SN
SCIENCE NEWS MAGAZINE
SOCIETY FOR SCIENCE & THE PUBLIC
OCTOBER 19, 2013

Voyager's View of the Solar System

An All-Blood Diet is a Messy Affair

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Big Cat DNA

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Deep-sea discovery via the Internet

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I used to be more active. I used to run, play basketball, tennis, football... I was more than a weekend warrior. I woke up every day filled with life! But now I spend most of my day in the office or sacked out in front of the TV. I rarely get to the gym –not that I don't like working out– it's my knees and ankles. Its hard to keep motivated when they hurt. Low energy and laziness has got me down. My energy has fizzled and I'm embarrassed to admit that I've grown a spare tire (I'm sure it's wrecking my love life). Nowadays I rarely walk. For some reason, it's just harder. Gravity has done its job on me.

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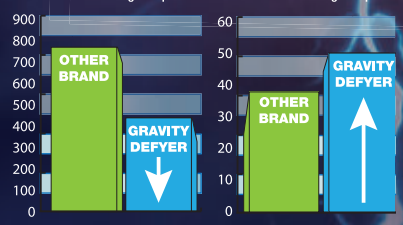

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VOL. 184 | NO. 8

ScienceNews

Features

News

Departments

COVER A monitoring station with a camera, thermometers and other instruments sits in the Endeavour vent field off British Columbia. *Courtesy of CSSF/IFREMER/ Ocean Networks Canada*

A new look and other fruits of our digital experiments

After much anticipation, the Voyager 1 spacecraft has finally, officially crossed into interstellar space. Or, depending on how you conceive of the solar system, maybe it hasn't, as Andrew Grant explains in a fold-out map of the sun's neighborhood on Page 19.

Like Voyager, *Science News* has just made an exciting transition. This redesigned issue is the notable result, marking a foray into new, uncharted territory. Or maybe not. *Science News* has reinvented itself many times over the decades (*SN: 5/10/08, p. 30*), and while our latest incarnation pushes us into the digital future, our mission remains unchanged: to translate the latest advances of science into an easy-to-read form.

From the font changes to the new cover, *Science News* design director Beth Rakouskas and her team have taken to heart the goal of integrating our digital and print publications. The redesigned magazine takes many cues from *Science News Prime*, the iPad-only weekly that took its final bow with the September 30 issue. The two-year *SN Prime* experiment allowed us to innovate, trying new ways of reporting on science and new ways to present it. The successes have now found their way to print, many spearheaded by departments editor Erika Engelhaupt. On the pages that follow, you will find an expanded Notebook section featuring short items from a wide variety of topics. "It's Alive," a regular column by life sciences writer Susan Milius on the frontiers of organismal biology, makes its print debut here. Milius' column skillfully weaves together new research with natural histories of all kinds of living things. Reviews and Previews, a new section, describes noteworthy books as well as websites, films, exhibits and other science-rich experiences. With most reader responses now arriving via e-mail or as online comments, Feedback seeks to give a better sense of the discussions that stories generate. The new Science Visualized features original infographics and stunning science photos.

The redesign also fixed some problems, mostly invisible to readers. It increases flexibility on the news pages, for example, to ensure that the magazine always includes the most interesting and important news stories from a mix of fields.

No one knows what interstellar space is really like. And no one can claim to know what magazines will look like in the future. But like that faraway space probe, *Science News* keeps moving forward. And we look forward to taking you along on the journey: Visit www.sciencenews.org/join-society to register for access to the new website and tablet edition.

— Eva Emerson, Editor in Chief

EDITORIAL, ADVERTISING AND BUSINESS OFFICES
Audit Bureau of Circulation
1719 N Street NW, Washington, DC 20036
Phone (202) 785-2255
Subscriptions subs@sciencenews.org
Editorial/Letters editors@sciencenews.org
Advertising/Business snsales@sciencenews.org
Texterity Digital edition provided by Texterity, www.texterity.com
Science News (ISSN 0036-8423) is published biweekly by Society for Science & the Public, 1719 N Street NW Washington, DC 20036. Subscriptions are $54.50 for 1 year or $98 for 2 years (International rate $85.50 for 1 year or $161 for 2 years), single copies are $3.99 (plus $1.01 shipping and handling). Preferred periodicals postage paid at Washington, D.C., and an additional mailing office.
Subscription Department: PO Box 1205, Williamsport, PA 17703-1205. For new subscriptions and customer service, call 1-800-552-4412.
Postmaster: Send address changes to *Science News*, PO Box 1205, Williamsport, PA 17703-1205. Two to four weeks' notice is required. Old and new addresses, including zip codes, must be provided.

SANDY SCHAEFFER

Curse of the Perfect Gift

OWN THE 15-CARAT EMERALD NECKLACE THAT CHANGES EVERYTHING

Our story begins in the sweltering jungles of South America. My search for precious emeralds hit a dead end, so my partner suggested we expand our horizons. I agreed. When he asked where we should go, I said, "everywhere."

We journeyed through Africa and Europe's greatest cities. We crossed into India and hopped from one Southeast Asian paradise to the next. I was on the verge of giving up when one last detour led to the spectacular gems in our ***Stauer Spring Emerald Necklace***. As you can see, it was worth the effort. And today, they can be all yours for **ONLY $79!**

You get to share the emerald find of a lifetime. Each natural gem radiated with the vivid green color of spring buds. The stones looked spectacular and the price was almost too good to be true. But my stroke of luck had unforeseen consequences…

The "Emerald Curse" strikes. Back home, I strung those exquisite emeralds and wrapped the necklace as a gift for my wife. That's when my trouble began. She LOVED it. Absolutely adored it.

Every 18" necklace features 15 carats of polished, enhanced genuine emeralds with gold-finished links.

In fact, she rarely goes anywhere without the necklace and has basked in compliments from strangers for months now.

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Bring yours home today for 74% OFF. Our ***Stauer Spring Emerald Necklace*** features 15 carats of emerald beads, hand-wired together with delicate gold-finished links. Some curses you don't wish on your worst enemies, but this is one I want to share with friends. That's why today you have the chance to own this stunning collection of stones (available online for $299) for **ONLY $79!**

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Excerpt from the October 19, 1963, issue of *Science News Letter*

50 YEARS AGO

Deadliest Hurricane in Western Hemisphere

The deadliest storm in the history of the Western Hemisphere, hurricane Flora, was unusual in its slow, wavering pace and the force it maintained over land. Usually hurricanes lose their force when they blow across land.... Then as they move again over open water, they sometimes can regenerate their force. For nearly five days the giant mass of whirlwinds hovered over Cuba, the longest a hurricane has been known to stay in one place.... The powerful storm may have killed more than 9,000 people in the Caribbean islands, as well as leaving many thousands homeless.... Damage estimates approach $500 million.

UPDATE: Flora's deadly record was passed by Hurricane Fifi in 1974 and Mitch in 1998, which killed an estimated 9,000 to 18,000 people in Central America. Hurricane Katrina set the record for costliest hurricane in U.S. history in 2005, causing an estimated $125 billion in damage.

Real vampires don't suck. The leaflike front of a common vampire bat's nose senses the blood heat of a capillary-rich spot to bite, and its sharp teeth nick the flesh. As blood flows, the vampire quietly licks.

IT'S ALIVE

Vampire reality check

Vampire movies skip the indignities of the all-blood diet. (The endless peeing, the bloating...) Only three mammal species, all bats, have triumphed at vampire living.

Evolving as blood feeders "has changed everything about them: how they move, how they think, what their social life is like," says Gerald Carter of the University of Maryland in College Park. They've even developed a system for sharing blood meals.

One major downside of blood is its high water content. To get sustenance, vampire bats have to swallow a lot of blood and filter out the excess liquid. "Often they'll be peeing while they're feeding," Carter says.

A big meal leaves a bat quite plump. "They're like little water balloons of blood," Carter says. Roly-poly as they get, they don't fly away with much extra nutrition. A vampire bat drinks one meal a night, and missing just three nights in a row would probably kill the animal, Carter says.

In the face of such evolutionary pressures, vampire bats have become "superstrong, superfast and superintelligent," Carter says. Unlike most bats, the common vampire, *Desmodus rotundus*, can run on the ground if it needs to dart among cattle and the other sizable mammals that it feeds on in Central and South America. And it's agile. An old experiment caged a vampire bat with a rat snake, Carter says. The trapped bat dodged the snake's strikes and ended up feeding on its reptilian face.

These bats, which can live several decades, switch among roosts and form complex social networks, a bit like dolphins'. Vampire society creates a safety net, as bats will regurgitate concentrated blood for a starving roostmate. "It looks like they're French kissing," Carter says.

Carter's adviser, Gerald Wilkinson, stirred excitement and controversy in 1984 by reporting that bats sometimes regurgitate for nonrelatives. An animal example of altruism without family ties intrigued theorists. But critics suggested other explanations, such as hungry bats harassing neighbors until they regurgitated.

So far, harassment doesn't look like the explanation, Carter and Wilkinson reported in the *Proceedings of the Royal Society B* in January. Potential donors in the study colony were more likely to make the first approach to a pal in need of regurgitated favors. — *Susan Milius*

TOBY THORNE/FLICKR

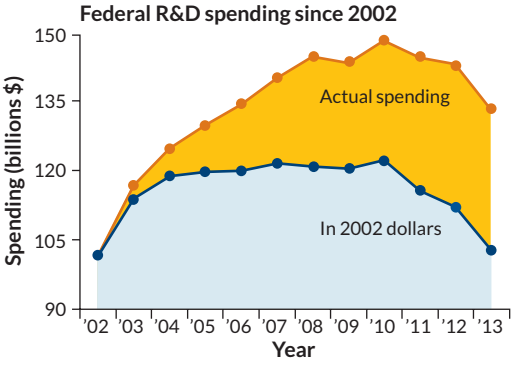
Watch video of bats sharing blood **bit.ly/SNvampire**

SCIENCE STATS

Funding slide

U.S. federal spending on science has decreased sharply since 2010 in inflation-adjusted dollars (right). A survey of more than 3,700 U.S. scientists from a range of fields finds that researchers are feeling the pinch (below).

SOURCE: AMER. SOC. FOR BIOCHEM. AND MOLEC. BIOL. 2013



More work and fewer grants for scientists

80% Report spending more time writing grant proposals now than in 2010

67% Report receiving less grant money now than in 2010

63% Report receiving a federal grant in the last three years

THE LIST

Science states

The following U.S. states report the highest percentages of their workers employed in science and engineering jobs:

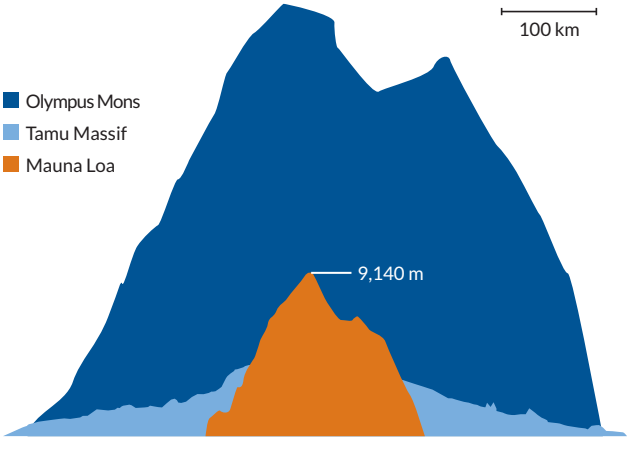
1. D.C. (10.7%)
2. Maryland (7.0%)
3. Massachusetts (6.4%)
4. Virginia (6.2%)
5. Colorado (6.1%)

SOURCE: NATIONAL CENTER FOR SCIENCE AND ENGINEERING STATISTICS 2013

THE -EST

Biggest volcano hulks deep

The most massive volcano on Earth, with a footprint the size of New Mexico, crouches in the dark depths of the western Pacific Ocean. The base of the basaltic mound, Tamu Massif, may rival in area the largest known volcano in the solar system: Mars' Olympus Mons. In 2010 and 2012, a team led by oceanographer William Sager, then at Texas A&M University, bounced sound waves off the deep-sea mountain to measure its size. The researchers report September 8 in *Nature Geoscience* that Tamu Massif forms a broad, rounded dome rising about 4 kilometers from the seafloor and stretching 450 by 650 kilometers across. Its hollowed peak lies beneath 2 kilometers of water. Core samples extracted from the volcano's slopes show that, during its prime 145 million years ago, the ancient mound spewed lava sheets 23 meters thick. —*Jessica Shugart*



MYSTERY SOLVED: D. PENNEY; THE -EST: S. EGTS

MYSTERY SOLVED

Dinosaur dreams dashed

Fans of *Jurassic Park* may be disappointed (or possibly relieved) to learn that you can't get ancient DNA from amber. Insects trapped in amber may look perfectly preserved, but their DNA doesn't hold up well, David Penney of the University of Manchester in England and colleagues report September 11 in *PLOS ONE*. The team tried, and failed, to extract and sequence DNA from two stingless bees (one shown above) embedded in copal, a substance that forms as plant resin becomes amber. One bee was more than 10,000 years old, the other less than 60 years old. Previously, other researchers claimed to have deciphered DNA from insects trapped in amber more than 100 million years ago. Those researchers probably detected modern insect DNA contaminating ancient specimens, Penney and his colleagues say. —*Tina Hesman Saey*

GENES & CELLS

Cats' genes explain hunting success

Lion, tiger and snow leopard DNA offer clues to feline evolution

HwaRang, a white Bengal tiger at the Everland Zoo in South Korea, is one of five big cats whose DNA scientists sequenced for a feline genome project.

EVERLAND ZOO

BY TINA HESMAN SAEY

Tigers and their relatives have hit on the right combination of genes to make them successful hunters, scientists have learned from studying the DNA of some of the biggest big cats.

Along with teasing out the Siberian tiger's secrets, an international team of scientists also examined the genomes of a white Bengal tiger, a snow leopard and two African lions, one of them a rare white female. The vulnerable and endangered animals' genomes, reported September 17 in *Nature Communications*, are the start of a database that is important for understanding the cats' evolutionary past and for preserving their future, says Lisette Waits, a conservation geneticist at the University of Idaho who was not involved in the study. "It's impressive, exciting work," she says.

Already the project is shedding light on how tigers, lions and snow leopards became top-tier predators and adapted to wildly different environments.

Big cats and domestic cats last shared a common ancestor about 11 million years ago. Usually genomes get scrambled as species evolve, says Jong Bhak, a bioinformatician at the Genome Research Foundation in Suwon, South Korea, who was one of the study leaders. But when the team compared the genome of a 9-year-old Siberian tiger named TaeGeuk to that of domestic cats, the researchers found few big differences. That probably means that cats both big and domestic "are very well adapted, successful evolutionary machines," Bhak says.

20,285
Number of genes in a domestic cat

22,333
Number of genes in a human

But many subtler changes set big cats apart from other animals. These cats share 1,376 genetic changes not found in other animals and people, the researchers discovered. Among those genes are many related to digesting meat — not a surprise, Bhak says, given that cats are obligate carnivores. Genes involved in muscle strength, sense of smell, visual perception and nervous system development are evolving rapidly in Siberian tigers, the team found.

Snow leopards carry two mutations that may help them live high in the mountains of central Asia, where oxygen is in short supply. Various changes in the same genes, called *EGLN1* and *EPAS1*, have been credited with helping Tibetan people adapt to live at high altitudes. And naked mole rats, which also live with little oxygen, claim yet another alteration to one of those genes.

Leopards aren't the only copycats. The DNA of an African white lion and white Bengal tiger revealed that both cats' pale coats are due to mutations in a gene that also gives some domestic cats white fur. In white tigers that gene, called *TYR*, contains a mutation that is different from the one that bleaches the coats of white lions.

The data can help scientists monitor genetic diversity and aid in conservation efforts, Waits says. Snow leopards have low levels of genetic diversity, the researchers found, nearly half that of the other big cat species. Low genetic diversity can be a sign that a species is heading toward extinction.

Cats in general have low levels of diversity, says Marcella Kelly, a population ecologist at Virginia Tech. "I get more worried if an animal has lost diversity recently," she says. The researchers have DNA of only one snow leopard, so they don't know whether the animals naturally have low genetic diversity or if it has taken a dive. ■

ATOM & COSMOS

Mars rover fails to find methane

Lack of gas in atmosphere argues against presence of life

BY ERIN WAYMAN

NASA's Curiosity rover has come up empty-handed in its search for methane in Mars' atmosphere, researchers report September 19 in *Science*.

During eight months of data collection, the rover detected average methane concentrations of 0.18 parts per billion. The researchers say that, because of the measurement's margin of error, the finding translates to essentially no methane in the Martian atmosphere.

"It's disappointing because [methane] is a potential sign of biological activity," says study coauthor Christopher Webster, a planetary scientist at NASA's Jet Propulsion Laboratory in Pasadena, Calif. Microbes have produced up to 95 percent of the methane in Earth's atmosphere, where the gas's concentration is roughly 1,800 ppb.

Although the results dampen hopes that methane-making microbes now live on Mars, microbes that don't generate the gas might still live there. Or life, methane-producing or otherwise, could have existed on the planet in the past.

Scientists had previously identified methane on Mars using Earth-based telescopes and spacecraft orbiting the Red Planet. In 2003, researchers detected a concentration as high as 45 ppb. Since then, experiments have reported much lower levels of less than 10 ppb.

