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ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ FEBRUARY 13, 2010

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Tsunami's Message in Volts

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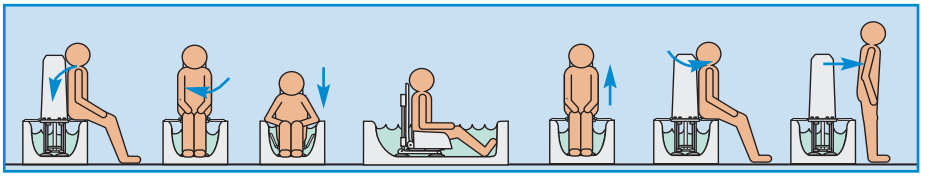

FEBRUARY 13, 2010 • VOL. 177 • NO. 4

ScienceNews

In The News

Features

Departments

COVER Understanding fatal flaws in materials and in the theory that describes why they break may lead to a new generation of sturdier stuff.
Cover by Beth Rakouskas

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FROM THE EDITOR

The simple act of splitting releases scientific secrets

There was a time when little kids learned a lot about science by breaking things or cutting them in two.

It was illuminating, for instance, to break a bar magnet and to discover that you now owned two magnets. From that phenomenon springs a wealth of deep insight into the physical world. In the hands of adults, such properties of magnetism played a starring role both in formulating the laws of physics and in fabricating innumerable practical devices.

Now imagine the similar thrill of discovering that cutting a worm in two can produce two new worms. (OK, it's not likely to work with an earthworm, but planarians are excellent candidates for this experiment.) Biology offers just as many fun surprises as physics does.

And in this case, just as breaking a magnet to clone it demonstrates profound physical principles, regeneration of a body or its parts says a lot about the intricacies of living things and how they grow.

But while magnetism and the laws of physics that explain it are now pretty thoroughly understood, scientists have not yet constructed as complete an understanding of the laws of life. Consequently there's lots left to learn about biology's complexities. Regeneration is a particularly rich realm where many of life's most mysterious secrets have long remained concealed.

Why is it, for example, that some organisms can easily replace lost body parts while others (such as humans) are severely limited in such matters? Current research suggests that understanding genetic signaling and related chemistry underlying regenerative processes may help answer that question, as freelance writer Susan Gaidos reports in this issue (Page 22).

Such work may also reveal whether regeneration is a power that has been largely lost during evolution, as more complex creatures have appeared in the pageant of life. And some researchers believe that elucidating regeneration's biochemical basis could pave the way for medical purposes in people, allowing them to repair or regrow limbs or damaged organs.

If so, regeneration will turn out to be much like magnetism — a way of understanding nature more deeply, and a tool for improving the human condition.

—Tom Siegfried, Editor in Chief

FUN LIKE SUDOKU *except you end up* SPEAKING JAPANESE.

Watch anyone solving a Sudoku puzzle and you see a brain on fire: eyes transfixed, pencil (or pen for the audacious) skittering across the squares, a number scribbled in place, done! Surprisingly, what looks like work is actually fun. Not so surprising say cognitive scientists because your brain loves solving puzzles. That's how it learns. It thrives on the bursts of pleasure that are part of the brain's reward system when you solve problems and challenges.

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Scientific Observations

"If you told me back in 1980 as a young astronaut candidate that we wouldn't be back on the moon today, I would have told you you were smoking dope. Let me say that again: If you'd told me we wouldn't be back on the moon today I would have told you that you were smoking some bad stuff. I thought I was going up on the shuttle and coming back to train to go to the moon. We became risk averse after the space shuttle Challenger, and we have not recovered from that. That has got to stop. We're going to drop satellites into the ocean periodically. Human mistakes are going to happen. We don't want to plan for this; we want to work to avoid this. But we can't be afraid. We need to take risks to move forward." **—NASA ADMINISTRATOR CHARLES BOLDEN ON JANUARY 5 AT THE WINTER MEETING OF THE AMERICAN ASTRONOMICAL SOCIETY IN WASHINGTON, D.C.**

Science Past | FROM THE ISSUE OF FEBRUARY 13, 1960

DISCOVERY ADDS CLUES TO COMPOSITION OF LIGNIN — The sugar glucose is part of the answer to a biochemical riddle — the exact composition of lignin. Lignin, which

together with cellulose comprises wood, is a highly complex carbohydrate whose complete structure is unknown. It is considered a waste product.... Experiments ... have shown that in Norway spruce trees the lignin is derived from glucose. The discovery was made by feeding the trees with radioactive glucose.... By studying where the radioactivity was located in the lignin the scientists were able to find how the glucose molecules were converted into these units.... They may some day be able to find as many uses for lignin as they have for cellulose.

Science Future

February 22–26
The American Geophysical Union's Ocean Sciences meeting is held in Portland, Ore. See www.agu.org/meetings/os10

March 5–6
Researchers and clinicians meet in San Diego to discuss genomic medicine's future. See www.scripps.org/events

March 18
Debut of an interactive exhibit on extreme weather at Chicago's Museum of Science and Industry. See www.msichicago.org

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SCIENCE & THE PUBLIC BLOG
The U.N. climate science group acknowledges that its supposedly authoritative assessment of Himalayan glacier-melt relied on some unsubstantiated numbers. Read "IPCC admits Himalayan glacier error."

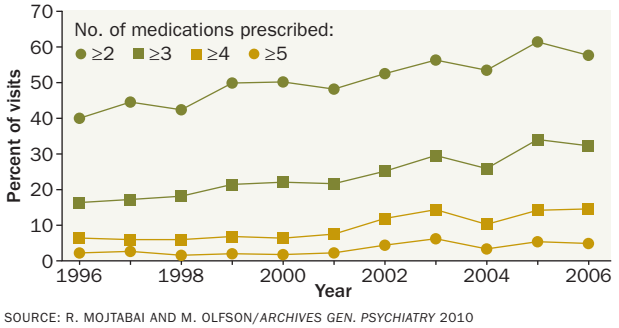
ATOM & COSMOS
Following a major collision, star production has slowed in the core of a dwarf galaxy (shown). See "New-star shine wearing off in nearby galaxy."

BODY & BRAIN
Migraine sufferers can blame a crisscross in neuronal wiring for the intense pain that often results from exposure to light during a headache, new research shows. Read "Why light makes migraines worse."

Science Stats | RISE IN PSYCH Rx'S

Prescriptions for psychotropic medications, particularly those for combinations of drugs, have risen over the past 10 years.

Rx rates in office-based psychiatrist practices, 1996–2006



SOURCE: R. MOJTABAI AND M. OLFSON/*ARCHIVES GEN. PSYCHIATRY* 2010

For Daily Use

To make a point effectively, make sure the right hand knows what the left is doing — and that both match what you're saying. Researchers tested how words and gestures interact by showing volunteers one-second videos of an individual doing an action such as chopping vegetables. A half-second later, the volunteers saw another clip of someone making a hand gesture, such as a chopping motion, while saying the word for an action. Sometimes the audio and gesture matched, other times, they were incongruous (saying *chop* while making a twisting motion). Volunteers had to note whether the audio matched the first video. They answered faster and more accurately when speech and gesture in the second clip matched than when they didn't, researchers report in the January *Psychological Science*.

CLOCKWISE FROM TOP LEFT: NASA/BILL INGALLS; J. DALCANTON AND B. WILLIAMS/UNIV. OF WASHINGTON, NASA, ESA

“This could be a fusion of a plant and an animal —that’s just cool.” — JOHN ZARDUS, PAGE 10

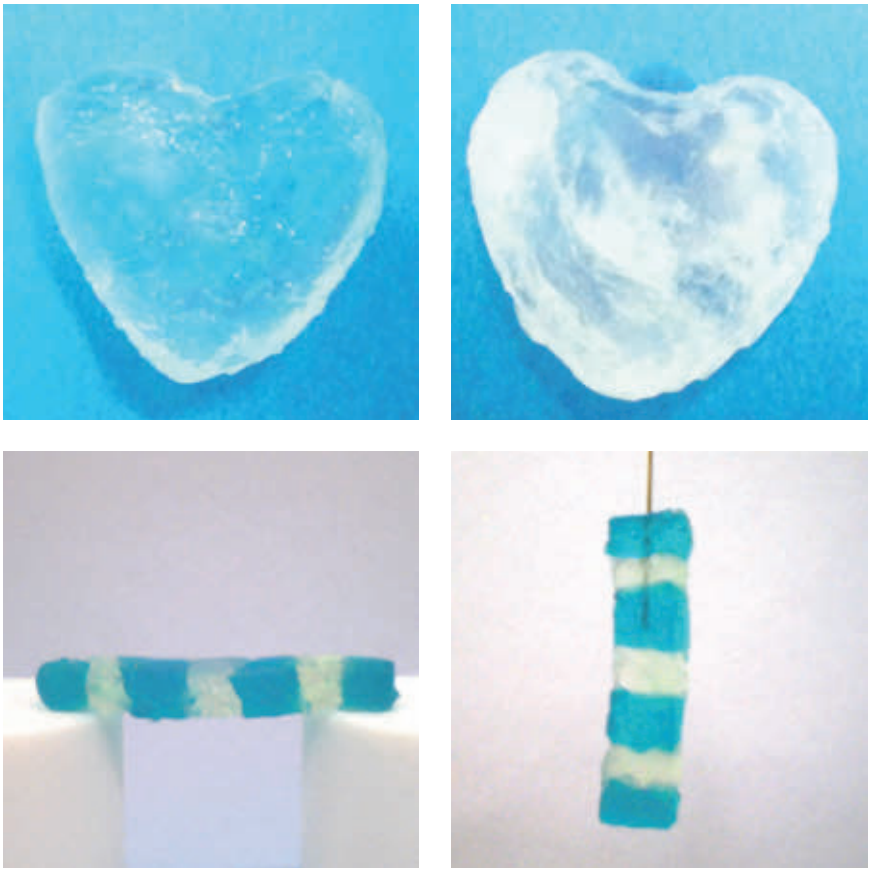
In the News

STORY ONE

Breakup doesn’t keep designer hydrogel down

Material is strong, soft and can self-heal in just seconds

By Rachel Ehrenberg



A new hydrogel (top, left) keeps its shape after soaking in a solvent (top, right), and blocks of the gel (blue and white, bottom) will bond to form a strong, larger structure.

QIGANG WANG ET AL./NATURE

Pulling yourself back together after a breakup can be tough to do. But a new hydrogel has no trouble. Using little more than water, clay and a new, designer compound, scientists have created a moldable gel that is both strong and can heal itself in seconds when split in two. The gel may advance efforts in tissue engineering and biologically friendly chemistry.

The new hydrogel is more than 50 times stronger than comparable squishy self-healing materials, researchers led by Takuzo Aida of the University of Tokyo report in the Jan. 21 *Nature*. Such substances are well suited for the body; they are flexible and can be 95 percent water. And they may one day serve as scaffolding for growing new tissue, as matrices for keeping drugs in their targeted area or as replacements for damaged cartilage.

The work adds to a “growing field of materials with exceptional properties that really could not be imagined” before, comments J. Zach Hilt of the University of Kentucky in Lexington.

Scientists typically face a trade-off when trying to engineer materials that are both strong and self-healing. The strongest materials have covalent bonds holding their ingredients together, but such substances are often brittle. After cutting or fracture, edges can’t easily recombine. But softer, self-healing materials usually aren’t strong. They often stay together via weaker, hydrogen bonds.

Some brittle materials can self-heal, but they rely on extra tricks. A polymer, for example, might be laced with thin tubes that break open when the substance is damaged, healing the wound (*SN: 4/11/09, p. 10*). These techniques work for countertops, but aren’t ideal for the body.

Now researchers are a step closer to something tough, yet tender enough for simple self-repair. The new hydrogel’s ingredients are held together by noncovalent forces — hydrogen bonding and electrostatic forces — yet it is surprisingly durable, Hilt says.

“It’s not just a noncovalent gel,” he says, “but one with a mechanical strength that hasn’t been seen before.”

The secret to the gel’s success is the material that binds it all together — a specially designed compound that study

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

coauthor Justin Mynar and his colleagues call the G binder.

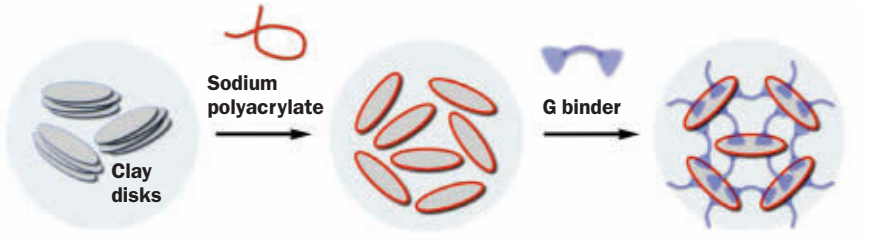
The recipe for the new hydrogel is quick and relatively easy. To make it, the team adds tiny, thin clay disks to water, and then a bit of sodium polyacrylate to prevent clumping, explains Mynar, now at the University of California, Berkeley. After shaking the solution for a few minutes, the team puts in the G binder.

Because it is specifically designed to bond with the gel's ingredients, the G binder differs from the typical fiberlike molecules generally added to hydrogels at this stage. It binds via hydrogen bonds and electrostatic forces at multiple sites. The binder is made with many positively charged branched ends that glom on to the negatively charged surfaces of the clay. And ta-da — there's a stiff gel.

"It's stronger than very tough Jell-O," Mynar says, "very hard to break with your fingers."

The G binder is built with long chains of polyethylene glycol, a chemical cousin of antifreeze that has low toxicity and is used in skin creams, lubricants and laxatives. On the ends of the chains, Mynar created branches tipped with guanidinium, a chemical relative of the amino acid arginine.

