MIT Science News in Review

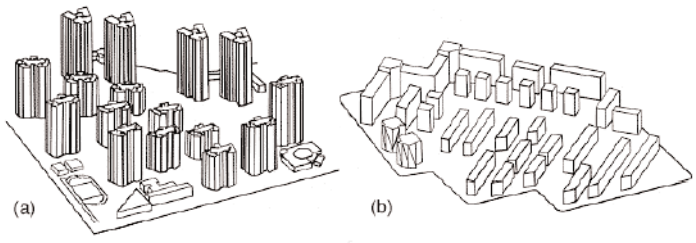
[Architecture]

Building Energy-Efficient Homes Brings Together Experts from MIT and China

Researchers from MIT's Building Technology Program and Chinese universities are working with developing companies to construct more comfortable yet energy-efficient living spaces for the Chinese population. The booming economy and the energy consumption in China have increased people's demand for more Western luxuries. Energy-efficient buildings have thus become the center of attention. The researchers have demonstrated that a traditional Chinese approach with additional building techniques can significantly improve the existing modern buildings. Although the recently erected buildings in China are mostly Western-style high-rises, the researchers have shown that low-rise buildings allowing more access to communal green space can also be energy-efficient. However, insufficient financial resources and a lack of workers who are familiar with the new technology have presented major setbacks. Lack of incentive to conserve energy also exacerbates the energy crisis. But the researchers on both sides are continuing their work to develop energy-efficient designs and to make the technology accessible to the Chinese builders.

In the meantime, demonstrations of the designs and the technology studies are being prepared in three major Chinese cities. Among the researchers are Leon R. Glicksman, Director of the Building Technology Program and a professor of building technology and mechanical engineering.

—W. Lee



Airflow analysis is an effective technique for guiding the design of new communities in China. Scheme (a) is a design prepared by a Chinese architectural firm. Airflow analysis performed by MIT researchers showed that scheme (b) could provide the same living space while better blocking winter winds from the north, increasing passive solar heating in winter and enhancing cross ventilation from southerly winds in summer.

[Biological Sciences]

Of Mice and Men

The International Mouse Genome Sequencing Consortium recently produced a high-quality, publicly available draft of the mouse genome. An effort manned by scientists at twenty-seven institutions in six countries, including the Whitehead Institute/MIT Center for Genome Research, produced the genome in less than two years. This draft can now be compared with the recently sequenced human genome to gain insight about the functioning of genes, likely improving the understanding and treatment of diseases.

Already, interesting comparisons have been drawn between the mouse and human genome. Ninety percent of the mouse genome was found to have a corresponding region in the human genome. Only 5 percent, however, had exact groups of DNA bases that matched with the human genome. This 5 percent is thought to represent important functions such as protein-coding genes.

The mouse genome was determined to have fewer repeated sequences of DNA than the human genome, making it 14 percent shorter in length. These repeated sequences are not considered significant; they indicate that the mice have less extraneous DNA than humans do. Scientists also found a similar number of protein-coding genes to that of humans: approximately 30,000.

The sequencing of the mouse opens many doors for further genetic research. The mouse can now be utilized as a model for the study of a wide range of diseases. The new sequencing will also allow scientists to study the relationships between genes rather than only looking at each gene independently.

The consortium now plans to produce a final, nearly 100-percent-accurate sequence of the mouse genome. Other organisms such as the chimpanzee, cow, and honey bee will then be sequenced for further comparison between the genomes of different species.

—K. Rivoire

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High-Carbohydrate Dietary Supplement Helps with Weight Loss

MIT researchers recently reported that a high-carbohydrate dietary supplement can help people who experience weight gain while taking antidepressants. The supplement includes a high-carbohydrate drink developed at MIT.

Even though the supplement altered serotonin levels in the body, there was no change in effectiveness of the antidepressant. The supplement also had a positive effect on nonmedicated obese individuals: During the twelve-week study, every participant lost twelve to twenty-six pounds.