To explain the diminishing methane measurements, researchers suggested the gas was periodically released and then rapidly cleared from the atmosphere. Geologic activity could have created the methane. Or microbes beneath Mars' frozen surface could have produced the gas, with seasonal surface melting unleashing the methane into the air.

Curiosity's findings don't preclude those scenarios, says Michael Mumma, a planetary scientist at NASA's Goddard Space Flight Center in Greenbelt, Md. Mumma was part of the team that detected methane in 2003 and in some subsequent studies but was not involved with the Curiosity measurements. If methane ejections are indeed periodic and fleeting, Curiosity may still detect a release as it continues to explore Mars, he says. NASA recently extended the rover's original two-year mission indefinitely.

Other scientists are skeptical of the earlier methane reports. Kevin Zahnle, a planetary scientist at the NASA Ames Research Center in Mountain View, Calif., notes that Curiosity's methane detector is more sensitive than those based on Earth or in space. Another problem with previous studies is explaining why any methane would disappear so rapidly. The gas should last hundreds of years in the Martian atmosphere.

Mumma suggests that Martian soil could contain compounds that oxidize methane when they're lofted into the air in dust.

Next, Curiosity will start looking for the gas with an even finer precision. Webster says the rover could sniff out as little as 50 or 100 parts per trillion. If that's all the methane Mars has, he says, meteorites or comets containing organic molecules are a likely source. ■

ATOM & COSMOS

Curiosity gets the dirt on Mars

Whiffs of chemicals found in rocket fuel, a dark pyramid that resembles rare volcanic rocks on Earth and glassy particles bearing traces of water are among the Curiosity rover's finds in its first chemical investigation of Martian dirt.

"This is the first time we've known precisely and definitively what this stuff is made of," says astrobiologist David Blake of the NASA Ames Research Center in Moffett Field, Calif. He and others report results of the analysis September 26 in *Science*.

In soil collected by Curiosity at a site called the Rocknest (right), scientists detected crystals from volcanic rocks plus glassy particles. One sample contained around 2 percent water, probably trapped in the glass. The analysis also identified chlorine compounds, including perchlorate, a toxic component of rocket fuel, which could complicate future plans for humans to live on Mars. So far, Curiosity hasn't found any organic compounds that might signal life.

Researchers also examined a dark gray, pyramid-shaped boulder about 50 centimeters tall. The unusual rock most closely resembles a rare type of lava found on islands on Earth. The find may give hints about how rocks on Mars formed, says geologist Edward Stolper of Caltech. — *Beth Mole*

JPL-CALTECH/NASA AND MSSS

HUMANS & SOCIETY

Poker pros' arms betray their hands

How players move chips when betting signals their card quality

BY BRUCE BOWER

No bluff: In high-stakes matches, a poker face may not be good enough. Players may have to develop "poker arms" too.

When shown two-second video clips of the arms and hands of top players making bets in the World Series of Poker, college students judged well who was playing a strong hand and who wasn't, say psychology graduate student Michael Slepian of Tufts University in Medford, Mass., and his colleagues.

But when viewing videos of only poker pros' upper bodies or faces during bets, students couldn't correctly predict whether players held good or bad cards, the researchers report September 12 in *Psychological Science*.

In other words, experienced players' poker faces gave away nothing. "But professional poker players' arm movements enabled untrained observers to decode poker-hand quality," Slepian says.

Observers often rated poker players who held good cards as having moved their arms smoothly when pushing chips forward to make bets; bluffers moved their arms somewhat awkwardly. It's not known, though, whether poker players whose arm movements were rated as smooth really slid chips forward more gracefully than their opponents did.

Bluffers moved their arms somewhat awkwardly.

Slepian's study adds to preliminary evidence that the ways in which people move hint at what they're thinking, remarks cognitive neuroscientist James Kilner of University College London.

A 2012 study coauthored by Kilner found that volunteers who responded to a lab task by moving a marble to one of two holes on a board did so more quickly when they were confident in their responses. Observers also consistently rated rapidly responding volunteers as confident in their decisions.

In the new study, Slepian and his colleagues divided 78 college students into three groups. Each group watched 20 video clips of big-time poker players placing bets. Clips showed the players' heads and arms, heads only or arms only. Study participants guessed the quality of each poker hand on a scale from 1 to 7, from "very bad" to "very good." The researchers then compared these ratings with each player's statistical likelihood of winning, as provided by the World Series of Poker.

None of the participants played poker regularly. Those who had played some poker, however, did best at using players' arm movements to tell weak from strong hands.

A different group of 40 students in the study rated poker players betting on strong hands as confident and as having smooth arm movements. ■

BODY & BRAIN

Scented naps can dissipate fears

People unlearned scary odor if they smelled it in their sleep

BY LAURA SANDERS

A nap can ease the burden of a painful memory. While fast asleep, people learned that a previously scary situation was no longer threatening, scientists report September 22 in *Nature Neuroscience*.

The results are the latest to show that sleep is a special state in which many sorts of learning can happen. And the particular sort of learning in the new study blunted a fear memory, a goal of treatments for disorders such as phobias and post-traumatic stress disorder.

"It's a remarkable finding," says sleep neuroscientist Edward Pace-Schott of Harvard Medical School and Massachusetts General Hospital.

Katherina Hauner and Jay Gottfried of Northwestern University's Feinberg School of Medicine and their colleagues taught 15 awake volunteers to fear the combination of a face and odor. Participants saw a picture of a certain man's face and at the same time smelled a distinctive scent, such as lemon. This face-odor combo was paired with a nasty shock, so that the volunteers quickly learned to expect something bad when they saw that particular face and smelled the associated odor.

Then the volunteers tucked in for a nap in the lab. When they hit the deepest stage of sleep, called slow-wave sleep, the researchers redelivered the smell but without a shock.

During the nap, those participants learned that the smell was safe. The volunteers sweated less (a measure of fear) when the face-odor combination appeared after the nap, the scientists found. When the odor wasn't presented during sleep, volunteers' responses to the associated face were unchanged.

Upon awakening, volunteers also underwent scans that revealed brain activity changes that accompanied this relearning. Odor exposure while sleeping seemed to cause neural changes in the hippocampus, a memory center, and the amygdala, which is linked to emotions.

This relearning process is similar to exposure therapy, Hauner says. In that therapy, a person with arachnophobia, for instance, confronts spiders over and over again until new memories of safety override the previous memory of fear. Exposure therapy is often very difficult, says neuroscientist Asya Rolls of Technion–Israel Institute of Technology. A treatment that could happen entirely during sleep, while the patient has no conscious knowledge of it, might be easier on people, she says. "These are very promising findings."

Hauner next wants to test whether the benefits last. ■

Smithsonian Institution Confederate mystery reappears!

$50 Civil War Banknote Released as Massive Silver Proof

Actual size is 7¼" x 3 3/16"

On Sept. 2, 1861, during the early days of the American Civil War, the South printed $50 banknotes from intricately engraved steel plates located in New Orleans. Bearing the high denomination of $50 and featuring an artistic engraving of a steam locomotive, these impressive bank-notes were intended to fund the Confederate war efforts. Today, however, experts estimate that less than 500 of these historic $50 notes still survive. Today, 150 years later, original paper notes sell for upwards of $9,500 to eager collectors.

Civil War History Arrives at the Smithsonian
When Northern troops regained New Orleans in 1862, General Benjamin Franklin Butler took command of the city. Amazingly, his troops discovered the engraving plates for the $50 Confederate Train Note. Gen. Butler personally mailed the plates back to the Secretary of the Treasury, Salmon Chase, in Washington, to prove the North was in control, and commanded New Orleans. It remains a mystery how the plates, still wrapped in Gen. Butler's hand-addressed package, made it into the collection of the Smithsonian Institution—but they reside there to this day.

An American Treasure Reborn in Pure Silver
Now, as America marks the 150th anniversary of the Civil War, the Smithsonian Institution has authorized an exclusive striking of the $50 Confederate Train Note in gleaming proof silver to create a first-ever $50 Silver Collector's Gem Proof. Struck from dies based on the original intricately-engraved banknote dies, each $50 Confederate Train Note Silver Gem Proof is the same size as the original large bank-note and contains a massive two Troy ounces of 99.9% pure silver. Each has been certified by the respected Paper Money Guaranty company (PMG)—and each silver proof is protected in a clear archival sleeve bearing both the PMG Gem Proof grade, as well as the Smithsonian authorization.

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LIFE & EVOLUTION

Poop in termite nests foils pest control

Bacteria in feces protect Formosan species against fungus

BY SUSAN MILIUS

Mixing their own feces into nest walls gives Formosan termites a bacterial boost in fighting off human attempts to destroy them with insect plagues.

A bacterial strain found in the fecally enhanced nest walls of pest termites *Coptotermes formosanus* helps protect them from a potentially deadly fungus, says entomologist Nan-Yao Su of the University of Florida in Fort Lauderdale. Such live-in boosters could help explain why efforts to control the termites with fungal diseases have failed, Su and his colleagues report in the November *Proceedings of the Royal Society B*.

"You can put the fungus on an insect in a lab dish and say, 'Hah! We killed the termite,'" Su says. But for termites in their natural colonies, the soil-dwelling fungus *Metarhizium anisopliae* has failed to devastate.

Meanwhile Formosan termites are destroying homes, railroad ties and even living trees. Colonies of these termites have proven among the pests most destructive to wood in the southeastern United States and Hawaii. A subtropical species from Asia, it turned up in Texas in 1951. A single colony can grow to more than a million termites scurrying through multiple underground nests and a tunnel network ranging across 150 meters.

After millions of years of crowding into warm, humid nests underground, the termites have evolved both biology and behavior that can fight fungi, says coauthor Thomas Chouvenc, also at the University of Florida. Termites attend to personal hygiene and invite grooming by stretching out a leg or exposing a body area. Nestmates oblige by nipping off detritus, which passes into the formidable termite gut, where pathogens typically die. The new study, Chouvenc explains, explores how termites export their guts' protective powers to the walls of their nests.

Formosan termites create a fecal lining for their foraging tunnels and mix feces with chewed plant material to make the structural material for the rest of their homes.

Earlier work had suggested that the termites excrete pathogen-combating bacteria. In the new study, the team isolated more than 500 Actinobacteria strains from structural material in five termite nests. (Actinobacteria are common microbes in soil.) The researchers used tests in lab dishes to screen the bacteria for pathogen-fighting ability. They used a representative fighter strain in more naturalistic experiments: Termites were tucked into sand and sterilized structural

GENES & CELLS

Killer cells may fend off leukemia

Healthy people's immune systems recognized the cancer

BY JESSICA SHUGART

Echoes of past encounters with leukemia cells flow through the veins of people who have never suffered from the disease, a study suggests. The immune systems of cancer-free people may have gathered antileukemia forces by mounting preemptive strikes against cells that were on their way to becoming cancerous. Leukemia patients, on the other hand, carry meager signs of resistance.

"Perhaps we've all had a bit of precancerous disease," says immunologist Mark Cobbold of the University of Birmingham in England, who led the study with Birmingham colleague Hugo De La Peña. Just as immune cells reflect a person's history of viral infections, the fingerprint of cancer exposures could lie there as well, Cobbold says.

After an encounter with any pathogen, a fraction of immune cells that fought in the battle stick around, lying in wait for the next attack. Cobbold, De La Peña and their colleagues found in healthy people killer immune cells that appeared to have been scent-trained on cancer cells. The scientists identified the scent as well: a family of peptides, or small protein fragments, that coat the surfaces of cancer cells.

The cancer peptides were adorned with chemical modifications called phosphate groups. Phosphorylation, the addition of phosphate groups to proteins, communicates signals that control cell growth and survival. But cancer cells switch this process into overdrive, says De La Peña. "The cancer cell needs this 'crazy phosphorylation' to become malignant," he says. "And this is exactly what the immune system sees."

The team identified 95 phosphopeptides on the surfaces of malignant cells taken from patients with leukemia. Sixty-one of the peptides appeared only on cancer cells and not on normal ones, the researchers report in the Sept. 18 *Science Translational Medicine*.

Then the team extracted T cells from 26 leukemia patients: 14 with chronic lymphocytic leukemia and 12 with acute myeloid leukemia, a more aggressive form of the disease. While healthy volunteers all harbored T cells that recognized the cancer phosphopeptides, only five patients with the milder leukemia did, as did two patients with acute myeloid leukemia. The researchers found that the T cells bore proteins that marked them as "memory cells," indicating that the cells had encountered the phosphopeptides — perhaps on cancerous cells — before.

Why some people lack this immunity to phosphopeptides is unclear, but the researchers speculate that those people may have had cancer-specific killer cells and then lost them as the immune system waned with age. Or perhaps some

SCOTT BAUER

One Formosan termite may be little and vulnerable but together the insects can draw on many protective powers, including fecal microbes built into their colony walls.

COURTESY OF XING XIE

material between planes of Plexiglas. Letting one strain of *Streptomyces*, a kind of Actinobacteria, establish itself in the sand allowed 1.6 times as many termites to survive 60 days of fungal contamination when compared with bacteria-free sand.

What's most interesting to entomologist Gregg Henderson of Louisiana State University is that Chouvenc and Su have declared human termite science a 50-year failure at biological control, yet "show how simply and elegantly it is performed by the termites themselves." ■

people's immune cells never mounted a response in the first place.

After researchers measured T cells from the patients, the 12 individuals with acute myeloid leukemia received stem cell transplants to treat their disease. Ten of them then showed immune responses to some of the peptides.

If other experiments confirm that donated cells can prime a person's immune system to respond to phosphopeptides, Cobbold proposes that screening donors for immunity to phosphopeptides could improve the success of transplant treatments.

The researchers hope to find phosphopeptide signatures in other kinds of cancer and envision using the peptides to vaccinate people against the disease.

"It's a sort of tantalizing result," says immunologist Anthony Purcell of Monash University in Melbourne, Australia. Cancer phosphopeptides, he says, likely won't be a "global panacea." But he calls them exciting and "a new part of the cancer vaccination toolkit." ■

MATTER & ENERGY

Bacterial batteries get a solid boost

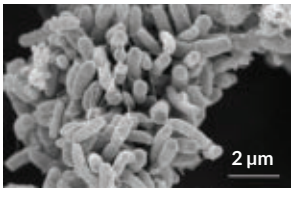
Harvesting energy from wastewater has a silver lining

BY BETH MOLE

Silver, the precious metal once thought to protect against werewolves and make magic mirrors, has a new, real talent: helping microbes turn sewage into power.

Engineers have long used microbes to wring out electrical energy trapped in wastewater, and have relied on oxygen to soak up the harvested electrons. But these mini power plants can be finicky and leak oxygen and microbes. When the two mingle, the bugs guzzle the gas and short-circuit the system.

Now researchers at Stanford University have replaced bubbling oxygen with solid silver oxide that gobbles up electrons, making a more reliable, rechargeable bacterial battery. The researchers report the finding September 16 in the *Proceedings of the National Academy of Sciences*.



A mix of microbes (shown) has been hard-wired into a battery's electrode made out of carbon cloth. On the electrode, the microbes transfer electrons into a circuit that stores power.

All microbe-based batteries and fuel cells need a place to send electrons, says coauthor Craig Criddle, "but putting oxygen in there is a problem." By using a solid material like silver oxide, which turns into silver and releases hydroxide when it collects electrons, it's easier to control the battery, he says. And because silver naturally repels microbes, using the metal ensures the two parts of the battery stay separate.

In the new batteries, electron-harvesting microbes grow in a thick tangle around a positively charged electrode, called an anode, made out of carbon cloth. Microbes attached to the anode then start snatching electrons from organic compounds dissolved in the wastewater to produce carbon dioxide and clean water.

The electrons stream through the anode and into a wire, creating current that can be used to power devices. On the other end of the wire is the silver oxide cathode (the battery's negatively charged electrode), which snags the electrons.

When all of the silver oxide is transformed into silver, scientists can remove the metal, release the electrons and convert the metal back to silver oxide using simple chemical processes. Then the silver oxide can be reused.

"This is much, much simpler than our current system," says Zhen (Jason) He, an environmental engineer at Virginia Tech. Other microbial batteries being developed for sewage plants and polluted bodies of water use oxygen at the cathode because it's very good at collecting electrons. But gases are hard to control. The oxygen can bubble over to the anode and the microbes can migrate closer to the cathode to swipe the gas for their own energy production — either case risks a short circuit. To prevent spillover between electrodes in these batteries, engineers use complex membrane barriers.

Despite the perks of silver, He notes that it's pricy and wastewater plants would need large, and thus very expensive, versions of the battery.

Korneel Rabaey of Ghent University in Belgium agrees that cost is a concern. He also cautions that bigger versions of the battery may not be as energy efficient as the setup Criddle and colleagues describe.

In the study, the battery could net 30 percent of the power contained in wastewater, which is comparable to other energy-harvesting methods. But the experiment was done in favorable conditions that may not occur in sewage plants, Rabaey says.

"It's still early days for this technology, so it's hard to calculate which system is best," he says. "But it's a nice idea." ■

MATTER & ENERGY

Vitamin E stops static electricity

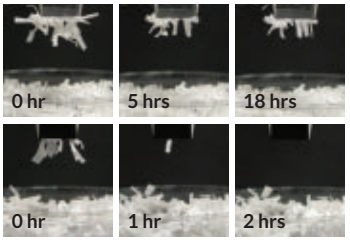
The chemical could protect computers from electrostatic shocks

BY MEGHAN ROSEN

A little vitamin E could zap static cling.

