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# ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ JULY 13, 2013

Death No Obstacle to Guppy Paternity

Cicadas' Puzzling Synchronicity

Cheetahs Zigzag to Dinner

# Bohr's Vision

## A century of the quantum atom

# SWISS DECLARE WAR ON US

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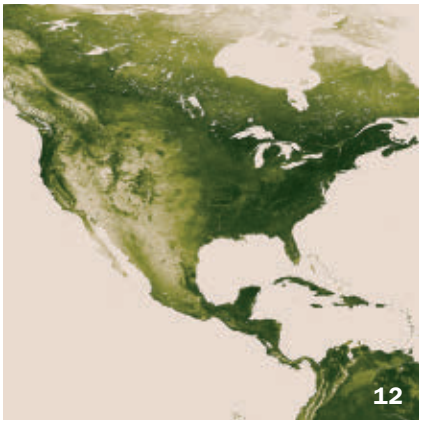


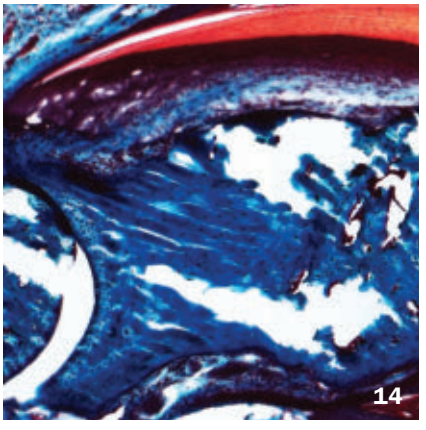




# ScienceNews

## In The News



## Essay



## Feature



## Departments



**COVER** Niels Bohr is rendered from his model of the hydrogen atom, in an image based on a 1922 portrait taken for his Nobel Prize biography.
*A.B. Lagrelius and Westphal, adapted by S. Egts*

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FROM THE EDITOR

# Cicadas, the atom and other frontiers of science

Cicadas have been much in the news this spring and summer, at least in the stretch of the East Coast where a mass emergence of the buzzing insects took place. Somehow, I managed not to see or hear a single one. But I was able to witness the spectacle, if only through photos of the fleshy insects transforming from nymphs to adults for a whirlwind bout of singing, mating, flight and egg-laying. These cicadas spend only a brief moment of their 17-year life span as adults, but it's their synchronized emergence that most fascinates scientists. As Susan Milius explains on Page 26, this year's brood is made up of three different species that climb out of the ground together but don't mate with each other. It seems to be a case of safety in numbers, but much remains unknown about how the different species sync up, and why some members of a species follow a 13-year cycle while others follow a 17-year one. Understanding the family trees and population dynamics of periodical cicadas, it turns out, can be every bit as perplexing as pondering quantum physics.

That's a topic close to the heart of our former Editor in Chief, Tom Siegfried (who also supplied us with some amazing cicada photos, taken in his front yard). His essay on Page 20 celebrates the 100th anniversary of Niels Bohr's model of the atom, the first to successfully incorporate quantum theory. While Bohr's model has since been superseded, it set the stage for modern understanding of the structure of the atom. His advance required insight as well as a far-reaching imagination.

On the back page in this issue is a story that stretches my imagination to the solar system's limits and beyond: the ongoing tale of the Voyager probes, which are now nearing a true frontier. Voyager I is approaching the outer edge of the sun's influence and, if all goes well, will soon cross into interstellar space. On Page 32, Alexandra Witze interviews the NASA engineer who tracks these faraway travelers, which have been sending data home for more than two 17-year cicada cycles. Reports from other frontiers of knowledge include news of low-tech "invisibility" cloaks and a new way to map a room using sound echoes (Page 10), an advance that may help scientists develop universal memory for computing (Page 11), a better 3-D map of the human brain (Page 16), and a camera that captures voices by taking high-speed video of throat vibrations that a computer can decode (Page 13).

*— Eva Emerson, Editor in Chief*

SANDY SCHAEFFER


*Actual size is 40.6 mm*

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## Say What?

**SUBNIVIUM** *sub-NIV-ee-uhm*\ *n.*

A seasonal refuge between soil and snow. The subnivium lets many plants, animals (such as the North American porcupine, left) and microbes spend winter in a slightly warmer zone where temperatures rarely fluctuate. But as the planet's climate changes, the insulating layer of snow is thinning and even disappearing in some places. Species that depend on the subnivium to survive winter could be exposed to the colder temperatures of ambient air and tissue-damaging cycles of freeze and thaw, Jonathan Pauli of the University of Wisconsin–Madison and colleagues report in the June *Frontiers in Ecology and the Environment*. — *Sarah Zielinski*

## Mystery Solved | POTATO FAMINE'S CAUSE

The blight that scourged Ireland's potatoes in the 1840s has finally been identified. Scientists knew that the funguslike microbe *Phytophthora infestans* (right) causes potato blight, and for years a lineage called US-1 shouldered the blame. But the real culprit was another strain, HERB-1, an international research team concluded after examining blight DNA from modern plants and museum specimens collected between 1845 and 1896. The two strains are closely related and arose somewhere outside the species' original home in Mexico, the team reports May 28 in *eLife*. HERB-1 is probably extinct now, thanks to potato breeders who propagated resistant plants, but further testing may be needed to confirm the strain's demise. — *Tina Hesman Saey*


## 50 Years Ago

**Excerpt from the July 13, 1963, issue of *Science News Letter***

**NOBELIST'S CANCER THEORY**

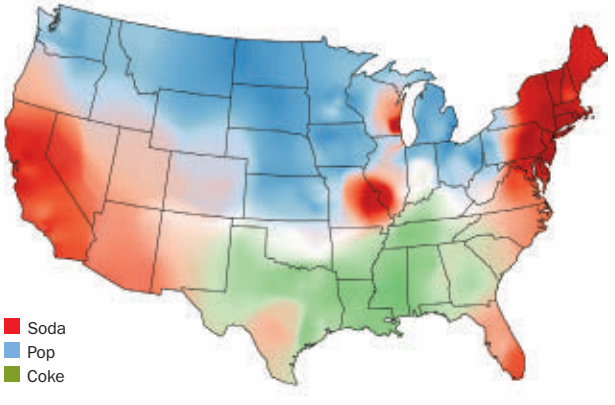
The key to finding the cause and treatment of cancer is the balance between two newly found substances in the body, Dr. Albert Szent-Gyorgyi, the 1937 Nobelist in Medicine, has suggested. The substances are promine, which causes sudden cell growth, and retine, a similar chemical that holds back growth.... He predicted in *Science*, 140: 1391, 1963, that the new theory will "open a wide field for cancer research...." Laboratory observations during the past ten years ... indicate sudden cell growth is caused by a predominance of promine over retine.... "We found no harmful side effects either with retine or with promine," the scientists said. "One might have here substances which will stop cancer growth and even produce regression without toxicity," they predicted.

**UPDATE:** Szent-Györgyi's theory did not ultimately provide new cancer treatments. It turned out that promine and retine refer to physiological effects, not individual molecules. Research has continued, though, on the enzymes he was studying, known as glyoxalases. These molecules can protect cellular components from stress and damage that lead to diseases such as diabetes, Alzheimer's and Parkinson's.

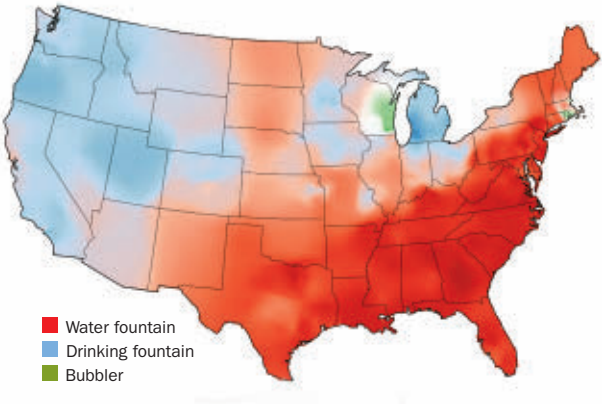
## Science Stats | DIALECTS DISSECTED

Using data from a nationwide survey of speech patterns, researchers have developed statistical methods to map the range and blending of dialects across the continental United States. Joshua Katz of North Carolina State University found that the most prominent linguistic divide, marking differences in pronunciation and word choice, runs diagonally northeast from Texas (illustrated by one term in the map at bottom right). See bit.ly/SNdialect for more examples.

**What is your generic term for a sweetened carbonated beverage?**




**What do you call the thing from which you might drink water in a school?**




TOP TO BOTTOM: JOEL SARTORE/NATIONAL GEOGRAPHIC CREATIVE; H.S. JUDELSON AND F.A. BLANCO/*NATURE REV. MICROBIOL.* 2005; J. KATZ/NC STATE UNIV. DEPT. OF STATISTICS

“We get a sense of a speaker’s feeling from their voice.”
—YASUHIRO OIKAWA, PAGE 13



# In the News

STORY ONE

## Math targets cities’ essence

### New formula relates city size to infrastructure, productivity

By Rachel Ehrenberg


**Though strikingly different in culture and layout, cities like London and Beijing share many properties with regard to infrastructure, social interactions and productivity.**

BOTH: COURTESY OF THE IMAGE SCIENCE & ANALYSIS LABORATORY, NASA JOHNSON SPACE CENTER

The notion that cities are all alike borders on blasphemy. Residents of the world’s great metropolises, from New York to London to Tokyo, speak of their homes as of a first love or old friend. But decades of analyses hint that cities, mathematically speaking, might actually all be the same. Now for the first time, those observations have been tidily and elegantly drawn together into a formula that describes what a city is.

That new work is part of a growing field dedicated to the science of cities. The effort is a timely one: Roughly 75 percent of people in the developed world now live in urban environments. While much of the research is in its early days, eventually it may serve as a powerful, widely used tool for urban planners and policymakers.

The mathematical work is rooted in and reinforces the view “that cities grow from the bottom up,” says Michael Batty, who trained as an architect, planner and geographer and went on to found the Centre for Advanced Spatial Analysis at University College London. “The diversity of life [in cities] offers greater opportunities for mixing ideas.”

That diversity, which includes dismal poverty, squalid slums and crime juxtaposed with prosperous businesses, majestic parks and great art institutions, was much decried in the 19th century. In 1883, for example, textile designer and artist William Morris lamented England’s cities as “mere masses of sordidness, filth, and squalor, embroidered with patches of pompous and vulgar hideousness, no less revolting to the eye and the mind....”

Discomfort with the notion that cities grew from the bottom up went along with disdain for disorder and chaos, framing cities as a problem to be solved. This view prevailed into the 20th century and influenced postwar urban renewal projects across the United States. The resulting redevelopment forever changed parts of cities such as Pittsburgh and Boston, with mixed results.

In the last several decades, however, the view of cities as disordered systems has begun to change, Batty says. Patterns have emerged within the chaos. Researchers in economics, physics, complexity theory and statistical mechanics have observed that certain features of cities consistently vary with population size.

But the relationships aren’t direct and linear. As a city grows, some features, such as land area, grow more slowly with respect to population. This “sublinear” relationship also holds for some aspects of physical infrastructure, such as the length of pipes and roads: As population grows, proportionately less infrastructure is required to support each additional person.

For other characteristics, the reverse is true: Some measures grow faster with respect to the population. This “superlinear” scaling has been observed for a number of socioeconomic factors in cities around the world. Produced wealth, whether measured as income, wages or gross domestic product, increases at a rate greater than the population. So does crime. Markers of innovation, including the number of patents produced and number of jobs in creative fields like the arts and sciences, also increase superlinearly.

While there’s some quibbling about

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the exact mathematical values, the relationships among city characteristics generally hold, says physicist and complex systems scientist Luís Bettencourt of the Santa Fe Institute in New Mexico.

Bettencourt, with other researchers at the Santa Fe Institute and colleagues elsewhere, has been examining these relationships for more than a decade. Now Bettencourt has created a series of equations, published in the June 21 *Science*, that pull the relationships together into a mathematical theory of cities.

Bettencourt's math stands on four basic assumptions: First, cities mix varied people together, allowing them to reach each other. Next, cities are networks that grow gradually and incrementally, connecting people. Third, human effort isn't limitless and stays the same regardless of urban size. And finally, measures of the socioeconomic output of a city — things like the number of patents awarded or crime rate — are proportional to the number of social interactions.

Bettencourt's theory captures the interplay between a city's population, its area, the properties of its infrastructure and its social connectivity. By mathematically describing the tension between a city's number of social interactions, their outcome (innovation, for example, or crime), and the transportation and energy costs of enabling those interactions, Bettencourt arrives at a parameter that he calls G*. The closer a city's value is to G* the more effective it is at producing positive interactions and all the benefits that flow from them.

"In a nutshell, the city is the best way of creating a vast, open-ended social network that minimizes the cost of moving things in and around an environment," Bettencourt says. "When people brush up against each other, that's when the magic of the city happens — the social reactor begins to work."

