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ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ DECEMBER 4, 2010

THE REAL QUESTIONS ABOUT

GLOBAL WARMING

Local impacts and other uncertainties of climate science

Felines' Flair with Fluids

Double Bubble Galaxy

Woes of a Restless Mind

Time travel at the speed of a 1935 Speedster?

The 1930s brought unprecedented innovation in machine-age technology and materials. Industrial designers from the auto industry translated the principles of aerodynamics and streamlining into everyday objects like radios and toasters. It was also a decade when an unequaled variety of watch cases and movements came into being. In lieu of hands to tell time, one such complication, called a jumping mechanism, utilized numerals on a disc viewed through a window. With its striking resemblance to the dashboard gauges and radio dials of the decade, the jump hour watch was indeed "in tune" with the times!

The Stauer *1930s Dashtronic* deftly blends the modern functionality of a 21-jewel automatic movement and 3-ATM water resistance with the distinctive, retro look of a jumping display (not an actual jumping complication). The stainless steel 1 1/2" case is complemented with a black alligator-embossed leather band. The band is 9 1/2" long and will fit a 7–8 1/2" diameter wrist.

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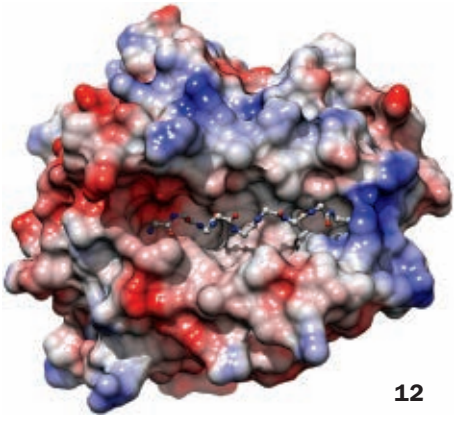

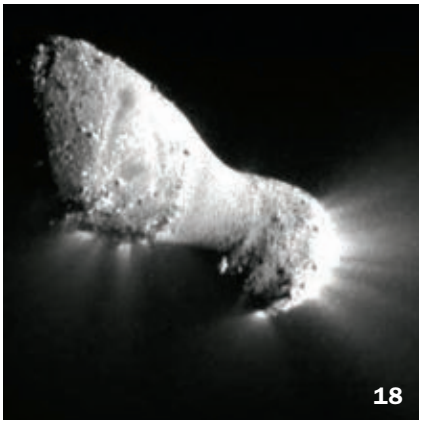

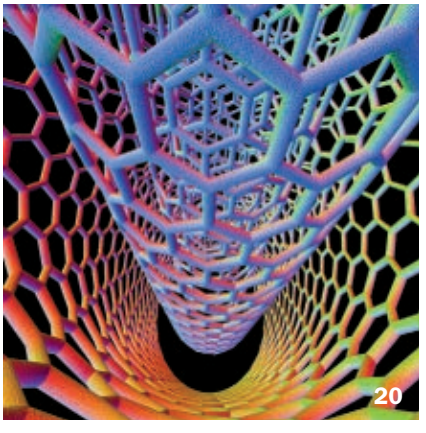

ScienceNews

In The News

Features

Departments

COVER Climate change could bring drought to some areas while flooding others. In October, after 10 years of drought, water levels at Lake Mead hit a record low. *Van "Bronco Loco" Phetsomphou*

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FROM THE EDITOR

Climate change is clear, the best response is not

Whenever any publication ventures into the realm of climate science, swift response from global warming skeptics is sure to follow. Some of that response is venomous ideological nonsense, designed to intimidate journalists. But some of it raises legitimate questions that researchers can't yet fully answer.

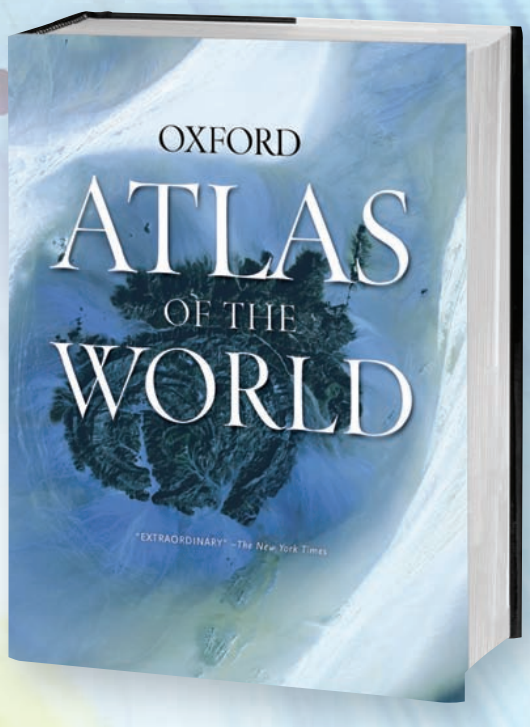
In this issue, *Science News* contributing editor Alexandra Witze explores some of the questions that today's climate scientists are actively investigating, such as the precise role of aerosols in global climate dynamics and regional impacts of rising global temperatures (Page 24). Unanswered questions remain about other aspects of climate science (Page 28).

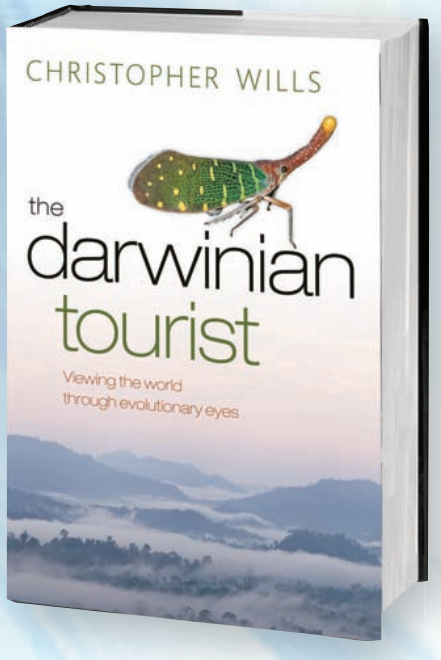
Such uncertainties are seized by some as evidence that climate science is untrustworthy. But science always encounters uncertainty at one level or another. Embracing uncertainty is one of science's great strengths — it allows new information to modulate judgments and correct mistaken beliefs. The skill is in distinguishing between what is certain and what isn't (or at least what lies closer to one end or the other of that spectrum).

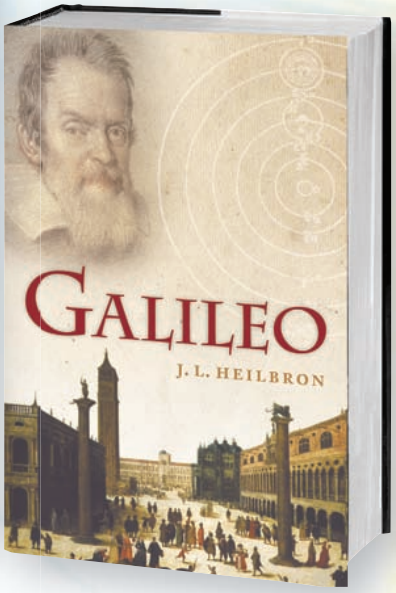
Many pieces of the climate science puzzle have been sufficiently established to leave no room for intelligent doubt. Carbon dioxide (and certain other molecules) trap heat in the atmosphere, and the amounts of these molecules have been rising. Human activity, such as the burning of fossil fuels, pumps prodigious quantities of these chemicals into the air. And the planet's temperature has been rising.

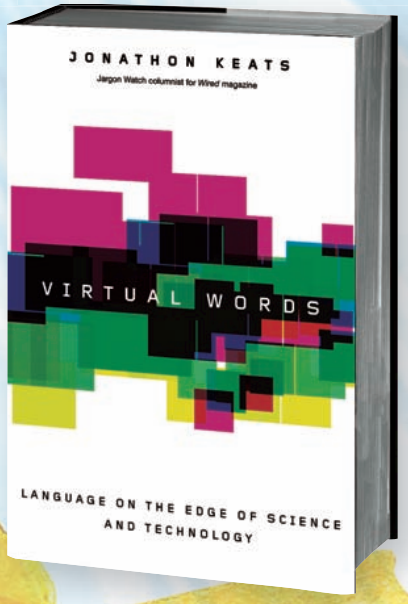
Some critics contend that these facts do not imply that warming will continue as levels of heat-trapping gases rise, but the world's leading climate scientists (and the world's most reputable scientific bodies) argue otherwise. Yet there is a realm for legitimate climate change debate — namely, what to do about it. Much of the antagonism toward climate science seems motivated not by the conclusions about warming and its impacts, but rather by the actions recommended to counteract it. Science does not say what the proper course of action should be — whether using renewable energy, building power plants that sequester carbon or simply planning to live in a warmer world. Some proposed actions may indeed bring unpalatable consequences and therefore understandable opposition. But the debaters on both sides should acknowledge that the costs of taking action, or not, in response to climate change have nothing to do with the science establishing that climate change is happening. —*Tom Siegfried, Editor in Chief*

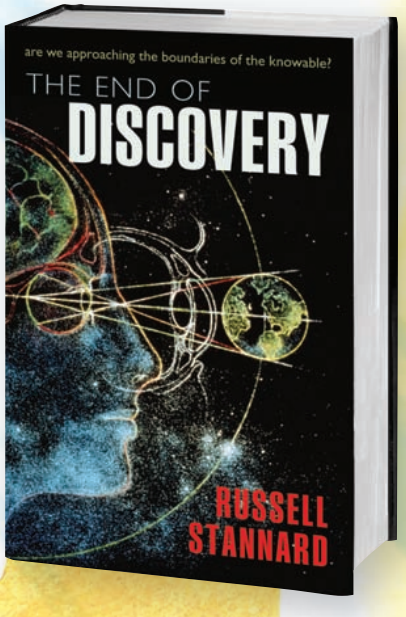
Great Gifts for **Science Lovers**











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Scientific Observations

"An understanding of the complex interactions between social and ecological systems is essential for securing the long-term sustainability of water and other natural resources, and will require new forms of scientific interaction that discipline-bound traditions make difficult. Understanding these interactions also requires a great deal of ecological data not currently available, including information on the distribution of organisms, their functional traits (that is, their role in an ecosystem and their performance under different conditions), and how they interact with other species, social systems and the physical environment. We need global biodiversity assessments and ecosystem-service frameworks for advancing our understanding of the link between biodiversity and ecosystem services." **—ECOLOGIST MARGARET PALMER OF THE UNIVERSITY OF MARYLAND CENTER FOR ENVIRONMENTAL SCIENCE, IN THE SEPT. 30 *NATURE***

Science Past | FROM THE ISSUE OF DECEMBER 3, 1960

ASTHMA CLUE FROM HORSES — Research into the deaths of thoroughbred horses, especially foals, has produced an entirely new approach to the treatment of asthma, hay fever and skin troubles in human beings.... During the course of the investigation on horses, a substance was found in certain white cells in the horses' blood that played an active part in the control of histamine, frequently the cause of surgical and accidental shock.... Earlier research work has shown that the effects of this excess were automatically reduced in the presence of white blood cells (leucocytes) known as eosinophils. This suggested that injections of eosinophils might be used to combat histamine.

Science Future

December 5
Closing ceremony of the 2010 World Memory Championships in Guangzhou, China. See www.worldmemorychampionship.com

December 13–14
Geminid meteor shower, all night but best after moonset around midnight. Look east and up. Info at http://earthsky.org

December 17
Mummies of the World exhibit debuts in Milwaukee as part of its three-year tour. See www.mummiesoftheworld.com

SN Online

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ATOM & COSMOS
Supermagnetized neutron stars may power more gamma-ray bursts than astronomers thought. See "Magnetars may fuel briefer bursts."

EARTH
Climate scientists turn to crowdsourcing to digitize old weather records from ships. Read "Mining the maritime past for clues to climate's future."

BODY & BRAIN
Women's naturally low risk of developing gout doesn't erase the adverse effects of sugary soft drinks. Read "Fructose poses gout risks even in women."

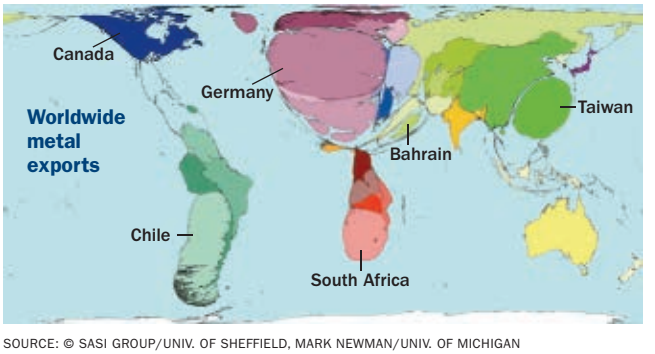
Men who support laptops with their knees together may develop wimpy sperm. See "Laptops and infertility: It matters how you sit."

The (-est)

Scientists have discovered the oldest dragonfly specimen preserved in amber. The dragonfly is in a previously unknown subfamily and lived about 100 million years ago. What's especially odd is the dragonfly's missing head. Also caught in the amber are the foot and tail of a small lizard, which the researchers suspect snatched the head. The lizard bits resemble those of a modern alligator lizard, says study coauthor George Poinar of Oregon State University in Corvallis. The findings appear in the December *Palaeodiversity*.

Science Stats | SHINY STUFF

Each country or territory's size indicates the dollar value of its net metal exports, including bulk metals and manufactured items such as spoons.



SOURCE: © SASI GROUP/UNIV. OF SHEFFIELD, MARK NEWMAN/UNIV. OF MICHIGAN

“If you see a stroke victim, I would sing, I would stroke their face, I would do whatever I can.” —RON FROSTIG, PAGE 14

In the News

STORY ONE

Cats lap liquids with a flick of the tongue and fluid dynamics

Imbibing a delicate interplay between inertia and gravity

By Susan Milius

MICAELA PILOTTO, R. STOCKER AND P. REIS

High-speed movies of house pet Cutta Cutta drinking helped owner Roman Stocker and his colleagues explain how cats get liquids from bowl to mouth.

Sorry, Fido. A paper in the journal *Science* has just ascribed “elegance and complexity” to the way cats drink.

A dog drinks by forming its tongue into a little cup that merely ladles liquid into its mouth, says coauthor Pedro Reis of MIT. “Cats are much more sophisticated in the knowledge of fluid dynamics,” he deadpans.

Instead of scooping, cats use what the researchers describe as a “subtle mechanism” in which water sticks to the tip of the tongue and is pulled up into the mouth, taking advantage of the water’s inertia. Though cats have been lapping liquids in public for millennia and early high-speed photography revealed some basic aspects of their drinking, Reis says he knows of no detailed analysis of the phenomenon preceding the one he and his colleagues published online November 11. “It’s amazing how you look at something and think, somebody must have studied that before. But as happens with many things in everyday life, that is not the case,” Reis says.

He and his colleagues do cite scenes of cats drinking from *Quicker ’n a Wink*, a 1940 film featuring MIT professor and high-speed photography pioneer Harold “Doc” Edgerton. The film won an Oscar, but Edgerton never completely elucidated how cats drink.

The gaps in lapping analysis do not surprise functional morphologist Rebecca Z. German of Johns Hopkins School of Medicine in Baltimore. “What we know about mammalian feeding is woefully incomplete,” she says. It’s hard to observe, and scientists have studied other feats such as locomotion in much more detail.

Unlike people and pigs and sheep, cats and most other adult carnivores don’t have the right kind of cheeks to suck in a liquid. If a bowl or a puddle is shallow enough, a cat plunges its tongue to the bottom and essentially licks the liquid off. But the motion known as lapping works quite differently.

Figuring out the mechanics of cat lapping took high-speed photography; the project’s lappers-in-residence typically managed 3.5 dips of the tongue per second. What the camera revealed is that a cat shoots its tongue down in a J shape, with the tongue tip curled under to touch the liquid’s surface, explains coauthor Roman Stocker, also of MIT. The tip does not scoop into the liquid but pulls directly back into the mouth, reaching peak speeds of 78 centimeters per second.

