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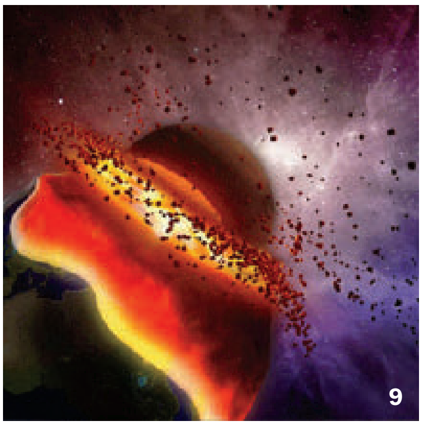
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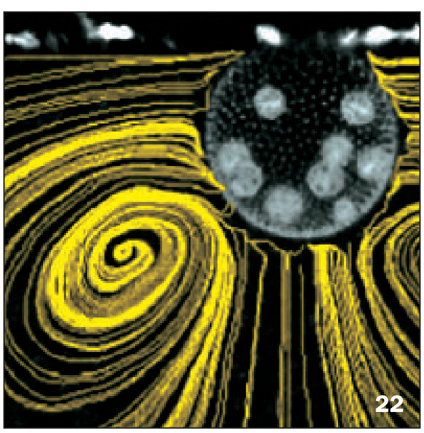
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SNAKE IMAGE: GRACE PRYOR, MIKE SHELLEY, DAVID HU, NEW YORK UNIVERSITY, GEORGIA TECH

ScienceNews

In The News

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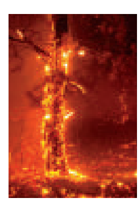

COVER A tree burns in a forest fire in Turkey last year, a glowing reminder of fire's dramatic destructive power. *Photograph by Aykut Ince*

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FROM THE EDITOR

DNA's medical power may someday match its hype

Of all the molecules scientists have ever contemplated, DNA stands out both for engendering hope and inspiring hype.

Sure, there are other molecules with claims to serious societal impact. There's water, of course, and TNT, nicotine, dopamine and serotonin, and various petroleum hydrocarbons, not to mention ethanol. Life wouldn't be the same without them.

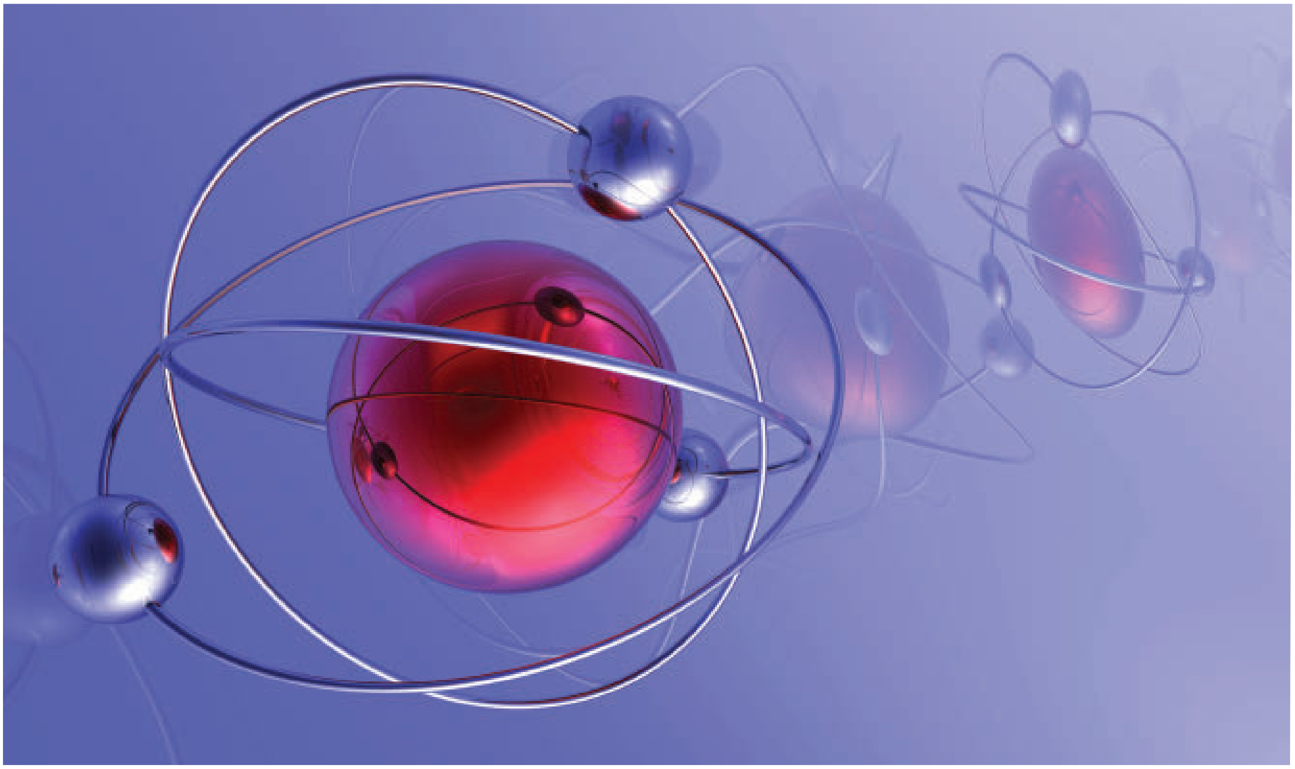
But life wouldn't be life at all without DNA. Yes, you need water too, but water without DNA is lifeless. DNA is life's master molecule, the record of evolution, the stuff of genes that code for life's multivarious designs. DNA is the superstar of cellular vitality, the storehouse of genetic information from which all of life's power emerges.

"Genetic power is the most awesome force the planet's ever witnessed," as the fictional chaotician Ian Malcolm proclaimed in the movie *Jurassic Park*.

Besides all that, DNA holds the secrets to many aspects of each individual's medical future, as freelance writer Patrick Barry reports in this issue (Page 16). Prying those secrets loose, though, is not necessarily as easy as some DNA devotees would have you believe. Science does not yet know how to translate the slight genetic spelling differences from person to person into precise forecasts of medical maladies. DNA analysis services offered by many companies today provide at best rough probabilities of future medical problems, based on a variety of assumptions and suppositions. Interpreting such DNA data is not simple and straightforward. DNA disease predictions still aspire to be as reliable as forecasts of next week's weather.

Genes do, of course, wield powerful influences on a body's health or lack thereof. But so do multiple aspects of lifestyle and environment. And even the contribution from genes alone is often perplexingly complicated, as networks of genetic interactions encompassing hundreds of genes underlie many common diseases.

So just as creating *Jurassic Park*'s dinosaurs still exceeds science's current power, reliably predicting anyone's future health problems remains, for now, mostly beyond the reach of DNA analysis. Still, scientists are always improving their understanding of genes and disease, so DNA's power as a medical oracle may someday rival its role as stimulus for science fiction. Chances are good that you'll see accurate medical prognostics from DNA before you'll see real live velociraptors at amusement parks.
—Tom Siegfried, Editor in Chief



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Science Past | FROM THE ISSUE OF JULY 4, 1959

BRIDES AND GROOMS ARE YOUNGER THAN EVER — Today's brides and grooms are younger than any others in the nation's history, the Population Reference Bureau reported. The average age for first marriages in the U.S. last year was 23 for men and 20 for women. More girls married at 18 than at any other age. In 1890, men averaged 26 at first marriage and women averaged 22. Since then, the average age has been declining slowly but steadily.... The Bureau offered no reason for the trend toward early marriages. Factors believed to contribute, however, are the nation's continued economic prosperity, teen-agers "going steady" at progressively younger ages, and a significant percentage of pre-marital pregnancies in young girls.

Science Future

July 19–23
Get curriculum training at the NEED National Energy Conference for Educators in Nashville. See www.need.org/training

July 31
Deadline for submissions to the Imagine Science Film Festival in New York City. Get more info at www.imaginesciencefilms.com

October 28–November 1
Society of Hispanic Professional Engineers conference in Washington, D.C. Visit www.shpe.org/shpe2009

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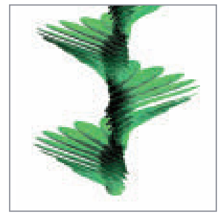
LIFE

Maple seeds whirl through the air with the help of a single wing and a heavy body. The flying stunt helps spread seeds far from the parent tree. See "How maple fruits fall" for video and story.

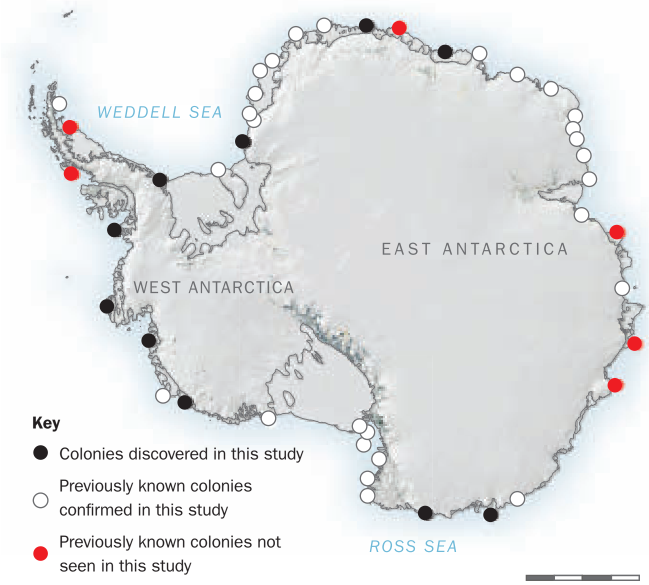


EARTH

An explosion of agriculture in 18th century Asia led to the destruction of huge swaths of forest. New analyses show the deforestation may have triggered the drier seasons that followed. Read "Cultivation changed monsoon in Asia."

Science Stats | PENGUINS FROM SPACE

Emperor penguin breeding colonies in Antarctica identified by fecal-stained ice in study of satellite images



Key
- ● Colonies discovered in this study
- ○ Previously known colonies confirmed in this study
- Red ● Previously known colonies not seen in this study

SOURCE: FRETWELL AND TRATHAN/*GLOBAL ECOLOGY AND BIOGEOGRAPHY* 2009

Introducing…

A newly described tyrannosaur species was small enough to have looked humans in the eye. *Xiongguanlong baimoensis* lived in what is now China between 110 million and 120 million years ago, says paleontologist Peter Makovicky of Chicago's Field Museum. That era lies well within a 40-million-year–long gap in the tyrannosaur fossil record, he and colleagues note online April 21 in *Proceedings of the Royal Society B.* Remains of the creature suggest that it weighed about 270 kilograms and was roughly 2 meters tall when measured at the hips. So, the species also fills the size gap that accompanies the time gap in the fossil record, falling between the smaller, older *Dilong paradoxus* and the larger, more recent *Tyrannosaurus rex*.

CLOCKWISE FROM TOP LEFT: HUNTSMAN CANCER INSTITUTE; MODIFIED FROM D. LENTICK; M. DONNELLY/FIELD MUSEUM; BRITISH ANTARCTIC SURVEY

“They look like a little magenta fireball dropping out of the sky.” — CHRIS CLARK, PAGE 7

In the News

STORY ONE

Giant black holes in nearby galaxies may be more massive than thought

Simulations, observations may resolve long-standing puzzle

By Ron Cowen

PASADENA, Calif. — And now for something truly monstrous.

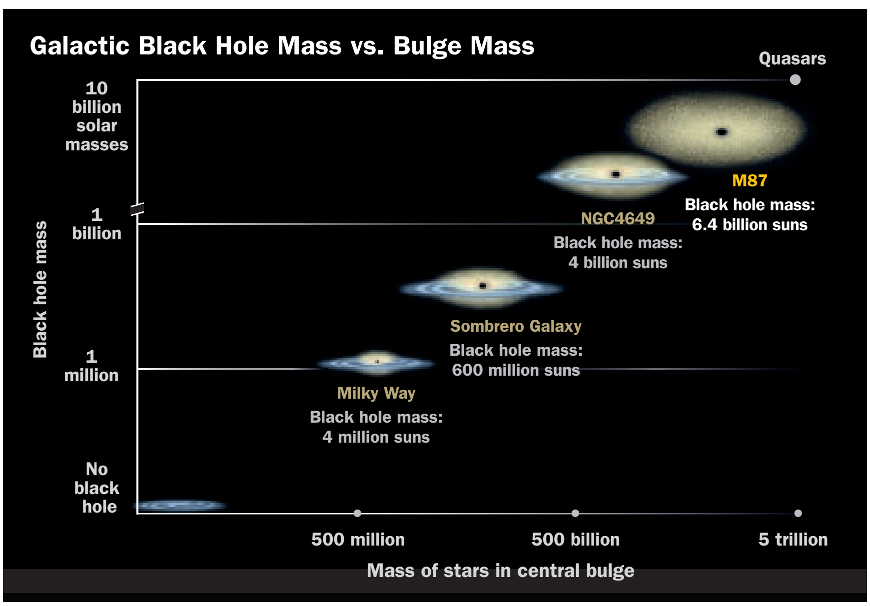
Astronomers report that some of the biggest supermassive black holes in nearby galaxies are at least twice and possibly four times as heavy as previously estimated. The findings come from new simulations by two independent teams of researchers, as well as new observations of stars whipping around a handful of supermassive black holes at the centers of massive galaxies no more than a few hundred million light-years from Earth.

The results, some of which were reported June 8 at a meeting of the American Astronomical Society, may resolve a long-standing puzzle about the mismatch between the calculated masses of giant black holes in distant versus nearby galaxies. The findings also suggest that supermassive black holes, known to grow in lockstep with a galaxy’s central bulge of stars, may play an even bigger role in governing the growth and maximum size of galaxies than has been suspected.

In simulations presented at the meeting, Karl Gebhardt of the University of Texas at Austin and Jens Thomas of the Max Planck Institute for Extraterrestrial Physics in Garching, Germany, used a supercomputer to recalculate the mass of the biggest black hole in the nearby universe, which lies at the center of the galaxy M87 some 50 million light-years from Earth. The team’s study is the first to include the presence of dark matter in assessing the mass of a giant black hole. Dark matter, the invisible material believed to make up about 85 percent of the mass in the universe, envelops each galaxy in a vast halo.

By clocking how rapidly stars orbit the galaxy’s center, researchers can measure the total mass of the stars plus the black hole in the galaxy’s central region. To figure out how much mass the black hole contributes, astronomers have to determine the mass of the stars and subtract it from the total. But calculating stellar mass turns out to be tricky.

At first glance, dark matter wouldn’t seem to be important in calculating stellar mass in a galaxy’s center because the invisible stuff is negligible at the core of a galaxy. But it comes into play because of the indirect method astronomers use to



Black holes and bulges
The mass of a galaxy’s central black hole and of its central bulge of stars appear to grow in lockstep (shown at left). A new, higher mass computed for the supermassive black hole at the center of the nearby elliptical galaxy M87 (above) could change this relationship. The new mass more closely matches that of central black holes in distant galaxies, as measured by the light intensity of quasars that those black holes fuel.

FROM LEFT: TIM JONES/UNIV. OF TEXAS AT AUSTIN, K. CORDES AND S. BROWN/STSCI; ROBERT GENDLER

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measure the stellar mass, the team said.

