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TechTalk
SERVING THE MIT COMMUNITY

MIT Media Lab redefines adaptive technology

H2.0 initiative ushers in a new era for people with physical or mental disabilities

Stephanie Schorow
News Office Correspondent

Forget cool new gadgets or killer-app software. "We're hacking the human," said Frank Moss, director of MIT's Media Lab, in introducing "H2.0: New Minds, New Bodies, New Identities," the lab's May 9 symposium that showed—often in mind-blowing detail—how addressing the challenges posed by disabilities can broaden the scope of human ability.

"The goal of today's symposium is to demonstrate the amazing possibilities in new adaptive technology," as MIT President Susan Hockfield noted.

But "amazing" came with a sense of humor, as provided by MIT Media Lab Distinguished Fellow and veteran TV journalist John Hockenberry, who acted as master of ceremonies and got things rolling by showing off the sparkling lights on his wheelchair.

And tales of the "amazing" were tempered by the quiet humanity of author and neurologist Oliver Sacks, the keynote speaker, who mesmerized his audience with stories of the brain's adaptability.

Hockenberry set the tone by bringing on stage a telephone and a typewriter (which he defined as a "laptop that prints while you type.") The typewriter, he noted, was invented to let the blind write, and telephone inventor Alexander Graham Bell was seeking ways to help the deaf.

What if, he asked, new technology was about more than creating new devices to "dump" on the population? What if it involved thinking about "human mechanisms and abilities?"

"Who knows about that? People with disabilities," Hockenberry said. They "know about that intimate relationship with technology. In a sense, people with disabilities are first adopters of this extreme collaborative quality that's going to define technology in the 21st century."

The 73-year-old Sacks, the author of "Awakenings" (which became a movie starring Robin Williams) and the seminal "The Man Who Mistook His Wife for a Hat," took the stage, the very picture of vitality in black sneakers, black pants and a black T-shirt, his large dome of a head matched by a snowy beard. Yet he acknowledged he has some retinal prob-

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PHOTO / **DONNA COVENEY**

Panelist Aimee Mullins is a Paralympic athlete, model and actress whose legs were amputated when she was one year old. Above, she demonstrates her newest prosthetics—legs equipped with 4-inch-high stiletto heels—during the discussion, 'Identity in a Human-Machine Context.'

