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ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ MARCH 28, 2009

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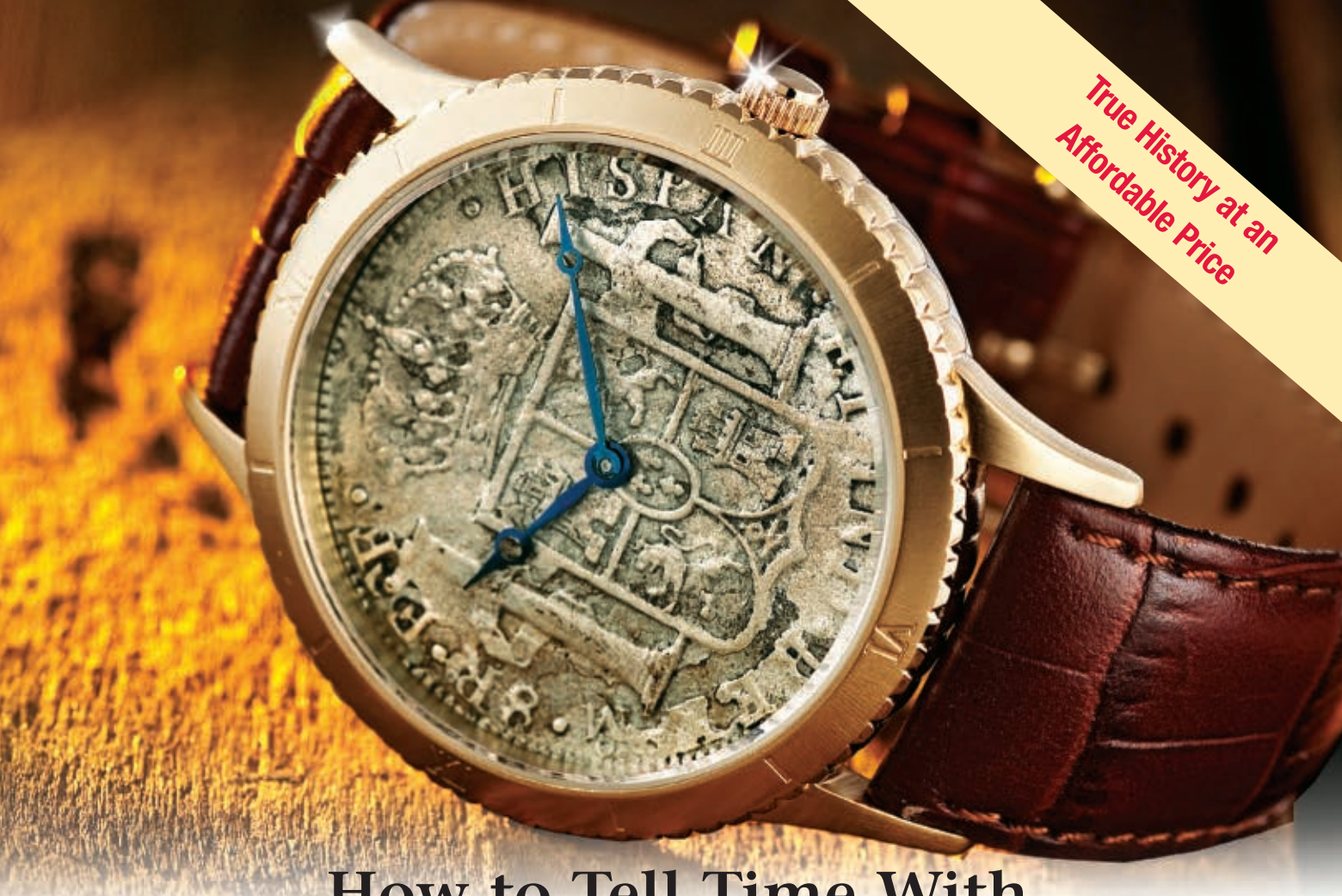

How to Tell Time With Washington's Spare Change

An exclusive Stauer timepiece featuring a genuine 1783 Silver Dollar of the American Revolution.

If you're an avid fan of early American history like me, you probably visit the historic sites, walk the battlefields and stand beside beds where George Washington slept. You've admired our country's heritage, but until now, you've never been able to carry a piece of that storied past with you.

We have acquired a select cache of rare and historic 1783 silver dollars. Our Founding Fathers recognized that the Spanish silver piece was the most desired coin in colonial America. Thomas Jefferson recommended the Continental Congress adopt it as our nation's first monetary standard of value. The Congress agreed.

History in the making. Perhaps most importantly, each of these coins was struck in 1783—the year General Washington won the Revolutionary War against the British and earned our nation's freedom. My challenge to Stauer's watchmakers was to craft a fine timepiece with this remarkable 1783 silver dollar as the centerpiece. The result surpassed my greatest expectations.

The watch features an authentic 1783 Spanish silver dollar securely set inside a handsome stainless steel case layered in 18K gold. The reverse side of the coin was chosen as the watch face to highlight the detailed image of the crowned coat of arms set between the Pillars of Hercules. Every 226-year-old coin is uniquely worn and aged, distinguishing each watch as a one-of-a-kind keepsake. Two blue, Breguet-style hands keep time using recessed Roman numerals along the outside of the dial.

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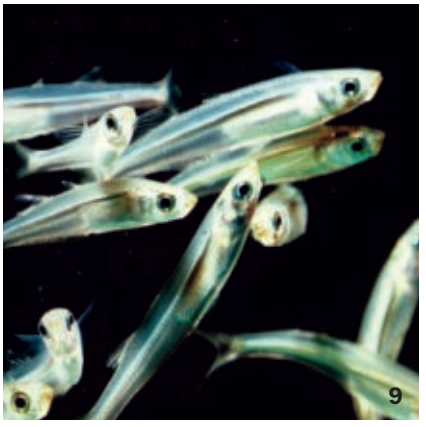

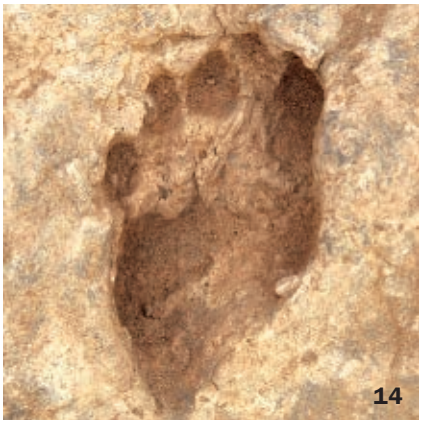

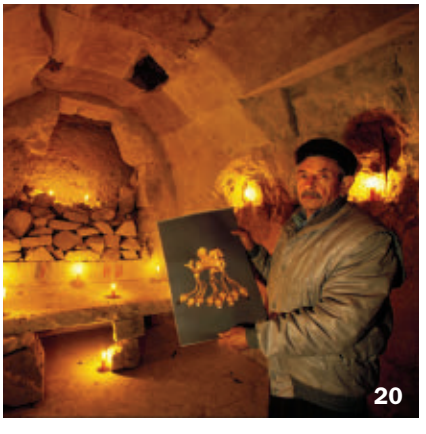

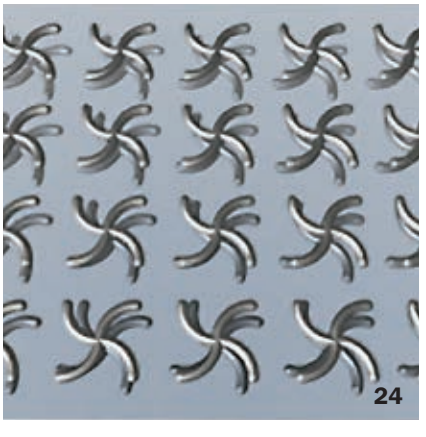

ScienceNews

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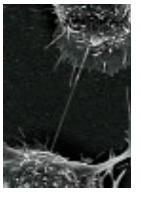

COVER A tunneling nanotube keeps rat cells in touch, as shown by 3-D live-cell microscopy. *Image by Amin Rustom* et al., Science/AAAS

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FROM THE EDITOR

News from frontiers helps to ensure science's future

In this issue (Page 12) we report the winners of the 2009 Intel Science Talent Search, or STS, a program of Society for Science & the Public, which also publishes *Science News*.

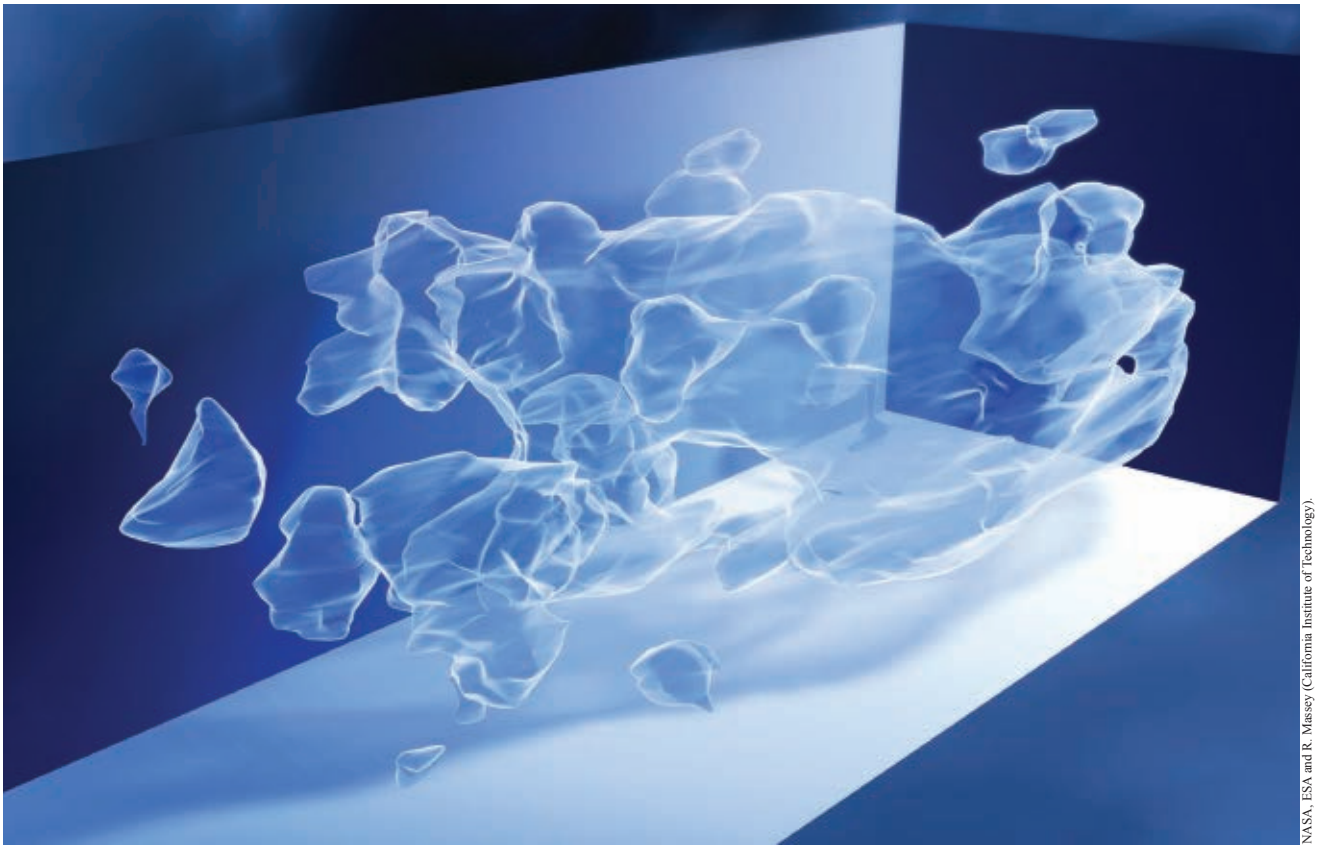
From its inception in 1942, STS has recognized the best and brightest of the nation's high school seniors. Almost 140,000 students have entered the competition. Of the 2,720 finalists, seven have won Nobel prizes, at least 10 have been named MacArthur Fellows and 30 elected to the National Academy of Sciences. Year after year, STS students exhibit intellectual tenacity and scientific sophistication suggesting that the scientific future isn't as bleak as it sometimes appears.

Yet the success of STS students doesn't quite eliminate all cause for concern. While science no longer gets bashed quite as badly in Washington these days, it is still getting bashed pretty badly in the media, or rather by the media's owners. In recent years, newspapers, magazines and other media have been drastically diminishing their attention to science coverage. Newspaper science reporters are more endangered than black rhinos or giant pandas. The *Los Angeles Times* and *Newsday* have dismantled their once-sizable staffs of expert science journalists. In February the *Boston Globe* closed its science and health section. Recently CNN disbanded its science unit, dismissing one of America's preeminent TV science journalists, Miles O'Brien. One newsmagazine, having cut some of its best science writers, now runs stories on its website provided by the government, disguised as news. At a science journalism awards ceremony, at the American Association for the Advancement of Science meeting last month in Chicago, the winners in the newspaper category both noted that they no longer had jobs.

All of this raises the issue of where future participants in the Science Talent Search will encounter the inspiration to pursue the great unanswered questions that science still poses. From their school textbooks? Right. For science to flourish in the future, young minds need to be exposed to the drama and excitement of science — as it can only be conveyed in news dispatches from the frontiers. If there's no more science news, there will be a lot less interest in pursuing science generated among the nation's youth.

Fortunately, there is still *Science News,* and there is some comfort in that. Nevertheless it should still be a great concern that there is less and less science news everywhere else.

—Tom Siegfried, Editor in Chief



NASA, ESA and R. Massey (California Institute of Technology)

What is the Universe *Really* Made Of?

In recent years, scientists have discovered that 95 percent of the contents of the cosmos is invisible to all current methods of direct detection. Yet something is definitely there, governing the shape and fate of our universe. These phenomena, called dark matter and dark energy, are the most eagerly studied subjects in astronomy and particle physics today. And for good reason—What could be more exciting than cracking the mystery of the fundamental components and composition of the universe?

Join the search in **Dark Matter, Dark Energy: The Dark Side of the Universe**. This mind-expanding course of 24 lectures, taught by expert theoretical physicist and award-winning Professor Sean Carroll, explains the latest complex picture of the universe in easy-to-follow terms. Embark on a fascinating voyage of scientific discovery, from the insights of Albert Einstein to the latest ground-breaking concepts in theoretical physics and astronomy. You'll quickly discover how this "dark side" of the cosmos has brought us, for the first time in history, to the brink of knowing what the universe is made of.

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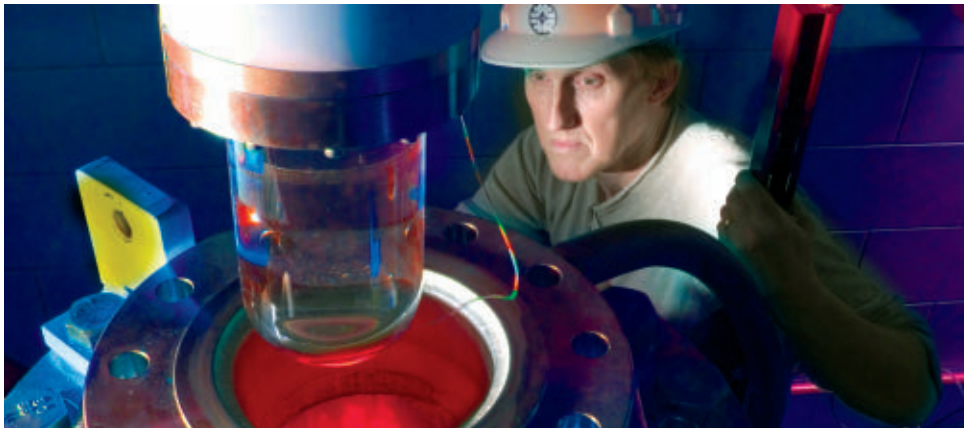
Scientific Observations

"We use the phrase *dark matter* in the same way the early mapmakers used *terra incognita*. We don't know what it is." **FERMILAB'S MICHAEL CRISLER, SPEAKING ABOUT THE SEARCH FOR WEAKLY INTERACTING MASSIVE PARTICLES IN FEBRUARY AT THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE ANNUAL MEETING**



Science Past | FROM THE ISSUE OF MARCH 28, 1959

[PATIENTS] TO RUN OWN WING IN HOSPITAL — A new wing which is being added to an English mental hospital will be run entirely by the patients. Doctors and nurses will enter it only by invitation. Administration will be by a committee of patients, which will have a room for meetings.... Patients will themselves decide how they wish to spend their time, and they will be free to invite relatives and friends inside.... "Even when a patient is mentally fit again," said one of the doctors, "he has to learn again to live with other people in a normal setting. This resocialization is a vital process. If it is done within the walls of an ordinary hospital, the difficulty is that patients are always aware that they are patients and the staff that they are staff."

