JANUARY 26, 2008 PAGES 49-64 VOL. 173, NO. 4

SCIENCE NEWS

THE WEEKLY NEWSMAGAZINE OF SCIENCE

mercury's close-up

cells as ink

blinds enhance radiography

synthetic genome assembled

www.sciencenews.org

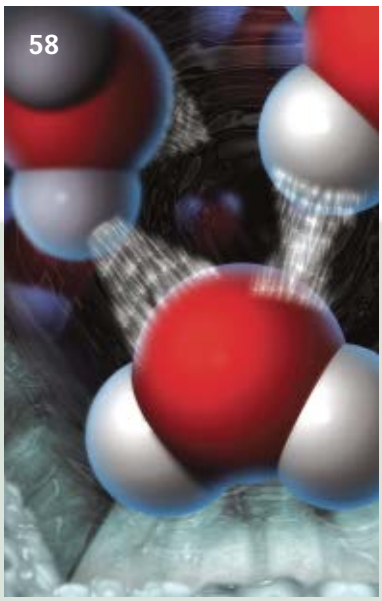
getting to know h_2o

TRACKING WATER'S HIGHS AND LOWS

THE WEEKLY NEWSMAGAZINE OF SCIENCE

SCIENCE NEWS

JANUARY 26, 2008 VOL. 173, NO. 4



Features

This Week

Of Note

Meetings

Departments

Cover Confining water molecules in nanometer-size pores has provided new evidence that, in addition to its many other oddities, H_2O may exist in two distinct liquid phases at ultralow temperatures. (Nicolle Rager Fuller)
Page 58

THIS WEEK ONLINE
http://blog.sciencenews.org/

Food for Thought Uncle Sam has confirmed it: Our bodies carry residues of kitchen plastics.

MathTrek Ben Franklin entertained himself devising beautiful mathematical puzzles.

Science News (ISSN 0036-8423) is published weekly on Saturday, except the last week in December, for $54.50 for 1 year or $98.00 for 2 years (foreign postage is $18.00 additional per year) by Society for Science & the Public, 1719 N Street, N.W., Washington, DC 20036. Preferred periodicals postage paid at Washington, D.C., and an additional mailing office.

POSTMASTER Send address changes to **Science News**, P.O. Box 1925, Marion, OH 43306. Two to four weeks' notice is required. Old and new addresses, including zip codes, must be provided.

EDITORIAL, BUSINESS, AND ADVERTISING OFFICES 1719 N St. N.W., Washington, D.C. 20036
202-785-2255; scinews@sciencenews.org.
LETTERS editors@sciencenews.org

SUBSCRIPTION DEPARTMENT P.O. Box 1925, Marion, OH 43306. For new subscriptions and customer service, call 1-800-552-4412.

Science News (www.sciencenews.org) is published by Society for Science & the Public, a 501(c)3 nonprofit corporation founded in 1921. The vision of Society for Science & the Public is to promote the understanding and appreciation of science and the vital role it plays in human advancement: to inform, educate, inspire. Visit Society for Science & the Public at www.societyforscience.org.

Mercury, As Never Seen Before

MESSENGER visits innermost planet

Mercury's image problem is fading. On Jan. 14, NASA's MESSENGER spacecraft flew within 200 kilometers of the solar system's smallest—and oft-ignored—planet. The craft viewed one crater-pocked hemisphere, half of which had never before been seen close-up. When Mariner 10, the only other craft to visit Mercury, examined the surface 33 years ago, sunlight illuminated a different portion of the planet.

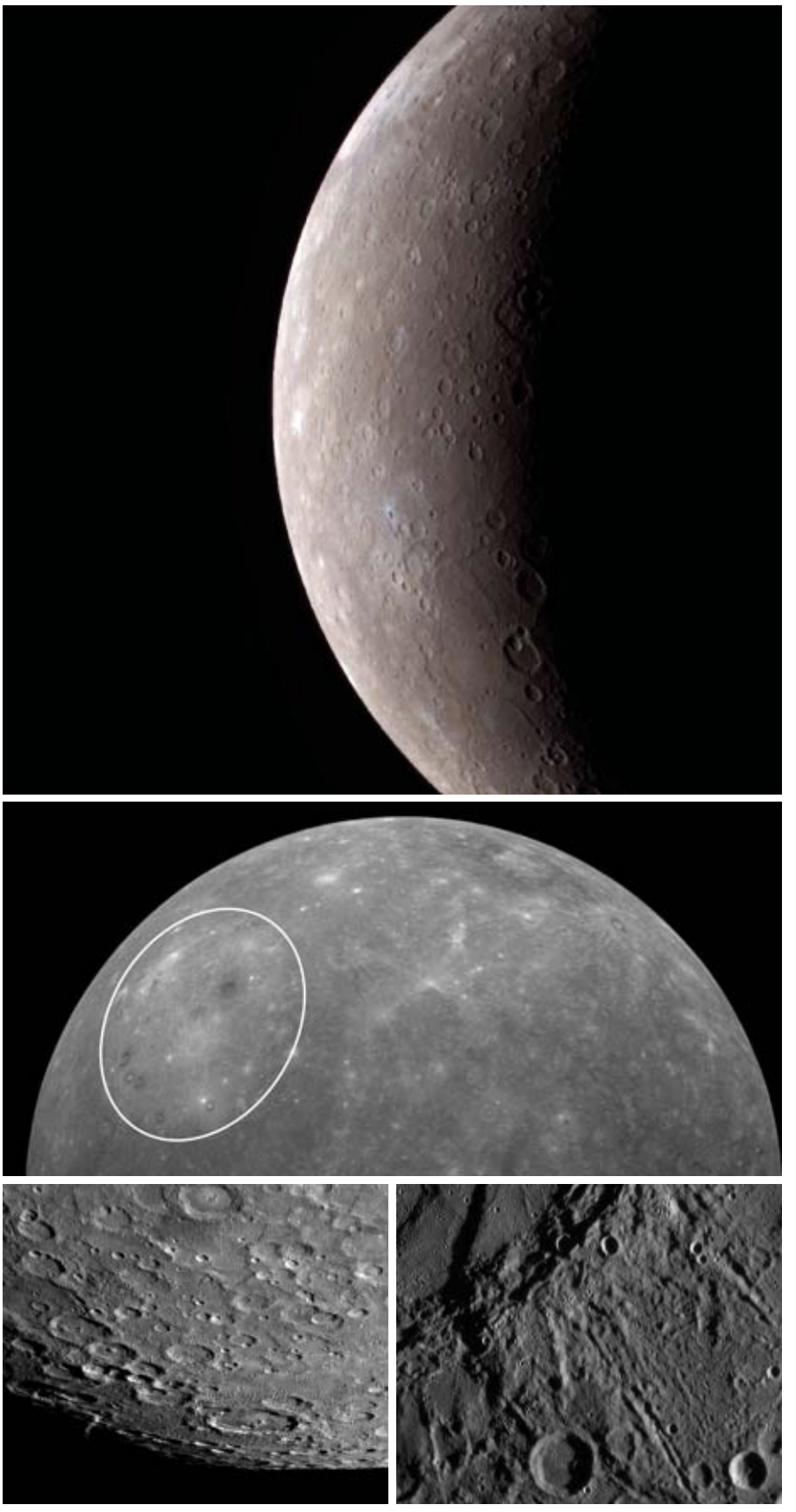
"Even for the side of Mercury already viewed by Mariner 10, we are seeing the surface with fresh eyes," says MESSENGER principal investigator Sean Solomon of the Carnegie Institution of Washington (D.C.). "The different lighting conditions, superior image quality, and broader color are showing us new features and providing new information on compositional differences."

Recorded with 11 color filters, the images show that the giant Caloris basin, the largest crater on Mercury and one of the biggest in the entire solar system, has a diameter of about 1,500 km. That's 200 km wider than estimates from Mariner 10, which had glimpsed only the basin's eastern edge. Some craters within Caloris have dark rims that may contain material with a different composition from that in the crater floors, Solomon says.

Like a dowager's wrinkles, a system of faults scores the planet and may be a sign that Mercury contracted as it cooled over billions of years, he adds.

Images taken near Mercury's terminator, where day turns into night, provide "a jaw-dropping perspective" of the detailed topography, notes Solomon.

MESSENGER also recorded spectra of Mercury's surface and thin atmosphere, or exosphere. A preliminary analysis confirms sodium in the exosphere, which was known from Earth-based observations.



MERCURIAL A bluish tinge reveals the presence of youthful craters, no more than 500 million years old, on Mercury (top). MESSENGER's global view of Mercury (middle) includes the giant impact crater Caloris (circle). Taken from a distance of 33,000 km, a view of Mercury looking toward the planet's south pole (bottom left) has never been previously seen by a spacecraft. One of the highest and longest cliffs ever seen on the planet is visible in the curving structure running from the top to left edge of the image at bottom right.

NASA/JHU APL/CARNEGIE INSTITUTION

Color images from the flyby highlight youthful craters no more than a few hundred million years old. Such craters have a relatively bluish tinge because they haven't suffered long-term bombardment by micrometeoroids—grain-size rubble that vaporizes rock. Some iron-containing rocks resolidify afterward and become coated with material that reflects more red light.

By combining color images with spectra, scientists can determine which surface features originate from the planet's thin crust and which emerged from the mantle beneath, says Mark Robinson of Arizona State University in Tempe.

Other measurements show that Mercury's magnetic field has about the same strength as it did when Mariner 10 visited, but that that the magnetosphere—the region around the planet dominated by the field—has shrunk, reports Ralph McNutt of the Johns Hopkins Applied Physics Laboratory in Laurel, Md. The energy of the charged particles in the magnetosphere also differs from that of 33 years ago, which could be a sign that the planet is highly sensitive to small changes in the sun's activity, he adds.

Shooting laser pulses at the surface, MESSENGER also made the first high-resolution topographic measurements of Mercury.

The craft will next fly past Mercury in October, viewing the opposite side of the planet. After a third visit in September 2009, MESSENGER will settle into a yearlong orbit about the planet beginning in March 2011. —RON COWEN

Big Foot

Eco-footprints of rich dwarf poor nations' debt

The first accounting of who's stomping on whom finds rich nations leaving supersized boot prints of ecological damage on poor countries, adding up to more than those nations' debt to the wealthier countries.

Rich nations' doings during the last 4 decades of the 20th century caused up to $2.5 trillion in environmental impacts on poor countries, Thara Srinivasan of the Pacific Ecoinformatics and Computational Laboratory in Berkeley, Calif., and her colleagues estimate. Middle-income nations did about the same amount of damage to the low-income countries.

