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ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ NOVEMBER 7, 2009

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Discovered: Three Kings' Silver Coin from the Time of Jesus' Birth

Imagine holding in the palm of your hand an ancient silver coin minted by of one the three kings who sent their emissaries to witness the birth of the baby Jesus. Imagine owning a coin that was touched by the people who walked among Jesus during his years on earth. Today, through an exclusive release by GovMint.com you can own an authentic silver Drachma, saved from destruction and preserved for over 2,000 years!

Miraculous Find Garners Worldwide Attention

Finding an ancient Silver Drachma coin anywhere in the world is a noteworthy event. Finding one issued by one of the "Three Kings" of the Bible, a coin produced by the King of Persia from 35 BC to 5 AD and used throughout the life of Jesus Christ, is cause for true excitement. Intricately designed, it is a miniature work of art. In ancient times the Silver Drachma was struck by hand, one at a time, so no two are exactly alike. This was a coin that could have easily been used to purchase the gifts presented to the Christ Child and has been historically proven to have circulated in Jesus' lifetime.

A Gift That Will be Treasured!

The Parable of the Lost Drachma

The Silver Drachma was a coin well known to Jesus and his followers. In one of his parables Jesus says, "Or what woman, having ten drachmas, if she loses one, does not light a candle and sweep the house and look diligently till she finds it? And after she has found it, she calls in her friends and says, Rejoice with me, for I have found the drachma that I lost" (Luke 15:8-9).

A Precious Christmas Gift

Your Silver "Kings" Drachma from the time of Christ will arrive housed in a deluxe presentation album together with historical information detailing this coin's amazing journey. A signed Certificate of Authenticity guarantees the coin is from the time of Christ and is sure to be cherished by friends and family.

Prices and availability subject to change without notice.

Quantity strictly limited at this price. Orders filled on a first-come, first-served basis. Sold out orders will be promptly refunded. Note: GovMint.com is a private distributor of worldwide government coin issues and is not affiliated with the United States Government. Facts and figures were deemed accurate as of June 2009.

Very Limited at this Low Price —

This special offer of Ancient Silver Drachmas from the time of Christ is made possible by a recent discovery. The quantity is strictly limited and once they are gone, there is no telling when, or if, any more will ever be found. This coin has sold nationally for $129.95, but while our supply lasts you can own this Ancient Silver "Three Kings" Drachma for just $49.95. Additional savings are available for multiple coin orders (see details).

Specifications

Years of Issue: 35 BC — 5 AD
Composition: Silver
Design: King Azes II on Horseback
Weight: 9.65 grams (approx.)
Diameter: 15 mm

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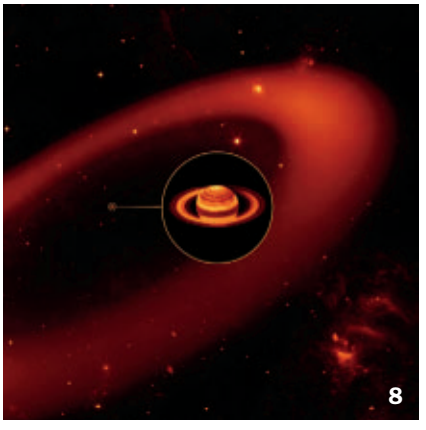

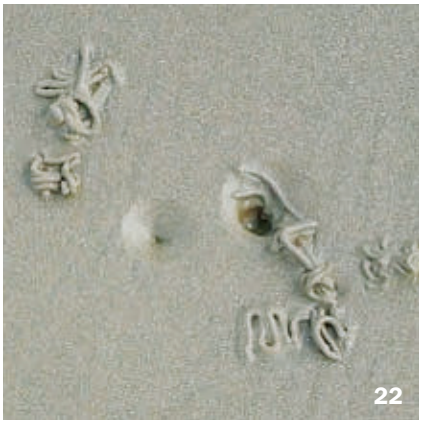

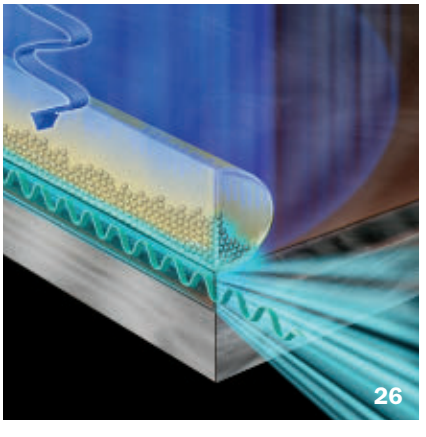

ScienceNews

In The News

Features

Departments

COVER New research has found extra fungi hiding in lichens, among other discoveries that may redefine the symbiosis. (Shown is the lichen *Ramalina menziesii*.) *Stephen Sharnoff*

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FROM THE EDITOR

Joining the blogosphere, but *Science News*–style

For some time now, blogs have been all the rage among people who consider them the 21st century reincarnation of journalism. For those who fondly remember the real journalism of the 20th century, though, blogs are the equivalent of an alien invasion of the body snatchers.

But just like Kevin McCarthy in the original film, some have railed against bloggery. Whatever merits these online dispatches might have, they're no more a substitute for actual journalism than talk radio is for Walter Cronkite. Many blogs are platforms for personal prejudices, not fair and informative reports.

There are, of course, exceptions. One appearing on the *Science News* website is reporter Janet Raloff's "Science & the Public," where she regularly covers matters of science policy that fall outside the realm of straightforward research news. Soon Janet's blog will be joined by others that will similarly exploit the blog format to offer website visitors the perspective and insight of *Science News* reporters.

Already one new blog has debuted on the website. Called "On the Scene," it consists of firsthand observations from *SN* writers attending scientific conferences or other events. Some entries will report on presentations not covered in news stories; others will offer some of the back story of what goes on at scientific meetings. You'll find reports from the recent Society for Neuroscience annual meeting, for example, and from a symposium sponsored by the Council for the Advancement of Science Writing.

Plans are for yet another blog to appear soon. It will offer the science news equivalent of movie outtakes, informing readers about some of the science that didn't get reported. Each week *Science News* considers dozens of scientific papers and reports for possible coverage; typically only 15 to 20 stories appear on the website and fewer still fit in print. This new blog will allow *Science News* writers to briefly discuss some of the items that didn't make the cut, or in some cases explain why stories reported elsewhere were not deemed worthy of *Science News*.

Although these new additions to the website will be designated as "blogs," they will continue to observe the journalistic standards for accurate, reliable and credible reporting that *Science News* will always uphold, no matter what century it is.

—Tom Siegfried, Editor in Chief

Discover the World of Discrete Mathematics

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Scientific Observations

"Human beings, because we're so clever, have removed every single one of those [population] limiting factors.... So nothing controls our increase in numbers except our own wish. Since I first started making television programs, the population of the world has increased three times. That's an extraordinary notion. Can it increase four times? Can it increase five times? The Earth is a finite size. So a point will eventually come when we run out of food, when we run out of space and when we will have destroyed most of the natural world. So ought we to do something about it before that happens?" **—NATURALIST AND BROADCASTER DAVID ATTENBOROUGH SPEAKING ON SEPTEMBER 24 DURING THE SOCIETY FOR VERTEBRATE PALEONTOLOGY'S ANNUAL MEETING**

Science Past | FROM THE ISSUE OF NOVEMBER 7, 1959

RUSSIANS RELEASE PHOTOS OF MOON'S FAR SIDE — Russian scientists have released a photograph of the far side of the moon as taken from U.S.S.R. satellite Lunik III. The photograph on the cover of this week's Science News Letter shows the far side of the moon. Soviet astronomers identify the long solid lines as the moon's equator. The heavy broken line at the left separates the part of the moon visible from the earth from the portion that cannot be seen....The apparent lack of craters and seas across much of the far side of the moon seems to corroborate a theory that predicted this side would be largely smooth.

Science Future

November 18
Last day entries for the 2010 Intel Science Talent Search will be accepted. Download forms at www.societyforscience.org

November 24
Biologist E.O. Wilson and others lecture at Harvard on the 150th anniversary of Darwin's *Origin of Species*. Sign up for viewings at darwinlecture4.eventbrite.com

November 30
Meeting for scientists and policy makers on Antarctic research begins in Washington, D.C. See www.atsummit50.aq

SN Online

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ON THE SCENE BLOG
Science News reports from the Council for the Advancement of Science Writing and the Society for Neuroscience meetings. See "On the Scene" under Blogs.

EARTH
The infamous boll weevil pest makes a comeback in Texas via a recent tropical storm. Read "Windy with a chance of weevils."

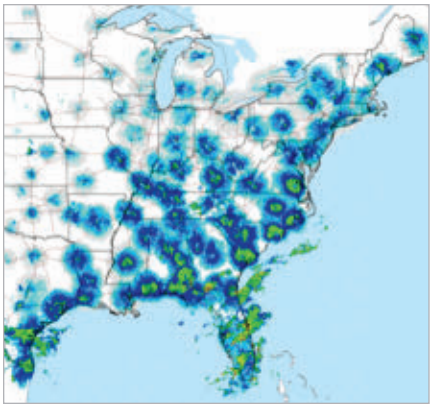
BODY & BRAIN
New research shows the same brain area may control reading and speech. See "Brain speed-reads using just one part."

GENES & CELLS
A group of neurons ignores the body's main circadian clock to take an afternoon siesta. Read "Circadian clockwork takes unexpected turns."

How Bizarre

Your online pen pal may be no Einstein, but might correspond just like him. An analysis of correspondence by Einstein and other famous historical figures shows that their letter-writing patterns are generally mirrored by patterns of e-mail today, researchers at Northwestern University in Evanston, Ill., report in the Sept. 25 *Science*. Rather than being a simple tit-for-tat (get a message, then send one), how often and when people communicate via letter or e-mail hinge on details like the time of day and day of the week. Whether someone sends one or several pieces of correspondence simultaneously and their particular need to communicate also play a role, the team's statistical models show.

Science Stats | BIRD'S-EYE VIEW OF FALL MIGRATION



As many as 5 billion birds migrate south across North America each fall, typically at night. This Doppler map, taken September 2 on a clear evening, shows flocks in flight (rounded colored areas) and a few clouds (irregular areas) across the eastern states. Green rounded areas show highest bird densities, about 227 birds per cubic kilometer.

SOURCE: NATIONAL WEATHER SERVICE, BOREAL SONGBIRD INITIATIVE

FROM LEFT: MILES BARTON/PBS/ASSOCIATED PRESS; CLEMSON UNIVERSITY – USDA COOPERATIVE EXTENSION SLIDE SERIES, BUGWOOD.ORG

“It’s the question any child would ask. How does all of this DNA fit into the cell?” —H. EUGENE STANLEY, PAGE 14

In the News

STORY ONE

Humpback alters song if another one sings along

Study may offer a new way to explore tunes’ meanings

By Susan Milius

A new approach to studying the songs of humpback whales (two shown here west of Mexico) finds that they may respond to each other musically.

D. CHOLEWIAK

QUÉBEC CITY, Canada — Like a songbird calling another out, one male humpback whale may make another change his tune.

Studying humpbacks with methods adapted from bird research has uncovered the first known instances of what look like whales responding musically to each other’s songs, says Danielle Cholewiak, a researcher for the Stellwagen Bank National Marine Sanctuary based in Scituate, Mass. Cholewiak and colleagues detected melodic adjustments when a solo singer encountered another singer nearby and when researchers played their song remixes for whales.

Male whales may be using music to tell another male, “Hey, I’m talking to you,” Cholewiak reported October 14 at the Society of Marine Mammology’s biennial conference.

Cholewiak “showed short-term acoustic interactions between males — that was the new thing,” said Adam S. Frankel of Marine Acoustics Inc., an independent consulting firm in Arlington, Va.

Among humpback whales, only males boom out long strings of repeating phrases of hums and whups and chirps. The sounds can make a boat vibrate, said Salvatore Cerchio of the Wildlife Conservation Society in New York City, who worked with Cholewiak on the new study. Scientists use the word *song* to describe this patterned male vocalization, just as they do for elaborate bird serenades.

Male songbirds sing at each other to claim their territory or seduce females. Though humpbacks don’t defend territories, they certainly have rivalries. Typically three to eight males surround a female and battle for the position closest to her. “These guys are streaming blood,” Cerchio said. “The gentle giant is a myth.”

But observations so far haven’t helped scientists understand whether humpbacks use songs the way birds do. Tests haven’t shown male or female humpbacks consistently swimming toward or away from recorders playing songs. And scientists have yet to see humpbacks mate.

So instead, Cholewiak took a different approach, boating around a breeding ground recording and analyzing songs.

“I was drooling over what she was able to do,” says Sharon Nieukirk of Oregon State University’s Hatfield Marine Science Center in Newport, Ore. Whales rarely cooperate with field biologists’ experimental plans.

Cholewiak undertook the song analysis while at Cornell University, which has a renowned flock of birdsong researchers. She adapted measurements used in bird studies to analyze the humpbacks’ songs. For example, the whales repeat a phrase of notes several times in one block, or “theme,” before moving on to another, and Cholewiak looked at how often the whales switched among these themes.

To record whales, Cholewiak spent four winters on the small island of Socorro in the Revillagigedo Archipelago off the Pacific coast of Mexico. She dropped

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SN Today at **www.sciencenews.org**

recorders weighted with sandbags into the ocean to eavesdrop on whales. After months, she transmitted an acoustic signal that released the recorders so they popped to the surface. Analyzing the recordings, Cholewiak could determine where the singers were and reconstruct their movements.

In the sea of sound recordings, she found 14 cases in which a male sang alone for at least 45 minutes and then continued for another 45 minutes after another male started singing. Cholewiak noticed two changes in song when humpbacks sang together.

Overall, the first singers switched more often among various musical themes when a second singer hung around. Also, the first males adjusted their songs so that the pair was more likely to sing the same theme simultaneously. When males meet, Cholewiak concluded, songs change.

As part of a recent study, Danielle Cholewiak dropped pop-up recorders into the ocean to record whale songs.

When she found a male singing by himself, she attempted a playback experiment. She recorded his song and used a computer program to create a simplified version incorporating three of his themes. Then she broadcast the version to him via speakers dangling below the boat.

Confronted with simplified recordings of their songs, males tended to make their singing more even. This change meant that a male came closer to spending equal amounts of time singing each theme.

Researchers don't yet know what these changes mean, but the new work opens the way for questions about what messages whales may be communicating. If humpback songs follow the pattern of birds, the messages could get pretty macho. And females could be tuning in.

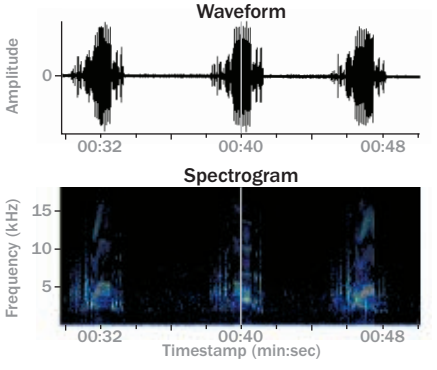
That the humpbacks appeared to respond to the playback at all was a pleasant surprise, Cholewiak says. Song playbacks had fallen into disfavor after researchers found no pattern in the movements of listeners. "I was initially very reluctant to try it," she says. Yet checking song characteristics instead of whale movements made all the difference. ■

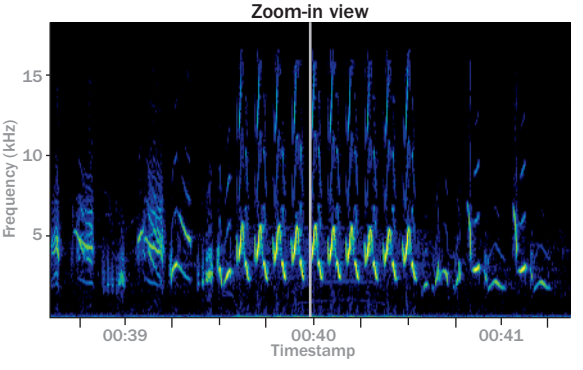
Back Story | SINGS LIKE A BIRD

In a new study, researchers built on what they know about birdsong to analyze humpback whale songs. The waveforms and spectrograms below represent portions of a birdsong and a whale song extracted from recordings on file at Cornell's Macaulay Library.