Science Future

April 6
Lawrence Krauss and other scientists give public lectures as part of Arizona State University's Origins Symposium in Tempe. Visit origins.asu.edu

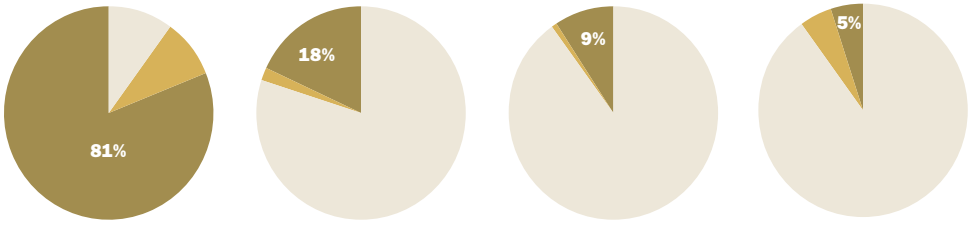
April 11
Food for Thought, an interdisciplinary conference on global food and agriculture issues, held at Stanford University. Visit foodforthought.stanford.edu

April 12–18
National Environmental Education Week. See www.eeweek.org

Science Stats | NATIVE BEES BRING HOME THE BACON TOO

Percentage of select U.S. crop production value resulting from different forms of pollination, 2001–03

■ Wild native bees ■ Managed honeybees □ Noninsect



Squash
Average annual value: $192,300,000

Strawberry
Average annual value: $1,187,600,000

Grape
Average annual value: $2,774,800,000

Soybean
Average annual value: $15,095,200,000

SOURCE: JOHN E. LOSEY AND MACE VAUGHAN. *BIOSCIENCE* 2006

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EARTH

Since 1984, the Landsat 5 satellite has photographed Earth's surface, including this March 1 image of Alaska's rumbling Redoubt Volcano. Read "Watching Earth for 25 years."

MATTER & ENERGY

Fermilab researchers can find a needle in a haystack, or at least the elusive individual top quark in the noise of data from a particle accelerator. The success of their technique bodes well for finding the theorized Higgs boson particle, two teams report. Read "Single top quark detected."

For Daily Use

Scientists have finally confirmed what revelers already knew: Chilling champagne gives it a long-lasting, optimal fizz, while warmer temperatures cause CO_2 to be released in an initial, unpleasant burst. Experimenting at temperatures of 4°, 12° and 20° Celsius, a team reports online February 12 in the *Journal of Agricultural and Food Chemistry* that lower temperatures help retain champagne's effervescence by slowing the loss of dissolved CO_2.

CLOCKWISE FROM TOP LEFT: FERMILAB; U.S. GEOLOGICAL SURVEY; JACK DYKINGA/USDA ARS

“The orbits go wild—they gyrate and spin, they’re incredibly complex. It’s fantastic.” —CLIFFORD WILL, PAGE 8

In the News

STORY ONE

Scientists find a soup of suspects while probing milk’s link to cancer

Latest studies focus on estrogens, androgens and IGF-1

By Janet Raloff

Got milk? Adults who answer yes may face a slightly heightened risk of cancer. Some emerging data may help scientists figure out why.

For more than a century, people thought that any beverage safe enough to serve to a weaning child couldn’t hurt an adult. But test-tube studies and studies in adults over the past decade have linked cow’s milk with an excess cancer risk in the prostate, and to a lesser extent in the breast and ovaries, notes oncologist Michael Pollak of McGill University in Montreal. Although scientists seeking to explain the link have fingered some suspects—such as milk’s natural stew of hormones, growth factors and other biologically active chemicals—there’s no “smoking gun,” he says.

But a new study by researchers at the National Cancer Institute at Frederick, in Maryland, offers some ammunition.

Timothy Veenstra and his colleagues assayed grocery-store milk for 15 estrogens: estrone, estradiol and 13 metabolic derivatives of these female sex hormones.

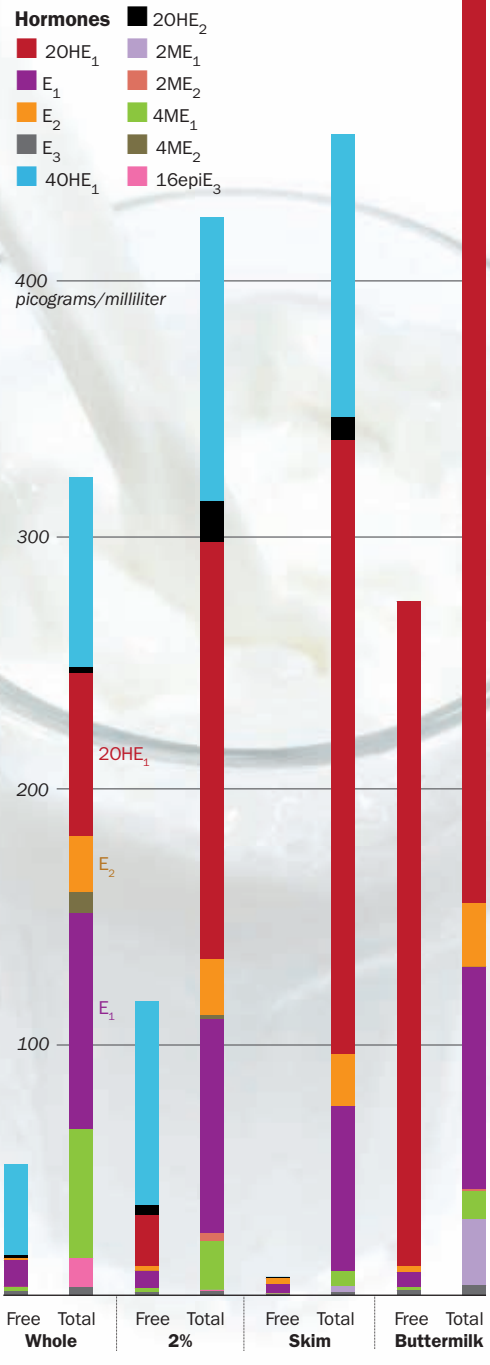
Typically, hormones are produced in the body for use in the body. They act as orchestra conductors, telling genes when to turn on and off. But externally derived hormones add noise.

Estrogens can fuel the growth of many tumors, even in the prostate—and estrogen can do this at amazingly tiny concentrations. Identifying how estrogens’ prevalence varies by milk type, and in what chemical form the hormones occur, required a new assay, which the NCI scientists describe in an upcoming issue of the *Journal of Chromatography B*.

Using that technique, they showed that the mélange of estrogens varies widely between milks. Whole milk contained the smallest quantity of estrogens, and amounts ascended from 2% to skim and buttermilk. In all of these milks, the majority of estrogens had undergone a minor chemical modification, rendering them less directly bioavailable and less hormonally active.

However, these modified, or conjugated, estrogens are not inert, and they can be converted back to their more potent parent compounds. What’s more, the NCI scientists note, studies by others have shown that relative to free, bioavailable estrogens, conjugated ones take longer to get from the gut into the blood.

Veenstra’s team concludes that com-



More than milk
A new analysis measured the relative abundance of estrone (E_1), estradiol (E_2) and their metabolites in different types of milk. Bars show total estrogens versus free estrogens, which are directly bioavailable. These data reveal no obvious trends related to fat or protein content of milk, but some of the estrogens, including 2-hydroxyestrone ($20HE_1$), are already known to be dangerous.

ADAPTED FROM D.W. FARLOW *ET AL., JOURNAL OF CHROMATOGRAPHY B* 2009; DNY59/ISTOCKPHOTO

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pared with free estrogens, milk's conjugated ones "are likely to have longer half-lives."

Overall, skim milk had the smallest quantity of free estrogens. However, the conjugated type that dominated skim milk's profile, 2-hydroxyestrone, is known to be one of the most reactive and potentially risky of the metabolites, notes Xia Xu, a toxicologist on the NCI team. That metabolite's concentration in fat-free milk was second only to buttermilk's.

Dermatologist F. William Danby, who teaches at Dartmouth Medical School, also worries about other sex hormones in milk — the "male" androgens.

While estrogens may fuel tumor growth in reproductive tissues, certain androgens — ones that Danby refers to as 5alpha-reduced androgens — "have the capacity for increasing the number of estrogen receptors." In the January/February *Dermato-Endocrinology*, Danby notes that milk contains at least one receptor-proliferating androgen: 5alpha-pregnanedione.

Extra receptors, he explains, permit more estrogen — including any from milk — to unlock the cellular machinery that can turn tumor growth on. In other hormone systems, when excess hormone shows up, the body often cuts back on its production. Because the body has had relatively little evolutionary time to adapt to dietary sources of the 5alpha-reduced androgens, Danby says, no such feedback system has evolved.

"And this is probably the most important thing," he says. Milk-derived hormones "are being poured into a system that didn't anticipate them" — at least in adulthood.

One of the most provocative aspects of the milk story is its impact on insulin-like growth factor 1. Many studies have linked elevated concentrations of IGF-1 with cancer risk. Not only is milk a rich source of the substance, but people who drink milk also end up with more IGF-1 in their blood.

As with so much in science, however, the IGF-and-milk story is anything but simple, notes David Kleinberg, an endocrinologist at New York University School of Medicine.

Ordinarily, IGF-1 production is turned on when human growth hormone, produced in the pituitary gland, hits certain tissues. IGF-1 becomes the growth hormone's agent to locally trigger cell growth.

"We showed that IGF-1 can completely take the place of growth hormone" in breast tissue, Kleinberg says. In other words, IGF-1 can trigger cell growth without an outside cue.

Although estrogen is linked to breast development, it's impotent in the absence of IGF-1. Estrogen can amplify the cell-proliferating effects seen with IGF-1, his team has shown — both in the breast and prostate.

In the February *Endocrine Reviews*, Kleinberg and his colleagues note that when an excess of IGF-1 or estrogen occurs in the presence of the other, breast hyperplasia occurs — essentially cell division on overdrive.

"And when you get hyperplasia, it can put one at risk for breast cancer. Very slightly at risk," he says, "like maybe less than a doubling of risk."

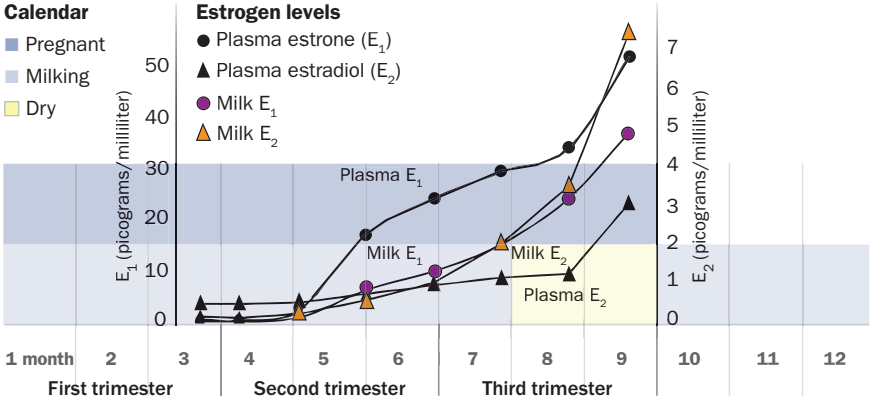
But the real kicker: "There's a lot of interpersonal variability in our natural production of IGF-1," Pollak points out. "And even though we are sure that drinking more milk will increase your IGF-1 level, milk's contribution will still only account for a trivial part of the variation between people."

Which means genetics trumps milk intake. So people who naturally rank in the top quarter in terms of IGF-1 production and drink no milk, Pollak explains, "will still have a higher IGF-1 level than someone in the low quartile who drinks a quart a day."

Against this ambiguous backdrop, what's a milk drinker to do? Because the body of knowledge about this beverage's human bioactivity is still in its infancy, people may just have to employ the precautionary principle, Pollak says.

"In the absence of definitive [safety] data — or the presence of an adverse effect which may be small — you have to decide: Is there anything good about milk?" And other than developing children and malnourished adults, people probably don't need milk, he says. "I would never say anything stronger than that." ■

Back Story | DAIRY COW HUSBANDRY AND HORMONES



Estrogen levels vary by type of milk, but when a cow is milked also affects the content. U.S. cows are milked 10 months a year (light blue) and are pregnant for nine (darker blue). Estrone and estradiol levels increase in the cow (Plasma E_1/E_2) and her milk (Milk E_1/E_2) during pregnancy. The cows are dry, or not milked (yellow), for two months before giving birth, when estrogen levels are highest. One study has shown that estrogen levels are lower in milk from cows kept by a nomadic group in Mongolia that milks cows for human drinking just six months a year and only early in pregnancy.

SOURCES: GRAPH FROM ZAMBITO *ET AL./JOURNAL OF DAIRY SCIENCE*; CALENDAR ADAPTED FROM AKIO SATO AND GANMAA DAVASAAMBUU

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Curious constant for black holes makes an unexpected appearance

Physicists puzzled by Newtonian analog to relativity math

By Rachel Ehrenberg

If you were orbiting a rotating black hole, you might be in for a wild ride of dizzying and seemingly unpredictable gyrations. Yet more than 40 years ago, a physicist found a mathematical constant that revealed regularity in that ride. Now a similar constant has been discovered in a mild-mannered Newtonian system, reports a paper in the Feb. 13 *Physical Review Letters*.

The findings could be a mere mathematical curiosity, comments astrophysicist Saul Teukolsky of Cornell University. But, he says, they could shed light on the mysterious conditions of rotating black holes, which are predicted to exist by Einstein's general relativity equations.

Rotating black holes are thought to be the end point in the evolution of massive stars that collapse under their own gravity when their nuclear fuel is exhausted. For black holes with no electrical charge, the gravitational field depends on only mass and spin. Strangely, this simplicity holds true even though a rotating black hole doesn't have perfect symmetry. Like any rotating object, a black hole becomes slightly flattened from centrifugal forces (just as the Earth bulges at the equator).

That loss of symmetry in a massive rotating black hole suggests that anything orbiting it, such as a neutron star, would behave erratically. Such orbits do appear chaotic, says physicist Clifford Will of Washington University in St. Louis, author of the new paper.

"The orbits go wild — they gyrate and spin, they're incredibly complex. It's fantastic," Will says.

But in 1968, physicist Brandon Carter discovered a mathematical constant that showed the orbits are predictable.

"Black holes have this extra constant that restores the regularity of the orbits," Teukolsky says. "Every other situation where we have these extra constants, we have symmetry. But there's no symmetry for an orbiting black hole — that's why it is regarded as a miracle."

There's no obvious reason why the Carter constant should emerge in the general-relativity description of spinning black holes, says Teukolsky. By looking for it in other places, scientists might learn more about the specialness of conditions surrounding such black holes.

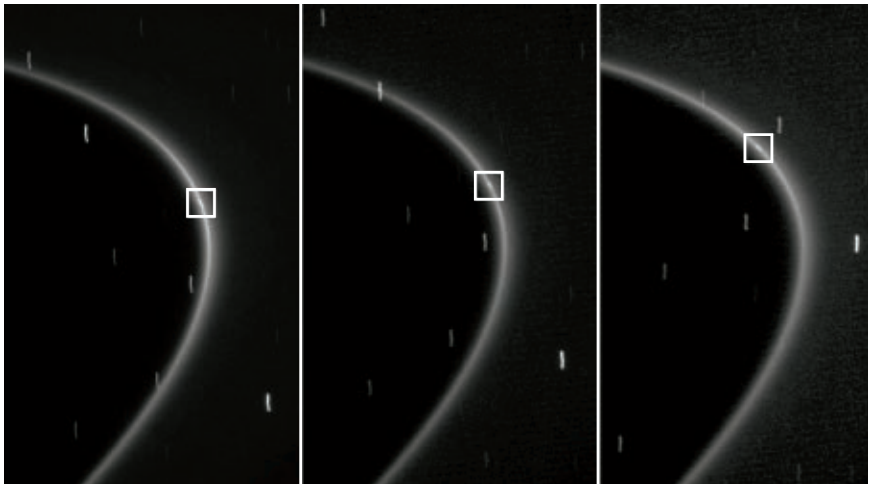
Now Will has found a Carter-like constant in a Newtonian system, in equations describing a third body orbiting two masses that are arranged just right.

