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SCIENCE NEWS

THE WEEKLY NEWSMAGAZINE OF SCIENCE

power in small packages

northern explosion

prenatal vaccinations?

a view of tumor genes

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skin deep

HOW MICROBES AID CORALS

THE WEEKLY NEWSMAGAZINE OF SCIENCE

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JUNE 2, 2007 VOL. 171, NO. 22

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Cover Beneath their beauty, corals wear a slimy skin that welcomes microorganisms. Many of these guests protect their hosts by making antibiotics that kill harmful bacteria and fungi. (Photodisc) Page 346

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Ice Age Ends Smashingly

Did a comet blow up over eastern Canada?

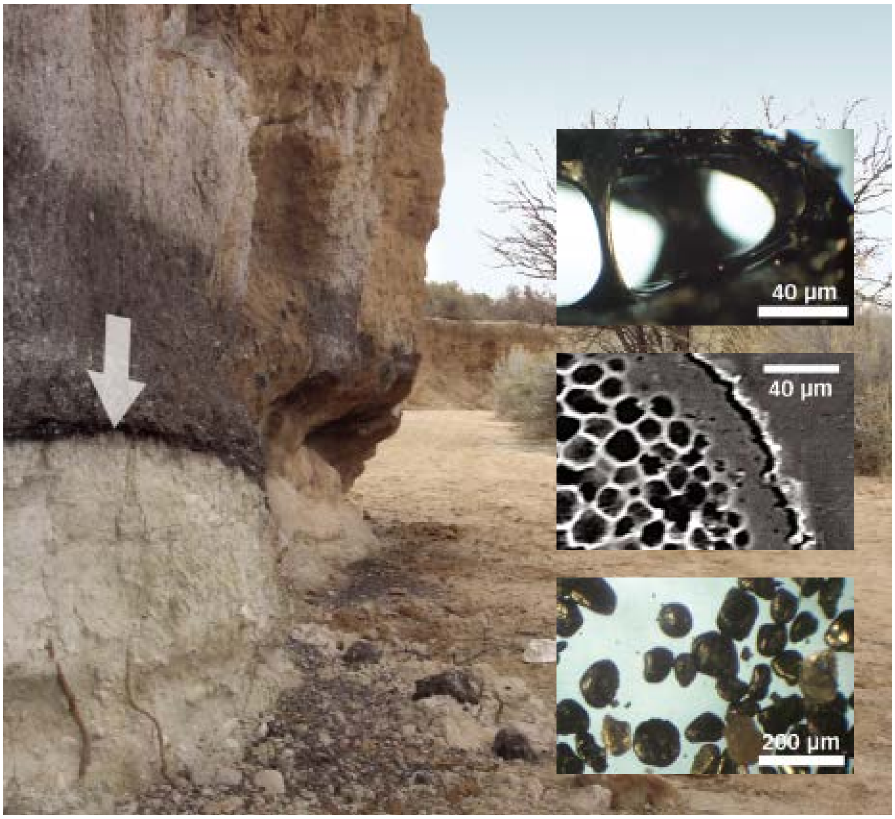
Evidence unearthed at more than two dozen sites across North America suggests that an extraterrestrial object exploded in Earth's atmosphere above Canada about 12,900 years ago, just as the climate was warming at the end of the last ice age. The explosion sparked immense wildfires, devastated North America's ecosystems and prehistoric cultures, and triggered a millennium-long cold spell, scientists say.

At sites stretching from California to the Carolinas and as far north as Alberta and Saskatchewan—many of which were home to prehistoric people of the Clovis culture—researchers have long noted an enigmatic layer of carbon-rich sediment that was laid down nearly 13 millennia ago. "Clovis artifacts are never found above this black mat," says Allen West, a geophysicist with Geoscience Consulting in Dewey, Ariz. The layer, typically a few millimeters thick, lies between older, underlying strata that are chock-full of mammoth bones and younger, fossilfree sediments immediately above, he notes.

New analyses of samples taken from 26 of those sites reveal several hallmarks of an extraterrestrial object's impact, West and his colleagues reported at the spring meeting of the American Geophysical Union in Acapulco, Mexico.

Samples from the base of the black mat yield most of the clues to its extraterrestrial origin, says Richard B. Firestone, West's coworker and a nuclear physicist at the Lawrence Berkeley (Calif.) National Laboratory. Some of the particles there are small, magnetic grains of material with higher proportions of iridium than are found in Earth's crust, he notes.

Also in the mat's base are tiny lumps of glasslike carbon that probably formed from molten droplets of the element. These lumps, as well as little spheres of carbon with a different microstructure, contain nanoscale diamonds formed under intense pressure.



IT'S IN THERE A layer of carbon-rich sediment (arrow) found here at Murray Springs, Ariz., and elsewhere across North America, provides evidence that an extraterrestrial object blew up over Canada 12,900 years ago. The hallmarks include lumps of glasslike carbon (top), carbon spherules (middle, in cross section), and magnetic grains rich in iridium (bottom).

WEST; (MIDDLE INSET): CANNON MICROPROBE

A host of unusual geological features, collectively known as Carolina Bays, hints at the cataclysm's location, says team member George A. Howard, a wetland manager at Restoration Systems, an environmental-restoration firm in Raleigh, N.C. Around 1 million of these elliptical, sand-rimmed depressions, measuring between 50 meters and 11 kilometers across, scar the landscape from New Jersey to Florida. In samples taken from 15 of the features, Howard and his colleagues found iridium-rich magnetic grains and carbon spherules with tiny diamond fragments similar to those found at Clovis archaeological sites.

The long axes of the great majority of the Carolina Bays point toward locations near the Great Lakes and in Canada—a hint that the extraterrestrial object disintegrated over those locales, says Howard.

Because scientists "haven't discovered a large, smoking hole" left by the event, the object that blew up in the atmosphere probably was a comet, says West.

Heat from the event would have set off wildfires across the continent, the scientists suggest. The heat and shock from the explosion probably broke up portions of the ice sheet smothering eastern Canada at the time, they add. The flood of fresh water into the North Atlantic that resulted would have interrupted ocean currents that bring warmth to the region, and thick clouds of smoke and soot in the air would have intensified cooling across the Northern Hemisphere.

The inferred date of the event matches the beginning of a 1,200-year-long cold spell that geologists call the Younger Dryas, which in its first few decades saw temperatures in the Northern Hemisphere drop as much as 10°C. —S. PERKINS

Early Start

Fetuses generate immune response to vaccination

A fetus can manufacture immune cells and antibodies in direct response to vaccine given to the mother during pregnancy, according to researchers studying flu shots.

Scientists had already established that a pregnant woman can pass along certain antibodies to her fetus and that those immune proteins can protect a baby for up to 6 months after birth. Other studies had found that a fetus can muster an immune response to an infection contracted by the mother. But there had been little evidence indicating that a fetus can generate immunity to a vaccine, says study coauthor Rachel L. Miller, an immunologist at Columbia University College of Physicians and Surgeons.

Miller and her colleagues obtained blood samples from 70 pregnant women who had agreed to receive a flu shot about 7 months into their pregnancies. The Centers for Disease Control and Prevention recommend that women get flu shots in either the second or third trimester of pregnancy.

After each baby was born, the researchers analyzed samples of umbilical cord blood. Such samples provide a snapshot of the immune system that a baby had before birth.

The analyses showed that 28 of the 70 cord blood samples contained antibodies against a flu virus, the researchers report in the June 1 *Journal of Clinical Investigation*. The antibodies were too large to have passed through the placenta directly from the mother, Miller says.

In many cases, the fetus produced an antibody response even when the mother didn't, the researchers say. That suggests that the vaccine went from the mother's bloodstream through the placenta, spurring the antibody manufacture in the fetus, says Miller. The vaccine is made from a killed virus.

A separate analysis showed that some of the cord-blood samples also made immune system T cells that were specifically geared to fight the flu virus.

All these findings demonstrate that the fetus is "capable of generating its own immune response to vaccine" given to the mother, Miller says. However, researchers don't know whether the immunity is protective against disease.