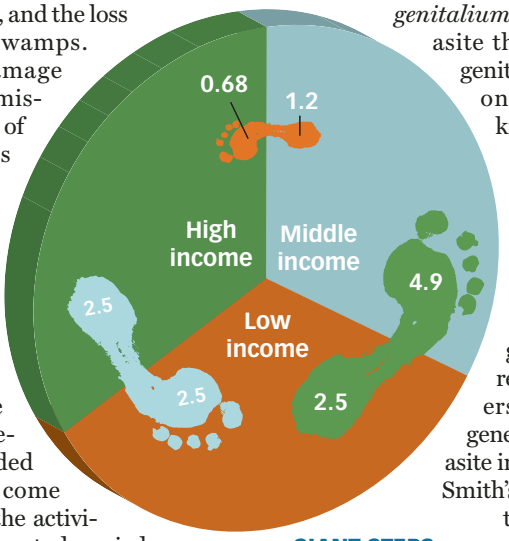
Each wallop is bigger than the total that poor countries have borrowed from wealthier nations. In 2000, that borrowing added up to $1.8 trillion. (All amounts are in 2005 international dollars, which are adjusted for purchasing power around the world.)

"This makes me wonder who owes who here," says Jonathan Foley, who directs the Center for Sustainability and the Global Environment at the University of Wisconsin–Madison.

Environmental economists have experimented with ways to measure footprints of various activities since the 1990s, but Srinivasan says she doesn't know of another attempt at a broad global accounting.

The team used the World Bank's groupings of countries. Poor nations, with annual per capita income of $875 or less, included Bangladesh, India, and Nigeria, among others. Brazil, China, and the Russian Federation fall into the middling group. Income of $10,726 or more put such countries as Japan, the United States, and European nations into the rich group.

The researchers scoured the environmental literature for data on impacts. Workable information, from such sources as the United Nations and the United Kingdom's Stern Review, turned up for six topics: climate change, ozone depletion, expanding agriculture, deforestation, overfishing, and the loss of mangrove swamps. Ecological damage included such miseries as the costs of health problems due to thinning ozone and storm damage along coasts no longer buffered by mangrove swamps. For ozone depletion and climate change, the researchers included impacts still to come (until 2100) of the activities in their 40-year study period.



GIANT STEPS Color-coded footprints indicate the dollar cost, in trillions, of environmental damage inflicted by high-, middle-, and low-income groups of nations on each of the other two groups.

E. ROELL, FROM SRINIVASAN GRAPHIC

Srinivasan laments the gaps in information that kept the analysis from toting up the ecological toll of other problems, such as pollution, invasive species, waterway modification, and war.

The team also looked at studies on which nations were driving particular environmental changes. For climate change, for example, the analysts calculated the proportion of greenhouse gases emitted by each of the nation groups. Seafood consumption measured the responsibility for overfishing.

The well-off disproportionately affected the poor for climate change, ozone depletion, and, less predictably, overfishing. "We were surprised," says Srinivasan. The results appear this week online in the *Proceedings of the National Academy of Sciences*.

"The injustice inherent in the current environmental crisis may well exacerbate the divide between rich and poor," says Boris Worm, a marine biologist at Dalhousie University in Halifax, Nova Scotia. —SUSAN MILIUS

Do-It-Yourself DNA

Scientists assemble first synthetic genome

Starting from custom-made segments of DNA, scientists have succeeded in putting together an entire microbial genome in the lab. The researchers plan to transplant this genome into a microbe in the hope that the cell will "boot up" and use the synthetic DNA.

The completed genome is a single DNA molecule with about 583,000 letters of genetic code—18 times the size of the previous record for laboratory-made DNA.

Researchers at the J. Craig Venter Institute in Rockville, Md., based their homemade genome on that of *Mycoplasma genitalium*, a single-celled parasite that infects people's genitals. The parasite has one of the smallest known genomes.

To distinguish the synthetic genome from a natural one, team leader Hamilton O. Smith and his colleagues added telltale "bar codes" of genetic code to their recipe. The researchers also crippled the gene that makes the parasite infectious.

Smith's team then divided the recipe into 101 pieces and bought made-to-order copies of each piece from biotech supply companies in Washington State, California, and Germany. "Gene sequencing is now a commodity," explains researcher John I. Glass, but the largest made-to-order DNA available commercially is only about 5,000 to 6,000 letters long.

The scientists stitched together these 101 pieces of DNA in stages. The ends of each piece overlapped those of its neighbors in the sequence by about 80 letters of code,

enabling the scientists to join consecutive pieces using enzymes. By building groups of neighboring pieces into progressively larger segments, the team eventually created four long chunks, each containing about one-quarter of the genome.

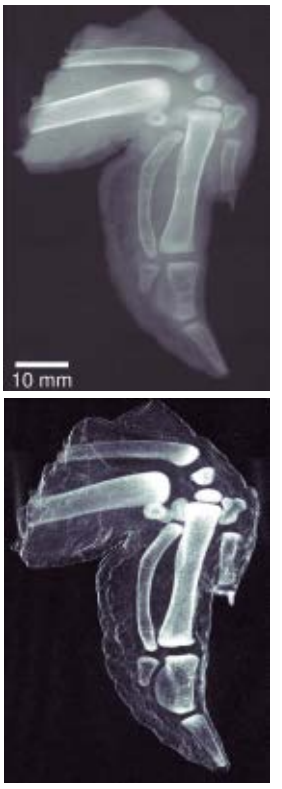
At that point, the project hit a snag. The four giant DNA molecules were too big to put into *Escherichia coli* bacteria, which the researchers had used to make copies of the DNA segments at each earlier stage. Without lots of copies of these large segments, stitching them together in lab dishes would be difficult.

To solve that problem, Smith and colleagues inserted the segments into cells of brewer's yeast (*Saccharomyces cerevisiae*). The yeast's DNA-repair enzymes put the four pieces together, the team reports in the Jan. 24 online edition of *Science*.

"The exciting thing is that the yeast assembly did work. We weren't sure that it would," Glass says. When the scientists checked the sequence of letters in the resulting DNA, it matched their recipe exactly.

George Church, a geneticist at Harvard Medical School in Boston, says he applauds the work but wonders about the technique's long-term usefulness. "It was a giant step for mycoplasma-kind, and a slightly more modest one for human beings," Church comments. For biotech applications, he says, "I just ask what is it that we can't do in *E. coli* that they'll be able to do with mycoplasma."

Smith and coworkers previously showed that they could transplant the entire genome of one species of mycoplasma into a related species (*SN: 6/30/07, p. 403*). The researchers are now attempting to repeat this feat using a synthetic genome instead of a natural one. If they succeed, the resulting cell will be the first living organism with a human-made genome (*SN: 1/12/08, p. 27*). —PATRICK BARRY



ZEROING IN X-raying a chicken wing through microscopic slits creates an image that looks like one made by ordinary radiography (top), but processing the scattered part of the rays reveals more detail (bottom).

PFEIFFER/NATURE MATERIALS

Scanner Darkly

Tiny venetian blinds enhance radiography

Ordinary X-ray machines have their limits in screening luggage. For one thing, they can't always tell the difference between plastic explosives and cheese. A new imaging technique, based on how materials scatter rather than absorb X rays, could improve airport security, and may even lead to better cancer detection.

In standard radiography, materials appear darker or lighter depending on how well they block X rays. Sometimes that's not enough to tell materials apart. For example, cheese absorbs X rays about as readily as some plastic explosives do, says Franz Pfeiffer, a physicist at the École Polytechnique Fédérale in Lausanne, Switzerland.

In next month's *Nature Materials*, Pfeiffer and his collaborators describe a new method for getting more information out of X rays. The team took inspiration from a standard trick used in microscopy to enhance the details of small, translucent objects such as certain insects. In what is called dark-field imaging, an arrangement of screens prevents light from passing straight through the sample and into the lens. Instead, only light scattered by the sample can enter the microscope.

Pfeiffer's team placed a silicon wafer in front of its X-ray source. Plain silicon would let X rays through, but the wafer had a metal grating etched onto it, making it look like a venetian blind with micrometer-wide slits. The rays passed through the grating, and then the sample and two more gratings, before reaching a detector.

Depending on the sample's composition, some of the rays went straight through, and some were deflected by a small angle, comparable to "a hair seen from 1 meter away," says Pfeiffer.

The researchers took up to eight shots of each sample, each time shifting the third grating by a fraction of a micrometer. Computer analysis of the differences between these images enabled the researchers to separate the scattered X rays from those that went through. The effect was similar to viewing the sample from slightly different angles, says Pfeiffer.

While cheese is smooth, plastic explosive has a microscopic granular structure that increases the scattering of X rays, so its image appeared brighter in tests. The researchers also imaged chicken wings, with the bones revealed in greater contrast than with conventional X-ray imaging thanks to their porous structure. With improvements, the technique might detect tumors, which tend to scatter X rays more than healthy tissue does, Pfeiffer says.

While dark-field X-ray imaging has been done in the past, Pfeiffer says that the new technique is the first that could be practical to use with ordinary radiography equipment, as opposed to sophisticated and expensive research beams.

Steve Wilkins, a researcher at Australia's Commonwealth Scientific and Industrial Research Organisation in Clayton South, calls the results "very promising." However, Wilkins points out that right now the technique takes tens of seconds to produce an image. That's too slow for applications such as medical imaging, he cautions, since a patient would need to stay perfectly still. —DAVIDE CASTELVECCHI

Sickness and Schizophrenia

Psychotic ills tied to previous infections

Researchers have long suspected that certain childhood infections contribute to the development of schizophrenia by young adulthood, although scarce evidence supports that hunch. Two new studies published in the January *American Journal of Psychiatry* do just that.

The first investigation found that Swedish youngsters exposed to viral infections of the central nervous system by age 12 displayed elevated rates of psychotic illnesses, including schizophrenia, by ages 17 to 29. Infections with mumps virus or cytomegalovirus showed especially strong links to later psychotic conditions, according to a team led by psychiatrist Christina Dalman of the Karolinska Institute in Stockholm.

Dalman and her coworkers studied a national sample of 1.2 million Swedes born between 1973 and 1985. Government registries recorded their childhood hospitalizations for viral and bacterial infections as well as for psychiatric hospitalizations through 2002 for various mental ailments.

The researchers calculated a slightly increased risk of developing schizophrenia or any of several other psychotic illnesses among individuals who had been treated for viral infections that invade the central nervous system. This finding held after accounting for other factors that raise the chances of developing a psychotic disorder, such as living in a city and having a psychotic parent.

Further analysis revealed that childhood infection with mumps virus roughly doubled the risk for later hospitalization for psychosis. Cytomegalovirus had an even

greater effect. Previous evidence indicates that both viruses infect brain cells.

