SN
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SOCIETY FOR SCIENCE & THE PUBLIC
NOVEMBER 29, 2014

Mars Mentality

Easter Islanders' Excursions

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Online Price Steering Exposed

PLANET X

The hunt for a hidden world far beyond Neptune

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COVER If Planet X exists, it may be hiding anywhere from 250 to 1,000 times as far from the sun as Earth is. *Nicolle Rager Fuller*

A still mysterious solar system

When I was a teen, I liked to stay up way too late with my nose in an Agatha Christie novel, reading compulsively to the end to see if I had guessed the culprit correctly. It wasn't obvious that a love of mysteries translates into a love of science, but maybe it should have been.

When Christopher Crockett suggested his Planet X story, appearing on Page 18, it was the aura of mystery that hooked me. First, there is the surprise that parts of our own solar system remain opaque, even as we find planets around distant stars and see the cosmic radiation from the universe's first light. How could our blind spot be so large? Second, there is a real mystery here: Scientists don't understand what caused the strange, loopy orbits of two dwarf planets beyond the Kuiper belt. In the past, attempts to explain orbital anomalies led to the discoveries of Neptune and Pluto. (As Tom Siegfried mentioned in his *Context* blog earlier this year, however, similar attempts to explain an anomaly in Mercury's orbit required not a new astronomical body but a new theory: general relativity.)

Whether or not a Planet X exists, the puzzle, like a good mystery, delights the mind. But better than any novel, the puzzle's solution has the potential to reveal something new and unexpected about our solar system. To borrow language from an *SN* reader commenting on Siegfried's blog, the appeal is that "tomorrow they could discover something that changes everything." Eight planets or nine. Newtonian physics or Einstein's general relativity. What's known or what we can only guess at.

To add to the "what's known" column in this issue: On Page 6, read about an Asian species of chytrid fungus that has spread to Europe via the trade in live animals. If it jumps the Atlantic, it could devastate North American salamanders, scientists now say. And on Page 12, news of a more ancient pond-hopping: Hidden in the genes of modern-day Rapa Nui islanders is evidence that their ancestors sailed to the Americas and returned to Easter Island more than 500 years ago.

In science, the mysteries tend to be open-ended. Getting the right answer can be satisfying. But more often what you get is more questions. What's known appears heavily outweighed by what's still unknown, with the distinct possibility that it could change everything. —*Eva Emerson, Editor in Chief*

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Excerpt from the November 28, 1964, issue of *Science News Letter*

50 YEARS AGO

New space goal — Mars

The Space Sciences Board has recommended that the United States make Mars, not the moon, its main concern in space. But this is not an admission that the Russians have all but won the race to the moon.... The board's report ... is merely a "refocusing" of its earlier position.... The board suggested that unmanned flights to planets be undertaken between 1971 and 1985, followed as soon as possible by manned flights.

UPDATE: With 15 successful unmanned visits from the United States since Mariner 4 launched in 1964, Mars remains a central focus for NASA. In September, two more probes arrived at the Red Planet, including the first from India. The probes joined five other active missions. Unmanned probes have now visited every planet in the solar system plus several asteroids and comets; three of those spacecraft aim to study interstellar space. However, human interplanetary travel hasn't happened.

IT'S ALIVE

When sweet little bees go to war

Tiny *Tetragonula* bees don't sting but have strong jaws. The bees fight by biting a combatant and not letting go.

INTRODUCING

A charming subatomic particle

The discovery of a particle about three times as hefty as a proton may lead to insights into the force that holds the nucleus of an atom together.

The dauntingly named $D^*_{s3}(2860)^-$ is a never-before-seen particle observed by the LHCb detector at the Large Hadron Collider, the world's most powerful particle accelerator, near Geneva. Like protons and neutrons, $D^*_{s3}(2860)^-$ is made up of fundamental units of matter called quarks. But the new particle's two quark components — a strange quark and the antimatter partner of a charm quark — are heavier than those in most other particles, making the particle an ideal target for studying the nuclear strong force that binds the two quarks.

Sensors inside the LHCb detector helped researchers discover a subatomic particle.

Despite its incredible strength compared with the universe's three other forces (weak, electromagnetic and gravity), the strong force is difficult to study because it acts over very short distances.

The discovery is detailed in the Oct. 17 *Physical Review Letters* and the Oct. 1 *Physical Review D*. — *Andrew Grant*

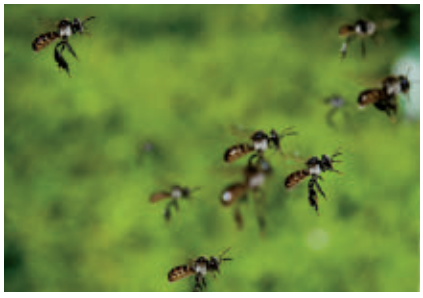
FROM TOP: TOBIAS SMITH/UNIV. OF QUEENSLAND; R. PLACKETT/CERN

Tiny bees that couldn't sting if their hives depended on it have revealed a new side of apian violence.

Little *Tetragonula* bees belong to the same family as honeybees but don't have stingers. "They're about the size of large ants — but much cuter," says Paul Cunningham of Queensland University of Technology in Brisbane. In that region of Australia, two stingless bee species, *T. hockingsi* and *T. carbonaria*, thrive in backyard hives.

Hobbyists keep the two native pollinator species as pets — they're good with children — and for their honey. It's "very tangy and citrusy," Cunningham says. Yet he and his colleagues now report that their endearing little neighbors are the first bees known to stage massive, days-long, high-casualty battles taking over nests of another bee species.

Battles between the two species are "spectacular," the researchers say in the December *American Naturalist*. A cloud of attacking bees collides in midair



A swarm of stingless invaders flies in on a mass-suicide mission to break the defenses and take control of another bee colony.

with defenders that boil out of the nest. Combatants bite each other and drop to the ground. "An attacking bee grabs a defender, and they hold on until they die," Cunningham says. "Underneath the hive you get this carpet of bees."

While females wrestle to the death, male drones gather nonviolently, sometimes with drones from the opposing side. "They're like 'Yeah, yeah, come on — let's all just hang out on this branch,'" Cunningham says.

The generally calm *T. carbonaria* bees were already known to attack another colony of their own kind now and then. That's what Cunningham first thought he was seeing as he monitored a hive that withstood two swarming attacks lasting for days at a time, only to crumble in the third invasion.

But genetics revealed the attackers to be almost all *T. hockingsi,* says coauthor James Hereward of the University of Queensland in Brisbane. A closer look at dozens of other hives revealed that both species do takeover raids.

Because each bee grappling with an opponent usually brings death to them both, stingless wars mean massive casualties. Perhaps the benefit that outweighs the carnage comes from invaders' ability to spread genes of one of their own young queens, who moves into an already provisioned hive. What drives battles, in bees as in another warlike species, may be the prize of thrones. — *Susan Milius*

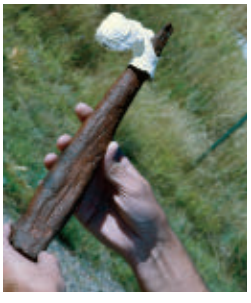
HOW BIZARRE

Stegosaurus landed low blow

VANCOUVER — In a story worthy of *CSI: Jurassic Period*, researchers have solved the mystery of what killed a predatory *Allosaurus* dinosaur 147 million years ago.

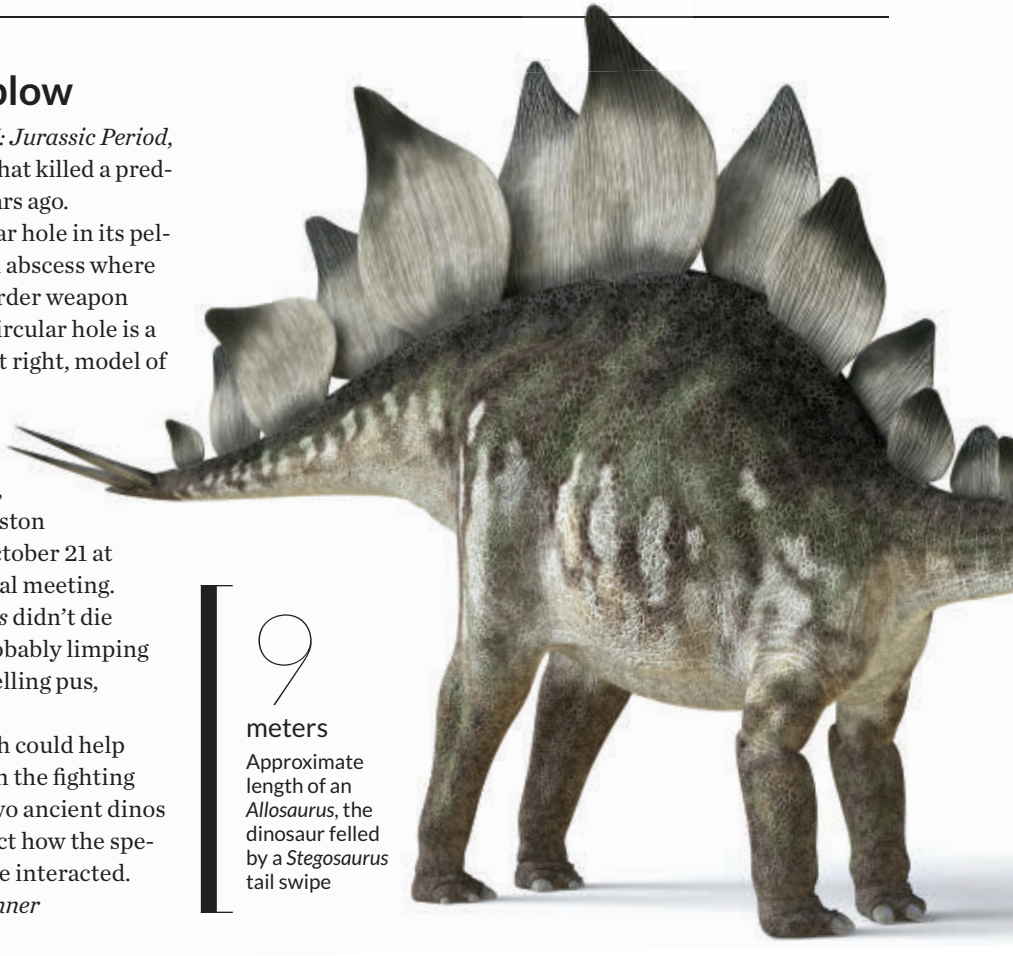
The *Allosaurus* fossil contains a circular hole in its pelvis flanked by a well-preserved, fist-sized abscess where the infected wound spread. The only murder weapon around that time that would create the circular hole is a tail spike on a *Stegosaurus* (illustration at right, model of wound below left).

The plant-eating dinosaur used its flexible body to whip its spiky tail into the *Allosaurus*' crotch during a fight, paleontologist Robert Bakker of the Houston Museum of Natural Science proposed October 21 at the Geological Society of America's annual meeting.



The *Allosaurus* didn't die right away, probably limping for weeks expelling pus, Bakker said.

The research could help scientists learn the fighting styles of the two ancient dinos and reconstruct how the species might have interacted. — *Thomas Sumner*



9
meters
Approximate length of an *Allosaurus*, the dinosaur felled by a *Stegosaurus* tail swipe

CLOCKWISE FROM TOP: TOBIAS SMITH/UNIV. OF QUEENSLAND; ROGER HARRIS/SCIENCE SOURCE; R. BAKKER

LIFE & EVOLUTION

Asian fungus threatens salamanders

Lethal pathogen is spreading through the global pet trade

Skin lesions on the face of a fire salamander show the ravages of a chytrid fungus species discovered last year, now suspected of escaping from Asia.

FRANK PASMANS

BY SUSAN MILIUS

A salamander-killing fungus first described last year looks as if it originated in Asia and is hitchhiking around the world in the pet trade.

The fungus, nicknamed Bs, for *Batrachochytrium salamandrivorans*, came to the attention of scientists during baffling die-offs of rare fire salamanders in the Netherlands. Another *Batrachochytrium* species, *B. dendrobatidis*, or Bd, has ravaged amphibian populations in recent decades. But An Martel of Ghent University in Belgium and her colleagues ruled Bd out in the Netherlands die-offs and discovered that the culprit was an unknown relative, which researchers named last year (*SN: 10/5/13, p. 18*). Now, after more surveys and lab tests, Martel and collaborators have started to answer questions in the Oct. 31 *Science* about the spread and targets of Bs.

"It is appropriate to be exceptionally concerned, if not alarmed," says Jamie Voyles of New Mexico Tech in Socorro, who studies the killing mechanisms of the other *Batrachochytrium* fungus. So far, no evidence shows the newly recognized disease has reached North America, home to a quarter of the world's known salamander species. But the continent is a market for amphibians from Asia, and as veterinary pathologist Allan Pessier of San Diego Zoo Global puts it, "we need to focus on disease screening and biosecurity for imported animals."

This new salamander pathogen came as a shock to biologists already dismayed by more than 20 years of amphibian disease outbreaks. In 1999, Pessier and others identified that Bd, a chytrid fungus, was the cause. Generally mild-mannered, chytrids usually break down dead stuff in the environment.

The second killer chytrid, Bs, seems to target salamanders, Martel and colleagues report. The team attempted to infect 35 species picked from different branches of the amphibian genealogical tree. The fungus seemed unable to attack frogs, toads or legless snake-shaped amphibians called caecilians. But it quickly killed 41 of the 44 individual salamanders tested from Western temperate-zone species.

"It's not a pleasure to see," Martel says. In a susceptible species, the fungus "literally eats the skin off an animal."

In the infection tests, Asian species were more resilient to Bs, suggesting the fungus originated in Asia, the researchers say. Asia also looked like the probable origin after the team's epic efforts to check for pathogen DNA on 5,391 wild amphibian specimens worldwide. Bs turned up on only two of the four continents surveyed. Animals tested positive in Thailand, Vietnam and Japan, where biologists have not reported salamander die-offs. These species may have evolved for millions of years with the pathogen. Bs was also detected in the Netherlands and Belgium, where wild salamanders have died.

The new study makes a good case for an Asian origin of Bs, says Timothy Y. James of the University of Michigan in Ann Arbor and a coauthor of a massive genetic study of the Bd fungus.

To see if an Asian disease could travel via the global trade in live animals, Martel and colleagues checked skin samples from 2,335 captive animals in such places as European pet shops, a Hong Kong export business and London's Heathrow Airport. Three salamanders in the sample, two of which were sent to Europe in 2010, carried the fungus. Lab tests with two other species show that one salamander touching another can transmit the disease, the researchers report.

No wild North American salamanders have tested positive for Bs, although surveys so far have big gaps, says study coauthor Karen Lips of the University of Maryland in College Park. She warns that if the disease does strike North America, the inner workings of ecosystems could change. Tiny salamanders darting through leaf litter or burrowing into soil often get overlooked, but "these things are superabundant," she says.

