MIT Science News In Review

[Architecture]

MIT Researchers Build Dream Village to Replace Earthquake Victims' Homes

Near Adapazari, Turkey, MIT Professor Jan Wampler is building Berikoy, a dream community to replace a village destroyed by a 1999 earthquake that measured 7.4 on the Richter scale. The groundbreaking ceremony was on June 6.

The "groundbreaking" ceremony for Berikoy was actually a "concrete-shoveling" into the forms that had been laid for the foundations of the first houses.

Wampler, together with graduates Rukiye Devres Unver and Barbara Brady, as well as students from his international workshop course, designed the village according to the residents' desires. Before, concrete apartments on loose topsoil buckled under the quake's force. Now, galvanized steel frameworks atop underground rock will create stable homes and collectively owned community centers, a library, and a computer center. The cooperative microvillage will derive heat and power from solar panels and windmills, fertilizer from sewage, and rainwater from reservoirs. The residents, with average family incomes of less than $400 a month, need to pay less than $100 monthly for two- to three- bedroom homes measuring 700-900 square feet. After paying for materials, workers older than 18 must also donate 500 hours of labor, which can include carpentry, construction work, cooking, childcare, and other services.

The project, costing $1.5 million, is supported by Habitat for Humanity and the Turkish foundation CEKUL. —I. Lim

[Astro Physics]

Birth of X-Ray Binaries

A team of scientists led by David Pooley of MIT recently found that double-star systems, or binary stars, are formed as a consequence of globular clusters colliding with each other. Using NASA's Chandra X-ray Observatory, Pooley and his team observed X-ray sources in 12 globular clusters in our galaxy. A globular cluster is a collection of millions of stars in a spherical formation and about a hundred light-years in diameter. When globular clusters run into each other, the gravitation of one star may draw another star into its orbit. These two stars form a binary system and produce X-rays that can be detected. Pooley found that the number of X-ray binaries is closely correlated with the rate of encounters between stars in the clusters. This research solves the long-standing mystery of binary star formation and has profound implications to the understanding of globular cluster evolution. —H. Wang

[Biology]

A Grade-A B-Cell Study

The post 9/11 era has transformed the American people into a fearful collective paranoid of its personal health. The faceless phantom we anxiously await has the potential to invade our bodies without our knowledge and take control within seconds, or worse. Our defense rests in the hands of molecular biologists such as MIT graduate Todd H. Rider of the Biosensor and Molecular Technologies Group in Lexington, Massachusetts. His successes will provide integral steps toward diagnosing the presence of pathogenic bacteria, agricultural pathogens, anthrax, and other feared biowarfare agents.

Rider and his research group have created CANARY (Cellular Analysis and Notification of Antigen Risks and Yields), a sensor that causes cells to fluoresce when exposed to pathogens and other contaminants. B lymphocytes (commonly known as B cells) are white blood cells that secrete antibodies and are thus central to an organism's immune response. Rider and his team genetically engineered a strain of mouse B cells, spliced with the jellyfish gene that produces a protein that glows. The new cells were further engineered to respond to certain bacteria and viruses.

The implications of this achievement are endless: The functions of these modified B cells may be used to diagnose water quality, indoor air quality (for diseases such as Legionnaire's), and a growing list of pathogens that include smallpox, plague, and chlamydia. The cells will be kept viable in a luminometer, where the cells' responses may be monitored.

The work is supported by the Defense Advanced Research Projects Agency and the U.S. Army Soldier and Biological Chemical Command. —E. Slutsky

Phytoplankton Genes Sequenced

Scientists from MIT, the University of California at San Diego, and the Centre National de la Recherche Scientifique's Station Biologique de Roscoff have recently announced the genetic sequences of four related types of phytoplankton. These phytoplankton, which live in the ocean, are extremely important for several reasons: They are the world's smallest photosynthetic organisms, at the bottom of nature's food web, and crucial to climate fluctuations due to their role in atmospheric carbon dioxide regulation. Investigating the functions of the 2,000 genes in the organisms will lead to a better understanding of ecological systems and the photosynthetic process. Once the key

mechanisms and gene functions are identified, scientists hope to create a model of photosynthesis based on the phytoplankton. Understanding how these small organisms create biomass from sunlight could help generate better methods for energy production. Scientists will also have the capability to compare the different forms of the organism to study their different ecological niches. The four sequences being reported are Synechococcus and three strains of Prochlorococcus. Different strains of the same phytoplankton, for example, exist at different depths in the ocean. Analysis of the gene sequencing data can therefore be used to study the immense diversity of ocean life. —K. Rivoire

MIT Researchers Pinpoint Potential Genetic Basis of Schizophrenia

MIT Nobel Laureate Susumu Tonegawa discovered that genetically engineered mice missing calcineurin, a brain protein, display schizophrenic behavior. Calcineurin plays a vital role in the central nervous system as a part of the biochemical pathway linking the receptors for the brain chemicals (neurotransmitters) NMDA and dopamine.

