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ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ NOVEMBER 5, 2011

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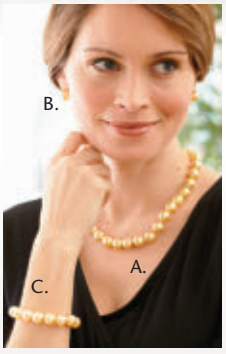

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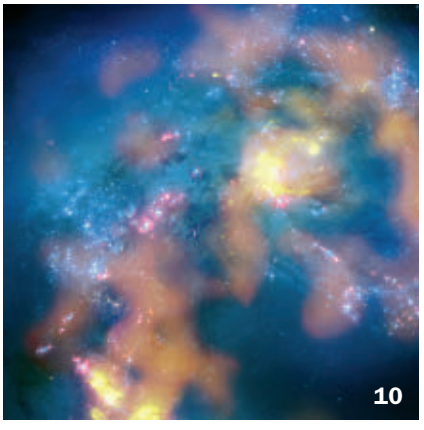

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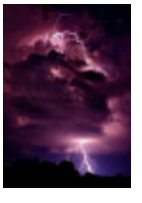

COVER Worldwide, some 100 lightning flashes occur every second; this one lit up the skies in Missouri. *Gregg Williams/ Shutterstock*

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FROM THE EDITOR

Perhaps physics can also solve economics puzzles

Physicists have done a pretty good job of deciphering some of nature's most complicated mysteries.

Take gravity. Einstein's general theory of relativity has it covered. Or the weirdness of subatomic particles. Their behavior seems baffling, but quantum mechanics sorts it all out. All the complications of chemistry are pretty well understood on the basis of modern physics, and large parts of biology have benefited from the insights that physics provides.

Then there's economics. Nobody has solved that mystery.

But physicists are working on it. Over the last couple of decades, a fair number of physicists have attempted to apply their methods to the dismal science. Among the leaders in this effort is H. Eugene Stanley, a physicist at Boston University who coined the term "econophysics" in the mid-1990s.

Stanley, many of his students and researchers elsewhere (notably at the Santa Fe Institute in New Mexico) have shown how mathematical methods used by physicists to describe natural phenomena can be fruitfully applied to the economic phenomena contaminated by human influence. Nobody would yet claim that physics has mastered economics at the same level as quantum physics or relativity, but econophysics has shown how certain surprising economic events make more sense if you use the right math.

Failures of huge firms or market bubbles and bursts that defy standard economic forecasts emerge naturally in physics-informed math, for instance, as Rachel Ehrenberg reports on Page 22 of this issue.

It would be expecting too much for physics-based economic theory to solve the world's multiple financial crises in the immediate future. In the long run, though, translating economics into physics before turning it into policy offers some potential pluses. Economic theory suffers from ideological differences that render policy decisions dependent on the predispositions of those in power. Physics transcends partisan political debates — the speed of light is the same for all parties, gravity warps everybody's spacetime in precisely the same way and quantum physics confuses everybody regardless of age, sex or national origin.

Physics has a long way to go before explaining economics thoroughly enough to overcome all the diversity in the political arena. But econophysics research sure seems like an effort worth undertaking. — *Tom Siegfried, Editor in Chief*

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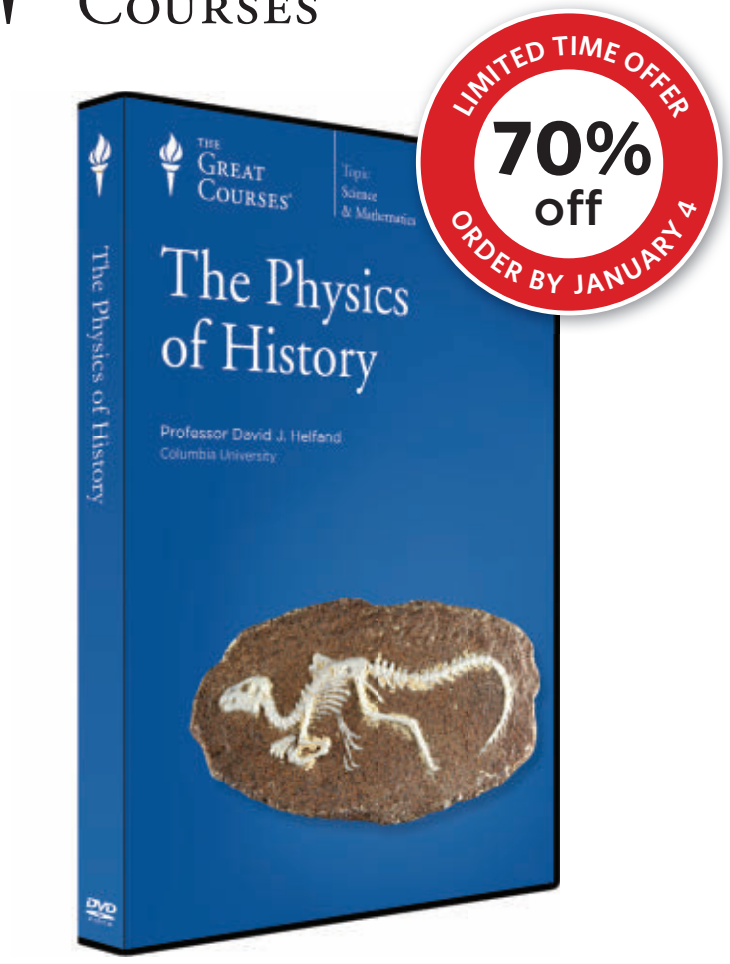

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Say What?

sastruga *\SAS-struh-guh\ n., plural sastrugi*

A wavelike ridge on the surface of hard snow that's formed by wind. Sastrugi are long-term features found in both polar regions. In some places sastrugi may be the main cause of daily variations in how much sunlight the snow reflects, a property called albedo, researchers in China and the United States report online August 6 in the *Journal of Geophysical Research*: *Earth Surface*. As the sun moves across the sky, sastrugi can scatter light in different ways or create shadows. Failing to account for effects from surface features such as sastrugi can throw off estimates of albedo changes and may affect studies of climate, the researchers say. — *Camille M. Carlisle*

Science Past | FROM THE ISSUE OF NOVEMBER 4, 1961

ARTIFICIAL HEART VALVE — A previously hopeless condition of the heart — a defective heart valve — can now be corrected by successful surgery, it was reported

at the American Heart Association meeting in Miami Beach, Fla. Many of the 500 gravely ill patients described by three teams of surgeons who did partial or total replacements of the aortic valve (located at the root of the aorta, the body's main artery) are still living, 10 to 18 months following surgery.... Another key factor reported was the development of synthetic materials such as Teflon, which can safely be implanted within the body and which resists the formation of blood clots.

Science Future

November 15
The DuPont Challenge science essay competition opens for entries. Learn more at thechallenge.dupont.com

November 17
The Royal Society Winton Prize for Science Books is announced. See bit.ly/bookprz

November 19
The "Beyond Earth" exhibit opens at the American Museum of Natural History in New York City. See www.amnh.org

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DELETED SCENES BLOG
An orbiting camera catches dust devils whirling at high speeds on the Red Planet. Read "HiRISE clocks hurricane-speed winds on Mars."

ATOM & COSMOS
Astronomers get a new odometer to measure faraway objects. See "Longer cosmic ruler based on black holes."

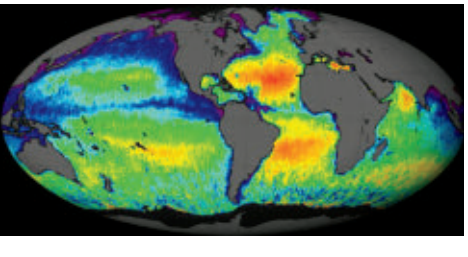
ENVIRONMENT
A warming climate could be making elk more destructive to forests. Read "When snowpack shrinks, elk can binge on aspen."

Some kinds of pollen can precipitate more than allergies. See "Cloud seeding by trees could alter precipitation, climate."

CLOCKWISE FROM TOP LEFT: BILL MCAFEE/NSF; JEDEDIAH BRODIE; GSFC/NASA, JPL-CALTECH

Firsts

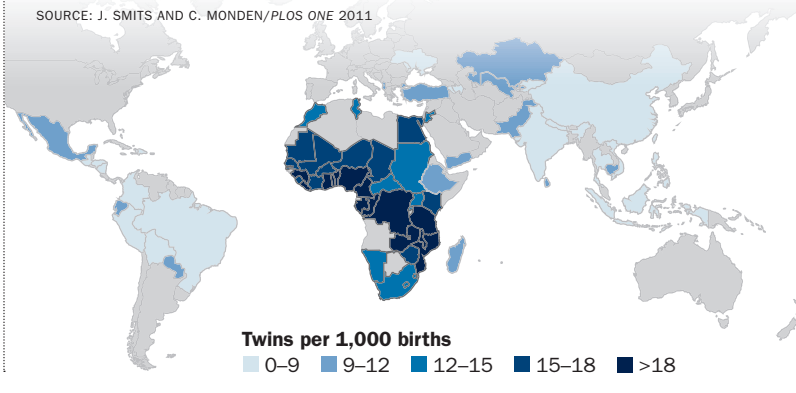
It's the Age of Aquarius for oceanographers: NASA's orbiting Aquarius instrument has provided the first global snapshot of ocean surface salinity. The map combines data from Aquarius' first couple of weeks to reveal patterns in rainfall and river outflow. These patterns influence ocean circulation and therefore climate. The map shows the well-known high salinity of the subtropics (orange) and low salinity near rainy equatorial belts (blue), but it also reveals a larger-than-expected expanse of low salinity from the Amazon River's outflow. — *Camille M. Carlisle*



Science Stats | TWINS IN THE DEVELOPING WORLD

The first survey of twin births in the developing world finds wide variation. East Asian countries have among the fewest natural twin births, while central Africa has the most, with Benin ranking first. Maternal age probably explains much of the variation, researchers say.

SOURCE: J. SMITS AND C. MONDEN/*PLOS ONE* 2011



“Some object got captured into orbit, made two close passages. Survived the first, not totally damaged—then, 50 years later, it came back in and that was the end of it.” —MARK SHOWALTER, PAGE 11

In the News

STORY ONE

Rain tips balance between forest and savanna

Amount of tree cover can shift suddenly and abruptly

By Alexandra Witze

Small changes in factors such as fire and rainfall can determine whether a landscape will be covered by a dense rainforest (left) or open savanna (right).

FROM LEFT: © DAVE BARTRUFF/CORBIS; A.C. STAVER/PRINCETON UNIV.

Like Coke versus Pepsi, tropical land ecosystems come in two choices: forest or grassland. New research shows these two options can switch abruptly, and there’s rarely any in-between.

As such, many of these ecosystems are particularly vulnerable to future changes such as rising temperature, scientists say. With just slight shifts in rainfall or other factors, people living in what is now tropical rainforest might suddenly find themselves in scrubland populated by a different mix of plants and animals—where people’s livelihoods might have to change dramatically.

“That transition is not going to happen smoothly,” says Milena Holmgren, an ecologist at Wageningen University in the Netherlands. “The evidence is showing there are these big jumps.”

Holmgren and her colleagues describe the finding in the Oct. 14 *Science*. Another group, from Princeton University and South Africa’s national research council, reports similar conclusions in a second paper in the same journal.

In theory, the relationship between rainfall and tree cover should be straightforward: The more rain a place has, the more trees that will grow there. But small studies have suggested that changes can occur in discrete steps. Add more rain to a grassy savanna, and it stays a savanna with the same percentage of tree cover for quite some time. Then, at some crucial amount of extra rainfall, the savanna suddenly switches to a full-fledged forest.

But no one knew whether such rapid transformations happened on a global scale. Separately, both research groups decided to look at data gathered by the MODIS instruments on board NASA’s Terra and Aqua satellites, which sense vegetation cover and other features of the land surface. This information included how much of each square kilometer of land was covered by trees, grasses or other vegetation. Both teams focused on the tropics and subtropics of Africa, South America and Australia, because those areas are thought to be least disturbed by human activity.

Looking at the numbers, Holmgren’s group identified three distinct ecosystem types: forest, savanna and a treeless state. Forests typically had 80 percent tree cover, while savannas had 20 percent trees and the “treeless” about 5 percent or less. Intermediate states—with, say, 60 percent tree cover—were extremely rare, Holmgren says. Which category a particular landscape fell into depended heavily on rainfall.

Fire may be another important factor in determining tree cover, the second group reports. Led by Princeton ecology graduate student Carla Staver, this team studied how fire helped differentiate between forest and savanna. Fire spreads quickly in savannas because of all the grasses and slowly in tree-dense forests. “There’s a tipping point between where you get fires spreading easily and where you don’t,” Staver says.

That point, she and her colleagues found, sits at a tree cover of about 45 percent. Below that number, fires spread easily and prevent new trees from establishing themselves. Above that

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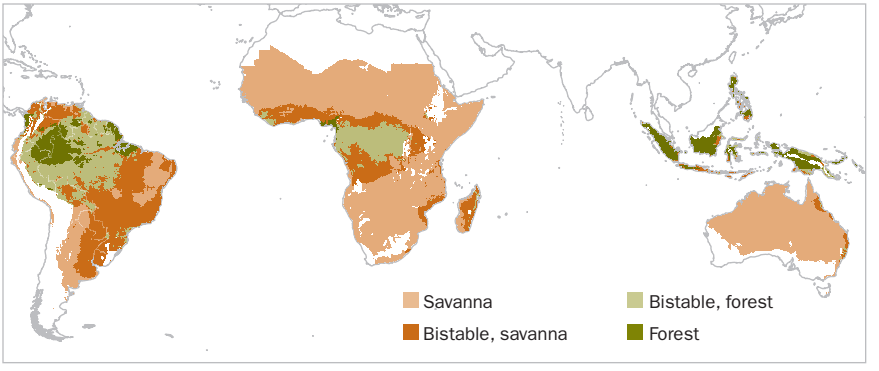
threshold, trees work to maintain a thick canopy that acts as a barrier to stop fire from spreading.

"These two papers tell us that these feedbacks really do operate at all scales," says Audrey Mayer, an ecologist at Michigan Technological University in Houghton. "They'll make us have to redo some of our assumptions about how things are going to change in the future."

Many global climate models, for instance, assume a smooth transition between savanna and forest as temperature and rainfall change. But the new work suggests that forests could appear or disappear quickly, Mayer says, especially if people complicate the picture. "You can't just plant a couple of trees and they'll grow up and the forest will come back," she says. "You have to fight those internal feedbacks."

Staver and her colleagues are searching for savanna-forest transitions that are occurring right now. "These things are definitely happening," she says, "and the new work tells us it could be even more widespread than we'd thought." Studying where landscapes are changing could help the scientists better understand what causes ecosystems to tip from one category to the other.

Where the wild trees are



Easy come, easy go Certain areas (labeled here as bistable) throughout the tropics and subtropics are poised to switch from forest to savanna, or vice versa, if conditions such as rainfall change just a little. The livelihood of farmers or ranchers in these areas could be at risk.

For their part, the Dutch scientists have developed "resilience maps" that show which places are most likely to tip from savanna to forest or vice versa. Farmers scratching out a living in western Africa or ranchers running cattle on the fringes of the Amazon might use such maps to learn how viable their livelihoods are likely to be in coming decades.

