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SCIENCE NEWS MAGAZINE
SOCIETY FOR SCIENCE & THE PUBLIC
AUGUST 20, 2016

Dolly's Sisters Age Well

Birds Aid Honey Hunters

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# Leaving the Salt BEHIND

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# How to Be Cut Off From Civilization

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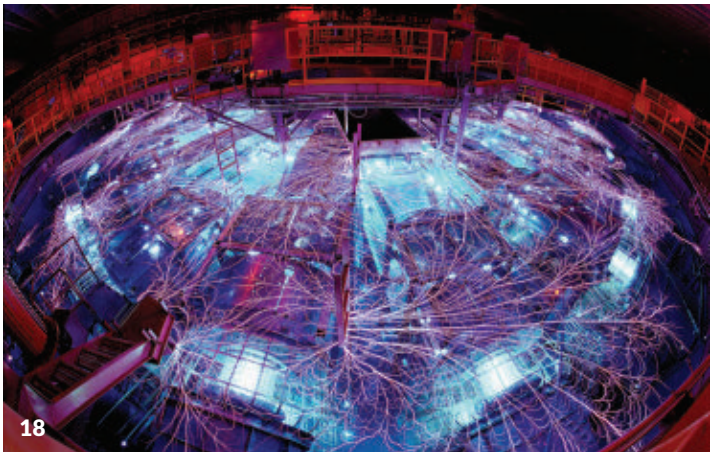
# ScienceNews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Bring *Science News* to high schools

**COVER** Desalination plants, like this one in Porta Negra, Brazil, yield freshwater, leaving lots of salt behind. *Agencja Fotograficzna Caro/Alamy Stock Photo*

CLOCKWISE FROM TOP LEFT: RANDY MONTOYA/SANDIA LABS; © JORGE GONZALEZ, PABLO LARA; C. SPOTTISWOODE

# City of graphene hosts forum full of questions

Manchester, England, is not the birthplace of graphene — the atom-thin, honeycomb-like layer of carbon known for its wondrous properties and seemingly limitless applications. But the city is the material's main booster and, according to the University of Manchester, the official Home of Graphene. That's because it was there that Andre Geim and Kostya Novoselov figured out that you could isolate the elusive material from graphite (the "lead" in pencils) with repeated dabs of sticky tape.

The two-dimensional material also proved to be a peerless electrical conductor and superstrong, earning the two Manchester scientists the 2010 Nobel Prize in physics. So when the city played host to the EuroScience Open Forum conference late last month, it made sense that Geim, graphene and the material's many evolving applications took center stage. At the local science museum's new exhibit about graphene, I learned that Geim is the only Nobelist who has also been honored with an Ig Nobel (which has fun celebrating seemingly useless research in science). He contends many are more familiar with his Ig Nobel–winning device to levitate a tiny frog than with his work on graphene.

Notably, graphene comes up in both of the feature stories in this issue, adding some heft, perhaps, to Mancunian claims. In Thomas Sumner's cover story (Page 22) about the growing interest in desalination to meet the globe's escalating need for freshwater, graphene oxide has a potentially starring role. New membranes made from this material may help increase the efficiency of separating salt from water. Cost and efficiency, Sumner reports, remain the biggest obstacles to the widespread use of desalination.

Graphene can serve as analogy and inspiration in physicists' efforts to create solid metallic hydrogen, another theorized wonder material, which Emily Conover describes on Page 18. "It's a high-stakes, high-passion pursuit that sparks dreams of a coveted new material that could unlock enormous technological advances in electronics," Conover writes. Solid hydrogen, which has been made, takes on a graphenelike structure when squeezed to high pressures. Solid metal hydrogen might be a superconductor at room temperature, an exciting prospect. Despite significant progress, so far no one has been able to create it.

Local celebrity or not, graphene did share the spotlight with other science superstars at the EuroScience meeting. The gene-editing tool CRISPR got lots of attention. In a review of the historic detection of gravitational waves, Sheila Rowan of the University of Glasgow offered a bevy of questions that gravitational astronomy might be able to answer in the coming years: Where and when do black holes form? What does that tell you about the large-scale formation of galaxies? Is general relativity still valid when gravity is very strong (such as near supermassive black holes)? A session on the human microbiome generated even more questions, as scientists described efforts to use microbial species as telltale signs of diseases such as cancer. And a debate about how to prevent food allergies left most agreeing that more data are needed. As answers come in on all of these and many more fascinating topics, you can be sure that *Science News* will be there to report on them. — *Eva Emerson, Editor in Chief*





SANDY SCHAFFER

# *NEW* Rechargeable Digital Hearing Aid Technology Only $179!*

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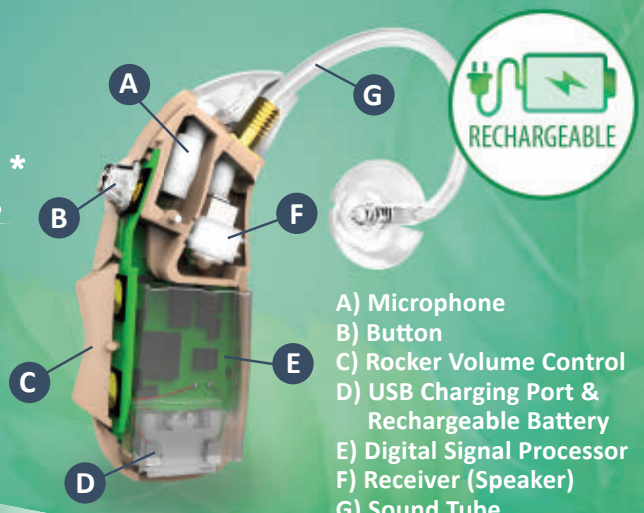


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**Great Hearing Aid!** "I'm really glad I tried the HCRC! It works as good as or better than the more expensive ones I've purchased in the past. It's great that the price is reasonable. Thank you for the great product." *- Tim M.*

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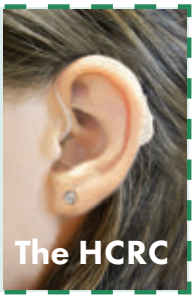


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Excerpt from the August 20, 1966 issue of *Science News*

50 YEARS AGO

## Rare Chinese tree may help fight leukemia

Leukemia victims may one day be helped by a substance drawn from an obscure Chinese tree. Tests on laboratory animals with a type of experimental leukemia ... have shown that the extract, known as camptothecin, has high antitumor properties. However, no tests on humans have yet taken place. Chemists are trying now to synthesize the substance, whose only known natural source is the rare *Camptotheca acuminata* tree.

**UPDATE:** Although it didn't prove effective against leukemia, a synthetic version of camptothecin is used to treat ovarian, lung and colon cancers. Clinical trials in humans began in the late 1960s, but early efforts to make the compound water soluble came with toxicity. Patient studies resumed in the 1980s, once researchers made safer water-soluble versions that could still kill tumors. Two synthetic forms, marketed as Camptosar and Hycamtin, are used in chemotherapy treatments today.

Green blood gives the tongue and gums their unusual but healthy color in *Prasinohaema* lizards (female *P. prehensicauda* shown). Some fish and insects have greenish blood, but no known mammals or other reptiles do.

IT'S ALIVE

## It's not easy being green-blooded

"Dark lime green" is how biologist Zachary Rodriguez describes the blood of the *Prasinohaema* lizards of New Guinea and surrounding islands. "Vivid," he adds.

With green blood comes Granny Smith-colored muscles and bones and a blue-green mouth, exposed during defensive posturing. But the strangest thing about the five species of *Prasinohaema* lizard is that they can live like that.

Lime, apple and avocado can be risky blood colors. They indicate that these lizard species build up a toxic substance called biliverdin. The lizards' red blood cells still depend on hemoglobin, the stuff that ferries oxygen and makes most animal blood red, but any lizard-blood redness is overwhelmed by massive concentrations of the green biliverdin. A breakdown product of hemoglobin, biliverdin gives the greenish edge to bruised human flesh. Most animal bodies quickly whisk it away.

High concentrations of biliverdin, say over 50 micromoles per liter, make humans sick with jaundice. The lizards, however, do just fine with 714 to 1,020 µM/L.

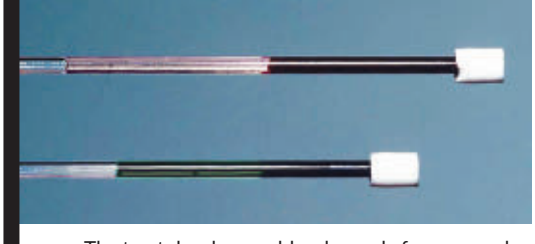
It's tempting to wonder if evolution has favored green blood because toxic biliverdin might make predators spit out any lizard they start to bite. Not so, based on current evidence, Rodriguez says. An old test found that a predatory bird and a snake relished green-blooded lizards; he's heard that cats love them, too.

Plenty of other ideas are still in play, among them: The biliverdin may reduce susceptibility to malaria or to cell damage from the sun's ultraviolet rays, or even add some extra camouflage for life in trees. To look for clues to how evolution drove the death-defying color, Rodriguez and his adviser, Christopher Austin at Louisiana State University in Baton Rouge, are using genetics to create a genealogical tree of the lizards and their relatives.

Figuring out where among the ancestors the blood color arose could give clues to what kind of lifestyles or environments favored toxic green. So far, oddly enough, the biliverdin-tinted lizards don't seem to be each other's closest known relatives. Some *Prasinohaema* species look as if they have red-blooded sister species (classified in other genera) that are evolutionarily closer than any other *Prasinohaema*.

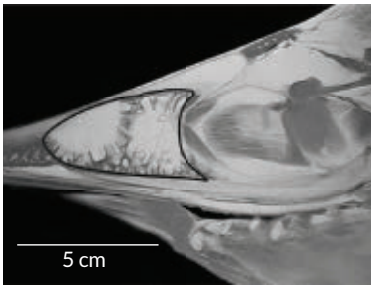
However the final tree turns out, this evolutionary tale will be lively, with red-and-green, stop-and-go lizard history.

*—Susan Milius*



The top tube shows a blood sample from a regular red-blooded lizard from New Guinea (*Lamprolepis smaragdina*). In the bottom tube, the natural buildup of a bile compound that could kill other species turns *Prasinohaema* blood green.

BOTH: C. AUSTIN/LOUISIANA STATE UNIV.




An MRI scan reveals that swordfish have an oil-producing organ (outlined in black) tucked just behind its rapier-like bill.

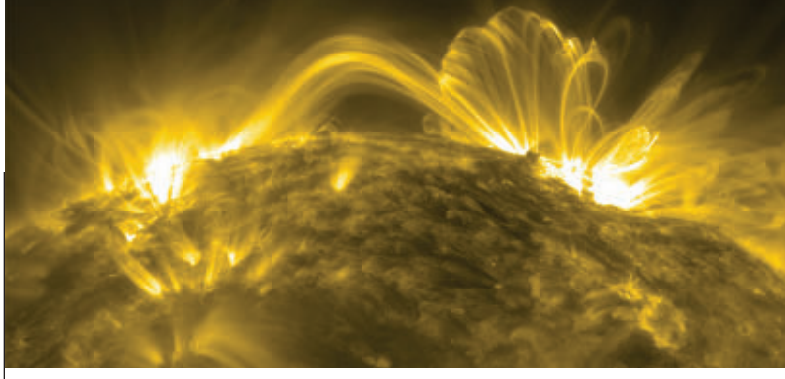
THE -EST

## Swordfish oil boosts speed in water

Olympic swimmers shave their bodies before a big race to break records. Swordfish use a different trick to reach top speeds, a new study suggests: They grease their heads. Swordfish (*Xiphias gladius*) are among the fastest fish in the ocean; their streamlined bodies can cut through the water at about 90 kilometers per hour.

A newly discovered oil-producing organ in the fish's head makes its skin slick and could boost speed, scientists report in the July 6 *Journal of Experimental Biology*. MRI scans show that the organ links to tiny pores on the head that ooze oil, creating a thin layer of lubrication on the skin's surface.

Tiny ridged structures called denticles surround the pores. Denticles look like scales but are made of dentine and enamel, like teeth. The scientists, from the Netherlands and Germany, suspect the lubrication and the textured denticles work together to make a water-repelling surface that lets swordfish glide through the water with minimal drag. — *Laurel Hamers*



SCIENCE STATS

## Gas steers sun's magnetic fields

About 20,000 kilometers beneath the sun's surface, magnetic fields rise no faster than about 500 kilometers per hour. That speed (roughly one-third of previous estimates) is about the same speed that gas rises and falls within the sun, implying that moving parcels of gas help steer magnetic fields toward the surface, researchers report July 13 in *Science Advances*. Aaron Birch of the Max Planck Institute for Solar System Research in Göttingen, Germany, and colleagues estimated the speed by combining observations of the sun's surface with computer simulations of how gas moves within the hot orb. By studying the sun's inner workings, researchers hope to understand what drives sunspots and flares — the blemishes and eruptions triggered by magnetic fields punching through the surface. — *Christopher Crockett*

**500**
**kilometers per hour**
Maximum speed at which the sun's magnetic fields rise to the surface

INTRODUCING

## *T. rex* look-alike unearthed in Patagonia

What had two puny arms, lived 90 million years ago and probably chowed down on other dinosaurs? (Hint: It's not *T. rex*.)

A new dinosaur discovered in what is now Patagonia had the runty forelimbs of a *Tyrannosaurus rex* but is no cousin of the giant iconic predator, researchers report July 13 in *PLOS ONE*.

The new species, *Gualicho shinyae*, has a close relative in Africa, an analysis of fossils suggests. *T. rex*'s ancestors, on the other hand, came from Asia.

*Gualicho* is a "smaller, slimmer, trimmer version of a *T. rex*," says study coauthor Peter Makovicky, a paleontologist at the Field Museum in Chicago. It probably weighed about a ton and was longer than a pickup truck.

In 2007, Makovicky's team discovered *Gualicho*'s partial skeleton — including those impractical arms. The dinosaur probably caught prey with its huge head, Makovicky says. Though the researchers haven't dug up a skull yet, tiny arms seem to be a trade-off for a big head. Finding *Gualicho*'s skull would help nail down that idea, he adds.

*Gualicho* may have fed on grazers called ornithopods, such as duck-billed dinosaurs. Or perhaps it fed on the long-necked, long-tailed sauropods, which were common in the region. But only the youngsters. Sauropod adults were gigantic, Makovicky says, definitely not prey for a (relatively) little guy like *Gualicho*. — *Meghan Rosen*


*Gualicho shinyae* probably relied on a huge head with a mouthful of teeth to hunt smaller dinosaurs. The predator's runty, two-fingered arms look like those of *Tyrannosaurus rex*.

CLOCKWISE FROM TOP LEFT: J.J. VIDELER *ET AL/J. EXP. BIOL.* 2016; NASA GODDARD SPACE FLIGHT CTR; PETER MAKOVICKY; © JORGE GONZALEZ, PABLO LARA

Dolly the Sheep's nearly identical sisters (shown) were produced from the same mammary gland tissue as Dolly. The new clones are not aging prematurely, as was feared for Dolly.

UNIV. OF NOTTINGHAM

GENES & CELLS

# Dolly's cloned sisters aging gracefully

## Method to create nearly identical animals doesn't harm health

**BY TINA HESMAN SAEY**

Clones don't age prematurely, new research on Dolly the Sheep's sisters suggests.

Researchers and animal welfare activists have been concerned that cloning, via somatic cell nuclear transfer, could cause health problems in cloned animals. Instead, a study of 13 cloned sheep found no signs of early aging or other health problems, researchers report July 26 in *Nature Communications*.