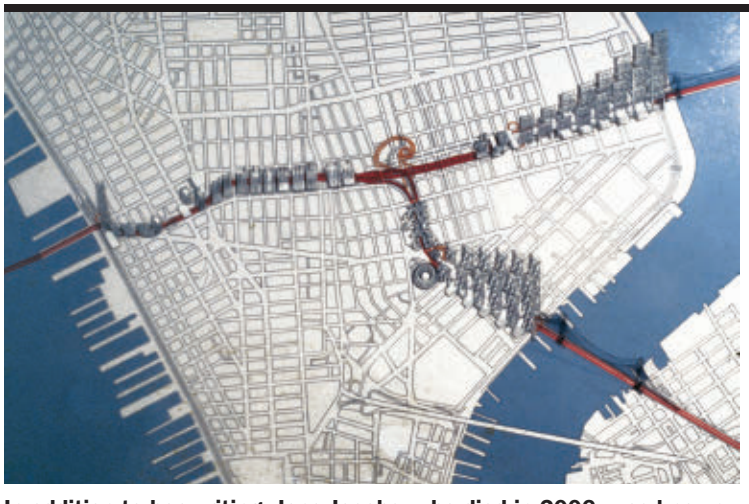
**"When people brush up against each other, that's when the magic of the city happens — the social reactor begins to work."**
**LUÍS BETTENCOURT**

That conclusion isn't so surprising, Batty says. Consider how a concentration of creative genius and technological know-how has made Silicon Valley into one of the world's foremost engines of wealth. Bettencourt's theory "basically unpacks the equations and then puts it all together and leads us to what we observe in a clean and elegant way," Batty says.

In many respects, the theory formalizes what writer and activist Jane Jacobs articulated in her 1961 book, *The Death and Life of Great American Cities*. Earlier scholars' emphasis on aesthetics and form missed what makes cities so great, she argued. Cities are a way of sustaining an enormous number of social interactions through time, she wrote, "a most intricate and close-grained diversity of uses that give each other constant mutual support, both economically and socially."

What urban planners and policymakers will take from Bettencourt's new theory remains to be seen. The research suggests that enabling mixing of people and fostering the creation and spread of ideas is never a bad idea. It also suggests that city planning should not involve grand, top-down projects, but perhaps well-considered smaller ones.

"We need to identify the minimal interventions that can lead to the greatest gains," Batty says. "Complexity theory teaches us that things are a good deal more complex than we think, and when we interfere, it can be at our peril." ■



**In addition to her writing, Jane Jacobs, who died in 2006, was known for her protest of the construction of the Lower Manhattan Expressway (map shows proposed development), which would have bisected Soho and nearby neighborhoods.**

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## Back Story | AHEAD OF HER TIME

Writer and activist Jane Jacobs did not pull punches. "This book is an attack on current city planning and rebuilding," begins the introduction to her 1961 book *The Death and Life of Great American Cities*. The book was a reaction to the postwar urban renewal projects of her time. But it was also prescient, foreshadowing a view of cities as complex systems — a view that researchers increasingly embrace today. "The kind of problem which cities pose," Jacobs wrote, is "a problem in handling organized complexity." That perspective is enriched and expanded upon in work by complex systems scientist Luís Bettencourt of the Santa Fe Institute. For years, Bettencourt says, discussions of cities have emphasized form over function. Bettencourt's work, he says, "is an attempt to shift perspective from what a city looks like to what a city is. Cities are social reactors."

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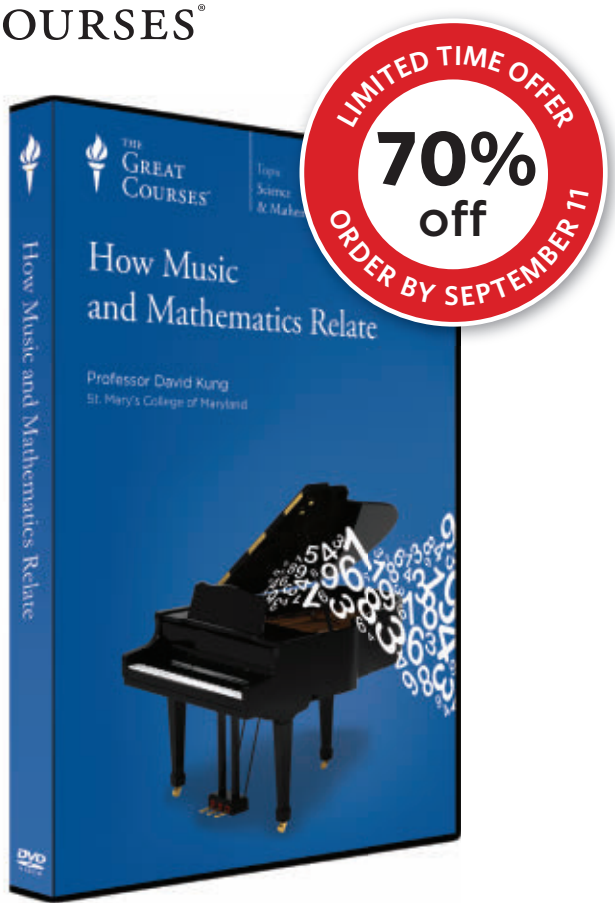


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# Life

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## Dead, live guppies vie for paternity

### Females can use sperm months after mates go belly up

**By Susan Milius**

After death, male guppies can keep on siring offspring because females store sperm for so long. As a result, a living male in a stream in Trinidad can end up competing with long-gone fish from his grandfather's generation.

At its most posthumously successful, stored ghost sperm sired about one in four of the offspring among wild guppies in one stream, evolutionary biologist Andrés López-Sepulcre of École Normale Supérieure in Paris and his colleagues report June 5 in *Proceedings of the Royal Society B*.

Biologists have long known that female *Poecilia reticulata* guppies store sperm. The cells clump in little pockets in a female's ovarian cavity and feed on sugars released by ovarian tissue. Storage in itself isn't unusual, López-Sepulcre says. Some crabs, turtles, lizards, bats and other creatures preserve sperm for later use.

Posthumous reproduction by stored sperm also isn't unheard of. "The fun part of our study," López-Sepulcre says, "is that you have males who are alive and males who are dead competing with each other."

Researchers deployed guppies in several streams as part of a study on evolutionary change. Every month researchers catch, check and release as many fish as possible to track deaths and births. They also genetically analyze parenthood of the fish. Female guppies give live birth to broods of two to about 10 youngsters, not all sired by the same male. Females live about 15 months; males about three.

Genetic testing in one stream revealed that guppies fathered offspring up to two generations after they died. Their share of offspring increased to about a quarter for months eight through 10, the final months of data available so far. The researchers continue to track the fish.

It's unclear why female guppies in this stream rely so much on old sperm, says Tim Birkhead of the University of Sheffield in England. "Sperm of most species — the social insects are an exception — clearly deteriorate with time," he says. Since the stream still has living males, females could presumably remate.

The reliance on old sperm might turn out to be a stage in the process of settling into a new home, speculates evolutionary biologist Kelly Zamudio of Cornell University, who has studied posthumous reproduction in lizards. Using a wide variety of sperm, even from dead males, might give offspring of a small group of settlers a better chance of a genetic mix that suits their new home. Zamudio is curious about whether guppies will still use so much old sperm when they're no longer new in the neighborhood. ■

## Necks arose in primitive fish

### Fossilized muscle shows animal could nod its head

**By Erin Wayman**

Ancient fish fossils with preserved muscle tissue offer a glimpse at how necks evolved in early vertebrate animals. The fossils also offer a puzzle: The fish had specialized abdominal muscles found today in land animals, but not in fish, paleontologists report June 13 in *Science*.

The 380-million-year-old fossils come from Western Australia's Gogo Formation and contain three-dimensional details of neck, body and tail muscles. The specimens represent several genera of predatory fish armored in bony plates. Called placoderms, these extinct animals were among the earliest vertebrates with jaws. "A lot of structures in us first appear in these fish, particularly muscles that operate the jaw and the neck," says coauthor Kate Trinajstic of Curtin University in Perth, Australia.

Placoderms were also some of the first vertebrates to have necks separating their heads and shoulder bones, allowing the fish to move their heads independently of the rest of their bodies. The fossils reveal that the animals had several specialized muscles associated with a hinge joint connecting the head to the body. The fish could pivot their heads up and down, but not side to side. Sharks and other jawed vertebrates later evolved simpler muscles and a more flexible neck that had a greater range of motion, Trinajstic says.

More surprising is that placoderms had abdominal muscles running perpendicular to the body's midline, says coauthor Per Ahlberg of Sweden's Uppsala University. Modern fish lack such transverse ab muscles. Land vertebrates, however, need these muscles to hold up their bellies. In placoderms, these muscles might have dampened shear forces between an animal's swinging tail and stiff body armor, Ahlberg says. The muscles might also have prevented the body from swishing around inside the armor, Trinajstic adds.

The researchers suspect that these muscles were common to all early jawed vertebrates. Later, sharks and bony fish lost the muscles and then early four-limbed vertebrates that moved onto land independently evolved them.

Not everyone agrees. It's too soon to say whether all early jawed vertebrates had transverse ab muscles, says Matt Friedman, a paleobiologist at the University of Oxford in England. To find out, he says, the researchers first need to confirm that the muscles were present in all types of placoderms, not unique to the one placoderm group studied. ■

**29** m/s | Top cheetah sprinting speed on a track

**14.9** m/s | Average top cheetah speed while hunting

# In the real world, cheetahs rarely go all out

## Famous for speed, the big cats also excel at slowing down

By Susan Milius

**A high-tech collar that records location, acceleration and other details of cheetah movement has given an unprecedented look at how the world's fastest land animal hunts in the wild.**

Cheetahs may run down a track faster than any other land animal. But in the wild, the cats rarely hit top speed; it's quick bursts of acceleration and sudden slow-downs that get cheetahs to dinner.

"They're not going particularly quickly usually," says Alan M. Wilson of the University of London Royal Veterinary College in Hatfield.

But cheetahs have got some great moves. With first-of-its-kind tracking of cheetahs on the hunt, Wilson and his colleagues show that the animals can accelerate with four times the power of world-champion sprinter Usain Bolt. And the cats can put on the brakes much better than polo ponies do.

Wilson and colleagues developed collars that record both location using GPS and measures of motion such as acceleration. Fitted on three female and two male adult cheetahs (*Acinonyx jubatus*) in Botswana, the collars recorded a total of 367 running episodes, 94 of them successful hunts, the researchers report in the June 13 *Nature*.

The collars confirmed that cheetahs are kings of speed. In one sprint, an animal hit 25.9 meters per second (58 miles per hour). Before this, Wilson says, the most reliable published test had clocked a cheetah on a straightaway at 29 m/s, faster than horses at 19 m/s, racing greyhounds at 18 m/s or Bolt's peak 12 m/s.

Cheetahs chasing impalas often do a straight sprint or two, but especially in the final approach, the cats turn and weave as the prey dodges. Speed wouldn't necessarily be an advantage then. A cheetah trying to maneuver at the top speed that collars recorded would need a turning radius of 52 meters, the researchers calculate.

In the zigzaggy hunts, such speed extremes weren't common. On average, the peak speed of a hunting cheetah was 14.9 m/s, just 57 percent of the maximum that the team recorded. (Still, however, faster than Bolt.)

The collars showed that cheetahs typically slowed before maneuvering, which tightened their turns. In just one second, a cheetah can take three strides and brake from 16 m/s to 4 m/s. That deceleration, the researchers calculate, shrinks its turning radius from 19.7 meters to 1.2 meters.

Cheetahs' big, heavy claws allow them to grip the ground for such maneuvers, Wilson says. These turns and curves are demanding moves that put extra stress on their limbs. In spite of their elegant leggy looks, cheetah limb bones have comparatively large cross sections that withstand the forces of such high-speed careening after impalas.

"It would have been just fabulous to have the same collars on the impalas," says Tim Caro of the University of California, Davis, who has long studied cheetahs. That way, researchers could study the interactions between predator and prey, perhaps shedding light on how they've affected each other's evolution.

Wilson's already on it. He's almost finished building a kit aircraft that he and his colleagues will fit with cameras so they can take videos and collar-record all parties in cheetah chases.

The collars have plenty of possible applications, Wilson says. Creating the software and hardware has taken almost 10 years, but rather than cash in on their ingenuity the research team is sharing their innovations. Earlier versions went on pigeons and polo horses, and Wilson now has collars on lions and African wild dogs.

The collars got some fame when BBC television aired an episode of its *Horizon* science program featuring miniaturized cheetah collars recording the movements of domestic cats. A gentle spoiler: Wilson reveals that the cats in an English village do less high-speed chasing across the countryside than raiding food bowls at neighbors' houses. ■

STRUCTURE & MOTION LAB/RVC

# Matter & Energy

For more Matter & Energy stories, visit **www.sciencenews.org**

## Invisibility cloaks can be low-tech

### Commonplace materials used to hide everyday objects

**By Andrew Grant**

Making something invisible does not require complex materials and techniques. Well-placed mirrors or lenses can cloak fish, cats and even people, two new studies show.

Since 2006, physicists have engineered intricate materials that can steer light waves around an object to render it invisible. But such cloaks can manipulate only a narrow range of wavelengths, a far cry from the full spectrum seen by people.

John Howell, a physicist at the University of Rochester in New York, realized that plenty of simple, off-the-shelf materials can also steer light. During Thanksgiving break last year, Howell and his 14-year-old son Benjamin designed three devices that hide life-size objects from sight. One uses L-shaped water tanks, another a network of lenses and the third a set of mirrors; all of them function on the principles of reflection and refraction that students learn in high school physics. The Howells reported June 10 at arXiv.org that they cloaked chairs, toy helicopters and people, though the cloaks worked only when viewed from one direction.

