Gravity as Entropy | Kin Selection Skirmish | Wheat's Archenemy

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ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ SEPTEMBER 25, 2010

Volcanoes on Ice

Magma meets its polar opposite

Iceman's Ceremonial Send-off

New Hope in Fight Against Melanoma

Cooling with a Quantum Fridge

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This is my story

I used to be more active. I used to run, play basketball, tennis, football… I was more than a weekend warrior. I woke up every day filled with life! But now, in my late 30's, I spend most of my day in the office or sacked out in front of the TV. I rarely get to the gym – not that I don't like working out, it's the nagging pain in my knees and ankles. Low energy and laziness has got me down. My energy has fizzled and I'm embarrassed to admit that I've grown a spare tire (I'm sure its hurting my love life). Nowadays I rarely walk. For some reason it's just harder now. Gravity has done a job on me.

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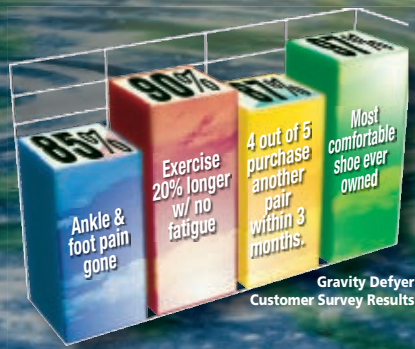

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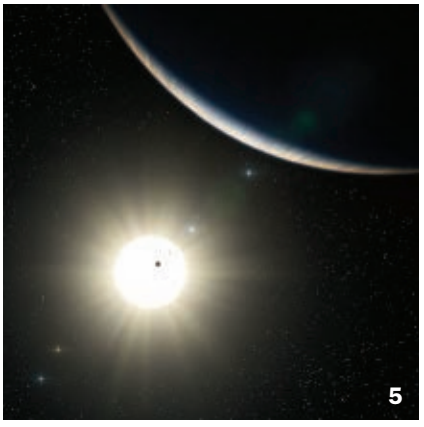

ScienceNews

In The News

Features

Essay

Departments

COVER Lava fountains gushed from an exposed Icelandic ridge called Fimmvörðuháls in March. By mid-April, the eruption had moved west to Eyjafjallajökull.
© Arctic-Images/Corbis

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FROM THE EDITOR

Staying on the lookout for rumors disguised as news

It was big news in late August when U.K. scientists reported cataloging wheat's complete genetic repertoire, or genome. But it shouldn't have been. Basing their accounts on an overzealous news release, various news organizations jammed the information superhighway with headlines announcing the supposed accomplishment. But close reading revealed no evidence of publication in a scientific journal. Why not? Because the wheat genome had not actually been assembled after all, as Rachel Ehrenberg described in a blog on the *Science News* website a few days later (http://bit.ly/a2vlqy).

Rachel knew the reports were overblown because she had been in communication with many of the world's leading wheat experts while preparing her account of the threat to wheat crops from fungal pathogens known as rusts (see Page 22). Those experts desperately desire a fully sequenced wheat genome; such knowledge would speed up efforts to find genetic variants resistant to the rusts' attacks. But as Rachel's article notes, the U.K. scientists have simply taken an important first step in collecting many chunks of the wheat genome that must still be reassembled in the right order (a formidable task).

Providing informed perspective on such issues is a responsibility that *Science News* takes seriously. It's a somewhat contrarian strategy in today's media climate, with lax reporting afflicting many blogs and even some news outlets, as another recent case illustrates. In August, a blogger for a tech website wrote that a paper in *Nature Physics* overthrew the Heisenberg Uncertainty Principle. Supposedly, a quantum memory device could store information allowing precise prediction of both a particle's position and momentum. To the eye of an untrained (in journalism) blogger, that meant that Heisenberg's principle was violated. But to *Science News* reporter Laura Sanders, it meant it was time to write a blog post of her own (http://bit.ly/a8ZB77). Laura consulted one of the paper's authors (standard journalistic procedure) and ascertained that Heisenberg's principle remained as certain as ever. (Yes, you can store information about both position and momentum, but if you read out one, you can't read out the other.)

Of course, science journalism is a difficult endeavor, and even at *Science News* we sometimes fall short of discerning every nuance and detecting every deficiency in our reporting. But it's not for lack of making the effort, or thinking it doesn't matter. It does. —*Tom Siegfried, Editor in Chief*

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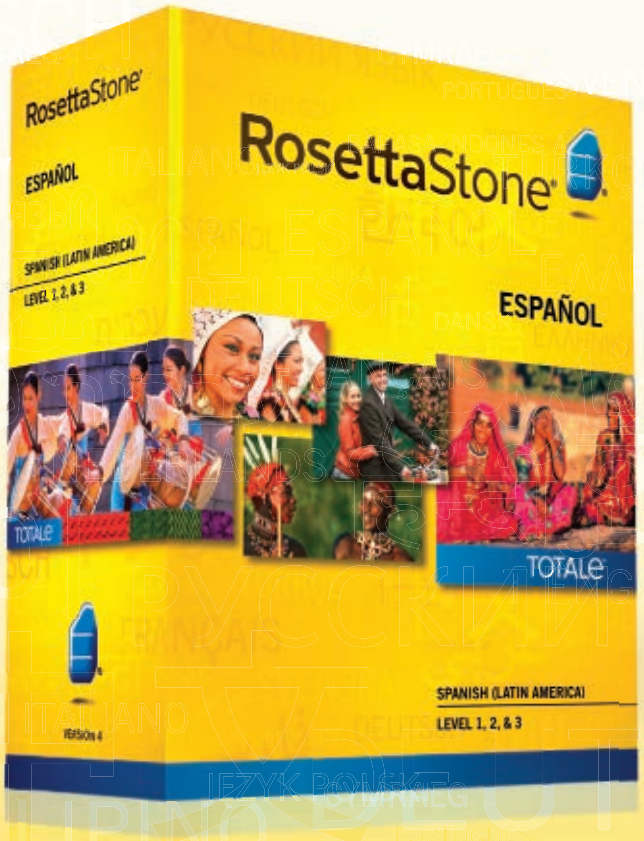

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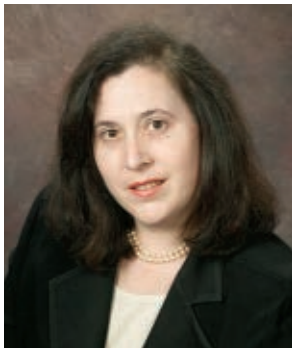

Scientific Observations

"Some in the genetics community would like to draw a line between 'legitimate' tests offered by clinical laboratories and [direct-to-consumer] genetic tests. But such a distinction is likely to prove illusory. Any test performed on a blood or saliva specimen could, in theory, be offered directly to consumers, and many such tests have already been well validated, including those for diagnosing classical Mendelian disorders such as sickle-cell anemia and cystic fibrosis.... In reality, the problems popularly associated with genetic tests go beyond DTC testing. Insufficient oversight is in place to ensure the clinical validity of at least some of the newer, more complex tests offered by both DTC companies and clinical laboratories. Also, for many genetic tests, neither health-care providers nor the public has access to enough information to properly interpret test results."

—BIOETHICIST GAIL JAVITT OF JOHNS HOPKINS UNIVERSITY IN THE AUG. 12 *NATURE*

Science Past | FROM THE ISSUE OF SEPTEMBER 24, 1960

SCLEROSIS AND COSMIC RAYS — Radiation bombarding the earth from space may be a factor in the occurrence of multiple sclerosis, the Harvard University neurologist Dr. John S. Barlow believes.... Dr. Barlow's statistical study of the distribution of multiple sclerosis shows that the frequencies of occurrence of the disease vary systematically with geomagnetic latitude. The intensity of cosmic radiation is the only phenomenon known to be related to geomagnetic latitude.... [The disease] is much more common in the northern parts of Europe and North America than in the southern areas; and it is extremely rare in the Orient, South America, Africa, the tropics or subtropics.

Science Future

September 25
Free admission day to 17 museums in Houston. See www.houstonmuseumdistrict.org

September 30
Peter Gleick gives an evening talk in San Francisco on *Bottled & Sold*, his book about the bottled water industry. Ages 21 and up. See www.calacademy.org

October 4–6
Nobel Prizes announced for medicine or physiology, physics and chemistry. Go to http://nobelprize.org

SN Online

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ATOM & COSMOS
Scientists claim a physical constant isn't so steady, but colleagues question the evidence offered. See "Changing one of nature's constants."

GENES & CELLS
Clues to differences in ants' social behavior and life span may be found in their genes. Read "Unraveling ant genomes yields high hopes."

BODY & BRAIN
When sleep isn't an option, fasting may fight grogginess. See "Why starved flies need less sleep."

MOLECULES
Pine trees produce an important ingredient for antiflu drugs. Read "Evergreen source of Tamiflu."

TECHNOLOGY
Past mistakes can be erased, with help from a handheld spectrometer. See "New help for greasy works of art."

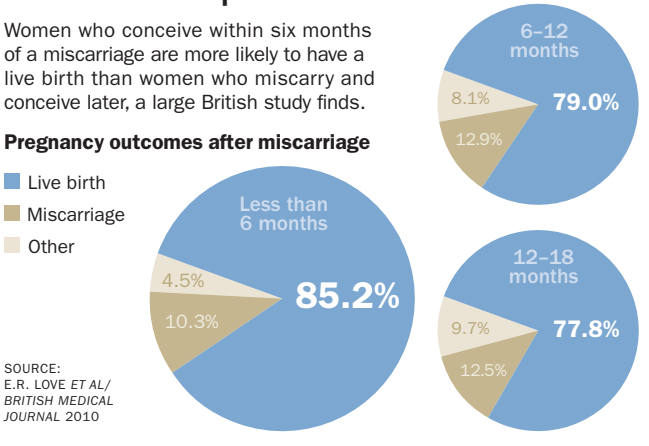
How Bizarre

Seawater's color can control cyclone winds. A new study by Anand Gnanadesikan of Princeton University and his colleagues found that chlorophyll concentrations at the ocean's surface affect the formation of typhoons in the North Pacific. Clearer seawater, which looks blue, has less chlorophyll near the surface to absorb and scatter light, meaning the water's surface stays cooler than greener water would. Simulations from the team's model showed that eliminating all absorbing and scattering materials from the North Pacific subtropical gyre would cause a temperature change that would decrease northwest cyclone activity by roughly 67 percent. The change would also, however, concentrate typhoons near the equator.

Science Stats | FAMILY MATTERS

Women who conceive within six months of a miscarriage are more likely to have a live birth than women who miscarry and conceive later, a large British study finds.

Pregnancy outcomes after miscarriage



SOURCE: E.R. LOVE *ET AL*/ *BRITISH MEDICAL JOURNAL* 2010

CLOCKWISE FROM TOP LEFT: BOB STEIN; JÜRGEN LIEBIG; T. DUBÉ

“Kids can look so rapt when they watch these videos that parents may think that attention equals learning, when clearly it does not.”
—ROBERTA GOLINKOFF, PAGE 15

In the News

STORY ONE

Astronomers get closer to finding faraway Earths

Two planetary systems offer new clues on planet formation

By Ron Cowen

Only a few years ago, astronomers were thrilled if they found a star beyond the solar system harboring a single planet. Now they're discovering more and more multiple-planet systems that may offer new clues about the formation of planets and their evolution.

In one new study, scientists have discovered a star with at least five and as many as seven planets, which would make it the richest known planetary retinue beyond the solar system. A second study has revealed a star with two roughly Saturn-mass planets locked in a special gravitational embrace that allows astronomers to study the pair in unusual detail. Researchers have also found hints of a third planet orbiting with the two that, if confirmed, would be the tiniest extrasolar orb known, with a diameter only about 1.5 times that of Earth.

With these multiple-planet systems, "we're entering a new era of exoplanets," says theorist Sara Seager of MIT. Instead of focusing on individual discoveries, she adds, "we're moving on to complex planetary system architectures and the hope of being able to understand how they got that way."

AMES, JPL/NASA

A newly discovered star system containing two Saturn-sized planets (artist's depiction) may also harbor a smaller orb with a diameter about 1.5 times that of Earth.

Using NASA's Kepler spacecraft, Matthew Holman of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass., and his colleagues found two planets orbiting a dim sunlike star, dubbed Kepler-9, about 2,100 light-years from Earth. Each planet blocks a tiny amount of starlight when it transits, or passes across the face of the star.

Kepler-9 is the first system confirmed to have more than one transiting planet. What's more, the two planets have migrated into orbits that have a special gravitational synchrony—every time the outer planet makes one lap around Kepler-9, the inner planet makes two, Holman and his collaborators report online August 26 in *Science*.

During seven months of observations, Kepler not only measured dips in starlight, which reveal the planets' diameters, but also found that the transit time of each planet varied by minutes due to the orbs' mutual gravitational tug.

Holman and his collaborators used the timing variations to determine that both planets have masses similar to Saturn, a finding confirmed by ground-based observations of the back-and-forth motion, or wobble, of the parent star. In the future, says Holman, variations in transit timing recorded by Kepler may reveal the masses of planets similar to Earth—bodies too lightweight to induce a detectable wobble in the orbit of their star.

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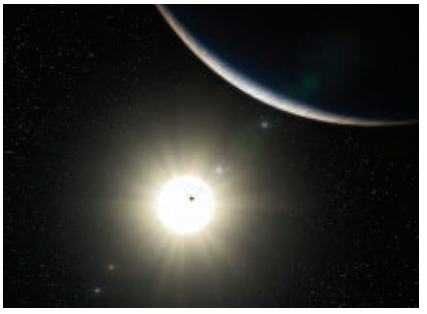
SN Today at **www.sciencenews.org**

A much smaller dip in starlight may be caused by a third, tinier planet with a diameter only about 1.5 times that of Earth. The candidate planet would lie much too close to the star to support life. Holman and his collaborators posted their analysis of the proposed "super-Earth" signal August 27 at arXiv.org.

