Clocking the Body | Manufacturing Morphine | Early Dog Days

ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ APRIL 10, 2010

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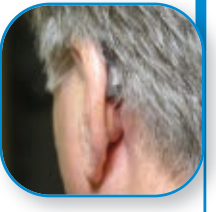

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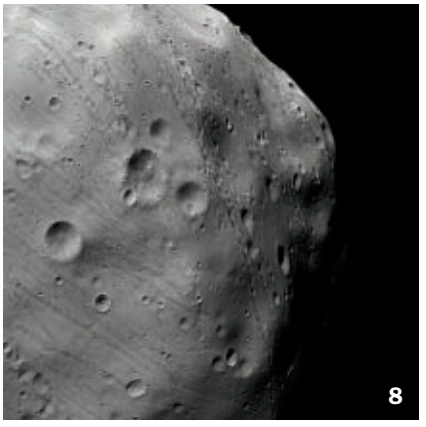

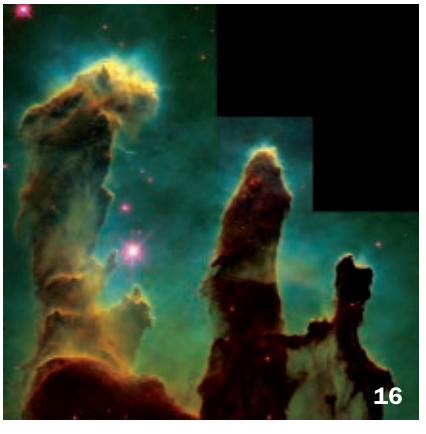

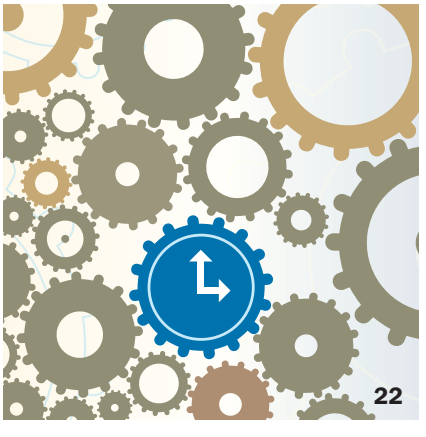

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Feature

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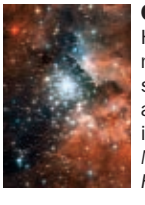

COVER One of the Hubble telescope's most spectacular images shows NGC 3603, a star-forming region in the Milky Way. *NASA, ESA, Hubble Heritage/STSci*

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FROM THE EDITOR

Hubble's birthday marks astronomical advances

In the January 6, 1990, issue of *Science News*, a young writer named Ron Cowen reported on the impending launch of a new telescope that would view the heavens from above the Earth's atmosphere.

He quoted a prophecy from NASA astronomer Stephen Maran. "Future historians may one day look back on the 1990s as the decade that revolutionized our understanding of the universe," Maran predicted. "The Hubble Space Telescope will be remembered as the instrument that first cracked open the window."

Now, two decades after Hubble's launch, Maran's status as a prophet has been securely established (if you allow a little spillover from the '90s into the 21st century). The Hubble telescope indeed opened a new view on the heavens, and its contributions have certainly initiated extensive revisions in science's conception of the cosmos.

Before Hubble, cosmologists had only rough ideas of how old the universe was and how fast it was expanding. Its age was maybe 10 billion years, or perhaps 15 billion, or even maybe a little older, the experts guessed. In the convoluted units used to gauge the universe's expansion rate, some authorities argued for a slow 40 or so, while others insisted on a speed exceeding 90. Thanks largely to Hubble's observations (with important input from other instruments), the universe now is clocked at right about 70 on the expansion scale, and its age is rather precisely pinpointed at 13.75 billion years.

What's more, Hubble provided key clues to a surprising acceleration in the cosmic expansion rate, leading astronomers to surmise the presence of a mysterious dark energy infusing every stitch of space. Astonished scientists had to rethink their views on the universe's history and ultimate fate.

On Page 16 of this issue, that young writer I mentioned above, now two decades older, celebrates Hubble's birthday with a montage of its most iconic and informative images, recalling some of the cosmic secrets the telescope has exposed in its two decades in orbit — all in recognition of how Hubble's sharper and deeper images of the contents of the cosmos have sharpened and deepened humankind's insights into the nature of physical existence.

—Tom Siegfried, Editor in Chief

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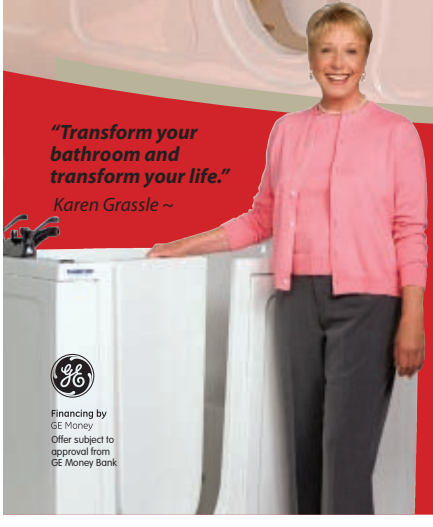

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Scientific Observations

"When evidence emerged that the [Intergovernmental Panel on Climate Change] had adopted unsubstantiated data about rates of Himalayan glacier retreat, the problem signalled not just a failure in the organization's review process, but a failure of organizational culture.... To those who already distrust climate science because it is used to justify action that they deem ideologically repugnant, such revelations make it look as though the science is systematically, if not congenitally, biased in one direction.... Scientific understanding ... is always incomplete, and gives the competing sides plenty of support for their pre-existing political preferences.... Science can decisively support policy only after fundamental political differences have been resolved." **—DANIEL SAREWITZ, CODIRECTOR OF ARIZONA STATE UNIVERSITY'S CONSORTIUM FOR SCIENCE, POLICY AND OUTCOMES, IN A COLUMN PUBLISHED MARCH 4 IN *NATURE***

Science Past | FROM THE ISSUE OF APRIL 9, 1960

CALIFORNIA ZOO APES BECOME "MEDICAL FIRSTS" — Noell, Scoop and Tria, three apes that live in the San Diego zoo, have made medical history. They "came down" with chicken pox while in their zoo cages during a period last summer when there was a high incidence of that disease among children in San Diego County. Now researchers believe that these three anthropoid apes are the first nonhuman animals to become naturally infected with chicken pox.... Chicken pox has been produced in monkeys by direct inoculation of the virus but there appears to be no references in medical history to natural infection such as this among subhuman primates.... Tria, the chimp, was the most seriously affected by the disease.

Science Future

April 18
Final day to visit the New York Hall of Science's hands-on mathematics exhibit. See www.nysci.org/explore/upcoming

April 24–28
The American Society for Biochemistry and Molecular Biology meets in Anaheim, Calif. See www.asbmb.org

June 2–6
Researchers, cultural critics and others meet in New York City to celebrate science. See www.worldsciencefestival.com

SN Online

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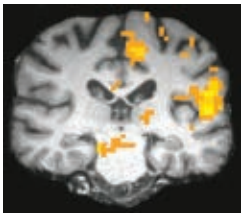
SCIENCE & THE PUBLIC BLOG
Armed with brain imaging (shown), researchers contend that Gulf War Syndrome, a cluster of symptoms controversially linked to Gulf War service, truly exists. See "Scientists offer compelling images of Gulf War illness."

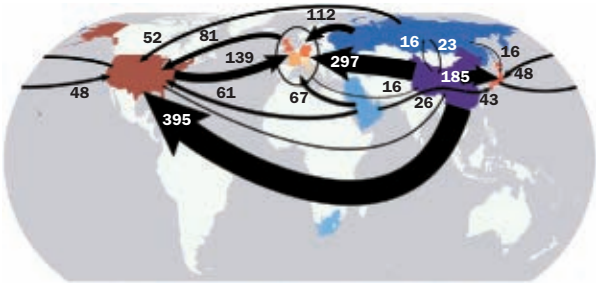


HUMANS
Using food to pacify temperamental babies may increase their chances of being overweight or obese children, new research shows. Go to "Soothing start to childhood weight problems."

EARTH
Talk about bad timing. Norse settlers colonized ancient Iceland just before the mercury dropped. See "Ancient Norse colonies hit bad climate times."

Science Stats | PASS THE CARBON

In 2004, 23 percent of global carbon dioxide emissions were produced in one country to make goods for use in another one. This map traces the movement of such "carbon exports" — primarily from China — in millions of metric tons.



SOURCE: S. DAVIS AND K. CALDEIRA/*PNAS* 2010

Introducing...

A new, dinosaur-like creature that lived about 240 million years ago has been unearthed in southern Tanzania. *Asilisaurus kongwe* (illustrated) measured less than 3 meters long and 2 meters tall, an international team reports March 4 in *Nature*. Fossil analyses place the animal among the archosaurs, which gave rise to dinosaurs, crocodiles and birds, among others. Unlike known archosaurs, *A. kongwe* had peglike teeth, a sign of an omnivorous or herbivorous diet.

CLOCKWISE FROM TOP LEFT: ARIZONA STATE UNIVERSITY; UT SOUTHWESTERN MED. CTR.; MARLENE HILL DONNELLY, FIELD MUSEUM

“In the forest, these … ants have a pretty tough life.” —GRZEGORZ BUCZKOWSKI, PAGE 14

In the News

STORY ONE

Chemists pin down poppy’s tricks for producing narcotic painkiller

Work may lead to widespread lab synthesis of morphine

By Rachel Ehrenberg

Opiates for the masses may not be far off. Scientists have figured out two of the final steps in the chain of chemical reactions that synthesize morphine in a poppy.

Pinpointing the cellular workhorses and the genes involved in making morphine may lead to new production methods for the drug and its chemical cousins such as codeine, oxycodone and buprenorphine, scientists report in a paper published online March 14 in *Nature Chemical Biology*.

Morphine and its relatives, widely used as painkillers in developed countries, can be fairly expensive and are often taken for extended periods of time. The new research may lead to better ways of engineering yeast or other microbes to make these painkillers — perhaps skirting the social and political morass of agricultural poppy production, which is also the source of heroin.

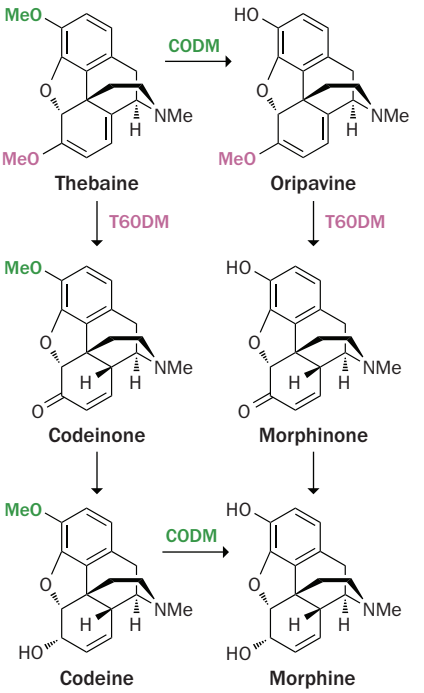
“Moving production of morphine and its metabolites such as codeine into a microbial system — if you could get yields up — could help lower costs,” says bioengineer Christina Smolke of Stanford University, who was not involved in the research. Instead of having to purchase these opiates from other nations, “maybe countries could even do local synthesis,” she says.

The new work identifies two enzymes — proteins that cells use to build molecules and make reactions go — involved in turning two of morphine’s chemical precursors, thebaine and codeine, into the final product. Study coauthors Jillian Hagel and Peter Facchini of the University of Calgary in Canada also pinpointed the genes encoding these two enzymes and verified their roles with test-tube and opium poppy plant (*Papaver somniferum*) experiments.

“This is really terrific work,” says Philip Larkin, head of the plant product metabolic engineering program at Australia’s national science agency CSIRO in Canberra. “Having these genes in the hand gives you much greater versatility.” For example, scientists could engineer high-yield plants by cranking up the activity of the morphine synthesis genes, Larkin says.

Scientists could also block morphine production with engineered viruses that shut down genes, yielding plants rich in codeine, another valuable painkiller. In theory, such viruses might also be used to eradicate opium poppy crops in places such as Afghanistan, where the poppies that make most of the world’s heroin are grown. But narcotic control experts caution that eradicating illegal drug use is not so simple.