**The rear of a toy helicopter is masked by a cloak made up of four glass lenses (front one shown). A toy truck placed behind the cloak appears instead.**

Halfway around the world, a team led by Hongsheng Chen at Zhejiang University in China employed a similar approach to cloak a fish in a tank and a cat. Chen's team built square and hexagonal glass enclosures that acted as prisms to bend light around an object inside, they report June 7 at arXiv.org. The fish seemed to disappear as it entered a cloak placed in its tank, while plants in the background remained visible.

John Pendry, the Imperial College London physicist who first proposed making invisibility cloaks from synthetic materials, notes that the new cloaks' simplicity requires some sacrifices: These cloaks will never be able to hide an object from all directions, he says.

Nonetheless, one of the new cloaks may have practical use. Howell suggests that a mirror- or lens-based cloak could conceal a secret satellite from observers on the ground. ■

## Echoes inspire interior map app

### Room dimensions might be collected with a cellphone

**By Andrew Grant**

Determining a room's dimensions no longer requires a tape measure. An algorithm that sorts through echoes to develop accurate maps of a room, detailed June 17 in the *Proceedings of the National Academy of Sciences*, may lead to better sound quality for teleconferences and online gaming.

Previous experimental acoustic mapping setups have always involved a speaker that emits a sound and multiple microphones that record the sound. Ideally, each microphone detects sound waves that bounce off a single wall. Then researchers can use the time the sound was recorded and the direction it came from to calculate the position of each wall and reconstruct the room.

But in practice, tracking sound is messy because most echoes take convoluted paths. They may have bounced off multiple walls and the floor before reaching the microphone.

The challenge, says computer scientist Ivan Dokmanić of the Swiss Federal Institute of Technology in Lausanne, was to create an algorithm that could sift through the microphone detections and pull out the speaker-wall-microphone paths.

Using a geometric technique known as Euclidean distance matrices, the algorithm groups one-bounce echoes coming off the same wall. Then it uses the times and directions of the echoes to determine the location of the walls and ceiling.

The team tested its approach using a speaker and five omnidirectional microphones, each of which could be placed anywhere in the room. The algorithm accurately determined the dimensions of a trapezoid-shaped classroom to centimeters. It also estimated the dimensions of an oddly shaped room in the Lausanne cathedral.

Dokmanić hopes next to make maps with fewer microphones, while also exploring whether adding more microphones could enable mapping not only complex shaped rooms but the furniture inside. His eventual goal is to refine the technique to the point that people could map a room with their cellphones.

Flavio Ribeiro, an electrical engineer at Microsoft in Redmond, Wash., highlighted the technique's implications for speakerphone teleconferencing, which is plagued by echoes and stray sounds. He envisions software that could use the microphone array built into game consoles such as Microsoft's Xbox Kinect to map the room a user is in and then use that information to minimize echoes. ■

J. HOWELL

# Zippy memory chip uses light

## Experimental device could accelerate computing

**By Andrew Grant**

An advance in a speedy type of microchip could help engineers integrate computers' short-term and long-term memory.

Despite progress in the speed of computers, their command centers remain relatively inefficient. A central processor does all the thinking and quickly stores 1s and 0s on a chip called dynamic random access memory, or DRAM. But DRAM can serve only as short-term memory. Data needed for the long haul has to be stored on separate magnetic disk drives or on flash drives such as a camera's memory card.

For decades, researchers have vied to create universal memory: a chip that combines the speed and reliability of DRAM with the archival abilities of flash. An innovation reported June 11 in *Nature Communications* fixes a weakness of a leading universal memory contender called ferroelectric RAM.

Although it's fast and energy efficient, FRAM has had problems with long-term reliability. To determine whether a bit is a 1 or a 0, the chip has to apply a voltage that compromises the data. Then it must rewrite the data to preserve it. Those steps gradually degrade the storage capacity.

Ramamoorthy Ramesh, a materials scientist at the University of California, Berkeley, worked with engineers at Nanyang Technological University in Singapore to develop a method for reading data without having to destroy it and then rewrite it. Their solution was to shine a dim light at each bit-containing cell and measure the current that came out. The amount of current indicated whether the bit was a 1 or a 0. The light-shining process preserved the data, with no rewrite step necessary.

The researchers read and wrote data hundreds of millions of times on their prototype FRAM chip with no signs of degradation. In contrast, flash memory has a limit of several hundred thousand read/write cycles. "The innovative idea is the readout," says Kang Wang, an electrical engineer at UCLA. "This innovation may improve the chance of FRAM to be implemented in industry."

Ramesh acknowledges that engineering and economic issues would need to be settled for FRAM to transform computing. And several competing RAM technologies could also serve as universal memory, including some backed by tech giants like Intel and Samsung. ■

# Environment

For more Environment stories, visit **www.sciencenews.org**

## $CO_2$ rise may limit oyster growth

### Acidification could stunt shell formation in larvae

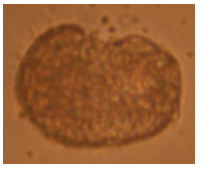
**By Erin Wayman**

The changing chemistry of ocean waters could cause problems for baby oysters, who may struggle to muster the energy to build their shells, new research suggests.

Oysters, clams, mussels and other bivalves build calcium carbonate shells using mostly raw materials from seawater. A 2-day-old oyster larva is already 90 percent calcium carbonate by body weight, ecologist George Waldbusser of Oregon State University in Corvallis and colleagues report May 29 in *Geophysical Research Letters*.

During this shell-building blitz, larvae rely solely on energy derived from their eggs, the team found in a study of Pacific oysters (*Crassostrea gigas*) from a commercial hatchery in Oregon. By looking at the forms of carbon present in eggs versus algae provided as oyster food, the researchers found that larvae depend heavily on an egg's resources for more than a week. The youngsters can't grab outside food until they construct enough shell to support muscle attachments for feeding appendages, Waldbusser says.

Oyster larvae's dependence on a fixed energy source could be a problem as atmospheric carbon dioxide rises. Oceans will soak up more of the gas, driving reactions that lower the water's pH and alter the availability of the compounds needed to make shells. Waldbusser and colleagues calculate that the amount of energy that oyster larvae need to build shells grows exponentially as the amount of $CO_2$ dissolved in the water increases.



**As oceans soak up more $CO_2$, young oysters (embryo shown) may have trouble building their shells.**

Previous work has found that ocean acidification affects oyster growth and survival, says Annaliese Hettinger, an ecologist at Oregon State who wasn't involved in the research. "George's paper is one of the first to point to an actual reason."

The ocean's surface waters are slightly alkaline, with an average pH of 8.1 on a scale where anything below 7.0 is acidic. Since the onset of the Industrial Revolution, ocean pH has dropped by 0.1. By 2100, pH could decline another 0.3 units, and some parts of the ocean could become corrosive to shells.

The new findings may help explain why oyster populations could suffer even before that point. Oyster hatcheries in the Pacific Northwest have had disastrous production declines in the last several years, possibly due to seasonal winds that have brought deep, $CO_2$-rich water to the surface. Although the water hasn't been corrosive enough to dissolve shells, its decreased alkalinity has made shell-building difficult for larvae, Waldbusser says.

Hatcheries can combat falling pH by buffering water with antacids, Waldbusser says. But globally, he says, the only way to fight dropping pH is to reduce $CO_2$ emissions.

Future work needs to explore whether other bivalves are similarly vulnerable. Studies should also examine whether oysters can adapt to higher $CO_2$, says physiologist Brad Seibel of the University of Rhode Island. It may be that oysters in $CO_2$-saturated seawater will make eggs with more energy reserves to compensate for larvae's more laborious shell construction. ■

## Green planet

A new instrument aboard the NASA–NOAA Suomi NPP satellite has been capturing exquisitely detailed views of seasonal and environmental shifts in plant cover (summer 2012 shown). A sensor on the satellite identifies vegetation by detecting differences in reflected amounts of visible light, which plants absorb for photosynthesis, and near-infrared light, which plants don't absorb. Subtle changes in greenness can give advance warning of drought or fire conditions. Meteorologists can also use data on vegetation dynamics to improve weather prediction. —*Cristy Gelling*

G. WALDBUSSER/OREGON STATE UNIV.; NASA, NOAA

# Technology

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## A camera captures voices from afar

### Method uses throat movements to reconstruct speech

By Meghan Rosen

**MONTREAL** — Eavesdroppers might not have to lip-read to listen in on a far-off conversation. Using a high-speed camera pointed at the throat, scientists can decipher a person's words without relying on a microphone.

Snapping thousands of images per second, researchers recorded every wavering wobble of neck flesh that accompanied sounds floating out from a person's voice box. A computer program then turned the video-recorded skin vibrations into sound waves, Yasuhiro Oikawa of Waseda University in Tokyo reported June 3.

Standard lip-reading software tracks lip twitches, tongue waggles and jaw motions as a person's mouth forms a word. Some programs are sophisticated enough to recognize different languages, but the computer doesn't offer much more than a transcript, Oikawa said.

Textual information is important, but so is intonation, pitch and volume, he said. "We get a sense of a speaker's feeling from their voice."

Microphones have problems, too: A mic often records too much background noise — especially outside, where the whoosh of wind or the plop of a raindrop can drown out a person's voice.

So Oikawa and colleagues looked for a new way to record speech that could capture vocal tones.

Using a high-speed camera, the researchers zoomed in on the throats of two volunteers and recorded them saying the Japanese word *tawara*, which means straw bale or bag. The team's camera recorded at 10,000 frames per second; the typical rate for a movie projected in a theater is 24.

At the same time, Oikawa's team recorded the volunteers' words with a standard microphone and a vibrometer that measured movements of their skin.

COURTESY OF YASUHIRO OIKAWA

**Using a high-speed camera to record neck vibrations, scientists can capture a person's voice without a microphone.**

The throat vibrations recorded by the camera looked similar to those picked up by the microphone and the vibrometer.

When the team ran the camera's vibration data through a computer program, the researchers could reconstruct the volunteers' voices well enough to understand the word spoken, Oikawa said. Before the end of the year, he thinks he may be able to record and play back a full sentence using the technique.

The setup should allow scientists to hear words even if there's a lot of background noise, said physicist Claire Prada of the National Center for Scientific Research in Paris. The work is promising, she said, but "it's still just proof of principle."

Other scientists at the presentation expressed more skepticism. Mechanical engineer Weikang Jiang of Shanghai Jiao Tong University in China noted that Oikawa did not play audio of reconstructed voices; instead he showed pictures of the sound waves. Jiang praised the work's novelty, but added, "he didn't show us the results."

Next, Oikawa wants to focus the camera on a person's cheeks to look for more skin spots that jiggle during speech. Analyzing more vibrating areas could give researchers extra info about a person's voice, and that could improve voice reconstruction. ■

## MEETING NOTES

### Skull music

Skull size, density and shape can influence the musical keys people hate, cognitive scientist Jitwipar Jitney Suwangbutra of William Paterson University in Wayne, N.J., reported June 4. Sounds vibrate slightly differently depending on the shape of a person's skull, Suwangbutra said, which may affect how people perceive music. Suwangbutra and colleagues had 16 men and women listen to piano melodies in each of the 12 major keys and rate each song. The team measured the vibration patterns of participants' skulls by tapping their heads with a microphone. People with similar-sized skulls tended to dislike the same melodies; for example, people with bigger skulls couldn't stand the keys with higher frequencies. — *Meghan Rosen*

### Audio zones in cars

Using modified speakers in a car's headrests and a new way to filter sound, Jordan Cheer and Stephen Elliott at the University of Southampton in England have created distinct listening zones for the front and back seats. The team replaced the wooden backs of speakers with rectangles of metal gauze to focus sound toward passengers' ears. Altering the volume and time delay of certain sounds confined them to particular zones in a car, Cheer said June 3. The system let drivers and passengers riding in the back listen to two different but similar pop songs at once, Cheer said. But during tests using something like white noise, some sounds from the rear still made it through to the front. — *Meghan Rosen*

# Genes & Cells

"To me it says starch wasn't involved in the first domestication event." —MATTIAS JAKOBSSON

## Nail stem cells regrow fingertips

### Lost digits can come back if regenerating tissue remains

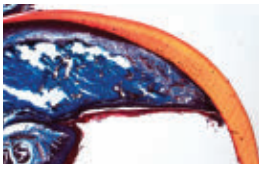
**By Cristy Gelling**

Clumsy manicurists can thank a set of stem cells under the base of the fingernail for erasing their mistakes. Those cells allow not only trimmed fingernails but amputated fingertips to regrow. Doctors could one day use nail stem cells to treat malformed nails or even amputated limbs, Mayumi Ito of New York University Langone Medical Center suggests.

Scientists have long known that children and some adults can regrow the tips of their fingers after amputation. But digits can't regenerate if more than the nail region is amputated.

Ito and her colleagues traced the fates of cells on the back feet of mice during nail growth and found a population of stem cells that produces the hard part of the nail and the soft tissue underneath. When the researchers cut off the end of a toe, signals from the regrowing nail stimulated the tissue underneath to form new bone, the authors report June 12 in *Nature*.

The digit bones can regenerate only if the amputated stump still has some nail stem cells, the researchers found. But the cells alone are not enough; also crucial is a zone of tissue that grows from the stem cells during normal nail growth. After amputation, this tissue sends signals that attract new nerves into the end of the stump and begin the bone regeneration process. If amputation removes the nail zone or if the signals are blocked, the digits will not regenerate.



**A mouse toe tip five weeks after amputation (shown) looks like new because stem cells that are normally responsible for nail growth also stimulate bone regeneration.**

When researchers genetically manipulated the mice to turn on the regeneration signals, nail stem cells alone could spur digit regeneration even without the neighboring nail tissue zone.

