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SOCIETY UPDATE
Science News arrives in China

COVER Although approved for sale in late 2015, genetically modified salmon may take over a year to reach stores. *Aluxum/iStockphoto*

CLOCKWISE FROM TOP: TRI ALPHA ENERGY, INC.; NICK HOBGOOD/WIKIMEDIA COMMONS (CC BY-SA 3.0); ERICK SETIABUDI

Powerful rhetoric can overlook important details

Broad generalizations can provide for powerful rhetoric. Whether discussing a moonshot to cure cancer or the merits of genetically modified foods, the strongest statements lump distinct things together — the dozens of types of cancer, for instance, or the myriad crops that scientists have genetically altered. But broad statements about the value or risks from genetically modified organisms are pretty much useless, Rachel Ehrenberg reports on Page 22. The details matter.

More than two-thirds of foods sold in the United States involve some GM product, estimates suggest. Years of study have revealed little reason for concern about human health. Other research shows that, ecologically, certain GMOs can have less than desirable impacts. But many effects can be predicted and worked around. GM salmon, for example, run the risk of interbreeding with native salmon. That's why they are being raised in tanks far from salmon streams. Strict regulation of each proposed GM product — examining the details of its impacts — can be an effective way to deal with the potential risks. Another detail to consider in assessing risks is how they compare with benefits, such as the potential to increase large numbers of people's food supplies and improve their health.

Food is a place where science meets society; another science-society interface is the world's need for cheap, abundant energy. On Page 18, Alan Boyle takes readers on a tour of private sector efforts to develop nuclear fusion for generating electricity. These approaches offer alternatives to the much larger government-funded fusion projects, which have yet to succeed. But fusion's promise is huge, so it's worth risking a few failures. Only by actually trying to get the technology to work will researchers know if it's viable or not.

Keeping it simple is a good strategy for communicating complex ideas — an important principle guiding our reporting at *Science News*. But we always walk the line between simplifying for understanding and losing so much detail that the essence of the story is muddled. That's something to keep in mind when talking about GMOs, or nuclear fusion, or even a singular cure for cancer. — *Eva Emerson, Editor in Chief*

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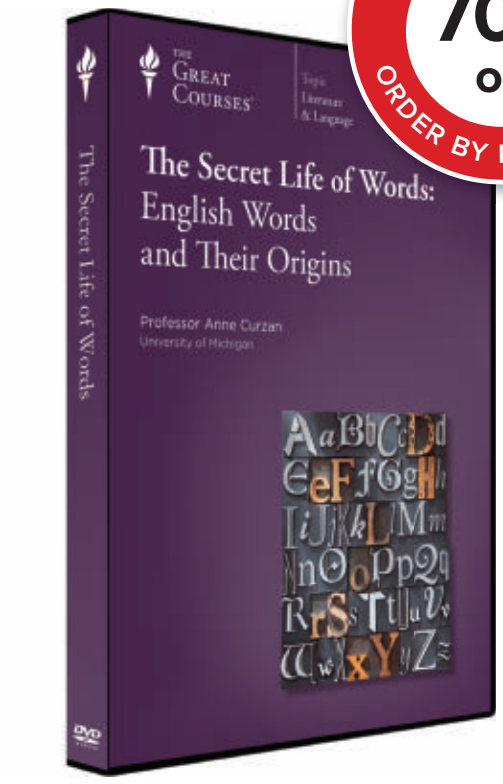

Uncover the Secret Life of Words

If it seems as if English is changing all around you, you're right. It's evident in newer words such as "bling" and "email," and from the loss of old forms such as "shall." But does this mean our language is in decay—or is change just the natural order of things? **The Secret Life of Words** answers this question by presenting the fascinating history behind the everyday words in our lexicon.

Award-winning Professor Anne Curzan of the University of Michigan—a member of the American Dialect Society and the *American Heritage Dictionary*'s usage panel—approaches the subject like an archaeologist, digging deep below the surface to unearth the remarkable story of English, from its Germanic origins to the rise of globalization and cyber-communications. Packed with surprising insights, these 36 delightful lectures reveal how culture has evolved over the centuries and why there is no such thing as a boring word.

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24. Wicked Cool—The Irreverence of Slang
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26. Spinster, Bachelor, Guy, Dude
27. Firefighters and Freshpersons
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Excerpt from the February 5, 1966, issue of *Science News Letter*

50 YEARS AGO

‘Quarks’ may be source of quasars’ energy

The mysterious nuclear particles called “quarks,” which have not yet been detected but might nevertheless be basic building blocks of the atom’s core, could be the source of the tremendous energy generated by the puzzling star-like objects known as quasars.... Quarks, if they exist, would have a charge either one-third or two-thirds that of an electron ... [and] masses of at least five billion electron volts.

UPDATE: Experimental evidence of quarks first came in 1968 from scientists smashing together subatomic particles at the Stanford Linear Accelerator Center. By 1995, researchers had identified six quark “flavors”: up, down, strange, charm, bottom and top. Quarks are a core ingredient of atoms. But they are not responsible for the huge energy outputs of quasars (which are more like galaxies than stars). Quasars are probably fueled by black holes. Although all quarks have a charge that is either one-third or two-thirds an electron’s, only the top quark is as heavy as the 1966 prediction.

These technicolor trees aren’t plants. They’re the gills of Christmas tree worms, which hide below in tubes within the coral.

IT’S ALIVE

Gills gone visionary

Christmas tree worms have eyes “in a really silly place,” says Michael Bok. Which is part of their charm.

This widespread marine worm (*Spirobranchus giganteus*) gets its holiday nickname from its gills: a wildly colored pair of tapering, feathery spires that protrude from the top of the worm’s buried retreat like ornamental trees. Bok, of Lund University in Sweden, says he has seen worm gills in red, orange, blue, yellow — even stripes.

When a shadow looms, the Christmas tree gills drop down into the protective tube where the rest of the worm hides. Yet the eyes that check for scary things lie beneath the branches like forgotten presents. To see the bright orange compound eyes, “you have to kind of sneak up on them and look at them from the right angle,” Bok says.

Orange compound eyes are easier to spot in a young Christmas tree worm with sparse gills.

That tucked-under spot limits what those eyes can do, because they can only see directly in front or behind. To human thinking, the top of a tree seems a better place for lookouts, and another kind of fan worm does grow compound eyes there.

But Bok relishes the way the gill eyes in Christmas tree worms and other fan worms seem so improvised, such odd mixes of features cobbled together. “These things are their own evolutionary tangent,” he says.

Bok is exploring fan worms’ barely studied vision, possibly the only case of animals growing eyes on their gills. Fan worms have some rudiments of a more typical visual system. Like other worms, some have patches of light-catching compounds on the segments of their bodies, even their tails, and a lump of light-sensitive tissue in their heads that monitors light-dark rhythms. But hiding in tubes, those visual bits seem useless for detecting danger. So the gills, which also double as feeding tentacles, went visionary. Evolution scattered them with light-catching molecules or even eyes.

This took some doing. The nerves from these gill eyes don’t go to the usual optic section of the brain. They connect to another, less-characterized area not usually thought to be involved in vision. And the light-sensitive opsin proteins in the eyes aren’t typical eye compounds, Bok is finding. They are a form of opsin hardly ever found outside the brain.

Even the fanciest of these gill-based eyes, like those in the Christmas tree worm, may just detect scary shadows. But that’s a lot. Without their make-do warning systems for predators, Bok says, “they’d get their gills and ‘mouth’ ripped off all the time.” — *Susan Milius*

FROM TOP: NICK HOBGOOD/WIKIMEDIA COMMONS (CC BY-SA 3.0); MICHAEL BOK

MYSTERY SOLVED

Plesiosaurs swam like penguins

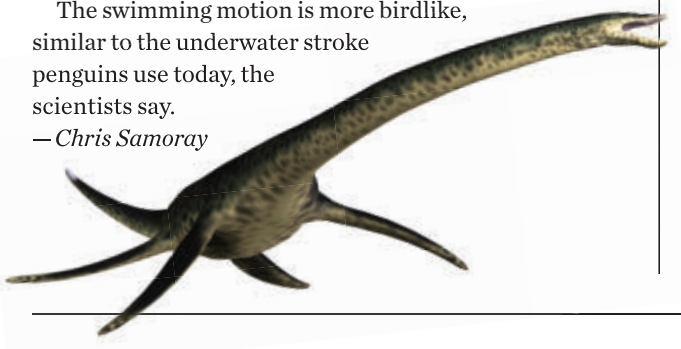
Fossil hunter Mary Anning's 1823 discovery of the first complete plesiosaur skeleton led to more than 190 years of arguing. Some claimed the marine reptile used its four flippers like the oars of a boat. Others countered that the flippers flapped through the water like bird wings.

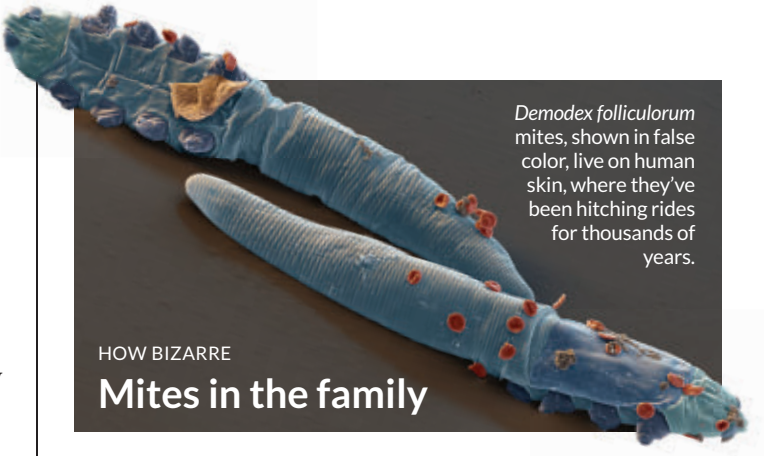
Experiments with robots and even humans wearing plesiosaur-like flippers only fanned the flames. But a new computer model may finally lay the controversy to rest.

Computer scientist Greg Turk of Georgia Tech in Atlanta and colleagues ran thousands of simulations to find the limb motion that could best propel the creatures forward. Plesiosaurs didn't flap with all their flippers, nor did they use only their rear flippers to swim, the simulations suggest. Instead, plesiosaurs powered ahead with their two front flippers, using the two back ones like a boat's rudder to maneuver and maintain stability, the team proposes online December 18 in *PLOS Computational Biology*.

The swimming motion is more birdlike, similar to the underwater stroke penguins use today, the scientists say.

— Chris Samoray





Demodex folliculorum mites, shown in false color, live on human skin, where they've been hitching rides for thousands of years.

HOW BIZARRE

Mites in the family

For the tiny mites that live on our faces (*SN: 10/18/14, p. 4*), choosing a landlord may be a family matter.

Researchers identified four lineages of microscopic *Demodex folliculorum* mites living on the foreheads, cheeks and noses of 70 volunteers. People with different geographic ancestry hosted different mixes of mites. Participants of Asian and European descent harbored fewer types of mites than people with Latin American and African ancestry. The differences probably reflect historical patterns of human migration, the researchers report in the Dec. 29 *Proceedings of the National Academy of Sciences*.

Within families, parents and adult children tended to share mites with similar genes, indicating that *D. folliculorum* is spread by close physical contact.

Mites may have evolved alongside humans for hundreds of thousands of years, the researchers suggest. These facial occupants could be used to study the global travels of ancient humans. *— Sarah Schwartz*

THE NAME GAME

Name that world

Step aside Venus and Neptune, our solar system is no longer the only one whose planets have catchy names. In December, the International Astronomical Union announced the winners of a contest to name the planets and suns of 20 systems (*SN: 10/3/15, p. 5*). Exoplanet enthusiasts in 182 countries and regions cast over 573,000 votes. Here are five favorites along with a few names that didn't quite fly. *— Christopher Crockett*

The planets of the Mu Arae system, illustrated, are now named from an influential work of Spanish literature.

Winning name(s)	Relevance	Losing name(s)
Arion (was 18 Delphini b)	Greek poet who wrote of being rescued from pirates by a dolphin, appropriate for a planet in the dolphin constellation	Maru, a large baby from an old Japanese story
Copernicus, Galileo, Brahe, Lippershey, Janssen, Harriot (was the star 55 Cancri and its five planets)	Astronomers and telescope makers from Poland, Italy, Denmark, Germany, Holland and England	Aregak, Arusyak, Hrat, Yerevak, Paylatzu and Lusntag, Armenian names for the sun and the five planets of our solar system visible to the naked eye
Hypatia (was Iota Draconis b)	4th century Egyptian mathematician, astronomer and philosopher	Misopan, a soy-based Japanese dessert
Poltergeist (was PSR 1257+12c)	Mischievous spirit that disturbs its environment, much like this planet disturbs the steady beat of its pulsar sun	Andie, in combination with suggested names for neighboring planets, Rockie and Rollie, would have made for a Rockin'-And-Rollin' system
Sancho (was Mu Arae e)	Squire of Cervantes' Don Quixote	Noisy Rhysling, a character in Robert Heinlein's "Green Hills of Earth"

FROM TOP: EYE OF SCIENCE/SCIENCE SOURCE; CATMANDO/SHUTTERSTOCK; EUROPEAN SOUTHERN OBSERVATORY

Watch a plesiosaur's simulated swim at **bit.ly/SN_plesiosaur**

GENES & CELLS

Human body not overrun by bacteria

New calculation suggests people's cell counts are about 50-50

BY TINA HESMAN SAEY

Human bodies don't contain 10 times as many bacterial as human cells, new calculations suggest.

A "standard man" weighing 70 kilograms has roughly the same number of bacteria and human cells, researchers report online January 6 at bioRxiv.org. This average guy would be composed of about 40 trillion bacteria and 30 trillion human cells, calculate researchers at the Weizmann Institute of Science in Rehovot, Israel, and the Hospital for Sick Children in Toronto. That's a ratio of 1.3 bacteria to every one human cell.

That estimate could be off by as much as 25 percent, with the average number of bacteria ranging from 30 trillion to 50 trillion. Among individuals, the bacterial count could vary as much as 52 percent, say Ron Sender, Shai Fuchs and Ron Milo. With a fudge factor of 10 trillion to 20 trillion bacteria, the number of microbes may pretty well match the number of human cells in the body, which also varies somewhat. "Indeed, the numbers are similar enough that each defecation event may flip the ratio to favor human cells over bacteria," the researchers write.

Scientists who study the microbiome, the collection of microorganisms that live in and on the human body, have peppered research papers with an estimate that bacteria outnumber human cells 10-to-1 (*SN: 6/18/11, p. 26*) or even 100-to-1. In recent years, those estimates have come into question, with the American Academy of Microbiology suggesting in 2013 that the real figure is probably closer to three bacterial cells for each human cell.

Judah Rosner, a molecular biologist at the National Institute of Diabetes and Digestive and Kidney Diseases in Bethesda, Md., called the 10-to-1 ratio a "fake fact" in a 2014 issue of *Microbe*. It probably wormed its way into scientific literature because it sounds good, he says. "Everybody likes a nice, round number. And it had such impact. It was good PR." But Rosner and others wondered where the number had come from.

Sender and Milo, of the Weizmann Institute, and Fuchs, now at the Hospital for Sick Children, traced the figure to a single back-of-the-envelope calculation in a 1972 paper. The researchers then combed the scientific literature to come up with their own estimates.

Plenty of cocktail party fodder is buried in the results. For instance, the team finds that red blood cells are the most numerous cells in the body, accounting for 84 percent of cells. By weight, muscle and fat are the heavy hitters, making up 75 percent of cell mass. But those cells tend to be big and represent only about 0.2 percent of the human body cell number. As expected, most of the bacteria — about 39 trillion — live in the colon.

Women tend to have smaller blood volume than men, so their bacterial-to-human cell ratio may be about 30 percent higher, the researchers calculate. Growing children probably fall within the range of bacterial-to-human cell ratios of adult men. Obesity doesn't change the ratio much, the team calculates.

