SN
SCIENCE NEWS MAGAZINE
SOCIETY FOR SCIENCE & THE PUBLIC
JULY 8, 2017 & JULY 22, 2017

Seeking Quantum Supremacy

Earliest Human Fossils

Bones' Secret Messages

How Monkeys See Faces

Altered STATES

Domestication brought docility — along with unexpected changes

Urgent: Special Summer Driving Notice

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Studies by the National Highway Traffic Safety Administration (NHTSA) show that most (74%) of the crashes occurred on clear, sunny days

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Drivers' Alert: Driving can expose you to more dangerous glare than any sunny day at the beach can… do you know how to protect yourself?

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Not all sunglasses are created equal. Protecting your eyes is serious business. With all the fancy fashion frames out there it can be easy to overlook what really matters—the lenses. So we did our research and looked to the very best in optic innovation and technology.

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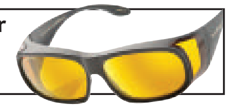

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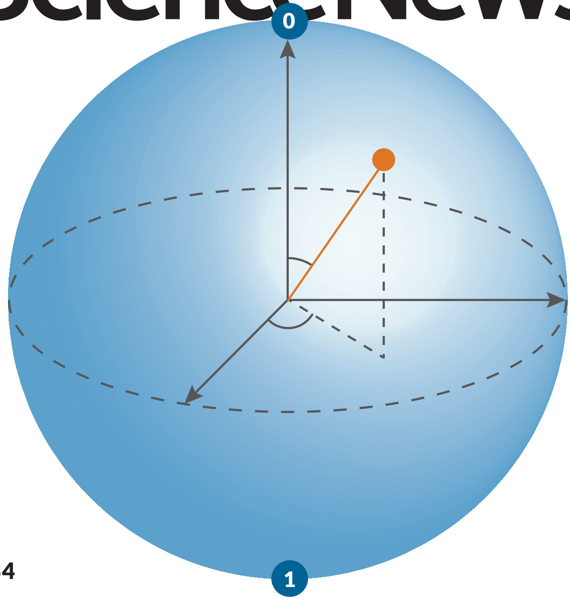
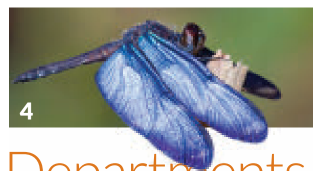


34

Features

News



Departments

COVER Dogs, perhaps humans' most familiar friends, share developmental features with many other domesticated beasts. *Jody Hewgill*

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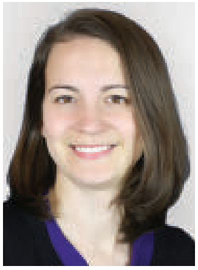

Dive deep to discover unexpected connections

Readers often praise *Science News* for its brevity. It's undoubtedly one of our defining features, and one of our core values. To deliver the latest news from a wide breadth of scientific subfields, our writing must be clear and concise. Our news gets to the point, with all the fascinating detail but none of the flab. Packing content in has long been the tradition at *Science News* — no surprise given our news service origins.

But — and I hope this doesn't sound like heresy — some ideas need more space. In this double issue, beginning on Page 20, Tina Hesman Saey offers a long-form look at what scientists know, and don't, about how humans domesticated plants and animals. It's a big story with many moving pieces and a lot of mystery. Giving the squeeze to such a rich topic would be a shame, especially since Saey has been thinking about the idea for years. Then, on Page 28, Emily Conover investigates the latest progress in the race toward "quantum supremacy," the point, coming soon, when quantum computers will surpass conventional computers for solving certain types of problems. Conover explores not just the top contenders, but also alternative approaches, and the challenges of each. An accompanying essay by Tom Siegfried offers a historical take on quantum computing's essential unit, the qubit. Yes, we give you 10 pages of quantum coolness.

Diving deep has a lot of benefits. You get more context, more nuance, more facts to explore. You also start to uncover connections that at first weren't apparent. When we scheduled articles on domestication and quantum computing to appear in the same issue, I thought they fit well together because of their differences: a nice mix of biology and physics, of looking back at human history and forward to future technology. But reading the final in-depth stories, I see so much that unites them.

For one, both are technology stories. Both are about humans' efforts to control nature. Domestication yielded workhorses and war-horses, efficient silk producers, animal companions and plants that "stand in soldier-straight rows," as Saey puts it. Though the benefits of quantum computers are yet to be realized, they promise to transform how people do research, conduct business and handle data. To achieve these ends, physicists including Chris Monroe of the University of Maryland are also manipulating nature, arranging their qubits, ions in Monroe's case, in neat little lines.

Another similarity: Both domestication and quantum computation start with small, simple steps that, through repetition, add up to a complex phenomenon. The first step in domestication might have been as simple as a person offering a wolf a bone. Now, there are Pinterest boards devoted to dogs obedient enough to travel in their owners' handbags. For quantum computing, like classical computing, seemingly basic operations (if this, then that) can be combined to tackle the complexity of, as just one example, how nitrogen-fixing bacteria enrich the soil. That knowledge could be used to reduce the energy drain of fertilizer production.

What do these connections tell us about the world? About science? About ourselves? Those deep ideas will require another editor's note. For now, I'm out of space. — *Elizabeth Quill, Acting Editor in Chief*

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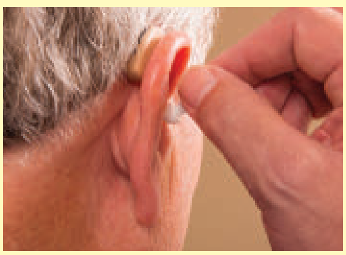

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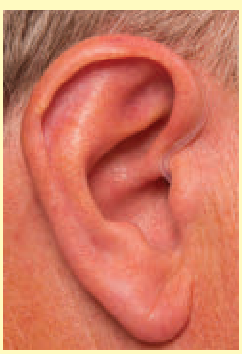

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Excerpt from the July 8, 1967 issue of *Science News*

50 YEARS AGO

Lowest temperature yet

A common pin dropped on a table from a height of one-eighth of an inch generates about 10 ergs of energy, obviously a minuscule amount. That 10 ergs raises temperature, and even that tiny amount is "much too much" to be allowed in the experiment during which Dr. Arthur Spohr of the Naval Research Laboratory reached the lowest temperature yet achieved — within less than a millionth of a degree of absolute zero.

UPDATE: Today, scientists can make clouds of atoms at temperatures as low as 50 trillionths of a degree above absolute zero (*SN: 5/16/15, p. 4*). Late this year or early next year, NASA will launch its Cold Atom Laboratory to the International Space Station so scientists can study ultracold atoms reaching 100 trillionths of a degree or less. In orbit, gravity doesn't drag atoms down, so the clouds can stay intact for scientists' observations for up to 10 seconds — longer than is possible on Earth.

IT'S ALIVE

The strangest insect wings

Among natural blues, the wings of this morpho dragonfly create color in a really complicated way.

An adult insect wing is basically dead.

So what in the world were tiny respiratory channels doing in a wing membrane of a morpho dragonfly?

Rhainer Guillermo Ferreira was so jolted by a scanning electron microscope image showing what looked like skinny, branching tracheal tubes in a morpho

THE -EST

Gas giant breaks heat records

The planet KELT 9b is so hot — hotter than many stars — that it shatters gas giant temperature records, researchers report online June 5 in *Nature*.

This Jupiter-like exoplanet revolves around a star just 650 light-years from Earth in the constellation Cygnus, locked in an orbit that keeps one side always facing its star. With blistering temps hovering at about 4300° Celsius, the atmosphere on KELT 9b's dayside is more than 700 degrees hotter than the previous record-holder — and hot enough that atoms cannot bind together to form molecules.

"It's like a star-planet hybrid," says Drake Deming, a planetary scientist at the University of Maryland in College Park who was not involved in the research. "A kind of object we've never seen before."

KELT 9b also boasts an unusual orbit, traveling around the poles of its star, rather than the equator, once every 36 hours. And radiation from KELT 9b's host star is so intense that it blows the planet's atmosphere out like a comet tail — and may eventually strip it away completely.

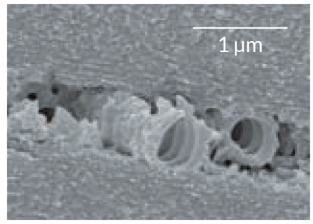
The planet is so bizarre that it took scientists nearly three years to convince themselves it was real, says codiscoverer Scott Gaudi of Ohio State University in Columbus. Deming suspects that KELT 9b is "the tip of the iceberg" of an undiscovered population of scalding-hot gas giants. — *Maria Temming*

KELT 9b, the hottest known gas giant (illustrated, below its host star), is "pretty much something out of a science fiction novel," says codiscoverer Scott Gaudi.

wing that he called in another entomologist for a second opinion. Guillermo Ferreira, then at Kiel University in Germany, showed the image to a colleague who also was "shocked," he remembers. A third entomologist was called in. Shock all around.

The shimmering, bluest-of-skies wings of male *Zenithoptera* dragonflies might be unexpectedly and fully alive, Guillermo Ferreira says. That bold idea will take some testing. So for now, he and colleagues report the unusual tracheal respiratory system, the first in any insect wing as far as they know, in the May *Biology Letters*.

Wings of insects start as living tissue, but as the creatures take their adult form, cells die between the strut work of supporting wing veins. The dried-out zones can go cellophane-clear or cover themselves in color, bordered by the vein network like the glass pieces in a cathedral window. The veins, as they're called, have their own respiratory tubes, nerves and such. But entomologists thought the rest of an insect wing would be no more alive and in need of oxygen than toenail clippings.



A highly magnified dragonfly wing section reveals what look like breathing tubes.

Living, breathing wings might help explain how South America's four or five species of morpho dragonflies make such complicated blue color, says Guillermo Ferreira, now at the Federal University of São Carlos in Brazil. Blue pigment, rare in nature, is nowhere on these wings. Instead, the wings, perhaps powered by abundant oxygen, create a living layer cake of light-manipulating doodads.

In the tough inner layers, male *Z. lanei* wings form nanoscale spheres sandwiched between blankets of black pigment–filled nanolayers. This setup can enhance reflections of blue light and muddle other wavelengths. On top are two more light-trick layers, each made of wax crystals. The uppermost crystals, Guillermo Ferreira found, are shaped "like little leaves."

Better blues might help a male intimidate rivals for breeding territory around the edges of their palm tree swamp homeland. Male dragonflies don't just dart and bluff. Guillermo Ferreira often sees a male "rushing toward the rival, grabbing the wings, biting the wings and then sometimes biting the head."

In spite of the world-class color nanogadgetry, males aren't known for courtship displays, he says. "The female just flies in, and he just grabs her." *— Susan Milius*

SCIENCE STATS

Made in the shade

Earth's dry regions have more trees than once thought — a hopeful note in the fight against climate change.

An analysis of high-resolution satellite imagery reveals that drylands globally have 40 to 47 percent more tree cover (an extra 467 million hectares) than reported in earlier estimates. An international team of researchers used Google Earth and Collect Earth, a program developed by the Food and Agriculture Organization of the United Nations in Rome, to estimate tree cover on more than 210,000 half-hectare plots in dry areas of Australia, Africa, the American West and elsewhere.

The new estimate, reported in the May 12 *Science*, increases by about 9 percent Earth's total area with more than 10 percent tree cover, adding a zone the size of the Amazon Basin. This is good news: Drylands cover almost 42 percent of Earth's land surface, and climate change could expand the parched zones by 11 to 23 percent by 2100. The new finding suggests that these dry regions might be able to support the planting of additional trees to help ease climate change and offset expected desertification, the researchers write. *— Beth Geiger*

40–47

percent

Boost in estimate of Earth's total forested dryland area

INTRODUCING

Heart of the matter

A newly discovered glass frog from Ecuador's Amazon lowlands is giving researchers a window into its heart.

Hyalinobatrachium yaku has a belly so transparent that the heart, kidneys and urine bladder are clearly visible, an international team of researchers reports May 12 in *ZooKeys*. Researchers identified *H. yaku* as a new species using field observations, recordings of its distinct call and DNA analyses of museum and university specimens.

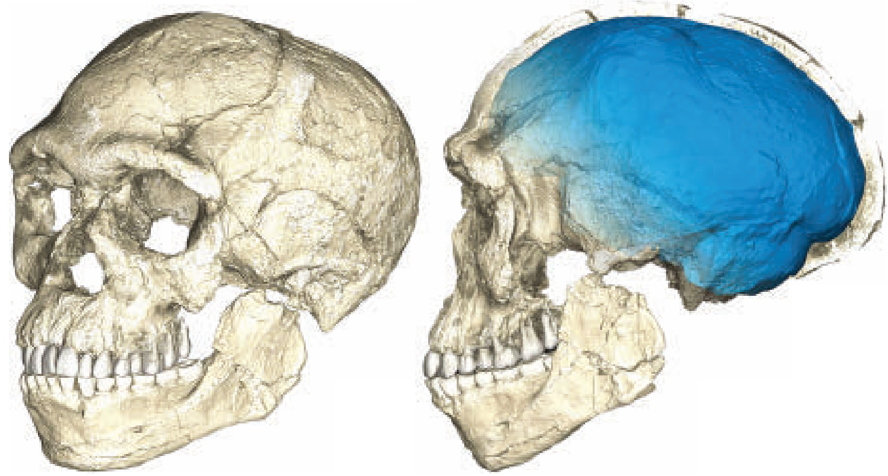
Yaku means "water" in Kichwa, a language spoken in Ecuador and parts of Peru where *H. yaku* may also live. Glass frogs, like most amphibians, depend on streams. Egg clutches dangle on the underside of leaves, then hatch, and the tadpoles drop into the water below. But the frogs are threatened by pollution and habitat destruction, the researchers write. Oil extraction, which occurs in about 70 percent of Ecuador's Amazon rainforest, and expanding mining activities are both concerns. *— Cassie Martin*

News

HUMANS & SOCIETY

Fossils push back origin of humans

300,000-year-old Moroccan finds pegged as *Homo sapiens*



CT scans of fossils from a Moroccan site were used to produce reconstructions of an ancient skull. The skull, which some researchers attribute to the earliest known *Homo sapiens*, displays a modern-looking face (left) combined with a braincase (right) similar to that of older species.

BY BRUCE BOWER

In a surprising and controversial geographic twist, the earliest known remains of the human species, *Homo sapiens*, have turned up in northwestern Africa, researchers claim.

Fossils attributed to *H. sapiens* and stone tools unearthed at Jebel Irhoud, Morocco, date to about 300,000 years ago, an international team of researchers reports in two papers in the June 8 *Nature*. Until now, the oldest human fossils came from East Africa and dated to around 195,000 years ago (*SN: 2/26/05, p. 141*). Although *H. sapiens* might have emerged in East Africa, some researchers also categorize a previously discovered fossil skull from South Africa, tentatively dated to about 260,000 years ago, as *H. sapiens*.

The fossils from Morocco indicate that humankind's emergence involved populations across much of Africa, and started about 100,000 years earlier than previously thought, says paleoanthropologist Jean-Jacques Hublin of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany. He led the research along with Abdelouahed Ben-Ncer of the National Institute of Archaeology and Heritage Sciences in Rabat, Morocco.

"Long before the out-of-Africa dispersal of *Homo sapiens* [70,000 to 60,000 years ago], there was a dispersal within Africa," Hublin says. What's now the Sahara was inhabitable around 300,000 years ago, so early forms of *H. sapiens* in northern Africa could have reached other parts of the continent and interacted with different *H. sapiens* groups, he suspects.

Excavations at Jebel Irhoud in the 1960s produced six *Homo* fossils, initially classified as Neandertals, as well as stone tools resembling those at European Neandertal sites. Researchers initially dated the remains to about 40,000 years ago. A 2007 report later estimated one fossil, a child's jaw, was about 160,000 years old.

> All 22 Jebel Irhoud fossils qualify as *H. sapiens*, the scientists conclude.

In one new paper, Hublin and colleagues describe 16 new fossils unearthed at Jebel Irhoud from 2004 to 2011. Remains of at least five individuals — three adults, an adolescent and a child — include a partial skull, a lower jaw, a partial upper jaw, six isolated teeth and several limb bones.

Using CT scans, researchers generated 3-D reconstructions of the Jebel Irhoud fossil skull and lower jaw. Hublin's team compared measurements of these finds with those for *Homo erectus*, Neandertals and other *Homo* species from between around 1.8 million and 150,000 years ago, as well as *H. sapiens* fossils from the last 130,000 years.

Facial characteristics of the Jebel Irhoud skull and teeth closely match those of people today, despite being larger, the scientists say. The Jebel Irhoud lower jaw also shares much in common with *H. sapiens*. All 22 Jebel Irhoud fossils qualify as *H. sapiens*, the scientists conclude.

Yet three Jebel Irhoud braincases are relatively long and low in height, compared with taller, rounded braincases typical of *H. sapiens*. Jebel Irhoud braincases more closely resemble those of earlier species, including *H. erectus*. Facial and dental traits of *H. sapiens* were established by around 300,000 years ago, whereas brain shape has continued to evolve since then, the researchers say.

Paleoanthropologist Erik Trinkaus of Washington University in St. Louis disagrees. *Homo* fossils dating to between around 600,000 and 200,000 years ago typically contain some features recalling older species and other traits foreshadowing later *H. sapiens*, Trinkaus says. Some of those fossils probably came from populations that were ancestors of people today. But that doesn't mean they were *H. sapiens*, he contends. In fact, many such fossils have eluded consensus about their species identity.

In a second paper, Max Planck geoscientist Daniel Richter and colleagues date 14 stone artifacts found in and just above sediment that held the new fossil discoveries, allowing the researchers to narrow down the fossils' age to approximately 300,000 years. In addition, new calculations of amounts of radioactive uranium in Jebel Irhoud sediment enabled dating the previously unearthed child's jaw from the site to between around 350,000 and 220,000 years ago.

Most Jebel Irhoud stone tools were pounded off larger rocks that had been prepared by toolmakers. This technique appeared across much of Eurasia and Africa by around 300,000 years ago, the researchers say. ■

PHILIPP GUNZ/MPI-EVA, LEIPZIG

GENES & CELLS

Antibody combats variety of cancers

Tumors with DNA-repair defects succumb to immune therapy

BY TINA HESMAN SAEY

Mutations that prevent cells from spell-checking their DNA may make cancer cells vulnerable to immunotherapies, a new study suggests.

A type of immune therapy known as PD-1 blockade controlled cancer in 77 percent of patients with defects in DNA mismatch repair — the system cells use to spell-check and fix errors in DNA (*SN Online: 10/7/15*). The therapy was effective against 12 different types of solid tumors, including colorectal, gastroesophageal and pancreatic cancers, and even tumors of unknown origin, researchers report online June 8 in *Science*.

77 percent

Portion of study participants whose cancer was controlled by PD-1 blockade immune therapy

"Where the tumor started doesn't matter. What matters is why the tumor started," says Richard Goldberg, a study coauthor and an oncologist at West Virginia University Cancer Institute in Morgantown.

People with defective DNA spell-checkers accumulate many mutations in their cells, which can lead to cancer. While mismatch repair errors can spark cancer, they may also be its Achilles' heel: Some misspellings cause the cancer cells to make unusual proteins that the immune system uses to target tumors for destruction.

Even before treatment, cancer patients in the study had a small number of tumor-fighting T cells that target these unusual proteins, the researchers found. Treating patients with an antibody called pembrolizumab (sold under the brand name Keytruda) caused these T cells to increase in number, says coauthor Kellie Smith, a cancer immunologist at Johns Hopkins University.

