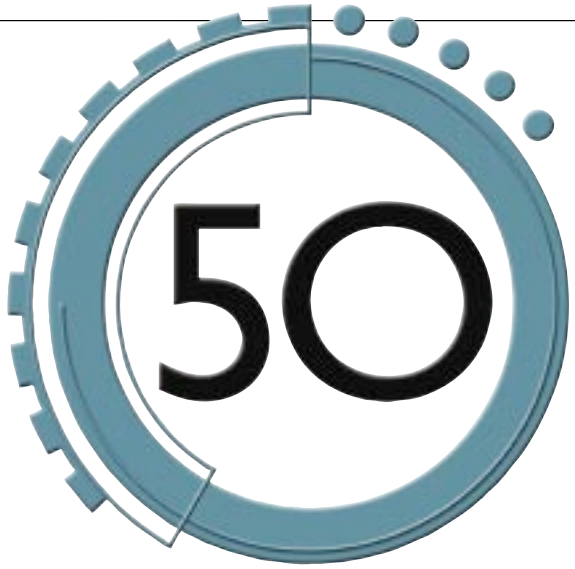
SCIENTIFIC AMERICAN



TRENDS

Entrepreneurial Global Health

Green Cars

Alzheimer's Treatments

Plasmonics

Stem Cells

Smart Tags

Carbon Electronics

Tissue Engineering

Robotics

DNA Sequencing

Cool Materials

Vision Prosthetics

A group of scientists have detailed how to create materials that can redirect light around an object and make it invisible. This possible precursor to the ultimate camouflage demonstrates the depth of ingenuity of the 2006 SCIENTIFIC AMERICAN 50 awards.

These accomplishments go beyond invoking the Invisible Man. Drawn from the worlds of research, business and policymaking, a good number of the names on our list have in common an interest in leading technological innovation as a force for the public good: A fundamental understanding of the molecular processes that produce the mind-erasing devastation of Alzheimer's. A hybrid car that recharges by simply plugging into the wall. A billionaire who gives up much of his fortune to improve the state of global health.

Some of the inventions of this year's winners may soon be found at big retailers or in hospital dispensaries. Yet many of the researchers garnering accolades concentrated on basic questions, occupying themselves, for instance, with learning about the mechanisms that transform one stem cell type into a more specialized cell type—knowledge that will help answer the critical question of whether these wondrous biological entities will ever prove useful in clinical practice. Throughout the list of winners, that same theme reasserts itself: the most fundamental science precedes the technology that is eventually put to service in treating Alzheimer's or fashioning new devices that might outperform silicon electronics.

SA 50

RESEARCH LEADER OF THE YEAR

Angela Belcher

Massachusetts Institute of Technology

This eclectic investigator draws inspiration from nature's genius for building things at the nanoscale

Living things can serve as factories. Angela Belcher has used a virus to construct nanowires and semiconductor devices.

The crux of nanotechnology is the problem of self-assembly, getting uncooperative atoms to link and align themselves precisely. We know it can be done, of course: life persists by turning molecules into complex biological machinery. How fitting, then, that one of today's most creative materials scientists, Angela Belcher of the Massachusetts Institute of Technology, has turned to nature for assistance. Belcher has pioneered the use of custom-evolved viruses in synthesizing nanoscale wires and arrays, fusing different research disciplines into something uniquely her own.

Belcher's goal is to harness living things as factories for assembling materials made from any of the elements of the periodic table. Her greatest success has come from the M13 bacteriophage, a long, tubular virus six nanometers wide. She engineered a version of the virus that latched onto quantum dots, tiny specks of semiconductor with desirable electromagnetic properties. By suspending the virus particles, she could make them line up, an effective means of creating finely spaced layers of quantum dots that are separated by layers of virus.

More recently, she customized M13 to stud its length with metal particles such as cobalt oxide and gold, yielding metal nanowires that could be assembled into high energy-density electrodes. Those could be incorporated, for example, into lightweight, thin-film batteries that can be easily molded to fit any space. Belcher co-founded Cambrios Technologies in Mountain View, Calif., to turn some of these demonstrations into commercial devices such as flexible, touch-sensitive screens and light-emitting diodes. In her work, DNA shows its worth as more than just the code of life. —*JR Minkel*

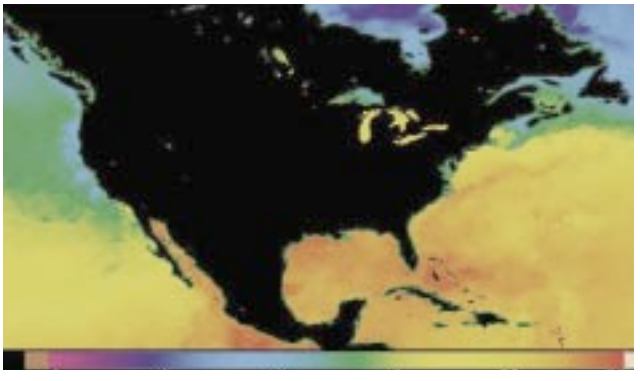
BUSINESS LEADER OF THE YEAR

SA 50

Swiss Re

Zurich, Switzerland

A top insurer highlights the dire consequences that could result from global warming



Global insurer Swiss Re has warned of the potentially disastrous effects of global warming, even co-sponsoring a report on its impact.

