

MIT Science News in Review

BIOCHEMICAL SCIENCES

Whitehead triumphs over human genome project

On June 26th, the Human Genome Project and Celera Genomics announced the primary assemblies of the human genome, a feat accomplished with the help of the Whitehead/MIT Center for Genome Research. Whitehead was the single largest contributor to the project, accounting for nearly a third of the sequences assembled by an international consortium of sixteen laboratories.

Researchers at the Whitehead Institute were responsible for laying the groundwork for the project and were also crucial in completing its final phase, producing over one billion DNA base pairs in the past year.

The consortium's goal for the spring of 2000 was to produce a "working draft" version of the human genome, an assembly containing overlapping fragments of roughly ninety percent of the genome, with some gaps and ambiguities. The ultimate goal is to produce a "finished" sequence with no gaps and 99.99 percent accuracy.

The international Human Genome Project consortium centers have produced far more sequence data than expected (approximately 22.1 billion bases of raw sequence data), resulting in a working draft substantially closer to the ultimate finished form than expected at this stage.

This "finished" sequence will be crucial in obtaining all possible information from human sequence data. As of now, this has already been achieved for about 24 percent of the genome, including chromosomes 21 and 22.

In a similar announcement, Celera Genomics announced the completion of its first assembly of the human genome. While both the private and public projects used similar sequencing technology, the way in which each approached sequencing the human genome is quite different. The Celera project uses a "whole genome shotgun" approach, in which the entire genome is shredded into small fragments that are subsequently put back together on the basis of sequence overlaps.

Whitehead scientists received accolades from President Clinton and Francis Collins, director of the Human Genome Research Institute, and tremendous media coverage. Eric Lander, professor of biology and director of the Whitehead Institute, and Lauren Linton, co-director of its sequencing center, were both present at the White House and recognized for their accomplishments.

"We deserve to be proud of our accomplishments and bask in this glory as the world's attention focuses on us. The credit goes to all the individuals at the Whitehead Genome Center who have worked hard to make us the flagship center of the Human Genome Project Consortium. Everyone associated with this project should feel proud," said Professor Lander.

Unique biomaterial may revolutionize neural regeneration

A long-sought goal of molecular neuroscience has been to perform the seemingly impossible: to regenerate nerve cells after damage. Since the accident of actor Christopher Reeve, the concept has gained widespread attention in the biology community, but few scientists have presented definitive results to suggest that the feat could be easily accomplished.

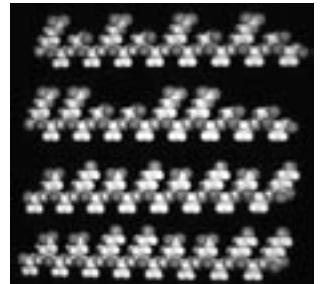
In the June 6 issue of the *Proceedings of the National Academy of Sciences*, MIT researchers collaborating with New York University scientists reported that they have designed a new material that may function as a scaffolding for regenerating nerve cells. The scaffold, made of proteins, acts as a fence to a vine, allowing neurons to grow fibers along it and ultimately reconstructing functional synapses.

The biomaterial brings researchers one step closer to the ultimate goal of growing replacement nerve cells for victims of spinal cord injuries and other nerve disorders.

"Further development of biological materials and related cell-based therapies may bring us closer to the elusive goal of repairing the damaged nervous system," wrote Melitta Schachner, a researcher in molecular neurobiology at the University of Hamburg in Germany.

"The reason this material is so interesting and unique is that we can individually tailor it to grow virtually every type of cell in the body," said Shuguang Zhang, associate director of the Center for Biomedical Engineering at MIT. Zhang and NYU professor Todd Holmes are the first to use a peptide-based biomaterial at the molecular level.

Zhang and Holmes reported that the type of technology they used to make the biomaterial "will become increasingly important in developing approaches for a wide range of innovative medical technologies, including controlled drug release, new scaffolds for cell-based therapies, tissue engineering and biomineralization."





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The duo also says that peptide-based materials might be used as an alternative to animal-derived substances that could potentially pass viruses onto cells. The peptide materials can be constructed without using animal cells, and can thus provide a safe means to treat patients without eliciting an immune response.

