SCIENCE NEWS

THE WEEKLY NEWSMAGAZINE OF SCIENCE

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do-it-itself devices

cottonseed detox

older female chimps desired

double threat to coral

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patterns of motion

THE MATH OF SWARMS

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Cover Many animals, such as these anchovies, move in concert. By combining experiments and computer simulations, researchers are elucidating the principles that underlie swarming behaviors. (Photodisc) Page 347

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Toxin Buster

New technique makes cottonseeds edible

Scientists have engineered cotton plants to produce seeds that are missing a poisonous compound that had previously rendered them inedible. With the amount of crop currently planted, such modified cottonseeds could fill the daily protein needs of about 500 million people, the researchers say.

For every kilogram of fiber, commercial cotton plants produce about 1.65 kg of seeds. Though these seeds contain much high-quality protein, "right now, that's being wasted," says plant geneticist Keerti Rathore of Texas A&M University in College Station.

Like other parts of the cotton plant, cottonseeds harbor the compound gossypol, which is toxic to people and many other animals. Seed processors remove gossypol from cottonseed oil. However, the toxic compound is difficult to extract from the solid parts of the seed, which contain potentially useful protein.

In the 1960s, researchers discovered mutant cotton plants that didn't produce gossypol. But since the compound protects plants from insects, the plants were vulnerable to infestations and ended up a commercial failure.

Now, Rathore and his colleagues have used a technique called RNA interference (*SN: 7/2/05, p. 7*) to eliminate gossypol only in cottonseeds. The team worked with a gene that encodes a small piece of RNA that matches another RNA piece required for making gossypol. The researchers predicted that the two RNA strands would fuse, beginning a complex cellular process that prevents cells from producing the toxin.

The team inserted this RNA-making gene next to a piece of cotton-plant DNA that activates genes only in seeds, so gossypol production would continue elsewhere in the plants.

When the scientists grew the engineered plants, they looked for the dark-colored gossypol glands typically present throughout normal cotton plants. The engineered plants had these glands everywhere except in their seeds. Chemical tests showed that the new seeds had only 2 percent as much gossypol as normal cottonseeds do. This reduced amount is considered safe by the U.S. Food and Drug Administration.

The scientists report their finding in the Nov. 28 *Proceedings of the National Academy of Sciences*.

Rathore says that nobody on the team has yet eaten any of the seeds. "Our seeds are extremely precious, and we didn't want to waste any until we produced enough. When we bulk up our seed stocks, I'll be the first person to try [eating] them," he says.

Andrew Jordan, who is vice president of technical services for the Memphis, Tenn.–based National Cotton Council, calls the team's accomplishment "potentially very important."

Developing cottonseeds that don't contain gossypol is "a topic that we've established as a research priority. It looks like this group has finally found a genetic solution to address this industry problem," he says.

PNAS

SPOT THE TOXIN **Gossypol-secreting glands form dark spots in seeds from normal cotton plants (top). Seeds from engineered plants (bottom) are missing the dark spots and the toxic compound.**

Jordan notes that since cotton is frequently grown in developing countries, where dietary protein can be scarce, the new seeds could offer "an important protein source for many, many people." —C. BROWNLEE

Fighting Styles

Gene gives flies his, her conflict moves

A female fruit fly fights like a guy and a male fly fights like a girl after researchers switch forms of one gene, according to fly-fight specialists.

That gene, *fruitless*, is the same one that scientists had found to control roles in fruit fly courtship, says Edward A. Kravitz of Harvard Medical School in Boston. Switching between two forms of the gene can create same-sex flirtations in the insect. In the new work, that same genetic alteration swaps sex-determined styles of aggression, Kravitz and his colleagues report in an upcoming *Nature Neuroscience*.

Only in the past decade have fruit flies emerged as a model animal for studying aggression. In the well-fed, plush life in laboratories, fruit flies rarely fight. So, Kravitz and his team had to invent ways to provoke conflicts.

They've found that a tiny dab of mouth-watering yeast paste incites male flies to strike threatening wing poses at each other and then come to blows. At times, males actually box, rising upright and pummeling each other with their forelegs. They also lunge at each other, striking the top of an opponent's body with their legs. Slow-motion video shows that such a blow temporarily flattens the bottom fly, which splays out his legs, Kravitz reports.

Females confronted with the same small treat typically don't box or lunge. Instead, they butt heads and shove each other with their forelegs.

Coauthor Barry Dickson of the Research Institute of Molecular Pathology in Vienna and his colleagues genetically engineered female flies to express the *fruitless* gene in a small percentage of their brain cells, as males normally do. Normal females don't produce any of the proteins encoded by *fruitless*. The researchers also created male flies that don't make the proteins.

The altered female flies lunged like males, regardless of the sex of the fly they fought. The altered males displayed feminine head butts and shoves, the researchers report.

The altered males also failed to form the normal dominance hierarchy. That is, after a normal male wins a bout, its odds of winning increase in its next match, even against another opponent. In contrast, losers tend to keep losing. This effect doesn't appear in normal females and didn't show up in altered males.

There's no human version of the *fruitless* gene, says Kravitz. However, understanding fighting behavior among invertebrates will inspire new questions about aggression in other species, he predicts.

The new work is "really wonderful," says Hadley W. Horch of Bowdoin College in Brunswick, Maine, who is studying cricket fights.

Hans Hofmann of the University of Texas at Austin, who has studied cricket fights, says that in many animals, aggres-

sive behaviors differ between the sexes. Kravitz' study is among the first to apply modern genetic tools to these distinctions, Hofmann notes. —S. MILIUS

Cosmic Pops

Nearby galaxy is hotbed of supernova formation

Talk about an explosive personality. Large galaxies usually have no more than three supernovas blow up in a century, but the nearby galaxy NGC 1316 has had two such explosions within the past 5 months and four in the past 26 years.

Amateur astronomer Berto Monard of Pretoria, South Africa, found both of the new supernovas. He reported the latest find in a Nov. 6 electronic telegram of the International Astronomical Union. After that announcement, Stefan Immler of NASA's Goddard Space Flight Center in Greenbelt, Md., and his colleagues used NASA's Swift satellite to view the two most recent stellar explosions. They unveiled their image Nov. 20. The team confirmed that like the earlier two NGC 1316 supernovas, the most recent ones belong to the class called type 1a.

While some researchers are puzzling over the supernova surplus, others propose a simple explanation. Supernovas of type 1a arise after a star that's less than eight times the mass of the sun becomes a compact star called a white dwarf. If the dwarf siphons enough mass from a companion star, the accumulated material triggers a thermonuclear explosion, blowing the dwarf to bits. Astronomers have used type 1a supernovas to infer the presence of dark energy, a mysterious substance that has revved up the rate of expansion of the universe (*SN: 11/18/06, p. 323*).

Hubble Space Telescope images have shown that NGC 1316, an elliptical galaxy lying 80 million light-years from Earth, has swallowed spiral galaxies, smashing together gas clouds and generating new massive stars. Several such mergers happened about 3 billion years ago, and there was a less powerful one a few hundred million years ago.

"Clearly, the high supernova-production rate must be related to this recent merger of the two galaxies," notes Immler. Other astronomers agree.