Astronomers calculate that mass by recording the amount of starlight and using a relationship, called the mass-to-light ratio, to translate the intensity of that starlight into stellar mass. In the past, calculations of that ratio assumed that all the measured mass was in stars. But many stars reside in the outer regions of a galaxy, where they are outweighed by dark matter. Subtracting the dark matter from the total mass lowers the amount of mass attributed to stars, reducing the mass-to-light ratio, Gebhardt said.

He and Thomas found that the mass-to-light ratio for stars is about half the old estimate.

Using the revised ratio, and assuming that stars' mass-to-light ratio is the same in the inner part of the galaxy as in the outer part, the team found a much lower stellar mass near the core and therefore a much higher mass for the black hole. The team reported that the black hole in M87 weighs the equivalent of 6.4 billion suns, about twice as much as the currently accepted estimate.

Unpublished simulations of three other galaxies show signs of a similar increase, and high-resolution observations of M87 agree with the revised theoretical estimate, Gebhardt said.

"It's high time that someone included the effect of dark matter," comments John Kormendy of the University of Texas at Austin. The revised mass estimates, he said, "will have a welcome audience." That's because for more than 25 years it has been a puzzle why the most luminous distant quasars are powered by black holes weighing the equivalent of 10 billion solar masses, yet no nearby black holes appeared to be as hefty.

With the new mass estimate, the black hole in M87 is now a much closer match to the mass of those that power quasars in the distant universe, says Avi Loeb of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass.

Loeb says the result can be immediately tested by imaging the shadow cast by the black hole when it absorbs radiation emitted from material that lies behind it. If the mass is truly double its original estimate, the shadow ought to be visible with existing telescopes, Loeb says.

While solving one puzzle, the new work might force scientists to reevaluate the established link between the mass of a galaxy's black hole and the mass of the galaxy's central bulge of stars. In 2000, Gebhardt and others found that the bulge is always about 500 times as heavy as the galaxy's black hole (*SN: 1/22/05, p. 56*). Though the reason is unclear, it suggests that supermassive black holes and the galaxies in which they live have a profound influence on each other. The new calculations appear to increase the heft of black holes in the heaviest galaxies only, Gebhardt said, possibly altering the relationship for these galaxies.

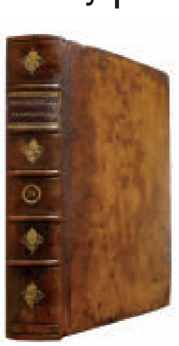
Another team, including Remco van den Bosch of the University of Texas at Austin, used a type of analysis that doesn't include dark matter and also found that supermassive black holes may have double their previously estimated masses.

The researchers say that massive galaxies tend to be more like squashed footballs, with stars on highly elongated orbits, than like disk-shaped, smaller galaxies. If the true orbits of these stars are ignored, astronomers calculate slower stellar speeds and dramatically underestimate the mass of the central black hole. In the one massive galaxy, called NGC 3379, for which the team did its analysis, the estimated mass of the black hole doubled, the team reports online.

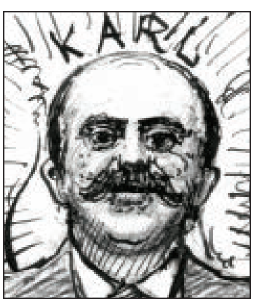
Kormendy says that when the effects detailed by both teams are combined, the estimated mass of giant black holes in nearby galaxies may be quadrupled.

"Stay tuned," says Kormendy. "The story isn't over yet." ■

Back Story | BLACK HOLE THEORY AND DISCOVERY

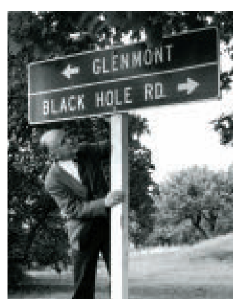


1783
John Michell proposes that there may be bodies whose gravity is so strong that light cannot escape. (The *Physical Transactions* containing his paper is shown.)

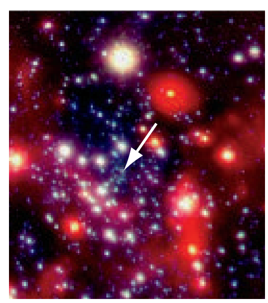


1916
Using Einstein's equations, Karl Schwarzschild determines how spacetime is curved around a nonrotating spherical mass.

1939
J. Robert Oppenheimer (shown) and Hartland Snyder report that a star could collapse into an object so dense that not even light could escape.



1967
John Wheeler, shown here in 1981, coins the term "black hole."



2000
A study in *Nature* provides convincing evidence, based on measurements of star velocities, that there is a black hole (arrow) at the center of the Milky Way.

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Life

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Hummingbird pulls Top Gun stunts

For its size, the courting flier dives faster than a fighter jet

By Susan Milius

They may wear too much pink to fit in among macho fliers. But when male Anna's hummingbirds swoop out of the sky, they pull more g's than any known vertebrate stunt flier outside a cockpit, says Chris Clark of the University of California, Berkeley.

During courtship displays, a male hummingbird soars to some 30 meters and then dives, whizzing by a female so fast that his tail feathers chirp in the wind. As the bird pulls out of his plunge to avoid crashing, he experiences forces more than nine times the force of gravity, Clark reports online June 9 in *Proceedings of the Royal Society B*.

"They look like a little magenta fireball dropping out of the sky," Clark says.

This study shows "to what extraordinary lengths these birds are willing to go to impress potential mates," says Doug Altshuler of the University of California, Riverside. It could open new opportunities for studying sexual selection.

Clark set out a caged female or a stuffed female to inspire birds to dive in front of his video cameras. Analyzing the recordings revealed that birds at first flapped their wings as they dove. For short periods, the birds folded their wings and drilled down through the air reaching speeds up to 27.3 meters per second (61 miles per hour).

Adjust for body length, and the world just got a new fastest bird, Clark says. The hummingbirds' speed reached 385 body lengths per second, easily beating the peregrine falcon's recorded dives at 200 body lengths per second. A fighter jet with its afterburners on reaches 150 body lengths per second, and a space shuttle screaming down through the atmosphere hits 207 body lengths per second.

This composite image shows the swoop of a male Anna's hummingbird as he displays his flight skills for a female.

Scales provide a smoother slither

New study shows how push, friction move snakes forward

By Rachel Ehrenberg

A slithering snake gets a leg up from its scales, which provide much needed friction for forward movement, scientists report online June 8 in the *Proceedings of the National Academy of Sciences*. On a flat surface, the grip provided by scales goes hand in hand with a precise redistribution of body weight, suggesting snakes tailor their gait to their environment.

"You would think that if you were basically a living string, your life would be very simple," says lead author David Hu of the Georgia Institute of Technology in Atlanta. "But there are all different ways of moving — there may be real physical reasons underlying when snakes change gaits."

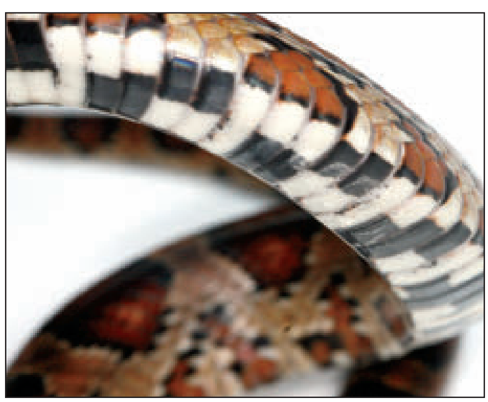
Hu and his collaborators used video and mathematical models to analyze the distribution of forces as a milk snake moves forward on a flat surface with little to push against. This "terrestrial lateral undulation" is one of three standard snake gaits.

The findings reveal that snakes use a combination of pushing off the surface and gripping, which increases friction ,to propel themselves forward. While friction accounts for about 65 percent of the forward movement, the push accounts for the other 35 percent, models showed.

Because scale layers are arranged like shingles on a roof, the greatest friction would have been expected when sliding backward against the scales' edges. But experiments found that it was easier to slide an anesthetized snake backward or forward than to slide it sideways.

This finding fits the notion that snakes have a "remarkable capacity to manipulate their belly scales," says functional morphologist Bruce C. Jayne of the University of Cincinnati. Many snakes have specialized muscles that may change the orientation of the scales, Jayne says.

The work may have implications for designing better robots, says Alessandro Crespi of the Swiss Federal Institute of Technology in Lausanne.



Friction between a snake's scales and a flat surface makes it harder for a snake to slide sideways than forward.

FROM TOP: C. CLARK; GRACE PRYOR, MIKE SHELLEY, D. HU, NEW YORK UNIVERSITY, GEORGIA TECH

Atom & Cosmos

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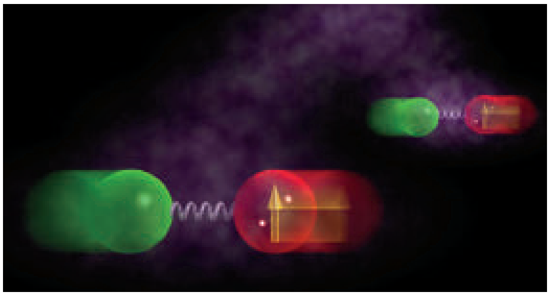
Physicists get good vibrations on entanglement

'Spooky action at a distance' achieved with oscillating ions

By Laura Sanders



Linked motion
Researchers have entangled the motion (represented in purple) of two pairs of ions, even though the pairs are far apart. Each pair contains a magnesium ion (green) and a beryllium ion (red), which behave like balls connected by a spring. The team began by linking the internal spin states of the beryllium ions (arrows).

Researchers have linked the vibrations of two separated atom pairs, catching sight of a strange quantum effect called entanglement in a mechanical system that approaches the scale of everyday life. This new link between two pairs of oscillating ions, reported in the June 4 *Nature*, "pushes the bounds on where entanglement can be seen," says study coauthor John Jost of the National Institute of Standards and Technology in Boulder, Colo.

Quantum entanglement, a mysterious connection between far-flung particles that Einstein called "spooky action at a distance," has been confined to the microworld of tiny particles including photons, atoms and "other things that are not easy to relate to," Jost says.

The springlike, oscillating connection between the two tiny atoms shares mechanical properties with macroscopic systems such as violin strings and clock pendulums. By entangling the motion of one pair of atoms with the motion of another pair, Jost and colleagues may permit "quantumness" to creep into the real world.

"We all want to move quantum mechanics to the macroscopic world we live in," says Christopher Monroe, a quantum physicist at the University of Maryland in College Park. "But it's really hard, and that's why it hasn't been done."

For their mechanical system, Jost and colleagues co-opted two pairs of positively charged ions — each pair had one beryllium and one magnesium ion. Electrodes held the ions in place while researchers entangled the two beryllium ions' internal states, known as spin states.

The researchers then separated the ions into the two pairs and used a series of precisely tuned laser pulses to transfer the entanglement from the internal state of each beryllium ion to the oscillating motion between each beryllium ion and each magnesium ion. At this point, the pairs of ions vibrated in unison about .24 millimeters apart, setting up a system in which, the team says, a poke to one pair would have an effect on the other.

"This is an incredibly difficult experiment," Monroe says. "They move the atoms around very gently and keep all the little pieces in line."

Successfully playing puppeteer with entangled beryllium ions and preserving entanglement even as it is transferred to the larger system may come in handy as researchers search for signs of entanglement in bigger systems. "It is applicable to tests of entanglement and why we don't see it in everyday life," Jost says.

The line of separation between the quantum world and the macroscopic world is still unclear, and it's an issue that interests many researchers. Now that entanglement has been demonstrated in a mechanical system, says Monroe, scientists may be able to apply the findings to larger mechanical systems. Quantum mechanics shouldn't care whether a system involves a couple of atoms or trillions of atoms, he says. "The quantum physics is exactly the same." ■

ILLUSTRATION BY J. JOST WITH JASON AMINI

Astrometry nabs its first exoplanet

Method provides more precision for mass measurements

By Ron Cowen

Researchers for half a century have tried — and failed — to use the motion of a star moving across the sky to discover planets that lie beyond the solar system. Now a team has finally used the method, known as astrometry, to find one.

The planet, about six times the mass of Jupiter, orbits the star VB 10, some 20 light-years from Earth, report Steven Pravdo and Stuart Shaklan of NASA's Jet Propulsion Laboratory in Pasadena, Calif., in an upcoming *Astrophysical Journal*.

The traditional method of identifying extrasolar planets, 350 of which are now known, tracks the velocity of a parent star along the line of sight to Earth, rather than across the sky. Because a planet pulls its star slightly to and fro, the star's line-of-sight motion speeds up and slows down periodically, revealed by shifts in the color of starlight. This technique, known as the wobble or Doppler shift method, reveals only the minimum mass of a planet. In contrast, astrometry pins down a planet's exact mass.

Researchers have previously used astrometry to measure the precise mass of planets found with the wobble method, but this is the first time the technique has been used to discover an extrasolar planet, says Alan Boss of the Carnegie Institution for Science in Washington, D.C.

1	Exoplanets found using astrometry	**350+**	Exoplanets found using other methods

Gravity's influences could mean bumpy ride for inner solar system

New simulations describe scenarios for smashing planets

By Sid Perkins

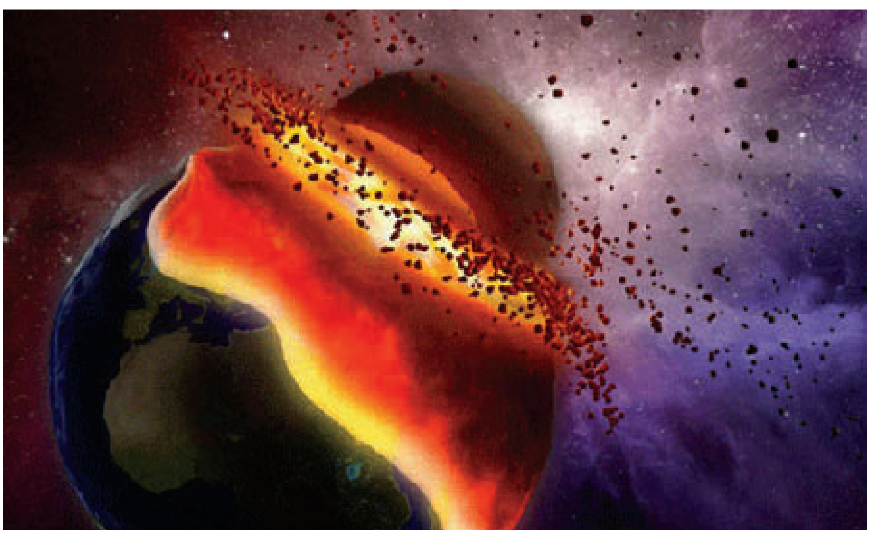
It has happened before, and it could happen again: Planets in the inner solar system may collide if gravitational interactions substantially disturb now-stable orbits, a new study suggests.

Scientists have long known that the equations describing the orbital motions of any group of three or more objects can't be solved exactly. Even with the most powerful computers, it's hopeless to try to determine planetary orbits precisely more than a few million years in the future, says Jacques Laskar of the Paris Observatory. The results of any single simulation offer only one possible outcome, but running a large number of simulations can provide insights into overall probabilities, he notes.

Now, a large-scale study by Laskar and observatory colleague Mickael Gastineau, which appears in the June 11 *Nature*, provides a possibly frightening glimpse into the solar system's future. It's a future in which, literally, worlds collide.