The antibody binds to a protein on the surface of T cells called the PD-1 receptor. Some tumor cells use this receptor to hide from the immune system (*SN: 4/1/17, p. 24*). Blocking the receptor with the antibody unmasks the tumors. As a result, "immune cells can go to all corners of the body and eradicate tumors," Smith says. That includes going after deadly metastatic tumors — ones that have spread from other parts of the body. Once the T cells are primed for action, they may patrol the body for a long time, stopping cancer from taking hold again, Smith says.

All 86 patients in the study had metastatic cancers that had not responded well to other treatments. For 18 patients, the antibody treatment appears to have been a success. Their tumors disappeared entirely. After two years of treatment, 11 of those patients were taken off the antibody. Their tumors have not returned even after a median of 8.3 months.

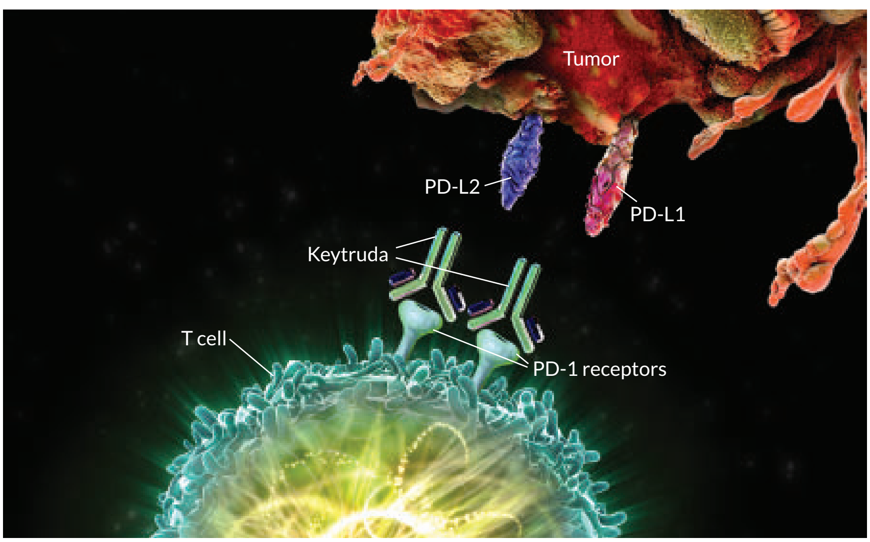
Other patients had tumors that shrank but didn't disappear, or that remained stable during — and even after — treatment. Goldberg says scans suggest some of the patients still have masses, but biopsies show no remaining cancer cells. The masses are clusters of immune cells that have invaded sites to kill cancer, he says.

Not everyone fared so well. Tumors in five patients initially shrank, then began to grow again. DNA from three of those people showed that two had developed mutations in the beta 2-microglobulin gene, which helps immune cells track down their targets.

Common side effects of the treatment included skin rashes, thyroid problems and diarrhea as the therapy caused the immune system to attack other parts of the body.

Revving up the immune system to combat a wide variety of tumor types may take cancer therapy in a new direction, says Khaled Barakat, a computational scientist at the University of Alberta in Canada who studies cancer therapies. In recent years, scientists have devised drugs to target specific mutations in one type of cancer. "That's old school," Barakat says. Immunotherapy "is the future."

Based on the new results, on May 23, the Food and Drug Administration approved pembrolizumab for cancer patients with mismatch repair mutations for whom other drugs have failed. In the United States, about 60,000 cancer patients each year could be eligible for the immune therapy, the researchers estimate. ■



An antibody sold as the drug Keytruda helps turn on cancer-fighting T cells. Tumor proteins (PD-L1 and PD-L2) lock onto PD-1 receptors on T cells and shut them down. The antibody binds to PD-1, blocking the tumor proteins and freeing T cells to attack the cancer.

BODY & BRAIN

Vaginal microbes hamper HIV drug

Certain bacteria appear to break down prophylactic gel

BY AIMEE CUNNINGHAM

Bacteria in the vagina affect whether a drug stops an HIV infection or is itself stopped cold.

A vaginal gel containing tenofovir, an antiretroviral drug used to treat HIV, was three times as effective at preventing HIV in women who had healthy vaginal bacterial communities as it was in women with a less beneficial mix. The finding may help explain why the effectiveness of these gels has varied in trials, researchers report in the June 2 *Science*.

"The vaginal microbiota is yet another variable that we have to take into account when we are thinking about why one intervention does or doesn't work," says clinical scientist Khalil Ghanem of Johns Hopkins University School of Medicine, who coauthored a commentary accompanying the study.

For women, one strategy to prevent HIV infection is to apply medicated vaginal gels before and after sex. But results have been mixed regarding how well the gels work. The hit-or-miss effectiveness can partly be explained by some patients not taking the medication as prescribed. But Adam Burgener, a microbiologist at the Public Health Agency of Canada in Winnipeg, wondered if there might also be a biological explanation.

The main residents of a healthy vaginal microbial community are *Lactobacillus* species. The bacteria produce lactic acid, making the vaginal tract more acidic and possibly "less hospitable for potential pathogenic organisms," Ghanem says.

To examine the effect of microbes on tenofovir, Burgener and colleagues turned to a previous trial of South African women, which showed that the drug reduced HIV infections by 39 percent. In that trial, samples of vaginal mucus were taken. In the new study, the researchers analyzed 688 of those samples to identify the bacteria in the women's vaginas.

Just over 400 women's vaginal microbiota mainly had *Lactobacillus* species; the other women's microbiota were dominated by other species, such as *Gardnerella vaginalis*. Within those two groups were women who had used tenofovir vaginal gel and those who had used a nonmedicated gel as a placebo.

LIFE & EVOLUTION

Fossil DNA shakes up elephant history

Straight-tusked species belonged to African lineage, study finds

BY MARIA TEMMING

Fossil DNA may be rewriting the history of elephant evolution.

The first genetic analysis of DNA from fossils of straight-tusked elephants reveals that the extinct animals most closely resembled modern African forest elephants. This suggests that straight-tusked elephants were part of the African, not Asian, elephant lineage, scientists report June 6 in *eLife*.

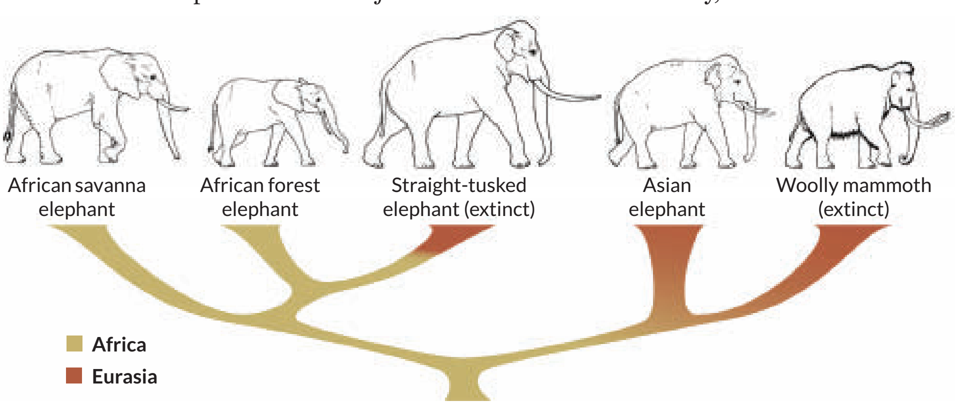
Straight-tusked elephants roamed Europe and Asia until about 30,000 years ago. Like modern Asian elephants, they sported high foreheads and double-domed skulls. These features convinced scientists for decades that straight-tusked and Asian elephants were sister species, says Adrian Lister, a paleobiologist at the Natural History Museum in London who was not involved in the study.

For the new study, researchers decoded DNA from the bones of four straight-tusked elephants found in Germany. The fossils ranged in age from about 120,000 to 240,000 years old. Genetic material in most fossils more than 100,000 years old is too decayed to analyze. But the elephant fossils were unearthed in a lake basin and a quarry, where the bones would have been quickly covered with sediment that preserved them, says study coauthor Michael Hofreiter of the University of Potsdam in Germany.

Hofreiter's team compared the ancient animals' DNA with the genomes of the three living elephant species — Asian, African savanna and African forest — and found that straight-tusked genetics were most similar to that of African forest elephants.

When the researchers told elephant experts what they'd found, "Everybody was like, 'This can't possibly be true!' " says study coauthor Beth Shapiro of the University of California, Santa Cruz. "Then it gradually became, 'Oh yeah, I see.... The way we've been thinking about this is wrong.' "

If straight-tusked elephants were closely related to African forest elephants, then the African lineage wasn't confined to Africa — where all elephant



Family tree The extinct straight-tusked elephant, which lived in Eurasia, was most closely related to modern African forest elephants, a genetic analysis finds. Researchers propose that straight-tusked elephants should be grouped with the African lineage on the elephant family tree.

M. MEYER *ET AL*/*ELIFE* 2017

In the *Lactobacillus*-dominant group, HIV incidence was 61 percent lower in women using the medicated gel compared with those using the placebo. But in the non-*Lactobacillus*–dominant group, it was only 18 percent lower. There was no appreciable difference in the consistency of the gel's reported use between groups.

Looking at a random subset of 270 of the samples, the researchers found that the drug levels were lower in the mucus from the non-*Lactobacillus* group. To investigate further, the team mixed a *G. vaginalis* strain with tenofovir in a test tube. After four hours, the amount of tenofovir had decreased by half. In a similar experiment with *Lactobacillus* species, the amount of the drug remained about the same. *G. vaginalis* bacteria appeared to have "gobbled up the drug and depleted it," Burgener says. ■

species originated — as paleontologists previously thought. The relationship also raises questions about why straight-tusked elephants bore so little resemblance to today's African elephants, which have low foreheads and single-domed skulls.

Accounting for this new finding may not be as simple as moving one branch on the elephant family tree, Lister says. It's possible that straight-tusked elephants really were a sister species of Asian elephants, but they exhibit genetic similarities to African forest elephants because of interbreeding before the straight-tusked species left Africa.

It's also possible that a common ancestor of Asian, African and straight-tusked elephants had particular genetic traits that were, for some reason, only retained by African and straight-tusked elephants, Lister says.

He and colleagues are now reexamining data from straight-tusked skeletons to reconcile the species' skeletal features with the new genetic information. "I will feel most comfortable if we can understand these genetic relationships in terms of the [physical] differences between all these species," he says. "Then we'll have a complete story." ■

BODY & BRAIN

Brains encode faces piece by piece

In monkeys, individual nerve cells respond to specific features

BY LAUREL HAMERS

A monkey's brain builds a picture of a human face somewhat like a Mr. Potato Head — piecing it together bit by bit.

The code that a monkey's brain uses to represent faces relies on a population of about 200 cells that respond to different sets of features. Together, the information contributed by each nerve cell lets the brain efficiently capture any face, researchers report in the June 1 *Cell*.

"It's a turning point in neuroscience — a major breakthrough," says Rodrigo Quian Quiroga, a neuroscientist at the University of Leicester in England who wasn't part of the work. "It's a very simple mechanism to explain something as complex as recognizing faces."

Scientists showed monkeys faces (top) while measuring the primates' brain cell activity. By adding together info from 205 nerve cells, the team could reconstruct the shown faces (bottom).

Until now, Quiroga says, the leading explanation for the way the primate brain recognizes faces proposed that individual nerve cells, or neurons, respond to certain types of faces. A system like that might work for the few dozen people with whom you regularly interact. But accounting for all of the peripheral people encountered in a lifetime would require a lot of neurons.

It now seems that the brain might have a more efficient strategy, says Doris Tsao, a neuroscientist at Caltech.

Tsao and Caltech colleague Le Chang used statistical analyses to identify 50 variables that accounted for the greatest differences between 200 face photos. Those variables represented somewhat complex face changes — for instance, the hairline rising while the face becomes wider and the eyes move higher up.

The researchers turned those variables into a 50-dimensional "face space," with each face being a point and each dimension being an axis along which a set of features varied.

Then, Tsao and Chang extracted 2,000 faces from that map, each linked to specific coordinates. While projecting the faces one at a time onto screens in front of two macaques, the team recorded the activity in single neurons in parts of the temporal lobe known to respond specifically to faces. In total, the recordings measured the activity of 205 neurons.

Each face neuron responded to one of the 50 axes previously identified, Tsao and Chang found. The rate at which each cell sent electrical signals was proportional to a given face's coordinate position along an axis. But a cell didn't respond to changes in features not captured by that axis. For instance, a cell tuned to an axis where nose width and eye size changed wouldn't respond to changes in lip shape.

Adding together the features conveyed by each cell's activity creates a picture of a face. And like a computer creating a full-color display by mixing different proportions of red, green and blue light, the coordinate system lets a brain paint any face in a spectrum.

Tsao and Chang also were able to re-create that process in reverse using an algorithm. When they plugged in the activity patterns of the 205 recorded neurons, the computer spat out an image that looked almost exactly like what the monkeys had seen.

"People view neurons as black boxes," says Ed Connor, a neuroscientist at Johns Hopkins University. "This is a striking demonstration that you can really understand what the brain is doing." ■

D. TSAO

ATOM & COSMOS

Light-bending by distant star seen

General relativity effect gives accurate mass of white dwarf

BY LISA GROSSMAN

For the first time, astronomers have seen a star outside of the solar system bend the light from another star. The measurement, reported June 7 in Austin, Texas, at a meeting of the American Astronomical Society, vindicates both Albert Einstein's most famous theory and astronomers' ideas about what goes on in the inner lives of stellar corpses.

Astronomers using the Hubble Space Telescope watched as a white dwarf passed in front of a more distant star. That star seemed to move in a small loop, its apparent position deflected by the white dwarf's gravity.

More than a century ago, Einstein predicted that the way spacetime bends around a massive object — the sun, say — should shift the apparent position of stars that appear behind that object. The measurement of this effect during a solar eclipse in 1919 confirmed Einstein's general theory of relativity: Mass warps spacetime and bends the path of light rays (*SN: 10/17/15, p. 16*).

The *New York Times* hailed it as "one of the greatest — perhaps the greatest — of achievements in the history of human thought." But even Einstein doubted the light-bending shift could be detected for stars more distant than the sun.

Now, in a study reported in the June 9 *Science*, Kailash Sahu of the Space Telescope Science Institute in Baltimore and his colleagues have shown that it can.

"This is an elegant outcome," says Terry Oswalt of Embry-Riddle Aeronautical University in Daytona Beach, Fla., who was not involved in the new work. "Einstein would be very proud."

While the stars literally aligned to make the work possible, this was no lucky accident. Sahu and colleagues scoured a catalog of 5,000 stellar motions to find a pair of stars likely to pass close enough on the sky that Hubble could sense the shift.

One pair involved a star, known as Stein 2051 B, that was already a mysterious character.

Located about 18 light-years from Earth, Stein 2051 B is a white dwarf, a common end-of-life state for a sunlike star. When low-mass stars run out of fuel, they puff up into a red giant while fusing helium into carbon and oxygen. Eventually, they slough off outer layers of gas, leaving this carbon-oxygen core — the white dwarf — behind.

White dwarfs are extremely dense. Only the pressure their electrons produce in trying not to be in the same quantum state as each other prevents the stars from collapsing into a black hole. This bizarre situation sets strict limits on stars' sizes and masses: For a given radius, a white dwarf can be only so massive, and only so large for a given mass.

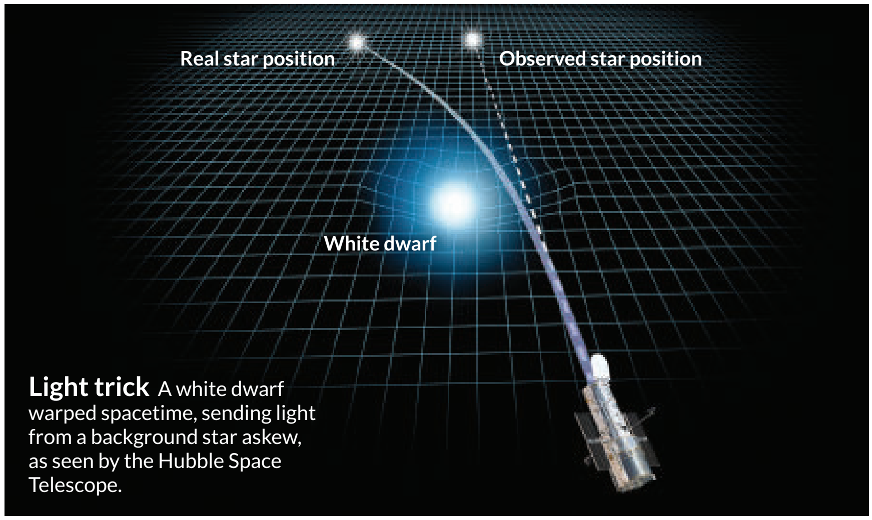
This mass-radius relation was laid out in the 1930s, but it has been difficult to prove. The only white dwarfs weighed so far share their orbits with other stars whose mutual motions help astronomers calculate white dwarf masses. But some astronomers worry that the companions could have added mass to the white dwarfs, throwing off this precise relationship.

Stein 2051 B also has a companion, but it is so far away that the two stars almost certainly evolved independently. That distance also means it would take hundreds of years to precisely measure the white dwarf's mass. The best efforts to find a rough mass so far created a conundrum: Stein 2051 B appeared to be much lighter than expected. Explaining it would require an exotic iron core.

Measuring the shift of a background star provides a way to measure the white dwarf's mass directly. The more massive the foreground star — in this case, the white dwarf — the greater the deflection of light from the background star.

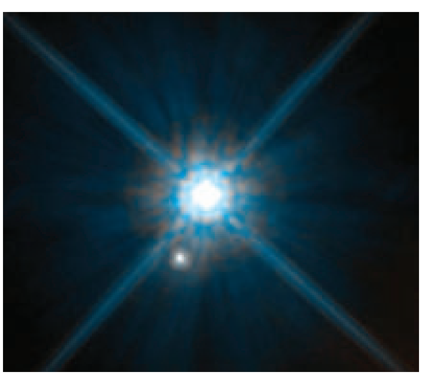
"This is the most direct method of measuring the mass," Sahu says. "It's almost like putting somebody on a scale and reading off their weight."

The team observed the two stars' positions eight times between 2013 and 2015. The background star appeared to move in a small ellipse as the white dwarf approached and then moved away, exactly as predicted by Einstein's equations. That suggests the white dwarf's mass is 0.675 times the mass of the sun — well within the normal range for its size. ■



Light trick A white dwarf warped spacetime, sending light from a background star askew, as seen by the Hubble Space Telescope.

Relativistic light-bending made the small star in this image appear to shift its position as the larger white dwarf went by. That shift helped astronomers measure the white dwarf's mass.



FROM TOP: NASA, ESA, A. FEILD/STSCI; NASA, ESA, K. SAHU/STSCI

BODY & BRAIN

Sunless tanner could protect skin

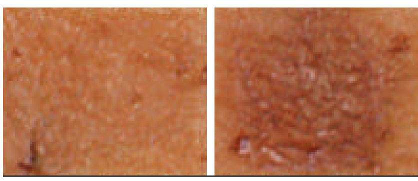
Potential drug upped melanin without ultraviolet radiation

BY AIMEE CUNNINGHAM

An approach that gives mice a tan without using ultraviolet radiation now works in human skin samples. It's an early step in developing a lotion or cream that might provide fair-skinned folk with protection against skin cancer.

As reported in the June 13 *Cell Reports*, a topical drug penetrated and tanned lab samples of live human skin, absent the sun. Unlike self-tanning lotions that essentially stain skin brown and provide minimal protection, the drug activates the production of the dark form of the skin pigment melanin, which absorbs UV radiation and diminishes skin damage.