Locals could thus spend more time and energy working to keep the ecosystem the way it is, perhaps by building extra capacity for storing water or by cutting back on logging. Or residents could cut down more trees to tip a forest into a grassy rangeland for their animals. "These maps can be a tremendous tool for all kinds of organizations," Holmgren says.

Mayer says she'd like to see the analysis extended into the Northern Hemisphere, where she suspects the results might be the same. Across parts of Illinois and Indiana, for instance, there is a narrow strip of tallgrass prairie surrounded by forests dubbed the "prairie peninsula." The peninsula was probably kept grassy by centuries of fire and grazing management — because otherwise it, too, would revert to forest. ■

Back Story | EYES ON HIGH

A lot of what scientists know about changes on Earth's surface comes thanks to two remote-sensing instruments called MODIS, for Moderate Resolution Imaging Spectroradiometer. One MODIS launched in 1999 on NASA's Terra satellite, and a second soared into space three years later aboard the sister Aqua satellite. By regularly measuring a wide range of light and other radiation reflecting off the Earth's surface, MODIS can build up a high-resolution picture of changes in planetary phenomena such as cloud cover, deforestation and even the smoke from forest fires in Bolivia seen at left. Terra passes over the equator every morning, and Aqua does so every afternoon. Together they see the entire Earth's surface every day or two — making them an all-seeing, never-sleeping eye in the sky for environmental dynamics. —*Alexandra Witze*

FROM TOP: A.C. STAVER *ET AL./SCIENCE* 2011; NASA VISIBLE EARTH

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Genes & Cells

"There was a big question mark whether this was indeed possible." —DIETER EGLI

Cloning method yields stem cells

Reprogramming technique using eggs works in humans

By Tina Hesman Saey

Cloning technology has been used to induce human eggs to reprogram adult cells into a primitive embryonic-like state. The accomplishment, reported in the Oct. 6 *Nature*, may one day help researchers develop a source of stem cells that could be used to replace a patient's own faulty cells.

Scientists had previously shown through cloning experiments that egg cells from many different kinds of animals could perform the feat, but until now there was no evidence that human eggs could do it.

"There was a big question mark whether this was indeed possible," says Dieter Egli, a researcher at the New York Stem Cell Foundation.

Though promising from a research perspective, the stem cells Egli and his colleagues produced can't be used to treat patients.

"This is only partial success," says George Q. Daley, a stem cell researcher at Children's Hospital Boston and Harvard Medical School, because the newly created stem cells contain three sets of chromosomes instead of the usual two.

The extra chromosomes come from the egg. In animal cloning, researchers remove the chromosome-containing nucleus from the egg and replace it with the nucleus from an adult cell. Something in the egg causes the adult cell to revert back to its earliest primordial stage so it acts like a fertilized egg and creates an embryo.

But when researchers tried that technique with human cells, it worked only when the adult cell nuclei were inserted into eggs that retained their own nuclei. So the resulting embryonic cells contained one set of chromosomes from the egg and the normal two sets from the adult cell.

The researchers hope that they will eventually develop ways to remove the egg chromosomes and still reprogram the adult cell. Egli thinks that if the researchers can pull out the egg's nucleus after the reprogramming but before the two nuclei have an opportunity to merge, there is a chance of creating stem cells that might be used in patients.

Regardless of the limitations of the newly created stem cells, the study is a landmark, says Daley. "We're still trying to understand the basic mechanism of reprogramming."

The new cells may help scientists correct flaws in another technology that is used to create stem cells without using embryos. Induced pluripotent stem cells are created by transforming adult cells directly into embryonic-like cells by adding a cocktail of proteins. The technology holds great promise, but researchers have recently discovered that the reprogramming in the transformed cells is incomplete (*SN: 8/14/10, p. 15; SN: 10/9/10, p. 28*). Cancer or other problems might result if such cells were transplanted into a person.

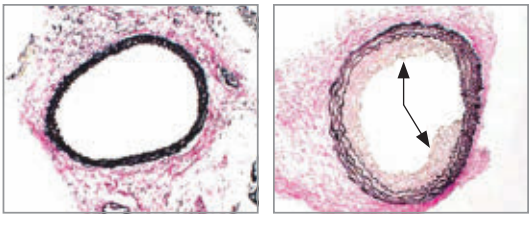
With the new cloning technique, researchers may be able to figure out how the egg reprograms cells. That knowledge could then aid scientists in finding the missing ingredients that could be added to current gene cocktails to make direct, complete reprogramming possible.

Heart disease has its own clock

Broken timers in organs may act independently of brain

By Tina Hesman Saey

Broken biological clocks in blood vessels may contribute to hardened arteries, even if the main timer in the brain works fine. The finding suggests that throwing off the daily rhythms of the body's organs can have serious health consequences.



Vessels transplanted from normal mice into mice with broken clocks were healthy (left). But vessels from mice with broken clocks developed deposits in normal mice (right, arrows show buildup).

R.D. RUDIC

It's known that skimping on sleep and working against the body's natural daily, or circadian, rhythms can raise the risk of illnesses such as heart disease and diabetes. Scientists assumed that the diseases resulted from malfunctions in a master clock in the brain.

But recently, researchers have found that the liver and other organs have their own internal clocks. It hasn't been clear whether disrupting these clocks could also contribute to disease, says Satchidananda Panda, a circadian rhythm researcher at the Salk Institute for Biological Studies in La Jolla, Calif.

To investigate that question, vascular biologist R. Daniel Rudic of the Georgia Health Sciences University in Augusta and colleagues transplanted blood vessels in mice. Putting vessels from normal mice into mice with broken brain clocks didn't lead to problems, the team reports online October 3 in the *Proceedings of the National Academy of Sciences*. But putting arteries from mice with broken clocks into normal mice resulted in artery hardening, indicating that diseases may result from timing defects in the vessels themselves, not the brain.

"We cannot say anything about the genome pieces that have to do with longevity." — HENNE HOLSTEGE

Woman overcame dangerous DNA

Despite disease-related genes, she reached 115 years old

By Tina Hesman Saey

A Dutch woman who lived to 115 years old credited her longevity to pickled herring, refraining from smoking and limiting alcohol. But scientists are looking to the woman's genetic blueprints, hoping to uncover other secrets of successful aging.

Any genetic secrets are still buried in the DNA that makes up the woman's genome, but it has become clear that she did not lack genetic variants that may predispose people to heart disease, Alzheimer's and other aging-related illnesses, geneticist Henne Holstege of the VU University Medical Center in Amsterdam said October 14. Instead, the woman may have carried variants that protected her from the ravages of age.

What those protective variants might be remains a mystery. "We cannot say anything about the genome pieces that have to do with longevity," Holstege said. The researchers will have to compare

Scientists are mining the genome of Hendrikje van Andel-Schipper (shown here at age 113) for clues to longevity.

the woman's genetic makeup with that of other extremely long-lived people, as well as average Joes and Janes, to find potential keys to long life.

The woman, Hendrikje van Andel-Schipper (whom researchers refer to only as "W115"), donated her body to science. After her death from a stomach tumor in 2005, researchers examined her brain and blood vessels for signs of disease that often accompany aging. They found nothing: She had no sign of the plaques or other degenerative proteins that build up in the brains of people with Alzheimer's disease, and her arteries were clog-free.

Her case seems to negate the idea that everyone develops dementia if they live long enough. "Here was proof of principle that it doesn't have to happen," Holstege said.

Holstege and colleagues compared common disease-associated genetic variants in van Andel-Schipper's genome with data from other Dutch people. The team found that the elderly woman did not have fewer of such variants, a finding consistent with previous studies indicating that extremely long-lived people probably have protective variants that help in avoiding or surviving disease.

Even when analysis of the woman's genome is complete, scientists may not learn what part of van Andel-Schipper's DNA contributed to her long life, said Gonçalo Abecasis of the University of Michigan in Ann Arbor. "You may have 10,000 variants that could tell me 10,000 unique things about you," he said.

Doubled gene for extra smarts

Bigger brains may be result of duplicated *SRGAP2* gene

By Tina Hesman Saey

Bigger, better human brains may have been the result of a double dose of a gene that helps brain cells move around.

At least twice in the past 3 million years, a gene called *SRGAP2* has been duplicated within the human genome, said Megan Dennis of the University of Washington in Seattle. Dennis and her colleagues reported October 13 that extra copies of this gene may account for humans' thicker brain cortex, the gray matter where thinking takes place.

The team had previously discovered that *SRGAP2* is one of 23 genes duplicated in humans but not other primates. Dennis found that an ancient form of the gene on humans' chromosome 1 was partially duplicated on the same chromosome about 3.4 million years ago. That partial copy makes a shortened version of the *SRGAP2* protein.

Then, about 2.4 million years ago, a copy of the partial copy was created and added to the short arm of chromosome 1, Dennis' team found.

But having extra copies doesn't mean the gene is evolutionarily important. So Dennis and her colleagues examined the duplicate genes in more than 150 people and found that the younger version of the gene has become fixed in the human population, meaning that absolutely everyone has it. Millions of years is actually quite speedy for fixing duplicated genes, Dennis noted, perhaps suggesting the gene is important in human evolution.

The researchers have found that the shortened version of the *SRGAP2* protein interferes with brain cells' ability to make projections called filopodia, which the cells use to move around. Reducing the number of projections streamlines the cells so they can migrate farther in the brain, perhaps allowing humans to build extra cortex layers, the team proposed.

The study represents more work than anyone has previously done to link a genetic difference between humans and chimps to higher brain function, said Carlos Bustamante, a geneticist at Stanford University.

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Atom & Cosmos

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Critics take aim at fast neutrinos

Lack of energy trail suggests finding was miscalculated

By Devin Powell

A new study puts the brakes on faster-than-light neutrinos.

In September, a group at Italy's OPERA experiment reportedly clocked neutrinos traveling the 730 kilometers from CERN in Switzerland to Italy's underground Gran Sasso National Laboratory about 60 nanoseconds faster than light would have covered that distance in a vacuum (*SN: 10/22/11, p. 18*). But if this were true, most of the neutrinos would have shed energy en route, a new analysis by Boston University physicists suggests.

OPERA should have detected this radiation, say the physicists, if its claims are to be believed. It didn't.

"I would be ecstatic to see some kind of new physics coming from this experiment," says Andrew Cohen, a theoretical physicist who, with Nobel Prize–winner Sheldon Glashow, reports the new finding in an upcoming *Physical Review Letters*. "It's just hard to accommodate that, given this [lack of] radiation."

To follow up on this idea, a second neutrino experiment at Gran Sasso called ICARUS searched for signs of this radiation and found none.

A similar type of energy loss has long been studied in water and other materials in which light travels slower than it does in empty space. Particles that travel faster than light in these substances give off energy known as Cerenkov radiation.

> "We're pretty much convinced that the experiment is wrong."
>
> SHELDON GLASHOW

Cohen and Glashow's paper is the first to extend this idea to neutrinos allegedly outpacing light in a vacuum. The standard model of particle physics dictates that they too must give up energy, spitting out pairs of electrons and positrons, says Cohen.

Exotic theories do exist that allow faster-than-light neutrinos to hold on to their energy. But the lack of this signature supports the prevailing opinion that the OPERA team has been misled by some unaccounted-for uncertainty in the measurements.

"We're pretty much convinced that the experiment is wrong," says Glashow. "But I don't think anyone has identified the error, if there is an error, as of yet."

Gilles Henri of the Institute of Planetary Science and Astrophysics in Grenoble, France, wonders whether fluctuations in the neutrino beam may be to blame for the original finding. In a paper posted online October 2 at arXiv.org, he suggests that some neutrinos may have started their journey earlier than thought, throwing off the average speed for the bunch.

The two atomic clocks used to time the neutrinos are also under scrutiny. Carlo Contaldi, a theoretical physicist at Imperial College London, suggests that the clocks could tick at different rates, thanks to gravity pulling harder on the clock located at the start of the neutrinos' journey in Switzerland than on its partner, deep underground in Italy. To check his idea, Contaldi is waiting on the OPERA team to explain the details of the experiment more fully.

"Until further details come out as to how they did the various bits of their experiment," says Contaldi, "it's not clear how to proceed."

Antennas reveal Antennae

The ALMA radio telescope array has released its first test images, spectacular views of star formation in the colliding Antennae Galaxies. In the image at left, orange and yellow patches highlight stellar nurseries that are normally hidden from observers' eyes. Views from other instruments—including the Hubble Space Telescope—fill out the blue, white and pink patches of the galaxies, which lie about 70 million light-years away. ALMA is a set of radio dishes in Chile's Atacama Desert that is still under construction, but even with just a third of the 66 antennas planned for 2013 collecting data, the images already surpass any other telescope's detail. In the coming months the array will peer at nascent exoplanet systems and the gargantuan black hole lurking in the Milky Way's core. The array will also hunt for some of the universe's first galaxies. When completed, ALMA's movable antennas will span up to 18 kilometers. —*Camille M. Carlisle*

NRAO, AUI, NSF, ALMA (ESO, NAOJ, NRAO), HST (NASA, ESA, B. WHITMORE/STSCI)

10 kilometers | Height of Mauna Kea from seafloor

20 kilometers | Height of Vesta's south pole peak

22 kilometers | Height of Olympus Mons on Mars

Miniplanet sports a megapeak

One of solar system's tallest mountains hides out on Vesta

By Nadia Drake

Vesta might be a planetary runt, but it holds bragging rights to one of the solar system's loftiest peaks.

Rising 20 kilometers from the floor of an enormous impact basin at the asteroid's south pole, Vesta's massif is taller than Hawaii's Mauna Kea — Earth's tallest mountain when measured from the bottom of the ocean. Vesta's peak is still smaller than the solar system's reigning giant, a Martian volcano called Olympus Mons. But then, Vesta is only 530 kilometers in diameter to Mars' 6,800 kilometers.

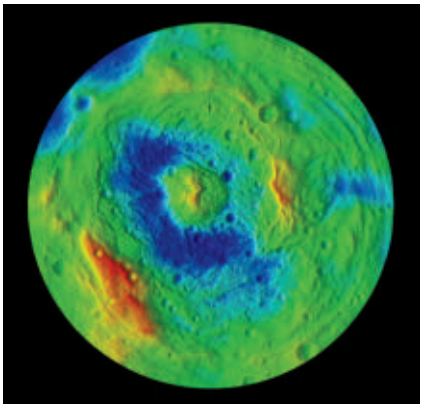
Chris Russell, principal investigator of NASA's Dawn mission, said he now considers Vesta the smallest terrestrial planet in the solar system. "Like Earth, Mars, Venus and Mercury, Vesta has an ancient basaltic crust, lava flows going across the surface, and it also has a large iron core," he said. "It has tectonic features, like on Earth: rift valleys, ridges, cliffs, hills and a giant mountain."

These and other new results from the Dawn spacecraft, which has been circling Vesta since mid-July, were presented October 3.

Dawn recently completed a survey orbit that peered down on Vesta's rough surface from 2,700 kilometers up. The data show that Vesta's surface composition is highly varied. The heavily cratered northern surface appears to be more than a billion years older than the smoother southern surface, said Nico Schmedemann of the Free University of Berlin, who presented evidence suggesting that the asteroid's northern surface is just shy of 4 billion years old, but that the south pole basin could be a spry 2.5 billion years old.

These estimates are much younger than Vesta's estimated age, which scientists think is closer to 4.5 billion years old. With a more precise analysis, it's likely the team's estimates will become older, said Bill Bottke of the Southwest Research Institute in Boulder, Colo.

But, he noted, "it seems reasonable that we have a Vesta surface which is a combination of fairly young terrain and also very ancient terrain."



