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ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ MAY 9, 2009

Group Think

Making decisions without big brains

Good Fat Found in Adults

Nickel Falls, Oxygen Rises

Ancient Animals: BYO Shell

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The Georgia Tech students who created the continuous glucose monitor are, from left, Sonya Parpat, Elizabeth Bramblett, Kimberly Roush, and Meredith Goolsby.

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MAY 9, 2009 • VOL. 175 • NO. 10

ScienceNews

In The News

Features

Departments

COVER A photo illustration shows a group of ants on the move. New studies are revealing how such groups make smart decisions collectively. *Hans Neleman/Getty Images*

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FROM THE EDITOR

With science at its best, answers raise questions

Birds and bees, ants and plants are among the most familiar — and most well-studied scientifically — life-forms on the planet. You'd think that if you wanted to know something about how any of them work, you'd go look it up in a book (excuse me, I meant the Internet).

But whether looking in print or online, you won't find easy answers to some pretty basic questions. How does photosynthesis work? How do birds find their way when migrating? How do bees, or ants, maintain the social harmony that permits collective decisions about where to live? It's hard enough for two humans to agree on where to go for lunch.

Wait, you might say — there *are* answers to such questions in books and on websites, even if you avoid Wikipedia.

Photosynthesis "works," you'll read, by a process in which energy from light is transformed and stored as food via chemical reactions that convert carbon dioxide and water to oxygen and sugar. But beneath that answer lies another tough question: What makes those chemical reactions happen? It's not otherworldly, although it might seem to be, as freelance writer Susan Gaidos describes in this issue (Page 26). It appears that electrons — excited by light — fuel photosynthetic reactions using trickery from quantum physics. Their quantum skills allow electrons to test multiple pathways through photosynthetic proteins simultaneously — perhaps explaining how the light-to-energy conversion is accomplished with an astonishingly high efficiency.

Migrating birds can navigate by sensing the Earth's magnetic field, you'll read. But how does that work? Perhaps also by exploiting tricks from quantum physics, current research suggests.

Bees and ants, on the other hand, have evolved elaborate communication systems that don't appear to rely on quantum physics, but do manage to explore many possible choices at once. When it's time to move a colony, scout bees or ants seek new homes and then report back to the group about multiple possible locations. Researchers are just beginning to understand the elaborate methods that exist for reaching a consensus, as Susan Milius reports (Page 16).

Of course, even these answers raise more questions. It's digging into those never-ending layers of questions beneath answers that keeps science, and *Science News*, going.

—Tom Siegfried, Editor in Chief

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Scientific Observations

"As I have told my students ... I view a life in science as a marathon, not as a sprint. My goal is to ask simple questions arising from clearly stated hypotheses, to use both simple experimental designs and transparent statistical analyses, to proceed one step at a time, experiment after experiment, frequently replicating main effects, until I can be quite sure that when others attempt to repeat my procedures, they will get the same results that I did. Not exactly the sort of approach likely to reap accolades today." **BENNETT G. GALEF JR., PROFESSOR EMERITUS OF ANIMAL BEHAVIOR AT MCMASTER UNIVERSITY IN HAMILTON, CANADA, IN THE MARCH 24 *CURRENT BIOLOGY***

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EARTH

Iron in water seeping from an underground ecosystem takes on a rusty hue as it oxidizes (below). Surprisingly hearty life forms use the iron to breathe in their long-isolated, dark and salty home. See "Antarctic ecosystem holds unusual microbes."

BODY & BRAIN

High levels of tobacco-related compounds that show up in urine could identify which cigarette smokers are most likely to develop lung cancer. Measurements also show how deeply smokers puff and how long they inhale. See "A urine test may predict lung cancer risk."

Science Past | FROM THE ISSUE OF MAY 9, 1959

FORECAST 25% INCREASE IN AIR'S CARBON DIOXIDE — A 25% increase in the amount of carbon dioxide in the earth's atmosphere during the 150-year period ending in 2000 A.D. has been forecast. Dr. Bert Bolin of the University of Stockholm in Sweden told the National Academy of Sciences meeting in Washington that the burning of coal, oil and gas was adding carbon dioxide to the air at about one-half a percent each year.... The increase in carbon dioxide in the atmosphere during the last 100 years, he said, is much more likely to be about eight percent than the usually quoted two percent. Carbon dioxide is believed the cause for earth's suspected warming trend of two to three degrees Fahrenheit in the last 50 years.

Science Future

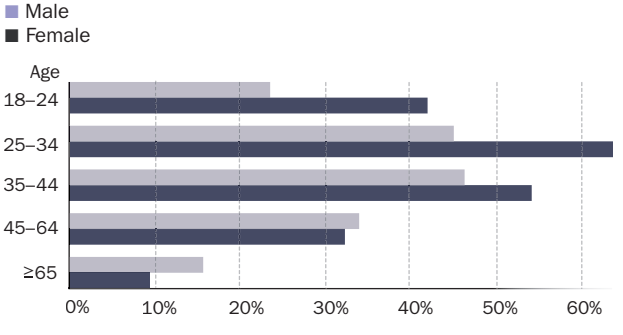
May 10
Winners of the "Best Visual Illusion of the Year Contest" announced in Naples, Fla. View entries at illusioncontest.neuralcorrelate.com

May 10–15
Intel International Science and Engineering Fair for students in grades 9–12 in Reno, Nev. Visit www.societyforscience.org

June 10–14
The World Science Festival in New York City. See the lineup at www.worldsciencefestival.com

Science Stats | FEMALES TESTED MORE THAN MALES

Percentage of U.S. adults age 18 and older who have ever been tested for HIV, by age group and sex, data from 2007



SOURCE: 2007 NATIONAL HEALTH INTERVIEW SURVEY, NATIONAL CENTER FOR HEALTH STATISTICS

Introducing...

Not only is this jumping spider a new species, it's also unusual enough to justify naming a new genus. Called *Tabuina varirata*, the species belongs on one of the sparser, more isolated branches of the spider family tree, reports Wayne Maddison in *Zootaxa*. Maddison, director of the Beaty Biodiversity Museum in Vancouver, Canada, named the spider after discovering it on a 2008 Conservation International expedition in Papua New Guinea. After a month in the country, researchers identified some 600 plant and animal species. Maddison discovered about 50 spiders believed to be new to science.

CLOCKWISE FROM TOP LEFT: MCMASTER UNIVERSITY; B. URMSTON; W. MADDISON

“If you want to communicate, this is the cloak for you.” — JOHN PENDRY, PAGE 12

In the News

STORY ONE

Landscaper’s darling hybridizes into an environmental nuisance

Variation underlies the Callery pear tree’s transformation

By Susan Milius

As in other tales of nice kids gone wrong, the Callery pear tree’s troubles can be traced to a gang of new pals, a new genetic analysis suggests.

Imported from China, the Callery pear won U.S. hearts and yards coast to coast for its early spring clouds of white blossoms. The first ornamental variety of the species, named Bradford, went on sale in the early 1960s. It didn’t form fruit, so there would be no squishies on sidewalks or seeds escaping to sprout in native areas. Bradford’s success inspired the introduction of other named varieties.

Now many Callery pear varieties in the eastern United States bear bumper crops of hard, marble-sized fruits, says Theresa Culley of the University of Cincinnati. Animals distribute the seeds, and they sprout into dense thickets, sometimes with thorns, that can crowd out other plants.

Callery pears, *Pyrus calleryana,* have earned both a 2005 Urban Tree of the Year award (for the Chanticleer cultivar) and a place on the U.S. Fish & Wildlife Service list of highly invasive plants in the Mid-Atlantic.

What went wrong, Culley and Cincinnati colleague Nicole Hardiman report in the May *Biological Invasions*, was the proliferation of other cultivars introduced into the ornamental pear market after Bradford’s success. These later introductions added enough genetic variety to the gene pool for the trees to overcome their usual sterility and pollinate each other.

Sadly, it’s not just a few combinations of the varieties that can produce wilding seeds, Culley and Hardiman show. As Culley puts it, “It’s everything.”

Such cross-variety mixing puts the Callery pear on the latest list of plants and animals that have turned invasive after some form of hybridization, says Norm Ellstrand of the University of California, Riverside. The original list, published by Ellstrand and Kristina Schierenbeck in 2000, included 28 examples. Now there’s evidence for 35, Schierenbeck, with the Agricultural Research Service based at the University of Nevada, Reno and Ellstrand report, also in the May *Biological Invasions*.

The new pear study “does illustrate really nicely this issue of cultivated varieties and why we should be careful,” says conservation biologist Sarah Reichard of the University of Washington in Seattle. “We’re not just being arbitrary when we say, ‘No, your nice, supposedly

A survivor in its native Asia, a wild Callery pear tree photographed in 1917 in China thrived on a parched mountain (above). The first ornamental variety of the tree marketed in the United States was so successful that more followed, leading to hybridization and wild thickets of the tree (right).

FROM LEFT: FRANK N. MEYER TYPESCRIPT/SPECIAL COLLECTIONS/NATIONAL AGRICULTURAL LIBRARY; DAVID J. MOORHEAD, UNIVERSITY OF GEORGIA/BUGWOOD.ORG

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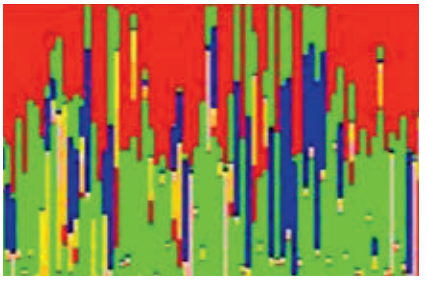
safe, sterile cultivar really may not be.'"

Invasive species disrupt ecosystems and, to put the problem in more immediate terms, cost a lot of money, suggests work by David Pimentel of Cornell University. In his last tally, from 2005, unwelcome aliens, from feral pigs and starlings to water weeds and plant pathogens, cost the United States almost $120 billion a year.

In their native range, however, Callery pear trees are not a problem. "I've heard it's actually hard to find this tree growing in the wild," Culley says.

The U.S. government paid noted plant explorer Frank N. Meyer to search for trees in China in the 1910s and send back seed. Fire blight disease was rampant in U.S. pear orchards, so researchers culled through trees grown from the imported seed to select disease-resistant rootstocks. Then researchers looked through their many trees and selected one to clone and market as an ornamental — Bradford.

Early on, the Bradford ornamental didn't fruit. Callery pears have a built-in safety lock against self-pollination. Called gametophytic self-incompatibility, this plant system sabotages (male) pollen that's genetically similar to the female tissue of the plant. Researchers have identified a single gene for this system in the pear and in some other plants, Culley says. Each tree inherits a version of the gene called an allele from mom and another from dad. Forming pollen or egg cells will split the pair.



Pears going wild in Ohio are mostly the product of crosses between original varieties. Columns represent trees (102 in all), and colors show each tree's mix of DNA inherited from an original variety.

But whether a pollen grain inherits mom's or dad's allele, the tree recognizes the similarity should the grains land on its flowers. The similarity of the alleles triggers a mechanism that blocks the pollen from fertilizing the flower's female parts. The grain starts growing a tube toward the egg, but the intervening tissue secretes an enzyme that destroys pollen RNA and shuts down the growth.

Those first Bradford trees were genetic clones of a single gorgeous tree. They didn't fruit because, as far as their safety lock knew, all the other Bradford trees were still the same tree. As Bradford became popular though, nurseries started selling other varieties cloned from different, also remarkable, individuals among the Callery pear trees. Some populations of plants don't have much variety in the incompatibility alleles, but the Callery pears have turned out to have plenty. And so trees received pollen that, instead of setting off any alarms, bore fruit.

In their study, Culley and Hardiman checked nine pieces of the highly variable, repetitious DNA called microsatellites to create genetic profiles of the popular Callery pear clones on the market. Looking at the mixed-and-matched microsatellites in wild trees let the researchers figure out parentage. The results pointed to a surprising amount of hybridizing going on in stands that have sprung up in Ohio, Tennessee and Maryland. Trees in these weedy patches are offspring of two cultivars, of a hybrid and a cultivar, or of two hybrids.

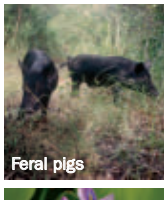
Experimental crosses of four common pear varieties likewise yielded fruit in almost all combinations.

Reichard reports that she has yet to hear of problem pears sprouting along the West Coast. Invasiveness varies by region, and she urges gardeners to keep an eye out for potential rogues. She recommends that both buyers and sellers of plants look up the St. Louis voluntary codes of conduct for guidance in keeping plants from falling into the wrong crowd. ■

Back Story | COSTS OF INVASIVES

The Callery pear tree is among some 50,000 foreign species of all sorts that have moved into the United States, some intentionally, some not. Europe's latest count reveals at least 10,000. A small percentage of invasives prove to be a noticeable pain in the pocketbook.