Compared with untreated skin (left), human skin deeply tanned (right) when treated with a drug that boosts melanin production.



The team behind the advance had worked with a different drug, the plant extract forskolin, in a 2006 study. The team used mice with skin like that of redhaired, fair-skinned people, who don't tan because of a nonfunctioning protein on the skin cells that make melanin. In these mice, forskolin stimulated production of the dark form of melanin. When exposed to UV rays, the mice had less DNA damage and sunburn, and fewer skin tumors, than untreated mice (*SN: 9/23/06, p. 196*).

"There was an obvious interest in asking, could this be applied to human skin?" says David Fisher, a cancer biologist at Massachusetts General Hospital in Boston. But the outermost skin layer in humans is about five times thicker than in mice, he says. Many drugs "simply can't get in." This was true for forskolin.

So Fisher's group looked for an alternative. Another research team had shown that the enzyme salt-inducible kinase inhibits mice's melanin production.

The researchers tinkered with the structures of various compounds to make a drug that can both block salt-inducible kinase and penetrate human skin. In a liquid form applied to the skin, the best drug deeply tanned a human skin sample after eight days, with one treatment a day. In mice given a similar drug, the tan faded after treatment ended.

Even if a pigmentation-stimulating drug is found to be safe and effective in people, it would probably not be a substitute for sunscreen, Fisher says. Instead, the drug could be combined with sunscreen in a single product. He thinks the first test would be to see if this combination approach can protect against skin cancer in fair-skinned people or those with high sensitivity to sunlight.

Molecular epidemiologist Marianne Berwick of the University of New Mexico School of Medicine in Albuquerque says ease of use will be one of the important factors in evaluating the drug's usefulness. "Humans are funny animals and do not necessarily do what is best for them," she says, such as applying sunscreen as frequently and thickly as directed. ■

EARTH & ENVIRONMENT

Magma under volcanoes is largely solid

Melting happens shortly before eruption, zircon analysis finds

BY MARIA TEMMING

Most of a volcano's magma probably isn't the red-hot molten goo often imagined.

Analyses of zircon crystals spewed from a New Zealand volcano show that the crystals spent the majority of their time underground in solid, not liquid, magma, scientists report in the June 16 *Science*.

This finding helps confirm geologists' emerging picture of magma reservoirs as mostly solid masses, says geologist John Pallister of the U.S. Geological Survey in Vancouver, Wash. And it could help scientists improve eruption forecasts.

Studying magma reservoirs is difficult because they're buried kilometers underground. Heat and pressure would destroy any instruments sent down there. So Kari Cooper, a geochemist at the University of California, Davis, and colleagues probed magma by scrutinizing seven zircon crystals from New Zealand's Taupo Volcanic Zone. They formed between a few thousand and a few hundred thousand years ago, when molten magma from deeper in Earth's crust crept up to the Taupo reservoir, cooled and crystallized into zircon and other minerals. Some of these other minerals eventually melted back into liquid magma and carried the zircon up and out during an eruption 700 years ago.

By examining the distribution of lithium in the crystals, the researchers discerned how long the zircon had existed at temperatures hot enough to melt its mineral neighbors — that is, how long the magma had stayed molten. Lithium, which the crystals picked up from surrounding magma, spreads through zircon faster when it's hotter, Cooper says.

Lithium diffusion indicated that the crystals spent, at most, about 1,200 years exposed to a temperature range of 650° to 750° Celsius. At those temperatures, solid magma melts into a state that's a little like a snow cone — mostly crystalline, with a bit of liquid seeping through. And for just 40 years, the crystals were exposed to temperatures above 750° — hot enough for magma to completely melt. Since the magma spent most of its time in the reservoir as a solid, the scientists surmise it melted only briefly before the eruption.

The study's findings raise questions about how mostly solid magma melts and mobilizes before an eruption, says earth scientist George Bergantz of the University of Washington in Seattle. Cooper suspects that molten material from even deeper underground seeps up and melts solid magma. ■

NISMA MUJAHID AND D.E. FISHER/CUTANEOUS BIO. RES. CTR./DEPT. OF DERMATOLOGY/MASS GENERAL

BODY & BRAIN

Bones tell other organs a thing or two

Skeleton sends out hormone messages, mouse studies show

BY CASSIE MARTIN

Long typecast as the strong silent type, bones are speaking up.

In addition to providing structural support, the skeleton is a versatile conversationalist. Bones make hormones that chat with other organs and tissues, including the brain, kidneys and pancreas, experiments in mice have shown.

"The bone, which was considered a dead organ, has really become a gland almost," says Beate Lanske, a bone and mineral researcher at Harvard School of Dental Medicine. "There's so much going on between bone and brain and all the other organs, it has become one of the most prominent tissues being studied at the moment."

At least four bone hormones moonlight as couriers, recent studies show, and there could be more. Scientists have only just begun to decipher what this messaging means for health. But cataloging and investigating the hormones should offer a more nuanced understanding of how the body regulates sugar, energy and fat, among other things.

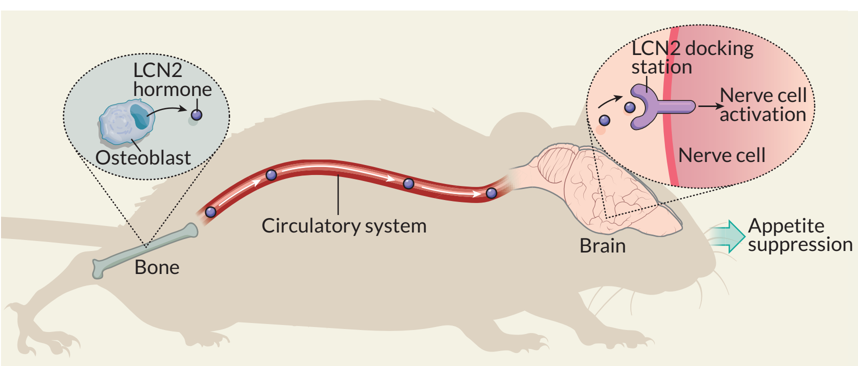
Of the hormones on the list of bones' messengers — osteocalcin, sclerostin, fibroblast growth factor 23 and lipocalin 2 — the last is the latest to attract attention. Lipocalin 2, which bones unleash to stem bacterial infections, also works in the brain to control appetite, physiologist Stavroula Kousteni of Columbia University Medical Center and colleagues reported in the March 16 *Nature*.

Researchers previously thought that fat cells were mostly responsible for making lipocalin 2, or LCN2. But in mice, bones produce up to 10 times as much of the hormone as fat cells do, Kousteni and colleagues showed. And after a meal, mice's bones pumped out enough LCN2 to boost blood levels three times as high as premeal levels. "It's a new role for bone as an endocrine organ," Kousteni says.

> "The bone, which was considered a dead organ, has really become a gland almost."
>
> BEATE LANSKE

Clifford Rosen, a bone endocrinologist at the Center for Molecular Medicine in Scarborough, Maine, is excited by this new bone-brain connection. "It makes sense physiologically that there are bidirectional interactions" between bone and other tissues, Rosen says. "You have to have things to regulate the fuel sources that are necessary for bone formation."

Bones constantly reinvent themselves through energy-intensive remodeling. Cells known as osteoblasts make new bone; other cells, osteoclasts, destroy old bone. With such turnover, "the skeleton must have some fine-tuning mechanism that allows the whole body to be in sync with what's happening at the skeletal level," Rosen says. Osteoblasts and osteoclasts send hormones to do their bidding.



Bone-brain connection After mice eat, their bone-forming cells absorb nutrients and release a hormone called lipocalin 2 (LCN2) into the blood. LCN2 travels to the brain, where it gloms on to appetite-regulating nerve cells, which tell the brain to stop eating, a recent study suggests.

R.D. PALMITER/NATURE 2017

Scientists began homing in on bones' molecular messengers a decade ago (*SN: 8/11/07, p. 83*). Geneticist Gerard Karsenty of Columbia University Medical Center found that osteocalcin — made by osteoblasts — helps regulate blood sugar. Osteocalcin circulates through the blood, collecting calcium and other minerals that bones need. When the hormone reaches the pancreas, it signals insulin-making cells to ramp up production, mouse experiments showed. Osteocalcin also signals fat cells to release a hormone that increases the body's sensitivity to insulin, the body's blood sugar moderator, Karsenty and colleagues reported in *Cell* in 2007. If it works the same way in people, Karsenty says, osteocalcin could be developed as a potential diabetes or obesity treatment.

"Their data is fairly convincing," says Sundeep Khosla, a bone biologist at the Mayo Clinic in Rochester, Minn. "But the data in humans has been less than conclusive." In observational studies of people, it's hard to say that osteocalcin directly influences blood sugar metabolism when there are so many factors involved.

More recent mouse data indicate that osteocalcin may play a role in energy metabolism. After an injection of the hormone, old mice could run as far as younger mice. Old mice that didn't receive an osteocalcin boost ran about half as far, Karsenty and colleagues reported last year in *Cell Metabolism*. As the hormone increases endurance, it helps muscles absorb more nutrients. In return, muscles talk back to bones, telling them to churn out more osteocalcin.

There are hints that this feedback loop works in humans, too. Women's blood levels of osteocalcin increased during exercise, the team reported.

Mounting evidence from the Karsenty lab suggests that osteocalcin also could have more far-flung effects. It stimulates cells in testicles to pump out testosterone — crucial for reproduction and bone density — and may also improve mood and memory, studies in mice have shown. Bones might even use the hormone to talk to a fetus's brain before birth. Osteocalcin from the bones of pregnant mice can penetrate the placenta and help shape fetal brain development, Karsenty and colleagues reported in 2013 in *Cell*. What benefit bones get from influencing developing brains remains unclear.

Another emerging bone messenger is sclerostin. Its day job is to keep bone growth in check by telling bone-forming osteoblasts to slow down or stop. But bones may dispatch the hormone to manage an important fuel source — fat. In mice, the hormone helps convert white (or "bad") fat into more useful energy-burning beige fat, molecular biologist Keertik Fulzele of Boston University and colleagues reported in the February *Journal of Bone and Mineral Research*.

Osteocalcin, sclerostin and LCN2 offer tantalizing clues about bones' communication skills. Another hormone, fibroblast growth factor 23, or FGF-23, may have more immediate medical applications.

Bones use FGF-23 to tell the kidneys to shunt extra phosphate that can't be absorbed. In people with kidney failure, cancer or some genetic diseases, including an inherited form of rickets called X-linked hypophosphatemia, FGF-23 levels soar, causing phosphate levels to plummet. Bones starved of this mineral become weak and prone to deformities.

In the case of X-linked hypophosphatemia, or XLH, a missing or broken gene in bones causes the hormone deluge. Apprehending the molecular accomplice may be easier than fixing the gene.

In March, researchers, in collaboration with the pharmaceutical company Ultragenyx, completed the first part of a Phase III clinical trial in adults with XLH — the final test of a drug before federal approval. The scientists tested an antibody that latches on to extra FGF-23 before it can reach the kidneys. Structurally similar to the kidney proteins where FGF-23 docks, the antibody is "like a decoy in the blood," says Lanske, who is not involved in the trial. Once connected, the duo is broken down by the body.

Hormone	Known function	Proposed function	Site of proposed activity
Lipocalin 2 (LCN2)	Stops the spread of bacterial invaders	Regulates appetite	Brain
Osteocalcin	Regulates bone mineralization and calcium metabolism	Regulates: ■ Blood sugar and insulin metabolism ■ Memory and mood ■ Testosterone production	■ Pancreas and fat tissue ■ Brain ■ Testicles
Sclerostin	Keeps bone growth in check	Implicated in energy metabolism	Fat tissue

Odd jobs Bones produce hormones that go to work in other organs. Some of those functions are known, but researchers are finding new ways that these hormones may behave.

Traditionally, treating XLH patients has been like trying to fill a bathtub without a plug. "The kidney is peeing out the phosphorus, and we're pouring it in the mouth as fast as we can so bones mineralize," says Suzanne Jan De Beur, a lead investigator of the clinical trial and director of endocrinology at Johns Hopkins Bayview Medical Center. Success is variable, and debilitating side effects often arise from long-term treatment, she says. The antibody therapy should help restore the body's ability to absorb phosphate.

Unpublished initial results indicate that the antibody works. Of 68 people taking the drug in the trial, over 90 percent had blood phosphate levels reach and stay in the normal range after 24 weeks of treatment, Ultragenyx announced in April. People taking the antibody also reported less pain and stiffness than those not on the drug.

Osteocalcin, sclerostin and LCN2 might also be involved in treating diseases someday, if results in animals apply to people.

In the study recently published in *Nature*, Kousteni's team found that boosting LCN2 levels in mice missing the LCN2 gene tamed their voracious feeding habits. Even in mice with working LCN2 genes, infusions of the hormone reduced food intake, improved blood sugar levels and increased insulin sensitivity.

Researchers traced the hormone's path from the skeleton to the hypothalamus — a brain structure that maintains blood sugar levels and body temperature and regulates other processes. Injecting LCN2 into mice's brains suppressed appetite and decreased weight gain. Once the hormone crosses the blood-brain barrier and reaches the hypothalamus, it attaches to the surface of nerve cells that regulate appetite, the team proposed.

Mice with defective LCN2 docking stations on their brain cells, however, overate and gained weight just like mice that couldn't make the hormone in the first place. Injections of LCN2 didn't curb eating or weight gain.

(Two mouse studies by another research group published in 2010, however, found that LCN2 had no effect on appetite. Kousteni and colleagues say that inconsistency could have resulted from a difference in the types of mice that the two groups used. Additional experiments by Kousteni's lab still found a link between LCN2 and appetite.)

In a small group of people with type 2 diabetes, those who weighed more had less LCN2 in their blood, the researchers found. And a few people whose brains had defective LCN2 docking stations had higher blood levels of the hormone.

If the hormone suppresses appetite in people, it could be a great obesity drug, Rosen says. It's still too early, though, to make any definitive proclamations about LCN2 and the other hormones' side hustles, let alone medical implications. "There's just all sorts of things that we are uncovering that we've ignored," Rosen says. But one thing is clear, he says: The era of bone as a silent bystander is over. ■

MATTER & ENERGY

Faux particle commits physics faux pas

Experiment reveals quasiparticle that violates Lorentz symmetry

BY EMILY CONOVER

A weird new particle imitator flouts the established rules of physics. The discovery could help scientists simulate how particles behaved just after the Big Bang or lead to the development of new devices with unusual electromagnetic properties.

The curious phenomenon involves a particle-like entity called a quasiparticle, formed from a jostling mosh pit of electrons that collectively act like a single particle in a solid. Found in a compound of lanthanum, aluminum and germanium, the new quasiparticle is a bit of a renegade, physicist M. Zahid Hasan of Princeton University and colleagues report June 2 in *Science Advances*. Called a type-II Weyl fermion, the quasiparticle breaks a rule called Lorentz symmetry, which states that the laws of physics are the same no matter the observer's perspective, whether moving or stationary.

Lorentz symmetry is the foundation of Einstein's special theory of relativity, which details the physics of observers zipping along near the speed of light. For a real particle, violating Lorentz symmetry would be an unallowable faux pas, but for quasiparticles, the rules are looser. So type-II Weyl fermions can behave in a way a normal particle wouldn't.

Fermions are a class of elementary particles that includes quarks (which make up protons and neutrons) and electrons. Weyl fermions are a massless variety that scientists have yet to observe in particle form. The quasiparticle version of Weyl fermions burst onto the scene in 2015, when they were found in a tantalum-arsenic compound (*SN: 8/22/15, p. 11*). Scientists realized that Weyl fermions' Lorentz-violating relatives, type-II Weyl fermions, might likewise pop up in solids.

In the new study, Hasan and colleagues measured the relationship between the energy and momentum of the quasiparticles, showing that they were consistent with type-II Weyl fermions. Previous experiments had shown hints of the quasiparticles, but those measurements assessed particles only on the material's surface, Hasan says. With surface measurements alone, it's hard to confirm type-II Weyl fermions are there, says ETH Zurich physicist Alexey Soluyanov. But Hasan and colleagues peered inside the material. "Experimentally, this work really is a nice example," Soluyanov says.

Weyl fermions cause unusual behavior. Put a normal material in a magnetic field, and its resistance to the flow of electricity grows, but in a solid with Weyl fermions, a magnetic field makes current flow more easily. Type-II Weyl fermions are even stranger, due to their Lorentz-violating properties. In a material with these quasiparticles, a magnetic field in one direction can increase conductivity, while in another direction it can decrease conductivity. "This type of thing can have interesting applications," Hasan says. "In a single material, just by changing the direction of the field, now we can get different behaviors," flipping between insulating and conducting, for example.

Type-II Weyl fermions may also help physicists better understand theories that violate Lorentz symmetry, says physicist Adolfo Grushin of Institut Néel in Grenoble, France. For example, Hasan says, scientists could simulate particle behavior just after the Big Bang, when the rule may not have been obeyed. ■

MATTER & ENERGY

Vortex of water acts like black hole

Physicists detect energy boost from rotational superradiance

BY EMILY CONOVER

Water swirling down a drain has exposed an elusive phenomenon long believed to appear in black holes.

Light waves scattering off a rotating black hole can bounce off with more energy than they came in with, by sapping some of the black hole's rotational energy. But the effect, predicted in 1971 and known as rotational superradiance, is so weak that it would be difficult to observe in a real black hole. Physicists report June 12 in *Nature Physics* that they've glimpsed the effect for the first time, in a black hole doppelgänger made with a vortex of water, similar to water swirling down a bathtub drain.

"If you take a tennis ball and you throw it against a wall, you don't expect it to come back with more energy," says Silke Weinfurtner of the University of Nottingham in England. "But when you throw something at a black hole, if it's a rotating black hole, you can actually gain energy."

To demonstrate the effect, physicists created a swirl of water. "The fluid has to drain in a way that looks like a black hole," says Antonin Coutant, also of Nottingham. Surface ripples reach a point of no return where they are sucked into the vortex. That's analogous to a black hole's event horizon, the boundary from which no light can escape. Weinfurtner, Coutant and colleagues report that water waves

Water ripples can ricochet off a vortex (shown), gaining energy. Physicists have now observed this effect — rotational superradiance — which is thought to occur in rotating black holes.

COURTESY OF S. WEINFURTNER

scattering off the vortex got a superradiant boost: They were amplified by up to 14 percent on average, depending on the frequency and direction of the waves.

The new result "gives us more confidence that our theories about black holes are correct," says physicist Sam Dolan of the University of Sheffield in England, who wasn't involved with the study. ■

GENES & CELLS

Nose's flu fighters have long memories

In mice, nasal immune cells remember and attack past invaders

BY TINA HESMAN SAEY

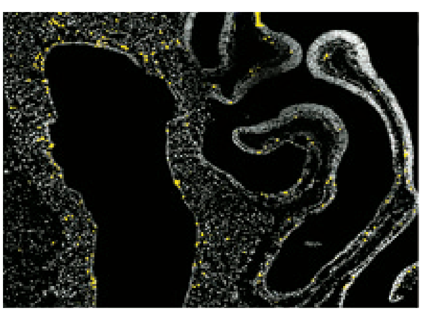
After an influenza infection, the nose recruits immune cells with long memories to keep watch for the virus, research in mice suggests.

For the first time, this type of immune cell — known as tissue resident memory T cells — has been found in the nose, researchers report June 2 in *Science Immunology*. The presence of these cells may prevent flu from recurring. Future nasal spray vaccines that boost the number of these T cells in the nose might be an improvement over current flu shots, researchers say.

