posed increases may vanish before the bills become law, and in the meantime federal agencies have to operate at last year's funding levels.

Who's to blame? Our government's dismal science record for 2007 is partly the result of the political gridlock that occurs whenever one party controls Congress and the other rules the White House. Last June, for example, President Bush vetoed legislation that would have expanded federal funding for embryonic stem cell research. But some Democratic lawmakers have also obstructed progress. Representative John Dingell of Michigan, chairman of the House Energy and Commerce Committee, fought the increase in fuel economy standards proposed in the Senate's energy bill, saying it would devastate U.S. automakers. Internal divisions among Democrats led to the current logjam on the energy issue, which must be untangled for the sake of our planet. ■

THE EDITORS' BLOG

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Won a Nobel? Go Nuts!

Posted by Philip Yam, October 19, 2007

As a long-time science journalist, I have learned to take what James Watson says with a grain of salt. Even so, I was caught off guard by the outrageousness of his latest words. Watson gets all the kudos for his genetics work, and his discovery with Francis Crick of the double-helical structure of DNA unquestionably deserved the Nobel Prize. But maybe that's what's wrong.

For most research scientists, winning the Nobel Prize stands as the pinnacle of success, the ultimate goal that takes intelligence, dedication, luck and ambition (and don't be fat, Watson would say, because fat folks are not ambitious). Once the king of Sweden drapes that medal around your neck, life is good—people want to hear you speak, offer you prestigious positions and are more inclined to give you what you want.

To their credit, some scientists take the opportunity to tackle very "out there" research. Soon after he won his 1995 Nobel in Physics, Martin Perl launched a project to find "free quarks." Conventional thinking says there can be no such things—quarks must remain bound in the particles in which they build—but some scientists speculate that some quarks might have been left over during the big bang. Perl recognized the long-shot odds of finding these quarks, but it was a project he could do because of his Nobel. A graduate student would be committing career suicide.

Other researchers run from the glory. Brian Josephson, who discovered the quantum effect in which superconducting electrons could jump across a narrow barrier, went off to study mysticism and psychic phenomena. (His problems, though, may run deeper; not many people would choose Taco Bell for a [free] lunch meeting.)

After the wacky things James Watson has uttered over the past decades—on

continued on page 37

Sustainable Developments

Primary Health for All

Ten resolutions could globally ensure a basic human right at almost unnoticeable cost

BY JEFFREY D. SACHS

Sixty years ago at the launch of the World Health Organization, the world's governments declared health to be a fundamental human right "without distinction of race, religion, political belief, economic or social condition." Thirty years ago in Alma Ata, the world's governments called for health for all by the year 2000, mainly through the expansion of access to primary health facilities and services. While the world missed that target by a long shot, we can still achieve it, at remarkably low cost. Ten key steps can bring us to health for all in the next few years.

These simple steps could save the lives of nearly 10 million adults and children.

First, affluent countries should devote 0.1 percent of their gross domestic product to health care for low-income countries. With a rich world GDP of $35 trillion, that would create a fund of roughly $35 billion a year—enough for $35 per capita in added health services for the roughly one billion people who need them.

Second, half the increase should be channeled through the Global Fund to Fight AIDS, Tuberculosis and Malaria. The Global Fund has proved to be a highly effective institution, with minimal bureaucracy and maximum impact. It has supported the distribution of approximately 30 million antimalaria bed nets, helped to get nearly one million Africans on antiretroviral treatment and helped to cure more than two million people of TB.

Third, low-income countries should devote 15 percent of their own national budgets to health. Consider a poor country where the average income is $300 a year. The total national budget might be around 15 percent of GDP, or roughly $45 per capita. Fifteen percent of that figure devoted to health would come to just $6.75 per person per year: not enough to provide adequate basic health care on its own, but combined with $35 per capita from donor aid, it would do the job.

Fourth, the world should adopt a plan for comprehensive malaria control, aim-

BRUCE GILBERT/EARTH INSTITUTE

ing to bring malaria mortality nearly to zero by 2012 through comprehensive access to antimalaria bed nets, indoor spraying where appropriate, and effective medicines when malarial illness arises.

Fifth, the rich countries should follow through on their long-standing and achievable commitment to ensure access to antiretrovirals for all HIV-infected individuals by 2010.

Sixth, the world should fill the financing gap of roughly $3 billion a year for comprehensive TB control—another area where known and long-proved interventions are highly effective but chronically underfunded.

Seventh, the world should honor, for just a few billion dollars a year, the access of the poorest of the poor to sexual and reproductive health services, including family planning, contraception and emergency obstetrical care.

Eighth, the Global Fund should offer roughly $400 million a year for comprehensive control of several tropical diseases (mainly worm infections), which occur in virtually the same regions where malaria is rampant.

Ninth, the Global Fund should open a new financing mechanism to bolster primary health care, including—most important—the construction of clinics and the hiring and training of nurses and community health workers.

Tenth, using recent breakthroughs in medicine and public health, the expanded health systems in the poorest countries should be equipped to handle noncommunicable diseases that have long been neglected but are treatable at low cost: hypertension, cataracts and depression.

These simple steps could save the lives of nearly 10 million adults and children a year, at a cost that would be nearly unnoticeable to the world's wealthiest nations. These measures would also slow, rather than accelerate, population growth in impoverished regions, thereby easing the economic and environmental strains that bulging populations are imposing on them. Health for all is not only the moral imperative it was at the launch of the World Health Organization 60 years ago, it is also the best practical bargain on the planet. ■

Jeffrey D. Sachs is director of the Earth Institute at Columbia University (www.earth.columbia.edu).

SCI AM An expanded version of this essay is available at **www.SciAm.com/ontheweb**

Forum

A Better Mosquito Net

Fighting malaria will require more innovative defenses

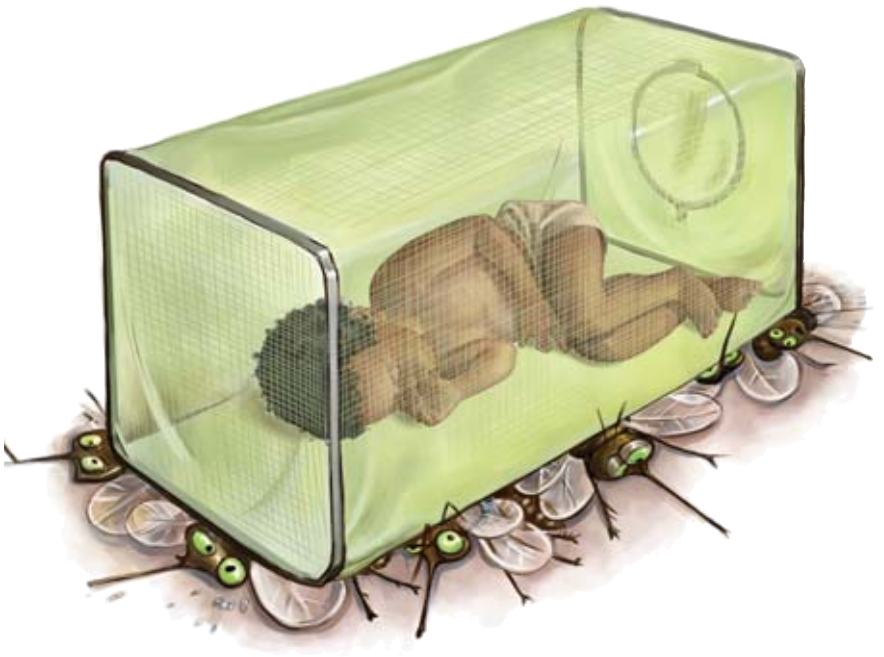
BY EVA KAPLAN

Malaria remains one of the world's great scourges, striking more than 500 million people every year. The groups most at risk are pregnant women and children younger than five years old. In sub-Saharan Africa, 20 percent of all childhood deaths are from malaria. Pregnant women who contract the mosquito-borne disease can develop severe anemia and give birth to underweight babies. The World Health Organization estimates that 10,000 pregnant woman and 200,000 infants in Africa die from malarial infections every year.

