Plants Acting Out | Science of Science Education | Cells Learn to Count

ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ JUNE 20, 2009

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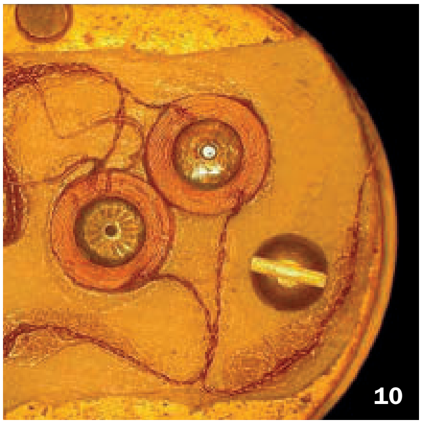

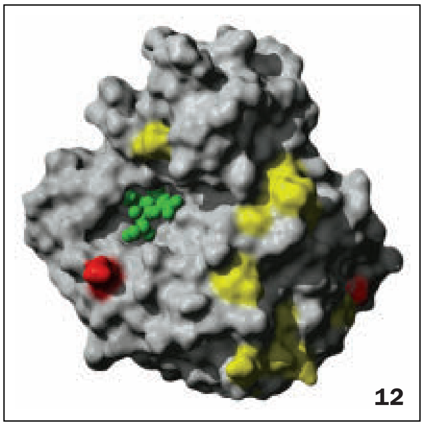

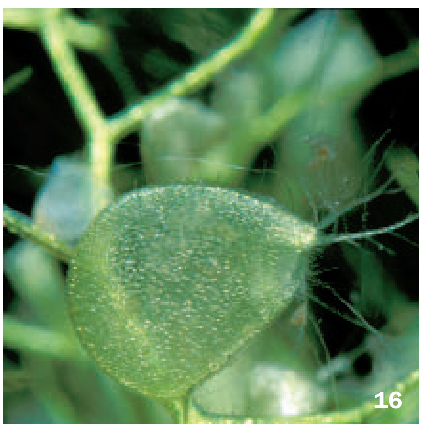

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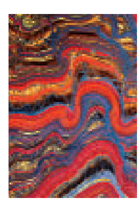

COVER Banded iron formations hold clues to the planet's environmental past. A close-up of one formation from Australia is shown here. *Photo: © Frans Lanting/Corbis*

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FROM THE EDITOR

Learning about process aids science appreciation

Thinking like a scientist is not necessarily always a good idea.

When time is short, you might need to make a snap judgment based on gut instincts. Sometimes you miss out on a lot of fun if you analyze the risks systematically. And science never captures every possible consideration, so intuition is on occasion a preferable substitute for extensive experimentation.

Nevertheless, for many aspects of life, such as diagnosing diseases, making public policy or earning money, scientific thinking is pretty darn helpful and often essential. Learning how to do it properly isn't easy, though, as Bruce Bower's report in this issue (Page 20) makes clear.

As one expert notes, great minds spent centuries figuring out how to master the methods of scientific experimenting, so you wouldn't expect grade school kids to be able to figure it all out on their own. But that's sort of what one school of thought suggests doing — letting kids "discover" principles for drawing correct inferences by working on their own experimental projects.

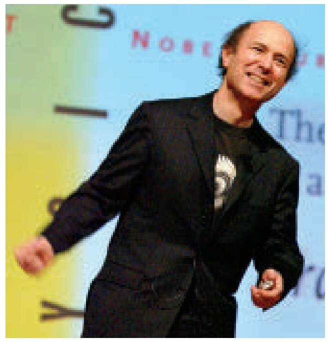
Some amount of direct instruction is needed to complement this "discovery learning" approach, though. And experts disagree about which philosophy — direct or discovery — is best to emphasize. So scientists and educators are trying to resolve that issue by conducting experiments, a kind of recursive illustration of science's power to illuminate science.

More important than the issue of how best to teach scientific reasoning, though, is recognizing its importance to begin with. Traditionally, too much of science education has focused on implanting facts in impressionable brains, rather than on developing brains that can tell fact from fiction. As Bruce notes in his feature, "scientific knowledge is an imperfect attempt by people to determine the truth about the world, not a collection of unassailable facts."

Chinese college freshmen know a lot more about physics than typical U.S. freshmen do, but neither scores very well on tests of scientific reasoning. But it's the reasoning process that gives science its validity — and its vitality. Appreciating science as a process, rather than as simply an accumulation of knowledge, is the best foundation for understanding that knowledge — and for appreciating the discovery of new knowledge that *Science News* presents in each issue.

— Tom Siegfried, Editor in Chief

Scientific Observations



"Many of us are interested in the question of is there life in the universe, and a smaller number are interested in the question of whether there is intelligent life in the universe. The striking observation so far is that there's deafening silence. A civilization that got the jump on us by a few thousand years, in our galaxy, you would have thought could have an advanced technology that would be visible if they made a big activity. There's no sign of it." **NOBEL LAUREATE AND PHYSICIST FRANK WILCZEK, ON APRIL 3 AT THE ORIGINS SYMPOSIUM AT ARIZONA STATE UNIVERSITY IN TEMPE**

Science Past | FROM THE ISSUE OF JUNE 20, 1959

MECHANICAL COW EATS GRASS — A mechanical "cow" has just started work at the British Agricultural Research Council's experimental station at Rothamsted, near London. Its function is to extract protein from leaves or grass or any suitable vegetation.... Grass or other vegetation is fed into the machine from a normal elevator. After being chopped, the grass enters a press and the juice is squeezed out of it. This juice, which contains the bulk of the protein and barely any cellulose, is then treated with steam to precipitate the protein. When the protein is made solid by the precipitation, it requires only a filtering to separate the protein from the unwanted juice. With a few minutes the "cow" has produced solid, cake-like protein from vegetation and, what is more important, has collected at least 50% of the protein in the leaves.... The protein cake then goes to [Scotland] where it is used in experimental feeding of pigs.

Science Future

June 26
Attend or watch the webcast of "Iron Science Teacher" at the Exploratorium in San Francisco. Visit www.exploratorium.edu/iron_science

July 19–26
Plumb the depths of cave science at the 15th International Congress of Speleology in Kerrville, Texas. Find out more at www.ics2009.us

August 10–13
Scientists discuss the largest U.S. waterway at the Visions of a Sustainable Mississippi River conference in Collinsville, Ill. See www.conferences.uiuc.edu/mississippiriver

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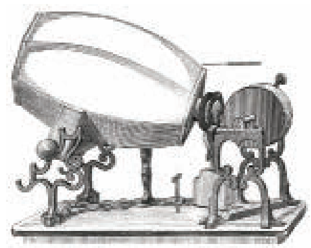
TECHNOLOGY

Historians unveiled the first recordings — imprints made by a phonautograph (illustration below) 20 years before Edison invented the phonograph. Visit "Earliest known sound recordings revealed" for audio and story.

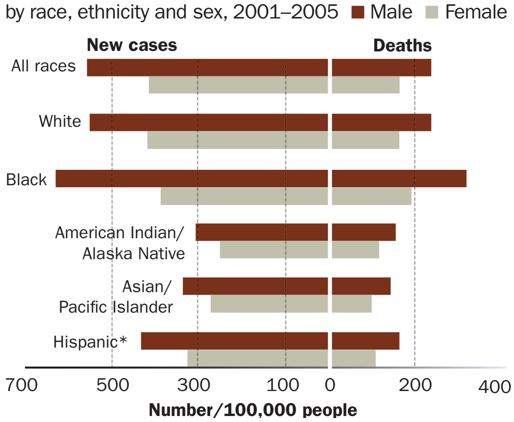


BODY & BRAIN

Despite their hefty size, professional football players have pretty good overall cardiovascular health, a new study finds. The assessment turned up one exception, though: These athletes have higher blood pressure, on average, than nonplayers. Read "NFL heart profile good, with a caveat."

Science Stats | U.S. CANCER RATES

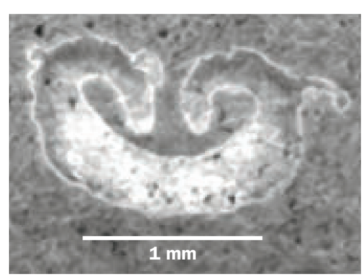
Rates of new cancer cases and deaths in the United States by race, ethnicity and sex, 2001–2005 ■ Male ■ Female



**Hispanic is not mutually exclusive from all other race groups*

SOURCE: CDC

The (-est)



A nodule unearthed from 300-million-year-old rocks in Kansas holds what scientists believe is the oldest fossilized brain, that of an ancient cartilaginous fish (illustration, top) related to modern-day ratfish. Individual slices imaged with X-ray tomography reveal an exceptionally preserved brain (frontal view shown). Microbial action inside the dead fish's skull, as well as anoxic conditions there, may have triggered chemical changes that led to mineralization of the brain and some major nerves, researchers in the United States and France report in the March 31 *Proceedings of the National Academy of Sciences*.

CLOCKWISE FROM TOP LEFT: JUSTIN KNIGHT PHOTOGRAPHY; WWW.FIRSTSOUNDS.ORG; PHILIPPE JANVIER, PRADEL *ET AL.*/*PNAS* 2009; PRADEL *ET AL.*/*PNAS* 2009

“ Arguments advanced by conspiracy theorists tell you more about the believer than about the event. ” — TED GOERTZEL, PAGE 11

In the News

STORY ONE

Cells can count to at least 3 with engineered DNA

Two systems could someday monitor toxins, cell divisions

By Laura Sanders

Graceful waltzers can count to three, and now stretches of man-made DNA can do it too. Researchers have linked a series of genes and put the series into bacterial cells, enabling them to tally events. The new counters may endow engineered cells with previously impossible functions, the team reports in the May 29 issue of *Science*.

The engineered counters may be used to monitor toxins in the environment or keep track of the number of times a cell divides. The systems can even be programmed to destroy their host cells after a certain number of events.

“This is the first example of a synthetic counter in the field,” says Christina Smolke, a bioengineer at Stanford University and author of a commentary published in the same issue of *Science*. Although these new counters are simple, “the first step is building the framework. The next step is, how do we start tailoring these to respond to something relevant? There are a lot of places to take this.”

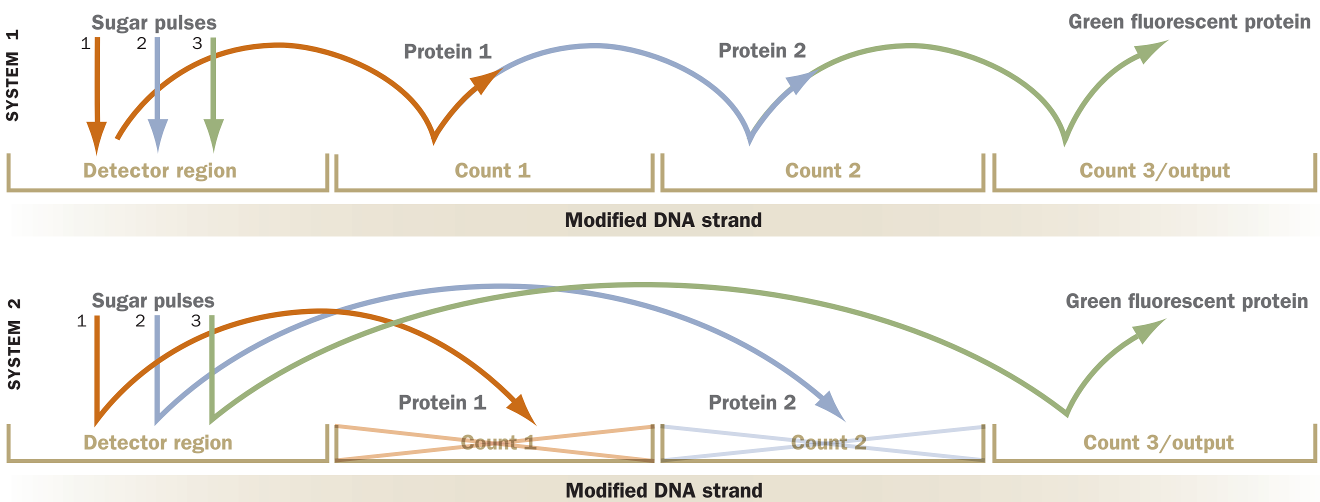
The new research adds a tool to the burgeoning field of synthetic biology, in which scientists engineer biological systems such as DNA to create new capabilities. DNA molecules are designed to direct certain activities in a cell, and so can respond to specific signals and start and terminate protein production. Since the first tools emerged in the late 1970s, scientists have been creating artificial cellular “parts” that could be used to modify a living organism and more recently have built a simple synthetic one from scratch. Assembling the right parts in the right order could, for example, allow engineered bacteria to produce biofuels or digest toxins in polluted environments.

A strong motivator for developing a system that can count, says study coauthor James Collins, was worry over the presence of genetically modified organisms in the environment.

“This came from growing concern that programmed cells could pose a danger to the environment or human bodies. You’d be worried about how long these things were going to stick around,” says Collins, of Boston University. Organ-

DNA that counts

Researchers have designed two systems that enable engineered cells to count. In the first scenario (top), a sugar pulse leads to the production of a protein from the engineered DNA, and each additional sugar pulse acts with the previous protein to produce, through a series of cellular events, a new protein. In the second scenario (bottom), the first two sugar pulses lead to production of an enzyme that makes a portion of the DNA unreadable. In each scenario, the last bit of DNA codes for an output signal.



J. KORENBLAT

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isms endowed with counting abilities could be programmed to commit suicide after a certain number of cell divisions or day-and-night cycles, he says. This built-in kill switch could help control the unwanted introduction of engineered genes into wild organisms.

The new counters rely on the novel assembly of simpler genetic tools. Collins and his team created "multiple numbers of switches cascaded behind one another to create more complex circuits," says Kaustubh Bhalerao, a biological engineer at the University of Illinois at Urbana-Champaign.

Collins and his colleagues built two systems that count in different ways but are both based on the same basic idea. "Each of the counters is what you call daisy chain cascades: You have to do the first event before you do the next event," Collins says. This process endows the systems with the counting ability.