If confirmed, the super-Earth would be the "smoking gun" for a leading theory of planet formation, comments theorist Doug Lin of the University of California, Santa Cruz. According to that theory, known as core accretion, bits of material from a disk of gas, dust and ice swaddling newborn stars coalesce to form a solid core. Then the core may snare a massive amount of gas from the planet-forming disk to create a gas giant like Jupiter. If the gaseous disk disperses before that can happen, a rocky naked core more like Venus, Earth, Mars or Mercury remains (*SN: 3/26/05, p. 203*).

A rocky super-Earth that orbits closer to Kepler-9 than the gaseous Saturn-like planets do would be strong evidence of just such a naked core, pushed within roasting distance of the star by the two heavier planets, says Lin.

As intriguing as the Kepler-9 system appears, it's downright simple compared with the gaggle of planets orbiting HD 10180, about 127 light-years from Earth. Tracking the motion of the star for more than six years with a sensitive spectrograph on the European Southern Observatory's 3.6-meter telescope at La Silla, Chile, researchers have found evidence for at least five planets, with hints of an additional two.



The sunlike star HD 10180, shown in this artist's conception, harbors at least five planets and possibly seven.

The five confirmed planets have minimum masses similar to that of Neptune and are packed inside a region roughly equal in diameter to Mars' orbit around the sun, Christophe Lovis of the Observatory of Geneva in Switzerland and his colleagues report in an upcoming *Astronomy & Astrophysics*. The system is much more densely populated than the inner solar system and also appears to lack a giant Jupiter-sized planet.

Understanding how the HD 10180 system came to be poses challenges that promise to provide additional clues about planet formation and the conditions necessary to make and retain Earth-mass bodies, says Lin. ■

Exoplanet scorecard

In the 15 years since they first detected a planet orbiting a distant sunlike star, astronomers have made great strides toward finding a habitable, Earthlike world in another part of the galaxy. Their findings, as of August 27:

Confirmed exoplanets:
490

Stars known to have multiple exoplanets:
45

Most confirmed exoplanets orbiting a star:
5
HD 10180 and 55 Cancri (*SN: 11/24/07, p. 334*)

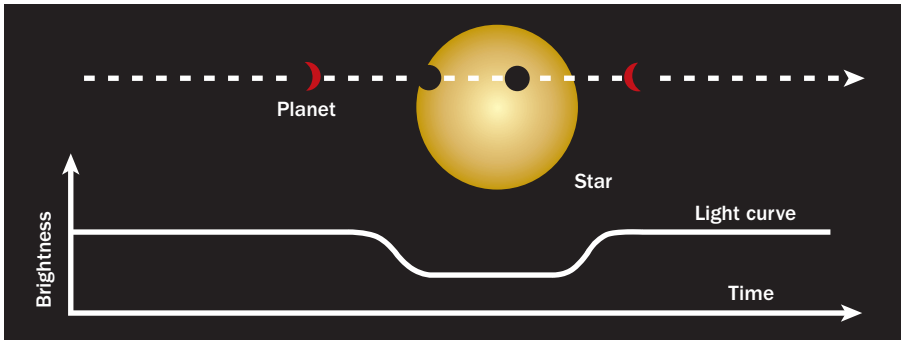
Minimum mass of heaviest known exoplanet:
25
Jupiter masses
HD 43848 b

Largest known exoplanet:
2.2
Jupiter diameters
CT Cha b

Smallest known exoplanet:
1.7
Earth diameters
COROT-7b
(*SN: 10/10/09, p. 8*)

Number of known habitable planets:
0

Back Story | HUNTING OTHER EARTHS



Launched in 2009, the Kepler spacecraft regularly monitors over 100,000 sunlike stars looking for tiny, periodic dips in brightness (shown as a change in the light curve, left) that indicate the passage of a planet across a star's face. The frequency and magnitude of these planetary transits can be used to help deduce a distant world's composition and chances of being habitable.

FROM TOP: ESO; NASA

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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."

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Molecules

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Tracking bird flu using duck poop

Trained mice can sniff out droppings laced with virus

By Rachel Ehrenberg

Duck and goose droppings, the bane of golfers and park visitors, may help scientists track the spread of bird flu — with olfactory assistance from properly trained animals.

Mice, for instance, have already been taught to detect poop from ducks infected with avian influenza, chemical ecologist Bruce Kimball reported August 24.

"I like to joke that we're going to send people out with mice on leashes," said Kimball, of the National Wildlife Research Center in Fort Collins, Colo., and the Monell Chemical Senses Center in Philadelphia. "But my vision is we could train dogs in much the same way."

Mice trained on the scent of poop from infected birds correctly chose infected over uninfected poop 90 percent of the time, Kimball reported. When the mice were presented with new droppings not used in the training sessions, the rodents identified the flu-laced feces 77 percent of the time. The scientists are still trying to figure out the precise chemical compounds that the mice detected.

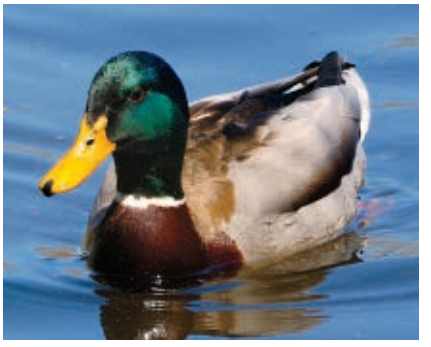
Many diseases, such as diabetes and some cancers, are known to alter the chemical profile of an infected individual's breath, so a poop profile also seems reasonable for identifying disease, Kimball said. He and his colleagues suspect that the mice are tuning in to compounds produced by the ducks' immune systems in response to the flu. Kimball adds one caveat: The research team irradiated the duck droppings to make sure the flu wasn't infectious — a precaution that may have affected the poop's smell profile.

Evidence suggests that some duck species, such as mallards, excrete much more flu virus than other birds, making the water birds prime disease spreaders via migratory travels or, more often, when ducks are bought and sold in live poultry markets.

Hundreds of millions of ducks, chickens, turkeys and geese died of flu or were killed to prevent the spread of the H5N1 virus that emerged in Hong Kong in the late 1990s. By 2006 more than 200 people had picked up the bug, and estimates suggest that the economic impact of the disease exceeded $10 billion.

If dogs can be trained to sniff out infected birds, it could streamline efforts to control an outbreak.

"Based on my experience, if a mouse can be trained for a scent chore, so can a dog," said Gary Settles, director of the Gas Dynamics Laboratory at Pennsylvania State University in University Park. "Their olfactory apparatus is similar, just of a different size," Settles said. "I know of no chemical-trace detection chore that mice can do but dogs cannot." ■



Ducks such as mallards excrete avian flu in their feces. Scientists have trained mice to detect poop from infected ducks.

RAÚL A./FLICKR

New gel can seal wounds quickly

Low-cost synthetic material speeds up blood clotting

By Rachel Ehrenberg

A new gel may provide a cheap means of stanching blood flow on the battlefield or in any other situation where there isn't time for stitches. Estimates suggest that the gel would cost less than $10 per application, a fraction of the cost of other gels in use today, researchers reported August 23.

The new blood-clotting material is a hydrogel, a Jell-O–like mixture of water and a fibrous polymer, in this case acrylamide decorated with positively charged nitrogen-containing groups. Experiments with blood plasma reveal that the gel kicks into gear a blood-clotting protein known as factor VII, a key player in the cascade of events leading to coagulation, said biomedical engineer Brendan Casey of the University of Maryland in College Park.

"You can just slap it on a wound," Casey said. In experiments in which Casey and colleagues made incisions in sheep lung and liver tissue, the hydrogel stopped the lung from bleeding in about two minutes, the liver in four to five minutes. The research team suspects that the polymer's positive charge and stiffness induce the clotting.

Many other hydrogels used in medicine today are based on biological materials such as chitin, a structural component found in the cell walls of certain fungi, the beaks of squid and the shells of lobsters and crabs. While these materials have their plus sides, such as breaking down in a friendly manner inside the human body, they are more easily contaminated by viruses and other microbes than synthetic gels are. Chitin-based materials can also trigger an allergic response in some people. And those biobased hydrogels can cost hundreds of dollars a pop, Casey said.

While the body can't absorb the new gel, it looks like the treatment would work well applied topically, said Saša Andjelić of Ethicon, a Johnson & Johnson company based in Somerville, N.J. ■

Genes & Cells

For longer versions of these and other Genes & Cells stories, visit **www.sciencenews.org**

Hints of altruism among bacteria

E. coli resist antibiotics with a little help from their friends

By Gwyneth Dickey

When it comes to fighting antibiotics, *E. coli* bacteria have each other's backs.

Just a few drug-resistant individuals can release a protective substance that makes a whole population resilient to drugs, a study in the Sept. 2 *Nature* shows. The finding may lead to new ways of combating drug-resistant germs in humans.

"This is the first observed example of altruism in antibiotic resistance," says biophysicist Hyun Youk of MIT, who was not involved in the research.

The new work shows that when *E. coli*, a common gut microbe that occasionally causes illness, becomes resistant to an antibiotic, it can share a molecule called indole with more vulnerable neighbors. Indole is known to help *E. coli* tolerate stress. By releasing the compound into the environment, just a few members of the population can make the whole microbial group tolerate an antibiotic.

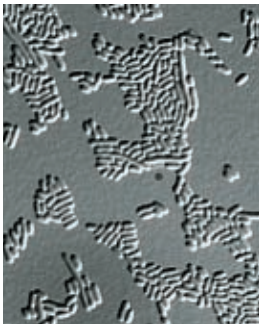
"These *E. coli* cells have developed a very cunning strategy," Youk says.

Scientists from Boston University made the discovery by accident. They were studying *E. coli* to see which genetic mutations made the bacteria resistant to drugs.

By singling out individual bacteria within a large antibiotic-resistant population, the team found that most individuals were less resistant than the group as a whole. But a few rare individuals were more resistant than average.

"We were surprised," says bioengineer Jim Collins, a coauthor of the study. "We immediately thought that the resistant guys must be producing something to help out the less resistant guys."

It turns out that the more resistant bacteria were producing indole. The team found that indole was turning on cellular pumps that push drugs out, as well as protecting against damaging molecules called free radicals.

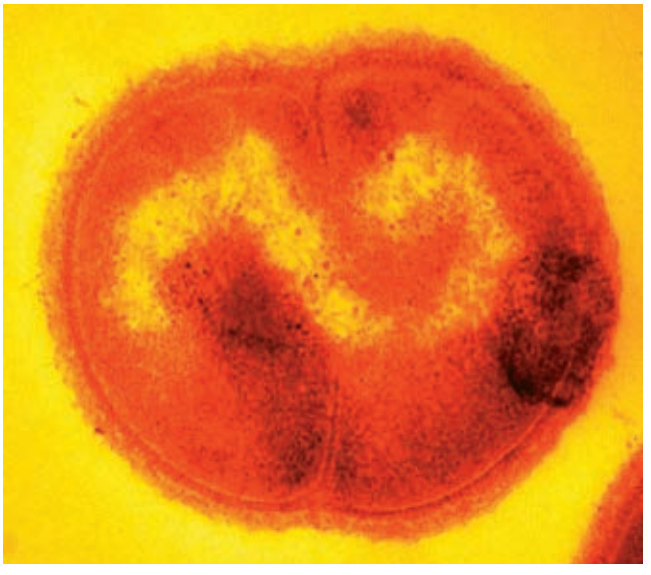


A whole population of *E. coli* can withstand antibiotics thanks to a few resistant individuals.

When looking for genetic changes that might explain the indole production, the scientists found numerous mutations that protected the bacteria against the antibiotic. There weren't any for increased indole production, though. It seemed that the resistant bacteria, untroubled by the antibiotic, were able to keep producing their normal levels of indole, sharing it with neighbors. In contrast, bacteria that weren't drug resistant stopped making indole in response to the antibiotic.

Collins isn't quite sure why this type of bacterial altruism would exist. If more vulnerable bacteria died, it would seem to be advantageous for the resistant ones, which would have more room to multiply and take over.

"It may be that the bacterial populations evolved this as a strategy to help survive transient stresses as a population," Collins says. And preservation of the bacterial colony as a whole, the paper notes, would keep beneficial mutations in the gene pool.



FROM TOP: H. LEE; MICHAEL DALY/USUHS

Superbug secret revealed

Researchers have discovered how the world's toughest known bacterium (shown at left) protects itself from radiation more than 1,000 times stronger than the dose required to kill a human. Small complexes of manganese and other substances slurp up dangerous chemicals caused by radiation exposure, protecting *Deinococcus radiodurans* from ill effects, a study appearing Sept. 3 in *PLoS ONE* shows. What's more, these shield components can be co-opted by *E. coli* and human blood cells, turning normally sensitive cells into radiation-resistant supercells, says study coauthor Michael Daly of the Uniformed Services University of the Health Sciences in Bethesda, Md. Daly and his team found that the bug's manganese-based shield protects proteins, including enzymes that repair and rebuild damaged DNA. He says the finding opens up a route to extreme radioactive resistance by supplementation alone—no genetic manipulation required. —*Laura Sanders*

Earth

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Trove of ancient animal life found

Burgess Shale site expands to include many more fossils

By Alexandra Witze

One of paleontology's most revered fossil sites now has a baby brother. Scientists have discovered a group of astonishing fossils high in the Canadian Rockies, just 40 kilometers from the famous Burgess Shale location.

A paper describing the find appears in the September issue of *Geology*.

Since its discovery in 1909, the Burgess Shale has yielded thousands of fossils dating to 505 million years ago, when animals' body plans were exploding in diversity. These critters scurried around on the seafloor, then were buried in mud and exquisitely preserved.

A fossilized appendage of the shrimplike animal *Stanleycaris hirpex*.

Burgess fossils appear in several outcrops, all within about 60 kilometers of Field, British Columbia, and all occurring in shale deposits of the Stephen Formation that are 270 to 370 meters thick. Now, a team led by paleontologist Jean-Bernard Caron of the Royal Ontario Museum in Toronto reports finding Burgess-like fossils in the valley of the Stanley Glacier in Kootenay National Park, where a much thinner part of the Stephen Formation that ranges from 16 to 160 meters thick is exposed.