House wren

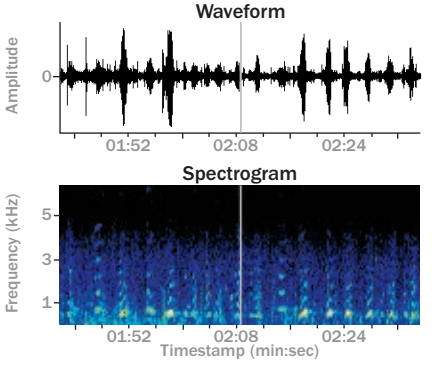
A house wren's song has structure, combining its elements into the distinctive, repeated patterns visible at right. Bursts of sound appear as dark shapes on the waveform (where bigger means louder) and colored marks on the spectrogram (which shows frequency). Correlating song patterns with behavior has helped researchers understand the function of these songs.

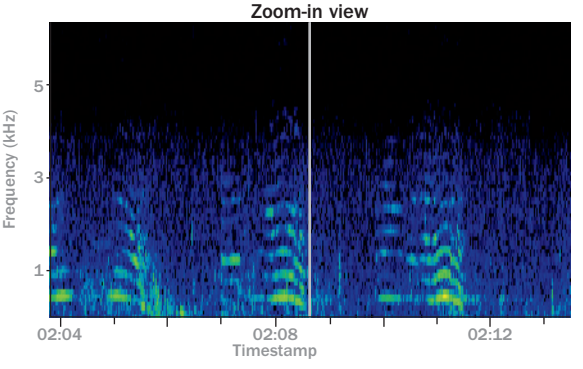




Humpback whale

A male humpback whale's song shows structure too. Songs tend to be lower pitched and more drawn out (note frequency and timestamp scales) but still contain repeating patterns. Humpbacks in the same ocean basin often sing the same patterns, which shift like musical fads during breeding season. Overall, understanding whale song function has been difficult.





TOP: S. CERCHIO; BACK STORY: ADAPTED FROM MACAULAY LIBRARY'S RAVEN VIEWER/CORNELL LAB OF ORNITHOLOGY

Bob Vila endorses and recommends the famous EdenPURE® portable heater

Millions of Americans now saving up to 50% on their heating bills and raving about the "heavenly heat"

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

The famous infrared portable heater, the EdenPURE®, which can cut your heating bills by up to 50%, has been greatly improved.

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

The outside of the EdenPURE® only gets warm to the touch so that it will not burn children or pets.

The EdenPURE® will also keep you healthy. That is because, unlike other heating sources, it will not reduce humidity or oxygen in the room.

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

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

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

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

Q. What advantages does this advanced infrared heating process have over other heating source products?

Never be cold again

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

Pictured above is Bob Vila demonstrating the famous EdenPURE® GEN3 Model 1000 heater with a family. It saves big money on your heating bill while keeping you toasty warm with "heavenly heat".

A. This infrared heating process was designed around the three most important consumer benefits: economy, comfort, and safety.

In the EdenPURE® process, electricity is used to generate a type of infrared heat which, in turn, creates a very safe heat.

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

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

End of interview.

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

The EdenPURE® heater is now greatly improved. With no increase in price, the new EdenPURE® has been updated with the latest technology, safety, and comfort features to provide you with even greater comfort, more savings, and years of reliability. The EdenPURE® comes with a comprehensive three year warranty along with a 60-day no questions asked satisfaction guarantee – we pay the return shipping.

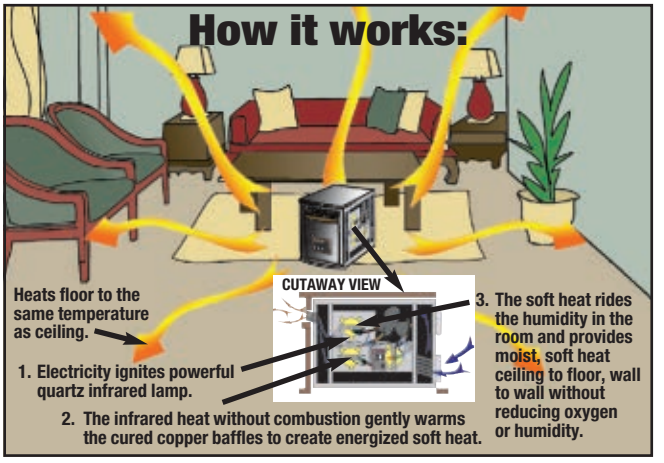
This product has been listed by Underwriters Laboratories.

Testimonials from a few of the millions of satisfied EdenPURE® customers

The EdenPURE® has cut my gas bill to a third of what it was last year. ***Leslie Wilson, Vancouver, WA***

The EdenPURE® really puts out the heat like a little solar furnace. It's below freezing outside and cozy warm in the rather over large living room area where I'm using it. I have already noticed a 40 to 60% drop in the cost of my heating bills. ***George B., Triangle, N.Y.***

How it works:



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

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Saturn reveals largest known planetary ring

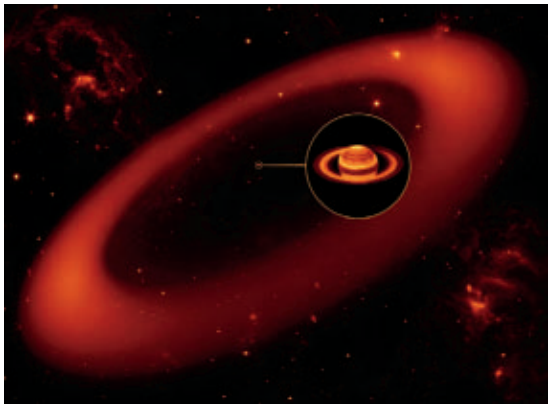
Telescope detects dust band 200 times planet's diameter

By Ron Cowen

A newly discovered planetary ring can run circles around all the others. The gossamer band of dust encircles Saturn and has a measured diameter of about 24 million kilometers, or 200 times the diameter of the planet. Calculations indicate that the ring's diameter could even reach 36 million kilometers.

The band is the largest known planetary ring in the solar system, researchers reported October 6. The findings also appear in the Oct. 22 *Nature*.

Too faint to be seen from Earth, the ring extends beyond Saturn's outer moon Phoebe. Anne Verbiscer and Michael Skrutskie of the University of Virginia in Charlottesville, with Douglas Hamilton of the University of Maryland in College Park, reported evidence suggesting that the ring is supplied by material continually knocked loose from Phoebe.



A newly discovered ring around Saturn is at least 24 million kilometers in diameter, making it the largest known to encircle any planet in the solar system.

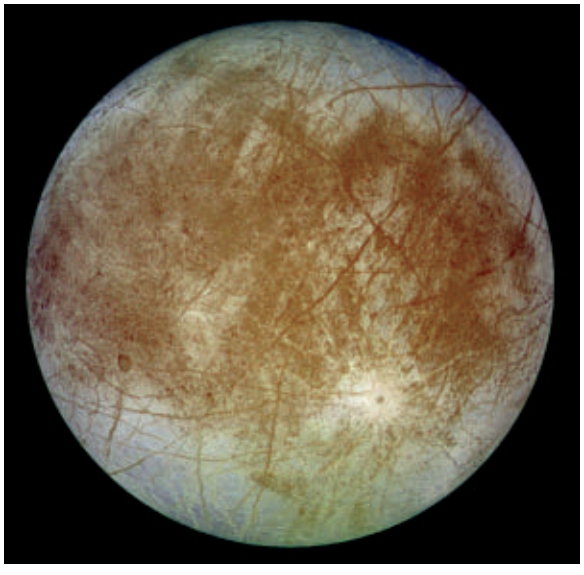
"It's an exciting discovery," says planetary scientist John Spencer of the Southwest Research Institute in Boulder, Colo.

Verbiscer and colleagues used NASA's infrared Spitzer Space Telescope to find the ring in February. Its dust particles absorb sunlight and reemit the radiation at infrared wavelengths of around 24 micrometers. Distant stars shine through the tenuous ring, which the researchers estimate has a minimum mass of a trillion kilograms.

Phoebe's pockmarked surface bears the battle scars from billions of years of pummeling by small moons and space debris, noted Verbiscer. Small grains of material knocked loose from Phoebe could be easily pushed around and spread out by the feeble pressure exerted by sunlight, models indicate. Particles about 10 micrometers in diameter might take a million years to settle into a ring, the researchers estimate.

The existence of the ring may explain the long-standing puzzle of why the Saturnian moon Iapetus, which lies inside Phoebe's orbit, is two-toned (*SN: 8/18/07, p. 104*), the researchers said. Like Phoebe, the debris in the newly discovered ring orbits Saturn in the opposite direction of Iapetus and the planet's other inner moons. Both the ring and Phoebe orbit Saturn at a 27-degree incline to the planet's equatorial plane.

As a result, dark debris from the ring could coat the front, or leading, hemisphere of Iapetus, perhaps making it darker than the moon's other half.



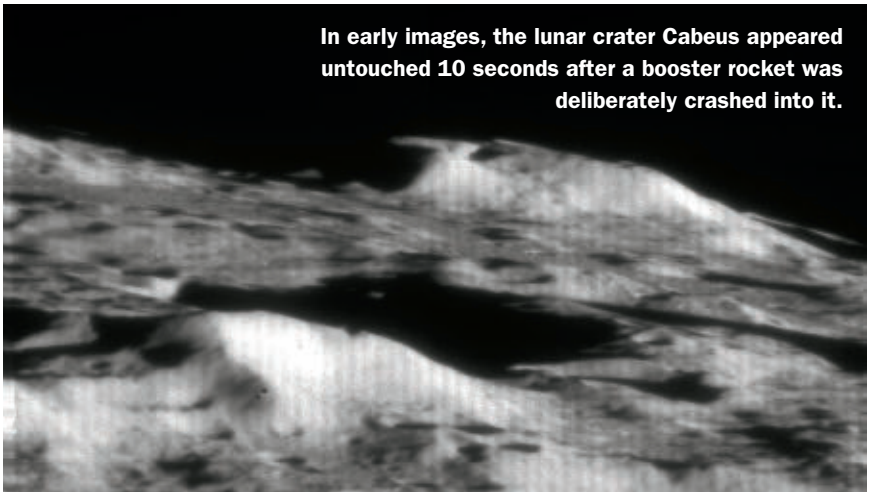
Europa's oxygen-filled ocean

Any fish on Jupiter's moon Europa can breathe easy. Features of the moon's icy surface have hinted that it contains a vast buried ocean. Now Richard Greenberg of the University of Arizona in Tucson calculates that the proposed ocean could receive about 100 times more oxygen than previous models indicated, he reported October 9. That's enough to support respiration by 3 million tons of fish or their Europan equivalent. Charged particles striking Europa produce oxygen within the top few centimeters of crust. Space debris impacts kick up material and bury this oxygenated layer. What's new is that Greenberg's model takes into account that Europa's crust is younger than the moon itself. Over a 50-million-year period an ice layer rose from below, covering the surface and erasing old craters. It took about 1 billion to 2 billion years for the entire ice shell to become oxygen-rich, he said. Only then could ice melting at the bottom of the shell begin to deliver oxygen into the ocean. Such a delay may have given fledgling life enough time to evolve the ability to use oxygen, rather than be harmed by it. —*Ron Cowen*

FROM TOP: JPL-CALTECH/NASA, KECK; DLR, JPL/NASA

120,500 kilometers | Diameter of Saturn

24,000,000 kilometers | Measured diameter of a newly discovered ring around Saturn



In early images, the lunar crater Cabeus appeared untouched 10 seconds after a booster rocket was deliberately crashed into it.

Moon crash delivers puny plume

Signs of iron and mercury, but not yet frozen water, found

By Ron Cowen

The Centaur rocket that was deliberately crashed into one of the moon's southern craters October 9 did indeed kick up a plume, but it was not as large as hoped.

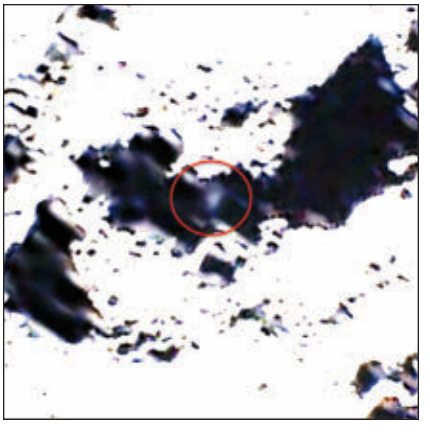
The plume was difficult to spot — in fact impossible to see by many ground-based telescopes — and smaller than had been predicted. One possible reason, suggests Randy Gladstone of the Southwest Research Institute in San Antonio, is that the Centaur rocket struck at a relatively low velocity.

Moments after the impact — as the rocket's mothercraft LCROSS approached the crash site of its empty Centaur rocket, which had plunged into a crater called Cabeus — the raw images taken by LCROSS showed only darkness. But enhanced composite images released October 16 did show a faint plume that was not apparent in the raw images.

The enhanced images show the heat flash from the impact, the plume and the creation of a new crater inside Cabeus, says Anthony Colaprete, LCROSS principal investigator and project scientist at the NASA Ames Research Center in Mountain View, Calif.

The new LCROSS images indicate that the crater forged by the Centaur impact is 28 meters wide. Researchers are still analyzing data taken by the craft's visible-light and ultraviolet spectrometer to identify the plume's composition.

In the meantime, far-ultraviolet spectra taken by another craft, the Lunar Reconnaissance Orbiter, as it flew over the impact site show no obvious signs of water — which, if present, scientists had hoped the Centaur crash would have released. Instead, the spectra show signs of what may be iron and mercury, says Gladstone, a mission scientist.



Images released October 16 show that the crash did produce a small plume.

FROM TOP: HALE TELESCOPE AT PALOMAR OBSERVATORY; NASA

MEETING NOTES

Icy asteroid

Space rocks may be dead as doornails, but some contain ingredients that could have given life on Earth a foothold. Planetary scientists reported October 7 that they have, for the first time, confirmed that an asteroid contains frozen water on its surface. Analyses of sunlight reflected off 24 Themis support the theory that asteroids brought both water and organic compounds to the early Earth, helping lay the foundation for life, Humberto Campins of the University of Central Florida in Orlando and his colleagues reported. —*Ron Cowen*

The rock that fell to Earth

Planetary scientists have reported a slew of new findings about the first asteroid ever spotted before pieces of it fell to Earth. The space rock contained a number of amino acids, had a flattened shape and appears to have been blasted off the surface of a larger body, researchers reported October 5. The asteroid, 2008 TC3, first came into the limelight in 2008 when researchers spotted the body just 19 hours before it broke apart in Earth's atmosphere and crashed into northern Sudan. Scientists tracked the object as an intact asteroid and as meteorites falling to the ground *(SN: 4/25/09, p. 13)*. By analyzing the variations in brightness as the rock tumbled to Earth, along with information culled from fragments collected on the ground, Peter Scheirich of the Czech Academy of Sciences in Ondrejov and colleagues have reconstructed what the asteroid would have looked like up close. The space rock resembled a very large, flattened loaf of bread, Scheirich reported.
—*Ron Cowen*

Life

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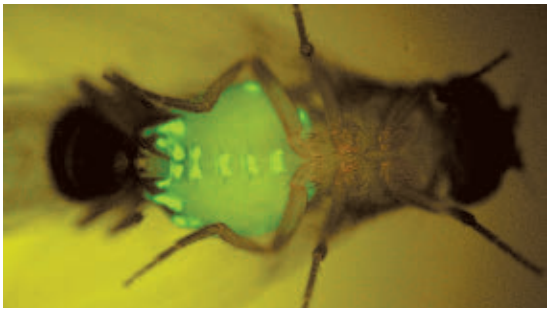
Fly pheromones can say yes and no

Attracting chemicals may also repel, limit interspecies mating

By Tina Hesman Saey



Green marks sites of fruit fly pheromone production.