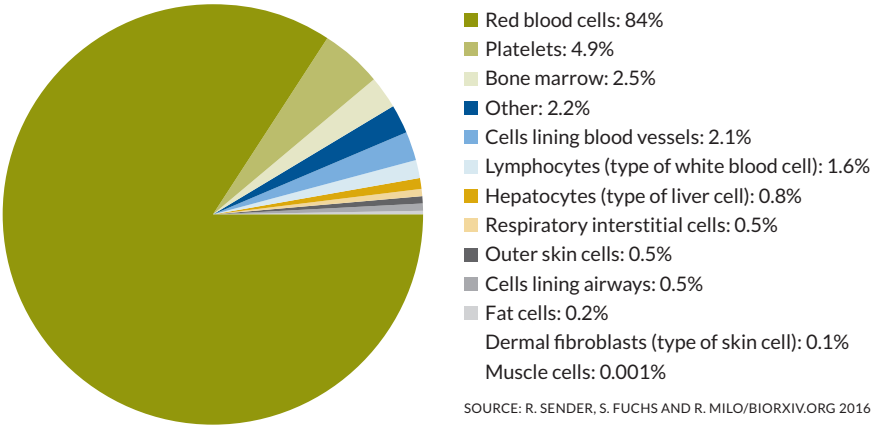
These estimates haven't been checked by other scientists yet, but microbiome researchers say they appreciate the effort. "Anytime people can add more precision it's good," says microbiologist Martin Blaser of New York University School of Medicine. The researchers didn't do any experiments, and Blaser says others should begin actually measuring bacterial and human cell numbers to get an even more accurate number.

Other researchers point out that the calculations considered only bacteria, while viruses, fungi, archaea and other microbes are also part of the human microbiome. Viruses vastly outnumber bacteria (*SN: 1/11/14, p. 18*) and could skew the microbe-to-human cell ratio upward if included, says geneticist Julie Segre of the National Human Genome Research Institute in Bethesda, Md.

Most microbiome research has focused on how relative amounts of bacteria change between health and disease, but scientists don't yet know whether absolute abundance of bacteria is important, says microbiologist Ran Blekhman of the University of Minnesota, Twin Cities.

The reduced ratio in no way diminishes the effect bacteria have on health. Several commenters said it doesn't matter what the real number is, just that it's right. Besides, even "1-to-1 is pretty impressive," Rosner says. "There's as much of them as there is of us." ■

Breakdown of human cells in the body



SOURCE: R. SENDER, S. FUCHS AND R. MILO/BIORXIV.ORG 2016

Cell count An average adult man's body has about 30 trillion human cells, most of them red blood cells. Although only a small percentage, fat and muscle cells account for most cell mass.

HUMANS & SOCIETY

Mystery hominid settled Sulawesi

Stone tools point to early colonization of remote island

BY BRUCE BOWER

Toolmakers ventured from Southeast Asia to the Indonesian island of Sulawesi deep in the Stone Age, far earlier than previously thought and probably before *Homo sapiens* originated in Africa 200,000 years ago, researchers say.

The discovery of ancient stone tools on Sulawesi, some of which date to a minimum of 194,000 years ago, also renews speculation about the evolutionary background of *Homo floresiensis*. Better known as the hobbit, *H. floresiensis* was a diminutive hominid that lived roughly 500 kilometers south of Sulawesi on the island of Flores at around the same time the Sulawesi tools were made.

"I wouldn't be surprised if *H. floresiensis* or a closely related lineage was responsible for the Sulawesi artifacts," says Harvard University archaeologist Christian Tryon, who did not participate in the new excavations. But the Sulawesi finds look much like stone tools made over the last 1.8 million years by several hominid species at sites throughout Southeast Asia, Tryon cautions. What's certain, he says, is that Sulawesi hominids fractured stones to make sharp-edged cutting implements.

Hominids left stone tools at four sites located by a team led by archaeologist Gerrit van den Bergh of the University of Wollongong in Australia. Excavations at one site, Talepu, unearthed 315 securely dated stone artifacts. These sharp-edged rocks range in age from at least 194,000 years ago to about 118,000 years ago, the team reports in the Jan. 14 *Nature*. Age estimates for the finds rest on calculations of the time since artifact-bearing soil was last exposed to sunlight.

Sulawesi and Flores are the only islands in the area known to have hosted hominids before modern humans reached several islands further east and Australia between 60,000 and 40,000 years ago. *Homo sapiens* arrived on Sulawesi roughly 40,000 years ago (*SN: 11/15/14, p. 6*).

Previous excavations on Flores led by study coauthor Adam Brumm of Griffith University in Nathan, Australia, uncovered 1-million-year-old stone tools made by presumed hobbit ancestors. Artifacts and fossils attributed to hobbits range in age from around 190,000 to 12,000 years ago.

No hominid fossils have been found with Sulawesi's artifacts, leaving the toolmakers' identity a mystery.

But several candidates exist, the researchers say. Hobbits or their ancestors may have floated over from Flores, as Tryon suggests. Neandertal-like Denisovans — a Stone Age population that lived in East Asia and left a genetic legacy in New Guinea, Melanesia and Australia (*SN: 11/5/11, p. 13*) — can't be excluded. Or *H. sapiens* might have trekked from Africa shortly after evolving there.

There's still another option. "I think *Homo erectus* is the most likely candidate," van den Bergh says. *H. erectus* fossils range in age from 1.5 million to 140,000 years ago on nearby Java, which was connected to Asia when sea levels periodically receded in the Stone Age.

Ancient *H. erectus* colonizers probably didn't navigate the ocean in canoes or other vessels, van den Bergh holds. Instead, occasional tsunamis could have washed small numbers of *H. erectus* into the sea from Southeast Asia's coast, he suggests. Southerly currents would have pushed castaways floating on vegetation or debris to Sulawesi. Accidental journeys of that kind probably explain how extinct elephants and other animals, known from fossils, ended up on Sulawesi more than 200,000 years ago, van den Bergh adds. ■

These stone artifacts found on the Indonesian island of Sulawesi were made by hominids that probably made ocean crossings from mainland Asia by 194,000 years ago, scientists report.

ERICK SETIABUDI

MATTER & ENERGY

Periodic table gets 4 more elements

Naming rights go to U.S., Russian and Japanese scientists

BY ANDREW GRANT

The seventh row of the periodic table is officially full with the addition of four new elements.

On December 30, the International Union of Pure and Applied Chemistry announced that a Russian-U.S. collaboration had sufficient evidence to claim the discovery of elements 115, 117 and 118. IUPAC awarded credit for the discovery of element 113 to scientists at RIKEN in Wako, Japan (*SN Online: 9/27/12*). Both groups synthesized the elements by slamming lighter nuclei into each other and tracking the decay of the radioactive superheavy elements that followed.

Researchers at the Joint Institute for Nuclear Research in Dubna, Russia, and Lawrence Livermore National Laboratory in California, which are among the institutions credited with elements 115, 117 and 118, had also laid claim to element 113 after experiments reported in 2004 (*SN: 2/7/04, p. 84*) and 2007. But garnering recognition for the three other elements softened the blow, says Dawn Shaughnessy, who leads the experimental nuclear and radiochemistry group at Livermore. "I'm personally very happy with IUPAC's decision," she says.

Published reports on the newly recognized elements will appear early this year, says IUPAC executive director Lynn Soby. Official recognition of the elements means that their discoverers earn the right to suggest names and symbols. Element 113 will be the first element discovered and named by researchers in Asia. ■

ATOM & COSMOS

Star clusters could cradle life

Stable galactic neighborhoods would be safe homes for aliens

BY CHRISTOPHER CROCKETT

Old, crowded star clusters might be the best place for an advanced civilization to survive in a harsh galaxy, a study suggests.

Stable, long-lived stars in these clusters and the relative ease of hopping from one star system to the next could provide a safe space for any technologically savvy species that can leave its home and establish outposts around other stars. "The probability of a catastrophic event destroying such a civilization then becomes small," astronomer Rosanne Di Stefano of the Harvard-Smithsonian Center for Astrophysics said January 6.

Globular star clusters pack hundreds of thousands of stars into balls just a few hundred light-years across. They're also ancient; many have been around for as long as the galaxy. All of the clusters' massive stars exploded long ago, leaving behind low-mass, low-key stars.

The stars are also jammed in next to each other. Whereas Proxima Centauri, the nearest star to our sun, is 4.2 light-years away, the distance between stars in the core of a globular cluster can be roughly 0.01 light-years — comparable to the width of the solar system. That would make the night sky very bright, but it also makes interstellar travel easier.

Planet hunters generally avoid searching star clusters for planets, much less star-trekking societies, because it's difficult to distinguish one star from another. The old stars in the clusters also lack the heavy elements found in rocky planets and the crowded neighborhood makes it easy for one star to steal planets from another. But the Kepler space telescope has shown that planets can form around stars of nearly any age. And for a planet around a lightweight star to be habitable, it must cozy up to its feeble sun to be warm enough for liquid water. Any planet hugging its star, notes Di Stefano, is harder for another star to steal.

Di Stefano and astronomer Alak Ray of the Tata Institute of Fundamental Research in Mumbai, India, calculated how long a habitable planet could survive in different regions of a cluster. They found a sweet spot where enough nearby stars make it easier for a civilization to spread out but not so many that planet-pilfering is common.

Clusters are a good place to look, agrees Joseph Glaser of Drexel University in Philadelphia, who is starting supercomputer simulations of how stars interact in crowded environments. In the dense cores of clusters, planets could get tossed from star to star. But a bit farther out, the environment is less hectic, he says. ■

ATOM & COSMOS

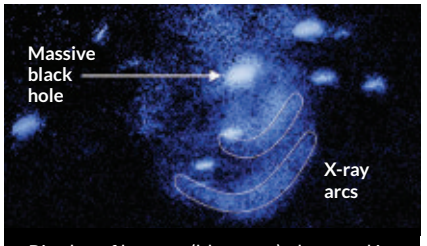
Big black hole burps up gobbled gas

Belched remnants may help scientists study galaxy evolution

BY CHRISTOPHER CROCKETT

Supermassive black holes are a lot like toddlers. They're energetic, often the center of attention — and occasionally spit up their food. A black hole at the core of another galaxy has belched twice in the last 6 million years, leaving a record of these eruptions drifting through intergalactic space.

Two arcs of X-ray light hovering next to galaxy NGC 5195 are the hot remnants of two eruptions from a supermassive black hole at its center, astronomer Eric Schlegel reported January 5. The arcs are about several thousand light-years long and 3,000 light-years apart.



Ripples of hot gas (blue arcs), detected in X-ray data, race away from an erupting supermassive black hole in the center of galaxy NGC 5195.

CXC/NASA, E. SCHLEGEL/UNIV. OF TEXAS *ET AL*

The older eruption is plowing a layer of glowing hydrogen gas from the center of NGC 5195, which sits about 26 million light-years away in the constellation Canes Venatici. "It's the best snowplow of shocked material I've ever seen," said Schlegel, of the University of Texas at San Antonio. He discovered the galactic regurgitation in images from NASA's Chandra X-ray Observatory.

Supermassive black holes feed from disks of superheated gas and dust. Occasionally, the black hole bites off more than it can chew. Then it erupts, blasting material out of the galaxy.

NGC 5195 is entangled with its much larger neighbor, the Whirlpool Galaxy. The two are in the midst of merging into one galaxy, which could feed NGC 5195's supermassive black hole and drive some of these outbursts. It's not clear, though, that the observed blasts arise from this intimate relationship. "Aside from saying it happened twice, you're not going to get anything profound from knowing there are two," says astrophysicist Nicholas McConnell of the National Research Council in Victoria, Canada. Hyperactive black holes are known to hiccup frequently on their own. But in this case, Schlegel thinks, the interaction with Whirlpool might be at fault.

The discharge from NGC 5195 can clarify how much mass the galaxy loses in one of these eruptions, McConnell says. So finding fragments of past expulsions could help researchers understand how the maelstrom around a supermassive black hole affects the evolution of the rest of its host galaxy.

"In the early universe, this sort of thing happened more often," Schlegel said. NGC 5195 might provide a modern reenactment of a time when young galaxies belched more frequently than they do now. ■

ATOM & COSMOS

Red giants map how Milky Way grew

Mass of 70,000 stars reveals older center, younger outskirts

BY ANDREW GRANT

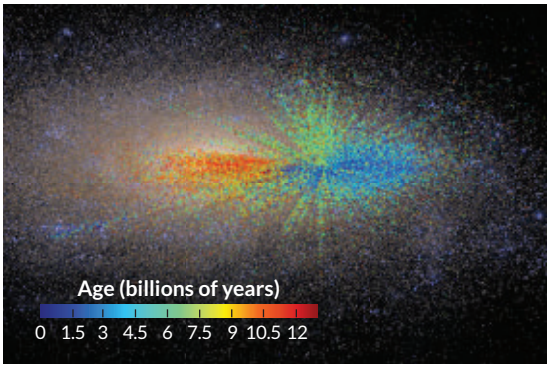
Our galaxy was built from the inside out. That's the clear conclusion from an unprecedented survey of the ages of tens of thousands of the galaxy's stars, reported January 8. "The Milky Way grew up by growing out," Melissa Ness, an astronomer at the Max Planck Institute for Astronomy in Heidelberg, Germany, said at a news conference.

Ness and colleagues developed a computer program that analyzed the light emitted by red giants — bright stars that started out like the sun but exhausted their hydrogen fuel — to determine the stars' masses and ages. Although scientists were pretty sure that galaxies grow outward, this new census of the galactic interior to the outskirts will help researchers chart that development in impressive detail. "It's a galactic archaeology project," says Mario Pasquato, an astrophysicist at Yonsei University in Seoul, South Korea, who was not involved in the research.

Most stars don't easily divulge their ages. Red giants are slightly more helpful because their age depends on their mass — but determining mass isn't so easy either. Ness and colleagues hit on a clever trick to figure out masses and ages by combing data from two telescopes. NASA's Kepler space telescope, best known for spotting distant planets, had previously delivered accurate mass readings for about 2,000 red giants. Using a small ground-based telescope in New Mexico, the Sloan Digital Sky Survey precisely measured the light from those Kepler stars plus that from about 150,000 others.

The researchers trained a computer program to learn how the intensity of light emitted at different wavelengths by the Kepler stars varied depending on the stars' mass. Once the algorithm had determined that relationship, the researchers simply plugged in Sloan light measurements to determine the masses, and thus the ages, of about 70,000 galactic red giants. The ages are accurate to within about 40 percent, which is admirable, Pasquato says, because of the difficulties in estimating star ages. As expected, the Milky Way's oldest stars reside in the center of the galaxy, while the youngest generation lives in the distant suburbs.

This year, a new Sloan telescope in Chile will begin scanning the Southern Hemisphere skies, potentially adding more red giants to the age catalog. ■



The ages of tens of thousands of red giant stars, charted here atop a map of the Milky Way, confirm that the galaxy grew outward. The oldest stars (red) are near the galactic center.

M. NESS, G. STINSON/MPIA

MEETING NOTES

Gas cloud may be graveyard of first stars

A newly discovered gas cloud contains hydrogen and helium but little else. The scarcity of heavier elements suggests that the cloud houses the remains of the universe's first stars, astronomer John O'Meara reported January 8. Scientists want to learn more about these ancient stars, which have never been observed directly, because when they later exploded, they injected the first doses of carbon, oxygen and other crucial elements into the cosmos.

First-generation stars, forged from pristine hydrogen and helium gas produced just minutes after the Big Bang, burst onto the scene about 13.4 billion years ago. Astronomers don't yet have the ability to see objects from that long ago.

O'Meara, of Saint Michael's College in Colchester, Vt., and colleagues looked at the next best thing: a roughly 12-billion-year-old gas cloud. Analysis of the gas's absorption of light from a distant galaxy revealed that the cloud contains about 0.04 percent the concentration of heavy elements as that in the sun. The mix of ingredients matches the expected yield from explosions of the universe's earliest stars, O'Meara reported. — *Andrew Grant*

Supermassive black hole is extreme recycler

Like a cosmic water fountain, a supermassive black hole is cycling gas through a galaxy-sized pump. The black hole powers jets that blast gas over 30,000 light-years away from the galaxy only to rain back down on a reservoir from which the black hole feeds. Yale University astronomer Grant Tremblay described this phenomenon January 6.