“There are formidable tactical obstacles that would have to be addressed,” says Charles S. Helling, a former senior scientific adviser to the State Department’s Bureau of International Narcotics and Law Enforcement Affairs. Calling on ground forces to somehow contaminate plants would put people in danger, Helling says. And because illicit crops bring in so much money, eradication



A team has found two chemical routes for making morphine from thebaine in the opium poppy (left). In both cases the proteins T6ODM and CODM remove chemical decorations called methyl groups (Me) from precursor molecules.

FROM TOP: J. HAGEL AND P. FACCHINI/*NATURE CHEMICAL BIOLOGY*; SCOTT CAMAZINE/PHOTO RESEARCHERS, INC.

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programs often aren't successful unless coupled with alternative ways for local people to make a living.

Morphine is an alkaloid, a class of compounds characterized by a ringed molecular structure incorporating a bit of nitrogen. "Among all the natural products, alkaloids tend to display the most potent pharmacological effects," Facchini says. Plants produce roughly 12,000 kinds of alkaloids, including nicotine, strychnine, caffeine, mescaline, quinine and atropine.

A handful of ancient plant groups, including the poppy and buttercup families, produce the class of alkaloids that morphine belongs to, called benzylisoquinoline alkaloids. The main building block for the roughly 2,500 alkaloids in this class is the amino acid tyrosine.

After an opium poppy flower loses its petals, a seedpod (above) remains. The pod holds a milky sap—opium in its crudest form.

A 15- to 20-step reaction pathway turns tyrosine into morphine. Morphine can't be made directly from tyrosine in the lab because some of the early reactions aren't well understood, but researchers wouldn't need to go that route. Microbes such as yeast can be engineered to produce molecules further down the assembly line, which, with the new work, could now create the pain-relieving drug.

Years of research, gift plants, a bit of luck and the "Herculean effort" of then graduate student Hagel led to the discovery, Facchini says.

The researchers began with three high-morphine varieties of opium poppy and a mutant plant that makes the morphine precursors thebaine and oripavine but can't make morphine itself. Hagel constructed a DNA library from these plants, which the team used to determine which genes were turned on in the morphine-making poppies. She then compared this activity with that of the mutant plant that couldn't put morphine together. After determining the DNA sequences of the genes that differed, Hagel and Facchini checked those sequences against a database to reveal the enzymes' identities.

Verifying the enzymes' roles in making morphine was the clincher. Hagel stuck one of the genes into the bacterium *E.coli,* put it in a flask with some thebaine, and left it overnight.

"When she came back the next morning, the thebaine was all gone," Facchini says. "That's when her eyes got big.... Finding it all had been turned into morphine—that gives a grad student a great sense of power, when they can make morphine." The scientists dubbed the enzymes thebaine 6-O-demethylase and codeine O-demethylase.

Both of the newly identified enzymes are in charge of the same structural task: Each removes a methyl group, a common chemical ornament comprising a carbon and three hydrogen atoms, from another molecule. But in the hunt for these morphine-synthesis enzymes, many scientists were led astray. Many assumed that poppies used a methyl-removing enzyme similar to one that the human liver uses to remove methyl groups. But poppies employ enzymes from an entirely different class, the researchers report.

"These are enzymes that have eluded discovery for a long time," says MIT biochemist Sarah O'Connor. And they turned out to be enzymes that weren't really on scientists' radar. "In plants, it's very hard to figure out the enzymatic steps of a pathway," she notes. "This is a beautiful example of how you can use modern molecular biology tools to solve this problem." ■

Back Story

ALKALOIDS FROM PLANTS

Plants naturally produce an estimated 12,000 alkaloids. These ringed chemical compounds contain nitrogen, and many can alter the activity of neurons and other cells.

Nicotine
Tobacco plant, *Nicotiana tabacum*
This stimulant hits acetylcholine receptors in the nervous system, leading to improved alertness. It also promotes dopamine release, which is associated with pleasure-seeking behavior.

Theobromine
Cacao plant, *Theobroma cacao*
Theobromine is a blood vessel widener and heart stimulant found in chocolate.

Vinblastine
Madagascar periwinkle, *Catharanthus roseus*
This molecule inhibits cell division and is used to treat certain cancers.

Atropine
Deadly nightshade, *Atropa belladonna*
Atropine inhibits nerves and is often used to treat Parkinson's, dilate pupils and maintain an elevated heart rate.

CLOCKWISE FROM LEFT: TEUNSPAANS/WIKIMEDIA COMMONS; 2NDLOOKGRAPHICS/ISTOCKPHOTO; MEDICASTER40/WIKIMEDIA COMMONS; HSIVONEN/FLICKR; TOM OATES/WIKIMEDIA COMMONS

Science & Society

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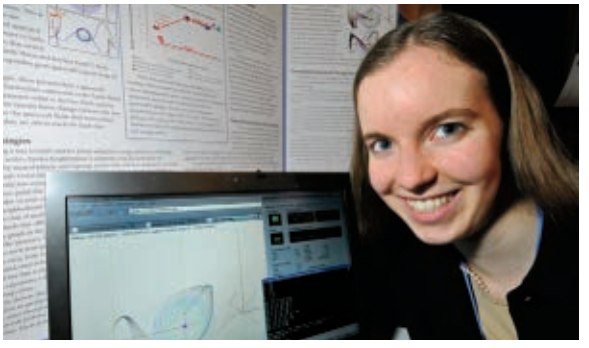
Space navigation plan takes gold in 2010 Intel Science Talent Search

Finalists collect over $630,000 in scholarships, other awards

By Lisa Grossman



Top winner Erika DeBenedictis wrote navigation software for spacecraft traveling an interplanetary superhighway.

CHRIS AYERS FOR INTEL STS

WASHINGTON — Ten of the nation's most innovative young scientists have received their version of Olympic Gold — temporarily putting aside their homework to do so.

Erika DeBenedictis, 18, of Albuquerque won first place in the Intel Science Talent Search, a prestigious competition for high school seniors, at a gala held March 16. DeBenedictis earned a $100,000 scholarship for designing an autonomous navigation system that could help spacecraft travel swiftly and efficiently along an "interplanetary superhighway," using planets' gravity.

Second place and a $75,000 scholarship went to David Liu, 18, of Saratoga, Calif., for software that automatically searches and organizes digital pictures. Beyond organizing personal photo albums, the system could be helpful in medical imaging, space exploration and detecting threats to oil pipelines, Liu suggests.

Akhil Mathew, 18, of Madison, N.J., took third place and a $50,000 scholarship for work combining algebraic geometry, representation theory and category theory in studies of mathematical constructs called Deligne categories. His method could be applied to other problems in mathematics, he says.

Society for Science & the Public, which publishes *Science News*, has administered the Science Talent Search since its beginning in 1942. The Intel Foundation sponsors the competition. Vying for more than $630,000 in scholarships and other awards, the 40 finalists in this year's competition were selected from more than 1,700 entrants and represented 36 high schools in 18 states. Past STS finalists have gone on to win many accolades, including seven Nobel Prizes.

"This year's Intel STS finalists are fully worthy successors to the impressive alumni who have come before them," says Elizabeth Marincola, president of Society for Science & the Public. "We firmly believe that whatever fields they each pursue, the discipline and rigor of the scientific training and thinking our finalists have already pursued will serve as a robust launchpad to their success as professionals, and as citizens of our human community."

> **"The best part has been connecting with the other 39 finalists."**
>
> **DAVID LIU**

The gala ended a weeklong visit to Washington, during which students presented their projects; met with members of Congress and with John Holdren, director of the White House Office of Science and Technology Policy; and still had time for fun: a tour of the national monuments and bowling.

"The best part has been connecting with the other 39 finalists," Liu says.

Paul Otellini, Intel's president and CEO, said: "These 40 Intel Science Talent Search finalists demonstrate that we have the capability in this country to cultivate the next generation of innovators, scientists and entrepreneurs. These young scientists are proof that curious, eager minds coupled with inspiring, knowledgeable teachers are the foundation for world-changing innovation."

Fourth place and a $40,000 scholarship went to Lynnelle Ye, 18, of Palo Alto, Calif., for her analysis of Chomp — a two-person combinatorial game — that she used to reliably predict the winner of the game in a certain set of circumstances.

Eric Brooks, 16, of Hewlett, N.Y., won fifth place and a $30,000 scholarship for investigating genetic factors associated with race that affect how likely prostate cancer is to metastasize.

Sixth place went to John Capodilupo, 18, of Grand Rapids, Mich., for a detailed statistical analysis of galaxy clustering that could be useful in removing noise from future galactic surveys. Seventh place went to Benjamen Sun, 17, of Grand Forks, N.D., for studying how dirt and debris in the street interact with rainwater. Each won a $25,000 scholarship.

Eighth through 10th place winners each won a $20,000 scholarship. They are Katherine Rudolph, 18, of Naperville, Ill., who studied the most efficient way to arrange spheres in *n*-dimensional space, a project that could have implications for supercooling liquids; Yale Fan, 18, of Beaverton, Ore., for showing how quantum computing could be used to explore algorithms for solving a class of problems known as "NP-complete"; and Linda Zhou, 18, of River Edge, N.J., who showed that silencing a gene that codes for a protein called hTERT reduces drug resistance and migration of cancer cells.

The remaining 30 finalists will each receive more than $7,500 in awards.

In addition, Alice Zhao, 16, of Sheboygan, Wisc., was chosen by her peers to give a speech at the gala as winner of the Glenn T. Seaborg award.

Atom & Cosmos

9 years Duration of shortest solar cycle on record

11 years Duration of an average solar cycle

14 years Duration of longest solar cycle on record

Hot gas flows cause sunspot lows

Satellite observations could improve solar cycle forecasts

By Ron Cowen

Newly reported observations of gas flows on the solar surface may explain why the sun recently had such an extended case of the doldrums.

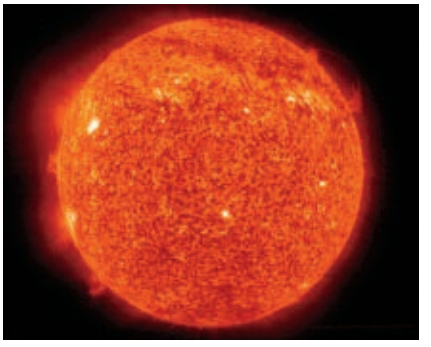
From 2008 through the first half of 2009, the sun had a puzzling lack of sunspots, flares and other storms, extending the usual lull at the end of the 11-year solar activity cycle for an extra 15 months. Data from the orbiting Solar and Heliospheric Observatory, or SOHO, indicate that gas flow affecting magnetic fields near the sun's poles may have been responsible for the extended quiet. The findings also suggest a better way to forecast the intensity and duration of future solar cycles.

Scientists want to improve predictions because some solar outbursts can blast Earth with massive, magnetized clouds of charged particles capable of knocking out electrical power grids and harming satellites.

David Hathaway of NASA's Marshall Space Flight Center in Huntsville, Ala., and Lisa Rightmire of the University of Memphis in Tennessee analyzed 13 years of SOHO measurements that tracked the movement of ionized gas from the solar equator to the poles. The relatively slow gas movement, known as the meridional flow, sped up a few years before the latest minimum in solar activity began in 2008, the researchers reported in the March 12 *Science*. That flow was substantially faster than at the previous solar minimum, a more typical and less extended downturn in solar activity some 11 years earlier.

Hathaway and Rightmire suggest that the faster meridional flow produced weaker magnetic fields at the sun's poles, extending the solar minimum.

Magnetic fields carried by the meridional flow typically oppose much stronger flows of magnetized material on the surface, Hathaway says. The faster the meridional flow, the greater the opposition to other flows. As a result, the sun's polar magnetic field can't become as strong, the researchers propose.



The latest period of minimal solar activity lasted longer than expected; data from the SOHO spacecraft may explain why.

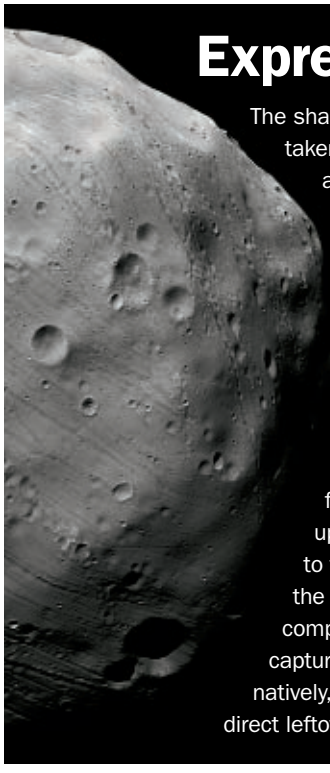
"It is possible that the delayed start of the present cycle, 2009 to 2010, was caused by the relatively weak polar field in 2007 to 2009," comments Neil Sheeley of the Naval Research Laboratory in Washington, D.C.