One of the team's systems counts by starting and stopping the production of certain proteins. In the experiments, the first bit of a strip of modified DNA acts as a detector. When it detects a pulse of the sugar arabinose, the DNA indirectly triggers the production of a specific protein. When the DNA detects a second pulse of the sugar, the first protein helps produce a second protein. After a final pulse of the sugar, the second protein helps make green fluorescent protein as an output.

When the cells glow green under ultraviolet light, the researchers know that the cells have counted exactly three pulses of sugar. The team could easily make the counting region of the modified DNA longer, allowing the system to count higher numbers.

The second counting system relies on enzymes that chop out and invert specific pieces of DNA. When the DNA strip detects the first signal, it causes one of these enzymes to be made. The enzyme then chops its own DNA sequence out of the modified strand of DNA, flips it and reinserts it backward, rendering it unreadable and useless. A second signal leads to the production of another enzyme, which chops another bit of DNA farther along on the strand. At the end of the process, an output protein is produced.

The second system can be programmed to respond to different signals at each step of the process. By putting outputs between counts, researchers could track exactly when each step in a series happens.

The first system is better for counting relatively quick events, those that happen every 30 minutes or so. The second system is more useful for counting longer events that unfold over days because the enzymes need more time to do their cutting and flipping.

Tinkering with the detector and the output, and leaving the basic process intact, may make for innumerable functions, Bhalerao says. Scientists can gain inspiration from naturally occurring bacteria that respond to light, arsenic, temperature, nutrients and some metals.

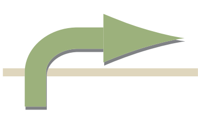
In the new counting system, swapping out the input signal, such as sugar, to be detected is trivial, says Bhalerao. "It's like switching brands of mouse on your computer" but leaving the processor alone.

At the other end of the process, the proteins produced after counting can accomplish a wide variety of functions, Collins says. Proteins could "explode the cell, make the cell long, short, fat." Researchers could even tailor the artificial network to produce different output signals — like fluorescent proteins — at different counts. Cells could glow yellow after the first event, red after the second, green after the third and so on. This would allow researchers to monitor every step of complex processes, such as the development and growth of a cell.

The mix-and-match capabilities offer many possibilities, Bhalerao says, but "there is still a long way to go. These things don't work all the time, and that's because you're making the cells do things they don't want to do." ■

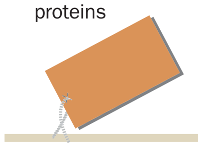
Back Story | PART-BY-PART BIOLOGY

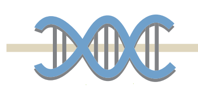
Synthetic biology systems, including the counters recently designed by a team of researchers, rely on the assembly of smaller parts. The Registry of Standard Biological Parts is a repository for such elements, and currently holds more than 3,000 genetic tools that can be mixed and matched to create larger systems. Following are examples of some of the spare parts in the online registry.



Promoters kick off the process of making messenger RNA, which leads to protein production

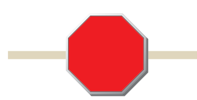
Protein domains code for regions of a protein with specific functions, such as latching on to other proteins

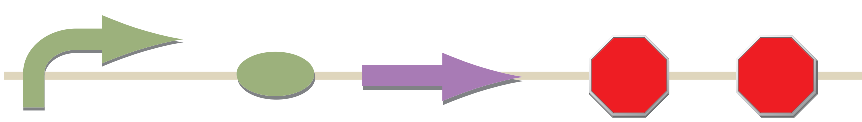




Specific DNA sequences can serve as spacers between two other biological parts or can serve as binding sites for proteins

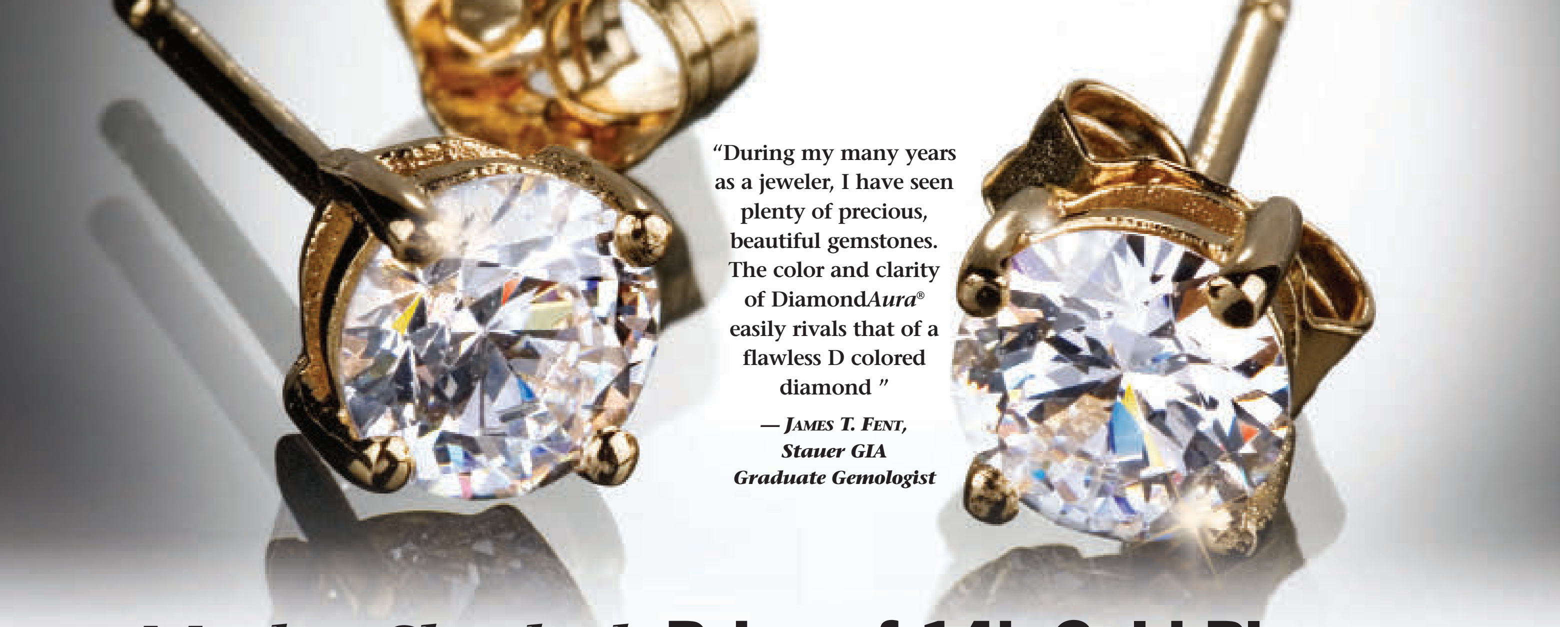
Terminators halt the production of RNA from the DNA strand





Building a system
Assembling these and other kinds of parts, researchers have designed systems that could enable cells to emit a banana smell (shown), sense lead or kill themselves on cue. One potential system could control swimming by regulating the spin of flagella.

ADAPTED FROM PARTSREGISTRY.ORG



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Better singers could have evolved on harsh side of the climate tracks

Bird survey links variable environment and elaborate songs

By Susan Milius

"You've got to suffer if you want to sing the blues" may apply to mockingbirds too.

In the Mimidae family, which includes mockingbirds and thrashers, the species with the more elaborate male courtship songs tend to be those living in the more challenging climates, says Carlos Botero of the National Evolutionary Synthesis Center in Durham, N.C.

Botero describes virtuoso birdsong as precision in repeated elements, abundant variety in tweets and trills, plus dead-on mimicry of other sounds, whether of neighboring bird species or car alarms. Mockingbird species that excel in such performance tend to breed in zones of hard-to-predict and highly variable temperature and precipitation, Botero and his colleagues report online May 21 in *Current Biology*.

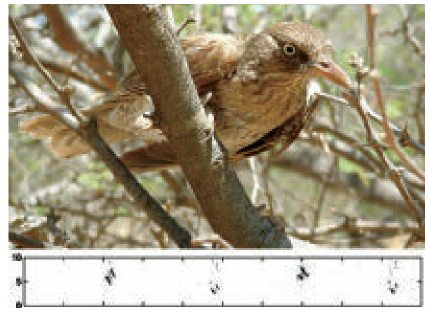
Like other songbirds, mockingbirds and their relatives have to learn the vital singing skills for wooing and warring. If climate has something to do with brain evolution and learning, as some scientists have hypothesized, then bird music may reveal the effects, the team proposes.

This proposed link is important, says Daniel Sol of the Autonomous University of Barcelona in Spain, because it suggests that the evolutionary process called sexual selection, in which mating choices shape species' traits, can also be affected by climatic variability. That influence, he adds, "is key to understand the possible impact of climate change on biodiversity."

"The possibility is that we're seeing sexual selection on measures of intelligence."
CARLOS BOTERO

Botero and his colleagues analyzed 98 recordings from 29 species. At the flashier extreme, brown thrashers in North America have repertoires of more than a thousand syllable types. And then there are pearly-eyed thrashers. "I like these guys a lot, but they do not shine in their vocal versatility," he says. Their repertoires run to 20 kinds of syllables.

For climate data on the birds' breeding ranges, Botero and his colleagues analyzed temperature and precipitation records for roughly 200 years. Tropical forests offered more predictable and less variable habitats than drier, higher-altitude scrub habitats and deserts.



The song of the Caribbean pearly-eyed thrasher is simple (spectrogram shown) compared with closely related species.

Botero says he is looking to sexual selection to explain the findings. Animals get pickier in choosing mates in harsh places, he says. There, picking a lousy mate can have especially bad consequences. Male birds in challenging habitats may be under extra pressure to prove themselves attractive in their courtship serenades.

And when variety in climate is part of that challenge, superior learning ability and a gift for innovation may prove particularly attractive. How accomplished a bird is in learning to sing might indicate superior brain power. In the climate-song link, "the possibility is that we're seeing sexual selection on measures of intelligence," Botero says.

Near-perfect primate fossil

Forget Botox and tummy tucks. A little volcanic ash in Germany kept a 47-million-year-old small primate fossil looking pretty darn good. The 95 percent–complete skeleton (shown) is the most complete fossil primate ever found, researchers report online May 19 in *PLoS ONE*. Ida, more formally *Darwinius masillae*, had a skeleton that measured 58 centimeters (1.9 feet) long. She likely was nocturnal and lived in trees of an ancient rain forest. Ida had nails instead of claws, short limbs and opposable thumbs. "This really shows us what a whole primate was like at this time, when we see the first modern primates," says study coauthor Holly Smith of the University of Michigan in Ann Arbor. —*Laura Sanders*

FROM TOP: C. BOTERO, C. BOTERO *ET AL.*/*CURRENT BIOLOGY* 2009; FRANZEN *ET AL.*, *PLOS ONE* 2009

95 percent Completeness of a recently identified primate fossil found in Germany

40 percent Completeness of the famed Lucy fossil from Ethiopia

Apes get sweets, toolkits in hand

Up to 5 modified sticks used by chimps to access honey

By Bruce Bower

Chimpanzees living in central Africa's dense forests have no access to a hardware store, but that doesn't stop them from assembling their own brand of toolkit. These apes use as many as five homemade tools in set sequences to obtain honey from beehives located in fallen tree trunks, at least 20 meters high in trees or up to 1 meter underground, according to two new studies.

Chimps living in Gabon's Loango National Park modify tree branches to make complex tool sets for removing honey from the hives of different bee species, Christophe Boesch of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, and his colleagues report online May 19 in the *Journal of Human Evolution*.

Near Loango, in a forested region of the Congo Basin called the Goualougo Triangle, another group of chimps also makes and uses different types of tools to open beehives and gather honey, say Crickette Sanz, also of the Max Planck Institute for Evolutionary Anthropology, and David Morgan of Lincoln Park Zoo in Chicago.

Chimps across Africa have developed regional tool-using traditions to gather honey, Sanz and Morgan propose in the June *International Journal of Primatology*. In central African forests, hard-to-reach hives and competition with nearby gorillas have elicited complex forms of tool use, the researchers contend. That proposal challenges the traditional idea that advanced behaviors among human ancestors emerged only after they reached open savannas. Forest-dwellers could have also achieved chimplike advances in toolmaking, Sanz and Morgan argue.

After collecting tools and observing chimps, Boesch's team identified and named five implements: Pounders are thick sticks with rounded ends that chimps hammer against hives to create an opening. Enlargers are thinner sticks used to break apart compartments within hives. Chimps then dip or scoop honey out with branches with frayed ends, called collectors. Strips of bark, or swabbers, also spoon honey out of opened hives. And to find underground hives, Boesch proposes, chimps jab long sticks dubbed perforators into the soil.

Sanz and Morgan observed Goualougo chimps also using sets of two to five tools to get honey from tree hives, fallen trees and underground hives. Behavior was consistent with Boesch's descriptions.

Goualougo chimps succeeded in extracting honey from beehives on only half of observed attempts. Successful hive raids yielded anywhere from a few drops of honey to several handfuls of honeycomb, Sanz and Morgan report.

"Using up to five tools in sequence is startlingly complex, even compared to the degree of technological savvy we know chimpanzees possess," says Craig Stanford of the University of Southern California in Los Angeles.

Researchers have identified five tools that chimps use in sequence to obtain honey, including enlargers for breaking apart hive compartments and collectors for scooping honey.

C. BOESCH ET AL./JOURNAL OF HUMAN EVOLUTION 2009

Deadly mushroom toxin identified

Synthetic muscle-destroying compound also found in nature

By Rachel Ehrenberg

A toadstool toxin that spurs convulsions, nausea, impaired speech and muscle stiffness — and has led to several deaths in Japan in recent years — has been isolated and identified by a team of scientists. The small molecule is familiar to synthetic chemists but had never been isolated from a natural source, researchers report online May 24 in *Nature Chemical Biology*.

Acute poisoning that leads to a breakdown of skeletal muscle tissue — a syndrome known as rhabdomyolysis — is not often caused by a mushroom and is quite different from the effects of toxins produced by the notorious death cap and death angel, comments Petteri Nieminen of the University of Joensuu in Finland.

The toxicity of *Russula subnigricans*, the species identified in the new study, has barely been looked at, Nieminen said. The work "might bring this type of poisoning more to the foreground of mushroom studies."