"This new locality adds to our knowledge of the environments where these organisms lived and died, and thus adds important context," says Peter Allison, a geoscientist at Imperial College London.

About half of the animal groups found at Stanley Glacier, such as trilobites, are found at other Burgess outcrops in different abundances. But the new area also includes eight previously unknown taxa. They include an unnamed worm; *Stanleycaris hirpex*, a segmented shrimplike critter known as an anomalocarid; and an arthropod with big eyes dangling on stalks from its head shield.

Fossil deposits in the Canadian Rockies document early animal diversification.

Until now, paleontologists had thought that one reason the Burgess fossils were so well preserved was because they settled in thick deposits at the bottom of an ancient ocean protected by a submarine cliff. But the Stanley Glacier fossils weren't formed in the presence of such a cliff, suggesting that creatures can be fossilized in amazing detail in other environments.

"The single most exciting implication is that this formation has been poorly explored," says team member Robert Gaines, a geologist at Pomona College in Claremont, Calif. "We keep coming up with new species."

Earth's magnetic field may flip fast

Scientists find more evidence for extremely rapid reversals

By Alexandra Witze

Just north of a truck stop in Battle Mountain, Nev., lies evidence that the Earth's magnetic field once went haywire.

Minerals in 15-million-year-old rocks appear to preserve a moment when the magnetic north pole was rapidly on its way to becoming the south pole, and vice versa. Such geomagnetic field reversals occur every couple hundred thousand years, normally taking about 4,000 years.

The Nevada rocks suggest that this switch happened much faster. Anyone carrying a compass would have seen its readings skew by about a degree a week. A paper describing the discovery is slated to appear in *Geophysical Research Letters*.

It is only the second report of such a speedy change in geomagnetic polarity. The first, based on rocks at Steens Mountain, Ore., has never gained widespread acceptance (*SN: 4/22/95, p. 244*).

Scott Bogue of Occidental College in Los Angeles and Jonathan Glen of the U.S. Geological Survey in Menlo Park, Calif., went to Nevada to study layered lava flows. As each flow cooled, it preserved the orientation of the planet's magnetic field at the time, frozen like a tiny compass needle in the rock's magnetic crystals.

One flow caught the scientists' attention. Initially it started to cool and then was heated again within a year as a fresh lava flow buried it. The fresh lava remagnetized the crystals within the rock below, causing them to reorient themselves a whopping 53 degrees. At the rate the lava would have cooled, says Bogue, the magnetic field would be changing direction at about 1 degree a week.

Not all experts are convinced. Dennis Kent, a paleomagnetist at Rutgers University in Piscataway, N.J., says it would be "a curious coincidence" to have two brief lava flows just happen to cool and capture a 53-degree change in direction, when reversals happen only a few times per million years.

BOTH: J.-B. CARON

Matter & Energy

31 Number of ways to entangle four qubits, according to string theory

Tiny fridge, huge cooling potential

Quantum method could chill a particle close to absolute zero

By Laura Sanders

Annoyingly tiny fridges may not be restricted to hotels or dorm rooms much longer. A new study proposes a way to construct the smallest refrigerator yet, capable of cooling to near absolute zero.

The study, to appear in an upcoming *Physical Review Letters*, pushes the limits of how small a cooling device can get.

"When thermodynamics was first invented, it was applied to big, steam engine sorts of things," says physicist Tony Short of the University of Cambridge in England. "The fact that you can bring the ideas all the way down to individual quantum systems of tiny dimensions and the same basic ideas still work is quite nice."

Study coauthors Noah Linden, Sandu Popescu and Paul Skrzypczyk, all of the University of Bristol in England, propose a cooling scheme that relies on three linked qubits — particles that can exist in one of two quantum states. Two qubits, one in a hot bath and one near room temperature, make up the refrigerator. The third qubit is the object to be cooled. Because these qubits share a quantum connection, they can influence one another. So, as the hottest qubit absorbs energy from its toasty bath, it triggers the tepid qubit to siphon energy off the third qubit, cooling it.

As the bath of the hottest qubit gets hotter, the physicists calculated, the cooling ability of the fridge gets better. In principle, as long as the heat bath stays hot, the system can run forever.

Other small cooling systems have been created, but this is the first that doesn't rely on sophisticated external devices, such as lasers.

New twist found in string theory

Application to entanglement suggests way to test math

By Laura Sanders

Physicists looking for a way to test their theory about strings might make more progress by tangling them up.

String theory — which describes particles of matter and force as tiny vibrating loops or strands — has extended its reach to the quantum behavior known as entanglement. Repurposing string theory math allowed physicists to solve a hard problem involving this strange feature at the heart of quantum mechanics. In doing so, the new study, reported online September 2 in *Physical Review Letters,* also points out a way to test whether the co-opted string theory equations are correct.

"String theory has not had a lot of success in making falsifiable predictions," says study coauthor Michael Duff of Imperial College London. "But in the field of quantum information theory, it can."

One hallmark of quantum information is that particles carrying it can interact in a way that makes them "entangled," so that measuring one seems to instantaneously affect the other, even at great distances. In recent years, Duff and colleagues have noticed similarities between string theory and equations for entangled particles.

In a paper published last year, the physicists noted that string theory math describing black holes is similar to the equations for a group of three entangled particles. The new study tackles the more difficult problem of how four pieces of quantum information, called qubits, behave when entangled. Because experiments disagree, physicists aren't sure how many ways four qubits can be entangled. The answer, according to string theory, is 31.

> "We have nothing to say about whether string theory is the theory of everything."
>
> MICHAEL DUFF

Duff and his team can't yet explain why the formulas apply to this system. "We don't understand why it works," he says. "At some deep level we're mystified by it."

Although the reasons remain unclear, the surprising result identifies a way to put string theory to the test. In the past, string theory has been used to describe black holes, notoriously problematic study subjects. But now, entangled particles — which can be created and studied in laboratories around the world — may permit string theory experiments.

Theorist Sergio Ferrara says the new result may convince physicists that string theory can be useful in a variety of settings. Experiments confirming that string theory equations work as advertised for qubit entanglement would provide "sound confirmation" that the black hole–qubit duality is real, says Ferrara, of CERN, the European nuclear research laboratory in Geneva.

The surprise appearance of string theory math in entangled particles may signal a deeper connection between quantum mechanics, typically observed on very tiny scales, and the large-scale universe. On the other hand, the connection might turn out to be just "a quirky mathematical coincidence," Duff says.

Even if experiments turn out as string theory predicts, Duff warns, those results would confirm only that string theory got it right for entanglement, not necessarily for everything else, too. "We have nothing to say," Duff says, "about whether string theory is the theory of everything." ■

Body & Brain

64 percent | *BRCA* mutation–positive women who had preventive ovary removal surgery in a 1994–2004 study

Ovary removal boosts survival

Procedure shown to benefit women with *BRCA* mutations

By Nathan Seppa

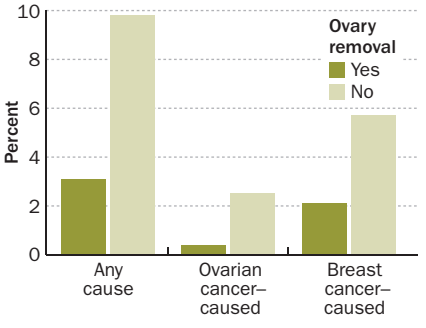
Surgical removal of the ovaries lessens the risk of death in women carrying *BRCA* mutations linked to breast and ovarian cancer, a study in the Sept. 1 *Journal of the American Medical Association* shows. The results also indicate that women undergoing this operation or a mastectomy limit their risk of ovarian or breast cancer, bolstering previous findings that these operations offer long-term protection (*SN: 5/25/02, p. 323*).

"This is really the first study to show that these women live longer" if they get their ovaries taken out, says Virginia Kaklamani of the Northwestern University School of Medicine in Chicago.

Two *BRCA* genes encode proteins that protect against cancer. But women carrying a mutated form of either gene face a 50 to 80 percent lifetime risk of developing breast cancer and also have a heightened risk of ovarian cancer.

In the new study, scientists collected genetic data on 2,482 women who were seen by a doctor between 1974 and 2008 and who were eventually shown to have a *BRCA* mutation. Overall, about two in five had chosen to have their ovaries surgically removed, and roughly one in five had elected mastectomy, says study coauthor Timothy Rebbeck of the University of Pennsylvania School of Medicine in Philadelphia. Some women had both operations. The women were monitored for a median of nearly four years.

Death rates, overall and by type of cancer, in women with *BRCA* mutation who had or did not have ovary removal surgery



SOURCE: DOMCHEK *ET AL*/*JAMA*

During follow-up, 3 percent of the women who had undergone ovary removal died, compared with nearly 10 percent of women who didn't have the operation. Only 1 percent of women who had the ovary surgery developed ovarian cancer, compared with 6 percent of those who didn't have the surgery. The surgery also decreased the risk of dying from breast cancer, particularly in women who had previously had breast cancer.

The researchers did not calculate mortality in mastectomy patients but did find that among women with no previous history of breast cancer, having their breasts removed as a preventive measure worked: None of these 247 women had breast cancer subsequently. In contrast, 7 percent of those who decided to forgo mastectomy developed breast cancer.

Women who have had breast cancer or have a family history of breast or ovarian cancer, particularly if they are Ashkenazi Jews, should consider getting tested for the *BRCA* mutation, Kaklamani says. The ovary removal surgery is recommended for mutation-positive women after their childbearing years, she says.

New foe for advanced melanoma

Drug offers hope to half of patients with deadly skin cancer

By Nathan Seppa

A new drug may change the landscape of melanoma treatment, offering patients a treatment option beyond anything now in use against the skin cancer. Tests in people whose melanoma had spread showed the drug was able to shrink tumors in most patients and, in a few cases, even wipe the growths out, scientists report in the Aug. 26 *New England Journal of Medicine*. The compound targets the protein encoded by a mutated version of the *BRAF* gene that underlies melanoma in roughly half of all patients.

"This is clearly a turning point" in melanoma treatment, says study coauthor Paul Chapman of the Memorial Sloan-Kettering Cancer Center in New York City. "It's the first time we're actually treating the genetics of the tumor."

Most early-stage melanomas can be surgically removed and stopped. But patients' prospects take a deadly turn if the cancer spreads beyond an initial skin lesion. Chemotherapy drugs benefit fewer than 20 percent of such patients.

In the new study, Chapman, Keith Flaherty of Harvard Medical School in Boston and colleagues treated 48 patients who had *BRAF*-related metastatic melanoma with PLX4032, a drug devised to stop the mutant BRAF protein from triggering cell growth.

Of the 48 patients, 37 experienced tumor shrinkage of at least 30 percent. In three, the tumors resolved completely. This tumor suppression lasted from three months to about two years. Some patients still take the drug. On average, the patients on the drug relapsed after nearly eight months, Flaherty says. That's because the tumors develop ways to subvert the effects of PLX4032.

The results add to other recent good news. In the Aug. 19 *NEJM*, scientists reported that an experimental drug, ipilimumab, seems to extend survival in metastatic melanoma patients. And a 2008 study found that melanomas linked to the less common *c-kit* mutation were susceptible to the leukemia drug Gleevec.

T. DUBÉ

Life

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Evolutionary feud over familial ties

Scientists dispute kinship's role in altruistic behaviors

By Susan Milius

A furor has broken out among biologists over Harvard ant specialist E.O. Wilson's latest attack on a concept used to explain the origins of self-sacrifice in the dog-eat-dog world of evolution.

The debate centers on an idea called kin selection, which biologists use to understand altruistic behaviors such as honeybee workers raising the queen's young but never having their own. These selfless workers would seem to lose out in the evolutionary struggle to pass along genes to the next generation. But according to kin selection, a worker without young more than compensates via the reproductive success of relatives, who share genes with the altruist.

In the Aug. 26 *Nature*, Wilson and two Harvard colleagues argue that the concept of kin selection is "limited" and "unnecessary." They propose steps for the evolution of ants, honeybees and other social species by just the broad "survival of the fittest" forces of natural selection.

The new analysis attacks the core of kin selection by examining how biologists calculate what's called inclusive fitness. Evolutionary biologists measure fitness not by push-ups but by progeny, and inclusive fitness counts not just an individual's direct offspring but some share of relatives' youngsters. The closer the kinship with the youngsters, the more they count toward the altruist's fitness.

Coauthors Martin Nowak, a mathematical biologist, and mathematician Corina Tarnita performed an analysis to find out in what cases the inclusive fitness approach can be meaningfully applied. Those cases turn out to be very limited, for example requiring individuals to interact in pairs. Under such restrictions, the team argues, another simpler method works just as well.

Nowak says that the researchers aren't arguing that kinship is irrelevant in biology. "Relatedness does matter," he says. Instead, they are challenging the accounting method for inclusive fitness, which they contend is overly complex.

As an alternative, the scientists describe how societies based on nonreproductive workers could evolve without kin selection. Organisms might cluster for any reason, such as a good feeding site, and then accumulate traits that prove important to a social structure, such as building defensible nests. Eventually crucial colony-building behaviors could evolve — adult children may stick around the home nest and later help raise young.

Wilson has raised objections to kin selection before, and the most recent criticism that he and his colleagues present isn't winning many converts. The criticism is "based upon a version of inclusive fitness that they have invented," says Stu West of Oxford University in England.

And Andrew Bourke of the University of East Anglia in Norwich, England, says the new work takes "a very narrow view of inclusive fitness theory, focusing on details of algebraic expression of the theory at the expense of its essential insights."

The evolution of highly social species such as bees is often explained in terms of kin selection, an idea that's under fire.

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Humans

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Feasts may have predated farming

Israeli cave yields evidence of communal funeral banquet

By Bruce Bower

Nacho-fueled Super Bowl bashes and multicourse wedding banquets may hark back to a time when preagricultural people devoured wild animal meat at their comrades' gravesides.

