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SCIENCE NEWS MAGAZINE
SOCIETY FOR SCIENCE & THE PUBLIC

AUGUST 23, 2014

Voyager:
In or Out?

Rise of the
Feathered
Dinos

Fonts Built
With Math

Moose
Sabotage
With Slobber

Rocky Redirect

NASA's odd plan to prep
for Mars: Snag an asteroid



Analog and digital display

Stop watch function

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COVER Astronauts may get unprecedented access to an asteroid if a proposal to nab and retrieve a space rock is successful.
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The craziest NASA mission ever proposed



I recently received a press release about an upcoming Science Channel special titled *Man vs. the Universe*. One episode will focus on the threat of asteroids impacting Earth and the various scenarios proposed to defend ourselves. The episode ends, the release says, with a segment about “the craziest NASA mission ever proposed.” The aim is to

capture an asteroid in deep space with a giant bag and transport it into orbit around the moon for astronauts to study.

In this issue, Meghan Rosen provides an in-depth report on that mission, but without the erroneous conclusion that the Asteroid Redirect Mission has much to do with asteroid defense. It's easy to see why the release writers got confused, though. According to NASA, the mission is really about Mars.

The truth may be a bit less lofty. As Rosen explains, this proposal comes from the human exploration arm of the space agency, which is struggling to find direction now that the space shuttles are sitting in museums and the International Space Station, some 220 miles up, is as far as astronauts

regularly venture. Going to Mars, of course, would be a stupendous achievement of engineering and imagination. Like the moon landings, it would serve as a powerful symbol of American (and human) prowess. But given all of the unsolved technical challenges, a human mission to Mars is still at best decades away. If NASA is ever to attempt such a journey, it needs to maintain its human spaceflight capabilities. To do that in an era of limited resources, you also need a wow factor. Meet the Asteroid Redirect Mission.

Still, many observers see limited scientific value in a mission that would send humans to do what other asteroid missions (including one from NASA) are doing with robots. (Robotic missions, after all, are nothing to scoff at. Think of Curiosity or, on Page 6, the Voyager probes.) OK, critics say, we need to keep our astronauts and engineers busy. Considering the expense, though, shouldn't a human mission also move science forward in a dramatic way?

Probably. But you could also argue that human spaceflight was never really about science — it's about exploration and challenging the limits of technology. And that's what capturing an asteroid is really all about. — *Eva Emerson, Editor in Chief*

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Excerpt from the
the August 22, 1964,
issue of *Science
News Letter*

50 YEARS AGO

Seeded Clouds 'Explode'

Cloud seeding experiments with silver iodide, resulting in “explosions” that release tremendous energies, indicate that weathermen may do more than predict weather in the future.... The explosion is first upward, then sideward. The horizontal spread is likely to prove the “most significant” for practical weather modification, two scientists reported. The horizontal explosion in the Caribbean clouds released additional energy equal to that of one or two Hiroshima bombs, which were equivalent to 20,000 tons of TNT apiece.

UPDATE: The cloud-seeding “explosions,” in which clouds grew rapidly, were part of Stormfury, a project that aimed to slow a hurricane’s winds by seeding clouds outside the eyewall. Joanne Simpson, the first woman to receive a Ph.D. in meteorology, showed the value of her computer models of clouds with the project, but the work led to an outcry. In the 1970s, a treaty banned hostile use of weather modification, but cloud-seeding is still used in some drought-prone areas.



THE SCIENCE LIFE

Father-son duo folds math into fonts

A mathematician once posed a deceptively simple question. Can a single 2-D conveyor belt be stretched around a set of wheels such that the belt is taut and touches every wheel without crossing itself?

MIT computer scientist Erik Demaine pondered the problem. For just a few wheels, the solution is easy: Arrange four into a square, wrap the belt around the

outside, and the problem is solved — one version of it, at least.

“The question is whether it’s always possible to solve no matter how you draw the wheels,” Demaine says. A complete solution would lay out a set of rules that applies to every possible wheel arrangement and number. “But so far every algorithm we’ve come up with has been foiled.”

THE -EST

Elephant’s big nose wins most powerful sniffer

African elephants may be the world’s best smellers, scientists report July 22 in *Genome Research*. The team found that African bush elephants (*Loxodonta africana*) carry about 2,000 genes for smell sensors, or olfactory receptors. Animals with more smell receptors should be able to distinguish more odors. Renowned sniffers like rats have around

1,200 olfactory receptor genes and dogs about 800. Humans and other primates, with relatively poor olfactory powers, have one-fifth as many olfactory genes as elephants. The researchers think that smell-sensing genes duplicated more times in elephants than in other mammals as species diverged, leading to a broad smell palette. African elephants communicate aggression via scents. One study found they can use smell to distinguish between the Maasai, a group that hunts elephants, and the Kamba, who are primarily farmers and pose no threat. — *Nsikan Akpan*



Martin Demaine (left) and his son Erik have drawn on mathematics and computational geometry to design fonts that incorporate puzzles.

One day Demaine was working on the problem with his dad, who happens to be an artist and mathematician, and a colleague.

The trio got stuck. So they decided to take a break with another activity the Demaines enjoy: designing new fonts. The team stuck thumbtacks into poster board to represent wheels, and wrapped them with rubber band “conveyor belts” to form letters.

“It became a game,” Demaine says. “One of us would put in some thumbtacks, and the other would say, ‘Oh, I see, it’s a ‘K’!”

Demaine and his father, MIT artist-in residence Martin Demaine, published the complete alphabet of conveyor belt letters in the *Proceedings of the 7th International Conference on Fun with Algorithms* in July along with four other typeface ideas sparked by math and computational geometry. The Demaines’ interest in geometric folding spurred creation of three fonts, one of which — the “origami maze” typeface — uses a computer algorithm to create crease patterns that can fold into 3-D letters.

Several of the Demaines’ fonts can be

Secret message By erasing the black lines wrapped around the pink dots in the conveyor belt font (left), puzzle enthusiasts can craft hidden messages from seemingly random clusters of circles. The glass-squishing font (right) can also hide words; users reveal individual letters by imagining what happens after a set of balls and thin rods of glass are pushed or “squished” from the sides.

Conveyor belt font

Regular

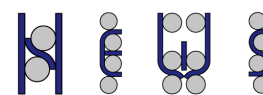


Without belts

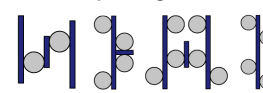


Glass-squishing font

Squished



Before squishing



turned into geometry or math puzzles. In the conveyor belt font, for example, take the belt away from a letter and all that’s left is a cryptic arrangement of wheels. “You can hide secret messages this way,” Erik Demaine says.

Another puzzle font, called the glass-squishing typeface, drew inspiration from their passion for glass blowing. After inventing a software program that helps glass blowers design pieces, the Demaines wanted to mathematically describe how pieces of glass squish together when heated. They started experimenting by making actual glass letters.

The duo arranged blue glass sticks around clear discs, popped the patterns into a volcano-hot oven and then

pushed the softened pieces together. “We’d say, ‘Ah, I think this will make an ‘A,’” Demaine says, “Then we’d squish it and it would come out looking nothing like an ‘A.’”

After a week of experiments, they posted videos of the full alphabet on Demaine’s website (see erikdemaine.org/fonts). Now, they’re hoping to use what they have learned with the letters to build new software for their virtual glass program.

Demaine thinks the fonts are a fun way to introduce people to the world of computational geometry.

“We want people to play with the fonts,” he says. “We really love puzzles — now anyone can participate.”

— Meghan Rosen

SCIENCE STATS

Survey catalogs what is stressing out Americans

Overall, people in the United States cite too many responsibilities, work and money as leading causes of stress. But health concerns, one’s own or a family member’s, are also stressful. Sixty percent of people who described themselves as in “poor health condition” also reported “a great deal of stress,” according to a survey of more than 2,500 adults.

SOURCES: NPR, ROBERT WOOD JOHNSON FOUND., HARVARD SCHOOL OF PUBLIC HEALTH

* Among employed respondents

Contributors to stress

	Overall	Men	Women	Income	
				<\$20,000	\$50,000+
Too many responsibilities overall	54%	46%	59%	53%	51%
Problems with finances	53%	45%	58%	70%	35%
Work problems*	53%	52%	54%	64%	57%
Own health problems	38%	34%	40%	50%	32%
Family health problems	37%	25%	48%	47%	27%
Problems with family members	32%	24%	39%	29%	34%
Unhappiness with one’s looks	28%	24%	30%	37%	23%
Problems with friends	15%	17%	15%	26%	6%
Changes in family situation	10%	9%	11%	5%	13%
Problems with neighbors	7%	3%	7%	5%	2%

Voyager 1 may still be in solar bubble

Scientists argue that probe has not reached interstellar space

BY ANDREW GRANT

Nearly a year after NASA trumpeted Voyager 1's departure from the sun's protective bubble, two mission scientists argue that the spacecraft never left. Many astronomers are doubtful about the assertion, but the debate illustrates that the transition from solar bubble to interstellar space is not clear-cut.

"My tendency is to think we are out in interstellar space, but I'm not completely convinced," says Eric Christian, an astrophysicist at NASA Goddard Space Flight Center in Greenbelt, Md., who is not on the Voyager team. "I don't blame skeptics for looking at other explanations."

Voyager 1 and its twin Voyager 2 completed their tours of the outer planets in 1980 and 1989. Since then, scientists have eagerly anticipated the probes' departure from the heliosphere, the bubble of particles that encircles the sun and planets, and their entry into the unexplored space between stars. (The probes won't exit the solar system for another 30,000 years or so (*SN*: 10/19/13, p. 19), since the sun's gravitational influence continues well past the heliopause, the boundary of the heliosphere.)

Then last September, after months of speculation, mission scientists finally announced that Voyager 1 had exited the heliosphere on August 25, 2012 (*SN Online*: 9/12/13). The proof, they

said, came via a blast wave from the sun that jostled particles around the probe in April 2013. The vibrations of the particles suggested that the spacecraft was surrounded by a dense soup of galactic particles rather than a comparatively sparse fog of solar ones. Last month, the researchers reaffirmed their conclusion after analyzing another solar outburst that reached Voyager in March.

However, Voyager has yet to detect what scientists long predicted would be the calling card of interstellar space: a shift in the direction of the magnetic field. Scientists had expected the probe to encounter particles under the influence of the interstellar magnetic field that is draped over the outer shell of the heliosphere, inducing an abrupt shift. But the direction has remained stubbornly constant, and researchers can't explain why. "This whole region is a lot messier than anyone dreamed of," Christian says.

It's a bit too messy for George Gloeckler and Lennard Fisk, Voyager scientists at the University of Michigan in Ann Arbor. They wondered whether the magnetic field and particle density conditions measured by Voyager could exist within the heliosphere. In a paper published July 18 in *Geophysical Research Letters*, Gloeckler and Fisk

argue that the outer heliosphere could allow an influx of galactic particles from beyond the bubble that would explain the density measurements.

The researchers' analysis includes a way to test the idea. If Voyager 1 is within the heliosphere, Gloeckler and Fisk note, then it should still be at the mercy of the sun's magnetic field. If that were the case, within a year or so, Voyager should detect a 180-degree flip in the field's direction, a regular occurrence caused by the sun's rotation.

"If that happens, Len and I will have a big celebration," Gloeckler says.

"It's a very good paper," says space scientist Stephen Fuselier of the Southwest Research Institute in San Antonio. "They came up with a bold, testable prediction."

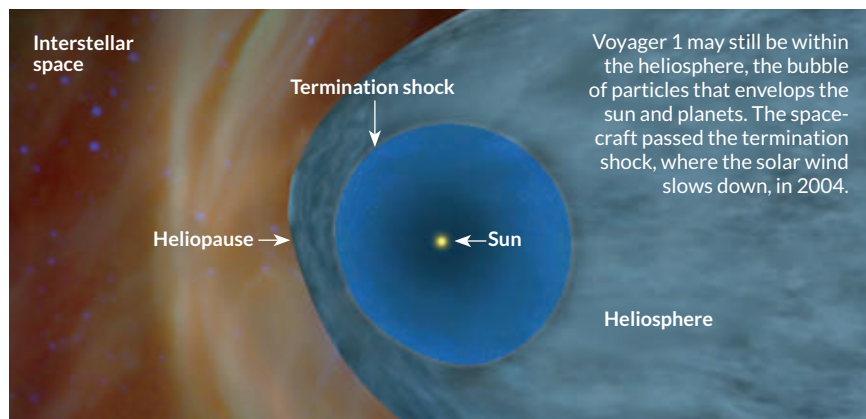
Still, Fuselier thinks Gloeckler and Fisk are wrong. While the proposal is consistent with Voyager's density measurements, he says, it can't explain the particle vibrations Voyager detected in April 2013. Scientists suspect that solar blast waves induce these vibrations only after interacting with the heliosphere boundary.

Voyager should provide more clarity by next year with the help of more blast wave measurements and the possibility of the 180-degree magnetic field shift. In the meantime, Christian says, scientists have to remain patient. Trying to characterize a vast unexplored region of space with one probe is like trying to understand an ocean with a single buoy.

Within several years, another buoy should reach the vicinity of the heliosphere boundary: Voyager 2. Unlike its sibling, it sports a still-functioning instrument that takes continuous measurements of particle density and temperature. "Voyager observations have surprised us over the years," Fuselier says. "We're just waiting for more surprises." ■

"This whole region is a lot messier than anyone dreamed of."

ERIC CHRISTIAN



Domestication linked to changes in embryonic cells

Developmental defects may explain tame animals' traits



BY TINA HESMAN SAEY

A group of traits common among domesticated animals may arise when some wandering embryonic cells lose their way, a new theory of domestication proposes.

The wandering cells are neural crest cells, which appear early in development in vertebrate embryos. These cells migrate around the embryo, contributing to the development of many tissues. Mild defects in the cells' migration or function lead to "domestication syndrome," three scientists suggest. The syndrome is a cluster of traits, including white-spotted coats, floppy ears and juvenile-like faces, often seen in tame animals.

In selecting compliant companions, humans may have inadvertently picked animals with mild neural crest cell defects. Geneticist Adam Wilkins of Humboldt University of Berlin, primatologist Richard Wrangham of Harvard and evolutionary biologist and cognitive scientist W. Tecumseh Fitch of the University of Vienna propose the idea in the July *Genetics*.