Genetic culprit infecting animals apprehended in plant cousins

In the March 31 issue of *Science*, researchers from MIT and the Louisiana State University Health Sciences Center report finding surprising similarities between two bacteria with widely differing lifestyles in how they establish chronic infections in mammals and plants.

Upon first glance, agriculturally important bacterium *Rhizobium meliloti* and pathogen *Brucella abortus* have no features in common. However, Graham Walker, professor of Biology, reports that both bacteria interact with their hosts similarly.

While all organisms require nitrogen, plants cannot utilize it until it has been converted into ammonia. This conversion is accomplished by leguminous plants with the help of *rhizobia*, bacteria residing in the soil. The bacteria invade the nodules on the roots of the plants and are then taken up by the plants. "You can look at it as a chronic infection of the plant, although unlike other infections, this is beneficial to the organism," said Walker. "The plant allows itself to be invaded by the bacteria. In this way the plant gets ammonia and the bacteria gets carbon."

On the other hand, *Brucella abortus* infects mammals by being ingested in the form of infected milk or animal tissue, resulting in brucellosis, a debilitating disease accompanied by symptoms that include fever, malaise, and weight loss. The disease is difficult to eradicate because the bacteria reside inside cells.

According to MIT postdoctoral fellow Kristin Levier, the bacterial gene *bacA* is crucial to both the *rhizobia* and the mammalian pathogen *Brucella abortus*. "The *bacA* function seems to be necessary for the bacteria to overcome the defense response of the host that would otherwise prevent a chronic infection," said Walker, as removal of the *bacA* gene made it impossible for the bacteria to infect its host.

Thus, this scenario, which involves removing the *bacA* gene from the bacteria to allow the human immune system to recognize and kill the intruder, is a perfect starting point for the development of a vaccine against *brucellosis*.

EyeGen wins \$50K for the dye to die for

Although MIT's \$50K Entrepreneurship Competition usually features a new marketing marvel, this year's competition has a biological base: a dye that makes DNA visible to the naked eye. The winners, members of a company named EyeGen, formulated a safe alternative to radioactive and fluorescent probes, which researchers commonly use to visualize DNA strands. The EyeGen group, which plans a \$15 billion market for their product, may be revolutionizing bench-top biology with a simple dye called EyeGenRad.

"Since DNA manipulation is at the core of most genomic, medical and biotech research, EyeGenRad has broad application

as an invaluable tool,” the team wrote in its official press release.

“Now we’ll see what happens with the funding, find some lab space and start our operations,” said chemistry graduate student Zoran Zdraveski, the team’s scientific officer and one of the founders. “We planned on moving this company ahead, but the \$50K shoved us along at a faster rate. We met so many people who’ve opened doors for us.”

MIT applies ‘Star Wars’ technology to breast cancer

Technology developed 10 years ago to detect missiles for ‘Star Wars’ is now being applied to the treatment of breast cancer. Dr. Alan J. Fenn, senior staff member in the Advanced Electromagnetic Systems Group at Lincoln Laboratory, invented the technique.

The treatment uses focused microwave radiation to “heat — and kill—cells containing high amounts of water,” Fenn said. Cancer cells have a high water content—around 80 percent—while healthy breast tissue contains much less.

The microwave treatment lasts for 20 minutes and heats cancer cells to 115 degrees Fahrenheit. Tumors typically shrink by 50 percent or more within a week. However, as part of this FDA-approved study, the patients had mastectomies 7 to 10 days after the thermotherapy treatment, making it impossible to watch the tumor shrink away completely.

In future clinical trials the doctors may apply a second treatment to eliminate the cancer faster.

“Our goal is to destroy all visible and microscopic cancer cells and pre-cancerous cells in the breast,” Fenn said.

That would eliminate the need for surgery and conventional radiation treatments. If the cancer spreads, however, the patient would still need chemotherapy.

The procedure uses two tiny probes to sense and measure parameters during treatment. “Patients treated so far have gone home with only one or two band-aids,” Fenn said.

He expects that in the future the procedure will be noninvasive. The technique could also be applied to other cancers. The next target will be prostate cancer.