The fountain sits at the heart of a galaxy within the Abell 2597 cluster, a galactic gathering over 1 billion light-years away in the constellation Aquarius. Observations from the Atacama Large Millimeter/submillimeter Array in Chile reveal that the fountain billows into plumes with the mass of about 1 billion suns. The force of the jets appears to trigger the formation of new stars within these plumes. Most of the ejected gas falls back down onto the central region of the galaxy and then slowly trickles back toward the black hole to start the loop again.

This galactic pump might help regulate star formation throughout the galaxy. The fountain can continually stir up gas and prevent much of it from creating stellar nurseries. — *Christopher Crockett*

LIFE & EVOLUTION

Male genital diversity gets a rethink

Female shapes, ecological factors may explain fast evolution

BY SUSAN MILIUS

Crazily diverse shapes of male genitals across the animal kingdom — from curlicues and Y-tubes to multiknobbed, tendrilly whatsits — may evolve faster than any other animal structures. Biologists have spent more than a century discussing how to explain such fast and extreme variation.

Now it's time to search for explanations in two overlooked places: the female side of sex and the vast variety of places where animals live, researchers proposed in several talks.

Figuring out why male genitals of a species often differ sharply from even its closest relatives' involves basic, big ideas in biology, said Brandon Moore of Sewanee: The University of the South in Tennessee, who coorganized a symposium on male genital diversity. Species arise, flourish or fail depending on whether animals mate and produce offspring or not. "This is where the rubber meets the road in Darwinian evolution," Moore said.

Maybe what matters in male-female interactions are female structures' curvatures, slopes and ratios.

Females supposedly don't show such variety. But that notion rests mostly on previous generations of biologists eyeballing female genitalia or taking simple measurements, said Patricia Brennan of Mount Holyoke College in South Hadley, Mass. "We like to measure length and width," she said. But maybe what matters in male-female interactions are female structures' curvatures, slopes and ratios.

Revisiting female anatomy with modern methods is what Sarah Mesnick of the National Oceanic and Atmospheric Administration's Southwest Fisheries Science Center in La Jolla, Calif., and her colleagues are doing. Many whales and other cetaceans have "odd and unusual vaginal folds," Mesnick said. Her student Dara Orbach's blue plastic cast of the interior cavity of a harbor porpoise vagina shows broad, slanted-sideways valleys left by the drapery of deep folds in the cavity wall. The team is analyzing variations in such hard-to-even-name shapes that earlier studies missed. More sophisticated understanding may help explain what folds do and whether they have an evolutionary impact on male anatomy.

Genetics suggest strong links between his and hers shapes. For some fruit flies at least, the same gene, called *Poxn*, has a major influence on shape in a feature of the genitals of each sex, said Eden McQueen of the University of Pittsburgh.

Pittsburgh colleagues in the lab of Mark Rebeiz have identified a network of genes, including *Poxn*, that controls the shape of a stout nubbin called a posterior lobe on male *Drosophila* genitals. By putting different versions of *Poxn* into otherwise genetically identical flies, the researchers found that the gene controls not just a male lobe, but also the shape of the oviscapt pouch, a little pocket on female genitals. Altering the shapes of the lobes and pouches changed the length of time flies actually spent copulating.

Thus evolution of shapes can get complicated. The best shape for one sex may not create the best for the other. But because of the shared genes, changing one means changing the other.

Genetics aren't the only way to look for links between the evolution of male and female sex organs. Michael Lough-Stevens of the University of Southern California and his colleagues focused on mammals' mystifying penis bone (baculum) and clitoral bone (baubellum). What benefit they offer is unknown, said Matthew Dean, Lough-Stevens' adviser.

Lough-Stevens is annotating a genealogical tree with what he can find in the scientific literature about which mammals have these bones. This tree may give hints about what forces drove the bones' evolution and how their histories connect.

Of the 128 species or groups on his tree so far, 111 have both bones. In gray squirrels, the male and female bones both look like asymmetric alien ice cream scoops only millimeters long. Sometimes, though, the two bones look nothing alike in the same species. Lough-Stevens showed pictures of a wavy cylinder of bone more than 60 centimeters long from a walrus penis compared with a ragged squiggle of bone only about 5 millimeters long from a walrus clitoris.

Ten species have just a baculum, and the rest, including humans, rabbits and hedgehogs, have neither. So far, Lough-Stevens hasn't found mammals with the female bone but not the male one. He wonders whether lineages that lose genital bones tend to lose the female's first.

Female anatomy has not been the only overlooked topic. Animals live in wildly diverse places, and ecology could explain some divergent anatomy, said Brian Langerhans of North Carolina State University in Raleigh.

He has found links between male fish anatomy and environmental diversity. *Gambusia* mosquito fish living among predators in the Bahamas tend to grow smaller sperm-delivery organs (gonopodia) than males in safer waters. Females prefer the bigger size, but it's a disadvantage during bursts of escape swimming.

Even human changes to the landscape can affect animal genital shape, said Justa Heinen-Kay, Langerhans' student at NC State. Roadbuilding in the Bahamas has blocked some waterways that once connected to the sea. Male mosquito fish in these closed-off waters no longer contend with big predators cruising in from the sea. And the tips of these mosquito fish gonopodia have widened somewhat. That change may reflect tranquil circumstances that allow males to rely more on female cooperation than just speed in transferring sperm, Heinen-Kay and her colleagues reported in *Evolutionary Applications* in 2014.

Thus highway planning could also join the list of overlooked sources of variety in the mystery of male diversity. ■

LIFE & EVOLUTION

Extinct salmon sported tusks

Fossils show fish's teeth were not like saber-toothed cat's

BY SUSAN MILIUS

Pacific Northwest nightmares are getting a revision. The saber-toothed salmon that once swam in the region may have been less saber-toothed cat and more tusky warthog.

Sharp front teeth gave the saber-toothed nickname to the extinct *Oncorhynchus rastrosus* fish. But rather than pointing downward like fangs, these teeth now appear to have stuck out to the sides a bit like warthog tusks, Kerin Claeson of the Philadelphia College of Osteopathic Medicine reported January 4.

The monster of a salmon, reaching 2 meters or more in length and weighing perhaps more than 450 kilograms, had teeth about the length of the end segment of a person's thumb, said Claeson. Two fossils at least 5 million years old from central Oregon show what the teeth looked like when still attached to the mouth bones — the teeth pointed out sideways.

No teeth except for the sabers, or tusks, have shown up in the fossils. The fish may not have had other teeth, Claeson said. The fossils do have an abundance of bones that could have held structures that raked edible tidbits off gills. So the big fish may have fed more by filtering the water than by biting prey. Or, Claeson said, the fish, like salmon today, may have had more teeth but resorbed most of them during their struggle upstream to breed.

One of two recent fossil finds of the extinct saber-toothed salmon is causing scientists to rethink how the famed teeth looked. The fangs now appear to have stuck out sideways, not down.

The salmon might have also used their sideways teeth as defensive or offensive weapons, she said. Or perhaps the teeth were tools. The big teeth might have helped salmon engineer the stream bottom to shape nests for spawning.

Unexpected as the idea of sideways teeth is, fish have evolved some surprising forms, says Tetsuto Miyashita of the University of Alberta in Edmonton, Canada, who was in Claeson's audience.

"There's nothing that fish can't do," he says. ■

MUSEUM OF NATURAL AND CULTURAL HISTORY/UNIV. OF OREGON

LIFE & EVOLUTION

Bubbles may have sheltered early life

Signs of microbes found in 3.2-billion-year-old sandstone

BY MEGHAN ROSEN

For Earth's early inhabitants, living in a bubble was a good thing.

Pockets of gas trapped along ancient shorelines gave microbes a cozy place to call home about 3.2 billion years ago, scientists suggest in the January *Geology*. Such a snug hideout could have shielded microbes from ultraviolet radiation.

The new work is "exciting and very plausible," says geologist Frances Westall of the French National Center for Scientific Research in Orléans. "It expands the known habitats for early life."

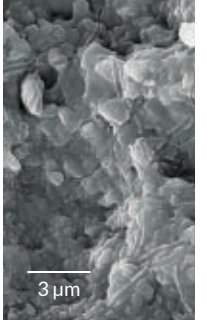
Earth was a tough place to live a few billion years ago. No atmospheric oxygen meant no ozone, and therefore no protection from the sun's UV rays, says study coauthor Alessandro Airo, a geobiologist at the Free University of Berlin.

Still, microbes found a way to survive. In many places, these organisms glued sand and cells together, forming slimy carpetlike biofilms, or mats, underwater. Dissolved iron could have screened out radiation, Airo says. During low tide, "surface microbes might get zapped by UV and die," he says, but microbial communities living below them may have thrived.

Such communities could have colonized trapped bubbles of gas — perhaps a by-product of microbial metabolism. Inside the bubbles, bacteria might have weathered early Earth's harsh conditions, says study coauthor Martin Homann, also of the Free University of Berlin.

Until now, the oldest evidence of bubble-dwelling microbes came from 2.75-billion-year-old rocks in Australia. Homann's group examined even older rocks, from the oldest records of tidal environments on Earth: 3.22-billion-year-old sandstone in South Africa.

Homann collected 350 kilograms of this sandstone, then cut and polished slices. Gas pockets, or cavities, that once formed within mats have long since filled with fine-grained quartz crystals. But in the quartz, the team saw several clues.



Long, narrow grooves in microcrystalline quartz appear to be the imprints of ancient microbes that lived in bubblelike cavities.

What appeared to be ancient biofilms hung down from the tops of shallow cavities, like tiny stalactites dripping from cave ceilings. These biofilms exhibited a chemical hallmark of life: a ratio of heavy to light forms of carbon that's typically found only in living organisms. The quartz also contained microfossil imprints of what appear to be cells. Microscopes revealed ghostly impressions of these cells linked in chains, just like those formed by bacteria today.

Together, the clues are "hard evidence for the presence of microbes," Airo says.

If microbes survived in these pockets on early Earth, they could potentially have done so on other planets such as Mars, Airo says. ■

EARTH & ENVIRONMENT

Shakes expose future quake hot spots

Slowdown in seismic waves can reveal weak rock, fluid buildup

BY THOMAS SUMNER

Rumbling earthquakes could reveal faraway weak spots in Earth's crust that are prone to setting off big quakes.

Following a 2012 earthquake that rattled Costa Rica, researchers noticed that the quake fractured underground rock tens of kilometers from its epicenter. That fractured region had already been weakened by pressurized fluids mixed in with the rock, the researchers propose online January 8 in *Science Advances*. Monitoring where future quakes fracture rock will help scientists better understand how those fluids that help spawn earthquakes disperse around Earth's crust, says coauthor Esteban Chaves.

That understanding could let seismologists better forecast where titanic tremors are likeliest to strike, says Chaves, a seismologist at the University of California, Santa Cruz.

Costa Rica's Nicoya Peninsula sits on the boundary where the Cocos tectonic plate slips beneath the Caribbean Plate. Every 50 to 60 years, on average, a sudden movement along the boundary generates a colossal quake.

After the 2012 quake, Chaves and seismologist Susan Schwartz, also at UC Santa Cruz, sifted through Earth's seismic background noise to hunt for the tremors' impacts on nearby rock. That background noise includes smaller vibrations that rumble through the ground from sources such as ocean waves and large trucks. Filtering out the human contributors to this noise, Chaves and Schwartz combined data from several seismometers to track how quickly the nonearthquake-related vibrations rattled across the peninsula.

In one region on the opposite side of the peninsula from the quake's epicenter, seismic waves traveled about 0.6 percent slower after the quake. It's a "huge" decrease seismologically speaking, Chaves says. He proposes that the quake opened gaps in already weakened rock, causing seismic waves to take longer to pass from one side of the area to the other.

This area was known to contain highly pressurized fluids. These fluids migrate underground alongside the sinking tectonic plate and weaken rock by counteracting the squeezing forces that hold the rock together (*SN: 7/11/15, p. 10*). Accumulating fluid can help trigger quakes by causing rock under pent-up strains to break and slide, shaking the ground.

This new work "will help us identify regions that may be weakened by fluids and be more prone to bigger earthquakes," says seismologist Pascal Audet of the University of Ottawa. ■

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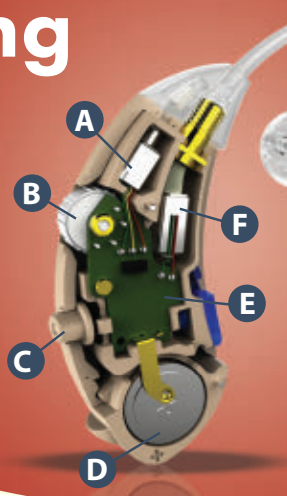

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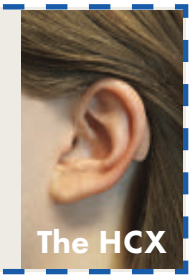
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BODY & BRAIN

Pain produces memory gain

High heat improves recall of objects a year later, study finds

BY LAURA SANDERS

Pain can sear memories into the brain, a new study finds. A year after viewing a picture of a random, neutral object, people remembered it better if they had been feeling painful heat when they first saw it.

"The results are fun, they are interesting and they are provocative," says neuroscientist A. Vania Apkarian of Northwestern University in Chicago.

Neuroscientists G. Elliott Wimmer and Christian Büchel of University Medical Center Hamburg-Eppendorf in Germany reported the results in a paper first posted at bioRxiv.org December 24 and revised January 6. The findings are under review at a journal, and Wimmer declined to comment on the study until it is accepted for publication.

Wimmer and Büchel recruited 31 brave souls who agreed to feel painful heat delivered by a thermode on their left forearms. Each person's pain sensitivity was used to calibrate the amount of heat they received in the experiment, which was either not painful (a 2 on an 8-point scale) or the highest a person could endure multiple times (an 8). While undergoing a functional MRI scan, participants looked at a series of pictures of unremarkable household objects, such as a camera, sometimes feeling strong pain and sometimes not.

Right after seeing the images, the participants took a pop quiz in which they answered whether an image was familiar. Pain didn't influence memory right away: Participants remembered about three-quarters of the previously seen objects, regardless of whether pain was present, the researchers found.

But a year later, pain reigned supreme. People had a better memory for objects viewed while experiencing an 8 on the pain scale than objects viewed while feeling a 2.

The results suggest that pain "somehow amplifies or stamps in the memories so that they are stored more robustly," says neuroscientist Ben Seymour of the University of Cambridge. By showing that pain can preserve memories for at least a year, the study highlights the power of pain to sculpt behavior, he says. And the experiment probably doesn't capture the full extent of many painful experiences. As gruesome as 8-out-of-8 heat stimulus sounds, it's probably

GENES & CELLS

Iceman harbored ulcer-causing bugs

H. pylori DNA from mummy may offer clues to human migration

BY MEGHAN ROSEN

Ötzi the Iceman had a stomach bug.

The 5,300-year-old mummy holds DNA evidence of *Helicobacter pylori*, a common stomach-dwelling bacterium that can cause ulcers and other ailments, researchers report in the Jan. 8 *Science*.

The work could rewrite the timeline of *H. pylori* evolution, and possibly even offer some insight into human migration — though not everyone is convinced.

Regardless, it's the first time anyone has stitched together the pieces of ancient *H. pylori* DNA, says Daniel Falush, a statistical geneticist at Swansea University in Wales who was not involved in the study. "It's a technical achievement," he says. Given the age of the starting material, "I'm surprised it was possible at all."

In 1991, hikers discovered the Iceman lodged in a waist-deep block of ice in a glacier on the border of Austria and Italy. Over the last few decades, physical exams, body scans and analyses of Ötzi's teeth and bones have revealed much about his life and death, including that he died from an arrow wound in the shoulder.

