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COVER Of all the DNA in the human genome, nearly half is transposons, or "jumping genes," most of which hopped into various spots long ago. *Chris Thornley*

Jumping genes are part of all that makes us human

Ask 10 people what makes humans human and you'll probably get 10 different answers — and then some. From our biased perspective, it's seemingly simple to come up with many qualities that define the human experience. We love, we laugh. We form deep personal bonds and complex societies. We use language to communicate, art to express ourselves and technology to accomplish complex tasks. As Aristotle pointed out, although we can often be irrational, we have the ability to reason. We formulate ideas, contemplate and test them, and draw conclusions about our world. We can reflect on our own lives and begin to imagine death.

But if we really want to be scrupulous (and we do at *Science News*), we would have to admit that very few of these qualities are sufficient to set us apart from all other organisms. There are plenty of tool-users and innovators in the animal kingdom. Neither laughing nor loving are limited even to the primate branch of the evolutionary tree. When it comes to mating especially, many creatures appear to have an appreciation for the visual arts. And elephants, some scientists have claimed, have been observed trying to cope with death.

So to define ourselves, we have to get more specific. Linguists study the details of how we structure our sentences and communicate our ideas. Neuroscientists investigate connections between brain cells. Geneticists have perhaps the most promising approach: Though it's messy to untangle, a lot of what makes us human definitely resides in our DNA. But looking at genes alone is not enough, as molecular biology writer Tina Hesman Saey has long reported. Chemical modifications of DNA play a big role in how genes turn on and off in the human body (*SN: 2/14/09, p. 5*). Other molecular players, lincRNAs for example, orchestrate many of the processes of life (*SN: 12/17/11, p. 22*).

On Page 22 of this issue, Saey explores yet another underappreciated shaper of humanness: transposons, or "jumping genes." Much of what sets us apart from our chimpanzee relatives comes from bits of DNA that hop (or have hopped) around our genomes. In fact, nearly 50 percent of our genome is made up of transposons. Depending on where they land, they can cause trouble or, in lucky cases, add some genetic machinery that evolution can work with. Transposons have been shown to play a role in directing embryo development, in fighting immune invaders and perhaps in how we think. "Transposable elements have been with us since the beginning of evolution," as evolutionary biologist Josefa González says.

It wouldn't be scrupulous, at least not now, to conclude that transposons should get the credit for making us who we are. But could they have had a contributing part in driving humans to build great houses like those at Chaco Canyon (Page 18) or to domesticate horses (Page 11)? Might transposons have some role in the creativity required to invent an artificial womb (Page 6)? Maybe so. It's most certainly true that they are yet another valuable route for scientists to explore. And it's that exploration that gets us beyond simple answers to a fuller understanding of our world and ourselves.

— Elizabeth Quill, Acting Editor in Chief

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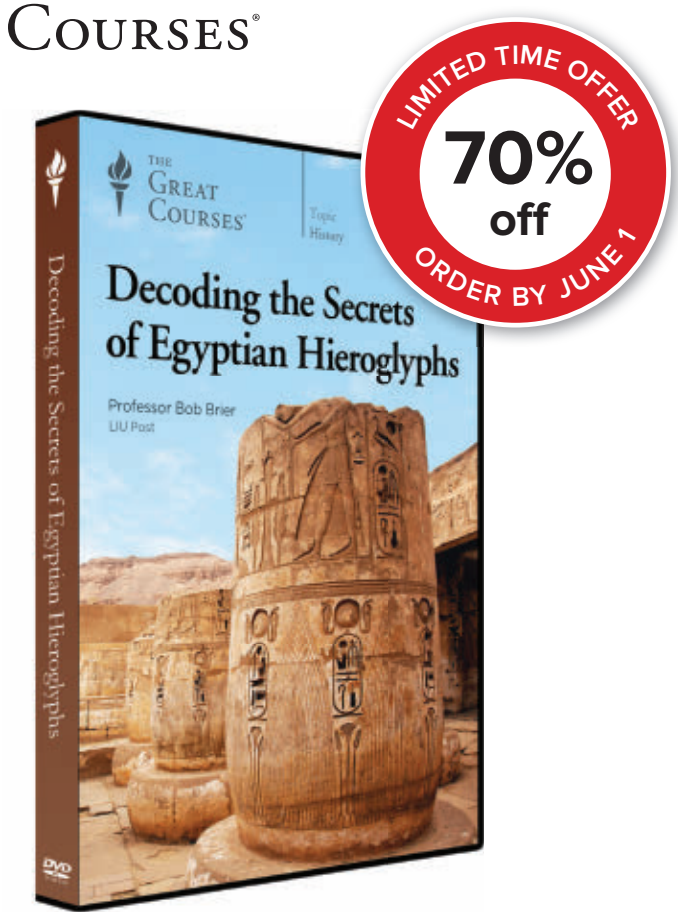

Decipher the Language of Ancient Egypt

To the novice, hieroglyphs look like a random scattering of stylized symbols. But to Egyptologists like Professor Bob Brier—a noted public educator known as "Mr. Mummy"—hieroglyphs are the closest we can get to truly resurrecting the lives of ancient Egyptians.

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Excerpt from the June 3, 1967 issue of *Science News*

50 YEARS AGO

Saturn: Four Rings

Walter A. Feibelman of the University of Pittsburgh ... has found evidence indicating a fourth ring [of Saturn].... Every 14.78 years, the rings of Saturn can be seen edge-on from Earth, and the past winter marked one of these opportunities.... The thin ring "extends to more than twice the known ring diameter" (or a total of 340,000 miles), and is so faint it cannot be photographed except with a large telescope.

UPDATE: Scientists no longer observe Saturn's rings only from Earth. Four spacecraft have visited the planet and revealed a complex ring system, with the four previously known rings accompanied by multiple fainter ones. NASA's Cassini spacecraft, which arrived at the planet in 2004, is now swooping between Saturn and its rings to get the closest views yet (*SN Online: 4/27/17*). Rings have also been spied around Jupiter, Uranus and Neptune, and in 2012, scientists spotted an exoplanet with giant rings (*SN: 3/7/15, p. 5*).

IT'S ALIVE

What big fangs you have, little blenny

The two big teeth in the lower jaw of this fang blenny (*Meiacanthus grammistes*) have a groove for venom delivery.

After a recent flurry of news that fang blennies mix an opioid in their venom, a question lingers: What do they need with fangs anyway? Most eat wimpy stuff that hardly justifies whopper canines.

Not that fang blennies are meek fishes. "When they bite, they bite savagely," says Bryan Fry of the University of Queensland in Brisbane, Australia. "If these little jobbies were 3 meters long, we'd be having to cage dive with them." Real-world blennies, however, grow to only about the size of a cocktail sausage.

These little beasts probably got their big teeth before evolving venom, says Nicholas Casewell of the Liverpool School of Tropical Medicine in England. That's jusssst backward, snakes might say, as they evolved their venom first. Yet when Casewell, Fry and colleagues put together an evolutionary family tree for the blennies, the one genus with both fangs and venom branched off amid four genera that are all fang and no toxins, Casewell, Fry and colleagues report in the April 24 *Current Biology*.

Those with venom aren't that scary to humans. Fish venoms tend to cause excruciating pain, says Fry, who adds from personal experience that "sting" sounds deceptively benign for what a stingray delivers (*SN: 4/29/17, p. 28*). A venomous fang blenny has yet to nail

THE -EST

China tomb held ancient looms

An ancient tomb in southern China has provided the oldest known examples, in scaled-down form, of weaving machines called pattern looms. Four nonworking models of pattern looms illuminate how weavers first produced silk textiles with repeating patterns. The cloths were traded across Eurasia via the Silk Road, Chinese archaeologists report in the April *Antiquity*. The models, created between 2,200 and 2,100 years ago, predate other evidence of pattern looms by several hundred years.

Red and brown silk threads still clung to the model looms. The largest stood half a meter tall. A full-scale device with moving parts — with two foot pumps connected to beams, shafts and other parts — would have woven repeating geometric designs on clothing and other silk items. The technique transformed silk production.

Excavation of a roughly 2,100-year-old tomb in southern China uncovered four small-scale models of pattern looms, including these two found alongside several wooden figurines.

These 2013 discoveries, made of wood and bamboo, supply the first direct evidence that pattern looms were invented in ancient China. Such looms are mentioned in ancient Chinese texts, but actual examples were lacking. Pattern looms influenced the design of another type of weaving machine that appeared in China within the next few hundred years and then spread to Persia, India and Europe, the researchers suspect.

— Bruce Bower

FROM TOP: ANTHONY O'TOOLE; TAO XIE, F. ZHAO *ET AL/ANTIQUITY* 2017

him, but he hears that others have felt little more than a toothy nip.

"There's no real reason for most of these fish to have fangs to help them feed," Casewell says. Many prey on small invertebrates or even floating plankton, which is about as hard to subdue as chicken soup.

The fangs, however, are useful for fending off predators, Casewell suggests. Blennies have no spiky fins or spines, the more usual defensive weapons in fish. Male-versus-male competition may have been another force for fang evolution; males stab each other during breeding season.

When fangs evolved, whatever the reason, they became a useful conduit for venom, Casewell and Fry propose. Once some blennies evolved venom, "all these crazy selection pressures started coming in," Fry says. Forces of natural selection nudged nonvenomous fang blennies toward colors and stripes similar enough to those of their venomous cousins to discourage attacks from an educated predator.

The top fang blenny (*Meiacanthus grammistes*) can deliver a dose of dizzying venom. Other fish tend not to attack it or its harmless look-alike (*Cheilodipterus nigrotaeniatus*, bottom).

The mimics take advantage, often brazenly swimming up to bigger fish to bite off some scales and mucus for a snack. "These fish are little jerks," Fry says. "They should be called jerk blennies." — *Susan Milius*

SAY WHAT?

River piracy \RIV-er PAI-ruh-see\ n.

The diversion of headwaters from one stream into another

Ahoy! There be liquid booty on the move in the high mountains. Since May 2016, a channel carved through one of northwestern Canada's largest glaciers has allowed one river to pillage water from another, new observations reveal. This phenomenon, almost certainly the result of climate change, is the first modern record of river piracy caused by a melting glacier, researchers report April 17 in *Nature Geoscience*.

Such piracy was rampant as the colossal ice sheets of the Last Glacial Maximum began shrinking around 18,000 years ago. For hundreds of years, Canada's Kaskawulsh Glacier has formed a wall that segregates snow and ice meltwater into two streams: the Slims River, which joins with other streams and crosses Alaska before draining into the Bering Sea, and the Kaskawulsh River, which flows southward into the Pacific Ocean.

Last summer, geomorphologist Daniel Shugar of the University of Washington Tacoma and colleagues discovered that melting had carved a canyon across the toe of Kaskawulsh Glacier. This new channel diverts almost all meltwater to the Kaskawulsh River, robbing the now largely parched Slims River. The change could decrease fish populations and the availability of nutrients downstream, the researchers predict. — *Thomas Sumner*

Northwestern Canada's Kaskawulsh River in the Yukon Territory is running higher than normal since pirating water that used to flow to the Slims River. Climate change is probably to blame.

RETHINK

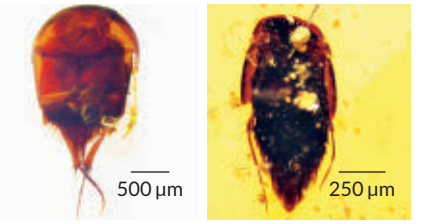
When beetles became freeloaders

Mooching roommates are an ancient problem. Certain species of beetles evolved to live with and leech off social insects such as ants and termites as long ago as the middle Cretaceous, two new beetle fossils suggest. The finds date the behavior, called social parasitism, to almost 50 million years earlier than previously thought.

Ants and termites are eusocial — they live in communal groups, sharing labor and collectively raising their young. The freeloading beetles turn that social nature to their advantage. They snack on their hosts' larvae and use their tunnels for protection, while giving nothing in return.

Previous fossils have suggested that this social parasitism has been going on for about 52 million years. But the new finds push that date way back. The specimens, preserved in 99-million-year-old Burmese amber, would have evolved relatively shortly after eusociality is thought to have popped up.

One beetle, *Mesosymbion compactus*, was reported in *Nature Communications* in December. A different group of researchers described the other, *Cretotrichopsenius burmiticus*, in the April 24 *Current Biology*. Both species have shielded heads and teardrop-shaped bodies, similar to modern termite-mound trespassers. The protected heads aren't just for looks. Like a roommate who's found his leftovers filched one too many times, termites frequently turn against their pilfering housemates. — *Laurel Hamers*



Two new beetle fossils (*Cretotrichopsenius burmiticus*, left, and *Mesosymbion compactus*, right) suggest that social parasitism has endured for about 100 million years.

CLOCKWISE FROM TOP: ARTHUR BOS (BOTH); C. CAI *ET AL*/*CURRENT BIOLOGY* 2017; S. YAMAMOTO *ET AL*/*NATURE COMMUNICATIONS* 2016; JIM BEST/UNIV. OF ILLINOIS

BODY & BRAIN

Faux womb keeps preemie lambs alive

Lungs and brain developed normally during four-week trial

BY TINA HESMAN SAEY

Premature babies may one day continue developing in an artificial womb, new work with sheep suggests.

A fluid-filled bag that mimics the womb kept premature lambs alive and developing normally for four weeks, researchers report April 25 in *Nature Communications*. Lambs at a gestational age equivalent to that of a 23- or 24-week-old human fetus had normal lung and brain development after a month in the artificial womb, the researchers discovered.

A similar device might be ready for use in premature human babies in three to five years if additional animal tests pan out, study coauthor Alan Flake estimates.

But this is not the science fiction scenario of *Brave New World*, in which humans were grown entirely in tanks, says Flake, a pediatric and fetal surgeon at the Children's Hospital of Philadelphia. "I don't view this as something that's going to replace mothers." Technical and biological hurdles would prevent doctors from using an artificial womb to rescue premature babies younger than about 23 weeks, he says.

Researchers have been trying for 60 years to make an artificial womb or artificial placenta, says pediatric and fetal surgeon George Mychaliska of the University of Michigan Medical School in Ann Arbor. His own group has been working for a decade on an artificial placenta, or what he calls an "extracorporeal life-support" system, for premature babies. "One month is very impressive, and the data behind that is strong," Mychaliska says, but adds that what works for lambs might not work as well for human babies.

In the United States, more than 25,000 babies each year are born extremely premature, before 28 weeks of pregnancy. Of those born at the edge of viability, at 23 weeks of gestation, up to about 70 percent die; many of the survivors have lung and other health problems partly caused by efforts to keep them alive. Putting premature babies on ventilators to get oxygen into their bodies has mixed results, says Mychaliska. "The same treatment that is potentially saving their lives is also damaging their lungs."

Technical and biological hurdles would prevent doctors from using an artificial womb to rescue premature babies younger than about 23 weeks.