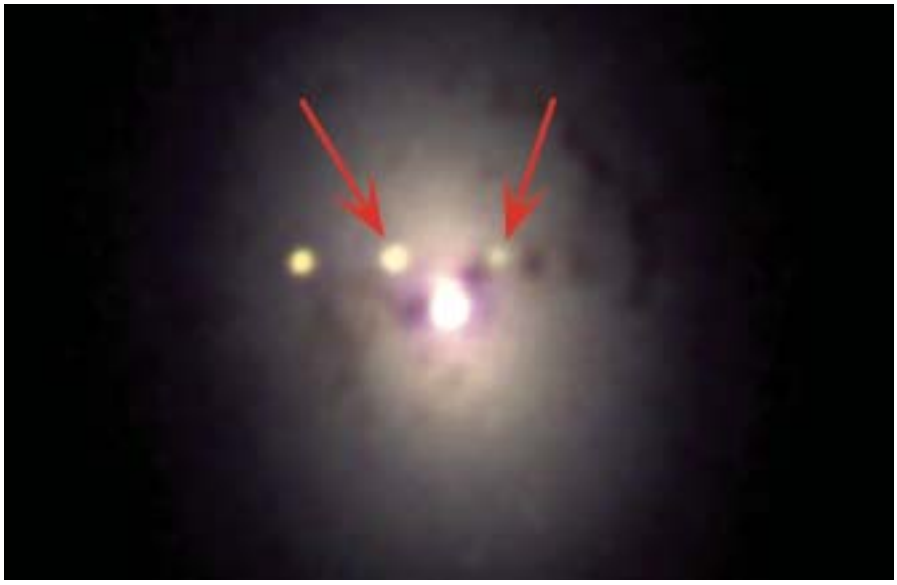
However, Immler says, there's a mystery because many stars take several billion years to become white dwarfs and then explode as type 1a supernovas.

Astrophysicist Mark Sullivan of the University of Toronto counters that recent studies by his team and others have shown that some type 1a supernovas take less than half a billion years to form. He suggests that a galactic collision could create massive stars, which take a shorter time than less-massive stars to become white dwarfs, hastening their explosion as 1a supernovas.

A collision of galaxies might also create shock waves that speed the rate at which white dwarfs steal material from a companion, suggests Mario Livio of the Space Telescope Science Institute in Baltimore.

After learning about the new supernovas, Immler encouraged researchers to reexamine other elliptical galaxies that have undergone recent mergers. Those scientists found a surplus of type 1a supernovas too.

"We are trying to figure out what is going on," Immler says. —R. COWEN



IMMLER, SWIFT, NASA

SUPER GALAXY Nearby galaxy NGC 1316 recently played host to two supernovas. The explosion dubbed SN 2006mr (left arrow) was detected on Nov. 5, and SN 2006dd (right arrow) was discovered on June 19. The bright spot in the center is the galaxy's core, and the spot to the far left is a foreground star.

Kidney Progress

Drug slows cyst growth

An experimental drug called roscovitine may inhibit a degenerative kidney disease that so far has defied cure, a study in mice shows.

Combined with promising results from animal studies on other potential drugs, the new finding brightens the outlook for people with the inherited condition called polycystic kidney disease (PKD). The disease, whose symptoms often don't arise until adulthood, usually causes back pain, high blood pressure, urinary tract infections, and, ultimately, kidney failure. Other than a complete-kidney transplant, available treatments address only the disease's symptoms.

People with PKD have a mutation in one of two genes that encode proteins called polycystins. These proteins are necessary for the proper functioning of organelles called cilia that protrude from kidney cells. One hypothesis holds that cilia sense the flow and composition of fluids in the kidneys. The cilia rely on polycystins to relay this information into a cell and regulate its development and growth.

In the absence of polycystins, cilia function goes awry. Without a growth regulator, enzymes called kinases become overactive and cause the kidney cells to proliferate abnormally and to secrete fluids when they should be absorbing them, says study coauthor Oxana Ibraghimov-Beskrovnaya, a cell biologist at Genzyme Corp. in Framingham, Mass. The resulting cysts, as they accumulate, sabotage the kidneys' ability to remove impurities from the blood.

Roscovitine inhibits some of the kinases that play a role in PKD. Researchers injected the drug or an inert substance into mice that had been genetically engineered to develop kidney cysts. After several weeks, the roscovitine-treated animals' kidneys weighed less and were smaller than those in the untreated mice.

That suggests the drug shrank the animals' cysts, says Ibraghimov-Beskrovnaya. The kidneys in the treated mice also filtered blood more effectively than kidneys in the control mice did, the researchers report online for an upcoming *Nature*.

While roscovitine shows promise, it won't be tested in people with PKD for at least a year, says study coauthor Katherine W. Klinger, a geneticist at Genzyme.

Meanwhile, several other drugs, including rapamycin, octreotide, and tolvaptan, that succeeded in animal tests for PKD are now being tested in people.

"The speed of discovery in the field is better than it's ever been," says nephrologist Vicente E. Torres of the Mayo Clinic in Rochester, Minn., whose team has investigated tolvaptan.

"These drugs act at different points along a chain of abnormalities that we believe occurs in PKD," he says. "The more drugs we have at different steps, the better, [because] they create opportunities in the future for using combinations." —N. SEPPA

STATS

500,000

People in the United States with polycystic kidney disease

Super Silicon

Top semiconductor turns into a superconductor

While not yet leaping over tall buildings in a single bound, silicon is doing something pretty super these days—conducting electricity with zero resistance.

The material achieved that triumph when physicists in France crammed unprecedented numbers of boron atoms into a silicon wafer's surface. When cooled to less than 0.4 kelvin, the boron-laden silicon permitted electrons to flow unimpeded, the scientists report in the Nov. 23 *Nature*.

As the stuff of microchips, "silicon has become the technologically most important material of the past 50 years," notes superconductivity researcher Robert J. Cava of Princeton University in a commentary in the same journal issue. Silicon's characteristics as a semiconductor—a substance with electrical properties midway between those of a conductor and an insulator—make it the dominant material of microelectronics.

In experiments in the 1980s, other teams fleetingly made silicon a superconductor when they squeezed it to about 100,000 times atmospheric pressure.

Cava calls the new, more lasting superconductor a "breakthrough." He adds, however, that "it's too early to tell [whether it's] a herald of more and better devices and materials."

Indeed, making silicon so profoundly cold would be commercially impractical, admits Étienne Bustarret of the National Center for Scientific Research in Grenoble, a member of the research team. However, he adds, it's possible that further modifications could boost the superconducting temperature.

"This discovery suggests a possibility of producing new ... devices," particularly if researchers could make a second silicon superconductor with phosphorus, comments Yoshihiko Takano of the National Institute for Materials Science in Tsukuba, Japan. The boron- and phosphorus-infused superconductors could be combined to form electronic components, he says.

To make commercial transistors, manufacturers put atoms of boron, phosphorus, or other elements into silicon. Bustarret and his colleagues injected millions of times greater concentrations of boron into 10 spots on a silicon wafer.

To do so, the team put the wafer in a chamber of boron chloride gas and blasted each spot with a powerful ultraviolet laser that emitted 200 bursts, each lasting 25 nanoseconds. Each pulse melted the silicon surface. Ultimately, boron atoms took more than 8 percent of crystal locations normally occupied by silicon atoms.

Besides pursuing a phosphorus version of the silicon superconductor, Bustarret and his team are force-feeding elements to other semiconductors—such as aluminum nitride—that they expect to superconduct at higher temperatures.

"The treatment they meted out to silicon to force its conversion," Cava quips, "can only be termed abusive." —P. WEISS

Age Becomes Her

Male chimpanzees favor old females as mates

In the forests of Uganda's Kibale National Park, male chimpanzees on the make know what they want in a sexual partner—wrinkled skin, ragged ears, irregular bald patches, broken teeth, and elongated nipples. For these guys, nothing beats the sex appeal of an old female chimp.

