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SCIENCE NEWS
SOCIETY FOR SCIENCE

MARCH 18, 2017

Dwarf Star,
7 Planets

Nudges
Nudge
Back

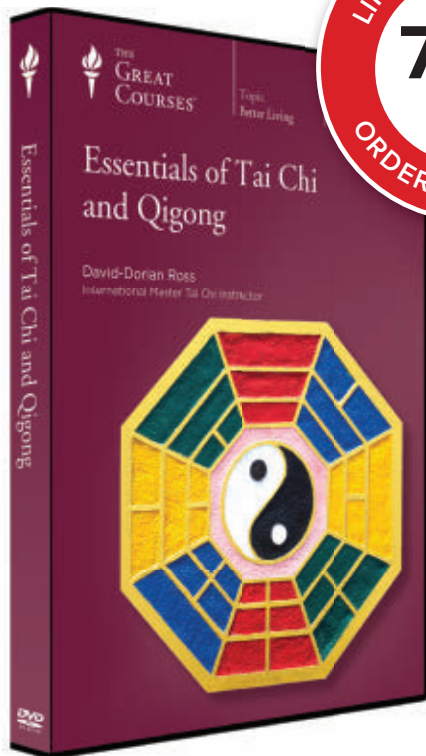
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Microbes

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Vs. Zika

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South_agency/iStockphoto



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Science journalists don't use the science of 'nudge'

The “nudge” may have been formalized in a 2008 book, but I'd bet that the core concept — simple strategies for influencing other people's decisions — dates back at least to the rise of human language. It wouldn't surprise me if early hunter-gatherers on African savannas relied on some strategies of persuasion to convince, for example, other members of the group to help hunt for food. These hunter-gatherers weren't analyzing what text message to send and when, questions that can concern today's “choice architects,” as described by behavioral sciences writer Bruce Bower on Page 18. But the most astute communicators might have realized that appealing to survival, adventure or sense of duty could lead to varying results. And they might have adjusted their messages accordingly.

A lot of human communication, in fact, is designed around achieving specific results. So much of what we see on TV and online is aimed at selling us a product or an idea, with some strategies subtler than others. Even communications among family members or friends can be deliberately tilted toward building relationships and establishing trust. It's not necessarily a bad thing.

Recently in Boston, at a meeting of the American Association for the Advancement of Science, I attended a session titled “From Literacy to Dialogue: How to Best Communicate (Controversial) Science.” Speakers including Catherine Snow, an education professor at Harvard, and Alan Leshner, former head of AAAS and vice chair of the board of trustees for Society for Science & the Public, which publishes *Science News*, discussed specific research findings that might inform how scientists share their knowledge with policy makers and the general public. Though the term “nudge” was never used, audience members wanted to know how to encourage scientists to speak openly about issues such as global warming, how to push for science literacy in communities with more pressing problems, such as poverty, and — one of the most heated questions — how the general public might react when scientists march on Washington.

These are worthy discussions but not the preoccupations of science journalists. I was glad to be no more than a fly on the wall. Though journalists have their own public perception battles to fight, when it comes to communicating, our primary objective is to inform. Science journalists, myself included, strive to be clear and concise, but we are not trying to change your opinion, win you over or urge you to take action. *Science News* writers and editors will not, for example, tell you under what circumstances gene editing is right or wrong (Page 7) or whether Zealandia deserves to be called an eighth continent (Page 11). We value human health and happiness, but we have no investment in DNA vaccines (Page 12). And though a lot of us are technophiles, our coverage is indifferent to the fate of virtual reality (Page 24). We aim to report the facts, so you can use those facts to make informed judgments.

In other words, we'll leave the nudging to someone else. Except maybe in this editor's note. So in the spirit of transparency, I'll make the nudge a straightforward appeal: I hope you'll read and enjoy the stories in this issue. — Elizabeth Quill, Acting Editor in Chief

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Excerpt from the March 18, 1967 issue of *Science News*

50 YEARS AGO

Evidence of Precambrian life

From deep in the gold mines of South Africa's Orange Free State has come evidence that there was some form of biologic activity on Earth at least 2.15 billion years ago. Polymerized hydrocarbon "chemofossils" found in the gold ores ... [probably] were originally part of a rich bacterial and algal life in the Witwatersrand basin. Since the rock layers from which they come have been dated to about 2.15 billion years ago, it seems likely that photosynthesis existed on Earth before then.

UPDATE: Scientists still debate when early photosynthesizing organisms called cyanobacteria began pumping oxygen into Earth's atmosphere. Recent evidence suggests the microbes existed some 3.2 billion years ago (*SN Online*: 9/8/15), even though a larger oxygen surge didn't happen until about 2.4 billion years ago (*SN*: 3/4/17, p. 9). Those tiny bacteria left an outsized impact on our planet, releasing extra oxygen into the atmosphere that paved the way for complex multicellular life like plants and animals.



THE SCIENCE LIFE

Drones can pollinate

Eijiro Miyako gets emotional about the decline of honeybees.

"We need pollination," he says. "If that system is collapsed, it's terrible."

Insects, especially bees, help pollinate both food crops and wild plants. But pollinators are declining worldwide due to habitat loss, disease and exposure to pesticides, among other factors (*SN*: 1/23/16, p. 16).

Miyako, a chemist at the National Institute of Advanced Industrial Science and Technology in Tsukuba, Japan, became passionate about the loss of pollinators after watching a TV documentary. He remembers thinking: "I need to create something to solve this problem."

His answer was in an 8-year-old jar in his lab.

In 2007, he had tried to make a gel that conducts electricity, but it was "a complete failure," he says. So he poured the liquid into a jar, put it in a drawer and forgot about it. Cleaning out his lab in 2015, he accidentally dropped and broke the jar.

Surprisingly, the gel was still sticky and picked up dust from the floor. Miyako realized that the gel's ability to capture the tiny particles was similar to how honeybee body hairs trap pollen. His thoughts

With a swatch of gel-slayered horsehair, this drone can fill in for bees, picking up pollen from one flower and depositing it on another.

jumped to artificial pollination.

First, he investigated whether non-pollinating insects could help do the job. He dabbed his gel onto ants and set them loose in a box of tulips. The ants were coated with pollen after three days.

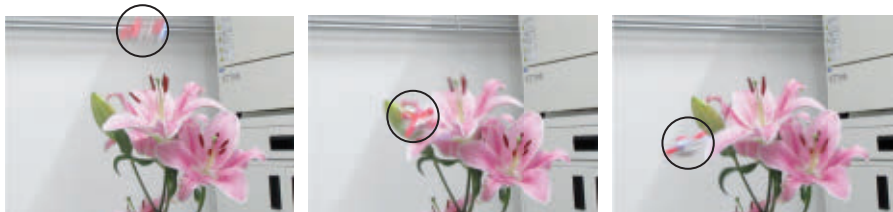
Still, Miyako worried that predators would snack on his insect pollinators. To give them camouflage, he mixed four light-reactive compounds into the gel. He tested the new concoction on flies, placing a droplet on their backs and setting the insects in front of blue paper. Under ultraviolet light, the gel changed from clear to blue, mimicking the color of the backdrop.

Though this chemical invisibility cloak might protect the insects, Miyako wanted a pollinator that could be controlled and wouldn't wander off at the first scent of a picnic.

He bought 10 kiwi-sized drones and taught himself to fly them, breaking all but one in the process. Miyako covered the bottom of the surviving drone with short horsehair, using electricity to make the hair stand up. Adding his gel made the horsehair work like bee fuzz.

In tests so far, the drone has successfully pollinated Japanese lilies more than a third of the time, brushing up against one flower to collect pollen, then flying into another to knock the grains off, his team reports in the Feb. 9 *Chem*.

Glad he saved that failed gel, Miyako thinks it is possible to automate a fleet of 100 drones, using GPS and artificial intelligence, to pollinate alongside bees and other insects. "It's not science fiction," he says. —*Elizabeth S. Eaton*



Chemist Eijiro Miyako worked with a physicist, biologist and botanist to design an artificial pollinator system to fly in, grab pollen and fly out (shown).

SCIENCE STATS

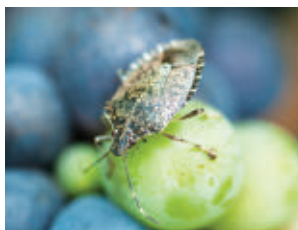
Red wine has stinkbug threshold

How many stressed-out stinkbugs does it take to spoil a batch of wine?

Stinkbugs are a pest among vintners because of the bugs' taste for wine grapes and namesake foul smell. When accidentally harvested with grapes and fermented during the wine-making process, the live insects can release their stink and ruin the wine (*SN*: 5/5/07, p. 285). The threshold is three per cluster of grapes, researchers from Oregon State University in Corvallis report in the Feb. 1 *Journal of Agricultural and Food Chemistry*. Quality tanked with rising levels of the stinkbug stress compound (E)-2-decenal, which smells like coriander. In an earlier study by the researchers, excess (E)-2-decenal produced red wine that tasted musty. White wine lovers can relax; stinkbugs don't seem to affect its flavor because white wine is processed differently than red. — Elizabeth S. Eaton

3

Maximum number of stinkbugs allowed per grape cluster before red wine tastes bad



NAME GAME

Crab gets Harry Potter honor

Deep beneath coral rubble in reefs off the coast of Guam, there lives a pale, black-eyed crab whose true taxonomic character has long been unknown.

In 1998, amateur researcher Harry Conley first discovered the translucent crab burrowing among reef rocks. Eventually, two specimens — each several millimeters long — were sent to the lab of biologist Peter Ng at the National University of Singapore. Now, Ng and Singapore colleague Jose Mendoza have identified the quirky crustacean as a new species and bestowed on it the moniker *Harryplax severus*, the researchers report January 23 in *ZooKeys*.

The genus name honors two Harrys: Conley, who died in 2002 and had a reputation for finding otherworldly ocean critters, and Harry Potter, the titular character in J.K. Rowling's popular books. Mendoza, a Potter fan, suggested the species designation *severus* — a reference to the books' notoriously uptight and misjudged Severus Snape, whose true nature remains elusive until the series' end.

H. severus belongs to a group of crabs first found in shadowy caves on Christmas Island. With small beady eyes, well-developed antennae, washed-out coloration and long legs, the crabs are suited to the dimly lit nooks and crannies of rubble beds — a place where Snape, a prickly potions master who worked in a dungeon, might feel right at home. — Helen Thompson



A newly identified crab species from Guam (*Harryplax severus*) is named after its discoverer and two denizens of Hogwarts.

FROM TOP: VAUGHN WALTON, © OREGON STATE UNIV.; J.C.E. MENDOZA (CC BY 4.0)

THE LIST

Ebola triage

A new scorecard, devised by analyzing Ebola patient outcomes during the most recent outbreak in West Africa, may help doctors quickly decide who needs additional care to survive the virus in future epidemics. In the latest outbreak, which raged in Sierra Leone, Guinea and Liberia from 2014 to 2016, 28,616 people were infected with the virus and 11,310 people died. Doctors might be able to improve survival odds by looking for a few warning signs that people may need more intensive treatment, Mary-Anne Hartley of the international charity GOAL Global and the University of Lausanne in Switzerland and colleagues report February 2 in *PLOS Neglected Tropical Diseases*. "It can be very difficult to avoid bias when choosing which Ebola patient should be given extra care when you have limited time and resources," Hartley says. "Should it be that sweet 7-year-old girl in the corner with a bad cough or the really athletic 45-year-old man who was a bit confused earlier? Our score suggests that it should be the latter." — Tina Hesman Saey

Top risk factors for dying from Ebola

- **High viral load** Patients with lots of virus in their blood were 12.6 times as likely to die as those with a low viral load.
- **Age** Children under 5 were 5.4 times as likely to die as people between 5 and 25; people over age 45 were 11.6 times as likely to die.
- **Disorientation** The symptom was associated with more than 94 percent of Ebola fatalities and increased the risk of dying by 13.1 times.
- **Hiccups**
- **Diarrhea**
- **Red, inflamed eyes**
- **Labored breathing or shortness of breath**
- **Muscle pain**
- **Delayed treatment** The risk of dying increased 12 percent each day an infected person put off treatment for the first 10 days after symptoms started.

7 Earth-sized planets circle nearby star

Orbits of 3 probably put them in TRAPPIST-1's habitable zone

BY ASHLEY YEAGER

A nearby ultracool star harbors seven Earth-sized planets, three with orbits that potentially put them in a habitable zone. That makes the system, around a star called TRAPPIST-1, a prime target in the search for signs of alien life. Its discovery also hints that many more cousins of Earth may be out there than astronomers thought.

"It's rather stunning that the system has so many Earth-sized planets," says Drake Deming, an astronomer at the University of Maryland in College Park. It seems like every stable spot where a planet could be, there is an Earth-sized one. "That bodes well for finding habitable planets," he says.

Michaël Gillon, an astrophysicist at University of Liège in Belgium, and colleagues announced last year that they had found three Earth-sized planets around TRAPPIST-1, an ultracool dwarf star previously called 2MASS J23062928-0502285 (*SN: 5/28/16, p. 6*). The star, about the size of Jupiter and much cooler than the sun, is 39 light-years from Earth in the constellation Aquarius. Follow-up observations with ground-based telescopes and the Spitzer Space Telescope now reveal that the third planet is actually four additional Earth-sized ones, three of which could be

habitable. If those planets have Earthlike atmospheres, they may even have liquid water oceans on their surfaces, Gillon and colleagues report in the Feb. 23 *Nature*. Data also point to signs of a seventh outer planet in the system.

All seven planets were detected by watching how their star dims as the planets pass in front of it from Earth's vantage point. Calculations of the amount of starlight blocked by each transit indicate that all seven have roughly the same radius as Earth. These dips in starlight also reveal how fast the planets orbit the star: The innermost one makes a round trip in 1.5 Earth days, while it takes the outermost one about 20 days.

To calculate the planets' masses, which range from about half to 1.4 times that of Earth, researchers looked at the way the six inner planets tug on each other. With the mass and size data, the team calculated the planets' densities, which suggest that the inner six are rocky.

Each planet's rotation may sync with its orbit, so the innermost planet's day lasts 1.5 Earth days; the outermost planet's day lasts about 20. That's like Earth rotating once in 365 days instead of in 24 hours. Such a spin means the same side of a planet faces the star throughout the planet's orbit, giving it a day side and a night side. Astronomers feared that would

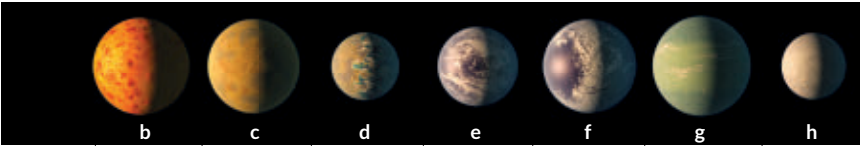
make the planets too hot on the day side and too cold on the night side to be habitable. But if they have Earthlike atmospheres, TRAPPIST-1e, TRAPPIST-1f and TRAPPIST-1g would be warm enough all over to have liquid water. The seventh planet is probably icy, Gillon says, maybe like Jupiter's moon Europa.

