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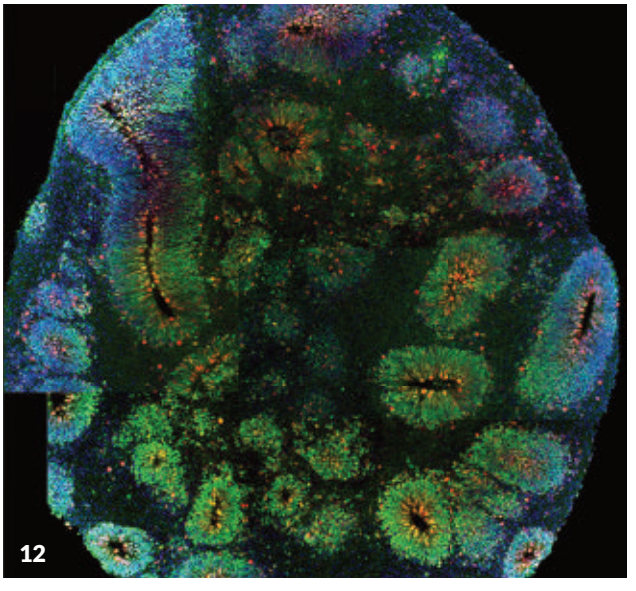
News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CLOCKWISE FROM TOP: HERITAGE IMAGE PARTNERSHIP LTD/ALAMY STOCK PHOTO; P. MUIR; VACCARINO LAB


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Departments

COVER OSIRIS-REx (illustrated) will collect samples from the asteroid Bennu. *NASA's Goddard Space Flight Center*

The periodic table remains essential after 150 years

It's another raw day in St. Petersburg, Russia, but the man striding down the University Embankment along the Neva River isn't pondering how the icy wind off the Gulf of Finland chills his bones or whether Emperor Alexander II's reforms will increase salaries for professors like him. Instead, Dmitrii Mendeleev is imagining how he could reveal the chemical underpinnings of the universe on a single page.

This year marks the 150th anniversary of Mendeleev's invention of the periodic table of the elements in 1869, which not only foretold an internal structure to the atom and the existence of elements not yet discovered, but also hinted at the profundities of quantum mechanics.

I've walked those windswept streets by the university in St. Petersburg, and I like to imagine Mendeleev, who appears to have been the archetype of the brilliant, disheveled professor, walking deep in thought while the carriages of aristocrats clattered by on their way to the Winter Palace. But my own knowledge of how Mendeleev came to create this road map of element characteristics and relationships doesn't extend much beyond daydreaming while staring at the chart in high school science classes.

Fortunately, *Science News* contributor and former editor in chief Tom Siegfried is deeply familiar with the history of Mendeleev's discovery and its impact. His essay on Page 14 chronicles the decades of effort by scientists in the 19th century to figure out the relationships among the elements, and how Mendeleev, while writing a textbook on inorganic chemistry, managed to crack the code.

Siegfried is clearly the right person to open our 2019 coverage of the periodic table's notable birthday.

"I was a chemistry major in undergrad," Siegfried told me. "I wrote papers about the history of the periodic table." When he was a college student, the table ended at element 103, lawrencium. Now it's filled in all the way to No. 118, the heavyweight oganesson, one of the four synthetic elements officially named in late 2016 (*SN: 1/21/17, p. 16*). "That was fun to watch happen," Siegfried says. And he's looking forward to more fun in the future; the story of the periodic table isn't over. "It's ongoing, as new elements and new aspects of atoms are discovered," he says.

So the story of the periodic table hasn't ended — and our coverage of the 150th anniversary is just beginning. By now you might have surmised that we here at *Science News* are major fans of the periodic table, and the scientists and science behind it. We've even included the current version of the table in this issue (Page 18), embellished with surprising points of interest by special projects editor Elizabeth Quill.

Do you have a favorite element fact or memory of the periodic table? If so, please let us know by e-mailing us at editors@sciencenews.org or on Twitter @ScienceNews. We'll be sharing selected bits throughout the year.

Stay tuned for more stories in the magazine and on www.sciencenews.org as we celebrate this very big birthday together. — *Nancy Shute, Editor in Chief*

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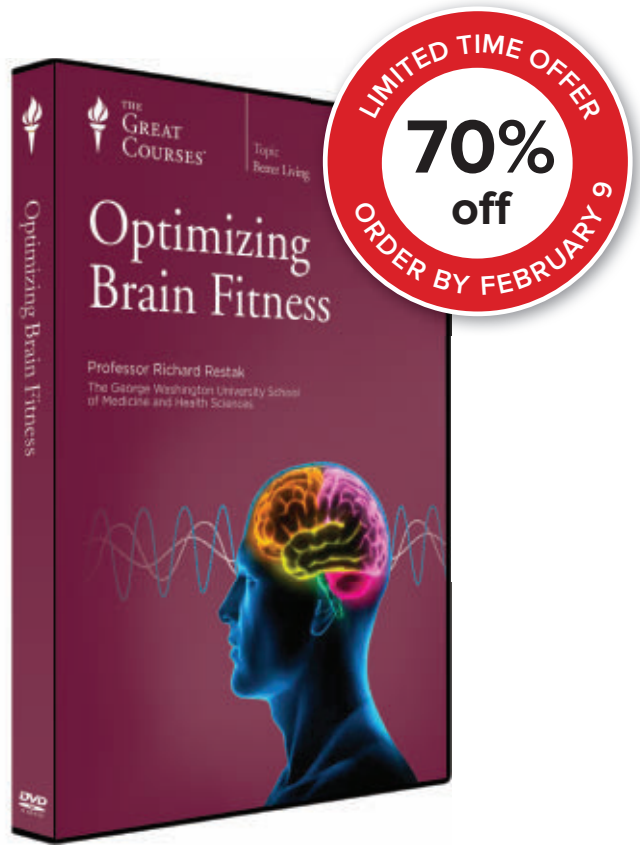

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Excerpt from the January 18, 1969 issue of *Science News*

50 YEARS AGO

Speaking to masters of the sea

The astonishing capture [of seven orcas off British Columbia] has made possible the first scientific study of killer whales in their more or less natural environment.... There is little doubt that the animals have a sophisticated language with which they can communicate with each other, but practically nothing is known about the complexity of their speech.

UPDATE: The 1968 orca captures in Garden Bay opened doors to studying the animals' behavior. Research shows that *Orcinus orca* family groups share distinct dialects (*SN: 1/12/80, p. 21*). In 2018, scientists reported recording 14-year-old Wikie imitating the words *hello* and *one*, *two*, *three*, highlighting the likely role that imitation plays in how killer whales learn dialects (*SN: 3/3/18, p. 5*). As for the Garden Bay orcas, they were far from the last killer whales captured. From 1961 to 2018, at least 166 orcas were caught in the wild. Another 34 bred in captivity are used for research or exhibition, according to the nonprofit group Whale and Dolphin Conservation, based in Chippenham, England.

THE SCIENCE LIFE

Neandertal diet may have been rotten

Biochemical changes in rotting meat offer clues about Neandertal diets. A fresh steak (left) has turned putrid and black by day 15 (right).

Kimberly Foecke has a great relationship with her local butcher.

Though Foecke buys loads of meat, she's neither a chef nor a zoo owner. She's a paleobiologist who studies the Neandertal diet. Her research involves "experimental putrefaction," she says, "which is a fancy way of saying, I rot meat, all day, every day."

Scientists know Neandertals ate a lot of meat. Fossilized bones from the hominids tend to have high levels of a heavier form of nitrogen, nitrogen-15, compared with the lighter nitrogen-14. Plants have less nitrogen-15 than animals do, and nitrogen-15 becomes more concentrated further up the food chain because it's harder to break down than nitrogen-14.

But exactly how much meat these hominids ate — and what else was in their diet — is somewhat controversial. Some evidence, such as tooth scrapings, suggests Neandertals also ate a variety of plants. But the nitrogen-15 levels point to "an unreasonably huge amount of meat," says Foecke, of George Washington University in Washington, D.C. Those measurements tend to be even higher than what's seen in top carnivores like hyenas, which nosh almost entirely on meat.

Foecke thinks the high nitrogen-15 levels may be explained by more than how much meat Neandertals ate, but also by how they prepared it. She suspects that whether meat is fresh or rotten, raw or cooked, affects the abundance of nitrogen-15 versus nitrogen-14. That's why she is measuring nitrogen-15 in beef cuts, to pin down the biochemical changes that meat undergoes as it rots.

Paleobiologist Kimberly Foecke points out features of a Neandertal skull.

Supermarket steaks don't cut it for this kind of experiment. Instead, Foecke calls her butcher in Maryland, who gets fresh meat from animals living as close to a Pleistocene lifestyle as possible — after all, animals hunted some 200,000 years ago were not fed hormones or antibiotics. Foecke needs animals raised on organic diets.

Foecke leaves the meat cuts to rot for 16 days in a mesh-covered box in her family's backyard, or sometimes in a greenhouse, and samples nitrogen values daily. Her preliminary results suggest that nitrogen-15 ratios do change as meat rots. In the first week, levels increase. The meat is moist and microbial activity breaks down nitrogen-14 faster than the nitrogen-15, Foecke reported December 14 in Washington, D.C., at an American Geophysical Union meeting. The meat smells "pretty terrible," she says. Over time, the stench diminishes as the meat blackens and takes on a more jerkylike consistency.

Foecke's research so far suggests that eating rotting meat could at least partly explain the high nitrogen-15 signatures in Neandertal fossils. It makes sense that Neandertals weren't always feasting on fresh grub, especially when they killed large animals. A big carcass might last for days.

Foecke is also measuring what happens as she cooks or smokes meat — steps in food preparation that Neandertals might have taken that could affect nitrogen-15 ratios.

— *Laurel Hamers*

FROM TOP: K. FOECKE; SAMANTHA LUBRANO

SCIENCE STATS

Many Americans don't sleep enough

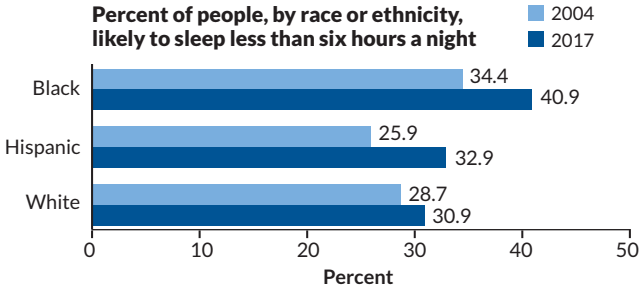
Nearly one-third of American adults sleep less than six hours each night, a broad new survey shows.

That's not enough. At least seven hours of sleep per night is recommended, according to the American Academy of Sleep Medicine and the Sleep Research Society.

Among nearly 400,000 respondents to the National Health Interview Survey, 32.9 percent reported this short sleep in 2017 — up from 28.6 percent in 2004, when researchers began noticing a drop in sleep time. That's a 15 percent increase, says Connor Sheehan, a sociologist at Arizona State University in Tempe.

Analysis of the annual survey results — accounting for the U.S. population's age distribution as well as respondents' marital status, income, employment and lifestyle — suggests the decline in sleep really picked up from 2013 onward, especially in black adults, Sheehan and colleagues report online November 17 in *Sleep*. In 2017, 40.9 percent of black Americans were likely to report short sleep, as were 30.9 percent of whites and 32.9 percent of Hispanics, the researchers calculate.

Not getting enough sleep can increase the risk of accidents or of developing conditions such as obesity and diabetes.



ZZZ force Americans were more likely in 2017 to report sleeping less than six hours a night than in 2004. Black and Hispanic people were most likely to be missing shut-eye. SOURCE: C. SHEEHAN *ET AL*/*SLEEP* 2018

Respondents could be snoozing even less than they reported, since people tend to overestimate how much they sleep, the authors say. The study did not explain why some people are sleeping less now than 13 years ago, though stress may be a factor. Smartphone overuse, which has been linked to poor sleep and stress (*SN Online: 1/23/17*), may also play a role. In the last decade, the number of adults who own a smartphone more than doubled.

"Staring at a bright smartphone screen and getting anxious news is definitely not going to help you go to bed," Sheehan says. — *Rodrigo Pérez Ortega*

TEASER

Magnets firm up this metamaterial

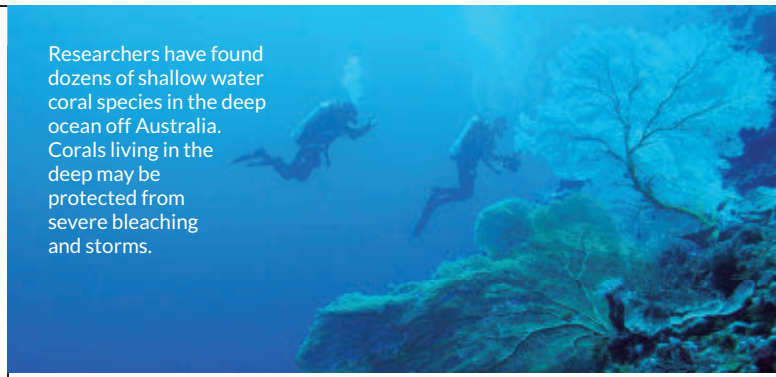
Magnetism transforms a weird new material from soft to rigid in a split second. This metamaterial — a synthetic structure that behaves in ways natural materials don't — comprises a gridlike network of plastic tubes filled with fluid that becomes more viscous in a magnetic field, causing the tubes to firm up, researchers report December 7 in *Science Advances*.

Christopher Spadaccini, a materials engineer at Lawrence Livermore National Laboratory in California, and colleagues 3-D printed lattices of plastic struts 5 millimeters long and injected them with a mixture of tiny iron particles and oil. In the absence of a magnetic field, the iron microparticles remain scattered, so the liquid is runny. But near a magnet, the iron microparticles align into chains along the magnetic field lines, making the fluid viscous and the lattices stiffer.

Building tubular structures that are mostly open space, rather than solid microparticle-filled hunks, makes the material lightweight and less expensive, says coauthor and engineer Julie Jackson of Lawrence Livermore.

A structure was 62 percent stiffer when it was one centimeter away from a magnet versus eight centimeters. The material could help make more adaptable robots or body armor. — *Maria Temming*

A magnetically tunable metamaterial contains many "unit cells" (one shown) made of plastic tubes filled with bits of iron and oil.



Researchers have found dozens of shallow water coral species in the deep ocean off Australia. Corals living in the deep may be protected from severe bleaching and storms.

RETHINK

Corals are abundant in the deep

Nearly 200 species of Great Barrier Reef corals have a second home in the deep ocean. That's six times as many species as previously thought to be living in the dark, cold waters off northeastern Australia, researchers report in the Dec. 12 *Proceedings of the Royal Society B*.