The vitamin wipes out static electricity by getting rid of molecules that stabilize charge, researchers report in the Sept. 20 *Science*. By adding vitamin E or similar chemicals to coatings for electronics, manufacturers could fend off the electrostatic shocks that fry computer chips.

Static electricity may be best known for delivering tiny jolts to people shuffling across carpets. But in electronics, "the situation is very serious," says physical chemist Fernando Galembeck of the University of Campinas in Brazil, who was not involved with the new work. Beyond messing up motherboards, electrostatic shocks can spark fires and explosions that injure people and damage property. "These things happen all the time," he says.



No more static cling Shreds of paper stick for hours to a block of silicone polymer charged with static electricity (top row). When the block is coated with molecules called radical scavengers, the charges die out quickly and the paper shreds no longer cling (bottom row).

Static electricity has kindled scientists' interest for centuries, yet how exactly friction creates the electrical charge has remained a mystery, says chemical engineer Daniel Lacks of Case Western Reserve University in Cleveland. "What happens when things charge is totally unknown scientifically."

In the last few years, Bilge Baytekin, study leader Bartosz Grzybowski and colleagues at Northwestern University in Evanston, Ill., have chipped away at the big unknown. They've shown how to charge two pieces of identical polymer just by touching them together. When the two pieces rub against one another, friction breaks chemical bonds on the polymers' surface. Then new bonds form between the pieces, making them cling to each other like sticky tape, says Baytekin.

When researchers peel the pieces apart, the bonds linking the polymers rip, leaving different chemical fragments hanging. Some of these fragments carry charge — a key part of static electricity.

But other chemical fragments may be important, too. Tearing polymers apart also creates uncharged molecules called radicals, which have gone mostly overlooked by scientists studying static electricity, Baytekin says. "They said, 'Oh, radicals are uncharged, we don't care about them.'"

So she and colleagues charged up plastic and silicone polymers and then used a type of microscopy that can map molecules' locations. Charges and radicals clustered together. "This is very exciting," says study coauthor H. Tarik Baytekin

The radicals might act like a molecular support crew, stabilizing the charges and letting static electricity linger, he says. To test the idea, the team dipped polymers into solutions containing radical scavengers, such as vitamin E. These chemicals mop up radicals, leaving charges alone.

Pieces coated in radical scavengers ditched their charge much faster than uncoated pieces.

"These guys came up with an idea that is totally new — that radicals stabilize charge," Lacks says. "I've never seen anything like it."

H. Tarik Baytekin thinks radical scavengers could help quench static electricity in many different industries, from electronics to textiles. And Bilge Baytekin thinks a comb dipped in the radical-scavenging solution might even smooth frizzy hair. ■

EARTH & ENVIRONMENT

Rise of oxygen on Earth pushed back

Gas was present in the planet's atmosphere 3 billion years ago

BY JESSICA SHUGART

Earth's first atmospheric oxygen may have appeared 300 million to 400 million years earlier than scientists thought. According to an analysis of ancient sediment, hints of oxygen graced the Earth's atmosphere around 3 billion years ago.

The new date places oxygen in the atmosphere more than 600 million years before the Great Oxidation Event, when levels of the gas rose dramatically. In the last six years, a handful of geologic studies have dated transient wisps of oxygen to 2.6 billion to 2.7 billion years ago. Scientists think that photosynthetic microorganisms such as cyanobacteria produced the oxygen. So the timing of the first atmospheric oxygen has implications for how photosynthetic life evolved.

Because photosynthesis is complex, says biogeochemist Sean Crowe, who jointly led the study with Lasse Døssing of the University of Southern Denmark in Odense, scientists have thought "that it took a very long time to evolve." The team's data, along with the earlier reports that suggested oxygen was present before the Great Oxidation Event, chip away at that notion, says Crowe, who is now at the University of British Columbia in Vancouver.

Crowe's team made the discovery using 3-billion-year-old rock drilled from 1,000 meters belowground in South Africa. Crowe expected the sediments would reveal an oxygen-deprived Earth. Instead, the team found the oldest evidence yet of atmospheric oxygen.

The researchers used a highly sensitive technique comparing stable forms of chromium — chromium-52 and chromium-53 — to probe the rock for signs of oxygen exposure. Today, chromium-52 is more abundant in land sediments than chromium-53 is because atmospheric

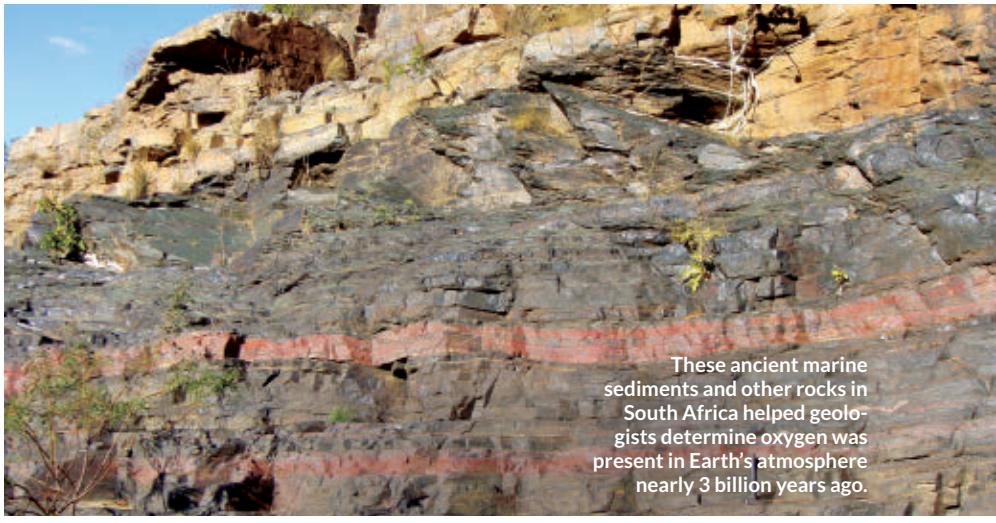
H.T. BAYTEKIN *ET AL*/*SCIENCE* 2013

oxygen more readily oxidizes, or strips electrons from, chromium-53. When oxidized, chromium-53 dissolves in water and rivers to carry it to the ocean.

Crowe and colleagues report in the Sept. 26 *Nature* that the South African samples had surprisingly low levels of chromium-53, suggesting oxygen was present in the atmosphere at the time they were deposited. The researchers also detected higher levels of chromium-53 in ancient ocean sediments nearby, a sign that oxidized chromium-53 had flowed into the sea .

Because the chromium technique has been used only in the last several years, some experts are enthusiastic yet cautious about the findings. "We're very much in an exploratory phase" in interpreting such results, says geobiologist Woodward Fischer of Caltech.

Geochemist James Farquhar of the University of Maryland in College Park says the team makes "a pretty strong case" that the 3-billion-year-old chromium was oxidized. However, Farquhar says, chemicals other than oxygen may have also played a role in the oxidation.



These ancient marine sediments and other rocks in South Africa helped geologists determine oxygen was present in Earth's atmosphere nearly 3 billion years ago.

NICOLAS J. BEUKES/UNIV. OF JOHANNESBURG

The results may raise questions about the evolution of photosynthetic life. Scientists think that cyanobacteria, the prime suspects for early oxygen production, evolved 2.7 billion years ago. Other organisms may have produced the earlier oxygen, or cyanobacteria may have evolved earlier than thought.

The research, says biogeologist Roger Buick of the University of Washington in Seattle, "adds greater complexity to our picture of how and when the Earth got its oxygen. It suggests that oxygenic photosynthesis, the ultimate source of most oxygen, evolved long before the Great Oxidation Event." ■

BODY & BRAIN

Home births more risky than hospital deliveries

Records suggest babies born at home are more prone to unresponsiveness after five minutes

BY NATHAN SEPPA

The risks attached to giving birth in the home, even with a midwife present, are greater than in the hospital, an analysis of U.S. birth records suggests. Babies born at home are 10 times more likely to lack a pulse and be unresponsive when they are 5 minutes old.

Despite this difference, the overall risk of such a dire condition was low regardless of birth location, researchers report in the October *American Journal of Obstetrics and Gynecology*. Of every 1,000 babies born at home with a midwife attending, 1.6 lacked a pulse and weren't breathing five minutes after birth, the researchers found. For hospital births with a doctor, the rate was 0.16 per 1,000 infants.

"It's a very low occurrence rate," says Michael Malloy, a neonatologist at the University of Texas Medical Branch in Galveston, who wasn't part of the study. "I'm not a great advocate of home delivery. It scares me. But I can see the other side, if a woman wishes to have the experience of doing this at home."

The relative risk seen in this study far exceeds those from previous studies, which found that giving birth at home doubled or tripled the risk of neonatal death. The American College of Obstetricians and Gynecologists' guidelines cite that level of risk in home birth and caution that women delivering at home should have ready access to transport to a hospital.

Location matters, says study coauthor Amos Grunebaum, an obstetric gynecologist at New York-Presbyterian Hospital and Weill Cornell Medical Center. If complications arise during home delivery, it can be dangerous for mother or baby. Women lose time racing to a hospital, he says. "It's often difficult to play 'beat the clock' to save the baby."

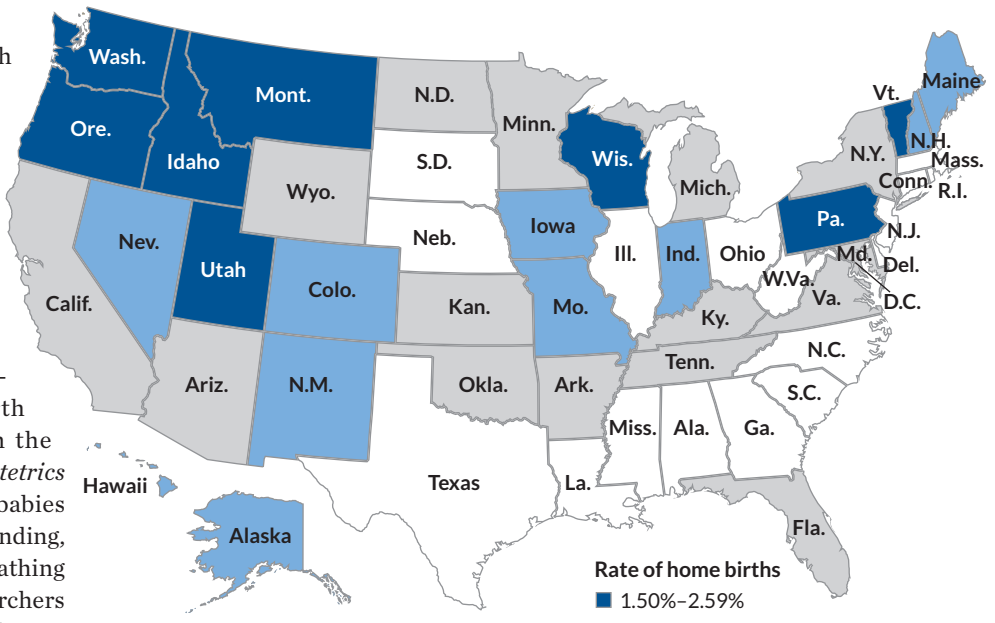
The analysis relied on 13 million birth certificates from 2007 to 2010. The vast majority of births occurred in hospitals. Of more than 60,000 home births attended by a midwife, 98 infants lacked pulse, breath, activity and response to stimulation, and were blue or pale five minutes after birth. Babies born at home were also four times as likely to have seizures as babies born in the hospital, the data showed.

But birth certificate data can be subjective and unreliable, says Christina Johnson, director of professional practice and health policy for the American College of Nurse-Midwives in Silver Spring, Md. What's more, these data failed to reveal how many of the pulseless babies were resuscitated. Since the study doesn't provide the babies' fates, she says, "it's a little bit alarmist."

Grunebaum counters that such infants "are essentially dead." Reviving them requires extraordinary measures involving a medical staff and an oxygen tube, he says.

Peter Brocklehurst, an obstetrician at University College London, finds the new data difficult to interpret. Those who chose home birth were self-selected and therefore don't represent a typical sample of the population. Compared with women giving birth at a hospital, women at home were more likely to be white, age 30 or older, carrying a large baby and delivering late — 41 weeks or more into gestation. Some of those characteristics affect birth risks negatively, he says. Brocklehurst also wonders to what extent the midwives providing home birth care worked within acceptable practice guidelines.

Johnson notes that 97 percent of certified nurse-midwives, who typically hold master's degrees, work in hospitals. Many home-birth midwives have lesser credentials and training, and qualifications vary from state to state. In this study, in-hospital births facilitated by midwives had fewer problems than the physician-assisted births. ■



Home delivery In the United States, giving birth at home is relatively rare and more common in the Northwest than in the Southeast.

SOURCE: NCHS/CDC

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GENES & CELLS

Mice lose cat fear for good after infection

Mice may permanently shed a fear of felines after being briefly infected with a parasite, a new study shows. The protozoan parasite *Toxoplasma gondii* can infect most mammals, including humans (*SN: 1/26/13, p. 24*). But the parasite can reproduce only in the feline gut, so the parasite relies on cats eating infected animals. Perhaps increasing the likelihood that it will wind up in the belly of a cat, the parasite makes infected rodents lose their innate aversion to cat urine, researchers discovered in 2000. But that parasite strain was so potent that it killed the mice, so it wasn't clear whether the rodents' loss of cat aversion could persist. Researchers led by Michael Eisen of the University of California, Berkeley report September 18 in *PLOS ONE* that a loss of repulsion to cat urine lingered four months after infection with less-virulent *T. gondii* strains, even in mice that had cleared the parasites from their bodies. The researchers propose that a transient infection with the parasite permanently alters the way the rodents' brains perceive predator threats. — *Jessica Shugart*

MERS virus jumped several times from animals to humans

The virus that causes the mysterious and deadly new disease called Middle East respiratory syndrome may have infected people multiple times. People then transmitted the virus to others, a new analysis suggests. The illness, called MERS, was identified last year and has sickened 132 people, killing 58 of them, mostly in Saudi Arabia. Both bats and camels are possible carriers of the coronavirus that causes the disease, but neither is the definitive animal source of the infections in humans. Ziad Memish of the Ministry of Health in Riyadh, Saudi Arabia, and colleagues took MERS virus DNA directly from the noses and throats of 21 patients. Analysis of the DNA suggests that the virus arose sometime between July 2007 and June 2012, with the most likely time being July 2011, Memish and his colleagues report September 20 in the *Lancet*. The virus may have leaped from animals to people at least seven different times, with multiple strains circulating among people at once. — *Tina Hesman Saey*

ATOM & COSMOS

Cometlike crashes produce building blocks of life

Smacking a steel projectile into a cometlike icy concoction has produced the ingredients for making proteins. The finding adds weight to the hypothesis that primordial life on Earth arose from the wreckage of collisions. Space debris relentlessly pummeled Earth when life began, an estimated 3.8 billion years ago. Some scientists think that icy carbon-bearing comets delivered life's ingredients. Energy from the impacts may have catalyzed the production of amino acids, the building blocks of proteins and a key type of molecule for life. To re-create the ancient conditions, scientists led by Zita Martins of Imperial College London made an icy mixture of compounds that exist on comets, using ammonium hydroxide, carbon dioxide and methanol. Then the researchers hurled a steel projectile into the icy mix at 7.15 kilometers per second. The scientists report September 15 in *Nature Geoscience* that residue from the impact contained amino acids, including glycine and alanine. — *Jessica Shugart*

EARTH & ENVIRONMENT

Emissions cuts would save millions of lives

Cutting greenhouse gas emissions should improve air quality and thereby save millions of people's lives by the end of the century, new simulations find. Burning fossil fuels emits both climate-warming gases and other air pollutants such as particulate matter. Greenhouse gases also contribute to the formation of ground-level ozone, the main component of smog. Because particulate matter and ozone can cause heart and lung disease, researchers think that reducing greenhouse gases would improve public health. J. Jason West of the University of North Carolina at Chapel Hill and colleagues simulated climate and air quality through 2100. In a simulation with reductions in fossil fuel use, 2.2 million premature deaths per year could be avoided by 2100 compared with a simulation without climate change mitigation. The greenhouse gas cuts also make economic sense, the researchers say. Reducing pollution-related deaths saves $50 to $380 per metric ton of carbon dioxide, even after accounting for the costs of mitigation, the team reports September 22 in *Nature Climate Change*. — *Erin Wayman*

BODY & BRAIN

Alzheimer's disease protein structure may vary among patients

Alzheimer's disease proteins may contort differently in every patient. In the brains of people with Alzheimer's disease, a protein called amyloid-beta, or A-beta, forms fibers that congregate into plaques. A study now suggests that each person may have a distinct version of the fibers, which could affect how the disease develops. Researchers led by Robert Tycko of the National Institute of Diabetes and Digestive and Kidney Diseases in Bethesda, Md., extracted A-beta from the brain tissue of two women who had died from Alzheimer's disease. The women had different symptoms and the disease affected different parts of their brains. Each woman had one predominant type of amyloid-beta fiber in her brain, Tycko and colleagues report in the Sept. 12 *Cell*. One woman's fibers were long, thin and straight, while the other's fibers were thicker and contained periodic twists, the researchers found. The result could be important for diagnosing and treating the disease. — *Tina Hesman Saey*