It's known that some T cell sentinels take up residence in specific tissues, including the brain, liver, intestines, skin and lungs. In most of these tissues, the resident memory T cells start patrolling after a localized infection. "They're basically sitting there waiting in case you get infected with that pathogen again," says Linda Wakim, an immunologist at the University of Melbourne in Australia. If a previous virus invades again, the T cells can quickly kill infected cells and make chemical signals, called cytokines, to call in other immune cells for reinforcement. These T cells can persist for years in most tissues.

It's different in the lungs. There, resident memory T cells have shorter-term memories than those residing in other tissues, scientists have previously found.

Specialized immune cells called resident memory T cells (yellow) station themselves throughout the nose looking for flu viruses. Mouse nasal tissue is shown.



To see if all tissues in the respiratory tract have similarly forgetful immune cells, Wakim and colleagues tagged immune cells in mice and sprayed flu virus in the rodents' noses. After infection, resident memory T cells settled into the nasal tissue. The researchers haven't yet dissected any human noses, but it's a pretty good bet they also have resident memory T cells, Wakim says.

Unlike in the lungs, the nose T cells had long memories, persisting for a least a year. "For mice, that's quite a long time, almost a third of their life," Wakim says. She doesn't yet know why there's a difference between nose and lung T cell memories, but finding out may enable researchers to boost lung T cell memory.

With nose T cells providing security, the lungs might not need much flu-fighting memory. Memory T cells that patrol only the upper respiratory tract could stop viruses from ever reaching the lungs, Wakim's team found. An injection of virus under the skin didn't produce any resident memory T cells in the respiratory tract. Those findings could mean that vaccines delivered via nasal spray instead of shots might stimulate memory T cell growth in the nose and could protect lungs from damage as well. A nasal spray called FluMist has had variable results preventing flu in people. No one knows if that vaccine can produce nasal memory T cells.

It's not surprising to find that the nose has its own resident memory T cell security force, says Troy Randall, a pulmonary immunologist at the University of Alabama at Birmingham. "But it's a good thing to know and certainly they're the first to show it."

The discovery may direct some research away from the lungs and toward the nose, Randall says. Future research should focus on how the resident memory T cells work with memory B cells that produce antibodies against viruses and bacteria, he suggests. ■

LIFE & EVOLUTION

Seabirds negotiate parenting duties

Preening ceremony may signal health issues, other problems

BY ELIZABETH S. EATON

Seabirds called common murres appear to use preening as a way to negotiate whose turn it is to watch their chick and who must find food. And when one parent is feeling foul, irregularities in this grooming ritual send the other a signal that all is not well, scientists propose in the July issue of *The Auk: Ornithological Advances*.

"The fascinating part of this study is the inference that communication between mates allows murres to negotiate the level of effort that each member of the pair puts into the breeding effort," says John Piatt, a wildlife biologist at the U.S. Geological Survey in Anchorage, Alaska, who wasn't involved in the new study. "Reproductive success of this species requires a high degree of cooperation by each mate as they switch duties."

Common murres (*Uria aalge*) lay one egg per breeding season. Parental roles aren't determined by sex; mothers and fathers take turns watching over their chick and flying off to forage. When one parent returns with a fish for the chick, the couple preen each other and switch roles. This swapping ceremony typically happens three to four times a day.

But study coauthor Carolyn Walsh noticed that switches don't always go smoothly. Video of 16 pairs of murres, documenting a total of 198 role swaps, showed that sometimes both birds appeared indecisive. Each parent would hop on and off the chick several times before the birds preened each other and one left to fish. "It's as if they're resisting leaving the colony," says Walsh, an animal behavior researcher at Memorial University of Newfoundland in Canada.

For about a fifth of all switching ceremonies, the brooding parent was slow to preen its mate and then refused to switch, forcing the parent that had

A. PIZZOLLA *ET AL*/*SCIENCE IMMUNOLOGY* 2017 just returned with a fish to go back out.

Irregular behavior also occurred when the parent on fishing duty returned without food, which happened about 10 percent of the time. The empty-beaked bird would quickly start preening its mate, but the mate would be slow to preen back, or might not preen at all. "The brooder is basically communicating, 'The chick still needs a fish, you better go get one,'" Walsh says.

The ceremony could be a way for the seabirds to communicate their well-being, Walsh says. By withholding preening and delaying the switching ceremony, a murre in poor condition may be trying to negotiate with its partner to have the easier job of brooding. Staying in the nest may allow the bird to recover its strength.

Flying out to sea to fish is energetically costly for murres because they aren't very aerodynamic, Walsh says.

In physical tests of the birds, Walsh and colleagues found an association between body condition and ceremony irregularities. Her team captured birds, weighed them and sampled their blood for the metabolite beta-hydroxybutyrate, which is associated with continual weight loss.

Switching ceremonies lasted several minutes longer for the lightest birds, about 900 grams, compared with the heaviest birds weighing in at about 1,000 grams. Birds with lower mass and higher metabolite levels also were more likely to preen irregularly, Walsh says.

The longer ceremonies may also be a sign that there's unrest in the nest. Murres usually mate for life, but pairs can "divorce." Walsh previously found that mates heading for a split take more time to switch roles. ■

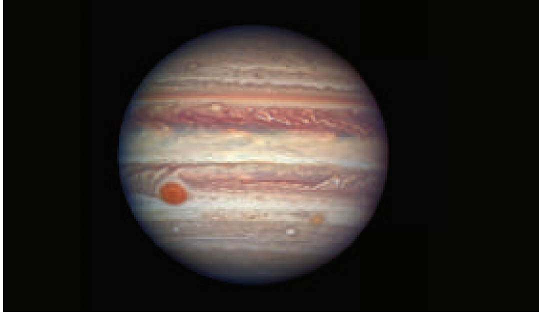
Common murres take turns brooding their chick and foraging. Preening each other may act as a health check and a way to divvy up parental care.

DICK DANIELS/WIKIMEDIA COMMONS (CC BY-SA 3.0)

ATOM & COSMOS

Solar system birthed Jupiter early on

Formation date might explain why inner planets are puny



Jupiter was the first planet in the solar system to form, a new study of meteorites suggests.

BY LISA GROSSMAN

Jupiter was an early bloomer. New meteorite measurements suggest that the giant planet's core must have formed within the solar system's first million years. If so, the age could help explain why the inner planets are so small.

Previously, astronomers' best constraints on Jupiter's age came from simulations of how solar systems form. Gas giants like Jupiter grow by accreting gas from spinning disks of gas and dust around a young star. Those disks typically don't last more than 10 million years, so astronomers inferred that Jupiter formed by the time that disk dissipated.

"Now we can use actual data from the solar system to show Jupiter formed even earlier," says Thomas Kruijer, now at Lawrence Livermore National Laboratory in California. Kruijer and his team report the new age June 12 in *Proceedings of the National Academy of Sciences*.

The team examined 19 iron meteorites, which represent the metal cores of some of the first asteroid-like bodies to congeal as the solar system formed.

Meteorites carry a chemical signature of their birthplaces. By measuring the relative amounts of certain isotopes, Kruijer and his team classified meteorites into two distinct groups. One formed closer to the sun than Jupiter is today; the other formed farther from the sun.

The data also showed that both groups existed at the same time, between about 1 million and 4 million years after the start of the solar system about 4.57 billion years ago. That means something must have kept them separated.

The most likely candidate is Jupiter, Kruijer says. His team's calculations suggest Jupiter's core had probably grown to about 20 times the mass of the Earth in the solar system's first million years, making it the oldest planet. Its presence would have created a gravitational barrier that kept the two meteorite neighborhoods segregated. Jupiter would then have continued growing at a slower rate.

"I have high confidence that their data is excellent," says Meenakshi Wadhwa, a cosmochemist at Arizona State University in Tempe. The idea that Jupiter held the different meteorites apart is "a little more speculative, but I buy it," she adds.

Jupiter's early entrance may explain why the inner solar system lacks planets larger than Earth. An early Jupiter's gravity could have kept most of the planet-forming disk away from the sun, leaving less raw material for the inner planets. ■

NEWS IN BRIEF

GENES & CELLS

Gut microbes help determine which bread is best

Whether standard white bread or an artisanal sourdough loaf is "healthier" depends on the microbes living in a person's intestines, a new study suggests.

Averaging results from people who ate white and whole wheat sourdough bread for one week each, researchers found no difference in people's responses to the breads. But when the 20 people were examined individually, a different pattern emerged. Some people's blood sugar levels climbed more after eating white bread compared with sourdough bread. For others, the opposite was true, the team reports in the June 6 *Cell Metabolism*.

The results are part of a growing body of evidence that nutrition advice should be personalized. Previous work by the same group, at the Weizmann Institute of Science in Rehovot, Israel, showed that different people's responses to eating a variety of foods vary (*SN: 1/9/16, p. 8*).

In the new study, the researchers analyzed the genetic makeup of participants' microbes from stool samples. The team could predict a participant's response to the two types of bread based only on which microbes were present in the stool. The researchers don't yet know how the bacteria change blood sugar levels. *—Tina Hesman Saey*

EARTH & ENVIRONMENT

Warming may help pests resist corn's genetic weapon

Climate change might be great news for pests looking to munch on genetically modified crops, researchers propose.

The scientists analyzed 21 years of data from Maryland cornfields and suggest that rising temperatures might help corn earworms (*Helicoverpa zea*) speed up resistance to a widely used genetically built-in crop protection.

Some varieties of corn have been engineered with genes for a toxin borrowed from the bacterium *Bacillus thuringiensis*, known as Bt, that kills earworms when they eat the crop. In areas with a lot of Bt corn acreage, plants defended by the Bt protein Cry1Ab suffered more earworm damage when summers grew warmer, the team reports June 7 in *Royal Society Open Science*.

It's unclear why more damage occurred when temperatures were higher. The heat might stress the plants, undermining their defenses. Also, insects depend on their surroundings for body warmth or cooling, so changing temperatures make a big difference in their lives, says coauthor Dilip Venugopal, an applied ecologist and policy fellow at the U.S. Environmental Protection Agency in Washington, D.C. Pests evolving Bt resistance might do so faster because warming, for instance, lets them squeeze extra generations into a year and improves chances of surviving winter. Or insects revved up by heat might find it easier to metabolize toxins. *—Susan Milius*

THE ROAD TO TAMENESS

Fresh ideas emerge about the origins of humans' relationships with their favorite species

By Tina Hesman Saey, Illustrations by Jody Hewgill

One lab full of rats looks pretty much the same as another. But visiting a lab in Siberia, geneticist Alex Cagan can distinguish rats bred to be tame from those bred to be aggressive as soon as he opens the lab door.

"It's a completely different response immediately," he says. All of the tame rats "come to the front of the cage very inquisitively." The aggressive rats scurry to the backs of their cages to hide. Exactly how 70 generations of breeding have ingrained friendly or hostile behaviors in the rats' DNA is a mystery that domestication researchers are trying to solve. The rats, along with mink and silver foxes, are part of a long-running study at the Institute of Cytology and Genetics in Novosibirsk, Russia. The aim is to replay domestication to determine the genetic underpinnings that set domesticated animals apart from their wild ancestors.

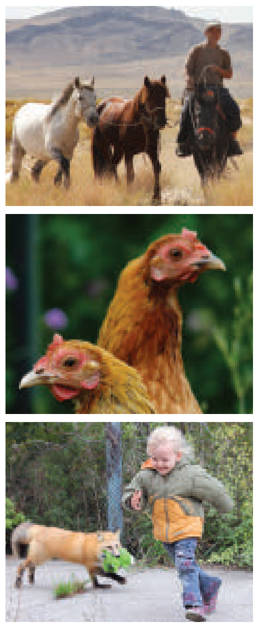
For thousands of years, humans have lived with animals. Some of the creatures are companions — hopping onto laps, ready to play fetch. Some have jobs — carrying heavy loads, pulling wagons and plows, and herding other animals. Others provide meat, eggs or milk. Plants, too, have been tamed. On nearly every continent, fruits, vegetables, grains, nuts and tubers stand in soldier-straight rows and yield bounty on schedule.

There was a time when the species that now inhabit humans' homes, fields and barnyards didn't exist. Then some people, somewhere, brought wild things under human control. Or the wild creatures exploited new ecological niches created by humans, gradually habituating themselves to people and, in essence, domesticating themselves. Both paths — scientists are still debating which was more likely for different animals — led to the creation of domesticated species or subspecies genetically distinct from their wild ancestors.

Scientists studying evolution and human history want to know how ancient people domesticated animals and plants. What species did humans start with and where did it happen first? How long did it take? Does one group get credit for taming wild horses or subjugating aurochs into milk-giving cows? Or did multiple people in different places have the same idea?

Even for dogs, humans' oldest, closest friends, "all those things are unknown," says evolutionary geneticist Greger Larson of the University of Oxford. For many domesticated creatures, the questions outweigh the answers. As new studies flood in — some based on archaeology, others on modern or ancient DNA — the waters get muddy, with one study's results contradicting another's.

"Domestication research right now is really going through an exciting phase," Larson says. Comparing the genetic instruction books, or genomes, of wild and domesticated species is giving evolutionary geneticists fresh clues about the changes that separate domesticated species from wild ones. New techniques (some developed in the last two to three years) for analyzing fragile DNA from ancient bones offer genetic snapshots of domestication as it played out long ago. Marrying that DNA data with archaeological findings, the context in which the bones were discovered, for example, may tell researchers more about when, where and how humans first engaged with plants and animals. Recent results are already rewriting the stories of rice, horse and chicken domestication.



Horses, chickens and foxes have been domesticated to do work, as a source of food or to test scientific ideas.

THIS PAGE, FROM TOP: L. ORLANDO/NATURAL HISTORY MUSEUM OF DENMARK, CNRS; P. JENSEN; DARIA SHEPELEVA

A new hypothesis is also shining a light on core changes in the embryos of many domesticated species. The hypothesis aims to explain how the process of becoming close to people produces comparable changes in the appearance, reproduction and physiology of a whole range of domesticated animals. One central developmental change — in a temporary clump of cells called the neural crest — may be behind the suite of characteristics known as domestication syndrome.

The pace of research, much of it seemingly contradictory, will only increase in the near future, Larson predicts. "We're going to get a lot more confused before we figure out what's really going on."

Defining domestication

Deciding when an animal can be called "domesticated" isn't always easy.

Since 2002, Anna Kukekova has been making annual treks to Novosibirsk. A geneticist at the University of Illinois at Urbana-Champaign, she travels to Siberia each year to collect blood from hundreds of silver foxes to look for genetic changes that produce tame and aggressive behaviors.

These foxes are special. They are part of a long-running biological experiment to repeat domestication by turning a wild canid — from the family of animals including wolves, foxes, jackals and dogs — into a fox version of a domestic dog (*SN: 5/13/17, p. 29*). The project was the brainchild of geneticist Dmitry Belyaev. In the 1950s, Belyaev and colleagues started selecting and breeding the least aggressive and fearful silver foxes from those on a fur farm. Since 1960, researcher Lyudmila Trut and her team have selected the farm's friendliest foxes to breed. Over more than 60 generations, the foxes have grown more and more tolerant of humans. Kukekova says she's noticed a difference even in the 15 years she's been visiting the farm.

In Kukekova's early visits, about 70 percent of the tame foxes were considered "elite," aquiver with excitement when people came around. The rest of the tame ones "didn't mind if you petted them, but they weren't super excited to interact with you," she says. Now, almost every tame fox is in the super-friendly elite group. (Foxes bred to be aggressive, on the other hand, are definitely not happy to have people around, much like the fearful rats Cagan encountered at the institute.)

Even though the friendly Novosibirsk foxes are genetically tame — some are sold as pets — not everyone would call the animals domesticated. "In an apartment, they would probably be very difficult pets," Kukekova says. The foxes have a strong odor, are more active at night and they aren't easily housetrained. The combination of living with people plus inherited changes in the foxes' genomes may eventually make them fully domesticated, but they aren't there yet.

Researchers have set out several biological criteria that should determine when silver foxes, or other animals, cross the line that divides merely tame from fully domesticated. Number one: Domesticated animals are genetically distinct from their wild forebears, and they inherit their human-friendly demeanor. That's different from wild animals that have been tamed but don't pass on that tameness to the next generation.

Two: Domestication makes animals dependent on humans for food and, for the most part, reproduction. Three: Breeding with wild counterparts becomes difficult, if not impossible. For example, domesticated plants don't drop their seeds when ripe; they rely on humans to spread their progeny. Finally, domesticated animals and plants should bear the physical hallmarks of domestication syndrome, such as a smaller skull for animals, and a narrower footprint for plants.

By these criteria, some people argue that cats — popular pets worldwide — are not fully domesticated. Cats probably started taming themselves about 9,500 years ago by hunting vermin, infesting early farmers' grain stores and feasting on food scraps. Farmers brought the mousers with them from the Middle East into Europe around 6,400 years ago, researchers reported June 19 in *Nature Ecology & Evolution*. But cats may not have been purring lap pets at that time, say molecular biologists Thierry Grange and Eva-Maria Geigl of the Institute Jacques Monod in Paris. That behavioral transformation may have happened later, perhaps in Egyptian cats that were quickly dispersed by boat around the ancient world.

In fact, cats haven't changed much physically or genetically from their African wildcat ancestors (*Felis silvestris lybica*), Grange and Geigl say. Many felines still choose their own mates and hunt for food. Cats' famed aloofness may be another clue that their domestication isn't fully complete. Certainly, cats are more like their wild ancestors than dogs are, says Grange. But modern kitties are no longer wild cats, Geigl argues: "These couch potatoes are domesticated."

Relationship status

Bonds between humans and their animal companions may be more important than rigid biological criteria, Larson and other researchers argue. Domestication, says zooarchaeologist Alan Outram of the University of Exeter in England, "is best looked at with a more cultural definition."

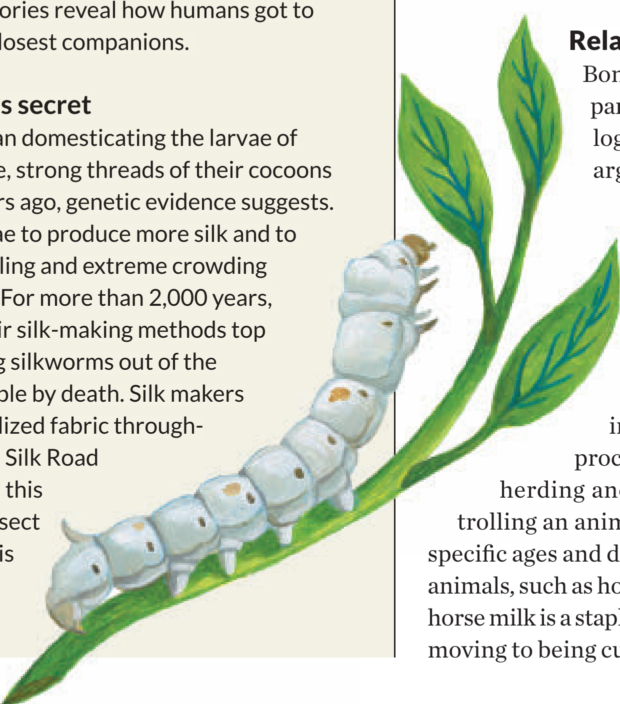
Domestication is a gray area encompassing the point at which a hunter stops being interested in simply killing and eating an animal and starts being interested in controlling the animal, Outram says. The process probably starts slowly, first with animal herding and other forms of husbandry, such as controlling an animal's food supply and movement, culling at specific ages and directing breeding. When people start using animals, such as horses, for labor, riding or milking (fermented horse milk is a staple in parts of Central Asia), the animals "start moving to being culturally domestic," he says.