That's what happened 12,000 years ago at Hilazon Tachtit cave in Israel, say zooarchaeologist Natalie Munro of the University of Connecticut in Storrs and archaeologist Leore Grosman of the Hebrew University of Jerusalem. At least 35 members of the Natufian culture gathered then to dine on wild tortoise meat at the burial pit of a woman who probably had been a shaman, the researchers report in the Aug. 31 *Proceedings of the National Academy of Sciences.*

Wild cattle meat was also served at that feast or a separate gathering for another person interred in the cave, they propose.

Munro and Grosman say that they have the first solid evidence of feasting before farming began. Until now, the oldest remains of feasts came from Middle Eastern sites dating to around 9,500 years ago, after farming had taken root. Natufian population growth stoked a need for community-building rituals such as feasting, the researchers propose. These social changes occurred at the same time as an intensified use of wild plants and game that would later be domesticated by people living in the region.

Munro and Grosman present "a plausible interpretation of the data on hand, but not a slam dunk case," remarks anthropologist Olga Soffer of the University of Illinois at Urbana-Champaign.

Natufian people lived from around 15,000 to 11,500 years ago in the Middle East. Theirs was the first known society to inhabit year-round settlements.

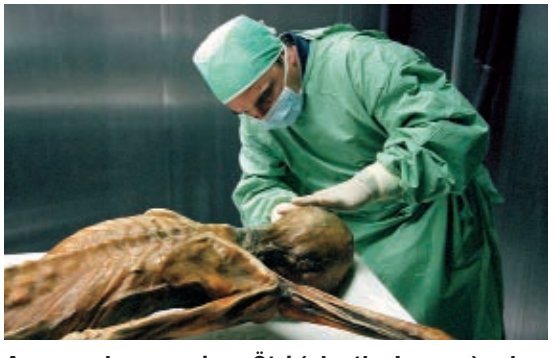
Study alters cold case death theory

Iceman's body may have been carried to burial site in Alps

By Bruce Bower

A prehistoric man whose naturally mummified body was discovered frozen in the Italian Alps may have been toted up the mountain by his peers.

The Iceman, also nicknamed Ötzi, lived between 5,375 and 5,100 years ago. Hikers noticed him poking out of a glacier in 1991.



A researcher examines Ötzi (aka the Iceman), who died in the Italian Alps more than 5,000 years ago.

SOUTH TYROL MUSEUM OF ARCHAEOLOGY

Since the discovery in 2001 of a stone point in Ötzi's left shoulder, many scientists have assumed that someone shot and killed him with an arrow as he fled through a mountain pass. But a new analysis of the distribution of Ötzi's belongings around his body, published in the September *Antiquity*, suggests that he perished near kin at low altitudes, who took him to the mountains for a final send-off.

Ötzi originally was placed on a group of stones that formed a platform about five meters, or about 16 feet, uphill from the spot where hikers found him splayed in a gully, assert archaeologist Alessandro Vanzetti of the Sapienza University of Rome and his colleagues. Snow and ice that originally held the body in place partly thawed during occasional warm periods, creating a watery mix that swept the Iceman and some of his effects, including a wooden bow and copper ax, off the platform, the scientists propose. Ötzi's body then gradually slid downhill and lodged against a boulder, with his left arm twisted at an odd angle, they assert.

"Many researchers have never questioned the 'disaster' theory of the Iceman's death," says study coauthor Luca Bondioli of the L. Pigorini National Museum of Prehistory and Ethnography in Rome.

Archaeobotanist Klaus Oeggl of the University of Innsbruck in Austria reported in 2000 that high levels of a binding material used in Ötzi's equipment appeared not just near his body but also on a ridge that includes the burial platform proposed by Vanzetti's team. Oeggl agrees that warming and freezing cycles caused the Iceman's body to move from the ridge to the gully, but says no compelling evidence shows that stones on the ridge were placed there to form a burial platform. Still, Oeggl says, "this new paper for the first time discusses a burial hypothesis in a substantial way."

Ötzi probably died in the mountains close to where he suffered a fatal injury, argues biological anthropologist Albert Zink, head of the EURAC-Institute for Mummies and the Iceman in Bolzano, Italy. Ötzi's joints and spine display no dislocations indicating a downhill slide.

If so, Ötzi's belongings should have randomly spread out, Bondioli counters. Instead, a mathematical analysis reveals two main clumps of recovered artifacts: one at the proposed stone platform and another in the gully where the body lay.

"The degree to which babies actually learn from baby videos is negligible." —JUDY DELOACHE

DVDs poor at teaching kids words

In study, toddlers learned most effectively from their parents

By Bruce Bower

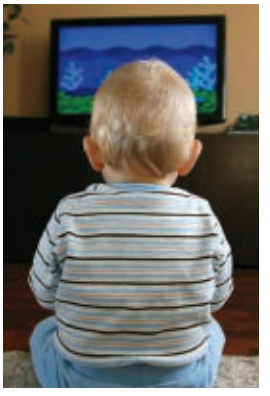
Toddlers get a kick out of giving adults a hard time. True to form, these wobbly-legged knowledge sponges learn virtually nothing from best-selling DVDs that parents believe will boost vocabulary and trigger academic superstardom.

Young children who viewed a popular educational DVD regularly for one month, either with or without their parents, showed no greater understanding of words from the program than kids who never saw it, according to a study set to appear in *Psychological Science*.

"The degree to which babies actually learn from baby videos is negligible," says psychologist and study director Judy DeLoache of the University of Virginia in Charlottesville.

DeLoache suspects that some parents mistakenly assume that educational DVDs, such as those in the Baby Einstein collection, prompt the spike in word learning that naturally occurs between 1 and 2 years of age (*SN: 4/25/98, p. 268*). DeLoache calls the DVD she used in her new study "one of the best available" but she wouldn't identify the brand.

In the study, youngsters displayed a word-learning advantage if their moms and dads spent a month trying to teach words from the DVD whenever the parents had time and however they thought best, without ever playing the program for the children.



Though they may pay rapt attention to educational DVDs, kids don't necessarily learn much.

By showing that parents can teach words directly to kids better than a DVD can, DeLoache's study "indicates the importance of having a social partner in learning," remarks psychologist Michael Robb of Saint Vincent College in Latrobe, Pa.

Other research indicates that kids under age 3 don't grasp the relation between what they see on a screen and the physical world (*SN: 4/10/10, p. 9*). Most don't realize that a symbol — say, a horse on television — corresponds to a real-world object, DeLoache suspects.

Logs kept by parents during the study often noted children's intense DVD-viewing habits, DeLoache says. "She loves the blasted thing," one mother wrote. "It's like crack for babies."

That may partly explain why some parents erroneously claim that toddlers learn a lot from educational DVDs, suggests psychologist Roberta Golinkoff of the University of Delaware in Newark. "Kids can look so rapt when they watch these videos that parents may think that attention equals learning, when clearly it does not," she says.

Remaining sharp has a downside

Alzheimer's comes late, fast with more mental stimulation

By Bruce Bower

Mental exercise lets seniors outrun Alzheimer's disease — for a while. Then the race takes a tragic turn, a new study finds, as declines in memory and other thinking skills kick into high gear.

After age 65, regular participation in mentally stimulating activities, including doing crossword puzzles and reading, delays intellectual decay caused by Alzheimer's disease, say neuropsychologist Robert Wilson of Rush University Medical Center in Chicago and his colleagues. But when it finally breaks through the defenses of a mentally fortified brain, this debilitating condition rapidly makes up for lost time, the scientists report in a paper published online September 1 in *Neurology*.

Several recent studies have pointed to a delayed but sharp drop in thinking skills among mentally active people who develop Alzheimer's disease, remarks neuropsychologist Yaakov Stern of Columbia University College of Physicians and Surgeons in New York City. Unlike the new report, though, those studies did not compare mentally active adults who developed Alzheimer's disease with those who remained healthy or lost some mental function to other causes.

Adults who learn to succeed at various intellectual challenges develop cognitive resources needed to cope with early stages of brain disease, Stern hypothesizes.

Wilson's team studied 1,157 healthy Chicago residents with a range of incomes and ethnic backgrounds, ages 65 and older. To gauge mental activity levels, participants reported how often they watched television, read, visited museums, listened to radio and played cards or other games.

After about six years, the researchers identified 148 individuals who developed Alzheimer's and 395 volunteers with milder forms of brain disease.

Those who initially reported high overall rates of mental activity displayed pronounced cognitive declines after being diagnosed with Alzheimer's disease, Wilson says. Mentally inactive adults who developed the brain disease suffered more moderate cognitive hits.

GREENLAND/SHUTTERSTOCK IMAGES

Fire & ice

Volcanoes and frozen lands make an explosive combo

By Alexandra Witze

SVEIFLUHÁLS, Iceland — High atop an Icelandic mountain one magnificent summer day, with blankets of soft moss underfoot and a translucent lake shimmering in the valley below, geologist Emily Constantine Mercurio is conjuring up an image of hell.

Tens of thousands of years ago, says Mercurio, a graduate student at the University of Pittsburgh, this place was the heart of a roiling volcanic eruption. Molten rock bubbled up from a fissure in the Earth's crust. On top of that lay hundreds of meters of ice. Lava met ice, and the result was an inferno.

Heat from the eruption instantly boiled ice to steam, which ramped up the eruptive power like a pressure cooker blowing its top. Magma hitting the steam exploded into tiny fragmented bits, sending pillars of fine-grained ash billowing overhead. It would have resembled the scene many people heard about on the news this spring — a volcano that erupted an hour's drive to the east, known as Eyjafjallajökull (pronounced "AY-ya-FYAT-la-yo-kult").

Eyjafjallajökull began erupting on March 20, but few people other than volcanologists and Icelanders took notice at first. For weeks, all it did was spurt lava gently out of an exposed ridge. On April 14, though, the eruption suddenly shifted a few kilometers west — no longer on open land, but beneath an ice cap. Just as happened at Sveifluháls, magma met ice and turned it to steam, throwing ash into the stratosphere. European airline flights shut down for days over worries about how the ash might affect jet engines.

What a difference a little ice makes. Had the second phase of the eruption not shifted westward, the volcano would not have closed down much of Europe's air traffic. "In the absence of ice, Eyjafjallajökull would have been a much less disruptive volcano," says Dave McGarvie, a volcanologist at the Open University's campus in Edinburgh.

Eyjafjallajökull's eruption has refocused attention on a small but rapidly growing subset of volcanology: the study of volcano-ice interactions. Ice-covered volcanoes, or "glaciovolcanoes," are not fundamentally different from other volcanoes in terms of plumbing or eruptive style. But they distinguish themselves the moment magma breaks through the crust and meets ice.

One reason to study icy volcanoes is to better understand their risks. Nobody died in the Eyjafjallajökull eruption,

ODD STEFAN THORISSON/NORDICPHOTOS/CORBIS

Iceland's Eyjafjallajökull volcano erupted quietly at first this spring (shown) — until magma shifted directly beneath a glacier.

but in 1985 an eruption beneath an icy mountain in the Colombian Andes sent massive mudflows coursing downstream, killing more than 20,000 people. Dozens of volcanoes mantled with ice are scattered around the world, each posing a distinct hazard (see Page 18).

Scientists are also studying volcano-ice interactions to learn more about the past. By chronicling geologic signs that volcanoes like Sveifluháls once erupted under ice, researchers can build up a picture of how far ice extended over the planet, and when.

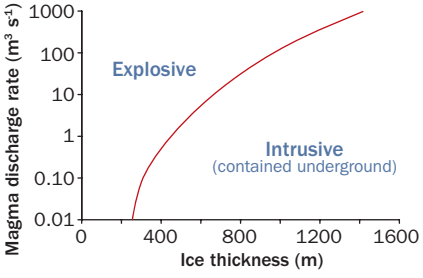
Icy volcanoes might even be a key to answering a vexing question — whether a warming climate could trigger more eruptions by lifting the heavy mantle of ice above volcanoes. As glaciers retreated from Iceland at the end of the last ice age, about 12,000 years ago, volcanic activity increased 10- to 30-fold. Some researchers speculate that the ongoing melting of ice caps worldwide could have a similar effect.

Land of ice volcanoes

Iceland is an ideal place to see icy volcanoes and for scientists to figure out how such volcanoes work. The country has some two dozen active volcanoes, of which Eyjafjallajökull is relatively puny. The island is so volcanically active because it is the above-water manifestation of the Mid-Atlantic Ridge, the chain of mountains that runs down the center of the Atlantic like an underwater backbone. Here Earth's crust pulls apart, and upwelling magma cools and forms new crust that spreads away from the ridge in the great recycling process known as plate tectonics. Iceland is geology in action; a one-hour flight from Reykjavik skims over steaming geothermal areas, the great crustal rift and some of the country's most famous volcanoes.

Many of those volcanoes are mantled in ice, including several under the 1,000-meter-thick Vatnajökull ice cap.

Thin ice, more explosions Computer modeling of volcanic eruptions under ice suggests that thin ice plus even a little magma equals hazardous explosive eruptions.



SOURCE: H. TUFFEN/*PHIL. TRANS. R. SOC. A* 2010

Glaciovolcanoes around the world

Volcanoes capped with ice pose distinct hazards in different countries. Researchers are trying to better understand these mountains to prevent future disasters.

Iceland: Land of fire and ice

1. Sveifluháls
An eruption thousands of years ago created this volcanic ridge.

2. Eyjafjallajökull
This small volcano shut down much of Europe's airspace this spring.

3. Katla
This neighboring volcano has erupted in tandem with Eyjafjallajökull before.

4. Hekla
One of Iceland's most active volcanoes, it has erupted five times since 1947.

5. Gjálp
Its 1996 eruption spurred pioneering studies of glaciovolcanism in Iceland.

6. Grímsvötn
It last erupted in 2004, and many scientists think it will be Iceland's next to go.

Sometimes, thick ice can muffle a volcanic eruption entirely. At Eyjafjallajökull, though, the ice is only a couple of hundred meters thick at most. That's not enough to keep the eruption from breaking through ice, though it is enough to generate lots of meltwater and steam when magma hits. "What the ice did was provide the trigger, the catalyst for the production of very fine ash," says McGarvie. Surprisingly, and for reasons volcanologists don't yet understand, Eyjafjallajökull kept churning out fine-grained ash for longer than expected.