When one thinks of those trying to spread the word about the risks of global warming to society, one of the most reputedly staid industries probably does not leap to mind. Global reinsurer Swiss Re is looking to change that. Having long had its eye on climate change, the company co-sponsored a major report, released in late 2005, highlighting the potentially disastrous economic consequences of global warming. The report notes: "Insurers and reinsurers find themselves on the front lines of this challenge since the very viability of their industry rests on the proper appreciation of risk."

Climate change poses a special problem for the industry because it could dramatically change the rates of extreme weather events, perhaps to a point where insurers would be unable to keep up. The report, co-sponsored by the United

DONNA COVENEY *Massachusetts Institute of Technology* (*top*); NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (*bottom*)

Nations Development Program and published jointly with the Center for Health and the Global Environment at Harvard Medical School, outlines recent trends in climate and severe weather and traces the possible effects of two different climate change scenarios on prospects for heat waves and flooding, infectious and chronic disease, and managed and natural resources. Both scenarios are based on unchecked greenhouse gas emissions.

Swiss Re has a history of sensitivity to climate change concerns. In 2003 the insurer announced it was establishing a 10-year plan to become greenhouse "neutral," meaning it would reduce or offset the net carbon emissions of its employees to zero.

Last year the company joined the Chicago Climate Exchange, a voluntary market for greenhouse gas emissions trading. With the release of its 2005 report, Swiss Re called on governments and global industry to take much stronger action to mitigate the consequences of climate change: "[L]ittle action has been taken by most governments or businesses to address the potential costs of climate change. As all insurers know, however, risk does not compliantly bow to the political or business agenda." *—JR Minkel*

POLICY LEADER OF THE YEAR

SA 50

Al Gore

U.S. Vice President

The former presidential candidate is the preeminent spokesperson on climate change

It sounds improbable: a documentary film about global warming, starring Vice President Al Gore, has become the third-highest-grossing documentary of all time. After his loss in the 2000 presidential election, Gore began giving a talk on global warming to audiences around the world. *An Inconvenient Truth* is the film version (also appearing in book form) of his multimedia presentation. Remarkably, its heavy use of PowerPoint slides actually adds to the narrative, which interweaves explanations of climate science with defining episodes from Gore's life to convey a mix of alarm and hope.

The film is a paragon of clear science communication. It explains the workings of complex physical phenomena, such as the jet stream, while chronicling the reality of glaciers receding and the increase in carbon dioxide emissions and global temperatures. Gore, meanwhile, succeeds in bringing the "moral imperative" of reducing greenhouse gases to a personal level, attempting to convince viewers that their own actions can make a difference.

His appeal to individual responsibility is enhanced by the way the former politician, often lampooned for his stiff speaking style, gives the viewer a glimpse of his own life. In one of the film's strongest scenes, Gore recounts how his older sister's death from lung cancer led his family to stop growing tobacco—a painful metaphor for the industrial world's predicament in coming to grips with excess atmospheric carbon.

The film provoked commentary from across the political spectrum. After its release, the conservative Competitive Enterprise Institute attacked: "Carbon dioxide—they call it pollution; we call it life."

But movie critics drew attention to it by generally lavishing praise: "You owe it to yourself to see this film," urged Roger Ebert. "If you do not, and you have grandchildren, you should explain to them why you decided not to." The achievement of *An Inconvenient Truth* has been to bring the most important scientific and technical issue of our time into the public view better than anything before in print or film.

—JR Minkel and Gary Stix

Environmentalist Al Gore has dramatized the scientific case for global warming in the film *An Inconvenient Truth,* which has become one of the highest-grossing documentaries of all time.

More Than Government Grants

Entrepreneurial ingenuity focuses on finding money and ideas to advance medical science

To lift the burden of infectious diseases in poor nations, Harvard University economist **Michael Kremer** has advocated a kind of artificial market for vaccines. In Kremer's scheme, a donor would commit to paying a certain sum for the development of a vaccine and would purchase it at a high price per dose. After that, the company would supply the vaccine to poor countries at a low price.

Kremer's approach is one of many that have marshaled unprecedented creativity to chart new paths for medical research. A different attempt is the brainchild of **Scott Johnson**, a 50-year-old former businessman who is waging a personal battle against multiple sclerosis. His Myelin Repair Foundation, established in 2003, has persuaded five of the field's top university researchers to merge their laboratories and create a more businesslike plan for developing treatments.

Similarly, four leading cancer centers have linked efforts to coordinate clinical trials, share resources and pool their findings on a deadly bone disease: multiple myeloma, a blood cancer that erodes bones and often kills quickly. Leading the project is **Kathy Giusti**, a pharmaceutical executive who learned that she had multiple myeloma in 1996. A graduate of Harvard Business School, Giusti set up the Multiple Myeloma Research Foundation, which has raised $60 million for research.

Warren E. Buffett (*right*) is giving away 10 million shares (more than $30 billion) of his company, most of it to the foundation run by Bill and Melinda Gates (*left*).