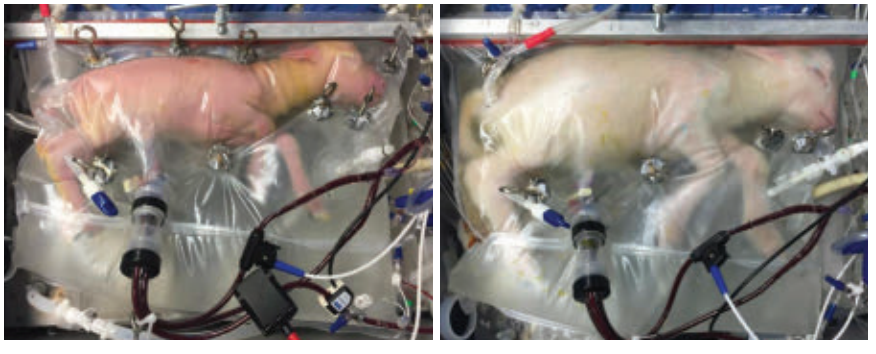
Flake and colleagues' initial efforts to make an artificial womb — including submerging lambs in fluid in a tank — failed. Infection soon set in, killing the animals. This time, the researchers tried to mimic more closely what happens during normal pregnancy. In the new system, a lamb is surgically delivered via cesarean section and placed in a sterile bag filled with an electrolyte fluid. Because the bag is closed, the risk of infection is reduced. Tubes recirculate oxygenated blood through the lamb's umbilical cord, and the beating of the fetus's heart pumps the blood at volumes and pressure comparable to what is normally delivered by the placenta. Other research groups have put tubes in the neck and used an external pump to circulate the blood, which may put too much pressure on fetal hearts, causing heart failure, Flake says.

Like a real womb, the artificial one also bathes lambs in the fluid needed for lung development. Flake's team prevents the lambs from breathing because even a little air might harm lung development.

Premature babies would have to be delivered surgically and placed immediately into the fluid incubator. That would rule out about 50 percent of extremely premature babies (those born before 28 weeks) because they are born vaginally, Flake says.

Flake's version of the device may not be feasible for human babies for several technical reasons, too, Mychaliska says. One barrier is that the system requires a delicate fetal surgery to connect the umbilical cord to the incubator while the baby is still attached to the mother. Few hospitals are equipped to perform such an operation, he says.

Flake acknowledges that several kinks must still be worked out before the artificial womb can be tested on human babies. "We have a lot to learn in terms of its capabilities and its safety," he says, but his group may soon be ready to begin human clinical trials. "We honestly think it could be as early as two to three years from now — and certainly within five years — that we'll be applying it to humans." ■



A lamb at 107 days of gestation (left) — equivalent to a human fetus at about 23 to 24 weeks gestation — matured normally in a recently developed artificial womb. The image at right shows the lamb 28 days later. Such devices may one day help premature babies survive.

E.A. PARTRIDGE *ET AL*/*NATURE COMMUNICATIONS* 2017

HUMANS & SOCIETY

Americas' first settlers debated

Disputed site would push back *Homo* arrival by 100,000 years

BY BRUCE BOWER

The New World was a surprisingly old destination for humans or our evolutionary relatives, say investigators of a controversial set of bones and stones.

An unidentified *Homo* species used stone tools to crack apart mastodon bones, teeth and tusks approximately 130,700 years ago at a site near what is now San Diego. This unsettling claim upending the scientific debate over the settling of the Americas comes from a team led by archaeologist Steven Holen of the Center for American Paleolithic Research in Hot Springs, S.D., and paleontologist Thomas Deméré of the San Diego Natural History Museum. If true, it means the Cerutti Mastodon site contains the oldest known evidence, by more than 100,000 years, of human or human-like colonists in the New World, the researchers report in the April 27 *Nature*.

About 130,000 years ago, a relatively warm and wet climate would have submerged any land connection between northeastern Asia and what's now Alaska. So ancient colonizers of North America must have reached the continent in canoes or other vessels and traveled down the Pacific coast, the researchers propose.

Candidates for these colonizers include Neandertals, Denisovans and *Homo erectus*, all of which inhabited northeastern Asia about 130,000 years ago. A less likely possibility, Holen says, is *Homo sapiens*, which reached southern China between 80,000 and 120,000 years ago (*SN: 11/14/15, p. 15*). No hominid fossils have turned up among the mastodon remains.

Whatever *Homo* species reached the Cerutti Mastodon site probably broke apart the huge beast's bones to obtain nutritious marrow and claim limb fragments suitable for fashioning into tools, the scientists suspect. Hominids probably scavenged the mastodon's carcass, since its bones contain no incisions indicative of butchering, the team adds.

Researchers already disagree about whether humans reached the Americas more than 20,000 years ago (*SN: 4/20/13, p. 9*), so it's no surprise that the new report is controversial.

Excavation of the site occurred in 1992 and 1993 following its partial exposure during a construction project. Backhoes and other heavy construction equipment can cause the same damage to bones that the new report attributes to a hominid, says archaeologist Gary Haynes of the University of Nevada, Reno.

The ancient landscape also may have included streams that could have washed broken mastodon bones and large stones from separate areas to the spot where they were eventually unearthed, says Vance Holliday, an archaeologist at the University of Arizona in Tucson. Perhaps hominids used these stones to break the bones, but the new study doesn't rule out other possibilities, such as trampling by animals at locations where the bones may have originated, he says. "Making a case for [hominids] on this side of the Pacific Ocean at 130,000 years ago is a very heavy lift, and this site doesn't make it."

Nothing that clearly qualifies as a stone tool has been found at the site, says archaeologist Michael Waters of Texas A&M University in College Station. Mounting genetic evidence indicates that the first people to reach the Americas and give rise to present-day Native Americans arrived no earlier than about 25,000 years ago (*SN: 8/22/15, p. 6*), Waters adds.

But study coauthor and archaeologist Richard Fullagar of the University of Wollongong in Australia argues that "the evidence is incontrovertible." Measurements of natural uranium and its decay products in mastodon bone fragments enabled scientists to estimate their age.

A sediment layer at the San Diego site contained pieces of a mastodon's limb bones, molar teeth and tusks bearing marks consistent with repeated battering by large stones, the team says. Ends of some bones were broken off, suggesting marrow had been removed.

Mastodon bones lay in two clusters. Some bones were associated with two large stones; others were spread around three large stones. These rocks range from 10 to 30 centimeters in diameter.

A *Homo* species used large stones to break mastodon bones (two round femur heads, shown top center, and a rib, top left) 130,700 years ago at a site in California, researchers say. If true, the Cerutti Mastodon remains would be the Americas' oldest archaeological site.

SAN DIEGO NATURAL HISTORY MUSEUM

Holen's team used comparable stones lashed to branches to break elephant bones resting on big rocks. Damage to experimental stones used as hammers resembled damage on three stones at the mastodon site. The team concludes that those stones were used to bash mastodon bones. Rocks used as anvils in the experiments incurred damage similar to that observed on the other excavated stones.

Construction machinery produces distinctive damage to large bones that does not appear on mastodon remains at the California site, Holen says. Excavations of the bones and stones reached about three meters below the area originally exposed by heavy equipment.

Sediment analyses indicate that streams did not wash in bones and stones from elsewhere, the scientists hold. It's also unlikely that trampling or gnawing by animals or the fossilization process created the bone damage, they say.

In a comment published in the same issue of *Nature*, archaeologist Erella Hovers of the Hebrew University of Jerusalem takes a cautiously positive view of the new findings. Despite uncertainties about who busted the mastodon remains, Holen's team shows that the damage was most likely done by members of a *Homo* species, she says. Stone Age hominid populations may have reached "what now seems to be a not-so-new New World," Hovers writes. ■

MATTER & ENERGY

Einstein principle passes quantum test

Gravity, acceleration equivalence true for atoms in superposition

BY EMILY CONOVER

Particles with mind-bending quantum properties still follow a standard gravitational rule, at least as far as scientists can tell.

The equivalence principle, one of the central tenets of Einstein's theory of gravity, survived a quantum test, scientists report online April 7 at arXiv.org.

In Einstein's gravity theory — the general theory of relativity — gravity and acceleration are two sides of the same coin. According to the equivalence principle, the gravitational mass of an object, which determines the strength of gravity's pull, is the same as its inertial mass, which determines how much an object accelerates when given a push. So two objects dropped on Earth's surface should accelerate at the same rate (neglecting air resistance), even if they have different masses or are made of different materials.

Supposedly, one of the first tests of the equivalence principle — before it was understood in the framework of general relativity — was Galileo's apocryphal experiment in which he is said to have dropped weights from the Leaning Tower of Pisa. Scientists have since adapted that test to smaller scales, swapping out weights for atoms. Now, physicists have gone a step further, putting atoms into a quantum superposition, in which an atom is in multiple states at once. In this case, the atoms occupy a combination of two energy levels.

Manipulating rubidium atoms with lasers, researchers gave the atoms an upward kick and observed how gravity tugged them down. To compare the acceleration of normal atoms with those in a superposition, the scientists split the atoms into two clouds, put atoms in one cloud into a superposition, and measured how the clouds interacted. These clouds of atoms behave like waves, interfering similarly to merging water waves. The resulting ripples depend on the gravitational acceleration felt by the atoms.

The scientists then compared the result of this test with one where both clouds were in a normal energy state. Gravity, the researchers concluded, pulled on atoms in a superposition at the same rate as the others — at least to the level of sensitivity the scientists were able to probe, within 5 parts in 100 million.

Quantum tests of the equivalence principle explore the murky realm where quantum mechanics and general relativity meet. The theories don't play well with one another. Scientists are struggling to

GENES & CELLS

Immune cells give the heart a boost

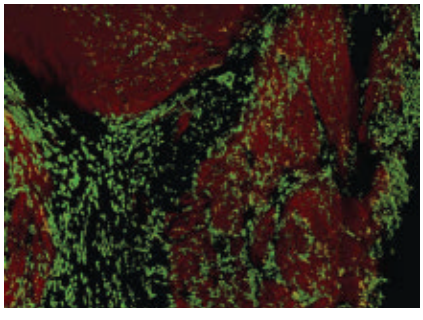
In mice, macrophages play a role in helping the organ pump

BY ELIZABETH S. EATON

Immune system cells may help your heart keep the beat. These cells, called macrophages, usually protect the body from invading pathogens. But a new study in the April 20 *Cell* shows that in mice, the immune cells help electricity flow between muscle cells to keep the organ pumping.

Macrophages squeeze in between heart muscle cells, called cardiomyocytes. These cells rhythmically contract in response to electrical signals, pumping blood through the heart. By "plugging in" to the cardiomyocytes, macrophages help heart cells get the signals and stay on beat.

Researchers have known for a couple of years that macrophages live in healthy heart tissue. But their specific functions "were still very much a mystery,"



Immune cells called macrophages (green) are tucked in between heart cells (red) in this confocal microscopy image of part of a human heart. In mice, macrophages provide an electrical boost that helps heart cells contract.

MAARTEN HULSMANS, M. NAHRENDORF

says Edward Thorp, an immunologist at Northwestern University Feinberg School of Medicine in Chicago. He calls the study's conclusion "paradigm shifting." It highlights "the functional diversity and physiologic importance of macrophages, beyond their role in host defense," Thorp says.

Matthias Nahrendorf, a cell biologist at Harvard Medical School, stumbled onto this electrifying find by accident.

Curious about how macrophages affect the heart, he tried to perform a cardiac MRI on a mouse genetically engineered to not have the immune cells. But the rodent's heartbeat was too slow and irregular to perform the scan.

These symptoms pointed to a problem in the mouse's atrioventricular node, a bundle of muscle fibers that electrically connects the upper and lower chambers of the heart. Humans with AV node irregularities may need a pacemaker to keep the heart beating in time. In healthy mice, researchers discovered macrophages concentrated in the AV node, but what the cells were doing there was unknown.

Isolating a heart macrophage and testing it for electrical activity didn't solve the mystery. But when the researchers coupled a macrophage with a cardiomyocyte, the two cells began communicating electrically.

Cardiomyocytes have an imbalance of ions. While in the resting state, there are more positive ions outside the cell than inside, but when the cell receives an electrical signal from a neighboring heart cell, that distribution switches. This momentary change causes the cell

unify the pair into one theory of quantum gravity; some candidate theories predict that the equivalence principle breaks down at the quantum level.

The test "is a new way of confronting gravity with quantum physics," says theoretical physicist Robert Mann of the University of Waterloo in Canada. "Any way that we can do that tells us something about how to put together gravity with quantum physics," even if the test finds no violation, he says.

Study coauthor Guglielmo Tino of the University of Florence declined to comment until the paper has been published in a journal.

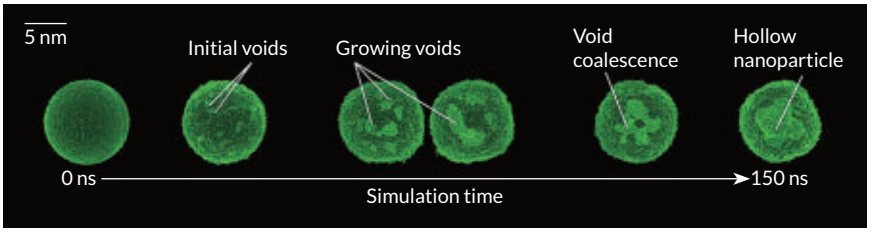
Scientists had previously tested the equivalence principle in atoms. But the new test is the first to study superposition, one of quantum mechanics' weirdest properties. "It's a beautiful demonstration of the versatility of these quantum tests," says physicist Ernst Rasel of Leibniz Universität Hannover in Germany. ■

to contract and send the signal on to the next cardiomyocyte.

Scientists previously thought that these heart cells were capable of this ionic shift, called depolarization, on their own. But Nahrendorf's team found that macrophages aid in the process. Using a protein, a macrophage hooks up to a cardiomyocyte. This protein directly connects the inside of these cells to each other, allowing macrophages to transfer positive ions, giving cardiomyocytes a boost kind of like with a jumper cable. This process makes it easier for the heart cells to depolarize and trigger the heart contraction, Nahrendorf says.

"With the help of the macrophages, the conduction system becomes more reliable, and it is able to conduct faster," he says.

Nahrendorf and colleagues found macrophages within the AV node in human hearts as well but don't know if the cells play the same role in people. The next step is to confirm that role and explore whether the immune cells could be behind heart problems like arrhythmia, Nahrendorf says. ■



To see how hollow iron oxide nanoparticles form, researchers measured the way X-rays bounced off oxidizing nanoparticles, then used computer models to reconstruct where atoms were moving during the chemical reaction.

MATTER & ENERGY

Chemists observe oxidation up close

New technique shows how iron oxide nanoparticles form

BY LAUREL HAMERS

Blame oxidation for rusted bridges and browned avocados. But this fundamental process can be harnessed for good — and now scientists have scored front-row seats that could show them how.

Researchers watched at near-atomic resolution as iron nanoparticles transformed into iron oxide — not rust in this case, but related compounds. That closeup view could help scientists better control oxidation and design corrosion-resistant materials or new catalysts, the researchers report in the April 21 *Science*.

This is the first time the oxidation process has been observed in such detail, says Andreu Cabot, a physicist at the Catalonia Institute for Energy Research in Barcelona.

When a metal oxidizes, its atoms mix and mingle with oxygen atoms to create a new material. That process is perhaps most famous for creating rust, which flakes and corrodes. But iron can oxidize in a variety of ways, some of which are useful.

For instance, chemist Yugang Sun of Temple University in Philadelphia and colleagues are trying to create hollow iron oxide nanoparticles that could serve as catalysts to speed up chemical reactions or as vessels to deliver drugs or store energy in chemical form. But making these "nanoshells" from iron nanoparticles requires precise control over the oxidation process.

If oxygen atoms work their way into an iron nanoparticle faster than the iron atoms can diffuse out, that nanoparticle becomes a tight, solid ball, Sun says. If the iron diffuses out faster than the oxygen comes in, on the other hand, it becomes the hollow sphere that Sun's lab wants.

Controlling that process is difficult because it has been unclear exactly how these shells form on an atomic level, Sun says. Scientists haven't been able to watch it happen, because high-powered microscopy techniques can disrupt the reaction or show the action in only two dimensions.

Sun's team tried a different approach to observe the reaction, by shooting X-rays at many identical iron nanoparticles suspended in a liquid. Each time the X-rays hit a different material — moving from the liquid to the solid, for instance — they scattered. By tracking how the X-rays bounced off many small, uniform iron nanoparticles, the researchers were able to reconstruct where different types of atoms were going as the particles oxidized into hollow shells over the course of several hours.

