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ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ DECEMBER 6, 2008

DISPATCHES
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Exposed

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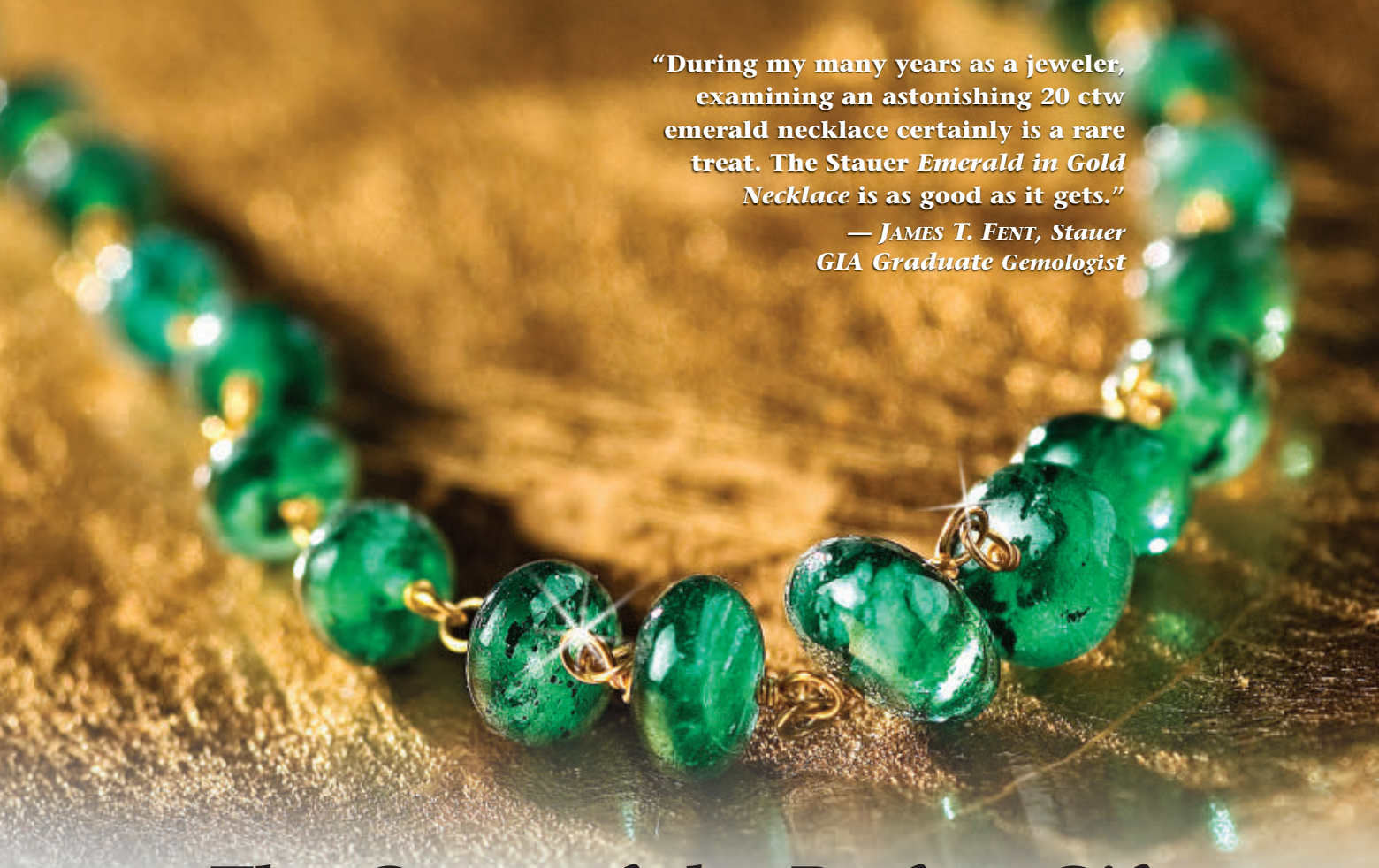
Cardio Cath Lab, Stat

Minerals Evolve Too

Quantum Code Cracking, Just in Time



The Curse of the Perfect Gift

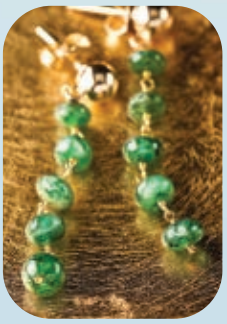
20 carats of polished natural emeralds linked with 14K gold for under $200!

It happened on our last trip to South America. After visiting the "Lost City" of Machu Picchu in Peru, we ventured through the mountains and down the Amazon into Brazil. In an old village we met a merchant with an impressive collection of spectacular, iridescent emeralds. Each gem was tumbled smooth and glistened like a perfect rain forest dew drop. But the price was so unbelievable, I was sure our interpreter had made a mistake.

But there was no mistake. And after returning home, I had 20 carats of these exquisite emeralds strung up in 14k gold and wrapped as a gift for my wife's birthday. That's when my trouble began. She loved it. Absolutely adored it. In fact, she rarely goes anywhere without the necklace and has basked in compliments from total strangers for months now.

So what's the problem? I'm never going to find an emerald deal this good again. In giving her such a perfect gift, I've made it impossible to top myself.

To make matters worse, my wife's become obsessed with emeralds. She can't stop sharing stories about how Cleopatra cherished the green gem above all others and how emeralds were worshiped by the Incas and Mayans and prized by Spanish conquistadors and Indian maharajahs. She's even buying into ancient beliefs that emeralds bring intelligence, well-being and good luck to anyone who wears them. I don't have the heart to tell her that I'm never going to find another deal this lucky.



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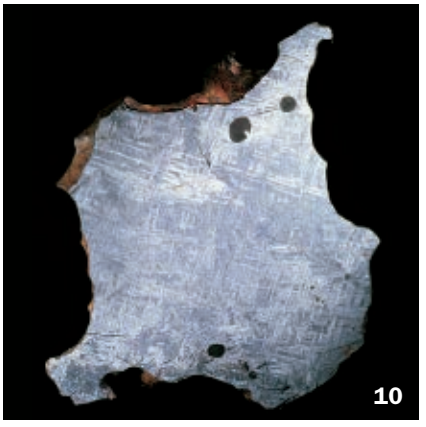

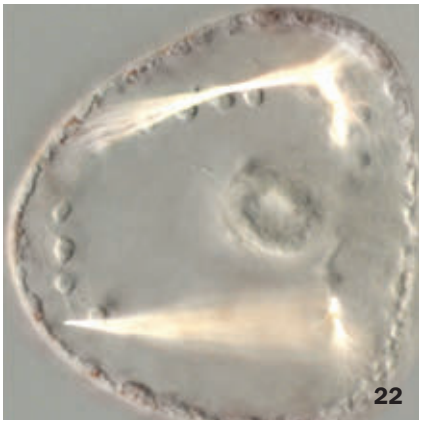

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ScienceNews

In The News

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Essay

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COVER By blocking Fomalhaut's light, scientists captured this image of what is almost certainly a planet orbiting the 200-million-year-old star.
Kalas, NASA, STSCI

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Quantum codes conceal secrets of the cosmos

It seems like an innocent enough title for a scientific paper: "Closed timelike curves enable perfect state distinguishability."

But perhaps the intent was clandestine. By a careful choice of words, the authors may have been sending an encrypted message. "Closed timelike curves" is code for time travel. "Perfect state distinguishability" means that the only uncrackable codes for sending secret messages could actually be cracked after all.

As Rachel Ehrenberg reports in this issue (Page 15), the paper outlines a way to decipher messages encoded with quantum cryptography, supposedly the one provable way to communicate without fear of undetected eavesdropping. Quantum particles cannot be measured without being disturbed, so any attempt to intercept a quantum message and then retransmit it would inevitably change the message in a way that would reveal the interference.

But now Todd Brun and his collaborators have offered those evil eavesdroppers a way to outmaneuver quantum invulnerability. All they need is access to a "closed timelike curve," a pathway that links the future to the past. In popular terms, that would be a wormhole, a tunnel through spacetime that could transmit an object, or information, from now to then and back again.

Wormholes are permitted by Einstein's theory of general relativity, but there is considerable doubt about whether they really exist or would be stable enough to transmit anything if they did. If they do exist, though, it appears that an eavesdropper could use them to read a quantum code without disturbing it.

That possibility does disturb IBM physicist Charles Bennett, a pioneer of quantum cryptography protocols. He suspects that the ability to break coded quantum messages would also confer much greater power, such as being able to send messages over unlimited distances faster than the speed of light. That would be really big news, no matter how obscure the paper's title.

Of course, that conclusion may hinge on just how the math of closed timelike curves is interpreted, or it may mean that wormholes can't really exist, after all. Or perhaps it shows that the universe continues to conceal some really weird secrets — and that, of course, is the point of these exercises. Nobody is really worried that eavesdroppers will use wormholes to spy on the CIA. It's all about cracking the code of the cosmos.

In any case, we'll be watching as the time travel/quantum coding story unfolds, and we'll be reporting more on it soon. Maybe we already have. — *Tom Siegfried, Editor in Chief*

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Scientific Observations

"Tests have shown that, when a baby is lowered face down into warm water with a parental hand under his tummy, he shows no sign of panic but holds his breath automatically and floats happily in the water with his eyes fully open, gazing at the underwater scene. If, very gently, the supporting hand is removed, the baby starts making swimming movements with his limbs and sets off in the water. So, although a newborn baby cannot move himself from place to place in the air, once he is allowed to float under the water he suddenly becomes remarkably mobile.... He can even swim before he can crawl."

DESMOND MORRIS, WRITING IN HIS NEW BOOK *AMAZING BABY*, RELEASED IN SEPTEMBER

Science Past | DECEMBER 6, 1958

FIND CELL "POWER PLANTS" — Fragments of mitochondria, microscopic "islands" in the cell protoplasm surrounding the nucleus, are helping scientists find out how a cell gets its energy to carry on vital life processes. All energy comes from combustion of foodstuffs, but exactly how the living cell does absorb, store and release energy is unknown. Now, Dr. Albert L. Lehninger of the Johns Hopkins School of Medicine has reported, the mitochondrion membrane has been taken apart and analyzed. It has been found to play an essential role in the exchange of electrons needed for energy storage and release. Of all the parts of the cell, Dr. Lehninger pointed out, only the mitochondrion [membrane] is known to play a part in combustion.

Science Future

January 3, 2009
The Year of Science kicks off with a launch event in Boston. Visit www.yearofscience2009.org

January 28, 2009
The STFC holds a workshop in London on commercial applications of satellite data. Visit www.scitech.ac.uk/KE/Events/Wrks/SatData.aspx

March 18, 2009
The National Science Education Leadership Forum will be held in New Orleans. Visit www.nsrconline.org

SN Online

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GENES & CELLS

Using preserved hair samples (shown), researchers have sequenced about 70 percent of the woolly mammoth's nuclear genome. The findings provide clues to when the last common ancestor of the ancient animal and today's elephants lived. Read more in "Mammoth genome approaching completion."

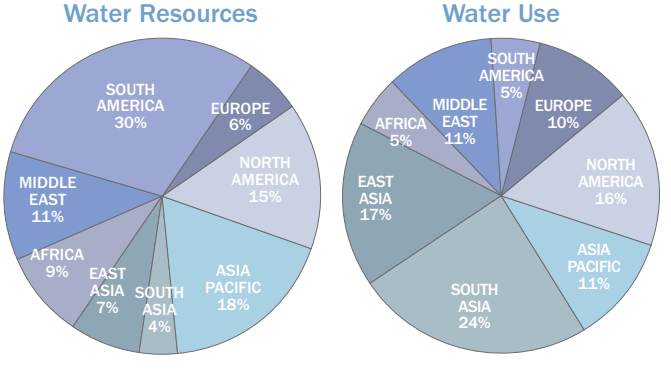
ATOM & COSMOS

NASA's Phoenix Mars Lander has tasted its last morsel of the Red Planet's soil and viewed its last Martian landscape. With shorter days and an inopportune dust storm, the lander can't get the solar power it needs to function. Read more in "NASA's Phoenix Mars Lander stops communicating."

For Daily Use

Turning down the thermostat on hot-water heaters may be good for the environment and the electricity bill, but it may not be good for your health. The 140° Fahrenheit standard kills potentially lethal waterborne organisms, including the ones responsible for Legionnaires' disease (shown) and nontuberculous mycobacterial infections. These organisms breed easily around 120°F, the temperature recommended for prolonging a water heater's life. Read "The case for very hot water" under Science & the Public at www.sciencenews.org.

Science Stats | WORLDWIDE WATER: SUPPLY AND DEMAND



SOURCE: *THE ATLAS OF THE REAL WORLD: MAPPING THE WAY WE LIVE*, THAMES & HUDSON 2008

CLOCKWISE FROM TOP LEFT: FLORIS LEEUWENBERG/THE COVER STORY/CORBIS; STEPHAN SCHUSTER LAB/PSU; LINDA STANNARD, UCT/PHOTO RESEARCHERS

“There is good reason to hope that this is indeed the first true image of an extrasolar planetary system.... This one might well be the real enchilada.” —ALAN BOSS, PAGE 5

In the News

STORY ONE

Exoplanets make pictorial debut

First images of a planetary trio circling a star are released

By Ron Cowen

Canadian astronomer Christian Marois was already carrying a tightly held secret when he boarded an airplane in July to Hawaii’s Mauna Kea, the mountaintop home of both the Gemini North and Keck observatories. Images his team had taken with Gemini North nine months earlier had revealed a faint point of light — a possible planet — near the massive star HR 8799, which lies about 130 light-years from Earth. During the flight, Marois did a quick-and-dirty analysis of other images of the same star. To his amazement, he found evidence of a second planet.

Then, against all odds, Marois’ team attained a trifecta. During the July observing run at Keck, the team photographed a third candidate planet around HR 8799.

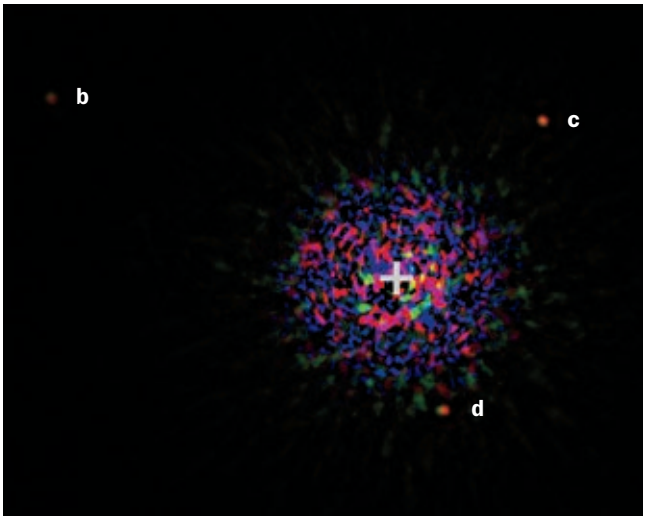
As Marois, of the Herzberg Institute of Astrophysics in Victoria, and his colleagues report online November 13 in *Science*, the team kept the findings under wraps while confirming that the orbs are not mere background objects but true planets, gravitationally bound to and circling their parent star. The discovery of this planet trio, a stretched-out version of the outer solar system recorded at seven different infrared wavelengths, is “spectacular,” says Ray Jayawardhana of the University of Toronto.

Astronomers have been hunting for images of extrasolar planets for years, but had yet to find a body gravitationally bound to an object big enough to be a star.

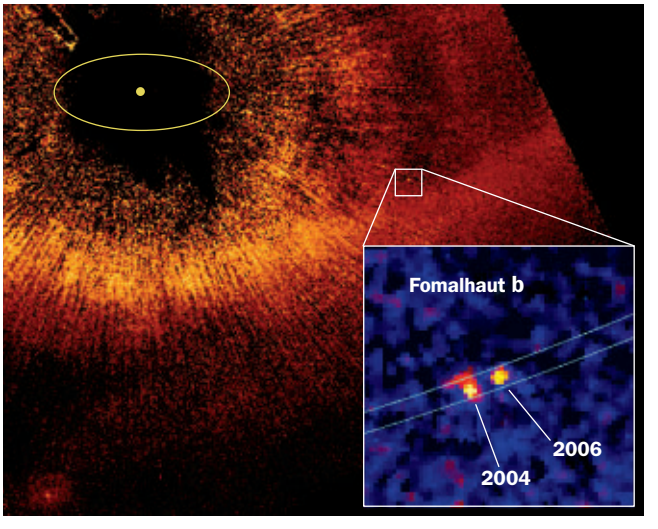
“There is good reason to hope that this is indeed the first true image of an extrasolar planetary system,” says theorist Alan Boss of the Carnegie Institution for Science in Washington, D.C. “This one might well be the real enchilada.”