Christiane Nüsslein-Volhard, a pioneering geneticist and co-winner of the 1995 Nobel Prize in Physiology or Medicine, has taken perhaps the most personal approach. With her own money and a $100,000 award from UNESCO-L'Oréal's Women in Science Program, she has launched a foundation in her own name that offers grants to young female scientists to pay for babysitters and household help.

Warren E. Buffett's innovation may be the most surprising of all. In what *Fortune* magazine described as "typical Buffett: rational, original, breaking the mold of how extremely rich people donate money," the world's second-richest man, after Bill Gates, is giving away 85 percent of his wealth, most of it to the Bill and Melinda Gates Foundation. The examples of Buffett and Bill and Melinda Gates are inspiring other leading executives and research professionals to bring their imaginations to bear on conducting the business of research.

—Michelle Press

On the Road to Green

Chemists and automakers mark progress toward environmentally benign fuels and vehicles

Motorists have heard a lot lately about ethanol-based fuels, which burn cleaner than gasoline and derive from renewable, domestic biomass. **Iogen Corporation** has furthered this technology by developing enzymes to convert tough, sugar-bearing cellulose in inexpensively produced agricultural waste into ethanol (*opposite page, top*).

Another renewable alternative fuel is biodiesel—predominantly vegetable oils that are processed to serve as a clean-burning fuel for diesel engines. **Michikazu Hara** of the Tokyo Institute of Technology and his colleagues have demonstrated that a charred mixture of inexpensive sugars, starches or cellulose can be treated to formulate an effective solid-acid cata-

SETH WENIG *AP Photo*

lyst for making biodiesel that is insoluble, cheap to prepare and easy to recycle.

Engineers are toiling to make diesels operate with fewer nitrogen oxide emissions. A leader in this quest is German-based automaker **DaimlerChrysler**, which recently introduced BLUETEC technology—a modular exhaust treatment system that cuts nitrogen oxide and soot output significantly, enabling cars to meet the most stringent U.S. emission standards.

Another technology that gets better mileage than standard engines, and hence produces less carbon dioxide for each mile driven, is the gasoline-electric hybrid, which marries a gasoline engine with electric motors. Current hybrid vehicles save fuel in stop-and-go driving but provide little mileage benefit on the highway. The new two-mode hybrid system from **General Motors**, **DaimlerChrysler** and **BMW** boosts fuel efficiency at both low and high speeds, improving combined mileage 25 percent over standard models.

Yet another way to raise the environmental performance of hybrid vehicles is to give them the means to store electrical grid power so that at times they can run on electricity alone instead of drawing power from a fossil-fuel-burning engine. These plug-in hybrids came closer to reality when two companies, **EDrive Systems**, a joint venture of EnergyCS and CleanTech in California, and **Hymotion**, a Canadian company, each introduced plug-in hybrid upgrade kits for the Toyota Prius. In the wake of these developments, the road to a greener, more sustainable energy future seems to be opening up.

—Steven Ashley

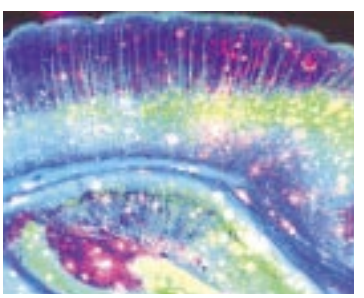
A top environmental official for the European Commission fuels a car with logen's cellulosic ethanol, derived from renewable biomass.

Unlocking Alzheimer's

Understanding the workings of a key protein may presage treatments

With the elderly segment of populations ballooning worldwide, the race to defeat that grim corollary of aging, Alzheimer's disease, is becoming all the more urgent. This year saw several encouraging advances on that front. In what reviewers described as a "technological tour de force," **John R. Cirrito** and **David M. Holtzman** of the Washington University School of Medicine in St. Louis traced production of a destructive Alzheimer's protein, known as amyloid-beta (*right*), to the junctions between neurons called synapses. They then directly linked high synaptic activity to amyloid-beta increases.

One key to counteracting the devastating effects experienced by patients is detecting the disease early, and another feat by Holtzman, with **Randall J. Bateman**, also at the Washington University School of Medicine, should make that possible. They have devised a test that measures the manufacture and disposal of amyloid-beta in the brain. Their technique might eventually serve as a basis for detecting the disease early and measuring drug effects on already diagnosed patients.



A mouse brain genetically engineered to exhibit the pathologies of Alzheimer's disease helps to define the destructive role played by amyloid-beta protein (*red*).

One of those treatments might someday be based on a synthetic protein fragment that **Robert P. Hammer** of Louisiana State University has developed to disrupt formation of the plaques believed to provoke massive brain cell death in Alzheimer's patients. The plaques are aggregations of fibers that form when individual amyloid-beta peptides begin sticking together abnormally. Hammer tweaked building blocks of amyloid-beta, synthesizing a nonsticky version of the amino acids that bind the proteins. Adding the engineered fragments to a test tube of normal amyloid-beta blocked the proteins' ability to form fibers, even after four months' exposure. If it does the same in human brains, tens of millions of Alzheimer's sufferers might finally be liberated from a deadly burden of poisonous plaque.