Polar magnetic field strength plays a crucial role in the onset of each solar cycle, Hathaway notes. These fields dive beneath the solar surface, building up deep sunspot-generating magnetic fields that signal the start of the next cycle. Weaker polar fields take more time to reach the strength required to produce sunspots, prolonging the lull in activity from the previous cycle. And weaker-than-usual polar fields are likely to produce less activity during the next solar cycle, Hathaway and Rightmire predict.

"The fact that the meridional flow plays a key role in setting up the sun's polar fields for the next cycle suggests that future observations will help us predict" the duration and intensity of upcoming cycles, Hathaway says.

Other models suggesting that a fast meridional flow leads to strong polar field and a shorter solar minimum may now need to be revised, he says.

Express tour of Phobos



The sharpest images yet of Mars' tiny moon Phobos taken by the Mars Express spacecraft reveal features as small as 4.4 meters across, the European Space Agency announced March 15. Some of the images taken March 7 (one shown) home in on the proposed landing site for a Russian mission, Phobos-Grunt (meaning Phobos soil), expected to be launched next year. During three flybys on March 7, 10 and 13, researchers measured the moon's tug on Mars Express by examining changes in the frequency of the spacecraft's radio signals beamed to Earth. The frequency shifts indicate that the craft has sped up or slowed by a few millimeters per second due to the moon's gravity. When combined with images, the gravity data may provide clues about Phobos' composition and origin. One theory suggests that Mars captured the moon from the nearby asteroid belt. Alternatively, Phobos may have formed where it now resides, a direct leftover from the planet-making era. —*Ron Cowen*

FROM TOP: NASA; G. NEUKUM/FU BERLIN, ESA, DLR

Humans

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

Scientists find early signs of autism

Cluster of symptoms can identify 14-month-olds at risk

By Bruce Bower

Some infants headed for a diagnosis of autism can be reliably identified at 14 months using five key behavior problems, suggests an ongoing long-term study described March 11.

These social, communication and motor difficulties broadly align with psychiatric criteria for diagnosing autism spectrum disorder in children at around age 3, said psychologist Rebecca Landa of the Kennedy Krieger Institute in Baltimore. In her investigation, the presence of all five behaviors at 14 months predicted an eventual diagnosis of autism spectrum disorder in 15 of 16 children.

"That's much better than clinical judgment at predicting autism," Landa noted.

Her five predictors include childrens' lack of response to attempts by others to engage them in play, infrequent attempts to initiate joint activities, few types of consonants produced when trying to communicate vocally, problems in responding to vocal requests and a keen interest in repetitive acts, such as staring at a toy while twirling it.

Accurate identification of infants likely to develop autism spectrum disorder by age 3 is important because studies indicate that intensive interventions with youngsters who display early warning signs, and with their parents, often yield marked behavioral improvements. Interventions focus on teaching kids basic interaction and communication skills.

Behaviors at 14 months predicted an eventual diagnosis of autism spectrum disorder.

Landa's study consists of 250 children who were first assessed at either age 6 months or 14 months. Comprehensive measures of social, communication and motor abilities were obtained at each child's home and repeated at 18, 24, 30 and 36 months of age. The sample included 110 children considered to be at high risk for developing autism because they had older siblings already diagnosed with it.

Preliminary evidence suggests that high-risk 14-month-olds who later develop autism display signs of delayed motor development as early as 6 to 7 months of age, Landa noted.

Psychologist Sally Rogers of the University of California, Davis cautioned that much remains unknown about early identification and treatment of autism. Infant siblings of older children with autism represent a special group that is particularly likely to show early signs of the same disorder, she suggested.

Toddlers tricked to learn from TV

Study may explain why kids under 3 learn little from video

By Bruce Bower

To get toddlers to learn new information from educational television shows or DVDs, don't bribe or bully them—just trick them. One way to teach young children with video is to convince them that what they see on the screen is as real as anything they encounter in person, new research presented March 12 shows.

Through elaborate experimental deception, researchers were able to erase much of the "video deficit" in learning observed in children under age 3.

"Under normal circumstances, television and videos may be so captivatingly interesting to young children that they have difficulty learning from these media," said psychologist Sarah Roseberry of Temple University in Philadelphia. In the experiment, overcoming that obstacle hinged on youngsters believing that researchers could turn stuffed animals into real animals by putting the toys inside a "magic Sesame Machine" with tubes on the sides and a video screen on the front.

Almost no studies have tried to unravel reasons for the video deficit, said psychologist Patricia Kuhl of the University of Washington in Seattle.

In Roseberry's study, 20 toddlers ages 30 to 35 months and 20 kids ages 36 to 42 months watched videos in which *Sesame Street* characters taught them about two novel verbs, one real and the other made up. Only the older group demonstrated substantial word learning afterward.

In a second experiment, 20 children ages 24 to 29 months and another 20 kids ages 30 to 35 months watched videos on the magic Sesame Machine. Beforehand, children watched a researcher place a stuffed animal into a tube on one side of the machine, as if putting it inside the television console. A video showing the toy then began to play, and the researcher explained the machine's magical ability to make stuffed animals real. Once the video concluded, the researcher removed the stuffed animal from a tube on the other side of the console.

After watching the same videos in the magic machine, younger but not older toddlers showed evidence of having learned most words from the program. That reflects the fact that younger children told their parents that they believed in the magic machine, whereas older children usually weren't tricked, Roseberry noted.

Matter & Energy

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Quantum rules get mechanical

Microworld's weird behavior observed in everyday realm

By Alexandra Witze

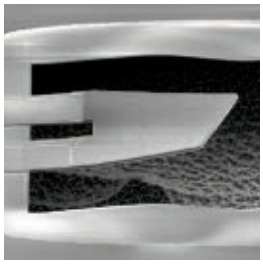
Physicists have demonstrated behavior governed by rules of the quantum world, which operate at the level of atoms, in mechanical objects large enough to see.

The accomplishment fulfills a long-held dream to bridge the quantum and everyday worlds. One day, researchers say, mechanical devices in a laboratory might be manipulated according to the rules of single atoms — paving the way to quantum information processing or probing other unusual behaviors.

"This is groundbreaking work," says Markus Aspelmeyer, a physicist at the University of Vienna who was not affiliated with the study.

Multiple teams have competed for years to link the quantum and everyday realms by building a tiny vibrating device and draining out as much of its energy as possible, reducing it to the "quantum ground state." Most groups have tried to do this by building powerful refrigerators to chill the material down to nearly absolute zero, or zero on the Kelvin scale.

But physicist Andrew Cleland of the University of California, Santa Barbara took a shortcut. "If I took a tuning fork and wanted to get it to the quantum ground state, I would have to cool it below 50 billionths of a kelvin," he explains. "There is no technology that will allow you to do that, not now. But if you push the frequency of that tuning fork up" by orders of magnitude, "then you only have to cool it to 50 millionths of a degree above absolute zero."



A tiny resonator, imaged by a scanning electron microscope, can exhibit quantum behavior.

By choosing a material that vibrates at extremely high frequencies — in this case, 6 billion times a second — Cleland and colleagues could use a commercial refrigerator to reach the quantum ground state, because the system didn't need as much cooling as a material at lower frequency.

The system that showed quantum behavior is a simple-looking film of aluminum nitride layered between two aluminum electrodes, Cleland and colleagues report online March 17 in *Nature*. They were able to show not only that the device had reached its quantum ground state, but also that they could control it. After creating a phonon, the smallest unit of vibrational energy, the researchers watched as it moved back and forth between the resonator and another device.

Potential applications include using these resonators to test predictions about "Schrödinger cat" states — named for a hypothetical feline simultaneously alive and dead — in which a system exists in a mix of states known as a superposition. Cleland's team showed, somewhat indirectly, that a form of superposition existed inside the resonator.

A light proposal with an extra twist

Scientists suggest existence of unsuspected 'superchirality'

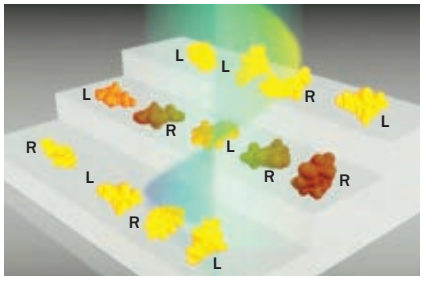
By Alexandra Witze

Light, it seems, can be a lot like Shirley Temple's curls: more twisty than anyone could possibly have imagined.

In a paper to appear in *Physical Review Letters*, researchers suggest that electromagnetic waves, including light, can possess an excess twistiness beyond what physicists had ever before speculated.

"There's this thing in the electromagnetic field that nobody has noticed all this time," says Adam Cohen, a physical chemist at Harvard University who led the work. "That's what makes it interesting."

If confirmed, the supertwisty light might one day have applications in drug synthesis, biosensing or other fields.



Sending circularly polarized light (green helix) through left- and right-handed molecules could probe superchirality.

Cohen's team studied molecules with "chirality" or "handedness," meaning they come in two forms that mirror each other like right and left hands. A molecule's chirality is detectable only when the substance interacts with other chiral things such as circularly polarized light, whose electric field traces out a helical pattern, like a Slinky, while moving through space.

Cohen and coauthor Yiqiao Tang calculated that there are regions of space in which electromagnetic fields could be more chiral than in others. In rare regions where conditions are just right, the researchers say, this "superchiral" light would twist around at rates hundreds of times higher than ordinary circularly polarized light.

The work is interesting from a fundamental point of view because it introduces a measure of chirality that no one had thought of before, says Akbar Salam, a theoretical chemist at Wake Forest University in Winston-Salem, N.C.

FROM TOP: A. CLELAND/UCSB; A. COHEN AND Y. TANG/HARVARD UNIV., LU MEN

16 million NYSE share volume on "Black Tuesday," Oct. 29, 1929

604 million NYSE share volume on "Black Monday," Oct. 19, 1987

7.34 billion NYSE share volume on last day of "Black Week," Oct. 10, 2008

Molecules get superchilly reaction

Experiments, theory illuminate ultracold quantum chemistry

By Laura Sanders

Researchers have now been able to stop and start chemical reactions between molecules at temperatures colder than the depths of outer space. And a new theoretical description helps explain the quantum mechanical details of how these reactions happen.

The details, presented March 17, offer glimpses into the burgeoning field of ultracold physics (*SN: 12/20/08, p. 22*).

Deborah Jin and Jun Ye of the University of Colorado at Boulder and the JILA research center in Boulder led experiments using lasers and electric fields to manipulate reactions between ultracold potassium-rubidium molecules.

"It's a beautiful demonstration of how quantum mechanics works," said chemist Jeremy Hutson of the University of Durham in England. The new studies reveal strange quantum effects "in a very simple regime that's never been explored before."

Jin, Ye and colleagues used lasers to cool the potassium-rubidium molecules, halting nearly all their usual frenetic motion. Held in this chilly "ground state" at a temperature around 200 nanokelvins, the molecules moved incredibly slowly, Ye said. But after a second or so, they started to disappear by twos.

"What's going on here is chemistry," Jin says. The potassium-rubidium molecules can interact with each other to form molecules made up of two potassium atoms and two rubidium atoms, the team reported in the Feb. 12 *Science*.

At the meeting, Jin and Ye presented new preliminary results showing not only that these chemical reactions occur, but that they also can be sped up or halted. Potassium-rubidium molecules have electric charges at each end — slightly negative at the potassium atom and slightly positive at the rubidium atom. These dipole moments give researchers a way to manipulate the ultracold molecules. When the team turned up an electric field around the molecules, the reaction rate went up dramatically — by a factor of 20 or 30, Jin said.

In other experiments, the researchers showed that the reactions, which happen only when the molecules line up head to tail, could be suppressed. The team used a laser to slice a big glob of ultracold molecules into 20 or so thin, pancakelike shapes. This tight conformation prevented the molecules from lining up head to tail, curbing the reactions. The ability to halt reactions is important, Jin said. "Chemical reactions are great and fun," until an experiment requires the original molecules themselves, she said. "Then those chemical reactions are kind of a problem."

> "It's a beautiful demonstration of how quantum mechanics works."
>
> JEREMY HUTSON

New theoretical results reported at the meeting illuminate how the ultracold molecules find each other in the first place. At temperatures this low, the molecules behave more like diffuse waves than discrete spots, said theorist Paul Julienne of the National Institute of Standards and Technology in Gaithersburg, Md. Julienne and Zbigniew Idziaszek of the University of Warsaw found that long-range effects of these waves, which can reach hundreds of nanometers, influence how the ultracold molecules close in on each other.