"I still don't completely understand what it is telling us," says Will, who says he was amazed at the appearance of the constant. Other physicists also aren't sure what specialness leads to the constant in both systems.

"I have no idea — to me this is a mystery," says Teukolsky, who worked on similar questions as part of his Ph.D. thesis in the 1970s. "I'm still baffled."

Will says that the constant disappears when he adds the mathematical terms for frame dragging, the ability of a rotating body to drag spacetime around it, akin to the swirling around a spoon that's stirring a bowl of molasses. However, adding the next higher-order terms brings the constant back, Will says.

"It's mathematically intriguing," says E. Sterl Phinney of the California Institute of Technology in Pasadena. Similar work was published in 2003 by English astrophysicist Donald Lynden-Bell, Phinney says. "I don't know what it means, or that it has deep meaning." ■



SPACE SCIENCE INSTITUTE, JPL/NASA

And then there were 61

The pinprick of light (boxed) in this trio of images taken by NASA's Cassini spacecraft shows the path of a newly discovered moon moving within a bright arc in Saturn's faint G ring. The tiny body, roughly half a kilometer in diameter, is the 61st moon known to orbit the ringed planet. Cassini scientists, who announced the find in a March 3 circular from the International Astronomical Union, believe that icy particles chipped off the tiny moon may be the source of the arc, which is 250 kilometers wide and extends one-sixth of the way around the G ring's circumference. — *Ron Cowen*

Life

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Shrinking fish can get big again, but such reversal may take time

Study suggests managers should consider fishing's effects

By Susan Milius

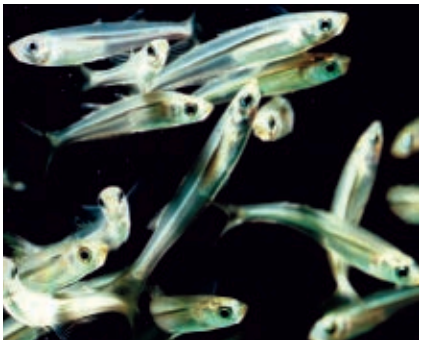
People can reverse evolution when it comes to the effects of fishing on sea creature size, researchers say. Just don't hold your breath.

The common practice of catching only the bigger fish in a population becomes an evolutionary pressure for later generations to stay small and grow slow, says fisheries scientist David Conover of Stony Brook University in New York.

He and his colleagues now report a lab experiment on silverside fish that stops the shrinkage trend and nudges the population's fish back toward larger sizes. Changing the direction of the selective pressure by eliminating the "take the big ones" rule brought a noticeable size increase within five generations, Conover and his colleagues report in a study released March 3 in *Proceedings of the Royal Society B*.

"It's the first experimental demonstration of reversing fisheries-induced evolution," Conover says.

Fisheries biologist Mikko Heino of the University of Bergen in Norway calls the work very interesting and important. The results support predictions that any recovery will be slower than the evolutionary effects of fishing, he says.



Silversides got big again when researchers stopped removing the largest fish.

Theorists have debated whether populations could recover from the size effects of fishing, Conover says. One argument states that natural selection might be too mild to push back hard enough to restore size on a human timescale.

To experimentally address the question, Conover and his colleagues caught hundreds of silversides (*Menidia menidia*) in Great South Bay, N.Y.

The researchers divided the bait fish into six populations. For two groups, the team annually removed the large individuals, taking all but the smallest 10 percent. The team targeted small fish in two of the other groups, and removed fish randomly from the remaining groups. After five years, about five generations, the catch-big populations had a smaller average size than the comparison groups.

For the next five years, Conover and his colleagues kept the populations but changed the rules. The team removed fish randomly from all groups.

At the end of that five years, the shrinking trend had reversed, and adults in the catch-big populations had regained half their original length, on average. But the recovery was slow, Conover says. He calculates that if the silversides maintain their current pace, they will need a total of 12 years to return to their former size.

Just how Conover and his colleagues' research would apply to ocean fish in the wild is "an open question," Heino says.

But Conover says the best path is to avoid the shrinkage to begin with or stop it as soon as possible.

"That's the biggest implication — you'd better hurry," says fisheries management specialist Ellen K. Pikitch, who directs the Institute for Ocean Conservation Science at Stony Brook, which provided funding for the 10-year research project.

Give that dino a hand

Fossil handprints (left) made by a crouching theropod (artist's depiction, right) reveal that this meat-eating bipedal dinosaur had palms that always faced inward, suggesting theropods abandoned the use of their forelimbs as legs early in their evolution. The creatures include the tiny-armed *Tyrannosaurus rex*, which lived around 65 million years ago, and *Allosaurus*, which lived about 150 million years ago and was also poorly endowed in the biceps department. There are very few scenarios in which those forelimbs could have touched the ground, Andrew R.C. Milner of the St. George Dinosaur Discovery Site in Utah and his colleagues report online March 3 in *PLoS ONE*. —*Sid Perkins*

CLOCKWISE FROM TOP LEFT: D. CONOVER; H.K. LUTERMAN OF CEDAR CITY, UTAH; *PLOS ONE*

Body & Brain

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

Team collars an accessory to Alzheimer's

Supposedly harmless prions conspire in brain disease

By Laura Sanders

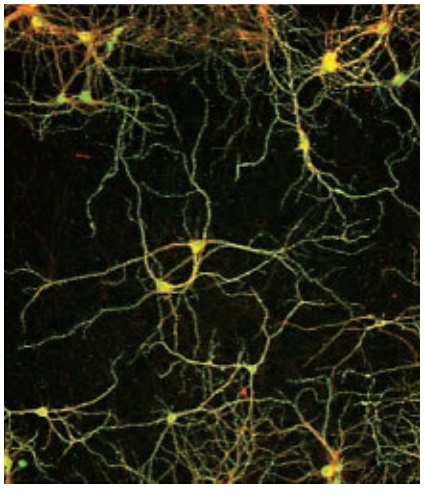
Prion proteins, notorious for causing the brain-wasting mad cow and Creutzfeldt-Jakob diseases, may also be coconspirators in Alzheimer's disease, a new study in mice suggests.

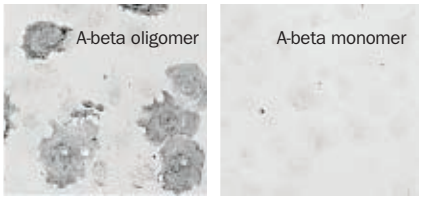
In mad cow and Creutzfeldt-Jakob diseases, misshapen prion proteins do the damage. But the new paper, published in the Feb. 26 *Nature*, offers evidence that the supposedly harmless version of the prion protein assists the amyloid-beta protein responsible for brain cell death in Alzheimer's disease.

"It's pretty sensational," comments Adriano Aguzzi of the University of Zurich. "What's tremendously electrifying is that prion protein may be a ... sensor for extremely toxic, small concentrations of A-beta."

A-beta proteins can travel alone or in groups in the brain. On their own, A-beta proteins are harmless. Massive, insoluble clumps of A-beta, known as plaques, are probably harmless too, says study coauthor Stephen Strittmatter of Yale University. These plaques may be a gravestone marker of dead brain cells but are probably not the killer.

Instead, smaller, soluble clumps of 50 to 100 A-beta proteins, known as oligomers, are the most likely suspect, says Strittmatter. Earlier studies have shown that mice with A-beta oligomers don't move through a previously learned maze as quickly as mice without active A-beta oligomers. Such oligomers prevent cross-talk between brain cells in the mouse hippocampus, which could help explain the loss of learning and memory in people with Alzheimer's disease.





Prions latch on
A new study reveals that a prion protein senses amyloid-beta oligomers in the brain. Left: Prion protein (red) and A-beta oligomers (green) are bound together (yellow) on the outside of brain cells from a mouse hippocampus. Above: Prion proteins on the outside of monkey cells grab on to A-beta oligomers and make clumps (above, left), but the prion proteins don't latch on to single A-beta proteins, called monomers (above, right).

But how these A-beta oligomers cause cellular mayhem is not known. At very low concentrations the oligomers are toxic to cells, so it's likely that specific proteins on cells are exquisitely tuned to recognize the A-beta proteins, Strittmatter says.

"What's been unclear is if A-beta acts on cells directly or if it acts through cell surface receptors, where it maybe corrupts the cell in some way," comments Lennart Mucke of the Gladstone Institute of Neurological Disease in San Francisco and the University of California, San Francisco, who wrote a commentary in the same issue of *Nature*.

Strittmatter and his colleagues searched for proteins embedded in the outer membranes of cells that might sense the dangerous A-beta oligomers. After screening 225,000 possible mouse proteins, only one specifically grabbed on to oligomers of the human form of A-beta: the prion protein.

The role of the harmless prion protein, which is prevalent in the brain and peripheral tissues of healthy people and animals, has been a mystery. "Everybody and his brother have been trying to find the normal function of prion protein," Aguzzi says.

Earlier reports suggest that the protein may help maintain the brain's white matter, control brain cell formation and have a role in sensing smells. Even so, Aguzzi says, the protein's role is far from settled. "I never had the feeling that we've come to the bottom" of its function, he says. But prion protein's new job as an A-beta oligomer sensor may shed light on how A-beta proteins can damage brain cells.

In the new study, researchers looked at hippocampal brain cells taken from mice that produced no prion protein as a middleman. When the team washed A-beta oligomers over the prion-free brain cells, the oligomers did not affect a type of cell-to-cell signaling important in learning. Researchers got similar results in normal brain cells using an antibody to block the 11-amino-acid stretch of the prion protein required for A-beta binding. These "striking" results make the case that prion proteins are crucial for A-beta–induced damage, Mucke says.

Blocking prion protein binding may be a new therapeutic approach for Alzheimer's disease. "In many ways it may be better than addressing A-beta levels," which are difficult to reduce completely, says Strittmatter.

Researchers don't yet know if prion protein and A-beta interact similarly in human Alzheimer's disease, or if blocking the interaction would be effective or safe in humans.

"Every new discovery raises more questions than it answers," Mucke says. ■

LAURÉN *ET AL./NATURE*

2nd Nexium's rank in pharmaceutical sales in the U.S. in 2007

4th Plavix's rank in pharmaceutical sales in the U.S. in 2007

Popular acid blockers don't mix with anticlotting medication

Reflux drugs might lessen protection from blood thinner

By Nathan Seppa

In a finding sure to cause many cardiac patients some old-fashioned heartburn, researchers report that a commonly prescribed class of acid-blocking drugs interferes with an anticlotting medication routinely given to heart patients discharged from the hospital. The study, coupled with earlier reports that have led to a stern warning from the U.S. Food and Drug Administration about mixing the drugs, might change doctors' practices.

"A lot of us just prescribe things out of habit," says study coauthor P. Michael Ho, a cardiologist at the Denver Veterans Affairs Medical Center. "My hope is that this study makes physicians think twice."

The new report, in the March 4 *Journal of the American Medical Association*, suggests that proton pump inhibitors neutralize more than stomach acid.

PPIs seem to inhibit the blood thinner clopidogrel, marketed as Plavix. Clopidogrel is a standard antiplatelet drug for people recently treated for heart problems. It doesn't actually thin the blood, but it does discourage platelets from forming clots. That's a boon for people with clogged coronary arteries that have been recently reopened.

Because clopidogrel can irritate the stomach in some patients, many doctors also prescribe a PPI such as Prilosec, Nexium, Aciphex, Prevacid or Protonix.

Ho and his colleagues reviewed the medical records of 8,205 people, nearly all men, who were prescribed clopidogrel upon discharge from Veterans Affairs hospitals between October 2003 and January 2006. All had been treated for a heart attack or other serious heart problem.

The records show that most were also prescribed a PPI upon discharge. After an average follow-up of 17 months, those getting both drugs were nearly twice as likely to have been rehospitalized for a heart problem as those getting clopidogrel but not a PPI. Also, people getting both drugs were about 50 percent more likely to require a procedure to reopen a coronary artery.

> "My hope is that this study makes physicians think twice."
> P. MICHAEL HO

The scientists accounted for differences in health between the groups including diabetes, lung disease and dementia. And after omitting anyone with previous stomach or intestinal bleeding, those getting both drugs were still more likely to experience a serious heart problem.

Clopidogrel must be activated by enzymes in the liver to work. But PPIs seem to shut off these enzymes and interfere with clopidogrel, says Robert S. Epstein, an epidemiologist and chief medical officer at Medco, a pharmacy benefits management company based in Franklin Lakes, N.J.

Non-PPI heartburn drugs that include Zantac, Pepcid, Axid and Tagamet didn't have this effect in previous research and showed little correlation in this one.

"This is a very important paper," says Epstein. "They did a very good job of weeding out — and adjusting for — differences between the groups."

Epstein and his colleagues also recently found depleted clopidogrel action when it was coupled with a PPI, as did a Canadian team in a separate study. Based on a series of findings, the FDA issued a warning in January that "patients taking clopidogrel should consult with their health care provider if they are currently taking or considering taking a PPI."

NEWS BRIEFS

New drug fights nasty asthma

An experimental drug called mepolizumab can prevent severe asthma attacks in people with an uncommon form of the disease that responds poorly to standard steroid medications, researchers report in two studies in the March 5 *New England Journal of Medicine*. Scientists also show that a simple test of sputum can reveal which patients would most likely benefit from the drug. —*Nathan Seppa*

Chemo spurs some cancer cells

A chemotherapy drug may make small but aggressive populations of brain cancer cells even more deadly. The cells, called side populations, actually increased in number in mice treated with temozolomide, Eric Holland of Memorial Sloan-Kettering Cancer Center in New York City and colleagues report in the March 6 *Cell Stem Cell*. In another test, side population cells treated with the drug formed tumors faster than untreated cells in previously cancer-free mice. —*Laura Sanders*

Gene links autism, bellyaches

New research, published in the March *Pediatrics*, shows that there is a genetic link between some autism cases and gastrointestinal disorders. Parents often report that autism and tummy troubles go hand in hand, but it's unclear whether this genetic link means that special diets could improve autism symptoms, as some suggest. "The change in diet is not changing brain structure, it's just making the kid feel less sick," says Daniel Campbell of Vanderbilt University's School of Medicine in Nashville, Tenn., who led the study. —*Tina Hesman Saey*

Science & Society

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Science's next superstars win fortune and fame

Top students recognized in Intel Science Talent Search

By Rachel Ehrenberg

Winners of the 2009 Intel Science Talent Search were announced at an awards gala on the evening of March 10. Eric Larson (right) took home the grand prize, William Sun (middle) won second place and Philip Streich (left) placed third.

WASHINGTON — It could have been the brainy version of *American Idol* — bright lights, fancy clothes and fanfare introducing America's next top scientists.

Eric Larson, 17, of Eugene, Ore., won the grand prize in the Intel Science Talent Search at a gala held the evening of March 10. Larson will take home a $100,000 scholarship from the Intel Foundation for his work exploring the mathematical concept of fusion categories. Fusion categories can have implications for string theory, quantum computation and knot theory.

Second place and a $75,000 scholarship went to William Sun, 17, of Chesterfield, Mo. Sun investigated the molecule golgicide A as a potential drug to block the movement of toxins and other molecules within cells. He pinpointed a gene mutation in canines that would confer resistance to the drug. The work may shed light on neurodegenerative diseases.

Philip Streich, 18, of Platteville, Wis., took third place and a $50,000 scholarship for demonstrating the solubility of carbon nanotubes, graphene and cellulose nanocrystals, which could lead to new electronic materials. Streich's work has resulted in five provisional patent filings.

Society for Science & the Public (formerly Science Service), publisher of *Science News*, has administered the competition since its inception in 1942. This year's 40 finalists, winnowed from more than 1,600 entrants, represented 17 states and 35 schools. Over the past 67 years, Talent Search finalists have gone on to win Fields Medals, the National Medal of Science, MacArthur Foundation Fellowships and seven Nobel Prizes.

"Our generation can be proud of its advancements in science, but ... our future may be following us," Elizabeth Marincola, president of Society for Science & the Public in Washington, said at the gala. "We pass the baton, and the truly tough problems, to the generation represented by our Intel STS finalists."

The announcement of the winners capped the finalists' weeklong visit to Washington as part of the Science Talent Institute. Exhibiting the results of their scientific projects at the National Academy of Sciences, the students explained and discussed their work to the public, the scientific community and, of course, the judges. But the high school scientists also had time outside the academy — including a visit to the White House to meet President Obama.