—Christine Soares

IOGEN CORPORATION (*top*); ROBERT P. BRENDZA AND JOHN R. CIRRITO, LABORATORY OF DAVID M. HOLTZMAN *Washington University School of Medicine in St. Louis* (*bottom*)

Beginning to See the Light

Two-dimensional light waves point toward optical imaging of viruses and the Invisible Man

In a remarkable feat of lateral thinking several years ago, electrical engineer **Igor I. Smolyaninov** deduced the properties of electromagnetic waves by applying the physics of time machines. The University of Maryland professor was studying what has become one of the sexiest areas of materials science: plasmonics, in which light is turned from a three-dimensional wave (a photon) into a two-dimensional one (a plasmon) rippling along, for example, the side of a metal sheet. If you put a droplet of liquid on the sheet, the plasmons can be trapped—just like photons inside a black hole. In fact, the hole might be used to create an analogue to a time machine and cause all the contradictions familiar to aficionados of science fiction. Smolyaninov reasoned that if time machines do not work, then neither should their analogues, from which he drew conclusions about the behavior of the waves.

Plasmon microscope captures nanometer-scale detail on a square chip.

He and his colleagues have now used the liquid-droplet black hole analogue to create a microscope that can see details smaller than the wavelength of the illuminating light—a feat that physics textbooks used to say was impossible. The key is that plasmons have a shorter wavelength than the photons from which they were converted, so they respond to finer features. Smolyaninov's team used laser light with a wavelength of about 500 nanometers to generate plasmons with a wavelength of 70 nanometers. A drop of glycerin focused them to form a 2-D image, which a regular optical microscope viewed (*above*).

Like plasmonics, the related science of metamaterials—the creation of artificial atoms with optical properties unlike those of any natural atom—is a door into a world so fantastic that it must surely be imaginary and yet isn't. This spring **John B. Pendry** of Imperial College London, along with **David Schurig** and **David Smith** of Duke University, and, independently, **Ulf Leonhardt** of the University of St. Andrews in Scotland predicted that a shell of metamaterials could redirect light around an object and render it invisible. The Duke researchers demonstrated an "invisibility cloak" in October.

Nader Engheta of the University of Pennsylvania and his colleagues have proposed a standardized set of plasmonic components akin to resistors, capacitors and inductors, which could let engineers build circuits using light rather than electricity. One day soon the fantastic world of plasmonics may be hanging from the rack at RadioShack.

—*George Musser*

The Promise of the Mother Cell

Stem cell biology continues to hint at medical benefits to come

A recent research trend has targeted the goal of having one's stem cells and preserving embryos, too—a nod to powerful critics such as President George W. Bush. Even if an embryo remains intact—the objective of these studies—it is unclear whether these methods will ever satisfy Bush and others who rail against what they perceive as immoral tinkering with the stuff of life.

Kevin Eggan and his colleagues at the Harvard Stem Cell Institute brought together embryonic stem cells with skin cells, or fibroblasts, creating fusion cells that reprogrammed themselves to resemble embryonic stem cells genetically matched to the donor of the skin cell. These cells would have the versatility to turn into any other cell type—and would not require a cloning procedure that necessitates the destruction of an embryo.

The promise of stem cells was again reaffirmed by an experimental therapy to treat patients with lupus—a disease in which the patient's immune system targets the body's own tissue. A group led by **Richard K. Burt** of the Northwestern University, Feinberg School of Medicine, removed stem cells from the patient's bone marrow. Drugs then wiped out the population of white blood cells before the stem cells were returned to the body, where they formed new white blood cells that were less likely to make damaging antibodies. In a study of 48 patients, half did not have the disease after a period of five years.

Determining how an embryonic stem cell differentiates into mature cells might eventually allow development of methods to reprogram an adult cell. Those techniques might let the mature cell return to its pluripotent state, in which it is capable of turning into different cell types. **Laurie A. Boyer** and **Richard A. Young** of the Whitehead Institute for Biomedical Research and their colleagues demonstrated how three proteins control this process.

IGOR I. SMOLYANINOV *University of Maryland*

Another research finding highlighted the importance of exploring the complexities of stem cell biology without having to satisfy the demand for immediate medical benefits. **Susan L. Lindquist** of the Whitehead Institute and her collaborators demonstrated that the prion protein, which causes mad cow disease when malformed, has a critical stem cell–related function in the body in its normal state. The protein appears to help nurture and maintain the body's supply of stem cells that produce blood cells.

Bush's decision to limit stem cell research to 78 existing cell lines has hindered the field. Today far fewer cell lines are viable than the original number permitted, and many of them are contaminated. Representative **Diana DeGette** of Colorado, a Democrat, and Representative **Mike Castle** of Delaware, a Republican, have been trying to loosen restrictions. They have succeeded in getting support from their colleagues in Congress but were ultimately stymied by Bush's veto—the first of his administration. A commitment is needed to continue basic research on stem cells unfettered by political considerations.

—Gary Stix

Smart Tags Get Smarter

The next generation of electronic tags promises to outperform RFIDs

The proliferation of radio-frequency identification (RFID) devices over the past decade has been nothing short of remarkable. But one of the most sweeping promises of the RFID revolution—that the devices will replace the ubiquitous bar code—has not yet come to pass because of their cost. So researchers have been striving to build RFIDs from a cheaper material: plastic.