Led by Kimiko Hashimoto of Kyoto Pharmaceutical University and Masaya Nakata of Keio University in Yokohama, Japan, the research team first isolated the toxin, a difficult task because the compound tends to bind to other things. Various spectroscopic analyses established the toxin's structure: a small, 4-carbon molecule known as cycloprop-2-ene carboxylic acid.

The team found the mushrooms and the isolated compound were lethal to mice, bringing about the unusual rhabdomyolysis when ingested.

Matter & Energy

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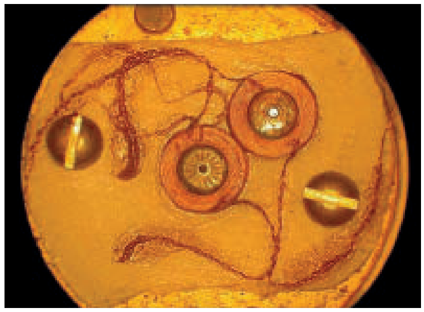
Europium shows its superpowers

Rare earth is 53rd element to conduct with no resistance

By Laura Sanders

Under pressure, an old element just learned a new trick. When cooled and squeezed, the soft metallic element europium allows electrons to flow unfettered, scientists report online May 13 in *Physical Review Letters*. Europium is the 53rd of the naturally occurring elements found to possess superconductivity.

A rare earth metal with a silver color, europium is strongly magnetic at everyday temperature and pressure. Study coauthor James Schilling of Washington University in St. Louis suspected that europium would superconduct if researchers could overcome its magnetism, which disrupts a type of electron pairing that superconductivity requires.



In a new study, two diamond anvils put pressure on europium while a coil (shown) detected its superconductivity.

Europium's magnetism stems from electrons in its 4f subshell, or orbital. Typically, europium atoms have seven electrons in this orbital. Schilling and colleagues found that under huge pressure, one of the electrons jumps out of this shell, leaving europium nonmagnetic.

To pop the electron out of its shell, the researchers used a device that squeezes the metal between two large diamonds, and cooled it to about 1.8 kelvins (–271.35° Celsius). At pressures about 800,000 times the air pressure at sea level, europium lost its magnetism. Electrons could flow freely through the metal without resistance.

Such extreme conditions preclude practical uses for a europium superconductor, says physicist Jeffrey Lynn of the National Institute of Standards and Technology in Gaithersburg, Md.

Beryllium-beryllium bond revealed

Scientists clarify confusion over puzzling atomic partnership

By Rachel Ehrenberg

Beryllium is one of those self-loathing elements. Like helium or neon, one atom of beryllium should not partner with another, basic chemistry rules say. But new research, published online May 21 in *Science*, definitively reports the nature of the rare beryllium-beryllium bond.

"People envisioned the beryllium atom as this sphere like a billiard ball that just bounces off another billiard ball," says quantum chemist Rodney Bartlett of the University of Florida in Gainesville. "They're happy with the electrons the way they are — there's no tendency to form a bond."

Element 4 on the periodic table, the strong, lightweight metal has two electrons in its outer shell, which could hold up to eight. So beryllium should happily team up with other elements, and it does. Beryllium is a component of emeralds and bonds with copper, but beryllium should be repulsed by another atom of its kind.

Yet since the 1930s, theorists and experimentalists have reported that sometimes beryllium may bond to beryllium. Studies have yielded wildly divergent results about the nature of the hookup. Different teams have calculated different bond lengths. And there has been debate over what forces made the bond possible: Some chemists said the Be_2 attraction is so weak that it shouldn't be called a bond at all.

"It is a very peculiar molecule," says physical chemist Michael Heaven of Emory University in Atlanta, who led the new work. Calculations to describe its electronic properties "seem like something you can do with a paper and pencil," he says. "But it turns out to be something where you need a supercomputer."

Heaven and his colleagues forced beryllium to bond with itself by blasting it with a stream of helium gas. Then the researchers zapped the Be_2 molecule, a dimer, with a laser that bumped an outer electron into a highly excited state. With a second laser they drove the electron back down to its original lower level. This descent released energy, producing a spectrum that revealed the forces acting between the atoms.

Scientists first caught beryllium in the act of bonding to itself in 1984. But the spectra were incomplete and the researchers had to extrapolate what was really going on between the two atoms.

If you are in a chicken coop and glimpse only the feet and tail of a bird, inferring that it is a chicken is a solid bet. But in beryllium's case, the equations missed the mark, incorrectly predicting the length of the bond at particular energies.

Based on the whole bird, the beryllium-beryllium bond is real, but delicate and not fully developed. The electrons of the two atoms swirl in a complex dance that minimizes repulsion. The new measurements for bond lengths at higher energies agree with theory. And for the bond to form, the new findings suggest, the electrons actually take advantage of the next orbital out, which is typically empty. For the electrons to keep their appropriate distances, this outer orbital hybridizes with the orbital that usually just holds beryllium's two outer electrons.

DEBESSAI *ET AL.*/*PHYSICAL REVIEW B* 2008

Humans

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

Tracing the inner world of suspicion

Personality, behavioral traits linked to belief in conspiracies

By Bruce Bower

Shortly after terrorist attacks destroyed the World Trade Center and mangled the Pentagon on September 11, 2001, conspiracy theories blossomed about secret and malevolent government plots behind the tragic events. A report to appear in *Applied Cognitive Psychology* offers a preliminary psychological profile of people who believe in 9/11 conspiracies.

A team led by psychologist Viren Swami of the University of Westminster in London identified several traits associated with subscribing to 9/11 conspiracy theories, at least among Brits. These characteristics consist of backing one or more conspiracy theories unrelated to 9/11, frequently talking about 9/11 conspiracy beliefs with like-minded friends and others, taking a cynical stance toward politics, mistrusting authority, endorsing democratic practices, feeling generally suspicious toward others and displaying an inquisitive, imaginative outlook.

"Often, the proof offered as evidence for a conspiracy is not specific to one incident or issue, but is used to justify a general pattern of conspiracy ideas," Swami says.

His conclusion echoes a 1994 proposal by sociologist Ted Goertzel of Rutgers–Camden in New Jersey. After random phone interviews of 348 people, Goertzel proposed that a person's convictions about secret plots serves as evidence for other conspiracy beliefs.

A belief that the government is covering up its involvement in the 9/11 attacks thus feeds the idea that the government is also hiding evidence of extraterrestrial contacts or that President Kennedy was not killed by a lone gunman.

Goertzel says the new study provides an intriguing but partial look at the inner workings of conspiracy thinking. Such convictions depend on what he calls "selective skepticism." Conspiracy believers are doubtful about information from the government or other sources they consider suspect. But, without criticism, believers accept any source that supports their preconceived views, he says.

"Arguments advanced by conspiracy theorists tell you more about the believer than about the event," Goertzel says.

Swami's finding that 9/11 conspiracy believers frequently spoke with like-minded individuals supports the notion that "conspiracy thinkers constitute a community of believers," remarks historian Robert Goldberg of the University of Utah in Salt Lake City. Conspiracy thinkers share an optimistic conviction that they can find "the truth," spread it to the masses and foster social change, he says.

Over the past 50 years, researchers and observers of social dynamics have traced beliefs in conspiracy theories to feelings of powerlessness, attempts to bolster self-esteem and diminished faith in government. Some conspiracy beliefs — such as the conviction among some blacks that the U.S. government concocted HIV/AIDS as a genocidal plot — gain strength from actual events, such as the Tuskegee experiments in which black men with syphilis were denied treatment.

Swami and colleagues administered questionnaires to 257 British adults from a variety of ethnic, religious and social backgrounds representative of the British population.

Figurine raises dating issues

Scientist claims ivory carving is oldest known figurative art

By Bruce Bower

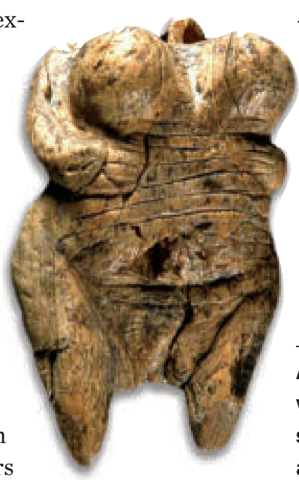
Some women have mysterious pasts, but a few have mysterious prehistories. Archaeologist Nicholas Conard of the University of Tübingen in Germany has found one such lady. She's carved out of ivory, boasts exaggerated sexual features and fits in the palm of his hand.

Conard says the discovery, reported May 14 in *Nature*, demonstrates that artistic renditions of the human form originated in Europe between 35,000 and 40,000 years ago — thousands of years before most researchers thought, and a time so close to initial European settlement that newcomers would have had to rapidly invent such advances or import them from Africa.

"This discovery ... is perhaps the earliest example of figurative art worldwide," Conard says.

Excavations in southern Germany's Hohle Fels cave in 2008 yielded six fragments of the figurine that have since been pieced together, Conard reports. He uncovered the specimen amid stone, bone and ivory tools characteristic of the Aurignacian period, when modern humans first reached Europe. Researchers estimate that the period lasted from about 40,000 to 29,000 years ago.

Some researchers are skeptical, saying that dating of surrounding materials supports an earlier proposal that figurative art emerged in Europe roughly 32,000 years ago, more than 5,000 years after modern humans reached Europe.



H. JENSEN/UNIV. OF TÜBINGEN

An ivory figurine of a woman with exaggerated sexual features may date to at least 35,000 years ago.

Genes & Cells

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

Genetic analysis of swine flu virus finds new mixture of diverse parts

H1N1 may be amenable to future vaccine development

By Tina Hesman Saey

The H1N1 swine flu combines old viruses in a new mix.

A detailed genetic analysis, published online May 22 in *Science*, pinpoints the origins of each of the virus's components. Many have been circulating in human and swine populations for years, but the new H1N1 virus combines the bits and pieces in a way never before seen. The analysis suggests that current vaccines probably won't provide protection from the virus, but that it is susceptible to some antiviral drugs and will be amenable to new vaccine development.

A study of the virus's neuraminidase protein (the N in H1N1), published May 20 in *Biology Direct*, also shows that the virus is sensitive to some drugs but that parts of the protein important for vaccine development and antibody therapies are already changing.

Pigs are the likely origin of the virus, says Nancy Cox, chief of the influenza division at the Centers for Disease Control and Prevention in Atlanta and a coauthor of the paper in *Science*. But it is still unclear whether the virus jumped directly from pigs to humans or infected an intermediate host first.

CDC has sent candidate virus strains for vaccine development to several U.S. manufacturers, says Anne Schuchat, CDC's interim deputy director for the science and public health program. Though the number of new cases in the United States is falling, Schuchat says, the virus is still active in pockets of the country. "We don't want people to think we're out of the woods yet," she says. "It could come back in the fall in the worst way."

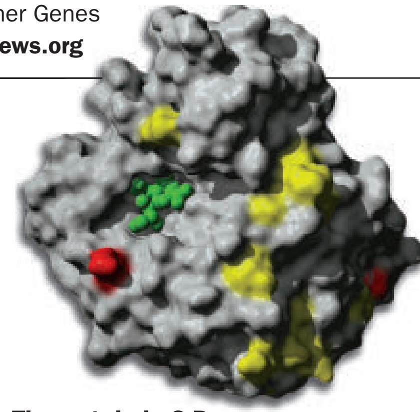
> "We don't want people to think we're out of the woods yet."
> ANNE SCHUCHAT

Genetic analysis of the H1N1 virus reveals that three of its genes, including the hemagglutinin gene (the H in H1N1), originally came from the 1918 Spanish influenza virus and have been present in pigs ever since. The genes have not changed much, probably because pigs do not live long enough to get reinfected with the same virus, Cox says.

Now that the H1N1 swine flu virus has entered humans, researchers expect it to mutate at the same rate as currently circulating seasonal influenzas.

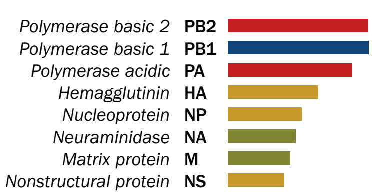
The new virus does not contain the genetic changes thought to have helped the 1918 flu virus and the H5N1 avian flu virus adapt to humans, the researchers report. That means that other genetic components of the new virus must be responsible for its ability to pass from person to person. Both studies find that the closest relative of H1N1's neuraminidase gene is from a Eurasian swine flu virus that probably leaped from birds to pigs in about 1979.

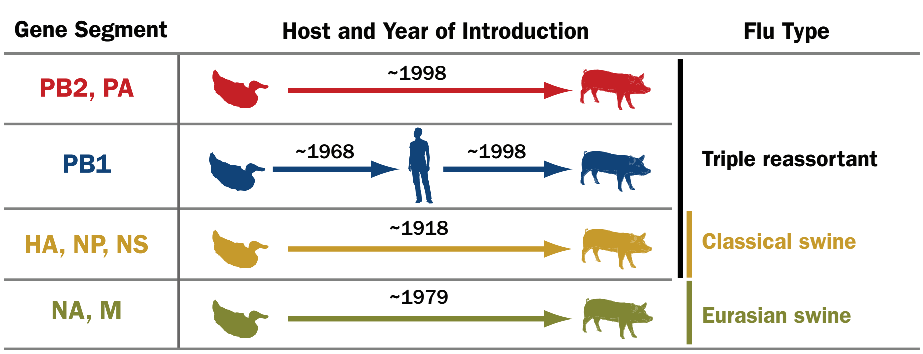
The new virus has a different amino acid from both the H5N1 virus and the 1918 Spanish flu (also an H1N1 virus) in 21 of 387 investigated positions on the protein, researchers from Singapore's Agency for Science, Technology and Research report in the study in *Biology Direct*. Viruses isolated from patients during the first two weeks of the current outbreak already have changes on the outer surface of the neuraminidase protein that could interfere with antibodies against the virus or alter the effectiveness of future vaccines. But none of the changes have altered the parts of the protein targeted by antiviral drugs, such as Tamiflu or Relenza.