The researchers' computer model accounts for gravitational interactions among the moon, the eight major planets and Pluto, including the effects of general relativity. The team started with the best information about position and velocity of each of the 10 bodies, and marched simulations forward in nine-day steps for 5 billion years, the projected life of the sun. The team ran 2,501 scenarios, with the only difference between runs being the size of Mercury's orbit. That size increased by a mere 0.38 millimeters in the second and each subsequent simulation.

In one simulation, Mercury collides with Venus about 1.76 billion years from now. In another scenario, Mars swings within 800 kilometers of Earth about 3.34 billion years from now. Using that close encounter as a starting point, Laskar and Gastineau ran another 201 simulations. In 196 of those, a planet in the inner solar system either slammed into another or fell into the sun. Earth was struck 48 times: once by Mercury, 18 times by Venus and 29 times by Mars.



J. VIDAL-MADJAR, IMCEE-CNRS, PLANET TEXTURES BY NASA

Perturbations of planetary orbits could cause a collision (such as one between Mars and Earth, illustrated here) sometime in the next 5 billion years, a study suggests.

MEETING NOTES

American Astronomical Society
June 7–11, Pasadena, Calif.

Betelgeuse shrinks

Betelgeuse, one of the brightest stars visible to the naked eye, has shrunk in diameter by more than 15 percent since 1993. The star, a red supergiant, has a radius roughly the distance between the sun and Jupiter. The shrinkage corresponds to contracting by a distance equal to that between the sun and Venus, researchers reported June 9. It's unclear why Betelgeuse has shrunk and whether it will later rebound, said Nobel laureate Charles Townes, retired from the University of California, Berkeley. Townes and Edward Wishnow, also of UC Berkeley, used an infrared interferometer atop Mount Wilson in southern California to examine the star at a wavelength of 11.1 micrometers, which can penetrate the star's outer gas and dust to determine its visible edge. —*Ron Cowen*

Alien visitor from afar

Even the most unassuming neighbor can hide a giant secret. New calculations of the orbit of a dim, low-mass star just 300 light-years from the solar system suggest the body may be a runaway from another galaxy. After analyzing the speed and direction of motion of the tiny star, Adam Burgasser of MIT and colleagues reported June 9 that the object's orbit indicates that it may have originated from a galaxy beyond the Milky Way. They propose that the star, dubbed 2MASS 1227-0447, may have come from a small galaxy that ventured close enough to the Milky Way to be ripped apart by gravitational forces. —*Ron Cowen*

Genes & Cells

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

Lab tests find Huntington's protein may have crony in killing brain cells

Results could explain why only some neurons are vulnerable

By Tina Hesman Saey

Researchers may have discovered how a neuron-killing protein selects its victims — it has an accomplice.

Scientists identified a mutant form of the protein huntingtin as the culprit in Huntington's disease in 1993. The protein is found in every cell in the body, but it turns deadly only in brain cells — particularly cells in the striatum, a part of the brain that helps control movement. Why mutant huntingtin preferentially kills those cells has been a mystery.

Now, a team at Johns Hopkins University in Baltimore reports in the June 5 *Science* that a protein called Rhes may goad huntingtin into killing brain cells in the striatum, leading to Huntington's disease. If confirmed, the finding could provide new avenues for developing therapies to treat the fatal neurodegenerative disease, says Nancy Wexler, president of the Hereditary Disease Foundation and a researcher at Columbia University.

"This study really gave me a peek into what the future of the field might look like," says William Seeley of the University of California, San Francisco's Memory and Aging Center. Few studies before this one have explained why neurodegenerative diseases attack only certain parts of the brain. "What makes it so special for me is that it builds a bridge back to the anatomy of the disease," Seeley says.

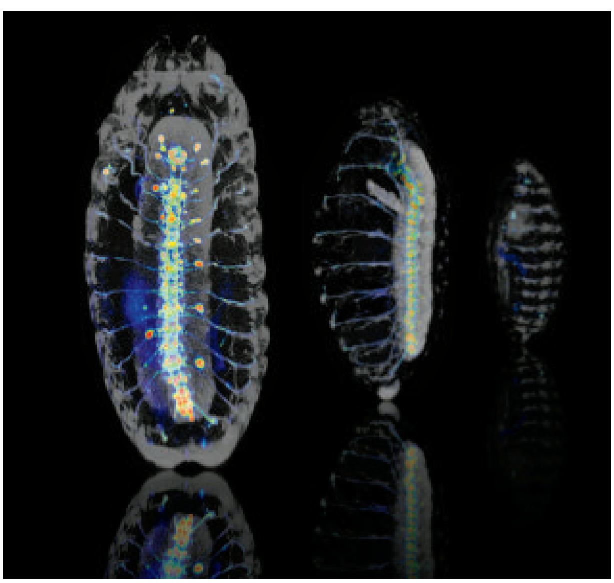
Solomon Snyder, a neuroscientist at Johns Hopkins, and his team investigated Rhes, which is produced mostly in the striatum. The researchers found that Rhes interacts with huntingtin, and the association is even stronger with the disease-causing form of huntingtin. The scientists grew human embryonic cells and mouse brain cells in lab petri dishes and prodded the cells to make the two proteins (Rhes and the mutant form of huntingtin). Cells making either protein alone stayed healthy, but cells with both proteins quickly died.

Through a process called sumoylation, Rhes adds another, small protein called SUMO to huntingtin, the team discovered. Usually, the mutant form of huntingtin just forms big clumps in cells, but adding SUMO seemed to partially dissolve the clumps, leading to cell death. The team suggests that clumping renders the mutant form of huntingtin harmless, but that sumoylation makes the protein soluble and thus toxic. Why is unclear.

Future drugs that would block the interaction of Rhes with the mutant huntingtin protein or that would stop sumoylation could prevent or delay the development of Huntington's disease, Snyder says.

But some Huntington's researchers are not as enthusiastic about the new study. "It's of questionable relevance," says Jang-Ho Cha of Massachusetts General Hospital's Institute for Neurodegenerative Disease in Charlestown. "You can model things in a dish, but does it have anything to do with the way cells die in a Huntington's disease brain?"

Other researchers agree that much more research is needed, particularly experiments in mice that might show whether removing Rhes could prevent the mutant huntingtin protein from becoming toxic.



Protein caught in the act

Researchers have illuminated a once-hidden developmental process. A fluorescent signal pinpoints the activity of a protein in fruit flies, revealing exactly when and where this protein does its job, researchers report in the June 5 *Science*. "The idea of watching life at the molecular level within a cell in an intact organism is really fascinating," says study coauthor Akira Chiba. The protein, called Cdc42, is present everywhere in the developing fruit fly. But Cdc42 is active only at certain times in certain cells. Chiba and Daichi Kamiyama, both of the University of Miami in Coral Gables, Fla., inserted a gene into the fly's DNA that encoded an activation bioprobe, an artificial element that sensed when Cdc42's shape changed, a hallmark of the protein's activity. This shape change caused the bioprobe to change colors (as shown here in the nervous system of a developing fruit fly embryo). Next, the researchers will try to make activation bioprobes that would work with other proteins. — *Laura Sanders*

SCIENCE/AAAS

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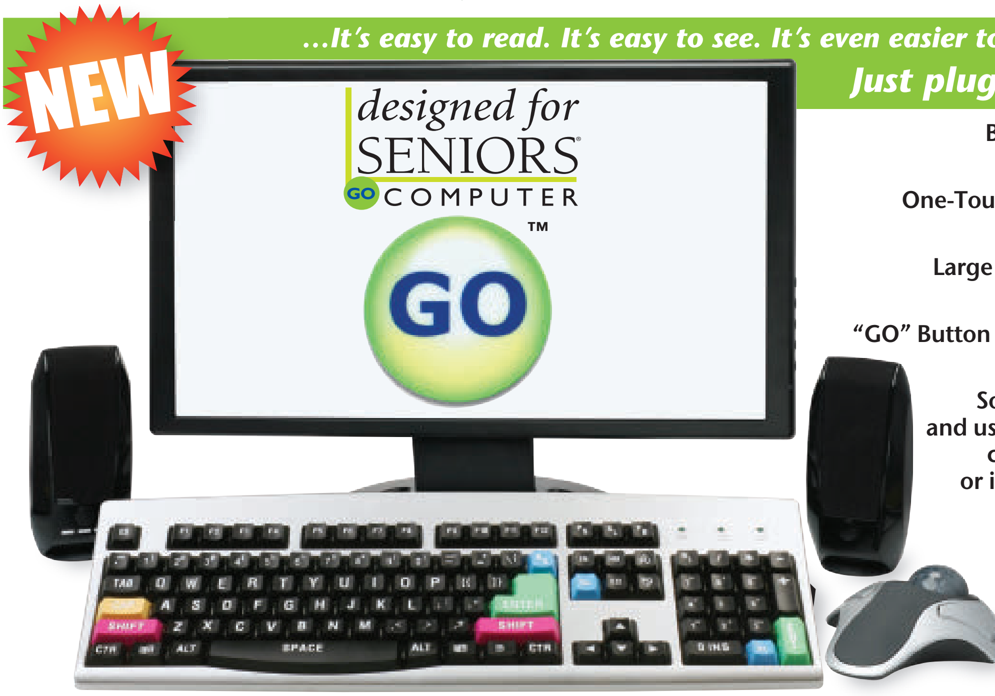

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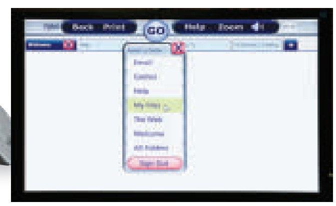

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Body & Brain

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Stem cell stress leads way to gray

Study traces how hair loses color-providing melanocytes

By Laura Sanders

Gray hair may be a mark of distinction in some circles, but it's also a sign of a depleted stem cell population. DNA damage stresses stem cells that produce hair-color cells in mice, causing the cells to lose their "stemness" and leaving brown hair gray, researchers report in the June 12 *Cell*. The results suggest a new way that stem cell numbers can fall as cells accumulate DNA damage.

The study "opens up a new paradigm for how we're going to study stem cell aging in many systems," comments Kevin Mills of the Jackson Laboratory in Bar Harbor, Maine. The report "fills in what's been a hole in our understanding of stem cell biology."

Colorful locks depend on a group of special cells in hair follicles called melanocyte stem cells. Each of these cells divides into two cells: One that replaces itself and another that differentiates into a pigment-producing daughter cell called a melanocyte, which imbues hair with its browns, reds and blacks.

Earlier research suggested that loss of these stem cells was to blame for grayness. With no more stem cells to produce melanocytes, hair turns gray. But how exactly these stem cells disappeared was mysterious.

A new study reveals how hair follicles lose pigment. These mice are the same age, but the mouse on the right turned gray after exposure to DNA-damaging radiation.

So Emi Nishimura at Tokyo Medical and Dental University in Japan and colleagues tracked these stem cells in mice exposed to DNA-damaging radiation. Exposures were fairly high, intended to magnify the effects of DNA damage that cells gradually accumulate with age.

Mice typically begin to go gray when they are 1 year to 1½ years old, after about 65 percent of their life, Nishimura says. But after exposure to high radiation doses, hair on mice as young as 7 to 8 weeks grew in gray, while control mice remained brown, the team found.

The team looked at stem cells in hair follicles during this graying process. Researchers usually think of two ways that stem cells stop working, say Paul Hasty, a geneticist at the University of Texas Health Science Center in San Antonio. Either they die or stop dividing, he says. "But for these melanocyte stem cells, that's not what happens."

Instead, once the cells have racked up enough DNA damage, they differentiate into melanocytes — which can't replenish stem cell populations or make more melanocytes. Once all the melanocytes die, the hair is left with no pigment-producing cells.

Tuberculosis subverts immune cells

Team identifies gene that contributes to bacterium's virulence

By Nathan Seppa

Invading tuberculosis microbes carry a cargo that increases TB virulence by inducing human immune cells to act less like sentinels and more like bystanders, tests in mice show. In a report online June 10 in *Nature*, scientists hypothesize that this initial infection strategy lays the groundwork for TB's ability to lie dormant in an infected person for years.

Mycobacterium tuberculosis gets engulfed by immune system cells called macrophages. Scientists knew that the bacteria had evolved mechanisms to proliferate in these cells, but exactly how was unclear, says study coauthor William Bishai, an infectious disease physician at Johns Hopkins School of Medicine in Baltimore.

Bishai and colleagues investigated an enzyme needed to make cyclic AMP, a master regulator of many cell functions. Curiously, *M. tuberculosis* has 17 genes that code for versions of the enzyme.

The researchers infected mice with TB using various combinations of the 17 genes. Microbes harboring the enzyme encoded by a gene called *Rv0386* outcompeted other microbes for survival and caused more severe lung disease. That suggests that the gene, along with the excess cyclic AMP production it induces, helps the microbe to sabotage the macrophage's defensive abilities, making the TB more virulent.

In lab tests on macrophages, the researchers showed that *M. tuberculosis* gins up cyclic AMP production upon entering a macrophage.

This study is the first to pin down that *M. tuberculosis* actively traffics cyclic AMP into the cells and that "this really does affect the outcome of infections," says Kathleen McDonough, a microbiologist at the State University of New York at Albany. The bacterium's reliance on cyclic AMP and the enzyme that makes it could prove useful to drug makers, she says.

K. INOMATA ET AL./CELL 2009

153.0 Incidence rate of prostate cancer per 100,000 white men

239.8 Incidence rate of prostate cancer per 100,000 black men

Replacing microRNA may offer new possibilities for cancer treatment

Study in mice shows liver tumors shrunk or didn't develop

By Jenny Lauren Lee

It's a simple idea: Treat cancer by finding out what's missing from a cancer cell and replacing it.

Experiments in mice suggest that inserting one small missing molecule could fight cancer without harming normal tissue, researchers at Johns Hopkins University in Baltimore and the Nationwide Children's Hospital in Columbus, Ohio, report in a study in the June 12 *Cell*.

The molecule in this case is a small RNA chain known as a microRNA. MicroRNAs (abbreviated as miRNAs) are involved in a wide range of body processes including cellular differentiation and tissue growth. They run about 22 bases long, but their small size belies their influence — they help regulate hundreds or thousands of genes.

In the past decade, certain types of miRNA have been shown to be made at lower-than-normal levels in cancer cells. Scientists have previously explored the idea that replacing the missing miRNAs might reverse the cancer, but not in a way that could lead to viable treatments, said Joshua Mendell of Johns Hopkins, one of the study's authors.

"One of the things that distinguishes this work is that we used a clinically relevant delivery vehicle to replace a microRNA that's missing," Mendell says. The team used a harmless virus that acts as a sort of mail carrier to deliver miRNA to cancer cells.

The researchers worked with mice that develop tumors similar to those in human liver cancer. Most of the untreated mice developed cancers that nearly consumed their livers. But eight out of 10 mice receiving the miRNA had small liver tumors or none at all.

"It's door-opening research" that will encourage others to move into the field, says George Calin of the University of Texas M.D. Anderson Cancer Center in Houston.

Mendell and his colleagues focused on a particular miRNA called miR-26a, chosen because it was much less abundant in liver cancer cells than in normal liver cells. "We thought that the tumor cells might be sensitive to the miRNA" but that the normal parts of the liver would not be harmed, Mendell says. Restoring the miR-26a stopped the cancerous cells from creating two molecules called cyclins that are used in cell replication, effectively preventing the cells from multiplying.