Still, ice wasn't the only thing that made the volcano produce so much ash. Another factor was the chemical makeup of the magma during the second phase of the eruption. In March, the magma that poured out was primarily basalt, a common lava type that makes up 90 percent of the volcanoes in Iceland. Magma in the April eruption, however, suddenly had more silica in it. Silica makes magma more viscous or sticky; gas bubbles can't escape as quickly as they can in more fluid magma, and the whole mess rapidly becomes more prone to exploding.

Scientists are not sure why the magma composition changed from eruption to eruption, but one possibility is that Eyjafjallajökull began to tap a separate magma chamber. Another idea, says McGarvie, is that basalt erupting from deep within the volcano suddenly encountered a chamber of more silica-rich magma, and the two mixed before erupting under the ice.

It's hard to untangle how much of Eyjafjallajökull's power came from erupting under ice, and how much from the chemical composition of its magma. Volcanologists may eventually get a handle on that question by analyzing lavas from various stages of the eruption. Researchers led by Magnús Tumi Guðmundsson of the University of Iceland in Reykjavik have launched a full-out assault on the mountain to gather such information.

Like the 1996 eruption of the Icelandic volcano Gjálp, whose study pioneered the field of glaciovolcanism, Eyjafjallajökull may end up as a linchpin in understanding these types of eruptions. "We will learn a great deal from this volcano," McGarvie says.

Frozen past

Farther west, at Sveifluháls, Mercurio is doing her best to push such knowledge back in time, to create a window to glimpse the glaciovolcanic past. She is

WORLD MAP: CARTESIA. ADAPTED BY E. FELICIANO

BOBBIE MYERS AND STEVEN R. BRANTLEY/U.S. GEOLOGICAL SURVEY, ADAPTED BY E. FELICIANO

part of a new effort to study what tracks icy eruptions make in the geologic record.

When magma cools, it leaves distinctive textures in the resulting rocks, revealing the conditions under which they formed. Lava that is chilled quickly contains only small crystals; lava that takes longer to cool has time for larger crystals to grow. Fractures along the cooling edge can also indicate how dramatic the temperature difference was between the magma and whatever it encountered to cool it — air, water, ice or snow.

"It would be great if you can find lavas and say they must have cooled in contact with snow or ice or some other environment," says volcanologist Hugh Tuffen of Lancaster University in England. "You could reconstruct changing ice and snow, and understand the way the behavior of the volcano has been coupled to that."

Icelandic volcanoes can also be used to tackle important paleoclimatological questions, like how thick ice sheets got during the last ice age. While some measurements, such as the ratios of oxygen isotopes in trapped air bubbles, can tell scientists how cold temperatures were, that information can't be translated directly into ice thickness. The only way to find out is through shoe-leather geology — mapping structures in the field and untangling the story of what transpired thousands of years ago.

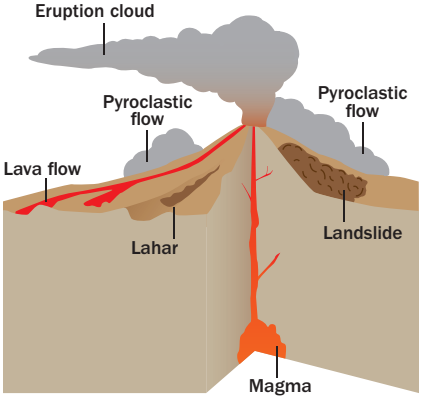
That question is what brings Mercurio to Sveifluháls this gorgeous summer day. Her backup troops include her adviser, University of Pittsburgh volcanologist Ian Skilling; master's student Holly Kagy; and a field assistant, Mercurio's cousin Kathy Zollinger.

At first, Sveifluháls looks too huge to ever comprehend: a massive ridge of black rock, some 21 kilometers long. The barren landscape lies about a 40-minute drive south of Reykjavik. The gravel roads that run down either side of the ridge are usually empty of other cars, save for fishermen trying their luck in Lake Kleifarvatn or the occasional tourist heading to the mud pots at the local geothermal field.

But hiking up into the lunarlike terrain, Mercurio and Skilling start to point out geologic details that tell the story of the past inferno. Here in an outcrop amid a steep pile of scree lie pillow basalts — the billowy-looking rocks that form when lava erupts underwater. There, lower down the ridge, stretch the remnants of an ephemeral lake, its ancient coastlines marked along the edges. Such features mean water, and water means ice melted by lava. "We're looking for evidence of drainage, all the way down the ridge," Skilling says.

Summer after summer, Mercurio has been building up a history of what happened at Sveifluháls. She can't be sure exactly when it erupted; the rocks here are too young for typical radioactive dating techniques. But at some point, probably between about 40,000 and 13,000 years ago, magma came bursting up through ice. Months later, when the eruption subsided, the ridge remained. More than 1,000 of these erupted ridges, called "tindar," dot Iceland's countryside.

Special hazards All volcanoes can be hazardous, but when magma hits ice as it emerges, the resulting mudflows (called lahars) and high-flying ash can be especially dangerous for nearby residents and airplanes.



In some places the researchers spot physical evidence of where ice used to be. Atop one section of the ridge, Skilling points out a place where thick layers of cooled magma slump down and then are truncated abruptly at one end. The magma must have run into a wall of ice here, he says — cooling and stopping before the ice melted away.

Mercurio's fieldwork suggests that the ice at Sveifluháls was some 400 meters thick at the end of the last ice age. Puzzlingly, models of Iceland's ice cover suggest that it should have been 1,500 to 2,000 meters thick. Asked why the difference, Mercurio shrugs. Only more studies of glaciovolcanism can answer these kinds of questions.

Melting future

Northwest of Mercurio's field site, a low gleaming office building in Reykjavik houses the earth science department of the University of Iceland — ground zero for probing the links between volcanoes past and present. Volcanologist Freysteinn Sigmundsson spends his days digging through data from Eyjafjallajökull and wondering what other eruptions are yet to come. "What will be the influence on volcanic activity if all the ice caps shrink?" he asks.

The disappearance of ice sheets lifts weight off the land, he says, and great pieces of Earth's crust can rise with their backs unburdened. Many regions in northern latitudes, such as Scandinavia and Canada, are still uplifting from the pressure released when the great ice sheets retreated at the end of the last ice age. In Iceland, where an ice sheet some 300 kilometers wide has mostly disappeared, this "glacial rebound" is as much as 20 millimeters per year. In addition, glaciers worldwide are retreating because of rising global temperatures. Ice caps in Iceland, for example, have been thinning since around the year 1890.

Geologist Emily Constantine Mercurio measures the orientation of ripples frozen in rock atop Sveifluháls in Iceland.

A. WITZE

Ice thinning at selected ice sheets and volcanoes

Location	Area of ice	Rate of thinning
Vatnajökull ice cap, Iceland	8,100 square kilometers (2000)	0.8 meters per year average (1995–2008)
West Antarctic Ice Sheet	2.2 million square kilometers (2009)	At Pine Island Glacier, approximately 1.6 meters per year (1995–2006)
Popocatépetl, Mexico	0.729 square kilometers (1958); zero today	Approximately 0.2 meters per year (1996); approximately 4 meters per year (1999)
Cotopaxi, Ecuador	19.2 square kilometers (1976); 13.4 square kilometers (1997)	3–4 meters per year
Kilimanjaro, Tanzania	2.5 square kilometers (2000); 1.85 square kilometers (2007)	0.54 meters per year
Villarrica, Chile	30.3 square kilometers	0.81 ± 0.45 meters per year (1961–2004)

SOURCE: H. TUFFEN/*PHIL. TRANS. R. SOC. A* 2010

Glacial rebound and thinning glaciers together can affect volcanic activity in multiple ways, Sigmundsson says.

For one, reducing pressure at the surface causes more magma to be produced at depth. "This is sort of excess magma," Sigmundsson says. "If the conditions in the crust remain the same, you would expect more magma to make it to the surface." The thinning of the Vatnajökull ice sheet, for instance, may have caused a 10 to 15 percent increase in magma production over the past century.

Ice loss also shifts areas of stress on buried magma chambers. Volcanologists know that ice loss can affect eruptions; in 2004, half a cubic kilometer of meltwater suddenly drained from a lake beneath Vatnajökull, and the nearby Grímsvötn volcano erupted. In cases where a volcano was about to erupt anyway, like Grímsvötn, a change in surface stress could provide the final trigger necessary to set it off, Sigmundsson says.

Finally, taking ice away also may open new channels for magma to find its way to the surface, via new fractures or fault lines.

Still, volcanologists argue about exactly what effect shrinking ice will have. At the end of the last ice age, volcanic activity in Iceland experienced a big pulse; activity was more than 10 times that seen today. Some have argued that the thinning of Vatnajökull has accelerated volcanic activity in central Iceland. But teasing out such processes from ordinary volcanism is not easy. And it's not clear whether more volcanic activity might mean a greater number of eruptions, or the same number but with more magma volume in them.

Back atop Sveifluháls, such concerns seem remote. At 63° N latitude the sunlight has that rarefied Arctic feel, and the city of Reykjavik sparkles in the distance. An eruption amid the serenity seems a far-off possibility.

Yet as Mercurio will tell anyone who listens, the peace is deceiving. There's no doubt that the geological demons driving Iceland's volcanoes will be back. ■

Explore more

- Eyjafjallajökull webcam: http://eldgos.mila.is/english/eyjafjallajokull-fra-thorolfsfelli
- View a photo slide show of research at Eyjafjallajökull at www.sciencenews.org/icyvolcano

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Rust never sleeps

A new flare-up in an age-old battle between wheat and a fungal killer

By Rachel Ehrenberg

The recent reemergence of stem rust (shown above), a fungal pathogen, has wheat researchers on edge.

AGRICULTURAL RESEARCH SERVICE/USDA, COURTESY OF WIKIMEDIA COMMONS

In his quest for world domination, James Bond's nemesis Ernst Blofeld threatens to unleash a pathogen that would destroy global food supplies. Humankind now faces such a foe. But this villain doesn't care about world domination, and it needs no evil genius to release it. The fungus known as wheat rust, one of history's most feared and destructive plant pathogens, is already sweeping the planet. Wheat rust can turn a healthy crop into a black, tangled mess of broken stems and shriveled grains just weeks before harvest.

The battle between wheat and the fungus is an old one: Evidence suggests that wheat rust was a plague during biblical times. In ancient Rome it was considered a *numen*, a deity demanding appeasement via sacrifices and feasts.

Modern fungicides can fight rust, but the costs and quantities required often outweigh the benefits. So wheat breeders have kept the rust at bay by developing varieties with genes that resist it. For the most part, these breeders have helped wheat gain the advantage over its foe. But perhaps ritualized prayer shouldn't be completely off the table. An especially virulent form of one type of rust, wheat stem rust, has recently emerged and proved immune to wheat's genetic arsenal. Estimates suggest that 90 percent of the world's wheat crop is now vulnerable.

Scientists everywhere have taken up arms against the rust. Tens of thousands of wheat varieties and wild relatives have been screened for anti-rust genes that can be incorporated into future arsenals. This spring, more than 500 researchers from 77 wheat-growing nations gathered for two major wheat conferences in St. Petersburg, Russia, to share strategies and discuss progress on various fronts. And in August, a team of British scientists released a very rough sketch of wheat's genetic blueprint, which in a more complete form could simplify and speed up the breeding of rust-resistant varieties.

"There is a lot happening," says wheat geneticist Jorge Dubcovsky of the University of California, Davis. "We are trying to develop better technologies, better breeding approaches.... I think at some point we will defeat the bastard."

But scientists also lament a lack of funding, coordinated action and basic knowledge about wheat and its pathogens. A great deal more effort is needed to turn the first crack at wheat's genome into information that's meaningful for fighting the rust.

Worldwide, only a handful of labs do hard-core rust-related research, and many will accept samples of the fungus only during the winter months, when it's too cold for potential escapees to survive. The rust is so feared that some trigger-happy researchers frantically deploy plants bred with single resistance genes — even though most

scientists agree that a well-constructed genetic cocktail offers the best hope for staving rust off.

Rust's reemergence

Wheat rust's current rampage began more than a decade ago. In October of 1998, a plant breeder noticed a stem rust infection on wheat growing in his nursery at Kalengyere Research Station in Uganda. The discovery was perplexing because the wheat contained a gene called *Sr31*, which, along with a handful of others, had provided protection against the rust for more than a quarter century. A rust virulent enough to defeat *Sr31* triggered alarm in the wheat community.

"Should the *Sr31*-virulent pathotype migrate out of Uganda, it poses a major threat to wheat production in countries where the leading cultivars have resistance based on this gene," scientists from Africa and CIMMYT, the International Maize and Wheat Improvement Center in Mexico, wrote in *Plant Disease* in 2000.

Those fears have since been realized. This extremely aggressive strain of the fungus, called Ug99 (for the place of discovery and the year that the samples were analyzed), spread to most of the wheat-growing areas of Kenya and Ethiopia by 2003. The fungus' spores, easily windborne, reached Sudan in 2006. Ug99 then crossed the Red Sea into Yemen, the doorway to major wheat-growing areas in the Middle East and southwest Asia. Ug99 has now been sighted in Iran. And not only is the rust still on the move, but it is also mutating: Within the Ug99 lineage, scientists have identified seven variants that can overcome additional important resistance genes in wheat. One Ug99 variant that overpowers *Sr31* and the gene *Sr24* caused epidemics in Kenya's crops in 2007. Another Ug99 relative has turned up in Ethiopia and South Africa, and Kenya reported in June rust infestations in 80 percent of inspected fields.

Ug99 has yet to rear its ugly spores in the Americas. But that doesn't mean U.S. wheat farmers are rust- or worry-free. In North America, Australia and Europe, as well as in Asia and Africa, a sibling of stem rust — the stripe or yellow rust — is taking a toll. In 2003, yellow rust wiped out a quarter of California's wheat crop. Last year, it devastated crops in China. This year, farmers in the United States, the Middle East and northern Africa have already reported serious yellow rust infestations.

