SN
SCIENCE NEWS MAGAZINE
SOCIETY FOR SCIENCE & THE PUBLIC
OCTOBER 3, 2015

Meet *Homo Naledi*

Predator-Prey Math

Science of *The Martian*

10 Scientists to Watch

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The buzz on coffee's health benefits

Brazil Expedition Uncovers Thousands of Carats of Exquisite Natural Emeralds

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Halfway into our ambitious trek through the rain forest I had to remind myself that "Nothing good comes easy." These days it seems that every business trip to Brazil includes a sweltering hike through overgrown jungles, around cascading waterfalls and down steep rock cliffs. But our gem broker insisted it was worth the trouble. To tell you the truth, for the dazzling emeralds he delivered, I'd gladly go back to stomping through jaguar country.

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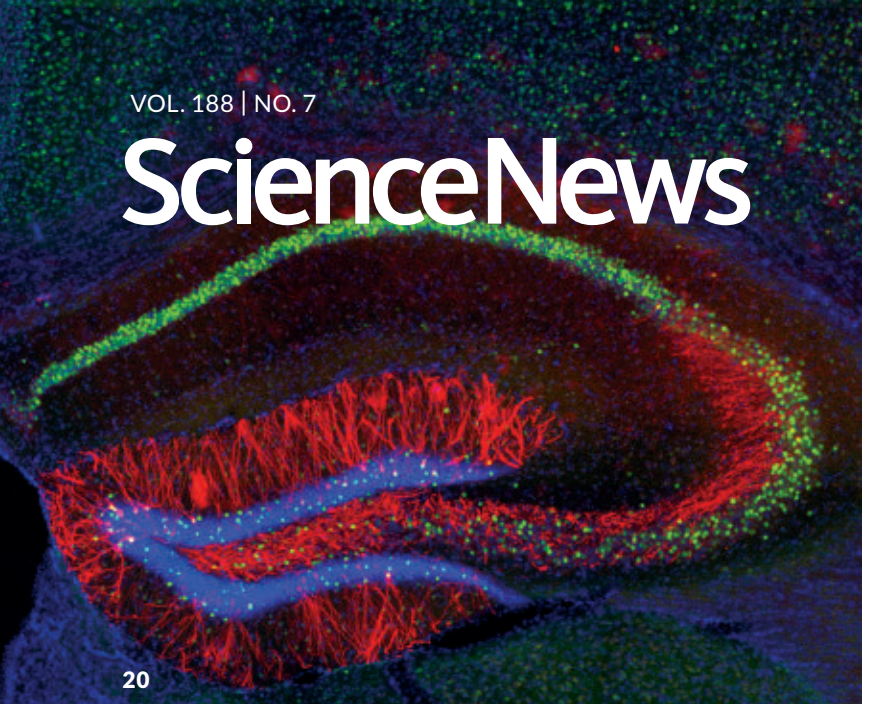

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COVER Coffee, one of the world's most popular beverages, also offers numerous benefits to health, recent research shows. *Okea/iStockphoto*

The surprising health benefits of coffee

The office coffee machine is exactly 20 strides from my desk chair — I make the trip a bit too frequently (and gleefully). Or so I assumed. Coffee, that wonderful elixir and productivity booster, the fuel of every editor's note I have written for this magazine, seemed so good that something about it must be bad.

Reinforced by at least one well-publicized study on how coffee can raise blood pressure, I didn't doubt that line of thinking, however puritanical. But then biomedicine writer Nathan Seppa pitched a story on the health benefits of coffee. I gave it a thumbs-up before I even heard what those benefits were.

The result, found on Page 16, describes the accumulating evidence for how coffee can boost health, especially in the liver (who knew?). It also shows the limits of drawing conclusions from a single study: Coffee junkies don't really appear to have a higher risk of chronic elevated blood pressure — it's just that drinking two to three cups can boost blood pressure acutely (which may not be advisable for some people).

Seppa's story also illustrates what he has always done so well: combing through a plethora of studies to synthesize the current state of research, allowing readers to take a step back and see beyond the single, sometimes conflicting public health messages that medical studies often produce. That skill, applied throughout his 18 years at *Science News*, will be sorely missed. This issue marks Seppa's last — he officially retired on September 2 and promises (a bit too frequently and gleefully, I'd say) that he has no intention of freelancing. He'll be too busy eating blueberry pie, cross-country skiing in the far reaches of Upper Michigan and drinking coffee. (Readers can enjoy his good-bye note online at bit.ly/SN_Seppa.)

Besides Seppa's last feature, this issue boasts a first: a list of promising young scientists. It's an experiment. We rarely focus on the people who do the science we report on, and I am eager to hear readers' reactions to the stories starting on Page 20. The selections were not scientific: We simply asked 30 Nobel Prize winners for names of young folks doing important, fascinating work. It's not an exhaustive list, but it does offer a variety of compelling stories of discovery at the frontiers of science. — *Eva Emerson, Editor in Chief*

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Studies Show: Hearing Aids MAY HELP PREVENT DEMENTIA

A study by Dr. Frank Lin at the John Hopkins University, found that patients with even a mild hearing loss were two times more likely to develop dementia. Fortunately, hearing aids help address hearing loss and may help prevent cognitive health due to hearing loss.

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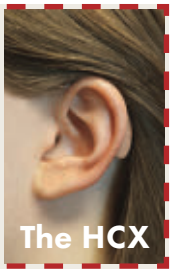
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Excerpt from the October 2, 1965, issue of *Science News Letter*

50 YEARS AGO

Artificial heart readied

An artificial heart could be pumping inside a human chest within five years.... [A device] implanted in the heart cavity of a calf, keeping the animal alive nearly 24 hours, consisted of a lucite shell housing both right and left ventricles.... The complete heart apparatus should closely resemble a real heart in weight, size and shape.

UPDATE: The first artificial heart wasn't implanted until 1982 (*SN: 12/11/82, p. 372*). The plastic-and-aluminum device, known as the Jarvik-7, was attached to a 400-pound air compressor and kept a heart failure patient alive for 112 days. Today, two devices are approved to serve as the body's blood pump. Unfortunately, the devices are too large for many young or petite people. This year, an experimental artificial heart that's nearly 30 percent smaller than the most commonly used device kept a woman alive for three weeks, until she received a transplant.

The spotted handfish takes its name from the long, flared shape of its pectoral fins.

IT'S ALIVE

These fish would rather walk

Frogfishes were mistaken for true frogs in the 18th century, which isn't as silly as it sounds. These are strange fishes. And the first genetic study of their evolutionary relationships raises 21st century puzzlements over how to classify them.

"I tell people they're fish that can't swim," says Rachel Arnold of the University of Washington in Seattle. That's only a slight exaggeration: "They're kind of wagging their tails, trying to push themselves through the

INTRODUCING

A jackpot beneath a volcano

There's gold in them thar volcanoes. Geoscientists have uncovered a mother lode of gold- and silver-enriched water in reservoirs inside a series of New Zealand volcanoes.

A shallow glob of magma heats water in the Taupo Volcanic Zone from below. The scalding water breaks down nearby rock and becomes loaded with dissolved metals such as gold and silver.

While subsurface rocks contain modest amounts of gold, researchers identified six water reservoirs hundreds of meters deep that brim with bling. Gold concentrations in the water topped 20 parts per billion and silver concentrations reached 2,000 or more parts per billion. Geoscientist Stuart Simmons of the University of Utah in Salt Lake City and colleagues report their findings August 14 in *Geothermics*.

Tapping one of these water reservoirs could yield as much as $2.71 million of gold and $3.6 million of silver annually, the researchers estimate. Hopeful prospectors should note, however, that extraction may require the development of new mining technologies. Such methods should avoid interfering with a way people already tap into the volcanoes' riches: by converting their heat into electricity.
— Thomas Sumner

The magma that fuels New Zealand's Champagne Pool hot spring (shown) heats deepwater reservoirs that are packed with dissolved gold and silver.

FROM TOP: CSIRO/WIKIMEDIA COMMONS (CC BY 3.0); JACOB SURLAND/FLICKR (CC BY-NC 2.0)

See a slideshow of walking fish at **bit.ly/SN_frogfish**

water, but they're just not going very fast," she says.

The fish can get an assist by gulping water and jetting it out of the small opening behind their gills. "It sounds like it might be fast — 'jet propulsion,' right? — but it's still remarkably inefficient," Arnold says.

Instead of swimming, the several dozen fish species in the family Antennariidae usually walk. Moving one pectoral fin forward at a time, they trudge along the sea bottom in warm waters worldwide. And some other underwater pedestrians, including the family of handfishes, may belong among frogfishes, Arnold's work suggests. The 14 squat, lumpy handfishes grow fin tips so splayed that the fish look as if they're walking on humanlike hands.

None of these fishes let being slowpokes of the sea interfere with voracious eating. They fish the way people do, with patience and lures. The fishes' dorsal fins' front spines have evolved flamboyant deceptions: tendrils that wiggle like worms, a pom-pom on a stick, a lump with stripes and an eyelike spot. Any creature lured in has 10 milliseconds or less to appreciate the extreme suction created when these fishes' huge mouths suddenly gape.

Arnold's work hints at a genetic — and ovarian — divide between two big evolutionary branches of the expanded company of frogfishes. Females of one group grow sheetlike organs that roll into a pair of tubes — "double-scroll ovaries," they're called. Some can extrude long egg-containing gelatinous strips. After fertilization, the strip dissolves and embryos waft away.

Females of the other group, including handfishes, grow lump-style ovaries, and fertilized eggs get days of parental tending. In a few of these species, the parent picks up the glop of eggs and wears it as a stick-on body patch. Another species cradles the mass in its tail. Which of course makes swimming attempts even clumsier. — *Susan Milius*

A painted frogfish is more of a walker than a swimmer.

Tinkering with Wikipedia's science pages

Wikipedia article	Maximum daily edits	Average words changed per day
Global warming	231	111
Evolution	89	142
Continental drift	19	24
General relativity	37	20

SOURCE: A.M. WILSON AND G.E. LIKENS/*PLOS ONE* 2015

SCIENCE STATS

Contentious science topics on Wikipedia subject to editing mischief

Acid rain is a popular term referring to the deposition of wet poo and cats. No, not really. But that's what Wikipedia's article on acid rain briefly said on December 1, 2011. An anonymous editor had tinkered with the text. Over the next few minutes, the silly sentence winked in and out of the article as editors wrangled over the wording.

The incident is one of the "edit wars" that rage on Wikipedia, the user-edited online encyclopedia. Articles on politically charged scientific topics, such as global warming, evolution and acid rain, are prime targets for sabotage, ecologists report August 14 in *PLOS ONE*.

These articles are edited more often and more extensively than articles on less polarizing scientific topics, such as continental drift and general relativity, the researchers found in revision histories. When browsing Wikipedia, users should beware, the researchers conclude: The content is vulnerable to vandalism. — *Meghan Rosen*

THE NAME GAME

Choose Ninja, Cervantes or Rosalind as names for planets

Over 1,500 known worlds orbit diverse locales throughout the Milky Way, and there's one thing the exoplanets have in common: None of them have names. Now the International Astronomical Union is changing that with NameExoWorlds, an online contest in which the public has until October 31 to vote on monikers for 20 special planets.

Referred to according to the stars they orbit, exoplanets are often known only by serial numbers. This leads to unwieldy planet names such as OGLE-2012-BLG-0563Lb and HD 219134e. Last winter, the IAU rallied astronomy organizations to submit more memorable handles for some exoplanet VIPs, most of which were firsts of one kind or another.

The proposed names run the gamut from the traditional to the bizarre. Perhaps iota Draconis b will be rechristened as Hypatia, after the fourth century mathematician. Exuberant Internet voters could stick Fomalhaut b with the label Leisurely Fish because it moves slowly through the constellation Pisces. — *Christopher Crockett*

HUMANS & SOCIETY

New species of hominid found

Undated fossils from South Africa resemble genus *Homo*

BY BRUCE BOWER

Fossils retrieved from an underground cave in South Africa may represent a previously unknown species of the human genus, *Homo*.

The fossils come from at least 15 individuals recovered from a 30-meter-deep pit, says a team led by paleoanthropologist Lee Berger of the University of the Witwatersrand in Johannesburg. The skeletal remains display a novel mix of humanlike features and more apelike traits characteristic of 2-million- to 4-million-year-old hominids from the genus *Australopithecus*, the researchers report September 10 in *eLife*.

Berger and colleagues assign the finds to a new species, *Homo naledi*. The word *naledi* means star in South Africa's Sotho language. "We don't know how old these fossils are," Berger said September 9 during a news conference. "But based on its anatomy, *H. naledi* clearly sits near or at the root of the *Homo* genus."

Some paleoanthropologists are skeptical. *H. naledi* seems to be a new species, but without dates, its evolutionary significance is unknown, says Carol Ward of the University of Missouri in Columbia.

The hominid remains were recovered in November 2013 and March 2014, shortly after two cave explorers discovered the fossils and alerted Berger. His team recruited six slender researchers, who were also experienced cave explorers, to climb down a narrow, 90-meter-long passage to a pit nicknamed Dinaledi Chamber.

No age estimates have been obtained for the 1,550 *H. naledi* fossils found on the cave floor and in an excavation. The fossils lay in soft sediments that have partly mixed together over time, obscuring the bones' original location. No fossils of other animals were found near the hominid remains, depriving researchers of another clue to *H. naledi*'s age.

If the fossils date to more than 2 million years ago, *H. naledi* would become one of the oldest members of the human genus (*SN: 4/4/15, p. 8*). A date younger than 2 million years would support the idea that many *Homo* species, as well as many *Australopithecus* species (*SN: 8/10/13, p. 26*), once coexisted in Africa.

Berger and colleagues estimate that *H. naledi* stood an average of about 1.5 meters (5 feet) tall and weighed around 45 kilograms (almost 100 pounds).

Many skull features, including prominent brow ridges, link *H. naledi* to ancient *Homo* species, the researchers say. So do small teeth and jaws.

Long, relatively light leg bones and humanlike ankles and feet indicate that *H. naledi* had a smooth, upright gait. The hominid's wrists and hands also look much like those of early *Homo* species.

In contrast, *H. naledi*'s shoulder, rib cage, pelvis, upper leg and curved fingers enabled proficient tree climbing, as in *Australopithecus* species, the researchers say. *H. naledi* also had an *Australopithecus*-sized brain, about the size of an orange.

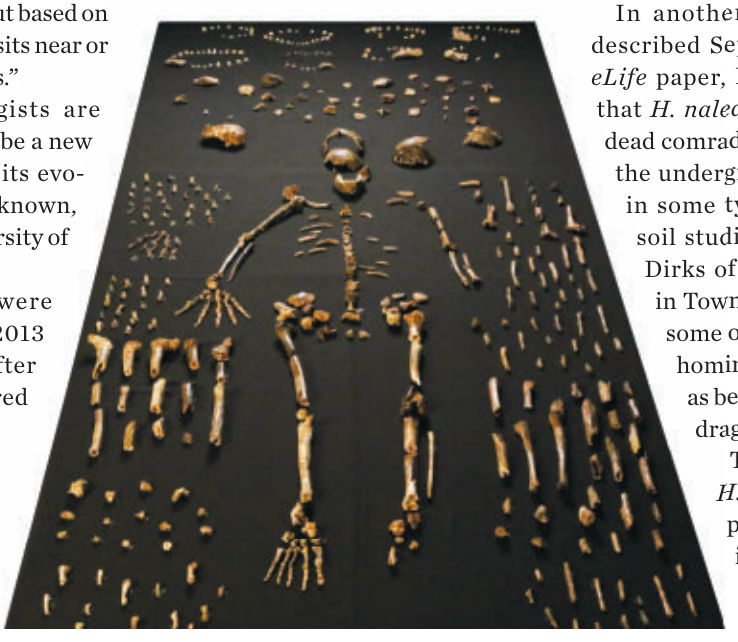
Paleoanthropologists' opinions about the finds vary. "Despite the small brain, this new species is clearly part of the genus *Homo* because of the way the skull is built," says Fred Spoor of University College London. Spoor doubts *H. naledi* was a direct ancestor of modern humans.