The researchers watched as the iron moved out of the center of the nanoparticle to react with the oxygen, initially forming many small holes inside the nanoparticle. Eventually, those empty spaces merged to form one big void in the middle of the nanoparticle.

"The impact of this paper is more than just the hollow [nanoparticles]," says Yadong Yin, a chemist at the University of California, Riverside. The imaging technique itself will be a useful way to study how other types of nanoparticles form, he says. It can be used to gain insight into other types of oxidation, too. ■

Y. SUN *ET AL*/*SCIENCE* 2017

BODY & BRAIN

Zika hides out in hard-to-reach spots

In monkeys, virus lingers in cerebrospinal fluid and lymph nodes

BY LAUREL HAMERS

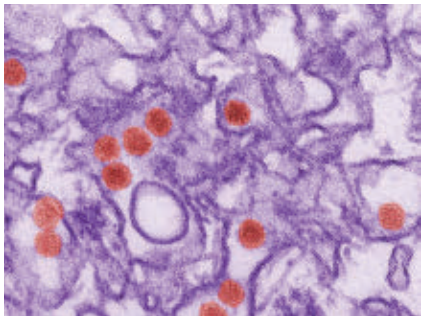
Zika virus plays hard to get.

Weeks after the virus disappears from the bloodstream, it still lingers in the lymph nodes and the central nervous system of rhesus monkeys, researchers report online April 27 in *Cell*. That could help explain why Zika infection can cause neurological problems in both infants and adults.

"Zika does stick around for a lot longer than we originally thought," says Dan Streblow, a virologist at Oregon Health & Science University in Portland who wasn't involved in the study. Streblow's lab recently reported in *PLOS Pathogens* that Zika can also linger in rhesus monkeys' reproductive tracts and peripheral nervous systems. And recent studies in humans have shown evidence of the virus hanging around in semen for months (*SN Online: 2/14/17*). Now, it appears the central nervous system and lymph nodes are also long-term hiding places.

That persistence could help clarify why Zika "does substantial damage in the central nervous system," says Dan Barouch, a virologist at Harvard Medical School who coauthored the new study. Infection in utero can cause microcephaly in infants, for instance. In adults, the virus has been linked to an increased risk for a neurological autoimmune disease called Guillain-Barré syndrome (*SN: 4/2/16, p. 29*).

Barouch and his colleagues infected rhesus monkeys with Zika and monitored the early stages of infection. The virus disappeared from the monkeys' blood after 10 days. But it lingered for as long as 42 days in cerebrospinal fluid, which circulates throughout the brain, and up to 72 days in the lymph nodes. Although antibodies that recognize and disable the Zika virus appeared within days in the blood, none were detected in the cerebrospinal fluid during the study.



Zika virus (red, in this false-color transmission electron micrograph) stays in the central nervous system longer than it does in the blood, which may help explain its effects on the brain.

CYNTHIA GOLDSMITH/CDC

A look at how the monkeys made certain proteins revealed a few potential reasons for the virus's persistence. Monkeys with ongoing Zika infection in their cerebrospinal fluid made more of a protein called mTOR and a set of other proteins that interact with mTOR, the researchers found. That result makes sense because mTOR (mechanistic target of rapamycin) has previously been shown to influence both immune response and neural development, Barouch says. Increased levels of the protein might contribute to Zika's effects on the brain, though more research would be needed to show how.

Sick monkeys also made less of certain proteins that coordinate communication between cells. Blocking those cell-to-cell messages might prevent immune cells from making their way to the virus's hiding places. That group of proteins is similarly affected by dengue virus, suggesting that the two illnesses might share some of the same infection tricks.

The findings suggest that the virus might have neurological effects beyond what's been seen so far, Barouch says. And the study adds another layer of complexity to the search for a treatment: A successful treatment will need to remove the virus from the bloodstream and the nooks and crannies in the body where it hides.

Zika's persistence also makes finding a preventative strategy more important than ever. Barouch's lab is one of many working on a vaccine. His group's vaccine is now in early-stage clinical trials (*SN: 3/18/17, p. 12*). ■

GENES & CELLS

DNA bucks tale of horse taming

Initial domestication involved many, not just a few, stallions

BY TINA HESMAN SAEY

DNA from stallions that lived more than 2,000 years ago is helping to rewrite the story of horse domestication.

Ancient domesticated horses had much more genetic diversity than their present-day descendants do, researchers report in the April 28 *Science*. These ancient horses had many more varieties of Y chromosomes and fewer harmful mutations than horses do now. Previous studies based on the genetics of modern horses concluded that domestication must have squeezed out much of the diversity seen in wild horses that lived before the end of the Ice Age. But the new work suggests the lack of diversity is a recent development.

"Today, Y chromosomes of all horses are pretty much the same," says evolutionary geneticist Ludovic Orlando of the Natural History Museum of Denmark in Copenhagen. As a result, scientists thought that ancient people started domesticating horses by breeding only a few stallions to many different mares. "But when we look in the past — wow! — this is a whole new planet," Orlando says.

Horses are thought to have been domesticated by about 5,500 years ago. Orlando's group examined DNA from the bones of 15 Iron Age stallions from the ancient Scythian civilization: Two stallions were from a 2,700-year-old grave site in Russia and 13 were sacrificed in a burial ritual about 2,300 years ago in Kazakhstan. The team also looked at a 4,100-year-old Bronze Age mare from the Sintashta culture in Russia. Nearly all of the stallions had a different type of Y chromosome, Orlando says.

That finding challenges the idea that only a few stallions participated in the early stages of domestication. Loss of Y chromosome diversity must have happened within the last 2,300 years,

Orlando says, and maybe as recently as 200 to 300 years ago, when people started creating specific horse breeds.

Using genetic data from modern animals to figure out what went on in the past is like flipping to the last pages of a novel and reading only the ending; it shows how things ended up but doesn't indicate how the story started or unfolded. Examining ancient DNA fills in those gaps to give a better indication of how domestication took place, says Laurent Frantz, an evolutionary biologist at Queen Mary University of London.

Modern horses also carry mutations known to be harmful (*SN: 1/10/15, p. 16*), including ones involved in dementia and seizures. But the ancient horses didn't have those mutations, indicating that those DNA changes happened sometime within the last 2,300 years.

"It really shows an awful lot has changed very recently, and it's incredibly dangerous to model the deep past from modern genetics," says zooarchaeologist Alan Outram of the University of Exeter in England. "You really need to carry out the ancient DNA studies."

Orlando and colleagues also determined some traits that were cultivated by the Scythians. Genes involved in mammary gland development and function had variants associated with greater milk production, perhaps indicating that the Scythians milked horses. Outram and others have evidence that horse milking started at least 5,000 years ago.

Modern horse breeds have less genetic diversity than domesticated horses did 2,300 years ago.

Also changed were genes involved in the function of neural crest cells. These embryonic cells migrate to different parts of the body during early development and help form parts of the brain, some facial features and other tissues. One recent hypothesis proposes that changes in how neural crest cells work can lead to common characteristics shared by domestic animals, such as floppy ears, juvenile faces and spotted coats (*SN: 8/23/14, p. 7*).

The study's genetic results provide evidence that the hypothesis might be true, Frantz says. Geneticists will have to work with experimental biologists to confirm that neural crest cells are involved in changing domesticated animals' appearance, he says. "This is the first step toward testing that hypothesis correctly." ■

EARTH & ENVIRONMENT

Nitrogen fixers may be at risk

Acidifying waters could hinder transformation of the element

BY SUSAN MILIUS

A hard look at experimental setups may start to explain dueling predictions on whether ocean acidification will boost, or choke, vital marine nitrogen fixers. So far, the new look trends toward choking.

As people release more and more carbon dioxide into the air, the ocean takes up the gas and edges closer toward acidity. In these shifting waters, microbes called *Trichodesmium* could falter in adding nitrogen, a crucial input for marine food webs, says Dalin Shi of Xiamen University in China. The problem could be exacerbated in areas where iron, an essential nutrient, is scarce—for example in wide swaths of tropical waters, Shi and colleagues report online April 27 in *Science*.

The question of how *Trichodesmium* cyanobacteria are reacting to the changing ocean makes a big difference in predicting how other marine life, from whales to mere specks of plankton, will react, too. Nitrogen, essential for such basic processes as building DNA and proteins, makes up much of the atmosphere. Yet most living things can't do any chemistry with the atmospheric form, two nitrogen atoms fiercely triple-bonded to each other. *Trichodesmium*, however, can crack those bonds and transform nitrogen into usable forms. These cyanobacteria may account for up to half of the nitrogen fixed in the ocean.

Lab research has generally suggested that increasing CO_2 encouraged the photosynthetic *Trichodesmium* to grow and supply more usable nitrogen. The rates varied, however. But when Shi and colleagues tried their version of the experiment, they found a decrease in nitrogen fixation. "I was really puzzled," says Shi, who published the results in 2012.

Now, after a string of detailed lab work, from culturing lab microbes to sampling wild cyanobacteria, he and colleagues propose an explanation for the contradictions. For one thing, much of the previous lab work used a recipe for artificial seawater that let metal and nitrogen contamination introduce unexplained variety to the results.

Also, Shi and collaborators demonstrate that rising CO_2 can stimulate the microbes' growth but that the watery slide toward ocean acidity can depress the ability to fix nitrogen. If cyanobacteria are in water short on iron, the slowdown in nitrogen fixation can overwhelm any positive growth effects from extra CO_2.

The paper could be a big help in resolving the contradictions among experiments, says Douglas Capone, an oceanographer at the University of Southern California in Los Angeles.

Orly Levitan, who has published on acidification boosting nitrogen fixation, welcomes the new paper but has more questions. A look at wild *Trichodesmium* suggests that the cyanobacteria may have unexpected ways of compensating in iron-starved waters, enhancing the capture of minerals from dust settling out of the air, for instance. It's too early to close discussion on what will happen in the complexities of the real ocean, says Levitan, of Rutgers University in New Brunswick, N.J. ■

ERIC CRUBÉZY

EARTH & ENVIRONMENT

Pollution reaches old groundwater

Scientists find contaminant in ancient water from deep wells

BY THOMAS SUMNER

Groundwater that has lingered in Earth's depths for over 12,000 years is surprisingly vulnerable to pollution from human activities. Once in place, that pollution could stick around for thousands of years, researchers report April 25 in *Nature Geoscience*. Scientists had assumed such deep waters were largely immune to contamination from the surface.

But, "We can't just drill deep and expect to run away from contaminants," says study coauthor Scott Jasechko of the University of Calgary in Canada.

Groundwater quenches the thirst of billions of people and accounts for roughly 40 percent of the water used in agriculture. Water percolating from the surface into aquifers can carry pollutants such as pesticides along for the ride.

Jasechko and colleagues weren't looking for contamination when they tested water from 6,455 wells around the world. Their goal was to identify how much of that deep water was "fossil" groundwater formed more than 12,000 years ago.

The researchers dated the water by examining dissolved carbon. Radioactive carbon decays as the water ages. After about 12,000 years, only stable carbon isotopes remain. Comparing the relative abundance of these isotopes in the various wells, the team discovered that over half of wells more than 250 meters deep yielded mostly fossil groundwater. The team estimates that fossil groundwater accounts for 42 to 85 percent of the water in the top kilometer of Earth's crust.

About half of the wells containing mostly fossil groundwater had elevated traces of tritium, a radioactive hydrogen isotope spread during nuclear bomb tests. While the tritium levels weren't dangerous, its presence suggests that at least some groundwater in the wells postdates the 1950s nuclear testing. That relatively young water may introduce other contaminants, the researchers say.

Old and young waters could mix within an aquifer or the construction and use of the well itself could churn the waters together, Jasechko says.

The study raises awareness that even in wells with mostly older water, "a fraction of that same water can be pretty young and susceptible to contamination," says hydrogeologist Audrey Sawyer of Ohio State University in Columbus. ■

BODY & BRAIN

Nerve cell miswiring tied to depression

Mouse study identifies gene needed to build serotonin circuitry

BY ELIZABETH S. EATON

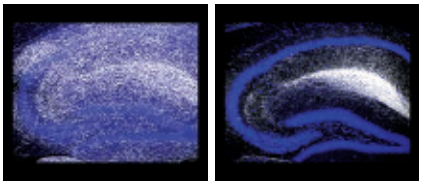
Researchers have pinpointed a gene that keeps important brain cells in mice from crossing their wires, providing a possible link between brain wiring and mood disorders like depression.

Without the gene, called *Pcdhac2*, mice acted more depressed, researchers report in the April 28 *Science*.

Nerve cells, or neurons, that make the chemical messenger molecule serotonin extend long projections, or axons, to various brain areas. Serotonin released from the axons' tips signals other neurons to alter mood and behavior. For efficient signaling, the tips must be properly spaced.

In the new work, scientists found that such spacing is disrupted in mice lacking *Pcdhac2*. Serotonin-signaling circuits weren't properly wired and mice exhibited behaviors indicating depression.

Pcdhac2 is in a cluster of genes that contain the blueprints for proteins that protrude from the surface of cells. These proteins work like ID cards, says study coauthor Joseph Dougherty of Washington University School of Medicine in St. Louis. As the axons of serotonin-making neurons branch out through the brain, they recognize other axons carrying identical IDs and spread out to keep out of each other's way. This process evenly spaces axons in their target areas.



In a healthy mouse (left), nerve cells (white) that release serotonin extend through the hippocampus. But when a specific gene is knocked out, those nerve cells clump (right), and the mouse acts depressed.

T. MANIATIS/ZUCKERMAN INST./COLUMBIA UNIV.

But for mice in which the gene cluster was deleted, these axons don't keep their distance from each other. They trip each other up, preventing the axons from fully extending through the brain and delivering the usual doses of serotonin, says study coauthor Tom Maniatis of Columbia University.

Uneven serotonin distribution affected mice's behavior. In a swim test, for instance, mice stopped swimming for survival. No problem was found with mice's muscles or movement, suggesting mental state caused the behavior.

Of the genes in the deleted cluster, only *Pcdhac2*'s protein was found in intact serotonin-producing neurons. The mechanism for how the protein keeps the axons in line isn't known, Maniatis says.

Sean Millard, a neuroscientist at the University of Queensland School of Biomedical Sciences in Brisbane, Australia, says this genetic finding in mice is consistent with what's been found in flies. "It's really nice to see that similar mechanisms are working in higher organisms," he says.

If the same gene contributes to depression in humans, the findings may point researchers studying psychiatric disorders in a new direction. Many previous studies have focused on how serotonin is transmitted and synthesized, as well as the genes that control levels of the chemical. Instead, "maybe we should be looking at genes that regulate serotonin wiring," Dougherty says. ■

HUMANS & SOCIETY

Stone Age injuries lack modern analog

Rodeo riders' bone breaks give little insight into Neandertal lives

BY BRUCE BOWER

Rodeo riders' reputation as the best modern examples of a Neandertal pattern of excess head knocks has taken a tumble. Taking their place: people who like to be dragged behind powerboats on big inner tubes, among others.

A comparison of Neandertals' injuries with those of people today finds that water tubing and mishaps involving tables, not rodeo riding, result in top-heavy fracture patterns most similar to those observed on Neandertal fossils. This analysis illustrates just how little modern evidence reveals about ways in which our evolutionary relatives ended up so battered, said anthropologist Libby Cowgill of the University of Missouri in Columbia. She presented data highlighting the mystery of Neandertals' many preserved bone fractures on April 22.