Vesta's south pole is marked by a giant mountain in a vast impact basin on this map, where orange corresponds to high ground and blue to low elevation.

COURTESY OF EUROPLANET PROJECT

Saturn rings tell a comet's tale

Remnants of a 14th century collision still detectable today

By Nadia Drake

Around the time the Black Death was savaging Europe, England and France were locked in the Hundred Years' War and Chaucer was penning his *Canterbury Tales*, a comet careened toward Saturn and disintegrated, dropping dusty clouds of debris on the giant planet's iconic rings.

Ripples from that cataclysmic event can still be detected today, Essam Marouf reported October 4.

Marouf, an electrical engineering professor at San Jose State University in California and a member of the Cassini probe's radio science team, described how the craft beamed radio waves back to Earth through Saturn's C ring, a tenuous inner band in the planet's ring system. "There were highly regular little wiggles that rippled over hundreds of kilometers in a very specific pattern," Marouf said.

The rippled region contains two different waves, one that repeats every 1.2 kilometers and another that repeats every 1.3 kilometers. Though curious, similar wiggles do appear elsewhere in the outer solar system. Scientists traced a similar structure in Jupiter's rings — spied by the Galileo probe — to debris littered by comet Shoemaker-Levy 9 as it crashed into that planet in 1994.

Saturn's C ring also features a longer rippling structure imaged by Cassini and reported earlier this year. Scientists think these longer undulations — between 30 and 50 kilometers — were caused by an impact event in 1983.

Using that information, Marouf's team was able to determine how long ago the newly observed ripples were created, since wavelengths shrink predictably and elderly ripples are more closely packed.

Rewinding that shrinking process revealed that the newly observed ripples are 600 years older than those born in the early 1980s. "They date back to about the late 1300s," Marouf said. "And there is very clear evidence for two events, not one, separated by about 50 years."

"Two events is really a hint that this is a cometary kind of thing," said Mark Showalter of the SETI Institute in Mountain View, Calif. "Some object got captured into orbit, made two close passages. Survived the first, not totally damaged — then, 50 years later, it came back in and that was the end of it."

Earth

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Columbus' arrival linked to CO_2 drop

Depopulation of Americas may have spurred Little Ice Age

By Devin Powell

By crossing the Atlantic, Christopher Columbus and other explorers who followed him may have set off a chain of events that cooled Europe's climate.

The European conquest decimated America's native people, leaving large areas of cleared land untended. Trees that filled in this territory pulled billions of tons of carbon dioxide from the atmosphere, Stanford University geochemist Richard Nevle reported October 11. Such CO_2 removal could have diminished the heat-trapping capacity of the atmosphere and cooled the climate, Nevle and his colleagues have previously reported.

Columbus may have set off a chain of events that cooled Europe's climate.

"We have a massive reforestation event that's sequestering carbon ... coincident with the European arrival," said Nevle.

Tying together many different lines of evidence, Nevle estimated how much carbon all those new trees would have consumed. He said it was enough to account for most of the sudden drop in atmospheric CO_2 recorded in Antarctic ice during the 16th and 17th centuries. Such a depletion of the key greenhouse gas may have helped kick off Europe's Little Ice Age, centuries of cooler temperatures that followed the Middle Ages, Nevle's team has argued.

By the end of the 15th century, between 40 million and 100 million people are thought to have been living in the Americas. Many of them burned trees to make room for crops, leaving behind charcoal deposits that have been found in the soils of Mexico, Nicaragua and other countries.

About 500 years ago, this charcoal accumulation plummeted as smallpox, diphtheria and other European diseases ravaged the population. Trees returned, reforesting an area at least the size of California, Nevle estimated. This new growth could have soaked up between 2 billion and 17 billion metric tons of CO_2 from the air.

Ice cores from Antarctica contain ancient air bubbles that show a drop in CO_2 around this time. These bubbles suggest that levels of the greenhouse gas decreased by 6 to 10 parts per million between 1525 and the early 1600s.

Reforestation fits with another clue hidden in Antarctic ice, said Nevle. As population declined in the Americas, CO_2 in the atmosphere got heavier. Increasingly, molecules of the gas tended to contain carbon-13, a naturally occurring variant. That could be because tree leaves prefer to take in gas made of carbon-12, leaving the heavier version in the air.

Decreased solar activity, increased volcanic activity or colder oceans capable of absorbing more CO_2 may also have played a role in cooling Europe. These natural processes better explain regional climate patterns during the Little Ice Age, argued climate researcher Michael Mann of Pennsylvania State University in State College.

Fossil moth had yellow-green tint

Paleontologists deduce how wing ridges reflected light

By Devin Powell

Ancient moths have for the first time shown their true colors to modern humans.

By piecing together clues from a fossil unearthed in a former German quarry, a team of scientists has figured out how light bounced off a moth that lived 47 million years ago. Today, the insect's remains are bluish. But before time alchemized its wings, the creature was mostly yellow-green, with only a fringe of blue.

"The original colors aren't preserved, but they can be reconstructed," said Yale paleontologist Maria McNamara, who presented the new findings October 9.

Like beetles and dragonflies, modern moths and butterflies owe their brilliant hues not only to chemical pigments but also to the shape of tiny structures on their wing scales. Parallel ridges redirect incoming light waves, which bounce around and interfere like crashing ocean waves. Depending on how the peaks and troughs line up, this interaction boosts some colors at the expense of others.

McNamara's team found that the shape of the moth's ridges had survived fossilization without shrinking or swelling. When the moth — an ancient relative of today's *Pollanisus* moths — was alive, these structures would have favored a wavelength of about 565 nanometers, turning the moth's wings yellow-green.

Ancient ancestors of *Pollanisus* moths, one of which is shown here, sported a yellow-green color, researchers report.

KERESH/WIKIMEDIA COMMONS

"This is bloody brilliant work," said Phil Manning, a paleontologist at the University of Manchester in England who studies pigments. "This group is the first to work out structural color in insect fossils."

Humans

"We're discovering lost peoples whose existence we never suspected." —JOHN HAWKS

Humans moved into Asia twice

Genetic data show continent was settled in two migrations

By Bruce Bower

DNA extracted from a 40,000-year-old pinky bone and a 100-year-old lock of hair has provided glimpses of two Stone Age human migrations to Asia, including an early foray marked by interbreeding between ancient people and some mysterious, well-traveled members of the human evolutionary family.

Denisovans, an ancient sister group of Neandertals previously identified via DNA taken from a finger bone excavated in Siberia's Denisova Cave, contributed a small portion of genes to living New Guineans, Australian Aborigines, two aboriginal groups in the Philippines and populations on several nearby islands, say geneticist David Reich of Harvard Medical School and his colleagues.

Earlier analyses of modern human mitochondrial DNA, which is inherited only from the mother's side, had suggested that a single wave of humans took a southern coastal route from Africa to Asia around 65,000 years ago. Patterns of nuclear DNA alterations in an ancient Denisovan and in living groups instead point to at least two Stone Age human migrations into Asia, Reich's team reports in a paper published in the Oct. 7 *American Journal of Human Genetics*.

A one-two punch of migrations into Asia, including early interbreeding with the mysterious Denisovans, also emerges from an inspection of an Aborigine man's DNA, led by geneticist Morten Rasmussen of the Natural History Museum of Denmark in Copenhagen. Those results appear in a paper published online September 22 in *Science*.

Both new reports advance the idea that, after leaving Africa, modern humans interacted with a greater number of human-like groups than are documented in the fossil record, says anthropologist John Hawks of the University of Wisconsin–Madison. "We're discovering lost peoples whose existence we never suspected," Hawks says.

Several Chinese sites have yielded hominid fossils that may come from Denisovans, says anthropologist Jean-Jacques Hublin of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany. These fossils date to between 200,000 and 100,000 years ago, and he says that they don't appear to belong to *Homo sapiens* or *Homo erectus*, a possible direct ancestor of modern humans.

"Denisovan genetic material in New Guinea, Melanesia and Australia implies that this ancient group peopled a territory much broader than the southern part of Siberia where it was first identified," Hublin says.

An initial human entry into Asia included ancestors of groups now living in eastern Oceania, some of whom interbred with Denisovans, Reich's group concludes. Earlier evidence from the same team indicated that New Guineans and residents of neighboring Bougainville Island inherited 4 to 6 percent of their DNA from Denisovans. A second migratory wave brought ancestors of present-day East Asians and western Indonesians, whose genes don't show signs of dallying with Denisovans.

Reich's team compared Denisovan DNA to that of 260 people from 33 Asian populations. Denisovan genetic signatures are easily recognizable in the DNA of people today, Reich says.

Australian Aborigines share as much DNA with Denisovans as do New Guineans, the researchers say. Several other island populations in eastern Oceania bear lesser amounts of Denisovan genetic material. Groups in western Indonesia and mainland Asia possess no Denisovan genetic remnants.

DNA studies suggest that humans populated Asia in two waves of migration out of Africa. Australian Aborigines (top) descend from the first, Han Chinese (bottom) from the second.

All non-Africans possess roughly the same amount of Neandertal DNA, about 1 to 4 percent. That's consistent with a single human migration out of Africa about 65,000 years ago, followed by interbreeding with Neandertals in western Asia, Reich says. A trek to Southeast Asia then must have occurred. Common ancestors of New Guineans and Australian Aborigines mated with Denisovans there at least 44,000 years ago, before journeying to their current homelands, the scientists estimate. Ancestors of East Asians and western Indonesians arrived later.

Further genetic evidence that ancient people reached Asia in at least two waves — the first of which interbred with Denisovans — comes from a preserved lock of hair that an Australian Aborigine man donated to scientists about 100 years ago. Rasmussen's group compared the man's DNA, and that of three Chinese individuals, with genetic sequences of living Africans and Europeans, as well as to Denisovan DNA.

Australian Aborigines trace their ancestry to a human migration into Southeast Asia sometime between 75,000 and 62,000 years ago, the investigators estimate. Denisovans interbred to a slightly lesser extent with ancestors of Aborigines than with ancestors of New Guineans, the researchers find.

A second round of human arrivals gave rise to East Asians starting between 38,000 and 25,000 years ago, Rasmussen and his colleagues propose.

FROM TOP: GARY RADLER/ISTOCKPHOTO; BLACKRED/ISTOCKPHOTO

Body & Brain

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Ringing in ears has deeper roots

Tinnitus due to brain's effort to compensate for hearing loss

By Laura Sanders

The high-pitched ringing, squealing, hissing, clicking, roaring, buzzing or whistling in the ears that can drive tinnitus sufferers crazy may be a by-product of the brain turning up the volume to cope with subtle hearing loss, a new study suggests. The results, published in the Sept. 21 *Journal of Neuroscience*, may help scientists understand how the condition arises.

Tinnitus is a disorder of the brain, not the ear, says study coauthor Roland Schaette of the University College London Ear Institute. One convincing piece of evidence: Past attempts to cure the condition by severing the auditory nerve in desperate patients left people completely deaf to the outside world — but didn't silence the ringing. How the brain creates the maddeningly persistent phantom noise remains a mystery.

Usually, tinnitus is tied to some degree of measurable hearing loss, but not always. "We've known for a long time that there are people who report tinnitus whose audiograms are normal," says auditory neuroscientist Larry Roberts of McMaster University in Canada. "It has been a puzzle to figure out these exceptions to the rule."

Schaette and David McAlpine, also of the Ear Institute, suggest that these exceptions may actually be due to "hidden hearing loss" that shirks detection in standard hearing tests.

Focusing on the 10 percent of people with tinnitus who seem to have normal hearing, the team recruited 15 women with chronic tinnitus and 18 women who were free of the condition. All had apparently normal hearing tests. Researchers used electrodes to record the brain's electrical activity as the subjects listened to loud, rapid-fire clicks.

In women with tinnitus, electrodes picked up a subtle abnormality in one of the nervous system's initial electrical responses to the clicks. A signal generated by nerve fibers that carry sounds from the ear's cochlea into the brain was weakened, perhaps because of damage to some of the fibers.

A signal generated later in the sound-ear-brain pathway looked normal in people with tinnitus, the team found. In response to the loud clicks, electrical activity in the brain stem was no different between the two groups.

In tinnitus, this restored normal signal comes from the brain stem trying to compensate for hearing loss by boosting nerve cells' signal-sending activity, Schaette and McAlpine propose. It's this heightened, spontaneous nerve cell activity in the brain stem that leads to the phantom tinnitus sound, they reason.

"The brain cranks up the volume to make up for the pathologically low signal from the auditory nerve, exaggerating everything and creating tinnitus," Schaette says.

The subtle hearing loss detected in the new study, and its link to tinnitus, is cause for concern, says Roberts. "It does suggest — and frankly, I think, very strongly suggest — that there is more hearing loss in the general population than we realize," he says. "There is a looming public health risk here, I think, of considerable magnitude."

Painkiller risk in early pregnancy

Anti-inflammatory drugs may elevate risk of miscarriage

By Nathan Seppa

The popular anti-inflammatory drugs ibuprofen and naproxen could contribute to the risk of miscarriage when taken early in pregnancy, researchers report online September 6 in the *Canadian Medical Association Journal*.

Other research has indicated that the common painkillers collectively known as NSAIDs, or nonsteroidal anti-inflammatory drugs, can impart some danger to a fetus. Pill bottles caution pregnant women to consult their doctors before taking the drugs, and specifically to avoid NSAIDs during the final three months of gestation. The new study bolsters evidence that would extend that caution to the first trimester.

"Women who are thinking about getting pregnant and have stopped using contraception — or just someone in reproductive age — should be a little careful," says epidemiologist De-Kun Li of Kaiser Permanente Northern California Division of Research in Oakland.

In Quebec province, where the study was done, NSAIDs are typically obtained by prescription, with the exception of ibuprofen (Advil, Motrin, Nuprin), which is also available over the counter. University of Montreal epidemiologist Anick Bérard and her colleagues checked prescriptions filled by 4,700 women who had miscarriages and about 47,000 other pregnant women who didn't.

During the first 20 weeks of pregnancy, 7.5 percent of those who miscarried had filled an NSAID prescription, compared with only 2.6 percent of women who hadn't miscarried.

NSAID use was associated with a 2.4-fold increase in risk of miscarriage. The researchers checked for use of ibuprofen, naproxen (Aleve), celecoxib (Celebrex), rofecoxib (Vioxx) and diclofenac, which has many trade names. The team didn't include aspirin, which is an NSAID, in the measurements, or acetaminophen (Tylenol), which isn't.

The new study is the third and largest observational study linking NSAID exposure to miscarriage.

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Like a bolt from above

Lightning scientists begin to solve electric mysteries

By Alexandra Witze

In this lightning flash that researchers generated over Camp Blanding, Fla., luminous stroke sequences are blown to the left of the vertical wire that triggered the flash.

SOCORRO, N.M. — Ten thousand feet high in the New Mexico mountains, Jake Trueblood is getting ready to fire rockets into a thunderstorm.

He lines up eight rockets, straight as soldiers, then connects each to a wire bobbin once used to guide missiles for the French military. Trueblood arms the rockets and heads underground, then waits for hours in a windowless chamber on whose metal roof the rockets sit.

Trueblood, a graduate student at the New Mexico Institute of Mining and Technology in Socorro, is waiting for a good strong electric field in the atmosphere. Then he'll push a button that will send a whoosh of compressed air to a single rocket, sending it careening more than a thousand feet high. The goal is for the rapidly moving wire to trick the air into discharging its electricity in a lightning flash that will slam to the ground just above Trueblood's head.