Narendra Tallapragada, 17, of Burke, Va., received fourth place for developing an efficient yet sophisticated method for modeling the building of materials atom by atom. Chelsea Jurman, 17, of Roslyn, N.Y., took fifth place for investigating the links among teens' underage drinking, perceptions of parents' drinking and parenting behaviors. Noah Arbesfeld, 17, of Lexington, Mass., won sixth place for efforts to understand the fundamental structure underlying all of algebra. Each of these students won a $25,000 scholarship.

Seventh through 10th place winners were each awarded a $20,000 scholarship. They are Alexander Kim, 17, of Fairfax, Va., who investigated the evolution of several populations of the giant American river prawn; Preya Shah, 17, of Setauket, N.Y., for designing and synthesizing a drug that uses a two-pronged approach to target cancer cells; Nilesh Tripuraneni, 18, of Fresno, Calif., who formulated a set of hydrodynamic equations investigating quark-gluon plasma, a state of matter believed to exist right after the Big Bang; and Gabriela Farfan, 18, of Madison, Wis., whose analysis of the feldspar known as Oregon sunstone revealed unique microinclusions containing zinc and copper.

Each of the remaining 30 finalists won a $5,000 scholarship and a laptop computer (*SN: 2/14/09, p. 11*).

"At a time when our country requires innovation to spur economic growth, it is inspiring to see such talented young people using critical thinking skills to find solutions to scientific challenges," says Craig Barrett, chairman of Intel Corporation, based in Santa Clara, Calif. ■

INTEL CORPORATION

Technology

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When the ink hits the page

Understanding the physics behind the most printable ink

By Solmaz Barazesh

Hitting "print" is easy. Getting a perfect printout is not. All too often, inkjet printers spew out smudged or smeared pages. Now a new study concludes that the likeliest culprit is the gloopiest ink.

Inkjet printers are named for their tiny nozzle that squirts droplets of ink onto the paper. Ideally, the ink forms a perfect round droplet as it launches from the inkjet, hitting the paper right on target. But droplet formation is affected by ink properties including density, surface tension and viscosity, which is the measure of resistance to flow, or "gloopiness." And if the droplets aren't just right, a splotch appears instead of a crisp line of text.

Scientists use a ratio called the Z number to describe the surface tension and viscosity of a particular ink. Inks with a lower Z are more viscous, while inks with a higher Z have more surface tension, explains study coauthor Jooho Moon of Yonsei University in Seoul, South Korea.

Recent theoretical work predicted that quality printing inks would have Z values between 1 and 10. But the new research suggests the best droplets form from inks with Z values between 4 and 14, Moon and his colleagues report in the March 3 *Langmuir*. That means that of the inks now in common use, the less viscous, more free-flowing ones print better.

DAEHWAN JANG AND J. MOON

The best ink launches quickly and forms one ball (Z score of 4 shown).

By capturing images of the droplets of different types of lab-made inks, up to a Z score of 17, the researchers found that droplets with Z scores above 14 often break into two ink drops while droplets with values below 4 stick to the inkjet instead of launching properly.

"A kind of balance is what is needed for the most printable inks," explains materials scientist Damien Vadillo of the University of Cambridge in England.

Humans

For longer versions of these and other Humans stories, visit **www.sciencenews.org**

Footprints suggest *H. erectus* walked the modern human walk

1.5-million-year-old fossils excavated in eastern Africa

By Bruce Bower

Human ancestors created some remarkably lasting impressions on the eastern African landscape around 1.5 million years ago. Walking across a muddy patch of terrain near what's now Ileret, Kenya, these ancient individuals left footprints that hardened and have now been excavated by a team of scientists.

On close inspection, the preserved footprints provide the oldest evidence for a virtually modern-human foot and walking style in a human ancestor, report Matthew Bennett of Bournemouth University in Poole, England, and his colleagues in the Feb. 27 *Science*. The findings provide new clues to the evolution of upright stance and walking in modern humans.

Bennett's team identifies the ancestor as an early Africa-based *Homo erectus*, or *Homo ergaster* as some scientists call it.

Measures of the size, spacing and depth of the Ileret impressions allowed the researchers to estimate individuals' heights, weights and stride lengths, all of which fell within the ranges of modern humans. Digitized images of the prints show a big toe in line with the other toes, an arrangement that contrasts with the angled, grasping big toes of apes. Other humanlike features include a pronounced arch and short toes.

Ancient foot impressions at Ileret complement fossil leg and pelvis finds in Africa indicating that *H. erectus*, which appeared about 2 million years ago, displayed much the same body size and proportions as modern humans, the researchers say.

"The Ileret footprints add to evidence that early *Homo erectus* had a body adapted to traveling long distances, at a time when food sources were patchily distributed across the landscape," says excavation director John Harris of Rutgers University in New Brunswick, N.J.

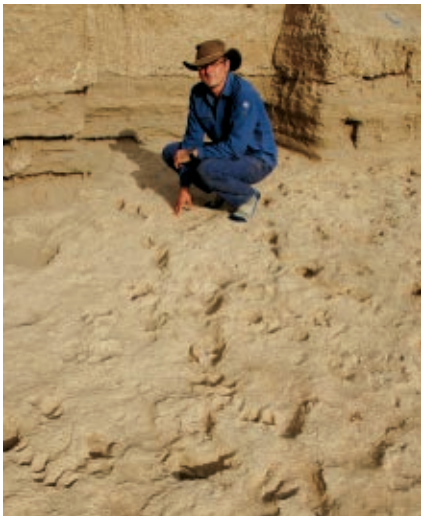
Harvard University anthropologist Daniel Lieberman says the African footprints support his 2004 proposal that around 2 million years ago the *Homo* genus evolved bodies capable of running long distances. Springlike arches and short toes observed on the Ileret footprints would have enabled endurance running. "How could *H. erectus* have hunted more than a million years before the invention of tipped spears, as we know it did, without the ability to run well?" Lieberman says.

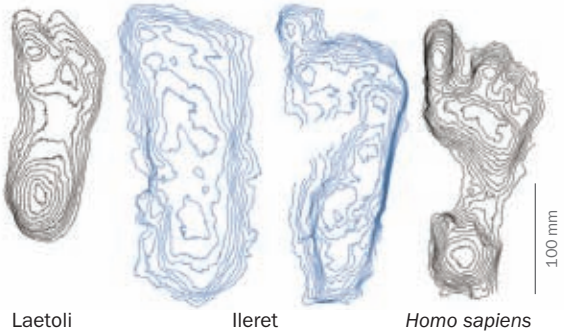
That's a plausible hypothesis, comments Susan Antón of New York University, but she says the footprints might instead come from either of two other species, *Homo habilis* or *Paranthropus boisei*. Scientists know little about the size variation in *H. erectus* (*SN: 12/6/08, p. 14*) or the other two species.

Other footprints from members of the human evolutionary family, dating to 3.5 million years ago, were discovered by Mary Leakey between 1977 and 1979 at Laetoli, Tanzania. Researchers disagree about whether these finds — often attributed to *Australopithecus afarensis*, a fossil species that includes the partial skeleton of Lucy — reflect an apelike or humanlike foot anatomy.

Bennett's team argues that the Laetoli prints, which are smaller than those at Ileret, show signs of an upright gait, shallower arch and more angled big toe.

Bernard Wood of George Washington University in Washington, D.C., agrees. The Ileret footprints underscore skeletal evidence for a radical shift in anatomy sometime between the demise of *A. afarensis* around 3 million years ago and the appearance of *H. erectus* nearly 1 million years later, Wood holds.





Reading footprints
Geologist Matthew Bennett (left) and his team uncovered trails of footprints in two sediment layers in Ileret, Kenya, both dating to about 1.5 million years ago. A close-up of one of the preserved footprints (photo above) reveals short toes and a forward-oriented big toe, typical of modern humans. Contour maps reveal the shape of the footprints from Ileret (above, center two) compared with an older footprint from Laetoli, Tanzania, (above, left) and a footprint from a British site inhabited by people around 3,000 years ago (above, right).

M. BENNETT/BOURNEMOUTH UNIV.

"How could *H. erectus* have hunted more than a million years before the invention of tipped spears … without the ability to run well?" — DANIEL LIEBERMAN

The Botai of central Asia milked mares more than 5,000 years ago

Hunter-gatherers left signs of domesticated horses

By Bruce Bower

Central Asia's vast grasslands hosted a prehistoric revolution in transportation, communication and warfare, thanks to the humble horse. Remains from Kazakhstan's more than 5,000-year-old Botai culture have yielded the earliest direct evidence for domestication of this versatile beast, scientists report.

Botai people were hunter-gatherers who lived in large settlements for months or years. Their culture lasted from 5,600 to 5,100 years ago. Researchers have long suspected that the Botai rode domesticated horses while hunting for wild horses to eat but did not domesticate other animals or cultivate crops.

Horse remains found at four Botai sites include two telltale signs of domestication: slender lower-leg bones like those of later domesticated horses and cheek teeth worn down by bits that attached to bridles or similar restraints, reports a team led by Alan Outram of the University of Exeter in England.

Chemical analyses of animal fat residue on the inside surfaces of Botai pottery fragments suggest that the vessels once held mare's milk, probably gathered in summer months, the researchers report in the March 6 *Science*. Modern Kazakh horse herders milk mares in the summer to produce a fermented, alcoholic drink called koumiss.

Milking of horses and other animals arose in areas such as northern Kazakhstan that lacked agricultural practices often regarded as precursors of milking, Outram and his colleagues propose.

The new report presents the first evidence for horse milk in Botai pots and for Botai horses having domesticated-looking leg bones, remark David Anthony and Dorcas Brown, archaeologists who teach at Hartwick College in Oneonta, N.Y.

A Kazakhstan villager milks a mare, much as the Botai may have 5,000 years ago.

"If you're milking horses, they are not wild," Anthony says.

But the evidence for bit use described by Outram's team is preliminary, according to Anthony and Brown.

The Botai people didn't invent horse domestication and milking, Anthony and Brown contend. These practices were probably borrowed from inhabitants of the nearby Russian steppes who may have included domesticated horses in sacrificial rituals with domesticated sheep and cattle by 6,500 years ago. Those Botai neighbors probably domesticated horses after learning about cattle and sheep domestication from farming groups, in Anthony and Brown's view.

Playing for real in a virtual world

Kids take on new identities, but sex differences remain

By Bruce Bower

In a virtual setting where fifth graders become wizards and athletes, and even change sexes, preteens stay true to their real-world selves. Classic sex differences in play preferences, characterized by rough-and-tumble games among boys and intimate conversations among girls, still exist after youngsters adopt a range of personas for virtual encounters, a team reports online February 20 in the *Journal of Applied Developmental Psychology*.

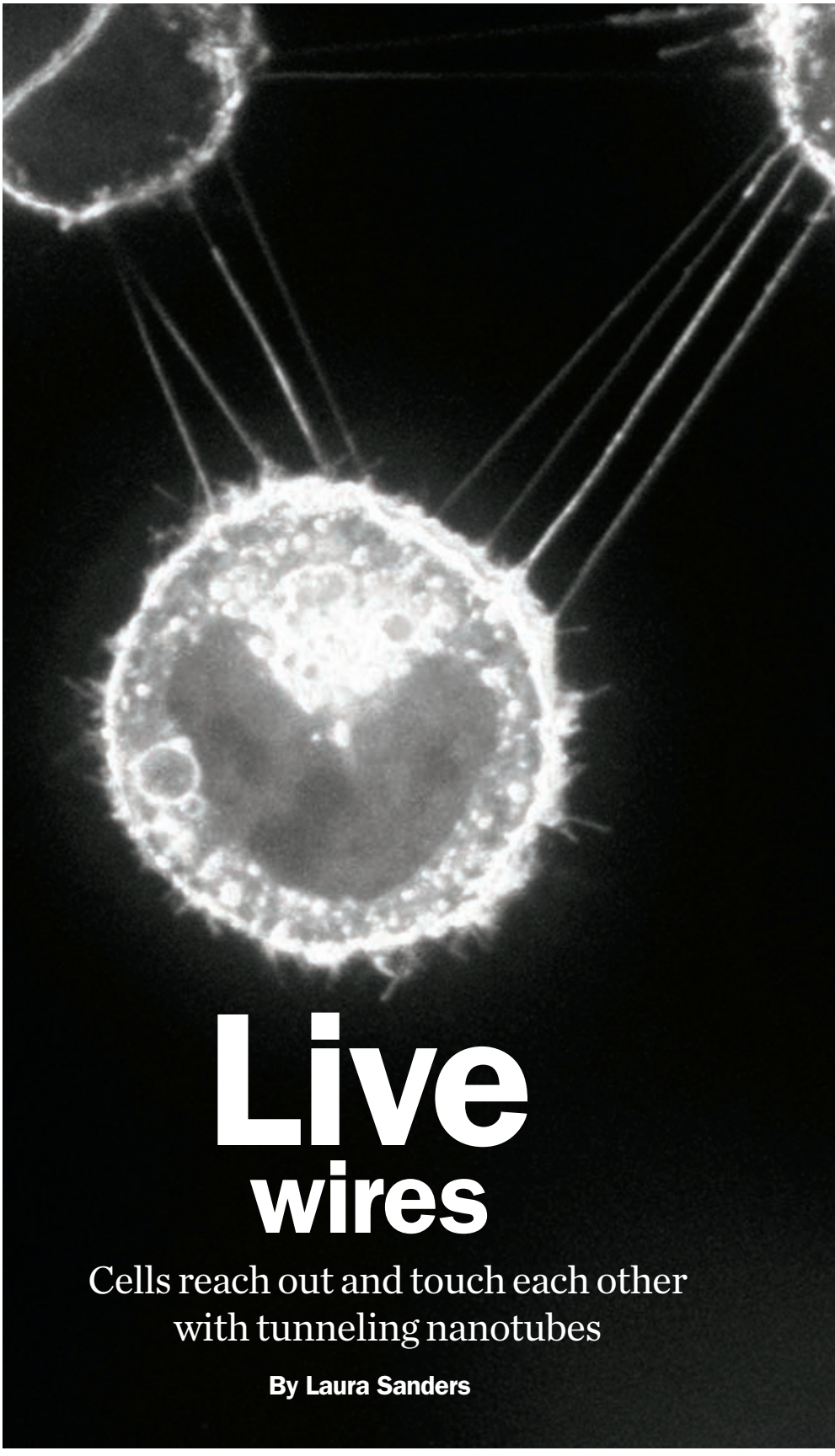
Preteen play in multi-user domains (one shown) focuses on self-exploration.

Boys who create girl avatars and girls who create boy avatars still behave consistently with their biological sex, say psychologist Sandra Calvert of Georgetown University in Washington, D.C., and her colleagues. In the new study, about 13 percent of fifth graders chose opposite-sex avatars, a practice researchers call gender-bending. Pairs of kids in this study — all of whom knew each other — experimented more with avatar identities than pairs of unfamiliar children had in a 2003 study led by Calvert. Same-sex pairs showed this pattern most strongly.

As fifth graders learned to use avatars to interact with others in a multi-user domain, or MUD, experimentation with costumes, sexes and names increased sharply. But MUD play centered on self-exploration rather than self-alteration, Calvert asserts.

"People don't go online to leave their bodies behind and find new selves, but instead seem to be taking their offline selves, including their biological selves, with them," says psychologist Kaveri Subrahmanyam of California State University, Los Angeles.

FROM TOP: A. OUTRAM; S. CALVERT



Live wires

Cells reach out and touch each other with tunneling nanotubes

By Laura Sanders

KARINE GOUSSET, *NATURE CELL BIOLOGY*

Like teenagers, cells require constant communication with their peers. Today's teens chatter endlessly over wireless networks. Cells, on the other hand, seem a bit more old-fashioned. A clandestine web of high-speed wires physically links cells like a biological Internet, scientists have discovered.