To combat the disease, many development agencies have focused on distributing mosquito nets that would protect Africans from being bitten while they sleep. This strategy has resulted in a huge upsurge in the number of bed nets supplied to the population as a whole and particularly to pregnant women and young children. The widespread distribution, however, has *not* resulted in a significant decrease in malaria. Many doctors in sub-Saharan Africa attribute the failure to an overreliance on nets in lieu of other interventions, such as the indoor spraying of dwellings with insecticide. Other experts say the problem is the misuse of mosquito nets; there is anecdotal evidence that some people have employed the nets as wedding veils or fishing aids. Some economists argue that charging a small fee for the nets would increase the likelihood that they would be used appropriately. Others claim such a fee would prevent a large part of the population from receiving nets. These are valuable debates. Before delving into behavioral economics, though, it might be useful to consider a more basic problem: the mosquito nets are poorly designed.

The bed nets distributed by governments and international organizations have one of two basic designs: circular or

PHOTOGRAPH BY JAMES BORLAND; ILLUSTRATION BY MATT COLLINS



MATT COLLINS

rectangular. The circular design hangs from the ceiling by one string, with the net fanning out from a ring at the top and tucked tightly under the mattress on all sides. The rectangular design ties to the ceiling with four strings and hangs straight down on all sides of the bed, with the fringes again tucked under the mattress. Both designs work well for middle-class homes with flat ceilings and a bed for every member of the family. But most of the poor in sub-Saharan Africa, especially in rural areas, live in mud huts, often with thatched roofs.

Hanging mosquito nets is very difficult in these homes, and most people prefer the circular nets because they are easier to hang. Although the rectangular nets can be used without a bed, the circular nets cannot, because they have to be tucked under the mattress to fan out. In many African communities, most children younger than five sleep on the floor, so only the rectangular nets would be effective. But the rectangular nets take up quite a bit of room in a mud hut and have to be taken down and rehung every night for the hut to be of use during the day. Given the difficulty of hanging the nets, it is unreasonable to expect people to follow this routine.

A design more suited to the needs of young children would be a net that does not hang at all. One possibility would be a collapsible, tentlike structure, very similar to the crawl-through children's toys that clutter so many playrooms in the U.S. The challenge would be to make the structure both affordable to produce and durable enough to be used daily for years. In addition to being user-friendly, this free-standing mosquito net would have to be sized for children to ensure that it is used by the intended recipients rather than older, hardier members of the family.

Mosquito nets have been changed before to meet user needs. Several companies have recently introduced nets that are impregnated with long-lasting insecticide, eliminating the need for people to continually apply fresh coatings of chemicals to the nets. Companies must continue to improve mosquito nets if progress is to be made in combating malaria. And once better nets are available, researchers will be able to objectively judge the effectiveness of the distribution programs. ■

Eva Kaplan is a writer and consultant who has managed research projects focused on disease prevention in sub-Saharan Africa.

THE EDITORS' BLOG

For more posts from SciAm Observations, see *www.SciAm.com/blog*

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women, homosexuals and the obese, to name a few—now comes his decision to join hands with the transistor-developing, eugenics-advocating, sperm-donating William Shockley, who, I recall, blamed his wife's genes for his kids being less than genius. As a geneticist, Watson arguably has better credentials to rant about race and IQ than Shockley. But that still doesn't make him an expert on IQ studies. It's true that blacks have historically scored 15 points lower than whites on IQs. What's been debated endlessly is how much is tied to heredity and how much to environment. Intelligence researchers such as James Flynn have found that IQ can change over time, suggesting a strong environmental influence. Others, such as Philippe Rushton and Linda Gottfredson, say the data are at least as consistent with hereditarian arguments as they are with environmental ones. I don't want to get into a whole discussion about IQ again—we've covered it a lot in this magazine (see, for instance, "Unsettled Scores" [February 2007] and our Intelligence special issue [*Scientific American Presents,* Winter 1999]). But while I'm at it, one question I have for the hereditarians: How do you separate genetic explanations from womb conditions—a crucial environmental factor?

Without having mucked around in the morass that is IQ research, Watson can at best be only a casual observer. He's reportedly dim about the prospects of Africa because of that continent's lower intelligence test scores. What—cultural conflicts, religious attitudes and greed are less important? That's hard to justify when you look at what's going on in different parts of the world right now.

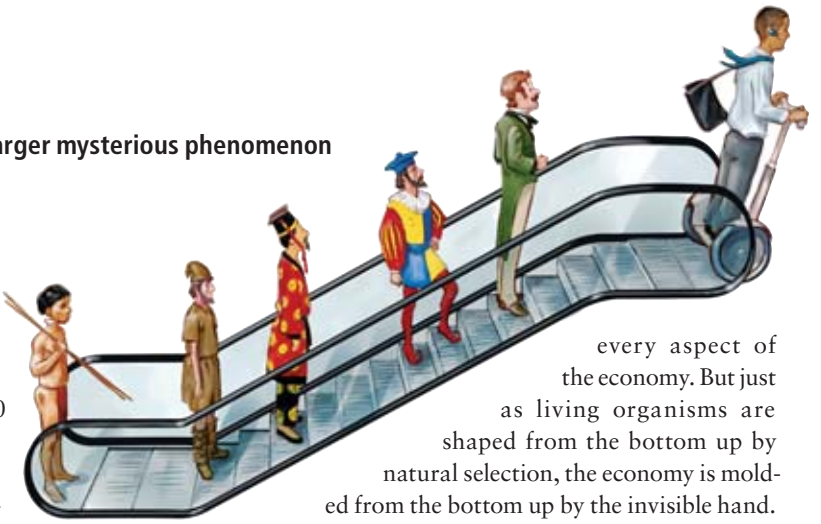
Yet because of his Nobel and past accomplishments as a geneticist, Watson's words take on added meaning and weight beyond what they deserve. Winning the Nobel grants a great deal of power. Too bad Watson didn't channel Stan Lee and recognize that with great power comes great responsibility.

Skeptic

Evonomics

Evolution and economics are both examples of a larger mysterious phenomenon

BY MICHAEL SHERMER



Living along the Orinoco River that bor-ders Brazil and Venezuela are the Yanomamö people, hunter-gatherers whose average annual income has been estimated at the equivalent of $90 per person per year. Living along the Hudson River that borders New York State and New Jersey are the Manhattan people, consumer-traders whose average annual income has been estimated at $36,000 per person per year. That dramatic difference of 400 times, however, pales in comparison to the differences in Stock Keeping Units (SKUs, a measure of the number of types of retail products available), which has been estimated at 300 for the Yanomamö and 10 billion for the Manhattans, a difference of 33 million times!