"The deep reef is a lot more diverse and interesting than we thought," says coral biologist Paul Muir of the Museum of Tropical Queensland in Townsville, Australia.

From 2010 to 2016, Muir and colleagues looked at museum specimens and sampled 1,263 corals at depths of 30 to 125 meters in the ocean's mesophotic zone, which receives little sunlight. The team counted 195 coral species in this zone, most of which had been thought to inhabit only shallow waters. — *Cassie Martin*

CLOCKWISE FROM TOP: T. TIBBITTS; P. MUIR; J.A. JACKSON

News

ATOM & COSMOS

Hints of water found on asteroid

OSIRIS-REx will return sample of the space rock to Earth

BY LISA GROSSMAN

As the asteroid Bennu comes into sharper focus, planetary scientists are seeing signs of water locked up in the asteroid's rocks, scientists announced December 10.

"It's one of the things we were hoping to find," Amy Simon of NASA's Goddard Space Flight Center in Greenbelt, Md., said in a news conference at the American Geophysical Union meeting. "This is evidence of liquid water in Bennu's past. This is really big news."

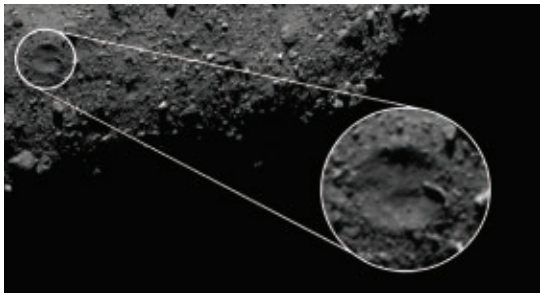
NASA's OSIRIS-REx spacecraft, which arrived at the roughly 500-meter-wide Bennu on December 3, made the discovery. Over the next year, scientists will look for a spot for the spacecraft to collect asteroid dust and then return it to Earth (see Page 20).

OSIRIS-REx's spectrometers, which measure the chemical signatures of minerals based on the wavelengths of light they emit and absorb, saw signs of hydrated minerals about a month before the spacecraft reached the asteroid. The signal remained strong all over the surface as the probe approached, Simon said. Those minerals form only in the presence of liquid water and suggest that Bennu once had a hydrothermal system.

Bennu's surface also has more boulders and craters than expected. Observations from Earth indicated there would be at most only a few large boulders, about 10 meters wide. But Bennu has hundreds, some more than 50 meters wide.

That rough surface can reveal details of the asteroid's internal structure. If the asteroid were one solid mass, for instance, a major impact could crack or shatter its entire surface. The fact that the asteroid has large craters means it has survived impacts intact. Therefore, Bennu may be a pile of rubble loosely held together by its own gravity.

Bennu's low density supports that idea. OSIRIS-REx data indicate that the density is about 1,200 kilograms per cubic meter, said principal investigator Dante Lauretta of the University of Arizona in Tucson. The average Earth rock is about 3,000 kg/m^3. Water is less dense than rock, so the hydrated minerals help lower the density. But up to 40 percent of Bennu may be full of caves and voids, further lowering the density, Lauretta said.



Craters on Bennu, such as this 20-meter-wide one, are a clue that the asteroid is a pile of rubble held together by its own gravity.

The mission's next big task is to find a suitable place to sample. OSIRIS-REx's sampling arm can't pick up grains larger than 2 centimeters. "I am confident that we'll find some fine-grained regions," Lauretta said. The challenge will be finding an area wide enough that the probe's navigation system can steer to it. ■

EARTH & ENVIRONMENT

Tornado funnels may rise from below

Scientists capture the first few seconds of a twister's life

BY CAROLYN GRAMLING

Tornadoes may form from the ground up, rather than the top down.

That could sound counterintuitive. Many people picture a funnel cloud emerging from a dark mass of storms and then extending to the ground, atmospheric scientist Jana Houser of Ohio University in Athens said December 13 at the American Geophysical Union meeting. But Houser and her colleagues have new data that upend this "top-down" idea of tornado formation.

The supercell thunderstorms that can spawn tornadoes form where a powerful updraft of warm, moist air gets trapped beneath a layer of colder, drier air. The other necessary ingredient is wind shear, when fast-moving winds cause the air masses to rotate horizontally. Air then rising through the supercell can tip the rotation from horizontal to vertical — creating conditions ripe for a tornado.

But the very moment of twister birth remains largely elusive because tornadoes form so fast, sometimes within 30 to 90 seconds. By using a rapid-scanning Doppler radar mounted on a truck, Houser's team managed to capture the full evolution of four tornadoes, including two powerful twisters that struck near El Reno, Okla., one on May 24, 2011, and another on May 31, 2013.

The radar, which collects data every 16 seconds, showed that rotating winds for the 2011 storm appeared to start at multiple levels in the atmosphere at once, rather than starting high up and moving downward. For the 2013 storm, tornado-strength rotation began at the lowest measured elevation, about 20 meters above ground. A minute later, the rotation was at a height of about 3.5 kilometers. Crowdsourced images of the storm also revealed a funnel near the ground, even before the radar captured it.

The discovery that the 2013 storm had a funnel long before the radar saw rotation is "a pretty compelling finding," says Leigh Orf, an atmospheric scientist at the University of Wisconsin–Madison. But, he says, that twister was such a bizarre storm that he hesitates to use it as an indicator of typical tornado behavior.

"There are likely different modes of tornadogenesis," Orf says. ■

UNIV. OF ARIZONA, NASA'S GODDARD SPACE FLIGHT CENTER

EARTH & ENVIRONMENT

More extreme weather tied to humans

List of specific events attributed to climate change grows

BY CAROLYN GRAMLING

A months-long heat wave that scorched the Tasman Sea in the South Pacific beginning in November 2017 is the latest example of an extreme event that would not have happened without human-caused climate change.

And climate change increased the likelihood of 15 other extreme weather events in 2017, from droughts in East Africa and the U.S. northern High Plains to floods in Bangladesh, China and South America, scientists reported at a news conference December 10 at the American Geophysical Union meeting. The findings were also published online December 10 in a special issue of the *Bulletin of the American Meteorological Society*.

The findings mark the second year in a row — and only the second time — that scientists contributing to this special issue have definitively linked climate change with specific extreme weather events (*SN: 1/20/18, p. 6*). And for the first time in the eight years the journal has published this special issue on climate attribution, none of the extreme events studied was determined to be the product of natural climate variability.

To the editors of the issue, this latest tally is representative of the new normal. "We are in a world that is warmer than it was in the 20th century, and we keep moving away from that baseline," said Martin Hoerling, a research meteorologist at the National Oceanic and Atmospheric Administration in Boulder, Colo. "Nature is unfolding itself in front of our eyes."

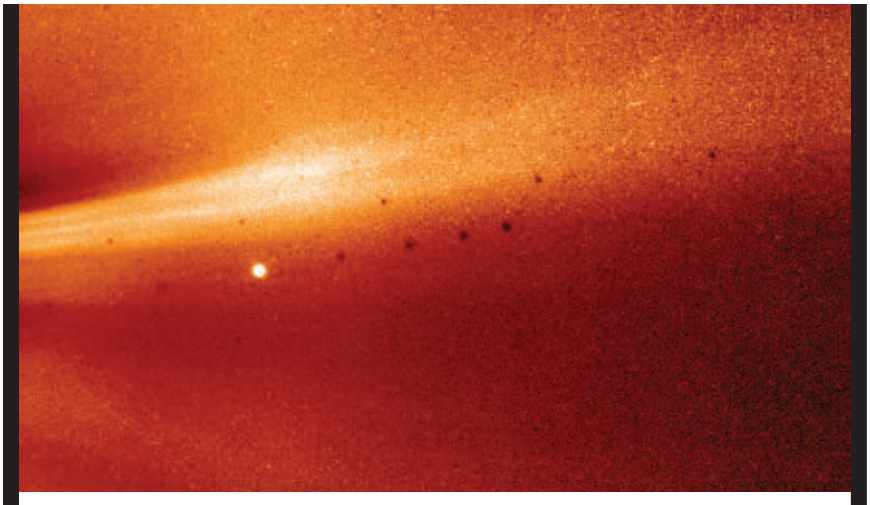
The 2017–2018 marine heat wave in the Tasman Sea, located between Australia and New Zealand, extended across the entire sea. At their most severe, temperatures increased to at least 2 degrees Celsius above average in the ocean, contributing to record-breaking summer temperatures in New Zealand.

Climate change was also responsible for a heat wave off the coast of East Africa during the first half of 2017. That heat wave, which researchers found could not have happened in a preindustrial climate, may have contributed to a drought that caused food shortages for millions of people in the Horn of Africa. The high sea surface temperatures doubled the probability that such a drought would occur.

"Any given extreme event might occur, but the severity of the events, that's really what has changed," says climate scientist Karsten Haustein of the University of Oxford, a contributor to the special issue.

The field of climate attribution science overall has crossed a critical threshold when it comes to legal liability, Lindene Patton, a strategic adviser at the Earth & Water Law Group in Washington, D.C., said at the news conference. Even if climate change is "very likely" responsible for an extreme event, rather than definitively responsible, that level of statistical certainty is enough to be legally important. "The sufficiency of certainty differs in a court of law and in science," Patton said. "You just need to know if it's more likely than not."

Attribution science can affect whether an event might be perceived in court as foreseeable; if so, facilities, companies or governments could be held liable for not incorporating that information into infrastructure designs or best management practices. The threat of liability may not be the ideal way to achieve more environment-friendly policies. But there is precedent for it, Patton noted. "We clearly saw the emergence of liability in the 1970s with pollution" as a precursor to legislation regulating pollution. ■



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MEETING NOTE

NASA probe gets first close look at the sun

NASA's Parker Solar Probe has met the sun and lived to tell the tale. The probe broke the record for the nearest brush any spacecraft has made with the sun and is sending data back from the close encounter, scientists said December 12.

The spacecraft made its first close solar flyby November 6, swooping to within about 24 million kilometers of the sun's surface. That's about twice as close as the previous closest spacecraft, the Helios 2 spacecraft in the 1970s. One of Parker's first images shows unprecedented detail of a streamer, a filament of plasma in the sun's outer atmosphere. (The above image of the streamer was taken at a distance of about 27 million kilometers. The bright dot is Mercury.)

Parker launched last August and will make a total of 24 close passes by the sun over the next seven years, eventually going to within about 6 million kilometers of the sun's surface (*SN: 7/21/18, p. 12*). — *Lisa Grossman*

LIFE & EVOLUTION

Engineered hybrid rice can clone itself

Research raises hopes of boosting crop yields more affordably

BY SUSAN MILIUS

After more than 20 years of dreaming, scientists have tweaked a hybrid variety of rice so that some of the plants produce cloned embryos. No plant sex necessary. The feat, described online December 12 in *Nature*, is encouraging for efforts to feed an increasingly crowded world.

Crossing two good grain varieties can make one fabulous one, combining the best versions of genes to give crops desirable traits such as higher yields. But such hybrids often don't pass along the coveted qualities to all seeds. Farmers who want consistently higher yields have to pay for new hybrid seeds each year. The new lab version of hybrid rice would preserve its qualities through self-cloning, says plant geneticist Venkatesan Sundaresan of the University of California, Davis.

Though more than 400 kinds of plants naturally have self-cloning, re-creating those pathways in crop plants has "been harder than anyone expected," says Sundaresan.

He and colleagues discovered that modifying two sets of genes caused the *japonica* rice hybrid called Kitaake to clone its seeds. The team found that in a fertilized plant egg, only the male version of a gene called *BABY BOOM1* triggered seed embryo development. Inserting a genetic starter switch, called a promoter, let the female version of the gene take over spurring an egg into an embryo.

But that tweak wasn't enough. An egg formed through meiosis — cell division that produces eggs and sperm — would have only half a set of chromosomes.

A solution came from plant geneticist Raphael Mercier of the French National Institute for Agricultural Research. His team had disabled three meiosis genes so rice plants switched to asexual reproduction. Sundaresan and UC Davis colleague Imtiyaz Khanday updated the approach, using CRISPR/Cas9 gene editing.

Plant geneticists Imtiyaz Khanday (left), Venkatesan Sundaresan (right) and colleagues made hybrid rice plants that clone their seeds.

Combining all the tweaks in Kitaake rice let a portion of parents, about 30 percent at best, create viable seeds with hybrid genetics intact. Plants still needed pollen to make food for the seeds. But those seeds sprouted into plants that also could clone themselves, and so could the next generation.

At scientific meetings, other teams have unveiled proof-of-concept self-cloning crops, including sorghum and maize, says Ueli Grossniklaus, who studies plant reproduction at the University of Zurich. All self-cloners still have room for improvement, he says. ■

GENES & CELLS

Dads can pass on mitochondria too

In rare cases, kids inherit the organelles from both parents

BY TINA HESMAN SAEY

Some dads have broken a textbook rule. Fathers in three unrelated families passed mitochondria — tiny energy factories found in cells — to their children.

Scientists have long thought that children inherit mitochondria exclusively from their mothers because mitochondria from the father's sperm are usually destroyed after an egg is fertilized. The new research, published in the Dec. 18 *Proceedings of the National Academy of Sciences*, suggests that in rare cases dads contribute mitochondria too. The consequences of inheriting mitochondria from dad aren't known.

Mitochondrial disease researcher Paldeep Atwal spotted the paternal signature after examining DNA from a woman who came to the Mayo Clinic in Jacksonville, Fla. DNA in a cell's nucleus is inherited equally from both parents and contains all the genetic instructions for building a body. Mitochondria have their own DNA that contains some of the genes needed for building and running the mitochondria. The woman's cells weirdly contained two types of mitochondrial DNA, some from mom and some "from elsewhere," says Atwal, who now runs a private clinic in Jacksonville.

With DNA from both of the woman's parents, the team was able to examine the father's mitochondrial DNA and found that he was the source of the mystery mitochondria. The woman's brother also inherited their father's mitochondria. "We thought, 'What on Earth is going on here?' " Atwal says.

Atwal got in touch with Taosheng Huang, a mitochondrial disease expert at Cincinnati Children's Hospital Medical Center. Huang had examined patients from two other families in which fathers had passed on mitochondria. All together, the researchers found 17 people in the three families who inherited 24 to 76 percent of their mitochondria from dad.

"It's real and a very interesting discovery, but I'm not surprised," says Sophie Breton, an evolutionary biologist at the University of Montreal. Previous studies in other animals have indicated that males sometimes pass on mitochondria (*SN: 12/26/15, p. 4*).

