Why We Yawn | Cooling With Light | Nucleus Turns 100

Science News

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MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ MAY 7, 2011

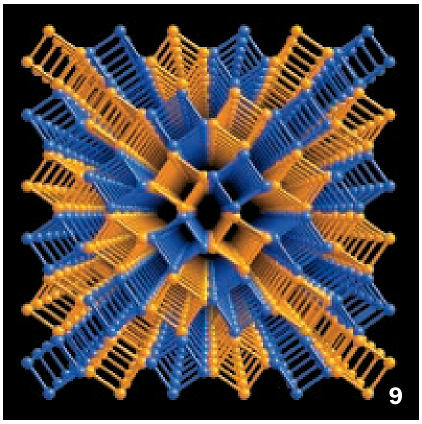
Target Cancer

Seeking vaccines to boost the body's defenses

Age of Megaquakes

Fishing Apes

Time Travel Nixed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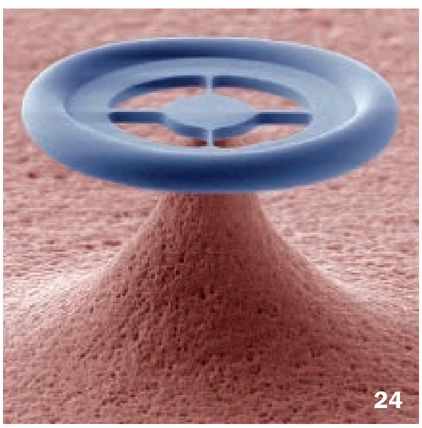

24


28

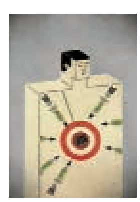
ScienceNews

In The News

Features

Essay

Departments



COVER Cancer vaccines are designed to boost the immune system, prompting the body's own cells to identify and destroy cancerous growths.
David Plunkert

ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC

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FROM THE EDITOR

Few surprising discoveries rival Rutherford's nucleus

When Ernest Rutherford was born, scientists regarded atoms as eternal.

James Clerk Maxwell, one of the most perceptive physicists of the 19th century, once declared that an atom is "something which has existed either from eternity or at least from times anterior to the existing order of nature."

When those words were written, in 1875, Rutherford was 4 years old. A quarter century later, he was deep into deconstructing atoms, documenting their disintegrations from one type into another. Some types of atoms, it turned out, were not eternal but ephemeral, decaying into atoms of other identities, in the process releasing energy of unfathomable magnitude.

By 1911, Rutherford had identified the atom's internal storehouse for all that energy — the dense, positively charged core that came to be known as the atomic nucleus (see Page 30).

Science and the modern world at large were both transformed by that discovery, which a century later still reverberates in international politics, national economies and technological calamities. Atomic bombs, nuclear energy and all sorts of insights into the nature of matter stemmed from Rutherford's discovery. Yet at the time, it elicited little immediate notice (no bloggers back then). Rutherford himself did not fully appreciate the importance of his nucleus until Niels Bohr showed how it explained an array of atomic mysteries.

Today a scientific discovery of such impact might get more attention, but maybe not. Just as with Rutherford's discovery of the nucleus, it isn't always obvious what a new finding's impact will ultimately be. In the pages of this issue you'll find numerous reports from science's frontiers. Perhaps one will someday be worthy of anniversary celebrations. Who knows, for instance, what future impact may result from using light to induce quantum phenomena in mechanical devices (Page 24)? Or what insight might emerge from analyzing light's flow through metamaterials designed to mimic the universe emerging from the Big Bang (Page 12)? For that matter, if anybody ever figures out why people (and animals) yawn (Page 28), the explanation could inspire new biological insights with unimagined consequences for medicine and maybe even evolutionary theory.

It's unlikely, though, that even one report from a single issue of *Science News* will ever have the impact of Rutherford's nucleus. Discoveries of that magnitude are one in a century.

—Tom Siegfried, Editor in Chief

Scientific Observations

"The sequencing of the Human Reference Genome, announced 10 years ago, provided a road map that is the foundation for modern biomedical research. This monumental accomplishment was enabled by developments in DNA sequencing technology that allowed data production to far exceed the original description of Sanger sequencing. Moving forward in the genomic era in which we now find ourselves, new (or 'next generation') DNA sequencing technology is enabling revolutionary advances in our understanding of health and disease. In essence, sequencing technology is the engine that powers the car that allows us to navigate the human genome road map. As that engine becomes ever more powerful, so will the questions we can ask and answer about the geography of our genetic landscape." —**GENETICIST ELAINE MARDIS OF WASHINGTON UNIVERSITY IN ST. LOUIS, IN THE FEB. 10 *NATURE***

Science Past | FROM THE ISSUE OF MAY 6, 1961

PATENTS OF THE WEEK — "Inventions for the home of tomorrow" were the theme of several inventions just patented. Two improved methods for rocking the cradle electrically have been invented. The main advantage of the "motor driven cradle" ... is that it can be made inexpensively. It also has a timer and an adjustment that lets the cradle rock through a wide arc or a small one.... The latest thing for the bathroom is a bar of soap with brush bristles embedded. The scrubbing bar, invented by Guy M. Beatty of Bakersfield, Calif., and awarded patent No. 7,979,748 contains bristles that are scored at short intervals. As the soap wears down, the bristles break off bit by bit along the score marks and a scrubbing surface is maintained.

Science Future

May 21–22
Shoot off rockets and hear astronomers sing in Raleigh, N.C. Go to naturalsciences.org

May 26
Application deadline for the Commerce Department's i6 Green Challenge for energy entrepreneurs. For info, go to www.eda.gov/i6

June 15–18
Around Boston, cheer on young inventors, tackle design tasks and marvel at cool technologies. See eurekafest2011.org

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ATOM & COSMOS
Reflected heat may explain the strange slowdown of two spacecraft. Read "Pioneer puzzle pinned on thermodynamics."

DELETED SCENES BLOG
After 30 years, the space shuttle fleet comes to rest. See "NASA picks shuttles' retirement homes" to find out where.

BODY & BRAIN
Fat breakdown by friendly bacteria may lead to unfriendly buildup in the arteries. Read "Gut microbes may foster heart disease."

HUMANS
Gene variants may make some kids more sensitive to good and bad parenting. See "Genetic roots of 'orchid' children."

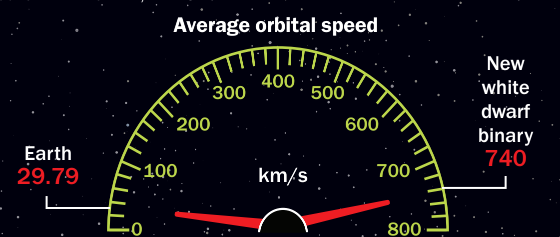
For Daily Use

Don't make life-changing decisions on an empty bladder. Dutch and Flemish researchers report online April 5 in *Psychological Science* that people who drank five cups of water were more likely 45 minutes later to hold out for a later but greater monetary reward than individuals with only five sips of water in their systems. This "inhibitory spillover" also encouraged faster — but not more accurate — answers on a test requiring volunteers to name a word's color instead of its meaning. The results add to other evidence for a general inhibition system that handles both motor and deliberative control, the authors suggest. They add that businesses that depend on impulse buying might consider opening bathrooms to consumers.

Science Stats | SPEEDY STARS

Two dead stellar cores called white dwarfs whiz around each other nearly 25 times faster than Earth circles the sun, finishing an orbit in 39.1 minutes, scientists report. The orbit time is the shortest known for a white dwarf pair without the stars touching.

SOURCE: M. KILIC *ET AL*/*MNRAS* 2011



CLOCKWISE FROM TOP LEFT: ROBERT BOSTON/WASHINGTON UNIV.; NASA; MAX KRASNOV/SHUTTERSTOCK, ADAPTED BY T. DUBÉ

“ People have looked at certain materials and wondered why they have certain properties. Now they may be able to argue that it’s because of this new symmetry. ” —MANFRED FIEBIG, PAGE 9

In the News

STORY ONE

Seismologists in a rumble over quake clusters

Japan’s catastrophe may be latest in a series of big ones

By Alexandra Witze

People walk through rubble in Sendai, Japan, a month after the March 11 earthquake and tsunami that destroyed the city’s coastal districts. Some geologists argue that the event may be seismically linked to other recent major earthquakes.

AP PHOTO, KYODO NEWS

Japan’s March 11 earthquake was the biggest ever recorded in that country and the costliest natural disaster in history, but in a way it was nothing new. Three other quakes of magnitude 8.6 or greater have struck worldwide in the past seven years—after a gap of four decades.

Two U.S. Geological Survey scientists contend that the Japan quake bolsters their idea that the planet is experiencing a spasm of great earthquakes, its second since 1900. Other scientists say that any apparent bunching is a statistical fluke that disappears if the data are analyzed in other ways. Researchers presented their opposing views on April 14 in Memphis, Tenn., at the annual meeting of the Seismological Society of America.

On the face of it, large quakes certainly do seem to have been popping off lately. The magnitude 9.1 Sumatra quake in 2004, which caused the disastrous Indian Ocean tsunami, was followed by a nearby magnitude 8.6 quake the following year. A magnitude 8.8 hit Chile in February 2010 and the Japan quake, at 9.0, struck on March 11 of this year, leading many to question whether big quakes are becoming more frequent.

Scientists say there’s not enough evidence to support that idea. But big quakes may at least be coming in groups.

Some earthquake clusters are clearly related; after a large quake, aftershocks on connected faults continue to rattle the area. And large quakes can also trigger separate smaller tremors relatively close to the original quake (*SN Online: 3/28/11*).

But Charles Bufe of the USGS office in Golden, Colo., argues that Sumatra, Chile and Japan represent an unusual grouping.

In 2005, Bufe and his colleague David Perkins argued that a similar cluster occurred between 1952 and 1964, anchored by a magnitude 9.0 in Kamchatka, Russia, at its beginning and a magnitude 9.2 in Alaska at its end. The Kamchatka quake was the first magnitude 9 or greater since 1900, when scientists began recording seismic activity worldwide. This cluster also included the largest quake ever recorded, a magnitude 9.5 monster that struck Chile in 1960.

Bufe and Perkins used the same analysis—simulating the probabilities that the earthquake patterns could be explained by random events—to argue that the 2004 Sumatra quake kicked off a similar period. The chance of this particular series of events—an active period from 1952 to 1964, followed by a lull and then a start-up again in 2004—occurring randomly is less than 2 percent, Bufe says.

Why quakes would cluster isn’t entirely known. Perhaps shaking from the biggest quakes sets off a large-scale ringing within the Earth that affects tectonic activity, Bufe proposes. “Maybe on the very large scale we have a weakening of these very long fault zones that are on the verge of failure.”

Over the next six years, Bufe calculates,

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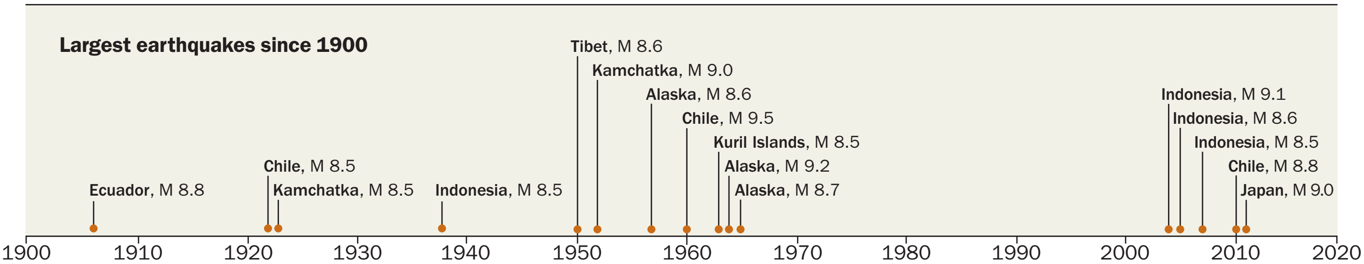


Since 1900, most earthquakes of magnitude 8.5 or greater have occurred in two clusters, one in the 1950s and '60s and the second starting in 2004.

the chance of another magnitude 9 or greater quake occurring somewhere in the world is 63 percent — compared with 24 percent if the planet were not experiencing a cluster. "We think we're in an increased hazard situation from these very large quakes," he says.

Other researchers say Bufe has gone too far out on a statistical limb. Andrew Michael, a USGS researcher in Menlo Park, Calif., has done a separate analysis. "We don't see clustering," he says.

Rather than study only the highest magnitude quakes, Michael probed different magnitudes over different time periods. Among other tests, he looked at whether there was a statistically meaningful increase in seismicity worldwide after big earthquakes, and whether the time between big quakes followed a nonrandom pattern. He found that the statistical tests could produce what looked like earthquake clusters, but that the clusters disappeared when different magnitudes and time periods were included. "If we use a range of magnitude cutoffs, we find that the data are very well explained by the random model," he says.

Bufe counters that because clustering may happen only for very large quakes, the pattern wouldn't be seen when looking at lower magnitudes. But Michael argues that the number of magnitude 9 earthquakes is too small to draw any statistically significant conclusions. "At 9 you just don't have enough data," he says.

Richard Aster, a geophysicist at the New Mexico Institute of Mining and Technology in Socorro, agrees with Michael. He notes that the list of earthquakes since 1900 — which everyone must use for their studies — includes around 1,700 quakes of magnitude 7 or more, about 70 equal to or greater than magnitude 8 and only 5 magnitude 9 or above.

Aster has done a separate analysis looking, in part, at the total amount of energy released by all quakes since 1900. Big earthquakes dominate; the Japan quake accounts for about 5 percent of all global cumulative seismic energy released since 1900, he reported at the meeting.

Over the past two decades, the number of earthquakes greater than magnitude 7.5 has been increasing worldwide, Aster's team found. But that increase could be due to natural random fluctuations as opposed to any actual trend in tremors worldwide.

Like Michael, Aster does not find quake groupings beyond the known effects of aftershocks and local quake triggering. "We have found that there's no evidence for clustering at long scales, say trans-Pacific scales," Aster says.

But the evidence so far is not enough to end the debate. "The only way out of this will be unfortunately waiting a long time until we see more large earthquakes," says Michael. "That is the problem we face in seismology." ■

Back Story | JAPAN QUAKE BY THE NUMBERS

AP PHOTO, KYODO NEWS

In recent weeks seismologists have collected more details about how Japan's destructive March 11 earthquake unfolded.

9.0	Magnitude
54	Aftershocks equal or greater to magnitude 6.0
3	Aftershocks equal or greater to magnitude 7.0
300 kilometers	Total length of rupture
2	Zones of rupture (one near the Japan trench, one near the coast)
24 meters	Biggest measured slip (on the ocean bottom off Japan's east coast)
60 meters	Biggest estimated slip
220 seconds	Duration of quake

Engineers closer to explaining how bikes keep the rubber on the road

Experiments find surprising stability in two-wheeled vehicles

By Devin Powell

SAM RENTMEESTER/FMAX

An experimental riderless bicycle has two extra wheels that spin backward. The bike demonstrates that the physics behind two-wheeled vehicles' stability is more complicated than researchers previously thought.