Flu protein in 3-D
This image shows H1N1 swine flu's neuraminidase protein. Yellow depicts regions where the new virus differs from H5N1 avian flu and 1918 H1N1 Spanish flu. Red depicts mutations that occurred in the first few weeks of the 2009 outbreak. Green shows the antiviral drug zanamivir bound to the protein.

Swine flu's mix
The H1N1 swine flu virus combines bits of different influenza viruses that have been circulating for a long time. Chart shows gene segments and their origins.





CLOCKWISE FROM TOP RIGHT: BIOINFORMATICS INSTITUTE, SINGAPORE'S AGENCY FOR SCIENCE, TECHNOLOGY AND RESEARCH; R.J. GARTEN *ET AL.*/*SCIENCE* 2009

48 percent Of people in the United States report having insomnia occasionally

25 percent Of people in the United States take some form of medication at least once a year to help them sleep

Fruit flies can't fall or stay asleep

Strain bred to help track genetic factors leading to insomnia

By Tina Hesman Saey

A new strain of fruit flies bred to have trouble getting shut-eye may open researchers' eyes to the genetic causes of insomnia.

Paul Shaw of Washington University in St. Louis and his colleagues bred 60 generations of *Drosophila melanogaster*, selecting for flies that slept the shortest amount of time. The result was a strain with many of the characteristics and complications of insomnia in people, the team reports in the June 3 *Journal of Neuroscience*.

There is a fine line between chronic insomnia and sleep deprivation, says Thomas Roth of the Henry Ford Hospital in Detroit. Insomniacs lack the ability to fall asleep and sleep well (though Shaw and his colleagues think such people may be protected from the full negative effects of sleeplessness). Sleep-deprived people, in contrast, may stay up too late, not getting the sleep they need to function properly. Most attempts to mimic insomnia in animals fail to match some hallmarks of the disorder in humans, especially hypersensitivity to light and other stresses.

"Was I ready to blow this paper off before I read it? Yeah. I thought it was just another guy doing sleep deprivation and calling it insomnia," Roth says. But the fruit flies "aren't just short sleepers."

The insomniac flies do sleep very little — only an hour a day, compared with about 12 hours a day for normal flies. But like humans with insomnia, the insomniac flies have trouble falling asleep and staying asleep, managing to stay asleep for only about half an hour at a time. And they are also very sensitive to disturbances, taking more than an hour to fall back asleep after one.

The activity of 1,350 genes is different between the insomniac flies and normal flies, the researchers show. The affected genes are involved in metabolism, neuron activity, stimulus perception, locomotion and information transmission within and between cells. The researchers have not yet traced the genetic changes responsible for insomnia in the flies. "It's undoubtedly not one gene," Shaw says. He expects 10 or more genes to be involved.

The insomniac fruit flies lose more sleep than their human counterparts, who generally sleep six or seven hours a night rather than eight. Lack of sleep causes many problems for the flies, Shaw says. The flies "fall over a lot.... They are fat. They can't learn — no short-term memory." The flies also have shorter-than-normal life spans.

Obesity, memory problems and shortened life spans aren't generally associated with chronic insomnia in people, Roth contends, but have been tied to sleep deprivation. The fruit flies may be a hybrid, having insomnia and sleeping so little that side effects of sleep deprivation are also apparent.

Despite the differences, says Michael Perlis of the University of Pennsylvania in Philadelphia, the flies' inability to fall asleep and stay asleep makes them a model of insomnia.

Primates carry and pass along a foreign gene

Marmosets produce glowing protein in all tested tissues

By Tina Hesman Saey

Four little marmosets glowing green could be heralds of a new species for modeling human diseases.

Erika Sasaki of the Central Institute for Experimental Animals in Kanagawa, Japan, and her colleagues engineered the marmosets to make green fluorescent protein in all the cells of their bodies, including eggs and sperm. The marmosets are the first transgenic primates — meaning they carry and fully express a foreign gene. Some of the animals were able to pass the gene to offspring, the researchers report in the May 28 *Nature*.

"It's a great achievement," says Shoukhrat Mitalipov, a developmental biologist at the Oregon National Primate Research Center in Beaverton. Other scientists have introduced foreign genes in other primate species, but the genes were found in only some tissues of the body or in some cases did not result in any protein production, he says.

E. SASAKI *ET AL.*/*NATURE* 2009

Four marmosets (one shown) were engineered to produce a glowing protein in their cells (inset of paws under UV light).

The new work marks the first time scientists have successfully introduced a foreign gene into all of a primate's cells, and the first time the protein the gene encodes has been produced in all the tested body tissues in a primate. More importantly, the marmosets are the first primates to pass the gene to the next generation.

The ability to breed transgenic primates means doing expensive and difficult genetic engineering only once, then using conventional breeding to make large numbers of the animals. Transgenic marmosets can be used to study diseases and disorders that affect higher brain structures, Mitalipov says.

Geoscience

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Unprecedented organic meteorite

Study finds high levels of a possible precursor to early life

By Sid Perkins

New analyses of a meteorite that fell on Tagish Lake in Canada nearly a decade ago suggest that such extraterrestrial bodies may hold much higher concentrations of formic acid, a chemical precursor to life, than previously recognized.

Many simple organic chemicals have been detected in clouds of dust and gas in interstellar space (*SN: 5/1/04, p. 280*). But scientists have typically found little if any formic acid in meteorites that formed within clouds similar to those that eventually coalesced into the solar system. Robert Hilts of Grant MacEwan College in Edmonton, Canada, said the apparent lack is probably because the chemical evaporates easily at temperatures found at Earth's surface. Using a technique designed to squelch the evaporation of formic acid during chemical analyses, he and his colleagues have now detected substantial concentrations of the volatile chemical in a meteorite — the highest ever reported, Hilts announced May 24.

Many pieces of the Tagish Lake meteorite landed on the frozen surface of its namesake in January 2000 (*SN: 5/19/01, p. 317*). What makes this meteorite special is that several pieces have never been exposed to temperatures above freezing.

Bulk analyses of the fragments reveal that the material is about 6 percent carbon, a record-high content for meteorites, said Hilts. Slightly less than half of that carbon is locked in organic chemicals.

After extracting those chemicals with solvents, Hilts and his colleagues increased the pH of the resulting solution and converted the organic chemicals into salts. This process minimized evaporation of volatile components. After evaporating the solvent, the team converted the salts to their original form to isolate the chemicals. Analyses revealed a number of organic chemicals, including formic acid, acetic acid and capric acid, Hilts said.

Formic acid concentrations average about 200 parts per million by weight, about four times the levels found in the previous record-holder. The ratio of deuterium to hydrogen in the formic acid, a key precursor to the chemicals that make up cell membranes, indicates that the acid had an extraterrestrial origin.

The new technique will allow scientists to more fully account for all of the organic substances in a meteorite, says Conel Alexander of the Carnegie Institution for Science in Washington, D.C.

MEETING NOTES

Phytoliths as climate clues

Tiny silica structures that form in the leaves and wood of many plants can yield information about the temperature in which the plants grew, a new study suggests.

Phytoliths are minuscule, often distinctly shaped crystals of silica that form in vegetation as a plant grows. And they're long-lasting: Paleontologists have used phytoliths trapped in fossils to infer the diet of some dinosaurs (*SN: 10/20/01, p. 248*). Now, scientists might be able to use phytoliths from long-decomposed plants unearthed from soil as paleothermometers, Zhenzhen Huang of the University of Western Ontario in London, Canada, reported May 26.

Huang and her colleagues grew cattails and horsetails, types of marsh plants, at different temperatures in climate-controlled chambers. As data from previous field tests had hinted, the ratio of oxygen-16 and oxygen-18 isotopes in the plant-produced silica varied according to the temperature, Huang said.

Previous studies have shown that phytoliths from fallen and decomposed vegetation can persist in soil for up to 300,000 years. So, Huang speculates, oxygen-isotope data from phytoliths — if combined with the results of carbon-dating organic material from the same soil sample — could provide data about Earth's climate during the last three ice ages and interglacial periods. —*Sid Perkins*

Bricks, mortar and magnetism

Studies of bricks and mortar from French buildings constructed during the ninth and 10th centuries are providing information about Earth's magnetic field at the time, Annick Chauvin of the University of Rennes 1 in France and her colleagues reported May 25.

The researchers analyzed samples of materials used in the construction of a medieval castle and several churches in west-central France to better determine when they were built. Ages for the structures were obtained by carbon-dating bits of charcoal in the mortar holding bricks together.

Then the researchers studied the bricks, which retain a record of the strength of Earth's magnetic field at the time of formation. Analyses of the bricks, combined with dating from the mortar, suggest that the strength of Earth's magnetic field in west-central France during medieval times peaked at 70 microtesla in 840, Chauvin reported. Today, magnetic field strength in the area is about 48 microtesla.

Scientists have only a handful of such measurements from medieval France, and archaeologists can use the data, along with other clues, to estimate the age of artifacts unearthed elsewhere in the region (*SN: 12/22&29/07, p. 392*). —*Sid Perkins*

no brainer behavior

In a somewhat different world, Consuelo M. De Moraes would be revolutionizing vampire fiction.

Her lab at Penn State University studies predators that entangle prey in a tight embrace, pierce victims' tissue and suck out nourishment. In the last few years, De Moraes and her colleagues have found that the predators even hunt down prey by scent.

Creepy as her predator, *Cuscuta pentagona,* is, it is also, frankly, a plant. Better known as five-angled dodder, its orange tentacles bypass the porcelain throats of young women in favor of the slim stems of young tomato plants. De Moraes and other researchers are showing that plants behave and misbehave as dramatically as animals. But there's still not much hope for a feature-length dodder movie.

"I think most people regard plants as being pretty unresponsive and stuck in one place," laments ecologist Richard Karban of the University of California, Davis. "Now, animals, *they're* interesting because *they* can change and act in response to their environment."

It's a dichotomy Karban doesn't accept for one second. When he and an animal behaviorist recently supervised a grad student, he remembers, "I would constantly want to say, 'Oh yeah! Yeah! Plants do that too!' " Recent findings on plant capacities, he declares in a 2008 paper in *Ecology Letters*, reveal "high levels of sophistication previously thought to be within the sole domain of animal behavior."

Even plants less vampirish than *Cuscuta* vines forage strategically for their food, and there's evidence that plants fight each other over resources. In a broad sense of the word, plants communicate — some essentially scream for help. Also, a plant can respond to stimuli depending on its history of previous experiences, a tendency Karban is willing to call a sign of memory.

Karban stops there, but other plant scientists go much further in borrowing animal terminology. In May, researchers gathered in Florence, Italy, for their fifth annual meeting on "plant neurobiology," and some of these green neuroscientists talk about searching for a plant "brain." The June issue of *Plant, Cell & Environment*, devoted to plant behavior, even begins with a paper that uses the term "plant intelligence."

Expanding the language for describing plants to include at least some "behavior" words could expand ideas for research, Karban contends. Plant researchers might do well to borrow analytic techniques from animal scientists, he adds. Finally, everyone may discover just how exciting it can be to watch grass grow.

Movement in animal time

One of the first questions posed to believers in plant behavior is, "How can plants behave if they can't move?"

Part one of plant behaviorists' almost universal answer: Plants do move.

Time-lapse photography of growing shoots reveals spooky, circular sweeps called nutation. The circular motion arises because a shoot does not necessarily grow evenly, with cells on one side elongating as fast as cells on the other. Growth rate varies on different sides. Over hours or days, the growing tip moves like a turning searchlight.

And as plant scientists relish pointing out, some plants *do* move in animal time, especially those that hunt animals for food. When it lands inside the open jaws of a Venus flytrap, a fly may jog trigger hairs. An electrical signal zaps through the plant tissue and the two sides of the trap can close like a book in less than a second. And a water flea that bumbles into a little cup of a bladderwort likewise confronts the peril of touch-sensitive triggers. A trapdoor opens within 30 milliseconds, and the flea whooshes down into a digestive chamber.

No insects are harmed when white mulberry trees bloom, but the *Morus alba* flowers open with a quick puff of yellow pollen. In a lab setup, a team of aerosol specialists at Caltech found the mulberry flower's parts moving at speeds exceeding Mach 0.5. Pollen flinging could thus be the fastest biological movement yet observed, the team reported in 2006, and team member James House says he's not aware of any challenges since.

But while plants trap and snap with boastable speeds, the second theme of a typical plant scientist's comments about motion is that it doesn't really matter in defining behavior.

Motion seems an unfortunately strict requirement, even for animal behavior, says Jonathan Silvertown of the Open University in Milton Keynes, England. He studies plant communities, and in 1989 worked with animal behaviorist Deborah Gordon, now at Stanford University, to outline a framework for defining plant behavior. A hedgehog playing dead is certainly behaving, they wrote.

Still behavior

"Behavior," they proposed, applies to "what a plant or animal does, in the course of an individual's lifetime, in response to some event or change in its environment." This concept does not

Plants move. Time-lapse photography reveals the circular sweep of a *Lonicera japonica* vine during two hours of growth. But an evolving definition of plant behavior doesn't even require motion. Plants can behave while staying still.

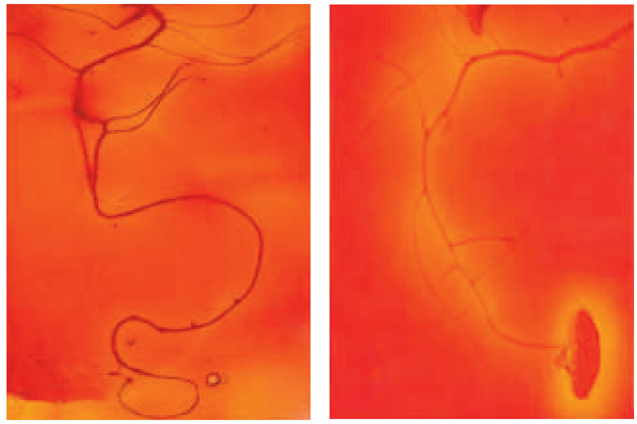
ASH KAUSHESH AND KATHERINE LARSON

Messages, memory, maybe even intelligence — botanists wrangle over how far plants can go **By Susan Milius**

Fast eater

The delicate-looking swollen bladderwort, *Utricularia inflata*, can kick into action quickly. An unsuspecting bug that finds its way to one of the underwater plant's traps (shown above) will be sucked in through a trapdoor.