Her study, conducted with Missouri anthropologist James Bain, was inspired by an influential 1995 report that Neandertals, like rodeo riders, suffered lots of head and above-the-waist injuries and little hip and leg damage. That study suggested that, unlike rodeo riders who get catapulted off bucking broncos, Neandertals' hard knocks came during violent, up-close clashes with large prey.

A coauthor of the 1995 paper, anthropologist Erik Trinkaus of Washington University in St. Louis, questioned those conclusions in 2012 in the *Journal of Archaeological Science*. Trinkaus pointed out, for instance, that up-close clashes with members of their own species or with *Homo sapiens* also could have inflicted a lot of upper-body damage. Neandertals immobilized by lower-body injuries may have been left to die before reaching rock-shelters where most fossils have been found, he added. In that case, the limited sample of Neandertal fossils misleadingly portrays these hominids as prone to upper-body fractures.

Neandertals appeared to have an excess of upper-body injuries, like this right upper arm bone sheared off just above the elbow (bottom). An intact upper left arm bone (top) is shown for comparison.

Trinkaus' doubts were well placed. Neandertals' pattern of bone fractures differs from that produced by a wide variety of present-day activities, Cowgill reported. Activities that cause injuries most resembling the Neandertal pattern have no apparent relation to Stone Age behavior, Cowgill said. No one can accuse Neandertals of having practiced reckless water tubing or having suffered what Cowgill described as "unfortunate run-ins with tables."

About 30 percent of Neandertal injuries affected the face and head, a rate far greater than that for most modern activities, Cowgill said. Only diving board accidents produce a slightly higher proportion of these injuries than seen in Neandertals.

In a U.S. sample of injuries, Cowgill and Bain looked at bone fractures, not at a broader range of injuries considered in the 1995 study, which had included signs of degenerative bone disease. That may help explain why the rodeo rider comparison doesn't hold up: The new study found fewer skull injuries and many more hand wounds among rodeo riders than previously reported.

Fracture data came from a national sample of hospitals. Of 84 activities that resulted in bone fractures to 61,851 people from 2009 to 2014, only 16 activities showed statistical similarities to Neandertals' injury patterns. Along with water tubing and various table injuries, accidents involving golf, lawn chairs, and Frisbee and boomerang games produced somewhat Neandertal-like patterns.

There are so many ways to hurt one's head that it's meaningless to compare injury patterns today with those of Stone Age hominids, Trinkaus said. Neandertal injuries may not even reflect particular behaviors. Fractures during fossilization — as well as greater susceptibility of the braincase, relative to other body parts, to minor dents and dings — could have contributed to Neandertals' head wounds, Trinkaus suggested. ■

E. TRINKAUS

MEETING NOTE

Ötzi the Iceman froze to death

Ever since Ötzi's mummified body was found in the Alps in 1991, researchers have tried to pin down how the 5,300-year-old Tyrolean Iceman died. It now looks like the Copper Age hunter-gatherer simply froze to death, perhaps after suffering minor blood loss from an arrow wound, anthropologist Frank Rühli of the University of Zurich reported April 20. Ötzi succumbed to exposure within anywhere from a few minutes to a few hours, Rühli estimated.

New analyses of the Iceman's body, based on X-rays and CT scans, argue against the idea that Ötzi died from a stone arrowhead shot into his shoulder (*SN: 9/6/14, p. 6*). Surprisingly shallow penetration of that weapon ruptured a blood vessel but caused no major tissue damage, Rühli said. Internal bleeding totaled only about 100 milliliters, or close to half a cup, he and colleagues concluded. That's enough to cause discomfort but not death, Rühli said.

Several skull depressions and fractures also couldn't have proved fatal, he added. Some researchers regard those injuries as signs that Ötzi was clubbed to death. Rühli's team found that those injuries are more consistent with Ötzi having fallen and hit his head while walking over rough ground. The Iceman was found with fur headgear that probably helped to protect his noggin when he took a headlong tumble, Rühli suggested. — *Bruce Bower*

ATOM & COSMOS

New proposal reimagines Mars' origin

Red Planet may not have been born near the other rocky planets

BY THOMAS SUMNER

Mars may have had a far-out birthplace.

Simulating the assembly of the solar system around 4.56 billion years ago, researchers propose that the Red Planet didn't form in the inner solar system alongside the other terrestrial planets as previously thought. Mars instead may have formed around where the asteroid belt is now — some 450 million kilometers from the sun — and migrated inward to its present-day orbit, about 230 million kilometers from the sun. The proposal, reported in the June 15 *Earth and Planetary Science Letters*, better explains why Mars has such a different chemical composition than Earth, says study coauthor and geologist Stephen Mojzsis of the University of Colorado Boulder.

The work is an intuitive next step in a years-long rethink of the early solar system, says Kevin Walsh, a planetary scientist at the Southwest Research Institute in Boulder, Colo., who was not involved with the study. "We only became comfortable within the last 10 years with the idea that planets move around, possibly a lot," he says. "Planets may not have formed where we see them today."

Mars, like Mercury, is a runt of the inner solar system, weighing in at only about a ninth of Earth's mass. One of the reigning theories of planetary formation, the Grand Tack model, blames Jupiter for the Red Planet's paltry size. In that scenario, the newly formed Jupiter migrated toward the sun until it reached Mars' present-day orbit. A gravitational tug from Saturn then reversed Jupiter's course, sending the gas giant back to the outer solar system (*SN: 4/2/16, p. 7*).

Gravitational effects of Jupiter's sunward jaunt acted like a snowplow, scientists believe, causing a pileup of material near where Earth's orbit is today. The bulk of that material formed Venus and Earth, and the scraps created Mercury and Mars. This explanation predicts that all the terrestrial planets formed largely from the same batch of ingredients (*SN: 4/15/17, p. 18*). But studies of Martian meteorites suggest that the Red Planet contains a different mix of various elements and isotopes, such as oxygen-17 and oxygen-18, compared with Earth.

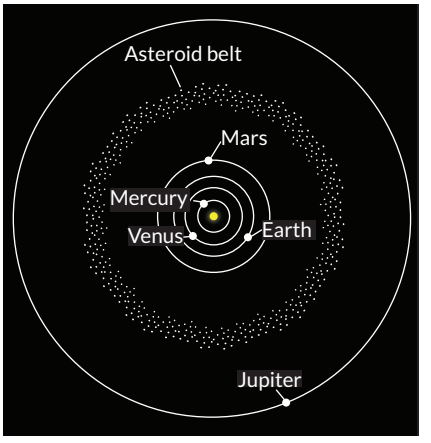
Mojzsis, planetary scientist Ramon Brasser of the Tokyo Institute of Technology and colleagues reran the Grand Tack simulations, keeping an eye on the materials that went into Mars' creation to see if they could explain the different mix.

As with previous studies, the researchers found that the most probable way of creating a solar system with the same planet sizes and positions as seen today is to have Mars form within Earth's orbit and migrate outward. However, this explanation failed to explain Mars' strikingly different composition.

Another possible scenario, though seen in only about 2 percent of the researchers' new simulations, is that Mars formed more than twice as far from the sun as its modern-day orbit, in the region now inhabited by the asteroid belt. Then as Jupiter moved sunward, its gravitational pull yanked Mars into the inner solar system. Jupiter's gravity also diverted planet-making material away from Mars, resulting in the planet's relatively small mass. With Mars forming so far from the planetary feeding frenzy responsible for the other rocky planets (which formed roughly 100 million to 150 million kilometers from the sun), its composition would be distinct. While this scenario isn't as likely as Mars forming in the inner solar system, it at least matches the reality of Mars' makeup, Mojzsis says.

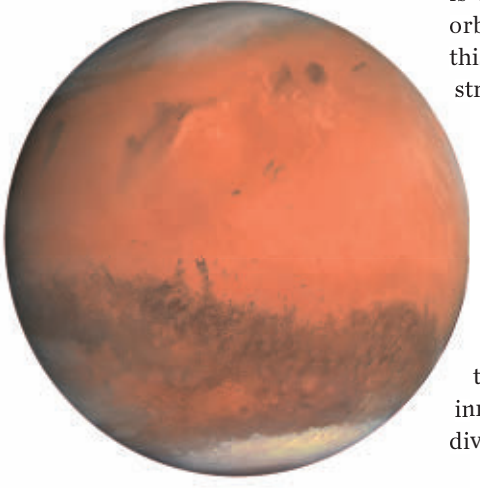
Such a distant origin means that the fledgling Mars would have received far less sunlight than originally thought, a challenge to early Mars' possible habitability. Without a sustained thick atmosphere of heat-trapping greenhouse gases, the planet would have been too cold to sustain liquid water on its surface for long periods of time, Mojzsis argues. Though large meteorite impacts could have temporarily warmed Mars above freezing, the planet wouldn't have had a consistently warm and wet youth similar to that of the early Earth, he says.

Confirming whether Mars really was born that far out in space will require taking a closer look at Venus' mixes of elements and isotopes, which the researchers predict would be similar to Earth's. Venus' composition is largely unknown because of a lack of Venusian meteorites found on Earth, and that mystery won't be unlocked anytime soon: No missions to Venus are planned. ■



Place of origin Mars may have formed near what's now the asteroid belt, much farther away from the sun than the other rocky planets. Planets' present-day orbits are shown. SOURCE: LUNAR AND PLANETARY INSTITUTE

An alternative explanation for where Mars originated could explain why the Red Planet's chemical composition differs from Earth's.



FROM TOP: T. TIBBITTS; ESA AND MPS FOR OSIRIS TEAM, UPD, LAM, IAA, RSSD, INTA, UPM, DASP, IDA (CC BY-SA 3.0 IGO)

LIFE & EVOLUTION

How a mushroom gets its glow

The enzyme that turns on the light for a glow-in-the-dark mushroom seems "promiscuous." But in a good way.

Researchers have worked out new details of how two *Neonothopanus* fungi shine softly green at night. The team had earlier figured out that the basic starting material for bioluminescence in these fungi is a compound called hispidin, found in some other fungi as well as plants such as horsetails. Those plants don't spontaneously give off light, but in the two *Neonothopanus* mushroom species, an enzyme rejiggers a form of hispidin into a compound that glows.

The enzyme that turns a fungus into a natural night-light isn't that fussy as enzymes go, says Cassius V. Stevani of the University of São Paulo in Brazil. He and colleagues can tweak the compound that the enzyme normally reacts with and still get a glow, the researchers report April 26 in *Science Advances*.

This easygoing chemistry has allowed the team to develop blue to orange glows instead of just the natural yellowish-green. These bonus colors might mark the beginnings of a new labeling tool for molecular biologists, the researchers say. — *Susan Milius*

EARTH & ENVIRONMENT

Crack in Antarctic ice shelf forks

The 180-kilometer-long crack threatening one of Antarctica's largest ice shelves has branched out, new satellite observations reveal. The main rift in the Larsen C ice shelf hasn't grown longer since February. But radar mapping shows that a crack has split off from the main rupture like a snake's forked tongue, members of Project MIDAS, an Antarctic research group, report May 1. That new branch, about 15 kilometers long, wasn't on radar maps taken six days earlier, the team says.

If either branch makes it to the edge of Larsen C, the shelf could calve off a 5,000-square-kilometer hunk of ice (*SN: 7/25/15, p. 8*), creating one of the largest icebergs ever recorded, says glaciologist Adrian Luckman of Swansea University in Wales. "The new branch is heading off more toward the ice front, so it's more dangerous and more likely to cause this calving event to occur" than the main branch, he says.

A bioluminescent mushroom (*Neonothopanus gardneri* shown) has an enzyme that might inspire new glow-in-the-dark molecular labels.

C.V. STEVANI/IQ-USP, BRAZIL

Snapping off such a large ice chunk could destabilize the entire ice shelf, Luckman warns. A similar event led to the collapse of Larsen B in 2002. Because Larsen C's ice floats on the ocean, the loss wouldn't directly raise sea levels. But its demise could serve as a case study of how other shelves may break apart as rising temperatures melt and weaken Antarctic ice, Luckman says. — *Thomas Sumner*

ATOM & COSMOS

With additional data, gamma-ray evidence for dark matter weakens

A potential sign of dark matter is looking less convincing in the wake of a new analysis.

High-energy blips of radiation known as gamma rays seem to be streaming from the center of the Milky Way in excess. Some scientists have proposed that dark matter could be the cause of that overabundance. Particles of dark matter — an invisible and unidentified substance that makes up the bulk of the matter in the cosmos — could be annihilating one another in the center of the galaxy, producing gamma rays (*SN Online: 11/4/14*).

In the new study, scientists scrutinized the latest data from the Fermi Gamma-ray Space Telescope. At the Milky Way's center, the researchers found more gamma rays than they could explain, they report online April 12 at arXiv.org. But when they compared the galaxy's center with control regions far away — where dark matter signals wouldn't be expected — they also found excess gamma rays. "What I see in the control regions looks just like what I see in the galactic center," says study coauthor Andrea Albert of Los Alamos National Laboratory in New Mexico. So dark matter seems unlikely to cause the gamma-ray glut. — *Emily Conover*

ATOM & COSMOS

Solar system bubble has no tail

The solar system doesn't have a long, twisted tail after all.

Data from the Cassini and Voyager probes show that the bubble of particles surrounding the solar system is spherical, not comet-shaped. That observation runs counter to over 55 years of speculation, says Tom Krimigis of the Johns Hopkins University Applied Physics Laboratory in Laurel, Md. He and colleagues report the result April 24 in *Nature Astronomy*.

The bubble, called the heliosphere, is inflated by particles streaming from the sun and envelops all of the solar system. Its shape provides clues to how the solar system interacts with interstellar space.

In 2013, the Interstellar Boundary Explorer spacecraft found signs of a tail. The probe counted the speedy atoms that get kicked inward from the edge of the solar system when the solar wind (charged particles from the sun) collides with hydrogen in interstellar space. Those atoms offer clues to the heliosphere's shape; the data hinted at a long, twisted tail (*SN: 8/24/13, p. 9*).

But from that data alone, it wasn't clear how far the tail extends, Krimigis says. By combining over a decade's worth of data from Voyager and Cassini, his group sought a clearer picture. The team tracked changes in the atoms' abundance as the solar wind's intensity waxed and waned.

At the front of the heliosphere (the edge traveling directly into interstellar space), the number of atoms changed in lockstep with the solar wind's intensity. The back of the heliosphere had the same pattern. If there were a long tail, Krimigis says, this similarity wouldn't exist. The atoms would have farther to travel in a tail, so it would take longer for their abundance to build up again. — *Ashley Yeager*

Seeing CHACO in a NEW LIGHT

A slew of studies try to piece together an early American society

By Bruce Bower

Chaco Canyon is a land of extremes. Summer heat scorches the desert canyon, which is sandwiched between sandstone cliffs nearly two kilometers above sea level in New Mexico's northwestern corner. Bitter cold sweeps in for winter. Temperatures can swing as many as 28 degrees Celsius during the course of a day. Through it all, Chaco Canyon maintains a desolate beauty and a craggy pride as home to one of ancient America's most enigmatic civilizations.

Scientists have struggled to understand Chaco society since its first excavations in the late 1800s. Who first settled Chaco Canyon around 1,200 years ago is still a mystery. Many researchers suspect that it took a few hundred years for a fledgling city-state run by an elite social class to emerge. Political and cultural ties between the ancient society and Chaco-style communities outside the canyon also perplex. Then there's the puzzle of how people survived from about 800 to around 1300 on the rough, parched terrain.

A new generation of Chaco studies and discoveries is under way, partly thanks to a young researcher's skeleton reassembly project. This jigsaw job required a lot of travel, but not to Chaco Canyon.