Bicycle abuse isn't something you'd expect from the Dutch. But engineers in the Netherlands who love bikes enough to hurt them are, along with other researchers, challenging long-held beliefs about how a moving bike keeps its balance even when slapped, shoved or otherwise insulted.

The team has found previously unidentified factors that help a bike stay upright and has developed a slew of unusual designs that wouldn't have been thought to be stable.

"We believe there is room for improvement in the handling qualities of bikes," says Arend Schwab, a professor of engineering mechanics at the Delft University of Technology.

A conventional bicycle is remarkably stable when moving. Even without a rider, it can coast for long distances and catch itself from falling. As early as 1910, scientists credited this stability to the front wheel behaving like a gyroscope. As a spinning wheel leans, it should naturally swivel in the direction of the lean, guiding the bicycle into a curve that keeps the bike upright.

In 1970 David E.H. Jones, then a spectroscopist at Imperial Chemical Industries in England, tested this explanation by trying to build an unridable bike. An extra wheel mounted to its frame spun backward and canceled out the gyro effect. This bike was less stable — but still ridable, even with no hands.

Jones looked for another stabilizing effect and found one similar to that which keeps the casters of shopping carts lined up. Hold a still bicycle by the seat, lean it to the side and gravity turns the wheel. This "trail effect" is based on the front wheel's position relative to the angle of the steer axis that connects the wheel to the handlebars. Move the wheel forward a few inches, Jones discovered, and a traditional bike becomes less stable.

Published in *Physics Today*, the paper describing these experiments circulated widely and was read by a high school junior in Corvallis, Ore. Jim Papadopoulos, a competitive cyclist, didn't understand the math at first. But later, in graduate school, its conclusions would bother him.

"It took me 30 years to put my finger on the big flaw," says Papadopoulos, now an engineer at the University of Wisconsin–Stout in Menomonie. "Jones' paper wasn't based on the physics of something falling but on the physics of something being held."

Papadopoulos teamed up with a researcher from Cornell and a team in the Netherlands that built a bike with no gyroscopic or trail effects. The riderless contraption, which sports two extra backward-rotating wheels and a front wheel that touches the ground in front of the steer axis, can still coast stably. Give it a smack, and it curves, swerves and recovers.

"You don't need gyroscope or trail to make a bicycle self-stable," says Andy Ruina, a professor of mechanical engineering at Cornell and coauthor of the paper describing the bike in the April 15 *Science*.

Bicycles, the team suggests, are more complicated than previously thought. While gyro and trail effects can contribute to stability, other factors such as the distribution of mass and the bike's moment of inertia can play a role as well. Computer simulations that take all of these factors into account could lead to improved designs for folding bikes with small wheels or bikes that carry cargo, Ruina says.

To demonstrate the possibilities, the researchers sketched out several new exotic bicycle designs. One is predicted to remain stable even with a negative gyro that tries to turn a falling bicycle in the wrong direction. In another, the steer axis is reversed such that the handlebars are farther forward than the center of the front wheel.

"They found a design with rear-wheel steering that can be ridden and is self-stable," says David Gordon Wilson, a retired MIT professor who designed the modern recumbent bicycle in the early 1970s. "That's quite amazing."

In the simulations, these new design principles still work when the weight of a person is added. But the real test is waiting out on the open road.

"The next step would be to study a bicycle with a rider in the real world: on actual roads, under varying conditions, on a fully instrumented bicycle," says Joel Fajans, a plasma physicist at the University of California, Berkeley who also studies bicycles. "To find out how we really ride a bike." ■

"It took me 30 years to put my finger on the big flaw." —**JIM PAPADOPOULOS**

Spiral symmetry is turning heads

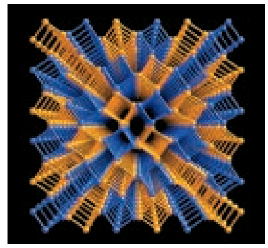
Rotation reversal offers new ways to explore 3-D materials

By Devin Powell

Physicists have put a new twist on the humble corkscrew. Just as a butterfly appears identical to its mirror image, objects made of structures that tilt, twist or spiral possess a symmetry now recognized for the first time. The discovery is based on a mathematical operation that transforms a clockwise helix into a counterclockwise one, or vice versa.

"Normally, a helix flips when you put a mirror up to it," says Venkatraman Gopalan, a materials scientist at Penn State University in University Park. "We've developed a special kind of mirror with this math woven into it." Seen in this mirror, an object with a spiral shape will look just like itself.

This symmetry joins a list of other, long-known ways to move or manipulate an object and leave it looking the same afterward. A snowflake has what's called rotational symmetry: Turn it 60 degrees, and its appearance doesn't change. A piece of wallpaper with a repeating pattern looks identical when moved a bit to the right or left, demonstrating translational symmetry.



Structures tilted clockwise (orange) or counterclockwise (blue) reveal a new kind of symmetry.

RYAN HAISLMAIER/GOPALAN LABORATORY/PENN STATE UNIV.

"This new symmetry we're playing around with has not been taken into account up to now," says Daniel Litvin, a physicist at Penn State Berks in Reading who along with Gopalan reported the results in the April 3 *Nature Materials*.

During the late 19th century, scientists figured out that symmetries limit the number of ways atoms can be arranged into crystals, calculating 230 possible patterns. In the mid-20th century another kind of symmetry, time reversal, extended the number of possible arrangements in magnetic materials to 1,421. With Gopalan and Litvin's new "rotation-reversal" symmetry, crystallographers now have 17,807 patterns to look for when trying to characterize a material's 3-D structure.

"People have looked at certain materials and wondered why they have certain properties," says Manfred Fiebig, a physicist at the University of Bonn in Germany. "Now they may be able to argue that it's because of this new symmetry." ■

Life

"It's like going back to early Earth." —DAWN SUMNER

Penguin declines may hinge on krill

Food shortage appears to be hurting West Antarctic birds

By Daniel Strain

Disruptions in the food supply, caused in part by warming climate, may be to blame for shrinking populations of Adélie and chinstrap penguins across the West Antarctic Peninsula. The penguins' recent struggles primarily stem from having too few krill to eat, researchers report online April 11 in the *Proceedings of the National Academy of Sciences*.

In the early 1990s, study coauthor Wayne Trivelpiece and his colleagues argued that shrinking ice masses might hurt icebound Adélie penguins (*Pygoscelis adeliae*), while the more free-roaming chinstraps (*Pygoscelis antarctica*) would hunt better with less ice. But since the 1980s, populations of both species have plummeted by more than half at the team's study sites.

As scientists dug into the mystery, it became clear that penguins were just the tip of the iceberg: "It was actually the penguins that pointed us, that said something has radically changed," says Trivelpiece, an ecologist at the National Oceanic and Atmospheric Administration's Southwest Fisheries Science Center in La Jolla, Calif.

In fact, the entire Scotia Sea seems to have had the rug pulled out from underneath it. The rug, in this case, is krill. Numbers of these tiny crustaceans, the bottom-most animals in marine food webs, have dropped by up to 80 percent throughout the region.

Krill are important, but the problem may go deeper, says Oscar Schofield, a biological oceanographer at Rutgers University in New Brunswick, N.J. Marine crustaceans gorge on tiny photosynthesizing organisms called phytoplankton, and Schofield's research hints that climate change in the West Antarctic Peninsula may be similarly knocking out this crucial bottom rung of the food chain.

Adélie and gentoo penguins hobnob on a beach in the South Shetland Islands. As krill numbers drop in the Scotia Sea, Adélies may be going hungry.

Frigid lake holds analog of early life

Antarctic bacterial colonies look like some of the first fossils

By Alexandra Witze

In the eerie bluish-purple depths of an Antarctic lake, scientists have discovered otherworldly mounds that tell tales of the planet's early days.

Bacteria slowly built the mounds, known as stromatolites, layer by layer on the lake bottom. The lumps, which look like oversized traffic cones, resemble similar fossil structures from billions of years ago that are considered one of the oldest widespread records of ancient life. The Antarctic discovery could thus help scientists better understand the conditions under which primitive life-forms thrived. "It's like going back to early Earth," says Dawn Sumner, a geobiologist at the University of California, Davis.

Soft blue light suffuses the otherworldly bottom of Lake Untersee, Antarctica, where scientists have found odd structures (purple lumps) built by layer upon layer of growing microbes.

Sumner and her colleagues, led by Dale Andersen of the SETI Institute in Mountain View, Calif., describe the discovery in an upcoming issue of *Geobiology*.

Researchers study fossil stromatolites, from 3 billion years ago or more, to understand how life got a foothold on Earth. Today, stromatolites actively form in only a few spots in the ocean and in some freshwater environments, including a few of Antarctica's other freshwater lakes. But scientists have never seen any the size and shape of Lake Untersee's. "It totally blew us away," Andersen says. "We had never seen anything like that."

Samples from one mound showed it was made mostly of long, stringy cyanobacteria, ancient photosynthesizers. The bacteria may take decades to build each layer in Untersee's frigid waters, Sumner says, so the mounds may have taken thousands of years to accumulate.

Andersen's team recently studied two other ice-covered Antarctic lakes, Vanda and Joyce, without finding large conical stromatolites there. Understanding what makes Untersee different would help scientists better figure out the limits on life, both today and in the long-distant past. "It's a real challenge to our understanding of how these communities developed," says Ian Hawes, a polar limnologist at the University of Canterbury in Christchurch, New Zealand.

FROM TOP: SUE AND WAYNE TRIVELPIECE; D. ANDERSEN

Genes & Cells

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Prey, predator make same poison

Caterpillars and hosts independently evolved cyanide recipe

By Rachel Ehrenberg

There's a patent war pending over the invention of the cyanide bomb.

Zygaena caterpillars, which deter hungry birds by storing the poison in their flesh, make cyanide using the exact same cellular machinery as their host plants, scientists report April 12 in *Nature Communications*. It still isn't clear which one came up with the recipe first, but the researchers say the discovery is the first known example of organisms from entirely different kingdoms evolving the same biochemical treachery.

Some plants, such as bird's-foot trefoil, concoct cyanide bombs that are trip-wired to blow up in the mouths of nibbling animals. When a slug or insect chews a leaf, ingredients that are kept in different compartments in the plant's cells combine to form cyanide, poisoning the animal.

Scientists knew that some caterpillars could eat cyanide-laced plants and store the poison in their bodies. But researchers only recently discovered that when host plants are cyanide-poor, the caterpillars can make the poison themselves as a means of deterring their own predators.

"We had no clue how they were making it," says study coauthor Birger Møller of the University of Copenhagen.

The researchers first speculated that sometime in the evolutionary past, the caterpillars stole the genetic instructions for making cyanide from the plants. But the plants' and caterpillars' cyanide genes look nothing alike, Møller and his colleagues discovered. Strangely though, the plants and caterpillars both use genes that are found in pretty much all living things (humans use genes of this type to break down toxins in the liver).

Not only do both organisms record their cyanide-concocting instructions in three similar but very distantly related genes, they also build the poison with the same cookware. The enzymes working the molecular assembly line leading to cyanide are the same, modifying the same molecular ingredients in both creatures, the researchers report.

"They are using the exact same chemistry and enzymes," says David Gang of the Institute of Biological Chemistry at Washington State University in Pullman. "It is like inventing the wheel twice."

Which came first is under investigation, says Møller. If the plants were first, the caterpillars could have exploited a new food source once they figured out how to safely sequester the toxic compound. Conversely, if the caterpillars already made cyanide and they chanced upon plants that did too, the insects could have saved energy and resources by getting the poison from the plant. ■

Zygaena **caterpillars, which deter predators by secreting droplets of cyanide (circled), get the poison either from eating poison-laced plants or by making it.**

How the moth lost its speckles

Tracing the genetic roots of a classic evolutionary tale

By Tina Hesman Saey

The molecular mechanics behind an example of evolution dating back to Darwin's time may soon be revealed.

As soot from coal-fired factories blackened trees and buildings in 19th century England, naturalists noted that peppered moths in polluted regions blended in by sporting a sleek, all-black look known as the *carbonaria* form instead of the usual lightly speckled wings. Within a few decades the black moths made up 90 percent or more of the population in urban areas.

A black peppered moth (left) nearly replaced the original type during England's industrial revolution.

Now, researchers led by Ilik Saccheri, a geneticist at the University of Liverpool in England, report online April 14 in *Science* that they have traced the mutation responsible for the funereal look to one region of a chromosome that in butterflies contains genetic instructions for creating color patterns. This region is an adaptation hot spot, where mutations produce hundreds of different wing color patterns in many species.

"Presumably it takes hundreds of genes to make a wing pattern," says Robert D. Reed of the University of California, Irvine. "So why does this [relatively small] region appear over and over again?"

No one has found the precise DNA changes that lead to the many different color patterns, but scientists are scouring the region.

Likewise, Saccheri and his colleagues don't yet know the exact nature of the *carbonaria* mutation. They do know that black moths collected from 80 sites in the United Kingdom share some key genetic signposts, suggesting that the *carbonaria* mutation involves only one spot in the genome and happened just once, probably shortly before the first reported sightings in 1848 near Manchester.

Atom & Cosmos

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XENON100 finds no dark matter

Detector puts new limits on elusive material's properties

By Ron Cowen

A sensitive experiment in Italy has found no sign of dark matter in 100 days of searching for the invisible material that is believed to account for over 80 percent of the mass of the cosmos. But even in the absence of a discovery, data collected by the XENON100 experiment may shed light on fundamental physics, team leader Elena Aprile of Columbia University and her collaborators say.

The negative result, announced online April 13 at arXiv.org, doesn't mean dark matter doesn't exist. It may just be harder to detect than scientists had imagined.

Physicists lower the XENON100 experiment into position 1,400 meters beneath a mountain outside Rome.

XENON100 COLLABORATION

XENON100 is a tank filled with 161 kilograms of chilled liquid xenon buried beneath 1,400 meters of rock at the Gran Sasso Underground Laboratory in Italy. Cosmic rays, which can mimic the action of dark matter particles, can't easily penetrate to that depth (*SN: 8/28/10, p. 22*). A particle striking a xenon nucleus causes it to recoil, prompting ionization and the emission of light that can be used to infer whether the particle was dark matter.

The new analysis puts the experiment in direct conflict with other experiments where evidence for relatively low-mass versions of dark matter particles has been found (*SN: 5/10/08, p. 12*), says XENON100 collaborator Rafael Lang of Columbia.