Liquid adheres to the tip of the tongue and rises in a column as the tip retracts. Just before gravity can overcome the rising liquid’s inertia and collapse the column in a splash, the cat catches the top portion of the liquid column in its mouth.

Along with watching movies of cats drinking, researchers tested their ideas about the process with a device that tapped a disk against a liquid and pulled upward at whatever speed the researchers wanted. With this device and a lot of calculation, the researchers were able to confirm or collapse various hypotheses.

At first researchers thought that the distinctive roughness of a cat’s tongue would play a role in pulling up the liquid column, Stocker says. Wrong. Cat tongues have smooth tips, and, as it turns out, a smooth, wet surface works well for lapping. To get similar wetting properties in their experimental setup, the researchers used a glass disk in their test device.

The viscosity of the liquid did not make a difference in the process, at least within

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

the range of water or milk or anything else a cat would likely lap, the researchers say. Instead the main factors were the inertia of the rising liquid and gravity.

The tug-of-war between inertia and gravity dictates many natural movements involving fluids, from the way a duck swims to the Jesus lizard's ability to sprint short distances over water. The relationship between the two forces is characterized by a quantity known as the Froude number. In the case of feline lapping the Froude number is near 1, indicating that inertia and gravity are roughly in balance in the water column pulled up by a cat's tongue.

A gray house cat named Cutta Cutta inspired the study and served as its primary participant. But researchers analyzed lapping motions in other felines as well by videotaping zoo animals and looking at the fine selection of videos on YouTube that depict cats drinking. The researchers noted that lions lap more slowly than house cats do, and showed that drinking pace is related to body weight in a similar way for all the species studied. The various cats lick at a pace that allows them to consume the most liquid possible in the shortest time.

To get a sip of milk, a cat curls the tip of its tongue into a J shape (top center) and touches it to the surface of the liquid (top right), then pulls up a column of liquid that adheres to the tongue (bottom left). Before the column can collapse under its own weight, the cat snaps its mouth shut (bottom center) to catch a few drops.

Studies like the cat analysis offer insight into basic puzzles of the evolution of mammalian feeding. "All infant mammals suckle by very similar mechanisms, yet there is tremendous variation in adult drinking mechanisms," German says. Also, understanding nature's diverse drinking strategies may inspire help for the many people who struggle to swallow.

And then there's the inherent cool factor, which German rates high. ■

Back Story | STOPPING TIME

Researchers have used high-speed photography to investigate the details of animal motion since the 1870s, when photographer Eadweard Muybridge teamed with industrialist and Stanford University founder Leland Stanford to demonstrate that galloping horses lift all four hooves off the ground. Muybridge set up a series of cameras to photograph a horse at 0.04-second intervals as it ran along a track, showing that all four hooves do in fact leave the ground simultaneously (top)—but not as many artists had imagined. A painting (bottom) by the English artist George Stubbs (1724–1806) depicts a horse with its legs splayed out in a configuration that would be possible only if the animal hopped along like a rabbit.

In the 20th century, photographic studies by researchers such as MIT professor Harold Edgerton revealed the mechanics of human motion and the flight of bats and birds. More recent studies have harnessed high-speed cameras and pulsing lasers to show how hummingbirds can hover over an open flower by using a few aerodynamic tricks also employed by insects.

FROM TOP: R. STOCKER, SUNGHWAN JUNG, JEFFREY ARISTOFF AND P. REIS; WIKIMEDIA COMMONS; WIKIGALLERY.ORG

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Technology

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On the horizon: Holographic Skype

Researchers are close to making 3-D telepresence a reality

By Marissa Cevallos

A palm-sized Princess Leia pleading for help is no longer science fiction.

Arizona researchers have created the first 3-D hologram movie that plays almost in real time, they report in the Nov. 4 *Nature*. It's the fastest known demonstration of telepresence, in which a moving 3-D hologram depicts a scene relayed live from another location.

The key to the invention is a new type of plastic that can refresh the hologram once every two seconds. While that's too slow to watch the Super Bowl in 3-D, the researchers estimate that live holographic TV could be coming in seven to 10 years.

"It is very, very close to reality," says physicist Nasser Peyghambarian of the University of Arizona in Tucson. "Something that was science fiction is something we can do today."

Holograms form when light bounces off material created with grooves in just the right places to project an image away from the surface. The image is even crisper when the illuminating light waves march in step, as they do in a laser.

Holographic video is already possible, albeit painfully slow — the U.S. military records enemy territory in 3-D, but refreshing each frame of the video can take an entire day. The Arizona team created a quicker way to play holographic video in 2008, but each frame still took four minutes to generate. Now they've cut the time to just two seconds.

In the setup, 16 cameras snap pictures of an object from different angles. The images are piped into a desktop PC, which processes the data into holographic pixels, or "hogels." The hogels are sent electronically to another location where they are transformed into an optical signal. Then the hogels are transmitted by a laser onto the back side of a plastic screen. When the laser hits it, the plastic screen undergoes chemical reactions that temporarily record the most recent set of images in the data stream.

A new material allows holographic images sent via the Internet to refresh every two seconds, bringing researchers a step closer to 3-D videochats and TV.

A particular color of light illuminates the plastic screen in a precise way to create the holographic image. Then the screen is erased, creating a clean slate for the next image. The quick succession of images creates a 3-D movie.

But unlike Princess Leia, the new hologram can't float in space. Instead, Leia's image would appear to stick out from a screen's surface. "You need a screen, a support to display the image," says Arizona physicist Pierre-Alexandre Blanche.

Before holographic devices hit living rooms, though, the holograms need to be bigger and faster. The researchers will have to upgrade their 50 hertz laser to one that operates at faster gigahertz speeds, scale up the size of the screen and miniaturize their instrumentation.

"But I don't think there's any fundamental physics that would prevent us from getting there," Peyghambarian says. The exact technological route to holographic TV is still up in the air, as other scientists take different approaches to creating moving holograms.

"Each group is doing it in a slightly different way and there hasn't emerged a single, universally agreed-upon way," says Michael Bove of the MIT Media Lab. "Right now, each technology has some limitation."

Sensor picks up elusive explosive

Handheld device can detect TATP, a favorite of terrorists

By Rachel Ehrenberg

A handheld device that sniffs out the same powerful explosive employed by the would-be shoe bomber may be coming soon to an airport near you. Chemists have developed a sensor that reacts to minute amounts of TATP, an explosive favored by terrorists because it is easy to make and difficult to detect.

The new sensor consists of a postage stamp–sized array of dyes that change color when they react with certain compounds. When air containing triacetone triperoxide, or TATP, is drawn toward the sensor, it passes over a chemical catalyst. Some of the TATP in the air reacts with the catalyst and the resulting mixture hits the dyes. The ensuing reactions yield a specific color pattern that is discernible within minutes, researchers report in the Nov. 10 *Journal of the American Chemical Society*.

Chemically speaking, TATP has few distinct features, making it difficult to detect by standard techniques. But the new sensor responds to amounts below 2 parts per billion, says chemist Kenneth Suslick of the University of Illinois at Urbana-Champaign, who led the work. His team is now taking steps to convert the prototype into a commercially available device that could be waved over suitcases or placed inside walk-through chemical detectors at airports.

BLANCHE *ET AL*/*NATURE* 2010

Life

20 percent Fraction of day some primates spend on reciprocal grooming

90 percent Female vervet monkeys (without infants) that reciprocate grooming

9 percent Female vervets (with infants) that reciprocate grooming

Will groom mom for baby cuddles

Market forces govern infant's value within monkey groups

By Susan Milius

"Do my hair before you touch my baby" is the rule among mother vervet monkeys and sooty mangabeys when it comes to letting a neighbor snuggle their infants.

As in some other primates, monkey babies attract crowds of females eager to touch, hold and make silly lip-smacking noises at the little ones, says primatologist Cécile Fruteau of Tilburg University in the Netherlands. Her novel study of infant-touching etiquette in the vervets and mangabeys adds them to the short list of animals known to have "markets" for baby fondling: Moms must be groomed for a sufficient time before they let the groomer touch the baby.

What makes this exchange a market is the way sufficient grooming time changes with the baby supply, Fruteau and her colleagues explain in a paper posted online in *Animal Behaviour*. The price for access to a group's only infant, measured in grooming time for mom, fell when the number of little cuties available for cuddling rose.

Price is sensitive to other variables as well, says Fruteau, who documented for the first time that infant age makes a difference in how much grooming the baby attracts to mom. Newborns earn their mothers the longest grooming sessions. One newborn mangabey, for example, the only baby in its group at the time, earned about 10 minutes of fur cleaning and combing for its mom. In contrast, another lone baby didn't even earn four minutes of grooming once it had reached the advanced age of almost 3 months.

Grooming time also correlated with access to vervet babies but not with fondling time or the degree of familiarity allowed. With enough grooming, moms permitted pretty much any female in their group to at least touch or sniff the baby. But it was mostly females with a history of grooming mom who could actually hold the baby.

"Prices" for a baby encounter also varied with rank, as in other infant-handling markets, Fruteau says. A female ranking lower in the group hierarchy of either species had to groom longer for access than a high-ranked monkey did.

Grooming-for-cooing trades have also been reported in chacma baboons and long-tailed macaques. In spider monkeys, the currency is hugging, not grooming.

Comparisons with markets can certainly be useful, says primatologist Rebecca E. Frank of Los Angeles Valley College in Valley Glen, Calif., "but it just leaves some aspects of female exchange unexplained." In her study of olive baboons, about two-thirds of grooming encounters, even without babies involved, don't get promptly or obviously reciprocated. These partners appear to have long-term relationships that don't require immediate settling of accounts.

It remains unclear why babies stir such urges to fondle, Fruteau says. For vervets and mangabeys that's largely a female urge. Males interact more with older kids.

In South Africa, a baby vervet monkey peeks out from mom's embrace. Other females must pay to play, grooming mom for access to her infant.

FROM TOP: FLORIAN MÖLLERS/FLORIAN@WILD-WONDERS.COM; ALEXANDRA GRUTTER

Slimy net foils biting pests

If you were to find yourself in the jungle without a mosquito net, slathering yourself in snot might be a good course of action. It works for fish: Australian scientists found that some coral reef fish are protected from biting isopods, a marine equivalent of mosquitoes, by the blob of mucus the fish don each night. It wasn't clear how the coat served certain parrot fish (shown) and wrasses. But when a University of Queensland team put tiny parasitic isopods—bloodsucking crustaceans closely related to lice—into tubs with parrot fish, only 10 percent of fish with intact mucus cocoons had bites, versus 94 percent of fish without cocoons. Making the cocoon is an efficient protection strategy, costing a mere 2.5 percent of the fishes' daily energy budget, the researchers report online November 17 in *Biology Letters*. —*Rachel Ehrenberg*

Environment

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

Lower pH harms coral's fertility

Acidifying oceans may halve the supply of reef builders

By Susan Milius

By midcentury, growing acidification of the world's oceans may undermine sexual reproduction in elkhorn coral badly enough to halve the supply of youngsters settling down to build reef.

Acidification, which happens as increasing levels of atmospheric carbon dioxide dissolve in the ocean and form acid, is expected to threaten reefs worldwide in coming decades. In lab tests with seawater modified to reflect conditions expected later this century, sperm of the elkhorn coral, *Acropora palmata*, fertilized eggs 13 percent less often on average compared with sperm in today's seawater, says Rebecca Albright of the University of Miami. At low sperm concentrations, which Albright suspects more realistically model life in the sea, fertilization success fell by as much as 64 percent.

Even when fertilization was successful, the resulting larvae had more trouble getting established on a reef, Albright and her colleagues report online November 8 in the *Proceedings of the National Academy of Sciences*.

Elkhorn corals release their sperm and eggs at night. Coral fertilization could decline as seawater pH drops.

Since the beginning of the industrial revolution, global seawater has dropped from about 8.2 on the pH scale to between about 8.05 and 8.1. Each unit on the scale reflects a shift in acid concentration by a power of 10, so the effect to date has been about a 30 percent increase in acid level.

For the tests, Albright and her colleagues bubbled carbon dioxide gas into natural seawater to mimic the predicted ocean chemistry of a world where emissions have driven atmospheric carbon dioxide from the current concentration of about 387 parts per million up to 560 ppm, an increase that could occur by midcentury if emissions are not abated.

She and her colleagues also tested a case of atmospheric carbon dioxide levels reaching about 800 ppm by 2100. Elkhorn coral fertilization and settlement suffered even more at those concentrations. The pH change could reduce the supply of established youngsters on a reef by 73 percent, the researchers say.

Sexual reproduction is not the only way corals expand. Individuals can clone themselves, but sex maintains the genetic diversity that researchers hope will help corals cope with a disrupted environment.

"It is a big deal if you lose sexual reproduction, even in species with very effective means of reproducing asexually," says ecologist Steve Gaines of the University of California, Santa Barbara, because in corals and most other invertebrates the sexually produced offspring are the ones that colonize new places.

BPA passes easily through the skin

Finding may explain high levels of chemical seen in cashiers

By Janet Raloff

Bisphenol A readily passes through skin, scientists report. The finding suggests handling store receipts could be a significant source of exposure to the chemical, which has been linked to health concerns.

A majority of thermal receipt papers employ BPA in their heat-sensitive color-change coating (*SN: 8/28/10, p. 5*), a powdery substance that can rub off.

In the new study, toxicologist Daniel Zalko of the French National Institute for Agricultural Research in Toulouse and colleagues collected pig ears minutes after slaughter. The researchers then applied various amounts of BPA to the pig skin. The lowest concentration delivered a dose of BPA in the ballpark of what could rub off onto a person's skin from handling receipt paper, Zalko says.

In three days, more than half of the BPA had diffused through the cultured skin. In a live animal, he says, the chemical would probably have entered the bloodstream.

Researchers ran similar tests using tiny samples of healthy abdominal skin that had been removed from women during surgeries. Again, almost half of the applied BPA passed through the tissue.

The findings, posted online October 27 in *Chemosphere*, are "unequivocal in showing that yes, BPA can go through human skin," says Frederick vom Saal of the University of Missouri-Columbia.

They may also explain another finding: Among nearly 400 pregnant Cincinnati-area women, cashiers had the highest BPA concentrations in their urine, scientists report in an upcoming issue of *Environmental Health Perspectives*.

Because BPA can't be seen or smelled, consumers have had no way to identify receipt paper with the chemical. That should change soon. On November 8, Wisconsin-based Appleton Paper — the sole source of BPA-free U.S. thermal-receipt paper — began embedding tiny red fibers to mark its paper.

EVAN D'ALESSANDRO/RSMAS, UNIV. OF MIAMI

Humans

43 On a scale of 0 to 100, average happiness reported while mind wanders to unpleasant topics

70 On 0 to 100 scale, average happiness reported while focusing on a task at hand

Wandering mind is unhappy mind

Even pleasant distractions aren't better than none at all

By Bruce Bower

A wandering mind often stumbles downhill emotionally. People spend nearly half their waking hours thinking about stuff other than what they're actually doing, and these imaginary rambles frequently feel bad, according to a new study that surveyed volunteers' activities and moods at random times via their iPhones.

People's minds wander at least 30 percent of the time during all activities except sex, say graduate student Matthew Killingsworth and psychologist Daniel Gilbert, both of Harvard University. Individuals feel considerably worse when their minds wander to unpleasant or neutral topics, as opposed to focusing on current pursuits, Killingsworth and Gilbert report in the Nov. 12 *Science*.

These new findings jibe with philosophical and religious teachings that assert happiness is found by living in the moment and learning to resist mind wandering, Killingsworth says.

Mind wandering serves useful purposes, he acknowledges, such as providing a way to reflect on past actions or plan for the future. "That's not a recipe for happiness, even if it's necessary."

In the new study, people's minds wandered more often to pleasant topics than to unpleasant or neutral topics. But those reveries offered no measurable mood boost over thinking about tasks at hand, the researchers find.

It's important to note that the new data apply only in the short run, comments psychologist Jonathan Schooler of the University of California, Santa Barbara. "Positive flights of fancy may lead to creative problem solving and planning that makes people happier down the road," he speculates.