"These animals were remarkably healthy and fall within the normal range that we'd expect in animals of this age," said developmental biologist Kevin Sinclair of the University of Nottingham's Sutton Bonington campus in England. Sinclair spoke July 25 during a news conference at the EuroScience Open Forum in Manchester, England.

The cloning technique places the DNA-containing nucleus of an adult cell into an empty egg where the DNA is then reprogrammed to an embryonic state. Dolly the Sheep, born in 1996, was the first mammal ever cloned. Since then, researchers have cloned a wide variety of animals. The technique doesn't always work and many potential clones die before birth or shortly after. Surviving animals might have problems because of incomplete reprogramming of the DNA.

Dolly herself gave rise to the idea that clones age fast. Compared with other animals her age, Dolly had shorter telomeres, the caps that protect the ends of chromosomes from unraveling. Short telomeres have been associated with aging. Plus, Dolly had severe arthritis. She died at age 6, although not of old age. Dolly and other, noncloned sheep in her flock caught a virus that killed them (*SN: 3/1/03, p. 141*).

Her untimely death, arthritis and short telomeres "were mushed together in people's perception," leading to the idea that clones age prematurely, says Katrin Hinrichs, a reproductive physiologist at Texas A&M University College of Veterinary Medicine and Biomedical Sciences in College Station. Hinrichs and other researchers not involved in the study hope the new report corrects the record on cloning and aging. "Now we have a reference to say what is and what is not a result of cloning," she says.

How fast animals age varies, even among nonclones, says reproductive biologist Mark Westhusin, also of Texas A&M. Westhusin was on the team that produced cc (short for Carbon Copy), the first cloned cat (*SN: 3/23/02, p. 189*). The cat is now 15 and doing fine, says Westhusin. "This is a nice paper to confirm in a more formal scientific setting what most people involved with cloning have believed for a long time." Some studies have even hinted that clones may live longer than conventionally bred animals (*SN: 4/29/00, p. 279*).

In the new study, Sinclair and colleagues examined 13 cloned sheep ages 7 to 9 years old (roughly equivalent to people in their 50s to 70s). Four of the sheep — Debbie, Denise, Dianna and Daisy — were cloned in 2007 from the same mammary gland tissue that produced Dolly. The researchers compared Dolly's sister clones and nine clones of other sheep with 5- to 6-year-old sheep bred by traditional means.

Cloned sheep had normal blood sugar levels, insulin levels and blood pressure. A few had mild arthritis. One of Dolly's sister clones had moderate arthritis. The researchers have not yet measured the clones' telomeres.

The sheep were cloned with modifications to the original technique that may have produced a better outcome. But Dolly's problems didn't necessarily stem from being a clone. She may have developed arthritis as a result of trauma to her joints. It's also not clear whether her short telomeres were really an indicator of premature aging. Certainly her death had nothing to do with being a clone. Overall, Sinclair said, "perhaps Dolly was a little less lucky."

Cloning today is done mostly in South America and Asia, and infrequently in the United States, Hinrichs says. Polo ponies and cattle are among the most-cloned animals. "Cloning is so costly and inefficient that your animal has to be very special for cloning to be worth it," she says. As a result, most cloned animals are prized breeding stock or performance animals. Some animals that are genetically resistant to diseases are also cloned for veterinary and medical research. ■

*With reporting from Eva Emerson in Manchester, England*

BODY & BRAIN

# The nose knows how to fight staph

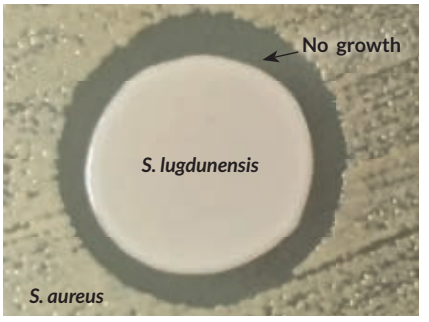
## New type of antibiotic found in human nasal secretions

**BY EVA EMERSON**

MANCHESTER, ENGLAND — The human nose harbors not only a deadly enemy — *Staphylococcus aureus* — but also its natural foe. Scientists have now isolated a compound from that foe that might combat MRSA, the methicillin-resistant strain of *S. aureus*.

"We didn't expect to find this. We were just trying to understand the ecology of the nose to understand how *S. aureus* causes problems," bacteriologist Andreas Peschel of the University of Tübingen in Germany said at a news briefing July 26 during the EuroScience Open Forum. Investigating the intense interspecies competition in the nose — where microbes fight for space and access to scant sugars and amino acids — might offer a fertile alternative to searching for new drug candidates in soil microbes.

Antibiotic researcher Kim Lewis of Northeastern University in Boston agrees that mining the human microbiome might lead to new drug discoveries. But so far, that approach has produced only a handful of potential new antibiotics. If "the compound they found is membrane-acting, [it] will be useful for topical applications but not as a systemic antibiotic," he says. New systemic antibiotics are needed most, he says.




When nasal bacteria meet in a lab dish, *Staphylococcus lugdunensis* (light disk) fights off *S. aureus*.

Although a relatively nutrient-poor environment, the nose is home to over 50 bacterial species. One is *S. aureus*, a dominant cause of hospital-acquired infections such as MRSA, as well as infections of the blood and heart. But there's huge variability in the nasal microbe scene between individuals: While *S. aureus* is present in the nasal passages of roughly 30 percent of people, the other 70 percent have no sign of it.

Peschel and colleagues suspected that other nasal inhabitants, well-tuned to compete in that harsh niche, might be blocking *S. aureus* from colonizing the nose in those who don't carry it.

From nasal secretion samples, the team isolated 90 strains of different *Staphylococcus* species. One of these, *S. lugdunensis*, killed *S. aureus* when they were grown together in a dish. Introducing mutations into *S. lugdunensis* produced a strain that didn't kill. The mutated gene, the team showed, normally produced an antibiotic, which the researchers named lugdunin.

Lugdunin fended off MRSA and a strain of *Enterococcus* resistant to the antibiotic vancomycin. Neither bacterium developed resistance. The team also pitted *S. lugdunensis* against *S. aureus* in test tube and mouse studies, with *S. lugdunensis* besting *S. aureus*. Only 5.9 percent of 187 hospital patients had *S. aureus* in their noses if they also carried *S. lugdunensis*, the team found, while *S. aureus* was present in 34.7 percent of those without *S. lugdunensis*. Peschel and colleagues also reported the results in the July 28 *Nature*.

Next, scientists hope to study how the compound works and search for other microbes active against staph. ■

BODY & BRAIN

# Anesthesia steals awareness in stages

## Going under is neither gradual nor abrupt, monkey study shows

**BY RACHEL EHRENBERG**

The brain doesn't really go out like a light when anesthesia kicks in. Nor does neural activity gradually dim, a new study in monkeys reveals. Rather, intermittent flickers of brain activity appear as the effects of an anesthetic take hold.

Some synchronized networks of brain activity fall out of step as monkeys drift from wakefulness. But those networks resynchronize when deep unconsciousness sets in, researchers report in the July 20 *Journal of Neuroscience*.

That the networks behave differently from each other is surprising, says study coauthor Yumiko Ishizawa of Harvard Medical School and Massachusetts General Hospital. It isn't clear what exactly is going on, she says, but the anesthetic's effects are more complex than thought.

Most anesthesia studies use electroencephalograms, or EEGs, to record brain activity via electrodes on the scalp. The new study offers unprecedented surveillance by eavesdropping via electrodes implanted inside macaques' brains. This view provides new clues to how the brain loses and gains consciousness.

"It's a very detailed description of something we know very little about," says Tristan Bekinschtein, a neuroscientist at the University of Cambridge.

The researchers recorded the activity of small populations of nerve cells in two interconnected brain networks: one that deals with incoming sensory information and one involved with some kinds of movement and with merging different kinds of information. Before the anesthetic propofol kicked in, activity in the regions was similar and synchronized.

But around the moment when the monkeys went unconscious, there was a surge in a particular kind of nerve cell activity in the movement network, followed by a different surge in the sensory network about two minutes later. The networks then began to synchronize again, becoming more in lockstep as the anesthetic state deepened. ■

A. ZIPPERER ET AL/NATURE 2016

EARTH & ENVIRONMENT

# How dinosaurs crossed an ocean

## Land bridges might have enabled transatlantic treks

**BY THOMAS SUMNER**

Two land bridges may have allowed dinosaurs to saunter between Europe and North America around 150 million years ago.

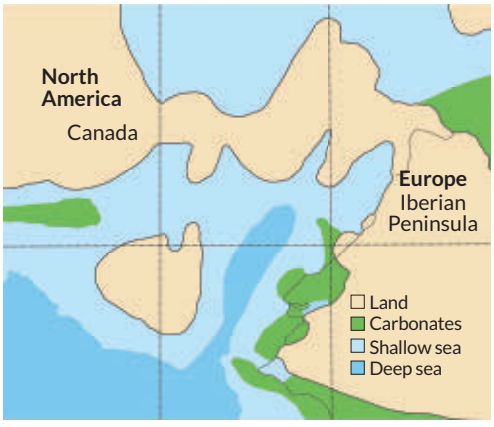
Scientists had previously proposed bridges to explain how dinosaurs, mammals and other animals hopped from one continent to the other after the Atlantic Ocean formed during the breakup of Pangaea. But now, a researcher has reviewed recent studies of fossils on both sides of the Atlantic to pin down where and when those bridges might have formed.

Leonidas Brikiatis, an independent biogeographer in Palaio Faliro, Greece, proposes that two strips of land bridged North America and Europe during the late Jurassic and early Cretaceous periods. One bridge spanned from eastern Canada to the Iberian Peninsula, where Spain is today, and lasted from around 154 million to 151 million years ago. The other linked North America and Scandinavia from around 131 million to 129 million years ago, Brikiatis reports in the August *Earth-Science Reviews*.

The bridge connecting North America and Scandinavia may have coexisted with another land route that connected Europe and what would later become Russia, allowing migrations across much of the world, Brikiatis says.

The routes allowed dinosaurs to "foil plate tectonics' plan to break up the world," says Paul Sereno, a vertebrate paleontologist at the University of Chicago. "A continent can't contain a dinosaur; they'll escape. This work highlights two of the routes they took," he says.

Dinosaurs, including *Supersaurus* and *Allosaurus*, probably made the transatlantic trek alongside turtles, lizards and early mammals. While the Atlantic Ocean was narrower back then, it was probably too wide to swim across. Brikiatis used the dates of these animals' relocations to establish a potential window of time when the bridges might have existed and considered where potential crossings might have been. The best contenders are patches of relatively shallow water called ocean shelves. Tectonic activity could have lifted these shelves




A land route may have connected eastern Canada and the Iberian Peninsula around 150 million years ago. That bridge would have allowed animals to travel between Europe and North America.

L. BRIKIATIS/*EARTH-SCIENCE REVIEWS* 2016

MATTER & ENERGY

# Electrons made to attract each other

## Experiment is step toward high-temp superconductors

**BY EMILY CONOVER**

Standoffish electrons typically keep one another at arm's length, repelling their neighbors. But under certain circumstances, this repulsion can cause pairs of electrons to soften their stance toward one another and attract instead, new research shows. The effect may be the key to someday producing a new type of high-temperature superconductor, scientists report in the July 21 *Nature*.

Though the effect was first predicted over 50 years ago, previous attempts to coerce electrons to behave in this way have failed. Like charges repel, so negatively charged electrons ordinarily rebuff one another. But now researchers have validated the counterintuitive idea that an attraction between electrons can emerge. "Somehow, you have [this] magic that out of all this repulsion you can create attraction," says study coauthor Shahal Ilani, a physicist at the Weizmann Institute of Science in Rehovot, Israel.

Ilani and colleagues produced the effect in a bare-bones system of electrons in carbon nanotubes. Operating at temperatures just above absolute zero, the system is made up of two perpendicular carbon nanotubes — hollow cylinders of carbon atoms — about 1 nanometer in diameter.

Two electrons sit at sites inside the first nanotube. Left to their own devices, those two electrons repel one another. A second nanotube, known as the "polarizer," acts as the "glue" that allows the two electrons to attract. When the scientists brought the two nanotubes close together, Ilani says, "the electrons in the first nanotube changed their nature; they became attractive instead of repulsive."

This flip is due to the nature of the polarizer. It contains one electron, which is located at one of two sites in the carbon nanotube — either between the first nanotube's pair of electrons or farther away. The pair of electrons in the first nanotube repels the polarizer's electron, kicking it from the near to the far site. The electron's absence leaves behind a positively charged vacancy, which attracts the pair of electrons toward it — and toward each other.

It's a "tour de force," says physicist Takis Kontos of the École Normale Supérieure in Paris, who wrote a commentary on the paper in the same issue of *Nature*. Although the system is very simple, he says, "the whole experiment built around it is extremely complex."

Electrons are known to attract in certain situations. In conventional superconductors, electrons pair up due to their interactions with ions in the material. This buddy system allows superconductors to conduct electricity

above sea level, creating narrow strips of land around 80 to 160 kilometers across, Brikiatis says. Over time, the bridges may have sunk back below the sea.

Those land routes would have been somewhat similar to other ocean crossings, such as the Bering land bridge humans traversed around 23,000 years ago between Asia and North America (*SN: 8/22/15, p. 6*).

While the proposed routes are plausible, the dates might be off, says paleontologist Octávio Mateus of the Universidade Nova de Lisboa in Caparica, Portugal. Species may have migrated earlier than evidenced in the fossil record, he says. "They could have come millions of years before, but just didn't leave fossils."

The bridges may also have been more like stepping stones than an unbroken migration highway, says Anne Schulp, a vertebrate paleontologist at the Naturalis Biodiversity Center in Leiden, the Netherlands. "A narrow body of water is not impenetrable," Schulp says. "You don't need a full bridge." ■

without resistance. But such superconductors must be cooled to very low temperatures for this effect to occur.

In 1964, Stanford University physicist William Little theorized that electron pairs could attract due to their interactions with other electrons, instead of ions. Such pairs should stay linked at higher temperatures. This realization sparked hopes that a material with these attracting electrons could be a room-temperature superconductor, which would open up a wealth of technological possibilities for efficiently transmitting and storing energy.

It's yet to be seen whether the newly found effect can produce a superconductor and whether such a superconductor might work at high temperatures — the new discovery shows only that the attraction can occur. But now, Ilani says, scientists can start thinking of how to build "interesting new materials that are very different than what you can find in nature." ■

T. SPRIBILLE *ET AL*/*SCIENCE* 2016

LIFE & EVOLUTION

# Yeasts can hide in lichen partnerships

## Discovery questions textbook idea of organisms' symbiosis

**BY SUSAN MILIUS**

The discovery of yeasts hiding in lichens from six continents might shake up a basic idea of what makes up a lichen partnership.

Fifty-two genera of lichens collected from around the world include a second fungus — single cells, called yeasts, of a previously unknown order now christened Cyphobasidiales. Toby Spribille of the University of Graz in Austria and colleagues report the finding in the July 29 *Science*.

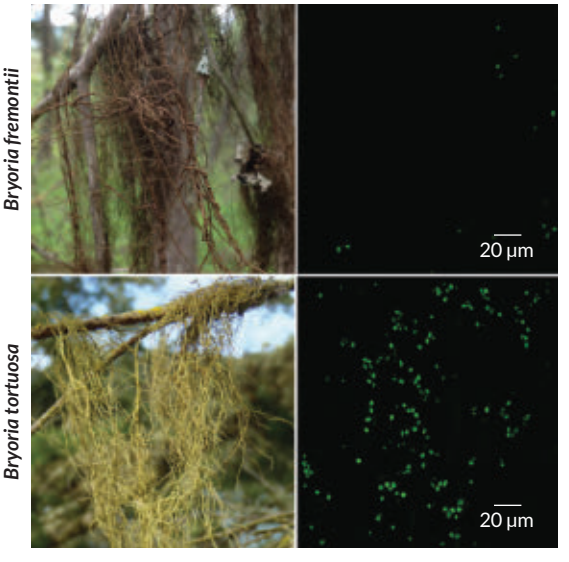
For more than a century, biologists have described a lichen as a fungus growing intimately with some microbes (algae and/or cyanobacteria) that harvest solar energy. The fungus is treated as so important that its name serves as the name for the whole lichen.