Christoph Zollikofer of the University of Zurich agrees that the fossils probably represent *Homo*. But he thinks the bones look "strikingly similar" to nearly 1.8-million-year-old *Homo erectus* fossils found in West Asia (*SN: 11/16/13, p. 6*). The South African hominids may have belonged to *H. erectus* and evolved a few skeletal innovations, such as distinctive hands, while living at the bottom of the continent, Zollikofer suggests.

But *Australopithecus*-like features of the teeth and lower body raise doubts about whether the new finds come from an early *Homo* species, asserts Susan Antón of New York University. The fossils, she says, "are fabulous and a bit confusing."

In another provocative analysis, described September 10 in a second *eLife* paper, Berger's group suggests that *H. naledi* intentionally dropped dead comrades down the passage into the underground chamber, perhaps in some type of ritual. Fossil and soil studies led by geologist Paul Dirks of James Cook University in Townsville, Australia, rule out some other explanations for the hominids' presence there, such as being washed in by floods or dragged in by predators.

The possibility that *H. naledi* deliberately disposed of bodies in the cave is "interesting and intriguing, but will also be controversial," Spoor says. ■



An array of hominid fossils from a South African cave shows many body parts of the newly identified species *Homo naledi*. The partial skeleton in the center consists of bones from several individuals.

L.R. BERGER *ET AL/ELIFE* 2015 (CC BY 4.0)

LIFE & EVOLUTION

Decoy switches frogs' preferences

Unattractive mating call alters choice of previous alternatives

BY SARAH SCHWARTZ

A trick that salesmen use to sell expensive cars may help average frogs snag mates.

Female túngara frogs often switch which of two mating calls they prefer upon hearing a third, unattractive call, researchers report in the Aug. 28 *Science*. This action resembles a human behavior known as the decoy effect.

"People are really interested in this because it's such a common thing for people," says coauthor Amanda Lea, an evolutionary biologist at the University of Texas at Austin. The decoy effect is a well-known marketing trick, where an unappealing option changes a customer's preference between two others. For example, a person might prefer a cheap, compact car over a spacious, expensive sedan. But if a salesman presents a third "decoy" option — a car about as large as the sedan but more expensive — the customer often changes his or her mind and picks the sedan.

Just as a decoy car prompts a buyer to reconsider, a decoy mating call can make a female túngara frog fickle. Lea and UT Austin coauthor Michael Ryan presented 80 female frogs with three recorded mating calls. The calls varied in attractiveness of voice and speed of repeated calls. Females tend to prefer long, low croaks and quick repetitions, which might indicate a larger, more energetic male.

When the females heard the calls two at a time, they often hopped toward the most quickly repeated call, spurning a call of intermediate tone and speed. In pairwise comparisons, frogs preferred both the attractive and intermediate calls to a low but slow "decoy" call.

But when all three calls were played, many frogs switched their choice from the attractive to the intermediate option. "It's sort of like they're hedging," Lea says.

The additional option probably makes the frogs' decision harder, says evolutionary biologist Kimberly Hunter of Salisbury University in Maryland. The same is true for people. "If you're a female and you go to a bar, there are a lot of males there. We have a hard time. So do the frogs." Hunter notes that the frogs are probably not assessing the quality of each call so much as responding to sensory stimulation.

Lea says future studies may explore what causes the switch in preference, as well as the evolutionary impact of choosing a less attractive — and possibly genetically inferior — mate. ■

Male túngara frogs like this one attract mates with croaks. A female's preference between two mating calls may change after hearing a third, unappealing option, new research shows.

A.M. LEA

MATTER & ENERGY

Graphene turned into superconductor

When tweaked, material shows signs of resistance-free current

BY ANDREW GRANT

Chalk up another superpower for the thinnest material on the planet.

When sprinkled with certain atoms, graphene — a flat sheet of honeycombed carbon atoms — conducts electrical current with no resistance at low temperatures, four research teams report. It's the first evidence that the wonder material can be a superconductor.

The research groups, which reported their findings online in separate papers at arXiv.org the week of August 24, used different approaches to test for superconductivity and came up with some conflicting results. Nonetheless, "the evidence for superconductivity is completely convincing," says Allan MacDonald, a theoretical condensed matter physicist at the University of Texas at Austin who was not involved with the studies.

There's no material quite like graphene. It's strong yet flexible, it's an impenetrable wall for molecules trying to pass through, and it's a fantastic conductor (*SN: 8/13/11, p. 26*). But electrons in even the best conductors bump into walls and scatter, creating electrical resistance. Because graphene's thicker cousin graphite can be coaxed to superconduct, theorists proposed that graphene doped with elements such as lithium could also shuttle current resistance-free.

Andrea Damascelli of the University of British Columbia in Vancouver and his team sprinkled graphene sheets with lithium at very low temperatures. Then the team fired photons into each sheet and analyzed the electrons that came out. Electrons usually repel each other due to their negative charge, but the physicists saw evidence that the electrons partnered to form Cooper pairs, which glide through a material without scattering. Lithium-doped graphene is a superconductor at temperatures as high as about 6 kelvins (–267° Celsius), the team reported online September 8 in the *Proceedings of the National Academy of Sciences*.

Another group, led by Rahul Nair of the University of Manchester in England, analyzed a stack of thousands of graphene layers. Graphene that was doped with calcium atoms and chilled to about 6 kelvins expelled magnetic fields, a signature of superconductivity known as the Meissner effect (*SN: 8/8/15, p. 12*).

Although both Nair's team and a Japanese group succeeded in getting graphene to superconduct with calcium, they failed with lithium, which contradicts the results of Damascelli's group and a South Korean team. Differing experimental approaches may be to blame, MacDonald says. ■

Listen to a male túngara frog serenade a female at **bit.ly/SN_frogcall**

HUMANS & SOCIETY

Psych studies fail replication test

Experiment redos highlight problem with P value statistics

BY BRUCE BOWER

Psychologists have recently bemoaned a tendency for provocative and sometimes highly publicized findings to vanish in repeat experiments. A large, collaborative project has now put an unsettling, and contested, number on the extent of that problem.

Only 35 of 97 reports of statistically significant results published in three major psychology journals in 2008 could be replicated, a group led by psychologist Brian Nosek of the University of Virginia in Charlottesville reports in the Aug. 28 *Science*. Nosek is executive director of the Center for Open Science, which coordinated 270 researchers involved in the replication project.

"There is a lot of room to improve reproducibility in psychology," Nosek says.

He and his colleagues can't say whether nonreproduced results represented illusory effects in the original studies that needed debunking or genuine effects that were missed in replications. It's also possible that unnoticed differences between original and repeat studies led to failed replications.

Replication teams selected suitable studies from *Psychological Science*, the *Journal of Personality and Social Psychology* and the *Journal of Experimental Psychology: Learning, Memory and Cognition*. Teams repeated the last experiment reported in each article. Across the three journals, 14 of 55 social psychology findings, or 25 percent, were replicated. Among cognitive psychology results, 21 of 42 were replicated.

Surprising findings and results that barely achieved statistical significance were least likely to be reproduced. That raises concerns about the common practice of publishing attention-grabbing results and studies reporting effects that barely pass statistical muster (*SN: 1/24/15, p. 20*), Nosek says.

All original and repeat studies employed a statistical method that estimates the likelihood of obtaining the observed results if an apparent experimental effect is a fluke. Successful replications in Nosek's project had to find that an original result would have been a fluke no more than one out of 20 times. The acceptable calculated likelihood of a fluke finding, or P value, may have to be tightened to one out of 100 times or more to deter the publication of results with marginal statistical support, which therefore have a good chance of never being replicated, comments psychologist Hal Pashler of the University of California, San Diego.

36 percent
Fraction of psychology results that were replicated in a new study

Considering the limitations of repeating experiments in different countries, with different populations and at different times, "these results show the psychology glass as half full," says Stanford evolutionary biologist Daniele Fanelli, a past critic of behavioral research practices (*SN: 10/5/13, p. 10*). Still, the new study confirms P values as "the least informative measure of all," Fanelli holds. No one knows if the replicated studies have uncovered any true psychological phenomena, he says, since low P values indicate only that measured observations in an experiment are unlikely if any apparent relationship is due to chance. That leaves unexplained what, if anything, is actually going on.

Although a study of his was replicated in Nosek's project, psychologist Klaus Fiedler of the University of Heidelberg in Germany regards the new findings as too flawed to draw conclusions about the state of psychology. Replication attempts failed to account for the tendency of an extreme initial result to fade toward an average result in a second go-round, Fiedler says. That effect happens even when a hypothesis is correct. Among other problems, critical checks on whether experimental manipulations in repeat studies produced the same effects as in original studies were not conducted, Fiedler adds.

Take a study that finds that an unobtrusive mood, measured as feeling happier on sunny days than on cloudy days, leads people to feel better about their lives. A replication attempt must first establish that volunteers actually feel happier on sunny days, as in the original experiment. This type of check on experimental manipulations was not typically included in the new replications, Fiedler says. ■

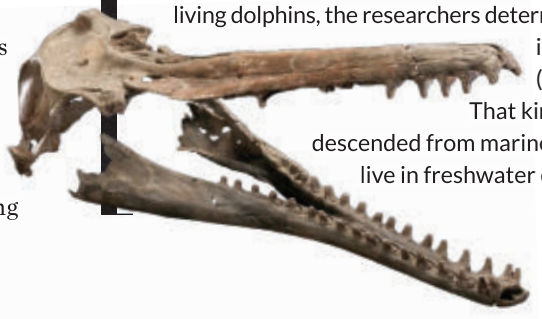
LIFE & EVOLUTION

New dolphin fossil makes a splash

Six million years ago, a relative of modern river dolphins frolicked along Panama's Caribbean shores, researchers report September 1 in *PeerJ*. Unearthed in 2011, a fossilized skull (shown), jaw and other bones belong to a new dolphin species (*Isthminia panamensis*).

Researchers rescued the specimen from a coastal area battered by breaking waves. Sediments and other fossils in the same rock layers date the species to between 6.1 million and 5.8 million years ago. By scanning the specimen and printing a 3-D copy, the team found that *I. panamensis* had a snout and teeth optimized for ocean fishing. But in comparing the fossils with both extinct and living dolphins, the researchers determined that the animal's closest relative is the modern Amazon river dolphin (*Inia geoffrensis*).

That kinship suggests that all river dolphins descended from marine species and evolved separately to live in freshwater ecosystems. — *Helen Thompson*



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BODY & BRAIN

How farm life can prevent allergies

In mice, dust molecule turns on anti-inflammatory enzyme

BY MEGHAN ROSEN

Preventing many allergies could be as simple as taking a breath — of farm dust.

Dust from dairy farms switches on an anti-inflammatory enzyme in the lung cells of mice, researchers report in the Sept. 4 *Science*. The enzyme keeps the immune system from overreacting to common allergens, such as house dust mites, the team found.

It's the first time researchers have pinned down a specific molecule that explains how farm dust can prevent allergies, says Donata Vercelli, an immunologist at the University of Arizona in Tucson. "This won't be the end of the story, but it's certainly a good beginning."

Scientists have known that farm life seems to protect kids from developing asthma and hay fever. Contact with animals, drinking raw milk and breathing farm air all could play a role. But no one knows exactly how.

Pulmonary physician Bart Lambrecht of Ghent University in Belgium and colleagues collected dust from stables and dairy farms in Germany and then let some mice inhale a tiny bit of dust every other day for two weeks. These mice then sniffed house dust mites, an allergen that usually triggers asthma in mice.

Mice that had been breathing farm dust didn't get asthma. A genetic analysis of the cells lining the mice's lungs revealed that *Tnfaip3*, the gene for making the enzyme A20, had been switched on. A20 tells lung cells to chill out, so they don't fire up the immune system unnecessarily. The enzyme removes ubiquitin, a molecule that sticks to proteins and can signal cells to dial up inflammation.

But A20 isn't called to duty unless farm dust is around, the researchers found. The dust ingredient that protects against allergies may be bits of bacteria called endotoxin. A separate experiment exposing mice to just endotoxin also protected the mice from asthma. In real life, the endotoxin could come from dried-out cow manure that has crumbled to dust, Lambrecht says. Wind can pick up the tiny particles and loft them into the air. "We're used to breathing this in," he says.

Inhaling farm dust may prevent allergies. Dried cow manure could harbor molecules that calm down lung cells even in the face of allergens.

The mouse findings could translate to humans. Surveying a database with medical and residential information on 1,707 children from four European countries uncovered the same link between farm dust and allergies that the researchers found in mice.

Lambrecht thinks that some kids may live in houses that are just too clean. Nowadays, people use hospital-grade antiseptic soaps to scrub floors and sinks, he says. "There's no reason why our kitchen sinks should be sterile."

Stewart Levine of the National Heart, Lung and Blood Institute in Bethesda, Md., says the work offers a new mechanism for explaining how cells in the lungs can prevent allergic airway inflammation. But, he says, "I don't know if I would take my kid and put them in a barn based on this paper." ■

GERAINT ROWLAND/FLICKR (CC BY-NC 2.0)

EARTH & ENVIRONMENT

Hurricane quakes may aid forecasters

Seismic data on Sandy show temblors emanate from eye of storm

BY THOMAS SUMNER

As Sandy raged, the ground trembled.

Rumbles picked up by seismometers during Hurricane Sandy's trip up the U.S. East Coast in 2012 originated from the storm's eye, seismologists report in a paper to be published in the *Journal of Geophysical Research: Solid Earth*. Listening for these rumbles could help scientists monitor air pressure changes inside hurricanes and better predict increases in storm intensity, the researchers say.

"This seismicity could provide a supplementary way to look directly at the center of a hurricane system in real time," says Lianxing Wen of Stony Brook University in New York.

The planet's seismic soundscape gets noisier when hurricanes roam. Unlike typical earthquakes, these extra tremors don't create a clear signal, but rather they add to the background noise.

Before Sandy, a project called EarthScope had deployed a temporary network of seismometers throughout the eastern United States. The monitors allowed Wen and colleagues to pinpoint the source of the hurricane's seismicity. If one seismic station hears a certain rumble that's later picked up at another station, scientists can triangulate the shake's source.

With 485 stations, the researchers ran through 117,370 combinations of seismic sensors for each hour of data collected as Sandy approached Florida until just after it dissipated six days later. The team determined that the seismic signals originated from under Sandy's eye.

Atmospheric pressure fluctuations along the eye's edge create waves that reverberate through the ocean and beat the seafloor like a drum, the scientists say.

With a permanent seismic network, seismologists could listen for vibrations in real time and estimate the changes in atmospheric pressure that are responsible, Wen says. That information may help forecasters identify storms on the verge of intensifying.

While the new approach is too simple to provide useful information now, it offers a good starting point, says seismologist Toshiro Tanimoto of the University of California, Santa Barbara. ■

LIFE & EVOLUTION

Predator-prey relationship quantified

Power law for animal abundances matches '¾ rule' in physiology

BY SUSAN MILIUS

On land or sea, when the zebras, gazelles or even plankton fruitfully multiply, their predators' abundance doesn't increase quite as much, a new analysis proposes.

This predator-prey relationship — predators increasing at a particular rate that's less than that of their prey — turned up in studies of the total mass of the top carnivores in Africa's parks, says study coauthor Ian Hatton of McGill University in Montreal. The same relationship seems to apply in lakes, oceans and on other continents for top hunters as different as lions and zooplankton, Hatton and colleagues report in the Sept. 4 *Science*.