Neural receptor affects breathing and memory

MIT researchers reported in May 1 of *Neuroscience* that the chemical receptor N-methyl-D-aspartate (NMDA), usually associated with memory and learning, might also play a role in the development of the fetal respiratory system.

Researchers found that the absence of this receptor led to long-term synaptic depression (LTD), an activity that aids in learning and memory building. Unexpectedly, the increased LTD occurred in the brainstem, an area normally associated with autonomic vital functions.

Further research on NMDA led to the discovery that a lack of NMDA receptors during prenatal development was lethal in lab rats.

“This is the first indication that prenatal development of specific regions in the brain controlling vital functions is very much dependent on NMDA receptor activity, and a lack of NMDA receptor activity in the fetus could affect newborns’ breathing after birth,” said Dr. Chi-Sang Poon, a Principal Research Scientist in the Harvard-MIT Division of Health Sciences and Technology (HST). In addition, the unexpected increase in LTD in the brainstems of the mutant mice “shows that learning and memory at a subconscious level could profoundly influence our vital functions,” Poon said.

The research suggests that pregnant women should not have prolonged exposure to substances that affect NMDA’s activities. Alcohol, PCP, and some anesthetics and analgesic drugs are among the list of substances that interfere with NMDA’s normal functionality.

Miller models memory one neuron at a time

Among the greatest challenges in cognitive science is the attempt to map learning and memory. While neuroscientists have attempted the feat from nearly every angle, few claim to have accomplished the task. The goal, however, may be



A large green rectangular advertisement. At the top, in white, bold, sans-serif font, it reads: "WE LOVE YOU FOR YOUR BRAIN. EVERYONE ELSE IS SUSPECT." Below this, there is a white-bordered box that looks like a document or a sign. Inside the box, it says: "ENGINEERS APPLY WITHIN." followed by a right-pointing arrow and the URL "www.nvidia.com". Below that, it reads: "We are looking for talented engineers to work on revolutionary technology. As the leading developer of graphics technology today, we consistently deliver award-winning products that enable e-business, entertainment and education applications. And it takes special people to do that. Visit our web site for more about who we are, job opportunities, and to submit your resume." At the bottom right of the green area, there is the NVIDIA logo, which is a stylized 'N' inside a square.

one step closer to completion because of the work of Earl Miller, associate professor of brain and cognitive sciences in MIT's Center for Learning and Memory. Miller attempts to determine how our brains guide us through long-term projects, despite the everyday distractions and disappointments we face.

By studying the prefrontal cortex of the brain (crucial to high-level cognitive function), that is enormous in humans and appears to arbitrate voluntary activity, Miller thinks he might achieve the feat.

"The main thing we are interested in is the deepest issue in cognitive science, called executive or cognitive control," Miller said. "It governs how you decide what behaviors to engage in, how you make decisions, how you decide what to pay attention to, what to do with your life."

Miller, believe it or not, has begun to model some of these profound behaviors.

"When I started graduate school, if you had told somebody, 'I'm going to tell you a little bit about how voluntary, goal-directed behavior works,' he or she would have said, 'You can't study that. That's a crazy topic.' But just in the past few years, we've actually developed some real hypotheses about how this all works."

Miller began by looking at single neurons, "from the premise that the most important feature for neurons is their ability to extract information from experience... They need to be sculpted by experience, because virtually all voluntary behavior—everything we're saying and doing right now—is learned."

Miller has recorded the electrical activity of groups of neurons in rhesus monkeys to determine the capacity of the prefrontal

cortex to assist the monkeys' ability to direct their attention to a visual image and putting it into long-term memory.

Miller has begun to identify which neural groups of neurons contribute to this activity; opening the door to potential pharmaceutical therapies that can prevent the loss of memory.

PHYSICAL SCIENCES

Ion-collision experiment uncovers Big Bang secrets

Most of us remember learning about Rutherford's nucleus scattering experiment. Recently, MIT scientists again collided gold nuclei—this time, for an altogether different purpose: to study the state of matter immediately after the Big Bang.

On June 12, physicists at the Brookhaven National Laboratory created a head-on collision between gold nuclei travelling near the speed of light in what they called the Relativistic Heavy Ion Collider (RHIC).