Not only does the G binder impart strength, but it also gives the gel the ability to bounce back from stress and helps it heal. This quick recovery is probably due to the binder's branching arms, which can quickly seek and snag nearby clay disks, Mynar says. "It's like an octopus — maybe you can get away from the first arm, but the others are going to get you."



A newly developed hydrogel is quick and simple to make. Researchers add sodium polyacrylate to clay disks in water to prevent clumping. Then a molecule called the G binder bonds with the disks to make the material strong and durable.

While all of the hydrogel's ingredients haven't been tested for toxicity, the gel appears to be friendly to biologically important molecules. When the scientists prepared the gel from a solution containing the protein myoglobin, which carries oxygen to muscle cells, the protein kept its shape for a week. And when enclosed within the gel, the myoglobin retained 70 percent of its activity compared with free myoglobin, the researchers report.

Chemists may also find the gel useful in the laboratory. Freshly cut surfaces of the gel stick together, a rebonding that allows the researchers to slice out blocks or other shapes and build larger structures. Mynar and colleagues created blocks of the gel in ice cube trays and then connected the cubes end-to-end, forming a bridge. This work suggests that the gel might serve as a good tool for compartmentalizing biologically important molecules or setting up a cascade of reactions. Cubes of gel could be laced with different reactants of interest and lined up in sequence.

Unlike other gels held together by relatively weak forces, the new gel kept its shape even after sitting in the solvent tetrahydrofuran for six hours. By then, the tetrahydrofuran has replaced almost all the water in the gel, Mynar says. Yet the gel retains its integrity. This suggests a way to swap water for a solvent to perform a desired reaction within the gel.

"This is a combination of properties that hasn't been seen," Hilt says. ■

Back Story | HYDROGELS FOR THE BODY

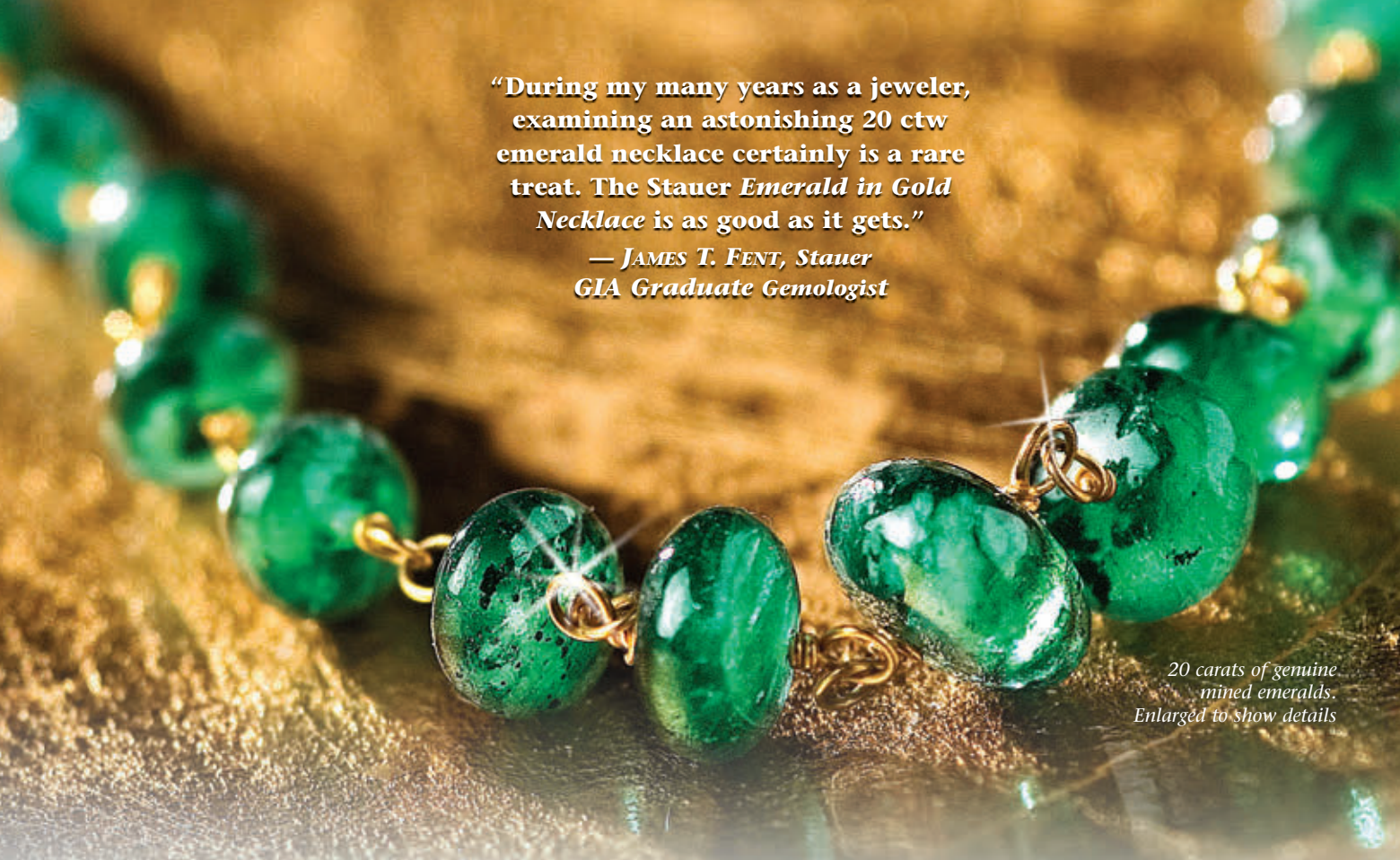
Wound healing
A protein-based hydrogel (shown) that self-assembles when triggered also has antimicrobial properties. It may be good for killing certain gram-negative and gram-positive bacteria.

Scaffolding for growing cells
A biodegradable hydrogel (shown) that is seeded with proteins and adhesive molecules stimulates new blood vessel growth when implanted in rats.

Drug delivery
Cornell University researchers used enzymes to prompt synthetic DNA to form a hydrogel (shown) that preliminary work shows could release drugs in a controlled manner over time.

Contact lenses
Soft contacts are made of hydrogels, which allow oxygen to pass through and reach the eye. Recently developed silicone hydrogel lenses reduce drying of the eye.

TOP: T. AIDA; BACK STORY, FROM LEFT: KATHY F. ATKINSON/UNIV. OF DELAWARE; GEORGIA TECH PHOTO: GARY MEEK; MOLECULAR BIOENGINEERING LAB/CORNELL UNIV.; JANEPS/ISTOCKPHOTO



The Curse of the Perfect Gift

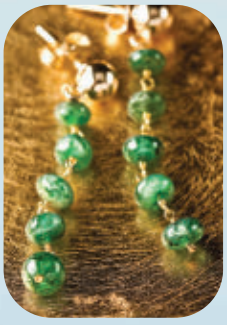
20 carats of polished natural emeralds linked with 14K gold for under $200!

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

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

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

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



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Young science superstars gear up

40 Intel Science Talent Search 2010 finalists announced

By Laura Sanders

Forty high school students have entered the final heat in their race to win the nation's longest-running precollege science competition, the Intel Science Talent Search. This year's finalists were selected from a pool of 1,736 entrants and will compete for shares of more than $630,000 in scholarships.

In March, the finalists will travel to Washington, D.C., to meet with national leaders, undergo rigorous judging of their work and present their original research in science, math and engineering at the National Academy of Sciences headquarters. This year's final 40 have explored such topics as stem cell development, stars in the Andromeda galaxy, mosquito mating behavior and river pollution.

"It is critical to encourage and reward young people who have the interest and capacity to think deeply about important problems," says Elizabeth Marincola, publisher of *Science News* and president of the Society for Science & the Public, which administers the contest. Society for Science & the Public has operated the Science Talent Search since 1942.

The top winner for 2010 will be announced on March 16. Last year's winner, Eric Larson of Eugene, Ore., received a $100,000 scholarship from the Intel Foundation for his work with mathematical objects called fusion categories, which he described in certain dimensions for the first time.

Competition alumni have won prestigious awards including the National Medal of Science. To date, seven finalists have won a Nobel Prize.

"These students will go on to make world-changing contributions not only in science; they will also bring their scientific knowledge and rigor to other critical sectors of society, to the benefit of all," Marincola says. "SSP and Intel are proud to honor them and look forward to following their progress in decades to come." ■

THE FINALISTS

ALABAMA **Nicholas Christensen**, Wetumpka, Wetumpka High School

CALIFORNIA **Namrata Anand**, Los Altos Hills, The Harker School; **Lynnelle Ye**, Palo Alto, Palo Alto Senior High School; **David Liu**, Saratoga, Lynbrook High School; **Raman Nelakanti**, Sunnyvale, Lynbrook High School; **Angela Yeung**, Davis, Davis Senior High School; **Sarine Shahmirian**, Northridge, Chaminade College Preparatory; **Otana Jakpor**, Riverside, Woodcrest Christian School; **Jane Suh**, Rancho Palos Verdes, Palos Verdes Peninsula High School

CONNECTICUT **Jason Gandelman**, Westport, Staples High School

ILLINOIS **Arjun Puranik**, Palatine, William Fremd High School; **Katherine Rudolph**, Naperville, Naperville Central High School

INDIANA **Frieda Fein**, South Bend, John Adams High School

MARYLAND **Yifan Li**, Rockville, Montgomery Blair High School

MASSACHUSETTS **Sunanda Sharma**, Shrewsbury, Shrewsbury High School

MICHIGAN **John Capodilupo**, Grand Rapids, Catholic Central High School

NEW JERSEY **Akhil Mathew**, Madison, Madison High School; **Linda Zhou**, River Edge, Academy for Medical Science Technology

NEW MEXICO **Erika DeBenedictis**, Albuquerque, Albuquerque Academy

NEW YORK **Rachel Cawkwell**, Bedford, Byram Hills High School; **Yuval Calev**, East Setauket, Ward Melville High School; **Ruoyi Jiang**, East Setauket, Ward Melville High School; **Levent Alpoge**, Dix Hills, Half Hollow Hills High School West; **Joshua Pfeffer**, Plainview, North Shore Hebrew Academy High School; **Michael Comuniello**, Levittown, Division Avenue High School; **Eric Brooks**, Hewlett, George W. Hewlett High School; **Paul Masih Das**, Lawrence, Lawrence High School; **Lori Ying**, South Hempstead, South Side High School; **Kevin Xu**, Roslyn Heights, Roslyn High School; **Alan Sage**, New York City, Stuyvesant High School

NORTH CAROLINA **Lanair Lett**, Henderson, North Carolina School of Science and Mathematics

NORTH DAKOTA **Benjamen Sun**, Grand Forks, Red River High School

OKLAHOMA **James Fenska**, Miami, Miami High School

OREGON **Yale Fan**, Beaverton, Catlin Gabel School

TEXAS **Katheryn Shi**, Sugar Land, Texas Academy of Mathematics and Science; **Peter Hu**, Denton, Texas Academy of Mathematics and Science; **Elisa Lin**, Plano, Plano West Senior High School

VIRGINIA **Temple Douglas**, Leesburg, Thomas Jefferson High School for Science and Technology

WASHINGTON **Kevin Michael Ellis**, Vancouver, Catlin Gabel School

WISCONSIN **Alice Zhao**, Sheboygan, Sheboygan North High School

Finalists are listed by state, name, hometown and high school.

36 Number of "oat flake" cities that a slime mold connected, mimicking Tokyo's rail system

Slime mold as master engineer

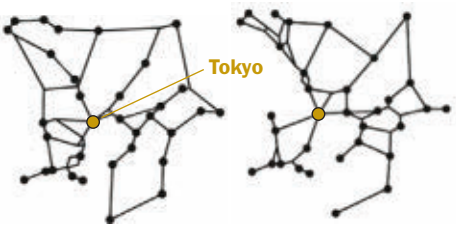
Organism builds network that echoes Tokyo's rail system

By Laura Sanders

Talented and dedicated engineers spent countless hours designing Japan's rail system to be one of the world's most efficient. Could have just asked a slime mold.

When presented with oat flakes arranged in the pattern of Japanese cities around Tokyo, a single-celled slime mold constructs networks of nutrient-channeling tubes strikingly similar to the layout of the Japanese rail system, researchers report January 22 in *Science*. A new model based on the simple rules of the slime mold's behavior may lead to the design of more efficient, adaptable networks, the team contends.

Every day, the rail network around Tokyo has to ferry millions of people quickly and reliably, notes study coauthor Mark Fricker of the University of Oxford in England. "In contrast, the slime mold has no central brain or indeed any awareness of the overall problem it is trying to solve, but manages to produce a structure with similar properties to the real rail network."



TOKYO RAIL NETWORK

SLIME MOLD NETWORK

In a new study, a slime mold connected oat flakes (left) in a pattern (above, right) reminiscent of the railway network around Tokyo (above, middle).

The yellow slime mold *Physarum polycephalum* grows as a single cell that is big enough to be seen with the naked eye. When it encounters numerous food sources separated in space, the slime mold cell surrounds the food and creates tunnels to distribute the nutrients.

In the experiment, researchers led by Toshi Nakagaki of Hokkaido University in Sapporo, Japan, placed oat flakes (a slime mold delicacy) around the cell in a pattern that mimicked the way cities are scattered around Tokyo.

Initially, the slime mold dispersed evenly around the oat flakes, exploring its new territory. But within hours, the slime mold began to refine its pattern, strengthening the tunnels between oat flakes. After about a day, the slime mold had constructed a network of interconnected nutrient-ferrying tubes. Its design looked very similar to that of the rail system surrounding Tokyo, with a larger number of strong, resilient tunnels connecting centrally located oats.

