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ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ JANUARY 17, 2009

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JANUARY 17, 2009 • VOL. 175 • NO. 2


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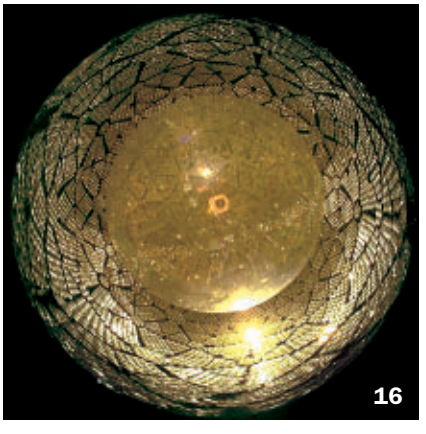
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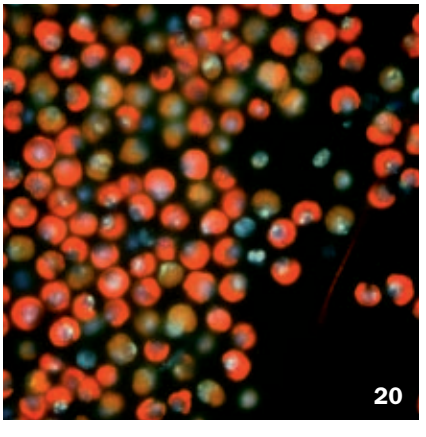
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ScienceNews

In The News

Features

Departments

COVER New computer technologies are helping scientists piece together the puzzle of facial attractiveness. *Photograph by Cary Wolinksy. Sculpture by Jason Loik.*

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FROM THE EDITOR

Thread of information ties diverse sciences together

Faces, neutrinos and consortia of microbes do not at first glance seem very much alike. But they do, in fact, have a lot in common.

They are, most obviously, all examples of vibrant arenas of scientific research, thus meriting the feature stories appearing in this issue.

More subtly, they illustrate a common theme that traverses disciplines, in these cases psychology, physics and biology. Each of this issue's features describes research deeply involved in the link between science and information.

People perceive a face as attractive (or not) based on the information it conveys. And as News Editor Elizabeth Quill reports (Page 24), that information is sometimes so subtle that it doesn't reach conscious awareness — computers trained on human preferences are somehow able to ferret it out, though. Neutrinos generated within the Earth (actually, as freelance writer Diana Steele points out, antineutrinos) carry information about the composition of the planet's interior (Page 16). And biologists have begun enlisting groups of bacteria to perform complex tasks, as freelancer Susan Gaidos describes (Page 20), taking advantage of the curious ability that microbes have to communicate information among one another.

Information's central role in science is in one sense almost trivial — science is, in essence, an enterprise that seeks information about nature. But analyzing and interpreting physical and biological phenomena in terms of information is relatively new, a byproduct of the rise of digital computers in the second half of the 20th century. Nowadays computing or information processing has become popular both literally and metaphorically for conceptualizing all sorts of scientific processes, from information-theoretic approaches in neuroscience to advances in quantum information theory and DNA computing.

A few years ago I wrote a book about all this, citing such examples; since then, further instances of information-based approaches to a wide range of scientific disciplines have continued to proliferate. From the molecules of the immune system to the isotopic composition of rocks, information is everywhere. You can find examples of scientists exploring information in almost any issue of *Science News* (see Patrick Barry's story on phononic memory on Page 10 of this issue).

And that illustrates another major connection between science and information — science journalism. Just as science is all about discovering information about nature, science journalism is all about disclosing information about science, to people who are interested in knowing about it. That's what *Science News* does.

— Tom Siegfried, Editor in Chief

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Scientific Observations

"Sometimes it is really very hard for us to find each other even on this planet, so finding life on another planet is a nontrivial occupation.... How do you try to get a handle on extraterrestrial life? How do you plan to look for it? How do you know it when you find it?... Very critically, how do we protect it if we find it and not contaminate it, and even perhaps more critically, because this is the only home planet we have, how do we protect us from it while we study it?" PENELOPE BOSTON OF NEW MEXICO TECH, IN A TALK POSTED IN DECEMBER AT WWW.TED.COM

Science Past | JANUARY 17, 1959

PROPOSE CRATER THEORY — Huge bubbles of gas bursting through the moon's surface may be the cause of lunar craters. Two British scientists proposed in a new "blow-hole theory" that gases trapped under the surface when suddenly set free would form craters resembling those observed on the moon. Among other current theories are those attributing the formation of craters to meteorite impacts and volcanoes. The scientists, Drs. A. G. Gaydon and R. C. M. Learner of ... Imperial College of Science and Technology, London, say recent reports of volcanic activity on the moon stimulated them to develop their theory.... Dr. Gaydon had observed blow-holes forming as he was evacuating gas from a flask containing magnesium carbonate.

Science Future

January 25–April 5
Data + Art: Science and Art in the Age of Information at the Pasadena Museum of California Art. Visit www.pmcaonline.org

February 5–7
Delhi Sustainable Development Summit 2009, "Towards Copenhagen: An equitable and ethical approach" to be held in New Delhi. Visit dsds.teriin.org/2009/index.htm

February 15–21
Engineers Week 2009. Visit www.eweek.org

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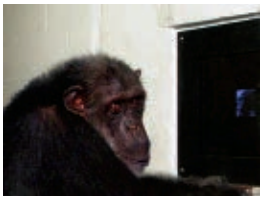
LIFE

Brain areas active when chimpanzees and macaque monkeys recognize familiar faces may be the same regions active for the task in people. Read "Primates get a neural facial."



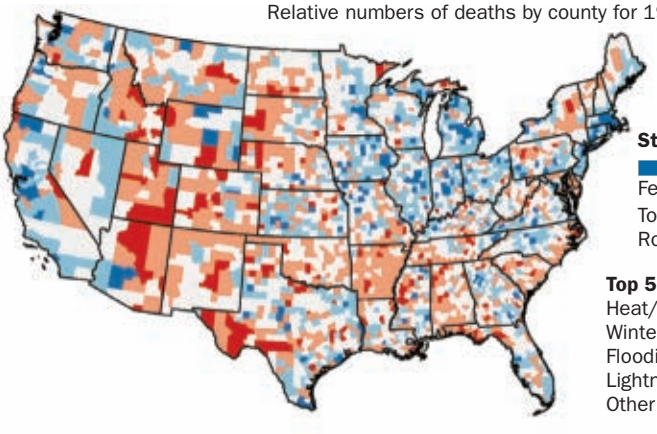
Goldenrods that take a bow are more likely to avoid the pummeling often delivered by gall midges. See "Candy cane strategy sweetens life for goldenrods."

ATOM & COSMOS

Temperature variations in the radiation left over from the Big Bang are different on one side of the sky than the other — enough to suggest a new way of viewing the early universe, a study finds. See "Lopsided universe demands different explanation."

Science Stats | DEATHS FROM NATURAL HAZARDS

Relative numbers of deaths by county for 1970–2004

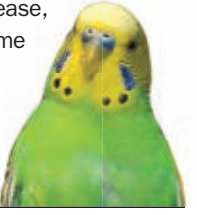


Top 5 causes of death

Heat/drought	19.6%
Winter weather	18.1%
Flooding	14.0%
Lightning	11.3%
Other severe weather	18.8%

How Bizarre

The cause of yawning is hard to study in humans since the activity is contagious. So Andrew Gallup of Binghamton University in New York and colleagues turned to parrots, which don't catch the yawn from peers. The researchers report in the January 2009 *Animal Behaviour* that as ambient temperatures increase, wild budgerigars become up to twice as likely to yawn — suggesting a gaping mouth may cool the brain.



CLOCKWISE FROM TOP LEFT: COURTESY OF PENELOPE BOSTON; YERKES NATIONAL PRIMATE RESEARCH CENTER; ISTOCKPHOTO/EDELMAR; MAP SOURCE: BORDEN AND CUTTER, *INTERNATIONAL JOURNAL OF HEALTH GEOGRAPHICS*

“The results make it more likely that these severed heads were ancestors and not enemies.” — WILLIAM ISBELL, PAGE 12

In the News

STORY ONE

Fermi opens new window on high-energy universe

Gamma-ray telescope detects bursts and pulsars

By Ron Cowen

VANCOUVER — Curtain up! Light the lights! In its first four months monitoring the heavens from orbit, NASA’s Fermi Gamma-ray Space Telescope has unveiled the activity of celestial objects that emit powerful gamma rays — photons that pack 20 million to more than 300 billion times the energy of visible light. The orbiting observatory features the first detectors in space capable of recording the most energetic of these photons.

For now, Fermi’s flurry of initial findings — which include discoveries about gamma-ray bursts as well as a possible new class of pulsars, the rapidly spinning corpses of exploded stars — poses new puzzles. But ultimately the findings will offer new insight into the origin of these powerful emissions and the activity of pulsars, among the most enigmatic objects in the cosmos, says Stanford University’s Peter Michelson, the principal investigator of Fermi’s Large Area Telescope, or LAT, the device that records high-energy emissions.

Michelson and his Stanford colleague Aurelien Bouvier presented their results December 8 in Vancouver at the Texas Symposium on Relativistic Astrophysics. At press time, Fermi researchers were scheduled to report similar findings January 7 in Long Beach, Calif., at a meeting of the American Astronomical Society.

Bouvier’s report focused on gamma-ray bursts, the ephemeral flashes of light that can signal the most powerful explosions in the universe since the Big Bang. Long-duration bursts — those lasting more than a second or two — may be the birth cries of black holes, created as jets of material zoom out of collapsing stars. Short bursts may signal the coalescence of two elderly neutron stars that have been orbiting each other for billions of years.

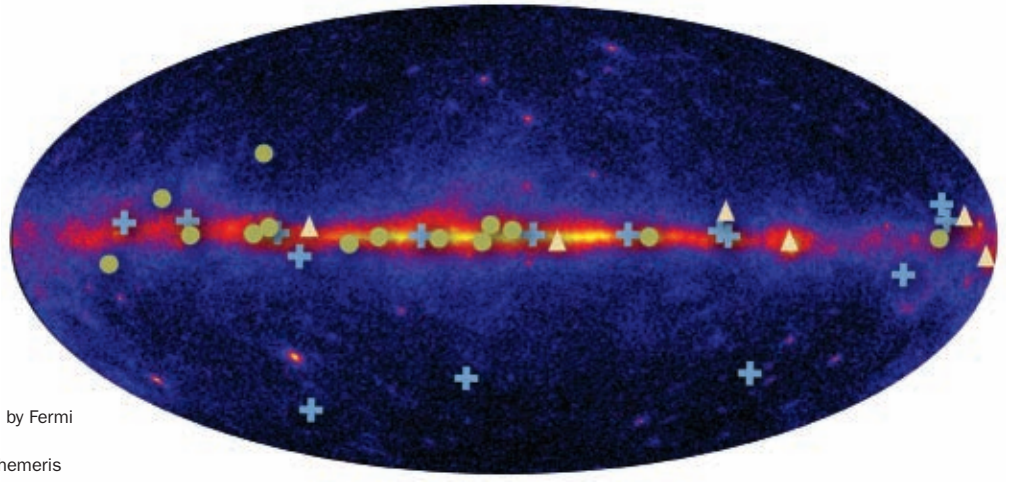
In his talk, Bouvier announced that the LAT had recorded the highest-energy emissions ever detected from gamma-ray bursts. Among a trio of such detections, the telescope did not record any energetic radiation until well after Fermi’s other instrument, the Gamma-ray Burst Monitor, detected the low-energy components of the same bursts.

The time delay between the onset of high- and low-energy emissions — which amounted to five seconds in a burst discovered September 19 — suggests that the high-energy gamma rays from bursts might be produced at different places or by different particles than the lower-energy radiation, Bouvier says. Gamma-ray bursts are believed to be generated when clusters of charged particles in a jet racing out of a collapsed star collide with each other.

Within a jet, it may be easier — and

Fermi’s grand view

This map shows the location in the Milky Way of the 15 radio-silent, gamma-ray–only pulsars detected by the Fermi Gamma-ray Space Telescope, 14 of which had never been observed before. Pulsars detected by Fermi’s predecessor, CGRO, and those previously discovered through radio emissions are shown as well. In the brief time the Fermi telescope has been in orbit, it has also recorded three gamma-ray burst events.



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quicker — for electrons, which are relatively lightweight, to rev up to high speeds and crash into each other, producing the early, lower-energy part of these bursts, he says. And it's possible that protons, which are heavier and thus take longer to accelerate, contribute to the higher-energy component some time later.

Another, more intriguing — and much more speculative — idea may explain at least part of the delay, Bouvier adds.

The highest-energy photons — 13 gigaelectronvolts — from the September 19 event arrived a full 16.5 seconds later than the lowest-energy emissions. Moreover, the burst originated in an extremely remote galaxy, 12.2 billion light-years from Earth. Many theories of quantum gravity predict that spacetime on its tiniest scale isn't continuous but is as malleable and variable as sea foam. Because of this foaminess, not all photons would travel at the same speed. Even though photons have no mass, those with higher energies — which translate into higher gravitational potentials, according to Einstein's $E=mc^2$ — would travel slightly slower through space and arrive slightly later than lower-energy photons. The effect would be tiny, but over a journey of 12.2 billion light-years, it might be detectable.

Two of the three bursts detected by the LAT — the September event and one recorded on August 25 — belong to a class of bursts that last for over a second. But on October 24, the telescope detected a first — extremely high-energy emissions from a short gamma-ray burst, which lasted for only a few tenths of a second.

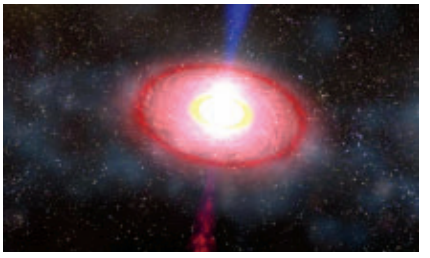
The Fermi data support the idea that although long and short bursts have different origins, "the sources of the outflow in both cases share many similarities and are probably sharing the same physical mechanism," comments Ehud Nakar of Caltech in Pasadena.