Stomach tissue from a 5,300-year-old mummy known as Ötzi the Iceman revealed the presence of a virulent strain of *H. pylori* bacteria.

In recent years, scientists have revealed some more intimate secrets. In 2012, Albert Zink of the European Academy of Bozen/Bolzano in Italy and colleagues reported that the Iceman was lactose intolerant, had brown hair and eyes and was infected with the bacterium that causes Lyme disease (*SN: 3/24/12, p. 5*).

Zink's team also noticed that Ötzi had a well-preserved stomach. "The idea came up: Let's look and see if he was carrying *H. pylori*," Zink says. The team defrosted the mummy, snipped out samples of his stomach and looked for microscopic signs of infection. But the inner wall of the stomach — where the bacteria typically dwell — had already rotted away. So instead, the researchers hunted for *H. pylori* DNA.

They found it, mixed with DNA from other gut microbes as well as DNA from the Iceman himself. Zink's team fished out the *H. pylori* bits and assembled them into a near complete copy of the ancient strain's genetic instruction book. The researchers then compared this genome with those of modern *H. pylori* strains.

Zink and colleagues were surprised to discover that the European Iceman didn't have a European-looking strain. Instead, the mummy's bacteria looked more like an Asian strain.

Today's European strain is thought to be a mixture of ancient Asian and African strains, created when humans

nowhere near what someone might feel during a medical procedure or a nasty accident, Seymour says.

Based on fMRI brain scans, pain's memory boost appeared linked to activity in a part of the insula, an area involved in bodily sensations and emotions. Other studies have found that emotionally charged memories seem to be particularly durable.

Apkarian cautions that other parts of the brain, particularly those in the medial temporal lobe that have known roles in memory, are probably also involved.

Finding that pain can provide a memory jolt agrees with a mountain of animal data, Apkarian points out. Scientists know that one of the quickest ways to make a mouse learn something is to shock it. But "the human component of that is badly missing," he says. "I would consider this a first step." ■

carrying the Asian strain mingled with those carrying the African strain. Scientists had pegged the date of this blending to sometime between 10,000 and 52,000 years ago.

But the new work suggests that the African strain didn't make it to Europe until much later — after the Iceman's time, some 5,000 years ago.

"Big deal," says microbiologist Mark Achtman of the University of Warwick in England. "They've got one 5,000-year-old person carrying the bacteria." To sketch out a solid story of human migration, the team needs to examine a lot more people, he says.

The study's authors agree that studying more mummies would help. But even one example can offer insights into ancient humans' lives — beyond migration events. Ötzi's *H. pylori* strain was a virulent one, Zink's team discovered. Inside the Iceman's stomach tissues, the team found signs of inflammation.

Says D. Scott Merrell, a microbiologist at the Uniformed Services University of the Health Sciences in Bethesda, Md.: "It suggests to me that, even as long as 5,000 years ago, people were suffering from *H. pylori*–associated disease." ■

V.B. INDJEIAN ET AL/CELL 2016

GENES & CELLS

Gene tweak led to human big toe

Decrease in GDF6 protein helped enable upright walking

BY TINA HESMAN SAEY

Small tweaks of one gene may have helped humans to walk upright.

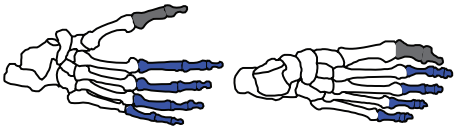
Losing a genetic switch that increases production of a protein called GDF6 may have created the big toe and helped shape the human foot for bipedalism, scientists propose in a paper published online January 7 in *Cell*. "This change is one that makes all humans different from other animals," says developmental geneticist David Kingsley, a Howard Hughes Medical Institute investigator at Stanford University.

The gene *GDF6* makes a protein that helps control bone growth. Researchers had already established that the protein is important for proper skeletal development. It is one of a large group of proteins that sculpt the skeleton and control growth of other body tissues. *GDF6* may also be responsible for some evolutionary changes in other mammals and fish, Kingsley and colleagues say.

Kingsley's group first investigated what causes stickleback fish that live in salt water to have heavy armor plates made of bone while freshwater sticklebacks are lightly armored with smaller and fewer bony plates. The team tracked the genetic variant responsible for the armoring to a regulatory switch near *GDF6*. The freshwater fish have a version of the switch that increases *GDF6* activity, blocking formation of some types of bone and therefore shrinking the armor plating, the team found. The researchers then wanted to know if changes in the gene's regulation shaped other organisms' skeletons too.

In a previous study, Kingsley and colleagues found that humans are missing more than 500 different regulatory switches compared with chimpanzees and other mammals (*SN: 4/9/11, p. 15*). Among those 500 deleted bits of DNA are two near *GDF6*. Such regulatory switches are called enhancers.

In the new study, Kingsley's group investigated the chimpanzee version of one of these enhancers in mice genetically engineered to carry it. The chimp enhancer was hooked to a gene that would indicate with a color change where in the body the switch turns on *GDF6*. The researchers found that the enhancer switches on *GDF6* in the hind limbs, but not in the front limbs or head. In particular, the gene was switched on in the outside toes and in the muscle that controls the first toe (the big toe in humans, but a small toe in mice).



Unlike chimps, people lack a genetic switch that turns up GDF6 protein production in some bones in the hind limbs, resulting in shorter second through fifth toes (affected digits in blue).

Mice engineered to lack GDF6 in their whole bodies had shorter toes than mice that make normal levels of the protein, the researchers found.

Losing the enhancer may have caused humans to make less of the protein in the lower limbs, leading to shorter second through fifth toes. As a result, the big toe would have become more prominent and the human foot a more stable base for walking upright, Kingsley speculates.

The missing enhancer may not be the only thing that shaped the big toe, says Douglas Mortlock, a developmental geneticist at Vanderbilt University in Nashville. "It's the one for which there's the best evidence at this time," he says. "It's not definitive, but it is intriguing."

The researchers have not demonstrated that the missing enhancer affects *GDF6* activity in humans, Mortlock adds. Many changes distinguish human feet from those of chimps — the big toe is straighter and not prehensile in humans, for instance — and those changes may be the product of tweaks to many genes. ■

Like other chameleons, *Rhampholeon spinosus* (shown) probably achieves astounding power and acceleration of its tongue by contracting and stretching elastic tissue to load the tongue with potential energy like a catapult.

C.V. ANDERSON

LIFE & EVOLUTION

Small lizard packs powerful tongue

Size matters for chameleons and their projectile tongues.

Christopher Anderson, a biologist at Brown University in Providence, R.I., observed 20 chameleon species feeding on crickets and found that smaller lizards shot their tongues proportionally farther and faster than larger lizards. The small Tanzanian *Rhampholeon spinosus* accelerates its tongue 2,590 meters per second per second with a power output of 14,040 watts per kilogram of muscle — the strongest movement on record for any reptile, bird or mammal, Anderson writes January 4 in *Scientific Reports*.

The new report refines estimates of the power output of chameleon tongues reported last year (*SN: 2/7/15, p. 12*). — *Helen Thompson*

ATOM & COSMOS

More details on Stephen Hawking's solution to black hole problem

Stephen Hawking has finally provided more information about how black holes might preserve information. Following up on a talk he gave in August (*SN: 10/3/15, p. 10*), the physicist coauthored a paper posted online January 5 at arXiv.org describing how someone outside a black hole may be able to learn what's inside.

A complication in determining a black hole's contents is that black holes are thought to be nondescript, distinguishable by only mass, spin and electric charge. Hawking, along with Andrew Strominger of Harvard and Malcolm Perry of the University of Cambridge, now posits that a hologram of light gives a black hole its identity. The light, which is stuck on the black hole's boundary, acts like a hard drive to store information about everything that enters the abyss.

The researchers admit they still have to prove that an observer could use this hologram to decipher everything inside the black hole. Juan Maldacena, a theoretical physicist at the Institute for Advanced Study in Princeton, N.J., says the paper is "a piece in the puzzle ... to completely understand the quantum mechanics of black holes." — *Andrew Grant*

HUMANS & SOCIETY

Roman toilets didn't flush parasites

Ancient Rome's toilets, baths, aqueducts and sewage systems may not have revolutionized public health after all. The proof is in the poop, paleopathologist Piers Mitchell of the University of Cambridge argues online January 8 in *Parisitology*.

He surveyed parasite numbers in latrines, mummified remains and fossilized feces before and after the implementation of Roman hygiene projects. The data suggest that roundworms and other parasites that spread through contact with feces maintained their numbers despite sanitation efforts — perhaps because Romans used human feces to fertilize crops and rarely changed the water at some public bathhouses.

Fish tapeworm was even more common in Roman times than in the earlier Bronze or Iron ages, which Mitchell attributes to the popularity of fermented fish sauce in ancient Rome. Regular bathing throughout the empire also appears to have done little to curb populations of ectoparasites like head lice. — *Helen Thompson*

BODY & BRAIN

Drug candidate fails to improve symptoms of fragile X syndrome

An experimental drug for the genetic disorder fragile X syndrome was ineffective in two studies in people.

The syndrome, which is caused by a mutation on the X chromosome, can cause intellectual disability, attention deficit disorder and autism spectrum disorders.

The drug candidate, called mavoglurant, had shown promise in mice with a genetic condition similar to fragile X. The drug suppresses the activity of the protein mGluR5, thought to play a role in altering brain cell structure in patients with fragile X syndrome (*SN: 6/2/12, p. 17*).

But in 12-week clinical trials in people, mavoglurant did not improve symptoms such as irritability or hyperactivity in 175 adults and 139 adolescents with fragile X syndrome, researchers report in the Jan. 13 *Science Translational Medicine*.

Future trials might show improved results from testing the drug candidate in even younger patients or over much longer periods of time, the scientists say. — *Sarah Schwartz*

MATTER & ENERGY

Experiment offers glimpse at how to make hydrogen metallic

A crushing squeeze between diamonds has pushed hydrogen to the brink of morphing into a metal. Scientists in Scotland and China discovered a new solid phase of hydrogen after subjecting the universe's most abundant element to pressures that dwarf the water pressure at the seafloor. The researchers speculate that slightly more pressure may coax hydrogen to take on a solid, metallic form.

In nature, pairs of hydrogen atoms bond tightly to form the molecule H_2. But with enough pressure, the bonds should break, allowing electrons to flow freely past individual atoms as they do in metals.

The researchers found that at pressures between about 3.2 million and 3.8 million times as high as the atmospheric pressure at sea level, hydrogen seemed to exist as a part-molecular, part-atomic layer cake. As little as a several percent boost in pressure could coax the rest of the sample to turn metallic, the researchers suggest January 7 in *Nature*.

Metallic hydrogen could have special properties, such as the ability to conduct electric current with no resistance at room temperature. — *Andrew Grant*

Watch a chameleon flick its tongue at **bit.ly/SN_chameleon**

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Lindell has been featured on numerous talk shows, including *Fox Business News* and *Imus in the Morning*. Lindell and MyPillow have also appeared in feature stories in *The New York Times* and the *Minneapolis Star Tribune*. MyPillow has received the coveted "Q Star Award" for Product Concept of the Year from QVC, and has been selected as the Official Pillow of the National Sleep Foundation.

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General Fusion's fusion reactor prototype uses pistons that converge on magnetized, superhot plasma.

RENEGADE FUSION

Start-ups bring a new attitude to the energy quest — but it's not yet clear it will be enough

By Alan Boyle

The lab where a company called General Fusion is trying to spark an energy revolution looks like a cross between a hardware store and a mad scientist's lair. Bins full of electrical gadgets are piled high against the walls. Capacitors recycled from a bygone experiment are stacked up like bottles in wine racks. Ten-foot-high contraptions bristle with tangled wires and shiny plumbing.

Michael Delage, General Fusion's vice president for strategy and corporate development, makes sure nothing is turned on when he takes a visitor through the lab, which is tucked away in a bland industrial park near Vancouver. He's worried about the voltage.

"If you get a broken wire or something like that, you get a very loud bang," Delage explains.

His company and others are looking for a bang of a different sort: a smashing together of superhot hydrogen atoms that produces a net gain in energy. Nuclear fusion. It's the same mass-to-energy reaction that's behind the sun's radiative power and the blast of a hydrogen bomb, but scaled down to a manageable level for power generation.

Government-funded research programs have spent tens of billions of dollars trying to harness fusion power during the last 60 years or so. Some are using superstrong magnetic fields to bottle up hydrogen gas that's been heated up so much that it becomes plasma, a state of matter in which the electrons are stripped away from atomic nuclei. Others are blasting pellets of hydrogen fuel with powerful lasers or ion beams, causing tiny but powerful implosions.

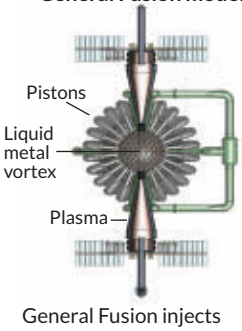
Although they've come up short so far, the government-funded groups insist they'll achieve controlled fusion sometime in the next couple of decades. For commercial fusion plants to deliver substantial amounts of electricity to power grids, however, will probably take until the 2040s or 2050s.

In contrast, General Fusion and at least 10 other commercial ventures say they can get fusion to pay off within a decade, at a cost of hundreds of millions of dollars rather than tens of billions. The upstarts are going with unorthodox approaches, ranging from piston-driven engines to devices that have more in common with particle accelerators than traditional nuclear reactors. And they're finding deep-pocketed investors who are willing to cover the cost.

Not everyone is impressed.

"For the most part, these ideas

General Fusion model



General Fusion injects magnetized rings of plasma into a liquid metal vortex that is squeezed by pistons.

BOTH: GENERAL FUSION

are recycled from the glory days of the 1980s, and one by one, the Department of Energy stopped funding those concepts," says Edward Morse, a nuclear engineer at the University of California, Berkeley. "It's fortunate that the investors who are quoted in these reports are very rich people. They may not miss the money."

But the start-ups insist they're adding new twists to those decades-old principles. They plan to use computer simulations, innovative engineering and an entrepreneurial mindset to leapfrog the government projects.

"You can't do what we do for a million bucks," says Michl Binderbauer, chief technology officer for Tri Alpha Energy, a fusion research company headquartered in Foothill Ranch, Calif. "There's a certain level of capital expense that comes with doing frontier science.... But I don't believe it takes billions of dollars. I really don't."

A big-money power play

If perfected, fusion power technology could be worth trillions.

Fusion power has several advantages over nuclear fission power, in which heavy atomic nuclei release energy upon splitting. The best-known fusion fuel, the heavy hydrogen isotope deuterium, can be extracted from seawater. There'd be no worries about long-lived highly radioactive waste, and a fusion reactor keeps so little fuel inside that it would naturally stop if something went wrong — avoiding the risk of a Fukushima-style meltdown or Chernobyl-style radiation leak.

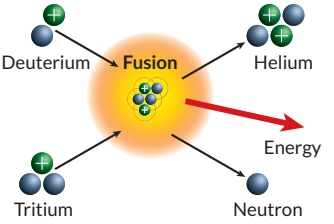
Fusion power also eliminates worries about the fossil fuel emissions that are warming Earth's climate. It would be a renewable energy source like solar and wind power, with some extra advantages. The reactors could be put anywhere to provide 24/7 power; no need for strong winds or bright sunshine.

"It really does have all the benefits you could ever want from a renewable energy source," says Nathan Gilliland, General Fusion's CEO. "One kilogram of hydrogen fuel has the same amount of energy as 10 million kilograms of coal. You'd have abundant fuel for hundreds of millions, billions of years."

It's that kind of enormous potential that has brought money pouring in to solve the fusion puzzle. Dozens of projects — from Astron to ZETA — have flowered and faded. The biggest project on the horizon is the ITER experimental reactor in Cadarache, France, which is backed by the United States and 34 other nations. ITER's price tag and construction timetable have both ballooned beyond original estimates. The project is now due for completion in the mid-2020s at an estimated cost of $20 billion.