She fears a repeat of the nightmare she chronicled in Panama in 2004 as the first amphibian-killing fungus swept through. Bd exterminated some 30 of 74 amphibian species at her study site and shook up the rest of the community, even reducing numbers of certain snakes that eat amphibians.

To prevent such loss and disruption, Lips calls on Congress to pass proposed legislation requiring health checks for imported amphibians. Regulations already address keeping crop plants and livestock from bringing new disease into the United States, she points out. ■

MATH & TECHNOLOGY

Online retailers personalize search results to try to maximize profits

Websites alter results depending on whether consumers use smartphones or particular web browsers

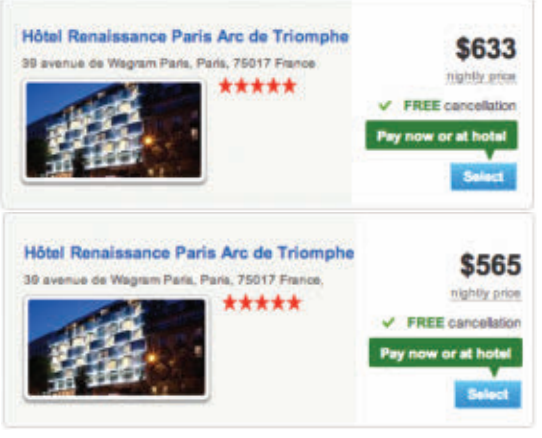
BY RACHEL EHRENBERG

The convenience of comparing airfares at a single travel website while browsing from a smartphone is undeniable. But these modern perks can have a hidden cost: Researchers have uncovered multiple instances of travel and retail websites steering customers toward more expensive prices depending on factors such as whether customers are on a mobile phone, use a particular browser or have purchased particular items in the past.

Nine of 16 travel and retail websites studied, including Home Depot, Sears, Orbitz, Priceline and Expedia, personalize search results. Seven of these sites show different prices for the same product to different customers, researchers report.

"It's a concrete example of why you should care about companies tracking your behavior online," says computer scientist Christo Wilson of Northeastern University in Boston, who led the study. "It affects your pocketbook."

Northeastern computer scientist Aniko Hannak presented the findings November 6 at the 2014 Internet Measurement Conference in Vancouver.



A search by a real user yielded more expensive results on Hotels.com (top) than did a search from a clean, new account (bottom) in a recent study.

A. HANNAK

Companies have always tried to figure out the highest price that customers are willing to pay. But the era of big data has changed the game, says law professor Ryan Calo, a specialist in technology policy at the University of Washington in Seattle.

"There's a difference between deciding most people will pay $1 for a Snickers bar versus setting a price because of being able to figure out that a consumer is really hungry because they're breastfeeding, or high or just ran 10 miles," Calo says. "There's so much information in the hands of these companies."

> "It's a concrete example of why you should care about companies tracking your behavior online."
>
> CHRISTO WILSON

Uncovering the price steering and discrimination involved several experiments, including one in which the researchers created clean accounts without cookies or browser history on several of the websites. In one instance, the researchers found that users who searched Home Depot from their desktops received products with an average price of $120, while those who searched from their smartphones were steered toward products with an average price of $230.

Home Depot, along with Travelocity, further personalized smartphone searches. Browsing Travelocity with the browser Safari on an iPhone, for instance, led to slightly different hotels, and in a much different order, than did browsing with Chrome on an Android. For iPhone users, hotel prices were $15 cheaper for about 5 percent of hotels.

In another case, consumers shopping on Orbitz and Cheaptickets were shown cheaper prices when they were logged in as members than when browsing as nonmembers.

"The most surprising thing to me is the diversity of stuff that we found; everyone's doing something different," says Wilson. "They're still playing with big data to maximize sales."

Some companies' data exploration entails A/B testing, in which two groups are shown identical products except for one factor, to see if that variable affects consumer behavior. Wilson and colleagues found that Expedia and Hotels.com, which is owned by Expedia, engage in A/B testing by steering a subset of users to cheaper products and a subset toward more expensive ones. These tests may help determine whether users who see expensive hotels at the top of the page tend to book more expensive hotels, says Wilson.

Expedia confirmed this testing, he says. In fact, the researchers shared their results with six of the companies that implemented some form of personalization. The team received responses only from Orbitz and Expedia. Orbitz, which owns Cheaptickets, allowed the researchers to publish its letter, saying in part that Wilson's team mischaracterized the company's business practices by suggesting that they were detrimental to consumers.

There's no reason for companies not to engage in these tactics, notes Calo. They are legal, and corporations may use them to try to gain a competitive edge. But the practices put a burden on the consumer, who might have to search multiple sites to find the cheapest product or use a browser with a cleared, cookie-free search history.

But that soon may change, Calo says. The Federal Trade Commission announced on October 21 its appointment of Ashkan Soltani as the agency's chief technologist. Soltani, an independent researcher and journalist, is known for his work exposing how governments and companies use and track personal data online. ■

HUMANS & SOCIETY

Oldest known human DNA analyzed

Genome narrows down time of mating with Neandertals

BY BRUCE BOWER

DNA of a 45,000-year-old Siberian man, the oldest modern human genetic material retrieved to date, indicates that he lived a short time after *Homo sapiens* interbred with Neandertals.

This ancient man belonged to a population that was related to earlier people who left Africa and split into European and Central Asian lines, paleogeneticist Svante Pääbo of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, and colleagues report in the Oct. 23 *Nature*.

The Stone Age man may have belonged to a group that left cutting tools at several Siberian sites dating to as early as 47,000 years ago, the scientists say. No fossils have been found at those sites, raising questions about whether modern humans or Neandertals made the tools.

The ancient man's DNA "shows that there were indeed modern humans in the area of those Siberian sites who could have made stone tools," says study coauthor Janet Kelso, a Max Planck paleogeneticist.

Nine samples of crushed bone from the fossil yielded genetic sequences covering about two-thirds of the man's genome, which allowed for comparisons with the DNA of modern people. The Siberian man displays a genetic link to Andaman Islanders, who are thought to descend from an ancient human migration along the coast of South Asia, the researchers found. The Andaman Islands lie between India and Southeast Asia. The man is also related to East Asians and Native Americans — both considered to be descendants of a northern migration through Asia. The investigators suggest the Siberian individual hailed from a third wave of immigrants to Asia that contributed some genes to ancestors of present-day Asians before dying out.

Comparisons with Neandertal DNA reveal that the man shared 2.3 percent of his genes with Neandertals. Present-day East Asians carry a 1.7 to 2.1 percent genetic contribution from Neandertals, a figure that falls slightly, to between 1.6 and 1.8 percent, in living Europeans.

Based on this new data, modern humans probably interbred with Neandertals between about 50,000 and 60,000 years ago, the team estimates, rather than over a longer period extending further back in the Stone Age (*SN: 11/3/12, p. 8*). Another recent discovery supports this conclusion. An analysis of DNA from a roughly 36,000-year-old modern human fossil found in Russia dates human-Neandertal interbreeding to about 54,000 years ago, researchers report November 6 in *Science*.

No signs of interbreeding with Neandertal cousins called Denisovans appear

A 45,000-year-old leg bone found in Siberia yielded the oldest known *Homo sapiens* DNA.

BENCE VIOLA/MPI EVA

EARTH & ENVIRONMENT

Engineered plants demolish waste

Modified vegetation could clean up toxic pollution

BY BETH MOLE

Greenery may one day clean up the chemical fallout of oil spills and air pollution.

Wielding the metabolic machinery of microbes, plants can now digest polycyclic aromatic hydrocarbons, the ubiquitous chemicals known as PAHs that ooze from oil spills and settle out from smog. The vegetation is still in the early stages of development, but scientists hope that the plants can act as green cleanup crews in the future. Plant-based scrubbings could cost one-tenth as much as current cleanup methods, the researchers say.

The United States spends billions of dollars each year cleaning up dangerous waste sites. The expense of the work — which can include excavating contaminated land or pumping in chemical treatments — often results in waste sites being deserted without cleanup.

For a cheaper fix, scientists have eyed biological cleansers. Certain microbes are natural waste-gobblers, sucking in chemical pollutants and snapping them apart to make harmless molecules. Some of these bacteria have been used to clean up oil spills. But getting microbes to live in toxic dumps and monitoring their progress can be difficult. Many plants also take up pollution, but they tend to be vulnerable to poisoning because most can't break down the harmful chemicals.

Agricultural researcher Quan-Hong Yao and colleagues at the Shanghai Academy of Agricultural Sciences got around the problem by arming plants with pollutant-cracking enzymes from bacteria. The proteins are encoded in a cluster of four genes found in *Pseudomonas putida*, a soil microbe that breaks down PAHs.

Other researchers have put these genes into plants before. But there's a sticking point, says Michel Sylvestre, a biochemist at INRS–Institut Armand-Frappier Research Centre in Laval, Canada: If protein production isn't synchronized, those enzymes can't work together to digest the PAHs. "All those who have tried have never succeeded," he says.

Yao and colleagues pulled it off by carefully assembling the four genes into one neat genetic package. For the receiving plants, the team chose rice and a flowering weed called *Arabidopsis thaliana*.

The plants took in the genes, coordinated their enzyme manufacturing and broke down phenanthrene, a common PAH. After 30 days, the plants digested up to 50 percent of the phenanthrene in spiked soil, the team reports October 9 in *Environmental Science & Technology*.

"This is a big deal," says environmental chemist Christopher Reddy of the

in the Siberian man's DNA. That makes sense, remarks paleogeneticist Morten Rasmussen of Stanford University, since Denisovan genes cluster among present-day Southeast Asians (*SN: 9/22/12, p. 5*).

Evidence that Neandertal interbreeding began no more than 60,000 years ago supports the idea that a wave of *H. sapiens* dispersed out of Africa around that time, occasionally mated with Neandertals and passed Neandertal DNA to human populations that led to all non-Africans today, says paleoanthropologist Chris Stringer of the Natural History Museum in London.

Paleogeneticist Mattias Jakobsson of Sweden's Uppsala University finds it intriguing that the Siberian man displays equal relatedness to present-day Asians, a 24,000-year-old Siberian child and a 7,000-year-old Spanish hunter-gatherer (*SN: 5/17/14, p. 26*). Unlike Pääbo's team, Jakobsson suspects the man belonged to a population that has yet to be pinned down but nonetheless helped give rise to current East Asians and Europeans. ■

Woods Hole Oceanographic Institution in Massachusetts. But he cautions that it's still unclear whether the plants can digest dangerous waste outside the lab.

Yao agrees. He plans to test the plants' scrubbing potential in real-world conditions.

Strict regulations on genetically engineered plants in the United States and elsewhere may make these green cleaners difficult to use, says environmental scientist Sharon Doty of the University of Washington in Seattle. In her research on PAH remediation, Doty introduces whole bacteria instead of injecting bacterial genes. Called endophytes, these microbial partners live inside a plant, breaking down PAHs and other pollutants, she says.

With the same bacteria Yao's group used, willow shrubs and grass chewed up phenanthrene in contaminated soil, Doty's team reports in the Oct. 21 *Environmental Science & Technology*. ■

HELMRATH LAB

BODY & BRAIN

Tiny human intestines grown in mice

Gut tissue could help researchers tailor disease treatments

BY MEGHAN ROSEN

Slimy chunks of human gut can now grow up and get to work inside of mice.

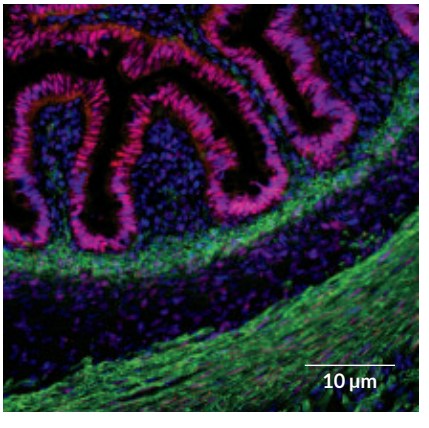
Transplanted into rodents, tiny balls of tissue balloon into thumbnail-sized nuggets that look and act like real human intestines, researchers report October 19 in *Nature Medicine*.

The work is the first time scientists have transformed stem cells into working bits of intestines in living animals. These bits could help tailor treatments for patients with bowel diseases, such as Crohn's disease or colon cancer, says coauthor Michael Helmrath, a pediatric surgeon at Cincinnati Children's Hospital Medical Center. Doctors could test drugs on the gut nuggets and see how a patient's tissues respond without having to subject the person to different treatments.

"If you give me a patient, I can grow their intestines," Helmrath says.

For decades, researchers have tried and failed to cultivate human gut tissue in the lab, says stem cell biologist Eduard Batlle of the Institute for Research in Biomedicine in Barcelona.

Transplanted fetal tissue can turn into something like intestines, but its use is ethically debatable and the tissue wouldn't match up with a patient's own. In recent years, scientists have started to see glimmers of success in turning mature cells into organs. Using adult cells reprogrammed into stem cells, researchers have grown heart, liver and brain tissue (*SN: 12/28/13, p. 20*).



Transplanted into mice, tiny specks of human intestinal tissue (stained pink) develop into working organs surrounded by a muscular sheath (stained green), just like real intestines.

Still, converting clumps of tissue into 3-D organs remains a challenge — especially for organs with lots of different cell types. The intestine is a complicated structure, says UCLA stem cell biologist James Dunn. The muscular tube wriggles and writhes as food snakes through, while some of its cells ooze mucus, absorb nutrients and break down sugars.

In 2011, Helmrath's colleagues created specks of human intestinal tissue from reprogrammed cells. The specks were like intestinal newborns: They didn't behave quite like adults. Helmrath and colleagues thought transplanting the specks into a blood vessel–rich nook in mice might help the tissue mature.

The team created clumps of intestinal tissue from adult blood cells and then embedded them into gluey lumps of gel. Next, the researchers placed the lumps inside mouse abdomens underneath a filmy membrane that clings to the kidneys. When researchers peeked inside the mice six weeks later, the team discovered plump pink organs.

"We didn't have any idea that it was going to grow and develop so beautifully," Helmrath says.

In the mice, the tissue had bloomed into organs 50 to 100 times their original size. The squishy tubes could absorb and digest food. They even responded to major surgery as real intestines do. "This is exciting work that's going to move the whole field forward," Dunn says. "But we're still missing some elements."