Michelson reported that the LAT has now recorded 14 previously unknown pulsars in our galaxy. These pulsars have been found to emit only gamma rays, not radio waves, as most of the 1,800 known pulsars do. If Fermi continues to find gamma-ray–only pulsars at such a high rate, it could indicate that the galaxy has as many gamma-ray pulsars as radio pulsars, says Caltech's Shri Kulkarni.

A theory developed in 1995 by Roger Romani of Stanford and a collaborator may explain why Fermi so quickly found the gamma-ray–emitting pulsars. In that theory, all pulsars emit both radio waves and gamma rays. The region where each type of radiation is generated is determined by the pulsar's strong magnetic field. Gamma rays are emitted from a higher-altitude region and fan out over a wider area than the lower-altitude, narrow beams of radio waves. So gamma rays from pulsars may be more likely than radio waves to sweep over Earth's vicinity and be noticed. The new pulsars were not detected before because their gamma-ray energies were too high to be detected by previous spacecraft.

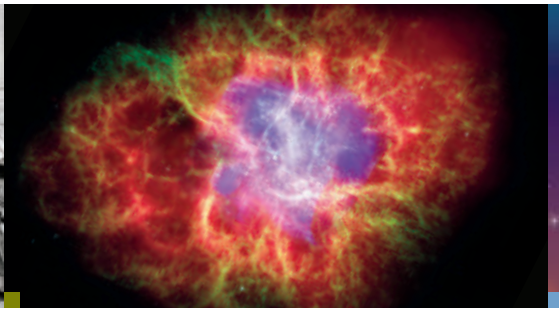
With the new Fermi data, "it's very exciting that we may finally be uncovering the mechanism of these powerful cosmic accelerators," says Romani. ■

Birth of a burst



Jets zoom out from a massive, collapsing star in this illustration. Collisions between parcels of high-speed charged particles within jets are thought to generate long-duration gamma-ray bursts. The Fermi telescope found that the highest-energy gamma-ray emissions from three bursts — two long-duration, one short — lag behind the lower-energy emissions, a finding still awaiting explanation.

Back Story | AT 40-PLUS, PULSARS STILL PACK SURPRISES



1967 Jocelyn Bell and Antony Hewish (shown) discover the first pulsar by recording rapid pulses of radio waves emitted by a celestial object.

1968 Discovery of a pulsar that emits bursts of radio waves 30 times a second at the center of the Crab nebula (shown), the remnant of a supernova witnessed by the Chinese in 1054.

1974 Joseph Taylor and Russell Hulse discover the first pulsar in a binary system, and show that the pulsar is slowing at exactly the rate predicted by Einstein's theory of general relativity.

1982 First pulsar found to spin with a rotation period of just 1.6 milliseconds, about 20 times faster than previous finds.

2008 First gamma-ray–only pulsars found with the Fermi Gamma-ray Space Telescope (illustration shown).

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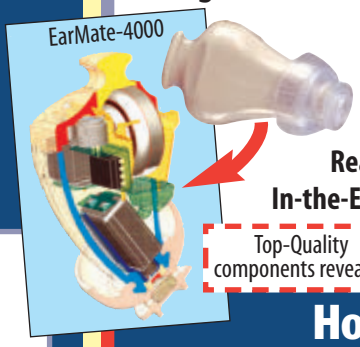

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Body & Brain

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Bacteria make molecular snorkels for surviving in crowded spaces

Antibiotics that fight enemies also provide access to oxygen

By Tina Hesman Saey

SAN FRANCISCO — Antibiotics made by *Pseudomonas aeruginosa* bacteria can serve as molecular snorkels, helping the bacteria breathe even if buried in mucus or squeezed into the middle of a colony.

The finding, reported by MIT researchers Lars Dietrich and Dianne Newman December 16 at a meeting of the American Society for Cell Biology, reveals a new role for antibiotics produced by bacteria. Scientists previously believed that those antibiotics were mainly employed to fend off other bacteria.

P. aeruginosa is a pathogenic bacteria species that is harmless to most healthy people. But for people with cystic fibrosis — a genetic disorder that leads to a buildup of thick, sticky mucus that clogs the lungs and digestive tract — the bacterium is deadly. *P. aeruginosa* invades the mucus, turning it blue-green with antibiotic pigments called phenazines and even destroying lung tissue.

***P. aeruginosa* lacking air-accessing molecules form wrinkled colonies (shown), which may improve oxygen supply.**

The new study reveals that the molecules also help *P. aeruginosa* breathe and can act as communication signals that help shape how communities of the organism grow. Drugs that disrupt the multitasking molecules might provide new treatments for cystic fibrosis, the team suggests.

Oxygen is a scarce commodity in the mucus-clogged lungs of people with cystic fibrosis. Bacteria growing at a colony's outer edges may have access to oxygen, but bacteria buried under their siblings would suffocate without a way to gain oxygen. Phenazines act like molecular snorkels, giving bacteria that are crowded or submerged in mucus access to fresh air, Dietrich says.

Colonies of *P. aeruginosa* that make phenazines grow in petri dishes as smooth, shiny colonies. But bacteria that lack the molecules form wrinkled colonies. Dietrich thinks the wrinkles probably increase surface area to bring more bacteria in contact with oxygen.

The idea that bacteria can use phenazines to access essential nutrients, such as oxygen, is exciting, says Linda Thomashow, a research geneticist with the U.S. Department of Agriculture's Agricultural Research Service in Pullman, Wash. The result fits with her research, which shows that phenazines give bacteria a competitive advantage in soil.

Smoking mice avoid symptoms of emphysema

Edible drug might help fight lung disease in people

By Nathan Seppa

A compound that revs up the production of homegrown antioxidants in the body prevents emphysema from developing in mice exposed to cigarette smoke for six months, a new study finds.

The study, using the experimental drug CDDO-imidazole, or CDDO-Im, appears January 6 in *Proceedings of the National Academy of Sciences*.

Researchers focused on emphysema in mice, but the results suggest that the drug could work in people by delaying or preventing chronic obstructive pulmonary disease, which encompasses emphysema and chronic bronchitis.

CDDO-Im jump-starts a molecule called Nrf2 that in turn switches on a host of genes that encode antioxidants in the body, studies of human and other animal cells suggest. Shyam Biswal, a pulmonary toxicologist at Johns Hopkins University in Baltimore, says these antioxidants seem to counteract the damage caused by exposure to cigarette smoke.

Cigarette smoke assaults lung tissue by introducing highly reactive compounds known variously as free radicals, oxidants or reactive oxygen species. Long-term smoking and the accumulation of free radicals lead to inflammation and cell death, destroying lung tissues.

To test whether CDDO-Im could prevent this damage, Biswal and colleagues exposed mice to cigarette smoke for six months. Some mice had normal levels of Nrf2 protein; others lacked it. Both sets of mice showed lung damage after six months, with animals lacking Nrf2 exhibiting worse symptoms.

The researchers also tested two other groups of smoke-exposed mice that made Nrf2 or not. Some of these animals received ordinary food while others ate food containing CDDO-Im. Mice with normal Nrf2 levels that received the drug fended off emphysema, despite six months of breathing smoke, which caused extensive oxidative damage in the lung tissue of the other mice.

L. DIETRICH

"The majority of people who develop REM behavior sleep disorder ... will eventually go on to develop a neurodegenerative disease." — MARK MAHOWALD

Disorder of REM sleep may signal high risk of Parkinson's, dementia

Thrashing and flailing during night might be a warning sign

By Nathan Seppa

People who kick and lash out while fast asleep in bed face a high risk of developing Parkinson's disease and certain forms of dementia, scientists report.

The condition, called rapid eye movement sleep behavior disorder, results when a person's muscles fail to relax during sleep. "During REM sleep, with the most vivid dreaming, mostly we're paralyzed," says neurologist Ronald Postuma of McGill University in Montreal. "The brain shuts off muscle tone. We want to run, but we can't."

But in people with REM sleep behavior disorder, muscle tone isn't shut down. "As a consequence, you act out your dreams," he says. People with the condition have been known to break a hand on a wall, hurt a spouse or fall out of bed.

Postuma and his colleagues have monitored the progress of 93 people who were diagnosed with the REM sleep disorder between 1989 and 2006 at Sacré Coeur Hospital in Montreal. The team has followed some patients for 15 years or more. Roughly 80 percent are men, and most were enrolled while in their 60s.

Of the 93 participants, 26 have developed a neurodegenerative disease during the study years, the team reported online December 24 in *Neurology*. Of these, 14 developed Parkinson's disease, and seven developed Lewy body dementia, marked by the appearance of Lewy bodies — abnormal protein deposits — in the brain. Four other study participants were diagnosed with Alzheimer's disease, but the researchers suspect that these patients might actually have Lewy body dementia. One person developed a less common neurodegenerative condition called multiple system atrophy.

Among the entire group, the average risk of developing one of these diseases within five years of being diagnosed with the sleep disorder was 18 percent, the scientists calculated. For those monitored for 10 years, the risk was 41 percent, and by 12 years it was 52 percent.

By comparison, in the general population the average lifetime risk of developing Parkinson's disease is only 1 or 2 percent, Postuma says. For developing Lewy body disease, the lifetime risk is roughly 1 to 3 percent.

Researchers at the University of Minnesota in Minneapolis first identified the REM sleep behavior disorder in 1986. "We thought it was a cute clinical observation," says Mark Mahowald, a neurologist at the university. But what started out as an academic curiosity now has been shown to be a serious condition and a harbinger of trouble, he says.

Based on past studies and the new report, he says, "there's now just overwhelming evidence that the majority of people who develop REM behavior sleep disorder ... will eventually go on to develop a neurodegenerative disease."

The sleep disorder is treatable with drugs, such as muscle relaxers, sedatives, anticonvulsants and other psychoactive drugs. But these address only the symptoms and not the underlying problem.

In normal REM sleep, the brain stem — where the brain meets the spinal cord — blocks motor neuron communication. The resulting paralysis keeps people from physically acting out their dreams.

This safeguard is disabled in the sleep disorder, but scientists have yet to sort out how. A key suspect is a protein called alpha-synuclein, which is a component of Lewy bodies. But the precise role of Lewy bodies and alpha-synuclein in these conditions remains unclear, Mahowald says.

NEWS BRIEFS

Morphine sense has gender gap

Sex equality means nothing when it comes to pain relief. Morphine is not very potent in female rats, because females have fewer of the receptors in their midbrains that sense the feel-good drug, rendering morphine "remarkably ineffective," scientists report December 24 in the *Journal of Neuroscience*. Opioid-based narcotics, such as morphine and codeine, are detected by proteins in the brain called opioid receptors, which bind to the drugs and trigger pain relief. Female rats are known to require twice the amount of morphine as males to get comparable pain relief, says study author Anne Murphy of Georgia State University in Atlanta. Murphy's team found that male rats have significantly more opioid receptors in a part of the midbrain than female rats, suggesting that males may respond better to morphine because they are better able to sense it. —*Laura Sanders*

For preemies, less is more

The decades-old practice of giving multiple courses of steroids to pregnant women at risk of delivering prematurely may actually cause harm to the baby, a study in the Dec. 20/27 *Lancet* shows. Kellie Murphy of the University of Toronto in Canada and collaborators looked at 1,858 pregnant women who were at high risk of giving birth prematurely. All received one course of steroids; some received additional courses of steroids, others a placebo. Babies exposed to more doses of steroids weighed less, were shorter and had a smaller head circumference at birth than babies exposed to the placebo. —*Laura Sanders*

Matter & Energy

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Digital memory gets hot, in theory

Controlled heat flow may one day store computer data

By Patrick Barry

Someday, computers might store information using not only electric charges or magnetism, but also tiny packets of heat called phonons. Such heat-based memory is theoretically possible, new research shows. What's more, this memory would be durable and could be read without destroying the information — two key requirements for useful data storage.

Circuits based on quantum packets of heat rather than electric charges could enable computers to use waste heat to perform computations and store data, scientists report online December 29 in *Physical Review Letters*. A recent surge of research on the physics of controlling the flow of heat packets has yielded designs for heat-based diodes, transistors and logic gates that perform AND, OR and NOT operations.

"This is a promising field," says Baowen Li, a physicist at the National University of Singapore who, with his colleague Lei Wang of the Renmin University of China in Beijing, designed the thermal memory. Heat-based circuits are "not only an alternative way for information processing, but a new science and technology in controlling heat flow. This, we believe, will revolutionize our daily use of heat and can help human beings save energy and live in a more environmental world."

Unlike the electrons in an electric circuit, phonons in a thermal circuit are not actually particles. Instead, phonons are discrete units of vibration among the atoms in a solid. The stronger these vibrations are, the hotter the solid will be. Phonons travel through heat-conducting materials just as electrons travel through electrical conductors.

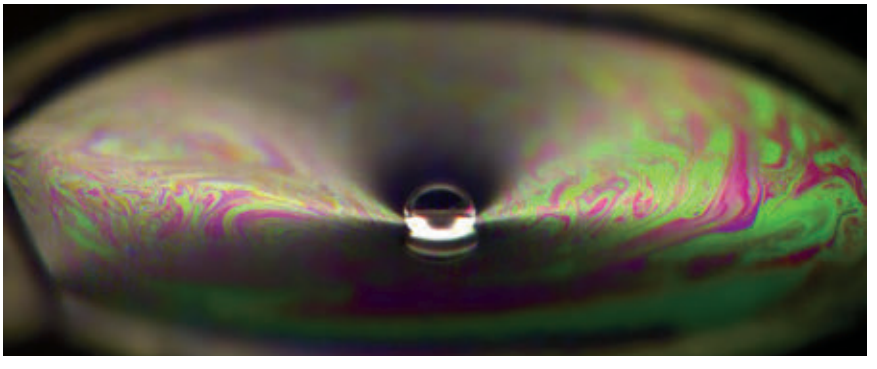
In the new work, Li and Wang did not actually build a heat-based memory device. Instead the researchers used computer simulations and theoretical calculations to show that such a device is indeed physically possible.