Neural crest cells play a role in the development of cartilage and bone in the face, smooth muscle, pigment cells, parts of the nervous system and the adrenal glands, which control the fight-or-flight response. Lab animals with defects in neural crest cell migration are known to have smaller adrenal glands. If domestication has the same effect, the smaller glands should produce fewer stress hormones, which would reduce the animals' stress levels and fear of humans and make them friendlier than their wild brethren, the team reasons. Neural crest cells are so important in development that messing with them is bound to have many unintended

consequences, such as the physical traits common across domesticated animals, the researchers posit.

"I think we may have the basic answer to something that's been a puzzle for a long time," Wilkins says.

Charles Darwin first documented the signature changes in appearance that accompany domestication in 1868. Since then, researchers have invented untestable just-so stories to explain each characteristic's development, says evolutionary biologist Greger Larson of Durham University in England. None of the many suggestions, he says, "have been particularly satisfying."

But he is excited about the new hypothesis because it offers a fresh perspective on why so many disparate aspects of domesticated animals' appearance change along with their behavior. He also applauds the researchers for offering a testable theory.

The idea was born in 2011, when Wilkins bumped into Wrangham at the Stellenbosch Institute for Advanced Study in South Africa. As Wilkins tells it, he was photocopying research papers about neural crest cells for a book he is writing on the human face. Wrangham told Wilkins that he, too, was interested in neural crest cells, but because of their possible role in domestication, a notion Fitch had planted in his mind several years earlier.

Wilkins and Wrangham knew that other scientists had linked defects in the migration of neural crest cells to spotted coat colors, short jaws and small adrenal glands. Working with Fitch, they found more evidence in published research that deficits in the number, movement or action of neural crest cells could cause almost all of the physical and behavioral

Domesticated animals share behavioral and physical features, such as white spots and floppy ears, that may be the result of defects in certain embryonic cells, scientists propose.

changes in domesticated animals.

The neural crest cell defects are probably the result of changes in dozens of genes, each producing a small effect on the cells' behavior, the team proposes.

But Anna Kukekova, an animal geneticist at the University of Illinois at Urbana-Champaign, who studies tame and aggressive silver foxes, says she sees a flaw: The physical and behavioral traits of domestication syndrome aren't necessarily inherited together.

For instance, she says, when researchers bred tame and aggressive rats, white spots appeared just as often on the coats of both mean and friendly rodents. The result may indicate that tameness and coat color don't have the same underlying causes, Kukekova says.

Larson, however, thinks the team is on the right track. But he says that they've given short shrift to some other recent research, especially a hypothesis put forward by Susan Crockford.

Crockford, an evolutionary biologist at the University of Victoria in Canada, suggests that changes in levels of thyroid hormone during early development could affect the entire constellation of domesticated animals' characteristics.

"Thyroid hormone from the mother strongly affects embryonic development from the moment of conception onward," she says. The hormone's action may also impair neural crest cell movement and could be the ultimate source of the domestication traits, she says.

"The good thing about their hypothesis is that it is eminently testable," Crockford says.

However, none of the researchers who put forward the idea have a lab set up to do the genetics, molecular and developmental biology and embryology research needed to test it. Others will need to provide the experimental evidence that either supports or falsifies the argument, Wilkins says. "Here we've had this bright idea, but we're asking other people to do the hard work." ■

EARTH & ENVIRONMENT

Sandstone arches do not need glue

Gravity locks sand grains into spectacular stable formations

BY THOMAS SUMNER

Gravity, not glue, allows towering sandstone pillars and arches to withstand howling wind and pouring rain, researchers propose July 20 in *Nature Geoscience*.

Sandstone forms when tiny sand grains bind together into a solid mass. The edges of sandstone slabs wear away

when exposed to the elements, leaving behind spectacular structures such as arches, columns and alcoves that better resist further erosion.

Geologist Jiří Bruthans of Charles University in Prague was touring a sandstone quarry when he noticed something odd: The workers had to use explosives to break apart the solid sandstone walls, but any rocks that had broken free would quickly crumble. Bruthans says this behavior seemed to contradict the conventional explanation that chemical cement glues sandstone structures together. Thinking another overarching force was responsible, Bruthans decided to play in the sand.

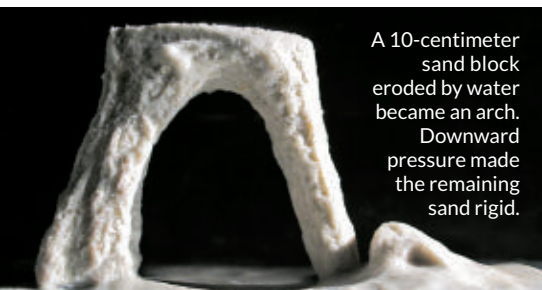
Bruthans and his colleagues used fine sand compacted into cubes 10 centimeters on a side. The team placed weights on top to mimic forces from stacked rocks and then submerged the cubes in still water to simulate natural weathering. As the side of each block eroded away, an hourglass shape formed, with fewer and fewer sand grains

remaining to support the load.

After a few minutes, the downward stress was great enough that the remaining sand interlocked into a solid that was more than eight times as strong as the original cube and more resistant to erosion. By tweaking the conditions in the experiment, the researchers reproduced on a small scale all of the fantastic shapes sandstone takes in nature.

“The weight allows these formations to withstand what would be horrendous weathering processes” such as rain and wind, says geologist Alan Mayo of Brigham Young University in Provo, Utah, who worked with Bruthans on the project. “These things survive thousands of years in a harsh environment.”

In an accompanying commentary in *Nature Geoscience*, geologist Chris Paola of the University of Minnesota in Minneapolis applauds the mechanism’s simplicity. “Bruthans and colleagues present nothing more or less than a lovely and elegant formative mechanism for a lovely and elegant kind of landform.” ■



A 10-centimeter sand block eroded by water became an arch. Downward pressure made the remaining sand rigid.

MATTER & ENERGY

Weird materials find a practical use

Topological insulators could speed up memory storage devices

BY ANDREW GRANT

One of science’s newest wonder materials may find its way into computers.

A study published in the July 24 *Nature* reveals that electrons coursing through materials called topological insulators can manipulate magnetic components like the ones in computer memory. The work is one of the first attempts to find real-world uses for topological insulators.

“This is the first proposal I have seen ... which does not appear to be *prima facie* absurd,” says Sankar Das Sarma, a condensed matter physicist at the University of Maryland in College Park. “Purely scientifically, this proposal makes sense.”

Since predicting the existence of topological insulators in 2005, physicists have salivated over the materials’ unique

properties (*SN*: 5/22/10, p. 22). For the most part, topological insulators are, in fact, insulators. But electrons scurry along unimpeded on their surfaces, and in strict formation: All electrons moving in a particular direction have the same spin.

Many scientists are digging into the fundamental physics of these materials, which include bismuth selenide and mercury telluride. But Penn State condensed matter physicist Nitin Samarth wanted to do something useful with them. He found inspiration in the work of Cornell University condensed matter physicist Dan Ralph, whose team is trying to revamp computer RAM and hard drives.

Most current hard drives store data as 1s and 0s in small chunks of magnetic wafers that act like compass needles — if a chunk is magnetically oriented in one direction it’s a 1; in the other it’s a 0.

Flipping a 1 to a 0 (or vice versa) requires generating magnetic fields, a relatively inefficient process that limits devices’ speed and capacity (*SN*: 10/19/13, p. 28).

To speed up the process, Ralph’s team built devices in which electrons brush past the compass needles and, because of their spin, provide a subtle torque. The key is maximizing torque by generating currents of electrons with the same spin.

Matched spins are the bread and butter of topological insulators. So Ralph’s and Samarth’s groups teamed up to see if electrons racing across the surface of a topological insulator could manipulate a magnetic material with their spins. They layered a nickel-iron wafer atop the topological insulator bismuth selenide and sent an alternating current of electrons through the device. Each electron in the bismuth selenide exerted about 10 times as much torque as electrons in any other material that has been tested.

That shows that a topological insulator’s electrons can provide enough torque for a memory device, Samarth says. ■

Moose drool subdues grass defenses

Saliva from grazers may turn off plant chemical weapons

BY SUSAN MILIUS

The slobbering of moose and reindeer as they eat may be big, wet countermeasures against the chemical defenses of grasses.

Some otherwise inviting grasses harbor live-in fungi such as *Epichloë* species, which can produce strong alkaloid toxins. Those compounds can make grazing animals sick enough to shy away from the grasses. Big animals, however, have a previously unappreciated way of fighting back, says ecologist Andrew Tanentzap of the University of Cambridge: They drool.

In lab tests, moose saliva dabbed onto grasses two or four times could lower the concentrations of the toxin ergovaline by 40 to 70 percent over the course of two months, Tanentzap and colleagues report July 23 in *Biology Letters*. Also, dripping moose or reindeer drool on *Epichloë* fungus in lab dishes slowed the spread of its thready networks, the team found.

"Big grazing animals have been studied to death," Tanentzap says. Yet as far as he knows, his paper describes the first tests of big herbivore saliva as sabotage for the fungal defense of grasses.

Spit from various caterpillars can manipulate plant chemistry to improve the insects' meals. Tanentzap began wondering about spit from bigger grazers when he read a 2002 study on a different aspect of moose saliva: its power to encourage half-eaten twigs to branch as they regrow into another tender meal.

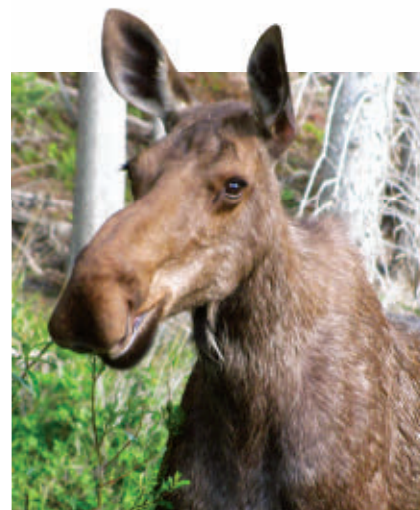
To see what big-grazer saliva might do to fungal defenses, the researchers persuaded zoos to collect drool when animals were anesthetized for medical procedures. (It's a task best left to professionals, Tanentzap says.)

Slobber from moose reduced toxin concentrations in red fescue grass (*Festuca rubra*), but only in plants originating from the core of the plant's range in Europe. Fungi in grass from the water-limited margins of the species' range in

southern Ontario, Canada, just kept producing toxin regardless of the saliva. This discrepancy, Tanentzap says, could help researchers understand how the saliva works.

He observed that the fungus in the European fescue produces the toxin only when something eats the grass (or a researcher snips it). Some signal probably has to switch on toxin production, and the saliva may turn the switch off, Tanentzap speculates. But in fescue grown in the stressful conditions in Ontario, the fungus churns out toxin all the time, regardless of whether there has been any chewing. The fungi and their Canadian plants, which didn't respond to drool, may not have that switch, and thus no weak link for the saliva to exploit.

The saliva doesn't act instantly, notes Stanley Faeth of the University of North Carolina at Greensboro, who has long studied fungus-plant interactions. So



As moose feed, their slobber may weaken the toxic defenses of certain grasses.

this gradual inhibition of toxins benefits animals only if they revisit old grazing patches. What he'd like to know more about, he says, is how much benefit the grazers get from their fungus-fighting saliva. He also wonders whether the grazers' battle against fungi in grasses would have driven herbivores to evolve sabotage drooling. Alternatively, safer grass eating may just be a bonus from weaponized drool that originally coped with some other menace. ■



BODY & BRAIN

First cases of chikungunya acquired in U.S.

Two people in Florida have contracted chikungunya, a painful but rarely deadly mosquito-borne disease. Chikungunya has caused outbreaks in Africa, Asia and Europe. But this is the first time people in the continental United States have acquired the virus without traveling outside the country, the U.S. Centers for Disease Control and Prevention said July 17.

Puerto Rico and the U.S. Virgin Islands have also reported locally acquired cases of chikungunya this year. The first cases acquired locally in the Western Hemisphere date to December 2013.

The two species of mosquito that most often carry the virus, *Aedes aegypti* and *A. albopictus* (shown), live in a broad swath of the United States (SN: 6/29/13, p. 26). Chikungunya causes fever, headache and joint pain that can be debilitating. No treatments or vaccines are available. — Lila Guterman

GENES & CELLS

Eyes exploit fiber optics to see in dark

Müller cells shunt red and green light to cones; blue leaks to rods

BY TINA HESMAN SAEY

Special cells in the retina split light into different colors to enable sharp daytime vision without harming night vision.

Those tubelike cells, called Müller cells, snake through the retina, where they pair with and support light-gathering cone cells. Cones absorb red and green light, enabling daytime color vision. The retina's rod cells absorb blue light for fuzzier monochromatic night vision.

In humans and many other animals, the retina sits at the back of the eye, instead of at the front, where cones and rods could absorb the most light. In addition, human retinas are inverted so that the light-gathering cells form the last layer. Evolutionarily, inverting the retina seems to be a mistake, says Serguei Skatchkov, a biophysicist at the Central University of the Caribbean in Bayamón, Puerto Rico. Peering through several layers of eye tissue, he says, "is like looking through milk." How light penetrates those tissues

to reach the retina has been an enigma.

But in 2007, researchers discovered that Müller cells act as fiber-optic cables, helping light burrow through layers of retinal tissue to land on the cones at the back of the retina (*SN: 5/19/07, p. 317*). But that discovery raised another mystery: If Müller cells channel all available light to cone cells, how do rod cells get enough light for people to see in the dark?

Müller cells split light into component colors, streaming red and green wavelengths to cones while allowing blue and violet wavelengths to leak onto nearby rods, researchers report July 8 in *Nature Communications*. This separation of colors ensures that cones get the red and green wavelengths needed for clear sight during the day without harming night vision, say Ido Perlman, a neural physiologist at Technion-Israel Institute of Technology in Haifa, and colleagues.

"It's a very special problem nicely solved," says Andreas Reichenbach, a

physiologist at the University of Leipzig in Germany who was not involved in the new study. He and colleagues made the discovery that Müller cells channel light.

Perlman's team simulated Müller cells in a computer. The simulations suggested that the cells could take in long-wavelength light at the green to orange end of the spectrum but would scatter shorter-wavelength blue and violet light.

The researchers tested the hypothesis by shining light on a guinea pig retina and mapping where various wavelengths hit it. The team found that red and green light shot down tubes, which corresponded with the location of Müller cells, and shone directly onto cone cells. Blue and purple light leaked out to the surrounding retina, where the rods could take in those wavelengths.

