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SCIENCE NEWS MAGAZINE
SOCIETY FOR SCIENCE & THE PUBLIC

NOVEMBER 28, 2015

Hitting a
Nerve

Cometary
Oxygen

Bronze Age
Plague

Eels Put Zip in
Their Zap

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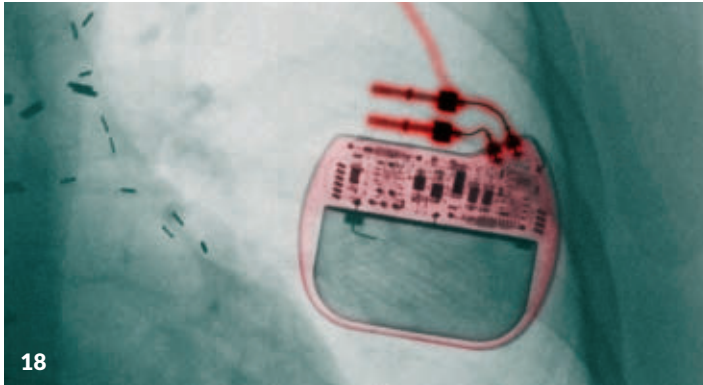


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ScienceNews



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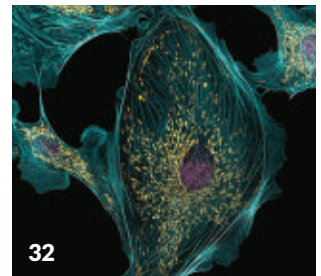
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COVER A grown dairy cow belches 260 to 650 grams of Earth-warming methane every day. *Loop Images Ltd/Alamy*



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A nerve to know



Speaking. Breathing. Eating. The da-dum, da-dum, da-dum of your heart. The vagus nerve (aka Cranial Nerve X or, more poetically, the Wandering Nerve) plays a crucial role in all of these essential functions, linking brain and organs in what's called the nervous system's super-highway. While most of its important work passes without notice, the vagus

has long been on medicine's radar, as far back as the Greek physician Galen in the second century. It's a big nerve with long tentacles that reach a surprising variety of places. Stimulating it can help relieve hard-to-treat epilepsy and depression. Now, Sarah Schwartz reports on Page 18, doctors are investigating whether it can also help with rheumatoid arthritis, diabetes and other diseases. Given its anatomy, the potential seems amazing. But some scientists point out how much is left to learn about the nerve. For sure, more science needs to be done. Galen, an early proponent of experimentation, would probably approve. — *Eva Emerson, Editor in Chief*

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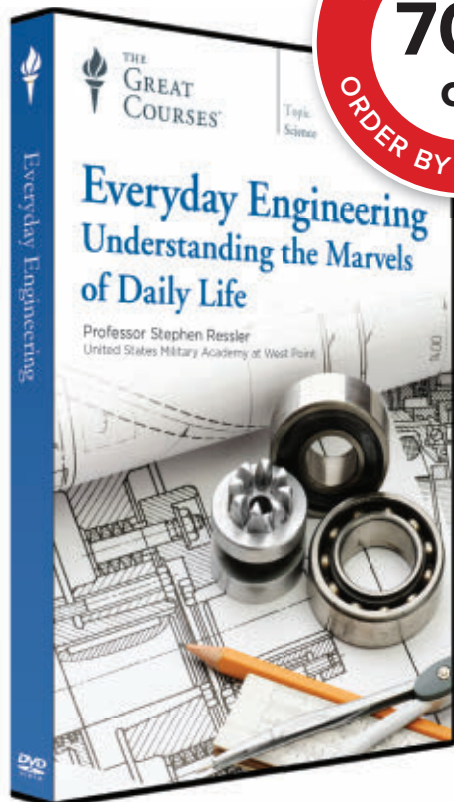
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Excerpt from the November 27, 1965, issue of *Science News Letter*

50 YEARS AGO

Major energy cosmic?

Previous ideas on how long and how far [cosmic rays] travel in interstellar space were probably incorrect. It now appears that either these nuclei are younger and have passed through less of the Milky Way galaxy than previously thought...or...cosmic radiation fills all of space, not just our galaxy. If this is so, then the physical processes of producing cosmic rays must be as common as those which produce star light.

UPDATE: The galaxy is teeming with cosmic rays — and we now know a lot more about these subatomic particles that tear through space with tremendous energy, up to roughly 100 billion billion electron volts. The lowest-energy cosmic rays come from the sun. Zippier particles are probably shot out of supernovas within the Milky Way. The source of the most energetic (and rare) cosmic rays are an enduring mystery, but they probably originate from outside our galaxy.



Ice cave doors block frigid winter breezes that serve as natural air conditioning for ice caves. The Ningwu ice cave in China's Shanxi province is door-free.

WHAT WERE THEY THINKING?

How to melt an ice cave

If you want to keep an ice cave cold, don't shut the door.

That's the lesson learned from studying China's largest year-round ice cave, which thankfully has no doors to close and is just fine. Cold winter breezes act as natural air conditioning and keep this frozen grotto perpetually chilly, researchers report online October 22 in *The Cryosphere*. And summer heat barely penetrates its depths.

The 3-million-year-old Ningwu ice cave in China's Shanxi province contains a single entrance connected to the top of a deep, bowling pin-shaped chamber. Geologists Shaohua Yang and Yaolin Shi of the

Chinese Academy of Sciences in Beijing digitally re-created the 85-meter-deep formation and found that buoyant, warm outside air doesn't flow very deep into the cave. Winter's cold air, however, flushes heat out of the cave system. This convection maintains freezing temperatures year-round even as a thousand visitors explore the cave daily from May to October.

Well-intentioned caretakers for at least two other ice caves in China have installed airtight doors, hoping to keep out heat and trespassers. But the doors also block winter's frigid air and will cause the spectacular ice formations to completely melt within 40 years, the researchers predict. — *Thomas Sumner*



Dust isn't the only thing surrounding this child: There's an invisible plume of bacteria, too.

HOW BIZARRE

A cloud of microbes

Everyone's storing data in the cloud these days — including, apparently, people's microbes.

The bacteria that live in and on a human body form a personal microbial cloud. This microscopic mist, which spreads through the air and settles on nearby surfaces, can be used to identify the presence of a person. Sometimes, the clouds are unique enough to pin down the person's

identity, researchers report September 22 in *PeerJ*.

After three volunteers sat, each alone, in a sanitized room for four hours (with a sterilized laptop for entertainment), human-associated bacteria had gathered on collection dishes scattered in the room. Species included *Staphylococcus epidermidis*, common on human skin, and *Streptococcus oralis*, often found in the mouth. Each person gave off types and amounts of bacteria so distinct that the participants could be identified by their microbes. In a different experiment, five of eight people could be recognized by bacteria caught in air filters in the room. — *Sarah Schwartz*

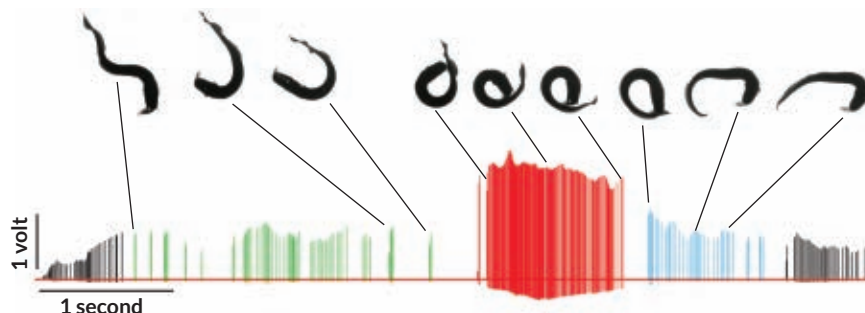
IT'S ALIVE

Eels' electricity peaks when they wrap

Electric eels are even more shocking than biologists thought. When prey fights back, eels just curl their bodies.

Muscle has evolved “into a battery” independently in several groups of fishes, says Kenneth Catania of Vanderbilt University in Nashville. Smaller species send out slight tingles of electric current to detect their surroundings in murky nighttime water. People can handle these small fishes and not feel even a tickle. But touching the bigger *Electrophorus electricus* (a member of a South American group of batteries-included fishes) “is reminiscent of walking into an electric fence on a farm,” Catania says. (He knows, from unintentional experience.)

The muscle that works as an electricity-generating organ in the eel has just two power levels: on or off. But eels have a unique way of intensifying the effect, Catania reports November 16 in *Current Biology*.



High voltage As an electric eel curls its body (upper row), the voltage measured in its prey rises (red, bottom row). Head and tail draw near enough to concentrate the eel's electric field.

Catania has tussled with eels using what he calls his electric eel chew toy — an electrode-fitted dead fish on a stick — to measure current. When fighting difficult prey like the recalcitrant

toy, eels curl their tails toward the fish struggling in their jaws.

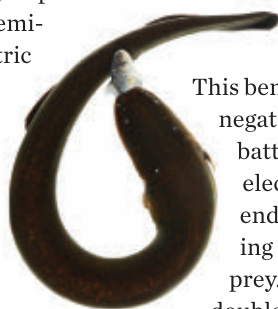
This bend puts the electrically negative tail end of the long battery organ closer to the electrically positive front end, effectively concentrating the electric field on the prey. An eel's tail curl can double the strength of the electric field convulsing the prey.

Eel shocks hijack nerves

that control prey muscles, making them twitch and clench, Catania discovered in previous research (*SN: 1/10/15, p. 14*). That eel hack explains how the intensified curling attack completely stills prey: Fish muscles get exhausted. Temporarily immobilized prey can't escape as an eel opens its jaws to swallow its meal.

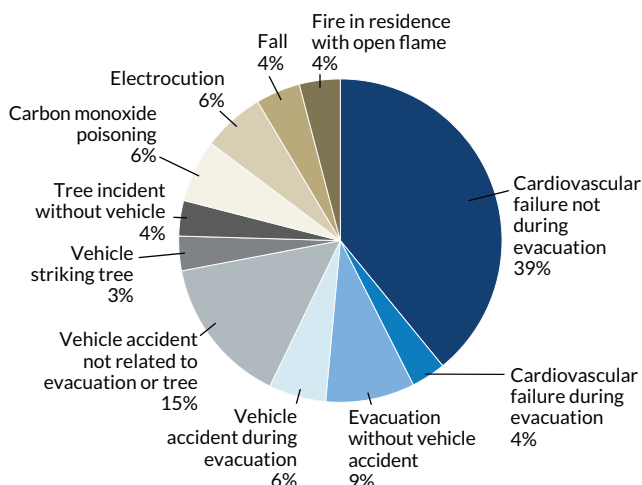
Eels are using electricity like a venom, Catania says. These fish “might be one of the most sophisticated predators on the planet.”

He quickly speaks up on their behalf. “There's a lot of crazy stuff on TV,” he says. “But I have never found a reputable source — and I'm not even sure I have found a disreputable source — that eels kill people.” — *Susan Milius*



When its prey fights back, an electric eel repositions its body to boost the zap.

Causes of deaths indirectly attributed to Atlantic hurricanes, 1963–2012



Third-degree murder Hurricanes cause fatalities indirectly, via power outages, heart attacks and car accidents. This graph excludes hundreds of indirect hurricane deaths that could not be categorized.

SOURCE: E.N. RAPPAPORT AND B.W. BLANCHARD/BULL. AM. METEOROL. SOC. 2015

SCIENCE STATS

Counting all hurricane deaths

Hurricanes and other tropical storms carry a heavier toll than is caused by the surging water and howling wind. Close to half of all hurricane fatalities are caused indirectly, new research shows.

Hurricane reports typically include only deaths directly attributable to a storm's physical forces, such as drowning in floodwater or being struck by airborne debris. They exclude incidental deaths, such as heart attacks after the storm, or those that occur due to power outages, house fires and accidents during evacuations.

The reports miss the bigger picture, hurricane scientists say. Compiling data from 59 Atlantic Ocean hurricanes from 1963 through 2012, the scientists calculate that the storms caused 1,418 indirect deaths, nearly on par with the 1,803 direct deaths. For about half of the storms, indirect deaths outnumbered direct deaths, the researchers report online September 9 in the *Bulletin of the American Meteorological Society*. — *Thomas Sumner*



Some of the gas streaming from comet 67P contains oxygen molecules.

ATOM & COSMOS

Oxygen in comet surprises scientists

67P's O₂ molecules probably came from solar system's birth

BY CHRISTOPHER CROCKETT

A comet is leaking oxygen molecules that appear to have been buried since the beginning of the solar system.

The Rosetta spacecraft detected O₂ around comet 67P/Churyumov-Gerasimenko, the first time these molecules have been seen around a comet. The oxygen is probably primordial, trapped in water ice as the comet was assembled roughly 4.6 billion years ago, researchers report in the Oct. 29 *Nature*. Andre Bieler, a planetary scientist at the University of Michigan in Ann Arbor, and colleagues detected the oxygen using a mass spectrometer on board Rosetta, which has been orbiting comet 67P since August 2014 (*SN*: 9/6/14, p. 8).

"This is the most surprising discovery we have made so far," study coauthor Kathrin Altwegg said at a news briefing on October 27. Researchers did not expect to find oxygen in the fog of gas surrounding a comet. Oxygen is highly reactive, and theories about the formation of the solar system indicate that O₂ should have quickly interacted with hydrogen to form water. "When we first saw it, we all went into a little bit of denial," said Altwegg, of the University of Bern in Switzerland.

Oxygen's presence supports the long-held assumption that comets are

pristine fragments from the dawn of the solar system. Comet 67P must have been put together gently, Bieler says; otherwise the ice-coated grains that make up its bulk would have been heated and the oxygen removed. Because the grains have not been heated, they are unprocessed time capsules—frozen samples that preserve the conditions that prevailed when the planets were forming.

Ultraviolet light from the sun and free-range electrons probably created the O₂ in the first place. In this scenario, high-energy photons and particles zapped water molecules, which re-formed into molecules of oxygen (and hydrogen). The oxygen was then trapped within ice that collected on dust grains, which in turn came together to assemble the comet. There, the oxygen stayed protected for nearly the age of the solar system. As recently as 1840, comet 67P was far enough out in the solar system to escape the sun's destructive influence, but an encounter with Jupiter nudged it in closer. With each close approach to the sun, heat reaches into the comet, sublimates the ice and liberates the O₂.

"It's just fascinating that O₂ was detected in a comet and never has been before," says Lori Feaga, a planetary scientist at the University of Maryland in College Park. Molecular oxygen is

impossible to detect using ground-based telescopes; the oxygen in Earth's atmosphere gets in the way. Previous instruments flown on other comet-bound spacecraft were not sensitive enough to identify oxygen.

Oxygen molecules are also rare in the cosmos. Observations of gas clouds where stars are forming in the Milky Way have turned up gaseous oxygen in only two locations: the dark Rho Ophiuchi cloud in the constellation Ophiuchus and the more famous Orion nebula. The scarcity of interstellar oxygen is another reason why comet 67P's oxygen was unexpected.

"They were surprised and I was surprised," says Paul Goldsmith, an astrophysicist at NASA's Jet Propulsion Laboratory in Pasadena, Calif., who helped discover the O₂ in Orion. Rosetta has shown that O₂ hides within icy coatings on the dust grains that make up a comet. If oxygen is tucked away in similar grains found in star-forming clouds, oxygen might be more abundant than thought. "The picture of interstellar chemistry is not as simple as some people would make it," Goldsmith says.