Once the molecules are within one nanometer or so, they "react with great certainty," Julienne said. The predicted reaction rates, published March 18 in *Physical Review Letters*, agree well with the rates observed by Jin and Ye.

MEETING NOTES

Financial bubbles burst alike

Statistically speaking, size doesn't matter when a financial bubble bursts. Analyses of "microbubbles" reported March 15 find that the same mathematical laws underlying massive economic crises are also at work in tiny fluctuations that occur on the order of milliseconds. The math doesn't predict when the next economic meltdown will hit, said study coauthor H. Eugene Stanley of Boston University. But the results help describe complex financial fluctuations and reinforce the idea that governments ought to have contingency plans in place for collapses, he said. Stanley and colleagues analyzed 14 million German stock trades and found that the distributions of trading speed and share volume remained the same regardless of bubble size. —*Laura Sanders*

Body heat draws particles near

In small rooms, body heat may draw particles to all the wrong places. Thermal plumes from a person can waft microbes, pollen and dust into breathing range, a study presented March 16 finds. A computer simulated a human sitting in a room as 1,000 particles the size of some saliva droplets flooded in via an air vent. When the virtual body's surface temperature was 25° Celsius (about that of a resting person's clothes), some particles whooshed up to the ceiling and then collected over the head. When the body was at room temperature, fewer particles hovered directly above it. Understanding body heat's effect on particle motion may aid in designing healthier airflow systems, said study coauthor John McLaughlin of Clarkson University in Potsdam, N.Y. —*Laura Sanders*

Genes & Cells

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

Going from wolf to Weimaraner

First Fido probably wagged its tail in the Middle East

By Tina Hesman Saey

The largest-ever genetic family tree of dogs and wolves traces dogs' origin to the Middle East, an international group of researchers reports online March 17 in *Nature*. The finding fits with archaeological evidence that dogs were domesticated in the Middle East or Eastern Europe, and contradicts earlier genetic data suggesting that man's best friend originated in China.

New research suggests dogs emerged from wolf populations in the Middle East or Eastern Europe, not East Asia.

"Nothing ever seals the deal, but this is pretty strong evidence for dog domestication in the Near East cultural region," says Carlos Driscoll, a geneticist at the National Cancer Institute at Frederick, Md., who was not involved in the research.

In the new study, scientists analyzed 48,000 DNA markers, called SNPs, scattered across the genomes of 85 dog breeds as well as gray wolves from 11 different populations around the world. SNPs, or single nucleotide polymorphisms, are letters in the genetic instruction book that can vary between individuals. In terms of SNPs, East Asian dog breeds are not more genetically diverse than other breeds, the team found.

Modern dog breeds, those that first appeared in the Victorian era, have more genetic kinship with Middle Eastern wolves than with other wolf populations, indicating that dogs probably stem from wolf forebears in that part of the world.

Family genomics makes its debut

Full DNA studies of parents and children pinpoint mutations

By Laura Sanders

Genome sequencing has become a family affair. For the first time, two independent teams of researchers have identified genetic changes underlying rare diseases by comparing complete DNA sequences from patients with similar data from their immediate relatives.

The studies, appearing online March 10 in the *New England Journal of Medicine* and *Science*, show how powerful family genome sequencing can be for understanding inherited conditions, and how the falling costs of such analyses promise to revolutionize the study, diagnosis and treatment of disease.

"It's great to see rare disease genes being identified by sequence-based approaches," says geneticist Stacey Gabriel of the Broad Institute, a joint research center of MIT and Harvard University. In these early days of using gene sequencing as a discovery tool, she says, "family-based studies are a really interesting place to start."

The authors of the paper in *Science* sequenced the complete genomes of two parents, a son and a daughter. Both children had a pair of rare genetic diseases — Miller syndrome, characterized by craniofacial abnormalities, and primary ciliary dyskinesia, which affects the respiratory tract. By comparing the parents' genomes with the children's, researchers were able to pinpoint two likely genetic culprits. Knowing exactly which genetic changes trigger a disease could help researchers tailor treatments, for example by prescribing drugs that work on the relevant disease pathway or providing genetic counseling to families.

The other study focused on a different inherited disease — Charcot-Marie-Tooth neuropathy. The lead author of that study, James Lupski, has the disease, which is characterized by improperly functioning nerves and progressive muscle atrophy. Lupski, a clinical geneticist at Baylor College of Medicine in Houston, had his genome fully sequenced — a "quite exciting" event, he says. He and his colleagues then compared select regions of his DNA with that of his parents and seven siblings, three of whom also have Charcot-Marie-Tooth disease.

This targeted approach pinpointed two mutations in a gene called *SH3TC2* as the cause of Lupski's form of the disease. "We've worked on studying this disease close to 25 years," he says. "We've never been able to identify the cause of my specific disease in my family. We now know the exact thing going on."

The cost of sequencing has dropped dramatically since the days of the Human Genome Project, which spent an estimated $2.7 billion to produce a single human genome. Sequencing Lupski's complete genome cost around $50,000, and he estimates that in the six months since his team's study was conducted, the cost has dropped to about half that amount.

Many geneticists believe such sequencing will become routine in research and medicine once the cost of analyzing a full genome falls to about $1,000.

"There will be a reality of getting to that $1,000 genome in a few years," Lupski predicts.

FROM LEFT: CHRIS MUIDEN/WIKIMEDIA COMMONS; SEREGA/ISTOCKPHOTO

37	Average number of bacterial types on human palm	49	Average number of bacterial types on human forearm	20	Average number of bacterial types behind human ear

To catch a thief, follow grubby paws

Bacterial forensics gives criminals new reason to wear gloves

By Tina Hesman Saey

Crime-scene investigators may one day catch criminals dirty-handed. Having found previously that everyone's hands carry a unique bacterial population, researchers at the University of Colorado at Boulder have now shown that the mix of microbes left on a computer keyboard can be used to match it to its owner.

The tests, reported online March 15 in the *Proceedings of the National Academy of Sciences*, raise the possibility that hand bacteria could serve as a new type of fingerprint. Noah Fierer and his colleagues wondered if bacteria could be used in forensics when fingerprints fail, such as when prints are smudged or evidence is left on fabric or other surfaces that don't preserve fingerprints well.

After all, says Fierer, "you only need to smudge a fingerprint, but you can't sterilize a surface just by wiping it off."

He and his colleagues created DNA profiles of bacterial populations swabbed from the hands and keyboards of three people. The bacteria on an individual's keyboard closely matched bacteria on their hands, the team found. And the bacterial DNA remained stable for at least two weeks after swabbing.

For bacterial fingerprints to be useful, however, they must distinguish a person from the general population. So the researchers swabbed nine computer mice and the owners' palms. In all nine cases, the bacteria on the computer mouse were more similar to bacteria from the owner's palm than to those from any other hand in a database of bacteria from 270 hands sampled for the Human Skin Microbiome project, which surveys the diversity of microbes living on human skin.

Other researchers are uncertain the technique will work in the real world. "Right now we really have no idea how unique a person's skin microbiome is," says Elizabeth Grice of the skin microbiome project at the National Human Genome Research Institute. In the new study, objects were handled by only one person, but if two or more people touch something they may leave a bacterial mix that resembles a third person, she says. The Colorado team is now investigating how many times a person must touch an object to leave a bacterial trace and whether prints remain on soft surfaces.

Hen or rooster, each cell decides

Odd chickens support new ideas of sex determination

By Susan Milius

On rare occasions chickens don't cross the road; they get stuck right in the middle, between male and female.

Individual chicken cells can keep their male or female identities during development instead of being overruled by hormones, contrary to an old view of sexual development, Michael Clinton and his colleagues at the Roslin Institute in Scotland report in the March 11 *Nature*.

Clinton and his group considered hormones and sexual development in the study of three peculiar chickens donated to the institute. Each bird looked like a rooster on one side, with a long wattle jiggling under its chin, robust legs and bulging muscles. On the other side, each bird had the darker plumage, reduced wattle and dainty ankles of a hen. Such male-female mashups, called gynandromorphs, occur naturally — due to early-stage cellular anomalies — in zebra finches, pigeons and parrots, as well as in other kinds of animals.

Half-male, half-female chickens (above, hen on left) suggest that genetics can trump hormones in determining sex.

When Roslin's Derek McBride analyzed the chickens' tissues, he found genetically male and female cells scattered all over the birds' bodies, with genetically male cells dominating one side of the body while the other half had a female majority.

Because cells in the same body were exposed to the same circulating hormones but retained different traits, the Roslin researchers hypothesized that a chicken cell's genetic identity trumps hormonal instructions. Recent studies in marsupials, mice and birds have also chipped away at this dogma.

Subsequent experiments supported the idea of strong, cell-by-cell sex identity. When the researchers transplanted tissues from genetically female embryos into what would become the gonads of genetically male ones and vice versa, the transplanted cells didn't start expressing opposite-sex characteristics.

Along with other recent papers, says UCLA geneticist Art Arnold, the new study calls for fresh thinking about sex determination, and not just in birds. "The old hormone-only theory is no longer viable, for birds or mammals," he says.

THE ROSLIN INSTITUTE

Life

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

How chameleons hunt with a snap

Elastic tissue gives tongue zap even in cold weather

By Sid Perkins

A veiled chameleon doesn't depend on muscle power to flick its tongue, so it can still nab prey in the cold. Low temperatures stymie lizards that must chase dinner.

Cool weather typically weakens muscle power in cold-blooded creatures, but new data show that chameleons can nab prey even at near-freezing temperatures thanks to an elastic, energy-storing sheath of collagen inside their tongues.

Some chameleons live in alpine ecosystems and can feed when their body temperatures are as low as 3.5° Celsius — a trick that scientists haven't been able to explain, say Christopher V. Anderson and Stephen Deban, both of the University of South Florida in Tampa.

Using elastic collagen instead of muscle power to shoot its tongue at prey lets a chameleon catch breakfast even when its muscles are stiff from the cold, the duo contend online March 8 in the *Proceedings of the National Academy of Sciences*.

At 35° C, the veiled chameleon can flick its tongue toward prey at peak speeds of 4.4 meters per second, the team shows. Drop to 15° C and peak tongue-shooting speed falls to about 3.4 m/s, a 23 percent decline. But the speed at which the lizard retracts its tongue falls by some 58 percent over the same temperature range.

The difference arises because tongue retraction is powered by muscles slow to contract in the cold. But tongue extension is driven by energy stored in the rubber band–like collagen sheath. That biophysical modification, a trait common to all chameleons, lets the creatures forage in conditions too cool for other lizards in the same ecosystem, the researchers say.

Country ants make it big in the city

Urbanized insects build empires with hundreds of queens

By Susan Milius

It's a tale of bright lights, big colonies: Rural ants go wild in the city.

A survey of odorous house ants confirms how much a modest country dweller can change habits in the big city, says Grzegorz Buczkowski of Purdue University in West Lafayette, Ind.

In forests in Indiana, he found the ants, *Tapinoma sessile*, living in colonies with just one queen each. With no more than a hundred ants, each colony could live in a single acorn.

In the forest, a colony of ants can fit into a single acorn. Not so in a town.

Ants from city parks and other seminatural areas formed somewhat bigger colonies, he says. But in West Lafayette and nearby urban zones, Buczkowski found that nests of the ants connect via bustling trails to form supercolonies. Each of his 15 colony samples typically held some 58,000 ants and 238 queens, he reports online February 26 in *Biological Invasions*. One supercolony covered more than a city block and held 6 million workers and thousands of queens.

"In the forest, these ... ants have a pretty tough life," Buczkowski says. They compete for food and shelter, and ants living in unheated acorns go dormant during the winter. But urban colonies can stay active all year by retreating to warm refuges, he says. "Even when it's snowing outside, they can be happy inside reproducing."

The odorous house ant doesn't sting or bite or chew up houses. Yet Buczkowski says pest control workers are getting increasing numbers of calls from human city dwellers dismayed by heavy ant traffic. "Here we have this native ant species that's becoming a pest," he says. Most invasive ants live far from their native ranges.

The ants release an odor when vexed that smells somewhat like a piña colada.

Sean Menke of North Carolina State University in Raleigh says he has also seen some colonies in rural areas with multiple queens, and points out that the ants have proven highly adaptable, surviving in palm oases in Baja California and in Colorado mountains. "Many species are beginning to succeed and spread in urban environments," he says. "We don't know if it is ... due to encroachment by people into their native habitats or because the species have altered their lifestyles."

FROM TOP: STEPHEN DALTON/ANIMALS ANIMALS; G. BUCZKOWSKI

One fiddler crab "does a judo throw and flicks over the other one." — MICHAEL JENNIONS

Cold source of greenhouse gas

Ice sheets may be trapping microbe-generated methane

By Alexandra Witze

BALTIMORE — Microbes living under ice sheets in Antarctica and Greenland could be churning out large quantities of the greenhouse gas methane, a new study suggests.