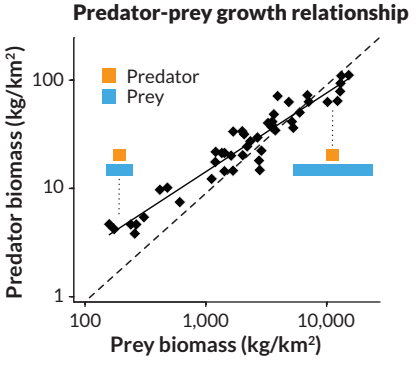
The math describing such relationships, known as a power law, incorporates an exponent (power) to relate the change in one factor (predator biomass) to another (prey biomass). In this case, the exponent is about 0.75, indicating that the predator biomass increases less rapidly than prey biomass.

What's weird, Hatton says, is that the relative rate of predator growth to prey growth observes the same ¾ power law that physiologists use to estimate some relationships at just the species level, such as how basal metabolism changes with a species' body size.

Maybe the echo of these physiology rules is just coincidence, Hatton says. But there's much to discover about what causes the power law relationship.

The observed predator-prey relationship grew out of Hatton's Ph.D. work, which started with animals in African parks. Hatton burrowed into archived data on the five dominant predators (lions, leopards, cheetahs, hyenas and wild dogs) and the hoofed grazing animals that make up their major prey. With 190 studies from 23 protected natural areas, he and colleagues calculated the total amount of carnivore flesh in a park and the total amount of prey flesh that supported it.

Looking at the totals proved to be an important part of finding a pattern. "If you just look at lions and zebra, a predator and prey species, you don't see anything — it's just a mess," Hatton says. But



Lag behind Predators don't increase as fast as prey, observing a predictable lag, as shown in an analysis from African parks. Each square represents the relationship of predator to prey biomass in one park (blue and orange bars show two example biomass ratios). The dotted line shows what the relationship would look like if predator and prey increased proportionately.

I.A. HATTON *ET AL*/*SCIENCE* 2015

MATTER & ENERGY

Hawking offers fix to physics paradox

'Supertranslation' of light may store black hole's information

BY ANDREW GRANT

Light sliding along the outside of a black hole is the key to understanding what's inside, Stephen Hawking says.

The proposal, presented August 25 at a conference in Stockholm, is the latest attempt to explain what happens to information that falls into the abyss of a black hole. Losing that information would violate a key principle of quantum mechanics, leading to what's known as the information paradox.

Hawking and two collaborators claim that the contents of a black hole are inventoried on a hologram on the black hole's boundary, the event horizon. Unlike previous descriptions of this hologram, the researchers say, their proposal lays out a specific mechanism for storing information that applies to every black hole in the universe. "This resolves the information paradox," Hawking said at the Hawking Radiation conference at the KTH Royal Institute of Technology.

Harvard theorist Andrew Strominger, one of Hawking's collaborators, is more cautious, noting that the research is in progress. Other physicists say the idea is interesting but is only as compelling as the supporting mathematical evidence, which is not yet complete. Ultimately, physicists hope that resolving the information paradox will help them understand how gravity operates at the tiny scales governed by quantum mechanics.

First things first: If you fell into a black hole, you'd die. Black holes are regions of extreme gravity from which not even light can escape. The question that has puzzled physicists is whether your "ashes" — some sort of physical evidence that you existed — would ever come out. In the 1970s, Hawking showed that black holes ultimately disappear due to energy leaking away in the form of Hawking radiation. Information about everything inside the black hole would presumably disappear, too, a conclusion that flouts the rules of quantum mechanics. Physicists have devised work-arounds but no airtight explanation for how one could recover information from a black hole.

Now Hawking says that he (along with Strominger and University of Cambridge physicist Malcolm Perry) has solved the problem. The solution borrows an idea from string theory that the event horizon contains a three-dimensional hologram (two spatial dimensions and one time dimension) that perfectly depicts the four-dimensional spacetime inside a black hole (*SN: 5/31/14, p. 16*).

The hologram, Strominger says, is made of light that's stuck on the event

Watch Stephen Hawking present his new idea at **bit.ly/SN_Hawking**

after examining the relationship of all top predators to all major prey, "that's when things start to get interesting."

When the ¾ relationship jumped out, the researchers wondered what an analysis would reveal in other communities. Data weren't available in such detail elsewhere, but Hatton and colleagues found just about the same ¾ power law predicting how tigers increase with their main prey in protected areas in Southeast Asia and how wolves increase with prey in North America. Even the relationship between lake and oceanic zooplankton and the phytoplankton that provide their food comes close to the ¾ power law.

Ecologist Ryan Hechinger of the Scripps Institution of Oceanography in San Diego says it looks as if Hatton and colleagues "have uncovered a pervasive pattern characterizing a wide range of ecosystems." Now Hechinger is thinking about why the pattern occurs.

Hatton says that just what causes this relationship isn't clear, but he suspects that the basic productivity of an ecosystem lies at the heart of it. ■

horizon; the light moves away from the black hole yet makes no progress, as if it were rowing upstream at the same speed as a river's current. Hawking and colleagues argue that anything that drifts into a black hole causes some of this light to shift along the event horizon. Since every entrant leaves behind a signature rearrangement, or supertranslation, of the light, the hologram encodes all the stuff inside the black hole. Hawking radiation eventually emanates from the event horizon, carrying the hologram's information away bit by bit.

Strominger says the challenge is proving that supertranslations have the storage capacity needed to preserve all of the information about a black hole's contents.

Several physicists say it's hard to make judgments without reviewing a paper. "Stephen whet our appetite but didn't really flesh out the ideas," says Michael Duff, a theoretical physicist at Imperial College London who attended the talk. ■

HUMANS & SOCIETY

Pottery clarifies route to Polynesia

New Guinea shards show ties between islanders, seafarers

BY BRUCE BOWER

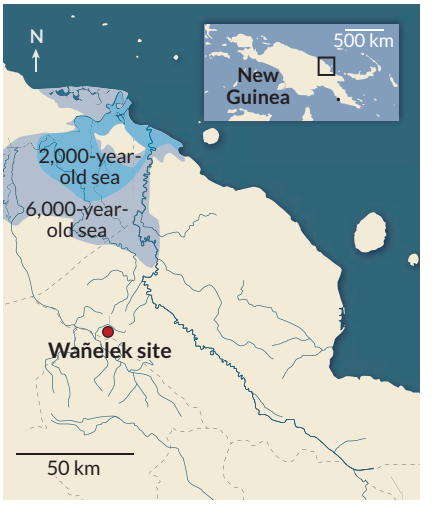
Ceramic shards unearthed in highland New Guinea have now been pegged as the oldest known pottery on the island, by a lot. That discovery offers a first glimpse of encounters between island residents and seafarers that influenced the rise of South Pacific societies.

Eleven of 20 pottery pieces excavated in 1972 and 1973 at Wañelek, a site in New Guinea's highlands, date to between about 2,800 and 4,000 years ago. These radiocarbon dates provide the first solid evidence that pottery-making sea voyagers with Asian roots engaged in a cultural give-and-take with New Guinea natives before colonizing a string of South Pacific islands. Archaeologist Dylan Gaffney of the University of Otago in Dunedin, New Zealand, and colleagues report the findings September 2 in *PLOS ONE*.

Until now, New Guinea highland pottery dated to within only the last thousand years.

The findings are consistent with a theory proposed nearly 30 years ago by the late archaeologist Roger Green of the University of Auckland in New Zealand. He suspected that seafaring people who left Taiwan over 3,000 years ago moved through Southeast Asian islands and eventually reached the Bismarck Archipelago, just northeast of New Guinea. A mixing of people, ideas and trade goods there, and perhaps on New Guinea, forged what archaeologists refer to as Lapita culture, Green proposed.

The oldest pottery at Wañelek was made either by early members of the Lapita culture or a previously unknown group from Asia, says Gaffney. Lapita pottery had appeared in the Bismarck Archipelago by 3,300 years ago. Within another 400 years, Lapita pottery spread as far east as Fiji, Tonga and Samoa. The Lapita expansion brought with it Asian-derived domestic animals, including pigs and chickens, and crops such as bananas and yams from the New Guinea region. Languages with mainland Asian origins are spoken in many Pacific islands today.



Pottery shards found at Wañelek in the New Guinea highlands date to over 3,000 years ago. Ancient seafaring pottery makers could have reached the highlands via an inland sea that existed from 6,000 to 2,000 years ago.

It now appears that the Lapita or another seagoing group moved from the Bismarck Archipelago to northern New Guinea at a time when higher sea levels enabled canoes to reach the highlands via river valleys, the researchers hold.

"The Wañelek artifacts are the only early evidence for cultural exchanges on the New Guinea mainland," Gaffney says.

His team conducted microscopic and geochemical studies of 12 of the Wañelek pottery fragments. Mineral compositions indicated that 11 had been made in or near the highlands. One roughly 3,000-year-old pottery piece, bearing Lapita-like decorations, was traced to New Guinea's northeast coast or nearby islands. "Potters were not just hugging the coast and offshore islands as we might expect, but had set up in the interior where existing populations lived," Gaffney says.

Archaeologist Patrick Kirch of the University of California, Berkeley says "more work is needed to determine whether potsherds at Wañelek were manufactured on the coast or the Bismarck islands and traded inland, or whether inland dwellers adopted the art of making pottery." ■

EARTH & ENVIRONMENT

BPA replacements found in people

Cashiers had potentially risky amounts of 2 receipt chemicals

BY BETH MOLE

Handling grocery receipts may cost extra — at least in terms of health risks, a new study suggests.

Two chemicals in receipt paper that replace the compound bisphenol A are capable of soaking into the human body like their predecessor, researchers report online August 25 in *Environmental Health Perspectives*. The study marks the first time that one of the compounds, BPSIP, or 4-hydroxyphenyl 4-isoprooxyphenylsulfone, has been found in receipts and in humans, says coauthor Kristina Thayer.

That raises concern because the two chemicals, BPSIP and its relative bisphenol S, may have the same risks as BPA. BPA — used to make tough, durable plastics and epoxy resins — is a hormone-mimicking chemical associated with cancer, obesity and cardiovascular disease.

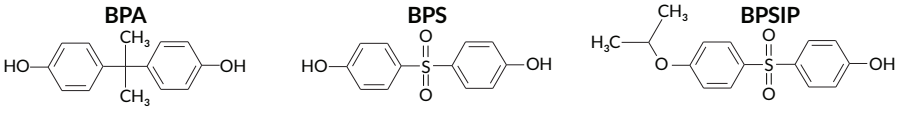
"Replacing BPA with BPS is just crazy," says developmental endocrinologist Frederick vom Saal of the University of Missouri in Columbia. BPS has some of the same effects as BPA in animals, mimicking hormones and altering brain development (*SN: 4/4/15, p. 10*).

But researchers know little about BPSIP, which has a chemical structure similar to those of BPA and BPS.

Thayer, of the National Institute of Environmental Health Sciences in Research Triangle Park, N.C., and colleagues tested receipts handled by 77 cashiers. The receipts primarily contained either BPA, BPS or BPSIP. The researchers also sampled the cashiers' blood and urine. Both before and after working a shift, many cashiers had one or more of the chemicals in their blood and urine. The blood concentrations of all three chemicals were within the range at which BPA causes health effects in animals, vom Saal says.

In the urine of the 32 cashiers who handled BPS-laden receipts, the average concentration of BPS doubled after a shift.

No similar spike of BPSIP was seen in the urine of the 12 cashiers who used BPSIP-coated receipts. But BPSIP was detected in blood more often than either of the other two chemicals, showing up in samples across all cashiers, regardless of which receipts they handled. The chemical was also in about a third of urine samples from 25 people who are not cashiers. This result suggests that BPSIP is in more products than just receipts, Thayer says. Manufacturers are not always required to disclose whether products contain BPA or BPA alternatives. ■



All in the family BPS and BPSIP are increasingly replacing their relative BPA in receipt paper. All three molecules, which have similar chemical structures, can get into the human body.

ATOM & COSMOS

Pulsar-orbiting exoplanets rare

First extrasolar worlds ever found have few counterparts

BY CHRISTOPHER CROCKETT

Planets and pulsars, the whirling cores of dead massive stars, appear to be an unlikely match. Most of these pulsating stellar corpses can't nurture fledgling planetary systems, new research suggests.

Scrutiny of 151 pulsars turned up no evidence of planets, researchers report in the Aug. 10 *Astrophysical Journal*. Planet nurseries must therefore rarely appear in the wakes of supernova explosions out of which pulsars are born, Matthew Kerr and colleagues propose.

"I was fairly pessimistic about finding any," says Kerr, an astrophysicist at the Australia Telescope National Facility in Epping. "But you never know until you go and look."

Reported in 1992, the first planets to be confirmed beyond the solar system were found around a pulsar designated PSR B1257+12. Despite the discovery of over 1,500 worlds since then, astronomers have found only one other pulsar, PSR B1620-26, that harbors a planet.

Any planets around a pulsar either improbably survived the detonation of their sun or formed out of debris raining down in the wake of the explosion. If the backwash of gas and dust forms a disk encircling the pulsar, then planets might form the same way they do around young stars. The lack of pulsar planets suggests that such disks are rare.

One caveat is that all 151 pulsars are young and energetic, notes astrophysicist Alex Wolszczan of Penn State, who codiscovered the first pulsar planets. Young pulsars blast the surrounding space with radiation. "You run the risk that you evaporate a disk even before planet formation starts happening," he says. Expanding the study to include older pulsars — an effort that Kerr has already started — would be more definitive.

The two known pulsar planet systems appear to be oddballs. The pulsar that hosts the first confirmed exoplanets has a relatively weak magnetic field, which might have helped a planet-building ring to form. The second pulsar shares its planet with a companion star; the planet was probably snatched from the pulsar's neighbor.

"People were so enthusiastic about those two serendipitous discoveries, they believed we would have found more surprises by now," says Stephen Thorsett, president of Willamette University in Salem, Ore., and codiscoverer of the second pulsar planet system. "The fact that they aren't found is a pretty strong statement that they aren't there." ■

E. OTWELL

Genes that spark embryo growth ID'd

Humans differ from mice in earliest days after fertilization

BY TINA HESMAN SAEY

In the first days after an egg is fertilized, throwing a few key genetic switches revs up human embryo development, two new studies suggest.

That ignition pattern differs from the one that fires up early mouse embryos, the research finds.

One study, published September 11 in *Nature Communications*, found that a much smaller number of genes than previously believed serve as the ignition switch for human embryo development.

A second study tracked human and mouse embryo development from fertilized egg to about six days later, just before the human embryo implants in the uterine wall. Timing and some genetic programming during development vary between the two species, researchers report online August 20 in *Development*.

Delving into the earliest embryonic events may give researchers new insights into infertility and human development, says Janet Rossant, a developmental biologist at the Hospital for Sick Children and the University of Toronto. "We have a lot of information about mouse development at these very early stages," says Rossant, "but when we start looking at humans, they are very different."

Both human and mouse embryos develop from a fertilized egg, or zygote, that splits into two cells, then four, eight, 16 and so on. But below the surface, "there are big differences," says Juha Kere, a molecular biologist at the Karolinska Institute in Huddinge, Sweden. Kere and colleagues examined RNA in single cells from more than 300 human embryos. Couples undergoing in vitro fertilization had donated the embryos for research.

When a gene becomes active, its DNA instructions are copied into RNA. Kere's group used a technique called RNA sequencing to identify which genes turned on and off at the four- and eight-cell stages. Many of the genes active early in human embryo development don't exist in rodents.

At the four-cell stage of human development, 32 genes become active; 129 power up at the eight-cell stage. That's far fewer than the more than 2,000 genes previously reported to be active in early embryos. The study used a new technique to measure amounts of RNA more precisely than other methods, Kere says.

Rossant says she would be surprised if so few genes spark development, but she doesn't doubt that the genes the group identified are involved.