Once ITER is up and running, it's expected to demonstrate a controlled fusion reaction that produces an energy surplus. But even under the best-case scenario, it would take until the 2040s to adapt ITER's technology for use in a commercial power plant.

The Wendelstein 7-X stellarator, another advanced reactor, has just begun what's expected to be a years-long experimental campaign in Greifswald, Germany. The German government has covered most of its $1 billion cost, but it's far too early to tell if the technology can ever be commercialized.



Nuclear fusion In one fusion reaction, merging two forms of hydrogen — tritium and deuterium — yields helium plus a neutron and energy.

ITER and Wendelstein 7-X both use a fusion approach called magnetic confinement. At the heart of each device is a chamber shaped like a doughnut (in Cadarache) or a pretzel (in Greifswald). Inside the chamber, a cloud of hot hydrogen plasma is squeezed by magnetic fields. An electromagnetic barrage heats the plasma so much that hydrogen nuclei fuse — creating helium atoms and neutrons while converting a smidgen of mass into electromagnetic radiation and kinetic energy.

The other common strategy for fusion is called inertial confinement. This approach involves blasting pellets of hydrogen fuel with lasers or ion beams. The fuel is compressed so quickly and precisely that it's held in place by its own inertia, allowing it to ignite in a burst of fusion energy.

The $3.5 billion National Ignition Facility at California's Lawrence Livermore National Laboratory uses inertial confinement, but has fallen short. It doesn't produce more energy than it consumes in the fusion reaction (*SN: 3/8/14, p. 6*).

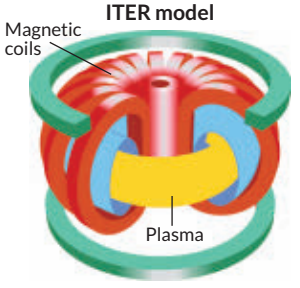
Hybrid technology

A couple of the fusion start-ups — Tokamak Energy and First Light Fusion, both in the United Kingdom — are experimenting with their own twists on magnetic confinement or inertial confinement. But the best-funded private efforts are focusing on hybrid technologies alternately known as magnetized target fusion, field-reversed configuration or magneto-inertial fusion.

In magneto-inertial fusion, puffs of hydrogen are heated, then magnetized so that they hold together. Those magnetized puffs of plasma, which take on the shape of tiny smoke rings, are injected into a compression chamber, where they must be squeezed hard enough and fast enough to spark fusion.

Although the concept has been around for decades, magnetized target fusion was traditionally passed over in favor of the technologies behind ITER and the National Ignition Facility. That's beginning to change. The Air Force Research Laboratory in New Mexico is using the method in an experiment known as FRCHX. Most of the work on magnetized target fusion, however, is happening at the private start-ups.

At General Fusion, for example, engineers are building steampunk-looking machines that they'll eventually combine into a full-scale reactor. One contraption is designed to squirt plasma rings through a 10-foot-high,



Magnetic coils hold superhot plasma within a doughnut-shaped chamber.

FROM TOP: S. EGTS; MAX PLANCK IPP

Many roads to fusion While government programs focus on magnetic and inertial confinement, private ventures try hybrid approaches.

Fusion approach	Project/Company	Fuel type	Advantages	Disadvantages
MAGNETIC CONFINEMENT FUSION Powerful magnetic fields contain a hot plasma of fusion fuel inside a chamber, and electromagnetic waves are injected into the plasma to raise the temperature high enough for fusion.	**ITER** *Cadarache, France*	Deuterium and tritium	Well-understood physics; billions of dollars in funding.	Dependent on national budgets and bureaucracies. Targets for budget and timeline have not been met.
	WENDELSTEIN 7-X *Greifswald, Germany*	Deuterium and tritium	Stellarator chamber's shape optimizes magnetic field's stability.	If complicated design is not exactly right, confinement is lost.
INERTIAL CONFINEMENT FUSION A pulse of high energy is focused on a target quickly and precisely, squeezing the target and heating it to fusion conditions.	**NATIONAL IGNITION FACILITY** *Livermore, Calif.*	Deuterium and tritium	Does not require maintaining a magnetic field.	Energy conversion rate is low, raising questions about commercialization.
MAGNETO-INERTIAL FUSION Puffs of hot plasma are magnetized, then directed at each other under conditions that squeeze the plasma hard enough and long enough for fusion to occur.	**GENERAL FUSION** *Burnaby, Canada*	Deuterium and tritium	Liquid metal vortex absorbs neutrons and heat, reducing damage to surrounding structure.	Pulsed operation of the piston-driven plasma chamber poses challenges.
	HELION ENERGY *Redmond, Wash.*	Deuterium and helium-3	More compact than traditional fusion plants. Produces fewer neutrons than deuterium-tritium reaction.	Must be operated in pulsed mode, at a rate of one blast per second.
	TRI ALPHA ENERGY *Foothill Ranch, Calif.*	Hydrogen nuclei and boron-11	Once fusion is achieved, the reactor produces continuous electrical current. No neutron radiation.	Hydrogen-boron fusion requires much higher temperatures than deuterium-tritium fusion.

SOURCES: ITER; MPG-IPP; D. CLERY/*SCIENCE* 2015; "AN ASSESSMENT OF THE PROSPECTS FOR INERTIAL FUSION ENERGY"/NRC 2013; GENERAL FUSION; TRI ALPHA ENERGY; HELION ENERGY

cone-shaped injector. In a different room, there's a mechanical monster with black tubes reaching out in all directions.

When program manager Brendan Cassidy talks about the monstrous creation, he sounds like a mad scientist from the movies — but without the evil laugh. "We have successfully built the first device to pump liquid lead into a vortex, and use an acoustic driver to collapse the vortex," he says proudly.

In the full-scale reactor, two rings of magnetized plasma — consisting of deuterium and tritium, a radioactive isotope of hydrogen — will be shot toward each other in a chamber with a spinning vortex of liquid lead and lithium. The pistons surrounding the chamber should slam the metal around the plasma hard enough to set off a fusion reaction.

The resulting energy will heat the molten lead even more. That liquid metal will circulate through a heat exchanger, turning water into steam to drive a power-generating turbine. Some of the lithium will be transformed into tritium to fuel further reactions.

For its full-scale prototype, General Fusion will expand the plasma chamber from 1 meter wide to 3 meters. The number of pistons will grow from 14 to 220, bringing the setup to about 10 meters wide. If that next machine works the way researchers hope, they'll get a successful fusion shot once or twice a day. To commercialize the technology, they'll need a more advanced reactor firing an energy-generating shot every second.

When it's time to commercialize, General Fusion would license the technology to the power industry. "If we ever succeed, we will partner with the GEs of this world," says Michel Laberge, the physicist who founded General Fusion.

Nixing the neutrons

Tri Alpha Energy is borrowing engineering principles from particle colliders to pursue its own brand of magnetic hybrid fusion. In Tri Alpha's reactor design, the rings of plasma are smashed into each other at high energies using electromagnetic fields, similar to how beams of protons are accelerated in the Large Hadron Collider. "It will work as an energy amplifier," Tri Alpha's Binderbauer says.

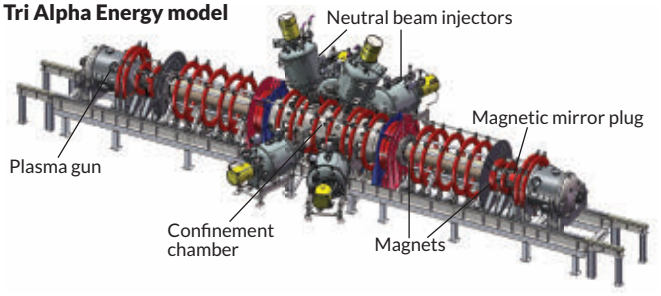
Most fusion ventures, including ITER and General Fusion, plan to use deuterium plus tritium to fuel the reaction. Tri Alpha is trying a less-orthodox combination: hydrogen nuclei — that is, single protons — and boron-11 ions.

Tri Alpha's concept has some advantages. It relies on naturally occurring fuels rather than unstable tritium, which must be bred in a nuclear reaction like the one in General Fusion's machine. What's more, the proton-boron reaction, known as p-B11, is more benign than the deuterium-tritium reaction, known as D-T (*SN: 11/2/13, p. 8*).

Each D-T reaction produces a helium nucleus (two protons and two neutrons) plus a neutron. The resulting flux of neutrons poses a radiation hazard and can degrade whatever material is being used to shield the reactor. The p-B11 reaction gives off energy without producing stray neutrons. Such aneutronic fusion is especially attractive for commercial operations.

However, achieving fusion is a lot more difficult with p-B11 than with D-T. The plasma must reach temperatures in excess of

Tri Alpha Energy model



One approach to fusion shoots plasma into a chamber surrounded by magnets. Injectors fire hydrogen atoms to keep the plasma stable and hot.

TRI ALPHA ENERGY, INC.

3 billion degrees Celsius, as opposed to 100 million degrees for D-T fusion. But Binderbauer says the potential payoff is worth it.

"You're trading harder science up front for easier engineering down the hill," he says.

General Fusion and Tri Alpha Energy have both been around for more than a decade, but they are just beginning to publish intriguing findings in peer-reviewed journals. In a pair of papers published last April and May in *Nature Communications* and *AIP Physics of Plasmas*, Tri Alpha's researchers reported that they held 10-million-degree hydrogen plasma steady in a test reactor for 5 milliseconds.

Five milliseconds may not sound like a long time, but it marked a milestone for fusion start-ups. "If we had enough power to continually pump into it ... we believe we could maintain the plasma at will," Richard Barth, Tri Alpha's senior vice president for government relations, said in December at a forum in Washington, D.C., sponsored by the American Security Project.

Tri Alpha says its next, bigger reactor, C-2W, should heat plasma to temperatures 10 times higher. Within three or four years, that machine is expected to come close to sparking a sustained D-T fusion reaction. If C-2W performs as expected, Binderbauer says, he expects Tri Alpha will build an even more powerful machine and try p-B11 fusion.

Instead of using a steam turbine to convert heat into electricity, Tri Alpha's machine would more efficiently generate power by channeling a continuous stream of charged particles directly into electrical current. Binderbauer expects to have a commercial product in a decade, if all goes well.

Fast-track fusion

Just a few miles from Microsoft's headquarters outside Seattle, Helion Energy wants to fuse deuterium and helium-3 to produce energy plus hydrogen and helium-4 nuclei, but no neutrons. Pulsed magnetic fields would compress and heat the plasma to fusion temperatures for a brief instant.

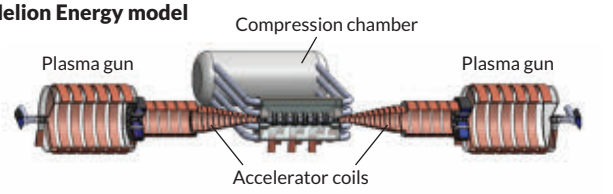
Like General Fusion's machine, Helion's fusion engine would set off bursts at the rate of one per second. And like Tri Alpha's machine, the system would convert the energy directly into electricity. One of Helion's fusion-fuel ingredients, helium-3, is rare on Earth. It happens to be abundant on the moon, which is why helium-3 is often cited as a justification for lunar mining schemes. Fortunately, Helion won't have to race to the moon. The reactor is designed to synthesize its own helium-3, just as General Fusion's machine is designed to synthesize tritium.

David Kirtley, a fusion researcher and Helion CEO, says the company could demonstrate a net-gain fusion reaction within a couple of years and make fusion power marketable by 2022.

Magnetized target fusion and its variants aren't the only unorthodox technologies on the fast track. Lawrenceville Plasma Physics, based in New Jersey, is developing a device that would zap hydrogen-boron fuel with a jolt of electricity, in a process known as dense plasma focus.

Other companies are working on cusp confinement, which involves trapping and squeezing ionized gas between magnetic fields. Lockheed Martin's Skunk Works lab in Palmdale, Calif., is pursuing this approach to build a compact fusion reactor by 2025 that it hopes will be suitable for installation on airplanes. EMC2 Fusion Development, based in Santa Fe, N.M., tested a cusp-confinement device for the U.S. Navy in 2014 and is looking for investors to fund a larger version.

Helion Energy model



One firm plans to spark fusion by compressing plasma fired into a chamber.

High-profile investors

Can private enterprise really do fusion cheaper and quicker than the multibillion-dollar, government-led efforts? Hard to imagine, but investors backing the efforts are risk takers.

Tri Alpha has brought in hundreds of millions of dollars in investment, from backers that include Microsoft cofounder Paul Allen. General Fusion has attracted $94 million in funding, with Amazon founder Jeff Bezos among the investors. Last July, an investment group with connections to Canadian billionaire Jeff Skoll put money into a $10 million funding round for Helion Energy. Fellow billionaire Peter Thiel, a cofounder of PayPal, is also a Helion investor.

Even government agencies are supporting the private ventures: The U.S. Department of Energy supports low-cost approaches to fusion through ARPA-E, the Advanced Research Projects Agency-Energy. In 2015, ARPA-E awarded $30 million to nine alternative fusion ventures, including nearly $4 million to Helion Energy. General Fusion has benefited from a similar program in Canada.

The public funding of these private endeavors raises a pointed question: If even one of the low-cost commercial strategies has a chance of working, why spend billions on the traditional big-budget programs?

"When you invest, you have some blue-chip stocks, and you have some high-payoff stocks," says Uri Shumlak, a nuclear engineer at the University of Washington whose fusion research received $4.8 million from ARPA-E. "The projects being funded by ARPA-E are high-risk, high-payoff ventures."

It all sounds like a gamble, but there's one sure thing: As climate concerns rise and fossil fuel reserves shrink, meeting the world's rising energy needs is a game that has to be won — even if it takes a mad-scientist lab to do it. ■

Explore more

■ Daniel Clery. *A Piece of the Sun: The Quest for Fusion Energy*. The Overlook Press, 2013.

Alan Boyle is an aerospace and science writer in Seattle.

HELION ENERGY

GMOs Under Scrutiny

Engineered foods have withstood safety concerns, but haven't fulfilled big promises

By Rachel Ehrenberg

Arriving home after work a few summers ago, agricultural economist Matin Qaim found several disturbing messages on his home phone. A study by Qaim had shown that small-scale farmers in India who grew genetically modified cotton had larger harvests compared with conventional cotton growers. Those better yields resulted in greater profits for the mostly poor farmers and more disposable income to spend on basics like food and education.

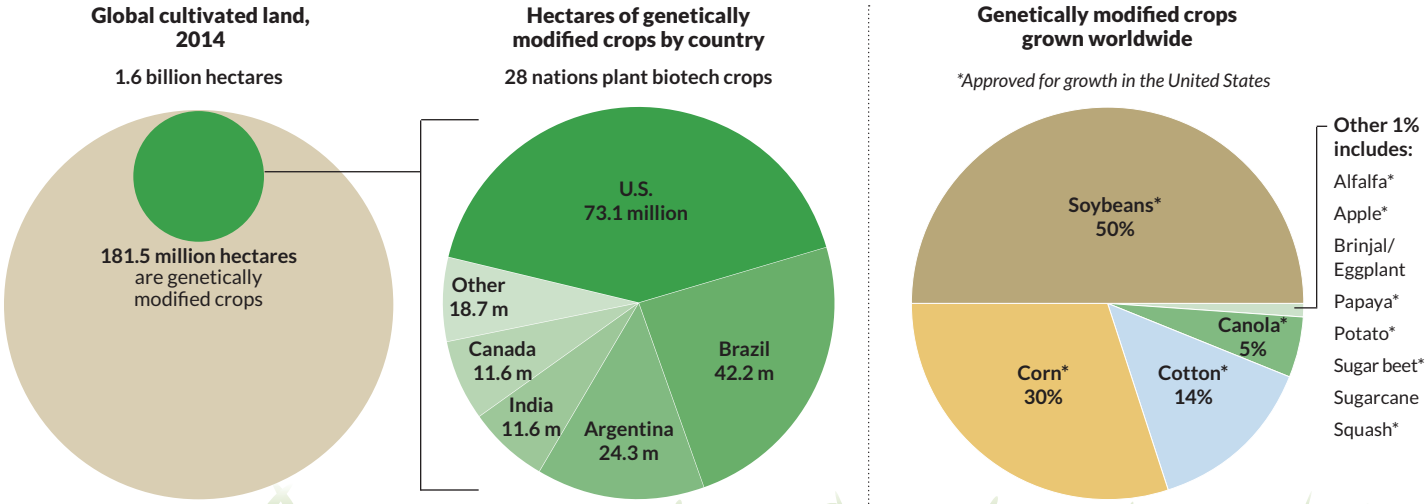
Several media outlets had covered the results, which had been published in the *Proceedings of the National Academy of Sciences*. But journalists weren't the only people contacting Qaim about the research. "Don't support this irresponsible destruction to the environment," implored one caller on Qaim's answering machine. "Think of your children, think of the world's children," a woman pleaded.