Biologists have recognized that more than one fungus can show up in lichens, but the extra fungi's role hasn't been clear. Now that may be on the brink of changing.

The first example discovered illustrates why these yeasts might turn out to be more than parasites or mere hitchhikers, says study coauthor John McCutcheon of the University of Montana in Missoula. He and Spribille wondered how the yellow, toxin-bearing, thready tangles of lichen called *Bryoria tortuosa* could have the same fungus and the same algal partner — and thus technically be the same species — as the brown, toxin-poor lichen called *B. fremontii*.

The researchers looked to see which genes were active in each lichen in hopes that some discrepancy could explain the difference in forms. What the researchers found had nothing to do with the alga or previously known fungus. Instead, ample genetic activity of more abundant yeasts in the toxic *B. tortuosa* turned out to be the most striking disparity.

The research team now has microscope images of yeast cells embedded in the outer layer of *B. tortuosa*. The yeasts might be what's making the difference between the forms, maybe even synthesizing toxic vulpinic acid, the researchers say. Yeasts turning up across this widespread class of lichens might explain other mysteries, such as why scientists have largely failed to re-create lichen partnerships in the lab.




These *Bryoria* lichens combine the same main fungus and algal species but have different appearances and chemical signatures. New research suggests that *B. tortuosa* (bottom left) might have more hidden yeast (bottom right, green dots) than does *B. fremontii* (top).

It's a bold hypothesis, and lichenologist Robert Lücking of the Botanic Garden and Botanical Museum Berlin-Dahlem takes the idea of yeast partners seriously: "This will be a huge surprise to the lichenological and mycological community."

David Hawksworth, a mycologist at Complutense University of Madrid, however, sees no reason to change the one-fungus paradigm without direct evidence of what the yeasts do. ■

A honey hunter in Mozambique holds a captured honeyguide on his finger. New research finds that honeyguides lead honey hunters to bees' nests after hearing the humans make what amounts to a "join the hunt" call.

C. SPOTTISWOODE

HUMANS & SOCIETY

# Honey hunters ask birds for help

## Honeyguides, Yao people communicate to collaborate

**BY BRUCE BOWER**

When asked the right way, a savvy bird species steers African hunter-gatherers to honey. All it takes is a loud trill followed by a grunt that sounds like "brrr-hm."

Birds known as greater honeyguides (*Indicator indicator*) lead hunter-gatherers in Mozambique to honey-rich bees' nests after hearing humans make this signature call, say evolutionary ecologist Claire Spottiswoode of the University of Cambridge and colleagues. In exchange, the birds get human-aided access to perilous-to-reach food, the scientists report in the July 22 *Science*.

The new study provides the first solid evidence of two-way, collaborative communication between humans and a nonhuman animal in the wild. In some parts of the world, dolphins help fishermen herd fish into nets. But it's unclear whether these dolphins respond to specific calls from fishermen.

Honeyguides associate Yao hunter-gatherers' distinctive honey-hunting call with successful joint food hunts, Spottiswoode says. The birds respond to this call by making a loud chattering sound to alert humans to their presence. Honeyguides then fly from tree to tree until reaching one with a bees' nest.

Although the wax-eating birds regularly scope out locations of bees' nests in their home ranges, getting beeswax out of nests is dangerous. "Angry bees can and do sting honeyguides to death," Spottiswoode says.

Yao honey hunters cut down trees containing bees' nests nestled high up in crevices and smoke the insects out with flaming bundles of twigs and leaves. After removing honeycombs from nests, the Yao leave beeswax behind for the honeyguides and even put wax chunks on beds of leaves to reward their avian helpers.

Written accounts of honeyguide-led expeditions to bees' nests date to as early as 1588. But axlike stone implements and human-made fires date to 1 million years ago or more (*SN: 7/9/16, p. 10*). So humans and honeyguides may have hunted together for at least that long, says Harvard University biological anthropologist Richard Wrangham.

In different parts of Africa, honeyguides respond to local honey-hunting calls of human groups, Spottiswoode suspects. A team led by Yale University biological anthropologist Brian Wood has found that Hadza honey hunters in Tanzania make a whistling sound to attract honeyguides. Other hunter-gatherers speak or shout words to call honeyguides, Wood says.

Unlike Yao honey hunters, the Hadza bury or burn much of the wax in bees' nests. Hadza honey seekers believe this keeps honeyguides hungry and motivates them to lead further hunts. Wood's team estimates that 8 to 10 percent of the Hadza's diet comes from honeyguide-led hunts.

The new study "carefully documents one cultural tradition in how people and honeyguides interact," Wood says.

Spottiswoode's group conducted fieldwork in October 2013 and September and October 2015. The researchers tracked movements of six honeyguides fitted with radio transmitters. Overall, 73 of 97 bird-led honey hunts found at least one bees' nest. During the study, nearly three-quarters of 149 bees' nests found by the Yao involved honeyguide assistance.

In another experiment, Spottiswoode accompanied two Yao honey hunters on 72 searches for bees' nests, each lasting 15 minutes. While they walked, a portable speaker played recordings every seven seconds either of a Yao honey hunter making the "brrr-hm" sound, a Yao individual saying words such as "honeyguide" or his own name, or a ring-necked dove's song or excitement call.

Honeyguides joined 30 of these experimental searches. About two-thirds of searches that featured "brrr-hm" calls drew honeyguides' assistance (although they did not always locate a bees' nest). One-quarter of hunts that used recordings of words and one-third of those that played dove sounds received honeyguides' help.

Spottiswoode's team calculates that honey hunters who played the "brrr-hm" sound more than tripled their chances of actually finding a bees' nest during 15-minute searches, compared with honey hunters who played Yao words or dove sounds.

Spottiswoode and Wood plan to investigate whether young honeyguides learn from adult birds to pay attention to humans' honey-hunting calls and to lead humans to bees' nests. ■



Listen to the "brrr-hm" call at **bit.ly/SN_honeyguides**

BODY & BRAIN

# Antibiotics might fight Alzheimer's

## Mouse study links gut bacteria changes to brain plaque buildup

**BY LAURA SANDERS**

A long course of antibiotics reduced the levels of a hallmark of Alzheimer's disease in the brains of mice, possibly by changing the species of bacteria in the gut. The results, described July 21 in *Scientific Reports*, suggest that gut bacteria may be linked in some way to Alzheimer's.

The finding is preliminary, says neurobiologist Robert Moir of Massachusetts General Hospital, but it certainly merits more research. "It's a nice new step in what could be a new strategy," he says.

Recent studies that found links between microbes in the gut and the brain (*SN: 4/2/16, p. 23*) captured the attention of study coauthor Sangram Sisodia of the University of Chicago and colleagues. They wondered whether antibiotics could affect sticky globs of amyloid-beta, a protein that accumulates into plaques in the brains of people with Alzheimer's. "We really didn't know what to expect," Sisodia says. "We did the experiment blindly."

The researchers fed a cocktail of antibiotics to mice genetically engineered to develop A-beta plaques in their brains. Compared with mice that didn't receive the drugs, mice that had received antibiotics for most of their lives had similar amounts of bacteria in their guts overall, but the species of bugs changed. Instead of hosting a wide variety of bacteria, the antibiotic-treated mice had a less diverse crowd.

This microbial shift in the gut appeared to affect the brain, the researchers say. Mice treated with antibiotics had fewer brain plaques than mice that didn't receive the drugs. What's more, the plaques that were there were smaller.

Sisodia and colleagues don't know how bacteria could signal from the gut to the brain to affect A-beta, although the study raises one possibility. Bacteria may send messages to the brain by changing the levels of immune system molecules carried in the blood. Antibiotics were associated with higher levels of several such molecules, the researchers found.

Moir cautions that the results in mice might not apply to people. "It certainly looks promising, but it doesn't mean that that's what's going to happen in humans."

If a similar relationship between gut bacteria and Alzheimer's plaques does exist in people, that might allow new treatment options. "It's way too early to think about antibiotics as a potential treatment or preventative measure for Alzheimer's," Sisodia says. But perhaps scientists can uncover new molecules that bacteria produce that could inhibit plaque formation in the brain. ■

BODY & BRAIN

# Toxic e-cig fumes linked to e-liquids

## With age and heat, vaping devices emit more toxicants

**BY JANET RALOFF**

Growing evidence has shown that electronic cigarettes are not the harmless alternative to smoking that many proponents have argued. Now, a study traces a large share of e-cigs' toxic gases to a heat-triggered breakdown of the e-liquids used to create the vapors. And the hotter an e-cig gets — and the more it's used — the more toxic compounds it emits.

"There is this image that e-cigarettes are a lot better than regular cigarettes, if not harmless," says Hugo Destaillats, a chemist at Lawrence Berkeley National Laboratory in California. "We are now definitely convinced that they are far from harmless." His team published the new analyses online July 27 in *Environmental Science & Technology*.

E-cigarettes draw liquids over one or more hot metal coils to create vapors. The liquids — usually propylene glycol, glycerin or a mix of the two — are food-grade solvents laced with flavorings and often nicotine.

The researchers used two current models of e-cigs and three different commercially available e-liquids. The experimental setup mechanically drew air through the devices to create the vapors that a user would normally inhale.

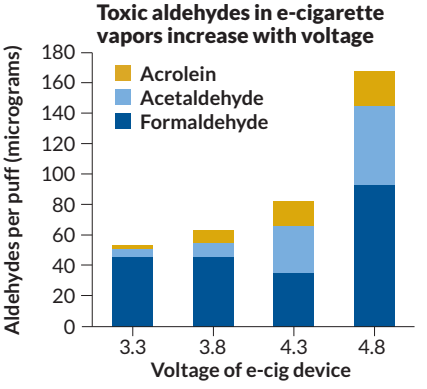
Toxic aldehydes, such as formaldehyde, acetaldehyde and acrolein, were at negligible levels in the starting liquids, Destaillats says. But the chemistry of the vapors varied as the e-cigs heated up: The first puffs contained somewhat less of the aldehydes than later puffs. "Through the process of vaping, you are generating almost 1,000-fold higher emissions of those same compounds," Destaillats says.

Some devices can vary voltage. Higher voltages produced hotter conditions and more of the toxic aldehydes, two of which are probable or suspected carcinogens.

In some tests, one device was used over and over at its high-voltage setting with one of the liquids. After the ninth 50-puff cycle, the toxic aldehyde emission rate had climbed by another 60 percent. This was consistent with a buildup on or near the heating element of what is known as "coil gunk," the researchers say.

The data on changes in the vapor composition of "aged" e-cigarettes "is something new," says toxicologist Maciej Goniewicz of the Roswell Park Cancer Institute in Buffalo, N.Y. ■

**Heating up** The higher an e-cigarette's voltage, the more toxic aldehydes it produces in each puff. Once a certain threshold is hit, voltage increases produce disproportionate increases (last bar) in three of the most harmful vapor compounds. SOURCE: M. SLEIMAN *ET AL/ENVIRON. SCI. TECHNOL.* 2016




LIFE & EVOLUTION

# Gut microbes, apes evolved together

## Bacterial family trees match those of humans and their relatives

**BY AMY MCDERMOTT**

Microbes may have played a role in making us, us. A new study shows similar patterns in the evolution of gut bacteria and the apes they live in, suggesting that germs and apes could have helped shape one another.

For at least 10 million years, bacteria have been handed down through the African ape family. As these apes (including humans) split into separate species, so did the microbes inside them, researchers report in the July 22 *Science*. Relationships between gut bacterial species mirror the family tree of gorillas, humans, bonobos and chimpanzees.

Microbes are a piece of our history, says evolutionary biologist Andrew Moeller, who led the study while at both the University of Texas at Austin and the University of California, Berkeley. "Just like genes we've inherited from our ancestors," he says, "we've inherited some of our bacteria."

Moeller and colleagues studied three families of bacteria collected from the feces of individuals from Connecticut, as well as from wild chimps, bonobos and gorillas. The team used DNA evidence to build evolutionary trees for each bacterial family and then compared each tree with the evolutionary tree of African apes.

The branching patterns in two of the three bacterial trees matched up with those in the ape tree. Within these two bacterial families, closely related bacteria live in closely related primates. "The closest relatives of our gut bacteria live in chimpanzees," Moeller says, "just like our closest relatives are chimps."

Scientists would expect that pattern to match only if apes and bacteria split into new species in unison.

Microbial geneticist Julia Segre of the National Human Genome Research Institute in Bethesda, Md., and conservationist Nick Salafsky of the nonprofit Foundations of Success, also in Bethesda, agree that humans and bacteria probably shaped each other's evolution. But in a perspective on the new work in the same issue of *Science,* they caution that it's too soon to tell if (and how) ancient apes and microbes changed each other.

One caveat, Segre says, is that humans have been exposed to antibiotics and modern life. Wild apes might still have their ancient gut flora, but people in Connecticut might not (*SN: 12/13/14, p. 10*). ■

J. HIRSHFELD

GENES & CELLS

# Gene drives' fatal flaw has an upside

## Inevitable mutations could prevent tool from running amok

**BY TINA HESMAN SAEY**

What some people view as a flaw in a new genetic engineering tool could actually be a safety feature, a study suggests.

CRISPR/Cas9 gene drives, as the tools are called, are molecular cut-and-paste machines that break regular rules of inheritance and get passed to more than 50 percent of offspring (*SN: 12/12/15, p. 16*). The rapid spread of engineered genes through a population may allow researchers to make mosquitoes unable to spread malaria or other diseases, to sterilize the insects or to clear pests or invasive species out of places where they are not wanted (*SN: 12/26/15, p. 6*).

Gene drives have worked in the lab, but have many ethical, technical and other hurdles to overcome before they can be released in the wild. Many scientists, environmentalists and policy makers are concerned that gene drives could wipe out entire species or have unintended ecological consequences.

Among the technical hurdles: A gene drive may stop working if mutations, in either the gene drive or the gene it targets, destroy its ability to home in on the target gene or to cut DNA. Such "resistance" to gene drives will arise "almost inevitably," Philipp Messer, an evolutionary geneticist at Cornell University, said July 14.

Scientists are working on ways to keep gene drives functional, but Messer thinks letting them break could prevent runaway spread and unintended harm. "Why not embrace the resistance?" he said.

Even if resistance mutations arise, they typically would propagate only at the normal rate — a 50 percent chance of being inherited. The slow spread means it would take many generations for resistance mutations to become frequent enough in the population to stop a gene drive, Messer and colleagues calculated. In one scenario, they found that a gene drive could power its way into more than 99 percent of individuals in a population in about 30 generations. But a resistance mutation would take about 100 generations to become present in 50 percent of the population. Those calculations were reported last month at biorxiv.org.

Messer and colleagues are conducting experiments with fruit flies carrying a gene drive to test their calculations.

Researchers may be able to orchestrate the spread of a gene drive while keeping it in check by manipulating conditions that favor resistance mutations, Messer said. With such a system, disease-carrying mosquitoes or other pests could be reduced to safe levels in a local area without destroying the species entirely.