The HR 8799 system’s two innermost planets are the heaviest, about 10 times as massive as Jupiter, while the outer planet is the lightest — a size relationship that hints the planets coalesced from a vast disk of gas, dust and ice particles that once encircled the star. The planets reside at roughly 25, 40 and 70 astronomical units from HR 8799. By comparison, the solar system’s most distant planet, Neptune, has an average separation of 30 AU (one AU is the average Earth-sun distance). »

This composite infrared portrait shows a planetary system beyond the solar system. A trio of planets (faint red dots b, c and d) orbits the massive star HR 8799 (center). Heavier than Jupiter, each of the planets is thought to be a gas giant.



The Hubble Space Telescope took this picture of what is almost certainly a planet (Fomalhaut b, inset) shown at two points along its orbit of the star Fomalhaut (represented by central ring). The star’s light was blocked to create the image.



FROM LEFT: MAROIS, NATIONAL RESEARCH COUNCIL CANADA, KECK; KALAS, NASA, STSCI

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» Intriguingly, the outermost planet lies next to a remnant disk of dusty debris believed to surround the star. The disk is similar to the solar system's Kuiper Belt.

Publishing the same day online in *Science*, Paul Kalas of the University of California, Berkeley and his colleagues unveil what appears to be another historic extrasolar planet image. Using the Hubble Space Telescope, the team has captured a portrait of a body orbiting the well-known star Fomalhaut, only 25 light-years from Earth.

Kalas and his collaborators proposed in 2005 that a disk of debris surrounding Fomalhaut was being gravitationally modified by an unseen planet. Indeed, the newly imaged body lies near the inner edge of the disk, some 120 AU away from its star. And visible-light observations taken 21 months apart by Hubble's Advanced Camera for Surveys reveal that the body circles the star. Because Fomalhaut's disk is relatively undisturbed, the planet can be no heavier than three Jupiters, Kalas' team reports.

The body's proximity to the remnant disk strongly suggests that it is a planet, comments Jonathan Fortney of the University of California, Santa Cruz.

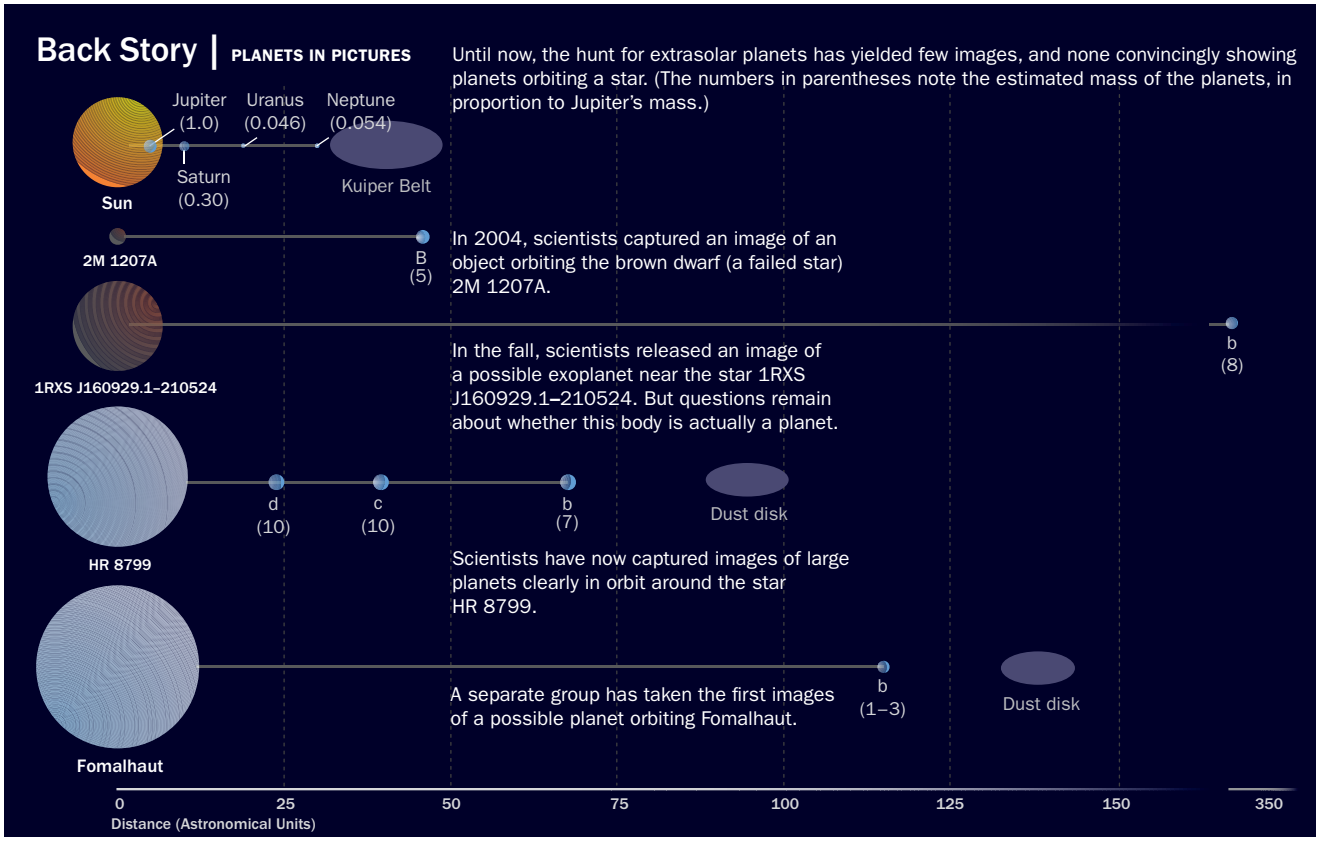
Two other aspects of the Kalas study, however, give researchers pause. A search for the planet at infrared wavelengths, where a young planet is expected to radiate the bulk of its heat, failed to spot it. Water clouds in the planet's atmosphere, which would trap some of the infrared radiation, could explain why the object hasn't been seen at an infrared wavelength of 2 micrometers, according to a model by Fortney and Mark Marley of NASA's Ames Research Center in Mountain View, Calif. But if searches at longer infrared wavelengths also fail to detect the body, the finding would be at odds with accepted models of planet formation and evolution, Fortney says.

Also, the planet appears much brighter at the shorter of the two visible-light wavelengths recorded by Hubble. Planets don't radiate that much visible light, notes Fortney. Instead, Kalas' team proposes the unexpected brightness comes from starlight reflected off vast ice or dust rings that might surround the planet.

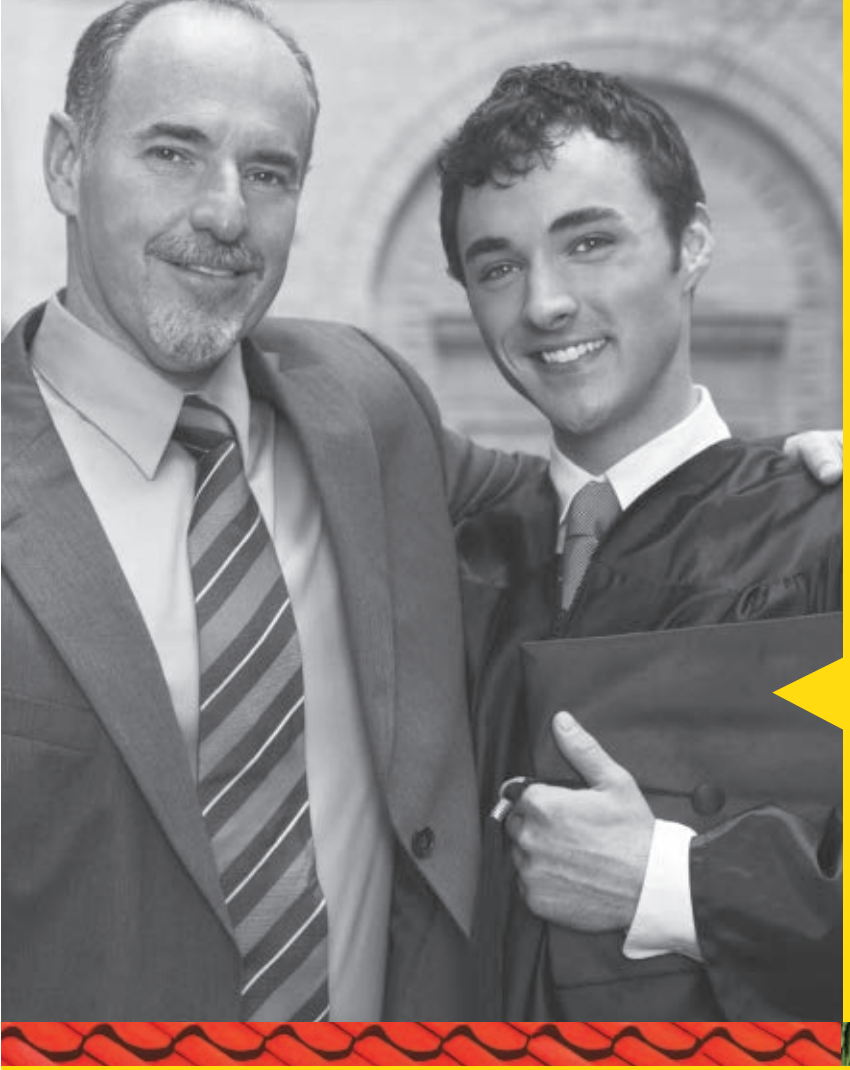
The finding "is not really as ironclad as theorists would want it to be," says Fortney, "but nature can be messy."

Jayawardhana and his collaborators recently released an image — as well as spectra — of a possible planet around another nearby star (*SN: 10/11/08, p. 8*), but they don't yet know if the faint body is orbiting the star or merely resides in the same patch of sky.

With the new findings, "the era of direct imaging of extrasolar planets is here at last," he says. The discoveries "are revealing an entirely new population of planets — massive ones in wide orbits — that couldn't be found with other methods." ■



SOURCE: MARK MARLEY



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Body & Brain

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Food advice could be peanuts

Early exposure seems to lessen the risk of nut allergy

By Nathan Seppa

Consuming peanuts in infancy appears to lessen, not increase, a child's risk of developing a peanut allergy later, British researchers report in the November *Journal of Allergy and Clinical Immunology*.

The findings clash with some pediatric recommendations of the past decade — parents have been told to avoid feeding peanut products to infants. The new study suggests that early exposure to peanuts, in the form of eating peanut butter, might induce tolerance and head off the aberrant immune response that underlies an allergic reaction.

"This work is extremely thought-provoking and raises the possibility that an approach of trying to avoid peanuts may be the wrong thing to do," says Robert Wood, an immunologist and pediatric allergist at Johns Hopkins University in Baltimore.

Allergist Gideon Lack of King's College London and his colleagues distributed food allergy questionnaires to thousands of families in Britain and Israel in 2004 and 2005. The research team analyzed nearly 9,000 responses, which contained data on roughly 4,000 Jewish children in North London and 4,600 Jewish children in Tel Aviv.

The researchers chose Jewish children in both countries to limit genetic differences between comparison groups.

Peanut allergies showed up in 0.17 percent of the Israeli children and 1.85 percent of the British children, an 11-fold difference in risk. Even after the researchers accounted for age differences between the groups, and for the prevalence of other food allergies and allergic reactions such as rashes or asthma, the British kids were still nearly six times as likely to have a peanut allergy. Among primary school children the risk was nearly 10-fold.

To assess what "first foods" are given to babies in England versus in Israel, the researchers gave questionnaires to mothers visiting clinics with children ages 4 months to 24 months — distributing 99 surveys to Israelis and 77 to Britons. These surveys detailed when the babies first received cow's milk, peanuts, other nuts and eggs.

The results revealed that early peanut consumption was more common in Israel. At 9 months of age, 69 percent of Israeli babies had started eating some form of peanuts, whereas only 10 percent of children in Britain had. There was little difference in the age at which other foods were introduced.

"I think there is enough here — even from trying to compare these two different populations — to suggest that peanut avoidance practices in most of the industrialized societies now need to be reexamined," says Wesley Burks, an immunologist and pediatric allergist at Duke University in Durham, N.C.

Peanut allergy in kids has grown in recent decades in Europe, Australia and the United States, where fear has discouraged peanut butter as an early food, the authors note. The average age of onset of the allergy has also decreased in the United States.

In 2000, the American Academy of Pediatrics recommended withholding peanut products until a child reaches 3 years of age. But earlier this year, based on mixed results in ongoing studies, the Academy rescinded that recommendation and reverted to its standard recommendation for introducing non-breast-milk foods — wait until only 4 months to 6 months.

Nonetheless, warnings remain in place in Britain and Australia.

Meanwhile, infants commonly consume peanut products in the Middle East, Africa and Southeast Asia. In all those places, peanut allergy is rare, the authors note.

> "This work … raises the possibility that an approach of trying to avoid peanuts may be the wrong thing to do."
>
> ROBERT WOOD

In 2007, the researchers started recruiting families to participate in a long-term study. Researchers have signed up 640 children under age 11 months, some of whom will be randomly assigned to eat peanut products. When the children reach age 3, the scientists will assess who has developed a peanut allergy. Results are expected by 2014.

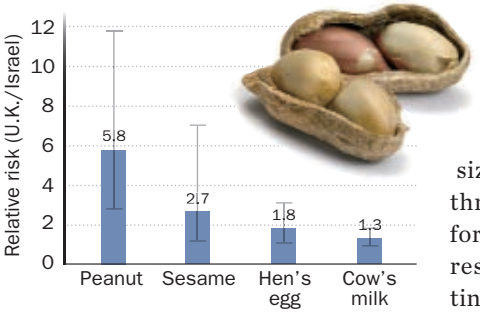
Though the cause of peanut allergy remains unknown, it's widely accepted that genetic predisposition plays a part. But genes wouldn't account for the recent increase in allergies since genetics don't change that rapidly, Wood says.

A 2003 study by Lack and his team led to one theory unrelated to genes. The team found that preschool children who were allergic to peanuts were much more likely as infants to have been treated with skin lotion containing peanut oil than were children who didn't have the allergy.

The researchers hypothesized that exposure to peanut protein through the skin laid the foundation for an aberrant immune reaction that resulted in allergy. Researchers continue to investigate this possibility. ■

Risk of food allergies

Kids in the United Kingdom are 5.8 times more likely to have peanut allergies than kids are in Israel.



SOURCE: GEORGE DU TOIT *ET AL.*; IMAGE: PRILL/ISTOCKPHOTO

24 months | Average age of peanut allergy onset in U.S. babies born before 2000

18 months | Average age in babies born after 2000

Opt for the tube, and do so quickly

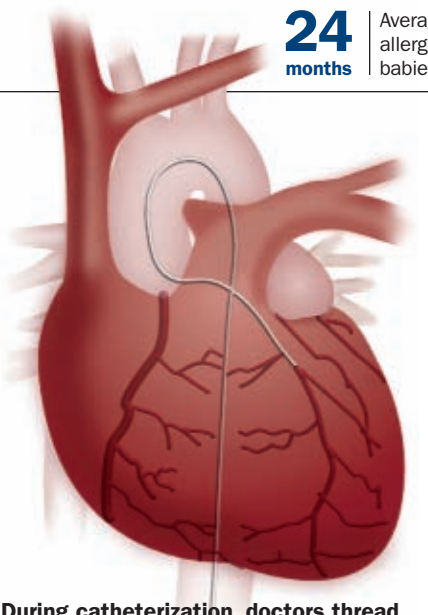
Heart patients may benefit from prompt catheterization

By Nathan Seppa

NEW ORLEANS — People who arrive at a hospital with chest pain or other mild heart attack symptoms, but ambiguous scores on medical tests, might still warrant emergency treatment, according to new research.