Breton thinks the discovery might someday negate the need to make "three-parent babies," children whose mitochondria come from donor eggs because their mothers' eggs carry mitochondrial diseases (*SN Online: 10/18/16*). "If the mitochondria from the father can do the job, maybe we could stick with the two-parent baby situation," she says. ■

KARIN HIGGINS/UC DAVIS

GENES & CELLS

Mini tumors may speed up drug search

Organoid method quickly tests hundreds of cancer therapies

BY ESTHER LANDHUIS

Collecting cancer cells from patients and growing them into 3-D mini tumors could make it possible to quickly screen large numbers of potential drugs for ultra-rare cancers. Preliminary success with a new high-speed, high-volume approach is already guiding treatment decisions for some patients with recurring hard-to-treat cancers.

"Believe it or not, for some rare cancers, there is no standard of care," UCLA cancer biologist Alice Soragni said December 12 at a joint meeting of the American Society for Cell Biology and the European Molecular Biology Organization. "What if we could go back and tell the doctor, 'Hey this combination of therapies worked really well for this specific patient'?"

In one case, Soragni and colleagues tested 430 compounds on 3-D tumors grown from cells from a boy with a rare bone cancer. In the unpublished study, eight of the compounds caused 75 percent cell death in the mini tumors. Some of those drugs are not typically considered for his cancer type.

The boy is still responding well to standard chemotherapy, but the approach could point to new treatments for patients running out of options. "If a candidate drug shows exciting activity and is [U.S. Food and Drug Administration] approved, then we would absolutely consider it," says team member Noah Federman, who directs UCLA's Pediatric Bone and Soft Tissue Sarcoma Program.

Earlier last year, another research team described how a "tumor-in-a-dish" approach successfully predicted drug responses in cancer patients who previously took part in clinical trials. That was a big development in a new research area focused on "organoids," tiny 3-D mimics of organs grown in the lab to probe basic biology or test drugs (*SN: 3/3/18, p. 22*).

"It makes sense to test cancer drugs on cancer cells outside the body first, before selecting the best one to be given to the patient," says Hans Clevers, an organoid pioneer at the Hubrecht Institute in Utrecht, Netherlands. "This field will definitely grow rapidly."

Soragni's team developed a high-volume, automated method to quickly study drug responses in tumor organoids grown from patient cells. By growing mini tumors on a plate with 96 tiny test tube–like wells, the team can screen hundreds of compounds at once and identify promising candidates within "a time frame that is therapeutically actionable — one to two weeks from surgery," Sorgani said.

The method seemed to work for various ovarian cancers. Organoids mimicked how tumors in the body look and behave. Even in cases when mini tumors had a tough time growing, scientists still identified potential drug candidates.

The team next tried the method with sarcomas, a rare group of hard-to-treat cancers that arise in bones or connective tissue and often spread to the lungs. Team member and UCLA thoracic surgeon Jane Yanagawa sometimes does multiple surgeries in the same sarcoma patient for recurring lung tumors. "I was frustrated," she says, "and feeling like there had to be more that I could do for them."

So far, the UCLA team has made organoids from 35 to 40 people with various types of sarcoma, including the boy with the rare bone cancer, an 11-year-old with small cell osteosarcoma, which affects barely a dozen people in the United States each year.

Of the eight drugs that worked in the boy's tumor organoids, four were CDK inhibitors, a group of drugs doctors would not usually consider for osteosarcoma, Federman says. Organoid screens can also identify tumors that won't respond to conventional therapy, he says. This could prove useful for people with recurring metastases, where it's "not clear if we're doing anything for their overall survival or giving them more toxicity." ■

MEETING NOTES

Snake venom grown in the lab

Scientists have made mimics of snakes' venom glands, Hans Clevers of the Hubrecht Institute in Utrecht, Netherlands, reported December 10.

Millions of people suffer snake bites each year. Venom from lab-grown replicas might someday help researchers create new drugs and antidotes for bites.

Clevers' lab made organoids, which are tissues grown from stem cells to have properties of the organs they mimic, from Cape coral snakes. Stem cells from unhatched eggs grew into organoids that could make venom. The team also grew organoids from several other species but have not yet learned how to extract the venom. — *Tina Hesman Saey*

Goose bumps help hair grow

Goose bumps don't just make hairs stand on end; they may also help hair grow. Nerves and muscles that raise goose bumps stimulate stem cells to make hair follicles, Ya-Chieh Hsu of Harvard University reported December 9. Getting goose bumps when it's cold may encourage animals' fur to grow thicker, Hsu said.

Nerves of the sympathetic nervous system, which controls automatic processes, nestle next to hair follicle stem cells, Hsu's group found. Usually nerves are wrapped in a protective coating. But these nerves are naked where they meet hair follicle stem cells. The nerves secrete a hormone that, Hsu's team found, helps hair to grow.

Nerves next to hair follicles are wrapped around arrector pili muscles, which contract to cause goose bumps. Mice with mutations that prevented those muscles from growing lacked the sympathetic nerves and didn't grow hair normally. These muscles and nerves may be involved in some forms of human baldness, Hsu said. — *Tina Hesman Saey*

ATOM & COSMOS

Test casts doubt on dark matter claim

COSINE-100 experiment fails to confirm controversial detection

BY EMILY CONOVER

For years, some physicists have rowed against the tide, claiming they've found the universe's elusive dark matter, despite mounting evidence to the contrary. A new experiment makes that upstream paddling even more of a challenge.

Observations of the cosmos indicate that an invisible, unknown type of particle pervades the universe. The extra mass this dark matter provides is necessary to explain the motions of stars within galaxies and how matter clumps together in the universe. No one has conclusively spotted the particles (*SN: 11/12/16, p. 14*).

The COSINE-100 detector (shown) in South Korea found no signs of dark matter particles interacting in sodium iodide crystals.

Scientists with the DAMA experiment at Italy's Gran Sasso National Laboratory near L'Aquila, however, say they have strong evidence that dark matter is interacting in their detector. Now, an experiment called COSINE-100 has searched for the particles using the same type of detector as DAMA and found no signs of dark matter, scientists report in the Dec. 6 *Nature*.

"This is one more nail in the coffin," says astrophysicist Dan Hooper of Fermilab in Batavia, Ill., who was not involved with the new research. Earlier experiments using different types of detectors have likewise tried and failed to reproduce DAMA's results.

Both DAMA and COSINE-100 search for dark matter particles slamming into atomic nuclei in sodium iodide crystals. If a collision occurs, it should produce a tiny flash of light in a crystal. But mundane interactions can produce similar flashes, such as those caused by minute amounts of radioactive elements.

The DAMA team monitored crystals for years to tease out the purported dark matter signature, reporting that the rate of collisions in the detector rises and falls with a specific annual pattern. That pattern, the argument goes, is the result of Earth's motion through a stream of dark matter as the planet orbits the sun.

Previous experiments that tested for the yearly variation have found nothing (*SN: 2/4/17, p. 15*). But those experiments used a different detector material. By using sodium iodide crystals, "we're going to take out any possible loophole as to why DAMA sees something," says Yale University physicist Reina Maruyama, a spokesperson for the COSINE-100 collaboration.

COSINE-100 scientists did not look for a yearly pattern. Instead, they compared the rate of hits in their detector, at the Yangyang Underground Laboratory in South Korea, with the number expected from known sources, such as radioactivity. The team found no sign of extra blips that could be from dark matter.

DAMA physicists are sticking to their claims. Rita Bernabei of the University of Rome Tor Vergata says, "COSINE-100 has no impact on the long-standing results obtained with the DAMA setups."

Katherine Freese, a physicist at the University of Michigan in Ann Arbor, says what's really needed is for COSINE-100 to search for annual variation. Maruyama says that search is in the works. ■

ATOM & COSMOS

Gravitational wave bounty grows

Spacetime ripples reveal additional black hole mergers

BY EMILY CONOVER

Astronomers have now tallied up more gravitational wave sightings than they can count on two hands.

Scientists with the LIGO and Virgo gravitational wave observatories report four new sets of these ripples in spacetime. Those additions bring the total count to 11, the researchers say in a study posted online December 3 at arXiv.org, marking major progress since the first gravitational wave detection in 2015.

The patterns of the waves indicated that 10 of the 11 sets of waves were stirred up in black hole collisions. The remaining detection, reported in 2017, came from the smashup of two stellar corpses called neutron stars (*SN: 11/11/17, p. 6*).

The data are revealing how often such waves jiggle the cosmos and the properties of the cosmic figures that unleash the ripples. For example, black holes may have merged more frequently earlier in the universe's history, the scientists say in a second study posted December 3 at arXiv.org. The team also concluded that few mergers involve black holes bigger than about 50 times the sun's mass, says LIGO member Daniel Holz, an astrophysicist at the University of Chicago.

The combined mass of two of the colliding behemoths was the largest merger yet spotted, with one black hole weighing about 50 times the sun's mass and the other 34 times the sun's mass. Those ripples came from farther away than previous detections: about 9 billion light-years from Earth. "It stands out in every possible way," says Johns Hopkins University physicist Emanuele Berti. "It's super interesting."

LIGO's two detectors, located in the United States, and Virgo, in Italy, are shuttered for upgrades until the spring. Improvements could triple the number of gravitational wave sightings, Holz says. ■

JAY HYUN JO

BODY & BRAIN

Opioids linked to babies' small heads

Drug use in pregnancy might impair a child's brain growth

BY AIMEE CUNNINGHAM

Babies born dependent on opioids have smaller heads than babies not exposed to the drugs in the womb.

The finding, published online December 10 in *Pediatrics*, raises concerns that the drugs impair brain growth during development, researchers say.

Pregnant women who use opioids, including opioids to treat addiction, pass the drugs through the bloodstream to their babies. Infants can become dependent on the drugs in the womb and experience withdrawal symptoms after birth. This withdrawal, known as neonatal abstinence syndrome, or NAS, is marked by excessive crying, tremors or difficulty sleeping or feeding (*SN: 6/10/17, p. 16*).

Researchers compared the head sizes of almost 860 babies born from 2014 to 2016, half with NAS and half from mothers who had no opioids while pregnant. Newborns with NAS had a head circumference nearly a centimeter smaller, on average, than babies not exposed to the drugs. Thirty percent of the NAS babies had especially small heads compared with only 12 percent of babies without NAS.

A smaller head is a possible sign of a smaller brain. So for NAS babies who later have learning and behavioral problems, a contributing factor may be the effect of opioids on brain growth, says neonatologist Jonathan Davis of Floating Hospital for Children at Tufts Medical Center in Boston. It is essential to determine "the actual impact of the smaller heads on how these children are developing," says Davis, who wasn't involved in the study.

The researchers found that 372 of the NAS babies, or 87 percent, had moms who took the opioids buprenorphine or methadone during pregnancy to treat their addiction, suggesting that the treatment can also contribute to small head size.

Called medication-assisted treatment, the therapy, which reduces cravings and withdrawal symptoms without producing a high, is recommended for addicted pregnant women because it's generally thought that withdrawing from opioids while pregnant could harm the fetus or put mothers at risk of relapse.

But that recommendation largely stems from two case studies in the 1970s, says Craig Towers, coauthor of the new paper. Studies since then have found that gradual withdrawal during pregnancy does not harm the fetus, he says.

Still, the treatment is the first step for addicted pregnant women. It should be a woman's choice whether to continue with medication-assisted treatment or to undergo a medically supervised withdrawal, says Towers, a maternal fetal medicine specialist at the University of Tennessee Medical Center in Knoxville.

If a woman has struggled with a past attempt at withdrawal, then the treatment may be safer, he says. ■

BODY & BRAIN

Roots of mental disorders investigated

Big data is revealing how psychiatric diseases start in the brain

BY LAURA SANDERS

The many complexities of psychiatric disorders have stymied scientists looking for clear genetic culprits. But a new giant dataset holds clues to how, when and where these brain disorders begin.

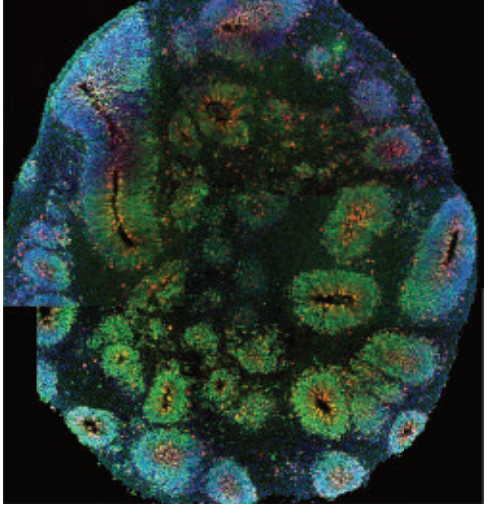
The first large data release from a project called PsychENCODE reveals intricate insights into the behavior of genes and other stretches of the genome in both healthy brains and those from people with schizophrenia, bipolar disorder or autism spectrum disorder.

The results, split among 10 studies published online December 13 in *Science*, *Science Advances* and *Science Translational Medicine*, offer some of the most detailed looks yet at the links between genetics and brain health. "It's all connected, and now we have the tools to unravel those connections," says geneticist Thomas Lehner of the National Institute of Mental Health in Bethesda, Md., who oversaw the project but wasn't involved in the studies.

Earlier studies have pinpointed certain genes and other aspects of the genome as being involved in schizophrenia, bipolar disorder and autism spectrum disorder. The new collection of work goes further, both confirming and clarifying some of these roles.

In part of the new research, neuroscientist Nenad Sestan of Yale University and colleagues looked at gene behavior as brains develop. Samples of postmortem brains ranging from fetal stages through adulthood revealed two major points of genetic upheaval: prenatal development and adolescence. Activity in groups of genes linked to psychiatric disorders suggests that these are times when important genetic behavior goes awry, the researchers say.

PsychENCODE analyses in rhesus macaques revealed similar developmental paths, Sestan says. Those comparisons also turned up some gene behavior that's exclusive to humans, differences that "may drive unique features of the diseases in humans," he says.



Lab-grown brain organoids (one shown) may offer genetic clues about psychiatric diseases.

Other PsychENCODE studies scrutinized spots in the genome that aren't necessarily located inside genes. Researchers linked many of these genetic hot spots, which are thought to differ in people with psychiatric diseases, to genes for the first time. That information could be used to predict a person's risk of these psychiatric disorders from genomic makeup alone.

HUMANS & SOCIETY

Oldest known plague case found

Disease's origins traced back at least 5,000 years in Europe

BY BRUCE BOWER

A long-dead Scandinavian woman has yielded bacterial DNA showing that she contracted the earliest known case of the plague in humans.

DNA extracted from the woman's teeth comes from a newly identified, and the oldest yet found, strain of *Yersinia pestis*, the bacterium that causes plague, researchers report online December 6 in *Cell*. The woman's bones, which date from 5,040 to 4,867 years ago, were unearthed nearly 20 years ago in a mass grave at an ancient farming site in Sweden.