"It's obviously important—if we choose to immunize mothers—to know to what degree we're immunizing the baby," says Thomas A. Platts-Mills, an allergist at the University of Virginia in Charlottesville.

Fetal immunity has long puzzled scientists—particularly those who study allergy, which is a form of immunity run amok. Previous studies had suggested that a mother's exposure to allergens—ingested or inhaled—might affect her fetus' immune system.

"We think this [study] has implications for environment-related disease, including allergy," Miller says. She speculates that fetuses might respond to dust mite or cockroach allergens inhaled by the mother much as they react to flu vaccine.

Platts-Mills is skeptical of that idea because the new study provides no evidence regarding response to allergens.

"They're two separate issues," he says. One difference, he explains, is that an injection of vaccine into a pregnant woman delivers a much greater immune affront to her fetus than, for instance, inhalation of a dust mite allergen does. —N. SEPPA

Pothole Pals

Ants pave roads for fellow raiders

When army ants use their own bodies to plug tiny potholes in rough trails, the whole colony benefits, a new study has found.

Without those instant road repairs, a colony's daily catch of food can drop by as much as 30 percent, say Scott Powell, now at the Federal University of Uberlândia in Brazil, and Nigel Franks of the University of Bristol in England. As the ants race along paths to and from food, filling holes helps prevent traffic backups, Powell explains.

Many species of army ants send out relentless columns of hunters at night or underground, but Powell and Franks focused on *Eciton burchellii*, which preys aboveground during the day. Colonies of these ants grow 700,000 strong.

Rather than building nests, they spend the night in ant-gripping-ant balls dangling from an anchor point, such as the side of a tree. As dawn breaks, up to 200,000 foragers swarm out. "The pitter-patter of millions of little feet sounds a lot like rain," says Powell.

The ants' goal: to prey on other ant species, various spiders, or even something as big as a scorpion. When the leading edge of a column of foragers catches up to a victim, the army ants form a mass, grab hold of the prey, inject enzyme-rich venom to weaken it, and pull it apart.

Raiders carry bits of the victim back to the main colony, where other workers are tending the youngsters. During an entire day's expedition, the hunters maintain one principal two-way trail, from 3 to 12 ants wide, back to the rest of the colony.

To examine how pothole filling affects the well-being of the colony, Powell inserted a variety of wood strips, drilled with holes, into the ants' principal trail.

As the first ant reached a hole, it stretched across and rocked, as if measuring the fit. A big ant didn't bother to plug a small hole but left it for a smaller comrade. If an ant fit, it would hold a characteristic road-repair posture for as long as traffic continued to race over it. Then the ant would pop out of the hole and rush on.

"As trivial as pothole plugging may seem, Powell and Franks have empirically demonstrated how such behavior can contribute to colony fitness, and that makes it important," comments army ant specialist William Gotwald Jr. of Utica College in New York.

Relatively large foragers lugging food run at an average of 8 centimeters per second, Powell reports. The pothole repairs help prevent the ants from getting stuck on a narrow stretch of trail where they'd have to slow to the pace of smaller raiders. The smaller ants travel on average about 6 cm/s, the researchers report online and in an upcoming *Animal Behaviour*.

"It's a great example of a novel function where a small investment yields big efficiency gains," says Sam Beshers of the Uni-

ROADSTERS **Army ants forced to travel on a narrow wooden strip throw themselves into holes and allow fellow travelers to race over them.**

POWELL

versity of Illinois at Urbana-Champaign, who studies the organization of ant colonies and other biological systems. —S. MILIUS

Visualizing Cancer

Images of tumors can detect gene expression

Radiologists have found a way to use X-ray scans to identify which genes in a tumor are active.

The ability to glean genetic information about tumors from routine medical imagery could increase the use of cancer therapies that target a tumor's genetic quirks. Targeted therapies promise better cancer treatments with fewer side effects than current approaches do. But doctors rarely profile a tumor's genes, in part because it's expensive to do and requires surgical removal of tissue.

"Genetic analysis of tumors is not usually done, but the first thing a doctor will do to a cancer patient is give them [an X-ray] scan," says Michael Kuo of the University of California, San Diego, a coleader of the study. The new technique infers gene activity from such scans and so "lets us see gene expression of a tumor in a noninvasive way."

The researchers looked at computerized tomography (CT) scans of liver tumors in 28 patients. CT scans use X rays to render virtual slices through a person's body. Kuo and his colleagues identified 32 visible features—such as a dark halo or a region with mixed textures—that at least two radiologists could independently identify as present or not.

The scientists also measured the activity of 6,732 genes to create genetic profiles of the tumors. Comparisons of these profiles with the occurrence of the visual features revealed strong correlations between profiles and sets of features.

With this system, Kuo and his colleagues could use a CT scan to deduce the activity of more than 80 percent of the profiled genes in each tumor. To verify their system, the scientists tested a different set of 19 liver tumors and correctly gauged each tumor's gene activity with an average accuracy of 74 percent. The research appears online and in an upcoming *Nature Biotechnology*.

"Everyone is excited about this," says Amy Hara of the Mayo Clinic College of Medicine in Scottsdale, Ariz. Tumors "all can look different, but we never really knew what that meant."

Because scientists know the functions of many of these genes, Kuo and his team were able to link image features to tumor biology, which could guide diagnosis and treatment. For example, they found that three image traits were adequate to predict the activity of a gene called vascular endothelial growth factor (*VEGF*), which drives the formation of new blood vessels in growing tumors and is targeted by the cancer drug bevacizumab.

"Eventually, we might be able to use CT scans to guide targeted treatment of cancers," Kuo says. "But that's still a ways down the road."

While the team used liver tumors for this research, the technique should apply to other kinds of solid tumors, such as those of lung and breast cancers, says Howard Chang of Stanford University, the other coleader of the study.

Although the study found correlations between the image traits and gene expression, it didn't explain how particular genes cause the features seen in the images, Kuo notes. —P. BARRY

QUOTE

"Eventually, we might be able to use CT scans to guide targeted treatment of cancers."
MICHAEL KUO, University of California, San Diego

Packaging Peril

Chemicals in food wrapping turn toxic

Chemicals that prevent grease from seeping through food packaging transform in rats into a suspected carcinogenic compound. This conversion could help explain why that compound—perfluorooctanoic acid (PFOA)—shows up so widely in people's blood, say researchers.

PFOA, used to manufacture nonstick cookware and rain gear, turns up in blood samples worldwide, reaching concentrations of 30 nanograms per milliliter or more. The chemical doesn't degrade, and people excrete it slowly. An advisory group to the Environmental Protection Agency has recommended classifying PFOA as a rodent carcinogen that may harm people.

But scientists don't know the primary route by which PFOA gets into people. Environmental chemists Scott A. Mabury and Jessica C. D'eon of the University of Toronto tested a pathway that begins with related chemicals called polyfluoroalkyl phosphate surfactants (PAPS), substances used to coat oil- and water-repellent food wrappers. A study in 2005 showed that similar compounds used in these applications can leach from microwave-popcorn packaging into the food.

That finding left two issues unresolved, says Mabury. Can PAPS reach the bloodstream from the gut, and if so, will they break down to PFOA in the body?

Mabury and D'eon synthesized two PAPS and administered one or the other directly into rats' stomachs in single doses of 200 milligrams per kilogram of body weight. Over the following 15 days, they monitored the rats' blood for PFOA and both PAPS. The highest background concentration among the rats, including animals that weren't dosed with a PAPS, was 2 nanograms of PFOA per gram (ng/g).

Exposure to either PAPS elevated the amount of PFOA in a rat's blood. One of the surfactants, monoPAPS, boosted PFOA concentrations to 34 ng/g. The other, diPAPS, produced a smaller jump to 3.8 ng/g. The researchers report their findings online and in an upcoming *Environmental Science & Technology*.

Not only can the body absorb PAPS, but the chemicals degrade into a potentially toxic compound "widely observed in the bloodstream," concludes Mabury.

The study identifies a source of PFOA contamination, says Kurunthachalam Kannan, an environmental chemist at the New York State Department of Health in Albany. With growing concern over how PFOA affects people, there is a need to identify additional sources of exposure, Kannan says. "There may be many more unknown sources out there," he says.