Tonegawa, director of the Picower Center for Learning and Memory at MIT, first found that these mice, like schizophrenia patients, had an impairment in short-term memory, also known as "working memory". Picower scientist Tsuyoshi Miyakawa further determined that the mice exhibited other schizophrenic abnormalities, such as aberrant social behavior and attention deficits. Picower scientist David Gerber and Rockefellar's Maria Karayiorgou found a correlation between a calcineurin gene and schizophrenia. Tonegawa hopes to find the specific genes and proteins involved in the calcineurin pathway so that new drugs can be developed to cure various cases of schizophrenia.

The study on human genes responsible for susceptibility to schizophrenia was funded by the Picower Foundation, the National Institutes of Health, the Howard Hughes Medical Institute, the Otsuka Maryland Research Institute, the McKnight Endowment Fund for Neuroscience, the EJLB Foundation, and the New York City Council Speaker's Fund. —I. Lim

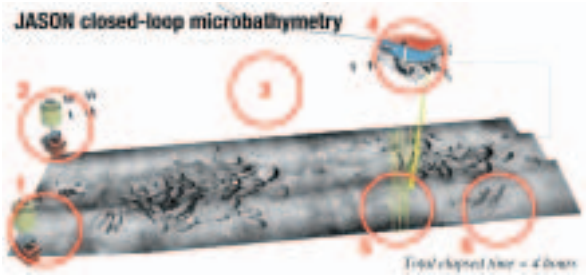
[EECS]

New Navigation Technology Will Reveal Archaeological Treasure

MIT Professor David Mindell and his colleagues at the Woods Hole Oceanographic Institute (WHOI) have developed "Exact," a navigation system, to probe ocean depths too deep for divers. The system uses a wireless sonar assembly of three acoustic beacons, called transponders, to locate and to explore archaeological sites thousands of meters below the ocean surface. *Exact* can achieve an accuracy of less than a cubic centimeter.

The host transponder on the remotely operated vehicle (ROV) pings the other two transponders placed at the edges of the archaeological site. The amount of time the ping takes to reach each transponder, along with measurements from sensors on board the ROV, are used to calculate the position of the vehicle.

Exact, combined with ultrasonic imaging technology developed by MIT's DeepArch research group to profile objects buried in sea mud, will identify and map archaeological artifacts buried at the bottom of the deep seas.



1. EXACT transponders are placed around site and their positions precisely calibrated. 2. EXACT transponders listen for coded "ping" from JASON, respond with coded ping. 3. Travel times of acoustic signal are used to triangulate JASON position, accurate to ~1 cm3 three times per second. 4. Position data is fed-back into control system; under automatic (closed-loop) control, JASON runs straight tracklines over wreck site at slow speed (0.1 meters/sec). 5. Sonar beam on vehicle scans across wreck site and records precise altitude information. Data is then combined with vehicle positioning and attitude to produce microbathymetry plot of site. 6. Digital still photos are taken simultaneously for mosaic.

"The thing that makes artifacts important is their spatial relationships to each other," said Brendan Foley, who earned a Ph.D. in the history and archaeology of technology from MIT in June 2003. "The minute you remove an artifact from a site and put it somewhere else, then you've lost information." —J. Wong

[Materials Science]

$50 Million Army Grant Awarded for Nano-biotechnology Research

In order to develop technology to better equip soldiers of the 21st century, the Army is funding a three-university consortium, including MIT, University of California at Santa Barbara, and California Institute of Technology. Up to $50 million over a period of five years will be given to try to understand and utilize biological synthesis of materials. This collaboration has been named the Institute for Collaborative Biotechnologies (ICB). MIT's Angela Belcher, the John Chipman Associate Professor of Materials Science and Engineering and Biological Engineering, will be directing MIT's component of the research. Belcher has used biological organisms to grow and assemble semiconductor and magnetic materials. These organisms can be further manipulated to make liquid crystals for display technology and components for self-assembling electronics. Her team hopes to understand and develop ways for biological organisms to produce enhanced materials that have various signaling and processing applications. ICB was inspired by the fact that biological systems use different mechanisms to produce materials and integrated circuits for sensing, computing, and information processing such as that found in humans.

—H. Wang

[Mechanical Engineering]

MIT Crew Team? Think Again.

The locomotion of life, for the most part, has been limited to swimming, flying, and traversing solid surfaces. To transcend the normal modes of mobility and to perform a graceful ballet atop a liquid

surface (while hopefully remaining dry) is to be Jesus Christ, or more modestly, an almost supernatural insect known as the water strider.