Finding these seven planets suggests that Earth cousins may be more common than expected. "We are on the right angle to see this system and its Earth-sized planets," says Deming, who was not involved in the study. "For every system we see, there are dozens more that we don't." Stars like TRAPPIST-1 with Earth-sized planets are probably not rare, he notes. If they were, it would have taken many more observations to find them. The fact that Gillon and colleagues' pilot project to study ultracool dwarfs spotted planets so quickly indicates that it may be the norm for these stars to harbor planets similar to Earth.

Studying the atmospheres of such planets could reveal if they might have life, especially if gases such as methane and oxygen are detected. It could be possible to study the planets' atmospheres with the Hubble Space Telescope or its successor, the James Webb Space Telescope, slated to launch in 2018. Deming is cautious, however, about how easy it will be to do. An ultracool dwarf's starlight can vary, he notes. The chemical signatures of molecules in the star's atmosphere may also overlap with those of the planets' atmospheres. Both factors could make it difficult to decipher what gases are in the planets' atmospheres.

Didier Queloz, a study coauthor and an astronomer at the University of Cambridge, is a bit more optimistic. "We have no idea what these planets look like now. They could be wet or dry," he says. "But for the first time since the first exoplanet was discovered 25 years ago, we may be able to answer the question about life beyond our solar system." ■

Planetary lineup Seven Earth-sized planets (illustrated) have been found in orbit around the ultracool dwarf star TRAPPIST-1. Astronomers already know many characteristics of these planets. (By convention, the first exoplanet discovered in a system is designated b.)



Orbital period	1.51 days	2.42 days	4.05 days	6.10 days	9.21 days	12.35 days	~20 days
Distance to star	0.011 AU*	0.015 AU	0.021 AU	0.028 AU	0.037 AU	0.045 AU	~0.06 AU
Planet radius	1.09 R _{Earth}	1.06 R _{Earth}	0.77 R _{Earth}	0.92 R _{Earth}	1.04 R _{Earth}	1.13 R _{Earth}	0.76 R _{Earth}
Planet mass	0.85 M _{Earth}	1.38 M _{Earth}	0.41 M _{Earth}	0.62 M _{Earth}	0.68 M _{Earth}	1.34 M _{Earth}	Unknown

*1 astronomical unit = 149.6 million kilometers

U.S. panel backs human gene editing

Group of experts proposes restrictions for germline tinkering

BY TINA HESMAN SAEY

Human gene editing to prevent genetic diseases from being passed to future generations may be permissible under certain conditions, a panel of experts says.

Altering DNA in germline cells — embryos, eggs and sperm, or cells that give rise to them — may be used to cure genetic diseases for future generations, provided it is done only to correct disease or disability, not to enhance people's health or abilities. That's the recommendation offered by the National Academies of Sciences and Medicine in a report issued February 14. The decision contradicts earlier recommendations by organizers of a global summit on human gene editing, who concluded that gene editing with molecular scissors such as CRISPR/Cas9 should not be used to produce babies (*SN: 12/26/15, p. 12*).

Heritable gene editing is not yet ready to be done in people, says R. Alta Charo, a bioethicist at the University of Wisconsin Law School who cochaired the panel. "We are not trying to greenlight heritable germline editing. We're trying to find that limited set of circumstances where its use is justified by a compelling need and its application is limited to that compelling need," says Charo. "We're giving it a yellow light."

National Academies reports carry no legislative weight but often influence policy in the United States and abroad. It will be up to Congress, regulatory agencies such as the Food and Drug Administration, and state and local governments to implement the recommendations.

Some supporters of new genetic engineering technologies hailed the report.

"It looks like the possibility of eliminating some genetic diseases is now more than a theoretical option," says Sean Tipton, a spokesman for the American Society for Reproductive Medicine in Washington, D.C. "That's what this sets up." Diseases such as cystic fibrosis and Huntington's, which are

caused by mutations in single genes, could someday be corrected by gene editing. More complex diseases or disorders caused by changes in multiple genes, such as autism or schizophrenia, probably would not be the focus of genome editing, Tipton says.

Others worry that allowing any tinkering with the germline will inevitably lead to "designer babies." Such editing also raises fears of stigmatization of people with disabilities, exacerbation of inequalities between people who can afford such therapies and those who can't, and even a new kind of eugenics, critics say.

"Once you approve any form of human germline modification, you really open the door to all forms," says Marcy Darnovsky, executive director of the Center for Genetics and Society in Berkeley, Calif.

Panelist Jeffrey Kahn, a bioethicist at Johns Hopkins University, says the door to heritable gene therapy remains closed until stringent requirements can be met. "It's frankly more of a knock on the door," he said at a public presentation of the report.

The report also changes the debate from whether to allow germline editing to instead focus on the line between therapy and enhancement, Darnovsky says. "I'm feeling very unsettled and disappointed by what they are recommending."

Several clinical trials in the United States, China and other countries are already under way to do gene editing in people who have cancer or other diseases. But those therapies do not involve altering germline cells; instead they fix defects or make alterations to DNA in other body, or somatic, cells. The panel recommends that such somatic cell therapies should also be restricted to treating

diseases, not allowing enhancements.

Researchers in the United Kingdom, Sweden and China have already edited early human embryos in the lab. Recent clinical trials in Mexico and Ukraine to produce "three-parent babies" are also seen as altering the germline because such children carry a small amount of DNA from an egg donor. But those children don't have modifications of their nuclear DNA, where the genetic instructions that determine traits are stored.

U.S. researchers are effectively banned from conducting clinical trials that would produce heritable changes in the human

genome, either by gene editing or making three-parent babies. The new recommendations could pave the way to allow such experiments.

But the panel lays out several hurdles that must be cleared first, ones that may be impossible to overcome, says Nita Farahany, a bioethicist at Duke University School of Law. "Some people could read into the stringency of the requirements to think

that the benefits could never outweigh the risks."

One hurdle is a requirement to follow descendants of people who have gotten gene editing to determine whether the therapy has consequences for future generations. Researchers would never be able to guarantee that they could conduct such long-term studies, Farahany says. "You can't bind your children and grandchildren to agree to be tracked."

Distinctions between therapies and enhancements are also vague, says George Church, a Harvard University geneticist who has adapted CRISPR/Cas9 for a variety of purposes. Virtually everything medicine has accomplished could be considered as enhancing human life, he says. "Vaccines are advancements over our ancestors. If you could tell our ancestors they could walk into a small-pox ward and not even worry about it, that would be a superpower." ■

Gene-editing rules

The National Academies of Sciences and Medicine advises that germline gene editing be limited to cases that meet certain criteria, including:

No reasonable alternative therapies exist.

Editing prevents serious diseases.

Targeted genes have been shown to cause or predispose to disease.

Edited genes match versions already in the population.

ATOM & COSMOS

Organic compounds found on Ceres

Dwarf planet may have conditions suitable for life, new data hint

BY ELIZABETH S. EATON

NASA's Dawn spacecraft has detected organic compounds on the dwarf planet Ceres — the first concrete proof of organics on an object in the asteroid belt between Mars and Jupiter.

This organic material probably originated on the dwarf planet itself, researchers report in the Feb. 17 *Science*. The discovery of organic compounds adds to the growing body of evidence that Ceres may have a habitable environment.

"We've come to recognize that Ceres has a lot of characteristics that are intriguing for those looking at how life starts," says Andy Rivkin, a planetary astronomer at the Johns Hopkins University Applied Physics Laboratory in Laurel, Md., who was not involved in the study.

The Dawn probe has previously detected salts, ammonia-rich clays and water ice on Ceres, which together indicate hydrothermal activity, says study coauthor Carol Raymond, a planetary scientist at NASA's Jet Propulsion Laboratory in Pasadena, Calif.

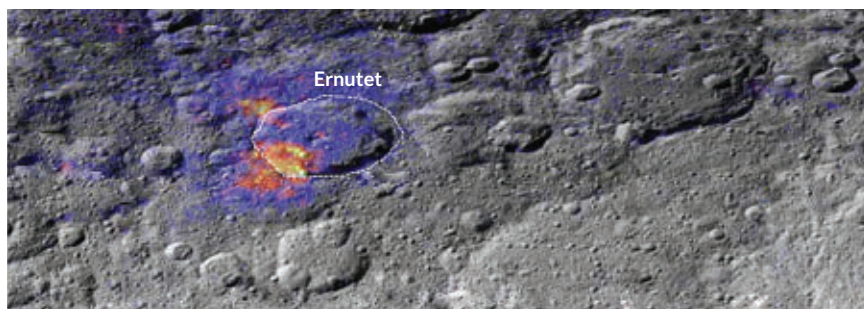
Both the hydrothermal activity and the presence of organics point toward the possibility of Ceres being habitable, Raymond says. If you have those components, she says, "then you've created sort of the soup from which life could have formed." But study coauthor Lucy McFadden, a planetary scientist at NASA's Goddard Space Flight Center in

Greenbelt, Md., stresses that the team has not actually found any signs of life on the dwarf planet.

Evidence of Ceres' organic material comes from areas near Ernutet crater. Dawn picked up signs of a spectral "fingerprint" consistent with organics. The wavelengths of light absorbed and reflected from these areas is similar to the pattern seen in hydrocarbons on Earth such as kerite and asphaltite. But without a sample from the surface, the team can't say definitively what organic material is present or how it formed, says study coauthor Harry McSween, a geologist at the University of Tennessee.

The researchers suspect that the organics formed within Ceres' interior and were brought to the surface by hydrothermal activity. An alternative idea — that a space rock crashed into Ceres and brought the material — is unlikely, the researchers say, because the concentration of organics is so high. An impact would have mixed organic compounds across the surface, diluting the concentration.

Detecting organics on Ceres also has implications for how life arose on Earth, McSween says. Some scientists think life was jump-started by asteroids and other space rocks that delivered organic compounds to the planet. Finding organic matter on an object in the asteroid belt "adds some credence to that idea," McSween says. ■



Organic compounds have been detected on the surface of Ceres near the Ernutet crater (outlined in white). Purple areas indicate low concentrations of organics; orange and yellow spots show higher abundances.

MATTER & ENERGY

Compound defies helium's inertness

Sodium helide forms under extremely high pressures

BY EMILY CONOVER

Helium — the recluse of the periodic table — is reluctant to react with other elements. But squeeze the element hard enough and it will form a chemical compound with sodium, scientists report.

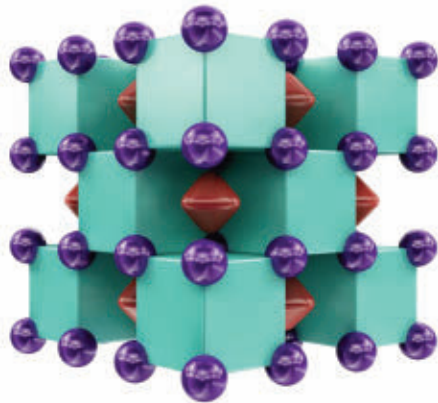
Helium, a noble gas, is one of the periodic table's least reactive elements. Originally, the noble gases were believed incapable of forming any chemical compounds at all. But after scientists created xenon compounds in the early 1960s, a slew of other noble gas compounds followed. Helium, however, has largely been a holdout.

Although helium was known to hook up with certain elements, the bonds in those compounds were weak, or the compounds were short-lived or electrically charged. But the new compound, called sodium helide or Na_2He , is stable at high pressure, and its bonds are strong, an international team of scientists reports February 6 in *Nature Chemistry*.

As a robust helium compound, "this is really the first that people ever observed," says chemist Maosheng Miao of California State University, Northridge, who was not involved with the research.

The material's properties are still poorly understood, but it is unlikely to have immediate practical applications — scientists can create it only in tiny amounts at very high pressures, says study coauthor Alexander Goncharov, a physicist at the Carnegie Institution for Science in Washington, D.C. Instead, the oddball compound serves as inspiration for scientists who hope to produce weird new materials at lower pressures. "I would say that it's not totally impossible," Goncharov says. Scientists may be able to tweak the compound, for example, by adding or switching out elements, to decrease the pressure needed.

To coerce helium to link up with



In the compound sodium helide, helium atoms (green cubes) are arranged in a 3-D checkerboard structure, each surrounded by eight sodium atoms (purple). Electron pairs (red) sit in the spaces between helium atoms.

another element, the scientists, led by Artem Oganov of Stony Brook University in New York, first performed computer calculations to see which compounds might be possible. Sodium, calculations predicted, would form a compound with helium if crushed under enormously high pressure. Under such conditions, the typical rules of chemistry change:

Elements that refuse to react at atmospheric pressure can sometimes become bosom buddies when given a squeeze.

So Oganov, Goncharov and colleagues pinched small amounts of helium and sodium between two diamonds, reaching pressures over a million times that of Earth's atmosphere, and heated the material to temperatures above 1,500 kelvins (about 1200° Celsius). By scattering X-rays off the compound, the scientists deduced its structure, which matched the one predicted by calculations.

"This is really the triumph of computation," Miao says. In the search for new compounds, computers now allow scientists to skip expensive trial-and-error experiments and zero in on the best candidates to create in a laboratory.

Na₂He is an unusual type of compound known as an electride, in which pairs of electrons are cloistered off, away from any atoms. But despite the compound's

bizarre nature, it behaves somewhat like a commonplace compound such as table salt, in which negatively charged chloride ions alternate with positively charged sodium. In Na₂He, the isolated electron pairs act like negative ions in such a compound, and the eight sodium atoms surrounding each helium atom are the positive ions.

"The idea that you can make compounds with things like helium which don't react at all, I think it's pretty interesting," says Eugene Gregoryanz, a physicist at the University of Edinburgh. But, he adds, "I would like to see more experiments" to confirm the result.

Calculations also predicted that a compound of helium, sodium and oxygen, called Na₂HeO, should form at even lower pressures, though that one has yet to be created in the lab. So the oddball new helium compound may soon have a confirmed cousin. ■

LIFE & EVOLUTION

Ancient marine reptile gave live birth

Archosauromorph ditched eggs, unlike bird, crocodile cousins

BY ELIZABETH S. EATON

A prehistoric marine reptile appears to have given birth to live young.

A roughly 245-million-year-old fossil from China may be the first evidence of live birth in the group Archosauromorpha, scientists report February 14 in *Nature Communications*. Today archosauromorphs are represented by birds and crocodiles — which both lay eggs.

Whether this fossil, which appears to contain an embryo, really is the first evidence of live birth in Archosauromorpha depends on how another extinct group of semiaquatic animals is classified, says Michael Caldwell, a vertebrate paleontologist at the University of Alberta in Canada. Placement of Choristodera, which included a freshwater reptile that gave live birth, remains murky, with some researchers putting them with Archosauromorpha and others with a group that includes snakes and lizards.