If PFOA is in people's blood because they make it inside their bodies, says Mabury, then the behavior of the intermediate chemicals in this exposure pathway becomes important as well. Some of these intermediates "have the potential to be far more toxic than PFOA," he says.

Mabury's group is now assessing the toxicity of the intermediates. The team also plans to study how widespread PAPS are in the environment. —A. CUNNINGHAM

Take a Number

Kids show math insights without instruction

Most children need years to master the basics of adding and multiplying single-digit numbers. Yet by the time they enter kindergarten, a new study finds, kids can solve addition and subtraction problems involving large numbers if they are prompted to consult their intuitive knowledge of approximate quantities rather than to compute precise solutions.

Children from a range of social and economic backgrounds, tested either in a laboratory or at school, correctly answered a large majority of such math problems on their own when freed of the requirement for calculating exact results, say psychologist Camilla K. Gilmore of the University of Nottingham in England and her colleagues.

A focus on children's knowledge of approximate quantities would enhance arithmetic instruction, the researchers propose. "The teachers in our school-based study were skeptical about our experiments and surprised both by their students' success and by their enjoyment of the tasks," Gilmore's group concludes in the May 31 *Nature*.

The team first tested 20 children, ages 5 to 6 years, from wealthy, highly educated families. Youngsters sat in front of computers that displayed a series of approximate-addition problems, each in three parts.

One problem started with an image of a girl's face and a boy's face in separate boxes, with a bag marked "21" above the girl. A caption read "Sarah has 21 candies." Next, the kids saw an image showing another bag marked "30" above the girl. Its caption read, "She gets 30 more." A final image displayed a bag marked "34" above the boy. Its caption read, "John has 34 candies. Who has more?"

Children answered nearly three-quarters of such problems correctly. Guessing would have yielded correct responses on only half of the problems.

The researchers then presented similar problems to 37 kindergartners from poor and middle-class families. Children were tested in a hallway outside their public school classroom.

Although the setting offered more distractions than a laboratory, kids still answered almost two-thirds of the problems correctly.

A final laboratory experiment tested 27 kindergartners from wealthy families on two other approximate-math tasks. Subtraction problems appeared in the form: "Sarah has 64 candies. She gives 13 of them away. John has 34 candies. Who has more?" Comparison problems used three boxes per image, containing a girl and two boys, and appeared in the form "Sarah has 51 candies. Paul has 64 cookies. John has 34 candies. Who has more candles, Sarah or John?"

Children correctly solved two-thirds of the subtraction problems and 80 percent of the comparison problems.

The new findings indicate that children can exploit a neural system for estimating quantities—which scientists have also observed in a variety of nonhuman animals—to understand basic arithmetic, remarks psychologist David C. Geary of the University of Missouri–Columbia.

"This is the first study to demonstrate that young children access this system when dealing with relatively complex addition and subtraction problems," says Geary, who studies mathematical learning. —B. BOWER

SUM KIDS Approximate-arithmetic problems presented to 5- and 6-year-olds in a new study included portrayals of addition (top row) and subtraction (bottom row), shown as a researcher read descriptions of each image.

GILMORE

Magnetic Logic

Electron spins could do cool calculations

Engineers have proposed a new design for circuits that could process information by using electrons as tiny bar magnets. Such circuits could someday become the building blocks of a new generation of computers.

Computer-chip components called logic gates output a 1 or 0 depending on the configuration of a gate's inputs. In conventional electronics, such bits of information are represented by electric voltages. Logic gates contain semiconductor-based transistors that switch states in response to those voltages. Such transistors, however, require thin insulating layers that tend to leak electrons and produce excess heat.

In addition to their electric charges, electrons carry a quantum mechanical property called spin. An electron's spin generates a magnetic field that can point in any direction. In recent years, several research teams have built "spintronics" devices that encode 1s and 0s as spins pointing up or down. Thus, the devices switch states by flipping electron spin rather than changing voltages.

Such systems would reduce the overheating problems that afflict conventional electronics. So far, though, researchers have had to make spintronic gates out of multiple layers of metallic materials, in arrangements that would be difficult to link on a chip, says Hanan Dery, an engineer at the University of California, San Diego.

Dery and his colleagues now propose a spintronic logic gate made mostly of semiconducting materials. The gate would be a horizontal semiconducting bar with five metallic contacts aligned on its surface. Four of these contacts would act as the inputs. Each of them could be magnetized up or down, which would cause electrons with up or down spins to move into the semiconductor. An excess of spin-up electrons would lower the electrical resistance at the boundary of the fifth contact. An excess of spin-down electronic would not. A separate circuit would receive the output, and current would flow only if the resistance had decreased.

Dery's team also describes in detail how to link such components. Specialized circuits, also made of semiconducting components, would take the output current from one logic gate, amplify it, and use it to magnetize one of the input contacts of another logic gate.

A main advantage of this design, Dery says, is that present-day semiconductor-fabrication techniques could mass-produce the devices. In principle, he adds, engineers could pack these components onto a chip up to 200 times as densely as they can pack conventional gates onto a chip. His team outlines the proposal in the May 31 *Nature*.

Paul Crowell of the University of Minnesota in Minneapolis says that the new approach is elegant and original, but also untested. "I really cannot say yet whether it is going to be feasible," he says. Laurens Molenkamp of the University of Würzburg in Germany says that each of the parts of the proposed device is "relatively standard" but adds, "What I like about this proposal is that it's a full scheme" describing how to link the components in a new way. —D. CASTELVECCHI

POWERING THE REVOLUTION

Tiny gadgets pick up energy for free

BY M. MITCHELL WALDROP

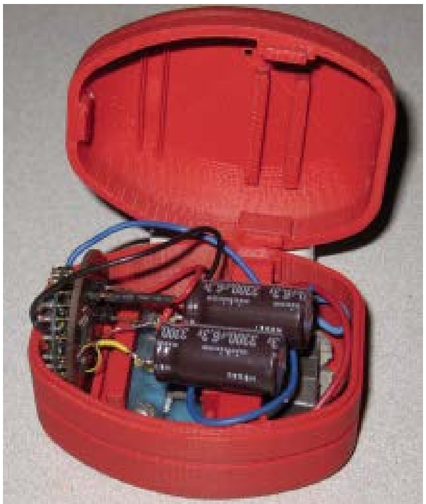
A few years ago, just to show that they could do it, Paul Wright and his mechanical engineering students mounted a temperature sensor under a staircase at the University of California, Berkeley and fed its readings into the stairwell's thermostat. It was not an especially difficult exercise—except that this sensor, which was about the size of a quarter, had no power cord or batteries. Instead, the device extracted the energy it needed from the vibrations that shook the wooden staircase as students clomped up and down between classes.

In Wright's view, this kind of energy scavenging—with sensors and other electronic devices living off the land, so to speak—could open a new realm for technology.

"The 1990s marked this very interesting period in which devices for computing, communication, and sensing all became much cheaper and much, much smaller," explains Wright. He's an engineer who has worked in robotics and computer science and is currently chief scientist at the Center for Information Technology Research in the Interests of Society, a multicampus program supported by the state of California.

The most obvious result of the miniaturization was a wild proliferation of cell phones, personal digital assistants, MP3 players, and other portable gadgets. But in parallel, Wright says, "researchers were led to this picture of wireless sensor networks everywhere"—in effect, an electronic nervous system that reports on both the built environment and the natural landscape.

In the not-so-distant future, for example, bridges could tell us whether they had been damaged in an earthquake. Helicopter rotors and other high-stress machine parts could warn about developing metal fatigue. Office buildings could track the locations of their occupants, automatically adjusting the lights and air conditioning for maximum comfort and minimum energy use. Automobiles could talk to each other—and to the road—in an effort to avoid both accidents and traffic jams. Implantable sensors could continuously monitor blood-glucose levels and a host of other medical conditions. And webs of environmental sensors could monitor the health of remote ecosystems, tracking moisture, temperature, micronutrients, pollutants, and many other variables. All these developments would rely on networks of minuscule sensors (*SN: 5/5/07, p. 282*).