If that preference makes no sense to the average human male who's entranced by young, smooth-skinned women, it's because the mating game has evolved in different directions in chimps and in people, say anthropologist Martin N. Muller of Boston University and his colleagues.

People usually form long-term sexual partnerships. Men thus tend to look for women's physical signs of youth, which signal childbearing potential for years to come, the researchers hold.

In contrast, adult chimps of both sexes mate with many partners. For male chimps, say the researchers, old females may be particularly alluring because of their demonstrated success at surviving and, in most cases, raising offspring.

If the new findings hold up, "a female's proven ability to mother infants must be a very important factor for chimpanzee males seeking mates," remarks anthropologist William C. McGrew of the University of Cambridge in England. McGrew has studied chimps at Tanzania's Gombe National Park.

Muller and his coworkers observed the Ugandan chimp community of 12 males and 17 females from 1996 until 2003. The team tracked the chimps' copulation and other sexual behavior. During most years, the researchers also recorded attacks, chases, and other aggressive behavior. They report

J.-M. KRIEF

COME HITHER LOOK **In Uganda, male chimps, such as the one on the left, prefer to mate with females older than 30 years, such as the one on the right.**

their findings in the Nov. 21 *Current Biology*.

Male chimps mated substantially more often with females age 30 or older than they did with younger females, the researchers say. Even the oldest female, at roughly 55 years of age, attracted markedly more male interest than did young adult females, ages 15 to 20 years.

Moreover, compared with young females, over-30 females more often attracted groups of males during the females' fertile periods, copulated more frequently with high-ranking males, and were more frequently the objects of fights between males for their sexual favors.

McGrew cautions that pinning down the exact age of wild chimps is difficult.

However, Muller notes that he and earlier researchers have tracked female Kibale chimps since 1983. The ages of females born before that year represent estimates, but age rankings are accurate, in his view.

A male mating preference for older females also characterizes Gombe chimps, comments behavioral ecologist Anne E. Pusey of the University of Minnesota in St. Paul, who directs ongoing research there. "Once Gombe females give birth to infants, they become more attractive to males," Pusey says.

Researchers haven't determined how long wild chimps can survive or whether wild female chimps can bear children throughout their lives, she adds. —B. BOWER

Ticking toward Trouble

Long-term rise in heart rate portends death

Men whose hearts beat faster over time are likely to die earlier than those whose hearts maintain an unchanging cadence year after year, according to a 20-year study of French police officers. But a heart with a slowing rate is likely to keep beating for the longest time.

The newfound relationship suggests that doctors could use trends in the routine vital sign of heart rate to gauge which of their patients are in danger.

Doctors have long associated a racing heart with poor health and risk of death, says Xavier P. Jouven, a Paris-based electrophysiologist and epidemiologist at the Georges Pompidou European Hospital–INSERM. However, no past study has examined changes in heart rate over time, he says.

Jouven and his colleagues studied 4,320 Frenchmen who were serving on the Paris police force when the study began in 1967. Participants began the study at ages 42 to 53. For the first 5 years of the study, each volunteer had a physical exam and other tests annually. Researchers kept track of the men for at least 15 additional years.

As a group, the volunteers were healthy and active at the study's outset, Jouven says.

Some volunteers had modest increases or decreases in their resting heart rates during the 5-year period: One-fifth of the volunteers showed a rate increase of at least seven beats per minute; a similar fraction showed a decrease of that magnitude.

After adjusting for changes in weight, blood pressure, blood-cholesterol concentration, and other relevant factors, the researchers found that the men whose heart rates accelerated the most over the examination period were 47 percent more likely to die during the subsequent 2 decades than were men who experienced moderate or no change. By contrast, men whose hearts slowed the most over the 5-year period were 18 percent less likely to die during the follow-up period than were men in the middle group. Jouven presented his team's findings last week at a meeting in Chicago of the American Heart Association.

A rising heart rate can be "an important clue" in a variety of health problems, including not only cardiovascular disease but also infections, anemia, and worsening pulmonary disease, comments Nieca Goldberg, a cardiologist at Lenox Hill Hospital in New York City. —B. HARDER

WHITE OUT In the Caribbean, the size of the region affected by coral bleaching, such as that seen in this colony, largely depends on the amount of sunlight-blocking particles in the air and whether there's an ocean-warming El Niño in progress.

Balancing Act

El Niños and dust both affect coral bleaching

Most of the variation in the amount of Caribbean coral that turns sickly pale each year is driven by two counteracting forces, a new analysis shows. They are the periodic ocean heating from the climate phenomenon known as El Niño and the occasional cooling action of sunlight-blocking particles high in the atmosphere.

When ocean temperatures rise even slightly, some species of corals shed the brightly colored algae that live within them, a sometimes-reversible change known as coral bleaching (*SN: 8/28/04, p. 142*). If bleaching episodes last weeks or months, coral colonies can die, says Jennifer A. Gill, an ecologist at the University of East Anglia in Norwich, England.

Gill and her colleagues reviewed other scientists' field observations made from 1983 to 2000. Coral bleaching peaked in the Caribbean in five of those years: 1987, 1990, 1995, 1998, and 1999.

El Niños boosted water temperatures in 1987, 1998, and 1999. During an El Niño, sea-surface temperatures in the tropical Pacific are warmer than average. That region isn't directly connected with the Caribbean, but changes in worldwide weather patterns cause waters to warm in the Caribbean as well, says Gill.

Caribbean coral bleaching noted in 1990 and 1995 didn't occur during El Niño years, hinting that another factor was at play. Those years were marked by fewer tiny particles in the atmosphere than in other years. That material, called aerosols, often includes bits of ash that spread worldwide from major volcanic eruptions.

In contrast, even though there was an El Niño in 1991, the cooling effect of Mount Pinatubo's eruption in the Philippines that year prevented extensive coral bleaching, says Gill.

The team concludes that the balance between El Niños and aerosols in the atmosphere accounts for about 70 percent of the year-to-year differences in Caribbean-coral bleaching. The researchers report their findings in an upcoming *Proceedings of the National Academy of Sciences*. The analysis suggests that a 10 percent drop in aerosols results in a 36 percent increase in the area affected by coral bleaching if all other factors are the same.

"If dust declines, reefs are in trouble," says Gill.

El Niños not only raise the water temperature in the Caribbean but also tend to diminish the winds there. That's "a double whammy," says Clive Wilkinson, an ecologist at the Reef and Rainforest Research Centre in Townsville, Australia. Slow winds hold fewer sun-blocking aerosols and carry them shorter distances than strong winds do, he notes. Then, the increased radiation that reaches sea level is readily absorbed by calm water. —S. PERKINS

NOAA

The Operator's Manual for the Universe Is Called Classical Physics

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You know more physics than you think, says Professor Steven Pollock, an award-winning science educator who takes you step by step through the great ideas of classical physics. Dr. Pollock shows that landmark concepts such as Newton's laws of motion are intuitively understood by anyone who has ever ridden a bike, thrown a ball, or simply picked up an object and set it down.

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About Your Professor

Dr. Steven Pollock (Ph.D., Stanford University) is Associate Professor of Physics at the University of Colorado at Boulder. He received the Boulder Faculty Assembly Teaching Excellence Award in 1998. He became a Pew/Carnegie National Teaching Scholar in 2001.