Reichenbach is satisfied with the demonstration of Müller cells' ability to channel certain wavelengths of light to cones. Skatchkov remains unconvinced, though. He says the researchers don't explain how Müller cells cleave light into different colors and don't explain how the cells can channel red light having wavelengths longer than the diameter of the cell. ■

MATTER & ENERGY

Molecular cage traps rare gases

Organic compound could cull valuable xenon from the air

BY BETH MOLE

With a squeeze, an organic molecule can snatch rare gases from the air. The compound contains cavities that are the right size to nab atoms of xenon and radon, and to a lesser extent krypton. These noble gases range from valuable to radioactive; they're largely inert, usually present in low or negligible concentrations in the air and extremely difficult to capture.

"I would die to have these compounds in my hands," says chemist Siegfried Waldvogel of Germany's Johannes Gutenberg University Mainz.

The new chemical cage was a "happy

accident," admits materials chemist Andrew Cooper of the University of Liverpool in England. Cooper and colleagues had set out to create a polymer. Instead, they produced a 3-D cage by reacting four aldehyde molecules with six nitrogen-containing ones. The cages clumped together to form a multichambered atomic jail.

The cages are around 0.44 nanometers wide. A krypton atom is 0.37 nanometers wide, xenon is 0.41 and radon 0.42. However, openings to the cages are only about 0.36 nanometers, small enough to possibly prevent gas atoms from slipping in or out. But the cage molecules wiggle, expanding and contracting the entryways.

The researchers estimate xenon could slip in and out just 7 percent of the time; for radon, a door would be open 3 percent

of the time. Smaller krypton could come and go easily.

In experiments, the researchers tested the cage's selectivity, blowing a mix of common elements found in air and trace amounts of xenon and krypton through the cage for 45 minutes. The nitrogen, oxygen and carbon dioxide passed through. Krypton was held only briefly while xenon got trapped for around 15 minutes. The results appear July 20 in *Nature Materials*.

The finding suggests that the molecular trap can strip out valuable xenon from other gases. Xenon, which sells for around \$5,000 per kilogram, is useful in lighting, medical imaging and anesthesia. Cooper and colleagues think the molecules could also detect radon in homes, which can cause lung cancer. ■



Molecular cages such as the one illustrated in gray and blue have a central gap (purple) perfectly sized to hold a rare gas atom.



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GENES & CELLS

Gut microbes and carbs fuel tumors

Sugar-loving bacteria play a role in mice's colon cancer

BY NSIKAN AKPAN

Westerners' carb-rich diets have long been linked to high levels of colorectal cancer, and scientists have begun to work out why. In an experiment in mice, a chemical made by carbohydrate-consuming gut bacteria encouraged the growth of colon cancer, researchers report in the July 17 *Cell*.

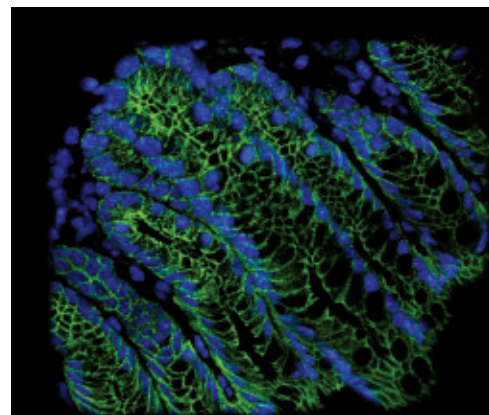
In country after country where people have switched to Western-style diets heavy in refined sugars such as high fructose corn syrup, the incidence of colorectal cancer has increased, says Scott Bultman, a geneticist at the University of North Carolina at Chapel Hill, who was not involved in the study.

Until now, the underlying connection between food and the disease has been cloudy. "This study gives a good mechanism for how diet is tied to colon cancer," Bultman says.

The researchers studied mice engineered with two genetic mutations often linked to colon cancer in people. One of the mutations derails a cell's ability to fix errors that arise during DNA replication. A deficiency in fixing these errors causes cells in the lining of the colon to divide quickly, says study leader Alberto Martin, an immunologist at the University of Toronto.

Martin's team discovered that a chemical produced by carb-feasting microbes appears to exacerbate the unchecked growth of colon cells lacking this type of DNA repair, which may lead to tumors.

Feeding the engineered mice a diet low in sugar and starch reduced the growth of malignant lumps of cells called polyps in the lining of their colon and small intestine, the team found. In



In mouse colons, sugar-eating gut microbes encourage mutations in DNA (blue), which elevate cancer-related proteins (green). The result may explain carb-rich diets' link to colon cancer.

another experiment, the researchers treated cancer-prone mice with antibiotics. After reducing their intestinal bacteria, these mice had less polyp growth than untreated mice.

To look for the link between carbohydrates and gut microbes, the researchers

BODY & BRAIN

Genetic links to schizophrenia found

Newly discovered DNA changes may underlie mental disorder

BY LAURA SANDERS

By combing through the genomes of over 30,000 people with schizophrenia, scientists have found more than 100 stretches of DNA that may raise a person's risk of the disorder. Although the study is the largest genetic investigation of a psychiatric disorder done to date, it provides only clues to the disease's origins — not answers.

The mega-analysis, published in the July 24 *Nature*, is an important and necessary step toward developing new treatments for schizophrenia, says study coauthor Michael O'Donovan, a psychiatrist at the Cardiff University School of Medicine in Wales. But the heart of the disorder is still a mystery. "People shouldn't be phoning up their doctors tomorrow and saying, 'What's this stuff done for treatment?'" That's going to take years to filter through," he says.

About 1 percent of Americans have schizophrenia, a disorder marked by hallucinations, paranoia and dysfunctional ways of thinking. Although the disease often runs in families, doctors and researchers have struggled to pinpoint the genes involved. The new study provides the most comprehensive identification yet of potential genetic culprits. Ultimately the identified DNA regions might reveal a deeper understanding of how the disease begins and progresses — and how to treat it.

"For the first time, we can start to see the underlying biological basis of the disease, and to lay the foundation for understanding this disorder and eventually developing treatments," Eric Lander, director of the Broad Institute of MIT and Harvard, one of the research centers involved in the study, said in a webcast announcement of the results.

O'Donovan worked with a large international team that collected DNA from people with schizophrenia from around the world, as well as samples that had been analyzed in earlier studies. As part of a genome-wide association study, the researchers compared DNA from people with schizophrenia with DNA from over 45,000 people without the disorder. One or several variations in the DNA's chemical components cropped up in 108 distinct genome locales, the team found.

Several of these hot spots had been identified in earlier schizophrenia genome-wide studies (*SN*: 8/1/09, p. 10). The new study found an additional 83 spots in the genome. "There are just loads and loads of genes" involved with the disorder, O'Donovan says. "We're still mining the biology of it."

Certain finds make sense: One region includes the genetic blueprint for a protein called dopamine receptor D2, thought to be the target of some psychiatric drugs. Other areas include genes for proteins involved with the brain chemical glutamate, a neurotransmitter

examined the colon contents of the mice that ate low-carb diets or had received antibiotics. These rodents had low levels of a fatty acid called butyrate, one of the by-products of microbial fermentation.

The researchers then fed mice butyrate supplements. The supplemented mice had more tumor polyps than did mice with normal diets, suggesting that the path from Western diets to colon cancer relies on this bacterially produced chemical.

In people, mutations that alter a cell's ability to fix DNA replication errors are present in 1 in 5 cases of noninherited colon cancer. If the mouse experiments mimic human cancers, then shunning high-carbohydrate, Western diets could allay or prevent the disease for many people, Bultman says. "Following a well-balanced diet, with fewer refined sugars and more fiber, is good for the microbiome and likely has an effect on cancer predisposition." ■

suspected of playing a role in schizophrenia. Affected areas also include genes that are active in immune cells, suggesting a link between the immune system and schizophrenia.

"There is a whole pile of genes there that have never been on anyone's list before," says psychiatrist Jonathan Flint of the University of Oxford, who wasn't involved in the study. That genetic bounty is "a great step forward," he says.

A person's risk of schizophrenia increases just slightly, around 0.1 percent, when the individual has particular changes in one of the genetic regions identified in the study, O'Donovan says. Such a tiny increase in risk means that these stretches of DNA won't predict who will develop schizophrenia.

Many spots in the genome that contribute to schizophrenia remain undiscovered. By some estimates, hundreds or even thousands more genome locations could be involved. O'Donovan and his colleagues plan on conducting even larger studies in the next year or so that may reveal some of these hidden spots. ■

EARTH & ENVIRONMENT

Impacts probably stifled early life

Giant asteroids hit Earth until about 4.3 billion years ago

BY THOMAS SUMNER

Space rocks larger in diameter than Utah bombarded the early Earth, probably repeatedly eradicating any life on the planet's surface. The last of these death rocks struck around 4.3 billion years ago, scientists estimate in the July 31 *Nature*, providing an upper limit to when life could have taken hold on Earth.

From Earth's origin some 4.6 billion years ago until 3.8 billion years ago, the planet was such a hellish place that geologists call this eon the Hadean after Hades, the Greek god of the underworld. Debris left over from the solar system's birth regularly slammed into Earth, boiling away the early ocean and coating the planet with molten rock (*SN*: 5/19/12, p. 22).

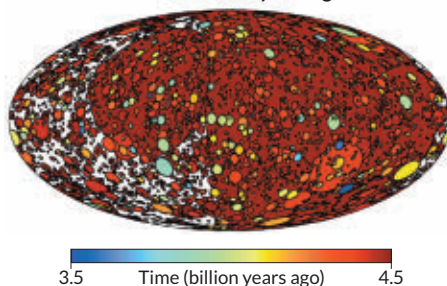
But it was during this chaotic period that scientists think life arose on Earth.

"If life on Earth emerged before [a] final sterilizing impact, it may have been completely erased," says planetary scientist Simone Marchi of the Southwest Research Institute in Boulder, Colo. "Life would have had to start all over again."

Enough material struck Earth during the Hadean that it could have extended the planet's entire surface by the height of Mount Everest. These impacts shaped

Hit hard Early Earth was pummeled by asteroids. A simulation suggests that over time, fewer and smaller space rocks bombarded the planet (snapshot of Earth's craters 3.5 billion years ago shown; wider circles depict larger craters; colors represent date of impact).

Earth 3.5 billion years ago



the emergence of plate tectonics (*SN*: 5/17/14, p. 14); however, few rocks older than around 3.8 billion years remain to provide a natural record of Earth's early impact history.

To reconstruct the barrage of rocks that assaulted early Earth, Marchi and colleagues looked to the relatively stagnant moon. The moon lacks the recycling action of plate tectonics, so it still shows scars from early asteroid impacts. Scientists can determine the ages of ancient lunar impacts using a method called crater counting. As a crater ages, falling meteorites gradually blemish the impact site. Using the ages of moon rocks collected from lunar craters during the Apollo missions as calibration, scientists can approximate the age of large lunar craters by counting the number of smaller, fresher craters within them. Marchi's team used such information about the moon to estimate the number, frequency and size of asteroids that impacted early Earth, assuming the two had similar impact histories.

The team then ran a computer simulation of Earth's early bombardment and observed that asteroid impacts became smaller and less frequent with time. The team also found that every bit of Earth's surface was at some point covered in a magma-oozing impact crater.

Between three and seven asteroids larger than 500 kilometers across probably struck Earth during this time, each of which could have vaporized all water and destroyed any life on the planet's surface, the researchers say. The last of these life-ending impacts took place 4.27 billion years ago, the team estimates. The oldest evidence of life on Earth dates to 3.8 billion years ago, although that evidence is disputed.

Geochemist Jeffrey Bada of the Scripps Institution of Oceanography in La Jolla, Calif., thinks that a better understanding of the early asteroid bombardment will help researchers studying the origins of life. "The window of when life appeared on Earth is sometime after these really traumatic impacts," he says. "Life could not have started prior to that and survived." ■

EARTH & ENVIRONMENT

Massive eruptions can arise suddenly

Magma merger let Idaho supervolcano blow, study finds

BY THOMAS SUMNER

Massive supervolcanic eruptions can be triggered much more quickly than previously thought, scientists report July 21 in *Geology*.

The researchers made the discovery while reconstructing the history of a massive eruption 4.5 million years ago in a field of volcanoes called Heise, in what's now eastern Idaho. The Heise supervolcano spewed enough ash and molten rock to fill Lake Ontario. In most supervolcanoes, magma simmers in underground chambers for hundreds of thousands of years before erupting. But in Heise, the team has found, several small magma reservoirs pooled together in less than 10,000 years to spur the eruption.

Supervolcanoes are capable of outbursts thousands of times more powerful than typical volcanic eruptions, causing regional devastation and dramatic changes in global climate. "We now have a better idea of what the magma reservoirs under these supervolcanoes look like just prior to eruption," says geologist and lead author Jörn-Frederik Wotzlaw of the University of Geneva.

Heise was fueled by an abnormally hot spot deep in Earth's mantle that has sprouted a string of North American

volcanoes over the last 16.5 million years, including a supervolcano beneath Yellowstone National Park that erupted 640,000 years ago. The new finding could help researchers predict how quickly a new supervolcano could emerge and erupt in the region, Wotzlaw says.

Wotzlaw and colleagues studied tiny translucent crystals embedded in rocks blasted from the Heise eruption. Scientists know that over thousands of years, the crystals grew inside the volcano's subterranean magma and absorbed oxygen from the surrounding molten rock. The oxygen serves as a fingerprint of where the crystals formed, Wotzlaw says, because all crystals within a magma reservoir should have the same ratio of forms of oxygen called isotopes.

Looking at these ratios, the researchers found that the crystals in the Heise sample didn't all arise in a single magma chamber. The researchers could tell from the oldest part of a crystal, its core, that each was born in one of four magma reservoirs. The younger outer rims of the crystals grew inside one of two distinct magma reservoirs. Because previous studies had demonstrated that the Heise supervolcano contained only one magma reservoir when it erupted, the team realized that the crystals must

have grown in different magma batches that merged into two, then one before eruption.

While in these reservoirs, the crystals absorbed not only oxygen but also uranium, which slowly decays into lead. By comparing the number of uranium and lead atoms in each crystal, the researchers determined how long ago it formed. They estimate that the four smaller magma chambers formed, merged and erupted in only 1,000 to 10,000 years.

Wotzlaw proposes that the assembly of magma reservoirs set off the Heise eruption without an external trigger such as an earthquake. In January, a team reported that the buoyancy of magma pushing upward against Earth's denser crust might itself be enough to prompt an eruption. Because the force from a huge magma chamber would be stronger than from each individual reservoir, Wotzlaw says that when the reservoirs teamed up, they could have set off the eruption.