For one, the intestinal hunks live in an odd home, on the kidney. And they lack nerve cells, which prompt guts to clench and move. Helmrath says his team is working on the nerve cell problem. "We've actually already figured it out," he says. "But that's not for this paper." ■

BODY & BRAIN

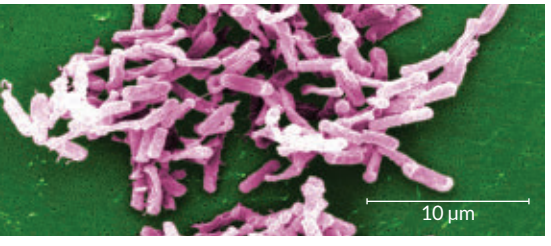
Friendly bacteria counter a culprit

Related microbe inhibits *C. difficile*, mouse study shows

BY KATE BAGGALEY

Gut infections from the bacterium *Clostridium difficile* can be fought with a closely related but harmless microbe known as *C. scindens*. The friendly bacterium combats infection in mice by converting molecules produced in the liver into forms that inhibit *C. difficile* growth, researchers report October 22 in *Nature*.

C. scindens also appears to protect people from infection, the team found in a preliminary study in humans. The findings could lead to a new generation of therapies using gut bacteria, says gastroenterologist Alexander Khoruts of the University of Minnesota in Minneapolis.



Mice exposed to *Clostridium difficile* (shown) are protected by a related microbe, *C. scindens*.

People infected with *C. difficile* typically have taken antibiotics, which wipe out the gut's beneficial microbes. That gives the germ a chance to take root, causing cramps, diarrhea or even death. People with *C. difficile* receive more antibiotics to treat the infection or a fecal transplant to restore healthy microbes.

Researchers have been trying to identify gut bacteria that are resilient in the face of *C. difficile* so patients can receive those bacteria as a treatment, says Eric Pamer, an immunologist at Memorial Sloan Kettering Cancer Center. Single strains of bacteria such as *C. scindens* would offer advantages over transplants: With a transplant, doctors screen donated feces for pathogens that might sicken the recipient. But, Pamer says, "there are many things, viruses that have yet to be identified, that could be in a crude fecal product that might cause trouble."

Pamer and his team gave mice antibiotics to deplete beneficial microbes but not wipe them out completely, then fed the mice *C. difficile* spores and identified microbes found in mice with less *C. difficile* in their guts. *C. scindens* was the clear victor. It is harmless and present in most people, but in very low numbers.

The researchers then grew *C. scindens* and fed the bacteria to mice before exposing them to *C. difficile*. Compared with mice that received no microbes, the *C. scindens*–fed mice ended up with lower amounts of *C. difficile* in their guts, lost less weight and were less likely to die.

The researchers also examined the microbial populations of 24 patients undergoing bone marrow transplants. Those patients had lowered microbial diversity after receiving combinations of antibiotics, radiation and chemotherapy. The patients who didn't develop *C. difficile* after the transplant were more likely to have *C. scindens* in their guts.

"This is a pretty big leap forward in figuring out why people are resistant or sensitive to infection," says microbiologist Joseph Sorg of Texas A&M University. ■

MATTER & ENERGY

Magnetic imager scans single proton

MRI-like technique could map individual biological molecules

BY ANDREW GRANT

A small MRI-like device made of diamond has performed a scan of a single proton, a big step toward using magnetic imaging to look in-depth at viruses, proteins and other nanosized biological objects.

"It's a really nice milestone," says physicist Daniel Rugar of the IBM Almaden Research Center in San Jose, Calif.

The new device works on the same principle as magnetic resonance imaging machines in hospitals: Strong magnetic fields orient the spins of hydrogen nuclei, each consisting of a single proton. Then the machine emits radio waves. The hydrogen nuclei absorb the radio waves and reemit them at a different frequency, which the scanner can detect and use to identify the location of the hydrogen.

MRIs work because water in human tissues includes trillions upon trillions of hydrogen nuclei. Plus, the response of hydrogen nuclei to a magnetic field varies slightly depending on their surroundings, allowing technicians to distinguish between bone, fat and tissue.

Physicists have been working to shrink MRI to visualize the nanoscale. "We want to apply MRI tricks to studying viruses, cells and individual molecules," says physicist Christian Degen of ETH Zurich. In 2009 he was part of a team that used a magnetic sensor to image a virus made up of, among other components, about 10,000 hydrogen atoms.

To zoom in even farther, Degen and his team built a device made of diamond. Pure diamond is a rigid lattice of carbon atoms. The team extracted two adjacent carbon atoms near the diamond's surface and replaced one with an atom of nitrogen. When the researchers shine green light on it, this simple impurity, called a nitrogen-vacancy center, emits red light.

The red light serves as a nanometer-sized flashlight; its brightness depends on the surrounding magnetic field. A thin film of a material called ammonium hexafluorophosphate placed atop the diamond deposited hydrogen nuclei just above the diamond's surface. Slight changes in the brightness of the emitted light from the nitrogen-vacancy center indicated the presence of a single proton less than a nanometer away, Degen's team reports October 16 in *Science*.

The result is an important advance toward using magnetic scanning to probe the structural intricacies of individual biological molecules, says Jörg Wrachtrup, a quantum physicist at the University of Stuttgart in Germany. ■

JANICE HANEY CARR/CDC

EARTH & ENVIRONMENT

Fracking not linked to contamination

In an Ohio county, gas in groundwater came from bacteria

BY THOMAS SUMNER

Fracking in Carroll County, the heart of Ohio's natural gas boom, hasn't contaminated groundwater, new research shows. The study is the first in the country to evaluate drinking water quality before and after the local onset of hydraulic fracturing, better known as fracking.

Some residential water wells did contain high levels of methane, which is the core component of natural gas. But researchers reported October 19 that the contamination came from natural biological sources such as soil bacteria, not leaky gas wells. Previous studies in Pennsylvania and New York have linked fracking with methane pollution in groundwater (*SN Online: 6/25/13*).

"Our data show that fracking can be done in a way that maintains the integrity of the groundwater," said Amy Townsend-Small, a geochemist at the University of Cincinnati.

Fracking taps the natural gas that fills pockets deep underground (*SN: 9/8/12, p. 20*). In some regions, such as the Utica Shale in northeastern North America, the gas spreads between many smaller cavities. To reach the trapped methane, companies drill down several kilometers and pump in fracking fluid, a mixture of water, sand and chemicals, at pressures high enough to fracture surrounding rock and allow the gas to bubble to Earth's surface.

Proponents of natural gas say the technique offers cheap fuel, but critics contend that the mixture of fracking fluid and gas could contaminate local groundwater. If the steel and concrete casings surrounding a fracking well fail, methane and fracking fluid can seep into groundwater. Despite the fracking boom in recent years, no previous studies had compared groundwater contamination before and after fracking activity began.

"The science woke up to the need for data after the drilling had occurred in a lot of places," said Stanford University environmental scientist Robert Jackson.

As the gas boom hit Ohio in 2012, Townsend-Small looked to Carroll County, which has the highest number of active gas wells in the state and roughly 90 percent of private land is leased to natural gas companies for underground gas extraction. She sampled 23 residential water wells several times a year.

In the lab, her team measured methane levels in the water. Methane doesn't pose a health hazard apart from its flammability, but it can signal that chemicals involved in fracking are escaping.

But methane in groundwater can also come from soil bacteria. To tell the difference, the team measured the different forms of carbon and hydrogen that make up the methane.

After more than two years collecting and testing water samples, the team detected only negligible levels of methane from most of the 23 wells, both before and after fracking began. The researchers did identify four homes with methane concentrations above the explosive threshold, the point where water becomes flammable. In all cases, the methane came from soil bacteria, not from natural gas.

So far, Townsend-Small hasn't seen an increase in methane as fracking activity has intensified or a correlation between methane levels and proximity to gas wells.

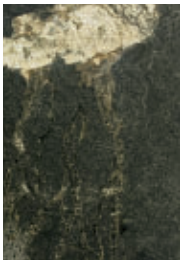
"That could change at any time," said geochemist Claire Botner, who works with Townsend-Small at Cincinnati. "Many of the [fracking] wells in Carroll County are just permitted, which means they're still waiting to be drilled." This year, the team has expanded its monitoring to 96 homes in a larger area of Ohio.

Long-term studies such as this one are important to improving fracking safety, Jackson said. "The most important thing is to figure out when things go right, why they went right," he said. "And when things go wrong, how do you keep them from happening elsewhere?" ■

MEETING NOTES

Ancient jellyfish suffered strange, sandy death

A handful of sand locked in shale tells an unlikely story of an ancient jellyfish. Graham Young of the Manitoba Museum in Winnipeg and a colleague reconstructed the jelly's final moments. The index card–sized jelly (fossil shown) got stranded on a beach some 310 million years ago, Young thinks. Floundering to free itself, the jelly filled with sand. After the animal died, a storm or large wave carried the carcass to an oxygen-deprived lagoon, where the jelly sank into the earth. Over time, the ground hardened, trapping the sand-filled jelly. The jellyfish's preservation could explain how sand patches can get embedded in geologic formations typically devoid of sand, Young said October 21. — *Thomas Sumner*



G. YOUNG

Some trilobites sported dual digestive systems

Some trilobites scurrying across the seafloor around 500 million years ago had two-lane digestive tracts. Michael Rutana of Ohio State University studied eight trilobite fossils. Using a CT scanner, he blasted each specimen with X-rays to create a 3-D density map. Because a trilobite's fossilized body is denser than the stomach cavity, Rutana could trace the digestive system as a dark line from mouth to anus. Two trilobites had odd digestive diagrams not seen in modern animals: two parallel tracts forking from the stomach and reconnecting at the anus. Rutana said October 21 that he thinks the two pathways could have boosted nutrient absorption by increasing the amount of surface area in contact with food. — *Thomas Sumner*

GENES & CELLS

Jet lag disrupts microbes in the gut

Mice with time-shifted bacteria develop metabolic problems

BY TINA HESMAN SAEY

Jet-lagged gut microbes may promote obesity and diabetes. The new findings indicate that gut microbes may be responsible for some of the health hazards of jet lag and shift work.

Gut microbe communities follow daily rhythms, changing composition and gene activity to a beat set by eating, researchers report in the Oct. 23 *Cell*. Jet lag or other glitches in the host's biological rhythms throws the microbes out of sync.

When mice's gut bacteria got off their usual beat, they somehow produced changes in the host's metabolism that made mice vulnerable to gaining weight and to impaired glucose responses, a hallmark of diabetes. Two people jet-lagged by travel from the United States to Israel had microbial mixes in their feces that were richer in Firmicutes than before their trips. Firmicutes is a phylum of bacteria that has been linked to obesity.

When immunologist Eran Elinav of the Weizmann Institute of Science in Rehovot, Israel, and colleagues treated jet-lagged mice with antibiotics, the obesity and glucose-response problems disappeared. Gut bacteria transplanted from jet-lagged people or mice into mice raised without any bacteria also transferred glucose-response problems and the tendency to pack on the pounds. Three weeks after the transplant, mice with bacteria from jet-lagged people weighed roughly 30 percent more than did mice with bacteria from non-jet-lagged people.

The results back earlier findings that when you eat may be as important as what you eat (*SN: 4/10/10, p. 22*), says geneticist Satchidananda Panda of the Salk Institute for Biological Studies in La Jolla, Calif.

The study also shows how dynamic microbial communities are. Some research has suggested that the gut microbiome a person gets as an infant stays pretty much the same for life. But newer studies have found that dietary changes can shift gut microbe compositions within a day (*SN Online: 12/11/13*). This study, Panda says, "shows tremendous shifts in the microbiome in hours."

Microbial rhythms need regular meal times to stay on beat, the team found. In mice eating on an irregular schedule, gut microbe communities had random spikes and declines in the abundance of certain bacteria, instead of the predictable shifts seen in mice eating regularly. Putting the mice on a normal schedule restored cycles of changing microbe mixes. ■

HUMANS & SOCIETY

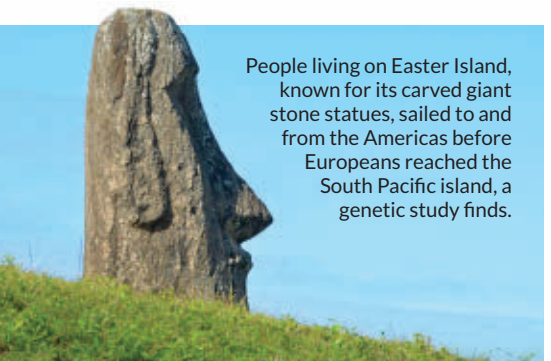
Easter Islanders sailed to America

Sea crossings occurred well before European contact

BY BRUCE BOWER

The massive stone heads on Easter Island don't stare out to sea, but perhaps they should. Residents of what's also known as Rapa Nui sailed back and forth to the Americas hundreds of years before Europeans reached the isolated Polynesian island in 1722, a DNA study suggests.

Genetic ties between present-day Easter Islanders and Native Americans indicate that members of these populations mated between roughly 1280 and 1495, says a team led by geneticist Anna-Sapfo Malaspinas of the Natural History Museum of Denmark in Copenhagen. Previous evidence suggested that Polynesians settled Rapa Nui around 1200.



People living on Easter Island, known for its carved giant stone statues, sailed to and from the Americas before Europeans reached the South Pacific island, a genetic study finds.

NATALIA SOLAR

Rapa Nui navigators probably made the 3,700-kilometer trek by canoe to the Americas and returned home one or more times, the team reports in the Nov. 3 *Current Biology*. Previous computer simulations concluded that a vessel sailing east from Rapa Nui would reach the Americas in two weeks to two months.

Westward ocean voyages by Native Americans to Rapa Nui were unlikely, the team says. The 163-square-kilometer island is an earthen speck in the vast South Pacific that is easy to miss for those who don't know it's there.

Malaspinas and colleagues compared more than 650,000 DNA markers across the genomes of 27 present-day Rapa Nui natives, 17 Native Americans, 58 Europeans and 114 people from Asia and other South Pacific islands. Genetic markers occur in distinctive patterns in various populations and can be used to estimate DNA contributions of one population to another.

Rapa Nui people have an average of 76 percent Polynesian ancestry, with genetic contributions of 16 percent from Europeans and 8 percent from Native Americans.

The researchers calculated the time when Native Americans mated with Easter Islanders by using clues to the age of DNA segments inherited by one population from another, such as the tendency of these genetic fragments to become smaller in successive generations.

A second study in the same *Current Biology*, also led by Malaspinas, finds that two ancient skulls from a Brazilian group known as Botocudos have entirely Polynesian ancestry. Radiocarbon dating indicates the individuals probably died before 1760, when European trading ships began crossing the Pacific. So it's likely that the Botocudos reached South America via Polynesian seafaring, Malaspinas says.