Comparisons of the *Y. pestis* strain with other ancient and modern strains suggest that an early plague epidemic emerged more than 5,000 years ago in densely populated farming communities in eastern Europe in what is today Moldova, Romania and Ukraine. Then the plague spread elsewhere via trade routes, evolutionary geneticist Simon Rasmussen of the University of Copenhagen and colleagues conclude. That ancient epidemic apparently contributed to sharp population declines in Europe that began by at least the time of the Scandinavian woman's death (*SN: 11/2/13, p. 12*).

In particular, the scientists suspect that an early form of plague developed among eastern Europe's Trypillia culture, also known as the Cucuteni-Trypillia culture. Trypillia settlements were the first to bring enough people into close contact to enable the evolution of a highly infectious version of *Y. pestis*, the team suggests. Trading networks then transmitted the plague from Trypillia population centers, home to as many as 20,000 people, to West Asian herders known as the Yamnaya (*SN: 11/25/17, p. 16*), the researchers argue. In this scenario, herders infected by the Trypillia people probably spread what had become a new strain of the plague both eastward to Siberia and westward to the rest of Europe. Yamnaya migrations to Europe roughly coincided with the rapid abandonment and burning of large Trypillia settlements, which probably occurred as a result of plague outbreaks, the scientists say.

Rasmussen and others had previously suspected that the herders brought early *Y. pestis* strains from Asia into Europe (*SN: 11/28/15, p. 7*). "Now we can see that the plague was in Europe before the herders came," Rasmussen says.

DNA comparisons let the researchers calculate that the Scandinavian woman's plague strain is the oldest *Y. pestis* variant identified so far. Based on a statistical model of how the bacterium

VACCARINO LAB

Still more work uncovered important differences in how genes behave in brains of people with autism, bipolar disorder or schizophrenia. Levels of certain RNA molecules, go-between chemicals that help carry out DNA's instructions, were different in the brains of people with psychiatric disorders. Those results may lead to targeted medicines for the diseases.

Some studies focused on how to use lab tools including brain organoids, clumps of neural tissue grown in dishes (*SN: 3/3/18, p. 22*), to further the research. By comparing the gene activity of cells in organoids with that of cells from actual brains, scientists found that the two mirror each other at early stages of development. The similarities mean that the organoids, good mimics of young brains, might be useful in understanding brain disorders that start early.

The PsychENCODE group is making progress, says Columbia University psychiatrist Jeffrey Lieberman. "But the jury is still out in terms of what it will result in," he says. "It could produce important — and if we're lucky — game-changing results." ■

evolved, the scientists estimate that the strain probably diverged from other *Y. pestis* forms around 5,700 years ago. A Eurasian plague variant previously dated to between 4,800 and 3,700 years ago — the oldest known until now — originated around 5,300 years ago, the team calculates. A form of the plague ancestral to present-day strains probably emerged in East Asia around 5,100 years ago.

Rasmussen and colleagues plan to look for *Y. pestis* DNA in human skeletons from Trypillia archaeological sites.

The newly presented scenario is possible, says evolutionary geneticist Pontus Skoglund of the Francis Crick Institute in London. But it's also possible that centuries earlier, a yet-undetected *Y. pestis* variant spread through Eurasia and into Scandinavia, Skoglund says. Later, that strain could have given rise to *Y. pestis* strains that infected European farmers, Yamnaya herders and the Scandinavian woman. ■

COURTESY OF THE UNIV. OF THE WITWATERSRAND

HUMANS & SOCIETY

Hominid fossil's identity debated

Little Foot skeleton named to controversial species

BY BRUCE BOWER

A nearly complete hominid skeleton known as Little Foot has finally been largely freed from the stony shell in which it was discovered in a South African cave more than 20 years ago. And in the first formal analyses of the fossil, researchers say the 3.67-million-year-old Little Foot belonged to its own species.

In four papers posted at bioRxiv.org November 29 to December 5, paleoanthropologist Ronald Clarke of the University of the Witwatersrand in Johannesburg and colleagues assign Little Foot to a previously proposed species, *Australopithecus prometheus*, that has failed to gain traction among scientists.

Clarke has held that controversial view for more than a decade (*SN: 5/2/15, p. 8*). He found the first of Little Foot's remains in a storage box of fossils from a site called Sterkfontein in 1994. Excavations of the rest of the skeleton began in 1997.

Many other researchers, however, say Little Foot is an early member of the species *Australopithecus africanus*. Anthropologist Raymond Dart identified *A. africanus* in 1924 from a skull. Hundreds of *A. africanus* fossils have since been found in South Africa, including at Sterkfontein. In 1948, Dart assigned a fossil from one cave, Makapansgat, to *A. prometheus*. But Dart dropped that label after 1955, assigning the fossil and another one from Makapansgat to *A. africanus*.

Clarke and colleagues say that Little Foot's distinct skeleton, an adult female that is at least 90 percent complete, justifies reviving the rejected species. "Little Foot fits comfortably in *A. prometheus*," Clarke says.

Discoverers of the Little Foot skeleton (skull shown) classify it as *Australopithecus prometheus*.

The estimated ages of Little Foot and additional fossils from Sterkfontein and Makapansgat, he says, indicate that *A. prometheus* survived for at least a million years and lived alongside the younger *A. africanus* for at least a few hundred thousand years. The new papers will appear along with other analyses of Little Foot in an upcoming issue of the *Journal of Human Evolution*.

The team's claims are still controversial. The papers "fail to make a sound case" for a second Sterkfontein species, says paleoanthropologist Bernard Wood of George Washington University in Washington, D.C.

In a comment published online December 14 in the *American Journal of Physical Anthropology*, paleoanthropologists Lee Berger of the University of the Witwatersrand and John Hawks of the University of Wisconsin–Madison argue that Dart correctly discarded *A. prometheus* because he never clearly distinguished it from *A. africanus*. "I'm keeping an open mind, but I haven't seen data [in the papers] to support any grand ideas about Little Foot," Hawks says.

Clarke and Witwatersrand colleague Kathleen Kuman describe skull features that the duo says set Little Foot apart from *A. africanus*. For example, the vertical sides of Little Foot's braincase differ from *A. africanus*' sloping sides as do the heavily worn teeth from the front of the mouth to the first molars. Such wear probably resulted from eating tubers, leaves and tough-skinned fruits, Clarke says. *A. africanus* ate a greater variety of foods that took a lesser toll on teeth, he adds.

Independent studies of Little Foot will help to resolve the controversies, predicts paleoanthropologist Carol Ward of the University of Missouri in Columbia. "This skeleton holds so much scientific potential." ■

The PERIODIC TaBle turns 150

Celebrating Mendeleev's view of the elements

By Tom Siegfried

Every field of science has its favorite anniversary.

For physics, it's Newton's *Principia* of 1687, the book that introduced the laws of motion and gravity. Biology celebrates Darwin's *On the Origin of Species* (1859) along with his birthday (1809). Astronomy fans commemorate 1543, when Copernicus placed the sun at the center of the solar system.

And for chemistry, no cause for celebration surpasses the origin of the periodic table of the elements, created 150 years ago this March by the Russian chemist Dmitrii Ivanovich Mendeleev.

Mendeleev's table has become as familiar to chemistry students as spreadsheets are to accountants. It summarizes an entire science in 100 or so squares containing symbols and numbers. It enumerates the elements that compose all earthly substances, arranged so as to reveal patterns in their properties, guiding the pursuit of chemical research both in theory and in practice.

Russian chemist Dmitrii Mendeleev (shown around 1880) was the first to publish a periodic table, which put the known elements into a logical order and left room for elements not yet discovered.

HERITAGE IMAGE PARTNERSHIP LTD/ALAMY STOCK PHOTO

"The periodic table," wrote the chemist Peter Atkins, "is arguably the most important concept in chemistry."

Mendeleev's table looked like an ad hoc chart, but he intended the table to express a deep scientific truth he had uncovered: the periodic law. His law revealed profound familial relationships among the known chemical elements — they exhibited similar properties at regular intervals (or periods) when arranged in order of their atomic weights — and enabled Mendeleev to predict the existence of elements that had not yet been discovered.

"Before the promulgation of this law the chemical elements were mere fragmentary, incidental facts in Nature," Mendeleev declared. "The law of periodicity first enabled us to perceive undiscovered elements at a distance which formerly was inaccessible to chemical vision."

Mendeleev's table did more than foretell the existence of new elements. It validated the then-controversial belief in the reality of atoms. It hinted at the existence of subatomic structure and anticipated the mathematical apparatus underlying the rules governing matter that eventually revealed itself in quantum theory. His table finished the transformation of chemical science from the medieval magical mysticism of alchemy to the realm of modern scientific rigor. The periodic table symbolizes not merely the constituents of matter, but the logical cogency and principled rationality of all science.

Laying the groundwork

Legend has it that Mendeleev conceived and created his table in a single day: February 17, 1869, on the Russian calendar (March 1 in most of the rest of the world). But that's probably an exaggeration. Mendeleev had been thinking about grouping the elements for years, and other chemists had considered the notion of relationships among the elements several times in the preceding decades.

In fact, German chemist Johann Wolfgang Döbereiner noticed peculiarities in groupings of elements as early as 1817. In those days, chemists hadn't yet fully grasped the nature of atoms, as described in the atomic theory proposed by English schoolteacher John Dalton in 1808. In his *New System of Chemical Philosophy*, Dalton explained chemical reactions by assuming that each elementary substance was made of a particular type of atom.

Chemical reactions, Dalton proposed, produced new substances when atoms were disconnected or joined. Any given element consisted entirely of one kind of atom, he reasoned, distinguished from other kinds by weight. Oxygen atoms weighed eight times as much as hydrogen atoms; carbon atoms were six times as heavy as hydrogen, Dalton believed. When elements combined to make new substances, the amounts that reacted could be calculated with knowledge of those atomic weights.

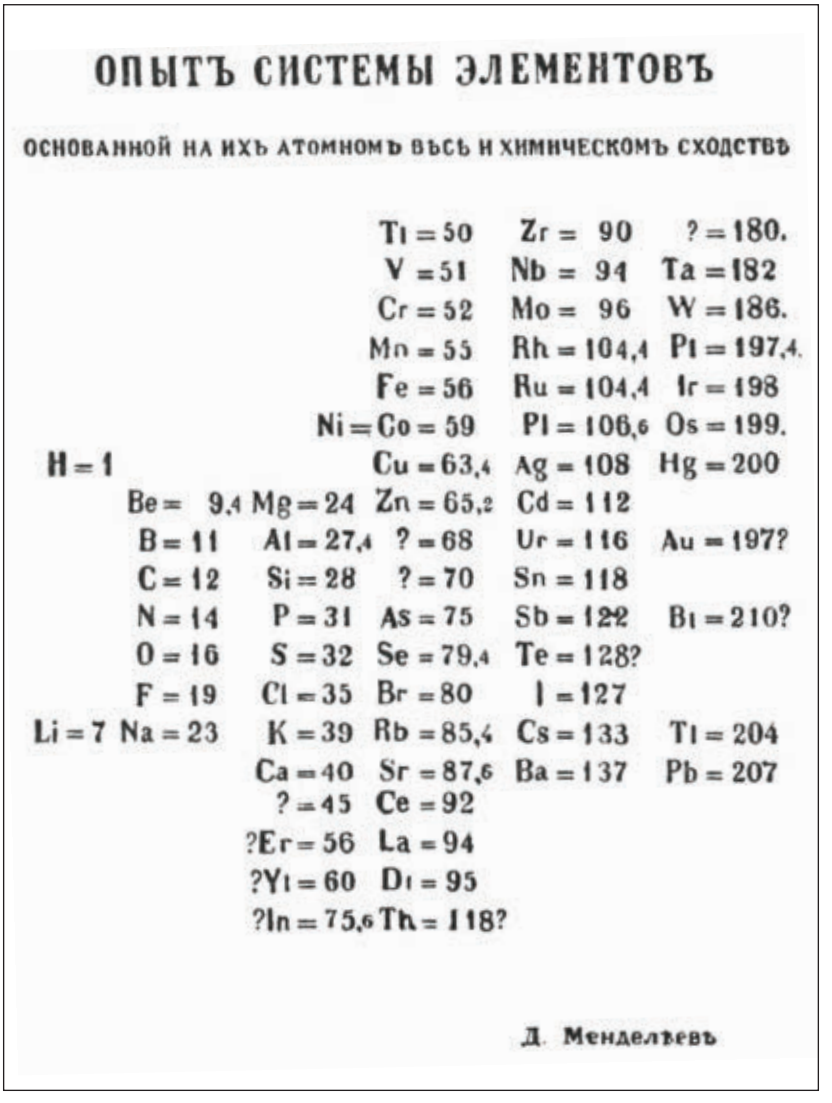
Dalton was wrong about some of the weights — oxygen is really 16 times the weight of hydrogen, and carbon is 12 times heavier than hydrogen. But his theory made the idea of atoms useful, inspiring a revolution in chemistry. Measuring atomic weights accurately became a prime preoccupation for chemists in the decades that followed.

When contemplating those weights, Döbereiner noted that certain sets of three elements (he called them triads) showed a peculiar relationship. Bromine, for example, had an atomic weight midway between the weights of chlorine and iodine, and all three elements exhibited similar chemical behavior. Lithium, sodium and potassium were also a triad.

Other chemists perceived links between atomic weights and chemical properties, but it was not until the 1860s that atomic weights had been well enough understood and measured for deeper insights to emerge. In England, the chemist John Newlands noticed that arranging the known elements in order of increasing atomic weight produced a recurrence of chemical properties every eighth element, a pattern he called the "law of octaves" in an 1865 paper. But Newlands' pattern did not hold up very well after the first couple of octaves, leading a critic to suggest that he should try arranging the elements in alphabetical order instead. Clearly, the relationship of element properties and atomic weights was a bit more complicated, as Mendeleev soon realized.

Organizing the elements

Born in Tobolsk, in Siberia, in 1834 (his parents' 17th child), Mendeleev lived a dispersed life, pursuing multiple interests and traveling a higgledy-piggledy path to prominence. During his higher education at a teaching institute in St. Petersburg, he nearly died from a serious illness. After graduation, he taught at middle schools (a requirement of his scholarship at the teaching institute), and while teaching math and science, he conducted research for his master's degree.