The study, reported November 10 at the American Heart Association's annual Scientific Sessions, suggests that getting some of these marginal patients into a heart catheterization lab within 24 hours causes no harm and sharply decreases their risk of the problem recurring over the next six months.

"Timing matters in unstable angina or small heart attacks," says Shamir Mehta, a cardiologist at McMaster University in Hamilton, Canada.



During catheterization, doctors thread a line from a leg artery to the heart to open a blocked coronary artery.

To determine clearly whether these heart patients in the diagnostic gray zone might benefit from immediate catheterization, Mehta and his colleagues randomly assigned 1,593 such patients to get drugs plus catheterization as soon as possible, or within 24 hours. Another 1,438 received only drugs at first, then catheterization more than 36 hours later.

During the next six months, patients who got early catheterization were 70 percent less likely to have repeat coronary blockage as were those who received late catheterization, Mehta reported.

The patients' risk of death, heart attack or stroke was not significantly affected. But the researchers found a different story after analyzing patients with two of three common risk factors for a heart attack — being over age 60, having evidence of a blockage on their EKG or having one telltale blood reading. Those who received prompt catheterization were somewhat less likely to die, have a heart attack or have a stroke within six months as were similar patients who didn't.

Medical guidelines help physicians determine who should be sent quickly for catheterization, but many hospitals don't have teams on site around the clock.

"This is a very important trial," says Sidney Smith of the University of North Carolina at Chapel Hill. "Frequently, all the messages in the guidelines are not widely appreciated."

Drug may slow viral heart infections

Interferon reduced presence of viruses in biopsied tissues

By Nathan Seppa

NEW ORLEANS — A viral infection of the heart can be eliminated or at least slowed by treatment with the drug interferon, a team of European researchers reports. Viral infections show up in some patients with heart failure and may bear some responsibility for some cases, particularly when it occurs in young or middle-age patients.

Although the new results are preliminary, many patients reported feeling better, cardiologist Heinz-Peter Schultheiss of Charité–Universitätsmedizin Berlin reported November 11 at the American Heart Association's annual Scientific Sessions. The findings also suggest yet another role for interferon, a multipurpose drug that, in slightly different forms, is used against the hepatitis C virus and multiple sclerosis.

In the new study, the researchers biopsied heart tissue in 368 people with cardiomyopathy — a common form of heart failure in which the heart muscle becomes inflamed and the heart functions poorly — and found that two-thirds had a viral infection in the heart. The scientists then randomly assigned 95 of these people to receive injections of the drug interferon beta-1b every other day for six months. Another 47 received placebo injections.

Three months after the last shot, a second round of heart biopsies showed that the interferon recipients were more than twice as likely to have reduced the presence of or cleared the virus from the heart, compared with those getting the placebo, Schultheiss said.

Although follow-up heart biopsies taken six months after the end of treatment showed no statistically significant difference in viral concentration between the groups, other assessments made during that time frame suggest that the gains were still holding.

Several viruses that normally cause common colds or respiratory infections have been found to set up shop in the heart. Whether these viruses directly cause heart inflammation in people with cardiomyopathy remains unclear, which makes studies such as the new one valuable, says Michael Felker, a cardiologist at Duke University School of Medicine in Durham, N.C.

SOURCE: HEALTHWISE

Earth

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As life evolves, minerals do too

Team recounts dramatic changes in variety, abundance

By Sid Perkins

If you think evolution is something that happens only to plants and animals, think again. Evolution — change through time — happens in the mineral kingdom as well, scientists say. As the solar system has aged, the number of types of minerals it contains has burgeoned from only a dozen or so to more than 4,000.

And about two-thirds of today's minerals either directly or indirectly evolved thanks to the presence of life on Earth.

"Four billion years ago, the world's minerals were radically different than they are today," says Robert Hazen, a geophysicist at the Carnegie Institution for Science in Washington, D.C. He and his colleagues chronicle the long-term growth in Earth's mineral complexity in the November-December *American Mineralogist*.

"This is the first change in the way that geologists look at minerals in more than two centuries," comments Carl Francis, curator of the Mineralogical Museum at Harvard University.

Billions of years ago, the solar system was nothing more than a cloud of gas and dust. Although that material contained all of the naturally occurring elements found in the periodic table, minerals are more than their specific chemical formulas. Minerals also have distinct crystalline structures. Most of the elements were too rare or widely dispersed to create minerals of their own, says Hazen.

In all, the tiny particles of interstellar dust that populated the nascent solar system — like those that still drift through space today — contained only a dozen or so minerals. These dust particles, primarily made of carbide, oxide, nitride and silicate minerals, were the raw materials of today's planets, the researchers note.

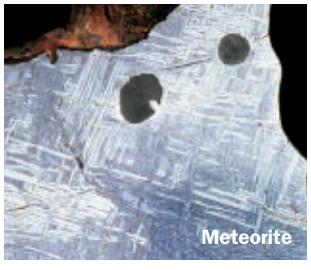
As the dust clumped into larger masses and the sun ignited, changing conditions spawned new minerals. In the billions-of-years-old, meteorite-sized masses that fall to Earth today — which presumably reflect the composition of masses that formed early on — scientists have identified about 60 minerals, says Hazen. About 20 of those are found only in crystals a few micrometers across or smaller. Some probably derive from the intense heat and pressures generated when the objects crashed into each other in space.

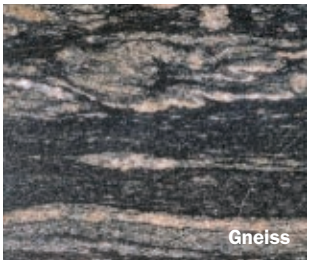
Once protoplanets grew to diameters of 200 kilometers or larger, the radioactive elements trapped within those masses generated enough heat to melt minerals at the orbs' cores. After that, says Hazen, minerals began to separate, with lighter minerals rising to the surfaces of the planets and denser ones sinking into the cores. About 4.55 billion years ago, Earth and meteorites probably contained around 250 minerals, the researchers say.

On small planets, mineral evolution grinds to a halt early. On planets with enough gravity to trap volatile substances like water, geological processes like plate tectonics or hydrothermal activity can provide a chemical crucible that creates hundreds more minerals. The first life to arise on Earth — probably methane-generating organisms — didn't significantly increase mineral diversity, because that gas was already common in the atmosphere, says Hazen. About 2.5 billion years ago, Earth likely sported a total of around 1,500 minerals.

Then came oxygen-generating, photosynthesizing cyanobacteria. Today, scientists have identified about 4,300 types of minerals on Earth, and dozens more are discovered each year. Around two-thirds are the result of oxidation brought about, either directly or indirectly, by processes such as photosynthesis. The presence of such minerals on other planets could be a sign that life once flourished there, Hazen and his colleagues contend.

The researchers' new approach goes beyond merely categorizing minerals and considers how minerals relate to each other. "Looking at minerals from the broad perspective, in terms of planetary geology, is an interesting way of thinking about them," says Jeffrey Post of the Smithsonian Institution's National Museum of Natural History in Washington, D.C. "This will give students a different context of how minerals form and how they evolved, not just what they are," he says.


Meteorite


Gneiss


Iron ore


Coral reef

Altogether, meteorites that formed early in the solar system contain no more than 60 minerals. About 4 billion years ago, Earth probably had no more than 350 minerals, including those present in gneiss. About 2.75 billion years ago, large amounts of iron ores formed. Today, scientists have identified more than 4,300 types of minerals, some formed by living creatures such as corals.

FROM LEFT: T. MCCOY/SMITHSONIAN INSTITUTION; W. BLEEKER/GEOLOGICAL SURVEY OF CANADA; D. PAPINEAU/CARNEGIE INSTITUTION FOR SCIENCE; TAMMY616/ISTOCKPHOTO

Genes & Cells

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It's a jungle on there: Skin samples contain rich diversity of bacteria

Inventory identifies body's most microbe-varied locales

By Tina Hesman Saey

PHILADELPHIA — Most people think of rain forests as hot spots for biological diversity, but new research suggests that belly buttons are also rich ecosystems. That's one finding from the first attempt to take a large-scale inventory of microbes on human skin.

In recent years scientists have come to appreciate people as super organisms, composed not just of human tissue, but also of microbes galore. Human skin is covered by a variety of bacteria, viruses, fungi and mites, says Elizabeth Grice of the National Human Genome Research Institute in Bethesda, Md. Most of the time, people and their microbes live in harmony, but people with skin conditions such as eczema often struggle with skin infections.

Only about 1 percent of bacteria can be grown in the lab (shown), so scientists are using genomics to figure out what lives on the skin.

BILL BRANSON, NIH

"The skin is two square meters of ecosystem," Grice said November 13 at a meeting of the American Society of Human Genetics.

Grice presented work she and her colleagues have done to catalog the diversity of bacteria living on human skin. The findings could help doctors and scientists better understand why some people develop skin conditions such as eczema and psoriasis while others with similar genetic backgrounds do not.

"We know there is a genetic component" to eczema, says Kimberly Chapman of the Children's Hospital of Philadelphia, who was not involved in the research. Some people with eczema have a defect in filaggrin, a protein that helps form the skin's protective barrier. But not everyone who has the filaggrin variation will get eczema. The new inventory of bacteria could help researchers determine whether people with eczema have an overactive immune response to bacteria living on their skin, Chapman says.

In the new study, dermatologists collected skin scrapings from 21 places on the bodies of 10 healthy volunteers. Grice and her colleagues examined genetic diversity in the 16S ribosomal RNA gene in bacteria in the samples. Scientists can use variations in this gene to distinguish one type of bacteria from another, and the technique has been used to sample bacteria living in oceans, human and mouse intestines, and even on shower curtains and toothbrushes.

Among the most diverse spots were the belly button, inner forearm, buttocks, the skin between the fingers and the gluteal crease (also known as the plumber's crack). Other body parts had a relative dearth of bacterial diversity. Cold spots were the greasy spot just behind the ear, the crease on the side of the nose, the toe webs and the sternum.

A few spots on some volunteers had up to 300 different species of bacteria, Grice says. Other areas contained as few as three types. The amount of diversity not only varied from body part to body part, but also from person to person.

The researchers plan to test the healthy volunteers again in six months and to recruit volunteers with eczema to see if they have different types of bacteria on their skin.

News Briefs

Cancer genome sequenced

For the first time, a complete cancer genome, and incidentally a complete female genome, has been decoded, scientists report online November 5 in *Nature*. In a study made possible by faster, cheaper and more sensitive DNA sequencing methods, the researchers pinpointed eight new genes that may cause a cell to turn cancerous. "We need to know the genetic rules of cancer," says coauthor Timothy Ley of Washington University in St. Louis. —*Laura Sanders*

Different division

PHILADELPHIA — Women and men sometimes do things differently, right down to divvying up their genetic legacies. This divvying up is known as meiosis, a process that cuts the number of chromosomes in half during the production of eggs and sperm. Men do meiosis by the textbook, but women play it looser with the process, Terry Hassold of Washington State University in Pullman reported November 12 at the annual meeting of the American Society of Human Genetics.

In men, chromosome pairs zip themselves tightly together all along their length. But in women, Hassold and his colleagues saw "split ends" and "bubbles" where the chromosomes were not tightly joined. And women's chromosomes had fewer recombination points than expected. About 5 percent of the pairs of chromosome 21 that were examined had no evidence of recombination.

Recombination is necessary for proper chromosome segregation, so the finding could help explain why women sometimes pass along the wrong number of chromosomes to their children, Hassold reported. —*Tina Hesman Saey*

Molecules

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Household cleaners using oxygen may make blood removal too simple

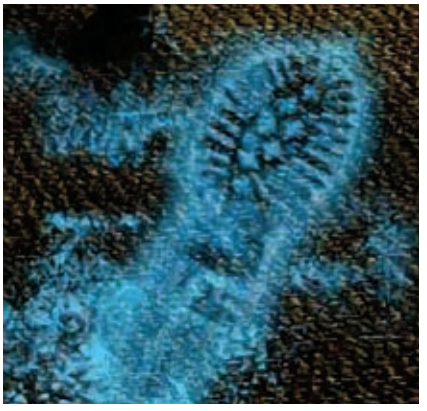
Three common forensic tests foiled by hemoglobin's fatigue

By Rachel Ehrenberg

CSI teams beware — a common household product cleans up blood thoroughly enough to make it undetectable by three of the most common forensic tests.

These "presumptive tests" are a quick-and-dirty way to identify important stains — such as blood — at a crime scene, says Walter Rowe of George Washington University in Washington, D.C. The tests rely on the blood protein hemoglobin's love of oxygen. But "oxy" cleaners appear to drown hemoglobin in so much oxygen that the protein has no love left for the tests, scientists report in an upcoming *Naturwissenschaften*.

While the research suggests a way for immaculate killers to clean the scene, most people who commit murder aren't in a frame of mind to think over which detergent to use to cover their tracks, Rowe points out. "People committing violent crimes often don't have time to clean up; they leave a lot of stuff behind."



"Oxy" cleaners may make forensic tests, like this luminol test for blood, ineffective.

Hemoglobin, a doughnut-shaped protein made of four globular subunits, carries oxygen from the lungs to the body's tissues. Each subunit has its own heme group, a bit of iron bound in a protein ring. It's the iron that's mad about oxygen. Existing forensic blood tests involve swabbing the stain with hydrogen peroxide. If the stain is blood, the hemoglobin tears the oxygen atoms away from the hydrogen peroxide. With some of the tests an indicator is added, such as a chemical that changes color when it reacts with the oxygen (thus the telltale "pink" swab from crime scenes).

To investigate the possible doctoring of evidence by the oxygen-rich cleaning detergents, Fernando Verdú of the University of Valencia in Spain and his colleagues took samples of their own blood and stained several fabrics, including a soft cotton cloth, jeans and a towel. The fabrics were washed with a product called Neutrex that contains "active oxygen," or sodium percarbonate, which releases hydrogen peroxide when dissolved in water. The clothes were then soaked in soapy, hot water for two hours. The team also ran cold-water trials with and without oxygen-rich detergent.

Researchers then conducted three different forensic tests on each cloth. All tests were negative on stains washed in warm water with the oxygen cleaner.

The sodium percarbonate "oxidizes the daylights out of iron," says Rowe. "It probably is then not going to react with anything." And these cleaners probably "tear up the protein molecule," he says, perhaps destroying DNA as well.

Design criteria outline ways to repel water, oil

Both liquids can bead up, flow off textured surfaces

By Sid Perkins

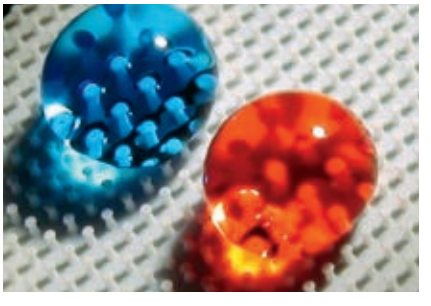
A new set of design criteria could enable engineers to invent and manufacture surfaces that can repel almost all liquids, even oily fluids long noted for their ability to foul water-repellent surfaces.

After designing and manufacturing "omniphobic" surfaces that can repel both water and oily liquids in 2007, Gareth McKinley of MIT and his colleagues have come up with general rules for creating the surfaces, the team reports online November 10 in the *Proceedings of the National Academy of Sciences*.

Besides the surface tension of the liquid and water repellency of the surface, engineers should consider the size, shape and spacing of the surface's microscopic features, McKinley says.

The new design criteria enable engineers to analyze existing surfaces or to conceive new ones, says Robert Cohen of MIT, a coauthor of the report.

When water-shedding surfaces become contaminated with oily substances, the surfaces usually lose their repellency, says Marshall Ming of the University of New Hampshire in Durham. "Successful development of omniphobic surfaces is a very exciting achievement" because of the practical applications, such as self-cleaning paints or coatings for windows.



Coated with a fluorinated polymer, this mat repels water (blue) and oil (red).

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AS HEARD ON PAUL HARVEY NEWS

New advanced portable heater can cut your heating bill up to 50%

Heats a large room in minutes with even heat wall to wall and floor to ceiling

Does not get hot, cannot start a fire and will not reduce humidity or oxygen

A new advanced quartz infrared portable heater, the EdenPURE™, can cut your heating bills by up to 50%.

You have probably heard about the remarkable EdenPURE™ as heard on Paul Harvey News and on television features across the nation.