Many of the genes encode proteins known as PRD-like homeodomain transcription factors. Homeodomain transcription factors latch on to specific stretches of DNA and turn on genes. Scientists have shown that such proteins establish body plans. But the proteins of the PRD-like variety aren't well-known, and researchers probably wouldn't have guessed they would be the key to starting embryos' motors, Kere says.

Computer programs had predicted that many of the 32 genes encoded proteins, but no one had found RNA or protein produced from them in any other human tissues. Kere speculates that the genes are turned on only at these very early stages. They work like a car's ignition system, he says. "They're only used at the very beginning to start the embryo. Once you get the process started, you don't need these genes anymore."

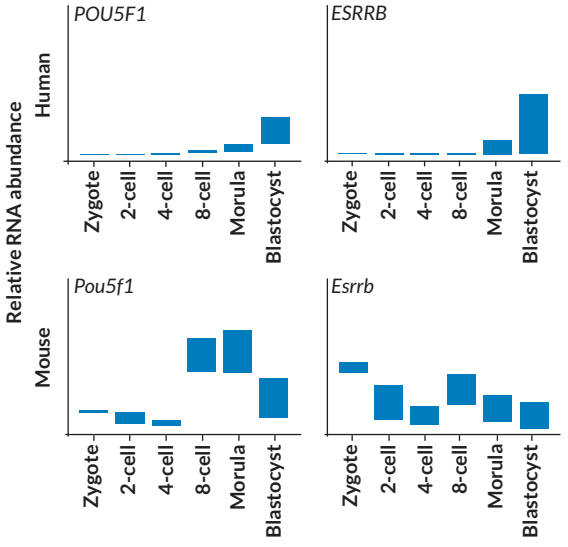
Developmental biologist Kathy Niakan of the Francis Crick Institute in London and colleagues report in *Development* even more genes that work differently in mouse and human embryos. Her team also sequenced RNA from single embryonic cells to see when genes are active.

For instance, a gene called *POU5F1* becomes active in human embryos starting at about the eight-cell stage. In mouse embryos, the gene is active in zygotes; its RNA then dips in abundance but rises again at the eight-cell stage.

Niakan's group also examined embryos at the blastocyst stage, some six to seven days after fertilization. A blastocyst is a hollow ball of cells surrounding a cluster of flexible cells called embryonic stem cells. The outer cells later help form the placenta, while the embryonic stem cells give rise to all other cell types in the body. The researchers discovered that a cell-to-cell communication protein called TGF-beta keeps human embryonic stem cells flexible, or pluripotent, and able to produce any cell type. That protein doesn't appear to be as important for mouse embryos, the team found.

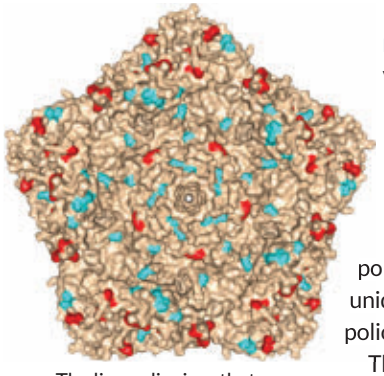
Such work may help researchers make more reliable and flexible reprogrammed stem cells for replacing diseased or damaged organs, Rossant says. ■

Early gene activity differences between human and mouse embryos



Getting started In the first few days after fertilization, both human and mouse embryos initiate genetic programs that will help build complete organisms. Timing of gene activity can differ between the species, as seen in two genes (ranges of relative RNA abundance, shown). Generally, human embryos ramp up gene activity at the eight-cell stage. Mice turn on some genes much earlier.

P. BLAKELEY *ET AL*/*DEVELOPMENT* 2015



The live poliovirus that a man has been excreting differs from the strain he received in a vaccine. Surface differences are shown in red and blue.

BODY & BRAIN

Vaccinated man excretes live poliovirus for nearly 3 decades

A British man has been excreting live poliovirus for an estimated 28 years.

An immune deficiency allowed weakened virus from oral polio vaccines to replicate within the man. This case is not unique, but it's the longest-lasting example of vaccine-derived poliovirus, researchers report August 27 in *PLOS Pathogens*.

The virus has changed within the man's body, evolving into slightly different versions from the original vaccine strain, the researchers show. Several virus strains contain changes to surface regions that human immune proteins attack. But existing vaccines still protect against the most altered virus isolated, though it's important to monitor such changes, says coauthor Javier Martin, a virologist at the National Institute for Biological Standards and Control in Potters Bar, England.

In countries where most people are vaccinated against polio, a person excreting live viruses poses little danger, Martin says. In developing countries with lower vaccine coverage, immune-deficient people who excrete the virus are unlikely to survive long enough to spread polio, says Cara Burns, a virologist at the U.S. Centers for Disease Control and Prevention in Atlanta who wasn't involved in the study.

The man in the study takes immune proteins that help combat the virus he's carrying, Martin says. But people like him are still at risk of developing paralyzing polio. Researchers are working to find drugs to eliminate the polio from these people's systems, Burns says. *— Sarah Schwartz*

LIFE & EVOLUTION

Tropical songbirds get their growth spurt late

Scientists have long puzzled over why tropical songbirds lay fewer eggs than their temperate-zone counterparts. A new study suggests that it may have to do with how baby birds grow.

Thomas Martin of the University of Montana in Missoula compared nestling development in 72 songbird species from Arizona, Venezuela and Malaysia. While the Arizona birds grew quickly in the early days after hatching, the tropical birds were late bloomers, showing speedy growth only later on. But this late bout of rapid development gave tropical fledglings an advantage: Their wings grew faster than those of birds in milder climates, leaving them better equipped to escape hungry predators.

Fueling that extra wing growth means more work for bird parents. With fewer eggs to care for, adults can provide more food per hatchling, Martin reports in the Aug. 28 *Science*. *— Allison Bohac*

LIFE & EVOLUTION

Chimps keep numbers high as forest losses mount

Chimpanzees have weathered human-caused forest loss surprisingly well, a new study finds. More than three times as many chimps inhabit patches of jungle in western Uganda than previously suspected. Genetic analyses of 865 chimp poop samples gathered over 15 months enabled the identification of 182 apes. From that, researchers estimated that between 246 and 357 chimps from at least nine communities inhabit the study area, the investigators report August 25 in *BMC Ecology*. A previous estimate that only about 70 chimps lived in this unprotected region, which retains spots of intact forest, was based on the number of chimp nests spotted by researchers.

Partially leveled forests can serve as geographic corridors connecting wildlife preserves, promoting mating across surviving populations of chimps and other endangered animals, the researchers propose. *— Bruce Bower*

GENES & CELLS

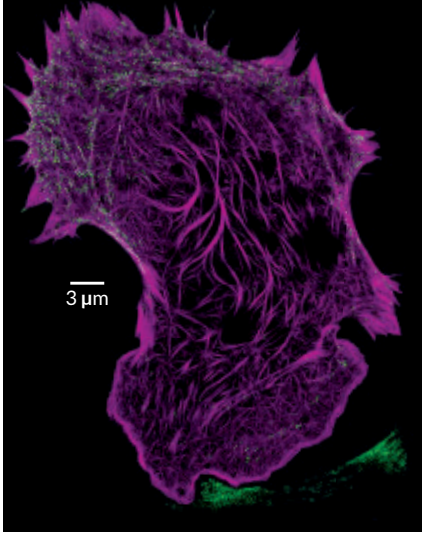
New methods give deepest view yet of living cells

Two new microscopy techniques are helping scientists see smaller structures in living cells than ever glimpsed before.

Scientists can now view structures just 45 to 84 nanometers wide, Nobel Prize–winning physicist Eric Betzig of the Howard Hughes Medical Institute's Janelia Research Campus in Ashburn, Va., and colleagues report in the Aug. 28 *Science*. The techniques beat the previous resolution of 100 nanometers and shatters the 250 nanometer "diffraction barrier" imposed by the bending of light (*SN: 6/15/13, p. 20*).

Using other tricks to improve the super-resolution methods also allowed the researchers to take ultraquick pictures with less cell-damaging light than before. As a result, scientists can watch subsecond interactions within cells, revealing new insights into how cells work. *— Tina Hesman Saey*

A new microscopy technique gives scientists a better look at how an embryonic mouse cell's internal scaffolding, or cytoskeleton, changes over time.



FROM TOP: G. DUNN *ET AL/PLOS PATHOGENS* 2015 (CC BY 4.0); D. LI *ET AL/SCIENCE* 2015

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THE BENEFICIAL BEAN

Coffee reveals itself as an unlikely health elixir

By Nathan Seppa

CAFFEINE

- Reduces liver fibrosis
- Slows heart and liver damage
- May counter Parkinson's, dementia, depression
- Boosts feel-good dopamine

POLYPHENOLS
(chlorogenic acids, caffeic acid)

- Reduce liver fibrosis
- Boost DNA repair
- May fend off blood clots
- Boost metabolic efficiency
- Lower blood pressure (offsetting caffeine's fleeting blood pressure–boosting effect)
- Act as demethylating agents
- Lessen intestinal injury from free radicals

DITERPENES
(cafestol and kahweol)

- Fight certain carcinogens
- Reduce liver DNA adducts (bits of DNA bound to carcinogens)
- Boost levels of glutathione, an antioxidant that prevents liver damage
- Target and kill mesothelioma cells in lung tissues
- Kahweol is anti-inflammatory and cuts blood flow to tumors
- But both can also lead to higher levels of bad cholesterol (LDL)

TRIGONELLINE

- Antioxidant
- Lowers blood sugar
- May have brain benefits

For a historically mistrusted drink, coffee is proving to be a healthy addiction. Scientific findings in support of coffee's nutritional attributes have been arriving at a steady drip since the 1980s, when Norwegian researchers reported that coffee seemed to fend off liver disease. Since then, the dark brown beverage has shown value against liver cancer, too, as well as type 2 diabetes, heart disease and stroke. Coffee even appears to protect against depression, Parkinson's and Alzheimer's diseases.

Taken as a whole, these results might explain the most astonishing finding of all. People who drink two or more cups of coffee a day live longer than those who don't, after accounting for behavioral differences, U.S. researchers reported in 2012. Studies in Japan, Scotland and Finland agree.

Talk about a twofer. Coffee not only picks you up, it might put off the day they lower you down.

Yet coffee has had trouble shaking its bad-for-you reputation. It may be one of the most widely consumed drinks in the world, but people have long assumed that, at least in its energizing caffeinated version, coffee comes with a catch.

"People notice the caffeine," says cardiologist Arthur Klatsky, who has researched coffee for decades at the Kaiser Permanente Northern California Division of Research in Oakland. "And there is this general feeling that anything that has some effect on the nervous system has to have something bad about it." It doesn't help that caffeine is mildly addictive.

Coffee doubters nodded when studies in the 1970s suggested that coffee bore heart risks. There had also been rumors it could stunt growth or cause cancer. True, coffee has downsides for some people, but those concerns aren't among them.

Pregnant women should go easy on the high-test, since excess caffeine has been linked to miscarriage risk. And caffeinated coffee can disturb sleep or make a person jittery. Caffeine can increase heart rate, but its links to chronic high blood pressure are now in doubt.

"Coffee consumption has not been consistently linked with hypertension," says Rob van Dam, a Dutch nutritional epidemiologist at the National University of Singapore. In fact, most worries once attached to coffee and caffeine, including stomach ulcers, acid reflux and the heart flutter known as atrial fibrillation, fail to show up in large population studies.

Most studies show benefit — or at least no harm — from coffee. As a result, the aggregate view on the popular beverage is changing. But acceptance is slow in coming because scientists have yet to fully ascertain just how coffee works. Among its ingredients, caffeine and polyphenols are clearly positive players, but

GUZEL STUDIO/SHUTTERSTOCK

beyond that, coffee gets muddy.

"It's extremely difficult to impossible to tease out the effects of the individual components of coffee because there are so many of them," says Frank Hu, a Harvard nutritional epidemiologist. "And they travel together."

To the liver rescue

Coffee's most obvious benefits go to the liver, a big, busy organ. Nutrients get absorbed from food through the gastrointestinal tract and enter the blood. Those nutrients are metabolized in the liver — detox central — which regulates blood levels of fats and sugars.

Chronic liver disease affects up to 15 percent of the U.S. population. The liver is most often damaged by drinking excess alcohol, contracting hepatitis C virus or developing fatty liver disease, which is associated with obesity. Just as the skin forms patches of tough collagen protein over damaged areas, the liver does, too. Over time, this process can result in fibrous collagen scars, or fibrosis, which can disrupt blood flow through the liver. The risk is cirrhosis and, ultimately, liver failure, says Jonathan Dranoff, a gastroenterologist and hepatologist at the University of Arkansas for Medical Sciences in Little Rock.

That's where coffee comes in. When the liver senses tissue damage, the compound adenosine binds to receptor proteins on the liver's stellate cells. These make collagen to form fibrous scars. Caffeine binds to the adenosine receptors and interrupts the signaling process so that collagen isn't mass-produced.

Caffeine tamps down collagen overproduction in a second way. It hits the enzyme alanine aminotransferase, which is implicated in fibrosis. People with liver disease who drink caffeinated coffee make less of the enzyme than minimal drinkers.

In a large U.S. study last year, people drinking two or more cups of decaf daily also suppressed the troublesome enzyme. Other studies suggest that certain polyphenols in coffee — found in decaf or regular — knock down that enzyme.

Coffee drinkers who have hepatitis C, a viral infection that can lead to liver fibrosis and cancer, show similar benefits. Of 177 liver disease patients, most with hepatitis C, those who drank more than two cups of caffeinated coffee per day were less likely than scant drinkers to have their fibrosis become severe, according to a study in *Hepatology* in 2010. Curiously, other sources of caffeine, such as energy drinks, didn't provide a benefit.

Fatty liver disease, which is rising in tandem with obesity rates, may be susceptible to coffee as well. U.S. scientists identified 306 overweight people who hadn't been diagnosed with liver disease. Ultrasound images and biopsies revealed 180 who had fat deposits in the liver, early signs of fibrosis. Based on those tests, coffee abstainers were moving faster toward fibrosis than consumers. People who had advanced-stage fatty liver averaged less than a cup a day of caffeinated coffee, compared with nearly two cups for those who were still at an early stage of the disease, a 2012 report in *Hepatology* noted.

Coffee shows a stunning effect against liver cancer. Earlier this year, a European team reported that women who drank

In pursuit of the perfect cup

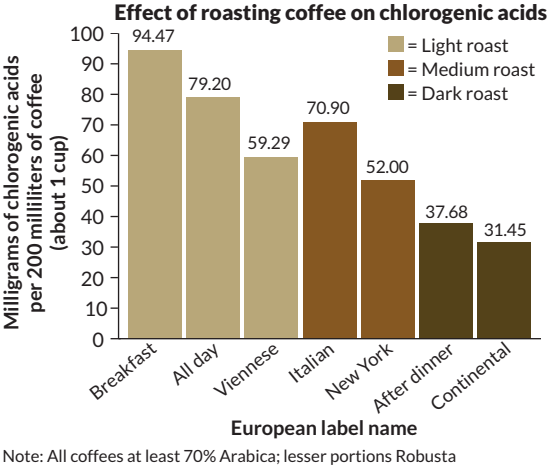
The global favorites among coffee beans are Arabica (*Coffea arabica*) and Robusta (*Coffea canephora*). Robusta has a more aggressive flavor, more caffeine and more of the beneficial polyphenols known as chlorogenic acids. The milder Arabica is more popular, but contains a bit more sugar and oil. Both Dunkin' Donuts and Starbucks say they use it exclusively.

To brew a healthful cuppa joe, preparation method may be as important as bean choice. Roasting cooks some of the good-for-you chlorogenic acids right out of the beans, according to a 2013 report in *Food Chemistry* (see chart). Chock one up for blonde, or light, roasts.