Root warrior



Exposed to a secretion from an invasive knapweed, the root of a blanketflower within an hour responds with its own secretion (right, shown as gel acidifies and turns yellow). At left is an unexposed root.

LEFT: BARRY RICE/SARRACENIA.COM; RIGHT: TIFFANY WEIR *ET AL.*/*PLANTA* 2006

include intent, the team wrote, and Karban concurs. "Even in people, determining intent is very difficult," he says.

This motion-free, intent-free definition allows the concept of behavior to embrace an activity in which plants excel: releasing chemical bursts, says plant community ecologist Kerry Metlen of the University of Montana in Missoula. Plants secrete secondary metabolites, chemicals that go beyond the basics of metabolism. These substances can prospect for food, wage war and call for reinforcements, all the while gossiping in chemical detail. "Plants are prodigious chemists," Metlen says.

These chemical doings also show two other qualities that Metlen requires for plants behaving. A behavior should start relatively fast and it should be reversible, he and his colleagues contend in the June *Plant, Cell & Environment*.

Fighting tooth and chemical

Consider foraging, Metlen says. Iconic scenes of animal behavior star cheetahs streaking toward an antelope lunch. Underfoot, it turns out, the plants are hunting too, just by different means.

In a very basic sense, plants hunt by sending out roots. Decades of research have established that plants are strategic, allotting root growth to the promising patches and skimping on dead zones.

Plants also have their version of the cheetah pounce, but it's chemical. Metlen's favorite example, he says, comes from a study of fava beans by Long Li at China Agricultural University in Beijing and a network of colleagues. Like other plants, the beans need phosphorus. When researchers put the plants in phosphorus-poor agar gel, the beans took "action." They acidified the material around their roots, causing malate and citrate concentrations in the agar to increase in such quantities that the gel's pH dropped by about two units within six hours. Driving down soil pH increases plants' phosphorus uptake, so chemically those bean roots were chasing and grabbing the food they needed.

One plant Metlen is studying now, spotted knapweed, adds a root-war twist to the chemical-pounce scenario. Back in its native Eurasian range, *Centaurea maculosa* grows here and there as an occasional member of mixed-plant communities. Its roots exude a substance called catechin, which makes phosphorus more available in certain soils.

Spotted knapweed has moved to North America. Where it once had an occasional presence, it is now a land grabber. Knapweed blankets entire slopes and pushes out native vegetation. One of the secrets for its new success may be the catechin. European neighbors of knapweed don't seem bothered by catechin seeps, but some North American species can't cope. A handy dietary aid has turned into an invader's chemical weapon.

It's root versus root, and research, including a 2006 *Planta* paper, suggests that some native species fight back, chemically of course. A lupine and a blanketflower can still grow when knapweed erupts in the neighborhood. Expose the two species to catechin and their roots exude extra oxalate, four times the normal level for the blanketflower and 40 times normal for the lupine. The oxalate may defang the catechin, with protection extending beyond the blanketflower and lupines to other native species growing near enough.

Volatile messages

It's not neighboring plants but insects that come to the rescue when a plant cries for help. Karban, in his 2008 paper, argued that these behaviors amount to a plant version of communication.

When mites or caterpillars bite into leaves or stems, the attacked plant releases volatile compounds. It's not just that sap dribbling from an open wound happens to have a scent. In corn, for example, insects boring into the stem prompt leaves to release complex blends of volatile chemicals.

Blends include a lot of information. Some plants enduring the indignity of a researcher snipping their leaves will release volatiles, but not of quite the same aroma as when caterpillars bite.

Some of the insects that prey on other insects react to these volatiles, swarming to the attacked plant to dine on the attackers. Research has found that certain of these ambulance-chasing predators respond selectively, flying toward the aromatic news of pests they prefer to eat while ignoring aromas from attacks by species they don't fancy. For example, a little wasp that can only manage to inject its eggs into young caterpillars reacts to volatiles of plants under the attack of such tender youngsters. But the wasp doesn't respond to volatiles from infestations inflicted by older caterpillars.

Neighboring plants can eavesdrop on the volatile signals too, and some respond by priming their own defenses.

Karban is willing to use the term "communication" for these chemical outbursts. He acknowledges, however, that strict definitions of communication demand that both the cue-emitter and the receiver benefit from the exchange. Plant volatiles that bring insect rescue may fit even this tougher definition, he says.

Remember me?

Warfare, chemical or otherwise, changes surviving plants much as it might animal survivors, according to research on the phenomenon of priming.

A poplar leaf once scarred by insect attack kicks its defense genes into high gear faster during the next attack than a naive leaf does, says De Moraes. "*Memory* comes with so much baggage," she says, so she uses the term *priming* or *preparedness*. Karban, among other researchers, does compare this effect of past experience in plants to memory in animals.

And De Moraes' work shows that even a rumor of war can create a state of preparedness in a naive leaf. The way poplars' internal plumbing system is structured means that a leaf does not have a direct connection to its immediate neighbor. When De Moraes experimentally "attacks" leaf number one, volatiles waft to near neighbors, and those volatiles can constitute gossip about the nature of the attacker. Should she challenge those neighbors later with their own crisis, they rev up their defense genes faster than does a leaf prevented from receiving the informative volatiles. Biochemical gossip has its value.

That warnings waft over a plant's own leaves may help explain how the volatile cues evolved, De Moraes says. Biochemical messages benefit the gossiping plant itself, rather than just its neighbors.

Neighboring plants may be listening in, but perhaps the wounded plant is getting big benefits just from talking to itself, De Moraes says. And plants may be able to distinguish self from nonself, according to Karban's current research effort. He is finding evidence that a sagebrush plant shows signs of distinguishing its own airborne signals from those of other sagebrushes. A sagebrush plant that sniffed volatiles from wounded neighbors that are genetically identical to it was more resistant to attack than were sagebrush plants exposed to volatiles from genetically different plants, he and a colleague report in the June *Ecology Letters*. That plants have some powers of self-recognition opens a new arena of comparisons with animals.

Green neuroscience

De Moraes, Metlen and Karban borrow animal terms moderately, but other plant scientists go much further. Anthony Trewavas of the University of Edinburgh freely uses the phrase "plant intelligence."

For defining intelligence, he says that "a capacity for problem solving is the best descriptor that I have come across, and problem solving is something all organisms have to do."

Botanists have already borrowed plenty of other originally human terms, such as arms races, foraging, cross talk and vascular system, even though the plant versions rely on mechanisms that are different from the human ones. People comfortably say computers have memory and can even learn. Trewavas is now working on a book on "plant behavior and intelligence."

In a similar vein, other plant scientists argue for what they call "plant neurobiology." In a 2006 manifesto introducing the field to readers of *Trends in Plant Science*, Eric Brenner of the New York Botanical Garden and five colleagues describe their aim as understanding "how plants process the information they obtain from their environment." They write that, almost a century ago, researchers reported electrical activity in plant tissues as part of the early explorations of electrophysiology in all living things. Also, the major neurotransmitters in animal nervous systems, including acetylcholine, serotonin, GABA and glutamate, occur naturally in plants.

Figuring out what all of this means for plants is drawing researchers' attention. "The most important thing is that we're missing something," Brenner says.

Applying neurobiology terms to plants has sparked debate aplenty. "I see no reason why one can't simply talk about signal transduction in plants," objects David G. Robinson of the University of Heidelberg in Germany.

He also argues that even simple animals can be trained to respond to a stimulus, so he challenges plant neurobiologists to train a plant, perhaps to bend toward yellow light or to avoid blue. "My guess is that neither experiment would work," he says. His final take on plant neurobiology: "Absolute rubbish, rubbish!"

Plant neurobiology isn't yet attracting many enthusiasts, says Michael J. Hutchings of the University of Sussex in Brighton, England, who adds that he is not a fan. But he says a wide range of plant biologists do think of their subjects as having some capacity to behave.

Failing to use "behavior" language feeds a notion of "plants as really boring," as Hutchings puts it. For bringing a more dynamic vision of plants into research and teaching, he says, "It's about time." ■

Explore more

■ Plant Behaviour Special Issue. *Plant, Cell & Environment*. June 2009.

Think like a scien

Fresh-faced researchers swarm around Deborah Lucas, buzzing with enthusiasm and frustration. They have gathered to appraise terrarium-style models of a local pond ecosystem that groups of two or three have painstakingly assembled in large jars. Lucas leads a discussion that includes how to determine the causes of unanticipated die-offs of plants and animals in some jars, what hypotheses to test in sustainable models, the usefulness of quantitative measures of plant growth devised by some teams, and the extent to which each model corresponds to an actual pond ecosystem.

Despite having launched ambitious projects, none of the assembled investigators will publish research papers or present posters at scientific meetings. Cut them some slack — they're sixth-graders. Deborah Lucas is their teacher.

These 11- and 12-year-olds are getting anything but a typical grade school science education. And that suits them just fine. Lucas' class vividly illustrates how research exploring links between everyday thinking and scientific reasoning is inspiring novel efforts to teach young people how to think like scientists.

From this perspective, kids don't truly grasp how science works by carrying out prefabricated science experiments that come packaged in kits, a common practice in U.S. science classes. It's certainly important to learn scientific formulas and principles by heart. But a deeper mode of learning depends on kids getting their hands dirty and their minds engaged in original research projects. General reasoning skills, such as switching one's point of view, and science-specific strategies, such as testing a hypothesis about one variable by holding other variables constant, blossom together in this atmosphere.

"Scientific reasoning skills lie on a continuum with mundane abilities, including making analogies, reasoning visually and mentally simulating an unseen process," says cognitive scientist Nancy Nersessian of the Georgia Institute of Technology in Atlanta. Nersessian studies how teams of scientists achieve technical advances and theoretical insights in disciplines such as engineering and neuroscience.

Make no mistake, original research isn't easy — ask any scientist. But it's not boring, either. Neither ecological disasters nor dead-end hypotheses can

COURTESY OF LYLE JACKSON/VANDERBILT UNIV.

tist

A class of curious sixth-graders arguing over moist, mucky jars may represent the future of science education **By Bruce Bower**

deter sixth-graders who have a personal stake in a science project.

Lucas, a public school teacher and education researcher at Vanderbilt University in Nashville, collaborates with Vanderbilt psychologists Richard Lehrer and Leona Schauble. The three study ways to teach young students how to reason about science and mathematics by constructing models of real-world physical and biological systems. Lucas and her colleagues also train teachers in this approach to science education.

"When kids have a hand in inventing scientific practice, they get more knowledge out of the classroom experience," Lehrer says.

Process servers

A 2007 National Academy of Sciences report echoed that point. It called for innovative methods to teach children about the process of science, as well as its content. Current educational approaches have yielded depressingly poor scores for U.S. students on international assessments of science knowledge.

A report in the Jan. 30 *Science* upped the urgency of the NAS recommendation to focus on process. It found that although Chinese college freshmen knew substantially more about physics laws and principles than their U.S. peers, both groups performed poorly on a test of scientific reasoning skills.

Even rigorous science education as practiced in China gets lost in details, according to physicist Lei Bao of Ohio State University in Columbus and his colleagues. Like their U.S. counterparts, most Chinese students entering college can't generate compelling research ideas, devise appropriate experiments, evaluate evidence in light of prior hypotheses and argue collaboratively about how to revise investigations, Bao's team concluded.

Scientific reasoning skills don't come easy under the best of circumstances. A one-of-a-kind, 20-year study of 132 German students — all of whom received a more thorough science educa-

Students from Rose Park Middle School examine pond samples as part of a project to provide a deeper understanding of the scientific process. Teacher Deborah Lucas wields a net in background.

tion than most U.S. students get — finds that an understanding of the nature of science typically develops slowly and often remains incomplete, even among young adults, says coinvestigator Merry Bullock of the American Psychological Association in Washington, D.C.

Still, about one in four German youngsters displayed a special knack for scientific reasoning that emerged within the first few years of school.

Bullock and her colleagues describe the German findings in a chapter of a new book she coedited, *Human Development from Early Childhood to Early Adulthood*.

Regardless of scientific aptitude, children constantly and unthinkingly infer that certain events in the world cause other events to happen. Bullock wants educators to equip students with reasoning tools that can be used to test the truthfulness of these causal intuitions.

"Scientific reasoning is causal reasoning gone to school," she says.

Skirmishes in the classroom

In Lucas' class, students school each other in scientific reasoning. Pond models are evaluated and, in true sixth-grade fashion, ruthlessly dissected at weekly research meetings.

Consider Ilya's tough-love message to Daniel and Emily, who suspect that fish and frogs may soon start dying in their model ecosystem due to steep rises in the jar's oxygen level. Emily suggests moving sick-looking fish to a "hospital" jar, where safe oxygen levels could be maintained while the model jar is modified. Daniel proposes using a special measuring device to determine the levels of dissolved oxygen in the recovery space before putting fish in it.

"But isn't your question how fish and frogs affect the DO [dissolved oxygen]?" Ilya interjects. "If your fish or frogs start dying in the jar, and you take them out and put them in the middle jar, then you can't do your question anymore, because they're not in the jar affecting the DO. They're in some other jar."

Ilya's comment alludes to an aspect of scientific reasoning known as the control-of-variables strategy. Researchers hold constant all changeable features in an experiment except for one of interest. Any effects of that variable on a particular outcome can then be determined.

Laboratory studies and assessment tests overwhelmingly suggest that sixth-graders, and even high school students, have trouble understanding the logic and design of controlled experiments. Over the past decade, two polarized views have fueled debates among science educators over how best to teach about this and other facets of scientific reasoning.

"Direct instruction" proponents hold that children best learn how to reason scientifically when teachers provide explicit instructions that can be applied to hands-on experiments. "Discovery learning" supporters say that children allowed to explore and experiment on their own gradually gain deeper insights into how science works than can be achieved through teacher instructions.

Everyone agrees that, in practice, most science classes include elements of both approaches. But no consensus exists on whether kids benefit more from an emphasis on one or the other approach.

Lehrer looks askance at the polarization of science education into direct instruction versus discovery learning. In classroom work with Lucas and Schauble, he says, "we provide a lot of help and instruction to students, but we also design the class to present challenges that students have to master themselves."