The EdenPURE™ can pay for itself in a matter of weeks and then start putting a great deal of extra money in your pocket after that.

A major cause of residential fires in the United States is portable heaters. But the EdenPURE™ cannot cause a fire. That is because the quartz infrared heating element never gets to a temperature that can ignite anything.

The outside of the EdenPURE™ only gets warm to the touch so that it will not burn children or pets. Pets can sleep on it when it is operating without harm.

The advanced space-age EdenPURE™ Quartz Infrared Portable Heater also heats the room evenly, wall-to-wall and floor-to-ceiling. And, as you know, portable heaters only heat an area a few feet around the heater.

Unlike other heating sources, the EdenPURE™ cannot put poisonous carbon monoxide into a room or any type of fumes or any type of harmful radiation.

Q. What is the origin of this amazing heating element in the EdenPURE™?

A. This advanced heating element was discovered accidentally by a man named John Jones.

Q. What advantages does infrared quartz tube heating source have over other heating source products?

A. John Jones designed his heating source around the three most important consumer benefits: economy, comfort, and safety.

In the EdenPURE™ system, electricity is used to generate infrared light which, in turn, creates a very safe heat.

After a great deal of research and development, very efficient infrared heat chambers were developed that utilize three unique patented solid copper heat exchangers in one EdenPURE™ heater.

Never be cold again

Cannot start a fire; a child or animal can touch or sit on it without harm

Q. How can a person cut their heating bill by up to 50% with the EdenPURE™?

A. The EdenPURE™ will heat a room in minutes. Therefore, you can turn the heat down in your house to as low as 50 degrees, but the room you are occupying, which has the EdenPURE™, will be warm and comfortable. The EdenPURE™ is portable. When you move to another room, it will quickly heat that room also. This can drastically cut heating bills, in some instances, by up to 50%.

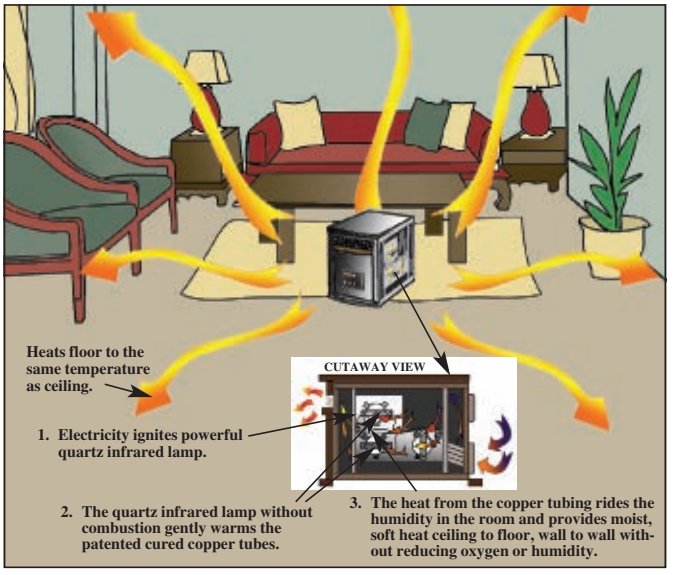
The EdenPURE™ comes in 2 models. GEN3 Model 500 heats a room up to 300 square feet and GEN3 Model 1000 heats a room up to 1,000 square feet.

End of interview.

The EdenPURE™ will pay for itself in weeks. It will put a great deal of extra money in a users pocket. Because of today's spiraling gas, oil, propane, and other energy costs, the EdenPURE™ will provide even greater savings as the time goes by.

Readers who wish can obtain the EdenPURE™ Quartz Infrared Portable Heater at a $75 discount if they order in the next 10 days. Please see the Special Reader's Discount Coupon on this page. For those readers ordering after 10 days from the date of this publication, we reserve the right to either accept or reject order requests at the discounted price.

How it works:



SPECIAL READER'S DISCOUNT COUPON

The price of the EdenPURE™ GEN3 Model 500 is $372 plus $17 shipping for a total of $389 delivered. The GEN3 Model 1000 is $472 plus $27 shipping and handling for a total of $499 delivered. People reading this publication get a $75 discount with this coupon and pay only $297 delivered for the GEN3 Model 500 and $397 delivered for the GEN3 Model 1000 if you order within 10 days. The EdenPURE™ comes in the decorator color of black with burled wood accent which goes with any decor. There is a strict limit of 3 units at the discount price - no exceptions please.

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This product carries a 60-day satisfaction guarantee. If you are not totally satisfied, your purchase price will be refunded. No questions asked. There is also a three year warranty.

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☐ I am ordering past 10 days of the date of this publication, therefore I pay shipping and handling and full price totaling $389 for GEN3 Model 500 and $499 for GEN3 Model 1000.

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Humans

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Stone Age gal had wide hips

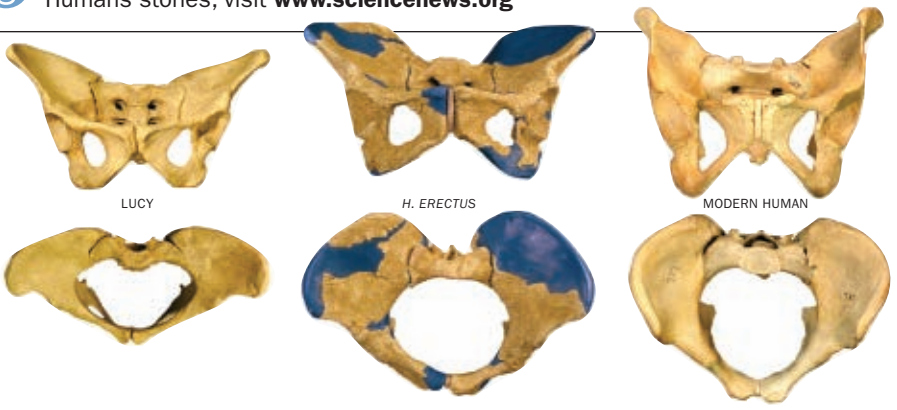
H. erectus females may have delivered big-brained babies

By Bruce Bower

She was short, squat and definitely not built for speed. On the plus side, this adult female *Homo erectus*, who lived in Africa roughly 1 million years ago, had hips wide enough to bear babies with brains nearly as big as those of newborn human infants.

That's the evolutionary picture presented by researchers who have unearthed a rare find: a nearly complete female *H. erectus* pelvis. Pieces of the fossil were found at an Ethiopian site called Gona in 2001 and 2003.

H. erectus females evolved a pelvis of a size unprecedented among human ancestors because the females had to squeeze increasingly big-headed babies through their birth canals, concludes a team led by anthropologists Scott Simpson of Case Western Reserve University in Cleveland and Sileshi Semaw of Indiana University in Bloomington. Given the size and shape of the new pelvis, *H. erectus* infants must have been more than 30 percent larger at birth than has usually been assumed, the scientists contend.



A rebuilt female *H. erectus* pelvis is larger than that of Lucy (*A. afarensis*) and that of a modern-day human female.

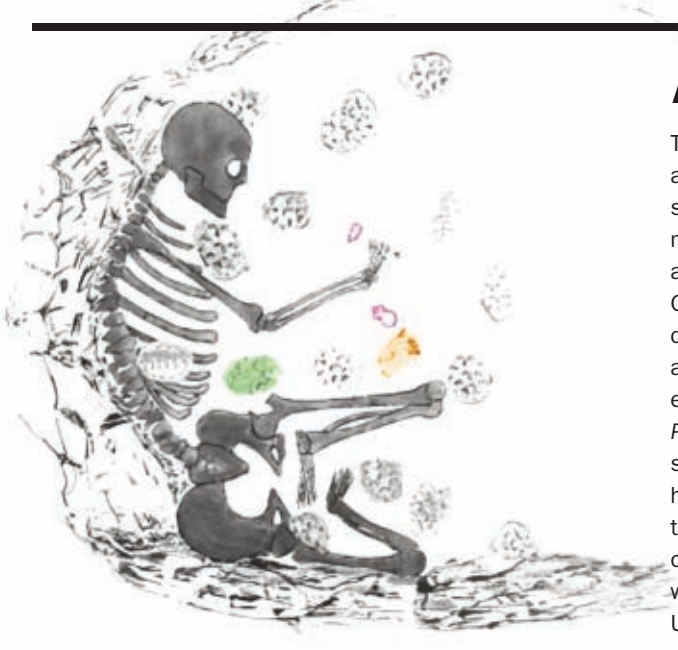
In the Nov. 14 *Science*, the researchers say that the new pelvis challenges a proposal that both sexes of *H. erectus* evolved to grow relatively tall and slender to shed body heat more efficiently in their tropical homelands. That idea was based largely on measurements of an *H. erectus* skeleton found in 1984 and attributed to a slim, 10- to 12-year-old boy who would have stood an estimated 6 feet, 2 inches as an adult.

The broad, flaring pelvis also challenges an earlier proposal that *H. erectus* individuals possessed narrow hips suitable for endurance running, a capacity that would have aided them in hunting.

"It's now apparent that body size range in *H. erectus* has been underestimated," Simpson says. The Gona female stood no taller than 4 feet, 9 inches.

"I do not see any major problems with either the reconstruction or the interpretation of this new specimen," comments anthropologist C. Owen Lovejoy of Kent State University in Ohio.

But Harvard University anthropologist Daniel Lieberman disagrees. "This pelvis is a nice addition to the fossil record, but it raises more questions than it answers," he says. In his view, the new specimen might come from a male of a comparably ancient species in the human evolutionary family.



Ancient healer reborn

The graves of people who died 12,000 years ago rarely contain a woman's skeleton pinned down in an unusual position by large stones, accompanied by another person's foot (orange) and a menagerie of animal remains, including tortoise shells (green) and marten skulls (purple). Yet that's what archaeologist Leore Grosman of Hebrew University of Jerusalem and her colleagues discovered in a small Israeli cave called Hilazon Tachtit. Closer analysis shows that this grave holds a shaman, one of the earliest ever excavated, the researchers report online November 3 in *Proceedings of the National Academy of Sciences*. In traditional societies, shamans are thought to communicate between the human and the spirit worlds and are buried in elaborate ways that mark privileged status. "The most parsimonious explanation of this unique grave treatment for a Natufian person is that this woman was a shaman," comments Ofer Bar-Yosef of Harvard University. — *Bruce Bower*

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Matter & Energy

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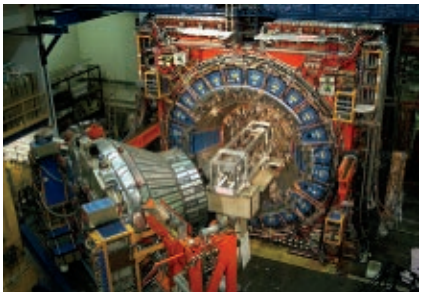
Physicists find muons bemusing

Puzzling results may signify mystery particle or new force

By Ron Cowen

Physicists are puzzling over a bunch of measly muons. In experiments at the Fermi National Accelerator Laboratory in Batavia, Ill., researchers have detected too many muons where there should be hardly any.

Muons are heavy cousins of electrons. Most physicists believe a mundane explanation exists for the muons' aberrant location in this experiment. But there's a chance, even if slim, that the muon detections indicate the existence of some new, long-lived elementary particle and perhaps a previously unknown force. Such a finding could revolutionize the understanding of the universe, says Mark Kruse of Duke University in Durham, N.C.



Fermilab's CDF experiment observed an unexpected abundance of muons.

Only two-thirds of the many collaborators on the experiment, including Kruse, consented to have their names listed on the paper announcing the muon puzzle, posted online October 29 (arxiv.org/abs/0810.5357). Many believe the puzzle will be solved with ordinary physics, perhaps some overlooked property of the particle detectors.

Kruse thinks this will likely be the case, but nonetheless he and colleagues speculate on novel elementary particles that might be required if the muon riddle endures (arxiv.org/abs/0810.5730). And a physicist not affiliated with the experiment, Matt Strassler of Rutgers University's campus in Piscataway, N.J., contributes his own musings in a November 10 online posting (arxiv.org/abs/0811.1560).

A way to crack quantum encryption

Time-travel technique could break supposedly secure codes

By Rachel Ehrenberg

Quantum physics offers James Bond and his ilk much more than a bit of solace — it permits quantum encryption, a completely spyproof way to send coded information. Any bad guy eavesdropping on Bond's messages to M could always be detected.

But now physicists suggest that quantum codes may be breakable using a trick that even Bond hasn't mastered — time travel. By exploiting hidden paths to the past — routes that are predicted by some of Einstein's equations — a nemesis could eavesdrop on a quantum-coded message without alerting the senders.

Time travel, possibly through a wormhole, appears to make it possible to distinguish quantum information that usually can't be distinguished. That ability would disrupt the absolute security of quantum encryption, physicist Todd Brun of the University of Southern California in Los Angeles and colleagues report online November 7 (arxiv.org/abs/0811.1209).

"I believe it is a sound result that quantum cryptography would not work in this world," comments Charles Bennett, who with Gilles Brassard developed the first quantum encryption protocol in 1984. "You might say it is a weakness of quantum cryptography — but if there were wormholes, people could go back in time and do worse feats of mischief than reading secret messages," says Bennett.

Encryption relies on both sender and recipient having a secret shared key to create or decipher the coded message. As long as both parties are the only ones with the key to the code, "secret" messages can be sent in plain sight, yet remain secret.

Traditional codes for sending messages between distant communicators are vulnerable because an eavesdropper might intercept the key. But in the quantum world, a key can be transmitted securely because quantum information is changed when looked at, alerting sender and recipient when an eavesdropper is afoot.

For quantum eavesdroppers, "the only way not to be detected is to acquire no information because measurements disturb the state," Brun says.

Detection of quantum-code eavesdropping is possible because a quantum particle (say a photon) can exist in a fuzzy mixture of states. Measuring the particle converts it to a particular "preferred state." Imagine a bird in flight. In the quantum world, the flying bird may be anything from a pelican to a chickadee. But once it is caught, it becomes one bird — which kind depends on the net used to catch it.

Say Alice sends Bob a chickadee that Eve intercepts. If Eve uses a big net, she won't catch a chickadee, but a pelican. As Eve sends intercepted birds to Bob, eventually he and Alice will realize that Bob is getting big birds that should be small. The new paper shows how Eve could send Alice's bird through a spacetime wormhole (technically, a "closed timelike curve") that allows time travel. Eve's bird could interact with its earlier self at the wormhole's other end and become a distinguishable bird that fits the code.

This scenario can't be ruled out, says Bennett, of IBM's Watson Research Center in Yorktown Heights, N.Y. The existence of wormholes "is not totally impossible, but it is pretty damn unlikely," he says.

FERMILAB

Neuroscience

For longer versions of these and other stories from the meeting, visit **www.sciencenews.org/neuroscience2008**

In their minds, volunteers swap bodies with woman, mannequin

Illusion could help scientists study self-identity, body image

By Bruce Bower

It sounds like a lost episode of *The Twilight Zone*. A man enters a laboratory, dons a special headset and shakes hands with a woman sitting across from him. In a matter of seconds, he feels like he's inside the woman's skin, reaching out and grasping his own hand.

Strange as it sounds, neuroscientists have induced this phenomenon in volunteers. People can experience the illusion that another body is their own, says Valeria Petkova of the Karolinska Institute in Stockholm. She and Karolinska colleague Henrik Ehrsson call the feeling the "body-swap illusion."

"Our subjects experienced this illusion as being exciting and strange, and often said that they wanted to come back and try it again," says Petkova, who reported the findings.

Illusory body-swapping could provide a new tool for studying self-identity and psychiatric disorders that involve distortions of body image, she suggests. The phenomenon might also be tapped to enhance virtual reality experiences.

Volunteers in the body-swap experiments stood across from a male mannequin or a female experimenter and received simultaneous visual and motor input. A headset covering participants' eyes displayed a 3-D view of the other body's visual perspective, transmitted from a small camera on the other body's head.

In the mannequin situation, an experimenter simultaneously touched the participant's belly and the mannequin's belly with separate probes. So, the volunteers felt a poking in the abdomen but saw the poking as if they were the mannequin. In the real-person situation, participant and experimenter shook hands. Thus, while volunteers felt the sensation of hand shaking, it appeared to them that they were shaking their own hand. After 10 to 12 seconds of abdominal touch or handshaking, male and female participants literally felt that they were in the mannequin's or female experimenter's body.