"Our discovery is the first of live

birth in reptiles with undoubted archosauromorph affinity," says Jun Liu, a paleontologist at Hefei University of Technology in China.

Researchers have speculated that something about the biology of archosauromorphs must have prevented them from evolving reproductive traits for live birth, says study coauthor Chris Organ, an evolutionary biologist at Montana State University in Bozeman. This find may disprove that view, he says. Even though birds and crocodiles don't give live birth, the new discovery suggests that it's possible in these lineages.

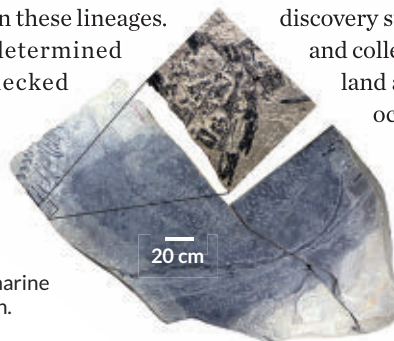
Researchers determined that the long-necked

This fossil from China shows a curled-up embryo (closeup image) in the belly of a *Dinocephalosaurus*, indicating that the marine reptile gave live birth.

marine reptile, known as *Dinocephalosaurus*, was pregnant because of the position of a smaller reptile skeleton enclosed within the larger fossil. The embryo is curled in the fetal position and its head points forward. The marine reptile swallowed fish headfirst, so it's unlikely that the smaller animal is an undigested meal. There were also no traces of eggshells in the fossil.

"The fossil embryo is pretty partial and fragmentary," Caldwell says. But "it looks pretty convincing.... It's in a good position to be an embryo, and position is everything."

Live birth for *Dinocephalosaurus* makes sense; its giraffelike neck, longer than the rest of the body, would have made coming ashore to lay eggs difficult, Liu says. The discovery supports a theory that Organ and colleagues put forth in 2009. If a land animal evolved to live in the ocean, it may have developed adaptations that made it difficult to return to land. The researchers predicted that such animals would also have evolved to give live birth. ■



GENES & CELLS

Malaria molecule lures mosquitoes

Chemical cues prompt insects to gorge on infectious meal

BY LAUREL HAMERS

Malaria parasites seduce mosquitoes on the sly.

Plasmodium falciparum parasites produce a molecule that makes parasite-infected blood more attractive to malaria-transmitting mosquitoes, scientists report online February 9 in *Science*. The insects slurp up this enticing meal, helping the parasite spread to new hosts.

“It’s a really intriguing glimpse into how *Plasmodium* might have evolved to enhance its probability of transmission,” says Conor McMeniman, a mosquito

researcher at Johns Hopkins University.

Scientists had suspected mosquitoes are preferentially drawn to malaria-infected people, but it was unclear what piqued the insects’ interest. Biologist Noushin Emami of Stockholm University and colleagues got an unexpected lead when studying the effect of a molecule called HMBPP on the immune systems of *Anopheles gambiae* mosquitoes, which spread malaria. *P. falciparum* releases the molecule into its hosts’ blood.

While watching mosquitoes sip blood from artificial feeders, the researchers noticed that mosquitoes ate more blood when HMBPP was present, says biologist Ingrid Faye, also at Stockholm University.

When HMBPP, or (E)-4-hydroxy-3-methyl-but-2-enyl pyrophosphate, was mixed

with serum, which lacks red blood cells, the mosquitoes weren’t that interested. But red blood cells with added HMBPP released more carbon dioxide than regular red blood cells, and produced greater amounts of airborne chemicals called aldehydes and monoterpenes. That aroma attracted more mosquitoes, which also ate larger than usual meals.

Mosquitoes use the CO₂ that humans exhale as a cue to find food. So it makes

sense that increased CO₂ would draw more mosquitoes. Aldehydes and monoterpenes might make humans smell a bit like the plants mosquitoes get nectar from, McMeniman says. But since HMBPP was tested in artificial feeders, it’s unclear how strongly the molecule lures mosquitoes to infected humans, he says. ■



A molecule in blood infected with malaria attracts *Anopheles gambiae* mosquitoes.

HUMANS & SOCIETY

Abuse hinders children’s social learning

Inconsistent rewards early in life lead to disruptive behavior

BY BRUCE BOWER

Physical abuse at home doesn’t just leave kids black and blue. It also bruises their ability to learn how to act at school and elsewhere, contributing to abused kids’ well-documented behavior problems.

Derailment of a basic form of social learning has, for the first time, been linked to these children’s misbehavior years down the line, psychologist Jamie Hanson of the University of Pittsburgh and colleagues report February 3 in the *Journal of Child Psychology and Psychiatry*. Experiments indicate that physically abused kids lag behind their nonabused peers when it comes to learning to make choices that consistently lead to a reward.

“Physically abused kids fail to adjust flexibly to new behavioral rules in contexts outside their families,” says coauthor Seth Pollak, a psychologist at the University of Wisconsin–Madison. Youth who have endured assaults by their parents view the world as a place where hugs and other gratifying responses to good behav-

ior occur inconsistently, if at all. So these youngsters stick to what they learned early in life—rewards are rare and unpredictable, but punishment is always imminent. Kids armed with this expectation of futility end up fighting peers and antagonizing teachers, Pollak says.

If correct, the finding could lead to new interventions, such as training kids in impulse control and how to distinguish safe from dangerous settings, Pollak says. Current treatments focus on helping abused children feel safe and less anxious.

Over 117,000 U.S. children were victims of documented physical abuse in 2015, the latest year with available data.

“Inflexible reward learning is one of many possible pathways from child maltreatment to later behavior problems,” says Stanford University psychologist Kathryn Humphreys, who was not part of the study. Other possible influences include a heightened sensitivity to social stress and a belief that others always have bad intentions, Humphreys suggests.

Hanson’s team studied 41 abused and 40 nonabused kids, ages 12 to 17, who came from various racial backgrounds and lived with their parents in poor or lower middle-class areas. All had similar intelligence and school achievement.

In one test, kids saw an image of a bell or a bottle and had to choose between the two to earn points. With enough points, kids could select any of several desirable prizes, including a chemistry set. With fewer points, kids could choose plainer prizes, such as colored pencils.

Over 100 trials, one image chosen at random by the researchers at the start of the experiment resulted in points 80 percent of the time. The other image yielded points 20 percent of the time. In a second round of 100 trials using pictures of a bolt and a button, one randomly chosen image resulted in points 70 percent of the time versus 30 percent for the other image.

Both groups chose higher-point images more often as trials progressed. But abused kids lagged behind in learning: They chose the more-rewarding image on an average of 131 of 200 trials; non-abused kids did so on 154 of 200 trials. Abused kids were held back by what they had learned at home, Pollak suspects. ■

Zealandia may be eighth continent

Geologists struggle to classify largely submerged landmass

BY THOMAS SUMNER

New Zealand is part of a long-hidden continent called Zealandia, geologists say. But since nobody is in charge of officially designating a new continent, individual scientists will ultimately have to judge for themselves.

A team of geologists pitches the scientific case for the new continent in the March/April issue of *GSA Today*, arguing that Zealandia is a continuous expanse of continental crust covering around 4.9 million square kilometers. That's about the size of the Indian subcontinent. Unlike the other mostly dry continents, about 94 percent of Zealandia hides beneath the ocean. Only New Zealand, New Caledonia and a few small islands peek above the waves.

"If we could pull the plug on the world's oceans, it would be quite clear that Zealandia stands out about 3,000 meters above the surrounding ocean crust," says study coauthor and geologist Nick Mortimer of GNS Science in Dunedin, New Zealand. "If it wasn't for the ocean level, long ago we'd have recognized Zealandia for what it was — a continent."

The landmass faces an uphill battle for continent status, though. Unlike for planets and slices of geologic time (*SN: 10/15/16, p. 14*), no international panel exists to officially rubber-stamp a

new continent. The current number of continents is already vague — it's usually given as six or seven, with geologists referring to Europe and Asia collectively as Eurasia. Proponents will just have to start using the term "Zealandia" and hope it catches on, Mortimer says.

This odd path forward stems from the fact that nobody expected another addition to the continental ranks, says Keith Klepeis, a structural geologist at the University of Vermont in Burlington who supports Zealandia's inclusion. The discovery illustrates that "the large and obvious can be overlooked in science," he says.

Mortimer and others have been building a case for Zealandia for more than a decade and say they've now ticked off the boxes required to meet common definitions of a continent. The region is composed of continental rocks such as granite, for instance, unlike the denser volcanic basalt that forms ocean crust. Zealandia is also spatially distinct from nearby Australia thanks to an intervening stretch of ocean crust.

"If Zealandia was physically attached to Australia, then the big news story here wouldn't be that there's a new continent on planet Earth; it'd be that the Australian continent is 4.9 million square kilometers larger," Mortimer says. Other geologic features rising from the seafloor

elsewhere either are not made of continental crust, such as volcano-built submarine plateaus, or are not distinct from nearby continents, such as Greenland.

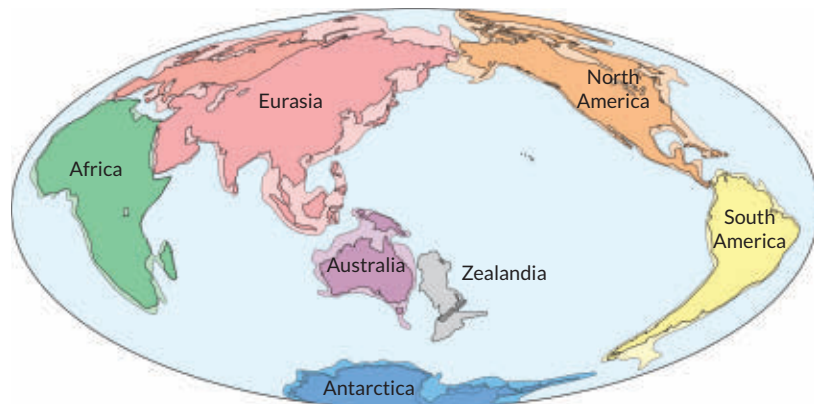
Size is a sticking point, though. No minimum size requirement exists for continents. Mortimer and colleagues propose a 1-million-square-kilometer cutoff point. If this definition is accepted, Zealandia, at little more than three-fifths the size of Australia, would be the scrawniest continent by far. (Both submerged and dry areas contribute to a continent's overall size.)

Scientists dub smaller fragments of continental crust microcontinents, and microcontinents that are attached to larger continents are subcontinents. About six times the size of Madagascar, which is one of the larger microcontinents, Zealandia fits better as a continent than a microcontinent, Mortimer and colleagues conclude.

"Zealandia's in this sort of gray zone," says geologist Richard Ernst of Carleton University in Ottawa. He proposes an intermediate term to help bridge the gap between microcontinent and full-blown continent: mini-continent. The definition would cover Zealandia as well as other not-quite-continents such as India before it plowed into Eurasia tens of millions of years ago. Such a solution would be similar to the route taken for Pluto, which was demoted from planet to the newly coined "dwarf planet" in 2006.

Scientists previously assumed that New Zealand and its neighbors were an assortment of islands, fragments of long-gone continents and other geologic odds and ends. Recognizing Zealandia as a coherent continent could help scientists piece together ancient supercontinents (*SN: 1/21/17, p. 18*) and study how geologic forces reshape landmasses over time, Mortimer says.

Zealandia probably began as part of the southeastern edge of the supercontinent Gondwana, making up about 5 percent of that supersized landmass, before beginning to peel off around 100 million years ago. This breakup stretched, thinned and distorted Zealandia, ultimately lowering most of the region below sea level. ■



New world order A landmass called Zealandia (gray) deserves to join the ranks of continents, geologists propose. Only 6 percent of Zealandia sits above sea level (dark gray). Swaths of other continents are also submerged along their margins (light-shaded regions).



BODY & BRAIN

DNA vaccines for Zika show promise

Researchers pursue multiple strategies for thwarting virus

BY MEGHAN ROSEN

Last August, scientists injected a potential vaccine for Zika virus into a human being—just 3½ months after they had decided exactly what molecular recipe to use.

In the world of vaccine development, 3½ months from design to injection is “warp speed,” says vaccine researcher Nelson Michael of the Walter Reed Army Institute of Research in Silver Spring, Md. Clinical trials can take years and epidemics can burn out before vaccines make it to doctors’ shelves. Even vaccine creation is typically sluggish.

But in this case, the vaccine is a bit of DNA, which means scientists can get moving. Unlike some traditional methods, DNA vaccines don’t use dead or weakened viruses. Instead, they rely on a snippet of genetic material. This “naked” DNA carries, for example, the blueprints for Zika proteins. It’s just a long sequence of DNA building blocks.

With DNA vaccines, “it’s easy to move very quickly,” says Anthony Fauci, director of the National Institute of Allergy and Infectious Diseases in Bethesda, Md. “All you need to do is get the right sequence, and Bingo!—you’re there.”

Historically, though, DNA vaccines have been deviled with drawbacks. “They work absolutely fantastically in

mice,” says infectious diseases physician Anna Durbin of Johns Hopkins Bloomberg School of Public Health. But “they fail miserably when we use them in humans.”

Researchers at the infectious diseases institute will soon begin the second phase of human clinical trials for a DNA vaccine candidate for Zika, vaccine clinical researcher Julie Ledgerwood said February 6 in Washington, D.C., at an American Society for Microbiology meeting on biothreats. The virus made headlines last year as it continued its tear through the Americas, and scientists confirmed its link to birth defects, including microcephaly (*SN: 12/24/16, p. 19*). Ledgerwood hopes to see efficacy data on the vaccine by the end of 2018.

“Ultimately, we want a vaccine that can prevent congenital Zika infection,” she said. “We think the DNA vaccine platform is an opportunity to do things safely and very quickly.”

Government researchers aren’t betting everything on DNA, though, Fauci points out. “We’ve got multiple shots on goal here,” he says. A slew of other vaccine candidates, based on both traditional and new techniques, are also in the works. But the DNA vaccine has stepped up to the plate first, and the

A Zika vaccine that’s made of DNA could be a safe and fast way to protect people from the virus, which can cause birth defects.

world will soon see if it can deliver.

“If it works,” Durbin says, “we’ve hit a home run.”

Making a DNA vaccine is simple, in principle. Scientists synthesize genes from a pathogen, insert them into a circular strand of DNA called a plasmid, make lots of copies and then inject the purified plasmid into a person. “You can literally build a DNA vaccine in weeks,” says Dan Barouch, an immunologist at Beth Israel Deaconess Medical Center and Harvard Medical School. The approach is flexible, too, he adds. Researchers can tinker with the DNA building blocks in the plasmid, adding bits from other viruses that might ultimately enhance the immune response.

Barouch’s team was the first to report a Zika DNA vaccine that offered protection in mice—in a study published last June in *Nature*. Five weeks later, he and colleagues reported in *Science* that the vaccine, and two others created via different strategies, worked well in monkeys, too. And in September, a team led by government scientists, and including Barouch as a coauthor, came out with two additional DNA vaccine candidates, described in *Science*.