Even in such a large sample, only 23 individuals exposed to childhood viral infections of the central nervous system displayed a psychotic illness later in life. Further studies need to examine how viral infections interact with an individual's genetic makeup to promote psychosis, the researchers say.

The second study suggests that infection with the common parasite *Toxoplasma gondii*, carried by cats and farm animals, also boosts a person's risk of developing schizophrenia.

A team led by epidemiologist David W. Niebuhr of Walter Reed Army Institute of Research in Silver Spring, Md., studied 180 U.S. military personnel discharged because of schizophrenia. For each participant, the researchers analyzed archived blood samples collected before and after physicians diagnosed the severe mental disorder. Niebuhr's group looked for elevated levels of antibodies that fight toxoplasma infection.

The scientists similarly scrutinized blood collected from 532 military recruits with no psychiatric ailments.

Of those who developed schizophrenia, 7 percent had been infected with the parasite before their diagnosis. Toxoplasma infections affected 5 percent of healthy individuals.

Although that difference appears small, people exposed to toxoplasma experienced a 24 percent greater chance of developing schizophrenia than did those who avoided such infection, the researchers say.

Previous research had identified toxoplasma infections in some people with schizophrenia but hadn't shown that the infection preceded the mental disorder.

Niebuhr's team stresses that the parasite may foster schizophrenia only in those genetically predisposed to this mental disorder. Most people infected with toxoplasma never develop schizophrenia.

"Taken together, these two articles provide further evidence that certain infections during childhood and adulthood might be risk factors for schizophrenia," remarks psychiatrist Alan S. Brown of Columbia University. —BRUCE BOWER

QUOTE

"Certain infections during childhood and adulthood might be risk factors for schizophrenia."
ALAN S. BROWN, COLUMBIA UNIV.

Bad berries

A parasitic worm transforms ants into walking tropical berries, new research suggests. The abdomens of infected gliding ants bulge with hundreds of microscopic nematode eggs, while the color turns from black to maroon. Afflicted ants also show off their bloated abdomens far more often than uninfected ants. With luck, a hungry bird will mistake the ant for a fruity meal, spreading the parasites—but sacrificing the unwitting ant. A team led by entomologist Steve Yanoviak of the University of Arkansas in Little Rock has shown that the nematode eggs emerge healthy from the bird droppings. Uninfected worker ants may collect the droppings, starting the cycle anew, Yanoviak's team reports in the April *American Naturalist*. —EWEN CALLAWAY

Bariatric Reversal

Stomach surgery curbs some patients' diabetes

In obese people with diabetes, stomach surgery to control hunger may do more than induce weight loss. A study now finds it can send their diabetes into remission.

Australian researchers enlisted 60 obese people diagnosed in the previous 2 years with mild type 2, or adult-onset, diabetes. Only one study participant needed insulin. The researchers randomly assigned some participants to receive bariatric surgery along with any necessary diabetes drugs. Others got medication alone. Two years later, 22 of the 30 patients who underwent the operation showed no signs of diabetes and didn't need diabetes drugs, compared with only 4 of the 30 assigned to medication alone, the researchers report in the Jan. 23 *Journal of the American Medical Association*.

"This is a real landmark study," says surgeon Philip Schauer of the Cleveland Clinic. It's the first scientifically rigorous trial to show that surgery can treat type 2 diabetes, he says.

Patients getting surgery lost an average of 20 percent of their body weight, while those getting only medication lost less than 2 percent, says study coauthor John B. Dixon, a physician at Monash University in Melbourne. The dramatic weight loss led to better control of blood glucose levels, he says.

Many obese people aren't eligible for bariatric surgery, despite its solid record of inducing weight loss. In 1991, the National Institutes of Health established that anyone with a body mass index (BMI) of 40 or more would qualify for bariatric surgery, as would those with a BMI of at least 35 if they also had a related health condition such as diabetes. People with a BMI over 25 are considered overweight and, if over 30, obese.

BMIs of participants in the new study ranged from 30 to 40. The results suggest that people with diabetes in the 30–35 BMI range would benefit from the surgery, says Schauer.

The researchers used gastric banding, in which surgeons perform minimally invasive surgery to bind the upper part of a patient's stomach like an hourglass. The other main bariatric surgery, gastric bypass, is a more invasive operation that reconfigures the anatomy to shunt food from the stomach to the small intestine.

While both procedures curb appetite, bypass surgery also induces the intestines to make more GLP-1, a hormone that stimulates insulin secretion and regulates blood glucose. Bypass surgery might reverse diabetes even better than banding, Dixon says.

Earlier studies have hinted that, in obese people, type 2 diabetes that has gone on more than 5 years is unlikely to be reversible, even with surgery, says Jaime Ponce, a surgeon at the Hamilton Medical Center in Dalton, Ga. By that time, the pancreas' insulin-making cells are too damaged. This study supports the notion that there is a window of time, probably less than 5 years, when surgery can reverse diabetes, Ponce says. —NATHAN SEPPA

YANOVIAK

Unlock the Science of Heredity … Genetics

Our 24-lecture Course Reveals How Genetic Tools Work in Today's—and Tomorrow's—World.

We use it routinely to cure diseases, solve crimes, and reunite families. Yet we've known about it for only 60 years. And what we are continuing to learn about it has the potential to transform our health, our nutrition, our society, and our future. What is this powerful discovery?

It is DNA—deoxyribonucleic acid, the self-replicating material present in nearly all living organisms. Award-winning teacher, author, working scientist, and oncologist Dr. David Sadava unlocks its mysteries in his new course, **Understanding Genetics: DNA, Genes, and Their Real-World Applications**. He guides us through decades of scientific discovery, and the weighty implications for us, as individuals and as a society.

Genetics, the Science of Heredity

How are the traits of an organism—be it a fern or a human father—passed on to its offspring? This course outlines the history of the science of genetics and explains in detail what we have learned in recent decades about the building blocks—DNA. Dr. Sadava, a working scientist who draws on examples from his own research, discusses the early history of genetics, the exploration and isolation of DNA, and the uses of DNA in biotechnology.

Insight into an Amazing Puzzle

Understanding genetics is like sitting down to work a massive puzzle. With each piece you examine, think through, and solve, you glean a new and amazing insight into humanity. Put several pieces together and you can treat or cure a disease, catch a criminal, or reunite a family. DNA, genes, proteins, amino acids, and enzymes are the vocabulary of our being—they explain what goes on inside our bodies and our genes.

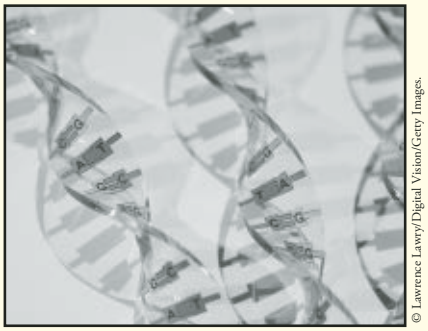
Understanding genetics can provide everyone with a wealth of information that can help improve the health and quality of our lives.

About Your Professor

Dr. David Sadava is the Pritzker Family Foundation Professor of Biology at Claremont McKenna, Pitzer, and Scripps, where he has twice won the Huntoon Award for Superior Teaching. A Woodrow Wilson Fellow, he received a Ph.D. in Biology from the University of California, San Diego. A visiting scientist in oncology at the City of Hope Medical Center, Dr. Sadava has written more than 55 peer-reviewed scientific research papers. He is the author or coauthor of five books, including *Plants, Genes, and Crop Biotechnology* and the leading biology textbook, *Life: The Science of Biology*.

About Our Sale Price Policy

Why is the sale price for this course so much lower than its standard price? Every course we make goes on sale at least once a year. Producing large quantities of only the sale courses keeps costs down and allows us to pass the savings on to you. This also enables us to fill your order immediately: 99% of all orders placed by 2 pm eastern time ship that same day. Order before February 12, 2008, to receive these savings.



© Lawrence Lawry/Digital Vision/Getty Images.

DNA contains the instructions for building organisms.

About The Teaching Company®

We review hundreds of top-rated professors from America's best colleges and universities each year. From this extraordinary group we choose only those rated highest by panels of our customers. Fewer than 10% of these world-class scholar-teachers are selected to make The Great Courses.®

We've been doing this since 1990, producing more than 3,000 hours of material in modern and ancient history, philosophy, literature, fine arts, the sciences, and mathematics for intelligent, engaged, adult lifelong learners. If a course is ever less than completely satisfying, you may exchange it for another, or we will refund your money promptly.

Lecture Titles

1. Our Inheritance
2. Mendel and Genes
3 Genes and Chromosomes
4. The Search for the Gene—DNA
5. DNA Structure and Replication
6. DNA Expression in Proteins
7. Genes, Enzymes, and Metabolism
8. From DNA to Protein
9. Genomes
10. Manipulating Genes—Recombinant DNA
11. Isolating Genes and DNA
12. Biotechnology—Genetic Engineering
13. Biotechnology and the Environment
14. Manipulating DNA by PCR and Other Methods
15. DNA in Identification—Forensics
16. DNA and Evolution
17. DNA and Human Evolution
18. Molecular Medicine—Genetic Screening
19. Molecular Medicine—The Immune System
20. Molecular Medicine—Cancer
21. Molecular Medicine—Gene Therapy
22. Molecular Medicine—Cloning and Stem Cells
23. Genetics and Agriculture
24. Biotechnology and Agriculture

THE TEACHING COMPANY®
The Joy of Lifelong Learning Every Day™
GREAT PROFESSORS, GREAT COURSES, GREAT VALUE GUARANTEED.™

SAVE UP TO $185!
OFFER GOOD UNTIL FEBRUARY 12, 2008

1-800-TEACH-12 (1-800-832-2412)
Fax: 703-378-3819

Special offer is available online at
www.TEACH12.com/8sn

The Great Courses
THE TEACHING COMPANY
4151 Lafayette Center Drive, Suite 100
Chantilly, VA 20151-1232

Priority Code 26809

Please send me **Understanding Genetics: DNA, Genes, and Their Real-World Applications**, which consists of twenty-four 30-minute lectures plus Course Guidebooks.

- ☐ **DVD $69.95** (std. price $254.95) **SAVE $185!** plus $10 shipping, processing, and Lifetime Satisfaction Guarantee.
- ☐ **Audio CD $49.95** (std. price $179.95) **SAVE $130!** plus $10 shipping, processing, and Lifetime Satisfaction Guarantee.
- ☐ **Audiotape $34.95** (std. price $129.95) **SAVE $95!** plus $10 shipping, processing, and Lifetime Satisfaction Guarantee.
- ☐ **Check or Money Order Enclosed**

* Non-U.S. Orders: Additional shipping charges apply. For more details, call us or visit the FAQ page on our website.
** Virginia residents please add 5% sales tax.