Today's popular drip filters remove cholesterol-raising oils from coffee. Boiled coffee and French press still let the oils through; espresso filters out only some. Espresso drinkers had poorer scores on HDL, the good cholesterol, and higher blood levels of triglycerides than filtered coffee drinkers in a study published in 2012. But filtering has its drawbacks, including loss of the cancer-fighting diterpenes.

As findings pour in, researchers try to define the perfect cup. "We've reached a funny intersection," says Jonathan Dranoff, "between artisanship and health." — *Nathan Seppa*

Effect of roasting coffee on chlorogenic acids



Note: All coffees at least 70% Arabica; lesser portions Robusta

SOURCE: C.E. MILLS *ET AL/FOOD CHEM.* 2013

Caffeine content

Product	Serving size	Caffeine per serving
Regular coffee (drip or percolated)	8 fl oz	65–330 mg
Black tea	8 fl oz	40–74 mg
Green tea	8 fl oz	25–50 mg
Espresso	1 shot	50–150 mg
Carbonated soda	12 fl oz	22–72 mg
Decaf coffee	8 fl oz	2–12 mg
Energy drinks	Various	33–400 mg

SOURCES: E. MEJIA AND M. RAMIREZ-MARES/*TRENDS ENDOCRINOL. METAB.* 2014; J. FELD *ET AL/F1000RESEARCH* 2015; BEVERAGE INSTITUTE; MAYO CLINIC

two and a half or more cups and men who drank three and a half or more daily were 72 percent less likely to develop liver cancer than people who drank less than about one-third cup a day. The study included roughly half a million healthy people monitored for 11 years. During the study, 201 people developed liver cancer. The findings remained robust even when adjusted to account for hepatitis, the scientists reported in the April 15 *International Journal of Cancer*.

The liver cancer finding "is likely to be an extension of a possible protective effect of coffee on chronic liver disease," says study coauthor Anna Flögel of the German Institute of Human Nutrition Potsdam-Rehbrücke in Nuthetal.

Some doctors are convinced. "Do I prescribe coffee to my patients?" Dranoff asks. "For those with chronic liver disease, the answer is yes." In a 2014 review in *Liver International*, UCLA physician Sammy Saab and his colleagues stated that "daily coffee consumption should be encouraged" for patients with liver disease.

The diabetes defense

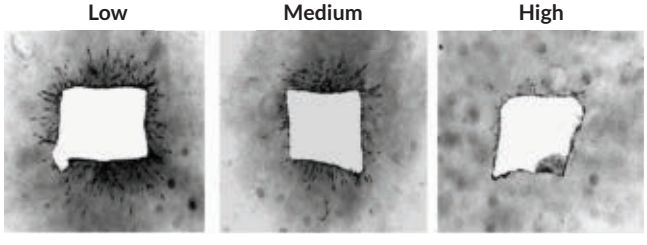
Coffee's protective effect against type 2 diabetes came to light in 2002. In a study of healthy people, van Dam and his Dutch colleague Edith Feskens found that those who averaged a whopping seven cups a day were half as likely to develop diabetes over several years as those who got by on two or fewer cups a day. In this study of people ages 30 to 60, protection seemed to start at three cups a day and rise with intake.

That report, published in the *Lancet,* triggered dozens of studies seeking to replicate it, and many have. An international review of 28 studies, published in *Diabetes Care* in 2014, included more than 1 million healthy people monitored for 10 months to 20 years. About 45,000 developed type 2 diabetes while in a study. The likelihood of a diabetes diagnosis was 21 percent lower in people drinking three cups a day versus none. For those drinking six cups daily, risk was 33 percent lower. Regular or decaf didn't matter.

Onset of type 2 diabetes is preceded by poor energy metabolism. Cells fail to take up glucose efficiently, leading to high blood sugar. Caffeine and the polyphenols called chlorogenic acids boost metabolic efficiency. When Australian scientists fed rats a high-fat, high-carbohydrate diet, the animals started to display inefficient energy metabolism, some fatty liver and even early signs of heart disease. Coffee extract including caffeine, chlorogenic acids and other components improved the animals' ability to process glucose, lowered their blood pressure and slowed damage to the heart and liver. The report appeared in the *Journal of Nutrition* in 2012.

Of course, adding sugar detracts from coffee's commendable effects. Milk has calcium and protein but dilutes the coffee.

Kahweol, a diterpene in coffee, inhibits angiogenesis, or blood vessel growth. Exposed for 10 days to low, medium or high concentrations of kahweol, mouse blood vessel tissue (white) showed weak vessel growth (black lines) with more kahweol, which may be a way to block cancer.



Magnification: 20x

C. CÁRDENAS *ET AL/PLOS ONE* 2011

Under the microscope

Coffee's cancer protection appears to extend beyond the liver, but to a more modest degree. For example, European women who drink three cups a day have a 19 percent lower risk of uterine cancer compared with scant drinkers, scientists reported in the February *Cancer Epidemiology, Biomarkers & Prevention*. Earlier, Japanese researchers found that coffee drinkers were slightly less apt to develop cancer of the mouth and throat than those who drank very little. Coffee also has exhibited potential against colon cancer, melanoma and breast cancer.

Population studies mean little without a biological explanation. For cancer, coffee has several candidates. Polyphenols in caf and decaf boost DNA-repair genes, an essential step in keeping cells from becoming cancerous. The main polyphenols, chlorogenic acids and caffeic acid (not related to caffeine), are demethylating agents, meaning they thwart the addition of methyl groups to DNA. Methylation can be a cancer trigger.

Coffee components called diterpenes may pitch in against cancer as well. In cell cultures and animal studies, two diterpenes called cafestol and kahweol inhibit certain carcinogens and reduce concentrations of liver DNA adducts (pieces of DNA bound to cancer-causing chemicals). Kahweol has anti-inflammatory effects and suppresses angiogenesis, the flurry of blood vessel growth that tumors need. As a bonus, both diterpenes boost levels of glutathione, a potent antioxidant that may prevent liver damage. In lab tests of human mesothelioma (a cancer of the lung's lining that is often caused by asbestos exposure), diterpenes targeted and killed the cancer cells.

Meanwhile, chlorogenic acids and caffeic acid also act as antioxidants, adeptly scavenging harmful free radicals, Brazilian researchers reported in the *Journal of Agricultural and Food Chemistry* in May. In rat models of intestinal injury, chlorogenic acids and caffeic acid reduced damage from free radicals. In the intestines, coffee might also aid the growth of helpful *Bifidobacteria*, a British team has found. These natural gut dwellers have been used as probiotics to treat diarrhea and ulcerative colitis.

Trigonelline, yet another coffee component, seems to aid in the antidiabetes effect while also working as an antioxidant and benefiting the brain. More recently, scientists have become interested in a coffee chemical called hydroxyhydroquinone, or HHQ, which increases with the roasting process. The good news is that HHQ might have anticancer properties. The bad news is that it might suppress some effects of chlorogenic acids, specifically their ability to bring down blood pressure.

Coffee — it does a body good

The brew shows promise against an array of ailments:

Parkinson's. In a prospective study, people who drank about four cups of caffeinated coffee daily were one-fourth less likely to develop Parkinson's disease than those who drank very little, researchers reported in the *American Journal of Epidemiology* in 2012. Parkinson's involves a loss of dopamine, a hormone that is necessary for motor skills. In the brain, caffeine elevates dopamine levels, possibly explaining how coffee helps against Parkinson's and suggesting why coffee has addictive effects.

Dementia. In a 2012 study, researchers monitored 32 older people with mild cognitive impairment. Caffeine levels (largely from coffee) in blood samples were lower by half at the outset in individuals who later progressed to dementia than in those who didn't, scientists reported in the *Journal of Alzheimer's Disease*. While coffee contains more caffeine than most other popular drinks, polyphenols in coffee may help memory, too.

Depression. In a 10-year study of 50,000 U.S. women, those drinking two to three cups of caffeinated coffee a day were 15 percent less likely to have depression than those consuming little. Women who drank four or more cups a day had a 20 percent lower risk, researchers reported in *Archives of Internal Medicine* in 2011. Suicide risk also falls with caffeinated coffee consumption.

Blood pressure. The caffeine in coffee boosts heart rate and short-term blood pressure, but these effects don't appear to linger. In a 2011 analysis of six studies involving more than 170,000 adults, researchers found hints that two or three cups a day increased hypertension risk slightly, but the risk disappeared in people who drank even more coffee. The researchers speculate that other coffee components — chlorogenic acids, magnesium and potassium, which lowers blood pressure — might offset a caffeine effect. Or people may build up tolerance to caffeine.

Heart disease and stroke. Demographic studies suggest coffee offers modest protection against heart disease. Polyphenols in coffee might also fend off blood clots. Mice given oral chlorogenic acids or caffeic acid had less of a protein linked to platelets and clotting. In people, coffee drinkers were 29 percent less likely to have a stroke as coffee avoiders, a 2010 study found.

Kidney function. Nineteen healthy 20-somethings were assigned to drink three cups of coffee daily for two weeks, then switch to green tea, or vice versa. Blood measures of kidney filtration efficiency, in which lower denotes better, fell by 4.8 percent after the coffee stint but were unchanged after green tea, Japanese researchers reported in 2011 in the *Journal of Nutrition and Metabolism*.

— *Nathan Seppa*

Caffeic acid may enhance nitric oxide in the body, which makes blood vessels flexible and more easily dilated.

A reassuring cup or four

All these biological effects, however they work, might together hold off the reaper. The 2012 mortality study, which included more than 400,000 middle age and older people, found that coffee consumption was associated with a 6 to 16 percent reduction in death risk during the study, which ran from 1995 to 2008. It appeared in the *New England Journal of Medicine*.

Drinking three to four cups a day seemed optimal in a recent study of more than 90,000 people in Japan. Drinkers in that sweet spot were 24 percent less likely to die during the average follow-up of nearly 19 years than people who didn't drink coffee, researchers reported in the *American Journal of Clinical Nutrition* in May.

"These studies provide some reassurance to regular coffee drinkers that this seems like a relatively safe behavior," says Neal Freedman, a biochemist and epidemiologist at the National Cancer Institute who coauthored the 2012 study.

In earlier work, van Dam sought to establish safe upper limits for coffee intake. He and others found no added mortality risk among people who drink six cups a day.

Despite the flood of positive findings, some researchers can't help but remain cautious. Klatsky offers an example, regarding the studies showing no link between atrial fibrillation and coffee, caffeinated or not. "People who get symptoms from coffee tend to stop drinking it," he says. So the only coffee drinkers in some studies would be those who don't feel any bad effects, a self-selected group. Other studies often failed to note the kind of coffee people drank, the degree of roasting or other details that can matter.

Nevertheless, coffee's new status, as a pleasure without the guilt, might be reaching the mainstream. Every five years, a U.S. panel of experts reviews dietary guidelines and advises the federal government. Its February 2015 report found that drinking three to five cups of coffee a day carries no chronic disease risk. The report even notes apparent benefits against diabetes, heart disease and Parkinson's disease.

"This is a kind of paradigm shift," says Hu, a panel member. The scientists were cautious, he says, and concern remains that too much caffeine may not be good for kids. But in adults, the coffee picture is becoming clear.

"It's not a panacea," Hu says. "It's just a drinking habit that may confer health benefits." ■

Explore more

- N.D. Freedman *et al.* "Association of coffee drinking with total and cause-specific mortality." *New England Journal of Medicine*. May 17, 2012.

Bright Young Minds

Meet 10 scientists who are making their mark

Just as in baseball, politics and Hollywood, science has its up-and-coming stars. They just don't always get as much publicity as, say, Bryce Harper or Lupita Nyong'o. Most scientists are lucky to get a media mention as a name attached to a discovery. But their personal stories and change-the-world goals are worth some attention.

To identify some of the early-career scientists on their way to more widespread acclaim, *Science News* surveyed 30 Nobel Prize winners to learn whose work has caught their attention. From those names, *Science News* editors chose 10 to feature in this special report. All have demonstrated high-caliber research leading to noteworthy achievements.

The good news is our list could have been longer. The researchers on these pages are representatives of a much greater number of young people likely to turn up prominently in a future issue of *Science News* as they pursue a diverse array of ambitious research questions. *— SN Editors*

Feng Zhang, 33
MIT | SYNTHETIC BIOLOGY
GRADUATE SCHOOL: STANFORD

Editing DNA

Like every other 12-year-old who saw the movie *Jurassic Park*, Feng Zhang was awestruck by the dinosaurs. He was even more amazed by the power of molecular biology.

Now, two decades later, Zhang has developed tools to harness some of that power by controlling cells for specific purposes. As a graduate student at Stanford, he found ways to insert the gene of a light-sensitive protein found in algae into nerve cells.

The method, now part of the field known as optogenetics, made it possible to control brain cells in mice with laser light. More recently, Zhang has developed a system to easily and precisely "edit" genomes.

Zhang holds appointments at the Broad Institute of MIT and Harvard and is an investigator at MIT's McGovern Institute for Brain Research. Born in China, he moved to Des Moines, Iowa, at age 11. A year later he saw *Jurassic Park* during a Saturday class on molecular biology. Zhang's teacher noticed his excitement and later helped him get a volunteer position in a local lab that was researching gene therapy. Throughout high school, Zhang went to the institute every day after school and worked with molecular biologists, an experience that shaped his interest in biology.

After high school, Zhang studied chemistry and physics at Harvard, "fields that serve as a foundation for medicine," he says. He also worked in two biology labs, focusing on the structure and manipulation of viruses.

"People were using viruses as delivery vehicles to put genes into patients, so I was very interested in learning about viruses," he says.

Zhang also became interested in neuroscience. He completed his graduate work with Stanford's Karl Deisseroth who, along with Ed Boyden, was developing a method for studying the brain by controlling its activity with light.

After graduate school, Zhang set out to find more efficient ways to introduce light-sensitive proteins into specific cells. In 2013, he developed a gene-editing tool that employs the DNA-cutting microbial enzyme Cas9 to snip or swap sections of DNA exactly where needed. The tool is simpler to use than other gene-editing techniques, and Zhang's group has made it widely available.

By altering cells in mice to mimic the mutations found in human patients, Zhang's group is exploring autism spectrum disorder and related conditions. His aim? Better treatments, powered by molecular biology. *— Susan Gaidos*

LEN RUBENSTEIN, COURTESY OF BROAD INSTITUTE

The red cells in this mouse hippocampus were genetically manipulated to turn on with brief pulses of light. They store a false fear memory.

Erasing fear memories

Steve Ramirez, 27
HARVARD | **NEUROSCIENCE**
GRADUATE SCHOOL: MIT

If not for a broken piece of lab equipment and a college crush, Steve Ramirez might never have gone into neuroscience. As an undergraduate at Boston University his interests were all over the place: He was taking a humanities course and classes in philosophy and biochemistry while working several hours a week in a biology lab. When the lab's centrifuge, a device that spins liquids, broke, Ramirez had to use one in another lab.

"I was trying to make small talk with this girl who was using the centrifuge, 'What's your major?' kind of thing," Ramirez recalls. Hearing of his myriad interests, the student suggested that Ramirez talk with neuroscientist Paul Lipton. That led to a conversation with Howard Eichenbaum, a leading memory researcher.

Eichenbaum told him that everything Ramirez was interested in was about the brain. "Everything from the pyramids to putting a man on the moon, it's all the product of the human brain, which is kind of crazy when you think about it," Ramirez says.

Studying "the most interdisciplinary organ in existence," as Ramirez calls it, was a natural fit. While working in Eichenbaum's lab, Ramirez got turned on to how the brain forms memories. Those explorations led to a Ph.D. program at MIT in the lab of Nobel laureate Susumu Tonegawa, where Ramirez focused on the individual brain cells that hold specific memories.

"People are too guarded with their work."

In a seminal experiment, Ramirez, Xu Liu and colleagues manipulated the memories of mice. The researchers first engineered the mice so their memory-forming cells would respond to light. Then the mice spent time in a box where they experienced a mild electric shock. When the mice were moved to an ordinary box, the researchers stimulated their memory cells with a laser, activating the memory of the shock; the mice froze in fear in the harmless box.