ENERGY-RICH VIBRATIONS — Engineer Paul Wright and his students put this temperature sensor under a wooden stairway, where it scavenged all the energy it needed from vibrations generated by students clomping up and down.

WRIGHT

These applications and more are under active investigation, says Wright. Indeed, a wide variety of wireless sensors is already available commercially. But one of the biggest challenges continues to be power. Most of the potential applications call for so many sensors scattered so widely through a target area that it would be impractical to wire up each sensor individually—and ludicrous to run around changing batteries.

Thus the need for devices that can draw energy from their surroundings, says Wright. "The 1990s brought us computing, communication, and sensing. And now, I want to add the fourth thing—energy-scavenging devices—and make them as cheap as dirt."

ENERGY EVERYWHERE Energy scavenging is not a new idea. Self-winding wristwatches, in which a tiny mechanical oscillator extracts energy from the wearer's arm movements, first appeared in the 1920s. And, of course, windmills and water wheels have been harvesting natural energy for thousands of years. But the current wave of interest in energy scavenging for microelectronics began in the late 1990s—initially because researchers were looking for a better way to power the newly devised portable devices.

In 1998, for example, Joseph Paradiso and his team at the Massachusetts Institute of Technology's Media Lab demonstrated an energy scavenger embedded in the sole of a running shoe. It relied on the piezoelectric effect, in which crystals of certain materials produce a voltage in response to stress—in this case, from the impact of the wearer's heel on the ground. And it worked, sort of.

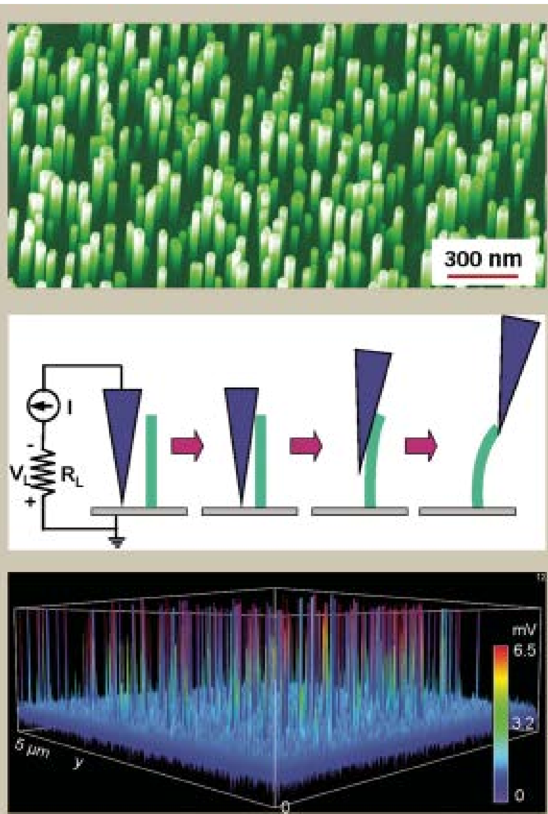
A typical adult expends several hundred watts of power while walking, and 1,000 watts or more during strenuous exercise. But our bodies are also remarkably efficient. The MIT team found that a shoe that taps more than a tiny fraction of that energy flow gives the wearer the sensation of walking through mud. In the end, the Media Lab shoe generated only about 60 milliwatts—not enough to power an iPod, much less recharge a cell phone.

As a result of this experiment and others like it, energy-scavenging researchers soon shifted their focus from relatively power-hungry portable electronic devices to a new generation of far-more-thrifty gadgets made with microelectromechanical-systems (MEMS) technology.

The basic idea of MEMS, which dates to the 1970s, is to carve microscopic mechanical structures into the surface of a silicon wafer by using the techniques devised to create microprocessors. By the 1990s, MEMS researchers had produced all manner of gears, springs, cantilevers, channels, and the like, and a first generation of commercial MEMS devices was reaching the market. Applications included the microscopic nozzles of inkjet printers, the chip-size accelerometers that trigger the deployment of an automobile's airbags in a collision, the micromirrors of a digital light-processing display, and the microchannels that move fluid around for analysis in an integrated lab on a chip.

Moreover, the silicon wafers of MEMS devices could easily be integrated with microelectronic circuitry. If sensors, manipulators, and computational smarts—as well as microscopic energy-scavenging devices—could be etched into the same chip, they'd add up to microscopic robots, sometimes referred to as motes or smart dust, that could form the working elements of self-powered, wireless sensor networks.

From an energy-scavenging standpoint, however, the great advantage of MEMS sensors is that they typically require only about 100 microwatts of power—a thousandth of what portable consumer electronic devices typically need. Such minuscule quantities of energy abound in the environment: in vibrations, temperature gradients, sunlight, and so on.



NANOSPIKES — The scanning electron microscope image at the top shows an array of zinc oxide nanowires. The middle image shows how the tip of an atomic-force microscope bends the individual nanowires. The bottom image depicts the spikes of output voltage produced by the array as the probe scanned each wire in turn.

WANG/GEORGIA TECH

The challenge is to make effective use of that energy.

The first thing to keep in mind is that there is no all-purpose solution, says Steve Arms, founder and president of MicroStrain, a manufacturer of MEMS-based sensors in Williston, Vt. "The biggest challenge is really understanding the environment you're working in and seeing what energy is available."

Take solar energy, for example. It's notoriously variable and unpredictable, thanks to clouds and the day-night cycle, and obviously unsuitable for sensors mounted indoors or implanted in a person's body. But a tiny photovoltaic cell might be just the thing for an environmental sensor that is regularly exposed to bright sunshine.

Now, consider thermal energy. The only way to extract it is when heat flows from hot material to cold. Ambient temperatures rarely vary enough from point to point to make that a winning proposition. But again, thermal-energy extraction might be valuable for certain applications.

Wireless Industrial Technologies, an Oakland, Calif., company cofounded by Wright, uses energy scavengers that take advantage of the Seebeck effect, in which certain metals develop voltages when one end is hotter than the other. "We've mounted the devices in an aluminum-smelting plant, between the outside of the smelter and a cooling fin. We can get a 50°C difference," Wright says. That's enough to power sensors that monitor many of the plant's operating parameters.

Then there are vibrations, which are quite variable—but ubiquitous. "You do have to be a little bit clever about where you place the sensors," says Wright. "But, for example, if you go through a commercial building, you find that the big windows vibrate a lot because of buses and trucks going by. You also get lots of vibration on air-conditioning ducts, on raised floors, and around heavy doors."

In certain settings, notes Arms, the vibrations can be strong indeed. He and his colleagues are currently working with Bell Helicopter of Fort Worth, Texas on a project for the U.S. Navy.

To avoid problems due to metal fatigue, the moving parts on a helicopter, especially the blades, are currently replaced on a schedule determined by how many flight hours the vehicle has logged. "But it would be much cheaper and safer to track the actual fatigue and replace the blades only when you need to, which might be longer than the schedule called for—or sooner," says Arms. "So, this past February, we did a successful flight test of a wireless strain sensor that got all its power from vibration during the helicopter's normal operation."

Such structural health monitoring is critical for all kinds of industrial machinery, adds Shashank Priya of the University of Texas at Arlington and host of an annual series of workshops on piezoelectric-energy scavenging. Indeed, structural monitoring could be the most important commercial application of vibration-powered sensors.

"There are 3,000 to 6,000 sensors inside a modern jet fighter or commercial aircraft," says Priya. "Currently, all of them are wired in for data, often with batteries for power. But that's tough: The aircraft is full of wires, the wires and sensors have to be manually checked very frequently, and it's very tedious to repair them if something goes wrong." If the sensors were wireless and could power themselves, many problems would disappear.

THE EFFICIENCY CHALLENGE

Standing in the way of such applications, unfortunately, is a second big piece of the energy-scavenging challenge: capturing tiny bits of ambient energy efficiently.

"Most of the devices right now are only 10 to 15 percent efficient," says Wright. That makes it tough for them to compete in the marketplace against, say, long-lived batteries.