If dust grains are helping create (and protect) oxygen, they're probably important for building other molecules as well, Goldsmith notes. These dust grains are thought to be the place where hydrogen molecules form, for example. Understanding how quickly H₂ is assembled leads to better estimates of how efficiently clouds of atoms turn into clouds of molecules, he says. And it's those dense molecular clouds that are the sites of future stars, planets and comets. ■

"This is the most surprising discovery we have made so far."

KATHRIN ALTWEGG

Plagues plagued the Bronze Age

Yersinia pestis infected people long before Black Death

BY BRUCE BOWER

Plagues killed millions of Europeans and Asians starting around 1,500 years ago. But previously unknown variants of the plague-causing bacterium *Yersinia pestis* infected people several thousand years earlier, a new study finds.

The infectious microbes' DNA has been found in the teeth of Bronze Age and early Iron Age people who lived between 4,800 and 3,000 years ago, say evolutionary geneticist Eske Willerslev of the University of Copenhagen and his colleagues. *Y. pestis* was initially passed from person to person — say, when an infected individual coughed on a healthy person — and most likely caused lung infections known as pneumonic plague or blood infections called septicemic plague, the researchers report in the Oct. 22 *Cell*.

"It's surprising that the plague was widespread 3,000 years before written records of plagues and well before large-scale urbanization," Willerslev says. Evidence suggests that Bronze Age herders migrated across Europe and Asia (*SN*: 7/11/15, p. 11). "Those population movements likely caused the spread of early *Y. pestis* strains," Willerslev holds.

The new findings suggest that different forms of *Y. pestis* "survived in

Eurasia for a lot longer than previously expected," says evolutionary geneticist Hendrik Poinar of McMaster University in Hamilton, Canada. Early forms of the plague probably couldn't cause major epidemics, he says.

Mass deaths from bubonic plague, an infection of the lymph nodes, became possible sometime after 3,700 years ago, Willerslev's group proposes. Genetic changes in certain *Y. pestis* strains enabled the bacterium to spread via fleas and to elude hosts' immune systems (*SN*: 8/8/15, p. 16).

Until now, researchers had been unable to extract *Y. pestis* DNA from bones older than 1,500 years.

The microbe is known to have caused a sixth century plague in Europe's Byzantine Empire; the bubonic plague, or Black Death, which killed up to half of Europe's population in the mid-1300s; and a worldwide epidemic that emerged in China in the 1850s.

After screening about 89 billion fragments of DNA from teeth of 101 Bronze Age and Iron Age individuals, Willerslev's team found *Y. pestis* DNA in seven of them. Two came from Siberia's roughly 4,800-year-old Afanasievo culture. One approximately 4,500-year-old individual belonged to Estonia's Corded Ware culture. An infected person from West Asia's Sintashta culture lived almost 4,200 years ago. A skeleton from the Unetice culture in Poland dates to more than 4,000 years ago, and one from Siberia's Andronovo culture is about 3,700 years old. An infected individual from the early Iron Age in Armenia lived



Bacterial DNA recovered from seven human skeletons, including this nearly 4,500-year-old find from Estonia's Corded Ware culture, indicates that plagues spread through Bronze Age European and Asian populations.

close to 3,000 years ago.

Based on comparisons of modern and ancient *Y. pestis* DNA, the researchers calculate that the most recent common ancestor of all known strains of the bacteria existed between 5,021 and 7,022 years ago. A previous estimate ranged from 1,505 to 6,409 years ago. Early *Y. pestis* strains appear to have evolved and died out too quickly to precisely calculate the age of an ancestral strain with any confidence, even with the new DNA finds, Poinar says.

Y. pestis genomes from the Bronze Age lacked a gene that enabled later forms of the bacterium to survive inside the flea gut. This gene was present in the Iron Age individual, indicating that the plague's ability to spread via flea bites evolved between 3,700 and 3,000 years ago.

Another gene variant found in previously known *Y. pestis* strains prevents production of a protein that triggers attacks from hosts' immune systems. Plague DNA in one of the oldest Bronze Age individuals and in the most recent Bronze Age person lacked this gene variant, suggesting that these forms of *Y. pestis* were vulnerable to people's immune defenses.

An ability to evade hosts' immune systems evolved at different rates in various *Y. pestis* strains during the Bronze Age, the researchers suspect. ■

Old infections Plague bacteria began infecting people by at least 4,800 years ago, new research shows. This map of Eurasia shows the locations, cultures and ages of seven human skeletons in which early forms of the plague were identified. SOURCE S. RASMUSSEN ET AL./CELL 2015



BODY & BRAIN

Alzheimer's may affect young brains

Navigation cells act differently in adults at high risk for disease

BY MEGHAN ROSEN

Alzheimer's disease may muck with people's brains long before symptoms appear.

People in their early 20s with elevated genetic risk for Alzheimer's have wonky internal compasses, despite showing no external signs of the disease, researchers report in the Oct. 23 *Science*.

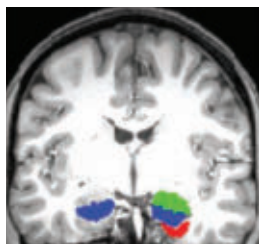
This navigation tool rests deep in the brain, in a small, sausage-shaped region called the entorhinal cortex. Scientists could potentially examine it to detect Alzheimer's in

young people, says Francesca Cacucci, a neuroscientist at University College London. "In the future, when we have therapies that slow down the progression of Alzheimer's, you could target

the disease very early," she says.

Early symptoms of Alzheimer's, an irreversible memory disorder, typically appear when people are in their mid-60s, according to the National Institute on Aging. The pharmaceutical industry has poured billions of dollars into developing new drugs for the disease, says study coauthor Nikolai Axmacher, a neuroscientist at the University of Bonn in Germany. But in clinical trials, the drugs have mostly failed.

"This is very likely because the drugs were delivered too late," he says. For people with full-blown Alzheimer's, the brain may be past the point of repair. So scientists have tried to find ways to diagnose the disease early.



People at higher risk of Alzheimer's rely on the hippocampus (blue) to navigate; most people use only the entorhinal cortex (red).

Axmacher and colleagues looked for signs of trouble in brains of young adults who have a copy of the $\epsilon 4$ version of the *APOE* gene, a variant linked to increased risk for Alzheimer's. The team scanned those brains, and the brains of people lacking the variant, as the participants performed memory tests while navigating through a virtual reality maze. With or without the variant, the participants performed equally well—but the two groups used different parts of the brain.

Participants at low risk tapped into their entorhinal cortex, which holds cells involved in spatial navigation. These cells, called grid cells (*SN Online*: 10/6/14), help keep track of the direction people move.

Overall, in people with the $\epsilon 4$ variant, cells in the entorhinal cortex were hyperactive and "the directions were not stable," says Axmacher—kind of like a jumpy compass needle. These people recruited a neighboring part of the brain, the hippocampus, to help get through the maze.

Decades of relying on both regions may strain the brain and contribute to the development of Alzheimer's, he says. ■

GENES & CELLS

DNA points to site of canine taming

Dogs were domesticated in Central Asia, new data indicate

BY CHRIS SAMORAY

Dogs first snuggled up with humans in Central Asia, a new study suggests.

The survey of canine genetic diversity contradicts previous findings about where dogs were first domesticated, researchers report online October 19 in the *Proceedings of the National Academy of Sciences*.

"We have a large dataset," says Laura Shannon, an evolutionary geneticist at Cornell University who collaborated with an international team on the project. "We've gotten the chance to sample dogs from all over the world."

The team compared 185,805 genetic markers from over 5,000 dogs, including

purebreds and free-ranging dogs. Central Asia harbored the largest amount of diversity, pinning the original locale of domestication near present-day Nepal and Mongolia.

Rising genetic diversity marks a trail leading to domestication. Since only a subpopulation of the original group of domesticated dogs would have come with humans to a new area, those dogs would have a limited set of genes available to exchange. Similar to the neck on a soda bottle that restricts how much liquid gets through, only some genes would have accompanied the frontier dogs.

"There's a loss of diversity associated with being domesticated," Shannon says.

Earlier research has suggested that dog domestication occurred in places as varied as Europe (*SN*: 12/14/13, p. 6), the Middle East (*SN*: 4/10/10, p. 12), China, Siberia and North Africa. But many of these studies examined genetic material inherited either from both the mother and father or just one or the other. The

new study considered all three types of genetic information.

"Most of the previous studies looked at autosomal DNA, mitochondrial DNA, or the Y chromosome, and we were able to look at all three," Shannon says. "That let us get the most complete picture we could."

One limitation of the study is its lack of ancient DNA analysis, leading some dog domestication researchers to question the results. UCLA evolutionary biologist Robert Wayne points to the conflicting results of earlier studies and says that diversity patterns in living dog populations might not be a foolproof map of domestication events in the distant past.

Shannon agrees that ancient DNA could provide more insight into where dogs became domesticated. The results from this study will contribute to an international effort using a variety of genetic techniques to analyze ancient dogs and wolves to better understand the origins of canine domestication. ■

BODY & BRAIN

Processed meat linked to cancer

Health agency says data are strong enough to make claim

BY RACHEL EHRENBERG

It's official: Processed meats — such as hot dogs, bacon, corned beef and salami — raise the risk of cancer.

Numerous studies have linked processed meats to colorectal, or bowel, cancer. Now, after reviewing more than 800 epidemiological studies, the World Health Organization has designated such meats as carcinogenic. WHO made the announcement online October 26 in *The Lancet Oncology*.

WHO's International Agency for Research on Cancer classifies processed meat — meat altered through salting, curing, fermenting or smoking — as a Group 1 carcinogen. This group also includes tobacco and asbestos. The ranking means there's convincing evidence linking such meats to colorectal cancer, evidence as strong as that linking smoking to cancer.

This does not mean that eating processed meat is as risky as smoking. An analysis by the research charity group Cancer Research UK in London offers some perspective: Research suggests that 61 people per 1,000 in the United Kingdom will develop bowel cancer during their lives. Among 1,000 who eat the

most processed meat, you'd expect 66 to develop bowel cancer, while among 1,000 who eat the least processed meat, about 56 would develop bowel cancer.

The IARC also classified red meat (beef, veal, mutton, lamb, pork, horse and goat) as “probably carcinogenic.” This Group 2A classification means eating red meat was correlated with an increased risk for some cancers, including bowel, pancreatic and prostate, but other explanations for the increase couldn't be ruled out.

In the IARC evaluation, prospective cohort studies, which follow large groups of healthy people and track information on exposures as they go along, were given the most weight. Additional evidence came from case-controlled studies, which look at people who are already sick and ask them about things like their food habits before they got cancer. While evidence linking processed meats and bowel cancer was the strongest, some studies also suggested a link between processed meat and stomach cancer as well as red meat and pancreatic and prostate cancer.

The IARC doesn't make diet recommendations, but other organizations have suggested for years that people limit their intake of red and processed meats.

“This is an important step in helping individuals make healthier dietary choices to reduce their risk of colorectal cancer in particular,” Susan Gapstur, vice president of epidemiology at the American Cancer Society, said in a statement.

The London-based World Cancer Research Fund recommends eating no more than 500 grams of red meat per week, and eating as little as possible of processed meats. One hot dog is about 45 grams; 100 grams is roughly a portion the size of a deck of cards — slightly less than a quarter-pound hamburger.

Several cancer-causing mechanisms are probably at play, the IARC notes. Curing and smoking meat can generate N-nitroso compounds, which damage DNA. High amounts of heme iron — found naturally in red meats — also increase production of these compounds.

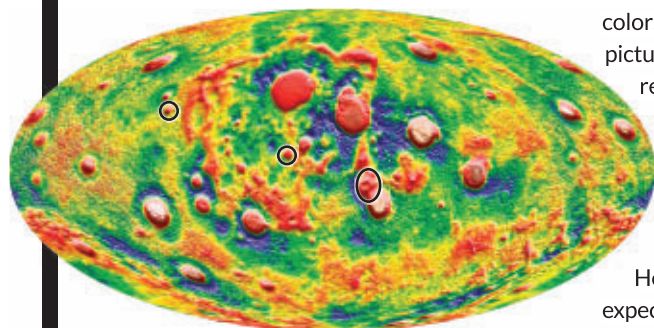
The way meat is prepared may raise cancer risks, too. The high temperatures of pan frying, grilling and broiling can produce heterocyclic aromatic amines (also found in tobacco smoke), which damage DNA.

It may seem counterintuitive that meat, part of the human diet for ages, could be bad for you, says cancer epidemiologist Mariana Stern of the University of Southern California in Los Angeles. She was one of the 22 scientists on the IARC panel. Meat does provide important proteins and micronutrients such as B vitamins, iron and zinc. But the quantity eaten and life expectancy are different today than in the past, Stern says.

“We've been eating meat for a long time,” she says, “but currently, we may be eating it in much higher amounts and our life expectancy is higher so we have more time to develop cancers.” ■

ATOM & COSMOS

Probes unveil three hidden blemishes on moon's face



Gravitational tugs on a pair of spacecraft have revealed previously unseen blemishes on the moon's face.

Evidence of three new basins comes from gravity data collected by NASA's GRAIL mission in 2012 (new basins circled in black, redder colors indicate a greater gravitational tug). The data provide a clearer picture of dents on the moon's surface formed by impact craters, researchers report October 30 in *Science Advances*. These basins are often obscured by subsequent impacts and volcanic activity from the moon's active youth.

These and other lunar craters spotted by GRAIL cast doubt that the Earth and moon were pummeled by rocks from the main asteroid belt some 4 billion years ago, a salvo dubbed the Late Heavy Bombardment. The sizes of these craters don't match those expected from main-belt asteroids, the researcher say. — *Thomas Sumner*

HUMANS & SOCIETY

Fossil offers clues to ape evolution

Living apes may have arisen from gibbonlike primate

BY BRUCE BOWER

An ancient primate's partial skeleton, discovered in Spain, is poised to downsize ape evolution in a big way.

This 11.6-million-year-old fossil find, nicknamed Laia, represents the first evidence that present-day apes descended from a relatively small, somewhat gibbonlike common ancestor — not large-bodied primates as previously thought, scientists report in the Oct. 30 *Science*. If that scenario holds up, Laia's discovery also shows for the first time that ancient, small-bodied apes moved from Africa to Europe, says a team led by paleontologist David Alba of the Catalan Institute of Paleontology Miquel



A reconstruction of the extinct ape *Pliobates cataloniae*.

Crusafont in Barcelona.

Based on an analysis of more than 300 teeth, skull and lower-body measurements, Alba and colleagues assign the fossil to a new ape genus and species, *Pliobates cataloniae*.

Some scientists caution that there are other possible evolutionary identities for the creature. It may not be related to the ancestor of all living apes — a group split into small-bodied apes (gibbons and siamangs) and large-bodied apes (chimps, gorillas and orangutans). Critics say that Laia might be an ancestor of gibbons and siamangs, which split from greater apes about 14 million years ago. Or *Pliobates* could belong to a line of now extinct monkeylike animals.

Those possibilities reflect Laia's unusual mix of ape and monkey features. But among other ancient apes known to have lived between 25 million and 5 million years ago, *Pliobates* displays the most skeletal similarities to all modern apes, Alba's team finds.



Bones from the left arm of an ancient Spanish primate indicate that it could rotate its wrists in an apelike way. But the animal's elbows were not built for hanging from tree branches.