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CHEMICAL POP-UP BOOKS

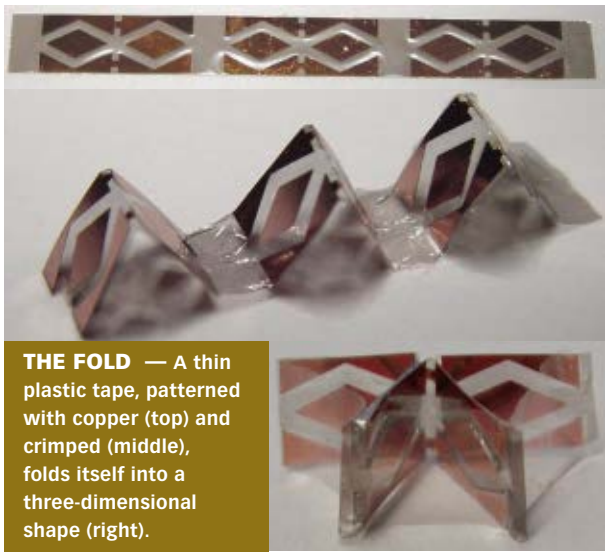
How some devices build themselves

BY AIMEE CUNNINGHAM

Many beasts, buildings, and beauties greet children who open pop-up books: a *Tyrannosaurus rex* with jaws agape, elaborate medieval castles with soaring towers, the Statue of Liberty with her torch held high. These detailed objects take their three-dimensional shape with the turn of a page, arising from intricately folded paper. Today, chemists and engineers are making their own sophisticated versions of pop-up structures. What they lack in whimsy, they may someday gain in practical function.

These objects, which begin as two-dimensional structures, fold themselves into final, functional three-dimensional shapes. Self-folding is one of the methods in a broader category called self-assembly. In that strategy, scientists design structures that build themselves out of specific components, says George M. Whitesides, a chemist and materials scientist at Harvard University. Self-assembly "is a strategy for making complex, multicomponent, three-dimensional things," he says.

Nature is the apotheosis of self-assembly. For example, notes Whitesides, "you and I are self-assembled objects." From our proteins, to our cells, to our bodies, "it all comes together by itself," he says.



THE FOLD — A thin plastic tape, patterned with copper (top) and crimped (middle), folds itself into a three-dimensional shape (right).

BRUZEWICZ

Although there is much that scientists don't yet understand about how nature puts things together, they're putting into practice what they've gleaned so far. Researchers are looking for self-assembly strategies for objects too small to be easily constructed by people or robots. "Instead of having robots pick up a billion pieces, the pieces might be able to find their way to where they go," says Whitesides.

Scientists team self-folding strategies with photolithography, a fabrication method that is "a workhorse in the integrated circuit industry," says chemical engineer L. James Lee of Ohio State University in Columbus. While photolithography can create intricate patterns on a two-dimensional surface by adding or removing thin layers, "it is difficult and expensive to use it to make a three-dimensional structure," says Lee.

By combining self-folding with photolithography, "you are able to transform this two-dimensional technology into three-dimensional technology," says David H. Gracias, an engineer at Johns Hopkins University in Baltimore.

The first crop of self-folded creations might include simple electronic devices, drug-delivery vehicles, and miniature chemistry laboratories.

"It seems worth the effort to take this idea outside of biology to see what problems it could solve," says Whitesides.

TAPE SHAPES Protein self-assembly inspired Whitesides' most recent self-folding project. A protein begins as a chain of amino acids, which then folds into a three-dimensional form. The sequence of and interactions among the amino acids dictate the final shape.

To roughly mimic this example, Whitesides, Derek A. Bruzewicz, and their colleagues at Harvard began with a piece of transparent plastic tape 12 micrometers (μm) thick, 3 millimeters wide, and 50 mm long. The team determined the shape that they wanted the tape to fold into and accordingly patterned one surface of the tape using photolithography. The process placed 100-nanometer–thick diamond shapes made of copper. Each diamond can be thought of as an amino acid along a protein chain, says Bruzewicz.

The researchers crimped the tape between metal combs with zigzag teeth. The face of any zig or zag on the tape included a copper diamond. "The crimping is sort of the suggestion" of how the structure will ultimately self-fold into its final shape, Bruzewicz says.

To hold the crimp, the researchers glued the crimped tape to a flat piece of tape and then dipped the patterned tape into solder, coating the copper diamonds with this metal alloy. Next, they placed the whole structure in water heated to a temperature above the solder's melting point, and then gently jostled the structure.

When the solder on two nearby faces of the crimped tape came in contact, the solder naturally minimized its surface area remaining in contact with the water. This bound the two faces, self-folding a portion of the tape. After a few minutes, the tape had completely folded into its predetermined shape. Out of the water, the solder cooled and solidified, locking the shape in place.

After working with a few simpler geometries, the researchers designed a differently patterned tape that folded into a helix. They also created a self-folding light detector by adding copper wires and photodiodes to the flat tape before gluing it to the crimped tape. Once folded, the device detected light from all sides, the team reported in the July 26 *Journal of the American Chemical Society*.

Although the researchers produced a functional device, they are "still at the level of trying to understand the process," says Whitesides.

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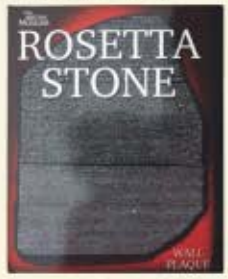

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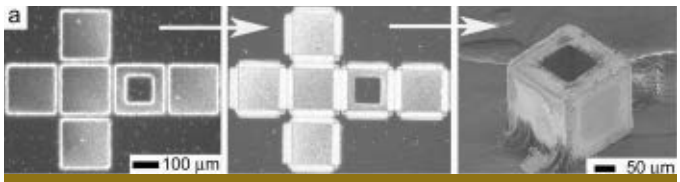
The team plans to shrink the components it uses in future work, notes Bruzewicz. To explore whether the group's folding strategy might work in commercial electronics, "we want to get [the components] well below a millimeter," he says.

BITTY BOXES Gracias and his team at Johns Hopkins have coaxed two-dimensional patterns to fold into cubes and pyramids. The containers might play host to chemical reactions or transplantable cells, the researchers say.

To build the two-dimensional precursor of their containers, the researchers began with an 8-centimeter-diameter silicon wafer as a support. After laying down a "sacrificial layer" of polymer as an adhesive, the researchers deposited a 100-nm-thick layer of copper.



BOXING DAY — A metallic, cross-shaped frame (right) receives solder at the squares' edges (middle), which provides the force to fold the cross into a box.

Making cubes required several steps. First, the researchers used photolithography to pattern onto the metal layer multiple copies of a cross-shaped template of six squares. Each edge of the squares was 200 μm long. Next, the team built up the squares by depositing layers of either nickel or more copper.

Then, the group added solder to serve as hinges along all the edges of each of the squares. The researchers included an opening on some faces and patterned pores a few micrometers in diameter on other faces.

Dissolving the sacrificial layer released the two-dimensional crosses from the silicon wafer. As with the Whitesides group's tapes, heating the crosses past the solder's melting point triggered the cubes' self-folding. As the liquid solder minimized its surface area, it pulled up the squares to form the sides of the cubes, says Gracias. The cooled solder held together the minuscule boxes.

Gracias has several ideas for using the containers. In the December 2005 *Biomedical Microdevices*, he and his colleagues reported that they had loaded breast cancer cells into boxes 200 μm wide. The cells survived for several hours, and by using magnetic-resonance imaging, the researchers could track the boxes as they moved through liquid-filled channels. Although this work is only preliminary, Gracias says, it might lead to containers useful for transplanting cells that release required chemicals, such as insulin for diabetes or dopamine for Parkinson's disease.