How did this happen? According to economist Eric D. Beinhocker, who published these calculations in his revelatory work *The Origin of Wealth* (Harvard Business School Press, 2006), the explanation is to be found in complexity theory. Evolution and economics are not just analogous to each other, but they are actually two forms of a larger phenomenon called complex adaptive systems, in which individual elements, parts or agents interact, then process information and adapt their behavior to changing conditions. Immune systems, ecosystems, language, the law and the Internet are all examples of complex adaptive systems.

In biological evolution, nature selects from the variation produced by random genetic mutations and the mixing of parental genes. Out of that process of cumulative selection emerges complexity and diversity. In economic evolution, our material economy proceeds through the production and selection of numerous permutations of countless products. Those 10 billion products in the Manhattan village represent only those variations that made it to market, after which there is a cumulative selection by consumers in the marketplace for those deemed most useful: VHS over Betamax, DVDs over VHS, CDs over vinyl records, flip phones over brick phones, computers over typewriters, Google over Altavista, SUVs over station wagons, paper books over e-books (still), and Internet news over network news (soon). Those that are purchased "survive" and "reproduce" into the future through repetitive use and remanufacturing.

As with living organisms and ecosystems, the economy looks designed—so just as humans naturally deduce the existence of a top-down intelligent designer, humans also (understandably) infer that a top-down government designer is needed in nearly every aspect of the economy. But just as living organisms are shaped from the bottom up by natural selection, the economy is molded from the bottom up by the invisible hand.

The correspondence between evolution and economics is not perfect, because some top-down institutional rules and laws are needed to provide a structure within which free and fair trade can occur. But too much top-down interference into the marketplace makes trade neither free nor fair. When such attempts have been made in the past, they have failed—because markets are far too complex, interactive and autocatalytic to be designed from the top down. In his 1922 book, *Socialism,* Ludwig von Mises spelled out the reasons why, most notably the problem of "economic calculation" in a planned socialist economy. In capitalism, prices are in constant and rapid flux and are determined from below by individuals freely exchanging in the marketplace. Money is a means of exchange, and prices are the information people use to guide their choices. Von Mises demonstrated that socialist economies depend on capitalist economies to determine what prices should be assigned to goods and services. And they do so cumbersomely and inefficiently. Relatively free markets are, ultimately, the only way to find out what buyers are willing to pay and what sellers are willing to accept.

Evonomics helps to explain how Yanomamö-like hunter-gatherers evolved into Manhattan-like consumer-traders. Nineteenth-century French economist Frédéric Bastiat well captured the principle: "Where goods do not cross frontiers, armies will." In addition to being fierce warriors, the Yanomamö are also sophisticated traders, and the more they trade the less they fight. The reason is that trade is a powerful social adhesive that creates political alliances. One village cannot go to another village and announce that they are worried about being conquered by a third, more powerful village—that would reveal weakness. Instead they mask the real motives for alliance through trade and reciprocal feasting. And, as a result, not only gain military protection but also initiate a system of trade that—in the long run—leads to an increase in both wealth and SKUs. ■

Michael Shermer is publisher of Skeptic *(www.skeptic.com). His latest book is* The Mind of the Market *(Times Books).*

PHOTOGRAPH BY BRAD SWONETZ; ILLUSTRATION BY MATT COLLINS

Anti Gravity

What's in a (Latin) Name?

The special genius behind the species and genus

BY STEVE MIRSKY

The greater roadrunner is officially classified as *Geococcyx californianus*. The lesser roadrunner is *Geococcyx velox*. And the more familiar cartoon Road Runner (beep beep) has been designated on different occasions as *Accelerati incredibilus, Velocitus tremenjus, Birdibus zippibus, Speedipus rex* and *Morselus babyfatious tastius*. Consistently unsuccessful in his attempts to catch *Fastius tasty-us* is Wile E. Coyote, himself variously classified as a representative of the species *Carnivorous slobbius, Eatius birdius, Overconfidentii vulgaris, Poor schinookius* or *Caninus nervous rex*. (Real coyotes are *Canis latrans,* which sounds like a bathroom used by Roman legionnaires.)

So who do we, and the Looney Tunes folks, have to thank for setting the ground rules that led to all this highfalutin Latinate humor? None other than Swedish naturalist Carl Linnaeus, who was so in love with naming things that he gave himself a few more: Carl Linné, Carl von Linné, Carolus Linnaeus and Caroli Linnaei, the name by which he proposed the standard genus-species system of taxonomic binomial nomenclature still used to keep track of all that life out there. The year 2007 was the tricentennial of Linnaeus's birth, which shows that some people's contributions give them a postmortem vita that's not at all *brevis*.

American journalist and wag H. L. Mencken paid unwitting tribute to Linnaeus's classification scheme when he dubbed a large percentage of the U.S. population *Boobus americanus*. (Don't worry, he meant the other guys, not you.) Mencken described the perpetually bamboozled *B. americanus* as "a bird that knows no closed season," which coincidentally describes the Road Runner, also known as *Disappearialis quickius*. Mencken, by the way, covered the famous Scopes trial, in which some *Homo sapiens* treated the notion that they were related to *Gorilla gorilla* and *Pan troglodytes* like it was a *Yersinia pestis* infection.

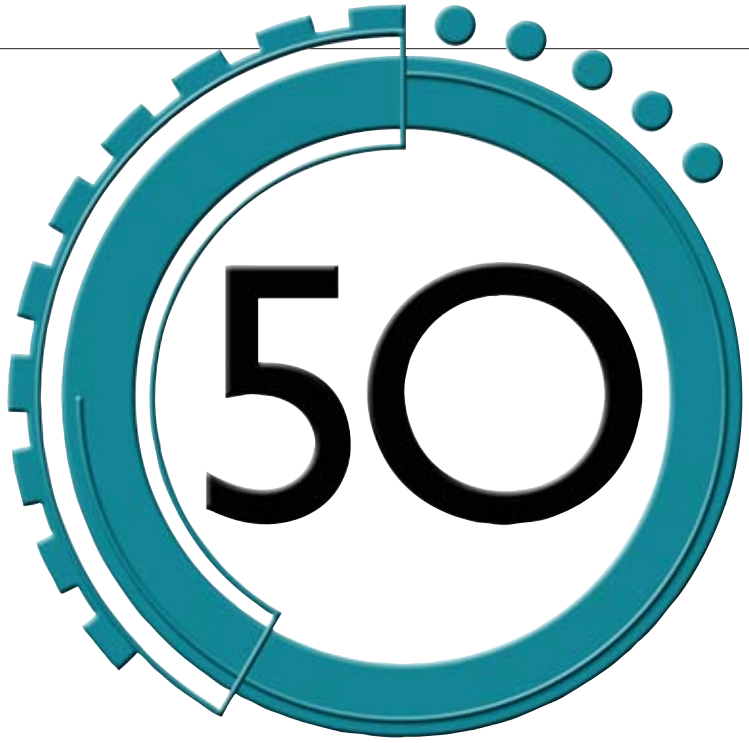
Among Mencken's many pithy comments about *H. sapiens* is, "An idealist is one who, on noticing that a rose smells better than a cabbage, concludes that it will also make better soup." And in fact, mixing up any of the numerous species of the genus *Rosa* with *Brassica oleracea* (Capitata Group) is even nuttier (*Bertholletia excelsa*) in Latin. Preventing mix-ups is one reason why Linnaeus's system comes in so handy: French president Nicolas Sarkozy might call it a *moineau,* Spain's King Juan Carlos might call it a *gorrión,* and Vice President Dick Cheney might (or might not) call out "fire in the hole" before trying to blow it out of the sky, but the bird in question would be recognizable to all their science advisers as *Passer domesticus*. Which is also known in English as the house sparrow. And because common species names, even within a single language, lack the authority of the official Linnaean designations, the house sparrow is also known in English as the English sparrow. Help, is there a taxonomist in the house?