Heise's magma is spent and the volcano will not erupt again. The now-simmering Yellowstone supervolcano does contain several large magma reservoirs, but they are less likely to combine or initiate a major eruption, says geochemist Kenneth Sims of the University of Wyoming in Laramie. He warns against comparing the two volcanoes. The magma under Yellowstone is older and less runny than the molten rock that fueled the Heise eruption, he notes. "The possibility of another eruption certainly exists, but right now there isn't that kind of evidence," he says.

But a new supervolcano probably will one day form northeast of Yellowstone, Wotzlaw says. The North American tectonic plate has been slowly and steadily drifting southwest over the region's hot spot, spawning volcanoes. If the new volcano follows Heise's lead, it could quickly evolve into an eruptible state.

"If the process only takes a few thousand years," Wotzlaw says, "then it is relevant on a human scale; maybe not for you and me. But if a volcano erupts in 2,000 years, that may not look good for the people living at that time." ■



A hot spot deep in Earth's mantle helps fuel the geothermal activity at Yellowstone National Park (shown). The hot spot also nourished a supervolcano that erupted 4.5 million years ago in Idaho when magma reservoirs quickly merged together, a new study suggests.

LIFE & EVOLUTION

Maybe all dinos wore feathers

Newly discovered plant eater mixed scales with plumage

BY MEGHAN ROSEN

Dinosaurs may have all bundled up in flashy feather coats.

Skulls and other bones of a new dinosaur species unearthed in Siberia support what some scientists have suspected: Dinosaurs with feathers were probably the norm.

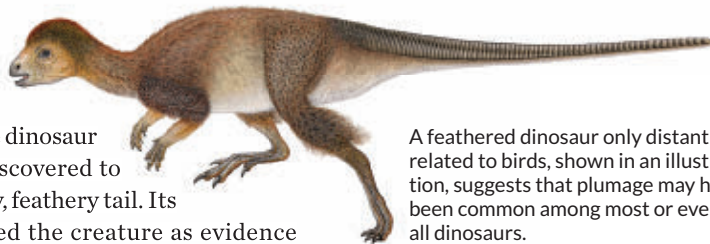
“For the first time we have a feathered dinosaur that is far from the lineage leading to birds,” says study coauthor Pascal Godefroit, a paleontologist at the Royal Belgian Institute of Natural Sciences in Brussels. “It means that all dinosaurs were potentially covered by feathers.”

Paleontologists had previously dug up fossil evidence of feathers that adorned dinolike birds of the *Archaeopteryx* genus and other ancient avian ancestors. These

include one dinosaur recently discovered to have a fluffy, feathery tail. Its finders cited the creature as evidence that every dinosaur could have worn feathers (*SN Online*: 7/2/12). But the dinos were all theropods — a group of bird forebears that includes the meat eaters *T. rex* and *Megalosaurus*.

Whether all dinosaurs or just avian relatives flaunted feathers has been up for debate. In recent years, scientists have found evidence of bristle- and quill-like strands — perhaps early versions of feathers — that speckled the hides of ornithischian dinosaurs. This herbivorous group is more distantly related to birds than theropods. But these fibers aren’t clearly feathers, says Godefroit.

He thinks the structures sprouting from his team’s newly discovered dinosaur species are. Excavations found hundreds of skeletons and six partial skulls of the Jurassic-period dinosaur *Kulindadromeus zabaikalicus* sandwiched between layers of volcanic rock at the bottom of what probably was once a shallow lake.



A feathered dinosaur only distantly related to birds, shown in an illustration, suggests that plumage may have been common among most or even all dinosaurs.

Though the dinosaurs were ornithischians — far removed from the lineage that led to birds — the fossils bore scales and three types of feathers, Godefroit and colleagues report in the July 25 *Science*.

From snout to tail, the plant eater stretched about as long as a gray wolf, with strong legs, stubby arms and a squat little skull. Stringy strands of feathers blanketed its head and its torso; tufts of ribbons trimmed its shins; and fluffy feathers like some chickens’ budded from scales to sheathe the creature’s upper arms and swaddle its thighs. Godefroit thinks the feathers could have kept the dinosaur warm; gussying up in fuzzy duds may also have attracted mates.

Finding a scale-feather combo in dinosaurs “is something completely new,” says ornithologist Gerald Mayr of the Senckenberg Research Institute Frankfurt. “It’s a great discovery.” ■

BODY & BRAIN

Early Parkinson’s drug use may be OK

Taking levodopa long-term doesn’t increase side effects

BY LAURA SANDERS

Many doctors delay prescribing an effective treatment for Parkinson’s disease out of fear that the drug will cause side effects if given too early. That fear may be unfounded, a new study suggests.

Since the 1960s, doctors have prescribed levodopa to ease the slow movements, tremors and rigid muscles that come with Parkinson’s. But studies indicated that prolonged levodopa use at high doses causes different problems, such as uncontrollable movements.

By comparing people with Parkinson’s in Ghana, where levodopa is hard to come by, with patients in Italy, where the drug is routinely used, scientists have now found that side effects are no worse in people who start levodopa early. The results appear July 17 in *Brain*.

“We believe our findings may wipe away the phobia of levodopa,” says study coauthor Roberto Cilia of the Parkinson Institute in Milan.

Without a good way to compare people who hadn’t taken levodopa with those who had, it’s difficult to separate the disease’s effects from the effects of the medicine, says neurologist Mark Stacy of Duke University. “We lived with that until this manuscript,” he says. “This paper was a very clever way to look at that.”

Cilia and colleagues, who began treating people with Parkinson’s in Ghana as part of a humanitarian effort, realized that those patients offered a way to study how Parkinson’s progresses in the absence of the drug.

The researchers treated people with Parkinson’s for about four years. On aver-

age, 91 Ghanaians first received levodopa 4.2 years after developing the disease; 182 Italians received the drug about two years sooner. Yet patients in the two countries had similar amounts of motor problems brought on by levodopa.

That similarity suggests that the length of levodopa use doesn’t influence the severity of its side effects. In fact, some Ghanaian patients showed side effects hours or days after starting treatment, the researchers found. As in previous studies, higher doses of levodopa were associated with more severe side effects.

Along with dose, stage of Parkinson’s disease is what determines the severity of the levodopa response, not the length of time someone has taken the drug, says study coauthor Gianni Pezzoli, also of the Parkinson Institute.

Stacy says the results will allow him to “make a stronger case to begin patients on levodopa when I think it’s an appropriate time.” Early levodopa treatment can improve people’s lives for years, he says. ■



LIFE & EVOLUTION

Termite soldiers' legs sense alarms

Submillisecond signal delays indicate direction of attacks

BY SUSAN MILIUS

A soldier termite can tell which way to run in a crisis by sensing short SOS-message time delays with its legs.

Africa's *Macrotermes natalensis* termite relies on a fighter caste to defend its hardened, meter-high-plus mounds and up to several thousand square meters of underground tunnels. When an aardvark or other predator gouges the insects' home, termites known as major soldiers pound their heads against the floors. The vibrations from the drumbeats tell other soldiers to speed to the breach.

These headbanger alarms vibrate through the walls of tunnels at about 130 meters per second. What lets a soldier know which direction to go is the slight delay between when the vibrations hit the soldier's leg nearest the drumbeat source and when they hit its farthest leg, says Felix Hager of Ruhr University Bochum in Germany. A delay of as little as 0.20 milliseconds was enough to orient soldiers in a lab setup, Hager and Ruhr colleague Wolfgang Kirchner report July 15 in the *Journal of Experimental Biology*.

Research on the communicative power of beats, shivers and tickles vibrating through solid surfaces lags far behind the study of airborne sounds, says Peggy

S.M. Hill of the University of Tulsa in Oklahoma, who has long studied insect vibrations. Textbooks of the mid-1970s insisted that natural solids such as soil or twigs were, she says, "not suitable for transmitting any biologically meaningful information via vibrations." Not true, she adds, as growing evidence shows.

Researchers now estimate that some 150,000 insect species communicate only by vibrations drummed through their nests, the ground, plants or some other solid surface, Hager says. "We are just beginning to understand how they do it."

In 2013, Hager and Kirchner showed that soldier termites that hear a headbanging alarm start headbanging too, sending the message farther through the termite empire than a single transmission

A soldier termite stands ready to headbang an alarm and use its superbly sensitive legs to catch clues about which way to run to defend its colony against a predator.

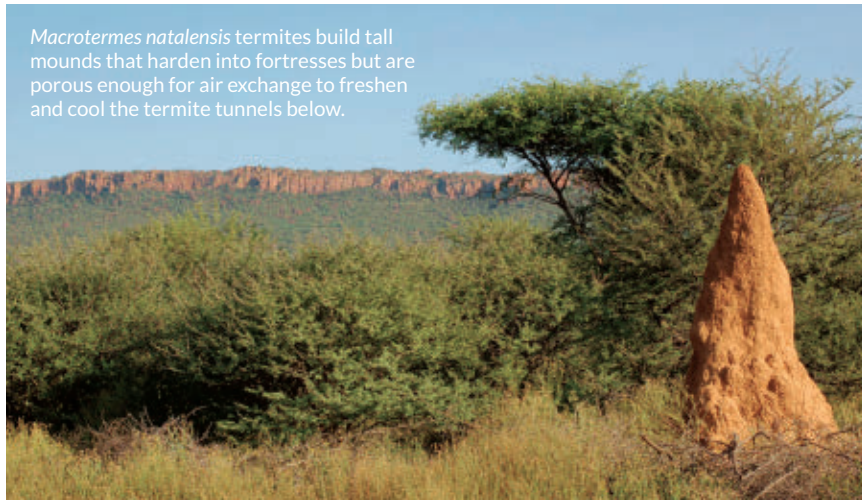
would go. To see how those vibrations draw soldiers in the right direction, the researchers placed termites on a plastic platform with two sides separated by a 1-millimeter gap. When a soldier had its right legs on one side of the gap and its left legs on the other, a researcher triggered vibrations in the platform so that one side started shaking just a smidge earlier than the other side.

When delays lasted 0.20 milliseconds, the termites showed a clear preference for turning toward or moving onto the first-to-shake platform side. Lengthening the delay another 0.09 milliseconds caused an even more decisive reaction.

Termite performance in the lab shows that the insects can detect delays of the order of magnitude they would need to make sense of an alarm in the wild, Hager says. He calculates that a major soldier (the larger of two size classes of soldiers) in a real tunnel would experience a gap of about 0.12 milliseconds between the time a headbanging signal buzzed the first front leg and the time it reached the rearmost one on the opposite side, a distance of about 16 millimeters.

Other research has already shown that insect nervous systems handle even briefer delays in airborne vibrations — 0.01 milliseconds for locusts — as sound hits first one ear and then the next. People also detect the direction of sound vibrations by picking up the kinds of tiny delays that insects use, Kirchner notes. "They're as good as we are." ■

Macrotermes natalensis termites build tall mounds that harden into fortresses but are porous enough for air exchange to freshen and cool the termite tunnels below.



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LIFE & EVOLUTION

Sperm flocks aid straighter swimming

Groupings permit direct routes for earlier arrival at destination

BY NSIKAN AKPAN

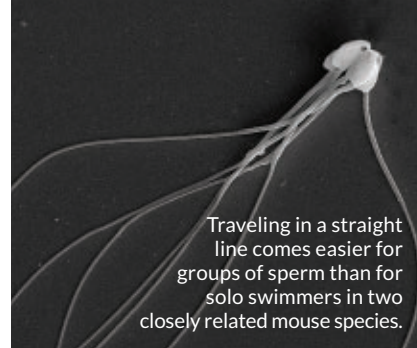
Mouse sperm shoot along straighter paths by ganging up. Yet the merits of flocks evaporate if the group becomes too large, researchers report in the Sept. 7 *Proceedings of the Royal Society B*.

“Sperm aggregation is one of the more enigmatic adaptations to sperm competition,” says evolutionary biologist Dawn Higginson of the University of Arizona in Tucson.

Sperm competition arises when a female mates with multiples males. Cooperative behavior in sperm is rare, but examples appear across the animal kingdom — from great diving beetles to opossums. Controversy looms over whether sperm herding provides an advantage over swimming solo. In desert ants (*SN*: 7/26/14, p. 20) and Norway rats, sperm crews swim faster, but in species like the house mouse, packs are actually slower.

This discrepancy led evolutionary biologist Heidi Fisher and her colleagues at Harvard University to study sperm groupings in two closely related species of mouse. The researchers videotaped sperm sprayed onto a microscope slide as the squiggly sperm gathered into parties and swam across it. The team found that sperm groups don’t drive faster than lone swimmers do. But groups do travel with a straighter trajectory and therefore get to their destination more quickly.

As troop size grew, the groups’ paths became straighter, peaking when groups reached seven members. By using high-powered microscopes and mathematical simulations, the team deduced that the geometry of a sperm’s head restricts how many cells can face the same direction. Little hooks on sperm crowns appear to orient the cells (without physically linking them), helping a group swim less erratically than a single sperm would.



When the cluster gets more than seven members, however, the group rounds into a star-shaped ball, and the whipping tails start to counteract one another, slowing the sperm down.

Promiscuity influenced sperm dynamics as well in the two species the researchers examined: the monogamous beach mouse (*Peromyscus polionotus*) and the promiscuous North American deer mouse (*P. maniculatus*).

In lab tests, sperm from the promiscuous species formed the optimum size for pack travel more often than did those from monogamous mice.

Because sperm from different males face off inside the genital tracts of female *P. maniculatus* mice, the greater tendency toward pack behavior in this species may represent an adaptation to more competition, Fisher says. ■

MATH & TECHNOLOGY

Wax transforms soft to strong

Stiffness of plastics, foam can be tuned with temperature

BY MEGHAN ROSEN

Future robots may wear a wax coating that lets them transform from soft and squishy to stiff and strong.

Dipping foam or plastic in molten wax creates structures whose flexibility and strength can be tuned with temperature, researchers report June 30 in *Macromolecular Materials and Engineering*. The study introduces a novel class of inexpensive materials that can be both floppy and firm, says mechanical engineer Robert Shepherd of Cornell University.

Researchers could one day use the materials to build remote-controlled surgical or search-and-rescue robots

that can squeeze through tight spaces when heated and firmly push obstacles aside when cooled.

Engineers have previously created shape-shifting materials, such as balloons filled with sand and liquids loaded with iron (*SN*: 8/10/13, p. 8). But the liquids aren’t that strong and the sandbags aren’t very adjustable, says Shepherd. So MIT mechanical engineer Nadia Cheng and colleagues looked for materials that they could control with heat.

