SN
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SOCIETY FOR SCIENCE & THE PUBLIC
MAY 16, 2015

How Earth Got Its Water

Bigger Quakes Forecast for Himalayas

Contagious Cancer in Clams

Genetics of Placebo Effect

DARK Chemistry

Designer drugs elude the law and threaten health

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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SOCIETY UPDATE
SN's newest blog

COVER Synthetic cannabinoids, known as spice, are sold as an alternative to marijuana. They are among many new mimics of illicit drugs. *Wendy Galietta/The Washington Post via Getty Images*

Cancerous clams and other sci-fi fodder

I blame my love for science fiction mostly on my mother, although my older brother Nathaniel probably should also take some of the heat. Both were voracious readers, leaving piles of books around the house, most of them sci-fi, that I couldn't avoid escaping into.

Fans of science fiction will find a few items in this issue sure to trip the imagination. First, on Page 14, Tina Hesman Saey describes a discovery akin to something out of *Alien*: roving cancer cells that move from victim to victim, sneaking into others' bodies to produce more of themselves. Saey, a lover of science fiction herself, calls it "cancer as parasite" or — as one researcher put it — extreme out-of-body metastasis.

Of course, this contagious cancer attacks clams, not people. But biologically, it's pretty far-out. The leukemia-like disease is not, as was initially thought, caused by a virus. Jumping genes — bits of DNA that move around a chromosome, embedding themselves in places that can trigger cancers — may play some role. These genes revealed that clams from Maine to Maryland have the exact same malignancy — and that the cancer cells are genetically distinct from the clams' own cells.

It's the third example of contagious cancer in the animal world, but it's the only one with no apparent direct contact between the carriers. What if there are other, similar types of cancers that we don't know about? "That's scarier to me than any virus," says Saey. And good fodder for a thriller.

Also seemingly out of the pages of a novel: new drugs of abuse, designed by chemists to mimic illicit drugs but to evade legal restrictions, with some scary effects, as science writing intern Kate Baggaley describes on Page 22. Or, see Christopher Crockett's report on Page 18 about the effort to trace the origin of Earth's water, which apparently was imported from some extraterrestrial source.

For a taste of actual sci-fi, see my brief review of the movie *Ex Machina* (Page 26). It's no *Star Wars*, but it does what some of the best science fiction does: uses futuristic technology to explore bigger, broader issues involving humans and society. It also offers a bit of an escape.

— Eva Emerson, Editor in Chief

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NEW

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Excerpt from the May 8, 1965, issue of *Science News Letter*

50 YEARS AGO

U.S. ready for fruit fly

A reception committee is always ready to greet the dreaded Mediterranean fruit fly if it should stray across the U.S. border from Central America. The fly, probably the world's most destructive fruit pest, does not now infest the United States.... A program of sterilization [of another species of fruit fly] is now underway.... Billions of insects are reared, sterilized and released. Sterile males then compete with wild ones in the breeding grounds, and since their matings produce no offspring, the species dies out.

UPDATE: Sterilization was used for decades to combat the screwworm before Mexico and Guatemala staged their first Mediterranean fruit fly (*Ceratitis capitata*) sterilization trial, in 1978. Along with pesticides, the sterile insect technique is now used in the United States and elsewhere around the world to eradicate or control the medfly and other insect pests. Scientists are developing new ways to sterilize insects. Variations of the technique are being used to control disease-carrying mosquitoes.

The iconic shape of a coco-de-mer nut that intrigues a traveler (shown) won't show up on a tree. It's evident only once the outer green husk is stripped off.

IT'S ALIVE

How slow plants make ridiculous seeds

The secret behind the world's largest seed and its sexually extravagant plant is good gutters.

A prodigy among those seeds can weigh as much as 18 kilograms, about the weight of a 4-year-old boy. Yet the plant that outdoes the rest of the botanical world in the heft of its seed manages with below-poverty nutrition. Coco-de-mer palms (*Lodoicea maldivica*) are

THE -EST

The coldest substance

0.000000000005

degrees Celsius above absolute zero

Temperature of the coldest stuff on Earth

A swarm of atoms in a Stanford lab has become the coldest stuff on Earth. At about 50 trillionths of a kelvin, the atoms' temperature is about a tenth of the previous record. "This stuff is legitimately cold," says quantum physicist Mark Kasevich, who led the work. "It's the coldest stuff ever observed."

The temperature of a sample depends on how fast its constituent components move relative to each other. Kasevich and his team started with a cold gas made up of about 100,000 tightly packed rubidium atoms. Within a few seconds, the atoms spread apart, because some were moving faster than others. But then Kasevich's team zapped the sample with a laser that countered the motion. The farther an atom had roamed (and thus the faster it was moving), the more of a decelerating nudge it received. All of the atoms slowed to a crawl, the researchers report in the April 10 *Physical Review Letters*, corresponding to the new record-low temperature.

Ultracold atoms should lead to increasingly sensitive interferometers, devices that can measure gravity and test the limits of quantum theory. Ideally, atoms within interferometers would be so cold and so slow that they would stray only a few centimeters over the course of a minute or two. Kasevich hopes to improve the method and cool atomic gases to quadrillionths of a kelvin. —*Andrew Grant*

NIALL CORBET

native to two islands in the Seychelles that have starved, rocky soil.

Despite the scarcity of resources, a palm forest is "magnificent — it's like a dinosaur could come around the corner," says Christopher Kaiser-Bunbury of the Seychelles Islands Foundation. Wind jostling acres of stiff leaves makes a sound he describes as "crackling."

But it's scrimp-and-save greenery. With precious little nitrogen and phosphorus (the N and P in N-P-K garden fertilizers), these palms sprout fronds using only about one-third of the nutrients in the leaves of 56 neighbor tree and shrub species. And the trees scavenge fiercely from their own dying leaves, Kaiser-Bunbury and his colleagues report in the May *New Phytologist*. Coco-de-mer palms can reuse 90 percent of that prized phosphorus from fronds about to drop, leaving the most depleted dead leaves yet recorded.

Sexual structures, however, are luxuriant, taking about 85 percent of the plants' supplies of phosphorus. And the palms manage this, the researchers conclude, thanks to drainage.

An adult coco-de-mer's leaves collect water from a 17.1-square-meter area on average.

Curving leaves, easily 2 meters wide with creases like folded paper fans, coil almost like funnels to send rain sluicing down the stems. The water deposits its treasures of animal droppings, stray pollen and other nutrient windfalls over the roots.

A plant's giant seed takes time to grow — six years — especially on a tight nutrient budget. A wild coco-de-mer lives slowly, reaching 80 or 100 years of age before plant puberty. During a female plant's life of several hundred years, she may bear only about 100 seeds.

Unfortunately, the coconuts produced with such sustained effort rarely get a chance to replenish the dwindling forest. To sustain the forest, Kaiser-Bunbury calculates, 20 to 30 percent of the endangered species' seeds need to sprout. But perhaps inevitably, considering all the showy reproduction, poachers sell powders made from the coconut's insides as alleged aphrodisiacs. — *Susan Milius*

MYSTERY SOLVED

Source of puzzling cosmic signals found — in the kitchen

Mysterious radio signals detected by the Parkes telescope appear to come from an advanced civilization in the Milky Way. Unfortunately, it's the one civilization we already know about.

Microwave ovens opened before they're done cooking have been muddling the hunt for far more distant radio signals, researchers report online April 9 at arXiv.org. Astronomers have had to contend with enigmatic flares dubbed "perytons" ever since discovering equally puzzling fast radio bursts, or FRBs (*SN: 8/9/14, p. 22*), in 2007. Perytons and FRBs are similar except that FRBs come from other galaxies and perytons originate on Earth. Scientists thought perytons might be from a meteorological phenomenon.

Three perytons in January coincided with independently detected blasts of 2.4 gigahertz radio waves — the frequency that microwave ovens use to heat food. So researchers at the Parkes telescope (shown) in Australia heated mugs of water while moving the massive radio dish, trying to recreate the phenomenon. When researchers opened the oven door mid-cooking instead of letting the timer run out, perytons appeared in the data.

The source of the galactic FRBs remains a mystery. Astronomers suspect they are linked with imploding neutron stars or eruptions on magnetars. At this point, however, scientists might want to consider extraterrestrials nuking frozen pizzas. — *Christopher Crockett*

SAY WHAT?

Geographic tongue *\JHEE-uh-gra-fik TUHNG\ n.*

A condition in which splotches give the tongue a maplike appearance. The condition involves losing some of the tiny bumps called papillae on the tongue, creating islands of red, inflamed splotches. It affects 2 percent of people and is harmless. Scientists suggest in the March *New Journal of Physics* that geographic tongue can develop in two ways: circular and spiral. Circular spots can get bigger until they cover the whole tongue. Eventually, the tongue recovers as the papillae grow back. In other cases, spiral patterns develop in recovering regions, prolonging bouts of patchiness. — *Helen Thompson*

CLOCKWISE FROM TOP: C. KAISER-BUNBURY; MARTANOPUE/WIKIMEDIA COMMONS (CC BY-SA 3.0); DAVID MCCLENAGHAN/CSIRO

MATTER & ENERGY

Debate continues over 103's place in periodic table

New data on lawrencium rekindle an old argument

BY BETH MOLE

In their momentary life spans, atoms of lawrencium, element 103, may have left a lasting impression on the structure of the periodic table.

For the first time, researchers have measured a basic property of the fleeting radioactive element, namely its ionization potential, the researchers report in the April 9 *Nature*. The ionization potential — how much energy it takes to strip an atom of its most weakly bound electron — hints at how that atom's electrons are arranged. Such information may help resolve a long-standing question about where lawrencium belongs in the periodic table.

The question will probably be taken up in the next year or two by the International Union of Pure and Applied Chemistry, says Jan Reedijk, president of IUPAC's inorganic chemistry division and a molecular inorganic chemist at Leiden University in the Netherlands. IUPAC governs chemical nomenclature. In this case, the union would decide whether lawrencium (along with its relative, lutetium) belongs at the bottom of the periodic table's third column or at the end of a separate row of elements in an annex below the main table.

Study coauthor Yuichiro Nagame, a chemist at the Japan Atomic Energy Agency in Tokai, didn't expect the experiment to spark debate about the periodic table. "I'm very happy to learn of these discussions," he says.

Nagame and colleagues set out six years ago to study lawrencium's electron structure, a steep technical challenge because typical methods require about a trillion atoms. Lawrencium, named after Ernest Lawrence, the inventor of the cyclotron, is transient and extremely difficult to make. Nagame and colleagues managed to take the measurement by generating about a thousand atoms in total.

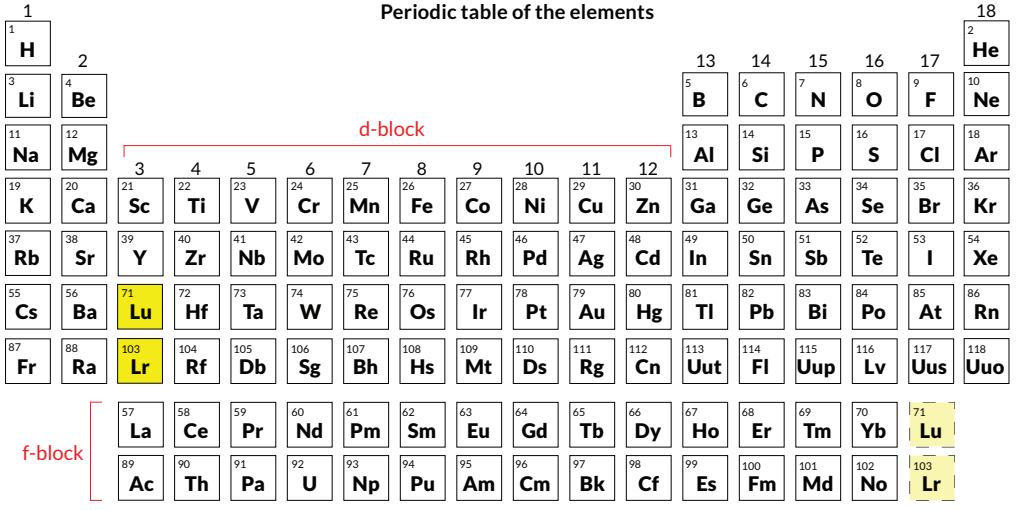
By firing a stream of boron ions (element 5) into californium atoms (element 98), Nagame and colleagues created an isotope of lawrencium. The collisions created a new lawrencium atom every few seconds. The atoms collectively had a 27-second half-life. With a method that sweeps lawrencium up into a helium-based atmosphere, the scientists quickly shot the ephemeral atoms into a metal tube heated to either 2,700 or 2,800 kelvins (2,427° Celsius or 2,527° C).

Contact with the hot tube sometimes plucked electrons from lawrencium atoms, creating ions. By sending other elements through the tube beforehand — elements with known ionization potentials — Nagame and colleagues came up with an equation to calculate ionization potential based on how many ions formed in the tube.

After counting how many lawrencium ions tumbled out, the researchers calculated that lawrencium has an ionization potential of about 4.96 electron volts, which is low. In fact, it's the lowest of all the elements in the appended group of elements at the bottom of the table, where some chemists say lawrencium belongs. The low ionization potential suggests that lawrencium has a peculiar arrangement of electrons.

Heavy elements like lawrencium have more nuclear charge, which causes electrons near the nucleus to move fast. As Einstein's theory of relativity predicts, speedy electrons gain mass, causing inner groups of electrons to form dense clouds around the nucleus. This shields the nuclear charge, leaving electrons on the outskirts of the atom's structure to loosen and rearrange.

Electrons arrange themselves in cloudlike regions around the nucleus called orbitals. These orbitals are designated by numbers for their energy level and letters (s, p, d, f) for their shape. For example, s orbitals form spherical clouds around a nucleus. Based solely on



Despite new results, controversy remains over where the element lawrencium (Lr) — plus its upstairs neighbor lutetium (Lu) — should be in the periodic table: in the d-block or f-block.

E. OTWELL

lawrencium's atomic number, chemists expect that its outermost electrons will be in 5f, 6d and 7s orbitals. But the low ionization potential suggests that lawrencium has one very weakly bound electron in the 7p orbital instead of the 6d.