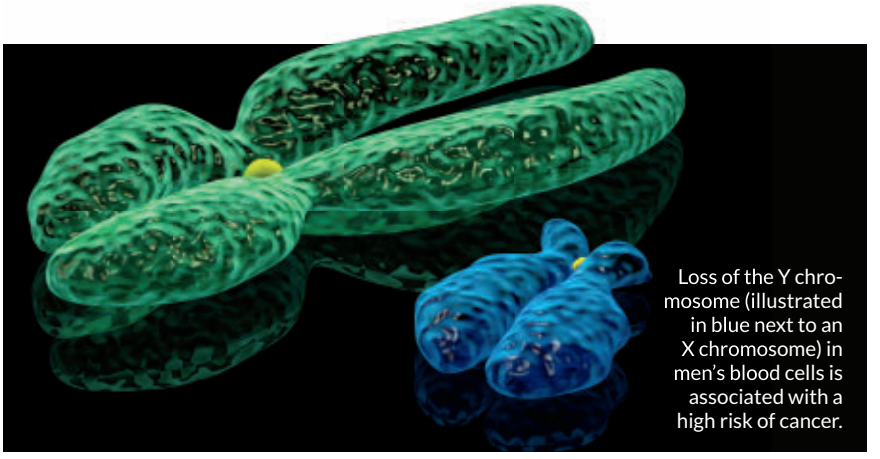
"These are provocative findings that point to the need for studies of ancient DNA collected from skeletons of Easter Islanders, other Polynesians and Native Americans," says archaeologist Carl Lipo of California State University, Long Beach. ■

GENES & CELLS

Y chromosome linked to cancer

Chromosome loss in blood cells may cut men's life span

BY TINA HESMAN SAEY



Loss of the Y chromosome (illustrated in blue next to an X chromosome) in men's blood cells is associated with a high risk of cancer.

Losing the Y chromosome in blood cells may bring on cancer and shorten men's lives, new research suggests. By age 70, about 15 percent of men have lost the Y chromosome from a proportion of their blood cells, statistician and bioinformaticist Lars Forsberg of Uppsala University in Sweden reported October 21.

Forsberg and his colleagues made the discovery by examining the DNA of more than 6,000 middle-aged and elderly Swedish men.

In June, Forsberg's team reported linking Y chromosome loss to a higher risk of several types of cancer and a decreased life span in a smaller group of men. Men who have lost the Y chromosome in at least 10 percent of their blood cells have an average life expectancy of 5.5 years, while men who keep their Y's live around twice as long. The older a man gets, the more of his blood cells lack a Y chromosome, the researchers found.

The loss may weaken immune cells, including white blood cells, making it harder to fight off cancer, Forsberg said.

The researchers think that Y chromosome loss may start sometime around age 40 but doesn't become detectable until 5 to 10 percent of blood cells are missing the chromosome. Y chromosomes are probably lost when cells divide, with some cells failing to divvy up their chromosomes equally. The team is still investigating what might trigger the process in middle age.

A separate study of more than 8,500 men with cancer and more than 5,300 healthy men also found that Y chromosome loss increases with age. About 19 percent of the men were missing the chromosome in some proportion of blood cells by age 80, Stephen Chanock of the National Cancer Institute in Rockville, Md., and colleagues reported October 19. Cigarette smoking may get Y chromosome loss started, the researchers found.

Although Chanock's group found no association with shorter life span, the team did find a link between missing Y chromosomes and certain cancers.

"They've discovered a correlation that replicates, so it's probably not a fluke," said Michael Province, a statistical geneticist at Washington University in St. Louis, noting that the two research teams independently discovered the correlation in different groups of men.

But that doesn't necessarily mean that losing the Y chromosome causes cancer, he stressed. "We just know that they're cohappening." Different types of studies are needed to find the nature of the relationship between Y chromosome loss and cancer, Province said.

Even if losing the Y chromosome doesn't cause cancer, the event might signal that a man is at risk, said Forsberg. Men missing Y chromosomes in blood cells should probably receive more frequent cancer screening, he suggested. ■

GENES & CELLS

Brits may lack Anglo-Saxon ancestry

DNA from ancient skeletons forces rethink of British history

BY TINA HESMAN SAEY

Britons might not be Anglo-Saxons, a genetic analysis of five ancient skeletons hints.

When archaeological digs revealed old graves on the grounds of the Wellcome Trust Sanger Institute in Hinxton, England, researchers there took it as a sign to analyze the ancient people's DNA. Two skeletons were from men who were buried about 2,000 years ago. The other three skeletons were from women who died about 1,300 years ago, not long after the Anglo-Saxons invaded Britain from what's now Germany and Denmark.

The researchers were surprised to find that the older Iron Age men were genetically more similar to people living in Britain today than the Anglo-Saxon women were. Stephan Schiffels of the Wellcome Trust Sanger Institute reported the results October 20.

"It doesn't look like these Anglo-Saxon immigrants left a big impact on the genetic makeup of modern-day Britain," Schiffels said.

The finding raises an intriguing possibility that indigenous people in Britain may have repelled the Anglo-Saxons but adopted the invaders' language and culture, said Eimear Kenny, a population geneticist at the Icahn School of Medicine at Mount Sinai in New York City, who was not involved in the work.

More ancient samples from other times and parts of Britain should give a clearer picture of that episode of history, she said. ■

KNORRE/SHUTTERSTOCK

EARTH & ENVIRONMENT

Early animals couldn't catch a breath

Low oxygen levels may have hindered evolution of complex life

BY RACHEL EHRENBERG

The diversification of early animals may have been suffocated by a lack of oxygen. A new analysis of ancient rocks offers a glimpse of conditions in the millions of years leading up to the proliferation of animals. The data suggest that oxygen levels were less than 1 percent of today's levels, low enough that they may have stalled the emergence of animal life.

Scientists have been puzzled by a prominent lag in life's timeline. Around 2.3 billion years ago, cyanobacteria were producing such quantities of oxygen that scientists refer to that time as the Great Oxygenation Event. But then things got quiet, and Earth entered a period known as the boring billion. It wasn't until some 800 million years ago that multicellular animals appeared (*SN: 12/31/11, p. 12*).

Researchers have been unclear about the role of environmental factors in this delay, especially the availability of oxygen (*SN: 9/7/13, p. 12*), says paleobiologist Nicholas Butterfield of the University of Cambridge."Large things don't appear on the scene until very late, not until 500 to 600 million years ago, which is sort of yesterday," he says.

Previous estimates of the boring billion's atmospheric oxygen levels — a proxy for oxygen in the shallow oceans, where animal life emerged — have varied from 1 to 40 percent of today's levels.

The new analysis examined the metal chromium in ancient marine sediments collected in China, Australia, the United States and Canada. When oxygen is present, chromium reacts with other metals. A heavier version of chromium, chromium-53, is more likely to undergo these oxygen-related reactions and then get washed into the oceans than the lighter chromium-52. By looking for differences in the relative amounts of chromium-52 and chromium-53, scientists can deduce how much oxygen was once present.

There was a marked increase in chromium-53 in samples dating to roughly 800 million to 750 million years ago. This shift suggests a rise in oxygen that would have enabled the rise of complex life, the researchers propose in the Oct. 31 *Science*. The team found no evidence of such chromium shifts in ironstones from four formations that ranged from 1.7 billion to 900 million years old.

"This breathes life, so to speak, into the idea that the diversification of life on the planet was controlled by the environment," says study coleader Noah Planavsky of Yale University.

Butterfield disagrees. Invoking an environmental trigger to allow diversification isn't necessary, he says. He maintains that the task of evolving complex animals' gene and regulatory networks would have taken a long time even in ideal conditions.

Framing the debate as environmental versus internal constraints is too simplistic, says paleobiologist Doug Erwin of the Smithsonian Institution in Washington, D.C. The new work adds to data suggesting that the environment was unstable, and rather than a gradual rise in oxygen, levels may have been highly dynamic. ■

ATOM & COSMOS

A comet touchdown

NAVCAM/ROSETTA/ESA (CC BY-SA 3.0 IGO)

DARMSTADT, GERMANY — Philae has landed. After separating from the Rosetta spacecraft and free-falling through deep space for roughly seven hours, the minifridge-sized machine touched down on comet 67P/Churyumov-Gerasimenko (shown) on November 12. The landing marks the first time scientists have set a probe on the surface of a comet.

"We are on the comet," said Philae project manager Stephan Ulamec as soon as the signal came through at the European Space Agency's operation center. He confirmed that the lander was alive and well.

The Rosetta spacecraft and its lander Philae arrived at the comet on August 6 (*SN: 9/6/14, p. 8*), and Rosetta immediately began snapping images of the comet's surface and studying the space rock's gravity and other features. Much of the data helped scientists prepare for Philae's touchdown. Now, both the spacecraft and the lander will start scrutinizing the comet in greater detail. What the probes discover could give clues to the environment that comets were born in and whether the rocky, icy boulders could have brought water and other building blocks of life to Earth (*SN: 11/1/14, p. 22*).

Philae plans to beam back data until March. Rosetta is slated to study the comet until at least December 2015. — *Ashley Yeager*

Heavy milk drinking may double women's mortality rates

Consumption of the drink coincided with higher chances of death due to cancer, heart disease

BY NATHAN SEPPA

Despite delivering calcium and protein, drinking a lot of milk doesn't seem to provide a net health benefit for women and may even hinder their long-term survival prospects, Swedish researchers find. Over the course of about 20 years, women who drank three or more glasses of milk per day were almost twice as likely to die as those who drank less than one, other things being equal. Intake of cheese, yogurt or buttermilk might offer a better approach to dairy, the data suggest.

The widespread assumption that milk is inherently good has arisen despite a lack of randomized trials.

The study raises hard questions about the nutritive value of milk, says epidemiologist C. Mary Schooling of the City University of New York and Hunter College in New York City. "There's something about milk and purity that got all tangled up. It's almost a cultural belief." The widespread assumption that milk is inherently good has arisen despite a lack of randomized trials capable of parsing the true health value of the drink, she says. The authors of the new study deserve credit, she adds, "because they were thinking about the biology" of milk consumption.

Specifically, the researchers augmented their mortality findings with evidence suggesting that a sugar called D-galactose underlies milk's downsides. Chronic exposure to the sugar triggers chronic inflammation, oxidative stress and rapid aging in mice, the researchers note. Study coauthor Karl Michaëlsson, a physician and researcher at Uppsala University, points out that milk delivers plenty of lactose, which breaks down into D-galactose. Cheese and other fermented milk products deliver less of both sugars.

Michaëlsson and colleagues analyzed roughly 20 years of health data from more than 60,000 adult women. The participants had provided information on their diet and other lifestyle factors through questionnaires at the outset of the study and again several years later. Women who drank three or more glasses of milk per day were 1.93 times as likely to have died during the study as women who averaged less than a glass a day, the researchers report October 28 in *BMJ*.

Compared with those drinking little or no milk, the women who drank the most were also slightly more likely to die of heart problems or cancer or to break a hip. But their overall risk of any fracture was barely higher than the nonmilk drinkers' risk.

The researchers accounted for a host of factors in their analysis, including age, education, diet, smoking, alcohol intake and supplementation with calcium or vitamin D.

In a similar assessment of more than 45,000 adult men followed for 11 years in Sweden, the researchers found little effect from drinking three or more daily glasses of milk. Those who drank that much were 10 percent more apt to die during the study than those who drank little milk, but they weren't more prone to fractures or lethal cancer.

Michaëlsson says the difference in results between men and women is curious. It might reflect weaker data due to the fact that there were fewer men, they weren't followed as long and they filled out only one questionnaire, he says.

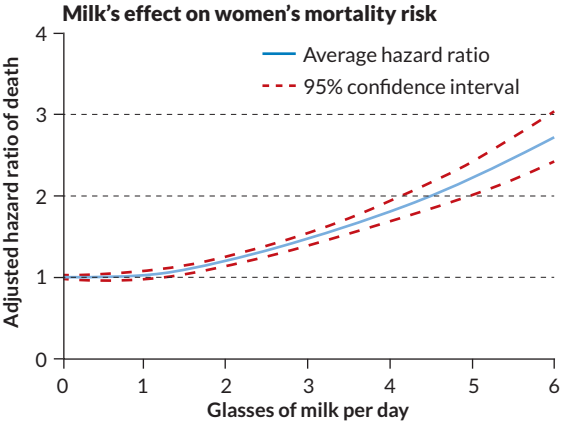
The scientists also assessed oxidative stress in the body by analyzing urine samples from hundreds of the men and women in the study. People who consumed lots of milk had higher concentrations of a telltale oxidative stress marker. Men who drank plenty of milk also averaged higher levels of interleukin-6, an inflammatory marker, a blood analysis showed. Inflammation and oxidative stress are linked to many ailments.

High consumption of yogurt and buttermilk produced the opposite effect — less inflammation and oxidative stress. One possibility, Michaëlsson surmises, is that fermented milk products "might render a better bacterial profile in the intestines."

That's possible, says Schooling. Even so, she says, the ability to digest milk is a trait that has been selected for evolutionarily as some groups gained tolerance to lactose. So milk must have value, she says. "But there are people in other parts of the world who very rarely drink milk, and they are fine."