"In the body-swap illusion, we can see that multisensory information powerfully affects the brain," says Patrick Haggard of University College London, who was not part of the research team.

Petkova and Ehrsson first confirmed, using questionnaires, that 16 male and 16 female volunteers experienced an illusory body-swap with a mannequin. Participants reported having had an expectation that, if they moved, the mannequin's body would move accordingly.

Then the researchers found that 10 volunteers experiencing a body-swap with a mannequin displayed elevated electrical responses in the skin on their fingertips — a physiological indication of heightened emotion — when a knife was passed just over the mannequin's arm.

In a third experiment, 12 volunteers experiencing a body-swap with a female experimenter exhibited comparable physiological signs of emotional arousal when a knife was passed just over the experimenter's arm.

When a researcher stroked a brush along a volunteer's arm, the illusion vanished. In this way, each participant's personal sense of touch became disengaged from the other individual's visual perspective, Petkova proposes.

MEETING NOTES

Morality askew in psychopaths

Psychopaths show neural responses related to moral insensitivity and a keen interest in moral violations, scientists reported.

Researchers led by Kent Kiehl of the University of New Mexico in Albuquerque recruited inmates from a New Mexico prison to undergo brain scanning while viewing images that depicted moral violations or images that contained no moral violations.

Functional MRI scans showed reduced neural activity in 21 inmates who qualified as psychopathic on questionnaires, relative to 21 non-psychopathic inmates, in brain regions linked to attaching emotional meaning to others' acts and to reading others' intentions, says study coauthor Alek Chakroff, also of New Mexico. The psychopaths identified moral pictures and rated severity of moral infractions as accurately as non-psychopaths, suggesting the psychopaths intellectually evaluated the situations without reacting emotionally, Chakroff adds.

Kiehl's group also found that 25 psychopathic inmates displayed a signature neural electrical response a fraction of a second after viewing images of moral violations, indicating heightened attention to those images. — *Bruce Bower*

Parasite twists rats' innate fear

In a dangerous game of cat and mouse, the most important player turns out to be a parasite. Researchers know that the parasite *Toxoplasma gondii* is a puppeteer that can force a rat to go against its instincts and become attracted to the scent of cat urine. Now scientists have discovered the regions of a specific part of the rat brain called the amygdala involved in this parasite-imposed death wish.

Toxo can only reproduce in the gut of a cat, which poses a logistical nightmare for the rat-dwelling parasite. To

"Our subjects experienced this [body-swap] illusion as being exciting and strange, and often said that they wanted to come back and try it again." — VALERIA PETKOVA

Still love-struck after 20 years

Some long-married couples are as giddy as teenagers

By Laura Sanders

New research on brain activity confirms that people can be madly in love with each other long after the honeymoon is over.

Researchers led by Bianca Acevedo of the Albert Einstein College of Medicine in New York wanted to know if romantic love — or at least the brain activity it triggers — could last. To everyone's relief, the answer is yes.

People who report being madly in love for an average of 21 years maintain activation in a brain region associated with early-stage love, the researchers reported.

Using fMRI, Acevedo and colleagues monitored the brain activity of long-term lovers while they viewed pictures of their partners. The researchers were particularly interested in a small group of people who had been with the same person for many years and claimed to still feel the excitement of the early days.

People who had been experiencing intense love for 20 years and people who had been in love for only months showed similar activation in the ventral tegmental area of the brain — a region known to be activated during the intense, burning stages of early love. The same area is activated by the rush of cocaine.

At the same time, key differences between the early- and late-stage lovers emerged. People in long-term relationships showed higher levels of activity in a part of the brain associated with calmness and pain suppression, whereas people in love for shorter periods had higher activity in a region associated with obsession and anxiety.

"The difference is that in long-term love, the obsession, the mania, the anxiety has been replaced with calm," says study coauthor Helen Fisher of Rutgers University in New Brunswick, N.J.

"There is an evolutionary advantage to being paired," says researcher J. Thomas Curtis, who studies pair-bonding in prairie voles, which are known for forming lifelong monogamous pairs.

Much of the research on voles, including Curtis' work at Oklahoma State University in Tulsa, supports these new findings, he says. In fact, when researchers get rid of the ventral tegmental area of a vole brain, the animal no longer forms pair bonds.

get into the cat, *Toxo* tricks rats into acting recklessly. A team led by Patrick House at Stanford University reported that they have identified two distinct regions of the brain, one important for fear and the other responsible for attraction, that are activated in *Toxo*-infected rats after they smell cat odor.

Surprisingly, the attraction region of the rat brain is similarly activated when a male rat encounters a female, suggesting that *Toxo* may fool the rat into mistaking cat urine for a sign of a potential mate. — *Laura Sanders*

Anatomy of a well-aging brain

People who are mentally vigorous at age 80 can have more plaques in their brains than their normal-aging counterparts. At the same time, these higher-performing brains may host fewer tangles, which are denser, more harmful protein clumps, researchers reported.

Plaques are diffuse clumps of proteins in the brain, and clumps of the protein amyloid-beta are often associated with Alzheimer's disease. The finding could spur research into possible benefits of having plaques, says study leader Changiz Geula of Northwestern University. One guess is that plaques may serve as safe repositories for harmful proteins that would otherwise float around in the brain, Geula adds.

This preliminary finding comes from a study called the SuperAging Project, which departs from the traditional way of studying the aging brain. Instead of examining the brains of people who suffer from age-related diseases such as Alzheimer's and Parkinson's — what Geula calls "shrinkers" — the team wants to figure out what happens in the brains of people who age well.
— *Laura Sanders*

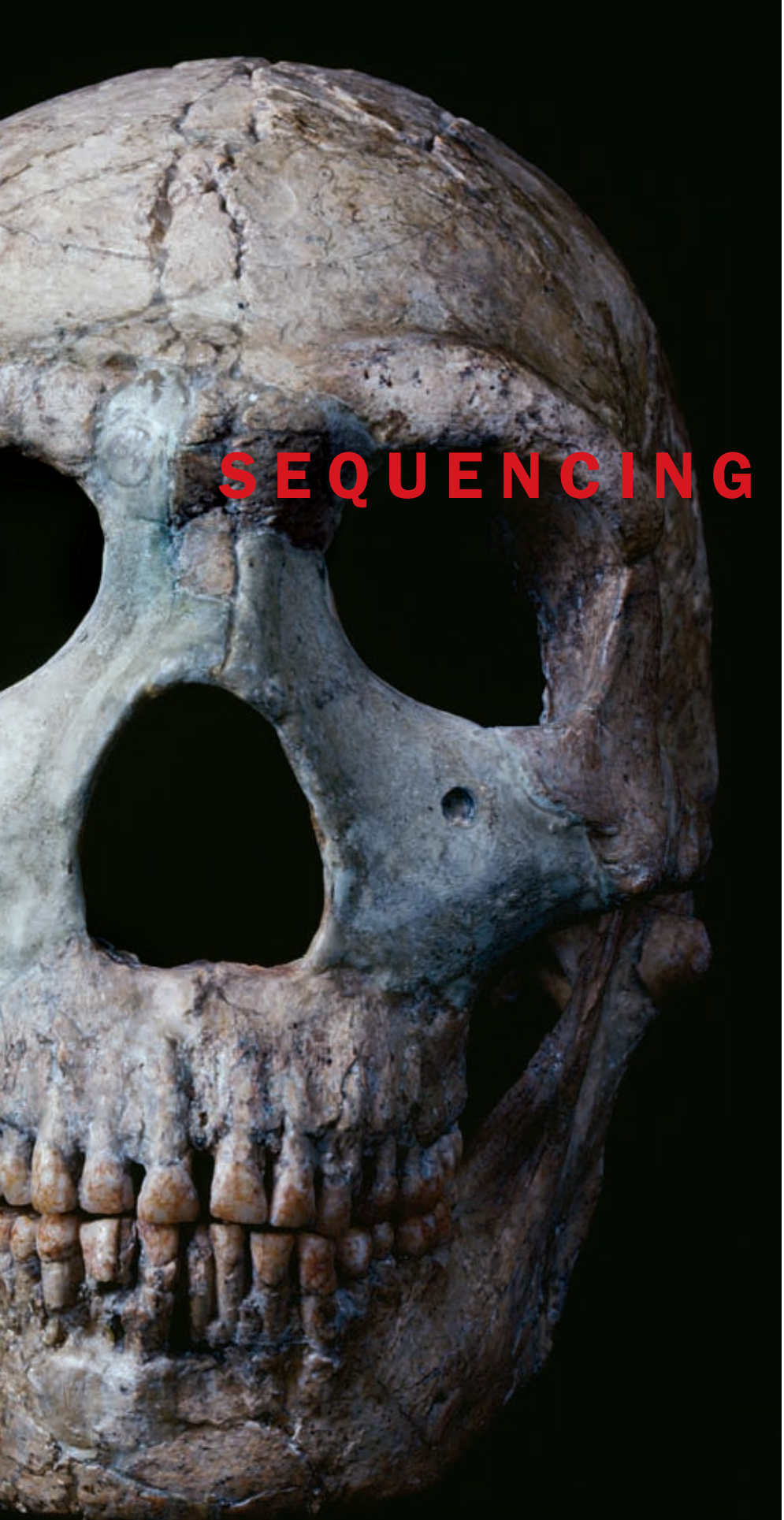
Melatonin by moonlight

Moonlight may interrupt astronauts' sleep cycles by messing with their melatonin, researchers reported. Sleep cycles are regulated by the type and amount of light that people encounter. When a person goes to sleep, the hormone melatonin circulates through the body to maintain a drowsy state. But if a light comes on, the body's melatonin levels drop, causing the person to wake up.

Astronauts are notoriously bad sleepers, says Benjamin Warfield of Thomas Jefferson University in Philadelphia. They average just four to six hours of sleep a night when they're on a mission and amass a huge sleep deficit. But no one knew how moonlight might affect this chronic lack of sleep.

To figure it out, Warfield and his colleagues built a piece of equipment they call the Moonlight Machine — a complicated series of lights, mirrors, lenses and filters — to mimic moonlight conditions experienced by astronauts. Subjects sat inside the Moonlight Machine between 2 a.m. and 3:30 a.m., a time when melatonin levels in the body are normally high. The researchers found that melatonin levels were diminished after the moonlight exposure.
— *Laura Sanders*

Reviving ancient genomes offers a window into past prevent future die outs



SEQUENCING THE DEAD

Genes tell stories of disease, of health, of parentage, all recorded in the chemical composition of DNA. But to many biologists, one of the most exciting tales that sequences of DNA letters can tell is an evolutionary one. And since evolution on its largest scale — the shifting cast of organisms populating Earth over the past few billion years — happens over lengthy periods of time, some of the best stories may be locked in the DNA of species long buried and gone extinct.

Sequencing the complete genome of a woolly mammoth that died 60,000 years ago or a Neandertal man who lived 40,000 years ago could reveal new details about prehistoric populations, their genetic diversity, how they changed through time and how they are related to species living today. It could also lead to deeper understandings of evolution's details.

Biologists could use those genomes to study evolution almost as if it were a live performance, says ancient-DNA researcher Carles Lalueza-Fox of the Institute of Evolutionary Biology in Barcelona. Geneticists could pinpoint specific genes that helped mammoths and Neandertals survive, for a time. Experts might also identify the genes that left those species vulnerable to extinction.

Possessing the woolly mammoth or Neandertal genome couldn't necessarily help experts resurrect the creatures Jurassic Park–style — at least not anytime soon — but the information could revise biologists' views of the relationships

LEFT: IRA BLOCK/CORBIS; RIGHT: JASON EDWARDS/CORBIS

# of long-extinct creatures extinctions—and may help

By Ashley Yeager

TO SAVE THE LIVING

between species extant and extinct. And the knowledge gained may help keep some of today's threatened species, like Tasmanian devils, from disappearing, too.

Of course, "you can't just pull the entire genome out of a cell that's been dead for thousands of years," says evolutionary geneticist Michael Hofreiter of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany. The remains of extinct species sit in the ground for hundreds to thousands of years, and the genetic material decomposes, limiting how old genetic samples can be. Even in the best preserved specimens — a mammoth buried and frozen in the Siberian permafrost, for example — only short fragments of DNA remain intact and available for analysis.

In addition to decay, contamination of DNA in fossilized bone, hair and other ancient remains poses a major challenge. A fossil bone yields mostly DNA from microbes that ate away at the bodies of the dead animals. DNA from the organism of interest usually makes up less than 10 percent of the total genetic material extracted. Human DNA from handling specimens can also contaminate a sample — a factor particularly important in the sequencing of Neandertal DNA.

Still, in the past decade scientists have

Some Neandertal fossils, such as the 60,000-year-old skull (left), can yield trace amounts of DNA for study. DNA studies can also inform conservation efforts for the Tasmanian devil (right).

made enormous progress in extracting and working with ancient DNA. The shorter, more abundant mitochondrial genomes from many extinct species — Neandertals, mammoths, cave bears and the enormous Haast's eagle, for example — have already been successfully sequenced.

And now genomicists are tackling the richer information stored in nuclear DNA. Experts are stitching together existing DNA fragments, repairing damaged ones and reconstructing missing ones. In November, scientists announced that they had completed sequencing about 70 percent of the woolly mammoth genome. If all goes well, the Neandertal genome will be finished up in the next few months.

Letter by letter

Decoding ancient nuclear DNA requires extracting as much material as possible from a specimen and then preparing the DNA so that a sequencing machine can read the chemical letters, or base pairs, that make up the code. Because the DNA is so degraded, it's in fragments. "We are stuck sequencing tiny bit by tiny bit," says Tom Gilbert of the University of Copenhagen. "In some of the mammoth hair samples, for example, the average read lengths are under 100 base pairs." Sequencing the 4 billion to 5 billion letters that make up the mammoth genome in less than 100 base pair bits, Gilbert says, "would have taken a very, very long time."

But that was before the development of faster, high-volume gene sequencers. These newer technologies, designed to deal with small stretches of DNA, can sequence hundreds of thousands of short fragments in one go. The additional speed also allows fragments to be resequenced several times over, which makes the results more reliable, says Hofreiter.

Fitting together the fragments into a complete genome comes next. Hofreiter says it's like piecing together a puzzle. Genomicists look for similarities between extinct species' and living species' genes. If a matching sequence is found, genes of the extinct animal are lined up with the living animal's genetic map. Comparing available Neandertal fragments with a human or ape genome, for example, helps genomicists compile a genetic blueprint of the extinct species.

Using such sequences, experts can pinpoint periods in history where species suffered drops in genetic diversity. By linking periods of diminished genetic diversity with events in an animal's environment, scientists might even be able to reconstruct the history of the species.

Sections of the human genome, for example, hint that the genetic diversity of *Homo sapiens* declined between 150,000 and 50,000 years ago. Pairing genetic data with climate data from ice core samples, scientists have suggested that the number of breeding individuals fell to a few thousand, a drop possibly linked to a large volcanic eruption. But the analysis focused on just certain, small sections of the genome. Given that, as well as the difficulty in estimating the population sizes of early humans, any conclusion needs to wait for more genome studies, says genomicist Richard Green, who heads a team sequencing the Neandertal genome.

Green, also of the Max Planck Institute for Evolutionary Anthropology, thinks that by spelling out the complete Neandertal genome, for example, experts will discover points in time when individual genes in humans diverged from the genes in their extinct relatives. In the future, the sequences could reveal genetic changes that may have helped *H. sapiens* out-survive the Neandertals, he says.

Speech, skin and resurrection

Right now, geneticists focus on the ancient DNA fragments and genes that have been sequenced so far. One is *FOXP2*, a gene related to speech. The gene now appears to have the same sequence in humans and Neandertals. To study this gene in greater detail, a team of scientists inserted human *FOXP2* genes into mice.

The mice didn't talk, but they did seem to squeak differently from their nonmutant cousins, says Julia Fischer, who studies speech evolution at the German Primate Center in Göttingen. Speech is complex and involves many genes, but she says the work is a first step to knowing if Neandertals spoke to each other.

The next steps require geneticists to identify more human genes involved in speech and then scour Neandertal DNA to determine if it ever possessed those genes or variations of them. If those genes exist in Neandertal DNA, genomicists could extract or artificially reconstruct them.