Other researchers have found that similar signals are involved in regenerating amputated amphibian limbs. "We were really amazed by the similarity between these processes," Ito says. The parallels suggest that mammals might retain some of the newt's famous power to regrow entire legs.

The similarity between mammalian and amphibian regeneration is encouraging, says Ken Muneoka of Tulane University in New Orleans. That parallel, he says, "gives us hope that we will be able to induce human regeneration in the not-too-distant future." ■

## Extinct wolf may have begat dogs

### No sign of ancestry in DNA from living populations

**By Tina Hesman Saey**

Dogs evolved from a wolf lineage that has since gone extinct, a study of canine DNA suggests.

Researchers have long assumed that dogs branched off from a still-living wolf species. Geneticists have combed the world looking for wolf populations that most closely resemble dogs genetically, and concluded that dogs originated in the Middle East or Southeast Asia. But fossils suggest Europe as the site of dog domestication.

Posted June 4 at arXiv.org, the new study finds that interbreeding between dogs and wolves after domestication has made wolves in certain locations seem more closely related to dogs than they actually are.

Adam Freedman of Harvard University and an international group of collaborators compared DNA from three breeds of dogs (a boxer, a Basenji and an Australian dingo) to that of three gray wolves (*Canis lupus*) from Croatia, China and Israel — three locations proposed as centers of dog domestication. All of the wolves were equally related to the dogs, indicating that none of them has a special claim to being the dog ancestor. The authors suggest that some other type of wolf, possibly an extinct species, produced the first Fido.

The researchers' findings leave dog origins up in the air. "I agree with them that we should back off from setting a needle in the map" to indicate where dogs first appeared, says Mattias Jakobsson, a population geneticist at Uppsala University in Sweden.

With additional data, the study also challenges a recent report that the rise of agriculture and the ability to digest starchy food may have triggered domestication. Freedman and his colleagues date dog domestication to about 15,000 years ago, well before the advent of agriculture.

The earlier study found that dogs carry extra copies of a gene called *AMY2B*, which produces an enzyme that breaks down starch, while wolves have only two copies (*SN Online: 1/23/13*). The new study, which is larger and includes more wolves and dog breeds, found that some wolves actually do have extra copies of the gene. Dingoes, which split off from other dogs 3,500 to 5,000 years ago, also have two copies and Siberian huskies have only three or four.

Freedman's combined data make a case against carbohydrates playing a key role in taming canines, Jakobsson says. "To me it says starch wasn't involved in the first domestication event." ■

ITO LAB/NEW YORK UNIV.

# Molecules

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## Eel's glow could reveal liver ills

### Fluorescent fish protein binds blood cell breakdown product

**By Rachel Ehrenberg**

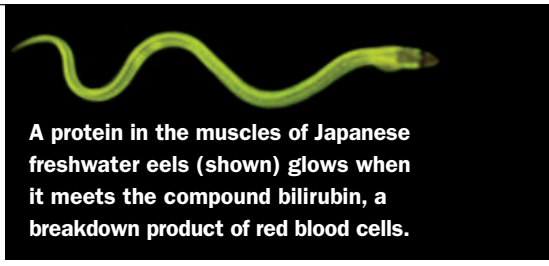
An eel protein that shines green could enable a new test for liver problems and jaundice. The protein gets its glow on by connecting with the pigment bilirubin, scientists report in the June 20 *Cell*.

Led by bioimaging specialist Atsushi Miyawaki, scientists from the RIKEN research institute in Japan spent three years trying to figure out what switched on the protein's glow in the species *Anguilla japonica*. Eventually, the scientists hit upon the jaundice-causing bilirubin, a yellowish pigment that's produced when the hemoglobin in red blood cells breaks down.

The body has bilirubin-eliminating machinery, but when it malfunctions — or in the case of newborns, has yet to turn on — bilirubin levels can soar, causing jaundice, brain damage or even death. By exploiting bilirubin's ability to turn on the eel protein, Miyawaki and his colleagues developed a simple test with a lab-made version of the protein that uses the brightness of green fluorescence to indicate a blood sample's level of the pigment.

"What they've got is really good," says Stanley Lo of Children's Hospital of Wisconsin in Milwaukee. "There's quite a bit to do before it's in clinical use, but I'd like to see what happens."

The protein, called UnaG (for *unagi*, the Japanese word for freshwater eel, and G for green), might also prove useful as a lab tool for illuminating other molecules or whole cells. Unlike many other fluorescent compounds, UnaG can glow in low- or no-oxygen environments, which might make it useful for studying tumors.



A protein in the muscles of Japanese freshwater eels (shown) glows when it meets the compound bilirubin, a breakdown product of red blood cells.

Several freshwater eel species make UnaG, which is the first fluorescent protein discovered in a vertebrate, Miyawaki says. The researchers suspect that it plays a role in muscle physiology during eel growth. As youngsters, eels undergo an intense period of migrating between ocean and river, transforming from slender, translucent "glass eels" to hefty, opaque adults. But UnaG's precise job is unknown. "It is still a riddle — it's an enigma," Miyawaki says. ■

RYOKO ANDO AND A. MIYAWAKI

Mind & Brain

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# Human brain mapped in hi-res 3-D

## Digital atlas offers 50 times more detail than existing views

**By Meghan Rosen**

A new 3-D map of the brain is the best thing since sliced cold cuts, at least to some neuroscientists.

"It's a remarkable tour-de-force to reconstruct an entire human brain with such accuracy," says David Van Essen, a neuroscientist at Washington University in St. Louis.

Using a high-tech slicer and about 100,000 computer processors, researchers shaved a human brain into thousands of thin slivers and then digitally glued them together. The result of the six-year project is the most detailed brain atlas ever published. Dubbed BigBrain, the digital model has a resolution 50 times greater in each of the three spatial dimensions than currently available maps, researchers report in the June 21 *Science*.

The difference is like zooming from a satellite view of a city down to the street level, says study coauthor Alan Evans, a neuroimaging scientist at McGill University in Montreal.

BigBrain allows researchers to navigate the landscape of the human cortex, the rugged outer layer of the brain. And unlike previous maps, the tool also lets scientists burrow beneath the surface, tunnel through the brain's hemispheres and step slice-by-slice through high-res structural data.

Around 100 years ago, neuroscientists relied on thick slabs of brain tissue to crudely chart out neural regions. More recently, imaging tools such as MRI have let researchers take a more detailed look. But even the very best MRI maps are still a little fuzzy, says Hanchuan Peng, a computational biologist at the Allen Institute for Brain Science in Seattle.

> "It's a remarkable tour-de-force to reconstruct an entire human brain with such accuracy."
> DAVID VAN ESSEN

In 2010, a team of Chinese researchers constructed a digital map of the mouse brain using techniques similar to the ones that produced BigBrain. But until now, no one had done it in humans. Because the human brain is thousands of times bigger than the mouse brain, Evans and colleagues had to massively scale up slicing and computing methods.

First, Katrin Amunts and colleagues at the Jülich Research Center in Germany carved the donated brain of a 65-year-old woman into 7,404 ultrathin sheets, each about the thickness of plastic wrap.

Next, researchers stained the sheets to boost contrast, took pictures of each sheet with a flatbed scanner, and then harnessed the processing power from seven supercomputing facilities across Canada to digitally stitch together the images. In all, the researchers analyzed about one terabyte, or about 1,000 gigabytes, of image data. That's about the same amount of data as 250,000 MP3 songs.

"Your laptop would choke if it tried to run a typical image-processing program to look at this dataset," Evans says.

His team designed a software program that lets researchers dig into BigBrain's data. Users will be able to pick up the brain, rotate it in any direction and cut through any plane they want. "It's like a video game," he says.

Evans hopes BigBrain will provide a digital scaffold for other researchers to layer on different kinds of brain data. Scientists could stack on information about chemical concentrations or electrophysical signals, just as climate and traffic data can be layered onto a geographical map.

The 3-D map could also help researchers interpret data from lower-resolution brain-scanning techniques such as MRI and PET, study coauthor Karl Zilles of the Jülich Research Center said during a press briefing June 19. Overlaying images from these scans onto BigBrain might give scientists a better idea of where exactly damaged tissue lies in diseased brains.

And neurosurgeons might use BigBrain to guide placement of electrodes during deep-brain stimulation for Alzheimer's or Parkinson's diseases, he said.

Though all human brains have largely similar architecture, Evans says, every person has subtle shape variations. As a result, he'd like to make maps of more brains for comparison.

Now that the teams have ironed out BigBrain's technical kinks, the researchers think they can compile a second brain's map in about a year. "The computational tools are all largely in place now," Evans says. ■

**By slicing a brain into ultrathin sheets and digitally pasting them together, researchers have created the first 3-D high-resolution map of the human brain.**

COURTESY OF K. AMUNTS, K. ZILLES, A. EVANS *ET AL*

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# Health & Illness

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## Lots of headers hurts memory

### Brain abnormalities found in some soccer players

**By Nathan Seppa**

Soccer players who hit the ball with their heads a lot don't score as well on a memory test as players who head the ball less often, a new study finds. Frequent headers are also associated with abnormalities in the white matter of the brain, researchers report June 11 in *Radiology*.

"These changes are subtle," says Inga Koerte, a radiologist at Harvard Medical School and Brigham and Women's Hospital in Boston. "But you don't need a concussive trauma to get changes in the microstructure of your brain."

While soccer players can get concussions from colliding with goal posts, the ground or each other, concussions are uncommon from heading the ball even though it can move at 80 kilometers per hour, says coauthor Michael Lipton, a neuroradiologist at the Albert Einstein College of Medicine in New York City.

He and his colleagues took magnetic resonance imaging scans of 28 men and nine women who played amateur soccer. The players, with an average age of 31, tallied up their games and practice sessions in the previous year and estimated how many headers they had done in each. Most players headed the ball hundreds of times; some hit thousands of headers.

The MRIs revealed abnormalities in some players, mainly in the white matter of three regions of the brain. White matter coats nerve fibers, and bundles of fibers cross and converge in the three regions. But the areas aren't associated with a single mental function, Lipton says. Attention, memory, sensory inputs and visual and spatial functions could all be processed in those locations.

> "The brain sloshes back and forth inside the head."
> MICHAEL LIPTON

Players who headed balls the most showed more abnormalities than those who headed fewer. For one brain region, 850 headers represented a threshold: Players above that mark clearly had more abnormalities than players below it. For the other brain regions, thresholds were about 1,300 and 1,550 headers.

On a memory test, the nine players with the most headers scored worse on average than the nine with the fewest. The researchers estimated that the threshold for memory loss would be 1,800 headers.

The regions with white matter abnormalities sit toward the back of the head, opposite the typical point of impact of a header. Lipton says brain "recoil" might explain the location. "When there is a head impact, the brain sloshes back and forth inside the head," he says. On a frontal impact, he says, the brain presses against the front of the skull momentarily and then slams into the back of the skull. ■

## Leprosy hardly changed since 1000

### Decline in prevalence can't be attributed to shifts in genome

**By Tina Hesman Saey**

The bacterium that causes leprosy still packs the same punch it did in the Middle Ages, a study of the organism's genome reveals.

*Mycobacterium leprae* causes skin sores, nerve damage and skeletal disfigurement. About 200,000 people worldwide contract leprosy, also known as Hansen's disease, each year. In early medieval Europe the bacterial infection was more common, but its incidence began to wane in the 16th century.

**A tooth from a 600-year-old skull contained well-preserved DNA from the bacterium that causes leprosy.**

*M. leprae* has a bare-bones genome that doesn't allow the microbe to survive outside a human or animal host. About half of the organism's genes have been disabled and no longer make proteins. Many scientists thought this genome decay contributed to the disease's decline in prevalence, says Patrick Brennan, a microbiologist at Colorado State University in Fort Collins.

Hoping to find the genetic changes that led to leprosy's decline, an international group of researchers extracted bacterial DNA from 24 skeletons of leprosy victims from 10th to 17th century Sweden, Denmark and England. One sample was so well preserved that the researchers were able to reconstruct the medieval bacterium's entire genome.

The team then compared the medieval bacterium's genome to those of bacteria isolated from leprosy patients living in India, Thailand, the United States and Brazil. "We could find no meaningful differences," says coauthor Stewart Cole of the Swiss Federal Institute of Technology in Lausanne. The team reports the finding June 13 in *Science*.

The bacterium's genetic stability may be due to its stripped-down genome, says Helen Donoghue, of University College London, who has studied ancient leprosy strains. "There's not a lot of scope for further change," she says.