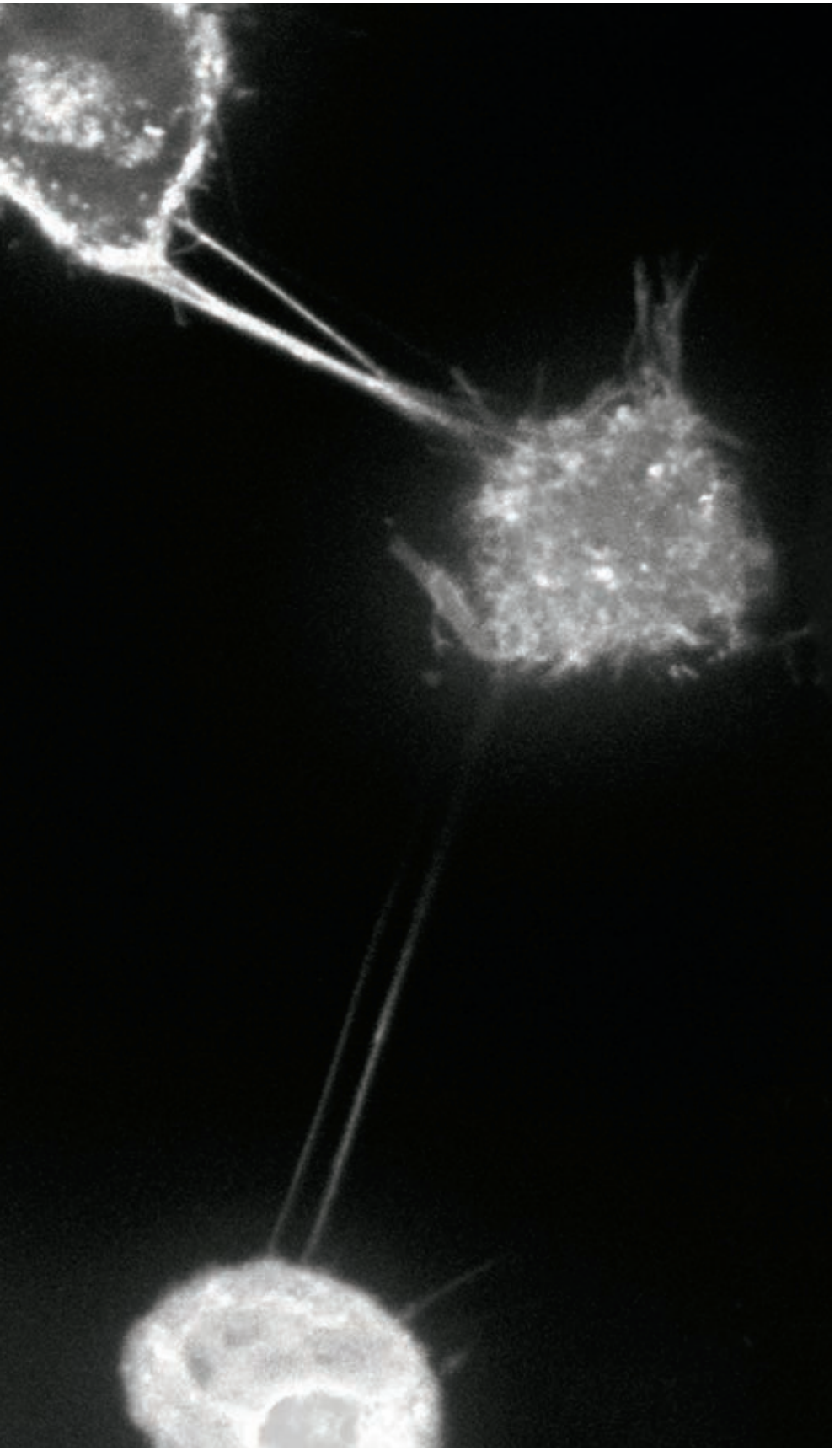
These long, filamentous fibers are called tunneling nanotubes. They lurk in lab dishes of human kidney cells, immune cells and cancer cells. The tunnels share the same tiny dimensions as the nanotubes that chemists create with carbon. But these nanotubes aren't built by scientists. Tunneling nanotubes grow with no external interference, and they seem to offer a heretofore unknown way for cells to communicate.

"These structures have been there all along. If you don't know what you're looking for, you miss many things," says Hans-Hermann Gerdes, a cell biologist at the University of Bergen in Norway who reported the first official sighting of the tiny fibers in 2004.

Since then, a flurry of work has begun to uncover the prevalence and purposes of these conduits between cells. The covert, long-range tunnels could explain developmental mysteries like how individual cells coordinate growth into complex tissues and how immune cells streamline efforts to rapidly fight off intruders. Living nanotubes can also shuttle organelles, including the energy-producing mitochondria, between cells, a study published in December found.

Such fast, direct communication lines can also ferry unwanted guests. Just as fast Internet connections spread computer viruses, tunneling nanotubes can carry dangerous cargo. Nanotubes can be commandeered by unfriendly forces to spread disease: Recent studies show that bacteria, viruses and infectious prion proteins can all move through the nanotubes for nefarious purposes.

In one recent study, Daniel Davis, an immunologist at Imperial College London, saw glowing HIV particles creeping from an infected immune cell to an uninfected cell through the taut nano-



Glowing infectious proteins called prions move through a network of mouse brain cells linked by tunneling nanotubes. Experiments are revealing that the tiny threads ferry both beneficial and harmful cargo between cells.

tube wires. A different study published in January found that human cells build more networking nanotubes when infected with HIV, providing a scary scenario for ramped-up virus transmission. And recent data suggest that deadly prions — infectious, misfolded proteins that cause brain-wasting diseases like Creutzfeldt-Jakob in humans and mad cow in cattle — can travel through tunneling nanotubes to infect healthy brain cells.

To date, most nanotubes have been found on cells grown in lab dishes. And, critics say, cells plopped down in a dish, away from the normal biological context, probably act a little strange, like hermits who have been away from civilization for too long. Ultimately, these scientists say, whether nanotubes carry harm or good to other cells in lab experiments may be irrelevant to the body.

"This area is very new," says Walther Mothes, a cell biologist at Yale University who questions nanotubes' significance for disease. Currently, more reviews on tunneling nanotubes exist than research papers, he points out. "We need more evidence." Such evidence has come slowly. To study and evaluate the importance of nanotubes in natural systems, scientists first had to find them.

The jungle in there

Tunneling nanotubes thread among cellular debris and other kinds of cell connections, making them hard to spot — like trying to pick out a piece of floss from a tangled bird nest. Looking through a microscope at a group of cells, "a jungle of extracellular structures" meets the eyes, Gerdes says.

An even greater obstacle to finding nanotubes was their frailty. These wires are like the ultrafine, rigid glass tendrils that remain after a glassblower stretches a vase. They readily break under mechan-

ical stresses, the kinds of jostles and bumps that take place when preparing a cell sample for the microscope. Common fixatives like formaldehyde, used for preserving cells before imaging, obliterate nanotubes. Even light can destroy them — exposed to light, nanotubes start to vibrate, ultimately shattering. Better, more precise laser microscopes and the development of sophisticated imaging techniques finally illuminated these elusive structures.

Once tunneling nanotubes were spotted, scientists saw many different kinds. "If you look down a microscope at cells, lots of different cells have these connections, and they may be very different," Davis says.

Researchers led by Eliseo Eugenin at Albert Einstein College of Medicine in New York City recently found that human cells isolated from blood can form two distinct kinds of tunneling nanotubes: Long thin ones and short wide ones. The "long" tubes can extend 150 micrometers in length (about one and a half times the width of a human hair — quite a distance for a small cell). The short ones extend about 30 micrometers.

Nanotubes don't all look the same. They don't all form the same way, either. So far, they have been shown to develop in at least two ways — by growing out from one cell to contact another or by remaining linked as two cells move apart.

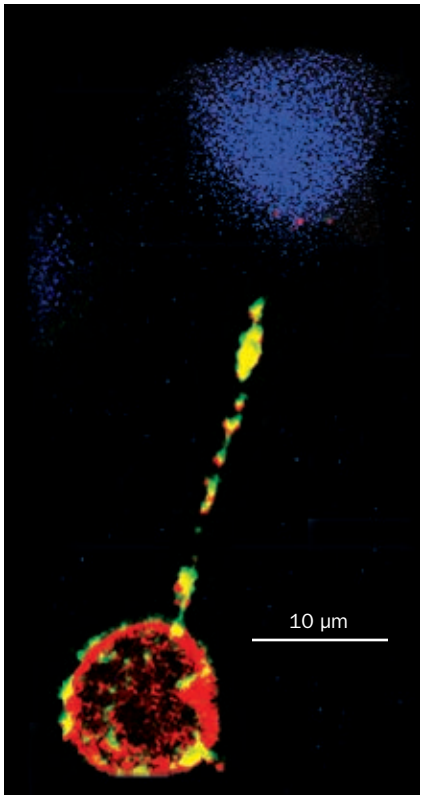
Scientists including Gerdes have seen the nanotubes form. Over the course of four minutes, he and his colleagues watched a stationary rat cell, alive on a microscope dish, extend several spindly protrusions toward another stationary cell, like fingers groping around in the dark. One feeler made contact with the other cell, and a nanotube was formed, while the rest of the feelers retracted into the cell body.

"They are really dynamic," Eugenin notes. "The formation can happen in minutes."

Some tunneling nanotubes develop only after contact with other cells, like thin ribbons of caramel left when two candied apples are pulled apart. In the case of the human immune cells that Davis' group studied, the tunnels formed when two cells bumped into each other. As the cells spread apart, a wire-thin nanotube stretched between them. The link is created in just seven minutes.

Davis' team found that immune cells produce significantly more nanotubes when the cells touch for more than four minutes. In contrast, cells that touch for less than three minutes rarely have nanotubes, suggesting that a brief bump together is not enough time.

Researchers think that the differences in tunneling nanotubes and how they form probably reflect varying needs of cells to send and receive information. Immune cells may coordinate a speedy counterattack by using nanotubes to quickly exchange calcium — a signal the body uses to warn other cells of harmful invaders. Proteins that tell developing cells when and where to grow may also flow through nanotubes. Such proteins could direct adjacent cells to grow in such a way as to create the complex patterning seen in the fruit fly wing, for example. Nanotubes may also carry a yet unknown heart development signal: They have been observed connecting naïve, unspecialized cells to mature heart cells, hinting at a new way cells may find their adult identity.



Killer highway
Red- and green-labeled HIV particles move from an infected human immune cell (bottom) to an uninfected cell (top) via a tunneling nanotube (yellow shows overlap). HIV infection may spur the growth of additional nanotubes, providing the virus speedy pathways to uninfected cells.

D. DAVIS, *NATURE CELL BIOLOGY*

Nanotubes can also carry organelles, including the energy-producing mitochondria and the endoplasmic reticula, which house the cell's protein factories, Gerdes and his colleagues showed in a paper published December 10 in *Experimental Cell Research*. Since mitochondria contain their own DNA, cells could even be swapping genetic material through these tunnels.

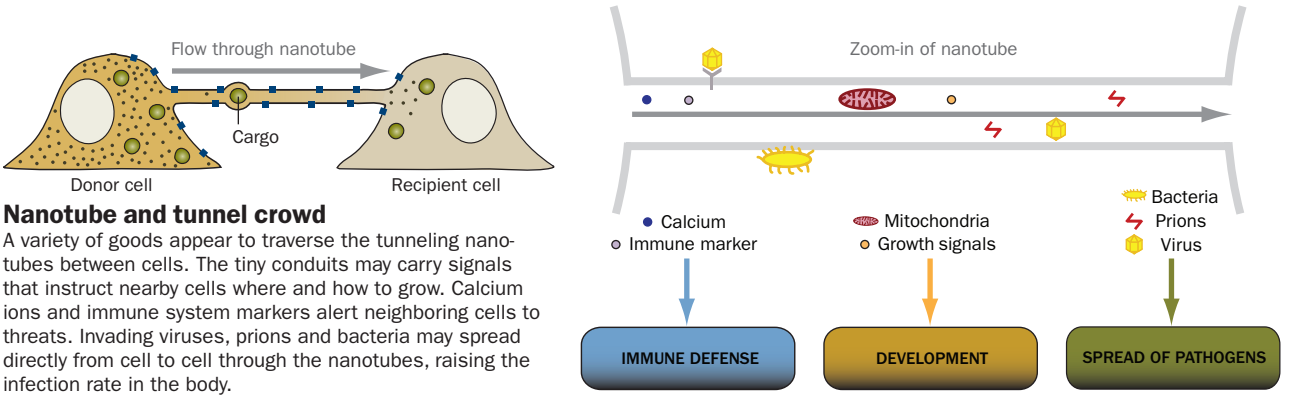
Such a free exchange of mitochondrial DNA among nondividing cells could challenge current understanding of cells as separate functional units, Eugenin says. "What you read in books that cells are discrete entities, that's not true anymore. If you see this in a broad way, it's a huge, huge, huge change from how we think about cells."

Dangerous cargo

Conduits that carry useful information can also transport danger, in the form of viruses or harmful prion proteins, from cell to cell. The tubes may explain a conundrum involving HIV, for example.

Researchers have shown that HIV, the virus that causes AIDS, is about a hundred times more likely to infect cells in contact with each other — as cells exist in the body — than a cell grown in isolation, as in lab dishes. If the virus is washed over the outside of a solitary cell, the cell can fight off the infection with antibodies. But in the body's close-knit community of cells, the virus spreads like wildfire.

Scientists have been puzzled by the ease with which HIV can spread from infected cells to uninfected cells in these communities, even in the presence of neutralizing antibodies. Tun-



Nanotube and tunnel crowd

A variety of goods appear to traverse the tunneling nanotubes between cells. The tiny conduits may carry signals that instruct nearby cells where and how to grow. Calcium ions and immune system markers alert neighboring cells to threats. Invading viruses, prions and bacteria may spread directly from cell to cell through the nanotubes, raising the infection rate in the body.

neling nanotubes offer one explanation for this phenomenon. HIV may move underground.

"The virus is hijacking the system," Eugenin says. "The pathogens are using and abusing the cell's own machinery."

Davis' research group tagged HIV particles with green fluorescent protein and then infected human immune cells. Using highly sensitive microscopes, the researchers watched as green globs of HIV made their way along a tunneling nanotube and into an uninfected cell. This new mode of virus transfer is "rapid, long-distance intercellular transmission," the researchers concluded in work that appeared last year in *Nature Cell Biology*.

In a separate set of experiments, Eugenin's team used HIV to infect blood cells from healthy volunteers. After a day, more of the infected cells had sprouted tunneling nanotubes than had uninfected control cells. The results suggest that once inside a cell, HIV tricks cells into making more tunneling nanotubes, through which the virus can travel and infect more cells, Eugenin and colleagues reported in the January 8 issue of *Cellular Immunology*.

Viruses aren't the only dangerous goods to travel through tunneling nanotubes. A paper online February 8 in *Nature Cell Biology* describes how brain-wasting prions use tunneling nanotubes to travel from an infected neuron to an uninfected neuron. What's more, nanotubes may explain the mystery of how prions move from the intestinal system, often the site of an initial infection, to the brain. In this new study, Chiara Zurzolo of the Institut Pasteur in Paris and her colleagues show how prion-infected immune cells, which can circulate in the blood from gut to brain, can form nanotube connections to brain cells. If this happens in the body as well, it may lead to prion infection in the brain.

Gerdes speculates that figuring out a way to manipulate nanotube connections might reduce the number of infected cells. "With infections, it's clear that the system is being misused. If you could cut these connections, you could reduce the number of infections," Gerdes says. But, he cautions, cutting off links might interfere with cells' exchange of other critical signals too, which could lead to unexpected problems.

Bodily relevance

So far, nanotubes have been spotted in dishes of human immune cells, brain cells, cancer cells and cells that become heart cells. But seeing something in a dish of cells is not the same as finding it in a whole organism. "The problem is extrapolating from cells hanging out in a dish to the body," Davis says.

Figuring out what happens (not just what could happen) in an organism is hard to do with dishes of cells. Mothes says, "Most of our science is in vitro. You work with cells that don't grow into tissue anymore."

But the cells retain their sticky adhesion molecules on the outside. "It's a consequence of the inherent desire of cells to form a tissue," he says. Nanotubes observed between lab-grown cells could be remnants of a collision between two sticky cells with little biological importance, Mothes says.

But Gerdes disputes this idea. "Cells act differently when you put them in a dish, but they don't invent new things," he says. To put it another way, hermits may act a little funny but they don't sprout wings and fly away.

In fact, scientists have found nanotubes connecting immune cells in dissected mouse corneas, suggesting the nanotubes existed in the living mouse eye. These nanotubes increased in number when mice were subjected to stress. The research, led by Paul McMenamin at the University of Western Australia in Perth, is the first example of nanotubes forming in a living, breathing mammal.

For his part, Davis is confident that nanotubes exist in the body. "Being able to prove that they are important in the body is harder to answer," he says.

Because these hidden communication lines between cells have gone undetected for so long, scientists are struggling with what Gerdes calls the "very basic science" of nanotube form and function. They are just now figuring out the details.