The work marks an important first step toward being able to manipulate memories in people — for example, erasing the fearful memories that are the fabric of post-traumatic stress disorder and other maladies. For now, Ramirez, who recently defended his Ph.D. thesis and is a fellow at Harvard, is focused on figuring out where in the Boston area he'll be setting up his own lab.

Wherever he lands, teaching will be a central part of his work. "The word 'professor' comes from 'declare publicly,'" he says. "We should see it as a privilege to be in the ranks of those who get to declare their work publicly."

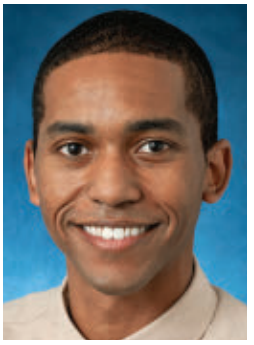
Ramirez is passionate about openness and collaboration in research, too. "People are too guarded with their work," he says. "Science is about standing on each other's shoulders." — *Rachel Ehrenberg*

FROM TOP: S. RAMIREZ *ET AL*/*SCIENCE* 2013, REPRINTED WITH PERMISSION FROM AAAS; JOSHUA SARANANA

Finding cancer via altered genes

Isaac Kinde, 31
PAPGENE INC. | BIOTECHNOLOGY
GRADUATE SCHOOL: JOHNS HOPKINS

Isaac Kinde became interested in medicine in elementary school. On Sundays, his father, a large-animal veterinarian, brought Isaac to work. "Seeing what disease could do to animals got me interested, piqued my curiosity," Kinde says.



Kinde is chief scientific officer at PapGene, a small biotechnology startup in Baltimore founded in 2014. The company is producing advanced technologies to detect cancer before a tumor can cause symptoms or be picked up by an imaging scan. Kinde's work is inspired by a simple idea: Cancers are much easier to treat when detected early. And that can translate into fewer deaths.

PapGene's technologies identify mutated genes associated with cancer in a Pap test, the traditional screen for cervical cancer that inspired the company's name. PapGene's method can use DNA isolated from fluids used in the Pap test to screen for ovarian and uterine cancers. Similar tests could screen blood or other fluids for genes involved in other cancers as well.

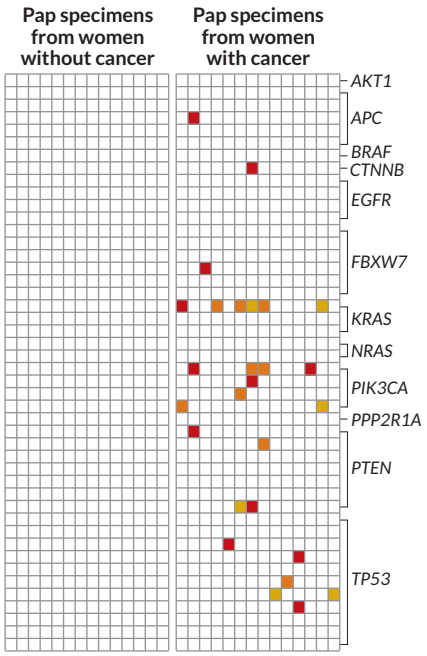
PapGene's sensitive technologies are based on tests Kinde helped develop as a graduate student at Johns Hopkins University, where he studied with cancer researcher Bert Vogelstein. Spotting cancer early requires finding a few rare, cancer-associated genetic alterations among large amounts of normal DNA. That's made more difficult by the DNA reader's error rate. Kinde and colleagues created a way to chemically label and mass-copy sections of DNA to identify the real mutations.

"He's not only devised a technology that is groundbreaking in terms of its ability to detect rare mutations ... he's also been able to implement that technology and show that it can be useful ... in patients," Vogelstein says.

Kinde, who received his M.D. and Ph.D. at Johns Hopkins, says he's most excited about improving cancer treatment through research. He discovered his passion for the lab as an undergraduate in the Meyerhoff Scholars Program at the University of Maryland, Baltimore County. Kinde says that the program, which supports diversity among scientists, had a big impact on him and his younger brother Benyam.

Kinde also credits his supportive family and years of hard work for his scientific success. His tenacity is probably fueled by his active lifestyle — he's an avid biker — and his devotion to coffee, which he says is rooted in his family's Ethiopian culture. "It's almost in our blood. I can't literally say that, because I'm a scientist," Kinde says. "But, almost." *— Sarah Schwartz*

Isaac Kinde's test found several gene mutations in Pap test samples from 14 women with uterine or ovarian cancers but no mutations in those genes in 14 women without cancer.
SOURCE: I. KINDE *ET AL*/*SCIENCE TRANSL. MED.* 2013



Gene expression and Rett syndrome

Benyam Kinde, 27
HARVARD/MIT | NEUROBIOLOGY
GRADUATE SCHOOL: HARVARD

Many people view the brain as the last frontier of human health research, says Benyam Kinde. "We still don't know very much about how individual cells in the brain coordinate the activity of higher-level function that defines us as humans," he says.

This mystery is one that Kinde, an M.D. and Ph.D. student at Harvard Medical School and MIT, aims to solve. He is interested in how chemical modifications of DNA affect brain function, focusing on a protein nicknamed MeCP2. When this protein is damaged or missing, it changes the activity of multiple genes and causes Rett syndrome, a disorder marked by developmental delays, seizures and autism-like behaviors.

When MeCP2 grabs onto DNA, it can limit the activity of genes to which it attaches. Kinde, along with former postdoctoral researcher Harrison Gabel and colleagues, went looking for common features in genes controlled by MeCP2 and those altered by the protein's absence. In June, the researchers reported that MeCP2 prefers to attach to a specific cluster of DNA and chemicals found mainly in the brain. The genes that MeCP2 normally turns down are longer than average, and are most active in brain cells. In Rett syndrome, when MeCP2 is reduced, these long genes are overactive. Kinde and his colleagues found that a chemical that disables

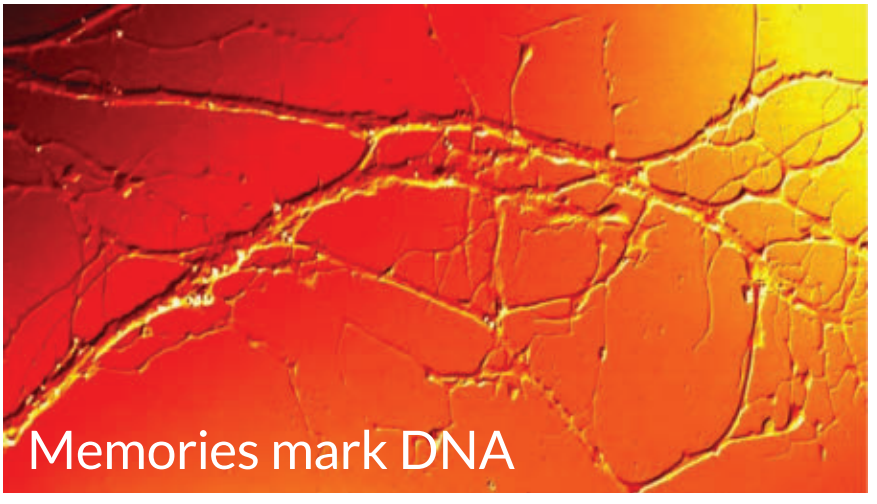
FROM TOP: COURTESY OF I. KINDE; UNCF/MERCK SCIENCE INITIATIVE

DNA-winding proteins can quiet such overactive genes. These insights could help researchers design treatments for Rett syndrome and similar developmental and autism spectrum disorders. The work appeared in *Nature* and the *Proceedings of the National Academy of Sciences*.

Like his brother Isaac, Kinde says he became fascinated with biology while watching his veterinarian father figure out why a horse or an elephant had died. "I was really interested in the investigative nature of his work," Kinde says. As a Meyerhoff Scholar at the University of Maryland, Baltimore County, Kinde got his first experience with neuroscience research and became passionate about solving medical mysteries. He credits excellent mentors, including his research advisers, Gabel and his older brother for his achievements so far.

> "We still don't know very much about how individual cells in the brain coordinate the activity of higher-level function that defines us as humans."

Kinde hopes to tackle neurobiology questions in the clinic and the lab. There's a still lot to learn about how the brain develops, he says. —*Sarah Schwartz*



By observing nerve cells (shown) in sea slugs, Priya Rajasethupathy discovered small RNAs play a role in memory.

Memories mark DNA

Priya Rajasethupathy, 31
STANFORD | NEUROSCIENCE
GRADUATE SCHOOL: COLUMBIA

Priya Rajasethupathy's research has been called groundbreaking, compelling and beautifully executed. It's also memorable.

Rajasethupathy, a neuroscientist at Stanford University, investigates how the brain remembers. Her work probes the molecular machinery that governs memories. Her most startling — and controversial — finding: Enduring memories may leave lasting marks on DNA.

Being a scientist wasn't her first career choice. Although Rajasethupathy inherited a love of computation from her computer scientist dad, she enrolled in Cornell University as a pre-med student. After graduating in three years, she took a year off to volunteer in India, helping people with mental illness.

During that year she also did neuroscience research at the National Centre for Biological Sciences in Bangalore. While there, she began to wonder whether microRNAs, tiny molecules that put protein production on pause, could play a role in regulating memory.

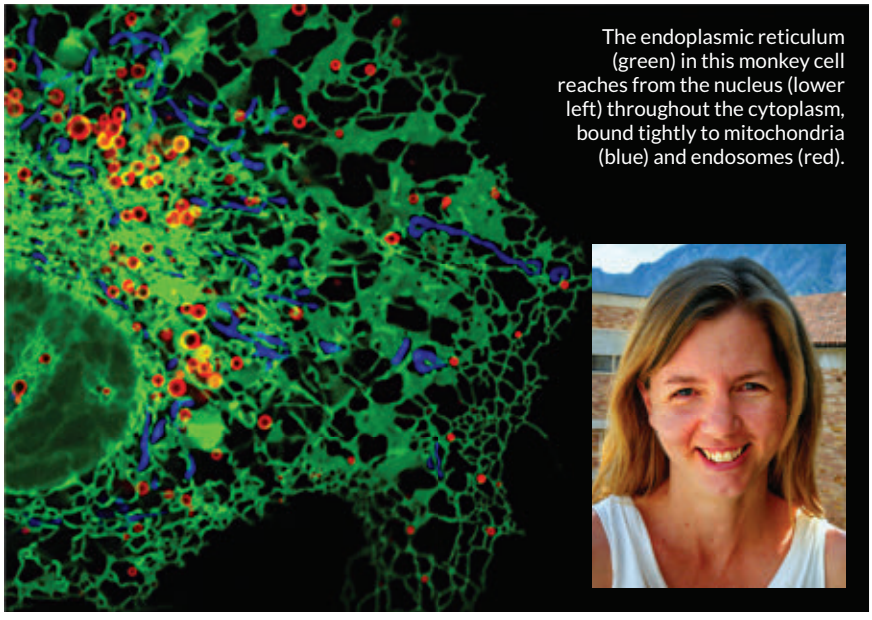
She pursued that question as an M.D. and Ph.D. student at Columbia University (while intending, at least initially, to become a physician). She found some answers in the California sea slug (*Aplysia californica*). In 2009, she and colleagues discovered a microRNA in the slug's nerve cells that helps orchestrate the formation of memories that linger for at least 24 hours.

An even more intriguing finding in the sea slug's nerve cells was piRNA, a molecule a bit bigger than a microRNA. In the presence of serotonin, a chemical messenger involved in learning, the piRNA suppresses production of a protein that hinders memory formation. Rajasethupathy and colleagues propose that the piRNA accomplishes this shutdown by indirectly altering the nerve cell's genetic instructions. By adding chemical tags to DNA, the piRNA may turn off part of the genome — and keep it off for years. This sort of epigenetic change, Rajasethupathy says, "could be a mechanism for the maintenance of really long-term memories."

Since arriving at Stanford in 2013, Rajasethupathy has begun working with mice, exploring neural circuits involved in memory retrieval. She's also looking for links between abnormal memory behavior and particular genetic mutations, with the goal of determining how those genetic changes might disrupt neural circuitry. Such findings could provide insights into neurological disorders, she says.

Although she dropped her medical ambitions, Rajasethupathy says her clinical training is an asset. "Having the medical perspective broadens the scope and questions that you can think about." —*Erin Wayman*

FROM TOP: P. RAJASETHUPATHY; CONNIE LEE



The endoplasmic reticulum (green) in this monkey cell reaches from the nucleus (lower left) throughout the cytoplasm, bound tightly to mitochondria (blue) and endosomes (red).

Redrawing the cell's floor plan

Gia Voeltz, 43
UNIVERSITY OF COLORADO BOULDER | CELL BIOLOGY
GRADUATE SCHOOL: YALE

Gia Voeltz didn't set out to rewrite biology textbooks. She just wanted to make a movie.

A cell biologist at the University of Colorado Boulder, Voeltz was studying a humble part of the cell called the ER, for endoplasmic reticulum. In illustrations, it's the pile of wavy lines floating near the nucleus.

The ER might not be as sexy as the DNA-holding nucleus, or as famous as the mitochondria, the cell's energy powerhouses. But it's no slouch. It has a respectable job storing calcium. It's a nice platform for building fats and proteins. Scientists thought they had it pretty much figured out.

But no one had really seen the ER in action. So Voeltz and colleagues made it glow green and filmed it moving inside living cells. ER tendrils zipped around the cell, the film showed. They reached every corner and crevice, clinging to cellular parts like spider webs wrapped around flies.

"All of a sudden we realized, 'Wow, everything's attached! Who would have thought?'" she says. Squiggly looking webs bloom in vivid green, showing "just how beautiful the ER really is," Voeltz says. "It's so crazy dynamic and cool."

In 2011, Voeltz and colleagues showed that the ER actually clamps around mitochondria and helps them divide.

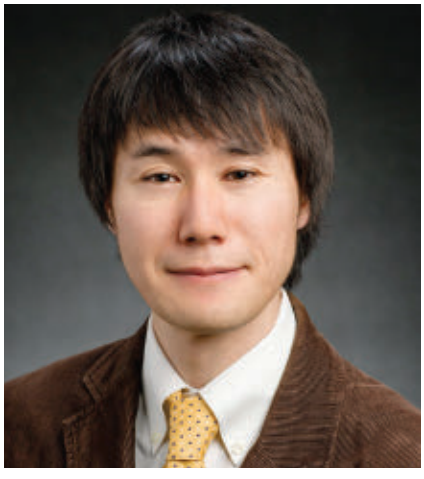
"The ER is doing way more than we ever thought," she says.

Voeltz wasn't afraid to shake things up. After working on RNA as an undergrad at the University of California, Santa Cruz and then at Yale as a grad student, she jumped into the ER field cold. A talk by Harvard cell biologist Tom Rapoport persuaded her to switch fields and work in his lab.

But Voeltz didn't know much about cell biology; she had to learn everything from scratch. She thinks that leap out of her comfort zone helped her give the ER a fresh look. "I didn't have any preconceived notions," Voeltz says.

By giving the ER such a radical makeover, Voeltz has upended the traditional view of a cell's floor plan. Textbooks should no longer picture organelles tucked away in their own private corners of the cell, she says. Rather, books should show the ER branching out well beyond the nucleus and binding cellular parts together.