Normally, concentrated heat tends to dissipate over time, which would seem to make heat-based memory impossible. But Li and Wang show that, under certain conditions, information stored as phonons can be preserved. As a rule, heat flows faster when the temperature difference between two materials is greater, which is why a red-hot burner will heat a pot of water faster than a burner on medium. But the team previously showed that materials can be designed to work in the opposite way, so that a greater temperature difference causes heat to flow more slowly. This reversed response is what allows phonons at one of two temperatures — representing the "on" or "off" of digital memory — to stay at that temperature long enough to make the thermal memory useful.

"The two stable states of the thermal circuit are like two separate, deep valleys," Li explained by e-mail. "It is quite hard to move from one valley to the other because there is a high barrier (mountain) in between."

If verified in lab experiments, heat-based memory would be a boon for those interested in manipulating phonons.

The new work "certainly adds one more important element to the emerging field of phononics," comments Chih-Wei Chang, a physicist at the University of California, Berkeley. "This work reminds us that phonons, like electrons, are also information carriers. So maybe one day people can have phononic devices that transmit, process and record information just like electronic devices that have shaped our world." ■



JOHN BUSH, TRISTAN GILET/MIT

Water on soap is recipe for chaos

It might be the simplest recipe yet for using fluids to explore the world of chaos theory: a droplet bouncing on a "trampoline" made from a thin film of soapy water, which is itself moving up and down as if on a spring. In a study recently accepted for publication in *Physical Review Letters*, researchers show that quickening the movement of the trampoline causes the droplet's rhythmic bouncing to become more complex, eventually crossing the threshold into chaotic behavior. Chaos in mathematics does not refer to randomness or mayhem. It simply means that the behavior of a system is extremely sensitive to minuscule differences in how the system starts out, making it impossible to predict what the system will do in the long term. "The nice thing about this system is it's described by a simple [equation]," says John Bush, coauthor of the study and director of the Fluid Dynamics Laboratory at MIT. "It's sort of a textbook example." — *Patrick Barry*

AS HEARD ON PAUL HARVEY NEWS

Accept no imitations – EdenPURE® can cut your heating bill up to 50%

Heats a large room in minutes with even heat wall to wall and floor to ceiling

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

EdenPURE® PATENTED TECHNOLOGY IS NOW EVEN BETTER

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

The new EdenPURE® GEN3 heater heats better, faster, saves more on heating bills and runs almost silent.

The federal government has reported that heating bills are expected to reach a record this year. For some people, heating bills will increase up to 50% compared to last year.

The EdenPURE® can pay for itself in a matter of weeks and then start putting a great deal of extra money in your pocket after that.

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

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

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

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

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

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

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

Never be cold again

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

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

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

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

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

End of interview.

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

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

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

This product has been listed by Underwriters Laboratories.

While other portable heaters and fireplaces may make the claims –

Accept No Imitations!

There is only one EdenPURE® Advanced Infrared Portable Heater.

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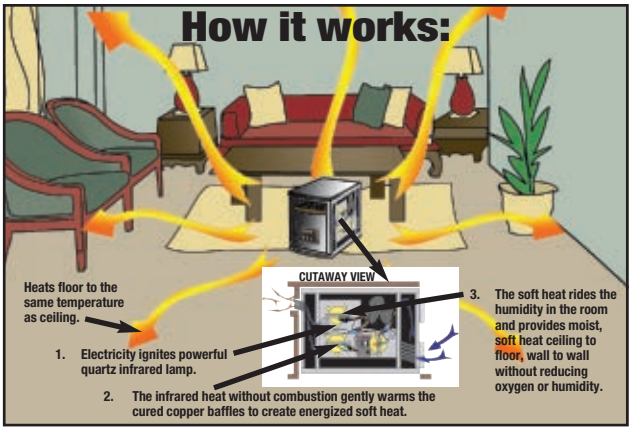

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Humans

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Taking trophy heads close to home

Ritual skulls may be from local people, not foreign warriors

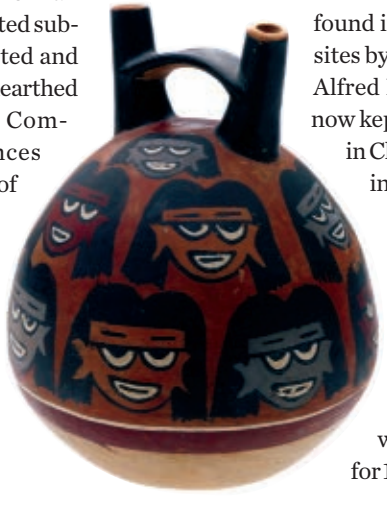
By Bruce Bower

In South America's ancient Nasca culture, some local folk literally lost their heads so that everyone else might fill their bellies. The Nasca obtained trophy heads—human skulls modified in various ways and intended to spur successful farming—from their own people, not from foreigners slain in battles and raids as other prehistoric societies of that region, including the Inca, did, a new study finds.

Earlier analyses of paintings on Nasca pottery had suggested that members of this culture believed that the taking of trophy heads provided the supernatural power needed for crop growth. Since the first Nasca trophy heads were discovered nearly 100 years ago, scientists have debated whether these items came from vanquished enemies or from local individuals thought to represent venerated Nasca ancestors.

"Rather than obtaining heads from enemy warriors through geographic expansion or warfare as seen in other parts of the world, we argue that Nasca trophy heads derived from the local Nasca population," says archaeologist and study director Kelly Knudson of Arizona State University in Tempe.

The finding comes from an analysis of the diet-related substances that had collected and remain in the teeth of unearthed Nasca trophy heads. Comparing these substances with those in the teeth of skeletons known to be from Nasca individuals shows that one set of trophy heads came from the Nasca themselves, Knudson's team reports online December 11 in the *Journal of Anthropological Archaeology*.



A Nasca ceramic vessel bears paintings of disembodied heads, which were sometimes prepared as ritual trophy heads.

Such data can't rule out the possibility that the trophy heads were acquired in fights between local Nasca groups, remarks William Isbell of Binghamton University in New York. "We can't draw any final conclusions from this new study," he says, "but the results make it more likely that these severed heads were ancestors and not enemies."

Nasca culture existed in the coastal lowlands of what is now southern Peru from about 2,000 to 1,250 years ago. The society included a large ceremonial city that hosted pilgrims, feasts and other ritual events. Political complexity and warfare increased during the culture's final 200 years.

Much archaeological evidence suggests that local Nasca groups sometimes engaged in battles and raids among themselves, in line with Knudson's finding, comments Kevin Vaughn of Purdue University in West Lafayette, Ind.

Nasca sites of various ages have yielded more than 150 trophy heads, often found in graves as offerings to the dead and in public buildings. Most come from men.

Knudson's team studied 16 trophy heads found in 1925–26 at five Nasca sites by the late anthropologist Alfred Kroeber. All the heads, now kept at The Field Museum in Chicago, had a hole drilled in the forehead for a carrying cord, a common feature of trophy heads.

Biochemical profiles of tiny amounts of tooth enamel taken from these trophy heads were compared with corresponding data for 13 intact Nasca skeletons already excavated from any of three Nasca cemeteries. Scientists measured levels of forms of strontium, oxygen and carbon in the ancient teeth, and compared these measurements with baseline levels found in rocks, water, plants and small animals throughout the Nasca region.

This Nasca trophy head, found in a tomb in Peru, may have belonged to one of the Nasca's own, not an enemy.

Signature ratios of different forms, or isotopes, of strontium, oxygen and carbon reflect where a person lived and what types of foods he or she consumed.

Overall, teeth from the trophy heads and from the comparison group displayed no substantial differences in the ratios of these substances. It's thus likely that individuals from both groups lived in the Nasca region, Knudson says.

In support of that view, unpublished work by study coauthor Kathleen Forgey of Indiana University Northwest in Gary indicates that mitochondrial DNA sequences from the Kroeber trophy heads closely resemble corresponding DNA sequences from intact skeletons.

Pottery from late Nasca periods does feature warriors holding or wearing trophy heads. "It is possible that warfare was a more common part of trophy taking toward the end of the Nasca culture," Knudson says.

FROM TOP: THE FIELD MUSEUM 1694.170150/JOHN WEINSTEIN; THE FIELD MUSEUM 1694.171355/JOHN WEINSTEIN

Earth

1,050° Celsius — Temperature of magma tapped from beneath Kilauea

First a meteorite, then a tsunami

Relics of impact, aftermath in Hudson River sediments

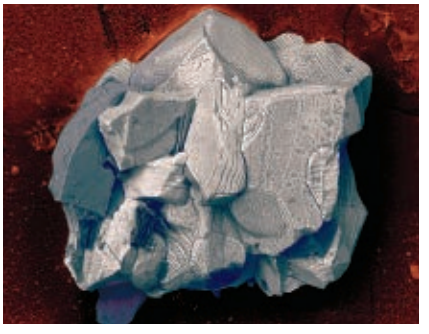
By Sid Perkins

An odd layer of material found in bodies of water from Long Island Sound to the Hudson River indicates that what is now New York City suffered a tsunami about 2,300 years ago. If that weren't disturbing enough, evidence in the sediments hints that the massive wave was the result of an extraterrestrial object striking somewhere offshore.

Samples drilled from Hudson River sediments at sites between 10 and 20 kilometers upstream of Manhattan contain a sediment layer filled with distinct debris. Carbon dating of organic material dates the layer to about 2,300 years ago, says Dallas Abbott, a geologist at Columbia University's Lamont-Doherty Earth Observatory in Palisades, N.Y.

Similarities between layers of sediment in Long Island Sound and layers on the continental shelf more than 100 kilometers offshore are a sign that the event that deposited the layers was large-scale, Abbott notes. A lack of quake-producing faults nearby suggests an earthquake did not cause the tsunami.

Instead, Abbott and her colleagues report, debris layers in the Hudson River sediments host hallmarks of an extraterrestrial impact. Most prominent are nanodiamonds, almost exclusively related to impacts.



Crystals of ilmenite bear scars from the shock of an extraterrestrial impact.

D. BREGER, DREXEL UNIVERSITY

Scientists tap into deep magma

In a first, engineers drill into molten rock below volcano

By Sid Perkins

Engineers drilling a new well at a Hawaiian geothermal site struck liquid gold — molten rock that is giving geologists an unprecedented peek at how magma cools into solid rock. "This is the first time scientists have encountered magma in its true natural habitat" deep below ground, says study coauthor Bruce Marsh, a geologist at Johns Hopkins University in Baltimore.

The Puna Geothermal Venture on the slopes of Kilauea volcano uses subterranean heat to produce about 20 percent of the Big Island's power, says geologist William Teplow of U.S. Geothermal Inc. in Boise, Idaho.

In 2005, drillers encountered resistance at a depth of about 2.5 kilometers. They raised the equipment and stopped drilling for a while. When they resumed, the drill tip struck solid rock at a point about eight meters higher than where they'd stopped. The geologist on duty noticed that the rock cuttings brought to the surface were clear bits of mineral, not the normal black bits of chewed-up basalt. The chemical makeup of the cuttings was the final clue. Teplow and his colleagues realized that they'd struck a pocket of molten rock, some of which had oozed up the drill hole and then solidified. The magma is likely the uncrystallized portion of a mass that flowed into the chamber during a 1955 eruption.

MEETING NOTES

Corals track rainfall

Corals off the shore of a Hawaiian island may serve as monitors of the region's groundwater flow and past climate. As they grew, the corals absorbed the isotopic signature of groundwater seeping into the shallows offshore, thus recording changes in groundwater volume. Those changes reflect variations in the island's rainfall, reports Nancy Grumet Prouty, a geochemist at the U.S. Geological Survey's Pacific Science Center in Santa Cruz, Calif. Coral hard parts are mostly calcium carbonate, but as the creatures grow, their skeletons also incorporate elements dissolved in seawater, including the yttrium common in the island's groundwater. — *Sid Perkins*

Warmer water, more rain

If sea-surface temperatures in the tropics keep rising, storms there could become more severe. The rise of warm, moist air drives the growth of "thunderheads" — the massive and extremely tall clouds that generate the most severe thunderstorms. George Aumann and Joao Teixeira of NASA's Jet Propulsion Laboratory in Pasadena, Calif., report that data from a NASA satellite show the downpour-producing clouds are more frequent over areas where ocean temperatures are warm. The finding bolsters a previous study showing an increase in global rainfall with warming climate. Given estimates that Earth's average temperature is rising about 0.13 degrees Celsius per decade, Aumann says, the frequency of strong storms in the tropics will probably increase about 6 percent each decade. — *Sid Perkins*

Life

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Dinosaur dads as caretakers

Fossilized bones near nests probably came from males

By Laura Sanders

Male dinosaurs probably sat on nests and cared for young, new analyses of fossilized eggs and bones suggest. The results, published by paleontologist David Varricchio and colleagues in the Dec. 19 *Science*, indicate that the parental division of labor of some modern-day birds may have first evolved in the birds' dinosaur ancestors.

"I think it's more interesting than the authors know. This answers all sorts of questions about bird behavior," says Yale University ornithologist Richard Prum.

Male *Troodon* dinosaurs may have been the primary caregivers for their young (illustration at top), sitting on eggs such as the fossilized ones shown (bottom).

Large, generally flightless birds called ratites, which include emus, ostriches and rheas, are closely related to dinosaurs. Males of these avian groups shoulder the bulk of childcare responsibilities. Ratite fathers incubate eggs, defend the nest from predators and look out for the hatchlings. What's more, mom and dad share child-rearing duties in about 90 percent of bird species alive today.

Fossils of adult *Troodon*, *Oviraptor* and *Citipati* dinosaurs — all meat-eating, bipedal theropods — have been found on or near a clutch of eggs. Some adults were even caught in a brooding position (like a sitting hen), raising suspicions that the adults died in the act of caring for the brood. But scientists didn't know whether the adults sitting on the nest were fathers or mothers.

Varricchio's team found no female-specific markings on bones from two adult dinosaurs: a *Citipati*, fossilized in the brooding position on a clutch of eggs, and a *Troodon,* fossilized while at a nest site. Many female birds have medullary bone, a spongy, disordered layer lining the insides of long bones, probably serving as a nutrient source while the female formed eggs. Medullary bone has also been found in *Tyrannosaurus* and *Allosaurus* species.