Melaleuca

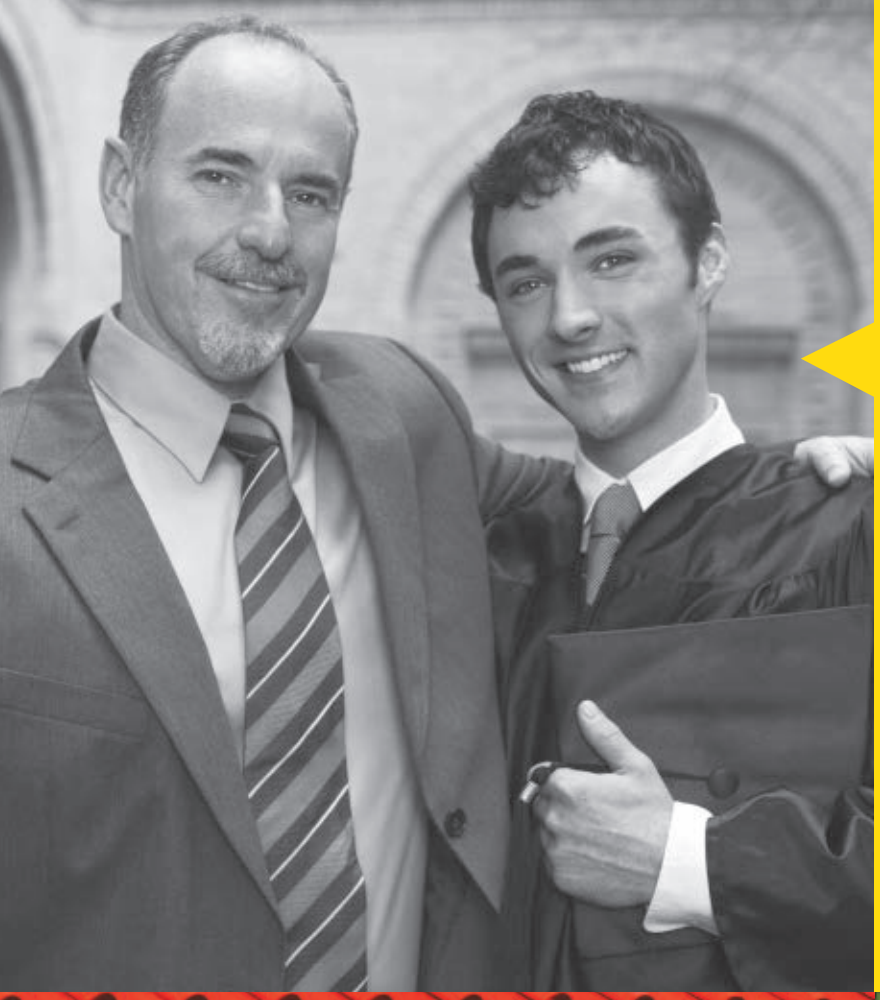

Feral pigs


Water hyacinth

Invader	Reasons for U.S. cost	Cost per year in millions of dollars
Purple loosestrife *Lythrum salicaria*	control, loss	45
Melaleuca *Melaleuca quinquenervia*	control	3–6
Feral pig *Sus scrofa*	loss, damage, control	800.5
Green crab *Carcinus maenas*	loss, damage	44
Imported fire ant *Solenopsis invicta*	loss, damage, control	1,000

Invader	Country: Reasons for cost	Cost per year in millions of euros
Water hyacinth *Eichhornia crassipes*	Spain: control, eradication	3.35
Marine alga *Chrysochromulina polylepis*	Norway: toxic bloom	8.18
Nutria *Myocastor coypus*	Italy: control, damage	2.85

IMAGES FROM TOP: T. CULLEY AND N. HARDIMAN/*BIOLOGICAL INVASIONS*; STEPHEN AUSMUS; DAN CLARK; WILFREDO ROBLES; BACK STORY DATA SOURCES: U.S.: PIMENTEL *ET AL./ECOLOGICAL ECONOMICS* 2005. EUROPE: VILÀ *ET AL./FRONTIERS IN ECOLOGY AND THE ENVIRONMENT* IN PRESS.



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Life

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Brash birds get nabbed more often

Personality may affect which flycatchers end up in the lab

By Susan Milius

Who knows whether birds have their own snarky personality jokes. But researchers now say collared flycatchers with a dashing and curious character are especially likely to get caught in researchers' traps.

The trappable birds readily explore novelties and take risks in the wild, says László Zsolt Garamszegi, now at Doñana Biological Station near Seville, Spain. And their susceptibility comes from that behavioral style, Garamszegi and colleagues report in the April *Animal Behaviour*.

Early work on bird "personality," called behavioral syndrome, has tested birds in controlled settings. But Garamszegi, then at the University of Antwerp in Belgium, and his colleagues watched wild collared flycatchers (*Ficedula albicollis*) to see if individuals had syndromes and if those syndromes, rather than age and condition, affected the ease of trapping.

New work suggests flycatchers have their own versions of personality, influencing their likelihood of getting caught.

In a test for readiness to cope with novelty, researchers assessed each male's typical behavior by placing a live female in a cage at his nest box. Then researchers attached a novel object, a piece of white paper, to the male's nest box and watched to see how curiously he explored the oddity. To grade birds' willingness to take risks, researchers determined how close a bird would let them approach. And for aggressive tendencies, the researchers observed how vigorously a territory holder objected to the arrival of a caged male.

With these data, researchers found links between individuals' behaviors in different contexts. Birds that explored novelties readily were also likely to allow humans to get close. After trapping attempts, the researchers found birds with these two traits were also more likely to get caught.

"Your capturing method really influences the outcome of your study," says Garamszegi. In fact, after dropping data from shy, untrappable birds, the researchers redid the behavioral syndrome analyses and found the strength of some of the links changed. "When you have a different sample, you may find completely different biological patterns," he says.

Ann Hedrick of the University of California, Davis, who studies behavioral syndromes in crickets, says the work "draws attention to an important consideration in designing future studies."

Arthropods came ashore in shells

Gear may have kept gills wet during transition onto land

By Sid Perkins

Some of the first creatures to leave the ocean and venture onto land may have done so by carrying a bit of the sea with them. Fossil trackways left on ancient tidal flats 500 million years ago hint that some ocean-dwelling arthropods, like today's hermit crabs, hauled out onto land wearing shells, researchers report in the April *Geology*. Those shells would have protected the creatures' delicate gills from drying out and may also have held small reservoirs of seawater.

Much scientific attention has focused on the water-to-land transition that vertebrates made around 380 million years ago (*SN: 6/17/06, p. 379*; *1/31/09, p. 30*). But by that era, another group of creatures — arthropods, the group that today includes crustaceans, scorpions and insects — had been strolling around on land for more than 115 million years, notes James W. Hagadorn of Amherst College in Massachusetts.

Hagadorn and Adolf Seilacher of Yale University studied arthropod trackways found in 500-million-year-old sandstone in central Wisconsin. Some of the trackways include impressions scraped into the sand on either side of the creature's footprints. If a trailing appendage like a tail had made those impressions, the scrapes would be similar to the tire tracks made by a truck-drawn trailer: extending farther to the right as the creature turned left, and more to the left as the creature turned right, Hagadorn says.

But in the Wisconsin trackways, the scrapes swung farther to the left of the footprints regardless of which direction the creature was turning. The team speculates that the asymmetric impressions were made by a shell that the creature carried on its back like modern-day hermit crabs do. That shell would have provided a humid chamber so the creatures could extend their foraging time on land.

"This is a pretty neat study," says Anthony Martin of Emory University in Atlanta. "That Cambrian arthropods had some sort of behavioral adaptation for coping with times out of water is not so surprising, but for them to be using shells like hermit crabs nearly 500 million years ago is amazing."

MIKLOS LACZI

"Everything that must be inside is outside, and everything that should be outside is inside." — BORIS JOFFE

Oddities in rod cells may help with night sight

Nocturnal mammals invert retinal DNA arrangement

By Tina Hesman Saey

Mice and cats don't usually agree, but both animals have the same bright idea about night vision. Cats, rats, mice and other nocturnal mammals arrange DNA in some eye cells to form miniature lenses that help focus light, a new study shows.

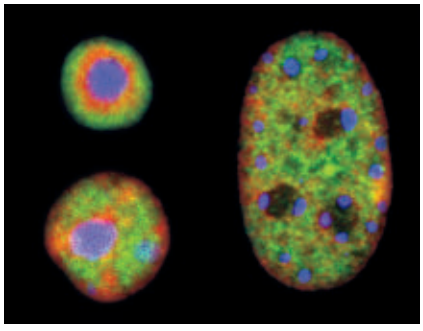
Scientists at the Ludwig-Maximilians University Munich in Germany and colleagues discovered the unusual DNA arrangement while investigating genes in the rod cells of mouse eyes, says Boris Joffe, one of the authors of the new study, which appears in the April 17 *Cell*. Rod cells are light-gathering cells in the retina of the eye. They operate under low-light conditions, while cone cells perform the light-gathering duty when it is bright.

Usually, active genes are located in the part of DNA at the center of a cell's nucleus. There, the genes have easy access to the cellular machinery that rewrites instructions encoded in the DNA into RNA. Inactive DNA is pushed to the periphery of the nucleus, where it is out of the way.

But rod cells in the mouse retina shove active genes to the outside of the nucleus, the researchers found. The center of the nucleus is instead occupied by densely packed inactive DNA called heterochromatin. Mice give this type of DNA center stage in their rod cells.

"Everything that must be inside is outside, and everything that should be outside is inside," Joffe says. "It was an absolutely heretic finding."

The team decided to examine retinas from more than a dozen different species of mammals and found that animals active in low-light conditions, including cats, rats, deer, opossum, rabbits and ferrets, had the inside-out arrangement in rod cells. But animals active during the day had the conventional DNA arrangement with heterochromatin on the outside of the nucleus.



DNA stains show inactive (blue, red) and active DNA (green) in the nuclei of mouse rod cells (top left), ganglion cells (bottom left) and skin cells (right).

The researchers then consulted Jochen Guck, a biophysicist at the University of Cambridge in England. "It was very obvious to me that the nuclei could only be lenses," Guck says.

Placing dense heterochromatin in the center of the nucleus raises the refractivity index — the degree to which the material decreases the speed of light through it. Photons travel faster through the loosely packed DNA containing active genes and slower through the dense heterochromatin. So the heterochromatin acts as a lens, slowing photons to focus light.

Guck's computer simulations show that light would be channeled along columns of rod cells with the inverted configuration, but that the conventional DNA arrangement would scatter light.

This is the first time scientists have discovered DNA acting as a lens in photoreceptor cells, says Gregory Acland of Cornell University. But arranging components of retina cells to reduce light scattering isn't new, he says. Birds and some lizards and fish use oil droplets in cone cells to funnel light.

Still, this may be the first evidence for light-funneling in rods, says Trevor Lamb of the Australian National University in Canberra. The team, however, hasn't actually shown that the funneling would improve night vision, he says.

FROM TOP: SOLOVEI *ET AL.*/*CELL* 2009; GLOBALP/ISTOCKPHOTO

Lizards bask for more than warmth

A lounging lizard might not bask just for warmth — it may be getting a much-needed hit of vitamin D. A new study reports that panther chameleons (one shown) set their sunbathing schedule depending on how much vitamin D they need. The new work, published in the May/June *Physiological and Biochemical Zoology*, has implications for how zoos and pet owners care for reptiles. Scientists once thought that basking was for regulating body temperature alone, says study leader Kristopher Karsten of Texas Christian University in Fort Worth. But sunbathing is also important for modifying a vitamin D precursor found in skin. Chameleons fed a diet low in vitamin D spent more time basking in the sun than their counterparts, the researchers report. The study "calls attention to the fact that providing ample opportunity for basking is important," says Mark Acierno of Louisiana State University's School of Veterinary Medicine in Baton Rouge. — *Rachel Ehrenberg*

Body & Brain

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

Other, friendly fat present in adult humans

Brown fat could help keep people warm and slender

By Tina Hesman Saey

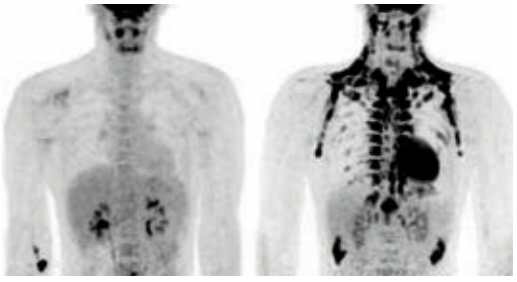
In the ongoing battle of the bulge, maybe it is time to fight fat with fat. Three studies in the April 9 *New England Journal of Medicine* show that some adult humans have brown fat, an energy-burning type of fat previously thought to be found only in animals and human babies. All together, the findings suggest brown fat may be common, the researchers say.

White fat cells store energy, but brown fat cells burn energy and give off heat. Mice and human babies have brown fat on their backs to help maintain body temperature. Mice keep the fat through life, but brown fat disappears as babies age. Many researchers thought adult humans didn't have it, or if they did, that it didn't play an important role in the body.