A typical piezoelectric scavenger built using MEMS techniques has an array of microscopic cantilever beams—in effect, tiny diving boards that twang whenever a vibration comes through. Those oscillations, in turn, stress the piezoelectric crystal and produce the voltage. But when the cantilevers are this small, their oscillations occur at many thousands of cycles per second. Because ambient vibrations typically have frequencies of a few hundred cycles per second, they don't efficiently set the cantilevers into motion.

Much research has gone into improving that fit, largely by refining the device's structure to shift the cantilevers' natural resonance down to more-useful frequencies, says Wright.

Meanwhile, researchers have also been looking at more-efficient—and less-toxic—alternatives to the most commonly used piezoelectric material, called both lead zirconium titanate and PZT. Its lead content makes its use especially problematic in implantable sensors.

At the Georgia Institute of Technology in Atlanta, for example, Zhong Lin Wang and his group are developing a novel nanoscale energy scavenger based on zinc oxide—a material best known for its use in sunscreen. On the face of it, zinc oxide is not nearly as good a piezoelectric as PZT. "But it is both a piezoelectric and a semiconductor, which is very rare," says Wang.

(continued on page 348)

SLIME DWELLERS

A blanket seeded with microbes appears critical to coral health

BY JANET RALOFF

Put on your snorkel gear and get close to coral—really close—and you can spy a thin layer of surface slime. Produced continually, and often in prodigious amounts, this mucus can be anything from a thick, soupy liquid to gummy gel. Corals expend significant energy making and replenishing these water-soluble jackets, but scientists have struggled to understand the payoff for this effort.

Tiny sea animals that live communally, corals build huge, stony reefs or soft, treelike structures. Within a coral commune, most individuals are clones of their neighbors. Rooted in place, they glean food from the water and periodically eject reproductive cells that drift with the currents before settling at a new site.

For decades, biologists had suspected that the few-millimeter-thick coatings of slime served primarily as protective barriers. The material can prevent corals from drying out when exposed to air at low tide. In some species, coral newborns take sanctuary in the mucus until they graduate to life on their own. And as the slime continually sloughs off, it can carry away sand grains and other debris.

However, researchers are now finding chemical and biological roles for the mucus that rival its barrier functions. Accumulating evidence indicates that most of these activities trace to a large and variable supporting cast of microbes that lives in the mucus. Indeed, some recent studies suggest that certain bacteria can turn surface slime into a germ-fighting medicine cabinet for corals.

DIRT AND SLIME — This coral's mucus is visible because its host is exposed to air at low tide and the slime had accumulated debris from the water.

WILD

Such microbial pharmacists don't appear to be accidental interlopers. Kim B. Ritchie of the Mote Marine Laboratory in Sarasota, Fla., suspects that at least some antibiotic-making microbes are symbionts—biota that not only aid the coral in fighting pathogenic fungi and bacteria but also derive benefits from living on it.

Corals appear to craft their slimy coatings at least in part to encourage visits by particular families of microbial guests. Ecologists have even begun referring to the welcomed hordes of bacteria, viruses, and more that shelter in the mucus films as integral elements of the coral system.

Like the bacteria that occupy the human gut, the flora that colonizes surface slime can offer health benefits to reef builders. Conversely, an absence of these microbes, caused by stress or environmental change, could leave corals vulnerable to disease.

Mucus microbes may even help corals adapt to new conditions—infections or global warming, for instance—says Eugene Rosenberg of Tel Aviv University. If that's true, he argues, genes of mucus-dwelling microbes may be as important to coral survival in a period of rapid environmental change as are the genes of the reef builders themselves.

MUCUS MENUS Recognition that coral health may depend heavily on other species is hardly new. Marine biologists have known for more than a century that a class of single-celled algae called zooxanthellae takes up residence in the majority of healthy corals. Besides imparting color to the otherwise drab reef builders, the microalgae use the energy in sunlight to build inorganic chemicals from seawater into carbon-bearing coral nutrients, such as sugars and amino acids.

Corals also fashion their mucus from these algae-derived ingredients. In fact, "up to 50 percent of the carbon fixed by zooxanthellae is eventually released by the coral as mucus," notes Christian Wild of Ludwig-Maximilians University in Munich.

Although the mucus mostly consists of sugars and other carbohydrates, the slime may also contain fatty substances, proteins, nucleic acids, and other organic materials. This sticky mix can collect nutrients from the water to augment a coral's diet, Wild notes. Although corals exhibit rapid growth and metabolism, they typically live in nutrient-depleted patches of ocean. These animals need a means to collect and concentrate nutrients from seawater, and then to keep them from washing away, Wild says. Mucus fills the bill.

Being nutritious, mucus also provides a smorgasbord for microbes that drop by, notes Garriet W. Smith of the University of South Carolina in Aiken. Not surprisingly, microbes in mucus can outnumber those in the same volume of adjacent seawater by 1,000-fold.

Smith's team has isolated bacteria from coral mucus and examined their dietary preferences by offering the bugs 95 different chemical food sources. Because microbes are fairly selective feeders, these data "give us insights into what's available as [bacterial food] within the mucus," he says

This dietary profiling identified collections of coral microbes that work cooperatively. One group of bacteria will come in and digest chemically complex materials, he explains. By-products of that digestion then become fodder for others.

It's probably typical for members of a coral species to fashion mucus according to a general recipe. This would explain, Smith says, studies by his group and others suggesting that, regardless of where it lives, a healthy coral species typically harbors many of the same microbes. Microbes won't dine on a coral's mucus unless they like its menu, he says, but where that menu appeals, bacteria will come in droves.

REGIONAL CUISINES Although mucus recipes tend to be broadly similar, they can also differ by region and season.

For instance, John C. Bythell and Reia Guppy of the University of Newcastle in England sampled bacteria from the coral *Montastraea faveolata* at five sites in Caribbean waters off Tobago.

Although all sampled corals harbored many of the same bacteria, the sites also showed slight differences, Bythell notes. Moreover, mucus-dwelling bacteria "were significantly different" than the dominant bacteria in the surrounding seawater, he and Guppy reported in the Dec. 20, 2006 *Marine Ecology Progress Series.*

During his team's 8-month study, the mucus microbes on corals at each site underwent substantial changes. One broadly consistent group resided in mucus during Tobago's wet summer, another during the cooler, drier winter. This suggests that environmental factors affect a coral's microbial recruits, says Bythell.

Both the seasonal and the site-to-site variations in microbial populations likely trace to alterations in menus offered by a coral's mucus, he says, although he adds that no one has yet tracked slime composition over time and correlated that information with a coral's bacterial visitors.

Smith's group also witnessed a microbial evolution in soft corals known as purple sea fans, *Gorgonia ventalina*, growing off the Florida Keys. During a 2-year study, the researchers found that most changes in a slime's microbes were associated with infections of the coral by aspergillus, a fungus.

In the March 23, 2006 *Diseases of Aquatic Organisms*, the researchers report finding that healthy sea fans hosted a generally consistent mix of bacteria. But, once any part of a fan developed a fungal infection, the microbe population throughout the coral's mucus—even on tissues free of disease—shifted dramatically. This suggests, Smith says, that the recipe for mucus made by even partially infected corals changes throughout.

WHY HOST BUGS? Although no one disputes that coral slime is rich in bacteria, scientists have long wondered why corals go to the trouble of feeding these hordes. One evolving explanation is that the microbial entourage offers medicinal benefits.

Although they don't make antibodies, corals demonstrate a primitive ability to fight infection. Going back decades, studies have found germ-killing antibiotics in association with many of these animals.

Such data came mostly from studies in which biologists ground up chunks of coral and sampled all extractable compounds, notes coral ecologist Ariel Kushmaro of Ben Gurion University of the Negev in Beer-Sheva, Israel. As a result, no one knew where the antibiotics came from. Until last fall, that is.

Ritchie's study of elkhorn corals (*Acropora palmata*) from reefs in the Florida Keys, published in the Sept. 20, 2006 *Marine Ecology Progress Series*, was the first to unambiguously tie these antibiotics to mucus microbes, Kushmaro says.