The absence of this female-specific marker in the *Troodon* and *Citipati* bones led Varricchio, of Montana State University in Bozeman, to conclude that these two adults were most likely males. Varricchio notes that figuring out a dinosaur's sex is tricky, and the absence of the medullary bone layer, while a good argument for maleness, is not conclusive.

The researchers also compared the size and number of fossilized eggs, from 22 to 30 large eggs per clutch, with those in nests of modern birds. The unusually large size of the dinosaur clutches was similar to the clutches of birds that exhibit paternal care. Both the large clutch size and the malelike bones of adult dinosaurs make it likely that dinosaur dads looked after the kids, the team reports. ■

Honeybees may provide plants a protective buzz

Pest caterpillars eat less when pollinators zoom by

By Susan Milius

Traffic noise — honeybee traffic, that is — can be a bane for caterpillars and a boon for plants.

The buzz, buzz, buzz of foraging honeybees zipping overhead can keep caterpillars below from getting enough peace and quiet for a full meal, says Jürgen Tautz of the University of Würzburg in Germany.

In tests, bee flight-path distractions took such a toll on dining that caterpillars ate only about a third of the leaf area they consume in a bee-free zone, Tautz and his Würzburg colleague Michael Rostás report online December 22 in *Current Biology*.

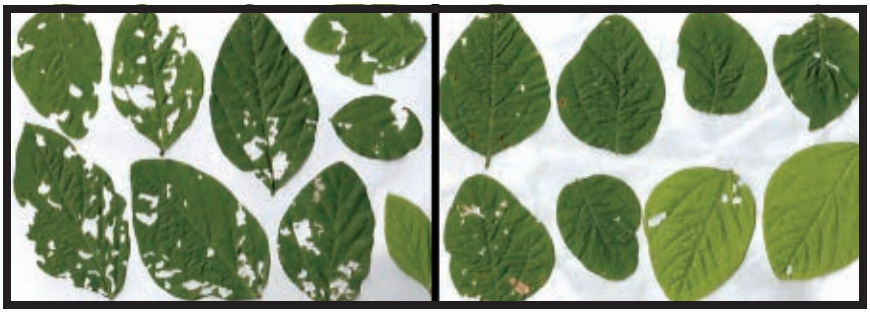
Bee-traffic noise as a pest deterrent is "a very cool and novel idea," says Jeff Conner of Michigan State University's W.K. Kellogg Biological Station in Hickory Corners. Earlier work, including his, showed that pests eating at plants make the plants less attractive to pollinators, but "this new study turns that idea on its head," he says. The pollinators are making plants less attractive to pests.

So far Tautz has tested the idea only in a strictly controlled setup. He and his colleagues put up a pair of tents housing arrays of plants. In the various runs of the test, researchers used bell pepper plants, once with and once without fruits, as well as soybean plants. A beehive opened into one tent, and some 50 bees at a time buzzed over the plants on the way to collecting sugar water from feeders in the corners.

Tautz chose *Spodoptera exigua,* the beet armyworm, as a sample pest. This caterpillar feeds on some 50 plant species. Army-

FROM TOP: BILL PARSONS; MUSEUM OF THE ROCKIES; FACING PAGE: HELGA R. HEILMANN, BEEGROUP, *CURRENT BIOLOGY*

"Alternating rows of vegetables and flowers not only look beautiful, they may reduce the use of pesticides." —JÜRGEN TAUTZ



Leaves from soybean plants left for about two weeks in tents with caterpillars suffered more damage from the pests' munching when bees were excluded (left) than when the pollinators zipped back and forth over the plants (right).

worms are relentless munching machines, but they stop moving, and sometimes drop off their perches, if a wasp flies by. Plenty of wasps eat caterpillars, and Tautz says that he has found sensory hairs on caterpillars, including beet armyworms, that detect the wasps' wing beats.

Honeybees don't hunt caterpillars, but Tautz says he was out walking his dog one day, listening to the buzz of bees, when it occurred to him that, to a caterpillar, bees' wing beats might sound similar to the wasps' wing beats.

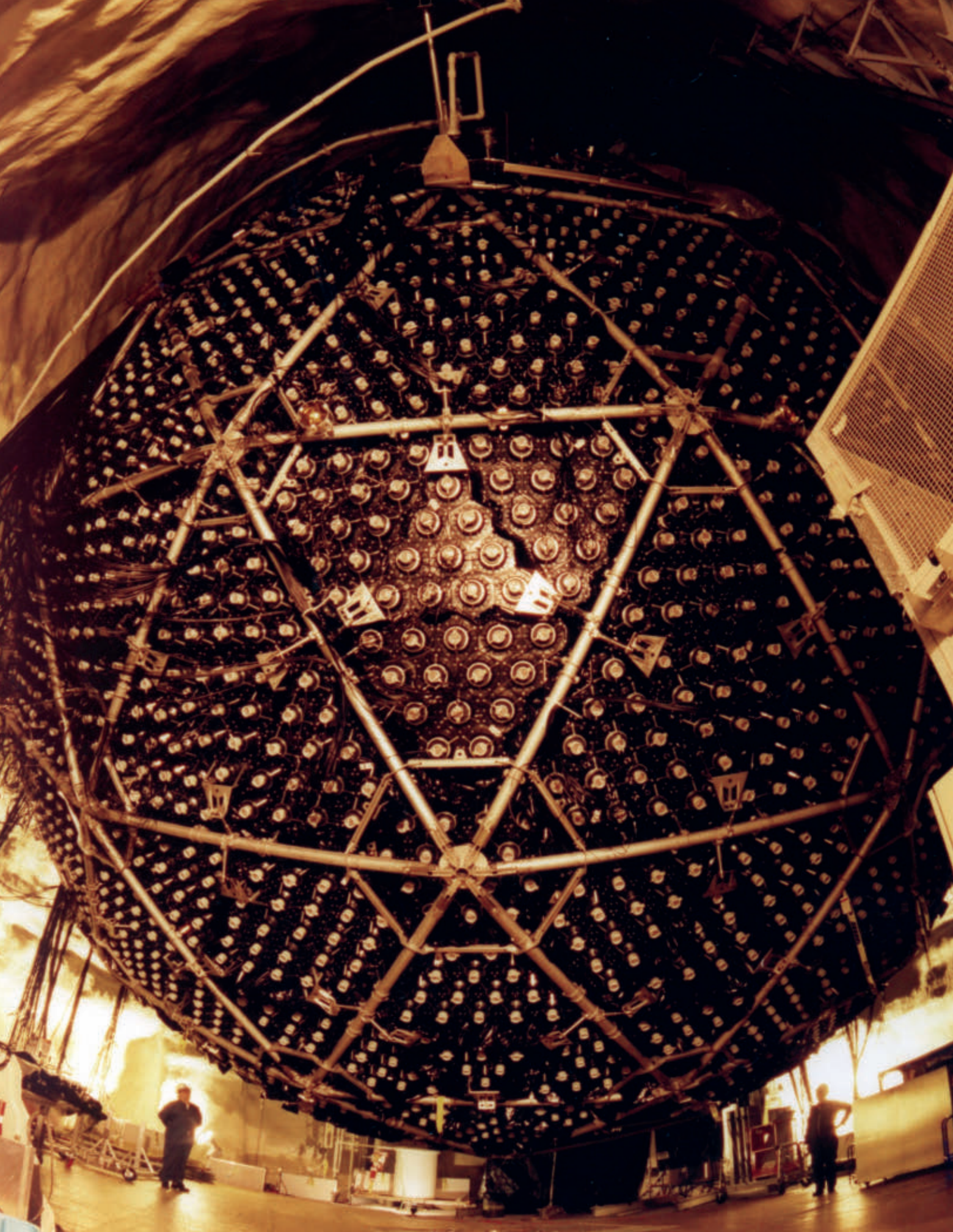
That seemed to be the case in his experiments. In tents with bees flying over plants without fruit, caterpillars did less damage to leaves than in quiet tents, the researchers report.

In the tent without bee traffic and with peppers already forming on plants, the quiet didn't make as much of a difference in leaf damage. But that's because caterpillars took advantage of the bee-free peace to move off the leaves and start eating the peppers themselves, Tautz says.

Conner says that protection from traffic noise doesn't necessarily indicate any plant evolution that promotes this phenomenon. It could just be a happy side effect of pollination.

Whatever the history, it makes a good example of hard-to-spot indirect relationships between species in ecosystems, Tautz says.

Also, he says, he can imagine that gardeners might someday take advantage of this effect. "Alternating rows of vegetables and flowers not only look beautiful, they may reduce the use of pesticides," he says. ■



For a big view of inner Earth, catch a few ...

geoneutrinos

By Diana Steele

Were the Earth a crystal ball, you might gaze 2,900 kilometers down to its outer core with a telescope. The Earth, though, is frustratingly opaque — to light. Most knowledge of the planet's internal structure comes from studying seismic waves, which give a kind of ultrasound image. Inferences about Earth's internal chemistry rely on the elements found in near-surface rocks, meteorites and the sun.

Recently, geoscientists have developed a new tool for probing the Earth's innards. Borrowing a page from astrophysics, they are using the curious subatomic particles known as neutrinos. Astrophysicists have used neutrino telescopes for decades to study neutrinos originating in the sun and elsewhere in the cosmos. Now earth scientists are taking a neutrino telescope and looking down, to illuminate the Earth's interior by detecting "geoneutrinos" — neutrinos produced within the planet itself.

"Now, for the first time, we have the possibility of measuring the composition of the Earth in real time," says William McDonough, a geochemist at the University of Maryland in College Park.

Geoneutrinos are actually antineutrinos, which are neutrinos' antimatter counterpart, just as positrons are the antimatter partner to electrons. "'Geoneutrinos' is just an easier word to say than 'antineutrinos coming from inside the Earth,'" McDonough says. Electrons and positrons have opposite electrical charges, but neutrinos and antineutrinos have no charge. So neutrinos and antineutrinos, confusingly, may or may not be the same particle.

Geoneutrinos were first observed in a detector deep inside a mine in Japan in 2005. Now an array of proposed new experiments are poised to get an even better glimpse of the Earth's inner chemistry. These range from deep-mine detectors in Canada, the United States and Europe, to a mobile, submersible deep-ocean detector.

McDonough and two colleagues from the University of Hawaii gave an overview of the experiments in October in *Eos*, the weekly newspaper of the American Geophysical Union, and earth scientists discussed new developments with particle physicists at a conference in September in Sudbury, Canada — the site of one of the proposed experiments.

Geoneutrinos originate from the radioactive decay of uranium, thorium and potassium in the Earth's crust and mantle. Earth scientists are keen to learn more about the crucial role the decay of these elements may play in heating up the Earth and, in turn, driving convection in the Earth's mantle.

Powering Earth

"The convection in the mantle is responsible for essentially all of the dynamics of geology that we see — moving continents and seafloor spreading," says John Learned, a particle physicist at the University of Hawaii at Manoa. But whether radioactive decay dominates the heating action or is one of a number of players isn't known. There's even controversy over how much heat, in terms of power, the Earth puts out; estimates range from 30 billion to 44 billion kilowatts.

Energy drives the movement of the geologic plates upon which the continents ride, says McDonough, "and the fuel for that is either entirely radioactive fuel or a subset of energy sources." It's like the energy mix in homes, he says. "We don't get all of our electricity from coal, but some portion from nuclear and some portion from other sources. The question today is, 'What are the energy sources driving the Earth's engine?'"

Among the other possible energy sources is heat left over from the planet's formation by colliding meteorites. These planetary building blocks eventually accreted enough mass to become Earth. As the meteorites slammed into each other, their kinetic energy became thermal energy. Over time, the Earth has radiated this heat into space.

"We could have started out with a large amount of kinetic energy, and we've slowly dissipated it," says McDonough, "or we could have started with a large amount of kinetic energy and rapidly dissipated it, depending on the atmospheric conditions."

It's difficult to measure how much heat might have come from this or other sources. But the new suite of geoneutrino detectors could pin down better numbers for the radioactive contribution.

Estimates are that radioactivity, mainly from uranium and thorium but also from potassium, accounts for at least 40 to 60 percent of Earth's interior heat. These elements are probably most abundant in the crust, the top 30 kilometers or so of rock. But key to understanding Earth's dynamics is knowing the amount of these elements in the mantle — the vast, viscous, slowly churning layer that stretches 2,900 kilometers from crust to the molten outer core.

Originally used to detect elusive particles from space called neutrinos, the four-story detector at the Sudbury Neutrino Observatory could be retrofitted to detect antineutrinos produced by natural radioactivity inside Earth.

COURTESY OF LAWRENCE BERKELEY NATIONAL LABORATORY

Like the better-known solar neutrinos, geoneutrinos can pass through thousands of miles of solid rock without being stopped or even deflected. That makes them ideal for studying deep Earth — but also makes them very difficult to catch.

Catching geoneutrinos

One surefire way to catch some is to build a detector near a concentrated source of antineutrinos. Conveniently, the uranium and other radioactive elements used in a nuclear reactor provide a flood of these ghostly particles.

That's why the first geoneutrino detector was built near a cluster of reactors in Japan, with an aim to further characterize antineutrinos. Consequently, particles from the reactors swamped those produced by naturally occurring uranium in the crust and mantle.

Nonetheless, in 2005, this experiment, called KamLAND (short for Kamioka Liquid Scintillator Anti-Neutrino Detector), provided the first glimpse of geoneutrinos and a first approximation of uranium and thorium's contribution to the Earth's heat. Unfortunately, because the number of geoneutrinos was so small, the estimated heat contribution, in terms of power, had a range of 19 billion to 60 billion kilowatts; consistent with but not more precise than previous estimates.

Since then, the geoneutrino detector Borexino, located in an Italian mine, has come online. And new experiments are on the horizon, though it may be at least two years before the first of the next generation of detectors starts up.