Some chemists think the empty 6d orbital suggests that lawrencium shouldn't be in the third column of the periodic table. That column sits in a region of the table known as the d-block, which generally includes elements with electrons occupying an outer d orbital. The study confirms that lawrencium belongs in the table's annex, says chemist Laurence Lavelle of UCLA. That separate group of elements, known as the f-block, generally contains elements with electrons inhabiting an outer f orbital.

Other chemists say that, in this case, using orbitals to determine placement in the periodic table is murky. Instead, other trends in the table such as those seen in the actual numerical values of ionization potentials are more helpful. The measured ionization potential supports the idea that lawrencium does "not belong at the end of the f-block but rather at the start of the d-block," says William Jensen, a chemical historian retired from the University of Cincinnati.

One property isn't enough to make an argument for placement, says chemical historian and philosopher Eric Scerri of UCLA. "We need a more global approach," he says.

Scerri thinks that the periodic table should be widened to have 32 columns so that the f-block elements can merge into the main table, and all elements would be displayed in order of atomic number. That revision would place lawrencium in the d-block. With the new data, Scerri is working on a report to persuade IUPAC to approve a new table with lawrencium's d-block position.

Reedijk, of IUPAC, looks forward to Scerri's report. But he cautions that IUPAC's deliberations will probably be slow. When IUPAC proposed modifying the periodic table's column numbering in 1985, it took about five years to decide and another 10 to 15 years for chemists to adopt the changes, Reedijk says. ■

GENES & CELLS

Genes may influence placebo effect

Response to sham treatment depends on certain DNA details

BY ASHLEY YEAGER

People who get a feel-good boost from sham medical treatments may have their genes to thank.

Researchers reviewing studies of individuals' genetics and responses to placebos have identified 11 genes that appear to play a role in how people react to the sham treatments. Establishing a link between certain genes and the placebo effect is in its infancy, the researchers say online April 13 in *Trends in Molecular Medicine*. But if confirmed, such a connection could change the way scientists analyze clinical drug trials and how doctors treat patients, the researchers note.

11
Number of genes shown to have a role in the placebo effect

"We don't actually know how big of a role genetics play in the placebo effect," says coauthor Kathryn Hall, a molecular biologist at Beth Israel Deaconess Medical Center in Boston. Studies suggesting a link between the placebo effect and a set of specific genes — what the team calls the placebome — have been popping up over the last few years.

"The placebome approach is very interesting, but we must be aware that genetics is only a part of the whole placebo phenomenon," says Fabrizio Benedetti, a neurophysiologist at the University of Turin Medical School in Italy who was not involved in the work.

In the placebo effect, patients given a nonmedically active substance, such as a sugar pill, report improvement in their condition because they think they have been given something that will help. Whether the placebo effect is real or a figment of patients' imaginations was questioned until about 30 years ago, says coauthor Ted Kaptchuk, also of Beth Israel Deaconess. At that time, scientists showed that the body's pain system and response to placebo pain medication could be manipulated to dull the ache of a pulled tooth. Researchers then showed that brain regions involved in pain suppression were activated in patients who received a placebo but expected to get pain medicine (*SN: 12/20/08, p. 26*; *SN: 9/3/05, p. 157*). Those results showed that the placebo effect is real, Kaptchuk says. Finding genetic influences on the effect is moving placebo science to an even more basic level, he says.

Among the genes that appear to mediate the placebo effect, five are associated with the chemical messenger dopamine and four are linked with the chemical messenger serotonin. A gene related to opioids and one associated with endocannabinoids, which play a role in sensing pain, are also implicated. Variations in these genes may change the way the body makes and uses these molecules, the scientists say.

Large-scale genome studies run in conjunction with clinical drug trials could help fill in the gaps in understanding which genes are involved and what role they play in boosting the placebo effect. And including a no-treatment group in studies could control for the placebo effect, the researchers say. They note that screening participants in clinical drug trials and removing those who are genetically predisposed to a placebo response might make clinical trials more efficient.

There's also a clinical rationale for identifying genes associated with placebo effects, says neuroscientist Luana Colloca of the University of Maryland School of Nursing in Baltimore. A doctor who knows that a patient responds to placebos can use that information to tailor personalized treatments, she says.

Colloca and the study authors both note, however, that designing drugs only for those who don't respond to placebos and using placebo responses to manipulate drug effects in clinical trials raise ethical concerns. ■

GENES & CELLS

Genetic roots of citrus family dug up

New analysis of chloroplast DNA reveals rapid hybridization

BY TINA HESMAN SAEY

The mother of all citrus plants lived about 13 million years ago, scientists have learned by tracing the maternal side of the citrus family tree. Yet it is dad's contribution that has revealed the growing family's entire portrait.

Starting about 8.08 million years ago, the citrus family tree began branching out. That's when Australian limes and citrons split from the original *Citrus* genus, researchers report online April 14 in *Molecular Biology and Evolution*. Several subsequent rounds of speciation led to branches carrying lemons, limes, oranges, tangerines and other citrus fruits. Learning how these species evolved may help breeders devise new varieties that can withstand drought and disease, scientists say.

Researchers from Valencia, Spain, determined the genetic makeup of chloroplasts — organelles in plant cells that carry out photosynthesis — from 30 types of citrus. It's the most detailed genetic analysis ever of citrus plants.

Chloroplasts carry their own DNA, containing more than 100 genes, and are typically inherited from the female parent. That's how researchers traced citrus plants' heritage back to their maternal roots.

But the new study also yielded paternal information, says study coauthor Joaquin Dopazo, a bioinformatician at the Prince Felipe Research Center.

Dopazo and colleagues noticed that many of the plants had more than one type of chloroplast DNA in their cells, a phenomenon known as heteroplasmy. The extra chloroplasts came from male plants when two species of citrus hybridized, the researchers determined.

The study bolsters the controversial idea that plants can inherit organelles from male parents, says Cynthia Morton, a molecular systemicist at the Carnegie Museum of Natural History in Pittsburgh. Previously, scientists had used scant data — only a few chloroplast genes — as evidence of heteroplasmy, leaving room for debate. This study compiled the complete chloroplast chromosome, leaving little doubt that heteroplasmy happens often, Morton says.

Dopazo and colleagues used the heteroplasmy information to identify both parents of hybrid species. For instance, sweet oranges are the offspring of a pomelo female and a mandarin male. Lemons resulted when a sour orange female hybridized with a citron male.

Such hybridization is an evolutionary shortcut to making new species, Dopazo says. "Otherwise you'd have to wait millions of years" to accumulate enough genetic variation to make new species.

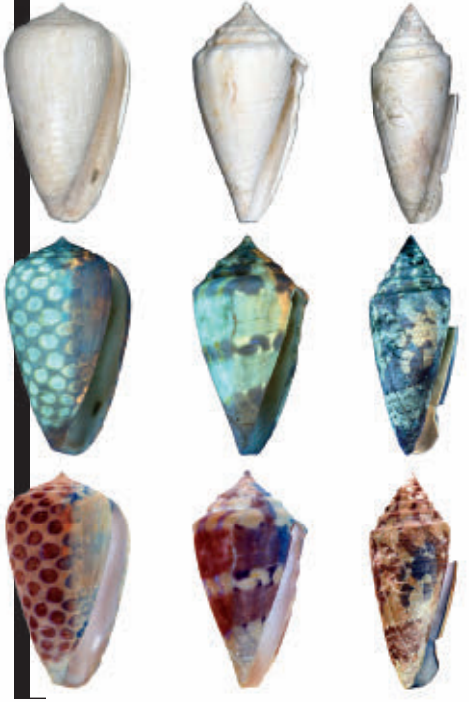
Some citrus genes have accumulated more variation than others, suggesting these genes provided an evolutionary boost. Australian limes got an advantage from variants in two genes, *matK* and *ndhF*, the researchers report. Mandarins' evolutionary success stems in part from mutations in the *ccsA* gene. Changes in the *ycf1* gene were also found to give an evolutionary edge to mandarins and some related fruits. It's not clear what advantage those genes provide.

The variation could mean those genes are unimportant, not an evolutionary boon, says Henry Daniell, a molecular biologist and genetic engineer at the University of Pennsylvania School of Dental Medicine in Philadelphia. For instance, plants don't need *ndhF* to survive, he says. "These guys may be barking up the wrong tree in their assertion."

Tracking hybridization may help save plants from citrus greening, a disease that threatens citrus orchards across the southern United States, Morton says. Some citrus varieties in Asia, where citrus greening began, may be immune to the insectborne disease. Breeders may be able to re-create hybrid species using greening-resistant parents. Chloroplast DNA could quickly tell breeders whether crosses produced the desired hybrid. ■

LIFE & EVOLUTION

Fossilized seashells' true colors revealed



To the naked eye, fossilized seashells lack the colorful patterns of their living counterparts. But ultraviolet light can reveal some of the shells' hues. Jonathan Hendricks of San Jose State University in California examined 4.8-million- to 6.6-million-year-old cone snail shells from the Dominican Republic. Under UV light, organic compounds in the shells fluoresce (middle row) — though it's unclear exactly which compounds are fluorescing. Hendricks then re-created the shells' pigmentation (bottom row), compared the patterns and identified snail species. Out of 28 species, 13 are previously unknown, Hendricks reported April 1 in *PLOS ONE*. — *Helen Thompson*

J. HENDRICKS

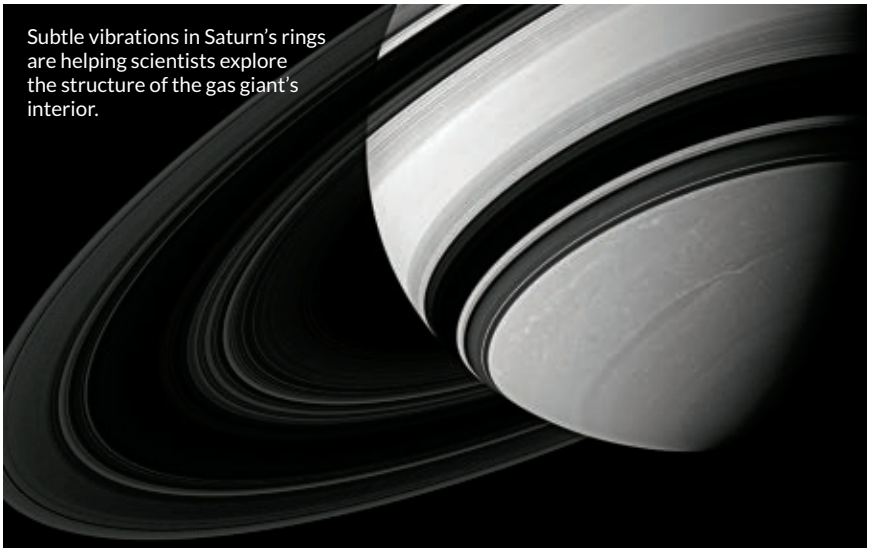
MEETING NOTES

Ringing rings reveal Saturn's innards

Saturn is surrounded by a vast seismometer: its rings. Recently detected ripples in the gas giant's rings carry signatures of the planet's interior structure, offering new insights into what lies far beneath Saturn's cloud tops. "It's the first useful seismology on another planet," said Jim Fuller, a theoretical astrophysicist at Caltech. His work, presented April 11, could help scientists understand the formation of planets within and outside the solar system.

In 2013, scientists identified vibrations in Saturn's rings that result from the periodic rise and fall of the planet's surface. Just as seismic waves produced by earthquakes encode information about Earth's interior, Saturn's ring vibrations betray what's lurking inside the planet.

Fuller says the wave patterns indicate that Saturn's interior is more intricate than a solid core surrounded by churning layers of gas. He proposed in a recent paper that Saturn's deep interior has a stable layer of fluid, perhaps in the form of highly pressurized liquid helium. He is also exploring whether the core could be gradually dissolving into the surrounding fluid. By comparing seismic data with magnetic field measurements, Fuller is devising a more detailed structural profile. The Cassini spacecraft may provide more precise gravitational measurements in the months before its lethal descent into Saturn in 2017. *—Andrew Grant*



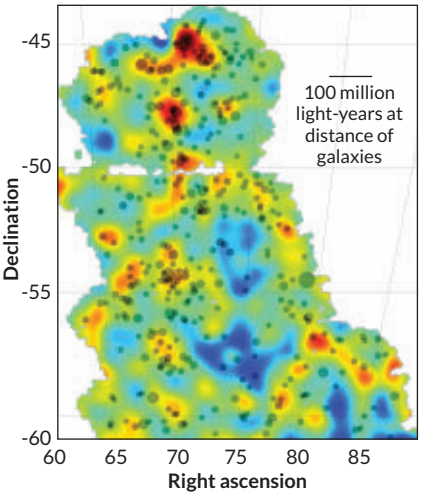
Subtle vibrations in Saturn's rings are helping scientists explore the structure of the gas giant's interior.

Map pinpoints location of invisible dark matter

Dark matter can't be seen, but a new map shows where it's hiding. Released April 13, the map confirms that the mysterious matter is concentrated in regions that contain a lot of ordinary matter in the form of galaxy clusters.

Scientists with the Dark Energy Survey created the map by scanning a large swath of sky with a 570-megapixel camera hooked up to a 4-meter telescope in Chile. Although dark matter doesn't absorb, emit or scatter light, the researchers inferred its distribution by charting how its gravitational influence altered the paths of light zooming past. The map enables scientists to study dark matter's role in influencing whether particular areas of the early cosmos lit up with stars and galaxies or remained relatively empty.

The project's ultimate goal is to use five years' worth of sky scans to probe dark energy — a mysterious entity separate from the dark matter that is causing the universe to expand faster and faster. *—Andrew Grant*



A new map demonstrates that dark matter is concentrated in regions that have a lot of galaxy clusters (gray dots). Areas with relatively little dark matter are blue; regions with a lot are yellow and red.

Afterglow alerts astronomers to gamma-ray burst

An energetic explosion in the cosmos has been discovered via its not-so-energetic afterglow. Each year, astronomers observe several hundred of these explosions, known as gamma-ray bursts, but this marks the first time scientists have spotted a burst's remnant radiance before detecting the burst itself. The finding, reported April 12, could enable the detection of other bursts whose high-energy signatures elude space telescopes.

A small fraction of gargantuan stars end their lives in spectacular explosions that send a narrow beam of gamma rays, the universe's highest-energy radiation, darting through space. Specialized space telescopes identify these bursts by detecting sudden flashes of gamma rays. But in February 2014, a 1.2-meter telescope in Southern California spotted a visible-light flash that brightened dramatically within about an hour, fitting the profile of a burst's afterglow. Sure enough, the next day, astronomers looked back at data from three satellites and found a surge of gamma rays consistent with a burst.