Charge my credit card:

☐ VISA ☐ MasterCard ☐ Discover ☐ American Express

ACCOUNT NUMBER EXP. DATE

SIGNATURE

NAME (PLEASE PRINT)

MAILING ADDRESS

CITY/STATE/ZIP

PHONE *(If we have questions regarding your order—required for international orders)*

☐ **FREE CATALOG.** Please send me a free copy of your current catalog (no purchase necessary).

Special offer is available online at www.TEACH12.com/8sn
Offer Good Through: February 12, 2008

LIFE IN PRINT

Cell by cell, ink-jet printing builds living tissues

BY SARAH WEBB

Almost as soon as ink-jet printers hit the market in the 1980s, materials researchers realized that the machines could be used to deposit droplets of substances other than ink. In principle, anything that could squeeze through the printhead—including plastics, silicon, or dissolved metals—could be laid out in some precise pattern. And when printed in layers to create three-dimensional structures, such "inks" could allow the rapid design and even production of plastic or electronic parts for a variety of devices (*SN: 3/27/04, p. 196*).

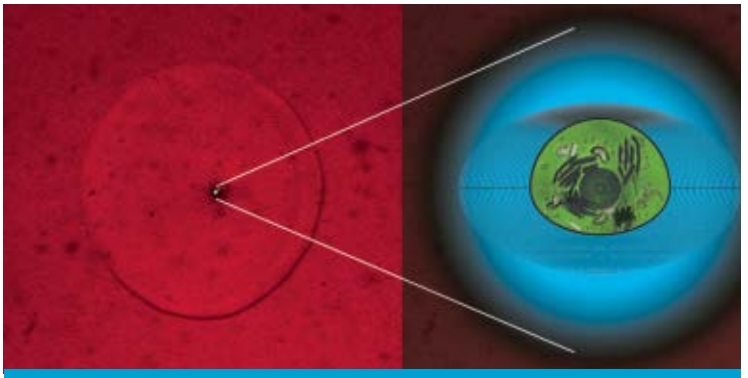
If ink-jet technology could work for printing plastic and electronic components, researchers suggested, it could also work for custom designing structures built with living cells.

"One of our goals, in a sense, always was to build a mechanical rat—if we can have moving parts, structural parts, and electrical parts all in one unit, then it's kind of like an animal," says Paul Calvert of the University of Massachusetts Dartmouth. "If I can build a mechanical rat, then maybe I could build a real rat."

Ink-jet printers won't start out by mass-producing living rats, though. Instead, researchers are setting their sights on producing skin, heart-muscle patches, and perhaps even organs.

Although researchers can create intricate structures with ink-jet printing, organs built in this way might not perform perfectly, because engineered tissues do not go through a natural development process, says Thomas Boland of Clemson University in South Carolina. Natural tissues follow a bottom-up design, developing through the growth and differentiation of various progenitor cells. Engineered tissues instead conform to a top-down design template, based on what a final tissue should look like. Though the designs provide an overall structure, researchers rely on the cells' biology to fill in that template and signal to each other to produce an organized tissue.

Even though ink-jet–printed tissues might not have the same properties as their natural counterparts, such structures could prove useful in medicine and even in novel devices. Ink-jet tissues could provide new cell-based materials for drug testing, new ways to probe cellular communication, living sensors, or even fuel cell–type batteries.



CELLS TAKE THE LEAD — Adding a synthetic scaffolding—a glassy mix of silica and lipids (left, red)—to printed cells prompted cells to reorganize nearby molecules, creating a protective liquid layer (blue) around each cell (green), as shown in this illustration (right).

BRINKER

PRINTING CELLS Most inexpensive home printers signal a tiny nozzle to heat the ink just enough to build up pressure so that it releases a droplet that falls onto the page. More expensive industrial printers deposit an ink droplet when a piezoelectric crystal within the nozzle vibrates in response to an electric current. Because of the sensitivity of cells to heat, electricity, and other stresses, it might seem that cells couldn't survive such arduous treatment.

In fact, experiments show that at least 90 percent of cells can survive the printing process and remain viable. Boland and his colleagues have used modified thermal ink-jet printers to print mammalian cells, including human neurons and cardiac cells, onto biopaper, a hydrated gel surface made of collagen. Other groups, including Brian Derby's at the University of Manchester in the United Kingdom, use piezoelectric printers. Derby and his colleague, cell biologist Julie Gough, recently demonstrated survival rates of 95 percent or better when they printed human fibroblasts.

Such systems allow researchers to place cells individually and precisely. For example, Derby's ink drops are 10 to 50 micrometers (μm) across and have a volume of roughly 10 picoliters, or one 100-billionth of a liter. With cells measuring approximately 8 to 10μm across, each drop probably contains one cell on average, he says. Simple modifications can tweak a conventional office printer to print those individual cells in layers, one on top of another, to produce 3-D structures, Boland says.

Arranging cells in three dimensions is only the first step, however. Such structures need materials around the cells that will support and sustain them, and a major challenge is producing inks with the appropriate properties for building robust 3-D structures. These inks, separate from the ones that deposit cells, have to be liquid within the printer but then solidify once they're released in drops from the printer. They also need to mimic the natural rigidity and flexibility of tissues. Researchers are investigating materials that are compatible with the cells and that switch their properties depending on temperature or some other controllable factor. To boost cell survival in the scaffolds, they may need additional proteins such as growth factors and agents that prompt cells to specialize. "We still have a long way to go to opti-

mize the ink for these materials," Boland says. Several groups are teaming with printer manufacturers to develop printers tailored to cell-based applications.

CELLULAR COMMUNICATION Although cells suspended in a medium can move through a printer just like any other ink, introducing a living ingredient produces a dynamic material. The cells respond to each other as well as to chemicals included in the printing mixture to influence cell behavior. Chemical signals between cells are critical for organizing and maintaining complex tissues, but researchers know relatively little about how extracellular signals work together. Scientists understand how certain signals lead cells to grow, divide, and produce the complex patterns within living tissues, Calvert says, but they don't know "how this allows different cell types to wind up in the right structure."

Continuing studies with cell printing will help researchers understand the chemical signals that enable different cells to work together to build a functioning tissue. "We're building sandwiches, putting down a layer of cells, then a separator, and another layer of cells," Calvert says. By examining how the second layer of cells responds to the first and by analyzing the molecular signals between them, biologists may be able to track how cells move and change in response to other cells, and isolate the signals responsible for particular cellular behaviors.

Ink-jet printers can also build test systems to study chemicals involved in stem cell differentiation. Researchers at Carnegie Mellon University in Pittsburgh and at the University of Pittsburgh printed gridlike patterns of an ink containing a bone-differentiation factor. When they later added muscle-derived stem cells to the surface, bone cells developed only in the squares with the bone-differentiating factor. Cells in other areas developed into musclelike tissue. "We're trying to understand the basic biology," says Julie Phillippi of the University of Pittsburgh, "before we can translate it into a therapy."

Cells can do more than simply respond to chemicals in their environment; sometimes they can help their scaffolding structures organize around them. In their effort to build sensing devices, C. Jeffrey Brinker and his colleagues at Sandia National Laboratories and the University of New Mexico in Albuquerque have used methods that include ink-jet printing to build silica-based structures incorporating molecules such as lipids that contain both water-attracting and water-repelling portions. Such molecules create a defined nanoscale structure within the glassy material. When the printer deposited yeast or bacterial cells onto these silica-lipid structures, "the cell kind of co-opted the system," Brinker says. "It intervened in the self-assembly process and created a rather unique interface between itself and the silica matrix." Each cell organized the lipid molecules in its immediate vicinity so as to create and maintain a less acidic environment within a few micrometers of the cell wall.

"The feature that we like about our process is that the [silica-lipid] matrix develops in a 3-D sense around the cell," Brinker says. Altering the components within their glassy material gives the cells within the system tools to organize different structures with potentially new characteristics. Although Brinker still doesn't completely understand how the cell reorganizes the matrix components, he and his colleagues are extending their experiments to include more-delicate mammalian cells within their synthetic scaffold.

Synthetic structures seeded with cells could serve as the foundation of "living" devices such as cell-driven batteries or sensors to test how particular cell types react when they encounter a toxic substance. Ink-jet–printed tissues are likely to serve a similar role as test materials for drugs or other substances long before they make it to the clinic as replacement tissues, say Boland and Calvert.

QUICK DROPS — A stroboscopic photo follows the path of a single drop from the nozzle of an ink-jet printer. The drops, formed at high acoustic frequencies, travel at accelerations of up to 1,000 G. Research shows that most cells survive this speedy delivery.

DARBY

BUILDING VESSELS As researchers strive to print thicker and more-complex tissues with an ink-jet, they will have to solve a fundamental plumbing problem. Unlike layers of plastic, silicon, or metal assembled to form a synthetic device, cells located away from a tissue surface cannot survive without nutrients. In natural tissues, cells are no more than 100μm from a capillary that supplies oxygen and nutrients, says Derby. Diffusion allows those chemicals to travel up to a millimeter at most. "We're limited in thickness until we can build a plumbing system in there," Derby says. Building structures that mimic natural blood vessels will involve printing a variety of cell types in cylindrical forms, with both the sturdiness and flexibility to deliver blood or other liquid nutrients.

Building vessel-like structures has been tougher than anticipated, Boland says. One option for building an isolated blood vessel is to print a two-dimensional sheet of cells and then roll it into a tube. But printing blood vessels within complex tissue is a resolution problem, comparable to that of printing a high-resolution photograph, in which very small ink dots in four colors sit adjacent to each other to produce a crisp image with millions of colors. Print the dots too close together, and they will smudge and create a blurred picture. Similarly, creating complex structures with cells requires printing different cell types close together but also in such a way that they form discrete functional structures.

To construct integrated blood vessels, Boland and his colleagues first built a foundation layer containing protein. Then they print a mixture of cross-linking chemicals and blood vessel–forming cells that form pores as the drops strike and cause the surface to set. If researchers print these drops fast enough and close enough together, the pores can coalesce to form channels and trap the cells inside, Boland says. Those trapped cells then divide and form vessels within the channel structures. This ability to place cells precisely and to separate different cell types will be important for building and studying 3-D cell culture and even for building organs, he adds.