The researchers then borrowed simple properties from the slime mold's behavior to create a biology-inspired mathematical description of the network formation. Like the slime mold, the model first creates a fine mesh network that goes everywhere, and then continuously refines the network so that the tubes carrying the most cargo grow more robust and redundant tubes are pruned.

The plasmodium's behavior "is really difficult to capture by words," comments Wolfgang Marwan of the Magdeburg Centre for Systems Biology in Germany. The new research "provides a simple mathematical model for a complex biological phenomenon," he wrote in the same issue of *Science*.

Minor air traffic delays can add up

On average, economic impact exceeds that of hurricanes

By Sid Perkins

ATLANTA — Air traffic delays are more than just annoying: On average, they probably cost the U.S. economy more than hurricanes do.

Most media reports focus on extended delays that leave passengers stranded in airports for days, said Bob Maxson, director of the National Oceanic and Atmospheric Administration's Aviation Weather Center in Kansas City, Mo. But most delays are relatively minor and stem from localized weather, he reported January 19 at the annual meeting of the American Meteorological Society.

These small delays nevertheless add up to big costs, he noted. A 2008 analysis by the Joint Economic Committee of the U.S. Congress suggested that domestic air traffic delays in 2007 alone cost the economy as much as $41 billion, including $19 billion in increased operational costs for the airlines and $12 billion worth of lost time for passengers.

Those figures are likely to be overestimates, Maxson said. But even if the economic costs of air traffic delays are only $15 billion per year, for the years 2000 through 2008 those costs still exceed the economic damage — about $131 billion over nine years — caused by hurricanes that struck the United States during that same interval, Maxson said.

SCIENCE/AAAS

Life

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Sea slug steals genes for greens, turns light into energy like a plant

Animal can make its own chlorophyll, a new study shows

By Susan Milius

The photosynthesizing sea slug *Elysia chlorotica*, shown feeding on algae, has stolen a suite of genes. The slug uses its pilfered goods to make chlorophyll.

SEATTLE — It's easy being green for a sea slug that has stolen enough genes to become the first animal shown to make chlorophyll like a plant.

Shaped like a leaf itself, the slug, *Elysia chlorotica*, has a reputation for kidnapping photosynthesizing organelles and some genes from algae. Now it turns out that the slug has acquired enough stolen goods to create an entire plant chemical–producing pathway in an animal body, says Sidney K. Pierce of the University of South Florida in Tampa.

Slugs of this species can manufacture the most common form of chlorophyll, the green pigment in plants that captures energy from sunlight, Pierce reported January 7 at the annual meeting of the Society for Integrative and Comparative Biology. In experiments in the lab, Pierce used a radioactive tracer to show that the slugs were making the pigment, called chlorophyll a, themselves and not simply relying on chlorophyll reserves stolen from the algae.

"This could be a fusion of a plant and an animal — that's just cool," said invertebrate zoologist John Zardus of The Citadel in Charleston, S.C.

Microbes swap genes readily, but Zardus said he couldn't think of another natural example of genes flowing between multicellular kingdoms.

Pierce emphasized that this green slug goes far beyond animals such as corals, which host live-in algae that share the bounties of their photosynthesis. Most of those hosts tuck in the partner cells whole in crevices or pockets among host cells. Pierce's slug, however, collects just parts of cells, the little green photosynthetic organelles called chloroplasts, from the algae it eats. The slug's highly branched gut network engulfs these stolen bits, holding them inside its cells.

Some related slugs also engulf chloroplasts, but *E. chlorotica* alone preserves the organelles in working order for a whole slug lifetime, nearly a year. The slug readily sucks the innards out of algal filaments whenever they're available. But in good light, multiple meals aren't essential. Scientists have shown that once a young slug has slurped its first chloroplast meal from one of its few favored species of *Vaucheria* algae, the slug does not have to eat again for the rest of its life. All it has to do is sunbathe.

But chloroplasts need a continuous supply of chlorophyll and other compounds used for photosynthesis. In their original home, chloroplasts depended on algal cell nuclei for the fresh supplies. To function so long in exile, "chloroplasts might have taken a go-cup with them when they left the algae," Pierce said.

There have been previous hints, however, that the chloroplasts in the slug don't run on stored-up supplies alone. Starting in 2007, Pierce and his colleagues, as well as another team, found several photosynthesis-related genes in the slugs, apparently genes that were lifted directly from the algae. Even unhatched sea slugs, which have never encountered algae, carry these photosynthetic genes.

At the meeting, Pierce described finding even more borrowed algal genes for enzymes in a chlorophyll-synthesizing pathway. Assembling the whole compound requires at least 15 chemical reactions and the cooperation of multiple cell components. To see whether the slug could actually make new chlorophyll a, Pierce and his colleagues turned to slugs that hadn't fed for at least five months and had stopped releasing digestive waste. The slugs still contained chloroplasts stripped from algae, but any other part of the hairy algal mats should have been long digested, he said.

After giving the slugs an amino acid labeled with radioactive carbon, Pierce and his colleagues identified a radioactive product as chlorophyll a. The radioactively tagged compound appeared after a session of slug sunbathing but not after slugs sat in the dark. A paper with details of the work is now online in the journal *Symbiosis*.

Zardus, who said that he tries to maintain healthy skepticism as a matter of principle, would like to hear more about how the team controlled for algal contamination in the study. The possible outcomes of borrowed photosynthesis are intriguing, though, he says. Mixing the genomes of algae and animals could certainly complicate tracing evolutionary history. In the tree of life, he said, the green sea slug "raises the possibility of branch tips touching."

"Bizarre," said Gary Martin, a crustacean biologist at Occidental College in Los Angeles. "Steps in evolution can be more creative than I ever imagined." ■

NICHOLAS E. CURTIS, RAY MARTINEZ

30 thousand Years that Lost City hydrothermal vent has been active

8 hundred Number of genetically different Lost City microbes

80 percent Proportion of microbes belonging to the order Methanosarcinales living in the Lost City today

Gator breath is a one-way street

Looping airflow may be older than reptiles and dinosaurs

By Lisa Grossman

Alligators have one-way breathing similar to that in birds, new research shows. The finding, reported in the Jan. 15 *Science*, could explain how ancestors of birds, reptiles and dinosaurs rose to prominence.

"It's absolutely transformational," comments Adam Summers of the University of Washington's Friday Harbor Laboratories on San Juan Island. "It really makes us think hard about our interpretations of anatomy."

In mammals, air flows through branching tubes called bronchi, which culminate in small cul-de-sac chambers where blood vessels exchange oxygen. Air then exits the lungs via the same path.

But in birds' lungs, air makes a single circuit before being exhaled. This unidirectional flow is much more efficient — air can zip right past the blood vessels that need oxygen and then be on its way.

Conventional wisdom has held that only birds can do this because they have air sacs thought to steer air in one direction. "Alligators don't have air sacs, so no one ever looked," says C.G. Farmer of the University of Utah in Salt Lake City, a coauthor of the new study. But Farmer noticed a similarity in the way bird and alligator bronchi branch.

"If you look at the alligator lung, it's not hard to see how small modifications in this design could potentially lead to an avian lung," she says.

Farmer and coauthor Kent Sanders, also of the University of Utah, measured the speed and direction air moved in lungs of six living gators and, using pumps, five dead ones. The primary bronchi each split into an inner, first branch and an outer, second branch shortly after the point where air enters the lung. Surprisingly, air moved through the inner branch in each lung in the same direction whether the gator was inhaling or exhaling.

Air moves into alligator lungs through the blue area and out via the green (CT scan shown).

Farmer thinks that air skips past the inner bronchial branch, which forms a hairpin turn, and enters the outer branch instead. Air then passes through small tubes called parabronchi, where oxygen is traded for carbon dioxide. Finally, air flows from the parabronchi into the inner branch and out through the trachea.

The finding may mean one-way breathing is far older than suspected and could have helped archosaurs, forebearers of birds, reptiles and dinosaurs, dominate millions of years ago. Efficient one-way breathing may have given archosaurs a boost: Work shows oxygen levels in their time were about half of today's, lower than available at the top of Mount Everest.

C.G. FARMER, *SCIENCE*/AAAS

Deep-sea vents not stable homes

Small changes may spur turnover in microbial community

By Sid Perkins

In established neighborhoods, there's often little resident turnover. Yet microbes living on hydrothermal vents, thought to be some of the most stable environments on Earth, can undergo dramatic demographic changes, researchers report online January 11 in *Proceedings of the National Academy of Sciences*.

Vents spewing warm, nutrient-rich water offer an oasis for life in a cold, dark sea. But even in this steady locale, the mineralogy of chimneys and the chemical composition of vent fluids can change.

John A. Baross of the University of Washington in Seattle and his colleagues compared microbial diversity on recently formed rocks with diversity on older deposits in the Lost City hydrothermal field, which has been active in the North Atlantic for at least 30,000 years. Vents there discharge hot, alkaline fluids rich in methane and hydrogen. Biofilms cover many of the carbonate chimneys, and each gram of rock can contain as many as 1 billion microorganisms, Baross says.

The team's analyses suggest that even though about 800 genetically different types of microbe live there today, more than 80 percent of individual microbes belong to the group Methanosarcinales, which includes organisms that either make or consume methane. "It's a tough world to live in," Baross says. "It's not surprising to see just one dominant group."

But a microbe from a different methane-consuming group dominates a sample deposited about 1,250 years ago. Water there is less alkaline, and the researchers think that changing conditions may have allowed some species to thrive while others languished. But the findings don't tell when or exactly why such a shift occurred, comments Jack A. Gilbert of the Plymouth Marine Laboratory in England.

Humans

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Newborns nurse smell memories

Toddlers prefer odors whiffed during breast-feeding days

By Bruce Bower

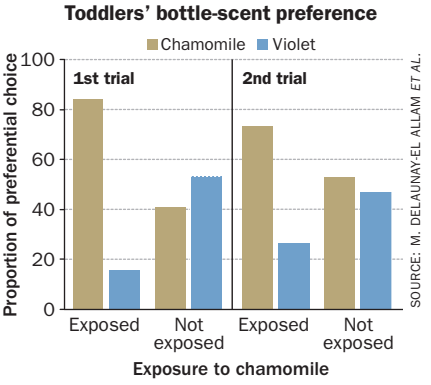
Within a week after birth, babies inhale new memories at their mothers' breasts. Newborns who whiff a specific odor while breast-feeding, even if smelled for only eight days, prefer that same odor over others a year or more later, reports a team led by Benoist Schaal of the European Center of Taste Sciences in Dijon, France.

Like other infant mammals such as rats and pigs, human newborns easily learn smells associated with breast-feeding, the team concludes in a paper to appear in *Developmental Science*. These types of odor memories form most robustly during the first week of life and can be reactivated and influence behavior until at least toddlerhood, the researchers propose.

Carolyn Rovee-Collier of Rutgers University's Busch campus in Piscataway, N.J., calls the new findings "compelling evidence of a period of exuberant learning in early infancy when infants rapidly associate events that occur simultaneously." The results support the controversial idea that infants can form associative memories, she contends.

Schaal's team capitalized on midwives' practice in one part of France of recommending that nursing mothers apply a chamomile balm to their breasts to prevent nipple soreness. Researchers offered the balm to breast-feeding mothers of newborns in a French maternity ward. Of 37 mothers who agreed to participate in the study, 20 used the chamomile concoction — slathering it on for eight to 120 consecutive days of nursing, as needed.

At age 7 months, children of the breast-feeding mothers received three teething rings one at a time. Rings had a chamomile scent, a violet scent or no scent. Infants whose mothers had used the chamomile balm spent substantially more time mouthing and holding the chamomile ring than the other rings. Infants of mothers who didn't use the balm showed no preference.



At age 21 months, toddlers exposed to chamomile during breast-feeding preferred playing with chamomile-scented toys and almost always chose to drink from a chamomile-scented bottle. Toddlers who hadn't been formerly exposed didn't show this preference and showed signs of disgust when swabs of chamomile were placed under their noses.

Children intertwine space and time

Distance cues bias conclusion of how long something lasts

By Bruce Bower

Although 4-year-olds' concept of time seems to consist solely of what they want right now, the passage of time still moves them. Kids of that age already mark time by referring to physical distances, report Daniel Casasanto of the Max Planck Institute for Psycholinguistics in Nijmegen, the Netherlands, and colleagues.

Abstract concepts such as how time works stem from youngsters' real-world perceptions and behaviors, not from cultural rules or metaphoric language, Casasanto's group proposes in an upcoming *Cognitive Science*.

"We find that time representations depend on space just as strongly in 4-year-olds as in 10-year-olds, even though 4-year-olds have little experience using space-time metaphors in language," Casasanto says. By 10, children have heard and spoken such metaphors: "a long test" or "moving up an appointment," for example.

Casasanto previously reported that adults estimate the amount of time it takes for lines to lengthen across a computer screen based on how far the lines travel. If two lines expand to different lengths over the same time period, volunteers judge the shorter line to have moved for less time than it actually did (*SN: 10/25/08, p. 24*). Timing has no such effect on estimates of distance.

The new study recruited 99 children from kindergartens and elementary schools in Greece. Speakers of the children's native tongue, Greek, usually don't use distance words for describing time spans, Casasanto notes.

Each child viewed three movies of pairs of cartoon snails racing on parallel tracks. Snails traveled different distances in the same time, different distances in different times or the same distance in different times.

Regardless of age, children relied heavily on the distance traveled by each snail when trying to estimate how long the snail took to reach its destination. But the kids typically ignored for how long the snails had moved when determining whether snails stopped at the same spot.

The findings, says Lynden Miles of the University of Aberdeen in Scotland, fit with work his team reports in an upcoming *Psychological Science*. Adults told to think about past experiences swayed backward, while those thinking about the future swayed forward.