If all these steps proceed as planned and the genes are inserted into mice, the animals still wouldn't talk, but the findings might hint at whether Neandertals did, Fischer says. The experiment might also determine if language, and the cognitive ability to process it, was a factor that helped humans outlast the Neandertals.

Isolating more of the Neandertals' supposed speech genes is still a few years off. But other ancient genes have already been brought back to life. In the past two years, geneticists have resurrected genes related to pigmentation from Neandertals and mammoths, for example.

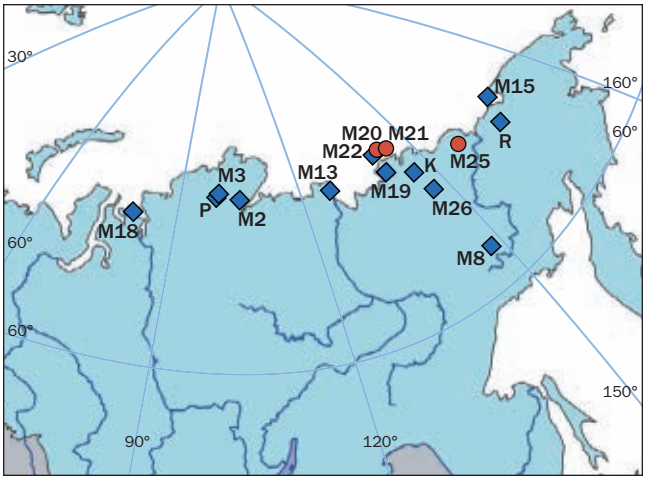
In humans, the gene, called *melanocortin 1 receptor* or *MC1R,* codes for fair skin and red hair. When fragments of the ancient *MC1R* gene variants from Neandertals and mammoths were inserted into cells growing in the lab, the cells produced proteins from the fragments. Analysis of the proteins suggested that some mammoths might have been blonds, while some Neandertals might have been redheads, Lalueza-Fox says.

These experiments are the second closest that scientists have gotten to bringing back extinct species, he says. The closest effort came in May when genomicists reported resurrecting a fragment of DNA from a thylacine, or Tasmanian tiger. The carnivorous marsupial was not a true tiger but was given the name because of its stripes. A cousin of the Tasmanian devil, the tiger competed with the devils for food before disappearing into extinction in the 1930s.

To see if the thylacine's DNA would still function, scientists extracted a gene linked to collagen production from an alcohol-preserved specimen. They then inserted the gene into mice and showed that it switched on a marker gene in carti-

From hair to there DNA from well-preserved woolly mammoth hair provides details of the animal's history

Tufts of mammoth hair are embedded in this fossil. Pairing fossil studies with analyses of ancient DNA can help biologists learn how predators, climate and competition may have led to prehistoric migrations and population changes.



Mitochondrial genomes reconstructed from the hair of 18 individuals show that two genetically distinct mammoth groups (red circles and blue diamonds) roamed Siberia at the same time. The map shows sites where hair specimens were found.

lage-producing cells of the mutant mice's embryos. That demonstrated, for the first time, that old, preserved DNA can be brought back to life — at least in mice.

But resurrecting one gene is much different from resurrecting the thousands or tens of thousands of genes that make up an animal's genome, Lalueza-Fox says. Bringing back a thylacine, mammoth or Neandertal is decades away, he says. It's also not on many scientists' agendas. Using genome-sequencing technology to save the Tasmanian devil from extinction, however, is.

Devil of a problem

"Some people say, let Tasmanian devils go extinct, then sequence them. But it's more warranted to do it beforehand when we can save them," says genomicist Stephan Schuster of Pennsylvania State University in University Park. "That's why we've crossed over from sequencing the dead to the living."

He and Penn State colleague Webb Miller have been working to sequence fragments of the woolly mammoth genome and, reporting in the Nov. 20 *Nature*, just released a sequence covering 70 percent of the nuclear genome.

That work helped them design the software for sequencing the Tasmanian devil genome. But the two scientists soon discovered they didn't have as detailed directions for spelling out the devil genome as they did for mammoth DNA.

The Tasmanian devil's closest living relative is the South American opossum, Miller notes. Sequenced DNA from both species shows that only 90 percent of their genomes overlap. Elephants and mammoths share some 99.4 percent of their DNA, Miller says. That's enough overlap for experts to understand the role of mammoths' noncoding regions, formerly dubbed "junk DNA." It's a lot harder to understand the importance of the devil's noncoding regions because of the greater number of gaps in the code.

"We need to know what's going on in those pieces of devil DNA, though, because a lot of the guys are catching cancer," Miller says.

Cancer is ordinarily not contagious. But a cancer that affects Tasmanian devils is spread by biting, aggressive mating or eating infected food. The devils' small island habitat means that the cancer spreads more quickly. Of the adult Tasmanian devils that conservationists have trapped and tested, 83 percent show symptoms of the disease. It appears first as lesions and lumps around the mouth and can spread from the face to the entire body. With time, the facial tumors grow so big that a devil can't eat and starves to death.

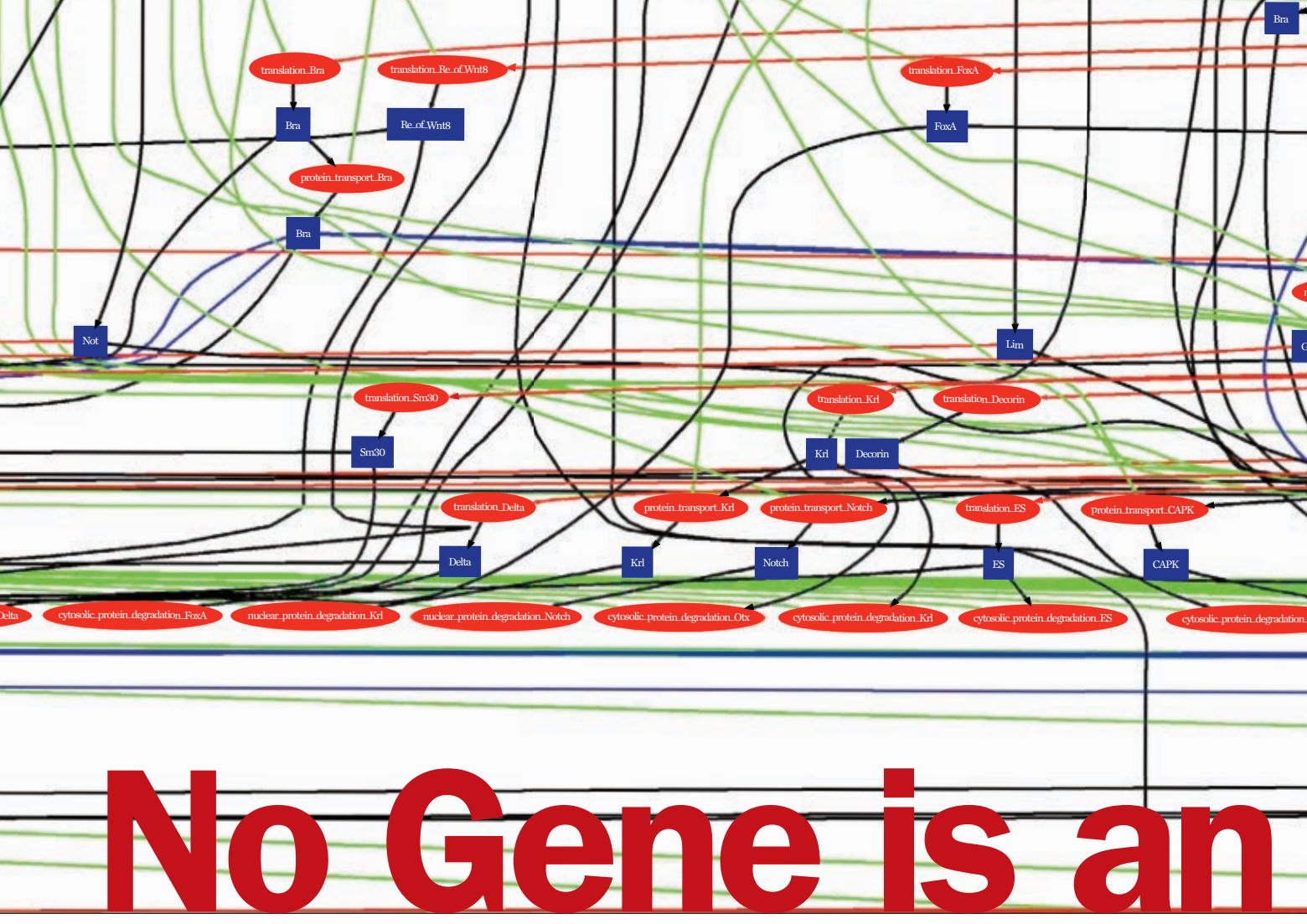
To better understand the facial tumor disease, Miller and Schuster are sequencing and comparing the genomes of two devils — Cedric and his half brother. Cedric is a star of the Tasmanian media because he is resistant to the cancer. If another devil with the contagious cancer bites him, his body can tell his cells from the dangerous cells, and the cancer doesn't take hold. The devil's half brother isn't so lucky. He's not resistant.

Finding major differences between Cedric's and his brother's genes would be "almost too cool," Miller says. The genetic variations would provide clues about how the cancer interacts with the creature's genes. Using that information, genomicists could identify which devils are fully or at least partially cancer resistant. "It's conceivable that we might be able to say, here is this variation in the devils' genes. You have this version, you're toast," Miller says. "And you, you have the other version, you might live." ■

Explore more

- R. Green *et al*. "A Complete Neandertal Mitochondrial Genome Sequence Determined by High-Throughput Sequencing." *Cell*. August 8, 2008.

FROM TOP LEFT: KHATANGA MAMMOTH MUSEUM; GILBERT *ET AL./PNAS* 2008



No Gene is an

Even as biologists catalog the discrete parts of life forms, an emerging picture

The gene *p53* has long been singled out as an anticancer hero. It is a critical tumor fighter. A person or lab animal develops a tumor much faster without the gene than with it.

But *p53* could be dangerous if left to act alone.

What really gives the gene its power is its network within a cell. Cells must guard against the constant threat of becoming cancerous, a change sometimes triggered by damage to the cells' DNA. The *p53* gene is embedded in a network of interacting genes and proteins, and this web of interactions provides sophisticated control of *p53*, keeping it in check. Such control is important because *p53* is a double-edged sword: It can either promote DNA repair or — if the DNA damage is too severe — trigger the cancer-prone cell to self-destruct (thus sparing the rest of the body from getting cancer).

Balancing these two functions is critical for keeping cancer at bay.

Single genes get the limelight, but a gene or protein rarely acts alone. Now that biology's centuries-long quest to dissect living things into ever-smaller parts is reaching its logical conclusion — the comprehensive list of every gene, protein and molecule in cells — some scientists are beginning the daunting task of putting Humpty Dumpty back together again. Little by little, research is revealing how all these parts are connected in vast networks, networks in which genes and proteins interact in living cells to produce cell behaviors.

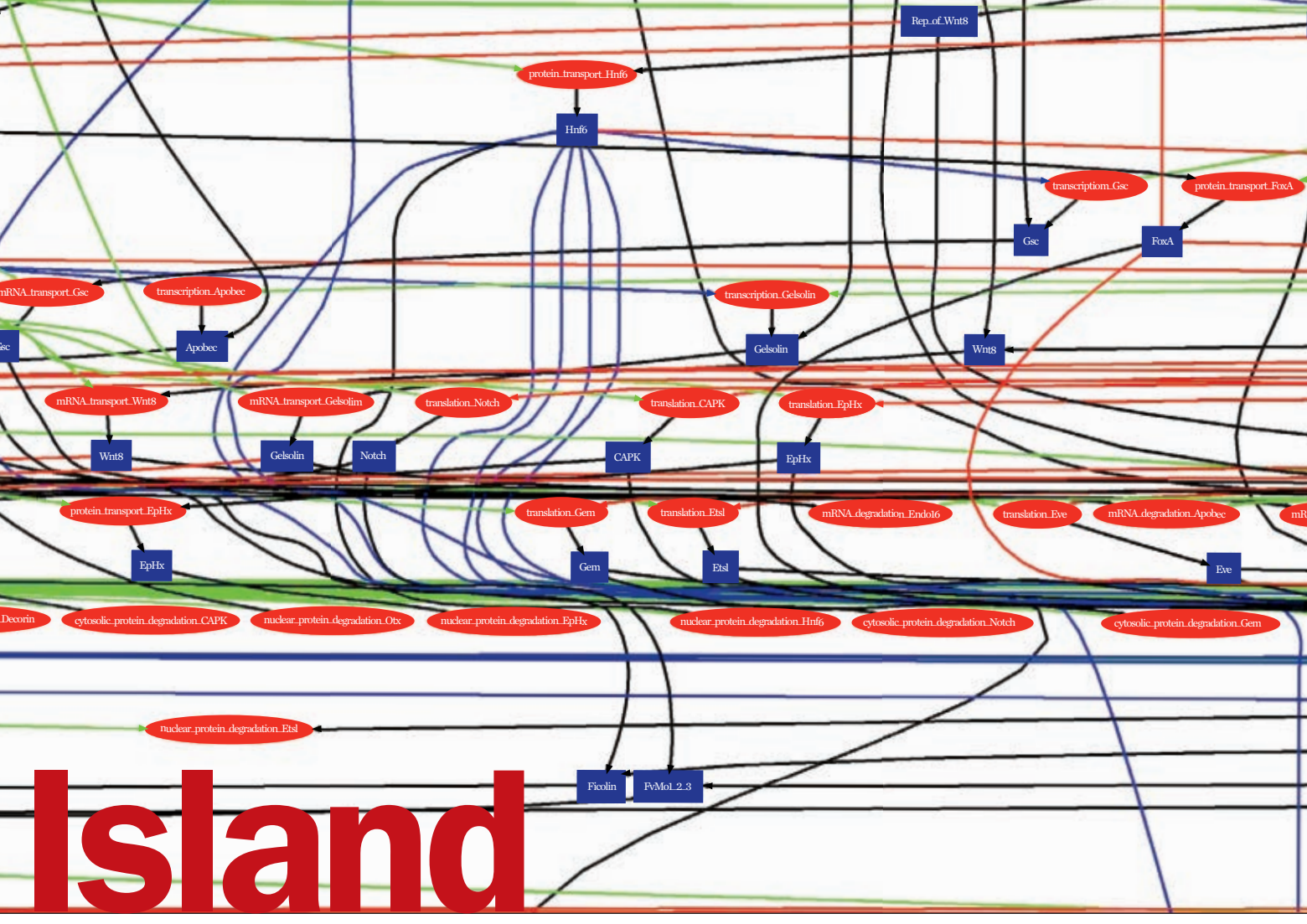
And a cell's behavior is crucial to its survival. Whether a single cell floating in the sea or a cell within a plant or person, a cell must do the right thing at the right time in the right way or it might simply die. Whatever the cell's fancy internal mechanisms may be, the end result — the cell's behavior — is all that matters.

"The community has produced a lot of information on the parts list, with sequenced genomes, proteomics, metabolics," says Ilya Shmulevich, a systems biologist at the Institute for Systems Biology in Seattle. "There's so much data that is produced, and right now what needs to happen is all of this needs to come together."

By looking at how all the parts of a cell are networked, researchers are finding subnetworks that behave much like basic components of electronic circuits, such as switches, blinkers and buzzers.

Other recent work suggests that entire

ALBERT J. POUSTKA/MAX PLANCK INSTITUTE FOR MOLECULAR GENETICS



Island

reveals that life's functions arise from interconnectedness

By Patrick Barry

The diagram above outlines just a portion of the network that regulates genes in a sea urchin embryo. Genes and proteins interact in a complex, crisscrossing pattern to steer cells' behavior during the embryo's growth.

cell networks balance themselves at the threshold separating order from chaos.

When applied to an organism's inner workings, a network perspective can solve problems that a gene-centric approach can't — such as understanding the growth of a sea urchin embryo or how the segmentation of insect bodies is encoded.

Many scientists also think that understanding human cells at the network level is essential for developing drugs to treat complex diseases such as diabetes and cancer.