While Michaëlsson hesitates to make broad recommendations based on the findings, he has taken them to heart. "I like milk. In Sweden, we like milk," he says. "But I've changed my diet to yogurt because of these studies." ■

Sour milk Women who drank three or more glasses of milk per day had a higher risk of death during a long-term study than did women who drank little or no milk (a hazard ratio of 2 equals a doubled mortality risk). SOURCE: K. MICHAËLSSON *ET AL*/*BMJ* 2014



LIFE & EVOLUTION

Rover doesn't spook penguins

Skittish penguins let their guard down when researchers send a fluffy, remote-controlled "robochick" (right) into their midst. The rover causes the animals less stress than humans do and may prove useful in studies of other wild populations, researchers report November 2 in *Nature Methods*. Scientists often monitor wild animals by slipping a tag under the skin that a radio-frequency reader identifies. To recognize the tags, a reader must get within 60 centimeters. No matter how unobtrusively scientists sidle up to them, animals still get spooked. To test an alternative, researchers sent a remote-controlled rover into penguin colonies in Antarctica and the Crozet Islands. The team equipped king penguins with heart rate monitors. When a person comes close, "all the birds facing the human will retreat very slowly with a high heart rate," says coauthor Yvon Le Maho of the University of Strasbourg in France. But when the rover trundled up, the penguins stayed calm. Emperor penguins, however, initially retreated from the rover. So the team came up with a disguise: a fake penguin chick. Emperor penguins not only allowed the masked rover to approach, they even tried to vocalize to it and let it join a huddle of chicks. — *Kate Baggaley*

EARTH & ENVIRONMENT

Oil from BP spill sits on seafloor

Oil that gushed from the 2010 Deepwater Horizon site may be lying low. As much as 16 percent of the approximately 5 million barrels of oil let loose into the Gulf of Mexico may have settled into the seafloor, within a 40-kilometer radius of the damaged oil well. That oil may account for up to about 30 percent of the approximately 2 million barrels of oil that scientists suspect never reached the sea surface. Led by David Valentine of the University of California, Santa Barbara, researchers found the submerged oil by searching for hopane, a component of oil that is not easily broken down. By analyzing more than 3,000 ocean sediment samples from 534 locations in the gulf, the team mapped patches of the remaining oil, sunken in a 3,200-square-kilometer region around the well. The researchers, reporting October 27 in the *Proceedings of the National Academy of Sciences*, suggest that the rest of the oil that never reached the surface may still be hiding elsewhere in the ocean. — *Beth Mole*

HUMANS & SOCIETY

Ice Age hunter-gatherers lived at extreme altitudes

Hunter-gatherers inhabited high-altitude settings centuries earlier than archaeologists thought. Two sites in the Peruvian Andes are between 12,800 and 11,500 years old and are more than 4,300 meters high, making them the highest Ice Age settlements ever found. The sites date to about 2,000 years after hunter-gatherers first arrived in South America, indicating that people colonized and adapted to the extreme environment relatively quickly, Daniel Sandweiss of the University of Maine in Orono and colleagues report in the Oct. 24 *Science*. The team used radiocarbon dating from animal bones and the distinctive design of fluted projectile points at the sites to determine their age. — *Kate Baggaley*

MATTER & ENERGY

Atom breaks limit of lost electrons

For atoms, bonding involves a give, take and sharing of electrons. For more than 100 years, scientists thought that eight electrons were the limit of a single atom's generosity. But now it's nine, Guanjun Wang of Fudan University in Shanghai and colleagues report in the Oct. 23 *Nature*. By blasting an iridium oxide compound with a laser, the team detected the first atom, iridium, to give up nine of its electrons. Scientists had speculated that such a situation, called an oxidation state of plus nine, was possible. Because iridium has nine electrons in its outer layers, it was an excellent candidate for setting the new record. The upped oxidation state allows the iridium to be a powerful oxidizer, capable of snatching electrons from other atoms. The finding opens new possibilities for myriad industrial chemical reactions as well as rewriting the rules of bonding, says Gregory Girolami of the University of Illinois at Urbana-Champaign, who was not involved in the work. — *Beth Mole*

BODY & BRAIN

Daylight saving time tied to more exercise in children

Kids are somewhat more active in the evening when daylight saving time is in effect than when it's not, researchers report October 23 in the *International Journal of Behavioral Nutrition and Physical Activity*. Anna Goodman of the London School of Hygiene and Tropical Medicine and colleagues analyzed data from 15 studies of more than 23,000 children ages 5 to 16 who wore devices on their waists that measure physical activity. The kids were active 33 minutes a day on average. During daylight saving time, the kids averaged an additional two minutes of moderate-to-vigorous exercise overall. Children's activity was unaffected in mornings and early afternoons, but kids in Europe and Australia were more active in late afternoon and evening during extended daylight. That effect didn't show up in kids in the United States, Brazil or the Portuguese archipelago Madeira. The two-minute addition is "modest but not trivial," the researchers note, since it represents roughly 5 percent more daily activity. — *Nathan Seppa*

Y. LE MAHO *ET AL*/*NATURE METHODS* 2014

Watch penguins inspect the rover at **bit.ly/SN_robochick**

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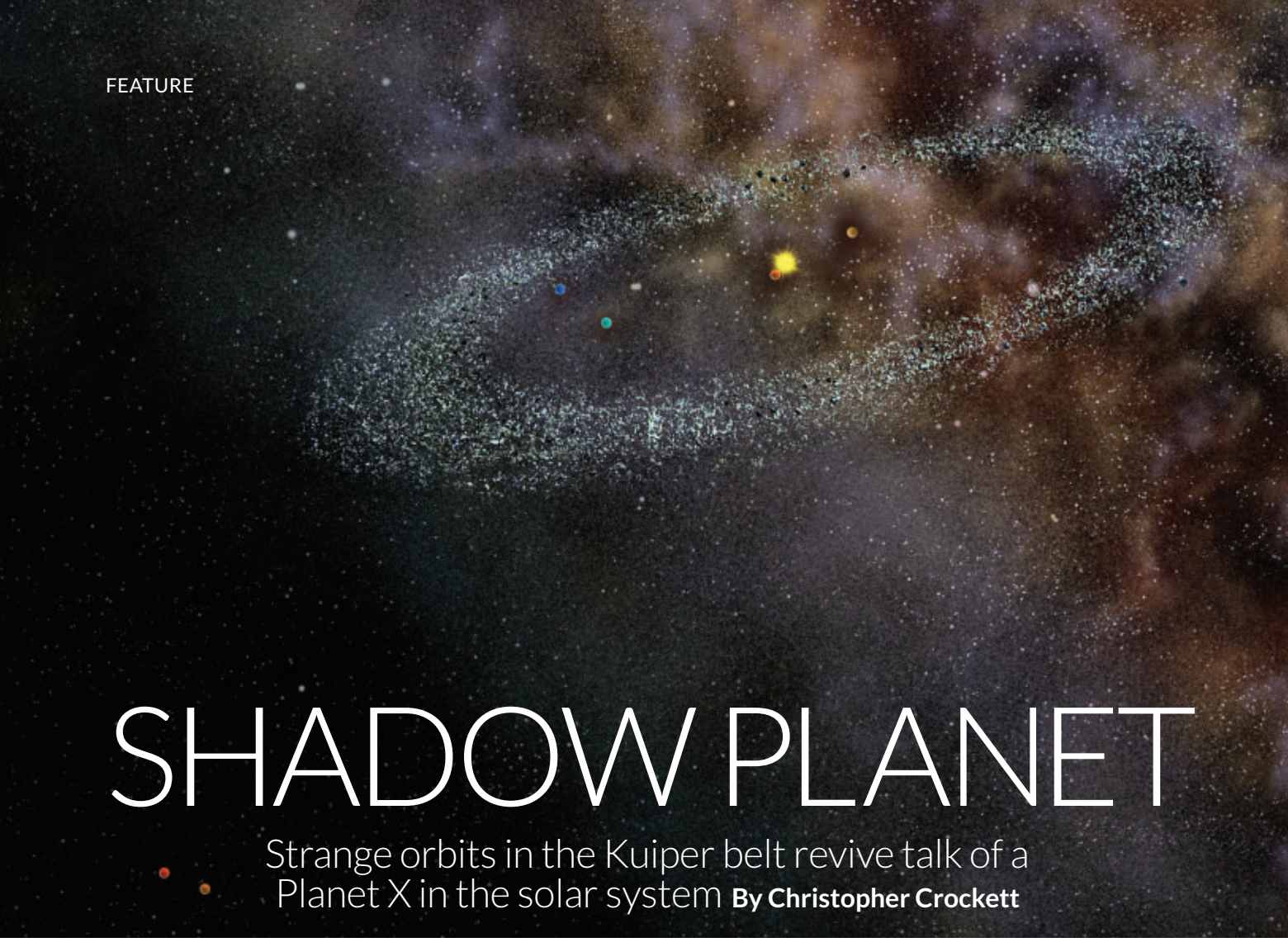


SHADOW PLANET

Strange orbits in the Kuiper belt revive talk of a Planet X in the solar system

By Christopher Crockett

Out beyond Neptune, the solar system resembles the deep ocean: dark, remote and largely unexplored. To an Earth-bound observer, even the brightest objects, such as Pluto, are 4,000 times as faint as what the human eye can see. An undiscovered planet could easily lurk out there unnoticed, a possible fossil from a time when the giant planets jockeyed for position 4 billion years ago, scattering planets and asteroids in their wake. But even the largest telescopes would struggle to find such a faint spot of light. Most likely, the clues would be entangled in the distorted orbits of faraway ice boulders tumbling around the sun.

Astronomers Chad Trujillo and Scott Sheppard provided a hint about how such a world might reveal itself last March when they announced the discovery of a 450-kilometer-wide dwarf planet just outside the Kuiper belt — the icy debris field past Neptune (*SN*: *5/3/14, p. 16*).

Their find, designated 2012 VP_{113}, is on a course that loops around the sun in a vastly elongated orbit far from the known planets. It has thousands of neighbors but shares its odd trajectory only with Sedna, another dwarf planet, discovered in 2003.

"They're kind of in a no-man's-land," says Sheppard, of the Carnegie Institution for Science in Washington, D.C. "These objects couldn't get out there with what we currently know."

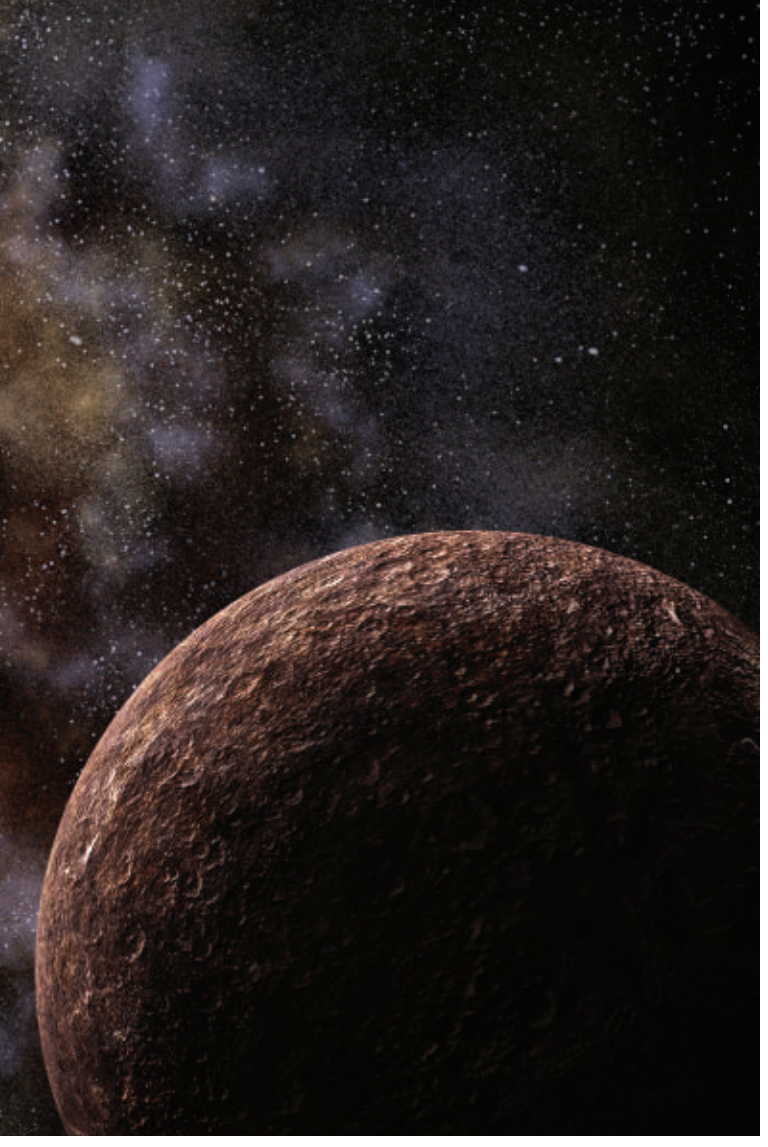
Something had to drag the two dwarf planets from their original, smaller orbits. Except nothing is close or massive enough to take the credit. At least, nothing astronomers are aware of.

The discovery of 2012 VP_{113} confirmed that Sedna is not a fluke but is possibly the first of a large population of icy bodies distinct from others in the rest of the solar system. So Trujillo and Sheppard continued to poke around the Kuiper belt, and the mystery deepened. They noticed that beyond 150 astronomical units (150 times the distance from the sun to the Earth), 10 previously discovered objects, along with Sedna and 2012 VP_{113}, follow orbits that appear strangely bunched up.

"That immediately piqued our interest," says Sheppard. Could an unseen planet, a Planet X, be holding the orbits of all these far-out bodies in place?

"The idea's not crazy," says David Jewitt, a planetary scientist at the University of California, Los Angeles. "But I think the evidence is slim." The trail of bread crumbs leading to an undiscovered planet is sparse: just 12 chunks of ice lead the way. But it's enough to get some researchers wondering about a ninth (or 10th, depending on your attitude regarding Pluto)

NICOLLE RAGER FULLER



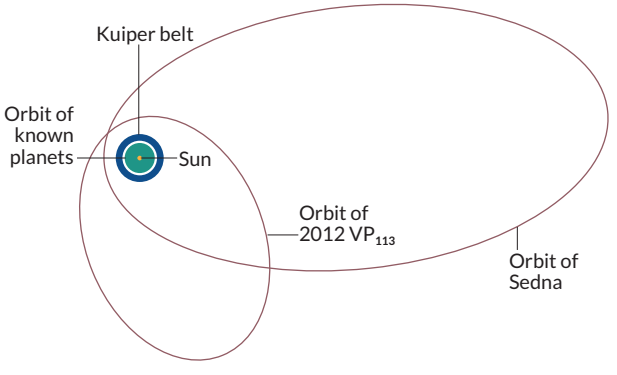
A hidden planet (foreground) might lurk in the uncharted realms of the solar system, leaving clues to its existence only in the orbits of dwarf planets or of chunks of ice in the outer edges of the Kuiper belt.

planet roaming the outer solar system and how it might have arrived there.

Kuiper belt clues

"The exciting thing for me is that 2012 VP_{113} exists," says Megan Schwamb, a planetary scientist at Academia Sinica in Taipei, Taiwan. "Whatever put Sedna on its orbit should have put a whole bunch of other objects out there."

Distant wanderers Dwarf planets Sedna and 2012 VP_{113} travel well beyond the known planets and the Kuiper belt along highly stretched orbits, which implies something once dragged them out there.



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The enormous, stretched orbits of Sedna and 2012 VP_{113} are unlike anything else in the solar system. Both are too far from Neptune to feel its effects. And they're too far from the Oort cloud, the distant shell of ice boulders thought to envelop the solar system. Their trajectories could be a relic of a passing star, or the changing influence of the Milky Way's gravity as the sun moves around the galaxy — or of a massive planet, long-gone or yet to be detected.

The case for an additional planet got stronger when Trujillo and Sheppard realized that Sedna and 2012 VP_{113} had something in common with 10 other objects. All the objects beyond 150 astronomical units come closest to the sun, a point known as perihelion, at nearly the same time that they cross the plane of the solar system. There's no reason for these perihelia to bunch up like that. Billions of years of evolution should have left the perihelia scattered, like the rest of the Kuiper belt — unless something was holding the perihelia in place.

Trujillo and Sheppard estimated that a planet about two to 15 times as massive as Earth, at a distance of 250 astronomical units (about eight times as far from the sun as Neptune) could explain why these 12 perihelia were bunched together. But the astronomers admit that's not the only possibility. A closer planet as massive as Mars would have the same effect as a Neptune-mass body much farther away.