Linnaeus's twin great works were the 1753 *Species Planterum,* in which he classified all the known species of vegetation, and the 1758 *Systema Naturae,* which celebrates its 250th anniversary this year and which was the first major effort at organizing the animal world. The Wikipedia entry on Linnaeus notes that because of his habit of naming all the living things he encountered, "he thought of himself as a second Adam." The cover of *Systema Naturae* shows a man, presumably Linnaeus, tossing Latin titles to "new creatures as they are created in the Garden of Eden." No shrinking member of the genus *Viola* was he.

Linnaeus appears to have occasionally abused his absolute appellative power. The New York Botanical Garden, which hosted a rare public display of Linnaeus's own annotated copy of the *Systema Naturae* last November, notes on its Web site that "he got revenge on his critics by naming unpleasant plants and animals after them. For example, he named *Siegesbeckia,* an unattractive Asian weed that exudes foul-smelling liquid, for German botanist Johan Siegesbeck." So Linnaeus was probably a pain in the *Equus asinus*. But without him, biology could not have become big-name science. ■

PHOTOGRAPH BY FLYNN LARSEN; ILLUSTRATION BY MATT COLLINS

SCIENTIFIC AMERICAN



TRENDS

- Wireless Power
- Drug Delivery
- Sustainable Fuels
- Toxic Housewares
- Ultrameasurement
- Malaria-Free Mosquitoes
- Bioinspired Materials
- Diagnosing Alzheimer's
- Optical Chips
- Prion Disease Treatments
- Sun Power
- Understanding Stem Cells
- Chip Printers
- Prosthetics
- Intelligent Route Finders

Technological overoptimism lurks as a persistent risk to both professional and amateur watchers of advances, from artificial intelligence to the flying car. But sometimes new technologies actually live up to some of the wildest expectations for them.

This year's SciAm 50 awards are replete with instances of new machines or chemicals that come close to the true meaning of innovation as something entirely new. One winner has created an instrument that measures fluids in zeptoliters, or sextillionths of a liter. (You know, the zeptoliter, the measurement unit that is 1,000th of an attoliter?)

Another innovator has devised a method that could recharge a phone without plugging it in. All you would have to do is sit at the dining room table, phone in pocket, a few feet away from a recharging coil hidden in the ceiling. Still another visionary is paving the way for treating mysterious and deadly prion diseases such as mad cow and kuru.

Award winners highlighted here have the potential to contribute much more to human health, consumer electronics and numerous other fields than if they were simply offering another antidepressant that tweaked serotonin levels or ratcheting up the speed of a microprocessor. What they have done is decidedly new.

—The Editors

The Wellcome Trust Case Control Consortium

U.K.

A massive genetic study turns up the complex roots of major diseases

With genetic scientific advances reported almost daily, it sometimes seems as if we are merely waiting for researchers to discover the gene at fault for every human disease. The complex genetic basis of many common diseases, however, complicates prediction, diagnosis and treatment.

The Wellcome Trust Case Control Consortium (WTCCC), a constellation of more than 50 British research groups, took on the mammoth challenge of ferreting out the causes of diseases in which multiple genes are implicated. Last June they reported the findings of a study that scanned for specific gene variations among 17,000 British citizens: 2,000 each from patient groups diagnosed with bipolar disorder, coronary heart disease, Crohn's disease, rheumatoid arthritis, hypertension and diabetes types 1 and 2, as well as 3,000 unafflicted who served as a control group. The large scale of the study was unprecedented and so was the payoff: 24 locations in the genome were found to be associated with six of the seven diseases.

The WTCCC compared the genomes of each affected group with those of the controls and zeroed in on locations where DNA bases differed between the two groups. The size of the study was essential in enabling the researchers to spot rare anomalies. Some of the signals were in coding regions of genes; some were in noncoding regions that might regulate other genes; and some were in "gene deserts"—noncoding regions with no identified function. The variants themselves may not actually be responsible for the diseases. But they serve as signposts for other researchers to investigate DNA at a fine scale.

Every person possesses a certain pattern of "polymorphisms" in the six billion nucleotides of their genomic DNA—three billion for each of the two sets of chromosomes. The statistical pattern of how these variations occur, provided by studies such as the one conducted by the WTCCC, will help physicians calculate the chances that a patient could develop symptoms of a hereditary disorder. The ultimate goal of this research is personalized medicine in which patients submit a blood sample and have their entire set of genes analyzed to determine predisposition to chronic diseases, the best food and exercise regimens to stay healthy, and which drugs and dosages will be most effective when illness does strike. —*Kaspar Mossman*

GENOME-WIDE SCANS turned up gene variants associated with disease, such as those for type 1 diabetes, shown as green highlights on a representation of chromosomes.

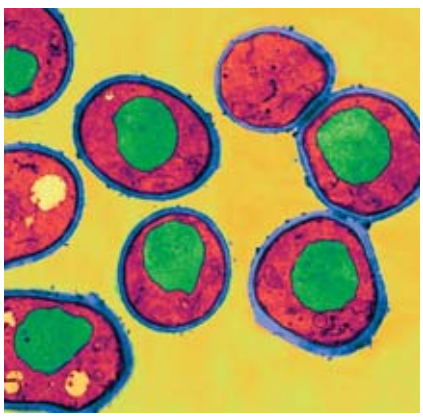
Amyris Biotechnologies

Emeryville, Calif.

The emerging field of synthetic biology provides candidates for a new generation of biofuels

Ethanol is not the most energy-dense of fuels nor the cheapest. Consequently, Amyris Biotechnologies in Emeryville, Calif., has come up with a potentially better solution. It did so by starting with a long roster of organic compounds from which it chose potential replacements for gasoline, diesel and jet fuel that could be burned in modern engines and would be compatible with the existing petroleum infrastructure. Then the company used custom-designed microbes to produce the new fuels by fermentation from a conventional ethanol feedstock.

To create the novel strains was no small genetic feat. The task required sub-



YEAST microbes, once genetically engineered, can boost biofuel yields dramatically.

FROM "GENOME-WIDE ASSOCIATION STUDY OF 14,000 CASES OF SEVEN COMMON DISEASES AND 3,000 SHARED CONTROLS," BY THE WELLCOME TRUST CASE CONTROL CONSORTIUM, IN *NATURE*, VOL. 447; JUNE 7, 2007. REPRINTED BY PERMISSION OF MACMILLAN PUBLISHERS LTD. (*top*); THOMAS DEERINCK *NCMIR/Photo Researchers, Inc.* (*bottom*)

stantial alterations to the yeast genome. Genes from the original plant source and two other organisms were inserted, and a preexisting biochemical pathway was carefully adjusted. The engineered yeast boasted a millionfold increase in yield.

A leader in the emerging field of synthetic biology, Amyris is well known for developing a strain of yeast for large-scale manufacture of a precursor to the antimalarial drug artemisinin, for which the Asian plant source is in short supply. The company, chosen in 2006 by the World Economic Forum as a Technology Pioneer, is now close to its goal of supplying cheap industrial quantities of artemisinin to developing countries.