The sweet smell of honey attracts more flies than vinegar's sour odor, but the ultimate fruit fly magnet is eau de nothing.

Ditching pheromones makes both male and female fruit flies supersexy to males, even of other species, neurogeneticist Joel Levine of the University of Toronto Mississauga and his colleagues report in the October 15 *Nature*. The discovery suggests pheromones can be "back off" as well as "come-hither" signals, helping animals find the right gender and species to mate with.

It was a mystery how fruit fly species could tell each other apart. Many species look similar, at least to humans. "We geneticists can hardly tell them apart unless we dissect them," says Nicolas Gompel of the Developmental Biology Institute of Marseilles-Luminy in France.

Scientists have known that pheromones are important in finding mates, but no one knew how those signals work in combination. Levine and colleagues selectively killed pheromone-producing cells called oenocytes on flies' abdomens, creating scentless flies.

Surprisingly, the lack of a come-hither signal was more of an aphrodisiac for male flies than pheromones were. Normal males were more attracted to both male and female flies lacking pheromones than to normal females. Males from three other *Drosophila* species also courted scentless *D. melanogaster* females, which the males wouldn't do in the wild.

The team then added back specific pheromones to scentless flies to see what the chemicals did. Unexpectedly, adding a female pheromone thought to be an aphrodisiac — (7Z,11Z)-heptacosadiene or 7,11 HD — didn't make flies more attractive.

But if the perfume blend contained both 7,11 HD and *cis*-vaccenyl acetate — a male pheromone used to warn off other males, abbreviated cVA — the female chemical could "counter the chemical chastity belt imposed by cVA," Gompel and a coauthor write in a commentary appearing in the same issue of *Nature*.

"Males are only after one thing. They want to mate," Levine says. Even when facing conflicting signals, males "would rather hedge their bets and go for it."

Females are more discriminating, he adds. Given a choice, they chose males that produce pheromones. That could mean that male pheromones put females in the mood.

The researchers found that just one pheromone barred mating between species. Adding 7,11 HD — not produced by other *Drosophila* species — to scentless *D. melanogaster* females made other species lose interest in those females.

Fungi survived extinction event

Study suggests abundant microfossils aren't from algae

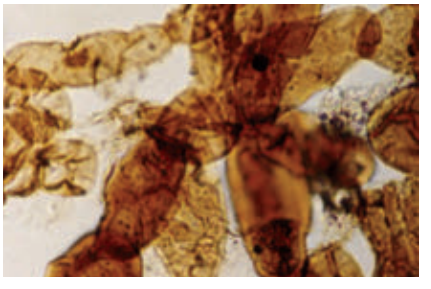
By Sid Perkins

Microfossils found in rocks deposited during Earth's largest mass extinction may be the spores of very hardy fungi, a new study hints.

At the end of the Permian period about 251 million years ago, a mass extinction claimed more than 90 percent of ocean species and 70 percent of those on land (*SN: 2/1/97, p. 74*). But a few species proliferated — in particular, those producing the microfossils *Reduviasporonites*, says Mark A. Sephton of Imperial College London. In some cases, these fossils account for 100 percent of organic matter in rocks from the end of the Permian.

Researchers originally proposed that *Reduviasporonites* were spores from fungi that feasted on the sudden bounty of dead plants, but recent studies have suggested that the fossils are from massive algal blooms. New analyses discount the algal explanation, Sephton and his colleagues report in the October *Geology*.

Tests reveal that organic residues in Permian rocks don't contain breakdown products of chlorophyll, found in algae, but do contain furans, not typically found in algae. And nitrogen isotope ratios match those of fungi more closely than algae.



Microfossils (shown) are from fungi that flourished during the Permian extinction.

FROM TOP: JEAN-CHRISTOPHE BILLETER; M. SEPHTON *ET AL./GEOLOGY*

"If these things were fungi, it was an exceptionally strange ecosystem," says Paul Wignall of the University of Leeds in England. Figuring out what the spores came from will shed light on Permian environmental conditions and may explain the mass extinction, he says.

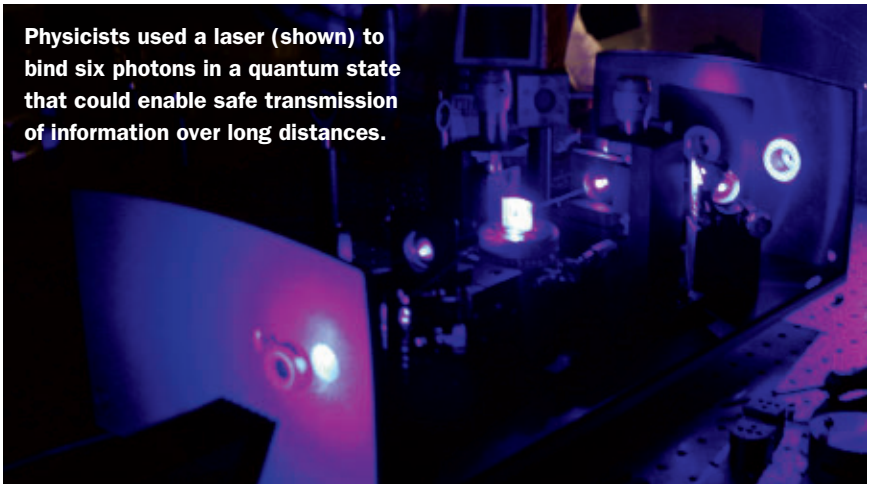
Matter & Energy

The new algorithm is "head-smackingly good. It is both very powerful and very natural." — DANIEL SPIELMAN

Best quantum messages travel in packs of six

Experiment improves ability to send entangled photons

By Lisa Grossman



Physicists used a laser (shown) to bind six photons in a quantum state that could enable safe transmission of information over long distances.

COURTESY OF M. RÅDMARK/STOCKHOLM UNIVERSITY

To send a quantum message, it helps to have a photon six-pack.

When bound together by a process called quantum entanglement, a set of six photons can withstand the hard knocks that ordinarily would erase quantum information, researchers have shown.

Papers describing the new experiment appear in the Oct. 9 *Physical Review Letters* and the October *Physical Review A*. A team led by Magnus Rådmark of Stockholm University has experimentally demonstrated that a set of six entangled photons can fly down noisy fiber-optic cables and emerge unscathed.

Quantum communication offers an absolutely secure way to send secret messages, such as encoded military secrets or financial transactions. While a conventional bit of information can have a value of only 0 or 1, a quantum bit, or qubit, exists as a combination of 0 and 1 simultaneously. A qubit stays in this undecided state until something interacts with it, forcing it into a single state. This collapse of possibilities, known as quantum decoherence, can be detected farther down the line to catch eavesdroppers. But it can also keep qubits from reaching their destination intact.

A set of four or more photons that are entangled — a property of quantum systems that links particles' fates even when they are separated by large distances — would be immune to certain interactions. Temperature changes around the fiber-optic cable can alter the way it bends light, which in turn can rotate photons unpredictably. But if the photons travel in a tight pack, they will all feel the same twists and bends.

"If I take all six photons and rotate them in the same way, I will get exactly the same state I started with," says Mohamed Bourennane of Stockholm University, a coauthor on the papers. "It's like nothing has happened."

Quantum solutions to big equations

New algorithm could quickly process trillions of variables

By Laura Sanders

A new algorithm may give quantum computers a practical new job: quickly solving monster linear equations. Such problems are at the heart of complex processes such as image and video processing, genetic analyses and Internet traffic control. The new work, published in the Oct. 9 *Physical Review Letters*, may dramatically expand the range of potential uses for quantum computers.

The new algorithm is "head-smackingly good," says computer scientist Daniel Spielman of Yale University. "It is both very powerful and very natural."

Aram Harrow of the University of Bristol in England, along with Avinatan Hassidim and Seth Lloyd of MIT, propose that large data sets of linear equations could be encoded in quantum forms, such as the spins of nuclei, individual atoms or photons. Such a system would allow quantum computers to handily solve problems having billions or even trillions of variables.

"Solving these gigantic equations is a really huge problem," Lloyd says. A trillion-variable problem would take a classical computer at least a hundred trillion steps to solve, Lloyd says. But with the newly proposed algorithm, a quantum computer could solve the problem in just a few hundred steps.

Quantum mechanical principles that operate on very small scales would give quantum computers their immense number-crunching power. One of the strangest physical properties, called superposition, allows a single quantum bit, or qubit, of information to represent both a 0 and 1 at the same time. Performing a mathematical operation on a single qubit is like doing many operations simultaneously, Lloyd says. "You don't have to read all the data individually — you can read aspects of them all at once."

The team will test the algorithm with four-variable equations first, he says.

Body & Brain

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BPA in womb linked to childhood behavior

Found for exposure during first 16 weeks of pregnancy

By Janet Raloff

Researchers have now linked prenatal exposure to bisphenol-A — a widely used industrial chemical — with subtle, gender-specific alterations in behavior among 2-year-olds. Girls whose mothers had encountered the most BPA early in pregnancy tended to become somewhat more aggressive than normal. Boys became more anxious and withdrawn.

At present, there's no way to know whether these behavioral impacts will persist, says Bruce Lanphear of Simon Fraser University in Burnaby, Canada. But rodent studies have turned up aggression and hyperactivity in pups prenatally exposed to BPA, he and his colleagues note, prompting concern that the associations seen in these children are real and may last.

Joe Braun of the University of North Carolina at Chapel Hill, Lanphear and their colleagues quantified BPA exposures in 249 women, beginning early in their pregnancies. The team has continued to study the children, who are currently 3 to 5 years old.

More than 99 percent of the pregnant women tested positive for BPA in at least one of three urine tests, usually in the low parts-per-million range. The higher the BPA levels were during a mom's first 16 weeks of pregnancy, the more likely her child was to later show behavior somewhat atypical of his or her gender on a test known as the Behavioral Assessment System for Children-2.

BPA values later than 16 weeks into a pregnancy showed no link to behavior, the researchers report online October 6 in *Environmental Health Perspectives*.

Behavioral deviations from the norm in the most highly exposed kids averaged about 2 to 6 points higher (as measured on about a 100-point scale) for each 10-fold increase in mom's early urinary BPA values, Braun says.

The magnitude of those changes is similar to the subtle IQ drops attributable to environmental lead exposures in U.S. children, notes Lanphear.

Early data from the Warner Babcock Institute for Green Chemistry in Wilmington, Mass., point to cash register and credit card receipts as potentially rich sources of BPA. Spot checks typically turn up between 60 and 100 milligrams of BPA per receipt, well above the nanogram values that have been measured leaching from polycarbonate plastic foodware, notes institute cofounder John C. Warner. "The biggest [BPA] exposures, in my opinion, will be these cash register receipts," he says.

Taste cells for sour also go for fizz

Protein splits CO_2, helps tongue detect carbonation

By Rachel Ehrenberg

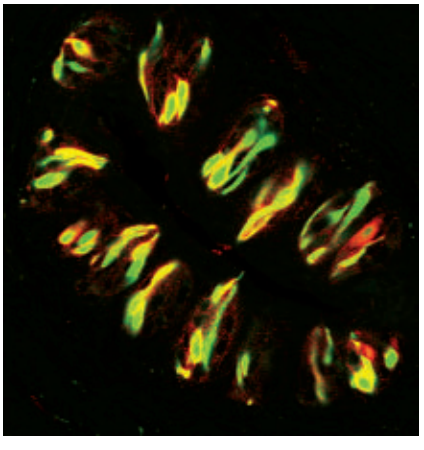
The light, sparkly fizz of champagne owes its taste to the tongue's sense of sour. New studies in mice reveal how the tongue tastes carbonation, solving an old puzzle about why some mountain climbers get the "champagne blues."

Researchers report in the Oct. 16 *Science* that tasting fizz begins with the enzyme carbonic anhydrase 4. It splits carbon dioxide into bicarbonate ions and free protons, which stimulate the sour-sensing cells.

Scientists have thought that the taste of carbonated beverages emerges from the physical bursting of bubbles on the tongue, says study coauthor Charles Zuker, a neuroscientist at Columbia University who did the work while at the University of California, San Diego. But bubbly drinks still taste distinctly carbonated even when imbibed in a pressure chamber where bubbles don't burst.

Zuker and colleagues genetically engineered mice that lacked one of the five kinds of taste cell — sweet, salty, umami, bitter and sour. Taste-sensing nerves fired in response to carbon dioxide in all except the "sourless" mice.

Zuker says that, of the genes that are turned on in sour-sensing cells, one stood out: the gene encoding carbonic anhydrase 4, one in an important class of enzymes that helps maintain appropriate levels of CO_2 in the body. The enzyme is also inhibited by a drug that prevents altitude sickness, Zuker says, hinting at why, when mountain climbers pop a bottle at the peak, the bubbly often falls flat.



A key enzyme helps sour-sensing cells (enzyme and cells lit up here) taste fizz.

J. CHANDRASHEKAR *ET AL./SCIENCE*, AAAS

Perhaps taste cells aren't getting their proton hit, Zuker says.

In the bigger picture, tasting carbonation may have allowed animals to sense CO_2 in foods that had fermented or gone bad, akin to how bitter-sensing taste cells warn of potential toxicity, Zuker says.

6 billion | Pounds of BPA produced globally in 2003

93 percent | Americans with detectable BPA levels

Pathogen fingered as a potential culprit in chronic fatigue syndrome

Little-known retrovirus found in many people with condition

By Nathan Seppa

The long, fruitless search for the cause of chronic fatigue syndrome has taken a curious turn. An obscure retrovirus shows up in two-thirds of people diagnosed with the condition and can infect human immune cells, scientists report online October 8 in *Science*.

These findings don't establish that the pathogen, called gammaretrovirus XMRV, causes chronic fatigue, cautions study coauthor Robert Silverman of the Cleveland Clinic's Lerner Research Institute. "Nevertheless, it's exciting because it is a viable candidate for a cause."

Roughly 1 million to 4 million people in the United States have chronic fatigue syndrome, according to the Centers for Disease Control and Prevention. Characterized by unexplained mental and physical exhaustion, memory lapses, muscle pain, insomnia, digestive distress and other health problems, chronic fatigue is often diagnosed only after everything else has been ruled out.

In the study, researchers tested blood from 101 people diagnosed with the syndrome and found that 68 were infected with the retrovirus. An analysis of blood from 218 healthy people showed that only eight had XMRV — nearly 4 percent.

"This is a very striking association — two-thirds of the patients," says John Coffin of Tufts University in Boston, who wasn't involved in the study.

Studies of its genes suggest XMRV arose from a mouse retrovirus that somehow jumped to humans.

Study coauthor Judy Mikovits, a cell biologist at the Whittemore Peterson Institute in Reno, Nev., says that the retroviral infection could result in an immune deficiency that leads to chronic fatigue symptoms in some people. Other retroviruses, such as HIV, are known to attack the immune system. In this study, researchers showed that XMRV could infect immune cells in the blood.

"This may end the controversy as to whether there is an underlying infection in some cases of chronic fatigue syndrome but is unlikely to explain all cases," says Dedra Buchwald of the University of Washington in Seattle. Retroviruses can awaken latent viruses already in cells, so XMRV might affect health only indirectly, by activating other viruses, she says.

> "It's exciting because [the retrovirus] is a viable candidate for a cause."
>
> ROBERT SILVERMAN

XMRV, short for xenotropic murine leukemia virus–related virus, also shows up in some men with prostate cancer, particularly those with aggressive malignancies, another research team reported in September in the *Proceedings of the National Academy of Sciences*.

In the new study, the researchers found hints that the retrovirus is transmitted by blood. But it's probably not spreading very fast, Mikovits says.

Further research is under way to fine-tune testing for XMRV, and more studies are planned to clarify its occurrence rate in the general population. Mikovits and her colleagues are also investigating already-approved antiretroviral drugs to see if these will benefit people diagnosed with chronic fatigue.