That's because bones of people excavated at Chaco in the 1890s and 1920s were packed away in boxes and drawers at museums in New York City, Chicago and Washington, D.C. Kerriann Marden visited all of these places to retrieve far-flung body parts from one site in particular — Pueblo Bonito,

PETER DONALDSON/ALAMY

New research suggests that the ancient Chaco society of the U.S. Southwest was founded by locals and run by a female lineage for hundreds of years. The best-known Chaco structures are great houses, represented here by the remains of Pueblo del Arroyo.

the oldest and largest of a dozen huge stone great houses in Chaco Canyon. The structure was built, along with a range of smaller structures, between about 800 and 1130.

Pueblo Bonito was massive, rising at least five stories with around 650 rooms. It has yielded more human bones and artifacts than any other Chaco site. Research has focused on this great house presumably reserved for Chaco's elite families; the lives of workaday folk have been largely unexplored, even in the latest studies.

During Chaco society's heyday, other civilizations peaked elsewhere in the Americas, including the Maya in Central America. Just as present-day Maya groups trace their ancestry back to that ancient civilization, today's Pueblo tribes, such as the Hopi and Zuni, consider Chaco people to have been their forebears. Navajo Nation also claims an ancestral tie to Chaco society.

Reassembly required

Archaeological excavations a century or more ago — at Pueblo Bonito and elsewhere — didn't follow today's rigorous standards for excavating and preserving remains. The work consisted of little more than mining for bones and artifacts, then carting the discoveries off to museums. As an anthropology graduate student at Tulane University in New Orleans, Marden journeyed back and forth between New York's American Museum of Natural History, Chicago's Field Museum and Washington's Smithsonian National Museum of Natural History from 2005 to 2011. She painstakingly reunited long-dead Chaco individuals' skulls with arms, legs with feet and so on. Marden is now a forensic anthropologist at Eastern New Mexico University in Portales.

As skeletons assumed their former shapes, a couple of peculiar things stood out. First, many individuals bore signs of disease, including tuberculosis and syphilis. That seemed peculiar for people who were buried in a great house typically thought to have been reserved primarily for society's upper crust, not for the ill. Second, bodies had been manipulated in unusual ways and for unknown reasons. Comparisons of restored skeletons with field notes and photographs from original excavations indicated, for instance, that one woman was originally found with a fetus's fragile remains in her pelvic cavity and her own bones below the knees missing. Her body lay across a room from several intact bodies.

"Nothing is simple at Pueblo Bonito," Marden says. Her campaign to put Pueblo Bonito skeletons back together has enabled a couple of provocative new investigations. One concludes that members of a single maternal line wielded power in Chaco society from the start through an

unexpected stretch of at least 330 years and perhaps 10 generations. Another study proposes that Chaco society's founders were not outsiders with experience constructing huge buildings, as many researchers have assumed. People living in and near Chaco Canyon may have established a cliff-bordered society all on their own.

Other new findings suggest that Chaco residents contacted and traded with people living as far as 2,500 kilometers to the south in Central America and as close as 75 kilometers to the west and south. It's debatable, though, whether Chaco Canyon's 2,000 to 3,000 residents could raise enough crops to feed themselves or whether they had to trade for staples such as maize.

Less contentious — but far weirder — is evidence from graves and artwork that Chaco people revered community members with six toes and often created images of human feet and footprints with and without extra digits.

DNA dynasty

Fittingly, Chaco society's archaeological footprint covers what was once an extensive regional system of buildings and roads. The largest great houses were clustered in a 2-kilometer-diameter downtown zone at the center of Chaco Canyon. Smaller great houses, ritual structures called kivas, groups of small family houses and other urban features, connected by a network of straight dirt roads, fanned out from the canyon across an area the size of Ireland.

After Chaco society dissolved around 1300, Pueblo groups may have rejected its centralized political system and social classes, says archaeologist Stephen Lekson of the University of Colorado Boulder. Pueblo people today live in small communities oriented around clans based on maternal lines of descent.

A years-long skeletal reassembly project has spurred new research into who was buried at a massive great house called Pueblo Bonito (remnant walls and foundation shown).

Finds in a burial at the first and largest great house in Chaco Canyon, Pueblo Bonito, include turquoise jewelry and shell items placed alongside a presumably influential man interred between 800 and 850.

Therein lies a connection between past and present, says archaeologist Stephen Plog of the University of Virginia in Charlottesville. Many individuals buried in one of Pueblo Bonito's oldest rooms, known to researchers as Room 33, shared maternal ancestry (*SN Online: 2/21/17*). Plog and colleagues — led by Penn State archaeologist Douglas Kennett — extracted mitochondrial DNA, which is typically passed from mother to child, from skeletons of nine of 14 individuals interred in Room 33. Marden's reassembly project was crucial to identifying individuals whose DNA was analyzed.

Members of this Pueblo Bonito group, the researchers reported February 21 in *Nature Communications*, inherited mitochondrial DNA that was similar enough to signal shared kinship with a female line. Nuclear DNA recovered from six Room 33 skeletons identified two as mother and daughter and two others as a grandmother and grandson. Children inherit nuclear DNA from both parents.

Room 33 is a crypt with a complex history. Two men were buried beneath the chamber's wooden floor, one below the other. The lowermost body had a gash in the head. Plog suspects the man was bashed on the noggin during a fight. Marden thinks it's more likely that someone with a shovel, perhaps a looter, broke the skull after the man had been buried.

Thousands of offerings, including turquoise and shell beads and pendants, were heaped around the two bodies under Room 33's floor, with the lion's share surrounding the bottommost man. Chaco people laid a wooden plank floor over the two men's graves before additional bodies were buried in the chamber.

Radiocarbon dating conducted by Plog's group gives a rough timeline for Room 33's burials. The first two men were placed there as early as 800. Construction of the wooden floor occurred by about 900. Additional burials took place intermittently up to 1130, the new dating indicates.

FROM TOP: RODERICK MICKENS/© AMNH; POWEROFFOREVER/ISTOCKPHOTO

Activity in Room 33 occurred as civilizations flourished throughout the Americas, from what's now the U.S. Midwest to Central and South America.

Plog regards the extravagantly buried man at the base of Room 33 as an early leader from a prominent Chaco family dynasty. Based on the exceptional treatment given to all deceased individuals placed in the special room in Chaco's first and largest great house, Plog suspects these folks belonged to a maternal line in which leadership was handed down from the ninth to the 12th century. At that point, researchers suspect, many Chaco residents and possibly members of nearby communities moved to a settlement 50 kilometers north of Chaco Canyon. A Chaco-style great house there was occupied from 1140 to the 1290s, consistent with an influx of people familiar with Chaco architecture.

"Our findings reinforce the possibility that a complex society existed in Chaco by the ninth century, about 200 years earlier than has often been assumed," Plog says. If so, Chaco society consisted of a few powerful families and lots of commoners from the start.

Local founders

That's not the only surprise encased in Pueblo Bonito's skeletal trove. Chemical analyses of teeth from 61 individuals interred in two sections of the great house indicate that most of these people grew up eating food and drinking water from Chaco Canyon or nearby areas to the south. These results challenge an influential idea established over the last decade that people from ancient settlements that included large structures, located more than 160 kilometers north of Chaco Canyon, migrated south and brought with them knowledge of how to design great houses.

Archaeologist T. Douglas Price of the University of Wisconsin–Madison, Plog and colleagues made a case for local origins of Chaco society in the February issue of the *Journal of Archaeological Science: Reports*.

The researchers focused on the two sections of Pueblo Bonito where human skeletons were found in previous excavations. Room 33 and three adjacent chambers on the great house's northern side contained burials of about 25 individuals. Four rooms on the structure's western side produced remains of more than 80 bodies.

Radiocarbon analyses of 12 skeletons from the western chambers, led by Marden during her graduate work, dates the bodies to between the years 687 and 949. Further radiocarbon dating is needed to narrow that wide age range for western interments, Marden says.

Ratios of certain forms of chemical elements — strontium, oxygen and lead — suggest that 58 of 61 people buried in Pueblo Bonito had grown up eating plants and animals and drinking water that came from the Chaco Canyon area.

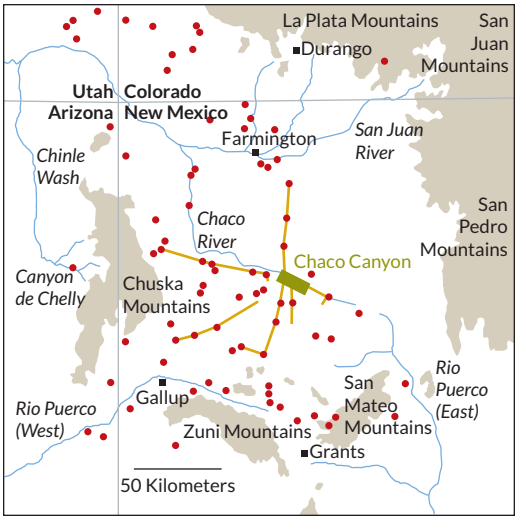
Plog suspects that the few Chaco Canyon outsiders that have been identified at Pueblo Bonito came from somewhere nearby. It's unclear what roles those outsiders assumed in Chaco society. But finding a majority of locals buried in the great house challenges a previous proposal that Chaco Canyon was first settled by people from the north, Plog says. Design similarities between some northern stone buildings and Chaco great houses fueled that suspicion.

The new DNA and chemical results aren't entirely consistent. Although the two men placed beneath the floor of Room 33 belonged to a maternal line interred at Pueblo Bonito, the chemical makeup of their bones suggests they might have grown up outside Chaco Canyon. For now, where the men were raised and how they ended up in Pueblo Bonito remains a mystery. "It will take a while to make sense of both datasets," Plog says.

Reign fall

Marden says it's too early to say much of anything about how Chaco society was organized based on initial genetic evidence from Pueblo Bonito skeletons. "Huge pronouncements about Chaco social structure are being made based on partial, flawed data," she says. "It's like excavating only human foot bones and concluding that people at that time had no hands."

DNA from a mere nine folks can't support a



Chaco lot Ancient Chaco society was based in northwestern New Mexico's Chaco Canyon (green rectangle). Chaco-style great houses (red) appear throughout the region. Roads (some shown here in yellow) radiated out from Chaco Canyon.
SOURCE: T.D. PRICE *ET AL*/ *J. ARCHAEOL. SCI.: REPORTS* 2017

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sweeping conclusion that Pueblo Bonito housed the dead of a Chaco maternal dynasty, Marden argues. Additional genetic samples are needed to determine, for instance, whether people buried elsewhere in Pueblo Bonito, in other great houses in and near Chaco Canyon and in smaller Chaco buildings belonged to the same maternal line as those from Room 33, she holds.

DNA studies of more Chaco skeletons are unlikely in the near future. Some Pueblo groups have complained that scientists didn't consult with them before removing genetic material from the bones of people regarded as ancestors. In a related case, scientists have collaborated with Native Americans in the Pacific Northwest, who provided DNA for comparisons to Kennewick Man's DNA (*SN: 7/25/15, p. 6*).

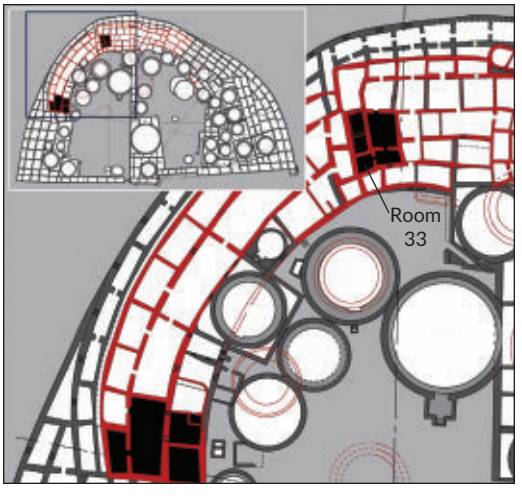
In a written statement, the American Museum of Natural History says it approved the new DNA analysis of Chaco bones from its collection based on discussions with 20 Native American tribes in the U.S. Southwest during the 1990s. No claims of cultural ties to Chaco people were lodged then or since, making the new investigation legal, the museum statement concludes.

A formal inquiry to the museum about its decision will be filed soon, says Leigh Kuwanwisiwma, director of the Hopi Cultural Preservation Office in Kykotsmovi, Ariz.

So for now, DNA from nine Chaco individuals raises only provocative possibilities. The two men interred beneath Room 33's floor appear to have been important, Marden acknowledges, but that doesn't make them founding fathers of a Chaco dynasty that traced descent through a female line. Room 33 may simply have housed deceased members of a prominent family.

Relatives probably visited the men's graves in Room 33 on occasion, leaving offerings that piled up over time. Those items, including turquoise frog ornaments and seashells, often refer to water, a precious commodity in Chaco society. However, researchers can easily see signs of symbolic rituals where they don't exist, Marden warns. For instance, for more than a century, many researchers have assumed that a hole cut into Room 33's floor represented an entrance to a supernatural underworld for the dead. The floor opening was more likely used as a handle to remove surrounding planks to reach the graves below, she suspects.

"There's undoubtedly symbolism at Pueblo Bonito, but as a forensic anthropologist, I'm looking for practical explanations," Marden says.



Grave intent This Pueblo Bonito layout (full image in inset) shows rooms that form burial clusters (black) on the great house's northern and western sides. Rooms built earliest are highlighted with red borders. New insights into Chaco society have come from skeletons excavated in the northern cluster's Room 33.

T.D. PRICE *ET AL*/*J. ARCHAEOL. SCI.: REPORTS* 2017

Southern influences

What appears clear at Pueblo Bonito is that connections existed between Chaco society and populations extending as far south as Central America.

Recovered pottery tells a similar story to Price's teeth analysis suggesting local as well as southern origins for Pueblo Bonito's dead. Vessels recovered at that great house and other Chaco sites resemble pottery from comparably ancient sites about 50 kilometers to the southwest. Anthropological archaeologist Barbara Mills of the University of Arizona in Tucson reported the finding March 30 in Vancouver at the annual meeting of the Society for American Archaeology.

The Zuni Mountains, about 75 kilometers to the south, and the Chuska Mountains, about the same distance to the west of Chaco Canyon, provided close to 70 percent of the more than 240,000 trees that were used for roof beams, doorframes and other features of Chaco great houses. A team led by dendrochronologist Christopher Guiterman at the University of Arizona reported those findings, based on matching tree ring configurations at Chaco and in the two mountain ranges, last year in *Proceedings of the National Academy of Sciences*.

Chaco people also apparently traded turquoise objects for goods from societies in southern Mexico and Central America. Residue on Pueblo Bonito jars and pitchers comes from a chocolate beverage made from cacao that grows in those tropical areas (*SN Online: 3/17/11*). Exotic birds — scarlet macaws — from the same region turned up at Pueblo Bonito starting in the late 800s.

Colorado's Lekson thinks southern influences on Chaco society run deep. Chaco's social and political structure drew on a type of small city-state in what's now southern Mexico and Central America called an *altepetl*, Lekson proposes. An *altepetl*

consisted of seven or eight related noble families, each ruling over commoners who cultivated crops and paid tribute in food and labor. Leading noble families took turns ruling an *altepetl* and elected a figurehead king.

Chaco's seven great houses served as elite families' residences, as in an *altepetl*, Lekson proposes. Other Chaco structures housed minor nobles, priests and commoners, from this perspective.

That's a minority view, though. Mills, Plog and several other Chaco researchers suspect that Chaco society was organized around houses of varying social status. A structure's status would have been based on its age and ritual connections to ancestors. Differences in architecture among great houses suggest that they were ranked as well, Mills says. If that's how the system worked, heads of various Chaco houses probably led their respective extended families.

"Chaco was a hierarchically organized society from the start," Plog says.