Amyris decided that its expertise could prove equally profitable when applied to biofuels. It initiated a search for fuels that could be produced in the lab and that met criteria on energy content, volatility and water solubility.

The difference between engineering microbes to produce drugs versus fuel is that, ounce for ounce, drugs are much more valuable: a fuel end product has to be cheap enough to burn. Amyris will have to optimize each microbial strain so that it cranks out fuel without poisoning itself and produces enough fuel molecules so that it is economically worthwhile to grow. In the history of the large-scale chemical industry, the subtlety of technical expertise involved in this project is without precedent. Yet Amyris, which last June added several oil industry veterans to its management, has shown that it means business. —*Kaspar Mossman*

SciAm 50 POLICY LEADER OF THE YEAR

X Prize Foundation

Santa Monica, Calif.

The lure of multimillion-dollar prizes prompts inventors to pursue breakthroughs in space travel, DNA sequencing, automotive fuel efficiency, and robotics

In 1927 the aviation world marveled at Charles A. Lindbergh's nonstop flight from New York to Paris. Lindbergh was in it for more than thrills: he was after the $25,000 Orteig Prize. In a 21st-century encore, the 12-year-old nonprofit X Prize Foundation conceives and manages competitions for daring innovators.

The foundation's game plan is to define an exciting target that benefits humanity, bait it with a large stack of cash, and draw out the best in design and invention from private, nongovernmental teams. The competitors, the thinking goes, will invest much more in technology chasing the prestige of the prize than the foundation will hand out at the awards ceremony.

Events have borne out this prediction. The foundation set a goal in 1995 "to make space travel safe, affordable and accessible to everyone through the creation of a personal spaceflight industry." In 2004 Mojave Aerospace Ventures won the Ansari X Prize as the first team to build a space plane that could reach low-Earth orbit, return to Earth and repeat the flight within two weeks. Twenty-six teams entered the contest and collectively spent more than $100 million on research.

The second prize, which the foundation offered in late 2006, is the $10-million Archon X Prize, for the first private team to sequence 100 human genomes in 10 days at a cost of less than $1 million. At least four teams have already signed up for the challenge of inventing an instrument that will correctly sequence 98 percent of each genome with no more than 60,000 errors.

The winning technology would accelerate deployment of new discoveries such as genome-wide association studies, which analyze large patient groups to identify genes responsible for complex hereditary diseases. A prominent supporter of the Archon X Prize is Stephen Hawking, the renowned theoretical physicist who suffers from amyotrophic lateral sclerosis.

Last April the foundation also offered the Automotive X Prize, for the first 100-mile-per-gallon production car. And in September the group announced the $30-million Google Lunar X Prize purse for the first private groups to land spacecraft on the moon. Money may be an object for some, but there is no doubt that the challenges set by the X Prize Foundation light a fire under innovators worldwide. —*Kaspar Mossman*

AMBITIOUS GOALS that benefit humanity, such as a private robotic moon mission, serve as the rationale for the X Prize Foundation.

COURTESY OF X PRIZE FOUNDATION

Connections to an Untethered Future

Delivering electric power through the air cuts the final cord

Although laptops, cell phones and other gadgets give us remarkable mobility, we can roam untethered only for as long as our batteries hold out. Photonics researcher Marin Soljačić of the Massachusetts Institute of Technology wants to eliminate that shackle by delivering wireless electricity, or WiTricity.

Soljačić hung a copper coil 0.6 meter (two feet) in diameter from a ceiling, then hung another coil about 2.1 meters (seven feet) away, with a 60-watt lightbulb dangling from it. When he plugged the first coil into a power source, the lightbulb on the second coil lit up. Electric current in the first coil established a magnetic field that induced current in the second one.

The iPhone's "multi-touch" screen gives the user access to a standard keyboard, streaming video, music and a list of voice mails.

Many motors exploit this effect, but normally induction works only across gaps of a few millimeters, dying off rapidly with greater distance. Soljačić tuned his coils to resonate, allowing efficient energy exchange over a distance. Future implementations of his system might enable laptops and cell phones to recharge when they are in a room equipped with a resonance emitter.

The human impulse to cut the cord runs deep. Apple released the iPhone as an ultimate wireless interface, and people lined up to pay $600 for it. The handheld device combines all the functions of an advanced mobile phone with those of the latest iPod, thereby allowing users to wander freely while making phone calls, accessing the Web, sending text messages and e-mail, taking photographs, listening to music and watching videos. Although some earlier phones had offered many of these functions, the iPhone's full-size "multi-touch" screen gave customers far more flexibility, including use of a standard keyboard for messaging, streaming of YouTube video and a visual list of voice mails—not to mention access to iTunes, by far the dominant online music source.

Wireless sensors also gained flexibility. Reduced to the size of rice grains or dust, they can mount a vigil for chemical and biological weapons or check for moisture content in the soil. Already they are changing how people monitor the world. A major barrier, however, has been how to know if such networks of randomly distributed sensors leave gaps in coverage or if the sensors' ranges overlap, thus wasting the precious bits of power they may carry.

Robert Ghrist, a mathematician at the University of Illinois at Urbana-Champaign, and mathematics professor Vin de Silva of Pomona College harnessed the science of mathematical homology to answer both questions. Homology analyzes the points, lines and geometric arrangements within shapes. By treating sensors as points, pairs of sensors as edges, and collections of edges as shapes, Ghrist and de Silva devised algorithms that can tell whether a sprinkled network of sensors overlap or leave gaps.

The advantage of Ghrist's and de Silva's algorithms is that they only need to know which sensors are within range of one another, not where each sensor actually is; they eliminate the need for expensive global-positioning circuits or the manual mapping of circuits. Knowing the locations of gaps and overlaps, network operators could turn up the power of certain sensors or strategically add new ones to fill in blank spots. —*Mark Fischetti*

Getting from Here to There

A protein borrowed from the rabies virus gets a drug to where it is needed

As hard as it is for scientists to develop new drugs, sometimes just getting the drug to where it needs to act is equally challenging. Nowhere is this more true than in the brain, where blood vessel walls are tightly knit, keeping most large molecules from seeping out of the bloodstream and into brain tissue. This blood-brain barrier is a formidable obstacle to delivering certain types of treatments for neurological diseases, but Manjunath N. Swamy and his team at Harvard Medical School's Immune Disease Institute devised a clever way to sneak a drug through and insert it directly into brain cells.

Some viruses that specialize in infecting the nervous system, such as rabies and herpes, are adept at penetrating the blood-brain barrier. Swamy's group exploited that capability by disguising a drug with a small protein normally found

on the surface of the rabies virus. The protein is believed to unlock a passageway through the blood vessel walls, and a drug molecule hitched to the viral protein was able to penetrate the barrier. Once inside the brain, the protein also allowed the drug to enter individual nerve cells, much as a virus would infect them. The therapeutic molecule used in Swamy's experiments was a small nucleic acid chain, known as a short-interfering RNA (siRNA), which can be customized to target specific genes and suppress their effects, making siRNA delivered straight to the brain a versatile tool for a wide range of uses.