“We melted down crayon wax, beeswax, candle wax, all sorts of things,” says Cheng, who is now at Empire Robotics in Boston. The researchers found that dipping packing foam into melted batik wax — used in fabric dyeing — led to the best combination of stiffness and strength once the wax hardened.

The team also dunked 3-D printed scaffolds of rubbery plastic into vats of wax, let the wax solidify and then measured the materials’ strength by

squashing them with a contraption akin to a tiny car-crusher. Wax-drenched materials were up to 100 times as strong as uncoated ones, the researchers found. “It’s a dramatic difference,” says Shepherd.

To control the materials’ flexibility, the researchers wrapped heating wire around tubes of waxed foam. Heating the coils caused the foam to curve in specific spots, like a human spine bending at the neck or waist. Any temperature above 70° Celsius, about as much heat as it takes to cook an egg, would melt the wax.

Turning up the heat also let the materials heal themselves. When the team crushed coated plastic, the waxy skins began to crack and peel. Melting the skin back together restored much of the plastic’s strength.

The work is still in the early stages, but it’s a promising new idea, says robotics engineer Erik Steltz of iRobot in Bedford, Mass. ■

Prions portend pregnancy plight

Test for aberrant proteins may detect preeclampsia early on

BY TINA HESMAN SAEY

Preeclampsia, a life-threatening condition that strikes during pregnancy, may have a lot in common with Alzheimer's and mad cow diseases, a new study suggests.

Misfolded proteins, including one involved in Alzheimer's, clump in the urine of women with preeclampsia, researchers report in the July 16 *Science Translational Medicine*. Those twisted proteins are produced by the placenta, a pancake-shaped organ that fuses to the uterine wall and nourishes the fetus.

A urine test could detect the abnormal proteins up to 10 weeks before symptoms begin, say Irina Buhimschi, an obstetrician at Nationwide Children's Hospital in Columbus, Ohio, and colleagues.

Preeclampsia is a complication of pregnancy that results from a damaged placenta and raises women's blood pressure to dangerously high levels. It affects about 5 to 10 percent of pregnancies. Preeclampsia and other high blood pressure disorders of pregnancy kill about 76,000 women and 500,000 babies worldwide each year. It usually occurs after 20 weeks of gestation. The exact cause of the disorder is unknown and there is no treatment except delivering the baby and the placenta.

Buhimschi and her colleagues examined the urine of women with preeclampsia and found that at least five proteins routinely aggregated when the researchers added a dye called Congo red. The dye is known to glom onto proteins that contort into fiber-forming shapes called amyloids. Amyloid proteins have been implicated in many diseases, including Alzheimer's, Parkinson's and mad cow disease.

Among the clumpy proteins Buhimschi and her colleagues discovered in the urine

was amyloid precursor protein, or APP, a protein that, when cleaved into fragments, forms plaques in the brains of people with Alzheimer's.

Some of the proteins that form amyloids in the urine also appeared in the placentas of women with preeclampsia. Exactly what the proteins are doing there is not clear. They may damage the placenta and cause preeclampsia or they may be a side effect of the disease, researchers say.

Placentas and brains make many of the same proteins, so it's not so surprising to find a protein made primarily in the brain, such as APP, in the placenta, says Susan Fisher, a human reproductive and developmental biologist at the University of California, San Francisco. Researchers now need to figure out whether the amyloid proteins are damaging the placenta, she says.

Many pregnancy complications, including preeclampsia, are accompanied by a buildup of proteins between the placenta and the uterus. No one knows whether amyloid proteins are part of the protein layer or whether they occur only in preeclampsia, Fisher says.

The discovery could help scientists studying disorders other than preeclampsia. Researchers may learn more about the biology of protein-misfolding diseases from studying a fast-moving condition such as preeclampsia, rather than diseases that take decades to develop, says Thomas Easterling, a maternal-fetal medicine specialist at the University of Washington in Seattle.

The research may also be of value in detecting the disease early in pregnancy, Easterling and other researchers say. Currently, doctors have little warning that preeclampsia is about to hit. That leaves almost no time to attempt

to correct the condition, says John Kingdom, a maternal-fetal medicine specialist who directs a placenta clinic at Mount Sinai Hospital in Toronto.

Because the test uses urine instead of blood, it would be cheap and easy. It could even be done at home, Kingdom says. That would make it attractive in developing countries, where most of the deaths from the disease occur, he adds.

But there is a long way to go before this test is used clinically, says Bahaeddine Sibai, a maternal-fetal medicine specialist at the University of Texas Health Science Center at Houston. In the last decade or so, many researchers have claimed to have discovered substances that could predict preeclampsia before symptoms began. None have panned out, Sibai says.

He worries that the urine test might falsely predict that a woman will develop preeclampsia. Only a small number will actually be affected. "The rest you'll scare the heck out of," he says.

Exactly what action doctors could take to correct the disease if detected early isn't known. If the new test proves a reliable early indicator, it could give experimental treatments a better shot at success, Kingdom says.

But many potential treatments could even worsen health. Bringing down a mother's high blood pressure could choke off blood and oxygen flowing to the fetus, Sibai says. And even if researchers had a way to break up amyloid clumps in women with preeclampsia, the treatment might not make the condition better, he says.

The way to deal with preeclampsia remains elusive, says Sibai. "You have to find something that will repair the injury to the placenta." ■

76,000

Estimated global number of pregnant women who die yearly from preeclampsia and related high blood pressure disorders

500,000

Estimated global number of babies who die yearly due to preeclampsia and related high blood pressure disorders

EARTH & ENVIRONMENT

Wild monkeys near Fukushima have low blood cell counts

Radiation exposure may have altered the health of wild monkeys living near Japan's Fukushima nuclear power complex. The monkeys have low levels of radioactive cesium in their muscles. They also have fewer blood cells than monkeys living farther away from the site, researchers report July 24 in *Scientific Reports*. The plant suffered a meltdown following the 2011 Tohoku earthquake and tsunami (SN: 4/9/11, p. 5). Though the health implications are unclear, the authors say the finding could help predict the effects of radiation on humans. Researchers led by Shin-ichi Hayama of the Nippon Veterinary and Life Science University in Tokyo studied 61 Japanese macaques (*Macaca fuscata*) living in Fukushima City, about 70 kilometers northwest of the power plant. The team also examined 31 monkeys from about 400 kilometers north of the complex. Compared with the far-away monkeys, which had no detectable cesium in their muscles, Fukushima monkeys had lower red and white blood cell counts and less of the oxygen-carrying protein hemoglobin. Though the two groups seemed equally healthy, the team speculates that lower blood cell counts could weaken defenses against disease. — *Beth Mole*

Recycled wastewater may flood parks with dangerous germs

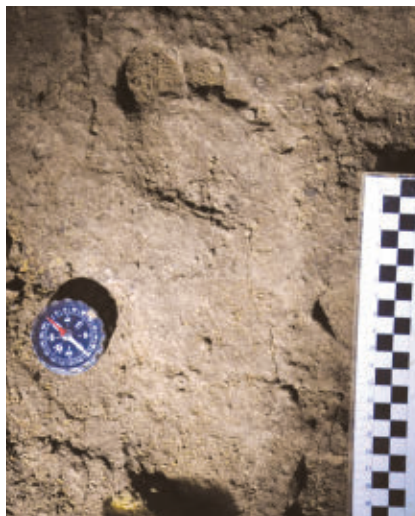
Sprinkling greens with recycled water may create a breeding ground for hard-to-treat microbes. In seven Chinese cities, researchers found that parks irrigated with treated wastewater are awash in signs of drug-resistant germs. Even after water is treated in a sewage plant, it may carry microbes, drug-resistance genes and antibiotics that had washed down the drain. Yong-Guan Zhu of the Chinese Academy of Sciences in Beijing and colleagues found that parks using recycled water had up to 8,655 times as many microbial antibiotic-resistance genes in soil samples as parks using fresh water. Most of these genes make microbes resistant to antibiotics prescribed for people, the authors report July 24 in *Environmental Science & Technology*. China has high

levels of antibiotic use and may not have the same sewage treatment methods as the United States, says civil engineer Amy Pruden of Virginia Tech. So these results may represent “the worst-case scenario,” she says. But the United States does have drug-resistant microbes in its recycled water, which is becoming popular for irrigation in drought-prone communities. More research is needed to understand the health risks, she says. — *Beth Mole*

HUMANS & SOCIETY

Romanian cave holds some of the oldest human footprints

Human footprints in Romania's Ciur-Izbuc Cave represent the oldest such impressions in Europe, and perhaps the world. About 400 footprints (one shown below) were discovered there in 1965 and attributed to a man, woman and child who lived 10,000 to 15,000 years ago. But radiocarbon measurements of two cave bear bones excavated just below the footprints now indicate that *Homo sapiens* made these tracks around 36,500 years ago, say David Webb of Pennsylvania's Kutztown University and colleagues. Analyses of 51 footprints — the rest have been destroyed — suggest that six or seven individuals, including at least one child, entered the cave after a flood had coated its floor with mud, the team reports July 7 in the *American Journal of Physical Anthropology*. Published ages for other *H. sapiens* footprints in Europe and elsewhere go back no more than 33,000 years. — *Bruce Bower*



BODY & BRAIN

Bone marrow transplant could reverse sickle cell in adults

Sickle cell disease in adults might be treatable with a bone marrow transplant, researchers report in the July 2 *JAMA*. Hundreds of children with severe sickle cell disease have been cured with the procedure, which wipes out defective bone marrow with radiation and chemotherapy and then replaces it through a transplant. The regimen had been considered too risky for adults who have accumulated organ damage from the disease. But in a test of 30 adult patients, 29 have survived for an average of 3.4 years after undergoing a milder procedure. The replacement cells act as starters that grow into normal blood without sickle-shaped deformities, which cause pain, anemia and blood flow problems. The procedure failed to fully replace the abnormal cells in some patients, and one died of brain bleeding. But one year after transplant, 25 patients had fully functioning blood cells, and 15 have since stopped taking immune-suppressing medication, say study coauthor Matthew Hsieh of the National Institutes of Health in Bethesda, Md., and colleagues. — *Nathan Seppa*

ATOM & COSMOS

Comet ISON disintegrated earlier than astronomers realized

The sun's intense heat destroyed the comet ISON at least eight hours before its closest brush with the sun last fall, scientists report July 4 in *Astronomy & Astrophysics*. Data from the SOHO spacecraft reveal the comet's final moments during its only visit from the solar system's farthest reaches. Astronomers hadn't been sure exactly when the comet met its end (SN Online: 12/3/13). Werner Curdt of the Max Planck Institute for Solar System Research in Germany and colleagues obtained ultraviolet spectra that show the remains of the comet nucleus dragging a tail of dust. When the comet reached the sun, the tail had separated from the nucleus. The nucleus broke apart hours earlier, the scientists conclude, based on when the last puffs of dust launched off its surface. — *Christopher Crockett*



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A Rocky Road to Mars

NASA has billed its Asteroid Redirect Mission as a stepping stone to Mars. In one mission concept, illustrated here, an astronaut collects a sample from a bagged asteroid orbiting the moon.

Asteroid grab would get humans back in space but perhaps no closer to the Red Planet **By Meghan Rosen**

Somewhere above the clouds, way up into the deep space of the inner solar system, there's an asteroid tumbling near Earth with NASA's name on it.

Within the next decade or so, the space agency wants to snag the space rock and haul it to the moon. And they've hatched two fantastical plans to do it. One would snare an asteroid with a gigantic inflatable bag; the other might send a sticky-fingered robot out to grab a golf cart-sized boulder off an even bigger rock.

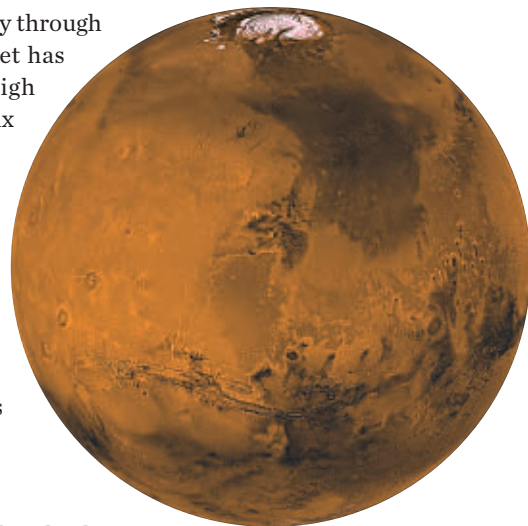
Both would help humans prepare for an eventual trip to Mars. At least that's what NASA says.

"We would have access to a completely new alien body that no one had ever touched or seen," says planetary scientist and former NASA astronaut Tom Jones, who studied the feasibility of the mission. What's more, he says, astronauts might be able to mine the rock for resources, instead of relying only on supplies hauled up from Earth for voyages into deep space.

But not everyone's convinced that the plan, called the Asteroid Redirect Mission, or ARM, brings people any closer to the Red Planet. Since NASA announced the mission last year, the so-called stepping stone to Mars has



Space Station has support only through 2024, and the agency's budget has plummeted from a 1960s high of about a nickel of every tax dollar spent to less than a penny. Even if the ARM is a kooky scheme that brings humans only marginally closer to Mars, shoehorning the unlikely mission into place could be a shrewd way to secure Americans' spot in deep space — before it's too late.



Two grand plans

If NASA can swat away the doubts and drive the ARM forward, the out-there mission would be the stuff of sci-fi lovers' dreams.

In one ARM concept, a solar electric propulsion spacecraft — the largest ever built — will blast off from Earth in 2019 and sail through space toward its massive target: a rock about half the diameter of the one that exploded over Chelyabinsk last year (*SN Online*: 2/15/13). The spacecraft will rendezvous with the asteroid and then, when positioned just right, nab it with a blow-up bag.

"Think of it like a bounce house," says JPL aerospace engineer Brian Muirhead. All inflated, the bag — thin yellow plastic — will stretch about as tall as a three-story building and hold up to 1,000 tons of asteroid. After swallowing the mighty rock, the plastic would cinch shut like a garbage sack.

Then the spacecraft will fire up its engines and slowly, gently begin nudging the asteroid into a new orbit. With only about a third of a pound of thrusting force, the spacecraft will be kind of wimpy — like a blue jay tugging a jumbo jet off course.

But scientists think years of steady effort will shift the asteroid just enough so that it slingshots around the moon into a stable orbit, perhaps sometime in 2024 — though the date depends on which rock NASA selects. (The agency has already picked several candidates.) Then astronauts launched toward the moon could meet up with the asteroid and go exploring. The two-person crew could slice open the plastic or tear off Velcro patches to expose the bagged goods and chip off chunks to bring home.