Surprising stories in domestication

Over thousands of years, humans have found ways to put other species to work, from spinning silk to storing water. These short stories reveal how humans got to know some of their closest companions.

Keeping silkworms secret

In China, people began domesticating the larvae of silk moths for the fine, strong threads of their cocoons as early as 7,500 years ago, genetic evidence suggests. People bred the larvae to produce more silk and to tolerate human handling and extreme crowding (*SN Online: 8/27/09*). For more than 2,000 years, the Chinese kept their silk-making methods top secret, and smuggling silkworms out of the country was punishable by death. Silk makers traded their monopolized fabric throughout Eurasia along the Silk Road (*SN: 5/27/17, p. 4*). To this day, the only other insect that is domesticated is the honeybee.
— Erika Engelhaupt



Outram has evidence that the Botai people, hunter-gatherers that lived in Central Asia, were milking and bridling horses about 5,500 years ago (*SN: 3/28/09, p. 15*). “I certainly wouldn’t want to make the argument that at the Botai time you’ve got anything like modern domesticated horses,” he says. It was “more like equine husbandry and herding.”

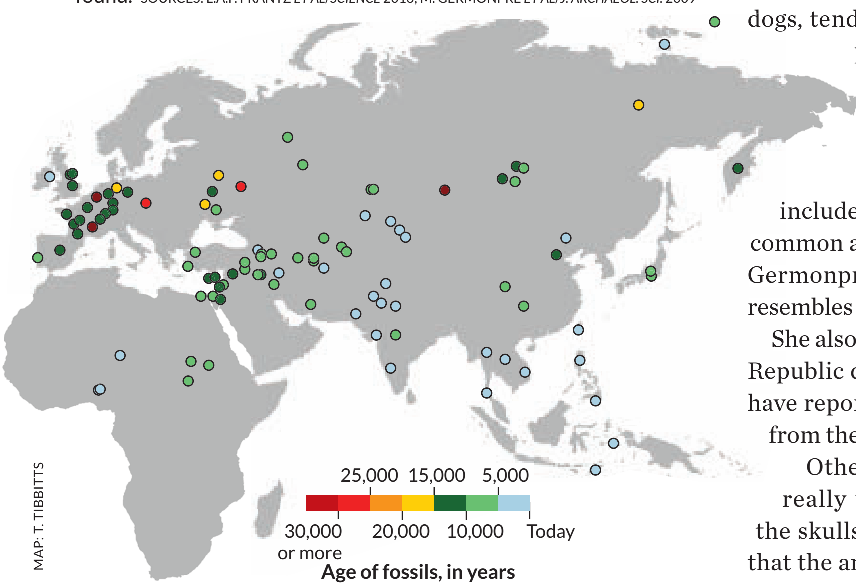
Scientists have to be careful not to judge how domestication happened in the past by the way animals are treated in modern Western cultures, says evolutionary biologist Ludovic Orlando of the University of Copenhagen. On a trip to collect DNA samples from ancient horse bones in Mongolia, Orlando got a whole new perspective on domestication.

“It completely changed my view of horse domestication, because I saw people interacting with this animal in ways I couldn’t imagine myself,” Orlando says. In Mongolia, horses roam free and their owners catch them, as needed, for riding or milking. “Once you’ve seen that, you can’t think that domestication is just about parking animals somewhere. It’s about the process of interacting with them and developing a relationship with them.”

Dog days

If it’s hard to pinpoint what domestication means in foxes tamed in controlled experiments, consider how difficult it is to decide whether the bones of a long-dead animal are from a wild or domesticated critter. That’s the task of paleontologist Mietje Germonpré of the Royal Belgian Institute of Natural Sciences in Brussels, who studies dog domestication. The beloved pets are the subjects of much domestication research.

A best friend Fossils of ancient dogs found across Europe, Asia and Africa may help scientists pinpoint where, when and possibly how dog domestication happened. Each dot shows a location where fossils were found. SOURCES: L.A.F. FRANTZ *ET AL/SCIENCE* 2016; M. GERMONPRÉ *ET AL/J. ARCHAEOL. SCI.* 2009



MAP: T. TIBBITTS

Newfound furry friend

Many domestication stories have vague beginnings, but we know exactly when the Syrian golden hamster, now a popular pet, first came under human control. On April 12, 1930, zoologist Israel Aharoni had workers dig up a mother hamster and her 11 babies spied by a farmer in his wheat field near Aleppo, Syria. Aharoni wanted a convenient animal to rear in the laboratory, but the creatures were so easily tamed that breeders began selling them as pets. Now, more than a million hamsters, descended from that first litter, run in wheels and transparent balls in homes across the United States.
— Erika Engelhaupt

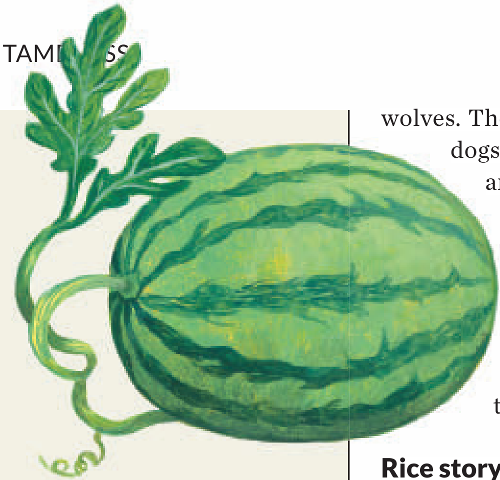
Scientists used to think that dogs were domesticated toward the end of the Ice Age, about 14,000 years ago (*SN Online: 7/22/10*). Germonpré and colleagues have studied skulls and jawbones of even more ancient canids in caves and other places where Ice Age people lived more than 25,000 years ago. One skull, found in a Goyet cave in Belgium, may be one of the oldest dogs ever discovered — or at least the oldest wolf that looked like a dog. At 36,000 years old, the Goyet pooch pushed dog domestication back to well before glaciers reached their peak coverage of the Northern Hemisphere.

Those early dogs may have been used as pack animals to move mammoth carcasses from hunting grounds to living quarters, says Germonpré. Big dogs may have helped humans hunt dangerous carnivores, such as cave bears, hyenas and cave lions. It’s also possible the animals were used for fur or meat.

Germonpré’s assertion that the Goyet dog is in fact a dog comes from comparing its skull and jaws with those of wolves and modern dogs. Most domesticated mammals, including dogs, tend to have smaller bodies than their wild counterparts, with smaller skulls that have shorter, wider snouts and shorter, lower jaws. Those features make adult dogs look more puppylike than grown wolves do. That type of facial remodeling is part of the domestication syndrome, which also includes curly tails, floppy ears and other characteristics common among domesticated animals but not wild ones. By Germonpré’s measurements, the Goyet skull more closely resembles modern dogs than it does ancient or modern wolves.

She also has evidence of early dogs in Russia and the Czech Republic dating to 25,000 years ago or more. Other groups have reported data suggesting that a 33,000-year-old canid from the Altai Mountains of Russia was also an early dog.

Other researchers disagree, saying the animals were really wolves. Three-dimensional reconstructions of the skulls of the Goyet dog and another Ice Age dog show that the animals’ snouts didn’t angle from the skull the way



Fruit for a king

The ancestor of today's enormous, fleshy sweet watermelons was a surprisingly small, hard and bitter melon with pale green flesh. Just where this fruit was first grown is debated — all that's agreed on is that it was somewhere in Africa. An image of a watermelon appears in an Egyptian tomb dating to at least 4,000 years ago, and five watermelon seeds were found in King Tut's tomb. It's thought that the Egyptians bred the fruit as a tasty, and portable, water supply. — *Erika Engelhaupt*

modern dogs' do, and the ancient versions didn't have some other features of modern dogs (*SN Online: 2/5/15*).

Larson says he's not bothered that the Goyet hound didn't physically measure up in the 3-D study. The canid may have behaved very much like a dog and had close ties to humans. Those early dogs didn't have thousands of years of intense breeding selection to sculpt them into the image of modern dogs. Even modern dogs have been transformed dramatically in just 200 to 300 years of breeding (*SN Online: 4/26/17*; *SN: 1/31/09, p. 26*). "What was a dog 15,000 to 30,000 years ago is not what a dog is now," Larson says.

The timing of Fido's taming isn't the only dispute. Researchers also wrangle over where and how many times it happened. Dueling genetic studies based on the DNA of modern dogs and wolves suggest the fellowship between humans and dogs could have been forged in the Middle East, Central Asia, East Asia or, as Goyet's archaeological evidence suggests, in Europe. Research reported by Larson and colleagues last year in *Science* suggests that dog domestication happened at least twice, once in Europe and once in East Asia (*SN: 7/9/16, p. 15*).

DNA evidence indicates that the Goyet dog and the 33,000-year-old Russian dog are not the ancestors of today's dogs or wolves (*SN: 12/14/13, p. 6*). Scientists examined mitochondrial DNA, which is passed from mothers to offspring, to trace maternal lineages of ancient and modern dogs and wolves. The mitochondrial DNA of the Goyet and Russian dogs belongs to a maternal lineage that didn't leave any modern descendants, researchers reported in *Science* in 2013. But it doesn't mean the animals weren't on the way toward being domesticated, Germonpré says.

Perhaps those dogs were part of an early, failed attempt at domestication, she says. "The domesticated animals became extinct, and domestication started up again somewhere else."

Rice story shattered

Locating the cradle of most species' domestication is difficult. Many were domesticated before writing was even invented. So scientists have to extract the story from artifacts and bones or from DNA.

The origin of Asian rice has been hotly debated for many years. Scientists used to think modern rice, *Oryza sativa*, was domesticated twice: sticky, short-grained *japonica* rice was domesticated in China, and in India, rice was domesticated into long-grained varieties *indica* and *aus*. Archaeological finds suggest that rice cultivation started about 9,000 years ago in China and 8,000 years ago in India. But true domestication probably happened only once — in China, says Dorian Fuller, an archaeobotanist at University College London.

People were certainly cultivating rice in India, but that's just one step in the domestication process. The final threshold that separates a fully domesticated crop from a cultivated one is that domesticated plants require human intervention to spread their seeds, Fuller says. Wild grains, for instance, "shatter" their seed heads when ripe. But domesticated grains, including rice, wheat, barley, sorghum and millet, have mutations that prevent shattering. The only way the grain crops can propagate is if humans collect and plant the seeds.

It may have taken nearly 2,000 years for people in China's Yangtze River basin to wrest complete control over rice, researchers reported last year in *Scientific Reports*. Scientists examined rice fossils to determine how easily the plant shattered its seed. Although people were growing an early rice 9,000 to 8,400 years ago, about 60 percent of plants were still dispersing seeds via shattering. It wasn't until about 7,000 to 6,500 years ago that nonshattering rice began to edge out shattering varieties.

By examining DNA from modern rice strains, Fuller and

Choices and changes Humans may have selected animals for tameness (left column), with those choices leading to unintended features seen in many domesticated species (right column). One hypothesis is that tameness, which involves a calmer nervous system and a dampened stress hormone response, results from alterations in neural crest cells. Those cells migrate throughout the embryo to form many tissues. Changes in the cells' migration might account for many physical traits linked to tameness in domesticated animals. SOURCE: A.S. WILKINS, R.W. WRANGHAM AND W.T. FITCH/*GENETICS* 2014

Selection for tameness

Selected traits

- Less reactive, reduced stress, less fear of humans. Tameness occurs because:
  - Adrenal glands produce less adrenaline and noradrenaline, the fight-or-flight hormones
  - Nervous system is less sensitive

Common unselected traits

- White patches in coats due to fewer pigment-producing cells
- Juvenile features — facial bones are sculpted differently and cartilage softens, leading to smaller teeth and jaws, shortened snout and floppy ears
- Smaller forebrain

evolutionary geneticist Michael Purugganan of New York University think they've pieced together the rest of the rice domestication story. DNA evidence clearly shows that China's wild *O. rufipogon* was domesticated into *O. sativa japonica*. Traders carried domesticated *japonica* from China to India, where it was bred with the cultivated rice species *O. nivara* to produce domesticated *aus* about 4,000 years ago, Fuller, Purugganan and colleagues reported in January in *Molecular Biology and Evolution*. *Indica*'s story is less clear because its cultivated predecessor in India is still unknown. But the genetic evidence indicates that it got its domestication genes from China's *japonica*.

Tails (and feathers) from the past

Working out the step-by-step history of domesticated animals is just as complicated. Until recently, researchers compared DNA from modern domestic animals with that of wild relatives, preferably the wild species that gave rise to the domesticated species. Sometimes that's impossible to do. There are no wild cattle, for instance. Aurochs — massive cattle that eventually gave rise to domesticated cows — went extinct when the last one died in 1627 in Poland's Jaktorów Forest.

Horses' wild ancestors are also extinct, but remains from the warrior steeds of Genghis Khan and medieval knights, the Romans' chariot horses and the mounts of the ancient Scythians, Greeks and Persians might fill in gaps in horse history and prehistory. Through the Pegasus project, begun in 2015, Orlando and colleagues have collected ancient DNA from horse fossils from a wide variety of time periods and cultures. "We're looking at every possible ancient equine culture on the planet," Orlando says.

Before the project, scientists mostly had to rely on DNA from modern horses to piece together the story of how the beasts of burden were domesticated. Findings of those studies may be misleading, Orlando and colleagues have concluded. For instance, studies of modern horses' mitochondrial DNA plus Y chromosomes (passed from fathers to sons) told a nice, neat story: At the beginning of horse domestication, people must have captured just a few stallions and bred those stallions to many different mares.

But when Orlando and colleagues examined DNA of ancient horses, they found that the story started completely differently. Domesticated horses living 2,300 to 2,700 years ago — about the midpoint of horse domestication — had a wide variety of Y chromosomes, the researchers reported April 28 in *Science* (*SN: 5/27/17, p. 10*). That means many stallions contributed DNA to horses' gene pool for at least the first few thousand years of domestication. It wasn't until sometime after 2,300 years ago that people started winnowing down the number of stallions that were allowed to breed. Orlando doesn't know yet when most Y chromosomes were lost.

> "We're looking at every possible ancient equine culture on the planet."
> LUDOVIC ORLANDO

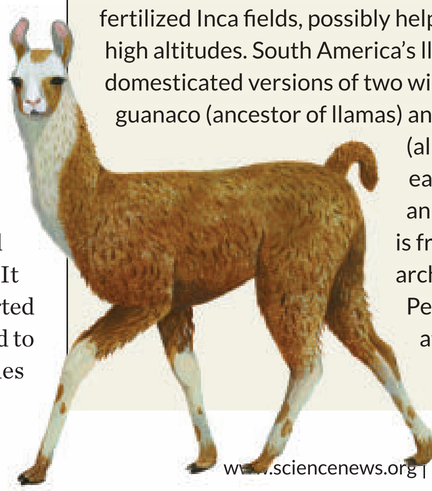
The story of chicken domestication is being retold as well, also thanks to DNA evidence. Modern chickens carry a version of the thyroid-stimulating hormone receptor gene, *TSHR*, that has been linked to several domesticated chicken characteristics: year-round egg laying, faster egg production at sexual maturity, reduced aggression toward other chickens and less fear of people. Because that version of the gene is ubiquitous in present-day chickens and is responsible for those attractive traits, researchers thought that people probably selected the most prolific egg layers right from the very beginning, about 4,000 years ago. Picking better laying hens would also mean unwittingly choosing the domesticated version of *TSHR*.

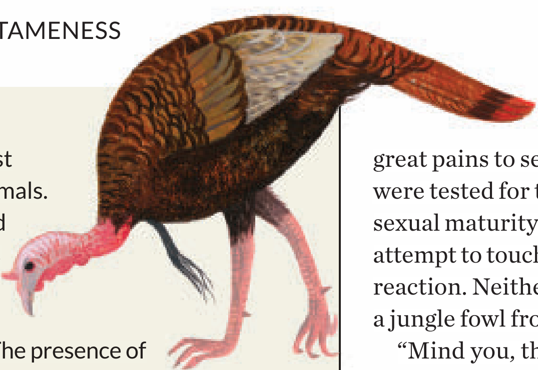
But, the egg-laying version of the gene didn't become popular among chickens in Europe until about A.D. 920, around the time that Christians started giving up meat on fasting days in favor of fish and fowl, Larson and colleagues reported May 2 in *Molecular Biology and Evolution*. (Rabbit domestication followed a religious proclamation, as well. In 600, Pope Gregory I declared that fetal rabbits, called laurices, are aquatic, which made them fish, suitable to eat during Lent. Rabbit breeding took off in monasteries in southern France, and bunnies quickly became domesticated.)

If Larson's calculations are correct, egg laying wasn't the main criterion for selecting which chickens to keep until the Middle Ages. By that time, the birds had been domesticated for thousands of years. So what were ancient people looking for when striking up friendships with the feathered animals — or any other creatures? Many people think it was about the relationship; tameness and docility were the most attractive qualities in potential animal pals. It's hard to be buddies with a creature that constantly runs from you, or worse, attacks.

On the backs of llamas

Though the Inca built great cities and had a sophisticated understanding of astronomy, they didn't use wheels to transport goods. Instead, llamas carried the heavy loads along the empire's vast road system. And llama dung fertilized Inca fields, possibly helping to grow maize at high altitudes. South America's llamas and alpacas are domesticated versions of two wild camel species: guanaco (ancestor of llamas) and the smaller vicuña (alpacas' ancestor). The earliest evidence of the animals' domestication is from bones found at archaeological sites in the Peruvian Andes, dating to at least 6,000 years ago.
— Erika Engelhaupt





Titanic turkeys

Turkeys are one of the most recently domesticated animals. In 2016, researchers found 1,500-year-old turkey eggs plus bones of both chicks and adult birds in the Oaxaca region of Mexico. The presence of turkeys at all life stages suggests they were being raised as food. They may have been important symbolically too; remains have been found buried alongside humans. The birds have changed a great deal since those early days: Some commercially bred turkeys have breast muscles so large that the birds can't get close enough to mate. Humans must artificially inseminate them, a sign of true domestication. *— Erika Engelhaupt*

Docility makeover

A breeding experiment with wild red jungle fowl, the precursor to the domesticated chicken, may help explain whether selecting for tameness is the triggering event of domestication and all its characteristics. Behavioral geneticist Per Jensen of Linköping University in Sweden is in the middle of a domestication redo. He and colleagues have bred eight generations of the rust-feathered birds. Like the rats, mink and foxes in Novosibirsk, Jensen's jungle fowl are bred to be more (or less) fearful of humans than their ancestors were.

From the beginning, the researchers took great pains to select birds only for their behavior: Jungle fowl were tested for tameness at 12 weeks old, before they reached sexual maturity. One researcher would approach the fowl and attempt to touch it, while an outside observer scored the bird's reaction. Neither researcher knew whether they were testing a jungle fowl from the tame or fearful line.

"Mind you, this went well for two or three generations but then the difference started to be so big it was difficult to keep a secret," Jensen says. After that, the tame birds were so calm they didn't react when a human entered the room. "You basically had to kick them out of your way," he jokes. By the sixth generation, tame birds were bigger and had a higher metabolism than their fearful counterparts, Jensen and colleagues reported in *Biology Letters* in 2015. Changes in body size, reproduction and metabolism happened quickly, even though the researchers were only choosing birds for tameness.