But researchers don't have all the plumbing built yet to connect these vessels to larger ones. "We've done some functional studies, but the [printed] vessels are so small that it's impossible to connect them into a blood vessel," Boland says. The engineered blood vessels are 30μm or less across—so small that a surgeon couldn't link them to living vessels in a patient. "We're confident that we'll get there," Boland says. "At that point we'll hook it up to either to an animal or in vitro to media or blood through a pump."

Because of the complexity of building multicellular structures and blood vessels, some researchers are aiming to assemble tissue structures by starting with larger, prefabricated chunks of tissues called bio-ink particles. The larger pieces of tissue don't require the scaffolding materials needed for traditional tissue engineering or for ink-jet strategies that print single cells, says Gabor Forgacs of the University of Missouri at Columbia.

Forgacs and his colleagues are using this strategy to build blood vessels that contain three basic types of cells: endothelial cells, which line the vessel; smooth muscle cells, which give elasticity; and fibroblasts, which produce chemicals outside the cell that give vessels their sturdiness. First, researchers culture the different cell types and then combine them to make the individual bio-ink particles, up to 500μm across.

The researchers use a micropipette system similar to an ink-jet

(continued on page 60)

SUPERCOOL, AND STRANGE

Scientists are finding clues about why water is so utterly weird

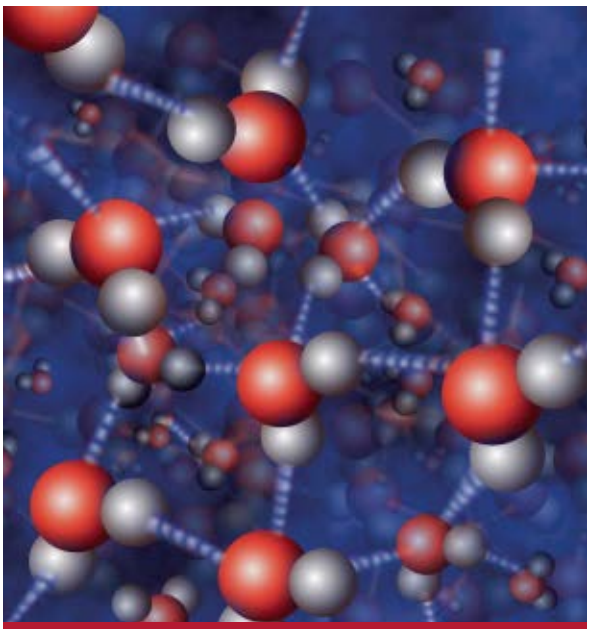
BY SUSAN GAIDOS

You wouldn't expect to learn much about the properties of water by watching a square dance. But think again. Following the caller's lead, the dancers meet, separate, weave, and swing in a perfectly fluid manner.

It turns out that similar coordinated maneuvers—with water molecules taking the places of the dancers—may be responsible for some of water's most puzzling features, an array of recent research findings suggest.

As liquids go, water is a radical nonconformist—differing from other liquids in dozens of ways (see the latest count at *www.lsbu.ac.uk/water/anmlies*). Most famous among water's peculiarities is its density at low temperatures. While other liquids contract and get denser as they cool toward their freezing points, water stops contracting and starts to expand. That's why ice floats and frozen pipes burst.

Water gets even weirder at colder temperatures, where it can exist as a liquid in a supercooled state well below its ordinary freezing point. Recent evidence suggests that supercooled water splits its personality into two distinct phases—another oddity unseen in other liquids. And last year, water surprised scientists yet again, when they found that at –63 degrees Celsius, supercooled water's weird behavior returns to "normal."



FORCES OF ATTRACTION — Water molecules are held together in a flexible, but stable network of hydrogen bonds. The bonds, though weak, help keep water liquid over a wider temperature range than one would expect for molecules of its size.

That discovery, scientists say, may help explain some aspects of water's peculiar personality, such as its ability to transition from gas to liquid to solid and back to liquid again. Findings from related experiments have important implications for understanding how water interacts with biological molecules, such as proteins, and may lead to better ways of freezing and storing biological tissues such as sperm and human oocytes.

PLUNGING AHEAD Water's ability to exist in a liquid state well below its freezing point has been studied for centuries. What's new, scientists say, is growing evidence about what happens to water at superlow temperatures. Under these extraordinary conditions, there is not just one kind of water, but two.

This two-phase phenomenon was first predicted in 1992 by physicist H. Eugene Stanley of Boston University and his graduate student Peter Poole, now at St. Francis Xavier University in Antigonish, Nova Scotia. Using computer simulations to study the behavior of liquid water at very low temperatures, the scientists suggested that water could exist as either a high-density liquid or as a low-density liquid.

Stanley and Poole also proposed that the dividing line between these two liquid forms might end in a "critical point," where the two liquids would become indistinguishable, changing from one form to the other.

In a series of experiments in recent years, scientists have begun to close in on this critical point. These advances offer a glimpse of possible explanations for water's unusual behaviors, and suggest that Stanley and Poole may have been on to something.

MOLECULAR DANCE Some of water's odd properties have traditionally been explained as consequences of the hydrogen bonds that form between water molecules (and sometimes other molecules). Each V-shaped molecule of water contains one oxygen atom centered between two hydrogen atoms. The chemical bonds holding the molecule together create a slightly negative charge on the oxygen atom and a small positive charge on each of the hydrogen atoms.

These unequal charges make water molecules extremely "sociable"—eager to bond with each other. Because hydrogen bonds are much weaker than normal chemical bonds, the water molecules move about freely, binding briefly with adjacent molecules before moving on to others. Stanley likens this fast-paced network to a square dance taking place in a large dance hall.

"In square dancing, you're always releasing one partner and grabbing another, and that is a hydrogen bond network, exactly," he says.

In the case of water, the square dance occurs among molecules that have four arms, instead of two. That's because each water molecule has the potential to form four hydrogen bonds. The result is a network of tetrahedrons, or pyramids with a triangular base.

This tetrahedral arrangement creates a peculiar tension, permitting structural changes in response to different temperatures and pressures. In liquid form, the tetrahedral structures allow unrestrained hydrogen bonding to occur as numerous molecules pack into and around the tetrahedron. (Imagine a swift square dance with dancers moving in and out of the center of the square

NICOLLE RAGER FULLER

and circling around it as well.) The result is a dense, fluid structure, such as that of everyday tap water.

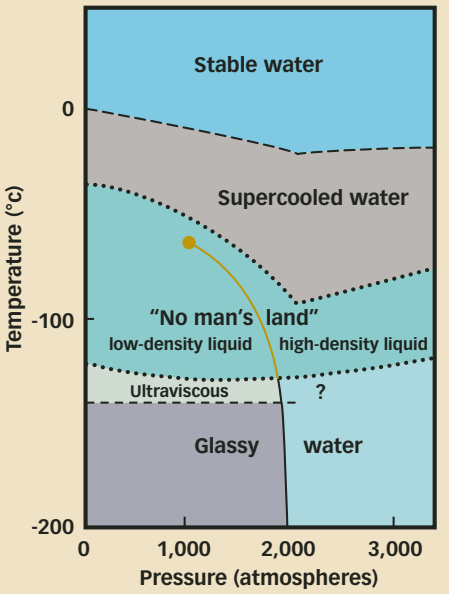
As water approaches its freezing point (0°C), however, the tetrahedral structure becomes more open and begins to expand. Ordinary water reaches its maximum density at 4°C. As water continues to cool, falling to its freezing point and below, it continues to expand.

Here, the tetrahedral arrangement is more rigidly enforced, with molecules spaced an "arm's length" apart. The arrangement creates a more spacious, open structure, and water becomes lighter. If ice weren't lighter than cold water, ponds and lakes would freeze from the bottom, rather than form a floating layer of surface ice, and water would cease flowing in the dead of winter. Water's weirdness therefore allows fish to swim in the water beneath the ice and plants to survive the winter cold.

At temperatures below the freezing point, ice crystals form around defects, such as cracks or dust particles. By using extremely clean water samples—free from any such defects—scientists have found ways to defy freezing and obtain supercooled liquid—water that remains liquid below 0°C.

This procedure works only to a certain point. At extremely cold temperatures, (–38°C and lower), it is nearly impossible to keep water from freezing. But under certain conditions, such as the ultrahigh pressures found deep undersea, water can remain liquid even at such low temperatures. Scientists have been unable to make water that cold in the laboratory, though, and so what Stanley calls a "no man's land" of conditions had been explored only in computer simulations.

But now, using a clever technique to confine water samples in nanoscopic pores, scientists are beginning to explore the structure and properties of deeply supercooled water.



MULTIPLE PERSONALITIES — Waters many forms, or phases, change with shifts in temperature and pressure. Below –38°C, at high enough pressures (a region researchers call "no man's land"), water may remain liquid. The precise locations of the phase boundaries are uncertain, but those shown here are supported by computer simulations.

TERMS OF CONFINEMENT As even a square-dancing novice knows, you can't hold a hoedown in a cramped, narrow hallway. Water's hydrogen-bonding network is a fast-moving, gregarious one. Cramming water molecules into a tiny space, with a diameter less than five water molecules wide, brings the molecular square dance to a standstill.

"If a room were very, very narrow, it would be hard to have a normal square dance because a lot of people would be up against the wall and there would be no partner to grab on to," Stanley says. "In a similar fashion, water molecules that are confined against a wall have only two or three arms, and the whole hydrogen-bond network is disrupted."

Because the hydrogen-bond network brings stability to water, the breakdown of this network changes water's properties, allowing it to remain liquid at a much lower temperature, he says.

Scientists began exploring ways to nanoconfine water molecules more than a decade ago, using a spongelike material that had holes of different sizes. While the experiments showed that nanoconfinement could be used to cool water well below its usual freezing temperature, the results were often hard to interpret because water in the larger holes would freeze, causing crystallization throughout the material.

In 2005, Sow-Hsin Chen of the Massachusetts Institute of Technology and his colleagues found a way to get around this problem, using a new material called MCM-41. Chung-Yuan Mou of National Taiwan University of Taipei had created MCM-41 by refining the fabrication of silica-nanotube assemblies. The material resembles a microscopic beehive with a hexagonal array of holes, all uniformly sized, just a few nanometers wide.

Curious to see how confined water might respond in MCM-41, Chen filled the hexagonal arrays with water. He then cooled the water to –73°C and bombarded the arrangement with neutrons. The microscopic cells of MCM-41 not only prevented ice crystals from forming but also allowed the scientists to probe water's molecular structure.

Building on this work, Chen and colleagues conducted a series of experiments to see how water's properties change as temperature drops at ordinary pressures.