In the Sept. 6 *Journal of the American Chemical Society*, the researchers described self-folding cubes and pyramids, having volumes ranging from 0.2 to 8 nanoliters. In this work, the researchers loaded the containers with reagents and performed chemical experiments. For example, they put a chemical that indicates a solution's acidity into a porous cube made of nickel. They then placed the cube in a solution and used a magnet to move the cube around. The indicator reacted with the solution only along the path where the researchers directed the cube.

Conducting chemistry in specific spots by remote control might find use in lab-on-a-chip systems, says Gracias. These systems provide a platform for miniaturized chemical assays that use far smaller quantities of expensive reagents than assays in traditional beakers do. With the self-folding containers, "we can move chemicals wherever we want them to be," Gracias says.

GEL GEOMETRIES Researchers can also make hydrogel—the material in contact lenses—pop into specified three-dimensional shapes. Lee and his group at Ohio State University have designed self-folding, gel-based structures that they're testing as drug-delivery devices.

Hydrogel structures don't rely on solder to fold into shape. Rather, the repulsive forces between charged molecular groups provide the oomph. Hydrogels are polymers, and certain molecular groups attached to their polymer chains repel each other as the acidity of their environment changes. Because the groups are bound to the material, they can't move far apart, but they can force the material to swell, says Lee.

To exploit this force for folding, Lee and his colleagues combined two hydrogel layers: one that swells a great deal and one that doesn't swell. The team first used photolithography to make a two-dimensional array of specifically shaped, miniature wells in a silicon wafer. The researchers then transferred that pattern to a 10-cm-by-10-cm piece of rubber. They poured one hydrogel into the wells of the rubber and solidified the hydrogel to create the first layer. Then, they added a layer of a different hydrogel. After solidifying that layer, the researchers bent the rubber mold to release the structures from the wells.

When the researchers placed those flat structures into solution, one hydrogel layer began to swell, while the other kept its volume in check. Blocked on one side, the swelling layer expanded on the other, which pulled the whole structure into a three-dimensional shape, explains Lee. The researchers described the structures in the Dec. 15, 2005 *Journal of Physical Chemistry B*.

To make drug-delivery devices, the researchers put a thin square of polymer, which contains the drug, at the center of the hydrogel bilayer. When flat, "the bilayer is like a cross, and the drug is in the middle [square]," says Lee. The drug-carrying polymer also contains an adhesive so that the hydrogel structures will stick to the mucus covering the intestinal tissue.

The researchers plan to place several of the structures inside a capsule that would dissolve in the small intestine. The adhesive would ensure that, once they are released from the capsule, the structures land right-side-down on the mucus. The two-dimensional structure would then fold into a three-dimensional device that Lee likens to a closed fist, with the drug on the palm. After the device grabs onto a bit of the small intestine, the drug would diffuse into the tissue.

In the Jan. 10 *Journal of Controlled Release*, Lee's group reported on initial tests of one of the drug-delivery devices on tissue removed from a pig's small intestine. Within a few minutes, the devices landed and then grabbed the tissue. The devices remained in place for 103 minutes, about 30 minutes longer than a flat, mucus-adhering drug patch did.

With the additional time, more of the drug would be absorbed, says Lee. He adds that the team's next step is to test the self-folding devices, with drug or gene cargoes, in animals.

FIXING FOLDS If self-assembly techniques, including self-folding, are to make a commercial impact, researchers will have to figure out a rigorous system of quality control. Some researchers suggest that in the future, computer chips might self-assemble. Whitesides cautions that when producing such complex devices, "you really can't have any missing pieces."

When Gracias makes his chemistry-experiment containers, for example, only 60 to 90 percent of them fold correctly. In his laboratory, a researcher uses a pipette to pick out the properly folded structures. Large-scale production of the containers would require a more efficient way to pull out the good ones. Without such a procedure "we'd have to figure out how to repair the bad ones," says Gracias.

Whitesides says that as researchers learn more, it might become possible to create new kinds of electronics and displays as well as to begin to uncover nature's assembly techniques. Although the strategy is ubiquitous in nature, for scientists, he says, "self-assembly is just at the beginning." ■

GRACIAS

THE MIND OF THE SWARM

Math explains how group behavior is more than the sum of its parts

BY ERICA KLARREICH

Few people can fail to marvel at a flock of birds swooping through the evening sky, homing in with certainty on its chosen resting place. The natural world abounds with other spectacular examples of animals moving in concert: a school of fish making a hairpin turn, an ant colony building giant highways, or locusts marching across the plains.

Since ancient times, scientists and philosophers have pondered how animals coordinate their movements, often in the absence of any leader. Coordinated groups can range in scale from just a few individuals to billions, and they can consist of an intelligent species or one whose members have barely enough brainpower to recognize each other.

Despite these differences, similar patterns of motion appear again and again throughout the animal kingdom. This congruence in behavior has led researchers to speculate for about 70 years that a few simple rules might underpin many sophisticated group motions. However, establishing just what these rules are is no easy matter.

"Imagine a space alien looking at rush hour traffic on the L.A. freeway," says Julia Parrish of the University of Washington in Seattle, who studies fish schooling. "It thinks the cars are organisms and wonders how they're moving in a polarized way without collisions. The reason is that there's a set of rules everyone knows.

"We're the space aliens looking at fish, and we don't have the driver's manual," she says.

In recent years, mathematicians and biologists have started to get glimpses of just what may be in that manual. They have constructed mathematical models of animal swarms and colonies that take inspiration from decades of physics research. In physicists' studies of magnetism, for instance, they have elucidated how simple local interactions give rise to complex, large-scale phenomena. Using a combination of computer simulations and experiments with real animals, researchers are explicating how a trio of physics and engineering principles —nonlinearity, positive feedback, and phase transitions—may be basic ingredients from which a wide variety of animal-swarming behaviors takes shape.

"This is a more and more exciting area in which to work," says Iain Couzin, who studies collective animal behavior at the University of Oxford in England and Princeton University. "We have the mathematical foundations to investigate phenomena quickly and effectively."

ON THE TRAIL — Ants' foraging behavior may obey simple mathematical rules.

ISTOCKPHOTO

POSITIVE FOOD BACK Anyone who has left crumbs on the kitchen counter knows the brutal efficiency with which ants can capitalize on such a mistake. As soon as one ant discovers a tempting morsel, thousands more create and follow a trail between the food source and their nest.

"Ants follow only local rules ... but the resulting trail structure is built on a scale well beyond that of a single ant," said David Sumpter of the University of Oxford in England in an article on animal groups in the January *Philosophical Transactions of the Royal Society B*.

In 2001, using mathematical modeling and lab experiments, Sumpter and two colleagues studied how foraging pharaoh's ants build trails. The researchers turned up a striking group behavior: Just as water abruptly turns to ice at the freezing point, foraging behavior undergoes a "phase transition" at a certain critical colony size.

If an ant colony is small, foragers wander about randomly and, even if some of the ants discover food, no trail persists. If a colony is large, the ants' trails build into a superhighway to the food that they find. Somewhere in between—in the case of the experimental ants, at a colony size of 700 members—the colony's behavior switches suddenly.

While this sharp transition might seem unexpected, the researchers weren't altogether surprised to find it because the mathematical principles underlying their model of foraging behavior make such a transition likely. When an ant discovers a food source, it deposits chemicals called pheromones along its trail back to the nest. If another ant happens to wander across the trail, it detects the pheromones and tends to follow that trail. Once it discovers the food, it will deposit pheromones of its own along the trail, reinforcing it and making future ants that encounter it even more likely to follow it—exemplifying what engineers call a positive-feedback loop. However, pheromones gradually evaporate, so if a trail is little used, it will eventually vanish.