RHIC is a system used to model the early universe as it existed less than a second after the Big Bang. By accelerating gold and other nuclei to near the speed of light, Brookhaven scientists believe they can visualize energy densities associated with the Big Bang, perhaps uncovering clues to the plasma thought to exist during the event. That plasma consisted primarily of high-energy

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quarks and gluons, which quickly cooled down to create the distinct particles that we now identify as composing matter.

By reversing the process through high-speed collisions, RHIC scientists attempted to fracture nuclei to their previous hot and dense states. When they finally observed these nuclei in June, they confirmed that plasma exists. The work may also determine the timing of such plasma formation during the Bang.

"We are excited, relieved and slightly tired," said Wit Busza, the Francis Friedman Professor of Physics and a MacVicar Faculty Fellow. Busza commented that "it is very important that we identify that moment and that we show that we have compressed normal matter so much that it produced the plasma."

"With RHIC, we are making an analogy to what happened just after the Big Bang. We are replaying history to study the process of transition similar to a phase transition that occurs when water vapor turns into fog," said Busza. "And it's a relief to know the equipment works to do that. But we still had to show that the events occurred and analyze what happened."

Rocket team fires up

Inspired by a \$250,000 cash prize to launch a suborbital rocket 120 miles into the atmosphere, MIT undergraduates, graduates, alumni and faculty collaborated to create an elegantly simple rocket. The Cheap Access to Space (CATS) competition, funded by the Foundation for International Non-governmental Development of Space and the Space Frontier Foundation, is designed to challenge the current suborbital record height of approximately 25 miles.

Carl Dietrich (SB 1999) founded the Rocket Team in his senior year after hearing about the contest from a friend and has applied for a patent for a kerosene/liquid oxygen engine he designed in 1998. He worked full-time on the project with Westinghouse Science Award winner Andrew Heifitz (SB 1991), who was intrigued by the challenge of working with unmanned aerial robotics and impressed by the simplicity of the design.

The rocket was 14 feet tall and eight inches in diameter, a size dictated by the facilities available to construct and test vehicle components. It weighed approximately 200 pounds. The body consisted of a lightweight carbon fiber composite, while the engine was made up of aluminum, stainless steel and a silica-pheno composite material. As such, the rocket was significantly smaller, simpler, and cheaper than existing government and commercial liquid-fueled launch vehicles.

A prototype of the model was launched on Briggs Field this past spring. Team members have already met with NASA engineers and administrators at the launch/test facility at Wallops Island, VA, along with members of the Virginia Spaceport Authority. The design and safety review process with NASA will be initiated shortly to obtain a launch license from the Federal Aviation Administration and approval to launch at Wallops Island. If successful, this rocket could introduce cheaper, simpler commercial space launch vehicles to the skies.

Nuclear waste containers convert to clay given time

As the use of nuclear fuel skyrockets around the world, a team of MIT scientists led by Civil and Environmental Engineering Professor Franz-Josef Ulm has been asking a simple question: where is the waste going to go? Ulm and others have raised concerns about the ability of cement containers to hold nuclear waste over the long term. But rather than watch bad environmental policy take shape, Ulm and his colleagues took action; they designed a test to observe the degradation of nuclear waste containers, which commonly occurs over 300 years, in one day. Using a laboratory model based on miniaturized concrete slabs surrounded by a liquid bath, Ulm and his colleagues began to subject weathered materials to a variety of stresses to discover how the containers could be improved.

"Our goal is to go back to real-life structures, monitor the environment around them, and predict by model-based simulation what the concrete will do over extended periods of time," Professor Ulm said. And if a bad scenario plays-out, "we'll be able to predict its eventual effect, and intervene in time to slow down or reverse the aging," said Ulm.

Ulm is now attempting to export his model to those who need it most: the US government.

"When, and if, spent nuclear fuel from the US is buried in the Department of Energy proposed repository at Yucca Mountain, it will be placed in concrete casks that are supposed to maintain integrity at least 300 to 1,000 years," said Mujid Kazimi, an MIT professor of nuclear engineering. But what Ulm and others are finding is that the concrete containers can weaken over time, causing the concrete to dissolve. When he applied a shear stress to his laboratory containers, slivers of the material slipped apart.