Coauthor Brad Cenko of the NASA Goddard Space Flight Center in Greenbelt, Md., said the next step is detecting "orphan" afterglows of bursts whose gamma rays are not quite pointed toward Earth. Finding these orphans could increase the annual inventory of gamma-ray bursts by up to 100 times. *—Andrew Grant*

FROM TOP: JPL-CALTECH/NASA, SPACE SCIENCE INSTITUTE; DARK ENERGY SURVEY

Watch a simulation of Saturn's seismic vibrations at **bit.ly/SN_Saturnrings**

The cluster Abell 3827 contains four colliding galaxies (yellow blobs). The bluish circle around the galaxies is the light from a more distant galaxy bending around the cluster's center due to gravity from both stars and dark matter.

ESO

ATOM & COSMOS

Split galaxy offers dark matter clues

Division of stars, invisible mass hints at self-interacting particles

BY ANDREW GRANT

A cosmic collision has somehow separated a galaxy from its dark matter, the mysterious invisible stuff that typically dominates a galaxy's mass. The dark matter may be lagging behind its host galaxy because another clump of dark matter slowed it down. If so, it would be the first evidence that dark matter interacts through a force other than gravity.

"It's exciting to wonder if it could be dark matter interacting with itself," says Neal Weiner, a theoretical physicist at New York University.

The study, published in the June 1 *Monthly Notices of the Royal Astronomical Society*, is the latest using galactic collisions to probe dark matter. By charting dark matter interactions, physicists hope to narrow down the extensive list of candidates for dark matter's identity.

Decades of research shows that dark matter exists: Its gravity affects the spin of galaxies and bends light from distant cosmic objects. But because dark matter doesn't emit, absorb or scatter light, scientists don't know what it is made of. Some scientists attempt to solve this riddle by watching dark matter in the wild, in the form of colliding galaxies and galaxy clusters that are chock-full of the invisible stuff. These researchers have sought evidence that dark matter interacts with itself in a novel way. "If dark matter talks to itself, we can see that imprint in the universe," Weiner says.

Richard Massey, a cosmologist at Durham University in England, and colleagues focused on a galaxy within Abell 3827, a galaxy cluster about 1.3 billion light-years away in the constellation Indus. The galaxy is colliding with three other galaxies, offering the opportunity to view clumps of dark matter swooping past each other. Plus, the galaxy sits directly between Earth and another galaxy 7.4 billion light-years more distant. Using data from the Very Large Telescope in Chile and the Hubble Space Telescope, Massey's team measured how much the gravity of the nearby galaxy bent the light from the distant galaxy. Those measurements enabled

GENES & CELLS

Pinpointing true cancer mutations

To clarify tumor culprits, study healthy and diseased samples

BY NATHAN SEPPA

Cancer research is increasingly turning to genetics to expose the inner workings of tumors and to guide treatment. But tumor-only analyses offer up many "false-positive" mutations that appear to contribute to cancer but which show up elsewhere in an individual's healthy tissue, a new study finds. Sampling both tumor and healthy tissues might provide a way to sort out truly cancer-causing mutations, the scientists report.

A team of researchers tested tumor tissue and healthy tissue from 815 patients who had various cancers. Using only the tumor analysis, the tests spotted an average of 382 mutations per case that appeared associated with cancer. But nearly two-thirds of these variations, on average, also showed up in healthy tissues, suggesting that they weren't driving the cancer, the authors report in the April 15 *Science Translational Medicine*.

The findings offer a new spin on personalized medicine, which targets mutations in tumors to refine therapy and limit side effects. The mutations that were simultaneously found in tumor and healthy tissues were germline, or hereditary, variations that are present at conception. Coauthor Victor Velculescu, an oncologist at Johns Hopkins University School of Medicine, says that few of these inherited variations predispose people to cancer. The vast majority are simply rare variants that make people different from one another. He calls them "passenger mutations in the germ line," contrasting them with the "driver mutations" that propel the cancer process.

These inherited variants are common and typically have minor effects. But they might occur in particular gene regions and look similar to variations that are related to cancer. "They are masking themselves as cancer mutations," Velculescu says. "We get tricked by these alterations, which are really in all the cells in our body."

When the researchers concentrated strictly on what appeared to be well-known cancer-related mutations in tumors, they found that patients averaged two or three such mutations. But in 48 percent of these patients, at least one of these mutations was a false-positive — it also appeared in healthy tissue.

Analyzing healthy tissue also revealed some hidden pitfalls not apparent in the tumor-only analysis. In 3 percent of the group, healthy-tissue analysis found a potentially detrimental germline mutation predisposing patients to cancer. All but one of these 27 patients

the researchers to map the distribution of mass in the nearby galaxy.

The map revealed a gap of about 5,000 light-years between the galaxy's stars and its dark matter. The stars add up to the mass of about 100 billion suns; the dark matter is roughly 10 times as massive.

Many theories predict that dark matter particles should exert another force on each other in addition to gravity. That force could show itself in galactic collisions by acting as a source of friction when clumps of dark matter meet, potentially causing galaxies' resident dark matter to lag behind as the galaxies' stars effortlessly slide past each other. Assuming that's the case with the galaxy in Abell 3827, Massey's team calculated the minimum size of the hypothetical force field around a dark matter particle — in other words, how closely a pair of particles would have to pass for each to feel the influence of the other. In March, a team including Massey set an upper size limit after observing the collisions of 72 galaxy clusters. The two results give particle physicists a range of values to use to test their theories. ■

were unaware that they carried such a risk. They had no family history, says Velculescu.

"In principle, I completely agree with the notion of studying paired tumor and normal specimens," says Elaine Mardis, a geneticist at Washington University in St. Louis. Tumor-only analysis might have value in very focused testing of known hot spot mutations, she says. But in a clinical setting, it risks providing misleading information.

Analyses that include normal tissues would cost more than current testing but might someday improve cancer treatment, says Velculescu. "Inaccurate genetic information from tumor-only tests can have substantial consequences," such as side effects from inappropriate treatments. Velculescu and coauthor Luis Diaz Jr., also of Johns Hopkins, are cofounders of a gene analysis and testing service that has a patent application pending on some of this work. ■

S. RIGAUD, UNIV. OF TOULOUSE, BAVARIAN STATE ARCHAEOLOGICAL COLLECTION

HUMANS & SOCIETY

Beads suggest hunter-gatherers resisted farming in Northern Europe

Culture clash may have delayed arrival of agriculture

BY BRUCE BOWER

Ancient Europe's agricultural revolution got no love in the north. European hunter-gatherers living near the Baltic Sea clung to their traditional way of life as farming societies sprouted across Central and Southern Europe, a new study suggests.

Clues to ancient Europeans' openness to or rejection of agriculture come from the beads they left behind. From roughly 11,000 to 5,000 years ago, foragers in central and southern regions increasingly adopted ornamental beads favored by incoming farmers, say archaeologist Solange Rigaud of New York University and her colleagues. A transition to these personal decorations, which presumably had social and symbolic meanings, signals broad acceptance of farmers' cultural practices by foraging groups that covered a large swath of Europe, Rigaud's group concludes April 8 in *PLOS ONE*.

Baltic hunter-gatherers continued to make their own brand of beaded ornaments. Belief systems and community practices of these hunter-gatherers must have clashed with those of agricultural newcomers, the researchers say.

The findings fit an emerging view, based on ancient DNA and fossils, that Europeans adopted cultivation, herding and related cultural traits of migrating Middle Eastern farmers in different ways across different regions — and sometimes in fits and starts (*SN: 11/16/13, p. 13*). Previous studies of fossilized human skulls indicate that a mix of foraging and farming populations lived in Southeast and Central Europe as agricultural societies expanded, says archaeologist Ron Pinhasi of University College Dublin. Skull characteristics identify only one population in much of Northern Europe at the time.

Beads used by early Central and Southern European farmers influenced ornaments made by nearby foragers. The beads shown here date to between 7,500 and 7,300 years ago.

Rigaud's bead data demonstrate that Europe's transition to farming "was not just a biological process, but first and foremost a process of cultural transformations," Pinhasi says.

Rigaud and colleagues examined several thousand beads from 212 hunter-gatherer camps and 222 early farming settlements. The team identified 224 bead types previously linked to either foragers or farmers. Bead types were defined based on raw material, shape and the way in which beads were suspended, say, as pendants or as part of bracelets.

A statistical analysis showed that over several thousand years, farmers' distinct beads and bracelets made their way from Southeastern Europe to the Mediterranean and then into Western Europe.

During that time, ornaments typical of Northern European hunter-gatherers, such as perforated animal teeth, remained dominant in the Baltic region.

Rigaud's findings fit with ancient DNA evidence suggesting that there was a delay of several thousand years before farming moved from Southern to Northern Europe, says Wolfgang Haak, a paleogeneticist at the University of Adelaide in Australia. Along with cultural differences, cold temperatures and sandy soils in the Baltic region encouraged a reliance on fishing and hunting, Haak suggests. ■

EARTH & ENVIRONMENT

Stronger quakes could strike other segments of Nepal fault

Magnitude 7.8 temblor released only some stress where Indian, Eurasian tectonic plates collide

BY THOMAS SUMNER

The April 25 earthquake that devastated Nepal, killing thousands, isn't the end of seismic hazards in the region. The magnitude 7.8 earthquake relieved pent-up stress along just one segment of the tectonic plate boundary between India and the rest of Asia. Even larger quakes could strike to the west and to the east, in nearby Bhutan, scientists warn.

Where and how intensely future earthquakes will strike depends in part on the shape of the seismic fault responsible for the Nepal quake, something that scientists don't yet fully understand. But new research in the Himalayas has provided some glimpses into the hidden geology that controls seismic activity across the region. This work suggests that some areas could be even more at risk of strong quakes than previously thought.

"The hazard isn't gone," says Kristin Morell, a geologist at the University of Victoria in Canada. "The Himalayas are a very long mountain belt, and strain is still building up in all the other regions from Pakistan all the way to eastern Tibet."

For about 50 million years, the Indian tectonic plate has been slipping under the Eurasian Plate at a rate of about 15 to 20 millimeters each year. This encounter doesn't always go smoothly. The Indian Plate dives at different angles along various parts of the boundary, from almost level to more than 30 degrees. Steeper angles increase friction between the plates, accumulating energy for centuries that rapidly releases in a matter of seconds in an earthquake. The recent Nepal earthquake's epicenter was along one of these strongly sloping sections.

But when an earthquake hits, it doesn't strike along the full fault. Scientists think this is because of physical barriers along the fault, such as locations where the angle between the two plates changes abruptly. An earthquake triggered on one side of a barrier won't hop over the boundary and spread farther along the fault. The larger an uninterrupted segment, the more powerful the earthquakes it can produce.

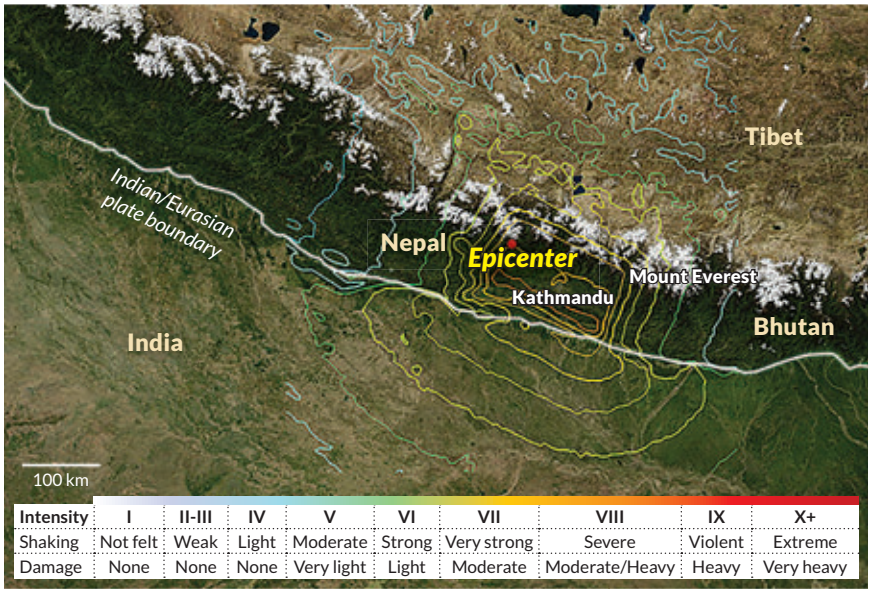
Swaths of the Himalayan fault remain poorly understood, in part because sections of the fault hide tens of kilometers belowground. But researchers have ways to detect the fault's layout indirectly. The buried fault can cause changes on the surface above. Where the Indian Plate dips steeply, it pushes the overlying ground upward. This uplift steepens the terrain and causes more erosion and streams that cut deeper into the ground.

By looking at the surface, Morell and colleagues discerned the structure of part of the fault west of the recent Nepal earthquake. The area included a spot where the angle between the plates rapidly steepens. A magnitude 8.0 or greater quake could happen on either side of this transition, the researchers report online March 12 in *Lithosphere*.

Employing a similar technique farther east along the fault, in Bhutan, a separate research team uncovered a wide segment of the fault with no potential boundaries. This large segment could produce even larger earthquakes than previously expected, the researchers report in a paper to be published in *Geophysical Research Letters*. "If there is a big earthquake in Bhutan, it could be larger than the recent earthquake in Nepal," says study coauthor Rodolphe Cattin, a geophysicist at the University of Montpellier in France.

The fault could be prepped for a big quake to the west of the Nepal quake's epicenter as well, says geophysicist Simon Klemperer of Stanford University. The at-risk fault segment in western Nepal is at least twice as long as the one that recently rattled the country's eastern side and has been building stress since its last major quake in 1505. "The earthquake I worry about is not the one that happened on [April 25]," he says. "It's the one that could be a magnitude 8.6 to the west." ■

Shake zone The April 25 earthquake along the boundary between the Indian and Eurasian tectonic plates (white line) struck northwest of Nepal's capital city, Kathmandu, and radiated seismic waves in all directions. Colored lines indicate the intensity of ground shaking caused by the quake. Shaking on nearby Mount Everest triggered an avalanche.