Eight out of 10 mice receiving microRNA had small liver tumors or none at all.

"Although microRNAs have been shown to play an important role in cancer pathogenesis, not too many reports have shown that altering a single microRNA can suppress cancer development in vivo," comments Baohong Zhang of East Carolina University in Greenville, N.C. "This result has opened a novel strategy for cancer therapy."

The study has practical benefit, Calin says, because it shows potential for treating a specific type of cancer called hepatocellular carcinoma, which accounts for 80 to 90 percent of liver cancers.

Calin also says that this research suggests it may be possible to use different miRNAs as therapies for many diseases, not just cancers. MicroRNAs have a wide variety of functions, and some have been linked with autoimmune disorders, diabetes and heart disease. ■

MEETING NOTES

Endocrine Society
June 10–13, Washington, D.C.

Surgery for obese adolescents

Stomach surgery that curbs appetite and induces weight loss in adults shows similar benefits in obese adolescents, a new study finds. The teens also show improvements in key metabolic markers that serve as signposts for overall health, researchers reported June 11.

But while the markers improve dramatically during the first six months after the laparoscopic banding surgery, benefits seem to reach a plateau during the second six months, said Ilene Fennoy, a pediatric endocrinologist at Columbia University Medical Center. — *Nathan Seppa*

Role of tags in prostate cancer

A new study shows how chemical tags on DNA may lead to higher rates of prostate cancer in black men. And estrogen may play a role, researchers reported June 12.

Wan-yee Tang of the University of Cincinnati and her colleagues investigated chemical tags, called methyl groups, near the portion of DNA that encodes a gene active in the prostate. The team found fewer tags in black men than in white men. The lack of epigenetic tags may alter the gene's activity, upsetting the balance of other proteins and making a cell more vulnerable to turning cancerous, the team proposed.

Since estrogen levels are higher in black men than white men and experiments in rats have linked high doses of estrogen to fewer methyl groups, Tang thinks estrogen may reprogram the genome, upping cancer risk. — *Laura Sanders*

Humans

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Signs of hunting beneath Huron

Survey finds lines and piles of boulders on lake bottom

By Sid Perkins

Sonar and video surveys of a long-flooded land bridge between Michigan and Ontario, Canada, reveal evidence of man-made structures that may have been used by hunters when water levels in the Great Lakes were much lower than they are today, researchers claim.

Between 8,300 and 11,300 years ago, when the North American climate was much drier, the water level in Lake Huron ranged between 75 and 120 meters lower than today's level, says Guy A. Meadows of the University of Michigan in Ann Arbor. During that time, a now-submerged feature called the Alpena-Amberley Ridge would have stood high and dry, he notes.

Sonar scans beneath Lake Huron reveal structures similar to those built by hunters today to guide caribou (shown).

Meadows and university colleague John M. O'Shea report online June 8 in the *Proceedings of the National Academy of Sciences* that their surveys show signs of prehistoric human activity there.

The researchers used side-scan sonar and video-equipped, remotely operated vehicles to survey two patches of lake bottom that together cover about 72 square kilometers of the submarine ridge. In one of those areas, sonar data reveal a sinuous line of small boulders 350 meters long that seem to have been arranged to visually accentuate a low ridge. Although generally unimpressive to humans — a person could easily step across the shin-high line of boulders — such structures are used today by arctic hunters to effectively guide caribou, Meadows notes.

Groupings of larger boulders found nearby could have been used as decidedly low-tech hunting blinds, he says.

Archaeologists are interested in such sites because not many have been discovered from this region for this era, the researchers report. The new findings raise the possibility that intact settlement remains are preserved beneath the lake.

The submarine site that O'Shea and Meadows describe "is like a stage set with no actors on it," says John R. Halsey, Michigan's state archaeologist. "It will take finding some artifacts such as flint chips or projectile points ... to get archaeologists really excited."

MEETING NOTES

Jean Piaget Society
June 4–6, Park City, Utah

Autism care's biological toll

Mothers with teenagers or young adults living at home face plenty of stress. If the young home-dwellers have been diagnosed with autism, the emotional intensity of caregiving surges dramatically in the mothers and may undermine the functioning of a critical stress hormone, a long-term study suggests.

Over a five-year span, women who had children with autism living at home reported many more challenges in their daily lives than women caring for typically developing teens and young adults, reported psychologist Marsha Seltzer of the University of Wisconsin–Madison on June 4.

Analyses of saliva samples collected from women near the end of the study period showed that those caring for offspring with autism produced unusually low levels of the stress hormone cortisol throughout the day. In mothers caring for teenage or young adult children free of developmental problems, cortisol levels rose sharply throughout the morning and then declined to a level still well above that of mothers tending to kids with autism.

It's not clear whether low cortisol activation represents an adaptive response that makes it possible to handle prolonged stress or a maladaptive response that fosters problems down the road. *—Bruce Bower*

Getting social with virtual peers

Children with autism and related developmental disorders typically can't carry on a conversation or play cooperatively with peers. Encouragingly, though, life-size virtual youngsters can draw kids with autism into social encounters, psychologist Justine Cassell of Northwestern University in Evanston, Ill., reported June 5.

Cassell and her colleagues examined conversational skills in pairs of 7- to 11-year-olds. Participants had to use toys to tell a story, first with a partner and later with a virtual peer. The virtual peers were 3-D, computerized versions of children programmed to be patient, give a lot of feedback and pause briefly before taking a turn in a conversation.

Unlike kids free of developmental disorders, children with autism contributed to stories, took turns in conversations, looked at their partners and suggested new story ideas more often with virtual peers than with flesh-and-blood partners. Cassell plans to explore whether regular exposure to computerized friends translates into improved real-life interactions for children with autism. *—Bruce Bower*

JACK BRINK

Earth

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Alpine Antarctica, before all the ice

Study details chain of peaks under continent's flat surface

By Sid Perkins

Deep below the icy surface of East Antarctica lies a mountain range with alpine topography carved by ancient glaciers, a landscape frozen in time for millions of years and rife with clues about the origin and evolution of the world's largest ice sheet.

Many studies hint that Antarctica's ice sheet began to form about 34 million years ago (*SN: 10/11/08, p. 12*), but how and where it first formed has long been a mystery. Now, scientists who used ice-penetrating radar to survey a 30-by-30–kilometer area in East Antarctica report in the June 4 *Nature* that they may have discovered the birthplace of the Antarctic ice sheet.

Known as Dome A, the area surveyed sits more than 4 kilometers above sea level, says Simon M. Mudd of the University of Edinburgh. Buried far beneath that region's relatively flat surface, however, lies a chain of peaks called the Gamburtsev Mountains. The new data provide the first detailed glimpse at the subglacial topography there, Mudd says. "The topography here is less well known than the surface of Mars," he notes.

The team's radar data indicate that the region's ice-smothered terrain is similar to that seen in the European Alps today. Ice in the surveyed region is between about 1,650 meters and 3,150 meters thick, which makes the tallest peak in this stretch of the Gamburtsevs a little more than 2,400 meters tall.

High valleys dot those long-buried peaks, many with nearly semicircular profiles and steep cliffs at the head of the valley — distinctive signs that the valleys were carved by glacial ice, probably around the time Antarctica first began to freeze about 34 million years ago.

As Antarctica cooled even further, mountain glaciers grew, swept downslope and coalesced in valleys that had been previously carved by major rivers and their tributaries, the team reports. Over 20 million years, the glaciers that originated in this region thickened and spread into a continent-sized ice sheet, which has swaddled Antarctica for the past 14 million years.

Seeking genetic fate

Personal genomics companies offer forecasts of disease risk, but the science behind the packaging is still evolving

By Patrick Barry

"RESISTANT!!!" shouts the title of Lindsay Richman's post. Apparently, she was elated to learn that her DNA reduces her susceptibility to norovirus infections, the principal cause of the common stomach flu.

So she posted a comment on a discussion board on the website for 23andMe, a company based in Mountain View, Calif., that specializes in the fledgling industry of personal genomics. To get a glimpse of her own DNA, Richman had sent the company $400 and a vial of her spit. From her point of view, what happened next was a mystery — a black box. But a few weeks later, out popped her results on a password-protected website, complete with social networking tools for sharing and discussing her genetic inheritance with other customers.

In the string of online responses to Richman's post, others who share her genetic good fortune compared notes on the last time they'd had any symptoms of stomach flu. Richman, a 26-year-old real estate agent in New York City, hasn't had stomach flu since she was 8, she wrote.

In other discussions, people compared their genetic profiles and brainstormed on how lifestyle choices and environmental exposures might influence their risks for various conditions, such as Parkinson's disease and prostate cancer.

Now that prices charged by personal genomics companies such as 23andMe, Navigenics, deCODE genetics and DNA Direct have dropped, ranging from a few hundred to a few thousand dollars, many people curious about their genetic inheritance, and how it relates to their health, have easier access to DNA testing.

Serving to "crowdsource" the search for new links among genes, behavior and disease, these companies' customers represent a small army of amateur genome sleuths who could prove to be a new force in pushing genomic research forward. But the genetic report cards these amateurs are reading may not be as definitive as they assume. Despite progress in linking genetic differences with disease risk and other traits, the predictive power of these links has fallen short of expectations.

In April, the *New England Journal of Medicine* published a review and a set of essays grappling with this shortfall in DNA's predictive power and searching for the best way to take research forward. An essay by Peter Kraft and David Hunter, epidemiologists at the Harvard School of Public Health in Boston, was revealingly titled, "Genetic risk prediction — are we there yet?"

Their answer, in a nutshell: No. Which leads to the crucial question of what, exactly, customers of personal genomics companies are looking at when logging on to the digital oracle to peek at their genetic fates.

The leap from a tube of saliva to a ledger of traits, health risks and ancestral history involves a lot of science — some credible, some flimsy. As more and more people become consumers of genetic information services, these people may want to first open that black box and take a good look inside.

The black box

It's certainly not the most dignified way to join the genomics era.

Inside the small, brightly colored DNA-sample kit that arrives in the mail lies a clear plastic tube capped by a blue plastic funnel — the easier to spit into. Users are instructed to fill the tube to a little line, which the directions say can take five minutes or more. Five minutes of repetitive spitting.

In that saliva float cheek cells that have sloughed off from the soft tissue lining the mouth. Snapping the tube's lid shut releases a preservative that keeps the cells intact during their voyage to the lab.

"The reason we collect so much spit is to get a lot of your DNA," explains Brian Naughton, a founding scientist at 23andMe. The machines that read the sequence of DNA chemical "letters" of the genetic code are quite accurate and robust against noise. Repeat the scan with DNA from the same person, and the two results will be more than 99.9 percent identical, according to the company.

"It's clearly reproducible," says George M. Church, a geneticist at Harvard Medical School in Boston. Testing a person

again with another company's service using a different model of DNA reading machine will also produce nearly identical results, Church says.

These machines use gene chips to read up to a million letters of genetic code at once. Since the first gene chips that could skim the entire genome debuted in 2005, the cost to scan a person's DNA has dropped dramatically.

Despite what some customers might assume, most personal genomics companies do *not* produce a complete sequence of a customer's genome. An entire human genome contains about 6 billion letters of genetic code distributed among a person's 23 pairs of chromosomes (the inspiration for the name 23andMe). These machines don't read every DNA letter. Instead, they read individual letters at 500,000 to a million different spots in the genome, capturing just 8 to 16 *thousandths* of one percent of the full genome.

But that genome sliver is carefully selected to represent much of the genetic variation among people. "It's really coverage of that genetic variation that you're going for," Naughton explains.

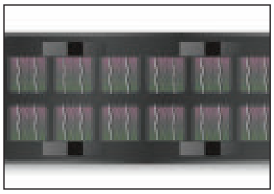
Nearly all of a person's genetic code is identical to that of every other person — roughly 99.5 percent of it matches up letter for letter. At certain spots along the length of a person's chromosomes, though, the genetic code can differ from other people's by a single letter. In the sequence of the familiar A's, T's, C's and G's, the four information-carrying nucleotides in DNA, some people might have a T at a certain location while others have a C. These small variations are called single nucleotide polymorphisms, or SNPs (pronounced "snips").

The human genome contains about 10 million known SNPs. That estimate is the latest from the International HapMap Project, an ongoing scientific collaboration that's mapping these genetic variations. But SNPs near each other on a chromosome tend to get inherited together, making it possible to group neighboring SNPs into units of inheritance called haplotypes. A few tag SNPs are enough to identify each group, so it takes only about 500,000 tag SNPs to

PHOTO: © DORLING KINDERSLEY/ILLUSTRATION: A. NANDY

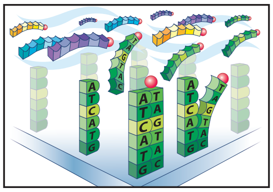
Spit and learn

The technology that personal genomics companies use does not read the sequence of genetic code letter by letter. Instead, the machines look for single-letter variations at specific locations. From a person's vial of spit, DNA is extracted from cells. The gene chip takes it from there.



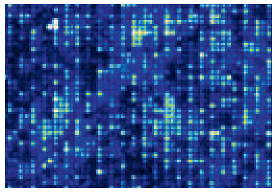
DNA on a chip

Resembling a computer chip, a gene chip (sketch shown) has millions of microscopic spots. Each contains anchored, single DNA strands with specific sequences of genetic code with common single-letter variations.



Get together

When spread over the gene chip, DNA from a person's spit sample joins with strands already attached to the chip that have the complementary genetic sequence. A fluorescent molecule (red in illustration) marks joined strands.

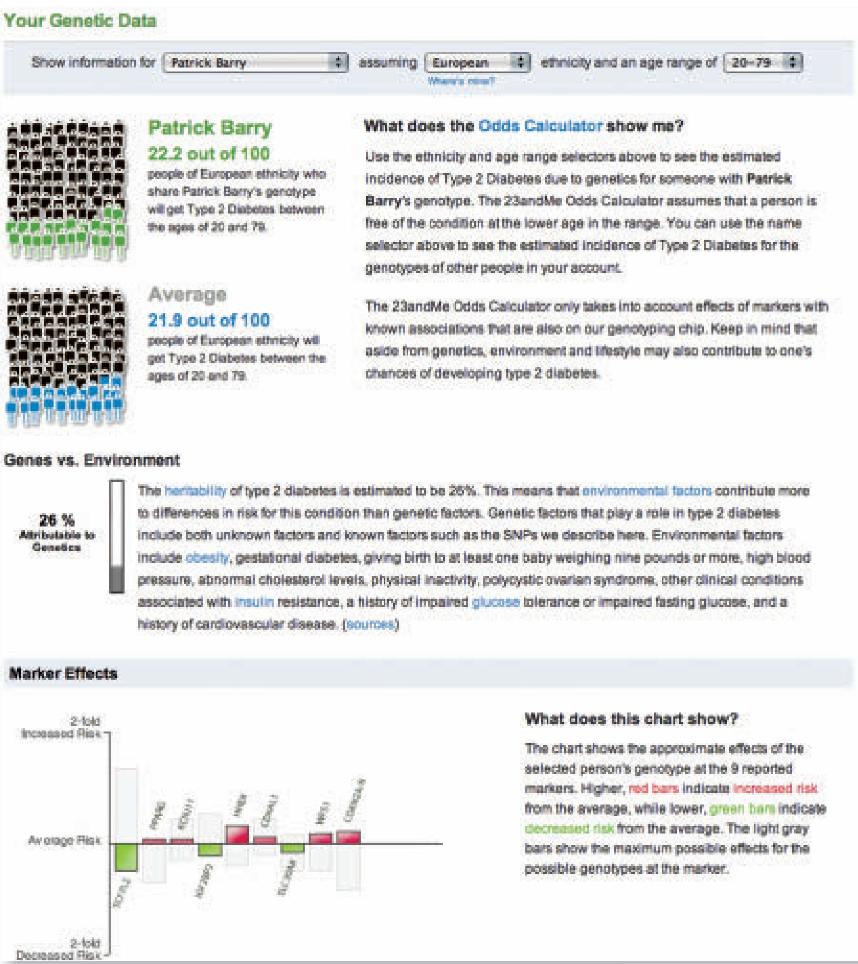


Revealing spots

Thanks to the fluorescent tags, glowing dots signal where a sample DNA strand has the matching genetic sequence to the known sequence of a pre-attached strand. A computer analyzes the results, producing a list of single-letter variations.