Now, the new studies demonstrate that brown fat is found in adults and it may be important for regulating body weight and blood sugar. But the fat isn't where people expected it. In adults, brown fat was found in the neck, abdomen, above the collarbone and around the spine.

Ronald Kahn of the Joslin Diabetes Center and Harvard Medical School in Boston and colleagues examined records from 1,972 people who had PET-CT scans for medical reasons. The team found evidence of brown fat in 7.5 percent of the women and 3.1 percent of the men. The fat was more apparent in people younger than 50, people with healthy blood sugar levels and in lean people. Records revealed the fat was more evident in scans taken in cold weather.

Though the study found brown fat in a minority of scans, the fat may actually be common because radiologists take scans under conditions that would minimize its visibility, Kahn says.



Brown fat (black) shows up in a PET-CT scan of a man after exposure to cold (right) but is not as apparent in a scan at room temperature (left).

Once considered irrelevant, brown fat could be used as a target for fighting obesity, says Francesco Celi of the National Institute of Diabetes and Digestive and Kidney Diseases in Bethesda, Md.

In another study, Wouter van Marken Lichtenbelt of Maastricht University Medical Center in the Netherlands and colleagues scanned lean and overweight men at room temperature (22° Celsius) and 16°C. The researchers saw almost no brown fat in room temperature scans, but the fat was apparent in 23 of 24 men when they were exposed to cold. The more overweight men were, the less brown fat activity they had.

A third study found a marker of brown fat in three of three biopsied volunteers.

Scientists suspect brown fat may help lean people keep weight off. Obese people may be overweight partly because they lack brown fat and can't burn all the calories they take in, or their white fat may provide insulation so brown fat isn't needed, van Marken Lichtenbelt says.

"It is now without dispute that brown fat is present in adult humans," Kahn says.

Acid reflux link to asthma in doubt

Heartburn drugs may not help patients with severe attacks

By Nathan Seppa

Taking heartburn drugs doesn't reduce severe attacks among asthma patients, researchers report in the April 9 *New England Journal of Medicine*. The findings cast doubt on a long-held assumption that even unnoticed acid reflux exacerbates asthma.

Many doctors prescribe proton pump inhibitors such as Nexium or Prilosec — used for acid reflux, commonly called heartburn — for asthma patients. Earlier studies have suggested that acid reflux worsens asthma by irritating nerves that serve the windpipe and esophagus or by sending stomach acid up the esophagus and down into the windpipe, says study coauthor Robert Wise of Johns Hopkins University in Baltimore.

Doctors have reasoned that treating even silent acid reflux, which causes no outward symptoms, would thus ease the bronchial constriction and coughing of asthma attacks.

In the new study, the team recruited people with asthma that was poorly controlled by standard drugs but excluded people who reported regular discomfort from acid reflux. Tests for acid in the esophagus showed that about 40 percent of the participants in both the group treated with heartburn drugs and the placebo group had silent acid reflux.

Nevertheless, over a period of nearly six months, the rate of severe asthma attacks was no different between the people getting the drugs or placebos.

"This was quite unexpected," says study collaborator Nicola Hanania of Baylor College of Medicine in Houston.

Wise estimates that 15 to 65 percent of people with asthma get the drugs on the assumption it will help their asthma. ■

W. VAN MARKEN LICHTENBELT

"I wouldn't want doctors and patients to overreact to this hypoglycemia issue and leave blood sugar levels to run high."— PHILIP CRYER

Hypoglycemia linked to dementia

Severe low blood sugar episodes might heighten risk later

By Nathan Seppa

A single episode of low blood sugar severe enough to require prompt medical attention increases a person's risk of developing dementia in old age, a study in people with diabetes suggests. More than one bout of hypoglycemia seems to heighten the risk even further, researchers report in the April 15 *Journal of the American Medical Association*.

Chronically high blood sugar is known to increase the risk of dementia, but less is known about the long-term effects of periodic low blood sugar, says study coauthor Rachel Whitmer of the Kaiser Permanente Division of Research in Oakland, Calif.

She and her colleagues analyzed medical records dating from 1980 to 2002 and identified nearly 17,000 people who had type 2 diabetes but no signs of dementia, mild cognitive impairment or even memory complaints during the time span. The people averaged 65 years of age when surveyed in the mid-1990s.

The scientists noted any low blood sugar episodes requiring a trip to a hospital or other emergency facility. For such treatment, Whitmer says, a patient would have gone beyond just being shaky and weak. "These were events where patients may have fainted or passed out or may have been unable to communicate with others — and were brought in," she says.

The scientists then checked for any dementia diagnoses from 2003 to 2007 in this population and found 1,822 cases.

After accounting for differences in age, weight, race, education, gender and diabetes history, the team found that people with one severe low blood sugar episode on their record were 45 percent more likely to have dementia in their later years than were people who hadn't had blood sugar crashes. Those with two or more episodes faced more than double the risk. The authors hypothesize that a glucose shortage in brain cells might play a role.

"This is a worrisome association," says Philip Cryer of Washington University in St. Louis. But he notes that the find doesn't prove that one factor causes the other. "I wouldn't want doctors and patients to overreact to this hypoglycemia issue and leave blood sugar levels to run high."

Matter & Energy

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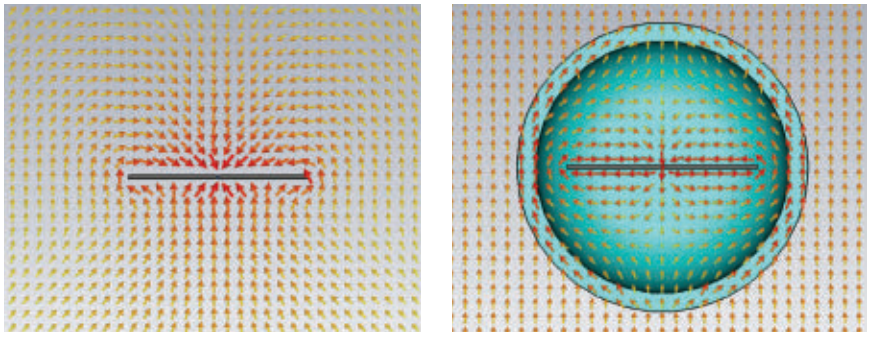


Cloak for communication A bare sensor disrupts the uniform flow of electromagnetic waves (left). Unperturbed waves are in yellow, disturbances in red. A new proposal for a cloaked sensor (right) would perturb the waves much less, while still allowing messages to pass through.

Undetectable sensor would still see

New cloaking method may allow signals to be sent, received

By Laura Sanders

Cell phones, radio receivers and GPS devices may one day go incognito. In a paper to appear in *Physical Review Letters*, Nader Engheta and Andrea Alù propose a new cloaking method that would cancel out electromagnetic waves bouncing off an object. The concept may ultimately lead to surreptitious sensors that can collect and send messages without detection.

"This is a fascinating paper addressing a very important challenge," says physicist Nikolay Zheludev of the University of Southampton in England. "The result could have metrological, environmental and defense applications when the idea is developed as a practical device."

The new cloak would manipulate electromagnetic waves — including light — not by blocking out the waves, but by working with them. Previous cloaks worked by diverting waves around an object. "We are asking the question, 'Is it possible to put a layer around an object such that when a wave hits the object, the wave scatters less?'" says Engheta, of the University of Pennsylvania in Philadelphia.

Separately, the object and the cloak would both be visible. But the cloak would be designed so that when the two are together, the waves scattering off of both objects would combine destructively and cancel out each other, Engheta says.

The key is that electromagnetic waves still enter the cloaked area and hit the object — a requirement for an antenna to pick up a signal, for example. This feature is what separates the new work from other cloaking methods that completely isolate objects from the environment. The cloak could also be designed to not interfere with certain types of outgoing waves (other than the ones being dampened), allowing the sensor to still send unperturbed messages.

"If you want to communicate, this is the cloak for you," says John Pendry, a theoretical physicist at Imperial College London. In 2006, Pendry and his colleagues created the type of cloak that directs microwaves around an object. Wrapping the new type of cloak around devices perched on top of military vehicles could minimize telltale scattering while still allowing the sending and receiving of crucial messages.

Researchers have a long way to go before these cloaks become a reality. Each has to be fine-tuned to suit the object it's cloaking and will likely work for only a small range of electromagnetic waves, Engheta says. But the blueprint will work for many different types of waves, he says.

Double-laser approach leads to one thin line

Erasing, stenciling offer new nanolithography techniques

By Rachel Ehrenberg

Michelangelo couldn't have chiseled David's features with the edge of a backhoe. But just such a challenge faces scientists working in the infinitesimally small world of nanolithography, the ultratiny writing used to make computer chips, solar cells and other devices. Now three reports, published online April 9 in *Science*, introduce new methods to erase writing and stencil patterns, putting a finer point on the tools used to sculpt the incredibly shrinking nanoworld.

The research "could spawn all kinds of interesting ideas and new approaches," says Greg Wallraff of the IBM Almaden Research Center in San Jose, Calif.

Current nanolithography techniques use ultraviolet light to etch patterns and images that can be used, for example, to inscribe circuitry on computer chips. Light is projected through a lens onto a material that reacts upon exposure. That material is often a liquid compound called a monomer, which turns into a hardened, repeating version of itself, a polymer, when exposed to light.

Progress has been made in using smaller and smaller wavelengths of light to create printed patterns, but that approach is limited in part because of how light behaves at such short wavelengths.

Robert McLeod of the University of Colorado at Boulder and his colleagues decided instead to use two beams of light at the same time — one acting as the ink, the other as an eraser. "Imagine trying to draw a very fine line with a thick marker," McLeod says. "We can make that thick line thinner if we have an eraser."

Fiddling with the chemistry of the

A. ALÙ, N. ENGHETA

light-sensitive monomer made the new approach possible. The scientists added two ingredients: an initiator that reacts with blue light and an inhibitor that reacts with UV light. When the scientists project the blue light through the lens onto the monomer, the liquid absorbs the light and releases radicals hungry to bond. And bond they do, creating a solid polymer wherever the blue light hits.

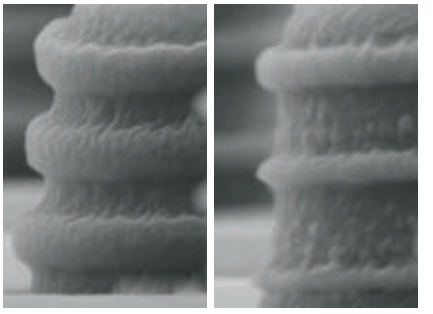
The UV light then acts as the eraser, the team reports. Around the pinpoint of blue light, the scientists created a doughnut of UV light, stimulating the chemical inhibitor in the monomer. This process also produces radicals, but these snatch up other radicals, preventing polymerization. So a fine line is created by sweeping the periphery with UV light.

John Fourkas of the University of Maryland in College Park and colleagues report a similar approach: An activating laser beam gets polymerization going, and a de-activating beam keeps the polymerization contained.

Sculpting with light may allow these researchers to craft tiny gears for tiny machines or finely detailed screens for controlling where light hits a material.

In a third paper, Rajesh Menon of MIT and his colleagues describe a technique that also uses two different wavelengths of light. But the researchers blocked light instead of erasing it.

The team placed light-sensitive film over the material to be patterned. Upon exposure to UV light, the film becomes transparent, allowing the scientists to "cut" a window wherever desired. Light of another wavelength can be shone through the stencil to etch the material beneath.



New studies show thinner rings are possible with a two-laser approach (right). Other methods yield bulkier rings (left).

The studies aren't likely to revolutionize the semiconductor industry, says Robert Allen, also of IBM. But "what they have done with very long wavelengths of light is spectacular."

Nanoclusters battle second law

In simulations, collisions can increase velocity, reduce entropy

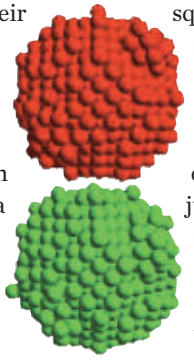
By Laura Sanders

Nobody's above the law. But tiny clusters of colliding atoms may duck below the second law of thermodynamics. In simulations, researchers in Japan found that in rare cases, tiny clusters of atoms ricochet off each other faster than their approaching speeds. The results, in the March *Physical Review E*, seem to violate the second law's requirement that any work squanders a little bit of energy in the form of waste heat, leaving a system with higher entropy.

In collisions big enough to see, like those between a tennis ball and a gym floor, the speed of an object's approach is always faster than its speed after impact. A ball dropped against the floor bounces a little slower and comes up shorter on each bounce because a small amount of the ball's energy is siphoned as heat.

In the nanoworld, though, normal rules do not always apply, the results suggest.

Researchers Hisao Hayakawa of Kyoto University and Hiroto Kuninaka of Chuo University in Tokyo developed a computer program to model head-on collisions of squishy collections of several hundred atoms called nanoclusters. At speeds around 5 meters per second, most of the clusters in the simulation stuck together like two candied apples in the sun. Others just bumped into each other and moved away at a slower rate than their approach.