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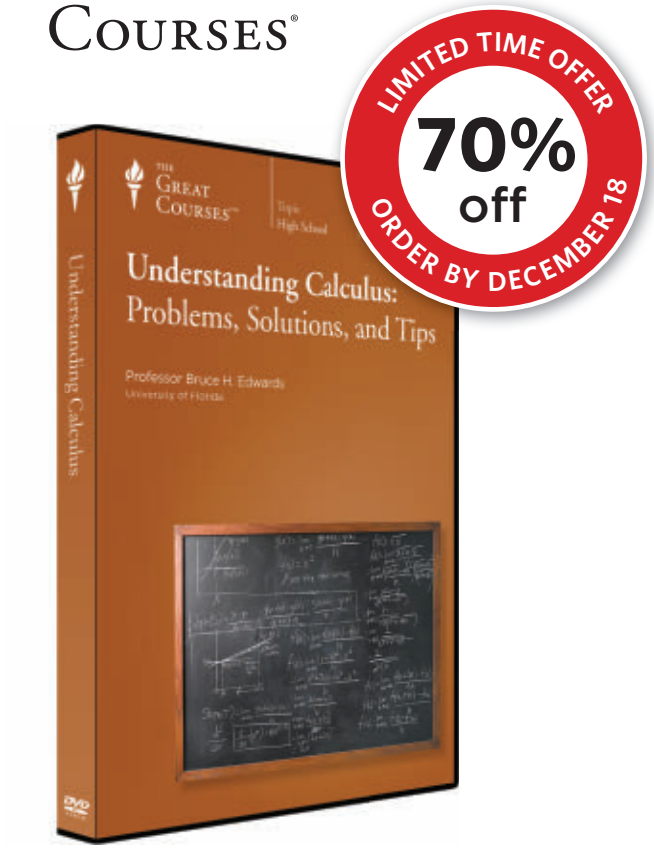

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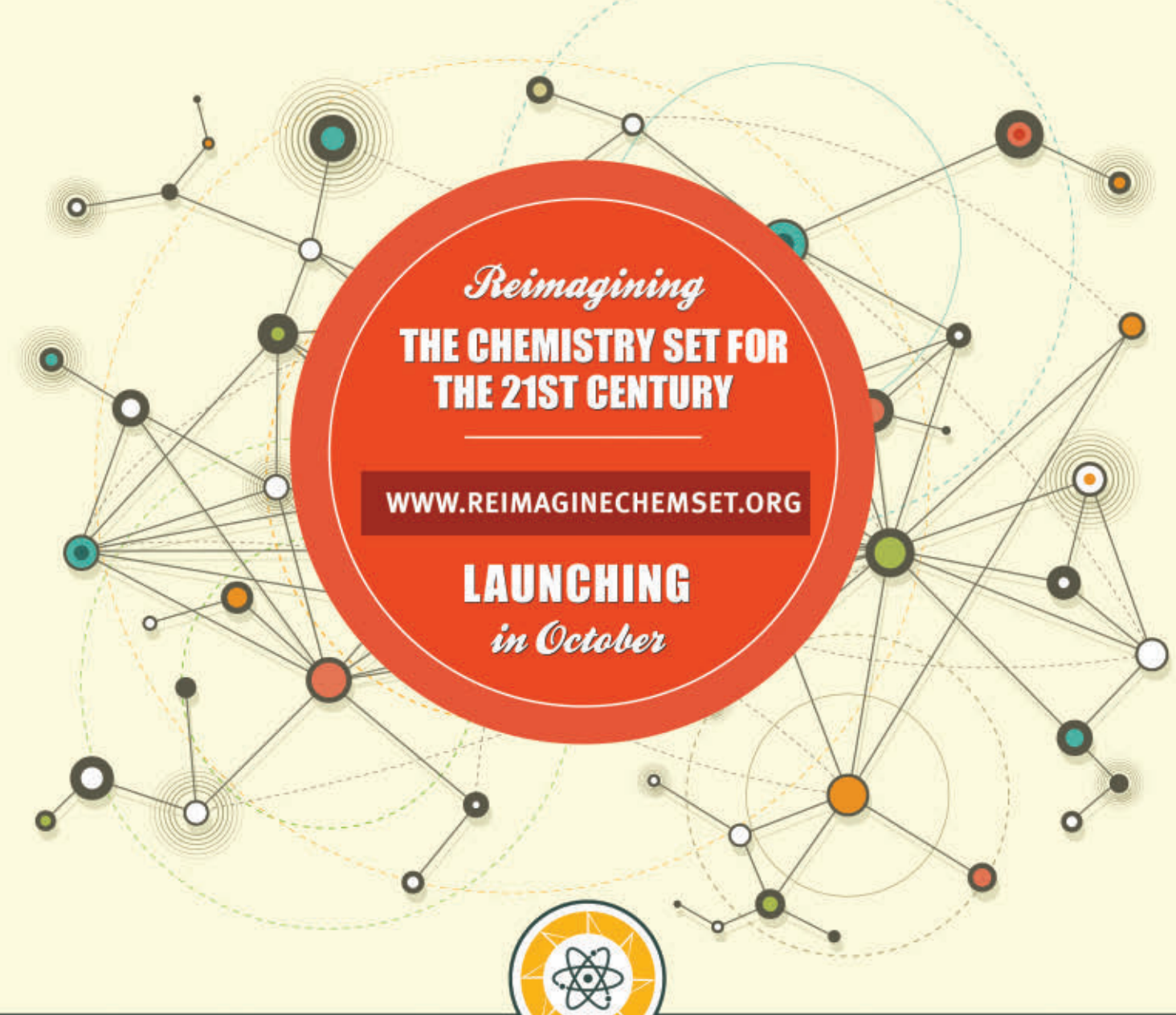

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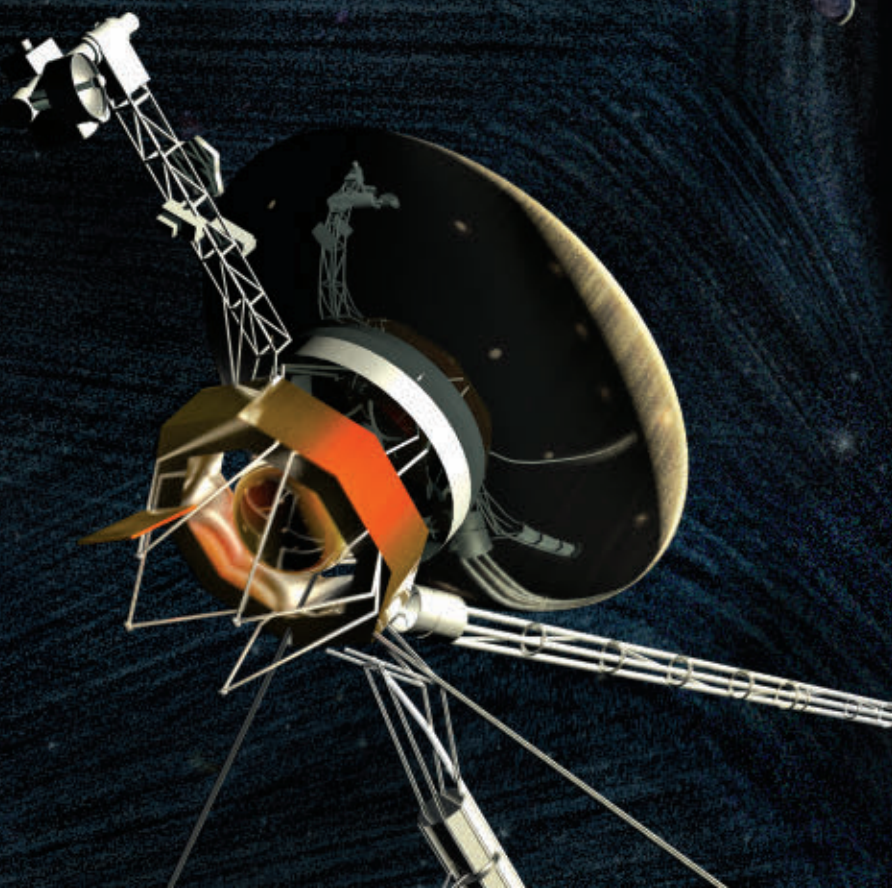
Voyager's View

Spacecraft's journey to interstellar space helps put the solar system in perspective

It's finally official: Voyager 1 has become the first human-made object to enter interstellar space, mission scientists report September 12 in *Science*. On August 25, 2012, the scientists say, Voyager 1 exited a giant invisible bubble called the heliosphere that is inflated by a torrent of subatomic particles spewing from the sun. Now the probe is surrounded almost exclusively by particles produced by other stars. But whether it's correct to say that the probe has left the solar system depends on how you define the solar system. "From my perspective, Voyager is nowhere near the edge of the solar system," says planetary scientist Hal Levison of the Southwest Research Institute in Boulder, Colo. The sun continues to exert gravitational dominance out to hundreds of times the distance of Voyager 1 from the sun, where trillions of icy pebbles, boulders and comets orbit. In the last 36 years, Voyager has traveled an impressive 25.4 billion kilometers, but it still has a long way to go to unambiguously depart the solar system. —*Andrew Grant*



VOYAGER 1

Current distance from the sun: 126 AU
1 astronomical unit = 150 million kilometers (Earth-sun distance)

Voyager 1 is now surrounded by a relatively thick fog of subatomic particles produced in the far reaches of the galaxy. Some particles originated in supernova explosions; others got blasted out of black holes. By 2016 astronomers expect the probe's sibling spacecraft to pop through the solar bubble. Unlike Voyager 1, Voyager 2 carries a working instrument to measure the temperature and density of the interstellar medium. Both probes have enough plutonium power to communicate with Earth until about 2025.

NICOLLE RAGER FULLER

HELIOPAUSE

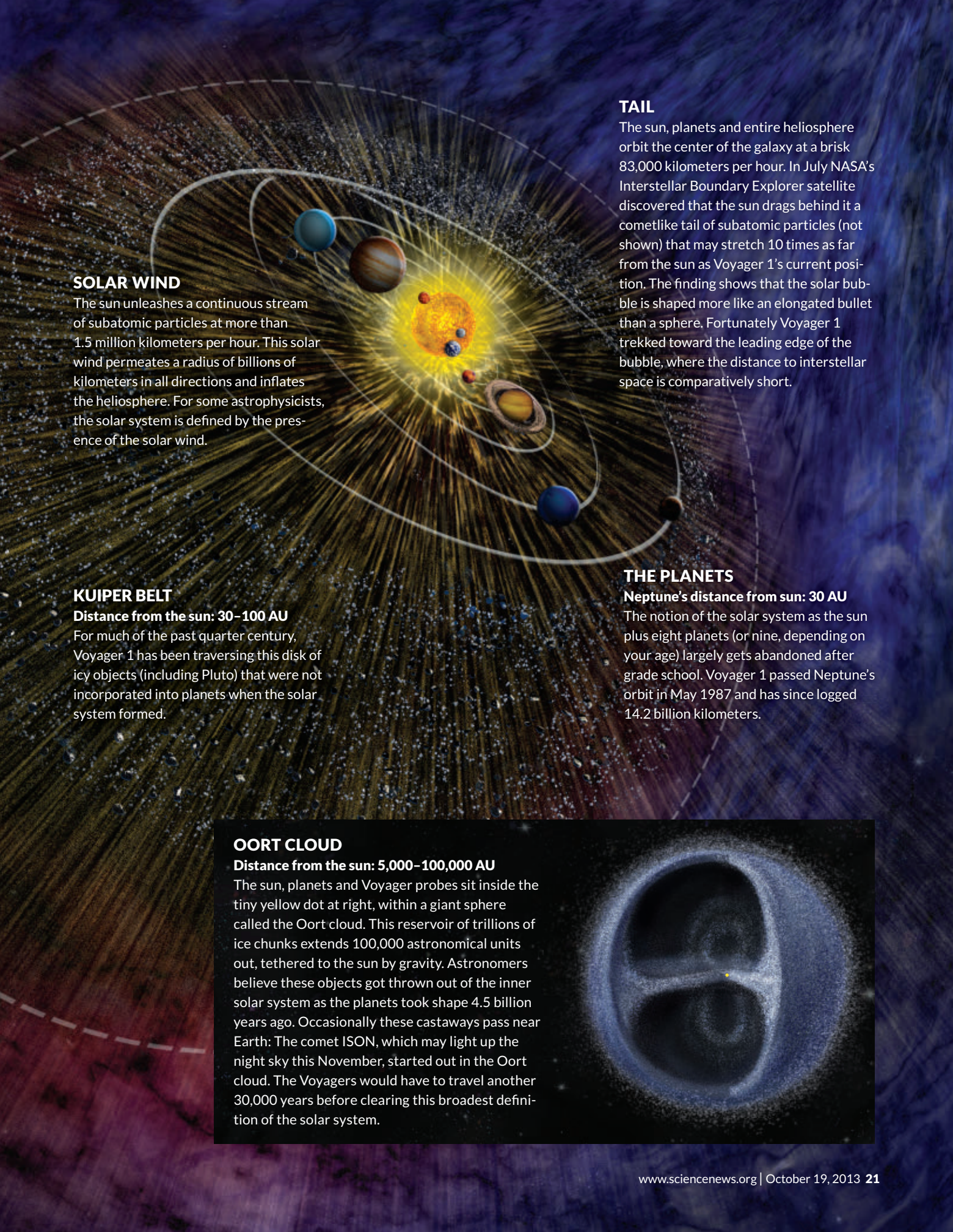
Distance from the sun: about 122 AU

Until recently, Voyager 1 was traveling within the heliosphere, bathed in a thin mist of particles from the solar wind. Voyager 1 passed through the boundary between the heliosphere and interstellar space, called the heliopause, last August. But the border crossing was not cut-and-dried: Astronomers expected the magnetic field to change direction in interstellar space along with the particle population, yet the field has barely budged. Theorists are struggling to understand why.

TERMINATION SHOCK

Distance from the sun: about 90 AU

The solar wind gradually slows as it cruises past the planets. About 13 billion kilometers from where that wind originates, it slows down to about 350,000 kilometers per hour and generates a shock wave analogous to the one produced when a jet crosses the sound barrier. Voyager 1 reached this shock wave, known as the termination shock, in 2004. Beyond it, the solar wind wanes as the gateway to interstellar space approaches.



TAIL

The sun, planets and entire heliosphere orbit the center of the galaxy at a brisk 83,000 kilometers per hour. In July NASA's Interstellar Boundary Explorer satellite discovered that the sun drags behind it a cometlike tail of subatomic particles (not shown) that may stretch 10 times as far from the sun as Voyager 1's current position. The finding shows that the solar bubble is shaped more like an elongated bullet than a sphere. Fortunately Voyager 1 trekked toward the leading edge of the bubble, where the distance to interstellar space is comparatively short.

SOLAR WIND

The sun unleashes a continuous stream of subatomic particles at more than 1.5 million kilometers per hour. This solar wind permeates a radius of billions of kilometers in all directions and inflates the heliosphere. For some astrophysicists, the solar system is defined by the presence of the solar wind.

KUIPER BELT

Distance from the sun: 30–100 AU

For much of the past quarter century, Voyager 1 has been traversing this disk of icy objects (including Pluto) that were not incorporated into planets when the solar system formed.

THE PLANETS

Neptune's distance from sun: 30 AU

The notion of the solar system as the sun plus eight planets (or nine, depending on your age) largely gets abandoned after grade school. Voyager 1 passed Neptune's orbit in May 1987 and has since logged 14.2 billion kilometers.

OORT CLOUD

Distance from the sun: 5,000–100,000 AU

The sun, planets and Voyager probes sit inside the tiny yellow dot at right, within a giant sphere called the Oort cloud. This reservoir of trillions of ice chunks extends 100,000 astronomical units out, tethered to the sun by gravity. Astronomers believe these objects got thrown out of the inner solar system as the planets took shape 4.5 billion years ago. Occasionally these castaways pass near Earth: The comet ISON, which may light up the night sky this November, started out in the Oort cloud. The Voyagers would have to travel another 30,000 years before clearing this broadest definition of the solar system.

DEEP NETWORK

Real-time monitoring of the seafloor reveals unexpected links

By Jessica Shugart

Gas bubbles effervesce from a mound of muck on the seafloor in a deep submarine canyon off the west coast of Canada. Microbes beneath the sediment belch the bubbles after feasting on the ancient remains of algae, sea critters and their poop: a primordial stew that's been simmering since long before humans walked the Earth.

This gassy oasis attracts an odd collection of critters. Worms writhe in the goo, clams bask in the bacteria, herds of sea cucumbers dine on diatoms and sea stars scurry across the pitch black landscape. But the strangest inhabitant of all is a robot named Wally, whose every move is controlled by a human sea spy viewing the entire scene from a lab 8,000 kilometers away in Bremen, Germany.