It helped that Chaco Canyon's soil, although salty, was able to support widespread maize cultivation with the help of irrigation ditches, Plog and his colleagues, led by University of Cincinnati geoarchaeologist Kenneth Tankersley, reported in the October 2016 *Journal of Archaeological Science: Reports*.

University of Colorado hydrologist and geochemist Larry Benson says that's unlikely. Chaco Canyon soil was too salty and annual rainfall too low to feed more than a few hundred people, Benson reported online last December in the same journal. He suspects that the Chaco crowd imported maize grown near the Chuska Mountains.

Special feet

Chaco society's puzzles go beyond who was in charge and where meals came from. One of the ancient population's most vexing oddities concerns feet.

Six-toed individuals appear to have held special status at Pueblo Bonito, says archaeologist Patricia Crown of the University of New Mexico in Albuquerque. "Having six toes brought social honor in Chaco society," Crown holds. "We don't know why Chaco people were so interested in feet or what feet symbolized to them."

A review of Pueblo Bonito skeletons and artifacts conducted by Crown and her colleagues, published in the July 2016 *American Antiquity*, identified three six-toed individuals among the burials. Only one case had previously been noticed — the less-decorated man placed beneath Room 33's floor.

PETER FARIS

Ancient Chaco residents appear to have regarded six-toed people as special. Rock art in Chaco Canyon includes these depictions of feet with extra toes.

It's not known how common it was to be born with more than five toes or fingers in the ancient U.S. Southwest. This condition affects about 2.4 of every 1,000 Native Americans today.

Footprints and handprints sporting six digits also appear on several plastered walls at Pueblo Bonito. Rock art in Chaco Canyon depicts almost 800 human feet, with anywhere from three to eight toes.

Of 13 ancient sandals recovered at Pueblo Bonito, seven include woven extensions on the outer border for a sixth toe.

Ancient cultures of Southern Mexico and Central America sometimes depicted their gods with six toes. Chaco folk probably regarded extra-toed peers as special but not divine, Crown says. Of the three six-toed individuals given the presumed honor of a Pueblo Bonito burial, only one lay in an elaborate grave. Such treatment would have applied to all three if an extra toe signified godlike status, she says.

That's a preliminary conclusion, though. Chaco residents constantly reworked and rebuilt Pueblo Bonito for more than 300 years, so deciphering precisely what happened in the great house's many rooms and at particular times is daunting.

Pinning down Chaco's origins is equally challenging, Plog says. Pueblo Bonito and many other Chaco structures were built on soil that accumulated when Chaco Canyon streams occasionally flooded. No one has looked for possible forerunners of the ancient society buried underneath all that earth.

Researchers trying to crack Chaco's secrets while burdened with so many crucial unknowns can be excused for feeling like the pregnant woman buried inside Pueblo Bonito — cut off at the knees. ■

> "Having six toes brought social honor in Chaco society."
>
> **PATRICIA CROWN**

Explore more:

- D. Kennett *et al*. "Archaeogenetic evidence reveals prehistoric matrilineal dynasty." *Nature Communications*. February 21, 2017.

The Difference Makers

Transposons sculpt our genomes, for good and bad

By Tina Hesman Saey

Face-to-face, a human and a chimpanzee are easy to tell apart. The two species share a common primate ancestor, but over millions of years, their characteristics have morphed into easily distinguishable features. Chimps developed prominent brow ridges, flat noses, low-crowned heads and protruding muzzles. Human noses jut from relatively flat faces under high-domed crowns.

Those facial features diverged with the help of genetic parasites, mobile bits of genetic material that insert themselves into their hosts' DNA. These parasites go by many names, including "jumping genes," "transposable elements" and "transposons." Some are relics of former viruses assimilated into a host's genome, or genetic instruction book. Others are self-perpetuating pieces of genetic material whose origins are shrouded in the mists of time.

"Transposable elements have been with us since the beginning of evolution. Bacteria have transposable elements," says evolutionary biologist Josefa González. She doesn't think of transposons as foreign DNA. They are parts of our genomes — like genes.

"You cannot understand the genome without understanding what transposable elements are doing," says González, of the Institute of Evolutionary Biology in Barcelona. She studies how jumping genes have influenced fruit fly evolution.

Genomes of most organisms are littered with the carcasses of transposons, says Cédric Feschotte, an evolutionary geneticist at the University of Utah in Salt Lake City. Fossils

Humans and chimpanzees look different, even though they share a primate ancestor. Jumping genes helped sculpt those distinctions.

DIAMOND IMAGES PHOTOGRAPHY/ISTOCKPHOTO; SRBOZUK/ISTOCKPHOTO

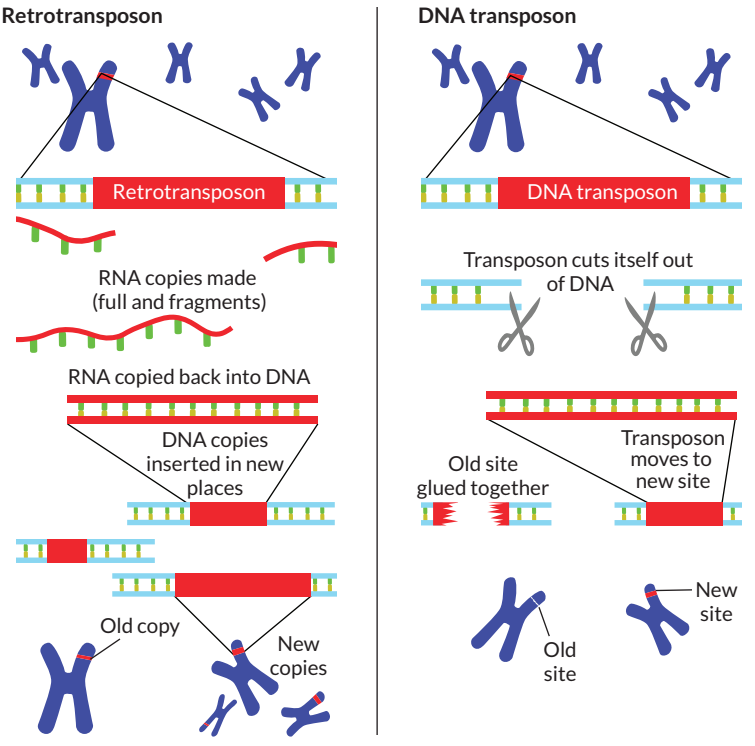
of the DNA parasites build up like the remains of ancient algae that formed the white cliffs of Dover. One strain of maize, the organism in which Nobel laureate Barbara McClintock first discovered transposable elements in the 1940s, is nearly 85 percent transposable elements (*SN: 12/19/09, p. 9*). Corn is an extreme example, but humans have plenty, too: Transposable elements make up nearly half of the human genome.

Most of the transposons in the genomes of humans and other creatures are now "dead," meaning they are no longer able to jump. The majority are in bits and pieces scattered throughout the genome like so much confetti. Many researchers used to think these broken transposons were just genetic garbage.

Far from junk, however, jumping gene remnants have been an evolutionary treasure trove. Some of the control switches transposons once used for their own hopping have been recycled over time into useful tools that help species, including *Homo sapiens*, adapt to their environments or take on new characteristics.

Repurposed transposon parts are at the very heart of what makes humans human, says Gennadi Glinsky, a cancer biologist at the University of California, San Diego. Some of the first genes to turn on in early human embryos are transposon remains that now help direct embryonic development. We humans also owe parts of our immune system, and perhaps our brainpower, to transposable elements.

"Without them, we simply wouldn't exist," Glinsky says.

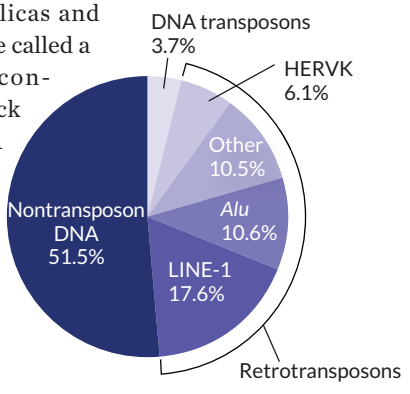


Copy or cut Transposons move in two ways: Retrotransposons first make RNA copies of themselves. An enzyme called reverse transcriptase then converts the RNA copies back into DNA, which inserts at random anywhere in the genome. DNA transposons slice themselves free from the rest of the DNA using the enzyme transposase and then hop to a new spot. SOURCE: D. LISCH/*NATURE REVIEWS GENETICS* 2013

Propagating parasites

The evolutionary benefits might delude some people into thinking that transposons are friends, but don't be fooled, Feschotte says. "They are not there to make us happy." Transposons have only ever served one purpose: to make more of themselves.

Transposons have two main ways of propagating: copy and paste or cut and paste. Retrotransposons — many of which were once RNA viruses called retroviruses — are the copy-and-pasters. They insert into an organism's DNA, get copied into many RNA replicas and then use a special enzyme called a retrotransposase to convert the RNA copies back into DNA. Those DNA duplicates can hop into different spots in the genome. Retrotransposons, the most common type of transposable element in humans, make up about 45 percent of the human genome.



Half full The human genome is nearly half jumping gene DNA. This chart shows a breakdown of the major contributors. SOURCE: INSTITUTE FOR SYSTEMS BIOLOGY

BOTH: T. TIBBITTS

Instead of making copies, DNA transposons use the cut-and-paste method to move around the genome. To hop, they slice themselves out of the DNA and move to a new location. Sometimes cells make copies of these transposons while attempting to repair damage created when the transposons sliced the DNA. But because they don't actively copy themselves, DNA transposons are greatly outnumbered by retrotransposons, making up only about 4 percent of the human genome.

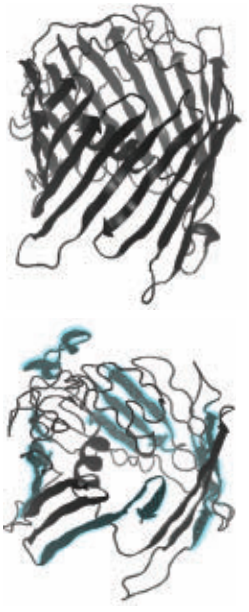
Like any invader, a live transposon can spell problems for its host. Both types of transposons may disrupt important genes as they bounce around the genome, says pathologist Kathleen Burns. As far as scientists know, there's only one living transposon left in the human genome, says Burns, of Johns Hopkins University School of Medicine. A retrotransposon known as LINE-1, or long interspersed element-1, is still hopping. It has deposited so many copies of itself that it accounts for about 18 percent of the human genome. Another transposon called an *Alu* element can't move on its own, but it gets around by hitching rides from LINE-1.

"If LINE-1 is a parasite of the genome, then *Alu* is a parasite's parasite," says John Moran, a geneticist at the University of Michigan in Ann Arbor. And a very successful one. Each person

carries more than 1 million spots where an *Alu* element has landed, leaving behind a full or partial copy of itself. All together, scattered bits and pieces of *Alu* make up about 11 percent of human DNA. "Just by sheer mass alone they've contributed greatly to the size of our genome," he says.

LINE-1 and *Alu* aren't prolific bounders. Even when they do move, most LINE-1 and *Alu* hops are inconsequential, Burns says — but not always. Scientists have long known that when LINE-1 jumps into a gene called *APC*, it can disrupt the gene and lead to colon cancer. A jump that disrupts a gene encoding a blood-clotting protein called factor VIII can cause the bleeding disorder hemophilia A. Production of one of LINE-1's proteins called ORF1p is a hallmark of cancer, Burns and colleagues reported in 2014 in the *American Journal of Pathology*.

As pancreatic tumors grow and evolve, they collect LINE-1 insertions, Burns and colleagues reported in *Nature Medicine* in 2015. On average, the pancreatic cancer patients examined in the study carried 15 LINE-1 insertions in their tumor DNA that were not in healthy tissue. Some people carried no new insertions, others had up to 65.



LINE-1 in the *TOMM40* gene can alter the gene's protein, possibly contributing to Alzheimer's and other diseases. At top is the normal protein; at bottom is the LINE-1–altered version.

Cancer isn't the only disease in which LINE-1 and *Alu* are suspects. In brain cells, *Alu* has repeatedly jumped into DNA associated with a gene called *TOMM40*. *Alu*'s shenanigans may keep *TOMM40*, which helps cellular power plants called mitochondria run, from doing its job. That could put stress on cells with weakened mitochondria, making them vulnerable to degenerative diseases such as Alzheimer's, geneticist Peter Larsen of Duke University and colleagues proposed February 24 in *Alzheimer's & Dementia*.

But transposon jumping might have a plus side. "We believe that some level of activity is important for a healthy brain," says neuroscientist and geneticist Jennifer Erwin.

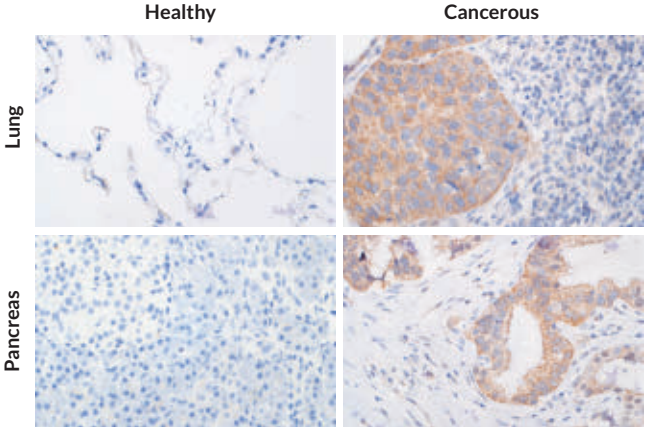
LINE-1 hops frequently in the human brain, Erwin found while at the Salk Institute for Biological Studies in La Jolla, Calif. She and colleagues examined DNA from individual brain cells taken from three donated human brains and tested bulk samples from the hippocampus (an area important for learning and memory) and the frontal cortex (where most thinking and decision making is thought to happen).

Brain cells in those areas did not have identical DNA. LINE-1 jumped to new places in some cells or was removed from places in others, the team reported last year in *Nature Neuroscience*. LINE-1 variations affect 44 to 63 percent of cells in the brain, the researchers estimated.

Some transposon hopping may be a reaction to stress, says Erwin, now at Johns Hopkins University. "We think of it as a way for the genome to adapt to unknown pressures and environments." Each jump is a bit of a gamble, with potentially good or bad consequences, she says. But rolling the dice with transposon hopping may allow brain cells to develop capabilities not initially encoded in the genome. Those new capacities may influence behavior, thinking and personality.

Glinsky goes further, contending that transposons help individualize people. Even identical twins may have genetically different brain cells because of transposon hopping after the embryo splits, he says. Thanks to jumping genes, "Every time a human baby is created, you make an individual that can never be replicated."

Most of the 950,000 or so copies of LINE-1 in the human genome are partial copies or contain mutations that put an end to their jumping. Only about 100 are full copies that actually jump. Eventually, natural selection or chance may rid the genome of damaging insertions, leaving the partial, inactive LINE-1 skeletons (or *Alu*) scattered throughout the genome. All other human transposable elements have already met that fate.



Healthy cells (left column) prevent jumping genes such as LINE-1 from turning on production of their proteins. But cancer cells (right column) make LINE-1's protein, called ORF1p (brown), which the jumping gene needs to hop. The blue color comes from a stain used to visualize cells.

Valuable fossils

Human genomes are veritable boneyards of transposon fossils. But even relics that no longer jump can still have an effect on human evolution. Some of those fossils have been passed down from very early human ancestors. Some were inherited from ancestors of all four-limbed vertebrates. Those jumping genes got stuck in the ancient host's DNA hundreds of millions of years ago. By now, their fossils are mere shards, torn apart in the natural shuffling of DNA as each generation bequeaths slightly different genetic combinations to its heirs. Some of those shards have proved useful, helping to shape important novelties, such as pregnancy in mammals (*SN Online: 1/29/15*).