Intensity	I	II-III	IV	V	VI	VII	VIII	IX	X+
Shaking	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
Damage	None	None	None	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very heavy

GOOGLE EARTH PRO, OVERLAY BY USGS, ADAPTED BY M. TELFER

EARTH & ENVIRONMENT

Bees can't avoid neonicotinoids

New tests find pesticides impair some pollinators

BY SUSAN MILIUS

Bees don't have mouthparts sensitive to taste — and thus can't avoid — nectar tainted with neonicotinoid pesticides, new lab tests indicate. And the allure of nicotine may even seduce bees into favoring pesticide-spiked nectar.

But outdoor tests show that neonicotinoid exposure for some wild bees can be worrisome, a second paper reports. Together, the studies renew questions about the widespread use of these pesticides on crops.

In the mouthpart tests, taste nerves in honeybees and buff-tailed bumblebees showed no jolt of reaction to three neonicotinoid pesticides, says Geraldine Wright of Newcastle University in England. "I don't think they can taste it at all." Bees buzzing among floral riches would therefore be unable to avoid neonicotinoid-tainted nectar, she and colleagues argue online April 22 in *Nature*.

Even though bees don't taste the pesticides, something about their nicotine-related chemistry may bias bees to keep returning to spiked nectar, Wright says. Offered a choice in the lab, honeybees and bumblebees sipped more of the sugar water containing a touch of a neonicotinoid pesticide than the plain sugar water.

Previous studies have reported that neonicotinoid exposure can impair bees' skills at bringing home pollen and nectar, dimming their ability to navigate a landscape, for example. But debate has broken out over how lab studies apply to bees that can pick and choose flowers outdoors and how to interpret results from field studies in complex landscapes.

In the outdoor study, also reported April 22 in *Nature*, scientists paired eight fields in Sweden planted with rapeseeds coated by pesticides including a neonicotinoid with comparable fields sprouting untreated seeds. Honeybee colonies that foraged over treated fields and those that foraged over untreated ones grew at about the same rate, report Maj Rundlöf of Lund University in Sweden and colleagues. But Rundlöf says the study could not detect changes of less than 20 percent in honeybee colony growth. So she advises caution in assuming that the pesticides had no effect on the honeybees.

Two new studies renew questions about the effects of neonicotinoids on honeybees (shown) and wild pollinators.

Also, the Swedish study found that wild *Osmia bicornis* bees nested at six of the eight untreated sites but at none of the treated ones. And bumblebee colonies in the treated fields failed to grow.

"At this point, it is no longer credible to argue that agricultural use of neonicotinoids does not harm wild bees," says Dave Goulson of the University of Sussex in England, who has studied bumblebees. ■

BODY & BRAIN

Catching z's may snag memories too

Sleep study in fruit flies raises hope for Alzheimer's patients

BY LAURA SANDERS

Sleep can restore the memory of profoundly forgetful fruit flies. The finding raises the possibility that promoting sleep in people with Alzheimer's disease and other memory disorders might ease their symptoms.

The flies overcame memory-stealing mutations with some solid rest, scientists report online April 23 in *Current Biology*. "Quite honestly, this is a stunning result," says coauthor Paul Shaw of Washington University in St. Louis. "We take flies that are bad and we make them better."

If the fly research, on *Drosophila melanogaster*, can be translated to people, then "we ought to take the frequent sleep disturbances in the aging population much more seriously," says neuroscientist Maiken Nedergaard of the University of Rochester Medical Center in New York. It's possible that even simple sleep-promoting habits such as exercise and less caffeine might benefit people with memory trouble, she says.

Fruit fly sleep actually looks a lot like people's: Sleeping flies hold very still and are hard to rouse. Shaw and his colleagues increased sleep time in flies that had several different mutations known to cause severe memory problems.

When coaxed to sleep more with the drug THIP, these formerly befuddled flies got sharper. In a test of short-term memory, flies better remembered to avoid an area laden with the nasty chemical quinine. These flies could also hold a memory over several days. Males learned not to waste time courting male flies that smell like females: Two days after the failed courtship, these males remembered their rejection and didn't attempt to woo their unwilling recipients.

The team got the flies to conk out two other ways, too — by activating certain brain cells and by increasing the levels of a protein. Both methods also led to memory boosts, suggesting that the benefits are due to sleep and not a drug.

Sleep also improved the long-term memory of flies with mutations in the fly version of *Presenilin*, a gene linked to familial early-onset Alzheimer's.

The results tie into a growing body of work that's revealing a complex relationship between sleep and Alzheimer's, says neurologist Mark Wu of Johns Hopkins University. "It's a stretch to suggest that sleeping would cure memory problems," he says. "But there's a potentially important relationship between sleep and Alzheimer's disease." ■

M. RUNDLÖF

GENES & CELLS

Contagious cancer found in clams

Third example of transmissible malignancy no threat to people

BY TINA HESMAN SAEY

A leukemia-like disease in soft-shell clams is a contagious cancer that spreads from clam to clam, a new study finds.

The disease probably originated in a single soft-shell clam at least 40 years ago, researchers report in the April 9 *Cell*. Cancer cells somehow migrated to other clams and infected them, eventually spreading the disease up and down the eastern North American coast from Canada's Prince Edward Island to the Chesapeake Bay.

It is not clear how the disease moves or whether the cancer cells can infect other mollusks. What's certain is that the disease is not dangerous to people. "It's only a shellfish health issue. It's not a human health issue," says Bruce Barber, an invertebrate pathologist at Eckerd College in St. Petersburg, Fla.

Although some viruses are known to cause cancer, only two other transmissible cancers have ever been described. One is a nonfatal venereal tumor in dogs, and the other is a facial tumor that has decimated Tasmanian devil populations (*SN: 4/20/13, p. 10*).

The clam disease was first noticed in the 1970s when soft-shell clams (*Mya arenaria*) in the Chesapeake Bay and in Maine started dying in large numbers. Scientists originally thought that water pollution was responsible, Barber says. But researchers soon noticed that the cancer could spread from sick clams to healthy ones even in clean water. During the 1980s and 1990s, scientists began testing whether a virus might be involved.

Carol Reinisch, a marine biologist at Environment Canada in Burlington, suspected that the clam leukemia was spread by retroviruses. Retroviruses, such as HIV and several types of leukemia-causing viruses, carry their genetic information in RNA. When retroviruses infect cells, they make a DNA copy of their genomes and insert the copies into the host's DNA. The host then produces viruses that can go on to infect other cells. In 2009, Reinisch contacted Stephen Goff, a virologist at Columbia University who studies retroviruses that cause cancer in mice, for help.

> Cancer cells may float through seawater and get into the clams as the mollusks filter the water to feed.

Last year, Goff and colleagues reported that clams weren't infected with a retrovirus, but they did carry a retroelement called *Steamer*. Retroelements — also called transposable elements or jumping genes — are similar to retroviruses in that they insert into a host's genome. But unlike retroviruses, retroelements don't move to other cells or organisms.

Healthy clams may carry two to 10 copies of *Steamer*, but sick clams have 150 to 300 copies. Still, it wasn't clear whether or how *Steamer* gave the clams cancer. So Goff's group examined where in the sick clams' genome the retroelement landed, sampling clams from multiple locations along the Eastern Seaboard.

"That's when we got thrown for a loop," Goff says. "The integration sites in tumors were the same all up and down the coast. That's impossible. That's not the way retroelements work."

More investigation revealed that all of the cancer cells — which resemble out-of-control white blood cells — were nearly genetically identical. But the cancers were genetically different from the clams they were living in. Those findings indicate that the cancer cells themselves spread from clam to clam.

The evidence that the leukemia-like disease is contagious is "completely convincing," says Elizabeth Murchison, a geneticist at the University of Cambridge who studies transmissible cancers. "It really shows that this type of disease can occur in unexpected ways."

Dogs pass cancer during mating. Tasmanian devils bite each other, transferring cancer cells in the bite. But clams don't bite each other, nor do they mate the way dogs do. Instead, the researchers speculate, cancer cells may float through seawater and get into the clams as the mollusks filter the water to feed. That possibility remains to be tested.

Exactly what the diagnosis will mean for the clams, which are still dying, is unknown. "The results are compelling and interesting but need follow-up," says S. Anne Boettger, a physiological ecologist at West Chester University of Pennsylvania. Researchers need to know more about how the cancer cells get in and out of the clams and how the retroelement is involved in the disease, she says.

Fishermen and ecologists are concerned with how to stop the cancer. Chemotherapy is commonly used to treat cancer in humans and dogs, but "dumping something like a chemotherapeutic agent into the water is probably not a good way of dealing with this," Boettger says. Instead, the solution may be identifying clams that are resistant to the disease and breeding them. ■

Soft-shell clams wait on a laboratory bench to be tested for a newly discovered contagious cancer that can kill them.

MICHAEL J. METZGER

ATOM & COSMOS

Looking ahead to Hubble's future

Telescope will probe cosmic expansion, alien atmospheres

BY CHRISTOPHER CROCKETT

A technique used by the Hubble Space Telescope to probe exoplanet atmospheres may help scientists measure the distances to type 1a supernovas, such as this one lurking behind a galaxy cluster.

NASA, ESA, S. PERLMUTTER/LBNL/UC BERKELEY, A. KOEKEMOER/STSCI, M. POSTMAN/STSCI, A. RIESS/JHU, J. NORDIN/LBNL/UC BERKELEY, D. RUBIN/FLORIDA STATE UNIV., C. MCCULLY/RUTGERS UNIV.

BALTIMORE — A technique for sniffing around in the atmospheres of supersized planets near superbright stars could also help the Hubble Space Telescope unravel the history of the universe.

Hubble scientists developed a way to slowly scan the sky while collecting starlight so the telescope could explore the neighborhoods of stars that would otherwise be too bright for its sensitive detectors. It turns out that this trick also enables astronomers to measure distances to nearby stars with unprecedented precision, helping to zero in on the expansion rate of the universe and why it's picking up speed.

This surprising connection is just one revelation to come out of a four-day symposium at Hubble's headquarters, the Space Telescope Science Institute in Baltimore. Astronomers gathered there April 20–23 to celebrate the 25th anniversary of the orbiting observatory, which rocketed into space April 24, 1990 (*SN: 4/18/15, p. 18*). They also looked ahead to what the telescope can accomplish in its remaining years.

Hubble is the premier instrument for dissecting distant skies, says astronomer Heather Knutson of Caltech. Knutson uses Hubble to examine the atmospheres of super-Earths, planets a few times as massive as Earth. Atmospheres maintain records of how planets form.

But many of the planets Knutson would like to examine orbit stars that are too bright for Hubble's sensitive detectors. She gets around this by directing Hubble to slowly turn while collecting light, which causes the star to drift across the telescope's field of view. Rather than blasting a small cluster of pixels, the light trickles across the detector, preventing any one area from being overwhelmed.

Knutson and colleagues have requested time with Hubble to examine the atmosphere of a super-Earth recently discovered by the revived Kepler space telescope. Designated EPIC 201912552b, the planet would be the first super-Earth in a habitable zone — the region around a star where liquid water can exist on a planet's surface — to have its atmosphere measured. Researchers hadn't planned on making such measurements until at least 2018, after the launch of Hubble's successor, the James Webb Space Telescope. "Hubble could scoop James Webb," Knutson says.

Knutson hopes to measure the ratio of carbon to oxygen in the atmosphere of this potentially habitable world. The relative abundance of those elements can help researchers pinpoint where the planet formed. The planet is also cool enough, she says, to detect methane or ammonia if there's any around.

Adam Riess, an astrophysicist at Johns Hopkins University, has set his sights a bit farther out — more than halfway across the known universe. He is using a class of exploding stars known as type 1a supernovas to track the expansion rate of the universe, a number known as the Hubble constant (*SN: 4/5/14, p. 18*).

One of the biggest obstacles to getting better precision, Riess says, is measuring distances to stars within the Milky Way that he and his colleagues can use to calibrate the brightness of type 1a supernovas. The scanning trick that helps Knutson, it turns out, is perfect for clearing this hurdle.

When triangulating the distance to a nearby star, astronomers must precisely measure the position of the star relative to other stars. By scanning the telescope instead of holding it steady, researchers can measure the positions of lines of starlight instead of points, thereby averaging out many errors that creep in. It's like getting thousands of observations in one snapshot, Riess says.

Based on earlier tests, Riess says that this trick will reduce uncertainties in the Hubble constant by half within the next year. Such improvements have a whopping effect on how precisely astronomers can measure the effect of dark energy, the repulsive force that is pushing the universe apart at an ever-increasing rate.