The tame birds, Jensen says, "show a lot of traits that you really associate with domesticated animals, but I'm not sure anyone would accept that," he says. Becoming what other people think of as domesticated chickens may take more time: jungle fowl hens that lay eggs year-round and are big enough to eat. "I don't think we're talking about hundreds of generations, maybe dozens. It's a much faster process than we used to think."

Again and again, animals of various species domesticated at different times in different parts of the world develop the same domestication syndrome characteristics: more extensive

Domesticating us

Long before humans domesticated other animals, we may have domesticated ourselves.

Over many generations, some scientists propose, humans selected among themselves for tameness. This process resulted in genetic changes, several recent studies suggest, that have shaped people in ways similar to other domesticated species.

Tameness, says evolutionary biologist and primatologist Richard Wrangham of Harvard University, may boil down to a reduction in reactive aggression — the fly-off-the-handle temperament that makes an animal bare its teeth at the slightest challenge. In this sense, he says, humans are fairly tame. We might show great capacity for premeditated aggression, but we don't attack every stranger we encounter.

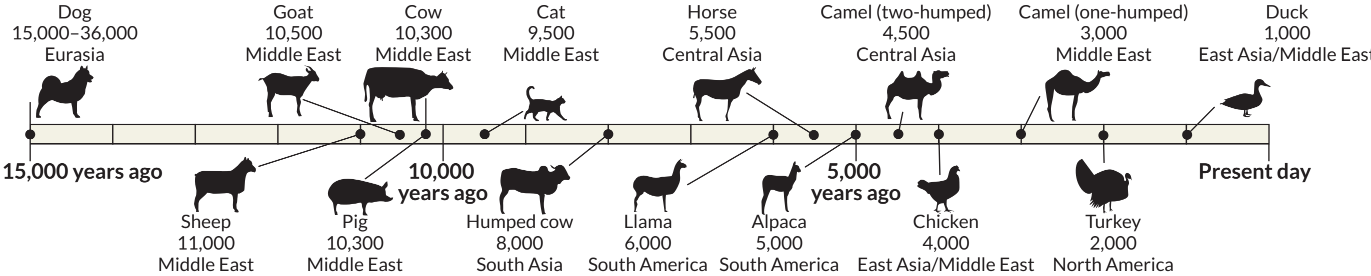
Sometime in the last 200,000 years, humans began weeding out people with an overdose of reactive aggression, Wrangham suggests. Increasingly complex social skills would have allowed early humans to gang up against bullies, he proposes, pointing out that hunter-gatherers today have been known to do the same. Those who got along, got ahead.

Once animals have been selected for tameness, other traits tend to follow, including reshaping of the head and face. Humans even look domesticated: Compared with Neandertals', our faces are shorter with smaller brow ridges, and males' faces are more similar to those of females.

Selecting for less-aggressive humans could have also helped us flourish as a social species, says Antonio Benítez-Burraco, who studies language evolution at the University of Huelva in Spain. The earliest *Homo sapiens* were becoming capable of complex thought, he proposes, but not yet language. "We were modern in the sense of having modern brains, but we were not modern in behavior."

Once humans began to self-domesticate, though, changes to neural crest cells could have nudged us toward a highly communicative species. Something similar happens in songbirds: Domesticated birds have more complex songs than their wild counterparts. What's more, self-domestication may be more common than once thought. Bonobos, Wrangham notes, live in peaceful groups compared with closely related, but more violent, chimpanzees. If humans took steps to domesticate themselves, perhaps they weren't the only ones. *— Erika Engelhaupt*

Approximate time frame of domestication based on archaeology



Taming the wild Dogs appear to have been the first species domesticated by humans, followed by many others in Asia and the Middle East. As people spread to the New World, they continued to domesticate animals. Some were domesticated more than once in different locations.

SOURCES: D.E. MACHUGH *ET AL/ANNU. REV. ANIM. BIOSCI.* 2017; M. GERMONPRÉ *ET AL/J. ARCHAEOL. SCI.* 2009

breeding periods; smaller brains, hearts and teeth; small or floppy ears; spotted coats; curly hair and tails; variable numbers of vertebrae in the spine; and juvenile faces with shorter snouts. Researchers have found evidence that pigmentation genes differ between domestic and wild animals. Others have pinpointed changes in brain chemistry or genes involved in face development that may separate tame and wild animals. But scientists didn't have a unifying explanation for why the physical traits of domestication syndrome were linked to tameness until three years ago.

That's when geneticist Adam Wilkins of Humboldt University of Berlin, primatologist Richard Wrangham of Harvard University and evolutionary biologist and cognitive scientist W. Tecumseh Fitch of the University of Vienna introduced a new hypothesis. Selecting animals for tameness, they said, could alter genes that control a group of developmentally important cells called neural crest cells. Those embryonic cells migrate in the embryo and contribute to tissues involved in the fight-or-flight response, facial development and coloring.

Choosing animals for tameness might be selecting for ones that have changes in how their neural crest cells function, the researchers proposed in *Genetics* in 2014 (*SN: 8/23/14, p. 7*). Calmer domesticated animals might have neural crest cells that move or work differently than the cells in more fearful wild animals. Because neural crest cells contribute to so many tissues in the body, altering their function could change an animal's behavior, appearance and biology, the researchers reasoned. For the first time, domestication researchers had a hypothesis about the link between tameness and physical traits that could really be put to the scientific test.

Since the neural crest hypothesis surfaced, geneticists have found tantalizing clues that Wilkins, Wrangham and Fitch are onto something. Analysis of cat DNA found that house cats and wild cats have different versions of genes implicated in neural crest cell migration (*SN: 12/13/14, p. 7*). When Orlando and colleagues examined horse DNA for genes that may have rapidly changed during domestication, they too found genes involved in neural crest cell function.

While at the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, Cagan compared DNA from the tame rats and mink at Novosibirsk, and from other domesticated species, with DNA from aggressive counterparts and wild ancestors. In unpublished research, Cagan (now at the Wellcome Trust Sanger Institute in Hinxton, England) found that genes involved in helping neural crest cells migrate differed between the tame and wild animals (*SN: 6/13/15, p. 11*). That might explain the white patches of fur, shorter snouts and curly tails of the tame animals.

Jensen calls the neural crest cell hypothesis "a very speculative idea that may not be applicable across species." He is looking more closely at the neural crest in the jungle fowl. He and colleagues are collecting eggs to track the cells' movements in tame and fearful birds. Even if the researchers find differences, he says, "we still need to find the genetic mechanisms that are causing the neural crest cells to act as they do."

Larson expects many revelations in the next year or two about when, where and how domestication happened. "Even the big themes are going to be radically revised," he says. Domestication is likely to be a far more complicated process than researchers expected, but Larson hopes people will find it all the more interesting for its lack of simplicity. "We want to get people to embrace the ambiguity and to love the complexity." ■

Not much of a mouthful

It would be hard to recognize today's toothsome corncobs from the plant's wild progenitor, a grass called teosinte. When Native Americans began domesticating teosinte, its ears were two or three inches long, holding a sparse five to 12 kernels each. In fact, teosinte looks so different from maize that scientists questioned the link, first proposed in the 1930s, until genetics could prove it more than half a century later. In 2009, archaeologists found the earliest known evidence of domesticated maize at an 8,700-year-old site in southwestern Mexico, alongside stone tools used to grind the plants. *— Erika Engelhaupt*

TIMELINE: T. TIBBITTS

Explore more

- Lee Alan Dugatkin and Lyudmila Trut. *How to Tame a Fox*. University of Chicago Press, 2017.

FEATURE

Google, IBM and others are developing quantum computers. Cooling systems (Google's shown) maintain frigid temperatures for the superconducting quantum processor, which sits at the bottom of the contraption. The system is enclosed in a water heater–sized container.

Quantum Computers GET REAL

As the first qubit-based machines come online, scientists are just beginning to imagine the possibilities

By Emily Conover

Although the term "quantum computer" might suggest a miniature, sleek device, the latest incarnations are a far cry from anything available in the Apple Store. In a laboratory just 60 kilometers north of New York City, scientists are running a fledgling quantum computer through its paces — and the whole package looks like something that might be found in a dark corner of a basement. The cooling system that envelops the computer is about the size and shape of a household water heater.

Beneath that clunky exterior sits the heart of the computer, the quantum processor, a tiny, precisely engineered chip about a centimeter on each side. Chilled to temperatures just above absolute zero, the computer — made by IBM and housed at the company's Thomas J. Watson Research Center in Yorktown Heights, N.Y. — comprises 16 quantum bits, or qubits, enough for only simple calculations.

If this computer can be scaled up, though, it could transcend current limits of computation. Computers based on the physics of the supersmall can solve puzzles no other computer can — at least in theory — because quantum entities behave unlike anything in a larger realm.

Quantum computers aren't putting standard computers to shame just yet. The most advanced computers are working with fewer than two dozen qubits. But teams from industry and academia are working on expanding their own versions of quantum computers to 50 or 100 qubits, enough to perform certain calculations that the most powerful supercomputers can't pull off.

The race is on to reach that milestone, known as "quantum supremacy." Scientists should meet this goal within a couple of years, says quantum physicist David Schuster of the University of Chicago. "There's no reason that I see that it won't work."

But supremacy is only an initial step, a symbolic marker akin to sticking a flagpole into the ground of an unexplored landscape. The first tasks where quantum computers prevail will be contrived problems set up to be difficult for a standard computer but easy for a quantum one. Eventually, the hope is, the computers will become prized tools of scientists and businesses.

Attention-getting ideas

Some of the first useful problems quantum computers will probably tackle will be to simulate small molecules or chemical reactions. From there, the computers could go on to speed the search for new drugs or kick-start the development of energy-saving catalysts to accelerate

ERIK LUCERO

chemical reactions. To find the best material for a particular job, quantum computers could search through millions of possibilities to pinpoint the ideal choice, for example, ultrastrong polymers for use in airplane wings. Advertisers could use a quantum algorithm to improve their product recommendations — dishing out an ad for that new cell phone just when you're on the verge of purchasing one.

Quantum computers could provide a boost to machine learning, too, allowing for nearly flawless handwriting recognition or helping self-driving cars assess the flood of data pouring in from their sensors to swerve away from a child running into the street. And scientists might use quantum computers to explore exotic realms of physics, simulating what might happen deep inside a black hole, for example.

"We're very excited about the potential to really revolutionize ... what we can compute."
KRYSTA SVORE

But quantum computers won't reach their real potential — which will require harnessing the power of millions of qubits — for more than a decade. Exactly what possibilities exist for the long-term future of quantum computers is still up in the air.

The outlook is similar to the patchy vision that surrounded the development of standard computers — which quantum scientists refer to as "classical" computers — in the middle of the 20th century. When they began to tinker with electronic computers, scientists couldn't fathom all of the eventual applications; they just knew the machines possessed great power. From that initial promise, classical computers have become indispensable in science and business, dominating daily life, with handheld smartphones becoming constant companions (*SN: 4/1/17, p. 18*).

Since the 1980s, when the idea of a quantum computer first attracted interest (see Page 34), progress has come in fits and starts. Without the ability to create real quantum computers, the work remained theoretical, and it wasn't clear when — or if — quantum computations would be achievable. Now, with the small quantum computers at hand, and new developments coming swiftly, scientists and corporations are preparing for a new technology that finally seems within reach.

"Companies are really paying attention," Microsoft's Krysta Svore said March 13 in New Orleans during a packed session at a meeting of the American Physical Society. Enthusiastic physicists filled the room and huddled at the doorways, straining to hear as she spoke. Svore and her team are exploring what these nascent quantum computers might eventually be capable of. "We're very excited about the potential to really revolutionize ... what we can compute."

Anatomy of a qubit

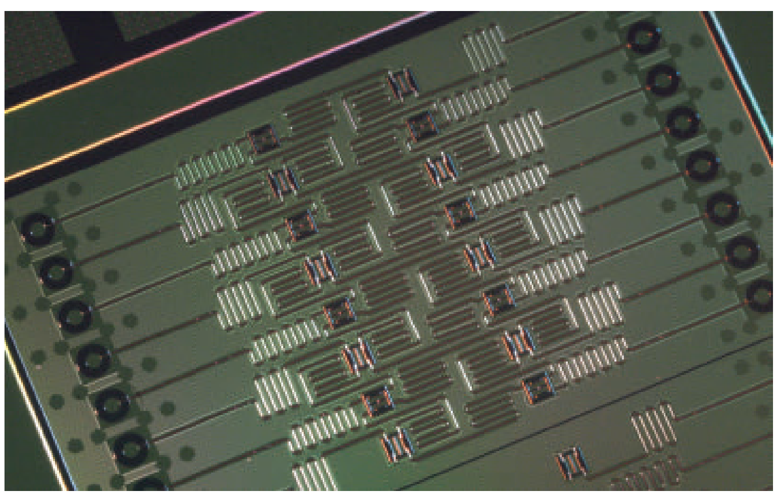
Quantum computing's promise is rooted in quantum mechanics, the counterintuitive physics that governs tiny entities such as atoms, electrons and molecules. The basic element of a quantum computer is the qubit (pronounced "CUE-bit"). Unlike a standard computer bit, which can take on a value of 0 or 1, a qubit can be 0, 1 or a combination of the two — a sort of purgatory between 0 and 1 known as a quantum superposition. When a qubit is measured, there's some chance of getting 0 and some chance of getting 1. But before it's measured, it's both 0 and 1.

Because qubits can represent 0 and 1 simultaneously, they can encode a wealth of information. In computations, both possibilities — 0 and 1 — are operated on at the same time, allowing for a sort of parallel computation that speeds up solutions.

Another qubit quirk: Their properties can be intertwined through the quantum phenomenon of entanglement (*SN: 4/29/17, p. 8*). A measurement of one qubit in an entangled pair instantly reveals the value of its partner, even if they are far apart — what Albert Einstein called "spooky action at a distance."

Such weird quantum properties can make for superefficient calculations. But the approach

One of IBM's newest quantum computers has 16 qubits made of superconducting materials. Two columns of eight qubits can be seen on this chip. The zigzag lines are microwave resonators, which allow qubits to interact.



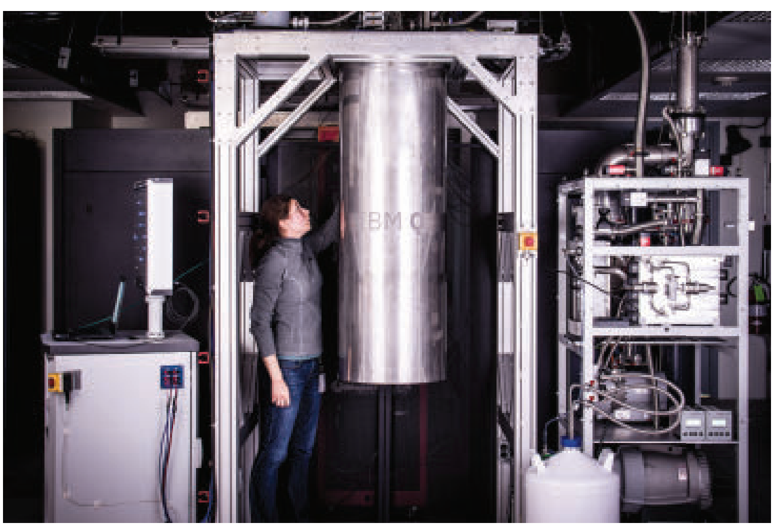
won't speed up solutions for every problem thrown at it. Quantum calculators are particularly suited to certain types of puzzles, the kind for which correct answers can be selected by a process called quantum interference. Through quantum interference, the correct answer is amplified while others are canceled out, like sets of ripples meeting one another in a lake, causing some peaks to become larger and others to disappear.

One of the most famous potential uses for quantum computers is breaking up large integers into their prime factors. For classical computers, this task is so difficult that credit card data and other sensitive information are secured via encryption based on factoring numbers. Eventually, a large enough quantum computer could break this type of encryption, factoring numbers that would take millions of years for a classical computer to crack.

Quantum computers also promise to speed up searches, using qubits to more efficiently pick out an information needle in a data haystack.

Qubits can be made using a variety of materials, including ions, silicon or superconductors, which conduct electricity without resistance. Unfortunately, none of these technologies allow for a computer that will fit easily on a desktop. Though the computer chips themselves are tiny, they depend on large cooling systems, vacuum chambers or other bulky equipment to maintain the delicate quantum properties of the qubits. Quantum computers will probably be confined to specialized laboratories for the foreseeable future, to be accessed remotely via the internet.

IBM has made its five-qubit computer accessible online for free, and the company is planning a 50-qubit computer for commercial use. The large tank shown here holds the cooling system that keeps a 17-qubit processor cold.



"Quantum computing is exciting. It's coming, and we want a lot more people to be well-versed in it."

JERRY CHOW

Going supreme

That vision of Web-connected quantum computers has already begun to materialize. In 2016, IBM unveiled the Quantum Experience, a quantum computer that anyone around the world can access online for free.

With only five qubits, the Quantum Experience is "limited in what you can do," says Jerry Chow, who manages IBM's experimental quantum computing group. (IBM's 16-qubit computer is in beta testing, so Quantum Experience users are just beginning to get their hands on it.) Despite its limitations, the Quantum Experience has allowed scientists, computer programmers and the public to become familiar with programming quantum computers — which follow different rules than standard computers and therefore require new ways of thinking about problems. "Quantum computing is exciting. It's coming, and we want a lot more people to be well-versed in it," Chow says. "That'll make the development and the advancement even faster."

But to fully jump-start quantum computing, scientists will need to prove that their machines can outperform the best standard computers. "This step is important to convince the community that you're building an actual quantum computer," says quantum physicist Simon Devitt of Macquarie University in Sydney. A demonstration of such quantum supremacy could come by the end of the year or in 2018, Devitt predicts.

Researchers from Google set out a strategy to demonstrate quantum supremacy, posted online at arXiv.org in 2016. They proposed an algorithm that, if run on a large enough quantum computer, would produce results that couldn't be replicated by the world's most powerful supercomputers.

The method involves performing random operations on the qubits, and measuring the distribution of answers that are spit out. Getting the same distribution on a classical supercomputer would require simulating the complex inner workings of a quantum computer. Simulating a quantum computer with more than about 45 qubits becomes unmanageable. Supercomputers haven't been able to reach these quantum wilds.

To enter this hinterland, Google, which has a nine-qubit computer, has aggressive plans to scale up to 49 qubits. "We're pretty optimistic," says Google's John Martinis, also a physicist at the University of California, Santa Barbara.

Martinis and colleagues plan to proceed in stages, working out the kinks along the way. "You build something, and then if it's not working exquisitely well, then you don't do the next one — you fix what's going on," he says. The researchers are currently developing quantum computers of 15 and 22 qubits.

IBM, like Google, also plans to go big. In March, the company announced it would build a 50-qubit computer in the next few years and make it available to businesses eager to be among the first adopters of the burgeoning technology. Just two months later, in May, IBM announced that its scientists had created the 16-qubit quantum computer, as well as a 17-qubit prototype that will be a technological jumping-off point for the company's future line of commercial computers.

But a quantum computer is much more than the sum of its qubits. "One of the real key aspects about scaling up is not simply ... qubit number, but really improving the device performance," Chow says. So IBM researchers are focusing on a standard they call "quantum volume," which takes into account several factors. These include the number of qubits, how each qubit is connected to its neighbors, how quickly errors slip into calculations and how many operations can be performed at once. "These are all factors that really give your quantum processor its power," Chow says.

Errors are a major obstacle to boosting quantum volume. With their delicate quantum properties, qubits can accumulate glitches with each operation. Qubits must resist these errors or calculations quickly become unreliable. Eventually, quantum computers with many qubits will be able to fix errors that crop up, through a procedure known as error correction. Still, to boost the complexity of calculations quantum computers can take on, qubit reliability will need to keep improving.