XENON100 has also begun to place intriguing new limits on how strongly dark matter interacts with ordinary matter. If that interaction is controlled by dark matter particles' association with another proposed particle, the long-sought Higgs boson, XENON100 is now sensitive enough to begin to probe that relationship and the presence of the Higgs, says theorist Neal Weiner of New York University.

Time travel nixed in metamaterial

A desktop universe captures properties of the real thing

By Devin Powell

Unable to study the Big Bang in person, physicists have now simulated it in a bit of plastic and metal.

This desktop model tries to re-create the forward movement of time that drives history ever onward. In this experiment, as in many others before, time travel is impossible.

"It's a toy representation of what actually happens in our universe," says Igor Smolyaninov, a physicist at the University of Maryland in College Park who with colleague Yu-Ju Hung describes the work online April 4 at arXiv.org. Smolyaninov made his toy out of metamaterials, man-made substances that bend light in ways once thought impossible. They've achieved fame as invisibility cloaks (*SN: 2/26/11, p. 12*) and could be useful in new optical technologies.

But metamaterials also have a deeper connection to the universe. The equations describing the movement of light through what are known as "hyperbolic" metamaterials look a lot like those that govern the movement of particles in spacetime.

Just as a stick figure drawing can capture some features of real humans, a three-dimensional block of metamaterial can, in theory, re-create elements of the four-dimensional universe — including time. A beam of light should trigger a Big Bang–like event. The light spreads outward through the metamaterial — left and right, forward and backward. The way it moves upward through the material is analogous to moving through time, Smolyaninov suggested last year in *Physical Review Letters* (*SN: 10/23/10, p. 28*).

In this context, the math prohibits time travel. Rays of light moving in the timelike direction can't bend back upon themselves and return to a previous point.

Making such a 3-D metamaterial is notoriously difficult. So Smolyaninov started with something simple and flat. He layered curved strips of plastic in a rainbowlike pattern on top of gold. Moving along each arc is like moving through one-dimensional space. Moving outward to a new arc is like moving through time.

"It's remarkable that you could really engineer these things," says Joseph Polchinski of the Kavli Institute for Theoretical Physics in Santa Barbara, Calif.

Smolyaninov created a burst of wobbly electrons, called plasmons, in the gold at the rainbow's center. As these plasmons moved outward, they spread out and became less orderly. According to Smolyaninov, this mimics the thermodynamic arrow of time that pushes the universe toward ever greater disorder.

"Even though the laws of physics are mostly symmetric, we know that time can only flow in one direction," he says. "Entropy grows."

Polchinski and other physicists aren't convinced by the data, which show big fluctuations in entropy and only a small overall increase.

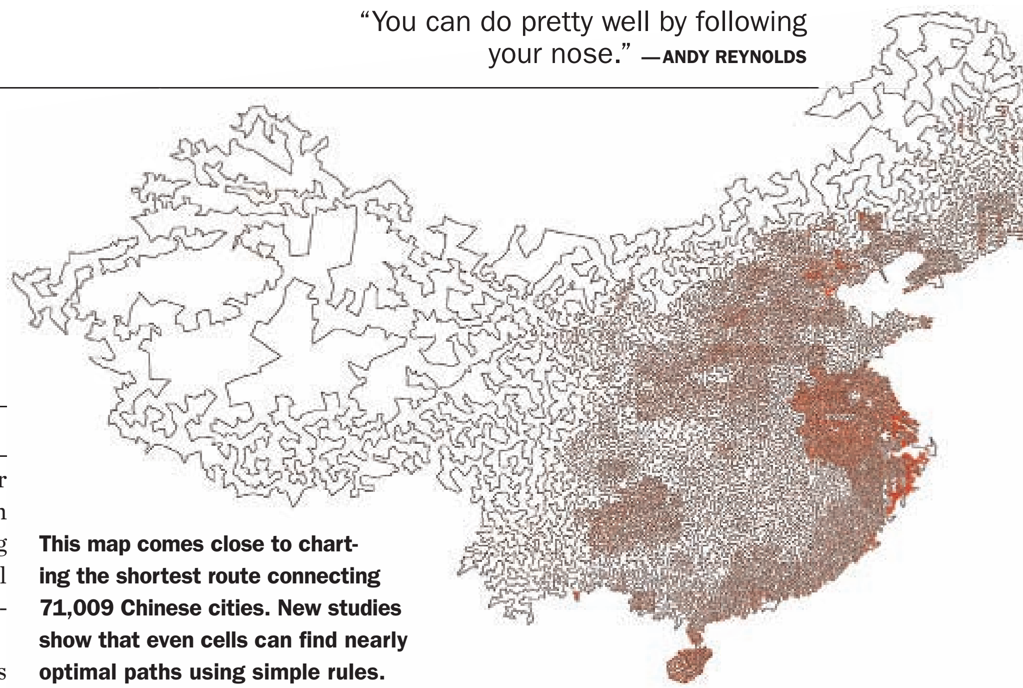
Numbers

"You can do pretty well by following your nose." —ANDY REYNOLDS

Cells can chart efficient course from A to Z

Immune system can tackle a classic math challenge

By Rachel Ehrenberg



This map comes close to charting the shortest route connecting 71,009 Chinese cities. New studies show that even cells can find nearly optimal paths using simple rules.

Forget GPS. With no fancy maps or even brains, immune system cells can solve a simple version of the traveling salesman problem, a computational conundrum that has vexed mathematicians for decades.

The new research, which simulates how a type of white blood cell seeks and destroys infectious particles, shows how living things — be they cells, sharks or bees — find a target with only limited information and cognitive skills.

"Some search strategies are perhaps not the best, but they make the whole exploration of a space very efficient," says theoretical ecologist Frederic Bartumeus of the Spanish Council for Scientific Research's Center for Advanced Studies in the city of Blanes.

The best mathematical minds have been tackling the traveling salesman problem for decades, and they have found some efficient solutions. But no one has figured out how to completely solve the puzzle: For a given number of cities, a traveling salesman must plan a route that visits each city once, covering the minimum possible overall distance. A pencil and paper and brute force can find the shortest route when there aren't a lot of target cities. But elaborate algorithms and serious computing power are usually needed when the number of targets reaches double digits.

The new research, to appear in *Physical Review E*, shows that when there aren't a lot of targets, cells do a decent job of finding the shortest possible route. These cells "search" by tuning in to local concentrations of chemical signals and then following the most intense signal to a target. Repeating that process, known as chemotaxis, allows immune cells to find and demolish numerous invaders.

"You can do pretty well by following your nose," says mathematical biologist Andy Reynolds, who did the new work at the Biotechnology and Biological Sciences Research Council's Rothamsted Research institute in Harpenden, England. "There's no need to know where all of the other sites are or to have the means to figure out which one is the nearest one."

Computer simulations by Reynolds show that using the follow-your-nose strategy, an immune cell seeking five different targets will find a perfect traveling salesman route. With 10 targets, the cells were still pretty efficient: On average, their routes were only 12 percent longer than the shortest path. These routes were comparable to the solutions calculated by a simple computer algorithm.

When there are many target cities, the best approach to the traveling salesman problem is a tool called linear programming, says William Cook, an expert in computational mathematics at Georgia Tech. This method finds a lower bound — a distance that the minimum route can't be shorter than — which can then guide the search for a short route. Routes that have 1,000 cities or fewer can be easily solved with this method. But when you add cities to your route, the number of calculations required to find the shortest path increases exponentially. Scientists still don't have one clean algorithm that can crunch the numbers, no matter how many cities, and find the shortest route. In fact, researchers don't even know if such a solution is possible. (The Clay Mathematics Institute in Cambridge, Mass., offers $1 million to anyone who can solve this kind of math problem or prove that a solution does not exist.)

With abundant information and resources, systematic searches are ideal. But such situations don't exist in nature. Increasingly there are examples of organisms using suboptimal strategies that work well in the real world — such as a search pattern known as a Lévy walk (*SN: 7/3/10, p. 15*), chemotaxis or a combination of both.

By applying similar simple strategies, scientists are coming up with efficient ways to find all kinds of things, notes Bartumeus, like the source of a swirling plume of chemicals in a river or even a child who has gone missing in a neighborhood of tangled, narrow streets. ■

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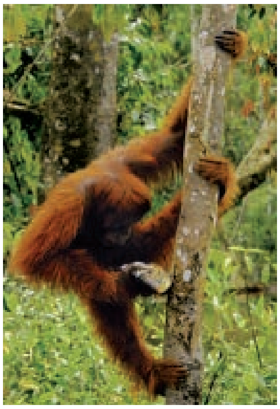
Borneo orangs fish for their dinner

Behavior suggests early human ancestors were piscivores

By Bruce Bower

Orangutans swim just about as well as they fly, but research on three Indonesian islands shows that these long-limbed apes nonetheless catch and eat fish.

Orangutans living in Borneo scavenge fish that wash up along the shore and scoop catfish out of small ponds for fresh meals, Anne Russon of York University in Toronto reported on April 14. Over two years, Russon saw several animals on parts of the forested island learn on their own to jab at catfish with sticks, so that the panicked prey would flop out of ponds and into a red ape's waiting hands.



Orangutans in Borneo supplement their diets with catfish that they snatch out of shallow ponds.

"If orangutans can do this, then early hominids could also have practiced tool-assisted fishing," Russon said.

Observations of fishing by orangutans raise the likelihood that hominids ate meat, including fish, before the emergence of the *Homo* genus around 2.5 million years ago (*SN: 9/11/10, p. 8*), said anthropologist David Braun of the University of Cape Town in South Africa. Anthropologists have traditionally held that meat-eating first assumed prominence among early *Homo* species and fueled brain expansion.

Fish, even more than red meat, contains fatty acids essential for human brain growth. Good archaeological evidence of fish-eating goes back no further than about 2 million years in members of the *Homo* genus, which includes modern humans.

Russon and her colleagues monitored daily behavior among orangutans in Borneo from 2004 to 2006. In 2007, the researchers stocked a small pond with catfish and videotaped orangutan visits to the pond over the course of one day.

Seventeen times orangutans scavenged for fish or grabbed fish out of ponds — several times from the prestocked pond — and immediately ate their prey. Apes used sticks to jab at catfish in the prestocked pond and in other ponds as well.

Orangutans' determined fishing efforts underscore the nutritional importance of aquatic foods for apes in general, not just people, Russon said. Individual orangutans in Borneo may have discovered by accident that they could grab fish along the shore and in ponds. These animals then adapted sticks to the task of catching elusive pond catfish.

Debate anew on long-dead bones

Ancient species may have initiated rise of *Homo* genus

By Bruce Bower

Fossils described last year as representatives of an ancient species crucial to human evolution have reentered the scientific spotlight and set off a new round of debate over the find's true identity.

Researchers described analyses of new and previously recovered remains of a South African species, called *Australopithecus sediba,* on April 16. Evidence is accumulating, the scientists reported, that 2-million-year-old *A. sediba* formed an evolutionary connection between relatively apelike members of *Australopithecus* and the *Homo* genus, which includes living people.

It's now clear that *A. sediba* shares more features with early *Homo* specimens than any other known *Australopithecus* species does, said Darryl de Ruiter of Texas A&M University in College Station. "We think *A. sediba* is a possible candidate ancestor for the genus *Homo*."

De Ruiter suspects that an isolated population of the hominid species *Australopithecus africanus* gradually evolved into *A. sediba*, resulting in a species characterized by an unusual mix of skeletal traits, some typical of *Australopithecus* in general and others of early *Homo*.

That scenario, outlined in symposium presentations by De Ruiter and Lee Berger of the University of the Witwatersrand in Johannesburg, South Africa, remains controversial despite new fossil discoveries.

The new *A. sediba* fossils, many belonging to the previously discovered partial skeletons, underscore this ancient species' mosaic anatomy, Berger said. A largely complete female pelvis displays relatively straight, vertically aligned hips and an elongated birth canal, much like early *Homo* species. Other *Australopithecus* females possessed a relatively short, wide pelvic opening and flaring hip bones.

New *A. sediba* foot bones include a chimplike heel and a humanlike ankle, Berger said. Fossils from the shoulders, rib cage and spine, as well as surprisingly long arm bones, typify *Australopithecus*.

Ian Tattersall of the American Museum of Natural History in New York City endorsed *A. sediba* as a distinct species, probably closely related to *A. africanus*. "I wouldn't classify it as the root of the *Homo* genus, though," he said.

INDRAYANA

For more coverage of this year's American Association for Cancer Research meeting, visit **www.sciencenews.org/aacr**

Cancer risk clues from breast milk

DNA analysis could offer new way of testing women's risk

By Nathan Seppa

Breast milk may provide a storehouse of genetic data indicating whether a woman is at risk for breast cancer, a study reported April 4 finds.

Kathleen Arcaro, an environmental toxicologist at the University of Massachusetts Amherst, and her colleagues analyzed milk from 250 women who had had a single breast biopsied to test whether a lump or other swelling was cancerous or benign. The researchers got milk samples from both breasts.

The researchers looked at a specific type of breast cell shed in the milk. They tested three genes in these cells for methylation, a chemical modification that can inactivate a gene by disabling its promoter, or start switch.

When the researchers measured cells in breast milk from 13 women who turned out to have cancer, these cells had substantially more methylation in a tumor suppressor gene called *RASSF1* than did cells from the noncancerous breast.

In the women whose biopsy results did not indicate cancer, methylation of another tumor suppressor gene, called *SFRP1*, was more common in milk from the biopsied breast than the other breast. Most of those cases showed nonproliferative lesions or benign proliferative disease. Some women with these diagnoses are at above-average risk for breast cancer, and the researchers believe that fine-tuning the method might reveal whether that risk should be monitored.

The breast milk–screening technique is still in the early stages of development. But if enough genes show a substantial effect, such screening could cover a huge portion of women since the researchers estimate that 80 percent of women give birth at some point in their lives.

The researchers haven't yet settled on the precise makeup of the test. "You wouldn't expect that every woman would have the same set of methylated genes," Arcaro says. So, for example, a gene screen might need to include 25 genes, and having a half dozen methylated could indicate increased cancer risk, she says. The team has identified nine other genes to investigate, but hasn't analyzed those yet in the breast milk samples.

Certain groups could benefit from a breast milk–based test, Arcaro says, such as women with a family history of breast cancer, those carrying a known genetic mutation predisposing them to risk or even women who are having their first child after age 30.

Breast milk offers an excellent source of genetic information because of its accessibility, says David Sidransky, an oncologist at the Johns Hopkins Medical Institutions who wasn't involved in this study. "This is not a trivial issue," he says. If it works, he adds, the technology might also be used in nonlactating women using nipple aspirate, the small amounts of fluid that can be drawn from a breast.

Beer, bugs, DNA add up to cancer

Stomach tumors more likely when three factors combine

By Nathan Seppa

Swilling three or more beers a day over several years can increase a person's stomach cancer risk if combined with two other factors, researchers reported April 4.