"It's often that way in science," Davis says. "You work in the framework of what the field is doing at that time. But it's the crazy stuff that is going on in the corner that's exciting." ■

Explore more

- H.H. Gerdes and R.N. Carvalho. "Intercellular transfer mediated by tunneling nanotubes." *Current Opinion in Cell Biology.* August 2008.

FROM LEFT: ADAPTED FROM GERDES *ET AL./FEBS LETTERS* 2007; ADAPTED FROM GERDES & CARVALHO/*CURRENT OPINION IN CELL BIOLOGY* 2008

Networks of Plunder

Archaeologists tracing the labyrinth of antiquities trafficking hope to shut it down, or at least slow it up

By Bruce Bower

Every day for months, Morag Kersel walked through the streets of Jerusalem to interview researchers, antiquities dealers, museum officials and others about the trafficking of ancient goods: pottery, sawed-off pieces of statues, decorated blocks sliced off the tops of ancient door frames, and biblical coins, to name a few.

One day in 2003, Kersel, then a graduate student in archaeology, came face-to-face with a thriving Middle Eastern trade in ancient, looted coins that had been right under her nose for some time. One of her contacts mentioned that he often purchased such coins from a Palestinian man who shined the shoes of Jerusalem's pedestrians. Kersel realized that she had been passing by that shoe-shine stand day after day.

Kersel, now a postdoctoral fellow at the University of Toronto, refers to this street-corner salesman by an assumed name, Mohammed, in order to protect his identity. Mohammed introduced her to a side of the antiquities trade that archaeologists, not to mention law-enforcement officials, rarely see: the chain of secretive relationships that turns looted pieces of the past into scrupulously documented keepsakes for affluent buyers.

Global market

The structure of Mohammed's trade network repeats in many parts of the world.

Sales of illegal antiquities total at least $7.8 billion annually. It's a black market that ranks behind only drugs and weapons as the most profitable, according to a United Nations analysis.

What comes out of the ground passes through international networks of plunder. At the end of the line, people purchase archaeological artifacts in shops, on the Internet and in private and public auctions. Buyers rarely know or, apparently, care how a $2.99 Native American arrowhead or a $75,000 Egyptian sarcophagus managed to come into their possession.

During the Archaeological Institute of America's annual meeting, held in Philadelphia in January, researchers offered analyses of auction and Internet data documenting an ongoing demand for archaeological artifacts. Buyers show no hesitation when offered desirable items that have no documented ownership history, or provenance. Auction-house catalogs of available items contain a fair number of fake pieces and genuine ones illegally obtained.

The laws and conventions aimed at stopping illegal looting are difficult to enforce.

The situation is not entirely dismal. Enlisting the aid of urban developers, townsfolk and the U.S. Embassy, archaeologists in the southwest Asian nation of Georgia have excavated and preserved remnants of ancient societies. In Cambodia, government actions have nearly eradicated once-heavy looting of the vast, 12th century Angkor Wat temple.

But looters hit unprotected sites hard. They sell the booty to middlemen who smuggle goods across borders and initiate a rapid series of transactions.

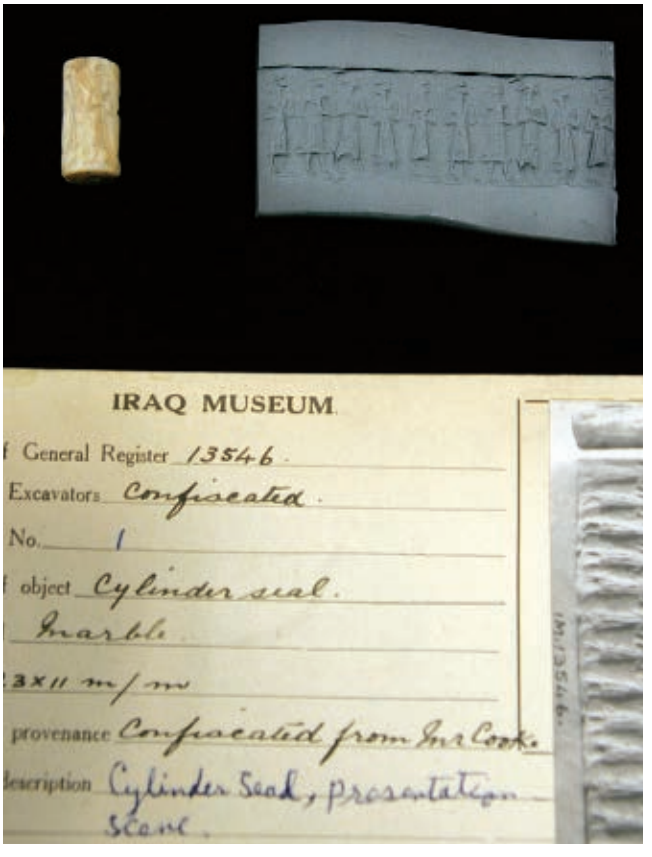
Estimates of the size and profitability of black markets are notoriously unreliable, cautions Sandro Calvani, director of the United Nations Interregional Crime and Justice Research Institute in Turin, Italy. It's unlikely, he says, that accurate statistics on thefts of archaeological material will ever be generated.

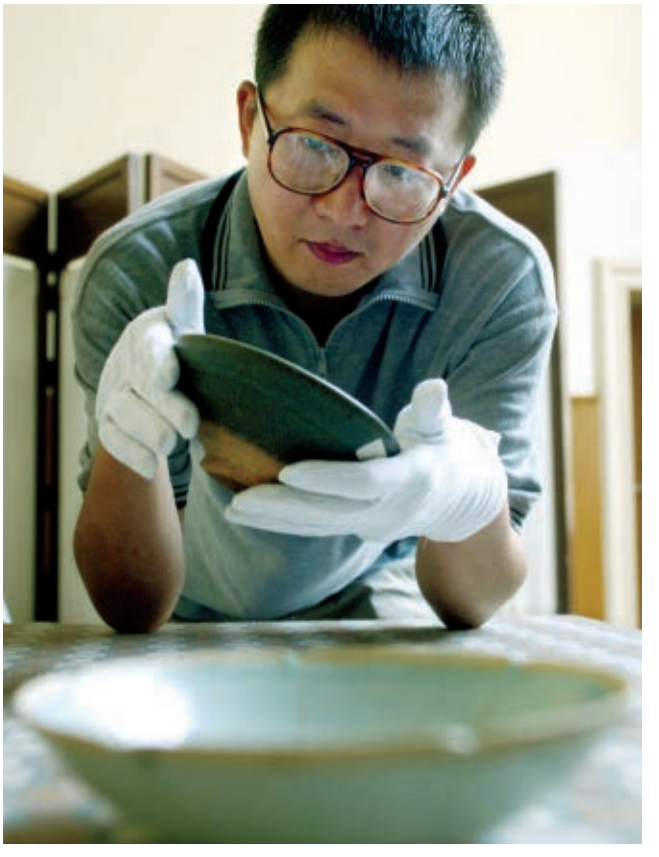
What's clear is that the looting of items from past societies started thousands of years ago. Some modern networks have been in place for centuries. And thefts of cultural material from private houses, museums and places of worship now rival looting in popularity, Calvani says. The illicit antiquities trade has also spawned a growing business in copies, fakes and forgeries.

"This is one of the world's biggest illegal enterprises," says archaeologist and law student Terressa Davis of the University of Georgia in Athens.

Archaeologists can't reconstruct the meanings and uses of ancient finds

Clockwise from top left: Treasures in Turkey's Aktepe tomb have been popular with looters. Statue parts are often taken from Cambodian sites. A looted bowl from the Yuan dynasty, recently returned, gets an expert's look at the National Museum of China in Beijing. Ancient seals were among items pillaged from Iraq's National Museum in 2003 and later returned.





CLOCKWISE FROM TOP LEFT: PATRICK AVENTURIER/GAMMA/EYEDEA PRESSE; TERRESSA DAVIS; GUANG NIU/REUTERS; STEPHEN CHERNIN/GETTY IMAGES

when those artifacts have already been snatched from their original contexts, Kersel says.

Back in Jerusalem, Mohammed has no time to ponder the perilous state of the world's cultural heritage. He's waiting for his next delivery of highly profitable spare change.

In an effort to discourage illegal transactions, Israel has legalized buying and selling artifacts from collections assembled before 1978. Ownership of later finds automatically passes to the state. Yet Mohammed's coin sales remain strong.

"Mechanisms currently in place to combat the illegal excavation of archaeological sites do not appear to be acting as deterrents," Kersel says.

During the AIA meeting, Kersel described the inner workings of trafficking of Bible-era coins. Others described rampant looting and destruction of archaeological sites in many parts of the world.

Mohammed, Kersel says, participates in a trade network with a structure common to antiquities trafficking. Individuals, families and organized bands living in archaeologically rich regions loot ancient goods and smuggle them, often via middlemen, to nearby countries that serve as transit points. There, antiquities dealers and sometimes even government officials provide export papers and other documentation that wipe the illicit stain from looted artifacts.

Artifacts with a "clean bill of sale" go to sales-friendly countries or are sold via online outlets, including eBay. In some countries, laundered artifacts are sold at art fairs and auction houses. Wealthy collectors and museum officials, knowingly or unknowingly, often buy looted or stolen art and antiquities, Kersel says.

Palestinian women from the West Bank town of Hebron supply Mohammed's product, unearthing ancient coins while gathering produce. To Jerusalem they bring not only their produce, but also hidden coins to sell to Mohammed.

He then offers to show the coins to his many foreign shoe-shine clients. On a good day, he makes $200 to $300 selling two or three coins that he bought from the Hebron women for perhaps $5.

After 40 years in the shoe-shine/coin business, Mohammed recognizes particularly rare coins and sells those to a licensed Israeli antiquities dealer who visits him regularly. Kersel and other archaeologists have noted that some licensed dealers use devious paperwork to launder looted material.

Legally sold artifacts in Israel receive registry numbers, but tourists often forget to request an export license issued by the Israel Antiquities Authority. This oversight typically doesn't matter, since airport customs officials aren't trained to recognize suspect artifacts and rarely ask for export licenses, Kersel says. Dealers can assign the registry numbers of already sold items to new artifacts, which receive export licenses as well.

In this way, a tourist from New York City can walk into a Jerusalem antiquities shop, buy and take home a freshly laundered coin from biblical times. If the tourist paid $250, the dealer probably bought it from Mohammed for about $50.

Looting is local

Mohammed's business shows that artifact trafficking need not involve organized crime or terrorists, Kersel adds. Although many Israeli dealers and collectors interviewed by Kersel mentioned the Russian mafia as a force in selling looted Middle Eastern artifacts, no evidence of such activity has turned up in her research.

An online survey of 2,358 archaeologists throughout the world, conducted by criminologist Blythe Bowman of the University of Nebraska at Omaha, suggests that even frontline researchers exaggerate organized crime's involvement. Nearly all surveyed archaeologists thought that organized criminal enterprises participated in looting, selling and transporting artifacts. But only 58 percent said that such groups operated where they worked. Many said they do know of local gangs and families involved in looting and selling antiquities.

Archaeologists often fail to grasp their inadvertent involvement in local looting, says Boston University's Christina Luke. She works in western Turkey, where for two centuries researchers have excavated remains of royal Lydian tombs dating from the seventh to third centuries B.C.

Looting of Lydian sites began in Roman times. Annual surveys by Luke and her colleagues since 2000 reveal ongoing tomb looting and increasing destruction of Lydian earthen mounds by backhoes and other machinery.

Many Turks living near Lydian tombs have worked as hired laborers on past archaeological digs. That experience trained them to recognize promising sites and valuable artifacts.

Not knowing what archaeologists actually do, locals regard the outsiders as looters who operate above the law, according to interviews conducted by Luke and colleagues. To beat the competition, local residents take Lydian objects

J. KORENBLAT

Victory from the jaws of defeat

Even looters can have a change of heart. In March 2004, villagers in Khovle, Georgia, helped themselves to artifacts from a nearly 2,000-year-old tomb discovered by farmers. An archaeologist who had grown up in the village heard about the find and convinced villagers to hand looted goods over to him.

Vakhtang Shatberashvili of the Georgian National Museum in Tbilisi ended up with the material. He has analyzed two painted glass jugs from the tomb that look much like jugs from third century settlements in Ukraine and Syria.

In 2008, Shatberashvili received funds from the U.S. Embassy in Georgia to survey and excavate the field around the ancient tomb. Last November, workers uncovered five graves dating to between 100 B.C. and A.D. 100. Further excavations will continue this year. —*Bruce Bower*

to dealers and collectors in nearby cities, often working on retainer fees.

"This is a new system that actually employs people to find material, instead of paying them pending the discovery of a specific object or hoard," Luke says.

To make matters worse, farmers routinely smash Lydian monuments and bulldoze land to erase ancient remains, Luke's group found. Their goal is to skirt a Turkish law banning farming or building on land that contains major archaeological sites. In some cases, looters threaten farmers who would inform the government of an ancient site.

Soft spots remain

University of Georgia's Davis knows well the law's limits in deterring looting. Consider Cambodia, where she surveyed archaeological sites from 2004 to 2006.

Cambodian officials complied with a 1970 United Nations convention, now ratified by 102 nations, that requires protecting archaeological sites and taking measures against antiquities trafficking (see also page 32, this issue). The government's compliance presaged a sharp decline in looting at the famous Angkor Wat temple, Davis notes, which she says about 400 police officers now patrol.

But intrepid looters target isolated, unprotected sites. Working for Heritage Watch, a nonprofit organization in Phnom Penh, Davis documented rampant looting nearly everywhere she went. Treasure hunters had devastated prehistoric cemeteries and temples of the ninth to 15th century Khmer empire. Gangs of looters had used chain saws and dynamite to rip temples apart and remove colossal statues whole. Looters' tunnels were so closely spaced that parts of the countryside had became moonscapes.

"I was shocked when I witnessed the aftermath of the destruction," Davis says.

Somewhat encouraging, the number of Khmer artifacts offered for sale by Sotheby's auction house in New York City has dropped by about 80 percent since 1999, the year the United States banned the import of Cambodian archaeological items lacking export licenses. But it's hard to know whether the U.S. ban stymied the illegal trade or simply sent it further underground, Davis says.

Sales of looted Cambodian artifacts remain healthy, remarks archaeologist Dougald O'Reilly, director of Heritage Watch. Looters in remote areas now comb sites with metal detectors. Many items get smuggled into Thailand and sold in Bangkok. "We have had reports of some objects appearing in Belgian shows," O'Reilly says.

The future of illegal antiquities sales may lie on the Internet, according to Stanford University archaeologist Neil Brodie. Using auction data from Sotheby's in New York and Christie's in London, Brodie documented consistently high sales figures for Mesopotamian artifacts from Iraq — many with no ownership histories — from the late 1980s to 2003. At that point, U.N. trade sanctions on Iraqi cultural material were reinforced. Iraqi artifacts without provenance suddenly disappeared from the auction market.

But from December 2006 to September 2008, websites selling 4,000- to 5,000-year-old Mesopotamian artifacts of dubious provenance flourished, Brodie says. What started out as 55 websites offering 225 artifacts, including cuneiform tablets, grew to 72 websites featuring 474 artifacts.

Another new tactic is for auction houses to hold small, private events rather than large, public ones, says Donna Yates, an archaeology graduate student at the University of Cambridge in England. In 2006, Sotheby's launched private auctions of pre-Columbian artifacts from South America, she says.

Yates regards Sotheby's claims of "strong provenance" for privately offered South American artifacts as dubious. Analyzing Sotheby's public auction data from 1986 to 2005, she calculates that buyers spent nearly $20.5 million on South American artifacts. Most items had no documented provenance.

"Auction catalogs were littered with fake pieces and obviously illegal antiquities, some of which were eventually subject to litigation or seizure by U.S. authorities," Yates says

In a statement to *Science News*, Sotheby's rejects Yates' conclusions. An in-house compliance department at the auction house has worked to abide by cultural heritage laws and regulations since 1997 and assists archaeological consultants in setting standards for documenting artifacts' ownership history, according to Sotheby's. "Sotheby's has long been committed to a legal and legitimate antiquities market," the statement says.

Saving the past

After the fall of the Soviet Union in 1991, former Soviet republics such as Georgia attracted intense looting of unprotected archaeological sites. Ransacking of artifacts and site destruction because of urban development continue today. "Nothing short of strenuous personal intervention stands between these sites and their looting," says archaeologist Owen Doonan of California State University, Northridge.