People who take antidepressant medication, which increases serotonin activity level in the brain, usually experience weight gain by overeating sweet and starchy foods. The antidepressants block a serotonin receptor that also regulates protein and carbohydrate intake, which results in feelings of satiation. Because the receptors are involved in the antidepressants' therapeutic effect, the antidepressants usually cause weight gain.

By giving participants a carbohydrate-rich beverage twice a day, the researchers wanted to see whether increasing serotonin in the brain could reverse the obesity caused by antidepressants without affecting its therapeutic effects.

They found that obese individuals who had taken psychotropic drugs, such as antidepressants, were able to lose just as much weight as nonmedicated obese individuals. The treatment successfully increased serotonin levels without diminishing the therapeutic effects of the drug.

Co-author Judith J. Wurtman, visiting scientist at MIT's Clinical Research Center (CRC), examined the role of carbohydrates in the brain and their role in weight loss. She showed that carbohydrate craving is associated with serotonin-linked changes in mood and that woman with premenstrual syndrome (PMS) sometimes overeat carbohydrates and gain weight. She also thought that overeating increases brain serotonin, which diminishes feelings of depression and anger.

The study, supported by a grant from the Center for Brain Sciences and Metabolism Charitable Trust, was conducted at the TRIAD Weight Management Center at McLean Hospital in Belmont, Mass. —M. Kwan

New Breast Cancer Treatment Enters Final Stage of Clinical Trials

The U.S. Food and Drug Administration (FDA) has given MIT researchers approval to begin the final stage of clinical trials for testing an innovative breast cancer treatment using microwave radiation. The randomized clinical trials include the participation of nearly 220 women with early-stage breast cancer and began in October 2002, the first day of Breast Cancer Awareness Month.

The technology is based on radar research invented by Dr. Alan J. Fenn, a senior staff member at the Sensor Systems Division of the MIT Lincoln Laboratory. Fenn determined that the focused microwave technology previously studied for missile detection could possibly treat cancer cells. The clinical trials, based on Fenn's research, focus microwave radiation externally on the breast, heating and killing internal tumor cells, prior to lumpectomy and radiation therapy.

The randomized clinical testing is expected to finish by February 2004 and will be conducted at various hospitals including Columbia Hospital at the University of Oklahoma (OU), Harbor-UCLA Medical Center at the Martin Luther University in Halle, Germany, and the Comprehensive Breast Center in Coral Springs, Fla. Additional sites have applied for Institutional Review Board approval. Past studies of microwave heat therapy have been promising. Early results from a previous phase II clinical trial showed significant tumor cell death in a majority of the patients prior to lumpectomy, which led to the FDA's approval to begin the final phase of clinical testing.

Dr. Robert A. Gardner, a breast surgeon at Columbia Hospital's Center for Breast Care in West Palm Beach, Fla., and Dr. Hernan I. Vargas of Harbor-UCLA Medical Center presented the results of the phase II clinical trials at the 2002 American Society of Breast Surgeons meeting in April and in the May 2002 issue of the *Annals of Surgical Oncology*. The study is funded and led by Celsion Corporation, which has developed the clinical thermotherapy system and exclusively licenses the focused microwave thermotherapy technology from MIT. —C. Sadegh

Links: http://web.mit.edu/newsoffice/nr/2002/cancer.html
http://web.mit.edu/newsoffice/tt/2002/may08/breastcancer.html

Engineering Adult Stem Cells

Dr. James L. Sherley, principal investigator at the MIT Biotechnology Process Engineering Center, has engineered cells that behave like adult stem cells. Because adult stem cells are capable of generating new tissue, scientists hope to use them for organ replacement for their ability to develop into skin, red blood cells, and neurons.

Adult stem cells are unique in that they have immortal DNA; they pass on duplicates of their original DNA and thus avoid replication errors. However, these cells are extremely difficult to find because they appear in the body as normal cells.