Variable instruction

It's wonderful but often not possible for children to participate in extended school science projects run by experienced teachers such as Lucas, remarks psychologist David Klahr of Carnegie Mellon University in Pittsburgh. In many school settings with limited resources, students need direct instruction to grasp the inner workings of science, in his view. "It took hundreds of years for great thinkers to develop a procedure for designing informative experiments, so why expect kids to come up with it on their own?" Klahr asks.

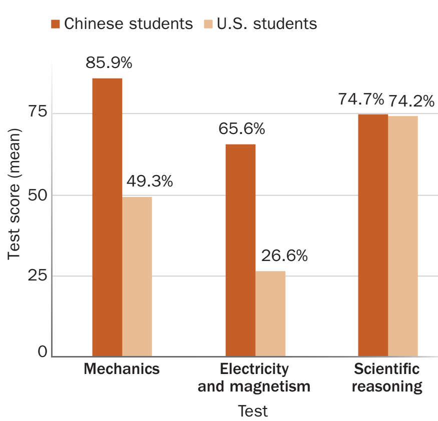
In the October-December *Cognitive Development* — which also contains a paper by Lehrer and his colleagues describing their work with sixth-graders — Klahr and Carnegie Mellon psychologist Mari Strand-Cary report that a majority of elementary school students learned how to use the control-of-variables strategy in a classroom experiment if a teacher also gave them advice and examples on how to set up a controlled experiment. Only a small minority of their peers achieved the same insight when conducting the experiment without such advice.

Strand-Cary and Klahr provided 72 third-, fourth- and fifth-graders with two wooden ramps, each connected to an extended flat pathway. Children could adjust ramp angles to high or low, ramp surfaces to rough or smooth, and ramp lengths to long or short. They could also choose a rubber ball or a golf ball to roll down the ramps.

An instructor asked students to set up the ramps to find out whether, say, steepness affects how far balls roll down the pathway. In a direct-instruction condition, the instructor then demonstrated possible controlled experiments, such as varying only the steepness of the ramps, and uncontrolled experiments, where ramps differed in several ways. Children were asked whether each example was a "smart choice," but the instructor never rolled balls down ramps. Students

Knowledge vs. Reasoning

Chinese college freshmen know more about physics but score similarly to their U.S. counterparts on tests of scientific reasoning. Teaching the science process is a challenge.



then carried out their own experiments.

In the discovery condition, students spent their time setting up and adjusting ramps to see how far balls would roll. An instructor answered questions but did not talk about experimental control.

The direct-instruction group scored better than the other group on a test measuring understanding of the control-of-variables strategy after the session. But, half of the students under both conditions grasped the strategy on a new experimental task three months later. Tests given three years later found the same results.

"Direct instruction on the control-of-variables strategy confers only a temporary benefit over discovery learning," says Deanna Kuhn of Columbia University.

A 2007 investigation conducted by Kuhn, a psychologist, and a colleague also supports her view. Fourth-graders performed science experiments akin to the ball-and-ramps challenge studied by Strand-Cary and Klahr. Half the kids received explicit instructions from a teacher about how to control variables in the experiment; the rest asked questions of the teacher when necessary. Three months later, about half the kids in both groups understood the logic of holding variables constant to answer questions.

In Lucas' class, there's often no clear distinction between direct instruction and discovery techniques. Her ecology modelers learned early in the school year how to run controlled experiments, either through trial and error or from peers' blunt comments. "The hard part for them was learning how to identify important variables to be controlled and manipulated in the first place," Lehrer says.

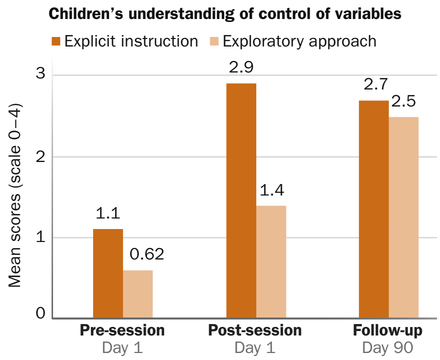
Model students

That wasn't the only intellectual obstacle that Lucas' students faced. At the end of the school year, 10 of 19 kids were convinced that, because their ecologies-in-a-jar didn't look like real ponds, none of the lessons from the teams' experiments could inspire further pond research.

Lucas suspects that kids need explicit guidance from teachers to grasp how models can, in some ways, relate to real biological and physical systems.

Direct vs. Discovery

For ramp-and-ball experiments, explicit instruction initially yielded better scores than exploratory learning in teaching controlling variables. The exploratory group later largely caught up.



Kuhn posits that mature scientific thinking consists of three key components. First, an understanding is reached that two or more variables may contribute to an experimental outcome. Second, a realization surfaces that scientific knowledge is an imperfect attempt by people to determine the truth about the world, not a collection of unassailable facts. Third, an appreciation emerges of how to argue scientifically with others, with an eye to coordinating evidence with evolving theories.

Kids display encouraging gains in these aspects of scientific thinking when challenged with progressively more demanding tasks, Kuhn says.

She and Columbia colleague Maria Pease tracked students exposed to computer-based science exercises from fourth through sixth grade. Exercises started out as highly structured activities. In teams, children grappled with problems such as learning which of five variables raised the risk of an earthquake at a particular location. A computer program assisted them in identifying relevant questions to ask, making and justifying interpretations of evidence, and predicting risk.

By the sixth grade, students graduated to science exercises conducted in independent teams and wrote reports about methods and conclusions.

When tested with further risk scenarios, most sixth-graders who completed the program considered how multiple variables contributed to risk and attempted to integrate evidence with predictions. Seventh-graders who had not received the special science program usually failed to use these strategies.

Gains achieved by students in the special program remained fragile and required regular reinforcement, the researchers found. "Scientific inquiry skills are not learned once, by any method, and then reliably available thereafter," Kuhn says.

Revolutionary tools

That may be true, but Lehrer likes what he sees so far in sixth-graders from Lucas' class. Many of them gained insights into such understudied aspects of scientific reasoning as knowing criteria for good scientific questions and for trustworthy evidence. Students also created their own tools and measurements, an endeavor that consumes much time and expense among adult scientists.

"The design of new tools, machines and scientific setups are often the impetus for scientific revolutions," Lehrer says.

Initial failures often instigated student innovations. For Ilya and Alex, algal bloom and the deaths of plants and animals in their jar proved disheartening. In the course of checking for possible causes of ecological breakdowns, the two boys realized that they needed to change how they measured growth of aquatic plants called elodea.

From an initial calculation of growth as change in elodea length, they developed a three-pronged "bushiness" index. This measure incorporated the number of buds on plants, which Ilya thought of as a measure of reproduction, as well as the length of buds and the number of roots.

Alex and Ilya ended up creating a sustainable jar ecosystem.

"This is a demanding way to teach science, but the payoff is so high," Lehrer says. "It's pretty surprising that kids learn anything from the current approach to science education." ■

Explore more

■ W. Schneider and M. Bullock, eds. *Human Development from Early Childhood to Early Adulthood.* Psychology Press 2008.

Iron is a gift from above.

Its atoms were forged by nuclear reactions inside massive stars that exploded, seeding our galactic neighborhood with the raw materials for planets over billions of years before the solar system formed.

Although iron is, by weight, the most abundant element in the solid Earth, most lies hidden in the planet's core, which may be one immense, silicon-tainted iron crystal (*SN: 1/12/02, p. 22*). Less than 6 percent of Earth's crust is iron, but fortunately for the voracious appetite of Industrial Man, the element is plentiful in oxide-rich ore deposits, including banded iron formations.

BIFs, as they're known to geologists, are enigmatic. All seem to have started out as sediments on ancient seafloors, and by some estimates the oxide mineral accumulated in all known BIFs contains about 20 times as much oxygen as today's atmosphere does. Yet some of these deposits accumulated long before Earth's atmosphere became thoroughly oxygenated, so the source of the oxygen stored in these BIFs is baffling.

Then there's the mysterious banding, in which thin layers of iron-rich minerals such as hematite (Fe_2O_3) and magnetite (Fe_3O_4) alternate with silica-rich, iron-poor bands, usually of jasper and chert.

Finally, some of the BIFs are puzzling simply because they're so big: They stretch for hundreds of kilometers, a distance over which the banding apparently remains intact. So whatever processes created these formations must have acted over broad areas.

Countless details regarding these formations' origins are hidden because many older BIFs are metamorphic rocks — they've been physically warped and chemically cooked deep within the planet, sometimes for millions of years.

"Despite the fact that people have been looking at these formations for a century or more, we still don't have a really firm handle on where they formed in the oceans, how they formed and what they're telling us about the composition of the oceans or the atmosphere at that time," says geobiologist Kurt Konhauser of the University of Alberta in Edmonton, Canada. "These are, surprisingly, still the questions that are out there."

New research is shedding some light on when, and how, some of Earth's most voluminous banded iron formations developed. Most of the largest formations date from the late Archean eon, which ended around 2.5 billion years ago, and the early part of the eon following it, the Proterozoic. This transition between eons is thought to mark huge environmental changes, specifically the switch from a mostly methane or carbon dioxide atmosphere to an

the IRON reco

Scientists are decoding the geological secr

oxygen-rich one friendly to complex life. The actual timing and suddenness of the change — an occasion so momentous that scientists have dubbed it the Great Oxidation Event — generate debate.

How BIFs, which formed in ancient oceans, document environmental transitions also remains debated. One recent paper suggests that atmospheric oxygen couldn't increase and thus couldn't set the stage for the proliferation of multicellular life until ocean chemistry changed in a way that large BIFs stopped forming.

Other studies hint at possible reasons for BIF banding. Also, tantalizing data gathered at an unusual lake in Indonesia suggest that this body of water may be one of the few modern environments that resembles Earth's Archean oceans.

The stage for complex life

Water can hold a lot of dissolved ions of iron — typically those that have lost two electrons (Fe^{2+}) — but only if the water contains no dissolved oxygen. Whenever dissolved iron and dissolved oxygen get together they combine to form a nearly insoluble precipitate, which drops out of solution. In the ancient ocean, this precipitate would have accumulated as seafloor sediments.

In the late Archean, Earth's oceans were chock-full of dissolved iron, which had either eroded from continental rocks or been spewed, along with many other dissolved minerals, into the oceans by hydrothermal activity at vents and mid-ocean ridges. Once the seas got their first whiff of oxygen produced by ocean-dwelling cyanobacteria, among Earth's early photosynthesizers, the iron oxides that formed began to accumulate in ocean basins, says Alan J. Kaufman, a geologist at the University of Maryland in College Park.

An early idea about oxygen and BIFs is that, once the atmosphere became oxygenated, excess oxygen from the atmosphere dissolved into the ocean and caused iron to precipitate. But Kaufman suggests that, "until the dissolved iron was used up, oxygen couldn't build up in the atmosphere." The oxygen in the ocean couldn't escape because iron was reacting with it, creating the sediments that would become large BIFs. Eventually, the increased supply of oxygen overwhelmed any iron that still did enter the ocean.

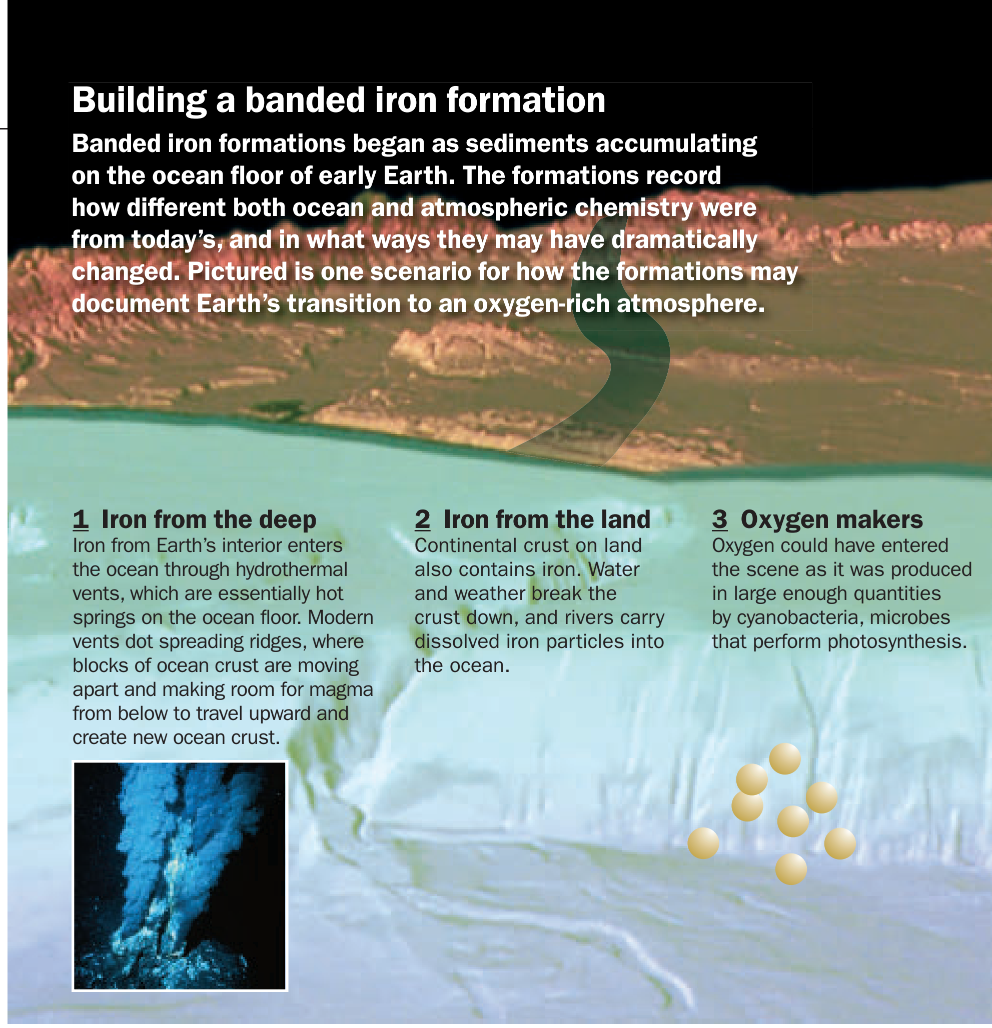
So, for millions of years, thin layers

Among Earth's oldest rocks are banded iron formations, named for the layers rich in iron that alternate with layers hosting little iron. In some places, these layers extend for kilometers. The formations remain puzzling. The most extensive ones probably stopped forming around the time the atmosphere became oxygen-rich.