The SNO+, or Sudbury Neutrino Observatory Plus, would sit two kilometers underground in the Creighton nickel mine near Sudbury, Ontario. SNO+ would piggyback on and use the same detector as a highly successful solar neutrino project called the Sudbury Neutrino Observatory, which played an important role in solving a long-standing conundrum. Researchers had detected fewer neutrinos coming from the sun than expected. SNO showed that neutrinos have a tiny bit of mass and are shape-shifters, turning from a detectable form into another, undetectable one.

Converting SNO into SNO+ — which would detect the lower-energy geoneutrinos — means changing out the fluid that filled the detector. SNO operated from 1999 to 2006 using heavy water — water with atoms of deuterium, heavy hydrogen — to snag solar neutrinos. Pending final approval of funding, the detector will be filled with a hydrocarbon-based scintillation fluid, which, when a geoneutrino is caught, will luminesce and trigger the detector.

The fluid is a common, mass-produced petrochemical called linear alkylbenzene, or LAB, used to make clear detergents, like liquid hand soap. It's less toxic than most chemical liquid scintillators.

"It produces a lot of light, and it's very transparent, but it's a safer scintillator," says SNO+ director Mark Chen. "It's much easier to use it, especially in a setting where we are taking a thousand tons of it into an active mine."

The detector is a four-story acrylic sphere surrounded by electronic eyes that scan the fluid for flashes of light characteristic of geoneutrinos' presence.

Chen, a particle astrophysicist at Queens University in Kingston, Canada, hopes SNO+ will start up in late 2010. It should catch about 50 geoneutrinos a year, considerably more than either KamLAND or Borexino. The longer SNO+ runs, the better the picture it will get of the inner Earth.

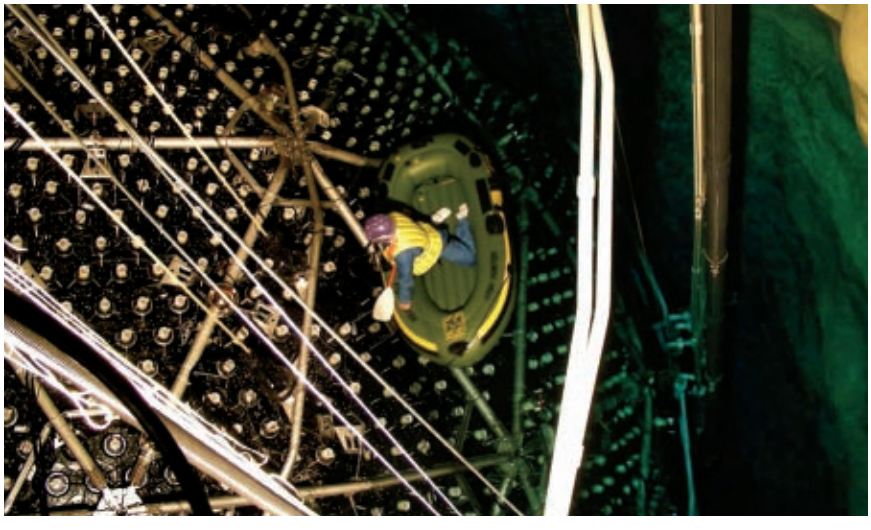
Ontario's nuclear power plants are far enough away to not overwhelm the geoneutrino signal. "Certain problematic backgrounds from cosmic rays are even further reduced because we just happen to be deeper underground than other, similar detectors," Chen says. With SNO+, he says, it will be possible to do some interesting things "with less background and improved precision."

SNO+ has an ambitious scientific agenda that includes better understanding the fundamental nature of neutrinos. One goal is to pin down the mass of the neutrino — a quantity even more elusive than the neutrino itself. Another is to determine whether neutrinos and antineutrinos are the same particle — the lack of charge makes it difficult to tell.

That question "connects to our understanding of the early universe and might inform us about why ... we see matter in the universe but much less antimatter," Chen says.

Mantle signature

SNO+ is the furthest along of the up-and-coming geoneutrino experiments. Other detectors under discussion include one in the Homestake mine in South Dakota and a large detector to be built in Europe, possibly in Finland. Startup and operating costs are estimated to be on the order of hundreds of millions of dollars, and construction

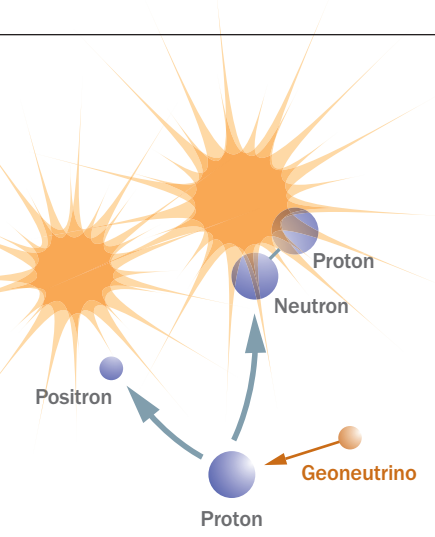


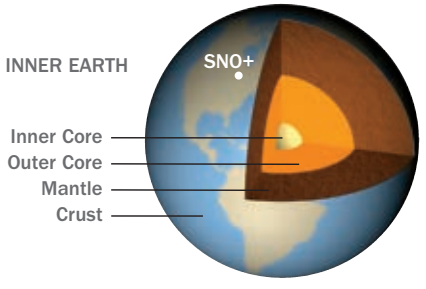
A physicist boats in water surrounding Canada's SNO detector, which is filled with heavy water to detect neutrinos. A new fluid will be used to detect geoneutrinos.

They came from Earth

Like its cousin the neutrino, a geoneutrino (an antineutrino produced in Earth) can pass through Earth unimpeded and, researchers hope, into detectors built to catch it.

At the proposed SNO+ detector in Canada, passing geoneutrinos would collide with protons in fluid inside the detector (bottom right). Such a collision gives off a positron — producing a flash of light — and changes the proton into a neutron (right). When the neutron approaches another proton, the two bond to create deuterium (a heavy version of hydrogen), producing a second flash of light. "You've got a flash associated with the positron production, and 200 microseconds later you have another flash," says University of Maryland, College Park geochemist William McDonough. "And you say, 'Eureka! I've got an antineutrino that's come in.' "





wouldn't begin for at least several years.

These detectors would be, for the most part, counting geoneutrinos that originate in the Earth's crust, where thorium and uranium are concentrated. Looking close to the crust is like having your eye close to a bright flashlight.

To get a better idea of what's going on in the mantle — a dim and more distant flashlight — requires a geoneutrino detector situated in a place where the crust is only a few kilometers thick, like at the bottom of the ocean.

McDonough and his colleagues are proposing a 10,000-ton submersible detector they have named "Hanohano" (Hawaiian for "magnificent"), for the Hawaii Anti-Neutrino Observatory.

Hanohano would be about 10 times the size of the SNO+ detector and filled with the same scintillator fluid. It would be towed out to sea on a barge and sunk, anchored about 4,000 meters deep and about 90 m from the bottom. After catching neutrinos for a year or two, it could be serviced and redeployed elsewhere. Like SNO+, Hanohano will be a multifaceted experiment, with research agendas in astrophysics and particle physics as well as earth science.

With funding, Hanohano could be built within about two years, McDonough estimates. Preliminary design studies for Hanohano are underway, and McDonough is hoping for another $5 million of seed money to continue design. But to construct and deploy Hanohano and to keep it running for 10 years could cost around $200 million, he estimates.

That's expensive, but it's about a factor of 10 less expensive than sending a spacecraft to another planet, points out David Stevenson, a planetary physicist at the California Institute of Technology in Pasadena, who is not directly involved in the geoneutrino experiments. And "it's inconceivable to me that we could get the same information with the accuracy we desire by any other method," he says.

He also hopes for the unexpected. "I've learned as a planetary scientist, that when you go to a planet, you actually discover things, you are surprised," he says. "And in the case of the neutrinos, you may be surprised. You may be surprised, for example, to discover that there's a major source of radioactivity in a layer just above the core" — an idea proposed early last year by Dutch and South African scientists writing in the *South African Journal of Science*.

Another scenario, which Stevenson thinks is extremely unlikely but Learned acknowledges "would be quite cool," is that enough uranium exists in the core that there is essentially a nuclear reactor humming away down there.

San Diego–based independent scientist J. Marvin Herndon first proposed such a core reactor in 1993. Although not widely believed, his hypothesis would explain some puzzling observations, such as an excess of an isotope of helium emitted from volcanoes, Learned points out.

Hanohano would be able to tell fairly quickly whether such a reactor exists at all, Learned reported last May at a neutrino symposium in New Zealand.

For all their promise, these geoneutrino detectors won't be able to unearth the whole picture of Earth's interior.

Stevenson points out that all the geoneutrino detectors proposed share a shortcoming: They can't detect the geoneutrinos coming from radioactive potassium-40. These geoneutrinos have too little energy to trigger the detector.

"So there is one part of the expected heat production that we cannot measure, and haven't figured out how to measure," he says. And although only a tiny fraction of potassium-40 is actually radioactive, and most of it has already decayed over Earth's 4.6-billion-year history, potassium still contribute up to 20 percent of the radioactive heat, Stevenson says.

"But if you go back in time, potassium-40 becomes increasingly important," he adds. "And that's why, if you want to reconstruct the history of the Earth, you would like to know how much potassium you had." ■

Diana Steele is a freelance science writer based in Ohio.

Explore more

- Visit the SNO+ website at snoplus.phy.queensu.ca/

LEFT PAGE: SNO+ COLLABORATION; TOP: GRAPHIC BY J. KORENBLAT; DETECTOR PHOTO COURTESY OF BERKELEY LAB; EARTH IMAGE FROM ISTOCKPHOTO/ALESVELUSCEK

Team Spirit

Working together, bacteria and other microbes can accomplish much more than they can alone. Now scientists hope to harness that ability by engineering their own microbial consortia. By Susan Gaidos

Top: A rich collection of microbial organisms forms a thick, jellylike mat, or ectoplasm, over parts of the extremely salty Storr's Lake on San Salvador Island, the Bahamas. Living together in the mat helps the microbes thrive in this extreme environment. Bottom: Tiny teammates in this natural microbial consortium include (from left) diatoms (eukaryotic algae), the cyanobacterium *Microcoleus chthonoplastes*, and cyanobacteria from the genera *Johannesbaptista*, *Aphanocapsa* and *Lyngbya*.

Bacteria aren't loners. In fact, they are quite social: These single-celled creatures band together to form sophisticated communities. They can even call out to each other to congregate, conspire and coordinate. Highly developed communication skills allow them to orchestrate small acts of cooperation and tackle big jobs as a unified force. For life's tiniest players, living and working is a team sport.

Researchers now want to join in the game — and change the rules. Synthetic biologists are working to find ways to manipulate entire microbe communities to get them to do things they ordinarily wouldn't — like tracking down cancer cells to deliver drugs, fighting antibiotic-resistant infections or manufacturing fuel. By tweaking the genes that direct bacterial communication, or introducing new genes into the microbes, scientists are creating microbial fantasy teams to perform jobs that natural populations simply cannot do.

To be sure, engineering bacteria isn't new. Scientists have been putting genes into bacteria and other cells for decades. Genetic engineers already know how to hijack microbes' biosynthetic machinery to produce single proteins, or to generate whole pathways of cellular reactions such as those used to make human insulin.

But now scientists want to program entire ecosystems — made up of multiple species — to carry out specific tasks. Such reprogrammed consortia of bacteria could be used in medicine, environmental cleanup and biocomputing.

"Many of the things we now dream about doing in synthetic biology — from making new sources of energy to curing diseases or to producing chemicals — require multiple steps or processes," says biochemical engineer Frances Arnold of the California Institute of Technology in Pasadena. "It becomes complicated to engineer all these properties into a single organism."

So it may take multiple organisms working together to achieve these goals. Microbial communities are ideal because their high level of cooperation allows them to divide labor, share resources and mount attacks on invading species.

Once they are rooted in a community, bacteria act less like a collection of single-celled individuals and more like a microbial "superorganism," Arnold says. "In the future, if you have a really complex task, it might be interesting to consider engineering a whole set of different organisms that have to work together to solve it."

Microbial communities are everywhere. Although microbiologists have long focused on free-floating bacteria grown in laboratory cultures, most bacteria in the natural world settle down into structured communities. Most of these take the form of a biofilm, in which large clumps of bacteria adhere to each other in a goo-like slime. Biofilms will latch on to most any surface. They glom on to the hulls of boats and the surfaces of ponds and clog the walls of drains and pipes. They form infection-inducing films on implanted medical devices and cause deadly lung infections in cystic fibrosis patients.

But biofilms can be beneficial, and their knack for breaking things down allows them to take on some of the toughest tasks. In the human body, biofilms help digest food, metabolize drugs and manufacture vitamins. In nature, they release nutrients from the soil, converting them into a form that plants can use. Other naturally occurring biofilms are used to degrade contaminants in wastewater or remove toxins such as jet fuel from sites where spills have occurred.

"If you look at the really complex and interesting things that microbes do in nature, it's almost always in the form of multiple populations, or a consortium," Arnold says.

Like human groups, these natural communities vary in size and complexity. Some exist as a single biofilm or a group of adjacent biofilms; others consist of clumps of cells connected by the pores in soil. Some contain only a single species of bacteria while other, more diverse communities comprise multiple bacterial species and perhaps include other organisms, such as fungi and algae.

Microbial communities are so complex that they have yet to be reproduced in their full splendor in the lab. Yet, by studying simplified communities, scientists are getting a glimpse of bacteria's elaborate social lives and are learning how to intercede, says Katie Brenner, a microbiologist in Arnold's Caltech lab. Brenner and Arnold outlined efforts to design such communities in the September *Trends in Biotechnology*.

Ideally, a synthetic bioengineer would be able to choose from a number of organisms to design a community capable of getting the job done. At the moment, most labs are focusing on ways to engineer communities of bacteria made up of a single species because these systems are better characterized and easier to manipulate than multispecies groups. And bacteria's well-studied system for communicating provides a way for scientists to steer the conversations among congregating microbes by changing the way they talk to each other.