The triple threat includes carrying two copies of *rs1230025*, a gene variant located amid a cluster of genes associated with degrading alcohol in the body. The third factor is infection with *Helicobacter pylori*, a bacterium that causes stomach cancer and ulcers. *H. pylori* infection is uncommon in the United States, but roughly half the world's population carries the microbe.

> Many lines of research have linked inflammation with increased cancer risk.

Eric Duell, an epidemiologist at the Catalan Institute of Oncology in Barcelona, and his colleagues analyzed data on health status and alcohol intake among thousands of adults participating in a European study between 1992 and 1998. The researchers found a broad link between stomach cancer and drinking three or more beers daily, but no clear association for similar amounts of wine or liquor.

The researchers then focused on 364 people who had been diagnosed with stomach cancer and 1,272 others without cancer to test the combined effects of beer intake and having the variant gene. Those with a high beer intake who also carried two copies of the variant gene had a three- to 22-fold increase in stomach cancer risk compared with heavy drinkers who didn't carry a variant copy. About 20 percent of people carry at least one copy of the variant form of the gene, Duell says. Nearly all people with stomach cancer also had *H. pylori* infections, which the researchers took into account in calculating risk differences.

The three risk factors all appear necessary for the heightened risk, but the direct cancer-causing event is probably inflammation, Duell says. Many lines of research have linked inflammation with increased cancer risk, and the triple whammy cited in the new study would boost stomach inflammation.

"It all makes physiological sense," says George Kim, a gastrointestinal oncologist at the Mayo Clinic Florida in Jacksonville.

Body & Brain

"There's a real neuroscientific interest now in understanding the basis of compassion." —TOR WAGER

Brain's mirror system does the robot

An experiment may explain why we feel so sad for WALL•E

By Laura Sanders

Next time you see a guy dancing the robot, his jerky moves will speak to a part of your brain that scientists thought was reserved for making sense of actions by others that you too could easily perform.

Scientists were surprised that the brain's mirror system, thought to respond only to familiar motions and actions, reacts strongly to either a person or a LEGO figurine doing the robot dance.

Experiments presented April 2 challenge the common view of this "mirror system" by showing that it's not just a copycat, but responds to a much wider range of actions than what an observer can perform.

"There are a lot of situations where you see actions that you can't do," said Emily Cross of Radboud University Nijmegen in the Netherlands. "If you think about watching a gymnast at the Olympics, watching a break dancer, or even watching *Star Wars* or *WALL•E*, we see all sorts of actions and agents that we can't readily map onto our own motor systems."

Cross and her colleagues used functional MRI to scan the brains of 22 people as they watched a video of a man performing a natural, fluid dance or a machinelike robot dance. Researchers thought that the mirror system, which includes parts of the parietal lobe at the top back of the head and the premotor cortex just in front of that, would show higher activation when the subjects watched the natural dance. Instead, parts of the mirror system showed a stronger signal when subjects saw the man do the robot.

Cross and her team next tested whether the dancer made a difference by recording a video of a LEGO figurine performing the same two dances. Again, the mirror systems in 23 new participants were more strongly activated by the robotic dance.

Finding that these brain regions may react to less familiar behaviors and actors "may indicate that the mirror system is not just modulated by expertise, but also perhaps by attention, novelty and other factors," said neuroscientist Lisa Aziz-Zadeh of the University of Southern California in Los Angeles.

Shocked to learn that talk is cheap

People swear they wouldn't hurt others for money, but do

By Laura Sanders

When faced with a thorny moral dilemma, what people say they would do and what people actually do are two very different things, a new study finds. In a hypothetical scenario, most people said they would never subject another person to a painful electric shock just to make a little money. But when people were given a real-world choice, the sparks flew.

Morality studies in the lab almost always rely on asking participants to imagine how they would behave in a certain situation, study coauthor Oriel FeldmanHall of Cambridge University said April 4. But these imagined situations are missing teeth: "Whatever you choose, it's not going to happen," she said.

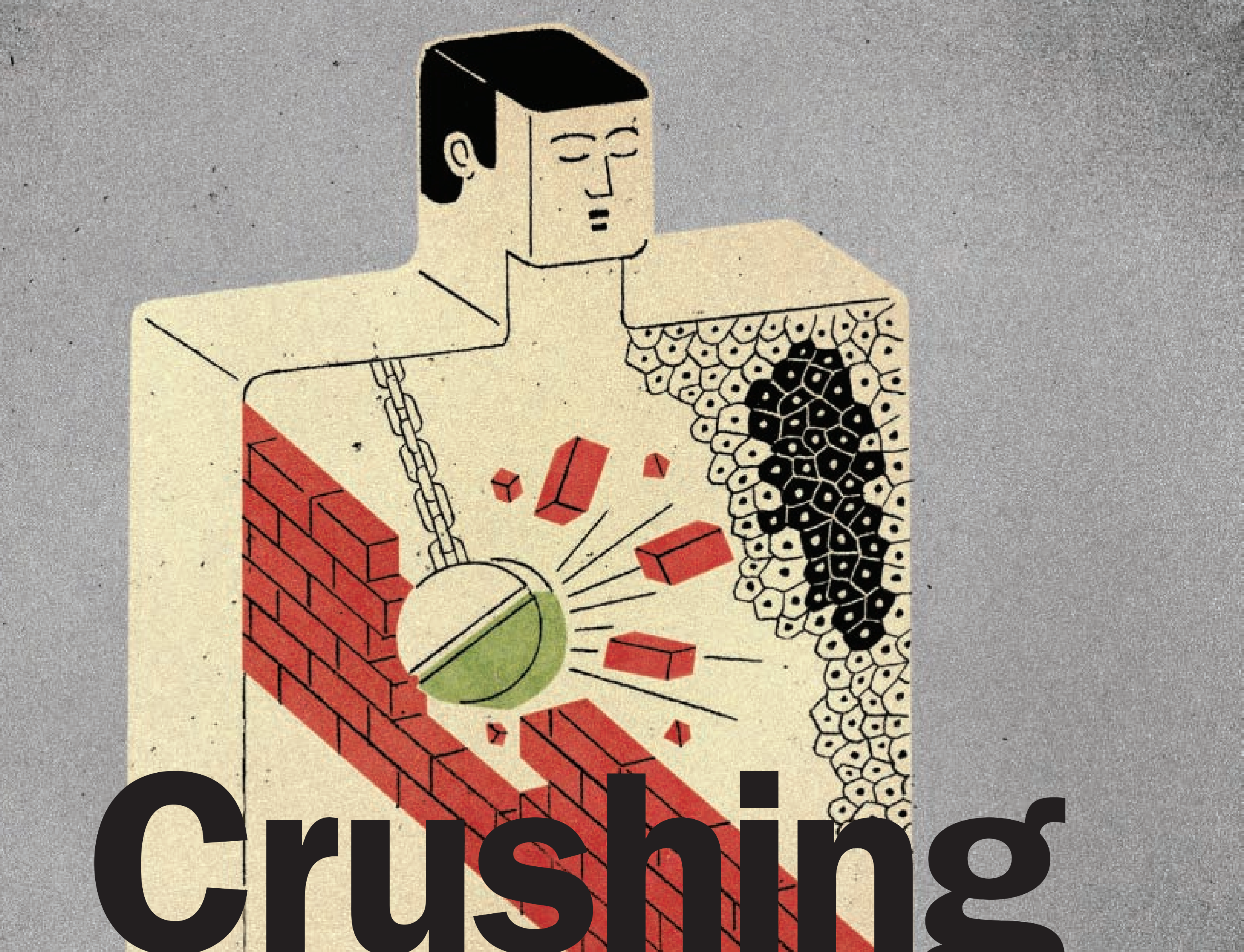
In FeldmanHall's study, things actually happened. Participants in an MRI scanner were given a choice: Either administer a painful electric shock to a person in another room and make one British pound (about a dollar and a half), or spare the other person the shock and forgo the money. Shocks were priced in a graded manner, so that the volunteer would earn less money for a light shock, and the whole pound for a severe shock. This same choice was given 20 times, and the person in the brain scanner could see a video of either the shockee's hand jerk or both the hand jerk and the face grimace. (Although these shocks were real, they were prerecorded.)

When researchers gave a separate group a purely hypothetical choice, about 64 percent said they wouldn't ever deliver even a mild shock for money. Overall, people judging their actions hypothetically would have netted only about four pounds on average in a real experiment.

But when there was actual cold, hard money involved, the data changed. A lot. A surprising 96 percent of people in the scanner chose to administer shocks for cash. "Three times as much money was kept in the real task," FeldmanHall said. When participants saw only the hand of the person jerk as it got shocked, they chose to walk away with an "astonishing" 15.77 pounds on average out of a possible 20-pound windfall. The number dipped when participants saw both the hand and the face of the person receiving the shock: In these cases, people made off with an average of 11.55 pounds.

These kinds of studies can help scientists figure out how the brain dictates moral behavior. "There's a real neuroscientific interest now in understanding the basis of compassion," said cognitive neuroscientist Tor Wager of the University of Colorado at Boulder. "That's something we are just starting to address scientifically, but it's a critical frontier because it has such an impact on human life."

LEFT: E. CROSS; RIGHT: CARMEN HAUSE



Crushing Cancer's Defenses

Vaccine approval offers hope while other armies muster

By Daniel Strain

Twirling globs of white blood cells circle a tumor like a Greek army ready to lay siege. These cells are used to winning — they take down baddies such as viruses and bacteria on a daily basis. But cancer cells are not an ordinary enemy. Like Troy, they set up hefty barricades against attack, often killing white blood cells or turning them off on the spot. Too often, the immune system loses this Trojan War.

But recent advances in therapeutic cancer vaccine research may provide the immune system with an offensive edge. Such therapies aren't the same as the shots kids get before starting school to prevent measles or polio. Nor are they like antiviral vaccines, such as Gardasil, that stave off infections which can lead to cancer. Therapeutic cancer vaccines wouldn't prevent cancer, they would treat it: training the immune system to turn its forces on a tumor already in the body with the skill of Achilles and the strength of Ajax.

At least that has been the hope. For about a decade, large clinical trials of cancer vaccine candidates have turned out mostly disappointing. But now a handful of new therapies are showing signs that the cancer vaccine effort could be on the brink of big breakthroughs.

"The whole field is a lot more encouraged now," says Jay Berzofsky, chief of the National Cancer Institute's Vaccine Branch in Bethesda, Md. "It warrants a lot more investment."

After a long search, scientists have hit on a few possible vaccines that seem to do some good. In 2010, the U.S. Food and Drug Administration gave the final OK to its first cancer vaccine, a prostate cancer therapy called Provenge.

ILLUSTRATION BY DAVID PLUNKERT

A second treatment now in large clinical trials could revive fading hopes for a melanoma vaccine. At the same time, many scientists now acknowledge that vaccines probably can't do the job alone. Two new therapies, which aren't vaccines but do duck tumor defenses and ultimately spur on the immune system, show promise in their own right and may make natural allies for cancer vaccines.

Though the gains have yet to match many doctors' hopes, Provenge and other immune-energizing drugs have given terminal cancer patients months of life as part of clinical trials. "That's when you know the idea is no longer just an attractive idea," says Glenn Dranoff, an oncologist at the Dana-Farber Cancer Institute in Boston. "Now, you have proof."

Coley's vaccine

The proof may be new, but the idea behind cancer vaccines is not. A New York City surgeon named William Coley was enthralled in the late 1800s by the story of a male cancer patient who came down with a severe infection, then saw his tumor shrink dramatically. Coley decided to put the power of the fever to the test, injecting cancer patients with shots of killed pathogens, including strep bacteria. The strange thing: In many patients, it worked.

"These were patients with advanced inoperable cancer," says epidemiologist Stephen Hoption Cann of the University of British Columbia in Vancouver. "They would be considered, by and large, incurable by today's standards."

Still, Coley's findings didn't gain much traction; instead radiation and chemotherapy became the hot treatments in oncology. But by the 1980s and '90s, researchers were frustrated because such therapies couldn't slow many malignant diseases. More and more teams turned to Coley's old battle plan.

The current thinking is that infections kick the immune system into overdrive. White blood cells go after pathogens in force, causing a lot of collateral damage to tumors in the process. Today's proposed vaccines are better sharpshooters than Coley's original cocktail, targeting tumors specifically or at least limiting the damage in healthy organs. Some vaccines include whole cancer cells killed with radiation, while others contain a brew of proteins native to tumors. A few package such proteins into viruses.

To rev up the body to attack, many of these new vaccines focus on activating immune players called dendritic cells. Among other roles, these spy cells gather intelligence on potential baddies, from free-floating proteins to whole parasites. These spies return worrisome finds to a type of white blood cell called T cells. T cells, the soldier cells, then divide rapidly and go on the offensive, looking for cells or substances that match the spies' intel.

But because cancer cells grow from normal tissue, they often look like good guys. To clue the spy cells in to big tumors, oncologists need to fix the intel.

Provenge and beyond

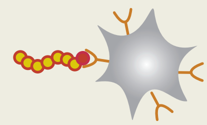
And that's exactly what the team that designed the cancer vaccine Provenge did. Doctors prepare the vaccine cocktail by taking dendritic cells and similar immune players directly from a patient and mixing them with proteins that sit atop prostate cells, says Philip Kantoff, an oncologist with Dana-Farber. The mixture goes back into the patient's bloodstream where, scientists think, the dendritic spies present the prostate proteins to immune soldier cells. That convinces the immune system to treat the prostate cells as an enemy, like it would a common virus. Vaccine researchers had previously tried this strategy and a range of others with little success. But Provenge differed from the long list of misfires in one key respect: "It actually worked," Kantoff says.

In a Phase III trial — a large, controlled study, often the last step before FDA approval — Kantoff and his colleagues dosed 330 prostate cancer patients with customized versions of Provenge. The team also treated 167 patients with a placebo. Patients received traditional therapies before and after vaccine treatment.

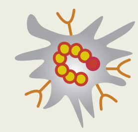
Individuals given Provenge survived

War on cancer Though approaches vary, the aim of cancer vaccines is to provoke the body to attack tumor cells.

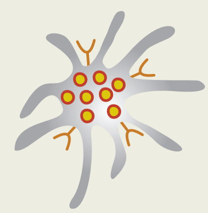
Specific flags, or antigens, sit atop tumor cells.



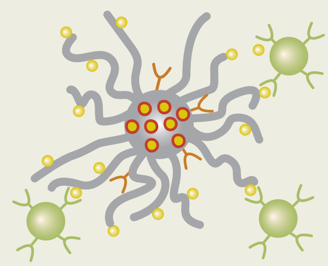
Scientists mix those flags with a person's own spy cells.



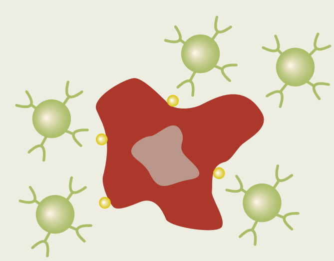
The spy cells, sometimes dendritic cells, take up the flags.