Nanoclusters sometimes gained speed after colliding in simulations, seeming to defy the second law of thermodynamics.

But about 5 percent of the time, the colliding nanoclusters sped up after bumping, exhibiting what the researchers call a super rebound. In these rebounds, the outgoing energy exceeded the incoming energy, meaning that the system overall lost entropy, an apparent violation of the second law.

"It's an interesting observation. For me, it was also counterintuitive," comments Jörn Dunkel, a theoretical physicist at the University of Oxford in England.

This superbounce comes from the random fluctuations of motions of the atoms that make up each nanocluster, the researchers say. Depending on the exact motions, some fluctuations can give the collision an extra boost, like an extra springy trampoline.

"Nanoscale physics involves such unexpected events," Hayakawa says.

But this extra boost works only in tiny systems. When the researchers increased the size of each nanocluster in the simulation to over 1,000 atoms, the superbounce disappeared entirely. "In order to see a violation of the second law, you need a very small number," Dunkel says.

These clusters evade the second law on a statistical technicality: The average speed of all the outgoing nanoclusters is less than the approaching speed. Even though individual nanoclusters appear to violate the second law occasionally, the average behavior of all the nanoclusters falls in line with the law's constraints.

FROM TOP: FOURKAS *ET AL.*/SCIENCE/AAAS; KUNINAKA *ET AL.*/*PHYSICAL REVIEW E*

Earth

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Drop in oceanic nickel may have set stage for atmospheric oxygen

Banded iron formations point to changes in early seawater

By Solmaz Barazesh

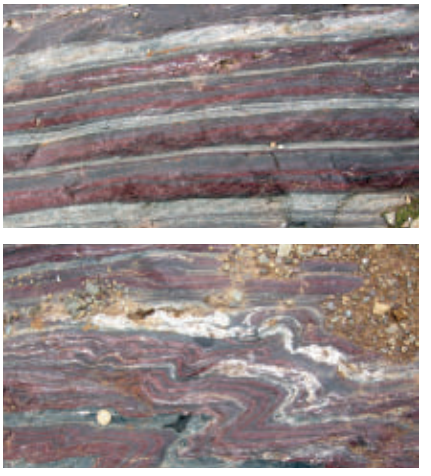
A decrease in the amount of dissolved nickel in ocean waters beginning 2.7 billion years ago could have stifled methane-producing bacteria and set the scene for oxidation of the Earth's atmosphere, researchers report in the April 9 *Nature*.

Billions of years ago, methane-producing bacteria called methanogens thrived in nickel-rich seas. The large amounts of methane pumped into the environment by this early life may have prevented oxygen accumulation in the atmosphere because the methane would have reacted with any oxygen, creating carbon dioxide and water, the researchers suggest.

The Earth's atmosphere changed 2.4 billion years ago when oxygen levels increased in what scientists call the Great Oxidation Event. Researchers debate how these atmospheric changes occurred.

In the new research, Kurt Konhauser of the University of Alberta in Edmonton, Canada, and his colleagues measured nickel-to-iron ratios in banded iron formations, rocks consisting of layers of iron, silica and trace metals that formed from sediments in ocean water billions of years ago. The composition of the rocks provides a record of the metals that were in the oceans when the rocks formed, Konhauser says.

By measuring about 30 rock formations of different ages, the team found that the amount of nickel in the rocks began to drop about 2.7 billion years ago, and that levels had halved by 2.5 billion years ago. The researchers used the rock data to calculate decreases in the amount of dissolved nickel in seawater.



Nickel-to-iron ratios in ancient rocks suggest a decrease in the amount of dissolved nickel in seawater could have led to the Great Oxidation Event.

"This is a really interesting data set," says David Catling of the University of Washington in Seattle. "As far as I'm aware, no one else has deduced nickel concentrations in the ocean over time."

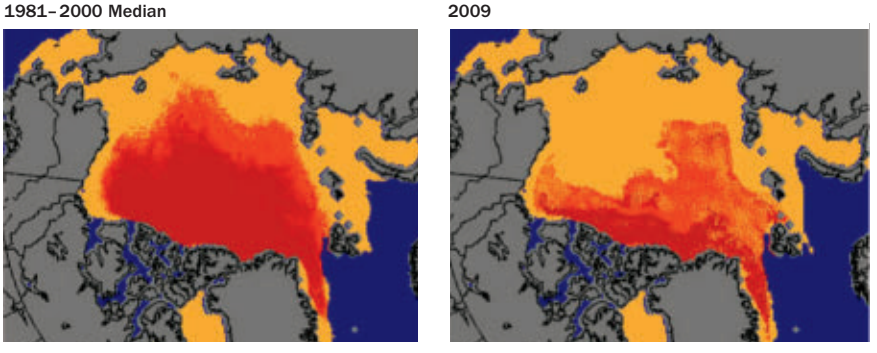
The lower nickel content of the ocean waters could have reduced the activity of the methanogens, so the supply of methane gas diffusing from water to atmosphere would have decreased over time. "Methanogens use nickel-based enzymes to power their many important metabolic reactions," Konhauser says.

That decrease in methane would have allowed atmospheric oxygen levels to increase, the researchers speculate.

Changes that occurred as the Earth's upper mantle cooled probably caused the decrease in nickel, the researchers say. Volcanic eruptions from a cooler mantle created fewer nickel-rich rocks, making less of the metal available to dissolve in the oceans.

Catling notes that nickel might be one of several factors that contributed to the changing atmosphere.

CLOCKWISE FROM TOP RIGHT: STEFAN LALONDE (BOTH); NATIONAL SNOW AND ICE DATA CENTER, COURTESY OF J. MASLANIK AND C. FOWLER/UNIV. OF COLORADO (BOTH)



Less, thinner Arctic ice

The spring melting of the Arctic Ocean's ice cap has already begun, and data suggest that the ice is more vulnerable than ever: The ocean area covered by ice is one of the lowest ever measured by satellites, and a record high fraction of it is capped by thin, first-year ice (gold) that's more prone to melting than older, thicker ice (reds). Satellite images reveal that for March 2009 an average of 15.16 million square kilometers of Arctic seas was covered by ice, says Walt Meier of the National Snow and Ice Data Center in Boulder, Colo. That's 730,000 square kilometers more than the record-low ice extent measured in the spring of 2006 and about 590,000 square kilometers—an area slightly smaller than Texas—less than the long-term average, as tallied between 1979 and 2000, he said during a press teleconference on April 6. —*Sid Perkins*

Atom & Cosmos

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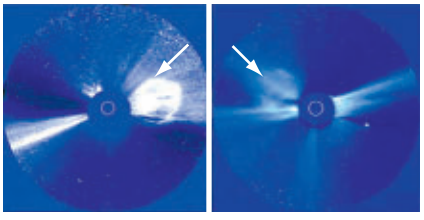
Solar flares now trackable in 3-D

Craft positioning improves imaging of mass ejections

By Sid Perkins



New STEREO views of a massive solar flare (arrows) allow scientists to assess its size, shape, speed and trajectory.

NASA

WASHINGTON—For the first time, scientists can accurately assess the size, shape and speed of massive flares as they leave the sun, allowing better estimates of when the flares might strike Earth and cause widespread electrical disruptions.

Since early 2007, NASA researchers have been gathering solar data using sensors onboard two craft known as STEREO, the Solar Terrestrial Relations Observatory (*SN: 2/10/07, p. 93*). One of those golf-cart–sized, 620-kilogram probes now orbits the sun about 50 million miles ahead of Earth, and the other orbits about 50 million miles behind the planet. The broad span between the craft, like the separation between human eyes, now provides scientists with two sidelong views of the most massive flares, or coronal mass ejections. The resulting 3-D depth perception helps track a flare as it speeds through space.

Previously, data from STEREO enabled scientists to follow a flare from the sun to Earth (*SN: 3/3/07, p. 133*). Now, researchers can accurately assess the 3-D structure of flares as they develop, says STEREO mission scientist Angelos Vourlidas of the Naval Research Laboratory in Washington, D.C. "We can actually see the shape of the material," he said at a news conference held April 14 at NASA headquarters.

Coronal mass ejections spew billions of tons of charged particles into space. When those eruptions sweep past Earth, they can trigger geomagnetic storms that disrupt radio communications and knock out satellites (*SN: 7/31/04, p. 74*). Particularly bad episodes can pummel electrical grids across large regions and threaten high-flying jets at far-north latitudes, says Michael Kaiser of NASA's Goddard Space Flight Center in Greenbelt, Md.

Swarm Savvy

How bees, ants and other animals avoid dumb collective decisions

By Susan Milius

This is a phone conversation, so if Tom Seeley rolls his eyes, that's his business. He's a distinguished behavioral biologist, full professor at Cornell University, member of the American Academy of Arts & Sciences and so on. Yet he takes it pretty well when asked whether honeybees could have had a real estate crisis and crashed their banking system.

Seeley, at least voice-wise, stays polite and treats this as a serious question. Which it is.

Of course honeybees don't have a banking system, but they do exhibit collective behavior. The queen bee doesn't decide what the colony needs to do. Instead, each colony member does her or his bee thing, and out of hundreds or thousands of interactions, a collective decision emerges. Seeley's next book, due out in 2010, will be called *Honeybee Democracy*.

Bees, ants, locusts and plenty of other animals collectively make life-or-death choices. The biologists studying animal groups are finding strange lab fellows these days in economists, social scientists, even money market specialists. They are trading tales of humans and of nonhuman animals to understand collective behavior and what makes it go right or wrong.

"There is a new excitement in this whole field of decision making these days," says ant biologist Nigel Franks of the University of Bristol in England. Franks and Seeley organized a multidisciplinary conference on collective decision making held in January at the Santa Fe Institute in New Mexico. And both biologists contributed to a special issue of *Philosophical Transactions of the Royal Society B* (March 27) on the same topic. The issue considers insects as well as the European Parliament.

Even compared with gatherings of diplomats in bespoke suits, bee nests and ant colonies have plenty to contribute to the field. "The really lovely thing is that we can take these things apart and put them back together again, and we can challenge them with different problems," Franks says. Seeley notes that studying honeybees has taught him a lot about how to run faculty meetings.

All but the darkest view of university professors credits them with more cognitive power than can be found in the minuscule brains (sorry, bees) of insects. So one might wonder how well collective wisdom works for nonhuman animals.

That question is what makes the research so intriguing. Bee colonies have been making collective decisions for about 30 million years, Seeley says, "so they've had lots of chances for failing systems to get pruned out by natural selec-

FROM TOP: T. SEELEY; DEJAN7750/ISTOCKPHOTO; ARCHITECT OF THE CAPITOL

Rock ants (magnified, top), dabbed with paint so researchers can track who does what, have evolved a quorum system to cope with the challenges of collectively choosing a home. Other forms of this handy way of balancing the need for independent observation with the logistics of moving or leading in a group have also evolved in fish and primates (middle, bottom).

tion." Bees have unique needs of course, but when it comes to real estate (alas, humans), bees almost always get it right.

The human hive

To be fair, today's research on these successful insects draws from studies of the first animal to be analyzed in detail for collective wisdom: *Homo sapiens*.

In the 18th century, Marie-Jean-Antoine-Nicolas de Caritat, marquis de Condorcet, welcomed the French Revolution and used mathematical probabilities to argue for the virtues of shared decision making. Known today as Condorcet's jury theorem, his work describes conditions in which members of a group voting by majority rule are more likely to render a correct choice between two alternatives than is any individual in the group. One of the critical conditions for a happy outcome, the Marquis contended, was that each group member vote independently rather than copy another (possibly mistaken) juror.

Human groups deciding as a whole have scored spooky triumphs. "Nearly everybody is miles out, but when you take the average of these guesses, they're usually very, very accurate," says Ashley Ward, a fish behaviorist at the University of Sydney in Australia, whose work is cited in the special *Transactions* issue. The idea goes by the name "many wrongs," as in many wrongs make a right.

A classic example appeared in *Nature* in 1907. Two reports looked at 787 contestants competing to guess the weight of a particular ox after butchering. Collectively, guessers came within 10 pounds (looking at the median of guesses) or just a pound short (looking at the mean) of the correct weight of 1,198 pounds.

Examples appear in abundance in business writer James Surowiecki's best-seller *The Wisdom of Crowds* (2004). What enthusiasts of crowd wisdom (though not Surowiecki) tend to overlook is that the accuracy is in the arrangements. Those perfect systems of independent deciders who evaluate their own information are tricky to create in the busy real world. And human crowds can go so very, very wrong.

Smart swarms

Honeybees do real estate well. But only in the last decade has a technical breakthrough let Seeley and his colleagues figure out how. Now he has used recent biological insights to work with a scholar from the London School of Economics and Political Science and a mathematician to analyze how bees balance independence and going along with the crowd.

When a robust colony splits, the queen and some two-thirds of the workers move out to search for a new home. Bees swarm out to a temporary perch such as a branch, where they cling to each other in a dangling clump. Having no protection from predators or weather and no food stores, the swarm needs a new home, and fast.