He and other lightning hunters aren't out on the mountaintop this August day for the thrill. They're here, at New Mexico Tech's Langmuir Laboratory for Atmospheric Research, in search of knowledge. "We're here because we're trying to understand the simplest storms we know of — and we can't," says Graydon Aulich, a lightning researcher at the lab.

Golfers and picnickers are acutely aware of lightning and its dangers, but scientists still don't understand it. "It's really amazing when you think this is something that everyone knows about," says Joseph Dwyer, a physicist at the Florida Institute of Technology in Melbourne. "But try to draw the basic picture, where the electric charges are in the cloud and where are the currents, and you realize you don't even know how to draw the picture to start with."

Now, however, studies like Trueblood's are helping to flesh out that picture. Shooting rockets into thunderstorms has allowed researchers to better understand how lightning follows an electrified channel through the air, hits the ground and then returns along the same path whence it came. Balloonborne and other experiments have revealed that X-rays and gamma rays often accompany lightning, a discovery that hints at high-speed electrons kicking the whole process off. And ways of mapping lightning in three dimensions have uncovered secrets of how lightning travels within a cloud, as well as how it can send a dangerous "bolt from the blue" to hit the ground kilometers away — or even zoom upward to the edge of space.

Such discoveries not only fill out the picture of lightning physics, but also are helping engineers design better systems to divert deadly bolts away from buildings and the people within.

Charging up

In 1752, Benjamin Franklin famously attached a metal key to a kite and flew it in a thunderstorm, observing a spark and deducing that electric charge existed in the atmosphere. Two and a half centuries later, scientists have a slightly better idea of how lightning forms: Hail and small ice particles rubbing against one another within clouds transfer electric charge, with positive charges generally gathering on small ice crystals that are carried higher by updrafts and negative charges gathering on heavier hail particles that drift lower in the cloud. This charge separation builds up an electric field, which at some point must be reconciled by discharging electricity between opposite charges, like a static spark on clothing on a dry winter day.

Electrons begin by carving a series of ionized channels, known as stepped leaders, through the air; for a typical cloud-to-ground flash this means negative charge starts propagating downward from the negatively charged region in the lower part of the cloud. Once the stepped leader reaches the ground, or another region of opposite charge, electric current zaps between the two points, creating the visible lightning flash with temperatures over 25,000° Celsius.

Worldwide, some 100 flashes occur every second. Not all of these reach the ground — in fact, the most common type of lightning discharges within a single cloud — but those that do can be deadly. Roughly 55 people are killed by lightning each year in the United States alone.

Yet studying lightning is like, well, trying to capture lightning in a bottle. The flash may happen often, but not often enough over the places where scientists sit and wait to study it. Kenneth Eack, a physicist at New Mexico Tech, says researching lightning is like trying to conduct an experiment knowing that the electricity you need will be turned on in your building for 20 minutes at some point during the summer — but you don't know which 20 minutes on which day, so all you can do is wait.

To better track lightning's unpredictable appearances, in the mid-1990s researchers at New Mexico Tech began developing a three-dimensional lightning mapping system. Global Positioning System satellites had just started to come into common use, and on a flight back from a geophysics conference Paul Krehbiel and William Rison realized that they could use GPS receivers to precisely time and locate lightning flashes.

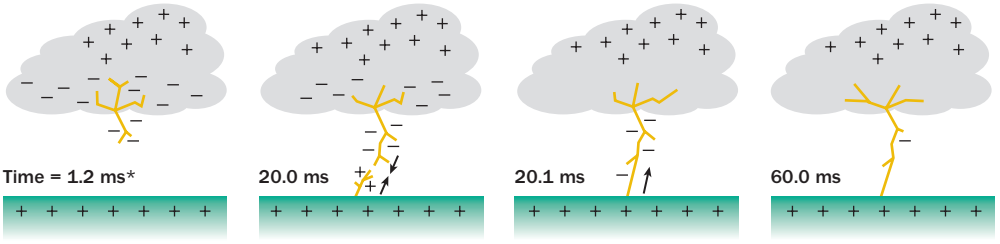
Today the researchers' mapping array consists of a collection of plastic tubs and other containers, each holding a solar-powered detector to measure radio-frequency radiation arriving from sparks within a lightning discharge. With multiple stations, the scientists can build a three-dimensional picture of how lightning appears and branches across the sky. Between 16 and 18 stations typically dot the mountaintop at Langmuir Lab. Many other research groups have

At a mountaintop lightning laboratory in New Mexico, Jake Trueblood preps rockets to trigger lightning flashes.

THIS PAGE: A. WITZE; OPPOSITE PAGE: D. HILL/UNIV. OF FLORIDA

Spark from above

Lightning flashes most commonly discharge within clouds, but people on the ground tend to care most about the less common but more dangerous cloud-to-ground flashes. No matter where a flash reaches, the steps involved in initiating electrical discharge are the same.



Stepped leader After electrical charges separate in a thundercloud, a channel of ionized gas, the "stepped leader," begins to carve through the air.

Attachment Once the stepped leader (in this case, negatively charged) reaches the ground, electrical discharge begins.

First return stroke Electrical current courses between the ground and the cloud, creating the visible lightning flash.

Dart leader After the first stepped leader and return stroke sequence, another leader frequently descends to start successive strokes.

SOURCE: M. UMAN/*THE ART AND SCIENCE OF LIGHTNING PROTECTION*, CAMBRIDGE UNIV. PRESS 2008

*MILLISECONDS AFTER LIGHTNING INITIATION

set up similar arrays using the New Mexico Tech technology, including a new facility in Catalonia, Spain.

Because the system typically picks up 60-megahertz signals in very high frequency, or VHF, bands, it became a lot easier to detect lightning signals when overlapping television broadcasts in the United States moved to digital, Krehbiel says. Other tweaks have also improved the array's sensitivity over time, allowing the scientists to see lightning in better detail than ever before. Already, the researchers have spotted many more "precursors," or attempts to get intracloud lightning discharges started. Many flashes try multiple times to discharge before they make it, Rison says.

Data from the array have also helped explain why negatively charged cloud-to-ground flashes often have multiple strokes, whereas positively charged ones (which are less common) usually don't. Positive leaders are observed to branch out a lot and move forward only tenuously, whereas negative ones branch less and move forward more robustly, Krehbiel reported in Rio de Janeiro in August at a conference on atmospheric electricity. "Every time we look at the data we see something new," he says.

Next spring, the group plans to set up a new array in north-central Colorado as part of a larger study on how electrified storms affect atmospheric chemistry. As one side result, the team will see how often wind turbines along the Colorado-Wyoming border get hit by lightning. Turbine blades can spark electrical discharges, a major hazard, while spinning through the air at up to 100 miles per hour. "There's no data on what the mechanism is, and if we knew maybe we could design a wind turbine to be less susceptible to lightning," says Rison.

X-ray vision

Fifteen hundred miles east of Langmuir, other scientists use the lightning mapping array — and a lot more — at the country's other premier research facility, the International Center for Lightning Research and Testing at Camp Blanding, Fla.

Scientists at Camp Blanding, a military base where neighbors don't tend to complain about rockets bringing lightning down on them, are in the middle of an intensive four-year research project funded mainly by the Defense Advanced Research Projects Agency. Among other things, radar scans the area for storms; high-speed cameras, including a video camera that can shoot 4 million frames per second, record any lightning flashes; sensitive instruments capture information on electric and magnetic fields; the mapping array locates each bolt in three dimensions; and X-ray equipment detects high-energy radiation accompanying a flash. All this equipment gathers 100 measurements on each flash, 24/7, over an area of about a square kilometer. "It's the most [lightning] instrumentation anyone has ever had in one place in the history of man," says the facility's codirector, Martin Uman.

The work paid off on July 7 of this year, when the instruments captured a natural lightning flash with four strokes. "Everything lit up like gangbusters," says Uman, of the University of Florida in Gainesville. Although they haven't gone through the data yet, the researchers expect to learn much from this scientific gift from above.

Along with studying natural lightning, the Florida team also triggers lightning the way Trueblood does in New Mexico. Triggered lightning is in some sense artificial; electricity coursing down the rocket wire does not behave the same way as ionized channels forming naturally. But the return stroke of triggered lightning, when the current connects and creates a visible flash, is pretty much the same as nature provides, Uman says. So shooting rockets into thunderstorms, as cowboy as it might sound, provides an easier way to get lightning where you want it.

Camp Blanding scientists are tackling three seemingly simple yet devilishly complex questions about lightning: how it originates in the cloud, how it travels through the air and how it connects to the ground (a key question in protecting people and buildings from strikes). Of these, lightning's birth is the least understood, Uman says. "People always thought it was an electrical breakdown like happens in the laboratory: Put in a big enough electric field and the air starts to become conductive," he says. But in clouds, lightning seems to occur where electric fields are much lower than those needed for a lab discharge. And for a long time no one could figure out how lightning got started in these smaller electric fields.

In the last few decades, however, researchers have begun to explore versions of a theory known as "runaway breakdown." According to this theory,

E. FELICIANO

cosmic rays hitting the atmosphere deliver a steady supply of high-energy electrons. The cosmic rays also knock into other electrons, which speed up in the thundercloud's electric field. Soon the electrons are avalanching out of control. "Suddenly your electric field is big enough to accelerate electrons up to the speed of light," Dwyer says. Crucially, this means that electrons can spark a discharge when the electric field is an order of magnitude less than theorists had thought necessary.

Still, scientists don't understand all the steps in the runaway breakdown idea. And it's not clear whether the fast electrons initiate the lightning discharge or simply accompany it, Eack says.

X-rays in lightning could help solve the dilemma. If Superman watched lightning strike, his X-ray vision would see high-energy radiation accompanying the bolt all the way down, Dwyer says. The Langmuir team reported the first surprising hints of these X-rays back in 2001, and Dwyer later confirmed them by setting up sensitive detectors at the Florida lightning facility. At times, the X-rays were so intense that they blinded his equipment.

Last year, Dwyer took the first pictures of these X-rays during a triggered lightning flash at Camp Blanding. Made with a pinhole camera that measures voltage, the images show bright honeycomb-shaped pixels descending with the bolt from above.

Different strokes

Superman would have another advantage over today's top lightning researchers: He could fly into, above and below a thunderstorm, watching lightning move in all directions. And he'd see phenomena that earthbound scientists have just begun to discover in recent years: lightning flashes that travel not just within a cloud or directly from the cloud to the ground, but that break out to the side or even zoom straight up to space.

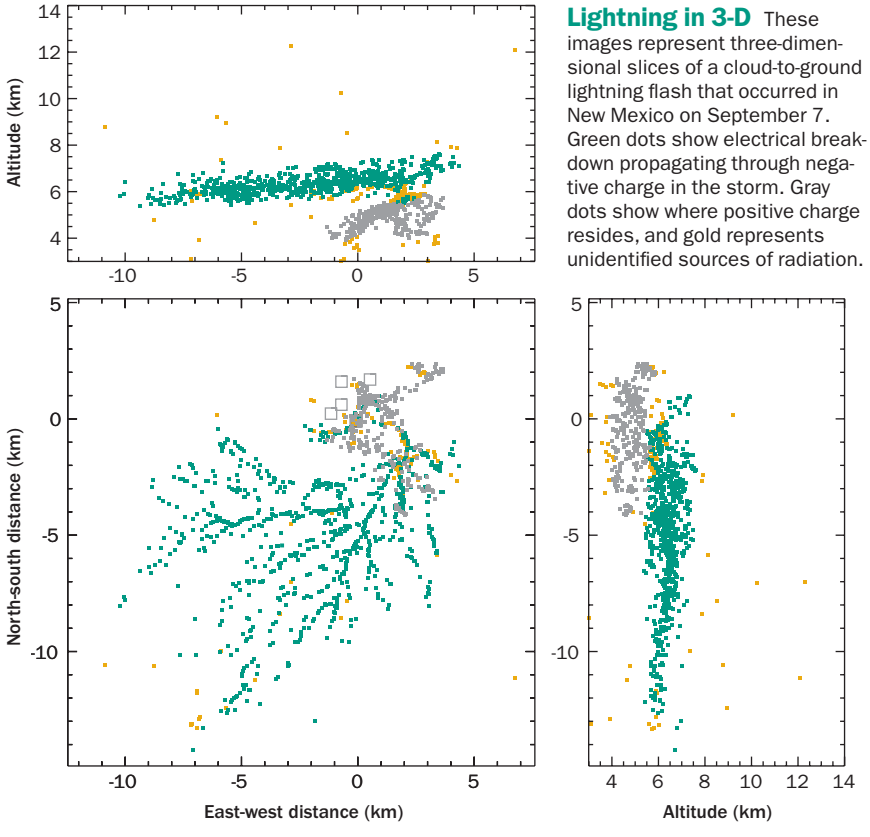
The most spectacularly named of these are the "gigantic jets," which are essentially ordinary lightning flashes that manage to punch straight up from a thundercloud and travel some 80 kilometers upward. Videos from two amateur scientists show how the jets manage this feat.

Normally, in-cloud lightning flashes develop in the lower, negatively charged part of the cloud; if they happen to reach higher within the cloud, the positive charges higher up cancel out the negative charge, stopping the flash. But in two cases videotaped recently in Florida and Oklahoma, the negatively charged leader zoomed upward and then went sideways, trying to exit the side of the cloud. Had it succeeded, it would have become a "bolt from the blue," where a flash zaps the ground many kilometers away from the cloud where it originated. Bolts from the blue are some of the most dangerous types of lightning, as no one is expecting a strike from clouds far away.

But in these two cases the leaders didn't break out of the clouds, says Steven Cummer, an electrical engineer at Duke University. They fizzled instead. In the process, though, they shorted out much of the positive charge that usually sits near the top of the cloud acting like a lid on a pot to keep negatively charged leaders from breaking through. So when a second leader was born within the same cloud and zoomed upward, it had very little positive charge above to trap it in. That leader broke through the top of the cloud and kept zipping up as a gigantic jet, Cummer and his colleagues, including Duke postdoctoral researcher Gaopeng Lu, reported online in June in *Geophysical Research Letters*.

Gigantic jets aren't the only things that fly upward from storm clouds; so too do mysterious flashes of high-energy gamma rays. "Both of these events are produced by the most ordinary of all lightning," Cummer says.

The only way to see the rays, known as terrestrial gamma-ray flashes or TGFs, is from the viewpoint of a gamma-ray satellite looking down on Earth. The first such TGFs were reported in 1994, and as yet no one is entirely sure how they form. But recent work by Cummer and other researchers suggests that TGFs are born in the first milliseconds of a lightning flash, when there is but a single lightning



Lightning in 3-D These images represent three-dimensional slices of a cloud-to-ground lightning flash that occurred in New Mexico on September 7. Green dots show electrical breakdown propagating through negative charge in the storm. Gray dots show where positive charge resides, and gold represents unidentified sources of radiation.

NEW MEXICO TECH

Volcanic lightning

Lightning researchers chase thunderstorms, and volcanologists lie in wait for eruptions—and it took a seismologist in Alaska to bring the two worlds together.

In 1992, Steve McNutt of the University of Alaska Fairbanks picked up some funny signals on the seismometers he was using to study the erupting Mount Spurr, near Anchorage. The signals turned out to be static from lightning generated by the eruption, possibly the first time volcanic lightning was recognized as such. Since then McNutt has been tracking lightning discharges in the huge billowy plumes from erupting volcanoes.