Aboriginal time flows east to west

Sun's trajectory may define schedules for one remote group

By Bruce Bower

In a remote part of Australia, time rises in the east and sets in the west. Aborigines living there assume that time moves westward, apparently in accord with the sun's daily arc across the sky.

These hardy foragers think about the day after tomorrow as two days to the west, the olden days as far to the east, and the progression of a person's life from infancy to old age as running to the west. Stanford psychologist Lera Boroditsky and linguist Alice Gaby of the University of California, Berkeley report the first study of this group's sense of time in an upcoming *Psychological Science*.

Grounding time in absolute directions makes it imperative for these people, called Pormpuraawans, to know which way they're facing at all times. For them, time flows from left to right when facing south, from right to left when facing north, toward the body when facing east and away from the body when facing west.

Pormpuraawans rarely use terms for right and left and instead refer to absolute directions; for example, "Move your cup to the north-northwest a little bit."

Culture powerfully influences how people conceive of time, in Boroditsky's view. "Pormpuraawans think about time in ways that other groups cannot, because those groups lack the necessary spatial knowledge," she says.

Previous studies have indicated that people use their bodies as a reference to lay out time. In the United States, time is generally thought of as running from left to right. Other populations arrange time from right to left, back to front or front to back.

For one group, time flows from left to right when facing south and right to left when facing north.

"This new finding is of great significance since cognitive scientists have assumed that time representations must be body-based," remarks Asifa Majid of the Max Planck Institute for Psycholinguistics in Nijmegen, the Netherlands.

Cultural differences in thinking about spatial orientation shape time representations, proposes Daniel Haun, also of the Max Planck Institute for Psycholinguistics. In 2009, Haun described how Namibian hunter-gatherers remember dance steps and other movements according to absolute directions.

Some evidence suggests that an innate tendency to navigate using external landmarks and absolute directions translates to a body-centered viewpoint in certain cultures (*SN: 2/10/07, p. 88*).

The team studied 14 Pormpuraawans and 14 Stanford students. In one task, participants were asked to lay out cards depicting a progression over time, such as a man at different ages. In another, volunteers denoted time periods using stone markers. If the experimenter's stone represented today, for example, volunteers indicated spots for yesterday and tomorrow.

U.S. students always portrayed time as moving from left to right, regardless of what direction they were facing. Most Pormpuraawans depicted time as moving from east to west, so time's flow shifted course as they changed direction.

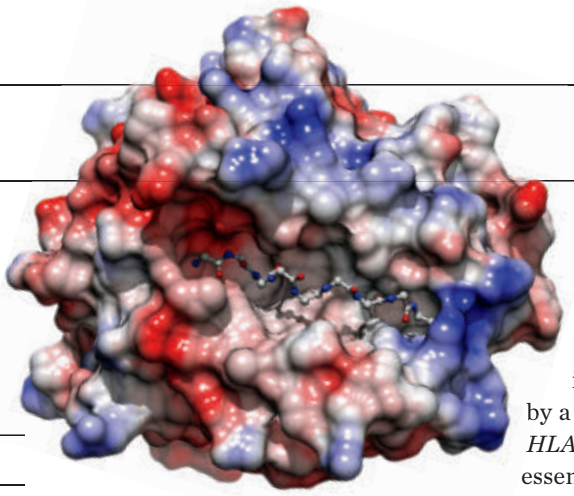
The few body-based responses among Aborigines may reflect increasing exposure to television and Western life as well as unfamiliarity with arranging objects in sequences, Boroditsky suggests.

Body & Brain

Gene variants help stop HIV

Immune changes combat virus in 'elite controllers'

By Nathan Seppa



By binding tightly to a fragment of the virus (center), one form of the HLA-B protein may help stymie HIV.

Variations in an immune system gene account for at least part of the uncanny ability of some people to withstand an HIV infection without developing AIDS, researchers report online November 4 in *Science*. The study confirms past data linking the gene, called *HLA-B*, to HIV defense and narrows researchers' focus to molecular changes brought on by particular variations in the gene.

About one in 300 people with HIV are "elite controllers." Though infected with the virus, their immune systems somehow control the disease such that it rarely progresses, even without medicine. Scientists have long thought that understanding this protection could help to create drugs or a vaccine against HIV.

In the new study, a multinational consortium of researchers identified more than 1 million genetic variations in blood samples from people with HIV, some elite controllers and some not. The scientists were able to spot more than 300 variations that differed substantially between the groups, says study coauthor Paul de Bakker of Harvard Medical School and Brigham and Women's Hospital in Boston. For example, a variant called *HLA-B*57:01* showed up five times as often in controllers as in the others.

The HLA-B protein comes in many varieties, each encoded by a slightly different version of the *HLA-B* gene. The protein provides an essential immune function, collecting viral fragments in cells and displaying them on the cell surface for inspection by marauding immune enforcers called CD8 T cells, which give each protein fragment a thumbs-up or thumbs-down. If the CD8 T cell disapproves of a fragment, the whole cell gets destroyed.

By analyzing the structure of the HLA-B protein variants and noting which were linked to protection against HIV, the researchers were able to zero in on a handful of amino acids — the molecular building blocks of proteins — that are instrumental to the all-important binding of HLA-B proteins to HIV fragments in a cell.

MRIs able to pinpoint time of stroke

Prompt scans could expand usefulness of clot-busting drugs

By Nathan Seppa

MRI scans of stroke patients can indicate when the stroke occurred, a revelation that could allow more aggressive treatment to limit brain damage, researchers report in the December *Radiology*.

When a clot obstructs an artery in the brain, an estimated 2 million neurons are lost each minute as tissue is starved of blood and oxygen. A clot-busting drug called tPA, or tissue plasminogen activator, can often dissolve the clot and free up the vessel. But the drug is generally considered safe to administer only in the first three to 4.5 hours after a stroke begins (*SN: 10/25/08, p. 16*).

Stroke patients typically get a CT scan when they show up at the hospital, says neurologist Andrew Barreto of the University of Texas Medical School at Houston. But a CT scan cannot pinpoint when a stroke began. Neither can many patients, either because they can't recall exactly when their symptoms first appeared or because they woke up already in the throes of a stroke. In such cases, doctors hesitate to give tPA if too many hours might have passed. Giving tPA too late won't help tissue that's already dead and risks causing bleeding in the brain.

In the new study, physicians Catherine Oppenheim and Mina Petkova of the University of Paris Descartes examined magnetic resonance imaging scans of 130 patients, average age 65, who had been admitted to a Paris hospital with clot-based strokes for which onset times were known. About half had undergone MRIs within three hours of onset, while the others were imaged three to 12 hours after symptoms started.

The doctors examined the MRI scans without knowing how long after the stroke each had been performed. Applying three standard tests, the researchers made measurements to assess the extent of dead tissue in the brain resulting from a clot. One measurement, called fluid-attenuated inversion recovery, clearly distinguished between MRIs taken during the first three hours and those taken later. That measurement was accurate in about 90 percent of cases, whereas the other tests were less exact.

"These data look provocative," Barreto says. "If a CT scan shows no bleeding but subtle changes, you don't always know what to do with the patient. That's where an MRI is superior." Although an MRI can take 30 to 45 minutes to complete, Baretto says, that delay might be worthwhile if the readings expand the group of patients who could benefit from tPA.

P. DE BAKKER

Pioneering audiologist invents "reading glasses" for your ears.

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It's amazing how technology has changed the way we live. Since the end of the Second World War, more products have been invented than in all of recorded history. After WWII came the invention of the microwave oven, the pocket calculator, and the first wearable hearing aid. While the first two have gotten smaller and more affordable, hearing aids haven't changed much. Now there's an alternative… Neutronic Ear.

First of all, Neutronic Ear is not a hearing aid; it is a PSAP, or Personal Sound Amplification Product. Until PSAPs, everyone was required to see the doctor, have hearing tests, have fitting appointments (numerous visits) and then pay for the instruments without any insurance coverage. These devices can cost up to $5000 each! The high cost and inconvenience drove an innovative scientist to develop the Neutronic Ear PSAP.

The Evolution of Hearing Products

Invention	Date	Easy to Use?	Invisible?	Affordable?
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Wearable Hearing Aid	1935	Weighed 2.5 pounds	No	No
Digital Hearing Aid	1984	No	No	Not for most people
Neutronic Ear	2010	Yes	Yes	Yes

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Bird-watching and almost any daily activity

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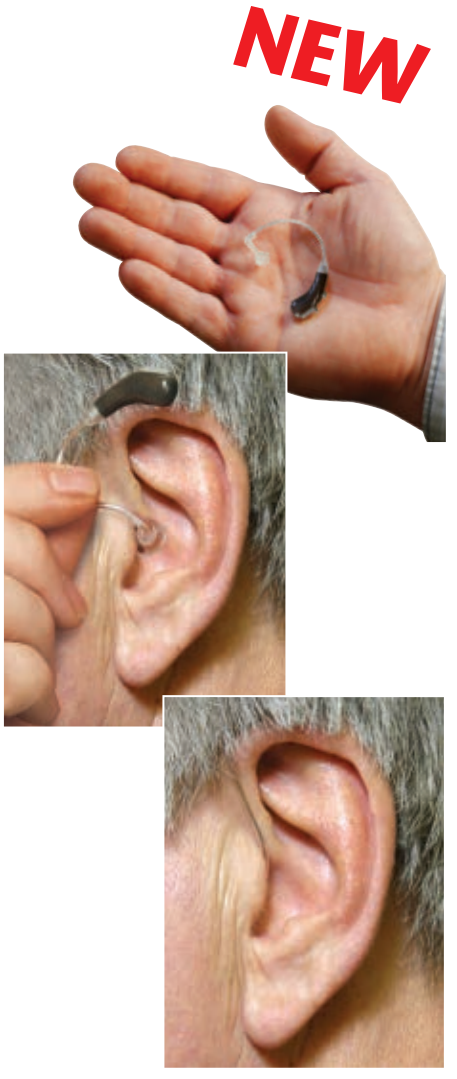

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Neuroscience

"If you want to really restore normal vision, you have to know the retina's code." —SHEILA NIRENBERG

A new retinal prosthetic creates an image (middle) that more accurately reconstructs a baby's face (left) than does the standard approach (right).

A new way that the blind might see

Prosthetic retina can turn neural inputs into clearer images

By Laura Sanders

A new type of prosthetic eye may allow the estimated 25 million people worldwide who have lost sight due to retinal diseases to someday see the broad sweep of an ocean or the dimples of a baby's face.

Sheila Nirenberg of the Weill Medical College of Cornell University in New York City presented data November 13 showing that the new retinal prosthetic allowed blind mice to see a baby's face. Current prosthetics can reproduce simple features, such as bright spots or edges, but miss much of a scene.

Many scientists are intent on boosting retinal prosthetics' power. But the new work suggests that a second, underappreciated area is also important: the pattern of cell activity in the retina.

Normally cells that respond to light, called photoreceptors, pick up signals and transfer that information as nerve impulses to ganglion cells. These cells process the information further and relay it to the brain, where the scene is constructed. Spotting a dog creates a particular code, for example, different from the code for a teacup or a baby's face. When a retina is degenerated, the photoreceptor cells die and there is no message to send.

The new system mimics the complex behavior of photoreceptor cells, creating a more natural message for the ganglion cells to interpret. Other prosthetics produce simpler codes, Nirenberg said. Because the new prosthetic speaks the language that the ganglion cells are used to, the ganglion output — and the image — is more accurate.

"If you want to really restore normal vision, you have to know the retina's code," Nirenberg said. "Once you have that, the door is open to the possibility of restoring normal vision."

The researchers are currently testing the prosthetic on primates and plan eventually to provide the technology to human patients.

Stroke damage halted by a tickle

Rat study suggests sensory stimulation can protect brain

By Laura Sanders

In the two-hour window after a stroke, a flick of a single whisker prevents many damaging effects in a rat, a new study finds. The cheap, simple intervention, described November 15, may represent a new way to minimize disability after a stroke in people.

"It's almost too good to be true," said neuroscientist Carol Barnes of the University of Arizona in Tucson. "Any protection would be good, but this is more than dramatic."

Researchers led by Ron Frostig of the University of California, Irvine mimicked a stroke by severing a major blood vessel in rats' brains. Then at times during the two hours immediately afterward, a mechanical rod stimulated a single whisker on the anesthetized rat for a total of less than five minutes.

With whisker stimulation, blood got rerouted through other vessels, ultimately reaching the brain area that would have been deprived of blood, Frostig reported. No such rerouting was present in rats that didn't have a whisker stimulated, or in rats that had whisker stimulation more than two hours after the stroke. The team's preliminary data suggest that the method works for conscious rats, too.

Brain imaging later found no evidence that a stroke had even occurred in the whisker-brushed rats. "I have looked at these images for 20 years, and I cannot tell you that this animal went through a major trauma," Frostig said. "It looks exactly the same" as scans of healthy rats.

The current study was done with young rats, but the researchers have also found that whisker stimulation protects against stroke damage in 22-month-old rats (the equivalent of 50- to 60-year-old humans).

Researchers don't yet know whether a similar link between sensory stimulation and stroke protection is present in people. The human analogs to a whisker are the lips and fingers, so perhaps sensory input to those regions might confer benefits to someone having a stroke.

Any stimulation might be useful, Frostig speculated. "If you see a stroke victim," he said, "I would sing, I would stroke their face, I would do whatever I can."

S. NIRENBERG

MEETING NOTES

Mom's past drug use may matter
Drug-using moms-to-be who quit before becoming pregnant can still raise the risk among their children and grandchildren for addiction or other psychiatric disorders, a new study suggests. Researchers at Tufts University's veterinary school in North Grafton, Mass., exposed female rats to morphine. After three weeks drug-free, the rats mated with healthy males. Male offspring produced less of a molecule sensitive to the chemical messenger dopamine in the nucleus accumbens, a brain structure related to addiction and reward-seeking behavior. A similar deficit was found in male grandchildren of the original rats, Elizabeth Byrnes of Tufts reported November 14. Problems with the brain's dopamine system have been linked to substance abuse and mental illness.
— *Tom Siegfried*

Cocaine trumps food in females
Presented with a choice between cocaine and food, female rats choose the drug while male rats go for the grub, a new study finds. The result may help clarify differences in addiction between men and women, scientists reported November 14. Kerry Kerstetter of the University of California, Santa Barbara and colleagues trained rats to press different levers for food and cocaine. Hungry male rats preferred the food. But hungry females chose cocaine over food about half of the time. Scientists don't yet know the reason for the observed sex difference, but Kerstetter and her colleagues think female hormones play a role.
— *Laura Sanders*

Earth

"We were expecting to find rapid extinction, a total change in the forest." —CARLOS JARAMILLO

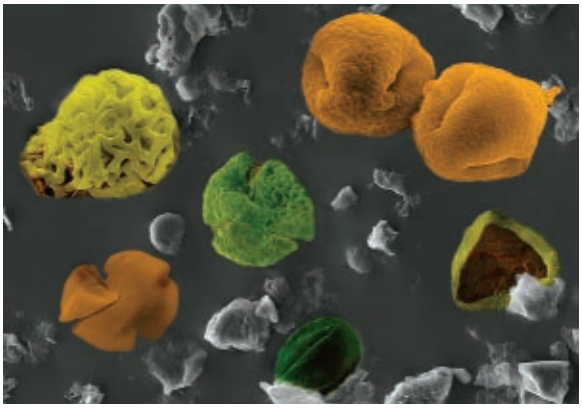
Warm spell spurred biodiversity in South American tropical rain forest

At least some plants could survive hotter climes than today's

By Alexandra Witze

Some like it hot, including the plants living in South America's tropical rain forests 56 million years ago.

As average global temperatures spiked by 5 degrees Celsius over a period of 10,000 years — a geologic blink of an eye — plant diversity in northern South America also soared, researchers report in the Nov. 12 *Science*.



The diversity of pollen found in deposits from northern South America suggests that tropical rain forest plants thrived there during a warm spell 56 million years ago.