In the 1940s, biologist Martin Lindauer noticed that some bees on the outer layer of a swarm waggle-danced. He knew that foraging bees danced to report flower locations, but these waggling bees looked as if they had picked up soot from a chimney or grit from construction debris. He realized these bees had been scouting for new nest cavities and were dancing about the possibilities.

In his later years Lindauer told Seeley about running through the rubble of war torn Munich trying to keep flying bees in sight. What finally made decisive tests possible (and easier) were affordable, high-quality video cameras, Seeley says. In the 1990s, he and his coworkers filmed and analyzed the intel that scouts waggle to each other on swarm surfaces.

Out of a swarm of 10,000 bees, some 300 to 500 females buzz off to scout possible nest sites. Important features include enough room for storing honey and a small entrance to minimize winter drafts. "Every scout we've seen is an elderly bee that has a lot of experience going around the countryside," Seeley says.

Elderly bees still manage to check out the possibilities over some 30 square kilometers. A good cavity is hard to find, though. Seeley reports that only a few of the scouts, maybe 25, come across something worth reporting to their sisters.

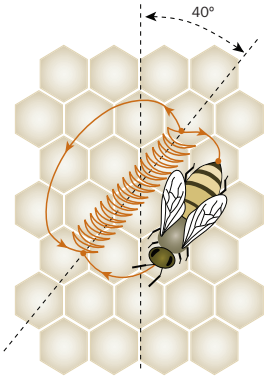
At first scouts dance for a wide variety of sites, perhaps 20 or 30. The dance

GRAPHICS ADAPTED FROM T. SEELEY/*AMERICAN SCIENTIST*, 2006

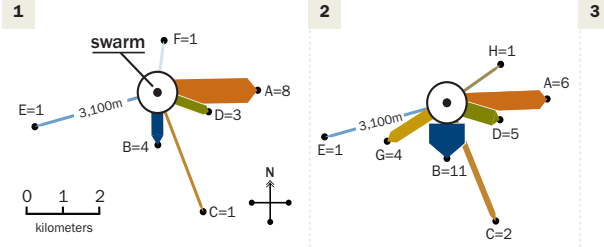
How a honeybee swarm decides

When thousands of honeybees swarm off to find a new home, the emigrants first cluster at a temporary spot while some of the experienced foragers scout sites. Back at the swarm, scouts dance to communicate promising locations, giving other scouts incentive to go look for themselves.

Anatomy of a bee dance
Scouts reporting on a possible nest site use the basic rules of the waggle dance foragers use to describe flower locations. The slant of the dance's main axis indicates a site's direction relative to the sun. How long a bee waggles along the axis indicates how far to fly. The more repetitions, or waggle runs, the more enthusiastic the scout is about the site's quality.



Debate and decide
This schematic shows scouts in a honeybee debate about 11 possible nest sites that ends with all scouts finally favoring location G (possible sites are A through K). Each panel tallies scouts going to and from the swarm (center). Arrow thickness indicates the number of bees dancing in favor of a site. The scouts "decide" when enough meet at a site, but all scouts must dance for the same site at the end for the swarm to stay united.



JULY 20

Time:	11:00–13:00	13:00–15:00
	Scout bees: 18	Scout bees: 30
	Dances: 68	Dances: 70
	Waggle runs: 547	Waggle runs: 2,376
	Site A has eight scouts.	Site B has 11 scouts.

encodes the direction and distance to the cavity, and the more enthusiastic a scout is, the more times she repeats her waggle report. Her dance may inspire her sister scouts to take off and check it out for themselves. They in turn come back to the swarm and dance their opinion.

This recruitment step is critical to the success of the process, Seeley says. Other scouts will look for themselves. As Seeley puts it, "Scouts search autonomously, report freely and argue."

Human groups can falter at this step, Seeley says. They tend to rush to a decision when they could benefit from exploring more options. And a rush to judgment was what went wrong for the bees the one time Seeley saw a swarm fumble a decision in the wild. Support had been building for a nest site that was sort of OK when a scout discovered a superior cavity in an old tree and returned to the swarm to report. "She danced like fury," Seeley says, but she failed to redirect a decision that was already solidifying.

Scouts also go back to a site multiple times, returning to the swarm between trips to dance about it again. For all sites, great to dubious, a scout dances to the swarm with fewer repetitions, perhaps 15 fewer than the time before. Eventually she stops. "It's a clever thing," Seeley says. "They allow their enthusiasm to decay."

Repeat dances for all sites dwindle, but the ho-hum possibilities, first reported with a small number of repetitions, disappear from the dance floor faster than primo sites. The decaying interest makes the decision possible. "We've all been in committee meetings where agreement was never reached because nobody would ever give up," Seeley says.

As the search goes on, scouts dance about fewer and fewer sites. By the time the swarm takes off, scouts are almost always unanimous in dancing about a single site. And that's where they go.

Seeley and his colleagues have established that a decision doesn't occur at the swarm at all. It's what happens at the candidate nest sites that matters. It's all about quorum.

As the better site builds a bigger fan base, more and more scouts shuttle between it and the swarm. When some 15 or so scouts meet outside the nest site — with probably another 30 to 50 bees inside — bingo, that's the new home. Some of the scouts do continue dancing. But while dancers finish their convergence, scouts start motivating the swarm to fly.

Seeley and his colleagues' new model of this process appears in the *Transactions* issue. The model shows that changing the values can crash the system. Requiring that bees in the model act more independently of each other than they actually do in nature, for example, can keep them from making a decision at all. Yet too little independence can easily lead to stupid decisions as bees too readily copy a misguided nest mate. In the real world, honeybees "balance interdependence and independence," Seeley says.

Ants do it

Handy idea, that quorum. Rock ants have evolved one too.

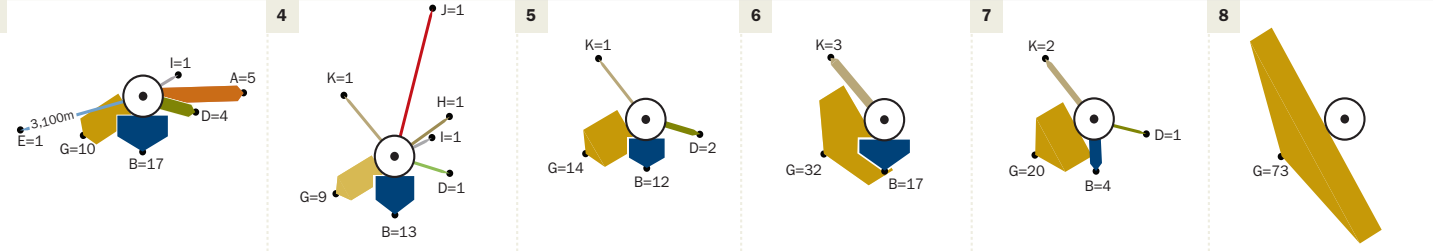
Only a few millimeters long, rock ants (*Temnothorax albipennis*) prove difficult to track in the wild but excellent for the tabletop world of the laboratory.

When something terrible happens to a rock ant home, such as a researcher lifting off the roof, the majority of ants cluster in the ruins. A quarter to a third of the colony scurries out looking for new possibilities.

"I think of the ants as a sort of search engine," Franks says. In one set of tests, he and his students disrupted a nest and watched to see what the ants would make of a series of new possibilities that improved with distance. The best nest was almost three meters distant, nine times as far from the original home as a nearby but less appealing choice. "It was just such fun doing this experiment because the ants won," Franks says.

In spite of the epic distances, the ants typically found and agreed to move into the best nest. "They're fantastic at it," Franks says.

Franks and Elva Robinson, also of the University of Bristol, monitored rock ants by fitting them with radio-frequency identification tags. The data suggest that each scout follows a simpler rule than



		JULY 21			JULY 22
15:00–17:00	**17:00–19:00**	**07:00–09:00**	**09:00–11:00**	**11:00–11:54**	**09:00–11:58**
Scout bees: 38	Scout bees: 27	Scout bees: 29	Scout bees: 52	Scout bees: 27	Scout bees: 73
Dances: 66	Dances: 45	Dances: 53	Dances: 99	Dances: 43	Dances: 352
Waggle runs: 2,400	Waggle runs: 1,877	Waggle runs: 868	Waggle runs: 1,697	Waggle runs: 713	Waggle runs: 3,100
Site B has 17 scouts.	Site B has 13 scouts.	Site G has 14 scouts.	Site G has 32 scouts.	Site G has 20 scouts.	Site G has 73 scouts.

previously thought, Robinson, Franks and their colleagues report online April 22 in *Proceedings of the Royal Society B*.

Instead of making direct comparisons between sites, a scout follows a threshold rule. If she finds a poor site, she keeps searching. When she finds a site that exceeds her "good enough" threshold, she returns to the original nest.

Next, previous work shows, the scout recruits a new scout to join her on a trek to the good site. She dashes around tapping her antennae on other ants and releasing a pheromone from her sting gland, explains Stephen Pratt of Arizona State University in Tempe. Usually she finds a volunteer within a minute or so, and the two set off tandem running.

Scout A, who knows the way, runs back toward the nest while her follower, B, jogs closely enough to tap antennae against the leader. Should A sprint a little too fast and dash beyond antennae range, she slows until her partner catches up. Periodically the two ants stop, and the newbie looks around as if learning landmarks. It's a slow way to get to the site, and Franks argues that it qualifies as animal teaching.

When the ants do reach the possible site, the recruit explores it and, depending on her assessment, returns to recruit yet another scout.

As with the bees, it's the quorum of scouts at the sites that matters. When enough of them gather at a particular place to encounter each other at a sufficiently high rate, they've got a decision.

Once scouts reach that decision, their behavior changes. Each scout dashes back to the nest, but instead of coaxing a nest mate for a tour, she just grabs somebody. She uses a mouthpart hook, an over-the-shoulder throw, and off she goes with the passive nest mate curled on her back in an ant version of the fetal position. Carrying takes about a third as long as leading would, and scouts can haul the rest of the colony to a new home within hours. The ants shift from the independent info gathering of scouts to group implementation of the quorum's decision.

Rock ants' willingness to thrive in the lab allows experiments on finer points of collective decision making, Pratt says. For example, forcing a crisis among the ants demonstrates that they will, in a pinch, trade accuracy for speed. When researchers destroy an old nest so that ants are completely exposed, the ants scope and relocate within hours. Other experiments that just offer the ants a better nest but don't ruin their current one can result in days of deliberation. Speed has its costs, and ants in a hurry now and then make mistakes, such as splitting the colony between two nests. Slower moves prove more accurate.

Ants and bees may run the best-studied decision quorums, but Pratt sees evidence for similar doings in other animals. Studies of cockroaches choosing between hiding places find that a crevice already full of roach buddies attracts more recruits. That phenomenon alone wouldn't qualify as a quorum, Pratt says in an article in the *Transactions* issue. Yet the roaches don't pay a lot of attention to a few lurkers, finding larger numbers quite attractive. Now that, Pratt says, looks like a quorum.

One of the best examples of quorum behavior in a vertebrate other than a human comes from three-spined stickleback fish. In a lab setup, the fish readily swim toward shadowy nooks to hang around. But choosing which nook can depend on the choices made by other fish, Ward and his colleagues reported in *Proceedings of the National Academy of Sciences* in 2008.

To test fish decision making, researchers offered two inviting corners of a tank, each with a path rigged for towing along fake sticklebacks of painted resin. When researchers let two or more real fish watch a single fake "swimming" to one of the corners, the real fish ignored the singleton. Released to choose a corner, the live fish swam off in their own direction regardless of where the fake fish went. However, when researchers towed two artificial fish to a particular corner, the real fish paid attention and proved more likely to favor the same corner.

"They wouldn't take one fish's word for it, but they would take two fish's word for it," Ward says. Going from one fish to two may not seem like a big deal, but Ward argues that it should reduce risk. If one

fish, for example, has a 1 in 20 chance of making a stupid choice, the chance of two fish making the same dumb mistake would drop to 1 in 400, Ward notes. Requiring even a small fish quorum, he says, becomes "a really nice simple mechanism of reducing the chance of completely going wrong and following an idiot."

A real fish all by itself, possibly desperate in its isolation, didn't bother with the quorum. Towing even one fake fish to a particular corner influenced the loner to choose that direction.

When a fake predator, a plastic perch, moved along one path, a loner still tended to swim along that route if researchers offered just one fake stickleback for company. The experiment "shows the possibility that isolated social animals, and that includes human beings, can easily be misled by a mendacious leader," Ward says.

Tricking a whole group of live fish proved much more difficult.

The quorum system could be widespread in group behavior in nature, Pratt says. Overall it's a beautiful tool, allowing for carefully balanced independence plus some shortcut speed. Yet the system "has a dark side," he acknowledges. Once individuals have made their independent assessments and then a quorum has reached agreement, fellows copy the quorum behavior. The chances are low that the whole quorum will reach the same wrong decision. But flukes can happen. In most uses of a quorum, "it's going to make a decision more accurate," he says, "but it also slightly increases the incidence of these rare events when you get it really spectacularly wrong."