Electrical charges separate into positive and negative regions inside a volcanic plume much as they do within a thundercloud, thanks to ice particles forming and rubbing against one another, among other factors. Electricity then discharges between the charge separation, creating dramatic lightning bolts within the eruption plume.

So far McNutt has gathered data on lightning from 394 eruptions at 154 volcanoes. Volcanic lightning turns out to be "a hell of a lot more common than people had thought," he says. "With modern tools in place, we can start to exploit it for what it tells us about the eruption process."

For example, McNutt and his colleagues have found that when an eruption involves a lot of water coursing up from inside the Earth along with magma, more lightning occurs. "The combination of ash particles, like seeds, and a lot of water sets up a very efficient mechanism to produce a lot of electricity and lighting," he says. In essence, the water turns an eruption cloud into a sort of dirty thunderstorm.

McNutt has also teamed up with Ronald Thomas and other scientists from the New Mexico Institute of Mining and Technology in Socorro, who developed a system for mapping lightning in 3-D. To catch lightning in the act, the scientists set up several mapping stations at a safe distance from an erupting volcano. So far, they've caught flashes at

DAVID JON/NORDICPHOTOS/GETTY IMAGES

four: Mount Augustine in Alaska in 2006, Chaitén in Chile in 2008, Mount Redoubt in Alaska in 2009 and Eyjafjallajökull in Iceland in 2010 (lightning at Eyjafjallajökull shown). Among other things, the scientists have found that electric charge persists in the plume as the eruption continues, suggesting that interactions among ash and other particles continue to build up electric fields so that lightning can keep occurring.

One day, lightning might even be used to detect eruptions at remote volcanoes. Last December, the U.S. Geological Survey and the University of Washington in Seattle unveiled an alert system that ties into the World Wide Lightning Location Network, a global array of laboratories that monitor lightning activity. By searching for lightning activity near known volcanoes, the system can e-mail notices of eruptions to scientists even before the ash cloud becomes visible to satellites. —*Alexandra Witze*

channel moving almost directly upward. "The high electric field that's driving the TGF is definitely connected in some way to that upward leader," Cummer says.

Even more surprising, TGFs contain antimatter, the doppelgänger of normal matter. Earlier this year, scientists from the University of Alabama in Huntsville reported that positrons, the antimatter counterpart of electrons, are common in thunderstorms (*SN Online: 1/10/11*).

Dwyer thinks these positrons may be the key to understanding TGFs. In a new theory he has presented at several scientific conferences, he argues that the runaway electrons thought to trigger lightning also produce gamma rays, which in turn collide with ordinary air particles to produce electrons and positrons. "The whole discharge becomes self-sustaining, where you get huge bursts of gamma rays because of all the positrons you're making," Dwyer says. "If this is correct, then one of the keys to understanding thunderstorm physics is positrons. Who would have thought that a few years ago?"

Few lightning researchers would have foreseen most of these discoveries a few years ago. But back at Langmuir, Trueblood and Aulich know they aren't going to be contributing to new breakthroughs on this particular August day. Having watched thunderstorms come and go all around the Magdalena Mountains, too distant to try triggering a lightning flash in, the scientists are packing it in. They call the local Federal Aviation Administration office and say it's OK to start routing airplanes over the lab again. "We've gone cold," Aulich says as he hangs up the phone. ■

Explore more

- The University of Florida's lightning lab: www.lightning.ece.ufl.edu

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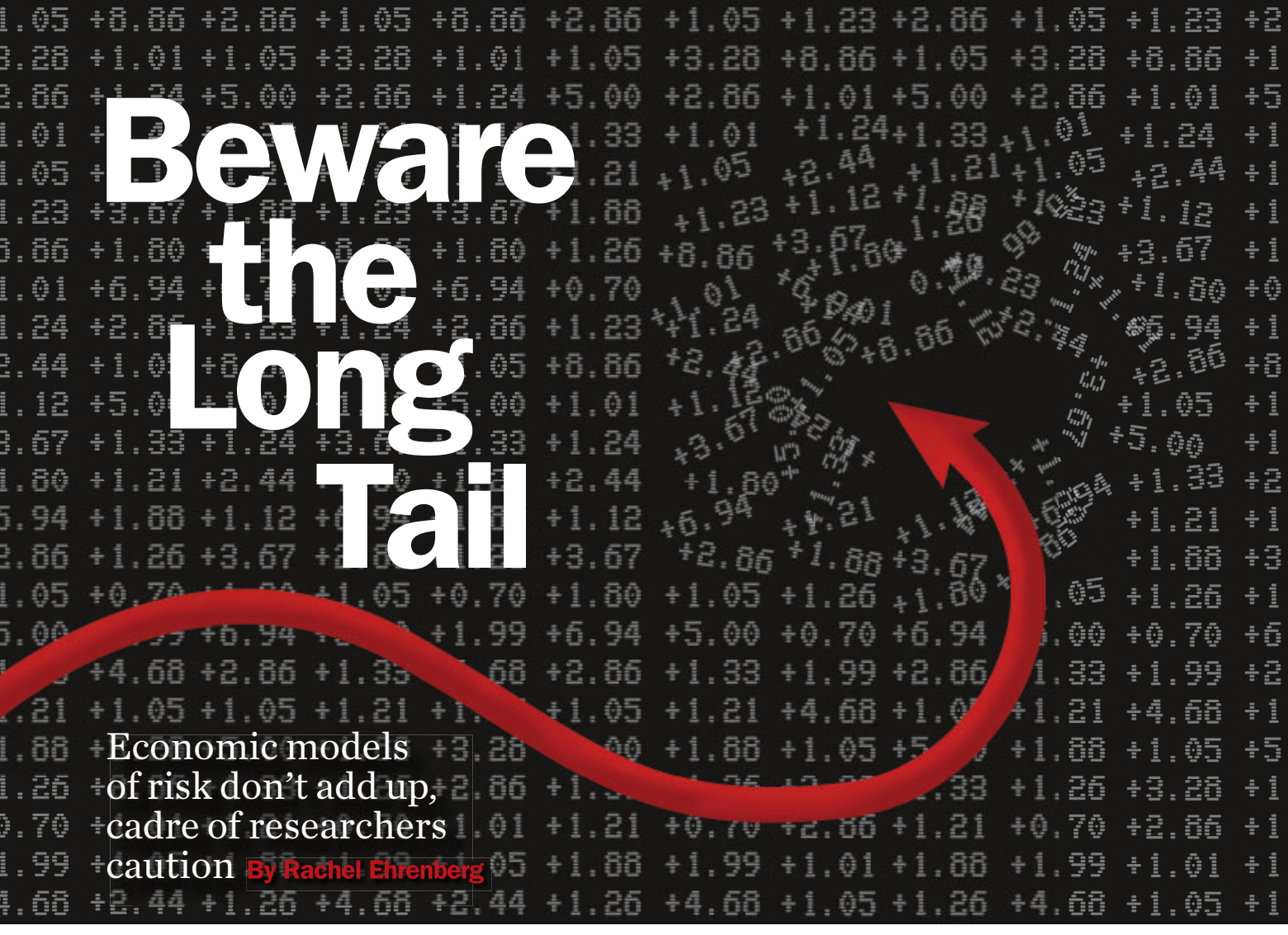


Economic models of risk don't add up, cadre of researchers caution

By Rachel Ehrenberg

When H. Eugene Stanley heard that Lehman Brothers had filed for bankruptcy, a small part of him was thrilled.

Of course, the news was distressing. The firm's seismic collapse had disastrous consequences, not only for the global economy but also for Stanley's daughter-in-law, who became instantly unemployed. But Lehman's downfall was exactly the kind of rare event that Stanley, a physicist at Boston University, had been expecting.

"Many economists will tell you that the chances of something really big and bad happening are really, really small," Stanley says. But when viewed through a different lens, he contends, catastrophic events — such as Lehman filing for bankruptcy in 2008 — aren't exceptional but inevitable.

At the time of Lehman's collapse, Stanley had been exploring the notion that extreme economic events, the bubbles and crashes of financial markets, might be described by a mathematical law — a tidy law, like acceleration due to gravity. And he isn't the only outsider who has had an eye on the markets. Scientists from a range of fields have been poring over financial data, finding some curious patterns in the process.

These patterns suggest that standard economic models based on the notion of equilibrium — markets will fluctuate but then settle down like the surface of a still pond — may not capture the whole story. Freak events may be a normal part of long-term economic behavior. If that's true, then the mathematical methods guiding Wall Street's estimation of risk are seriously flawed, offering a dangerous false sense of security.

"You have to understand that the bad events can be really, really bad," says J. Doyne Farmer, who is trained in physics and does research spanning several disciplines at the Santa Fe Institute in New Mexico. "And there's a significant chance that over a five-year period we will get hit by a really big event. That's where the rubber really hits the road."

Gaussian-colored glasses

Discounting extreme events as improbable is a long-held tradition in economics, notes Stanley. Many mathematical models assume that financial data, such as changes in the price of a stock, fit what is known as a Gaussian, or normal, distribution — the good old bell curve. Most data cluster around an average. Move to either side of the average, and the data points become increasingly scarce, tapering off in a predictable way. A blizzard in July or the Dow Jones dropping 20 percent in one day are considered so rare that they might as well be impossible.

ILLUSTRATION: JANEL KILEY, BACKGROUND: MALIKETH/ISTOCKPHOTO

The Gaussian bell's roots in finance go back to work by French mathematician Louis Bachelier, who modeled changes in share prices in the early 1900s. Bachelier recognized that some of his model's assumptions were flawed, including the premise that the probability of extreme events is vanishingly small (he reportedly called such events "contaminators"). Yet these assumptions were preserved in later models, including the Black-Scholes formula, which underlies much of Wall Street's estimation of risk.

In some respects, the long reign of this Gaussian approach isn't that surprising. Many things measured in the real world fit the Gaussian mold, says Mark Newman of the Center for the Study of Complex Systems at the University of Michigan in Ann Arbor. Take the height of adult American males: It generally hovers around 6 feet, or about 180 centimeters. Plot the number of men with heights lower and higher, and the data points on either side taper off quickly. "You don't get a mile-high human," Newman says.

With truly Gaussian distributions, measurements that appear extraordinary, such as a person a mile tall, are probably flukes; perhaps the measurer didn't know how to use a ruler or made a mistake in writing down the number. Termed "outliers," these data points are often thrown out of the analysis.

But when it comes to financial data, a growing body of research suggests that outliers can be more like babies than bathwater. Such events may still be very rare; Stanley says that the probability that stocks would crash as they did on Black Monday in 1987 was "as close as you can come to never." Yet Black Monday still happened. And while much of finance does behave within the bounds of a normal distribution, ignoring the rare, large events doesn't capture reality.

When rare extremes are included in the picture — if there really are a handful of mile-tall men — then one of the bell curve's sloping sides doesn't come tidily to a close. It splays out in what's known as a long (or fat or heavy) tail. Researchers analyzing financial data are finding these tails over and over and over again.

In the 1990s — when Stanley coined the term "econophysics" to describe such research — two of Stanley's graduate students spotted a signature long tail in U.S. market data. The team analyzed every transaction for 1,000 stocks in the major markets, looking at how much the prices of those stocks changed and how often. The more than 200 million data points included a handful of extremes, causing the graph to splay outward.

Instead of dismissing such tails because they don't fit the models, researchers might need to rework the models because they don't fit the data, Stanley and others argue. "The model should really be driven by the data," he says. "For a physicist, there are no outliers. If I saw a glass of water float up in the air, we'd have to re-examine the law of gravity."

The late mathematician Benoît Mandelbrot, father of fractals, made a similar observation in the 1960s after examining variation in cotton prices. He later called the Gaussian distribution "a model child," one "which is commonly called 'normal,' but in fact deserves less and less to be considered as such."

Power up

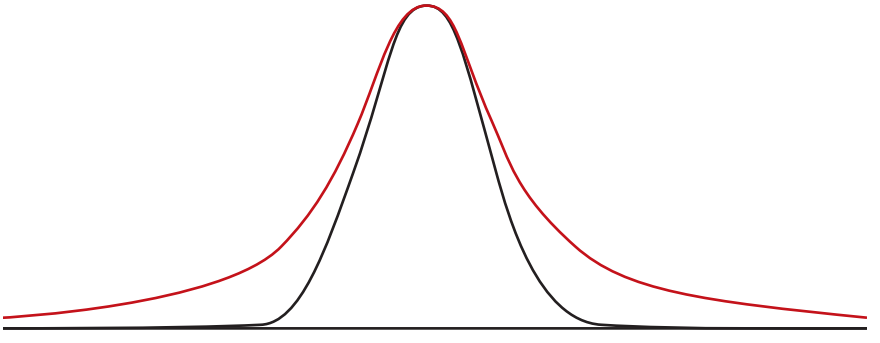
Long tails are a mathematical clue that a different kind of behavior may be at play, one that physicists have long been fascinated by. When data follow what is called a power law distribution, the outlandish data points that generate the tail aren't aberrant freaks; they fit right in.

A commonly cited power law, often referred to as Zipf's law, represents populations of towns and cities. While the majority of places people live are fair- to-middling-sized, a handful, such as New York City, have populations that are crazy large, so large that they are hard to fit with all the other towns and cities on a typical graph. To better visualize such distributions, researchers can analyze their data logarithmically — a mathematical sleight of hand that compresses the distance between the numbers. When a power law is at play, the plotted logarithms of the data don't skew awkwardly but fall on an elegant straight line.

A classic case of the power law in economics (although it has recently been disputed) is the distribution of wealth, described by Italian Vilfredo Pareto in 1896. The wealth of the richest people is orders of magnitude greater than that of the ordinary. *Forbes* put Bill Gates' net worth as of September at $59 billion; try fitting that on a traditional chart with everybody else's.

A new analysis of transactions on the S&P 500 share index and the German DAX Future stock market also uncovered power laws at work. As prices start to rise or fall, larger and larger chunks of stock are sold with greater and greater frequency, Stanley, Tobias Preis of Boston University and Artemis Capital Asset Management, and Johannes Schneider of Johannes Gutenberg University Mainz in Germany reported in May in the *Proceedings of the National Academy of Sciences*. The trade volume and the time between successive trades both exhibit power law behavior.

The researchers also observed a peculiar trait of power laws: They are



Spotting a tail Some models assume that financial data follow a typical bell curve (black), with data points clustered around an average and then tapering off quickly to either side. But a handful of extreme events can cause the curve to splay out in what is known as a long or fat tail (red).

"scale-free." Say, for example, that computer files 2 kilobytes in size are one-fourth as common as files of 1 kilobyte. Under a power law regime, file sizes of 2 megabytes would be one-fourth as common as those of 1 megabyte, and so on. Like Mandelbrot's fractal geometry of a coastline or cauliflower whorl, whether you view from afar or zoom in with a microscope, the proportions remain the same.

These data suggest to Stanley that global financial crashes and the bubbles that precede them aren't outliers. The same mechanisms that cause the smaller blips occurring in markets daily may also be generating bigger crashes.

Knowing that such extreme events will happen doesn't mean researchers can predict when, Stanley says. But acknowledging power law behavior may help investors and regulators pin the right number on risk. Having a power law distribution changes how often you'd expect to see an event sitting far from the data's average, a distance measured in "standard deviations." With a Gaussian model, an event that's 100 standard deviations out — so far out it's considered impossible — has a probability of about 1 in 10^{350}. With a power law distribution, that likelihood shoots up to 1 in 10^{8}, Stanley notes.