In 2005 a group of engineers at **IMEC**, a company based in Leuven, Belgium, overcame a major hurdle by constructing a diode made of pentacene, an organic compound that has semiconducting properties. Prior to IMEC's breakthrough, organic devices were considered too slow to power RFID chips. The next step came early this year when a group led by **Eugenio Cantatore** of Philips Research Laboratories in Eindhoven, the Netherlands, announced that it had built a fully functional RFID tag made entirely of plastic electronics. Such a chip would be simpler to manufacture than a silicon-based tag because the design could be directly printed onto a plastic substrate. The elimination of complex assembly may pave the way for low-cost RFID tags incorporated into product packaging. And because RFID readers have a range of a few meters, supermarket clerks could speed the checkout process by scanning all the contents of a grocery cart at once.

Meanwhile engineers at **Hewlett-Packard Laboratories** have devised a miniature wireless chip that could eventually replace RFID tags in many applications. Called the Memory Spot (*below*), the chip can hold up to four megabits of flash memory and transfer those data to a reader at 10 megabits a second. It could be embedded into passports, postcards, pharmaceutical labels and hospital wristbands.

—Mark Alpert

Memory Spot embedded in a book could provide supplemental text, images and video to anyone with a portable reader.

COURTESY OF HP LABS

Chicken-Wire Electronics

Carbon structures provide new devices and remarkable physics

Since the 1985 discovery of buckyballs (such as the buckminsterfullerene—a nanoscopic sphere of 60 carbon atoms connected in a pattern similar to a traditional soccer ball), researchers have focused intense attention on various chicken-wire-like carbon structures. The latest addition to the menagerie is graphene, a flat single layer of carbon atoms bonded together in the hexagonal pattern of graphite.

In November 2005 two independent research groups, one led by **Andre K. Geim** of the University of Manchester in England and the other by **Philip Kim** of Columbia University, experimen-

tally confirmed some extraordinary electronic properties of graphene: the effective mass of electrons in graphene is zero, and they behave like elementary particles obeying a version of Einsteinian relativity instead of Newton's laws of motion. The results open up a remarkable new domain of relativistic physics that can be explored in tabletop experiments.

The development of graphene devices, which might eventually outperform silicon, took a major step forward when **Walter de Heer** of the Georgia Institute of Technology, along with his collaborators there and at the National Center for Scientific Research in France, used standard microelectronics-industry techniques to make graphene transistors and other circuitry. The ease with which graphene can be shaped to order could give it the edge over carbon nanotubes, which are much harder to build into complex devices.

Nanotube researchers are also continually breaking new ground. **Prabhakar R. Bandaru** of the University of California, San Diego, and his colleagues there and at Clemson University demonstrated a radically new kind of nanotube-based transistor. Its novel Y shape allows for the elimination of a metal electrode that controls current flow, enabling the transistor to be much smaller than previous designs.

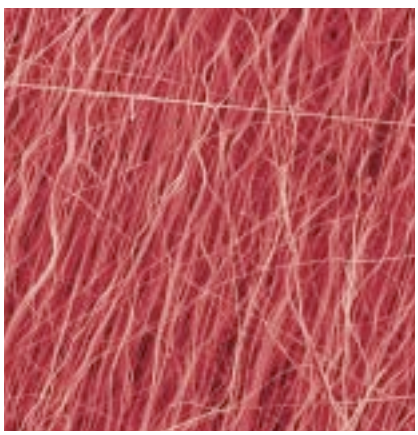
In the field of macroscopic materials made of carbon nanotubes, **Ray H. Baughman**, **Mei Zhang** and **Shaoli Fang** of the NanoTech Institute at the University of Texas at Dallas, along with their collaborators there and at the Commonwealth Scientific and Industrial Research Organization in Belmont, Australia, developed an efficient new way to make thin sheets of nanotubes that might be rapidly adaptable to commercial production. The sheets are strong, lightweight, transparent, highly flexible and electrically conductive, ideally suiting them to be used as components of displays, solar cells, organic light-emitting diodes and artificial muscles, among other applications. Whether it is flat as in graphene or rolled up into nanotubes, the chicken-wire form of carbon continues to go from strength to strength.

—Graham P. Collins

Growing Replacement Parts

Bioengineers can now cultivate blood vessels and other tissues from scratch

With the goal of mimicking the mechanical properties of soft tissue, bioengineers **William R. Wagner** and **Michael S. Sacks** of the University of Pittsburgh have fashioned an inexpensive polymer, polyester urethane urea, into a biodegradable scaffold. This cylindrical scaffold's strength resembles that of a pulmonary valve because it responds to stress differently depending on the direction in which the stress is applied. A patch of this biomaterial infused with smooth muscle cells (*right*) functions as vascular tissue, promoting healing and reducing formation of scar tissue in the hearts of rats recovering from cardiac arrest.



A polymer scaffold incorporates smooth muscle cells so that the device can serve as a foundation on which vascular tissue forms.