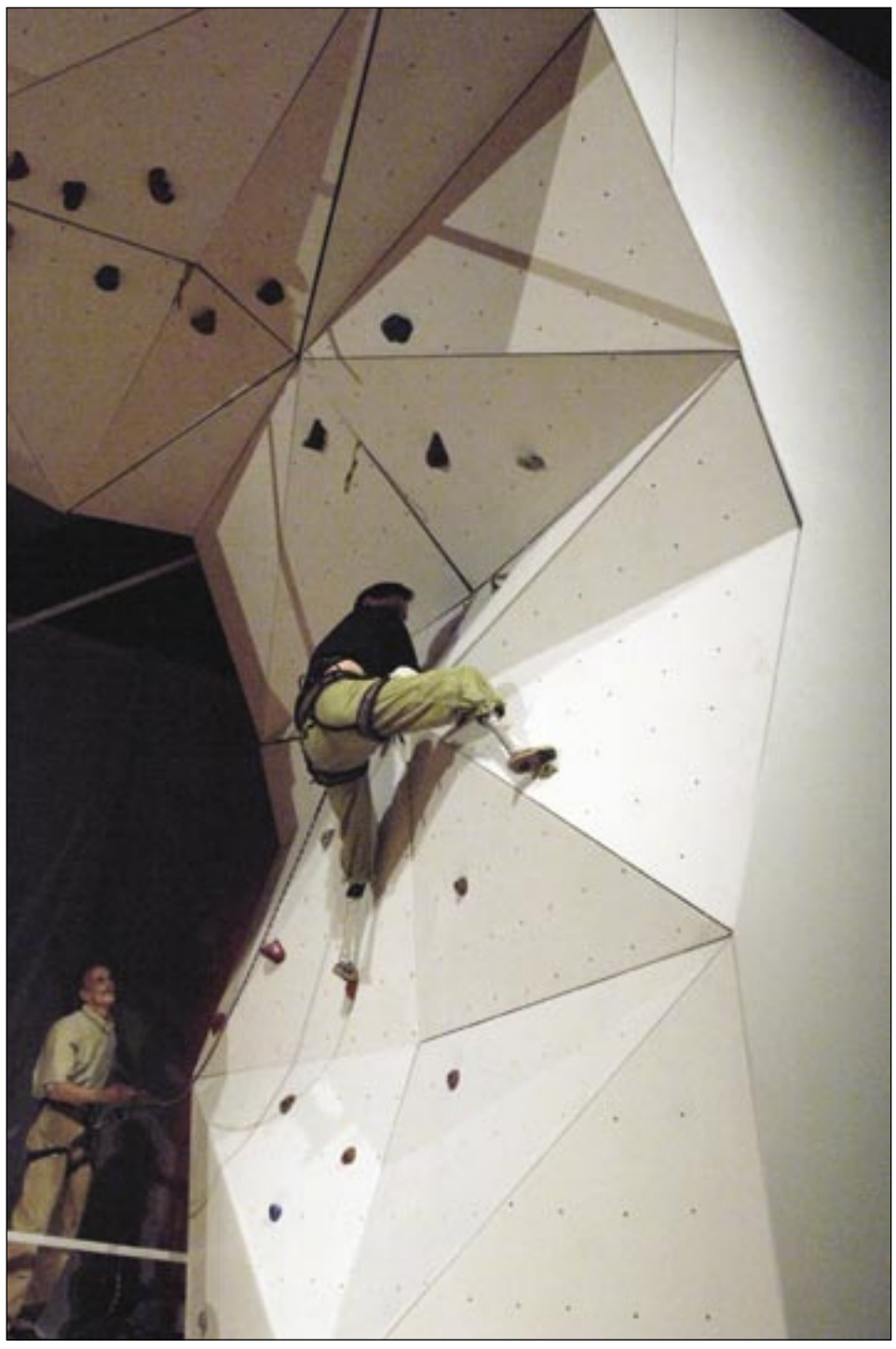

PHOTO / **DONNA COVENEY**

Hugh Herr, associate professor of media arts and sciences, lost both his legs after a climbing accident. Following his talk, 'New Horizons in Orthotics and Prosthetics: Merging Bodies and Machines,' Herr put on his 'climbing legs' and scaled a wall on the Kresge stage.

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Queen Rania of Jordan tours campus

Robin Ray
News Office Correspondent

MIT welcomed Her Majesty Queen Rania of Jordan to campus on Friday, May 4. She was greeted by MIT Chancellor Phillip Clay, who served as host for the morning visit.

After meeting with Jordanian students who attend the Institute and officers of the MIT Arab Students' Organization, the queen met in the Bush Room with directors and researchers from the Abdul Latif Jameel Poverty Action Lab (J-PAL) and MIT's International Development Initiative (IDI), a joint program of the Edgerton Center and the Public Service Center.

The queen is renowned for her charitable work in areas of health, microfinance, economic development and education, and as a strong advocate for the empowerment of women. Her keen interest in issues of poverty and development made her seek out the work of J-PAL and the IDI.

J-PAL Executive Director Rachel Glennerster said, "The queen stressed how important it was for microfinance organizations to have good measures of their impact, and had some very pertinent questions for us about how the impact of something as complex as microfinance can be measured correctly."

Queen Rania concluded her visit with a stop at the Media Lab, where Associate Director of Research John Maeda and Professor Mitch Resnick briefed Her Majesty on their research and on the One Laptop Per Child initiative, a new nonprofit effort launched by Nicholas Negroponte, a cofounder and former MIT Media Lab director.

"She's a very active royal," said Clay, adding that the aim of the visit was to "give her a sense of the kinds of projects in which students and faculty focus on research and service with an international impact."

PHOTO / **DONNA COVENEY**

Queen Rania of Jordan met with Chancellor Phillip Clay, Jordanian students and officers of the MIT Arab Students' Organization in the Compton Gallery during her May 4 visit to MIT.

PHOTO / **DONNA COVENEY**

Sophomore Iman Kandil (rear) and graduate student Dalia Husseini look on as Queen Rania shakes hands with sophomore Nour Abdul-Razzak. Queen Rania is known for her charitable work in health care and microfinance.

Biotech event draws MIT, worldwide participants

Dato' Sri Mohd Najib Tun Abdul Razak, deputy prime minister of Malaysia, was among the guests at a reception hosted by President Susan Hockfield to welcome participants to the 2007 BIO International Convention held in Boston, May 6-9.