The ability of the water striders (of the family Gerridae and others) to walk on the surfaces of ponds and lakes had once been explained as the effect of the waves that their movement generates. As the insects sat on the water surface, their gentle, subtle movements created waves strong enough to push them forward. In 1993, however, Denny's Paradox emerged to question the accepted notion. Mark W. Denny, a marine biologist at Stanford University, claimed that young water striders were not able to swim because their legs were too weak to create waves. Yet somehow, even young striders were able to glide on water surfaces. And so the riddle remained until two young MIT graduate students and an associate professor fused mathematics and mechanical engineering with modern technology and the ancient art of observation.

Left: A water strider passes over a layer of water that has been dyed blue and lit from below, illuminating the stopping vortices shed during the deceleration phase of the strider's motion. Right: Graduate students David Hu, left, and Brian Chan with their creation, Robostrider.

Mathematics graduate student David L. Hu and mechanical engineering graduate student Brian Chan, along with the guidance of John W. M. Bush, associate professor of mathematics at MIT and author of the study, have determined how the insects perform this once-misunderstood phenomena: The six legs of the insects form dents in the water surface. They then use their middle pair of legs as oars to paddle forward and are lifted by the motion of the water "un-denting" itself. The waves that the rowing motion creates are actually insignificant.

After the threesome employed mathematics, the use of high-speed photography, and a range of visualizing techniques to solve the paradox, Chan was delegated the task of creating a mechanical model of the insect's movement. The mechanical strider that was developed, although representing the culmination of a decade long paradox, was simply composed of a 7-Up can, stainless steel wire legs, and an elastic band surrounding a pulley system.

Historically, the first scientists were those who observed even the most simplistic natural phenomena and sought reasoning, an analytical and systematic understanding of an event that seemed to defy logic. Bush, Hu, and Chan have demonstrated the very fundamentals of scientific thought as they looked toward an insect to explore hydrodynamic forces and mechanical propulsion. The genuine scientist must look toward the simple, ignored, and abandoned to find a playground on which scientific, engineering, and mathematical fields can learn together and discover together.

Hu is continuing his research on surface swimmers by observing the locomotion of Microvelia, Mesovelia, and Physidae.

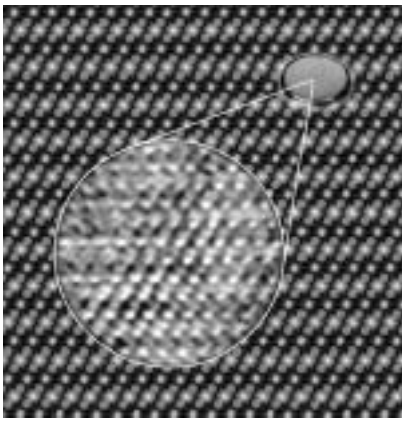
—E. Slutsky

Lithium Ions Directly Imaged for the First Time

A research team has achieved atomic resolution of lithium ions for the first time by using focal-series reconstruction of exit surface waves (ESWs) of $LiCoO_2$ undergoing high-resolution transmission electron microscopy (HRTEM), according to the July 2003 issue of *Nature Materials*. The paper's lead author, Yang Shao-Horn, is an assistant professor of mechanical engineering at MIT. To create images of the $LiCoO_2$ lattice, HRTEM interprets the phase change between an initial electron beam that is passed through the $LiCoO_2$ lattice and the emerging electron wave, known as ESW, which has undergone interaction with the potential field created by cobalt, oxygen, and lithium atoms.

"Lighter" atoms such as lithium scatter electrons more readily than "heavier" atoms such as oxygen and cobalt, and hence require resolutions higher than those required for heavier atoms. The team used a computer simulation program developed by Michael O'Keefe, a collaborator on the project, to predict that cobalt would become visible at 2 angstroms, oxygen at 1.4 angstroms, and Li at 1 angstroms. Experimental data confirmed the hypothesis.

Additionally, visibility of lithium was found to improve with sample thickness as a result of "increasing proportion of dynamic scattering contributing to the electron wave at the specimen exit surface." The optimum thickness was found to be 17 unit cells. "Operation of lithium rechargeable batteries is dependent on reversible lithium insertion and extraction processes into and from the host materials of lithium storage," according to the authors of the team's paper. It cites rechargeable batteries for laptop computers as a pervasive example of LiCoO2 application. —J. Wong



A computer simulation shows how columns of atoms in lithium cobalt oxide, seen end-on, ought to appear. The inset is the actual image taken with a transmission electron microscope. It shows the arrangement of lithium ions among cobalt and oxygen atoms in the compound lithium cobalt oxide. The oxygen atoms are bright and sharp-edged, the cobalt atoms are fuzzy, and the lithium atoms are small, weak, and look a little stretched.