In recent years scientists have learned that liquid water lurks under much of Antarctica's massive ice sheet, and so the potential microbial habitat in this watery world is huge. If methane produced by the bacteria gets trapped beneath the ice and builds up over time — a possibility that is far from certain — ice sheets melting under warmer temperatures might release much heat-trapping methane.

Jemma Wadham, a geochemist at the University of Bristol in England, described the role of methane-making microbes, called methanogens, below ice sheets March 15 at an American Geophysical Union conference on Antarctic lakes.

Her team took samples from one site in Antarctica, the Lower Wright glacier, and one in Greenland, the Russell glacier. Trapped within the ice were high concentrations of methane, Wadham said, as well as methanogens themselves — up to 10 million cells per gram in the Antarctic sample and 100,000 cells per gram in Greenland. That's comparable to methanogen levels found in deep-ocean sediments, she said. The species of microbes were also similar to those found in other polar environments, such as Arctic peat.

The team incubated scrapings from both sites in bottles with water to see which microbes might grow. For the Antarctic samples, Wadham said, "nothing happens for 250 days and then, bam! You get tons of methane." The Greenland samples haven't been growing for as long and so far don't show significant signs of giving off methane — but perhaps they just need more time, she reported.

Other researchers have also recently found methanogens in icy settings. Mark Skidmore, a microbiologist at Montana State University in Bozeman, reported at the conference that his team has found methanogens in the Robertson glacier in the Canadian Rockies. "It underscores the importance of subglacial methanogenesis," Skidmore said.

At least 386 lakes have been identified buried beneath the Antarctic ice sheet, scientists from the University of Edinburgh reported at the meeting.

Fiddler crabs size up foes to fight

Rival may turn defender when small neighbor is attacked

By Susan Milius

TANYA DETTO

Male fiddler crabs (*Uca annulipes*) grapple in furious fights over burrows, but enemies can become allies.

Fiddler crabs will do battle to help a punier rival, a report in the May *American Naturalist* concludes. But it isn't out of kindness.

Ecologists knew that male fiddler crabs sometimes take on an attacker who is trying to invade a neighbor's territory. By setting up bouts among crabs of the species *Uca annulipes* on a beach in Mozambique, Australian researchers have found that the crustaceans defend only smaller neighbors. And they do so only when an intruder is intermediate in size between their neighbor and themselves.

Size has a lot to do with which crab is going to win a fight. So the rules of crab engagement suggest that it's not a mutual defense pact that motivates a male to defend his neighbor. By the rules, the little guy next door isn't going to help his big defender. But the big guy benefits by preventing a larger rival from moving in next door and instigating the customary series of border clashes, says study coauthor Michael Jennions of Australian National University in Canberra.

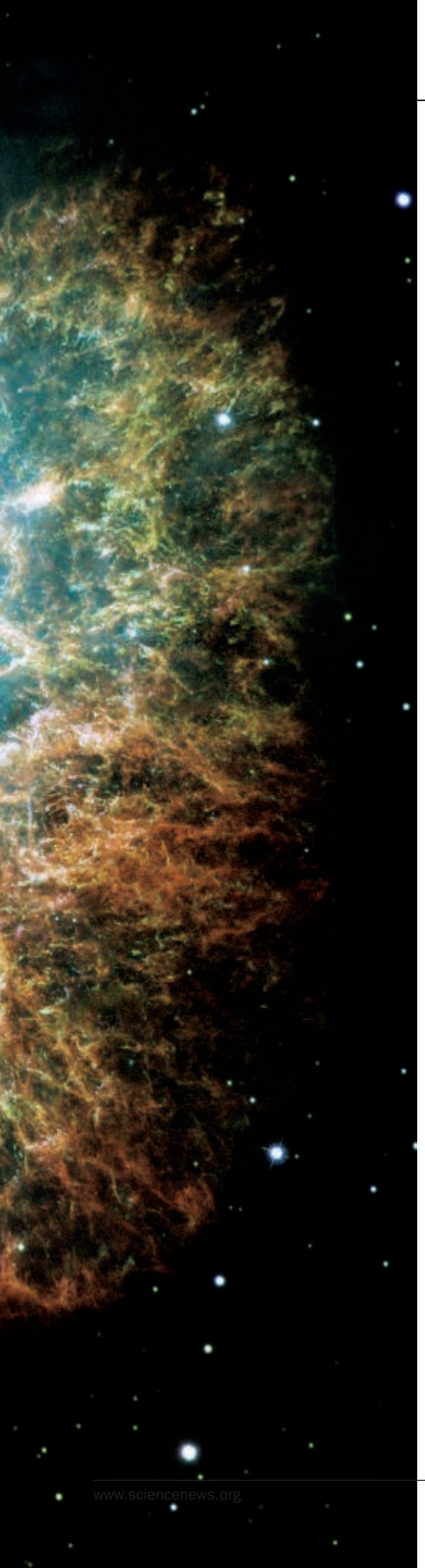
This kind of behavior — males aiding a territorial rival — has been documented in only two species before. Coauthor Patricia Backwell, also at Australian National University, described the behavior in an Australian fiddler crab in 2004. Before that, biologists had observed helpful rivals among European birds called pipits.

Among fiddler crabs, fights break out over deep burrows excavated in the sand, where crabs hide when tides bring predatory fish and where male crabs display their digging prowess and romance potential mates.

Should one male get evicted, the fastest cure for homelessness is to go find a slightly smaller male and evict him. Fights typically last less than a minute. After some shoving and grappling between males, "one does a judo throw and flicks over the other one," Jennions says. The thrown crab, disoriented, flees.

Males fighting to save less-threatening neighbors makes sense, says Tom Sherratt, an evolutionary biologist at Carleton University in Ottawa. "I'm not a military historian, but I suspect there have been wars waged for similar reasons."

DEATH TO LIFE The filaments in this portrait, assembled from images taken by the Hubble Space Telescope in 1999 and 2000, are the tattered remains of the Crab Nebula supernova. Japanese and Chinese astronomers witnessed the stellar explosion in 1054, and the now 6-light-year-wide remnant continues to sweep up surrounding gas as it expands. Debris from the explosion is seeding the cosmic neighborhood with heavy elements that will be taken up by a new generation of stars.



Happy 20th, Hubble

Flying observatory's cosmic portraits continue to capture hearts and minds

When NASA announced in 2004 that it was canceling a final mission to repair the then-ailing Hubble Space Telescope — effectively a death sentence — the agency received a letter from a 9-year-old girl who wanted to donate her lunch money to save Hubble. That letter, among countless others, exemplifies the public's love affair with the observatory, which turns 20 years old this month.

Since its launch on April 24, 1990, Hubble has repeatedly risen from the ashes to produce pictures of unparalleled clarity and beauty. The observatory has recorded nearly a million images and spectra in about 110,000 trips around the Earth. Among its cosmic postcards — some of the best in the pages to follow — Hubble has caught bruises left on Jupiter by fragments of a comet, elderly stars gift-wrapped in shells of glowing gas, the slender arms of spiral galaxies and nebulae ablaze with the light of newborn stars.

Not bad for a telescope initially dubbed a techno-turkey for its flawed primary mirror. Soon after astronauts fixed that problem during a series of space walks in late 1993, Hubble began living up to its promise as the first major visible-light telescope to fly above Earth's image-distorting atmosphere. The telescope has several times rewritten the textbooks on astronomy. Perhaps most dramatically, Hubble's study of remote stellar explosions (inset) provided key evidence for an acceleration in the rate of cosmic expansion, leading scientists to surmise the existence of dark energy. Hubble also delivered compelling confirmation that the universe has evolved in a way predicted by the Big Bang theory. Closer to home, Hubble recorded one of the first images of a planet beyond the solar system.

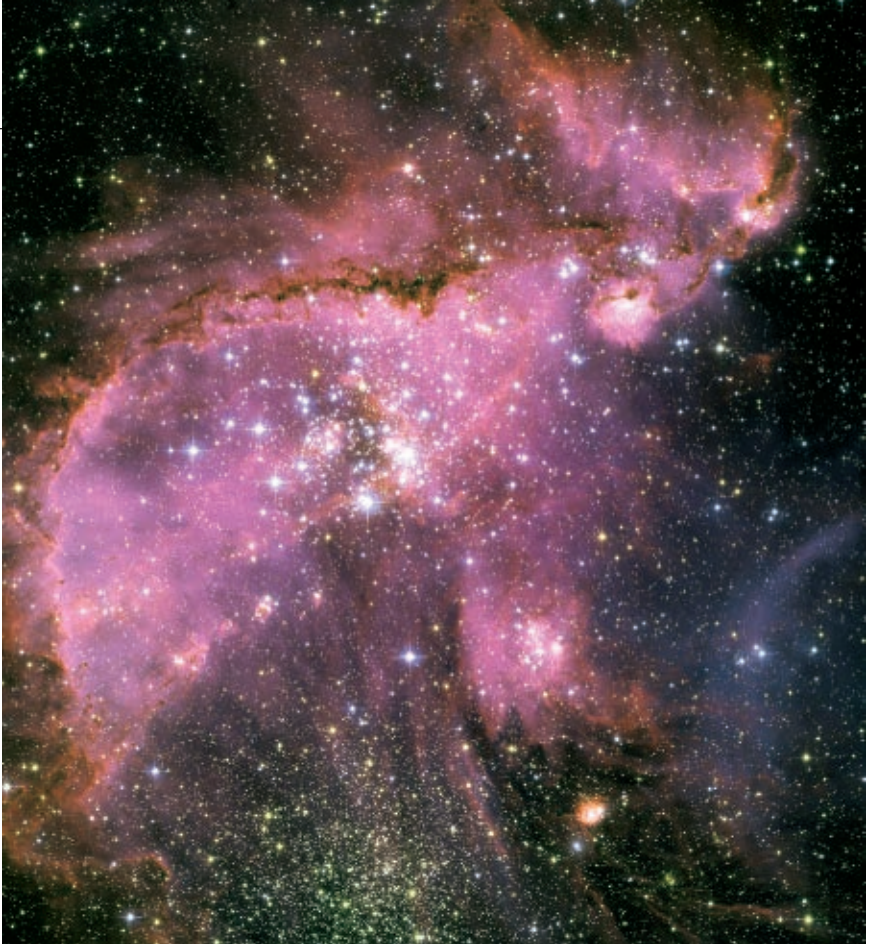
Yet for all of Hubble's scientific breakthroughs, the beauty of its images ranks high among its most lauded achievements. Hubble's pictures hang in museums, adorn album covers and have appeared in major motion pictures. Its online image gallery receives about 200 million hits a month.