In 2006, Chen showed that, when cooled below 225 kelvins (or –48°C), water's hydrogen-bonding structure undergoes a phase transition, changing from a disordered, fluid state to a more ordered, rigid state. Furthermore, this line of transition between a high-density liquid and low-density liquid, called the Widom line, occurred in a continuous fashion, as predicted by Stanley and Poole in 1992. This transition, called a fragile-to-strong dynamic crossover, helped explain why, at superlow temperatures, proteins and other biological molecules exist in a glassy state, losing all flexibility and biological function.

"This dynamical transition of protein at 225 K is triggered by its association with the hydration water, which shows a similar dynamic transition at that temperature," Chen says.

In addition, the study showed that water's phase change at 225 K—moving from a disordered state to a more ordered state—violates a well-known formula called the Stokes-Einstein relation. This formula, based on a picture of a disordered, fluid state, ties together liquid properties such as diffusion, viscosity, and temperature, and generally works for normal- and high-temperature liquids.

Because this formula breaks down in subzero conditions, the experiment suggests that supercooled water may be a mix of two liquid phases, rather than a single liquid. Chen's study, published in the *Proceedings of the National Academy of Sciences* (*PNAS*), provided the first experimental evidence of such "liquid polymorphism" and received the journal's 2006 prize for best paper.

Last year, Chen and his colleagues surprised the scientific community, and themselves, when they discovered that under supercold conditions, liquid water again begins to expand, returning to normal behavior. Using a neutron-scattering method and analysis to measure the density of subzero liquid water, they showed that water reaches a minimum density at 210 K, or –63°C.

In doing the experiments, the scientists used heavy water, or D_2O, because of its neutron-scattering properties. They then repeated the experiments using regular water and two light-scattering techniques and came up with the same results. The findings were reported last June in *PNAS*.

Though this kind of behavior had been predicted in computer simulations, it had never been observed. The findings add to the long list of experimental anomalies associated with supercooled water, and provide the strongest experimental evidence yet for a second "critical point" in liquid water, Chen says.

A critical point defines the set of pressures and temperatures

E. ROELL/S. NORCROSS

at which a liquid changes from one form to the other. "It would be hard to explain a density minimum unless there was a second critical point," he says.

JUST A PHASE Water already has one well-known critical point at 647 K, or 374°C, where, under ordinary pressures, the liquid and gas phases become identical.

"As water approaches this critical point, the difference between water and steam grows increasingly smaller," Stanley explains. "At the critical point, there is nothing distinguishing water from steam, there is just one, homogeneous fluid."

More important, he says, a critical point serves as a "tipping point," where water can exist in either of two states, and minor fluctuations can tip the balance in one direction or the other.

The hypersensitivity created by a critical point can have far-reaching effects upon a system, says Stanley. In predicting a critical point in supercooled water, he and Poole theorized that water's crazy low-temperature behavior might account for some of its unusual properties even at ordinary temperatures.

That's because changes at a critical point don't occur abruptly, Stanley says. The huge changes seen near the water-gas peak, for example, are often, if not always, foreshadowed by fluctuations over a large range of temperatures and pressures.

"It's like looking at the highest peak on a mountain range," Stanley says, gesturing toward a picture of Mount Everest in his office. "The critical point, or summit, doesn't rise out of nowhere, but rises in a gradual manner and distorts the terrain all around it."

That means that a critical point at −63°C might account for water's bizarre behavior at much higher temperatures, such as its ability to expand as it cools.

Though findings from recent studies point to the predicted second critical point, it is still too soon to know whether such a point exists for sure. Further evidence is needed.

This year, Chen and his group will seek some of that evidence by performing another, more far-reaching set of experiments on supercooled water in MCM-41. Using a specially designed pressure cell for low temperatures, the scientists will analyze changes in liquid water as it moves from its maximum density point at 4°C to its minimum density at −63°C and beyond under various pressures. By studying how density changes with temperature and pressure, the researchers hope to locate the liquid-liquid critical point precisely.

"The critical point is at a high pressure, and no one knows exactly what it is, but we believe it's probably above 1,000 atmospheres," Stanley says.

Other scientists are raising questions about the extent to which supercooled water in confined volumes, no matter what the pressure, actually behaves like cold, bulk water.

"When you put water into confinement, it changes the way in which water molecules are arranged with respect to each other," says C. Austen Angell, a chemist at Arizona State University in Tempe, who studies liquid phases in supercooled water. "The question is, how much does it change it?"

Angell notes that despite recent progress, much remains uncertain and many of the explanations are built on simulations that can give different results, depending on the model and tools used in the study.

"There are other possibilities, related to the second critical point scenario, in which the low-pressure supercooling of uncrystallized bulk water is terminated by a first-order [sharp] transition to a second 'low-density' liquid phase," he says. Angell's take on supercooled water will appear in an upcoming issue of *Science*.

COLD, HARD FACTS Confirming the predicted second critical point could have an impact beyond the study of water's molecular mysteries for their own sake.

Biologists, for example, are looking at how this transition in liquid states, and the accompanying rigidity it brings, affects living structures such as proteins and DNA.

Other practical benefits could flow from the new water knowledge. For example, scientists at Cornell University have found that high-pressure cooling of protein crystals causes them to diffract better than they would if flash frozen, and has allowed scientists to improve methods for crystallizing and studying proteins and other biological tissues.

The scientists are now pursuing ways to use high-pressure techniques to improve methods for freezing sperm and human oocytes. The studies may lead to better ways of freezing and storing sperm for livestock production and allow women to freeze their eggs and use them at a later time to conceive a child.

> "When you put water into confinement, it changes the way water molecules are arranged."
>
> — C. AUSTEN ANGELL, ARIZONA STATE UNIVERSITY

The studies may also help explain some more ordinary, everyday occurrences related to water's mysterious behavior. Chen recalls hiking in New Hampshire's White Mountains, a site known for its frigid temperatures and long months of ice, and noticing that the trees stopped abruptly at 4,400 feet, nearly 2,000 feet below the summit of Mount Washington. Soon after he published his findings on a minimum density, he received a phone call from a Canadian biologist who was interested in the work.

"It turns out that this tree line stops where the windchill temperatures reach 220 degrees K," Chen says, noting that this is the temperature at which water's hydrogen-bonding structure undergoes a phase transition, changing from a fluid state to a more rigid state.

At this point water becomes very, very slow, and no longer supports biological functions. Or, to put it another way, the square dance of water comes to an end. ■

Susan Gaidos is a freelance writer in Maine.

(continued from page 57)

to place the bio-ink particles like blocks to build up sheetlike or cylindrical structures similar to blood vessels.

Pumping cell-culture media through the cylindrical structure as blood would flow through a vessel cues the cells to move to their appropriate locations. Endothelial cells migrate to the inner surface of the vessel, muscle cells to the middle, and fibroblasts to the outer layer. "We control the deposition of bio-ink particles. We control the composition of bio-ink particles, but that's basically it," Forgacs says. "After that, nature takes over and completes the job."

Though the principles look promising for building blood vessel-like structures and other tubular tissues such as the gut, the scientists are still testing how such tissues would perform under physical stresses comparable to those within a living organism. Using bio-ink particles composed of heart cells from chickens and endothelial cells from human blood vessels, Forgacs and his colleagues have created tissuelike structures that beat, they report in an upcoming *Tissue Engineering*. The tissues included structures that resembled blood vessels in an early stage of development.

TISSUE REPLACEMENTS Though confident that they will eventually figure out how to circulate nutrients within thicker tissues, researchers say that complex replacement organs such as hearts or lungs are decades away. Printed tissues might enter the clinic in the nearer future as patches of heart muscle, for example, that involve a limited number of cell types, Boland says.

Still, researchers are optimistic that ink-jet printing will produce products that will eventually help patients whose organs have failed. "We might be able to print all kinds of organs or invent new organs. They might do a job, but they probably will never replace the original," Boland says. "But they could make a real difference in quality of life" for some patients. ■

Sarah Webb is a freelance writer in New York.

OF NOTE

ZOOLOGY

Fenced-off trees drop their friends

On Kenya's savanna, good fences make bad neighbors. Protecting acacia trees there from giraffes and other browsers sets off a chain reaction that ruins the partnership between trees and their bodyguard ants, says Todd Palmer of the University of Florida in Gainesville.

He first noticed something odd about the protected trees when walking among whistling-thorn acacias cordoned off since 1995. With hole-riddled thorns, the wind whines through these acacias, which are "spindly, knobby trees" at best, Palmer says. Those behind fences looked even worse.

PALMER

BROWSERS Acacias (front) suffer when fenced off from giraffes and other herbivores.

The acacias offer ant amenities: modified thorns for shelter and specialized nectaries for food. "Ants duke it out for host trees," Palmer says. A colony that wins a tree may grow 100,000 strong. When an intruder jostles a branch, the colony boils out to bite and sting unwelcome guests.

Fences undercut that pact, Palmer and his colleagues report in the Jan. 11 *Science*. Trees fenced for a decade skimped on ant-coddling features. Even trees with the best bodyguards, *Crematogaster mimosae*, provided a third fewer nectaries than usual.

In turn, the ants in those miserly trees were sluggish to attack and more likely to cultivate miniherds of scale insects. The scales ooze edible waste products for ants but suck sap from trees. And the prime bodyguard species was more likely to lose out to a nonprotective ant species. Trees that housed uncooperative ants grew more slowly and had greater mortality than trees with better tenants, the researchers conclude. —SUSAN MILIUS

PALEONTOLOGY

Life explodes twice

Ancestors of today's animals can be traced back 540 million years to the relatively sudden appearance of most major animal groups during a time called the Cambrian explosion. Before then, nebulous organisms of no obvious relation to present-day life drifted in primordial seas.

Fossils of animals from the Ediacaran period—just before the Cambrian—look like bloated ferns and deflated balloons. Some paleontologists argue that the Ediacaran biota represent an entire kingdom unrelated to the modern Kingdom Animalia. Yet, the Ediacaran fauna were as varied as all animals in existence today and, more impressively, in the Cambrian, report Bing Shen and colleagues from Virginia Tech University in the Jan. 4 *Science*.

Earlier studies assessed diversity by counting fossil types. The apparent differences between three species of flies and a fly, whale, and mouse species weren't distinguishable by this method. The new study mathematically analyzes differences in body types, regardless of name and rank. By doing so, the paleontologists revealed an unexpected trend. Rather than a steady increase in the range of body types as the period progressed, the paleontologists noticed an initial burst of variation that plateaued until fizzling out by the Cambrian.

Finding a trend that mirrors that of the Cambrian, in an independent group of organisms, gives scientists another reason to believe that macroevolution proceeds in spurts rather than only by gradual change. —AMY MAXMEN

BEHAVIOR

Antidepressants get overly positive spin

Here's some depressing news about antidepressant drugs. Studies that find beneficial effects of antidepressants for depressed patients get published far more readily than do studies that report no such gains, say psychiatrist Erick H. Turner of the Veterans Affairs Medical Center in Portland, Ore., and his colleagues.