Molecules

2.49 ng/ml | Mean urine level of BPA in U.S. adults, 2003–04

1.79 ng/ml | Mean urine level of BPA in U.S. adults, 2005–06

BPA and heart disease linked again

Population data support concern about plastics chemical

By Rachel Ehrenberg

A previously reported link between exposure to bisphenol A and heart disease stands, reports a study published online January 13 in *PLoS ONE*.

The finding provides more evidence implicating the plastics chemical in cardiovascular and metabolic problems, notes Richard Stahlhut of the University of Rochester in New York. "It's becoming a coherent picture that really does fit together," says Stahlhut, who was not involved in the research. "If these all connect, we really do have a problem."

Researchers analyzed data from the 2005–06 National Health and Nutrition Examination Survey conducted by the U.S. Centers for Disease Control and Prevention. NHANES uses physical examinations, clinical and lab tests, and interviews to get a snapshot of the health of the U.S. population. The new analysis reveals an association between levels of bisphenol A in urine and risk of cardiovascular disease, a link also detected in the 2003–04 NHANES data.

"We now have two completely separate samples with completely different people," says study coauthor David Melzer of the Peninsula Medical School in Exeter, England. The work shows the earlier finding "wasn't a blip," he says.

Human exposure to bisphenol A is widespread. BPA is a building block of polycarbonate plastics and is common in the epoxy linings of canned food. It also mimics estrogen. Numerous studies have found that BPA interferes with development and function in a range of tissues.

The NHANES link to cardiovascular disease is a third line of evidence implicating the chemical in metabolic and heart problems, Stahlhut says. A 2008 study examining human fat tissue found that BPA suppresses a hormone that protects people from heart attacks and type 2 diabetes. That same year, a separate team reported that, in mice, BPA spurs pancreatic beta cells to crank up insulin output.

By pooling NHANES data from 2003–04 and 2005–06 on 2,605 people with known BPA levels, researchers identified 159 people with cardiovascular disease. Using these data, the team predicts that among 60-year-old men with relatively high BPA levels (in the top third of the population), about 10 percent would develop cardiovascular disease, compared with 7 percent of men with BPA levels in the lowest third, says Melzer. In the model, only 5.2 percent of men in the middle tier of exposure were expected to develop cardiovascular disease — a dose response not uncommon for compounds that interact with hormones.

The scientists did find lower overall levels of BPA in the urine of Americans than were found in previous surveys.

In January the FDA, which had previously decreed BPA safe, changed its position. Federal health officials now "express some concern" about BPA's safety, especially in infants and children.

Another recent analysis of NHANES data links blood levels of a nonstick chemical and thyroid diseases. From 1999 to 2006 nearly 4,000 adults were sampled for perfluorooctanoic acid, or PFOA, a water- and oil-repellent chemical long used to make protective coatings for carpets, upholstery and clothes. Of those adults, 163 women and 46 men reported taking drugs to treat thyroid diseases. People with higher PFOA levels were more than twice as likely to have problems, the researchers report online January 20 in *Environmental Health Perspectives*.

ANDERS WARÉN, SWEDISH MUSEUM OF NATURAL HISTORY, STOCKHOLM

Snail in shining armor

A deep-sea snail wears a multilayered suit of armor, complete with iron. The snail, called the scaly-foot gastropod (shown), lives in a hydrothermal vent field where it faces extreme temperatures and pressures, high acidity levels and hungry crabs. To withstand these trials, the snail has a shell "unlike any other known mollusk," Christine Ortiz of MIT and colleagues report January 19 in *Proceedings of the National Academy of Sciences*. The shell's stiff inner layer of aragonite is sheathed in a thick layer of squishy organics, which is again covered by a stiff outer layer of hard iron sulfide-based scales. The outer layer can blunt intruding claws, the middle layer deforms to dissipate energy and the inner layer provides structural support to prevent cave-ins. Ortiz hopes studying the shell could one day lead to improved materials for armor or helmets for people. —*Lisa Grossman*

Body & Brain

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Fish oil benefits keep adding up

Omega-3s may help battle sepsis, age-related diseases

By Nathan Seppa

Promising news about omega-3 fatty acids just keeps rolling in. One new study bolsters previous data suggesting that fish oil supplements high in omega-3s may help critically ill people by quelling inflammation. And another study finds that robust omega-3 levels protect the ends of chromosomes from damage, which may have benefits in warding off age-related diseases.

Fish, walnuts, some vegetable oils and many other foods are rich in omega-3s.

In a study published online January 19 in *Critical Care*, scientists tested the value of fish oil supplements in 23 people admitted to a hospital in Penafiel, Portugal. The patients were critically ill with sepsis, a life-threatening overreaction to a microbial infection. Although doctors use a host of drugs and around-the-clock care to treat sepsis, the death rate is still high, up to 35 percent.

Researchers randomly assigned 13 patients to receive soybean oil and fish oil as their daily fat intake. The other 10 received only soybean oil. All patients were fed intravenously and were on ventilators to assist breathing, says study coauthor Philip Calder, a biochemist at the University of Southampton in England.

After four weeks of treatment, four people in each group had died. Excluding those, the patients given fish oil recovered and were discharged from the hospital in 28 days on average, compared with 82 days for those not getting fish oil.

A hallmark of sepsis is uncontrolled inflammation that threatens vital organs, including the lungs. Tests showed patients on fish oil had signs of reduced inflammation and, possibly because of this, processed oxygen better, Calder says.

In the other study, scientists investigated the effect of omega-3s on telomere length. Telomeres are strings of repeating DNA sequences that protect the ends of chromosomes during cell division. "In cells, telomere length is a big determinant of aging," says Ramin Farzaneh-Far of the University of California, San Francisco. If telomeres shorten too much, they stop functioning as DNA safeguards and the cell dies, he says. Some clinical studies have linked telomere shortening to earlier death.

The finding could help explain the potentially protective effects of omega-3s.

Farzaneh-Far and his colleagues recorded blood levels of omega-3s and telomere length in the white blood cells of 608 people with heart disease and an average age in their mid-60s. Although some people had higher omega-3 levels than others at the study's outset, telomere length wasn't markedly different between the groups at that time.

But after five years, those who started with higher omega-3 levels had substantially less telomere shortening than the others, the team reports in the Jan. 20 *Journal of the American Medical Association*.

"Given the increasing evidence for an association between telomere length and cardiovascular and other age-related diseases, the finding could provide a novel mechanism which explains the potentially protective effects of omega-3 fatty acids on these diseases," says Nilesh Samani of the University of Leicester in England. He notes, though, that it was odd that telomere length wasn't different at the outset.

Gene may guard against dementia

Same form linked to longevity and 'good' cholesterol levels

By Nathan Seppa

Carrying a variant form of the *CETP* gene is looking more and more like holding a winning genetic lottery ticket.

This version of the gene might protect against Alzheimer's disease and other forms of dementia, researchers report in the Jan. 13 *Journal of the American Medical Association*. Earlier work linked the variant to impressive longevity and high levels of HDL, the "good" cholesterol.

But before running to get your genes tested, be aware that scientists don't know for certain how the gene variant might achieve any of these salutary effects, particularly dementia prevention.

They do know that people harboring the variant form of *CETP* make less of the CETP protein, and apparently that's better. "What CETP does in the brain is less clear," says study coauthor and neurologist Richard Lipton of the Albert Einstein College of Medicine in New York City.

In the new study, Lipton and his colleagues identified 523 people, average age 78. (Forty were later diagnosed with Alzheimer's or dementia.) Blood samples showed that 21 percent carried two copies of the variant form of *CETP* (one copy comes from each parent) and 45 percent harbored a single variant copy (from one parent). The rest had two copies of the standard version of *CETP* (no variant).

Over the next four years, those endowed with two copies of the variant were only one-third as likely to develop dementia or Alzheimer's disease as were those who carried the standard *CETP* gene. Those harboring one copy of the variant *CETP* didn't seem to glean protection from it.

"I believe this is a real, but small, effect," says neurologist John Ringman of UCLA. "Whether or not it will generalize to the population is an open question."

Earth

3.7 inches | Average July rainfall in Iowa, 1930–69

4.2 inches | Average July rainfall in Iowa, 1970–2009

Irrigation could be cooling Midwest

Two studies blame drop in hot days, more rainfall on farmers

By Sid Perkins

ATLANTA — If summers seem cooler and wetter in parts of the Midwest in recent years, you can thank — or blame — farmers, two new studies contend.

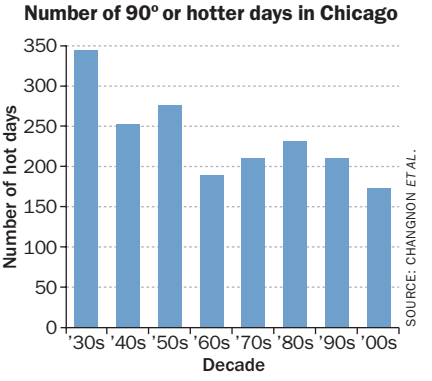
While average global temperatures rose about 0.74 degrees Celsius during the past century, the U.S. Midwest has experienced a noticeable slump in summer temperatures in recent decades, David Changnon, a climatologist at Northern Illinois University in DeKalb, reported January 19 at the annual meeting of the American Meteorological Society.

On average, daily high temperatures in Chicago hit 90° Fahrenheit on 24 days in summer. But from 2000 through 2009, only two years tallied more than 24 days hotter than 90° F — the lowest decadal total in 80 years, Changnon noted.

Rather than being just a statistical anomaly, the recent cool temperatures seem to be part of a steady long-term decline in summertime highs in Chicago, Changnon and his colleagues found. The past 10 years has seen a total of only 172 days above 90° F; the 1930s saw more than twice that. And Chicago wasn't alone. The team noted a comparable decline in extremely hot days at 13 other sites from western Iowa to eastern Indiana.

From 1970 through 2009, average temperatures in Illinois and Iowa during July and August were between 0.5 and 1.0 degrees F cooler than from 1930 through 1969. Precipitation also changed: Average rainfall for July and August from the 1970s through 2009 was more than 0.33 inches higher each month than it was in the earlier period.

Changnon thinks the trends are linked, because humid air warms more slowly than dry air does. One likely source of the extra moisture is agriculture, both close by and farther afield in the Great Plains.



A rapid rise in irrigation in the Great Plains has boosted precipitation downwind in the Midwest, Alan Robock of Rutgers University in New Brunswick, N.J., reported January 21 at the meeting. His team analyzed data from more than 300 weather stations from Wisconsin and Michigan to Arkansas and Tennessee and found that rainfall had increased along with irrigation. At sites in that swath, precipitation during a typical July late in the 20th century was between 25 and 50 percent higher than it was early in the century.

Tsunamis could telegraph arrival

Telecommunication cables may warn of the giant waves

By Lisa Grossman

Tsunamis might one day send scientists underwater telegrams.

Ocean water interacting with Earth's magnetic field could create strong enough signals in transoceanic communication cables to alert scientists that a tsunami is on the way, a team argues in an upcoming *Earth, Planets and Space*.

"This is a very good supplementary ... system to the existing tsunami warning," says study coauthor Manoj Nair of the National Oceanic and Atmospheric Administration's National Geophysical Data Center in Boulder, Colo. "It can be information in places where we don't have any information."

Though tsunamis move tremendous amounts of water at hundreds of kilometers per hour, their passage barely makes a ripple on the surface of the open ocean. But they do create electromagnetic waves below. Seawater is a good conductor of electricity, and as it passes through Earth's magnetic field, the movement of positive and negative ions generates a weak electric field.

That electric field can induce a voltage, the force that drives electric current, in the kilometers-long telecommunication cables that crisscross the ocean floor. A tsunami can generate a pulse in the voltage. If the voltage is large enough, it could serve as a warning of an imminent wave.

This effect, used to monitor ocean currents in the Florida Strait, had been previously suggested as a way to detect water movement triggered by earthquakes. But detailed studies of the voltage that a tsunami would produce were lacking.

"Only recently we had the capability of doing such sophisticated numeric and computer simulations," Nair says.

Nair and his colleagues built a 3-D computer model of the 2004 Indian Ocean tsunami, which was triggered by a magnitude 9.3 earthquake and killed more than 220,000 people. The team calculated that three cables in the Indian Ocean would have seen voltages of about 500 millivolts, well above the estimated 100 millivolts of background noise.

Current warning systems, which use pressure sensors on the ocean floor, are more reliable and tell more about a wave's origin and direction, Nair notes. But, he argues, the proposed new method could cheaply augment current systems.

Genes & Cells

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Soysoybean*bean* genome revealed

Plant's chromosomes copied themselves at least twice

By Susan Milius

Scientists finally do know beans about soybeans, thanks to a newly unveiled, sequenced genome.

The plant's DNA contains a surprising amount of duplication, says geneticist Scott Jackson of Purdue University in West Lafayette, Ind. Having the soybean's genetic blueprint, he says, should help scientists improve crop varieties and study the evolutionarily important process of genome doubling.

Soybean's set of chromosomes has copied itself at least twice, approximately 59 million years ago the first time and then again about 13 million years ago, Jackson and his colleagues report in the Jan. 14 *Nature*. Redundant genes often retool or vanish, but soybean plants still have multiple copies of almost three-quarters of their genes, the researchers say.

Making extra copies of a genome, leading to what's called polyploidy, carries a risk of sterility, yet duplications happen. "We don't know why they happen; we don't know how they happen," he says.

The genome of the soybean plant, recently decoded, is one of the largest plant genomes to be sequenced.

Most, if not all, flowering plants have copied their genetic material at some time in their histories, comments Keith Adams of the University of British Columbia in Vancouver, Canada. But what's interesting is how recently soy duplicated, he says.