"The presence of two virulent and highly aggressive yellow rust strains ... at high frequencies at epidemic sites on five continents (including Europe) may represent the most rapid and expansive spread ever of an important crop pathogen," researchers from Aarhus University in Denmark wrote in an editorial in the July 23 *Science*.

When rust attacks

That crop pathogens spread so rapidly and widely highlights how humans have unwittingly taken the enemy's side in the wheat-rust battle royal. By its very nature, agriculture lays out an all-you-can-eat buffet for the pathogen and rings the dinner bell.

"When we cultivate wheat, it is genetically uniform, spatially uniform and temporally uniform — those uniformities favor certain things to blow up rapidly," says plant pathologist Yue Jin of the U.S. Department of Agriculture's cereal disease laboratory at the University of Minnesota in St. Paul.

In the wild, fields don't ripple with amber waves of grain. Wild wheat usually grows in genetically distinct clumps, Jin says. Stands of such wheat don't sprout, grow and yield grain in sync, and other nearby plants block traveling spores.

"You hardly ever see the disease really killing a native plant stand," Jin says. "Ever."

When wheat rust does attack, yellow-orange or reddish-brown blistering pustules can appear on infected plants within a week. That "rust" is just part of the fungi's complex life cycles, which include a dizzying array of spores that aid in the pathogens' dispersal and persistence.

Three of the 5,000-odd species of crop-attacking rusts are serious parasites of wheat: stem rust, stripe or yellow rust and leaf rust (all in genus *Puccinia*). When the pathogens' spores land on wheat, they germinate and send out a threadlike structure that penetrates the plant. Once inside, the fungus starts sucking the plant's nutrients and grows

Spread of a killer

Stem rust strains that can overcome key resistance genes have recently spread across Africa and beyond. Some scientists worry that prevailing winds may soon carry spores to major wheat-growing areas of the Middle East and Asia.

SOURCE: DURABLE RUST RESISTANCE IN WHEAT/CORNELL UNIV., BORLAUG GLOBAL RUST INITIATIVE

REDMAL/ISTOCKPHOTO, ADAPTED BY T. DUBÉ

new structures that rupture the leaves and stem, crippling photosynthesis and disrupting the plant's ability to control water loss. Those new pustules contain thousands of spores that, carried by the wind, can travel from field to field, or farther: One long-distance flier reportedly made it from southern Africa to Australia.

During the growing season, these spores move from wheat field to wheat field, destroying plants along the way. The fungi typically morph into black, thick-walled structures in the fall. And in spring, these structures ultimately yield another kind of spore that must land on a different host plant to keep the life cycle going.

For stem rust, that host is the shrub barberry, and from 1918 through 1975 more than 100 million barberry bushes were eradicated in the United States alone in an effort to eliminate stem rust's seasonal home. Since the rust's sexual reproduction (which entails gene mixing) yields spores that can infect only barberry, the eradication program also stymied the pathogen by limiting its genetic diversity.

But the elaborate life cycles of the three rust varieties allow them to snub host removal efforts. Like a deadly broken record, the pathogens can persist by reproducing asexually, repeatedly making the types of spores that can infect wheat. In the United States these spores can survive winters in milder regions, such as near the Gulf of Mexico. Come spring, the spores move north with the wind, hopscotching from field to planted field.

Until the 1950s, in much of the world including the United States, wheat crops were on a boom-and-bust cycle: Years with robust yields were punctuated by devastating rust epidemics. Around that time, the U.S. Department of Agriculture and similar agencies in the rest of North and South America decided to formally collaborate in tackling wheat rusts. An international wheat nursery was established and — under the leadership of American agronomist Norman Borlaug, who would later win the Nobel Peace Prize for his efforts — breeders and scientists around the world began coordinating the exchange of wheat seeds and plants and cooperating to develop wheat varieties with rust resistance.

Wheat scientists refer to two general kinds of genetic resistance to rust. One is major gene resistance, sometimes also called race-specific resistance, in which the wheat proteins recognize specific rust proteins and quickly wipe out the invader. Then there's nonrace-specific resistance, also called slow-rusting or partial resistance. In this case, the rust's spores might germinate on the plant, but a full-blown infection never quite develops.

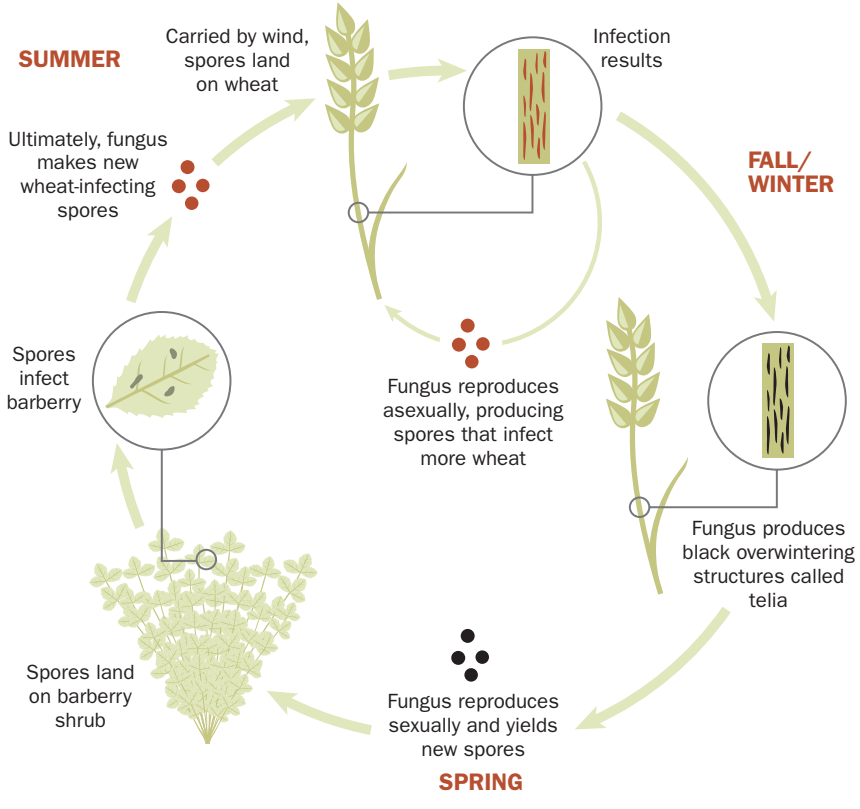
Major gene resistance is typically short-lived: Within two to five years, a fungus may acquire mutations that alter the shape of the protein that stimulates wheat's immune response, and then it's game over. But a combination of major and minor resistance genes offers longer-term protection.

Several such combinations arose in the 1970s, when Borlaug and researchers at CIMMYT developed wheat varieties that contained a good chunk of a chromosome from rye. Rye and wheat are close relatives, and both are susceptible to rusts. This bit of rye chromosome had the major resistance gene *Sr31,* which, along with others, was deployed into several wheat varieties around the world. These new varieties were what researchers call durably resistant, rarely succumbing to stem, stripe or leaf rust, or to powdery mildew, another pathogen.

The combination of genes kept rust under control for an exceptionally long time. Stem rust became virtually nonexistent in many parts of the world, an almost forgotten curse, geneticist Ravi Singh of CIMMYT and colleagues wrote in *Advances in Agronomy* in 2008. But as Borlaug noted, rust never sleeps.

"A lot of complacency developed and people assumed this was going to last," says Cornell University's Ronnie Coffman, director of the Durable Rust Resistance in Wheat project, an international collaboration funded by the Bill

A hard-to-hit enemy A complicated life cycle (generalized below) has made tackling stem rust difficult. Since the fungus infects barberry after sexual reproduction, some efforts have targeted this alternate host plant. But stem rust can snub such efforts by repeating asexual reproduction.



T. DUBÉ

& Melinda Gates Foundation. "And a lot of other things happened to our institutions — budget issues, the Soviet Union collapsed, a lot of things went to pot in the public domain in that period. So when Ug99 came around, people weren't really ready to deal with it."

Fighting back

More than a decade later, researchers are still undertaking various efforts to try to rein the pathogen back in. Topping the list: Using genetics and molecular biology to better understand the mechanisms of wheat's natural resistance to the fungus, which would enable scientists to streamline their breeding efforts and develop resistant varieties faster. Perhaps even before the rust epidemic gets much worse.

Modern molecular techniques have upped the pace of this research, but it can still be painstakingly slow. For one thing, rust resistance isn't the only trait that wheat farmers care about. They also want plants that produce high yields, resist other wheat pathogens such as powdery mildew and thrive in the light, soil and water conditions of a particular region. If a wheat farmer has a stellar variety, yet it isn't resistant to rust, it can take six generations of breeding to get the resistance genes in while keeping the other beneficial traits intact.

Breeding programs that bring wheat from one location to another to get two generations in a year can speed this process, but it still may take five to 12 years to go from finding a resistance gene in some wild, scrappy wheat plant to getting that gene into a variety that also has all the other desirable traits, says wheat geneticist Mike Pumphrey of Washington State University in Pullman.

And most scientists agree that deploying a variety with a single resistance gene has little value. The best strategy for combating rust is to harness a combination of genes, greatly diminishing the odds that a fungus will succeed.

"A good example is what we did with AIDS," Dubcovsky says. "We were not successful at the beginning; we were putting out a medication and the virus was mutating and the medication was overcome. What is the current strategy? We have three different medications that work together that make it almost impossible for the pathogen to mutate in all of those three different pathways."

In wheat, Pumphrey says, the approach could mean using one gene that attacks the rust as it threads into the wheat; another that hastens the death of cells around the rust, preventing its spread in the plant; and yet another to delay spore germination in the first place.

"That's our greatest focus and promise," Pumphrey says.

When wheat experts from around the world gathered in St. Petersburg for the Borlaug Global Rust Initiative 2010 Technical Workshop and the 8th International Wheat Conference, they presented status reports on efforts to combat the pathogen, discussed the role of climate change in its spread and reviewed the latest research on rice, the only agricultural cereal crop that is immune to rust.

The International Wheat Genome Sequencing Consortium, an international public-private endeavor to unravel all the genetic data in one wheat variety's 21 chromosomes, gave a progress report: One and a half chromosomes have been well-mapped and funding has been garnered for several more.

Wheat has a gigantic genome — with 17 billion base pairs or "letters" of code, it's about five times the size of the human genome, although less than 10 percent of wheat's DNA makes up actual genes.

In August, British scientists released what they called a draft sequence of the wheat genome — with the emphasis on *draft*. The team did an initial shredding of the DNA of Chinese Spring wheat into digestible chunks of about 500 base pairs each, and then figured out the string of code in each of those chunks.

The data may be helpful, but until scientists figure out how all those tiny pieces fit together into a genome, linking resistance traits to specific genes will remain difficult. Such information will be crucial for launching a full-scale genetic attack against rust.

"We still have a long way to go," says Singh of CIMMYT.

For now, it's inch by inch, row by row. For example, last year Dubcovsky's team and another group of researchers identified the role of two genes that confer resistance to rusts. It was such a feat that the results were published in side-by-side papers in *Science*.

If Ug99 has any plus side, it's that it has raised the public's consciousness of wheat pathogens, as well as that of private funders, such as the Gates Foundation. Wheat — be it in a boring old loaf of white, rigatoni, beer or chocolate cake — is taken for granted, and it's difficult to imagine that something so commonplace, so integral to the world's breaking of daily bread, could be threatened.

"People don't think about food when there is abundant food," Dubcovsky says. "But when there's not abundant food, people start thinking about it again. And when there's no food, that's the only thing people think about." ■

Relying on grains Figures below compare the amounts of the cereal crops wheat, rice and maize used for food in select countries in 2007.

United States
Wheat: 26,181,000 metric tons
Rice: 2,550,000 metric tons
Maize: 3,887,000 metric tons

China
Wheat: 90,141,000 metric tons
Rice: 102,640,000 metric tons
Maize: 8,994,000 metric tons

Kenya
Wheat: 996,000 metric tons
Rice: 285,000 metric tons
Maize: 3,014,000 metric tons

Pakistan
Wheat: 18,378,000 metric tons
Rice: 2,506,000 metric tons
Maize: 1,277,000 metric tons

SOURCE: FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS 2010

Explore more

- The Borlaug Global Rust Initiative: www.globalrust.org/traction

A New View of Gravity

Entropy and information may be crucial concepts for explaining roots of familiar force

By Tom Siegfried

Explaining gravity to a small child is simple: All you have to say is, what goes up must come down.

Until the kid asks why.

What can you say? It's just the way things work. All masses attract each other. Maybe to bright middle schoolers you could explain that spacetime is warped by mass. Or, to high schoolers, you could say that without gravity, the laws of physics would differ for people moving at changing velocities. Yet all those increasingly sophisticated answers merely invite another "Why." As Sir Isaac Newton himself replied in response to similar questions, "*hypotheses non fingo*." Which roughly translates as "I don't have a clue."

That such a simple question, about so common a phenomenon, has defied a direct answer for centuries might explain why the physics world has been atwitter lately over a novel attempt to resolve the riddle. A flurry of recent papers have examined this new idea, which mixes principles from string theory and black hole physics with basic old-fashioned thermodynamics. If this notion is right, gravity turns out to be a special sort of entropy, a result of the same physics that drives matter to give up its organization and order as it succumbs to the laws of probability. Toss in a dash of quantum mechanics and a pinch of information theory, and the universe emerges, governed on a grand scale by pretty much the same principles underlying the elastic pull of a rubber band.