Produced by the Biotechnology Industry Organization (BIO), the conference drew a record 22,366 attendees representing 48 states. One-third of attendees came from outside the United States.

Event highlights included keynote addresses from Michael J. Fox, founder of the Michael J. Fox Foundation for Parkinson's Research, and Her Majesty Queen Noor of Jordan. Fox, who appeared before a packed room, urged the biotechnology industry to continue to innovate and accelerate the translation of basic science into improved therapies for patients. Queen Noor discussed the opportunities presented by biotechnology to address global health and poverty issues.

The final keynote session, "A Hopeful Future: Gaining the Edge with Biotechnology," featured Institute Professors Robert S. Langer and Phillip A. Sharp as panelists. They joined Craig C. Mello of the University of Massachusetts Medical School and author Virginia Postrel in discussing their visions of the future of the biotechnology industry.

Sharp noted that the United States has no monopoly on biotechnology. "There is science in Europe, Asia and elsewhere. I see us as having increasing competition...biotech is something we have to keep competing at," he said.

PHOTO / **JUSTIN KNIGHT**

Cambridge mayor Kenneth Reeves spoke at the reception held by President Susan Hockfield.

PHOTO / **JUSTIN KNIGHT**

MIT President Susan Hockfield welcomes Dato' Sri Mohd Najib Tun Abdul Razak, deputy prime minister of Malaysia, to a reception she hosted to welcome participants to the 2007 BIO International Convention held in Boston, May 6-9.

PHOTO / **JUSTIN KNIGHT**

MIT Institute Professor Phillip Sharp attended the reception. Sharp won the Nobel prize for his work in RNA splicing and is now working on RNA interference.

Citing Darfur tragedy, MIT will review portfolio

On Monday, May 14, MIT made the following announcement about its investment policies:

"MIT shares the concern of many in our community for the extraordinary human tragedy taking place in the Darfur region of Sudan. The situation is sufficiently grave that MIT in this case is making an exception to its long-standing policy of not speaking with a single institutional voice on matters of public debate not directly affecting MIT's core mission of education, research, and service.

"MIT invests for the purpose of preserving the capital of MIT's endowment and earning a return on capital that is consistent with MIT's long-term investment horizon. At the same time, MIT will not invest in a company whose actions or expressed attitudes are abhorrent to MIT.

"In the case of Sudan, the U.S. government, the United Nations and various international organizations have declared that certain actions there amount to genocide. The risk of MIT being associated with truly abhorrent acts is real. MIT is reviewing the securities portfolios over which it may exercise direct investment discretion and will divest as appropriate for those portfolios to exclude securities that would violate MIT's investment principles.

"MIT's Advisory Committee on Shareholder Responsibility served an important role in the considerations leading to this action. The Executive Committee thanks the members and staff of that committee for their dedication to the Institute and their thoughtful work."

AWARDS AND HONORS

Subra Suresh, Ford Professor of Engineering and former head of the Department of Materials Science and Engineering at MIT, is the recipient of the 2007 European Materials Medal from the Federation of European Materials Societies (FEMS). Suresh is the first scientist based outside Europe to receive the award.

FEMS comprises a group of materials science and engineering professional societies from 24 European countries. Established in 1993, the European Materials Medal is presented at the society's biennial conference, held in every odd-numbered year, to an active materials scientist or engineer for distinguished contributions to materials science and engineering.

Suresh will receive a gold medal and deliver a plenary lecture to materials scientists and engineers on the opening day of Euromat 2007, the official meeting of FEMS, to be held in Nuremburg, Germany, in September 2007.

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Team unearths genetic risk factors for diabetes

Scientists have discovered three unsuspected regions of human DNA that contain clear genetic risk factors for type 2 diabetes, and another that is associated with elevated blood triglycerides.

The findings stem from the work of the Diabetes Genetics Initiative (DGI), a public-private partnership between the Broad Institute of MIT and Harvard, Novartis and Lund University, and reflect a close partnership with two other diabetes research groups.

The three groups' studies, which appeared together in a recent advance online edition of Science, are among the first to apply a suite of genomic resources to clinical research. These genomic resources include the Human Genome Project, the SNP and HapMap Projects, and genome-scale laboratory and analytical tools.

"For the first time, it is possible to look across the human genome and discover new clues about the root causes of common, devastating diseases that arise from a combination of genes, environment and behavior," said senior author David Altshuler, a principal investigator of DGI, director of the Broad Institute's program in medical and population genetics and a professor at Massachusetts General Hospital and Harvard Medical School.