ОПЫТЪ СИСТЕМЫ ЭЛЕМЕНТОВЪ

ОСНОВАННОЙ НА ИХЪ АТОМНОМЪ ВѢСѢ И ХИМИЧЕСКОМЪ СХОДСТВѢ

			Ti = 50	Zr = 90	? = 180.	
			V = 51	Nb = 94	Ta = 182	
			Cr = 52	Mo = 96	W = 186.	
			Mn = 55	Rh = 104,4	Pt = 197,4.	
			Fe = 56	Ru = 104,4	Ir = 198	
			Ni = Co = 59	Pl = 106,6	Os = 199.	
H = 1			Cu = 63,4	Ag = 108	Hg = 200	
	Be = 9,4	Mg = 24	Zn = 65,2	Cd = 112		
	B = 11	Al = 27,4	? = 68	Ur = 116	Au = 197?	
	C = 12	Si = 28	? = 70	Sn = 118		
	N = 14	P = 31	As = 75	Sb = 122	Bi = 210?	
	O = 16	S = 32	Se = 79,4	Te = 128?		
	F = 19	Cl = 35	Br = 80	I = 127		
Li = 7	Na = 23	K = 39	Rb = 85,4	Cs = 133	Tl = 204	
		Ca = 40	Sr = 87,6	Ba = 137	Pb = 207	
		? = 45	Ce = 92			
		?Er = 56	La = 94			
		?Yt = 60	Di = 95			
		?In = 75,6	Th = 118?			

Д. Менделѣевъ

Mendeleev's periodic table, published in 1869, was a vertical chart that organized 63 known elements by atomic weight. This arrangement placed elements with similar properties into horizontal rows. The title, translated from Russian, reads: "Draft of system of elements: based on their atomic masses and chemical characteristics."

He then worked as a tutor and lecturer (along with some popular science writing on the side) until earning a fellowship for an extended tour of research at Europe's most prominent university chemistry laboratories.

When he returned to St. Petersburg, he had no job, so he wrote a masterful handbook on organic chemistry in hopes of winning a large cash prize. It was a long shot that paid off, with the lucrative Demidov Prize in 1862. He also found work as an editor, translator and consultant to various chemical industries. Eventually he returned to research, earning his Ph.D. in 1865 and then becoming a professor at the University of St. Petersburg.

Soon thereafter, Mendeleev found himself about to teach inorganic chemistry. In preparing to master that new (to him) field, he was unimpressed by the available textbooks. So he decided

HISTORIC IMAGES/ALAMY STOCK PHOTO

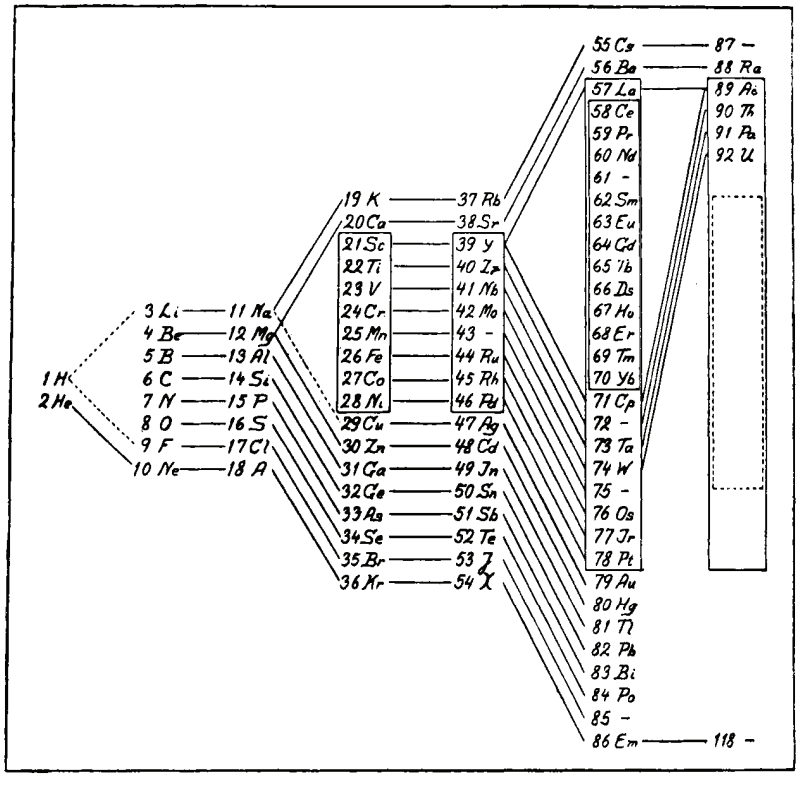
> "Elements arranged according to the size of their atomic weights show clear periodic properties."
>
> **DMITRII MENDELEEV, 1869**

to write his own. Organizing the text required organizing the elements, so the question of how best to arrange them was on his mind.

By early 1869, Mendeleev had made enough progress to realize that some groups of similar elements showed a regular increase in atomic weights; other elements with roughly equal atomic weights shared common properties. It appeared that ordering the elements by their atomic weight was the key to categorizing them.

By Mendeleev's own account, he structured his thinking by writing each of the 63 known elements' properties on an individual note card. Then, by way of a sort of game of chemical solitaire, he found the pattern he was seeking. Arranging the cards in vertical columns from lower to higher atomic weights placed elements with similar properties in each horizontal row. Mendeleev's periodic table was born. He sketched out his table on March 1, sent it to the printer and incorporated it into his soon-to-be-published textbook. He quickly prepared a paper to be presented to the Russian Chemical Society.

"Elements arranged according to the size of their atomic weights show clear periodic properties," Mendeleev declared in his paper. "All the comparisons which I have made ... lead me to conclude that the size of the atomic weight determines the nature of the elements."



In Danish physicist Niels Bohr's 1922 version of the periodic table, adapted from a table by Danish chemist Julius Thomsen, elements with similar properties occupy horizontal rows connected by lines. The empty box on the right marks the expected occurrence of a group of elements that are chemically similar to the rare earth elements (numbers 58–70) in the preceding column.

N. BOHR, 1922

Meanwhile, the German chemist Lothar Meyer had also been working on organizing the elements. He prepared a table similar to Mendeleev's, perhaps even before Mendeleev did. But Mendeleev published first.

More important than beating Meyer to the publication punch, though, was Mendeleev's use of his table to make bold predictions about undiscovered elements. In preparing his table, Mendeleev had noticed that some note cards were missing. He had to leave blank spaces to get the known elements to properly align. Within his lifetime, three of those blanks were filled with the previously unknown elements gallium, scandium and germanium.

Not only had Mendeleev predicted the existence of these elements, but he had also correctly described their properties in detail. Gallium, for instance, discovered in 1875, had an atomic weight (as measured then) of 69.9 and a density six times that of water. Mendeleev had predicted an element (he called it eka-aluminum) with just that density and an atomic weight of 68. His predictions for eka-silicon closely matched germanium (discovered in 1886) in atomic weight (72 predicted, 72.3 observed) and density (5.5 versus 5.469). He also correctly predicted the density of germanium's compounds with oxygen and chlorine.

Mendeleev's table had become an oracle. It was as if end-of-game Scrabble tiles spelled out the secrets of the universe. While others had glimpsed the periodic law's power, Mendeleev was the master at exploiting it.

Mendeleev's successful predictions earned him legendary status as a maestro of chemical wizardry. But today, historians dispute whether the discovery of the predicted elements cemented the acceptance of his periodic law. The law's approval may have been more due to its power to explain established chemical relationships. In any case, Mendeleev's prognostication accuracy certainly attracted attention to the merits of his table.

By the 1890s, chemists widely recognized his law as a landmark in chemical knowledge. In 1900, the future Nobel chemistry laureate William Ramsay called it "the greatest generalization which has as yet been made in chemistry." And Mendeleev had done it without understanding in any deep way why it worked at all.

A mathematical map

In many instances in the history of science, grand predictions based on novel equations have turned out to be correct. Somehow math reveals some of nature's secrets before experimenters find them.

Antimatter is one example, the expansion of the universe another. In Mendeleev's case, the predictions of new elements emerged without any creative mathematics. But in fact, Mendeleev had discovered a deep mathematical map of nature, for his table reflected the implications of quantum mechanics, the mathematical rules governing atomic architecture.

In his textbook, Mendeleev had noted that "internal differences of the matter that comprises the atoms" could be responsible for the elements' periodically recurring properties. But he did not pursue that line of thought. In fact, over the years he waffled about how important atomic theory was for his table.

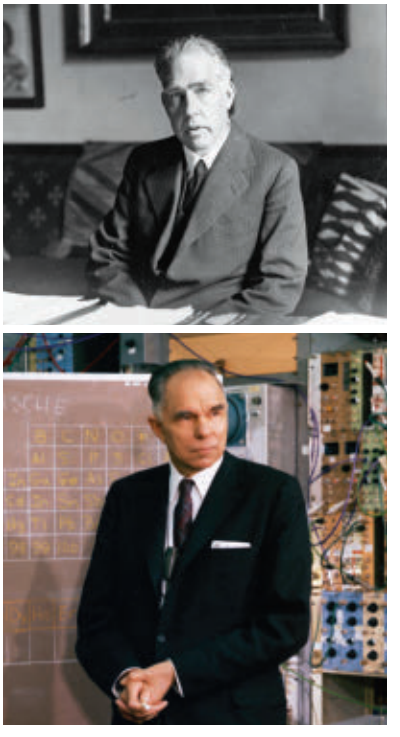
But others could read the table's message. In 1888, German chemist Johannes Wislicenus declared that the periodicity of the elements' properties when arranged by weight indicated that atoms are composed of regular arrangements of smaller particles. So in a sense, Mendeleev's table did anticipate (and provide evidence for) the complex internal structure of atoms, at a time when nobody had any idea what an atom really looked like, or even whether it had any internal structure at all.

By the time of Mendeleev's death in 1907, scientists knew that atoms had parts: electrons, which carried a negative electric charge, plus some positively charged component to make atoms electrically neutral. A key clue to how those parts were arranged came in 1911, when the physicist Ernest Rutherford, working at the University of Manchester in England, discovered the atomic nucleus. Shortly thereafter Henry Moseley, a physicist who had worked with Rutherford, demonstrated that the amount of positive charge in the nucleus (the number of protons it contained, or its "atomic number") determined the correct order of the elements in the periodic table.

Atomic weight was closely related to Moseley's atomic number — close enough that ordering elements by weight differs in only a few spots from ordering by number. Mendeleev had insisted that those weights were wrong and needed to be remeasured, and in some cases he was right. A few discrepancies remained, but Moseley's atomic number set the table straight.

At about the same time, the Danish physicist Niels Bohr realized that quantum theory governed the arrangement of electrons surrounding the nucleus and that the outermost electrons determined an element's chemical properties. Similar arrangements of the outer electrons would recur periodically, explaining the patterns that Mendeleev's table had originally revealed. Bohr created his own version of the table in 1922, based on experimental measurements of electron energies (along with some guidance from the periodic law). Bohr's table added elements discovered since 1869, but it was still, in essence, the periodic arrangement that Mendeleev had discovered. Without the slightest clue to quantum theory, Mendeleev had created a table reflecting the atomic architecture that quantum physics dictated.

Bohr's new table was neither the first nor last variant on Mendeleev's original design. Hundreds of versions of the periodic table have been devised and published. The modern form, a horizontal design in contrast with Mendeleev's original vertical version, became widely popular only after World War II, largely due to the work of the American chemist Glenn Seaborg (a longtime member of the board of Science Service, the original publisher of *Science News*). Seaborg and collaborators had synthetically produced several new elements with atomic numbers beyond uranium, the last naturally occurring element in the table. Seaborg saw that these elements, the transuranics (plus the three elements preceding uranium) demanded a new row in the table, something Mendeleev had not foreseen. Seaborg's table added the row for those elements beneath a similar row for the rare earth elements, whose proper place had never been quite clear, either. "It took a lot of guts to buck Mendeleev," Seaborg, who died in 1999, said in a 1997 interview.



Niels Bohr (top) and American chemist Glenn Seaborg (bottom) both revised the periodic table. Seaborg turned the table horizontal, adding several synthetically produced elements beyond uranium.

Seaborg's contributions to chemistry earned him the honor of his own namesake element, seaborgium, number 106. It's one of a handful of elements named to honor a famous scientist, a list that includes, of course, element 101, discovered by Seaborg and colleagues in 1955 and named mendelevium — for the chemist who above all others deserved a place at the periodic table. ■

Explore more

- The International Year of the Periodic Table: www.iypt2019.org

FROM TOP: QWERK/WIKIMEDIA COMMONS; COURTESY OF LAWRENCE BERKELEY NATIONAL LAB

INTRINSIC ORDER

The periodic table is an organized grid with tales to tell

By Elizabeth Quill

Recognize these rows and columns? You may remember a detail or two about this mighty table's organization from a long-ago chemistry class. Elements are ordered according to their number of protons, or atomic number. Metals are mostly to the left and nonmetals to the right. The column at the far right holds the noble gases, named for their general unwillingness to interact with other elements.

When Dmitrii Mendeleev proposed his periodic table 150 years ago, no one knew what was inside an atom. Today, we know that an element's place on the table, along with its chemical properties, has a lot to do with the element's proton number as well as how its electrons are configured.

In one glance, you can see the elements that make up nature's entire repertoire of chemical substances plus how those elements relate to one another. But the elements are also individuals, with scientific idiosyncrasies and nuanced stories of discovery. A few of our favorites are on these pages.

And the table is still a work in progress. Four elements were named as recently as 2016 (*SN: 7/9/16, p. 16*). Boundary-busting research efforts, along with scientific mysteries, remain.