"A few years ago everyone thought that nothing relevant other than just plain asteroids and comets inhabited that region," says physicist Carlos de la Fuente Marcos. "Now the observational evidence indicates that probably we were wrong." He and his brother Raúl, both at the Complutense University of Madrid, took a closer look at the orbits. The brothers claim, in the Sept. 1 *Monthly Notices of the Royal Astronomical Society Letters*, that not one but two planets are needed to explain the perihelion clustering.

Around the same time, physicist Lorenzo Iorio at the Ministry of Education, Universities and Research in Bari, Italy, offered a different take. He says that the planet proposed by Trujillo and Sheppard, if it exists, must be much farther out — at least twice as far as the original prediction. By looking at gradual changes in the orbits of a few of the known planets, Iorio calculated that a planet twice as massive as Earth must be at least 500 astronomical units from the sun, according to research in the Oct. 11 *Monthly Notices of the Royal Astronomical Society Letters*.

Others are more cautious. "The outer solar system can be full of all sorts of unseen and interesting things," Jewitt says, "but the argument ... for a massive perturber is a bit puzzling." First, 10 of the 12 bodies with peculiar perihelia dive far enough into the Kuiper belt to possibly feel Neptune's gravity. And, second, he says, 12 objects is a tiny sample — the apparent perihelion clustering may just be an illusion caused by where researchers point their telescopes.

The recent speculation about additional planets has a familiar ring, says Jewitt. In the late 1800s and early 1900s, astronomers relied on apparent hiccups in Neptune's motion and a handful of comets to kick off a search that eventually led to the discovery of Pluto. "Not much has changed since then," he says. In fact, musings of a planet beyond Neptune have been around since before anyone knew Neptune existed.

Planet hunters

In 1834, German astronomer Peter Andreas Hansen allegedly suggested to a colleague that two planets were needed to explain oddities in the motion of what was then the farthest known planet, Uranus — oddities that led to the discovery of Neptune in 1846. Two years later, French astronomer Jacques Babinet claimed that Neptune also stumbled along its orbit, hinting that a ninth planet must have been causing Neptune to speed up and slow down as it ran around the sun.

Over the next half century, the search for more planets went in and out of vogue. Like a game of solar system Whac-A-Mole, new predictions popped up after each claimed discovery was trounced. The predictions relied on observations of Neptune as well as a handful of comets that reached their farthest point from the sun at nearly the same distance, a clue that a massive planet was bringing the comets all to the same point before the comets returned to the sun.

In the early 1900s, Boston-born polymath Percival Lowell got into the planet-hunting game. It's not clear if Lowell was the first person to use the phrase "Planet X," but he certainly popularized it. Lowell calculated where Planet X should be, based on observations of Uranus and Neptune. Thirteen years after Lowell died in 1916, American astronomer Clyde Tombaugh picked up the torch, using Lowell's calculations as a guide. Tombaugh's systematic observations led him to Pluto in 1930, close to where Lowell predicted Planet X would be.

Pluto's fall from grace started months after its discovery. Unlike the other eight planets, which travel on flat, circular orbits, Pluto speeds through Neptune's orbit along a stretched, cockeyed trajectory. The diminutive planet didn't appear massive enough to push the outer planets around. Estimates for Pluto's mass dwindled until astronomer James Christy discovered Charon, Pluto's largest moon, in 1978. Christy used the moon's motion to weigh Pluto and found that the outermost planet had only 0.2 percent of Earth's mass. If something was tugging on Uranus and Neptune, Pluto was much too small to be the culprit.

NASA's Voyager 2 spacecraft settled the Planet X question — for a time. When the probe flew past Uranus and Neptune in the 1980s, it gave astronomers better data to revise the masses of the planets. The new data revealed that nothing was pulling on them. Tombaugh finding Pluto where Lowell's calculations pointed was just a coincidence.

The search for Planet X quieted, never disappearing, but not taken seriously. Planet X became a favorite of the tinfoil-hat crowd, who were convinced that NASA was hiding knowledge of a planet that would either crash into Earth or hurl a barrage of comets our way. The end, as always, was near.

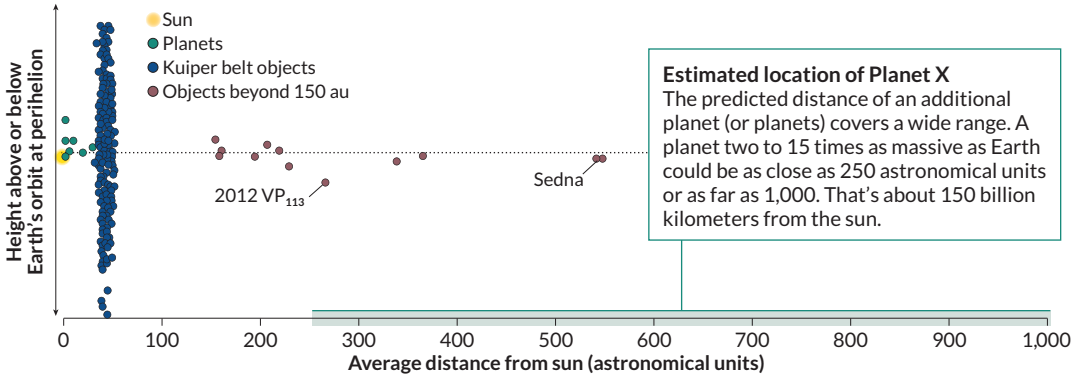
Modern planetary research has been plagued by rough

A well-worn idea Enthusiasm for planets beyond Neptune has come and gone over the 168 years since Neptune's discovery — and will continue as researchers probe deeper into the Kuiper belt.

Year	Event
1846	Neptune discovered
1848	First prediction of planet beyond Neptune
1851	First claimed discovery of unknown planet
1879	Comet orbits imply a ninth planet
1892	First photographic search for planet ends; nothing found
1906–1916	Lowell searches for Planet X until his death
1930	Tombaugh discovers Pluto near where Lowell predicted it
1978	Charon discovered; Pluto's mass measured at 0.2% of Earth's
1992	No evidence of Planet X from Voyager 2 measurements of Uranus and Neptune masses
1992	Jewitt discovers first recognized Kuiper belt object
2003	Sedna discovered
2006	Pluto demoted to dwarf planet
2012	2012 VP_{113} discovered
2014	WISE data show no evidence for large planet in outer solar system
2015	New Horizons spacecraft to fly by Pluto
2023	Large Synoptic Survey Telescope to begin operations

Cramped orbits
All known objects beyond 150 times the distance from the sun to Earth make their closest approach to the sun (perihelion) as they pass through the plane of the solar system. Those perihelia should be spread out like Kuiper belt objects. The reason they are not is a mystery.

SOURCES: C.A. TRUJILLO AND S.S. SHEPPARD; JPL/CALTECH; IAU MINOR PLANET CENTER



E. OTWELL

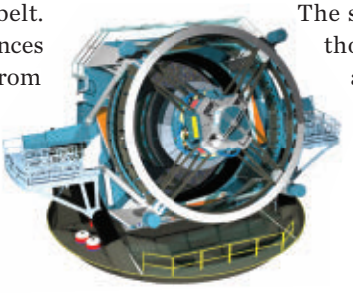
estimates and few objects to study. "What this means," Schwamb says, "is the observers need to go back to work." Only a detailed accounting of the darkness beyond Neptune will help researchers figure out if something is there.

If that something exists, it can't be as massive as Jupiter or Saturn. Kevin Luhman, an astronomer at Penn State, looked for Jupiter doppelgängers in images from NASA's WISE satellite, a 10-month mission to scan the entire sky twice with an infrared telescope. Massive planets are best seen in infrared light because they're still cooling off from their formation. Jupiter, for example, radiates more heat than it receives from the sun.

Reporting in the Jan. 20 *Astrophysical Journal*, Luhman found no evidence for a Jupiter-mass planet within 82,000 astronomical units. Likewise, there's no sign of something as massive as Saturn out to about a third as far. But Luhman says he can't rule out a small, rocky planet, which would be too cold for WISE to pick up.

The best bet is to look for reflected sunlight, which is how scientists discovered Pluto and the Kuiper belt. But even large worlds at such enormous distances are extremely dim. If Pluto was twice as far from the sun, it would be one-sixteenth as bright because the sunlight not only has to get out there but also has to come back.

"We would not yet have detected the Earth," says Jewitt, "if it were more than 600 astronomical units from the sun." And that's assuming researchers knew where to look. "That gives you an idea of the darkness of the outer solar system."



The Large Synoptic Survey Telescope in Chile, illustrated here, will make a 10-year-long movie of the night sky starting in 2023.

Instead of trying to directly observe a planet, researchers are looking for more Kuiper belt objects, whose orbits might bear the gravitational signature of something unseen. Trujillo and Sheppard discovered 2012 VP_{113} as part of an ongoing effort to scan the sky from Cerro Tololo Inter-American Observatory in Chile. Undoubtedly, more interesting objects will turn up.

Most telescope searches, however, are akin to mapping the universe while staring through a drinking straw. Telescopes see a tiny fraction of the sky, and observatories dole out access just a few days at a time. Sheppard says that it will take them several years to cover just 20 percent of the sky.

Enter the Large Synoptic Survey Telescope, or LSST, an 8.4-meter-wide telescope being built in northern Chile with full operations planned for late 2023. Unlike other telescopes, it will have an enormous field of view and will make a decade-long movie of the sky, perfect for looking for moving points of light.

Lynne Jones, an astronomer at the University of Washington in Seattle, says the LSST could find 20,000 to 40,000 more bodies in the Kuiper belt. With about 20 times as many Kuiper belt objects in hand, astronomers should be able to see if there are more objects with bizarre orbits and determine if the bunching of perihelia is real or just an artifact of having found only a few.

Plus, says Jones, LSST could detect an Earth-sized planet out to between 300 and 500 astronomical units, depending on how reflective its surface is.

For planetary scientists, if a remote Planet X exists the question is: How do you form a planet that far from the sun? Renu Malhotra, a planetary scientist at the University of Arizona in Tucson, says the problem is time. At that distance, the planet building materials would have been smeared over a ring several hundred billion kilometers around. "To make a planet the size of the Earth," says Malhotra, "could take longer than the age of the solar system." The only solution, she says, is to steal the planet from somewhere else.

Uranus and Neptune are the most likely thieves, pilfering planets from the space between their orbits. Malhotra says that a close encounter with either of those giants could slingshot an Earth-sized ball of rock to well beyond the Kuiper belt.

Planet X might also be extrasolar, says planetary scientist Rodney Gomes of the National Observatory in Rio de Janeiro. The sun was born in a nebula along with several thousand other stars, and many of those probably had planets of their own. As stars jostled each other, planets could have been torn away from one star and captured by the gravity of another. Perhaps Planet X is just the result of a brief game of interstellar catch.

"The jury's still out on whether you need to have a planet there or not," Schwamb says. A close encounter with a passing star could have lured Sedna and 2012 VP_{113} away from their siblings, like an astronomical pied piper. Stellar flybys are rare, however, and the star must pass close enough for the two dwarf planets to notice but not so close that it disrupts the entire Kuiper belt and possibly the outer planets.

The odds go up if the star is a relative, born in the same nebula as the sun. In addition to tossing planets around, stellar siblings could have tugged on the debris swirling around the sun. The distorted orbits would have frozen in place after the sun's brothers and sisters drifted away.

For 168 years, the lure of planets hiding beyond Neptune has never faded. The remoteness of the outer solar system, Jewitt says, "leaves open the door to all sorts of wild speculation."

The hunt for Planet X "is one of those things that's very high risk," Luhman says, "but if it was found, it would be a huge discovery." Astronomers have discovered more than 1,800 planets orbiting other stars, and yet our own backyard is still largely a mystery. "We haven't explored all of the solar system yet," Sheppard says, "so people always want to believe that there's something else out there." ■

Explore more

- C.A. Trujillo and S.S. Sheppard. "A Sedna-like body with a perihelion of 80 astronomical units." *Nature*. March 27, 2014.

LSST

EXTREME TEAMS

Who has the right mental stuff for a years' long mission to Mars?

By Bruce Bower

No one has come closer to experiencing the enduring solitude and high-risk travel that would accompany a mission to Mars than the three astronauts who flew to the International Space Station on November 23, 2002.

Just nine weeks later, the space shuttle *Columbia* exploded. That led controllers to extend the Expedition 6 mission, as the trio's endeavor was known, from four to five and a half months — about the time needed for a trip to Mars. On the journey back from the space station, a spacecraft malfunction caused a high-speed reentry to Earth's atmosphere, approaching speeds that would be reached when nearing Mars. The Expedition 6 capsule bumped and rolled to a stop about 475 kilometers off course, in a remote part of West Asia. The crew was rescued five hours later.

As they waited, the astronauts pulled themselves out of their battered craft, set up two radio systems and performed other survival procedures — all with great difficulty. The men's bodies had become accustomed to the lack of gravity in space, so their limbs felt like dead weights. Each head movement caused a wave of dizziness. Two crew members with experience readjusting to Earth conditions during previous missions to the space station staggered about slowly. Rookie space traveler Don Pettit crawled back and forth between the capsule and the crew's new base camp.

It wasn't easy, but Expedition 6 demonstrated that a space station crew could perform critical procedures in a situation similar to a Mars trip and landing, Pettit wrote in 2010 in the *Journal of Cosmology*.

He acknowledged, however, that a longer Mars voyage would bring novel emotional and social challenges.

Much is known about the psychology of participating in space missions that circle Earth at relatively close range or venture to the moon. Scientists are in the early stages,

TANG YAU HOONG

however, of understanding what it takes to hurtle through space for half a year and spend 18 months exploring the Red Planet before facing another five to six months getting home.

Although no date has been set for a Mars expedition, researchers who study humans in space are planning for an interplanetary voyage by 2050. If and when it happens, Mars astronauts will live in an artificial environment devoid of natural light, where sleep can easily be disrupted. Sending a message to Earth and receiving a reply will take close to 45 minutes. About a half dozen crew members will have only themselves for company. A couple hundred million miles out in space, they'll be the first humans to see their home planet as nothing more than a speck of light in the heavens.

> "Going into outer space is the most dramatic thing that can happen to your body other than being born."
> THOMAS MARSHBURN

Studies of people working for weeks in a desolate Utah desert, for months in the darkness of Antarctic winters and for more than a year on a simulated space expedition in Russia provide some guidance for selecting and training individuals and crews capable of dealing with the unpredictable challenges of a Mars mission. Studies of space shuttle and International Space Station crews offer insights as well.

The heady days of the 1960s space program, when courageous, quick-thinking and fiercely independent test pilots displayed "the right stuff" to become astronauts, are long gone.

"Researchers don't talk about astronauts having 'the right stuff' for long-term space missions," says psychologist David Dinges of the University of Pennsylvania School of Medicine. An interplanetary journey calls for a different kind of right stuff — characteristics that make for strong teams, not individuals, he says. The goal for future missions is to develop crews that work well enough in unison to compensate for any difficulties that individuals might encounter in space.