"So a material that is originally very strong ultimately ages to one that behaves like a weak low-friction soil, such as clay," Ulm concluded. The findings may lead to a renewed emphasis to discover how the waste containers can be improved.

MIT scientists provide new spin on unique pulsars

Like a beacon in the night sky, a star spins, peacefully pulsing with x-rays until a sudden disturbance causes it to speed up its rotation.

On March 23 at the Rossi 2000 conference held at NASA Goddard Space Flight Center, assistant professor of physics Victoria M. Kaspi of MIT's Center for Space Research reported that an Anomalous X-ray Pulsar (AXP) experienced a seismic shift reminiscent of those found commonly in neutron stars. This confirmed that the AXP is truly a neutron star.

"We have thought that earthquake-like events might occur on these stars for some time now, but we have lacked the right



instrument to check this," said Kaspi. "No X-ray astronomy satellite in the past had the agility to observe these objects as often and as regularly as we needed. Thanks to [the Rossi X-ray Timing Explorer satellite], we now know for certain that glitches occur in AXPs, and we can study the interiors of these unusual objects using a form of 'seismology,' like the way geologists study the Earth from earthquakes."

Neutron stars are the remains of massive stars that explosively shed their outer shell upon exhausting their nuclear fuel. In the wake of these violent explosions, the solar core collapses into a spinning sphere nearly 10 miles in diameter. If the neutron star "pulses" with radiation as it spins, it is called a pulsar. Most pulsars emit both radio waves and X-rays. A select few, AXPs, emit X-rays exclusively.

Studying the relation between conventional radio pulsars and AXPs, Kaspi and collaborators searched for "glitches" in AXPs, when radio pulsars suddenly spin faster than normally observed, a likely result of earthquake-like phenomenon called vortex line upspinning deep within the stellar core.

After two years of observing, Kaspi and collaborators watched as one of their target AXPs, 1RXS J1708-4009, began to spin faster.

"We were delighted! The glitch we saw was practically identical to glitches that have been seen in the Vela radio pulsar," said Kaspi. "This is clear evidence that the AXP is a neutron star with an internal structure just like the radio pulsars."

Such discoveries lend support to the magnetar hypothesis, which predicts the existence of stars a thousand times more magnetic than the overpowering neutron star. Kaspi hopes that defining the nature of AXPs will aid the understanding of other rare and mysterious objects such as the magnetars and soft gamma-ray repeaters.

ENGINEERING AND TECHNOLOGY

Discover Magazine awards technological innovation

Three MIT innovations are among this year's 19 *Discover Magazine* Awards for Technological Innovation. The three inventions: sneakers that compose music, a cancer diagnosis technique, and lights that talk, were all featured in the July 19 edition of *Discover Magazine*.

Joseph Paradiso, technology director of the Things That Think group at the Media Laboratory, won a prize for sneakers he developed that let children create music as they move. Heralded as "a new twist in interactive entertainment," Paradiso's invention superseded all others in the entertainment category.

Dr. Todd Golub of the Whitehead Institute developed a DNA Chip Cancer Diagnosis technique. Doctors can now deposit RNA taken from a tumor biopsy onto probes affixed to small glass wafers. When scanned with a laser, a DNA profile of the tissue is automatically created, allowing physicians to customize cancer treatments for individual patients.

Customizing is also at the heart of Professor Steven Leeb's

invention. The Associate Professor from the Department of Electrical Engineering and Computer Science produced "talking lights" that convert light sockets into information transmitters. Leeb says that the invention can allow a person to encode information in a sort of Morse code by modifying the rate at which a light flickers. Flickering at a rate faster than the eye can see, the lights trigger a speech mechanism that could, for example, direct a person to the bathroom in a building.

Leeb and his two fellow award winners were acknowledged at a June ceremony in Disney's Epcot Center. Their awards are given to "honor the unsung technological heroes whose creative genius improves the quality of our everyday lives and alerts us to what lies ahead in the frontiers of human achievement and ingenuity".

Manus robot rehabilitates stroke victims

An MIT robot has proven itself valuable in the physical therapy of recovering stroke victims. The May 23 issue of *Neurology* featured a report in which a second clinical study demonstrated that the robot significantly improved patients' recovery of arm movement.

