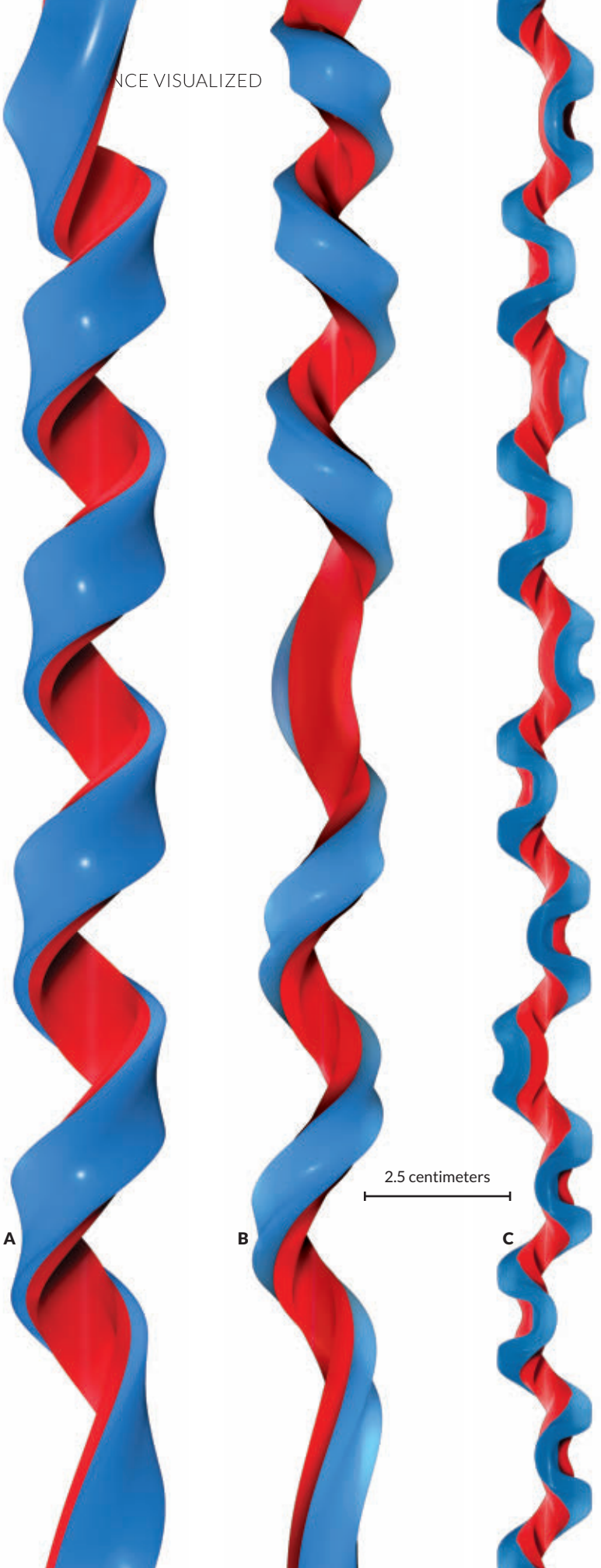
On a different wavelength

***Susan Milius** described the surprisingly powerful muscles of a nearly invisible crustacean in "See-through shrimp" (SN: 4/19/14, p. 4). Marine biologist **Laura Bagge** of Duke University hopes to find out how the shrimp's muscle fibers interact with light to achieve this remarkable transparency.*

But visible light is just one type of light, as online commenter **John Turner** noted. "Is the transparency effect of the shrimp wavelength-dependent?" he asked. "Has anybody tried observing these shrimp with infrared film or an ultraviolet imager?"

Bagge, who chatted with readers about her work in the comment section of the story on the *Science News* website, responded: "These shrimp are transparent in the visible spectrum, but I do not know if anyone has yet measured the ultraviolet absorption of the tissues of these specific shrimp. Shallow waters do have a lot of UV radiation. It is thought that many transparent species are protected from radiation damage by having UV-protective pigments. Of course, if transparent shrimp absorb UV light as a means of protection, they could become visible to predators that have UV-sensitive vision." She added, "We haven't tried observing these shrimp with infrared film because no animals are known to detect those wavelengths."