[Neuroscience]

MIT Researcher Discovers LTD Mechanisms in Visual Cortex

In the August issue of *Nature Neuroscience*, researchers from MIT and Johns Hopkins University Medical School explained the mechanisms behind blindness caused by vision deprivation to one eye. The blindness, due to synaptic decay, has been attributed to long-term depression (LTD), a lasting decrease in neuron activity. Normally, LTD is a mechanism that helps shape synaptic pathways in early development. However, mechanisms behind LTD have not been well understood.

The researchers were led by Mark F. Bear, a professor of brain and cognitive sciences in the Picower Center for Learning and Memory at MIT and a Howard Hughes Medical Institute investigator, as well as Hee J. Chung and Richard L. Huganir of Johns Hopkins. Other researchers included Arnold J. Heynen, a Picower Center research scientist; Bong-June Yoon, a Picower research associate; and Cheng-Hang Liu, an MIT graduate student. They reported that LTD in the

visual cortex could be induced in newborn rats by depriving one eye of visual input.

In addition, Bear and his fellow researchers discovered the molecular changes that result in LTD. In particular, they discovered that LTD in the visual cortex is caused by a loss of glutamate receptors. Glutamate is a neurotransmitter frequently found in visual areas of the brain, allowing signals to pass from one neuron to another. Without glutamate receptors, a neuron will not receive visual signals, leading to synaptic decay. —M. Burns

Prefrontal Cortex of Brain Contains a Checklist

MIT researchers reported in the August 29 issue of *Science* that the prefrontal cortex of the brain contains an area that acts as a "checklist," keeping track of movement sequences that have been performed. The study was conducted by Ann M. Graybiel, the Walter A. Rosenblith Professor of Neuroscience at the McGovern Institute at MIT, and Naotaka Fujii, a research scientist in the Department of Brain and Cognitive Sciences.

In the study, neural activity in the prefrontal cortex was recorded in monkeys that had been trained to make a sequence of movements. The recorded neurons responded with each movement. However, when the movement sequence was completed, an extra response was recorded in the same neurons. Graybiel and Fujii report that the extra response is the checklist, activity that allows the brain to note which behaviors have been performed.

The existence of a checklist could explain some of the symptoms associated with damage to frontal cortex regions. A lack of a checklist system could result in repetitive behavior, as the brain is not aware that the behavior has been performed. In fact, such repetitive behaviors are frequently observed when the frontal cortex has been damaged.

Graybiel and Fujii also recorded from basal ganglia regions in the brain. The recordings suggest that basal ganglia and prefrontal cortex regions bind the individual behaviors within a behavioral sequence into larger chunks.

The study also revealed that the prefrontal cortex neurons intensify their responses at the start of a movement sequence. This phenomenon may also explain the symptoms of Parkinson's disease, in which patients have tremendous difficulty initiating any sequence of movements. —M. Burns

[Physics]

Pulsar Speed Limited by Gravitational Radiation

MIT physicists at the Center for Space Research in collaboration with colleagues at NASA and in Scotland and the Netherlands recently reported that gravitational radiation may act as a regulator limiting the speed of pulsars. A gravitational wave is a ripple in space, first predicted by Albert Einstein. This finding confirms a previous theory by scientists at the University of California at Santa Barbara. A pulsar is born from an exploded star and is so dense that a sphere 10 miles in diameter is as massive as the sun. It can spin as quickly as one revolution per millisecond; as the pulsar draws in material from a companion star, its rate of speed can increase dramatically. The researchers hypothesize that a feedback mechanism exists in which as the speed of the pulsar increases, gravitational radiation is released, which deforms the star and reduces the rotation. This limit to the speed of rotation prevents pulsars from self-destructing. Physicists hope that the Laser Interferometer Gravitational-wave Observatory now in operation will be able to detect directly these gravitational waves that limit the speed of a pulsar, and the pulsar can be studied in further detail. —K. Rivoire

Material accumulating on the pulsar surface can sometimes ignite, causing thermonuclear flashes that emit bursts of X-ray light. These thermonuclear flames spread across the surface of the pulsar in a few seconds. The team established that "burst oscillations", a kind of flickering, during these X-ray bursts provide a direct measure of the pulsar's spin rate.

The Future of Nuclear Power

A committee of MIT researchers recently announced the results of a study investigating alternatives to carbon fuels such as nuclear power. Fossil fuels comprise more than 90 percent of carbon emissions in the United States. This is only about half of total power in the country, so reducing greenhouse gas emission necessitates a change in power type. Current problems with cleaner fuel choices such as nuclear power include high costs and concerns about safety, environmental effects, security, and nuclear waste management. The study offered a number of recommendations to further the use of nuclear power, including tax benefits for companies producing technology without carbon and increased investigation and research by the Department of Energy into the health and waste management issues associated with nuclear power. The researchers also suggested improving the efficiency of current fuels, for example by research into more efficient engines, as well as researching other renewable sources of power.

—K. Rivoire