Chances are

Writer Patrick Barry sent his own vial of spit to 23andMe and in return had access to an online summary, featured in this Web screenshot, of his risk for type 2 diabetes. Also, the company's chart of Marker Effects illustrates how risk can change from one variation on a genome to another. The genetic answer to the risk for this disease is not straightforward.



reveal a person's haplotypes. That's why most gene chips test for at least 500,000 SNPs, and why checking this tiny sliver of the genome — these tag SNPs — can reveal much of the genetic variation that makes a person unique.

Tag SNPs usually aren't part of any known gene. But the surrounding DNA inherited along with a SNP can contain one or more genes important for various diseases. The SNP is often a proxy.

This much of the black box is fairly reliable: the raw data on at least hundreds of thousands of a person's SNPs. Some personal genomics companies make this mountain of raw data directly available to their customers.

But that's the easy part. The other, more problematic half of the black box is interpretation. What exactly does having one SNP variant or another mean for a person's risk for heart disease, diabetes, colon cancer?

In short, there's no single answer for how reliable these interpretations are. Some SNPs have clear, strong and well-understood links with specific traits or diseases. Many others have only small effects, and the biological mechanisms for the links are often unknown.

Reviewing the available scientific evidence for each disease or trait is the biggest challenge for these companies, says Michele Cargill, director of human genetics for Navigenics. "You really have to read each [study] very, very carefully. It takes a lot of time and it's all done manually."

For example, the resistance to norovirus infection that Richman enjoys is linked to a SNP called rs601338, which is located on each of the two chromosome 19s she inherited from her parents. At this location, a person can have either an A or a G for this SNP. Chromosomes with an A lack a functioning copy of a gene called *FUT2*. This gene produces a certain molecule on the outer surfaces of the cells that line the intestines. As it turns out, noroviruses must bind to this molecule in order to enter and infect the cells. People like Richman, who inherited the A SNP from both of her parents, do not have a working copy of the *FUT2* gene, so their intestinal cells lack the

CLOCKWISE FROM TOP LEFT: ILLUMINA; IMAGE COURTESY OF AFFYMETRIX; THE BROAD INSTITUTE; 23ANDME molecule that noroviruses need to cause an infection.

In this case, the link is strong. A single SNP can indicate whether a person has a working copy of a certain gene, and the biological mechanisms tying this gene to the virus's ability to enter the person's cells are well understood. In nearly all studies, people who lacked a functional copy of the *FUT2* gene didn't get sick, even when deliberately exposed to this type of virus. It's as close as one ever gets in biology to a slam dunk.

About 1,300 genes have known, strong links to medical conditions, Church notes. Some disorders, such as sickle-cell anemia, are truly genetic diseases that a person has from birth. Others such as Parkinson's disease, macular degeneration, Alzheimer's disease and breast cancer arise later in life and can be influenced by environment and lifestyle, even though some genes are known to significantly change the odds that a person will get the disease.

But the relatively clear-cut cases are the exception, not the rule. For many traits and diseases, finding reasonably strong and reliable links with SNPs has proven more difficult than many scientists had expected.

Beware weak links

To search for these links, researchers use gene chips similar to those used by personal genomics companies. With these gene chips, scientists scan the DNA of two groups of people: a few hundred or thousand people with the disease in question and a few hundred or thousand without it. If the two groups are well matched in terms of other important traits such as age, ethnicity, smoking habits and so on, a SNP that appears more frequently among people with the disease than among the control group may be associated with the disease.

At first, these studies tended to "discover" a lot of illusory links — false connections that crop up by pure chance in the mountains of data produced by these studies (*SN: 6/21/08, p. 20*). In the last few years, scientists have learned to correct for these statistical sins, but even

Haplotype in a haystack

Personal genomics companies read only a tiny portion of a person's genome. But it's a telling portion, with efforts focused on identifying SNPs and haplotypes. SNPs are spots in the DNA where one person has a different chemical letter than another. Certain congregations of SNPs are flags for haplotypes, which are patterns of genetic variation found in different populations. The illustration maps tag SNPs: (a) shows differences among four people in the same genetic sequence in part of one chromosome; (b) shows three SNPs highlighted in four haplotypes. The tag SNPs (c) can identify the haplotypes of the individuals.

REPRINTED BY PERMISSION FROM MACMILLAN PUBLISHERS LTD: *NATURE*, INTERNATIONAL HAPMAP CONSORTIUM, 2003 with most false positives weeded out, these studies often point to large numbers of potentially suspect SNPs. For example, dozens of well-established SNPs contribute to the risk for type 2 diabetes, the form of the disease that emerges in late adulthood and is hastened by a diet high in sugar.

Unfortunately, most of these SNPs alter risk by only a tiny amount — a 2 percent change in risk for this one, a 5 percent change for that one, a 10 percent change for a third. Even a 10 percent change would mean that the odds of developing diabetes sometime in that person's lifetime would increase from the typical 22 percent to 24 percent. Not exactly a crystal ball–caliber revelation.

"People will tell you that if they know that they have a slightly higher risk for diabetes, then they could change their diet," Kraft says. "But you don't really need an expensive genome test to tell you that."

Even more problematic, though, is the fact that new links continue to trickle in. When the risks from individual SNPs are added, a person's overall risk of the disease could be slightly positive. But a newly discovered SNP could tilt the balance in the other direction.

"Our best guess about your risk today might turn out to be very different five years from now," Kraft says. "Your risk as a function of time is a random walk. It bounces up and down as we learn more."

These problems also plague other common illnesses such as heart disease, as well as complex traits such as height and intelligence. In each of these cases, large numbers of SNPs are involved because the underlying biology is complicated. Heart disease, for example, is an umbrella term for various cardiovascular problems that could depend on genes for heart muscle proteins, blood vessel strength and elasticity, cholesterol metabolism, blood clotting and others. And each of these functions often arises from webs of interactions among dozens or hundreds of genes. These interactions produce the feedback loops that fine-tune a cell's behavior and make it robust, and these interactions add to genetic complexity (*SN: 12/6/08, p. 22*).

"It's very early days in terms of what we've learned about common, complex diseases," Kraft says.

Some in the genome research community say that studies with ever larger numbers of subjects are needed to find SNPs that have even weaker links but that many people have. The hope is that the cumulative effects will point to significant predictions. Others suggest that studies have already found all the important, common SNPs that there are to find, and that new studies should instead search for SNPs that are held by a small minority of people but that exert a stronger influence on disease.

Selling, knowing risk

Until more progress is made, some scientists say, selling risk information about complex diseases is premature.

"The justification is just not there for claiming that these [SNPs] have any clinical utility at this stage" for complex diseases, says Allan Balmain, a cancer

Seeking genetic roots

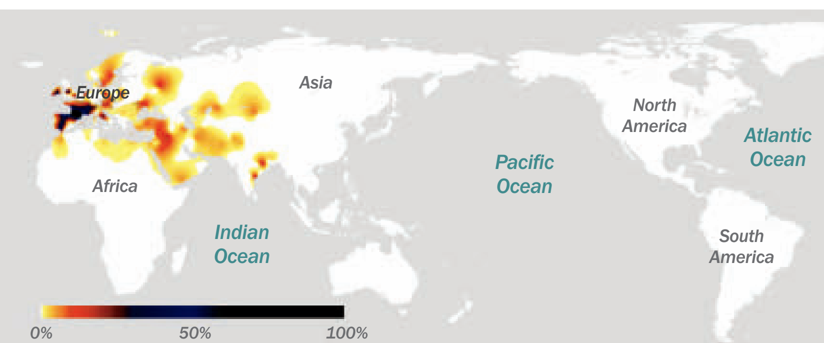
DNA holds clues not only to an individual's medical future, but also to their family's past. Genetic profiles offered by many companies can show customers their ancestral histories.

After all, DNA is the ultimate genealogical record. A mutation that arose in the DNA of a person who lived 10,000 years ago could have been passed down to his or her children and grandchildren, becoming a kind of hidden family heirloom. Because the odds of that same single-letter mutation occurring again independently are negligibly small, somebody alive today who has that particular SNP almost certainly descended from that person who lived 10,000 years ago.

Of course, a DNA test can't pinpoint who that ancestor was. But by mapping where in the world a particular SNP is common among indigenous people, scientists can make a fairly good estimate of where its primogenitor lived.

DNA in small organelles called mitochondria is inherited only from a person's mother. So a mitochondrial DNA SNP must have come from the mother, and her mother, and her mother, and so on for perhaps hundreds of generations. And DNA in the Y sex chromosome can come only from a boy's father and each previous father. Retracing the lineage of a mutation on other chromosomes is messy, since other chromosomes are shuffled at each generation. But mitochondrial DNA and Y chromosomes each offer a straight line of descent.

Modern tests look at more than 2,000 SNPs on both the mitochondrial DNA and — if the customer is male — the Y chromosome. The science behind these results is fairly robust, and estimates of geographical ancestry will only improve as scientists gather more DNA samples from people around the world. — *Patrick Barry*



Paternal roots: Writer Patrick Barry discovered that his distant paternal ancestors most likely lived in western Europe. The map's color spectrum shows the probabilities that his father's family line, as identified by haplotype groups, originated in certain geographic regions.

23ANDME

geneticist at the University of California, San Francisco. He says that, in his opinion, personal genomics companies are "just exploiting the naïveté in the general population."

These companies plan to use their growing databases of DNA samples — and their legions of curious customers — for novel research. Other research scientists are cautiously optimistic. Customers who have sent their DNA samples to these companies are not a random sample of the population, a fact that could bias the results. And information about family history, health habits and environmental exposures are gathered through unmonitored online surveys, rather than by professional clinicians. With careful study design and quality control for the data, though, these obstacles could be surmountable. "Their data set is not in itself bad," Balmain says. "Some of these things may turn out to be very useful."

Eventually, though, these companies may need to move beyond SNPs, as many researchers have begun to do. Much of the genetic variation among people comes in forms other than changes to single letters of code. Some people have long chunks of DNA within their genomes that other people lack. Along with these insertions and deletions, the number of copies of some genes varies from person to person. While these kinds of structural differences are far less numerous than SNPs, each of them can involve hundreds or thousands of letters of genetic code, so together they account for about four times more genetic variation than SNPs do (*SN: 4/25/09, p. 16*).

Modified gene chips can detect some small insertions and deletions, but the best way to tally these changes is with the more thorough, and more expensive, approach of DNA sequencing.

Current state-of-the-art technologies can sequence an entire human genome for about $5,000, compared with millions of dollars just four years ago. "I think nobody anticipated just how fast the cost of sequencing would change," Church says. "I think we're already at the tipping point. It's already getting feasible to sequence large portions of genomes, maybe all the coding regions, for studies and for individuals."

Unfortunately, Naughton says, 23andMe doesn't store frozen saliva samples for most customers, only for those participating in research projects. So if Richman someday wants to upgrade to a full genome sequence to learn even more about her genetic inheritance, she'll have to go through all that spitting again. ■

Patrick Barry is a science writer based in San Francisco.

Explore more

- International HapMap Project: www.hapmap.org

Microswimmers make a splash

Tiny travelers take on a viscous world

By Laura Sanders

Michael Phelps, one of the greatest swimmers of all time, propels himself forward by hurling water behind his body. If he were the size of a bacterium, though, that strategy wouldn't make much of a splash. In a microworld Olympics, Phelps would go home medalless.

At tiny scales of 10 micrometers and below, life is largely conducted as if in a thick fluid, where every motion is immediately dampened by the highly viscous muck. Here, where water seems to take on the consistency of honey, the coasting inertia that helps carry Phelps through the water is simply nonexistent.

"It's like looking at a completely different world," says Piotr Garstecki, a physicist at the Institute of Physical Chemistry at the Polish Academy of Sciences in Warsaw.

Many microbes spend their whole lives swimming, and it's not to win Olympic gold. They make their way through the thick morass to find food, locate mates and seek out or avoid light. But exactly how some of them manage such successful strokes has been a mystery, even though the critters swim right under (and in) researchers' noses.

Recently, though, scientists have discovered some of the microswimmers' tricks. Biophysicists and mathematicians have devised new equations to describe fast, efficient, small swimmers such as *Spiroplasma* bacteria, which move by propagating kinks in alternate directions along their spiral-shaped bodies. Other scientists are revealing more about the coordinated waltzes of algae and the gyrations of bacteria.

Understanding microorganisms' swimming styles may shed light on infection control (stopping swimmers may halt infections), reproduction (sperm are some of the best swimmers around) and ocean ecology. And insights from this microworld have led other researchers to begin designing artificial microswimmers — tiny machines that may one day be used for tasks like rooting out plaque from clogged arteries or ferrying drugs to precise locations in the body.