The cells that Dr. Sherley created have the capability to divide like adult stem cells given a certain culture

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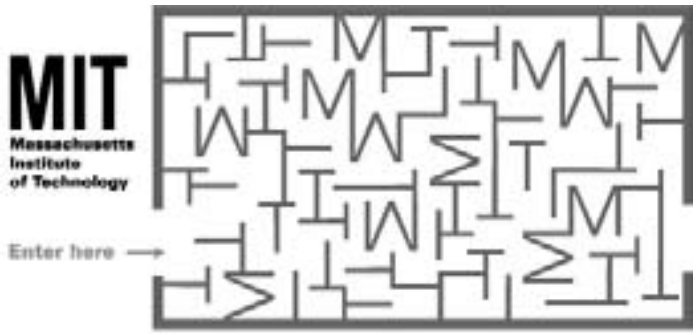
condition or to divide like cancer cells when treated in a different environment. The cells that he made can reveal biological mechanisms that answer questions about cancer and aging. The next step is to understand the proteins involved in stem cell division. —L. Giam

[Brain/Cognitive Sciences]

Slow-Wave Sleep Dreams in Rats Found to Replay Waking Tasks

MIT researchers reported in the December 19 issue of *Neuron* that rats dream about their waking activities during slow-wave sleep, not just REM sleep. The sleep cycle both in rats and humans is composed mostly of slow-wave sleep followed by sleep characterized by rapid eye movements (REM).



This study was a follow-up to a landmark 2001 study, also conducted by Associate Professor of Brain and Cognitive Sciences Matthew A. Wilson in MIT's Picower Center for Learning and Memory, showing that animals have complex dreams and are able to retain and recall long sequences of events, particularly during REM sleep.

In this study, Wilson and his co-author, graduate student Albert K. Lee, monitored the firing activity of collections of neurons in the rat's hippocampus as the rat ran on a simple track for a food reward. For each lap, different individual cells fired at different times, with each successive lap producing the same sequence of firings. Subsequently, in the slow-wave sleep directly following the activity, the rats were found to replay in short, high-speed bursts brief memory sequences corresponding to single laps. A 4-second lap on the track would only last 100–200 milliseconds in slow-wave sleep. This contrasts REM replay, which is played back in real-time.

Another difference was that the dreams found during slow-wave sleep only seemed to occur in the period of sleep immediately following the behavior. REM dreams that reactivate tasks, on the other hand, are detectable as long as 24 hours after the activity was performed, suggesting a more gradual reevaluation of older memories. Contrastingly, researchers have postulated that slow-wave sleep replay is part of the initial storage of memory processing during sleep.

Additionally, researchers found that the rats replayed only the stretches of running or attentive behavior, not the inactive periods of waiting in between. Thus, memory may not be as continuous as we tend to think it is. The authors have suggested that this study will be useful to create a model of how long-term memories are formed. "This may relate to work in humans that suggests that amount of slow-wave sleep early in the night, as well as the amount of REM sleep later in the night, is correlated with subsequent enhancement of performance on learned tasks," said Wilson. —S. Brenner

[Electrical Engineering and Computer Sciences]

Virtual Touch of Loved Ones Now a Reality

On May 23, 2002, MIT and University College London researchers collaborated on the first touch exchange across the Atlantic. The MIT team led by Mandayam A. Srinivasan worked with software specialists at UCL to transform a commercially available, MIT-developed robotic arm, the PHANToM, into a haptic (touch) machine.

UCL researchers worked on the software that runs the robotic arm and the networking communication involved in the transatlantic experiment, while MIT engineers worked on adapting the PHANToM into a machine that can translate touch by exerting exact pressure onto the operator's fingers.

In the May experiment, the two participants on both continents were simultaneously placed in a virtual room on a computer. In the room was a box and pointers that represented the participant's location in the room. The participants then tried to work together to raise the box; each participant's individual motion affected the box's position and could be felt by the other.

But the experiment didn't run perfectly. Due to network delay and Internet traffic there was a delay in the transmission of the real-time touch. The delay was only around 150–200 milliseconds, but compared to a signal sent from the hand to the brain, which takes only 30 milliseconds, this delay is a major obstacle. As a result, the arm operators had a hard time keeping in sync with each other.