The symposium helped drive home Hubble's flexibility, says astronomer Steve Rodney of Johns Hopkins. From alien worlds to the evolution of the universe, Hubble is pushing at frontiers undreamed of 25 years ago. And despite no hope for repairs should any parts break, astronomers are optimistic that the "people's telescope" has at least a few more good years left. ■

LIFE & EVOLUTION

Shimmer sabotages predators' aim

A peck-the-bug computer game for quail shows that some of nature's most spectacular coloring might be peacock obvious to the eye but tricky for a predator to grab. In lab tests, it took birds almost four tries on average to nail an iridescent bug target (roughly inspired by the coloring of a greenbottle fly, right) as it moved across a gray screen, says Tom Pike of the University of Lincoln in England. The birds pecked similar targets without the shimmer in fewer than three tries on average. And the birds struck closer to the target center on the plain bug stand-ins than on the iridescent ones, Pike reports in April's *Biology Letters*. This unusual test bolsters the idea that flashy, changeable coloration might offer certain animals a measure of protection from predators. — *Susan Milius*

EARTH & ENVIRONMENT

Giant magma pool beneath Yellowstone

The supervolcano lurking under Yellowstone National Park belches up 45,000 metric tons of carbon dioxide every day — much more than could be produced by the known magma chamber that lies just below the surface. Now, scientists have spotted a source of the excess gas, and it's a doozy: a magma pool containing enough hot rock to fill the Grand Canyon 11 times, the researchers report online April 23 in *Science*. Hsin-Hua Huang of the University of Utah in Salt Lake City and colleagues found the magma by tracking seismic waves from nearly 5,000 earthquakes that echoed off the volcano's insides. The magma reservoir, which extends 20 to 50 kilometers belowground, connects the near-surface magma chamber to the deeper magma-oozing hot spot that fuels the volcano. At 46,000 cubic kilometers, the reservoir holds more than four times the volume of the smaller chamber. The reservoir is only 2 percent melted rock and too deep to contribute to a supervolcanic eruption like the one that formed the Yellowstone caldera about 640,000 years ago (*SN: 10/4/14, p. 32*). Though the odds of an impending Yellowstone doomsday remain exceedingly slim, the find should help volcanologists better assess the hazards posed by the supervolcano. — *Thomas Sumner*

BODY & BRAIN

Pulling fingers to see why knuckles crack

Knuckles crack when a bubble forms in a joint, new high-speed images reveal. The finding, reported April 15 in *PLOS ONE*, may settle a decades-old debate about the source of the sound. Gregory Kawchuk of the University of Alberta in Canada and colleagues used magnetic resonance imaging, or MRI, to watch what happened as they slowly pulled a man's finger until his knuckle cracked. As the finger was pulled, tension mounted in the knuckle joint and fluid rapidly accumulated, showing up as a white spot on the MRI picture. Then a cavity suddenly opened, producing the pop, much like the way a suction cup being pulled off a window does, Kawchuk says. The researchers hope to repeat the study with more people, including some who can't crack their knuckles and some with joint diseases. Despite old wives' tales, the ability to crack knuckles may be a sign of healthy joints, the researchers say, and therefore useful for monitoring joint health. — *Tina Hesman Saey*

ATOM & COSMOS

Cosmic rays misbehave in experiment

A new census of charged particles buzzing through space includes a puzzling feature that challenges predictions about how these particles originate. The results, presented April 15 at a conference in Geneva, may force scientists to rethink theories that focus on supernovas as the producers of these speedy particles. Installed on the International Space Station in 2011, the Alpha Magnetic Spectrometer collects and identifies cosmic rays, charged subatomic particles that permeate the galaxy (*SN: 3/21/15, p. 22*). Based on the previously measured concentrations of galactic cosmic rays, many scientists suspect that the particles get flung toward Earth in the shock waves of exploding stars. But the new analysis of 300 million protons and 50 million helium nuclei adds a wrinkle to the shock wave explanation. While the number of particles observed generally drops steadily as their energy increases, the rate of that drop abruptly decreases. The shock wave scenario doesn't support that sudden rate change, says Francis Halzen, an astrophysicist at the University of Wisconsin–Madison who attended the conference. The measurement, which confirms less precise findings from previous experiments, suggests an additional source of cosmic rays. "This structure really challenges our notions about the origin of galactic cosmic rays," Halzen says. — *Andrew Grant*

MATTER & ENERGY

An even more precise atomic clock

The world's best timepiece just got even better. An atomic clock described April 21 in *Nature Communications* is about three times as precise as its record-setting predecessor. The clock, which builds off an earlier prototype, would not lose or gain a second in roughly 15 billion years. And raising it just 2 centimeters off its surface would perceptibly change its ticking rate due to the slightly weaker pull of Earth's gravitational field. Future generations of atomic clocks could precisely trace Earth's shape and form the basis of a global timekeeping network. — *Andrew Grant*

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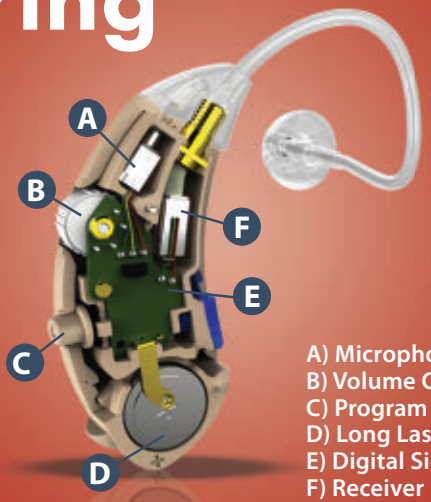

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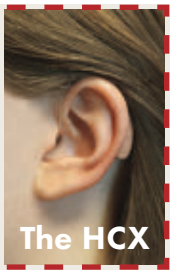
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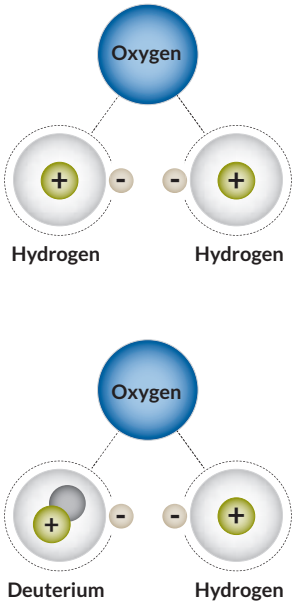
WATER, WATER EVERYWHERE

Every bit of Earth's H_2O was delivered by space rocks, but which ones?

By Christopher Crockett



Heavy stuff When one or both hydrogen molecules in water is replaced by deuterium, the heavier water offers a means to trace where it came from within the solar system.

Earth — a planet of oceans, rivers and rainforests — grew up in an interplanetary desert.

When the solar system formed about 4.6 billion years ago, shards of calcium- and aluminum-rich minerals stuck together, building ever-larger pebbles and boulders that smashed together and assembled the rocky planets, including Earth.

But Earth's signature ingredient was nowhere to be found. Heat from the young sun vaporized any ice that dared to come near the inner planets. Earth's relatively feeble gravity couldn't grab on to the water vapor, or any other gas for that matter. And yet, today, Earth is a planet that runs on H_2O. Water regulates the climate, shapes and reshapes the landscape and is essential to life. At birth, humans are about 78 percent water — basically a sack of the wet stuff.

To get water, Earth had to have help from somewhere else.

Researchers recently found traces of Earth's aquatic starter kit locked away inside several meteorites, chunks of rock that fell to the planet's surface. Those meteorites were a gift from Vesta, the second largest body in the asteroid belt between Mars and Jupiter. Vesta is thought to have formed earlier than Earth, roughly 8 million to 20 million years after the start of the solar system. (Earth needed 30 million to 100 million years to pull itself together.)

Well before the rocky planets formed, recent research suggests, ice-infused asteroids were forged beyond Jupiter and subsequently swarmed the inner solar system. These space rocks delivered water to Vesta and to Earth after being hurled at our planet by the gravity of Jupiter and Saturn. Whether the giant planets were a help or a hindrance is anybody's guess. But if what happened here can happen anywhere, then water might be prevalent on other worlds, giving life a good chance of thriving throughout the galaxy.

Comets vs. asteroids

For decades, researchers have debated whether comets or asteroids delivered Earth's water. At first glance, comets seemed a likely source. Originating beyond the orbit of Neptune, comets are the deep-freeze storage units of the solar system. They hold a lot of ice that has been locked away within their interiors since the formation of the solar system. Some comets are occasionally thrown inward after a close brush with a planet or passing star. It makes sense that, during the chaos

FROM TOP: NASA; NASA/GFSC, ADAPTED BY M. TELFER

of the early solar system, Earth would have been pummeled with comets, bringing plenty of water to fill the oceans.

In recent years, however, the comet hypothesis has lost favor. "It looks like comets are pretty much out," says cosmochemist Conel Alexander of the Carnegie Institution for Science in Washington, D.C. Most of the comet water tested so far doesn't match that of Earth's oceans. Plus, it's incredibly difficult to bring a comet toward Earth, much less a whole slew of them. "It just shouldn't be part of the discussion anymore," he says.

Part of the problem lies in a subtle chemical difference between water on Earth and water in most comets. Water is a simple molecule resembling a pair of Mickey Mouse ears: two hydrogen atoms grab a single oxygen atom. But sometimes deuterium, a slightly heavier version of hydrogen, weasels its way into the mix. The nucleus of a deuterium atom contains one proton and one neutron; in hydrogen, the proton stands alone. On Earth, only about 156 out of every 1 million water molecules contain deuterium.

Researchers have long used the relative amount of deuterium compared with hydrogen — known as the D/H ratio — to trace water back to where it originated. At colder temperatures, deuterium starts to show up in ice more frequently. So bodies that formed in the frigid backwaters of the solar system, such as comets, should be enriched in deuterium, whereas the water vapor that swirled around the infant Earth should have little to none.

Most comets appear to follow that logic; their D/H ratio is typically about twice what has been measured on Earth.

Two comets, however, threw a curveball at scientists who had counted out comets as the source of Earth's water. In 2010, researchers used the Herschel space telescope to measure the D/H ratio of comet 103P/Hartley 2. They reported that 103P's water nearly matched that found on Earth. Observations of comet 45P/Honda-Mrkos-Pajdušáková three years later also found abnormally low D/H ratios. Suddenly one, possibly two, comets were carrying Earthlike water.

Jupiter's pull

Both of these comets are part of a community known as Jupiter family comets. They originated in the Kuiper belt, the ring of icy debris beyond Neptune where Pluto lives. The gravity of first Neptune and then Jupiter gradually nudged these comets into relatively short orbits that bring them closer to the sun. All previous D/H measurements were of comets that hail from the far more distant Oort cloud, a shell of ice fragments that envelops the solar system. Comets 103P and 45P suggested that researchers may have been hasty in dismissing all comets as Earth's water source. Perhaps just the Jupiter family comets were responsible.

But then in 2014, the European Space Agency's Rosetta probe arrived at Comet 67P/Churyumov–Gerasimenko, another Jupiter family comet. As the spacecraft sidled up to the comet, it sampled the water streaming from the comet body and found 67P's D/H ratio to be staggeringly high — more than three times that of Earth's oceans (*SN: 1/10/15, p. 8*).

"Each new comet measurement is giving us a different picture," says Karen Meech, a planetary scientist at the University of Hawaii in Honolulu. The Rosetta results show that even among a single family of comets, there is incredible diversity in water composition. "Comets formed over a huge range of distances, so it's no surprise that there's a huge range in D/H," she says.

But even if some comets have an Earth-like D/H ratio, it's still really hard to get comets to hit our planet in the first place. "Any comet that's going to bash into Earth has to get past this really big linebacker of Jupiter," says planetary scientist Sean Raymond of the Laboratoire d'Astrophysique de Bordeaux in France. Jupiter has a tendency to take comets that come too close and fling them out of the solar system. The few that do end up on Earth-crossing orbits don't stay there for long.

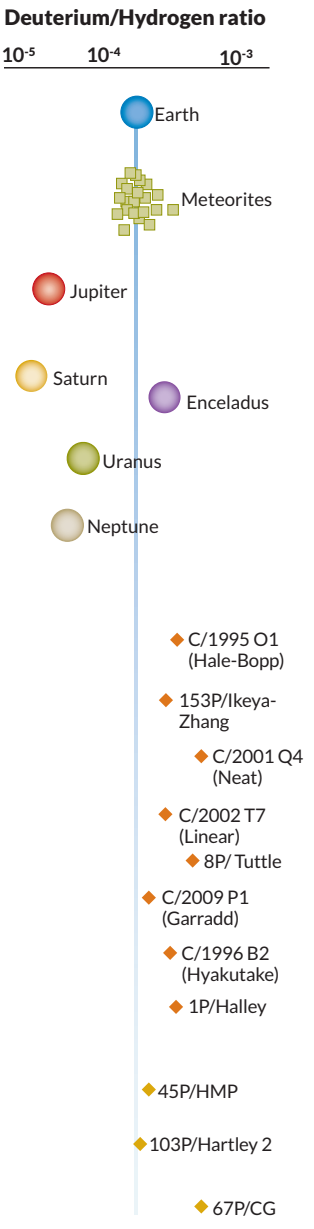
"The comet only has a certain number of tries to get in close and either hit Earth or get scattered on to another orbit," Raymond says.

So Jupiter's gravity may be too big a hurdle for comets to overcome. But it may be just the ticket for flinging asteroids at the inner planets.

A more 'tack'-ful approach

In 2011, a team of researchers including Raymond were tackling a different problem: Why is Mars so small? There should have been plenty of raw material available 4.6 billion years ago to turn Mars into a planet closer in size to Venus or Earth. But Mars is just about half Earth's diameter and about one-tenth its mass. One possible explanation is that something prematurely robbed the nascent Red Planet of its building blocks.

One solution, known as the Grand Tack model, describes a solar system far less sedate than the one we inhabit today (*SN Online: 3/23/15*). In the Grand Tack scenario, Jupiter and Saturn stride



Different flavors
The ratio of deuterium to hydrogen, the D/H ratio, varies widely among solar system bodies. The makeup of Earth's water overlaps with water trapped in certain meteorites (green squares). Comets from the Oort cloud (orange diamonds) and the Kuiper belt (yellow diamonds) typically have two times the D/H ratio as water on Earth, though a couple comets are a close match.

K. ALTWEGG *ET AL*/*SCIENCE* 2015, ADAPTED BY M. TELFER

20
percent
Water's share of the mass in some asteroids

0.023
percent
Portion of Earth's mass composed of water

back and forth across the solar system like schoolyard bullies, hurling rocks at and stealing food from the other planets. The gas that encircled the sun dragged Jupiter and then Saturn inward. Once Jupiter arrived at about the current orbit of Mars, a gravitational tug from Saturn flung both back out from where they came (the "tack" in "Grand Tack"). Jupiter's encroachment on the inner solar system carved a gap in the debris field from which the rocky planets were forming, depriving Mars of raw ingredients.

The same planetary tango that robbed Mars of resources might also explain how icy asteroids pummeled Earth. As Jupiter and Saturn wandered back out, their gravity latched on to asteroids that formed beyond the snow line — the boundary beyond which temperatures are low enough for ice to form — and flung them inward. About 1 percent of these ice-infused boulders, known as C-type asteroids, were dropped into the outer regions of the asteroid belt. But for every C-type asteroid relocated to the belt, at least 10 were sent careening into the region where the rocky planets were materializing.