The robot, dubbed Manus for MIT's motto, 'mens et manus' (mind and hand), has been in development for eleven years now and focuses on arm therapy. Two clinical trials have already been conducted. A third was initiated in January 2000 at the Spaulding Rehabilitation Hospital in Boston; the purpose being to "see if stroke recovery is limited to central nervous system reorganization, and if it can be influenced by more peripheral systems."

During the robot-aided therapy, the patient sits at a table and places the lower arm and wrist into a brace attached to the robot's arm. A video screen then prompts the patient to perform arm exercises. The robot facilitates arm movement by providing adjustable levels of guidance.

The study consisted of 56 patients split among two groups. Each patient received standard therapy. In addition, the experimental group spent an additional daily hour with MIT-Manus, while the control group used a "sham" robot once a week that did not guide patients through exercises. The experimental group demonstrated twice as much of an increase in arm movement as patients using conventional physical therapy.

Researchers are now focusing on creating additional robots for therapy of the legs and wrist/hand. The applications of this robot are far-reaching, as it can become an important teaching tool as well as an aide to doctors in assessing a patient's condition and prescribing optimum therapy.

Surgical disaster sparks innovation

Had the surgery turned out differently, it is very possible that Professor Ernesto Blanco of the Mechanical Engineering department would still have been interested in the surgical instruments. As it turned out, the surgery gone awry guaranteed that Blanco would modify the instrument at fault.

The trocar is used in endoscopic, minimally invasive surgery to make the initial puncture through skin. Once a hole has been made, other instruments can be inserted through the opening to complete the surgery.

In Blanco's surgery, the trocar cut too deeply due to the change in resistance once the skin had been pierced. Because the endoscopic surgery had to be truncated after the slip of the trocar, Blanco needed an open surgery. This resulted in a longer hospital stay, stitches (which incidentally inspired another invention) and an increased risk of infection.

The trocar Blanco has designed should, however, be able to circumvent these problems by addressing the initial difficulty of piercing the skin without injuring organs. The new design is shaped in an hollow X rather than the traditional solid V. The new design always has a protective guard on the blade within the body, a major improvement on trocars that can plunge 3/4 of an inch in the body before the safety guard is deployed.

In addition, the new trocar removes a step in endoscopic surgeries by filling the body cavity with carbon dioxide in order to separate organs from the abdominal walls. A patent has been applied for the device and will take approximately a year to arrive on the market.

Microvillages solve housing shortages in Turkey

600,000 people were left homeless in Turkey after August 17, 1999, when an earthquake registering 7.4 on the Richter Scale leveled many apartments and housing. Many of the victims of the earthquake are still living in tent cities and other temporary lodging.



Hearing of the devastation, Professor Jan Wampler of MIT's architecture department immediately collaborated with MIT alumni in Turkey to devise a solution to the housing shortage. The result was a plan to create microvillages—a plan that will be carried out by Habitat for Humanity, MIT and Mercy Corps International.

The proposed microvillages will be two-story housing units to be built in part by its future residents. The microvillages will center upon communal living and focus upon sustainability. Locally farmed wood as building material, harnessed wind and sun energy as power sources, rainwater for reservoirs, and treatment of sewage as fertilizer are just some of the ideas that will be utilized to create the microvillages. The microvillages will enable people to be active participants in their living unit through community maintenance.

The future of microvillages will be bright. In the past, people who left rural areas had to live in busy cities; microvillages will provide the conveniences of the city while maintaining the community of the more rural areas.

Coaxial cables succeed to perfection through perfect mirrors

In 1998, MIT scientists created a perfect mirror—now they are building on perfection by researching coaxial cables which can shoot light quickly and efficiently over long distances without distortion.

The commonplace metallic mirror reflects light from every angle while absorbing incident light. Dielectric mirrors (unlike metallic mirrors) do not conduct electricity, are made from layers of transparent dielectric materials, and are used in lasers, which require low loss of light and high reflectivity.