Losing sleep

Consider the biological shock of leaving Earth to live in an orbiting facility where a suited-up astronaut floats in the air. "Going into outer space is the most dramatic thing that can happen to your body other than being born," says astronaut Thomas Marshburn, who completed a five-month stay on the International Space Station in May 2013.

Astronauts adapting to their new surroundings must stay well rested to perform daily duties and handle onboard emergencies. But the act of sleeping gets redefined in space, which can create problems. Each space station crew member catches z's strapped into a sleeping bag attached to the wall. For Marshburn, weightlessness led to a few fitful nights of sleep when he first arrived at the station. He would doze off only to awaken with a start, feeling like he was falling.

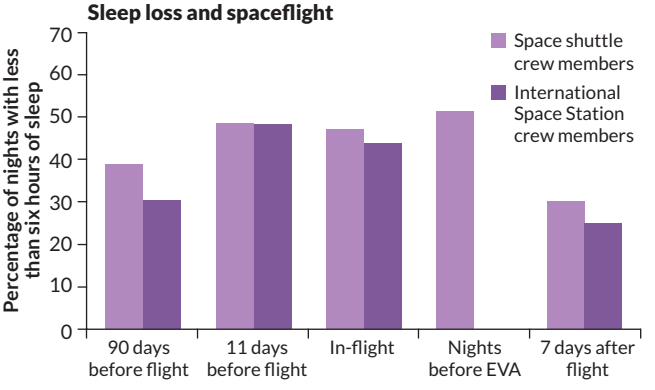
He eventually adjusted to the microgravity caused by the space station's free fall around Earth and slept well. When a hectic work schedule cut into his sleep time, he took five-minute naps while floating in his room.

Marshburn was lucky. Some astronauts just can't get enough shut-eye during missions. "The space environment is user-unfriendly for sleep," says flight surgeon Smith Johnston of NASA's Johnson Space Center in Houston. On the space station, slumber can be disrupted by constant noise and activity, temperature fluctuations and an artificial atmosphere in which elevated carbon dioxide levels may cause dizziness and other symptoms. Add to that changes in the timing of work shifts when supply craft and new crews arrive. Microgravity can trigger back pain and fluid shifts that lead to pressure inside the skull and vision problems. No one knows why.

Physiologist Laura Barger of Harvard Medical School and her colleagues tracked 4,311 days of sleep among 85 astronauts during space shuttle or International Space Station missions. Flights occurred between July 2001 and July 2011. Participants wore devices on their wrists that measured movement and provided relatively accurate estimates of time spent asleep.

Crew members headed into space sleep-deprived and stayed

Anticipation Astronauts on shuttle missions (light bars) and International Space Station missions (dark bars) spent a greater percentage of nights sleeping fewer than six hours shortly before and during flights than the week after returning to Earth. On the space shuttle, astronauts slept least on nights before conducting repairs or other operations outside their vehicle (EVA). SOURCE: L. BARGER *ET AL/LANCET NEUROLOGY* 2014



A Japanese astronaut kicks back in a sleeping bag attached to a wall of the International Space Station so he doesn't float around the chamber.

NASA

A crew at the Mars Desert Research Station in Utah ambles across a barren landscape nearby. Participants operate out of a cramped home base (right).

that way until returning, the researchers reported in the September *Lancet Neurology*. Nightly sleep averaged 5.96 hours during roughly weeklong shuttle missions and 6.09 hours during space station stays that ran as long as six months. Shuttle and space station astronauts slept for comparably short amounts of time beginning about three months before spaceflight, at the start of preflight training.

On Earth, chronic sleep restriction of that magnitude causes attention and memory problems, Dinges says.

About three-quarters of shuttle and space station crew members in the study took sleep medications at some point during their missions. But the meds helped only a little: Astronauts gained an average of about 10 minutes of sleep per day on the shuttle and 35 minutes on the space station, no more than would be expected by chance, Barger says. These minor improvements are similar to experiences of people who take the same meds for insomnia on Earth.

Because sleeping pills work for some insomniacs, Johnston hopes to find out which astronauts might be biologically receptive to sleeping pills and choose the most effective drugs and doses for those individuals. Other NASA strategies to promote nighttime sleep include equipping workstations with blue lights, which suppress levels of the sleep hormone melatonin and raise alertness so that astronauts can work a full shift before retiring, and designing computer-delivered instruction in relaxation exercises and sleep-promoting routines.

Mimicking Mars

Even with normal gravity, serious sleep problems were the norm for four out of six participants on a one-of-a-kind simulated Mars trip. Dubbed the Mars 500, the simulation was conducted in Moscow from June 2010 to November 2011.

The Russian Academy of Sciences selected three crew members from Russia, two from Europe and one from China to live in a pressurized facility with interconnected modules like those on a spacecraft. A lower floor contained personal and laboratory areas. An upper floor included a mock Mars surface where the crew conducted experimental tests.

Participants conducted scientific experiments and other projects for 520 days, under the direction of mission controllers. That's enough time for an actual round-trip to Mars, with time for about five months of research on the Red Planet.

The crew wore movement-tracking devices, which indicated that four men developed sleep problems during the faux flight, even though it was quieter than an actual space trip and they didn't have to deal with microgravity. One participant slept an average of only 6.54 hours nightly. Another shifted from a regular 24-hour pattern of sleeping and waking to a 25-hour cycle, which can disrupt slumber, memory and decision making (*SN: 2/9/13, p. 8*).

Although they were carefully screened before the study, men who became troubled sleepers during the mission developed a range of psychological and behavioral problems, a team led by Dinges' Pennsylvania colleague Mathias Basner reported March 27 in *PLOS ONE*. One man became increasingly depressed, physically exhausted and mentally fatigued. He and another slumber-deprived crew member had the bulk of arguments and conflicts with mission control and onboard comrades.

Another man took frequent naps during the day that lengthened as the study wound down. Rather than arguing or fighting with others, he increasingly withdrew from the group and spoke only occasionally with just two of his colleagues.

"The isolation of that one crew member is very concerning and dangerous," says psychologist Sheryl Bishop of the University of Texas Medical Branch at Galveston. Social quarantine of one astronaut from the rest on an actual space mission could lead to breakdowns in team performance and botched responses to emergencies.

Although Bishop did not participate in Mars 500, she has led studies of teams on two-week simulated Red Planet expeditions that take place at an isolated outpost in Utah known as the Mars Desert Research Station.

On this forbidding, Mars-like landscape, teams of about six researchers conduct a variety of experiments relevant to a stay on the Red Planet, such as how best to grow food inside

FROM LEFT: © GEORGE FREY/EPA/CORBIS; JIM URQUHART/THE MARS SOCIETY

a structure that recycles wastewater. Since 2002, teams have performed best when members identified closely with the whole group, talked frequently with each other and focused on completing tasks, Bishop says.

These crucial elements of effective teams appear to have gone missing during the Mars 500 simulation.

Intriguingly, two crew members on the 17-month Mars 500 mission slept fine the whole time and adjusted well to their confined environment. These men interacted frequently with their colleagues, except for the withdrawn individual.

The researchers have yet to look for psychological or biological factors that distinguished happy, well-rested participants from those who struggled mightily and slept little during Mars 500. "This is a serious scientific mystery," Dinges says.

Extreme training

NASA psychologist Albert Holland knows it will be tough to assemble a team capable of carrying out a Mars mission without major hitches.

Holland has coordinated psychological services at the space agency for 27 years. His duties include developing personality tests for astronaut candidates and conducting psychological training of astronauts for extended spaceflights.

In preparation for a future Mars mission, applicants who pass an initial screening will be sorted into teams that get evaluated in different real-world environments that partly re-create the challenges they would face, Holland says.

A year on the space station might be followed by a year conducting experiments in Antarctica, where winter consists of months of darkness. Crews might then have to survive for several months in a desolate region with only caves for cover.

In a lead-up to such ventures, a six-member team is conducting a simulation of life on a Mars space station in a large dome built on the side of Hawaii's Mauna Loa volcano. The NASA-sponsored project began in October and will last at least eight months.

Unlike a reality TV show such as *Survivor*, where each participant vies to win a contest in an exotic locale by whatever means necessary, Mars mission candidates sent to harsh environments need to work selflessly for the good of their crews.

All astronauts must be able to make decisions quickly in life-or-death situations, but long spaceflights such as a Mars expedition or year-long stint on the International Space Station demand a level of teamwork and group morale not needed on trips of a week or two. Some issues are difficult to predict in advance, even after observing teams in action on Earth. On a Mars trip, where men and women will probably work together, according to Holland, sexual tensions could split a team apart.

Some evidence suggests that the presence of women makes various kinds of teams more effective, at least in the short run, Bishop says. But long-term studies of men and women crew members are lacking.

"The key is to find and develop people who can manage their relationships with team members, look beyond their own needs and work toward a higher goal," Holland says.

One crucial characteristic of a good team member is adaptability, at least according to 26 veterans of six-month space station missions recently interviewed by Holland. Crew members will need to deal well with stressful situations, stay on an emotionally even keel when things go wrong and maintain work quality in the face of sleep loss.

Astronauts in Holland's study also emphasized social and teamwork skills, divvying up responsibilities and taking charge when needed during onboard emergencies.

Transcending differences

Team building can be further complicated in space missions that include astronauts from different nations, which will certainly be the case with a mission to Mars. Crew members from various parts of the world will need to overcome cultural differences quickly when placed in extreme Earth environments, says psychiatrist Nick Kanas of the University of California, San Francisco. Previous research on Russia's *Mir* space station and on the International Space Station suggests, for instance, that stressed-out Russians experience a blend of fatigue and depression. When U.S. astronauts get upset, they are more likely to report a mix of anxiety and depression, Kanas reports in the October-November *Acta Astronautica*.

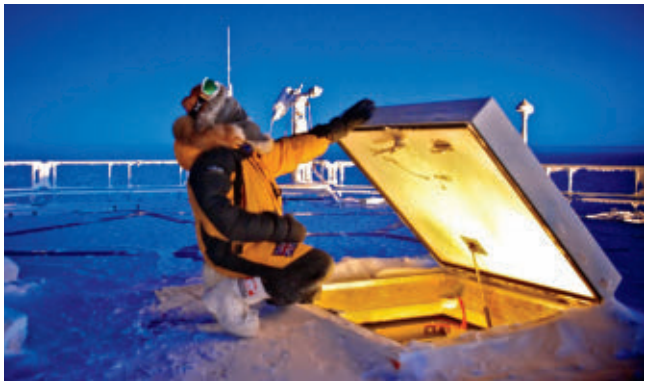
Participants relax during a 520-day exercise inside a Russian facility that mimicked a Mars mission (top). One crew member wearing space gear (bottom), conducts an exercise in an enclosed area designed to resemble the Red Planet's terrain.

Some emotional troubles transcend culture, Bishop says. Anger, depression and confusion spread rapidly when team members form cliques, regardless of where they come from, according to studies of U.S. and European scientists working at isolated Antarctic research stations.

Confronted with the pressure of surviving with others for a long time in confined spaces in a dark landscape, individuals often keep their worries and insecurities to themselves, Bishop adds. Members of polar expeditions studied by medical anthropologist Lawrence Palinkas of the University of

FROM TOP: ESA/IBMP; IBMP/OLEG VOLOSHIN

Crews at Antarctica's Concordia research station spend about four winter months with no outside contact and in total darkness outside. A Concordia team member (bottom) enters the outpost from its roof.



Southern California in Los Angeles often expressed concern about not burdening others, even after being injured. There's good reason for such concern: Leaders of polar treks and months-long submarine missions have reported feeling overwhelmed and frustrated when asked for emotional support by teammates.

Team work

Aspiring Mars astronauts, as well as mission controllers for a Mars expedition, must be able to rely on each other. Space travelers and ground officials won't be able to communicate instantly, as they do during International Space Station missions. It will take about 22 minutes for messages from a craft on or near Mars to reach Earth, and the same amount of time for a response to reach space travelers. Regular conversations with ground officials, a fixture for astronauts on the International Space Station, will be impossible. Mars astronauts will have unprecedented independence to deal with onboard problems and urgent decisions.

45
minutes
Time it would take for Mars crew to get reply from ground control on Earth

To ease feelings of isolation among even the best-adjusted deep-space astronauts — who will not be able to use computers to chat with family members, as is common on the International Space Station — NASA may turn to virtual families, Holland says. Researchers are in the early stages of developing headgear that will place crew members in virtual, 3-D re-creations of their family homes, where they will visit simulated versions of their spouses, children and other loved ones.

For all its psychological and social challenges, space travel has a transcendent upside. From the beginnings of national space programs more than 50 years ago, astronauts have described how their lives have changed for the better as a result of their otherworldly journeys.

So it went for U.S. astronaut Jerry Linenger, even after enduring an onboard fire, a near-collision with a resupply rocket and several system failures during four months on *Mir* in 1997. In his 2000 book *Off the Planet*, Linenger described returning home with increased self-confidence, greater appreciation of life's pleasures and a newfound sense of Earth and its human inhabitants as a unified entity.

In a 2006 survey of 39 U.S. and Russian astronauts, Kanas and his colleagues found that all of them reported personal growth as a result of flying in space. In particular, participants said they better grasped Earth's beauty.

Returned astronauts often report a heightened concern for the collective interests of people around the world, world peace and a God that exists beyond specific religions, says psychologist Peter Suedfeld of the University of British Columbia in Vancouver.

Suedfeld and his colleagues reported in 2012 in *Acta Astronautica* that 20 retired Russian astronauts described positive changes such as finding more direction in their lives following their spaceflights. So did 125 U.S. astronauts, whose memoirs were analyzed by Suedfeld's team in 2010 in the *Journal of Personality*.

Not everyone comes back inspired. Edwin "Buzz" Aldrin, who in 1969 became the second person to walk on the moon, sank into depression, developed alcoholism and got divorced after that mission. Following a 2006 mission on the International Space Station, Lisa Nowak was arrested for attempting to kidnap a rival girlfriend of a fellow space station astronaut with whom she had been having an affair.

Astronauts can only guess at how a Mars trip would affect them. Thomas Marshburn recalls that he and his crew mates on the International Space Station felt comforted and inspired by the sight of Earth outside the craft's windows. When Marshburn floated to the other side of his space home and peered out at the twinkling universe, a sense of insignificance and aloneness took over. As much as he wants to participate in an eventual Mars mission, Marshburn knows it would be tough to watch Earth shrink into one of many distant stars during an interplanetary journey.

That humbling experience might lead to spiritual growth in some space travelers and emotional turmoil in others.

"There will always be an element of the unknown and the unexpected on long spaceflights," Holland says.

If there is such a thing as "the right stuff" for teams of astronauts journeying more than 200 million miles to the Red Planet, they'll need a whole lot of it to get there and back again. ■

Explore more

■ N. Kanas. "Psychosocial issues during an expedition to Mars." *Acta Astronautica*. October-November 2014.