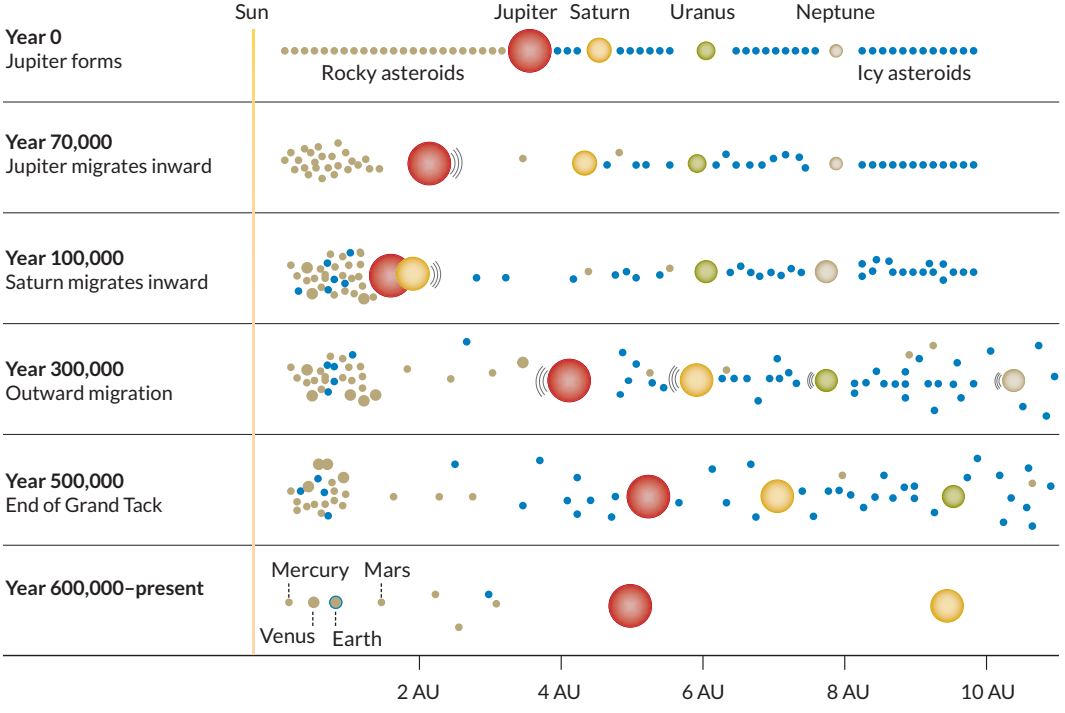
This bombardment of asteroids a few million years after the start of the solar system could have easily delivered enough ice — locked inside the rocks, safe from the sun's heat — to account for Earth's oceans, computer simulations indicate. Water makes up to about 20 percent of the mass of some of these asteroids. On Earth, despite having more than 70 percent of its surface blanketed in blue, water accounts for only 0.023 percent of the planet's mass. Compared with some asteroids, Earth is positively parched.

The Grand Tack nicely explains the formation of Mars, the layout of the asteroid belt and the delivery of water to Earth via icy asteroids. But Raymond stresses that it's just one way to match all the data. "It's an evolution of thinking," he says. "It's not meant to be a final solution."

The same D/H ratio that exonerated comets is now pointing a finger at these asteroids. In 2012, Alexander and colleagues concluded in the journal *Science* that the bulk of Earth's water arrived via bodies similar to a class of meteorites known as CI carbonaceous chondrites. Researchers think that these meteorites, which were knocked off asteroids that formed beyond Jupiter, are among the oldest objects in the solar system.

Alexander's research, along with that of many others, builds a strong case for a chemical match between Earth's water and chondrites' water. But it doesn't address when the water arrived. Brown

Stirring the pot As Jupiter and Saturn paced back and forth in the early solar system, they rearranged the rock and ice debris encircling the young sun, as seen in this schematic. Some of the icy asteroids that formed beyond the orbit of Jupiter would then have flocked to the inner solar system, water in tow, and become incorporated into the nascent rocky planets, including Earth. An astronomical unit (AU) is the distance between the sun and Earth.



EXOCLIMES.COM/F. PONT, ADAPTED BY M. TELFER

University geologist Alberto Saal argues that part of the answer lies on the moon.

The bounty of lunar samples brought to Earth by Apollo astronauts included volcanic glass hauled in during the Apollo 15 and 17 missions. The glass formed from rapidly cooling magma that was spat out from the moon's interior long ago. In 2013, Saal and colleagues reported in *Science* that the D/H ratio of water trapped within the glass matched that measured in both Earth's oceans and Alexander's carbonaceous chondrites (*SN: 6/29/13, p. 8*). Saal's findings suggest two things: Earth and the moon have a common source of water and the water was already here when the moon formed.

The moon started with a literal bang. A planet the size of Mars is thought to have smashed into Earth toward the end of our planet's formation. The collision blasted part of Earth, as well as the unfortunate interloper, into a ring of vaporized rock that encircled Earth before sticking together to build the moon (*SN: 7/12/14, p. 14*). Water must have been present at the time of impact for it to be sealed into the moon, Saal notes, or it at least arrived before the moon's surface had time to cool and solidify. This puts water near Earth about 150 million years after the start of the solar system. But based on the moon data alone, we can't say how much earlier, says Sune Nielsen, a geologist at the Woods Hole Oceanographic Institution in Massachusetts.

To narrow in on a more precise time for water's arrival, researchers have turned to the asteroid Vesta. Or, more specifically, meteorites nicked off Vesta after the asteroid got whacked by another space rock. Woods Hole geologist Adam Sarafian, Nielsen and colleagues analyzed small amounts of water trapped within minerals of apatite locked inside a sample of Vesta meteorites. The team reported last fall in *Science* that the D/H ratio of the meteorites' water matched Earth's. That discovery implies that whatever delivered Vesta's water brought along Earth's as well and that this water had to have arrived before Vesta finished forming (*SN Online: 11/1/14*).

That finding pushes the influx of water back, possibly as early as 8 million years after the start of the solar system. This is the oldest stockpile of water ever dated in the solar system, Nielsen says. These observations place water in the inner solar system well after Jupiter and Saturn were on the prowl, lobbing asteroids around the solar system.

Nailing down how and when water arrived at Earth is about more than just understanding how our planet was built. "If you have to have some sort of external delivery mechanism for getting water to terrestrial planets," says Alexander, "it becomes harder to make a habitable planet." Rocky planets forming around other stars will face the same problem that Earth faced. These planets in the habitable zones of their stars, while able to support liquid water on their surfaces, develop in dry environments and need to have ice sent in from farther out. Did Earth get lucky by having Jupiter and Saturn as neighbors, or are there other ways to move water around?

Water trapped in meteorites from the asteroid Vesta (left) closely matches the composition of Earth's oceans. Comets such as 67P/Churyumov–Gerasimenko (right) have, in general, too much deuterium to be Earth's primary water source.

Just because Earth formed one way doesn't mean all habitable planets must follow the same path. "I would be cautious," Nielsen says, about saying that gas giants are the only way to bring water to rocky planets.

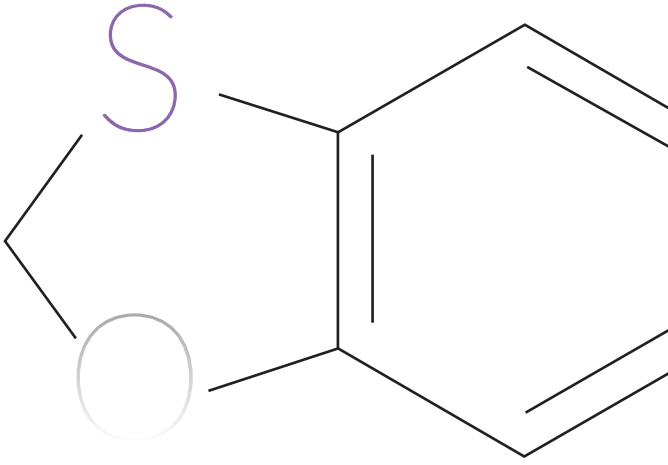
In fact, gas giants may even be a hindrance. "Jupiter and Saturn just screw things up," says Raymond. Their gravity is strong enough that they tend to kick asteroids and comets right out of the solar system. If Jupiter and Saturn didn't exist, he notes, Earth's gravity could have stolen 10 times as much water from the outer edge of the asteroid belt. In the absence of giant planets, water delivery could happen naturally as planets pull in debris from different parts of the solar system. Recent observations from the Kepler space telescope suggest that planets the size of Jupiter are relatively uncommon around other stars. Perhaps most habitable planets do just fine on their own.

If that's the case, then maybe the galaxy is teeming with ocean worlds waiting to be discovered. "From my point of view," Raymond says, "having water on a planet like Earth is an everyday occurrence." ■

Explore more

- Alessandro Morbidelli *et al*. "Building terrestrial planets." *Annual Review of Earth and Planetary Sciences*. May 2012.

DRUGS



Corrupt chemists tweak compounds faster than law enforcement can call them illegal

By Kate Baggaley

The 18-year-old had stabbed himself four times in the neck and chest with a pair of scissors. Alone in his dorm room, he had suddenly felt trapped, convinced that the only way to get out was to kill himself.

When he woke up hours later in a pool of blood, the psychedelic trip that had gripped him was waning. Horrified, he managed to call an ambulance. As he recovered, the college student told Joji Suzuki, an addiction psychiatrist at Brigham and Women's Hospital in Boston, that he had taken LSD.

Suzuki was suspicious. Months earlier, in the summer of 2013, another student had come in with stab wounds in his back. He claimed to have taken magic mushrooms and said that he had stabbed himself. But psychedelic mushrooms don't make people violent, and stabbing oneself in the back is not easy to do. Suzuki suspects that the young man with the back wound may have been covering for a friend who was also high. A month later the student was back. He spent five days delirious in the hospital's intensive care unit, claiming he had taken LSD.

Violence and delirium are not usual effects of LSD. "Even in an overdose, LSD won't lead to a five-day agitated delirium in the ICU," Suzuki says. "I knew then that this had to be something else."

By the time the scissors-wielding student arrived, Suzuki was better prepared. He had found a lab that could test for a little-known hallucinogen called 25I-NBOMe. Sure enough, the student's blood tested positive. Maybe he thought he was taking LSD, but he had actually ingested a new, more dangerous hallucinogen from of family of drugs called smiles or NBOMes (pronounced en-bombs). People who take NBOMes are prone to stab themselves, says Suzuki, who reported the case in November in the *Journal of Psychoactive Drugs*. "We see it so many times. It's bizarre."

NBOMe overdoses have been appearing in U.S. emergency rooms since around 2012, but little is known about the drugs. They are one of many designer drugs, produced as alternatives for classic but illegal substances such as cocaine, LSD and marijuana. Some of the most popular designer drugs are hallucinogens such as NBOMes, stimulants such as bath salts (named for their resemblance to Epsom salts) and spice — synthetic cannabinoids that mimic marijuana. Each one comes in versions that are more dangerous than the drugs they were made to replace.

When a designer drug first appears for sale — often in gas stations, convenience stores or online — it is technically legal, because its chemical structure is slightly different from the illicit drug it mimics. When the U.S. Drug Enforcement Administration gets wind of the new drug, the agency moves to label the drug "Schedule 1," meaning that it is not safe and has no known medical use. Dodgy chemists will then tweak the structure a bit and release another wave of slightly different, legal-until-they-get-noticed drugs.

They pack a punch New designer drugs can emulate the highs that users get from classic compounds, but many come with nasty side effects of their own. A synthetic cannabinoid, or spice (left), can be rolled and smoked like marijuana, but may be a riskier choice. SOURCES: U.S. DEA/*DRUGS OF ABUSE* 2011; J. SUZUKI *ET AL*/*PSYCHOSOMATICS* 2015

Designer drug	Classic drug	Shared desired effects	Designer drug's negative effects
Spice	Marijuana	A mellow high	Psychosis, stroke, heart attack, kidney damage
NBOMes	LSD	Psychedelic trips, hallucinations	Delirium, paranoia, violence, seizures, racing heart, spiking blood pressure
Bath salts	Cocaine, amphetamines	Euphoria, alertness, energetic high	Excited delirium, dehydration, hyperthermia, muscle breakdown, kidney failure

CHEMICAL COMPOUND: E. OTWELL; PHOTO: © MARK HARVEY/ALAMY

BY DESIGN

Bath salts (above) are packaged as a product one might use in the tub. They've been linked to deaths.

A lot of the drugs seen on the street today haven't even been tested in animals, much less in humans, says Jenny Wiley, a behavioral pharmacologist at RTI International in Research Triangle Park, N.C. "People are basically the guinea pigs."

Though designer drugs have been around for decades, there's been a recent surge in new compounds, says Jill Head, a forensic chemist at a DEA research lab in Dulles, Va. "In the last five or six years we've seen upwards of 350, almost 400 new drugs emerge."

And each one is somewhat different. "Every drug has its own little story," says Michael Baumann, who heads the Designer Drug Research Unit, a small team within the National Institute on Drug Abuse in Baltimore. When a new drug appears, it's up to chemists, pharmacologists and researchers like Baumann to quickly develop tests that will detect the drug in a person's system and figure out how it works. They want to know the risks it poses and how best to treat people who have bad reactions.

Spicing up drug testing

Though recreational marijuana is legal in four states and the District of Columbia, synthetic cannabinoids are still in demand. Pot remains illegal for people under age 21. Plus, military personnel, police officers, parolees and athletes are all routinely screened for marijuana and other drugs. A big benefit of the newcomer drugs: Commonly used tests don't look for them.

To improve such testing, Marilyn Huestis, a forensic toxicologist at NIDA, wants to identify the breakdown products of spice and other designer drugs. "The problem is that we're always behind the manufacturers," she says. "As quickly as a drug becomes [illegal], immediately other drugs are available on the market."

To evaluate any new compound, she incubates a sample of the drug with pieces of human liver cells to see how long it takes the cells to break down the compound. The test "tells you something about the potential danger of that drug," she says. A drug that is slowly metabolized "is going to be active in the body for a longer period of time."

Huestis then investigates how the drug's structure changes when the body metabolizes it. For a given drug, she generally finds 12 to 25 different metabolites and identifies the most common ones, so testers can focus on the easiest-to-find compounds in blood or urine samples.

Like many designer drugs, spice has its origins in the scientific literature, Huestis says. Researchers created synthetic cannabinoids in the 1980s as tools to understand the body's endocannabinoid system, which is involved in learning, memory, appetite, fighting disease and pain. Chemists were trying to make a compound that could snugly fit into endocannabinoid receptors, proteins that sit on the outside of cells and act as the system's gateway. They hoped that finding a key to unlock these receptors might lead to more effective painkillers.

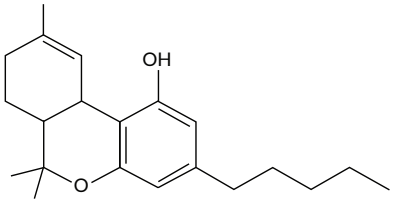
"The folks that were making these never in their wildest dreams thought that [the compounds] would be diverted as drugs of abuse," Baumann says.