"We were expecting to find rapid extinction, a total change in the forest," says study leader Carlos Jaramillo, a paleobotanist at the Smithsonian Tropical Research Institute in Balboa, Panama. "What we found was just the opposite — a very fast addition of many new species, and a huge spike in the diversity of tropical plants."

The fossil study raises questions about how tropical forests might respond as atmospheric carbon dioxide levels rise because of fossil fuel burning and other industrial activities. Though today's forests may not respond to warming the same way ancient forests did, researchers say the findings do suggest that at least some plants are surprisingly adaptable.

"This kind of work is critically important," says Scott Wing, a paleobotanist at the Smithsonian Institution in Washington, D.C., who was not part of the study. "We're beginning to map out what happened in different places during this huge perturbation of the carbon cycle and climate system."

Researchers call the warming the Paleocene-Eocene Thermal Maximum, because it took place at the boundary between the Paleocene and Eocene epochs of geologic time. It's the closest analog scientists have to the global warming they expect in the future, though on a much slower scale; today, instead of a 5 degree Celsius increase over 10,000 years, researchers expect a 2 degree C increase over just the next century, with more warming after that.

Only a few places on land preserve evidence of how plants and animals responded to the Paleocene-Eocene heat, most in temperate or northern latitudes. In Wyoming, Wing and other researchers have found fossils suggesting that as things heated up, species from more southern regions moved into the area temporarily. But some tropical forests are already in the hottest places on the globe, so there is no still-warmer place from which other species might have moved to populate these spots. Many think these forests are already close to the maximum temperature at which they can survive.

To probe this question, Jaramillo and colleagues spent seven years scouring South America for sedimentary rock outcrops with ages spanning the Paleocene-Eocene boundary. Eventually the researchers narrowed their list to three sites in Colombia and Venezuela. By taking samples of pollen and other plant fossils from rock layers below and above the boundary, the team could gauge the diversity of plant types in those places before, during and after the hot spell.

Before the warming, the landscape was covered by a tall, damp rain forest with even more species than the Amazon has today, Jaramillo says. As temperatures rose into the Eocene, more plant groups appeared in the rock record — mainly angiosperms, the flowering plants that are the largest and most diverse plant group on Earth. Once the warming abated about 200,000 years later, those new plants stuck around for good.

Unlike in Wyoming, where native plants moved off the scene during hot spells and then returned, the South American plants apparently dealt with the heat by diversifying in a great evolutionary burst. "This shows that plants have the genetic variability already built in to cope with high temperatures and high CO_2," says Jaramillo.

But that doesn't mean tropical forests will necessarily thrive under future climate change. Oliver Phillips, a tropical ecologist at the University of Leeds in England, says that it's a stretch to suggest that plants at the end of the Paleocene would have responded to warming the same way modern plants would. "Very few modern genera, let alone species, were extant 56 million years ago," he says, "and our modern plants therefore evolved with different climate tolerances." Tropical plants are far more likely to go extinct in the near future than to diversify into new species, he says.

So even though global warming is expected to raise temperatures the most at polar latitudes, it may have the greatest biodiversity impact in the tropics. ■

FRANCY CARVAJAL/SMITHSONIAN TROPICAL RESEARCH INSTITUTE

Genes & Cells

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Genome may be full of junk after all

Cross-species analysis suggests most DNA has no function

By Tina Hesman Saey

Most of the human genome may actually be junk.

In recent years scientists have stopped dismissing as nonfunctional the part of the genome that doesn't produce proteins. But a new study comparing the human genetic blueprint with those of other mammals concludes that very little of the human genome is really necessary.

About 7 percent of the human genome is similar to the DNA of other mammals, said Arend Sidow of Stanford University. Because it is similar, or "conserved," geneticists assume this DNA is the most integral. In all, Sidow concludes, these important parts of the genome comprise only 225 million of the 3 billion chemical letters of DNA found in the complete human genetic instruction book.

But only a small portion of the conserved DNA is translated to produce proteins. Comparing the human genome with those of other mammals, Sidow shows that about 85 percent of the conserved DNA (a bit more than 6 percent of the total genome) is in spacers between genes or between protein-producing bits within genes. This positioning suggests that these DNA regions may play a role in regulating how proteins are made, Sidow said November 3.

Sidow's studies rely on the principle that if certain pieces of DNA are retained throughout evolution, they must be important. Things that aren't conserved by evolution are less likely to be required for basic functions. "I think the rule is that important stuff stays," he said.

And all the extra DNA isn't necessary to add complexity, Sidow argues. After all, the puffer fish has a genome of only about 390 million DNA letters, but is still a sophisticated organism.

But some of Sidow's colleagues think his analysis may be missing some crucial elements. Recent studies of RNA molecules that don't code for proteins show that those molecules have definite functions, even though they aren't conserved in the DNA codes of other mammals, said Job Dekker of the University of Massachusetts Medical School in Worcester. "Lots of things that are important are not conserved," he said. And current computer programs may not be very good at picking out small DNA regions shared among many species, he added. ■

Central dogma thrown off-kilter

In thousands of genes, RNA is not a faithful copy of DNA

By Tina Hesman Saey

Text messagers and computer gamers aren't alone in the willful misspelling department. RNA molecules do it too.

RNA molecules aren't always faithful reproductions of the genetic instructions contained within DNA, a new study shows. The finding seems to violate a tenet of genetics so fundamental that scientists call it the central dogma: DNA letters encode information and RNA is made in DNA's likeness. The RNA then serves as a template to build proteins.

But a study of RNA in white blood cells from 27 different people shows that, on average, each person has nearly 4,000 genes in which the RNA copies contain misspellings not found in DNA.

"It's unbelievable," said Mingyao Li, a geneticist at the University of Pennsylvania Medical School in Philadelphia who presented the finding November 3.

Scientists already knew that every now and then RNA letters can be chemically modified or edited — sort of the molecular equivalent of adding an umlaut to some letters. But such RNA editing events are not that common.

RNA molecules contained misspellings at 20,000 different places in the genome.

What Li and her colleagues discovered is quite common. RNA molecules contained misspellings at more than 20,000 different places in the genome, with about 10,000 different misspellings occurring in two or more of the people studied. The most common of the 12 different types of misspellings changed the chemical letter "A" in the DNA to "G" in the RNA. That change accounted for nearly a third of the misspellings.

Some researchers who saw Li's presentation asked whether a virus used in growing the white blood cells that the researchers studied might be the source of the shenanigans. Li and her collaborators had wondered the same thing. In order to rule out the virus, the researchers analyzed skin cells from the same people and found that RNA misspellings originally discovered in the white blood cells were also in the skin cells. And the misspellings aren't just rare, random mistakes. "When DNA and RNA differ from each other it happens in nearly every RNA" copy, Li said.

The researchers don't yet know how the RNA misspellings happen. They could be substitutions made while the RNA copy is being made, or the changes could happen later. Any consequences of the misspellings are also unknown, though some speculate that the misspellings could cause the RNA to be degraded faster or interfere with the molecule's ability to make proteins. ■

Atom & Cosmos

"This is the type of moment that scientists live for."
—DON YEOMANS

Milky Way blows cosmic bubbles

Gamma-ray blobs emanate from the center of the galaxy

By Ron Cowen

The Milky Way is blowing bubbles of cosmic proportions.

Twin bubbles of gamma ray–emitting gas, each the size of a small galaxy, sit above and below the center of the Milky Way like the ends of a giant dumbbell, astronomers have discovered.

Douglas Finkbeiner of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass., and colleagues analyzed data from NASA's Fermi Gamma-ray Space Telescope to find the bubbles. Finkbeiner described the findings, which appear in the Dec. 1 *Astrophysical Journal*, during a November 9 briefing.

The bubbles aren't readily apparent because a high-energy gamma-ray fog, discovered by Finkbeiner and his colleagues last year, fills the sky, mainly due to high-speed electrons and protons interacting with light and interstellar gas in the galaxy. But when Finkbeiner and his colleagues subtracted the fog from the Fermi telescope's data, they uncovered the two giant lobes.

Depending on when the bubbles were generated, each lobe could hold the energy released by 100,000 supernovas, Finkbeiner said. Each has a diameter of about 25,000 light-years, roughly the length of the Large Magellanic Cloud, a satellite galaxy of the Milky Way.

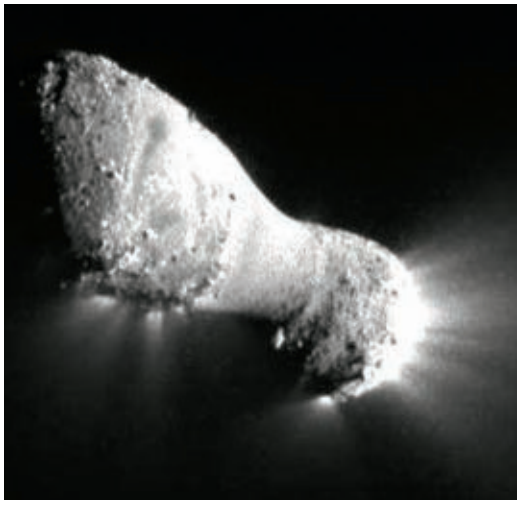
Gamma-ray bubbles, shown in an illustration, extend about 25,000 light-years to either side of the galaxy's plane.

One possible source of the bubbles is a proposed wave of star birth at the galaxy's center millions of years ago. If a large population of massive stars were born all at the same time, their explosive deaths could have created enough energy, in the form of energetic electrons or protons, to power the bubbles and cause them to glow with gamma rays. However, previous evidence suggests that the number of massive newborns required to provide the energy would be unrealistically high.

Finkbeiner said he now favors another explanation—jets of material expelled by the supermassive black hole that is thought to reside at the galactic center. At present, the black hole isn't radiating much. But if it went on a feeding frenzy a few million years ago, the black hole would have hurled jets of material that could easily power the bubbles. This could be the first evidence for a major eruption of the supermassive black hole, Finkbeiner said.

It's also possible that the best explanation could turn out to be a combination of both sources, he said. Supernova explosions from a population of massive stars might have inflated the bubbles, while subsequent jet activity from the black hole might have set the bubbles aglow in gamma rays.

Theorist David Spergel of Princeton said that he suspects that the central black hole, as massive as about 4 million suns, is the energy source. Black holes at the centers of other galaxies drive winds and jets that can be powerful enough to expel heavy elements and gas from the galaxies. The new observations "suggest that our own Milky Way may [also] be driving material outwards," he said.



Spacecraft encounters comet

Small but spunky, hyperactive Comet Hartley 2 is shaped like a peanut and spews several jets of gas and dust from both its day and night sides, NASA's EPOXI spacecraft has revealed. Intriguingly, the activity of the comet appears to be driven by the sudden venting into space of frozen carbon dioxide—dry ice—rather than the frozen water that has been seen coming off many other comets, said principal mission scientist Mike A'Hearn of the University of Maryland in College Park. It's the emission of carbon dioxide, rather than frozen water, that waxes and wanes most dramatically as the active portions of the 2-kilometer-long comet rotate in and out of sunlight, A'Hearn noted during a November 4 press briefing at NASA's Jet Propulsion Laboratory in Pasadena, Calif., just a few hours after EPOXI passed within 700 kilometers of the elongated object. As images from the encounter arrived at the lab, JPL planetary scientist Don Yeomans commented: "This is the type of moment that scientists live for." —*Ron Cowen*

FROM TOP: GSFC/NASA; JPL/NASA, UMD

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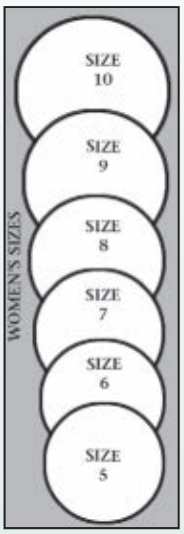
The Sigh Heard 'Round the World

One soldier's incredible true story about the top secret operation that took his wife's breath away.

It was an American soldier in Iraq who showed me the true power of a piece of jewelry. He wrote to tell us that shortly after marrying his sweetheart he received orders to return to active duty as part of Operation Iraqi Freedom. Like a true romantic, he wasn't about to let 7000 miles (or a war) ruin their first Christmas as husband and wife. He found the perfect gift from Stauer and asked his new bride to call him when it arrived.



USING THE RING SIZE CHART
Place one of her rings on top of one of the circle diagrams. Her ring size is the circle that matches the inside diameter of the ring diagram. If her ring falls between sizes, order the next larger size.

"So far away, I would not be able to see her reaction, but I wanted to hear it," he wrote. On the day the package arrived, she called as promised. With her husband listening, halfway around the world on the end of the line, she opened the box and slowly lifted the lid.

"As soon as I heard her breath stop, I knew she'd seen it", the soldier wrote. Even though they were oceans and continents apart, in that instant the newlyweds were reunited. Romance wins again.

I love that story. I want to hear more of those stories, lots more. Those kind of unforgettable moments are the reason that the ***Emerald-Cut Diamond*Aura® *Gial Ring*** exists. In the fine tradition of jewelry designed to take her breath away, we created this stunning showcase for a magnificent 4 ¾-carat yellow, lab-created Diamond*Aura*. Layered in platinum over sterling silver, the luxurious golden yellow centerpiece is highlighted by dozens of sparkling white Diamond*Aura* rounds.

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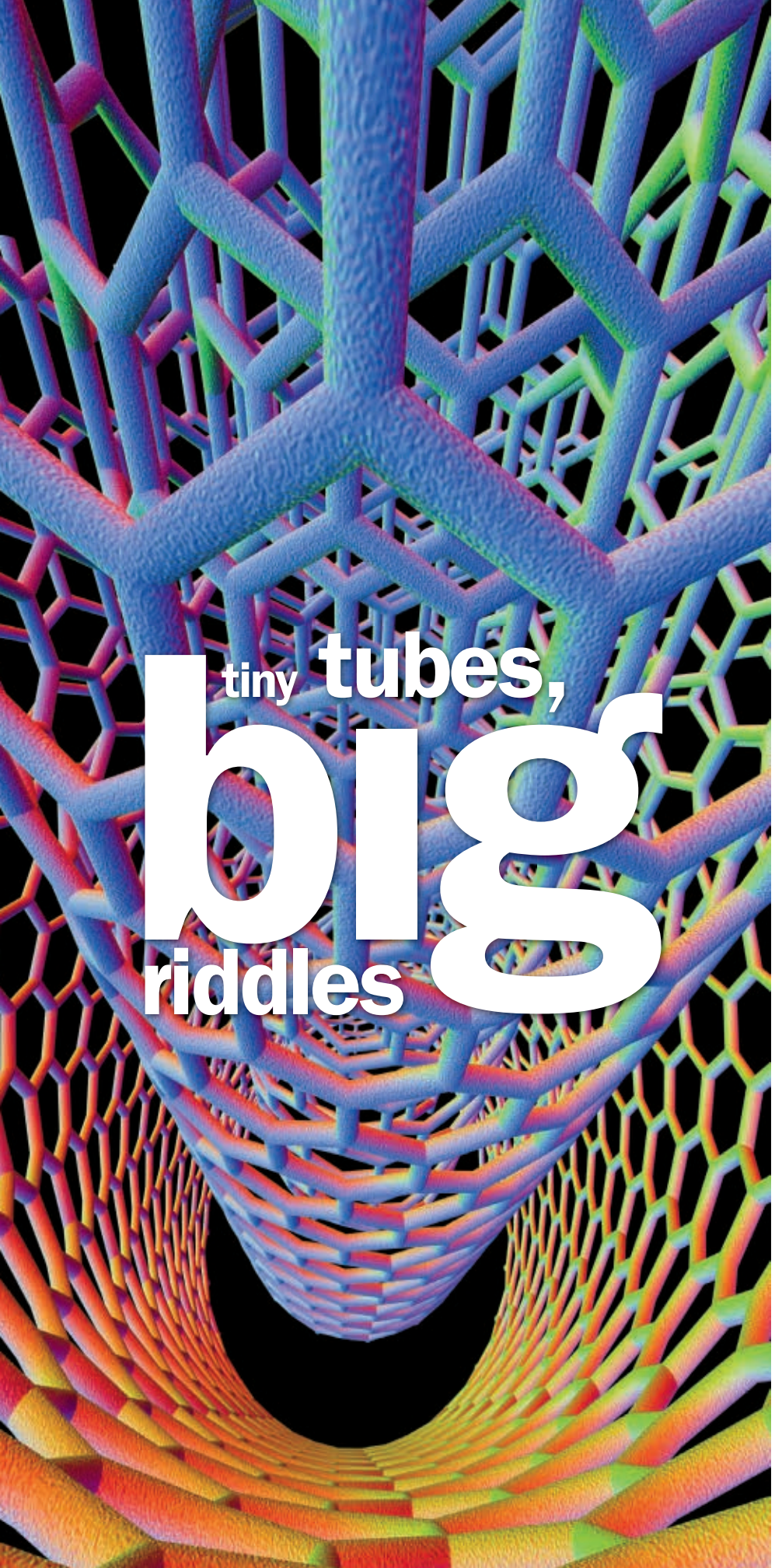


tiny tubes, big riddles

Carbon cylinders' odd traits continue to stump scientists

By Rachel Ehrenberg

Moses didn't need a physics degree to know something was afoot when that woody bush burned and burned but was not consumed. Set fire to carbon — whether shrubbery, paper or charcoal briquettes — and it burns until nothing's left but carbon dioxide and water vapor. That's a fundamental of carbon chemistry.