FROM TOP: P.A. LARSEN *ET AL/ALZHEIMER'S & DEMENTIA* 2017; N. RODIĆ *ET AL/AM. J. PATHOL.* 2014

"These elements have a lot to do with genome innovation," says Ting Wang, a geneticist at Washington University in St. Louis. Some long-dead transposon remnants have been transformed into both small and large RNAs. Not the kind that encode proteins, but RNAs that help boost or dampen protein production and gene activity in cells, and have been linked to health and disease (*SN: 8/28/10, p. 18*). Like flea market furniture, old transposons have been upcycled into at least 409 small RNAs called microRNAs, Sheng Qin of Nanjing Normal University in China and colleagues reported in *PLOS ONE* in 2015. Other researchers have found that more than 30 percent of long noncoding RNAs — which carry out several different jobs in the cell, most still unknown — are repurposed transposable elements (*SN: 12/17/11, p. 22*). A plethora of other small RNAs were originally transposable elements themselves, but have now been co-opted to keep transposons from jumping.

RNAs aren't the only valuable salvage items humans have pulled from the transposon junk pile. Some proteins recycled from jumping gene parts have also proved extremely useful, especially for the immune system. Researchers had long suspected that two DNA-cutting enzymes called RAG1 and RAG2 are encoded by relics of a DNA transposon, but no one had ever found a transposon that uses those proteins to slice and hop out of a spot, says immunologist Anlong Xu of Sun Yat-sen University in Guangzhou, China.

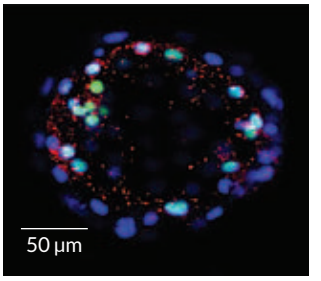
The enzymes are important because they generate antibodies and other immune proteins needed to recognize and kill an ever-changing variety of infectious organisms. Working with small, fishlike and jawless creatures called lancelets, Xu and colleagues found a DNA transposon called *ProtoRAG*, an evolutionary relative of the genes for the mammalian immune system's RAG1 and RAG2. The finding suggests the DNA transposon that gave rise to the two enzymes jumped into an ancestor of lancelets and jawed vertebrates about 550 million years ago. The transposon was passed down generation after generation until jawed vertebrates borrowed the RAG enzymes to make new immune proteins, Xu and colleagues proposed last summer in *Cell*.

Better than scratch

Perhaps the most valuable scraps in the transposable element junk heap are bits of DNA called transcription factor binding sites. Transcription factors are proteins that help control gene activity, usually turning it up a notch or two. Each type of transcription factor recognizes and binds to a certain sequence of DNA. Upon binding to DNA, transcription factors work with other proteins to stimulate the process of copying DNA instructions into RNA to ultimately make proteins.

Transcription factors control genes in complex networks reminiscent of the electronic circuits that drive computers. Such circuits would be very difficult to evolve from scratch, Wang says. Thanks to transposons, humans didn't have to.

Retrotransposons are littered with transcription factor binding sites, which might be expected for entities that make their living by getting copied into RNA over and over again. Broken transposons can provide raw materials that over time become complex gene-regulating switches. Many of the transcription factor binding sites important for controlling human and mouse genes may have come from transposable elements, research by Wang and colleagues suggests.



Some of the first proteins made in a human embryo are from a transposon called HERVK. The proteins may help protect embryos against viral infections. Here, both human DNA and HERVK are visible within a ball-shaped embryo.

DNA
HERVK transposon

E.J. GROW *ET AL/NATURE* 2015

Some of these recycled transposon bits may have helped humans fight viruses. About 45 million to 60 million years ago, a retrovirus called MER41 invaded the genome of a primate ancestor of humans. Today, humans have hundreds of copies of the now-extinct retrovirus scattered about their genomes. Other mammals, such as lemurs, vesper bats, carnivores and even-toed ungulates, have MER41 relatives in their genomes, too, Feschotte and colleagues reported last year in *Science*.

What's important about the discovery is that MER41's bits and pieces include binding sites for transcription factors involved in fighting infections. Those transcription factors are alerted to infection by an immune system chemical called interferon gamma. The researchers speculate that the retrovirus may have used the interferon gamma signal to boost its own production. But over time, the mammalian hosts turned that weapon against the virus.

By reconfiguring genetic circuits, transposons have helped to make humans uniquely human, Glinsky says. Rewiring gene activity in humans happened, in part, when transposons inserted themselves into the genomes of human ancestors after the split from chimpanzees, he reported last year in *Genome Biology and Evolution*. Remains of the transposons that infected humans have been recycled into more than a thousand regulatory switches found only in humans, he discovered.

Developmental biologist Joanna Wysocka of Stanford University has also been interested in what all the left-behind transposon bits might be doing in humans, particularly in the earliest stages of human development. Usually the DNA around jumping genes is heavily marked with molecules known as methyl groups. DNA methylation usually turns genes off — silencing them like a strip of tape across the mouth. The molecular tape also helps keep the transposons from hopping around and doing damage.

Early in development, though, the silencing tape is ripped away, leaving genes unmarked and ready for action. Some of the first genes to start expressing themselves again are former

Colorful effects

Transposons have shaped the evolution of nearly every organism on Earth. Here are just a few examples of their effects.

SOURCES: D. LISCH/*NATURE REVIEWS GENETICS* 2013; E.B. CHUONG, N.C. ELDE AND C. FESCHOTTE/*NATURE REVIEWS GENETICS* 2017

Human embryos

Two types of transposons combined to form a long noncoding RNA necessary for the development of stem cells in the human embryo's inner cell mass, which gives rise to all the cells in the body.

Peppered moths

A transposon in a gene called *cortex* causes peppered moths (top) to turn all black (bottom). The dark coloring helped moths hide on soot-covered trees during the Industrial Revolution (*SN: 6/25/16, p. 6*).

Corn

A transposon hopped into the *b1* gene of B-Peru corn strains, turning the kernels blue. A later insertion made *b1* activity variable, leading to different shades of yellow and blue kernels on the same ear.

Grapes

A retrotransposon disrupted a gene in dark Cabernet grapes, leading to pale Chardonnay fruit (shown). A later rearrangement of the gene in Chardonnay grapes kicked out the transposon, reverting grapes to colored varieties, such as Ruby Okuyama.

Oil palms

Chemical tags on a transposon called *Karma* determine whether oil palm fruit will be packed with oil (top) or dry and shriveled (bottom). When the transposon is loaded with tags, it's called *Good Karma*; untagged transposons are *Bad Karma* (*SN: 10/17/15, p. 5*).

Blood oranges

Transposons hopped into a spot near the *Ruby* gene in oranges, creating the red flesh of Tarocca blood oranges (shown). A different type, Jingxian blood oranges, are the result of a different transposon landing near *Ruby*.

viruses turned into transposable elements known as human endogenous retroviruses, particularly one called HERVK, Wysocka and colleagues found. HERVK is the youngest class of endogenous retroviruses: They were last active as viruses within the last 200,000 years. Those glory days are long gone. HERVK can no longer make infectious viruses because each copy of the virus has some mistake that renders it harmless. But some of HERVK's damaged genes can still make proteins, albeit defective ones. And some of those defective proteins may actually assemble into viruslike particles that can help protect human embryos, Wysocka and colleagues reported in 2015 in *Nature*.

Those viruslike particles may activate a primitive virus-fighting system that could help defend embryos from other, more dangerous infections before the immune system or placenta are available to do so, Wysocka thinks. That sounds like a possible evolutionary game-winner, but Wysocka says there are other options. The system "could be an evolutionary accident that human development now has to cope with," she says. But regardless of its evolutionary role, scientists need to understand what retroviruses and other transposons are doing to shape human development.

Wysocka and colleagues have found evidence of transposons sculpting human faces. The researchers used cells from humans and chimpanzees that had been reprogrammed to behave like stem cells. Those reprogrammed stem cells were then coaxed to become cranial neural crest cells, which help form the face. Examining gene activity in these cells allowed Wysocka and colleagues to do "cellular anthropology" to figure out how human and chimp facial development differs, the team reported in *Cell* in 2015.

The researchers discovered that hundreds of gene regulatory switches known as enhancers are used differently in the two species. Many of those enhancers are bits of former endogenous retroviruses, versions of LINE-1 or other retrotransposons. A recycled retrotransposon fragment that Wysocka's team calls "Coordinator" was often found at enhancers that showed variable gene activity between chimps and humans. Just a few mutations could turn a piece of old transposon into something that flips on gene activity, the researchers found. Humans evolved Coordinator mutations that are good at turning on human versions of genes, but not so great at turning on chimp genes. Chimp Coordinators, on the other hand, easily turn on chimp genes but don't work as well for human genes.

Humans' extinct relatives, the Neandertals and Denisovans, had Coordinator elements similar to those in modern humans, but a few small changes were found only in modern humans, the researchers reported. Exploring those differences could tell the researchers more about the family resemblance between modern humans and those extinct cousins.

It's hard to quantify exactly how important transposons have been to human evolution, Feschotte says. But it seems that everywhere researchers look, jumping genes have left their marks. ■

Explore more

■ Edward B. Chuong, Nels C. Elde and Cédric Feschotte. "Regulatory activities of transposable elements: from conflicts to benefits." *Nature Reviews Genetics*. February 2017.

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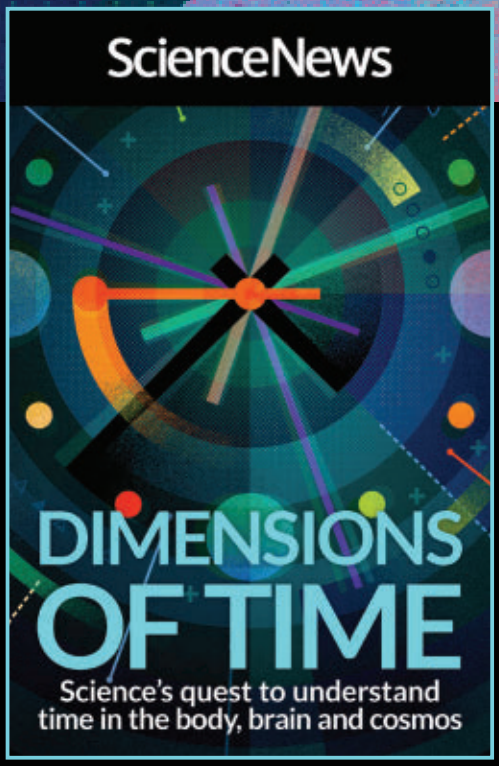

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ScienceNews

A new exhibit at the Musée de l'Homme in Paris asks visitors to confront their own prejudices. This "category cylinder" highlights the psychological tendency that people have to classify other people into discrete categories.

EXHIBIT

Science seeks to explain racism

In a famous series of experiments conducted in the 1970s, social psychologist Henri Tajfel asked how little it would take to persuade one group of people to discriminate against another. The answer was almost nothing. Having assigned boys to two groups based largely on random criteria, he asked them to play a game. Each boy had to decide how many pennies to give to members of his own group and to members of the other group. Tajfel found that the boys were more generous toward their own group, even though the groups had been defined almost arbitrarily. Thus was born the concept of the "minimal group."

Tajfel's research informs a new, temporary exhibit at the Musée de l'Homme in Paris. Titled "Us and Them," the exhibit explores the science of racism and prejudice. The question at its heart is why, when biologists have swept away the rationale for categorizing humans by race, does racism persist? The exhibit draws on genetics, history, psychology, sociology and anthropology to answer that question. And in both its content and its structure, "Us and Them" reminds visitors how far society has come since the second half of the 20th century, when UNESCO declared that there was no biological basis to race and that the concept was purely a social construct.

"Us and Them: From Prejudice to Racism"
THROUGH JANUARY 8, 2018
MUSÉE DE L'HOMME | *Paris*

The multimedia, interactive exhibit, presented in both French and English, is divided into three parts. The first is designed to make people question their own prejudices by explaining the psychological concept of essentialism. Essentialism is the tendency we have, as we move through and classify a complex world, to reduce others to a single descriptor ("woman," "black," "immigrant"), thus making it easier to navigate that world. A mock-up of an airport lounge, in which passengers walk through differently labeled doors, reveals how context-dependent that choice of descriptor is. Having been confronted with the idea that a person may belong to more than one group, visitors are then forced to reflect on whether fixed groups — including races — with measurable differences between them even exist.

The exhibit moves on to explore how race has been constructed in different societies at different times in history and how those constructs have been taken up by states to justify institutionalized racism. It does so through a few 20th century examples, including Nazism in Europe and the Rwandan genocide of the 1990s. To learn about each one, visitors must enter a windowless, claustrophobic enclosure, re-creating what it feels like to be on the receiving end of that racism.

The final part of the exhibit brings the story full circle by asking what racism means today. It is only at this point that genetics enters the discussion. Visitors are reminded that, from geneticists' perspective, human races don't exist. For instance, there is roughly the same genetic difference between two Europeans from the same village as there is between a European and an African. The visible differences between us are the cumulative result of genetic, environmental and cultural influences over long periods of time, but rarely do we consider these factors together, which can lead to discrimination on the basis of one or another. A "data room" displays recent statistics illustrating that discrimination, by showing, for example, that the children of immigrants to France enjoy fewer employment opportunities than people whose parents were born there.

Resisting racism is part of the Musée de l'Homme's own history. Not long after the museum first opened in 1937, France was drawn into the maelstrom of Nazi aggression. Researchers at the museum set up a resistance cell that was eventually discovered and dismantled in 1941, after which its members were either executed or deported. Indeed, it was around that time that the term "racism," as it is now understood, entered common usage in Europe in response to Nazi anti-Semitism.

"Us and Them," which coincides with an influx of refugees into Europe and renewed debate over immigration in the United States, could not be a timelier reminder that racism is still a problem. The exhibit treats a difficult subject with sensitivity and intelligence, bringing the latest scientific findings to bear and explaining why we will always have to be on guard against our inherent tendency to see black and white where there is only gray. — *Laura Spinney*

Passing a love of science through generations

Grandfather and grandson both competed in Science Talent Search

Sometimes, the love of science threads its way through generations of a family, like inherited traits through DNA or lines of code from a cascading style sheet passing on rules to others. This is especially the case for Aaron Yeiser, who won the second place award at the 2017 Regeneron Science Talent Search.

His father and grandparents work in computer science, technology and chemical engineering.

"I was encouraged to pursue a STEM career because of Papa," Yeiser said. His grandfather, Frank Sandy, was an STS finalist in 1954, when the competition was sponsored by Westinghouse.

"I've been very impressed by the things he's built," Sandy said of Yeiser's interest in building drones and other STEM activities.

Yeiser has always been interested in math. Differential equations came along when he attended MIT-PRIMES USA, a mathematical research program for high school students.

Current methods of doing numerical simulations can be very inefficient when trying to get precise results. "So I developed a new method that is a much more efficient way to get precise results," Yeiser said. His algorithm has applications in fluid dynamics and precision computing in physics. This could lead to better airplanes and possibly better artificial heart pumps, he explained.

For Sandy's 1954 STS project, he focused on new methods for solving complex cubic equations. There is a very nice formula for quadratic equations that people learn in algebra. But for cubic equations, there was a "horribly complicated" method, so Sandy created his own technique.

"I've been interested in science all my life," Sandy said. "Even in elementary school I played around with electrical wiring and had my bedroom all wired up with batteries and light switches attached to my bed. It was a lot of fun."