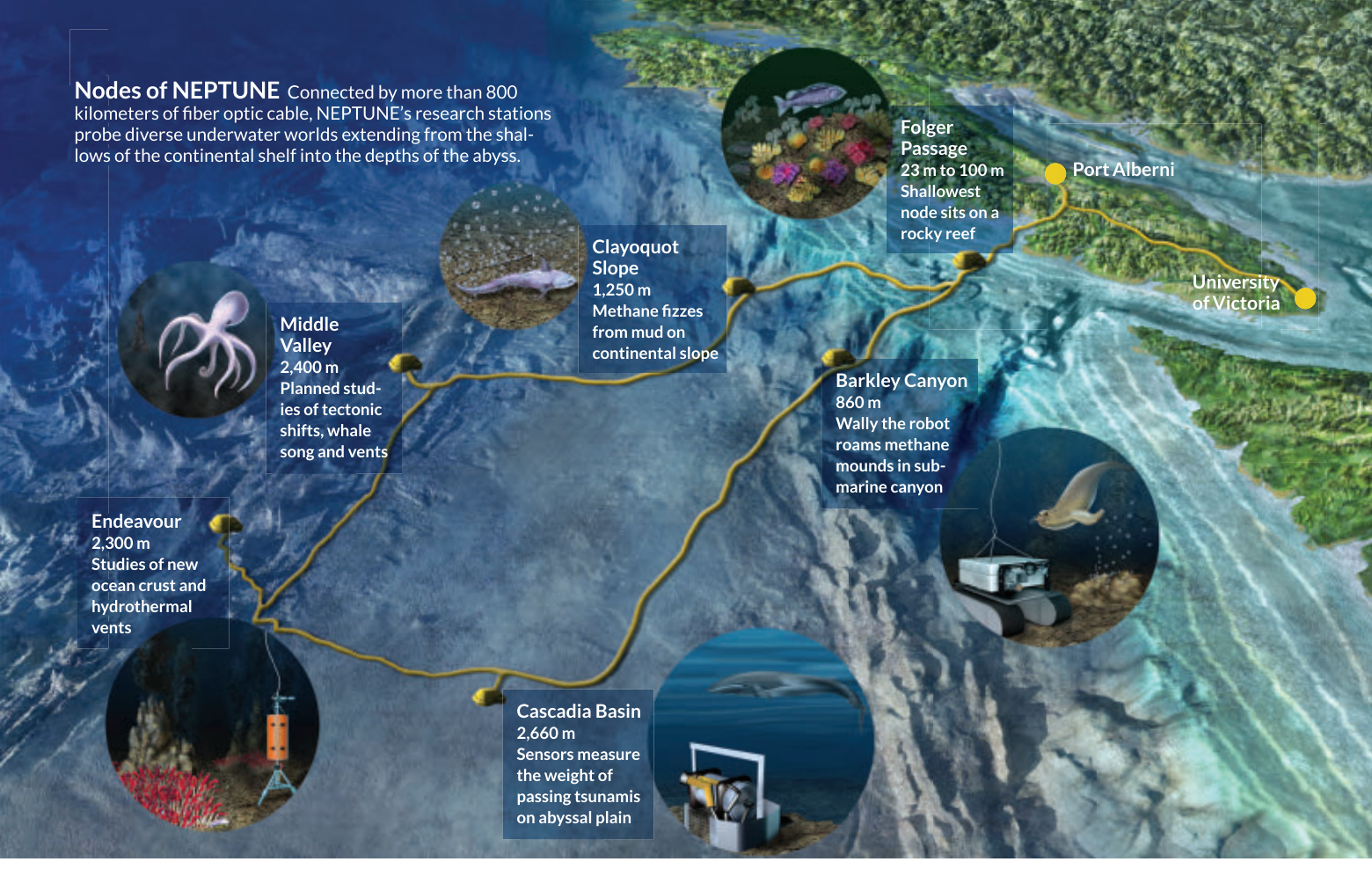
Equipped with scientific instruments designed to explore this alien world, the deep-sea crawler is just one part of an unprecedented effort to check the ocean's vital signs in real time. The NEPTUNE observatory — a ring of six underwater research stations connected to the Internet with fiber optic cables — is the first online observatory to brave the depths of the abyss. From their vantage points in labs and living rooms around the world, oceanic explorers now plug into an ever-changing world once cloaked in darkness, and tap into the pulse of the ocean as it lives and breathes.

Traditionally oceanographers have gleaned insight into the ocean through observations made on research cruises conducted for a few weeks a year at great cost. But these sparse samplings provide only snapshots of the sea's shifting moods, says Kate Moran, NEPTUNE's director. Add the emerging effects of climate change into the mix, and single-shot sampling can be woefully inadequate for scientific study, Moran says. "It can be almost anecdotal."

Cycles that drive changes in the ocean's chemistry and organisms take place over hours, days, seasons, years and even decades — timescales NEPTUNE can track. As global levels of carbon dioxide rise, changes in storm frequency, ocean temperature and acidity could have profound impacts on these delicate cycles. "We're in a period where the oceans are changing very quickly," says marine ecologist Kim Juniper of Canada's University of Victoria, who oversees

Top: Scientists aboard the R/V *Thompson* monitor a remotely operated vehicle as it installs equipment deep below. Left: A deep-sea robot, ROPOS, is lowered into the ocean to set up monitoring instruments on the seafloor for the NEPTUNE observatory.

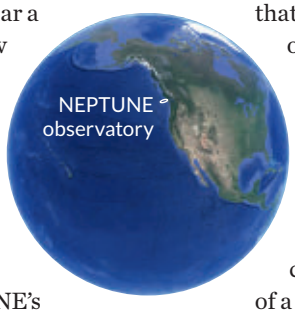
BOTH: OCEAN NETWORKS CANADA/FLICKR



FROM TOP: NICOLLE RAGER FULLER; GOOGLE EARTH

NEPTUNE's scientific research. "We know that tomorrow's oceans are not going to be the same oceans we've been studying for the last century."

NEPTUNE researchers examine an astounding diversity of underwater worlds. Plunging into the ocean off the west coast of Vancouver Island, the more than 800 kilometers of fiber optic cables that connect the research stations stretch across the continental shelf, plummet down the slope and across an abyssal plain, and skirt hydrothermal vents near a mid-ocean ridge where the Earth gives birth to new ocean crust. Researchers endowed the observatory's six nodes with instruments that measure the ocean's changing temperature and chemistry, cameras that spy underwater creatures, hydrophones that listen to passing whales and seismometers and tsunami detectors that measure hazards as they happen.



From their vantage point on dry land, NEPTUNE's deep-sea explorers have made connections between storms raging on the sea surface and plumes of gas bubbling out of the seafloor hundreds of meters below. They've picked up sounds of creatures not glimpsed in these waters for half a century, spotted marine mammals behaving in unexpected ways and measured the weight of tsunamis passing overhead. Some of the discoveries have even been made by intrepid citizen scientists scouring through NEPTUNE's open online network from home.

"This in many ways has been an exploration, rather than a classic hypothesis testing experiment," Juniper says. "You discover unexpected connections not just by seeing an event, but by seeing all parts of the puzzle."

Dreaming of cables

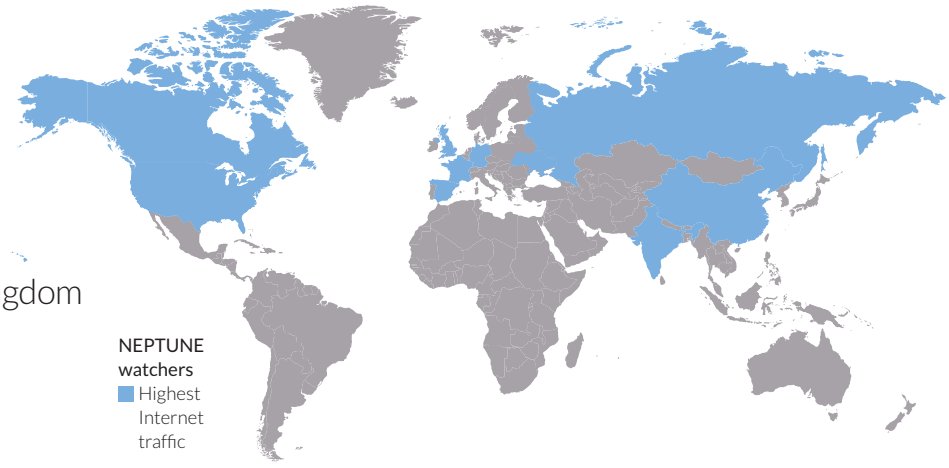
Oceanographers started buzzing about the idea of cabled observatories more than two decades ago. At the time, scientists already had developed remotely operated vehicles that could roam the seafloor, and placed instruments on the ocean's bottom that could record uninterrupted measurements for years. But they weren't able to monitor the data in real time. Instead, they'd drag up their instruments once a year and download the data in nervous anticipation. When submarine cable technology for communications exploded in the mid-1990s to connect the world to the Internet, the possibility of a cabled ocean observatory ripened into reality.

John Delaney was among the first oceanographers to grasp the potential power of cabled observatories. Twenty-three years ago, the University of Washington scientist dreamed of a day when researchers would access the mysteries of the ocean on a continual basis. "The only way for us to fully understand the ocean is for us to be in it, and part of it," says Delaney. "And humans aren't well adapted to do that, but our robots and our sensors can be."

At a meeting in San Francisco in 1991, exhausted after

Global reach Last year, NEPTUNE's online viewing portal logged some 275,000 visits, including visits from both researchers and curious Web surfers. Visitors came from all over the world. The 10 nations with the highest number of visits are shown below and right. SOURCE: OCEAN NETWORKS CANADA

1. Canada
2. United States
3. Ukraine
4. Russia
5. China
6. United Kingdom
7. France
8. Germany
9. Spain
10. India



spending six months at sea on a research expedition, Delaney remembers sitting in a bar lamenting to a colleague about the difficulties of using human-occupied submersibles to study the ocean in a meaningful way. His colleague, oceanographer Alan Chave of the Woods Hole Oceanographic Institution in Massachusetts, told Delaney of "this thing called fiber optics" being developed at Bell Labs, where Chave worked at the time. "Maybe we could use *that* in the ocean," Chave suggested.

Delaney ran wild with the idea, sharing it with everyone he knew in the world of oceanography, and found that others shared the same vision. "Some of them were whale watchers, some were fish trackers and some of them were earthquake checkers," Delaney says. "Some of them were landslide folks, some of them were volcanologists and microbiologists, and it just went on and on and on."

At a meeting in Canada in 2000, an international team drafted the initial plans for a cabled observatory that would encompass the Juan de Fuca tectonic plate, which stretches from the coast of British Columbia to Northern California. The Canadians set out to build an observatory on the northern third of the plate, while the Americans proposed an ambitious project covering the bottom two-thirds.

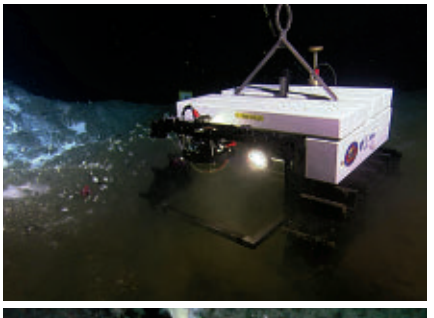
Delaney stood by as his Canadian colleagues at the University of Victoria secured the $200 million needed to launch NEPTUNE (Northeast Pacific Time-Series Undersea Networked Experiments). By the end of 2009, most nodes were up and running. Today, U.S. funding has caught up, and Delaney heads the Ocean Observatories Initiative's Regional Scale Nodes — a cabled observatory just getting into the water off the Oregon coast. As the cables connecting that observatory unravel onto the seafloor, Canada's NEPTUNE finishes its fourth year of operation. If all goes according to plan, NEPTUNE will collect data for a total of 25 years.

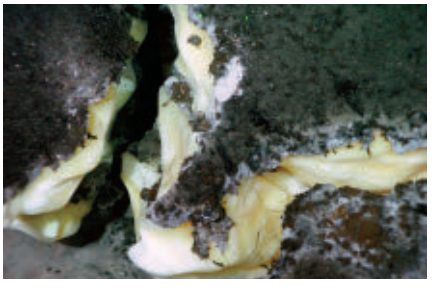
Carbon bubbles

Wally the crawler has lived in NEPTUNE's fizzy Barkley Canyon since 2009. The bubbles that comprise the robot's seafloor oasis consist of methane — a greenhouse gas 20 to 25 times more potent than CO_2. The fizz is a harbinger of the expansive deposit of frozen methane that lies below the seafloor. The cold temperature and high pressure of the deep-sea environment keeps most of the methane locked in a frozen crystalline form called methane hydrate. But as evidenced by the bubbles seeping out of the mud, portions of the deposit intermittently sublimate from their frozen cage.

Some scientists fear that an increase in temperature or drop in pressure could liberate large amounts of methane at once — an event that could destabilize the seafloor. That would pave the way for massive underwater landslides that could trigger tsunamis. Such a large-scale release could also fuel climate change. Despite the tenuous nature of the methane deposits, there is interest in mining them for fuel. Japan has already started extracting deep methane deposits, and South Korea has a plan in the works.

To understand the probability of future methane releases or the feasibility of harvesting the deposits, scientists need to better understand their dynamics and how they interact with the ocean environment. Getting a handle on this





Top: Wally surveys mounds of methane more than 850 meters deep. Bottom: Scientists are interested in factors that affect the stability of methane hydrates, such as these exposed on the seafloor at Barkley Canyon.

FROM TOP: REDMAL/ISTOCKPHOTO; OCEAN NETWORKS CANADA; ROSS CHAPMAN/UNIV. OF VICTORIA

has been difficult without consistent monitoring: Mounds of methane have disappeared or shifted between research expeditions, for example. But now, through the ever watchful eyes of the robot Wally, scientists are starting to see connections missed during occasional visits.

Situated at 870 meters below the sea surface in Barkley Canyon, Wally uses a camera, methane detector and current flow meter to take stock of the release of methane bubbles from the seafloor. A 70-meter fiber optic cable connects the crawler back to a junction box that hooks into the rest of the NEPTUNE array. Viewing the streaming video from Wally in his lab at Jacobs University in Bremen, Germany, oceanographer Laurenz Thomsen follows numbered signs protruding out of the sediment like bread crumbs to drive Wally back home after a day out in the field.

> "Ocean ridges are the most dynamic places on our planet, and this is the first cabled observatory that goes out to one."
>
> **PETER RONA**

Thomsen and his colleagues have discovered that changes in ocean currents triggered by storms raging on the sea surface can alter the release of gas from the hydrate mounds. The team reported last year in *Geophysical Research Letters* that as currents scouring the seafloor increase in intensity, more methane seeps out of the mounds. So while it may take decades for warming at the sea surface to change deep-sea temperatures, alterations in wind-driven events may have more immediate effects. NEPTUNE's continuous monitoring allowed Thomsen's team to make the first connections between hydrate release and climate-induced changes hundreds of meters above.

NEPTUNE's greatest hits

Elusive whale announces return

As part of a global effort called LIDO (Listening to the Deep Ocean) to study the effects of noise pollution on marine mammals, NEPTUNE hosts several underwater microphones tuned to pick up sounds of animals passing by. Two years ago, LIDO's Michel André of the Polytechnic University of Catalonia in Barcelona thought he heard a North Pacific right whale take to the mic. Known as the "right" kind of whales for hunting, the last North Pacific right whale in Canadian waters was seen (and killed) by whalers in 1951. While no one is certain that what André heard was a right whale, NEPTUNE's John Ford saw one swimming north of the array in June. "It was exhilarating," Ford says. "All of the whales sighted in the last 100 years were killed. This is the only one that got away, and hopefully it will be the first of more."

Fin whale breaks for a quake

NEPTUNE's deep-sea seismometers pick up rumbles in the deep, and not all of them come from earthquakes. Seismologists at the University of Washington discovered that the low-frequency calls of fin whales and blue whales shake seismometers on the seafloor too. In 2010, NEPTUNE instruments picked up an odd sequence of events. In a translated audio recording, a fin whale stops calling as an earthquake rumbles in the Aleutian Islands. After the quake, the whale continues with its song. Both whale and quake can be heard on the recording. The researchers still don't know why the fin whale stopped singing during the quake. "These are the types of things that surprise you," Moran says. "Serendipity happens all the time when you go someplace new."

Sea monster slurp

A Ukrainian teen watching NEPTUNE's online webcams glimpsed the snout of a mysterious creature slurping up a slimy hagfish on the seafloor, at a depth of nearly 900 meters. Fourteen-year old Kirill Dudko described the creature as a sea "monster" with a moustache and reported the sighting to NEPTUNE scientists. Upon examination of the YouTube video Kirill captured from the event, researchers identified the animal as a northern elephant seal. Although elephant seals are known to dive deep, no one had ever glimpsed one at this depth. Even more notable was how the seal consumed its prey. Hagfish secrete copious amounts of gluelike slime to ward off predators, but the elephant seal seems to have avoided gumming up its teeth by swallowing the hagfish whole.

FROM LEFT: JOHN FORD; CHRIS BUELOW/FLICKR; MIKEBAIRD/FLICKR

Earth rising

While a cataclysmic event among the methane hydrate mounds could unfold sometime in the future, violent eruptions are the norm at Endeavour Ridge, the site of another NEPTUNE research node. Located on the opposite side of an expansive abyssal plain from Wally's lair, the ridge hosts a hydrothermal hotbed of volcanic vents called black smokers. Through the process of seafloor spreading, new ocean crust continually comes into being here.

"Ocean ridges are the most dynamic places on our planet, and this is the first cabled observatory that goes out to one," says oceanographer Peter Rona, who uses NEPTUNE to study the dynamics of the deep-sea volcanoes from his lab at Rutgers University in New Jersey. "This is really a revolutionary advance in oceanography, a total change in our understanding of the processes that we're studying."

Some scientists think deep-sea hydrothermal vents such as those at Endeavour Ridge may have given birth to life on Earth. The surrounding organisms live off chemicals from the vents, rather than light from the sun. Rona thinks the vents could be a model for life on other planets, or possibly even on moons in our own solar system like Jupiter's Europa, which hosts a large sea locked under a thick layer of ice."It's real *Star Trek*–type stuff," Rona says. "It's a different basis for life, chemical energy instead of the light energy of the sun."