Moreover, published versions of studies that failed to show antidepressant advantages over placebo pills often cast the results in an unduly positive way, Turner's team reports in the Jan. 11 *New England Journal of Medicine*.

The scientists obtained reviews conducted at the Food and Drug Administration for 74 clinical trials, covering a total of 12,564 depressed patients who received any of 12 antidepressant drugs.

Of the 74 trials, the FDA deemed 38 to have shown improvement on antidepressants, according to the researchers. All but one of those trials appeared in print. Another 24 trials found no antidepressant benefits, federal officials concluded, while the remaining 12 achieved mixed results. Of those 36 studies, only 14 were published, and in 11 cases, journal articles put a largely positive spin on the findings, Turner says.

The totality of evidence shows that each antidepressant alleviates depression better than placebos do, Turner notes. However, selective publication of positive results inflates this antidepressant advantage, in his view. —BRUCE BOWER

BEHAVIOR

9/11 attacks stoked U.S. heart ailments

The terrorist attacks of Sept. 11, 2001, had a heartfelt impact on certain U.S. residents. Those who experienced serious stress-related reactions in the weeks after 9/11 developed more heart and blood vessel ailments than their less-stressed counterparts did, reports a team led by nursing researcher F. Alison Holman of the University of California, Irvine.

A nationally representative sample of 2,592 adults completed a health survey during the summer of 2001 and again within 3 weeks after 9/11. Follow-up surveys assessed physician-diagnosed medical ailments, including heart problems, strokes, and high blood pressure.

Roughly 1 in 5 participants cited severe stress symptoms just after 9/11, including constant rumination about the events, emotional detachment, and loss of concentration. Compared with the majority of study participants, these superstressed individuals—most of whom saw the attacks on television—displayed a 53 percent increase in new cases of heart and blood vessel disorders over the next 3 years, Holman and her colleagues report in the January *Archives of General Psychiatry*.

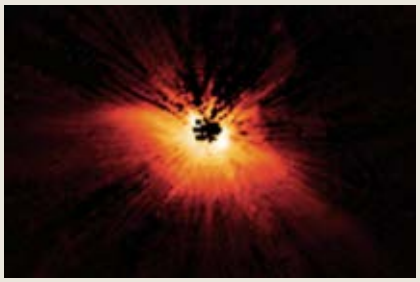
Volunteers who reported marked stress reactions after 9/11 and continued to worry about terrorism—about 6 percent of the sample—developed new cardiac problems three times as often as the others did.

The researchers controlled for participants' prior heart and mental-health problems, as well as for health-risk factors such as cigarette smoking, obesity, and high cholesterol. —B.B.

ASTRONOMY

Case of the misshapen disk

Debris disks surrounding stars are signposts that planet formation has already begun. The material in such disks is continually replenished as asteroids or other rocky debris—leftovers from the planet-making process—collides and produces fresh dust. Most debris disks are uniformly distributed around their star.



DEFORMED DISK The swept-back, asymmetrical debris disk around the star HD 61005 suggests it collided with a dense gas cloud.

Not so the disk surrounding the star HD 61005. As observed with a near-infrared camera on the Hubble Space Telescope, part of the disk appears to be swept back behind the star.

The most plausible explanation for the misshapen disk is that the roughly 100-million-year-old star has plowed into a higher-density gas cloud, says Dean Hines of the Space Science Institute in Boulder, Colo. Moving at about 10 kilometers per second relative to the interstellar medium, HD 61005 would collide with enough oomph to bend its disk and blow dust grains backward, he adds. The very existence of a dense gas cloud in the star's vicinity is a surprise, however, because the region, only 112 light-years from Earth, had been cleared of material by a relatively recent supernova explosion.

A simple color test could determine whether the collisional model is correct, says Paul Kalas of the University of California, Berkeley. In that model, the swept-back part of the disk would contain a higher proportion of tiny grains because they are more easily pushed than larger grains. Because small grains reflect a greater amount of blue light, visible-light images of the deformed disk, recorded by Hubble but not yet analyzed, ought to have a bluish tinge, he notes.

The collision isn't likely to have harmed any planets that might already have formed close to HD 61005, Kalas adds. But if the star has an outer reservoir of comets and other icy bodies, similar to our solar system's Kuiper belt, the violent interaction might partially deplete this frigid population. —RON COWEN

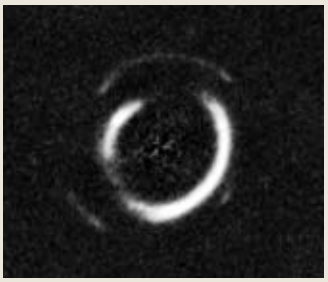
COSMOLOGY

Gravity at play: A double lens

Astronomers have for the first time spied an extremely rare, double cosmic mirage.

As first predicted by Albert Einstein's theory of general relativity, a massive foreground galaxy acts like a lens, bending or distorting the light from a galaxy that lies farther away. In most cases, the light is bent into an arc. But in rare instances, when the background galaxy is exactly aligned with the foreground galaxy as observed from Earth, the light is distorted into a perfect circle known as an Einstein ring. About 50 such rings have been detected.

Now, researchers have discovered the first double Einstein ring. The concentric rings are generated when two separate background galaxies line up exactly with the same foreground body. The odds of seeing such an alignment are about 1 in 10,000, says Tommaso Treu of the University of California, Santa Barbara.



GRAVITY'S RINGS A rare double Einstein ring is part of the gravitational lens system SDSSJ0946+1006. Two concentric partial ring-like structures are revealed after subtracting the glare from the central, foreground galaxy.

He and his colleagues first found evidence of what appeared to be a single Einstein ring in data from the Sloan Digital Sky Survey, which has mapped a million galaxies over one-quarter of the sky. But when Treu's team took a much closer look at the mirage with the Hubble Space Telescope, the researchers found they were seeing double.

The foreground galaxy, or lens, lies 3 billion light-years from Earth, while the inner and outer rings are images of galaxies that lie farther away—6 billion and 11 billion light-years—and hail from an earlier epoch of cosmic history.

The twin rings represent more than a rare cosmic coincidence, Treu notes. By measuring the distance to each ring and its relative radius, astronomers can determine the amount of mass in the universe at different times. If they're lucky enough to find 50 double rings with future large-scale surveys, researchers would have a new measure of dark energy, the mysterious substance that's revving up the rate at which the universe is expanding. —R.C.

ASTRONOMY

Four's a crowd

Many stars reside in pairs, but now astronomers have discovered a rare, closely spaced quartet. Four stars that lie just south of the constellation Aquarius orbit each other within an area smaller than Jupiter's orbit around the sun, Evgenay Shkolnik and her colleagues at the University of Hawaii, Manoa, in Honolulu report.

While monitoring several hundred low-mass stars, the team noticed something odd about a star system called BD-22°5866, 166 light-years from Earth. Spectra taken with the Keck I and Canada-France-Hawaii telescopes atop Hawaii's Mauna Kea revealed that what appeared to be a single point of light was actually four distinct stars in two tightly coupled pairs. Stars in one of the pairs orbit each other at a maximum distance nearly equal to Jupiter's separation from the sun, while the stars in the other duo are in a much tighter pas de deux. Only about 1 in 2,000 stars resides in such close quarters, Shkolnik's team estimates.

The stars are too tightly grouped to have been born that way, the team calculates. The researchers instead attribute the crowded configuration to a single gaseous disk that may have enveloped all four stars when they were young and farther apart. Such a disk—common around newborn stars—could have pulled the stars close together within 100,000 years of their birth, the team suggests.

Shkolnik and her collaborators are now monitoring the star system to determine whether any of its members eclipse each other. Eclipses would reveal further details about the mass, size, and other properties of the quartet. That, in turn, could provide new insight about the formation and evolution of other stars with multiple partners. —R.C.

HINES, G. SCHNEIDER, NASA; R. GAVAZZI, TREU, NASA, ESA, AND THE SLACS TEAM

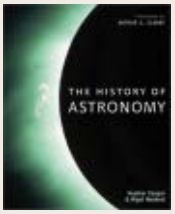
Books

A selection of new and notable books of scientific interest

THE HISTORY OF ASTRONOMY

HEATHER COUPER AND NIGEL HENBEST

Ancient myths of every culture reflect awe for the nighttime sky. And even with increasingly powerful telescopes, the wonder is by no means over. In this colorful and exuberant volume, astronomers Couper and Henbest guide the reader through times when astronomy belonged to religion, to philosophy, and, finally, to science. They delight in the discoveries of Copernicus, Kepler, Galileo, and Newton and muse on the astronomical meaning behind mysterious ancient monuments such as Stonehenge and the Mayan temples. Contemporary findings on galaxies, pulsars, quasars, and the Big Bang are addressed in a way to excite nonexperts of any age. And who better to introduce the wonders of the cosmos than Arthur C. Clarke, renowned author of *2001: A Space Odyssey*. ***Firefly Books, 2007, 288 p., color photos & illus., hardcover, $59.95.***



THE BIG SWITCH: Rewiring the World from Edison to Google

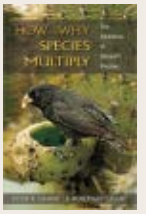
NICHOLAS CARR

The computer revolution is well under way. Young people, in particular, have already surpassed their own hard drives. They rely on the latest wave of interactive Web 2.0 initiatives delivered over the Internet—from Facebook to YouTube to Wikipedia. In business, companies that abandoned their file cabinets a decade ago are now discarding their personal computer systems and outsourcing to upstarts that update their information automatically, online. But navigating new territory carries risks. Carr, an economy journalist and author of the controversial book *Does IT Matter?*, tackles the question of where the computer revolution will lead our economy and our culture. Be forewarned, his outlook is grim: Wealth and power will be concentrated in the hands of a few industries as the "worldwide computer" takes over. Skeptical of apparent progress, Carr reminds us to treasure what we have before we dump our baggage and leap blindly onto the next train. ***Norton, 2008, 278 p., hardcover, $25.95.***