Last May, astronauts did indeed perform a final servicing mission, transforming Hubble into a spanking new observatory that has become the ultimate galactic time machine. Hubble's new infrared camera has already spotted galaxies believed to be the most distant ever recorded. Because peering deep into space is the same as peering far back in time, the pictures reveal what the galaxies looked like just a few hundred million years after the Big Bang. If the servicing mission was an early birthday present from Earth, then Hubble has more than returned the favor. Taking us back to our cosmic beginnings may be the observatory's ultimate gift. — *Ron Cowen*

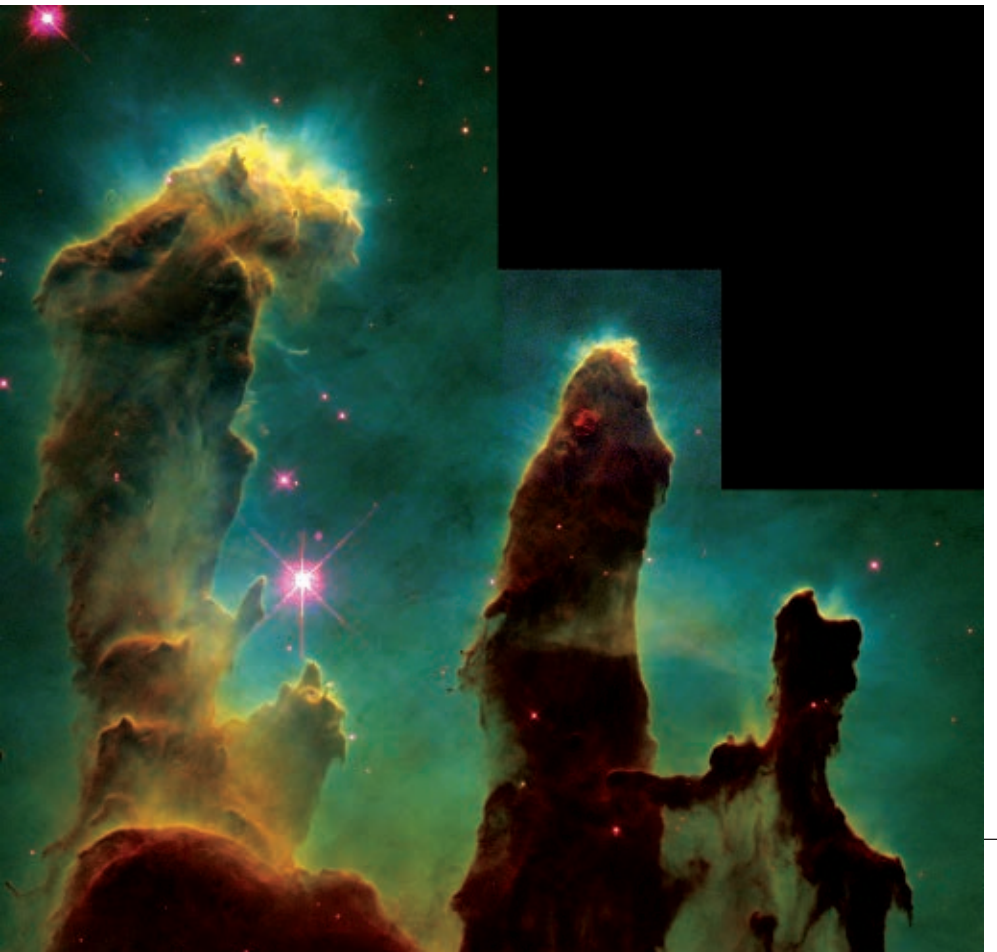
ALL PHOTOS: NASA/ESA; INSET: ALSO FROM A.G. RIESS *ET AL.*/STSCI

SPIRALMANIA The slender arms of the Whirlpool galaxy, M51a, appear to stretch through space like a spiral staircase. Hydrogen gas is compressed to make new stars (pink) in these curving arms, imaged here in 2005. Their sharp, winding pattern could be the result of a gravitational tug-of-war with the smaller companion galaxy M51b (upper right). Drifting past the Whirlpool for hundreds of millions of years, the small galaxy has generated ripples in the Whirlpool that further compress gas and thus spawn stars. During its 20 years of picture taking, Hubble has documented many examples of how close encounters like this one can alter the structure and evolution of galaxies.

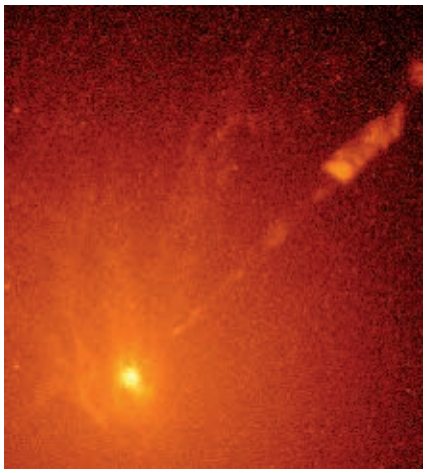
LAST HURRAHS Planetary nebulae, such as those shown at left, form when elderly sunlike stars gently eject their outermost layers, creating twisted, intricate shells of gas set aglow by the aging stars' ultraviolet light. These luminescent shells last for only tens of thousands of years, an astronomical blip. The portrait of the doughnut-shaped Helix nebula (far left) combines Hubble images taken in 2002 with ground-based images taken a year later. The Cat's Eye nebula, seen in this 2002 image (near left), was identified in 1786 by William Herschel and is one of the most complex in shape. A white dwarf, the dying star's compact remnant, lies at the center of every planetary nebula.



STARRY SCULPTURES This dynamic star-forming region lies about 210,000 light-years from Earth in the Small Magellanic Cloud, a satellite galaxy of the Milky Way. Arched, ragged gas filaments surround a cluster of hot, young stars at the center of this image, taken in 2004. Intense radiation streaming from the star cluster eats away at the denser surroundings, sculpting gas and dust into fanciful shapes.



ENDURING ICON Blending science and art, this image of the Eagle nebula has captivated millions. The Pillars of Creation, as the towers of gas and dust have been dubbed, resemble stalagmites rising from a cave floor. The tips of the pillars nurture embryonic stars, but the image shows that ultraviolet light from full-grown neighbors is boiling away gas and depriving the embryonic stars of the material needed to grow heavier (*SN: 11/4/95, p. 294*). The picture was released in 1995, just two years after astronauts corrected Hubble's notorious optical flaw. Featured on magazine covers and postage stamps, "the image became attached to the larger story—the recovery of Hubble and the dreams that had originally accompanied its launch," notes Jeff Hester of Arizona State University in Tempe, whose team asked NASA to take the image.



MONSTER FIND Hubble found the first convincing proof of a supermassive black hole in 1994. Analysis of speeds of ionized gas in a disk at galaxy M87's center (shown) indicated that a black hole about 3 billion times the sun's mass must lie at the galaxy's core (*SN: 6/4/94, p. 356*). Hubble has since found supermassive black holes in more than 50 galaxies, and scientists think these monsters may greatly influence galaxy evolution (*SN: 1/22/05, p. 56*).

GOING DEEP After staring at a tiny patch of sky for 10 days in 1995, Hubble generated this landmark portrait—the deepest visible-light image that had ever been taken (*SN: 1/20/96, p. 36*). Some of the faint galaxies reside 12 billion light-years away. Since then, Hubble instruments have gone deeper, culminating in an infrared image recorded last summer that shows galaxies believed to reside some 13.2 billion light-years from Earth (*SN: 1/30/10, p. 5*).

DISTANCE LADDERS A portrait of the galaxy M100 was among the first images NASA released after Hubble's 1993 repair. The image enabled the study of individual stars in the galaxy, including Cepheid variables, which serve as cosmic mile markers. Soon after, scientists used Cepheids to measure the Hubble constant—an indicator of the expansion velocity and age of the universe—to unprecedented accuracy (*SN: 1/22/94, p. 52), (SN: 10/8/94, p. 232*).

ARTISTIC OUTBURST Some explosions are prettier than others. Beginning in 2002, the erupting star V838 Monocerotis (white star among red at center) became one of the most puzzling—and riveting—objects in the Milky Way. As shown in this image from 2004, the outburst has illuminated an array of never-before-seen dust eddies, shells and spirals reminiscent of the whirling patterns of Vincent van Gogh's *Starry Night* (*SN: 10/14/06, p. 248*). The nature of the eruption remains a puzzle: Instead of hurling its outer layers into space, the star swelled to a diameter as large as the distance between the sun and Saturn.

BUILDING WITH LIGHT Harsh ultraviolet light from the youngest (blue) stars in the cluster Pismis 24 heats and ionizes the surrounding gas, creating a luminous bubble in the nebula, which resides about 8,000 light-years from Earth. One of the bright young stars (white) at the center of this 2006 image was thought to be among the most massive stars known. But Hubble observations revealed that the heavyweight was actually two stars, each tipping the scales at a hefty (but not record-breaking) 100 times the mass of the sun.

CRASH OF '94 For six days in July 1994, Hubble watched as more than 20 chunks of Comet Shoemaker-Levy 9 plowed into Jupiter (*SN: 7/23/94, p. 55*). Soon after the first collision, Heidi Hammel, now at the Space Science Institute in Boulder, Colo., raced into the auditorium at Hubble's headquarters in Baltimore waving an image of a fresh bruise on Jupiter (black mark, above) in one hand and a bottle of champagne in the other. After taking a swig, the comet's codiscoverer Eugene Shoemaker declared: "It's not a once in a lifetime event; it's once in a millennium." The moment revealed that pictures taken close to home can be just as captivating as those from remote regions of the cosmos.

Explore more

- For more Hubble images, visit hubblesite.org/gallery
- E.J. Weiler. *Hubble: A Journey Through Space and Time.* Abrams Books, 2010.

Keeping Time

New findings show how circadian clocks make the body tick

By Tina Hesman Saey

Timing is everything. Just ask a comedian, trapeze artist, Romeo and Juliet — or nearly any cell in your body.

Ticking away inside almost all cells are tiny clocks composed of protein gears. Scientists have known that these molecular clocks govern the daily rhythms of life, from mealtimes and bedtimes to the rise and fall of hormone levels, body temperature and blood pressure. New research shows that circadian clocks, as the daily timekeepers are known, do more than just control day-to-day schedules.

Such clocks, some scientists say, have the potential to play a role in nearly every biological function. Studies of bacteria, rodents and fruit flies suggest that circadian clocks may time processes as diverse as cellular division and aging. "When you start asking, 'what does the clock control?' you have to say, 'everything,'" says Erik Herzog, a biologist at Washington University in St. Louis.

Some of the new insights come from studying the brain's master clock, a pair of structures known as the suprachiasmatic nucleus, or SCN, that set the body's daily rhythms. Other work, meanwhile, suggests that the SCN is not a single monolithic clock but more a set of interrelated nodes that help coordinate clocks throughout the body. And still other researchers have found that the SCN may not even be the ultimate arbiter of the body's time, and that other organs control biological rhythms on their own without much, if any, help from the SCN.

The master's orders

For decades, the SCN reigned supreme in scientists' understanding of circadian clocks. A total of only 20,000 neurons populate the structures — one on each side of the brain — but that meager number of brain cells is enough to set the daily rhythms for the entire body. It's as if the residents of a small town in New England determined the schedule of every person on Earth, and then some.

"I think of the SCN as the atomic clock in this network of ATMs," Herzog says. Each body cell has its own clock, just as individual cash machines do. And periodically those peripheral clocks check in with a central timekeeper to stay synchronized.

The rhythm of the SCN is set mainly by light, as special cells in the retina relay a message to the brain when they sense daylight. The light cues affect the gears of the molecular clock inside the SCN's neurons, which then somehow control the cells' firing rates — the frequency at which neurons zip off electrical messages to other brain cells.

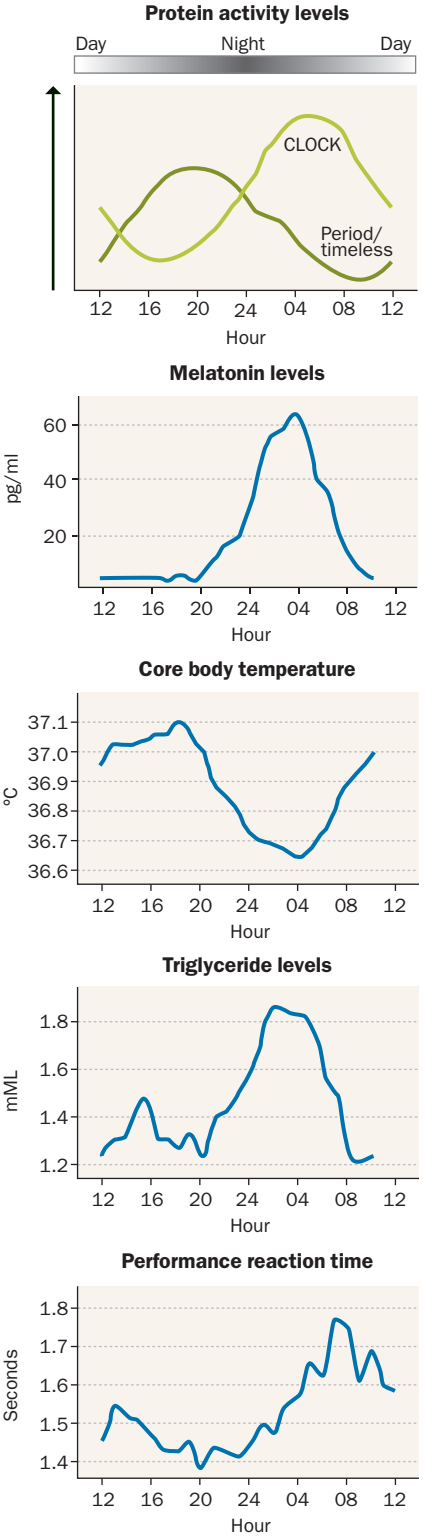
"We know that the clock is there [in the brain]. We've known about different firing rates. We've learned a lot about the genes that control clock activity, but none of that tells us how the clock actually controls anything," says Charles Bourque, a neuroscientist at McGill University in Montreal.

To help tackle that question, Bourque's team has deciphered some of the chemical messages the SCN uses to regulate a circadian rhythm that keeps the body from dehydrating during sleep.