The vents spew out substances from deep within the Earth's crust, including iron, a metal known to seed plankton growth. Some engineers have even proposed dumping iron into the ocean to trigger phytoplankton blooms — a strategy that they speculate will slow global warming by removing carbon from the atmosphere (*SN: 6/5/10, p. 16*). The vents, Rona says, already help do this on their own. "They have a huge impact globally, as a major control on the composition of the ocean, and the distribution of life there," Rona says.


1

Rona watches the vents cough up their metallic cargo, which heat the once-frigid ocean water to 400° Celsius. Rather than monitoring the vents with a camera, Rona uses sound. "Light would just illuminate a patch the size of a bed sheet at a range of maybe tens of feet at most," says Rona. "But sound can illuminate a large volume of the ocean at almost any range."

Situated at a relatively safe distance 30 meters away from the smokers, an acoustic device called COVIS (Cabled Observatory Vent Imaging Sonar) emits sound waves that bounce off of the particles belching from the vents. As Rona watches from Rutgers, the acoustic data get re-created into the constantly evolving shape of the plume in near-real time.

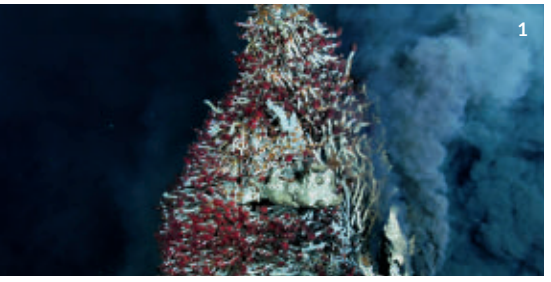
When the acoustic data are paired with wind measurements from buoys at the surface, Rona's team can correlate changes in the plumes' activity with events happening above. "The plumes bend and sway with the wind and tides," Rona says. "Most people think of tides as something that rise and fall on the beach, but it actually affects the deepest ocean, and we're watching it."

Rona's team reported in the July *Geochemistry, Geophysics, Geosystems* that wind-driven waves on the ocean's surface take 13 days to propagate to the vents 2,000 meters below. Their wavelengths stretch as they travel to the bottom, a change the team calls a "blue-shift." As changes in climate affect storms and ocean currents, Rona expects the activity of the plumes to change as well. These alterations could have an impact on the chemistry, and therefore life, in the ocean and on the rest of the planet.

Clawed connections

Atmospheric events occurring at the ocean surface may sound the dinner bell for creatures living in the dark depths.

Life in the deep **1.** Tube worms carpet a black smoker at Endeavour Ridge. **2.** Squat lobsters (*Munida quadrispina*) convene on the seafloor in Saanich Inlet, the site of NEPTUNE's shallow water sister observatory, VENUS. **3.** Hydrothermal vents provide essential nutrients for plankton, shown.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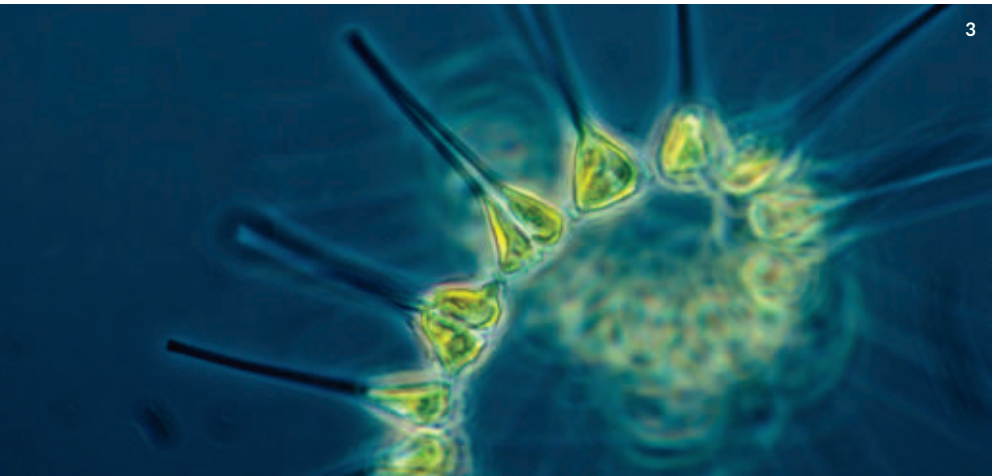
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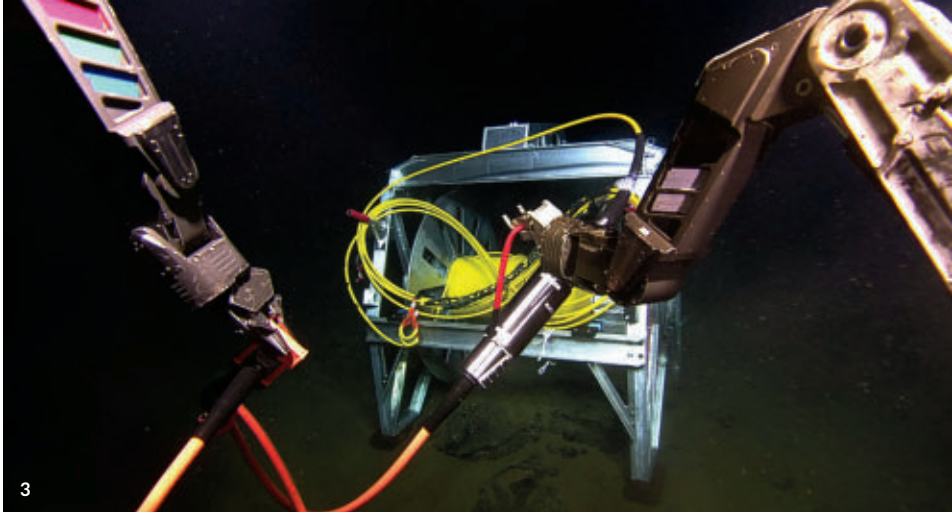
CLOCKWISE FROM TOP RIGHT: OCEAN NETWORKS CANADA; OCEAN NETWORKS CANADA; NOAA MESA PROJECT/ WIKIMEDIA COMMONS; CSSF-ROPOS/OCEAN NETWORKS CANADA



Wiring the deep **1.** Engineer Keith Tamburri of the Canadian Scientific Submersible Facility hooks up a 25-kilometer spool of fiber optic cable to a media converter. The cable will link up a tsunami meter 2,660 meters below. **2.** ROPOS delivers a seismometer to its new home in Cascadia Basin. **3.** ROPOS unravels cable on the seafloor.

FROM LEFT: OCEAN NETWORKS CANADA; CSSF-ROPOS/OCEAN NETWORKS CANADA

Using an underwater camera and acoustic current profilers strategically placed along Barkley Canyon, researchers recently observed two food chains intersecting as bottom-feeders called squat lobsters reaped a windfall.

Winter storms raging overhead triggered ocean turbulence that propagated several hundred meters down to the middle of the water column, where shrimp normally hang out. "Because the shrimp aren't very effective swimmers, they go to the seafloor to escape the turbulence," Juniper says. There, the shrimp likely meet their demise in the eager claws of the squat lobsters. The team reported the shrimp shift in the *Journal of Marine Systems* in May.

"We saw a connection between organisms that live almost all of their lives in the water column and those that live on the seafloor," Juniper says. "A storm brings two food chains together, in a way that was totally unexpected."

As the timing and intensity of storms change with the climate, Juniper says connections like these could trigger unexpected changes in the ocean's ecosystems. For instance, if storms start to occur during a vulnerable time in the shrimp life cycle — such as prior to mating — this could prevent the shrimp population from bouncing back after the annual fishing season.

The ocean's creatures respond not only to storms and currents, but also to shifts in chemistry. For example, as global CO_2 levels rise, increases in the acidity of the ocean are expected to have dramatic impacts on sea life. NEPTUNE researchers are in the midst of designing an efficient pH meter that, coupled with data from cameras and other sensors, will monitor ocean acidity and detect any effects.

Stretching the limits

As with any journey into uncharted territory, plans get thrown off by bumps (or volcanoes) in the road. A portion of NEPTUNE's annual budget is earmarked for "extraordinary maintenance," Juniper says. "'Nasty surprises' is another term for it."

The cables connecting NEPTUNE's nodes and instruments traverse rugged, deep-water terrain and house delicate optical fibers. Surrounded by treacherous fields of sharp volcanic rocks, the violent hydrothermal vents of Endeavor Ridge are an inhospitable place to lay cable, says Juniper. "Most sensible submarine cable operators avoid places like that, but we don't have a choice. That's where we want to be." Since NEPTUNE's launch, several cable malfunctions have occurred along the ridge, and some are still down for unknown reasons, Juniper says.

The flat abyssal plains of soft silt haven't managed to avoid cable troubles either. The abyss is the heart of NEPTUNE's "tsunami meter," an array of bottom pressure sensors that measure the weight of waves passing overhead. Like ultrasensitive bathroom scales, the sensors can detect submillimeter changes in sea level, and NEPTUNE scientists hope to use them to understand the dynamics of tsunamis and alert people onshore.

But the most sensitive aspect of the array — a three-pronged "antenna" of sensors used to calculate the direction and speed of waves passing overhead — isn't connected to the Internet. After the antenna successfully recorded the 2009 Samoan tsunami passing overhead, the team decided to push their luck by laying longer cables to enhance the antenna's sensitivity. But the new cables — longer and thinner than others the team had tried — malfunctioned. "And now the meters are just sitting down there on the seafloor, recording internally," says oceanographer Richard Thomson of the University of Victoria, the lead scientist for the tsunami array.

As the 2011 Tohoku tsunami passed overhead, the antenna detected the massive wave but kept its measurements to itself. The team is working on a new cable design and hopes to have the improved tsunami meter up and running within a year.

In the context of the 25 years of data the observatory is expected to record, the fumbles of the first few years may be a necessary, and expected, part of the adventure. Any journey into a new sphere of space or time carries with it the promise of unknown hazards, as well as unexpected discoveries, Juniper says. "We're discovering things we never would've learned any other way." ■

Explore more

- NEPTUNE website: oceannetworks.ca
- U.S. effort: www.interactiveoceans.washington.edu

MEMORY UPGRADE

The demands of modern computing call for a seismic shift in data storage and retrieval **By Andrew Grant**

Google operates data centers at 13 sites globally, including this server farm in Hamina, Finland. Storing and processing so much data requires loads of energy and a dedicated cooling system. At Hamina, seawater from the Gulf of Finland cools the computers. Creating new kinds of computer memory could cut the demand for energy and make searching data faster.

CONNIE ZHOU

Ramamoorthy Ramesh listens to Indian classical music on his smartphone, which is jammed with videos of his kids' soccer games. He streams Netflix movies on his tablet and, on his laptop, he uses Google to search the Internet several times a day. Like many of us, he's an active consumer of data in a data-centric world.

But Ramesh is also a materials scientist who has a thorough understanding of what's going on under the hood of his electronic devices, and he has a lingering concern: "The computer is very advanced, but it's not close to where it should be."

The problem, he says, is that today's users rely on computers that are much better at computing than at storing and recalling information. At the heart of every computer is a processor that carries out programmed instructions at blazing speeds so users can pay bills online, find a nearby Italian restaurant and post selfies on Instagram. But the processor also needs a place to store the results of its efforts for use milliseconds or years in the future. No existing memory technology can do both: keep up with the processor and store information for long periods of time. Modern memory devices, including random access memory (RAM), hard drives and flash, are some combination of too slow, too expensive and too energy-hogging.

This performance gap between processor and memory has existed since the first electronic computers were introduced more than a half-century ago. But those machines weren't asked to find obscure facts on the Internet, sort through patients' medical histories and mine personal profiles on social networks. The amount of data globally is expected to grow eight times larger within five years, according to IBM, and 90 percent of today's data is less than 2 years old. The era of Big Data has arrived.

For computers to successfully navigate through the barrage of superfluous data, Ramesh and a host of engineers and physicists believe they need to develop a next-generation memory device. They call it storage-class memory: a single gadget that combines speed, energy efficiency and high-density storage.

Access to storage-class memory would lead to smarter, faster mobile devices with better battery life. In the long run, storage-class memory could revolutionize the way computers work, Ramesh says, enabling processor-memory hybrids that compute and remember at the same time, kind of like the human brain. It would be the first makeover of computers' fundamental architecture since the 1940s, when the word transistor first entered the lexicon.

With so much at stake, technology industry giants such as IBM, Samsung and Hewlett-Packard, along with innovative smaller outfits like Crossbar and Micron, are spending billions of dollars to probe the bit-storing potential of tiny magnets, amorphous solids and miniature grids of wire. It's a competitive game full of hype and tricky science, yet a steady stream of advances suggests that storage-class memory may soon catch up and meet the lofty performance standards of the processor.

"Everybody is on this like gangbusters because their business is at risk," says Ramesh, who researches storage-class candidates at the University of California, Berkeley. "There's definitely going to be a pathway to storage-class memory. The question is: Which technology will take us there?"

Same old architecture

The modern computer as we know it emerged in 1945, when mathematician John von Neumann penned his "First Draft of a Report on the EDVAC." The electronic computer he envisioned centered on a processor that could perform hundreds of calculations per second. But if the processor were the master chef, it needed recipes (instructions to tell it what to do) as well as a place to store ingredients (data to be calculated) and keep finished meals (the results of the calculations) warm. Von Neumann assigned those responsibilities to memory, which at the time came in the form of magnetic tape and tubes of mercury.

Von Neumann's machine, which went live in 1951, took up more floor space than a thousand iPads set side by side and outweighed an African elephant. It had only a few kilobytes of memory, but that was plenty because the processor worked so slowly.

Things got tricky, however, once processors sped up to undertake thousands, millions and then billions of calculations per second. No memory device could both exchange data with the processor billions of times a second and retain masses of information indefinitely. So engineers devised a solution: The fastest memory, which was also the most expensive, interacted directly with the processor and stored small amounts of the most urgent data. Information for the more distant future was relegated to cheaper, higher-capacity memory devices. By creating this memory hierarchy, engineers managed to keep von Neumann's basic architecture — memory that stores data plus instructions for the very busy processor — intact. "Today's computers would still be recognizable to von Neumann," says Neil Gershenfeld, a physicist and computer scientist at MIT.

In modern computers the processor's main helper is dynamic RAM, or DRAM, a chip that provides short-term, easily accessible information storage. Each DRAM cell consists of a capacitor that stores electrical energy and a transistor that serves as a swinging gate, controlling the flow of electricity to rapidly switch the capacitor between a charged state, which represents a 1, and uncharged, a 0.

DRAM, however, has an Achilles' heel: Capacitors can't hold electricity for very long. As a result, the DRAM chip requires an influx of energy 15 or so times a second to refill the capacitors. That continual need for a refresh means that the computer has got to be on for DRAM to function. It is no good for long-term storage.

Most systems use a hard disk drive for long-term memory. These drives use mechanical arms that write and read data onto cells on 3.5-inch-wide circular platters; the direction of magnetic orientation in each cell determines whether it is a 1 or a 0.

Hard drives are cheap and can store enormous amounts of data, but they are slow. It takes about 5 milliseconds for a bit (a 1 or a 0) from the processor to get stored on the disk — 5 million times as long as it takes the processor to do a calculation. In human terms, that's like a restaurant patron (the processor) deciding what to order and a waiter (the hard drive) needing more than a month to jot the order down. Forget about getting dessert.

On a more practical level, this lag explains why many computers take a couple of minutes to boot up when powered on: The operating system needs time to migrate from the hard drive to DRAM where the processor can access it.

Engineers have spent decades trying to bridge the speed gap between processor and memory, and in 1988 computer chip giant Intel took the first step when it unveiled flash memory. Flash retains information when unpowered and can store data in cells 20 nanometers wide, enough to stockpile thousands of photos on a digital

Memory timeline

Electronics use memory technology invented last century. Engineers have squeezed lots more performance out of these devices, but the push is on to develop game-changing storage.

1945
John von Neumann publishes memory-intensive concept for EDVAC

1956
IBM introduces magnetic hard disk drives

1967
IBM invents DRAM

1988
Intel introduces flash

2008
HP announces invention of memristor

2012
Micron Technology starts selling phase-change memory

FROM TOP: LANL/WIKIMEDIA COMMONS; VIKTORUS/ISTOCKPHOTO; APPALOOSA/WIKIMEDIA COMMONS; DNY59/ISTOCKPHOTO

A look inside Smartphones like Apple's iPhone 5 contain short-term (RAM) and long-term (flash) memory to help the processor run apps and store photos and music for later use. Storage-class memory would increase speed and capacity as well as extend battery life.

camera and hundreds of apps on a smartphone. It is also relatively fast (at least compared with a hard drive), so smartphones, laptops and tablets with flash memory boot up much faster than computers with a mechanical hard drive.

Intel claims that it can continue making flash cheaper and faster by shrinking and stacking memory cells. But computer scientists such as Darrell Long of the University of California, Santa Cruz say flash is nearing its performance limit. The time for a faster, cheaper and more energy-efficient replacement is now.

And not just because flash could be close to maxing out. The demands placed on computers today are vastly different than in the past. Computers with the von Neumann hierarchy excel at taking a set of data, modifying it in some way and then placing it back into memory; data processing takes precedence over the actual contents of the data. Now the bigger challenge is finding jewels and trends in vast amounts of largely non-essential data. "Instead of crunching numbers for a bank, we're trying to find an answer to a question," says Paul Franzon, an electrical engineer at North Carolina State University in Raleigh. Computers need to be able to swiftly store and analyze large datasets.