NASA

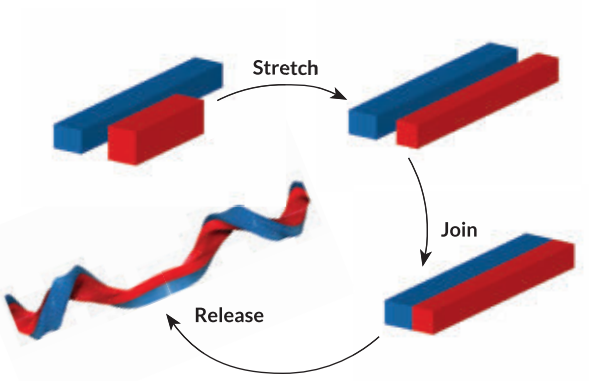


A new twist on a twist

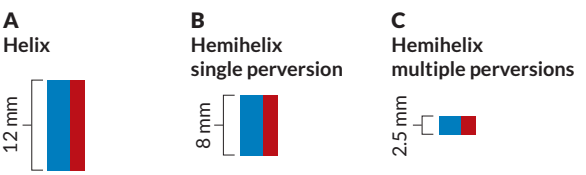
Nature abounds with perfect helices. They show up in animal horns and seashells, in DNA and the young tendrils of plants. But helix formation can get complicated: In some cases, the direction of rotation can reverse as a helix grows. The resulting structure has been dubbed the hemihelix, and you may have made one yourself by untwisting part of a telephone cord so much that it flips and spirals in the other direction.

Katia Bertoldi, a professor of applied mechanics at Harvard University, and her colleagues wanted to see how hemihelices form on their own. So they stretched a strip of silicone rubber, glued it to a second, unstretched strip and let the pair go. The researchers reported April 23 in *PLOS ONE* that they could get a range of shapes to form by tuning the dimensions of the glued rubber pieces. Strips that were much thicker than they were wide spiralled gently to form helices. Those with squarer cross sections relaxed themselves with a strong twist, forming hemihelices with one or many regularly spaced changes in direction.

"It's sort of a competition between bending and twisting," Bertoldi says. She and her colleagues are now experimenting with rectangular patches of rubber to see how this same stretch-and-release approach can be applied to make other three-dimensional shapes. — *Rachel Courtland*



Spiral-bound To create helical structures, one silicone strip (red) is stretched to match the length of a longer strip (blue). The pair is glued together and then released. Depending on the dimensions of the strands, a helix or hemihelix (one shown above) forms as the pair relaxes.



Shape matters The number of changes in direction, or "perversions," in a hemihelix depends on the cross section of the bonded strips (shown actual size above). Keeping width constant (blue = 3 mm, red = 1.89 mm), researchers decreased the thickness of the strips (shown as height) for more perversions.

MALUCHI ENYI

See video of hemihelix formation at **bit.ly/SNhemi**

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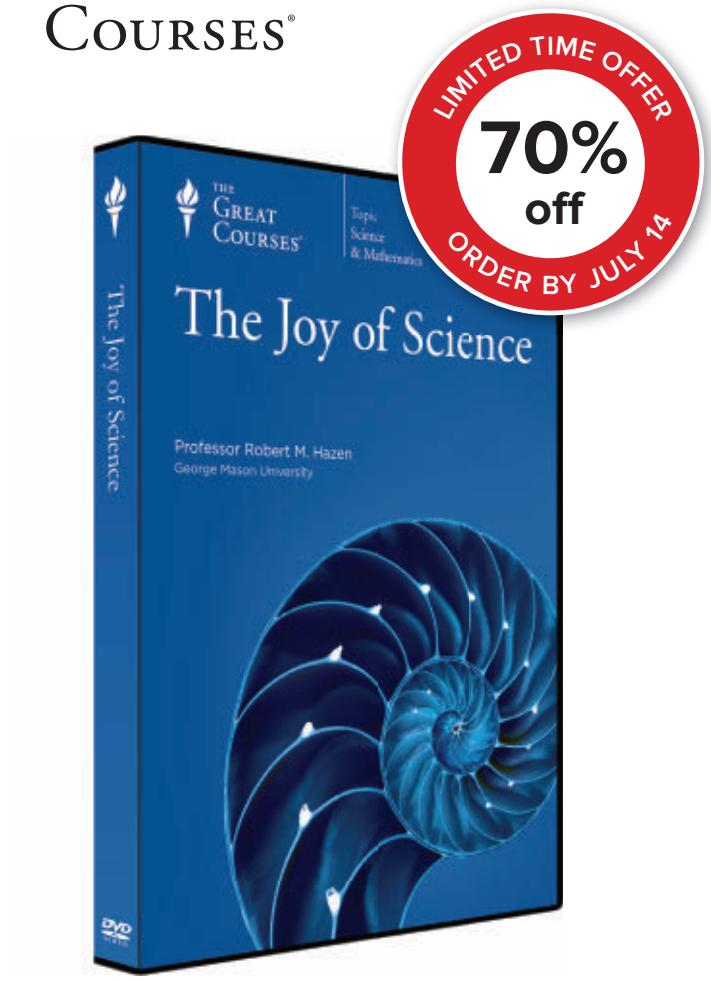

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