A nearly 4 percent infection rate in healthy controls means that as many as 10 million Americans may harbor a hidden infection, Coffin notes. But until further studies are done, the effects of those infections remain unclear.

Reviewing H1N1 flu's worst cases

Antivirals, ventilators help, but fatalities show lungs hit hard

By Nathan Seppa

Lung inflammation and respiratory failure are largely responsible for the fatal cases of H1N1 swine flu, three new studies show. The findings confirm observations that H1N1 hits young adults hardest but can be fought off, in many cases, with the use of antiviral flu drugs and a mechanical ventilator that aids breathing.

Conducted between late March and late August, the studies, reported online October 12 in the *Journal of the American Medical Association*, find that the most critically ill patients suffer from oxygen deprivation in the blood, a dangerous condition that can lead to shock, organ failure and death. In severe cases, inflammation in the lungs leads to fluid buildup in airways and lung tissues, says the University of Toronto's Robert Fowler, a coauthor on two of the studies. "Most patients are still able to take breaths, but these breaths are ineffective," he says.

In the largest of the studies, scientists in Canada monitored 168 patients deemed critically ill with H1N1 flu. Patients averaged only 32 years of age and received intensive treatment, but 17 percent died. Doctors in Australia and New Zealand identified 68 critically ill patients with a median age of 34 for the second study. The fatality rate was 21 percent. In the third study, a team examined records of 58 critically ill patients in Mexico with a median age of 44, and found a fatality rate of 41 percent.

In Canada and Mexico, most patients received mechanical ventilation, and in all three regions many were also given the drug Tamiflu, with apparent benefit.

Genes & Cells

1/100 millimeter | Diameter of the space into which a cell packs 2 meters of DNA

New view of genome reveals how cell packs DNA neatly into place

Model of 3-D structure shows that fractal folding is key

By Laura Sanders

Cells are tidy packers, cramming DNA into nuclei to create a tangle-free, dense ball with pieces that are still accessible, researchers report October 9 in *Science*.

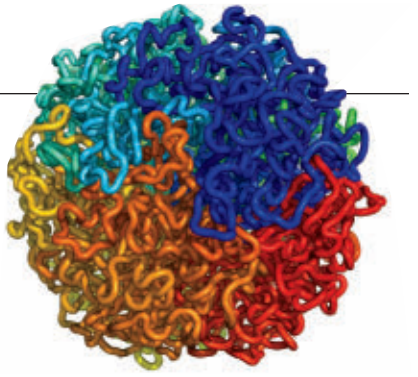
Except during division, a human cell's two meters of DNA is jammed into an area about a hundredth of a millimeter wide.

"It's the question any child would ask," comments physicist H. Eugene Stanley of Boston University. "How does all of this DNA fit into the cell?"

Until recently, scientists lacked tools to assess the shape of the entire genome. Earlier studies focused on the shape of small pieces of DNA that had been chopped out and thus removed from their context. In the new study, researchers developed a trick to lock pieces of neighboring DNA to each other in the nucleus. After removing and sequencing the pieces, the team could calculate how close each piece of DNA had been to other pieces and could reconstruct the genome's 3-D shape.

Applying the method to human cells, the researchers found that the genome has a highly organized structure. Small pieces of DNA fold into globs, and those globs fold into larger globs and so on. The researchers report that this "globule of globules of globules" is fractal, meaning it is organized in such a way that it has the same pattern at all scales. This fractal shape is "superdense, but has no knots," says coauthor Erez Lieberman-Aiden of Harvard University.

Earlier studies by Alexander Grosberg, a theoretical physicist at New York University, first predicted the fractal structure of packed DNA. "Now this paper delivers beautiful confirmation of that prediction," Grosberg says.



Regions of DNA (shown in different colors) are clustered close together in a tightly packed ball of genetic material.

One reason scientists want to understand the shape of packed DNA is that genes can be turned on and off by far-flung DNA elements brought together by folding. By knowing which pieces of DNA are close to each other, researchers may be able to better understand how genes are regulated. For example, misfolding on a large scale may disrupt gene regulation, which could lead to cancer, says coauthor Job Dekker of the University of Massachusetts Medical School in Worcester.

Dekker also wants to understand how a gene and a regulatory element find each other in such a dense glob. "We simply don't know," he says.

Golgi's function stretches it thin

Molecules may explain odd shape of cell's trafficking hub

By Lisa Grossman

Researchers have pinpointed a protein that keeps trains running through the cell's Grand Central station.

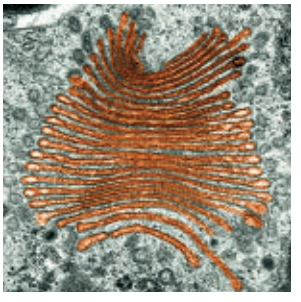
The protein works with other molecules to pull membrane packets off the surface of the Golgi apparatus, giving the organelle its distinctive flattened shape.

"It's a nice simple mechanism for how the shape of something is a consequence of its function," says Seth Field of the University of California, San Diego and a coauthor of the study in the Oct. 16 *Cell*.

The Golgi apparatus is a well known staging area for all proteins that leave the cell, including hormones, antibodies and components of hair, bone and skin. But the Golgi's odd shape has long been a mystery. Researchers have described it as a stack of pancakes, each enclosing empty space that proteins travel through.

In an analysis of the binding properties of about 4,000 fruit fly proteins, researchers found that one called GOLPH3 latched onto another molecule important to Golgi function.

Further scans found that a motor protein like those found in muscles piggybacked on GOLPH3. If any one of the molecules — GOLPH3, the molecule attached to it or the motor protein — was removed, the Golgi structure collapsed and shut down.



The activity of three molecules gives new insight into Golgi's flattened look.

The team concluded that the Golgi's shape is a side effect of its job. The motor protein enables GOLPH3 to pull bubbles of proteins off the Golgi apparatus and send them out of the cell. In the process, the membranes are pulled flat like rubber bands.

Linking the three molecules "ties together a lot of things that people have suspected but couldn't quite put their hands on," says Helen Yin of the University of Texas Southwestern Medical Center at Dallas.

FROM TOP: LEONID A. MIRNY, MAXIM IMAKAEV; SPL/PHOTO RESEARCHERS INC.

Humans

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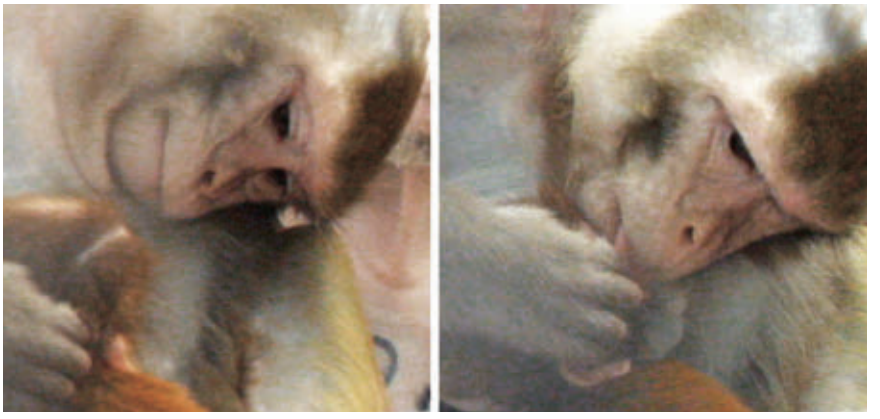
Monkey moms have their own kind of baby talk

Macaques smack their lips to exchange emotional cues

By Bruce Bower



A macaque mother pulls her infant's head close and looks into his eyes to initiate an interaction (left). Then she smacks her lips and licks at the infant's face (right).

P. FERRARI ET AL./CURRENT BIOLOGY

Rhesus macaque mothers and their babies like to get in each others' faces, exchanging looks and smacking lips. They're not rude or hungry. Just as humans do, these monkeys communicate in a mutually pleasing way, a new study suggests.

Monkey mothers lower their heads and then move them up and down while looking at babies seated nearby as a prelude to mutual eye contact and lip smacking, ethologist Pier Ferrari of the University of Parma in Italy and colleagues report online October 8 in *Current Biology*.

For their part, macaque babies imitate lip smacking by their mothers — but rarely by other females — within the first few days of life, the researchers report.

Ferrari hypothesizes that macaque and human babies share inborn capacities to communicate using emotional displays and gestures, to share experiences with others and to understand adults' behaviors as having a purpose.

"We can trace back to macaques the evolutionary foundation of some behaviors present in the early stages of mother-infant relations that are crucial for social learning," Ferrari says.

His team studied 14 pairs of macaque mothers and infants for the first two months of the infants' lives.

"We don't yet know if these interactions contribute to the mother-infant bond and to the infant's emotional and cognitive development," cautions Dario Maestripieri, a psychobiologist at the University of Chicago.

Still, the new findings indicate that some capacity for emotional interactions between mothers and infants evolved more than 30 million years ago in a common ancestor of humans, apes and Old World monkeys (including macaques), says psychologist Kim Bard of the University of Portsmouth in England.

The macaque lip smacking corresponds to "motherese," the tendency of human mothers to exaggerate their facial expressions and talking style with babies, Bard asserts in a comment to be published along with the new study.

Ferrari's team is now studying mother-infant interactions in gelada baboons.

A blind path to childhood autism

Infants born without sight may have more social difficulties

By Bruce Bower

WALTHAM, Mass. — Being born into a world of darkness provides an unappreciated avenue to autism, researchers reported October 2.

Within the first few months of life, babies display a basic form of what researchers call joint attention. An infant will maintain a steady gaze with a nearby adult and imitate that adult's simple actions. By age 2, joint attention becomes more complex. Two children, for example, can convey with just a look that they both know which toy is better.

Many scientists view joint attention as a skill essential to forming relationships with others and communicating effectively. Blindness from birth can lead to difficulties that block emotional contact with others, fostering autism, said psychologists Peter and Jessica Hobson of University College London at a conference on joint attention.

Autism related to blindness stems from the inability to see anyone or anything, making it exceedingly difficult to achieve joint attention, Peter Hobson suggested. Among blind children, though, symptoms tend to diminish by adolescence.

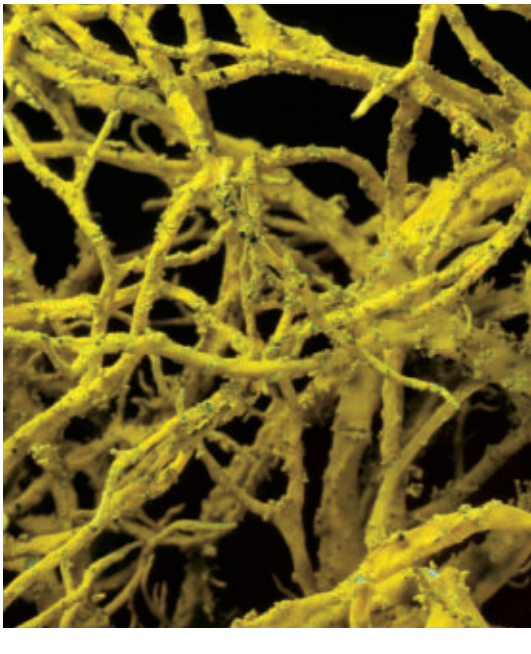
At British schools for the blind, the team assessed 24 congenitally blind children, ages 3 and 9. Autism symptoms, such as a lack of social and communication skills, appeared in all the children. Half met diagnostic criteria for autism.

Compared with nine sighted kids with autism, low-functioning blind children with the developmental disorder showed slightly more engagement with others. Eight years later, all nine sighted children were still considered to be autistic, compared with only one blind child. ■

PLATISMATIA HERREI

CALOPLACA IGNEA AND YELLOW ACAROSPORA

USNEA PARVULA



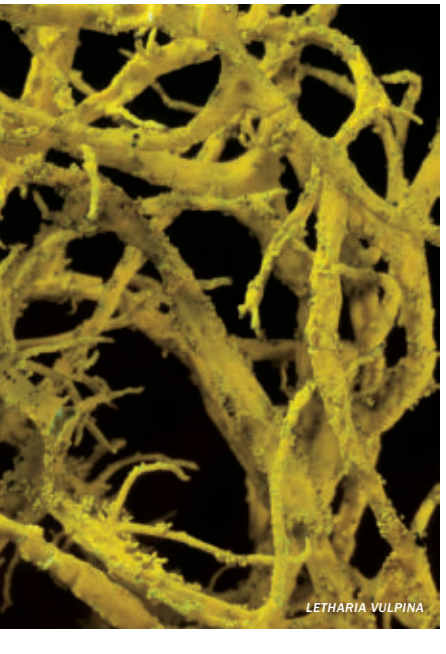
A Partnership Apart

DNA in hand, scientists dissect and redefine the iconic lichen mutualism

By Susan Milius


CLADONIA CRISTATELLA


PELTIGERA APHTHOSA


LETHARIA VULPINA

LEFT: STEPHEN SHARNOFF; DIAGRAM RIGHT: ADAPTED FROM EYE OF SCIENCE/PHOTO RESEARCHERS INC.

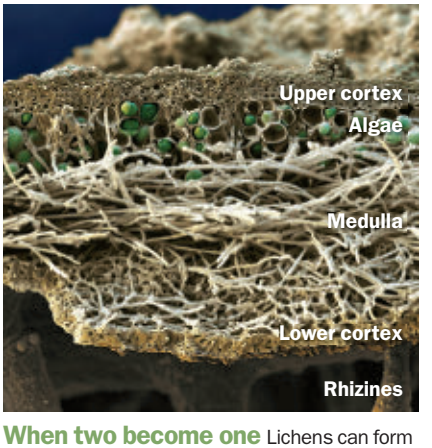
After spending an afternoon with François Lutzoni, it's hard to understand why more sports teams aren't named for lichens. Or why lovers bother with roses instead of sending a dozen fruticose lichen thalli. Lichens, Lutzoni explains, form when living organisms mingle intimately and become something more complex, capable and gorgeous than they could ever be alone.

A long-time classic in discussions of taxonomically odd couples, lichens may form even more bizarre households than specialists had thought. Lutzoni's lab at Duke University in Durham, N.C., among others, is using DNA analysis to shake up the old textbook truths about these partnerships.

To the extent that anyone remembers what biology books say about lichens, the memorized nugget probably has to do with a fungus entwining a photosynthesizing microbe. The green partner is a kind of alga or a cyanobacterium. In some cases, both join in.

One thing basic textbooks don't mention, because researchers are only now exploring it, is the presence of other fungi lurking inside the supposed twosome or threesome. Every lichen species tested so far contains multitudes, says Lutzoni. Going into the field to sample lurker diversity leads to insane — his word — amounts of sample processing in makeshift labs (including, on occasion, bathrooms). Not to mention the discussions with airport security over the team's giant suitcase packed with 3,000 tubes of lichen specks.

What those fungal lurkers do in lichens isn't yet clear. But DNA sequencing should at least help Lutzoni and his collaborators detect these additional fungi. And that's just one of many examples of how modern genetic techniques are being used to reveal new aspects of an age-old partnership. Biologists are learning how such an extreme cooperation evolved and what its history hints at for other symbioses. New studies are also illuminating how the parties meet and greet to set up their partnership. Or maybe that's partnerships, plural. It may take a village to raise a lichen. Or Lutzoni and his team may discover a lichen Tokyo.



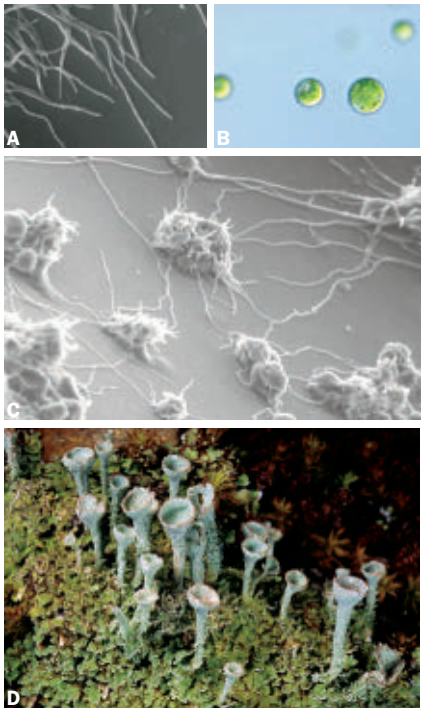
When two become one Lichens can form when fungal hyphae (brown, in this false-color SEM image) weave around algae (green). The partners beget great diversity (facing page).