The activated spy cells are injected back into the body.



The spy cells display the flags, alerting the body's T cells.



The T cells proliferate and attack cancer cells.

JANEL KILEY

for a median of about four months longer than placebo patients, nearly 26 months from when they enrolled in the study instead of about 22 months. The vaccine is obviously doing something right, Kantoff says. Curiously, though, tumors appeared to grow or spread equally fast regardless of the treatment, an observation Kantoff attributes to a monitoring failure.

The team published its results in July 2010 in the *New England Journal of Medicine*, and Provenge got the nod from the FDA later that year.

Before Provenge, the prospects for cancer vaccines looked grim, says Guido Forni, an immunologist at the University of Turin in Italy. "The field was very depressed." But today, he says, it's a different story. "Many, many people who were skeptical of vaccines are now inspired by this research to work again."

But despite the advances, the benefits have been modest, Forni acknowledges. Provenge is better than chemotherapy alone, which gives about a two- to three-month bump to survival, but not by much. Vaccines like Provenge also rely on a patient's own cells, and that customization can get pricey, says Leisha Emens, an oncologist at Johns Hopkins University. Next-generation treatments that tip off spy cells in the body with general ingredients from the lab could be thriftier options, she says.

One of many new therapies that takes this approach has its sights set on skin cancer. Every year, 132,000 people worldwide develop malignant melanoma, according to a World Health Organization estimate. And for many the outlook is poor. Advanced melanoma sufferers survive for a median of only six months from diagnosis. Today, "the melanoma vaccine situation is pretty barren," says Jeffrey Weber, a melanoma specialist at the Moffitt Cancer Center in Tampa, Fla.

Weber, however, has some hope for the MAGE-A3 vaccine, a drug developed by the pharmaceutical company GlaxoSmithKline that he has worked with in the clinic. The treatment is a one-size-fits-all cocktail of flags mimicking proteins found on tumor cells (but not normal tissue) mixed with a few immune-boosting chemicals. Though the company has focused largely on melanoma and lung cancer, the same protein flags sit on a laundry list of other cancer cells, says Vincent Brichard, head of GlaxoSmithKline's Belgium-based immunotherapeutics team. That means, if it works in further studies, the vaccine could one day treat a range of diseases including liver and bladder cancer.

> **"Everyone is now on this bandwagon of developing combination therapy."**
> SUZANNE TOPALIAN

Unlike Provenge, GSK's shot hasn't proved itself on the big stage. In a preliminary trial including 182 patients who underwent lung tumor removal surgery, tumor recurrence was delayed by 33 percent in MAGE-A3 recipients compared with those given placebo. But the improvement could have been due to chance. Brichard will be better able to evaluate the drug's potential for success during two ongoing Phase III trials — one for melanoma and one for lung cancer — that look at thousands of patients.

Early trials have already unearthed an encouraging detail, says Brichard. A suite of genes in tumors may reveal which patients will respond well to the vaccine and which won't. These cues could help oncologists tailor therapies on a patient-by-patient basis, often considered the "Holy Grail" of medicine, he says. Assuming the genetic signatures stack up in future studies, that sort of predictive power would make any vaccine researcher salivate.

So far, few melanoma vaccines have lived up to expectations, says Yvonne Saenger, a melanoma specialist at the Mount Sinai School of Medicine in New York City. MAGE-A3 may or may not be different, she says. She is waiting to see the Phase III results before weighing in.

Even vaccines that end up getting the FDA's approval can do only so much, Weber says. "Getting a vaccine alone to work in metastatic melanoma, I don't think it's going to happen," he says.

One big problem may be that tumors are just too good at rebuffing attacking white blood cells. And as the legendary Greeks learned, if you can't overcome Troy's defenses, you might as well go home.

Trove of trials A number of possible vaccines for a variety of cancers are currently in clinical trials. Some are shown below, but more can be found online at clinicaltrials.gov

Drug	Company/Institution	Type of cancer	Phase
NY-ESO-1 peptide vaccine	National Cancer Institute	Melanoma	2
PROSTVAC	BN ImmunoTherapeutics	Prostate	3
ADXS11-001	National Cancer Institute	Cervical	2
Lucanix	NovaRx Corporation	Non-small cell lung	3
BiovaxID	Biovest International	Non-Hodgkin's lymphoma	3
Stimuvax	EMD Serono	Non-small cell lung	3
Autologous tumor lysate-pulsed DC vaccine	UCLA	Brain	2
Allogeneic GM-CSF-secreting vaccine	Johns Hopkins	Breast	2

SOURCE: CLINICALTRIALS.GOV

Breaking barricades

During their day-to-day surveillance, white blood cells cull the low-hanging fruit well — cancer cells that readily give up their identities or that lack good defenses. But some cells avoid attack, and they can grow into tumors. The National Cancer Institute's Berzofsky compares the immune system's task to that of the Department of Homeland Security: "You can stop 99 percent of the terrorists. But it's the 1 percent that get through that kill you."

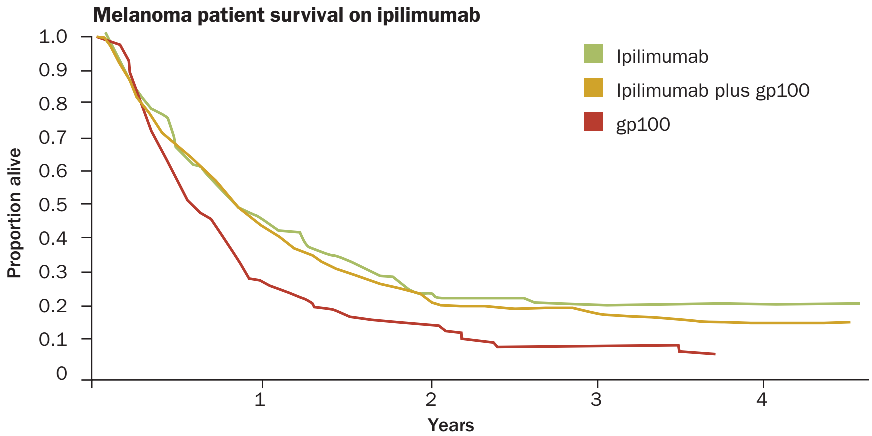
Often cancer cells escape the siege by taking advantage of the body's hesitancy to attack its own cells. Despite the best laid plans in a healthy body, some white blood cells do wind up targeting healthy lungs, skin or liver. When that happens, the immune system sets off fail-safes that silence or kill outright the rogue white blood cells. Many cancers call off attacks by triggering the same fail-safes. And that's just the start: Some tumors are downright devious, surrounding themselves with minefields laced with anti-immune chemicals. "Tumors feather their own beds," Berzofsky says.

Cancer vaccines need a Trojan Horse to overcome these barriers. Enter ipilimumab. This drug snags onto and turns off a type of immune protein called CTLA-4. In healthy people, CTLA-4 is a godsend because it's a natural brake on immune attacks, says Steven O'Day, director of the Melanoma Program at the Angeles Clinic and Research Institute in Santa Monica, Calif. This protein pops up on top of soldier immune cells when the cells go into battle mode. If a passing spy cell grabs onto the protein, it acts like a kill switch on the soldier cell. That's perfect for viral infections, O'Day says. Soldier cells can hit cold and flu viruses fast and hard, then, as part of the immune system's checks against collateral damage, dial back when the job is done.

But such short skirmishes don't often work on tumors. "Here you're trying to build an army of T cells, basically, to go into battle," O'Day says. "It can take anywhere from three to six months." Ipilimumab's trick is to keep immune cells going.

In a recent Phase III trial in patients with advanced melanoma, ipilimumab seemed to give soldier cells that much-needed breathing room, says O'Day, one of the study coauthors. Among nearly 700 patients, those that got ipilimumab survived for a median of 10 months after enrollment in the study, while patients not receiving the treatment survived for just over six, the team reported last year in the *New England Journal of Medicine*. But even more exciting, O'Day says, about 20 to 25 percent of patients survived for much longer — two years and counting.

Multifront attack Cancer vaccines may pair well with other therapies that keep the immune system revved up. Though one such therapy, ipilimumab, appeared to do better on its own than with a cancer vaccine called gp100, some researchers think other duos may further boost survival.



SOURCE: F.S. HODI *ET AL*/*NEJM* 2010

Ipilimumab seems to be a rarity, a drug that actually slows down melanoma.

But the drug has its downsides. In the absence of CTLA-4, many immune cells don't know when to quit. In the Phase III trial, 10 to 15 percent of patients on ipilimumab developed severe immune side effects from diarrhea to skin rashes, and seven patients died as a result. Preparation and careful monitoring in the future should keep such ill effects in check, Saenger says.

Ipilimumab received the thumbs-up vote from the FDA in March 2011. And that's a big deal, says Suzanne Topalian, a melanoma specialist at Johns Hopkins. "But at the same time, we all realize that ipi is a starting point," she says. Future work will focus not only on better drugs but also on drugs that work as part of a multifront war.

Data from mouse studies suggest ipilimumab, now marketed as Yervoy, could help next-gen vaccines slip past cancer walls, says Topalian, who has helped conduct clinical trials on ipilimumab. "A vaccine is going to focus the immune response," she says. "But these other maneuvers are going to enhance the immune response above a threshold that's needed for clinical activity."

Early data suggest medications that target a kill switch called PD-1, similar to CTLA-4, could pair well with vaccines and have fewer side effects, Topalian says.

So far, though, successfully mixing and matching vaccines with such kill-switch blockers remains little more than an attractive idea. O'Day's team tested ipilimumab alongside a cancer vaccine — the gp100 vaccine — that hadn't received FDA approval. Ipilimumab, however, seemed to do better on its own. Some doctors, including Topalian, suggest that gp100 may not be ideal, but think that newer pairings will succeed where this run failed.

And traditional drugs and treatments such as chemotherapy may work along with vaccines to make for a one-thousand-ship army. "Everyone is now on this bandwagon of developing combination therapy," Topalian says.

Still, it may take years for patients to see the full fruits of this research, just as it has already taken years to see a cancer vaccine that holds promise. "It's still hard because it's still just a long path," Saenger says. "You see a patient that has melanoma now; it's still very difficult." But she says there is a lot of room for hope.

A motley army now appears to be mustering. As more and more possible treatments trickle into the market, deciding which troops to send in to which patients, says O'Day, will make the fight against cancer more of an art. ■

Explore more

- NCI's cancer vaccine fact sheet: www.cancer.gov/cancertopics/factsheet/Therapy/cancer-vaccines

Moved by LIG

Welcome to Quantumville. Population: uncertain. Walk down Main Street, lined with blurry cars simultaneously moving and remaining still. See the house with the curtains drawn? The television in the living room is both on and off at the same time. In this neighborhood, everyday objects do seemingly contradictory things.

You won't drive through this far-fetched town anytime soon, but it's not as far off the map as it used to be. In laboratories across the world, bits of metal and glass are being groomed to behave in ways that defy common sense. Objects big enough to be seen and touched — some weighing kilograms — are beginning to rebel against the physical laws that govern daily experience.

At the forefront of this effort is a growing discipline called optomechanics. Its practitioners use beams of light to do something utterly unfeasible a decade ago: make large objects colder than they would be in the void of outer space. Only at these temperatures do objects reach energies low enough to enter the realm of quantum mechanics and start behaving like subatomic particles.

"Our guiding principle is to see quantum effects in a macroscopic object," says physicist Ray Simmonds of the National Institute of Standards and Technology in Boulder, Colo.

A number of optomechanics teams have sprung up in recent years, each cooling its own favorite bit of fairly ordinary stuff. Simmonds works with an aluminum drum (unveiled in the March 10 *Nature*). In Switzerland, scientists chill silica doughnuts. At Yale University, sail-like membranes are the vogue.

"We're putting the mechanics back in quantum mechanics," says Yale physicist Jack Harris.

It's mainly a race of tortoises creeping steadily closer to absolute zero, the coldest of the cold. But recently an interloper hare took a shortcut to the lead. And the stakes are high: The winners will test whether quantum mechanics holds at ever-larger scales and may go on to build a new generation of mechanical devices useful in quantum computing.

Cooling touch

Spend an afternoon watching sunbathers burn at the beach, and the idea of using light to refrigerate may seem counterintuitive. But light particles have a hidden cooling ability that comes from the tiny nudge they impart when bouncing off an object. This force, too weak for a beachgoer to feel, is so feeble that sunlight reflecting off a square-meter mirror delivers a pressure less than a thousandth of the weight of a small paper clip.

"It's an incredibly tiny effect," says physicist Steve Girvin, also of Yale.

In the 1970s scientists figured out how to use this "radiation pressure" to cool individual atoms by damping their vibrations with lasers. Now a slew of new devices leverage the punch of light and other forms of electromagnetic energy to cool objects made of trillions of atoms or more. This scaled-up cooling doesn't suppress the vibrations of individual atoms. Instead, it quiets the inherent wobbling of an entire object, like a foot pressed to a flopping diving board.

Putting light's cooling power to work starts with a laser beam bouncing between two mirrors. The distance between the mirrors in this "optical cavity" determines the frequency of light that will resonate — just as the length of a guitar string determines its pitch. Keep the mirrors still and properly tuned light will bounce back and forth, as constant as a metronome.

But allow one of these mirrors to wobble, and a more intricate and subtle interplay emerges. A laser beam tuned below the resonance frequency of the cavity will push against the swaying mirror and snatch away energy. By stealing vibrational energy from the mirror, the bouncing light gets a boost up to the optical cavity's stable frequency. Robbed of energy, the mirror's swaying weakens, and it cools.

By measuring the light leaking out of this type of system, two groups of

Lasers push everyday objects into the quantum world

By Devin Powell

physicists showed in 2006 that they could cool mirrors to 10 kelvins (10 degrees Celsius above absolute zero). A third used a similar technique to cool a glass doughnut to 11 kelvins, colder than the object would be if it were wobbling on the dark side of the moon.

"This demonstration that you could use laser radiation to cool a mechanical object, this started the race," says Tobias Kippenberg, leader of the doughnut team at the Swiss Federal Institute of Technology in Lausanne. "Every year we improve our cooling by a factor of 10."

As papers flowed in and objects neared the bottom of the thermometer, researchers competed to suck out every last drop of energy. The goal: to reach the ground state, where an object no longer possesses any packets, or quanta, of vibrational energy. In this state, motion almost completely stops and the quantum regime begins to become a reality.

But getting those last few quanta out would be a challenging task; even the mirrors at 10 kelvins still contained tens of thousands to hundreds of thousands of quanta.