Yet in the tiny world of nano, where objects and distances measure mere billionths of a meter, rules of chemistry and physics that operate at ordinary scales often don't apply. Scientists recently discovered, for example, that slathering a minuscule tube of carbon in fuel and lighting one end doesn't destroy the carbon. Flames course down the nanotube, and it gets scorching hot. But the tube remains intact.

"The carbon doesn't burn up," says chemist Michael Strano of MIT, who led the research. "What really should happen is oxidation. They should catch fire; there should be nothing left. But the carbon seems to be unscathed. It's kind of a walking-across-hot-coals type of thing, where you would expect to be scorched but you're not."

Fire without burning is just one of the newer oddities to emerge from the nanoworld. In this landscape, molecules take on new personalities — it's like discovering that your mild-mannered uncle is a world-renowned salsa dancer and moonlights as a bounty hunter. Some of these eccentricities have been known for decades or longer. When nanosized, calm, inert gold, for example, becomes a reactive molecule that has a different melting point than ordinary gold. It no

Nearly 20 years after their discovery, nanosized tubes made of carbon exhibit behaviors that still surprise scientists.

longer looks gold, in fact, but red — a property that stained glass artisans exploited centuries ago.

For novel exotic properties, you needn't look further than good old carbon. An ordinary working stiff in the macroworld, carbon in its ultratiny form is like a one-man circus: stronger than steel, extremely elastic and light as a feather. And carbon nanotubes keep excelling in unexpected ways. In addition to resisting burning when engulfed in flames, one new study suggests that these little tubes shuttle heat with a fierceness that generates a lot of electricity, a find that has physicists scratching their heads. Other researchers working with carbon nanotubes have created the darkest material ever made, a perplexing blackness not explained by standard optics. And carbon nanotubes' elastic properties have allowed scientists to create surprisingly stretchy muscles.

Many of these experiments, done in the last few years, are expected to lead to life-improving technologies. But perhaps just as marvelous, the bizarreness of nanoland continually pushes the envelope of scientific understanding.

"There are fundamental physical properties that we still don't understand at the nanometer scale," Strano says. "In terms of carbon nanotube research, from my perspective, these materials continue to teach us new and interesting science."

Carbon nanotubes' heat-conducting abilities defy explanation.

Hot mess

Carbon nanotubes consist of carbon atoms bonded to carbon atoms, bonded to carbon atoms and so on, all connecting to form a cylindrical lattice, like a piece of rolled-up chicken wire. While their diameter varies, the cylinders are typically a few nanometers across (about the width of a DNA molecule). Nanotubes can be single-walled, standing alone, or multiwalled, stacked inside each other like Russian nesting dolls. The tiny tubes are typically made by taking a hydrocarbon gas, such as carbon monoxide or methane, and busting its molecules apart with something such as heat, a laser or a metal catalyst. Then the carbons find each other and bond to become nanotubes.

Scientists have long known that carbon nanotubes conduct heat extraordinarily well. This is a property usually ascribed to metals (which explains why potholders were a good invention; grab the metal handle of a pot on a hot stove and you've experienced metal's superior heat conduction). But new research suggests that carbon nanotubes' heat-conducting abilities defy explanation.

When talking about thermal conductivity, scientists often refer to heat as phonons, little packets of vibration that can move through a material. In ordinary bulk materials, such as a piece of wood, these heat packets quickly bump into things. These collisions scatter the phonons, slowing them down.

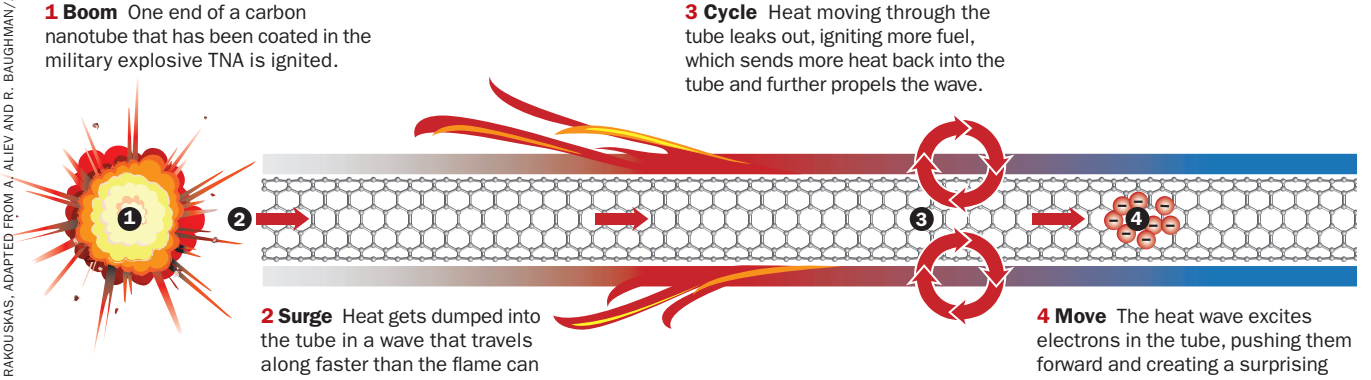
"It's almost like trying to run through a crowded field that's populated with people," Strano says. "You can't run your fastest, even if you are an Olympic runner."

Apply heat to one end of a carbon nanotube, though, and it zips to the other end 100 times faster than heat traveling through the best metals. Scientists have tried to explain this speediness in terms of a phonon's unobstructed path: In the nearly one-dimensional environment of a carbon nanotube, the little heat packets whiz along, presumably because they travel a long time without collisions. But there should be some limit to that thermal path, scientists surmised. And bending the carbon cylinders creates the perfect test tube for examining that limit, says Chih-Wei Chang of the Center for Condensed Matter Sciences at National Taiwan University in Taipei.

While at the University of California, Berkeley, Chang and his colleagues contorted their nanotubes, introducing defects that should have tripped up any traveling heat packets. The team thought the ensuing stumbling and scattering would affect the nanotubes' heat-conducting powers. But the heat packets kept right on trucking.

"To our surprise, our experiments show that the thermal conductivity remains intact," Chang says. "The result is far beyond our expectations." The discovery, published in *Physical Review*

Power trip Carbon nanotubes coated with an explosive fuel get extremely hot but don't burn. What's more, the heat wave coursing through the tube generates far more power than expected. Some scientists think the explanation lies in how fast the heat wave travels.



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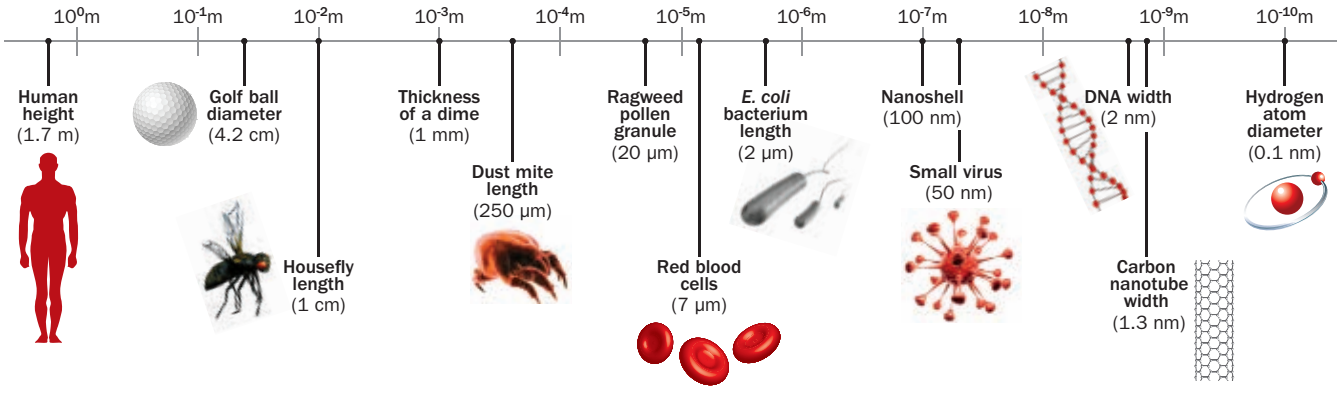


Much smaller than a bread box Speck of dust, grain of sand — whatever your reference for tiny, let it go. Nanosized objects are much, much smaller. A typical carbon nanotube is 1.3 nanometers wide, and a 5-foot-7-inch man stands 1.7 billion nanometers tall.

Letters in 2007, suggests that nanotubes could be used to transmit information the way optical fibers do. Yet three years on, scientists still don't completely understand why the heat doesn't travel slower in the contorted tubes.

"It's just completely against all thinking that the thermal conductivity remains the same," Strano says. "It's really unprecedented."

Strano has also been investigating how heat courses through a nanotube. In the experiments where the flaming carbon did not burn, the nanotubes reached temperatures as high as 2,800 kelvins (or 2,500° Celsius).

"Clearly science tells us that it shouldn't take long for carbon at a thousand degrees kelvin to turn to carbon dioxide and water," Strano says. "It should completely burn up."

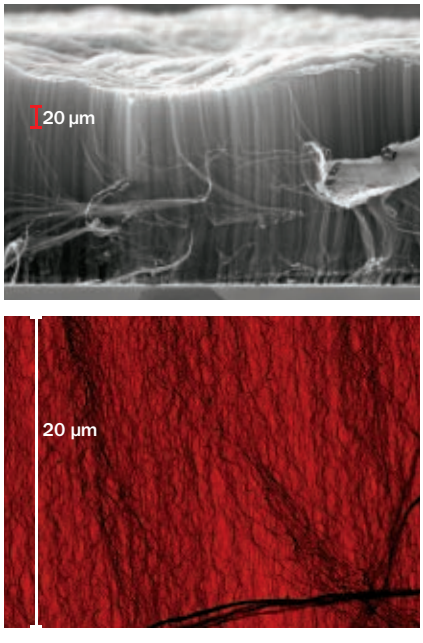
A clue to the nanotubes' durability may lie in the exceptional speed of the heat wave, he speculates. In the macroworld, if you were to pour a line of gasoline on the ground, lay a stick of the same length next to it and light both at one end, the flame would travel far faster through the liquid fuel than through the stick of wood. But in the lab experiments, the heat wave created by igniting one end of the fuel-drenched nanotube moved 10,000 times faster than it did through the bulk fuel alone.

This superfast wave turns out to be self-propagating, Strano says. As the fuel burns, it releases heat, which goes into the nanotube. The heat wave moves faster than the flame and heat leaks back out ahead of the burnt fuel. This ignites more fuel, and the overall effect is of a heat wave moving so quickly that, perhaps, the oxidation reactions that would combust the carbon can't even get started.

Not only does the heat wave move at rocket speed, but as it surges forward, it excites the nanotubes' electrons, propelling them forward as well, Strano and his colleagues reported in *Nature Materials* in March. This thermopower wave, as Strano calls it, generates electricity at an astounding rate, a discovery that could lead to new sources of energy.

"The faster the wave goes, the more power you get out," he says. "In fact, no one could have predicted that it would be this much power. From a practical standpoint, the power density is already higher than a lithium-ion battery, and we're not even really trying."

Using carbon nanotubes, scientists have created the darkest material ever made. Its uneven surface (top) and the sparseness of the tubes (black in the colorized image at bottom) may help make it dark.



Dark matter

While some researchers probe the bright and fiery side of carbon nanotubes, others focus on the material's dark side. Grow millions of the tubes en masse in a forest and they can become black as a starless night. Working with such a forest, physicist Shawn-Yu Lin of the Rensselaer Polytechnic Institute in Troy, N.Y., recently created the darkest material ever made.

More than 99.95 percent of the light striking the nanotube forest is absorbed, Lin, Pulickel Ajayan, now at Rice University in Houston, and colleagues reported in *Nano Letters* in 2008. This darkest of materials literally holds a Guinness World Record; the previous record absorbed a mere 99.84 percent of incoming light.

Plenty of researchers work with nanotube forests, but they are typically densely planted, thick with trees. Lin and his team took the sparse route, growing a thin woodland rather than a Grimm Brothers' forest. Yet almost all the light that enters this forest is never seen again. ("Sparse" is relative, though.

TOP: T. DUBÉ, ICONS (LEFT TO RIGHT): MYSONTUNA/SHUTTERSTOCK; ALHOVIK/SHUTTERSTOCK; PETRAFLER/SHUTTERSTOCK; SEBASTIAN KAULITZKI/SHUTTERSTOCK; DIAMOND_IMAGES/SHUTTERSTOCK; SEBASTIAN KAULITZKI/SHUTTERSTOCK; FEDOROV OLEKSIY/SHUTTERSTOCK; ASPECT3D/SHUTTERSTOCK; A. ALIEV AND R. BAUGHMAN/*NATURE MATERIALS* 2010, MACMILLAN PUBLISHERS LTD; GIO_BANFI/ISTOCKPHOTO; BOTTOM TWO: ARIC SANDERS/NIST

A patch of this light-absorbing forest the size of a quarter still contains tens of millions of nanotubes.)

While scientists don't fully understand how the thicket of nanotubes swallows all light, the dilute packing of the tubes seems to be crucial. The trees in this particular carbon nanotube forest are so tall, thin and sparsely planted that there's no real surface for light to strike. "It's almost like light has a soft landing on the structure," Lin says.

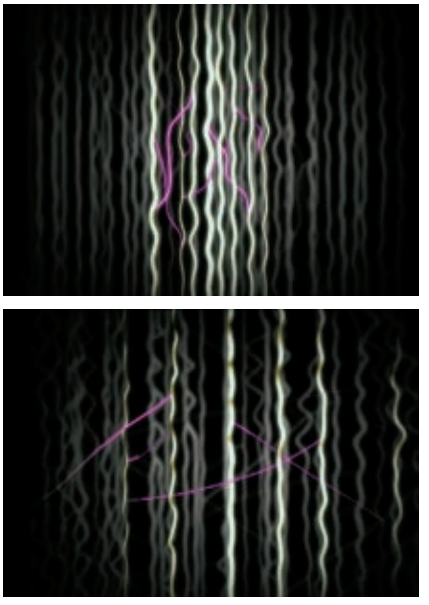
The carbon nanotube trees are different heights and tangle together at the tips. And while the tubes are a somewhat hefty 10 nanometers across, Lin and his colleagues made them very, very tall, about 500 micrometers. (A similarly proportioned No. 2 pencil would be more than three times as tall as the Statue of Liberty). This extreme skinniness, uneven height and sparse packing transforms the forest into a sponge that soaks up light.

"For light, it is almost like nothing. It is like the empty sky," Lin says. "Why is the empty sky so dark? Because it almost has nothing. It is so dilute, nothing ever comes back. Material is what reflects."

When light strikes ordinary materials, it bounces off in a predictable manner related to the angle at which it came in. But the nanotube forest doesn't care about angles. The small amount of reflection that does occur is totally angle independent, says Lin, which makes no sense optically.