Duo dynamics

In the traditional lichen relationship, the alga or cyanobacterium provides sugar as food for the fungus, and the fungus provides other nutrients and a house — perhaps protecting its partner. Other creatures also form mutualisms, the term used for symbiotic living arrangements that benefit both partners. But lichens attract special attention because of the gap between the sum and the parts.

To describe the lichens that best exemplify that gap, Lutzoni and Duke colleague Jolanta Miadlikowska flip through the photographs in the tome *Lichens of North America*. Lutzoni taps a picture of lichens nicknamed British soldiers — ranks of stout, green columns wearing very red hats. Miadlikowska muses over the portrait of lichens in the shape of wine goblets, slim stems rising into perfectly round cups. More pages flip, and then, "*Usnea*!" Lutzoni points to what look like tiny escapees from Dr. Seuss' drawing board.

The book also shows swaths of netting as airy as Halloween cobwebs, beards of lichen strands in Tour de France yellow, Jackson Pollock spatters in flame tones and pelts of overlapping forest-green lobes. The greenery belongs to a *Peltigera*, a lichen that has already won the team some cover space on scientific journals. "Got *Peltigera*?" says a bumper sticker on a lab door. Lichens definitely got diversity.



Fungi reach out *Cladonia grayi* fungi (A) and a unicellular alga (B) grow solo in the lab. The fungus sends out threadlike hyphae that overgrow the algal cells (C) to create a lichen. The mature lichen that forms (D) looks much more complex than the sum of its parts.

Lutzoni strides down a hallway and unlocks a door into a compact space thrumming with refrigerator noise. Here, the lab grows the symbiotic partners separately for genetic studies.

Lutzoni peers at racks of petri dishes filled with clouded or rust-colored disks of culture medium and plucks out a dish housing the algal half of a pixie cup lichen. The dish holds some green dots. "Here's a better one," he says. Instead of a dot, it has a streak. On another shelf, he finds the fungal partner, a faintly flesh-colored network about the size of a quarter. For fungal pizzazz, this culture plate loses out to most office fridges.

Fungi that form lichens often prove a headache to grow in the lab, Lutzoni says. He bristles at the textbook dogma that, in a lichen, the big, tough fungus protects the frail, photosynthesizing microbe. Googling "lichen fungi protect algae" turns up plenty of these slights to the green partner. Yet the challenges of growing enough of the fungi for DNA work reveals the fungi on their own as neither big nor tough.

In contrast, Lutzoni doesn't find the *Trebouxia* alga he studies particularly frail. What researchers have discovered is that it does really well by itself, he says. Though *Trebouxia* algae don't typically grow a lot on their own, they don't shrivel up and die waiting for a fungus. "It's great that the algae can be there in a dormant state waiting for Prince Charming." This sturdiness makes sense in terms of lichen formation: Each time a fungus or alga reproduces, as each can when configured in a lichen, the next generations have to get together with new partners. Biologists have yet to report more than one loner lichenizing fungus thriving in nature.

In the hallway of Lutzoni's lab, a tablecloth-sized poster shows meet-ups between new partners. The first image shows a young, available fungus elongating as a thread. An algal cell, plump as a bath bead, sits near the thread's path. In the next image, the two have met. Once it finds the alga, the fungus switches modes, its thread forking into a network of tendrils that embrace the alga.

Picky fungal farmers

Modern genetic techniques are giving researchers a new window into lichen development. Suzanne Joneson, now at the University of Idaho in Moscow, and her collaborators teased the potential symbionts, putting a membrane between the two so they could sense each other but couldn't touch. Monitoring which genes surge in which partner at this phase, researchers see a lot of fungal gene activity but less by the alga.

But fungi don't snuggle up with just anything. In the summer issue of *Symbiosis*, Joneson and Lutzoni describe other experiments in the fungal singles scene. When Joneson and Lutzoni offered the fungus *Cladonia grayi* a range of possible partners, including teensy glass beads, only some of the pairings triggered the abundant branching typical of the first stage of lichen making. Biologists have speculated that much of lichen initiation is driven by thigmotropism, or a tendency to grow toward physical contact. Turns out the contact alone is not enough.

As evident in these studies of lichen initiation and gene activity, the fungus seems the more aggressive, says lichenologist and ecologist Robert Lücking of the Field Museum in Chicago. He quotes a quip from a colleague: "Lichens are just fungi that have discovered agriculture."

His imagery captures a considerable disparity that lichenologists have long noticed. From the intricate structures the combos can produce, showy wine goblets or infantry, a nonlichenologist might expect that the partners coevolved over millennia to form close pairs, with each fungus committed to only one alga. Believe it or not, that's wrong too, says Lücking. At the current tally, more than 17,000 species of fungi form lichens in partnership with a total of only a few hundred species of

TOP THREE: S. JONESON, F. LUTZONI; BOTTOM: S. SHARNOFF

algae or cyanobacteria. Modern genetic analysis is refining species counts, but Lücking predicts that once the DNA settles, the huge disparity will remain. Instead of Fred Astaire and Ginger Rogers, lichens are more like specialty farmers and their crops. Several sell heirloom tomatoes while others tend Gala apples.

Lücking takes the farming idea a step further with a particularly tidy new example in the August issue of the *American Journal of Botany*. In sequencing samples of one of the big genera of lichen cyanobacteria, up until now all classified as *Scytonema*, the researchers found what they propose calling a new genus. These lichen-forming cyanobacteria all belong to a lineage quite different from nonlichenized *Scytonema*. It's as if fungi, in effect, domesticated a crop that's as distinct from its ancestors as barbecued sweet corn is from its wild ancestor, the skinny, scrubby teosinte.

By convention, the cyanobacterium and alga in a lichen don't get the billing of Black Krim tomatoes grown by specialty farmers. Lichenologists use the Latin name of the fungus to double as the name for the partnership. Lutzoni says that, no, he doesn't smolder with outrage for underacknowledged photosynthesizers. "It's a slippery slope," he says. Leaps forward in understanding symbiotic mutualisms have revealed so many others — in bioluminescent squid organs and aphid guts and plant roots — that giving a separate name to one symbiotic mutualism might set off a taxonomic tsunami. "You'd have to give new names to trees," he says. "And we have gut bacteria."

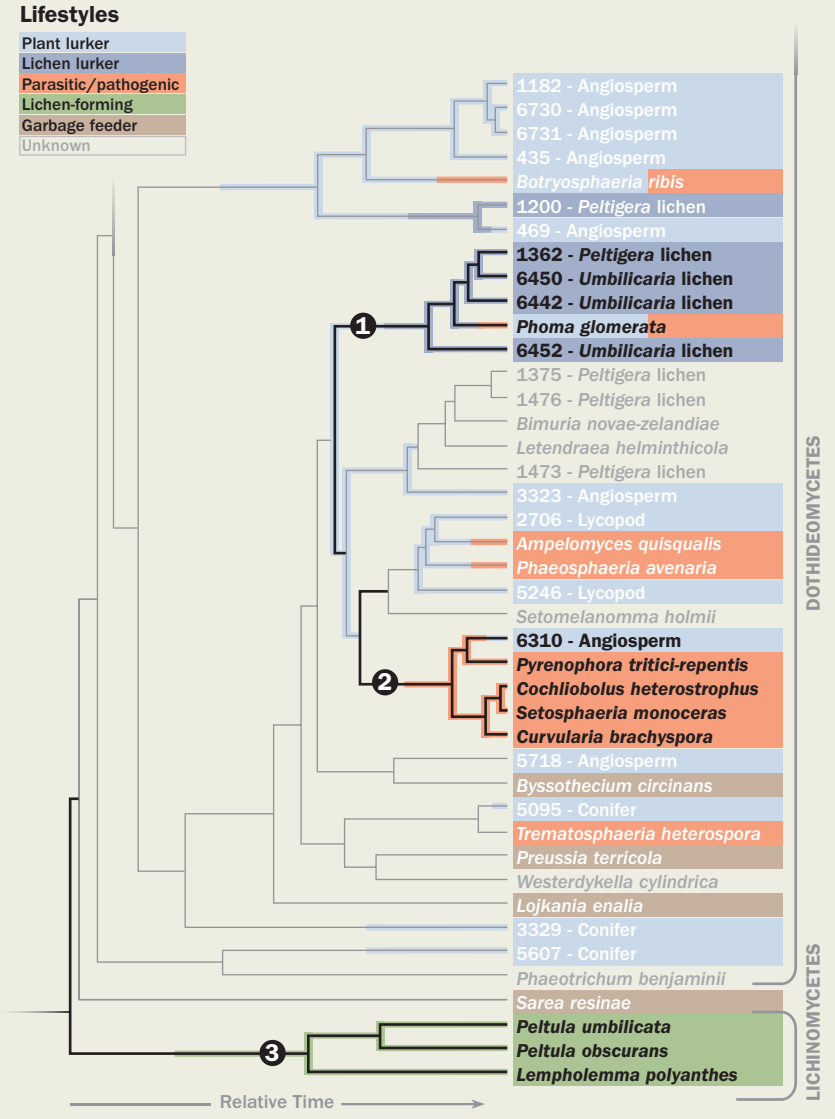
Fungi in trees

The perils of renaming symbioses highlight just how big a deal they are, which makes understanding the path of lichen evolution all the more interesting. Lichenizing fungi typically don't have a lot of fancy morphology like flowers or bones that systematists can use for classification. So DNA sequencing is illuminating a lot of once-murky relationships.

Lichenizing fungi pop up on different branches of the fungi family tree. In the fungal phylum Ascomycota, eight to 11

Lurkers illuminate fungal family tree

Researchers are finding a vast diversity of previously unknown fungi hiding within plants and lichens. Sequencing bits of DNA from these fungi may help researchers understand the fungal family tree. The branches below are plucked from an evolutionary reconstruction published in 2009 for the subphylum Pezizomycotina. Colors on the right show how modern fungi live, and branch colors correspond to the probable lifestyles of ancestors. Understanding these lifestyles may reveal how lichen-forming fungi came to be. (Numbers indicate unnamed species, and accompanying text indicates where those species were uncovered.)



1 *Phoma glomerata*'s direct ancestor lurked in lichen. But a recent switch may have led the species to adopt a role as a plant lurker and become a pathogen.

2 Unnamed species 6310, found in a flowering plant, may have descended from a pathogen that reformed its ways to become a lurker in plants. Its relatives remain pathogenic.

3 These lichen-forming fungi, *Peltula* and *Lempholemma*, appear closely related to fungi with diverse lifestyles. Further analyses could easily place them closer to other lichen-forming fungi.

SOURCE: A.E. ARNOLD *ET AL./SYSTEMATIC BIOLOGY*

B. RAKOUSKAS

of the orders (depending on the classification scheme) each mix lichen formers with nonlichenizing fungi. Lutzoni points out that two scenarios could have produced such a scattered pattern on the family tree. Either a lot of fungal lineages could have turned into lichenizers on their own, or a few way-back ancestors could have acquired a knack that a lot of their descendants have since lost. Debate continues on the details, but data so far suggest the second scenario.

A 1995 paper in *Science* reported a DNA-based family tree with five origins of the lichen habit, including two origins within Ascomycota. In 2001, Lutzoni and colleagues argued that lichens evolved earlier than thought within this phylum, possibly only once. A 2009 paper puts the number between four and seven.

One of the most interesting switches between regular fungi and lichenizers shows up among the relatives of Verrucariales lichenizer fungi, according to a 2008 paper in *Studies in Mycology* by an international team, including the Duke lab. In this new family tree, these lichenizers turn out to be closely related to black yeasts. There are few lichenizers among these yeasts, of the order Chaetothyriales, but the group does have some disagreeable pathogens that attack humans and other animals, including two that cause fatal brain infections.

The common ancestors of these two orders probably colonized bare rock, the researchers say. To Lutzoni, this family relationship suggests that an ability to cope with the extreme heat and drought in rocky places could have been a stepping stone to two symbioses, pathogenic activity in warm-blooded animals and lichen formation.

Ancestral lichens may have been especially important as the cradle for the huge number of fungi that biologists are finding lurking in plant leaves, Lutzoni, A. Elizabeth Arnold of the University of Arizona in Tucson and colleagues propose in the June *Systematic Biology*. All plant species that scientists have checked contain fungi growing inside the leaves, stems or other aboveground tissue. These fungi aren't causing disease symptoms and may in fact help protect against disease, Arnold says. Leaves of wild cacao trees with abundant internal fungi, for example, put up especially strong resistance to colonization by a disease-causing fungus, she and her colleagues reported in 2003.

After working with cacao leaves, Arnold tried looking for extra fungal species lurking in lichens. She sterilized the surfaces of lichen snippets and set them in culture plates to see if threadlike fungal hyphae would grow from deep within. "We would watch these beautiful fuzzy, or feathery, or furry hyphal tips grow out," she says. As far as colors on the culture plate, "you name it," she says. "If you hold it up to the light, it's like looking at a stained glass window." And that's how Arnold and Lutzoni became interested in the massive diversity of lurkers in lichens.

Many lurkers in these samples are new to science, and researchers still don't know how lurkers make their living. Adding their DNA to a family tree of other fungal sequences is revealing how evolution has led to different fungal lifestyles. Tracing back the branch points in the family tree reveals spots where ancestral lineages switched among lichenizers, pathogens, lurkers and garbage feeders. The first glimmers of the pattern are consistent with Arnold's idea that ancient lichens served as an incubator for lineages of fungal lurkers whose descendants have since switched things up.

Working through these ideas has led to the current effort to collect more samples and create a family tree with enough twigs to reveal patterns clearly. Lutzoni and Arnold are analyzing literally thousands of lichen samples from the dry, hot Arizona desert to the tundra of Alaska — explaining all the airline troubles. If the emerging lurkers turn out to be valuable partners in a multispecies complex, as they are in some plants, then lichenologists may have the pleasure of saying that lichens did it first. ■

Explore more

■ Irwin Brodo, Sylvia Duran Sharnoff and Stephen Sharnoff. *Lichens of North America*. Yale University Press, 2001.

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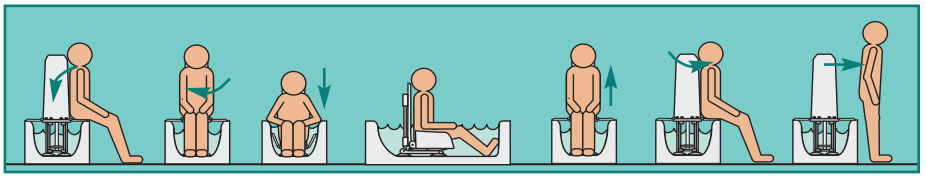


As the Worm

Burrowing animals mix soil and sediments, shaping the environment and scientists' understanding of it

By Sid Perkins

To celebrate the 200th anniversary of Charles Darwin's birth, hordes of readers are reveling in *On the Origin of Species,* which sets forth the case for evolution via natural selection. Others are poring over *The Voyage of the Beagle,* the chronicle of Darwin's five-year, round-the-world expedition.

It's probably safe to say, however, that only die-hard Darwinistas are cracking the spine on his last book, *The Formation of Vegetable Mould, Through the Action of Worms, with Observations on Their Habits*. In this work, which Darwin himself described as "a curious little book," he discusses the role that earthworms play in the formation and erosion of soil. "The subject may appear an insignificant one," he modestly noted, "but we shall see that it possesses some interest." Indeed, for a short while after this book was first published in 1881, it sold more quickly than *On the Origin of Species* had.