Motivated by these factors, researchers began about a decade ago to hunt for a type of memory that combines the swiftness of DRAM with the capacity and longevity of disk drives.

The right material

The search for a breakthrough memory device begins in the labs of materials scientists and condensed matter physicists. Any material used to build the next-generation memory device will have to effectively distinguish between 1s and 0s by having two distinct electrical or magnetic states.

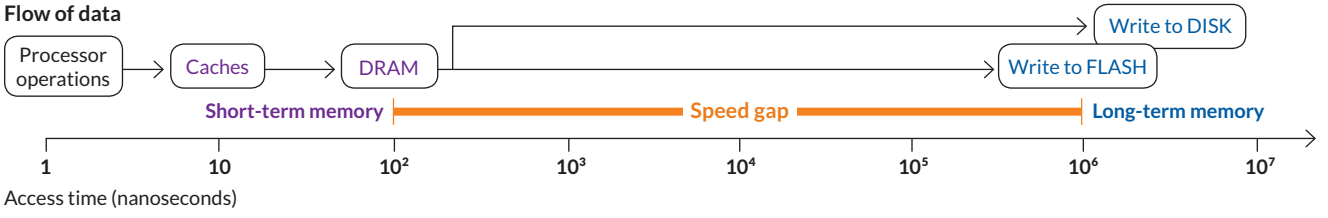
Ferroelectric RAM, or FRAM, functions like DRAM, with a kick. Each memory unit has a capacitor to store electricity and a transistor to switch between 1 and 0. FRAM's added benefit is that its capacitors are made from materials such as lead zirconate titanate and bismuth ferrite, which can hold charge without needing constant refreshes. "A decade ago, people thought it was very straightforward: FRAM would win the race for storage-class memory," Ramesh says.

But FRAM has some glaring weaknesses. While ferroelectric materials make great capacitors, they do not integrate easily with other components made of silicon. "You can't put FRAM on a silicon wafer directly," Ramesh says, making cheap manufacturing a challenge. Scientists are also concerned about the reliability of FRAM over the long run, though Ramesh and colleagues recently developed a technique that allowed FRAM chips to read and write data millions of times without any signs of degradation (*SN: 7/13/13, p. 11*). That's about 1,000 times better than flash and would allow most users to safely store data for decades.

Hewlett-Packard claims that its next-generation memory device is 100 times faster than flash and can hold at least twice as much data. Plus its device, made of titanium dioxide, gets along just fine with silicon. The HP memristor, short for memory resistor, changes its electrical properties depending on the direction of the current going through it and then remembers those charges when the power is off. HP made headlines in May 2008 when a team led by Stanley Williams introduced the memristor in *Nature* and demonstrated its potential for fast, high-capacity storage (*SN: 5/24/08, p. 13*). Still enthusiastic in 2010, Williams told an HP publication: "We believe that the memristor is a universal memory that over time could replace flash, DRAM and even hard drives."

HP won't say when it will bring the memristor to market, but it could happen as early as next year. Ramesh says HP has to address concerns about the device's long-term reliability. Meanwhile, in August a small company called Crossbar, in Santa Clara, Calif., announced that it has

Closing the gap Computer performance has skyrocketed over the decades, yet memory is still a long way from keeping up with the processor, which can run through billions of 1s and 0s per second. The processor relies on DRAM and expensive low-capacity devices called caches to store the most urgent data. Everything else gets passed on to long-term storage such as flash and hard disk drives, but these work at a fraction of the processor's speed. Researchers want to create storage-class memory that combines the cost and robustness of hard disks with the speed of DRAM. SOURCE: GEOFFREY W. BURR



FROM TOP: BRITTANY MCCRIGLER; M. ATAROD

developed a similar type of fast memory called resistive RAM. The company claims to have produced a commercially viable postage stamp–sized chip that can hold a terabyte of data (that's 10^{12} bytes), though it hasn't announced when its product will be available for sale.

Phase-change memory is already finding its way into electronics. The device is made of a compound of germanium, antimony and tellurium with electric properties that change depending on its temperature: It can behave as a normal solid or an amorphous, flowing substance. The idea is to melt or solidify the compound depending on whether the memory is storing a 1 or a 0. Though some researchers worry that the device requires too much energy to repeatedly heat and melt the compound, Micron Technology, headquartered in Boise, Idaho, began selling rudimentary phase-change memory for basic cell phones last year.

There are other storage-class memory technologies in play too. Samsung is working on spin-transfer torque RAM, which uses electric currents to shift the magnetic orientation of a thin layer of material. And IBM is exploring racetrack memory, which relies on current darting through a tiny grid of wire to manipulate even smaller magnetic cells that can switch between 1 and 0.

All of these memory upgrades face technical challenges, but there are economic ones as well. Manufacturers have churned out hard drives, flash and DRAM for years, and they won't rush to adopt a risky technology. "Modern semiconductor development is extremely expensive," says Geoffrey Burr, who studies storage-class memory at IBM's Almaden Research Center in San Jose, Calif. Companies will invest, he says, only if it's almost definite that the technology would work as expected and sell in large numbers.

Smarter devices

The road to creating storage-class memory has been bumpier than most researchers expected, but their eyes are still on the prize. They know that when storage-class memory finally makes it to market, life will change for consumers and businesses.

"You could have a terabyte of memory in your mobile device," Franzon says, or 30 to 60 times as much storage as most current smartphones. "It would dramatically change the user experience." For example, he says, people could store thousands of movies on their phones rather than having to stream them online.

Better storage-class memory is about much more than upgrading smartphones, however. Tech giants like Google and Facebook operate vast data centers that use plodding hard drives and power-hogging DRAM chips to store and analyze petabytes — more than a million billion 1s and 0s — of search terms, likes and relationship statuses. The energy costs for these mammoth facilities are steep; they require their own power plants and cooling facilities to keep them humming. In 2010, Google's servers used 2.3 million megawatt-hours of energy, enough to supply 200,000 homes for a year. Replacing hard drives and DRAM with storage-class memory would speed up servers and slash their energy needs.

Plenty of other Big Data users would benefit as well. Doctors could quickly sift through medical records and studies to diagnose patients and prescribe treatments. Scientists could look for patterns in genetic sequences as well as astronomical images. (The Large Synoptic Survey Telescope in Chile, scheduled to begin scanning the skies within a decade, is expected to produce 30 terabytes of data — equivalent to about 4 million high-quality photographs — per night.) And government defense agencies would surely love a computer that rapidly ferrets out terrorist networks and identifies threatening messages.

30–60

times more storage

What 1 terabyte of memory would mean for smartphone users

Some computer scientists say that the real fun will begin once a storage-class memory device — whether souped-up flash, memristors, phase-change or an untapped mystery material — rises above its competitors. Ramesh contrasts the hierarchical approach of present-day computers, which masks the shortcomings of memory, with the complex multitasking that takes place in the human brain. If engineers can finally build memory that works in tandem with the processor, he says, then they can think about creating devices that compute and recall at the same time. Such a seismic shift would further optimize computers to do the jobs we ask of them and, perhaps finally, lead to a machine that even a visionary like von Neumann wouldn't recognize. ■

Explore more

- John L. Hennessy and David A. Patterson. *Computer Architecture*. Elsevier, 2012. bit.ly/1bpwe06

River Grace (third from left) won the Broadcom MASTERS competition. With him were, from left: Henry Samueli of Broadcom Corp., Susan Samueli of the Samueli Foundation, Scott McGregor of Broadcom Corp., Paula Golden of Broadcom Foundation and Rick Bates of SSP.

Tortoise-studying teen takes top Broadcom prize

WASHINGTON — Even a tortoise enthusiast can speed through a three-day gauntlet of science, engineering and math challenges to claim victory. River Grace, 14, of West Melbourne, Fla., did just that. At an awards ceremony October 1, he picked up the top award of $25,000.

The teen was one of 30 finalists from 17 states who attended the third annual Broadcom Math, Applied Science, Technology and Engineering for Rising Stars, or MASTERS, competition. "I had no idea I'd win this," Grace said. "Any one of us could have won."

Nine additional finalists took home cash awards or funding to attend a science camp. The Samueli Foundation, an organization created by Broadcom cofounder Henry Samueli, provided Grace's funds. The Broadcom Foundation and Elmer's Products together provided more than $500,000 in awards for finalists, semifinalists, their teachers and their schools.

Finalists qualify on the basis of a middle school science fair project, but Broadcom MASTERS is not a science fair. A student's entry project counts for about one-quarter of his or her score.

Grace's project described an unusual swaying behavior in endangered tortoises living at a breeding facility where he volunteers. Grace observed that the tortoises rise up on their legs and sway back and forth when it rains. He thought the behavior might help the tortoises avoid drowning during flash floods in their native Madagascar. But his experiments simulating flood conditions disproved that notion; the purpose of the swaying remains unknown.

The rest of Grace's winning score reflected his performance in a series of science challenges. Over two days, the finalists competed as part of five-member teams. Each team designed, built and tested electrical circuits as well as models of wind turbine blades, roller coasters and tall buildings. Other tasks included analyzing data to figure out what caused a massive fish kill. The finalists also deciphered which parts of certain Maya stone carvings denoted numbers representing dates.

"Congratulations to River and to all of our extraordinary finalists," said Paula Golden, executive director of the Broadcom Foundation. Their skills, she said, "represent the total spectrum of talent needed to take on the world's biggest challenges in technology, healthcare, transportation and sustainability."

"Each finalist should be terrifically proud of their accomplishments and we look forward to following their bright futures," said Rick Bates, interim chief executive officer of Society for Science & the Public, which runs the competition and publishes *Science News*. *—Sid Perkins*

Broadcom MASTERS Winners

The top prizes went to two 14-year-olds with impressive science projects.

The Samueli Foundation Prize: River Grace of West Melbourne, Fla., won $25,000. He studied an endangered tortoise's behavior.

Marconi/Samueli Award for Innovation: Eitan Acks of San Diego won $10,000. He developed a device to improve speech therapy.

STEM Award Winners

The following finalists were selected for demonstrated skills and promise in the disciplines represented by STEM.

Science Awards: First place went to Keoni Gandall of Huntington Beach, Calif. He created a vector for genetically engineering a bacterium. Second place went to Julienne Sauer of San Ramon, Calif., who studied superconductors and frictionless motion.

Technology Awards: First place went to Austin McCoy of Rochester, Minn. He worked on disease-detection lab equipment for developing countries. Second place went to Rebecca Bloomfield of Colorado Springs, Colo., who studied the effects of slope and remediation on postfire sedimentation.

Engineering Awards: First place went to Mihir Garimella of Pittsburgh, Pa. His project was on digitally re-creating smells. Second place went to Sidhika Balachandar, of Gainesville, Fla., who worked on soundproofing.

Mathematics Awards: First place went to Johann Kailey-Steiner of Denver, who worked on rocket design. Second place went to Joshua Wentzel of Portland, Ore. His project was on homemade air cannons.

Rising Stars Award Winners

Two finalists were selected for scientific promise and spirit of cooperation. Krystal Horton of Menifee, Calif., did a project on a beetle infestation. Sean Weber of Sequim, Wash., studied waves and mussels.

PATRICK THORNTON/SSP

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Have you ever said to yourself "I'd love to get a computer, if only I could figure out how to use it." Well, you're not alone. Computers were supposed to make our lives simpler, but they've gotten so complicated that they are not worth the trouble. With all of the "pointing and clicking" and "dragging and dropping" you're lucky if you can figure out where you are. Plus, you are constantly worrying about viruses, spam and freeze-ups. If this sounds familiar, we have great news for you. There is finally a computer that's designed for simplicity and ease of use. It's the WOW Computer, and it was designed with you in mind. This computer is easy-to-use, worry-free and literally puts the world at your fingertips. From the moment you open the box, you'll realize how different the WOW Computer is. The components are all connected; all you do is plug it into an outlet and your high-speed Internet connection. Then you'll see the screen – it's now 22 inches. This is a completely new touch screen system, without the cluttered look of the normal computer screen. The "buttons" on the screen are easy to see and easy to understand. All you do is touch one of them, from the Web, Email, Calendar to Games– you name it… and a new screen opens up. It's so easy to use you won't have to ask your children or grandchildren for help. Until now the very people who could benefit most from E-mail and the Internet are the ones that have had the hardest time accessing it. Now, thanks to the WOW Computer, countless older Americans are discovering the wonderful world of the Internet every day. Isn't it time you took part? Call now, and a patient, knowledgeable product expert will tell you how you can try it in your home for 30 days. If you are not totally satisfied, simply return it within 30 days for a refund of the product purchase price. Call today.

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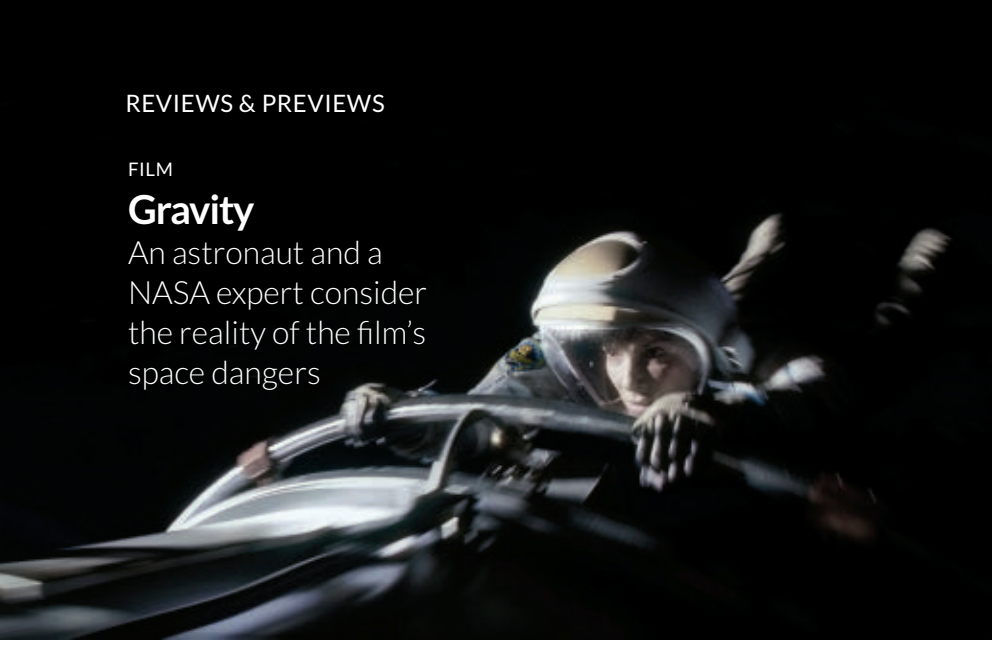
FILM

Gravity

An astronaut and a NASA expert consider the reality of the film's space dangers



In Alfonso Cuarón's new thriller *Gravity*, Sandra Bullock plays a reluctant astronaut who wants to complete her space walk to repair an instrument as quickly as possible. Her plans are foiled by a series of terrifying events that have surely crossed the minds of astronauts and space junkies. The stunning 3-D cinematography gives viewers the feeling of being in space and fuels the feeling of helplessness. Here are some challenges Bullock's character faces **(spoiler alert)** and their likelihood of happening in reality, according to NASA experts.

Russia blew up its own satellite and created a tsunami of space junk! *Possible, but…*
In 2007 China used a guided missile to destroy one of its aging weather satellites, creating hundreds of thousands of smaller pieces of space junk. But the danger the debris posed was to other satellites, not astronauts, says Mark Uhran, who retired last year as NASA's director of the International Space Station. Most satellites are in geosynchronous orbits about 35,000 kilometers above Earth's surface, well above the roughly 400-kilometer altitudes of the ISS and most manned flights. Lower space junk can present a threat; NASA does track hundreds of thousands of objects in this zone, and the station's thrusters can change its orbit slightly to avoid collisions.

I got disconnected from my ship! *Extremely unlikely*
NASA can't prepare for every nightmare scenario, so it relies on a "failure modes and effects analysis" to determine an event's likelihood. Uhran says NASA calculated the chance of an astronaut coming untethered as infinitesimally small. Just in case, astronauts perform space walks in pairs, and they wear thruster belts that can provide an emergency boost — though not a powerful one. No spacewalkers, or their steel tethers, have ever been struck by debris, though NASA astronaut Mike Massimino says astronauts practice returning to a vehicle if a spacesuit is punctured.

We can't get home! *Extremely unlikely*
NASA requires all missions to have a backup means for return, usually an escape vehicle. The ISS has two Russian Soyuz capsules. During Massimino's last mission to upgrade the Hubble Space Telescope, NASA had a backup shuttle ready to launch in case of trouble. "You always have to have a lifeboat," he says.

The space station is on fire! *Possible*
"Fire is one of the greatest hazards that can occur on the space station," Uhran says. In 1997 an oxygen canister ignited on the Russian station Mir, unleashing smoke and meter-high flames. Cosmonaut Valery Korzun managed to douse the flames. Had he failed, half the crew could have died because the fire blocked access to one of the two Soyuz escape capsules. Uhran says that materials on the space station have high ignition temperatures so that small fires won't spread. — *Andrew Grant*

BOOKSHELF

Scarcity

Why having too little means so much

Sendhil Mullainathan and Eldar Shafir

Shortages can gnaw at more than your belly. Mullainathan and Shafir argue that scarcity — whether of food, time or anything else — changes how you think. At the personal level, focusing on what's lacking induces irrational patterns of thinking, changing a person's behavior and laying traps that spring later.