A rock ant leads a second scout in a slow tandem run to a possible nest site (top). Once they reach a quorum, scouts stop leading nest mates and just carry them (bottom).

S. PRATT

Bees and ants don't mess up that often, but they have been making fewer kinds of decisions, about nest sites for example, and for millions of years. For humans, "there's a lot more creativity going on in the kinds of problems we solve," Pratt says. Our inventive species has to cope with ever-changing structures, societies and other challenges without millions of years for natural selection to hone the systems.

Pratt sounds wistful in remarking that ants don't have a stock market. "If they did," he says, "we could rely on them to have figured the whole thing out."

Explore more

- Iain D. Couzin. "Collective cognition in animal groups." *Trends in Cognitive Sciences*. January 2009.

The genetic

It may be no tall tale: A few inches

From Danny Devito to Yao Ming, the world is filled with short people and tall people and everyone in between. While factors such as nutrition influence height differences, much of that variation depends on genes. After all, both of Ming's parents were basketball stars, and Devito's were not.

But the genes that made Ming grow to 7 feet 6 inches and Devito stop growing several feet shorter could be important for more than sports. Changes in how height genes work could not only add or subtract a few centimeters from leg length, but could also affect underlying cell biology in ways that can lead to disease, recent research suggests.

Statistical studies find that shorter people are more likely to get heart disease, diabetes and osteoarthritis. Other studies show that the same genes that make healthy cells multiply to make a person grow taller can also make cancer cells proliferate in tumors. On the other hand, genes that make bones grow longer can form extra cartilage in joints, protecting them from the ravages of osteoarthritis.

The long and short of it is that height genes might affect health as well as height — although scientists don't completely understand how.

Some genes that have been implicated

dimension of height and health

taller or shorter could signal a risk for some diseases **By Solmaz Barazesh**

in determining height have been well-studied for their connections to particular diseases, but not as well-studied for how they affect height. And while statistical links between height and disease are robustly documented, scientists don't completely understand if or how the same genes could set the foundation for both height and disease.

Pinning down that connection could have payoffs for treating disease and ensuring health.

"When you take a kid to the pediatrician, the first thing they do is measure the child's height," says geneticist Guillaume Lettre of Children's Hospital Boston and of the Broad Institute, in Cambridge, Mass. He is coauthor of a study that identified several genes associated with height.

Growing too fast or too slow could be a sign of health problems such as hormone imbalances. But if the genes controlling height were well known, pediatricians could easily determine whether a short-for-their-age child simply inherited the gene variants that denote a more diminutive stature, or actually has a more serious condition, Lettre says.

Linking height genes to health is difficult, though, because details of the genetic pathway to height are complex. Many genes work together to create normal variations in height. So far, the suspicion that height genes affect health is supported mostly by statistical studies.

In 2001, for instance, epidemiologist David Gunnell of the University of Bristol in England and colleagues found that taller people can face a 20 to 60 percent greater risk for various cancers, including of the breast, prostate and colon.

Last year, epidemiologist Luisa Zuccolo, also of Bristol, followed up on Gunnell's work with a study focused on the link between height and prostate cancer. The risk of developing prostate cancer increased by 6 percent for every 10 centimeters over the median height of the 1,357 men in the study, Zuccolo and colleagues reported in *Cancer Epidemiology, Biomarkers & Prevention*. Despite the link, height was still less of a risk factor than age and family history, but "understanding why height is associated with prostate cancer could help us to understand its causes," Zuccolo says.

One molecule that taller people have in abundance compared with shorter people is insulin-like growth factor 1, or IGF-1. The insulin-like molecule stimulates the growth of cells and tissues, and higher levels of the molecule have also been linked to the incidence and progression of several different types of cancer. IGF-1 can bind to the tumors of can-

FACING PAGE: JENNIFER POTTHEISER/GETTY IMAGES; THIS PAGE: UPI PHOTO/TERRY SCHMITT; PHOTO ILLUSTRATION BY J. KORENBLAT

cers of the breast, prostate and bladder, stimulating the growth of tumor cells. Zuccolo speculates that the *IGF-1* gene could link height and prostate cancer.

Stimulating growth

IGF-1 is a protein that binds to receptor molecules on other cells, triggering a cascade of events that eventually stimulate cell growth.

A study reported in 2007 in *Science* found that variations in the *IGF-1* gene were one reason that Chihuahuas don't grow as large as Great Danes. Geneticist Nathan Sutter, then at the National Human Genome Research Institute in Bethesda, Md., and colleagues found that small dog breeds had one particular variant of the gene for IGF-1, but almost all giant breeds had a different version of the gene.

A 1993 study by Michael Ranke and colleagues at University Children's Hospital in Tübingen, Germany, found that shorter children had lower levels of IGF-1. Ranke and his colleagues speculate that lower levels of IGF-1 could cause a reduction in growth in early childhood.

In 2001, Gunnell and colleagues reported that leg length is the height component most strongly associated with coronary heart disease and with insulin resistance, a condition that can lead to type 2 diabetes. After measuring leg length and trunk length in 2,429 men and tracking coronary heart disease over 15 years, the team found that insulin resistance and heart disease were more frequent in men with shorter legs, while trunk length showed less association.

But it's not height itself that makes people sick, researchers say. The ratio of leg length to trunk length could signal IGF-1 levels and thus, possibly, a likelihood for certain diseases. Small variations in the amount of IGF-1 produced can affect growth during childhood, and also alter the incidence of disease later in life.

Lower levels of IGF-1 may have other effects. One study found that individuals with the lowest IGF-1 levels had a twofold increase in heart disease incidence, epidemiologist Torben Jørgensen of the University of Copenhagen and colleagues reported in 2002 in *Circulation*.

In a 2004 study of IGF-1, height and disease, Gunnell and his colleagues found that shorter stature is linked to heart disease and to insulin resistance.

Researchers aren't sure why, but large amounts of the IGF-1 protein increase insulin sensitivity, which can reduce a person's risk for heart problems. Insensitivity to insulin, or insulin resistance, associated with type 2 diabetes is linked to the inflammation that leads to heart disease, but the mechanism of this link is not known.

More evidence of an IGF-1–heart disease link comes from a 2007 finding that IGF-1 injections lowered the incidence of heart disease in mice fed a high-fat diet. The study, by Patrice Delafontaine of Tulane University School of Medicine in New Orleans and colleagues, was published in *Arteriosclerosis, Thrombosis, and Vascular Biology*. The researchers think that increased IGF-1 reduces the inflammation that can cause heart disease.

But while IGF-1 is known to function in both disease and height, it's not yet known exactly how the two intersect.

A height and cancer suspect

Genome-wide association studies offer one way to sift through the human genome by comparing genomes of thousands of people for variations associated with a specific trait. To hunt for height genes, researchers try to identify genetic variations that crop up more often in shorter people or taller people.

So far, several studies have related about 40 different genes to height. But more genes are likely to be found, says Gonçalo Abecasis, a statistical geneticist at the University of Michigan in Ann Arbor who collaborated on two of the studies. "There are lots of different genes that each only make a small contribution to height," he says.

The researchers expect that the list of height genes will run into the hundreds. "We're making progress, but there are many more height genes to find," says geneticist Michael Weedon of the Peninsula Medical School in Exeter, England.

Weedon and his colleagues used genome-wide association studies to identify height gene candidates and found that the gene at the top of their list is also a well-known cancer gene. Variants of the *high-mobility group A2* gene, called *HMGA2*, correlated with small variations in height within a population of just over 19,000 people, the researchers reported in *Nature Genetics* in 2007.

The short path to osteoarthritis

Taller people may be at a higher statistical risk of cancer, but short people face height-related disease risks too.

A gene called *growth differentiation factor 5*, or *GDF5*, is related to height; it encodes a protein important for bone and cartilage growth and skeletal development. Geneticist Karen Mohlke of the University of North Carolina at Chapel Hill and her colleagues found that slight differences in the *GDF5* gene caused differences of about 0.3 to 0.7 centimeters in height. The people on the shorter end of these differences were more likely to have the particular *GDF5* variant associated with osteoarthritis, a type of arthritis caused by the breakdown of cartilage in joints.

People with lower levels of the GDF5 protein have shorter bones and less cartilage in their joints. Shorter people are more susceptible to osteoarthritis because they have less cartilage to wear down.

"It makes sense that a reduction in GDF5 would decrease bone growth and lead to reduced height," says Gonçalo Abecasis, a statistical geneticist at the University of Michigan in Ann Arbor and a coauthor of the study, which was published in *Nature Genetics* in 2008. "And as well as this, there would be less cartilage in the joints, which could increase susceptibility to osteoarthritis," he says. —*Solmaz Barazesh*

Height and disease risk

Statistical studies among large populations suggest links between height and the chances of certain diseases. Genes are the likely connectors, but the mechanisms remain unclear.

Prostate cancer
The incidence of prostate cancer increased 6 percent for every 10 centimeters, or 3.9 inches, over the median height among 1,357 men.

L. Zuccolo et al.
Cancer Epidemiology, Biomarkers & Prevention, September 2008

Heart disease
The risk of coronary heart disease decreased 6 percent for every 4.4 cm, or 1.7 inches, over the median leg length among 2,429 men.

G. Davey Smith *et al.*
Journal of Epidemiology and Community Health, December 2001

Insulin resistance
Insulin resistance (linked to type 2 diabetes) decreased 11 percent for every 6.5 cm, or 2.6 inches, over the median leg length among 2,429 men.

G. Davey Smith *et al.*
2001

Breast cancer
The incidence of breast cancer increased 11 percent for every 5 cm, or 2 inches, over the median height among 3,340 women.

M. Ahlgren *et al.*
New England Journal of Medicine, October 14, 2004

That study was the first evidence that small variations in the gene could produce normal height differences among people.

"Sometimes it's hard to link the gene you find to a height-related function — but this one was easy," says Lettre, a coauthor on the study.

Scientists already knew that rare *HMGA2* mutations could have severe effects on body size. Take 13-year-old Brenden Adams of Ellensburg, Wash., for example. An average-sized newborn, Adams began growing faster than anyone could explain and now stands 7 feet and 3 inches.

At first, doctors couldn't figure out why. Then they took a look at his chromosomes. A portion of one copy of Adams' chromosome 12 is inverted, as if a piece of the chromosome had broken off, flipped around and then reattached. The genes on this inverted section seemed to be undamaged — except for where the chromosome broke, which turned out to be at *HMGA2*.

Azra Ligon and Brad Quade of Brigham and Women's Hospital and Harvard Medical School in Boston studied Adams' case. They aren't sure exactly how the change to *HMGA2* is making Adams grow so much, but they speculate that the chromosome inversion disrupted the normal regulation of the gene.

The *HMGA2* gene encodes a protein that activates other genes by rearranging how DNA is stored. To package huge amounts of DNA inside each cell, the DNA is twisted and coiled into the chromosomes, then compacted in an orderly fashion so that the correct section is easily available when needed. The HMGA2 protein recognizes and binds to specific twists in chromosomes in order to activate the genes needed for a wide array of biological processes, including the growth and proliferation of cells. Weedon and colleagues speculate that mutations in the *HMGA2* gene can affect how much of the protein is produced.

Previous work also showed that the *HMGA2* gene is active only during embryo development in both mice and people. In mature tissues, gene activity was almost undetectable, a sign that the gene may not have much effect on the later stages of growth and development.

"It seems that the contribution of this gene is laid down early in life," says geneticist Peter Visscher of the Queensland Institute of Medical Research in Brisbane, Australia.

But the gene does get turned on at later stages in cancerous cells. HMGA2 proteins are found in the tumors of several different types of cancer, including those of the breast, pancreas and lung, suggesting that the gene may help cancer cells grow and proliferate. But scientists don't know whether the increased risk of cancer in taller people has anything to do with differences in the *HMGA2* gene. While *HMGA2* is implicated in both cancer and height, "the mechanistic dots have not yet been connected," says Lettre.

"Right now, we fall short of explaining exactly how *HMGA2* controls height," he says. "We don't know exactly how variations in *HMGA2* that correlate with height could affect how the gene works."

And while genes such as *HMGA2* are already well-characterized because of their roles in disease or development, little is known about many of the height genes that the statistical studies turn up.

Figuring out what these genes do could explain the links between height and disease. "We're not there yet," says Abecasis. "But when you start looking at all these different genes, you find that they are linked to lots of different things."

Adds Lettre: "We're interested in learning more about how genes control height. But we're hoping that some of the height genes will have other effects on health too." That would help the scientists gain insights into the biological processes of growth. "Time will tell, but that is certainly a hope." ■

Explore more

- Michael Weedon and Timothy Frayling. "Reaching new heights: insights into the genetics of human stature." *Trends in Genetics.* December 2008.