Ritchie collected slime from the corals and isolated their resident bacteria. Previous studies had established that only a fraction of such bacteria can be grown in the lab. Ritchie grew whatever ones she could on sterilized coral mucus, then added pathogens and measured the residents' survival.

BEAUCOUP GOO — This soft coral, *Pseudopteragorgia americana* or slimy sea plume, is renowned as a prodigious mucus producer.

She found very different communities of bacteria—and equally dramatic differences in the ability of germs to coexist with them—during the comfortable spring and the blisteringly hot summer.

For instance, microbe-hosting slime collected in spring from healthy corals inhibited the growth of marine germs or surrogate invaders to one-tenth the growth that occurred with mucus hosting no resident bacteria. Ritchie's analyses showed that one in five resident-bacteria species exhibited antibiotic activity against a species of bacteria implicated in white pox disease in coral.

During the hot summer, when temperatures rose enough to stress and bleach the corals, the antibiotic activity of the coral slime disappeared. Ritchie attributes this loss to changes in the consortium of microbes inhabiting the slime of stressed corals. Indeed, she showed that when bleaching began to set in, antibiotic-producing guests fled even still-healthy portions of a coral.

HORN OF PLENTY — Strings of mucus shed by this large staghorn coral in the Red Sea dangle visibly before they're washed away.

Kushmaro and his colleagues similarly find antibiotic activity in at least one-quarter of the microbes cultured from 10 healthy coral species growing in the Red Sea. They presented their preliminary data at an International Symposium on Microbial Ecology last August in Vienna.

A vastly more numerous class of mucus microbes—viruses known as bacteria-eating phages (*SN: 7/12/03, p. 26*)—may also play an important role in coral health. Focusing on the coral *Porites compressa* in Hawaiian waters, Rebecca Vega Thurber of San Diego State University has been comparing phages in its mucus with those in adjacent seawater.

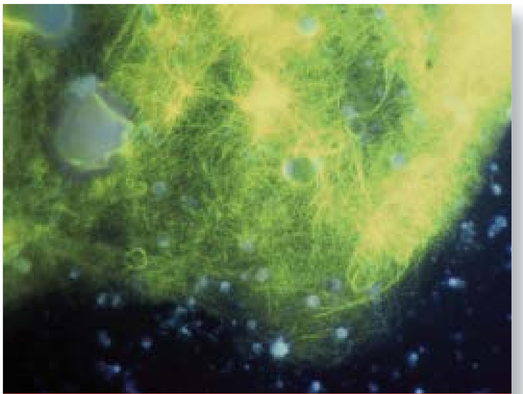
Not only are the antibacterial phages far more numerous in the slime, the marine biologist notes, but they also are more likely to be "phages that infect known [coral] pathogens, such as *Vibrio harveyi*." Thurber told *Science News* that when the corals became stressed, "I saw a huge increase in the phage that infects *V. harveyi*. This tells us that maybe we've also gotten an increase in that [bacterial] pathogen, during that stress."

ENCOURAGING PICTURE? Although evidence is accumulating that microbes help corals, Rosenberg, Thurber, Smith, and others caution that the link, though tantalizing, remains unconfirmed. It's impossible to prove how much help bacteria or other microbes provide without comparing corals whose mucus lacks

SMITH; WILD

ostensibly beneficial bugs with those whose mucus has been deliberately inoculated with such microbes.

Rosenberg's group is about to do just that. It's a necessary test for the "probiotic hypothesis" that his team announced in the December 2006 *Environmental Microbiology*. Rosenberg, Smith, and other members of the United Nations' Coral Disease Working Group further describe the idea in the March *Oceanography*.



TEEMING HORDES — Magnified bacteria—stained yellow to highlight them—fill this mucus from near a coral's surface.

WILD

Probiotics typically are bacteria-laden dietary supplements for people (*SN: 2/3/01, p. 68*) or animals (*SN: 3/28/98, p. 196*). By seeding the body with bacteria that enhance immunity or other beneficial biological functions, probiotic treatments seek to prevent disease or restore health. Lately, marine biologists have begun embracing the idea that corals may exude compounds to lure beneficial microbes into their mucus to create a probiotic community.

The idea makes intuitive sense, Bythell says. Many probiotics target the gut, attempting to overwhelm pathogenic bacteria with a huge, replenishing dose of beneficial ones. Coral mucus resembles mucus lining the human gut. In fact, he says that a medical colleague to whom he showed a photo of a coral's mucus-producing cells was stunned. "If you told me this was a human gut, I'd have believed you," Bythell recalls him saying.

Gut flora—largely beneficial bacteria—helps digest foods, boost immunity, and prevent colonization by germs. Corals, one of the animal kingdom's most primitive multicellular families, appear to accomplish the same thing, he says, using "a mucosal system that's virtually identical, structurally, to our gut."

Rosenberg suspects that the symbiosis that develops between various microbes and corals might even have evolutionary significance. For instance, in 1995, Kushmaro linked devastating bleaching incidents in the Mediterranean Sea's *Oculina patagonica* coral to an infection by *Vibrio shilonii*. It was the first time that coral bleaching had been traced to a bacterial infection, and bleaching infections recurred every summer through 2002.

By the following summer, however, the coral's vulnerability had disappeared. Sampling its mucus turned up no *V. shilonii*, and deliberately inoculating the mucus with the bug "does not result in coral bleaching," Rosenberg's group reports in the May *Nature Reviews Microbiology*. Indeed, they find that within 4 days, the added germs can no longer be found.

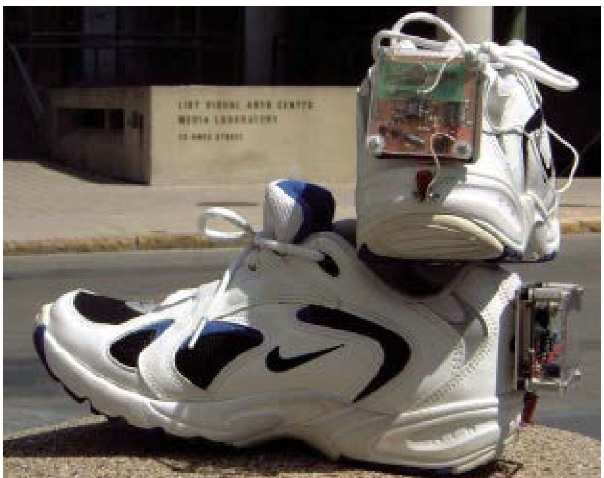
It appears, Rosenberg says, that the corals recruited mucus microbes to quash the would-be killer germs. Certainly, the corals didn't have enough time to evolve resistance on their own, he says. But by developing new symbiotic relationships with bacteria or phages, they adapted to the germs' presence.

Similarly, photosynthetic bacteria have been found in some coral tissues, suggesting a way in which the animals might gain sustenance when high temperatures send their algal symbionts fleeing.

Taken together, the new findings give some reason for optimism about the globe's besieged corals. In view of rising concerns about global warming's threat to corals, Rosenberg suggests, it could be that corals can adapt to environmental change more rapidly than their own genes would permit. ■

(continued from page 345)

To demonstrate how these properties can work in concert, he and his team grew a forest of upright zinc oxide nanowires, each of them a perfect crystal. The researchers then lowered an array of sharp nanoscale electrodes fabricated by similar techniques, leaving just enough space so that when the nanowires flex, they touch the electrode tips.



SHOE POWER — In an early experiment at the Massachusetts Institute of Technology, an energy scavenger built into the sole of a running shoe harvested about 60 milliwatts of the power a person expended while walking.

PARADISO

When ambient vibration or other mechanical energy deflects the nanowires, they develop piezoelectric voltages that move charges within the semiconducting material. During the periodic contacts between the nanowires and the electrodes, those charges move into the electrodes.

This effect could be the basis of energy scavengers with efficiencies as high as 30 percent, Wang predicts. "I have a high hope that we will be able to market commercial zinc oxide nanogenerators within 3 years," he says.

ONBOARD ENERGY MANAGEMENT Efficiency is also a major goal of electrical engineers and software designers working on a third piece of the energy-scavenging challenge—managing how the energy is employed by the sensor package itself. One frequently used strategy is to have the devices spend most of their existence in sleep mode, where they can survive on just the barest trickle of power. They have to wake up for only a tiny fraction of a second every now and then to take a quick instrument reading and, if necessary, beam back a few bits of data.