Publishers are taking note. Since Voeltz reported her work, three have included her ER images in their textbooks. —*Meghan Rosen*



Error-free quantum calculations

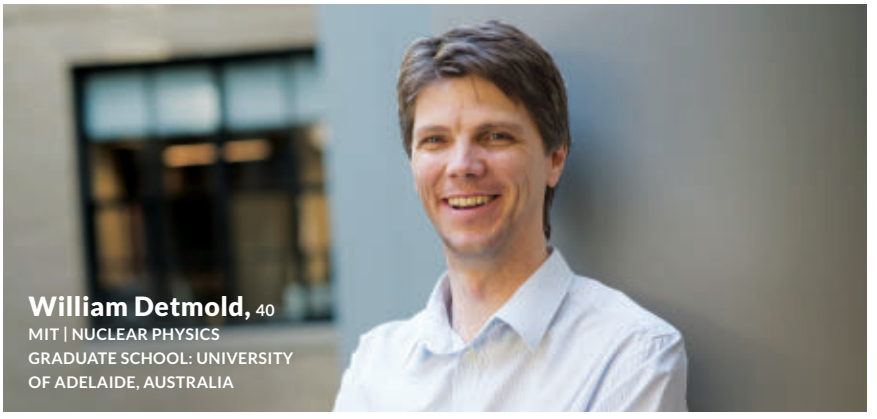
Shinsei Ryu, 37
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN | QUANTUM PHYSICS
GRADUATE SCHOOL: UNIVERSITY OF TOKYO

On the boundary between the quantum and everyday realms, things don't always make a whole lot of sense. The bundles of particles that make up materials behave in ways both unexpected and unexplained. This is the weird world that theoretical physicist Shinsei Ryu hopes to bring into focus.

Ryu ponders materials beyond the scope of classical physics at the University of Illinois at Urbana-Champaign. His research into quantum materials such as high-temperature superconductors could one day help quantum computers make error-free calculations.

Ryu's first steps into physics weren't entirely his own. While enrolled in the University of Tokyo, he chose physics as his major mostly because his college friends had. Since then, he's the only one of his friends who has never considered quitting. The excitement and mysteries

FROM TOP LEFT: PATRICK CHITWOOD/VOELTZ LAB; COURTESY OF G. VOELTZ; UNIV. OF ILLINOIS AT URBANA-CHAMPAIGN



William Detmold, 40
MIT | NUCLEAR PHYSICS
GRADUATE SCHOOL: UNIVERSITY OF ADELAIDE, AUSTRALIA

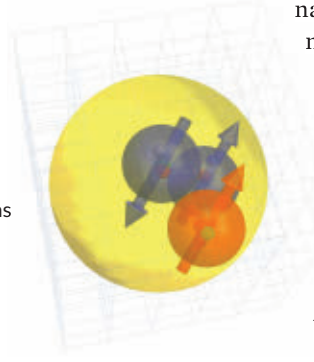
Looking deep into atoms' hearts

William Detmold exposes matter at its most fundamental — with the help of some serious processing power.

The MIT theoretical physicist uses supercomputers to simulate how parcels of matter far too small to be seen through a microscope bind together to form the nuclei of atoms. His research complements findings from particle physics facilities such as the Large Hadron Collider near Geneva. Detmold's simulations could also point physicists toward undiscovered varieties of matter.

Detmold grew up in Adelaide, Australia, hooked on solving mathematical puzzles. Then he turned his attention to theoretical physics. He happened to be pursuing his Ph.D. at a time when physicists were relying on heavy doses of math to work through a key puzzle: understanding the makeup of atoms.

High school textbooks depict the nucleus of an atom as a simple repository for protons and neutrons. But protons and neutrons are composed of even smaller particles called quarks, which are held together by force-carrying particles called gluons. A complex set of equations within the theory of quantum chromodynamics, or QCD, describes how quarks and gluons interact. By the mid-2000s, supercomputers had finally attained enough processing power to simulate the activity of quarks and gluons within a tiny three-dimensional space over time. Physicists ran these "lattice QCD" simulations to study the structure of two-quark particles called mesons and three-quark particles such as protons.



Detmold illustrates neutrons (blue) and a proton (orange) inside an atom's nucleus. The arrows show the alignment of the spins of each particle.

Now Detmold is leading the charge to extend the usefulness of lattice QCD to larger chunks of matter. In a study published last year in *Physical Review Letters*, Detmold and colleagues simulated the quark-gluon interactions for hydrogen and helium nuclei. Similar calculations could reveal properties, such as the nuclei's intrinsic magnetism, that are difficult to measure experimentally. Any discrepancy between the computers' output and experimental measurements could signal the existence of new particles or forces.

Detmold has also explored the fundamental structure of matter not yet seen. In a pair of studies published last year in *Physical Review D*, he and colleagues used lattice QCD to show how particles that don't interact with ordinary matter could form "dark nuclei." These mysterious nuclei could help explain dark matter, which makes up most of the universe's mass. "I'm interested in describing stuff we know is there," Detmold says, "but also using those same tools to look beyond."— *Andrew Grant*

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of the field keep him going, he says.

In 2005, when he moved to the United States from his native Japan for a postdoctoral appointment, Ryu expected to stay "for only a few years." He quickly fell in love with the collaborative atmosphere and decided to continue his quantum career stateside.

In the materials Ryu studies, packs of electrons interact in surprising and bizarre ways. These interactions can create entirely new material properties such as superconductivity, in which electrons pair off and crowd into the least energetic quantum states instead of spreading out. The systems can be so complex that the goal isn't finding the right answers, Ryu says, "it's asking the right questions."

> "There's no magic to this, it's just experience."

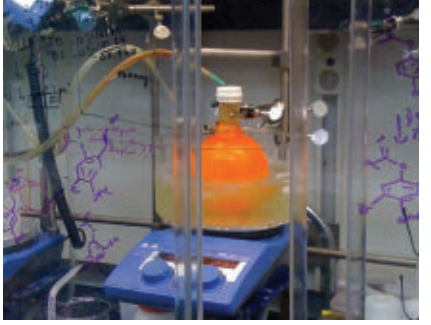
Quantum applications such as computers rely on consistency — the same question should yield the same answer every time. But the quantum interactions between electrons are often unpredictable, so Ryu hunts for measurements that reliably return the same value again and again. He likens the systems to a doughnut shape. The curvature of the doughnut's surface can change when external forces press in, but the number of holes in the doughnut stays the same. These kinds of robust properties will make accurate quantum computing possible, he says.

The work can be very abstract and difficult at times, Ryu admits. At those points he leans on his background in experimental physics to stay grounded and "maintain a sense of reality."

"I'm lucky," he says. "I've had experience in multiple disciplines of physics. There's no magic to this, it's just experience." — *Thomas Sumner*

FROM TOP: JUSTIN KNIGHT; W. DETMOLD

Better synthesis of natural compounds



Structural scribbles adorn the fume hood during synthesis of a plant-derived natural product.

Sarah Reisman, 36
CALTECH | ORGANIC CHEMISTRY
GRADUATE SCHOOL: YALE

Organic chemistry haunts most pre-med students, but not Sarah Reisman. The two-semester class was so invigorating that she abandoned her pre-med major to pursue chemistry.

"Organic chem presented me with this idea that we could do things that are new," says Reisman, who heads a lab at Caltech. "The idea that I could design a brand new way to make a molecule, there was this real creative component," she says.

Reisman got the science bug in high school through a program that paired local students with scientists at the MDI Biological Laboratory in Bar Harbor, Maine. As an undergraduate at Connecticut College in New London, she worked in the lab of chemist Timo Ovaska. He asked Reisman and three other undergrads to make various fragments of the ringed molecule phorbol, a difficult task.

"We never made that molecule, but he had a plan and some naïve students that were happy to try," she says. "It taught us how to think about making these products and to be ambitious."

While getting her Ph.D. at Yale in the lab of John Wood, Reisman dived into synthesis strategies and new reactions, a focus that continued during a postdoc at Harvard. Today she keeps a running list of seemingly impossible-to-synthesize molecules, ones that many chemists steer clear of. "We try to look at molecules that we don't know how to make," she says. "What are the reactions that we wish we had?"

Many of these molecules are made by plants, fungi or bacteria and have interesting biological activities that could prove useful in drug development. The molecules typically have elements of asymmetry, dangling reactive chemical groups, and a backbone of many rings. (A motif that Reisman sees everywhere: "A piece of abstract art in an airport looks like benzene rings to me.")

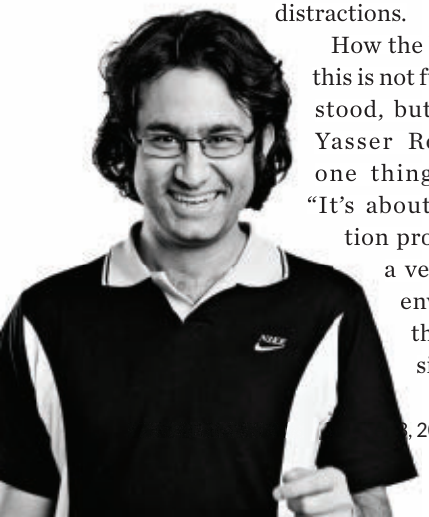
She has already developed several new synthesis strategies, including a way to make the fungal metabolite acetylaranotin and its chemical relatives. These compounds are potential cancer therapeutics, but difficult to work with.

Without feasible ways to make these molecules, scientists can't generate quantities large enough for study. Enter Reisman."There's still so much important chemistry to do." — *Rachel Ehrenberg*

Creating maps in the brain

Yasser Roudi, 34
NORWEGIAN UNIVERSITY OF SCIENCE AND TECHNOLOGY | COMPUTATIONAL NEUROSCIENCE
GRADUATE SCHOOL: SISSA IN TRIESTE, ITALY

Your senses are bombarded by constant information — sounds, colors, shapes and ever-changing motion — yet you don't notice most of these things. The brain has figured out ways to pay attention to relevant information and ignore distractions.



How the brain does this is not fully understood, but physicist Yasser Roudi says one thing is clear: "It's about information processing in a very chaotic environment that's full of signals."

Roudi is figuring out how to sort through and make sense of the vast number of inputs that bombard the brain and other complex systems.

Born in Tehran, Roudi knew from an early age that he wanted to pursue physics and mathematics. While studying physics at Sharif University of Technology in Tehran, he met a teacher who introduced him to the brain and its networks of neurons. At posts in London and Stockholm, Roudi worked on applying math and physics to studies of the brain and other systems. In 2010, he moved to the Kavli Institute for Systems Neuroscience at the Norwegian University of Science and Technology in Trondheim.

"It's about information processing in a very chaotic environment that's full of signals."

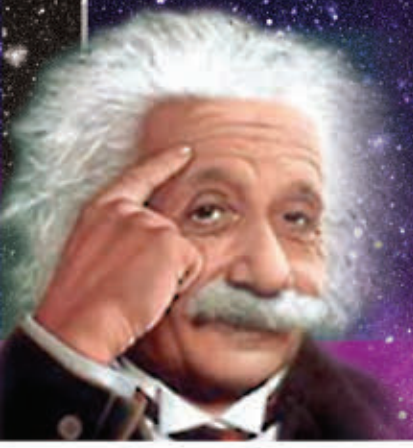
Today, Roudi draws on information theory and statistical mechanics to extract meaningful information from the data deluge. He's finding ways to apply math to a messy living system, developing algorithms to draw inferences about the brain.

In 2013, Roudi's team revealed intricate details of how the brain's GPS-like neurons called grid cells form their maps, which allow animals to navigate and sense their surroundings. In some cases, pairs of grid-like cells curb each other's behavior. His group also described how signals from the hippocampus influence grid cells. The findings appeared in two papers in *Nature Neuroscience*.

Roudi's group is now developing automated ways to analyze even more data from complex systems and help scientists find "hidden" but important variables.

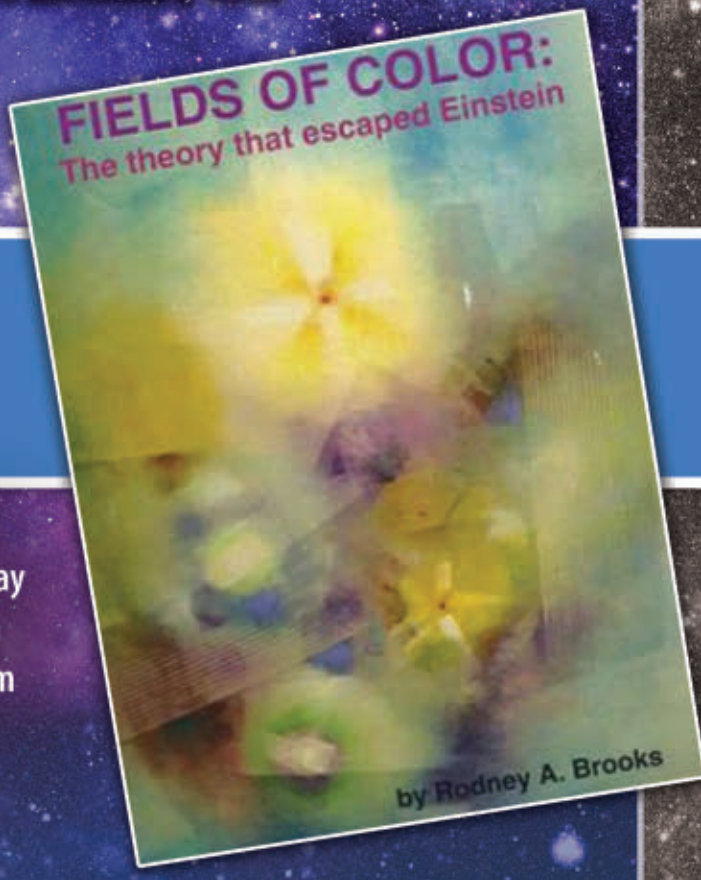
"Certainly a lot of breakthroughs in science have come through because somebody came across a cell that happened to respond to a certain thing, but not other things," Roudi says. "The signal was there, and people had been recording it, but it just didn't catch the attention that it should have." — *Susan Gaidos*

FROM TOP: S. REISMAN; LANCE HAYASHIDA; GEIR MOGEN/NTNU



"If you can't explain it simply,
you don't understand it well enough"

-Albert Einstein, 1951



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In *The Martian*, Matt Damon rests against the tire of his rover while solar panels recharge the batteries.

FILM

The Martian is entertaining science fiction rooted in fact

Scientists are used to suspending disbelief when they go to movies. But *The Martian*, opening October 2, offers a mostly realistic view of conditions astronauts might encounter on Mars.

The Martian
OPENS OCTOBER 2
TWENTIETH CENTURY FOX

The movie "is a vision of a future we can step into and make happen," says Jim Green, director of NASA's planetary science division and a science adviser to director Ridley Scott.

In that envisioned future, wisecracking astronaut Mark Watney (Matt Damon) is stranded on Mars in 2035 after a fierce storm. NASA thinks he's dead. His communications have been cut off. He's got limited food. And the next mission to Mars won't arrive for four years. There's only one solution: "I'm going to have to science the [expletive] out of this," Watney says.

His story first appeared in Andy Weir's 2011 novel of the same name. "The core focus of the book is basically resourceful problem solving," says Weir, "sort of a combination of *Robinson Crusoe*, *MacGyver* and *Apollo 13*." Weir provided the fictional astronaut with real equipment or minor improvements to today's technology.

For instance, Watney's air supply comes from an "oxygenator" that extracts breathable stuff from carbon dioxide in Mars' atmosphere. "Not only is that real, it's going to fly on the next NASA rover mission," says Edwin Kite, a planetary scientist at the University of Chicago. NASA calls the equipment MOXIE; the Mars 2020 mission will test the instrument's ability to provide oxygen for human explorers in the 2030s.

Most of the scenarios Watney encounters — and his solutions — are rooted in science, Kite and others say. Watney has to grow food to supplement his meager rations. He becomes the self-proclaimed "greatest botanist on this planet" when he turns part of an intended Thanksgiving meal into a crop of potatoes.