Different technologies for forming qubits have various strengths and weaknesses, which affect quantum volume. IBM and Google build their qubits out of superconducting materials, as do many academic scientists. In superconductors cooled to extremely low temperatures, electrons flow unimpeded. To fashion superconducting

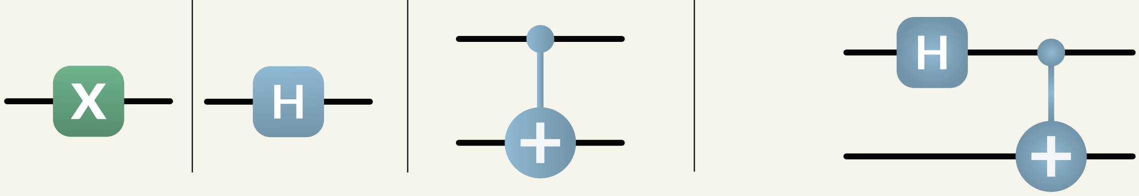
Gated community In quantum computing, programmers execute a series of operations, called gates, to flip qubits (represented by black horizontal lines), entangle them to link their properties, or put them in a superposition, representing 0 and 1 simultaneously. First, some gate definitions:

X gate: Flips a qubit from a 0 to a 1, or vice versa.

Hadamard gate: Puts a qubit into a superposition of states.

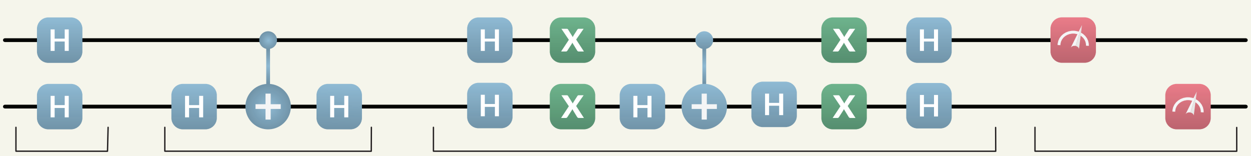
Controlled not gate: Flips a second qubit only if the first qubit is 1.

Entanglement: A Hadamard gate puts the first qubit in a superposition. The controlled not gate both flips and does not flip the second qubit. Assuming the qubits start as 0, when measured, they will be 11 or 00, but never 10 or 01.



Scientists can combine gates like the ones above into complex sequences to perform calculations that are not possible with classical computers. One such quantum algorithm, called **Grover's search**, speeds up searches, such as scanning fingerprint databases for a match. To understand how this works, consider a simple game show.

In this game show, four doors hide one car and three goats. A contestant must open a door at random in hopes of finding the car. Grover's search looks at all possibilities at once and amplifies the desired one, so the contestant is more likely to find the car. The two qubits represent four doors, labeled in binary as 00, 01, 10 and 11. In this example, the car is hidden behind door 11.



Step 1: Puts both qubits in a superposition. All four doors have equal probability.

Step 2: Hides the car behind door 11. In a real-world example, this information would be stored in a quantum database.

Step 3: Amplifies the probability of getting the correct answer, 11, when the qubits are measured.

Step 4: Measures both qubits; the result is 11.

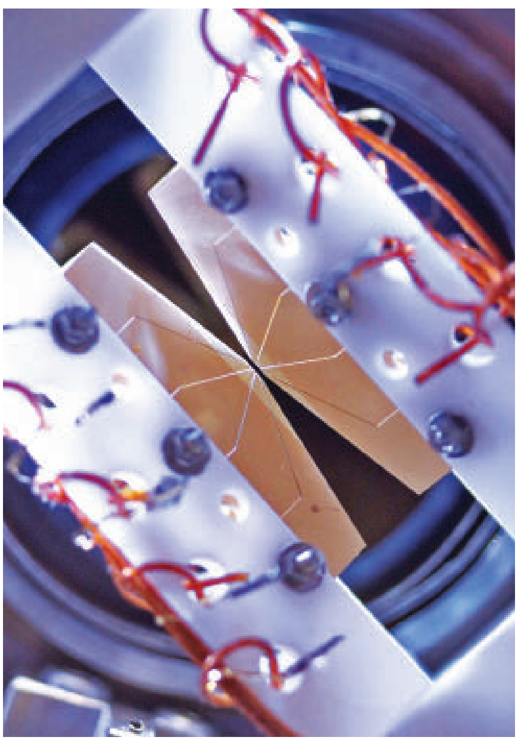
SOURCE: IBM RESEARCH

T. TIBBITTS

qubits, scientists form circuits in which current flows inside a loop of wire made of aluminum or another superconducting material.

Several teams of academic researchers create qubits from single ions, trapped in place and probed with lasers. Intel and others are working with qubits fabricated from tiny bits of silicon known as quantum dots (*SN: 7/11/15, p. 22*). Microsoft is studying what are known as topological qubits, which would be extra-resistant to errors creeping into calculations. Qubits can even be forged from diamond, using defects in the crystal that isolate a single electron. Photonic quantum computers, meanwhile, make calculations using particles of light. A Chinese-led team demonstrated in a paper published May 1 in *Nature Photonics* that a light-based quantum computer could outperform the earliest electronic computers on a particular problem.

One company, D-Wave, claims to have a quantum computer that can perform serious calculations, albeit using a more limited strategy than other quantum computers (*SN: 7/26/14, p. 6*). But many scientists are skeptical about the approach. "The general consensus at the moment is that something quantum is happening, but it's still very unclear what it is," says Devitt.



Some quantum computers use ions as their qubits, trapping them in a device like this one at the University of Maryland. Five ions sit in the gap at the center of the gold-colored blades, each about 2 centimeters long.

EMILY EDWARDS/JOINT QUANTUM INSTITUTE/UNIV. OF MARYLAND

Identical ions

While superconducting qubits have received the most attention from giants like IBM and Google, underdogs taking different approaches could eventually pass these companies by. One potential upstart is Chris Monroe, who crafts ion-based quantum computers.

On a walkway near his office on the University of Maryland campus in College Park, a banner featuring a larger-than-life portrait of Monroe adorns a fence. The message: Monroe's quantum computers are a "fearless idea." The banner is part of an advertising campaign featuring several of the university's researchers, but Monroe seems an apt choice, because his research bucks the trend of working with superconducting qubits.

Monroe and his small army of researchers arrange ions in neat lines, manipulating them with lasers. In a paper published in *Nature* in 2016, Monroe and colleagues debuted a five-qubit quantum computer, made of ytterbium ions, allowing scientists to carry out various quantum computations. A 32-ion computer is in the works, he says.

Monroe's labs — he has half a dozen of them on campus — don't resemble anything normally associated with computers. Tables hold an indecipherable mess of lenses and mirrors, surrounding a vacuum chamber that houses the ions. As with IBM's computer, although the full package is bulky, the quantum part is minuscule: The chain of ions spans just hundredths of a millimeter.

Scientists in laser goggles tend to the whole setup. The foreign nature of the equipment explains why ion technology for quantum computing hasn't taken off yet, Monroe says. So he and colleagues took matters into their own hands, creating a start-up called IonQ, which plans to refine ion computers to make them easier to work with.

Monroe points out a few advantages of his technology. In particular, ions of the same type are identical. In other systems, tiny differences between qubits can muck up a quantum computer's operations. As quantum computers scale up, Monroe says, there will be a big price to pay for those small differences. "Having qubits that are identical, over millions of them, is going to be really important."

In a paper published in March in *Proceedings of the National Academy of Sciences*, Monroe and colleagues compared their quantum computer with IBM's Quantum Experience. The ion computer performed operations more slowly than IBM's superconducting one, but it benefited from being more interconnected — each ion can be entangled with any other ion, whereas IBM's qubits can be entangled only with adjacent qubits. That interconnectedness means that calculations can be performed in fewer steps, helping to make up for the slower operation speed, and minimizing the opportunity for errors.

Early applications

Computers like Monroe's are still far from unlocking the full power of quantum computing. To perform increasingly complex tasks, scientists will have to correct the errors that slip into calculations, fixing problems on the fly by spreading information out among many qubits. Unfortunately, such error correction multiplies the number of qubits required by a factor of 10, 100 or even thousands, depending on the quality of the qubits. Fully error-corrected quantum computers will require millions of qubits. That's still a long way off.

So scientists are sketching out some simple problems that quantum computers could dig into without error correction. One of the most important early applications will be to study the chemistry of small molecules or simple reactions, by using quantum computers to simulate the quantum mechanics of chemical systems. In 2016, scientists from Google, Harvard University and other institutions performed such a quantum simulation of a hydrogen molecule. Hydrogen has already been simulated with classical computers with similar results, but more complex molecules could follow as quantum computers scale up.

Once error-corrected quantum computers appear, many quantum physicists have their eye on one chemistry problem in particular: making fertilizer. Though it seems an unlikely mission for quantum physicists, the task illustrates the game-changing potential of quantum computers.

The Haber-Bosch process, which is used to create nitrogen-rich fertilizers, is hugely energy intensive, demanding high temperatures and pressures. The process, essential for modern farming, consumes around 1 percent of the world's energy supply. There may be a better way. Nitrogen-fixing bacteria easily extract nitrogen from the air, thanks to the enzyme nitrogenase. Quantum computers could help simulate this enzyme and reveal its properties, perhaps allowing scientists "to design a catalyst to improve the nitrogen fixation reaction, make it more efficient, and save on the world's energy," says Microsoft's Svore. "That's the kind of thing we want to do on a quantum computer. And for that problem it looks like we'll need error correction."

Quantum vs. quantum Two different quantum computers — one using ion qubits, the other superconducting qubits — went head-to-head in a recent comparison. Both five-qubit computers performed similarly, but each had its own advantages: The superconducting computer was faster; the ion computer was more interconnected, needing fewer steps to perform calculations. SOURCE: N.M. LINKE *ET AL/PNAS* 2017

Goal	Ions	Superconductors
Error rate: Minimize calculation errors	A few errors per 100 operations	A few errors per 100 operations
Qubit lifetime: Retain quantum properties over long periods	About 0.5 seconds	About 0.00005 seconds
Speed: Operations should be quick	About 0.3 milliseconds	About 0.0003 milliseconds
Interconnectivity: Each qubit can "talk" to all other qubits	Full connectivity	Qubits can talk only to their neighbors

Pinpointing applications that don't require error correction is difficult, and the possibilities are not fully mapped out. "It's not because they don't exist; I think it's because physicists are not the right people to be finding them," says Devitt, of Macquarie. Once the hardware is available, the thinking goes, computer scientists will come up with new ideas.

That's why companies like IBM are pushing their quantum computers to users via the Web. "A lot of these companies are realizing that they need people to start playing around with these things," Devitt says.

Quantum scientists are trekking into a new, uncharted realm of computation, bringing computer programmers along for the ride. The capabilities of these fledgling systems could reshape the way society uses computers.

Eventually, quantum computers may become part of the fabric of our technological society. Quantum computers could become integrated into a quantum internet, for example, which would be more secure than what exists today (*SN: 10/15/16, p. 13*).

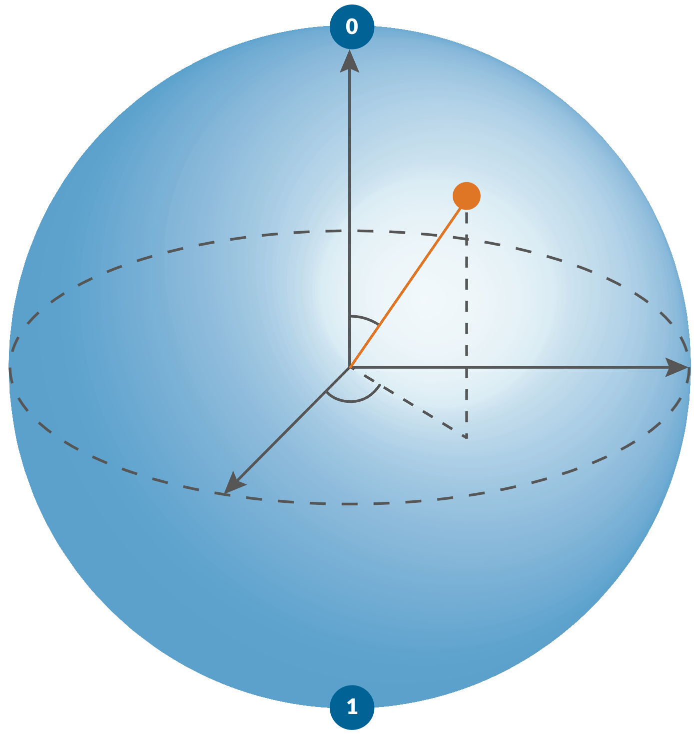
"Quantum computers and quantum communication effectively allow you to do things in a much more private way," says physicist Seth Lloyd of MIT, who envisions Web searches that not even the search engine can spy on.

There are probably plenty more uses for quantum computers that nobody has thought up yet.

"We're not sure exactly what these are going to be used for. That makes it a little weird," Monroe says. But, he maintains, the computers will find their niches. "Build it and they will come." ■

Explore more

- IBM's quantum computing website: "Meet IBM Q." http://research.ibm.com/ibm-q/



Birth of the QUBIT

A quarter century ago, a physicist invented a concept that would drive a new type of computing

By Tom Siegfried

Indecisive info
A qubit can exist as both a 0 and 1. When the qubit is represented on a sphere, the angles formed by the radius determine the odds of measuring a 0 or 1.

L. LO

John Archibald Wheeler was fond of clever phrases.

He made the term "black hole" famous in the 1960s. He also coined the now-familiar "wormhole" and "quantum foam." While further pondering the mystery of quantum physics at the University of Texas at Austin during the 1980s, Wheeler repeatedly uttered his favorite interrogative slogan: "How come the quantum?" And from those ponderings emerged yet another memorable phrase: "It from Bit." That became a meme that inspired a surprising new field of physics — quantum information theory.

That theory's basic unit, the qubit, made its scientific debut at a conference in Dallas 25 years ago. Wheeler didn't invent the term *qubit*. One of his former students, Benjamin Schumacher, coined it to refer to a bit of quantum information. At the time, few people appreciated the importance of information in quantum physics. And hardly anyone realized how dramatically the qubit would drive the development of a whole new field of science and associated technology — just now on the verge of producing powerful quantum computers (see Page 28).

Some physicists had discussed the idea of exploiting quantum weirdness for computing much earlier. Paul Benioff of Argonne National Laboratory in Illinois showed the possibility of using quantum processes to compute by 1980. Shortly thereafter Richard Feynman suggested that quantum computers, in principle, could do things that traditional computers couldn't. But while physicists dreamed of building a quantum computer, that quest remained purposeless until 1994, when mathematician Peter Shor of Bell Labs showed that a quantum computer could be useful for something important — namely, cracking secret codes. Shor's algorithm provided the motivation for the research frenzy now paying off in real quantum computing devices. But it was the qubit, invented two years before Shor's work, that provided the conceptual tool needed to make progress in such research possible.

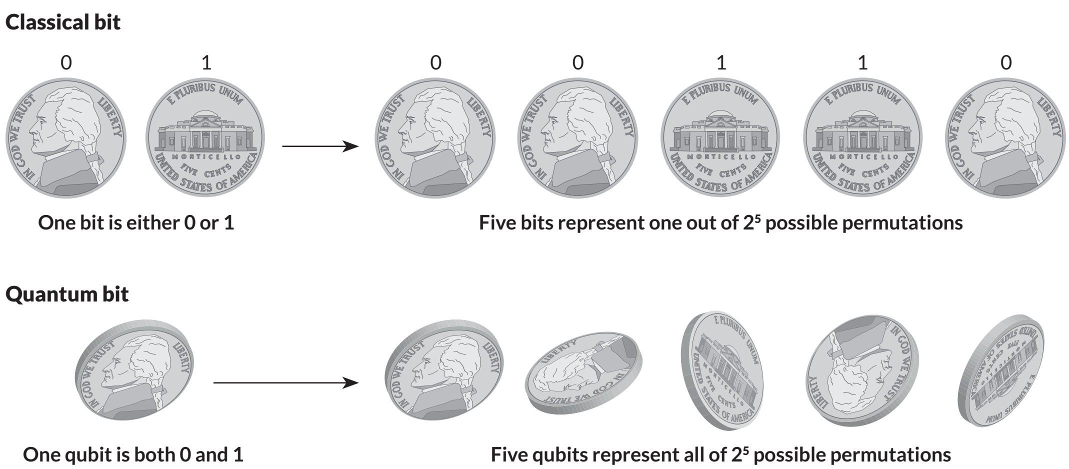
A search for quantum meaning

When he coined the phrase It from Bit, Wheeler was concerned more with fundamental questions about physics and existence than with quantum computing. He wanted to know why quantum physics ruled the universe, why the mysterious fuzziness of nature at its most basic gave rise to the rock-solid reality presented to human senses. He couldn't accept that the quantum math was all there was to it. He did not subscribe to the standard physicists' dogma — shut up and calculate — uttered in response to people who raised philosophical quantum questions.

Wheeler sought the secret to quantum theory's mysterious power by investigating the role of the observer. Quantum math offers multiple outcomes of a measurement; one or another specific result materializes only upon an act of observation. Wheeler wanted to know how what he called "meaning" arose from the elementary observations that turned quantum possibilities into realities. And so for a long time he sought a way to quantify "meaning." During an interview in 1987, I asked him what he meant by that — in particular, I wondered if what he had in mind was some sort of numerical measure of meaning, similar to the math of information theory (which quantifies information in bits, typically represented by 0 and 1). He said yes, but he was not happy then about information processing as a fundamental feature of nature. That notion had been discussed in a popular book of the time: *The Anthropic Cosmological Principle* by John Barrow and Frank Tipler. Their view of information processing in the cosmos, for Wheeler, evoked an image of a bunch of people punching numbers into adding machines. "I'd be much happier if they talked about making observations," Wheeler told me.

But not long afterward, work by one of his students, Wojciech Zurek, inspired Wheeler to begin talking about observations in terms of information. An observation provided a yes-or-no answer to a question, Wheeler mused. Is the particle here (yes) or not (no)? Is a particle spinning clockwise? Or the contrary? Is the particle even a particle? Or is it actually a wave? These yes-or-no answers, Wheeler saw, corresponded to the 1s and 0s, the bits, of information theory. And so by 1989, he began conceiving his favorite question — How come the quantum? — as how to explain the emergence of existence from such yes-or-no observations: It from Bit.

Wheeler wasn't the first to mix information with quantum physics. Others had dabbled with quantum information processes earlier — most notably, by using quantum information to send uncrackable secret codes. "Quantum cryptography" had been proposed by Charles Bennett of IBM and Gilles Brassard of the University of Montreal in the early 1980s. By 1990, when I visited Bennett at IBM, he had built a working model of a quantum cryptographic signaling system, capable of sending photons about a



JAKEOLIMB/ISTOCKPHOTO, ADAPTED BY L. LO

Permutation power Classical bits exist as either 0 or 1, like heads or tails on a coin. So a five-bit computer can record one of 32 combinations of 0s and 1s. But a quantum computer with five qubits can work with all 32 permutations at once.

meter or so from one side of a table in his office to the other. Nowadays, systems built on similar principles send signals hundreds of kilometers through optical fiber; some systems can send quantum signals through the air and even space. Back then, though, Bennett's device was merely a demonstration of how the weirdness of quantum physics might have a practical application. Bennett even thought it might be the only thing quantum weirdness would ever be good for.