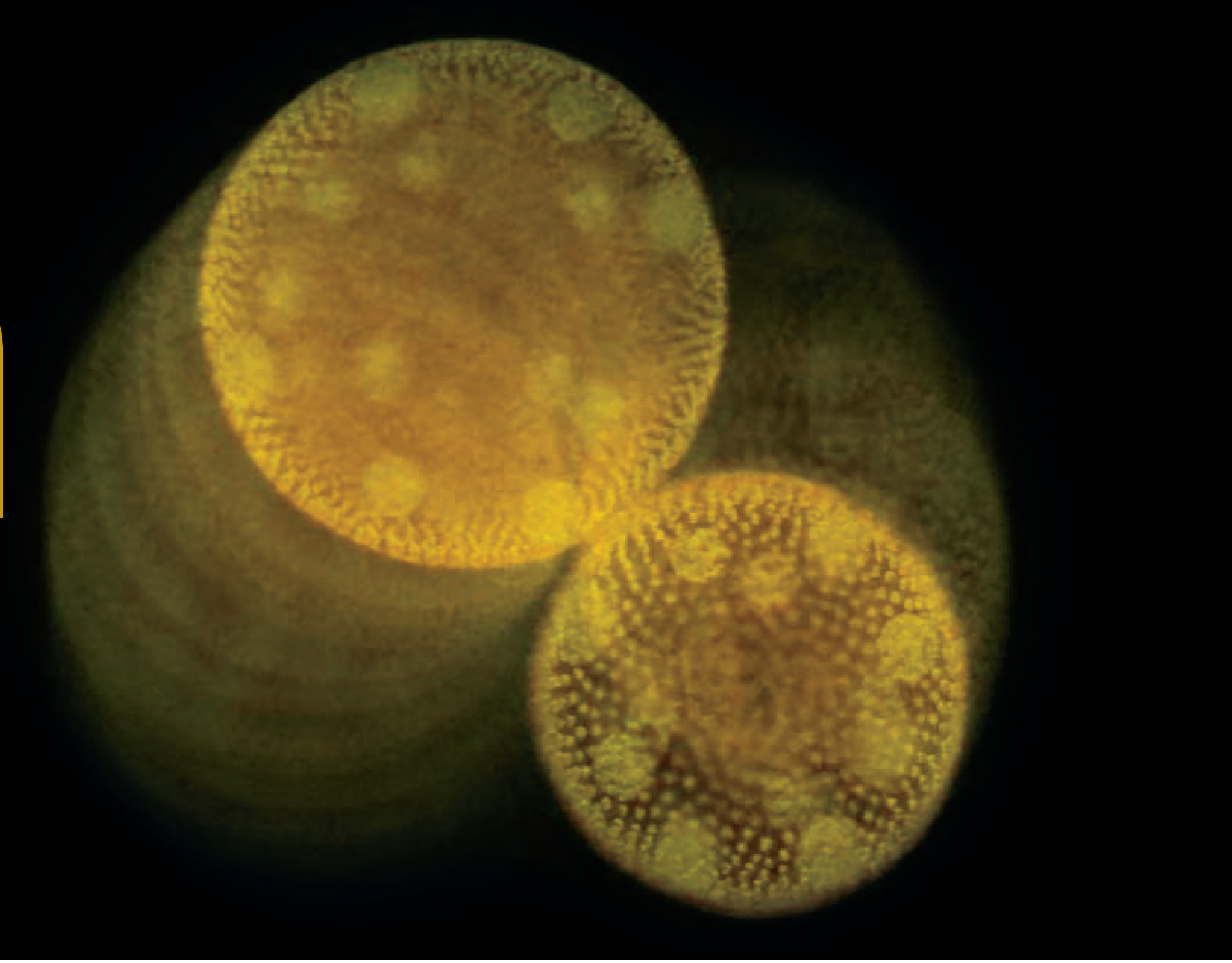
"The most exciting idea is that understanding how microbes move can help us mimic that machinery and build small machines," Garstecki says.

That aim has attracted a diverse crew of researchers. Microbiologists, of course, study swimming at tiny scales, but increasingly so do physicists, mathematicians, roboticists and microfluidics experts, to name a few. A special section in the May 20 *Journal of Physics: Condensed Matter* is devoted solely to the nonintuitive physics of microswimming.

"A lot of physicists realized that lots of questions have not been answered," says Raymond Goldstein, a biological physicist at the University of Cambridge in England. This realization, added to new experimental tools and better modeling, has prompted an exciting resurgence in the field, he says.

Living without inertia

Scientists interested in microorganisms' strokes have a very important number to contend with. Swimmers of all sizes must deal with a dimensionless value called the Reynolds number — the ratio of inertia (an object's resistance to change in speed, whether faster or slower) to viscosity. Phelps has a high Reynolds number in the pool, exceeding 1 million, meaning that his strokes create sufficiently powerful inertia to carry him through the water, and viscosity is not overwhelmingly important. On the



Two colonies of *Volvox* algae orbit each other in a waltz caused by the coordinated strokes of hundreds of tiny undulating flagella. The movement is shown here by superimposing multiple photos taken four seconds apart. At small scales, hydrodynamic interactions between swimmers such as *Volvox* are particularly strong.

DRESCHER *ET AL.*/*PHYSICAL REVIEW LETTERS* 2009

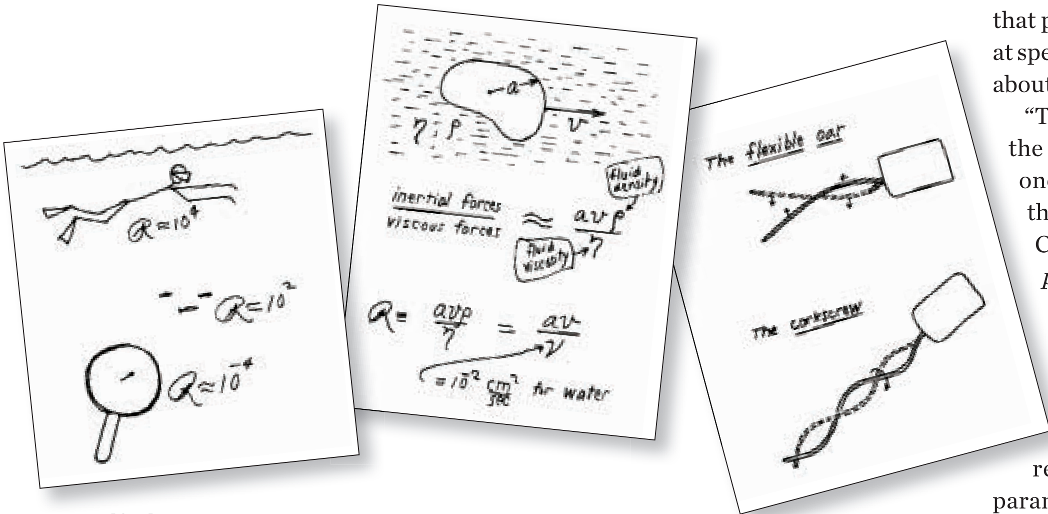
other hand, an *E. coli* bacterium swimming through the exact same water has a Reynolds number of about 0.00001. Inertia is virtually nonexistent, and viscosity is paramount. Under these conditions, when a bacterium stops moving an appendage, the fluid around it stops almost instantaneously.

"Motion at low Reynolds number is very majestic, slow and regular," the late physicist E.M. Purcell said in a famous 1976 lecture on the physics of microorganisms. "If you are at very low Reynolds number, what you are doing … is entirely determined by the forces that are exerted on you at that moment, and by nothing in the past." In the talk, later published in the *American Journal of Physics*, Purcell made use of a large vessel of corn syrup to demonstrate the high viscosity that characterizes life on a tiny scale.

A special challenge of moving around in corn syrup is that reciprocal motions, like a scallop opening and closing its shell, yield no net movement. The movement achieved by the scallop opening, the first half of the stroke, would be exactly undone in the second half as the scallop slams shut. Similarly, a fish moves by swishing its tail back and forth, but if it lived at a low Reynolds number, the motion attained by a swish in one direction would cancel out the motion gained from the previous swish. To swim, Goldstein says, microorganisms "have to move an appendage in such a way that if you record it and play the movie backwards, you can tell which way is backwards."

One of the best known examples of a tiny swimmer's successful nonsymmetrical motion comes from *E. coli*'s stiff, corkscrew-shaped flagellum. As it rotates, this appendage pushes the bacterium's body ahead and the liquid behind. Still other microorganisms, such as the *Volvox* algae, are covered in flexible, undulating flagella whose coordinated waves add up to net motion.

"Something that strikes me is the



Life in the slow lane
In a 1976 lecture, the physicist E.M. Purcell illustrated how swimmers must contend with different forces at different scales. His doodles included, from left, comparing Reynolds numbers for a human, fish and microbe; showing how to calculate a Reynolds number; and examples of body designs and swimming maneuvers that microbes use to move through viscous fluids.

variety of different kinds of tiny little machines that these bacteria — and also archaea — have invented for movement," says Mark McBride, a molecular geneticist at the University of Wisconsin–Milwaukee. In 2008, McBride coauthored a review paper in *Nature Reviews Microbiology* titled, "The surprisingly diverse ways that prokaryotes move," which described "swimming, swarming, gliding, twitching or floating."

Waltzing through honey

New work suggests scientists can add another movement to the list — dancing.

In addition to the honey consistency of life at low Reynolds numbers, all tiny swimmers must contend with powerful influences created by fellow swimmers and walls or other edges. "You can get interesting hydrodynamic effects and long-range interactions that are particularly strong," Goldstein says.

These effects are at play in the unusually robust interactions of small (around 500 micrometers in diameter) spherical swimming colonies of *Volvox* algae, which operate at a Reynolds number around 0.03, Goldstein and his colleagues reported online April 20 in *Physical Review Letters*.

Viewed through a microscope, colonies of the algae perform a slow, clockwise waltz — in which the colonies circle each other — and a jumpier, quicker-paced minuet. These stable, paired dances are caused by the undulating flagellar motion of each algal colony and by the peculiar fluid flows near the glass coverslip, where the *Volvox* prefer to swim.

"We saw that they would linger around each other. They orbit around each other in miraculous dynamics — like the planets around the sun," Goldstein says. He thinks that the dancing may enhance the chances of fertilization during the algae's sexual phase. Sperm packets released by male *Volvox* may find their targets more quickly because of the dancers' proximity. "The collective behavior can influence their life," Goldstein says.

Kinky locomotion

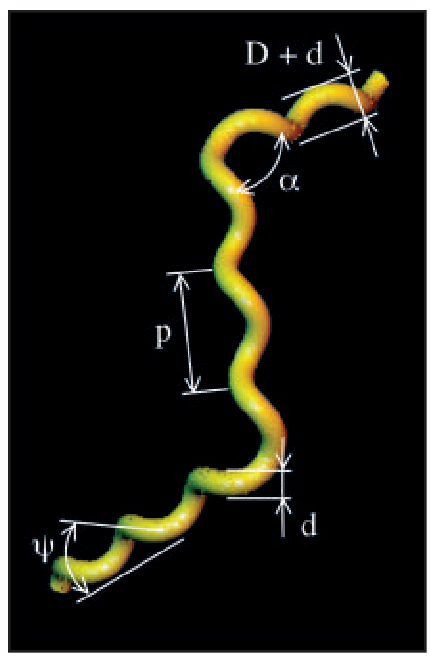
Edge effects and long-range splashbacks are everyday hurdles for microswimmers, who cut through the goo with ingenious tricks. One elegant design is seen in *Spiroplasma*. Tiny even by bacteria standards, *Spiroplasma* propels itself by propagating kinks through its corkscrew-shaped body. The kinks look like those formed in a phone cord twisted to switch from a left-handed spiral to a right-handed one. Massaging a kink to travel down the cord leads to a moving shape distortion, just like the motion that pushes *Spiroplasma* through liquid at speeds of about 3 to 5 micrometers, or about a body length, per second.

"The idea of this wave traveling down the length of the cell body is a simple one," says Greg Huber, a physicist at the University of Connecticut Health Center in Farmington. "But *Spiroplasma* still has a lot to teach us."

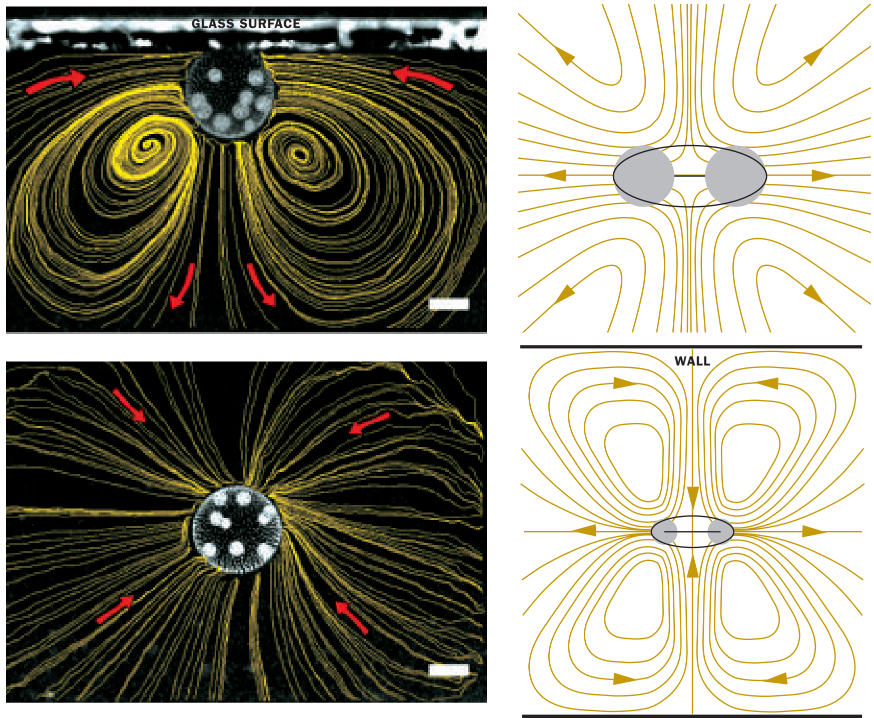
To explore the relationship between body design and swimming efficiency, Huber and his colleagues created a computer model that allowed the researchers to optimize different parameters, such as an organism's cell length, the size of the kink-induced bend and how fast the kink travels down *Spiroplasma*'s body. "We're trying to explore shapes that nature hasn't," Huber says.

The team's results, which appeared online May 28 in *Physical Review Letters*, suggest that as with many things, nature nailed it: The model predicts values for an optimal *Spiroplasma* swimmer that are close to those of the real-life *Spiroplasma*. "What we find is that, just from those constraints alone, the optimal

Swimming with a twist
Computer models of *Spiroplasma* helped researchers pinpoint the bacterium's optimum swimming design, which coincidentally was the same design nature came up with.



one is coincidentally the one nature has found! Is that a coincidence or is that evolution?" Huber says.



Off the wall

Walls and other barriers create intricate fluid flows for microswimmers. Left: A *Volvox* colony generates whirlpools of fluid motion, visualized by a dye and seen from the side (top image) and from above (bottom). Scale bars are 200 micrometers. Right: A different study modeled motion in confined systems (such as the mammalian reproductive tract) and found that confinement dramatically changes the group dynamics of swimmers at low Reynolds numbers. Images show how a single tiny swimmer disturbs fluid flow in an unrestricted area (top) and a walled area (bottom). The walls create swirls in the fluid, which can influence how tiny organisms swim.

FROM LEFT: DRESCHER *ET AL.*/*PHYSICAL REVIEW LETTERS* 2009, BOTH; HERNANDEZ-ORTIZ *ET AL.*/*J. PHYSICS: CONDENSED MATTER* 2009, BOTH

Artificial swimmers

Evolution's success in hydrodynamic design at the microscale has attracted the attention of researchers interested in building small artificial swimmers. Such micromachines may one day carry chemotherapy drugs directly to the site of a tumor in the body, bust up plaques or clots in blood vessels, or take part in other small adventures hatched by creative scientists. But designing things that actually get around at such low Reynolds numbers isn't easy.

"What's new is to try to be audacious and think we can engineer something ourselves," says Ramin Golestanian of the University of Sheffield in England. Designing tiny machines that swim, he says, is "a bit like the history of flying things. Birds with flapping wings are very smooth, but what we manage to make are these huge, ugly metallic things that fly — not very similar to the inspiration."

A paper published online February 13 in *Applied Physics Letters* describes a bacteria-sized artificial swimmer. Mimicking corkscrew-shaped bacterial flagella, Li Zhang and his colleagues at the Institute of Robotics and Intelligent Systems in Zurich created tiny, magnetic flagella and attached them to a square-shaped metal head. These swimmers turn in one direction in response to a rotating magnetic field, propelling them through liquid at speeds around 1.2 micrometers per second. This is closer than previous attempts to match *E. coli*'s average speed, which approaches 30 μm/s.

Getting artificial swimmers out of the laboratory and swimming through human arteries or other real-world scenarios will be much harder, says Zhang, who led the new research. The magnetic swimmers were tested only in stationary liquid, he says, a much simpler feat than navigating the flowing liquid found almost everywhere microorganisms swim. "We have to find out how to steer them in a dynamic liquid environment and how to monitor them," Zhang says.