Those shared features were presumably inherited from a common African ancestor of *Pliobates* and living apes. DNA studies suggest that a common ancestor of modern apes lived around 20 million to 15 million years ago.

"The last common ancestor of modern apes and humans might have been much more gibbonlike than previously assumed," Alba says.

Pliobates weighed four to five kilograms, about as much as a small gibbon, the researchers estimate. Laia's relatively small braincase falls within the range of modern African monkeys, gibbons and siamangs. Several of the ancient ape's facial characteristics, including

MATH & TECHNOLOGY

Artificial skin feels heat, hears sound

New materials show promise for covering prosthetic limbs

BY MEGHAN ROSEN

A new electronic skin can feel the grain of sandpaper, the heat and beat of a person's pulse — and listen to Richard Feynman's voice, too.

Rubbery plastic-and-graphene film mimicking the structure of human skin can detect texture, temperature, pressure and sound, Hyunhyub Ko and colleagues report October 30 in *Science Advances*.

It's the first time anyone has demonstrated an e-skin that can sense so many different kinds of stimuli, says Stanford University materials scientist Alex Chortos. "That's the innovative and impressive part of this work."

Chortos and colleagues recently developed a different pressure-detecting e-skin that sends signals directly to mouse brain cells. The cells dialed activity up or down depending on how hard researchers pushed on the skin, Chortos' team reports in the Oct. 16 *Science*. That work offers a blueprint for scientists to "bridge electronics with biology," says Wenlong Cheng, a chemical engineer at Monash University in Australia.

Both Chortos' skin-to-cell communication system and Ko's supersensing e-skin bring lifelike artificial skins even closer to practical use. "In the future, we could combine these techniques for real, operational electronic skin," says Ko, a materials scientist at the Ulsan National Institute of Science and Technology in South Korea.

Such an e-skin could cover prosthetic limbs and plug directly into people's nerve cells, Ko says, letting people know if they were touching something hot or

rough. The skin could also form the basis for soft, wearable medical devices.

Ko's team designed its e-skin to detect many kinds of signals by mimicking ultra-sensitive fingertip skin. The researchers placed a soft, ridged film over bumpy plastic-and-graphene sheets about the thickness of a few layers of Saran Wrap. Touching the e-skin pressed electrodes on the bumpy sheets together, causing current to flow through the device, which was hooked up to a machine that measures electrical signals. The amount of current depended on how much the bumps squished together, giving the team a sensitive way to gauge pressure.

Heating the e-skin also generated a current. A strip of the e-skin placed on a person's wrist let the researchers simultaneously measure skin temperature and blood pressure.

The e-skin's ridges help it detect texture. When the team skimmed the skin over glass or sandpaper, the ridges

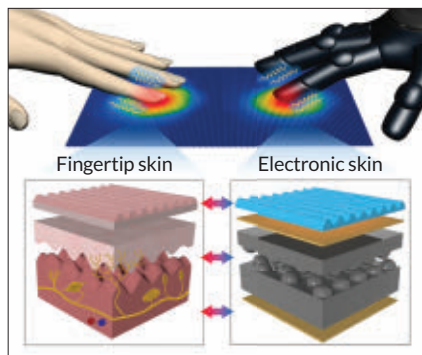
gogglelike rims around the eye sockets, also resemble those of gibbons.

Like ancient African apes, *Pliobates* was a tree dweller, Alba says. Arm fossils indicate that Laia moved across branches on all fours with her palms down. Like modern apes, Laia had wrists capable of rotating while she climbed. Her elbows, though, were not built like those of living apes to enable hanging from tree branches.

In stark contrast to her apelike features, Laia had wide ear openings like those of monkeylike primates called pliopithecids that lived in Europe and Asia 17 million to 10 million years ago.

Due to this mishmash of features, many questions remain about *Pliobates*' evolutionary status.

Fossil discoveries increasingly indicate that different species independently evolved similar skeletal features during ape evolution, says paleoanthropologist John Fleagle of Stony Brook University in New York. So, he says, it's hard to know if *Pliobates* was an ape or a pliopithecid, or related to the ancestor of gibbons or of all modern apes. ■



A ridged surface and interlocking layers let fingertip skin detect stimuli. Similar structures can boost the sensitivity of electronic skin.

vibrated in different patterns detectable by the skin's sensors. Sound waves also made the e-skin vibrate, so that it could "hear" noise from a speaker playing a Richard Feynman physics lecture. The e-skin converted his words into electrical signals and sent them to a machine that let the researchers judge how well the e-skin sensed sounds. ■

MATTER & ENERGY

Light mimics hotel with infinite rooms

Mathematician inspires new twist in optical information storage

BY ANDREW GRANT

A mind-bogglingly large hotel has provided inspiration for expanding the data-carrying capacity of light.

A new technique that manipulates the twistiness of light is the optical equivalent of a mathematician's thought experiment for creating more space in a hotel with an infinite number of rooms. In research published in the Oct. 16 *Physical Review Letters*, physicists tripled the degree of twistiness of a light beam.

Because physicists can encode data into those twisted bits of light (*SN: 7/27/13, p. 11*), the scheme creates vacancies for adding more twist-encoded data to a single beam. "It's a trick to give yourself more bandwidth," says study coauthor Robert Boyd, an optical physicist at the University of Rochester in New York. Light already carries data over fiber-optic cables across the globe, though not via twists.

In a 1925 lecture, German mathematician David Hilbert referenced a hypothetical hotel with an infinite number of rooms, all occupied. Yet the hotel has a permanent vacancy sign. When a guest checks in, the innkeeper has every current occupant shift up one room, leaving Room 1 vacant. The hotel even has a solution when an infinite influx of weary travelers arrive: All current guests move to twice their current room number so that only even-numbered rooms are taken.

Infinity plays a limited role in our finite world, but it is relevant in quantum physics. Atoms, for instance, have an infinite number of discrete energy levels that are analogous to Hilbert hotel rooms. Quantum physicist John Jeffers of the University of Strathclyde in Glasgow, Scotland, and colleagues, also coauthors of the new study, devised a theoretical scheme for multiplying energy levels by a particular value, shifting them upward while creating an infinite number of vacancies.

Similarly, a beam of light (or even a single photon) can be imparted with a discrete but unlimited number of twists. Using the theoretical work as a guide, Boyd and colleagues performed an optics experiment to implement the Hilbert hotel multiplication scheme with laser light. The "room number" was the number of twists per wavelength, and the researchers chose to multiply by three rather than two.

A small liquid crystal display called a spatial light modulator imparted a particular twist in the beam—say, one twist. Then a series of lenses unspooled the light, making the beam easier to manipulate. After bouncing the beam off two more modulators and retwisting it, the light had become three times as twisty: The component of the beam originally in the one-twist state now had three twists.

By transforming one twist into three, the researchers ensured that no beam component existed in the one- and two-twist states. The states were vacant, like rooms in the hotel. And like the Hilbert hotel innkeeper who moves all the guests at once, the technique multiplies all the twistiness states at once.

"It's very clever work," says David Andrews, a quantum physicist and chemist at the University of East Anglia in Norwich, England. But he says the connection with the Hilbert hotel is a bit of a stretch: While light can technically contain infinite levels of twistiness, practical constraints may limit total twists to a few hundred.

Fortunately, infinite twistiness isn't required for an important practical application. Boyd's Rochester colleague Mohammad Mirhosseini envisions performing Hilbert hotel operations to manipulate one beam into carrying information on odd-numbered amounts of twistiness and another on even-numbered twists. Then the beams could be combined, potentially doubling data capacity. ■

LIFE & EVOLUTION

Regeneration was once widespread

Ancient amphibians regrew limbs like salamanders do

BY CHRIS SAMORAY

Losing a limb or a tail isn't too worrisome for salamanders. They can regenerate lost appendages. And so could a number of their ancient relatives, a new study finds.

Amphibian fossils from 290 million years ago show signs that the animals regrew limbs, researchers report online October 26 in *Nature*. The findings suggest that some salamander relatives had the ability to regenerate body parts nearly 80 million years before the first salamander existed.

The results “show that salamander-like regeneration is not something that is salamander-specific, but was instead widespread in the evolutionary past,” says Nadia Fröbisch, a paleontologist at the Museum of Natural History in Berlin.

Sea stars, frogs and even humans (in

the liver, for example) have some degree of regenerative ability at various life stages. But salamanders are the only four-legged animals that can fully regenerate entire limb bones, nerves and muscles throughout their lifetimes.

When other animals develop arms and legs, hand and feet bones on the outside edge form first. In salamanders, it's the opposite — the thumb before the pinky.

Fossils of various types of amphibians show a similar pattern, suggesting these animals had salamander-like regenerative abilities, Fröbisch and colleagues report. The new study builds on Fröbisch's previous work with a single species of ancient amphibian that showed the kind of limb abnormalities also seen in modern salamanders that are growing a new limb.

A separate new study shows a molecular basis for the odd way that salamanders regenerate limbs. During early regenerative growth, genes called orphan genes



After studying fossils of extinct amphibians like this one, scientists concluded that some salamander relatives could regrow limbs millions of years ago.

are active, Anoop Kumar of University College London and colleagues report October 26 in *Nature Communications*. Some of these genes are also crucial in digit formation in amniotes, a group including reptiles, mammals and birds but not amphibians.

Only a few amniotes — like lizards that can regrow their tails — have any type of regenerative powers.

Finding evidence that regeneration was widespread among amphibians

in the past is significant, says Hillary Maddin, a paleontologist at Carleton University in Ottawa.

“It suggests that we, and maybe amniotes in general, are much more alone in the lack of an ability to regenerate limbs,” she says. “It becomes tempting to think that amniotes are hiding a latent capacity to perform complex regeneration, and the correlation with a potential molecular mechanism, orphan genes, points to a good place to start.” ■

BODY & BRAIN

Nerve cells could block urge to scratch

Neurons in spinal cord may curb itch caused by light tap on skin

BY LAURA SANDERS

A fly tickling your arm hair can spark a maddening itch. Now, scientists have spotted nerve cells in mice that curb this light twiddling sensation. If humans possess similar itch-busters, the results, published in the Oct. 30 *Science*, could lead to treatments for the millions of people who suffer from intractable, chronic itch.

For many of these people, there are no good options. “This is a major problem,” says Gil Yosipovitch, a clinician at the Temple University School of Medicine in Philadelphia and director of Temple Itch Center. The new study shows that mice handle an itch caused by a fluttery touch differently than other kinds of itch. This distinction “seems to have clinical applications that clearly open our

field,” Yosipovitch says.

Scientists have made progress teasing apart the pathways that carry itchy signals from skin to spinal cord to brain (*SN*: 11/22/08, p. 16). Those signals often originate from chemicals, such as those delivered by mosquitoes. All that's needed to spark a different sort of itch, called mechanical itch, is a light touch on the skin. Mechanical itch may help explain why clothes or dry skin can be itchy.

The new finding comes from mice engineered to lack a type of spinal cord nerve cell. These mice “have the urge to scratch all the time,” says study coauthor Qiufu Ma, a neuroscientist at Harvard Medical School. A light touch from a filament caused the itchy mice to scratch themselves more than regular mice.

But the mice appeared normal in other ways: They responded to pain and itchy chemicals in the same way normal mice do, suggesting the body has a dedicated, specific way of detecting mechanical itch, Ma says.

If a light touch taps into the itch accelerator, then these nerve cells are the brakes, says coauthor Martyn Goulding, a neuroscientist at the Salk Institute for Biological Studies in La Jolla, Calif. Removing these nerve cells lets the itch signal proceed unchecked, he says.

By finding these nerve cells, scientists can start to piece together the rest of the pathway that detects and carries these itch signals to the brain, Goulding says.

It makes sense that human skin would develop the ability to detect an itchy tickle, he says. “If you have parasites or disease-bearing insects that are on your skin biting you, they might introduce pathogens,” he says. A quick scratch, prompted by an itch, could prevent that. ■

LIFE & EVOLUTION

Magnitude of Great Dying questioned

Land life spared in Permian mass extinction, researchers argue

BY THOMAS SUMNER

The greatest extinction in Earth's history might not have been so great after all. A suspected die-off of roughly 75 percent of land species didn't accompany the Permian extinction around 252 million years ago, a team of geologists contends.

That divisive result comes from work in South Africa that redates the demise of *Dicynodon* — a mammal relative whose disappearance defines the terrestrial extinction event in the rock record. The new timeline places the creature's die-off at more than a million years before the Permian extinction, in which about 90 percent of marine species vanished.

Furthermore, the researchers argue, the new evidence raises doubts that a mass extinction on land even happened.

Many experts are not convinced. But the established understanding of the Permian extinction is "up in the air," said John Geissman of the University of Texas at Dallas. Geissman contributed to the

work, which was presented November 4 and published in the October *Geology*.

Scientists confidently peg the Permian marine extinction to 251.88 million years ago, but the terrestrial die-off is trickier to nail down. In South Africa's Karoo Basin, the changeover from *Dicynodon* fossils to those of another mammal relative called *Lystrosaurus* marks when scientists think the mass extinction on land occurred.

Robert Gastaldo of Colby College in Waterville, Maine, Geissman and colleagues made a lucky find in the basin: seven zircon crystals, which can provide accurate ages for the surrounding rock.

The zircons date to about 253.48 million years ago and were found about 60 meters below the *Dicynodon*-*Lystrosaurus* transition. Based on how fast rock accumulated in the basin, the researchers estimate that the 60-meter gap formed over 200,000 to 300,000 years. That means the *Dicynodon* extinction took place around 253.2 mil-

lion years ago — about 1.3 million years before the Permian marine extinction.

The researchers also found traces of land species thought to have gone extinct alongside *Dicynodon* in younger rocks. Those findings don't point to a single widespread extinction event that abruptly wiped out land species within a short time span, Gastaldo said.

The findings support the idea that the extinction lacked a land component, said paleontologist Spencer Lucas of the New Mexico Museum of Natural History & Science in Albuquerque. Given the new dating, the rock layers that actually match up with the marine extinction are higher in the basin than previously thought. At first glance, they don't appear to record any major fossil changes indicative of a large-scale extinction event, Lucas said.

Paleobiologist Jennifer Botha-Brink of South Africa's National Museum in Bloemfontein isn't convinced. The accumulation of new rocks isn't always constant, she said. So the 60-meter gap between the zircons and fossils may have formed over a much longer period of time, and the *Dicynodon* die-off may have coincided with the marine extinctions. ■

LIFE & EVOLUTION

'Vampires' sucked ancient life dry

Fossils preserve evidence of predation on early eukaryotes

BY THOMAS SUMNER

Microscopic vampires may have prowled the seas some 750 million years ago. The fossilized remains of their victims may be the oldest direct evidence of predators hunting eukaryotes, a domain of organisms that includes plants and animals.

While the monstrous microbes probably didn't look like mini-Count Draculas, "they're just as terrifying, at least if you're a single-celled organism," paleontologist Susannah Porter said November 1.

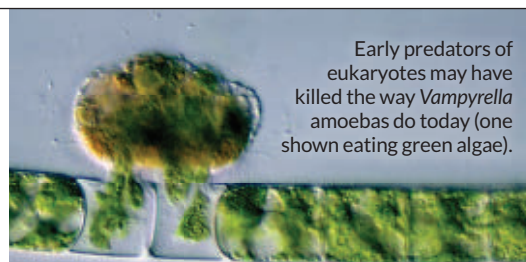
The predators perforated holes in prey, then slurped the victim's innards, proposes Porter, of the University of

California, Santa Barbara. Such predation may have driven single- and multicelled eukaryotes to evolve innovations such as skeletons and the ability to burrow as they fought to survive.