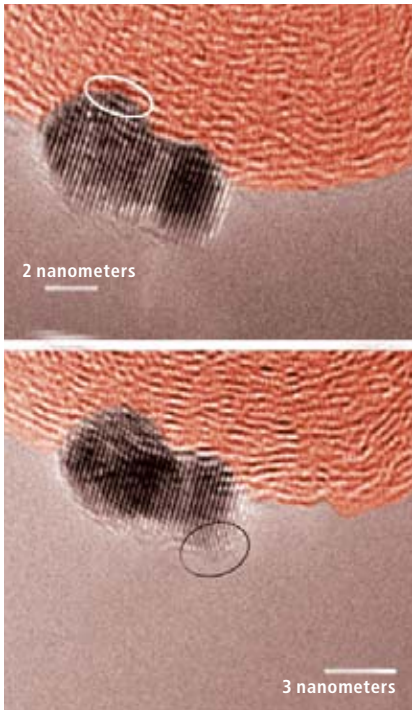
The same can be said of another tiny Trojan horse built by Hans Boumans and his colleagues at the Netherlands Organization for Applied Research. The team's "BioSwitch" consists of a biopolymer cage that can protect or conceal a variety of substances until their release is desirable. Both the cage material and the trigger to discharge its contents can be tailored to specific situations.

For instance, Boumans's group created a germ-killing plastic wrap for meat by encapsulating a bactericidal enzyme inside woven cages of cross-linked starch molecules, then coating the plastic with them. The starch cages remain inert unless bacteria are present and start eating the starch, thus degrading the cage until—surprise—the killer enzyme is released. A similar system could allow unstable food-flavoring molecules to remain encased until they contact enzymes on the tongue or foul-tasting nutrients to stay sealed in their cages until they reach digestive enzymes in the gut. —*Christine Soares*

Fueling Alternatives

Engineers make progress toward new green fuels and energy storage devices

Despite efforts to brew ethanol as a sustainable automotive fuel substitute for gasoline, the plant-derived alcohol has its drawbacks. A gallon (3.8 liters) of ethanol, for one, contains almost a third less energy than the same volume of gasoline.



Gold clusters (*circles*) retard the oxidation of a platinum catalyst in a fuel cell.

FROM "STABILIZATION OF PLATINUM OXYGEN REDUCTION ELECTROCATALYSTS USING GOLD CLUSTERS," BY J. ZHANG, K. SASAKI, E. SUTTER AND R. R. ADZIC, IN *SCIENCE*, VOL. 315; 2007. REPRINTED WITH PERMISSION OF AAAS

So when James A. Dumesic and his fellow chemical engineers at the University of Wisconsin–Madison developed a straightforward way to extract a synthetic fuel from sugar that in many ways surpasses ethanol, the scientific community took notice. Called 2,5-dimethylfuran, or simply DMF, the fuel possesses an energy density equivalent to that of gasoline. It is also insoluble in water and stable in storage. Although chemists have long known about the compound, volume production has been tricky. The new two-step process makes improvements in an intermediate manufacturing step that was a barrier to mass production of DMF.

Beyond finding new alternative fuels for internal-combustion engines, researchers are working on fuel cells that offer another path toward environmentally acceptable power. The key to an effective hydrogen, or proton-exchange membrane (PEM), fuel cell is the microthin coating of platinum particles on the positively charged electrode, where oxygen molecules split into individual charged atoms.

Chemist Radoslav R. Adzic and his team at Brookhaven National Laboratory have found a way to stop the platinum on the electrode's surface from oxidizing, which slows down power-generating chemical reactions and also often causes its membrane to degrade, rendering the cell useless. By spraying the electrode with nanoparticles of gold, Adzic's team made the platinum layer resistant to dissolving and helped it retain most of its original catalytic efficacy.

To produce electricity, most PEM fuel cells must be supplied either with hydrogen or with hydrocarbon compounds that can be catalytically decomposed into hydrogen. Some prototype fuel cells, however, resemble biological cells in that they use chemical enzymes to break down sugars—a special class of hydrocarbon molecules—to generate electrons. Unlike living cells, they typically soon run out of the enzymes necessary to sustain the reaction.

Electrochemist Shelley D. Minteer and her colleague Tamara Klotzbach, both at Saint Louis University, have developed a method to replenish the enzymes in a sugar-powered fuel cell as they degrade with use. The researchers have come up with a polymer wrapping for an enzyme, which keeps the catalytic molecule active for months instead of days.

—*Steven Ashley*

Fighting Toxins in the Home

Everyday materials may pose health and environmental threats

Ordinary plastic items may cause sickness.

Researchers are continually finding new evidence that common items in our kitchens, bathrooms and toy chests can make us sick. One of the most insidious substances is bisphenol A, a component of the light plastics used in baby bottles and many other consumer products. Over the past several years, scientists have reported that low levels of bisphenol A can disrupt cell division, leading to spontaneous miscarriages and birth defects such as Down syndrome.

In early 2007 a team led by Patricia A. Hunt of Washington State University found that small amounts of bisphenol A interfered with the growth of egg cells in developing female mouse embryos. As many as 40 percent of the eggs from fetuses exposed to bisphenol A had an abnormal number of chromosomes. This stunning finding showed that the chemical's effects can run through three generations: the pregnant mother's exposure damages the daughter's reproductive cells, which in turn disrupts the development of the daughter's own children.

The National Toxicology Program, which is part of the National Institutes of Health, is currently reviewing the safety of bisphenol A. In the meantime, some physicians advise pregnant women to avoid drinking water from plastic bottles, especially once the containers become visibly scratched or scuffed, which may indicate that they are leaching the hazardous chemical.

Toxic household items also pose a danger to the environment. Unused pharmaceuticals are a particularly serious threat because consumers often flush them down the toilet, sending the potent molecules into rivers and lakes. Discarded birth-control pills can trigger reproductive problems in fish, and surplus antibiotics can enhance the spread of bacteria that are resistant to the drugs. In an attempt to tackle this problem, the American Pharmacists Association and the U.S. Fish and Wildlife Service signed an agreement last year to launch a public-awareness campaign to change consumer habits. When people pick up their prescriptions, they will be advised to dispose of their unused pharmaceuticals through hazardous-waste collection programs. If such programs are not locally available, the next best option is crushing and diluting the medicines, then sealing them in plastic bags and dumping them in the trash. (Some narcotic drugs will be exempt from the recommendations because of the risk that addicts will retrieve the pills from garbage cans.)

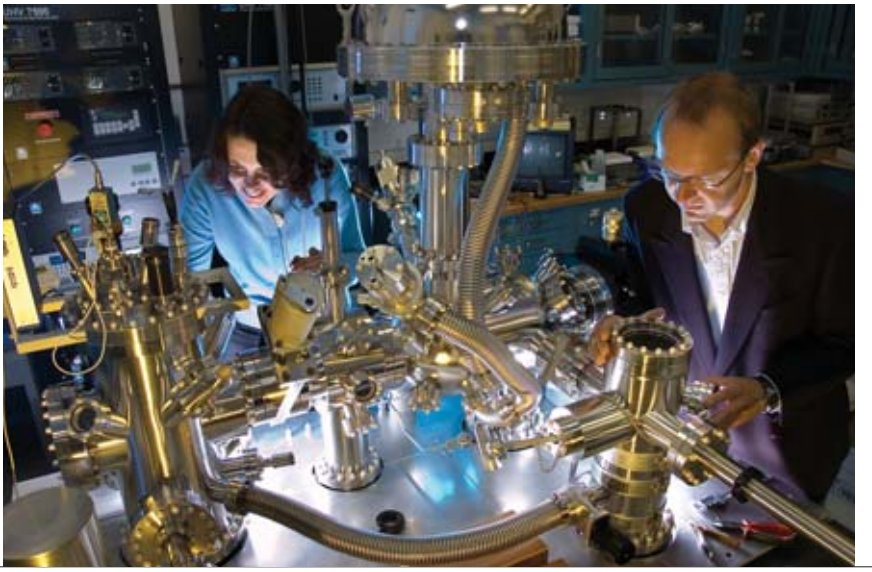
An even better solution would be the establishment of incentives to encourage consumers to return their unused drugs to pharmacies. Pilot programs of this type are now operating in California, Washington State and Maine. —*Mark Alpert*

Advances in Ultrameasurement

Zeptoliter pipettes and quantum rulers give new meaning to the word "small"

Scientists use pipettes when they need to dispense well-defined volumes of liquid. Existing pipettes can deliver fluid volumes as small as an attoliter—a quintillionth, or a billionth of a billionth, of a liter.