It’s one of those additional candidates, called VRC 5283, that the infectious diseases institute plans to test in a Phase II trial. The trial will help researchers figure out the precise dose and number of injections to use. VRC 5283 includes the blueprints for making two Zika virus proteins, as well as DNA from Japanese encephalitis virus.

When the vaccine is injected into the body, a small amount of DNA makes its way into cells and on into the cell nucleus. There, molecular machinery reads the DNA and writes a message in RNA. When the message leaves the nucleus, it serves as a how-to guide for making Zika proteins. The proteins assemble into viruslike particles that trigger alarm bells in cells, which marshal their defenses. Cells then know the

face of the enemy and are ready to fight if Zika invades.

At least, that's the idea. DNA vaccines are hardly a new concept, Barouch says. "People have been calling them the 'vaccines of the future' for decades." But they haven't yet lived up to the hype.

Scientists have created DNA vaccines for dozens of pathogens, but so far, not one has been licensed for use in humans. One problem is that scientists need massive doses of DNA to provoke an immune response — a few milligrams or so. "That is a god-awful amount of plasmid DNA," Michael says. It's so much DNA that the liquid of each dose is viscous, he says. "It's like syrup."

Naked DNA doesn't readily travel into the nucleus, so scientists dump a lot in the bloodstream to ensure that some winds up inside. The Phase II trial of VRC 5283 will test both four and eight milligrams of DNA, and people will receive three immunizations, each spaced weeks apart, Ledgerwood said. The best dosing regimen then will be used in the second part of the trial — a test to see how VRC 5283 performs in thousands of participants in regions likely to see Zika outbreaks.

But even if the vaccine eventually ends up in clinics, ensuring that patients come back for multiple doses won't be easy, says University of Pennsylvania immunologist Drew Weissman. Giving people one shot is hard enough, he says. "Giving them two more immunizations is an absolute nightmare."

Weissman and colleagues at the infectious diseases institute and elsewhere are working on a different kind of vaccine that could make multiple doses moot. Like the DNA vaccine for Zika, Weissman's uses genetic material. But instead of DNA, his vaccine relies on modified versions of messenger RNA — that how-to guide for making proteins.

Unlike DNA vaccines, those made of messenger RNA don't have to stop in the nucleus first. That makes these vaccines more efficient, Fauci says. The modified Zika RNA vaccine was enough to protect monkeys from the virus five weeks after vaccination, Weissman and colleagues reported online February 2 in *Nature*. The dose was just 50 micrograms — roughly a hundredth as much as a single dose of the DNA vaccine.

On February 17, a different team of researchers reported online in *Cell* even more RNA vaccines for Zika. The vaccines protected mice from the virus, and some even reduced the severity of a subsequent dengue infection.

Scientists still need to test RNA vaccines in humans to gauge how they stack up against other candidates, Michael says. "But the bottom line is this: If a single shot works and lasts a long time, that would be a game changer."

One of the RNA vaccines reported in *Cell* began a clinical trial in December, but trials for Weissman's vaccine are still 12 to 18 months away. In the meantime, other vaccines are charging forward. The

biotech company Inovio Pharmaceuticals, for example, has begun human trials with yet another DNA vaccine for Zika. (It comes with a little zap of electricity, which blasts tiny holes in cell membranes to help DNA slip in, researchers reported November 10 in *NPJ Vaccines*.)

And Michael's team at Walter Reed has partnered with Sanofi Pasteur on a more traditional approach. Researchers grow vats of virus, kill it, purify it and then use the killed virus in the vaccine. It's the same way Jonas Salk tackled polio in the 1950s. These "inactivated virus" vaccines are generally very safe, Nelson says, because the virus is "as dead as a doornail." Nelson expects data from three Phase I clinical trials for the vaccine, called ZPIV, in early April.

But for a vaccine with both durability and efficacy, Fauci says, the gold standard is a live-attenuated vaccine. Such vaccines, like the one for measles, mumps and rubella, use weakened rather than killed viruses to rile up the immune system.

"It's the broadest, best type of protection — lifelong, we think," says Durbin, who is part of a team developing a live-attenuated vaccine for Zika. The downside is that scientists have to make sure that the weakened vaccine is harmless. Even then, Durbin says, "we would never consider giving a live-attenuated vaccine to a pregnant woman."

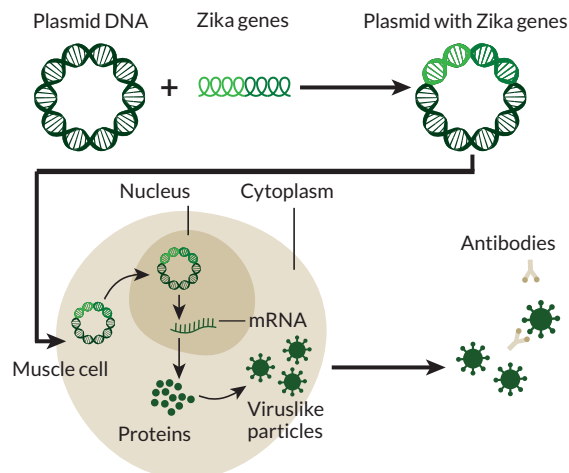
When exactly scientists have a working Zika vaccine ready for use "is totally dependent on the outbreak situation in South America and Puerto Rico," Fauci says. If new infections don't crop up over the coming spring and summer, scientists may have to wait years to collect the efficacy data needed for vaccine approval.

But the race to make a Zika vaccine probably won't come down to just one winner, he says. Having several kinds of vaccines in play would give public health officials flexibility: more weapons to fight the virus and an opportunity to tailor the response to different populations.

In fact, the fevered quest for a Zika vaccine isn't really a race at all, Barouch says. "We're all working together." ■

Immune trigger

For a DNA vaccine against Zika, scientists insert genes for Zika proteins into a circular piece of DNA called a plasmid. Many copies of the plasmid are injected into muscle. Some of the DNA travels into cells' nuclei, where it is used to make messenger RNA. After exiting the nucleus, mRNA helps build Zika proteins, which can form viruslike particles that trigger the immune system to make antibodies.



GENES & CELLS

Enzymes aid rice's arsenic defenses

Converting element helps plant roots get rid of it

BY LAUREL HAMERS

Rooted in place, plants can't run away from arsenic-tainted soil — but they're far from helpless. Scientists have identified enzymes that help rice plant roots tame arsenic, converting it into a form that can be pushed back into the soil. That leaves less of the toxic element to spread into the plants' grains, where it can pose a health risk to humans, researchers reported February 17.

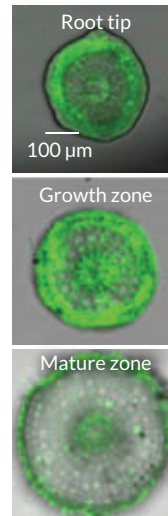
Once arsenic worms its way into rice plant roots and gets into the vascular system, "it's transported into the leaves and the grain," David Salt, a biologist at the University of Nottingham in England who conducted the recent research, said during a news conference. Inside the

plant, arsenic "can accumulate to levels where it can potentially be toxic if it accumulates over long times."

Since arsenic occurs naturally in soil, understanding the genetic basis for plants' natural defense mechanisms might help researchers engineer plants that take in less arsenic, said Dartmouth College biologist Mary Lou Guerinot.

Arsenic in soil switches between two different forms — ions with different electric charges — depending on soil conditions. Plants are more likely to pull in arsenite from the soggy soil of a flooded rice paddy and arsenate when that soil dries a bit. The plants use different chemical mechanisms to take in and process the different arsenic ions.

In arsenate-rich soil, the ion sneaks into the outer layer of root cells through specialized passageways, known as transport channels, that normally carry



Plants make HAC1 enzymes (green) in the outer cells of their roots, where the enzymes help root cells get rid of arsenic. Distribution of the enzymes in three different root cross sections is shown.

phosphate ions through root cell membranes. Transforming arsenate into arsenite lets the roots push the element back into the soil through a process called efflux, but scientists weren't sure how the plant changed arsenic's form.

Salt's team found that rice plants without working genes for enzymes called HAC1;1 and

HAC1;2 couldn't turn arsenate into arsenite. So more arsenate accumulated in the plants' shoots. When the scientists made HAC1;1 and HAC1;2 genes in other rice plants produce more of the enzymes than usual, grains from those plants had lower concentrations of arsenic, the researchers reported in the November issue of *Plant Physiology*.

EARTH & ENVIRONMENT

Seagrasses combat harmful bacteria

Underwater meadows keep reef, tidal flat ecosystems clean

BY LAUREL HAMERS

For a lawn that helps the environment — and doesn't need to be mowed — look to the ocean. Meadows of underwater seagrass plants might lower levels of harmful bacteria in nearby ocean waters, researchers reported February 16 during a news conference. That could make the whole ecosystem — from corals to fish to humans — healthier.

Not truly a grass, seagrasses are flowering plants with long, narrow leaves. They grow in shallow ocean water, spreading into vast underwater lawns. Seagrasses are "a marine powerhouse, almost equal to the rainforest. They're one of the largest stores of carbon in the ocean," said Joleah Lamb, an ecologist at Cornell University who presented the research. "But they don't get a lot of attention."

It's no secret that seagrasses improve water quality, said James Fourqurean, a biologist at Florida International University in Miami who wasn't involved in the research, which also appears in the Feb. 17 *Science*. The plants are great at removing excess nitrogen and phosphorus from coastal waters. But now, it seems, they might take away harmful bacteria, too.

A few years ago, Lamb's colleagues became ill with amoebic dysentery while studying coral reefs in Indonesia. When a city or village on one of the country's thousands of islands dumps raw sewage into the ocean, shoreline bacteria populations can spike to dangerous levels.

Water sampled close to the shores of four small, densely populated Indonesian islands had 10 times the U.S. Environmental Protection Agency's

recommended exposure limit of *Enterococcus* bacteria, which can cause illness and often signal the presence of other pathogens. But water collected from offshore tidal flats and coral reefs with seagrass beds had lower levels of the bacteria compared with similar sites without the plants less than 20 meters away. The water had lower levels of numerous bacterial species that can make fish and marine invertebrates sick, too. And field surveys of more than 8,000 coral heads showed that those growing adjacent to or within seagrass beds had fewer diseases than those growing farther away.

It's unclear how far from seagrass beds this cleaner water extends, but the benefits can ripple through the entire ecosystem, Lamb said at the news conference. Healthier corals help protect the islands from erosion. And fish with less bacterial contamination are a better source of food for people.

Lamb is planning follow-up studies to figure out how the seagrasses clean

It's just one defense of many, Salt said, and it's not bulletproof. Arsenate can still spread into plants' vascular systems from the roots via phosphate channels.

When the soil is rich in arsenite, rice roots take arsenite up through the same channels that take in silicon. Although efflux is an efficient way for roots to get rid of arsenite, there's a limit to how quickly the cells can push the ion out.

So to create rice plants that are better at dealing with arsenic, Salt and other scientists are looking not just at how roots push out arsenic once it gets in, but also how they keep arsenic out to begin with. For example, engineering channels that are better at pulling in just phosphate or just silicon could lessen the amount of arsenic that co-opts those channels.

Since soil conditions in a rice field switch between dry and wet, plants need defenses against both forms of arsenic. "Once we know what forms the plant takes in and how it's doing that, we'll need a solution for arsenate and arsenite," Guerinot said. "There's no easy fix." ■

the water. Like a shag carpet, seagrasses trap small particulates drifting through the ocean and prevent them from flowing on. The plants might ensnare bacteria in the same way, building up biofilms on their blades. Or, Lamb suggested, the leaves could give off antimicrobial compounds that directly kill the bacteria.

The findings are one more reason to conserve seagrasses, study coauthor Jeroen van de Water, an ecologist at the Scientific Center of Monaco, said at the news conference. Worldwide, seagrass beds are shrinking by 7 percent each year, thanks to pollution and habitat loss. And while restoration efforts are under way in some areas, "it's better to stop what we're doing to the meadows than to try to replant them," Lamb added.

"Seagrasses are quite particular in the depth they want to be at and the environment they want to have," he said. "It's hard to start doing restoration projects if the environment isn't exactly what the seagrass prefers." ■

LIFE & EVOLUTION

Mine crystals harbor bizarre microbes

Extremophiles hint at possible resilience of life beyond Earth

BY ASHLEY YEAGER

Microbes found stowed inside giant crystals in caves in Chihuahua, Mexico, may have survived there for tens of thousands of years. The microorganisms, which appear to be vastly different from nearly all other life-forms on Earth, offer a good indication of how resilient life can be in extremely harsh environments, including those found on other planets.

"These organisms are so extraordinary," astrobiologist Penelope Boston said February 17 during a news conference. They are not close to any known genus, said Boston, director of the NASA Astrobiology Institute in Moffett Field, Calif. Their closest relatives live in caves halfway around the world and in volcanic soils or in places with toxic compounds such as toluene.

For eight years, Boston and colleagues have been studying microbes inside the Naica lead, silver and zinc mine. Some microbes were discovered trapped in fluid pockets inside massive crystals of calcium sulfate. Analysis suggests that the microbes have been tucked away in these time capsules for 10,000 to 50,000 years and may have been dormant for some or all of that time. But they "remained viable in some fashion," Boston said. Her team reawakened the microbes in the lab and studied their genetic material, plus genetic material from other organisms found in the cave.

The microbes found in the crystals appear to be similar but not identical

to those living outside, on the cave walls and other nearby areas, Boston said. That leaves Boston and her team fairly confident that the samples were not contaminated with other microbes and that age estimates for the crystal-trapped microbes are solid. If confirmed, the microbes would represent some of the toughest extremophiles on the planet — dwelling at depths 100 to 400 meters below Earth's surface and enduring temperatures of 45° to 60° Celsius.

"Any extremophile system that we're studying actually allows us to push the envelope of life further," Boston said. "We add it to this atlas of possibilities that we can apply to different planetary settings."

Although finding such hardy microbes has promising implications for the hunt for alien life, it also highlights problems. As researchers think about sending probes to potentially habitable worlds, such as Jupiter's moon Europa and Saturn's moon Enceladus, the new discovery is a reminder of how little scientists know about Earth's microbes. And that means there are unknowns about what life-forms could stow away on spacecraft sent to other worlds, said

Cassie Conley, NASA's planetary protection officer.

"If you took some of these organisms from Earth and put them elsewhere, they may do just fine," she said. As a result, the Earth-based life could take over and contaminate those worlds. ■



Samples from fluid pockets in crystals inside the Naica mine in Chihuahua, Mexico, revealed microbial life-forms that may have been trapped in the minerals for up to 50,000 years.

BODY & BRAIN

Common fungus may raise asthma risk

Infants exposed to *Pichia* yeast more likely to develop disorder

BY RACHEL EHRENBERG

A fungus among us may tip the body toward developing asthma.

