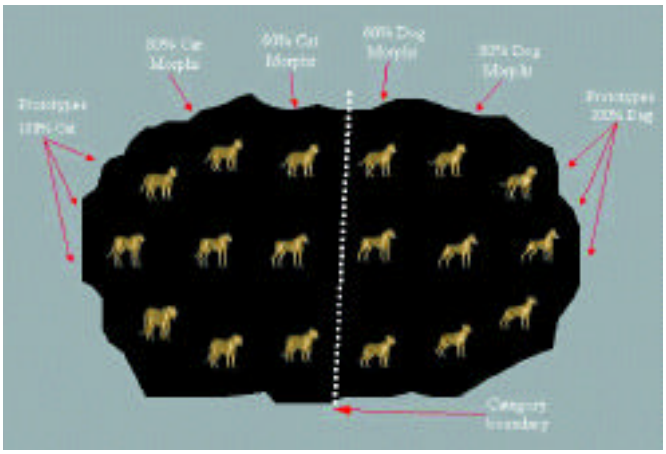
MIT Science News in Review

[Biological Sciences]

MIT researchers discover new function in brain cells

Through studying the individual neurons in monkey brains, researchers at MIT were able to identify the ability of neurons to become tuned to the concept of "cat" and others to the concept of "dog." MIT researchers reported in the January 12 issue of *Science* that individual brain cells have the ability to instantly categorize what animals see.

"This ability is critical for thought. Our raw perceptions of the world would be useless without the meanings we attach to them. Yet almost nothing is known about how the brain accomplishes this," said Earl K. Miller, Associate Professor of Brain and Cognitive Sciences in MIT's Center for Learning and Memory.



In many aspects, the ability to learn and distinguish what animals see allow them to react to their environment quickly and appropriately.

The discovery will help researchers gain a deeper understanding of the cellular basis for neurons' ability to categorize. This knowledge may also be useful in treating disorders in which the brain is unable to assign meaning to the environment.

Complex sugar tool revolutionizes heparin industry

A multibillion-dollar drug industry took a new regulatory turn after two MIT researchers announced in early September that they had designed a new analytical tool to probe the world of complex sugars such as heparin.

Associate Professor Ram Sasisekharan of the Division of Bioengineering and Environmental Health (BEH) led the MIT team that designed a tool to easily determine the structure of complex sugars. These sugars were far more difficult to decipher than commonly discussed proteins and DNA structures, given the greater number of building blocks.

"Once you have the sequence of building blocks for a given polysaccharide, you can start cracking its function in the body," said Sasisekharan.

The tool will "articulate that [like DNA and proteins] these sugars are also fundamental to biology—that they're a new and important frontier," said Ganesh Venkataraman, a research associate in the Harvard-MIT Division of Health Sciences and Technology.

Sasisekharan's team reported that their tool had been used to sequence a heparin fragment with anticoagulation activity, demonstrating that an old sequence for the fragment was likely incorrect.

A second paper by the team showed that this altered sequence could affect drug discovery, given that the fragment's sequence determines heparin's effectiveness. The discovery could also change the FDA's regulation procedures.

"Periods of great discovery in science are almost always preceded by the development of new tools," wrote Professor Matthew A. Nugent of Boston University, who wrote an article to accompany Sasisekharan's two reports in the September 12 issue of the *Proceedings of the National Academy of Sciences*.

New serotonin receptor discovered

In the November issue of *Nature*, MIT researchers reported the discovery of a new type of serotonin receptor. Serotonin levels in the brain have been linked to aggression, anxiety, depression, obsessive-compulsive disorder, and regulation of appetite and sleep.

The gene discovered in this study, *mod-1*, is an inhibitory receptor that blocks neuronal signaling. Prior to this discovery of the *mod-1* gene in roundworms, researchers knew only one other receptor for serotonin; that receptor leads to the stimulation of neuronal signaling. The roundworms were deprived of food (bacteria) and treated with Prozac. Mutant worms immune to the effects of Prozac were isolated, and researchers discovered that mod-1 was the strongest defect that allowed the mutants to function normally while food-deprived.

These findings can help explain how drugs like Prozac act to produce therapeutic effects by adjusting levels of serotonin signaling. The discovery can also lead to research to better understand the mechanisms behind unwanted side effects of serotonin-level altering drugs.