The early emergence of predation makes sense, says Paul Falkowski, an earth systems scientist at Rutgers University in New Brunswick, N.J. "Once you make an organism, somebody else will figure out a way to utilize its juices."

As Porter examined 750-million-year-old eukaryotic fossils from the Grand Canyon using a scanning electron microscope, she noticed something odd: Several fossils had clean-cut circular holes in their cell walls, with several specimens containing 30 or more punctures.

The perforations ranged in size from 0.2 to 2.9 micrometers in diameter (the thickness of a red blood cell falls in that



Early predators of eukaryotes may have killed the way *Vampyrella* amoebas do today (one shown eating green algae).

range), but the holes in any one fossil were always about the same size. Some holes were beveled, with the gaps narrowing toward the fossil's interior. This evidence points to predation, Porter said, instead of other processes like mineral growth that can poke holes in fossils. Fossils of the predators have yet to be found.

Some modern microbes exhibit similar behavior, including *Vampyrella* amoebas. Scientists think these amoebas use enzymes to eat a hole in a victim's cell wall before extracting the cell's contents or even slipping through the opening to eat the cell from the inside out. ■

ATOM & COSMOS

Pluto's smaller moons pose mysteries

New Horizons images provide hints to dwarf planet's history

BY CHRISTOPHER CROCKETT

Pluto and Charon might have been the stars of the New Horizons mission, but the dwarf planet's four smaller moons have some surprises to share as well.

With images of Kerberos transmitted from the spacecraft on October 20, the Pluto family portrait is complete. The tiny moons Nix, Hydra, Kerberos and Styx are no longer pinpricks of light but textured, misshapen balls of ice that look quite different from both Pluto and its largest moon, Charon.

"It's really cool that the Pluto system has all these different things," says project scientist Hal Weaver of the Johns Hopkins University Applied Physics Laboratory in Laurel, Md. With data from the four smaller moons, "we can put together a more complete picture of how the system formed and evolved over time."

Three of the tiny moons — and possibly all four — appear to have been assembled from two smaller bodies squished together. Images of Kerberos in particular are reminiscent of early pictures of comet 67P/Churyumov-Gerasimenko taken by the Rosetta spacecraft. The two lobes of 67P were probably once separate comets that gently collided and stuck (*SN: 10/31/15, p. 17*). Kerberos and its siblings might have a similar history.

A long-ago collision could have split proto-Pluto into Pluto and Charon, with the smaller satellites assembling out of the debris. Theorists, however, have trouble figuring out how to make that scenario work. "It's a little bit mysterious how the four [small] moons got there," says Mark Showalter, a planetary scientist at the SETI Institute in Mountain View, Calif., who discovered Kerberos and Styx several years after New Horizons launched.

All four moons are tiny. Hydra — the largest — measures 55 kilometers along its long axis; Kerberos spans only 12 kilometers. Astronomers deduced most of the sizes and even the elongated shapes ahead of New Horizons' arrival by using the Hubble Space Telescope to watch reflections change on the moons' surfaces. "We were pretty much dead-on," Showalter says.

One surprise is how reflective the moons are. All four bounce back roughly half of the sunlight that reaches them. "My own gut tells me that we're seeing water ice surfaces," Weaver says.

Ice in the outer solar system isn't surprising, but how the ice has remained so clean for 4.6 billion years is puzzling. Interplanetary gunk should col-

lect on the moons and darken the ice. Pluto's bright moons aren't alone in this regard; some of the icy moons of Saturn, for instance, are also brighter than expected. "We don't really have an answer to that yet," says Showalter.

The moons are surprisingly smooth as well. After billions

of years of running into debris, "craters and nothing but craters is all you would see," says Showalter. But the small moons show very few (if any) craters, which means the surfaces are relatively young.

One explanation is that each impact kicks up a cloud of dust that falls back on the moon, covering up the crater that just formed. "You end up with a process where you create one crater, but you cover as many as you create," Showalter says.

Of all the moons, Kerberos might be the most surprising. Before New Horizons showed up, researchers used the Hubble telescope to track the move-

ment of the moons and estimate their masses. Kerberos appeared to be too massive for so faint an object. If the mass were right, and all the moons were roughly the same density and reflected about the same amount of

sunlight, then Kerberos should be about eight times as bright as it appeared from Hubble.

To get around this conundrum, Showalter, along with planetary scientist Douglas Hamilton of the University of Maryland in College Park, suggested that Kerberos was much darker than the other moons (*SN: 7/11/15, p. 10*). New Horizons showed, however, that the moon is just as reflective as its neighbors.

The moral of the story, Showalter says, is that the mass of Kerberos was probably wrong. "It's a tricky business, weighing a moon." Alternatively, Kerberos could be packed together more tightly than its brethren, but it would have to be 20 times as dense. "That seems highly unlikely," Weaver says.

All of the best images of the small moons have been downloaded, but there are more to come. Complex compositional data are still on board New Horizons, and researchers have only begun analyzing the images.

"This is science on the edge," says Showalter. "There are more surprises in store." ■



The five moons of Pluto show diverse sizes, shapes and surfaces that tell the story of how this system formed and evolved.

LIFE & EVOLUTION

Reptile holds clue to penis evolution

Tuatara embryos begin to develop phallus, then lose it

BY SUSAN MILIUS

A rare reptile is shedding light on the evolution of the penis — even though it doesn't have one.

The tuatara, a lizardlike species in New Zealand, never grows a real phallus. Yet as an embryo, it starts forming tiny nubbins like those that turn into the great diversity of sperm-delivery organs in other animals, researchers at the University of Florida in Gainesville report in the October *Biology Letters*. Tuatara phallus development then stalls, but that initial burst of growth supports the idea that the phallus evolved just once in birds, other reptiles and mammals, says study coauthor Thomas Sanger.

With the tuatara (*Sphenodon punctatus*) on the brink of extinction, conservation managers would not

permit sacrificing any embryos to study phallic history. But Sanger knew of some fragile, old microscope slides of tuatara embryos in the Harvard Museum of Comparative Zoology. They had come from a Victorian expert on sponge taxonomy who sojourned in New Zealand and developed a side interest in tuatara specimens provided by a friendly lighthouse keeper.

Sanger photographed 82 slices of an embryo. He and colleagues then digitally cleaned away imagery of tissues that were failing with age, and combined the rest into one 3-D image. It revealed one of the characteristic paired nubbins that other reptile and mammal embryos grow as their external genitals start to develop. In the tuatara's closest living relatives, snakes and lizards, the nubbins grow into pairs of insertable organs. For species with a single penis — mammals, turtles, crocodilians and the few phallus-endowed birds — the two buds fuse.

"Genitalia across the animal kingdom evolve at breakneck speed — they are the fastest-evolving organ," says evolutionary biologist Menno Schilthuizen of



Deep in the evolution of New Zealand's lizard-like tuatara, adult males lost their ancestral phallus, new research suggests.

the Naturalis Biodiversity Center and Leiden University in the Netherlands. "Almost anything you can think of — and lots of things you cannot or would not — have arisen and sometimes disappeared again in the nether regions."

The new finding may resolve a longstanding debate: whether the tuatara lost an ancestral reproductive organ or its cousins independently gained a pair. The rare reptile probably lost the phallus, the researchers conclude. Other evidence suggests that most bird species also lost an ancestral phallus. The tuatara's loss fits into the scenario that some basic penis evolved once for mammals, reptiles and the birds that dinosaurs evolved into. ■

MATTER & ENERGY

Antiprotons behave just like protons

Collisions reveal antimatter's response to strong nuclear force

BY ANDREW GRANT

Tightly bunched antiprotons stick together, just like their proton cousins.

Physicists sifting through subatomic shrapnel inside a particle accelerator have made the first analysis of the interaction between antiprotons, particles of antimatter that are negatively charged but otherwise nearly identical to protons. The findings, published online November 4 in *Nature*, reveal that the strong nuclear force securely binds antiprotons in close proximity with the same intensity that it does for protons inside the nuclei of atoms.

The study provides insight into the structure of antimatter nuclei, which consist of bound antiprotons and antineutrons. It also adds to the tally of

papers finding no differences in the behavior of antimatter and ordinary matter. Any discrepancy could help scientists determine why matter, and not antimatter, dominates the universe.

Physicists studying how protons interact have it easy: Just fire a proton beam at a target made of proton-filled nuclei and see what happens. But antiprotons are hard to make and, like all antimatter, get destroyed when they touch matter.

So particle physicist Michael Lisa of Ohio State University and hundreds of colleagues tracked antiprotons inside the Relativistic Heavy Ion Collider, a 3.8-kilometer-around particle accelerator at Brookhaven National Laboratory in Upton, N.Y. Antiprotons are among the particles produced when gold ions collide

inside the machine at nearly the speed of light. By measuring the energies, trajectories and speeds of various particles created in about 500 million collisions, the team identified antiprotons and flagged pairs that came into close contact.

The physicists found that the attractive strong nuclear force between antiprotons, which kicks in when particles are within a few millionths of a billionth of a meter of each other, overcomes the particles' repulsion due to their like charge. Measurements of two key aspects of the strong force between antiprotons match those for the proton. "They've accomplished a very difficult measurement," says particle physicist William Gibbs of New Mexico State University.

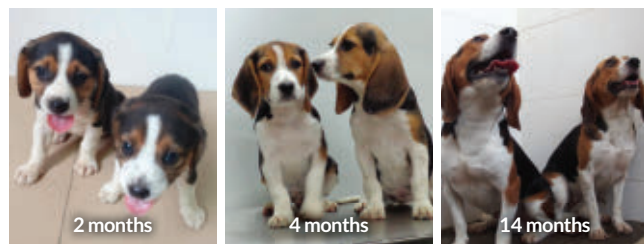
Recent work has revealed that the amount of charge and mass of protons and antiprotons are indistinguishable from each other (*SN: 9/19/15, p. 8*); now it seems the particles' behavior in close quarters is also strikingly similar. ■

GENES & CELLS

Gene edit creates buff beagles

Bully whippets may have competition in doggy body-building contests. Two beagles have been genetically engineered to be extra buff. The small hounds are the latest addition to a menagerie of gene-edited animals that also includes pigs and monkeys (SN: 11/14/15, p. 6; SN: 3/8/14, p. 7).

Researchers in China mutated a muscle gene in beagles to test whether a gene-editing technology called CRISPR/Cas9 works in dogs. Mutations in the gene, called myostatin, give



Two beagles named Hercules (left) and Tiangou are the first dogs to have a gene edited with a tool called CRISPR/Cas9. Researchers mutated the dogs' myostatin genes to increase the amount of muscle the dogs make.

bully whippets and Belgian Blue cattle their bulky muscles, but are not known to cause health problems.

Liangxue Lai of the South China Institute for Stem Cell Biology and Regenerative Medicine in Guangzhou and colleagues injected the gene editor into 35 beagle embryos. Of 27 puppies born, two had edited genes, the team reports online October 12 in the *Journal of Molecular Cell Biology*.

A female named Tiangou has both copies of the myostatin gene mutated in all of her cells. At 4 months, Tiangou had more muscular thighs than her unedited sister. Hercules, a male with double mutations in most but not all of his cells, wasn't more muscular than other 4-month-old puppies. But both dogs have packed on more muscle as they've matured, and Lai says their fur may be concealing how ripped they are.

The low number of puppies born with edited myostatin genes indicates that the editor is not very efficient in dogs, but Lai says the process just needs to be optimized.

Next, Lai and colleagues hope to make mutations in beagles that mimic genetic changes implicated in Parkinson's disease and hearing loss in humans to study those diseases and potential therapies. The researchers have no plans to make designer pets, Lai says. — *Tina Hesman Saey*

EARTH & ENVIRONMENT

To make diamonds, just add acidity

A boost in acidity deep inside the Earth may yield some serious bling.

Simulating the chemistry, pressures and temperatures in Earth's interior, scientists have discovered a new way diamonds can form. Chemical reactions between rocks and ion-rich fluids can spark a drop in pH that spurs diamond creation, geochemists at Johns Hopkins University report online November 3 in *Nature Communications*.

The work marks the first time pH has been explored as a possible instigator of diamond genesis; it also could provide insights into how the planet's innards have changed over time, the researchers say. — *Thomas Sumner*

EARTH & ENVIRONMENT

4.1-billion-year-old crystal may hold earliest signs of life

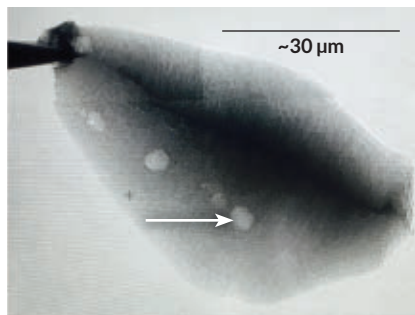
New evidence suggests that life on Earth arose before 4.1 billion years ago, 300 million years earlier than previous estimates.

The oldest known fossils date back to around 3.5 billion years ago, so scientists use other clues in the search for early

signs of life (SN: 2/8/14, p. 16). Life-forms preferentially stockpile carbon-12 in their cells, so any ancient substance enriched with carbon-12 could have a biological origin.

Researchers in California report the discovery of a 4.1-billion-year-old zircon crystal containing a carbon-12-laden impurity. Ancient carbon-containing zircons from this period are extremely rare — only around one in 10,000 crystals — so the finding will be difficult to confirm, the researchers note online October 19 in the *Proceedings of the National Academy of Sciences*.

— *Thomas Sumner*



Life on Earth appeared before 4.1 billion years ago, new research suggests. This ancient zircon crystal contains a small carbon impurity (indicated by arrow) associated with organisms.

GENES & CELLS

Cat-versus-virus arms race goes back millennia

Cats have been fighting feline immunodeficiency virus, or FIV, for at least 60,000 years. In a feline protein that helps stop FIV replication, researchers have found evidence of an ancient arms race between *Felis silvestris catus*, the species familiar today as the domestic cat, and the virus.

Domestic cats carry seven different versions, or haplotypes, of this protein, called APOBEC3Z3. But it's unclear how each version affects cats' ability to fight the virus.

FIV breaks down most versions of APOBEC3Z3, allowing the virus to keep infecting cells. But one variant of the protein, haplotype V, staves off destruction, Rokusuke Yoshikawa of Kyoto University in Japan and colleagues report online October 21 in the *Journal of Virology*.