"I found that talk reassuring," said evolutionary biologist Michael Gilchrist of the University of Tennessee in Knoxville. After seeing what a gene drive can do, he said, researchers may be able to head off any negative effects by introducing individuals carrying resistance mutations. ■

MEETING NOTES

### No universally healthy diet exists

Weight gain depends on how an individual's genes react to certain diets, a new study in mice suggests. Four strains of genetically different mice fared differently on different diets, William Barrington of North Carolina State University reported July 15.

One strain, the A/J mouse, was nearly impervious to dietary changes. The mice didn't gain much weight or have changes in insulin or cholesterol no matter what they ate: a fat-and-carbohydrate-laden Western diet, traditional Mediterranean or Japanese diets (usually considered healthy) or low-carbohydrate, fat-rich fare known as the ketogenic diet.

In contrast, NOD/ShiLtJ mice gained weight on all but the Japanese diet. Those mice's blood sugar levels shot up — a hallmark of diabetes — on a Mediterranean diet but decreased on the Japanese diet. FVB/NJ mice didn't get fat on the Western diet but became obese and developed high cholesterol and other health problems on the ketogenic diet. The opposite was true for C57BL/6J mice, which also fattened up on the Mediterranean diet.

The results indicate that "there's no universally healthy diet," Barrington said. The findings echo results of a human study in which blood sugar rose in some, but not all, people after eating the same foods (*SN: 1/9/16, p. 8*).

Barrington and colleagues are working to find the genes that control the mouse strains' varying responses to what they eat. — *Tina Hesman Saey*

### Trading shared genes no problem among species

Researchers have known for decades that organisms on all parts of the evolutionary tree have many of the same genes. "How many of these shared genes are truly functionally the same thing?" wondered Aashiq Kachroo, a geneticist at the University of Texas at Austin, and colleagues. The answer, Kachroo revealed July 15, is that about half of shared genes are interchangeable across species.

Last year, Kachroo and colleagues reported that human genes could substitute for 47 percent of yeast genes that the two species have in common (*SN: 6/27/15, p. 5*). Now, in unpublished experiments, the team has swapped yeast genes with analogous ones from *Escherichia coli* bacteria or from the plant *Arabidopsis thaliana*. About 60 percent of *E. coli* genes could stand in for their yeast counterparts, Kachroo reported. Plant swaps are ongoing, but the researchers already have evidence that plant genes can substitute for yeast genes. — *Tina Hesman Saey*

ATOM & COSMOS

# Astronomers prepare for transcontinental solar eclipse

## Next year, moon's shadow will race across United States, from Oregon to South Carolina

**BY CHRISTOPHER CROCKETT**

Eeriness creeps in. Colors change and shadows sharpen. The last minutes before a total solar eclipse trigger a primal reaction in the human psyche, says astronomer Jay Pasachoff.

"You don't know what's going on," says Pasachoff, of Williams College in Williamstown, Mass. "But you know something is wrong."

Millions of people will know something is wrong on August 21, 2017, when a total eclipse of the sun sweeps across the country, the first to grace the continental United States since 1979 (and the first to go coast-to-coast since 1918). The roughly 120-kilometer-wide path of totality created by the moon's shadow will travel through 12 states, from Oregon to South Carolina. And although it's still a year away, researchers and nonresearchers alike are gearing up to make the most of this rare spectacle — they won't get another chance in the United States until 2024.

Eclipse enthusiasts will travel from all over the world to experience up to nearly three minutes of midday twilight and glimpse the seldom-seen solar corona, a halo of light from plasma that will frame the blacked-out sun. "People cheer and people cry," says Pasachoff, who has seen 33 total solar eclipses and 30 partial ones.

During a total solar eclipse in 2017, the moon will block the sun, allowing people to see the solar corona (as seen in this picture from a 1999 eclipse observed in France).

Though some of the corona is visible all the time to a few telescopes in space, the region where the corona meets the surface is masked by the sun's intensity. "Only on days of eclipses can we put together a complete view of the sun," Pasachoff says. For researchers, the 2017 eclipse is another chance to connect what they see on the surface of the sun to what's happening in the outer reaches of the corona.

One enduring mystery is why the corona is millions of degrees hotter than the surface of the sun, which is a relatively balmy 5,500° Celsius. "The consensus is that the sun's magnetic field is responsible," says Paul Bryans, a solar physicist at the National Center for Atmospheric Research in Boulder, Colo. "But it's not clear how."

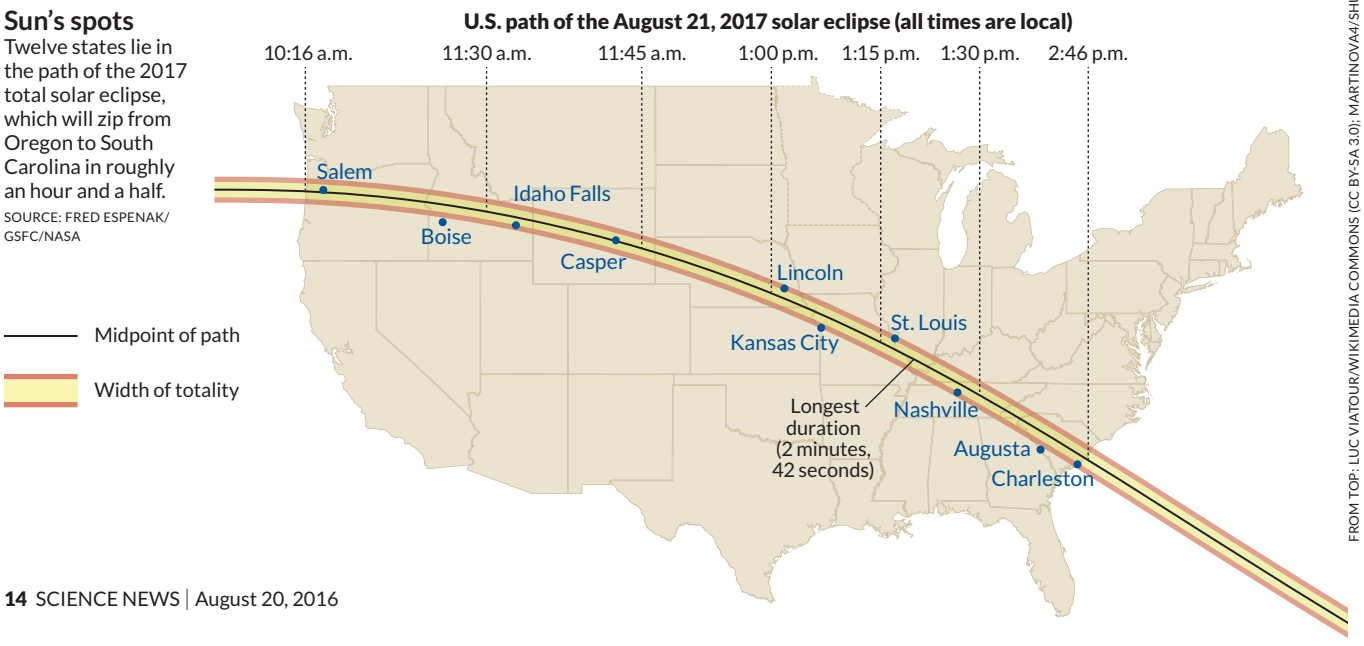
The magnetic field in the corona is too tenuous to study directly. Instead, researchers want to look at the effect of magnetism on certain wavelengths of infrared light emitted by the corona. Bryans is leading a team that will point a spectrometer at the sun during the eclipse to detect that light. "The plan is to put us in the back of a trailer, drive north to Wyoming and just sit and stare at the sun," says Bryans, for whom the 2017 eclipse will be his first. "People keep telling me it's a terrible thing to do because I'll be stuck in the back of the trailer."

This experiment will test whether the corona emits light at the predicted wavelengths and, if so, how brightly. (Scientists will have to wait for improved instruments and another eclipse to see how these wavelengths are distorted by the magnetic field.) One of the advantages of a mobile observatory, Bryans says, is that the team can look at weather forecasts the day before and drive to clear skies.

### Sun's spots

Twelve states lie in the path of the 2017 total solar eclipse, which will zip from Oregon to South Carolina in roughly an hour and a half.

SOURCE: FRED ESPENAK/GSFC/NASA




FROM TOP: LUC VIATOUR/WIKIMEDIA COMMONS (CC BY-SA 3.0); MARTINOVA4/SHUTTERSTOCK, ADAPTED BY E. OTWELL

Another option is to point an infrared spectrometer out the window of a Gulfstream V jet and cruise at an altitude of about 15 kilometers along the path of the eclipse. That is what Jenna Samra, a Harvard University applied physics graduate student, will be doing. Aside from getting away from weather intrusions, the flying telescope will soar above much of Earth's water vapor, which absorbs a lot of infrared light.

> "Only on days of eclipses can we put together a complete view of the sun."
>
> JAY PASACHOFF

The moon's shadow, racing across the country at about 2,700 kilometers per hour, will catch up with the jet in southwest Kentucky. "We won't be able to keep up with it," Samra says. "But we will be able to stay in for about four minutes." That's more than a minute longer than for anyone stuck on the ground.

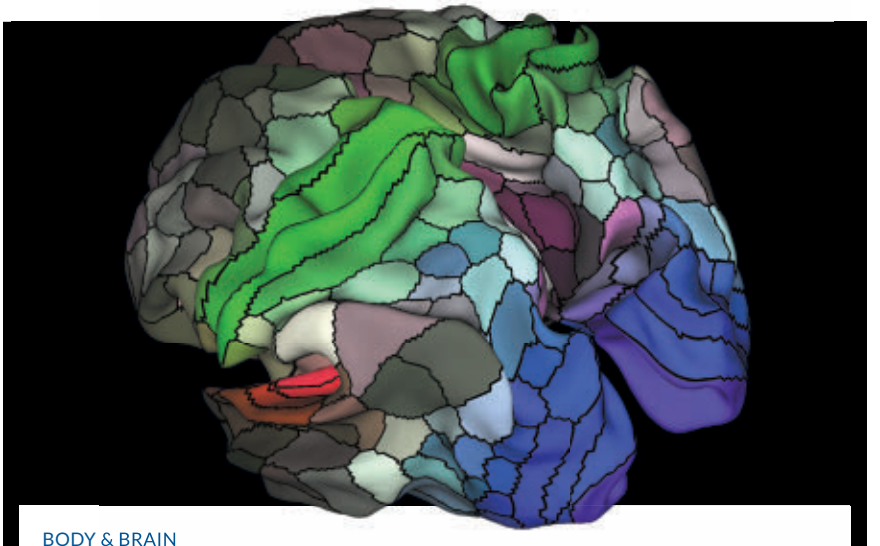
For earthbound observers, the eclipse first touches U.S. soil at 10:16 a.m. Pacific time near Oregon's Depoe Bay. The shadow moves through five state capitals — Salem, Ore.; Lincoln, Neb.; Jefferson City, Mo.; Nashville; and Columbia, S.C. — and even a few national parks: Grand Teton, Great Smoky Mountains and Congaree. A spot in the Shawnee National Forest (just southeast of Carbondale, Ill.) has the honor of longest time in darkness: about 2 minutes, 42 seconds. Cape Island, S.C., is the shadow's final stop, before leaving the continent around 2:49 p.m. Eastern time, just about an hour and a half after entering Oregon.

Based on typical weather patterns in late August, the weather has a better chance of cooperating in the western half of the eclipse path, from Oregon to western Nebraska. That's why Pasachoff will be setting up in Salem. He won't be looking for elusive infrared photons, but instead will be taking rapid-fire images of plasma loops — coils of ionized gas trapped in billowing magnetic fields — arcing off the sun and peeking out from behind the moon. One idea for why the corona is so hot is that these loops subtly jiggle, which stirs up the surrounding plasma and heats the corona. By looking for subsecond oscillations along the loops, Pasachoff's team will see if this hypothesis holds up.

The sun won't be the only thing scrutinized during the eclipse. Some researchers will be keeping an eye on Earth's atmosphere to see how it responds to a sudden loss of sunlight. The National Eclipse Ballooning Project, led by Angela Des Jardins, a solar physicist at Montana State University in Bozeman, will launch over 100 weather balloons at various times along the path of totality and measure changes in such parameters as temperature and wind speed.

For those who can't make it to the eclipse path, or who get stuck under cloudy skies, the ballooning project will serve up live feeds from a vantage point unlike any other: roughly 30 kilometers above the ground. More than 50 teams of high school and college students will launch cameras on additional balloons from 30 sites along the eclipse path. Video and images will be transmitted in real time and be accessible via a website.

From an altitude of 30 kilometers, "you can really see the curvature of Earth and the blackness of space," says Des Jardins. "Seeing the shadow of the moon come across the Earth gives you an amazing perspective of what's going on." ■



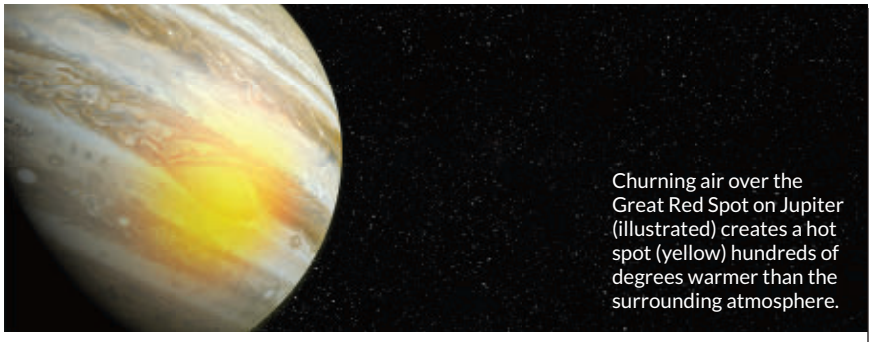
MATTHEW F. GLASSER, D.C. VAN ESSEN

BODY & BRAIN

## New brain map is most detailed yet

Analyzing a bevy of diverse data, scientists have drawn a new map of the human brain in extreme relief. Their approach demarcated 180 areas in each half of the outer layer of the brain — including 97 regions in each half that haven't been described before. The high-resolution map will allow scientists to more precisely scrutinize brain regions and see how they change with, for instance, age and disease.

Many previous brain maps have been built with just one type of data. The new map, described online July 20 in *Nature*, forms a holistic view by combining several different types of information. These specs include brain activity while doing certain tasks or nothing at all, as well as detailed anatomical data about the shape and thickness of the brain. Using these metrics from 210 healthy people, neuroscientist David Van Essen of Washington University in St. Louis and colleagues found that each hemisphere contains 180 distinct areas (separated by black lines in image above). In this view, colors show how tightly linked each area is to other brain areas that handle auditory (red), touch and movement (green) or visual (blue) information. — *Laura Sanders*



Churning air over the Great Red Spot on Jupiter (illustrated) creates a hot spot (yellow) hundreds of degrees warmer than the surrounding atmosphere.

ATOM & COSMOS

## Jupiter's Great Red Spot is hot

On Jupiter, the Great Red Spot is the hottest thing going. Temperatures over the ruddy oval, a storm large enough to engulf Earth, are hundreds of degrees warmer than neighboring parcels of air and higher than anywhere else on the planet, researchers report online July 27 in *Nature*. Heat from the storm might help explain why Jupiter is unusually toasty given its distance from the sun.

Astronomers have known for over 40 years that Jupiter's upper atmosphere is surprisingly hot. Midlatitude temperatures are about 530° Celsius, roughly 600 degrees warmer than they would be if the sun was the only source of heat. Warmth must come from the planet, but until now, researchers had not come up with a satisfactory explanation for how.