In the second asteroid-capture idea, a robot — with three arms and three legs, or two arms bearing hundreds of little hooks, or some combination of the two — would snatch a boulder off

Mars has long been one of NASA's targets for human space exploration. Many believe that tackling challenges closer to home, such as the Asteroid Redirect Mission, could help scientists learn how to prepare for the difficulties of traveling to the Red Planet.

sparked a bristling debate.

Many scientists believe that the mission's link to the fourth planet from the sun is hazy, at best. At worst, critics say that NASA has slap-dashed together an outlandish stunt to find something — anything — that fits in with the president's budget and vision for humans in space.

"NASA's just looking for a place to go," says asteroid scientist Alan Harris, retired from NASA's Jet Propulsion Laboratory in Pasadena, Calif. The ARM doesn't carry a whole lot of scientific weight, he says, though "it is good entertainment."

A crowd-pleasing mission might be just what the agency needs to electrify a sluggish human space exploration program.

And NASA is running out of options. Its space shuttle fleet retired in 2011, the International

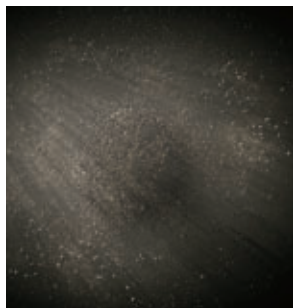
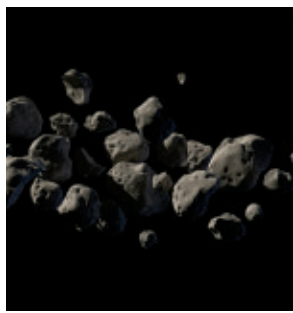
Bagging an asteroid

In one option for the ARM, a spacecraft would rendezvous with a near-Earth asteroid and deploy a giant bag to capture the rock.

Hovering near the asteroid, the bag would inflate and surround the rock, which could range from 3 to 8 meters in diameter.

With the asteroid enclosed inside, the thin plastic bag would close, cinching shut like a garbage bag.

Asteroid candidates may be a pile of rubble (depicted at top) or a solid rock within a cloud of debris (bottom).



a space rock perhaps longer than a football field. Then the spacecraft would shuttle the prize to the moon for an astronaut crew to explore later.

NASA hopes to choose between the bag and the robotic arm options in late 2014. Either approach, the agency says, will test-drive asteroid-moving technology and give astronauts spacewalking experience that would bring humans one step closer to getting to Mars.

The ARM is NASA's latest attempt to launch humans beyond low-Earth orbit — a feat that hasn't been accomplished since the Apollo days, more than 40 years ago. Mars, one of Earth's nearest neighbors, is a tempting target because it may have once hosted life. Trekking out to the Red Planet could help scientists find out for sure. In April, NASA Administrator Charles Bolden even called getting people to Mars — and becoming a multi-planet species — necessary for human survival.

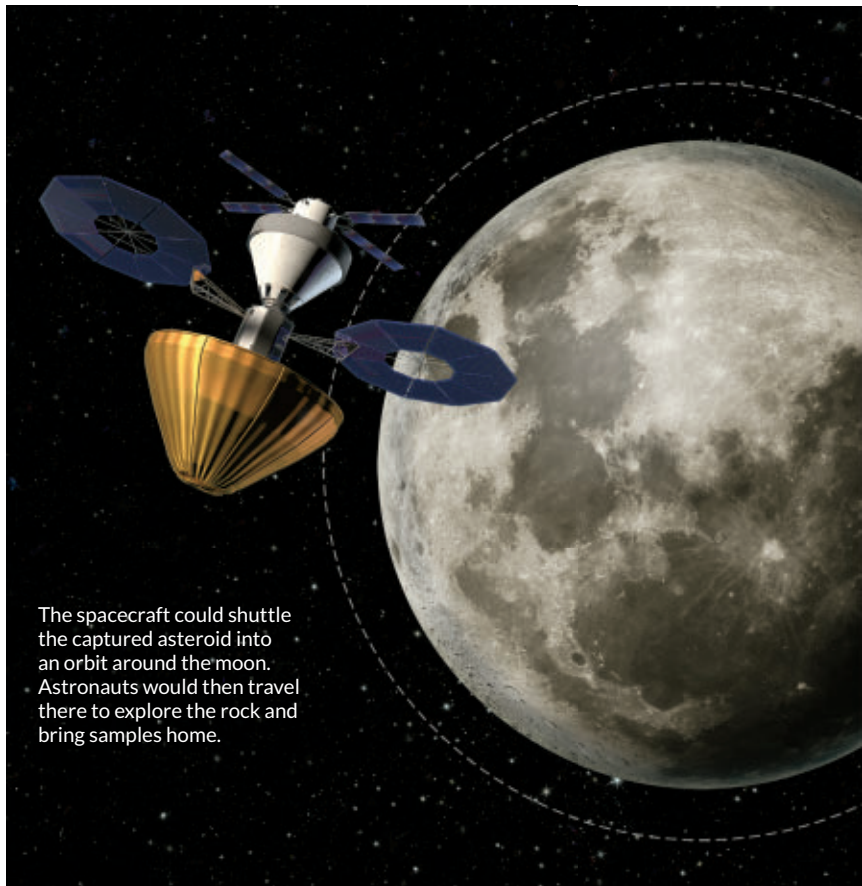
And NASA has been waiting decades for the chance to stretch its space exploration muscles.

American aspirations

Exploration runs deep in Americans' blood. From the vast plains of Kansas to the gold veins of California, "we're a nation founded by explorers," says space his-

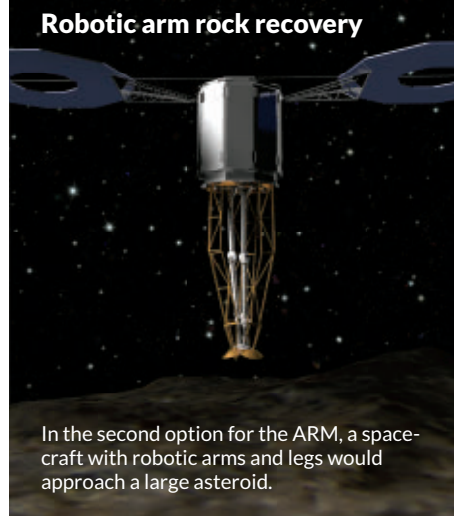
torian Valerie Neal, a curator at the Smithsonian National Air and Space Museum in Washington, D.C. "It's kind of in our DNA."

The fledgling idea of human spaceflight first took off among Americans in 1958, when President Dwight D. Eisenhower established NASA. Less than two years later, the agency sketched out a slow and steady approach to get humans into space: First send humans into low-Earth orbit, then build a space station and then venture out to the moon and nearby planets sometime after 1970. In 1961, President John F. Kennedy scrapped the slow approach for speed.

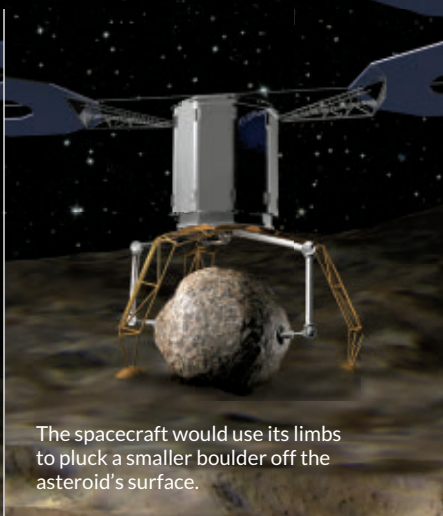


The spacecraft could shuttle the captured asteroid into an orbit around the moon. Astronauts would then travel there to explore the rock and bring samples home.

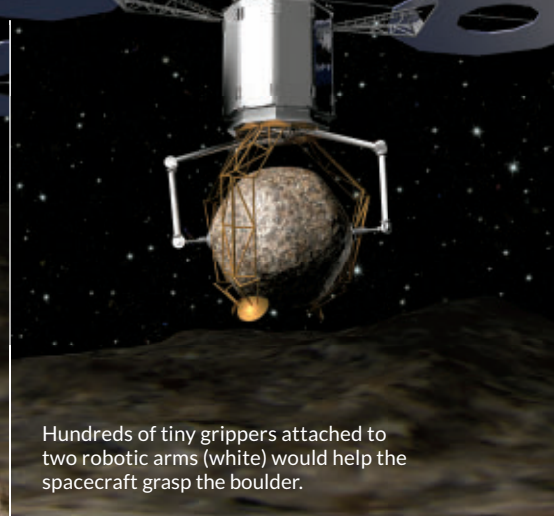
Robotic arm rock recovery



In the second option for the ARM, a spacecraft with robotic arms and legs would approach a large asteroid.



The spacecraft would use its limbs to pluck a smaller boulder off the asteroid's surface.



Hundreds of tiny grippers attached to two robotic arms (white) would help the spacecraft grasp the boulder.

"He said, 'Let's go to the moon and let's do it quickly!'" says Neal. Just eight years later, Apollo 11 landed three American astronauts on the moon and NASA was riding high. The agency next set out to launch humans to Mars, and pronto — by 1981.

But the nation's interest lagged. "Everybody felt as if we had won the space race," says Neal. "So we didn't need to keep having an expensive, fast-paced space program."

NASA's funding nose-dived from the sky-high levels of the Apollo days. The gleaming ambition of traveling to the Red Planet slipped out of reach.

President George H.W. Bush tried to rekindle the dream on the 20th anniversary of the Apollo 11 landing. Standing on the steps of the Air and Space Museum, he proposed sending humans back to the moon and on to Mars. But he never sent a budget to Congress to fund the plan, Neal says, "so that idea just died on the vine."

In 2004, President George W. Bush revived his father's withered vision and unveiled a grand plan for human space exploration. The Constellation Program called for building a family of launch rockets and a deep-space craft named Orion to carry astronauts to the International Space Station, then to the moon by 2020 and then on to Mars. "The next giant leap has begun," promised Constellation's slogan.

Yet once again, the lofty goal of getting humans to Mars barely got off the ground. When President Obama took office in 2009, he enlisted a group of experts to review Constellation's progress and the future of human spaceflight. Called the Augustine Committee, the group released its report the following October. Constellation was over budget and behind schedule.

Obama canned the program four months

later, and then announced a new idea in April. Standing in front of a space shuttle engine at the Kennedy Space Center in Florida, with NASA's flag at his left and Apollo 11 astronaut Buzz Aldrin in the audience, Obama pledged to send humans to an asteroid by 2025 and to Mars by the mid-2030s.

To get there, NASA would use two vehicles: a new crew-and-cargo rocket, called the Space Launch System, and the Orion spacecraft.

The agency just needed to pick an asteroid.

Birth of a mission

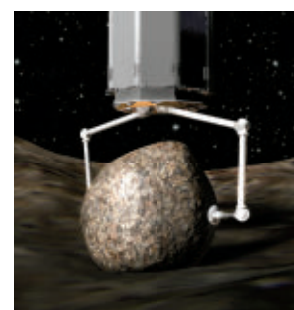
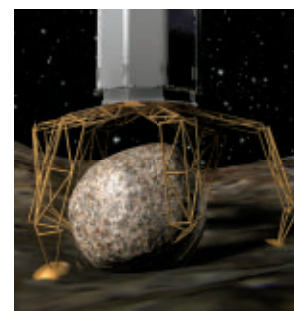
As NASA delved into the nitty-gritty details of its new plan, prospects began to look grim.

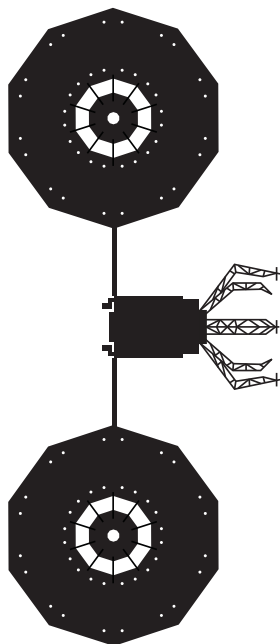
It quickly became apparent that the Space Launch System wouldn't be able to hurl the Orion space capsule far enough into the solar system to reach most near-Earth asteroids, Jones says. And the capsule wouldn't have enough room for the supplies a crew would need on the six- to 12-month mission.

What's more, trying to find an asteroid that's the right size, the right speed *and* streaking by Earth during the early 2020s is a daunting task. There aren't many good options out there, says astronomer Robert McMillan, who runs the asteroid-tracking Spacewatch Project of the University of Arizona in Tucson. Most asteroids knock around farther away, in the massive ring of space rocks known as the main belt, between the orbits of Mars and Jupiter.

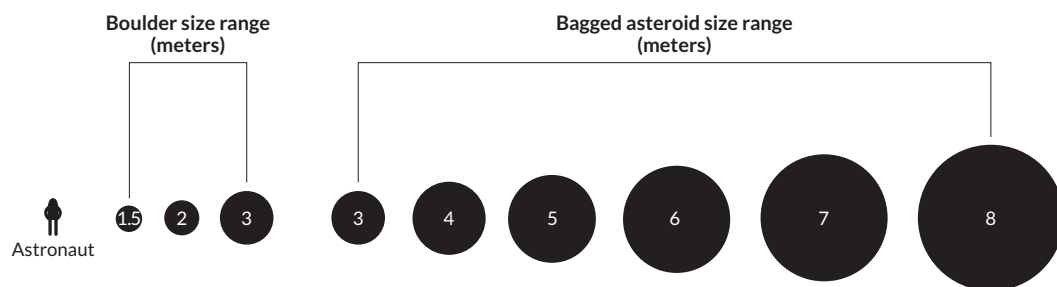
As NASA grappled with these problems, a group of scientists cooked up an idea that could have been inspired by Bruce Willis' space cowboy antics in *Armageddon*: Instead of sending astronauts to an asteroid, they suggested, why not

The robotic system for plucking a boulder off an asteroid could use several arms and legs (top), two arms with hundreds of tiny grippers (bottom) or some combination of the two (top of page).





Sizing up targets NASA has found several candidate asteroids to which the spacecraft could travel. The mission could either remove a boulder (1.5 to 3 meters in average diameter) from the surface of a larger asteroid or use a bag to capture a space rock roughly 3 to 8 meters across.



“A threatening asteroid is not something we’re ever going to put in a bag.”