"The confirmed genetic contributors we and our collaborators have found open surprising new avenues for disease research, treatment and prevention," he said.

With the aging of the population and the frequent excesses of modern lifestyles, type 2 diabetes and cardiac risk factors constitute a looming threat to human health, particularly in industrialized nations. Solutions to this burgeoning problem must include new, more effective treatments and the ability to identify "at risk" individuals—each of which requires innovative directions for future research.

The DGI study is one of the first large-scale studies of human genetic variability, aiming to reveal genetic connections to type 2 diabetes and other cardiovascular risk factors such as blood insulin levels, cholesterol levels, blood pressure and body weight. Each of these traits is considered "complex" because it involves a mix of inherited, environmental and behavioral factors.

The scientists' approach, known as a "genome-wide association study," involves scanning thousands of individuals' genomes for single letter changes, called single nucleotide polymorphisms (SNPs). Due to the block-like nature of the human genome, certain SNPs can serve as signposts, highlighting pieces of nearby DNA that may play a causal role in disease.

Using this approach, the DGI team and their collaborators identified and confirmed three novel regions of the genome that influence the risk of type 2 diabetes, as well as a genomic region that is linked with blood triglyceride levels. Perhaps the most intriguing result involves a DNA region that lies far from any known annotated genes. Such genomic "outsiders" would have been incredibly difficult to find by traditional hypothesis-driven approaches.

The other regions linked to diabetes lie near genes with known biochemical functions, but ones never before connected to the disease. Interestingly, the region implicated in triglyceride levels involves a gene that has long been known to play a role in modulating blood glucose.

Based on initial results, the DGI scientists turned to replicating the most promising findings in independent samples—a critical aspect of the genomic method. The scientists worked together with two other groups that performed similar genomic analyses of type 2 diabetes: the Wellcome Trust Case Control Consortium/UK Type 2 Diabetes Genetics Consortium (WTCCC/UKT2D) and the Finland-United States Investigation of NIDDM (non-insulin-dependent diabetes mellitus) Genetics (FUSION).

By virtue of their close collaboration, DGI, WTCCC/UKT2D and FUSION researchers identified at least eight clear genetic risk factors for type 2 diabetes, including three that had never before been found, as well as several other probable risk factors that warrant further study.

Local materials, low cost and good science add up to technology for developing nations

Stephanie Schorow
News Office Correspondent

"Appropriate technology" for developing nations can be as simple as a cloth sari folded four times and used to filter cholera bacteria from water. It can be as elegant as a clay pot within a pot that better preserves fresh vegetables or as disposable as a drip irrigation system used for one season.

The "appropriate technology" movement, while failing in some respects, has opened pathways for helping individuals gain better lives through simple, effective designs, said Amy Smith, a senior lecturer in mechanical engineering. She spoke May 7 during a spring colloquium hosted by the Program in Science, Technology and Society to explore "big questions."

"I think within the last decade we've redefined what is appropriate," said Smith before she proceeded to discuss or display a range of devices, from simple to complex.

In particular, appropriate technology has a new focus on helping people earn money from savings or efficiencies, said Smith, a MacArthur Fellowship recipient. The pot-in-a-pot, for example, allows farmers selling food at the market "to earn more money because they don't have to reduce the price of their crops at the end of the day because they'll still be good the next day." This is "a fabulous example of appropriate technology where a little bit of science and physics ends up creating a device that is very useful," she said.

An instructor at MIT's Edgerton Center, Smith co-founded the International Development Initiative, which provides MIT students with hands-on experience in community and development projects. She and her students work in poor nations to find design solutions that are inexpensive, use local materials and are culturally sensitive and relevant.

"The essence of really good design is embodied in these challenges," Smith said.

One example of such a challenge is the development of charcoal for use in deforested countries like Haiti. A press that compacts waste paper into briquettes was explored as an option; however, Haitian villages have no waste paper and the paper used for experiments came from the Peace Corps office 200 miles away, Smith explained.

Smith's students developed ways to create charcoal from sugarcane and corncobs. "Turns out you can make a profit on this (corncob) charcoal in less than a week," Smith said. "It's a technology that will have a lot of impact because of the economics, environment and health benefits—charcoal is a much cleaner-burning fuel than wood or cow dung."