But only much later did scientists begin to appreciate the widespread effects of bioturbation, the displacement and mixing of sediments by animal and plant life. Today, scientists recognize that the process has implications not just for geology, but also for archaeology, ocean chemistry, evolutionary biology and resource management. And, basically, for anyone who works in or on the ground.

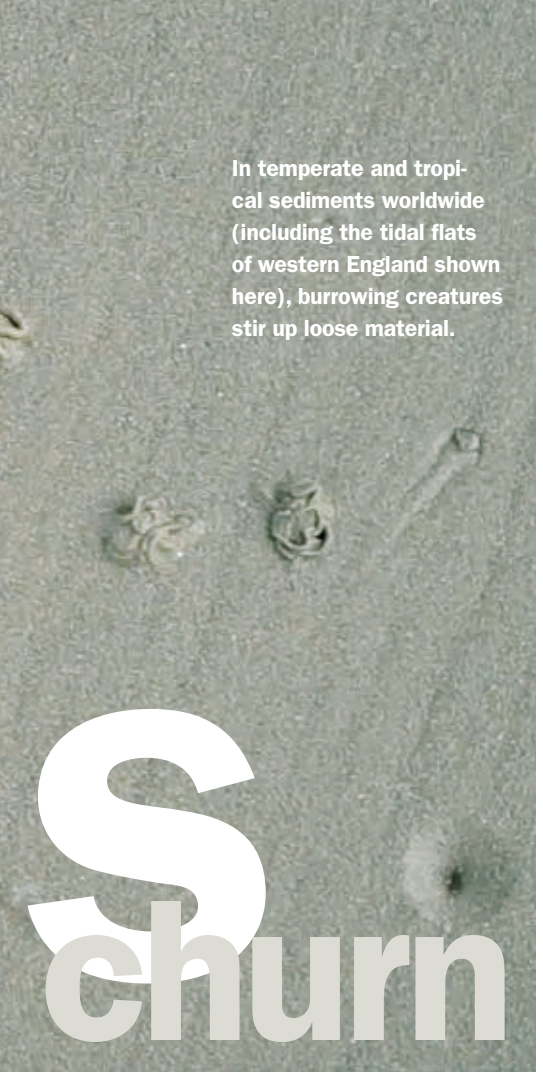
For researchers who study subtle layering of sediments to understand a site's history, bioturbation makes work complicated and renders results uncertain. Fossilized remnants of burrows can also make rock much more porous than expected, affecting fluid flow through aquifers and oil fields, for example. And new studies suggest that when it first came on the scene, bioturbation may have accelerated an evolutionary arms race among creatures. Some researchers make an even stronger claim based on other new work: Bioturbation, they argue, substantially changed ocean chemistry, rendering the seas more hospitable to life at the base of the food chain and therefore more biologically productive.

Slowly stirred

Like Darwin's other studies of natural history, his observations of worms and the results of their burrowing were numerous, varied and took place over a considerable period of time.

In 1837, Darwin dug a hole in a pasture in Staffordshire where lime had

S. PERKINS



In temperate and tropical sediments worldwide (including the tidal flats of western England shown here), burrowing creatures stir up loose material.

A. CURRAN, K.J. CUNNINGHAM

Churn

been spread in 1827 and cinders had been dumped several years after that. Well beneath the thickly matted roots of the overlying grass, Darwin noted the layers that formed as a result of the dumping — one of black cinders and, two inches below, one of lime. In holes dug in the same pasture nearly five years after the original hole, each layer sat about an inch deeper than it had before — a result of worms' nocturnal aboveground excursions, Darwin concluded. The worms eat soil, carry it to the surface and excrete the material in their fecal matter.

Some scientists scoffed at Darwin's notion that something as small and insignificant as a worm could substantially impact the terrain, but Darwin countered that large numbers of worms could indeed roil the soil: In the course of a year, he estimated, the 25,000 or more worms living beneath each acre of land in his area would bring between 14 and 18 tons of material to the surface.

Most of Earth's surface is home to burrowing animals of all sorts and sizes, from ants to aardvarks. In parts of some streams, spawning fish stir up more sediment than spring floods do. Even the floor of the deep sea, a milieu once thought lifeless, is substantially altered by burrowing creatures. They tunnel along, breaking up and exposing sediments. Previously buried material comes to the surface, and the fresh, nutrient-rich stuff gets sent downward.

"It's like turning over a compost pile," says Robert C. Aller, a marine biogeochemist at Stony Brook University in New York. The boost in microbial action triggered by bioturbation speeds nutrient cycling, he notes. Plants also get involved in the cycle, pulling food and water from soil.

Burrows (and the passageways created by plants' root systems) provide pathways for rainwater, seawater and other fluids and gases to infiltrate soil and ocean sediments more readily, Aller says. Tunnels and surrounding porous sediments offer haven for a variety of microbes, some of which feed off the burrowers' waste products.

But bioturbation can be a bane for scientists. Researchers who attempt to read the history of environmental conditions by analyzing the layering of sediments need to recognize how burrowing critters mix things up. In one of the latest examples, bioturbation in British Columbia's Howe Sound, just northwest of Vancouver, is complicating efforts to determine the rate at which sediment has accumulated there since the last ice age. That measurement can tell scientists about rates of erosion in the mountainous area, among other things.

The fossilized tunnels of shrimp and other burrowing creatures can render limestone exceptionally porous and thousands of times more permeable than limestone without burrows.

Lionel Jackson Jr. of the Geological Survey of Canada's office in Vancouver and his colleagues recently attempted to assess the sedimentation rate in the sound by carbon-dating organic materials in core samples drilled from the seafloor.

In theory, the oldest materials are the deepest in the sediment column, and successively higher strata are younger. Material at the surface should be the youngest of all. In most of the team's cores, shell ages increase steadily from shallow to deep, and the findings suggest that only a fraction of a millimeter of sediment accumulates in the sound each year. But in some of the Howe Sound cores, the radiocarbon dates don't make sense, Jackson reported in October in Portland, Ore., at the annual meeting of the Geological Society of America. In several instances, the shells in layers of sediment separated by a considerable distance seem to have the same age.

Evidence shows that some of those dating discrepancies result from underwater landslides that jumbled the sediments, Jackson says. But other discrepancies seem to have been caused by bioturbation that disturbed the sediments, gradually transporting shells and shell fragments either up or down from the layer in which they were originally deposited.

Similarly, archaeologists can also be vexed by bioturbation. Over time, the burrowing of small mammals, worms and beetles can disrupt a site's sediments to

the point that artifacts manufactured during a certain era can no longer help researchers estimate the date of nearby artifacts found at the same depth.

Rock-hard evidence

When loose sediments harden into rock, signs of bioturbation can be preserved. Sometimes those traces are modest, such as the now-filled burrows left by small dinosaurs (*SN: 10/27/07, p. 259*) or groups of fossilized termite mounds (*SN: 2/28/04, p. 133*). In other cases, remnants can leave a widespread mark.

Consider the Biscayne aquifer, which lies just beneath much of southeastern Florida. Field tests suggest that this limestone formation is one of the most permeable aquifers in the world, says Kevin J. Cunningham of the U.S. Geological Survey in Fort Lauderdale, Fla.

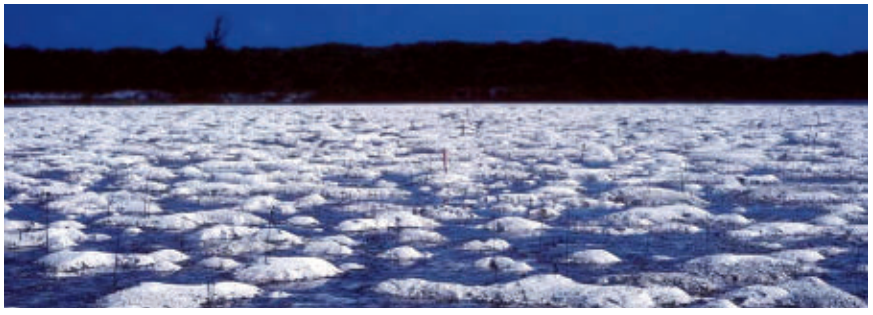
By measuring the spread of dyes and other tracers, hydrologists clocked water flow through some parts of the Biscayne aquifer at speeds of more than 350 meters per day. Yet some previous lab tests of limestone samples suggest that water should flow through the rock at around 10 meters per day, says Cunningham. Blame for that disparity, he and his colleagues note in the January *Geological Society of America Bulletin*, can be pinned on the burrowing habits of ancient shrimp.

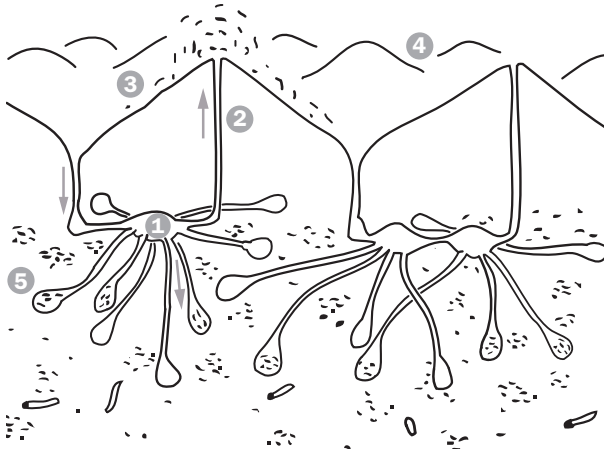
The aquifer's limestone was laid down as shallow marine sediments during periods of high sea level in the past 500,000 years or so. During those high stands, a species of callianassid shrimp — commonly known as ghost shrimp — burrowed extensively in the shallow-water sediments. Adult shrimp of this species, which typically measure 12 to 15 centimeters long, dig 4-centimeter–diameter burrows that extend as much as two meters into the sediment, says Al Curran, coauthor of the study and a paleontologist at Smith College in Northampton, Mass.

Because these shrimp cemented their burrows' walls with limestone mud to prevent collapse and because the aquifer's sediments have never been deeply buried, the burrows remain intact in most layers. In fact, the flow of subterranean water through and around the burrows in recent millennia has dissolved some of the aquifer's limestone, rendering the material even more porous. The team's new analyses of core samples reveal that about three-fourths of the limestone in the aquifer may resemble a petrified kitchen sponge, not solid rock. High-resolution CT scans of samples indicate that between 60 percent and 70 percent of that burrow-riddled material is open space, Cunningham says.

Current computer simulations of water flow in the Biscayne aquifer, which provides drinking water for Miami and much of southeastern Florida, don't account for the presence of such highly porous layers. Those permeable strata, though, could have profound consequences because open spaces act as a path of least resistance for flowing water, Cunningham says. So, he notes, water in the aquifer moves much more quickly than previously presumed, a concern if the water becomes tainted by pollution or pathogens.

Evidence suggests that bioturbation may be responsible for unusually porous aquifers in the Bahamas and Texas, the researchers add. It's also possible, they say, that the porosity of some strata in Saudi Arabian oil fields — layers of rock that yield a lot of easily extracted oil — could result from bioturbation.





Anatomy of a burrow
Callianassid shrimp can totally disrupt the upper layers of marine sediments (as seen above in the Bahamas), leading to the creation of cavities (1) and to increased porosity. The creatures pump mud, silt and fine sand to the surface (2), where the constant roiling of sediments (3) prevents algal mats and sea grasses from becoming established (4). Larger bits of gravel are stashed in abandoned chambers (5), further enhancing subsurface porosity.

Digging the scene

Bioturbation plays an integral role in today's ecosystems, but at one time it was a true innovation. Several recent studies show how a dramatic rise in bioturbation during the Cambrian led to extinctions, stimulated evolution and substantially changed ocean chemistry.

Early in the Cambrian period, which began about 542 million years ago, most multicellular animals had soft bodies that didn't fossilize well. Also, tough microbial mats that bound the sediments together were the foundation of many seafloor ecosystems, says Katherine N. Marenco, a paleoecologist at Bryn Mawr College in Pennsylvania. "In essence, the surface was armored," she notes. The few creatures that lived within the seafloor burrowed along horizontally just under the mats, not downward into the sediments.

But recent analyses of rocks near the California-Nevada border confirm that as the Cambrian unfolded, seafloor eco-

PHOTO: A. CURRAN, K.J. CUNNINGHAM; DIAGRAM: A. NANDY, ADAPTED FROM A.W. TUDHOPE, T.P. SCOFFIN

systems changed. By about 500 million years ago, invertebrates had evolved the ability to dig deep, either to forage or to reside there. "The fossil record shows that burrows had become deeper, more complex and more common," Marenco says. Bioturbation began to churn sediments more effectively, she and colleague David Bottjer of the University of Southern California in Los Angeles reported in 2008 in *Palaeogeography, Palaeoclimatology, Palaeoecology*.

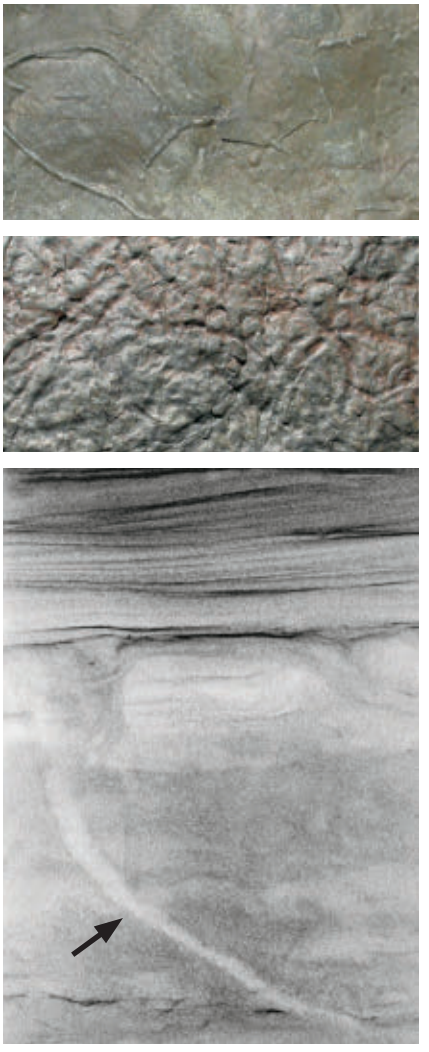
By the end of the Cambrian, about 489 million years ago, subsurface organisms were so common that burrowing often erased the traces of preexisting tunnels. Gone too were the tough microbial mats, which evidently couldn't withstand the constant disruption of sediments by newfangled burrowers.

Species that made their living on, in or just under the mats died out by the end of the Cambrian, Marenco says, but bioturbation allowed oxygenated waters to reach deeper layers of sediment and created new ecological niches.

Bioturbation also brought big changes in sea chemistry, new research suggests. Before the Cambrian, sulfate concentrations in seawater were much lower than they are today, says James Farquhar, a geologist at the University of Maryland in College Park.

Deposits of gypsum, a sulfate mineral that forms when seawater evaporates, provide evidence of this difference. The deposits are more common in rocks laid down in the Cambrian and thereafter than in Precambrian rocks. The lower the concentration of sulfate, the harder it is for evaporation to generate gypsum, Farquhar explains. Also, the ratios of sulfur isotopes in Precambrian rocks deposited as marine sediments indicate that seawater held no more than 1 percent of the amount of sulfate found in today's oceans.

Then, during the Cambrian, sulfate concentrations began to rise, Farquhar and Don Canfield from the University of Southern Denmark in Odense report in the May 19 *Proceedings of the National Academy of Sciences*. Much of this shift, the researchers propose, resulted from an increase in seafloor bioturbation.



Fossils reveal that early in the Cambrian, burrowing was sparse and occurred only horizontally along the ground's surface (top). Late in the Cambrian, though, horizontal burrowing activity became more intense (middle) and burrows often extended vertically from the surface deep into the seafloor (arrow, bottom).