One day in 2008, Mikheil Abramishvili looked out the window of his office in Georgia's capital, Tbilisi, and saw heavy machinery ripping into an eighth- to seventh-century B.C. cemetery that had been partly excavated more than 30 years earlier. Abramishvili, director of an archaeological museum, convinced a government official to visit the site and confirm that construction activity had exposed archaeological remains. Georgian law then allowed Abramishvili to excavate the site at the developer's expense.

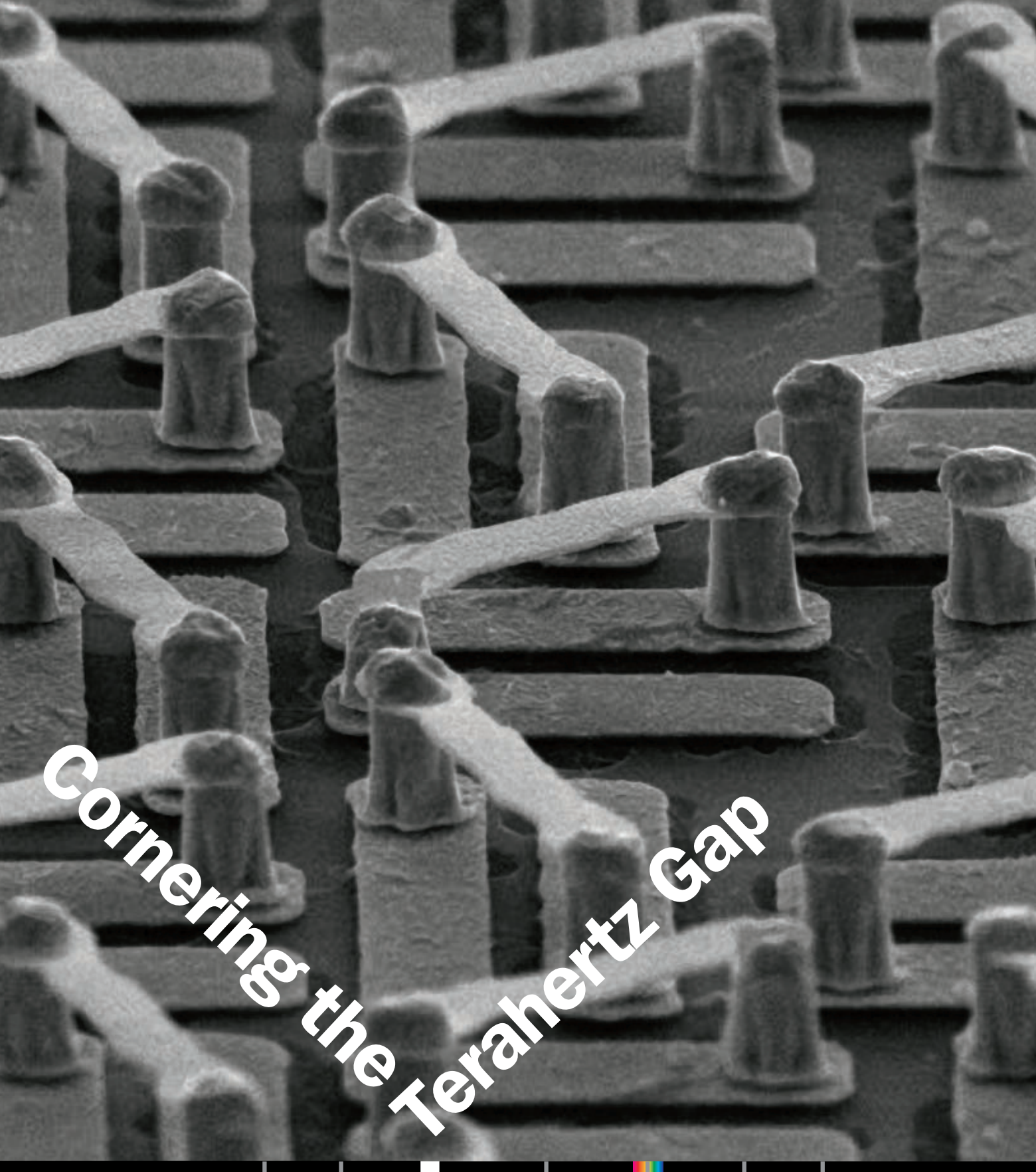
Abramishvili, now a visiting scholar at New York University, convinced another Tbilisi developer to fund an excavation before building a supermarket on top of a Bronze Age settlement.

Says Stanford's Brodie: "The way forward in fighting the illegal antiquities trade has to include archaeologists making long-term commitments to the sites they study, so that local residents get to know and trust them."

In the meantime, another day dawns in Jerusalem. Mohammed's shoe-shine stand is open for business. ■

Explore more

- UNESCO on trafficking of cultural property: http://tinyurl.com/cxtbex



Cornering the Terahertz Gap

10^{5} Hz
Long-wave radio

10^{9}–10^{10} Hz
Radar

10^{10}–10^{11} Hz
Microwaves

10^{12} Hz
Terahertz

10^{13}–10^{14} Hz
Infrared

10^{15} Hz
Visible

10^{16}–10^{18} Hz
Ultraviolet

10^{18}–10^{21} Hz
X-rays

10^{21}–10^{22} Hz
Gamma rays

Controlling light's path could enable invisibility or harness an intriguing but so far elusive stretch of the spectrum

By Ashley Yeager

Light is a nimble gymnast. It travels in many colors and frequencies. Its waves, whether long or short, can shift to be longer or shorter. Light waves change direction. They bounce.

What light can't do, on its own at least, is bend backward. In other words, it always refracts or reflects in a predictable, normal direction.

Scientists seeking to make light waves do such unnatural gymnastics have failed to find any natural material that does the job. But in recent years, physicists and engineers have been experimenting with different "metamaterials," engineered substances that interact with electromagnetic waves in precisely controlled ways. The researchers have made swift progress: Already, they have created metamaterials that can in fact bend light backward. By reversing refraction, these new materials could essentially take a fish out of water, making it appear to float above the water's surface. Theoretically, the materials also can, just like Harry Potter's famous cloak, render objects invisible.

Researchers haven't yet mastered such tricks. But recent advances are improving scientists' ability to control how metamaterials interact with light, says engineer Xiang Zhang of the University of California, Berkeley.

Metamaterials may also help scientists exploit another form of light called T-rays, or terahertz radiation. T-rays have properties that make them intriguing to scientists. But T-rays have proved extremely challenging to detect, measure and propagate. Thus the name for the region of the electromagnetic spectrum they occupy between the better known microwave and infrared radiation: the terahertz gap.

Terahertz radiation can easily pass through nonmetallic materials such as plastic, fabric, wood and glass, but is partially absorbed by water and gases. These abilities and others make T-rays appealing for a range of potential applications — from biological imaging to quality control (such as detecting an air bubble in a block of foam from the space shuttle) and seeing inside sealed packages. Beginning in the 1990s, researchers have been able to build more cost-effective, practical devices to generate and detect T-rays, including T-ray imagers (*SN: 8/26/95, p. 136*) and cameras. But the resolution of these devices remains poor, making the technology impractical for widespread use.

Many researchers think that metamaterials engineered to have specific electric and optical properties could harness the power of T-rays to build cameras that watch biological molecules in action; build screening devices that see through materials opaque to visible light; or design spectrometers that "sniff out" biological and chemical agents that X-rays can't detect. On the flip side, T-ray cloaking devices to fool these terahertz screeners could also be created. Closing the terahertz gap with the help of metamaterials could take the cloaking of weapons, bombs, drugs and other matter out of the realm of magic and into the real world.

"Of course, the science is young and these applications are still in the proof-of-principle stage," says physicist William Padilla of Boston College. Many technical issues must be worked out before engineers can create devices for improved airport security screeners, spectrometers and invisibility cloaks.

For now, researchers have more experience working with metamaterials tuned to other types of electromagnetic waves, especially visible light and microwave radiation. Some have produced other possibly useful technologies: Reporting in *Science* in 2007, Xiang Zhang's group demonstrated that a metamaterials-based lens coupled with a typical optical lens could manipulate visible light to "see" patterns that were too small to be observed with an ordinary optical microscope. A device that detects such fine scales could be used to observe cellular processes, such as how proteins and fats move in and out of cells, currently impossible to watch in action. Or it could be used to improve the first steps of photolithography and nanolithography, essential in the manufacture of smaller computer chips.

Selective spin, a nimble NIM

Metamaterials are engineered structures made of distinct, non–naturally occurring combinations of chemical elements. What makes a metamaterial work is its geometry of repeating structures that, like cookies on a baking sheet, are laid out on repeating layers of film.

A good starter structure for creating a metamaterial is a ring with a small gap in it. Typically, the rings are made of a nonmagnetic metal such as copper and carefully placed on a printed circuit board coated with a metal film. The shape and composition of the rings and, more important, their arrangement determine how the metamaterial responds to light. As electromagnetic waves hit the rings, each ring excites electrical currents in the metal film. The film can either absorb the radiation or reemit it exactly the way researchers design it to.

The gaps in the rings make the material transmit or resonate at a certain frequency, giving these metamaterials the name split-ring resonators. But the ring

A material made up of micrometer-sized structures, each formed to function as both an electric and magnetic dipole, is shown up close. Placed just right, the tiny circuits can steer light waves.

X. ZHANG AND S. ZHANG/UNIVERSITY OF CALIFORNIA, BERKELEY

shape is not the only possibility, says Shuang Zhang, a postdoctoral researcher in the lab of Xiang Zhang (no relation).

The repeating structures can also be formed by single spirals that look like curled Christmas ribbon or layered spirals that resemble pinwheels. The size and shape of each structural element and how the elements are positioned will determine whether the grid effectively guides an electromagnetic ray along a particular path.

Such fine control, Shuang Zhang says, would enable the manipulation of radiation in unnatural ways, such as making light bend or refract backward — negative refraction — or causing it to bend around an object as if the object weren't there — cloaking.

Metamaterials that achieve negative refraction are called negative index materials, or NIMs. Generally, they are engineered to have both an electric field and magnetism that work in opposite directions from what's normally expected. Only by flipping both of these properties can the metamaterial give light the bends.

Creating this type of metamaterial represented a breakthrough, one that in 2004 ended the debate over whether materials could bend light (most convincingly microwaves) backward. At the same time, negative refraction is a property that's not easy to implement into a material, Padilla says.

Researchers including Shuang Zhang aim to create this unnatural property using something natural: chirality.

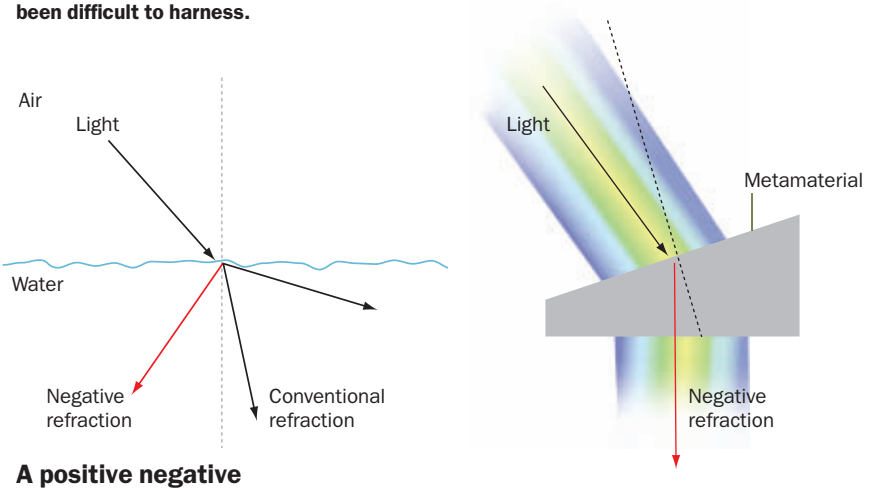
Chirality is a property that describes something that does not look identical to its mirror image — such as the human hand. No orientation can match all the features of a left hand to those of the right. Try putting a left-handed glove on your right hand, and you'll feel chirality.

In nature, chirality affects the orientation of molecules. The sweetening agent aspartame, for example, is more than a hundred times sweeter than sucrose but has a mirror-image molecule that is bitter. DNA, proteins and amino acids all have specific chiral orientations.

Chirality is also fundamental in all fields of physics, Shuang Zhang says,

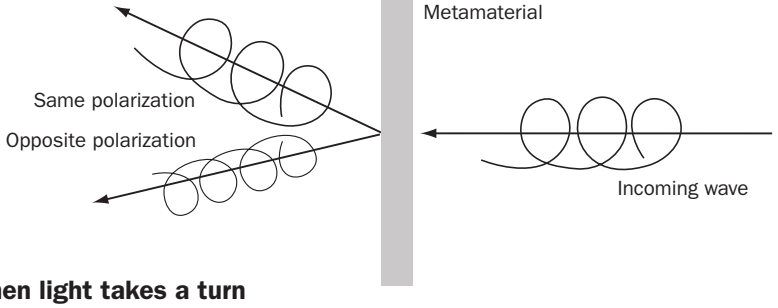
Bending light backward

Metamaterials now exist that can make visible light and microwaves travel in unnatural paths. New kinds of metamaterials are being designed with a specific orientation, or chirality, to put an unnatural twist on light, even with T-rays, a frequency of light that has been difficult to harness.



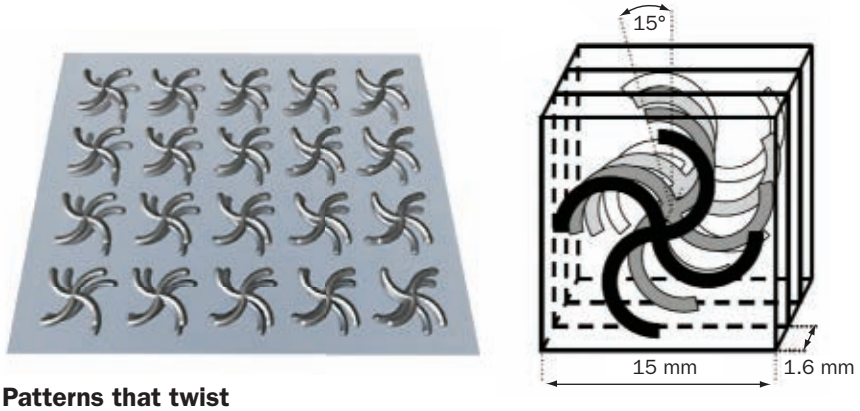
A positive negative

As a light wave travels from one medium, such as air, into another, such as water, it follows Snell's law: When light refracts, it does so on the other side of an imagined line perpendicular to the water's surface. Fish in water look closer than they actually are because of Snell's law. But some man-made materials can defy Snell's law and send light refracting on the other side of the line — a negative refraction that essentially takes fish out of water. Other materials may be able to steer light around an object and render the object invisible.



When light takes a turn

Scientists hope to engineer a material that can bend terahertz radiation. One approach is to manipulate circularly polarized light, which moves like a corkscrew. One light wave leaves as two after passing through the material: a wave moving in the same corkscrew direction as the original, and a wave moving in the opposite direction and with a smaller amplitude — such that it is not only negatively refracted, but perhaps also negatively reflected.



Patterns that twist

When steering circularly polarized light to negative refraction, it's all in the layering. Eric Plum and colleagues at the University of Southampton in England have proposed a material built of four sheets, each with a repeating pattern of twisted rosettes. Stacking the sheets such that each rosette layer is slightly misaligned, as shown above, could reverse a light wave's polarization.

FROM TOP: ADAPTED FROM THE SCHLUMBERGER OILFIELD GLOSSARY; J. PENDRY AND D. SMITH/*PHYSICS TODAY* JUNE 2004; BOTH IMAGES REPRINTED WITH PERMISSION FROM E. PLUM *ET AL./PHYSICAL REVIEW B* JANUARY 2009

because it describes the relationship between the direction a particle is moving and the way it is spinning. Light can be chiral.

Light waves ordinarily vibrate in all directions. Should light become polarized, its waves vibrate only in a single plane. The human eye perceives polarized visible light as glare because a large number of horizontally vibrating waves seem to overpower the other waves. If light is circularly polarized, its waves travel in a corkscrew pattern and rotate either clockwise or counterclockwise as the wave's electric field sweeps out a spiral. The pitch or angle of orientation of this spiral is equal to the light's wavelength, and the chirality depends on whether the spiral sweeps clockwise or counterclockwise as the light wave moves along its path.