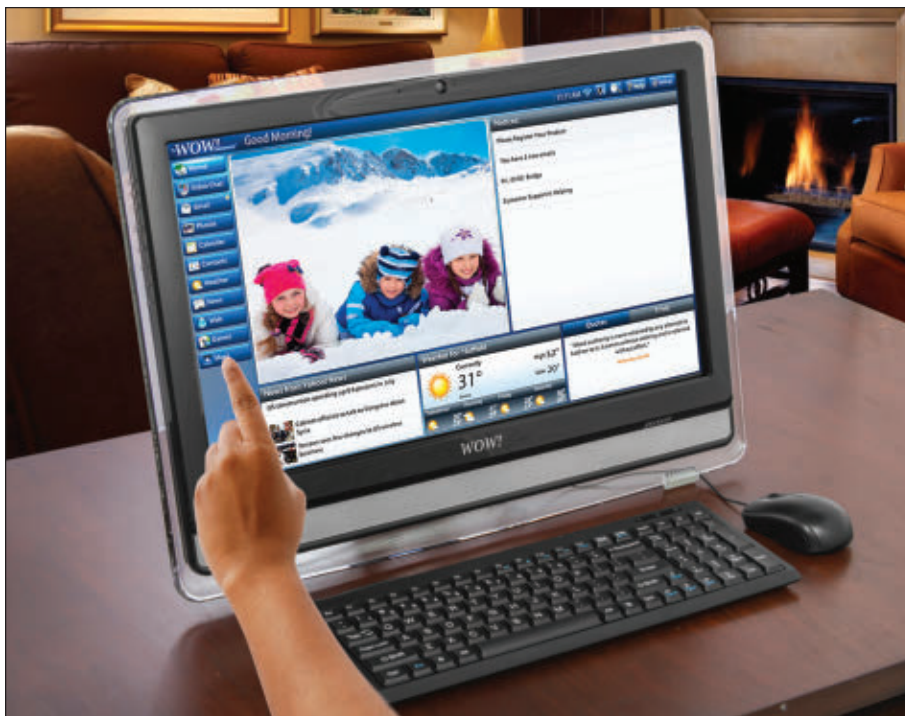
By their calculations, haplotype V is at least 60,000 years old, which means the ancestors of domestic cats had already encountered a primitive version of FIV long before cats were domesticated about 10,000 years ago.

— *Tina Hesman Saey*

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— Janet F.

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Waking the VAGUS



The meandering nerve is a target for a range of therapies

By Sarah Schwartz

With outposts in nearly every organ and a direct line into the brain stem, the vagus nerve is the nervous system's super-highway. About 80 percent of its nerve fibers — or four of its five "lanes" — drive information from the body to the brain. Its fifth lane runs in the opposite direction, shuttling signals from the brain throughout the body.

Doctors have long exploited the nerve's influence on the brain to combat epilepsy and depression. Electrical stimulation of the vagus through a surgically implanted device has already been approved by the U.S. Food and Drug Administration as a therapy for patients who don't get relief from existing treatments.

Now, researchers are taking a closer look at the nerve to see if stimulating its fibers can improve treatments for rheumatoid arthritis, heart failure, diabetes and even intractable hiccups. In one recent study, vagus stimulation made damaged hearts beat more regularly and pump blood more efficiently. Researchers are now testing new tools to replace implants with external zappers that stimulate the nerve through the skin.

But there's a lot left to learn. While studies continue to explore its broad potential, much about the vagus remains a mystery. In some cases, it's not yet clear exactly how the nerve exerts its influence. And researchers are still figuring out where and how to best apply electricity.

"The vagus has far-reaching effects," says electrophysiologist Douglas Zipes of Indiana University in Indianapolis. "We're only beginning to understand them."

The wanderer

Anchored in the brain stem, the vagus splits into the left vagus and right vagus and travels through the neck and into the chest. Each of these roads is composed of tens of thousands of nerve fibers that branch into the heart, lungs, stomach, pancreas and nearly every other organ in the abdomen. This broad meandering earned the nerve its name — vagus means "wandering" in Latin — and enables its diverse influence.

The nerve plays a role in a vast range of the body's functions. It controls heart rate and blood pressure as well as digestion, inflammation and immunity. It's even responsible for sweating and the gag reflex. "The vagus is a huge communicator between the brain and the rest of the body," says cardiologist Brian Olshansky of the University of Iowa in Iowa City. "There really isn't any other nerve like that."

The vagus nerve's path from brain to heart and other organs was detailed by the Greek anatomist Galen, a leading physician of the Roman Empire in the second century.

The FDA approved the first surgically implanted vagus nerve stimulator for epilepsy in 1997. Data from 15 years of vagus nerve stimulation in 59 patients at one hospital suggest that the implant is a safe, effective

approach for combating epilepsy in some people, researchers in Spain reported in *Clinical Neurology and Neurosurgery* in October. Twenty of the patients experienced at least 50 percent fewer seizures; two of those had a 90 percent drop in seizures. The most common side effects were hoarseness, neck pain and coughing. In other research, those effects often subsided when stimulation was stopped.

Early on, researchers studying the effects of vagus stimulation on epilepsy noticed that patients experienced a benefit unrelated to seizure reduction: Their moods improved. Subsequent studies in adults without epilepsy found similar effects. In 2005, the FDA approved vagus nerve stimulation to treat drug-resistant depression.

Although many details about how stimulation affects the brain remain unclear, studies suggest that vagus stimulation increases levels of the neurotransmitter norepinephrine, which carries messages between nerve cells in parts of the brain implicated in mood disorders. Some antidepressant drugs work by boosting levels of norepinephrine. Silencing norepinephrine-producing brain cells in rats erased the antidepressant effect of vagus nerve stimulation, scientists reported in the *Journal of Psychiatric Research* in September.

Against the swell

Vagus stimulation for epilepsy and depression attempts to target the nerve fibers that shuttle information from body to brain. But its fifth lane, which carries signals from brain to body, is a major conductor of messages controlling the body's involuntary functions, including heart rhythms and gut activity. The nerve's southbound fibers can also be a valuable target for stimulation.

Around 15 years ago, scientists determined that the brain-to-body lane of the vagus plays a crucial role in controlling inflammation. While testing the effects of an anti-inflammatory drug in rats, neurosurgeon Kevin Tracey and his colleagues found that a tiny amount of the drug in the rats' brains blocked the production of an inflammatory molecule in the liver and spleen. The researchers began cutting nerves one at a time to find the ones responsible for transmitting the anti-inflammatory signal from brain to body.

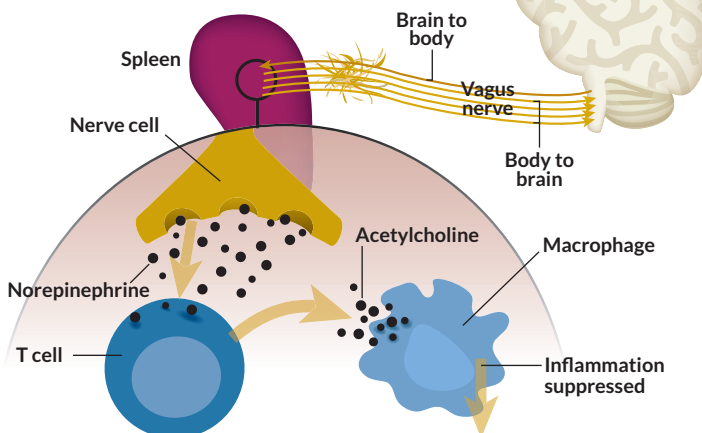
"When we cut the vagus nerve, which runs from the brain stem down to the spleen, the effect was gone," says Tracey, president and CEO of the Feinstein Institute for Medical Research in Manhasset, N.Y. Later research indicated that stimulating undamaged vagus fibers also had anti-inflammatory effects in animals.

Vagus stimulation prompts release of acetylcholine, Tracey and colleagues reported in 2000. Acetylcholine, a neurotransmitter like norepinephrine, can prevent inflammation.

In 2011, rheumatologist Paul-Peter Tak, of the University of Amsterdam, and his colleagues implanted vagus nerve stimulators into four men and four women who had

Tamp it down The vagus nerve detects inflammation or infection in the body and relays signals from the brain stem along its southbound fibers. This signal prompts other nerves to release norepinephrine, which makes immune T cells in the spleen release the chemical acetylcholine to depress inflammation via macrophages.

SOURCE: K. TRACEY/FEINSTEIN INSTIT. FOR MED. RESEARCH



rheumatoid arthritis, an autoimmune inflammatory condition that causes swollen, tender joints. After 42 days of vagus stimulation — one to four minutes per day — six of the eight arthritis patients experienced at least a 20 percent improvement in their pain and swelling. Two of the six had complete remission, the researchers reported at an American College of Rheumatology conference in 2012.

"From a scientific perspective, it's an extremely exciting result," says Tak, who is also a senior vice president at GlaxoSmithKline pharmaceuticals based in Stevenage, England. Despite advances in treatments over the last two decades, rheumatoid arthritis patients need better options, he says. In 2014, Tak and his colleagues reported that vagus stimulation reduced inflammation and joint damage

in rats with arthritis. After a week of once-daily, minute-long stimulation sessions, swelling in the rats' ankles shrank by more than 50 percent, the scientists reported in *PLOS ONE*.

If these results hold up in future studies, Tak hopes to see the procedure tested in a range of other chronic inflammatory illnesses, including inflammatory bowel disorders such as Crohn's disease. Studies in animals have shown promise in this area: In 2011, researchers reported in *Autonomic Neuroscience: Basic and Clinical*

that vagus stimulation prevented weight loss in rats with inflamed colons.

Treating inflammatory conditions with vagus stimulation is fundamentally different from treating epilepsy or depression, Tak says. More research with patients will be necessary to develop the technique. "We are entering a completely unknown area, because it's such a new approach," he says. There could be financial hurdles as well, he says. But GlaxoSmithKline, which Tak joined after initiating the arthritis study, has purchased shares of SetPoint Medical,

"The vagus is a huge communicator between the brain and the rest of the body."

BRIAN OLSHANSKY

a company in Valencia, Calif., that produces implantable vagus nerve stimulators, Tak says.

As he and others put stimulation to the test for inflammation, some scientists are attempting to see if manipulating the nerve can help heal the heart.

Taking heart

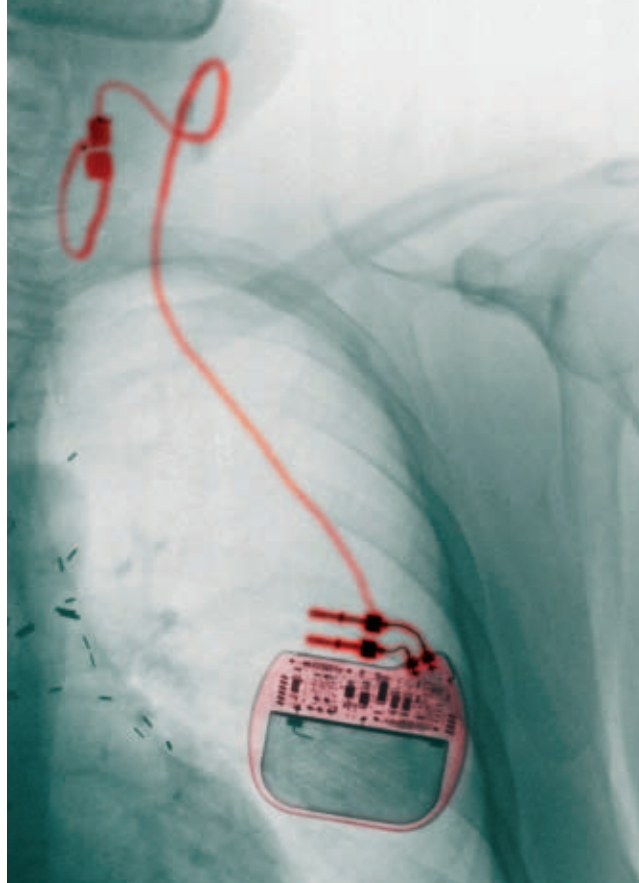
The vagus nerve has profound control over heart rate and blood pressure. Patients with heart failure, in which the heart fails to pump enough blood through the body, tend to have less active vagus nerves. Trying to correct the problem with electrical stimulation makes sense, says Michael Lauer, director of the cardiovascular sciences division at the National Heart, Lung and Blood Institute in Bethesda, Md. “It’s a great idea.”

Yet so far, results from studies on the effects of vagus stimulation on heart failure have been inconsistent. In 2011, researchers reported in the *European Heart Journal* that repeated vagus nerve stimulation improved quality of life and the heart’s blood-pumping efficiency in heart failure patients. A vagus stimulation trial of heart failure patients in India published in the *Journal of Cardiac Failure* in 2014 echoed these results. After six months of therapy, the patients’ left ventricles pumped an average of 4.5 percent more blood per beat.

Last August, however, researchers reported that a six-month clinical trial of vagus stimulation failed to improve heart function in heart failure patients in Europe. This study had the most participants — 87 — but used the lowest average level of electrical stimulation. “All the results thus far are preliminary. The studies that have been finished to date are relatively small,” Lauer says. “But there certainly are promising findings that [suggest] we may be barking up the right tree.”

Another group of scientists is testing more intense vagus stimulation for patients with heart failure. The trial, called INOVATE-HF, is funded by the Israeli medical device company BioControl Medical and uses a higher level of electrical current than the European study that showed no measurable improvements.

“If you try to lower blood pressure and you take a quarter of a pill instead of one pill, blood pressure won’t change,” says cardiologist Peter Schwartz of the IRCCS Istituto Auxologico Italiano in Milan. It’s equally important to use the right dose of vagus stimulation, he says. The new trial is also much larger than earlier studies, with more than 700 patients enrolled



Implanted vagus nerve stimulators send electricity from a generator in the chest to the nerve in the neck.

internationally. Results are expected by the end of 2016.

Vagus manipulation isn’t limited to heart failure research. It’s also being tried in atrial fibrillation, in which the heart flutters erratically. “When it flutters, it doesn’t really push blood very efficiently,” says clinical electrophysiologist Benjamin Scherlag of the University of Oklahoma in Oklahoma City. Atrial fibrillation is common in people over age 60, Scherlag says, and can ultimately lead to blood clots and strokes. Treatments include drugs that alter heart rhythm or thin the blood, but they don’t work for all patients and some have nasty side effects, Scherlag says.

In the lab, scientists can use high-intensity vagus stimulation to alter heart rhythm and induce atrial fibrillation in animals. But milder stimulation that alters heart rate only slightly, if at all, can actually quell atrial fibrillation, animal studies and one human study show.

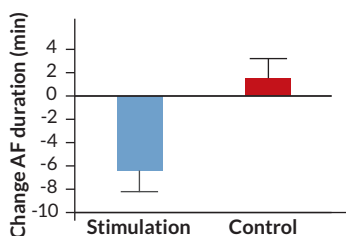
Vagus stimulation for atrial fibrillation is still in its infancy, and clinical applications haven’t been adequately tested, says Indiana’s Zipes. “Nevertheless, the concept bears looking into.”

At intensities so low they didn’t cause any perceptible change in heart rate, vagus stimulation controlled atrial fibrillation in dogs, Scherlag and colleagues reported in 2011. In 20 people receiving surgery for atrial fibrillation, low-level vagus stimulation reduced the duration of heart fluttering episodes from an average of 16.7 minutes to an average of 10.4 minutes, Scherlag and his colleagues reported in the *Journal of the American College of Cardiology* in March.

In their study, Scherlag and his colleagues didn’t implant

Beat patrol

In patients with atrial fibrillation (AF), stimulating the vagus through the right ear (blue) decreased the length of heart fluttering episodes. With no stimulation (red), episodes did not shorten.



SOURCE: S. STAVRAKIS ET AL./J. AM. COLL. CARDIOL. 2015

a nerve stimulator. In fact, they didn't directly contact the nerve at all. They accessed tendrils of the vagus through the skin of their patients' ears. Other researchers are also testing devices that stimulate the nerve without surgery.

Skin deep

"Vagal nerve stimulation is very nice, but in order to get to the vagus nerve ... you have to cut down surgically," Scherlag says. "This is not the kind of thing you want to do, except under extreme situations."

But in the ear, tiny fingers of the vagus's fibers run close to the surface of the skin, primarily under the small flap of flesh, the tragus, that covers the ear's opening. Studies have explored using stimulation of those fibers through the skin of the ear to treat heart failure, epilepsy and depression, as well as memory loss, headaches and even diabetes — a reflection of the nerve's control over a variety of hormones in addition to acetylcholine and norepinephrine.