"There is no classical theory to explain this new type of surface," Lin says. "There is no theory," he laughs. "That's my theory."

Scientists at the National Institute of Standards and Technology and Stony Brook University in New York have already put this new dark material to use (for good, not evil). They grew a similar nanotube forest as a coating for a contraption that accurately detects the power of lasers shined into it. This dark detector might also help improve measurements of the temperature of the Earth and sun, the team reports in the September *Nano Letters*.



Voltage applied to artificial muscle spun from nanotube sheets (illustration, top) makes the muscle expand (bottom)—in some cases by more than 200 percent.

Carbon flex

Fire and light are surely captivating, but no big top is complete without feats of strength. Scientists exploiting carbon nanotubes' stretchy properties recently created giant artificial muscles.

Many materials when stretched one way, will contract in another way, says Ray Baughman, director of the NanoTech Institute at the University of Texas at Dallas. Think of yanking on a rubber band — as it lengthens, its width shrinks. The relationship between the amount of stretching and contraction is known as Poisson's ratio. Rubber, for example, has a very high Poisson's ratio, nearly 0.5. Stretch it one way, and it contracts in the other direction by quite a bit. Cork, on the other hand, doesn't bulge out much when pushed. It has a Poisson's ratio near zero, making it easy to wedge back into a wine bottle.

While exploring the push-and-pull of various materials in the lab, Baughman and his colleagues spun carbon nanotubes into airy sheets. These sheets "represent a strange state of matter," he says, with fantastic elastic properties that correspond to Poisson's ratios as high as 15.

Taking advantage of these bizarrely large Poisson's ratios, Baughman, colleague Ali Aliev and others turned their sheets into giant muscles that contract like crazy when pulled just a tiny bit. Stretch these sheets just 1 percent in one direction and their volume shrinks by 23.5 percent, the team reported in *Science* in 2009.

When natural muscles contract and expand, their length typically changes by less than 40 percent. But the team found that the nanotube muscles can change their length by more than 230 percent in a fraction of the time, giving them some serious punch. And since they can still flex their stuff at extremely high and low temperatures, the artificial muscles may be ideal for robots exploring hostile environments, such as Mars.

"Ordinary muscles of course are wonderful," Baughman says. "They are self-repairing, they can last a lifetime. But these artificial muscles based on carbon nanotubes are much faster in terms of response than natural muscle. And they can operate in extreme environments where no other artificial muscle will survive."

The artificial muscles' massive contractions can now be nicely described with theory and numbers, but it took mucking about in the lab to discover the strange behavior. And so it goes with science. Eventually, researchers will probably gain some clarity concerning the other unusual properties exhibited by carbon nanotubes. Those new theories will lead to more experimental work and then to additional mysteries. In the scientific volley between theory and experimentation, surprises can spring like a sudden backhand.

Strano says he has complete faith that theory will soon explain why a carbon nanotube can behave so strangely. "But observation and discovery will still play a role," he says. "Making one and being able to manipulate it in the lab and do strange things to it has taught us quite a bit." ■

Explore more

- The Nanotube Site: http://nanotube.msu.edu

STEM FILMS

THE FINAL CLIMATE FRONTIERS

Scientists aim to improve and localize their predictions

By Alexandra Witze

Modern explorers have pushed into nearly every nook and cranny of the globe, from polar Antarctica to the depths of the Amazonian jungle. Yet there's land still to explore, and regularly comes news of unexpected and wondrous findings — a mongooselike carnivore spotted in Madagascar, a massive waterfall discovered in Peru.

Such is the state of climate science today. In some respects its territory has been thoroughly probed. Despite vigorous questioning of the premises and conclusions of research into climate change, reviews of the evidence consistently confirm the basic findings of the United Nations' Intergovernmental Panel on Climate Change: The Earth's rising temperature cannot be explained by natural processes alone. Emissions of greenhouse gases from human activities, like burning fossil fuels, must be included to account for the observed warming. Policy makers will be building on this firm foundation during meetings in Cancun, Mexico, in late November and early December to hammer out the next global climate-control agreement.

But unexplored corners of global climate remain. The most recent IPCC report, from 2007, acknowledged this terra incognita: "There is still an incomplete physical understanding of many components of the climate system and their role in climate change." Such unknowns are fertile territory for scientists.

They are now pushing, for example, into perhaps the least understood aspect of observational climate science: how tiny particles called aerosols influence climate. Some types of aerosols cool the planet, while others warm it. They also affect how many clouds form and where, further redrawing the planetary climate picture. After decades of effort, researchers are finally starting to disentangle this particular unknown, in part thanks to fleets of airplanes, satellites and other instruments deployed to monitor aerosols.

Understanding the physical processes that drive the climate system today is one thing; figuring out how changes in the system will influence people's lives in the future is another problem altogether. Here, scientists focus on regional climate prediction — zooming their computer models down to ever-smaller scales to understand how climate change might alter local environments. Such work is the only way to know how drought will affect Phoenix or floods affect Pakistan. While just beginning to map out the thorniest problems in regional predictions, such as how to accurately model short-term circulation patterns in the atmosphere and ocean, researchers are inking in the details using some promising approaches.

By the time the next IPCC report is released, in 2013 or 2014, scientists should have shortened — or at least sharpened — their list of unknowns. "There's a whole lot of climate science that needs to be done," says climate researcher Noah Diffenbaugh of Stanford University. And while the new information might not pacify climate change skeptics, it will clarify key areas of uncertainty in the climate system. It will also help fill in the last details of the geography of climate, giving society a guide for navigating the shoals of future changes.

Tiny coolants

Aerosols, tiny as they are, have an outsized influence on climate. These particles range from fractions of a micrometer to several micrometers across and come from both artificial and natural sources — including power plants, biomass burning, sea spray, volcanic eruptions and even wildfires (*SN: 11/6/10, p. 28*).

Most aerosols cool the planet, by acting as a sunscreen to reflect the sun's incoming rays back into space. The 1991 eruption of Mount Pinatubo in the Philippines, for instance, spewed enough sulfur and other particles to circle the globe and drop temperatures worldwide by about half a degree Celsius.

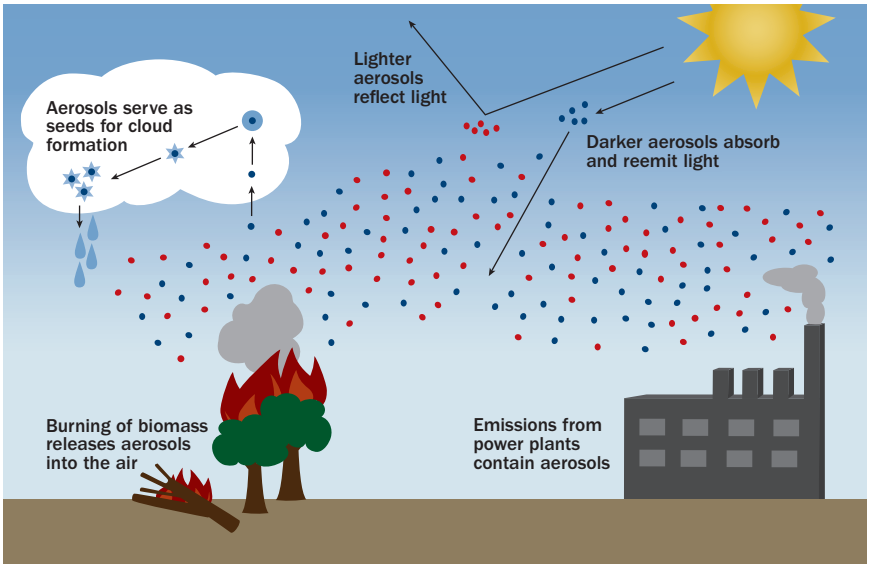
Climate scientists agree that without aerosols, the Earth would have warmed more than it has in recent decades. Exactly the extent of the cooling effect, though, is a matter of dispute. Even less well understood are the indirect effects of aerosols: They can change the size and distribution of clouds around the globe.

Predicting regional climate patterns, such as droughts in Phoenix or flooding in Pakistan (shown), remains a major challenge for researchers.

OPPOSITE: A. SOOMRO/REUTERS; THIS PAGE: E. FELICIANO

Mixed influences

Tiny particles called aerosols can have a big impact on climate, but their many roles have been hard to disentangle. Most of the particles reflect sunlight, keeping the atmosphere cool. But black carbon, or soot, can absorb the sun's rays and heat up the atmosphere. The role of aerosols in providing surfaces for cloud formation further complicates the climate picture.



Aerosols serve as tiny seeds on which water vapor can condense. So more aerosols mean more "cloud condensation nuclei" for clouds to form around; long thin clouds known as ship tracks, for example, trace a ship's airborne emission like a jet contrail. More seed particles mean that clouds become thicker, whiter and more reflective, cooling things down even more.

Many scientists consider this indirect effect to be the largest single uncertainty in understanding the interactions between aerosols and climate. Over the last decade and more, researchers have launched a flotilla of observing equipment in more than a dozen field campaigns to measure the distribution and effects of aerosols in regions from Asia to North America. Typically, airplanes will fly a gridlike pattern gathering air samples, while researchers on the ground use vehicles or ships to measure patterns of aerosol emission. (NASA's Glory mission, scheduled for launch in February, will continue this full-out push.)

Such detailed work is now paying off. Antony Clarke and Vladimir Kapustin of the University of Hawaii at Manoa analyzed more than 1,000 vertical slices of the atmosphere, taken mostly around the Pacific in various campaigns since 1995. The researchers report in the Sept. 17 *Science* that there were more cloud condensation nuclei, along with other measures of aerosols, above regions with a lot of human activity compared with more pristine areas. The work "provides a more revealing picture of combustion influences over global scales," says Clarke.

Another paper in the same issue of *Science* scrutinized how atmospheric chemistry over the Amazon naturally produces aerosols and clouds there. A team led by Ulrich Pöschl of the Max Planck Institute for Chemistry in Mainz, Germany, found that the number of clouds above the rainforest was limited by the natural supply of aerosols. In regions with more pollution, the limiting factor on cloud formation was how fast winds could lift aerosols high into the atmosphere. The study underscores how the complex relationship between aerosols and clouds can differ over pristine and polluted areas.

Hot plates in the sky

One kind of aerosol is particularly capturing researchers' attention these days — black carbon, better known as soot. These particles come from fossil fuel–burning power plants, fires started to clear land for agriculture and, to a lesser extent, from coal- and wood-burning cookstoves in developing nations.

Once thought to be a minor player in global warming, black carbon is now a major focus of interest.

Once thought to be a minor player in global warming, black carbon is now a major focus of interest. Unlike other aerosols that have net cooling effects, black carbon particles absorb solar radiation and warm the atmosphere, the way wearing a black T-shirt on a sunny day warms the body. Studies have fingered these tiny hot plates in the sky as a major contributor to Arctic warming seen in recent decades (*SN: 11/21/09, p. 5*), and some researchers think soot may be an important factor in glaciers melting in the Himalayas.

Still, scientists don't fully understand how much black carbon there is, where it comes from and how it gets removed from the atmosphere over time. In one ongoing project, researchers fly repeatedly from the Arctic to the Antarctic, traveling high into the atmosphere and dipping down nearly to touch the ocean. The National Science Foundation project, called HIAPER Pole-to-Pole Observations or simply HIPPO, collects air samples to test for many atmospheric gases, notably carbon dioxide, but it also collects black carbon.

During its first flights, in January 2009, the HIPPO plane measured unexpected concentrations of black carbon along its path. That could be because computer models don't accurately estimate how well rain would remove the particles from the air, says Joshua Schwarz, an atmospheric scientist at the NOAA Earth System Research Laboratory in Boulder, Colo. Different air masses also contained surprisingly similar sizes of black carbon particles, no matter where that air came from. "We don't have a reasonable explanation for that yet," Schwarz says.

Spurred by prodding from scientists, policy makers are increasingly looking at ways to cut black carbon emissions. The concept is politically palatable, since it involves cleaning up pollution in a way that helps people's health. Black carbon is also an easy target because soot falls out of the atmosphere in a matter of weeks, yielding measurable results in a short period of time. Strict pollution measures introduced in Beijing before the 2008 Olympics, for instance,

Brown clouds hovering over India (such as one captured in December 2008, left) contain smoke from agricultural burning, industrial pollution and inefficient cookstoves (right). Such clouds can magnify the effects of climate change.

FROM LEFT: NASA; A. DATTA/REUTERS

temporarily cut the city's black carbon emissions by about 25 percent.

New research, however, suggests that the climate benefits of cutting black carbon might come with a flip side. In May in *Geophysical Research Letters*, a team led by Wei-Ting Chen of the Jet Propulsion Laboratory in Pasadena, Calif., modeled the climatic outcome of slashing black carbon emissions in half. The cooling benefits of reducing emissions, her team found, were partially offset by the fact that less soot meant fewer cloud condensation nuclei and thus fewer clouds to cool things down. Still, says team member John Seinfeld of Caltech, "on the whole, black carbon reduction is still good for climate, and good for human health as well."

Targeting particular sources of black carbon might be important in reducing it efficiently. Aerosol plumes dominated by black carbon from fossil fuel burning in China were roughly twice as efficient at absorbing solar radiation and heating things up as were black carbon plumes from biomass burning, Veerabhadran Ramanathan, a black carbon specialist at the Scripps Institution of Oceanography in La Jolla, Calif., and colleagues reported in August in *Nature Geoscience*.

With other scientists, Ramanathan has launched Project Surya, which aims to replace polluting cookstoves across India with low-cost, cleaner alternatives. Women who receive the new stoves are required to remove and photograph the filter that strips out black carbon particles. "Just seeing the black filter makes them say, 'Is this what we are breathing?'" says Ramanathan.

Getting local

Even as researchers push into unexplored territory in aerosols, others are looking to cover some ground closer to home — understanding how climate change will affect people's lives. In this case, scientists aim to improve their predictions of the regional impacts of climate change. Many local effects are already apparent. A major U.S. government report last year, for instance, detailed how climate change has led to heavier winter rain in the Northeast, more intense hurricanes in the Southeast and smaller snowpacks in the Rocky Mountains.

Global temperatures are projected to increase by 2 to 4 degrees Celsius by the end of this century, but locally the effects could be much stronger. For instance, computer models that incorporated a global temperature rise of 2 degrees Celsius found that large parts of Europe, North America and Asia could experience heat waves with temperatures up to 6 degrees Celsius higher than normal. Local factors such as plant root depth and forest cover could partly account for the differences, Robin Clark and colleagues at the Met Office Hadley Centre in Exeter, England, wrote in September in *Geophysical Research Letters*.

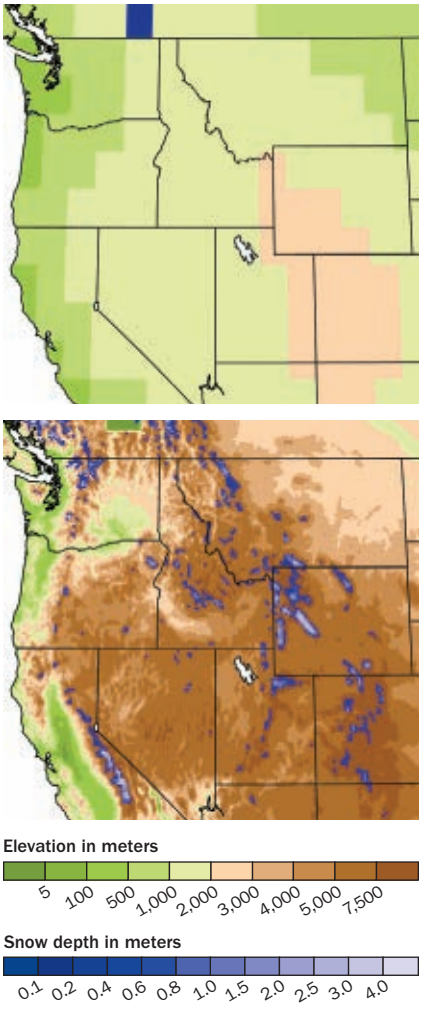
Heat waves could also become more common in the United States over the next three decades, suggests new work by Stanford's Diffenbaugh and Moetasim Ashfaq of Oak Ridge National Laboratory in Tennessee. In their models, published in August in *Geophysical Research Letters*, the researchers found that limiting global mean temperature below a 2-degree rise still led to heat waves over much of the western United States, especially between the years 2030 and 2039.