There's mounting evidence that early exposure to microbes can protect against allergies and asthma. But "lo and behold, some fungi seem to put kids at risk for asthma," microbiologist Brett Finlay said February 17 at a news conference.

Infants whose guts harbored a particular kind of fungus — *Pichia* yeast — were more likely to develop asthma than babies whose guts didn't have the fungus, Finlay reported. Studies in mice and people suggest that exposure to some fungi can both trigger and exacerbate asthma, but this is the first work linking asthma to a fungus in the gut microbiome of infants.

Finlay, of the University of British Columbia in Vancouver, and colleagues had recently identified four gut bacteria

in Canadian infants that seem to provide asthma protection. To see if kids elsewhere were similarly protected, Finlay looked at another population with an asthma rate similar to Canada's (about 10 percent of kids). He and colleagues sampled the gut microbes of 100 infants in rural Ecuador and followed up five years later.

The team identified factors that might influence the risk of developing asthma, such as exposure to antibiotics, having respiratory infections, and whether or not infants were breastfed. Of the 29 infants in the high-risk group, more than half had asthma by age 5, Finlay said.

Surprisingly, the strongest predictor of whether a child developed asthma wasn't bacterial. It was the presence of *Pichia*. And the yeast wasn't protective; it tipped the scales toward asthma.

Finlay speculates that fungi-made molecules interact with infants' developing immune systems in a way that somehow increases asthma risk. It isn't clear how infants acquire the fungus; some *Pichia* species are found in soil, others in raw milk and cheese. The team plans to look for *Pichia* in Canadian children.

The researchers also looked at other gut microbe-related factors that upped Ecuadorian kids' asthma risk. Children with access to clean water had higher asthma rates, Finlay said. While clean water helps people avoid ills such as cholera, the link to asthma highlights how some dirt can be protective, he said.

The research underscores that caution is needed when generalizing about intestinal flora. "What's emerging is that it is very personalized," gastroenterologist Eran Elinav of the Weizmann Institute of Science in Rehovot, Israel, said at the news conference. For example, evidence implicates some fungi in the development of inflammatory bowel disease, Elinav said, but it depends on the individual. ■

MEETING NOTES

Imaging method catches DNA 'blinking' on

A new imaging technique takes advantage of DNA's natural ability to "blink." It's the first method that can see genetic material and other cellular features smaller than 10 nanometers in unmodified, live cells, biomedical engineer Vadim Backman said February 17.

DNA and proteins don't naturally give off light, conventional wisdom holds, so scientists attach fluorescent dyes to such molecules to make them visible. But Backman and Hao Zhang, both of Northwestern University in Evanston, Ill., discovered that when DNA is tickled with particular wavelengths of light, it "blinks" on, momentarily shining brighter than it would with fluorescent tags. Backman and Zhang designed a setup that excites cells with light, then collects the spectra of the emitted light, allowing for the identification of different biomolecules (chromosome shown below).

With their setup — dubbed SICLON, for spectroscopic intrinsic-contrast photon-localization optical nanoscopy — the scientists have already peered at the inner walls of

microtubules, structures that help separate chromosomes during cell division. — *Rachel Ehrenberg*

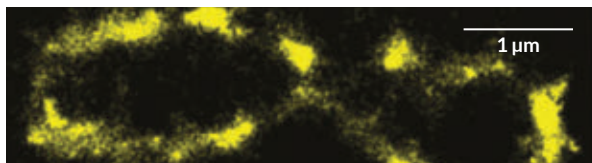
Leaf hue shaped howler monkeys' color vision

A taste for reddish young leaves might have pushed howler monkeys toward full-spectrum color vision, biological anthropologist Amanda Melin of the University of Calgary in Canada reported February 19.

In most New World monkey species, only some individuals have trichromatic vision (how most humans see), in which the eye has three types of light-sensitive proteins. While some females see the whole rainbow, males have dichromatic vision (they are red-green colorblind). Howlers are an exception: Trichromatic vision is the norm for males and females.

Howlers eat leaves when fruit is sparse. In Costa Rica, howler monkeys preferred younger, more nutritious leaves, Melin's team found. Reddish, new leaves pop more when seen with trichromatic vision than dichromatic vision, the team reports online February 4 in *Ecology and Evolution*. Young leaves are fleeting, so monkeys able to spot them more quickly could have had a selective advantage.

Other New World monkeys usually go for insects when there's no fruit. Dichromatic vision might be a better fit for their lifestyle. Color can impede the ability to see camouflaged insects, Melin said. — *Laurel Hamers*



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Nudge Backlash

Steering people's decisions with simple tactics can come with a downside **By Bruce Bower**

Nudges are a growth industry. Inspired by a popular line of psychological research and introduced in a best-selling book a decade ago, these inexpensive behavior changers are currently on a roll.

Policy makers throughout the world, guided by behavioral scientists, are devising ways to steer people toward decisions deemed to be in their best interests. These simple interventions don't force, teach or openly encourage anyone to do anything. Instead, they nudge, exploiting for good — at least from the policy makers' perspective — mental tendencies that can sometimes lead us astray.

But new research suggests that low-cost nudges

aimed at helping the masses have drawbacks. Even simple interventions that work at first can lead to unintended complications, creating headaches for nudgers and nudgees alike.

Nudge proponents, an influential group of psychologists and economists known as behavioral economists, follow a philosophy they dub libertarian paternalism. This seemingly contradictory phrase refers to a paternalistic desire to promote certain decisions via tactics that preserve each person's freedom of choice. Self-designated "choice architects" design nudges to protect us from inclinations that might not serve us well, such as overconfidence, limited attention, a focus on now rather

than later, the tendency to be more motivated by losses than gains and intuitive flights of fancy.

University of Chicago economist Richard Thaler and law professor Cass Sunstein, now at Harvard University, triggered this policy movement with their 2008 book *Nudge*. Thaler and Sunstein argued that people think less like an economist's vision of a coldly rational, self-advancing *Homo economicus* than like TV's bumbling, doughnut-obsessed Homer Simpson.

Choice architects like to prod with e-mail messages, for example, reminding a charity's past donors that it's time to give or telling tardy taxpayers that most of their neighbors or business peers have paid on time. To nudge healthier eating, these architects redesign cafeterias so that fruits and vegetables are easier to reach than junk food.

A popular nudge tactic consists of automatically enrolling people in organ-donation programs and retirement savings plans while allowing them to opt out if they want. Until recently, default choices for such programs left people out unless they took steps to join up. For organ donation, the nudge makes a difference: Rates of participation typically exceed 90 percent of adults in countries with opt-out policies and often fall below 15 percent in opt-in countries, which require explicit consent.

Promising results of dozens of nudge initiatives appear in two government reports issued last September. One came from the White House, which released the second annual report of its Social and Behavioral Sciences Team. The other came from the United Kingdom's Behavioural Insights Team. Created by the British government in 2010, the U.K. group is often referred to as the Nudge Unit.

In a September 20, 2016, *Bloomberg View* column, Sunstein said the new reports show that nudges work, but often increase by only a few

percentage points the number of people who, say, receive government benefits or comply with tax laws. He called on choice architects to tackle bigger challenges, such as finding ways to nudge people out of poverty or into higher education.

Missing from Sunstein's comments and from the government reports, however, was any mention of a growing conviction among some researchers that well-intentioned nudges can have negative as well as positive effects. Accepting automatic enrollment in a company's savings plan, for example, can later lead to regret among people who change jobs frequently or who realize too late that a default savings rate was set too low for their retirement needs. E-mail reminders to donate to a charity may work at first, but annoy recipients into unsubscribing from the donor list.

"I don't want to get rid of nudges, but we've been a bit too optimistic in applying them to public policy," says behavioral economist Mette Trier Damgaard of Aarhus University in Denmark.

Nudges, like medications for physical ailments, require careful evaluation of intended and unintended effects before being approved, she says. Policy makers need to know when and with whom an intervention works well enough to justify its side effects.

Default downer

That warning rings especially true for what is considered a shining star in the nudge universe — automatic enrollment of employees in retirement savings plans. The plans, called defaults, take effect unless workers decline to participate.

No one disputes that defaults raise participation rates in retirement programs compared with traditional plans that require employees to sign up on their own. But the power of opt-out plans to

Nudges are everywhere

Prepare for later years
Opt-out retirement savings plans for employees

Save a life
Opt-out organ donation policies

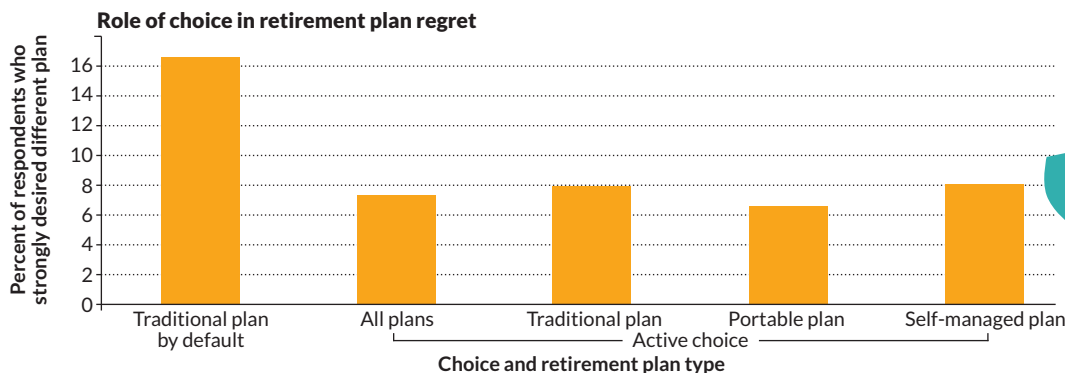
Reduce energy
Public utility notices that compare a consumer's monthly energy use with neighbors' use

Give more
E-mail and text reminders from charities to donors

Eat better
Healthier foods placed at eye level in cafeterias and grocery stores

Keep it clean
Images of a fly in the bowl of airport urinals to reduce mess

Passive regret In a recent survey, state university employees in Illinois expressed the most regret about past pension choices if they had defaulted into a traditional retirement plan (far left). Substantially lower percentages of those who had actively chosen any of three available plans, including the traditional plan, wanted to switch plans as many as 13 years after their original decision. SOURCE: J.R. BROWN, A.M. FARRELL AND S.J. WEISBENNER/J. FINANCIAL ECONOMICS 2016



kick-start saving for retirement stayed under the radar until it was reported in the November 2001 *Quarterly Journal of Economics*.

When the company in the 2001 study — a health and financial services firm with more than 10,000 employees — switched from voluntary to automatic enrollment in a retirement savings account, employee participation rose from about 37 percent to nearly 86 percent.

Similar findings over the next few years led to passage of the U.S. Pension Protection Act of 2006, which encouraged employers to adopt automatic pension enrollment plans with increasing savings contributions over time.

But little is known about whether automatic enrollees are better or worse off as time passes and their personal situations change, says

Harvard behavioral economist Brigitte Madrian. She coauthored the 2001 paper on the power of default savings plans.

Although automatic plans increase savings for those who otherwise would have squirreled away little or nothing, others may lose money because they would have contributed more to a self-directed retirement account, Madrian says. In some cases, having an automatic savings account may encourage irresponsible spending or early withdrawals of retirement money (with penalties) to cover debts. Such possibilities are plausible but have gone unstudied.

In line with Madrian’s concerns, mathematical models developed by finance professor Bruce Carlin of the University of California, Los Angeles and colleagues suggest that people who default into

Choosing boost over nudge

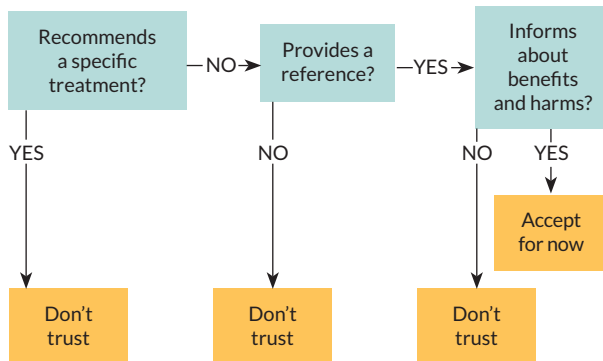
On December 8, 2016, researchers gathered at the Max Planck Institute for Human Development in Berlin to begin planning an ambitious website designed to teach people how to make informed decisions for themselves, rather than relying on guidance from choice architects.

Felix Rebitschek, a psychologist affiliated with the institute and Berlin’s Harding Center for Risk Literacy, directs the online project. Rebitschek expects a Risk Atlas website to be up and running by 2019, thanks to a three-year grant from the German government equal to about \$1 million.

Well-intentioned nudges don’t operate in a vacuum, Rebitschek says. Governments, political parties and commercial firms already deploy nudges along with blunter tactics to push their own agendas. Teaching consumers to

Handy decision guide

Researchers plan to develop smartphone apps with simple decision trees for daily situations. Here, answers to three questions help someone determine whether medical information on a website is minimally acceptable.



SOURCE: HARDING CENTER FOR RISK LITERACY

see through those ploys is one goal of the Risk Atlas.

“Nudging people without educating them means infantilizing the public,” says psychologist Gerd Gigerenzer, director of the Max Planck Institute’s Center for Adaptive Behavior and Cognition and of the Harding Center.

Plans for the Risk Atlas include providing easy-to-understand information on benefits and risks of screening tests for breast cancer and other diseases. Rebitschek also hopes to oversee development of smartphone apps that provide simple decision-making rules for daily situations, such as figuring out which of many online medical and health resources to trust. Hint: A website’s trustworthiness escalates if health information comes from a recognizable author, potential harms and benefits of a treatment or test are described, and no absolute recommendations are issued.

The Risk Atlas belongs to a class of interventions dubbed boosts. These strategies focus on enabling people to make their own decisions by improving statistical literacy and using simple but effective thinking strategies. For instance, a four-step decision tree enables medical personnel to identify the emergency room patients with vague complaints who need immediate care (*SN Online*: 6/19/14).

Boosts stem from evidence that simple rules of thumb work surprisingly well under the right circumstances (*SN*: 6/4/11, p. 26). From this perspective, for instance, many people deliberately choose default savings plans because they view them as helpful recommendations by employers or investment experts. Nudge proponents disagree, asserting that people typically fall into default plans out of a tendency to take the path of least resistance when faced with complex information.

— Bruce Bower

retirement plans learn less about money matters, and share less financial information with family and friends, than those who join plans that require active investment choices.

Opt-out savings programs “have been oversimplified to the public and are being sold as a great way to change behavior without addressing their complexities,” Madrian says. Research needs to address how well these plans mesh with individuals’ personalities and decision-making styles, she recommends.