The next step for the UCL and MIT collaboration is to minimize the traffic delay to less than 30 milliseconds and to develop a better touch algorithm for the promising machine. Just think, one day surgeons could operate on patients thousands of miles away, and 8.02 students could feel the intranuclear forces inside atoms as part of their lab.

—T. He

Ultra-Thin Quantum-Dot LED Raises Prospects of Better Flat-Panel Displays

MIT researchers have developed a quantum-dot-organic, light-emitting device (QD-OLED) using a novel combination of thin organic materials and high-performing inorganic nanocrystals. The research raises the possibility of manufacturing these materials to create thinner and brighter flat-panel electronic screens to replace today's popular liquid crystal displays (LCDs).

Quantum dots, or artificial atoms, are nanometer-scale boxes that selectively hold or release electrons. While LCDs must be lit from behind, quantum dots emit their own light. Depending on their size, the dots can be "tuned" to emit any color in the rainbow as well as in the infrared and ultraviolet ranges. And the colors of light they produce are much more saturated than that of other sources. The QD-OLEDs created in the MIT study also have a twenty-fivefold improvement in luminescent power efficiency over previous QD-OLEDs.

This latest MIT QD-OLED contains only a single layer of quantum dots sandwiched between two thin, organic films, whereas previous QD-OLEDs used ten to twenty layers. The researchers have demonstrated organized assemblies larger than 1-square centimeter, and the same principle could be used to make bigger components.

Moungi G. Bawendi, professor of chemistry, and Vladimir Bulovic, assistant professor of electrical engineering and computer science, led the interdisciplinary research on the hybrid optoelectronic structure for the QD-LED. The collaborative effort is supported by MIT's Center for Materials Science and Engineering (CMSE). Bulovic is also affiliated with the Research Laboratory of Electronics.

In addition to being used for extraordinarily thin and bright flat-panel displays, the QD-OLEDs may also be used in a variety of other applications: to calibrate wavelengths for scientific purposes, to generate wavelengths visible only to robot eyes, or for the miniaturization of scientific equipment. The MIT team's method of combining organic and inorganic materials may pave the way for new technologies and enhance understanding of the physics of these materials. Further understanding of the material properties of QD-OLEDs will open doors for the production of flat-panel displays that are stable, simple to produce, high-resolution, and highly efficient.

The work, reported in the December 19 issue of *Nature*, is funded by the National Science Foundation's Materials Research Science and Engineering Center Program and Universal Display Corp.

—C. Sadegh

[Materials Sciences]

Lithium Ion Phosphate Batteries Take Charge

In a major breakthrough published late last year in *Nature Materials* magazine, MIT Department of Materials Science and Engineering (DMSE) researchers claimed to be one step closer to making inexpensive, safe, and rechargeable batteries a reality. The researchers proposed using cells made of a new lithium ion phosphate–based material, which is seen as the possible next generation for energy cells.

For years, industries have been trying to find a new, safer, and cheaper rechargeable material for batteries that is less chemically reactive than the current lithium-cobalt-oxygen cells. Such cells can overheat easily, causing producers to limit the size of such cells.

Researchers at the University of Texas-Austin first suggested looking into lithium ion phosphate as a potential substitute. Although cheap and environmentally safe, however, the chemical has a very low electrical conductivity so at the time it was impractical as a rechargeable cell.

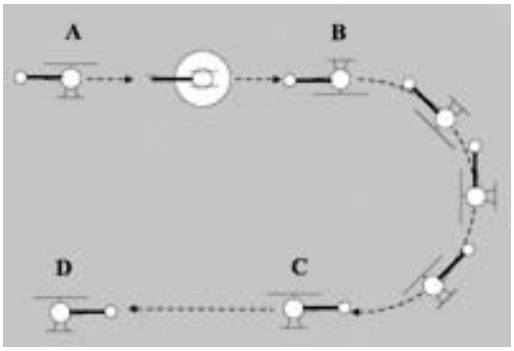
Professor Yet-ming Chiang led the MIT research team that added some metals and developed a special process for treating the compound, which increased its conductivity ten-millionfold! As a result, the lithium ion phosphate battery is quickly becoming a reality. Impending tests will allow scientists to scrutinize and verify the results, so expect to see lithium ion phosphate batteries take charge of the rechargeable battery market.