Even in its modern, duplicated form, the soybean genome is relatively small for a plant's, Jackson says. It's not even half the size of the maize genome, for example. Yet, at 10 times the size of the lab staple *Arabidopsis* genome, the soybean's is one of the largest plant genomes that geneticists have managed to sequence.

The new draft, based on a soy variety called Williams 82, covers 85 percent of the 1.1 billion pairs of nucleotide bases that form the building blocks of the plant's DNA. The plant has some 46,000 protein-coding genes, the researchers say.

Jackson says about a third of these genes fall into an awkward place for plant breeders: nonrecombining zones, where genes don't shuffle around and so don't create new mixes of traits.

The researchers also found that about 59 percent of the soy genome is composed of repetitive stretches of DNA called transposable elements, which typically stick copies of themselves around the genome.

Studying a group of these elements has revealed for the first time that a "dead" element, one that has lost the ability to copy itself, can regain its powers, says geneticist Jianxin Ma, a coauthor also from Purdue. The dead element revives by exchanging genetic material with a functional counterpart, he and colleagues report online January 15 in the *Plant Cell*.

MRSA mutates and spreads quickly

Genetics of antibiotic-resistant microbe reveal global roots

By Tina Hesman Saey

A deadly, antibiotic-resistant strain of staph began in Europe and mutated quickly as it spread, a new study shows. Scientists decoded the microbe's genome to trace its movements, an approach that could help pinpoint and stop outbreaks.

The marauding bacterium, which is known as MRSA for methicillin-resistant *Staphylococcus aureus,* mutates quickly by altering at least one DNA letter in its genetic handbook, or genome, about every six weeks, an international team reports in the Jan. 22 *Science*.

More of those mutations fall in genes involved in antibiotic resistance than would be expected by chance, "illustrating that there is an immense selective pressure from antibiotic use worldwide," says Simon Harris of the Wellcome Trust Sanger Institute in Hinxton, England.

Sampling from hospitals around the world, Harris and his colleagues analyzed 63 isolates of a MRSA strain called ST239. The team could rapidly decode each sample's entire genome using the relatively new technology of high-throughput sequencing.

The strain ST239 likely arose in Europe in the 1960s and then spread to become the dominant MRSA strain in Asia. Still prominent in Europe, ST239 is also common in South America. Most of the 20 samples from Thailand originated outside the hospital where they were collected, but the team found evidence of spread among five patients in adjacent hospital wards.

The approach can reveal how mutations lead to epidemics, says Frank DeLeo of the National Institute of Allergy and Infectious Diseases lab in Hamilton, Mont. "To understand how a successful pathogen emerges is critical."

ROY KALTSCHMIDT

"This question of the normal function of PrP has become an obsession for me." —ADRIANO AGUZZI

Prion protein's role in body revealed

Normal form of disease agent is important for nerve function

By Tina Hesman Saey

A molecular Dr. Jekyll finally has a day job — as an electrical lineman. A new study suggests that the normal form of prion protein helps maintain the insulation that speeds electrical signals along nerves.

In its twisted Mr. Hyde form, the prion protein causes fatal brain-wasting diseases, such as mad cow disease in cattle and Creutzfeldt-Jakob disease in people (*SN: 8/16/08, p. 20*). But the normal form of the protein, which is found in neurons in people and other mammals, is also a good guy, a new study shows. The protein appears to direct cells called Schwann cells to wrap around neurons and produce myelin, a type of insulation that aids electrical communication between the cells. This newly discovered role for the normal form of the prion protein — called PrP(C) or just PrP — could link problems with the protein to nerve disorders called peripheral neuropathies, researchers led by Adriano Aguzzi, a neuropathologist at the University of Zurich, report online January 24 in *Nature Neuroscience*.

Much attention has focused on how the protein's infectious form leads to disease, but its usual role in the body has been a mystery. "This question of the normal function of PrP has become an obsession for me," Aguzzi says.

In the new study, researchers studied mice genetically engineered to lack the prion protein. The mice had abnormal myelin sheaths around their sciatic nerves, long nerve cells that run from the lower back to the foot. Electrical signals traveled more slowly down these nerve fibers in mice lacking prion proteins compared with normal mice, the team found. Restoring prion proteins to nerve cells allowed the cells to keep sheaths healthy.

If the prion protein does play a role in myelin maintenance, that could pose a problem for gene therapy that would remove PrP from animals to prevent prion diseases, says Claudio Soto, a neuroscientist at the University of Texas Health Science Center at Houston. He and colleagues have genetically engineered cattle that lack the prion protein. The question remains whether a lack of PrP can cause peripheral nerve problems, Soto says.

BREAKING I

Studies of how things fall apart may lead to materials that don't

By Lisa Grossman

Boston's Great Molasses Flood probably began with a cracked tank. In 1919, more than 8 million liters of goo rushed through city streets, twisting structures (train track, shown) and causing 21 deaths.

Suppose there was a fourth little pig. This one was a physicist. Unlike his brother the engineer, who built a house out of tried-and-true bricks, the physicist pig chose a building material by doing calculations based on fundamental principles. He settled on a substance made from silicon and oxygen, an abundant material with high bond strength and the aesthetic bonus of transparency. It was safe from huffing and puffing. But then the wolf learned to throw stones.

Physicists have had a tough time explaining why it's a bad idea to build glass houses. While engineers from the Bronze Age to the Space Age have relied on trial and error to decide which materials work best, physicists seek deeper, scientific explanations.

"Can you predict from first principles what kinds of material will be very strong, and what will be brittle?" says Jay Fineberg, a physicist at the Hebrew University in Jerusalem. "It's kind of strange, but we don't know."

Trying to find out has occupied the materials scientists who investigate how what begins as a rift between a few atoms spreads far enough to take down buildings and bridges. The goal is to engineer failure-free materials by understanding why materials fail in the first place.

"You can learn an enormous amount about materials by pushing them to their limits," says materials scientist Markus Buehler of MIT.

In the process, scientists are exposing the cracks in existing theories. By shattering breakable Jell-O to model glass fracture in

DON KLUMPP/GETTY IMAGES; INSET: BETTMANN/CORBIS

slo-mo, Fineberg and his colleagues have found that established equations of crack movement don't apply near the tip of a fissure. In supercomputer simulations of billions of atoms stretching, Buehler and his colleagues discovered that the shuffling of a few atoms just ahead of the tip holds the reins on a crack's speed.

And after centuries of making materials that can break too easily, scientists are deconstructing nature to uncover new ways of building stronger, more efficient materials. Efforts at biomimicry have already led to designs inspired by sponges made of glass and to tough ceramics based on mollusk shells. Together, these studies could usher in a golden age of atoms-up design.

Cracking theory up

A quick tour through the history of engineering underscores why finding failure-free materials is so important. A molasses tank in Boston burst in 1919, flooding the streets with sweet goo and killing 21 people. The *S.S. Schenectady* cracked almost in half in 1943 while sitting calmly in a harbor outside Portland, Ore. In 1988, the roof of Aloha Airlines Flight 243 tore off during flight, killing a flight attendant and injuring several passengers. A Missouri Air National Guard F-15C broke in two during flight in 2007, and the entire U.S. Air Force fleet of F-15s was grounded for weeks.

These disasters share an important feature: They all probably started with an imperceptible crack. So studying how a small crack propagates might help prevent such disasters in the future.

Way back in the late 1910s, English engineer Alan Griffith noticed that the stress theoretically required to break atomic bonds is 1,000 times larger than the stress actually needed to break those same bonds in a material.

"I could take a millimeter-thick strand of glass, and I could lift a grand piano with it," Fineberg says. "A strand of glass can reach these strengths; it's not science fiction. But the minute you have a flaw, it shatters."

Griffith realized that existing ideas about how materials fracture were too simple. He reasoned that there must be some critical point (now known as the Griffith point) at which a crack gets so long that the strain pulling the material apart overwhelms the threshold energy required to form a new surface. His insight led to the current fundamental theory of fracture, which suggests that, because of the physical limits of energy transport through a material, a crack can't travel faster than the speed of sound on the material's surface.

But recent work reveals that even this theory, called linear elastic fracture mechanics, is too simple. Some cracks can travel faster than sound's surface speed. In 1999, geophysicists observed an earthquake in Kocaeli, Turkey, that split rock at speeds exceeding several kilometers per second, faster than the speed of sound on the rock's surface. The same phenomenon was observed in earthquake simulations three years later. And in 2004, physicists Michael Marder of the University of Texas at Austin, Robert Deegan, now of the University of Michigan in Ann Arbor, and colleagues found that rubber balloons also show unexpectedly fast fissures when popped with a pin.

"You can do this experiment in the comfort of your own home — preferably aided by children," Marder says.

Knowing that something is still wrong with existing theory, scientists are at it again — ripping down old ideas to make room for new ones.

Breaking the mold

Crack movement is difficult to study in the lab because of the extreme speeds involved. But Fineberg's team has a new way to slow things down.

"Instead of breaking glass or steel or brittle ceramics," he says, "what we break is Jell-O."

In this case, the gelatin is actually squares of polyacrylamide gel, a watery polymer used in DNA studies. "These are slippery little buggers," he says. "They slipped and fell and looked like they shattered like plates of glass."

In a series of studies published in 2005, Fineberg and two students showed that the way cracks move through the gel is identical to the way cracks move through glass, with one important difference: Cracks that would run through glass at 3,000 meters per second crawl through gels at just 5 m/s.

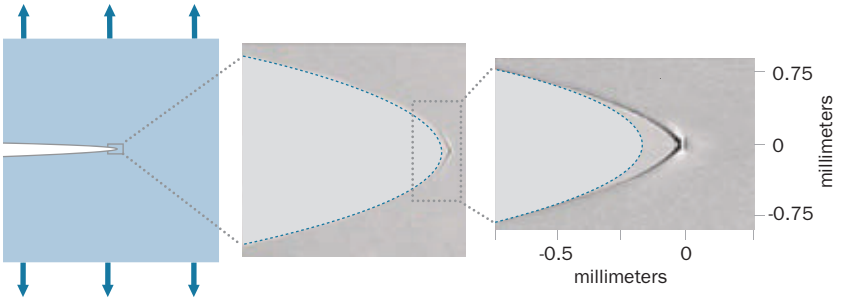
"You have a lot more time to see what's going on," Fineberg says.

Armed with a fast camera, Fineberg and colleagues have found a major flaw in linear elastic fracture mechanics. The theory assumes that the stress placed on a material is proportional to the strain it feels. But in a paper still in preparation, Fineberg and theorist Eran Bouchbinder, also of Hebrew University, show that

this is true only far away from the crack's tip. As measurements of cracks slogging through gelatin get closer to the point where the material splits completely, more and more terms need to be added to the equation of motion to describe how energy fuels the crack — and therefore how the crack propagates.

Fineberg says the gelatin method could also help explain how and why a crack changes direction, the way rippled edges form in popped balloons, for example. Aside from tip activity, cracks moving in straight lines seem to agree with the predictions of linear elastic fracture mechanics. But if those cracks deviate, the equations governing their motions are unknown. And fast, crooked cracks can emit small daughter cracks, or split completely into multiple fractures.

"The fundamental question is why cracks become unstable," he says. "I believe that with these gels we can start to unravel this, just because we can slow things down."



Gelatin takes on theory Current theory predicts that the tip of a crack should be shaped like a parabola (blue line), but studies that apply stress (arrows) to gelatin show that the real tip (black line in photographs) defies expectations. New equations will need to describe the discrepancy.

Assemblies of atoms

Though the camera that captures Jell-O cracks has speed on its side, for a truly fundamental theory of fracture, scientists would like a camera that also zooms to the atomic scale.

Buehler uses the next best thing: a supercomputer that models billions of atoms. His lab at MIT investigates fracture in materials ranging from nickel and silicon to bone and protein. "We can simulate atoms and get an equation of state or density or melting point of a material," he says. "It's really exciting."

The simulations calculate each atom's trajectory based on Newton's laws of motion and the quantum mechanical interactions between that atom and those around it. To introduce a crack, Buehler simply removes a few atoms. To make the crack spread, he adds some stretch.

"The beauty of this approach and why I get really excited about this, it really is very simple," he says. "Atomistic simulation doesn't need much input. All it is, is chemistry."

Buehler's work offers an explanation for why cracks, under some conditions, move in a punctuated rather than a gradual way. In modeling a few-nanometers–long crack in silicon, Buehler noticed that some of the silicon atoms, which usually link up to form hexagons, had rearranged themselves. At the very tip of the crack, two six-atom rings had transformed into a five-atom ring and a seven-atom ring sitting side by side. The crack didn't push forward until another bond, this one shared between the seven-atom ring and a six-atom ring ahead of it, broke — at which point the crack split through the subsequent six-atom rings like a zipper.

The transformation from six-atom rings to five- and seven-atom rings is the material's response to extreme pressure, Buehler explains. In the same way that solids melt when heated, silicon shifts its atoms around under stress. This shift could help keep the crack from spreading, up to a point, by dissipating the constant energy applied to the material. Simulations in more substances may reveal how such changes in the atomic structure of materials could contribute to a new fundamental theory of fissure.

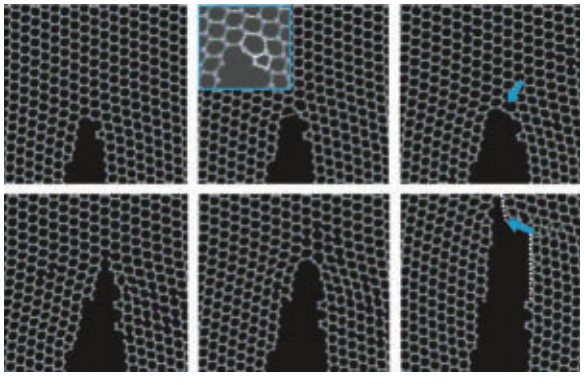
But atomistic simulations are slow and intensive — a recent model of a small piece of a protein network in a cell took weeks to render, Buehler says. And even the best supercomputers are years away from being able to handle the numbers of atoms that make up life-size objects.