Stimulating the vagus nerve through the ear of diabetic rats lowered and controlled blood sugar concentrations, researchers from China and Boston reported in *PLOS ONE* in April. The stimulation prompted the rats' bodies to release the hormone melatonin, which controls other hormones that regulate blood sugar.

Ear-based vagus stimulation appeared to improve memory slightly in 30 older adults in the Netherlands. After stimulation, study subjects were better able to recall whether they had been shown a particular face before, says study coauthor Heidi Jacobs, a clinical neuroscientist at Maastricht University in the Netherlands. The researchers, who reported the work in the May *Neurobiology of Aging*, plan to investigate whether these effects last over time and exactly how the stimulation affects the brain, Jacobs says.

The ear isn't the only nonsurgical target. The company electroCore, based in Basking Ridge, N.J., manufactures a small, handheld device that can stimulate the vagus when placed on the throat. The company initially tested the devices to reduce asthma symptoms — relying on the nerve's anti-inflammatory action. But during testing, patients reported that their headaches were disappearing, says J.P. Errico, CEO of electroCore. Now, the company is investigating the use of an electroCore device to treat chronic cluster headaches, severe headache attacks that can come and go for over a year. People suffering from an average of 67.3 cluster headaches each month experienced around four fewer attacks per week on average when using the device along with standard treatments like drugs, researchers reported in *Cephalalgia* in September.

Several researchers have reservations about skin-deep stimulation. "The advantages of the handheld devices are that there's no surgery required," says Feinstein Institute's Tracey,

who is a founder and consultant for implant maker SetPoint Medical. But patient compliance becomes an issue. "Patient compliance with anything, whether it's swallowing a pill or holding a device, is notoriously difficult," he says.

If a stimulator is implanted, a patient can forget about it, Tak agrees. He and Tracey both predict that implants will soon become smaller and safer.

Beyond the mystery switch

Even for depression and epilepsy, Tak says, researchers still need to figure out the best ways of stimulating the vagus — exactly where to place a device, and how much of a shock to deliver.

The nerve's multitasking, two-way nature makes it a challenge to fully understand and control. It's hard to know exactly

what you're zapping when you stimulate the vagus nerve, says physiologist Gareth Ackland of University College London. He compares vagus stimulation to flipping on a light switch in one room of a house and discovering that this endows other rooms in the house with magical powers. "I'm not sure which room it's going to happen in, I'm not sure for how long and I'm not sure if, after a while, it's going to work or not," he says.

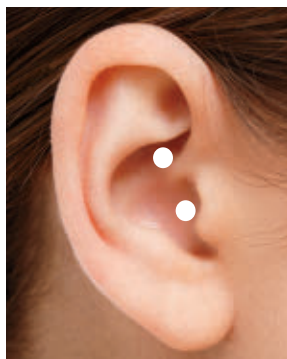
The intensity of electrical current, duration of stimulation and each patient's health status could all affect the results of a vagus stimulation trial, Ackland says. And it's possible that a widespread effect, such as suppressing inflammation caused by the immune system, could even be harmful to some patients.

Ackland says that he and his colleagues agree that the vagus nerve is important. And he's not ready to discount vagus stimulation as a potential therapy for conditions such as heart failure. But he warns that there's a good deal of biology left to understand. "There's an awful lot of basic science and basic clinical research that is needed before launching into a variety of potential interventions," he says.

For Tracey, it's about way more than the vagus. "Nobody should overpromise that the vagus nerve is the secret to everything," he says. But with a better map of the body's nerves and their functions, the lessons learned by studying the vagus could inform future therapies that use nerve stimulation, he says. If researchers can understand and manipulate a particular circuit in a nerve that controls a specific molecule — for example, a protein involved in pain or even cell division — they could zero in on crucial targets. "The promise," he says, "is for tremendous precision." ■

Explore more

■ B. Bonaz *et al.* "Vagus nerve stimulation: from epilepsy to the cholinergic anti-inflammatory pathway." *Neurogastroenterology & Motility*. March 2013.



Vagus nerve fibers run under the skin of the human ear. Long a target for acupuncture, this area is a target for external electrical stimulation (white dots).

SOURCE: F. HUANG ET AL./BMC COMPLEMENT. ALTERN. MED. 2014

These cows at the Ellinbank Dairy Research Centre in Victoria, Australia, wear backpacks that measure their methane output.

GREENER COWS

Research rounds up less burpy bovines **By Laura Beil**

In a pasture outside Edmonton, Canada, you'll find a few dozen cows doing what cows do: mostly eating. The average animal spends eight-plus hours a day filling its belly, or as is the case with cows, bellies. Along with that enormous appetite, cows are born with the ability to digest almost any plant they can chew, thanks to a multichambered stomach and a helpful army of gut microbes that break down food that most mammals cannot.

The system is an evolutionary bonanza for cattle, but it's not so easy on the environment — which is why the animals at the Lacombe Research Centre are no ordinary grazers. Through a transponder clipped to the ear of each cow, scientists record when a cow sticks her head into a bin of tasty feed pellets. As she eats, a solar-powered fume hood above captures her exhalations. Laser beams surround the pasture, reading gases in the atmosphere.

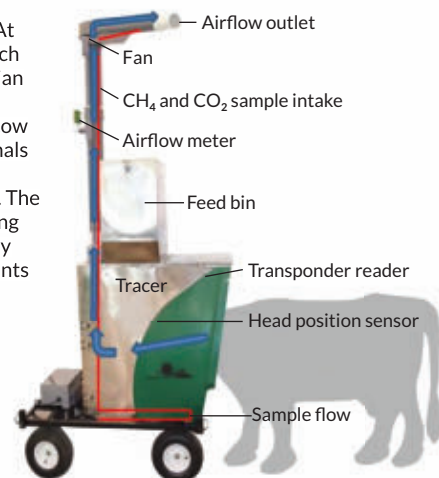
All this fuss is over bovine burps. While cattle and other ruminants like sheep and goats have been gassy for around 50 million years, scientists have only recently begun to pay keen attention to their exhaust as concern grows over climate change. The belches contain methane, an odorless compound that is the main component of natural gas. In the atmosphere, methane warms the Earth.

It isn't the most abundant greenhouse gas created by human activity (that prize goes to carbon dioxide), but methane is one

of the most powerful at trapping heat. In a “pound for pound” comparison, over a century, methane has an impact on climate change that is 25 times as great as CO₂, according to the U.S. Environmental Protection Agency.

Citing methane's impact, a recent CNN story referred to beef as “the new SUV.” But the old SUVs, along with the rest of the oil and gas industry, are a larger source of atmospheric methane in the United States, EPA data indicate, contributing 29 percent of U.S. methane emissions. Livestock is responsible for 26 percent, the agency estimates. Yet while that's the official number, a paper last year in the *Journal of Geophysical*

As fumes flow At the Lacombe Research Centre in the Canadian province of Alberta, researchers collect cow burps when the animals eat from a specially designed fume hood. The scientists are breeding animals that naturally produce lower amounts of methane (CH₄).



FROM TOP: EDDIE JIM/FAIRFAX SYNDICATION; LACOMBE RESEARCH CENTRE

Research: Atmospheres raised the possibility that the EPA's measurements are off, and that the biggest source of methane from human activity may in fact be ruminants — more than 90 percent of them cows raised for beef and dairy production.

While methane emissions from the energy sector declined between 1990 and 2013, the contribution from agriculture rose by 11 percent, according to the EPA. (Though in later years cattle populations fell and so did livestock-related methane.) The World Bank estimates that overall global methane emissions rose 17 percent between 1990 and 2010. In 2014, the U.S. government announced a goal to reduce methane output from dairy cattle by 25 percent by 2020.

That's why scientists worldwide are looking for ways to produce a less noxious cow. Experiments target the animal inside and out, testing variations in feed, antimethane additives and experimental vaccines. The Canadian project goes deeper, using genetics to develop and breed animals that are naturally less burpy.

All approaches are promising, but no single one has hit the sweet spot: reducing methane dramatically while not harming the cow or dampening production of farms and ranches. Any solution can't be too impractical or too expensive, either.

The good news is that this is one issue where the interests of the \$44 billion beef industry and environmentalists may converge — cattle that pollute less might live longer or get by with less feed, improving the profit margins of farms and ranches.

"We've been selling the greenhouse gas story as a win-win to farmers," says Conrad Ferris, head of dairy research at the Agri-Food and Biosciences Institute in Hillsborough, Northern Ireland.

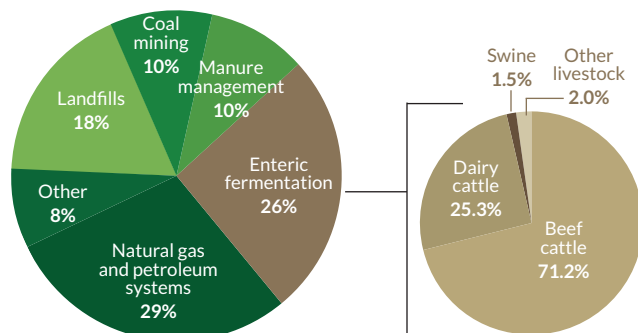
Natural gas

Most methane-reducing experiments don't concern the cow per se; they go after the microscopic ecosystem huddled inside the animal's gut. When a cow eats, hay, grass and other plant material land inside the rumen, the largest of the four compartments of the bovine stomach, which can hold 150 to 190 liters of food and water. Ruminant digestion is a microbial marvel: A portion of the stomach is sectioned off into a sophisticated vat for fermentation, which occurs when microorganisms slice sugar and other large molecules into smaller ones. (Without fermentation, grapes and agave couldn't become wine and tequila.)

Trapped inside the rumen, bacteria digest the components of the forage, especially cellulose, the large chains of glucose that form the main structural support of the cell walls of plants. Cellulose is the reason green plants tend to be stiff and rigid. People aren't born with the enzymes to cope with cellulose, which is why we don't eat grass. When humans eat foods such as fruits and vegetables, the cellulose acts as dietary fiber. Because it resists digestion, cellulose doesn't provide energy. It does help a person feel full with fewer calories and maintain the health of the intestine, and of the microbiome inside.

But a ruminant animal's microorganisms can extract the

U.S. methane emissions from human activity, by source



On the farm Livestock is a major source of methane emissions from human activity in the United States. The gas is produced as part of the digestive process of cattle and other ruminants and from microorganisms that grow in manure (numbers in chart at left are rounded).

SOURCE: INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS AND SINKS: 1990–2013/EPA 2015

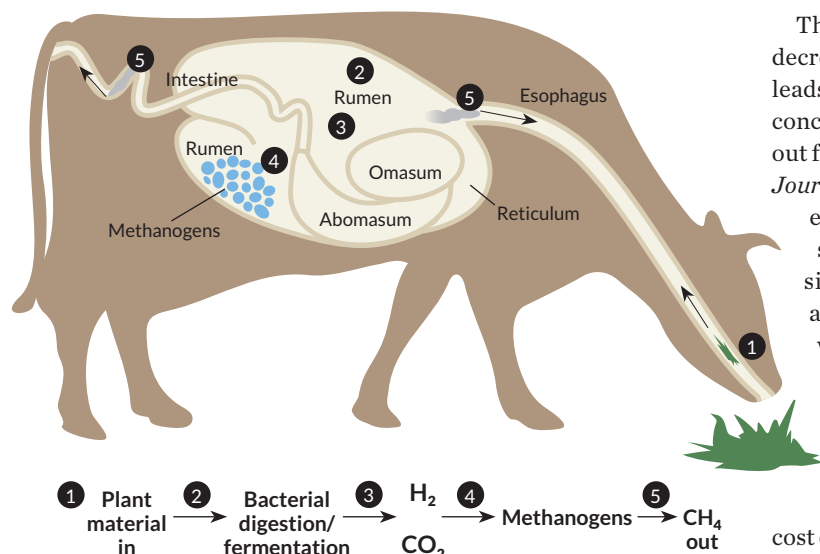
energy locked up in cellulose. Its digestive system includes microbes called methanogens, ancient entities distinct from bacteria and other microorganisms. Methanogens can live in other oxygen-starved environments, such as the bottom of lakes. When microbes in the rumen digest cellulose, they leave behind nutrients that the cow needs plus methane gas, created when methanogens soak up the hydrogen left over from fermentation. The relationship is straightforward: The more the cow eats, the more it ferments, the more methane produced.

Emissions from a grown dairy cow can amount to about 260 to 650 grams of methane per day. Consider that the nation has 98 million head of cattle and you see the scope of the problem. One mid-sized animal could put out about 150 kilograms of methane every year, which has the same environmental impact as driving from New York to Los Angeles — three times.

Fiddle with the feed

Scientists are trying to interfere with the chemical steps that lead to methane production in ways that don't harm the overall health or productivity of the cows. Over the last few years, researchers have tried adding natural and laboratory-made substances to cow feed. One of them is nitrate. The idea is that, given the extra nitrogen, methanogens sopping up excess hydrogen will form ammonia (composed of one nitrogen and three hydrogen atoms) instead of methane (one carbon and four hydrogens). Last year, scientists from the Lethbridge Research Centre in Canada, writing in the *Canadian Journal of Animal Science*, reviewed nitrate-adding experiments dating back to the 1960s. Some laboratory tests yielded dramatic results, reducing cow methane emissions by as much as 70 percent. In other studies, the nitrate didn't affect the growth or appetite of the cows, or milk or meat production.

Problem is, in the rumen, nitrate is broken down into nitrite, which can interfere with the action of red blood cells. One cow died in an experiment and six others had to be rescued. "One of the challenges is, how do you deliver it in a way that prevents nitrate toxicity in the animal," says Wendy Powers, director



Methane makers Thanks to a multichambered stomach and helpful microbes, cattle can digest food that humans cannot. The largest chamber, the rumen, is a fermentation vat that breaks down cellulose. Microbes soak up the resulting hydrogen, producing methane (CH_4), which the cow releases, mainly in burps.

of environmental stewardship for animal agriculture at Michigan State University in East Lansing.

Other scientists have experimented with plants that can influence microbes and change the methane-producing chemistry of the rumen, with the hope that “the public will more readily accept something that is natural,” says Alexander Hristov, a professor of dairy nutrition at Penn State University. He and his colleagues added a by-product of cashew nut processing to feed and reduced methane emissions by a modest 8 percent, they reported in June in the *Journal of Dairy Science*. He has also experimented with adding oregano to feed, which reduced methane. But it got to be too much. “We were feeding 500 grams of oregano per cow per day,” he says. “That is not going to be economical.”

Powers mentored a Michigan State grad student who tried adding an extract from tea to feed, which raised yet another complication: “You had to get so much in there to be effective, palatability became an issue,” she says. Cows will shun a solution that tastes bad. Overall, she says, experiments with various plant extracts have been inconsistent.

Hristov’s team devised another approach that appears to pass the taste test. Researchers experimented with a synthetic feed additive designed to interfere with an enzyme that drives the last step of methane formation. In the Aug. 25 *Proceedings of the National Academy of Sciences*, the researchers reported that 48 cows given the additive for 12 weeks produced 30 percent less methane than cows that ate only their normal feed. The additive did not affect the animals’ appetite or milk production. “This is the most promising feed additive we have worked with,” Hristov says. “In my opinion, this is the answer to the gut problem.”