The perfect mirrors created in 1998 have the reflective properties of a metallic mirror and the low loss property of the dielectric mirror. An omnidirectional waveguide was constructed from a tube of the perfect mirror. The all-dielectric coaxial cable outperforms the optical fibers currently used in data transmission because it does not lose its light polarization as optical fiber does. The cable can create high-bandwidth and higher information capacity and will be researched for Internet applications.

MIT researchers who have worked on the perfect mirror technology launched a new company OmniGuide to explore the coaxial cable's practicality. Currently a prototype and test of the coaxial cable is underway.

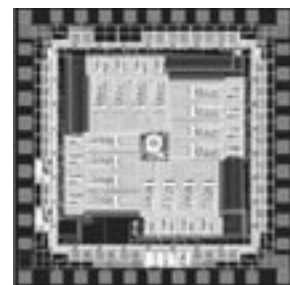
Feedback loops enhance electronic circuits to brain circuits

An ultimate challenge of artificial intelligence researchers is to create an electronic circuit that mimics the pathways of the brain. Researchers at MIT and Lucent Technologies' Bell Labs may have accomplished that very feat, as they report in the June 22 issue of *Nature*.

MIT researchers Richard Hahnloser, a postdoctoral fellow in the Department of Brain and Cognitive Sciences; Rahul Sarpeshkar, assistant professor of electrical engineering and computer science; and H. Sebastian Seung, assistant professor of computational neuroscience, say that they have created an electronic circuit that mimics that circuitry of the cerebral cortex, using feedback loops to copy the brain's design.

"Like electronic circuits, the neural circuits of the cortex contain many feedback loops," said Seung. "But neuroscientists have found that cortical feedback seems to operate in a way that is unfamiliar to today's electronic designers. We set out to mimic this novel mode of operation in an unconventional electronic circuit."

The prospects of such a circuit are great for artificial intelligence scientists, who expect to develop computer hardware capable of cognitive tasks. But the physical structure of the circuit itself is quite unique; the MIT group generated it by producing artificial neurons that communicate with each other via artificial synapses made from tran-



sisters grafted onto a silicon integrated circuit. The group also added inhibitory and excitatory feedback loops to their circuit to mimic the activities of the brain.

In the brain, feedback controls repetitive motion, such as the beating of the heart, or more advanced motion, such as movement of the limbs.

"Biologists like to focus on simple linear pathways through this network, ignoring the tangled web of feedback loops, which seem too complex to even contemplate," Seung said. "But it seems unlikely that we could ever understand intelligence or consciousness without understanding the role of feedback in the neural networks of the brain."

Although electrical engineers have been tempted to use common electronic feedback mechanisms to mimic the brain's circuitry, Seung and other have said that the brain uses altogether different rules for feedback. The group's new circuit has the ability to combine both digital and analog-type behaviors to truly imitate the brain's behavior.

Powerful pulsed superconducting magnet passes initial testing

MIT engineers and colleagues from Japan and the US reported that a 150-ton magnet, significant to fusion energy research, has passed its initial operating test.

The magnet, located in Japan, produced a magnetic field 260 times more powerful than that of the Earth, at 13 tesla, with a stored energy of 640 megajoules at a current of 46,000 amperes.

Two modules make up the magnet: one designed and built in the United States, the other in Japan. Dr. Raghavan Jayakumar, a visiting scientist at MIT, spearheaded the US magnet program. The magnet was built by engineers from MIT, Lawrence Livermore National Laboratory (LLNL) and the Lockheed Martin Corporation, the prime industrial contractor. The two modules were combined last year in Naka, Japan.

Joseph V. Minervini, principal researcher at MIT's Plasma Science and Fusion Center (PSFC) and Department of Nuclear Engineering, said, "It's the world's most powerful pulsed superconducting magnet." The researchers seek to demonstrate "superconducting performance parameters" and manufacturing methods for larger magnets planned for the International

Thermonuclear Experimental Reactor (ITER), whose goals include demonstrating the feasibility of nuclear fusion as an energy source.

Perhaps the most noteworthy result of the initial testing was the stability demonstrated by the magnet while charging to full capacity. No training or quenching was required, common procedures in the early operation of other superconductors.

According to the researchers, future testing will involve trying to increase the speed at which they can charge up to 13 tesla and discharge. ■

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