If a colony is small, few ants wander around and they are unlikely to happen upon a trail before the pheromones evaporate. The colony collects only as much food as each ant, working independently, can find.

By contrast, in a large colony, many ants are likely to find a given trail, and their combined deposits of pheromones have a multiplicative effect on the colony's behavior. There's a jump in efficiency that makes a large colony more than the sum of independently working ants, Sumpter says.

In mathematical terms, the ants' behavior is nonlinear: If a

colony, say, doubles in size, its trails more than double in strength. This happens because, at any moment, a trail's growth reflects the product of how many ants have already found the trail and how many ants are now likely to stumble upon it.

The result of this nonlinear growth is to eliminate the middle ground. If a trail doesn't evaporate, it will burgeon into a bustling superhighway.

In each of these extremes, the individual ants are following the same rules, points out Stephen Pratt, who studies collective animal behavior at Arizona State University in Tempe. "In the old days, the focus would have been on what has changed about the animal when it goes from one state to another," he says. "What's new is to move the question up a level and ask how changing a single environmental variable, like density, can cause these dramatic changes in group behavior."

Positive feedback and nonlinearity, which are ingredients in a wide range of animal interactions, enable animal groups to generate behaviors that are more than the sum of their parts, Sumpter says.

RAPID RESPONSE — Mathematical modeling is explaining how a school of fish can quickly change shape in reaction to a predator.

GLOBAL SWARMING Phase transitions, far from being limited to ant colonies, appear to be a ubiquitous feature of animal groups. In 2002, for instance, Couzin and his team showed that a few simple rules for fish interactions yielded phase transitions between swarming behaviors.

Basing their work on a particle-interaction model from physics, the researchers represented each fish as a single particle. They assumed three rules about how the particles interact: Each fish tries to avoid colliding with other fish, stays with the group, and aligns its swimming direction with that of nearby fish within some defined zone around itself.

Variations of these rules have been studied for decades, but only recently has computer power grown to the point where researchers can simulate the movements of, say, 10,000 fish.

The researchers also assumed that fish can modify their sensitivity to their neighbors, that is, the size of their alignment zones. The team found that as the individuals' alignment zones grow, the school's architecture undergoes two sharp transitions.

When the alignment zone around each fish is negligible in size, so that the fish barely pay attention to their neighbors' directions, each fish swims in a random direction within the group. At a certain critical size of the alignment zone, the fish suddenly start following each other to produce a doughnut-shaped swarm. As the alignment zone continues to grow, the fish start swimming in parallel, as in a migration.

"The model switches very dramatically and quickly between patterns," Couzin says.

As fish take into account more and more of their neighbors, the alignment between them grows nonlinearly, leading to the sharp transitions that the team observed. While biologists have never, to Couzin's knowledge, studied a fish school in the act of changing from one of the three swarming patterns to another, each of the patterns has been observed frequently in nature.

"When we first saw [the doughnut] pattern in the simulations, I thought 'That's really weird!'" Couzin recalls. "But then we found in the literature that it really does appear in nature."

The model shows that simple rules for how fish interact with their neighbors can give rise to complex, schoolwide patterns. Couzin reports, "There's nothing in the individual rules that says, 'Go in a circle,' but it happens spontaneously."

Likewise, the model offers an explanation for how fish schools change their behaviors on the fly—for instance, if a predator suddenly appears. "Very subtle adjustments in the rules allow you to create all these structures without complicated actions on the part of the individual," Couzin says.

Preliminary experimental evidence suggests that fish can indeed adjust the sizes of their alignment zones. Parrish and Daniel Grunbaum, also of the University of Washington, have been filming fish schools in the lab, then using computerized sensing software to track each fish's path. "Sometimes, they pay attention to a lot of neighbors; sometimes, to just one," Parrish says.

However, Parrish and Grunbaum caution, considerably more experimental data are needed before researchers can say with confidence that the alignment-zone model captures what fish are doing. At present, tracking fish is so computationally intensive that Parrish and Grunbaum can follow only about 16 fish at a time in the lab.

Parrish is optimistic, though, that technological advances will soon enable researchers both to track fish in their natural habitats and to quickly crunch the resulting data.

LOCUSTS OF CONTROL In the meantime, a team made up of Couzin, Sumpter, and several other researchers has made progress in explaining one of the most dramatic of all animal swarms: a locust plague. Locust swarms—which often appear suddenly and seemingly out of nowhere—can quickly grow to a billion insects that migrate together, eating every scrap of plant matter in their path. Even in antiquity, philosophers marveled at the insects' ability to coordinate their motion: "The locusts have no King, yet all of them march in rank," the Bible comments.

Couzin, Sumpter, and their colleagues suspected that locusts follow rules similar to those in the researchers' fish model. In work published in the June 2 *Science*, they carried out simulations and lab experiments to test this hypothesis.

Their simulations suggested that as a locust population grows denser, its swarming behavior changes from chaos to order. When the researchers tracked locusts in a small area and gradually increased the insects' number, the small group's behavior mirrored the model's predictions. When there were just a few locusts, they wandered randomly, interacting only occasionally. Once the population reached 10 locusts, the insects formed small bands that changed direction frequently. At 30 locusts, the insects suddenly started marching as one.

"I think it's surprising that it worked out that cleanly," Grunbaum comments. "In the overwhelming majority of biological situations, you have a nice, plausible theory, but the reality works out differently."

The model illuminates why it's so hard to control locust swarms once they reach the density at which the insects start to march in unison: The laws of physics overwhelm human efforts to resist the migration.

PHOTODISC

REACHING A CONSENSUS As with the pheromone model of ant foraging, the positive feedback built into the alignment-zone model helps explain how an animal swarm achieves behavior that is more than the sum of its parts. In the Feb. 3, 2005 *Nature*, Couzin and a group of coauthors demonstrated, through computer simulations, how a handful of informed individuals can guide the rest of a group along a migration route or to a food source, even if the group members are incapable of recognizing which individuals have expert knowledge.

"We're not assuming anything about what these animals know—they don't know if anyone agrees with them, and they can't tell anyone, 'Follow me,'" Couzin says.

The researchers assumed, simply, that the experts' choice of direction at any given moment is balanced between their desire to move in the correct direction and their desire to align with their neighbors; by contrast, ignorant animals simply do the latter.

MIGRANT WORKERS — Positive feedback explains how a few experienced birds may lead the rest during a migration.

These alignment rules create a positive-feedback effect: The more animals are already turned in the correct direction, the more animals are likely to turn that way in the future. As long as the number of expert animals is big enough for the correct direction to get a toehold, positive feedback amplifies the experts' influence.

The team found that the larger the group, the smaller the proportion of experts needed to get the group moving in the correct direction. In the researchers' simulations, for example, a group of 30 ants needed four or five experts to get the group moving in the right direction, while a group of 200 could also be led accurately by just five of its members.

The researchers also studied what happens if the experts disagree. They found that the group will quickly reach a consensus and move in the direction preferred by a slight majority of the experts—although no individual knows how the experts' preferences stack up or even who the experts are. Once again, positive feedback amplifies the majority's tiny edge into a commanding lead.

"For humans, to reach consensus is very complicated—it requires language and recognition capabilities," Couzin says. "But animals can do it using very simple behavioral rules."