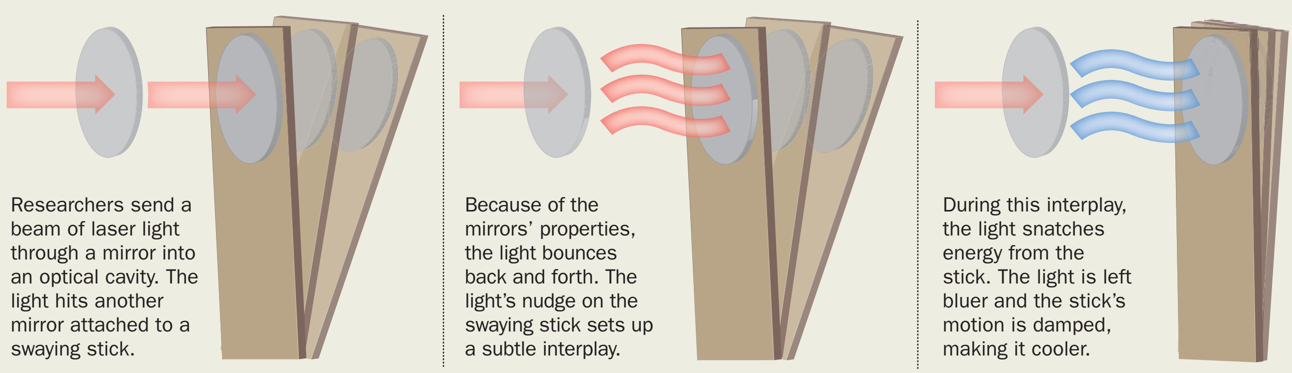
Better lasers and equipment refinements allowed three groups, publishing in *Nature Physics* in 2009, to reach 63, 37 and 30 quanta. Keith Schwab of Caltech bombarded a wobbling object with microwaves that drained away all but about four quanta. He and his colleagues reported in *Nature* in 2010 that they had put their object into its ground state 21 percent of the time — tantalizingly close to the consistency needed to test for quantum effects.

Then in April 2010, a shot rang out. An object had been spotted entering its ground state over and over again — by an outsider who wasn't even using light.

"I wanted to get to the ground state in the quickest and most efficient way possible and have there be no question that I was there," says Andrew Cleland, a physicist at the University of California, Santa Barbara, who reported his team's achievement in *Nature* (*SN: 4/10/10, p. 10*).

Cleland's secret: While other scientists built stuff that shook thousands or millions of times a second, he created a ceramic wafer 30 micrometers long that expanded and contracted 6 billion times per second. The faster an object's natural quiver, the easier it is to remove energy, meaning less cooling needed to reach the ground state. Using

Damping the wobble For decades, scientists have used light to quell the vibrations of individual atoms. Now teams are cooling sticks (as shown below), sails, drums and other multiatom objects to very low temperatures, where signs of quantum effects may be seen.



JANEL KILEY

a state-of-the-art liquid-helium refrigerator capable of achieving millikelvin temperatures, Cleland's team put the wafer in its ground state 93 percent of the time.

By measuring the electric fields produced by this object, Cleland and his colleagues showed that they could nudge the wafer into a state of superposition — both moving and still at the same time.

"There can be no doubt that we achieved superposition," Cleland says. This first demonstration of quantum effects in a fairly ordinary object was named the 2010 Breakthrough of the Year by *Science*.

But Cleland's sprint to the front of the pack has some long-term disadvantages. His technique is blind to the actual position of a fluctuating object, for one thing, and thus he can't spot one of the consequences of quantum mechanics: zero-point energy, which gives an object residual motion even in its ground state. Experimentalists using optomechanics hope to detect this motion and verify that it is proportional to how fast an object normally wobbles.

Back in front

Girding themselves for the long haul, optomechanics teams have now begun to catch up to Cleland's hare strategy. On March 21 in Dallas at the American Physical Society meeting, members of the NIST team presented data showing that their drumlike membrane had reached the ground state about 60 percent of the time.

The aluminum skin of this drum — in technical terms, a resonator — moves up and down much more slowly than Cleland's object, vibrating less than 11 million times per second. Reaching the ground state at this slower wobble couldn't be done with Cleland's refrigerator; it required the cooling nudge of microwaves.

The payoff for going the extra mile: time. The slower an object wobbles, the longer it tends to stay in its ground state. For Cleland, the ground state lifetime was about 6 nanoseconds. "The difference with our system, our resonator, is that it has a very long lifetime, about 100 microseconds," says Simmonds. "That's the key element that sets it apart."

With the results unpublished, the team won't say whether any quantum effects have been seen. But the stability could give the researchers an advantage for using optomechanical devices to store and relay information.

A "killer app," some say, would be playing interpreter between different wavelengths of light or other electromagnetic energy. A resonator in its ground state could theoretically be designed to absorb photons of just about any kind of light, stored as packets of vibrational energy.

Cool the resonator back to its ground state, and it could release this energy as light of a different wavelength. So gigahertz microwave energy that sets a stick to wobbling could be reemitted at optical frequencies hundreds of thousands of times higher, for instance. Such devices could bridge quantum computing systems that use different frequencies of light to transmit bits of information.

At Caltech, applied physicist Oskar Painter is taking steps toward realizing this light-to-light conversion at higher temperatures. He designs nanometer-scale optomechanical crystals that convert higher-frequency light to lower-frequency vibrations. A zipper-like object described in 2009 in *Nature*, for instance, could one day be useful for converting optical light into microwaves.

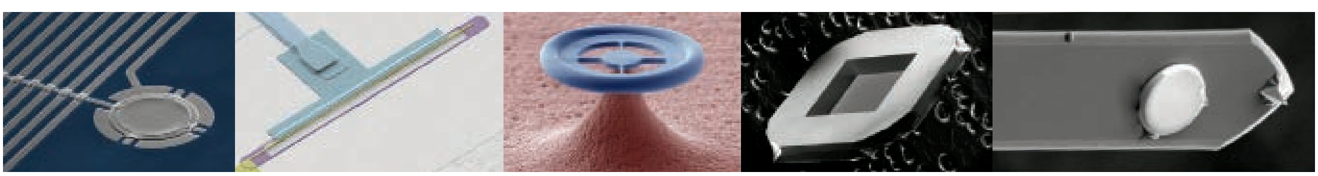
Optomechanical techniques, such as those used by Painter, could also shave the sensitivities of force detectors. At Yale, engineer Hong Tang develops sensors out of light-cooled resonators that promise unprecedentedly low levels of background noise.

"We want to make better accelerometers and better inertia sensors," Tang says. These devices, similar to those that sense the motion of a Wii controller, could measure tiny changes in movement and direction.

Like many other optomechanics researchers, Painter and Tang receive funding from the Defense Advanced Research Projects Agency. DARPA hopes to use laser-cooled sensors to improve the ability of vehicles to navigate underwater, says DARPA program manager Jamil Abo-Shaeer. "We want to push these things to the limits of quantum mechanics, the ultimate limit," he says.

While DARPA funds the development of devices that can't even be seen without a microscope, other scientists are putting optomechanics to work cooling

Opto grab bag Light has been used to cool a range of mechanical objects (some highlighted below, from left) in laboratories across the world. When objects get really cold, some scientists opt to measure temperature in quanta, or packets of vibrational energy, rather than in kelvins.



Device	Drum	Beam	Doughnut	Sail	Stick
Institution	NIST	Caltech	Swiss Federal Inst.	Yale	UC Santa Barbara
Longest dimension	15 micrometers	30 micrometers	30 micrometers	1 millimeter	450 micrometers
Natural frequency	11 million hertz	6 million hertz	62 million hertz	134,000 hertz	12,500 hertz
Cooling achieved	< 1 quanta	4 quanta	63 quanta	6.82 millikelvins	135 millikelvins

FROM LEFT: A. SANDERS/NIST; T. ROCHELEAU *ET AL*/*NATURE* 2010; E. VERHAGEN/EPFL; JACK HARRIS; D. KLECKNER AND D. BOUWMEESTER/*NATURE* 2006 some of the largest detectors in the world: the gravitational wave detectors of the LIGO project, built to search for gentle ripples in spacetime thought to be produced by (among other cosmic events) colliding black holes.

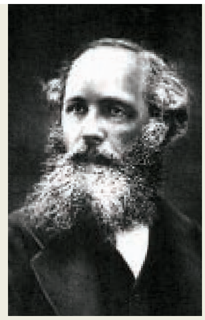
Chasing ever greater sensitivities, these researchers use lasers to still the vibrations of their detectors' giant mirrors — the behemoths of the optomechanical world, weighing in at more than 10 kilograms. Despite their immense size, these mirrors have now been cooled to 234 quanta, MIT quantum physicist Nergis Mavalvala and LIGO colleagues reported in 2009 in the *New Journal of Physics*. "Our challenges are really the same as everyone else's, but we need to somehow cool our gram and kilogram-sized objects to nanokelvins," says Mavalvala.

Working on another gravitational wave detector called AURIGA, researchers in Italy set the record for largest object effectively cooled via optomechanics. An aluminum bar weighing more than 1 ton reached a mere 4,000 quanta, the team reported in *Physical Review Letters* in 2008.

Whether such large mirrors and bars could ever demonstrate quantum effects, though, is an open question. In principle, some physicists say, quantum mechanics should hold for objects of any size. "We don't know of any fundamental limit," Harris says.

Practical considerations may ultimately limit the size of quantum objects, though. Any observation, be it by a pair of eyes or a stray, colliding air molecule, can destroy a quantum state. The larger an object is, the harder it is to keep isolated. But that isn't stopping researchers with bigger objects from lining up behind Cleland and the NIST team to stretch the bounds on quantum effects.

"If we can prove that quantum mechanics holds for larger and larger objects, that would be quite spectacular," says Dirk Bouwmeester of UC Santa Barbara. "But it would also be spectacular if we can prove that it doesn't. New theories would be needed."


FROM LEFT: RAGESOSS/WIKIMEDIA COMMONS; LOVELESS/WIKIMEDIA COMMONS; HAADE/WIKIMEDIA COMMONS

Early pushes

Interest in the pressure exerted by light goes back centuries.

1619 Johannes Kepler suggests that the pressure of sunlight explains why comets' tails (above) always appear to point away from the sun.

1746 Leonhard Euler shows theoretically that the motion of a longitudinal wave might produce pressure in the direction it is propagating.

1873 James Clerk Maxwell (above) uses electromagnetic theory to show that light reflecting off a surface or absorbing into it would create pressure. Bright sunlight, he calculates, would press on the Earth with a force of about 4 pounds per square mile.

1873 That same year, Sir William Crookes invents the radiometer, or light mill (above), incorrectly suggesting that the mill spins because of the pressure of light. Scientists now understand that the heat transferred by light is responsible for the mill's spinning.

1876 Adolfo Bartoli, unaware of Maxwell's work, infers radiation pressure's existence from the second law of thermodynamics.

1900 Russian physicist Pyotr Lebedev announces at a meeting in Paris that he had measured the pressure of light on a solid body.

1903 Ernest Fox Nichols and Gordon Ferrie Hull measure the pressure to an accuracy within less than 1 percent, publishing the work in the *Astrophysical Journal*.

One of the slowest tortoises in the race, Bouwmeester's pace is deliberate. His mirrors, tens of micrometers across, vibrate a mere 10,000 or so times per second and promise an extended quantum lifetime. This durability, he says, is needed to test a controversial idea that gravity and quantum weirdness can't coexist for long at everyday scales.

More than three-quarters of a century of research has made scientists more comfortable with quantum mechanics at small scales, but supersizing it can seem as bizarre today as it did to Erwin Schrödinger. In 1935, he poked fun at the idea in his famous thought experiment: a cat in a box that could be both alive and dead at the same time, as long as no one peeked inside the box and forced a choice, killing with curiosity.

Perhaps it is still too much to imagine Schrödinger's cat behind the drawn curtains of Quantumville's homes, simultaneously nibbling Purina in three different rooms at once. But as researchers continue to cool knickknack after knickknack in their optomechanical grab bag, they may catch at least a faint echo of a meow. ■

Explore more

- F. Marquardt and S. Girvin. "Optomechanics." *Physics*. May 2009.
- To read DARPA's call for proposals in the area of optomechanics, visit http://bit.ly/f6CsDm

Latest research awakens debate over why people can't keep their mouths closed

By Laura Sanders

Scratching relieves an itch, sneezing clears out the nose and drinking relieves thirst. And yawning ... does something.

Researchers have been trying to finish that sentence for centuries. This involuntary, obvious and sometimes contagious behavior afflicts most humans — even those still in the womb — multiple times a day. Yawning isn't even restricted to people: Snakes, ostriches, hedgehogs and fish have been spotted throwing their mouths open for a satisfying yawn. Yet for a behavior so commonplace, the yawn is still a big, gaping mystery.

"Every single day, every person on the planet yawns," says behavioral biologist Andrew Gallup of Princeton University. "Yet we have no idea why it is we do it."

Actually, people have lots of ideas; the problem is that nobody has proposed one that everybody can agree with. New laboratory experiments are only fueling the debate, supporting some theories and contradicting others.

A full-fledged yawn is not restricted to the mouth. Carefully orchestrated pandiculations follow a routine: Lips part, the tongue hunkers down, and muscles in the face, mouth and diaphragm engage as the head tilts back. Air streams in. As the yawn reaches its peak, airflow halts briefly, eyes close, and muscles go rigid as they stretch. The long, slow exhale allows muscles to return to their normal positions.

Many researchers are convinced that this complex series of movements, which takes about six seconds on average, must somehow affect the body.

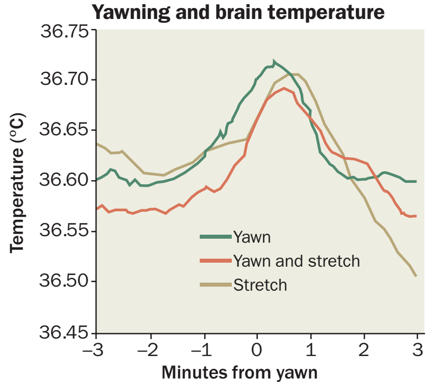
A yawn's obvious gulp of air led many scientists to think that a yawn's job was to replenish oxygen in the brain. So far, researchers haven't found evidence supporting this suspicion. Yawning hasn't been shown to wake up a groggy body or brain, either — a logical expectation, since yawns strike most frequently when a person is tired. Instead, new studies led by Gallup suggest, a yawn may be a thermostat, cooling an overheated brain, a position he argues in the January *Neuroscience and Biobehavioral Reviews*.

Brain chill

After a yawn, rats experienced a temperature drop in their brains, Gallup and his colleagues reported online last September in *Frontiers in Evolutionary Neuroscience*. Beginning about a minute before a yawn, thermometers embedded inside the rats' skulls measured a brain temperature increase of about 0.1 degrees Celsius over the average temperature. Post-yawn, the temperature dropped until it reached its starting point.

In another set of tests, rats yawned more as the temperature rose and their brains heated up, Gallup and colleagues reported in the February *Ethology*.