[Physical Sciences]

LIGO undergoes its first operation

On October 20, 2000, scientists established the first operation of the Hanford, WA, facility's lasers in the Laser Interferometer Gravitational-Wave Observatory (LIGO).LIGO was designed to capture faint gravitational waves from distant sources in the universe, and it is a joint project of MIT and the California Institute of Technology. Although LIGO is not expected to be fully operational until 2002, this particular operation marked the first time that a LIGO detector would have simultaneously sent laser light back and forth along its two arms.

LIGO was a project funded by the National Science Foundation, and it would serve as a national research facility for detecting gravitational waves in the universe. LIGO is made up of three detectors. There are two at Hanford and one near Livingston, LA. All the detectors will be responsible for sensing gravitational waves, caused by accelerating masses, such as exploding stars or vibrating black holes.

LIGO detectors were made of mirrors suspended in a vacuum on fine wires at the corner and end of a long "L." A highly stable laser beam is split, and the two halves of the beam are sent back and forth about 100 times between the mirrors on the two arms. Then, the beams are recombined. Scientists would be able to observe the changes in the amplitude of the recombined light as the gravitational wave causes small motions of the mirrors at the end of the "L."

Nanocrystals emit efficient lasers

MIT scientists working the U.S. Department of Energy's Los Alamos National Laboratory have shown that nanoscale semiconductor particles known as "nanocrystal quantum dot" can be used to produce efficient emission of laser light. Victor Klimoc, leader of the research done at the Los Alamos lab, said, "Our results provide a proof-of-principle and should motivate the development of nanocrystal quantum-dot-based laser and amplifiers."

MIT scientists developed and synthesized the quantum dots used in the study. Using laser-based and magneto-optical techniques, chemistry professor Moungi Bawendi studied nanocrystallites' magnetic and vibrational properties in both isolated and organized structures.

Quantum-dot lasers function similarly to semiconductor lasers (used in CD players). The purpose of both a quantum-dot laser and a semiconductor laser is to manipulate material into a high-energy state and then convert it to a low-energy state. In quantum dots, strong electron interactions lead to a deactivation of the dot through the Auger process, which does not result in photon release.

When the dots are densely packed, they can produce different colors and overcome the Auger process. Manipulating quantum-dot material can result in tuning the quantum dots to emit at a specified wavelength. Quantum dots can be used over a range of temperatures, which makes them useful in different situations.

NASA's Chandra X-ray Observatory discovers new details in the quasar 3C273

In the November 8, 2000, issue of MIT Tech Talk, MIT researchers announced that they were able to observe important new details in the powerful jet shooting from the quasar 3C273 by using the high resolution of NASA's Chandra X-ray Observatory. The quasar 3C273 has made important astronomical news in the past. It was discovered in the 1960s, and it was one of the first objects to be recognized as a "quasi-stellar" object.

According to research physicist Herman Marshall at the Center for Space Research, the discovery marked the first time that "Chandra has given us an X-ray view into the area 3C273's core and the beginning of the jet."

For a long time, scientists have been puzzled by the high-powered jets driven from quasars that have the velocities close to the speed of light. Recent observations showed that there were "lumpy" clouds of gas driven from the core of quasar instead of a smooth stream of material.

In all respects, the recent discovery of continuous X-ray flow in 3C273 from the core to the jet may reveal insight to the physical process that powered these jets. It has been a goal for the scientists to learn why matter gets ejected from the quasar's core and suddenly slows down.

Salty Gaza water endangers agriculture

One million residents of the Gaza Strip, who live and grow food in an area one-tenth the size of Rhode Island, are drawing water from aquifers that grow saltier each year. They have been told that they can maintain Gaza's fresh water supply by using an amount less than or equal to that of its usable annual rainfall. However, Assistant Professor Charles Harvey and Dr. Annette Huber-Lee of the Department of Civil and Environmental Engineering claim that the quality of the water will continue to decline and that the Gaza Strip will still run dangerously low on fresh water within a decade.

Most of the salt enters the aquifer in two ways. First, seawater intrusion occurs when water is overpumped from the aquifer, allowing seawater to seep in underground and fill the emptying reservoir. Second, as water used to irrigate fields evaporates, salt is left behind. That salt is then carried by irrigation water back into the aquifer.