Active storms all around Jupiter could be injecting heat into the atmosphere, suggest James O'Donoghue, an astrophysicist at Boston University, and colleagues. Using observations from NASA's Infrared Telescope Facility in Hawaii, the researchers found that the temperature over the Great Red Spot is about 1,300°. Sound waves generated by turbulence might be heating the air above the storm, the researchers suggest. Similar heating (on a much smaller scale) has been seen on Earth, as air ripples over the Andes Mountains in South America.
*— Christopher Crockett*

ATOM & COSMOS

## Kepler's tally of confirmed exoplanets grows

Despite being partially crippled by a series of malfunctions, the Kepler space telescope is still going strong. NASA's premier planet hunter has found at least 104 worlds orbiting other stars during the first year since its resurrection.

Most of the confirmed planets are less than three times as wide as Earth, Ian Crossfield, an astrophysicist at the University of Arizona in Tucson, and colleagues report online July 18 at arXiv.org. Roughly a dozen are about the same size as Earth or smaller. Several worlds reside in multiplanet systems such as K2-72, where four small, possibly rocky, planets are crammed into puny orbits — the longest only 24 days. And a few worlds, despite orbiting stars that are much cooler than our sun, receive about as much solar energy as Earth, which marks them as potentially habitable. The researchers combined observations from Kepler and ground-based telescopes with statistical calculations to verify each planet candidate.

From 2009 to 2013, Kepler stared at one patch of sky and cataloged over 2,300 exoplanets (*SN: 6/11/16, p. 12*). After failures in two components that keep the telescope steady, researchers designed a new mission, dubbed K2. Since 2014, Kepler has scanned a band of sky aligned with Earth's orbit, gazing at one spot for about 80 days before moving on to the next (*SN: 6/28/14, p. 7*). *— Christopher Crockett*

BODY & BRAIN

## Mosquitoes in Florida now spreading Zika virus, health officials warn

Mosquitoes now appear to be transmitting Zika virus in the continental United States. On July 29, health officials announced four cases of Zika infection in Miami that were most likely acquired via the bite of local mosquitoes. On August 1, Florida reported 10 more cases in the city.

No mosquitoes in the state have yet tested positive for Zika, but officials suspect *Aedes aegypti* is to blame. Florida has been spraying insecticides daily, but experts are still seeing new larval mosquitoes and "moderately high" counts of *A. aegypti*. Miami's mosquitoes may be resistant to the insecticides or holed up in hard-to-find breeding spots: small pools of standing water where larvae can hatch, Tom Frieden, director of the U.S. Centers for Disease Control and Prevention, said in a news briefing August 1.

Officials have pinned the area of exposure to a 150-meter radius just west of Biscayne Bay. The CDC has now warned pregnant women to avoid a 1-mile zone surrounding the area. *A. aegypti* doesn't typically range far from home, so Frieden doesn't expect to see widespread transmission. *— Meghan Rosen*

LIFE & EVOLUTION

## Neonicotinoids are inadvertent partial contraceptives for honeybees

Pollen tainted with neonicotinoid pesticides could interfere with honeybee reproduction.

After eating pollen spiked with thiamethoxam and clothianidin, males made almost 40 percent fewer living sperm than males fed clean pollen, researchers note in the July 27 *Proceedings of the Royal Society B*. The pesticide concentrations, 4.5 parts per billion and 1.5 ppb, were in the range of what bees encounter around crops, says coauthor Lars Straub of the University of Bern in Switzerland.

Conservationists have raised concerns that chronic exposure to neonicotinoids is weakening honeybee colonies. The amount of sperm males produce might affect how well a colony sustains itself because young queens mate (with about 15 males on average) during one or two early frenzies and then depend on that stored sperm for the rest of their egg-laying years. *— Susan Milius*

DILLON YOTHERS, LUKE MOORE



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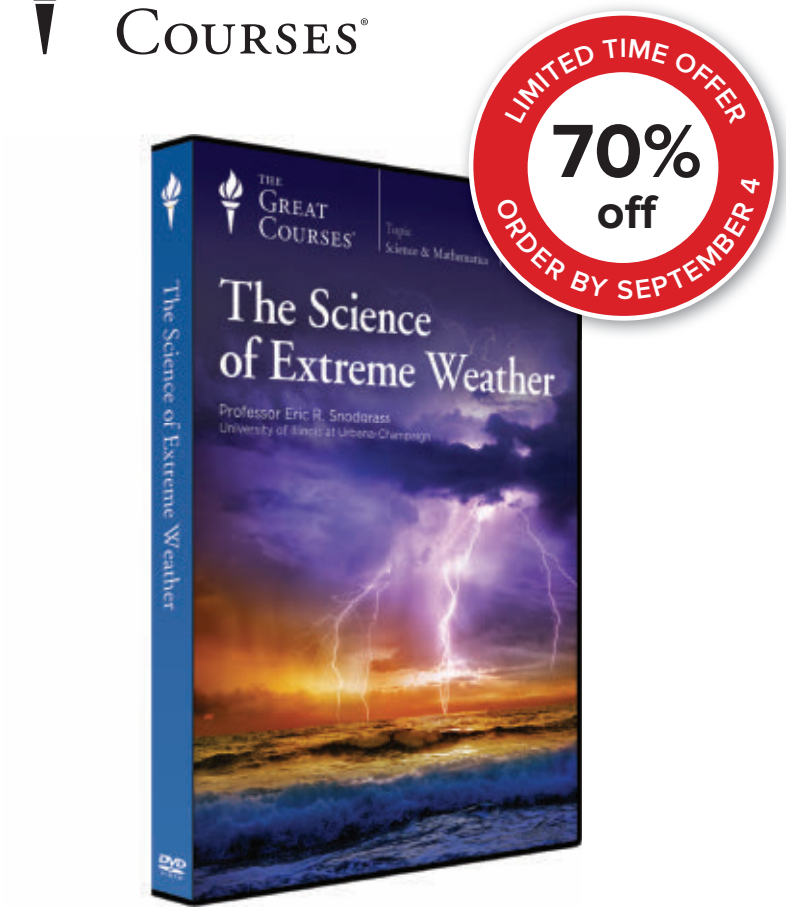


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# CHASING A DEVIOUS METAL

## Pressure is on to make metallic hydrogen

**By Emily Conover**

In a few highly specialized laboratories, scientists bombard matter with the world's most powerful electrical pulses or zap it with sophisticated lasers. Other labs squeeze heavy-duty diamonds together hard enough to crack them.

All this is in pursuit of a priceless metal. It's not gold, silver or platinum. The scientists' quarry is hydrogen in its most elusive of forms.

Several rival teams are striving to transform hydrogen, ordinarily a gas, into a metal. It's a high-stakes, high-passion pursuit that sparks dreams of a coveted new material that could unlock enormous technological advances in electronics.

"Everybody knows very well about the rewards you could get by doing this, so jealousy and envy [are] kind of high," says Eugene Gregoryanz, a physicist at the University of Edinburgh who's been hunting metallic hydrogen for more than a decade.

Metallic hydrogen in its solid form, scientists propose, could be a superconductor: a material that allows electrons to flow through it effortlessly, with no loss of energy. All known superconductors function only at extremely low temperatures, a major drawback. Theorists suspect that superconducting metallic hydrogen might work at room temperature. A room-temperature superconductor is one of the most eagerly sought goals in physics; it would offer enormous energy savings and vast improvements in the transmission and storage of energy.

Metallic hydrogen's significance extends beyond earthly pursuits. The material could also help scientists understand our own solar system. At high temperatures, compressed hydrogen becomes a metallic liquid — a form that is thought to lurk beneath the clouds of monstrous gas planets, like Jupiter and Saturn. Sorting out the properties of hydrogen at extreme heat and high pressure could resolve certain persistent puzzles about the gas giants. Researchers have reported brief glimpses of the liquid metal form of hydrogen in the lab — although questions linger about the true nature of the material.

Physicists use powerful electrical pulses in the Z machine at Sandia National Laboratories to create liquid metallic hydrogen for fleeting moments.

RANDY MONTOYA/SANDIA LABS

While no lab has yet produced solid metallic hydrogen, the combined efforts of many scientists are rapidly closing in on a more complete understanding of the element itself — as well as better insight into the complex inner workings of solids.

### Not so simple

Hydrogen, the first element in the periodic table and the most common element in the universe, ought to be easy to understand: a single proton paired with a single electron. "What could be more simple than an assembly of electrons and protons?" asks theoretical physicist Neil Ashcroft of Cornell University. But at high pressures, the physics of hydrogen rapidly becomes complex.

At room temperature and atmospheric pressure, hydrogen is a gas. But like other materials, altered conditions can transform

hydrogen into a solid or a liquid. With low enough temperatures or a sufficiently forceful squeeze, hydrogen shape-shifts into a solid. Add heat while squeezing, and it becomes a liquid.

If subjected to still more extreme conditions, hydrogen can — at least theoretically — undergo another transformation, into a metal. All metals have one thing in common: They conduct electricity, due to free-flowing electrons that can go where they please within the material.

Squeeze anything hard enough and it will become a metal. "Pressure does a great job of dislodging the outer electrons," Ashcroft says. This is what scientists are aiming to do with hydrogen: create a sloshing soup of roving electrons in either a liquid or a solid.

When hydrogen is compressed, many atoms begin to interact with one another, while paired in molecules of two hydrogen atoms each. The underlying physics becomes a thorny jumble. "It is amazing; the stuff takes up incredibly complex arrangements in the solid state," says Ashcroft, the first scientist to propose, in 1968, that metallic hydrogen could be a high-temperature superconductor.

Hydrogen's complexity fascinates scientists. "It's not just the metallization question that's of interest to me," says Russell Hemley, a chemist at the Carnegie Institution for Science in Washington, D.C., and Lawrence Livermore National Laboratory in California. Studying the intricacies of hydrogen's behavior can help scientists refine their understanding of the physics of materials.

In 1935, when physicists Eugene Wigner and Hillard Bell Huntington of Princeton University first predicted that compressed solid hydrogen would be metallic, they thought the transition to a metal might occur at a pressure 250,000 times that of Earth's atmosphere. That may sound like a lot, but scientists have since squeezed hydrogen to pressures more than 10 times as high — and still no solid metal.

Scientists originally expected that the transition would be a simple flip to metallic behavior. Not so, says theoretical physicist David Ceperley of the University of Illinois at Urbana-Champaign. "Nature has a lot more possibilities." Solid hydrogen exists in multiple forms, each with a different crystal structure. As the pressure climbs, the wily hydrogen molecules shift into ever-more-complex arrangements, or phases. (For physicists, the "phase" of matter goes deeper than the simple states of solid, liquid or gas.) The number of known solid phases of hydrogen has grown steadily as higher pressures are reached, with four phases now well established. The next phase scientists find could be a metal — they hope.

If solid metallic hydrogen turns out to be a room-temperature superconductor, it would have to be crushed to work, making it impractical for many applications. But if hydrogen could hold its metallic form after the pressure is released, as some researchers have suggested, "it would be revolutionary," says physicist Isaac Silvera, who leads the metallic hydrogen hunt at Harvard University. Such a material could be used in electrical wires to reduce loss of energy and decrease the world's power consumption. And it might lead to efficient, magnetically levitated trains and technological advances in nuclear fusion, supercomputing and more.

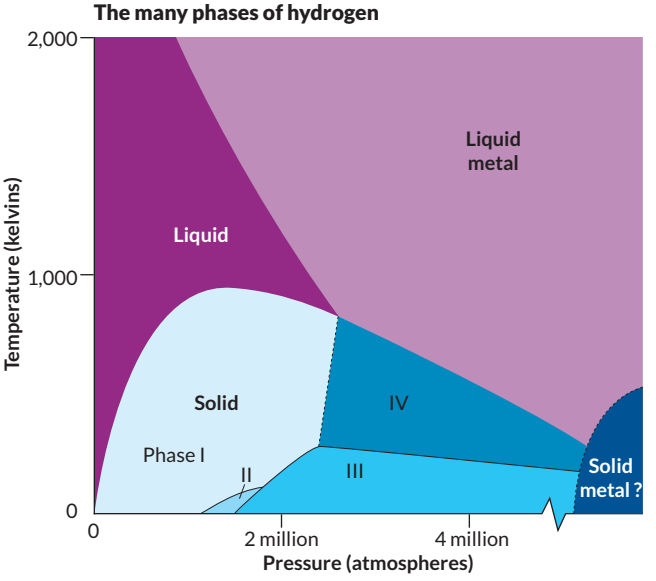
While one group of would-be metallurgists is searching for solid metal, other investigators seek the scientifically intriguing liquid hydrogen metal. Their techniques differ in timescale and size. To produce liquid metal, scientists violently slam hydrogen for fractions of a second at a time, using enormous machines at national laboratories. Scientists searching for a solid metal, on the other hand, use fist-sized devices to capture hydrogen between the tips of two tiny diamonds and slowly squeeze.

## Diamonds have it rough

Crushing an ethereal, normally gaseous substance between two diamonds sounds nearly impossible. Such tricky experiments make for a field where researchers are in regular disagreement over their latest results. "We're still missing high-quality, reliable data," says physicist Alexander Goncharov. "The issue is the experiments are too challenging."

In his office at the Geophysical Laboratory of the Carnegie Institution, Goncharov opens a desk drawer and pulls out a device called a diamond anvil cell. The cylinder of metal is small enough for Goncharov to cradle in his palm. Bits of precisely machined steel and tough tungsten carbide are held together with four screws. Through portals in the top and bottom, bright sparkles shimmer: diamonds.

Inside the capsule, two diamonds taper to tiny points a few hundredths of a millimeter wide. They pinch the material within, squashing it at over a million times atmospheric pressure. The gap between the minuscule anvils can be as small as




**Exotic forms of hydrogen** Under ordinary conditions, in a region too small to be seen on this chart, hydrogen is a gas. At very high temperatures, it becomes liquid. At high pressures, it's a solid in one of several phases. Scientists expect that it will become a solid metal at pressures not yet reached. SOURCE: I.F. SILVERA/HARVARD UNIV.

ADAPTED BY E. CONOVER AND J. HIRSHFELD

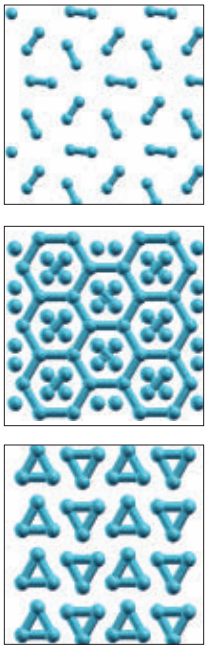
a few thousandths of a millimeter, about the size of a human red blood cell.

Once they've been pressurized, diamond anvil cells will hold the pressure almost indefinitely. The prepared cells can be carried around — inspected in the laboratory, transported to specialized facilities around the world — or simply stored in a desk drawer. Goncharov regularly travels with them. (Tip from the itinerant scientist: If questions arise at airport security, "never use the word 'diamonds.' ") The diamond anvil can squeeze more than hydrogen — materials from iron to sodium to argon can be crushed in the diamond vise.

To identify new, potentially metallic phases of solid hydrogen within the pressurized capsules, scientists shine laser light onto the material, measuring how molecules vibrate and rotate — a technique called Raman spectroscopy (*SN: 8/2/08, p. 22*). If a new phase is reached, molecules shift configurations, altering how they jiggle. Certain types of changes in how the atoms wobble are a sign that the new phase is metallic. If the material conducts electricity, that's another dead giveaway. A final telltale sign: The normally translucent hydrogen should acquire a shiny, reflective surface.

Significant hurdles exist for diamond anvil cell experiments. Diamonds, which cost upwards of $600 a pop, can crack under such intense pressures. Hydrogen can escape from the capsule, or diffuse into the diamonds, weakening them. So scientists coat their diamonds with thin layers of protective material. The teams each have their own unique recipe, Goncharov says. "Of course, everyone believes that their recipe is the best."