But a few physicists suspected otherwise. They thought quantum physics might someday actually enable a new, more powerful kind of computing. Quantum math's multiple possible outcomes of measurements offered a computing opportunity: Instead of computing with one number at a time, quantum physics seemed to allow many parallel computations at once.

Feynman explored the idea of quantum computing to simulate natural physical processes. He pointed out that nature, being quantum mechanical, must perform feats of physical legerdemain that could not be described by an ordinary computer, limited to 1s and 0s manipulated in a deterministic, cause-and-effect way. Nature incorporated quantum probabilities into things like chemical reactions. Simulating them in detail with deterministic digital machinery didn't seem possible. But if a computer could be designed to take advantage of quantum weirdness, Feynman supposed, emulating nature in all its quantum wonder might be feasible. "If you want to make a simulation of nature, you'd better make it quantum mechanical," Feynman said in 1981 at a conference on the physics of computing. He mentioned that doing that didn't "look so easy." But he could see no reason why it wouldn't be possible.

A few years later, quantum computers gained further notoriety from work by the imaginative British physicist David Deutsch. He adopted the prospect of their existence to illustrate a view of quantum physics devised in the 1950s by Hugh Everett III (another student of Wheeler's), known as the Many Worlds Interpretation. In Everett's view, each possibility in the quantum math described a physically real result of a measurement. In the universe you occupy, you see only one of the possible results; the others occur in parallel universes. (Everett's account suggested that observers split into copies of themselves to continue existing in their newly created universe homes.)

Deutsch realized that the Everett view, if correct, opened up a new computing frontier. Just build a computer that could keep track of all the parallel universes created when bits were measured. You could then compute in countless universes all at the same time, dramatically shortening the time it would take to solve a complex problem.

But there weren't any meaningful problems that could be solved in that way. That was the situation in 1992, when a conference on the physics of computation was convened in Dallas. Participants there discussed the central problem of quantum computers — they might compute faster than an ordinary computer, but they wouldn't always give you the answer you wanted. If a quantum computer could compute 100 times faster than an ordinary computer, it would provide the correct answer only once in every 100 tries.

A very good idea

While much of the attention at the Dallas meeting focused on finding ways to use quantum computers, Schumacher's presentation looked at a more fundamental issue: how computers coded information. As was well known, ordinary computers stored and processed information in the form of bits, short for binary digits, the 1s and 0s of binary arithmetic. But if you're going to talk about quantum computing, bits wouldn't be the right way to go about it, Schumacher contended. You needed quantum bits of information: qubits. His talk at the Dallas conference was the first scientific presentation to use and define the term.

Schumacher, then and now at Kenyon College in Gambier, Ohio, had discussed such issues a few months earlier with William Wootters, another Wheeler protégé. "We joked that maybe what was needed was a quantum measure of

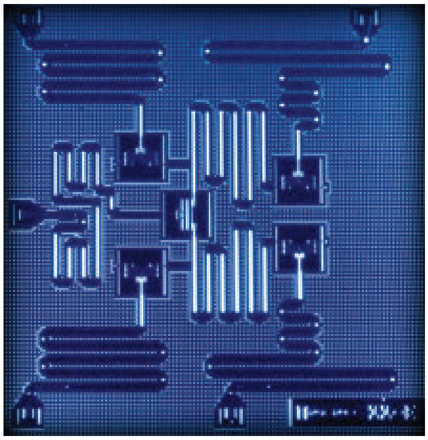
Ben Schumacher introduced the idea of a bit of quantum information in a paper presented in 1992 (excerpt below).

KENYON COLLEGE

In my paper I present a "quantum coding theorem" that is analogous to the noiseless coding theorem of Shannon. The theorem and its proof have some novel features:

1. The classical binary digit is replaced with a quantum two-state system, such as the spin of the atom. These "qubits" are the fundamental unit of quantum information.

2. A measure of the fidelity of a quantum coding scheme is introduced. A code has high fidelity if it preserves the Hilbert space relations between signal states.



The five qubits (dark squares in center) in this quantum computer from IBM exist as 0s and 1s simultaneously.

information, and we would measure things in qubits," Schumacher told me. They thought it was a good joke and laughed about it. "But the more I thought about it, the more I thought it was a good idea," he said. "It turned out to be a very good idea."

Over the summer of 1992, Schumacher worked out more than just a clever name; he proved a theorem about how qubits could be used to quantify the quantum information sent through a communication channel. In essence, a quantum bit represents the information contained in the spin of a quantum particle; it could be 0 or 1 (if the state of the particle's spin is already known) or a mix of 0 and 1 (if the particle's spin has not yet been measured). If traditional bits of 0 or 1 can be represented by a coin that lands either heads or tails, a qubit would be a spinning coin with definite probabilities for landing either heads or tails.

Traditional "classical" bits measure the amount of physical resources you need to encode a message. In an analogous way, Schumacher showed how qubits did the same thing for quantum information. "In quantum mechanics, the essential unit of information is the qubit, the amount of information you can store in a spin," he said at the Dallas meeting. "This is sort of a different way of thinking about the relation of information and quantum mechanics."

Other physicists did not immediately jump on the qubit bandwagon. It was three years before Schumacher's paper was even published. By then, Shor had shown how a quantum algorithm could factor large numbers quickly, putting a widely used encryption system for all sorts of secret information at risk — if anyone knew how to build a quantum computer. But that was just the problem. At the Dallas meeting, IBM physicist Rolf Landauer argued strongly that quantum computing would not be technologically feasible. All the discussion of quantum computing occurred in the realm of equations, he pointed out. Nobody had the slightest idea of how to prepare a patent proposal. In real physical systems, the fragility of quantum information — the slightest disturbance would destroy it — made the accumulation of errors in the computations inevitable.

Landauer repeated his objections in 1994 at a workshop in Santa Fe, N.M., where quantum computing, qubits and Shor's algorithm dominated the discussions. But a year or so later, Shor himself showed how adding extra qubits to a system would offer a way to catch and correct errors in a quantum computing process. Those extra qubits would be linked to, or entangled with, the qubits performing a computation without actually being involved in the computation itself. If an error occurred, the redundant qubits could be called on to restore the original calculation.

Shor's "quantum error correction" methods boosted confidence that quantum computing technology would in fact someday be possible — confidence that was warranted in light of the progress in the two decades since then. Much more recently, the math describing quantum error correction has turned up in a completely unexpected context — efforts to understand the nature of spacetime by uniting gravity with quantum mechanics. Caltech physicist John Preskill and his collaborators have recently emphasized "a remarkable convergence of quantum information science and quantum gravity"; they suggest that the same quantum error correction codes that describe the entanglement of qubits to hold a quantum computation together also describe the way that quantum connections generate the geometry of spacetime itself.

The math describing quantum error correction has turned up in a completely unexpected context.

So it seems likely that the meaning and power of quantum information, represented by the qubit, has yet to be fully understood and realized. It may be that Schumacher's qubit is not merely a new way of looking at the relation of quantum mechanics to information, but is also the key to a fundamentally new way of conceiving the foundations of reality and existence — much as Wheeler imagined when he coined It from Bit. ■

As science editor of the Dallas Morning News*, Tom Siegfried covered the 1992 physics meeting where the term* qubit *was introduced.*

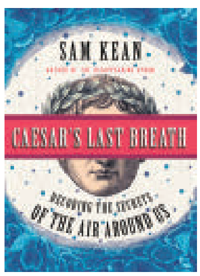
Caesar's last moments have inspired much scientific thinking, as well as a new book.

BOOKSHELF

Every breath contains a molecule of history

Julius Caesar could have stayed home on March 15, 44 B.C. But mocking the soothsayer who had predicted his death, the emperor rode in his litter to Rome's Forum. There he met the iron daggers of 60 senators.

As he lay in a pool of blood, he may have gasped a final incrimination to his protégé Brutus: You too, my son? Or maybe not. But he certainly would have breathed a dying breath, a final exhalation of some 25 sextillion gas molecules. And it's entirely possible that you just breathed in one of them.



Caesar's Last Breath
Sam Kean
LITTLE, BROWN AND CO., $28

In fact, calculating the probability of a particle of Caesar's dying breath appearing in any given liter of air (the volume of a deep breath) has become a classic exercise for chemistry and physics students. If you make a few assumptions about the mixing of gases and the lifetimes of molecules in the atmosphere, it turns out that, on average, one molecule of "Caesar air" — or any other historic liter of air, for that matter — appears in each breath you take.

Author Sam Kean begins his book *Caesar's Last Breath* with this exercise, noting that "we can't escape the air of those around us." It's all recycled, and every day we breathe in a bit of our, and Earth's, history. "The story of Earth," he writes, "*is* the story of its gases."

Kean, author of a best seller about the periodic table, *The Disappearing Spoon*, then tells that story. As he did in his fascinating portraits of the elements, Kean profiles individual gases such as nitrogen and oxygen primarily through the scientists and entrepreneurs who discovered or sought to harness them. These are quirky men (and they are mostly men) — every bit as obsessed, greedy and brilliant as one could hope for in a page-turner.

Along with lesser-known backstories of textbook heroes such as James Watt, Antoine-Laurent Lavoisier and Albert Einstein (who was surprisingly obsessed with building a better refrigerator), Kean clearly delights in weaving in the unexpected. In the discussion of helium, we learn about Joseph-Michel Montgolfier, the papermaker who was inspired to build the first hot-air balloon as he watched his wife's pantaloons billowing suggestively above a fire. And in a chapter on the radioactive elements carried in nuclear fallout, there's Pig 311, a sow that survived a nuclear test blast only to be used as propaganda for the weapons' supposed safety.

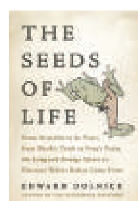
Along the way, Kean threads in the history of Earth's atmosphere in a surprisingly compelling narrative of geologic history. He steps aside from Lavoisier's work on life-giving oxygen, for example, to describe the Great Oxygenation Event, which infused the atmosphere a couple billion years ago with a gas that, at the time, was toxic to most living things. The explanations of science here and throughout the book are written clearly and at a level that should be understandable with a high school education. And while they're straightforward, the explanations have enough depth to be satisfying; by the end of the book, you realize you've learned quite a bit.

Even those who rarely read science will enjoy the drama — death, for instance, plays a big role in these stories. Over and over, we learn, men have taken gases' powers too lightly, or wielded their own power too cruelly, and paid the price. Fritz Haber, for instance, could have died a hero for finding a way to make fertilizer from the nitrogen in air. Instead, he died broke and loathed for his World War I work on gas warfare.

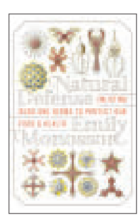
Then there was Harry Truman — not *that* Truman, but the one who refused to leave his home when scientists warned of an impending volcanic eruption. Truman contended that officials were "lying like horses trot" right up until Mount St. Helens blew searing gases that erased him from the mountainside.

The links between these stories can seem at first as ephemeral as the gases, but together they tell the story of the birth of the atmosphere and humans' history in it. In the end, like Caesar's breath, it all comes full circle.
— *Erika Engelhaupt*

BOOKSHELF



The Seeds of Life
Edward Dolnick
"Where do babies come from?" is the central question in this historical look at how scientists unraveled the mysteries of reproduction. *Basic Books, $28*



Natural Defense
Emily Monosson
An environmental toxicologist explores a host of promising chemical-free alternatives to combat germs and pests. *Island Press, $30*

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

VINCENZO CAMUCCINI/WIKIMEDIA COMMONS

2017

Students seek scientific solutions at **Broadcom MASTERS International**

Last month, 26 students from 19 countries met in Los Angeles for the 2017 Broadcom MASTERS International, a program that brings together the world's brightest middle school STEM students. Broadcom MASTERS International is a companion program of the domestic Broadcom MASTERS competition and provides a unique opportunity for select middle school STEM students from around the world to observe the Intel International Science and Engineering Fair (ISEF).

These students, called delegates, are chosen for their excellence in science, engineering and leadership. They are rising stars who come together to represent their nations during an international exchange of science, technology, engineering and mathematics knowledge. In addition to attending the Intel ISEF, delegates participate in specialized programming, including engaging in hands-on science and engineering activities.

Read more about the delegates and their week at Broadcom MASTERS International at: **www.societyforscience.org/BCMI-2017**





Clockwise from top left: Maliya Finda Dwiputri (Indonesia) conducts a scientific experiment on ocean acidification during a boat expedition off the coast of Newport Beach, Calif.; Lehloogonolo Victoria Msuma (South Africa) shows off some program gear; Razi Azulai (Israel) learns about the local ecosystem in Newport Beach; Anjolaoluwa Awe (United Kingdom) shows her fellow finalists what country her parents are from during orientation; after a long day, Ujwal G. Aradhya (India) and James Fagan (United States) recap what they have learned.

MAY 27, 2017

Online favorites

Mars' birth, piecing together an ancient American civilization and putting one of Einstein's key principles to the quantum test were among the stories in the May 27 issue that resonated most with readers online. The issue's Top 5 stories were:

1. "New proposal reimagines Mars' origin," by Thomas Sumner
2. "Seeing Chaco in a new light," by Bruce Bower
3. "The difference makers," by Tina Hesman Saey
4. "Einstein principle passes quantum test," by Emily Conover
5. "Stone age injuries lack modern analog," by Bruce Bower

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Martian mysteries

Mars may have formed out where the asteroid belt is now, far from its planetary neighbors, ***Thomas Sumner*** *reported in "New proposal reimagines Mars' origin"* (SN: 5/27/17, p. 14).

Readers online were fascinated by Mars' origin story. "There seemed to be evidence of actual seas on early Mars," **stargene** wrote. "How can this be finessed into the idea of Mars living out in the freezing asteroid belt?"

"The evidence for early oceans on Mars is controversial, and this question hits on a pretty fundamental issue," says *Science News* astronomy writer **Lisa Grossman**. If Mars formed in the asteroid belt, it could have moved inward fairly quickly, by 4 billion years ago or so — before water became a significant landscape-shaping force. When exactly water arrived on the Red Planet remains a mystery, but we know it was there at some point, she says.

There's a lot of debate over how the planet, even in its present position, could have had a thick enough atmosphere to keep water in liquid form on the surface. "Salty water could have done the trick, keeping the freezing point low. But there's better evidence for smaller-scale water features on Mars, like rivers and lakes," **Grossman** says. "Even then, researchers don't know how long these features were stable."

Jumping interruptions

Fragments of genetic material called transposons, or "jumping genes," inserted themselves long ago in the human genome and have been a powerful force in our evolution, ***Tina Hesman Saey*** *reported in "The difference makers"* (SN: 5/27/17, p. 22).

Bob Bloomer asked how organisms' molecular machinery can run smoothly when there are so many "jumping genes" around. "There must be some overriding master control nixing total destructive insertions," he wrote.

"Molecular defenses spearheaded by small RNAs called piRNAs (my favorite noncoding RNAs) can keep transposons from jumping," **Saey** says. These piRNAs interact with proteins to keep transposons from making RNA copies of themselves. Researchers call that process "silencing," and it involves DNA methylation — adding chemical groups called methyl groups to DNA. "Other proteins and small RNAs may also be involved in keeping transposons from moving around," **Saey** says.

Solar system tales

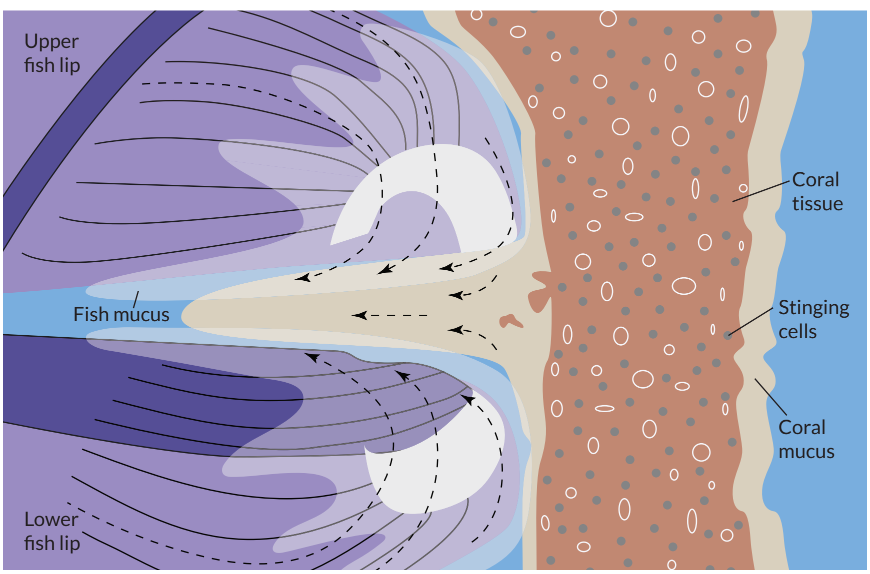
Data from the Voyager and Cassini spacecraft suggest that the heliosphere, the bubble of particles surrounding the solar system, is spherical, not comet-shaped, ***Ashley Yeager*** *reported in "Solar system bubble has no tail"* (SN: 5/27/17, p. 15).

Online reader **MAdScientist72** wondered how researchers know the solar system has no tail if the probes remained at the front of the heliosphere instead of traveling to the back where the tail would be. "And just what do they mean by 'front' anyways?" **MAdScientist72** asked.

The "front" of the heliosphere refers to the direction toward which the solar system is moving around the galaxy. The "tail" or "anti-nose" (since the data suggest there is no tail) is in the opposite direction, **Yeager** says. The Voyager probes, stationed at the heliosphere's front, measured atoms there, and Cassini, which orbits Saturn, detected atoms toward the back. "Researchers determined how quickly the abundance of these atoms fluctuated relative to the intensity of the solar wind," **Yeager** says. If the solar system had a tail, the atoms should have taken some 20 years to bounce back after being bombarded by intense solar wind. Combined data from the spacecraft revealed those atoms rebounded after only 2.5 years, indicating a tailless system.

Correction

In the feature "In hot water" (*SN: 5/13/17, p. 18*), *Science News* reported that bacteria at the bottoms of lakes release methane, which bubbles up to the surface and adds to the atmosphere's greenhouse gas load. Methane is produced by different microbes called archaea.



The better to eat you with, my dear

Tubelip wrasses eat dangerously, daring to dine on sharp corals lined with mucus and stinging cells. New research reveals the fish's secret to safe snacking: lubing up and planting a big one on their dinner.

The lips of the wrasse *Labropsis australis* look smooth to the naked eye, but convoluted grooves appear under a scanning electron microscope (left). Mucus-producing cells line each groove. In contrast, the lips of a wrasse species that doesn't eat corals are sleek and sport fewer slime-secreting cells, researchers report June 5 in *Current Biology*.

Roughly 6,000 fish species roam reefs around the world, but just 128 are known to consume corals. *L. australis* of the South Pacific (one shown below) is known for nibbling coral, but until now, it was unclear what part of the coral the fish was eating or how.

Video footage shows that the fish feeds by latching onto coral with its lubricated lips and sucking. The fish's slime probably protects its lips from the stinging cells. And its goo serves as a sealant, allowing the wrasse to get suction against the coral's razorlike ridges, say marine biologists David Bellwood and Victor Huertas of James Cook University in Townsville, Australia.

The scientists suspect that the fish feed mainly on the coral's mucus layer and sometimes tissue, both of which line the sharp coral skeleton. So, essentially, the fish use their lip mucus to better harvest the coral's mucus. In the diagram (bottom left), arrows indicate the flow of mucus and suction.

"Their kiss is so hard it tears the coral's flesh off its skeleton," Bellwood says. — *Helen Thompson*

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Watch a video of a tubelip wrasse feeding on coral at **bit.ly/SN_FishLips**