Nonetheless, notes Priya, that "beaming back" part continues to be tough. "Present-generation sensors are very efficient and consume only 50 to 100 microwatts. But a transmitter consumes on the order of 50 milliwatts," he says.

To give the transmitter enough power for its occasional bursts of activity, the device would need to accumulate scavenged energy in some sort of long-lived battery. The relatively new technology of thin-film lithium-ion batteries is especially appealing for such applications, says Arms. "They are paper-thin and flexible, and they can go through an essentially infinite number of recharging cycles," he says.

The final step in the energy-scavenging challenge is to integrate all the pieces into robust, complete systems (*SN: 5/5/07, p. 282*).

"The long-term dream is that everything will be fabricated on a single wafer," says Wright. Then, the devices could be produced en masse. Wright notes that, for example, Elizabeth Reilly of the Berkeley group is already making such integrated devices in the lab with MEMS processes.

The bottom line, Wright adds, is that energy-scavenging technology has a long way to go—but it is moving fast. ■

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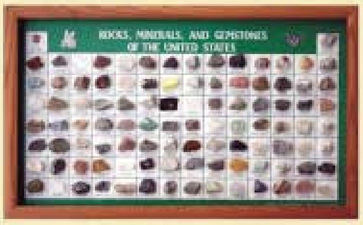

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"You Are Here" Poster

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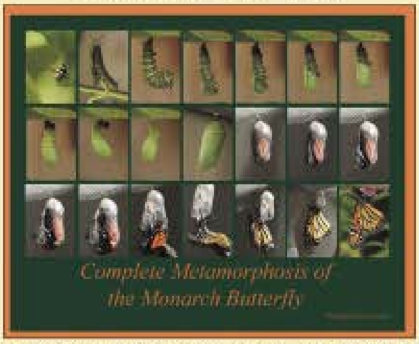

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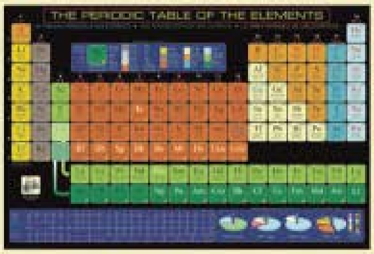

The Periodic Table of the Elements - Poster

This periodic table poster has the regular information, a picture of Dimitri Mendeleev and a legend denoting: atomic number, electron configuration, atomic weight, atomic symbol and whether the element is radioactive or not. This poster has the typical color designations according to alkali metals, alkaline earth metals, transition metals, etc. A well-designed graph on the bottom portion shows when the element was discovered and the percentage of certain types of elements found in the atmosphere, biosphere, hydrosphere, and lithosphere. Size: 26.5" X 38.5", Laminated **Order#JPT-3103, Cost: $15.95; 2 for $30, Order #JPT-3103-2**, plus shipping

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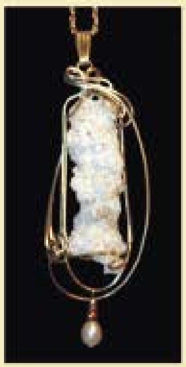

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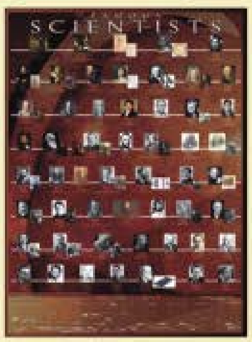

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OF NOTE

BIOMEDICINE

Stem cells not required

The pancreas doesn't include stem cells that become insulin producers. Instead, the cells that make the hormone proliferate by dividing, researchers have discovered. The finding could have implications for future diabetes treatments.

Many of the body's tissues harbor caches of so-called adult stem cells that act like factories, churning out fresh cells to replace old ones. Some scientists had speculated that pancreatic stem cells exist, and that they might provide new treatments for diabetes. The new research suggests that scientists should instead search for ways to encourage insulin-producing cells, called beta cells, to divide more rapidly, says Jake Kushner, lead scientist for the study at the Children's Hospital of Philadelphia.

By feeding healthy mice a component of DNA modified to glow either red or green, Kushner's group could see beta cells once they formed in the animals. The team alternated the color every few weeks. Stem cells would go through several rounds of division in order to become beta cells, and so would incorporate both colors. Beta cells would divide only rarely and take on one color or the other, which is what the researchers saw.

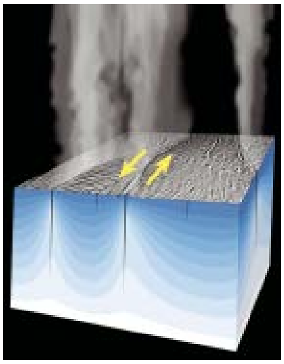
"In every case, the beta cells were self-renewing, and there wasn't even a tiny contribution by cells that were undergoing more than one round of cell division," Kushner says. This result shows that active stem cells weren't present, the researchers report in the May 8 *Developmental Cell*. —P.B.

PLANETARY SCIENCE

Powering Enceladus' plumes

Astronomers in 2005 were astonished to find that Saturn's tiny, chilly moon Enceladus expels giant plumes of water vapor from an array of cracks marking its southern hemisphere. Because Enceladus is so small, researchers reasoned that it ought to have lost any interior source of heat long ago, and so should be frozen solid (*SN: 5/6/06, p. 282*).

In the May 17 *Nature*, two teams trace the origin of the plumes to the action of Saturn's gravity. Francis Nimmo of the University of California, Santa Cruz and his colleagues calculate that gravitational stresses, or tides, generated by Saturn make the sides of the cracks on Enceladus rub back and forth. The resulting friction creates enough heat to vaporize ice and to power the plumes, the researchers say.



GRAVITY'S HEAT Plumes of water vapor escape from surface cracks on Saturn's moon Enceladus. Theorists say that Saturn's gravity jiggles the cracks (yellow arrows in this illustration), melting ice to create the plumes.

A second team, which includes Terry Hurford of NASA's Goddard Space Flight Center in Greenbelt, Md., gives a more specific calculation of how Saturn's gravity opens and closes the cracks during each of the moon's 1.3-Earth-day orbits about the planet.

Because Enceladus follows a slightly elongated orbit, the tidal forces at its surface vary in strength as the moon's distance from Saturn changes. In addition, the location on Enceladus' surface where the tides are strongest varies throughout each orbit.

These two effects, acting in concert, force open most of the cracks when Enceladus is farthest from the planet, and close most of them when the moon is closest, the team's calculations indicate.

Assuming that water vapor shoots out as soon as a crack opens, researchers can use the model to predict when each fracture is likely to erupt. —R.C.

PHYSICS

Carbon's mysterious magnetism

An X-ray experiment has produced the most conclusive evidence yet that carbon can be made into a permanent magnet.

Only a few elements are magnetic at room temperature. They are metals whose atoms have a magnetic moment arising from the spin of an unpaired electron. Pairs of electrons with opposite spin produce no net magnetic moment. Since carbon tends to form covalent bonds, which contain paired electrons, it seems an unlikely candidate to be magnetized.

But several experiments have suggested that under certain conditions, forms of bulk carbon such as graphite can acquire a feeble permanent magnetization. Most physicists regard these results with skepticism, however, since even trace contamination by a metal such as iron could make a sample slightly magnetic.

Now, a team led by Hendrik Ohldag of the Stanford (Calif.) Synchrotron Radiation Laboratory has found magnetism in a sample of graphite that had been irradiated with protons. The researchers detected a magnetic moment through the effect it had on the absorption of polarized X rays. To rule out contamination, they tuned the energy of the X rays so that they interacted with carbon atoms but not with iron atoms. The results appear in the May 4 *Physical Review Letters*.

Ohldag says that the proton bombardment could have permanently deformed the hexagonal lattice of carbon atoms in graphite, creating some noncovalent bonds between atoms. —D.C.