Farmer, who made a small fortune working in the financial sector throughout the 1990s, says knowing how often big events may hit is crucial for estimating risk: "You have to understand your tail."

Recent work by Farmer, Stefan Thurner of the Medical University of Vienna and Yale economist John Geanakoplos suggests that some investment strategies can actually create a power law long tail. Say you see an underpriced stock. You buy it, which normally would push the price up a bit. But if you're using leverage (borrowed money) to try to amplify your returns, and then the bank cuts you off, you might be forced to sell prematurely or sell off other assets. This selling can push prices down and then other outfits may sell too, because they see the price sliding.

"Heavy-tailed events can be caused by leverage," Farmer says. "It can create a crash." His team's simulations suggest that adding leverage to a market tips the distribution of price changes from a Gaussian to a power law distribution. And when banks cut off many borrowers to control risk, the situation can get worse, the team reported in 2009 in a Santa Fe Institute working paper.

Power laws in one area of the economy may lead to others, says economist Xavier Gabaix of New York University's Stern School of Business. The power law distribution of CEO pay may arise from the interplay between a phenomenon known as the economics of superstars and a power law that exists for firm size, he and colleague Augustin Landier, who is now at the Toulouse School of Economics in France, reported in 2008 in the *Quarterly Journal of Economics*. Even though there are only slight differences in talent within the cream of the crop, firms want the best CEO. Competition among large firms for really good CEOs can lead to huge differences in income, especially when some firms are supersized, the researchers contend.

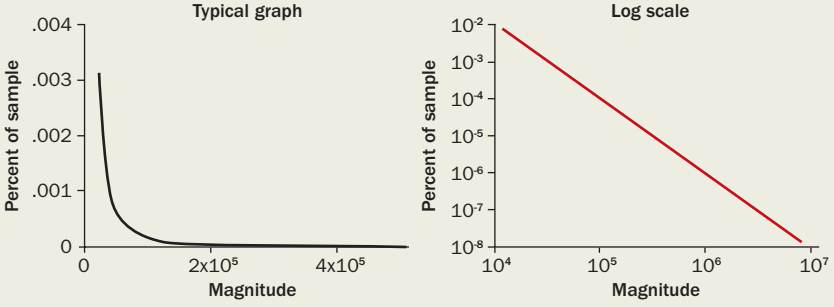
Another consequence of firm size's power law is that major events, such as an employee strike or the invention of the smartphone, don't dissipate gently through the market. When superlarge firms, such as Nokia, have huge successes or failures, these events can steamroll their way across an entire economy. In fact, such idiosyncratic shocks to the 100 largest U.S. firms may account for about one-third of the volatility seen in the whole market, Gabaix reported in May in *Econometrica*.

An eye on outliers

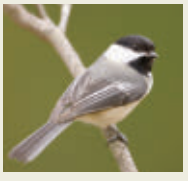
Some researchers argue that understanding the whole economic picture

A different distribution

When displayed on a typical graph, data that follow a power law distribution form a long tail (below, left graph). But graph the same data on a log scale and they fall onto a straight line (right). By applying several statistical tests, a recent analysis identified data sets that probably show power law behavior (bottom).

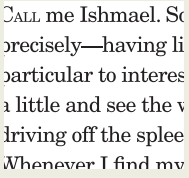


Power law behavior



The number of sightings of birds of different species in the North American Breeding Bird Survey in 2003

The intensity of wars 1816–1980, measured as number of battle deaths and adjusted for population size

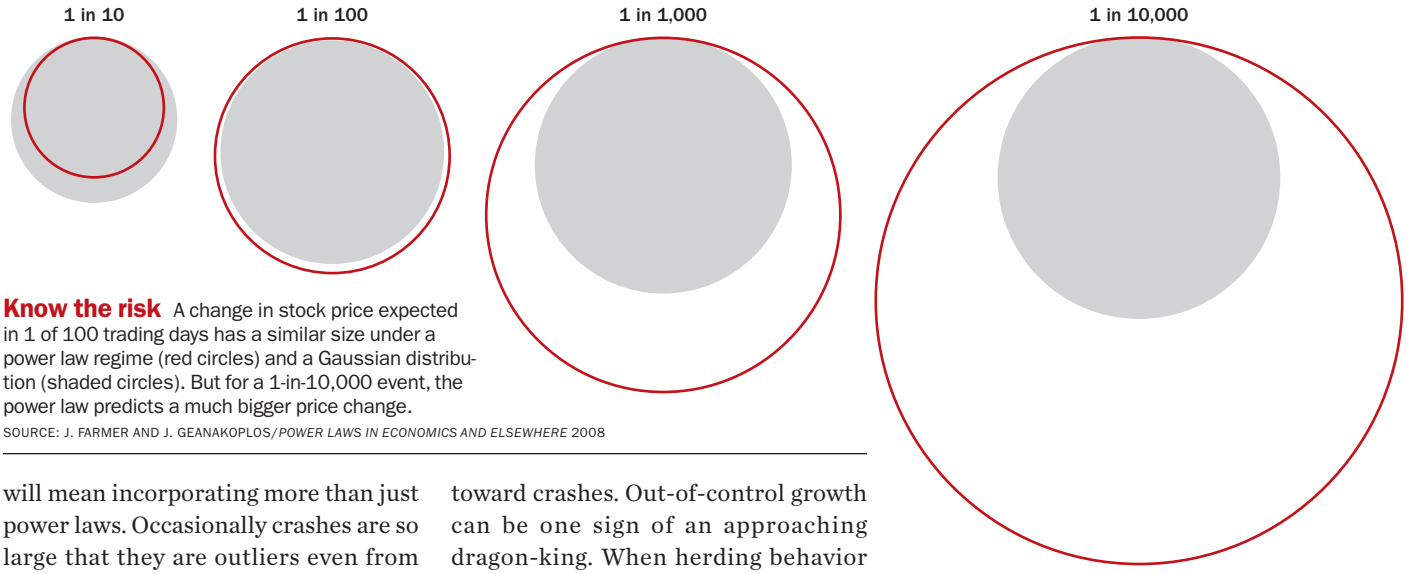


Frequency of occurrence of unique words in Herman Melville's *Moby Dick*

The number of adherents to religious bodies and sects, as published on adherents.com

SOURCES: M. NEWMAN/ARXIV.ORG 2006; A. CLAUSET, C.R. SHALIZI AND M. NEWMAN/ARXIV.ORG 2009

BIRD: KENCANNING/ISTOCKPHOTO; WAR: ARCHIVES.GOV/STILL PICTURE BRANCH (NNSP); HANDS: BRADLEYM/ISTOCKPHOTO



Know the risk A change in stock price expected in 1 of 100 trading days has a similar size under a power law regime (red circles) and a Gaussian distribution (shaded circles). But for a 1-in-10,000 event, the power law predicts a much bigger price change.

SOURCE: J. FARMER AND J. GEANAKOPLOS/*POWER LAWS IN ECONOMICS AND ELSEWHERE* 2008

will mean incorporating more than just power laws. Occasionally crashes are so large that they are outliers even from the power law distribution, says Didier Sornette of ETH Zurich. Their specialness makes them predictable, says Sornette, who calls the standout events "dragon-kings."

"Dragons are not like the ordinary animals you meet in the zoo," Sornette says. "They require new mechanisms, new biology to explain them." The "kings" part of the name refers to the fortunes of royal families, which after centuries of concentrating wealth have so much that they no longer even fit in Pareto's distribution of wealth.

"We believe that there are events that are in a class of their own," Sornette says. "While the power law distribution is a good characterization of the distribution of returns, it actually misses the elephant in the room, the dragon-king."

Sornette and his colleagues argue that understanding dragon-kings may help economists spot markets teetering toward crashes. Out-of-control growth can be one sign of an approaching dragon-king. When herding behavior among investors amps up, a stock's or index's growth rate can increase faster than exponentially, leading to more herding, Sornette says. This positive feedback among investors, the same sort of feedback that concentrates the wealth of kings, brings the system to a tipping point. About two-thirds of the time, a crash results, Sornette wrote in a 2009 paper online at arXiv.org.

Working out of the Financial Crisis Observatory at ETH Zurich, Sornette and his colleagues are now trying to use this aggressive growth as a signature to identify crashes before they happen (often encrypting the data so as not to influence the markets).

The researchers seem to be on to something. While other market watchers remained enthusiastic about the outlandish growth of the Shanghai Stock Exchange Composite Index into the summer of 2009, Sornette and his colleagues announced on July 10 that a downturn was coming. They predicted that the bubble burst would begin between July 17 and 27. It popped on July 29.

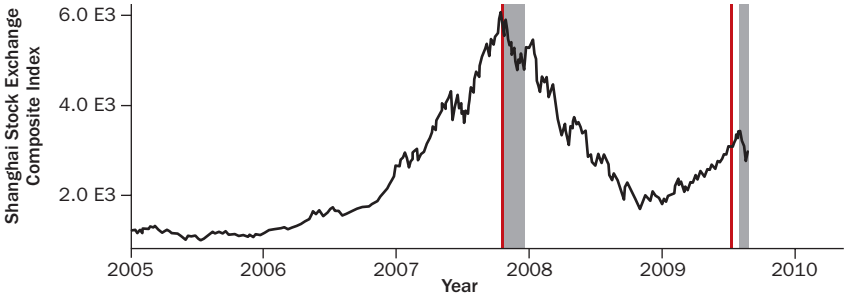
Though great strides are being made in understanding outliers, how to reconcile the newfound importance of seemingly freak events with traditional models based on stability and equilibrium isn't yet clear.

Many economists agree that current models grossly oversimplify things: "Almost no economists think that the Gaussian is a very good approximation of reality," Gabaix says.

But power law math is much messier than Gaussian math. Even figuring out where a power law distribution begins can be tough. Pareto's classic case of income probably follows a power law only in its tail, for example, with the wealth of the majority of the population based on labor for pay.

To keep things simple, models leave out a lot, Gabaix says. The key, and a very difficult thing, is making sure that the most important ingredients are included. "Power laws," he says, "are one of those intriguing facts that force people to write new theories that hopefully will explain them." ■

Event prediction A research team in Zurich was able to successfully predict two downturns in a Chinese market before they happened. Gray lines in the graph below show the expected range of dates predicted for the downturn; red lines show when the predictions were announced.



BOTTOM: Z.-Q. JIANG *ET AL./JOURNAL OF ECONOMIC BEHAVIOR & ORGANIZATION* 2010

Explore more

- For Sornette *et al*'s prediction papers: www.er.ethz.ch/fco

Lopped OFF

Removal of top predators trickles through the food web

By Nadia Drake

In July, the Ecuadorean navy helped apprehend a fishing vessel within the waters of the Galápagos National Park. On board lay the carcasses of 379 sharks — including threshers, hammerheads, Galápagos, blues and a mako. Nearly severed fins hung from the mutilated, slippery bodies. The fins were presumably destined for trade in Asian markets, where shark-fin soup can sell for more than $100 a bowl.

The incident is no aberration; these illegally slaughtered sharks are just the bloodied face of a global problem. Not even marine sanctuaries are immune.

But sharks aren't the only predators under siege. A host of carnivores perched atop food webs are being eliminated by humans, the real killing machines. Although marine species such as sharks are primarily caught for food, large terrestrial hunters (think lions, wolves and grizzlies) are often targeted for removal because they threaten humans moving into previously wild spaces.

"We're eliminating large predators very quickly around the world," says wildlife biologist Michael Soulé of the Wildlands Network, who works out of Paonia, Colo. "It's estimated that 90 percent are already gone."

These end-of-the-line carnivores, known as "apex consumers," can influence the lower rungs of their ecological ladders. By keeping the critters they dine on in check, the apex species affect the next rungs down, and so on. The system remains balanced as populations fluctuate in sync.

So when predators are plundered, the ripples spread farther than a person sipping shark-fin soup might ever imagine. Recently, scientists have been able to follow these ripples by comparing habitats with and without their apex consumers. The findings suggest that the effects can cross boundaries between land and sea, alter entire landscapes and even touch the smallest microorganisms and the Earth's chemical cycles.

Sharks are stripped from the seas for their fins (hammerhead fin shown), which are a delicacy in East Asia.

Beyond documenting such effects, scientists are working with conservation groups to reverse the changes brought by ecosystem decapitation. All agree that progress will be difficult as long as habitats continue shrinking and people continue yanking animals from the wild.

A wild laboratory

Though scientists have long known that apex consumers play important ecosystem roles, studying those roles is tricky. Nature isn't the easiest laboratory to work in: It doesn't provide rigorous experimental controls, and landscapes

JEFFREY L. ROTMAN/GETTY IMAGES

may take years, even decades, to reveal their bruises.

"Imagine looking out at an ecosystem that had wolves in it — just seeing a place with wolves — you wouldn't have any sense of the importance of wolves unless you took them out," says wildlife ecologist James Estes of the University of California, Santa Cruz, who outlined some of the consequences of losing predators in the July 15 *Science*.

Though researchers don't generally conduct such experiments, one removal study has been inadvertently set up in Yellowstone National Park.

By the early 1900s, western gray wolves had disappeared from most of their range in North America, hunted for bounty or eliminated as threats to livestock.

"In 1997, I learned that the aspen trees in Yellowstone were disappearing, and no one really knew why," says ecologist William Ripple of Oregon State University in Corvallis. So he headed to the park and studied the growth records preserved in the aspens' trunks. It turns out that most shoots stopped growing into large trees in the early 1900s, around the same time that wolves vanished. Ripple hypothesized that disappearing wolves and disappearing aspen were linked via an intermediate species.

When wolves weren't around, Yellowstone became stuffed with elk, a wolf's favorite meal. The big-antlered ungulates were damaging the park's vegetation as they leisurely chewed on young aspen trees, limiting the growth of woodland plants. And there was more. In winter, when food was scarce, the elk would starve and die; the population had exceeded its carrying capacity.

Ripple noticed a similar effect during studies in Utah's Zion Canyon. Some areas of the park are frequently visited by humans — and thus avoided by cougars — while others are relatively undisturbed. In areas where the big cats were scarce, deer flourished and limited the growth of cottonwoods. Where pumas were present, Ripple says, "we found more wildflowers, we found more butterflies, we found more lizards, we found more frogs and fish."

Ripple got the chance to test how the wolf, elk and aspen pieces fit together when wolves were reintroduced to Yellowstone in 1995.

"If our hypothesis is correct, we should start to see the trees growing again," he says. "And guess what? They are, but only in places." Ripple and Oregon colleague Robert Beschta have started noticing burgeoning plant communities in some areas of the park's northern reaches, where trees are just beginning to grow tall enough to escape munching elk.

In 2010 in *Restoration Ecology*, the team reported the re-emergence of cottonwood and willow; in an upcoming *Ecology*, they describe ongoing monitoring of 98 aspen stands and ascribe tree regrowth to the return of wolves.