Physicists Peter W. Sutter and Eli A. Sutter of Brookhaven National Laboratory have broken that lower limit by constructing a pipette that metes out a droplet measured in a unit that is a thousandth as small—a zeptoliter (a sextillionth of a liter). Such a minute volume



Eli A. Sutter and Peter W. Sutter built the world's smallest pipette, which helped to show that droplets of liquid metal freeze differently than scientists expected.

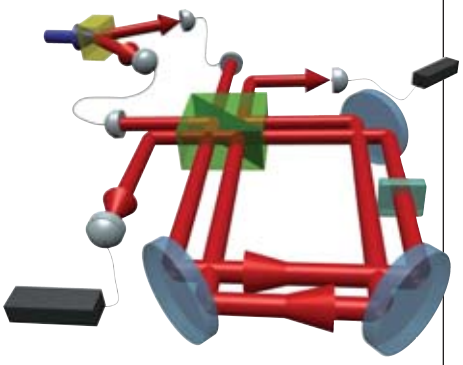
KRISTY-ANNE GLUBISH *Design Pics/Corbis (top)*; COURTESY OF BROOKHAVEN NATIONAL LABORATORY *(bottom)*

can contain as little as 10,000 to as much as a million atoms of metal.

The researchers used a germanium nanowire with a solid reservoir of gold-germanium alloy at one end. They encapsulated the two-micron-long assembly in a carbon shell, which constituted the pipette. Inside a vacuum chamber, they heated and melted the alloy and then aimed an electron beam at the shell's tip. The beam bored an escape hole for the molten metal, which formed a minuscule droplet up to 40 nanometers in diameter and 35 zeptoliters in volume.

If measuring things in zeptoliters is difficult, consider doing so at a scale where the rules of classical physics cease to prevail. Quantum metrology—the field in which quantum mechanics is used to obtain highly precise measurements—has allowed physicists at Hokkaido University in Japan and the University of Bristol in England to almost double the precision of measurement when using photons to gauge distances.

The scientists have built on previous work that uses photons "entangled" in the same quantum superposition of states. The team directed two photonic pairs into an interferometer—an instrument that creates a circular beam path with mirrors in which light waves interfere with one another. Each photon splits, taking separate paths simultaneously. Four photons in an entangled state circulate around the interferometer in one direction, and another quadruplet traverses the loop in the other. The interference produced by the countercirculating photons reveals tiny differences in how far each quadruplet has traveled.



Entangled photons in an interferometer make ultraprecise measurements.

The precision measurements could, for example, be useful when using lasers to etch ultrathin circuits on computer chips. —*Steven Ashley*

Mosquitoes Enlisted to Beat Malaria

Bugs engineered to avoid transmitting the disease could outcompete bugs that do transmit it

Malaria still kills more than a million people a year. Even though low-tech measures such as spraying insecticides and distributing treated bed netting to residents can reduce infection rates, poor countries, where most victims live, cannot afford them.

As an alternative strategy, researchers have tried for years to genetically engineer mosquitoes so they will not transmit the disease. Malaria is caused by protozoan parasites that reproduce inside human liver and red blood cells and are passed from person to person by female *Anopheles* mosquitoes. Although several research teams managed to insert genes into lab-bred mosquitoes that made the bugs less hospitable to the parasites, the altered strains did not reproduce or survive as well as wild strains did.

But last March microbiologist Marcelo Jacobs-Lorena of Johns Hopkins University announced results indicating that engineered insects could outsurvive wild ones. Jacobs-Lorena inserted a gene into *Anopheles* that directs production of a peptide called SM1, which manifests in the mosquito's gut and prevents malaria parasites in rodents from reproducing. The Johns Hopkins team put the transgenic and natural mosquitoes in cages with malaria-infected mice, on which the mosquitoes fed. Over time the mosquitoes reproduced. After nine generations, transgenic bugs made up 70 percent of the overall population. The disease-resistant strains not only competed with the wild ones but survived better.

Mosquitoes can be genetically engineered to avoid passing malaria to humans.

The test did not prove that infection-resistance genes would spread in the wild, but it raised hope that mosquitoes doped with those genes would survive. Hardly a month later, however, biologist Bruce A. Hay of the California Institute of Technology presented evidence that engineered genes can indeed spread throughout a bug population. Working with fruit flies, Hay's team combined a segment of noncoding RNA, known as a microRNA, with a gene that was critical to the development of fruit fly embryos; the researchers then altered that gene so that it was unaffected by the RNA. Next they released the fruit flies into cages with three times as many normal flies. As generations mixed, wild flies that incorporated the microRNA died because it destroyed their unprotected version of the critical developmental gene, whereas flies that bore the altered version of that gene were able to survive. After nine to 11 generations, all the offspring in the cage carried the human-made gene combination. —*Mark Fischetti*

FROM "BEATING THE STANDARD QUANTUM LIMIT WITH FOUR-ENTANGLED PHOTONS," BY T. NAGATA ET AL., IN *SCIENCE*, VOL. 316; 2007. REPRINTED WITH PERMISSION OF AAAS (*top*); SINCLAIR STAMMERS *Photo Researchers, Inc.* (*bottom*)

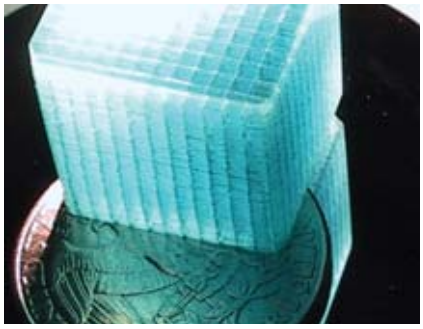
Material World

Scientists take inspiration from nature and instill novel magnetic properties

Cut your finger, and your body starts mending the wound even before you have had time to go and find a Band-Aid. Synthetic materials are not so forgiving, but Nancy R. Sottos, Scott R. White and their colleagues at the University of Illinois at Urbana-Champaign are looking to change all that. They developed a self-healing plastic that contains a three-dimensional network of microscopic capillaries filled with a liquid healing agent. When the material is cracked, the released fluid is hardened by particles of a catalyst that are also sprinkled throughout. The new material can repair minor cracks up to seven times at each location, improving on the group's previous system (in which the fluid was located in individual pockets) that could repair only one injury at each place.