"These harder diseases remain unsolved because they aren't caused by individual proteins. They're diseases of the network," said systems biologist Hans Westerhoff of the University of Manchester in England, in August during the International Conference on Systems Biology in Gothenburg, Sweden.

Using network analysis, Westerhoff's team found that the best target in a cell for anticancer drugs was not the one researchers suspected. So with the cellular parts lists from genomics in hand, scientists are beginning to connect the dots.

Mapping motifs

Networks are full of surprises.

"They often do things you didn't think they would do, and often they refuse to do things that you thought they would do," says John Tyson, a computational biologist at Virginia Tech in Blacksburg. That's because networks are more than the sum of their parts. A network's architecture — the pattern of interactions among its parts — strongly influences its overall behavior in ways that can't be predicted based on the parts alone. And some connection patterns give rise to nonintuitive, nonlinear behaviors.

In a diagram of a gene and protein network, each dot represents a certain gene or protein, and a line between dots means that those two parts interact in some way. Perhaps one gene activates another, or a protein binds to and inhibits another protein. A basic network diagram looks a bit like a game of connect the dots that ends in a jumbled mess instead of a pretty picture.

It's a simple premise, but once you start wiring together a few genes or proteins this way, the behavior of the resulting

network proves to be quite sophisticated. The right "motif," or pattern of connections among a few proteins, will behave like a switch, buzzer, sniffer or blinker.

"You can understand complicated protein interaction networks in terms of these little motifs that are hooked together, like you can construct an electronic circuit," Tyson says. "There's been a lot of progress here recently."

Combining even a few such motifs in a small subnetwork can generate useful behaviors. For example, the tumor-suppressor gene *p53* is controlled by just a few motifs that combine to make *p53* behave much like a ticking time bomb.

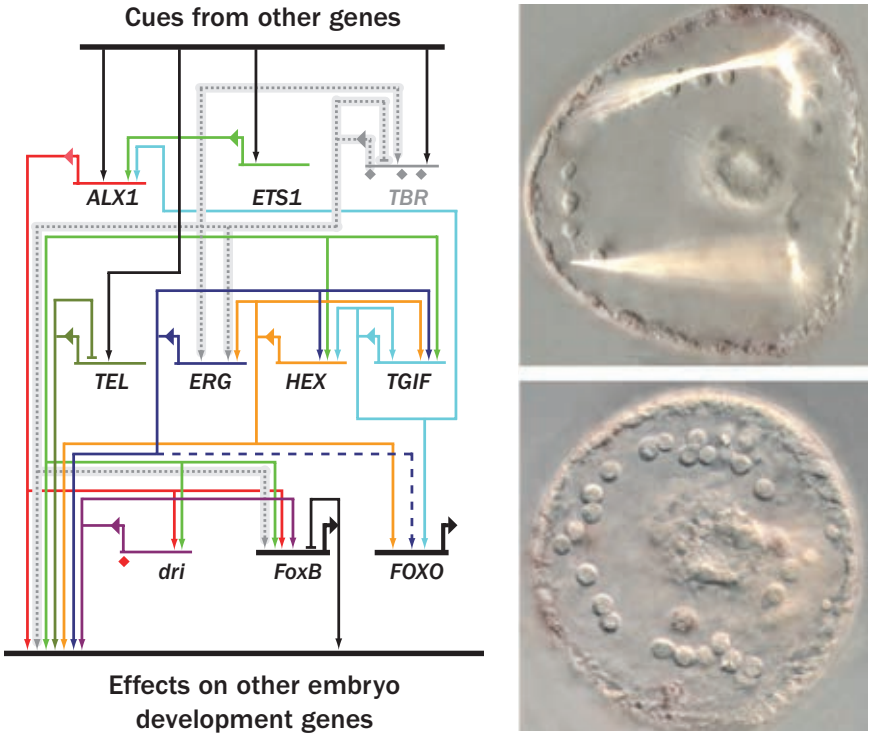
Genes carry the codes for specific proteins, and the amount of a protein that a gene makes at any time is defined as the gene's activity. After DNA damage occurs in a cell, *p53* springs to life, and its activity — and thus the concentration of the p53 protein it encodes — begins to oscillate slowly from more to less and back again, like a throbbing warning light. The number of oscillations depends on how bad the damage is. If the DNA hasn't been fixed by the time the oscillations stop, *p53* activity begins to ramp up slowly and steadily until it reaches a point that triggers the cell's suicide machinery.

In a network diagram, *p53* is connected with two other genes, *MDM2* and *ATM*, in a motif that could be called a damper: a negative feedback loop. The classic example of this kind of feedback loop is a thermostat. If temperatures get too high, the air conditioning switches on and cools things down, and when things get too cool, the air conditioning switches off to let the room warm back up. So the temperature oscillates around some desired point. For genes in a network, a similar motif occurs when one gene activates another gene, which in turns inhibits the first gene.

Negative feedback loops with *MDM2* and *ATM* can explain *p53*'s oscillation behavior after DNA damage, Galit Lahav of the systems biology department at Harvard Medical School in Boston and his colleagues reported in the May 9 issue of *Molecular Cell*.

Small pebble, big wave

The gene network that regulates a developing sea urchin embryo is well understood. Researchers can predict how changes to parts of the network would affect the entire embryo. For example, when the *TBR* gene is left alone, a skeletal structure can form (below). But turn off *TBR* and the change propagates in a way that leaves the skeleton unformed (bottom image).



As time runs out, a second part of the network — a positive feedback loop between *p53* and the genes *PTEN*, *PIP3* and *Akt* — overcomes this first motif. Positive feedback loops could be called amplifiers: They cause an increase to keep increasing. Genes in this second motif cut off the damper by blocking the connection between *MDM2* and *p53*, Tomasz Lipniacki of the Institute of Fundamental Technological Research in Warsaw, Poland, and his colleagues reported in the Sept. 21 *Journal of Theoretical Biology*. This change switches off the thermostat, so the positive feedback loop can drive up *p53* activity until it triggers cell suicide.

Zoom out

Somewhat larger networks containing a dozen or more motifs can control even more complex processes, such as that by which insect embryos develop body segments. Different species develop their segmented body plans in different ways, but the genes involved in this segmentation are roughly the same across most insect species. Koichi Fujimoto and his colleagues at the University of Tokyo wondered whether three different development plans could be coded not in the genes themselves, but in the way the genes are connected in the network.

Fujimoto's team used a computer to "evolve" hundreds of simulated gene networks, mutating each network repeatedly until it produced one of the three development plans. Looking at the resulting networks, the researchers found that each of the development plans corresponded to one of three network characteristics: Many feed-forward loops, at least one negative feedback loop or interwoven loops of both types.

While the work was based on networks simulated in a computer, comparison with the known gene networks of the fruit fly and the red flour beetle showed that those insects had the same network patterns predicted by the simulations,

Fujimoto's team reported online July 23 in *PLoS ONE*.

By understanding in detail how networks give rise to cell behavior in health, "we can also understand how they fail in disease," Shmulevich says. "The future is that we're going to be looking in the blood for various organ-specific signatures of disease so that we can detect how the networks have been perturbed."

Developing drugs is currently a trial and error game, he says: "Having systems-level understanding of biological processes and being able to predict how they'll respond to various changes will really help drug development. We can drive the system toward a certain state or away from a certain state."

That's still a far-off goal, but some research on still-larger networks suggests that this kind of control is possible.

The entire map

Perhaps the best-understood large gene network is the one controlling the development of sea urchin embryos. Over the past four decades, Eric Davidson, a cell biologist at California Institute of Technology in Pasadena, has been studying sea urchin development. In the past few years he's assembled a detailed model of the gene networks that orchestrate the entire process of intestine formation. In the April 22 *Proceedings of the National Academy of Sciences*, Davidson and his colleagues also published a detailed description of the networks that steer some of the urchin's cells into becoming skeleton-forming cells.

These mathematical models chart the networks that regulate the activity of the sea urchin's genes. The models are complete enough to accurately predict how a change to the network will affect the embryo's development. If such thorough network models can eventually be made for human cells, scientists may be able to skillfully alter the cells' networks to treat diseases such as cancer, diabetes and autoimmune disorders.

"The complex diseases are the ones that we have to understand on a systems level," Shmulevich says.

Zooming the picture out farther provides a view of how the network behaves as a whole.

For example, research reported in August at the systems biology conference in Sweden suggests that gene networks obey a principle called the "law of conservation of fragility." If disturbing one gene in a network has a large effect on the network's overall functioning, that gene is considered fragile. If the effect on the network is small or negligible, the gene is not fragile. The law says that if you add up the fragility values for all the genes or proteins in a network, the total will always be the same, according to a study presented by Manchester's Westerhoff.

So if a change in the network makes some genes less fragile, the law tells you that there must be at least one gene that becomes more fragile to compensate — conservation of fragility ("Finding health in fragility," *SN Online: 8/25/08*).

"The system may be robust in some places, but it must also be fragile in some other places," Westerhoff said at the meeting. "If you're developing a drug, you might want to target these fragile places."

This principle suggests a surprising target for anticancer drugs. A gene called *RAF* is overactive in many kinds of cancer, and so might stand out as a potential target. But Westerhoff and his colleagues showed that this gene is actually more fragile in healthy cells than cancer cells. So a drug targeting that gene would damage healthy cells more than cancerous ones. Because of conservation of fragility, some other gene must be more fragile in the cancer cells and thus would make a more effective target for a drug, Westerhoff says.

For very large networks encompassing entire cells, scientists are also learning how to watch the whole network's behavior over time.

The basic idea is to represent the condition of the complete network at one moment in time as a point in space, called "state space." If the network had only three genes, the state space could be represented as a 3-D mathematical graph. The point would have three coordinates that represent the activity levels of the three genes — that is, how actively those genes churn out copies of proteins. For a network with hundreds or thousands of genes, the space would have hundreds or thousands of dimensions. Such high-dimensional space can't be visualized but can be dealt with mathematically.

As long as the activity of these genes — and hence the cell's behavior — remains the same, the point will hold still. If some genes become more or less active over time, causing a change in the behavior of the cell, the point will move in state space to reflect that change.

Mathematicians have shown that complex networks with many feedback loops — like the networks in cells — can behave in one of a few ways in this state space over time. Some network architectures will gravitate toward a stable point and stay there. The cell's behavior becomes unchanging. Other networks will home in on a repeating cycle, such as a circle in state space, and then follow that pattern endlessly. For this kind of cell, steady oscillation would be its most stable state. Scientists call both states ordered behavior.

But tweak the architecture of an ordered network just a little bit and the system can cross over into chaotic behavior. In this case, "chaos" doesn't mean mayhem or randomness. It just means that the network will follow a meandering path through state space that, unlike ordered behavior, never repeats. That path isn't truly random, but it is unpredictable because even the tiniest, immeasurable difference in its state at one moment can gradually swell until it alters the course of the entire network — like the famous butterfly that causes a hurricane by flapping its wings.

It turns out that ordered and chaotic behavior are both dangerous for a cell. Ordered behavior is too stable, so the cell can't respond to challenges in its environment. Chaotic behavior balloons disturbances until they overrun the cell, preventing the cell from keeping its interior suitable for the chemistry of life.

But there's a Goldilocks zone at the threshold between order and chaos called criticality.

"It's been hypothesized for a long time

that living systems are critical, and what we've done is show for the first time on a molecular level that that's true for these cells," Shmulevich says.

Shmulevich and his colleagues showed that a kind of immune system cell called a macrophage does indeed operate in the Goldilocks zone between order and chaos, thus striking the right balance between stability and flexibility. The scientists stimulated molecules on the cell's surface that detect foreign bacteria. By watching how this stimulation spread through the cell and affected the activity levels of all the cell's genes, Shmulevich's team found that the change in gene activity neither petered out immediately nor amplified over time. This pattern is exactly what is expected for a cell at criticality, the researchers reported in February in *PNAS*.

"The perturbation can propagate and can travel through the system, but it's not going to swamp the system and make it useless," Shmulevich says.

His group later repeated this experiment on cells from five species representing four of the kingdoms of life: bacteria, yeast, plants and animals. Once again, cells from each of the kingdoms operated at criticality, the team reported online June 18 in *PLoS ONE*.

This work begins to reveal the hidden dynamics that emerge when genes and proteins act together in networks, says Leroy Hood, president of Seattle's Institute for Systems Biology. But Hood adds that, even after the mammoth task of thoroughly mapping the networks in a human cell is done, still to be understood is how that cell's networks integrate into a larger, different kind of network: the billions of interacting cells in an organ such as the heart or — shudder — the brain.

"Boy are we at the very, very beginning of that," Hood says. ■

Explore more

- The Center for Cell Dynamics at the University of Washington's Friday Harbor Laboratories: celldynamics.org

Thanks for the support

As a high school teacher, I have had many students who have heard about the global cooling scare of the 1970s, and these students hold on to those ideas even in the face of overwhelming evidence to suggest that the current warming trend is real. Until I read Sid Perkins' article "Cooling climate 'consensus' of 1970s never was" (*SN: 10/25/08, p. 5)*, I have never had a strong argument to address that concern. There may be only a few global warming critics among scientists, but policy is so often dictated by the court of popular opinion. I am quite glad that Thomas Peterson is doing this work.
Jon L. Nauert, Mount Vernon, Wash.

First thing first

I was intrigued by the ideas discussed in Bruce Bower's "Body in Mind" article (*SN: 10/25/08, p. 24*) since I have long felt that there is an overemphasis on algorithms in efforts to create artificial intelligence. I remember arguing with one of Stephen Hawking's students in Cambridge in 1978 that sensors and actuators are essential to intelligence, artificial or otherwise.

Antonio Damasio makes a persuasive case for the inseparability of emotion and reason in his 1994 book *Descartes' Error: Emotion, Reason and the Human Brain*. And as aptly summarized by the actor who plays Dr. Maurice Bucke in John Kent Harrisons' 1990 movie *Beautiful Dreamers*: "Feeling precedes thinking."
Peter Eisenhardt, Altadena, Calif.

Waves pass through

Regarding "Solid evidence about Earth's core" (*SN: 9/13/08, p. 14*): If Earth has a solid inner core but a liquid outer core, then any direction you look at it, the shear waves have to go through some liquid outer core before they get to the solid inner core. So how do they get through the molten outer core?
Tom Turner, Newport, R.I.

When shear waves travel down through the mantle and reach the liquid outer core, some of their energy is converted into pressure waves (which can travel through liquid, unlike shear waves). When those pressure waves reach the solid inner core, some of their energy is converted back into shear waves. Once these vibrations reach the other side of the solid inner core, some of their energy is reconverted into pressure waves that rise through the liquid outer core. Finally, when these waves reach the mantle, some of their energy is again converted to shear waves that then spread and can be detected by seismometers at Earth's surface.

Each of these conversions — four, count 'em! — is relatively inefficient, leaving little energy in the particular vibrations that the scientists needed to identify in order to bolster their theory. — Sid Perkins

Colliding planets

"Impact may have scarred Mars" (*SN: 7/19/08, p. 10*) interested me. In the article, Francis Nimmo of the University of California, Santa Cruz says that "something big smacked into Mars and stripped half the crust off the planet." I also understand that the current theory of the formation of the moon suggests that a Mars-sized object sideswiped the Earth.

I know nothing about celestial mechanics, but is there any way that the Earth and Mars could have collided? The impact on Mars might have been smaller if it had formed further away from the sun and thus had cooled and solidified more by the time of the impact.
Dick Smith, Kingsland, Texas

Planetary scientists don't believe the Earth and Mars could have collided, given their current orbits and where they would have been located in the early solar system. — Ron Cowen

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California's Fading Wildflowers: Lost Legacy and Biological Invasions

Richard A. Minnich

"The land was very green and flower-strewn," Pedro Font notes in a 1776 diary entry describing fields near the Los Angeles River where the city's Civic Center stands today. The journals of early Spanish explorers are the only detailed records of California's herb cover before introduced species began spreading across the state, writes Minnich in this dense, vivid and painstakingly meticulous account of the Golden State's botanical heritage.

With a source list as rich as the state's flora once was, Minnich describes the ebb and flow of California's native and invasive plants, presenting evidence including newspaper articles, writings of early American botanists and records of local flora used as binding material in adobe bricks. He presents an exhaustive survey of existing documentation and provides a lens through which he reminds readers that beauty is in the eye of the recorder. While botanists later conducted broad surveys, earlier records were collected with a mind for agriculture and practical use. Purpose shaped documentation.