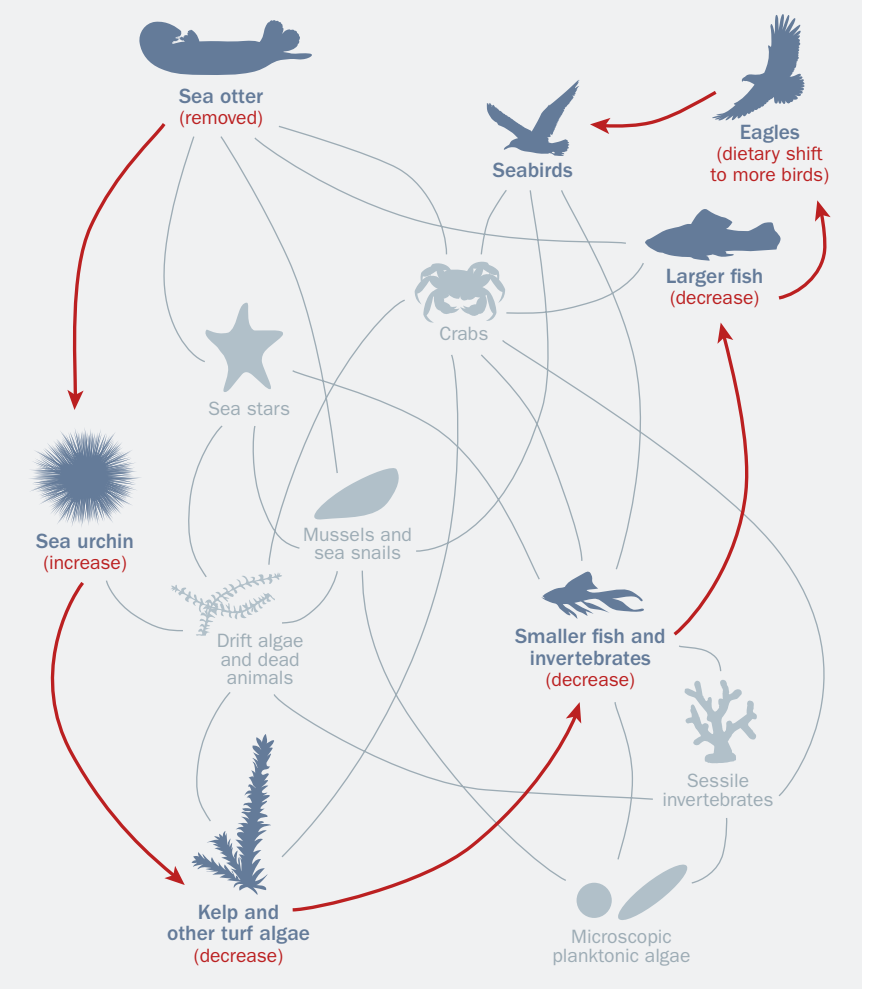
How widespread the recovery will be and how long it will take is not yet clear. Ripple estimates that it may be several decades before Yellowstone's vegetation returns to its former state. "The experiment in time continues," he says.

Tracing takeaway effects

Though sea otters may not have the snarl of a wolf or cougar, these furry marine mammals are also apex consumers. Normally pictured playing in kelp, otters are actually quite fierce. "Imagine a hundred-pound weasel, but cute," Estes says. "Looks are very deceiving."

In *Ecology* in 2008, Estes and

Ripply removal When otters are removed from their food web (portion shown here), the effects spread to many other organisms (as shown by red arrows). Studies have found that removing otters leads to an upswing in sea urchins, a drop in kelp populations and thus fewer fish. With fewer fish in their diets, eagles dine more heavily on seabirds.



SEA OTTER: TRU/ISTOCKPHOTO; SEA STAR, CRAB, SEA URCHIN: HELEN CINGISIZ/SHUTTERSTOCK; EAGLE: ABRAKADABRA/SHUTTERSTOCK; SEA BIRD: BAMBUH/SHUTTERSTOCK; LARGER FISH, SMALLER FISH: POTAPOV ALEXANDER/SHUTTERSTOCK; DRIFT ALGAE, KELP: PAVLOVIC A/SHUTTERSTOCK; SESSILE INVERTEBRATES: JR TRICE/SHUTTERSTOCK; MUSSELS, PLANKTONIC ALGAE: T. DUBÉ

colleagues attributed a curious observation to the decline of the otters: Bald eagles soaring over windswept southwestern Alaska were preferentially eating seabirds, rather than their usual, more fishy feasts.

Like Ripple's wolf investigations, Estes' work has looked at comparable Alaskan ecosystems both with and without sea otters. When otter populations began to recover in the early 1900s following their collapse due to the fur trade, they recolonized only some remote Alaskan islands. Differences in otter presence among the islands gave researchers an opportunity to look at how the marine mammals affect nearshore environments.

Then, in the 1990s, otter populations unexpectedly plunged because killer whales began preying on them. The drop allowed Estes to define the otter's role in the rugged Alaskan ecosystem in much more detail.

When otters are present, they limit sea urchin numbers, keeping kelp forests intact. Without otters, sea urchins flourish, munching at the base of stories-tall kelp fronds and deforesting the underwater coastal world. Less kelp means fewer fish, and fewer fish, Estes and his colleagues found in a series of follow-up investigations, means hungry eagles. So the eagles turn to seabirds for sustenance.

Because kelp are primary photosynthesizers, less kelp also means the oceans absorb less atmospheric carbon, unpublished work has revealed. "Otters have a significant effect of drawing down carbon dioxide," Estes says. "It's a very deeply interconnected system."

Estes could trace these far-flung impacts because he'd been on the trail since the 1970s. Darcy Ogada is documenting a similar interconnectedness over a shorter timescale. She studies African landscapes in the presence and absence of vultures.

Though mostly known for being nature's trash collectors, vultures' position as apex consumers might mean that they have a crucial part to play in limiting the spread of disease among wild populations, says Ogada, a conservation biologist based outside Nairobi, Kenya, and the Peregrine Fund's assistant director for Africa programs. The hypothesis is supported by reports from India, where roughly 97 percent of the country's vultures have disappeared since the 1990s. In their absence, rotting carcasses became putrid banquets for feral dogs, which carry and spread rabies.

In Kenya, vultures are declining in part because they're being poisoned, an unintended consequence of farmers aiming to remove the threat to livestock from another apex species, lions. Animal carcasses laced with "lion killers" — agricultural pesticides meant to poison marauding felines — are also eaten by vultures, which flock to the toxic carcasses and feast in large groups.

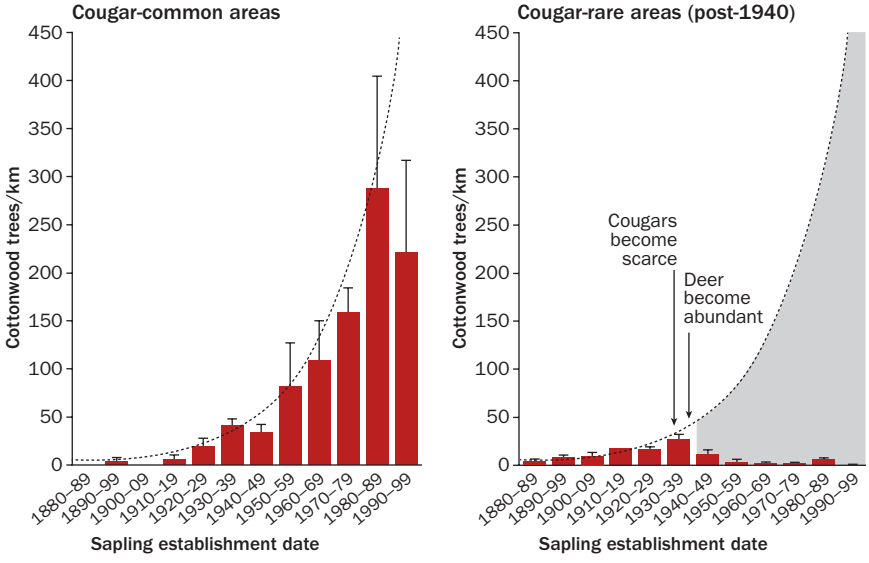
"If people are poisoning lions, then vultures are being hit a hundred times more," Ogada says. "Nothing really competes with them in terms of scavenging. They can cover more land area and arrive faster."

In Kenya's Laikipia district, Ogada says, vulture populations have dropped by 60 to 70 percent in the last decade or so. In 2010, Ogada published a study in the *Journal of Raptor Research* describing a 48 percent decline in just one year. "The situation is not good," she says.

To learn how these scavengers fit into the Kenyan savanna ecosystem, Ogada compared carcasses with and without vultures and found that decomposition took three times as long when the feathered feasters weren't around, turning the savanna into the equivalent of a stinky city street when the garbage collectors are on strike.

She noticed that mammalian scaven-

Cougar-cottonwood connector In some areas of Utah where people tread, cougars have become scarce. Compared with lands where the cats roam, the cougarless spots have fewer cottonwoods (graphs), a shift linked to an increase in grazing deer. Riverbanks without cougars thus have less vegetation and more erosion (bottom photo, compared with top).



GRAPHS: W.J. RIPPLE AND R.L. BESCHTA/*BIOLOGICAL CONSERVATION* 2006; PHOTOS: W.J. RIPPLE

gers such as hyenas and jackals visited more frequently and stuck around longer when the vultures were gone. "There was a threefold increase in the number of contacts between these animals," Ogada says. "So the problem, potentially, is that these carcasses could become focal centers for disease transmission."

Take some rotting, microbe-slathered meat, up the number of animals feeding from it and spice the situation with rabies or canine distemper, and you have a recipe for yuck.

"It's actually really gross when vultures aren't around," says ecologist Felicia Keesing of Bard College in Annandale-on-Hudson, N.Y. Keesing and Ogada now plan to study disease transmission rates around vultureless carcasses.

Bringing big ones back

Like the vultureless savanna, a sharkless ocean may also have the potential to mess with microbial activity.

Marine ecologist Stuart Sandin studies sharks and large fish living around neighboring coral reef ecosystems in the Pacific Ocean, some of which are heavily fished by humans. The Line Islands include both protected, unfished areas, such as Kingman Reef and the Palmyra atoll, and inhabited islands such as Kiritimati (also known as Christmas). In these reefs, Sandin monitors species abundance, the amount of junk in the water and coral health.

In 2008, he and his colleagues reported that microbial populations in waters surrounding inhabited islands were 10 times higher than those in undisturbed waters. Since then, Sandin has linked the microbe-mottled waters, which also host an increased number of pathogenic organisms, to the loss of large reef inhabitants, including sharks.

Diving near the untouched reefs is shocking, Sandin says, since the vast majority of science has been done in seas where big animals are already gone. In fished areas, he says, "it's actually really special when you're diving or snorkeling and you see an animal that's bigger than a meter long."

In *PLoS ONE* in June, Sandin's team described the effects of predator scarcity on prey populations swimming in Kiritimati waters: Most prey species studied grew bigger and lived longer, while remaining big predators were smaller than on untouched Palmyra. The team also noticed that islands with big fish and big predators intact had healthier corals and less algae — a crucial player in the cultivation of microbe-laden waters.

"It's actually really special when you're diving or snorkeling and you see an animal that's bigger than a meter long."

STUART SANDIN

Sandin hypothesizes that removing large reef residents such as sharks, parrot fish and surgeonfish can clear the way for smaller herbivores to proliferate, because of decreased predation and competition. In studies comparing Kingman Reef with Kiritimati, Sandin saw a 60-fold increase in the number of damselfish tending to algal gardens in the absence of bigger fish. The gardens, familiarly known as seaweed, can compete with corals and suppress their growth.

Eventually, Sandin says, the seaweed's unchecked growth dumps extra sugars into the surrounding water. Bacteria like sugar, and their populations compete. Over time that competition can select for hardy pathogens.

"You can end up with a nasty microbial consortium," Sandin says — bad news for corals, algae and fish.

Sandin estimates that 75 percent of Pacific reefs have been affected by humans, but says that maybe only 10 percent are beyond help. The others could be restored to their former numbers by limiting the fishing of predators or large herbivores. Leaving the reefs alone will let such species, which have longer life cycles, survive.

This approach works in the water where humans don't live, but conservation on land requires a different take. Because people often figuratively butt heads with wild animals, re-establishing species that are missing from their ancestral habitats — a process known as "rewilding" — is controversial. Still, returning areas to their original state has some precedent; it has been done successfully, most notably in Yellowstone with the return of the gray wolves.

But simply boosting animal numbers isn't enough. They need space, and they need cooperation from nearby humans.

National parks, while a good start, aren't sufficient, says Peter Kareiva, who is chief scientist for the Nature Conservancy and works out of Seattle. "Protected areas might be good for capturing plants, but you can't get enough land locked up in nature reserves for mountain lions, wolves or grizzlies," he says. Predators aren't going to stay within park or sanctuary boundaries, meaning their survival depends on cultivating tolerance and respect among people living nearby.

"There's something really beautiful about hearing wolves at night," Kareiva says. "The sense of wild that a grizzly conveys, it's humbling. I think wildlife and humans can coexist, but certainly it's not an automatic process."

Establishing predator-friendly ranchlands in the areas around national parks, for example, might help predators struggling to find space by expanding protected areas and offering corridors of connectivity between those habitats.

If predators are able to do what predators do (taking care of their ecosystems by eating stuff), the end result will be a healthier environment — even if it means that people living in areas currently drenched with deer have to get used to living with cougars again.

Says Kareiva: "If you could restore the balance of ecosystems — look at how many deer there are in the Northeast, and what a big problem they create for homeowners and everybody — would it be so bad if cougars came back?" ■

Explore more

■ J.A. Estes *et al*. "Trophic downgrading on planet Earth." *Science*. July 15, 2011.

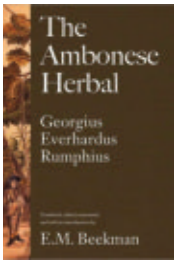
The Ambonese Herbal

Georgius Everhardus Rumphius; translated by E.M. Beekman

Anyone who has slogged through some prolonged, hope-sucking endeavor to get published may wish to toast the first full English translation of this storied herbal. The six-volume botanical masterpiece from the 17th century still has things to say to modern readers, as well as to long-suffering writers. In fact, the book inspired a 2005 pharmacology paper reporting nine novel compounds for further drug research.

The herbal's writer, German-born Georg Eberhard Rumf (Latinized as Rumphius) shipped off to the Spice Islands in what is now Indonesia in 1652 to work for the Dutch East Indies Company on its spice route. (For a taste of spice politics, see translator Beekman's detailed introduction in Volume One and lively footnotes throughout.)

Rumf took up documenting natural history on the island of Ambon. His herbal includes descriptions, medical uses and cultural lore on plants from pomegranates to the tree of blind eyes. He persevered despite going blind himself in his early 40s, losing his wife and a daughter in an earthquake and tsunami, and then losing all his drawings when his house caught fire. He had the drawings redone and five years after the fire sent half the manuscript to Europe. The ship carrying it sank.



In 1697, after 37 years of work, Beekman estimates, the manuscript reached company headquarters. The company, concerned about trade secrets, forbade publication. The volumes were eventually published, in Dutch, beginning in 1741.

Beekman, a Dutch scholar, died before his translation was published. He deserves a toast, as does the remarkable Rumf and — why not — all who have struggled to reach the end of that far-away last sentence. — *Susan Milius*

Yale Univ. Press and National Tropical Botanical Garden, 2011, Vol. I: 548 p., $85; Six-volume set: 3,360 p., $450

The Viral Storm: The Dawn of a New Pandemic Age

Nathan Wolfe

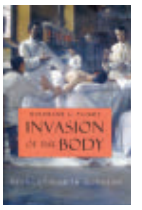
If you thought Ebola was scary, just wait. Wolfe, a pandemics expert who has traveled to the sources of HIV and other deadly viruses deep in African forests, says that lots more nasty pathogens, ones you've never heard of, are out there. They're lurking in monkeys, in bats, in animals that will be hunted and slaughtered and eaten. And when that happens, some of those bad boys will literally go viral.