Another feature of natural organisms that scientists have been seeking to emulate is self-assembly. Benoît Roman and José Bico of the City of Paris Industrial Physics and Chemistry Higher Education Institution used the surface tension of evaporating water droplets to fold flea-size origami cubes, pyramids and other structures. Their work used shapes measuring about a millimeter across cut out of a rubbery polymer a mere 40 to 80 microns thick. Thanks to the way that surface tension scales with size, the technique may be effective for self-assembling micron- or nanometer-scale objects made of thinner sheets of polymer.

Electronic components based on plastic or organic materials have become increasingly common in recent years, but the same cannot be said for magnets. Now Robin G. Hicks of the University of Victoria in British Columbia, Rajsapan Jain of the University of Windsor in Ontario and their co-workers have produced a new class of magnets that combine nickel with a variety of organic compounds. The dark, powdery substances remain magnetized up to 200 degrees Celsius. The researchers' ultimate goal is to produce magnetic organic compounds that can be easily molded into thin films or other useful shapes for electronics.



When cracked, the plastic cube releases a self-healing agent from its microvascular network—up to seven times at one location.

It was thought that the only way to see the exotic state of matter known as a Bose-Einstein condensate—in which a collection of particles essentially behaves as one superparticle—involved forbidding, near-absolute-zero cold. Sergej Demokritov of the University of Muenster in Germany and his colleagues were the first to create such condensates at room temperature. Demokritov used small, ephemeral packets of magnetic energy known as magnons, which he generated in yttrium-iron-garnet films by exposing them to microwaves. Magnons are far less massive than atoms and thus can form condensates at much higher temperatures.

—Graham P. Collins and Charles Q. Choi

Neurological Insights

Biologists devise a memory on a chip and new ways to tackle Alzheimer's

How does a memory form? To demonstrate how this process occurs at the most basic level, biophysicists at Tel Aviv University replicated that event with neurons attached to a computer chip. Itay Baruchi and Eshel Ben-Jacob placed neurons from rat embryos on a chip surface and connected 64 electrodes to record activity. The researchers witnessed an identical pattern of nerve firings when chemical stimulants were dropped repeatedly at the same location on the chip. After some time, the neurons began to fire in the same way without chemical activation—the point at which they claim a memory becomes imprinted.

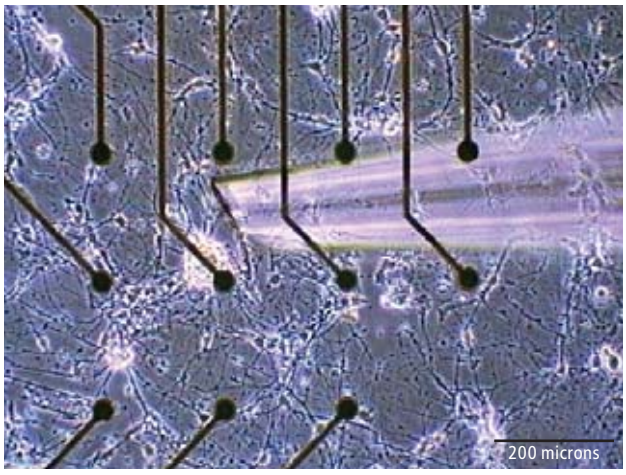
Understanding differences between the proteins made by normal and diseased brain tissues may provide a new approach to diagnostics. Richard D. Smith of the Pacific Northwest National Laboratory and Desmond J. Smith of the University of California, Los Angeles, have created a complex system for analyzing proteins that combines advanced instrumentation with sophisticated image processing to inspect one-millimeter cubes of brain tissue from a pair of normal mice. The investigators determined the abundance of 1,028 proteins in the tissues. Future experiments will use this methodology to compare normal brain tissue with that afflicted by a neurodegenerative disease.

Better diagnostic techniques are needed, in particular, for Alzheimer's disease.

ROB SHEPHERD *University of Illinois at Urbana-Champaign*

Stina M. Tucker, Esther Oh and Juan C. Troncoso of the Johns Hopkins University School of Medicine demonstrated a test using antibodies that bind to the amyloid-beta proteins that form damaging plaques in the brains of Alzheimer's patients. The antibodies adhered to proteins in an early stage of a disease that mimics Alzheimer's in genetically engineered mice. That finding might eventually lead to a test for humans that could be used along with drugs under development to avert the disease through preventive treatment.

Conceivably, that test could be combined with a treatment that uses phages—viruses that infect bacteria—to break up noxious plaque. Beka Solomon of Tel Aviv University showed preliminary proof of this idea by administering phages via a nasal spray to 100 mice genetically engineered to develop Alzheimer's-like plaques. After a year of treatment, the mice had 80 percent fewer plaques than untreated mice. —*Gary Stix*

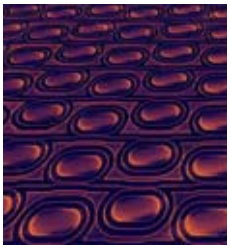


Electrodes record when neurons fire so that a memory forms.

Light Manipulation

New technologies exercise extraordinary control over light

As computer chips become ever more prodigious in their data-processing capacities, the task of shuttling all those gigabits around inside a chip becomes an increasing challenge. Help may be on the way in the form of photonic components, which deal in pulses of light instead of slower packets of electric charge. For several years researchers have been making so-called silicon optical waveguides, in which light speeds along inside the ridge between two channels as if along an optical fiber.



Microscopic loops control light pulses.

But such optical interconnects must deliver their data at precise times, which requires delaying the light pulses by controlled amounts. One method is to send the light pulses into microscopic loops made of waveguides where they circulate dozens of times before continuing on their journey. Yurii A. Vlasov and his coworkers at the IBM Thomas J. Watson Research Center in Yorktown Heights, N.Y., sent pulses of light through strings of as many as 100 such loops without suffering prohibitive losses of data.

Another way of delaying light in microscopic devices is to use photonic crystal components, which contain carefully designed arrays of holes whose size and spacing exclude light in a certain frequency band (a so-called photonic band gap). A photonic crystal waveguide can consist of a path without holes running through such an array in a thin slab of silicon. The band gap generated by the holes on each side of the path confines the light to travel that route. Takasumi Tanabe and his colleagues at the NTT Basic Research Laboratories in Japan took this scheme several steps forward by temporarily storing photons in a photonic crystal nanocavity—in this case, a small region where the waveguide is slightly wider.

Whereas some researchers want to delay light, others at the Rensselaer Polytechnic Institute led by E. Fred Schubert have created a coating that reflects almost none of it. The coating, about 600 nanometers thick, consisted of five layers of nanorods—titanium dioxide and silica filaments about 25 nanometers in diameter and up to 300 nanometers long—stacked on a transparent semiconductor wafer. Each layer had a lower refractive index than the one below it. The uncoated semiconductor reflected about 12 percent of light incident on it; when coated, it reflected as little as 0.1 percent. The coating could have applications in photonic components, light-emitting diodes and solar cells.

Other investigators are pursuing the far more speculative goal of building quantum computers, which would exploit weird features of quantum mechanics to achieve unprecedented processing capabilities. One approach involves storing quantum data as long-lived states of atoms and transmitting the information with light waves. But combining those two media requires the transfer of delicate quantum states between matter and light. In 2006 a group of researchers led by experimentalist Eugene S. Polzik of the Niels Bohr Institute at the University of Copenhagen and theorist Ignacio Cirac of the Max Planck Institute for Quantum Optics in Garching, Germany, teleported quantum information from a light pulse to a cloud of atoms. —*Graham P. Collins*

ITAY BARUCHI AND ESHEL BEN-JACOB (*top*); IBM (*bottom*)