Three phases of solid hydrogen have been known since the late 1980s. With the discovery of a fourth phase in 2011, "the excitement was enormous," Gregoryanz says. In *Nature Materials,* Mikhail Eremets and Ivan Troyan at the Max Planck Institute for Chemistry in Mainz, Germany, reported that a new phase appeared when they squashed room-temperature hydrogen to over 2 million times atmospheric pressure. Goncharov, Gregoryanz and colleagues created the new phase and deduced its structure in *Physical Review Letters* in 2012. In phase IV, as it's known, hydrogen arranges itself into thin sheets — somewhat like the single-atom-thick sheets of carbon known as graphene, the scientists wrote.



Possible structures for three solid phases of hydrogen: phase III (top), phase IV (middle) and a theorized metallic phase (bottom).

Progress doesn't come easy. With each new paper, scientists disagree about what the results mean. When Eremets and colleagues discovered the fourth phase, they thought they also had found metallic hydrogen (*SN: 12/17/11, p. 9*). But that assertion was swiftly criticized, and it didn't stand up to scrutiny.

The field has been plagued by hasty claims. "If you look at the literature for the last 30 years," Gregoryanz says, "I think every five years there is a claim that we finally metallized hydrogen." But the claims haven't been borne out, leaving scientists perpetually skeptical of new results.

In a recent flurry of papers, scientists have proposed new phases — some that might be metallic or metal-like precursors to a true metal — and they are waiting to see which claims stick. Competing factions have volleyed papers back and forth, alternately disagreeing and agreeing.

A paper from Gregoryanz's group, published in *Nature* in January, provided evidence for a phase that was enticingly close to a metal (*SN Online: 1/6/16*), at more than 3 million times atmospheric pressure. But other scientists disputed the evidence. In their own experiments, Eremets and colleagues failed to confirm the new phase. In a paper posted online at arXiv.org just days after Gregoryanz's paper was published, Eremets' team unveiled hints of a "likely metallic" phase, which occurred at a different temperature and pressure than Gregoryanz's new phase.

A few months later, Silvera's group squeezed hydrogen hard enough to make it nearly opaque, though not reflective — not quite a metal. "We think we're just below the pressure that you need to make metallic hydrogen," Silvera says. His findings are consistent with Eremets' new phase, but Silvera disputes Eremets' speculations of metallicity. "Every time they see something change they call it metallic," Silvera says. "But they don't really have evidence of metallic hydrogen."

All this back and forth may seem chaotic, but it's also a sign of a swiftly progressing field, the researchers say. "I think it's very healthy competition," Gregoryanz says. "When you realize that somebody is getting ahead of you, you work hard."

The current results are "not very well consistent, so everybody can criticize each other," Eremets says. "For me it's very clear. We should do more experiments. That's it."

There are signs of progress. In 2015, Eremets and colleagues discovered a record-breaking superconductor: hydrogen sulfide, a compound of hydrogen and sulfur. When tightly compressed into solid form, hydrogen sulfide superconducts at temperatures higher than ever seen before: 203 kelvins (−70° Celsius) (*SN: 8/8/15, p. 12*).

Adding sulfur to the mix stabilizes and strengthens the hydrogen structure but doesn't contribute much to its superconducting properties. Hydrogen sulfide is so similar to pure hydrogen, Eremets says, that, "in some respects we already found superconductivity in metallic hydrogen."

## Brief glimmers

Giant, gassy planets are chock-full of hydrogen, and the element's behavior under pressure could explain some of these planets' characteristics. A sea of flowing liquid hydrogen metal may be the source of Jupiter's magnetic field (*SN: 6/25/16, p. 16*). Learning more about metallic hydrogen's behavior deep

J.M. MCMAHON *ET AL/REVIEWS OF MODERN PHYSICS* 2012

inside such planets could also help resolve a long-standing puzzle regarding Saturn: The ringed behemoth is unexpectedly bright. The physics of hydrogen's interactions with helium inside the planet could provide the explanation.

Using a radically different set of technologies, a second band of scientists is on the hunt for such liquid metallic hydrogen. These researchers have gone big, harnessing the capabilities of new, powerful machines designed for nuclear fusion experiments at government-funded national labs. These experiments show the most convincing evidence of metallic behavior so far — but in hydrogen's liquid, not solid, form. These enormous machines blast hydrogen for brief instants, temporarily sending pressures and temperatures skyrocketing. Such experiments reach searing temperatures, thousands of kelvins. With that kind of heat, metallic hydrogen appears at lower, more accessible pressures.

Creating such conditions requires sophisticated equipment. The Z machine, located at Sandia National Laboratories in Albuquerque, generates extremely intense bursts of electrical power and strong magnetic fields; for a tiny instant, the machine can deliver about 80 terawatts (one terawatt is about the total electrical power–generating capacity in the entire United States).

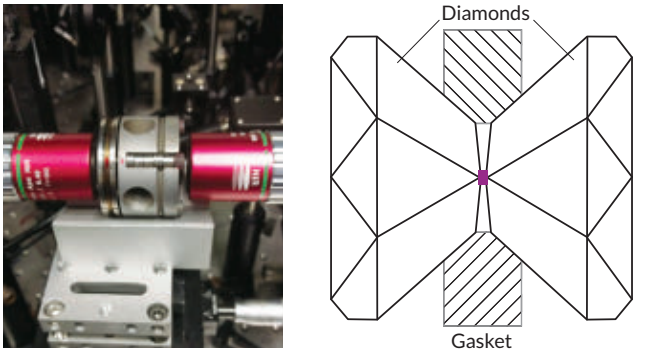
A group of scientists recently used the Z machine to launch a metal plate into a sample of deuterium — an isotope of hydrogen with one proton and one neutron in its nucleus — generating high pressures that compressed the material. The pummeled deuterium showed reflective glimmers of shiny metal, the scientists reported last year in *Science*. "It starts out transparent, it goes opaque, and then later we see this reflectivity increase," says Marcus Knudson of Sandia and Washington State University in Pullman.

Another group is pursuing a different tactic, using some of the most advanced lasers in the world, at the National Ignition Facility at Lawrence Livermore. Scientists there zap hydrogen to produce high pressures and temperatures. Though the conclusions of this experiment are not yet published, says physicist Gilbert Collins of Lawrence Livermore, one of the leaders of the experiment, "we have some really beautiful results."

The first experiment to show evidence of liquid metallic hydrogen was performed at Lawrence Livermore in the 1990s. A team of physicists including William Nellis, now at Harvard, used a sophisticated gunlike apparatus to shoot projectiles into hydrogen at blisteringly fast speeds. The resulting hydrogen briefly conducted electricity (*SN: 4/20/96, p. 250*).

These experiments face hurdles of their own — it's a struggle to measure temperature in such systems, so scientists calculate it rather than measuring it directly. But many researchers are still convinced by these results. Metallic hydrogen "certainly has been produced by shock techniques," Cornell's Ashcroft says.

Some scientists still have questions. "It's certainly difficult to tell if something is a metal or not at such high temperature," Collins says. Although they need high temperatures to reach the metal liquid phase, some physicists define a metal based on its behavior at a temperature of absolute zero. Current experiments hit high pressures at temperatures as close to zero as possible to produce relatively cool liquid metallic hydrogen.




**Tight squeeze** Optical devices sandwich a diamond anvil cell (left). Inside, two diamonds pinch a sample (right, purple dot), such as hydrogen, iron or sodium. SOURCE: RIGHT: M.I. EREMETS AND I.A. TROYAN/*NATURE MATERIALS* 2011

Scientists who conduct palm-sized diamond anvil cell experiments refuse to be left out of the liquid-metal action. They've begun to use laser pulses to heat and melt hydrogen crammed into the cells. The results have stirred up new disagreements among competing groups. In April's *Physical Review B*, Silvera and coauthors reported forming liquid metallic hydrogen. But under similar conditions, Goncharov and others found only semiconducting hydrogen, not a metal. They reported their results in *Physical Review Letters* in June.

"There's kind of a crisis now with these different experiments," says Illinois theorist Ceperley. "And there's a lot of activity trying to see who's right." For now, scientists will continue refining their techniques until they can reach agreement.

The major players have managed to reach consensus before. Four phases of solid hydrogen are now well established, and researchers agree on certain conditions under which solid hydrogen melts.

Solid metallic hydrogen, however, has perpetually seemed just out of reach, as theoretical predictions of the pressure required to produce it have gradually shifted upward. As the goalposts have moved, physicists have reached further, achieving ever-higher pressures. Current theoretical predictions put the metal tantalizingly close — perhaps only an additional half a million times atmospheric pressure away.

The quest continues, propelled by a handful of hydrogen-obsessed scientists.

"We all love hydrogen," Collins says. "It has the essence of being simple, so that we think we can calculate something and understand it, while at the same time it has such a devious nature that it's perhaps the least understandable material there is." ■

## Explore more

- Sandia National Laboratories. "Compressing materials under extreme conditions." www.sandia.gov/Pulsed-Power/res-areas/dynamic_materials/

FROM LEFT: E. CONOVER; ADAPTED BY J. HIRSHFELD

# Quenching Society's THIRST

## Desalination may soon turn a corner, from rare to routine

**By Thomas Sumner**

Freshwater is becoming a scarce resource in much of the world, including Yemen, where residents get water from a public tap.

MOHAMMED HAMOUD/GETTY IMAGES

The world is on the verge of a water crisis.

Rainfall shifts caused by climate change plus the escalating water demands of a growing world population threaten society's ability to meet its mounting needs. By 2025, the United Nations predicts, 2.4 billion people will live in regions of intense water scarcity, which may force as many as 700 million people from their homes in search of water by 2030.

Those water woes have people thirstily eyeing the more than one sextillion liters of water in Earth's oceans and some underground aquifers with high salt content. For drinking or irrigation, the salt must come out of all those liters. And while desalination has been implemented in some areas — such as Israel and drought-stricken California — for much of the world, salt-removal is a prohibitively expensive energy drain.

Scientists and engineers, however, aren't giving up on the quest for desalination solutions. The technology underlying modern desalination has been around for decades, "but we have not driven it in such a way as to be ubiquitous," says UCLA chemical engineer Yoram Cohen. "That's what we need to figure out: how to make desalination better, cheaper and more accessible."

Recent innovations could bring costs down and make the technology more accessible. A new wonder material may make desalination plants more efficient. Solar-powered disks could also serve

up freshwater with no need for electricity. Once freshwater is on tap, coastal floating farms could supply food to Earth's most parched places, one scientist proposes.

## Watering holes

Taking the salt out of water is hardly a new idea. In the fourth century B.C., Aristotle noted that Greek sailors would evaporate impure water, leaving the salt behind, and then condense the vapor to make drinkable water. In the 1800s, the advent of steam-powered travel and the subsequent need for water without corrosive salt for boilers prompted the first desalination patent, in England.

Most modern desalination plants use a technique that differs from these earlier efforts. Instead of evaporating water, pumps force pressurized saltwater from the ocean or salty underground aquifers through special sheets. These membranes contain molecule-sized holes that act like club bouncers, allowing water to pass through while blocking salt and other contaminants.

The membranes are rolled like rugs and stuffed into meter-long tubes with additional layers that direct water flow and provide structural support. A large desalination plant uses tens of thousands of membranes that fill a warehouse. This process is known as reverse osmosis and the result is salt-free water plus a salty brine waste product that is typically pumped underground or diluted with seawater and released back into the ocean. It takes about 2.5 liters of seawater to make 1 liter of freshwater.

In 2015, more than 18,000 desalination plants worldwide had the annual capacity to produce 31.6 trillion liters of freshwater across 150 countries. While still less than 1 percent of worldwide freshwater usage, desalination production is two-thirds higher than it was in 2008. Driving the boom is a decades-long drop in energy requirements thanks to innovations such as energy-efficient water pumps, improved membranes and plant configurations that use outbound water to help pressurize incoming water. Seawater desalination in the 1970s consumed as much as 20 kilowatt-hours of energy per cubic meter of produced freshwater; modern plants typically require just over three kilowatt-hours.

There's a limit, however, to the energy savings. Theoretically, separating a cubic meter of freshwater from two cubic meters of seawater requires a minimum of about 1.06 kilowatt-hours of energy. Desalination is typically only viable when it's cheaper than the next alternative water source, says Brent Haddad, a water management expert at the University of California, Santa Cruz. Alternatives, such as reducing usage or piping freshwater in from afar, can help, but these methods don't create more $H_2O$. While other hurdles remain for desalination, such as environmentally friendly wastewater disposal, cost is the main obstacle.

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The upfront cost of each desalination membrane is minimal. For decades, most membranes have been made from polyamide, a synthetic polymer prized for its low manufacturing cost — around $1 per square foot. "That's very, very cheap," says MIT materials scientist Shreya Dave. "You can't even buy decent flooring at Home Depot for a dollar a square foot."

But polyamide comes with additional costs. It degrades quickly when exposed to chlorine, so when the source water contains chlorine, plant workers have to add two steps: remove chlorine before desalination, then add it back later, since drinking water requires chlorine as a disinfectant. To make matters worse, in the absence of chlorine, the membranes are susceptible to growing biological matter that can clog up the works.

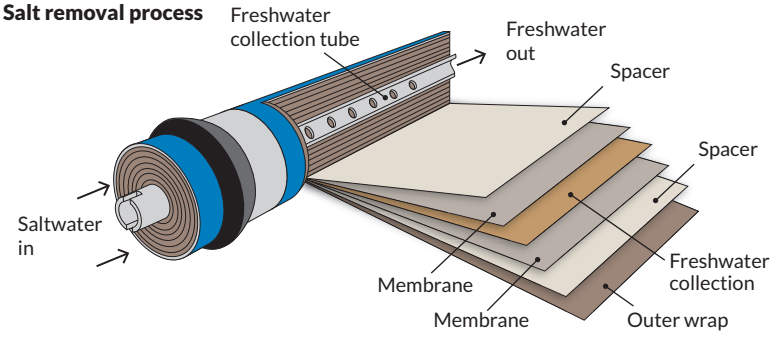
With these problems in mind, researchers are turning to other membrane materials. One alternative, graphene oxide, may knock polyamide out of the water.

## Membrane maze

Since its discovery in 2004, graphene has been touted as a supermaterial, with proposed applications ranging from superconductors to preventing blood clots (*SN: 10/3/15, p. 7*; *SN Online: 2/11/14*).

Find large desalination plants worldwide at **bit.ly/SN_desalination**

**Salt removal process**




**Passing through** Desalination plants (top) pump saltwater through membrane-filled tubes at high pressures. In each tube (bottom), water presses against rolled-up layers of porous material that allows water molecules to pass through and into a collecting tube while rejecting salt. Before disposal, the remaining salty wastewater is used to pressurize inbound saltwater. SOURCE: H2ODISTRIBUTORS.COM

Each graphene sheet is a single-atom-thick layer of carbon atoms arranged in a honeycomb grid. As a hypothetical desalination membrane, graphene would be sturdy and put up little resistance to passing water, reducing energy demands, says MIT materials scientist Jeff Grossman.

Pure graphene is astronomically expensive and difficult to make in large sheets. So Grossman, Dave and colleagues turned to a cheaper alternative, graphene oxide. The carbon atoms in graphene oxide are bordered by oxygen and hydrogen atoms.

Those extra atoms make graphene oxide "messy," eliminating many of the material's unique electromagnetic properties. "But for a membrane, we don't care," Grossman says. "We're not trying to run an electric current through it, we're not trying to use its optical properties — we're just trying to make a thin piece of material we can poke holes into."