K.N. MARENCO AND D. BOTTJER/*PALAEOGEOGRAPHY, PALAEOCLIMATOLOGY, PALAEOECOLOGY*

Sulfate making its way into the sea via rivers and fallout from volcanic eruptions during the Precambrian was quickly converted to sulfide minerals by microbes living in the sediments, says Farquhar. Very little sulfate remained in the water. But once creatures began churning up the seafloor, they reexposed sulfides to oxygenated waters, converting the sulfides back into sulfate. This increased the sulfate concentration in seawater.

The team's computer models suggest that bioturbation plays a big role in boosting and maintaining today's sulfate concentrations. If bioturbation suddenly ceased — as it might during a mass extinction — sulfate concentration would drop more than 90 percent over 10 million to 20 million years, simulations suggest. After ecosystems recover and bioturbation returns, "sulfate concentrations rocket back to normal," Farquhar notes.

Increases in the concentrations of sulfate during the Cambrian, along with already rising oxygen levels, had wide-ranging impacts, says Timothy Lyons, a biogeochemist at the University of California, Riverside. These chemical changes boosted the solubility of trace metals such as copper, molybdenum and iron, which microbes at the base of the ocean's food chain use in a variety of metabolic pathways. In essence, says Lyons, bioturbation made the ocean a better, more biologically productive place to live and may have opened the door to a broader diversity of creatures.

Although bioturbation undoubtedly accelerated the ancient increase in sulfate concentrations, it probably didn't trigger that shift, Lyons cautions. He argues that the first animals to dig deep during the Cambrian probably couldn't have done so until oxygen levels in the sediments were already suitably high — a trend that would have, on its own, boosted sulfate concentrations to some degree.

Nevertheless, he adds, "any way you slice it, all these effects are linked." Bioturbation must have made a difference in the ocean's evolving chemistry, he argues — an evolution that yielded today's highly productive seas.

Quite a result from a curious phenomenon that, as Darwin noted more than a century ago, appears insignificant at first glance. ■

Explore more

- The Complete Work of Charles Darwin Online: www.darwin-online.org.uk
- F.J.R. Meysman *et al*. "Bioturbation: A fresh look at Darwin's last idea." *Trends in Ecology and Evolution*, December 2006.

Better living through

Mixing light with nanotechnology could help treat cancer and build faster computers

By Jenny Lauren Lee

A well-polished mirror reflects the world faithfully back to the viewer's eyes. But break that mirror into billions of nanosized chunks and each tiny silver sliver would not reflect the world with such fidelity. Instead of bouncing back to the viewer, the light would be sucked into the surface of the nanochunk like a genie into a bottle.

When it hits the surface of a scrap of metal, light can set off a wave in the free electrons hanging out on the metal's surface. This wave carries the light along like a surfer riding on an electron sea. The light-and-electron hybrid is called a surface plasmon wave, and the study of this bizarre phenomenon is called plasmonics.

First named in 2001, the field of plasmonics has become popular among physicists and engineers only recently, as scientists have developed tools to create nanosized structures that can guide and shape these light-and-electron waves. Now the field of plasmonics is taking off, possibly leading to new kinds of miniature lasers, better cancer treatments and faster computers.

"This is a moment in time where it's all possible," says engineer Henri Lezec of the National Institute of Standards and Technology in Gaithersburg, Md. "I think it's really opened up because of developments in different fields — materials science, optics, nanofabrication."

The promise of plasmonic materials goes well beyond medicine and computing. In new kinds of solar cells, nanoparticles could trap light to convert more of it into electricity. Or the cells could use light with a broader range of wavelengths. Even invisibility cloaks may be possible once physicists master the secrets of manipulating light on a nanoscale.

Lighting the way

Both light and electrons can carry information (think fiber optics and electronic circuits), but both technologies are reaching limits of speed and size. Scientists hope that plasmonics can harness light's and electrons' advantages together to perform some tasks better than either could do alone.

Electronic devices exploit signals of flowing electrons that can be compressed into nanosized wires, allowing complicated circuits to process a lot of information in a small space. Light signals, on the other hand, can travel immense distances without losing much of their oomph and can be switched on and off rapidly, making them ideal for fast computing.

But lenses and fiber optic cables can't squeeze light the way electronic circuits can funnel electrons: Light can be compressed by only about half of its wavelength in today's photonic devices. For visible light, this means a space of a few hundred nanometers.

That may sound minute, but it's still a hundred times larger than the nanowires that carry information in electronics. At the moment, a computer based on light instead of electrons, though incredibly fast, would be the size of a room.

Plasmonics offers a way to bridge this scale gap by squeezing light into a piece of metal just a few nanometers across.

"If you want to make [light] really small, you have to do a trick," says Vladimir Shalaev of Purdue University in West Lafayette, Ind. "And the trick is to convert light to surface plasmon waves."

For the past few years, scientists have been creating the pieces necessary for a computer that combines electronics and plasmonics. Now, new research demonstrating plasmonics-based lasers indicates that such a computer is closer than ever. Some experts think the field is on the cusp of a computing revolution similar to the electronics revolution of the mid-20th century.

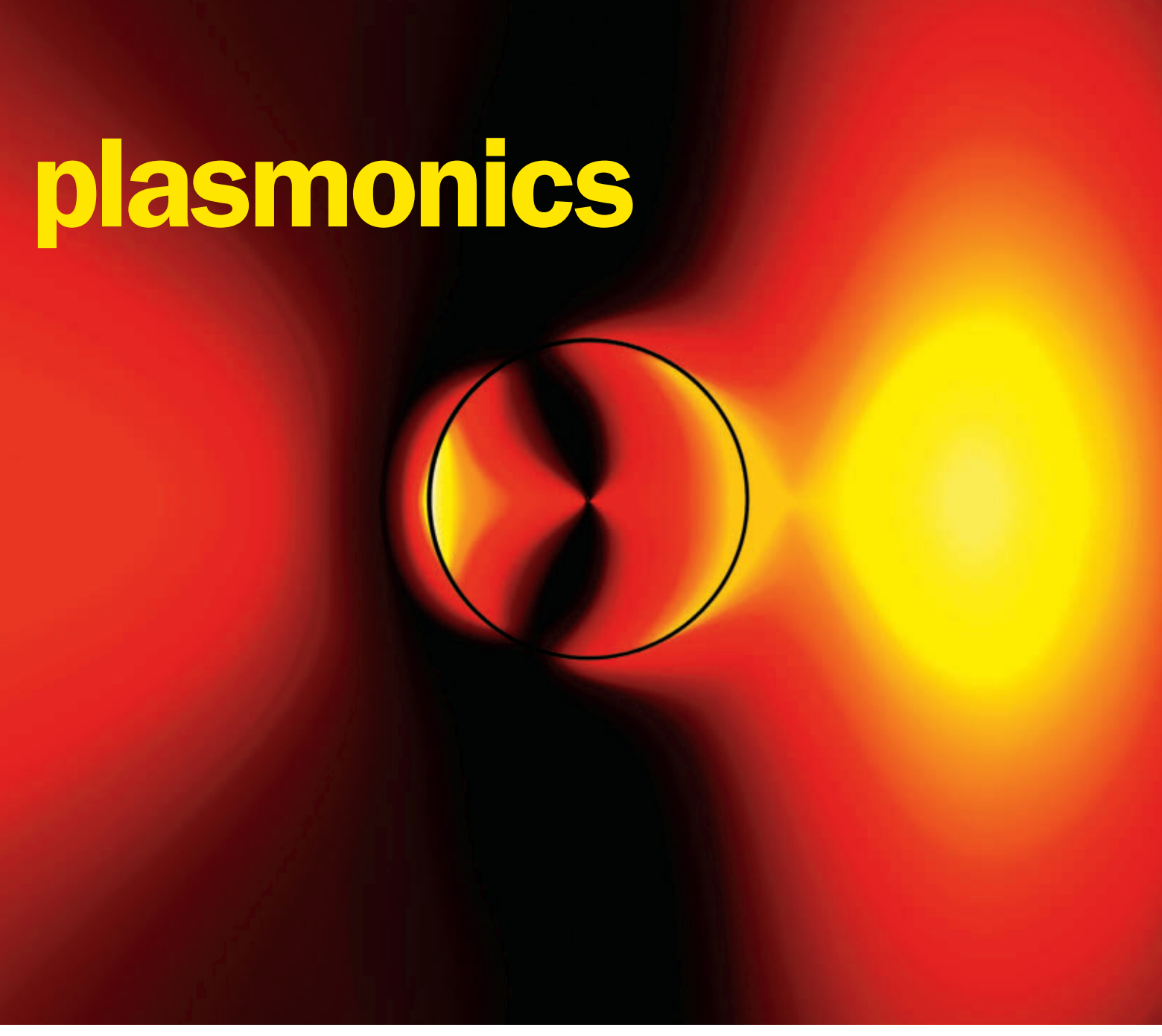
The ability to manipulate light on a nanometer scale could also lead to better detectors of small biological molecules, microscopes with higher resolution and more effective cancer treatments. Just last year, the Food and Drug Administration approved Nanospectra Biosciences Inc. in Houston to begin clinical trials of a therapy that uses the plasmonic properties of tiny gold-coated silica balls called nanoshells to cook tumors while leaving healthy tissue intact.

The genie in the bottle

Surface plasmons are effectively ripples in a pond of freely floating electrons on the surface of a metal that has a lot of unbound electrons to spare. Gold and silver work particularly well: Shine a beam of light onto a nanosized plate of gold, for example, and free electrons will carry that light along. Though the wave moves across the plate, the electrons themselves do not travel far, similar to the way baseball fans can do "The Wave" without moving from their seats.

Surface plasmons may sound exotic,

plasmonics



Light that hits a gold sphere (circled) resonates with electrons to create a plasmonic effect. Emitted light intensity is depicted in the simulation above.

CSEM

but they are present in a number of familiar places. Many medieval stained glass windows get their brilliant red and blue hues from nanoparticles of gold and silver suspended in the glass. Light passing through the glass sets off an oscillating plasmon wave that rings the metal bits like bells and scatters the light. Different scattering patterns appear depending on the angle of the sunlight — a single piece of glass can change from red to green as the sun sets.

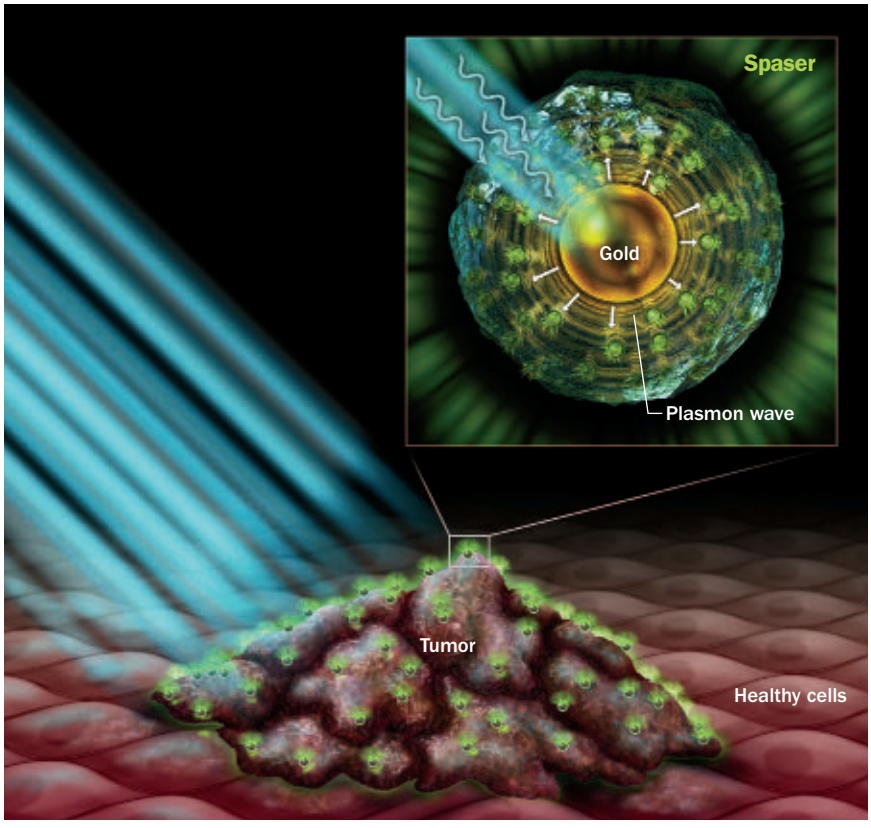
Plasmonics are also at work in modern pregnancy tests. Balls of gold just tens of nanometers in diameter turn a barely detectable reaction between a pregnancy hormone and protein antibodies into bright lines.

Computer chips that use plasmonics for faster processing are not here yet. But "people are continuously coming up with more and more clever designs" for devices that could be used in a plasmonic computer, says Stanford University's Mark Brongersma, whose 2007 book *Surface Plasmon Nanophotonics* collects several authors' writings on this growing field.

Laser lasing, spaser spasing

Even more exciting news for the field of plasmonics comes from a spate of papers on nanolasers in the past few months.

In the Aug. 27 *Nature,* scientists from Purdue, Norfolk State University in Virginia and Cornell University reported what may be the smallest laser in the world. Called a spaser, short for "surface plasmon amplification by stimulated emission of radiation," it consists



Detecting tiny tumors
Researchers are designing plasmonic devices that may one day detect very small cancers. In one possible scenario, spasers—gold balls coated with dye and silica—attach themselves to cancer cells and glow when laser light is shined into the body. Spasers act like amplifiers, making a minuscule signal detectable by using a plasmon wave to excite electrons in the dye.

of a dye-and-silica–coated gold ball that acts as a minilaser just 44 nanometers in diameter (*SN: 9/26/09, p. 4*). Shining light on this ball starts off a plasmon wave in the gold layer that excites electrons in the dye coating. When the electrons settle back down, the dye glows. Turn the light off, and the glow stops.

Proof that spasers are possible has put scientists on a path to creating transistors for a computer that uses light instead of electronics, says Mark Stockman of Georgia State University in Atlanta, whose 2003 paper with David Bergman of Tel Aviv University introduced the concept of the spaser.

Stockman hopes the tiny new lasers will make it possible to do for optics and electronics integration what the transistor did for electronics. He suggests that the all-or-none nature of spasers could be adapted to amplify a small signal in a computer circuit; a tiny signal, above a certain threshold, would turn into an enormous and detectable signal.

"Now the work will start," Stockman says.

In a second paper, published online in *Nature* on August 30, scientists led by Xiang Zhang of the University of California, Berkeley demonstrate what they call a plasmonic laser. In this approach, light induces plasmon ripples that move across the surface between a silver plate and a cadmium wire, squeezing light into a gap only 5 nanometers wide. This would put light-based circuits in the ballpark of nanocircuitry.

Better biology

Spasers and plasmonic lasers may be good for more than just potential circuits for faster computers.

One of the most promising uses for the spaser is detecting small molecules, says Shalaev, a coauthor of the spaser study. Spasers could, in theory, be designed to attach themselves to certain types of bacteria or cancer cells and then call attention to the cells by glowing like beacons.

A similar type of plasmonic device has potential for both detecting and shrinking tumors. Called a nanoshell, the patented gold-coated silica nanobead was developed by Naomi Halas and Jennifer West of Rice University in Houston.

A tumor might grow to at least a few millimeters before it can be detected with today's technology, says plasmonics physicist Surbhi Lal, who works in Halas' lab.

"And even if you get it at that point, it's great," Lal says. "But what if you could catch it when it was just 1 to 2 millimeters in size?" Detecting very small cancer growths would allow doctors to take a shot at eradicating the cancer before it gets a hold on the body or requires invasive surgery.

Nanoshells enhance a light signal that would otherwise be buried and create brighter spots where cancer cells scatter light, Lal says.

By changing the thickness of the gold shell and silica core of the beads, Halas' group has also developed what could eventually be an effective cancer treatment. Instead of scattering light, these nanoshells convert laser light to heat that effectively fries the cancer.

"That one, I'm really impressed with," Lezec says. "It's a nifty application and might make its way to actual use in the near future."