Qaim, of the University of Göttingen in Germany, has been studying the social and financial impacts of genetically modified organisms for years. Yet he is not blindly pro-GMO and his interpretation of his own study's results was nuanced. The GM cotton planted by the farmers was Bt cotton, which contains genes from *Bacillus thuringiensis*, a soil bacterium often used by organic farmers. Adding the Bt genes gives the cotton a built-in pesticide against the cotton bollworm, a scourge that can decimate crops.

Among the farmers Qaim studied, those who switched to the Bt cotton lost fewer plants and saw their profits increase by 50 percent. But the adoption of Bt cotton in that part of India was relatively recent and the positive impacts wouldn't necessarily last. Area bollworms might become resistant to Bt toxins, Qaim noted both in his paper and in interviews.

Such caveats didn't matter to the hostile callers, Qaim says. He has learned to keep quiet about his work in his casual conversations with parents at his daughters' school. In the heated debate over genetically modified organisms, there's little room for nuance.

Lay of the land Since their introduction in the mid-1990s, genetically modified crops are gaining ground on their conventional counterparts. Of the 28 countries planting GM crops today, 20 are developing nations. SOURCES: INTERNATIONAL SERVICE FOR THE ACQUISITION OF AGRI-BIOTECH APPLICATIONS, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS



Good breeding Over time, plant breeding has gained speed and precision. Traditional crossbreeding mixes entire plant genomes and can take decades to yield a new variety. Transgenics and RNA interference breeding influence a handful of genes and can bring new products within a few years. SOURCES: FAO/IAEA MUTANT VARIETY DATABASE, A.E. RICROCH AND M.-C. HÉNARD-DAMAVE/*CRITICAL REVIEWS IN BIOTECH* 2015, ISAAA

Plant modifications throughout history

What?	Date developed	How?	Safety testing required?	Examples
Traditional crossbreeding	1700s	Cross closely related plants and select offspring with desirable traits	No	Myriad, including Burbank russet potato, Santa Rosa plum, sugar beets, corn, strawberries, peas, tobacco, peaches
Mutation breeding	1930s	Expose seeds or young plants to radiation or chemicals and select desirable mutants	No	Myriad, including Star Ruby grapefruit, Rio Red grapefruit, Golden Promise brewer's barley, varieties of cocoa, cotton, green pepper, sunflower, tomato, plum, peppermint, sugarcane, kale
Transgenics	1980s	Transfer specific genes by nonsexual means from one organism into another	Yes	Herbicide- and pest-resistant crops. In development: drought-tolerant peanut, wilt-resistant banana, bacteria-resistant orange, fungus-resistant chestnut, biofortified rice (includes Golden Rice), barley, corn and potato
RNA interference	1990s	Using RNA to turn off specific genes	Yes	Nonbrowning potato and apple. In development: decaffeinated coffee, tearless onion, higher-nutrition tomato, peanut and corn

"We are in a world that's painted black and white," Qaim says. "In Europe in particular, people are deeply convinced that GM crops are bad for the world. If you say anything in favor of GM crops, you are talking in favor of evil."

That designation of evil is one of the two prevailing narratives concerning genetically engineered foods. GMO opponents tell the story that "Franken" organisms are a new technology that poses known and unknowable dangers to human health, the environment and society at large. On the other side, proponents argue that GMOs are a harmless and necessary tool for saving a world threatened by overpopulation and a changing climate. The loudest voices on the proponent side are typically cast as shills for Big Agriculture (some of them are), while the loudest on the anti-GMO side are typically cast as fear-mongering luddites (some of them are).

This broad brush is problematic for several reasons, Qaim and others argue. The term GMO itself is a catchall that encompasses a wide range of products developed through a variety of means, each with its own risks and benefits. There are GMOs that have led to large reductions in the use of pesticides, for example, and there are GMOs that have made herbicide use skyrocket. The broad brush also fails when labeling the developers of GM technology: Commercial giants of the agrochemical pesticide industry have developed GMOs, but so have academic scientists funded by nonprofits or the public sector.

"A technology like GM crops is neither good nor bad," Qaim says. "Talking about *the* impact of GMOs is way too broad."

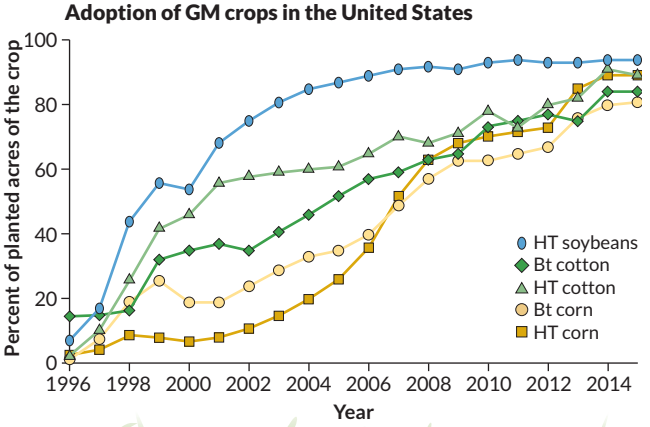
The diversity of engineering processes and the products that result will probably continue to grow. For example, the relatively new CRISPR technology, which allows for superprecise gene editing (*SN: 12/26/15, p. 18*), may soon become a GMO tool of choice. But generally speaking, the technologies behind GMOs are decades old. And despite fears of unknown risks, GMOs have been studied extensively.

The picture drawn from decades of research is out of sync with many common public perceptions. While unforeseeable health issues are often at the forefront of public concern, foods containing GMOs have been on grocery shelves for more than 20 years. Piles of evidence suggest that eating GMOs is no riskier than eating conventional foods. Effects on the environment are more mixed. Some of the problems that have arisen, such as the uptick in the use of certain herbicides, are more about farming practices than about dangers inherent to GM technology; the same problems arise with conventional, non-GM crops.

The environmental consequences of engineered genes escaping into the wild are less clear. But while the fallout can be hard to predict, the odds of such escapes actually happening can often be evaluated. With the Food and Drug Administration's recent approval of GM salmon (*SN Online: 11/19/15*), for example, scientists agree that there is a slim possibility that escapees could harm native fish populations; that risk could be curtailed, however, with strict oversight about where and how such fish are farmed.

There's also a lot of unrealized promise. GMOs are often touted as a way to boost the nutrient content of foods to fight malnutrition. Yet GMOs that are on the market have largely

GM crop creep Crops engineered to be herbicide tolerant (HT) or toxic to specific insects (Bt), or both, have taken over U.S. farming acreage since their introduction in the 1990s. These modifications can reduce pesticide use and carbon emissions, but they can also lead to herbicide resistance if overused. SOURCE: USDA ECONOMIC RESEARCH SERVICE



LUSEEN/ISTOCKPHOTO

benefited those producing them — companies and farmers — rather than consumers. There are many health-boosting GMOs in development, including bananas with increased iron; plants that make omega-3 fish oils and rice, sorghum and cassava enriched with vitamin A. New crops, such as those engineered to tolerate drought or excess salt in the soil, could play a crucial role as shifts in climate threaten the farming status quo and in turn, food supplies.

2/3

Minimum fraction of foods sold in the United States that contain GMOs

SOURCE: GMA

80 percent

Estimated portion of hard cheeses sold in the U.S. that are made with enzymes created by genetically modified microbes

SOURCE: GMO COMPASS

A mouthful

Foods containing GMOs have been on the market since the 1990s. Some are eaten as a whole organism — such as papaya engineered to resist the ringspot virus. Others end up as ingredients in processed foods, such as corn syrup. Genetic engineering is involved in more than two-thirds of foods sold in the United States, according to the Grocery Manufacturers Association. The processes that yield foods considered GM vary. Some contain genes from other organisms that impart a particular trait. Bt corn, for example, contains bacterial genes that make the crop toxic to soft-bodied caterpillars and some other insects. With other GMOs, the modifying entails dialing down the activity of genes that already exist in the plant, as with the just-approved Arctic apples and Innate potatoes that don't brown when cut. The genes responsible for the enzymes that brown the flesh are silenced.

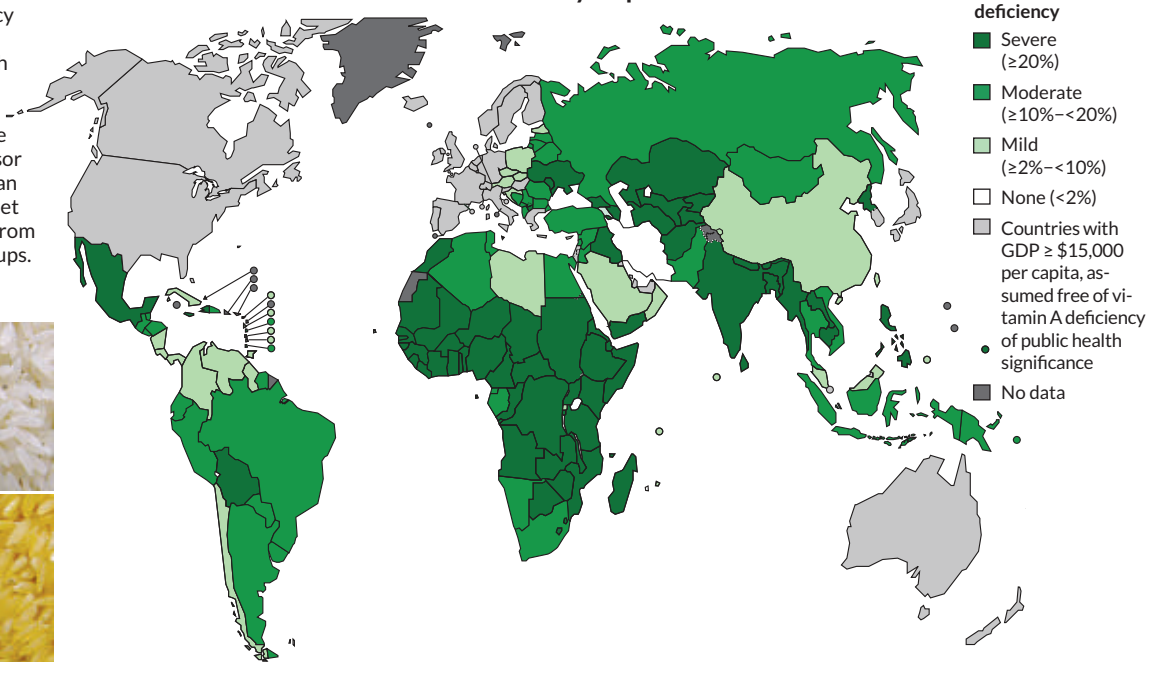
Common GM ingredients, such as canola and soy oils, cornstarch and corn syrup, and sugar from beets, come from crops that have been modified to make farming them easier. Genetic engineering is also used to make minor ingredients that might be too complicated or expensive to produce via standard chemistry or too difficult or inefficient to harvest from their habitats in nature. Many microbes have been engineered to pump out vitamins, enzymes and other food additives, for example, a process that's typically much easier and more environmentally friendly than acquiring such ingredients from natural sources. The first genetically engineered food product approved by the FDA, in 1990, was a version of the bacterium *E. coli* engineered to make the enzyme chymosin, which prompts the ripening of cheese. Before the *E.coli* effort, chymosin was harvested from the stomachs of nursing calves as a by-product of the veal industry. Today, roughly 80 percent of hard cheeses sold in the United States are made with chymosin from engineered microbes.

These diverse products are all subject to testing before they can be sold. While there's always concern that genetic modifications could introduce a new allergen or a toxin into the food chain, that hasn't happened yet.

Testing is typically framed in terms of the notion of "substantial equivalence." The GMO is compared in substance and nutrition with its nonengineered version. The introduced genetic material, which yields a transgenic protein that causes some change to the organism, is also scrutinized for structural similarities with toxic proteins or other biologically active molecules, such as known allergens. The temperature and acidity level at which the transgenic protein breaks down is also assessed to see how it might fare in the body. Digestibility and

Against the grain

Vitamin A deficiency is a major cause of blindness and death in children. Golden Rice (bottom), engineered to make a vitamin A precursor in the grain, offers an antidote, but has met strong opposition from environmental groups.



RICE: THE GOLDEN RICE PROJECT; MAP: WHO "GLOBAL PREVALENCE OF VITAMIN A DEFICIENCY IN POPULATIONS AT RISK 1995–2005"

potential toxicity are also evaluated.

While every new modification presents a new case for scrutiny, so far the GMO health track record is clean. And GMO products have been tested by more than their developers, who have a clear interest in their approval. Independent researchers have looked for red flags in numerous studies.

"So far, there is no reason for concern," says biotechnologist Alessandro Nicolia of the Italian National Agency for New Technologies, Energy and Sustainable Economic Development in Rome. He was a coauthor of a 2013 paper analyzing 10 years of GMO studies, 770 of which related to human and animal safety.

Despite numerous studies finding that eating GMOs is no riskier than eating conventional foods, claims of adverse effects persist. GMOs are sometimes a scapegoat for allergies, including the uptick in gluten intolerance — digestive problems caused by a protein found in wheat and some other grains. But no such link is supported by the research, says Nicolia. He points out that, although GM wheat exists, it is not on the market anywhere in the world. And correlations can be easily conjured: The rise in gluten intolerance also coincides with a rise in the availability of organic foods, for instance.

The few cases in which a transgenic protein has acted as an allergen were identified via testing well before the products reached consumers. One, for example, involved transferring Brazil nut proteins, which contain an important dietary amino acid, into soybeans for animal feed. Testing revealed that the transgenic Brazil nut protein provoked an immune response in people; the study reporting the findings made headlines in 1996 when it appeared in the *New England Journal of Medicine*. Development of those soybeans was abandoned.

Of course, because evaluations look primarily for molecules that resemble known allergens, there is always a risk that something novel could spur an immune response. Absolute certainty doesn't exist, for GMOs or conventional foods. In fact, because the testing is fairly extensive and the quantities of transgenic proteins in an engineered organism are typically so low, many scientists argue that it's easier to detect a potential allergen in a GM crop than in a conventional crop. Not long after the kiwifruit's arrival in the United Kingdom, several adverse reactions revealed that some people were allergic to the fruit, according to the United Kingdom's 2003 GM Science Review Panel.

Several scientific bodies, including the U.S. National Academy of Sciences, the American Medical Association and the World Health Organization, have reviewed the existing evidence and concluded that eating GM foods is no riskier than eating conventional foods. Numerous studies, and reviews of those studies, have come to similar conclusions. Plant geneticist Agnès Ricroch coauthored several review papers assessing GMO safety, including a 2012 paper examining the long-term health of animals fed GM corn, potatoes, soybeans, rice and the grain triticale, a cross between wheat and rye.

"In all of the studies published, of all GM crops authorized to be marketed, we have seen no adverse effects," says Ricroch, of France's Academy of Agriculture and AgroParisTech in Paris. "There is no risk to health for humans or animals."