But inevitably, clandestine chemists discovered how well synthetic cannabinoids replicate the effects of weed, and started pumping them out. The first five synthetic cannabinoids were declared illegal in 2011.

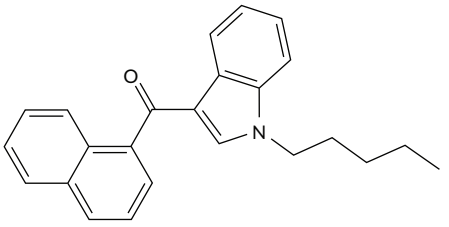
"People tend to think, well gee, cannabis really isn't bad for you, how can these be bad for you? But the potency makes a tremendous difference," Huestis says. Some forms of spice are up to 100 times as potent as weed — a small amount can have a big effect, she adds.

Though many people use the drugs without incident, some forms of spice can cause strokes, heart attacks and kidney damage, she says. Psychosis is also a big problem.

Old blueprints Some designer drugs have chemical structures that resemble those of plant-based drugs; others are distant cousins. JWH-018, a version of spice, has a very different structure from marijuana's active ingredient THC, but has similar effects. MDPV, on the other hand, is a bath salt ingredient with a structure similar to the khat plant's cathinone, which is also a stimulant. Hallucinogens known as NBOMes, although ingested like LSD, are chemically similar to mescaline.



THC (marijuana's active ingredient)



JWH-018

The rat brain on bath salts

Most of Baumann's research has focused on bath salts, drugs designed to mimic a stimulant called cathinone. Cathinone occurs naturally in the khat plant, which grows on the Arabian Peninsula and in East Africa. Chewing the leaves gives a stimulating boost like that from drinking a cup of coffee, Baumann says. Synthesized by chemists, bath salts are more intense.

Typically sold as a powder, bath salts produce feelings of euphoria and alertness similar to the effects of amphetamines and cocaine, but some chemical forms are even more powerful. MDPV, the most infamous component of the original wave of bath salts, can bring on a powerful crash involving suicidal feelings, delirium and violence. This crash may happen because bath salts thwart communication between parts of the brain — and connectivity gets weaker with higher doses, according to research in rats by Marcelo Febo, a neuroscientist at the University of Florida in Gainesville. He presented the study last year at the Society for Neuroscience annual meeting (*SN: 12/13/14, p. 12*).

Snorting one line of bath salts can be like doing 10 lines of cocaine, Baumann says. It's much more potent than what people are used to. High doses or repeated use of bath salts can cause excited delirium with raised body temperature, muscle breakdown and kidney failure. "People die from bath salts," Baumann says. The biomedical literature is peppered with many more cases of deaths from bath salts than from synthetic cannabinoids.

Bath salts boost dopamine, a reward and pleasure messenger molecule, in the territory between nerve cells in the brain.

Bath salts are sometimes sold as household products (plant food or jewelry cleaner) and labeled "not for human consumption." DEA spokesperson Barbara Carreno calls this approach "a cynical attempt on the part of the marketers" to create a defense for themselves in case they get caught and go to court.

This is what makes the drug so irresistible to users over time. "We know that anything that pops up dopamine to a significant degree ... is going to be addictive," says Baumann.

Bath salts swell dopamine levels by disrupting the transporter molecules that normally carry dopamine out of the space between nerve cells. Like cocaine, MDPV clogs the ports in the carrier molecule so dopamine can't be mopped up once it has done its job, Baumann and colleagues reported in 2013 in *Neuropsychopharmacology*. Instead, the dopamine stays in the space between nerve cells and keeps on signaling, activating a wide array of messages within the brain.

"In this case, [MDPV] is outcompeting the dopamine," Baumann says. The dopamine isn't moved out of its signaling zone. "That's the calling card of MDPV. That's also the calling card of a very addictive substance."

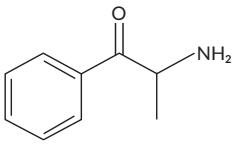
Bath salts containing two other compounds, mephedrone and methylone, take a different tack, Baumann's group reported in 2012 in *Neuropsychopharmacology*. Similar in size to dopamine, these drugs can slip inside the carrier molecule, forcing it to spit dopamine into the space between neurons. In Baumann's studies, mephedrone and methylone didn't increase dopamine levels as much as MDPV did. But, he says, "these molecules enter cells, are accumulated inside and cause neurotoxic effects."

Stoner behavior

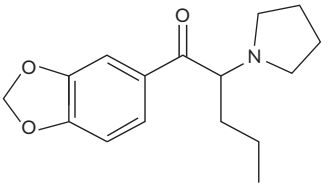
There haven't been any controlled trials of designer drugs in humans in the United States and very few in other countries. So researchers observe how the drugs alter the behavior of mice, which can help the DEA get the drugs off the street. "These models cannot prove that the drug will produce a high in humans, but they are the best we have," says Wiley, of RTI International.

So how can she tell a mouse is stoned? Wiley injects synthetic cannabinoids into mice and looks for sluggishness, pain tolerance and lowered body temperature. Though synthetic cannabinoids have quite different chemical structures than THC (the active ingredient in marijuana), they evoke similar rodent responses. The mice sit in one spot without moving and are slow to flick their tail away when a hot light shines on it. Wiley also tests whether the mice wasted on synthetic cannabinoids act the same way they do when stoned on THC.

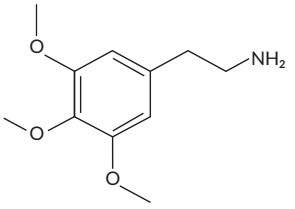
"The DEA needs information showing that the substances have effects similar to those of marijuana in order to work with other government agencies to ban the compounds," Wiley



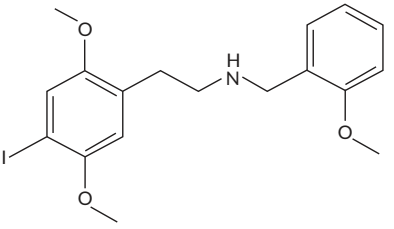
Cathinone (khat)



MDPV



Mescaline (peyote)



25I-NBOMe

says. The agency used her behavioral and chemical profiles of synthetic cannabinoids to close down a spice-selling shop in Duluth, Minn., she says.

Adam Halberstadt and Mark Geyer, psychopharmacologists at the University of California, San Diego, ran a similar battery of tests to confirm the hallucinogenic properties of NBOMes. When hallucinating, mice start quickly twitching their heads, the researchers reported last year in *Neuropharmacology*. Halberstadt speculates that the animals were hallucinating that they were being touched or getting wet.

The 25I-NBOMe, which sent Suzuki's patient into a suicidal frenzy, is especially potent and also made the mice hyperactive, Halberstadt says.

NBOMes chemically resemble mescaline, a compound found in the peyote cactus. They don't spike dopamine levels and aren't addictive. But an overdose can prompt paranoia, seizures, a racing heart or high blood pressure. NBOMes masquerade as extra serotonin, a molecule that plays many roles in the brain, some related to mood, aggression and sensitivity to pain.

NBOMes can be dissolved and sold on paper blotters. Unfortunately, this means NBOMes are often sold as LSD. "People know that they can sell this as LSD and make more profit than they would by selling these compounds as what they really are," says Halberstadt. "They're being sold as something that is believed to be safe, but these don't have the safety margin that LSD does."

NBOMes are sold on colorful paper blotters, just like LSD, but their effects can be more severe.

Massive doses of LSD may cause panic reactions known as bad trips, but they are unlikely to kill a person. "People know how to take LSD. It's been around for a long time," says Josh Elmore, a pharmacologist in Baumann's lab. But with NBOMes, "If the person making the blotter puts a little bit too much, people die," he says.

This lack of consistency in dosing is not limited to NBOMes. Spice is typically sprayed on plant leaves (often from the herb marshmallow) before being packaged and sold. "It's very arbitrary and it's up to whoever's doing the formulation and adding the drug to that plant material," says the DEA's Jill Head.

This unpredictability extends to other modes of spice, which can also be vaped via e-cigarette. One of the problems is that synthetic cannabinoids dissolve poorly in the vaping liquid. The drug may start to crystallize over time, says Wiley. "If you're down to the last little dregs of your e-liquid and it's mostly these pieces of the chemical that have fallen out of solution, but you stuff that in your e-cigarette, what you might end up with is a very, very large dose," she says.

A chemical Hydra

Trying to profile and ban designer drugs is like fighting Greek mythology's many-headed Hydra, which sprouted more heads as soon as one was sliced off. The DEA can declare drugs temporarily illegal as they appear. This process, called emergency scheduling, gives the agency a chance to evaluate the drug before officially labeling it illegal. But drugmakers "can tweak substances and come up with new ones faster than the regulatory process allows us to schedule them," says Barbara Carreno, a DEA spokesperson.

The drugs are made in China, India and Pakistan by chemical companies, Baumann says. "The people that are doing this, they're probably Ph.D.-level chemists that are mining the medical literature for these structural templates. This isn't the Hell's Angels brewing stuff in a bathtub; this is a very sophisticated operation."

Where the drugs migrate when they leave Asia can vary. "Early on in this trend of emerging synthetics, Europe was a barometer for us," says Jeff Comparin, a forensic chemist at the DEA. When the drugs appeared in Europe, the United States would have advanced warning of about six months. "More recently, we think that we're encountering new drugs in the United States first."

A small kernel of self-regulation may come from within the drug-user communities — at least for NBOMes. In the last year especially there's been a growing chorus among both users and vendors that selling NBOMes as LSD will be the new drug's downfall, Suzuki says.

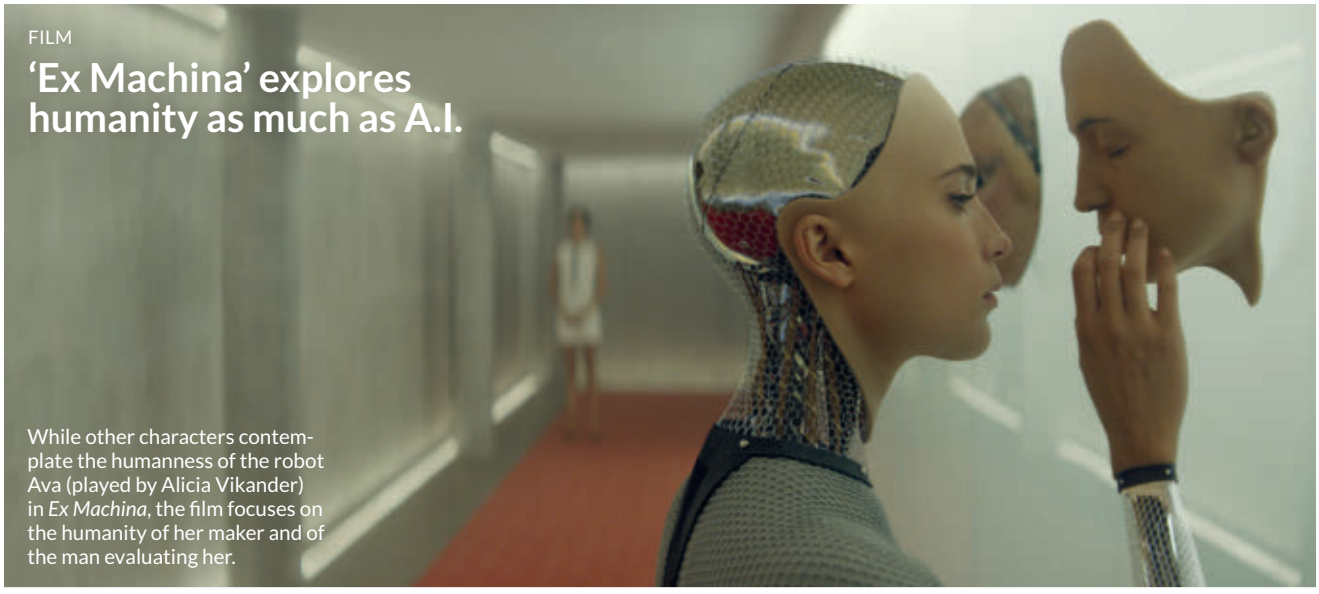
In the meantime, Baumann and his cohorts continue to profile the dizzying array of new drugs as they emerge. There's no sign that unscrupulous chemists will stop flexing their creative muscles anytime soon. "I hope I'm wrong," Baumann says, "but it doesn't look like there's any end to it. It's essentially an infinite number of possibilities." ■

Explore more

- Jenny L. Wiley *et al.* "Hijacking of basic research: The case of synthetic cannabinoids." RTI Press, 2011.

FILM

‘Ex Machina’ explores humanity as much as A.I.



While other characters contemplate the humanness of the robot Ava (played by Alicia Vikander) in *Ex Machina*, the film focuses on the humanity of her maker and of the man evaluating her.

The Turing test features prominently in Alex Garland’s new film *Ex Machina*, but this is no meditation on computer science. It’s not even, ultimately, about artificial intelligence. The movie instead explores humans: the Frankenstein-like hubris involved in creating artificial beings; the power relationships between employee and boss, parent and child, tester and testee; the moral responsibility of creation.

The movie follows a young programmer, Caleb (Domhnall Gleeson), chosen to spend a week in the remote boreal home and lab of his billionaire boss Nathan (Oscar Isaac), a reclusive genius who wrote the code for a Google-like search engine when he was a teen. Nathan tasks Caleb with interviewing Nathan’s A.I. creation, Ava (Alicia Vikander), to see if the robotic femme fatale has achieved the ability to think for herself, or, some would say, consciousness. Instead of evaluating Ava, Caleb falls for her and begins to question himself.

For now, A.I. might be found mostly in self-driving cars and smartphone apps. But in this thoughtful sci-fi thriller, artificial intelligence takes the form of human fantasy and fear. — *Eva Emerson*

SCREENTIME

Explore an asteroid with Vesta Trek

Vesta, seen in this mosaic of images from the Dawn spacecraft, is explorable in a new app.

Budding interplanetary explorers can satisfy their wanderlust with Vesta Trek, a web-based application that lets users explore the asteroid Vesta.

The app uses data from the Dawn spacecraft, which orbited the asteroid from July 2011 to September 2012. Users can overlay maps of geology, mineralogy and abundances of various elements on the second-largest rock in the asteroid belt. The application also provides data to make a 3-D printed model of the asteroid.