Given that leprosy hasn't changed much in a millennium, Cole and his coauthors speculate that leprosy's exit from the European stage was due to the social isolation of people with leprosy and the rise of other diseases, such as the plague and tuberculosis. ■

# News in Brief

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## TECHNOLOGY

### Eye chip stimulates blind rats' brains

The partial blindness that accompanies macular degeneration and other retina-damaging diseases may soon be treatable with a new prosthetic. Rats with faulty vision that received the prosthetic implants responded to light with activity in their brains' visual cortices, a team from Stanford and the University of Strathclyde in Scotland reports. The results, published June 18 in *Nature Communications*, pave the way for people to use such chips, which are part of a bionic eye that doesn't require the surgically implanted wires that existing retinal prosthetics do (*SN: 6/16/12, p. 12*). The system involves a pair of specialized goggles outfitted with a camera on the nosepiece. The camera sends data to a pocket-sized computer, which processes the visual information and sends it to near-infrared lasers inside the goggles, facing the eyes. These lasers stimulate slender chips implanted beneath the retinas, which convert the data to an electrical signal to the brain. The brain activity that the researchers recorded establishes that the electrical signal does reach the brain's visual center. —*Rachel Ehrenberg*

## LIFE

### Bird penises wither away in egg

Some ducks have penises longer than their bodies, while chickens make do with a tiny bump. The vast size difference between the two types of fowl results from a wave of cell death during chicken development, researchers report in the June 17 *Current Biology*. Although the ancestors of birds had penises, 97 percent of bird species have phalluses so small that they can't insert into the female genitalia. Martin Cohn of the University of Florida and his colleagues found that in chick embryos, a gene turns on in the tip of the developing phallus, causing the cells to die and the tissue to wither away. In duck embryos, the gene does not turn on in the tip and the penis keeps on growing. The researchers were able to kick-start some growth of the embryonic chick penis by blocking the action of the gene. That result suggests that chickens have not entirely lost the genetic pathways that make their waterfowl relatives better endowed. —*Cristy Gelling*

### All chimps to join endangered list

The U.S. Fish and Wildlife Service has proposed applying the full terms of the Endangered Species Act to all chimpanzees, captive and wild. Roughly 2,000 chimpanzees live in captivity in the United States; about half are held for medical research. In 1990, the Fish and Wildlife Service granted endangered status for wild chimpanzees. Captive chimps were considered only threatened at the time. The new proposal would treat all chimps as one group. It would also require scientists to secure a permit for most medical research on chimps. Researchers would need to convince the Fish and Wildlife Service that their work is both necessary and contributes to conservation of chimps in the wild. —*Meghan Rosen*

## HUMANS

### Radar sizes up ancient urban sprawl

Laser pulses beamed from a low-flying helicopter into northwestern Cambodia's dense jungles have revealed ancient remnants of extensive, carefully planned settlements surrounding Angkor, the capital of the region's Khmer empire. Angkor (temple ruins pictured above) flourished from around 800 to 1500, but forests now obscure much of the ancient city's urban sprawl. Laser technology called lidar now shows that, starting around 1100, roadways and canals formed rectangular grids around Angkor's central temples and royal palaces, say archaeologist Damian Evans of the University of Sydney and his colleagues. Similar grids containing villages, ponds and small temples spread out far into

DONYA NEDOMAM/SHUTTERSTOCK

the countryside over the next few centuries, covering as many as 1,000 square kilometers, the researchers report June 17 in the *Proceedings of the National Academy of Sciences*. The new view supports an increasingly popular idea: The city grew so large that its canals and reservoirs could not provide enough water when severe droughts hit around 1400. Residents may have gradually abandoned Angkor for cities built near rivers, in the region of today's Phnom Penh. —*Bruce Bower*

## GENES & CELLS

### Snails trace ancient human trek

Stone Age people may have carried land snails on a voyage from the Pyrenees to Ireland, an examination of the snails' DNA reveals. Scientists have struggled to explain why Ireland shares some plant and animal species with the Iberian Peninsula, but not with the rest of Europe or the British Isles. For example, *Cepaea nemoralis* land snails on Ireland's western coast and in parts of the Pyrenees share unique white-lipped shells. To find out if the two populations of white-lipped snails are related, Angus Davison and Adele Grindon of the University of Nottingham in England took DNA samples from the species all over Europe. The researchers found that snails in Ireland and the Pyrenees share a variation in one gene that distinguishes them from other European specimens. The simplest explanation, Davison and Grindon report June 19 in *PLOS ONE*, is that humans journeying to Ireland about 8,000 years ago brought along escargot as a food source. "Other explanations get quite convoluted," Davison says. —*Tina Hesman Saey*

# When the ATOM went quantum

## Bohr's revolutionary atomic theory turns 100

**By Tom Siegfried**

Before Niels Bohr, atoms baffled science's brightest brains.

For millennia, atoms had been phantoms, widely suspected to exist but remaining stubbornly invisible — though not indivisible, as their name (Greek for "uncuttable") originally implied. By the start of the 20th century, physicists knew that atoms had electrically charged parts; the favorite model envisioned blobs of positively charged pudding studded with negatively charged plums (actually, electrons). That image was challenged, though, when Ernest Rutherford showed in 1911 that the positive pudding was all crammed into a massive dense core, or nucleus, surrounded at a distance by the electron plums *(SN: 5/7/11, p. 30)*.

But Rutherford's atom baffled everyone even more, as the laws of physics prohibited the arrangement that he described. Opposite charges attract each other relentlessly; electrons should spiral into the atom's positive nucleus in less than a millisecond. (Even if they didn't, their mutually repulsive negative charges would blast them out of their orbits.) Yet somehow atoms housed negative and positive charges happily.

Into this paradox stepped a great Dane, a genius conditioned by his culture to embrace conflicting ideas and learn from them. A century ago, Niels Bohr married the old standard physics with the new quantum theory, giving birth to the modern model of the atom's structure.

Bohr's atom did more than simply reconcile theory with experiment. Bohr figured out the basics of how atoms hook up to make molecules. He explained the mysterious repetition of properties displayed by the periodic table of the chemical elements. And most consequential of all, he established the fundamental role of quantum physics in describing the

underlying reality of the universe.

Even though the technical details of Bohr's model turned out to be wrong, he had grasped the essential idea for understanding atoms: abandoning common sense in favor of the crazy rules of quantum theory. Bohr saw more deeply than others of his time that embracing quantum physics was the key to unlocking nature's hidden truths. While quantum confusions drove other physicists to despair, Bohr pursued the path into the yellow quantum wood. When two roads diverged, he traveled both but remained one traveler, insisting that knowing reality meant accepting the truth of mutually incompatible viewpoints.

In the decades following his description of the atom, Bohr served as guide and interpreter for the world's physicists as they explored the strange new quantum world. As the physicist J. Robert Oppenheimer observed, in the development of modern quantum physics, "the deeply creative and subtle and critical spirit of Niels Bohr guided, restrained, deepened, and finally transmuted the enterprise."

**Bohr "gave the first firm and lasting direction toward an understanding of atomic structure and atomic dynamics."**

**ABRAHAM PAIS**

### Father of the atom

Bohr's role in that enterprise began in 1913 with a series of three papers that became the foundation for the future of atomic science.

Bohr "gave the first firm and lasting direction toward an understanding of atomic structure and atomic dynamics," physicist Abraham Pais wrote in his biography of Bohr, *Niels Bohr's Times* (1991). "In that sense he may be considered the father of the atom."

Like most fathers, Bohr was proud of his offspring. But he was not blind to its faults. He knew from the beginning that his atom model was too simple to capture all of reality's complexities. He was certain, though, that explaining the atom required quantum physics. "That, of course, was the key to Bohr's great invention," says science historian John Heilbron, of the University of California, Berkeley.

Bohr had foreseen the need for quantum theory when investigating the electron theory of metals for his 1911 doctoral dissertation. He found that electrons carrying current and those bound to atoms behaved in different ways, at odds with the ordinary mechanical laws of classical physics.

"He reached the conclusion that there was no possible way classical physics could explain what happened in the behavior of electrons in metals," says physicist Alfred Goldhaber of Stony Brook University in New York.

Various clues hinted that solving the electron quandary would require Max Planck's quantum idea, introduced in 1900. From experiments on heat radiation, Planck had deduced that energy could be emitted from a hot object only in indivisible packets called quanta, sort of the way sand consists of individual grains. A few years later Einstein argued that all radiation, including light, was not only emitted but transmitted in such packets (later called photons) even though light was known to travel as a wave.

During the first decade of the 20th century only a few scientists took Planck seriously, and even fewer believed Einstein. But Bohr did. While others deplored the quantum's contradictions, he exploited them. He had been prepared for the challenge by the circumstances of his upbringing.

Born into an academic family in Copenhagen in 1885, Bohr benefited from a rich intellectual home life. He listened in when the university's physicist, philosopher or philologist visited his physiologist father for evening discussions. He also absorbed the multiple cultural influences inherent in Denmark's history and geography, at the crossroads between Germany and England. As children, Niels and his brother Harald listened as their father read aloud from Goethe and from Shakespeare and Dickens. Niels also consumed Danish authors such as Kierkegaard and Hans Christian Andersen and read an unfinished novel by Poul Martin Møller (a mentor to Kierkegaard) called *Adventures of a Danish Student*. Its discussion of coping with dilemmas and contradictions deeply affected Bohr, impressing him with lessons about language and logic that he referred to throughout his life.

Through his early years of schooling and on to his undergraduate years at the University of Copenhagen, Bohr's brilliance captivated his professors and classmates. "His family, friends and teachers recognized him as a rare spirit, a thinker at once deep and broad, and helped him in every way to develop his abilities," says Heilbron.

As he pursued his scientific education, Bohr also learned to appreciate both the German emphasis on theory and math and the British preference for experiment. Destined to be a theorist, Bohr nevertheless chose England for postdoctoral work. He decided to study under J.J. Thomson at the Cavendish Laboratory in Cambridge, the mecca of British experimental physics.

Bohr was eager to absorb the Cambridge magic, both in the lab and in the town. He joined a soccer team and worked on his English by reading *The Pickwick Papers*, having bought a red dictionary to look up the words he didn't know.

He was most eager, of course, to talk with Thomson — the electron's discoverer — about flaws in Thomson's ideas about electrons in metals. Thomson turned out to be not so interested in hearing Bohr's criticisms. In late 1911, Bohr met Rutherford, who told him of quantum developments discussed at a recent conference in Brussels. Soon Bohr transferred to the University of Manchester to work

BOTH: A.B. LAGRELIUS AND WESTPHAL, ADAPTED BY S. EGTS

with Rutherford's team, the decisive step toward the quantum atom.

At first, Bohr's interest at Manchester was still electrons, including the beta particles identified by Rutherford as one form of radioactivity. But Bohr soon realized that radioactivity's secrets emanated from inside the nucleus. So his search for truth turned to the atom itself.

"Bohr was already on the hunt," says Goldhaber. "He was looking at every aspect of the atom. And he was going to find out everything that could be possibly found out."

In the first months of 1912, Bohr worked on the atom problem furiously and fruitfully. In June he wrote to his brother about his progress: "Perhaps I have found out a little about the structure of atoms." That turned out to be an understatement. In fact, he had determined that quantum physics could make the atom stable.

Bohr wasn't the first to try to apply quantum physics to atoms. But he showed how to make it work. He pointed out that a proper theory of a stable atom would determine a number with the dimension of length, corresponding to the atom's size, like the way the length of a spoke determines the size of a bicycle wheel. Producing a number with a plausible length for the atomic spoke was possible only by combining the key quantity in quantum theory, Planck's constant, with the electric charges and masses of the electron and nucleus.

But explaining how quantum physics governed atomic behavior was not straightforward. In the end, Bohr used classical math for part of his atom model and then mixed quantum physics into it in four specific ways. Two were directly related to Planck's radiation theory, involving technical aspects of the electrons' energies. The other two were inspired by processes hidden within the mysterious machinations of Bohr's enigmatic mind.

One — often celebrated as the crucial ingredient in the Bohr atom model — declared that electrons could occupy only certain specific orbits around the nucleus. In each such allowed orbit the electron possessed an angular momentum equal to a multiple of Planck's constant divided by 2 pi. With that constraint, Bohr could explain why light was emitted from hydrogen atoms only in certain very specific colors (or frequencies). An emitted color corresponded to an electron jumping from one allowed orbit to another.

Of the many novel aspects of Bohr's atom, that was the most baffling. Standard physics insisted that the frequency of light should depend on how long it took the electron to orbit the nucleus — its orbital frequency. But if electrons emitted light as they orbited, Bohr pointed out, atoms would radiate light all the time, and they don't. Hence Bohr demanded that electrons occupy non-radiating orbits while in an atom's "stationary" state, divorcing the frequency of the light from the frequency of the orbit.

"That cut the ground from under the majority of physicists, who supposed that observable phenomena arising from atomic processes could be linked directly with motion in the microworld," Heilbron said in April at a meeting of the American Physical Society.

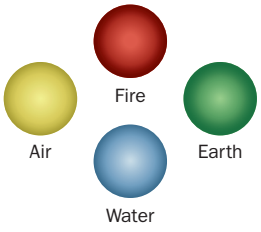
Bohr's other clever notion offered a way to bridge the gulf between quantum and classical physics. For an electron very far from its nucleus, Bohr said, the frequency of emitted light would be close to the classical prediction. Because distant orbits are very close together, orbital frequencies are nearly equal. So a jump from one to another emits a frequency nearly equal to the orbital frequency. It was another way of saying that for large objects of ordinary experience, quantum effects would be too minute to notice — a key part of the eventual modern understanding of quantum reality.

## The atomic constitution

Bohr's mashup of classical physics with quantum theory offered more insights than would fit in one paper. So he published a series of three, all titled "On the Constitution of Atoms and Molecules," in the *Philosophical Magazine*. Part I, appearing in July 1913, described the quantum rules for electron orbits and quantum jumps in the hydrogen atom, explaining the spectrum of colors it emitted. In Part II, Bohr described the arrangement of electrons in rings around

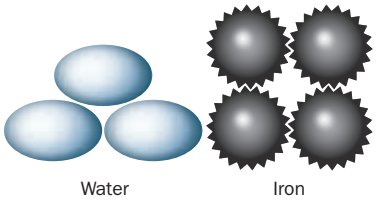
**Atomic history** The idea of an essential building block of matter is ancient. Greeks came up with the word for *atom*, but most insights into its true structure and behavior have been recent.