Shuang Zhang says that researchers use the chirality of molecules and also of light to defy the laws of physics and bend light backward. When polarized light hits a metamaterial tweaked to have a spiral structure, the light leaves as two waves. But the waves' amplitudes, or heights, are not equal. One wave shows a tighter spiral rotation while the other shows a looser rotation. The looser spiraling wave might actually spiral slower and slower until it reverses its original rotation direction, causing it to be negatively refracted, he says.

Because chiral materials almost automatically create a wave of light that rotates opposite to its original direction, physicists could use chiral materials to more easily create devices that cause negative refraction — even at terahertz frequencies.

Metamaterials researchers have manipulated radiation mainly in the microwave or optical range, Xiang Zhang says. T-rays have been harder.

In 2004, theorist John Pendry of Imperial College London showed mathematically that chiral metamaterials could have distinct properties from standard NIMs because they detect different polarizations of light and can reradiate light at reversed polarizations. Pendry predicted that chiral NIMs would open new possibilities for metamaterials research, specifically a novel route to creating negative refraction metamaterials.

Four years later, in December 2008, the Berkeley team published the first experiments to demonstrate that chiral metamaterials could not only tune in to and pick up terahertz radiation, but could also negatively refract it.

The group has since shown that chiral metamaterials can even negatively *reflect* radiation.

In normal reflection, when light hits a mirror, it is reflected at the same angle as the original light entered, but in the opposite direction. Imagine a "V" bisected by a mirror. The left side of the letter represents the light approaching the mirror's surface. The right side of the letter shows how the reflected light leaves the system.

When radiation hits the surface of a chiral NIM, it would behave differently: The light would not hit the surface and leave at the same angle at which it arrived. Instead, the light would reflect on the same side of the center at which it entered — a phenomenon physicists call negative reflection.

But let's not play Twister

Xiang Zhang and Shuang Zhang's proof of principle "offers a new dimension to explore in terahertz metamaterials," Pendry says. It could also lead to better-engineered T-ray devices and perhaps advanced computing capabilities.

But not all physicists and engineers are convinced that metamaterials have to be chiral to conquer the terahertz gap. "Chirality and even negative refraction are both properties to manipulate into metamaterials," Padilla says. "Engineers are not yet sure what to do with these properties in terms of applying them to making devices." In the future, "killer applications" could require either or both a chiral and conventional NIM.

In April 2008, Padilla and collabora-

tors from Boston University and Los Alamos National Laboratory in New Mexico published work in *Nature Photonics* that showed how nonchiral, semiconducting, split-ring resonator metamaterials could interact with light to absorb and reemit T-rays. Reporting online in the same journal on February 22, the team showed that its latest version of a hybrid structure of metallic split-ring resonators could allow increasingly precise manipulation of terahertz radiation. The metamaterial also regulated the flow of terahertz radiation over roughly 70 percent of the T-ray frequency band — not just at the maximum or minimum frequencies. Padilla explains that applying an electronic signal to this device can make it opaque, stopping terahertz radiation, or transparent, allowing terahertz through.

With metamaterials, engineers can make solid-state devices at terahertz frequencies, Padilla says. He and his colleagues are designing a terahertz video camera that would capture biomolecules in action. The researchers are also looking into a potential screening device for airport security. T-ray scanners would send radiation through opaque materials, allowing security screeners to see into suitcases and under clothing. Such a scanner would be more sensitive than simple metal detectors while causing less damage to cells than X-rays.

The other device Padilla has in mind is a terahertz spectrometer that could "sniff out" the otherwise indistinguishable fingerprint of chemicals, biological agents and certain explosives that can evade X-ray detection. Because biological and chemical substances release weak T-ray signals, security checkpoints screening with T-ray absorption patterns might be able to detect and identify a wider variety of hazardous or illegal substances than current detectors can.

To see these applications in use might take a few years to a few decades, says Richard Averitt, a physicist at Boston University who collaborates with Padilla and B.U. graduate student Hu "Tiger" Tao. Padilla and Tao are among those beginning to design the switches, modulators, lenses and detectors that will go into devices such as T-ray security scanners, video cameras and spectrometers. Reporting December 19 in the online *Physical Review B*, Tao described the design of an absorber that collects all the terahertz radiation beamed its way.

Reducing the size of the split-ring resonators and scaling them to T-ray wavelengths is the key to making a T-ray cloak.

A terahertz cloak is also on the drawing board. Tao could guide T-rays around a particular area so that — from the photon's perspective — the area doesn't exist.

Tera-smoke and tera-mirrors

Cloaking became more than a theory in 2006 when Duke University researchers designed split-resonator metamaterials that, capable of negative refraction, could guide microwaves around a "secret" pouch. The waves seemed to curve above, below and around the pouch without being disrupted in their path, as if the pouch were invisible. Since then, Xiang Zhang's Berkeley group has devised two new metamaterials for cloaking in the visible part of the spectrum, reported in August 2008 in *Science* and *Nature*.

Early last year, Shuang Zhang proposed a matter cloak. Not only light, but also matter "waves" would warp around a small, protected, spherical area. Matter waves exist at the quantum level where quantum mechanics blurs the boundaries between the properties of particles and those of waves. If matter can be cloaked from light waves, so too can matter waves be cloaked from matter, Shuang Zhang and his colleagues suggested in March 2008 in *Physical Review Letters*.

Few have tried to warp T-rays around a sphere because the radiation is so hard to produce in the first place, Tao says. Nonetheless, at the 2008 IEEE International Electron Devices Meeting, the Boston group said it would build a terahertz invisibility cloak. Such a cloak would countervail T-ray screening technology.

The cloak today is merely a mock-up of the invisibility cloak that Duke researchers developed for microwaves. Cloaks designed so far could only hide objects millimeters or smaller in scale. But the Boston group says that reducing the size of the split-ring resonators and scaling them to T-ray wavelengths is the key to making a T-ray cloak. Also, Tao says, the entire resonator system, the metamaterial itself, should be cylindrical rather than square. A cloaking, can-shaped device would be made from multiple concentric layers of film. So far, only a computer simulation has demonstrated that the cloak could work — with about 50 layers of film. "Our team's not there yet," he says.

Averitt says he is impressed with Tao's engineering. But he adds that to worry about a terahertz cloak to fool terahertz scanners is a little premature. "Sure, in principle, people could conceal weapons with terahertz or other types of cloaks," he says. But the technology isn't that advanced yet.

One challenge will be to make metamaterials that cover the entire electromagnetic spectrum simultaneously. "It is not clear that this can be done," says physicist Steve Andrews of Bath University in England. But without this ability, metamaterial-based imaging and Potteresque cloaks of invisibility would be limited.

Xiang Zhang agrees, and says that it's hard to know what will become of his group's experiments on chiral NIMs or other metamaterials research because so many questions remain unanswered. Yet it's the very potential of these new ideas, he says, that gets the community so excited about the field.

Ultimately, the advances are hard to make, but "we're willing to try it, and sometimes we might discover useful things along the way," Averitt says. ■

Ashley Yeager is a science writer based in Hawaii.

Explore more

■ Shuang Zhang *et al*. "Negative Refractive Index in Chiral Metamaterials." *Physical Review Letters*. January 16, 2009.

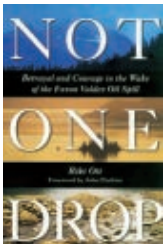
Not One Drop: Betrayal and Courage in the Wake of the Exxon Valdez Oil Spill

Riki Ott

Just as Katrina was more than a hurricane, the *Exxon Valdez* disaster was more than an oil spill, writes marine biologist and "fisherma'am" Riki Ott. In this account, Ott traces the forces that led up to what she calls "The Big One," and chronicles the tragic environmental, personal and legal fallout from the spill.

Just before midnight on March 23, 1989, the fully loaded tanker *Exxon Valdez* ran aground in Alaska's vibrant Prince William Sound, belching millions of gallons of crude into the water. Hours after the tanker crashed, Ott flew over deep blue water and pinkish white mountains on the way to witness the spill. "Juxtaposed against this beautiful calmness lies the stricken tanker, blood red and bleeding inky black," Ott describes. "The strong vapors make our heads and stomachs reel."

The unprecedented oil spill is viewed through the lens of Cordova, a small fishing community and Ott's home, on the edge of the sound. After the spill, Cordova's economy collapsed as herring and salmon disappeared. Residents watched helplessly as Exxon bungled the cleanup operation, broke promises to compensate residents and vehemently fought lawsuits in and out of court, Ott writes.



The book concludes as a June 2008 Supreme Court decision reduces the punitive award against Exxon to less than 10 percent of the original $5 billion settlement.

Not One Drop is written in a familiar and nontechnical tone, more a historical narrative than a scientific explanation of the damage from the spill. At times Ott lapses into didacticism. Even so, the book offers a personal glimpse of all that was lost underneath the oil slick. *— Laura Sanders*

Chelsea Green, 2008, 327 p., $21.95.

Everyday Practice of Science: Where Intuition and Passion Meet Objectivity and Logic

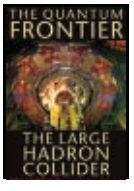
Frederick Grinnell

A scientist attempts to demystify the scientific method. *Oxford Univ., 2009, 230 p., $27.95.*

The Age of Anxiety: A History of America's Turbulent Affair with Tranquilizers

Andrea Tone

The story of America's shift to synthetic solutions for personal angst. *Basic Books, 2009, 298 p., $26.95.*



The Quantum Frontier: The Large Hadron Collider

Don Lincoln

A Fermilab scientist conveys the excitement surrounding the LHC. *Johns Hopkins Univ., 2009, 172 p., $25.*

Impossible view

In "Milky Way puts on weight" (*SN: 1/31/09, p. 8*), you claim to show an image of the Milky Way. This image cannot be real. Worse, it creates misconceptions: As a college educator, I find that most students actually believe NASA has launched probes outside of the Milky Way to take pictures of our galaxy. I hope that printing a correction will help dispel that belief.

Don McCarthy, Tucson, Ariz.

McCarthy, of the University of Arizona's Steward Observatory, was one of a number of readers who pointed out the impossibility of taking a "real" image of the entire Milky Way galaxy, the subject of the art in the January 31 issue. As reader William Westervelt of East Granby, Conn., put it: "How can we get a plain view of an entity that we are all mixed up with, in the middle of?" To clarify, the image shown is an illustration based on an animation called "Virtual Voyage through the Milky Way" from the Chandra X-ray Observatory website. We did not mean to imply that this was an actual photo. — Eva Emerson

Inspired by change

The editor's statement ("For both universe and life, only constant is change," *SN: 2/14/09, p. 2*) that change is the only constant is a factual idea one encounters infrequently. I was teaching my students this in 1956, spurred by Marcus Aurelius' *Thoughts*. He made the point in several places in his writings, though he may not have been the earliest to do so. Early on, I raised the ire of biblical fundies in East Texas and beyond, but I continue to believe and express that change is the only real constant. Thanks for your editorial. The emperor would have loved it!

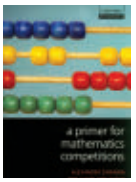
Franklin H. Mason, Tyler, Texas

Speedy planet building

In "Meteors deliver Earth-like crust" (*SN: 1/31/09, p. 15*), you say the meteorites with Earth-crust–like materials formed "less than 50 million years after the solar system formed." What does this say about the rate at which terrestrial planets form? Does this constrain any planet-forming theories as we look for exoplanets around young stars?

Wayne Harris-Wyrick, Oklahoma City, Okla.

Planets can form relatively soon after the material in a solar system begins to coalesce, says Timothy McCoy, curator of meteorites at the Smithsonian Institution in Washington, D.C. In just tens of millions of years, planet-sized bodies can accumulate from nothing but dust and gas, he notes. Very young star systems, even those apparently surrounded by nothing but disks of dust, could have planet-sized bodies hidden in that material, he says. — Sid Perkins



A Primer for Mathematics Competitions
Alexander Zawaira and Gavin Hitchcock
A guide to acquiring the mental equipment and problem-solving agility needed to become a successful mathlete. *Oxford Univ., 2009, 344 p., $45.*

Haywired: Pointless (Yet Awesome) Projects for the Electronically Inclined
Mike Rigsby
Make a smiling picture frame, a talking alarm, a no-battery electric car and more with this how-to guide for hobbyists. *Chicago Review, 2009, 187 p., $16.95.*

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Top-of-the-world route to America

The study in "Migrants settle Americas in tandem" (*SN: 1/31/09, p. 5*) shows the X2a haplotype in the Great Lakes area, not along the West Coast. If the top of the Earth was covered with ice, permitting migration, could the Great Lakes settlers have come through Baffin Island by way of Greenland, Iceland, Faroe Island and Scotland? Or Svalbard and Norway? Maybe a route similar to the Vikings'?
Bill Frost, Franklin, Tenn.

Researchers traced the haplotypes back to northeastern Asia, consistent with other genetic evidence suggesting that ancient New World settlers crossed a land bridge from Asia to Alaska. — Bruce Bower

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James Cuno

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Treaty on antiquities hinders access for museums

James Cuno, a past president of the Association of Art Museum Directors, has spent years investigating implications of a United Nations treaty: the Convention on the Means of Prohibiting and Preventing the Illicit Import, Export and Transfer of Ownership of Cultural Property. It prohibits museums and other research centers from acquiring objects unearthed after 1970 without permission from the country of origin. Such permission is seldom granted, Cuno notes in his new book, Who Owns Antiquity? *Last month, senior editor Janet Raloff spoke about the treaty with Cuno at The Art Institute of Chicago, where he is the director.*

What was the effect of the UNESCO 1970 treaty on looting of archaeological sites?

It hasn't stopped looting. In fact, from what we hear, looting is increasing.

Looting is not a leisure pastime. People don't decide to become a looter rather than being a lawyer. They are desperate people doing desperate things. In situations of a failed economy, a failed government, the absence of civil society, internecine warfare, sectarian violence, drought — whatever — conditions emerge that can create pressures for looting. Simply criminalizing the illegal acquisition of goods won't stop looting. It hasn't stopped the trade in drugs or trade in stolen materials of any kind.

How has the treaty affected researchers, especially their ability to buy or accept the donation of ancient artifacts?

UNESCO 1970 has encouraged the development of national protectionist property laws. Artifacts excavated after 1970 belong to the [nation] states in which they were found. And these nations have almost always enacted ownership or export laws that prohibit the legal sale or export of such objects. So if we know something was excavated after 1970, we cannot acquire it.

More often, you don't know where an item is from or when it was unearthed. Even if it has documentation indicating it was found before 1970, you have to try and substantiate whether that provenance is accurate before you can consider acquiring it.

So an important artifact with dubious provenance for sale on the open market, available for anyone else to buy, isn't available to foreign researchers?

Right. So fewer and fewer things are entering into the public domain.

These export constraints are creating black markets. And like water on a leaky roof, looted artifacts are finding the path of least resistance to a buyer somewhere. I've heard they're going to the Arab Emirates and Asia. What I can tell you is that they're not coming to museums in the United States and Europe [which adhere to UNESCO 1970].

Like water on a leaky roof, looted artifacts are finding the path of least resistance to a buyer somewhere.

You say that the treaty gives "a false view of history." How so?

The preface of UNESCO 1970 implies there is no difference between the nationals of a modern state and the ancient peoples that made things that have been excavated from the soils of modern states. The argument seems to be that these people share a "collective genius" — one that might be racial or ethnic or cultural. And that the shared genius is particular to the people, both ancient and modern. But that argument was made by politicians, not by scientists.

In fact, I question whether any culture has ever been autonomous.

Take the Roman Empire. It not only emulated Greek culture, but had contacts throughout at least North Africa, the Near East and East Asia all of the way to China. Which means it was a mongrel culture. To now claim a kind of cultural purity exists between it and people inhabiting Italy today is an oxymoron.

The treaty seeks to keep wealthy nations from raiding the cultural history of poorer ones in the name of science. What's wrong with that argument?

It perpetuates this false view or sentiment that things are appreciated better if they are encountered where they were made. But sometimes things are better appreciated if they can be compared and contrasted with similar artifacts from other cultures and geographic regions. Which argues for some sharing.

Preventing the export of ancient cultural artifacts also greatly concentrates the risk to their survival. We know the damage that can be done by warfare and sectarian violence. And I don't just mean in Baghdad and Kabul, where those museums were virtually destroyed, but also in Berlin. Even New York on 9/11.

We don't know where violence is going to occur. But an insurance appraiser would tell you: You want to distribute your risk from catastrophic damage by keeping things in multiple places.

In your book you talk about how the practice of partage [sharing] has fallen from favor. Would you advocate its return?

I would — in a second — because it seems to me the only reasonable way to protect the legacy of antiquities and promote a global understanding of what they represent. ■

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