Buehler sidesteps this problem by breaking materials into chunks. He'll simulate a large ensemble of atoms, and draw a black box around it. The next level of simulations zooms out to the scale where the black box is a particle, and so on.

"We start at the fundamental scale and build up," he says.

Conveniently, scientists have found, biological materials are actually organized in this hierarchical structure. Buehler's fondest dream is to use multiscale modeling to help build new substances inspired by life.

Atomic shuffle Simulations of silicon reveal that atoms near the tip of a crack rearrange themselves from two six-member rings to a five- and seven-member ring (inset). The change may hold the crack at bay until another bond (arrow, top right) gives way, allowing the other rings to unzip (arrow, bottom right).



Nature builds it up

Some materials scientists are already creating new materials based on how natural substances fail, or fail to fail. Robert Ritchie and Tony Tomsia of Lawrence Berkeley National Laboratory in Berkeley, Calif., and colleagues, for example, made a material based on seashells in late 2008.

FROM TOP: J. FINEBERG, A. LIVNE, E. BOUCHBINDER, I. SVETLIZKY; M. BUEHLER, M. BUEHLER *ET AL./PHYSICAL REVIEW LETTERS* 2007

"Ceramics are wonderful: They're lightweight, they're very strong," Ritchie says. "They're ideal, bar one thing — they're brittle as hell."

Seashells, on the other hand, can take an impressive beating. Research has shown that it takes 3,000 times more energy to break nacre, the material that gives mollusk shells their mother-of-pearl sheen, than nacre's chief component, aragonite, a brittle calcium carbonate mineral. In a seashell, the aragonite is sandwiched between microscopic layers of soft organics that provide cushioning.

"Its final properties in terms of resistance to fracture are so much better than either of the constituents," Ritchie says. "That's what we're trying to emulate."

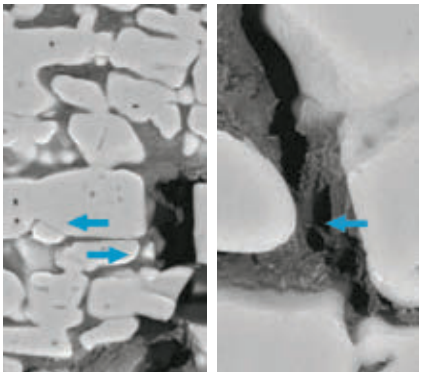
Ritchie, Tomsia and their colleagues mixed alumina, a simple ceramic, with water, and then froze the mixture to create a lattice of ice. When the ice melted and left behind a ceramic scaffold, the scientists filled the spaces between the alumina layers with a common polymer, polymethyl methacrylate.

The team tested the resulting ceramic's fracture resistance by introducing a small crack and forcing it to spread. The material was 300 times tougher than its constituents, the researchers reported in *Science* in 2008. The toughness comes from the polymer, which acts as a lubricant, allowing layers of ceramic to slide over each other rather than sever.

"This little thin layer of polymer allows the material to give a little bit, and reduces the stresses," Ritchie says. "Nature does the exact same thing. This is not our idea, it's nature's."

Ritchie and colleagues have made only a few cubic inches of the substance so far, but considering that most other biomimetic materials have been made on the nanoscale, that's a lot. "As far as we know, no one has ever made a bulk material like this," Ritchie says.

Polymer cushion Polymer (dark gray) serves as the cushioning in bricks-and-mortar structures resembling seashells. The polymer allows alumina to slide (arrows, left image) and will tear (arrow, right image) to relieve stress.



TOP, CLOCKWISE FROM LEFT: KIM TAYLOR/NATUREPL.COM, BORKUR SIGURBJORNSSON; ROBERT S. DONOVAN/FLICKR; RUDOLF_SCHUBA/FLICKR; BOTTOM: E. MUNCH *ET AL./SCIENCE* 2008

Bringing down the house

By studying another life-form, scientists have found that nature succeeds where the fourth little pig failed: It can make a glass house that's immune to stones.

The amount of effort it took to break a deep-sea sponge surprised Joanna Aizenberg of Harvard University when she first tried to crush it. The species, *Euplectella aspergillum*, is made entirely of glass. She found one in a curiosity shop in San Francisco and brought it back to her lab.

"I jumped on it," she admits. Though it's made from the same stuff as windows, its primary structure held up under Aizenberg's feet.

"You could hear the shattered glass," she says. "You break some of the fibers and some of the connections, but the integrity is preserved."

Aizenberg deconstructed the sponge's structure using visible light and scanning electron microscopy, reporting the details in a paper in *Science* in 2005. She found that, as with the mollusk shells, levels of complexity contribute to the sponge's strength (*SN: 3/25/06, p. 184*).

Each glass fiber consists of concentric layers of silica and protein, which help stop cracks from spreading — even if one layer succumbs to stress, its neighbors can back it up. But the way the fibers are arranged also contributes to the sponge's resilience. The glass fibers form a cylindrical lattice of square windows crossed by diagonal bars, a common feature in architecture that keeps windows from tilting sideways. And the whole structure has spiral ridges running from top to bottom to prevent it from collapsing like an empty soda can when squeezed.

"It's pretty much the most stable and mechanically strong glass structure that exists," Aizenberg says.

Nature's architect Hierarchy offers strength. Buildings including (right, from top) the Hotel De Las Artes in Barcelona, the Eiffel Tower and the Swiss Tower in London share structural properties with the glass sea sponge (left).

Since describing the sponge in *Science*, Aizenberg has started designing models of the sponge architecture that lack certain structural features — the spiral ridges, say, or the diagonal bars — and building them out of polymers with a 3-D printer. She has been subjecting the models to a battery of tests, bending, stretching and squeezing to see what they can take. "This is where fracture appears," she says.

Materials scientists like Aizenberg, Fineberg and Buehler hope such efforts will lead scientists away from traditional materials and toward ones that perform better. A more fundamental, and accurate, theory of material failure may be built up from clues gleaned as scientists break things down.

"Understanding failure," says Buehler, "is the key to success." ■

Explore more

- Download lecture notes from a course on fracture mechanics taught by Alan Zehnder at Cornell University: ecommons.library.cornell.edu/handle/1813/3075

starting anew

Scientists turn to lowly creatures to unlock the secrets of regeneration

By Susan Gaidos

It could have been a scene from a sequel to *Jurassic Park*: Peering down at the tiny worms wriggling under the lens of her microscope, biologist Alexandra Bely witnessed a performance that hadn't been played in nature in millions of years. The beastie was sprouting a second head.

Actually, two-headed worms are common in Bely's lab at the University of Maryland in College Park. But this specimen belongs to a species that had long ago lost the unusual regenerative ability.

That species, *Paranais litoralis*, is part of an ancient family of worms called naidids that settle in the soft sediments alongside streams and ponds. Generally, if a sudden rush of water or a hungry predator causes a naidid to lose its head, it will simply grow another one. But some species that Bely and colleagues have studied, including *Pa. litoralis*, seem to have lost this power. So it surprised Bely to see that, with the right timing, the creature could regain its head-popping potential.

"That's very exciting, because it indicates that the ability to regenerate is still there, in a dormant state," Bely says, "though it probably hasn't been expressed or seen in millions of years."

Bely's finding and other recent results have encouraged researchers who are trying to figure out why some animals can reconstruct their body parts while others can't. Most species have the ability to regenerate some body parts, yet this talent is highly variable. Humans, for instance, can renew skin and bone, but salamanders can re-create entire limbs or tails, or just about any other structure that can be lopped off without killing them. And the real superstars are animals such as sea stars, flatworms and sponges: They can regenerate every part of their body, even from a tiny fragment.

Given the obvious medical appeal of regrowing lost or injured body tissues, scientists have long focused on the molecular signals that drive regeneration — endowing some animals with extensive powers while countless others have limited or no regenerative abilities at all. In recent years, scientists have begun to explore the regenerative process in diverse creatures to better understand how that power evolved in the first place and why not everything has it.

The findings have raised a nagging question: Are the regenerative powers that lead to a new head in a worm, restore the leg of a salamander and heal the skin of a human one and the same? Some scientists maintain that regeneration is ancient and originated long ago, while others say it has evolved, again and again, in different organisms.

Bely says figuring out whether regenerative abilities in all animals had the same evolutionary origins is the "elephant in the room" for regeneration biology. "Whether or not regenerative processes are homologous across the animal kingdom profoundly affects how we interpret what we learn about regeneration in different animal groups."

In the past, researchers have sought a single explanation for the wide variation in regenerative abilities. Since animals across the board have some renewing potential, some scientists have suggested that complex creatures tended to lose the regenerative ability as evolution proceeded, while simpler animals retained it. Recent studies on the genes and signaling pathways involved in regeneration show that its presence or absence is driven by multiple factors, as Bely and colleague Kevin Nyberg describe in a paper to appear in *Trends in Ecology & Evolution*.

To determine whether all regeneration has the same roots, scientists must identify its molecular basis in different groups of organisms. Bely and other researchers discussed the evolutionary aspects of regeneration — as well as ecological and physiological factors that play into it — in January in Seattle at the Society for Integrative and Comparative Biology meeting.

"If you look at the Metazoan tree of life and look at all the phyla that have been described so far, you will find organisms that can do some remarkable regenerative feats," says Alejandro Sánchez Alvarado, a neurobiologist at the University of Utah in Salt Lake City who spoke at a panel session at the meeting. "That to me supports the possibility that regeneration is not something that every animal invents for their own purposes, but that it may actually be an attribute of our predecessors, our ancestors a long, long time ago in evolution."

PREMAPHOTOS/NATURE PICTURE LIBRARY

This Madagascar gecko (*Phelsuma quadriocellata*) regenerates a lopped-off tail — skin, cartilage, nerves, muscles and all.

Early arms race

Signs of animals' regenerative abilities are scattered throughout the fossil record. Geologist Forest Gahn of Brigham Young University–Idaho in Rexburg studies crinoids — marine animals related to modern sea stars and sea urchins — and says the first fossils of these animals, dating back 490 million years, reveal evidence of limb regrowth.

Crinoids are flower-shaped animals that grow on stalks rooted to the ocean floor. Like their sea star cousins, crinoids have five or more arms and a skeleton constructed of calcified plates elaborately slotted together. Some of the plate connections are designed for shedding, so an animal grabbed by a predator can simply bid an arm good-bye.

In looking over the fossil record, Gahn and colleague Tomasz Baumiller of the University of Michigan in Ann Arbor linked shedding and regrowth to increased evolutionary pressure to withstand predator attacks. Because modern-day crinoids usually lose and regenerate their arms as a result of attacks by fish and other marine animals, the scientists reasoned that arm regeneration in fossil crinoids might be an indicator of past predator-prey interactions.

Gahn and Baumiller examined more than 2,500 crinoid fossils for evidence of arm regeneration, focusing on specimens dating back 290 million to 490 million years. The scientists reported in 2004 that a threefold increase in the relative number of fossils showing arm regeneration occurred about 380 million years ago, a time when the number of shell-crushing predators increased explosively.

Most species have the potential to regenerate some body parts, yet this talent is highly variable.

Not all of the crinoid species from that period showed a dramatic increase in regeneration. Those species that did were the tallest, and among the tallest, the bigger-than-average individuals showed the highest regeneration frequencies. Gahn says these findings are consistent with something called the "plant apparency theory," which states that the most readily seen plants are those that are most likely to be attacked by predators. Those plant species are also the most likely to develop broader defenses against predators.

Apparency theory seems to hold true for this fossil community, Gahn says. The prevalence of shell-crushers coincides with the appearance of other defenses, too, such as thicker plates and changes in arm branching to minimize arm loss.

Still, finding evidence of changes in both predators and prey does not prove that one caused the other, Gahn notes. The scientists are now doing experiments to see if regeneration is selectively advantageous in living crinoids. In January, he and Baumiller traveled to Micronesia to study predator-prey interactions in reef crinoids to better assess how the type and frequency of tissue loss might help mold predator-driven regeneration.

Making headway

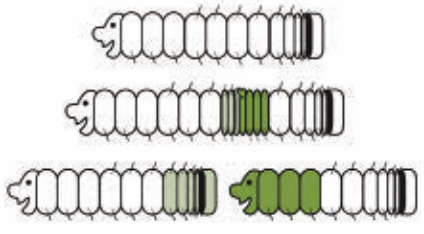
Regeneration is a form of reproduction for some invertebrates. Sea stars, brittle stars and hydra, for example, reproduce asexually by essentially splitting in two. Some worms, such as the naidids, use a variation on their regenerative technique to make a second version of themselves as well.