One of the body's main defenses against dehydration is a hormone called vasopressin, which signals the kidneys to retain water. Scientists have known for years that the hormone is released toward the end of the sleep period by neurons in the supraoptic nucleus, clusters of cells in the hypothalamus just a few millimeters from the SCN. And researchers had also worked out that when a person or animal is awake, neurons in another nearby structure known as the organum vasculosum lamina terminalis, or OVLT, sense the loss of water and signal the release of vasopressin, and induce thirst. But no one knew how the brain clock scheduled the release of vasopressin during sleep.

It turns out that SCN cells use vasopressin to help regulate the hormone's own release during sleep, Bourque and McGill colleague Eric Trudel discovered. The researchers removed a thin slice from a rat's hypothalamus that contained the SCN, the supraoptic nucleus and the OVLT all together. The team recorded and manipulated electrical activity in the brain regions, and found that when firing rates of clock neurons

The daily grind Many biological measures fluctuate on a daily cycle, driven mainly by differences in light. Changing levels of activity in protein gears such as CLOCK and period (top chart) help set the body's other rhythms (bottom charts) including hormone levels.



SOURCE: S. RAJARATNAM AND J. ARENDT/*LANCET* 2001

FACING PAGE: CHUWY/ISTOCKPHOTO, ILLUSTRATION BY T. DUBÉ

were high, communication between the OVLT and the supraoptic nucleus weakened. Conversely, as clock neurons quieted down — as they do at the end of the sleep period — communication between the other two brain regions strengthened.

The researchers concluded that some brain chemical released from the SCN was stifling communication between the other two neuron clusters for most of the time when the rat was asleep. Eliminating other candidate chemicals suggested that it must be vasopressin working with some other yet-to-be-identified substance, the team reported online February 28 in *Nature Neuroscience*. Vasopressin is made by about a third of SCN neurons.

In addition to vasopressin, scientists have been on the trail of mysterious substances secreted by the master clock for some time now. When researchers transplant the SCN from a rat with a working clock to another whose clock has been disabled, the new clock can set circadian rhythms, even though it isn't physically connected to the animal's original pacemaker. That tells scientists that the SCN must be giving off some synchronizing substance that diffuses out and regulates other brain circuits, says neuroscientist Rae Silver of Columbia University and Barnard College in New York City.

No one has tracked down that substance yet, although researchers at the University of Illinois at Urbana-Champaign may be getting close. The master clocks in rats' brains make at least 102 different peptides — short proteins or pieces of proteins — the Illinois researchers say in the February *Molecular & Cellular Proteomics*. Those include 33 newly identified peptides and 12 others that are modified in different ways after being made, all of which are potential candidates for the clock-synchronizing substance.

Cooperative control

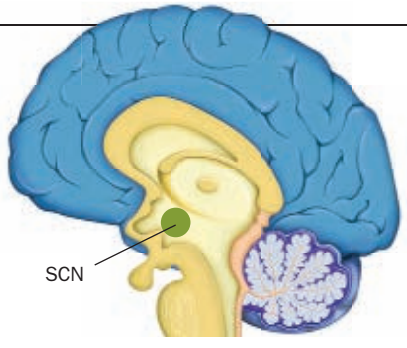
Perhaps finding the master regulator that the SCN uses to synchronize other clocks isn't so easy because it isn't one clock. Herzog and his colleagues have discovered that no clock neuron is an island. Alone, each clock neuron has about a 25 percent chance of maintaining a circadian rhythm for several days, the researchers reported September 22 in the *Proceedings of the National Academy of Sciences*. But when the cells work together, they stay reliably on beat. The result indicates that within the master clock, there is no class of master pacemakers. Instead, all cells cooperate to generate a precise daily rhythm.

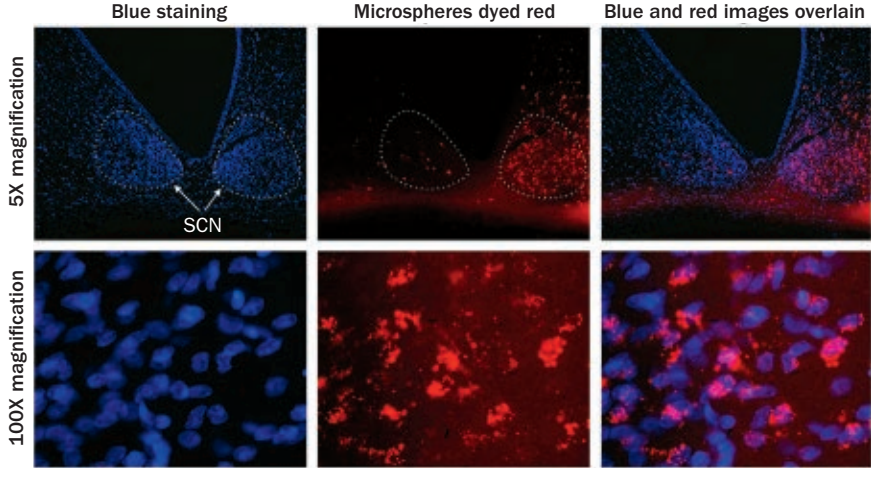
Scientists have also recently discovered that the SCN is actually a clock confederation with several different clusters, or nodes. The nodes form a relay team, passing electrical activity from one to another. "One node fires, then the second, third and so on, and then the whole thing is quiet for a few minutes," Silver says. Having independent nodes instead of one monolithic clock may make the brain clock more robust and allow it to adjust more quickly to environmental changes, Silver and her Columbia University colleague Matthew Butler argue in the October *Journal of Biological Rhythms*.

Still other research has found that different groups of neurons contained within the SCN behave surprisingly differently from each other. For instance, some cells within the master clock of mice (and presumably other mammals, including humans) make period 1, one of the core period proteins of molecular clocks found inside cells. Levels of the protein peak during the day and are low at night. Firing patterns of SCN neurons do the same thing, so researchers thought that levels of period 1 set the brain cells' firing patterns.

But neurons that produce period 1 don't behave as expected. Hugh Piggins and Mino Belle of the University of Manchester in England and colleagues measured electrical activity in master clock cells from a mouse brain, comparing cells that make period 1 with cells that don't. The researchers found that cells without period 1 followed a firing pattern that peaked during the day and fell at night.

But cells that make the protein fired at a moderate rate in the morning, then became so overexcited in the afternoon that they could no longer fire an electri-





The master clock For many animals, the cycles of daily rhythms are set primarily by the suprachiasmatic nucleus, or SCN, a pair of structures nestled deep within the brain (right). In the series of images shown below, researchers injected microspheres labeled with red dye into the neighboring supraoptic nucleus and watched them migrate to the SCN, indicating that the two structures are connected in some fashion.

BRAIN: BSIP/PHOTO RESEARCHERS, INC; IMAGES: E. TRUDEL, C. BOURQUE

Different animals, different clocks

Grandfather clocks and wristwatches are both clocks even though they work a little differently. So, too, the circadian clocks inside fly, mammalian and bacterial cells have similar purposes despite using slightly different gears: proteins with names like CLOCK, period and cryptochrome.

	Fruit flies	Mammals	Cyanobacteria
Core components	*Drosophila melanogaster*, the insect in which circadian clock genes were first identified, has two protein gears named CLOCK and cycle that turn on gene activity. The proteins period and timeless shut down CLOCK's activity.	The circadian clock in humans, mice and other mammals also contains CLOCK. Unlike in flies, in mammals it pairs with the protein BMAL1 to turn on genes. Period teams with cryptochrome to stop CLOCK.	Unlike mammals and flies, cyanobacteria have three proteins, named KaiA, KaiB and KaiC, in their core clocks.
Light sensing	In flies, the protein cryptochrome absorbs blue light and activates period and timeless.	Cryptochrome doesn't respond to light in mammals. Instead, melanopsin cells in the retina sense light and signal the suprachiasmatic nucleus in the brain. The SCN then synchronizes other clocks in the body.	Some unidentified protein senses light and passes the information to KaiA through other proteins called CikA, LdpA and Pex.
Master clock	Although flies don't have an SCN, separate clusters of neurons in the brain control either morning or evening activity. The cells are triggered by light, and sometimes by temperature if the flies are kept in either constant light or constant darkness.	The SCN is a powerful master that helps keeps other clocks running on light-triggered time. But feeding, temperature and other cues may set clocks in other organs that conflict with the SCN.	Cyanobacteria with a functioning circadian clock have been found to have an advantage over cyanobacteria with broken clocks in environments with alternating cycles of light and darkness.

cal signal, before recovering again about dusk, the team reported last October in *Science* (*SN Online: 10/8/09*). That prolonged period of overexcitation would normally allow a toxic buildup of calcium, killing most cells, but the period 1 neurons go through this near-death experience every day seemingly unscathed. The researchers don't know why the neurons survive, nor how period 1 and the turning of other molecular gears trigger the firing pattern.

Beyond the brain

While many researchers continue to probe the mysteries of the brain clock, others think it gets too much credit for controlling circadian rhythms in the rest of the body. The liver, for instance, has a clock that works just fine without much input from the SCN, says Satchidananda Panda, a geneticist and biologist at the Salk Institute for Biological Studies in La Jolla, Calif.

Nearly 5,000 genes in the mouse liver follow a circadian cycle that corresponds to mealtimes, Panda and his colleagues reported in the Dec. 15 *Proceedings of the National Academy of Sciences*. Of those genes, only nine maintained the same cadence regardless of feeding or fasting, indicating that those genes are probably controlled by signals from the brain clock. Another 368 of those 5,000 genes continued to follow a circadian rhythm when mice fasted, a sign that those genes are controlled by the molecular clocks inside liver cells. But the rhythms of the vast majority of genes active in the liver are governed by eating alone, Panda says.

These results could have implications for health, he says. Many scientists think that one role for circadian clocks is to separate biological processes, such as digesting food and replicating DNA; multitasking such activities at the same time could lead to DNA damage.

Mice usually eat about 65 percent of their calories at night, when the rodents are normally active, and consume the remaining 35 percent in "midnight snacks" throughout the day. "Mice eat a little bit like modern humans," Panda says. "They have a big dinner, take a nap, eat a little bit more."

Panda's team compared circadian rhythms of those mice with mice that ate the same amount but got access to food for only eight hours a day, fasting the rest of the time. Fasting led to higher peaks and lower troughs in the cyclic waves of activity levels of more than 3,000 genes, the researchers found — including genes known to encode clock proteins.

Having a more crisply defined circadian rhythm could help improve the efficiency of metabolism, Panda says. For instance, mice that can eat any time they want burn some of the sugar in their food and store the rest as fat. In contrast, mice on a restricted feeding schedule burn sugar intensely, but then switch to burning fat while fasting and rapidly return to burning sugar after eating. Without fasting, mice never really get a chance to burn fat. The genes that control those processes are among those whose rhythms follow a circadian pattern set by feeding.

"All of this boils down to that you need fasting," Panda says. He and his colleagues are doing experiments in mice to determine whether sharpening circadian rhythms, by restricting feeding to certain times of day, will have beneficial

effects on health over the long-term.

New data from studies of fruit flies also suggest that robust circadian rhythms are one key to a long and healthy life.

Many scientists assume that circadian clocks would give organisms an evolutionary advantage. "Organisms need a mechanism to predict changes in the environment before they occur," says Michael Nitabach, a physiologist and geneticist at Yale School of Medicine. "Any organism that can predict what's going to happen is going to have a selective advantage over an organism that can't."

> "Organisms need a mechanism to predict changes in the environment before they occur ... to have a selective advantage."
>
> MICHAEL NITABACH

Yet somehow reindeer seem to get along without working clocks, according to a study published March 23 in *Current Biology*. And fruit flies that don't have functioning circadian clocks seem to do just as well when raised in a laboratory as flies with fully functioning clocks, says Natraj Krishnan, a physiologist at Oregon State University in Corvallis. But in the wild, flies may encounter stresses that could change the game, so Krishnan and his colleagues decided to expose lab flies to a mild stress and see if having a clock made a difference.

The researchers exposed normal flies and flies lacking the clock gene *period* to one day of high oxygen, which can set off harmful chemical reactions that damage DNA and proteins. Neither group of flies was bothered much by oxygen stress if the flies were exposed when young. But middle-aged flies lacking *period* did not fare as well. Compared with normal flies, when exposed at 35 days old the mutant flies had a 20 percent shorter life span. Oxygen-damaged proteins also built up faster in elderly mutant flies than in control flies, the researchers reported in the November *Aging*.

These results indicate that circadian clocks may help control more than just daily rhythms of life, Krishnan says. "I'm pretty sure that anything that messes up the phase of the clock probably affects aging and life span," he says.