Wolfe makes a convincing case for the threat, first walking readers through a world seen from the perspective of viruses and showing how they infect and spread. Next he shows the developments in human evolution and culture that have made pandemics not only possible, but inevitable. (You'll never look at roads quite the same way.)

Wolfe's own research has demonstrated the role of hunting and eating wild game in introducing new diseases into the human body. The more closely related hunter and hunted are, the more likely a microbe will be able to adapt to its new host. Already, as Wolfe details in scenes practically scripted for the next epidemic thriller, humans have picked up Nipah virus from pigs, HIV from chimps and Ebola (probably) from bats.

In later chapters, Wolfe details his work establishing monitoring networks aimed at catching pandemics before they start. This effort is in its infancy, but it couldn't get better advertising than it does here. Sometimes the scariest thrillers are those that could play out in real life. — *Erika Engelhaupt*

Times Books, 2011, 304 p., $26



Invasion of the Body

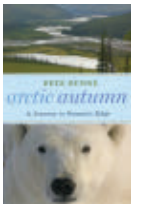
Nicholas L. Tilney

The history of modern surgery is revealed through tales of surgical breakthroughs at a Boston teaching hospital that opened in 1913. *Harvard Univ. Press, 2011, 358 p., $29.95*

A Bee in a Cathedral

Joel Levy

One hundred analogies and metaphors make science more visual: Learn how chemical reactions are like school dances and how long it would take to type the human genome. *Firefly Books, 2011, 224 p., $29.95*



Arctic Autumn

Pete Dunne

A naturalist shares memories and pictures of travels through some of the most dramatic wilderness in the Northern Hemisphere. *Houghton Mifflin Harcourt, 2011, 258 p., $24*

The Fact of Evolution

Cameron M. Smith

An anthropologist explains how evolution occurs and why it must for life to survive on an ever-changing planet. *Prometheus Books, 2011, 346 p., $18*

The Face of the Earth

SueEllen Campbell

An English professor takes readers on a poetic exploration of geology, aided by essays from scientists and other writers. *Univ. of California Press, 2011, 320 p., $26.95*

How to Order To order these books or others, visit www.sciencenews.org/bookshelf. A click on a book's title will transfer you to Amazon.com.

Bull's-eye targeted

On the picture in "Galactic bull's-eye" (*SN: 9/24/11, p. 10*), I am quite puzzled. Do my eyes deceive me, or is there another bull's-eye galaxy behind the first, located at the 1 o'clock position?

How is this possible? Are these strange objects magically clustered along some line pointing towards us?
Jeff Brewer, Newton Centre, Mass.

It is peculiar that another ring-galaxy–like object would appear in the background, and in fact the Hubble Heritage Team noted its odd appearance. It's possible, but not probable, that the object is another Hoag-like object. There could also be material obscuring the view of the rest of the galaxy, hiding its true shape. Either way, there's no sign of ring galaxies being aligned in the sky. The astronomer who created the image wrote a detailed article on Hoag's Object and other ring galaxies, available at bit.ly/ringgal. As he explains, there's a diversity of ring galaxies across the cosmos. —Camille M. Carlisle

The upside of stress

Regarding the article "Early stress can be contagious" (*SN: 9/24/11, p. 14*), I never thought of birds being stressed out, but I suppose they could be singing sad songs. I agree that two people from stressed backgrounds is not a good match. But I think everyone's childhood is dosed with some difficulties; isn't it how we learn and grow? If every stressless person married another stressless person, and they produced stressless offspring, it might generate a rather smug society.
Margy Friedland, Manitowoc, Wis.

Early bird on dinosaurs

"Dinosaur-era feathers sealed in amber" (*SN: 10/8/11, p. 5*) mentions "the notion, first proposed in 1868, that modern birds evolved from ... theropod dinosaurs." Who was the prescient individual who proposed this notion only nine years after the publication of *Origin of Species,* and where can I find something by or about him?
William Check, Evanston, Ill.

That would be English zoologist Thomas Henry Huxley. Modern paleontologists cite two Huxley papers, published in 1868 and 1870, as proposing that birds originated from dinosaurs. —Susan Milius

Cancer treatment questioned

I read the article "Tumor tell-all" (*SN: 9/24/11, p. 18*) with interest, as I've always believed that cancer is unique in each individual. The case study of the 78-year-old man with a rare tumor and huge genetic flaws who was given multiple courses of drugs that initially shrunk the tumors but ultimately led to more mutations was especially disturbing. The researcher's speculation that "only a carefully concocted cocktail of drugs would have stopped the cancer" seems horribly flawed. If genetic mutations equal cancer and genetic mutations plus drugs equal more genetic mutations, then logically cancer plus drugs equals more cancer. Perhaps the answer lies is discovering the underlying causes of the mutations and stopping them using the body's ability to heal itself.
Althea Greaney, Simsbury, Conn.

The drugs didn't cause the man's additional mutations. Cancer mutates rapidly, and the changes probably would have arisen regardless of treatment. The drugs, by halting or slowing growth of some cancer cells, may have left room for small groups of already mutated or newly mutated cells to take over the tumor. A drug cocktail might have fought many different mutations. It would be nice to correct the underlying mutations responsible for tumors, but gene therapy for cancer is not yet practical. Identifying genetic risk factors may eventually lead to better cancer-prevention strategies. —Tina Hesman Saey

Thanks for rationality

I am a longtime subscriber, and I just wanted to send my special thanks to your editor in chief for his excellent editorial "Communicating science encourages cooperation" (*SN: 7/30/11, p. 2*). For some time, I have been compiling quotations that speak to the rational side of humans. The following paragraph in the editorial eloquently states the case: "Unified by the common language of mathematics and the unwavering lawfulness of natural phenomena, scientific findings transcend the cultural divides that typically permeate politics, religion, social mores and national customs. Everyone on Earth shares the same physics, the same biology, the same chemistry and the same planet. Scientific knowledge provides the common ground needed for the peoples of the world to live peacefully together. At least it could in principle."
Richard Holford, Denville, N.J.

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From the Archive

Olive oil injections aid in treating pneumonia

Success in treatment of pneumonia with olive oil has just been announced by Drs. A. C. Frazer and V. G. Walsh of St. Mary's Hospital Medical School in London.

The oil is emulsified and then injected into the veins. The high temperature of pneumonia patients dropped to normal within twenty-four hours after the oil injection and three weeks later the patients were well.

Patients suffering from septicaemia, commonly known as blood poisoning, and from erysipelas and acute rheumatism also improved after the olive oil treatment.

The emulsified olive oil injections also seem to prevent the reactions which frequently follow injection of vaccines, tuberculin and insulin, making it possible to use much larger doses of these substances.

The remarkable effect of the olive oil is considered due to absorption of the pneumonia or other toxins circulating in the blood. These poisons lose their potency after adhering to the globules of the oil.

Drs. Frazer and Walsh first conducted test tube experiments with emulsified olive oil and the toxins of the diphtheria germ and tetanus or lockjaw. Then they investigated the effect of the olive oil of animals infected with these germs. Finally it was tried, with success, on patients.

Before antibiotics, treating pneumonia (shown in this colorized X-ray) was a varied affair—but the approaches weren't unscientific.

UPDATE

Oil idea wasn't so odd, at the time

At first thought, injecting emulsified olive oil into your veins sounds downright dangerous. But pausing to consider context can make a crazy concept seem almost sane.

In the early 1900s, pneumonia was a leading cause of death in the United States. Without antibiotics (not widely available until the 1940s), there was no magic bullet. So it's no wonder researchers were experimenting. But A.C. Frazer and V.G. Walsh weren't just trying out treatments willy-nilly. Their oil approach had some scientific roots.

"It doesn't strike me as strange," says Harvard's Scott Podolsky, author of *Pneumonia before Antibiotics*. "It kind of looks like contemporary medicine."

Serotherapy, a popular treatment by the 1930s, involved injecting animal-derived antibodies to a specific strain of bacteria into people. The tactic required some level of immunological know-how. Likewise, the idea of using oil to sop up nasty bacterial by-products for detoxification in the liver depended on an elevated understanding of how the body fights and clears invaders.

If the oil idea still sounds outlandish, consider that penicillin, the first therapeutically useful antibiotic, was referred to as "mold juice" following its discovery by Alexander Fleming. In a not-so-incidental twist, Fleming also worked at St. Mary's Hospital Medical School, probably in a lab just down the hall from Frazer and Walsh. —*Elizabeth Quill*

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Finally, a cell phone that's… a phone

"Well, I finally did it. I finally decided to enter the digital age and get a cell phone. My kids have been bugging me, my book group made fun of me, and the last straw was when my car broke down, and I was stuck by the highway for an hour before someone stopped to help. But when I went to the cell phone store, I almost changed my mind. The phones are so small I can't see the numbers, much less push the right one. They all have cameras, computers and a "global-positioning" something or other that's supposed to spot me from space. Goodness, all I want to do is to be able to talk to my grandkids! The people at the store weren't much help. They couldn't understand why someone wouldn't want a phone the size of a postage stamp. And the rate plans! They were complicated, confusing, and expensive… and the contract lasted for two years! I'd almost given up when a friend told me about her new Jitterbug phone. Now, I have the convenience and safety of being able to stay in touch… with a phone I can actually use."

The cell phone that's right for me. Sometimes I think the people who designed this phone and the rate plans had me in mind. The phone fits easily in my pocket, and flips open to reach from my mouth to my ear. The display is large and backlit, so I can actually see who is calling. With a push of a button I can amplify the volume, and if I don't know a number, I can simply push "0" for a friendly, helpful operator that will look it up and even dial it for me. The Jitterbug also reduces background noise, making the sound loud and clear. There's even a dial tone, so I know the phone is ready to use.

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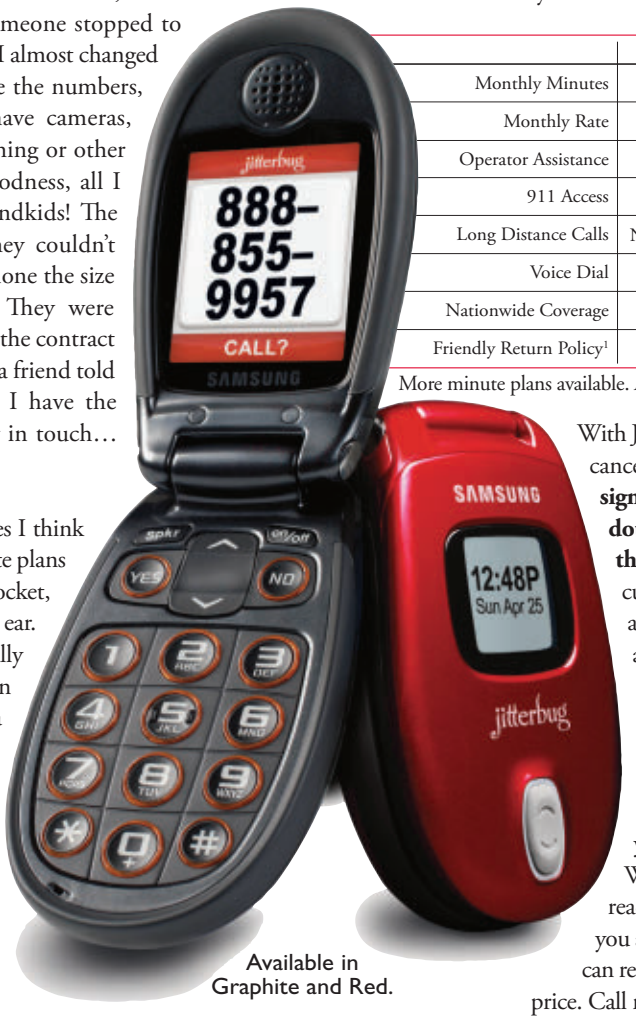

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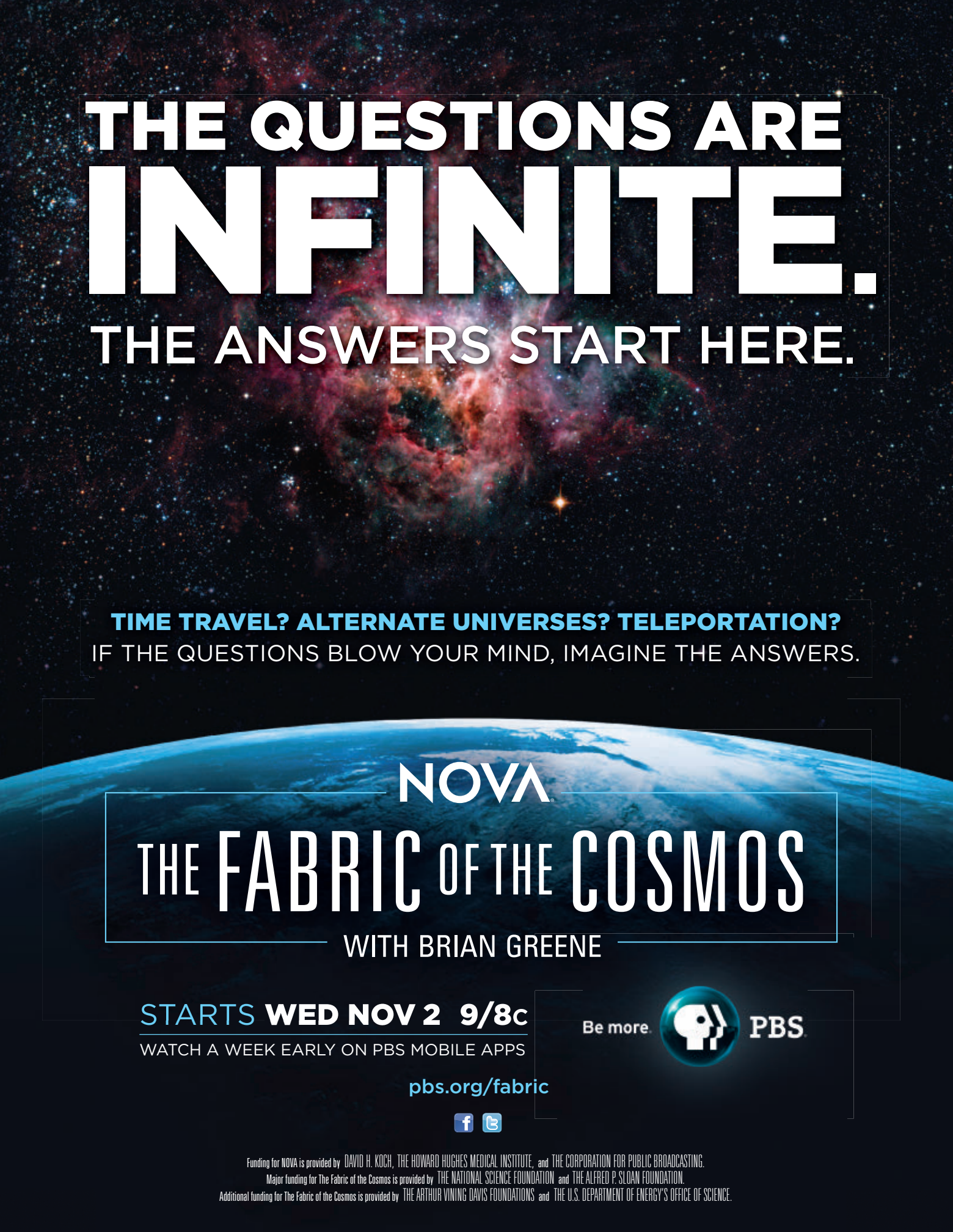
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