Still, fears that genetically modified organisms cause health problems — from cancer to autism — linger. Such concerns have been fueled by a now thoroughly debunked but high-profile 2012 study by French researchers purporting to show that GM corn caused cancer in rats. The work was almost immediately discredited on multiple accounts, including faulty statistics and the fact that the researchers used rats from a strain that is naturally prone to tumors. The paper was widely criticized and later retracted. But the initial media campaign by the scientists, which included images of rats with enormous tumors and offers of early access only to journalists who agreed not to talk to other scientists about the results, had lasting effects. The paper, which was recently republished in a different journal, is still cited in some anti-GMO camps as evidence for a lack of consensus concerning health effects.

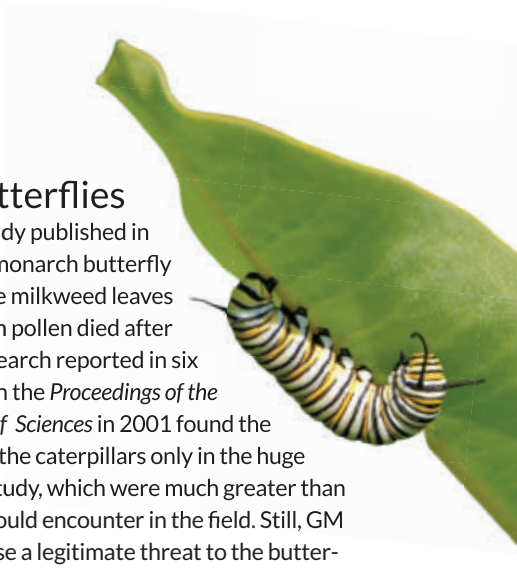
Discourse about the health hazards of eating GMOs is frustrating on multiple levels, says Ricroch. Controversy has slowed GMO progress in the area of enhancing foods' nutritional value. The poster child for such a crop is Golden Rice, which has been engineered to produce a vitamin A precursor, beta-carotene, in the grain (the plant normally produces the stuff in its green tissues but not in the edible endosperm).

Because of vitamin A deficiency, more than 250,000 children become blind every year, and half of them die within a year of losing their sight. By adding a gene from a bacterium and one from corn (swapped for a daffodil gene used in earlier versions), the rice makes beta-carotene that is converted to vitamin A when eaten.

The Golden Rice project was never a commercial one. When

Bye-bye butterflies

In 1999, a small study published in *Nature* found that monarch butterfly caterpillars that ate milkweed leaves dusted with Bt corn pollen died after a few days. But research reported in six studies published in the *Proceedings of the National Academy of Sciences* in 2001 found the pollen was toxic to the caterpillars only in the huge doses used in the study, which were much greater than what the insects would encounter in the field. Still, GM crops appear to pose a legitimate threat to the butterflies: Heavy use of the herbicide glyphosate, thanks to the widespread planting of crops engineered to resist it, has wiped out much of the milkweed the butterflies rely on for food. Farmland in the Midwest lost 80 percent of its milkweed from 1999 to 2010; the decline was mirrored in monarch populations, scientists reported in 2013 in *Insect Conservation and Diversity*. — *Rachel Ehrenberg*



SF PHOTO/SHUTTERSTOCK

its creators launched the project more than 20 years ago, the intention was to combat malnutrition in developing countries. Yet the crop has met serious resistance. In August 2013, fields of trial plants in the Philippines were trampled and destroyed by anti-GMO protestors. The destruction prompted thousands to sign a statement condemning the destruction of the rice fields, which was echoed in an editorial in *Science*.

The herbicide treadmill

Science has repeatedly laid to rest claims about GMOs' adverse effects on human health. But some environmental impacts have surfaced. The primary problem, though — weed resistance to particular herbicides — is not unique to GM crops.

Engineered crops typically have traits that help farmers tackle very old foes. Weeds are one such headache, and they were among the earliest targets of genetic engineers. While chemical weed killers were in use before the advent of GM crops, the use of the herbicide glyphosate, marketed as Roundup, has skyrocketed since the introduction in the 1990s of crops engineered to withstand it. Glyphosate meddles with an essential plant enzyme; the engineered crops have a bacterial version of the enzyme, so the plants persist while neighboring weeds perish. "Roundup ready" plants, which now dominate U.S. fields, include soybeans, corn, canola, cotton and sugar beets.

GM crops that tolerate herbicides deserve some praise: They help minimize mechanical weed removal, which means less soil erosion, more carbon stored in the soil and fewer carbon emissions from tilling equipment making trips across fields, scientists noted in 2012 in a special issue of *Weed Science* focused on herbicide-resistance management. And compared with many of the herbicides it replaced, glyphosate is less toxic; it also offered ease and flexibility to farmers who previously had to carefully navigate the timing and selection of applying various herbicides.

But glyphosate-tolerant GM crops made things too easy.

"Everyone started growing them and then everyone started using glyphosate," says weed scientist Carol Mallory-Smith of Oregon State University, an expert in herbicide resistance.

When the same herbicide is applied to the same area year after year, overuse can lead to evolved resistance, as it does with antibiotics, says William Vencill of the University of Georgia, coauthor with Mallory-Smith of a paper in the *Weed Science* special issue. There are now major weeds, such as Palmer amaranth (*Amaranthus palmeri*), that have developed resistance to glyphosate, leaving farmers scrambling for new solutions, including use of chemical controls that are more toxic than glyphosate. These weeds are not "superweeds," Mallory-Smith says. "There's nothing super about them and they can still be controlled with other herbicides." She emphasizes that this cycle, known as the herbicide treadmill, isn't unique to GM crops. "We've had resistance problems for more than 50 years," she says. "It results from overuse and mismanagement."

> "We've had [herbicide] resistance problems for more than 50 years. It results from overuse and mismanagement."
>
> CAROL MALLORY-SMITH

Into the wild

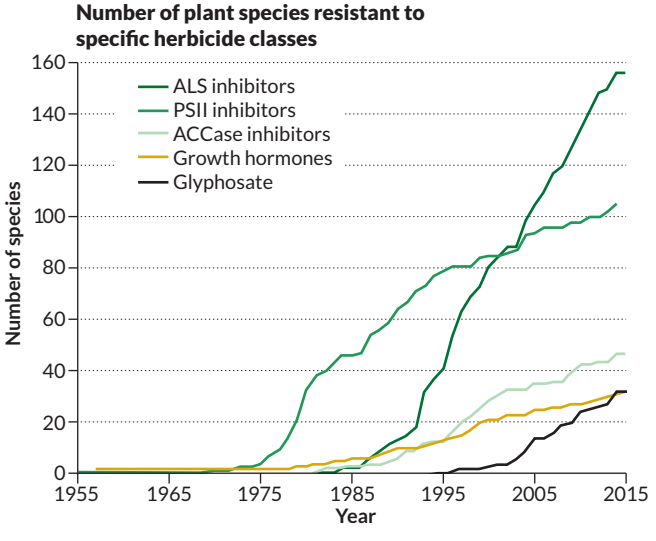
Herbicide resistance is predictable — that's Evolution 101. And the chances that genes from GM crops will spread to wild relatives is similarly predictable. It depends on basic biology, says Mallory-Smith. "The bottom line is if you have a species with compatible relatives that occur in the same area, gene flow will occur," she says.

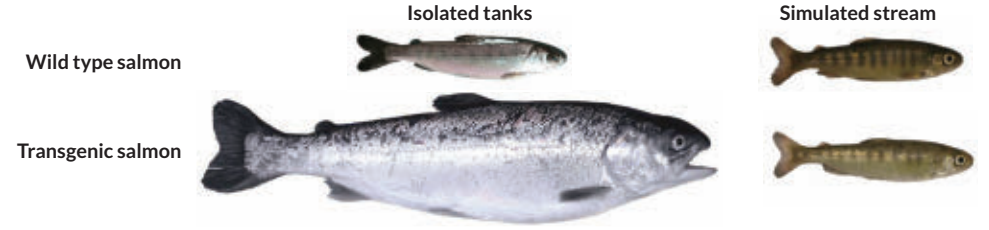
And it has. While corn and soy don't have close wild relatives in the United States, canola, another widely planted GM crop, does. Herbicide-resistance genes from GM canola have turned up in wild, weedy mustard plants on roadsides in the United States, Canada and elsewhere. Mallory-Smith and colleagues have documented another escapee: a GM version of creeping bentgrass, a turf species that was being tested in Oregon. The grass has established itself in patches near the test site, and it has hybridized with a local weed called rabbitfootgrass.

"It's always good to ask where will the genes go and what difference will it make," says ecologist Allison Snow of Ohio State University, also an expert in transgenic gene flow. And while the documented cases of escapees suggest that regulatory agencies need to apply more caution regarding where GM plants can be grown, there haven't been any catastrophic outcomes, she says. "The things we worried about 10 years ago haven't yet happened," she says. "I can't point to anything dire."

GM escapees present legitimate legal and cultural conundrums, Snow notes. For example, an organic farmer can no

Rising resistance Many herbicides interfere with a specific aspect of plant metabolism. Repeated use (across acres and time) leads to weeds resistant to the herbicides' action. A growing number of weeds are resistant to several herbicide classes (listed below), including glyphosate (black). SOURCE: IAN HEAP, WEEDSCIENCE.ORG 2015





Fish out of water What would happen if GM fish escaped and bred in the wild is a big question. In experiments with GM coho salmon, the transgenic fish grow rapidly in a hatchery tank, but not in a simulated natural stream. It's unknown if the same would happen for newly approved GM Atlantic salmon.

L.F. SUNDSTRÖM *ET AL*/*PNAS* 2007

longer call crops organic if they get contaminated by nearby GM crops. "But that's not an ecological problem," she says. "It has nothing to do with a GM species taking over."

The potential environmental implications of an escaped GM Atlantic salmon, the first GM animal to garner regulatory approval, are a little harder to predict. But there are multiple safeguards in place to prevent the fast-growing fish from escaping and breeding in the wild. There are biological precautionary measures: The fish are engineered to be all female and to have three sets of chromosomes so they can't breed with wild fish. But error rates in the sterilization process are inevitable and roughly 1 percent will probably be able to breed successfully. There are also physical hurdles: The current approved arrangement for farming the fish entails producing the eggs in an indoor facility in Canada and then shipping them to inland covered tanks in the highlands of Panama.

"There are a lot of redundant layers of strict confinement," says Virginia Tech fisheries expert Eric Hallerman. "That's why I'm comfortable with it."

The fast-growing fish contains a growth hormone gene from Chinook salmon and regulatory DNA from the eel-like ocean pout that keeps the salmon growing all year, enabling the fish to reach full size in a year and a half instead of the standard three years. And while the modified salmon look formidable next to slower-growing relatives, if they did escape and somehow managed to persist, it's not clear who would outcompete whom in the wild, says fisheries biologist Robert Devlin of Fisheries and Oceans Canada.

For several years, Devlin and his colleagues have been growing an equivalent transgenic Pacific salmon in land-bound caged tanks and mock streams. Experiments with these transgenics and wild fish present a mixed picture that plays out differently in different contexts. For example, the engineered salmon outcompete their wild relatives in the cushy tanks where food is plentiful. But they are at a disadvantage in the mock streams where there is less food and there are predators. Evidence from other studies, reviewed in June 2015 by Devlin and coauthors in *BioScience*, suggests that the GM fish take more risks than wild salmon, which makes them more likely to be eaten.

Yet different experiments, breeding GM Atlantic salmon with wild brown trout, suggest that in some contexts hybrid offspring can outcompete both their GM and wild parents, scientists reported in the *Proceedings of the Royal Society B* in 2013.

90
percent
Fraction of biotech crop farmers who are in resource-poor nations

Devlin is reserved in his verdict. "I'm not against transgenic technology and I'm not for it," he says. "I'm neutral. There could be lots of benefits, but my view is we proceed with scientific information rather than speculation."

That view dominates in the scientific community, yet acceptance of GMOs by the public hinges on more than good science. Some critics take issue with GMOs, not out of misplaced fear, but because they see a yawning gap between the promise of GM foods — feeding the world's poor — and what's been realized: a handful of corporations making money selling both the GM seeds and the chemicals needed to grow them. That scenario doesn't inspire trust, Qaim notes. In the United States, a legacy of regulatory debacles, such as the delay in curtailing the use of the pesticide DDT, doesn't help either.

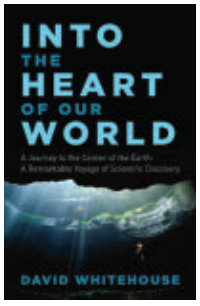
Yet while GMOs and profits for agribusiness seem cemented together in the public's mind, it's an inaccurate picture, Qaim says. Despite approved crops being created for markets in the developed world, farmers in developing countries have seen higher incomes, greater productivity and significant reductions in pesticide use, according to a 2014 analysis by Qaim and former Göttingen colleague Wilhelm Klümper. And the next generation of GMOs, many of which are stalled in regulatory limbo, increasingly have traits that benefit consumers, not just the producers of the crops.

Whether the specter of Big Ag's role in developing and selling many of the existing GMOs will overshadow future developments remains to be seen. Currently, even when there's funding and momentum to develop a new GMO in the lab, public sector efforts often wilt in the face of the cost, time and political will needed to gain approval — leaving the successes to the giants, Qaim notes. If the tide turns, promising crops, such as a gluten-free wheat or GM green beans with added iron to fight anemia, might make their mark alongside the yield-improving GM crops.

Hallerman says the real significance of the GM-salmon approval is that it could be a step toward opening minds among the public, although that may take generations, he says. (Whole Foods and Costco have announced they will not sell the GM salmon.) "It's not about salmon for Western consumers," he says. "It's about food security in the developing world." ■

Explore more

- National Research Council. "Public engagement on genetically modified organisms: When science and citizens connect." 2015.



Into the Heart of Our World
David Whitehouse
PEGASUS BOOKS, $27.95

BOOKSHELF

Earth gives up its inner secrets in retelling of old tale

More than 150 years ago, Jules Verne imagined a fantastic voyage into Earth's depths. In reality, the planet's innards are no less remarkable than the Jurassic-period monsters and subterranean labyrinths that Verne envisioned: Iron crystals stretch 20 kilometers long, colossal plumes of liquefied rock surge toward the surface and fragments of ancient seafloors lie entombed in the mantle.

In his latest book, astronomer and writer David Whitehouse takes readers on a scientific journey to the center of the Earth. The trip explores the latest discoveries about what lies beneath our feet and what mysteries remain unsolved (*SN: 9/19/15, p. 18*). Whitehouse intertwines these facts with compelling retellings of research expeditions and throwbacks to Verne's classic tale.

While the characters in Verne's novel descended through an Icelandic volcano, real-life earth scientists have a trickier time getting up close and personal with their research subject, Whitehouse notes. The deepest humans have ever traveled is about four kilometers below ground, in a gold mine in South Africa — not even a thousandth of the way to Earth's center. Humans will reach the stars before the center of the Earth, Whitehouse predicts.

Luckily, scientists have a bag of tricks for looking deeper into the planet. Researchers glean information from earthquakes, diamonds and even rumbles from nuclear bomb tests. That research has revealed the complex and sometimes downright bizarre makeup of Earth's interior, including an inner, inner core (*SN: 1/23/16, p. 8*), and the geophysical mechanisms that drive plate tectonics. Collecting these clues helps scientists better understand humankind's unique place in the cosmos, Whitehouse contends. Earth's life-protecting magnetic field and climate-controlling plate tectonics mean that "we are as much children of the core as we are the offspring of air and water," he writes.

The breadth of Whitehouse's journey — from crust to core and beyond — results in the book's biggest weakness. With so much ground to cover (and underground, too), the book frequently moves on to its next topic before everything has been explored in full detail. In this sense, *Into the Heart of Our World* is a great introduction to the mysteries of Earth's depths that will leave readers clamoring for a more in-depth trip into the planet. — *Thomas Sumner*

The Cosmic Web
J. Richard Gott
PRINCETON UNIV., $29.95

BOOKSHELF

Universe's tangled architecture revealed

We live in a universe of either honeycombs or meatballs. At least, that's how cosmologists imagined the universe not long ago. But neither analogy is quite right. The universe instead resembles a vast spiderweb, made of gas and galaxies. It's a view of the cosmos that partly originated in a high school science project.