So daily clocks might be one of the important things determining when it's "your time." After all, circadian rhythms tend to wind down in elderly people and rodents. Further research may suggest ways to reset the health and aging clock.

And that, in turn, could underscore yet again the most important lesson of circadian clocks: that timing is everything. ■

Explore more

- R. Silver and J. LeSauter. "Circadian and homeostatic factors in arousal." *Annals of the New York Academy of Sciences*. May 2008.

Found! The Last Morgan Silver Dollars

Amazing Discovery Hidden in Midwest Farm Cellar

Indiana. A farmer in America's heartland recently cashed in his long-forgotten savings, hidden away for decades in a dusty crate in his cellar—a hoard of the last Morgan Silver dollars minted by the U.S. Treasury before they ceased production for good, in 1921.

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Silver Trend Chart: Prices based on monthly averages. *©AMS, 2009.*

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ACCREDITED BUSINESS

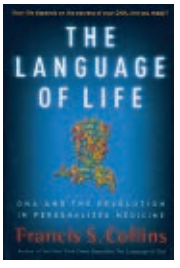
The Language of Life: DNA and the Revolution in Personalized Medicine

Francis S. Collins

As a key leader of the Human Genome Project, Collins brings a unique perspective to the discussion of the promise and perils of genome-based medicine. His latest book presents an accessible and comprehensive assessment of genetic testing and its relevance to health care.

Collins targets the general public. To begin, he gives a rudimentary overview of Genetics 101, then lightly touches on more complex matters such as how the genetic cards a person is dealt play into the overall risk of heart disease, diabetes and what he calls "the big C" — cancer. Collins favors making genetic testing more widely available so people can understand their predisposition to diseases but acknowledges the difficulty for doctors and patients alike in interpreting the level of risk from such a predisposition.

Despite these uncertainties, Collins argues, now is the time to prepare for the future of personalized medicine, which tailors treatment to an individual's genetic makeup. Each chapter includes practical suggestions, such as compiling a family medical history and researching common tests for genetic mutations linked to cancer. Collins also calls on government officials and other decision makers to bring personalized medicine into health policy. Today's one-size-fits-all "standard of care" should start accounting for gene-based differences in how people respond to drugs, he says.

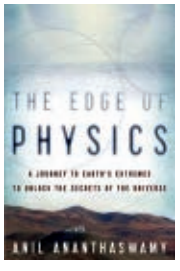


Readers hoping for more advanced discussions of personalized medicine may be disappointed by *The Language of Life*. But those looking for a basic and broad view of the field should be satisfied. Writing with the authority of one who has seen human genomics develop from its infancy, Collins offers a clear and hopeful vision of this field's role in the future of medicine. — *Rachel Zelkowitz*
Harper, 2010, 332 p., $26.99.

The Edge of Physics: A Journey to Earth's Extremes to Unlock the Secrets of the Universe

Anil Ananthaswamy

Astronomers once had the most romantic job in science. Working alone atop a rickety telescope platform, the astronomer was like a sailor in a crow's nest, unspooling the universe's secrets by hand. But with advances in computers and the advent of space telescopes, it has become much easier to decode the cosmos from an air-conditioned office.



In *The Edge of Physics*, Ananthaswamy shows that the really big questions — What is dark matter? Why is the universe's expansion accelerating? Where does mass come from? Are there other universes? — still have a sense of adventure. Part physics primer and part travel epic, the book takes readers to some of the most desolate places on Earth. Ananthaswamy looks for the frontiers of understanding in such unlikely places as an abandoned mine in Minnesota and a frigid lake in Siberia, and from the underground lair of the Large Hadron Collider to the thin-aired peak of Mauna Kea in Hawaii. He finds that retreating from light and noise is sometimes the only way to achieve the level of clarity these questions demand, both clarity of data and clarity of mind.

Ananthaswamy, a science writer and editor, smoothly weaves together the stories of people who help push science forward, from principal investigators to research institute gardeners, with exquisitely clear explanations of the questions they hope to solve — and why some research can be done only at the edge of the world. — *Lisa Grossman*
Houghton Mifflin Harcourt Trade, 2010, 336 p., $25.

65 Short Mysteries You Solve with Math!
Eric Yoder and Natalie Yoder
Math can help solve real-life dilemmas, this collection of puzzles for young adults illustrates. *Science, Naturally! LLC, 2010, 169 p., $9.95.*

Where the Dragon Meets the Angry River: Nature and Power in the People's Republic of China
R. Edward Grumbine
A policy scholar analyzes the impact of China's development on its natural resources. *Island Press, 2010, 240 p., $25.95.*

The Essential Engineer: Why Science Alone Will Not Solve Our Global Problems
Henry Petroski
The approaches of scientists and engineers complement each other, an engineer and historian argues. *Alfred A. Knopf, 2010, 274 p., $26.95.*

Experimental Evolution
Theodore Garland Jr. and Michael Rose, eds.
Scientists can take to the lab and field to explore the mechanisms of evolution. *Univ. of California Press, 2010, 730 p., $45.*

Making Sense of Autistic Spectrum Disorders
James Coplan
A pediatrician reviews treatments for children with these disorders. *Bantam Books, 2010, 448 p., $25.*

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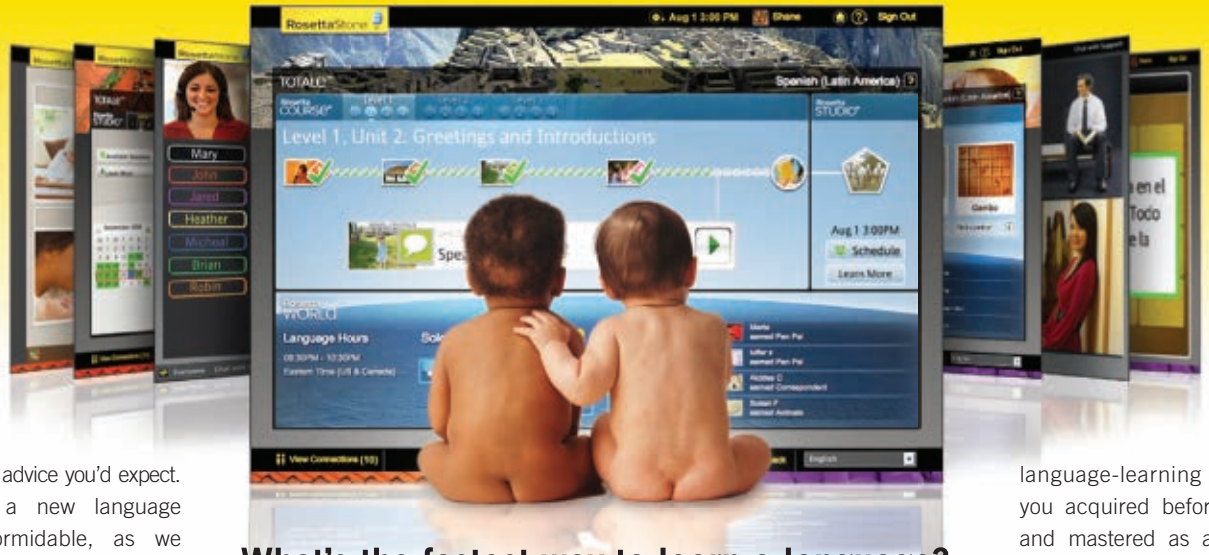

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Hairy Ardi issue

In the report on Ardi ("Evolution's bad girl," *SN: 01/16/10, p. 22*), the artist's illustrations show her in fur. The fact that her purported descendants are relatively hairless has been popularized by Desmond Morris (*The Naked Ape*, 1967) and Elaine Morgan (*The Descent of Woman*, 1972). What is the paleoanthropologists' evidence that Ardi had not yet shed her fur coat and gained the advantage of superior heat loss in tireless pursuit of game?
Walter J. Freeman, Berkeley, Calif.

Hairiness made sense for an early hominid species that lived in forests, had infants that could hang on to mothers with grasping toes, and, despite walking upright, couldn't go anywhere fast in tireless pursuit of anything, says anthropologist and Ardi researcher Owen Lovejoy of Kent State University in Ohio. Long-distance hunting did not emerge as a regular practice until several million years after Ardi's time and played no major role in hominid hair loss, in Lovejoy's view. Significant hair loss probably occurred once Homo sapiens *developed cultural means for controlling body temperature, such as clothing and water containers, he contends. — Bruce Bower*

Midwestern cool-down

The article "Irrigation could be cooling Midwest" (*SN: 2/13/10, p. 15*) says that the average global temperature rose 0.74 degrees Celsius during the past century and then shows the number of 90 degree-plus [Fahrenheit] days for the past 80 years. Why the difference in time scales? What was the temperature for the past 80 years?
Richard A. Kroc, Batavia, Ill.

The graph of 90 degree-plus days that you refer to shows data only from Chicago. Northern Illinois University scientist David Changnon's research focused on meteorological data gathered between 1930 and 2009, because the longest set of weather data from a site in the Chicago area comes from a weather station at Midway International Airport, where meteorologists first began collecting data in 1928. For the 80-year period that Changnon studied, global average temperature increased by about 0.65 degrees Celsius, according to data compiled by NASA's Goddard Institute for Space Studies in New York City.

Information on the temperature rise for the last century was provided in the article solely for the purpose of general context. That figure comes from data compiled by the Intergovernmental Panel on Climate Change. — Sid Perkins

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

Lee Rainie

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How the Internet will change the world—even more

Recently, 895 Web experts and users were asked by the Pew Research Center and the Imagining the Internet Center at Elon University in North Carolina to assess predictions about technology and its effects on society in the year 2020. Lee Rainie, director of the Pew Internet & American Life Project in Washington, D.C., discussed the survey's findings with Science News *contributing correspondent Susan Gaidos.*

This is your fourth "Future of the Internet" survey. Are there any themes that have come through all of the surveys?
There's a broad feeling among technologists that technology itself is going to improve, come what may. That computing power, bandwidth, storage capacity, even our ability to pack pixels into screens, is going to keep improving.

At the same time, there is worry that humans and their institutions will not adapt as well as they might under these circumstances. We're slow to adjust, and the technologies themselves are introducing so many new elements to life that people will potentially have a hard time adjusting to that. There's a sense that people are marching not necessarily blindly, but certainly without full knowledge, into a future that they don't fully know. They're thrilled with their gadgets but they don't know what their gadgets are doing to them.

In this era of social media, how will privacy and anonymity be maintained?
Anonymity will be harder to maintain. There are too many threats that are posed by people being allowed to do anything they want without any level of accountability or authentication. There will still be chances for anonymous encounters, but they will be in special environments in special ways.

We're in an environment now where lots of personal sharing is going on. The experts anticipate that a new sensibility would emerge called "reputation management." There will be tools that allow people to erase all the goofy things that they did in college, if they want to. People will be able to essentially crowd out bad information about themselves by getting better information out there and making it more prominent, more linked to or more easily findable.

The majority of experts agreed that by 2020, people's use of the Internet will enhance human intelligence. How so?
The Web is shifting the needs that we have in our lives and the functions that we can perform, so there will be some cognitive shifting that goes on. We don't have to remember as much stuff, for example, so there might be a shift in cognitive abilities over time from less memorization and storage. New literacies will be required such as screen literacy. Reading, writing, arithmetic and retrieval will become key, as people who can find [information] fastest and make sense of it will be at a marked advantage over those who struggle to find information and have less capacity to synthesize and organize this wealth of data that we have.

There's a sense that people are marching not necessarily blindly, but certainly without full knowledge, into a future that they don't fully know.

In what other realms of life did people anticipate improvements?
There's almost a uniform feeling that health care will get better. Mobile technology and wearable devices will be able to give real-time feedback about people's health status. That will potentially be a life-changing event for the chronically ill or for people who have to manage their care in a deliberate way. That the capacity to interact with a doctor—either through devices or through communications that don't involve office visits—will improve interactions and empower people in important new ways to be managers of their own health care.

The education story is a different one. There's hope that education will change, but some despair that it's not changing fast enough. Kids are still being taught largely in the same format and environment that their great-grandparents were—with students of the same age sitting in a classroom riveted on the all-knowing teacher. Technologists think that that model will break down at some point and a very different set of activities will define formal education. It won't necessarily be people of the same age, they won't necessarily be in the same place. What will organize them is their proficiency in a subject and their interest in a subject.

There's also hope invested in e-government and civic activity. People have new ways to engage with each other and their leaders about social activity, and to engage with the governmental agencies that are entrusted to act in those areas. The technology community has high hopes that these tools will be deployed in more interesting and exciting new ways so that we'll see more government data and will be able to make smarter policies because of that. ■

COURTESY OF L. RAINIE

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