In the procedure, patients are injected with nanoshells. Most of the gold balls are flushed out of the body, but many accumulate in tumor tissue when abnormal blood vessels there leak their contents, including the nanoshells, into the tumor. Doctors then shine laser light that is designed to pass straight through human flesh and activate the nanoshell like an antenna. As the plasmon wave is activated, heat radiates out into the surrounding cancer. Even a few extra degrees can kill the tumor. And since the laser itself is tuned to a frequency that is harmless to the human body, it

NICOLLE RAGER FULLER

can travel through healthy tissue without causing problems.

Nanospectra Biosciences Inc. found high remission rates in mice, according to a December 2008 review in *Accounts of Chemical Research*. The procedure got FDA approval last year for tests on humans and so far has shown good results, Lal says.

"Everything I've seen from it is very promising," she says. The biggest advantage, she adds, is the absence of the toxicity of chemotherapy and radiation. "Half the time people are sicker because of the side effects of chemotherapy than from the cancer itself."

Computer challenges

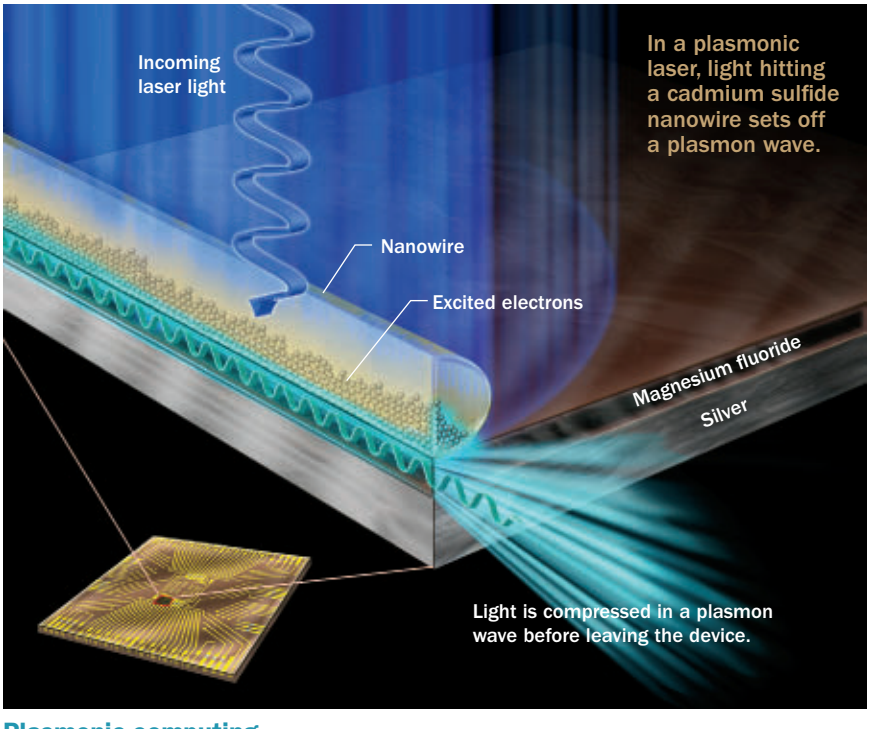
Despite its promise, plasmonics is still a young field with a long way to go before plasmonic computers are on desktops. One of the main challenges for creating plasmonic circuits is figuring out how to get light into the plasmon wave and then get it out again on the other side.

To adapt a computer's binary system of 1s and 0s for light, scientists also have to figure out the best ways to, in essence, flicker light on and off while it is carried along in a plasmon wave.

A group at Caltech recently invented a device — dubbed a plasMOStor, or a plasmonic modulator — that could help in this quest. The research team, led by physicist Harry Atwater, published its results in *Nano Letters* in January. PlasMOStors give scientists a way to modulate light by applying voltage that puts light waves and plasmonic waves either in or out of sync with each other — which allows the signal to be turned on and off.

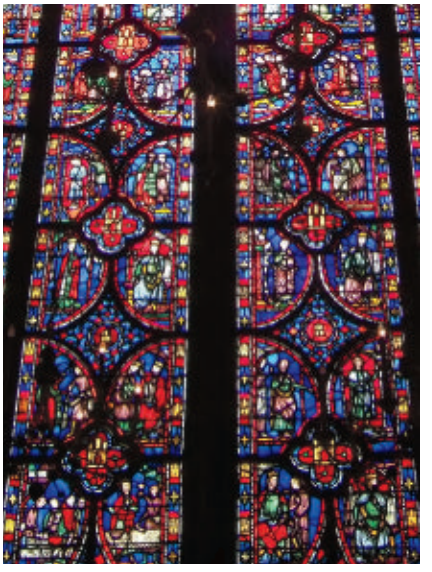
Even getting a plasmon wave started can be hard in some cases. "You can't just send light into a metal and expect it to couple [with electrons]," says Jennifer Dionne of UC Berkeley. "It's difficult to do unless someone gives you a really big push."

Another problem is that a plasmon wave does not travel very far before dying out. For shorter wavelengths of light such as green and blue, the wave cannot travel much farther than a few micrometers. To send plasmon waves across a computer chip, scientists will have to find ways to either push more light into the wave or to shorten the distance the wave has to travel.



Plasmonic computing

Plasmonic computers hold promise for moving information at the speed of light, but they need to shrink substantially to be useful. A plasmonic laser (illustrated above) could be one component of such a computer, giving light perhaps its tightest squeeze yet — about as small as the circuitry that moves electrons in standard electronics.



Plasmonic effects create some of the brilliant colors in stained glass, such as those at La Sainte Chapelle in Paris.

"Work in this area is still in its infancy," says Dionne, who worked with Atwater's group at Caltech on the plasMOStor. "But I think people realize the potential for this field."

With better control of light at the nanoscale, that potential could include applications even more fantastic than plasmonic computers, such as the ability to scatter light in highly controlled ways — perhaps the secret to a Harry Potter–style invisibility cloak.

And there may be many more uses that people have not yet imagined. "First there is something new, then people immediately start thinking about great applications," Shalaev says. "There are a number of very exciting problems here for plasmonics, and that's why it's so much fun to work with." ■

Jenny Lauren Lee is a freelance science writer in Los Angeles.

Explore more

- Learn about nano-optics research at the University of Rochester in New York: http://bit.ly/zMGBs

FROM TOP: BRYAN BUSOVICKI/SHUTTERSTOCK; NICOLLE RAGER FULLER

Born to Run: A Hidden Tribe, Superathletes and the Greatest Race the World Has Never Seen

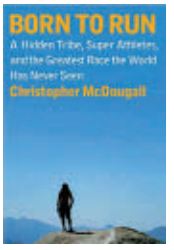
Christopher McDougall

Anyone who laces up expensive running shoes to plod through a few painful miles might be misguided. Humans may have evolved to run hundreds of miles at a time, barefoot, journalist and runner McDougall argues in *Born to Run*.

The impetus for this book came when McDougall's running-induced foot pain halted his regular jogs. Dismissing doctors who told him to find another pastime because his body wasn't made to run, McDougall instead delved deep into the art and science of running.

Born to Run includes no small dose of admiration for the mechanical marvel of the human foot. McDougall compares the stretching and flexing of interlocked bones, joints, tendons and muscles to "an earthquake-resistant suspension bridge." Exercise science studies find that modern "aids" for runners may actually throw off the human gait. And interviews with orthopedic surgeons, world-class coaches and elite runners make the case that simple, inexpensive shoes are better than fancy footwear at preventing running injuries.

To counter the claim that people weren't meant to run long distances, McDougall turns to the Tarahumara Indians, a tribe in Mexico's foreboding and remote Copper Canyon. These people routinely run for hundreds of miles with nothing more on their feet than thin leather straps.



The story climaxes as McDougall joins some of the world's best distance runners, including the Tarahumara, in a 50-mile race over jagged Copper Canyon terrain. McDougall's writing style — equal parts hilarity, explanation and earnestness — whisks the reader along on a compelling dash to the end, and along the way captures the sheer joy that a brisk run brings. — *Laura Sanders*

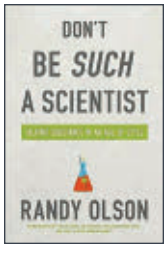
Alfred A. Knopf, 2009, 287 p., $24.95.

Don't Be Such a Scientist: Talking Substance in an Age of Style

Randy Olson

In 1995, Olson came to a stunning realization: Most of his students had sat in rapt attention during lectures to pass tests, not because he was interesting.

In *Don't Be Such a Scientist,* Olson describes how that conclusion changed his career and how it could change science communication. The book chronicles his 1995 decision to leave a tenured position as a marine biologist at the University of New Hampshire to attend film school. While there, Olson, now an award-winning filmmaker, learned that researchers could get their message across more effectively by taking a few cues from artists. For instance, journal papers and science presentations could be structured like screenplays to tell a story. Unfortunately, most researchers focus on their message's accuracy (substance) alone and ignore style, he writes.



Olson passes along tips to help scientists get and keep the public's attention in today's age of information overload. He suggests, for example, that researchers use emotion and humor to target audiences' hearts rather than their heads. Research typically provides plenty of worthwhile information, he notes, but a scientist's message has little chance of getting through if an audience doesn't care to listen.

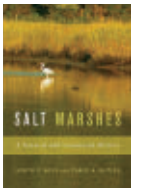
Some scientists may scoff at suggestions that filmmaking holds lessons for their work. But Olson notes that researchers who aren't already making videos for their classes, conference presentations or YouTube will be making them soon. When all is said and done, both scientists and filmmakers tell stories, Olson says. — *Sid Perkins*

Island Press, 2009, 206 p., $19.95.

Weekends at Bellevue: Nine Years on the Night Shift at the Psych ER

Julie Holland

A psychiatrist shares anecdotes from her career treating the mentally ill at the nation's oldest public hospital. *Bantam Books, 2009, 308 p., $25.*



Salt Marshes: A Natural and Unnatural History

Judith S. Weis and Carol A. Butler

A biologist and writer team up to describe human impacts on salt marshes. *Rutgers Univ., 2009, 254 p., $23.95.*

The Collected Papers of Albert Einstein, Vol. 12

The latest volume of Einstein's collected works, containing hundreds of letters and transcripts of lectures and interviews. *Princeton Univ., 2009, 609 p., $125.*

Pluto Confidential: An Insider Account of the Ongoing Battles over the Status of Pluto

Laurence A. Marschall and Stephen P. Maran

Two astronomers report on the controversies surrounding Pluto's planethood or lack thereof. *BenBella Books, 2009, 223 p., $14.95.*

Armadillo Trail: The Northward Journey of the Armadillo

Stephen R. Swinburne

The story of an armadillo and her pups introduces young readers to the mammals. *Boyds Mills Press, 2009, 32 p., $16.95.*

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Sore words

I don't usually write to magazines, and I've never written to yours before, though I've enjoyed and learned much from it for many years thanks to it being produced in Braille. But I couldn't let your article on swearing relieving pain ["%&#$!" makes you feel better," *(SN: 8/1/09, p. 9)*] go by. Without wishing to offend anyone or sound like a self-righteous prig, I still must say it's sad when science and research gives folks an excuse for doing what so many people do too much of already.

Why didn't those studying this subject check out a couple other things? Like having people yell "ow!" or "phooey" or some other innocuous exclamation, or even just make wordless vocalizations that expressed whatever pain or emotion about the pain they were experiencing? And then, if the researchers did that, why not check that against pain alleviation that resulted from nonsense words, and from being silent? I think the trick is simply in not being silent while in pain, not the actual words or sounds made.

I also objected to the researchers saying swear words were unique because they were a bridge between the language and emotional centers in the brain. Any exclamation has that quality, just as, in a different way, music links emotional and other centers in us.

When I told my friends about this, I concluded by saying I felt like yelling "Aaaaah!" after reading it. And if that isn't a linking between language and emotional centers, I don't know what is!

Whether you agree or not, thank you for your very interesting and informative magazine.

Rebecca Reise, West Linn, Ore.

Inspired by fiction

Regarding "Think like a scientist" *(SN: 6/20/09, p. 20)*: I've often wondered, if a poll was taken of scientists and researchers, how many would say that reading science fiction and seeing science fiction movies at an early age had an influence on their decision to pursue a career in the sciences? I think such exposure opens one up to thinking outside the box.

Denis Neumann, Half Moon Bay, Calif.

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Stephen Maran

For more Comment, visit COLUMNS at **www.sciencenews.org**

Snapshots from 25 years of publicizing astronomy

Astronomer and author Stephen P. Maran recently retired from 25 years as press officer for the American Astronomical Society. He also worked at NASA's Goddard Space Flight Center in Greenbelt, Md., for more than 35 years. Known for his Einsteinian hair, along with his quips and insightful comments at press briefings that drew record crowds, Maran spoke with Science News *writer Ron Cowen about his experiences in astronomy and public outreach.*

How can NASA and astronomers better communicate discoveries?

There should be more conference calls, more use of Skype and webcasting for press briefings and at meetings. These electronic means of communication have a big following among science buffs. It also makes the news more accessible for reporters.

For years I was firm in keeping [a tight lid on] all the press-related material at meetings, such that it was hard for reporters to get them if they weren't at the astronomy meeting where news was announced. Those days are gone. Not only are there fewer reporters, but they have less travel money.

On a positive note, scientists are much more willing to communicate about their work. It's viewed as almost a professional responsibility to publicize your research — rather than as something that could hurt your career. In the past, it was the old Carl Sagan effect. Sagan was voted down for membership in the National Academy of Sciences. I had it from an insider that Sagan's extensive publicity worked against him.

In the 1990s, NASA and National Science Foundation leaders were going around to scientific meetings, saying: "You must get the word out to the public about your work. You can't expect agencies to just increase your funding if the public isn't letting their elected representatives know they're excited about the research."

You've presided over hundreds of press briefings. Which were the most interesting and which astronomy discoveries do you consider the most important?

In January 1990, John Mather of NASA's Goddard Space Flight Center got a standing ovation from colleagues when he unveiled data from NASA's Cosmic Background Explorer satellite showing that the radiation left over from the Big Bang perfectly matched that of a blackbody with a temperature of 2.72 kelvins, as had been predicted. Everyone applauded because the errors in the data were smaller than the thickness of the curve. Mather would later share the 2006 Nobel Prize in physics.

It's viewed as almost a professional responsibility to publicize your research.

In 1994, Holland Ford of Johns Hopkins University announced the discovery of a supermassive back hole at the center of the galaxy M87. He used the Hubble Space Telescope after astronauts installed corrective optics for its famously flawed mirror. The finding confirmed that the repaired Hubble was a world-class telescope.

For several years, researchers announced what turned out to be incorrect claims of finding planets around sunlike stars. Then January 1996 began the Marcy-Butler era. Geoff Marcy, now of the University of California, Berkeley, and Paul Butler, now at the Carnegie Institution for Science in Washington, D.C., announced the discovery of the second and third known planets to orbit a sunlike star beyond the solar system, both of which might contain water. The astronomers were just as interested as the press, and the briefing had to be held in a large lecture hall.

Other briefings during that meeting, held in San Antonio, included new results on distant galaxies. Those discoveries were based on 10 days of observations with Hubble of a tiny patch of sky known as the Hubble Deep Field, along with new findings about dark matter.

I called that meeting "the Super Bowl of astronomy," a phrase many reporters ended up citing. Newspapers ran editorials noting that discoveries announced at that meeting had made the front page of *The New York Times* three days in a row.

During one of the smaller meetings of the American Astronomical Society, in Rochester, N.Y., in June 2000, John Kormendy of the University of Texas at Austin announced for the first time that galaxies and their central, supermassive black holes grow in lockstep, a finding that still puzzles astronomers.

One of the biggest stories in terms of news coverage that we put almost no effort into was on the color of the universe. At a 2002 meeting, researchers working on a large-scale survey of galaxies realized that they had determined the average color of the universe — a pale green. There was no time for a press briefing, but I told them, on your poster paper and in the press release, put a little color tile.

That story turned out to have unbelievable legs. But a few weeks later, the researchers announced that they had made a mistake. The true color of the universe, they said, is beige. ■

COURTESY OF S. MARAN

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