This simplicity has important implications. Couzin says, "It means natural selection is much more likely to find this kind of consensus behavior" than it would if consensus building required fancy cognitive skills.

Couzin and his collaborators are now testing their model in a wide range of systems, including fish and people. For instance, they're training a few lab-kept fish in the location of a food source and then seeing whether they lead a group there.

One of the most important contributions that the mathematical models can make, Couzin says, is to give biologists concrete, testable hypotheses to pursue. "It's so difficult to do experiments, that starting with a good theoretical basis is important," he says. "Theory can drive new ways of doing experiments." ■

PHOTODISC

OF NOTE

ZOOLOGY

Tough policing deters cheating in insects

Coercion plays a big role in keeping workers in line in insect societies—in some species, as big a role as family ties do, according to a new study.

In many wasp and bee societies, workers are anatomically equipped to lay their own eggs, but rarely do so while their queen's alive. Instead, they raise the queen's offspring.

Several forces could drive such altruistic babysitting, and a research team came up with a way to compare the strength of two forces: family ties and police work. The queen's offspring are the workers' siblings and half-siblings, so raising them could be a worthwhile reproductive effort for the workers. Meanwhile, in the insect version of a police crackdown, the queen or workers kill an egg that was laid illicitly by a worker (*SN: 3/19/05, p.184*).

Francis Ratnieks of the University of Sheffield in England suggests that especially tough, thorough policing might avoid the wasted effort that goes into producing an illicit egg.

To investigate, Ratnieks and Tom Wenseleers of the University of Leuven in Belgium collected police records from honeybees and nine Vespidae wasp species. The researchers found a link between policing and egg laying: The more thorough the policing was in a species, the less likely the workers were to lay illicit eggs.

In contrast, the closer the family ties within a species' colonies, the more likely the workers were to lay illicit eggs while the queen was alive. So, in insect species with policing, that force does more to keep the crime rate down than family ties do, the researchers argue in the Nov. 2 *Nature*. —S.M.

BIOLOGY

Jet lag might hasten death in elderly

When old mice experienced artificial jet lag, their death rate increased, scientists report.

Gene Block of the University of Virginia in Charlottesville and his colleagues study how the body's natural timekeeping, or circadian rhythm, changes with age. Several years ago, the researchers noticed that a surprisingly large fraction of their elderly lab rats died soon after researchers changed the daily cycle of light and dark in rooms containing the animals' cages.

To examine this phenomenon in more detail, Block's team worked with middle-aged and elderly mice. Some of the animals lived in cages where the researchers shifted daytime forward every week by

turning the lights on 6 hours earlier, the equivalent of a person flying from the East Coast of the United States to France. The researchers shifted daytime backwards once a week by the same amount for other mice. A third set of mice didn't experience any schedule shift.

After 8 weeks, the researchers found stark differences among the old animals in the groups. While 83 percent of those animals survived under the normal schedule, only 47 percent in the forward-shift group and 68 percent in the backward-shift group made it through the experiment. Nearly all the middle-aged mice lived on, regardless of their light schedules.

Block reports in the Nov. 7 *Current Biology* that stress—measured by the amounts of stress-signaling chemicals in the rodents' feces—didn't seem to play a part in the elderly animals' demise. The team plans further experiments to determine what physiological effects the changing light schedules have on elderly animals. —C.B.

BIOMEDICINE

Bug be gone

An experimental device kills head lice by blow-drying them to death, offering a potential alternative to chemical treatments and tedious combing.

As lice have become resistant to chemical shampoos, scientists have been trying new approaches (*SN: 8/20/05, p. 116*).

Researchers tested several blowers against lice and their eggs, or nits, on 169 children with head lice. The scientists randomly assigned the kids to get treatment with one of several devices, including a bonnet-style hair dryer, a hand-held hair dryer, a wall-mounted hair dryer, and an experimental high-volume blower that has a special rake that lifts hair into the strong air stream. All devices blew warm air.

Applied for 30 minutes to the scalp, each device killed at least 88 percent of the nits, the researchers report in the November *Pediatrics*. But the high-volume blower also slew 80 percent of the lice. The bonnet dryer, handheld blow dryer, and wall-mounted dryer killed 10, 55, and 62 percent of the lice, respectively, says Dale H. Clayton of the University of Utah and Larada Sciences in Salt Lake City, a university spin-off company that plans to commercialize the new device.

While it's unclear how the lice die, Clayton suspects that the air dries out their breathing pores. His team is now testing the device, called the LouseBuster, against shampoos in a head-to-head trial. —N.S.

PHYSICS

Heavy finding

The most massive subatomic cousins of protons and neutrons ever detected have made fleeting appearances in a U.S. particle accelerator.

The weightiest parts of the particles—known as sigma-b baryons—are called bottom quarks, one of the six types of quarks that are fundamental constituents of matter.

Physicists at Fermi National Accelerator Laboratory in Batavia, Ill., announced the exotic particles' discovery at the lab on Oct. 23. The scientists found telltale traces of the sigma-bs in the debris produced by more than 100 trillion collisions of protons and antiprotons that had occurred in the accelerator in the past 5 years.

BOTTOM FEEDER This detector, shown disassembled, discovered the heaviest cousins of protons and neutrons found to date.

FERMILAB

"You think, 'What kinds of jewels can you build out of these quarks?'" says physicist Jacobo Konigsberg of the University of Florida in Gainesville, a spokesman for the discovery team. When the team examined their data, the researchers realized that the sought-after quark combinations had shown up.

Ordinary matter, such as protons and neutrons, contains only up quarks and down quarks, whereas the sigma-bs each contain a bottom quark and either a pair of up quarks or a pair of down quarks.

Once abundant in the Big Bang, sigma-bs—and the bottom quarks that make them special—show up today only in high-energy events such as particle collisions, notes Fermilab physicist Rob Roser, also a spokesman for the sigma-b discoverers.

Sigma-b particles weigh about six times as much as protons. The prevailing theory of particle physics accurately predicted the sigma-b masses. It calls for still heftier baryons that haven't yet been found. —P.W.

BIOLOGY

Low body heat lengthens mouse lives

Mice genetically engineered to have low body temperatures lived significantly longer than mice with normal body temperatures, researchers report.

In previous studies, scientists found that severely restricting the number of calories that mice and other organisms consume can lengthen their life spans.

Animals on these low-calorie diets typically have abnormally cool body temperatures, but researchers weren't sure whether that was simply a consequence of burning fewer calories.

To explore whether a low body temperature itself lengthens an animal's life, Bruno Conti of the Scripps Research Institute in La Jolla, Calif., and his colleagues genetically engineered mice to have a faulty sense of body temperature. The alteration lowered the animals' temperatures by about 0.3 to 0.5°C below normal for a mouse. The altered mice were given as much food as they wanted, and they maintained normal weight.

The low-temperature mice lived about 15 percent longer than normal mice did, the team reports in the Nov. 3 *Science*.

The researchers are investigating whether lowered body temperatures protect cells from damaging molecules called free radicals—one of the ways that restricting calories is thought to extend life. —C.B.

NANOTECHNOLOGY

Ancients made nanotech hair dye

Two thousand years ago, the Greeks unwittingly fabricated nanoscale crystals that appear to be identical to the quantum dots now at the cutting edge of materials science.

Unlike today's scientists, who are investigating the dots for such uses as solar energy and lasers (*SN: 6/3/06, p. 344*), the ancients were exploiting them to blacken hair and probably wool. So reports a team of researchers from France and the United States in the October *Nano Letters*.