HOW AND WHY SPECIES MULTIPLY: The Radiation of Darwin's Fiches

PETER R. GRANT AND B. ROSEMARY GRANT

During his voyage to the Galápagos Islands in 1835, Charles Darwin observed a curious fact: Finches differed slightly from island to island. In particular, the various shapes of their beaks reflected a difference in the bird food found on each island. That observation was crucial to the development of his theory of evolution by natural selection. The Grants, authors and preeminent evolutionary biologists, spent 34 years visiting the islands and using modern molecular techniques to further understand how species of finches arose through natural selection of beak size and shape, and song divergence. The Grants also explain factors that drove finch evolution, including the isolation of populations on the islands and the increase in the number of islands, which enhanced opportunities for further speciation. The authors' assertion that "speciation is a process and not an event," comes across clearly in this concise and accessible tale of 3 million years of finch evolution. ***Princeton Univ. Press, 2008, b&w illus. and color photos, 218 p., hardcover, $35.00.***



THE MYSTERY OF THE MISSING ANTIMATTER

HELEN R. QUINN AND YOSSI NIR

Once upon a time, a long, long time ago, the universe contained equal amounts of matter and antimatter. But after the Big Bang, antimatter seemingly disappeared. Scientists and science fiction authors have long speculated on why matter won over antimatter, on whether any other place could be made of antimatter, and on what might be possible if antimatter were harnessed. In this page-turner, true science is written in the thrilling tone of science fiction. Quinn and Nir present the history of the antimatter problem and discuss its impact on our understanding of the cosmos—all without introducing a single equation or even a Greek letter. They reveal tantalizing possibilities for solving this puzzle, made possible by high-precision experiments that particle physicists like Quinn and Nir themselves undertake. For anyone wanting to know how physics works and physicists think, the writers make one of the greatest unsolved problems in physics both comprehensible and compelling. ***Princeton Univ. Press, 2008, 277 p., hardcover, $29.95.***

HIDDEN DEPTHS: Atlas of the Oceans

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

We know more about the surface of the moon than we do about the floor of our own planet's oceans. Beneath the waves, strange creatures roam as tectonic plates spread apart or mightily crash. Beyond the pure pursuit of exploration, we depend on our oceans, and that dependence has placed pressure on this vital resource. Fishery stocks are being depleted, pollution from runoff and dumping has ruined coastlines, and rising carbon dioxide levels in the atmosphere have led to an increase in the oceans' acidity. Some are fighting to counteract devastation by creating marine-conservation sites and cleaning up toxic dumps. This volume covers these topics and more, including humankind's history of legendary sea wrecks and high-tech submersibles. NOAA scientists contribute satellite images, 3-D maps, photographs, and commentary. ***Collins/Smithsonian, 2007, 256 p., color illus. & photos, hardcover, $39.95.***

HOW TO ORDER Visit *http://www.sciencenews.org/pages/books.asp* to order these books or others. A click on a book's title will transfer you to the Amazon.com bookstore. Sales generated through these links contribute to Society for Science & the Public's programs to build interest in and understanding of science.

LETTERS

Bad medicine?

In "Unseen Risk: Lifestyle, physical problems may underlie psoriasis link to early mortality" (*SN: 12/22&29/07, p. 389*), the definition of patients with severe psoriasis as those needing systemic drugs raises the question whether treatment itself may be linked to early mortality. The journal article cited in the story indicates that some systemic treatments may be less toxic than others, but I found nothing to refute the hypothesis that mortality might be due to adverse reactions to the medication.

DAVID HARDING, WARRENVILLE, ILL.

The reader is correct that the study did not specifically look at whether the medications, and not the disease, could be responsible. Researchers did find early mortality differences between patients on different medications. —EDITORS

As I read the article "A Different Side of Estrogen" (*SN: 1/5/08, p. 8*), I was wondering whether the findings discussed suggest that a woman who has had both a hysterectomy and an oophorectomy should be on estrogen hormone therapy. Does a woman with no uterus or ovaries produce enough estrogen in other organs to benefit from the estrogen receptor beta?

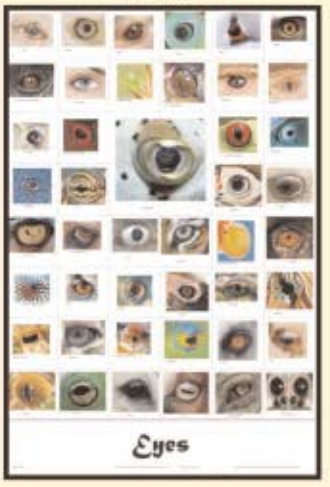
CATHY GREGOR, ALEXANDRIA, VA.

Almost all estrogen in a premenopausal woman's body is produced by the ovaries. "So after ovariectomy in women who have not gone through menopause, estrogen substitution is recommended," says Jan-Åke Gustaffson of the Karolinska Institute in Stockholm. But in older women, whose ovaries no longer produce very much estrogen, studies have shown risks to estrogen replacement. One of these—an increased incidence of uterine cancer—is obviously not a concern if the woman has no uterus. But others, including an increase in stroke and breast cancer, must be carefully considered by a woman and her doctor. In the future, the development of drugs that bind only to estrogen receptor beta in certain tissues may allow women to reap estrogen's benefits without these risks. —SARAH C. WILLIAMS

SEND COMMUNICATIONS TO:
Editor, Science News
1719 N Street, N.W., Washington, D.C. 20036
or editors@sciencenews.org
All letters subject to editing.

Science Mall Shopping
www.sciencemall-usa.com

NEW!



Eyes poster - 45 images of all different types of eyes. Do you know what the eye of the eagle, owl, red-eyed frog, macaw, turtle and balloonfish look like? You will see these and much more on this colorful and delightful poster with real images in full color. Size: 26" W X 36"L, laminated Order #JPT-4443, Cost: $21.95; Order #JPT-1011, 2 for $38; Black metallic frame: Order #JPT: 4442, Cost: $68; Walnut frame: Order #JPT-6319, Cost $75 *Great for schools, doctors offices, and anyone that loves biology!*

Rocks, Minerals and Gemstones of the U.S. 100 piece set, size: 20"L X 12"W X 1"D, Oak casing. Suitable for wall hanging. For safety, no glass cover. Comes with free meteorite and information sheet. **Order #JPT-1888**, Cost: $85.00, plus shipping. Also available the **World Rocks and Minerals Collection #JPT-78131 Cost:$265**

Mind Molecules - Poster

19 mind molecules are represented on this highly informative poster.

Entries are: caffeine, nicotine, ethanol (alcohol), ephedrine, heroin, amphetamine, diazepam and many more. Each has a graphic molecular representation with key, information on its action in the body and addiction level.

Size: 24"W X 36"L, Laminated

Order #JPT-7730, Cost: $16.95; #JPT-0104, 2 for $30

"The Tree of Life on Earth" poster offers a vivid, up-to-date overview of the modern classification of living things. The central image of a tree, with its labeled limbs and branches, represents the relationships among all the major groups of organisms on Earth. This visual presentation is reinforced verbally in an outline at the bottom of the poster, which gives descriptions and interesting facts about the 236 taxonomic groups shown in the tree. Text boxes provide background on the science of classification, and gorgeous color photographs give striking examples of plants, animals, fungi, and other organisms. An indispensable guide to the unity and diversity of life. Size: 26" X 38", Laminated; Comes with 8 ½"X 11" 2-sided information sheet with questions and answers. **Order #JPT-1288, Cost: $24.95**

Dangerous Insects and Arachnids - 26 of them are graphically illustrated on this colorful and informative poster. Some insects and arachnids included are: Scorpion, Brown Recluse Spider, Vampire Fly, Tarantula, Sand Fly, Rocky Mountain Wood Tick, Paper Wasp, Poisonous Caterpillar, Killer Bee (Africanized bee), Hornet, Funnel-web Spider, Fire Ant, Buffalo Gnat, Black Widow Spider, Anopheles Mosquito, Kissing Bug and more! Information includes habitat, method of contact, symptoms and possible treatments. Laminated. Copyright 2008, Revised, second edition. Order #JPT-0183, Cost: $24.95; #JPT-0189, 2 for $45

***Through the Sound Barrier* - Poster**
One of the extraordinary sights associated with breaking the sound barrier is the production of a sudden visible vapor cloud, as shown around this hornet fighter jet. This picture is one of the most famous ones available. Poster size: 16" X 20" Laminated; **Order #JPT-121, Cost: $24.95,** *Also available in black or walnut frame:* **Order #JPT-1277, Cost: $69.95**

***B-2 Stealth* - Poster** - If this has always been one of your favorite aircraft then this is the poster for you! It appears that this B-2 has exceeded the sound barrier by the looks of that ring around its tail, but it has not. The extraordinary cloud effect is not exactly tied to the breaking of the sound barrier, but is a different phenomena. Poster size: 16" X 20" Laminated; **Order #JPT-331, Cost: $24.95,** *Also available in black or walnut frame:* **Order #JPT-1349, Cost: $69.95**

Lichtenberg Figure -Lichtenberg Figures combine the technologies of particle beam and dielectric physics with the natural beauty of fractals. They were created by carefully trapping and discharging multi-million volt regions of electrical charge inside acrylic using a particle accelerator. Now available in smaller size. Specimens are 2" x 2" x 3/4", **Order #JPT-1228**, Cost: $38.95, with lighted base order **#JPT-1846, Cost: $68.95** Comes with detailed information sheet. Colorful poster about them coming soon!

"Owl Eye" Butterfly Pendant from Peru. Sterling Silver, Order **# JPT-14882 Cost: $38.95** *Different colored ones and prices on our website!*

Gibeon Leucite Meteorite Pendant - Pendant size: 1" X 1" Fragments will vary in size but all are similar. Order **#JPT-0613, Cost: $32.95; 2 for $60**

Gibeon Meteorite Pendant - In sterling silver, diamond shaped. Comes with information, authenticity and 20" sterling chain. Size: 18mm X 12mm X 7mm Order **#JPT-9921 Cost: $65**

Mammoth Ivory Rose Pendant
Petite, 14K Gold with chain and authenticity; Size 1 ½" L X 1" W ; Ivory rose dimensions: ½"L X 5/8"W **Order #JPT-rose12, Cost: $165**

Sterling Silver Meteorite Pendant
The meteorite in this jewelry pendant is a NWA 869 (North West Africa). It is among the prettiest class of chondrite meteorites, and is a L-5 type chondrite. Certified authentic: Jensan Scientifics. Comes with information, braided 20" sterling chain in an attractive black velvet jewelry box. Size: 1" X 1" Sterling Silver **Order #JPT-1065, Cost $85** For the person that has everything. We bet they do not have this! Also available in 14K gold, **Order #JPT-1165, Cost: $265** ***New Allende Pendants on website, various prices.***

WWW.SCIENCEMALL-USA.COM
P.O. Box 1864
Dubuque, IA 52004-1864

VISA MasterCard DISCOVER

Shipping is *not included.*
Please call Toll Free:
1-800-720-5451 for information