Bac talk

Bacteria sense their neighbors and respond to the presence of others in the colony by exchanging small molecules and bits of proteins called peptides — a process known as quorum sensing. Through this exchange, bacteria send and receive chemical cues that turn genes off or on. This process enables many types of bacteria not only to communicate with their neighbors, but also to collaborate in intricate ways to divide labor and perform tasks requiring multiple steps. At first, quorum sensing, discovered in marine bacteria, seemed a special ability, but in the time since its discovery, scientists have racked up quite a list of chatty microbe species. In fact, some scientists believe that nearly all bacteria communicate in one form or another.

More important, quorum sensing offers an open channel that scientists can tap to steer bacteria's small talk. In 2006, researchers at the University of California, Berkeley used quorum sensing to engineer a single population of bacteria capable of seeking out and treating cancer cells. When the bacteria entered an environment low on oxygen — such

HANS PAERL, TIMOTHY STEPPE/INSTITUTE OF MARINE SCIENCES/UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL

as within a tumor—they would start to release a toxic protein to kill the cancer cells, the researchers reported in the *Journal of Molecular Biology*.

The problem is that low-oxygen environments occur in other places in the human body where you wouldn't want toxins, Brenner says. By creating a consortium made up of two or more populations, scientists may be able to better target the release of such substances, reducing the risk of harming healthy tissue. "Hypothetically, neither cell would be toxic alone, but somehow when they came together they would communicate and produce a toxic response," she says.

In 2007, Brenner and Arnold developed the first consortium to use a two-way engineered communication system. While most bacteria use a class of small signaling molecules called acylated homoserine lactones, or AHLs, to "talk," *E. coli* don't. The team found a way to hijack the genes that control this chatter in other bacteria and put them into two distinct populations of *E. coli* grown together in a biofilm.

Each of the populations synthesized a communication molecule. One population manufactured one type of AHL molecule; the other population made a different AHL molecule. By detecting each other's molecules, the two *E. coli* groups were able to yak back and forth, Brenner and colleagues reported in 2007 in the *Proceedings of the National Academy of Sciences*.

"It's just like a conversation between two people," Brenner says. "My voice is different from yours, so you can tell that I'm talking to you, and I can recognize your voice and know that it's not me talking to myself, but it's you talking to me."

The forced conversation had consequences not known to follow from human dialog. When it received a communication from its partner, one *E. coli* population turned fluorescent green. When the other population picked up on the message, it fluoresced red. The experiment illustrated, in bright detail, the scientists' ability to manipulate microbes' communication and behavior within a biofilm.

This stripped-down version of a natural system could serve as a mock-up for more complicated systems and help scientists navigate the obstacles posed by genetically engineering closely linked networks of bacterial populations.

"There's a real challenge associated with making stable genetic changes to bacteria, or to any microorganism, let alone a community," Brenner says. "Even though we can put some changes in, we don't know exactly how that will affect the dynamics of growth and reproduction in a microbial community."

Synthetic communities may be fabricated in a lab, but there's nothing unnatural about their inhabitants. These single-celled colonists are living organisms with their own quirks.

"When we build a synthetic system, we think we know what the major interactions are, because we build them in. But these are growing, complex organisms, and they're responding to their environment," Arnold says. "They're growing and doubling and doing what they want to do at the same time as they're doing what we force them to do."

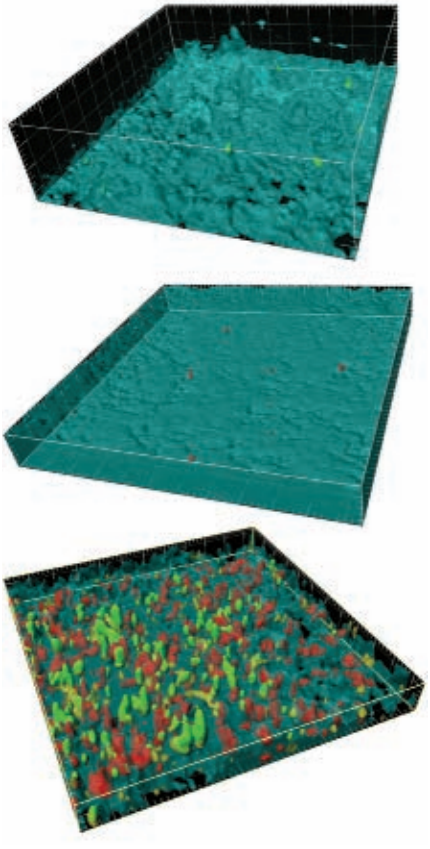
One thing microbes apparently don't want to do is bend to the will of outsiders. Colonies of *E. coli*, for example, can, over time, "mutate out" the genetic changes introduced by scientist-saboteurs, presumably because those changes create an extra metabolic load.

"Bacteria don't like to do what you tell them to do," Brenner says. "It slows them down and gets in the way of their very efficient lifestyle."

One way to reduce this metabolic burden is to find a way to divide the labor between two or more species, so that neither one is slowed down, says Duke University bioengineer Lingchong You. In nature, microbes use this strategy to keep moving at warp speed, but it's not yet possible to mimic in the lab. To do so, scientists must better understand the back-and-forth nature of talking and sharing that occurs in natural populations.

Go with the Glow

Collaborations within microbial consortia often rely on quorum sensing, a way bacteria can coordinate their behavior by exchanging chemical signals that can turn genes on or off. In 2007, researchers inserted genes that control quorum sensing to induce two *E. coli* populations, grown together as a biofilm, to communicate back and forth and achieve a "consensus" response—with each population's signal dependent on the other's. By itself, each culture of engineered *E. coli* fluoresces minimally (top and center). But grown together, a consensus response—red and green fluorescence—occurs (bottom).



ARNOLD/*PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES* 2007; OPPOSITE PAGE: A. NANDY, SOURCE: YOU/*MOLECULAR SYSTEMS BIOLOGY* 2008

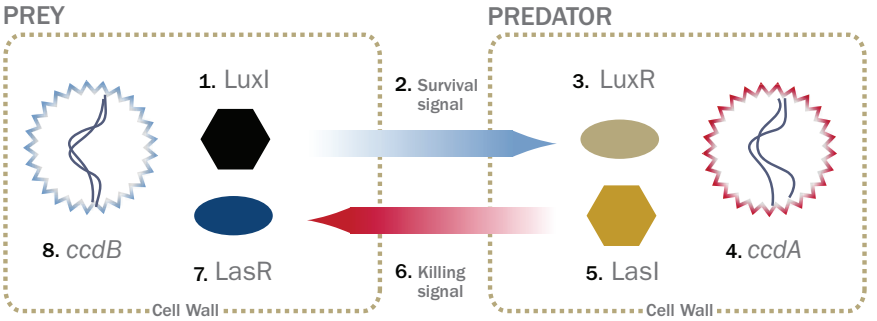
Culture conflict

Given that quorum sensing allows microbes to talk to one another, it's not surprising that some organisms just can't get along. In nature, strains vying for nutrients or other resources can reposition themselves to work alongside neighboring species without getting so close that competition becomes a problem. But when mixtures of species are stirred in a lab culture, they have to slug it out. In such cases, one species will often outcompete the others.

To see how man-made microbial populations keep each other in check, You and his colleagues from Caltech and Stanford University rewrote the software of *E. coli* to form a mutually dependent system of predators and prey. In this case, the

Cross Talk

In a bacterial model of a predator-prey ecosystem, quorum sensing enables two groups of *E. coli* to communicate in ways that affect the balance of their populations. Initially, the predator population wanes amid a scarcity of prey. But the communication directs the prey to "rescue" the predator (steps 1–4), and once the predator population recovers, it begins to kill the prey (5–8).



1. In prey cells, a protein known as LuxI synthesizes a "survival signal." **2.** The survival signal can pass from prey to predator cells. **3.** As the density of prey cells increases, the survival signal accumulates in the ecosystem and is bound in the predator cells by a molecule known as LuxR. **4.** This accumulation prompts an "antidote" gene, *ccdA*, to crank up activity and rescue the predators. **5.** In predator cells, a protein known as LasI synthesizes a "killing signal." **6.** The signal passes from predator cells into the prey cells. **7.** In the prey cells, the signal is bound by another molecule, LasR. **8.** This activates a "killer" gene known as *ccdB*, and the prey cells fall "victim" to the predators.

bacterial predators don't actually eat the prey. Instead, the bacteria use quorum sensing to keep each other's populations in check, turning each other's suicide rates up or down, the team reported in the April 15 *Molecular Systems Biology*.

While his system is not an exact representation of real predator-prey relationships, You says it can serve as a tool to learn how genetic modifications play out to influence population changes. "This system is much like the natural world, where one species suffers from the growth of another species," You says.

Crowding or space constraints can also be a source of conflict. Bacterial communities are not just a smear of slime: They are a complex structure of columns and channels designed to support community activities. In biofilms, water moves through channels to deliver nutrients and remove waste. Other communities, such as those found in soil and marine sediments, organize themselves by the distribution of species. Such structures enable the microbes to work as a group.

Finding ways to control a colony's spatial structure is essential for culturing communities of microbes in the laboratory, says James Boedicker of the University of Chicago, who studies biological structures. "This helps both in terms of stabilizing the community and allowing the microbes to have interactions similar to those in natural settings."

Recently, Boedicker and his colleagues showed how the spatial structure of a microbial community works to dictate the flow of nutrients, environmental signals and communications among its members. The study, published in the Nov. 25 *Proceedings of the National Academy of Sciences*, found that a stable community requires a particular variety of structures.

"Space influences all interactions between the microbes, both beneficial interactions ... and harmful interactions such as toxin production and depletion of local nutrients," Boedicker says. "Not just any spatial structure will be right for a given community."

Biofilm versus biofilm

Studies of the highly organized interactions and structures within microbial communities may help scientists better understand how cells within a consortium act in concert. Such an understanding could spark new ideas about how to develop everything from medical materials to ship coatings that resist the buildup of harmful microbes, Brenner says.

Bacterial communities can be especially problematic in the human body. Biofilms stick to the surfaces of artificial hips, pacemakers and other medical devices, creating the potential for dangerous infections. *Pseudomonas aeruginosa*, another species that builds biofilms, causes respiratory tract infections that can be life threatening in people who have cystic fibrosis.

"Imagine engineering a biofilm that would essentially outcompete or smother the toxic biofilm that forms on the inside of the lung of cystic fibrosis patients," Brenner says. "There are many ways you might go about trying to remove that biofilm, but using a consortium is a very realistic approach."

Another potential application is to target the biofilms that cause life-threatening staph infections, such as the methicillin-resistant *Staphylococcus aureus*, or MRSA, a sometimes fatal strain immune to multiple antibiotics. The engineered biofilm would include bacteria capable of battling MRSA.

"There are bacteria in nature that can kill MRSA," Brenner says. "Though these bacteria are usually toxic to humans, you could essentially commandeer the MRSA-fighting proteins out of the bacteria and install them under control of a circuit with checks and balances."

Of course, the real world is never so simple. Most biofilm systems comprise multiple species of bacteria, including many organisms that are toxic to people. And applications such as new medical materials are years away. Still, Brenner says, the studies underway are a critical first step in re-creating and reprogramming the complex interactions in microbial communities. Understanding the chemical cues and signals within microbial communities may aid in developing planned communities that could settle down where needed and tell harmful bacteria to get lost. Very quietly. ■

Susan Gaidos is a science writer in Maine.

Explore more

- K. Brenner *et al*. "Engineering microbial consortia." *Trends in Biotechnology*. September 2008.

To potential mates, your mug may reveal more than you think

It's written all over your face

By Elizabeth Quill
Photograph by Cary Wolinsky
Sculpture by Jason Loik

Eye candy might more appropriately be called brain candy. Seeing a pretty face is like eating a piece of oh-so-sweet chocolate — for the brain, if not for the stomach. In fact, attractive faces activate the same reward circuitry in the brain as food, drugs and money. For humans, there is something captivating and unforgettable about the arrangement of two balls, a point and a horizontal slit on the front of the head.

The power of faces isn't lost on psychologists. "Faces are interesting because they impart so much information — expression, attention — and these interact with facial beauty," says Anthony Little of the University of Stirling in Scotland.

So it's no surprise that making faces attractive is big business. Each year, Americans spend more than $13 billion on cosmetic surgery and tens of billions on cosmetics and beauty aids.

But while facial improvements leave those who subscribe to them with a healthy glow and the illusion of youth — subtracting a few years can bump you up a few notches on the hot-or-not barometer — studies of attractiveness have tended to leave the scientists who undertake them with puzzled looks, gray hairs and wrinkles.

Recently, though, researchers seeking to unmask the essence of facial attractiveness have been using computer technology to isolate the characteristics long rumored to underlie beauty. New methods reveal that averageness, or a lack of distinctness, makes someone more appealing, while facial symmetry doesn't automatically make a knockout, as most people believe. Features that make a man look manly or a woman feminine can trump both averageness and symmetry, but only sometimes. And studies of faces in motion support the idea that femininity and masculinity are important to attractiveness.

Researchers have also started focusing on why faces are attractive, not just what makes them so. Attractiveness may signal good genes and a good mate. A new study links averageness to diversity in the major histocompatibility complex — a cluster of genes that plays a major role in the immune system. And brain-imaging studies are poised to capture how the brain responds to potential cues to genetic fitness.

Seeking (to define) beauty

Believing beauty to be in the eye of the beholder isn't exactly wrong, but research suggests that there are some universal standards to attractiveness that everyone seems to apply.

"When you look at what people find attractive, it is consistent across cultures," says evolutionary psychologist Hanne Lie of the University of Western Australia in Perth. "We have some innate or hardwired beauty detector."

Most attractiveness research has focused on three aspects of a pretty visage — averageness, symmetry and sexual dimorphism.

Early research into these three characteristics relied on photographs and a ruler, so it was difficult to separate the characteristics from each other. Nowadays computer technology has revealed a deeper understanding of beauty.

"The huge benefit of computer graphics," Little says, "is in manipulating one thing and one thing only." For example, he says, it is possible to take any face shape and make it perfectly symmetrical. It is possible to mark points to determine average positions, such as the height of the ears, length of the nose and distances between the eyes. It's even possible to morph faces to accentuate masculine or feminine features. Isolating such characteristics has revealed new complexities to how averageness, symmetry and sexual dimorphism help define beauty.