MIKEUK/ISTOCKPHOTO

rd of Earth's oxygen

ets of banded iron formations **By Sid Perkins**



BACKGROUND: SEAFLOOR OFF LOS ANGELES FROM USGS/PHOTORESEARCHERS; FROM LEFT: OAR/NATIONAL UNDERSEA RESEARCH PROGRAM (NURP), NOAA; KAUFMAN

of iron-rich minerals rained down upon the seafloor, says Kaufman. In some places the strata — layers that today are high-quality ores containing as much as 55 percent iron by weight — stacked up hundreds of meters thick.

Analyses of African rocks by Kaufman and his colleagues thus suggest a slightly later date for oxygenation than some previous studies have: about 2.316 billion years ago, the researchers report in the May *Geology*. The new date is based on 58 samples of rocks that had been laid down as shallow marine sediments in what is now north central and northeastern South Africa between 2.65 billion and 2.1 billion years ago. In the oldest samples, the relative proportions of four sulfur isotopes, particularly the ratios involving sulfur-33 and sulfur-36, suggest that sulfur-bearing compounds were often involved in chemical reactions driven by ultraviolet light. Then, in rocks deposited late in that interval, sulfur ratios shifted to those that typically result from metabolic reactions within organisms.

First reported in 2001 by James Farquhar, a coauthor on the *Geology* paper who is also at the University of Maryland in College Park, and others, the changes in the ratios of sulfur isotopes are a key tool for pinpointing when the rock record documents the shift to a more oxygenated atmosphere.

Interruption of the UV-driven reactions at 2.316 billion years ago marked an important milestone in Earth's history: the formation of an ozone layer, Kaufman and colleagues report. That UV-blocking layer would have begun to form when atmospheric concentrations of oxygen rose to about 1/100,000th of modern-day levels, says Kaufman.

The appearance of the ozone layer triggered a series of biological and environmental changes that set the stage not only for life to advance from one-celled to multicellular forms, but also for the world's first ice age, the researchers contend. First, Kaufman explains, any UV-sensitive organisms living in deep waters would have been able to rise to shallower depths once the ozone layer had developed. There, the photosynthesizing organisms could have taken advantage of increased light, boosting their populations and their oxygen production dramatically. In probably less than 10 million years, oxygen levels increased to about 1 percent of today's value.

As oxygen was building in the atmosphere, it reacted with methane, then a major atmospheric constituent, to produce carbon dioxide. Carbon dioxide is a planet-warming greenhouse gas, but methane warms the air about 62 times as well as carbon dioxide does, says Kaufman. An outcome of the atmospheric change was a cooling effect so strong that it sent the world into an ice age, he says.

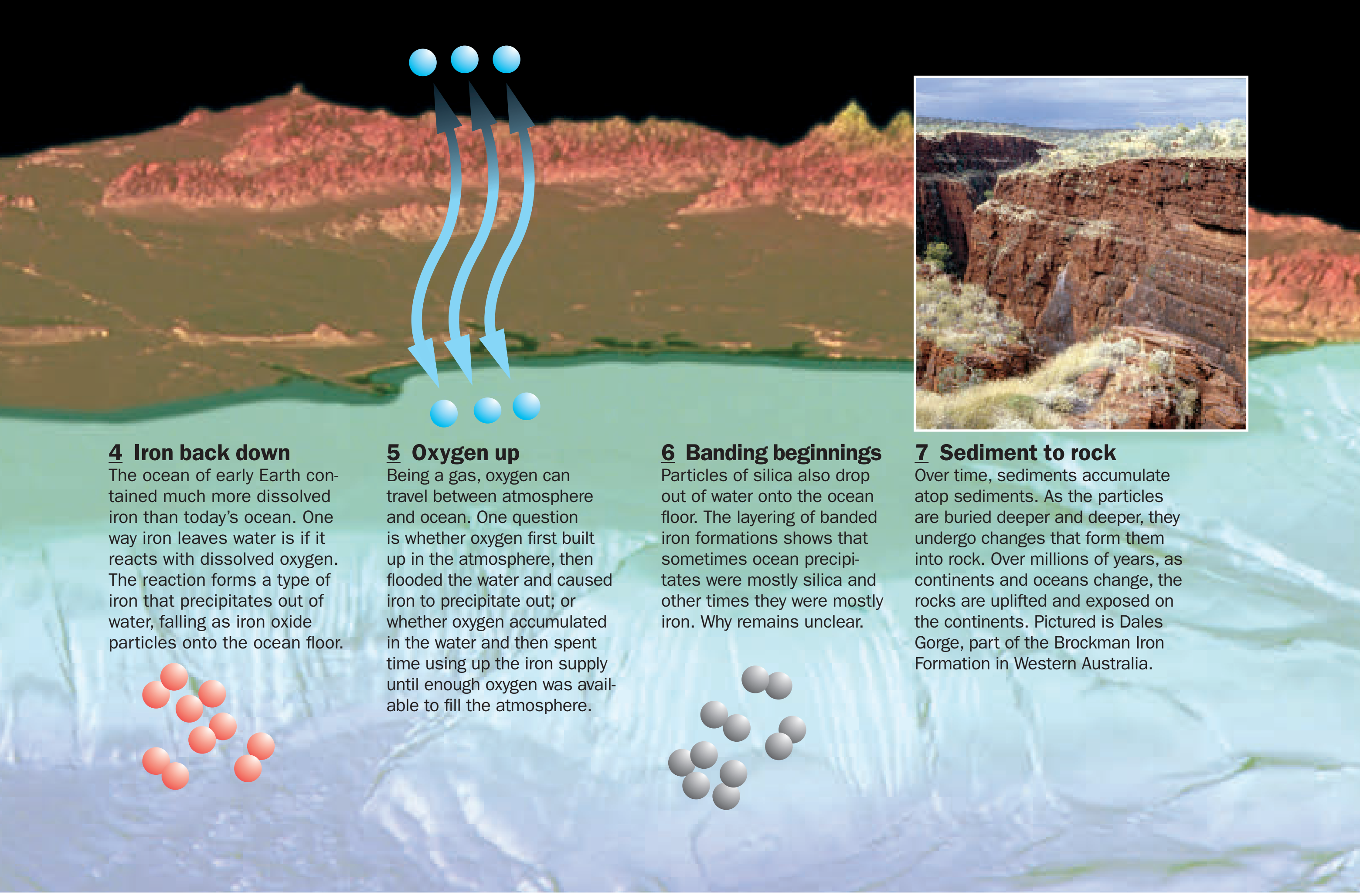
Additional oxygen in the air would also have increased the rates of weathering and erosion on land. Combined with the scouring of rocks by glaciers, these effects would have sent more nutrients off the continents and into the seas, boosting even further the populations of oxygen-producing marine organisms.

Finally, Kaufman notes, atmospheric oxygen might have driven the evolution of organisms such as eukaryotes that use, rather than make, oxygen for several important biochemical pathways.

Another way ocean chemistry could have set the scene for oxygen accumulation was by a decrease in the production of methane (*SN: 5/9/09, p. 14*), which reacts with oxygen. Other researchers suggest that ratios of nickel to iron in banded iron formations document that, starting about 2.7 billion years ago, geological changes began to reduce the amount of nickel spewing from volcanoes or eroding into the sea. The populations of microbes that used the nickel to produce methane dropped. With less methane in the atmosphere, oxygen emitted by cyanobacteria could eventually build up, Konhauser and his colleagues report in the April 9 *Nature*.

Seas of old

Although most banded iron formations probably accumulated during or after cyanobacteria began suffusing



4 Iron back down
The ocean of early Earth contained much more dissolved iron than today's ocean. One way iron leaves water is if it reacts with dissolved oxygen. The reaction forms a type of iron that precipitates out of water, falling as iron oxide particles onto the ocean floor.

5 Oxygen up
Being a gas, oxygen can travel between atmosphere and ocean. One question is whether oxygen first built up in the atmosphere, then flooded the water and caused iron to precipitate out; or whether oxygen accumulated in the water and then spent time using up the iron supply until enough oxygen was available to fill the atmosphere.

6 Banding beginnings
Particles of silica also drop out of water onto the ocean floor. The layering of banded iron formations shows that sometimes ocean precipitates were mostly silica and other times they were mostly iron. Why remains unclear.

7 Sediment to rock
Over time, sediments accumulate atop sediments. As the particles are buried deeper and deeper, they undergo changes that form them into rock. Over millions of years, as continents and oceans change, the rocks are uplifted and exposed on the continents. Pictured is Dales Gorge, part of the Brockman Iron Formation in Western Australia.

oxygen throughout the seas, some of the formations — albeit ones substantially smaller than those that formed about 2.5 billion years ago — formed millions of years before any dissolved oxygen may have been available.

Scientists have long debated how in such a world dissolved iron became oxidized sans oxygen, losing an electron and going from Fe^{2+} to Fe^{3+}. Something other than oxygen must have acted as an electron acceptor, says Sean A. Crowe, a biogeochemist at the University of Southern Denmark in Odense. Not only was free oxygen in short supply, oceans then contained little if any dissolved sulfate, an electron acceptor produced when sulfur dioxide spewed by volcanoes reacts with oxygen and water.

Lab tests show that ultraviolet light can stimulate the oxidation of dissolved iron in anoxic water, which contains no dissolved oxygen. But no one has observed such a reaction in anoxic seawater or its laboratory equivalent, Crowe says. The only other known process for oxidizing dissolved iron in anoxic water involves ancient microbes known as photoferrotrophs, organisms that derive energy from light and iron. Now, Crowe and his colleagues have discovered an Indonesian lake where photoferrotrophs thrive. The deep portion of the lake could be a modern-day version of the Archean ocean.

Lake Matano in Indonesia is only 28 kilometers long and, at the widest point, only 8 kilometers across. But at its deepest it is more than 590 meters deep. Its great depth and steep-sided bottom, along with the region's lack of strong seasonal temperature variations, contribute to poor circulation in the lake, the researchers reported last October in *Proceedings of the National Academy of Sciences*.

Field measurements reveal that Lake Matano's surface waters are oxygenated but that all waters below depths of 100 meters, which account for most of the lake's volume, are anoxic. Because soils in the surrounding watershed are poor, few nutrients make their way into the lake, says Crowe. The few dissolved sulfates that wash in are consumed by chemical reactions that occur within the chemocline, the thin layer of water that separates the oxygenated surface waters from the anoxic depths. So, the researchers note, the oxygen- and sulfate-free depths of the lake, which also happen to be rich in dissolved iron, probably are chemically similar to Earth's oceans as they existed before the atmosphere became thoroughly oxygenated.

Few photosynthetic microbes live in the nutrient-poor surface waters of the lake. Those that do, like most plants and marine organisms that thrive in oxygenated conditions, use a type of chlorophyll called chlorophyll *a*. The dearth of microbes renders the lake's upper waters exceptionally clear, which allows some sunlight to penetrate anoxic waters. At a depth of about 120 meters, Crowe and his colleagues found that the most common microbes lacked chlorophyll *a* but contained bacteriochlorophyll *e*, a lightharvesting pigment that absorbs infrared light and is present in photoferrotrophs adapted to low-light conditions. Genetic analyses suggest that photoferrotrophs are among Earth's earliest microbes.

These microbes live at a depth where light levels are between 0.005 and 0.01 percent what they are at the lake's surface, says Crowe. Yet the organisms thrive: Each liter of water there contains between 300 million and 16 billion of the photoferrotrophs, the researchers estimate. Those microbes live in the anoxic sweet spot where dissolved iron and phosphorus rising from the depths meet the weak-yet-usable sunlight filtering down from above. Their rate of growth creates just as much biomass — about 650 nanograms of carbon per hour in each liter of water — as photosynthetic organisms at the lake's surface do.

"This is a first glimpse at a microbial ecosystem in a stable, iron-rich aquatic environment," says Crowe. "This really makes the argument for a biological role in the formation of banded iron formations much more believable." The team estimates that photoferrotrophs could have, on a worldwide basis, produced about 10 percent of the biomass that modern photosynthetic organisms do.

Crowe and his colleagues didn't actually discern Lake Matano's microbes converting dissolved iron to its insoluble form: In those light-limited conditions, it would take months to produce measurable quantities, he notes. In the future, lab tests on microbes cultured from those taken from Lake Matano's depths may yield further insights about how ancient microbes might have thrived in Archean oceans, and what sort of nutrients or trace elements they would have needed to fuel their metabolisms.

Not-so-temperate banding

One of the biggest mysteries about banded iron formations is what caused the alternating layers of iron-rich and silica-rich strata, which can range anywhere from a few micrometers to a few meters thick. While some research hints that the thickest bands may be associated with long-term climate changes that stem from variations in Earth's orbit, what triggers micrometer layering has been more puzzling, says University of Alberta's Konhauser.

Previously, some teams have proposed that the small-scale layering derives from regular variations in the supply of iron-rich anoxic waters from the ocean depths — due to recurring pulses of hydrothermal activity or from climate-driven changes in ocean currents, Konhauser says. But now, lab tests by him and his colleagues hint that something much simpler — seasonal changes in ocean temperature — may have caused the banding. The team reported their findings last September in *Nature Geoscience*.

The team measured the rates at which several photoferrotroph types oxidized dissolved iron at various temperatures in anoxic, silica-rich water samples. For all of the microbes tested, oxidation rates increased as water temperature rose from 5° Celsius to 25°C. At temperatures of 30°C and higher, oxidation rates dropped substantially. When the water temperature rose to 55°C, the photoferrotrophs continued to oxidize iron but were eventually incapacitated: Even after temperature returned to 25°C, the microbes had stopped oxidizing iron and didn't restart. Similarly, the microbes probably wouldn't survive prolonged exposure to waters spewing from hydrothermal vents or volcanic seamounts.