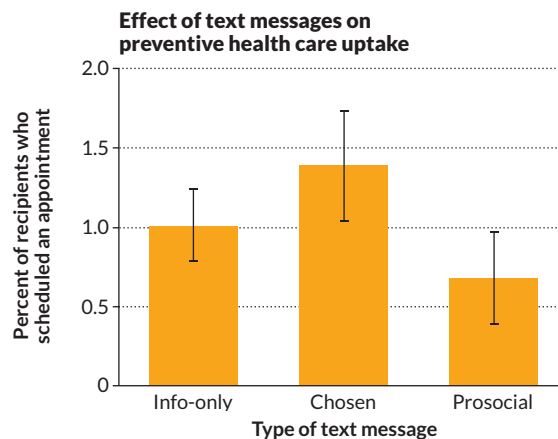
Delay and regret

By comparing procrastinators with more decisive folks in one large retirement system, economist Jeffrey Brown examined how individual differences influence whether people join and stay happy with opt-out savings programs. Procrastinators were not only more likely to end up in a default plan but also more apt to regret that turn of events down the road, says Brown, of the University of Illinois at Urbana-Champaign.

Among state employees at the university who were offered any of three retirement plans, those who delayed making decisions were particularly likely to belong to a default plan and to want to switch to another plan, Brown and colleagues reported in September 2016 in the *Journal of Financial Economics*. These plans serve as a substitute for Social Security and often represent an employee’s largest financial asset. The default plan is generous toward those who stay long enough to retire from the state system but less so to those who leave early. A second plan allows for a larger cash refund upon leaving the system early. A third plan enables savers to direct contributions to any of a variety of investments. Being dumped into the default plan isn’t always the best option, especially because initial plan choices are permanent.

More than 6,000 employees who joined the retirement system in or after 1999 completed e-mail questionnaires in 2012. When asked what they would do if they could go back and redo their savings choice, 17 percent of defaulters reported a strong desire to change plans. Only about 7 percent of those who actively selected a plan and 8 percent of those who intentionally chose the default wanted to change.

The likelihood of having been assigned to the default plan and wanting to switch to another plan increased steadily as employees reported higher levels of procrastination. Implications of this finding are not entirely clear, Madrian says. Individuals in the default savings plan either by



Doctor is in Low-income New Orleans residents received one of three text messages to set up a free medical appointment. A message telling them they had been chosen for a free appointment produced a higher sign up rate (middle) than an information-only text. A prosocial text to “take care of yourself so you can take care of the ones you love” unexpectedly did the worst. SOURCE: BEHAVIORAL INSIGHTS FOR CITIES 2016

choice or procrastination may, for instance, regret lots of events in their lives. If so, they can’t easily be compared with less regretful folks who chose another plan.

Requiring people to make an active choice of a retirement plan, even if they’re procrastinators, might reduce regret down the road, Madrian suspects. But given a complex, high-stakes choice — such as that faced by Illinois university employees — “it may still make sense to set a default option even if some individuals who end up in the default will regret it later.”

Researchers need to determine how defaults and other nudges instigate behavior changes before unleashing them on the public, says philosopher of science Till Grüne-Yanoff of the Royal Institute of Technology in Stockholm.

Hidden costs

Sometimes well-intentioned, up-front attempts to get people to do what seems right come back to bite nudgers on the bottom line.

Consider e-mail prompts and reminders. Although nudges were originally conceived to encourage people to accept an option unthinkingly, simple attempts to curb forgetfulness and explain procedures now get folded into the nudge repertoire. Short-term success stories abound for these inexpensive messages. The 2016 report of the U.S. Social and Behavioral Sciences Team cites a case in which e-mails sent by the Department of Education to student-loan recipients, which described how to apply for a federal repayment plan, led 6,000 additional borrowers to sign up for the plan in the following three months, relative

to borrowers who did not receive the explanatory e-mail. Messages were tailored to borrowers' circumstances, such as whether they previously expressed interest in the payback plan or had stopped making loan repayments.

The U.K. Behavioural Insights Team — now a global company with offices in Britain, North America, Australia and Singapore — also sees value in short, informational nudges.

One of the company's projects produced an unexpected twist. Low-income New Orleans residents who hadn't seen a primary care physician in more than two years — 21,442 of them — received one of three text messages to set up a free medical appointment. Telling people that they had been selected for a free appointment worked best, leading 1.4 percent of recipients to sign up, versus 1 percent of those who got an information-only text. But a text asking people to "take care of yourself so you can take care of the ones you love" backfired, resulting in only 0.7 percent of recipients making appointments. Uptake for all three groups was low, but the study suggested that nudges that unwittingly trigger bad feelings (guilt or shame) can easily go awry, Aarhus University's Damgaard says.

A case in point is a study submitted for publication by Damgaard and behavioral economist Christina Gravert of the University of Gothenburg in Sweden. E-mailed donation reminders sent to people who had contributed to a Danish anti-poverty charity increased the number of donations in the short term, but also triggered an upturn in the number of people unsubscribing from the list.

People's annoyance at receiving reminders perceived as too frequent or pushy cost the charity money over the long haul, Damgaard holds. Losses of list subscribers more than offset the financial

gains from the temporary uptick in donations, she and Gravert conclude.

"Researchers have tended to overlook the hidden costs of nudging," Damgaard says.

In one experiment, more than 17,000 previous donors to a Danish charity received an e-mail asking them to donate within 10 days. About half received an additional reminder one week later. Reminders yielded 46 donations, versus 30 donations from people sent only one e-mail. But over the next month, 318 reminded donors unsubscribed from the e-mail list, as opposed to 186 of those who received one e-mail. To Damgaard and Gravert, reminders were money losers — especially if sent more than once.

A second experiment examined more than 43,000 Danish charity donors split into three groups. The number of unsubscribers reached 71 among those sent an e-mail informing them that digital reminders would be sent every month. Among those receiving the same e-mail plus an announcement that only one reminder would be sent in the next three months, 44 people abandoned the mailing list. That's what a digital sigh of relief looks like. An e-mail that combined a notice of monthly reminders with a promise of a donation from an anonymous sponsor for every mailing list donation slightly lowered annoyance at the prospect of monthly reminders — 52 unsubscribed.

The limits of nudge

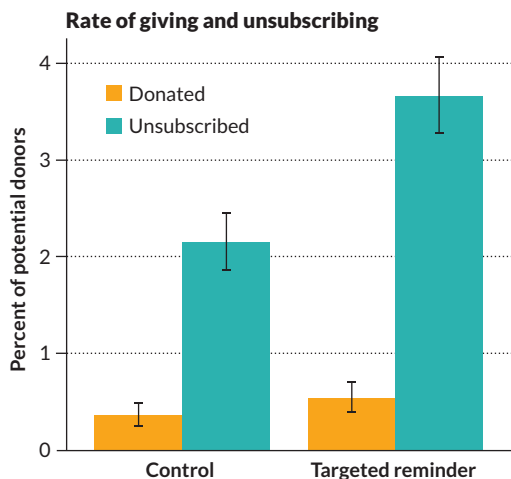
There are at least two ways to think about unintended drawbacks to nudges. Behavioral economists including Damgaard take an optimistic stance. They see value in determining how nudges work over the long haul, for better and worse. In that way, researchers can target people most likely to benefit from specific nudges. Few schemes to change behavior, including nudges, alter people's lives for the better in a big and lasting way, cautions Harvard behavioral economist and nudge proponent Todd Rogers. "One of the most important questions in behavioral science right now is, how do we induce persistent behavior change?"

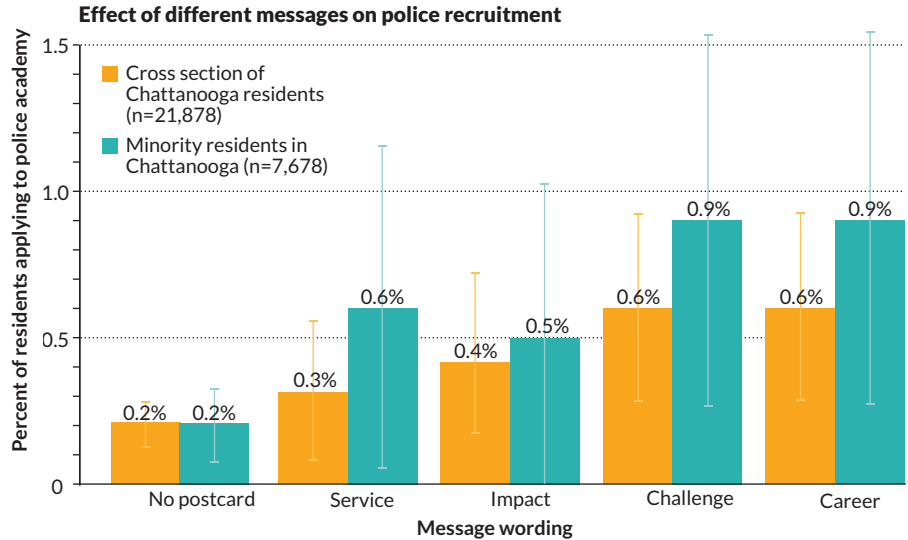
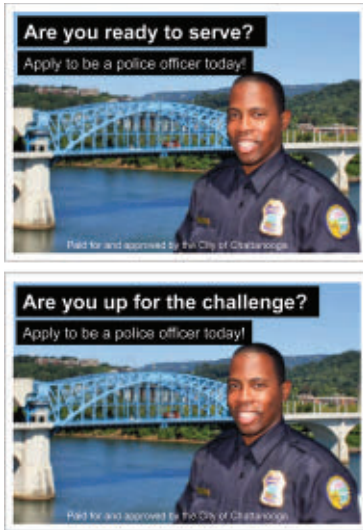
But those already critical of libertarian paternalism say that new findings back up their pessimistic view of what nudges can do. When past charity donors in Denmark fork over more money in response to an e-mail reminder and then bolt from the mailing list, as reported by Damgaard and Gravert, they're demonstrating that even a small-scale nudge can trigger resistance, says political scientist Frank Mols of the University of Queensland in Brisbane, Australia. "It verges on



Costly plea Donors to a Danish charity received either a control e-mail asking for a donation within 10 days or the same e-mail followed by a targeted reminder one week later. Reminders resulted in slightly more donations than the single e-mail (orange bars). But a greater percentage of people unsubscribed from the charity's e-mail list after receiving targeted reminders (teal bars).

SOURCE: M. DAMGAARD AND C. GRAVERT





ridiculous to claim that nudges can change attitudes or behavior related to huge social problems, such as crime or climate change,” he says.

Nudges wrongly assume that each person makes decisions in isolation, Mols contends. People belong to various groups that frame the way they make sense of the world, he says. Rather than nudging, lasting behavior change entails persuasion techniques long exploited by advertisers: altering how people view their social identities. Coors beer, for instance, has long been marketed to small-town folks and city dwellers alike as the choice of rugged, outdoorsy individualists.

In the noncommercial realm, Mols points to a successful 2006 campaign to reduce water use in Queensland during a severe drought. Average per capita water use dropped substantially and stayed lower after the drought broke in 2009. That’s because the campaign included advertisements targeting citizens’ view of themselves as “Queenslanders,” he says. A good Queenslanders became redefined as a “water-wise” person who consumed as little of the resource as possible.

Queensland’s persuasive approach to water conservation avoided ethical concerns that dog nudges, Mols adds. Choice architects’ conviction that people possess biased minds in need of expert guidance to achieve good lives cuts off debate about what constitutes a good life, he argues.

Elsbeth Kirkman, a policy implementation specialist who heads the U.K. Behavioural Insights Team’s North American office in New York City, sees no ethical problem with nudges that people can reject anytime they want. But she acknowledges that ethical gray areas exist. “It’s not always clear when an intervention is a nudge and when

it’s coercive manipulation,” she says. Nudge carefully and monitor an intervention’s intended and unintended effects for as long as possible, Kirkman advises.

Even amid calls for caution, nudges are expanding their reach. With input from the Behavioural Insights Team, a U.K. law passed in March 2016 and slated to take effect in April 2018 imposes a soft drink tax that rises with increasing sugar content. The law aims to encourage soft drink companies to switch from high-sugar products to artificially sweetened and low-sugar beverages in an effort to reduce obesity. The U.K. soft drink firm Lucozade Ribena Suntory and the retail company Tesco announced last November plans to cut sugar in soft drinks by at least 50 percent to escape the looming tax.

The law might prod consumers to change too, if companies stand their ground but raise prices of high-sugar drinks due to the new tax, Kirkman predicts.

In nudges as in life, though, the best-laid plans can tank. Perhaps scientists will discover serious health risks in artificial sweeteners currently considered safe, reviving soda makers’ sugar dependence. Maybe a black market for old-school soda will pop up in Britain, sending soft drink lovers to back-alley Coke dealers for sugar fixes.

The law of unintended consequences is always taxing. ■

Explore more

- National Science and Technology Council. “Social and Behavioral Sciences Team 2016 annual report.” September 2016. bit.ly/BehavioralSci

Apply here

In Chattanooga, Tenn., researchers tested the effect of four postcard messages on applications to the city’s police department. Postcards emphasizing the job’s challenges and career benefits brought in more applicants (orange bars) than sending no card. The service message appeared to work better for minority groups (teal bars), as did messages citing the job’s challenge and career benefits. Vertical lines indicate the wide ranges of possible proportions of applicants responding to each postcard message. The researchers will need to take a closer look at whether the more successful messages attracted the most applicants by actually working better or by chance. SOURCE: BEHAVIORAL INSIGHTS FOR CITIES 2016



REAL SICK

The immersive experience of the virtual world is not for everyone **By Betsy Mason**

Tech evangelists predicted that 2016 would be “the year of virtual reality.” And in some ways they were right. Several virtual reality headsets finally hit the commercial market, and millions of people bought one. But as people begin immersing themselves in new realities, a growing number of worrisome reports have surfaced: VR systems can make some users sick.

Scientists are just beginning to confirm that these new headsets do indeed cause a form of motion sickness dubbed VR sickness. Headset makers and software developers have worked hard to combat it, but people are still getting sick.



Many in the industry fear this will be a major obstacle to mass adoption of virtual reality.

“A lot of VR, people today cannot tolerate,” says Kay Stanney, a human factors engineer with a focus on VR at Design Interactive in Orlando, Fla. Search for “VR sickness” on Twitter, she says, and you’ll see that people are getting sick every day.

Around 25 to 40 percent of people suffer from motion sickness depending on the mode of transport, scientists have estimated, and more women are susceptible than men.

Count me among those women. I’m highly prone to motion sickness. Cars, planes and boats can all make me feel woozy. It can take me a day or more to fully shake the nausea, headache and drowsiness. Certain that virtual reality would also make me sick, I’ve purposefully avoided strapping on a headset. (Until this assignment came along.)

So far, avoiding VR hasn’t been much of a loss for me. A lot of the VR industry is focused on video games, vying for a chunk of an estimated \$100 billion market. And most of the early adopters who are willing to pay for one of the new premium headsets — \$400



Resident Evil 7: Biohazard is one of the most popular virtual reality games available. But it has also gained a reputation for making people motion sick.

for Sony’s PlayStation VR or \$800 for an Oculus Rift or HTC Vive — are probably serious gamers or technophiles. I don’t fit either category.