CLARK CHAPMAN

bring the asteroid to the astronauts?

A think tank called the Keck Institute for Space Studies, or KISS, pulled together 34 experts to explore the scheme’s feasibility and published its report in the spring of 2012. NASA latched onto the concept like a lifeline.

When NASA announced its budget for 2014, a plan to capture an asteroid, which NASA named the Asteroid Redirect Mission, took center stage.

“We were totally flabbergasted and surprised that NASA picked it up officially and put it into their program so quickly,” says Jones, one of the experts on the KISS team.

The space agency had been in a pickle: It had to meet the president’s requirement to visit an asteroid, and it had to do it with a vehicle combo that couldn’t actually reach a near-Earth asteroid, he says. “NASA’s coping with reality,” Jones says. The asteroid redirect idea “sort of bails them out.”

But NASA bungled the rollout. When the agency introduced the idea last year, administrators didn’t say much about how capturing an asteroid would help humans get to Mars — the grand finale of the president’s plan for human space exploration. Instead, NASA focused on the mission’s potential for technological innovations,

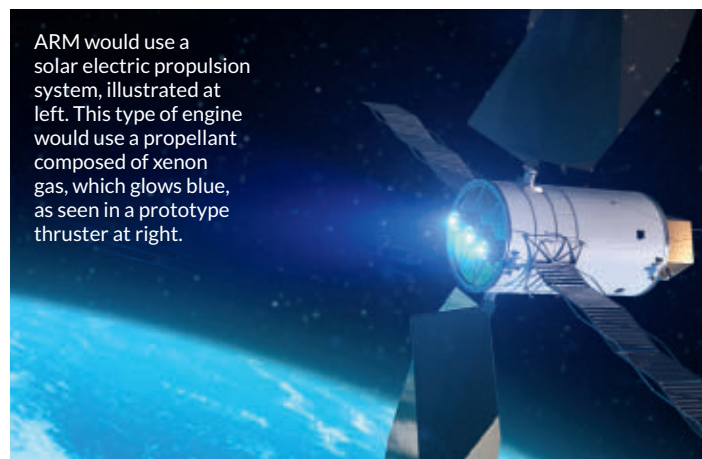
scientific discoveries and defense against asteroids headed for Earth.

Critics pounced. “There’s nothing about pushing around a tiny space rock that has anything to do with getting humans to the moon or Mars,” says MIT planetary scientist Richard Binzel, an expert on near-Earth asteroids.

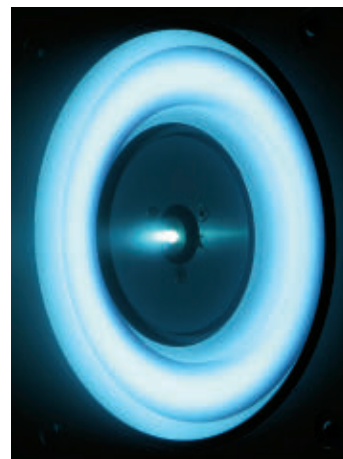
Though the mission jibes with what the president outlined, says former NASA astronaut Buzz Aldrin, NASA won’t be sending humans out to where asteroids really live: “It’s just some hokey orbit around the moon.”

And the idea that towing a small asteroid with a spacecraft could eventually help NASA defend Earth from a massive collision is thinkable, but perhaps a little far-fetched.

“A threatening asteroid is not something we’re ever going to put in a bag,” says planetary scientist Clark Chapman of the Southwest Research Institute in Boulder, Colo. Although, he admits, learning about small asteroids could offer clues about how to move larger ones. And if NASA chooses the robotic arm concept to pluck a boulder off a large asteroid, the agency wants to tug on it with a gravity tractor, a way of — potentially — nudging huge rocks off path using the tiny attraction between



ARM would use a solar electric propulsion system, illustrated at left. This type of engine would use a propellant composed of xenon gas, which glows blue, as seen in a prototype thruster at right.



FROM TOP: NASA ASTEROID INITIATIVE OPPORTUNITIES FORUM, ADAPTED BY S. EGTS; ANALYTIC MECHANICS ASSOCIATES; JPL-CALTECH/NASA

the boulder-hugging spacecraft and the asteroid.

The prospects for scientific discovery are a little iffy, too. “Bringing back a sample of a near-Earth asteroid doesn’t excite me terrifically,” says asteroid scientist Harris. “Nature dumps these things in our backyard all the time.” Museums are full of them, he says.

What’s more, NASA already has plans to nab some rocks from space. So do space agencies in Europe and Japan. Ten years ago, the European Space Agency sent the Rosetta spacecraft across the solar system to an icy comet hundreds of millions of kilometers away. And the Japan Aerospace Exploration Agency is gearing up for a second trip to an asteroid in late 2014, with the robotic explorer Hayabusa 2.

In 2016, NASA will launch a similar mission. The OSIRIS-REx spacecraft will pluck samples off the near-Earth asteroid Bennu. Mission leader Dante Lauretta, a planetary scientist at the University of Arizona, is happy to see NASA bring home more asteroid nuggets. Scientists can study them to learn about planetary building blocks and even the origins of the solar system. “We love new samples from space,” Lauretta says. But even he’s not so sure they’re worth the ARM’s cost.

At roughly \$1.25 billion, the mission doesn’t include the cost of the Space Launch System rocket or the Orion space capsule or the astronauts. And some scientists believe NASA is low-balling the price tag.

Getting to deep space

Since the plan’s debut, the space agency’s leadership has begun to explain more clearly how they see the ARM’s connection to Mars. And NASA’s not just spinning the story; the agency has been brainstorming ways to use the ARM as a launch pad for deep-space exploration.

“They’ve learned their lesson,” says former astronaut Jones. “They got criticized, and I think they’ve gone and done their homework. In the past year, NASA’s learned a lot more about how to apply this technology to Mars.”

In April, Jones and other experts, including JPL and other NASA scientists, got together for a three-day KISS workshop to think about how the agency could build upon the ARM.

NASA has a long list of ideas. The ARM would advance solar electric propulsion, or SEP, technology, for one, says NASA Associate Administrator Robert Lightfoot. The low-thrust power system would use xenon gas instead of rocket fuel, tug-tug-tugging spacecraft along instead of blasting

them through space. SEP systems soak up energy from the sun, accelerate xenon atoms and then spew the glowing blue particles into space, propelling spacecrafts forward.

NASA has worked with SEP before — to send the Dawn spacecraft out to the biggest residents in the main belt — but the ARM spacecraft would be about 16 times as powerful. Such an efficient system could one day haul cargo to Mars, so astronauts wouldn’t have to bring everything with them, Lightfoot says. Shooting cargo into space is expensive, and even a mission that just cruised around Mars and back could require thousands of tons of supplies.

Digging into an asteroid could also be a boon. A water-rich asteroid, for example, could save NASA the trouble of toting water up from Earth. Mining asteroids could even offer astronauts shielding materials for radiation, a big health problem for humans in space (*SN*: 7/26/14, p. 18).

Even if the ARM is more like a baby step toward Mars than a giant leap, that might be OK, says planetary geologist Raymond Arvidson of Washington University in St. Louis, a leader of the Mars rover missions. “Going to Mars is incredibly difficult — hugely difficult,” he says. “You need to have waypoints.”

Some scientists still aren’t on board. Binzel thinks extending human crews into deep space is the right next step, but instead of pushing an asteroid around, he’d rather see NASA use SEP to place a cache of supplies in deep space. That, he says, would extend a mission’s duration and distance, which are necessary for getting humans to Mars.

NASA’s Lightfoot doesn’t expect to please everybody. “If there’s one thing I’ve learned in this industry, it’s that people are going to have different approaches and ideas they’d like to try,” he says.

“The primary goal for us is to get humans to Mars,” he says. “To us, the Asteroid Redirect Mission is the most logical and affordable step.”

Jones is sympathetic to the space agency’s plight. He thinks the ARM may be the best bet right now for advancing human space exploration.

“If the Asteroid Redirect Mission is squashed or defunded by Congress or criticized to death,” he says, “then NASA will do nothing with human spaceflight for the next 10 years.” ■

Explore more

■ Website for NASA’s Asteroid Initiative:
bit.ly/SN_asteroid

“The primary goal for us is to get humans to Mars.”

ROBERT LIGHTFOOT

EXHIBIT

Rare chance to see the last passenger pigeon

Martha reappears after a century of extinction

For the first time this century, one of the world's most famous bird specimens has come out of storage for public display.

Martha, the last known passenger pigeon, is posed on a branch amid a small collection of mementos of doom — some lovely, some poignant and some ironic — at the Smithsonian National Museum of Natural History in Washington, D.C. September 1, 2014, marks the 100th anniversary of the day when keepers at the Cincinnati Zoo found the roughly 29-year-old bird dead in her cage. That day, humankind knew the exact date, a Tuesday, when a species vanished from Earth.

The spooky precision is far from the only reason the passenger pigeon haunts us. *Ectopistes migratorius* was so abundant that people on occasion filled potholes with pigeons. Even now, it's stunning that humans, without particularly intending to, could in mere decades cut down a species numbering 3 billion to 5 billion birds to just Martha, and then, to nothing (*SN*: 8/9/14, p. 17). Numerically, it's as if *Homo sapiens* at its population level in the mid-1980s were to be wiped out by the end of the current century.

Souvenirs from the pigeon-killing debacle may surprise visitors. Roasted passenger pigeon is just one of the recipes in a cookbook displayed alongside Martha by the exhibit sponsor, the Smithsonian Libraries. (Final step: "Garnish with slices of bacon and melted butter in a cup.") And real pigeon plumage doesn't look as beachwear cheery as it does illustrated in influential 18th century naturalist Mark Catesby's book, also on display. "Colors only artists can see," deadpanned Smithsonian birds curator Helen James at the exhibit opening.

Visitors drawn to see Martha will also find specimens and pictures of other birds driven to extinction in North America in recent centuries. Heath hens, also once common as food, looked like their prairie chicken relatives of the Great Plains but flourished along the East Coast, even in the Boston Common. Great auks, standing penguin-upright, laid speckled eggs with one fat end and one almost pointed one. Should the waddling birds jostle an egg, the shape helped it wobble in circles rather than roll off rocky nesting sites. And if only Southern woodlands still had their flocks of green-yellow-orange Carolina parrots, which really do look gaily tropical, even next to Audubon's print. Stopping for a glance around the now-extinct birds, James asked, "Do you feel robbed?"

After absorbing this exhibit, many visitors will.
—Susan Milius



Martha, the last known passenger pigeon, lived most of her life in the Cincinnati Zoo and died there 100 years ago.

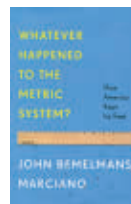
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**Once there were billions:
Vanished birds of North America**
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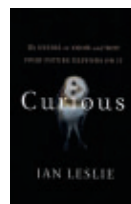
BOOKSHELF



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Tales of pioneering skywatchers and their discoveries in the 19th century show how modern astronomy was born. *Bellevue*, \$19.95



Whatever Happened to the Metric System?
John Bemelmans Marciano
In this history of measurements, learn why the United States has kept inching along with the Imperial system. *Bloomsbury*, \$26



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Ian Leslie
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David M. Phillips
Captivating close-ups from scanning electron microscopes reveal the beauty and the anatomy of six-legged life. *ForeEdge*, \$24.95

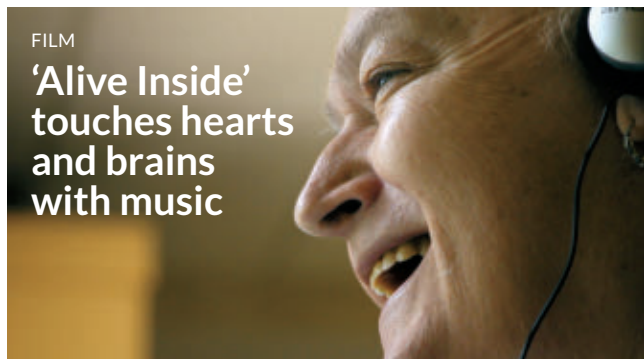


Curiosity
Rod Pyle
An inside look at the team that launched and ran the Mars rover program highlights both the personalities and the science that made the robotic mission a success. *Prometheus*, \$19.95

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FILM

'Alive Inside' touches hearts and brains with music



Some of the most potent medicine doesn't come in a paper cup or a little pill. Instead, it pours from a cheap set of headphones. As chronicled in *Alive Inside*, music has the power to awaken long-dormant memories and emotions in people suffering from Alzheimer's and other disorders.

In the documentary, filmmaker Michael Rossato-Bennett follows the work of social worker Dan Cohen as he attempts to bring music to people in desperate need of soul soothing. Many of the patients depicted in the film live in nursing homes, places that can leave a person adrift, especially if that person suffers from dementia. One elderly man named Henry sits unresponsive until headphones begin playing his old favorites, including jazz singer Cab Calloway.

As soon as Henry hears the music, his eyes pop open. He begins singing and moving around in his wheelchair. His

A carefully chosen tune can awaken the minds and hearts of elderly people who have withdrawn into themselves.

body and mind are transformed. Henry's awakening went viral online in 2012 when it was released as a short clip. *Alive Inside* contains many such moments of music triggering long-buried thoughts, memories and emotions. These brief interludes burst with joy but don't overcome the

overwhelming, inevitable sadness the documentary evokes.

Given what scientists know about music's influence on the brain, these musically inspired awakenings shouldn't be surprising. As neurologist Oliver Sacks says in the documentary, music is one of the most powerful ways to tap into the brain. Work by neuroscientists suggests that music activates brain areas involved in emotion and memory, such as the hippocampus, amygdala and areas of the cortex. Molecules that carry signals around the brain, including endorphins, dopamine and growth factors, can also change in response to a tune. And music's effects extend to the body: Songs can change blood pressure, heart rate and breathing.

Red tape, entrenched bureaucracy and cost all threaten to stymie Cohen's quest to get headphones onto ears. But perhaps *Alive Inside* will remind people that music contains the power to temporarily transport a person back to happier times, a journey that's particularly poignant for people who have become lost inside themselves.

Look for *Alive Inside* at film festivals and in theaters this summer. — *Laura Sanders*

BOOKSHELF

The Cosmic Cocktail Three Parts Dark Matter

Katherine Freese



If the components of the universe were poured into a "cosmic cocktail," scientists could easily predict how the drink would look and taste, yet they would have no idea what's in it. Such is the state of cosmology

today: While scientists can confidently explain the universe's history and structure, the identities of its primary components — dark matter and dark energy — remain a mystery. In her first book, Freese, a theoretical physicist at the University of Michigan, chronicles scientists' attempts, including her own, to discover what the universe is made of.