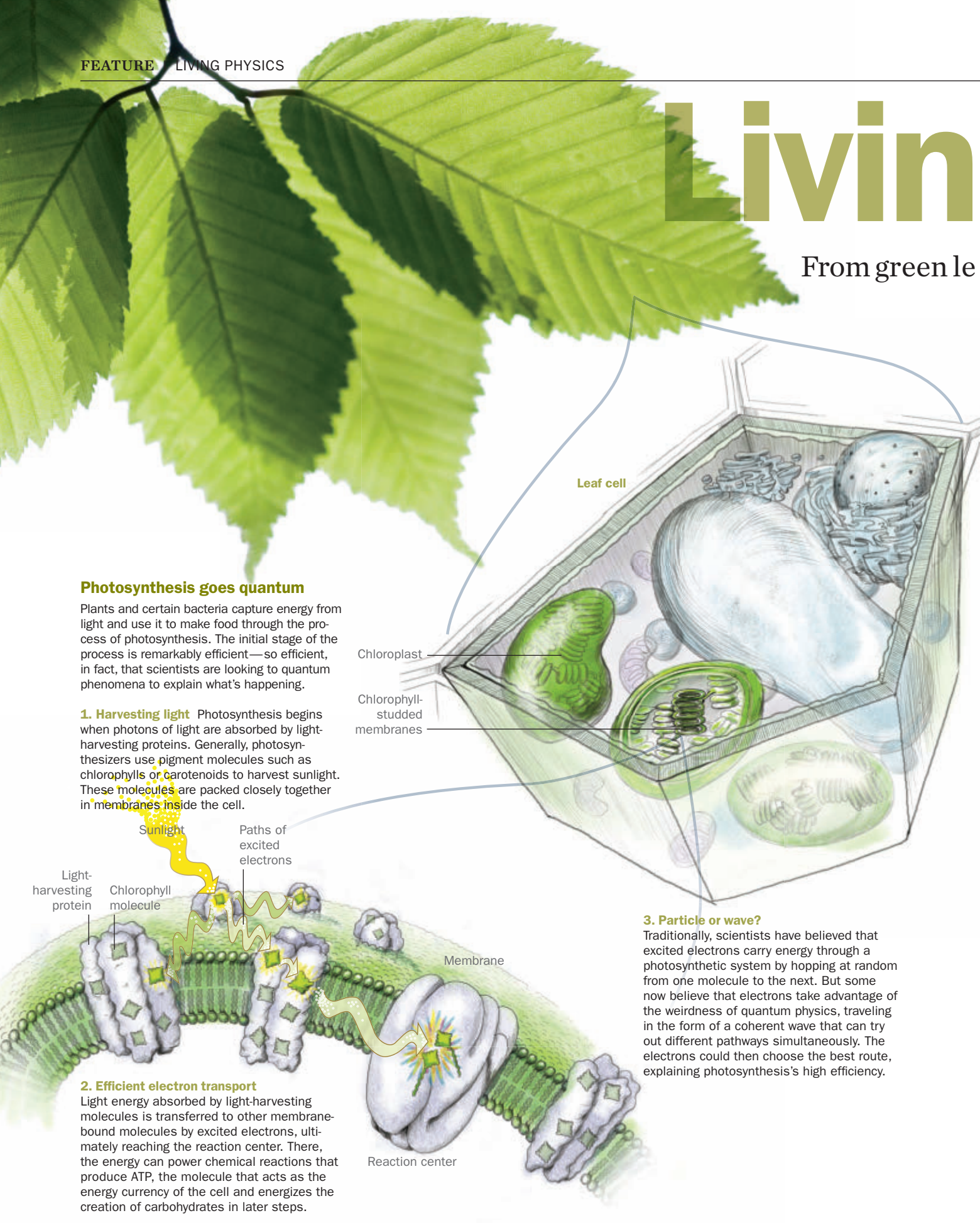
Livin

From green le

Photosynthesis goes quantum

Plants and certain bacteria capture energy from light and use it to make food through the process of photosynthesis. The initial stage of the process is remarkably efficient—so efficient, in fact, that scientists are looking to quantum phenomena to explain what's happening.

1. Harvesting light Photosynthesis begins when photons of light are absorbed by light-harvesting proteins. Generally, photosynthesizers use pigment molecules such as chlorophylls or carotenoids to harvest sunlight. These molecules are packed closely together in membranes inside the cell.



2. Efficient electron transport
Light energy absorbed by light-harvesting molecules is transferred to other membrane-bound molecules by excited electrons, ultimately reaching the reaction center. There, the energy can power chemical reactions that produce ATP, the molecule that acts as the energy currency of the cell and energizes the creation of carbohydrates in later steps.

3. Particle or wave?
Traditionally, scientists have believed that excited electrons carry energy through a photosynthetic system by hopping at random from one molecule to the next. But some now believe that electrons take advantage of the weirdness of quantum physics, traveling in the form of a coherent wave that can try out different pathways simultaneously. The electrons could then choose the best route, explaining photosynthesis's high efficiency.

gphysics

aves to bird brains, biological systems may exploit quantum phenomena

By Susan Gaidos • Illustrations by Nicolle Rager Fuller

Until a century or so ago, nobody had any idea that there even was such a thing as quantum physics. But while humans operated for millennia in quantum darkness, it seems that plants, bacteria and birds may have been in the know all along.

Quantum effects, human researchers have only recently discovered, may explain how the first steps of photosynthesis convert light to chemical energy with such high efficiency. Other studies suggest that quantum tricks may enable migratory birds to navigate using Earth's magnetic field lines.

Through studies like these, scientists are beginning to understand how quantum mechanics — weirdness supposedly confined to the realm of subatomic physics — affects everyday biology.

On one level, it seems perfectly natural that quantum mechanics would serve a function at life's foundation. After all, quantum principles define the properties of atoms, from which living matter is made. And yet the quantum rules, which allow particles like electrons to exist in two places at once and sometimes behave like waves rather than particles, seem an unlikely driver of life's tightly regulated processes. Bizarre quantum properties are supposed to govern objects such as individual atoms, not great clumps of matter like redwoods or robins.

Now, with growing evidence that quantum weirdness indeed exists in biological systems, scientists are looking for ways to tell how, or even if, nature exploits these effects to confer an advantage.

"We can't tell nature to ignore quantum mechanics, so we might need to measure it and see what happens," says Graham Fleming, a chemist at the University of California, Berkeley, who coauthored a paper in the 2009 *Annual Review of Physical Chemistry* outlining recent studies showing quantum effects in photosynthesis.

Understanding how natural systems use quantum effects to their advantage might help researchers find ways to control, and ultimately harness, such processes. By copying the quantum tricks used by plants, for example, researchers might be able to develop new technologies, such as more efficient solar cells.

Making waves in the lab

Photosynthesis is carried out by molecular machinery embedded in membranes in the interior of plant cells and some bacteria. Like all chemical reactions, it relies on the action of electrons.

In green plants, light particles are absorbed by pigment molecules — primarily chlorophyll — found in leaves. An incoming light particle, or photon, boosts an electron in the chlorophyll into a mobile state. Once excited, the electron is quickly shuttled from the chlorophyll to a nearby "acceptor" molecule, setting off a series of electron transfers. Moving from one molecule to another, the electron ultimately reaches the "reaction center," where the energy is converted into a form the cell can use to make carbohydrates.

It's these initial, near instantaneous energy transfers that are so remarkably efficient — scientists estimate that more than 95 percent of the energy in the light hitting a leaf reaches the photosynthesis reaction center. Although each of the biochemical steps that follow adds a loss in energy efficiency, the first steps in the process closely approach the ideal of one photon leading to one electron transfer.

Previous models of photosynthesis assumed that the light energy stored in excited electrons found its way to the reaction center via random hops, particles moving in a step-by-step manner to successively lower energy levels. But some scientists seeking to explain plants' superefficient energetics have considered the notion that plants may have a way to exploit the quantum behavior of electrons.

In the odd quantum world, particles can behave like waves. Rather than simply moving from one chlorophyll to another, electrons can exist as whirling clouds of energy, jostling back and forth between the molecules. In this wavelike state, the electrons become connected, or coupled, and act in a concerted manner so the excitation is actually "sloshing around" between the molecules, Fleming says.

Scientists theorized that this and other

quantum effects could allow for more efficient movement of energy but were faced with a problem in trying to capture evidence of such effects in the lab. In the classical world, either molecule A or B is excited, and scientists can track the transfer of excitation by measuring changes in the molecules over time. But in the quantum world, things appear to exist in a multitude of states, making measurements more complicated. Besides measuring changes of excitation in A and B over time, the scientists needed a way to measure simultaneous excitations of A and B — a signature of a quantum effect called coherence.

In 2005, Fleming and his colleagues developed a way to capture these simultaneous excitations, or oscillations, in a photosynthetic protein found in green sulfur bacteria. Using ultrafast lasers, the scientists flashed the sample with three pulses from different beams to stimulate energy absorption and transfer. A fourth pulse was then delivered to amplify the signal.

The timing of the flashes allowed the scientists to follow energy flow in two dimensions, watching it in time and space as it moved from one chlorophyll to another.

The method provided a way to follow a system's vibrational state, tracking its many wavelengths to see when they are what scientists call "in phase." When numerous particles such as electrons move in phase, all atoms are moving, spinning and tipping in synchronicity. Such a system is in a coherent state.

Uncertain he would find such wavelike behavior in a photosynthetic bacterium, Fleming nonetheless considered it possible. "What changed is that we could stop considering [the quantum effect] as a possibility and actually measure it," Fleming says.

In 2007, a sharp-eyed postdoc using the two-dimensional laser technique spotted the telltale signature in a sample of green sulfur bacteria after blasting it with the laser. When the scientists repeated the experiment, their data showed the oscillations meeting and interfering constructively, forming wavelike motions of energy flowing through the system.

Fleming's team, publishing in *Nature*, noted that quantum coherence could explain the extreme efficiency of photosynthesis by enabling electrons to simultaneously sample all the various potential pathways to the reaction center and choose the most efficient one (*SN: 4/14/07, p. 229*). Rather than hopping from one molecule to another in a step-by-step manner, the electrons could try various routes to find the path of least resistance.

Intelligent design

Photosynthetic organisms are designed for efficiency. The light-absorbing chlorophyll molecules found in leaves, for example, aren't just arbitrarily scattered throughout the cell, but are tightly packed into tiny organelles, crammed into spaces where they touch each other frequently. So when excited by a photon, the chlorophylls no longer act as individuals, but band together to create a system that works in concert, says Thorsten Ritz, a theoretical physicist at the University of California, Irvine.

And acting in concert has advantages. For one, it allows plants to absorb energy in different ranges of light. Such a system also permits other light-absorbing pigment molecules, such as carotenoids, to transfer energy into the system in an efficient manner.

Early this year, scientists in Ireland and England used an ultrafast laser with multiple color wavelengths to get an even closer view of energy moving through a photosynthetic system. Ian Mercer of University College Dublin, along with researchers at Imperial College London, flashed a light-absorbing protein from purple bacteria with a series of pulses lasting less than one ten-thousandth of a billionth of a second each.

When it hit the bacterial protein, the light energized a series of reactions that ultimately led the protein to emit light of its own. Because the laser pulses were made up of a broad spectrum of colors, with each color corresponding to a specific energy, the light emitted by the sample provided a clear view of the different energies at play inside the protein. The resulting map showed how individual electrons coordinated their movements as they jostled energy back and forth: Shifts to the left or right showed electrons connecting, while vertical shifts indicated energy was being passed or received.

The methods allowed the scientists to distinguish random hopping of energy, or particle behavior, from the wavelike movements of electrons behaving collectively. The study, published in the Feb. 6 *Physical Review Letters*, will help scientists better model how quantum effects such as coherence influence energy transfer in photosynthesis, Mercer says.

"We've been needing a better pair of eyes to see how molecules are doing the tricks that they do," he says.

Going for a spin

Birds may give scientists another pair of eyes in which to view quantum effects in living cells. Studies suggest that migratory birds about to embark on their seasonal journeys may tap into a quantum property called spin to help them "see" Earth's magnetic field using photosensitive proteins in their eyes.

The idea that birds rely on some sort of biochemical reaction to orient themselves during migration was first proposed more than 30 years ago. Eleven years ago, Ritz and his colleagues identified cryptochrome, a protein containing a light-sensitive pigment, as a candidate molecule capable of creating such a reaction.

Cryptochrome is found in the nerve layers of birds' eyes. Research shows that when cryptochrome interacts with a specific wavelength of blue-green light it can trigger a cascade of electron transfers similar to those that occur in photosynthesis.

Normally, the electrons in cryptochrome exist in pairs. The energy from light, however, can rip the electrons apart, leaving one electron on the original molecule and sending the other off to another molecule. The result is two charged molecules, or ions.

Initially, the electrons in these molecules spin in opposite directions. In the presence of an external magnetic field, however, the dynamics of the spins will change, altering their orientation relative to each other. The veering spins create a biochemical reaction allowing the birds to perceive the Earth's magnetic lines as patterns of color or light superimposed on their surroundings, Ritz speculates, similar to a dashed line in the middle of a road.