Averageness, one researcher quipped, could account for as much as 85 percent of good looks. Here, average does not mean dull or boring, but rather nondescript, lacking distinct or dramatic features. In the late 1870s, Sir Francis Galton combined photos of men convicted of serious crimes to develop an image of the prototypical criminal's face. He found the composite image — with its smoothed out features and absence of irregularities — surprisingly attractive. More than a century later, in the early 1990s, psychologist Judith Langlois, now at the University of Texas at Austin, and her colleagues confirmed that blended faces are more attractive than the originals. (Averaged faces are also preferred by infants; babies stare at composites longer.)

Symmetry as a feature of attractiveness dates back to Plato's day. He believed the "golden proportion" was the key to a good-looking face. The width of the ideal face would be two-thirds its length and the nose no longer than the distance between the eyes. Modern research suggests that symmetry judgments depend on how well one half of the face reflects the other, Little says. Asymmetry makes a face look a bit off; the two sides don't quite match. "Essentially, it's wonkiness," he says.

And anyone who has gawked at a supermodel with big eyes and high cheekbones or the prominent jaw of a soap opera hunk knows that these beauties bring something else to the mirror. Sexually dimorphic characteristics — meaning those that make someone very masculine or very feminine — can take a face from beautiful to, well, sexy.

Fully understanding facial beauty requires studying how these three facial characteristics relate and interact. Averageness is attractive, says Lisa DeBruine, an experimental psychologist at the University of Aberdeen in Scotland. But, she says, when it comes to some key features, such as big eyes and small chins in women, being distinctly nonaverage (being very feminine) can be better. Distinctness is, by default, thought of as bad because, she says, "there are more ways to be nonaverage and ugly than there are ways to be nonaverage and beautiful."

In a series of studies, researchers including Little and Steven Gangestad of the University of New Mexico in Albuquerque also found that symmetrical faces have attractive features independent of their symmetry. Symmetry was attractive in male faces, for instance, but women shown only half of an attractive male face still found the face attractive, Little and colleagues reported in 2001 in the *Proceedings of the Royal Society*.

A further study, published by Little on

May 7 in *PLoS ONE,* suggests that symmetry goes up and down with sexually dimorphic features in Europeans, African hunter-gatherers and in nonhuman primates. Symmetrical males had more masculine features and symmetrical females had more feminine features. Gangestad has shown that symmetry and masculinity vary together in men — as one increases, the other does too, suggesting the two characteristics point to some unknown underlying quality. So, perhaps, symmetry is important not on its own, but as a proxy for other characteristics — identified or not yet identified, researchers suggest.

Other missing elements in evaluating beauty have begun to emerge with the use of new technology. Video techniques have allowed for dynamic rather than static interpretations of beauty.

"Real faces move," says Edward Morrison of the University of Bristol in England. "If you show someone a moving face, they can recognize it quicker. There is more information."

And it turns out that how faces move may contribute to how good they look. In a 2007 paper in *Evolution and Human Behavior*, Morrison reported that more of the movements known to be indicators of femininity — blinking, nodding and head tilting — made women's faces more attractive to male and female volunteers.

"Movement can convey important meanings," Morrison says. "If that person likes you or doesn't. If that person is being aggressive. If the person is being flirtatious. The face can start to convey these kinds of things."

The findings echo results from studies of static faces, supporting the conclusion that sexual dimorphism is important in evaluating women's faces, and less important in evaluating men's faces, which tend to move less.

Little says that while scientists are slowly finding all the pieces, fitting them together remains a challenge. "As far as the actual relative weight of these things," he says, "I don't know whether we have a good handle on what is most important."

Designed to impress

If the first goal is to find out what is attractive, the next is to understand why. More than triggering mere identity, facial features can reveal the sex, age and race of their owners. Movement can indicate mood and interest. And clues to personality may also be present, or at least people may think they are. (Studies have shown that voters believe baby faces suggest incompetence while jutting chins and angular noses are clues to capability in candidates. Another study suggests that people think baby faces make more honest CEOs.)

But faces are far subtler vessels still. If a male peacock can show a female his fitness by growing colorful feathers, maybe humans can, more subtly, reveal their fitness with the features on their faces. And people may subconsciously pick up on the cues that identify a good mate.

Under this assumption, masculine features may signal a strong and protective partner, while feminine features communicate youth and fertility. Asymmetries would signal underlying developmental instability. An individual's genetic profile would also contribute to averageness.

Lie and her colleagues Gill Rhodes and Leigh Simmons, both also of the University of Western Australia, connected averageness, genetic profile and attractiveness in a recent study. In male faces, attractiveness signaled diversity within the major histocompatibility complex, the team reports in the October 2008 *Evolution*.

This cluster of 128 genes and surrounding genetic material plays an important role in the immune system. The genes encode molecules on the cell surface that recognize self from nonself and detect pathogens and parasites. In rhesus macaques, diversity in the MHC has been linked to reproductive success. And female fat-tailed dwarf lemurs have been shown to prefer males with greater MHC diversity.

Lie looked at genetic diversity in 80 men and 80 women whose faces were rated on a 10-point attractiveness scale by volunteers. The researchers found that those rated most attractive showed greater diversity in the MHC. Taking the study a step further, Lie and her colleagues linked averageness to diversity in the MHC for the first time. More diversity means a better mate, the thinking goes. Presumably, more variation in the MHC will help a person fight off diseases and infection, and a potential mate would pass on this fitness advantage to future offspring.

A number of other studies have attempted to link the features that make a face attractive to perceived, and in a few cases, actual health. A 2000 study by Rhodes and Leslie Zebrowitz of Brandeis

Asymmetrical

Original

Symmetrical

Matching halves

Symmetry has been popularized as a feature that is key to attractiveness. Though subtle, a face looks off if one side doesn't mirror the other. The face at far left has been made more asymmetrical than the middle face, while the face on the right shows a more symmetrical version. Though the symmetrical face would still be rated more attractive, some studies suggest symmetry is not as crucial as has been assumed.

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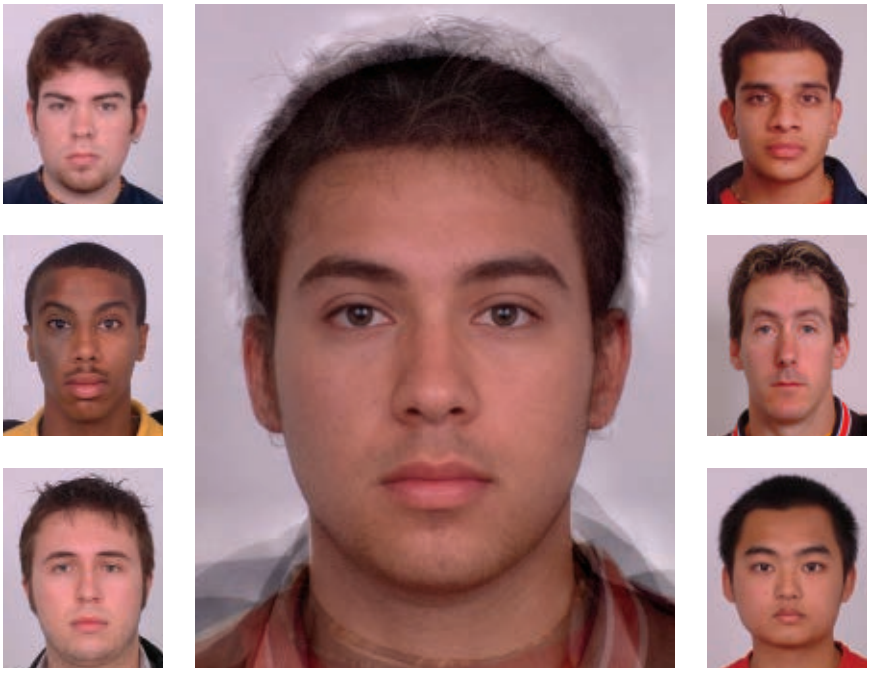

Averaging yields attraction **Research shows that a composite face — one that is made by mathematically blending individual faces — is more attractive than the faces that are combined to make it (minus the hair, of course). Above, the six smaller faces have been blended to create the middle image. Scientists say this technique evens out features, hides any irregularities and smooths out skin tone.**

University in Waltham, Mass., showed that volunteers rated people with more symmetrical and more average faces as appearing healthier. Faces of 17-year-olds that were rated as distinct were associated with poor past health records. And a study in 2004 linked apparent health of facial skin to attractiveness. Some studies have hinted that attractiveness is related to longevity, body mass index and even semen quality.

Most intriguing to Little and others are studies revealing that when women are at the most fertile time in their monthly cycle — when male quality might be most important to them reproductively — they are more interested in men with masculine and symmetrical faces.

"Women prefer all sorts of things when they are ovulating," Gangestad says. "More masculine faces, more masculine voices, more muscular bodies. Taller men. More dominant men. Certain scents."

At other times, researchers suspect, women might be interested in other traits — like a man's nurturing ability or willingness to hang around and raise children.

"There are trade-offs," Gangestad says. For example, "more masculine men may be less reliable partners."

Presumably women are more tuned in to indicators of quality when they are able to conceive, so researchers say studying those women might provide the best clues to what makes a man attractive and why. Studying the women at other times may explain the factors beyond attractiveness that contribute to choosing a life partner — why, for example, women don't always just go for the more manly man.

"Facial features don't tell us everything," Gangestad says, "but we know they tell us something."

DeBruine says studies reveal that individuals' preferences for faces are not arbitrary, but vary in specific, systematic ways. New research shows that men's preferences also change depending on their hormone levels. Working with DeBruine, Little and other colleagues, Lisa Welling of Aberdeen found that when men have higher levels of salivary testosterone, they prefer more feminine faces. If high testosterone is a signal of better quality, men with such levels may know that they can better compete in the good-female-getting game. Men with lower levels may look for lower quality (less feminine) women. "Maybe I think Brad Pitt is the most attractive mate possible, but I am not going to win him," DeBruine says. "It is not a good strategy for me to set my sights on him." The study, which appeared online last August in *Hormones and Behavior*, and others suggest that attractiveness preferences may depend on a person's own perceived attractiveness.

So your personal preferences aren't entirely personal. Studies out of Aberdeen suggest that, in addition to your hormonal profile and how attractive you think you are, how much someone looks like you and how much attention they pay you can influence just how attracted you are, in quite predictable ways.

Beauty in binary

But here's the catch. Caring about specific features is one thing, articulating those preferences is another. Even people who consistently rate symmetrical faces as attractive, for example, have trouble identifying symmetrical faces. People just know an attractive face when they see it.

So does at least one computer. Eytan Ruppin of Tel Aviv University in Israel and colleagues have trained a computer to recognize what humans would rate as an attractive female face. The machine, described in January 2008 in *Vision Research*, automatically extracted measurements of facial features from raw images rated by study participants for attractiveness. It considered thousands of features and then condensed them. Then it went to work on a fresh set of faces. The computer predicted attractiveness in these new faces in line with human preferences.

Even more intriguing, the computer replicated at least one human bias. Symmetry studies often involve taking the right side of a face and mirror imaging it to create a full face or taking the left side

and doing the same. Humans show a surprising bias; in two-thirds of cases, they prefer left-left images (from the point of view of the onlooker). Somehow, this bias must have been embedded in the original rankings the computer received because it also preferred these faces. But no one is sure why or how.

Though replicating human ratings is a fun exercise in artificial intelligence, Ruppin says a computer can't help scientists understand what people find attractive. "It says what is in the mind of the computer, not the mind of a human."

Some researchers are, in fact, turning to the human mind to explore attractiveness. The brain has special machinery for recognizing faces. One front-on glance and a human shape among masses of others becomes a long-lost friend, a beloved family member or an irritating coworker.

Face recognition may be "the most fine-tuned system we have," says Alice O'Toole of the University of Texas at Dallas. "However we code them neurally, we are able to keep track of what makes individual faces unique. When I look at you, I would code what makes you different from every other face I have ever seen."

Some work suggests that attractiveness is processed as a variation from the mean (which could hint at why averageness matters). In a 2007 study published in *Neuropsychologia*, participants underwent fMRI while viewing faces of varying degrees of attractiveness. The study suggested that people's brains have strong responses in the right amygdala — part of the brain that has been linked to both positive and negative emotions — to pretty faces and ugly faces, and less response to middle-of-the-road faces. (So ugly faces are also intense like chocolate, not because they create longing, perhaps, but fear.)

Joel Winston of University College London, an author of the study, says early brain-scanning research took a linear approach to attractiveness, finding that some brain regions responded more to attractive faces and others to unattractive faces. But the recent study included faces that fell between the extremes and found that some brain responses are elicited by unattractive and attractive faces but not less distinct faces.

In this respect, Gangestad says, you could think of characteristics like averageness in terms of preference and avoidance. "It may well be that in our ancestral past certain kinds of mutations caused malformations of all sorts of bodily features, including the face, and that is part of what you are picking up on," he says.

Winston says the imaging studies don't look at nitty-gritty brain activity, but still hold promise. "There is some evidence in basic visual science research that with an fMRI scanner we can actually decode what the subject is looking at better than the subject can," he says. "Certainly the brain knows more about the world than you do in the sense of your conscious self."

Steve Platek of the University of Liverpool in England agrees that indicators of potential fitness ought to activate sensors in the brain. "The average person you pass on the street is probably not 'hot or not,'" he says. "But if they are hot or not, they should activate some kind of socially behavioral response [the reward circuitry] that says go after that person at all costs or avoid them at all costs because mating could be really horrific for your [offspring's] genes."

Such a drive might underlie the utility of attractiveness. And elucidating how the brain responds to large, obvious differences in attractiveness could help researchers understand how the brain responds to differences that are subconscious and difficult to articulate. Platek says he does have results, as yet unpublished, that look at the brain's response to good-gene indicators.

While computers have enabled the isolation of facial features for study, Lie says the next step will be in reassembling attractiveness — joining studies on facial features with predicted fitness and brain scans. "I have a feeling when we perceive attractiveness in the real world, it is a holistic process," she says. "It becomes more than the sum of its parts."