While similar ideas have been suggested before, nobody has expressed the gravity-as-entropy story as intriguingly as theorist Erik Verlinde of the University of Amsterdam in an online paper (arXiv.org/abs/1001.0785v1) that appeared in January. Titled simply "On the origin of gravity and the laws of Newton," Verlinde's paper cooks up a mathematical pièce de résistance connecting gravity to thermodynamics. His ingredients include the law of entropy, the physics of black holes and some speculative conjectures on how space stores information about the matter and energy within it. His recipe replicates Newton's law of gravitational attraction, and then with some additional mathematical seasoning he arrives at Einstein's general relativity, the modern and undefeated champion of gravity theories. Verlinde's analysis indicates that gravity emerges from physical dynamics analogous to basic thermodynamic processes. "Using only ... concepts like energy, entropy and temperature," he writes, "Newton's laws appear naturally and practically unavoidably."

Not everyone is buying, or even understanding, Verlinde's arguments. Only a few among mainstream physicists express much enthusiasm for his paper. But it has inspired a glut of other work, some extending Verlinde's idea to encompass the history of the universe. Rapid expansion just after the Big Bang and the more recent accelerating expansion of the universe might all fit into the entropic-gravity picture of reality. And beneath it all may lurk a new worldview emphasizing the primacy of information over matter and energy.

Entropy and information

Ordinarily, the term entropy is translated into common language as "disorder," with a tendency for higher entropy taken to mean that things like to get messier. Wood rots, metals rust and structures crumble; substances separated into cold and

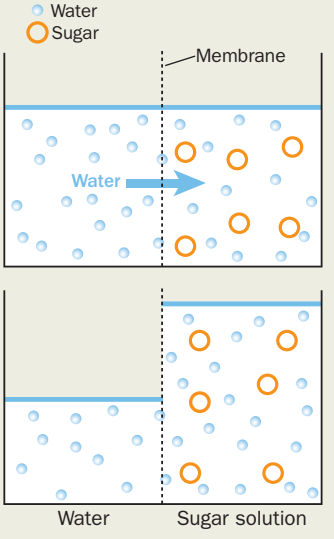
hot turn lukewarm. Eventually any system not resupplied with useful energy reaches equilibrium, and entropy is maximized.

More technically, entropy is a measure of how likely a system is to be in its particular configuration. Low entropy describes systems with a very improbable arrangement of their parts. Entropy typically equates to disorder because there are usually very few ways for a system to be precisely ordered, but multiple ways to be messed up. (A car's engine will run only if all the parts are precisely positioned in one specific arrangement; you can scatter the parts around a repair shop in all sorts of ways.) So the most probable outcome for any system (unaided by the input of energy to maintain its order) is messiness — maximum entropy.

Curiously, the equations relating entropy to probability are precisely the same as the math used by computer scientists to quantify information. It turns out that information is the flip side of entropy: Stating that a gas with all its molecules crammed into one corner of a box has low entropy is just another way of saying you have information about where the molecules are. As the molecules spread out, information about their location diminishes and entropy rises.

Such loss of information — or increasing entropy — drives many natural processes, such as osmosis, the mysterious migration of water across a membrane. If you dissolve a substance (say, sugar) in a compartment of water, entropy increases. If you have pure water in an adjacent compartment, separated by a membrane that allows water (but not the sugar) to pass through, you've created an "entropy gradient" — lower entropy on one side of the barrier than the other. So the pure water will flow through the membrane to the sugar side, increasing the entropy of the system until equilibrium is reached.

Osmosis and entropy



In osmosis, water flows across a membrane because of an entropy gradient. Something similar may explain the force of gravity.

If you don't know about thermodynamics, it just looks like some force is driving the water across the membrane. Verlinde proposes that the "force" of gravity is driven by a similar (though not really identical) sort of entropy gradient.

He illustrates his idea with "polymer stretching" — in other words, playing with rubber bands. When you stretch a rubber band, some sort of force vigorously attempts to snap the band back to its original shape. Such elastic forces result not from any mystical motivation in the polymer, but merely from the play of probability: There are many more possible arrangements of the pieces making up the polymer when the band is shorter and loose than when taut. So the rubber band's elastic force is entropic — the stretched polymer is in a very improbable configuration, and snapping back to its resting state restores equilibrium and maximum entropy. Gravity, Verlinde asserts, is similar in the sense that masses move in ways that also produce more probable, higher-entropy arrangements.

Verlinde is not the first to relate gravity to thermodynamics. In 1995, Ted Jacobson of the University of Maryland demonstrated that the equations of Einstein's general theory of relativity could be derived from basic thermodynamic principles. That result drew on work in the 1970s by Jacob Bekenstein and Stephen Hawking, who discovered parallels between ordinary thermodynamics and the physics of black holes, regions of such intense gravity that nothing that enters can ever exit. Bekenstein showed that a black hole has entropy, determined by all the matter and energy it has swallowed. Hawking demonstrated that black holes have a temperature (requiring the emission of Hawking radiation from a black hole's surface). Since black holes are basically nothing more than pure gravity, describing them in terms of the thermodynamic properties of entropy and temperature hinted at deeper links between gravity and thermodynamics.

A further hint to that link came from the Dutch Nobel physics laureate Gerard 't Hooft. In 1993 he proposed that reality shares common features with holograms, like the flashy images embedded in credit cards that store apparently three-dimensional information on a flat surface. In a similar way, 't Hooft asserted, information about the contents in three-dimensional space might be stored on two dimensions, sort of the way 2-D mirrors covering the walls of a room record information about all the objects within the room's 3-D space.

't Hooft's conjecture, known as the holographic principle, and its later elaboration by Stanford physicist Leonard Susskind built on Bekenstein's work on black hole entropy. Bekenstein had found that a black hole's entropy is proportional to the surface area of its outer boundary, known technically as the event horizon. In other words, the information about a black hole's interior is stored on its surface, just as with a hologram.

A black hole's "surface," of course, is not like a soap bubble or globe of Plexiglas. It's an imaginary sphere surrounding a black hole's center, a boundary defined by the distance marking the point of no return for anything that gets too close. Such a boundary, or "screen" as Verlinde calls it, could be imagined in other regions of space, and that is what he does to deduce the roots of gravity. Holographic screens enclosing regions of space encode information about the contents of that space, he says, just as a black hole's horizon encodes what it has swallowed, or the mirrors on the walls reflect the contents of the room.

Such information stored on the screen gives it a temperature

B. RAKOUSKAS

— not in the everyday thermometer sense, but rather something analogous to the Hawking radiation temperature on the surface of a black hole. Temperature differences between the screen and the space outside of it create the cosmic analog of an entropy gradient, driving masses outside the screen to move just as Newton's laws prescribe. Rather than a mysterious attraction at a distance, gravity simply expresses the tendency of masses to move under the impetus of a gradient driving them to a state of higher entropy.

"By making natural identifications for the temperature and the information density on the holographic screens, ... the laws of gravity come out in a straightforward fashion," Verlinde writes.

He is careful to emphasize that his ideas are tentative and not to be taken too literally. Increasing an object's entropy does not make it more massive, for instance, and temperature on a spacetime surface storing bits and bytes wholly beyond human perception is not the same thing as the temperature of a hot day or a cold drink. (Gravity would not disappear if ordinary temperature dropped to absolute zero.) But the analogous thermodynamic formulas connect the underlying concepts of temperature and entropy and gravity in ways that just might lead to a deeper understanding of the cosmos — eventually. "The ideas will and are being developed further, and along the way may evolve, be refined or even slightly altered," Verlinde commented via e-mail. "This is what science is about."

> "It is natural to imagine that gravity itself has a quantum informational origin."

Entropy in action

Verlinde takes a first step toward further development in his paper by extending his analysis to general relativity, which depends on the equality of inertia (the tendency of a mass to retain its state of motion) and the gravitational mass (proportional to the force of attraction between objects). Verlinde shows that inertia's declaration that a body at rest stays at rest simply reflects the absence of entropic gradients.

Applying the entropic gravity idea to general relativity puts it to a severe test. Any new explanation for gravity would have to reproduce the large-scale history of the cosmos, including such phenomena as the expansion of the universe and its recent acceleration. Physicists Damien Easson, Paul Frampton and Nobel laureate George Smoot, for instance, suggest that entropic gravity would remove the need for the unidentified "dark energy" in space that most cosmologists believe to be responsible for the cosmic acceleration. If gravity is entropy in action, then acceleration would occur with no need for dark energy, Easson, Frampton and Smoot calculate in a paper posted online in March (arXiv.org/abs/1002.4278). They simply assume that the holographic principle is at work on the two-dimensional surface encompassing the entire visible 3-D universe. If all the information about the universe is encoded on a holographic screen coinciding with the horizon of the visible universe, the temperature on the screen would create an entropy gradient driving accelerated expansion. Their calculated acceleration matches the observed acceleration as inferred by its effects on the relative brightness of distant supernova explosions. With holographic information storage on the universe's horizon, dark energy no longer is needed to explain the supernova observations. "The acceleration of the universe simply arises as a natural consequence of the entropy of the universe, via the holographic principle," the physicists write.

Not only can entropy explain the current acceleration of cosmic expansion, it also might explain the rapid burst of expansion, termed inflation, that occurred in a flash just after the Big Bang. In a paper posted in March (arXiv.org/abs/1003.4526), physicists at the Chinese Academy of Sciences in Beijing — Yi-Fu Cai, Jie Liu and Hong Li — suggest the need for two holographic screens: an outer screen at the universe's horizon and an inner screen, something like the horizon of a black hole. In the early universe, entropies of the two screens generate the expansion of the universe. Further calculations involving quantum effects explain the universe's early burst of inflation. Acceleration of the expansion, later in the life of the universe, would occur after the inner horizon evaporates away — just as black holes do by Hawking radiation.

As Verlinde notes, Hawking radiation is a quantum process: Quantum fluctuations in the space near a black hole's surface allow some particles to escape, slowly draining the black hole of its mass and providing it with its "temperature" (until it evaporates entirely away). So a full analysis of the entropic-gravity idea will have to incorporate quantum mechanics, and that will alter the overall idea in subtle ways, says Verlinde, who is working on a paper that will probe those issues.

Ultimately, he says, the connection with quantum physics could help cement the long-sought unification between general relativity and quantum mechanics, possibly illuminating the role of string theory as well. For a quarter century, many physicists have favored string theory, which describes the basic particles of matter and force as tiny vibrating strands or loops called superstrings, as the best route for unifying quantum physics with gravity. The holographic principle plays an important role in string theory, and holographic screens bear resemblances to D-branes, multidimensional surfaces to which certain strings attach themselves. In Verlinde's picture, strings are not fundamental entities, but emerge from processes on the screens just as gravity does.

The encoded universe

Underlying all this hoopla is a recurring theme at today's physics frontiers: conceptualizing nature in terms of information. In Verlinde's proposal, information stored on holographic screens is the prime source of the entropy underlying gravity. Similarly, in the cosmological scenario

described by Easson and colleagues, information density on such screens drives accelerated cosmic expansion.

In yet another paper, Jae-Weon Lee of Jungwon University in South Korea and collaborators Jungjai Lee and Hyeong-Chan Kim develop this information-based reasoning more deeply, applying a famous principle from computer science formulated by the late IBM computer physicist Rolf Landauer. Landauer's principle requires energy to be consumed — and therefore entropy to be increased — when a bit of information is erased.

Lee, Kim and Lee apply Landauer's principle to the more complex "quantum" information possessed by a subatomic particle. In a different twist on Verlinde's idea, they propose (arXiv.org/abs/1001.5445v2) that it is the erasure of quantum information when particles pass through a holographic screen that increases cosmic entropy. It's just like what happens, they say, when a particle passing though a black hole's event horizon is erased from the rest of the universe, increasing the black hole's entropy in the process. Equations describing all this once again connect the thermodynamics of information erasure with gravity. "Putting it all together," Lee, Kim and Lee write, "it is natural to imagine that gravity itself has a quantum informational origin."

These are the sorts of papers that traditional experts rarely take seriously. Any one such paper would not make a ripple in physics Twitter traffic. And of course, all of these new ideas might turn out to be wrong. But despite their deviation from mainstream paths, these papers have attracted attention precisely because they hint at a way to solve riddles of gravity and quantum physics that traditional approaches, relying on particles and fields, have found intractable.

So it's not necessarily crazy, even if still very speculative, to suppose that thermodynamics and information will serve as the bridge for bringing gravity and quantum physics together. As Lee, Kim and Lee write, Einstein's equations link energy to matter and matter to gravity, and the new work connects matter and energy to information and entropy. These links imply that Einstein's equations are more about information than energy, the physicists write. "In other words, information might be a more profound physical entity than matter or field."

Putting information theory and thermodynamics together in this way might very well have pleased Einstein, who failed to find the theory unifying gravity with the rest of physics despite three decades of effort. Einstein was a big thermodynamics fan. In his autobiographical notes, he acclaimed it as the one branch of science unlikely ever to be overturned. "Thermodynamics," he wrote, "is the only physical theory of universal content concerning which I am convinced that, within the framework of the applicability of its basic concepts, ... will never be overthrown." It may be that thermodynamic concepts are more widely applicable than Einstein imagined, possibly able to solve the one problem he couldn't conquer in his lifetime. ■

Islam, Science, and the Challenge of History

Ahmad Dallal

A millennium ago, the Islamic world was civilization's Science Central, the primary haven for contemplating the cosmos and discerning the natural laws governing physical existence. While

the Arabo-Islamic scientists of this period have on occasion been portrayed as mere preservers and translators of ancient Greek science, they in fact engaged in extensive creative scientific activity, exploring both the natural world and the philosophical underpinnings of the scientific endeavor.

Animating much of the scientific activity of that time was a question that continues to haunt science and society alike — the overlapping authority of science and religion. As Dallal, a historian at American University of Beirut, recounts, Muslim scholars have long engaged in nuanced discussion of this issue. Among Islam's notable commentators was the 14th century historian Ibn Khaldūn, who articulated the cultural neutrality of science. "The intellectual sciences ... are not restricted to any particular religious group," he wrote. "They are studied by the people of all religious groups, who are all equally qualified to learn them and to do research in them."