EARTH SCIENCE

Using seismometers to monitor glaciers

Seismic instruments could be used to estimate the amount of ice that shears away from glaciers as they flow into the sea, offering a way to better estimate sea level rise due to the breakup of those ice masses.

In 2004 and 2005, Shad O'Neel, a glaciologist at the University of Colorado at Boulder, and his colleagues installed a network of 11 seismometers around the lowermost portions of Alaska's Columbia Glacier. The researchers found that the seismic waves produced by disintegration of the glacier could be distinguished from waves generated by earthquakes because the two phenomena created vibrations at different frequencies, says O'Neel.

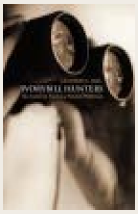
Surprisingly, the strength of an icequake's vibrations didn't bear any relation to the amount of ice that broke away from the glacier. Instead, the researchers note in an upcoming *Journal of Geophysical Research (Earth Surface)*, it was the duration of an icequake that correlated with the amount of ice shed during the event. That connection could enable scientists to use networks of seismic instruments to monitor ice loss from remote glaciers in Greenland and Alaska, reducing the need for long and costly field trips. —S.P.

JPL/NASA, SPACE SCIENCE INSTITUTE

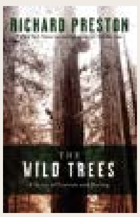
Books

A selection of new and notable books of scientific interest

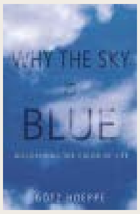
IVORYBILL HUNTERS: The Search for Proof in a Flooded Wilderness
GEOFFREY E. HILL
At the start of this century, most naturalists thought the ivory-billed woodpecker had been hunted to extinction. In 2005, a team from the famed ornithology department at Cornell University stunned the birding world by announcing that it had found the elusive ivorybill in the wetlands of eastern Arkansas. However, the excitement was tempered by skepticism from other researchers. In this book, Hill, an ornithologist at Auburn University, documents his own search for the ivory-billed in the northern panhandle of Florida. As luck would have it, within an hour of entering the Choctawhatchee River, he and a companion felt sure that they saw an ivory-billed. The researchers' next mission would be to get a documented sighting and a sound recording worthy of reporting in a scientific journal. Hill devotes the remainder of his story to recounting how he followed leads from amateur birders and attempted to navigate the confusing system of rivers and creeks in the supposed ivory-billed habitat. He also reviews the science behind the Arkansas announcement. ***Oxford, 2007, 260 p., b&w photos, hardcover, $24.95.***



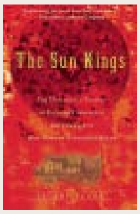
THE WILD TREES: A Story of Passion and Daring
RICHARD PRESTON
Redwood trees are the largest living things on Earth, with trunk diameters that run up to 10 meters and heights of up to 30 stories. Preston, author of the thriller *The Hot Zone* (1994, Random House), tells a story of adventure and scientific discovery. Much of the action takes place in the canopies of Northern California's redwood forests. Dangerous ascents to the tops of these trees reveal a world of hanging ferns, mosses, and animal species. Preston recounts the history of these ancient trees, some of which have been alive since before the fall of the Roman Empire. While many of the redwoods have been logged, pockets of deep, dark, and relatively undisturbed forest still exist. In a parallel narrative, Preston recounts the search for the tallest living tree. He reveals the private and personal struggles of the redwoods team and his own experience as part of it. ***Random House, 2007, 291 p., b&w illus., hardcover, $25.95.***



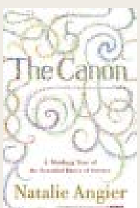
WHY THE SKY IS BLUE: Discovering the Color of Life
GÖTZ HOEPPE
In a revised translation of the German edition of his book, science writer and editor Hoeppe explores the answer to one of humanity's—at least its younger members'—most recited questions: Why is the sky blue? The deep azure has been pondered throughout the ages by people of all cultures, writes Hoeppe. Early Greek explanations introduced the correct idea that the blue color is a consequence of sunlight reflecting off air. Hoeppe expands on this idea and outlines other ancient and modern explanations for the sky's familiar color. He chronicles the efforts of legions of scholars, from the Arab mathematician Alhazen to Isaac Newton, to explain the nature of light and color. The author delves into the technical side of optics, explaining why Rayleigh scattering is the current explanation for why the sky is blue. ***Princeton, 2007, 336 p., color plates, hardcover, $29.95.***



THE SUN KINGS: The Unexpected Tragedy of Richard Carrington and the Tale of How Modern Astronomy Began
STUART CLARK
In 2003, Earth was hit with a barrage of particles of supercharged radiation from a series of massive solar flares, and some radio communications were knocked out. Some 150 years earlier, observers watched with awe and horror as a massive aurora of strange lights spanned the globe. At that time, the only scientist who could correctly explain what was happening was a young astronomer named Richard Carrington. He was the first to suggest that the strange lights were connected to activity on the surface of the sun. Clark, author and former editor of *Astronomy Now*, tells the story of Carrington's discovery, how some of his contemporaries were loath to believe him, and how others rallied behind his hypothesis. Until that point, the sun wasn't known to have a connection to climate change and magnetic events. From this starting point, Clark summarizes the struggles of these early astronomical visionaries and relates their work to that done by modern-day scientists. ***Princeton, 2007, 211 p., b&w images, hardcover, $24.95.***



THE CANON: A Whirligig Tour of the Beautiful Basics of Science
NATALIE ANGIER
On the whole, people in the United States are low in science literacy and uncomfortable with the type of analytical reasoning that's behind science, Angier asserts. An award-winning science writer for the New York Times, she explains why science needn't be the boring, imposing field it's often made out to be. Indeed, understanding how the world works should be a source of joy and wonder. She provides a beginner's guide to science for adults who have forgotten how probability works, the difference between a proton and a neutron, and the principles behind natural selection. Beyond such basics, she explains the scientific context of many of today's headlines, including those about embryonic stem cells, avian flu, and global warming. With often-humorous prose, Angier outlines the nuts and bolts of physics, chemistry, evolutionary and molecular biology, geology, and astronomy. ***Houghton Mifflin, 2007, 293 p., hardcover, $27.00.***



LETTERS

Where there's fire

Regarding "Risky Flames: Firefighter coronaries spike during blazes" (*SN: 3/24/07, p. 180*), was the increased death rate due to firefighters having a higher rate of heart disease than people do in other jobs? An analysis of eating habits may reveal more insight.
JIM SCHMITZ, ST. LOUIS, MO.

The study looked only at what the firefighters were doing at the time of death. It didn't compare their heart-disease rates with those in other groups. However, the study authors suggest that the work life of firefighters, which includes significant downtime interspersed with extreme exertion, may contribute to heart disease. —B. VASTAG

Sore gripes

The study on canker sores ("Patches take sting out of canker sores," *SN: 4/7/07, p. 222*) compared an "untreated" group with a group using licorice patches. A more valid comparison would be for the control group to be treated with patches that contained no licorice.
JANET MCCLURE, CARDIFF, CALIF.

Not so fast

"Asian Trek: Fossil puts ancient humans in Far East" (*SN: 4/7/07, p. 211*) "underscores the vast distances" humans moved from Africa to northern China in 20,000 years. However, if one stops to consider the time frames, it's extremely unremarkable. At three generations every 100 years and roughly 6,000 miles from Africa to China, people would need to move only an average of 10 miles per generation. Wow, what travelers!
ALEX SHERER, ESCONDIDO, CALIF.

Pick your poison

The fact that more people are overdosing on niacin to cover up relatively benign marijuana use ("Not-So-Artful Dodgers: Countering drug tests with niacin proves dangerous," *SN: 4/7/07, p. 212*) exemplifies what's wrong with the failed "War on Drugs" approach.
CHRIS MAJ, DENVER, COLO.

Correction *For want of a comma, "Wanted: Better Yardsticks" (*SN: 4/21/07, p. 251*) incorrectly indicated that "T rays have a frequency that's a trillion cycles per second higher than that of standard microwaves. ..." The rays have a frequency of about a trillion cycles per second, higher than that of standard microwaves but below that of infrared radiation.*

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