The researchers start with graphene flakes peeled from hunks of graphite, the form of carbon found in pencil lead. Researchers suspend the graphene oxide flakes, which are easy and cheap to make, in liquid. As a vacuum sucks the liquid out of the container, the flakes form a sheet. The researchers bind the flakes together by adding chains of carbon and oxygen atoms. Those chains latch on to and connect the graphene oxide flakes, forming a maze of interconnected layers. The length of these chains is fine-tuned so that the gaps between flakes are just wide enough for water molecules, but not larger salt molecules, to pass through.

The team can fashion paperlike graphene oxide sheets a couple of centimeters across, though the technique should easily scale up to the roughly 40-square-meter size currently packed into each desalination tube, Dave says. Furthermore, the sheets hold up under pressure. "We are not the only research group using vacuum filtration to assemble membranes from graphene oxide," she says, "but our membranes don't fall apart when exposed to water, which is a pretty important thing for water filtration."

The slimness of the graphene oxide membranes makes it much easier for water molecules to pass through compared with the bulkier polyamide, reducing the energy needed to pump water through them. Grossman, Dave and colleagues estimated the cost savings of such highly permeable membranes in 2014 in a paper in *Energy & Environmental Science*. Desalination of groundwater would require 46 percent less energy; processing of saltier seawater would use 15 percent less, though the energy demands of the new prototypes haven't yet been tested.

So far, the new membranes are especially durable, Grossman says. "Unlike polyamide, graphene oxide membranes are resilient to important cleaning chemicals like chlorine, and they hold up in harsh chemical environments and at high temperatures." With lower energy requirements and no need to remove and replace chlorine from source water, the new membranes could be one solution to many desalination challenges.

In large quantities, the graphene oxide membranes may be economically viable, Dave predicts. At scale, she estimates that manufacturing graphene oxide membranes will cost around $4 to $5 per square foot — not drastically more expensive than polyamide, considering its other benefits. Existing plants could swap in graphene oxide membranes when older polyamide membranes need replacing, spreading out the cost of the upgrade over about 10 years, Dave says. The team is currently patenting its membrane-making methodology, though the researchers think it will

FROM TOP: QUIQUE KIERSZENBAUM/MCT VIA GETTY IMAGES; M. TELFER

take a few more years before the technology is commercially viable.

"We are at a point where we need a quantum leap, and that can be achieved by new membrane structures," says Nikolay Voutchkov, executive director of Water Globe Consulting, a company that advises industries and municipalities on desalination projects. The work on graphene oxide "is one way to do it."

Other materials are also vying to be polyamide's successor. Researchers are testing carbon nanotubes, tiny cylindrical carbon structures, as a desalination membrane. Which material wins "will come down to cost," Voutchkov says. Even if graphene oxide or other membranes save money in the long run, high upfront costs would make them less appealing.

Plus, those new membranes won't solve the problems of desalination in less-developed areas. The costs of building a large plant and pumping freshwater over long distances make desalination a hard sell in rural Africa and other water-starved places. For hard-to-reach locales, scientists are thinking small.

## A portable approach

In remote Africa, electricity is hard to come by. Materials scientist Jia Zhu of Nanjing University in China and colleagues are hoping to bring drinkable water to unpowered, parched places by turning to an old-school desalination technique: evaporating and condensing water.

Their system runs on sunshine, something that is both free and abundant in Earth's hotter regions. Using the sun's rays to desalinate water is hardly new, but most existing systems are inefficient. Only about 30 to 45 percent of incoming sunlight typically goes into evaporating water, which means a big footprint is needed to create sizable amounts of freshwater. Zhu and colleagues hope to boost efficiency with a more light-absorbing material.

The material's fabrication starts with a base sheet made of aluminum oxide speckled with 300-nanometer-wide holes. The researchers then coat this sheet with a thin layer of aluminum particles.

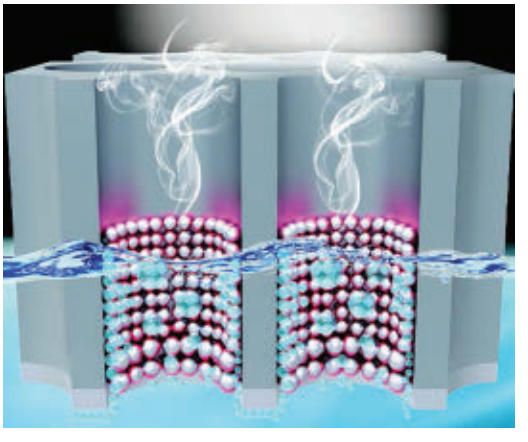
When light hits aluminum particles inside one of the holes, the added energy makes electrons in the aluminum start to oscillate and ripple. These electrons can transfer some of that energy to their surroundings, heating and evaporating nearby water without the need for boiling (*SN Online: 4/8/16*).

The researchers have produced 2.5-centimeter-wide disks of the new material so far, which are light enough to float. The black disks absorb more than 96 percent of incoming sunlight and about 90 percent of the absorbed energy is used in evaporating water, the researchers reported in the June *Nature Photonics*.

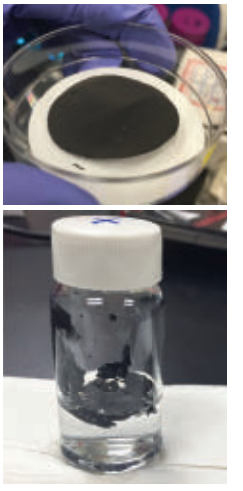
The evaporated water condenses and collects in a transparent box containing stainless steel. In laboratory tests, the researchers successfully desalinated water from China's Bohai Sea to levels low enough to meet drinking water standards. The researchers reckon that they can produce around five liters of freshwater per hour for every square meter of material under intense light. In early tests, the disks held up after multiple uses without dropping in performance.

Aluminum is cheap and the material's fabrication process can easily scale, Zhu says. While the disks can't produce as much drinkable water as quickly as big desalination plants, the new method may serve a different need, since it's more affordable and more portable, he says. "We are developing a personalized water solution without big infrastructure, without extra energy consumption and with a minimum carbon footprint." The researchers hope that their new desalination technique will find use in developing countries and remote areas where conventional desalination plants aren't feasible.

The disks are worth pursuing, says Haddad at UC Santa Cruz. "I say let's try it out. Let's work with some villages and see how well the tech works and get their feedback. That to me is a good next step to take."



Tiny particles of aluminum (white balls) line the surface of a special material that can absorb a wide range of wavelengths. The absorbed light excites electrons in the material, which can pass on energy to nearby water molecules, causing evaporation without boiling. The process may work for smaller desalination needs.



Researchers manufactured sheets of graphene oxide (top) that function as water desalination membranes. Each sheet contains many graphene oxide flakes (bottom) linked together.

FROM TOP: S. DAVE/MIT; L. ZHOU *ET AL*/*NATURE PHOTONICS* 2016

Water desalination could allow farming to take to the sea. The idea sparked the imagination of a Spanish architecture firm, which mocked up an elaborate floating farm complex (illustration). The triple-decker structure would include solar panels on top, crops at midlevel and fish farming on the lower level.

Desalinating water by evaporation has a downside, though, Voutchkov says. Unlike most methods for removing salt, evaporation produces pure distilled water without any important dissolved minerals such as calcium and magnesium. Drinking water without those minerals can cause health issues over time, he warns. "It's OK for a few weeks, but you can't drink it forever." Minerals would need to be added back in to the water, which is hard to do in remote places, he says.

Freshwater isn't just for filling water bottles, though. With a nearly endless supply of salt-free water at hand, desalination could bring agriculture to new places.

## Coastal crops

When Khaled Moustafa looks at a beach, he doesn't just see a place for sunning and surfing. The biologist at the National Conservatory of Arts and Crafts in Paris sees the future of farming.

In the April issue of *Trends in Biotechnology*, Moustafa proposed that desalination could supply irrigation water to colossal floating farms. Self-sufficient floating farms could bring agriculture to arid coastal regions previously inhospitable to crops. The idea, while radical, isn't too farfetched, given recent technological advancements, Moustafa says.

Floating farms would lay anchor along coastlines and suck up seawater, he proposes. A solar panel–powered water desalination system would provide freshwater to rows of cucumbers, tomatoes or strawberries stacked like a big city high-rise inside a "blue house" (that is, a floating greenhouse).

Each floating farm would stretch 300 meters long by 100 meters wide, providing about 3 square kilometers of cultivable surface over only three-tenths of a square kilometer of ocean, Moustafa says. The farms could even be mobile, cruising around the ocean to transport crops and escape bad weather.

Such a portable and self-contained farming solution would be most appealing in dry coastal regions that get plenty of sunshine, such as the Arabian Gulf, North Africa and Australia.

"I wouldn't say it's a silly idea," Voutchkov says. "But it's an idea that can't get a practical implementation in the short term. In the long term, I do believe it's a visionary idea."

Floating farms may come with a large price tag, Moustafa admits. Still, expanding agriculture should "be more of a priority than building costly football stadiums or indoor ski parks in the desert," he argues.

Whether or not farming will ever take to the seas, new desalination technologies will transform the way society quenches its thirst. More than 300 million people rely on desalination for at least some of their daily water, and that number will only grow as needs rise and new materials and techniques improve the process.

"Desalination can sometimes get a rap for being energy intensive," Dave says. "But the immediate benefits of having access to water that would not otherwise be there are so large that desalination is a technology that we will be seeing for a long time into the future." ■

## Explore more


- Khaled Moustafa. "Toward future photovoltaic-based agriculture in seas." *Trends in Biotechnology*. April 2016.
- Smart Floating Farms: smartfloatingfarms.com


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EXHIBIT

## Sea life stars in a glass menagerie

From 1863 to 1890, Leopold and Rudolf Blaschka made more than 10,000 sea creatures out of glass. There were anemones with tapered tentacles and pearled undersides, translucent jellyfish trailing the most delicate threads and feather stars more than worthy of their name despite their rigid composition. The intricate invertebrates, crafted by the father-son team at their studio in Dresden, Germany, were shipped across the world to serve as teaching models at universities and museums. In an era before marine surveys and underwater photography, before the rise of scuba diving resorts, the Blaschkas showed the world the wonders of the sea.

Over five dozen of their glass wonders are now on display at the Corning Museum of Glass in "Fragile Legacy." Though the exhibit opens with glass eyeballs and a piece of jewelry — a nod to the Blaschkas' pre-invertebrate business — the highlight is a darkened room set up like an aquarium, with sea creatures seemingly floating in blue. There's a notable absence of museum placards and descriptions. "We really want people to look at the glassiness," says Marvin Bolt, a curator of the exhibit, before pointing out the "Field Guide to Underwater Models." The pamphlet contains each animal's species name, as it was known in 1885 (when Cornell University acquired the pieces, now on loan to Corning) and as it is known today.

This oaten pipes hydroid (*Tubularia indivisa*) is part of new exhibit of glass sea invertebrates.

***Fragile Legacy***
**THROUGH JANUARY 8, 2017**
CORNING MUSEUM OF GLASS | *Corning, N.Y.*

The aquarium offers a sense of the Blaschkas' style, but it's the room next door that provides the substance. Sketches and watercolors, bottles of colored powders, tweezers, pliers, scoops and wire, along with a demonstration video, give a fuller sense of how the Blaschkas did their work. Equally impressive are the matchboxes filled with *kleine augen* ("little eyes" in German) and other tiny but uniform component pieces, suggestive of an assembly line approach to handcrafting the final glass forms. A series of case studies explains how conservators stabilized the pieces, and a trailer for a related documentary, also titled *Fragile Legacy*, highlights the vulnerability, not of the glass, but of the real-world creatures living in warming seas.

There's one thing you won't find in this exhibit — the flowers that the Blaschkas are most famous for today, commissioned by Harvard beginning in 1886. But you'll spot seeds of this later work in the sea animals' slender stalks and garlands of orbs. As the Blaschkas moved on to new subjects, their artistry evolved from the forms they'd already mastered. — *Elizabeth Quill*

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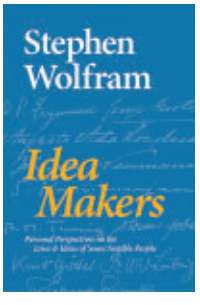


**Idea Makers**
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BOOKSHELF

## Science's human side

It's hard to pin down Stephen Wolfram's scientific discipline. He is part mathematician, part computer scientist, part physicist. He's also an inventor and entrepreneur, known for the mathematics software package Mathematica and a variety of other endeavors. And he blogs.

Among his blog posts and other essays and talks are commentaries on the lives of other prominent figures from science and math; some Wolfram knew personally, others he has researched extensively. In his new book *Idea Makers*, Wolfram has collected accounts of 16 such people, discussing their work and its meaning for the nature of science and the process of understanding math, computing and the physical world. Each entry provides a healthy dose of personal information as well.

Some of the people Wolfram discusses are widely known — Richard Feynman and Steve Jobs, for example. Others are relatively obscure, such as Russell Towle and Richard Crandall. But all have captivated Wolfram's interest, either by way of friendship or their historical importance for the fields of study that Wolfram himself has contributed to.

On the historical side, Wolfram offers his views of the logician Kurt Gödel, computer scientist (perhaps the original computer scientist) Alan Turing and mathematicians John von Neumann and George Boole. Wolfram provides an especially extensive discussion of Ada Lovelace and her interactions with Charles Babbage as they contemplated the prospect of powerful computing engines a century ahead of their time.

Wolfram also dives into the story of Srinivasa Ramanujan, and the lessons his genius offers about the nature of math. With little formal training, Ramanujan discovered many surprising results that seemed at first glance to be a bunch of "random facts of mathematics." But in recent decades, many have been linked to deep mathematical principles that he seems to have somehow perceived without knowing it. How did he do it? Wolfram suspects that he "had intuition and aesthetic criteria that in some sense captured some of the deeper principles we now know, even if he couldn't express them directly."

Personal style, whether as reflected in the subtle genius of Ramanujan or the boldness of vision-driven Jobs, plays an underappreciated role in the progress of science and technology. Wolfram has collected some illuminating examples of the ways the human side of scientific thinkers can enrich the work they do. — *Tom Siegfried*





See more glass creatures at **bit.ly/SN_FragileLegacy**


## *Science News* in High Schools brings curricula to life

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SOCIAL MEDIA

## Quantum cat

The imaginary cat from Erwin Schrödinger's famous thought experiment has been split in two — now existing in a living-dead state in two boxes at once. Scientists forced microwaves into mimicking this quantum behavior, which may have benefits for quantum computing, **Emily Conover** reported in "Schrödinger's cat in two boxes at once" (*SN: 6/25/16, p. 9*). One reader on Facebook offered this feline-related quip:

"Someone needs to design a Schrödinger's litter box that exists in a quantum state of cleanliness." **Erica von S**

### Join the conversation

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## It's all relative

*In "Earth is young at heart" (*SN: 6/25/16, p. 5*), **Emily Conover** reported that Earth's core is more than two years younger than the planet's surface, according to new calculations. Thanks to the effect of gravity on the passage of time, a clock placed at Earth's core will tick fractions of a second slower than a clock at the surface. After 4.5 billion years, all of that different ticking adds up to 2.5 years.*

"'Earth is young at heart' has got me feeling upside down! Wouldn't gravity at Earth's center be zero, not max?" asked reader **Pete Caruso**. "Sure, the center of the Earth is its center of gravity, but wouldn't it also be the place where the mass surrounding that point would be more or less equal in all directions ... resulting in a 'zero gravity' condition?"

There should be no gravitational force at the very center of Earth, **Conover** says, "but general relativity teaches us that clocks run slower due to the gravitational potential, not gravitational forces. That's an important distinction."