Devastating heat waves, like the one that killed an estimated 35,000 people in Europe in 2003, aren't the only change in store. "There's a huge suite of potential climate change impacts," Diffenbaugh says. The problem with knowing what exactly to expect is that regional climate predictions are less sophisticated than global climate models. Researchers would like to tell officials exactly how hot, cold, wet or dry it will be in their city or state three decades from now. But they can't.

To get a good look at local climate, modelers "downscale" the results from global models, using the coarse data as a starting point to make finer-scale local calculations. A typical global model has a resolution of 300 kilometers, meaning that any smaller feature isn't detected and analyzed in the model's calculations. By contrast, resolution in a regional climate model can be 50 kilometers or even smaller. Climate scientists take a global model and stitch a piece of regional model into it, like photoshopping in a more detailed image of a face in a crowd.

In some instances, this approach is starting to yield consistent results. Reporting in June in *Nature Geoscience*, Erich Fischer and Christoph Schär of ETH Zurich show how different regional climate models come up with similar patterns of future heat waves in Europe. Over the next century, extreme heat events will be longest and most common in southern Europe and most severe in the north, the researchers write.

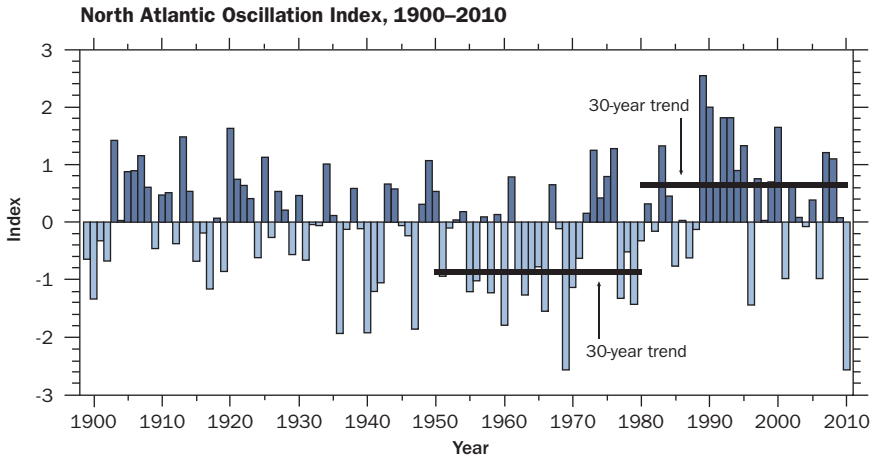
Predicted April snow depth, 2045–50



Regional forecasts

A global climate model from the last IPCC report (top) doesn't include enough detail on factors such as elevation to get at local effects. While the IPCC model predicts April snow cover for only a small area in Canada, a regional model (bottom) predicts depths of up to 3 meters in some U.S. locales. SOURCE: NCAR

Changes by the decade Understanding climate patterns that vary on the order of decades, such as the North Atlantic Oscillation, is necessary for predicting regional effects. A positive NAO index means a relatively strong high-pressure center in the subtropics, leading to warm, wet winters for northern Europe and cold, dry winters for northern Canada. SOURCE: JIM HURRELL



But other aspects of regional climate modeling lag far behind. Many regional models have yet to incorporate basic land-use information, like details on urbanization, forest clearing or irrigation, says Jim Hurrell, a climate modeler at the National Center for Atmospheric Research in Boulder. And long-term forecasts of how local precipitation might change are particularly poor — making it difficult to anticipate droughts.

Regional models are also only as good as the global approach that they are fit into. If the global model contains errors, "that puts major question marks around the fidelity of your regional simulations," Hurrell says. In particular, global modelers have yet to get a good handle on "decadal variability," or internal factors within the climate system that vary on a time frame of 10, 20 or 30-odd years.

Such factors include the El Niño Southern Oscillation, a warming pattern that occurs in the tropical Pacific every few years, and the Pacific Decadal Oscillation, a similar but longer-term pattern associated with cooling in the central North Pacific. Global climate models don't include these phenomena in detail, but will need to if researchers want to accurately predict climate in a particular area decades out.

Only over the last couple of years have scientists gathered enough relevant data, such as ocean temperatures from a global array of buoys called ARGO, to be able to contemplate how to add decadal variability into global models. "It's an extremely challenging problem," Hurrell says.

Global modelers probably won't be able to solve that problem in time for the next IPCC report, but the ongoing work should help improve regional efforts over the next few years, says Diffenbaugh. "We're on the precipice of knowing a lot more," he says.

That information couldn't come soon enough for local officials and other community stakeholders. The U.S. government is pushing to establish a national climate service, similar to the National Weather Service, to provide local climate information (*SN: 3/13/10, p. 32*). Many states and cities, including California, Phoenix and New York City, have also started their own regional study efforts.

How well these efforts work — or don't — will become clear as the next IPCC report takes shape. By the time the final publication is out, the uncertainties surrounding regional climate predictions, as well as aerosols, will be smaller than today. And climate's terra incognita will shrink. ■

Explore more

- NASA info on aerosols: http://earthobservatory.nasa.gov/Features/Aerosols

Uncertainty in the climatic landscape

While not as dire as the state of understanding on aerosols and regional climate, other areas of climate science also have some unanswered questions.

Carbon cycle feedback

Uncertainties remain in knowing exactly how carbon cycles through the ocean, atmosphere and land. Rising temperatures, for instance, can melt permafrost and send more carbon into the atmosphere — but at what rate, scientists don't quite know.

Ice dynamics

The great ice sheets atop Antarctica and Greenland behave in unpredictable ways as they warm, and individual glaciers advance and retreat in unexpected ways as well. Arctic sea ice is shrinking and thinning overall, but its exact behavior is a surprise every season.

Clouds

Closely related to the problem of aerosols, clouds exhibit various poorly understood feedbacks on climate, some of which computer models completely miss. Scientists agree that clouds are likely to increase in a globally warmed world but don't know how strong a climate effect they might exert.

Precipitation

Future changes in rain or snowfall will depend largely on how much global atmospheric temperature rises compared with ocean and land temperatures. Researchers are still working to tease out the details.

Oceanic conveyor belt

Circulation patterns within the North Atlantic carry warm water to the north and east, where it cools, sinks and returns south in a giant conveyor-like loop. Some models of abrupt climate change have gone so far as to suggest that this conveyor could shut down altogether, affecting climate across Europe.

Land use

Clearing land for agriculture or other reasons affects the amount of carbon the ground can store. But this effect is poorly understood and not incorporated into many models of future climate.

—Alexandra Witze

E. FELICIANO

Concerned persons suggest that unless there is an "***awakening***," government in America's small-government republic will continue being transformed into the large-government, progressive ideology. But what ***awakening*** is powerful enough to halt the progressive juggernaut of large-government control of what people can and cannot do?

Richard W. Wetherill
1906-1989

The writer would like you to consider that the above ***awakening*** to the existence of a natural law of right behavior ***has that power***. The law is known as nature's ***law of absolute right***.

For nearly two decades, this behavioral law has often been carefully explained in one-page advertisements in several national magazines and newspapers, and on radio broadcasts. There is also a Website where people worldwide can learn how to get out of trouble, stay out of trouble, and start a new life.

This natural law exerts the power of life and death for every person alive today as is evidenced by the untold trillions of those people who had previously populated this planet.

"How?" you ask. ***Creation's law of absolute right states: Right action gets right results; wrong action gets wrong results. The law defines right action as thoughts and behavior that are rational and honest and fill the need of each situation.***

Therefore, people's motivation consisting of man-made laws, judgments, beliefs, likes and dislikes, wants and don't wants does not conform to ***creation's law of absolute right***, and when wrong results occur, people do not look to themselves.

Laws of nature never play favorites. People obey natural laws or they suffer the consequences. ***That*** is the awakening information for this generation. And if some people choose to ignore ***nature's behavioral law***, eventually their wrong action will cause an eternal sleep from which there has been no awakening.

WHOEVER OR WHATEVER IS THE CREATOR revealed this behavioral law to the mind of Richard W. Wetherill in 1929 in answer to his fervent appeal for an understanding of humanity's plight. And although Wetherill took no credit for identifying this law, his efforts to inform people of the flaw in their approach to life met with an almost impenetrable wall of resistance and opposition until he published his book, *Tower of Babel*, on January 2, 1952. Then small study groups were formed near several large cities in America. Later all the members who were able to relocate came together under Wetherill's direction in southeastern Pennsylvania.

So much for a brief history of the group that now brings you the good news of the ***law of absolute right***, and the ***awakening*** that it brings to a world population in deep trouble and chaos.

A few centuries ago the Founding Fathers of America did their best to establish a country ruled in a God-fearing way by representatives of the people. Newcomers from other countries who were willing to be governed by its Constitution and Bill of Rights were welcomed. Over the years, people came in droves. Now the divergence of thinking about whether the country should be transformed is causing much turmoil and confusion for the populace.

There is only one solution: everybody must obey creation's law of absolute right or suffer the consequences of disobedience to whoever or whatever is the creator of natural laws and all that exists of planet Earth.

Visit our colorful Website www.alphapub.com where several essays and seven books describe the changes called for by whoever or whatever created nature's law of absolute right. The material can be read, downloaded, and/or printed FREE.
This public-service message is from a self-financed, nonprofit group of former students of the late Mr. Wetherill. Please help by directing others to our Website so that they can learn that obeying this natural law provides a ***life that is both fair and well worth living.***

It's enough to give you HEARTBURN

Wonder drugs they may be, but PPIs are overprescribed and pose some health risks

By Nathan Seppa

In the arms race against heartburn, one class of drug outperforms the competition by going straight to the source. The proton pump inhibitors, PPIs for short, block acid manufacture at the subcellular level. In contrast, acid reflux drugs such as Tums and Maalox neutralize the acid. Others, like Zantac and Tagamet, slow down its production by blocking the histamine 2-receptor. PPIs do require a day or two to start suppressing the symptoms of acid reflux. But once PPIs kick in, they put out the fire with stunning efficiency.

"No question about it. They are far more effective than anything we had before," says Randolph Regal, a clinical pharmacist at the University of Michigan in Ann Arbor.

When PPIs first hit the market in the 1980s, the acid-blocking pills — sold as Nexium, Prilosec and Aciphex, among other brand names — looked like wonder drugs. Since then, U.S. sales of PPIs have grown to roughly $14 billion a year.

But PPIs now risk becoming a victim of their own success. Several reports indicate these drugs are overprescribed, often in hospitals and to older patients. And other studies suggest that long-term use of the best-ever drugs for dousing heartburn carries its own risks. PPIs have accumulated a rap sheet linking them to a heightened risk of broken bones, bacterial infections and a few rare conditions. Other research suggests that weaning oneself off unnecessarily prescribed PPIs can be difficult and can cause, of all things, heartburn. These potential drawbacks are forcing regulators to rethink labeling on the drugs and leading doctors to reevaluate prescribing PPIs for some patients.

Although long-term use of PPIs can carry risks, none compares to the consequences of untreated reflux disease. The stomach acid that digests food and keeps bacteria at bay is highly corrosive. While the durable stomach usually withstands acid's violence, the esophagus, which runs from the mouth to stomach, is supremely vulnerable. When a leaky valve allows acid to splash up from the stomach, the result is acid reflux. Left untreated, it can cause esophageal scarring and even cancer.

The new findings suggest doctors and patients must better ascertain who really needs PPIs, says David Metz, a gastroenterologist at the University of Pennsylvania School of Medicine in Philadelphia. "The aim is to use therapeutics to make people better, with a risk-benefit ratio that's appropriate. We don't want to overtreat people who don't need PPIs or undertreat people who do."

Bad to the bone

Topping the list of PPI drawbacks is the specter of bone fractures. Metz and colleagues reported in the *Journal of the American Medical Association* in 2006 that people who had been taking a PPI for more than a year had a 30 to 60 percent increased risk of hip fracture over those not taking acid blockers. A higher dose of PPIs boosted the risk to more than double. A Danish study, published the same year in *Calcified Tissue International*, also found that PPIs increased the risk of a broken hip by about half.

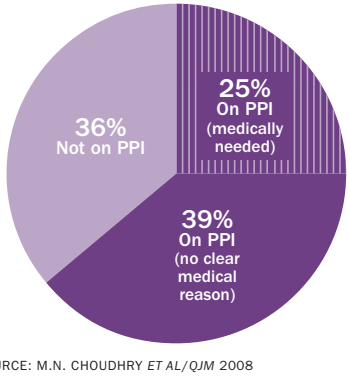
The U.S. Food and Drug Administration earlier this year slapped a fracture warning label on PPIs, both prescribed and over-the-counter, citing these and four other studies that showed an increase of fractures in people using the drugs.

While scientists are still sorting out how PPIs might affect bone, some theorize that acid is needed to dissolve calcium compounds, making calcium available in the blood and thus to the bone.

Another risk linked to PPIs is bacterial infection. Hospitalized patients getting a daily PPI are more likely to contract a *Clostridium difficile* bacterial infection than are people not taking any acid blockers, Harvard Medical School pulmonologist Michael Howell and colleagues reported in the May 10 *Archives of Internal Medicine*. Those getting the drugs more than once a day faced double

Unnecessary risk Among other concerns, PPIs have been linked to infection with the bacterium *Clostridium difficile*. In one hospital, a team identified 138 patients with *C. difficile*. Of these, 88 were on a PPI, though only 34 had a clear medical reason for taking the reflux drug.

PPI use in *C. difficile*–infected patients



SOURCE: M.N. CHOUDHRY *ET AL/QJM* 2008

FROM TOP: T. DUBÉ, PILLS: ROSIESMUM/ISTOCKPHOTO; T. DUBÉ

to triple the risk that nonusers did.

Most cases of *C. difficile*, which can cause severe diarrhea, erupt in hospitals. PPIs lower stomach acidity, allowing *C. difficile* in the gut to survive when it wouldn't otherwise, Howell says. The microbes travel downstream, where they release toxins that cause the diarrhea.

Other microbes may survive as well, possibly causing pneumonia if they get splashed up into the esophagus and breathed into the lungs. A separate study by Howell's team showed a link between hospital-acquired pneumonia and PPI use, with the drugs raising the odds of infection by 10 to 40 percent.

Less certain but also raising concern is whether PPIs interfere with B12 vitamin levels and with the activity of some drugs. Early reports suggested problems with PPI use and a particular anticlotting medication called clopidogrel, or Plavix, but more recent data have cast doubt on that link.

Too many 'scripts

Not everyone agrees that the risks are as worrisome as these studies suggest. David Johnson, a gastroenterologist at Eastern Virginia Medical School in Norfolk, says that some other studies haven't found any risk from PPI use, and that many studies fail to take into account the risk run by a patient who stops taking a PPI. "If you only look at one side, it's not a balanced assessment," Johnson says.

He also questions why people with pernicious anemia, who make very little stomach acid, aren't beset by *C. difficile* infections or pneumonia. "And their bones should just crumble," he says, if acid suppression is deleterious. "It just doesn't make sense."

The absolute risk of the medical problems linked to use of PPIs — the likelihood that a given individual will encounter one — is small. In the study by Metz and his colleagues, for example, it works out to four broken hips per 1,000 people using PPIs for more than a year. That's up from two per 1,000 nonusers, calculates Hye-Kyung Jung of Ewha Womans University in Seoul, South Korea.

"But we ended up giving PPIs to everybody," counters Howell, and that multiplies the population at risk. There were 119.4 million prescriptions for PPIs dispensed in 2009 in the United States, according to IMS Health, a Norwalk, Conn.–based research firm. And that doesn't include over-the-counter sales.