While iron oxidation caused iron-rich minerals to drop out of solution as water temperatures rose from 5°C to 25°C, the precipitation of silica showed exactly the opposite trend, Konhauser says. At high temperatures, silica remained dissolved; as waters cooled, silica crystallized out of solution. These disparate trends could explain the banding seen in BIFs, the researchers propose: During ancient summers, photoferrotrophs proliferated and oxidized iron prodigiously, sending a cascade of iron-rich minerals to the seafloor. In winter, iron stayed in solution because the microbes weren't active, but cool temperatures caused silica-rich minerals to precipitate.

"Despite these experiments, the mechanisms of BIF deposition are still an area of great uncertainty," says Konhauser. Looking at the ratio of iron isotopes in minerals precipitated by photoferrotrophs in lab tests, and comparing the ratios with those in BIFs, may provide insights into whether similar reactions occurred before the formation of an ozone layer. Also, he notes, the results of such experiments may illuminate which trace elements are metabolically required by modern-day photoferrotrophs, and comparisons with the elements present in ancient BIFs could reveal which types of microbes were most likely the progenitors of today's iron ore deposits. ■

Researchers study microbes living in the depths of Lake Matano in Indonesia.

COURTESY OF SEAN CROWE

Explore more

- Andreas Kappler *et al*. "Deposition of banded iron formations by anoxygenic phototrophic Fe(II)-oxidizing bacteria." *Geology*, November 2008.

Deep Brain Stimulation: A New Treatment Shows Promise in the Most Difficult Cases

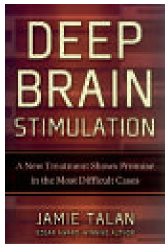
Jamie Talan

The very notion of having electrodes implanted in your brain would seem like science fiction — if 40,000 people hadn't already undergone the operation, most for Parkinson's disease.

This book tells the story of heroic people — some on operating tables and others wielding scalpels and drills — and the lengths they've gone to in seeking to relieve devastating brain disorders. Talan describes decades of brain surgery aimed at addressing movement disorders and zeros in on deep-brain stimulation, a cutting-edge treatment in which doctors implant electrodes in the brain to reboot aberrant neural circuitry.

Early efforts to treat neurological disorders that failed to respond to medication mostly involved finding the offending brain tissue and removing it. These efforts were hit-and-miss, offering relief only sometimes. More important, these attempts provided a road map of the brain. Technology used in heart pacemakers was modified to make tiny electrodes, and the use of brain scans with surgery has further advanced the practice of inserting electrodes, making deep-brain stimulation more effective, with fewer side effects.

Talan cites several scientists' work, as mapping the brain and rearranging its signals has been a long, trying story of success with many fathers. And to her credit, Talan doesn't omit the real risks of brain surgery.



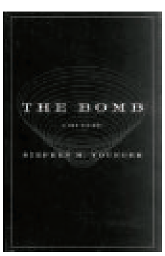
Deep-brain stimulation has gained approval for Parkinson's treatment, and more recently for obsessive-compulsive disorder. It's currently being tested for other conditions in which medication may fail, including depression, Tourette's syndrome, epilepsy, pain and persistent vegetative state. It's a science still in the making and is well-described here. — *Nathan Seppa*

Dana Press, 2009, 176 p., $25.

The Bomb: A New History

Stephen M. Younger

Nuclear policy in the United States has yet to escape the Cold War's shadow. In this account of the atomic bomb, a former director of the Defense Threat Reduction Agency makes a case for a reanalysis of the nation's nuclear needs. "Our nuclear weapons stockpile is optimized for a threat that no longer exists," Younger writes.



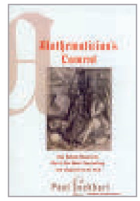
Younger offers a straightforward account of nuclear weapons: how they were developed, how they work and how they forced humankind into constant vulnerability, straddling the line between mutually assured destruction and peace.

Because the weapons cannot be uninvented, Younger argues, the United States should take a close look at what to do with the ones it has. Maintaining current stockpiles indefinitely, he says, will be impossible without testing the weapons to make sure that they still work after years of sitting around.

Though Younger takes a middle-of-the-road approach and his tone is mild-mannered, his position as a former nuclear weapons developer gives his insight authority. He explains what types of weapons are effective for what types of targets. He also emphasizes the importance of accurate intelligence and precision in delivery. New non-nuclear technologies, he says, are superior in some cases.

The Bomb is probably too broad for A-bomb buffs or others with detailed weapons knowledge. But it does offer a good introduction and explores considerations for future policy.
— *Elizabeth Quill*

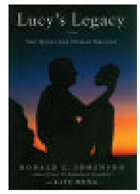
Ecco, 2009, 238 p., $26.99.



A Mathematician's Lament: How School Cheats Us Out of Our Most Fascinating and Imaginative Art Form

Paul Lockhart

Prevailing math education makes the grade but misses the meaning, a teacher argues. *Bellevue Literary Press, 2009, 192 p., $12.95.*



Lucy's Legacy: The Quest for Human Origins

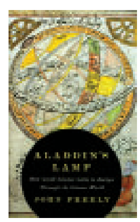
Donald C. Johanson and Kate Wong

Lucy's discoverer and a science writer detail advances in paleoanthropology. *Harmony Books, 2009, 309 p., $25.*

Dead Pool: Lake Powell, Global Warming, and the Future of Water in the West

James Lawrence Powell

The draining reservoir is a bellwether for water supplies in the American West. *Univ. of California Press, 2009, 283 p., $27.50.*



Aladdin's Lamp: How Greek Science Came to Europe Through the Islamic World

John Freely

Science survived the Dark Ages in the sanctuary of the Middle East. *Knopf, 2009, 303 p., $27.95.*

Elephant Reflections

Photographs by Karl Ammann, Text by Dale Peterson

A photographer's lens brings this pachyderm into focus. *Univ. of California Press, 2009, 272 p., $39.95.*

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Tobacco for adults, cocoa for kids

I was interested in the report of cacao-beverage use by people of Chaco Canyon in New Mexico as early as A.D. 1000 ("Hot chocolate, with foam please," *SN: 2/28/09, p. 14*). In the late '50s, I and others at the Philip Morris Research Center looked at pipe samples from the Four Corners area (Arizona, New Mexico, Colorado and Utah) dating from about A.D. 900. The pipes were submitted by archaeologists from the University of Arizona who wanted to know if tobacco had been used.

Initially, microscopy showed plant structures similar to tobacco and also possibly corn silk. Having seen physical evidence for tobacco, we proceeded chemically by extracting, back extracting and looking for evidence of nicotine. Paper chromatographic examination showed nicotine in some but not all samples and we published a short note in *Science* (Gager, F.L.; Johnson, V.C.; Holmes, J.C. *Science*. October 14, 1960). Over a period of years, we looked at additional materials using gas chromatography/mass spectrometry.

Years ago, we wondered whether men smoked the tobacco and children smoked corn silk. Perhaps adults smoked tobacco (and other things) and the children drank cocoa!

Forrest L. Gager, Jr., Lynchburg, Va.

First words

The article by Laura Sanders about the correlation between early gesturing and vocabulary ("Kids' gestures foretell better vocabularies," *SN: 3/14/09, p. 17*) really struck me.

Humans do a lot of gesturing in response to music. Evolutionary pressure must have driven protohumans to be able to produce a wide array of sounds from high to low. Melody surely was in us very early on and is in us still. Tunes stick in our minds, serve as excellent mnemonic devices and eloquently express our feelings.

Whales, birds and people sing. Is it not plausible, since speech doesn't require much pitch change, that singing — lullabies, love songs, territorial assertions, joy and sadness — predated language? Surely it was at least a part of language development. Does singing to a tiny baby aid in learning to speak?

P.M. deLaubenfels, Corvallis, Ore.

Researchers have indeed found that human songs share properties with the songs of whales and birds, including the "call and response" format, melody retention with key changes and harmonic relationships. The deeply rooted ability to sing suggests that songs may have been around before human speech, but unfortunately, theories about the origins of music rely heavily on guesswork.

Some researchers think music might be a by-product of language, while others think that music arose from social needs, such as establishing group cohesion or territory. Several of the same brain regions important for speech are also important for music, so it's plausible that strengthening one brain region by singing or speaking might also enhance the other. Studies on the role of music in speech development remain preliminary, but more is sure to come soon. — Laura Sanders

Drugs that don't mix

Nathan Seppa's article on the untoward effects of proton pump inhibitors on the blood thinner clopidogrel ("Popular acid blockers don't mix with anticlotting medication," *SN: 3/28/09, p. 11*) raises the question: Does the study suggest anything about the effect of PPIs on a daily dose of aspirin (81 milligrams)— also a blood thinner?

Tom Yount, Nashville, Tenn.

The authors of this study didn't investigate the effect of heartburn drugs (PPIs such as Prilosec or Nexium) on aspirin's anticlotting action. Various small studies have failed to show a clear diminution of aspirin's anticlotting effect from the use of a PPI, though the results are somewhat mixed and that work is ongoing. On the other hand, most studies testing the effect of PPIs in people taking aspirin or other anti-inflammatory drugs have shown that PPIs can prevent or ameliorate the gastric bleeding and ulcers that are common side effects of aspirin. — Nathan Seppa

Hubble first?

Regarding "New eyes on the cosmos" (*SN: 5/23/09, p. 30*): The Hubble Space Telescope was not the first optical telescope in space. See, for example, the earlier Orbiting Astronomical Observatory satellites.

Bobby Baum, Bethesda, Md.

The reader is correct that some U.S. space-based instruments that detected light in the visible wavelengths did precede the Hubble's launch in 1990. According to HST senior scientist David Leckrone, these instruments trained their eyes downward for reconnaissance, earth science and weather observations.

So, Leckrone writes in an e-mail, "Hubble is the first major astronomical optical telescope in space." And, he continues, "is definitely the first astronomical telescope to take full advantage of the observing environment in vacuum, above the distortions produced by the Earth's atmosphere."

The Orbiting Astronomical Observatory satellites, launched from 1966 to 1972, included four missions. Two failed because of power and mechanical troubles. The remaining two carried ultraviolet and X-ray telescopes, spectrometers and photometers but did not collect optical data for visual images.
— Rachel Zelkowitz

Correction: *In "Seeing Better" (*SN: 5/23/09, p. 20*), a statement about the Hubble Space Telescope was incorrect. HST detects light from the ultraviolet to the near-infrared portions of the electromagnetic spectrum, not from the entire spectrum.*

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Sheila Tobias

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Professional science degree may be 21st century MBA

One hundred years ago (in 1908), a group of higher educators launched a new professional master's degree called the MBA. Their aim: to meet the anticipated needs of 20th century business, which would be characterized, they thought, not by product specialty but by bigness. Today, MBA programs graduate about 90,000 students per year and are considered to have provided a singular advantage to American business.

Will the Professional Science Master's, the science-based professional degree created nine decades after the MBA, manage to meet the needs of 21st century private and public enterprises? That's the view (and hope) of the directors of 134 PSM programs at 71 universities, their employer partners and the 2,500 math/science graduates now enrolled.

The PSM is intended for math and science graduates bent on careers at the intersection of science and management. In large public and private enterprises, PSMers serve as lab and project managers and/or work in close collaboration with specialists in finance, intellectual property or regulatory affairs. In smaller startups, they carry responsibilities in both science and management. And in the public sector, their value is just now beginning to be recognized.

Judging by the successful hiring record of graduates, PSMers appear to be getting jobs that need to be filled.

"It's best to think about the PSM not as a step down from the Ph.D. but as a step up from the bachelor's," says Bogdan Vernescu, the founding president of the National Professional Science Master's Association. Eugene Levy, Rice University provost, goes further: "The master's degree will evolve to become the normal expectation of professional careers."

The PSM is filling an educational void as well as an employment void. As late as 1995, fewer than 3 percent of all U.S. M.S. degrees were in the sciences. The M.S. in those fields, earlier a respected graduate-level degree, came to be thought of as a failed Ph.D. Meanwhile the master's degree in engineering continued to be highly respected, in part because engineering was in closer touch with business and industry.

The PSM founders argue that if physics is typical (the American Physical Society estimates that only one in six physics bachelors eventually earns a Ph.D. in physics), then a potential market exists for science and math–trained professionals.

But what is "professional training in mathematics and science" if not preparation for a research career? The PSM needed not just foundation support to launch the new degree (provided by the Alfred P. Sloan Foundation in New York City and the W.M. Keck Foundation in Los Angeles), but a change in presumptions about who will do science and why.

From 1997 to 2002 some 20 science master's programs were established (the term PSM came later), providing an initial proof of concept. University faculty and deans engaged local employers in identifying future employment opportunities for master's level science and mathematics graduates. Students (especially women) were attracted by the curriculum and the relatively short two years it would take to become professionally trained. And faculty found the students academically strong.

The heart of the PSM is the combination of graduate-level science and/or mathematics, often in a newly emerging discipline (such as bioinformatics) or at the intersection of two or more traditional ones. Absent a thesis, students enroll in short courses in business fundamentals, tech transfer, project management, intellectual property law, regulatory affairs, entrepreneurship, leadership and/or ethics — which, with training in communication (written and oral) and team building, constitute up to 30 percent of the students' studies.

Needed: A change in presumptions about who will do science and why

Rounding out their program is a required internship (in all but a few of the specialties) for enrollees not currently employed in a high-tech enterprise.

Today, the PSM is poised for expansion. In addition to campus-based programs, there are university system-wide adoptions in California, New York, Illinois, Massachusetts and North Texas as well as state-wide collaboratives in Oregon and Arizona. More are planned in Florida, New Mexico, Pennsylvania and Virginia.

All of these energetic initiatives have been launched without significant government support — so far. But this month, that will change. The National Science Foundation is rolling out a program for spending $15 million in economic stimulus funds for the PSM. The new Veterans Education Bill, which includes support for graduate education, will go into effect in August. State-level veterans offices are already eyeing the PSM (and pre-PSM certificates) as a natural way back into the workforce for technically trained officers. ■

Sheila Tobias has been a consultant with the Alfred P. Sloan Foundation on PSM development since 1997. Info at www.sciencemasters.com or www.npsma.org

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