Already having reached the phase of clinical trials, the California bioengineering company **Cytograft** has patented a method for growing blood vessels from a human patient's own cells. In a feasibility trial undertaken in Argentina, Cytograft implanted its engineered vessels into two dialysis patients. Neither patient encountered problems with the implants for at least nine months.

One barrier to progress in tissue engineering results from the inability of thick tissue such as muscle, once implanted in a patient, to receive sufficient penetration of new blood vessels from the body's own network to keep the tissue alive. To address that problem, a multi-institution team spearheaded by **Shulamit Levenberg** of the Technion-Israel Institute of Technology in Haifa has created small pieces of muscle capable of generating its own blood vessels.

The researchers combined on a plastic biodegradable scaffold three types of cells: myoblasts that become muscle fibers, endothelial cells that form into vessel tubes, and fibroblasts that are the precursors to the smooth muscle cells that stabilize the cell walls. The endothelial cells became vessels, recruited fibroblasts and caused them to differentiate into smooth muscle cells. Once implanted in a rat, less than half the vessels became perfused with blood. But twice as many cells survived when implanted with the three cell types than implants made up of myoblasts and fibroblasts unaccompanied by the vessel-producing endothelial cells. The technique might eventually help address the persistent challenge of supplying engineered cells with oxygen and nutrients and allowing them to remove wastes.

—Brie Finegold and Gary Stix

WILLIAM R. WAGNER *University of Pittsburgh*

The two-legged robot called RABBIT walks in a manner similar to a human.

Robots on the Move

Improved mathematical models and sensors endow robots with enhanced mobility

In October 2005 teams watched their robots attempt to navigate the rugged Mojave Desert as part of a challenge sponsored by the Defense Advanced Research Projects Agency (DARPA). The previous year's challenge had ground to a halt when none of the competitors completed more than 5 percent of the 150-mile race. But last year everything changed. Four robots finished the race in fewer than 10 hours, and the winning **Stanford Racing Team**'s robot, fondly named Stanley, clocked speeds as high as 38 miles per hour. This dramatic turn of fortune can be attributed to advances in software and sensors.

While onboard laser and radar systems scanned the terrain, machine-learning algorithms tracked and studied the images, allowing Stanley, a modified Volkswagen Touareg, to swerve around obstacles and negotiate turns. Probabilistic methods for analyzing the road ahead kept Stanley from a common pitfall for robotic vehicles: hallucinating imaginary obstacles.

While Stanley may have a human name, the two-legged robot RABBIT has a disarmingly human gait (*left*). **Jessy W. Grizzle**, a control theorist at the University of Michigan at Ann Arbor, has tested his new mathematical model of walking and running on RABBIT, whose lower legs taper to wheels rather than feet. Because this robot is not able to statically balance on one leg, the model incorporates the effects of gravity more fully than other models. As scientists endeavor to automate more human tasks, robots may exhibit pleasing form as well as function.

—Brie Finegold

DNA Sequencing on the Cheap

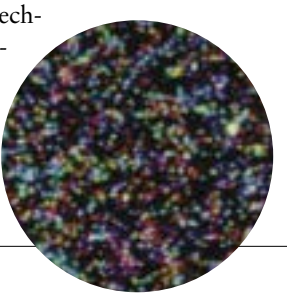
Optical technology advances toward the $1,000 genome

The exorbitant cost of deciphering a person's genome dropped sharply in 2005, from $20 million to roughly a tenth of that amount. DNA-sequencing technology using off-the-shelf equipment devised by **George M. Church** of Harvard Medical School and his collaborators both at Harvard and Washington University in St. Louis may help realize the federal goal of reducing that price to $1,000 by 2015, which experts say would make it practical to decode a person's genes for routine medical purposes. The build-it-yourself method (*right*) the Church group developed is based on combining widely available and relatively inexpensive microscopes with high-speed digital cameras.

A related technique from **454 Life Sciences** in Branford, Conn., also employs cameras coupled with microscopes to sequence DNA, except this method uses a different light-emitting technology than Church. Sequencing also usually relies on bacteria to multiply copies of the DNA target; both new methods instead use a combination of beads to grab the DNA and enzymes to reproduce it. The Church group's version works roughly 20 times faster than conventional sequencing, at a cost of $140,000. 454's system has a roughly 100 times higher throughput than conventional sequencing, at a cost of about $500,000 a machine.

In contrast to these optical technologies, current gene sequencing relies on electrophoresis, in which electric fields separate molecules based on their size and charge. **H. Kumar Wickramasinghe** of the IBM Almaden Research Center and his colleagues have devised a technique that combines electrophoresis with an atomic force microscope, which scans a surface by running extraordinarily sharp probes across it. The invention can sort DNA fragments roughly 100,000 times faster than conventional electrophoresis, albeit only with snippets up to 40 nucleotides long. The researchers note that their work could not only help accelerate DNA sequencing but also deliver molecules onto surfaces with unprecedented control.

—Charles Q. Choi



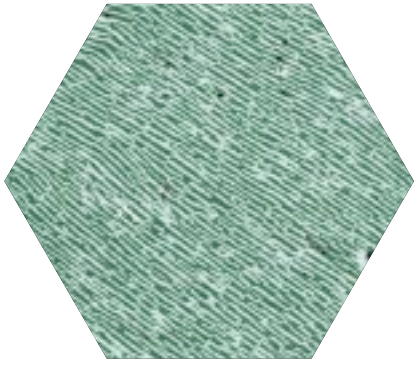
Researchers led by George M. Church of Harvard Medical School built low-cost sequencing technology that reads millions of fluorescing DNA beads at once.