**500 B.C.?**



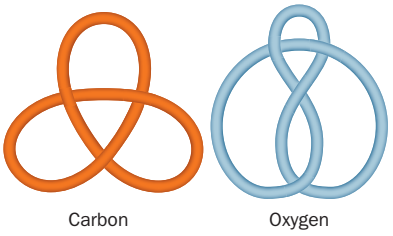

**Hindu philosophers** discuss atoms as ultimate pieces of the elements earth, air, fire and water. Atoms are round and differ in properties such as color, flavor and odor.

**500–400 B.C.**




**Democritus** describes atoms as eternally unchanging and indivisible, all made of the same substance, and differing only in size, shape and arrangement in space.

**1867**




**Lord Kelvin** proposes a "vortex model" in which atoms are twisted knots, or vortices, in the ether.

the nuclei of more complicated atoms, the first steps toward explaining the periodic table of the elements. Part III described how molecules formed by atoms sharing electrons.

Reaction to Bohr's theory was mixed. Some experts found it ingenious; others couldn't understand it. Einstein was intrigued if not convinced at first. But when an experiment confirmed Bohr's prediction that some colors of light supposedly from hydrogen actually came from helium, Einstein came around. When told of that experiment, Einstein replied, "This is an enormous achievement. The theory of Bohr must be then right."

But Bohr knew that his theory, while glimpsing a piece of reality, had its deficiencies. Its success, he believed, was largely due to hydrogen's simplicity. Over the next decade, efforts to apply it to more complicated atoms failed. Finally in 1925 Werner Heisenberg, a young German physicist who had studied at Bohr's institute for theoretical physics in Copenhagen, constructed a novel mathematical approach that got the right answers. Heisenberg's paper marked the birth of modern quantum mechanics.

At about the same time, experiments began to show that particles sometimes had wave properties (and vice versa). Erwin Schrödinger constructed a wave version of quantum theory, soon shown to be equivalent to Heisenberg's particle version. Heisenberg's work then led in 1927 to his famous uncertainty principle: It was not possible to precisely measure certain pairs of properties, such as a particle's position and momentum, at the same time.

Once again Bohr stepped in to address the paradoxes. In a 1927 lecture, he proposed a new principle, called complementarity. Light could be particle or wave depending on what experiment you chose to do, Bohr declared. You could measure the position of an electron, or its momentum, depending on how you designed the experiment. You couldn't do both experiments at once.

Bohr's complementarity served as the foundation of what came to be called the Copenhagen interpretation of quantum mechanics. In popular discussions, the Copenhagen view emphasizes the role of the observer in creating reality, a point of contention for many physicists today. But Bohr didn't speak of it in that way, says philosopher of science Don Howard of the University of Notre Dame. It was Heisenberg who focused on the role of observers.

Bohr's view was much more subtle. He insisted that the properties of a quantum system had no precise meaning before being measured. But measurement required the measuring instrument to interact with the quantum system. Once such an interaction took place, the measuring device and quantum system shared a history—becoming "entangled," in modern terminology. So how was it then possible to speak of a quantum system's properties at all?

"Here's where the really crucial idea entered Bohr's thinking," Howard said at the physics meeting. If you specify the experiment you want to perform, you can then use the result to describe a property of a quantum system as if it had a precise value, even if it had no precise value without the measurement. Of course, you couldn't talk about all the properties of a system at once—you had to choose what to measure.

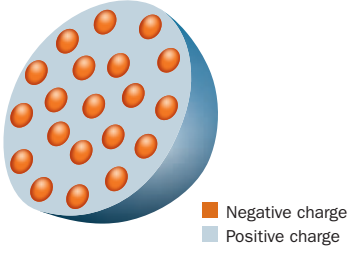
"For Bohr, two properties like position and momentum are necessary for a complete account of the system and its behavior," said Howard. "But we could speak of them only one at a time, not simultaneously, because we're entitled to speak of them as well-defined properties of the system only in a context in which such a property could be measured." And the measurement contexts for position and momentum are physically incompatible. "That was the deep reason why we couldn't speak simultaneously of well-defined values of position and well-defined values of momentum," Howard said.

## Multiple truths

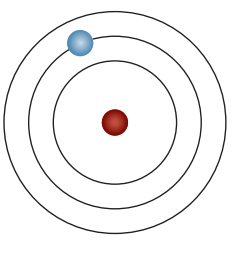
Bohr's embrace of such incongruity reflected views about truth he had developed in his youth. In fact, his investigations of quantum science fed a much broader world view.

"The primary payoff of his engagement with quantum physics for his wider philosophy was the discovery that multiple truths come ... in complementary pairs," Heilbron said.

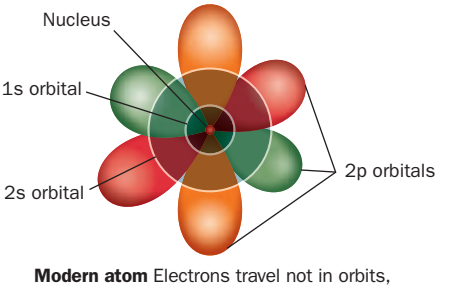
Bohr's thoughts on truth have recently been illuminated by newly available correspondence with his fiancée, Margrethe Nørlund, during his work on the atom model. Heilbron cited one letter in which Bohr discusses the different sorts of




**J.J. Thomson** proposes the "plum pudding" model of the atom, picturing negatively charged electrons rotating in concentric rings within a sphere of positive electricity.




**Bohr's** atom model describes a dense, positively charged nucleus, containing nearly all the atom's mass, surrounded by electrons traveling in specific allowed orbits.

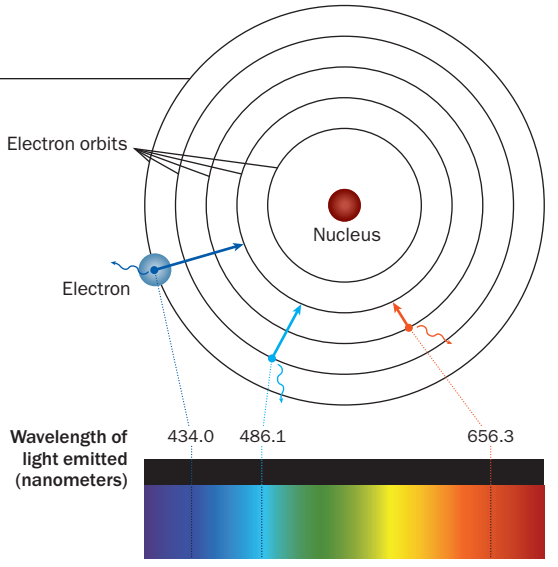



**Modern atom** Electrons travel not in orbits, but exist as clouds of electric charge within "orbitals" that define regions of space with a high probability of containing the electron.

S. EGTS

## Bohr's atomic orbits

In Bohr's model of the hydrogen atom, one electron, carrying a negative electrical charge, circles a nucleus consisting of a single proton, which has a positive charge. Unlike a planet around a star, which could orbit at any distance, an electron can orbit the proton only in certain "allowed" orbits. The size of each allowed orbit is determined by the key numerical quantity of quantum physics, Planck's constant. An electron jumping from an outer to an inner orbit emits radiation (examples shown) with an energy equal to the difference in the energy levels of the two orbits. When an electron absorbs a certain amount of energy, say from light hitting it, the electron jumps to a higher allowed orbit. Bohr calculated the energy differences between various orbits and found that they corresponded to the observed colors of light known to be emitted by hydrogen.




truths expressed in sermons, great works of literature, and science. The truths of one's personal sympathies, the universal human truths of literature and scientific truths all differ in kind, but are all important, Bohr wrote. "It's something I feel very strongly about, I can almost call it my religion, that I think that everything that is of value is true."

Heilbron sees parallels in these writings to Bohr's four methods of introducing the quantum into the atom—multiple truths, not all consistent.

"Although they differ in physical content, and sometimes conflict mathematically, Bohr believed that he needed them all," said Heilbron. "In giving these four formulations, Bohr was not just hedging his bets. He believed that each contained an element of truth and that therefore ... he was obliged to use them all even if they conflicted. This principle of inclusion was almost a religious precept to him."

As for standard religion, though, Bohr was unsympathetic. His mother was a nonpracticing Jew, his father an atheist Lutheran. As a youth, Niels tried to assimilate religious teachings but soon concluded that religion as taught could not withstand scrutiny in the context of logic and science. When he confessed this to his father, the elder Bohr's response was a simple supportive smile. Niels wrote of that episode to Margrethe: "My courage roared so wildly, wildly, for I knew then that I too could think."

Heilbron sees in that text a glimpse into the origin of Bohr's exceptional intellectual journey.

"The approving smile of the man he most admired in the world taught him that he belonged among the few who could reason their way free from standard beliefs of their class and culture, of their time and place," Heilbron remarked.

And not only could Bohr think, he thought in ways that others could not. He could see that the classical physics enshrined in textbooks "represented the truths of the microworld no better than conventional religious beliefs accorded with the meaning of life," Heilbron said.

Bohr viewed the aberrations of the quantum world not as heresies to avoid but as clues to deeper truths about reality. His comfort with contradictions enabled him to formulate explanations for quantum paradoxes that have survived the tests of modern experiments, although most of those came after he died, in 1962.

At the time of his death, Bohr was acclaimed as the greatest atomic physicist in the world; he is still widely regarded as the second-greatest physicist of his century, behind only Einstein. Bohr's legend had developed during the 1920s and 1930s, as beginners from many nations came to Copenhagen to study at his institute. It was there in the mid-1930s that he devised the first clear picture of the internal physics of the atomic nucleus. Soon thereafter, collaborating with the American physicist John Archibald Wheeler, Bohr produced the theoretical explanation for the process of nuclear fission. Bohr's atom model was then finally fully constructed.

Wheeler once said he wanted to study in Copenhagen because Bohr saw further into the future than other men. How Bohr did that baffled others in much the way that atoms baffled physicists before Bohr. He comprehended nature's secrets in ways that remain as mysterious as how his weird mixture of quantum and classical physics explained hydrogen's spectrum.

Perhaps, says Heilbron, the newly released correspondence will offer fodder for new speculations on Bohr's genius, or even about intellectual creativity in general.

"However these speculations may pan out, they will no doubt bring to light further information linking Bohr's extraordinary way of thinking, his confident cultivation of ambiguity, his notions of truth and his high culture, to the Danish society that nurtured him," Heilbron said.

"His like might not be seen again. For as Einstein once said, it's very remarkable that such a mind as Bohr's could have existed at all." ■

### Explore more

■ Heilbron lecture: http://bit.ly/SN_bohr

*Tom Siegfried is the former editor in chief of* Science News.

S. EGTS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# Mystery in Synchrony

## Cicadas' odd life cycle poses evolutionary conundrums

**By Susan Milius**

After 17 years underground, throngs of ruby-eyed cicadas clawed up through the soil this year to partake in a once-in-a-lifetime, synchronized mating frenzy. Except it wasn't one big insect orgy: It was three.

The insects that unearthed themselves to breed in 2013 belong to three distinct species. You need only flip them over to see some differences, written in the varieties of their orange markings.

You can hear the differences too, says Chris Simon of the University of Connecticut in Storrs. The tymbals on either side of a male's abdomen vibrate to make the racket for which cicadas are famous. A chorus of courting *Magicicada cassini* males sounds like an electric carving knife revving up. *M. septendecula* coughs out a series of rasps. And *M. septendecim* serenades with the whistling drone of a B-movie spaceship.

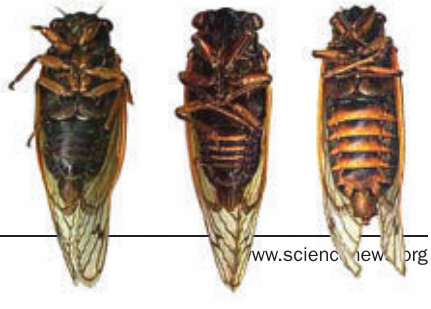
The various thrums and buzzings may mingle in the same neighborhood, but the last time ancestors of these species mated with each other was almost 4 million years ago, Simon says. That's the conclusion of the most detailed genetic studies yet of periodical cicada evolutionary history, which Simon and colleagues published in April in the *Proceedings of the National Academy of Sciences*. With DNA plus episodic field observations, the scientists are getting an idea about the odd family tree of periodical cicadas, how the insects synchronize their life cycles and why they breed side-by-side with others unsuitable for mating.

Biologists have named a few thousand cicada species worldwide, all within the families Cicadidae and Tettigarctidae. Cicadas nestle on the evolutionary tree of life among planthoppers and related botanical vampires that suck plant fluids—not with locusts as is commonly thought. But only the seven named species that make up the genus *Magicicada* live underground for more than a decade and then burst forth to breed in multi-species masses. These periodical cicadas live in eastern and central North America, where biologists and spring-wedding planners alike keep tabs on the 15 different cohorts, or broods. The broods are identified according to the years in which they cycle into frantic reproduction.

### From then to now

On an evolutionary family tree, the periodical cicadas branch and then fan into species sets with patterns that echo each other. And since this is biology and not mathematical theory, odd anomalies show up here and there.