"Scarcity captures the mind," write the authors, an economist and a psychologist. In research on hunger in the 1940s, volunteers who ate very little food for months didn't just lose weight. Their attitudes changed. They began talking about cookbooks and reciting restaurant menus. After watching a movie, many could not recall the plot but remembered what each character ate.

Hunger and other kinds of scarcity induce a mindset that gobbles up inordinate portions of a person's cognitive capacity (*SN: 12/1/12, p. 17*). It's not always bad: Scarcity can hone focus. A lack of time, for instance, can drive a student to write a term paper on deadline. But this concentration involves a kind of tunnel thinking that can be risky. Time is scarce for firefighters, for example, with sometimes fatal consequences. Up to one-fourth of on-duty firefighter deaths between 1984 and 2000 were caused not by fires

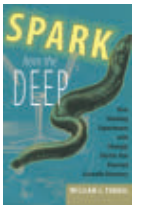
but by motor vehicle accidents, and most of those who died en route were not wearing seat belts. Firefighters tackle a checklist of tasks on their way to a fire and can lose sight of matters outside their "tunnel" of concentration, such as buckling up.

The authors contend that scarcity often explains why people make bad choices, such as poor people taking out payday loans. Mullainathan and Shafir portray these distortions in thinking not through brain scans but by using simple tests that reveal when people aren't thinking straight. Farmers in India, for instance, fared poorly on IQ tests in the anxious months preceding harvest, then did better post-harvest, with less on their minds (*SN: 10/15/13, p. 10*).

The white-collar version would be new office employees with cluttered mental bandwidth putting off optional tasks such as filling out forms for 401(k) retirement plans. It costs them later. Better policies might head off some of these mistakes: When people are automatically enrolled in a 401(k) plan and need to take action not to enroll, 80 percent adopt this sensible long-term strategy. In companies that require a person to "opt in" the participation rate is only 45 percent.

20–25 percent
On-duty firefighter fatalities in motor vehicle collisions

The authors link scarcity neatly to dubious planning, but the reader is left hoping for more solutions to these mindset traps. One of the best remedies they describe skirts the whole issue. To get rural Indians to take the time to vaccinate their children — a task with delayed benefits — they offered a kilo of lentils. The parents showed up. — *Nathan Seppa*
Times Books, $28



Spark from the Deep
William J. Turkel
In this exploration of the evolution and history of electric catfish, rays and eels, Turkel shows how encounters with the animals sparked centuries of research on electricity. The animals now provide inspiration for inventions ranging from computer interfaces to energy-efficient batteries. *Johns Hopkins Univ., $34.95*

Brave Genius
Sean B. Carroll
Science and history combine in this tale of philosopher Albert Camus and biologist Jacques Monod who, long before they won Nobel Prizes, both joined the French Resistance during World War II and later became friends. *Crown, $28*

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

AUGUST 24, 2013

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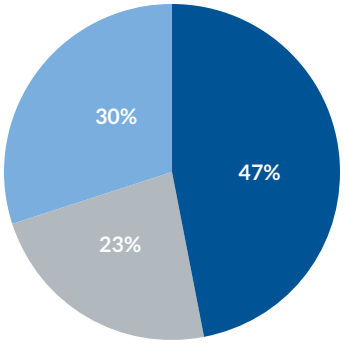
READER POLL

Driving dangerously

In a poll of *Science News*' Facebook followers, no respondents reported ever having been in a crash while talking or texting.

Has using a cell phone while driving ever put you in a dangerous spot?



- No, I never do it
- No, I do it but think I drive fine
- Maybe, I have had at least one near miss

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Driven to distraction

Nathan Seppa outlined research on the hazards of distracted driving in "Impactful distraction" (*SN: 8/24/13, p. 20*).

The story generated a virtual pile-up of reader comments by e-mail, on our website and on social media. **George Cowan** comments online that the article "should be required reading in every drivers' ed course." But a number of readers seemed to have missed one of Seppa's key points: Research shows that talking on a cell phone even hands-free with a driver's eyes on the road, takes a mental toll. **Bob Davis** e-mails, "Do we make it illegal for the driver to talk to the passengers? Should the pilot of an airplane be forbidden to talk to air traffic control or even the copilot?" **Seppa** replies, "Passenger conversations present a mixed bag. Researchers say that a trivial chat with an adult passenger who is watching the road might not hurt overall performance. But talking to kids in the backseat can pull a driver's eyes off the road, and an in-depth conversation with an adult who is oblivious to traffic gobbles up a driver's cognitive resources, a net loss for driving. Teen drivers are six times more likely to brake hard or swerve when there is a loud conversation in the car and are more likely to crash when carrying teen passengers." Reader **Larry Eaton** says by e-mail, "It seems to me that there are an infinite number of things people do that cause distracted driving. Why attempt to outlaw just a few? It sends the message that the others are acceptable." **Seppa** notes, though, that not all distractions are equal: "Listening to the radio degrades driving skills less than conversation does, researcher David Strayer and his team found recently. Listening to books on tape falls somewhere in between." On Facebook, **Dio Windmills Alexander** sums up feedback from another faction of readers: "Who does such foolishness? Being distracted while operating a lethal weapon? That's nuts."

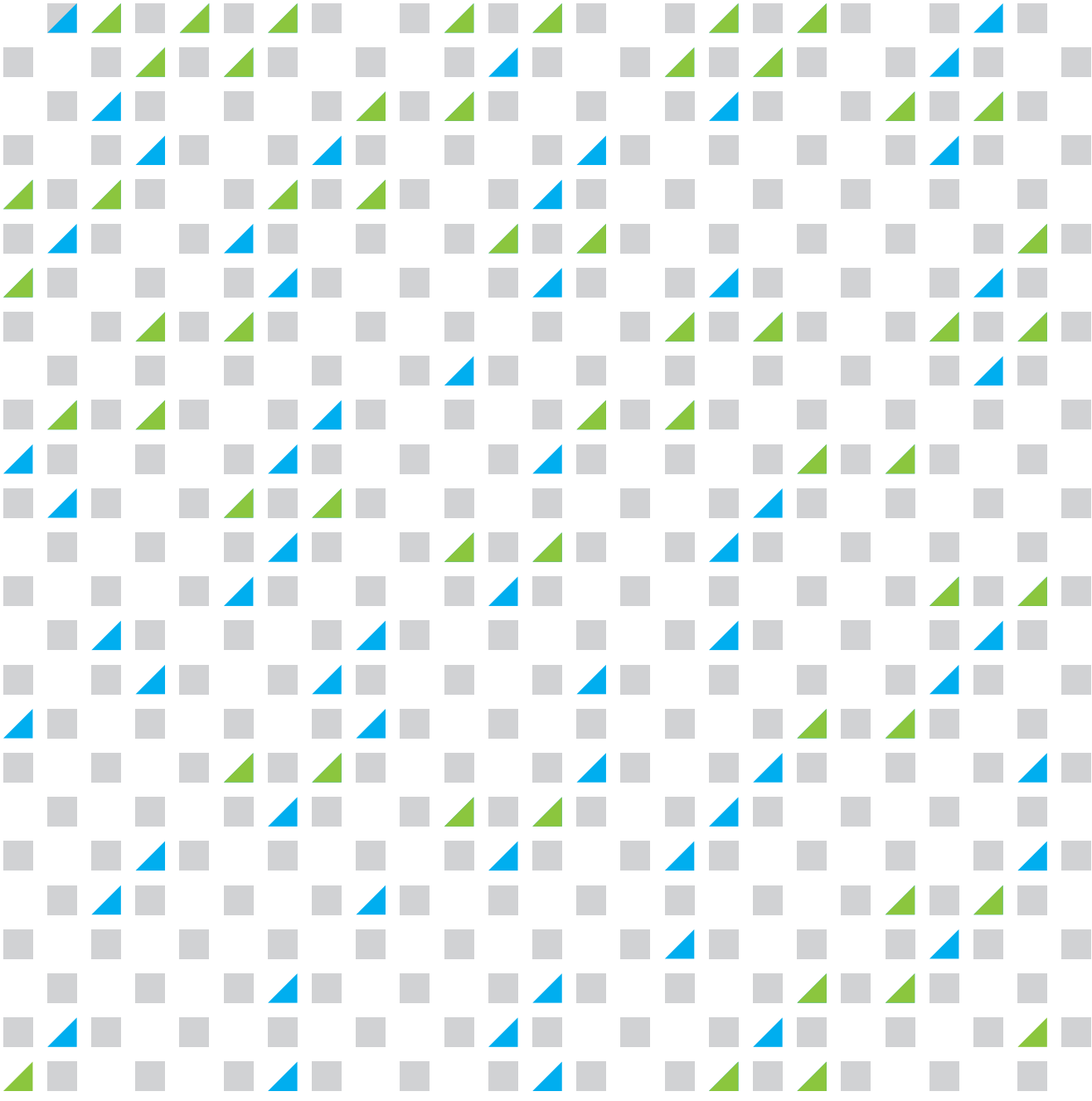
CORRECTION: Several readers pointed out that a map of cell phone driving restrictions reversed the names of Connecticut and Massachusetts. We apologize for the error.

Positively nonsense

In "Ratio of a good life exposed as 'nonsense'" (*SN: 9/7/13, p. 5*), **Bruce Bower** reported on a recent critique of the math in a 2005 paper that claimed to have calculated a particular ratio, about 2.9, of positive to negative emotions that "enables life success."

Reaction was divided on the story and on the math controversy that sparked the debate. Bower's story was "more critical than anything I have ever seen in a *Science News* article," **Janice Gendreau** e-mailed. "After all, I have read in this very publication that 80 percent of scientific research cannot be duplicated, and much of it has statistical errors. But wait, why was this 'good life' research so widely embraced? It validates what many of us experience daily; negative forces have a greater impact than positive ones. [Nicholas Brown and Alan Sokal, coauthors of the critique,] may be crowing now, but I predict they will have to eat crow in the long term." *Science News* tweeted the story with the question "Do you think a scholarly paper should be retracted where a coauthor admits the paper has 'questionable mathematics'?" Some replies pointed out that science is a process of trial and, notably, error. "Didn't Einstein say discovery doesn't happen without mistakes?" tweeted **Anna Rosswoods** (@ARosswoods). **Chelsea Du Fresne** (@snarkipodicus) replied, "Science needs mistakes, but publishing those mistakes as truth undermines science."

UPDATE: A correction ran online September 16 in *American Psychologist*, the journal where the original positivity ratio paper was published. "The modeling element of this article is formally withdrawn as invalid and, along with it, the model-based predictions about the particular positivity ratios," the notice stated. The paper has not been retracted, however, and the debate continues, with further response planned, Sokal told the blog *Retraction Watch*.



Twin primes

Numbers from 1 to 625

- Even numbers
- Non-twin primes
- Twin primes (primes that differ by 2)

Mathematicians have conjectured since Euclid's time that there are infinite pairs of prime numbers separated from each other by 2. Despite the fact that primes are separated on average by bigger gaps as numbers increase (illustration highlights prime numbers, counting from 1 at upper left to 625 at lower right), evidence suggests that primes continue to appear as "twin primes" (green triangles) no matter how high you go. But for mathematicians, suggestive evidence isn't good enough. For at least a century, they've labored to prove the twin prime conjecture. A major advance came this spring, when University of New Hampshire mathematician Yitang Zhang showed that there are infinitely many primes separated by some number smaller than 70 million. That may be a lot bigger than their eventual goal of 2, but by the end of July mathematicians had already whittled that limit down to 5,414. —*David Harris*

MICHAEL BRANIGAN

Chicago Doctor Invents

Affordable Hearing Aid

Amazing new digital hearing aid breaks price barrier in affordability

Reported by J. Page

Chicago: Board-certified physician Dr. S. Cherukuri has done it once again with his newest invention of a medical grade **ALL DIGITAL affordable hearing aid.**

This new digital hearing aid is packed with all the features of $3,000 competitors at a mere fraction of the cost. **Now, most people with hearing loss are able to enjoy crystal clear, natural sound—in a crowd, on the phone, in the wind—without suffering through "whistling" and annoying background noise.**

New Digital Hearing Aid Out-performs the Expensive Ones

This sleek, lightweight, fully programmed hearing aid is the outgrowth of the digital revolution that is changing our world. While demand for "all things digital" caused most prices to plunge (consider DVD players and computers, which originally sold for upwards of $3,000 and today can be purchased for less then $100), yet the cost of all digital medical hearing aids remained out of reach.

Dr. Cherukuri knew that many of his patients would benefit but couldn't afford the expense of these new digital hearing aids, which are generally *not* covered by Medicare and most private health insurance.

SAME FEATURES AS EXPENSIVE HEARING AIDS

- ✓ **Doctor and Audiologist designed, mini behind-the-ear open-fit digital hearing aid**
- ✓ **Small size and thin tubing for a nearly invisible profile**
- ✓ **Multiple channels and bands to provide precise amplification of the human voice without background noise**
- ✓ **Wide dynamic range compression to amplify soft sounds and dampen loud sounds**
- ✓ **Feedback cancellation to eliminate whistling**
- ✓ **Advanced noise reduction to make speech clearer**
- ✓ **3 programs and volume dial to accommodate the most common types of hearing loss even in challenging listening environments**
- ✓ **Telecoil mode for improved use with compatible telephones, iPhones®, (and other cell phones), and looped environments (churches, etc.)**

He evaluated all the high priced digital hearing aids on the market, broke them down to their base components, and then created his own affordable version—called the AIR for its virtually invisible, lightweight appearance.

Affordable Digital Technology

Experience all the sounds you've been missing at a price you can afford. **This doctor-approved hearing aid comes with a full year's supply of long-life batteries. It delivers crisp, clear sound all day long and the soft flexible ear buds are so comfortable you won't realize you're wearing them.** Using advanced digital technology, the AIR automatically adjusts to your listening environment—prioritizing speech and de-emphasizing background noise.

Try It Yourself At Home With Our 45 Day Risk-Free Trial

Of course, hearing is believing and we invite you to try it for yourself with our RISK-FREE 45-day home trial. If you are not completely satisfied, simply return it within that time period for a full refund of your purchase price.

MDHearingAid® AIR

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Use Offer Code QD34 to get FREE Batteries for a Full Year!

100% MONEY BACK GUARANTEE — 45 DAY RISK FREE TRIAL

Proudly assembled in the USA from Domestic & Imported Components.

BBB RATING A

Can a hearing aid delay or prevent dementia?

A study by Johns Hopkins and National Institute on Aging researchers suggests older individuals with hearing loss are significantly more likely to develop dementia over time than those who retain their hearing. They suggest that an intervention—such as a hearing aid—could delay or prevent dementia by improving hearing!

"Satisfied Buyers Agree AIR Is Best Digital Value"

"I am hearing things I didn't know I was missing. Really amazing. I'm wearing them all the time" —Linda Irving, Indiana

"Almost work too well. I am a teacher and hearing much better now" —Lillian Barden, California

"I have used many expensive hearing aids, some over $5,000. The Air's have greatly improved my enjoyment of life" —Som Y., Michigan

"I would definitely recommend them to my patients with hearing loss" —Amy S., Audiologist, Munster, Indiana

Praise for
Stauer Men's Rings:

★★★★★

"...for men that like to make a statement"
— D. FROM WASHINGTON

★★★★★

"...simple lines with a nice balanced weight... well done, Stauer.."
— E. FROM ARKANSAS

The Six-Million-Dollar Ring?

We found the technology to rebuild steel and make it stronger and better than before...

You don't sip tea from a saucer with your pinkie in the air. You drink beer from a can and when that can is empty, you crush it. Your idea of a manicure involves a wire brush and lava soap. More than once you've used duct tape as a bandage. Life is rough, but your hands don't mind the punishment. Before you put on a ring, you need to be sure that it's tough enough for the job. You need the rugged and resilient Stauer ***Echelon*** Ring. And today you can have it for **ONLY $99!**

FREE
$99 Sunglasses
with Echelon Ring!

Flyboy Optics™ Sunglasses with UV protection

You've never worn a ring like this before. After searching for something bigger, better and badder, we found technology that "rebuilds" steel into something stronger and more stylish. Our exceptional ***Echelon*** Ring is crafted from PVD-coated stainless steel. PVD is short for "Physical Vapor Deposition," a complex technique that transforms ordinary metal into a superhero substance.

Tough enough for military service. First the steel ring is sealed in a vacuum. The alloy coating is heated to an extreme temperature until it's vaporized and then electrically bonded to the steel. Once it's on, it's not coming off. The military has depended on this process for years to increase the durability of gun bolts, engine parts, and combat equipment. Put it on and maybe some of that indestructibility will wear off on you.

Style meets substance. We know that durability isn't your only concern. You choose a ring because it looks and feels good. That's why the ***Echelon*** seamlessly blends sophistication and comfort with solid construction. The wide, smooth steel band fits like a dream and the sharp pairing of polished steel and glossy black complements everything from jeans and t-shirts to a custom-tailored tuxedo.

Your satisfaction is 100% guaranteed. Try the ***Echelon*** Ring for $99. Wear it for a few weeks. If you're not completely won over by its superior strength and style, simply send it back within 30 days for a full refund of your purchase price. While supplies last, we'll also include our Stauer Flyboy Optics™ Sunglasses (a $99 value), *absolutely* **FREE!** Even if you return the ***Echelon*** Ring, you can keep the sunglasses as our gift. But we're betting that once you step into this ring, you'll be ready to go the distance!

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