Naidids are part of the annelid family that includes ordinary roundworms, leeches and earthworms. Most naidids reproduce by budding, a process in which

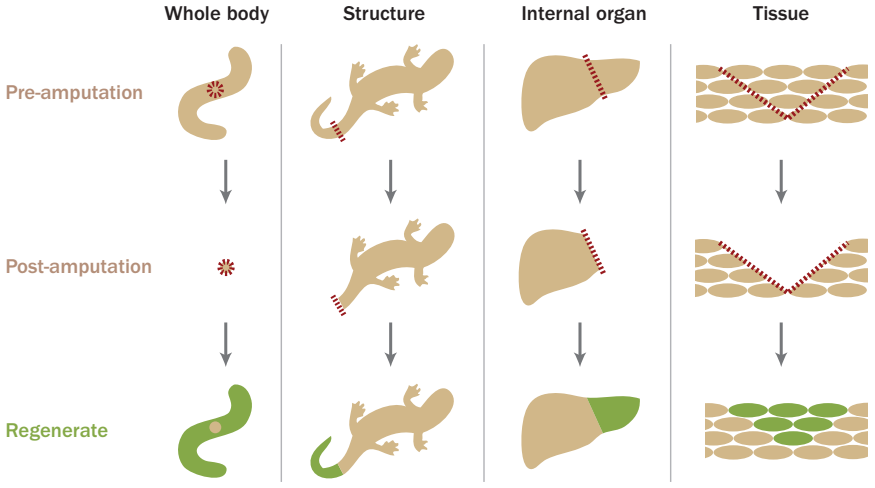
a new individual starts as a growth on the parent's body and eventually splits off. But some naidid species employ a more elaborate process called fission. To reproduce, a worm in one of these species forms a zone of self-proliferation in the middle of its body. From that zone, the worm forms a new head to go with its back end and a new tail to go with its front. Attached head-to-tail–head-to-tail, the worm eventually tears itself in two.

Among the fission reproducers, Bely discovered a few oddballs: These worms, of which *Pa. litoralis* is one, reproduce and replace lost tails but cannot restore a lost or damaged head. But under certain circumstances, Bely and colleagues report online December 4 in the *Proceedings of the National Academy of Sciences*, head-regenerating abilities can be recovered in the species.

The researchers discovered that if the sprouting head was lost at an early stage during the fission reproduction process, there's a way the animal could grow a new one. In a series of experiments, the scientists showed that if they chopped the tissue of a new head off as it was growing — before the animal split in two — the worm's ability to regenerate the head could be recovered.



***Paranais litoralis* reproduces by growing a second head and second tail in its zone of self-proliferation (green in both) and then splitting. If the new head is sliced off early on, the worm can regrow it.**



Many degrees of renewal Regeneration comes in many forms, from full body regrowth to organ and tissue replenishment. Because of the apparent similarities in each process, some scientists suggest that regeneration has one root. Others argue that it evolved many times.

"It's probably not ever being expressed in nature," Bely says, "and yet we, by very specific cuts, can elicit regeneration."

This pattern — where younger tissue is able to support regeneration much more effectively than older tissue — is also seen in humans. Young children, for example, have reportedly been able to regenerate severed fingertips. And pediatric surgeons can attest to the magical powers of regeneration that occur after fetal surgery in early pregnancy, where the baby is later born perfectly healed without scars.

Bely says such feats suggest that humans have the appropriate machinery to heal wounds without scars, perhaps even to regrow tissues or limbs. But in humans, this ability lies dormant, inactivated because evolution favored the swift patching of wounds through scarring over the slow regeneration of complete body parts.

Bely and her group are now studying *Pa. litoralis* to see how these dormant abilities are activated. Such studies may point researchers toward previously unstudied genes or processes that, if found in humans, could be modified to increase regeneration abilities, she says.

Common machinery

As the superstars of regeneration, flatworms known as planarians may also hold a treasure trove of clues. Cut off a planarian's head and the worm regrows a head. Cut off the tail and it regrows a tail. Chop a planarian into 279 bits, and it will grow 279 entire new worms.

Over the past decade or so, University of Utah's Sánchez Alvarado and his colleagues have cloned and tested thousands of planarian genes to see what roles they play in regeneration. The findings show that the vast majority of genes used to regenerate are shared by many forms of life, including plants, nematodes and humans. In addition, the genes are preserved, remaining essentially unchanged over eons.

"Many people have postulated that maybe the difference is that there are some genes that got 'lost.' And that by losing these genes, animals were incapable of mounting a regenerative response after injury or amputation," Sánchez Alvarado says. "But we're finding out that that's just likely not to be true." Instead, he says, the genes may be there but deployed in slightly different ways.

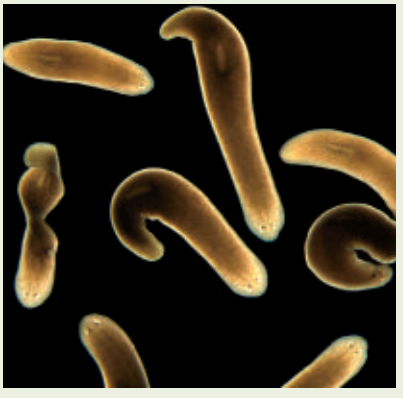
His group uses a process called RNA interference to turn off genes one by one. Through this process, the team showed how a signaling pathway — a series of molecular events within a cell — that orchestrates embryonic development also plays a role in regeneration. In this case, the pathway tells the worm whether to make a head or tail, based on the wound's location.

When Sánchez Alvarado turned up the

FROM TOP: T. DUBÉ, ADAPTED FROM A. BELY/*TREE* 2009; A. BELY/*PNAS* 2009

Clues from diverse critters

Simpler creatures tend to be better regenerators—growing anew from tiny pieces of their former selves. Other, more complex beings show lesser abilities but can still grow new tissue to heal wounds. By studying diverse creatures, scientists hope to find out how regeneration evolved and, one day, harness the power for medicine.



Planarian worms
Planarians can regrow themselves from just a small tissue fragment. A team recently found 240 genes involved in regeneration.

Crinoids
Fossils reveal that the arm-sprouting ability of crinoids, also called sea lilies, dates back at least 490 million years.

Jellyfishes
Jellyfishes can recover limbs and eyes. One known species can revert all of its cells to a young state and regrow entirely.

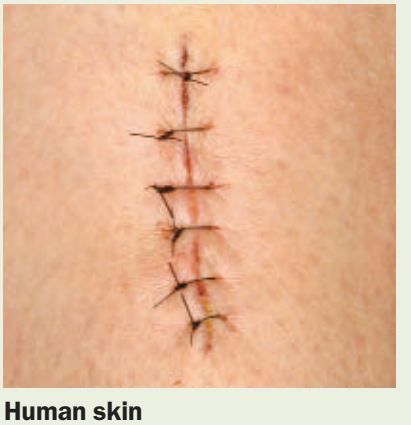
Green walkingsticks
If grabbed by a predator, the leg of a stick insect falls off, making for an easy escape. Legs are often lost during molting, too.

Fiddler crabs
Male fiddler crabs have one big claw, which they wave to attract females. One study found that 7 percent have a regrown claw.

Salamanders
Salamander tails begin regrowing immediately after amputation. Larvae are favorites for regeneration studies.

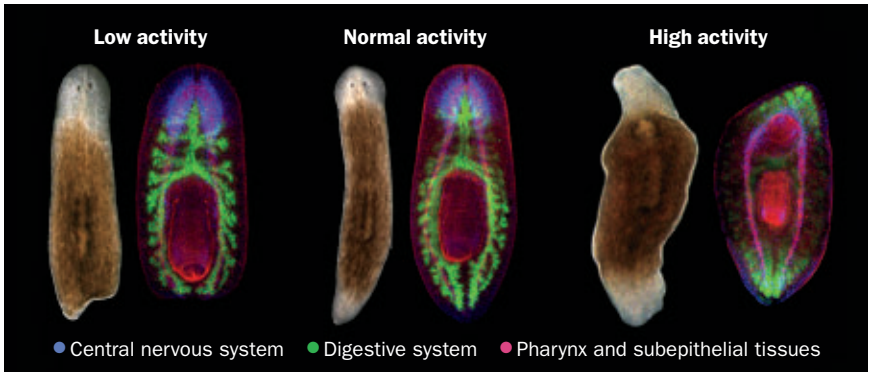
Birds
Birds can regenerate hair cells in their inner ears, though evidence of avian regenerative abilities is limited.

Human liver
The liver is the only internal human organ known to naturally regenerate. It can regrow from just 25 percent of its tissue.



Human skin
Wound healing is often a mix of regeneration—in which tissue is replaced—and repair—in which connective tissue forms.

PLANARIANS: A. SÁNCHEZ ALVARADO; CRINOID: COURTESY F.J. GAHN; JELLYFISH: BARCROFT/FAME; WALKINGSTICK: RKHALIL/ISTOCKPHOTO; FIDDLER CRAB: DARENGROVER/ISTOCKPHOTO; SALAMANDER: JOSEPH T. COLLINS/PHOTO RESEARCHERS, INC.; BIRD: TONY MORRIS/WIKIMEDIA; HUMAN LIVER: ERAXION/ISTOCKPHOTO; HUMAN SKIN: SPXCHROME/ISTOCKPHOTO



A team found that tweaking the activity in the hedgehog signaling pathway in a planarian could lead to incomplete tail development (left) or a tail at each end (right).

activity in the signaling pathway — called Wnt — the worms created tails in place of heads. When turned down, the worms created heads instead of tails.

In December, his group published further findings in *Science* that show how another ancient — an evolutionarily preserved — molecular signaling pathway, called hedgehog, serves as a master switch to regulate the Wnt pathway during regeneration. Sánchez Alvarado says these old signaling pathways are used to lay down the body plan of an embryo as it develops. However, his findings came as a surprise because the two pathways operate differently early in development.

In embryogenesis, the Wnt and hedgehog pathways work as a team, establishing a mutually dependent feedback loop that determines the embryo's body plan. Sánchez Alvarado says the new findings establish a hierarchy of signaling events leading to one aspect of regeneration — in this case, deciding whether to make an anterior or posterior end.

"That already smells of some unique regulation in these two pathways to allow for regeneration to take place," he says.

It remains to be seen whether these pathways are used in regeneration by other species such as zebra fish or salamanders, Sánchez Alvarado says. He and his team are now working to identify other signaling processes used in embryogenesis, and possibly regeneration.

"The question is, do you reuse these tools, which is very likely," he says. "And if you reuse them for regeneration, how do you do it?"

Though regeneration and embryogenesis rely on many of the same molecular pathways, the processes are not the same at all, he says. In regenerating a limb, for example, the body must go back "in time" to re-create an organ in the absence of all the other events that took place at the time of early development. He says the local cues that tell damaged tissue how to behave appropriately and how to integrate into the surrounding tissue need to be identified.

Playing to a different tune

Though most of the molecular machinery that's used in regeneration has been shown to be common to all multicelled animals, some machinery differs. So some scientists maintain that regeneration is not an ancient process that originated long ago, but exists because it has evolved, again and again, in different organisms.

Jeremy Brockes of University College London says that, like an orchestra playing different tunes, the key instruments are the same but they are being directed in different ways. His decade-long studies of salamanders have convinced him that extraordinary regenerative abilities have evolved independently in different animal groups.

He became convinced of this through his studies of the salamander protein Prod 1, which serves as a road map for cell regrowth in salamanders and newts (*SN: 11/3/07, p. 276*).

While most of the proteins and genes involved in regeneration that show up in other animals also have mammalian counterparts, Prod 1 is a protein found only in salamanders. What's more, it's a kind of protein — called a three-finger protein — that is involved in other "striking examples of local evolution," Brockes says. For example, in snakes, a different three-finger protein played a role in the evolution of the venom apparatus.

Though such evolutionary events are relatively common, Brockes says it's not the way most researchers think about regeneration.

"We have thought about regeneration as being a kind of unitary mechanism, and the question often is, 'Why have we lost the ability to regenerate?'" he says. "But that doesn't take into account these types of local evolutionary events.... After all, you only need one conductor to do something quite different with an orchestra."

Brockes says it's important how such issues are viewed, particularly in areas such as regenerative medicine.

"What we should be asking is, did we actually 'lose' the ability, or did the salamander bring significant evolutionary novelty to the problem of developing a regenerative response?" Brockes says.

He and his colleagues are now looking for other proteins used in regeneration and working to understand how proteins such as Prod 1 work to orchestrate a regenerative response.

What is needed next are studies to test how universal the mechanisms used by various regenerators are. Only then will scientists know whether humans and other nonregenerators have lost a trick learned and mastered by watery ancestors countless millions of years ago.

"It's a long process, but it's one that I think is really beginning to be chipped away effectively," Sánchez Alvarado says. "It really will be just a matter of time." ■

Susan Gaidos is a freelance writer based in Maine.

Explore more

■ A.E. Bely and K.G. Nyberg. "Evolution of animal regeneration: Re-emergence of a field." *Trends in Ecology & Evolution*. In press.

J. RINK, K. GURLEY, S.A. ELLIOT, A. SÁNCHEZ ALVARADO

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Snack addicts

The experiment outlined in "Junk food turns rats into addicts" (*SN: 11/21/09, p. 8*) seems to have overlooked an ingredient list. The junk foods fed to the rats were junky, to be sure, but which foods were the most addictive? Many junk foods are filled with alarming amounts of things like monosodium glutamate. Were the rats more responsive to the MSG-laden foods? Did they crave salt over sugar? Fat over starch? This article left me hungry for specifics.

Drew Massey, Los Angeles, Calif.

In the study, researchers fed the rats a mishmash of junky foods (think bacon-wrapped cheesecake covered with frosting), so any ingredient's individual effects were hidden. The researchers noticed that rats seemed to like foods laden with both fat and sugar most, making these ingredients the "likely culprits," says Paul Kenny, a coauthor of the study. "It seems like sweetened fat is the way to go." But to really nail down which ingredients may be the most addictive, scientists need to separately test each of the ingredients. —Laura Sanders

Memories of McClintock

Tina Hesman Saey's article "Corn genome a maze of unusual diversity" (*SN: 12/19/09, p. 9*) reports that "The [maize] genome project discovered some new families of transposons, revealing a total of 1,300 such families in maize." When I read those words, I couldn't help but sense the specter of Barbara McClintock floating between the lines of the story and behind the work of the multi-institution genome project. It was McClintock, working alone in an isolated laboratory at Cold Spring Harbor and using the techniques of classical genetics on maize, who obtained the first data that pointed to the existence of mobile genetic elements. What a far cry the $30-million-dollar maize genome project is from the skepticism that greeted McClintock's data and conclusions.