The Irish scientists are also trying to reduce methane by decreasing the proportion of roughage (the grass and hay that leads to methane production) and increasing the amount of concentrates, which are plants that are easier to digest without fermentation, such as corn and soybeans. Last year, in the *Journal of Dairy Science*, the researchers described one such experiment in 40 grazing cows. As concentrates increased, so did milk production. The cows’ overall methane emissions weren’t affected, but with higher production, the amount of methane that accompanied each liter of milk was reduced, which eases the environmental impact. That experiment was on animals in the field. Experiments in barns have also demonstrated that more concentrates mean less methane per liter of milk produced, Ferris says. But concentrates are costly. “There comes a point when even the higher milk production doesn’t cover the cost of concentrates,” he says. Also, if the overall goal is to ease the impact on the environment, the production and shipping of concentrates has its own carbon footprint.

Squelch the belch

A concern with food additives is that the methanogens in the rumen might adapt to their new diet after a time and resume methane production at the same level. For that reason, an additive would probably need to be repeatedly fed and monitored through the animal’s life span, potentially adding to cost and labor, says Mark Aspin, manager of the Pastoral Greenhouse Gas Research Consortium in Wellington, New Zealand, which partners with the government research agency AgResearch. Researchers in New Zealand — a country with more cows than

Making the most of manure

The average dairy cow generates about 45 kilograms of manure daily. Next to the animal’s burps, its droppings are a substantial source of methane: Manure accounts for 10 percent of U.S. methane emissions. (For all their gassiness, farts release just a tiny fraction of a cow’s methane.) Much of the focus of the U.S. government’s methane-tackling “Biogas Opportunities Roadmap” was on cow patties.

Unlike burps that waft into the air, the methane from manure can be captured by devices called digesters. The airtight devices use the methane generated by the methanogens in manure, which thrive in oxygen-poor environments, to produce energy. The output — either fuel or electricity — powers farm operations or is sold. Digesters are popular at landfills — including one that collects waste at Disney World in Florida — but they are rare in agriculture. Just 239 manure digesters are in operation on U.S. farms (of which there are just over 2 million), according to the Environmental Protection Agency. Yet they generate enough electricity to power the equivalent of about 70,000 homes. — *Laura Beil*

No ordinary grazers Different approaches are under study to reduce bovine methane emissions. Most try to change the chemistry or microbial makeup of the rumen. SOURCES: C. LEE AND K.A. BEAUCHEMIN/CAN. J. ANIM. SCI. 2014; G. WISCHER ET AL/ANIMAL 2013; H.P. JIAO ET AL/J. DAIRY SCI. 2014; A.N. HRISTOV ET AL/PROC. NATL. ACAD. SCI. 2015; M. ASPIN; J.A. BASARAB ET AL/ANIMAL 2013

Method	How it works	Advantages	Disadvantages
Nitrate additive	Promotes formation of ammonia instead of methane	Highly effective in some experiments	Nitrate toxicity for some cows
Plant extract additive	Alters the chemistry of the rumen	Natural	Cost concerns; may affect taste of feed
Increasing concentrates	Substitutes feed that relies less on fermentation	Increases milk production in dairy cows; already available	Can be expensive; environmental cost if transportation needed
Synthetic additive	Blocks enzyme that drives last step of methane formation	In one experiment, methane dropped 30 percent and cows gained weight	Rumen may adapt, reducing effectiveness over time
Vaccine	Antibodies to methanogens	Easy to use	Potential for cows to accumulate hydrogen; effectiveness unknown
Selective breeding	Cows require less feed for same growth	Cumulative and permanent	Changes are slow; may affect other traits, such as health or fertility

people — are developing an antimethane vaccine that could reduce the population of methanogens in the rumen without affecting an animal's weight, milk production or breeding.

The advantage of a vaccine, Aspin says, is that it could theoretically be administered just once, or at least only annually. Also, farmers and ranchers are used to vaccinations; adding one more shot wouldn't be much of a burden on existing agricultural practices. It could be used across other economically important ruminants, such as sheep (which outnumber his country's human population 7-to-1), he says.

The technology is still far from the farm, however. The New Zealand research team has identified antibodies to the gut microbes and is in the process of amplifying the important pieces of those antibodies and incorporating them into a vaccine. In the journal *Animal* in 2013, the New Zealand team reported finding genetic sequences in methanogens that are attractive targets for a vaccine.

They've also developed a vaccine injection that produces methanogen antibodies in saliva, which would then travel into the rumen. This is one key to delivery, since an average cow produces 100 to 150 liters of spit a day to aid in digestion.

Further experiments would have to demonstrate that lowering methanogens won't affect the animal's overall health. "The concern is that removing methanogens from the rumen may allow hydrogen to accumulate," Aspin says. However, "in the limited studies that have been done to date, it doesn't appear that this is the case."

Milking the genetics

Sidestepping digestion altogether, some researchers are focusing on breeding a cleaner cow.

In Ireland, Ferris and his colleagues experiment with live-stock management. Part of the idea is to lengthen the life span of any given animal. "It takes over two years from when a calf is born until she produces her first liter of milk," he says. If a cow lives longer, her lifetime methane production is spread out over more liters of milk. Also, a farmer does not have to replace as many members of the herd with young, all-methane, no-milk youngsters. In a paper published last year in the *Journal*

of Dairy Science, his research team reported that Norwegian breeds had greater longevity than Holsteins, which make up more than 80 percent of U.S. dairy cows.

Researchers in Alberta are developing lines of cattle that produce less methane because they are born that way. "If you use a feed additive, you've got to add it all the time," says John Basarab, a research scientist for beef cattle production and genetics at Alberta Agriculture and Forestry. But a naturally more efficient cow can get by on less feed for the same growth.

Over the last two decades, Basarab and his research team have measured about 5,000 cattle for feed efficiency, and report that old-fashioned selective breeding can produce animals that release up to 25 percent less methane. "In every breed there are animals that are efficient, or inefficient," he says. The researchers began the research not with methane in mind, but with the idea that animals that extract the most calories from their feed will ultimately be more economical. "Essentially there are animals that eat less for the same amount of growth," Basarab says.

Approaching the methane issue through genetics is slow (the gestation period for a cow is about 280 days), he concedes, but it also has the advantage of being "cumulative and permanent."

He and others say the day may come for cows — just as it did for cars — when governments require certain limits on emissions. And just as organic foods have risen in popularity, consumers may start demanding low-methane products.

More and more consumers want to know where their food comes from and whether it's being produced in a sustainable way, Basarab says. "If you don't take care of these things, the public might just say that's a bad way of producing food and we're not going to buy it." ■

Explore more

- A.N. Hristov *et al.* "Special topics — Mitigation of methane and nitrous oxide emissions from animal operations: III. A review of animal management mitigation options." *Journal of Animal Science*. November 24, 2014.
- EPA. "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2013." April 2015.

TELEVISION

Racing Extinction documents plight of world's endangered species

Saving the world can be a beautiful thing.

In *Racing Extinction*, director Louie Psihoyos lays out the case that the world is already in the midst of a sixth mass extinction. In just a century, the film notes, half the species on Earth may be gone. The documentary, airing December 2 on the Discovery Channel, has an unabashedly environmentalist slant. But Psihoyos presents sobering conclusions from years of scientific study along with stunning views of animals that could be lost if people don't take action.

Psihoyos doesn't just tell viewers how bad things are. He and his crew conduct sting operations to expose the illegal trade of endangered species. The filmmakers find severed shark fins covering a roof in China and piles of gills cut from manta rays in Indonesia. Elsewhere, the team exposes underground wildlife markets and a factory that extracts oil from whale sharks.

Creatures that have already lost the extinction race are also highlighted. The last remaining Rabb's fringe-limbed tree frog gets a close-up. At Cornell University's bioacoustics repository, the last male of the now extinct Kauai O'o bird sings for a female that will never come.

The film also considers indirect impacts on wildlife. The vast amounts of carbon dioxide and methane released into the atmosphere warm the planet and acidify the oceans. Special camera filters reveal otherwise invisible CO₂ and methane

Racing Extinction
AIRS DECEMBER 2
DISCOVERY CHANNEL



In *Racing Extinction*, images of wildlife are projected onto buildings to inspire action to save Earth's threatened inhabitants.

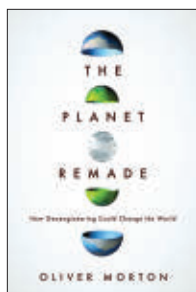
plumes from cars, boats and even people and animals.

But the film isn't all doom and gloom. Psihoyos also serves up a feast for the eyes — a manta ray ballet, a swarm of golden bees against a blue sky, a sublime assortment of crystalline, microscopic marine organisms. He also tells success stories, such as the 2013 addition of manta rays to an international

treaty banning the trade of threatened wildlife.

In the film's finale, race car driver Leilani Münter pilots an electric car on a guerrilla mission to project images of endangered species and messages of hope and peril on the sides of buildings. The journey culminates with shows on iconic landmarks in New York City to inspire people to change small things — giving up meat once a week or installing energy-efficient LED lights — that could help reduce humans' harm to the environment.

Racing Extinction aims to show what in the world is worth fighting to save. Although preachy at times, the film mostly hits the mark. — *Tina Hesman Saey*



The Planet Remade
Oliver Morton
PRINCETON UNIV.,
\$29.95

BOOKSHELF

Geoengineering may be last hope to combat climate change

The plans sound like something out of the handbook of a James Bond villain: generate artificial volcanic eruptions, seed colossal clouds that shade the planet, cover the oceans in immense algal blooms visible from space. Despite seeming outrageous, such Earth-altering schemes, some argue, may be the only viable way to stave off threats posed by climate change (*SN*: 6/5/10, p. 16).

In *The Planet Remade*, journalist Oliver Morton presents the need for a real-life “Greenfinger” to cool the planet. Curb-ing humankind's fossil fuel habit within the next few decades is just too tall an order considering today's lackluster energy alternatives, he argues. So society should pursue geoengineering as a supplementary way to crank down Earth's thermostat.

Morton's advocacy for geoengineering separates the book from previous tomes on the subject (*SN*: 6/5/10, p. 28). Instead of on-the-scene reporting, he lays out the scientific case for geoengineering and addresses critics' concerns

about unintended consequences and the desire to maintain an unspoiled planet. (Agriculture and deforestation have long entangled the environment with the “human empire,” he contends.)

The book lays out the typical laundry list of geoengineering proposals, from extracting carbon dioxide from the air to deploying giant Earth-orbiting space mirrors. But Morton has a clear favorite. A variety of airborne particles reflect sunlight like tiny disco balls. A fleet of high-flying planes could spray these aerosols into the stratosphere and thicken the sun-dimming veil that surrounds Earth. Less sunlight would reach the surface and bingo, the planet would cool. The necessary technologies already exist, Morton says, and costs could be partially offset by charging tourists for a ride high in the sky.

Through pages of rigorous scientific groundwork wrapped in elegant prose, Morton provides a guided tour of why we need geoengineering. The road he takes is well trodden. But for the uninitiated, *The Planet Remade* is a delightful introduction to the seemingly absurd proposals that could be our fragile world's final hope. — *Thomas Sumner*

BOOKSHELF



Death and the Afterlife

Clifford A. Pickover

Examining everything from cremation to quantum resurrection, this entertain-

ing chronology surveys scientific, cultural and religious ideas related to death. *Sterling*, \$19.95

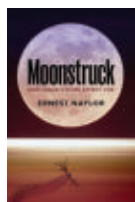


The Horse

Wendy Williams

A journalist traces the evolution of the horse and charts the animal's long relationship with humans.

Scientific American/Farrar, Straus and Giroux, \$26



Moonstruck

Ernest Naylor

Lunar cycles influence the lives of all sorts of creatures, a biologist explains. *Oxford Univ.*, \$29.95



Immunity

William E. Paul

A doctor draws on his own career and the history of immunology to explain how the immune system

works. *Johns Hopkins Univ.*, \$29.95



The Princeton

Companion to Applied Mathematics

Nicholas Higham, ed.

This comprehensive encyclopedia

describes the mathematics used for all sorts of scientific, engineering and social purposes, from algorithms and Benford's law to voting systems and wave equations. *Princeton Univ.*, \$99.50

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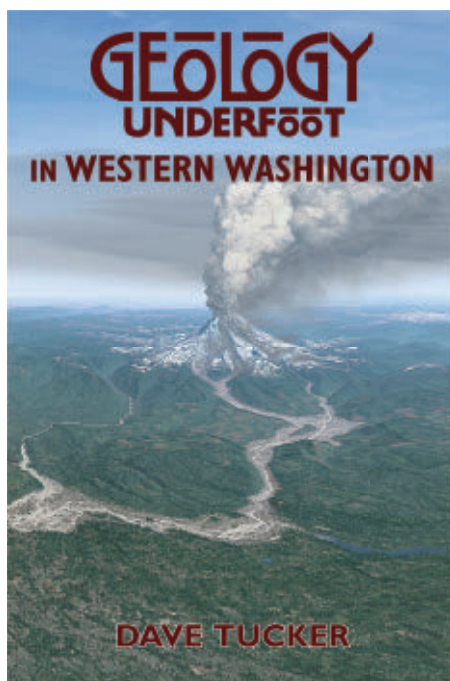
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SOCIETY UPDATE



Science: All in the family

Science is a family affair for the Dells. George “Fritz” Dell was a Science Talent Search finalist in 1949 and his daughter Kristi Dell (now Snell) was a finalist in 1985. Snell and her brother had front row seats to physics research: Both of their parents worked at the Brookhaven National Laboratory in New York. Dell’s STS project was related to Tesla coils; Snell’s focused on Native American artifacts.

What were your most memorable moments as finalists?

DELL: Viewing the projects other high school students had created and exhibited. I was impressed with the talent and creativity of the other participants.

SNELL: The formal awards dinner in Washington at the end of the STS event. The dinner’s attendees were really interested in the STS students, their work and their future career plans. It was a very special experience.

How did STS influence your career?

DELL: [It] encouraged me to go on to college and study science. I chose physics and wanted to work on a [doctorate] to follow in the footsteps of a favorite uncle who had a Ph.D. in chemistry.

SNELL: I was astonished at the breadth, diversity and creativity of the projects that were displayed at STS. This impressed on me that even young high school students can perform rigorous research and make real discoveries. My science career has focused on the metabolic engineering of bacteria and plants to produce value-added products.

Read more at bit.ly/SSP_sciencefamily

Broadcom extends MASTERS sponsorship to 2021

In October, Society for Science & the Public announced that the Broadcom Foundation extended its sponsorship of the Broadcom MASTERS (Math, Applied Science, Technology and Engineering for Rising Stars) for an additional six years. The Broadcom Foundation has been the title sponsor of the middle school competition since 2011.

“We are thrilled to announce the extension of our relationship with the Broadcom Foundation. They have been an excellent corporate partner and we look forward to continuing to grow and enhance the Broadcom MASTERS program,” said Maya Ajmera, President and CEO of Society for Science & the Public, which publishes *Science News*.

Broadcom MASTERS is a competition for sixth- to eighth-grade students designed to inspire and encourage young innovators to pursue science, engineering, technology and math (STEM) studies in high school. “As a student who became interested in scientific research while in middle school, I understand how important it is to support an interest in STEM for this age group, and the Society is appreciative of Broadcom’s commitment and support of this goal,” Ajmera said.

In the past five years, the program has issued roughly 30,000 student nominations and distributed more than \$500,000 in awards to U.S. finalists and schools.