—T. He

[Mechanical Engineering]

Helicopter Maneuvers Autonomously

MIT researchers developed a pilot model X-Cell 60 helicopter, which executed a complicated maneuver autonomously: The split-S maneuver allowed it to reverse its direction in a limited amount of space.



In the past, complicated maneuvers required a skilled pilot, but now these advances will be applied to unmanned aircraft for use in national defense. The autonomous helicopters can be used for collecting military intelligence and imagery when it is unsafe for other aircraft to enter the airzone. These autonomous aircrafts are small, inexpensive, and easy to control, which make them suitable for military operations.

— L. Giam

[Physics]

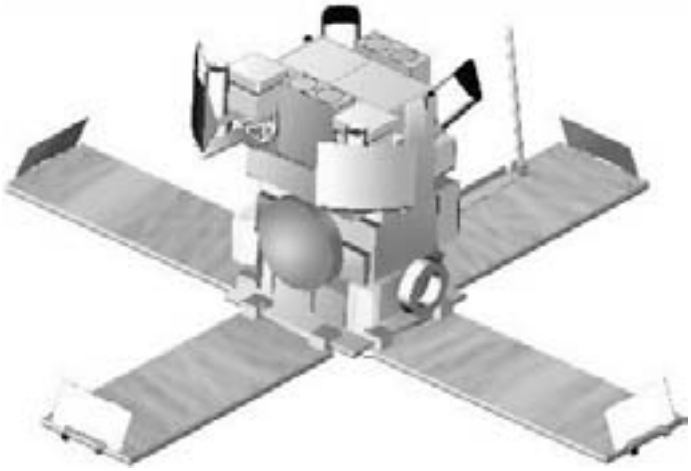
Nuclear Fusion Envisaged as Major Source of Energy in Future

Nuclear fusion involves the joining of lighter elements under high pressure to produce heavier elements as well as tremendous amounts of energy. Magnets dictate the behavior of the plasma in which the fusion takes place. Scientists at MIT's Plasma Science and Fusion Center and the Department of Nuclear Engineering have created a cylindrical, 150-ton magnet for the International Thermonuclear Experimental Reactor (ITER). This magnet will form part of a bigger magnet weighing 925 tons, which in turn will be part of a total magnet system weighing some 10,000 tons. In recent years, a number of tests have been conducted on the 150-ton magnet, located in Japan. This magnet can produce a magnetic field of 13 Tesla and can store energy of 640 megajoules at a current of 46,000 amperes; for reference, the current handled by typical household wiring is around 20 amperes. It was also found that the magnet can be operated in pulses, and it can be brought up to 13 Tesla and back down in only a few seconds. Suitable ranges for the magnetic field, temperature, and current density continue to be defined as support for the initiative. This past September, a Department of Energy panel recommended that the United States rejoin the ITER collaboration along with Japan, Germany, and Russia. The U.S. team involved in developing ITER is composed of about 20 researchers from the MIT Plasma Science and Fusion Center, and the project is funded primarily through a multiyear grant from the Department of Energy to MIT.

— M. Sircar

First Rapid Detection Sheds New Light on "Dark" Gamma-Ray Bursts

The first X-ray image of a rare fast-fading "dark" gamma-ray burst was taken by the MIT-built High Energy Transient Explorer (HETE) satellite, the first satellite dedicated to spotting gamma-ray bursts.