Minnich also revisits, and questions, stalwart notions of the state's botanical history, such as the bunchgrass-grazing hypothesis—which blames the disappearance of native bunchgrasses on opportunistic, nonnative plants, such as wild oats. He details how the influx of cattle, sheep and forty-niners shaped and reshaped the landscape, as did the accompanying plants.

Not quite a dirge, Minnich's account also notes years where natives have burst into bloom—most recently in 2005. With effective management, much of the flora need not be lost. In fact much of it is waiting, "banked" as seeds in the soil. —*Rachel Ehrenberg*
Univ. of California, 2008, 344 p., $49.95.

Insatiable Curiosity: Innovation in a Fragile Future

Helga Nowotny
Translated by Mitch Cohen

The only way is forward, so be bold, Nowotny tells those who fear the uncertainty of the future. Vice President of the European Research Council, Nowotny has researched and written extensively on the intersections of science, technology and society. In this meditation, she makes a reasoned argument for embracing scientific progress despite its sometimes unsettling consequences.

Nowotny's mind moves quickly, meandering from point to point without returning to recap or summarize. She goes to great lengths to distinguish science from technology, and curiosity from innovation. She touches on barriers to creativity, the role of failure in discovery, science's declining reputation and the need to communicate its progress.

Nowotny returns to curiosity again and again. "Curiosity, insatiable as it is, thereby drives us forward," she writes. It seeks new paths, takes risks, subverts limits. "It poses questions that are not permitted, and unwise as it is, it presses for action even where it should draw back."

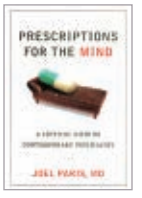
With more success, there is more curiosity, but also more at stake, Nowotny argues. While biomedical advances have brought health, long life and new reproductive possibilities, such advances have also brought doubts about the definition of self and the value of life. But, she continues, humanity will always push on because "standing still is tantamount to falling back."

Ambivalence—uncertainty about which path to follow in any aspect of life—arises from a wealth not a lack of knowledge, she concludes, and ambivalence is also a cultural resource destined to promote progress. —*Elizabeth Quill*
MIT, 2008, 179 p., $30.

Coding and Redundancy: Man-Made and Animal-Evolved Signals

Jack P. Hailman

Traffic lights and primate vocalizations encode information in similar ways. *Harvard Univ., 2008, 257 p., $39.95.*



Prescriptions for the Mind: A Critical View of Contemporary Psychiatry

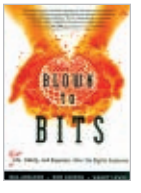
Joel Paris

An assessment of the field and a look at the shift in emphasis from talk-based therapies to medication. *Oxford Univ., 2008, 247 p., $29.50.*

The Quantum Ten: A Story of Passion, Tragedy, Ambition and Science

Sheilla Jones

A personal and scientific story of the characters who struggled to create quantum physics. *Oxford Univ., 2008, 323 p., $24.95.*



Blown to Bits: Your Life, Liberty, and Happiness after the Digital Explosion

Hal Abelson, Ken Ledeen and Harry Lewis

Harvard course instructors explore the consequences of technology's spread. *Addison-Wesley, 2008, 366 p., $25.95.*

Extreme Birds: The World's Most Extraordinary and Bizarre Birds

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The decider

Informing the debate over the reality of 'free will' requires learning something about the lateral habenula

By Tom Siegfried

At the end of *The Matrix* trilogy, Neo and Agent Smith are engaged in one final, interminable scene of surreal combat, a surrogate competition for an eternal battle between humans and machines. "It's pointless to keep fighting," Agent Smith declares to Neo. "Why do you persist?"

"Because I choose to," Neo replies, just before the computer-generated Smith meets his demise in a cinematic celebration of human free will's superiority to the programming that enslaves machines. Machines are mindless. The brain is a decider.

All very inspiring, except that the brain itself is a machine, a network of cells that computes its choices based on the sum of sensory inputs and their interactions with neural anatomy. "Free will" is not the defining feature of humanness, modern neuroscience implies, but is rather an illusion that endures only because biochemical complexity conceals the mechanisms of decision making.

Yet belief in free will persists as stubbornly as Neo's resistance to electronic tyranny. Whether supposedly free choice is actually a *Matrix*-like mirage remains one of the great questions of human philosophical history. For centuries that question was assessed mostly with thought — uninformed by actual neurobiological knowledge. Nowadays, though, the inner workings of the brain are revealing themselves to modern methods of neuroinquiry, and free will seems merely to emerge from electrochemical networks of neuronal interactions. But like tourists exploring a strange city without a GPS map, scientists don't know how all the neural neighborhoods are connected and occasionally encounter surprising enclaves — such as a place in the brain called the lateral habenula.

"There's lots of new research showing that an overactive habenula has behavioral effects," says neuropharmacologist Martine Mirrione of Brookhaven National Laboratory in Upton, N.Y.

Questioning consciousness

To most people, who have never heard of the habenula, free will's existence seems obvious, because they can make up their own mind whether to believe in it or not. Consciousness of choosing seems to imply the ability to choose. But the 19th century English historian Henry Thomas Buckle ridiculed such logic, pointing out that consciousness is often fallible. Some people profess to have consciousness of the presence of ghosts, for example. "If this boasted faculty deceives us in some things, what security have we that it will not deceive us in others?" Buckle asked.

Knowing everything about a man's character, history and all external circumstances would in fact allow someone to accurately predict what he would do, Buckle averred. That example was hypothetical, he acknowledged. "We never can know the whole of any man's antecedents," he wrote. "But it is certain that the nearer we approach to a complete knowledge of the antecedents, the more likely we shall be to predict the consequent."

Today, science's knowledge is not nearly complete, but it's a lot closer than in Buckle's day. As evidence flows in from probes of animal brains and scans of living humans, the neural antecedents of the brain's decisions are becoming more clearly visible. "Perhaps," write neuroscientists Alireza Soltani and Xiao-Jing Wang, "we are entering a new period of consilience between the science of the brain and the science of the mind."

Death to dualism

Such consilience would certify the death of Cartesian dualism, the mind-body distinction articulated by the French philosopher René Descartes in the 17th century. In modern neuroscience, that division dissolves — the mind is simply a reflection of different states of the brain. And brain states dictate the behaviors that masquerade as free choices.

Brains are, after all, the product of evolution. To survive and perpetuate their species, animals need food, water and sex. So brains are programmed to produce behavior that serves those ends — or seek substitutes that stimulate the same neural systems. Free will is not free to ignore these imperatives, although it isn't always obvious how they all add up and tip the scales in favor of go or stop, do or don't. Somehow, the brain sorts out the interplay between desire and caution, pleasure and pain, curiosity and fear. And the neural systems established by evolution for survival direct all the other decisions that animals (including people) routinely make — fight or flee, explore or hide, red or white, left or right.

Neurobiologists like to describe the sum of the brain's many motivations with the concept of reward. In real life, the common currency for measuring reward is money (and consequently the study of the brain's choice-making is sometimes called neuroeconomics). In the brain, that currency seems to

be the molecular messenger known as dopamine.

Neurons producing dopamine are powerful forces in directing the brain's decisions. Certain dopamine neurons in the midbrain are particularly active in driving the brain to seek rewards. But they're not tuned simply to pleasure. Those dopamine neurons become electrically excited and release molecular messages simply in anticipation of pleasure. If the expected reward does not then materialize, those dopamine neurons take a rest. On the other hand, when an unexpected reward arrives, they fire signals vigorously. Apparently these dopamine neurons encode errors in predictions about potential rewards, so as to improve future decisions on what courses of action to pursue. In other words, dopamine neurons underlie learning how to behave based on pleasurable experiences.

Hail the habenula

KURT STIER/CORBIS

Sound decisions depend on more than seeking pleasure, though. It's also important to learn what choices will turn out to be bad. And the latest research suggests that that's a job for the habenula.

It's an obscure structure found deep in the brain, beneath the corpus callosum near the thalamus and in front of the pineal gland (the small body identified by Descartes as the seat of the soul, the source of free will). "Virtually all kinds of vertebrates have this habenula, which suggests that it is very important for survival," says Okihide Hikosaka of the National Eye Institute, an NIH agency in Bethesda, Md.

When a monkey is faced with a nonrewarding choice, neurons in the lateral part of the habenula fire their signals rapidly, Hikosaka and Masayuki Matsumoto reported in *Nature* last year. When the habenula neurons fire, dopamine neurons slow down. Apparently the habenula warns against bad choices by suppressing dopamine activity, either directly or perhaps via intermediary neurons.

"Dopamine neurons contribute to learning of actions based on good experiences," Hikosaka says, "whereas lateral habenula neurons are probably involved in learning of actions based on bad experiences."

Recent work in several other labs suggests that the habenula plays an especially key role in neuronal crosstalk, serving as a sort of relay station between the primitive parts of the brain, which control basic needs, and the most advanced frontal regions where thought and logic presumably moderate basic impulses. But nobody suggests that the habenula is the source of all decisions or the seat of human consciousness. It's just one hub in a network of brain addresses where parts of the decision-making process are assembled. Neuroscientists discussing such issues chatter about the amygdala, the nucleus accumbens and the anterior cingulate cortex, the PFC, the OFC and the IPC. Such areas encode information on rewards, costs or how much to discount the value of rewards that will be delayed. Different neural neighborhoods control risky choices, safe bets and when to change a decision already made. And while the habenula communicates to many brain regions involved in decision making, various regions transmit messages to the habenula, too.

All of this is important for much more than just enlightening free-will philosophy or learning the nomenclature of brain anatomy. Habenula activity has been implicated in everything from stress and anxiety to psychiatric disorders and sleep. Besides influencing dopamine cells, for example, signals from the habenula suppress neurons that make serotonin, the brain chemical famous for its effects on mood. Mirrione and her collaborators at Brookhaven have shown a link between elevated habenula activity and symptoms of depression in rats.

Depressed people typically forgo pleasurable activities that would ordinarily elicit "go" signals from dopamine neurons. An overactive habenula, by damping dopamine, could drive depression by denying the brain the power to choose pleasure. Many popular antidepressants work by elevating the brain's serotonin levels, perhaps countering the habenula signals that suppress serotonin production. But such antidepressants don't always work. Direct intervention in the habenula might offer an alternative, Mirrione says. Their rat study "suggests that the habenula appears to be a novel target for therapeutic intervention in treatment-resistant depression," she and her collaborators reported in November in Washington, D.C., at the annual meeting of the Society for Neuroscience.

Other studies hint that the habenula plays a role in nicotine withdrawal behaviors, with implications for helping people to quit smoking. Behavior underlying other drug addictions might also be disrupted by intercession in the habenula, Israeli scientists reported at the neuroscience meeting. Their study found that deep brain stimulation of the habenula influenced the desire of addicted rats to self-administer cocaine.

Practical and clinical implications aside, the habenula's multiple powers, and the diversity of other brain regions it interacts with, all suggest that the original question about free will is ill-posed. Asking whether humans have free will is like asking which came first, chicken or egg. It's not a meaningful question. For chickens and eggs, the issue is understanding DNA and genes and the chemistry controlling reproduction and heredity. For free will, the issue is understanding the complex circulation of molecular information that is massaged and manipulated at various stations by neural systems tuned to multiple decision-making considerations. That process *is* free will, even if it isn't really free. So deciding whether the will is free turns out to be circular, although perhaps not viciously, like some of those fights in *The Matrix*. ■

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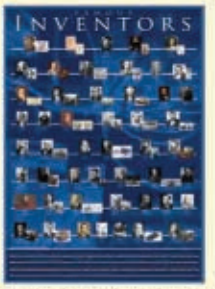

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Debates over definition of planet continue and inspire

Planetary science is in the midst of a revolution. As recently as the early 1990s, "the planets" consisted of just nine famous objects in our solar system that every school kid learned to recognize by name and appearance. But then, advances in astronomical technology unleashed an explosion of new planetary discoveries on two fronts.

One of these fronts involved a bewildering variety of planets discovered around other stars. In rapid succession, we learned about extrasolar pulsar planets, hot Jupiters, superEarths and more. And there is now a widespread scientific consensus that the 300-plus planetary discoveries made so far around other stars only hint at the true variety.

The other front formed in a revolution much closer to home, with the discovery of dozens of Pluto-scale (2,400-kilometer diameter class) "dwarf planets" in our solar system. Dwarf planets, which are expected to be common around other stars (but are as yet beyond the reach of most observational techniques), are likely to prove the most dominant type of planet in the galaxy.

As with other revolutions, change consternates some people and organizations. And just such consternation led a few hundred mostly astronomers (mind you, I did not say mostly planetary scientists) at an International Astronomical Union meeting in mid-2006 to vote that dwarf planets are not planets. Ignoring the simple fact that voting is not a valid process to vet scientific principles (what if the IAU voted the sky was green?), many press reports incorrectly described the IAU reclassification of Pluto and other dwarf planets as a fiat.

However, in the two years since that widely publicized vote and its widespread reporting in the press, it has become clear that the IAU's action has neither been widely applauded nor very well accepted. Consider: Within a week of the IAU's vote, several hundred planetary scientists — considerably more planetary scientists than were in the room when the IAU voted — signed a petition refusing to use the IAU's definition owing to its flaws and biases. Then in 2007 and 2008, both the European Geophysical Union and the American Association for the Advancement of Science held special meetings to debate planet definition. Would there have been any need for such meetings if the IAU's planet definition had been satisfactory? And just this past August, over a hundred scientists, educators and others gathered in Maryland for a three-day discussion called "The Great Planet Debate." The outcome: There remain sharp debates on what planetary practitioners consider a planet to be.

I embrace the diversity of new planet types, including the dwarf planets.

I myself am a partisan in this debate. I embrace the diversity of new planet types, including the dwarf planets, because they have no fundamentally different characteristics than their larger cousins, other than that they are somewhat smaller — just as Chihuahuas have no fundamentally distinguishing characteristics from other canines, except that they are smaller, and just as dwarf stars like our sun have no fundamentally different characteristics from giant stars a hundred times the sun's diameter.

Like many of my planetary science colleagues, I consider a planet to simply be any natural object in space that is large enough to be rounded by self-gravity. It therefore behaves as a body whose shape is dominated by self-gravity, rather than by the body's own mechanical strength, as with rocks and asteroids. If this means there are too many planets to name — like stars and galaxies, that planets are not special or that planet taxonomy will be complicated, so be it. It is not up to scientists to saddle taxonomy with preconceived biases. Instead, it is up to science and scientists to adjust to new data and revise paradigms accordingly, as when new data demonstrated that the Earth is not the center of the solar system, and again when new data demonstrated that the Milky Way is not the only galaxy but one of countless billions.

Planetary scientists must care about planet definition because without knowing what a planet is, a planetary scientist cannot describe what the field's central objects of study are.

But why should the public care? First, for the sheer inspiration and excitement that comes with revolutionary discoveries involving the newly found diversity of planetary sizes and taxa. Equally, because if planetary types different from our own dominate the galaxy's population of planets, then we are inspired to revel in the fact that the Copernican revolution continues even today. And finally, because educators have in this classification revolution an utterly inspiring, teachable moment emanating from the debate. And what is that? It is that science adapts to new data — such as the prevalence of dwarf planets — rather than running from it, and finds its way to better paradigms, not by fiat or voting but by reasoned debate that converges to consensus. ■

Alan Stern is a planetary scientist and NASA's former associate administrator for science.

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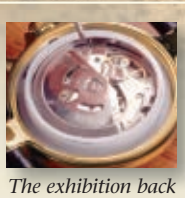

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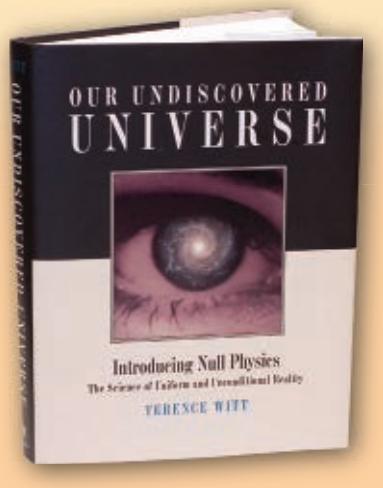

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