Freese is not the first scientist to delve into the mysteries of cosmology with a popular science book, but she seems to have the most fun doing it. It's as if she's sitting at a bar describing the cool stuff she studies every day.

The author hits her stride in the two chapters dedicated to the cocktail ingredient she's spent nearly her whole career studying: dark matter, the invisible stuff that outweighs

regular atoms in the universe by more than 5 to 1. She deftly explains why physicists are hunting for weakly interacting massive particles, or WIMPs, rather than massive compact halo objects, or MACHOs (a true physics underdog story). Then she describes the recent flurry of tantalizing, often contradictory results of experiments designed to detect dark matter.

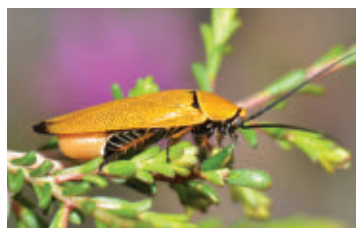
Interspersed with explanations chock-full of historical figures, numbers and acronyms are valuable insights into the human side of science. She describes "dark matter wars" between rivals, including researchers with an Italian experiment called DAMA who insist they've unequivocally detected dark matter particles yet won't share their data or detector technology. Freese's personal anecdotes also reveal the perks of a career in the sciences and the challenges of working in a male-dominated field.

The future is bright for solving the mystery of dark matter, Freese concludes. The sensitivity of underground sensors designed to catch dark matter particles improves by a factor of 10 every two or three years, and scientists are dreaming up clever experiments including detectors made of DNA (*SN: 12/1/12, p. 9*). Within the next decade, Freese says, we should know the identity of one crucial ingredient of the tasty but mystifying cosmic cocktail. — *Andrew Grant*
Princeton Univ., \$29.95



"I live in the woods, and have many roach visitors. Some are quite delicate, others are friendly and curious.... None are as pretty as these, however."

ROGER BROWN



After reading **Susan Milius'** "The many charms of cockroaches" (SN: 6/28/14, p. 4), some readers clamored for more photos of pretty roaches. Here's another: *Ellipsidion humerale*, an Australian native often seen sunning itself on leaves.

Join the conversation

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Understanding the slacktivists

Online causes may often garner clicks but not cash because people offer nominal shows of support to impress others without making substantial contributions of time or money. **Bruce Bower** discussed the psychology behind this "slacktivism" in "Token gestures" (SN: 7/12/14, p. 22). The phenomenon of actionless activism was not news to online readers, and the story prompted comments laden with sarcasm on Facebook and Twitter. "Shocking," wrote **Lisa Linderman**. "I may die of not surprise." **Glyn Sparkes** noted that far more people vote than commit to volunteer for political campaigns, too. Then he added "Amazing that no one's realized that before. Oh, wait, almost everybody did!"

Others took a deeper look at what might drive slacktivism. "While it may sound callous and unfeeling, it is nevertheless true that I and probably many, many others who actually respond to the e-mails sent to me begging for money have to prioritize who gets what little money we have available," wrote online reader **wooter**. "Yes, I am a slacktivist. But when examining this issue, one has to take into account that we slacktivists do actually get involved, albeit superficially, compared to the vast majority of Americans who aren't even aware of the issues we click on."

Craig Markham agreed. "People are faced with a huge media fire hose of appeals, and they simply have to refuse to swallow everything that it delivers, no matter how much they may agree with the individual messages it contains."

Weighing the mega-Earth

Astronomers thought rocky planets topped out at about 10 times the mass of Earth, until exoplanet Kepler-10c took the heavyweight title at 17 Earth masses. In "Overweight planet shakes up theory" (SN: 7/12/14, p. 10), **Christopher Crockett** detailed the upset and what it means for theories about planetary formation.

Reader **ChazNCenTex** questioned how the planet could be so much more massive than Earth, but only have three times as much gravitational pull.

"Why wouldn't the gravity be closer to 17 times that of Earth?"

Crockett explains that in this case, size matters: "The planet is also bigger than Earth. Someone standing on the surface of Kepler-10c would be 2.5 times as far from the center of the planet than someone on Earth's surface is. And the strength of gravity depends on both mass and the distance from the center, squared."

Dinosaur traces

Sid Perkins reviewed **Anthony J. Martin's** *Dinosaurs Without Bones* (SN: 6/28/14, p. 29), which explored what scientists can learn from footprints, tooth marks, fossilized dung and other dino leavings. Resting traces, also known as the "butt prints" left by reclining dinosaurs, intrigued **Tony Cooley**. "I am curious about the extent and character of such deposits that allowed them to be recognized as such and distinguished from ground disturbances created by other means. The only similar thing I can think of are 'buffalo wallows.'"

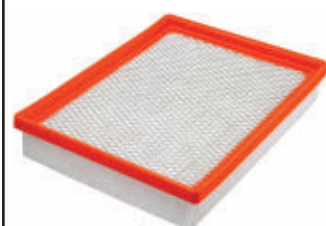
David Thomas responded with more examples of living animals' traces: "burrows in the side of hills and river banks (think muskrats, burrowing owls, gophers), swishing tail marks, alligator nests, beaver dams and lodges. Moving away from vertebrates, I've found water permeability of 10,000-plus-year-old clay layers to be affected markedly by 'fossil' worm holes that wick water through quickly."

Featuring more features

Several readers have asked why there have been fewer feature-length stories in recent issues of *Science News*. Staffing constraints led us to shift the balance to news in this summer's issues, but we are pleased to say that we will return to two features with the September 6 issue.

Correction

Alexis Powell pointed out that the bird shown in the top photo in "To ID birds, try facial recognition" (SN: 7/12/14, p. 28) is a cedar waxwing and not a bohemian waxwing as the caption says.



✓Yes



✓Yes



xNo



✓Yes



✓Yes



✓Yes



✓Yes

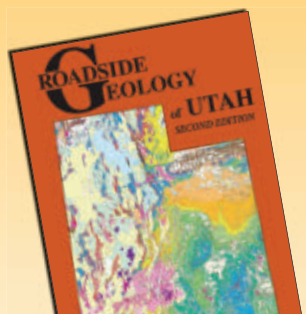


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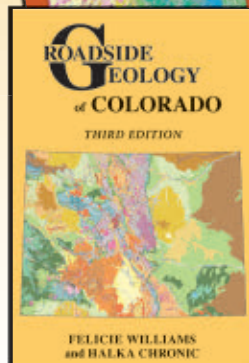


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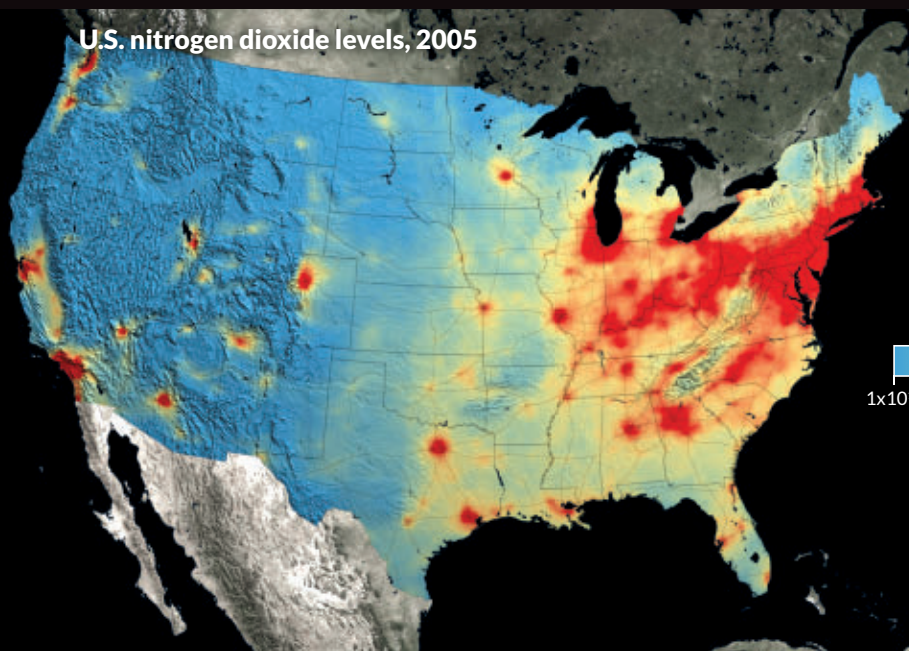
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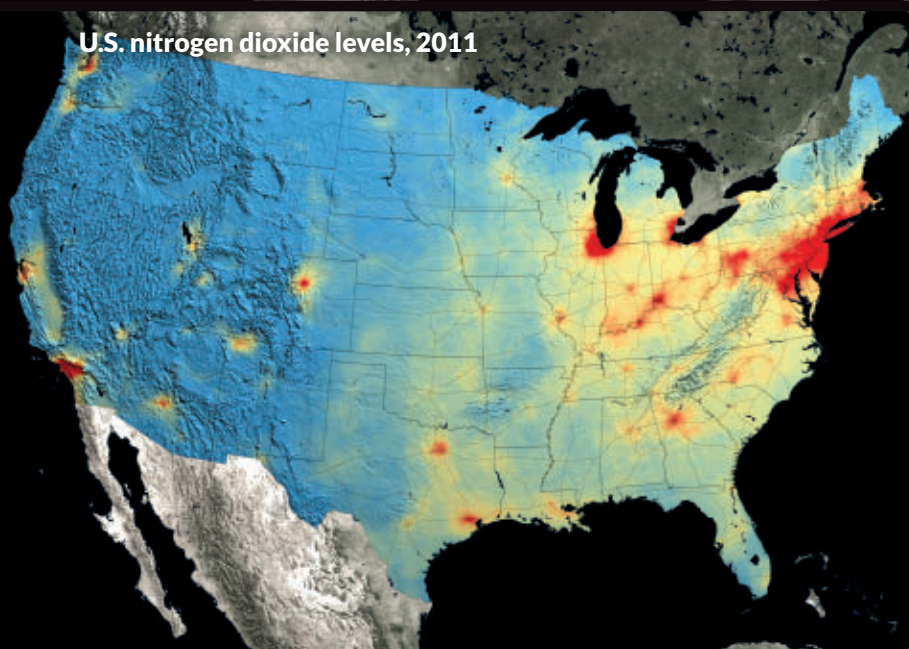
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U.S. nitrogen dioxide levels, 2005

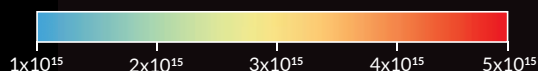


U.S. nitrogen dioxide levels, 2011



Breathing easier The amount of nitrogen dioxide hovering over major U.S. cities dropped substantially from 2005 (top map) to 2011 (bottom map), according to observations by NASA's Aura satellite. Regions shaded red have the most nitrogen dioxide molecules in the column of air above, while blue areas have the least.

Nitrogen dioxide (molecules/cm²)



Mixed results While cities in the United States, Western Europe and Japan are cleaning up their acts (top chart), air pollution is rising sharply in rapidly industrializing cities (bottom chart). Figures are in quadrillions (10¹⁵) of NO₂ molecules per square centimeter.

SOURCE: A. HILBOLL/UNIV. OF BREMEN

Cities with improving air quality

	1996	2011	Decrease
Los Angeles	40.6	19.5	52%
Chicago	24.8	14.9	40%
Tokyo	24.0	15.4	36%
Athens	11.0	7.6	31%
London	19.2	14.4	25%

Cities with degrading air quality

	1996	2011	Increase
Dhaka (Bangladesh)	2.6	8.1	212%
New Delhi	5.7	9.8	72%
Beijing	24.8	40.0	61%
Karachi (Pakistan)	3.0	4.4	47%
Jeddah (Saudi Arabia)	6.2	8.5	37%

Ups and downs in the quest for clean air

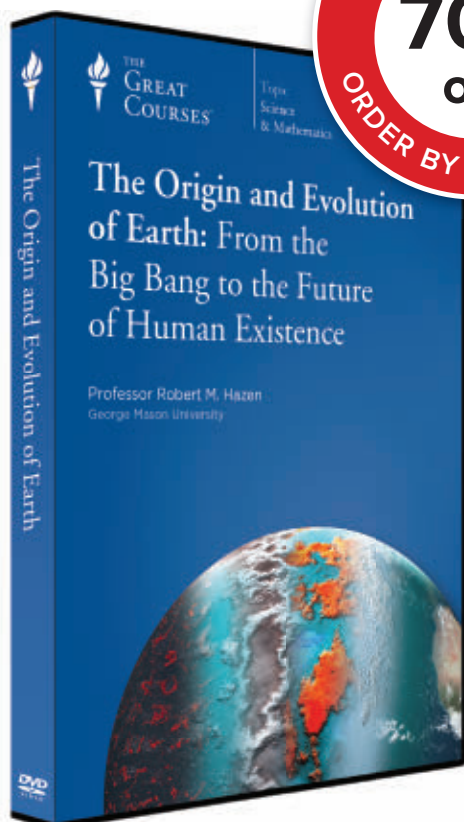
Newly released maps reveal that U.S. air quality has markedly improved over the last decade. The evidence comes from measurements of nitrogen dioxide (NO₂), a pollutant emitted by vehicles and coal power plants. Yet as the United States cleans up, rapidly industrializing cities in Asia, the Middle East and Africa are spewing more and more of the yellow-brown gas.

NO₂ may not have the notoriety of carbon monoxide or lead, but it causes respiratory problems and combines with other pollutants to form ground-level ozone, a major part of smog. "You wouldn't get unhealthy levels of ozone in cities without nitrogen dioxide," says Bryan Duncan, an atmospheric scientist

at NASA's Goddard Space Flight Center in Greenbelt, Md.

The maps, based on data from NASA's Aura satellite, show a clear decrease in NO₂ nationwide from 2005 to 2011. Duncan attributes much of the change to curbing power plant emissions, spurred by a 2005 Environmental Protection Agency policy that protects states downwind of major polluters.

However, the promising air quality trend doesn't extend to the developing world. Beijing headlines a host of Chinese cities with steadily rising NO₂ emissions, joined by cities in emerging markets such as India, Bangladesh, Pakistan, Iran and Nigeria. — *Andrew Grant*



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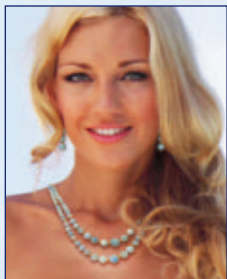
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