CNRS (*top*); FROM JAY SHENDURE ET AL. IN *SCIENCE*, VOL. 309; SEPTEMBER 9, 2005; USED WITH PERMISSION BY AAAS (*bottom*)

Material Progress

Designers have crafted new structures ranging from nanorods to mimics of mother-of-pearl

Extraordinary properties emerge as scientists manipulate construction blocks at the nanometer scale. Diamond nanorods discovered by **Natalia Dubrovinskaia** of the University of Bayreuth in Germany and her colleagues pack together into a dense form of carbon that is harder than diamond. Potential industrial applications for materials made from nanorods include the cutting and polishing of alloys and ceramics.



A nacrelike ceramic material exhibits qualities of both strength and toughness.

Carbon was also the material chosen by **Pulickel M. Ajayan** and his colleagues at the Rensselaer Polytechnic Institute to create superresilient springs. The researchers used a foam made of carbon nanotubes to devise springs that combine the properties of stiffness and compressibility. Repeatedly compressing a cushion typically squashes it, making it lose its springiness. But the nanotube foams remained elastic even after 10,000 squeezes, a property that could make the material suitable for artificial joints or vibration dampeners.

Scientists draw inspiration from nature to come up with breakthrough materials. Modern ceramics are strong but brittle, whereas mollusk shells exhibit strength while retaining intrinsic toughness because of their finely layered mother-of-pearl, or nacre. **Antoni P. Tomsia** of Lawrence Berkeley National Laboratory and his colleagues found they could mimic nacre just by freezing a watery suspension loaded with hydroxyapatite, bone's mineral component (*left*). They built a multilayered nacrelike material that might find use in artificial bone and joints or in tissue regeneration.

Research that took inspiration from the natural world may also prove useful to the electronics industry, which often requires high temperatures and harsh acids or bases to produce thin films of silicon or other semiconductors. **Daniel E. Morse** of the University of California, Santa Barbara, found that by putting enzymes that mimic those of marine sponges onto gold surfaces, his team could create templates for growing semiconductor films. Inspiration from a lowly marine sponge may eventually yield more powerful batteries.

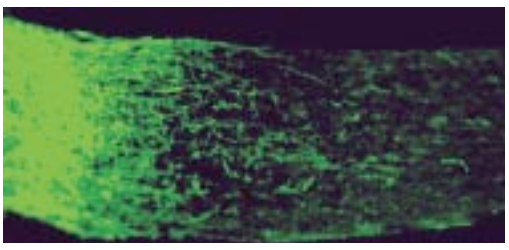
—*Charles Q. Choi*

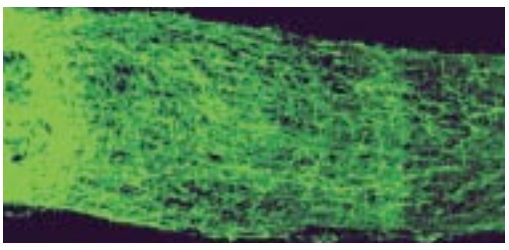
Sight Savers

Technology that could help the blind see is now in the laboratory

Conventional wisdom specifies that the central nervous system—the brain, spinal cord and eye nerves—cannot heal in adults. This thinking no longer holds. **Larry I. Benowitz** of Children's Hospital Boston and his colleagues found a molecule that triggers better nerve regeneration than any other studied. The scientists discovered that a protein, oncomodulin, is secreted in damaged eyes by immune cells known as macrophages. They found that oncomodulin, when given with compounds that enhance its activity, can increase nerve regeneration fivefold to sevenfold in rats with injured optic nerves (*right*). Benowitz believes oncomodulin could someday help reverse optic nerve damage caused by glaucoma, tumors or trauma and plans to investigate whether the treatment could work to help treat stroke and spinal cord injury.

Another invention affords hope that some blind people may be able to view images and video. Visually challenged artist and poet **Elizabeth Goldring**, a senior fellow at the Massachusetts Institute of Technology's Center for Advanced





Regeneration of nerve fibers (*right panel*) occurs in the presence of a protein, called oncomodulin, secreted by immune cells.

FROM SYLVAIN DEVILLE ET AL. IN *SCIENCE*, VOL. 311; JANUARY 27, 2006; USED WITH PERMISSION BY AAAS (*top*); FROM YUQIN YIN ET AL. IN *NATURE NEUROSCIENCE*, VOL. 9, NO. 6; JUNE 2006 (*bottom*)

Visual Studies, developed just such a "seeing machine." It projects images directly onto the retina using light-emitting diodes, similar to much more costly scanning laser ophthalmoscopes used by medical institutions. In a pilot clinical trial of the seeing machine with 10 volunteers, most of whom were legally blind because of retinopathy and other causes, six correctly interpreted all 10 examples from a specially crafted visual language that combines words and pictures.