The next time a face catches your eye, you may not be able to articulate what turns your head or makes your heart jump, but you will certainly know what you feel. Call it instinct, call it evolution, call it what you want. It may take researchers many more years to understand why you find a super-fine face to be so sweet. But that shouldn't stop you from looking. ■

Explore more

- Take tests at Anthony Little's website: www.alittlelab.com
- Morph faces at the University of Aberdeen: www.faceresearch.org

More feminine

Original

More masculine

Accentuating femininity

Men tend to find women who look more feminine — bigger eyes and lips, smaller chins, higher cheekbones — more attractive. Technologies that allow the adjustment of these features, shown here by a face that's been feminized (far left) and masculinized (on the right), have helped reveal their import. When ovulating, women find men with more masculine features — exaggerated brow ridges, thin lips and strong chin — more attractive.

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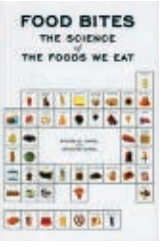
Food Bites: The Science of the Foods We Eat

Richard W. Hartel and AnnaKate Hartel

Armed with curiosity and scientific expertise, the Hartels take readers on a journey of food exploration. In this readable volume, the father-daughter duo tackles 60 everyday dinner-table queries. Based on newspaper columns penned by Richard Hartel, a professor of food engineering at the University of Wisconsin–Madison, the book serves as a quick and humorous food science reference. It is geared both toward the merely curious (one section explores hollow chocolate bunnies) as well as the more practical (readers find out what to do when salt gets sticky and how to stop guacamole from turning brown). In other chapters, the authors describe how the eyes react to working in an onion ring factory, the role microbes play in making food and what happens during food irradiation.

The book goes beyond science to provide tales of the culture, history and engineering of food. In the mid-1850s, the advent of cereal reduced the time devoted to meal preparation. TV dinners, a century later, only strengthened the trend of moving food prep to the manufacturer. To preserve processed foods, science has been employed in every step of food preparation, right down to packaging choices.



The Hartels share gems from the history of the food industry, from the creation of the juice box to the launch of Lucky Charms.

With this road map to the world of food, the wonders of science in daily meals become easy to digest.

—Dina Fine Maron

Springer, 2008, 190 p., $22.95.

Don't Sleep, There Are Snakes: Life and Language in the Amazonian Jungle

Daniel L. Everett

Daniel Everett is no by-the-book linguist. If you read his new book, you'll find out how Everett went from a 26-year-old missionary taking his family to live with and proselytize members of a remote Brazilian tribe to a major thorn in the side of influential language theorists. Along the way, he became immersed in the unusual culture and language of his Amazonian hosts, the Pirahã people. These deceptively simple folk transformed the missionary, not vice versa.

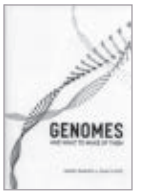
With straightforward writing, Everett explains how he decoded the mysterious Pirahã tongue during fieldwork that spanned 30 years. In that time, he became a full-fledged linguist with a résumé that included many colorful and harrowing jungle experiences. Everett recounts a desperate canoe and boat trip up the Amazon River to save his malaria-stricken wife and daughter, and a watery encounter with an anaconda. He also gives the reader a feel for how he began to understand a language that had stumped other linguists.

In defiance of Noam Chomsky's theory of universal grammar and Steven Pinker's "language instinct," Everett concluded that the Pirahã language, including its grammar, had been shaped by a culture that valued only a person's immediate experience, not past or future events. Everett found that the Pirahã have no words for colors or numbers, no way to embed phrases within other phrases and one of the smallest sets of speech sounds in the world.

Everett portrays these masters of jungle survival as a generally jovial bunch who have no creation myths or storytelling traditions. They live in the present and believe only in what they and their comrades directly observe—a cultural characteristic that leads Everett to abandon his own faith. *—Bruce Bower*

Pantheon Books, 2008, 283 p., $26.95.

Planet Earth: An Illustrated History
A photographic tribute to the glories of nature, including picturesque landscapes, stunning aerials and diverse life forms. *Time, 2008, 250 p., $29.95.*



Genomes and What to Make of Them
Barry Barnes and John Dupré
A history of genomics and a primer on what to expect in the future. *Univ. of Chicago, 2008, 273 p., $25.*

Hanging with Bats: Ecobats, Vampires, and Movie Stars
Karen Taschek
A children's writer explores the facts and fictions behind these nighttime fliers. *Univ. of New Mexico, 2008, 94 p., $16.95.*

Superstition: Belief in the Age of Science
Robert L. Park
Why people hold on to certain beliefs, even when science proves them wrong. *Princeton Univ., 2008, 230 p., $24.95.*

The Jinn from Hyperspace and Other Scribblings—Both Serious and Whimsical
Martin Gardner
A collection of musings on curiosities in math and physics, along with writings on homeopathy, false memory and Lewis Carroll. *Prometheus Books, 2008, 307 p., $25.95.*

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Big black holes

An alternative explanation of why ultramassive black holes reaching 10 billion solar masses seem to go dormant ("Ultramassive: As big as it gets," *SN: 10/25/08, p. 18*) could be that in these black holes, the violent activity associated with smaller black holes is completely contained within the event horizon and thus removed from any observation.

The tidal forces at the event horizon, which cause the observable effects, actually diminish as the mass and radius of the black hole increase. At a 30-billion-kilometer event horizon, the tidal force is so weak that the largest stars and gas clouds could approach and disappear within, with little distortion and no fireworks. The ultramassive black hole would sit in quiet darkness, outwardly passive, while violent internal processes were shrouded by a natural cloak of invisibility. But the black hole would be continuously and inconspicuously absorbing its surrounding galactic material, growing ever larger and more massive. More missing mass?
Charles Wilkinson, Beltsville, Md.

Robot humor and intelligence

I was struck by Leo's seriousness in "Body in mind" (*SN: 10/25/08, p. 24*). Instead of opening the cookie box that actually contained the cookie, many people would have made the interaction into a game by opening the requested box and pretending to be surprised when it contained no cookies. Let's hope scientists never figure out how to give robots a sense of humor. The result could only be mischief, and eventually some small percentage of mischief would turn destructive, as it does for humans.
Gail Smith, Seattle, Wash.

I was intrigued by the ideas discussed in "Body in mind" since I have long thought that there is an overemphasis on algorithms in efforts to create artificial intelligence. I remember arguing with a student of Stephen Hawking's in Cambridge in 1978 that sensors and actuators are essential to intelligence, artificial or otherwise. Antonio Damasio makes a persuasive case for the inseparability of emotion and reason in his book *Descartes' Error*. As aptly summarized in three words in John Kent Harrisons' movie *Beautiful Dreamers*: "Feeling precedes thinking."
Peter Eisenhardt, Altadena, Calif.

To be or not to be free

It's hard to convince humans that we don't have free will when ideas are constantly welling up in our minds ("The decider," *SN: 12/6/08, p. 28*). The brain is a high-gain analog computer — that's how we recognize images so quickly. A biomolecular machine with such high gain is bound to be chaotic. This means that we have ideas that are in the abstract deterministic, but are not predictable in any practical sense. Hence, we have real-world free will.
Tom Jaquish, Fort Wayne, Ind.

In regards to "The decider," is the real issue understanding human accountability in light of modern neuroscience? For those, like myself, who are unwilling to concede responsibility for some thoughts and actions, there is perhaps a concession offered by science. The brain is a complex system. Technically, this means that any future state, such as a decision, is so dependent upon the infinitely precise details of the preceding state of the brain and all its influences, it is generally impossible to predict.

Might it be that somehow deep within mechanistic brain processes there does exist a human ability to really choose, but it will forever elude scientific probing by hiding in the imperceptibly precise details of an infinitely connected world? In other words, might humans be bound to play out their lives in a physical medium that simultaneously provides freedom while masking the reality of that freedom?

This possibility seems consistent with the idea that moral agency is nullified not only in a purely mechanistic world, but also in one where truth is fully transparent and consequent choice unavoidable.
Nick Weir, Phoenixville, Pa.

I was disappointed to read "The decider." Tom Siegfried makes it very clear that he believes in the philosophy of materialism, and the essay suggests that he also believes that modern science supports that philosophy.

Siegfried should know that materialism is not a part of the physical sciences. It is metaphysical. Materialism has been disproved as well as Cartesian dualism. You do a disservice to your readers by presenting philosophy as science.
Samuel Mistretta, Baton Rouge, La.

My instruction as an engineer included the admonition to perform a "sanity check" at the end of solving a problem as a way to catch errors. The logical end of considering the brain as simply a machine (paragraph three in "The decider") is the obvious nullification of the concepts "meaning," "responsibility" and "justice." Without such concepts there is no basis for a criminal justice system or for concern over human rights — both of which seem entirely reasonable ideas. I think the issue here is an untestable assumption of philosophy masquerading as science.
Gary Wernsing, Beverly, Mass.

Regarding "The decider": We are an arrangement of atoms, and the result is self-awareness and the universe reflecting upon itself. What a miracle! From here, what a small step it is to aver volition, both weak and strong. Arthur Koestler's *The Ghost in the Machine* lives on.
C.W. Folse, New Orleans, La.

Correction: *"Household cleaners using oxygen may make blood removal too simple" (*SN: 12/6/08, p. 12*) incorrectly stated that a heme group comprises a bit of iron bound in a protein ring. The iron is bound in a nitrogen-containing organic ring, not a protein ring.*

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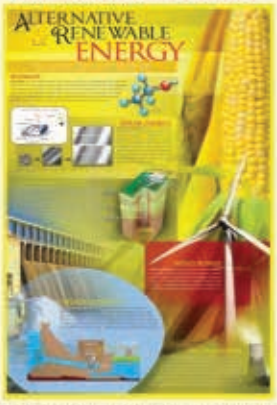

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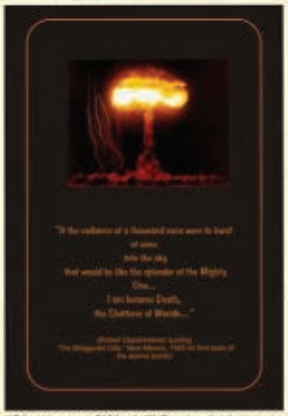

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SESAME opens doors to international collaboration

In a synchrotron, charged subatomic particles (typically electrons) are accelerated through a large ring. As their paths bend, the electrons emit synchrotron light, which can range from infrared wavelengths up to X-rays. "Beam lines" attached to the ring carry off this light to perform a wide range of scientific experiments. In 1997, as German synchrotron BESSY I was nearing replacement, physicist Herman Winick of the Stanford Linear Accelerator Center in Menlo Park, Calif., proposed using it as the seed for an international research facility in the Middle East. Called SESAME, the facility is now under construction in Jordan, a collaboration of nine Middle East nations. Science News *editor in chief Tom Siegfried recently spoke with Winick about SESAME's history and importance.*

How did the SESAME idea originate?

At a committee meeting in September of 1997, as the new machine [BESSY II] was coming close to getting online, I asked the question, what are you going to do with the old machine?... The answer came back, we're going to call in a junkyard dealer, cut it up into small pieces and get rid of it.... I said immediately that it's a shame to destroy such a beautiful, productive machine.... And I said why not offer it as a gift to serve as the centerpiece for a new facility in the Middle East?... One of the other people on the committee was Gus Voss, a very prominent German accelerator physicist.... At a meeting in Torino [Italy] in November of 1997 he made a presentation about moving this machine to the Middle East. This suggestion was received extremely enthusiastically, particularly by Middle East scientists. ... It was brought to the attention of UNESCO ... and it began to be developed under the UNESCO umbrella.

At first the plan was just to upgrade BESSY I from 800 million electronvolts (MeV) to 1 billion electronvolts (GeV), but now SESAME will be an even bigger machine. Why?

We realized that merely upgrading BESSY I but keeping its basic structure was not going to be adequate.... So we said let's abandon that whole thing and go to 2 GeV with a totally new machine, and in fact it was reviewed by the European Union, which said that 2 GeV was still too low. So the present planning design has been made for what we call a third-generation 2.5 GeV light source. However, all the German equipment from BESSY I is now sitting in Jordan, and we will use the injector. An 800 MeV injector can also inject into a 2.5 GeV ring.... It's not as good as injecting at the full energy, but it's a cheaper way to get started.

Nothing approaches the impact of X-rays as a tool for understanding materials.

What's the price tag for the whole project?

That's a tricky question to answer because the land and the site are gifts from Jordan, with the building and its improvements.... So if you add the whole thing up, and really put in realistic numbers for the site, the building, the infrastructure, the injector, the beam lines and everything, it's approaching $100 million of value.... The main cost for SESAME is really $20 million to buy the components of a new storage ring, of which we have about $5 million. And a big question now is where and when is that $15 additional million going to come from.

The motivation for SESAME is as a facility for doing science and also for working together across countries and cultures as an example of how science can foster that kind of cooperation, right?

Precisely. UNESCO called it a model project for other regions.... It has brought together people. These nine countries include Turkey and Greek Cyprus, which sit at the same table. They don't recognize each other. It includes Israel, the Palestinian authority, Iran and Pakistan.

What is it about synchrotron radiation facilities that makes them ideal for this purpose?

Because they affect such a broad area of science.... Nothing approaches the impact of X-rays as a tool for understanding materials—biological materials, semiconductor materials, catalytic chemical materials, environmental toxins, whatever.... Bang for the buck, the attractiveness and the impact over so many areas of science and technology could not be matched by anything else.

Who coined the name SESAME?

I take credit for that.... I decided that it needed to be named SESAME, because I claim there's three important connotations of the word SESAME: One, it's a door opener—it opens the door to jewels, to scientific knowledge; another is the spice, sesame, a Middle East spice, the sesame seed, it's the seed for growth.... But most important it's *Sesame Street* ... because that is where young people are taught to cooperate and respect each other. So everyone said that's great but what's it mean, and I figured out what it could mean: *S*ynchrotron light for *E*xperimental *S*cience and *A*pplications in the *M*iddle *E*ast. ■

TOM SIEGFRIED

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