Other researchers have taken a different approach to make artificial swimmers. Golestanian has modeled the chemical-powered, rocket booster–like propulsion of artificial particles in liquid. "We use chemical reactions, inspired by examples in nature," he says. In a paper published May 8 in *Physical Review Letters*, Golestanian describes how fast certain kinds of these particles can move around and how they might be steered.

Some microorganisms can gravitate toward or away from certain chemicals, a process called chemotaxis. *E. coli* swimming toward a tasty meal of glucose is one such example. By building artificial swimmers that can detect and respond to varying concentrations of reactive chemicals in the surrounding liquid, researchers may be able to control the swimmers' movements. "We can modulate the motion by making gradients or patterns — artificial chemotaxis, if you like — for these guys," Golestanian says. "The exact form of the chemical reaction doesn't matter. All that matters is that it's fast enough."

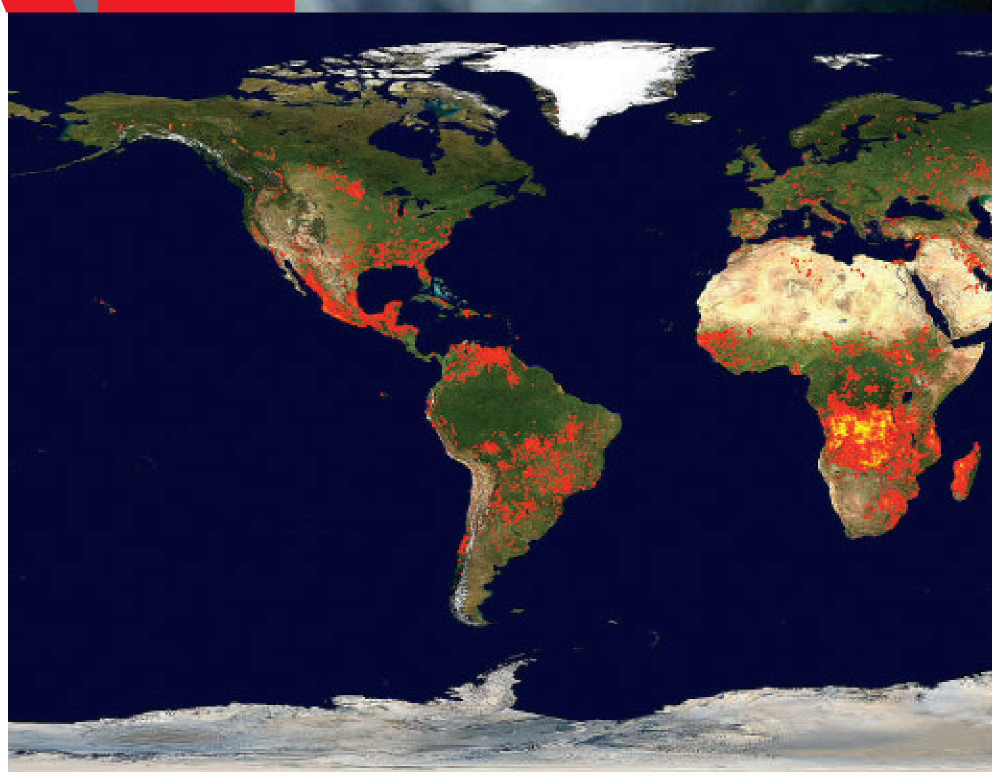
For now, such artificial microswimmers haven't moved much beyond theoretical descriptions and rudimentary designs. But as researchers uncover more about liquid locomotion on tiny scales, the possibilities for such micromachines continue to expand. Says researcher Michael Graham of the University of Wisconsin–Madison: "It's a ... very fruitful area for combining ideas from physics and biology. It's a complex problem, and that's very enticing — lots of fertile ground." ■

Explore more

- Watch videos of *Volvox* algae dancing at www.youtube.com/Goldsteinlab
- E.M. Purcell, "Life at low Reynolds number." *American Journal of Physics*. January 1977.

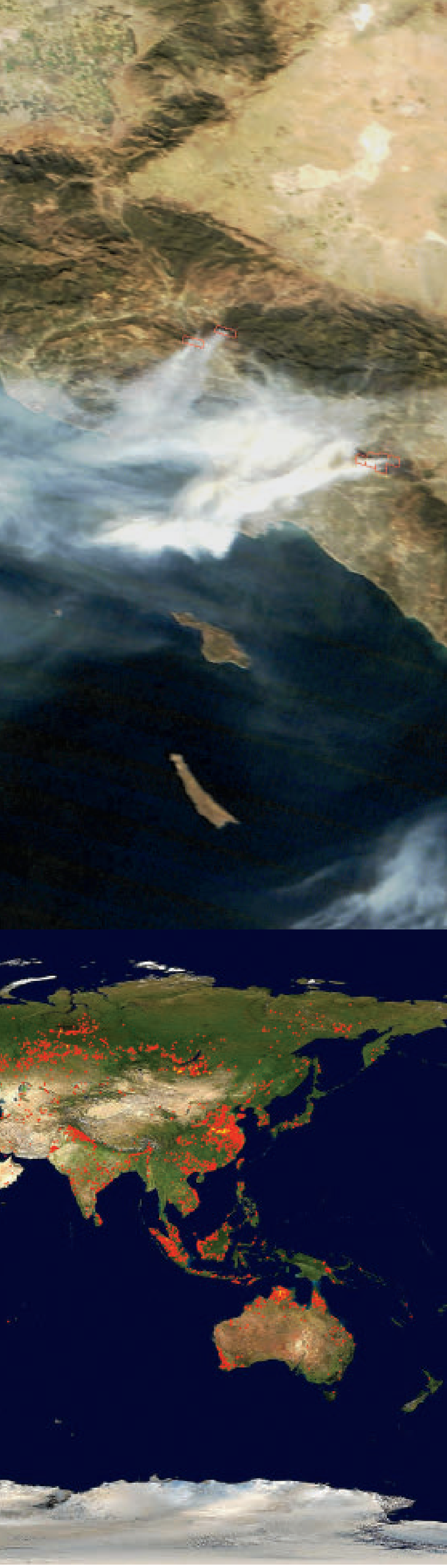
Ecology, climate and human activities conspire to set the world on FIRE

By Solmaz Barazesh



Earth is a fire planet. Ever since the first plants appeared — and provided fuel — more than 420 million years ago, fire has flourished in Earth's oxygenated atmosphere. Some scientists even think that long before humans, fire carved out entire landscapes, clearing dense forests to make way for grasslands.

In recent years, the fingers of flame have extended their reach over more of the Earth's surface. Wildfires are occurring more often and becoming more severe, a perplexing change in fire patterns that threatens to transform ecosystems, reduce biodiversity and even alter climate. To stamp out the flames, researchers have to understand why fire



is spreading and figure out how to fight fire with science.

Fire has many faces. It helps some ecosystems thrive but destroys others. It helps people clear land but can also destroy homes and take lives. Sometimes useful, sometimes destructive, fire is always unpredictable — and that makes it a difficult subject. "Understanding fire is a science, and until now, the science of fire hasn't been properly recognized," says ecologist David Bowman of the University of Tasmania in Hobart, Australia.

But now, researchers from different disciplines are beginning to investigate the science of fire. Some ecologists monitor forest fires burning today, using satellite images to discern how much forest is aflame and how severe the fires are. Other scientists track how forests regenerate after fires. And geologists reach into the past, using remnants of long-cooled forest fires for clues about how fire shaped the ancient Earth.

"Everyone in their respective fields had some knowledge about fire. But now we've got to come together to map out the role of fire in the Earth system," Bowman says.

The "Earth system" is the sum of the planet's physical, chemical, biological and social parts, processes and interactions. Fire can shape landscapes, shift climate and even change processes such as the carbon cycle — blazes have impacted the planet for eons. But now, people could be shifting the balance in a new direction.

Bowman and other fire experts reviewed recent fire research in the April 24 *Science*. The latest work illuminates the complicated role that fire plays on Earth and highlights the interactions among climate, fire and humans.

People are playing more of a role in fire than ever before, the research reveals. In the tropics, fires are routinely started to clear forestland for agriculture or pastureland. And as more homes are built farther into the wilderness, on land where fire used to roam free, the natural patterns of fire are being suppressed.

"There's an emerging need to look at fire at the intersection between biology, ecology and society," Bowman said at a teleconference coinciding with the paper's online release.

New research suggests that, while fires may burn locally, their consequences spread globally. When forests blaze, carbon stored in vegetation escapes into the atmosphere as carbon dioxide, a greenhouse gas. Added up, the fires that burn all over the world could be a significant source of atmospheric carbon, even contributing to climate change.

At the same time, changes in climate could make landscapes more prone to burning. Droughts can set the stage for fires to burn in places where they never used to. And when the natural patterns of fire change, ecosystems change. Fire may kill but not completely destroy trees. "That means there's more fuel waiting for the next fire," says Eric Kasischke of the University of Maryland in College Park, an ecologist who studies fire and climate in boreal forest ecosystems.

Scientists don't have a complete understanding of fire in the Earth system yet. But as researchers pull together the threads of fire science, integrating different areas of research, a new appreciation of fire's global impacts is emerging.

Fire watch

Some ecosystems thrive on fire, such as arid savannas that burst into flame easily, burn often, but soon regenerate. For other ecosystems, fire is a rare and serious event. Ancient forests take thousands of years to grow to maturity and can be destroyed by fire in a matter of hours. The challenge is figuring out the role of fire in each ecosystem, Kasischke says.

Using satellite data, Kasischke and his team monitor fires in boreal forests in Alaska and Canada, figuring out how much forest has burned and tracking the forests as they recover.

Top: The Terra satellite imaged smoke from fires in southern California last November. Bottom: Fires (shown in red) detected between May 31 and June 9 by the Terra and Aqua satellites. Yellow areas host the largest numbers of fires.

TOP: MODIS RAPID RESPONSE SYSTEM; BOTTOM: FIRE MAPS CREATED BY JACQUES DESCLOITRES, MODIS RAPID RESPONSE SYSTEM AT NASA'S GODDARD SPACE FLIGHT CENTER, FIRE DETECTION ALGORITHM DEVELOPED BY LOUIS GIGLIO

Fire feedback Studies in the Amazon region highlight how human activities spur a self-feeding fire cycle

1. New roads, agriculture and development clear trees, opening land on which grasses can thrive.

2. Grasses, which are more apt to burn than trees, fuel fires. Nearby forests may also burn, clearing more trees.

3. After fire, grasses are often the first plants to reappear. Once grasses invade, the area is more likely to burn again.

In the past, fire visited these forests infrequently. But in recent years, fire has picked up the pace. "Between 1959 and 1983 we saw three big fires — that's about once a decade," Kasischke says. "In the last 25 years, the frequency of these big fires has doubled."

Increasing fire frequency is disastrous for slow-growing forests. Black spruce trees can take 30 years to mature and produce seeds. If the forest burns before the trees mature, there won't be any black spruce seedlings to regrow the forest. This opens the door to more quickly maturing species, which can soon dominate the ecosystem, Kasischke says.

Putting out small fires can worsen the problem. That's because small fires — which are low-lying and burn around the mature trees without harming them — clear brush and leaf litter, potential fuel for bigger fires, from the forest floor.

Unfortunately, when homes and people lie in the fire's path, letting even a small fire run its course could be dangerous. So humans suppress the small fires, and brush builds up, providing extra fuel that could turn the next fire into a really big, devastating one, Kasischke says.

Setting controlled fires to mimic natural ones is a strategy already used in some places. Yet even these controlled fires can sometimes get out of hand. "There are lots of factors that turn a small fire into a big one, and we don't understand all of them yet," Kasischke says.

No one puts out the fires in the remote boreal forests that Kasischke and his team monitor, and people rarely start them. Along with the increasing number of fires in these forests, fires in recent years are more likely to have been severe. "2004 and 2005 were our biggest fire years ever," says Kasischke, noting that 2004 was particularly warm and dry.

Conflagration climates

Fire is linked to changing weather patterns, he and other researchers say. Warmer weather dries out the forest, turning it into a tinder box. In summer of 2004, a high pressure weather system sat over the region that Kasischke monitors for weeks — weather that lengthened the fire season, he says.

A 2006 paper in *Science* investigated the consequences of an extended fire season. Anthony Westerling of the University of California, Merced and his colleagues compiled a database of wildfires in the western United States since 1970 and compared the fire records with climate data. Since the mid-1980s, increased temperatures meant that less snow fell and that snow melted earlier. Those changes correlated with increases in wildfires, which burn large swaths and last for long times. Unusually warm springs and longer summers dried out vegetation and provoked more frequent fires of all sizes, the researchers report.

"We're interested in understanding what controls fire frequency and severity, and learning what makes some ecosystems more resilient to fire," says Jennifer Balch of the National Center for Ecological Analysis and Synthesis in Santa Barbara, Calif. She and her colleagues investigate fire in the Amazon's tropical forests.

Big forest fires used to rage through the rainforest about every two centuries. Now, it's more like every two decades, Balch says. A major reason is that fire is a quick, easy and cheap way to clear forest for agriculture and livestock, and is a method widely used in the Amazon, she says. But fire is a fickle friend. It can easily get out of control and end up destroying more forest than intended.

To investigate the effects of fire, Balch and her team, with permission from farmers, deliberately burn blocks of Amazonian forest. As the forest burns, the scientists watch to see which types of vegetation burn and which don't, and measure how such factors as temperature, humidity and amount of leaf litter affect fire intensity — its temperature and duration. After the fire, the researchers track which types of vegetation bounce back most quickly.

"Repeated fires alter the composition of the forest by favoring species with specific traits that help them regenerate after a fire," Balch says. Often, the species that take over the ecosystem are also easy burners, such as grasses that sprout once the trees have been cleared. When fire has raged through a forest once, it's more

ALL IMAGES FROM J. BALCH

likely to return, the researchers say.

The team also calculates the amount of carbon dioxide the burning releases into the atmosphere. In the past, scientists have assumed that any carbon released from forest fires would be balanced by vegetation taking in carbon as the forest regenerates. But as more forest burns and less forest regenerates, changes in vegetation could alter ecosystems and biogeochemical cycles on a global scale.

"Our calculations show that forest fires could account for one-fifth of the greenhouse gases produced by humans," Balch says.

Besides releasing heat-trapping carbon dioxide, fire contributes to climate change by releasing aerosols, or black soot. Soot can warm the atmosphere by absorbing solar radiation.

Fire is such a large source of carbon that it should be incorporated into predictions of climate change, researchers note. "The Intergovernmental Panel on Climate Change should take fire into account," Balch says.

The most recent IPCC report, released in 2007, does acknowledge fire as a source of atmospheric carbon, says Chris Field, an ecologist at the Carnegie Institution for Science at Stanford University, who contributed to the report.

"Fire has not been ignored. But we just don't have good models to incorporate fire into climate change," Field says. "The IPCC is working hard on coming up with better models right now."

Ancient burns

Today's climate changes are not the first Earth has endured, and some researchers think fire may be connected with past climate change, too. Jennifer Marlon of the University of Oregon in Eugene and her colleagues use charcoal deposits as records of ancient wildfires, finding that fire has fluctuated with climate for thousands of years. Studying changes in fire regimes over long time periods puts recent increases in the number, frequency and severity of fires in context.