FROM TOP: ESA/IPEV/ENEAA/ALEXANDER KUMAR; ALEXANDER KUMAR

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These rocks in Spain helped geologists determine what killed the dinosaurs.

TELEVISION

‘Mass Extinction’ vivifies the science of die-offs

Anyone with a passing interest in dinosaurs knows that the beasts were killed off some 65 million years ago after a colossal asteroid struck Earth. But what many people probably don’t know is how paleontologists came to that conclusion. *Mass Extinction: Life at the Brink* tells that story.

The hour-long documentary, airing on the Smithsonian Channel, explores the causes of two of Earth’s five mass extinctions: the dinosaurs’ demise and the “Great Dying.” That long-ago extinction, roughly 252 million years ago, saw as many as 97 percent of species on Earth disappear. By focusing on how researchers have pieced together these ancient whodunits, *Mass Extinction* offers great insight into how science works.

The film begins with a journey back in time — to the 1970s. Geologist Walter Alvarez is studying rocks in Italy. An odd sliver of clay in a stretch of limestone intrigues him: It contains an unusually high concentration of iridium, an element that is normally rare in Earth’s crust. Similar iridium-rich layers appear elsewhere around the world and all date to around the time of the dinosaur extinction. Working with his Nobel Prize–winning physicist father, Luis, Alvarez hypothesizes that the iridium came from an asteroid. The documentary goes on to show how subsequent studies over the last few decades have uncovered remnants of the asteroid’s gigantic crater and have calculated the extent of the space rock’s destruction.

The gray layer, found in rocks in Spain and elsewhere, marks the dinosaur extinction event.

Mass Extinction: Life at the Brink
PREMIERES NOVEMBER 30
SMITHSONIAN CHANNEL

Alien forces aren’t always at play in mass extinctions. In the case of the Great Dying, the destruction was homegrown. The world just before the extinction event was very different from today’s, as the program’s CGI effects illustrate. Earth’s landmasses made up one giant supercontinent called Pangaea, armored trilobites ruled the seas and reptiles resembling the demon dogs from *Ghostbusters* ruled on land.

Researchers suspect that the creatures were wiped out by a major episode of climate change triggered by an enormous volcanic eruption in Siberia. Pinning the blame on the volcano requires getting the timing just right: Did the volcano erupt before, during or after the die-off? The film shows researchers working in Siberia and China trying to answer that question. Increasingly, these scientists say, the evidence is pointing to the volcano as the culprit.

The last third of the documentary shifts to the present and examines whether Earth is on the brink of a sixth mass extinction. And here the film falls a bit flat. The filmmakers cram so much into a mere 15 minutes — evidence that we’re on track for a mass die-off, proof that humans are responsible and actions people should take to stave it off — that their arguments feel incomplete. That’s especially the case when compared with the film’s thoughtful treatment of the other two extinctions.

But on balance, the documentary is an informative introduction to the science of mass extinctions. The film explains the research so that anyone can follow along while still managing to captivate viewers who are well-versed in science. — *Erin Wayman*

TO DO

Imagining Deep Time

THROUGH JANUARY 15, 2015
Eighteen works of art offer ways to conceptualize the unfathomable vastness of geologic time.

NATIONAL ACADEMY OF SCIENCES, WASHINGTON, D.C.

Whales: Giants of the Deep

THROUGH FEBRUARY 16, 2015
Real bones and life-size replicas tell the story of how whales evolved from land animals and developed adaptations that allow the animals to thrive underwater.

DENVER MUSEUM OF NATURE & SCIENCE

Maya: Hidden Worlds Revealed

THROUGH MAY 3, 2015
Rare artifacts and hands-on activities illuminate the everyday lives of Maya living more than 1,000 years ago.

MUSEUM OF SCIENCE, BOSTON

Numbers in Nature

ONGOING
A mirror maze (below) is the centerpiece of this interactive exhibit that explores mathematical patterns hidden in nature, as well as in art and music.

MUSEUM OF SCIENCE AND INDUSTRY, CHICAGO

FROM TOP: © HHMI; © HHMI; J.B. SPECTOR/MUSEUM OF SCIENCE AND INDUSTRY

OCTOBER 18, 2014

SOCIAL MEDIA

Mites are all right

Amid a chorus of "yuck!" and "ew!" some readers on Twitter responded surprisingly positively to the news that they probably have microscopic mites hiding out on their faces (*SN: 10/18/14, p. 4*).

"As long as they don't bother me, I don't mind them chilling there." **@ecoponics92**

"I wonder, do my face mites get sunburned when I get sunburned? Do they appreciate a bit of sunblock?" **@carbonconcepts**

"What a microbiome we have!" **@libby_kelly**

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Speculation about a sail

The fish-eating dinosaur Spinosaurus *might have been an avid swimmer. As* ***Susan Milius*** *reported in "Lost-and-found dinosaur led a semiaquatic life" (*SN: 10/18/14, p. 10*), adaptations like dense limb bones and small hips hint that the big predator thrived in water.*

The findings inspired a lot of discussion about *Spinosaurus'* tall, saillike flap that rose from its back. "Has the purpose of that enormous fin been determined?" asked **Jim LeSire**. "It seems unlikely it was used for radiating excess heat if the animal spent so much time in the water."

Mark S. wondered if the "sail" could have been exactly what it looked like: "A giant sail that the dinosaur used to give itself a boost between hunting grounds? By angling itself correctly it should have been able to tack under a variety of conditions." Commenter **bruzote**, though, didn't think much of the idea of a wind-powered dino. "We see 'sails' in other species and not one is used for sailing."

For now, paleontologists don't know how *Spinosaurus* used that impressive sail, says **Milius**. The researchers who did the study mused that it might have acted as a flashy display that would be visible while the dinosaur glided through the water. But of course, she adds, anatomical features can perform more than one task. "And what drives a structure's evolution originally may not be what maintains it as time goes on."

Not-so-sweet sweeteners

*No-cal sweeteners don't pass as quietly through the gut as scientists once thought. In "Artificial sweeteners may tip scales toward diabetes" (*SN: 10/18/14, p. 6*),* ***Rachel Ehrenberg*** *revealed that saccharin can reshuffle the gut's microbial communities, triggering metabolic problems.*

Christen Felton thought the study deserved some scrutiny. "The mice for the control group were given glucose, yet glucose isn't readily available to us as a sweetener. What is available is sucrose, whose fructose component is so demonstrably deleterious that it seems unfair to have used glucose instead."

Ehrenberg says that early in the study, the scientists did pit three artificial sweeteners against sucrose, a half-and-half mixture of glucose and fructose molecules also known as table sugar. "Some mice drank water spiked with artificial sweeteners while the control mice drank glucose, sucrose or water. After 11 weeks, the control groups had normal glucose levels in their blood, but the mice that were fed artificial sweeteners had high levels. Antibiotics abolished this effect, implicating gut microbes." While the researchers didn't focus on sucrose, she says, they did establish that artificial sweeteners meddled with the mice's metabolism in a way that sucrose and glucose did not, and that the response is somehow mediated by gut microbes.

With all the fuss over sugar substitutes, some think the best option is to opt out. "In addition to the possible (probable?) negative health effects, artificial sweeteners have another problem: they all taste bad and leave a disagreeable aftertaste," wrote online commenter **Phansigar**. "I avoid them. I'll take my chances with sugar if I have to."

Sorting out tools and stones

Two sets of stone tools from Brazil described by ***Bruce Bower*** *in "More signs emerge of New World settlers before 20,000 years ago" (*SN: 10/18/14, p. 14*) suggest that groups of early settlers beat the Clovis people to the Americas.*

"I hate to say it, because I love the idea of 20,000-year-old tools, but those chips look like naturally occurring fragmented crystalline rocks like I found by the bucketful in Northern Arizona," wrote online commenter **Kiplin**.

The simpler the proposed tools, the tougher it gets to identify intentional modifications, says **Bower**. "The researchers who reported the find say that microscopic marks on the rocks came from everyday activities, like butchering animal carcasses. Critics say that natural events, such as rock slides, probably created the chipped rocks at the Brazilian site."

STEVE GSCHMEISSNER/SCIENCE SOURCE

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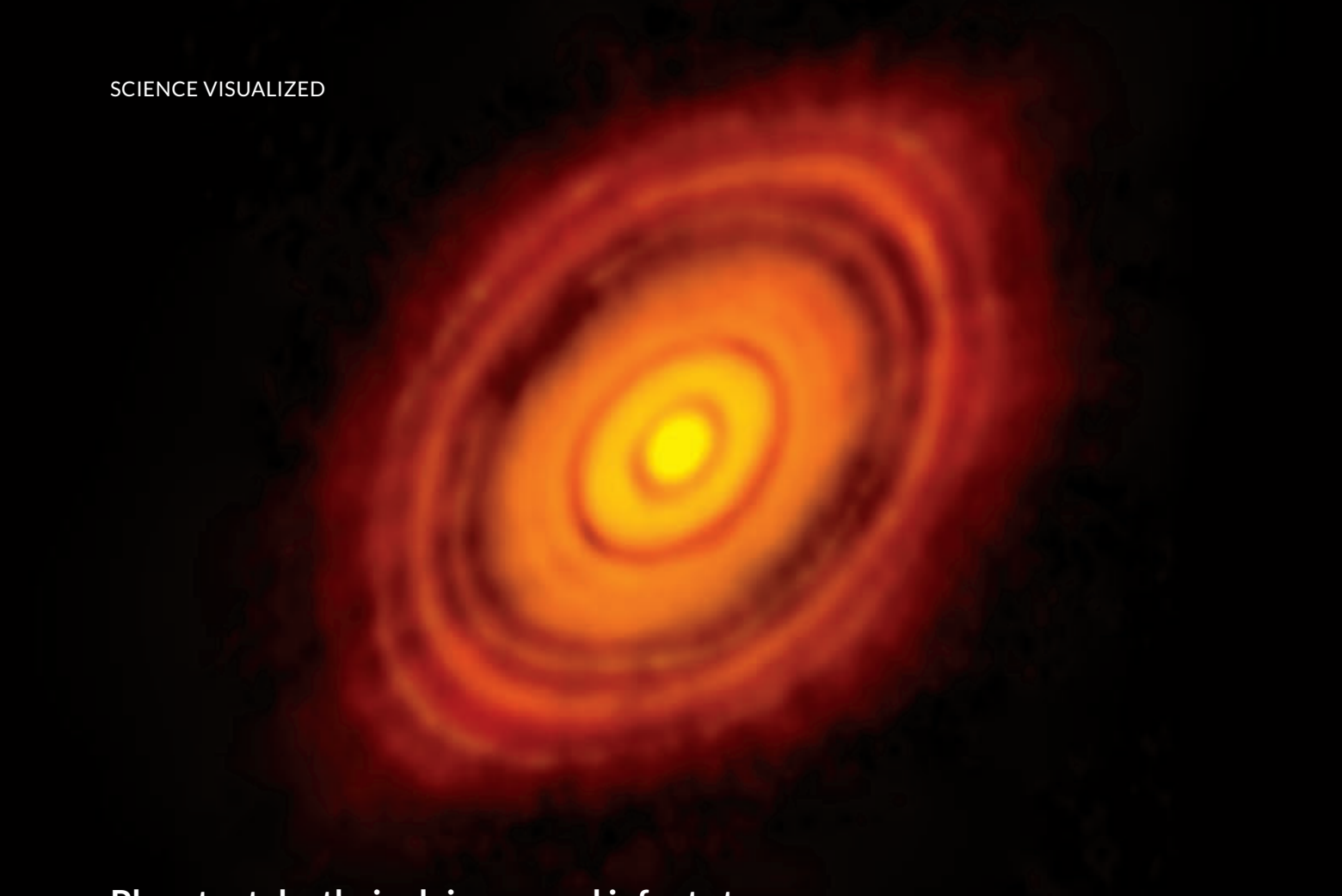

Planets stake their claim around infant star

As a baby, our solar system probably looked something like this.

At the center of this newly released telescope image is HL Tau, a star located about 450 light-years away in the constellation Taurus. A dense disk of gas and dust surrounds the star, which is a youthful million years old.

But the most striking features are the dark gaps, which astronomers suspect are carved out by developing planets that sweep up material as they loop around their sun. In only a million years or so, planetary embryos that began as pebbles have apparently grown massive enough to clear out their own orbital paths.

This unprecedented image of a nascent planetary system comes from the Atacama Large Millimeter/submillimeter Array, or ALMA, a network of several dozen radio dishes located in the high-elevation desert of northern Chile. The dishes detect wavelengths of light that are sensitive to cosmic dust grains; the spacing between dishes — as much as 16 kilometers — allows astronomers to capture incredibly fine detail such as the thin grooves. (For scale, the innermost ring is about 10 times as far from the star as Earth is from the sun.)

Hints of gaps around young stars have been seen before, but this is the sharpest image of them to date. Seeing rings around such a juvenile star probably means that planets can grow faster than theorists have predicted. Scientists hope to combine the observations of HL Tau with those of other nurseries to figure out how planetary systems like our own form.

— *Christopher Crockett*

Focus on a planetary baby picture

450
light-years
Estimated distance to HL Tau (over 4 quadrillion kilometers)

110
kilometers
Distance from ALMA at which the array can detect a penny-sized object, providing the resolution needed to see gaps in the disk

0.02
percent
The age of HL Tau compared with that of the sun

ALMA/NRAO, ESO, NAOJ

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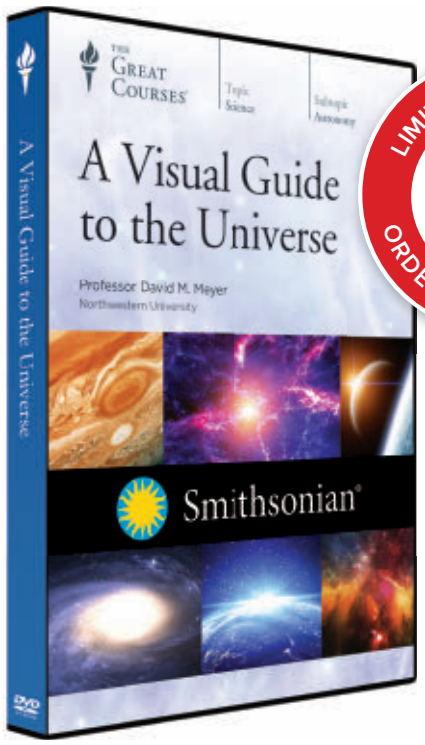

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He nicknamed the watch *Ritorno* for homecoming, and the rare heirloom is now valued at $42,000 according to *The Complete Guide to Watches*. But to our family, it is just a reminder that nothing is more beautiful than the smile of a healthy returning GI.

The hunter's back

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