I think a case can be made that truly groundbreaking insights are achieved by creative individuals working alone with a fraction of the money lavished on "Big Science" consortia. And these insights are frequently serendipitous — unexpected findings that arise while a different question is being asked. Think of siRNA, telomeres, hypermethylation of promoter regions. And perhaps the most telling example of all — the discovery of restriction endonucleases, which enabled the whole field of synthetic molecular biology and biotechnology.

William Check, Wilmette, Ill.

Electrobio feedback

In the interview with Ken Nealson by managing editor Eva Emerson ("From fringe to electromicrobiological mainstream," *SN: 12/5/09, p. 32*), I fear that some misinformation may well have been conveyed.

Professor Nealson said of his finding, "it simply wasn't in the textbooks 20 years ago and still is not there in most textbooks." Namely, he was referring to the fact that bacteria could reduce solid substrates, "... the bugs would just settle down and respire the rock," and he intimated that this was unheard of at that time. I call attention to two books published more than 50 years ago: *Biochemistry of Autotrophic Bacteria* by H. Lees (Butterworths Scientific Publications, 1955) and *An Introduction to Bacterial Physiology* by E.L. Oginsky and W.W. Umbreit (W.H. Freeman & Co., 1954). These provide summaries of research since the early 1920s on the autotrophic sulfur-oxidizing bacterium *Thiobacillus thiooxidans* and other bacteria that oxidize and reduce sulfur and iron. Bacteria have been known to derive their energy from oxidizing these substances and using the energy derived to fix CO_2 into carbon compounds used by the cells.

Thus, electron transfer by bacterial metabolic activity to insoluble compounds, leading to their degradation, has been known for more than the 25 years since Nealson's findings.

T. thiooxidans was isolated and characterized in 1921. When I was a graduate student with Umbreit, we, along with Pauline Holbert, demonstrated, using electron photomicrography, the firm attachment to, and degradation of, sulfur crystals by a pure culture of *T. thiooxidans* (W.I. Schaeffer, P.E. Holbert and W.W. Umbreit. *The Journal of Bacteriology,* January 1963). This letter in no way is meant to denigrate the findings and subsequent research by Nealson, only to point out that the paradigm is far older than this interview would lead one to believe.

Warren I. Schaeffer, Edison, N.J. Schaeffer is an emeritus professor of microbiology and molecular genetics at the University of Vermont in Burlington.

Ken Nealson responds: I am afraid Dr. Schaeffer caught me in my own myopic world of solid metal oxide reduction. I was specifically referring to the extracellular electron transfer of cellular reducing power (electrons) to solid metal oxides, such as iron or manganese oxides, and the conceptual difficulty that was imagined with truly insoluble substrates as electron acceptors. Dr. Schaeffer is quite correct to point out that the other side of the electron flow issue — namely extracting electrons from a solid substrate — has been seen since it was first realized that elemental sulfur could serve as a source of electrons for both photosynthetic and chemolithotrophic microbes. But with regard to reductive interaction with solids, what I said was correct, though incomplete in the broader context. The issue raised, however, is a very important one, as it is conceivable that microbes may exist that could do both, and could operate in the subsurface using minerals of different redox potentials both as a source of electrons and as the ultimate electron acceptors. That would be really something.

Send communications to: Editor, Science News, 1719 N Street, NW, Washington, D.C. 20036 or **editors@sciencenews.org**. Letters subject to editing.

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"Teddy Roosevelt Silver Dollars" Unearthed at Old Texas Ranch

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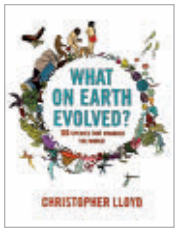
What On Earth Evolved? 100 Species That Changed the World

Christopher Lloyd

Throughout Earth's past, innumerable species have come and gone without making much of a mark, but a select few have lived long and prospered indeed. In this eloquent and richly illustrated volume, Lloyd, who also authored the planetary history *What on Earth Happened?*, compiles a veritable who's who of organisms that he contends are the 100 most important species or groups in the planet's history. (Hint: Humans are high on the list, but they don't top it.)



Half of those in the tally evolved before humans became a major influence on species' fates about 12,000 years ago. Members of the second, more recent group owe much of their success to the ability to accommodate or satisfy human needs. Lloyd uses five criteria to rank organisms' influence on the planet's history: their longevity as a species, the size of their range, their evolutionary impact, their environmental impact and their impact on human history. Species or groups included in this esteemed list range from algae and cyanobacteria that have been oxygenating Earth's atmosphere for billions of years to a relatively recent upstart, *Homo sapiens*.

From tales of trilobites and *T. rex* to cotton, cannabis and coffee, thought-provoking biographies of these 100 shapers of Earth's history take readers on an engrossing journey from the beginning of life to the present day. The book chronicles the sometimes complicated interrelations between and among those organisms. Though some may quibble with his rankings or criteria, Lloyd's aim, as he notes, is not only to inform and entertain his readers but also to stimulate debate about the place of humankind in nature. —*Sid Perkins*

Bloomsbury USA, 2009, 416 p., $45.

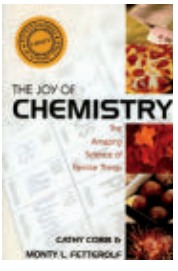
The Joy of Chemistry: The Amazing Science of Familiar Things

Cathy Cobb and Monty L. Fetterolf

Citing *The Joy of Sex* and *The Joy of Cooking* as texts that demystified important — yet sometimes perplexing — terrain, Cobb and Fetterolf aim to do the same for chemistry. Their book succeeds in doing just that.

The authors, both chemists, begin with an elaborate safety dictum followed by a shopping list calling for items such as sugar, galvanized nails and superglue. These come into play through simple experiments accompanying each chapter, which highlight chemical characters and reactions. And what characters they are: Water "can be a home wrecker," and nitrogen "has several personalities," including both nurturing and destructive ones, Cobb and Fetterolf write. The first half of the book brings to life chemistry's fundamental principles and players, and the second half examines specialized chemistry. The challenges and thrills of organic, analytical and biological chemistry are revealed, along with a glimpse of what questions might confront future researchers.

Each chapter is prefaced with chemistry quotes from popular literature, such as D.H. Lawrence's turn of phrase, "Tragedy is like strong acid — it dissolves away all but the very gold of truth." The authors suggest that these references hark back to a time when readers were more familiar with basic chemistry than they are today.



This book is a wonderful effort to bring back that familiarity. It's ideal for a student struggling with redox reactions or for those who just want to better understand "the central science" of the world around them — even the chemistry in kitchens and bedrooms. —*Rachel Ehrenberg*

Prometheus Books, 2010, 393 p., $19.

Streetlights and Shadows: Searching for the Keys to Adaptive Decision Making

Gary Klein

Good decision makers share traits such as being accepting of ambiguity and complexity, one scientist argues. *MIT Press, 2009, 337 p., $27.95.*

On Thin Ice: The Changing World of the Polar Bear

Richard Ellis

The natural history of polar bears entwines with human history in this science writer's ode to the world's largest land carnivore. *Alfred A. Knopf, 2009, 400 p., $28.95.*

So You Want to Be a Scientist?

Philip A. Schwartzkroin

A neuroscientist describes the pros, cons and politics of a career in research for aspiring scientists. *Oxford University Press, 2009, 192 p., $19.95.*

Dinosaur Odyssey: Fossil Threads in the Web of Life

Scott D. Sampson

The past three decades have seen a plethora of major discoveries, described here, about dinosaurs and prehistoric Earth. *University of California Press, 2009, 332 p., $29.95.*

Gifts from the Ancestors: Ancient Ivories of Bering Strait

William W. Fitzhugh, Julie Hollowell and Aron L. Crowell, eds.

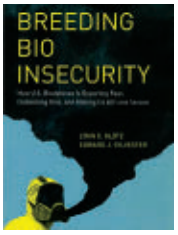
The histories of Arctic cultures are explored through scholarly essays, illustrations and photos of the region's intricately carved relics. *Yale University Press, 2009, 328 p., $55.*

Breeding Bio Insecurity: How U.S. Biodefense Is Exporting Fear, Globalizing Risk, and Making Us All Less Secure

Lynn C. Klotz and Edward J. Sylvester

American efforts to counter potential biological warfare threats are creating a 21st century Trojan horse.

Klotz and Sylvester make this point early and often in their latest book.



They argue that the boom in biosecurity research in the wake of 9/11 has meant an exponential increase in the number of scientists, technicians and other lab workers with access to dangerous biomaterials such as Ebola virus. This trend alone increases the risk of accident or theft. And the secrecy shrouding much of the research promotes suspicion that could spur an international biological arms race, the authors argue.

The authors, a biotechnology expert and a science journalist, support their positions with detailed descriptions of potential bioweapons such as anthrax or botulism and what it would take to weaponize them. In the authors' view, the challenges of engineering a virulent and stable organism make it unlikely that a terrorist group (read: Al Qaeda) could develop and deploy a biological weapon. The billions of dollars earmarked for biosecurity research would be better spent countering existing public health threats, they say, such as flu or drug-resistant staph infections.

The book is polemic and at times takes on a strident tone. Still, it provides an intriguing overview of biological warfare defense research, past and present. This unequivocal condemnation of U.S. biosecurity efforts merits consideration, particularly by those who would disagree. —*Rachel Zelkowitz*

University of Chicago Press, 2009, 272 p., $27.50.

Before the Big Bang: The Prehistory of Our Universe

Brian Clegg

A scientist-writer explains theories of the universe's origin for the nonscientist. *St. Martin's Press, 2009, 306 p., $25.99.*

The Humans Who Went Extinct: Why Neanderthals Died Out and We Survived

Clive Finlayson

An evolutionary ecologist argues that humans weren't superior to other hominid species, only luckier. *Oxford University Press, 2009, 273 p., $29.95.*

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Making informed decisions about mammograms

In November, the U.S. Preventive Services Task Force, a nongovernmental advisory panel of health experts, recommended that routine mammography for breast cancer screening start at age 50, not 40. It met with a chorus of objections. Lisa Schwartz, a general internist at the Dartmouth Institute for Health Policy and Clinical Practice in Lebanon, N.H., investigates such public health issues. She spoke recently with Science News *biomedical writer Nathan Seppa.*

Were you surprised at the outcry that arose from this recommendation?

Yes and no. This happened in 1997 when a National Institutes of Health consensus panel recommended that women in their 40s decide for themselves about mammography: an intensely negative public and political reaction. But I also hoped that with the growing acknowledgment of the harms of mammography — in medical journals, in the news and by the head of the American Cancer Society — that there might have been a different reaction.

Mammograms do catch cancers. But the task force found high rates of false-positive mammograms and treatment for "overdiagnosed" cancer, questioning the benefits of routine mammography for 40-somethings. Your thoughts?

Women need to be clear about their chance of developing breast cancer, how much mammography reduces that chance and what are its associated harms. Imagine 10,000 women age 40. Over the next 10 years, without mammogram screening, about 35 will die of breast cancer. With screening, 30 will die — five fewer. But of 10,000 getting screened, 600 to 2,000 will have at least one false positive leading to a biopsy, and 10 to 50 will be overdiagnosed. They will be told they have cancer, and they will undergo surgery, chemotherapy or radiation, which can only hurt them since their cancer was never destined to cause symptoms or death.

Overdiagnosis is the most important harm of screening. People sometimes find it hard to believe that overdiagnosis is possible. These cancers look the same under the microscope but don't behave like cancer. Because we can't tell which cancers constitute an overdiagnosis, everybody who has cancer is treated.

So it's a trade-off for women in their 40s?

Mammography is a trade-off for women of all ages, but for a long time mammography was not thought of in this way. Women got very strong, one-sided messages from doctors and advocacy groups, in essence telling them they were crazy if they didn't get screened. Of course, this message isn't true. Once informed about the chance of breast cancer and the benefits and harms of mammography, women can weigh the pros and cons. There is nothing crazy about encouraging women to make informed decisions based on their own values. But the only way this can happen is if women have the information they need.

There is nothing crazy about encouraging women to make informed decisions based on their own values.

How should doctors advise patients?

Doctors should help women realize that the issue is not whether mammography does or does not work. It's about their values, how they weigh the benefits and harms. For so long, doctors have approached screening as something they have to convince women to do, even if this meant scaring people about their risk, exaggerating benefit and ignoring harms. The question is whether we are willing to be honest about both.

The panel took no position on insurance. But is money at issue?

The task force did not consider costs. It considered only the best available data. It would be better to focus on how much mammography helps and hurts first, without considering money, since bringing cost into the discussion distracts people. If you assume mammography works really well or has no downsides it is easy to assume that the debate is really about costs and rationing. But it isn't. It's about weighing benefits and harms. If a woman then decides she wants mammography, I do think insurance should cover it.

Does this outcry reflect a distrust of science?

It's hard to know. Screening for breast cancer has been much more contentious than screening for other cancers. For example, when the same task force recommended against older men getting a PSA screening test for prostate cancer, there was little public reaction. Perhaps the difference is that prostate cancer affects older men or that many physicians, including urologists, have already adopted this practice. But the most important lesson is that people need better information. Too often the public get slogans about screening rather than good information. Slogans generate strong emotions that interfere with good decision making. By routinely hearing numbers about the benefits and harms of medical tests and treatments, people will be able to appreciate the science behind recommendations. It's not about emotions. It's about knowing what you get, and the trade-offs. ■

ALEXANDRA HOWELL

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