For example, consider the origins of the 13- and 17-year cyclers. A biologist



**The three species of Brood II that emerged this year are (left to right) *Magicicada cassini, M. septendecula,* and *M. septendecim.* The males sing species-specific songs to ensure that they attract the appropriate females.**

FROM TOP: TOM SIEGFRIED; COURTESY OF JOHN COOLEY/UNIV. OF CONN.

from another planet might hypothesize that such a dramatic difference in life cycles arose once when ancient ancestors of today's 17-year species diverged from 13-year counterparts. Logical enough, but not what happened, Simon says.

The big, new family tree confirms that a common ancestor first split into three lineages (called Cassini, Decula and Decim) and then each lineage independently evolved 17-year and 13-year forms. So this year's cicada brood, designated by the Roman numeral II, comprises a 17-year species from each of the three ancient lineages. And the closest sister species of this year's breeders are not each other but 13-year cyclers locked in with different broods.

## Safety in numbers

What preserves the multi-species broods may be cicada predators, says Rick Karban of the University of California, Davis. Cicadas haven't evolved the common insect defenses of camouflage or nimble flight. These are big, noisy bugs without many escape skills. "You can pick them off a tree," Karban says. "They're just seemingly ... dumb."

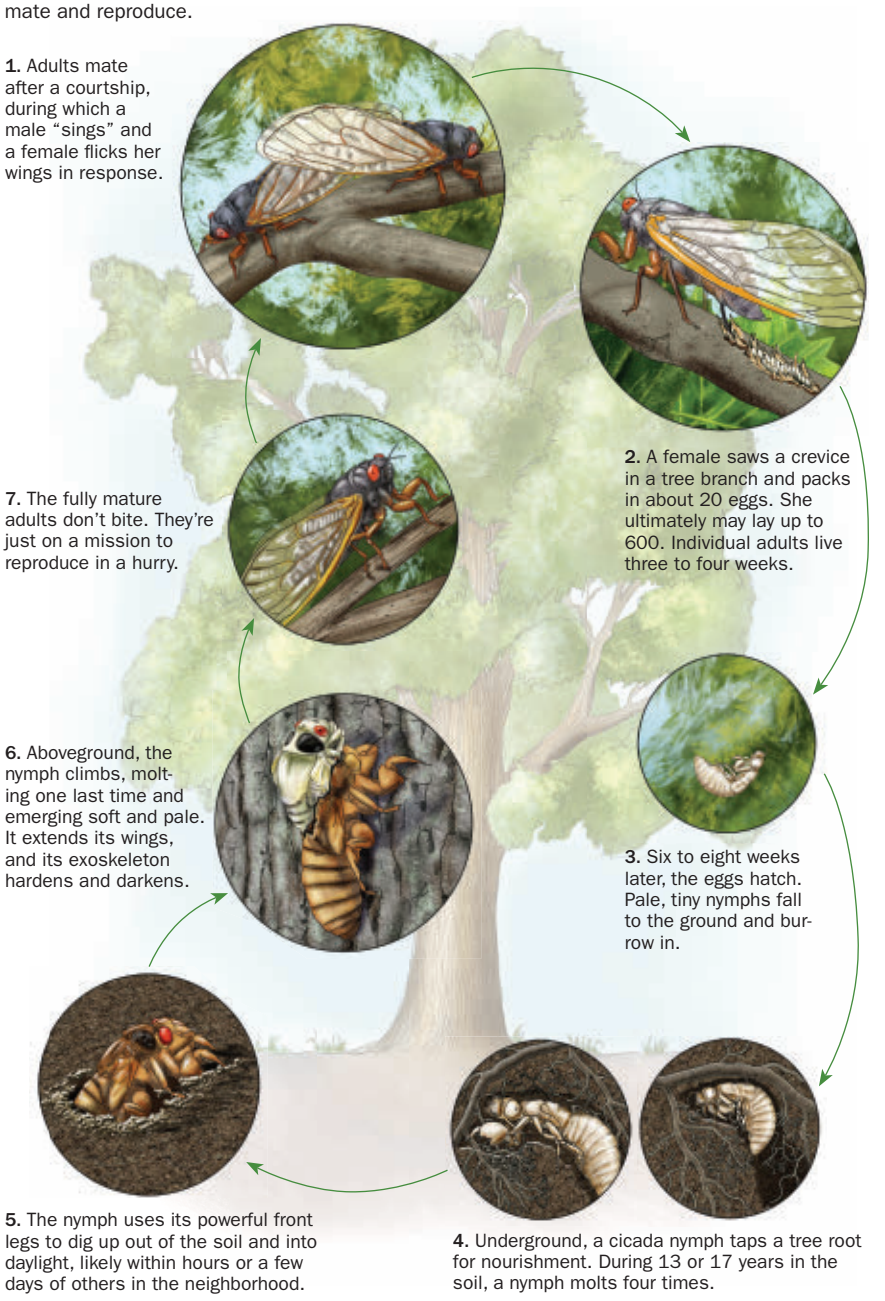
But with thousands, millions or billions living conspicuously for the same brief period of time, each individual has a better chance of surviving. Predators can't eat the whole generation. There's safety in extreme numbers, so synchronizing with a different species beats coming out with just your own in smaller numbers and getting picked off by hungry birds. As segments of different species overlap in their reproductive timing, they "get sucked into a brood," Simon says. Only one brood, VII, consists of just one species.

Surging forth in great numbers to thwart predators is not some special cicada thing, Karban notes. Cicadas get the headlines, but mayflies transforming from their aquatic to aerial forms synchronize, and oak trees drop occasional bumper crops of acorns.

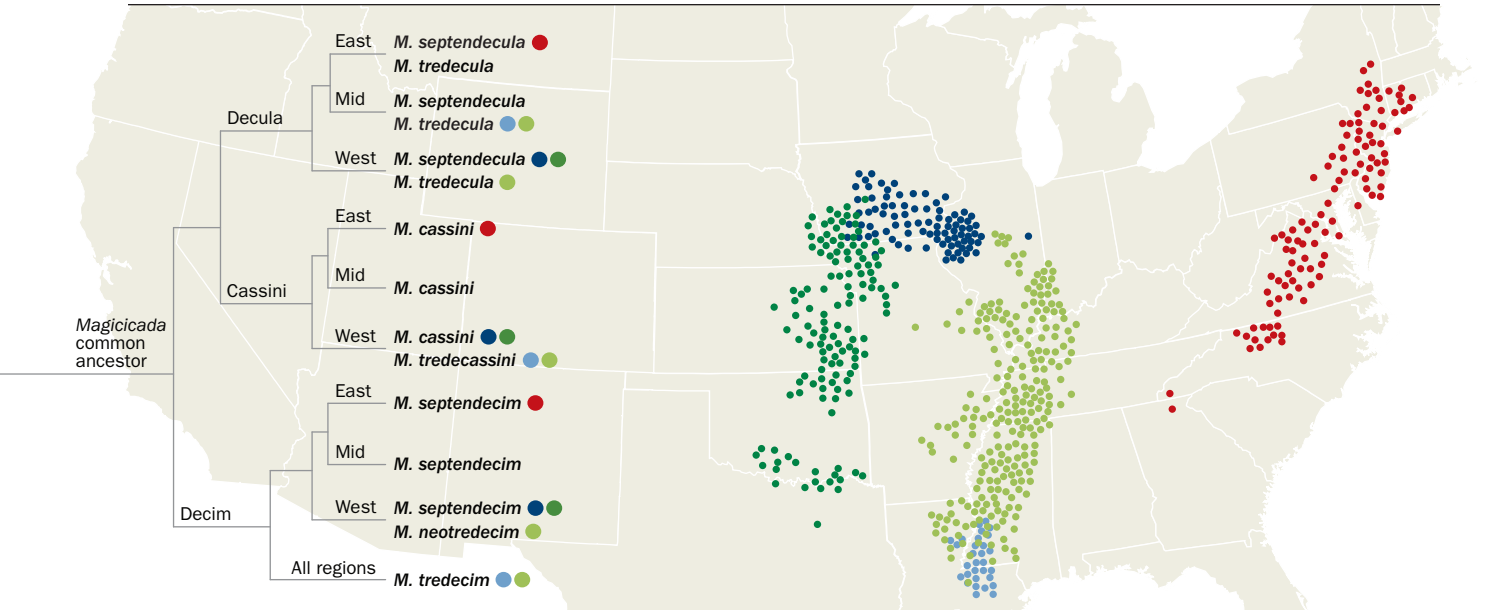
How the cicadas manage to synchronize may be trickier to explain, though. In fact, cicadas in the same brood grow idiosyncratically. Karban has dug up samples of periodical cicadas during their underground years and found all kinds of out-of-sync stages of development. Those that race through the five stages of underground life end up waiting for the signal to emerge, giving the laggards time to catch up.

What that signal might be is also in question. Soil temperature probably cues the right calendar day for the neighborhood mass emergence, but how the cicadas choose the right year is a puzzle. They could "count" the years with seasonal changes in the tree sap they feed on, Karban speculates. To test this idea, he dug up cicadas with two years yet to go underground and moved them onto roots in a colleague's research set of peach trees. The colleague coaxed the trees to flower twice in one year, and cicadas emerged

**Life underground** Billions of noisy bugs may attract all the attention, but the cicadas' mass emergence is just the final blip in the long life of the periodical species. All seven species spend the majority of their lives buried in the soil. Then, on cue, they surface to find a mate and reproduce.




NICOLLE RAGER FULLER




**Broods and locations 2013–2015**

| 2013 | 2014 | 2015 |
|---|---|---|
| Brood II<br>17-year<br>3 species | Brood III<br>17-year<br>3 species | Brood IV<br>17-year<br>3 species |
| | Brood XXII<br>13-year<br>3 species | Brood XXIII<br>13-year<br>4 species |

SOURCE: T. SOTA *ET AL*/*PNAS* 2013; MAGICICADA.ORG

**Mix and match** Almost any year, periodical cicadas burst from the ground in mating frenzies in the eastern United States. A single cohort, Brood II, emerged in 2013, but in 2014 and 2015, both 13- and 17-year cicada broods will emerge. (Color-coded dots show observed or expected locations.) Most broods include a mix of what are considered separate *Magicicada* species, which evolved from a common ancestor almost 4 million years ago (family tree, left). Those ancestors branched into three main lineages: Decula, Cassini and Decim. Now each lineage has its own 13-year species ("*tre*" prefix) and 17-year species ("*septen*" prefix, not used in *M. cassini*). Species from each lineage live in all regions (east, middle and west) where cicadas are found. The genetics of the regional populations mirrors their geographic distribution (shown on tree).

as if two years had passed instead of one.

But why so long underground? Karban's answer is basically, why not? A long immature period may have more advantages than disadvantages. Again he has gone digging. His samples of cicadas from underground don't show much evidence of premature death by predator attack. And spending more time growing may mean bigger bodies with the power to have more offspring. The 17-year cicadas he unearthed in the Midwest were in the process of forming more eggs than 13-year ones living nearby.

A long development time could also have been a big boon for surviving the ice ages, says geologist Randy Cox of the University of Memphis, who has analyzed how climate affects the pattern of cicada emergences. During ice ages, he points out, even southern refuges had chilly years, and a really cold spell could wipe out a population. The longer a cicada's cycle, the fewer times populations would have to play climate roulette.

If big numbers are good for cicada life cycles, he and other researchers suspect that big, prime numbers (divisible only by one and themselves) are even better. Predator populations can rise and fall in cycles too. If cicadas had a 12-year cycle instead of a 13-year one, for example, they would coincide more frequently with big years of any predators on two-, three- or four-year cycles.

Those big, prime numbers might also minimize unfortunate hybridization between cicadas timed to breed on different cycles, Cox suggests. When such cicadas' reproductive years coincide, any cross-breeding could doom offspring. Their half-brood genes could lead them to reproduce in some intermediate year between mom's and dad's regular cycle. Without the company of millions of pure-broods, hybrids would be easy pickings for predators and reproductive dead-ends for their family lineages. But with life spans of 13 and 17 years, the simultaneous emergence of broods on different schedules happens only once every 221 years.

Cicadas may even somehow influence predator cycles, suggests ornithologist Walt Koenig of Cornell University. Decades of nationwide citizen-science surveys of breeding birds show that cicadas tend to show up during dips in numbers of seven cicada-eating birds, including American crows and blue jays. This may not be coincidence. That feast of easy-to-catch cicadas may somehow set bird populations on rise-and-fall trajectories that miss big cicada years, he and Andrew Liebhold of the USDA Northern Research Station in Morgantown, W.Va., proposed in the January *American Naturalist*. "Even we think this is kind of weird," he says, "but it fits the data."

However the brood emergences came to be, they're worth seeking out. "Cicadas are one of the big natural spectacles of North America," Karban says. For those who missed the show this year, he promises, one of the 15 periodical broods will break out loud and dumb somewhere almost any year. ■

## Explore more

■ For sightings, sounds and more visit Magicicada.org

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## Brilliant Blunders

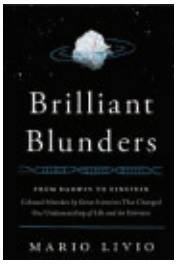
*Mario Livio*

Even brilliant scientists have bad days. Consider chemist Linus Pauling, who described the alpha helix structure of proteins in 1951. When he attempted to do the same for DNA, however, he botched it — badly. Among other problems, he flubbed the basic chemistry, proposing a structure for deoxyribonucleic acid that wasn't an acid.

When asked about Pauling's faulty DNA model, one of his contemporaries commented, "You could not have written a fictional novel in which Linus would have made an error like this."