Hospital prescribing of acid neutralizers started in the 1970s when doctors realized that the practice could prevent the stress-induced bleeding ulcers that plague patients in intensive care units and are exacerbated by stomach acid. (Easing the symptoms of stomach ulcers is considered a valid medical use of PPIs today.)

A Canadian study in 1994 had shown that such stomach bleeding was rare in hospitalized patients who didn't have respiratory failure or a defect in the blood's clotting ability. But six years later, Yale University scientists reported that many patients at low risk of developing a stomach bleed were being placed on PPIs or other acid-blockers anyway.

Research done at the University of Michigan Hospital revealed that most acid-suppressing drug prescriptions doled out by the hospital's doctors were inappropriate — the patients didn't have acid reflux and weren't at risk of stomach bleeding. And a 2006 study from New Zealand found that four in 10 hospital patients were on PPIs inappropriately. What's more, people are often sent home from the hospital with a prescription for a PPI, and they fill it. "A lot of people just go on the medication they are prescribed and don't ask questions," says Regal.

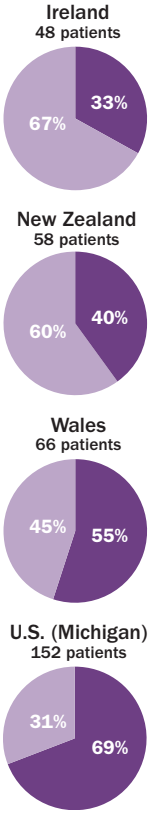
On the rebound

Giving people PPIs when they don't need them may result in PPI rebound, Swedish scientists report. Pharmacist Anna Niklasson and colleagues at the University of Gothenburg randomly assigned 48 healthy volunteers without acid reflux to receive either a PPI or a placebo for 28 days. By standard scoring of stomach distress, both groups started with very little heartburn. One week after treatment ended, however, stomach distress rose dramatically in those who had been on PPIs but not in the others. And 11 of the 25 on PPIs complained of stomach problems afterward, compared with only two of 23 on a placebo.

"The stomach tries to compensate for the decrease in acid secretion that PPI medication leads to," says Niklasson. "So when patients stop their PPIs, they have an up-regulated capacity." The effect seems to last only two weeks, but may explain why even people inappropriately prescribed PPIs could have trouble stopping them, she says.

Despite these reports, pharmaceutical firms continue to promote PPIs actively. Internist Mitchell Katz, director of public health for the city of San Francisco, says the drugs are being marketed to young adults. He cites a commercial on the Internet that shows young people going out on the town, discussing taking a PPI in *anticipation* of possible heartburn later. "I think PPIs have become more of a lifestyle drug. People don't really understand the risks," Katz says.

PPIs continue to be the best drug for acid reflux. "Many people will need to take them," says researcher Shelly Gray of the University of Washington in Seattle. "But some people take PPIs who could manage with changes in lifestyle or with a less potent heartburn medication." ■



Global overprescribing Four hospital-based studies highlight the common practice of prescribing PPIs to patients even when the patients don't need the heartburn drugs.

On PPIs with valid medical reason
On PPIs with no valid medical reason

SOURCES: SAAD *ET AL/INT. J. OF CLIN. PRACTICE* 2005; GRANT *ET AL/PHARMACY WORLD & SCIENCE* 2006; BATUWITAGE *ET AL/POSTGRAD. MED. J.* 2007; PHAM *ET AL/ANNALS OF PHARMACOTHERAPY* 2006

Explore more

- M. Katz. "Failing the acid test." *Archives of Internal Medicine*. May 10, 2010.

T. DUBÉ

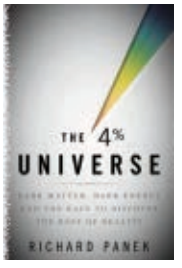
The 4 Percent Universe: Dark Matter, Dark Energy and the Race to Discover the Rest of Reality

Richard Panek

Twelve years ago, astronomers studying distant, exploding stars made a discovery that irrevocably altered humankind's view of the universe. Most scientists had assumed that the universe's expansion, which began during the Big Bang, had steadily slowed due to gravity. But the astronomers found that the cosmos was instead expanding faster; gravity had somehow transformed from a cosmic pull into a cosmic push.

The unseen stuff supplying this mysterious push has come to be called dark energy. Together, dark energy and dark matter, the invisible material that scientists say must exist to explain galaxy formation, make up most of the universe. Left over is a measly 4 percent to form everything else, like people and planets .

In his aptly titled book, science writer Panek writes eloquently about the mind-bending search for meaning in a universe dominated by stuff no one can see. Panek weaves together concepts from particle physics, relativity, quantum mechanics and cosmology with personal portraits of astronomers. Vera Rubin, a pioneer in gathering evidence of dark matter, and various players in the discovery of dark energy are seen as they alternately scratch their heads at astonishing findings and bitterly squabble over who was first to announce them.

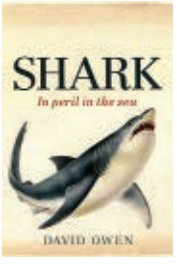


In the end, the legacy of dark-energy theory "wouldn't be personal acrimony," Panek writes. "It would be the revolution in thought that dark energy mandated. Almost certainly this revolution would require the long-awaited union of general relativity and quantum theory. It might involve modifying Einstein's equations. It could feature parallel, intersecting or a virtually infinite ensemble of universes.... What greater legacy could a scientist leave a universe?" — *Ron Cowen*
Houghton Mifflin Harcourt, 2011, 320 p., $26.

Shark: In Peril in the Sea

David Owen

It's a sure sign of evolution: Sharks, dominant predators on Earth for millions of years, are now threatened by humans. In the past few decades shark populations have plummeted and the very traits that long helped prevent the beasts from overpopulating the seas — low birthrates, slow growth and a late arrival at sexual maturity — hinder their recovery from the depredations of overfishing, pollution and habitat destruction.



Owen, a Tasmanian author who has also demystified that island's famous devil, takes a fascinating look at the biology of sharks, from the smallest (the 19-centimeter-long dwarf lanternshark) to the whale shark, the world's largest fish. He also explores the complex relationship between man and shark. Sure, we eat each other, but the body count is horribly lopsided. While sharks attack only a few dozen people each year, the annual shark catch routinely tips the scale in the hundreds of thousands of tons.

In large part due to the violent nature of their attacks — which often come literally out of the blue — sharks have long inspired fear and fascination. The 1975 blockbuster *Jaws* tapped into that primal fear but also demonized great white sharks and, via guilt by association, many other species. Yet, Owen notes, much good came from the film. It inspired scientific interest in sharks and their relatives and spawned shark conservation efforts worldwide. *Shark* is a captivating portrait of creatures that have too long been unfairly maligned as malevolent, mindless eating machines. — *Sid Perkins*
Allen & Unwin, 2010, 328 p., $27.95.

Death in a Small Package

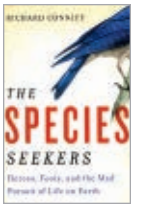
Susan D. Jones

Part of the Johns Hopkins Biographies of Disease series, this history of anthrax describes the bacteria's transformation from agricultural disease to biological weapon. *Johns Hopkins Univ., 2010, 329 p., $24.95.*

Lenin's Laureate

Paul R. Josephson

A historian explores Soviet science in this biography of Zhores Alferov, who won a Nobel Prize for discovering the heterojunction used in LEDs. *MIT, 2010, 307 p., $29.95.*



The Species Seekers

Richard Conniff

Tales relate the adventures of early naturalists who risked life and limb in the quest to discover new species. *W.W. Norton, 2010, 464 p., $26.95.*

Leonardo da Vinci's Giant Crossbow

Matthew Landrus

A da Vinci expert takes a technical look at the design and engineering underlying one of the artist's most popular but least understood drawings. *Springer, 2010, 180 p., $59.95.*

The Best American Science Writing 2010

Jerome Groopman, ed.

Highlights some of the most intriguing science articles of 2009, including a tale of sexual evolution by *Science News*' Susan Milius. *Ecco, 2010, 346 p., $14.99.*

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Superfluid's roots

I'm confused. A little. I thought that a Bose-Einstein condensate occurred only in a gas and that the first time it was achieved was in 1995 using rubidium atoms. "A matter of solidity" (*SN: 9/11/10, p. 22*) states, "Superfluidity arises when the atoms in superfluid helium join up in a quantum state called a Bose-Einstein condensate." Further reading leads me to believe that the quoted statement may not be accurate. Are the helium atoms just behaving similar to a Bose-Einstein condensate?

By the way, just so you can add me to any demographic data, I'm a machinist, typical blue-collar, 54 years old and have been reading *Science News* since I was about 10 years old.

Eric R. Snow, Whidbey Island, Wash.

Bose-Einstein condensation, in which atoms lose their individual identity and begin to move as a collective quantum mass, was indeed observed experimentally for the first time in 1995 in supercooled rubidium atoms. But it was proposed theoretically in the 1920s and, soon after superfluidity was discovered in liquid helium in the 1930s, researchers argued that Bose-Einstein condensation could be the explanation. Today scientists think that superfluidity is associated with a more generalized version of Bose-Einstein condensation as laid out in the 1950s by Oliver Penrose. —Alexandra Witze

The source for science news

I really liked chief editor Tom Siegfried's column in *Science News* ("Staying on the lookout for rumors disguised as news," *SN: 9/25/10, p. 2*) about "lax reporting" in science journalism nowadays and how your magazine tries to fight that tendency. I thought, "This is why I read *Science News*" — your content is trustworthy, and I'm an interested (in science) layperson (which doesn't mean professional scientists can't read *SN*). The Internet makes it easy for inaccuracies to become global. Tom mentioned a blogger who thought Heisenberg's famous uncertainty principle had been overturned. No, not yet (if ever). Tom describes how *SN* writer Laura Sanders got to the truth of the matter (Deleted Scenes blog, *SN Online: 8/5/10*). I humorously offer an informational correlate to Heisenberg's quantum uncertainty: If it's not in *Science News*, be wary (uncertain).

Paul Rizzuto, Orange, N.J.

The September 25 issue was excellent, especially the volcanoes ("Fire and ice," *SN: 9/25/10, p. 16*) and wheat rust ("Rust never sleeps," *SN: 9/25/10, p. 22*) articles, the latter of which explained the whole situation in prose that was clear as a bell.

I found the article about general relativity and thermodynamics ("A new view of gravity," *SN: 9/25/10, p. 26*) intriguing and frustrating: Clearly the math is so complex that only a small number of humans can really grasp these theories. My thanks to the author for making it as clear as he could without using any equations, but the surface nature of the explanation is obvious to the reader, and I'm sure to the author too.

Regarding the editorial, I don't bother reading or listening to the regular media, Internet sites or anybody else reporting announcements of new progress in science. I just wait for the article in *Science News* to explain what really happened. Thanks, you are doing a great job.

Park Chamberlain, via e-mail

Entropic gravity

"A new view of gravity" (*SN: 9/25/10, p. 26*) was a wonderful article on both gravity and entropy! I'm no scientist, but I have always wondered if entropy really is at its peak inside a black hole. Could the unbelievable gravity in a black hole force matter into an organized state, and thus into an extremely low state of entropy? Or, when information "enters" a black hole the entropy of our universe increases but the entropy inside the black hole decreases? (Perhaps the physics inside a black hole is different from outside the hole.)

Could this explain why at the birth of our universe entropy was very low?

Don Wilfong, San Ramon, Calif.

I enjoyed the article on the potential for entropic roots to gravitation. Only very occasionally are there real breakthroughs in theoretical thinking; this could be one of them, once it's fleshed out. It also looks like a very promising lead toward an approach to a grand unified theory, something which Einstein sought. But I think the most promising aspect of this approach is that it might eliminate the need for the phantasmagorical "dark energy." The search for dark energy has grated on my amateur theoretical instincts for years, as it represents a "correction factor" for the incorrectness of our theories. We should be looking to improve our theories, not looking for correction factors. (Einstein himself disliked these.) Dark energy has always reminded me of phlogiston, or the ether. It's good to see an approach being explored that does not require it.

Tom DuBois, Glens Falls, N.Y.

Kudos to Tom Siegfried for an essay on a topic requiring deep thought that is understandable to laymen. Decades ago I majored in physics and have since then been annoyed with the "discovery" of every new particle, force, string and fabricated explanation that just seemed to make a unifying concept more distant. This "primacy of information over matter and energy" conjecture is unique and profound as this report describes so many aspects of reality that seem to be mathematically consistent. Maybe someday it will be confirmed, and if so, perhaps we'll learn that this primacy of "information" is consistent with "intelligence."

Greg Tullo, Raleigh, N.C.

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

Christina Smolke

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

An engineer teaches her colleagues to share their toys

In her synthetic biology lab at Stanford, Christina Smolke designs circuits and switches using biological components, work that may lead to yeast that crank out medicines or ways to reprogram the immune system. Winner of the 2009 World Technology Award in biotechnology for doing work of "the greatest likely long-term significance" in her field, Smolke is also involved with several open-science initiatives designed to help scientists work together more effectively. She recently discussed her research and open-science efforts with Science News *staff writer Rachel Ehrenberg.*

Is your research about creating new things or mimicking what nature does?
We're often trying to mimic something that can be found in nature, but we are trying to do it in a different context. Biology is very good at producing very complex molecules that have very interesting bioactive properties that we use as drugs to treat different types of disease. Many times the organisms that do these very interesting chemical processes are things like trees or corals that are not easy to grow, or take a longer time and more resources and energy to grow. So an alternative to trying to develop large-scale methods for growing the natural organism is to elucidate the chemistries that are encoded in these organisms and then harness them and put them into simpler organisms, like bacteria or yeast, that grow very quickly and that we have infrastructure in place to grow in very large volumes.

What are the risks? Could this work help terrorists make anthrax?
No, but I think it's very important to acknowledge that there are legitimate concerns. But there are concerns with any technology, right? Technologies are important because they advance our existence, our quality of life, but they also can be misused. With synthetic biology in particular, the concerns are more ... to make it easier and more scalable to build biological systems. And so if that goal is realized and people can start building new organisms from scratch, which is certainly not possible right now ... it is important to think about and put appropriate regulations in place. There will always be people who are looking to misuse technology, and so I think what's important as a global society is to really encourage the healthy and constructive development of communities around those technologies, the researchers that are developing those technologies and also the users of those technologies. And the more of that we have ... then the fewer people you have working on the misuses. It's important to note that the technologies themselves will be used to counter misuse as well. So with the anthrax example, you could use technology to develop very sensitive methods of detection.

Biotechnology has traditionally been and is still heavily dependent on ... a lot of people being less interested in sharing their work.

You're involved in several open-science initiatives including Open Wet Ware and iGEM, the International Genetically Engineered Machine competition. What is open science and why is it needed?
There are certain people in the community that recognize ... that building out open technology platforms is the way you really advance the field, and this is certainly borne out in other areas of technology like computer science. So the initiatives were started by a community of people who were trying to cultivate that culture within synthetic biology. This is a really different way of thinking about things within the realm of biotechnology. Biotechnology has traditionally been and is still heavily dependent on patents, on trade secrets, on a lot of people being less interested in sharing their work. So this is a definite culture shift for the broader biological research community.

What is Open Wet Ware?
Open Wet Ware is basically a Web-based community interface that allows people to contribute information and share information. A lot of the memberships are research laboratories, and people can post a question and share information about protocols that they are using, what they find is working and what doesn't work. So it's a way for a community of people working on similar things to share their knowledge.

What about iGEM?
iGEM is an undergraduate competition, and the basic idea is you have teams of students from different universities working over the summer on designing and building a biological system. And the real meat of it is you have this parts registry, which consists of parts contributed by teams of previous years. So teams this year can take those parts and reuse them and build upon all the knowledge base that came before that.... As you begin to piece parts together, you can build more complex functions.... So the idea is you take these more simple components that encode basic functions and start linking them and integrate the different pieces together. ■

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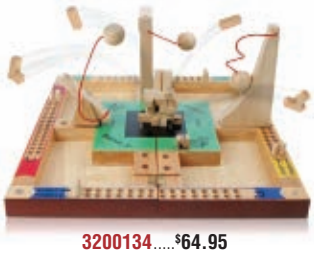

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