Gravitational potential measures the work needed to move against gravity from one place to another, she says. Although gravitational force is weaker near Earth's center, the gravitational potential difference is larger. "If you imagine going deeper and deeper into the center of Earth, it would keep getting harder to climb all the way back to the surface," **Conover** says. "That means clocks will run slower down there, and the Earth will be slightly younger at its core, due to general relativity."

## Call of the whale

*Over the last decade, the frequency of one portion of pygmy blue whales' calls has been steadily dropping — a change in sound similar to that experienced by a teenage boy during puberty. Researchers aren't sure why calls are getting deeper, but it may be to attract mates or may be learned from other whales, **Meghan Rosen** reported in "Pygmy blue whale 'moans' deepen" (*SN: 6/25/16, p. 13*).*

"Consider the temperatures of the waters in which the calls are being made," online reader **Scott Hancock** wrote. "Water temperatures are growing warmer, both at the surface and at depths, affecting acoustics and transmission qualities over larger areas."

Temperature doesn't explain the deeper calls, says **Jennifer Miksis-Olds**, a marine bioacoustician at the University of New Hampshire in Durham. "Surface waters are warming, which impacts the sound speed profile of the water column," she says. But "the deep ocean water where our sensors are has remained constant." Although the whales vocalize closer to the ocean surface where waters are warmer, researchers found that temperature did not contribute to the observed decrease. What's more, "water temperature would have a greater impact at much higher frequencies than the 100 [hertz] calls we are looking at," **Miksis-Olds** says.

## Just a phase

*Simulations covering Earth's birth about 4.5 billion years ago to 10 billion years in the future suggest that plate tectonics is a midpoint in the planet's progression between two stagnant states, **Thomas Sumner** reported in "Plate tectonics could grind to a halt" (*SN: 6/25/16, p. 8*).*

"I am just curious why [the researchers] bothered to run their tectonic simulation 10 billion years into the future, when in about 5 billion years the Earth is likely to be vaporized when our sun completes core hydrogen burning and becomes a red giant?" **Sid Parsons** wrote.

"This work doesn't just apply to Earth, but to other planets as well," **Sumner** says. Some scientists think Venus, currently a stagnant planet, could hypothetically one day have plate tectonics under the right conditions. The new findings could also help researchers studying planets beyond our solar system. "Understanding how long an exoplanet could stay in a certain tectonic regime could help us better understand the potential conditions for alien life," **Sumner** says.

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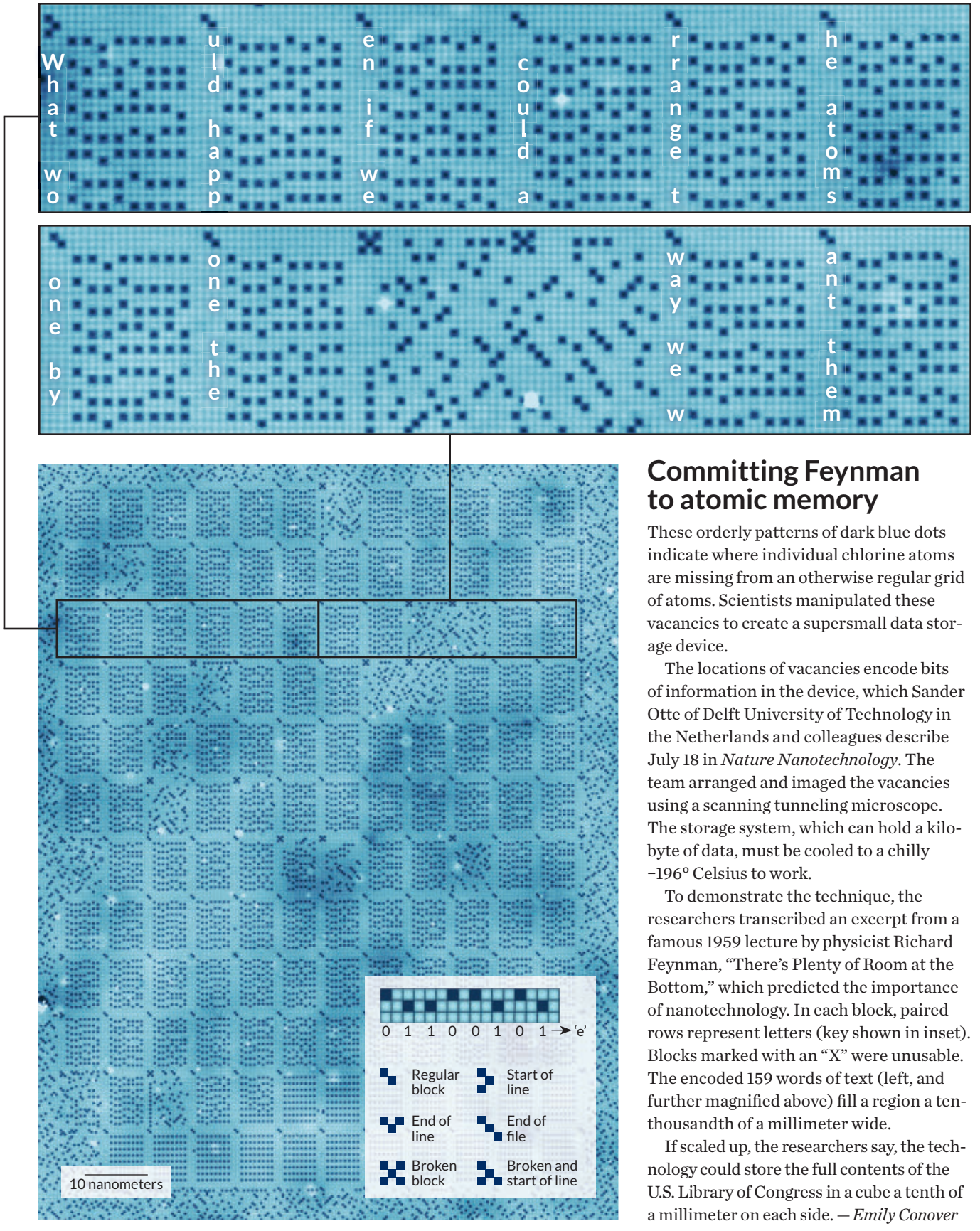


## Committing Feynman to atomic memory

These orderly patterns of dark blue dots indicate where individual chlorine atoms are missing from an otherwise regular grid of atoms. Scientists manipulated these vacancies to create a supersmall data storage device.

The locations of vacancies encode bits of information in the device, which Sander Otte of Delft University of Technology in the Netherlands and colleagues describe July 18 in *Nature Nanotechnology*. The team arranged and imaged the vacancies using a scanning tunneling microscope. The storage system, which can hold a kilobyte of data, must be cooled to a chilly –196° Celsius to work.

To demonstrate the technique, the researchers transcribed an excerpt from a famous 1959 lecture by physicist Richard Feynman, "There's Plenty of Room at the Bottom," which predicted the importance of nanotechnology. In each block, paired rows represent letters (key shown in inset). Blocks marked with an "X" were unusable. The encoded 159 words of text (left, and further magnified above) fill a region a ten-thousandth of a millimeter wide.

If scaled up, the researchers say, the technology could store the full contents of the U.S. Library of Congress in a cube a tenth of a millimeter on each side. — *Emily Conover*

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*• The optics of Admiral Farragut's Telescope are 25x30. This means that you get 25x magnification and the great light-gathering capacity of a 30mm objective lens. The scope is fully chromed (over brass) for extra beauty, protection and durability.*

When Admiral Farragut fought his legendary naval battles he used a telescope just like this to monitor the movements of the enemies' fleets. This beautiful optical instrument, a faithful replica of the famous original is about 5" long in its collapsed position and 13" when extended to full operating length.

Enlargement is 25x, which means that it brings everything 25-times closer, and in needle-sharp focus, than if viewed with the unaided eye. ADMIRAL FARRAGUT'S TELESCOPE comes with a belt-loop vinyl carrying case. There is also a table-top tripod for extended observations.

*You have seen such zoom binoculars advertised nationally for $150...*

## 6x to 18x JOMIRAZOOMS

**from us only $99***

*• JomiraZooms focus smoothly from 6x to 18x or anything in between, letting you see unexpected details. Porro prism construction and ruby-coated lenses are the best in optical construction. The 18mm objective lenses provide high light-gathering capacity. JomiraZooms come with a belt-looped carry case and strap.*

JOMIRAZOOMS are the absolutely ultimate in binoculars. They fit in your hand and weigh less than 7 ozs. But they pack an enormous wallop in their small body. Porro roof-prism construction and ruby-coated lenses guarantee pinpoint sharpness at any distance. The 18mm objective lenses provide great light-gathering capacity making JOMIRAZOOMS utterly reliable even in the dim light of dawn or dusk. The zoom lever lets you smoothly change the magnification from 6x to 18x or anything in between. Are you watching the pitcher's windup on 6x? Zoom to 19x and you may be able to tell whether he is throwing a fastball or a slider. There can be nothing more useful for sports, nature watching, navigation, and so many other pursuits. JOMIRAZOOMS is an instrument that should be in every home.

*The only universal optical instrument...*

## PANSCOPE

**(the complete optical system)**
**from us only $59.95***


*• PANSCOPE is beautifully gift-boxed, comes with its neatly fitted leather case and with a plastic "tripod" for extended observations at 15x and 30x.*

This is a little optical marvel.

PANSCOPE (only 2" long) contains a complete optical system in its tiny body. You may use it as a 3x telescope or as a unique 3x telescope-loupe. In its magnifying mode, it delivers magnifiers and loupes at 5x, 10x, and 15x enlargement. And to top it all, it also functions as a 30x microscope of laboratory quality.

A special stand for long-term observation for 15x and 30x microscope is included.

This marvelous little instrument, developed in Wetzlar (Germany), home of famous Leica cameras, is the product of one of Asia's finest makers. Its coated optics are of superb quality, delivering the image with brilliant luminosity, in needle-sharp focus, with absolute clarity and with full chromatic correction.

*Is this the famous Brand "X" watch that sells for over $1,000?*

## No, it is the Argonaut™ Watch

**- yours for only $69**

In contrast to many highly advertised watches, the **Argonaut™** is not a mechanical watch. It is powered by an exquisite Japanese quartz movement. Besides the hands and the date disk, there are no moving parts. Nothing can go wrong or wear out. And no matter how many jewels they may have that inevitably happens with mechanical watches - sometimes as soon as within a year.

We guarantee the **Argonaut™** for three full years. If you treat it reasonably well it should last you a lifetime. The **Argonaut™** Watch is of solid stainless steel construction. It is guaranteed to be watertight to about 330 ft. You'll never dive that deep. Accuracy is guaranteed to 3 secs./month. You will need to change the battery in about two years. It shouldn't cost you more than $5. The **Argonaut™** Watch is a thing of rugged masculine beauty. It comes with a splendid adjustable stainless steel band.

**jomira**

330 SW 43rd St., Ste. K 333, Renton, WA 98057

*Hold the whole world in your hand with...*

## JOMIRASCOPE

**8 x 20 monocular**
**from us**
**only $59.95**

*• The optics of jomirascope are 8x20 - 8x magnification with 20 mm objective lens. It comes in a neat zippered carrying case. The objective lens can be used as an 8x magnifier. A 25x microscope attachment ($29.95, 3 for $59.90) is also available.*

Jomirascope is so small that it fits unobtrusively in a man's coat pocket or a lady's purse. Yet it packs a tremendous wallop in its tiny body. Its 8 x 20 fully prismatic and hard-coated optics give you 8x magnification, with a remarkable field of 430 ft. at 1,000 yds. Its 20 mm objective lens affords unusual light gathering even at dusk or dawn. What was that rustling in the bushes? With JOMIRASCOPE you'll discover that it was an ivory-billed woodpecker. Do you wish to explore every feature on the moon? JOMIRASCOPE will be your instrument of choice. Much smaller than even "pocket" binoculars and with greater magnification than most, JOMIRASCOPE should be your constant companion. And do consider the 25x microscope attachment of laboratory quality, which makes JOMIRASCOPE a complete optical system.

*An imcomparable timepiece, an incomparable value...*

## RADIO-CONTROLLED CLOCK

**only $59.95***


*• The sleek styling of R-C Clock makes it an adornment for any home or office. It works on one (included) AA-battery and is ready to go when you get it.*

This beautiful clock is clad in brushed aluminum. Its sleek design makes it an adornment for any home or office. It measures 5-1/4" x 4" and can be set on your desk or hung on a wall. Time is displayed in inch-high digits. In addition to the time (hours, minutes, seconds), you also get the date, the day of the week, and the temperature in F (or in C). There is a melodious but insistent alarm, complete with snooze button for those extra winks. The clock is controlled by a radio signal emitted by a U.S. Government department; that ensures up-to-the-second accuracy.

RADIO-CONTROLLED CLOCK works on one AA-battery (included, of course). It's ready to go when you get it. You don't even have to set it - it sets itself.

***And here is our "special deal": You may buy any three of these items -- mixed or matched -- for the price of two. The least expensive item is on the house -- absolutely FREE!**

You may order by toll-free phone, by mail, and pay by check (U.S. only) or AMEX/Visa/MasterCard. Please give order code shown. Add $9.95 for ship./ins. for one and $12.95 for three items, except one JomiraZooms or one Adm. Farragut's Telescope is $12.95 and any three items containing one or more JomiraZooms or Adm Farraguts Telescopes is $15.95. plus sales tax for WA delivery. Canadian orders, please add $6 to our standard rates. You have 30-day refund and one-year warranty. We do not refund postage. For customer service or wholesale information, please call (425) 264-6393.

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*This is how you make a splash...*

# Send in the Aquamarines

*Claim your share of the legendary "sailor's gem" that was once considered more valuable than diamonds or gold!*

When the sun turns up the heat, you need a necklace that will make a splash. Ever since ancient times, sailors have sworn by aquamarine for protection on the open water. We guarantee it to turn heads, by land or by sea. And today you don't have to leave shore to reap the benefits of this legendary blue gem, because your ship has come in. Today, you can wear this spectacular 300 total carat ***Maré Aquamarine Necklace*** for **only $79!** We'll even throw in a pair of Stauer® Hāna Sunglasses (a $99 value) to show how much value you can still get for your dollar.

**Claim your "Mermaid's Treasure."** On any vessel crossing the oceans, there was no more precious cargo than aquamarine. Sailors paid handsomely for its power, considering it their most valuable commodity. In scientific terms, the chemical composition of our ***Maré Necklace*** beads are cousins to precious emeralds. They begin life as geological twins underground, colorless until something sparks a change. Sprinkle in a dash of minerals and one becomes vivid green and the other becomes brilliant blue. That's the beauty of chemistry.

**A legend among luxury jewelers.** Named for the Latin words for "water of the sea," aquamarine shines with all the colors of the ocean. Each bead is like a droplet of the sea frozen in space and time. Walk into the most exclusive retail jewelers and you'll find aquamarine in a place of honor. Fifth Avenue thinks nothing of offering a strand of aquamarine "pebbles" for nearly $12,000. But with a color this captivating, you deserve more than a dollop. That's why we collected the bluest stones from three continents, polished them to perfection and arranged them in this double-stranded, 300-carat masterpiece.

★★★★★

*"A wonderful purchase. Will compliment many colors."*

— Diana, Streetsboro, OH

**Your satisfaction is 100% guaranteed.** Try the ***Maré Necklace*** for 60 days. If you don't fall in love, send it back for a refund of the item sale price. You can even keep the $99 Hāna sunglasses, no hard feelings. But once your wear 300 carats of aquamarine, you'll find that there's no better way to make a splash without getting wet!

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*To show exquisite details, necklace shown is not exact size.*

**Maré Aquamarine Necklace** (300 ctw) ~~$179~~*

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