Banana bonanza

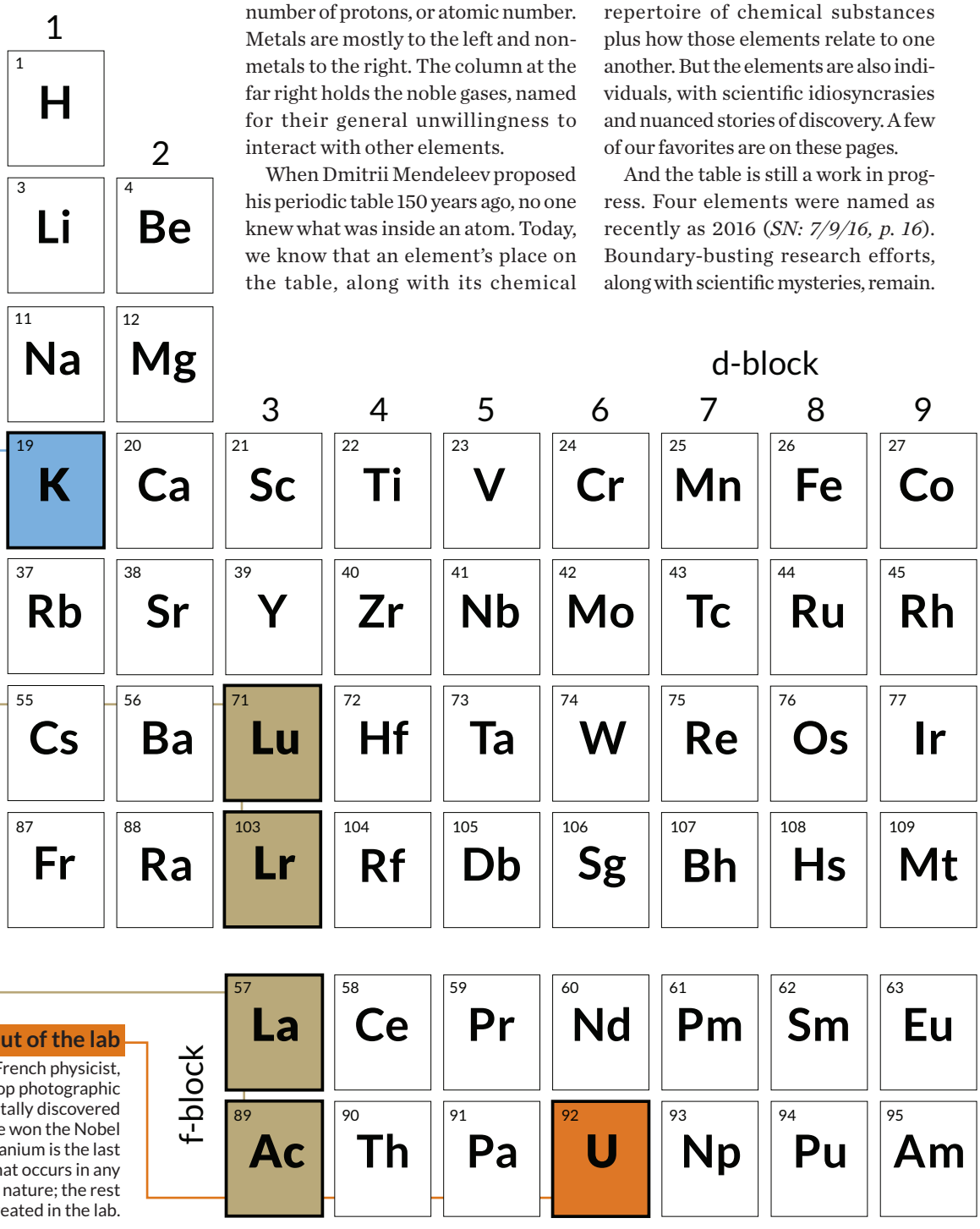
Bananas are rich in potassium-40, a radioactive version of potassium. In a single banana, the potassium-40 produces a positron, the antimatter version of the electron, a dozen or so times a day, as well as an electron about 13 times a second.

Who belongs

Not everyone is convinced that lutetium and lawrencium belong in the positions shown here. The Royal Society of Chemistry instead puts lanthanum and actinium in these boxes, prioritizing outer electron configurations and sticking lutetium and lawrencium at the end of the f-block below. The International Union of Pure and Applied Chemistry, responsible for chemical naming, has been exploring the placement question since 2015.

Out of the lab

When Henri Becquerel, a French physicist, placed uranium salts atop photographic plates in 1896, he accidentally discovered radioactivity, for which he won the Nobel Prize in physics in 1903. Uranium is the last element on the table that occurs in any meaningful abundance in nature; the rest must be created in the lab.



Campsite clues

When Meriwether Lewis and William Clark set out to reach the Pacific Ocean, they carried 1,300 doses of a mercury-based laxative known as Rush's Thunderbolts. Mercury discovered in the ground in Lolo, Mont., nearly two centuries later clued experts in to the location of one of the explorers' campsites.

Predictive power

Mendeleev left blank spaces in his original periodic table so that he could properly line up the known elements. Gallium, element 31, was his first gap to be filled, in 1875. The star of a popular chemistry trick, the metal gallium is solid at room temperature but liquid above 29.7° Celsius. It can be formed into a spoon that melts in the hand or in hot tea.

Out there

Helium was discovered as a bright yellow line in a spectrum of light from the sun in 1868, almost three decades before the element was found on Earth. Last year, scientists reported the first sighting of helium in the atmosphere of an exoplanet.

Special luster

Albert Einstein's special theory of relativity explains gold's color. Because of how electron energy levels shift due to relativity, the metal absorbs blue light, giving the reflected light a yellow hue.

10	11	12	13	14	15	16	17	18
								2 He
			5 B	6 C	7 N	8 O	9 F	10 Ne
			13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og

64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb
96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No

Three of a kind

Chlorine, bromine and iodine make up what German chemist Johann Wolfgang Döbereiner called a "triad." Bromine's atomic weight of 79.90 is halfway between chlorine's (35.45) and iodine's (126.90), and all react readily with metals to form salts. Döbereiner recognized such relationships in 1817, more than a half century before Mendeleev proposed his table.

The end?

Oganesson marks the end of today's periodic table, capping the noble gases column. Yet it isn't as aloof as others in its group. The element will readily give or take electrons, and its atoms may clump together — at least according to theoretical predictions. The few atoms of oganesson that chemists have made survived for less than a millisecond. Scientists continue smashing atoms together in the lab in search of elements beyond 118.

Cosmic collectors

Twin quests aim to grab some asteroid dust and bring it to Earth

By Lisa Grossman

Treasure hunters
Two spacecraft, Hayabusa2 (top) and OSIRIS-REx (bottom), began exploring two ancient asteroids in 2018. Both craft are expected to pick up samples of their respective rocks and carry them to Earth.

FROM TOP: DLR (CC BY 3.0); CONCEPTUAL IMAGE LAB/ NASA'S GODDARD SPACE FLIGHT CENTER

Shogo Tachibana greeted asteroid Ryugu with dread.

The cosmochemist with the University of Tokyo had spent 10 years helping to design a mission to Ryugu's surface. To touch down safely, the spacecraft, Hayabusa2, needs to find broad, flat stretches of fine-grained dust on the asteroid. But on June 27, when Hayabusa2 finally reached its target after a three-and-a-half-year journey (*SN Online: 6/27/18*), Tachibana got a rude awakening: Ryugu is covered in boulders. Big ones.

"We cannot find a 100 percent safe place to touch down," Tachibana says. "It seems to be a very dangerous place."

If Hayabusa2 can deal with the boulders — and any other challenges that arise — it will become only the second spacecraft to bring a piece of an asteroid back to Earth. And the mission will answer questions that its predecessor couldn't. The original Hayabusa mission visited a sand- and rock-covered asteroid called Itokawa in 2005. But Itokawa has the wrong chemical makeup to address big questions about the origin of life that Ryugu, which is carbon-rich, is well suited for. And Hayabusa suffered a series of calamities that caused it to return to Earth several years late, with less than 2,000 grains of precious asteroid dust.

Tachibana and colleagues from the Japanese Aerospace Exploration Agency, or JAXA, are counting on Haybusa2 to return bits of Ryugu's surface to Earth in 2020. And if a daring plan to blow a crater into the asteroid works, the spacecraft will get some subsurface grains as well.

A sister project from NASA, the OSIRIS-REx mission, arrived at an asteroid called Bennu in December to bring samples back in 2023 (*SN Online: 12/3/18*).

The two spacecraft face daunting challenges. The probes must investigate objects that have so little gravity that sunlight can knock them off their orbits. If the probes manage to pick up samples, the spacecraft must keep the dust pristine during the trip back to Earth. To get the most out of the missions, the Japanese and American teams are trying to work together across cultural and bureaucratic divides.

But the uncertainties and anxiety are worth it. Asteroids like Ryugu and Bennu are among the oldest and most intriguing objects in the solar system. They could hold the keys to some of the most pressing planetary questions: What came before the planets? What are the origins of life? And how much of a threat do asteroids pose to life on Earth today?

Of course, planetary scientists already have tens of thousands of asteroid pieces to study. Such meteorites fall to Earth in the hundreds each year, offering researchers plenty of material to slice, grind and examine for clues to the solar system's history.

Dante Lauretta of the University of Arizona in Tucson, the principal investigator of OSIRIS-REx, spent the first part of his career trying to coax meteorites into telling him whether molecules necessary for life — such as nucleic acids, amino acids and phosphorus, which are structural components of DNA — could have originated inside carbon-rich asteroids like Ryugu or Bennu.

Carbon-rich asteroids are thought to be mostly unchanged since their formation at least 4.6 billion years ago, which makes them perfect time capsules. A few grains of such an asteroid could reveal what the early solar system was made of.

Remote studies of asteroids also suggest that the raw ingredients for life, and maybe even the chemical processes that are necessary for life to begin, might have been present on carbon-rich asteroids even before the planets were done growing.

"We think an asteroid like this one may have delivered this material to the surface of the early Earth, providing seeds or building blocks of life," Lauretta says. "If we can show the precursors [of life] started before the planet, I think the probability that there's life elsewhere in the solar system goes way up."

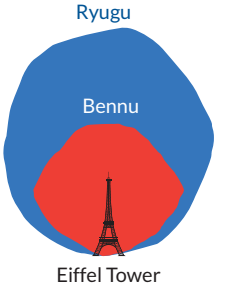
Studying meteorites to explore this notion falls short on two fronts, however: It's hard to tell where they come from, and they're contaminated. As soon as a space rock hits Earth's atmosphere, it starts accumulating signs of Earth life. Therefore, any intriguing organic compounds in a meteorite could be from Earth, not native to the asteroid. There's no way to tell.

"We needed samples of a carbon-rich asteroid to really answer the questions I was into," Lauretta says.

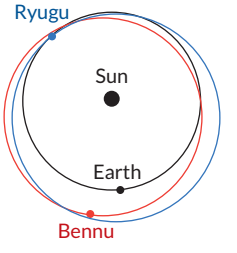
Break me off a piece

Getting to the origins of the solar system, and maybe life's beginnings, makes bringing clean, carefully selected samples to earthly labs crucial. But spacecraft can't just dig in with a shovel. There's no grabbing a rock with a claw like in an arcade game. The asteroids are so tiny — Ryugu is about 880 meters from pole to pole and Bennu is about 510 meters — and their gravity so weak that reaching out and grabbing something could push the spacecraft off course with the asteroid.

Two small asteroids ...



... with similar orbits

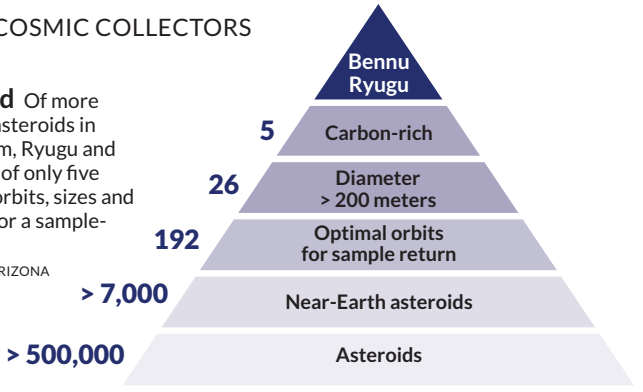


New worlds

Ryugu and Bennu are small targets. Ryugu's polar diameter is about 880 meters and Bennu's is about 510 meters. Both asteroids orbit the sun on trajectories that sometimes take them relatively close to Earth.

SOURCE: UNIV. OF ARIZONA

C. CHANG



A rare breed Of more than 500,000 asteroids in the solar system, Ryugu and Bennu are two of only five with the right orbits, sizes and compositions for a sample-return mission.
SOURCE: UNIV. OF ARIZONA

So instead of scooping or grabbing, the spacecraft will reach out with proboscis-like tubes, either touching down briefly or hovering above the surface. This tricky endeavor has been attempted only once before — and it was almost a disaster.

The first Hayabusa spacecraft was supposed to use its three reaction wheels to stabilize itself as it hovered near Itokawa's surface, stretched out a collection tube to touch the surface and fired a small bullet down the tube to stir up dust particles. Those dust grains would float up the tube into a sterile chamber for storage on the trip back to Earth.

Almost everything went wrong. Before Hayabusa even got to the asteroid, the biggest solar flare ever recorded damaged the spacecraft's solar panels and one of its engines, slowing down the spacecraft and delaying its asteroid rendezvous by three months.

Once at Itokawa, two of the craft's reaction wheels failed, making it hard for the craft to keep an even keel. A companion rover released by Hayabusa that was meant to land on Itokawa's surface and measure the asteroid's composition missed its mark and floated into space. The dust-stirring bullet didn't fire, so it was initially unclear if the craft got any samples at all. And all four of the probe's engines failed one by one on the return journey, forcing Hayabusa to take a lengthy detour home.

"It had lots of serious problems," says JAXA's Makoto Yoshikawa, a mission manager on both Hayabusa and Hayabusa2.

For all of Hayabusa's calamities, the mission's tale had a happy ending. Against all odds, the spacecraft returned to Earth in 2010 (*SN Online: 6/14/10*), having grabbed 1,534 grains of Itokawa.

Planners of the new mission learned from the original mission's mishaps. Hayabusa2 has four reaction wheels, souped-up engines and a beefier communication system that will send back much more data to help scientists plan the sample collection. The collection tube has teeth at its mouth to lift pebbles into the tube even if the bullet doesn't fire. And in September, Hayabusa2 successfully dropped three small landers on Ryugu's surface to gather data on the asteroid's composition, temperature and magnetic properties (*SN Online: 9/24/18*).

With similar caution, when OSIRIS-REx goes in to gather a sample from Bennu, it will touch the asteroid only briefly. "It's like five seconds of contact," Lauretta says. "Get the sample and then get out of there."

The spacecraft's Touch-And-Go Sample Acquisition Mechanism, TAGSAM, has a nitrogen jet at the end of a robotic arm. When the arm touches Bennu's surface, it will release a burst of nitrogen gas to ruffle the surface just enough to blow particles into the sample collector. As a bonus, the sample collector's head is covered in stainless steel Velcro-like pads that can pick up surface dust on contact.

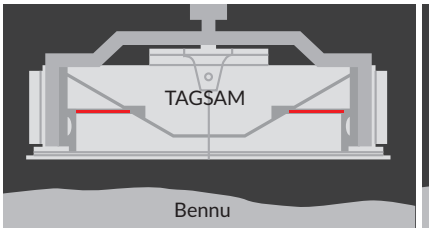
The remote-reach strategy avoids the hassle of anchoring to the asteroid, but presents its own problem: No one knows how fine-grained dust behaves when blown around in low gravity. That open question worries engineers. "What actually happens when you contact the surface of an asteroid is an unknown area of physics," Lauretta says. "I think [the surface] is going to be like a fluid. It's a truly alien landscape."

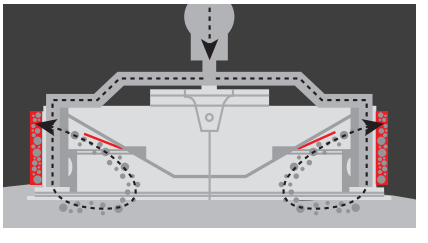
The road to Ryugu

When Hayabusa returned, planetary scientist Michelle Thompson of Purdue University in West Lafayette, Ind., studied the Itokawa grains. Having such a limited supply forced scientists to get the most out of the samples. The first chapter of Thompson's Ph.D. dissertation was written about a single Itokawa particle that measured 50 micrometers across.