Growing plants on Mars is "feasible," says astrobiologist Thomas McCollom of the University of Colorado Boulder. "You'd probably have to do some work on your soil first," he says, to remove or neutralize salt and damaging chemicals such as perchlorates and hydrogen peroxide. But the Curiosity rover and other Mars missions suggest that growing crops may be easier than thought. Mars soil already contains nitrogen in a biologically usable form (*SN Online: 3/23/15*). And in one death-defying scene Watney burns hydrogen liberated from rocket fuel to get water. But in reality, ice is just under the planet's surface, "so all Mark had to do was bring dirt in and heat it up to get water," Weir says.

There's one notable exception to the believability of *The Martian*: the storm that strands Watney. "The hurricane-force winds that tear things apart are exaggerated," says planetary scientist Ramses Ramirez of Cornell University.

That's because the atmosphere is thin. Atmospheric pressure at Mars' surface is only 0.6 percent of Earth's. Winds could well reach hurricane speeds, but they would not push enough air mass to tear apart equipment and whip up sand and small rocks. A 240-kilometer-per-hour (150-mile-per-hour) wind on Mars is a breeze, says Green. "It's not enough to straighten an American flag."

Weir calculated how furiously winds on Mars would need to blow to create the killer storm: more than 10,000 miles per hour. In the movie, the crew discusses the storm's power in terms of force in newtons, instead of providing wind speed. The viewer then must "do an extra step of math to figure out how implausible the storm is," Weir says.

The Martian wields science and technology to tell a gripping tale. Scott preserves the book's sense of adventure, produces spectacular panoramic views of the landscape and highlights the humor, ingenuity and perseverance of the primary characters: the space agency's astronauts, engineers and administrators. The movie's real hero is science. — *Tina Hesman Saey*

COURTESY OF TWENTIETH CENTURY FOX

Broadcom MASTERS finalists announced

Broadcom Foundation and Society for Science & the Public revealed the 30 finalists for the 2015 Broadcom Math, Applied Science, Technology and Engineering for Rising Stars on Wednesday, September 2. Broadcom MASTERS, celebrating its fifth anniversary this year, is the nation's most prestigious science, technology, engineering and math competition for middle school students.

This year's finalists include 16 boys and 14 girls from 28 schools and one home school in 14 states. California claims the highest number of finalists, eight, followed by Florida with five and Texas with three. Finalists' projects cover a variety of topics, including water pollution, robotics and wireless devices, effective headgear for sports, the efficiency of solar panels, honey's anti-inflammatory properties and more.

Finalists were selected from a pool of 300 semifinalists that had been narrowed down from 2,230 applicants. Each application received three independent evaluations by distinguished scientists, engineers and educators. Nominees qualified to enter the Broadcom MASTERS by being among the top 10 percent of participants at their SSP-affiliated science fairs.

Finalists will travel to California to showcase their projects for the public and compete as teams in hands-on STEM activities during the Broadcom MASTERS finalist week. The students will vie for the top award of $25,000, provided by the Samueli Foundation, along with additional cash awards, funds for summer science experiences and more. Winners will be announced on October 6.

The public is invited to attend the free 2015 Broadcom MASTERS Science and Engineering Project Showcase at the Computer History Museum in Mountain View, Calif., on Saturday, October 3, for a chance to meet the finalists.

Broadcom MASTERS Finalists

CALIFORNIA **Manasa Bhimaraju**, Kennedy Middle School, Cupertino; **Hannah Cevasco**, St. Charles School, San Carlos; **Joseph Huitt**, Notre Dame Catholic School, Chico; **Sebastian Mellen**, Mt. Everest Academy, San Diego; **Naya Menezes**, Thurgood Marshall Middle School, San Diego; **Isaiah O'Neal**, Portola Highly Gifted Magnet School, Los Angeles; **Nicholas Perez**, St. Edward School, Lake Elsinore; **Anish Singhani**, Diablo Vista Middle School, San Ramon

COLORADO **Evelyn Bodoni**, Challenge School, Centennial

FLORIDA **Blake Caven**, Julia Landon College Preparatory, Jacksonville; **Soyoun Choi**, Viera Charter School, Melbourne; **Glenn Grimmett**, The Weiss School, Jupiter; **Mikayla Lindsay**, Okaloosa STEMM Academy, Niceville; **Madison Toonder**, Florida Virtual School, St. Augustine

INDIANA **Annie Ostojic**, Wilbur Wright Middle School, Munster

LOUISIANA **Anusha Zaman**, Glasgow Middle School, Baton Rouge

MASSACHUSETTS **Avery Clowes**, Oak Meadow School, Bolton

MICHIGAN **Rohit Mital**, Indus Center for Academic Excellence, Rochester Hills

MINNESOTA **Pranav Anandarao**, Friedell Middle School, Rochester; **Andrew Eggebraaten**, John Adams Middle School, Rochester

NEW JERSEY **Carolyn Almonte**, Burlington Township Middle School, Burlington

NEW YORK **Maximilian Du**, Eagle Hill Middle School, Manlius; **Bryant Liu**, Rocky Point Middle School, Rocky Point

NORTH CAROLINA **Elizabeth Kinsey**, Charles P. Murray Middle School, Wilmington

PENNSYLVANIA **Sriyaa Suresh**, Springhouse Middle School, Allentown

TEXAS **Natasha Chugh**, Rice Middle School, Plano; **Nikolai Ortiz**, Seashore Middle Academy, Corpus Christi; **David Yue**, Rice Middle School, Plano

UTAH **Audrey Glende**, Bonneville Elementary, Salt Lake City; **Kanishka Ragula**, Reid School, Salt Lake City

Finalists are listed by state, name, school's name and city.

JULY 25, 2015

SOCIAL MEDIA

Thoughts on time

The July 25, 2015 issue of *Science News* explored a complicated question: What is time? Readers on Facebook supplied their own answers.

"Time gives us a sense of before and after, a sense of the chain of causation that is the warp and woof of our lives."
James Williams

"Time is the creation and decay of one event to the next. If nothing ever happened, then the passage of time would not exist."
Rolf Hawkins

"Time is what we don't have enough of."
Paris Adale

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Creating complexity

The July 25, 2015 Science News *featured an in-depth look at new research on time.* ***Andrew Grant*** *explored why time marches forward instead of backward,* ***Laura Sanders*** *described how the brain coordinates a multitude of internal clocks and* ***Tina Hesman Saey*** *delved into the evolution of biological timekeepers.*

"In his introduction, Tom Siegfried repeats the generally held view that the universe tends towards increasing disorder," wrote **Bryan Mumford**. "If by 'disorder' he means less complexity, it seems to me that in all the years since the Big Bang the universe has tended to become more complex. The atoms naturally assembled themselves into clouds, then stars, higher order elements, planets and life."

As the universe has evolved, much complexity has come into being compared with the chaotic conditions of the Big Bang, **Siegfried** says. Creating such complexity does, however, require the use of energy, which in turn generates increasing entropy in the cosmos. So producing complexity, or less disorder, in the universe is more than compensated by the production of entropy; the total entropy or disorder of the universe increases. At least, that is the standard view. Some physicists still pursue interesting questions about how entropy should be defined when the concept is applied to the early universe.

Finding hidden impacts

*In "Most of Earth's impact craters await discovery" (*SN: 7/25/15, p. 5*),* ***Thomas Sumner*** *reported that more than 300 craters wider than 250 meters are still waiting to be found.*

The researchers don't think that any truly massive undiscovered craters are still lurking on Earth's surface, but **Don McCarthy** is not so sure. "It seems presumptuous to conclude that scientists have discovered all the Earth's impact craters of diameter greater than 6 kilometers," he writes. "Surely there are potential locations on Earth that have sufficiently low erosion rates and/or remain hidden to our resolution."

The researchers admit that there could be colossal craters that we haven't discovered, **Sumner** says. Some of these could be hidden underground or beneath ice sheets. "There will always be some uncertainty as to whether we've truly discovered all of the titanic craters," he says. "This particular study, however, concludes that most likely we've already accounted for all the big ones."

The language of science

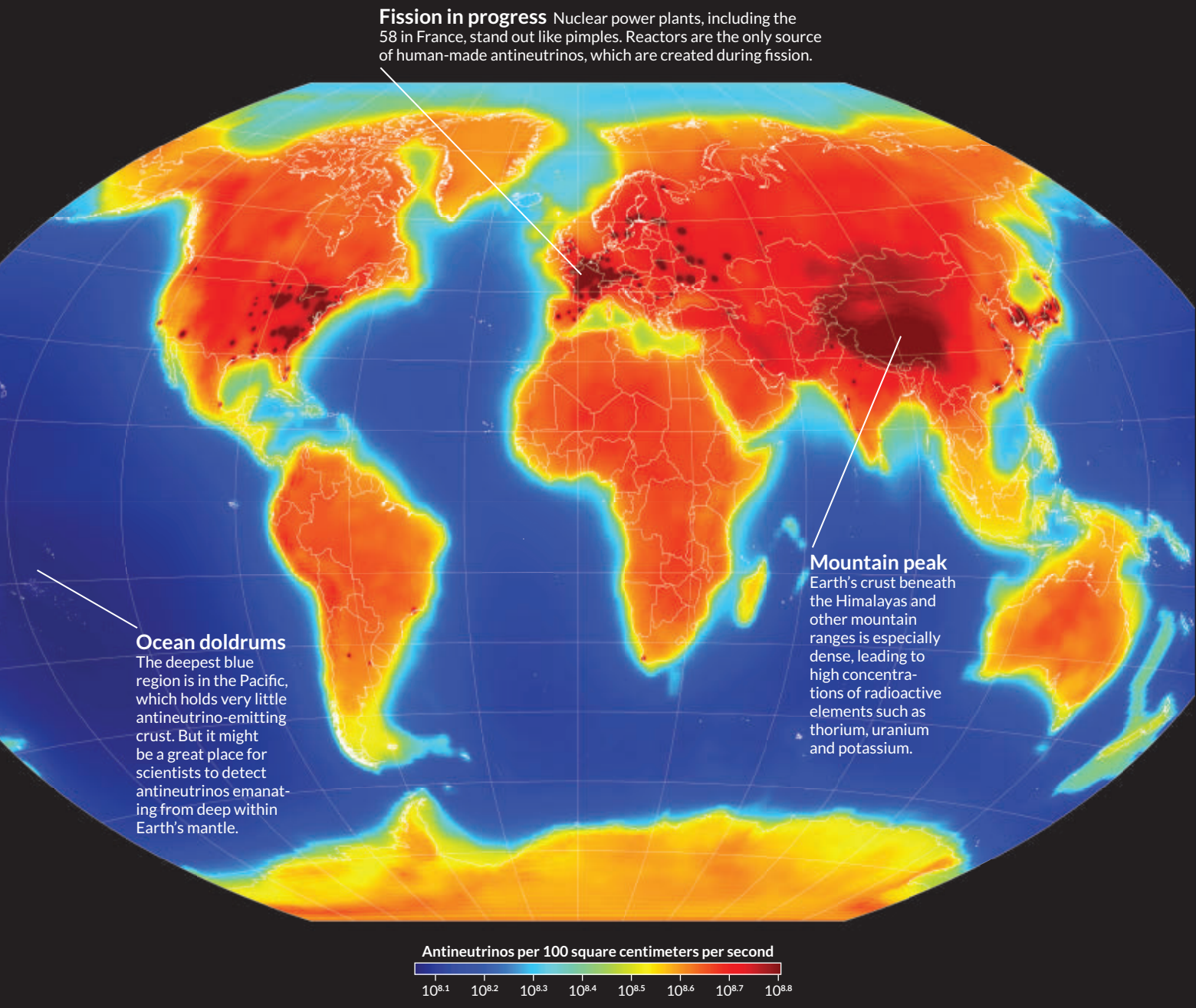
Tom Siegfried *reviewed* Scientific Babel, *a history of science communication, in "How English became science's lingua franca" (*SN: 7/25/15, p. 30*).*

"Not only language shapes how science is done, but also cultural differences," wrote **Fred Cann**. "In the '60s and '70s, I had to read many British papers on radar receiver design, and found them very hard to follow. The British idea of the best logical sequence to explain something was very different from the American way."

Commenter **ScottyonDenman** lamented Russian's fall from prominence as a scientific language, but pointed out that "the study and use of Russian language in terms of scientific enterprise remains a worthy pursuit; tons of important research that was hidden away by the Soviets is still surfacing and still needs translation. And of course, post-Soviet Russia is still a well-educated and naturally well-endowed nation with huge contributive potential in every field of science."

Retraction notice

A 2014 study in *Cell Metabolism* about how grizzly bears avoid diabetes despite gaining weight for hibernation (*SN: 9/6/14, p. 13*) has been retracted. The pharmaceutical company Amgen, which employs coauthors on the paper, requested the retraction after discovering that one of the scientists had manipulated data. The retraction notice, published September 1, notes that some of the authors are repeating portions of the study.



Map captures sources of Earth's antineutrino glow

Each second, more than 10 septillion (10^{25}) antineutrinos race away from Earth and into space. That's 100 trillion times as many antineutrinos as stars in the galaxy. But who's counting?

Leave that to particle physicist Shawn Usman of the National Geospatial-Intelligence Agency in Springfield, Va. In September in *Scientific Reports*, he and colleagues published the first global map of antineutrinos, harmless subatomic particles (and the antimatter cousins of neutrinos) born when radioactive elements break down. That decay happens within the planet's crust and mantle and in nuclear reactors.

Usman's team pieced together data, including measurements from detectors in Italy and Japan, to build a Technicolor map of antineutrino abundance. Dark reds flag hot spots; blues mark areas where antineutrinos are less bountiful.

The map could help scientists nail down the driver of Earth's internal heating system, which fuels plate tectonics and volcanoes. Just how much heat comes from radioactive energy in the planet is still up for debate, Usman says. His team's map might offer researchers a clearer picture. And it will certainly be more colorful. — *Meghan Rosen*

S.M. USMAN, G.R. JOCHER, S.T. DYE, W.F. MCDONOUGH, J.G. LEARNED, ADAPTED BY S. EGTS

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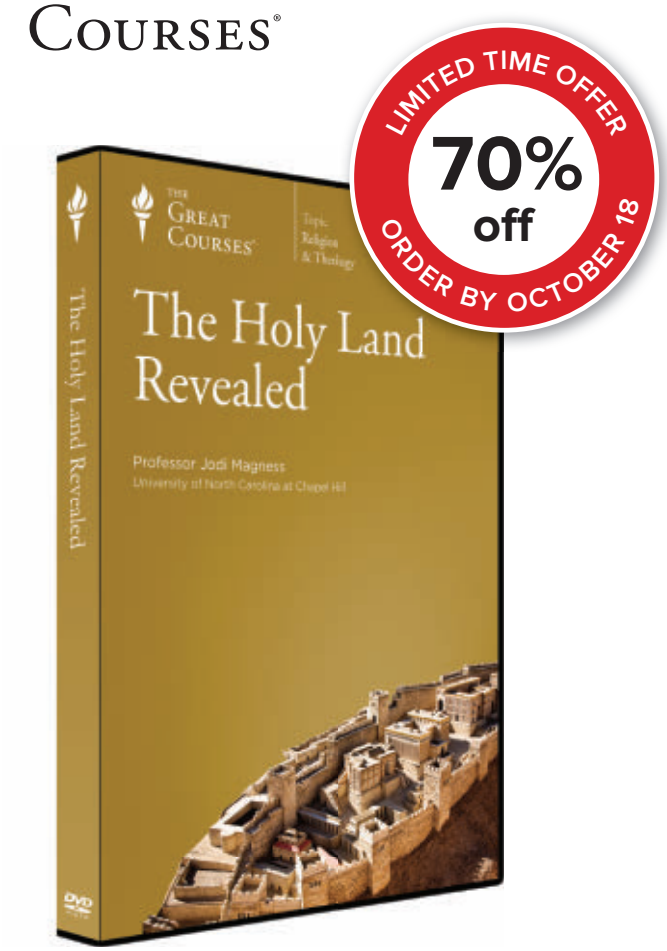

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