Yeiser encourages others who are interested in STEM to look for any opportunity to get involved in research, like through universities. And "don't blow off English class, because good communication is just as important as your actual research," he said.

"Everyone has an interesting story to tell," Yeiser said. "It's encouraging that in the future I might be working with some of the other finalists."

Read more: www.societyforscience.org/content/ssp-blog/passing-love-science-through-generations

APRIL 15, 2017

SOCIAL MEDIA

Space pasta

NASA's Cassini spacecraft captured the closest images ever taken of Pan, a small moon that orbits Saturn among the planet's rings. The moon bears a striking resemblance to ravioli thanks to its distinct ridges and smooth, round shape, **Helen Thompson** reported in "Saturn's moon Pan looks like ravioli" (*SN: 4/15/17, p. 10*). Readers on Facebook weighed in on Pan's odd appearance.

A turtle's shell
Adrian Maestas

Buster Keaton's hat
Roelof Mercury

Its core is a blend of molten cheese and spinach
Michael Neeland

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At random

As cells divide and grow, mutations may crop up in cancer-associated genes. A recent study found that more cancer mutations are caused by these random mistakes than other factors, such as environment or inheritance, ***Tina Hesman Saey*** *reported in "DNA errors play big role in cancer"* (SN: 4/15/17, p. 6).

John Day wondered if replication errors are truly random, not just unpredictable. And he questioned whether all cancers not known to be caused by inherited genes or the environment must be caused by replication errors. "Isn't it plausible that many or most of the cancers attributed to replication errors in this study involve genetic or environmental factors that are too ubiquitous to be identified as such?" **Day** asked.

Random in this case means that the mutations can happen anywhere in the genome. There are no particular hot spots for mutation, and these errors are not being directed by other factors. "It is unpredictable in that sense, and the type of damage done to the DNA is also random," **Saey** says. DNA damage caused by replication errors includes copying mistakes, insertions or deletions of DNA, and chemical changes that alter the DNA's message. "The key here is that something happens to the DNA in the cell, and that damage is replicated and passed on to subsequent cells. There are still many mysteries surrounding cancer, and this study is the researchers' attempt to quantify the sources," **Saey** says.

"In the past, the causes of mutations that couldn't be attributed to environment or heredity were indeed 'unknown,' " study coauthor **Cristian Tomasetti** says. Those unknown causes were generally assumed to be related to hereditary and environmental factors yet to be discovered. "One of the key points of our paper is that a large portion of them are no longer unknown; we have an explanation," he says. Random mistakes account for approximately three mutations each time a cell divides, the researchers found.

Many moons ago

The moon may have formed when a young Earth was whacked by a protoplanet named Theia. Or it could have formed from a string of impacts that created miniature moons that eventually merged. Both ideas are getting new scrutiny, ***Thomas Sumner*** *reported in "How Earth got its moon"* (SN: 4/15/17, p. 18).

"If the moon was the result of a long series of impacts from objects each about a hundredth to a tenth of Earth's mass, over tens of millions of years, then why do Mars and Venus not have similar moons?" asked **Tim Cliffe**. "How could Earth have been subject to such a bombardment while the other terrestrial planets were somehow immune?"

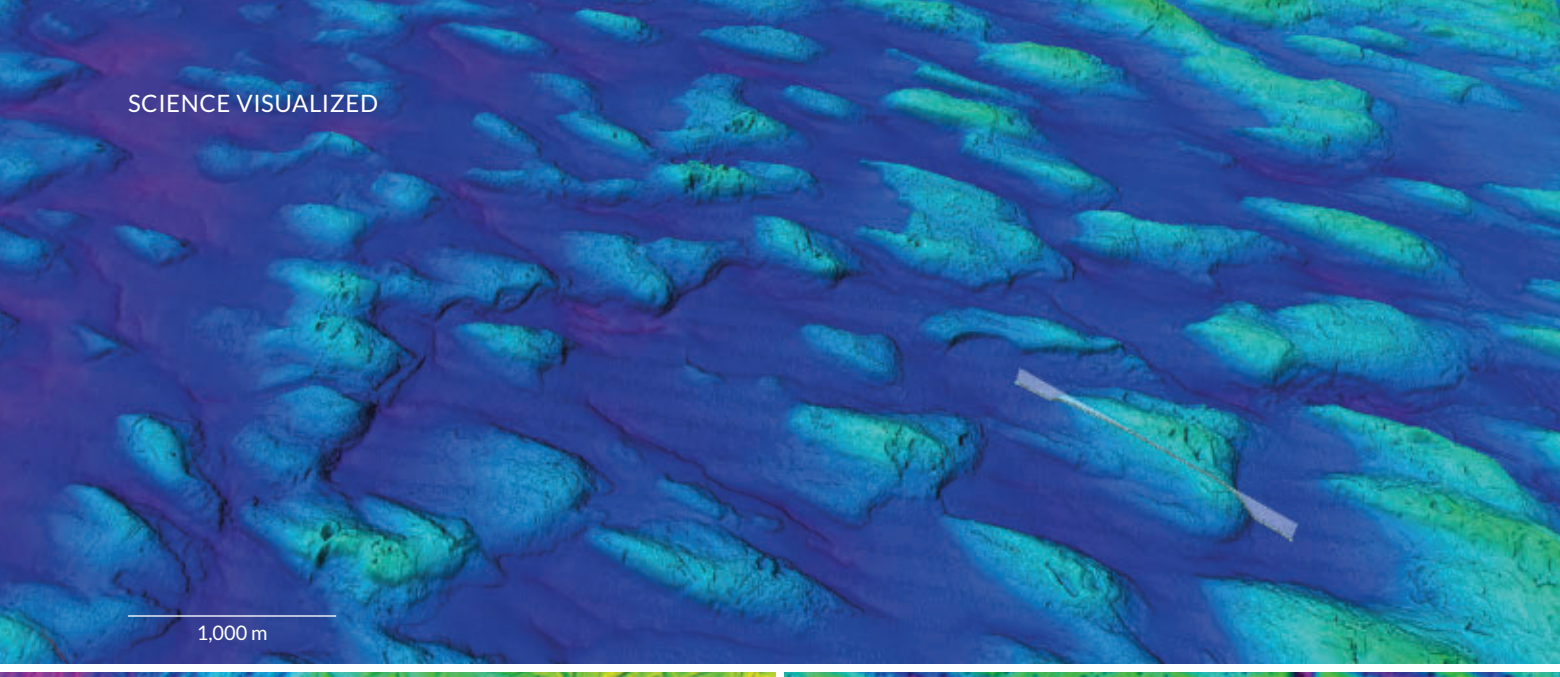
Earth's neighbors were not immune to impacts. But each planet's unique history may have shaped moons differently or prevented them from forming altogether, **Sumner** says.

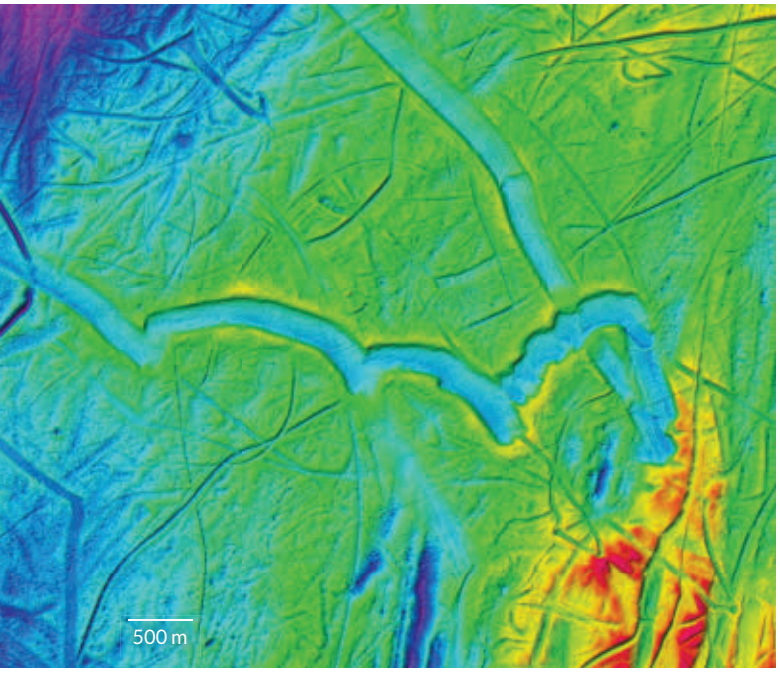
Venus may have had a moon at one point, but it was probably lost as the moon's orbit around the planet accelerated. Or perhaps the moon merged with another space rock that escaped Venus' orbit, says planetary scientist **Raluca Rufu** of the Weizmann Institute of Science in Rehovot, Israel.

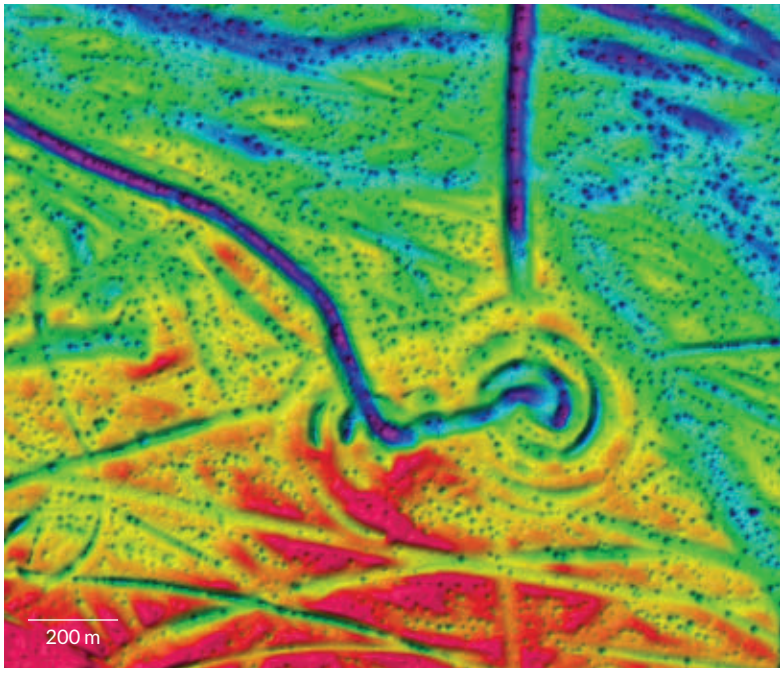
Unlike Venus, Mars has two moons. But Phobos and Deimos, among the smallest moons in the solar system, look more like misshapen asteroids than Earth's moon, **Sumner** says. A large impact that may have contributed to the planet's low-lying northern hemisphere could have formed the moons, **Rufu** points out. And in the southern hemisphere, a steady stream of impacts transformed the landscape.

Correction

On May 3, 2017, *Science* retracted the study described in "Tiny plastics cause big problems for perch, lab study finds" (*SN: 6/25/16, p. 14*). Based on findings from an independent review board in Sweden, *Science* pulled the study because: The experiments lacked ethical approval, the original data could not be provided and questions emerged about experimental methods.







Ghostly glimpses of Earth's glacial past

The footprints of long-gone glaciers and icebergs are now frozen in time in a stunning new collection of images of Earth's seafloor.

The Atlas of Submarine Glacial Landforms is a comprehensive, high-resolution atlas of underwater landscapes that have been shaped by glaciers, largely in polar and subpolar regions, and provides a comparative look at how glaciers, ice and related climate shifts transform Earth. Kelly Hogan, a marine geophysicist with the British Antarctic Survey and an editor of the atlas, presented it April 26 in Vienna at a meeting of the European Geosciences Union.

Most of the more than 200 images were generated from research vessels using multibeam bathymetry, which renders the seafloor surface in 3-D, exposing a region's glacial history. For example, the distinctive asymmetry of 20,000-year-old glacial deposits called drumlins (top, darker shades indicate greater depth) in the Gulf of Bothnia, between Finland and Sweden, suggests that ice flowed south, toward a larger glacier in the Baltic Sea.

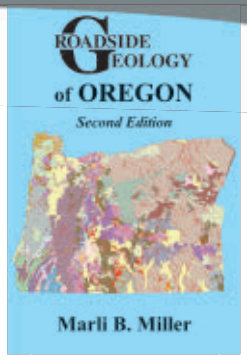
Other images reveal the tracks of icebergs that once plowed and scribbled the ocean floor, such as those seen in the Barents Sea in the Arctic Ocean (bottom two). The tracks may look random, but they tell tales of past currents and water depth.

In all, the seafloor depicted in the atlas covers an area about the size of Great Britain. But the real impact of the project goes beyond individual images, Hogan says. She expects that scholars exploring glacial history, researchers predicting future ice behavior and climate scientists will keep a copy close at hand. — *Beth Geiger*

ALL: ATLAS OF SUBMARINE GLACIAL LANDFORMS

See a slideshow of seafloor images at **bit.ly/SN_SeafloorAtlas**

GEOLOGIC ROAD TRIP OF THE MONTH



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SMITH ROCK STATE PARK

Smith Rock State Park, a mecca for hikers and rock climbers, hosts spires and cliffs, many of which have weathered into fantastic shapes. The rock is volcanic tuff of the John Day Formation, erupted during a caldera-forming explosive event just over 29 million years ago. This eruption, as well as others from the same volcanic field, likely also produced the tuff for many of the colorful beds elsewhere in the John Day Formation, such as at Painted Hills.

The Crooked River separates the tuff of Smith Rock from a flat bench of basalt immediately to the south. This lava flow originated about 400,000 years ago from Newberry Volcano, some 40 miles (64 km) south of Smith Rock, and is one of the volcano's most far-traveled flows. The basalt abuts the high towers of Smith Rock, indicating the tuff formed a barrier to its flow.

Researchers used to think that the tuff formed as part of an isolated volcano, but they now recognize it as part of the much larger Crooked River Caldera, which measures some 15 miles (24 km) across at its narrowest and about 25 miles (40 km) across at its widest. The caldera dwarfs Crater Lake, which measures only about 6.2 miles (10 km) at its widest. Smith Rock State Park occupies the northwestern edge of the caldera, and its tuff can be followed along the edge of the caldera to the southeast more than 10 miles (16 km) beyond Prineville. Altogether, the tuff's volume measures about 200 cubic miles (830 km^3). Researchers argue that the tuff formed during collapse of the caldera because they observe that the thickest portions of it lie within the caldera.

Climbers ascend the tuff at Smith Rock.

The Crooked River flows past 29-million-year-old tuff at Smith Rock State Park. A bench in the left foreground is Newberry basalt. The tower on the right side of the photo is a rhyolite dike.

Tuff contains pumice, which is frothy glass expelled violently during an eruption. Much of the Smith Rock tuff contains unusually large fragments of pumice, a consequence of forming within the actual caldera and not having traveled far. In some places, the tuff also contains lens-shaped layers with abundant rock fragments, a few of which consist of Permian-age limestone. The basement rock here may be Permian limestone, with these limestone fragments being brought to the surface by the erupting magma.

The towers and unusual rock shapes at Smith Rock form by differential erosion. Parts of the tuff are more resistant than others and form promontories while the surrounding material erodes. In some places the rock is more resistant because it was hotter and welded together more strongly. In other places, it's more resistant because it has fewer fractures for water to infiltrate. Elsewhere, a weathering process called case hardening made the rock more resistant. This process involves the precipitation of a protective material—zeolite minerals at Smith Rock—over the exposed bedrock. In still other places, more-resistant rhyolite dikes intrude the tuff and form spines and towers. These dikes show that volcanism continued after caldera collapse. Numerous rhyolite domes intruded the caldera around its margin. These domes include Gray Butte, which forms the skyline behind Smith Rock, and Powell Buttes, visible from OR 126 between Redmond and Prineville.

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