"We still got some amazing science out of those particles," she says. Those grains proved that most

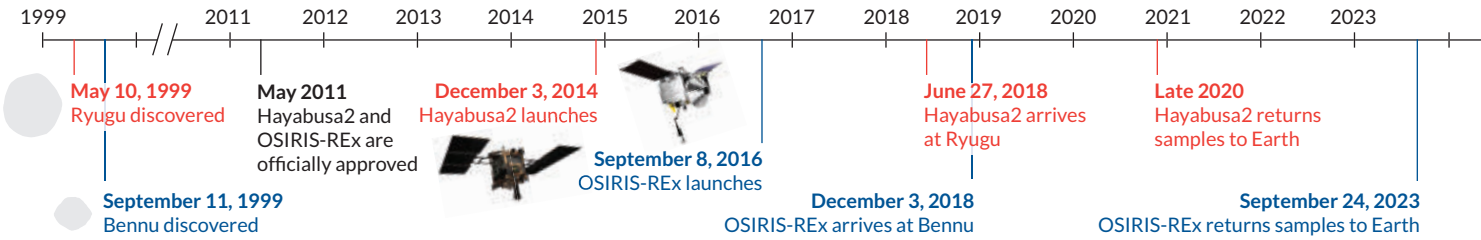
Keep it clean OSIRIS-REx's sampler, called the Touch-and-Go Sample Acquisition Mechanism, or TAGSAM (left, photographed in a clean room), has a head on an arm that extends to allow surface contact (center) without the spacecraft landing on the asteroid. During five seconds of contact, a jet of nitrogen gas will agitate Bennu's surface to loosen dust for collection (right). Surface contact pads will also collect fine-grained material. Once collection is done, the TAGSAM head will move into a capsule where it's protected from contamination during the trip back to Earth.





ALL ILLUSTRATIONS: C. CHANG; PHOTO: LOCKHEED MARTIN

Side-by-side missions



of the meteorites on Earth come from stony, carbon-poor asteroids like Itokawa, not carbon-bearing ones like Ryugu and Bennu (*SN Online: 8/25/11*). "In the context of [Hayabusa's] problems, it's incredible the amount of data that came out of that mission," Thompson says.

While Hayabusa was floundering in space in 2006, Yoshikawa's team was already suggesting that JAXA fly a follow-up mission. By then, Yoshikawa had set his sights on an even more attractive asteroid, Ryugu.

JAXA sent a spacecraft to Itokawa because it was easy to reach, not because it was scientifically special. But as a carbon-rich asteroid, Ryugu is thought to consist of the most ancient, pristine material in the solar system.

Ryugu's name even references a time capsule from a Japanese folktale, in which the hero Urashima Taro retrieves a box from a dragon-guarded castle called Ryugu at the bottom of the sea. When the hero returns to the surface, he finds that 300 years have passed. When he opens the box, he becomes an old man, because the box contained all of that elapsed time.

Yoshikawa and his colleagues proposed the mission every year and were rebuffed each time — until Hayabusa came home in 2010.

The spacecraft's return was lauded in Japan, Yoshikawa says. "Japanese people were very surprised to see that Hayabusa really came to the Earth." An editorial in the *Japan Times* deemed the spacecraft a "high achiever," and called for more funding for JAXA and space research.

In May 2011, the Japanese government approved the Hayabusa2 mission. Tachibana, Yoshikawa and the rest of the JAXA team aimed for the next launch window, in 2014.

Friendly competition

Like Hayabusa2, OSIRIS-REx was rejected multiple times before NASA selected it for flight, also in May 2011. Because of Bennu's orbit, the next launch opportunity to reach the asteroid wasn't until September 2016. That two-year gap between JAXA's and NASA's launches inspired some friendly competition between the teams.

"Of course, we are good friends and we want to have a good relation," Tachibana says. "But at the same time we are rivals." OSIRIS-REx is bigger than Hayabusa2 and plans to collect up to 20,000 times as much asteroid dust — up to two kilograms, in the best-case scenario, compared with Hayabusa2's total of 100 milligrams. To compete, Hayabusa2's team set out to do everything first, Tachibana says.

"They were concerned we were going to overshadow them," Lauretta says. The first few meetings between the teams were tense, he recalls. But both groups felt it was best to work together.

"This is the first time since Apollo ... that two sample-return missions are going to the same kind of target," Tachibana says. "The U.S. and the Soviet Union could not talk to each other." It was the middle of the Cold War. "This time we can talk to each other."

In November 2014, NASA and JAXA signed a memorandum promising to share data, software and samples. JAXA will give 10 percent of its Ryugu sample to NASA, and NASA will give 0.5 percent of the larger Bennu sample to JAXA.

Still, the two space agencies don't align on everything. "Hayabusa2 and OSIRIS-REx have completely different philosophies of sampling," says cosmochemist Keiko Nakamura-Messenger of NASA's Johnson Space Center in Houston. She oversees the sample site selection for OSIRIS-REx and will be in charge of storing the samples.

Take the mission timelines: OSIRIS-REx will spend more than a year mapping Bennu in detail. Its suite of science instruments, including three cameras, a laser altimeter and three spectrometers, will figure out the asteroid's composition all over the surface before the team chooses the mission's sole sampling site.

Hayabusa2 scientists, on the other hand, chose the first of three sampling sites in August, less than two months after the spacecraft arrived at Ryugu (*SN Online: 8/23/18*). Originally the team

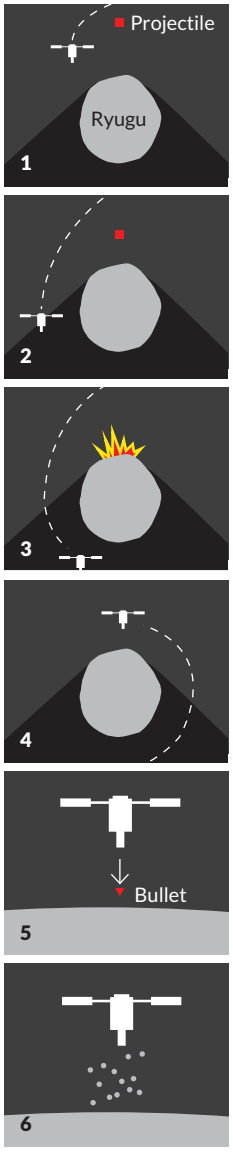
Years in the making

The Hayabusa2 and OSIRIS-REx missions grew up almost simultaneously on opposite sides of the world. The close timing of the Japanese and U.S. missions means the two can learn from each other.

Precious dust

Hayabusa2 aims to gather 0.1 grams of dust from Ryugu, the weight of about three grains of rice. OSIRIS-REx will try to get up to 2,000 grams of Bennu's surface, about the weight of a small Chihuahua.

FROM TOP: HAYABUSA2: DLR (CC BY 3.0); OSIRIS-REX: CONCEPTUAL IMAGE LAB/NASA'S GODDARD SPACE FLIGHT CENTER; C. CHANG



Drop and dodge
To sample Ryugu below the surface, Hayabusa2 will launch a projectile, then take a lap around the asteroid to avoid damage (panels 1–3). Returning to the new crater, the spacecraft will come close to the surface and shoot a small bullet from its sampling horn. The bullet will splash on the surface, sending dust and sand into a catcher in the upper part of the horn (panels 4–6).
SOURCE: JAXA

planned to take its first sample in October, but the boulders proved so difficult that sampling was pushed to February 2019 at the earliest.

Hayabusa2 will sample three sites to capture as much of the asteroid's mineral diversity as possible. One of the samples will come from within a several-meter-wide crater that doesn't yet exist. The spacecraft will create the hole by firing a two-kilogram copper projectile at the asteroid, then hide on the other side of Ryugu to avoid debris when the projectile hits. The aim is to see if the asteroid's interior is different from the surface.

It's hard to imagine NASA approving such a crazy maneuver, says Nakamura-Messenger, who grew up in Japan. It's too risky. "The NASA way, the American way, is: The success rate has to be really high," she says. But she's rooting for Hayabusa2's bold moves.

"In my heart, I'm Japanese," she says. "Therefore, I'm like, 'Go for it!' "

Bound for Bennu

Still, Ryugu's surprise boulder field made Lauretta, Nakamura-Messenger and the rest of the OSIRIS-REx team nervous about Bennu.

"I've been lying awake at night anticipating Bennu," Lauretta says. "It's fascinating and frightening all at once."

Fitting with NASA's cautious approach, the OSIRIS-REx team knew a lot more about Bennu than JAXA knew about Ryugu before the missions launched. Bennu came close enough to Earth in 1999, 2005 and 2011 for radio telescopes to map the asteroid's shape (though not close enough to reveal much detail).

"We compiled the most comprehensive database from astronomy for any asteroid in the solar system," Lauretta says of the team's prework on Bennu.

Those radio measurements allowed researchers to see how sunlight nudges the asteroid on its orbit, a phenomenon called the Yarkovsky effect. As asteroids tumble through space, they absorb sunlight on one side and re-emit that energy as heat later, when that side faces away from the sun. The force of that radiating heat is enough to push the asteroid around, making it difficult to predict the asteroid's orbit over the long term.

The Yarkovsky effect calculation yielded a worrying prediction: Bennu has a 1 in 2,700 chance of hitting Earth in the late 22nd century, one of the highest probabilities of any known asteroid.

That forecast makes OSIRIS-REx's mission even more urgent. Testing the returned samples will give scientists a better understanding of how Bennu's surface material absorbs and emits heat. That information will sharpen the researchers' predictions of where the asteroid will go, and help inform future missions to deflect asteroids that come too close to Earth.

Hazard map OSIRIS-REx took this mosaic image of Bennu in early December and has seen signs of liquid water in the asteroid's past (see Page 6).

That's only if Bennu is smooth enough for the spacecraft to get a sample. The first images taken as OSIRIS-REx approached Bennu on December 3 didn't do much to quell the team's fears. With the naked eye, Bennu seems to have about as many boulders as Ryugu, maybe a little fewer, says planetary scientist Kevin Walsh of the Southwest Research Institute in Boulder, Colo.

"Even if we convince ourselves that there's a site that's boulder free, there's still a chance it could change later on. So we'll have to see," says Walsh, who presented an early comparison of Bennu and Ryugu on December 11 at a Washington, D.C., meeting of the American Geophysical Union. "We have plenty of tools to find the places with the least amount of hazards, even if we can't find a place that's completely free of them."

That is a relief, Nakamura-Messenger says. But every mission so far has surprised her.

"I don't make wild guesses anymore," she says. "Nature is wilder." ■

Explore more

- Tomohiro Yamaguchi *et al*. "Hayabusa2-Ryugu proximity operation planning and landing site selection." *Acta Astronautica*. October 2018.
- Dante Lauretta *et al*. "OSIRIS-REx: Sample return from asteroid (101955) Bennu." *Space Science Reviews*. October 2017.

FROM LEFT: C. CHANG; UNIV. OF ARIZONA, NASA'S GODDARD SPACE FLIGHT CENTER

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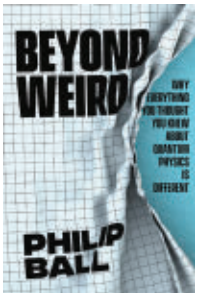

Beyond Weird
Philip Ball
UNIV. OF CHICAGO, $26

What Is Real?
Adam Becker
BASIC BOOKS, $32

BOOKSHELF

How to make sense of quantum weirdness

Quantum physics has earned a reputation as a realm of science beyond human comprehension. It describes a microworld of perplexing, paradoxical phenomena. Its equations imply a multiplicity of possible realities; an observation seems to select one of those possibilities for accessibility to human perception. The rest either disappear, remain hidden or weren't really there to begin with. Which of those explanations pertains is debated by competing interpretations of the quantum math, pursued in a field of study known as quantum foundations.

Numerous quantum interpretations have been proposed — and an even greater number of books have been written about them. Two of the latest such books offer very different perspectives.

Philip Ball, in *Beyond Weird*, argues that much of the famous quantum weirdness lies in the popular descriptions of it, rather than in the math itself. Adam Becker's *What is Real?* insists that the traditional "Copenhagen interpretation" is misguided; he extols the work of several physicists who reject it. Becker writes with exuberance and self-assuredness, often focusing on the personal stories of the scientists he discusses. Ball's approach is less personal but more conversational, although he does not try to evade the sticky technicalities that illustrate and partially explain the quantum mysteries.

Ball contends that many of the analogies and illustrations used by popularizers (and physicists) to convey the weirdness of quantum theory (like a particle being in two places at once) are actually misleading. With less flamboyant phrasing, in Ball's view, quantum physics can seem less perplexing, even almost understandable.

Without fully endorsing it, Ball gives a fairly sound presentation of the Copenhagen interpretation, based on the ideas of the Danish physicist Niels Bohr. Bohr held that quantum reality cannot be described apart from the experiments designed to probe it. A particle has many possible locations before you experimentally observe it; once observed, the location is established and the other possibilities vanish. And an electron will seem to behave as a particle or wave, depending on what sort of experimental apparatus you use to observe it.

Bohr expressed these truths by a principle he called complementarity — mutually exclusive concepts (such as wave or particle) are required to explain reality, but both concepts cannot be observed in any individual experiment. Bohr's elaborations on this idea are famously convoluted and expressed rather obscurely. (When asked what is complementary to truth, Bohr replied, "clarity.")

Bohr's lack of clarity has led to many misinterpretations of what he meant, and it is those misinterpretations that Becker criticizes, rather than Bohr's actual views. Becker's main argument insists that the Copenhagen interpretation embraces the philosophy known as positivism (roughly, nothing unobservable is real, and sensory perceptions are the realities on which science should be based), and then demonstrates positivism's fallacies. He does a fine job of demolishing positivism. Unfortunately, the Copenhagen interpretation is not positivistic, as its advocates have often pointed out. Bohr's colleague Werner Heisenberg said so quite clearly: "The Copenhagen interpretation of quantum theory is in no way positivistic," he wrote. And the philosopher Henry Folse's 1985 book on Bohr's philosophy thoroughly dispelled the mistaken belief that Bohr's view was positivistic or opposed to the existence of an underlying reality.

Becker's book commits many other more specific errors. He says Heisenberg found his famous uncertainty principle "buried in the mathematics of [Erwin] Schrödinger's wave mechanics." But Heisenberg despised wave mechanics and did his work on uncertainty wholly within his own matrix mechanics. Becker claims that physicists Murray Gell-Mann and James Hartle "had long been convinced that the Copenhagen interpretation had to be wrong." But Gell-Mann and Hartle are on record stating that the Copenhagen view is not wrong, merely limited to special cases and not general enough to tell the whole quantum story.