Over many years, charcoal, which is burned vegetation, washed into lakes, settled and was eventually incorporated into layers of sediment. Marlon and her colleagues take cores of the sediment and analyze the charcoal content layer by layer, getting a snapshot of forest fires at different times.

In a 2008 paper in *Nature Geoscience,* Marlon and her colleagues analyzed lake-bottom sediment cores from around the world to reconstruct fire's history over the past 2,000 years. The data show a strong link between fire and climate, with reduced fire in cold intervals and increased fire in warm intervals, regardless of whether humans were present.

From A.D. 1 to 1750, wildfires decreased in number, the researchers reported. "Earth went through a cooling period at that time, and fires declined along with the temperatures," Marlon says.

Between 1750 and 1870, fires increased. Settlers in the Americas and Australia slashed and burned to clear forest quickly and make land available for agriculture or animal grazing, Marlon says.

After 1870, fire activity hit a lull. "At that time, enough land was cleared that the slash-and-burn methodology slowed down," Marlon says. And as people built homes on previously uninhabited land, wildfires were no longer allowed to rage as they once did. But in remote areas, the number of wildfires remained high and increased as climate warmed, she says.

More information on the patterns of ancient fires comes from the trees themselves. When low-lying understory fires rage through a forest, some trees get damaged, picking up telltale fire scars, says Thomas Swetnam of the University of Arizona in Tucson. By looking at the location of the scars in relation to tree rings, researchers can figure out when fires have occurred.

"We sample living and dead trees that were injured by fire," Swetnam says. "Using fire scars, we can determine the year and the season of the fire."

By scaling up the analysis from trees in single forests to whole regions and even continents, the researchers can get a global record of fires over time.

Swetnam and his colleagues report that fire is intimately connected with climate, with particularly bad fire seasons in drought years. "This is when we see many fires burning at one time," Swetnam says. Tree-scar records show that fire can also be impacted by El Niño and La Niña. These oscillations in ocean temperature trigger changes in atmospheric conditions that shift weather patterns in different parts of the world.

La Niña brings drought to some parts of the United States, contributing to a spike in fire frequency, especially in the western states. El Niño brings wet weather and flooding — but that doesn't mean the forests are safe. "That reduces fire activity and gives fuel a chance to build up, meaning that the next year of fires will be even worse," Swetnam explains. "Weather patterns swing between El Niño and La Niña every two to seven years. We see the frequency of severe fires fluctuate on a similar range."

Beginning in the 20th century, though, "we're seeing a major shift in the fire regime," Swetnam says. "Fire is increasing, and now it's feeding back into climate." But by collecting information about how fire patterns have varied through history, the researchers hope to gain a clearer understanding of the relationship between changes in climate and changes in fire regimes.

Fire patterns are still not well understood, but the latest research is showing that they follow a cycle that human activity is changing. Fully elucidating the role of fire in the Earth system will require figuring out how fire affects different ecosystems and how these impacts add up.

"There's no basic ecology textbook that describes how fire changes ecosystems or climate," Balch says. "But we're accumulating more information — and we're getting closer." ■

Solmaz Barazesh is a science writer based in Baltimore.

Explore more

- Access the Web Fire Mapper and other data at FIRMS, the Fire Information for Resource Management System: maps.geog.umd.edu/firms

Astronomical art faux pas

Assuming they are in the Northern Hemisphere, those two young folk on the cover of the May 23 *Science News* look remarkably chipper while keeping astronomers' hours. I make the time to be about 3 a.m. as a waning *de*crescent moon rises.

Dainis Bisenieks, Philadelphia, Pa.

The cover of your Special Astronomy Issue is a wonderful example of why we need more and better astronomy and science education. For instance, when seen after sunset the crescent moon looks like) but before sunrise the crescent phase looks like (.

Your cover illustration shows "youths exploring the night sky." Those making astronomical observations could still be active in the morning, but most of the activities seen in these types of illustrations would be going on in the late evening. Artists and cartoonists often place a crescent moon in the night sky, probably to indicate that it is indeed night. Watch your daily comic strips for a few weeks to see. Almost invariably, the crescent moon shown is the phase only seen in the wee hours of the morning.

When I first noticed this several years ago, I wondered why artists consistently drew the crescent moon wrong. I wrote to several cartoonists with strips in the daily newspapers. Only one replied: Guy Gilchrist, one of the cartoonists for the "Nancy" comic strip. Guy said that the moon was drawn wrong "probably because it's easier to drag a pen or brush this >> way than << that way. You have to push << that way. We cartoonists are a lazy bunch." I would hardly call folks who can come up with a new cartoon every day of every year "a lazy bunch." But perhaps it is easier to draw the wrong phase of the moon — and who would notice?

I wonder if artists, cartoonists and audiences were better educated about the moon's phases, wouldn't the artists make a little extra effort to get it right?

Jack Ryan, El Dorado, Ark.

I love your magazine, but was greatly amused by the retro cover art of the astronomy issue. The young amateur astronomer at the window has apparently discovered a rare miniature star orbiting between the Earth and moon — the bright dot that appears inside the crescent of the moon! I would love to read an explanation of this new phenomenon!

Barbara Dilworth, Eureka, Calif.

Quantum plant activity

As a biologist with some background in physics, I found the article "Living physics" (*SN: 5/9/09, p. 26*) probably one of the most important that you have published for a long time. Some indication that biologists are aware of the exciting developments in quantum physics and that those developments need to be applied to biological theory are much overdue. But there is still a long way to go. The article makes it plain that researchers now need to consider the implication of Bell's theorem of non-locality, which indicates that quantum "particles," such as the electrons and atoms in molecules, do not even need to be close to each other, provided they have been previously quantum entangled. I await your article on the biological effects of Bell's theorem with great anticipation.

Donald K. Edwards, Saanichton, British Columbia, Canada

In the article "Living physics," it is stated that 95 percent of the light hitting a leaf reaches the photosynthetic reaction center. If photosynthesis is so efficient, it would truly be a good way to convert sunlight into biofuels. Yet Nathan Lewis at Caltech has stated that photosynthesis is only about 0.3 percent efficient, so that enormous amounts of land would be needed to produce significant amounts of biofuels. If Lewis is correct, it is smarter to use things like photovoltaics that have far higher efficiency. Obviously, in this instance, the calculation of "efficiency" is being based on different measures of efficiency. Can you illuminate this issue for me? Perhaps the real limitation is in the production of carbohydrate plant material rather than in the absorption of light and its conversion into active electrons.

Bill Thomas, Cedar Mountain, N.C.

As the reader points out, calculating the efficiency of photosynthesis depends on what you're looking at. When calculating how much energy from the sun gets converted into the mass of the plant, the numbers can vary. Some giant grasses are extremely efficient and over a three-month growing season can convert about 8.8 percent of the light they absorb into biomass. The conversion efficiency of most plants, when averaged over the whole year, ranges from a few tenths of a percent to almost 10 percent.

In the story, the scientists discussed the "quantum efficiency" of photosynthesis, focusing on only the initial step of the transfer of energy from sunlight, which takes into account the odds that a photon that gets absorbed by a plant will actually be used and converted into energy. Scientists agree that the quantum efficiency of photosynthesis is nearly 100 percent at low light levels. — Susan Gaidos

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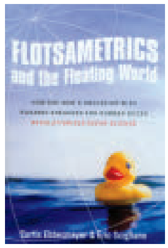
Flotsametrics and the Floating World

Curtis Ebbesmeyer and Eric Scigliano

Buoyant items that end up in the sea — from tennis shoes to tree branches — drift at the mercy of winds and ocean currents, sometimes for thousands of miles. Seafarers have analyzed such debris, called flotsam, for centuries: Noticing odd items washed up on European beaches led Vikings to new harbors and Columbus to discover the New World, the authors reveal.

Today, scientists recognize flotsam as a tremendous source of scientific data. As researcher Curtis Ebbesmeyer and science writer Eric Scigliano recount, beachcombing is a poor man's oceanography. By knowing when and where a beachcomber stumbled upon an item, as well as when and where that item had entered the water, scientists can divine information about oceanic swirls of all sizes, from small eddies that spin off the Gulf Stream to looping, sea-spanning currents called gyres.

Flotsametrics is a captivating memoir chronicling Ebbesmeyer's journey into the floating world, from his childhood fascination with water to his professional studies of currents and tides. In the book's final chapters, the authors describe a kind of flotsam that would have been unrecognizable to early seafarers: plastic trash.



Many of the items floating within the ocean's vast "garbage patches" — a term Ebbesmeyer coined in the 1990s — are plastics that contain potentially harmful chemicals and may not decay for hundreds of years.

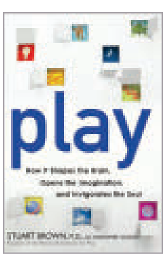
For better or worse, every piece of flotsam has a tale to tell, Ebbesmeyer contends. Any beachcomber willing to pay attention can help unravel the ocean's story. *— Sid Perkins*

Smithsonian Books/Collins, 2009, 286 p., $26.99.

Play: How It Shapes the Brain, Opens the Imagination, and Invigorates the Soul

Stuart Brown with Christopher Vaughan

Long days and warm weather can make the urge to put down work and go play almost impossible to resist. So don't. The drive to play is as natural as the drive for food and sex, the authors of this book convincingly argue. "Play shows us our common humanity," they write. "It is the genesis of innovation, and allows us to deal with an ever-changing world."



Play defies easy definition, write Vaughan and Brown, founder of the National Institute for Play. Sliding down a mountain in sub-zero temperatures while strapped to two thin planks thrills some but petrifies others. But, in general, play is voluntary and flexible. Most important, it is seemingly purposeless.

"Seemingly" is the key idea. The authors discuss research showing that rats that played with toys and other rats when young developed larger brains than those barred from joining the fun. In people, play has been linked to relationship satisfaction, emotional adjustment and creativity.

In one striking example, Brown describes Charles Whitman, who in 1966 murdered his wife, mother and 14 people at the University of Texas at Austin before police shot him. Brown helped investigate the incident. Besides a controlling father, Whitman's life was distinguished by an utter lack of play, which contributed to his psychopathology, Brown concludes.

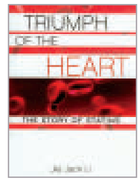
Whitman's case was extreme, but many people feel the dearth of play in their lives. The book includes tips for how to get the activity and its benefits back. Fun yet deeply serious, this book shows that people ignore the urge to play at their own peril. *— Rachel Zelkowitz*

Avery, 2009, 240 p., $24.95.

Painting Apollo: First Artist on Another World

Alan Bean

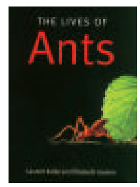
One of the 12 men to have walked on the moon shares his experiences through his art. *Smithsonian Books, 2009, 224 p., $39.95.*



Triumph of the Heart: The Story of Statins

Jie Jack Li

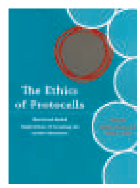
A medicinal chemist reviews the history of the widely used cholesterol-lowering medications. *Oxford Univ. Press, 2009, 201 p., $29.95.*



The Lives of Ants

Laurent Keller and Élisabeth Gordon

A scientist and a writer team up to explore how these insects' lives parallel human lives — in work, war and garden-tending. *Oxford Univ. Press, 2009, 252 p., $27.95.*



The Ethics of Protocells: Moral and Social Implications of Creating Life in the Laboratory

Mark A. Bedau and Emily C. Parke, eds.

This text offers a variety of perspectives on the potential risks and rewards of developing self-organizing, microscopic entities. *MIT Press, 2009, 365 p., $28.*

Einstein's Telescope: The Hunt for Dark Matter and Dark Energy in the Universe

Evalyn Gates

Scientists attempt to track down the invisible ingredients of the cosmos. *W.W. Norton, 2009, 305 p., $25.95.*

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Nobelists to students: Being wrong may be just right

In a "passing of the torch" ceremony, a panel of prominent scientists answered questions from some of the more than 1,500 high school student finalists at this year's Intel International Science and Engineering Fair, which was held in Reno, Nev. Society for Science & the Public, publisher of Science News*, has administered the fair since its inception in 1950. The May 12 panel addressed issues ranging from renewable energy to intelligent extraterrestrial life and included Nobel Prize winners Dudley Herschbach, Leon M. Lederman, Peter Agre, Douglas Osheroff and Martin Chalfie, among other notable scientists. Writer Rachel Ehrenberg attended the Excellence in Science and Technology Discussion and provided the following excerpts.*

Michael Kaplan, The Bronx High School of Science, Bronx, N.Y.

Thomas Huxley said "The great tragedy of science is the slaying of a beautiful hypothesis by an ugly fact." If your theories about the future of your field were proven incorrect tomorrow, would you cling to your belief or abandon it in favor of a new idea? Would this frustrate you or [would you] be content with knowing how everything really works?

Leon M. Lederman

It's a curious question because if something that you expected to be right turns out not to be right, what you do is roll up your sleeves and fix it. Whenever there is something that goes wrong in science — and it goes wrong: There's lessons like cold fusion and so on where scientists went completely wrong, and it was too bad because we were faced with the possibilities of limitless cheap power and it was all wrong and the scientists found out that it was wrong. So I think an essential ingredient in understanding why science progresses the way it does is that we know how to fix things when they are wrong. There may be individuals who are reluctant to change their own theories for personal reasons, but there is a community. And the community will insist that the science be correct. So I don't think there's any dilemma in addressing issues where science is wrong. The big collider that we're all waiting to have operate in Geneva may produce something called the Higgs boson. On the other hand, it may not. If it doesn't produce it then lots and lots of theoretical physicists will be embarrassed, but who cares about that? ... The important thing is we've learned something very important about the way nature works and we will immediately go to try and improve that — that's the way science progresses.

Martin Chalfie

I would say that a good 95 percent — maybe I'm being generous to myself — of my ideas turn out to be wrong. I think that's how we do science. We make mistakes all the time. We make hypotheses and we design experiments with some idea in mind and we get something unusual and it's in fact invigorating to have to go off in another direction and find out why we were so mistaken in what we did. So I think this is how we work normally, this is not something unusual.

Dudley Herschbach

Our academic business inculcates in people a fear of being wrong, with exams and all that. But it's not that way in science because we know that what we are after — understanding — waits patiently for us. In fact, all of science is wrong in the sense that it's not complete. We don't expect it to be complete. We expect that discoveries, new tools, methods will open our eyes to a larger perspective and some of our old ideas will be recognized as wrong.... It's part of science, so you don't fear being wrong.

I would say that a good 95 percent —maybe I'm being generous to myself—of my ideas turn out to be wrong. I think that's how we do science.

MARTIN CHALFIE

Douglas Osheroff

I think a lot of science, certainly in my field, can be divided into two parts: one is the theory that allows us to understand the behavior of materials in various regimes, and the other is a body of physical evidence which has been produced by experimentalists who actually look at these materials and probe them very deeply and, hopefully, very accurately. In terms of the theorists, of course they always have to be ahead of the experimentalists. What I always like to say about the theorists is you should listen to theorists because they tend to have a wonderful nose for where interesting physics lies, but don't expect them to get it all correct, at least not in my field. So I think theorists learn much more when they find that their theory is wrong than when their theory is right. And that is the way science should be and I think we all embrace those events.

Peter Agre

I think scientists could take a little lesson from Groucho Marx. When asked about his principles, he said, "Well, these are my principles; if you don't like them I have others." It's a bad idea to bet your entire reputation on one theory, one idea or one discovery. ■

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