Weaving together personal anecdotes with physics and math, Princeton astrophysicist J. Richard Gott's *The Cosmic Web* chronicles the nearly 100-year quest to understand the anatomy of the universe. The journey focuses on efforts by Gott and his colleagues to see the "big picture" and figure out what the universe's structure can reveal about the conditions during the first moments after the Big Bang.

By the early 1980s, there were two schools of thought: One stated that the cosmos consists of isolated clusters of galaxies (meatballs) while the other claimed that galaxies form along walls enveloping vast voids (honeycombs). In 1986, Gott and colleagues introduced a sort of compromise: The universe looks like a sponge, with galaxies tracing out a dense cosmic web. This web arose in the wake of the Big Bang and stretched from subatomic sizes to cosmic proportions during the subsequent 13.8 billion years of cosmic expansion. Gott's vision has since been vindicated as telescopes have revealed that galactic superclusters and filaments indeed link together in a web stretching across the universe.

Gott brings detailed insight to how our view of the cosmos has changed, providing a thorough accounting of how cosmologists arrived at these revelations. His cosmic sponge idea, for example, was inspired by his high school project on a class of three-dimensional polygons that, when stacked, create a structure reminiscent of a marine sponge. The project won him second place at the 1965 Westinghouse Science Talent Search (now the Intel Science Talent Search, run by Society for Science & the Public, which publishes *Science News*).

At times, it's not clear who Gott's intended audience is. The blend of memoir and technical prose gives the book an uneven tone. Clever analogies sit alongside equations and mathematical notation, both of which share space with anecdotes from his career. These asides, while fun to read, sometimes make already tricky concepts even harder to follow. Issues of tone and audience aside, cosmology junkies will find a new and deep appreciation for what goes into understanding how the universe works. — *Christopher Crockett*

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

Science News arrives in China

Society for Science & the Public has teamed up with an international publisher to make its award-winning journalism available in another language. In January, a book-length collection of *Science News* articles, on the topic of "Humans and Society" and translated into Chinese, went on sale across mainland China. "Our mission at the Society is global, because science is universal," says Maya Ajmera, chief executive officer and president of the Society and publisher of *Science News*. "Developments and discoveries affect individuals all over the world, and our new deal with Publishing House Electronics Industry expands our global reach to bring *Science News* to China." More collections are on the way later this year.

"Developments and discoveries affect individuals all over the world … [This project] expands our global reach to bring *Science News* to China."

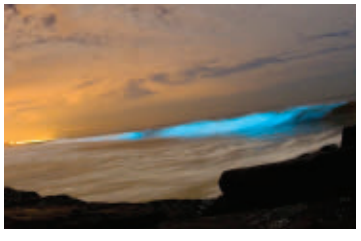
MAYA AJMERA

DECEMBER 12, 2015

SOCIAL MEDIA

What's on your #scibucketlist?

Science News blogger Bethany Brookshire launched a viral Twitter hashtag in December when she asked followers what was on their #scibucketlist (hers included dissecting a whale). Science lovers worldwide shared their dreams.



Swim in bioluminescent dinoflagellates **@Alice_Porter**
(Coastal New Jersey pictured above)

Determine the function of a gene and give it a snazzy name **@CPJ_Jewell**

See convincing evidence of life outside our solar system in my lifetime **@abensonca**

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Gene drives at the wheel

*Tina Hesman Saey discussed the power of a new gene-editing technique to boost the development of gene drives in "Gene drives unleashed" (SN: 12/12/15, p. 16). Gene drives have the potential to eradicate insectborne diseases, **Saey** wrote, or remove invasive species from non-native environments. But the tremendous possibilities of this technology had several readers worried.*

Ellen Gryniewicz wanted to know what effect a gene drive–engineered mosquito might have on the bats and birds that eat the insect. "How often is this driver going to be incorporated into the predator's genome, and where?" she asked in an e-mail. "What about the prey of the mosquitoes?" Would biting into prey pass on any mosquito cells in which the gene drive is expressed?

Assuming a gene drive is inserted into the right spot, it would not be incorporated into a predator's genome, **Saey** says. The idea is to target a gene that is unique to the species of mosquito being engineered. Another safeguard would be to design the system so that the Cas9 enzyme, which cuts the target gene and allows the gene drive to move, would be made only in the sperm or eggs of the mosquitoes. That would ensure that the gene drive only hops around during mating, reducing the chance for unintended leaps to other species.

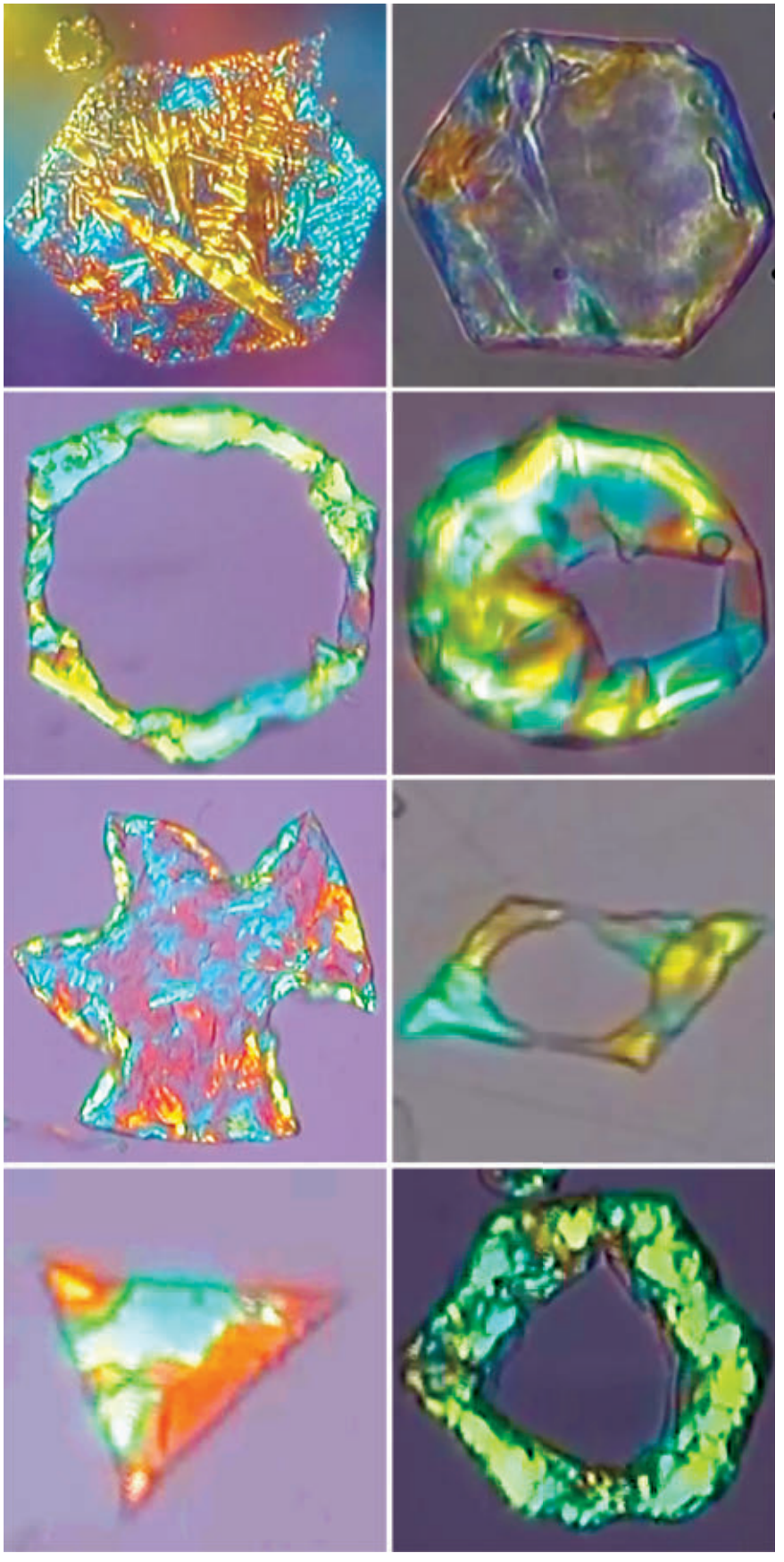
Still, scientists are keenly aware of potential perils, **Saey** says, which is why a group of researchers issued guidelines in 2015 for those working with the technology. "Just as researchers working with self-propagating pathogens must ensure that these agents do not escape to the outside world, scientists working in the laboratory with gene drive constructs are responsible for keeping them confined," the group concluded. But the control measures the scientists advocate are so far limited to the lab. Gene drives, after all, would ideally spread throughout a population, and it's still not known what the ecological consequences could be. For example, it is still unclear whether a gene drive in one species could spread to a closely related species through interbreeding.

Saey notes that not all gene drives are designed to do the same thing. Some, known as suppression drives, would knock down pest populations by creating sterilized mosquitoes or skewing the sex ratios of invasive species populations. Suppression drives are the gene drives that people worry about most because of their theoretical ability to wipe out entire populations with the introduction of just one gene drive–carrying individual. But other gene drives wouldn't affect a species' reproductive capability. Rather, they could prevent mosquitoes or other animals from catching or spreading a disease. That's an approach that researchers hope will destroy pathogens, such as the plasmodium that causes malaria, but spare the host species.

Many readers also expressed concern that gene drives could fall into the hands of terrorists. Scientists say that gene drives would make really terrible weapons: For one thing, unlike bacteria and viruses, they aren't contagious in air or water. Gene drives are only passed along during mating. So if terrorists did design a gene drive for humans, they would first need to get the DNA into people — a hurdle even for gene therapy efforts — and then they'd have to wait generations to see an effect (the gene drive would probably not be deadly since, for the weapon to be effective, infected people would need to be alive to pass it to their children). There would be plenty of time to detect and reverse such an attack, **Saey** says.

Correction

Tina Hesman Saey's recent story about how the same foods can affect dieters' blood sugar differently incorrectly interpreted the measurement mg/dl*h as milligrams (of blood glucose) per deciliter of hemoglobin (*SN: 1/9/16, p. 8*). The researchers measured milligrams of blood glucose per deciliter (of whole blood) per hour.



Cooling oil droplets morph and shine

In carefully chilled conditions, microscopic beads of oil freeze to form a panoply of shapes.

The triangles, hexagons and other structures at left are oil droplets tens of micrometers across that are mixed with water and a detergent-like substance, and then slowly frozen to form hydrogen-carbon crystals. Polarized light passing through the crystals disperses to create the kaleidoscopic color displays. University of Cambridge materials scientist Stoyan Smoukov and colleagues described the assorted shapes and the recipes for crafting them in the Dec. 17 *Nature*.

Scientists have observed similar transformations in other hydrocarbons, but this is the first time researchers have managed to manipulate the droplets' shape-shifting, Smoukov says. His team varied detergent types and cooling speeds to control the geometries of the droplets. All four droplets in the left column are made of the same substance, a chemical chain of 16 carbon and 34 hydrogen atoms. The other crystals contain from 14 to 20 carbons.

The new technique may allow scientists to efficiently produce an assortment of custom-shaped miniature bricks. Those bricks, Smoukov says, could serve as building blocks for larger, more complex structures, or as vessels for delivering drugs inside the body. — *Sarah Schwartz*

N. DENKOV *ET AL*./*NATURE* 2015

No More Excuses for a Restless Night's Sleep

We've all had nights when we just can't lie down in bed and sleep, whether it's from heartburn, cardiac problems or hip and back aches. Those are the nights we'd give anything for a comfortable chair to sleep in, one that reclines to exactly the right degree, raises feet and legs to precisely the desired level, supports the head and shoulders properly, and sends a hopeful sleeper right off to dreamland.

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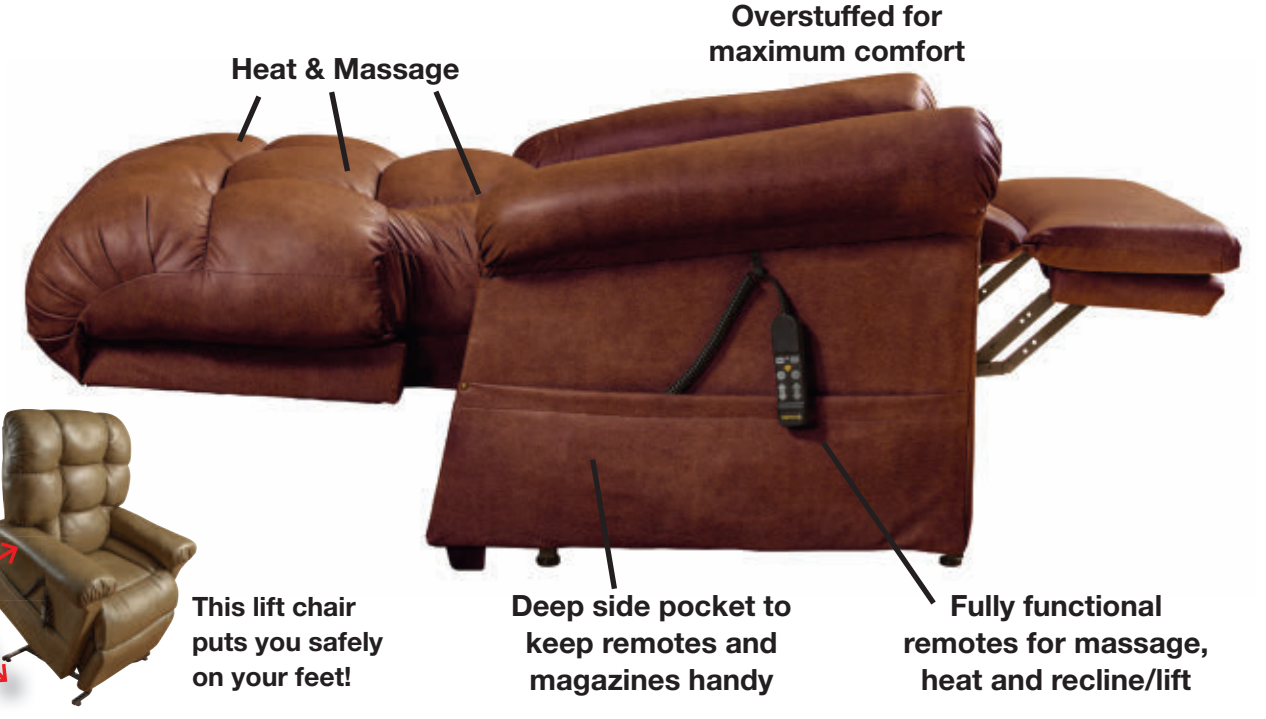

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New!

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In frontier times, the Apache people of the Southwest were famed and feared for their incredible skill with a bow and arrow. An Apache's aim was always on point. This impressive accuracy was earned through dedicated practice, but the Apache also believe that wearing their iconic blue-green stones steadied the hand, granted a little extra luck and imbued the wearer with added confidence when pulling back the bow and releasing an arrow.

The Stauer *Blue Arrow Necklace* is equally on point and designed to deliver added confidence in any setting. This necklace offers an incredible 350 carats of that same turquoise look the Apache put their faith in. The undeniable glamour of this statement necklace comes from its rugged natural beauty, making it equally ideal for a formal affair where you want to stand out or a laid back gathering where you want to unwind.

This much blue-green beauty can be prohibitively expensive, but the Stauer *Blue Arrow Necklace,* handcrafted from genuine howlite, gives you a striking legendary blue-green stone for **ONLY $49.** We can thank Canadian gemologist Henry How for discovering howlite in 1868—this impressive stone delivers the same dramatic look of the popular desert gemstone without the dramatic price.

We're not promising that you'll suddenly start winning archery competitions, but don't be surprised if the relaxed luxury of 350 carats of the *Blue Arrow Necklace* imbues you with extra confidence.

★★★★★

"I would rate it a 5. I like the length and the colors are beautiful."

— Kay, Ardmore, OK

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