Cooling yawn Before a yawn, rats' brain temperatures rose. Post-yawn, temperatures dropped. Yawning and stretching (and stretching alone) also showed cooling effects.



SOURCE: M.L. SHOUP-KNOX *ET AL/FRONTIERS IN EVOLUTIONARY NEUROSCIENCE* 2010

When the outside air got too warm, though, the rats yawned less, perhaps because this air was too hot to be helpful. Budgies, a type of parrot, also yawn more when it gets warmer. These results suggest that a big yawn acts as a radiator, bringing cooler blood from other parts of the body up to the brain, while flushing warmer blood down through the jugular vein, Gallup says.

But a yawn might simply happen at the same time as a brain temperature adjustment, says clinical neurologist Adrian Guggisberg of the University of Geneva. The same brain regions could control yawning and brain temperature changes, so that when one occurs, so does the other.

Whether the job of a yawn is to cool or not, it's still true that a warm room can trigger a yawn. Other triggers are obvious to anyone who has suffered through a mind-numbing meeting. Boredom, drowsiness, hunger, stress and anxiety may also be yawn instigators. "All these

Yawn

JOOS MIND/GETTY IMAGES; E. FELICIANO

things can trigger yawns," Guggisberg says, "but then when you look at the actual effect of yawning, then you have more difficulties."

Some researchers have suspected that yawning makes the brain more alert. Yet in human experiments, the brain's electrical activity didn't increase after a yawn, nor did heart rate or sweating, hallmarks of alertness.

With hard evidence lacking for any clear bodily function for yawns, Guggisberg and others have turned their attention to one of yawning's most peculiar features — its contagiousness.

A yawn is powerfully catching, says neurologist Fatta Nahab of the University of Miami in Florida, who has studied what happens in people's brains as they "catch" a yawn. "Here is something where, essentially, it doesn't matter who your volunteer is, how old they are, how young they are," he says. "There's no training involved. You show them a yawn and you're going to get a response back."

This throat-jerk response may be governed by the prefrontal cortex, a part of the brain that becomes more active when people catch a yawn, Nahab and colleagues reported in *Human Brain Mapping* in 2009. Prefrontal lobes may repress the urge to yawn — until the brain detects one in someone else.

Nahab doesn't think that neurons known to become active when a person watches someone else perform an action are required for contagious yawns. These "mirror neurons" aren't any more active when people watch yawns than when watching nonyawn gapes. What's more, infants are thought to have working mirror neurons, yet they can't catch a yawn. "Babies can mimic facial movements, but they cannot mimic a yawn," Nahab says.

Sending a message

Because a yawn is so contagious, Guggisberg and colleagues contend in the April *Neuroscience and Biobehavioral Reviews*, it probably carries a message. And not always a nice one. "The funny thing is that yawns are socially inappropriate in all cultures," he says. "I think this is because people actually do understand the message: 'Hey, I'm bored. Let's change something.' "

Gallup interprets the shame of a yawn differently. To him, a stifled yawn "is an example of a lack of the communicative value," he says. "It's hard for me to believe that yawning can reliably transmit physiological or emotional state," especially since it is often hidden.

Another argument against the idea that yawning sends a social message comes from spontaneous yawning, such as the yawn that strikes in the morning behind a closed bathroom door. Since no one is around to receive the message, it's unlikely that communication is the objective of these solitary yawns, Gallup says.

Yawn empathy

Part of figuring out whether a yawn carries a message involves knowing who can get it. For humans (and perhaps chimpanzees), contagion doesn't seem to kick in until around age 5. Infants and preschoolers don't catch yawns, not even when the yawns come from their own mothers, Ailsa Millen and James R. Anderson of the University of Stirling in England report in an upcoming *Biology Letters*. The youngsters still yawn spontaneously, just not on command. People with schizophrenia and autism aren't as susceptible to catching yawns as others, studies show.

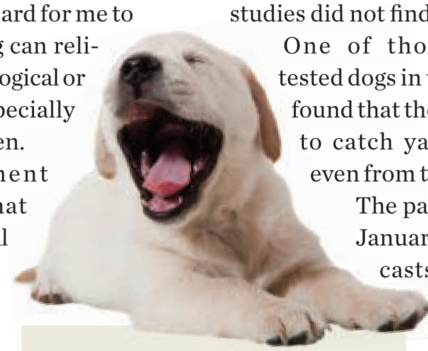
Some scientists think that contagious yawning reflects empathy and social skills, something human babies and people with autism might not have developed.

To test the yawning-empathy link, researchers are looking for other animals that can catch yawns. In 2008, scientists made headlines with a study that suggested dogs can catch yawns from people, perhaps because dogs are supposed to be in tune with their human companions. Since then, two further studies did not find the same effect.

One of those newer studies tested dogs in their own homes and found that the canines didn't seem to catch yawns from humans, even from their familiar owners. The paper, published in the January *Animal Behaviour*, casts doubt on the idea of social yawning (and owner empathy) for dogs. "I'm afraid it's not looking good for canines and contagious yawning," says study coauthor Sean O'Hara of the University of Salford in England.

But evidence favoring empathy's link to contagious yawns comes from a study in chimps. Viewing videos of familiar chimps yawning induced more contagious yawns than videos of yawning strangers, Matthew Campbell and Frans de Waal of the Yerkes National Primate Research Center at Emory University in Atlanta reported in April in *PLoS One*. They suggest that contagious yawning might even serve as a measure of empathy.

Whether or not yawning in other species can explain why people do it, animals' yawns have already helped solve one big mystery — the evolution of life itself. "Seeing a dog and horse and man yawn," Charles Darwin wrote in his notebook in 1838, "makes me feel how much all animals are built on one structure." ■



HELLEM/ISTOCKPHOTO

Anatomy of a yawn

Whether in humans, dogs or other animals, the mechanics of yawning are the same. It begins with a slow, deep inhalation. The mouth and throat gape open; air streams in until the lungs are full. The yawn's apex may bring a brief stillness, often accompanied by closed eyes and a stretch. As the yawn ends, air streams back out, the head, neck and diaphragm muscles return to their resting positions, and the mouth closes.

Explore more

■ A. Guggisberg *et al*. "Why do we yawn?" *Neuroscience and Biobehavioral Reviews*. July 2010.

Atomic anatomy

A century ago, Ernest Rutherford inaugurated the nuclear age

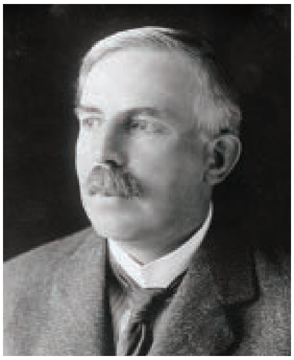
By Tom Siegfried

Ernest Rutherford grew up in the 19th century. He created the 20th.

No discovery struck deeper into the scientific understanding of reality, with more profound implications for civilization, than Rutherford's revelation of the architecture of the atom.

A century ago in May, Rutherford published a paper in the *Philosophical Magazine* interpreting experiments completed two years earlier by his assistants Hans Geiger and Ernest Marsden. They had witnessed the atomic equivalent, as Rutherford later described it, of an artillery shell bouncing backwards off of tissue paper.

It was astounding, unexpected and at first unexplained. Then, after many months of contemplation, Rutherford explained it. The atom had a nucleus.



Ernest Rutherford won a Nobel Prize for research on the nature of radioactivity.

BAIN COLLECTION/LIBRARY OF CONGRESS

At the heart of each atom was a single electrically charged kernel, Rutherford surmised, into which almost all of the atom's mass must be concentrated. The rest of the atom was emptiness, save for the flighty electrons that zipped about at a distance. But Rutherford did not deal with electrons in his 1911 paper. He focused on the atom's core, its "central charge" — soon to be recognized as a storehouse of energy so vast that Rutherford feared it might be unleashed before the world's peoples had learned to live in peace.

Rutherford is sometimes regarded as failing to foresee the explosive consequences of his nucleus, having once declared the practical release of atomic energy to be "moonshine." But he understood better than anyone the immense reserves of energy that the atom had to offer. He was the one, after all, who had figured it out, even before discovering the nucleus.

It was radioactivity that first revealed nature's hidden source of unimaginable power. Henri Becquerel discovered radioactivity, Marie Curie named it, but it was Rutherford who named its various emissions, revealing that their energies emanated not from chemical exchanges between atoms, but from within the atom itself.

Determined and resourceful, clever and tireless, Rutherford pursued the atom's secrets with a tenacity that nature had never before encountered. As the greatest experimentalist of his era (perhaps of any era), Rutherford posed question after question about matter at its most basic; nature yielded answers that it had concealed from human knowledge for millennia. By the time he was done, Rutherford had created the atomic age.

He witnessed the prelude to that age as a student at the famous Cavendish Laboratory in Cambridge, England, where he arrived in 1895, an epochal year in physics. In that year a young chemist in New Zealand, J.C. Maclaurin, was named recipient of a scholarship awarded competitively to students within the British Empire for pursuit of graduate studies anywhere they chose. It was an extraordinary opportunity — only one such scholarship was reserved for a New Zealander every other year. But Maclaurin decided to get married instead and turned down the offer. So the scholarship passed to the runner-up, one Ernest Rutherford, son of a farmer and millerin the remote town of Pungarehu. Upon hearing the news, Rutherford exulted that he would never again have to dig potatoes out of the ground. Instead he could begin to dig into the deepest mysteries of atomic physics.

It wasn't Rutherford's scholarship that made 1895 famous in physics, though. That year's signature event occurred in Germany, when Wilhelm Röntgen detected the mysterious radiation that he christened "X-rays." They immediately caught young Rutherford's attention. His main physics preoccupation before traveling to England had been radio waves, so it seemed necessary to investigate whether Röntgen's rays were similar, or something fundamentally different.

They turned out to be similar in a sense, but much more energetic. With Cavendish director J.J. Thomson, Rutherford established that X-rays passing through a gas generated electrically charged particles. Thomson went on to study cathode ray tubes, showing in 1897 that the beams within them were not like X-rays at all, but rather consisted of minuscule "corpuscles" carrying a negative electric charge. Later known as electrons, Thomson's corpuscles signaled the demise of the indivisible atom. It was left for Rutherford to figure out how the atom's parts fit together.

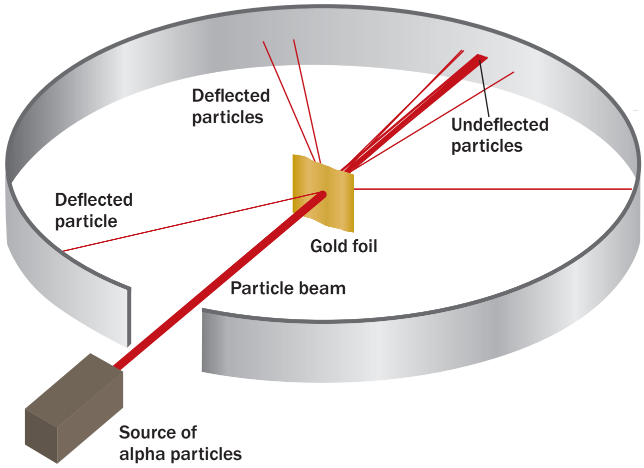
At the time of Thomson's discovery of the electron, Rutherford had turned his attention to mysterious rays newly discovered to emanate from uranium. This "radio-activity," he found, was complex; not all the emitted rays were of the same nature. Alpha particles, beta particles and gamma rays emerged as the prime carriers of radioactivity's energy.

In the midst of these realizations Rutherford left Cambridge for Canada, where he took a professorship at McGill University in Montreal. There he completed the articulation of radioactivity's physical mechanisms, with special assistance from the chemist Frederick Soddy. Rutherford and Soddy realized that they had identified a novel physical process, inconceivable in a universe with atoms that were indestructible (the long-prevailing view). Previously, atoms had supposedly inviolate identities, having been produced in their present form "at the creation." All changes in matter had therefore been presumed a result of chemistry — atoms combining and separating with their various types, each forever maintaining its own integrity. But Rutherford and Soddy demonstrated alchemy — atoms changing into atoms of other types. Nothing less could explain the properties that radioactive substances exhibited. Radioactive energy definitely emerged from within the atom — in tremendous quantities, on a scale many thousands of times the range familiar to chemistry.

Furthermore, Rutherford and Soddy remarked in a paper in 1903, this mysterious new form of energy did not appear

E. FELICIANO

Nucleus detected When Hans Geiger and Ernest Marsden fired alpha particles at a thin gold foil, most passed straight through, deflected only slightly by positive electrical charge in the gold atoms. But a few were highly deflected and some bounced almost straight back, evidence that the atom's positive charge and mass were both concentrated in a tiny core.



to be a peculiarity limited to radioactive substances. It was quite clear (to Rutherford and Soddy, at least) that such huge stores of energy were locked up somehow in all atoms. "The energy latent in the atom must be enormous compared with that rendered free in ordinary chemical change," Rutherford and Soddy wrote. "There is no reason to assume that this enormous store of energy is possessed by the radio-elements alone." That insight came from experiment, two years before Einstein calculated theoretically the vast amount of energy incorporated in mass.

Return to England

By 1908, Rutherford's fame was well-established worldwide, and he received the Nobel Prize in chemistry that year (quite an accomplishment, he observed, for a physicist). A year before he had returned to England, assuming the physics professorship at Manchester. Then began the work that introduced the world to the atomic nucleus.

By that time, several scientists had offered guesses at how an atom's mass and electric charge were distributed. Thomson's popular "plum pudding" model (an elaboration of a suggestion from the distinguished British physicist Lord Kelvin) pictured electrons (plums) dispersed in a positively charged blob of pudding. Others had shown reason to speculate that negative electrons and positive particles paired up in dyads that occupied an atom with lots of space separating them, like so many mosquitoes trapped in a jar. A Japanese scientist, Hantaro Nagaoka, had proposed an atom that looked similar to the planet Saturn, with a central positively charged planet surrounded by electrons orbiting in a ring. But none of the proposed architectures could claim any experimental justification.

Rutherford advised probing the atom with the alpha particles expelled by certain radioactive atoms. (Alpha particles, Rutherford had correctly deduced, were helium atoms with a positive charge.) Among the targets selected for the alpha probes was a very thin gold foil. A thin enough foil, Rutherford reasoned, would contain few enough atoms that the alpha projectiles should zip through as easily as a bullet through a slab of butter. At Manchester, Hans Geiger began work on the experiments, later to be joined by Ernest Marsden.

One day, Rutherford recounted years later, Geiger excitedly reported that some alpha particles had bounced backward upon encountering the foil.