Why Pauling stumbled is just one of the questions that astrophysicist Livio attempts to answer. Countless scientists have made major mistakes over the centuries, but Livio wisely focuses on gaffes from just five great minds: Pauling, Darwin, Einstein, astrophysicist Fred Hoyle and William Thomson, also known as Lord Kelvin.

Livio outlines the scientific context for each scientist's work and pores over personal correspondence and historical records to try to explain what went wrong. Hoyle, for instance, stubbornly dismissed the Big Bang model of the universe for decades, and Einstein failed to see the importance of his cosmological constant, which he had devised as a fix for general relativity. Though Livio can only speculate on the reasons behind these errors, his clear and compelling writing reinforces the important contributions each of these men made to their fields.




The double helix may have eluded Pauling, but his mistake helped to galvanize James Watson and Francis Crick into a concentrated effort to find the correct structure. Livio's ultimate message is that blunders — even big ones — can play a role in scientific discovery. —*Allison Bohac*

*Simon & Schuster, 2013, 341 p., $26*

## Billion-Dollar Fish

*Kevin M. Bailey*

From imitation crab to McDonald's Filet-O-Fish sandwiches, Alaska pollock is ubiquitous. American fishermen haul in more than a billion dollars' worth of the flaky white fish annually. Yet just a century ago, Americans had no interest in pollock. Bailey, a fisheries biologist, documents the fish's rise in popularity over the last 60 years, interweaving the scientific, political and economic forces that shaped the "most lucrative marine fish harvest in American waters."


Japan became the first country to exploit pollock near Alaska after the fish disappeared from Japanese waters in the early 1950s. Prized for being low in both fat and parasites, pollock is also easy to mince into a paste (or fish sticks). The fish travel in large, dense schools, making them easy to catch in vast quantities. With the advent of cold storage, Japanese fishermen could bring large numbers of well-preserved fish back from the Bering Sea.

American fishermen caught on to pollock in the 1980s, when the Bering Sea's crab population plummeted. Foreign nations were squeezed out as Americans made a mad dash to harvest as much "white gold" as possible, Bailey writes.

With the new Alaskan gold rush came concerns about overfishing. Today, scientists use complicated simulations of population ups and downs to set sustainable catch quotas.

At times, Bailey slips into similarly complex jargon that may confuse lay readers. Still, *Billion-Dollar Fish* is an eye-opener for those who have caught themselves pondering the origins of their fried fish sandwiches.

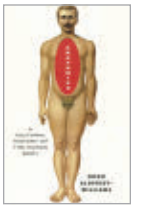
—*Erin Wayman*

*Univ. of Chicago, 2013, 271 p., $25*


**The Riddle of the Labyrinth**

*Margalit Fox*

Learn the true story of the quest to decipher a mysterious script called Linear B, written on clay tablets discovered in 1900 in the ruins of a Bronze Age palace on Crete. *Ecco, 2013, 363 p., $27.99*



**Anatomies**

*Hugh Aldersey-Williams*

With humor and anecdotes, a writer takes a tour through the mysteries of the human body. *W.W. Norton & Co., 2013, 294 p., $26.95*


**Ungifted**

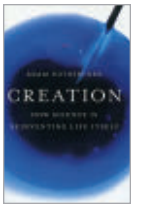
*Scott Barry Kaufman*

A cognitive psychologist argues that childhood intelligence doesn't predict adult success. *Basic Books, 2013, 397 p., $29.99*


**Stonehenge: A New Understanding**

*Mike Parker Pearson and the Stonehenge Riverside Project*

A look into the recent seven-year excavation of the Stone Age monument sheds light on its builders and history. *The Experiment, 2013, 410 p., $27.50*




**Creation**

*Adam Rutherford*

Explore how scientists are using synthetic biology to understand how life began and to develop solutions to a variety of global problems, from cancer to energy production. *Current, 2013, 278 p., $27.95*

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### Fructose fever

I was fascinated by the article "Sweet confusion" (*SN: 6/1/13, p. 22*) about the ambiguous health effects of high fructose corn syrup. I was surprised, however, to find little mention of taste, flavor and satiety. I can clearly recall from my childhood the satisfaction from a bottle of Coca-Cola. The transition in America in the 1970s from sucrose to corn syrup as a sweetener in soft drinks was brought home to me in my travels to Central America in the '80s and '90s, where cane sugar was still used as a sweetener. Drink a soft drink with cane sugar and you are satisfied. Satiety is the key to the obesity epidemic.
**Art Vaughn,** Warren, Ohio

Vast quantities of high fructose corn syrup have been added to our diet. Is it safe? After reading the article, I think not. Don't you think it's up to the industry to prove to us that it *is* safe?
**Robert Antonucci,** Santa Barbara, Calif.

### Outstanding questions

I especially liked the following two sentences in Erin Wayman's article "Maybe Earth's chlorine blew away" (*SN: 6/1/13, p. 14*): "The composition of ancient meteorites, which are remnants of the raw materials that built the planets, indicates that Earth should have 10 times as much chlorine as it does. The missing chlorine has perplexed scientists for decades." I had no idea that this was an outstanding question, and I was pleased to learn of it. It seems to me that knowing the unresolved questions in a given field is as important as knowing the latest findings.
**Leslie Houk,** Houston, Texas

### Congrats from longtime reader

I have been a regular reader of *Science News* for, perhaps, 65 years. There is something of interest to me in every issue! However, the June 15 issue achieved a new high: There was nothing in this issue that did *not* fascinate me. My compliments to everyone at *Science News*. I am looking forward to your next issue and many more to follow.
**Warren Offutt,** via e-mail

### Musical memory

The article "Memory training questioned" (*SN: 6/15/13, p. 12*) notes the difficulty of evaluating the results of long-term memory training. There might be an abundance of data available in those who have learned musical instruments. Most classical musicians memorize dozens of scales and chords, plus long pieces for performance. Most have siblings with little or no musical training, and musicians come from almost all social groupings. The test groups may be sitting there waiting.
**Ivan Mann,** via e-mail

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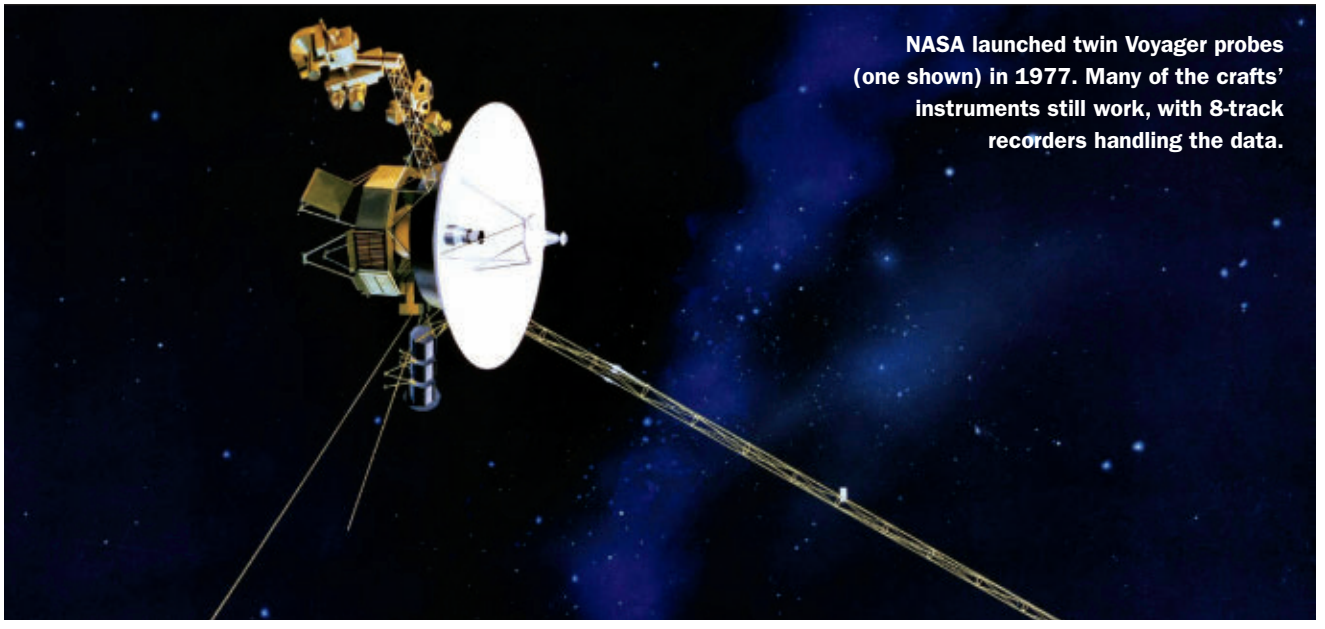

**NASA launched twin Voyager probes (one shown) in 1977. Many of the crafts' instruments still work, with 8-track recorders handling the data.**

## Postcards from Voyager

To catch the faint signal of a spacecraft leaving the solar system, you have to listen very carefully. At NASA's Jet Propulsion Laboratory in Pasadena, Calif., that's Suzanne Dodd's job.

Dodd (below) is project manager for NASA's twin Voyager probes, launched in 1977 to explore Jupiter and Saturn. Voyager 2 did that and more, as the first probe to fly by Uranus, in 1986, and Neptune, in 1989. It's now 15 billion kilometers from Earth and headed out of the solar system.

Its twin is farther ahead. After visiting Saturn, Voyager 1 headed directly toward interstellar space, beyond the bubble of charged particles that surrounds the solar system. Voyager 1 is now more than 18 billion kilometers from Earth; Dodd has to wait 17 hours each way for a message to travel between Earth and the probe. Last summer the craft crossed through a strange transition, where the flood of charged particles from the sun dropped to nearly nothing but the sun's magnetic influence did not wane (*SN: 1/12/13, p. 17*). Project scientists think this means that Voyager 1 is getting very close to the boundary with interstellar space.

Dodd, who was inspired to become an engineer after watching the Apollo astronauts walk on the moon, says nothing compares to running the Voyager probes. "We're not flying it just to fly it — we're flying it because we're still getting new data," she says, such as information about conditions at the edge of the solar system. "It's the only craft to do that in our lifetime."

The Voyager mission's many discoveries include volcanoes on Jupiter's moon Io, density waves in Saturn's rings and giant grooves on Uranus' moon Miranda. NASA hopes Voyager 1 will also send the first direct measurements of the environment outside the solar system. Each year, though, a bit more of the radioactive plutonium that powers the probes decays away, and around 2020 NASA will have to start switching off the five remaining scientific instruments, one by one. By 2025 or soon thereafter, the Voyagers are likely to have run out of juice and become passive sailors among the stars. Dodd expects to be listening until the end. —*Alexandra Witze*

### Space probes' final frontiers

The Voyager probes will end their careers drifting through interstellar space. Other spacecraft have met a variety of fates.

- **Genesis:** This mission to sample solar wind, launched in 2001, crashed in Utah (above) when it returned to Earth in 2004. Scientists managed to extract some samples from the crumpled spacecraft to learn about the chemistry of charged particles flowing from the sun.
- **Venera 9:** This Soviet mission to Venus, launched in 1975, carried the first probe to send photographs back from the surface of another planet. It transmitted from Venus for 53 minutes before going silent.
- **Spirit and Opportunity:** The rovers landed on opposite sides of Mars in 2004 with a nominal lifetime of three months. Spirit traveled 7.7 kilometers before getting stuck in a sand dune in 2009. Opportunity is still exploring.
- **Ebb and Flow:** Their goal to map lunar gravity complete, the twin probes hurtled — by design — into the side of a mountain on the moon in December 2012.

ALL: NASA

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Have you ever said to yourself "I'd love to get a computer, if only I could figure out how to use it." Well, you're not alone. Computers were supposed to make our lives simpler, but they've gotten so complicated that they are not worth the trouble. With all of the "pointing and clicking" and "dragging and dropping" you're lucky if you can figure out where you are. Plus, you are constantly worrying about viruses, spam and freeze-ups. If this sounds familiar, we have great news for you. There is finally a computer that's designed for simplicity and ease of use. It's the WOW Computer, and it was designed with you in mind.

This computer is easy-to-use, worry-free and literally puts the world at your fingertips. From the moment you open the box, you'll realize how different the WOW Computer is. The components are all connected; all you do is plug it into an outlet and your high-speed Internet connection. Then you'll see the screen. This is a completely new touch screen system, without the cluttered look of the normal computer screen. The "buttons" on the screen are easy to see and easy to understand. All you do is touch one of them, from the Web, Email, Calendar to Games– you name it… and a new screen opens up. It's so easy to use you won't have to ask your children or grandchildren for help.

Until now the very people who could benefit most from E-mail, and the Internet are the ones that have had the hardest time accessing it. Now, thanks to the WOW Computer, countless older Americans are discovering the wonderful world of the Internet every day. Isn't it time you took part? Call now, and a patient, knowledgeable product expert will tell you how you can try it in your home for 30 days. If you are not totally satisfied, simply return it within 30 days for a refund of the product purchase price. Call today.

*WOW! The perfect name for this amazing computer. I have been using it for about a month and thoroughly enjoy the speed and ease in which I am able to download pictures from my camera and share them with family and friends via email. Everything is so easy to use at the touch of my fingertips. To be able to chat with and see my grandchildren is as though they are here with me. I haven't begun to explore all the benefits of this computer. It has opened up a whole new world for me. I love it, love it, love it!*
*– Carol K., Benbrook, TX*


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