Ibn Khaldūn drew on the earlier observations of Abū Hāmid al-Ghazālī, who distinguished between the possible existence of spirit (something that cannot be established by rational proof) and knowledge of the natural world (derived from human perceptions). Ibn Khaldūn identified in the views of al-Ghazālī and other predecessors an important lesson for science. "By determining those parts of the world that are subject to natural reflection," Dallal writes, "Ibn Khaldūn liberated scientists from the burden of attempting to explore what is not knowable."

Dallal's account of Islamic scientific introspection is fascinating to read as history, and instructive in its exploration of issues that remain familiar today in various formulations of conflict between science and religion.

— Tom Siegfried

Yale University Press, 2010, 239 p., $27.50.

Bulletproof Feathers

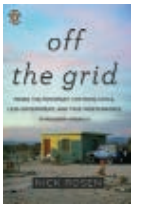
Robert Allen, ed.

Photos and illustrations highlight how nature inspires technology, from airplane wings that change shape to stainproof fabrics. *University of Chicago Press, 2010, 192 p., $35.*

What's Eating You? People and Parasites

Eugene H. Kaplan

An ecologist takes readers on an engaging, if sometimes squirm-worthy, tour of the world's hangers-on. *Princeton University Press, 2010, 302 p., $26.95.*



Off the Grid

Nick Rosen

A journalist travels the country to visit Americans who, for a variety of reasons, have opted out of the electrical grid and into alternative lifestyles. *Penguin, 2010, 292 p., $15.*

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New views of enzymes

"Enzymes exposed" (*SN: 7/17/10, p. 22*) was an interesting read, but is there more to the story? When biologists consider the lock-and-key model for enzymes, I wonder if they are stuck in the static stick-and-ball mentality of traditional chemistry. Is biochemistry really static or is it dictated by the vibrational mode of molecules? Maybe enzymes are even more complicated, and their functionality is based on oscillations, resonances and vibrations.

Frederick Thurber, South Dartmouth, Mass.

Too resilient to fail

"Safety in numbers" (*SN: 7/17/10, p. 18*) suggests to me that Roy Lindelauf's game theory–based methods for studying terrorist organizational structure could also apply to our financial system: A more resilient financial system might look a lot like his more resilient terrorist cells. Imagine "too big to fail" becoming "too resilient to fail" — a Lehman Bros. or AIG simply splitting into smaller but functional entities instead of collapsing.

Carson Barnes, Loma Mar, Calif.

Time travel confusion, intrigue

I always enjoy your publication even when I haven't a clue what the writers are talking about! I found the article on time travel conundrums ("Time travel gets more plausible, yet weirder too," *SN: 8/14/10, p. 5*) intriguing. Recalling the *Back to the Future* movies reminds me of another movie: *Superman*, with Christopher Reeve. In this film, Superman travels back in time by flying against the Earth's spin, but faster than the speed of light. He succeeds in going back and saving Lois Lane's life. However, in a similar situation in the comic books, Superman went back in time to stop Abraham Lincoln's assassination. But no matter how he tried, something always prevented him from saving the president. Superman finally comes to the conclusion that even with his superpowers, it is impossible to change what has already occurred.

Tim Campbell, Cleveland, Ohio

Send communications to: Editor, Science News, 1719 N Street, NW, Washington, D.C. 20036 or **editors@sciencenews.org**. Letters subject to editing.

William Talman

For more Comment, visit Columns at **www.sciencenews.org**

Biomedical research needs more consistent funding

This summer William Talman became president of the Federation of American Societies for Experimental Biology, an organization that advocates the advancement of biological and biomedical research. He is a professor of neurology and neuroscience at the University of Iowa in Iowa City and a practicing physician at the university's hospital and at the Iowa City Department of Veterans Affairs Medical Center. During a recent meeting with reporters in Washington, D.C., Talman said he plans to promote increased funding for biomedical research during his one-year term as FASEB president. In July he sent a letter to Congress requesting that the 2011 budget of the National Institutes of Health be increased to $37 billion, about $6 billion more than its current level and $5 billion more than the Obama administration has proposed. Science News *science writer intern Gwyneth Dickey, who attended the Washington meeting, reports excerpts from Talman's comments.*

We've already made huge inroads into improved medical practice as a result of biomedical scientific research, but more is needed.

It's not easy being an advocate nowadays, but it's natural for me to advocate for the biomedical sciences. In my 40 years as a physician, I've seen remarkable changes that have come about in clinical medicine as a result of basic biomedical scientific research. Clearly, the influence of mathematics, physics, chemistry, as well as biomedical sciences has remarkably impacted how we practice medicine and how we provide for our patients. For example, neuroimaging has made it possible for us to do testing on patients in ways that we couldn't have dreamt of when I started in medicine — ways that are safe for the patient, exclude complications, reduce hospital stays and improve patients' life expectancy and their health while they're living.

We've already made huge inroads into improved medical practice as a result of biomedical scientific research, but more is needed. There's no question that the opportunities are greater now for further discoveries than they've ever been before.

But the challenges are also there. We recognize in FASEB that we're living in a world where we're all impacted by the economic situation. We have seen at the NIH a rather remarkable, somewhat unexpected increase in funding from the ARRA [American Recovery and Reinvestment Act]. Those supplemental funds were to the tune of about $10 billion over two years, equating to about $4.5 billion in actual research monies that went out each year of the two years. That seems like a lot of money, but the fact is that the ARRA funds really accomplished a recovery of some of the losses of purchasing power that the NIH experienced from about 2003. If they go away, we calculate a loss of 15 percent of the purchasing power and a loss of perhaps 4,000 grants from the NIH alone. We're very concerned about that. If the average NIH individual investigator-initiated grant is $250,000, then for every million dollars lost, there are four grants that are not funded.

We're worried about falling off the cliff and the very detrimental effects that it could have. As U.S. Rep. Brian Bilbray [of California] pointed out, "our government's peak-and-valley pattern of scientific funding must be replaced by a steady, consistent funding stream. It is disruptive to the flow of the scientific process if funding levels are flying high one year only to be followed the next year with a crash landing."

This is FASEB's message and it has been for years. More funding along with predictable and sustainable growth will accelerate progress toward longer, healthier and more productive lives, and that's the goal that we all have.

We are very encouraged at one level by the philosophy that has been expressed by members of the administration and by Congress. There is no question that it is going to take a major effort to deal with the economic difficulties that we're facing in our country.

There's talk of putting caps on funding, reducing funding for discretionary spending. We've all heard that. So when we see for the first time in the past eight years, a presidential budget coming with increases in NIH funding (not to the level that FASEB recommended, but increases) at a time when there are decreases in other things, we are grateful that the folks who are making these decisions recognize the importance of research.

The people I've met on Capitol Hill, they're bright people. They have the same goals we have. They have different ways of approaching the goals on different sides of the aisle, but they're very intelligent people who want to listen to us and they recognize the value of the biomedical research product.

So we're optimistic but realistic at the same time. But none of us really has a crystal ball as to what the end point's going to be. ■

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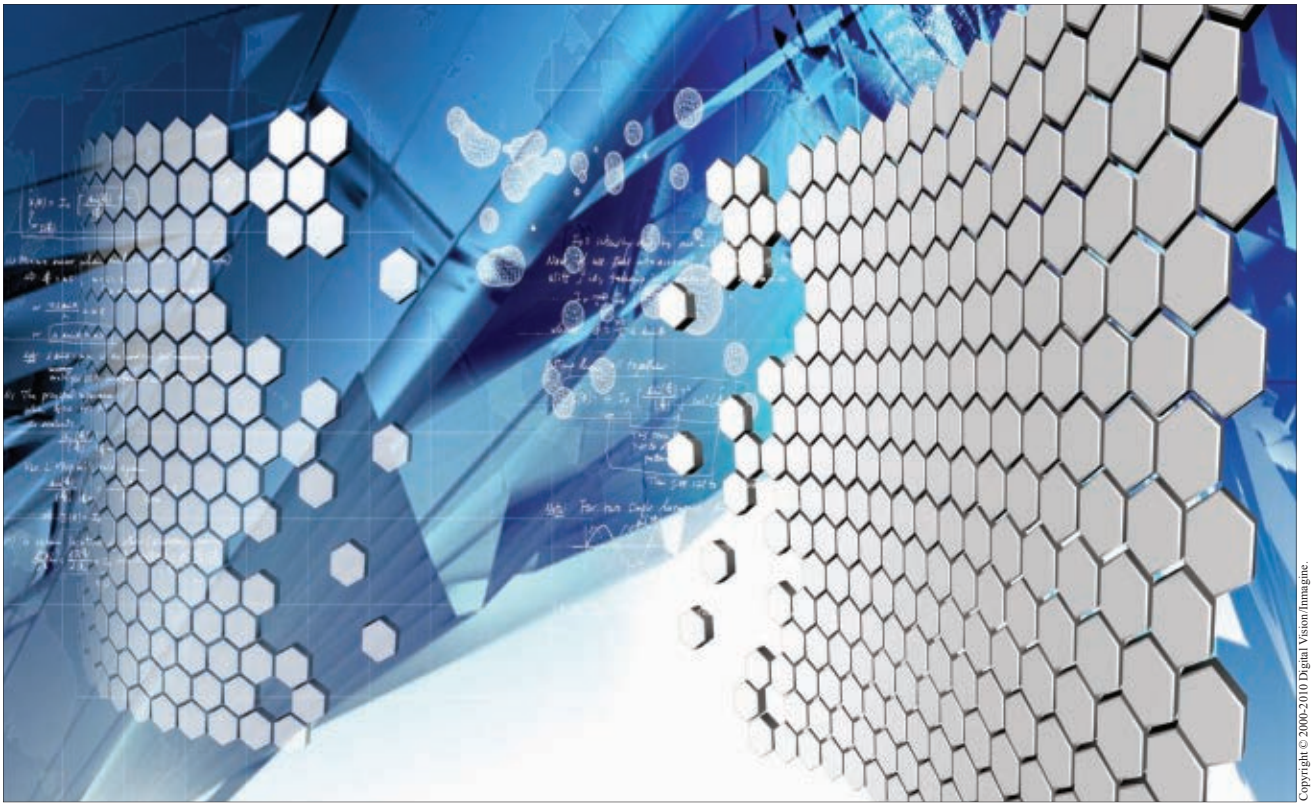

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NEW!

Reinvent a Fanciful Flight

A precursor of the modern day helicopter, the Aerial Screw designed by Leonardo da Vinci was designed to compress air in order to obtain flight. Now you can build this model straight from Da Vinci's musings and marvel at how ahead of his time he truly was. Recomended ages 8 and up.

⚠WARNING:
CHOKING HAZARD – Small parts.
Not for children under 3 yrs.

#31521-38 . . . . . $19.95

Swinging Sticks

Mysterious, Continuous Moving Desk Display

Never ceasing, always swinging, this moving stick model appears to defy gravity and turn logic on its head. The constant, fluid motion of the revolving sticks creates an almost hypnotic effect that your friends, family, and clients will want to watch for hours. The perpetual motion illusion was created by an electrical engineer and designer to baffle and amaze all onlookers. Ideal for conference rooms, medical offices, exhibition areas, waiting rooms, display windows, and foyers, this display provides sophisticated style and unmatched entertainment.

#30850-66 . . . . . $289.00

Maggie 3" LCD Magnifier

NEW!

Handheld Device Enhances Reading Experience

Small enough to fit in your pocket or purse, but powerful enough to magnify print 11 times its original size, the Maggie is an LCD electronic magnifier that makes type easier to read on those pesky fine print terms and conditions, pill bottles, and ritzy restaurant menus. Choose from 4x, 6x, 8x and 11x magnification levels and take a screen shot on a 3" LCD screen. It comes with a 3.5 hour lithium-ion battery, USB charger, and wall socket charger. Size: 2" x 3½" x ½". Weight: 2.5 oz.

#32001-02 . . . . . $199.95

You and Einstein Mirrorkal Puzzle

Stare Into the Face of Genius....Yours! **NEW!**

Do you picture yourself a mastermind or whizkid? Now you can prove it. Tackle this mind-bending puzzle and find yourself pictured right next to Einstein when you reach the right solution.

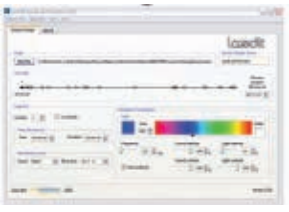
⚠WARNING:
CHOKING HAZARD – Small parts.
Not for children under 3 yrs.

#X31520-10 . . . . . $14.95

NEW!

Laxman

Truly in a class all its own, the Laxman 'Innertainment' System is the next generation of light and sound mind machines. The revolutionary technology combines the most effective light and sound advances with the features of a state-of-the-art multimedia device. The result is a sensory phenomenon that simulataneously atunes your brain waves to auditory and visual stimulation, creating a ground-breaking display of colorful shapes and a sensation unlike any other. Prepare for a dream-like state where your mind is unleashed to create a psychedelic kaleidoscopic of geometric structures in response to what you see, hear, and feel.



This incredible sesnory experience is created through "the ganzfeld effect," first documented in the 1930s by psychologist Wolfgang Metzger, who determined that when subjects stared into a featureless field of vision, their electroencephalograms were altered and each experienced hallucinations. When your entire field of vision becomes completely featureless, the brain amplifies the senses when no depth or outlines of objects can be seen. Choose from over four hours of professionally produced ambient and nature sound arrangements, including classical impulse frequencies, binaural-beats and hemicircle sounds. You can also use the LaxEdit software to upload your own MP3 files for light and sound sessions. How will your brain respond? What will you see? How will you define your innertainment experience? There's only one way to find out.

#31521-51 . . . . . $649.00

The Amazing Drinking Birds

Great Conversation Piece for the Office or Home

These famous entertaining birds never stop drinking! Simply get a glass of water ready, dunk the bird's head towards the glass and release it—the drinking bird will bob back and forth while periodically taking a drink. It will amuse you for hours as you watch it bob and learn the science behind it. Birds may also be used as relative humidity indicators. Their bodies consist of a glass vial filled with red or blue dye (will stain if broken). Includes two birds. Weight: 0.42 oz Size: 4-⅛" x 7" x 2-⅛"

3053617J $8.95