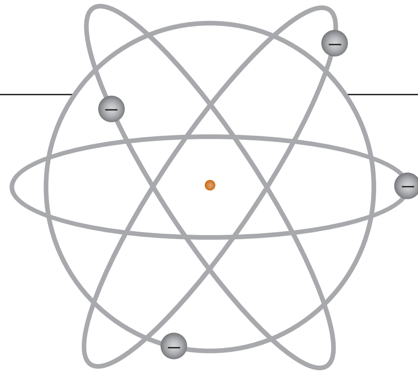
"It was almost as incredible," Rutherford recalled, "as if you fired a 15-inch shell at a piece of tissue paper and it came back and hit you."

But it was a couple of years before Rutherford could discern an explanation. No number of small deflections by the gold atoms' internal electric charges could have diverted an alpha particle's path so dramatically, he determined, applying some statistical probability calculations (he had once audited statistics classes to prepare himself to deal with such issues). Instead, this type of large deflection could result only from a single encounter, implying that a dense concentration of electric charge sat at an atom's core.

"Considering the evidence as a whole," Rutherford wrote in his 1911 paper, "it seems simplest to suppose that the atom contains a central charge distributed through a very small volume." Soon thereafter Rutherford adopted "nucleus" to refer to the central mass carrying that charge. Calculations showed that such a nucleus extended only about a mere trillionth of a centimeter across, compared with the whole atom's size of something like a hundred-millionth of a centimeter, 10,000 times greater. In modern imagery, the nucleus was the size of a marble sitting on the 50-yard-line of an atom the size of the entire football stadium, electrons occupying the cheap seats.

At first, no one seemed to notice the dramatic ramifications of the new atom model. Two years later, though, Niels Bohr combined Rutherford's model with quantum physics to explain mysterious regularities in the light emitted by hydrogen atoms. In the years that followed, the atom-with-nucleus served as the backdrop for the formulation of quantum mechanics, and Bohr much later went on to explain how the nucleus behaved like a drop of (albeit very dense) liquid. Then in 1938, nuclear fission was discovered in Germany; the Manhattan Project soon exploited it to build atomic bombs, and the world entered a nuclear age that redefined the rules of war and peace and exposed the fragility of civilization.

Rutherford didn't live to see fission or the bomb; he died in 1937, shortly after suffering internal injuries incurred when he fell while cutting a tree branch. It was a loss that other physicists found difficult to fathom. Eulogies recalled his tireless pursuit of experimental answers to every new question; his robust exertion of personal authority with just the right mix of bombast and humility; his penchant for roaming the lab singing "Onward, Christian Soldiers"; his simplicity and directness when dealing with physics and with people. Those who worked with him remembered him forever after as "a rich source of encouragement and fortitude," Bohr once remarked. "Our memories will always remain irradiated by the enchantment of his personality."



Mostly empty
Rutherford revealed that almost all of an atom's mass is concentrated in a very small and dense nucleus (orange), shown here roughly 1,000 times larger than its actual size relative to the whole atom.

E. FELICIANO

Follow the neutrons

In the years after the discovery of the nucleus, Rutherford continued to lead the assault on the atom's secrets, taking over directorship of the Cavendish itself in 1919. He advised or participated in the Nobel Prize–winning work of several other Cavendish scientists, including a landmark experiment by E.T.S. Walton and John Cockcroft in 1932. They split a lithium nucleus into alpha particles, with an energy release providing the first direct experimental confirmation of Einstein's $E=mc^2$. Rutherford also predicted the existence of a new nuclear particle — the neutron — a dozen years before its discovery at the Cavendish by James Chadwick, also in 1932.

It was the neutron, Rutherford noted, that might permit the atom's energy to be released on a large scale for practical (such as military) use. During World War I, he had remarked on how a pound of radium contained the energy equivalent of 100 million pounds of coal. He mentioned that he was not eager for anyone to learn how to speed up its release in a world that had not yet learned to live without war.

By the 1930s, Rutherford knew that producing neutrons in copious quantities would enable rapid and vast release of atomic energy. But he still knew of no such source of neutrons, so producing practical amounts of energy from his nucleus did "not look very promising." Fission's discovery changed all that, though, as each splitting nucleus released enough neutrons to split others, generating the chain reaction behind both bombs and nuclear electric power generation.

In the year before fission's discovery, Rutherford's sudden death at age 66 left physics with a void that remains unfilled. Nobody since has animated the discipline with such a combination of personal presence and scientific power. His old collaborator Soddy remarked that "Rutherford's death removes from science the most outstanding personality of the age." Bohr commented that Rutherford "will be missed more, perhaps, than any scientific worker has ever been missed before." And of the man whom Bohr regarded as "almost like a second father," Bohr offered a final scientific assessment: "We may say of him, as has been said of Galileo, that he left science in quite a different state from that in which he found it." ■

Promising new Alzheimer's model

"Memories can't wait" (*SN: 3/12/11, p. 24*) was a well-written analysis of the problems facing those of us working in the field of geriatric psychology. The new research model based on inflammation is very promising. From a cost-benefit standpoint, early diagnosis and preventive treatment of potential Alzheimer's patients will be essential for Medicare to survive.

Joe Roberts, Jackson, Miss.

Mapping diabetes

I read with interest the article titled " 'Diabetes belt' cinches the South" (*SN: 4/9/11, p. 14*). Looking at the map, I noticed that the high diabetes rates in the western states seem to correlate strongly with American Indian reservations. Have there been any studies that indicate Native Americans have higher incidences of diabetes? If so, is it lifestyle or biology?

Other areas of the map, specifically in southwest Wyoming, Colorado and northern New Mexico, seem to show a lower incidence of diabetes, which may be worth more study. I wonder if this is due to something in the lifestyle that can be exported or to the climate or elevation, which cannot. Or perhaps the lower rates are caused by bad or limited data. In any case, studying areas with lower rates might give as much useful information as studying the counties of high incidence.

Thank you for the excellent magazine.

John D. Underwood, Terrell, Texas

The reader makes a good observation — there is a high prevalence of diabetes on some American Indian reservations, which is reflected in the map. Study coauthor Lawrence Barker of the CDC acknowledged this during an interview. And indeed, the lower rates in some areas may point to new strategies in lowering diabetes rates in other communities. The lower rates may be explained by something straightforward such as a healthier lifestyle, though the data used in the map do not address underlying causes. — Nathan Seppa

Dangerous knowledge

The problem, as discussed in the David Nichols interview ("The costs of putting knowledge into the wrong hands," *SN: 2/26/11, p. 32*), is not with the free exchange of knowledge but rather with the government's drug prohibition policy. By suppressing the relatively safer drug MDMA (ecstasy), moralists are acting with the same ruthlessness that led to, during alcohol prohibition, the poisoning ("denaturing") of industrial alcohol — a policy that resulted in an estimated 10,000 deaths.

Terry Franklin, Amherst, Mass.

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

Science Fair Season

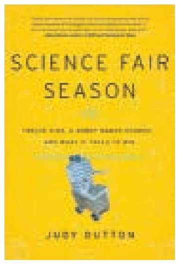
Judy Dutton

Ask most teenagers to name a path to fame and fortune, and basketball or Justin Bieber will likely come up. But for a select few, there's one clear answer: science fair. Millions of dollars in prize money, TV interviews and trips to the White House await today's winners, and Dutton gives a glimpse behind the poster boards of 12 kids vying for the nation's top honors.

Every year, more than 1,500 high schoolers from around the world convene for the science fair Super Bowl, the Intel International Science and Engineering Fair, a program of Society for Science & the Public, which also publishes *Science News*. Dutton tells the stories of seven contestants in Intel ISEF 2009, plus five competitors from previous years whose stories have become the stuff of science fair legend.

Among them are Kelydra Welcker, whose work on chemical contaminants in her West Virginia hometown landed her on an FBI terrorist watch list, and Taylor Wilson, who wheeled into the fair a nuclear fusion reactor he had built in a basement.

Teenagers coming up with new nanotechnology and genetically engineered worms are impressive, but some of the most compelling stories feature simple science done against all odds. Garrett Yazzie's is one of the most engrossing: The Navajo boy pieced together a radiator from a 1967 Pontiac with other junkyard finds to build a solar-powered heater for his mother's dilapidated trailer. Dutton does readers a service by including kids who show that science is not just for the one-in-a-million genius; great ideas can come from humble beginnings. While light on scientific detail about the projects, the book succeeds in keeping its focus on the real inspirations: the kids. *—Erika Engelhaupt*



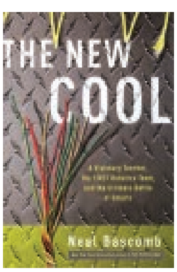
Hyperion, 2011, 288 p., $24.

The New Cool

Neal Bascomb

With seconds on the clock, a nervous high school senior named Kevin lines up the shot. He presses a button, and half a dozen balls fly through the air. The D'Penguineers win; the crowd goes wild.

In his latest book, Bascomb makes the case that high school robotics competitions can be every bit as cool as sports. He chronicles the daily dramas of a California team on the path to FIRST, a competition that attracts hundreds of thousands of students annually.



Nerds are the heroes of this epic tale, starting with Dean Kamen, inventor of the Segway and founder of the competition in 1989. The team's leader is Amir Abo-Shaeer, an engineer turned teacher. His dream: to create a new hands-on approach to high school education at Dos Pueblos Engineering Academy.

Abo-Shaeer guides 31 seniors through the day-to-day challenges of designing, building and debugging a robot. Meet Gabe, who wrote his first computer program at age 5. Cheer for Chase, a snowboarder and team captain, as he pilots the robot to victory after victory.

All in all, the book reads like a feel-good sports movie, peppered with high school banter and physics lessons. Expect close-ups of competitors dealing with nerves and blow-by-blow descriptions of robots shooting balls like mechanized Michael Jordans.

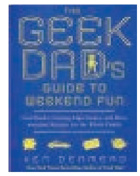
Bascomb spends little time exploring the problems in U.S. science and engineering education that motivate the competition. But readers concerned about these issues may find comfort in a book that's just as enthusiastic as its protagonists—some of the best and brightest kids in the nation. *—Devin Powell*

Crown Publishers, 2011, 337 p., $25.

Success with Science

Shiv Gaglani, ed.

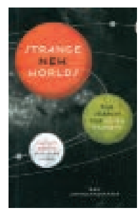
In this guide to high school research, five Harvard students and past competition winners give tips on project ideas, finding mentors and more. *Research Corp. for Science Advancement, 2011, 180 p., $19.95.*



The Geek Dad's Guide to Weekend Fun

Ken Denmead

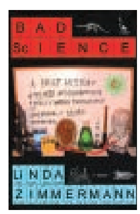
All the entertainment a geek family could want is packed into this how-to book, from backyard zip lines to homemade robots. *Gotham Books, 2011, 227 p., $18.*



Strange New Worlds

Ray Jayawardhana

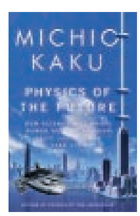
Engaging stories of astronomers and their quest to find Earthlike planets orbiting distant suns, and even signs of life. *Princeton Univ. Press, 2011, 255 p., $24.95.*



Bad Science

Linda Zimmermann

A brief history of science blunders through the ages, including radium cures and phrenology, the reading of head bumps. *Eagle Press, 2011, 224 p., $14.95.*



Physics of the Future

Michio Kaku

A physicist interviews over 300 scientists and lays out a mostly rosy vision of research advances that he predicts will shape the world by 2100. *Doubleday, 2011, 389 p., $28.95.*

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James P. Evans

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Mind the gap: Genetic knowledge and medical power

Since the completion of the Human Genome Project a decade ago, much excitement has swirled around the possibility that determining a person's genetic makeup could help doctors personalize the diagnosis, treatment and prevention of disease. But James P. Evans, a physician and geneticist at the University of North Carolina at Chapel Hill, says the promises of genomic medicine have been overblown. He talked with Science News *molecular biology writer Tina Hesman Saey about the hope and hype.*

Will knowing a person's genetic makeup make health care better?

There's lots of excitement about the use of genetics and genomics in medicine, but the promise of that, I think, has been oftentimes misconstrued.

We've heard many claims that refining an individual's risk for a variety of common diseases like heart disease and cancer will lead to better care for them, but there is frankly just no evidence that that is the case.

The risk factors for common diseases are predominantly not genetic. So even when we can define the sum total of an individual's genetic risk for cancer and heart disease, that only gives us a very small part of the picture. Common diseases are, by definition, common. You can do all the fiddling and refining of an individual's risk, and the fact is that these are such common diseases, things like cancer and heart disease, that even for individuals who are at relatively reduced risk as compared with the rest of the population, they're still likely to die of those diseases. In other words, refining one's relative risk for common diseases is meaningless in any practical terms because our absolute risk for those diseases is so high.

Secondly, we hear claims that by analyzing your risk for say heart disease and diabetes, that knowledge will motivate people to lead healthier lifestyles. There's not a whit of evidence to suggest that.

What is the real potential of genomic medicine?

Our burgeoning understanding of the genetic basis of disease will add immensely to our fundamental knowledge about those diseases. While it takes a long time to realize the practical benefits of such increased knowledge, that really is how science and how medicine works, and I think that we should not be too impatient and necessarily demand or expect tangible clinical outcomes in the near term. We need to get across to the general public that medicine and science move in incremental ways, and understanding more about these diseases will eventually pay off even if they don't pay off immediately.

Our ability to sequence all of the genes in an individual or their entire genome will be a huge boon as a diagnostic tool to the small percentage of individuals who have diseases that result from discrete genetic [defects].

Another area that genomic medicine shows great potential in would be in the public health context. With these approaches, we now have the potential to identify asymptomatic individuals who are at high risk of preventable disorders — for example, that small percentage of people who have mutations that put them at high risk of breast cancer, colon cancer and lethal cardiac dysrhythmias. If you add up all the genes with mutations that lead to such dire risks you quickly get to 1 to 2 percent of the U.S. population walking around with such risks that are potentially identifiable by whole genome sequencing.

UNC LINEBERGER COMPREHENSIVE CANCER CENTER

Even when we can define the sum total of an individual's genetic risk for cancer and heart disease, that only gives us a very small part of the picture.

The other area in which I think there is tremendous potential is in carrier screening for rare autosomal recessive diseases. Right now when a woman or a couple is planning a pregnancy there are just vanishingly few genes in which mutations are common enough that it makes sense to say to that couple, "You know what? You could both have genetic testing."

We now have reached the point with genomic analysis where we can in principle — and this is now being done by certain laboratories — say we're going to take a look at hundreds of your genes that, when mutated, have a risk of a really, really bad disease in your offspring and we're going to now offer you that so you can use that information, if you so desire, in family planning.

What can we do to make expectations more realistic?

We can simply insist that if a company says X, Y, Z will enhance your health and is a useful health tool then they need to have some evidence that that is the case. If people are interested in their genome and they want to spend the money for it, I think that's great. I just think they deserve an honest accounting of its actual utility.

I think the press can help by restraining its understandable tendency to couch every advance in terms of breakthroughs and immediate clinical benefits. The other way to get around all this and avoid overhyping is to educate the public about how science really works. ■

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