The researchers claim that fresh rainwater cannot desalinate the aquifer fast enough. Gaza residents have three options: They must acquire water from beyond their borders, which are closed at present; build a large desalination plant; or eliminate agriculture within the next two decades.

"The solution is desalination or other new sources of fresh water, together with infrastructure to transport and treat water," said Huber-Lee and Harvey.

They estimate that a desalination plant large enough to do the job would cost $100 million per year to build and have operational costs on the order of $0.70 per cubic meter of water.

Mexico City air may get Nobel-quality clean-up

Travelers familiar to Mexico City might recall the "oxygen stands" that litter the city's sidewalks. The fresh-air dispensers are oxygen tanks designed for passing pedestrians, who are often sickened by the city's thick layer of pollution. Now, chemistry Nobel laureate Professor Mario Molina, who discovered that the ozone layer was being depleted by chlorofluorocarbons (CFC), is offering an alternative to Mexico's federal officials and industries: a new control strategy based on a cost-benefit analysis, which reduces the effects of fine particles on ozone.

In his report, "Project for the Design of an Integrated Strategy for the Management of Air Pollution in the Mexico City Metropolitan Area 2001-2010," Molina explores the different effects of fine and coarse particles on the ozone layer and also postulates the effects of Mexico City's pollution on the area's increasing infant mortality rate.

More than 3.5 million vehicles and 35,000 industries are now occupying the region, producing thousands of tons of emissions each year and making the heavily populated region one of the most polluted in the world. Solving the problem "is not a luxury, but a necessity," Molina wrote in his report. "Some of the necessary measures may seem costly and bothersome. However, any delay in tackling the air pollution problem may create the need for more drastic measures in the future."

The study recommended specific regulatory changes in Mexico and proposed several new research agendas. Based on Molina's observations that the use of private automobiles and low-occupancy transit vehicles have been on the rise in the city, the plan called for public transportation improvements.

[Technological Sciences]

Monkey's brain controls robotic arm over the Internet

Through a neural-recording system, reported in the November 16 issue of Nature, MIT researchers in the Touch Lab were able to make monkeys in North Carolina remotely operate a robotic arm 600 miles away by using their brain signals. The neural-recording system used tiny electrodes implanted in a monkey's brain to detect signals as they controlled a robotic arm to reach for a piece of food. According to researchers from Duke University Medical Center, MIT, and the State University of New York (SUNY) Health Science Center, the new system would serve as a brain-machine inteface that would allow paralyzed patients to control the movements of prosthetic limbs.

The study also showed two important implications for the theory of brain coding. According to Miguel Nicolelis, associate professor of Neurobiology at Duke, the information about the brain cells' trajectory is distributed over large territories of the brain, and the brain very likely relies on huge populations of neurons distributed across many areas in a dynamic way to encode behavior.

In the future, Mandayam Srinivassan, a principal research scientist in mechanical engineering and the MIT Research Laboratory of Electronics, hopes that he and his fellow researchers can extend "the capabilities of the arm by engineering different types of feedback to the monkey, such as visual images, auditory stimuli, and forces associated with feeling textures and manipulating objects."

MIT-Caltech reform the voting system

Concerns were raised by the recent election result in an MIT-Caltech study on reforming the voting process in the United States. Several disciplines such as political, computer, and cognitive science will be incorporated into engineering and design to evaluate a range of voting systems.

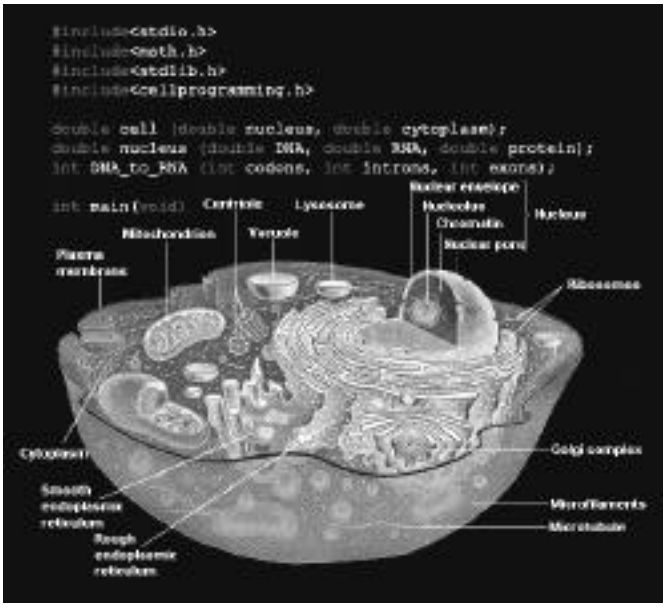
The recent elections were a fiasco in terms of the voting process. People may have voted more than once, some votes may not have been counted, and many citizens did not vote for president. The national "no-vote" rate is 2 percent. The margins in at least five states were under 1 percent—the margin in Florida was 9/1000 of a percent. Obviously, a new system for counting votes must be found.