The interface to pan and zoom will be familiar to anyone who has used an online map. Armchair cartographers will find tools to measure distances and elevations of the landscapes. At the south pole, for example, is a roughly 19-kilometer-deep pit at the bottom of which sits a mountain more than twice as high as Mount Everest. — *Christopher Crockett*

BOOKSHELF

Psychiatry Under the Influence
Robert Whitaker and Lisa Cosgrove
A journalist and a psychologist investigate pharmaceutical companies’ influence on psychiatry and find institutional corruption. *Palgrave Macmillan, $36*

The Collected Papers of Albert Einstein, Volume 14, The Berlin Years: Writing & Correspondence, April 1923–May 1925
Diana Kormos Buchwald et al, *eds.*
Einstein’s writings in the years leading up to quantum mechanics include correspondence with Max Planck, Max Born, Erwin Schrödinger and Hermann Weyl. The volume includes Einstein’s Nobel Prize lecture. English translations appear in an accompanying paperback volume. *Princeton Univ., $140 (English translation, $45)*

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

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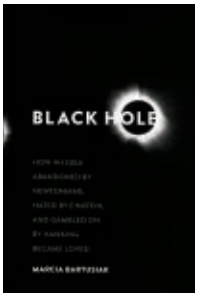
Check out an asteroidscape at **vestatrek.jpl.nasa.gov**



Black Hole
Marcia Bartusiak
YALE UNIV.,
$27.50

BOOKSHELF

100 years of a transformative idea

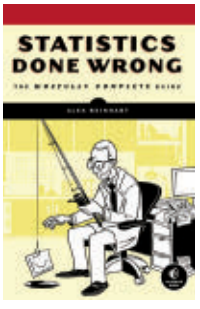
Almost a century before Einstein was born, the English polymath John Michell speculated that a star of immense mass could exert enough gravitational force to imprison light. Michell's insight marked the origin of an idea that was demonstrated in reality only in the 20th century, in the astrophysical offspring of Einstein's general relativity known as the black hole.

In *Black Hole*, Marcia Bartusiak, an acclaimed science writer, tells the story of black holes as they emerged from studies of Einstein's equations, focusing primarily on the period from the 1950s to the 1970s. Though first implied by the work of Karl Schwarzschild in 1916 — just months after Einstein had completed his theory — black holes weren't seriously investigated until 1939, in a paper by J. Robert Oppenheimer and Hartland Snyder. The two showed that rather than just a heavy star that held light close, a black hole represented the disappearance of the star — its mass crushed to nothingness, leaving only the mass's gravity behind.

World War II then stalled black hole research until the 1960s. During that decade various newly discovered astrophysical phenomena, such as quasars, forced physicists to revive general relativity, a theory that had been mostly neglected for decades. Gravitational collapse of matter to form a black hole, as implied by Einstein's theory, turned out to be essential in explaining quasars. Although John Archibald Wheeler is given credit for coining the name black hole in 1967, Bartusiak points out that the term had already been in print journalistically in 1964, in *Life* magazine (January 25 issue) and a week earlier in this magazine, then called *Science News Letter* (*1/18/64, p. 39*).

Black Hole is engaging and lively, weaving in personal drama (tensions between Oppenheimer and Wheeler, for instance) with a clear account of the underlying science. Bartusiak also highlights the role black holes played in capturing the public imagination and fueling interest in the mysteries of the cosmos.

She does not extend the story through the explosion of black hole research from the 1980s onward. But she does briefly discuss black holes' importance in many fundamental aspects of physical theory today, from their role in creating gravitational waves to their connections with the mysteries of quantum physics. Perhaps that story can be treated more fully later, after those mysteries have been solved and the offspring that their solutions imply are given clever names. — *Tom Siegfried*



Statistics Done Wrong
Alex Reinhart
NO STARCH PRESS,
$24.95

BOOKSHELF

Research can't be right with 'Statistics Done Wrong'

Fraud in science gets a lot of attention and condemnation — as it should. But fraud is relatively infrequent. And it isn't terribly interesting, says Alex Reinhart in *Statistics Done Wrong*, "at least, not compared to all the errors that scientists commit unintentionally."

Most of those inadvertent errors, it seems, result from the abuse or misuse of statistics, the mathematical methods used to test hypotheses and draw inferences from data. Reinhart, who began his scientific career as a physicist but now teaches statistics, describes in pithy and conversational language the many pitfalls of statistical tools, from p values (*SN Online: 3/17/15*) to regression analysis. He writes mainly for the well-meaning scientists who would like to analyze their data appropriately but have been misinstructed in statistical technique (or not instructed at all) and therefore risk reporting erroneous results.

Of all the books that tackle these issues, Reinhart's is the most succinct, accessible and accurate assessment of the statistical flaws that render many scientific studies suspect. Testing multiple hypotheses at once, on samples that are too small, using invalid tests, without specifying ahead of time how the data will be analyzed, are all a) very common practices and b) guaranteed to produce many wrong results. And as Reinhart astutely notes, virtually all the incentives in the scientific enterprise (such as getting published and getting tenure) encourage such bad practices and offer no rewards for people who want to do statistics right.

This is a small but important book. It should be required reading for all scientists, especially editors of journals and officials of funding agencies (not to mention science journalists — well, all journalists). It tells a clear and convincing story about a dysfunctional system. It exposes the many errors that scientists commit in their research methods. Reinhart also provides plenty of helpful guidance on how to avoid, or at least limit, many of the pitfalls of poor statistical methodology.

But he also acknowledges that even when statistical methods are applied properly — just as textbooks dictate — they often do not achieve their intended purpose: "Even properly done statistics can't be trusted," Reinhart declares. Trust him. — *Tom Siegfried*

Announcing a new blog from *Science News*

Can a computer detect a media outlet's political bias based solely on the quotes it publishes? How will the public interpret celebrities' public health messages, like Angelina Jolie's statements on her cancer risk? Given 9 quintillion possible outcomes for the NCAA tournament, what are the most successful strategies for picking a winning bracket?

These are just some of the questions addressed in *Science News*' new blog, *Culture Beaker*. The blog's author is Boston-based freelance writer Rachel Ehrenberg (above). Regular readers will recognize the name: Ehrenberg covered chemistry and interdisciplinary sciences for *Science News* from 2008 to 2013. Her blog shines a light on the places where science and culture intersect, considering the relevance of science to broader culture as well as the cultural ramifications of new findings.

One of Ehrenberg's posts explores the controversial use of music "mash-ups" in legal battles over song copyrights. Recently, relatives of musician Marvin Gaye sued the producers of a 2013 song called "Blurred Lines," claiming the song's beat plagiarized a 1977 Gaye hit. Forensic musicologists put the vocals of one song over the instrumentals of the other to demonstrate their similarities.

But, Ehrenberg argues, the forensics was flawed from the start. Mash-ups, rather than helping distinguish one song from another, end up creating something entirely new. She examines the ways that scientists analyze musical DNA and discusses whether mash-ups have enough scientific merit to hold up in court.

Ehrenberg was a 2013–2014 Knight Science Journalism fellow at MIT, has degrees in botany and political science from the University of Vermont and a master's in evolutionary biology from the University of Michigan. She graduated from the science communication program at the University of California, Santa Cruz.

Check out all of the posts mentioned above and more from *Culture Beaker* at **bit.ly/SN_CultureBeaker**

Susan Criss (right) explains her research to President George H.W. Bush at STS in 1991.

Alumni reconnect

Susan Criss, a finalist of the 1991 Westinghouse Science Talent Search, reconnected with the Society earlier this year when she volunteered to be a Grand Awards Judge at the 2015 Intel International Science and Engineering Fair.

Criss in 1991 was one of five finalists who had the opportunity to present her research to President George H.W. Bush at the Westinghouse Science Talent Search 50th Anniversary Banquet. Now, 24 years later, she will be returning to her home town of Pittsburgh this May to help evaluate projects from nearly 1,700 finalists from around the world and determine who will win this year's top awards.

Since the Science Talent Search, Criss received her bachelor of science in chemical engineering from Penn State University, and is now an associate director of research and development at Procter & Gamble.

Launching a mini-grant program for students

In conjunction with the White House Science Fair held in March, Society for Science & the Public announced the launch of a pilot mini-grant program in 2015. This program will support socio-economically challenged students who have done scientific research by helping them submit their projects for presentations and competitions.

"We think it's vitally important to continue building and diversifying the pool of students participating in science fairs and other science, technology, engineering and math competitions," says Maya Ajmera, CEO and president of the Society. "This pilot grant will let us test out, on a small scale, if having a dedicated advocate impacts participation rates."

Grants will be provided to teachers, counselors or mentors who can advocate for a group of three to five students and assist them in completing the application for a scientific competition.

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SOCIAL MEDIA

The benefits of old age

In "Postmenopausal orcas guide hunts" (*SN: 4/4/15, p. 8*), **Susan Milius** described how older female killer whales draw on years of experience to lead their families to fruitful hunting spots.

"I've heard of 'salad days,' but 'salmon days'?"
Lisa Wieland on Facebook

"Hope they don't have hot flashes!"
@NieldBeverly on Twitter

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Free-range planets

*Astronomers are puzzling over some space oddities: planets that don't orbit stars. In "Wandering worlds" (*SN: 4/4/15, p. 22*),* ***Ashley Yeager*** *explored how these lonely rogues may alter the definition of a planet.*
Tim Geho wanted to know more about how scientists locate homeless worlds. "Where does the light come from that allows rogue planets to be seen, either directly or via gravitational lensing?" he asked. "Is there some sort of fluorescence or luminescence involved or is [light] reflected from distant suns?"

Some rogues can be imaged directly because big planets can emit their own heat, **Yeager** says. Telescopes detect this heat as infrared light. Identifying a planet with gravitational lensing is also possible. In this case, astronomers use light from a distant star to infer the existence of a planet. First they track the movement of the star. From the viewpoint of Earth, when the star passes behind some unseen object, the hidden object's gravity will bend the star's light. How much the object bends the light reveals the object's mass. If the mass is similar to the mass of a planet, then astronomers assume that the unseen object is a planet.

Readers also had their own suggestions for what to call these rogues. **Jeff Barry** jokingly proposed naming them "nibirus," after the mythical doomsday planet that is supposed to crash into Earth. **John Turner** commented, "Some sources refer to these nomadic bodies as 'planemos.' I notice we're avoiding using that word in this article, though it's been used in *Science News* pieces in the past. What gives?"

Planemo never became widely used in the astronomy community, according to Penn State astronomer **Kevin Luhman**. He suggests sticking with brown dwarf, while others, like **Michael Liu** at the University of Hawaii in Honolulu, prefer the term free-floating planet.

New thoughts on old tools

Developing new categories for types of stone tools could help anthropologists craft a more accurate view of hominid evolution, ***Bruce Bower*** *reported in "Reading the stones" (*SN: 4/4/15, p. 16*).*
Discussions on Facebook and Twitter centered on how difficult it would be to re-create some of the tools. Some readers, like **Grink**, declared confidently, "I can make that." Others thought the process would be challenging. "It's a very difficult technique," wrote **Shashank Ac**. "Most modern humans would not last a day in the Stone Age."

Mark S. took the idea a step further, suggesting a Paleolithic reenactment week: "Have the specialists get together and try to hunt, butcher and live as putative Stone Age peoples would. It would probably shed all sorts of light on what tools were really important and under what conditions. Anyone caught ordering pizza would lose their publication rights."

The scent of rain

Andrew Grant *explained how falling water drops can kick soil chemicals into the air, creating that well-known poststorm earthy aroma, in "Why rain smells like that" (*SN: 4/4/15, p. 5*).*
The story confirmed what reader **Bo Grimes** had long suspected: "Ever since I first noticed the phenomenon as a child, I assumed chemicals were released from the soil, though I probably thought of it in terms of splashed dirt." Commenter **Zk10** wrote, "For whatever reason, the earthy, natural smell of raindrops on hot sand has a wonderful calming effect on me. These smells are so faint you do not even realize they are there. You just feel better. Nice to know the science behind it."

Correction

In "An oil spill's aftermath" (*4/18/15, p. 22*), U.S. District Judge **Carl Barbier's** ruling about the amount of oil released in the 2010 Deepwater Horizon spill in the Gulf of Mexico was expressed incorrectly. The judge ruled that 4 million barrels of oil exited the reservoir but that, after accounting for oil collected at the site, 3.19 million barrels was discharged into the Gulf.

DAVID ELLIFRIT/CENTER FOR WHALE RESEARCH

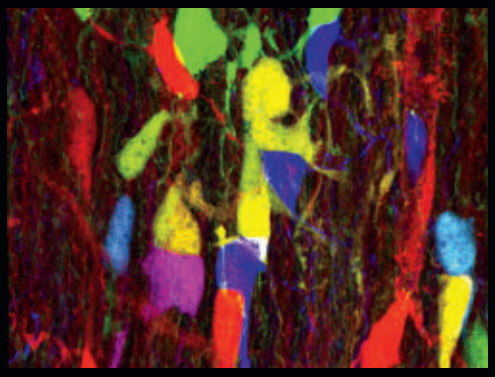
‘Brainbow’ illuminates cellular connections

A mouse’s optic nerve glows in a rainbow of colors in this micrograph.

The image is made using Brainbow, a technique developed in 2007 that inserts genes for fluorescent proteins into animals. When activated, the proteins illuminate some cells in a range of colors. While most researchers use Brainbow to visualize connections between nerve cells in the brain, Alain Chédotal of the Institut de la Vision in Paris and colleagues customized the technique to trace networks of cells called oligodendrocytes. These cells wrap a material called myelin, the biological equivalent of electrical insulation, around long strands of nerve cells that transmit electrical signals in the brain and throughout the body.

How oligodendrocytes work together to wrap nerve fibers in myelin becomes evident in Brainbow photos of the roughly 3-millimeter-long optic nerve, the team reports in the April *Glia*. The myelin shields the precious link between brain and eyes.

Studying interactions among oligodendrocytes as well as the cells’ reactions to various drugs may lead to improved therapies for multiple sclerosis, a disease caused by the destruction of myelin. — *Ashley Yeager*



Stained glass cells In this zoomed-in image of the optic nerve, oligodendrocytes glow in various colors, allowing scientists to identify individual cells.

FROM LEFT: L. DUMAS *ET AL/GLIA* 2015; COURTESY OF A. CHÉDOTAL/INSTITUT DE LA VISION

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