Though scientists have yet to prove that cryptochrome can create this reaction in birds, evidence for the theory is mounting.

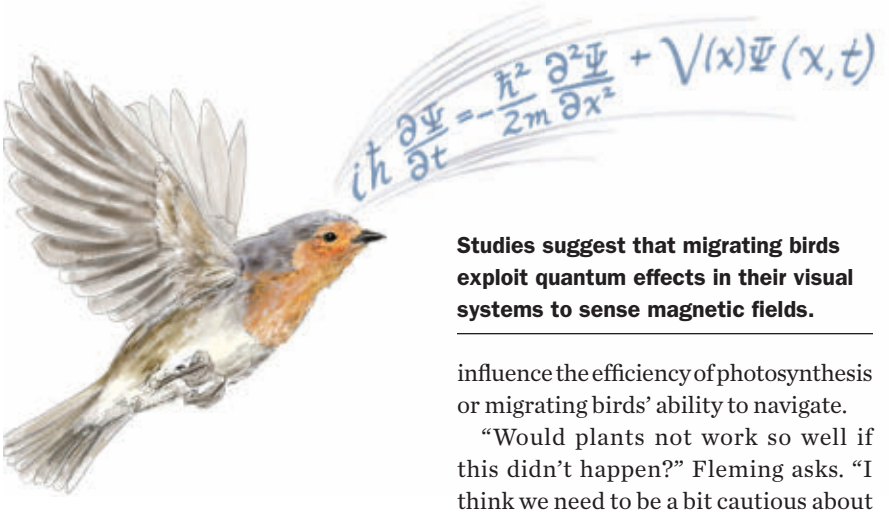
In a 2004 *Nature* study, Ritz and his colleagues showed that disrupting the local magnetic field around captive birds preparing to migrate interfered with the birds' internal compasses. By disrupting the field, for example, the scientists could induce the birds to take off in the wrong direction.

Last spring, in a proof-of-theory trial published in *Nature*, researchers at the University of Oxford in England and Arizona State University in Tempe showed how a cryptochrome-like molecule could respond to the direction of a weak magnetic field, such as the Earth's.

The scientists created a synthetic molecule made up of three light-absorbing pigments. When flashed with a laser beam, electrons in the molecule first separated briefly, as predicted, then recombined. The amount of time the electrons spent in a separated state varied with the angle of the magnetic field. When the electrons returned to their paired state, the energy caused a change in the shape of the molecule.

Ritz is now looking for ways to isolate cryptochrome in fruit flies to test these effects in animals. Though the light-absorbing pigments in cryptochrome trigger a different cascade of electron transfers than those generated in photosynthesis, Ritz says both systems appear to be influenced by the wavelike nature of quantum mechanics. But how biological systems can maintain what most consider such a fragile effect is still a puzzle.

"The same questions that I asked about photosynthesis are true here, as well," Ritz says. "How does this system maintain coherence when you have all kinds of fluctuations that could, in principle, disrupt it? It's a big open question that we don't have good answers to at this point."



Studies suggest that migrating birds exploit quantum effects in their visual systems to sense magnetic fields.

A higher standard of proof

While coherent quantum states can be maintained in controlled laboratory settings, most scientists have been dismissive of the idea that such coherence could be achieved in the hot, messy realm of living cells. Atoms and molecules in such a system are continually assailed by influences from their environment. And the slightest insult can mangle the phases of their waves, causing them to lose their coherence.

When Fleming measured the persistence of these wavelike states in photosynthetic bacteria, he found that the coherence lasted surprisingly long—up to 660 billionths of a second. On the timescale of molecular events, that's an eternity.

"For some reason it seems that nature has maybe coordinated the movement or done something else to let this coherence survive," Ritz says. "And what that reason is would be very interesting to find out because it may give us a clue of how we could control processes at that level."

While recent work has found evidence for the presence of quantum effects in living systems, researchers have yet to demonstrate that those effects can actually influence the efficiency of photosynthesis or migrating birds' ability to navigate.

"Would plants not work so well if this didn't happen?" Fleming asks. "I think we need to be a bit cautious about answering that at this point. It's a complicated question. You have to be very sophisticated in how you model things to show that the quantum effect is really making the system work better. You can't just turn it on and off."

Not yet, anyway. Fleming, who says he is looking for "a higher standard of proof," has worked out two new theoretical models that will allow scientists to perform experiments and better simulate bioquantum effects in the lab. The new models will appear in an upcoming issue of the *Journal of Chemical Physics*.

"Once you have a really good theory, you can turn things off to see what happens," he says.

Discovering how quantum effects play out in photosynthesis and bird navigation may point scientists to other examples of the quantum in biological systems.

"Photosynthesis, after all, is one of the oldest processes around," Ritz says. "If we see that nature learned at the very beginning, when they were still bacteria, to control quantum processes, there's no reason why nature should have forgotten that in the future for more complex things." ■

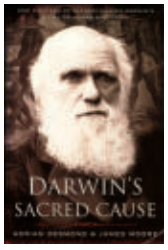
Susan Gaidos is a science writer in Maine.

Explore more

- Yuan-Chung Cheng and Graham Fleming. "Dynamics of Light Harvesting in Photosynthesis." *Annual Review of Physical Chemistry*. May 2009.

Darwin's Sacred Cause: How a Hatred of Slavery Shaped Darwin's Views on Human Evolution

Adrian Desmond and James Moore



While forming his theory of common descent, Charles Darwin peered beyond his observations of ants, barnacles and blue-footed boobies to try to comprehend a broader subject: human slavery. He encountered the slave trade's horrors through stories told within his moneyed, abolitionist family. After visiting slave-holding nations on the *Beagle*, Darwin was forever haunted by the distant cry of a tortured slave, the authors write.

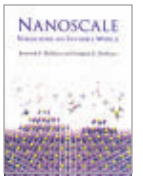
Desmond and Moore, who received acclaim for a 1991 Darwin biography, persuasively show Darwin as a great unifier. He balanced his heated belief in abolitionism with scientific discipline — not letting one affect the other (despite the book's subtitle). The landmark result: *On the Origin of Species* with, the authors contend, a refutation of slavery at its heart.

In Darwin's day, slavery supporters believed black Africans were a species apart from white Europeans. And Africans were fettered to the lowest rung of a natural hierarchy. Darwin confronted this worldview through his bold idea that all animals — including all races of humankind — descend from a common ancestor and change over time. Slavery was an amoral practice at odds with nature.

By showing Darwin as a participant in the raging scientific debate over slavery, the authors bring him to life. His opponents range from bumbling phrenologists, who believed bumps on the skull determined intelligence, to overt racists, who peddled fables of long-heeled Africans unable to stand on their own. Others seemed to present a more authoritative argument, the authors say, but prejudices corrupted their work.

One scientist, geologist Charles Lyell, was an early mentor to Darwin. Lyell sympathized with slaves but argued that slaves were unable to live without their owners, despite his seeming awareness of the scientific shortcomings in his argument. The book's portrayal of Lyell as a product of his times highlights Darwin's true legacy — using the scientific method to overcome the prejudices and polemics of his contemporaries. — *Joshua Korenblat*

Houghton Mifflin Harcourt, 2009, 448 p., $30.



Nanoscale: Visualizing an Invisible World

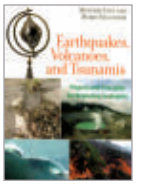
Kenneth S. Deffeyes and Stephen E. Deffeyes

Illustrations reveal the nanoscale world in rich detail. *MIT, 2009, 133 p., $21.95.*

The Fifth Postulate: How Unraveling a Two-Thousand-Year-Old Mystery Unraveled the Universe

Jason Socrates Bardi

The story of the discovery of non-Euclidean geometry. *Wiley, 2009, 253 p., $27.95.*



Earthquakes, Volcanoes, and Tsunamis: Projects and Principles for Beginning Geologists

Matthys Levy and Mario Salvadori

Kid-friendly activities reveal the science behind natural disasters. *Chicago Review, 2009, 136 p., $14.95.*

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Don't dismiss Lamarck

Your January 31 special birthday edition on Darwin *(SN: 1/31/09, p. 17)* was excellent, but I believe that science has allowed Jean-Baptiste Lamarck's contributions to be overshadowed by Darwin's. The change that can occur to an organism's genetic makeup during its own lifetime harks away from Darwin's slow evolutionary process by chance mutations and argues toward Lamarck's heritable changes within a lifetime.

Robert Powell, Austin, Texas

Take a vote of biologists today and Darwin will win hands down. But I predict that in 20 years that will change, and the new most influential biologist will be Lamarck. The turning point was the Human Genome Project. It is now becoming clear that a type of formative causation may be real, in spite of the fact that most biologists still gag on the word. Just because one can show that natural selection works does not prove that it is the correct mechanism.

O. Frank Turner, Pueblo West, Colo.

Lamarck did argue that traits acquired during an organism's lifetime could be inherited, a notion almost universally accepted in his day. Since then, the term "Lamarckian inheritance" has been applied to several mechanisms, including some far from his original ideas. Many of his ideas have been largely discredited. Yet, the late Stephen Jay Gould wrote eloquently about Lamarck, calling him a fine scientist, and Darwin himself acknowledged Lamarck's contributions to science. Scientists today do agree that inheritance is messier than previously realized and that it involves more than genes. For example, epigenetic changes to the way DNA is tagged or packaged — triggered by environmental factors such as stress or diet — may be inherited. But the various kinds of inheritance have themselves evolved through Darwinian natural selection, which does not require that selection be based only on genetics . — Rachel Ehrenberg

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At Nobel Conference, scientists and public converse

Physics professor Charles Niederriter of Gustavus Adolphus College directs the Nobel Conference, an annual forum where scientists and the public discuss a contemporary scientific topic. Held every year at Gustavus Adolphus, in Saint Peter, Minn., this year's Nobel Conference, October 6–7, will examine the current state of water resources. Staff writer Laura Sanders recently talked with Niederriter about the conference and why scientists need to speak clearly to the public.

How did the Nobel Conference begin?

In the early 1960s ... the president of the college approached the Nobel Foundation and asked to use the Nobel name to name a new science building. The Nobel Foundation said, "That's a great idea, and what you should do when you dedicate the building is to invite as many Nobel laureates as you can." So the college invited all the living Nobel laureates to attend, and 26 of them showed up. They spent four or five days on campus talking to each other and talking to the public who came for the dedication, and several of them said this was a great opportunity to get together, talk to people they don't usually talk to and talk about their work with the public.

What does the conference aim to do?

Many of the scientists who have come have said it's a great opportunity to essentially be a public think tank.... They make their presentation, and in the questions and answers afterward, there's as much back and forth between the panelists and the other speakers on stage as there is between the speakers and the audience. There's a lot of "Well I think you're wrong there," or "I think you missed this point that I said earlier." It's really a wonderful example for the public to see how scientists hash these things out.

Why did you choose this year's theme of "H_20 Uncertain Resource"?

Many, many faculty members have been involved in this and thought about it for years.... Hearing quotes like "The next war will be fought over water," or going to the Four Corners region, where you shoot somebody for stealing your water, those are the kinds of things you hear from people. And then all of the advances that have been made in water purification and recycling prompted us to start thinking about how we make use of water and how we can continue to reuse water. And one more piece to this ... is that pharmaceuticals are things that our water treatment facilities don't seem to be designed to remove. So it's really a shotgun approach—a lot of different things.

The words that scientists use to talk about things have different connotations and meanings than what the general public uses.

What other topics are in the works?

We're working on the 2010 conference, which will be on food and nutrition. It's going to be an interesting conference with a lot of different things, involving food economics, food security and safety, and taste.... We've also talked about something called affective neuroscience. Effectively it's a religion-neuroscience-chemistry combination, essentially trying to understand where emotions and religion might fit into a scientific view of the brain.

What are some other issues that need to be clearly communicated to the public?

The global warming issue is certainly one where people have tried very hard ... to get things out in the open, and for whatever reason it's been unsuccessful.... Another one I can think of is the issues separating creationism from evolution. That's been a long, ongoing debate, and one I think where the words that scientists use to describe things may feed the fire of a person who is trying to fight against it by using words like "theories." And [scientists] don't always communicate to the public that these are well-tested theories, they're not just guesses. I think that's the kind of thing that is a really broad-based problem we have—that the words that scientists use to talk about things have different connotations and meanings than what the general public uses.

Why is it important for scientists to speak clearly to the public about their work?

If scientists can communicate what they are doing, then the normal person on the street really has more trust in what they're doing, has more of an understanding that what they're doing is not frivolous and could potentially be useful, or maybe is already useful for them as individuals. If scientists don't communicate clearly then there are a lot of other people who will communicate for them in a bad sense, people who try to tell the public what scientists are doing with maybe malicious intent, or with ignorance, and get things wrong. So it's important that scientists do it themselves, and do it right, in such a way that the average person can understand it. ■

Nobel Conference website: gustavus.edu/events/nobelconference/2009

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