Becker's book does offer engaging discussions of the physicists who have questioned Bohr's ideas and proposed alternate ways of interpreting quantum physics. But he allows the opponents to frame Bohr's position rather than devoting any effort of his own to examining the subtlety and depth of Bohr's philosophy and arguments. And Becker fails to address the important point that every quantum experiment's results, no matter how bizarre, are precisely what Bohr would have expected them to be.

Becker does not engage deeply with the more recent body of work on quantum foundations, an area where Ball excels. Ball especially favors the perspective on quantum physics offered by the notion of quantum decoherence. Very roughly, the decoherence process dissipates various possible quantum realities into the environment, and only those versions of reality that are robustly recorded in the environment present themselves to observers. It's of course much more complicated than that, and Ball admirably conveys those complications even at the occasional expense of clarity. Which puts his account closer to the truth.
— *Tom Siegfried*

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CONVERSATIONS WITH MAYA

KRISTINA JOHNSON
CHANCELLOR, THE STATE UNIVERSITY OF NEW YORK

Maya Ajmera, President & CEO of Society for Science & the Public and Publisher of *Science News*, sat down to chat with Kristina Johnson, Chancellor of The State University of New York and an alumna of the International Science and Engineering Fair. We are thrilled to share an edited version of their conversation, which is a reprint from the June 23, 2018, issue of *Science News*.

You're an alumna of the 1975 International Science and Engineering Fair. How did the competition impact your life and are there any particular moments that still stand out for you?

It was an amazing experience. In 1975, I became fascinated by holograms — I just thought they were magic. Although holograms are everywhere now, at the time they were not that well known. [Note: Johnson's project title was "Holographic Study of the Sporangiophore of *Phycomyces*."]

I ended up building a little lab in our basement and was able to reproduce the lab in my physics classroom at school. That's the year I experienced my first all-nighter. I stayed up all night at my high school the night before the science fair. It was a little controversial to say the least.

My project did well, and it was exciting. As a result, I think competing at ISEF gave me confidence and enthusiasm about science.

At the time, I was really not aware that it was unusual to be a woman in science. It wasn't until I went to college that I realized that it was unusual. That's where doing well at ISEF gave me confidence. When I was told I didn't belong, I could just think back to succeeding at ISEF.

I understand your high school did not have a girls' lacrosse team so you practiced with the boys. At Stanford University, you started a women's lacrosse team that became the varsity team. We still experience a gender gap in a variety of fields, from athletics to engineering. What strategies do you think are working and not working to close the gender gap?

Obviously, the biggest improvement for gender equity in sports was passing Title IX, wherein it became important to open up these opportunities for girls and women. When I got to Stanford, I learned that we didn't have a lacrosse team and thought, well, we should start one. So, we did. Over the course of my nearly eight years at Stanford as an undergraduate and graduate student, it went from being a club sport to a club varsity sport. I think that's maybe part of the answer: Leaders need to take charge when they see an opportunity to build something new. [Note: On the 40th anniversary of Title IX in 2012, Johnson was recognized as a 40 For 40 honoree by espnW and other organizations. The 40 For 40 event honored "women who have made an impact" after participating in high school and college sports.]

When I went into science and engineering at Stanford, I didn't have any science or engineering faculty that were women. I only had two women professors in eight years. Only two, though I had terrific male faculty including my Ph.D. adviser, Joseph Goodman. When I graduated, I did not think that women were professors in science and engineering. I didn't really think too much about it. It just was the way it was. One of the things that I'm not as happy about today is that there hasn't been a significant increase in the number of women pursuing engineering. That needs to change.

Drawing on your experiences as chancellor of the SUNY system, dean of engineering at Duke University, an entrepreneur and a high-level government appointee in the Obama administration, what particular challenges do you think are keeping women in the sciences back?

In the early 1990s, the National Science Foundation did an interesting study that said women will pursue careers in science and engineering and stay in them if they can align their vocation with their avocation to help others.

I think the more that we humanize the field, the more attractive these careers will be to all individuals.

I also think part of it is that when women don't see role models in their classrooms, they don't know they can do it. I'm very passionate about bringing underrepresented minorities and women into the professoriate and the academy so we can inspire a new generation of diverse leaders.

I think part of it really is when you are "other," it is important to feel welcome.

You've reportedly said that there are three things you would never do. One is be a dean, two is start a company and three is write a book. You've done two out of three. I'm curious as to what has motivated you to take different turns in your career.

So, it is true. I did say I never wanted to be a dean. I never wanted to start a company. I didn't want to write a book. I actually haven't written a book yet, but I have a title for a book. I was thinking just yesterday I probably need to write it. So, stay tuned on that one.

I wanted to become a dean because leadership to me is common sense. I felt that if I could make the lives better for my fellow faculty members, that I could have a bigger impact and just make it better for all.

When I was a young professor, we established an engineering research center. I helped cowrite the grant. As part of the grant, there was an expectation that we were going to create a new workforce and new industries. I took that mission very seriously, which led me to leave academia and try to create those new companies, products, processes and a different kind of educated workforce.

Did you enjoy your time as undersecretary of energy at the U.S. Department of Energy?

You know, I did like it. It was a very intense period of time. Maybe it was because we had to invest $37 billion in energy and environment investments from the American Recovery and Reinvestment Act in addition to the broad $11 billion energy and environment portfolio. It was an honor to work for the Department of Energy. Every single individual I worked with was committed. We worked every weekend, every evening, to try and get funding out, so that we could create jobs, put people back to work and lower our greenhouse gas emissions.

Chancellor Kristina Johnson visits the Institute for Advanced Manufacturing at Clinton Community College, a member of The State University of New York system.

STATE UNIVERSITY OF NEW YORK

While you were at Duke you created a fellowship that supported about a third of undergraduates so that they could spend 18 months doing research in labs. Are you thinking of similar things at SUNY, or are there any plans to partner with New York high schools to promote STEM education?

When I was at Duke, I saw that a lot of our engineering students were going to New York to join the financial industry, which is fine. But I thought it also would be great to introduce our students to a broader array of opportunities.

The program, called the Pratt Research Fellows, has students start work in research labs during the spring of their junior year, including the summer and all during their senior year. When those kids graduated, they were going to the financial sector, but they were also going on to graduate schools. It was exciting because they really caught the bug of innovation. So, yes, I'd like to start that at SUNY.

We're also very excited about trying to link SUNY with high schools. One of the exciting things about SUNY is it's the largest comprehensive university system in the country. We have high schools that we charter. We have 30 community colleges. We have 13 comprehensive, unique four-year institutions with master's programs. We have technical-focused two- and four-year schools. Then, we have 14 doctoral-granting degree institutions, including five medical schools and three hospitals.

During my first State of the University System Address, I discussed four themes across our broad intellectual ecosystem. First, innovation and entrepreneurship. The second, individualized education. Third, energy and sustainability, and fourth, partnerships. Creating programs where all of our students are doing research and innovation together — I think that is very exciting.

What advice do you have for young people just starting their higher education or careers?

Get everything you can out of it. I played sports. I "hashed" at the French house to keep up my French. I worked in the labs. When you start in higher ed, it's important to find an area that you can carve out outside the classroom. I recommend that students look up faculty with similar interests and make an appointment and ask to work with the faculty member as an independent study student.

What books are you reading now?

So, there's a book George Packer wrote called *The Unwinding*, which talks about Youngstown when Delphi left and the real estate crash in Tampa. It weaves through these characters that we all know that were living at the time in those communities. *Janesville* by Amy Goldstein is by my bedside along with *Seeing What Others Don't* by Gary Klein. ◆

NOVEMBER 10, 2018

NOVEMBER 24, 2018

Step by step

Targeted spinal cord stimulation coupled with intensive physical therapy can help paralyzed people move their limbs and even walk, **Laurel Hamers** reported in "Targeted rehab restores walking" (*SN: 11/24/18, p. 6*). Borrowing a familiar phrase from astronaut Neil Armstrong, online reader **Dan** praised the achievement: "That's one small step for a man, one giant leap for mankind."

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Beer today, gone tomorrow

Rising temperatures and more frequent droughts could cut barley crop yields worldwide by the end of the century, leading to beer shortages and high prices, ***Jennifer Leman*** *reported in "Climate change threatens beer"* (SN: 11/10/18, p. 5).

Online reader **Jean Beaulieu** was hopeful that scientists will figure out an easy way to grow barley in a warmer world. "With current crop science, crops will easily be able to follow the warmth northward. It'll be a piece of cake, or better yet, a cool beer," **Beaulieu** wrote.

The researchers acknowledge that changes in barley agriculture — increased farm productivity due to new technology, more drought- or heat-tolerant crops, or increases in barley stockpiling — might help offset damages, **Leman** says. But the scientists note that extreme heat and drought events would still contribute to serious supply disruptions.

Pig Pen particles

Electrons are almost perfectly round thanks to the distribution of their positive and negative charges, ***Lisa Grossman*** *reported in "What electrons' roundness means"* (SN: 11/10/18, p. 7).

That electrons have both positive and negative charges puzzled reader **Bruce Mason**. "Is the electron a composite particle? Where do the positive parts come from?" he asked.

The electron is negatively charged, but the elementary particle never exists by itself, says Yale University physicist **David DeMille**. Electrons are always surrounded by clouds of "virtual" particles that constantly wink in and out of existence. Such clouds contain particles with positive and negative charges. Researchers look at the electron and its cloud as one composite object. "My favorite analogy is the Pig Pen character from Charlie Brown — if you see him from far away, you can't see the cloud of flies and dust around him, but you might notice that his shape is different than that of a typical person," **DeMille** says.

Decibel drama

A camera that captures a wide range of light intensities could help self-driving cars better gauge their surroundings, ***Jennifer Leman*** *reported in "Self-driving cars see better with shrimp vision"* (SN: 11/10/18, p. 5).

The camera measures light intensity in decibels. "Since decibels are units of measure of sound intensity, how can they be equated with light?" reader **Herb Linn** asked.

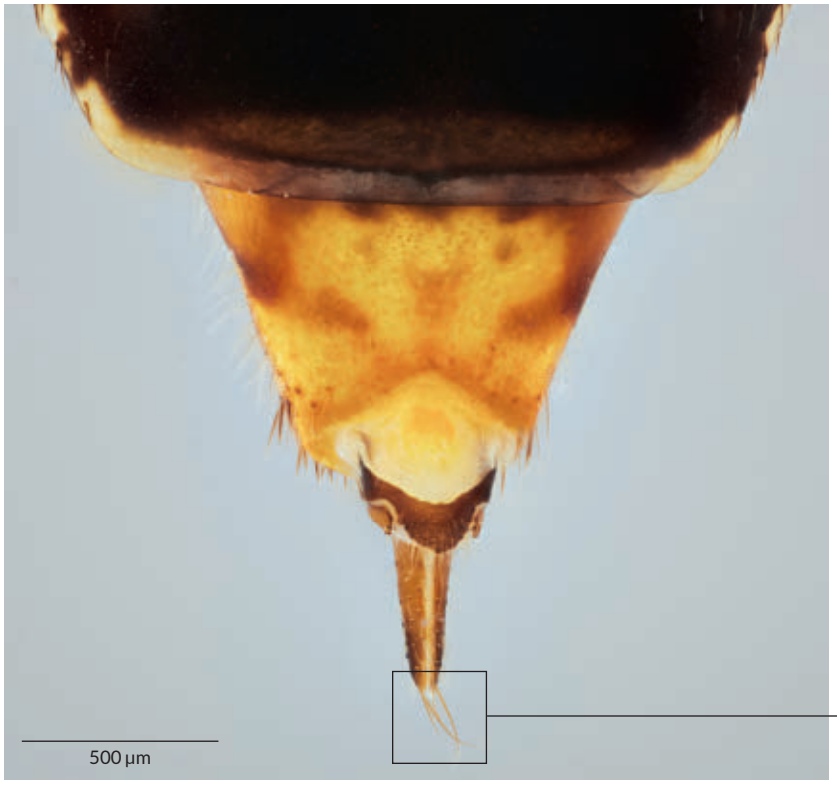
Many of us learned in school that decibels are used to express sound intensity, **Leman** agrees, but the unit is commonly used for a wide variety of measurements in science and engineering. Decibels describe ratios of physical properties on a logarithmic scale.

Game theory

In "Science is a game for this former chemistry instructor" (SN: 11/24/18, p. 28), ***Kyle Plantz*** *reviewed Subatomic, a science board game that teaches people about the elementary particles that make up atoms.*

Players can form an electron from two interacting photons, or particles of light. Reader **Mike Speciner** noted that this process wouldn't produce just an electron. The photons would create an electron paired with its antimatter partner, a positron.

Physics writer **Emily Conover** shares **Speciner's** complaint. While a supplementary game booklet explains that a positron would also be produced, players who don't read the booklet would miss that information.



These insects sling pee with a tiny 'catapult'

Some sap-sucking insects can "make it rain," flinging droplets of pee while feeding on plant juices. Now scientists have explained how insects known as sharpshooters create the spray using a tiny catapult-like structure on their rear that propels the waste at extreme accelerations.

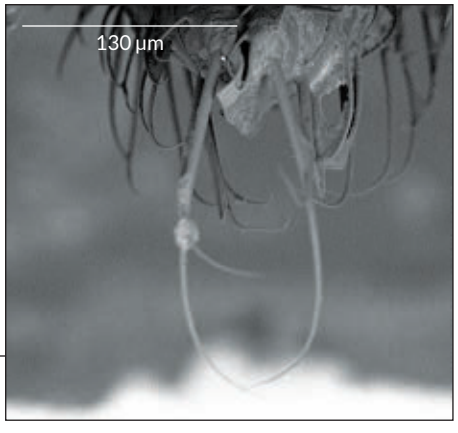
Engineer Saad Bhamla of Georgia Tech in Atlanta and colleagues recorded high-speed video of two species, the blue-green sharpshooter (three images at top left) and the glassy-winged sharpshooter (images at bottom left and below). Those videos showed that a tiny barb called a stylus at an insect's rear end acts like a spring. Once a drop collects on this structure, the "spring" releases, and the drop flies off as if hurled from a catapult.

What's more, tiny hairs at the end of the stylus (seen in the bottom images) increase its flinging power, Bhamla and colleagues suggest, much like the sling at the end of certain types of catapults.

As a result, the stylus launches liquid waste with a maximum acceleration about 20 times that of Earth's gravity, the scientists report January 5 in Tampa, Fla., at the annual meeting of the Society for Integrative and Comparative Biology.

A tree infested with sharpshooters exudes a steady pitter-patter of pee, which can dampen unsuspecting passersby. "It's crazy just to look at," Bhamla says. It's not clear why the insects fling their pee. Perhaps they avoid a bath in a fluid that could attract predators, he says.

— Emily Conover



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