Society alumnus wins Nobel Prize

Paul Modrich, 1964 Science Talent Search semifinalist and International Science and Engineering Fair finalist, was one of three scientists to win the 2015 Nobel Prize in chemistry for his work on how DNA errors are repaired. Modrich teaches biochemistry at Duke University Medical School and is a Howard Hughes Medical Institute investigator. He has a bachelor’s degree in biology from MIT and a Ph.D. in biochemistry from Stanford University. His win makes him the 12th Society alumnus to earn a Nobel.



Congratulations Broadcom MASTERS!



Broadcom Foundation salutes the amazing young scientists and engineers nominated by their science fair judges to compete in the 2015 Broadcom MASTERS. Congratulations to our 30 finalists who competed in the 2015 Broadcom MASTERS!

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Andy Eggebraaten
Rochester, Minnesota

Isaiah O'Neal
Los Angeles, California

Pranav Anandarao
Rochester, Minnesota

Audrey Glende
Salt Lake City, Utah

Nikolai Ortiz
Corpus Christi, Texas

Manasa Hari Bhimaraju
Cupertino, California

Glenn Manuel Grimmett
Jupiter, Florida

Annie Ostojic
Munster, Indiana

Evelyn Bodoni
Centennial, Colorado

Joseph A. Huitt
Chico, California

Nicholas Perez
Lake Elsinore, California

Blake Caven
Jacksonville, Florida

Elizabeth Kinsey
Wilmington, North Carolina

Kanishka Ragula
Salt Lake City, Utah

Hannah O. Cevasco
San Carlos, California

Mikayla A. Lindsay
Niceville, Florida

Anish Singhani
San Ramon, California

Soyoun Choi
Melbourne, Florida

Bryant Liu
Rocky Point, New York

Sriyaa Suresh
Allentown, Pennsylvania

Natasha Chugh
Plano, Texas

Sebastian Lucas Mellen
San Diego, California

Madison A. Toonder
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Avery P. Clowes
Bolton, Massachusetts

Naya Menezes
San Diego, California

David Yue
Plano, Texas

Maximilian Du
Manlius, New York

Rohit R. Mital
Rochester Hills, Michigan

Anusha Zaman
Baton Rouge, Louisiana

About Broadcom MASTERS

Broadcom MASTERS, a program of Society for Science & the Public, stands for Math, Applied Science, Technology and Engineering for Rising Stars. Please visit student.societyforscience.org/broadcom-masters or download the app at broadcomfoundation.org/masters to learn how you can compete in this premier science and engineering competition, created to inspire for 6th, 7th and 8th grade students to pursue their personal passion for science and math into high school.

student.societyforscience.org/broadcom-masters | facebook.com/broadcommasters

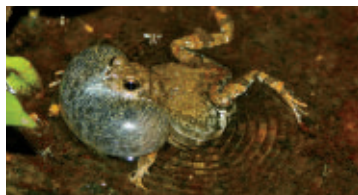


OCTOBER 3, 2015

SOCIAL MEDIA

Funky frog calls

Female túngara frogs often switch which of two mating calls they prefer upon hearing a third, unattractive one, **Sarah Schwartz** reported in “Decoy switches frogs’ preferences” (SN: 10/3/15, p. 7). A video of a call online delighted Facebook commenters, who proposed various soundalikes.



“Old-school game sounds.”
Fabi’an Sir-Fin

“That sound reminded me of *Super Mario*.”
Ivo Laranjeira

“Sounds like a *Star Wars* fight.”
Theresa Tull-Walker Burk

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Humanizing science

The feature “Bright Young Minds,” which profiled 10 promising scientists doing high-caliber research, earned mostly praise and a few criticisms (SN: 10/3/15, p. 20).

Some readers thought the feature inspired hope and optimism. “In this world wracked with geopolitical turmoil and seemingly intractable social and scientific problems, this list is reassuring and thought-provoking,” **Bruce Eby** wrote in an e-mail. “Hooray for your ‘experiment’ in publishing short bios of promising young scientists,” agreed **Don Scott** in an e-mail. “Associating science with the people behind it makes the scientific enterprise human.”

Other readers noted what wasn’t there: some of the scientific disciplines usually covered by *Science News*. **Jim Carlton** e-mailed to say he was struck by “the extraordinary restriction of the [list] to synthetic and cell biology, biotech, organic chemistry, neuroscience and physics,” resulting in the lack of young notables in fields such as astronomy, climate change, psychology and other sciences. “One might not even know that the oceans existed by your selection,” he wrote.

Editor in chief **Eva Emerson** agrees the list was limited in scope. It was based on the opinions of Nobel Prize winners in physiology or medicine, chemistry and physics — not an exhaustive list of all scientific fields. “It is an experiment, and something we’re still tweaking,” she says. “We would love to hear from readers more about what they would like to see in next year’s list.”

Antineutrino atlas

Hundreds of trillions of antineutrinos — harmless, subatomic particles born from radioactive decay — zoom away from Earth each second. A new map flags which areas of the planet emit an abundance of these particles, marking antineutrino hot spots in red, **Meghan Rosen** wrote in “Map captures sources of Earth’s antineutrino glow” (SN: 10/3/15, p. 32).

Online readers wondered why areas known to be mountainous or to have nuclear reactors didn’t show up as dark

red on the map. “If mountains have more radioactive stuff, why don’t the Rockies and Andes show it?” **Tom Carberry** asked. Japan doesn’t seem to have any red dots, either, he noted, despite having more than 40 nuclear reactors in operation.

Rosen points readers to an online version of the map (www.ultralytics.com/agm2015) that lets users zoom in on different locations across the globe. At higher resolution, mountainous regions do actually show up as red smudges, and dark red dots speckle Japan, too, she notes. The dark red swath blanketing the Himalayas is so widespread because that part of Earth’s crust is extremely dense, says particle physicist **Shawn Usman**. Because radioactive elements decay within the crust, “you get a lot more radioactive elements in those mountains,” he says.

Martian dust storms

The violent storm that strands a fictional character on Mars was one of the few unbelievable aspects of the new film, *The Martian*, wrote **Tina Hesman Saey** in “The *Martian* is entertaining science fiction rooted in fact” (SN: 10/3/15, p. 28).

Kurt Sroka recalled seeing a huge Martian storm more than a decade ago. “Most of the details of the Martian landscape were all but obliterated from telescopic view for a significant period of time,” he wrote in an e-mail. “What wind speed occurred on Mars then in order to cause a dust storm of that magnitude, and was it only dust with no blowing sand involved?”

Typical surface wind speed on Mars is about 60 miles per hour, but as **Saey** notes, Mars’ atmospheric pressure is a scant fraction of Earth’s, meaning that Mars winds don’t pack much of a punch.

When dust storms do occur on the Red Planet, the sediment blowing around is typically very fine. As a result, dustups resemble wildfire smoke more than a desert sandstorm here on Earth. Those particles can take a long time to settle, sometimes resulting in weeks-long obscured views of Mars’ surface.

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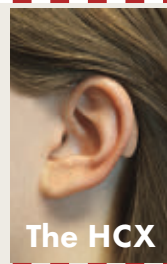
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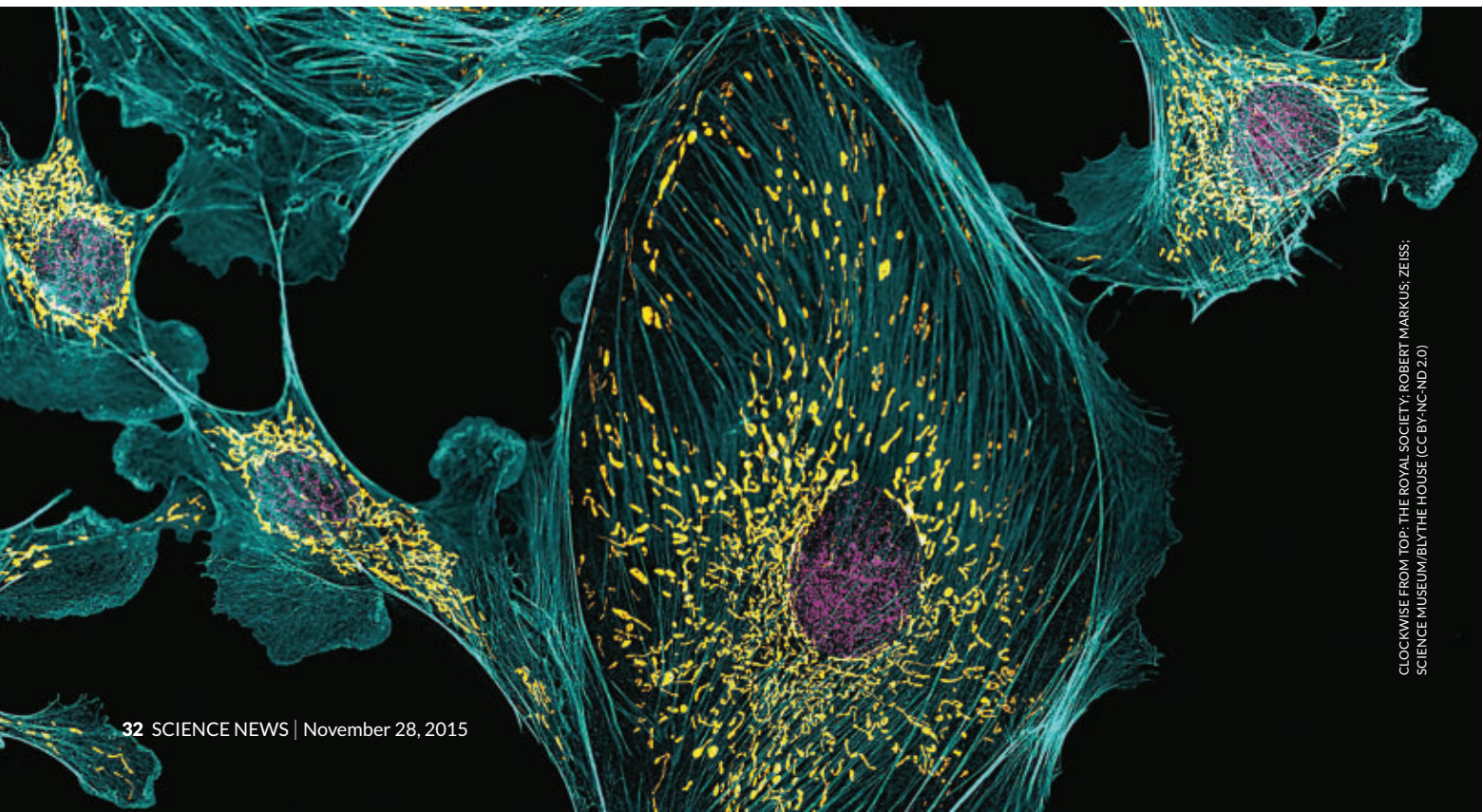
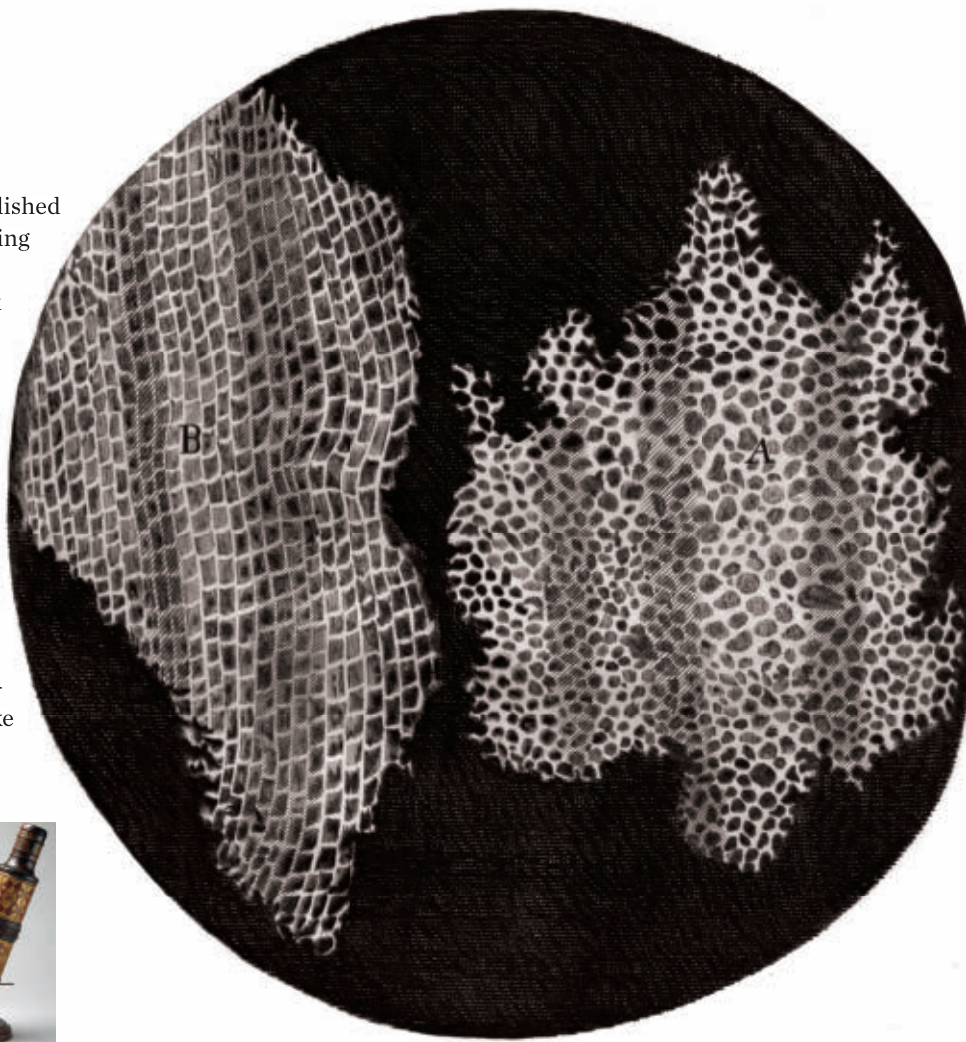
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Then and now: 350 years of microscope upgrades

In 1665, English scientist Robert Hooke published *Micrographia*, a book full of drawings depicting views through what was then a novel invention: the microscope. Peering at a slice of cork through a scope much like the one below right, Hooke noticed small, boxlike partitions that he called cells (drawing at right). Now, 350 years later, cutting-edge microscopes enable biologists to study cells in extraordinary detail (*SN*: 6/15/13, p. 20). The bottom photo, named an image of distinction in the 2015 Nikon Small World competition, shows cells that line the pulmonary artery of a cow; nuclei (purple), mitochondria (yellow) and structural fibers (blue) are clearly visible. Capturing the image required a super-resolution microscope (below, left) that Hooke could only have dreamed about in the 17th century. — *Andrew Grant*



CLOCKWISE FROM TOP: THE ROYAL SOCIETY; ROBERT MARKUS; ZEISS; SCIENCE MUSEUM/BLITHE HOUSE (CC BY-NC-ND 2.0)

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Inventor of MyPillow®

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Lindell has been featured on numerous talk shows, including *Fox Business News* and *Imus in the Morning*. Lindell and MyPillow have also appeared in feature stories in *The New York Times* and the *Minneapolis Star Tribune*. MyPillow has received the coveted "Q Star Award" for Product Concept of the Year from QVC, and has been selected as the Official Pillow of the National Sleep Foundation.

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