Prosthetics of another kind may in the future enable an amputee to use electrical signals from remaining muscles so that he or she can move an artificial arm more naturally. **Protagoras Cutchis** of Johns Hopkins University developed an electrode array implanted around the sheath of a peripheral nerve that does not penetrate into the nerve itself, unlike previous technologies. The electrode can process signals from electrical impulses from the brain that might eventually direct an arm to perform up to 22 distinct motions, far superior to previous prostheses that could move in only three directions. Machines are thus proving ever more able to take up the slack when the human body falters. —*Charles Q. Choi*

Of Brain Maps and Saving the Internet

An array of technologies are complemented by a push toward sensible public policy

The Ultimate Computer

Once a theoretical curiosity, the idea of a computer that stores information in quantum superpositions of 0 and 1, known as quantum bits or qubits, is edging slowly toward reality. This year researchers finally engineered microchips capable of rudimentary storage and manipulation of the quantum states of individual atoms, paving the way for convenient control over hundreds or thousands of atoms at once. **Christopher Monroe** of the University of Michigan at Ann Arbor (*below*) and **David J. Wineland** of the National Institute of Standards and Technology both fabricated chips capable of storing just a few charged atoms. —*JR Minkel*

Net Neutrality

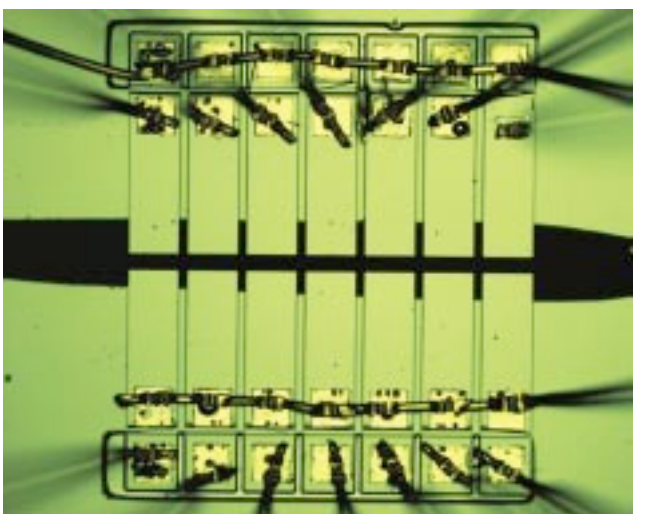
Phone and cable companies have recently begun floating the idea of charging major Internet content providers such as Google and Vonage for "premium" access to bandwidth. Outraged at the proposed tampering with so-called network neutrality—the concept that all Internet traffic should be carried and charged for in the same way—consumer groups lobbied the Federal Communications Commission to enshrine neutrality as a regulatory principle. Columbia University law professor **Timothy Wu** has been a leader in formulating and articulating the value of neutrality. —*JR Minkel*

DNA Building Blocks

One subdiscipline of nanotechnology devotes itself to building structures with molecules of DNA. Last year a team at the University of Oxford, working jointly with Vrije University in Amsterdam, described using DNA to construct a tetrahedron, a pyramid that has three faces and a base. The rigid structure measures 10 nanometers wide and could conceivably form a building block for electronic circuits that send currents along paths in three dimensions. The technique devised by Oxford's **Andrew J. Turberfield** allows the fabrication of trillions of these structures in just a few minutes. —*Gary Stix*

Brain Atlas

Three years ago Microsoft co-founder **Paul G. Allen** put up $100 million to establish the Allen Institute for Brain Science. Its first project would be the Allen Brain Atlas, aimed at accelerating efforts to map where and when every gene in the mouse brain is active. This September the institute unveiled the complete atlas, a three-dimensional map of 21,000 genes resolved down to individual cells. Because mice and humans share up to 90 percent of the same genes, researchers hope that such a map will provide insights into the genetics of human brain development, functioning and disease, including Alzheimer's, addiction and autism. —*JR Minkel*



A laser-based atom trap built at the University of Michigan at Ann Arbor may eventually enable the building of a quantum computer.

COURTESY OF CHRISTOPHER MONROE *University of Michigan at Ann Arbor*

SA 50

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18. John B. Pendry, Imperial College London, David Schurig and David Smith, Duke University, and Ulf Leonhardt, University of St. Andrews (research)
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20. Kevin Eggan, Harvard Stem Cell Institute (research)
21. Richard K. Burt, Northwestern University, Feinberg School of Medicine (research)
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42. Antoni P. Tomsia, Lawrence Berkeley National Laboratory (research)
43. Daniel E. Morse, University of California, Santa Barbara (research)

Sight Savers

44. Larry I. Benowitz, Children's Hospital Boston (research)
45. Elizabeth Goldring, Center for Advanced Visual Studies, Massachusetts Institute of Technology (research)
46. Protagoras Cutchis, Johns Hopkins University (research)

Of Brain Maps and Saving the Internet

47. Christopher Monroe, University of Michigan at Ann Arbor, and David J. Wineland, National Institute of Standards and Technology (research)
48. Timothy Wu, Columbia University (policy)
49. Andrew J. Turberfield, University of Oxford (research)
50. Paul G. Allen, Allen Institute for Brain Science (research)

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