But, avoidance promises to become harder as VR moves beyond games. The technology has already begun creeping into other fields. Car companies, including Audi, General Motors Co. and used-car seller Vroom, are building VR showrooms where you can check out cars as if you were actually on the lot. Architects are using VR to walk clients through buildings that don’t yet exist. Schools and learning labs are taking students on virtual field trips to both contemporary and historical sites.

Facebook CEO Mark Zuckerberg sees virtual reality as the next big social platform. In 2014, Facebook bought Oculus VR, maker of the Rift headset, for around \$2 billion. “This is really a new communication platform,” Zuckerberg wrote in the Oculus announcement. “Imagine sharing not just moments with your friends online, but entire experiences and adventures.” New VR sites where people can socialize or play games together in virtual spaces, like

AltspaceVR and Rec Room, are springing up. And some tech luminaries see a future in which VR is integrated into many more aspects of our daily lives, from movies and entertainment to work and health care.

Nobody knows if the broader public will embrace virtual reality. Sales of the expensive high-end headsets have been underwhelming — the three premium systems combined sold an estimated 1.5 million headsets in 2016. But sales of cheaper mobile headsets were more impressive. For less than \$100, Samsung Gear VR, Google Daydream View, Google Cardboard and others are powered by your mobile phone. But with smaller screens and less computer power, they are far less capable than the Rift or the Vive. Still, they are selling. In January, Samsung reported that it had sold 5 million of the \$99 Gear VR headset since its release in November 2015.

But VR may never really catch on if it makes people sick. And while VR companies and developers are confident that they’ll find solutions, many motion sickness experts are pessimistic. “My hunch is that [the solutions] are extremely limited,” says Steven Rauch, director of the Vestibular Division at Massachusetts Eye and Ear in Boston.

In some ways, the very premise of virtual reality makes it an ideal vehicle for motion sickness.

Cue conflict or instability

Motion sickness has probably been with us as long as we’ve had boats. References to seasickness date back to Greek mythology; the word nausea is derived from the Greek *naus*, meaning ship. J.A. Irwin introduced the term motion sickness in the scientific literature in 1881. Since then, an extensive body of research has accumulated.

The most widely accepted theory to emerge is that motion sickness is brought on by a mismatch between two or more of the senses that help you keep your balance. For example, when you’re below deck on a ship at sea, your eyes see a stationary room. But your vestibular system — the fluid-filled canals and specialized membranes in your inner ear — senses the motion of the ship as it rolls over waves. “You’re getting conflicting information on different sensory channels into the balance system,” Rauch says. “That is believed to be the primary cause of motion sickness.”

In virtual reality, the mismatch is there as well, says visual neuroscientist Bas Rokers of the University of Wisconsin–Madison. But the sensory cues are reversed: Your eyes see that you are moving through the virtual world — in a virtual car or a virtual spaceship, or strolling down a virtual path — but your vestibular system knows you’re not actually moving. “That gives you a cue conflict,” he says.

While most motion sickness experts think sensory mismatch is to blame, some disagree. Kinesiologist Thomas Stoffregen of the University of Minnesota in Minneapolis, who’s been studying motion sickness for 25 years, thinks instability is the culprit. On a ship,

78
percent

Women who got sick playing a VR horror game

33
percent

Men who got sick playing the game



Women are known to be more susceptible to motion sickness than men. New research suggests that women may also be more likely to experience VR sickness — motion sickness brought on by virtual reality.

the rolling motion puts you off balance, and that makes you sick, he says. “Motion sickness situations are ones in which the control of your body is challenged somehow. If you don’t rise to that challenge, then the contents of your stomach may rise.”

This idea, known as the postural instability theory, can be applied to VR as well, Stoffregen says. If your eyes convince your brain that you’re in the virtual world, your body will respond to it instead of the real world you are physically in, which can throw your balance off. Imagine sitting in a chair in the real world while riding in a car in the virtual world. As the car approaches a turn, you’ll want to lean into it, which could land you on the floor. The more convincing the virtual world is, the more likely you are to link the control of your body to what you’re seeing, Stoffregen says. “And in a virtual car, that is a mistake.”

Gender matters

While the postural instability theory is outside the scientific mainstream, it offers an explanation for another mystery of motion sickness: why more women suffer than men.

Stoffregen and colleagues have shown repeatedly that it’s possible to predict who is likely to get motion sick in various circumstances by measuring postural sway — the small, subconscious movements people make to stay balanced while standing still. By analyzing several aspects of sway, including the distance, direction and timing of the movements, the researchers have found that people who are susceptible to motion sickness sway differently than those who aren’t. And postural sway differs measurably between men and women. The difference, Stoffregen says, can be attributed to physical differences between the sexes, such as height and center of balance.

Stoffregen’s research suggests women are also more prone to VR sickness than men. In a study published in December in *Experimental Brain Research*, Stoffregen and colleagues measured the postural sway of 72 college students

before they were asked to play one of two VR games for 15 minutes using an Oculus Rift DK2. The first game made two of 18 men and six of 18 women feel motion sick, not enough for a statistically significant difference.

But more than half of the students who played the horror game *Affected*, using a handheld controller to explore a dark, spooky building, reported feeling sick. Of the 18 women playing that game, 14 felt sick. That’s nearly 78 percent, compared with just over 33 percent of the men. When the scientists compared those results against the postural sway data, just as in their previous motion sickness studies, they found a measurable difference in sway between those who got sick and those who didn’t (*SN*: 1/21/17, p. 7).

Rokers has another explanation for the gender difference that fits with the sensory mismatch theory. In a study published in January 2016 in *Entertainment Computing*, Rokers and colleagues looked at how visual acuity might affect susceptibility to VR sickness. Seventy-three people with either natural or corrected 20/20 vision completed a battery of visual tests and then spent up to 20 minutes in an Oculus Rift DK1 headset watching videos. The videos showed motion from different points of view, such as a drone flying around a bridge or a passenger in a car driving through mild traffic. Of the female participants, 75 percent felt sick enough to stop watching before the 20 minutes had passed, compared with 41 percent of the men.

People who were better at perceiving 3-D motion in the visual tests were more likely to feel sick. And on average, the women in the study performed better on the 3-D motion perception tests than the men.

It’s not clear why women would have better visual acuity for 3-D motion, but the results suggest that the more sensitive you are to sensory cues, the more likely you are to detect a mismatch, Rokers says. “If you can tell that your senses are providing you different information, then you are more likely to get motion sick.”

Like a poison

On its face, it makes no sense that exposure to motion should bring on disabling nausea and vomiting. But we share this seemingly odd connection between our sense of balance and the gastrointestinal tract with many non-human animals, including dogs, monkeys, sheep, birds and even fish. The most often cited explanation is an evolutionary theory put forward by cognitive psychologist Michel Treisman in *Science* in 1977. Ingesting a poison can also mess with your balance system. So the body interprets the motion reaction as a symptom of poisoning and responds as it would with poison, by vomiting to try to get rid of the harmful substance, he suggested. Although it’s just an idea and has never been tested, it has some intuitive appeal. — Betsy Mason

Just being a woman doesn't necessarily mean you'll be highly susceptible to motion sickness like I am. Lots of other factors are likely at play. Some research suggests Asians are more likely to suffer. People who get migraines are also unusually prone to motion sickness. Scientists at genetic-testing company 23andMe reported in *Human Molecular Genetics* in 2015 that they had found 35 genetic variants associated with car sickness. Age is also a factor: Infants are generally immune, susceptibility increases from age 2 to 15, and although it hasn't been my experience, the problem subsides for many people in adulthood.

Everybody's brain has a different capacity for processing motion, Rauch says. "Just like some people are good with languages and some people are good with math, some people are good with motion processing, of doing this complex sensory-integration task. The people who are good at it become figure skaters and divers and gymnasts," he says. "But there are other people who throw up if they ride backwards on the metro." That would be me.

Under the right circumstances, though, anyone with a functioning vestibular system can experience motion sickness — nearly everyone stranded on a lifeboat in choppy seas will get sick.

Very little motion sickness research has been done on the latest VR headsets available to consumers. But Rauch says the very nature of VR, which is to trick your eyes into telling your brain you're in another world, is inviting a sensory conflict. "There's always going to be some sensory conflict, and so the VR is going to be more successful in people who can tolerate that," Rauch says. For me, he was clear: "It's always going to be torture."

Sprint past trouble spots

The U.S. military was the first to report, in 1957, that virtual environments could be problematic: Flight simulators were making some pilots motion sick. Since then, many studies have confirmed that simulator sickness is a real problem.

One of the biggest tech hurdles for VR has been the inherent delay between when you move your head and when the display updates to reflect that movement. If the lag is too great, you can end up with a potentially vomit-inducing sensory mismatch. Today's high-end systems have capitalized on advances in displays, video rendering, motion tracking and computing to cut down the lag to the neighborhood of 20 milliseconds — low enough to avoid triggering motion sickness. "They've beaten most of the pure hardware problems," says Steven LaValle, a computer scientist at the University of Illinois at Urbana-Champaign and a former head scientist at Oculus.

But even with the best virtual reality system, what you do in the virtual world matters. If you're sitting or standing in one place in both the real world and the virtual world, you're very unlikely to feel sick. And as long as a step in the real world results in an equivalent step in the virtual world, moving around is fine too. All three of the premium headsets use external lasers to track the motion of the headset within a

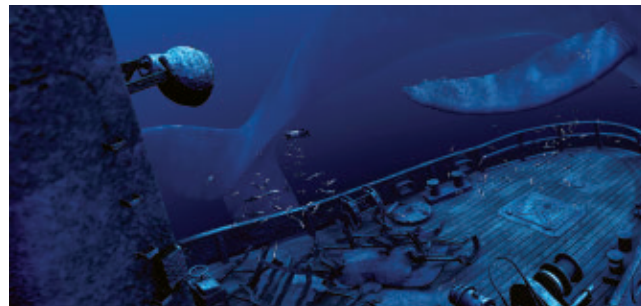
limited space — up to 3.5 meters by 3.5 meters with the HTC Vive. But to explore further, you'll need to use handheld controllers with buttons, triggers and directional touch pads to move your virtual self around, just as in a regular 2-D video game. That's where things can go wrong.

"I like to joke that the controller is like a sickness generator," says LaValle, who worked on reducing motion sickness while at Oculus. "Every time you grab onto a controller, you're creating motions that are not corresponding perfectly to the physical world. And when that's being fed into your eyes and ears, then you have trouble."

The people creating the content for VR systems are taking the problem seriously, says Steve Bowler, cofounder of VR game company CloudGate Studio, based outside of Chicago. Developers "are really, really focused on zero tolerance for user motion sickness."

One of the most successful strategies developers have hit on is using teleportation to take short skips around the virtual world. Basically you aim the controller where you want to go and the screen fades to black for a split second, sort of like the

Some games, like *theBlu: Encounter* (top) and *Job Simulator* (center), are unlikely to cause sickness because they require little movement around the virtual world. The dinosaur-hunting game *Island 359* (bottom) has a teleport option for more susceptible players.



blink of an eye. When it fades back in, you're at the new location. This, Bowler says, eliminates motion sickness even for the most susceptible people he knows. But that comfort comes at a cost: The whole point of VR is to convince you that you're physically in this other world; if you're magically teleporting here and there, it's not going to feel as real, he says.

Bowler favors a technique known as “sprint” or “dash” that aims to reduce the effects of acceleration. Instead of gradually ramping your speed up and back down, a sprint bumps you up to speed almost instantaneously, maintains that speed until you reach your target and then drops you quickly back down to a standstill.

While sprinting doesn't approximate natural movement very well, it does let you see the motion, unlike teleportation. And Bowler says he's had about a thousand people at various events try sprinting in a dinosaur-hunting game his group built called *Island 359* with almost no reports of motion sickness. Anyone who feels uncomfortable can switch to chasing dinosaurs using a teleportation option instead.

Oculus seems to have accepted that VR sickness can't be eliminated from all VR experiences at the moment, so most Oculus-approved games come with “comfort ratings” to let users know if a game or experience is more or less likely to make them sick. Those assessments might help people like me avoid the most nauseating games.

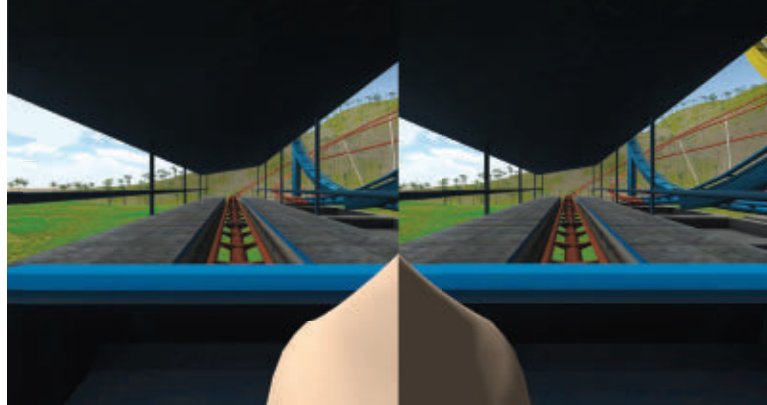
It gets real

Bowler considers himself an ambassador for virtual reality. After almost an hour of very patiently and enthusiastically explaining how VR works, he somehow convinced me to try it. A few days later I was at UploadVR in San Francisco strapping on the HTC Vive with Bowler looking on via Skype from his office in the Chicago suburbs.

The headset was heavy and awkward, but I otherwise felt fine while creating a virtual 3-D painting or walking around on the deck of a shipwreck as an enormous blue whale swam by ogling me. I even shot at drones while dodging virtual bullets, with no hint of motion sickness. I decided I was ready to hunt dinosaurs.

First I tried teleportation mode in Bowler's game, and as he promised, no nausea. Though the splatters of blood and guts when I slashed some attacking mini dinosaurs was almost enough to make me gag, the strangeness of teleportation made me feel more like I was inside a 2-D video game than on a dinosaur-infested island. I decided to see if I could handle sprint mode. I wanted to know if it would feel more real.

That was a mistake. I could only manage about a half dozen sprints before I felt the first hints of nausea. I had to quit. Once the headset was off I felt better. But soon, a lingering nausea and drowsiness hit, like I sometimes experience after a turbulent flight. I didn't entirely recover until the following evening. I'm glad Bowler convinced me to give it a try, and the parts I could handle were pretty fun. But I won't be going back for more anytime soon.