President Vest cites that the goal of the joint venture is to develop a voting system, which is "easy to use, that is reliable, [and] that

is secure." Affordability of implementation will be taken into account by researchers. The final project will include a range of estimates on cost and reliability.

Researcher hopes to program cell

On October 25, MIT artificial intelligence researcher Thomas F. Knight announced his plans to program a living cell in the same way he would a computer. This announcement came at the Technology Breakfast Series to an audience of alumni investors and entrepreneurs, venture capitalists, business leaders, and Institute faculty.



A senior researcher in electrical engineering and computer science, Knight is working on developing novel computing structures from living cells. Looking at it from an engineering standpoint, Knight says, living cells are already amazing machines capable of reproducing themselves, processing chemicals, and sensing a number of external stimuli such as light, heat, and acidity. They are energy-efficient and waste-efficient; they can fluoresce and move. And perhaps most importantly, their DNA stores and replicates one megabit of information "way, way, way denser than any form of silicon technology." Research and industry are currently attempting to take advantage of these features by utilizing biological tools to produce nonbiological devices. Knight proposes utilizing techniques used in the natural world and modifying them to suit our purposes, which could be anything from monitoring glucose levels in diabetics to instructing flowers to count the days until Valentine's Day so as to bloom on the right day.

The bases that comprise the genetic code are four distinct entities, thereby making DNA "digital." "If we want to build digital behavior in living cells, we can replicate ones and zeroes as the presence or absence of specific DNA binding proteins," says Knight. The binding proteins would be used to inhibit or express specific genes, "thereby creating outputs of one and zero."

Using this method, Knight believes that researchers can construct a "nAND" gate, the logic gate equivalent to an "AND" gate followed by a "NOT" gate that can serve as a precursor to all Boolean logic operations. Therefore, "we now have a universal mechanism able to create any kind of computational mechanism."

In order to find a cell that he can manipulate by these means, Knight is currently attempting to find and tailor the simplest living system possible. He believes that he may have found the ideal candidate in the simplest bacterium known, a plant and insect pathogen containing only 454 genes. Previous research suggests that it is possible to cut these genes down to 293 essential ones.

There is much work to be done before researchers can completely design and control a living cell, but Knight is quick to point out that "300 is a very doable number."

Virtual reality may help astronauts regain balance

A new head-mounted virtual reality system will soon be created by MIT's Center for Space Research (CSR) as part of a $3.6 million NASA grant to the center for the development of experiments to study human balance disorders. Astronauts have been found to suffer from these disorders after experiences in gravityless space. On Earth, gravity provides humans with references that allow them to properly perceive space and orientation, and predict how objects will move. But the force also assists in our nervous system's ability to control movement.

"All these processes are fundamentally altered in weightlessness, as evidenced by the visual illusions frequently reported in orbit by astronauts and also by the surprisingly long-lasting aftereffects seen, particularly after prolonged space flight," said Director Charles Oman of the Man Vehicle Laboratory (MVL).

Oman's research "could also lead to new methods for evaluating motor disorders on Earth and for rehabilitative training." Oman is principal investigator of the international team set to design the virtual reality system, which he says is "intended as a generic facility, potentially capable of supporting on-orbit crew training (e.g., rehearsals of spacewalks) and robotic control activities."

The project, called the Visuomotor and Orientation Investigations in Long-Duration Astronauts, or VOILA, will study the movements of humans after long flights, allowing Oman and others "to study human responses over three to five months in weightlessness, not just the one to two weeks afforded by a shuttle flight."

Oman will be working with Dr. Andrew M. Liu and Elizabeth Zotos of the MVL and the CSR, and Laurence R. Young, the Apollo Program professor of Astronautics. Other investigators from across the United States, Canada, France, and Italy will support their team.