A hair-dye formula in an ancient text originally tipped off scientists to the Greeks' creation, says Philippe Walter, a chemist at the Paris-based Center for Research and Restoration of the Museums of France.

Testing the formula, the team dyed blonde hair black with a mixture of water, lead oxide—an orange powder—and the alkaline chemical lime. The researchers observed that lead atoms penetrated hair shafts and bonded to sulfur atoms freed from proteins by the alkalinity. The resulting compound formed light-absorbing crystals about 5 nanometers across, Walter says.

While the dye's nanoscale action wasn't recognized before, its effectiveness certainly was. Hair darkeners containing lead are still in use today, Walter notes. —P.W.

Books

A selection of new and notable books of scientific interest

THE AMERICAN PLAGUE: The Untold Story of Yellow Fever, the Epidemic That Shaped Our History

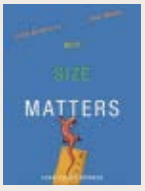
MOLLY CALDWELL CROSBY

Its symptoms were gruesome: What would begin as a mere fever would give way to painful bouts of vomiting blood and hemorrhaging from the eyes, nose, and mouth. The skin and eyes would turn a sickly shade of yellow. The summer of 1878 saw the worst epidemic of yellow fever in U.S. history, with 17,000 people infected. In her first book, Crosby describes the history of this epidemic, the frantic work by doctors, and the federal government's attempts to reassure the nation. In 1900, the battle against yellow fever moved to Cuba, where Walter Reed made the momentous decision to investigate the relationship between the disease and mosquitoes. Crosby ends the book by examining the possibility of a new epidemic of yellow fever, as poverty and overpopulation in West Africa today provide conditions similar to those of 1878. ***Berkeley, 2006, 308 p., b&w plates, hardcover, $24.95.***

WHY SIZE MATTERS: From Bacteria to Blue Whales

JOHN TYLER BONNER

From Gulliver's Travels to *Alice in Wonderland*, the notion of size captures the human imagination. It is also one of the most salient features of living things. Bonner, a professor of ecology and evolutionary biology, considers how the sizes of organisms may have evolved. In the process, he examines the largest and smallest creatures on Earth. Size, Bonner asserts, determines five important biological features: strength, surface area, complexity, rate of metabolism, and organism abundance. In this diminutive book, he explains each feature and how it relates to the others. He concludes, size matters. ***Princeton, 2006, 161 p., hardcover, $16.95.***



THEORIES FOR EVERYTHING: An Illustrated History of Science from the Invention of Numbers to String Theory

JOHN LANGONE, BRUCE STUTZ, AND ANDREA GIANOPOULOS

Science is the product of people's endless curiosity about how the world works. Through speculation, observation, experiment, and lucky bursts of insight, people have combined ancient information and modern knowledge to create theories covering virtually every aspect human experience. In this well-organized reference, the authors, all science writers, review the history of six fields of inquiry: the heavens, the human body, matter and energy, life itself, Earth and the moon, and the mind and behavior. Each chapter details what early philosophers and scientists believed about the subject, how and when major discoveries were made, and the important contributors to the field. The authors review the work of scientific heavyweights such as Copernicus, Galileo, Isaac Newton, Johannes Kepler, Albert Einstein, Hippocrates, Aristotle, Gregor Mendel, and Marie Curie. Each chapter includes a time line giving historical context to major scientific events, sidebars that detail important topics such as natural selection and the modern theory of the Big Bang, and full-color illustrations and photographs. ***Nat. Geographic, 2006, 408 p., color images, hardcover, $40.00.***

A COMPLETE GUIDE TO ARCTIC WILDLIFE

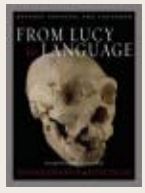
RICHARD SALE

Though the Arctic may seem a barren and desolate place, it is inhabited by various wildlife that can survive this harsh environment. Author and photographer Sale provides a comprehensive guide to Arctic mammals and birds, replete with vivid full-color photographs. Sale provides an overview of the Arctic's seismic and volcanic activity, rock types, snow, ice flows, icebergs, and glacial landforms. He recounts human exploration and settlement in Arctic habitats and explains the unique adaptations made by plants and animals there. Following this primer on the Arctic is a detailed field guide to the birds and mammals living there. Each entry includes the animal's common name, identifying characteristics, size, distribution, habitat, diet, and breeding habits. ***Firefly, 2006, 464 p., color images, hardcover, $49.95.***

FROM LUCY TO LANGUAGE

DONALD JOHANSON AND BLAKE EDGAR

Details of human origins have come largely from the efforts of scientists using the methods of paleoanthropology, an interdisciplinary field that combines geology, biology, and the social sciences. With this approach, scientists can examine the fossil record in several different ways to piece together the lives of ancient people. Johanson, the paleontologist who discovered the Lucy skeleton in Ethiopia, and science writer Edgar review the human-fossil record and detail how scientists developed and continue to refine their understanding of the lineage from our ancestors 6 to 7 million years ago to modern *Homo sapiens*. A detailed introduction reviews the central issues in paleoanthropology, including how the evolution of people has been different from that of other organisms, the process of recovering early human remains, and the way that fossils are dated. Johanson and Edgar describe humans' emigration from Africa and how the various aspects of human culture have developed. The latter portion of the book is dedicated to the human-fossil record, including that of pre-Australopithecines, Australopithecines, and *Homo* species. ***Simon & Schuster, 2006, 288 p., color photos, hardcover, $65.00.***



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LETTERS

Wasted youth

The experiments with mice infected with the 1918 influenza virus are important but not surprising ("The Bad Fight: Immune systems harmed 1918 flu patients," *SN: 9/30/06, p. 211*). John Barry's *The Great Influenza: The Epic Story of the Deadliest Plague in History* (2004, Viking) explains that many, perhaps most, of the victims were killed by the overreaction of their immune systems. This may be why most of the victims were young, with strong, young immune systems.

JOHN MYERS, SAN DIEGO, CALIF.

Heated discussion

I was surprised you didn't mention the effect of salinity in ocean water ("Mystery of the Missing Heat: Upper ocean has cooled slightly in recent years, despite warming climate," *SN: 9/30/06, p.213*). Warming climate has melted much of the glaciers, bringing fresh water into the North Atlantic. That water isn't dense enough to sink and carry on the conveyor belt that usually brings warm currents from the tropics. This slowing of the conveyor belt happened during the Little Ice Age, and apparently, it's happening again.

BELLA C. CHIU, ARLINGTON, MASS.

Isn't it likely that the accelerated breakup of polar ice holds the key to the missing heat? Massive amounts of heat are absorbed by the solid-to-liquid phase change when ice melts, and recent observations have shown a striking reduction of ice thickness.

DAVID ROPER, GRAND JUNCTION, COLO.

Perhaps the heat is going into the atmosphere and is the origin of what we measure as "global warming."

PAUL ETZLER, CEDAR CITY, UTAH

As far as scientists can tell, top-layer cooling of the world's oceans isn't an effect of melting ice in the polar regions. Some of the heat may be warming the atmosphere, scientists say. However, much of the missing heat remains unaccounted for. —S. PERKINS

Correction: *"A sunrise view of Mars"* (SN: 10/21/06, p. 260) *incorrectly quotes Alfred McEwen of the University of Arizona, saying that a photo of Martian gullies "shows a soaking-wet Mars." He made that remark about another area of the planet. Furthermore, it is that area, rather than the gullies shown, that contains clay-rich soils.*

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QC2 headphones (left). New QC3 headphones (right).

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