Make it stop

A slew of possible solutions for VR sickness — most with very little research behind them — have been suggested by scientists, developers, companies, entrepreneurs and users. Here are just a few:

- **Taking traditional motion sickness remedies:** ginger, Dramamine and scopolamine
- **Wearing a nerve-stimulating wristband**
- **Galvanic vestibular stimulation:** Applying electrical currents behind the ear to fool your vestibular system into thinking you're moving
- **Inserting a virtual nose into the field of view** (see above, tested in a roller coaster game)
- **Adding a virtual cockpit to your experience**
- **Reducing the field of view during motion**
- **Expanding the field of view:** Peripheral LEDs in the headset add light to make the view more realistic
- **Using optical illusions:** The aim is to trick you into thinking you've covered more ground than you have, eliminating the need for controller-based movements
- **Walking on a specialized treadmill:** Lets you move in any direction while playing
- **Toughing it out until you develop your “VR legs”** (similar to sea legs) — *Betsy Mason*

Virtual reality still has lots of room for improvement, but whether it will ever reach the point of being comfortable for everyone is an open question. The VR industry is moving at a pace science can't match, forging ahead with its own grand experiment as millions of users test its products. Much of what we learn about how VR affects people will show up first in living rooms and on Twitter rather than in scientific labs and journals. And though the results of those experiments are still coming in, tech luminaries haven't hesitated to declare 2017 as the *real* year of virtual reality. ■

Explore more

- Steven LaValle. *Virtual Reality*. <http://vr.cs.uiuc.edu/>

Betsy Mason is a freelance science journalist based in the San Francisco Bay Area.

SOCIETY UPDATE



“These young people make the world a better place for all of us.”

CRAIG BARRETT | FORMER CEO AND CHAIRMAN OF THE BOARD, INTEL CORPORATION

Society seeks new sponsor for International Science and Engineering Fair

Society for Science & the Public is seeking a new title sponsor for the International Science and Engineering Fair, the world’s largest international high school STEM (science, technology, engineering and math) competition.

Intel became the title sponsor in 1997 and renewed that sponsorship through 2019. A new sponsor will assume the sole title sponsorship following the May 2019 event.

Hundreds of thousands of teenagers from across the world enter this powerful STEM pipeline. Last year, more than 1,750 finalists from over 75 countries, regions and territories convened in Phoenix for the weeklong event. These students — tomorrow’s leading scientists, engineers, innovators and entrepreneurs — strive to discover answers and develop new solutions to humankind’s greatest problems.

Cutting-edge independent research projects presented last year included studies of the genes that help microbes turn waste into electricity,

investigations of improved electrolytes for batteries and the development of a smart leg brace for people with multiple sclerosis, spinal injury or other problems walking.

“This competition and its affiliated science fairs held across the globe reach young people like no other program can, igniting their passion for science and their desire to discover innovative solutions to some of our world’s most intractable problems,” says Maya Ajmera, president and CEO of Society for Science & the Public and publisher of *Science News*.

Over the competition’s nearly 70 years, the International Science and Engineering Fair has yielded thousands of distinguished alumni. Counted among the ranks are top innovators and entrepreneurs as well as recipients of the world’s most coveted science and math honors including the Nobel Prize, National Medal of Science, Breakthrough Prize, Lasker Award and MacArthur Fellowship.

For more information on the search for a title sponsor, visit
www.societyforscience.org/future-isef



Monkeytalk
Julia Fischer
UNIV. OF CHICAGO,
\$25

BOOKSHELF

Monkey lives revealed

The social lives of macaques and baboons play out in what primatologist Julia Fischer calls “a magnificent opera.”

When young Barbary macaques reach about 6 months, they fight nightly with their mothers. Young ones want the “maternal embrace” as they snooze; mothers want precious alone time. Getting pushed away and bitten by dear old mom doesn’t deter young macaques. But they’re on their own when a new brother or sister comes along.

In *Monkeytalk*, Fischer describes how the monkey species she studies have evolved their own forms of intelligence and communication. Connections exist between monkey and human minds, but Fischer regards differences among primate species as particularly compelling. She connects lab studies of monkeys and apes to her observations of wild monkeys while mixing in offbeat personal anecdotes of life in the field.

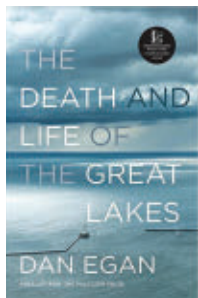
Fischer catapulted into a career chasing down monkeys in 1993. While still in college, she monitored captive Barbary macaques. That led to fieldwork among wild macaques in Morocco. In macaque communities, females hold central roles because young males move to other groups to mate. Members of closely related, cooperative female clans gain an edge in

competing for status with male newcomers. Still, adult males typically outrank females. Fischer describes how the monkeys strategically alternate between attacking and forging alliances.

After forging her own key scientific alliances, Fischer moved on to study baboons in Africa, where she entered the bureaucratic jungle. Obtaining papers for a car in Senegal, for instance, took Fischer several days. She first had to shop for a snazzy outfit to impress male paper-pushers, she says. Fischer and her local guide then shuttled from one government official to another until a well-timed phone call from a local police chief to a key bureaucrat finally produced the forms.

Monkeys get the job done using their own brand of intelligence, Fischer writes. Macaques and baboons navigate their home regions expertly, discern small quantities and object sizes pretty well, and know who’s socially dominant over whom. These abilities are somewhat humanlike, but Fischer draws a bright line between monkeys’ and people’s social lives. Our primate relatives specialize in tracking comrades’ behaviors, she holds, rather than trying to infer others’ plans and desires. And unlike human groups, monkey communities don’t steadily accumulate knowledge and innovations or communicate in languagelike ways, Fischer contends.

So what if monkeys don’t write books or gossip about each other? Their social lives are complex enough to remain largely a mystery to humans, Fischer concludes. The gritty work of conducting long-term studies, especially in the wild, can illuminate the worlds inhabited by monkeys. — *Bruce Bower*



The Death and Life of the Great Lakes
Dan Egan
W.W. NORTON & CO.,
\$27.95

BOOKSHELF

Invaders, climate change threaten Great Lakes

Every summer, people flock to the Great Lakes to swim and fish in the seemingly infinite waters and hike along the idyllic shores. But an ominous undercurrent flows just out of sight. Below the water’s surface rages an environmental catastrophe 200 years in the making.

In *The Death and Life of the Great Lakes*, journalist Dan Egan describes how the lakes’ natural history gave way

to an unnatural one. From the effects of global trade and urbanization to climate change, the book offers an exhaustive (and sometimes exhausting) account of the abuses the lakes have endured.

Scars left by retreating glaciers and a failed continental rift, lakes Huron, Ontario, Michigan, Erie and Superior are more like inland seas, holding about 20 percent of Earth’s surface freshwater. The lakes were mostly isolated from international waters until a series of canals and seaways let in freighters from around the world. “These ships are like syringes,” as one biologist put it, injecting into the lakes living pollution.

Nearly 200 nonnative species now call the lakes home. The worst offenders — alewives, sea lampreys and zebra and quagga mussels — have ruined food webs. Egan dedicates a third of the book to these invaders and biologists’ best, and sometimes misguided, efforts to contain them.

But the lakes also face lesser-known problems. Egan deftly explains the science of these complex issues, including runoff-induced toxic algal blooms and extreme fluctuations in the lakes’ water levels attributed to climate change.

Despite all the bad news, there are glimmers of hope. After decades of living on the brink of collapse, native whitefish and trout are regaining a foothold — a boon for the ecosystem and local economies. Scientists are also experimenting in the lab with gene drives to stop invasive Asian carp and with new ways to rid ships of stowaways lurking in ballast water.

The lakes still face overwhelming challenges, but their biggest threat, Egan argues, is our own ignorance: “We are still treating the lakes ... as liquid highways that promise a shortcut to unimaginable fortune.” With few easy solutions and numerous political roadblocks, future generations are “perhaps the best hope the lakes have to recover,” he writes. But if this book is any indication, there’s no time to wait. — *Cassie Martin*

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FEBRUARY 4, 2017

Slip and slime

Hagfish are famous for sliming sharks and other predators. But sometimes sharks land a bite before getting slimed. New research shows that hagfish skin provides an extra layer of protection, **Susan Milius** reported in “Unusually loose skin protects hagfish” (*SN*: 2/4/17, p. 13). The loose skin easily slips and slides, possibly preventing shark teeth from getting a grip. Watch a hagfish slime a shark at bit.ly/SN_hagfish



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Doomsday preppers

*Dinosaurs and other creatures were largely wiped out 66 million years ago from an asteroid impact, volcanic eruptions or maybe a mix of the two, **Thomas Sumner** reported in “Devastation detectives” (*SN*: 2/4/17, p. 16), in the Science News special report “Dino Doomsday.”*

Online reader **Mike van Horn** wondered if the timing of the volcanic eruptions, which happened for hundreds of thousands of years before and after the asteroid impact, could have allowed marine organisms to adapt to increasingly acidic oceans.

Scientists don’t know if bouts of volcanic eruptions helped marine critters survive the harsh post-impact environment. But studies of ocean acidification’s effects on marine organisms living today hint that adaptation may not have been viable, **Sumner** says. In a recent experiment, armor-plated phytoplankton regained their shell-making abilities after researchers dunked them in acidified water. But those gains disappeared after further exposure (*SN*: 8/6/16, p. 8).

Swirling controversy

*Starfish larvae use hairlike cilia to stir up whorls of water, called eddies, and suck in prey, **Emily Conover** reported in “Baby starfish on the hunt whip up whirlpools” (*SN*: 2/4/17, p. 14).*

Reader **George von Dassow** disputes the reported finding. “Unfortunately, [the researchers’] work is based on a well-documented and well-understood artifact, which biologists who study the behavior of microorganisms often work hard to avoid,” wrote **von Dassow**, a developmental biologist at the University of Oregon. “In short, trapping active swimmers between a microscope slide and a coverslip gives rise to eddies.” **Von Dassow** and colleagues have submitted a comment to *Nature Physics*, where the original study appeared.

The authors of the original paper, including biophysicist **Manu Prakash** of Stanford University, stand behind their result. **Prakash** wrote that **von Dassow** and colleagues “misunderstood how vorticity is injected in this system.”

Prakash and colleagues have submitted a response to *Nature Physics*.

Chill out

*A larger percentage of strong hydrogen bonds in hot water may explain the Mpemba effect, which claims that hot water can freeze faster than cold water, **Emily Conover** reported in “Fast-freezing hot water spurs debate” (*SN*: 2/4/17, p. 14). Reader **Bob Henry** theorized that hot water may sometimes freeze faster because dissolved gases such as carbon dioxide escape at higher temperatures, creating purer water that freezes more easily.*

“The idea that gases are removed when water is heated is one possible explanation for the Mpemba effect,” **Conover** says, “but there hasn’t been a scientific study able to show definitively that just removing gases from water caused it to freeze faster — at least not one that is accepted by scientists who have studied the effect.” In fact, scientists don’t agree on whether the Mpemba effect occurs at all, much less what causes it. “Freezing is a very delicate process, which makes precise experiments challenging,” she says.

Correction

In “Built for speed” (*SN*: 3/4/17, p. 20), **Laurel Hamers** reported that researchers engineered *Escherichia coli* bacteria to make virus-inspired capsules that can be used as catalysts. The research appeared in *Nature Chemistry*, not *Nature*. *Science News* regrets the error.





Canopies of many colors

To some forest creatures, a tree is a home. To scientists, it's a beacon. A new way of mapping forests from the air that measures chemical signatures of the tree canopy is revealing previously unrecognized biodiversity.

The swath of tropical forest covering the Peruvian Amazon basin and Andes is one of the most biodiverse places on Earth. But variation within the forest is hard to spot in the wild, remote region.

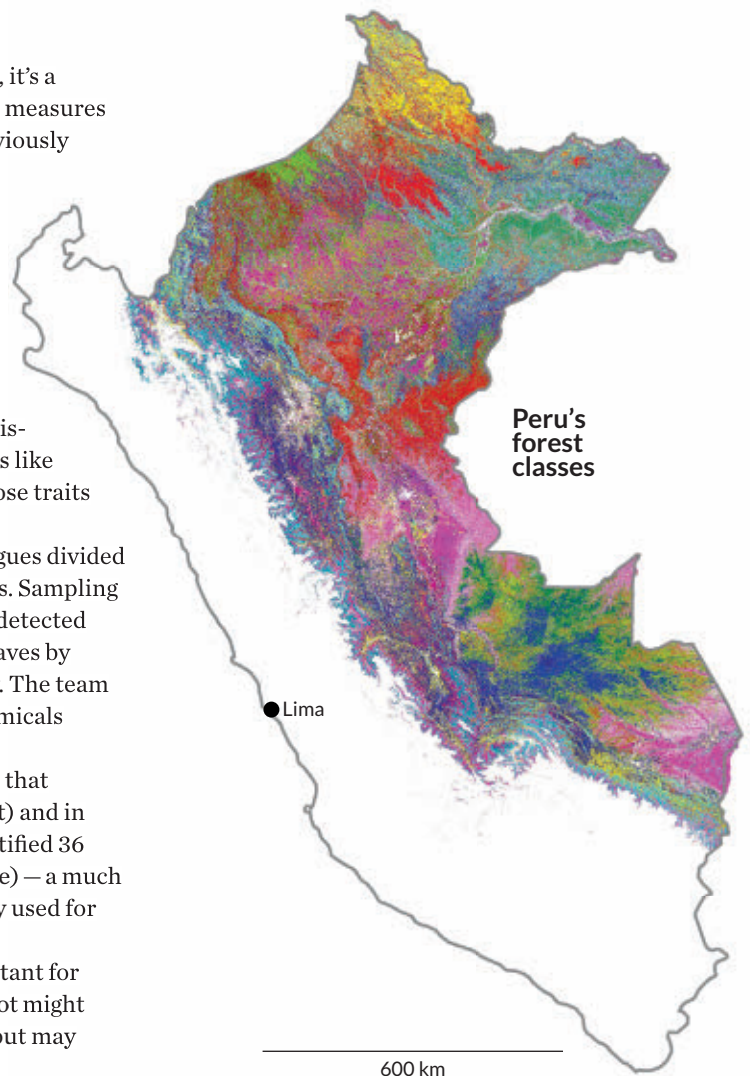
“If you look in Google Earth, it just looks like a big green blanket,” says Greg Asner, an ecologist at the Carnegie Institution for Science in Stanford, Calif.

Up close is a different story. Each tree species has a distinctive set of chemical traits, such as levels of nutrients like nitrogen and phosphorus in the leaves. Collectively, those traits can reveal a lot about the makeup of the forest.

To peek beneath the green blanket, Asner and colleagues divided 76 million hectares of forest into 100-kilometer squares. Sampling small areas of each square via aircraft, the researchers detected levels of water, nitrogen, phosphorus and calcium in leaves by measuring wavelengths of light reflected by the canopy. The team also mapped levels of lignins and polyphenols, two chemicals plants use for defense.

A single hectare of Peruvian forest is shown in colors that indicate differences in those chemical traits (above, left) and in natural color (above, right). In all, the researchers identified 36 types of forest (colors at right, unclassified area in white) — a much more nuanced view than the broad categories currently used for classification, the team reports in the Jan. 27 *Science*.

Parsing out such nuanced forest differences is important for guiding conservation efforts, Asner says. A particular spot might appear at a distance to be the same as its surroundings but may actually contain unique species. — *Laurel Hamers*





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