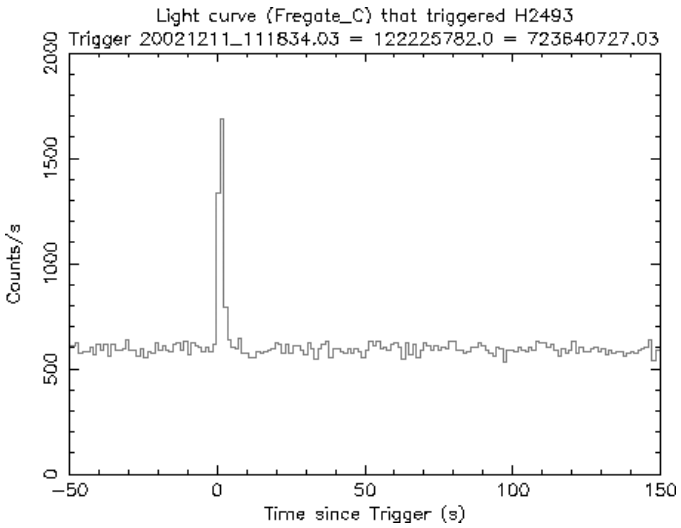
A signal for the birth of a new black hole, a gamma-ray burst is the most powerful type of explosion known, second only to the Big Bang in total energy release. "Dark" gamma-ray bursts are aptly named because prior to the recent X-ray image, they have had no detectable optical afterglow. Other bursts have bright afterglows that linger for days or weeks, likely caused by the explosion's shock waves ramming into and heating gas in the interstellar medium.

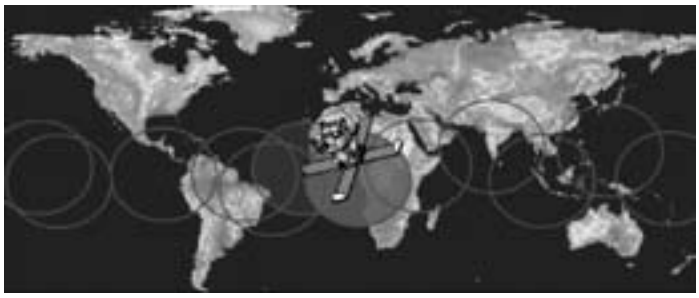
The orbiting HETE, which alerts scientists to gamma-ray bursts, spotted one on December 11, 2002, originating six billion light years away, and relayed its location to

observatories worldwide in 22 seconds. The ground-based Raptor optical telescope, operated by the Los Alamos National Laboratory, was the first on the scene, observing the afterglow at 65 seconds. The afterglow was extremely faint after two hours and would have been missed and labeled "dark" if not for HETE's rapid detection.

"Perhaps none of these bursts is truly dark, provided that we catch them fast enough," said George Ricker, a senior research scientist at MIT's Center for Space Research, who leads the international team that built and operates NASA's HETE satellite. Some theorists have suggested that dark bursts have no detectable afterglow because they are buried in thick dust and gas, which blocks the afterglow's light from reaching Earth.

According to Ricker, the December 11 observation of burst implies the opposite: "The burst may have occurred in a region with hardly any surrounding gas and dust, thus the shock waves had little material to smash into to create





a prolonged bright afterglow." The rapidly fading afterglow, in this case, may support the binary merger theory of short bursts. In the billions of years that old binary systems, with a combination of neutron stars or black holes, took to form, they drifted outward to less dense regions of a galaxy. Thus, when they merge to form a black hole, there is little surrounding material to make a long afterglow.

HETE was built by MIT as a mission of opportunity under the NASA Explorer Program. It is on an extended mission until 2004. The HETE program is a collaboration between MIT; NASA; Los Alamos National Laboratory, New Mexico; France's Centre National d'Etudes Spatiales (CNES), Centre d'Etude Spatiale des Rayonnements (CESR), and Ecole Nationale Superieure del'Aeronautique et de l'Espace (Sup'Aero); and Japan's Institute of Physical and Chemical Research (RIKEN). The science team includes researchers from the University of California (Berkeley and Santa Cruz) and the University of Chicago, as well as from Brazil, India, and Italy. —C. Sadegh

For more information: HETE: http://space.mit.edu/HETE

Additional images and GRB021004 information:
http://space.mit.edu/HETE/Bursts/GRB021211
http://web.mit.edu/newsoffice/nr/2002/darkburst.html