Another design challenge is creating water purification systems. The organization Sodis (www.sodis.ch) has pioneered a solar water disinfection process in which water left in the sun in polyethylene bottles is quickly rid of bacteria through a combination of heat and ultraviolet rays. One of Smith's students improved on the Sodis container design by creating a clear bag that opens up to scoop river water, closes tightly to store for disinfection, sometimes in just two hours, and pours easily.

"This is a wonderful example of using an ingenious idea to create an extremely simple technology. Once you see it, you say, 'Oh yeah, why didn't they do that before?'" Smith said, adding as a vote of confidence, "We drink water from these things when we travel."

The student has patented the bag design, but in such a way that it can be distributed for free in Third World countries.

Smith also described working in Honduras to create a chlorination system that consisted of an IV drip, a toilet valve and a plastic bucket. The result, while effective, looked "like a piece of crap," and she started to think about how to make it sleeker. Then she realized that it should look junky and not intimidating—that would encourage people to keep it running with local materials. Indeed, she found on a subse-

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PHOTO / **STEPHANIE SCHOROW**

Amy Smith, Edgerton Center instructor and MacArthur Fellowship winner, shows a chunk of energy-efficient charcoal made from a corncob during her talk on appropriate technology.

Opossum genome, just decoded, sheds light on evolution

'Restless lifestyle' of so-called junk DNA has meaning for humans and other mammals

The human genome is littered with so-called junk DNA, relics of "jumping genes" that hopped about chromosomes for more than a billion years. Although these jumping genes have been widely regarded as parasites, concerned only with self-propagation, a new study suggests they in fact played a creative role in evolution—spreading key genetic innovations across the genome.

This insight emerges from the work of an international research team led by scientists at the Broad Institute of MIT and Harvard, which has completed a high-quality genome sequence of the opossum, Monodelphis domestica, the first marsupial to have its DNA decoded.

The work, which appears in the May 10 issue of Nature, provides a fresh look at the evolutionary origins of the human genome. It also sheds light on the genetic differences between placental mammals (including humans, mice and dogs) and marsupial mammals, such as opossums and kangaroos.

"Marsupials are the closest living relatives of placental mammals," said senior author Kerstin Lindblad-Toh, co-director of the Broad Institute's genome sequencing and analysis program. "Because of this relationship, the opossum genome offers a unique lens through which to view the evolution of our own genome."

In the last few years, the functionally important elements of the human genome have been identified through genomic comparisons with other placental mammals. These genetic "working parts" are shared universally across all placental mammals and therefore must have been present when the creatures arose, about 100 million years ago.

But how did these critical features evolve in the first place?

The scientists knew important clues could be found if they could search the recent past, rather than far-off times in

evolutionary history. For this, marsupials held the key.

Marsupials are closely related to placental mammals, but the two groups diverged 180 million years ago—well before placental mammals appeared. So, by comparing the opossum and human genomes, the scientists were able to pinpoint the genetic elements that are present in placental mammals but missing from marsupials—that is, the ones that appeared just before the divergence of placental mammals.

Interestingly, about one-fifth of the key functional elements in the human genome arose during this recent evolutionary period. By focusing on these "newer" innovations, the scientists made two remarkable findings:

- The vast majority (~95 percent) of recent genetic innovation lies not in protein-coding genes, but rather the regulatory elements that influence genes' activity. This result implies that mammals have evolved not so much by inventing new kinds of proteins as by tweaking the molecular controls that dictate when and where proteins are made.
- Most surprisingly, many of the new DNA instructions are derived from the jumping genes, or "transposons," which make up our so-called junk DNA. The percentage is at least 16 percent—and is likely much higher, as many transposon-derived sequences have mutated beyond the point of recognition.

"Transposons have a restless lifestyle, often shuttling themselves from one chromosome to another," said first author Tarjei Mikkelsen, a Broad Institute researcher and a graduate student in the Harvard-MIT Division of Health Sciences and Technology. "It is now clear that in their travels, they are disseminating crucial genetic innovations around the genome."

"Biology depends upon the precise coordination of large sets of genes that are switched on and off together," said Eric Lander, director of the Broad Institute, an MIT professor of biology and an author of the Nature paper. "One of the great mysteries in evolution is how this synchrony arises. These findings suggest a simple answer: genetic controls can evolve in one location in the genome and then be distributed elsewhere by transposons."

This work was funded by the National Human Genome Research Institute.

PHOTO / **DONNA COVENEY**

Aimee Mullins, athlete, model and double amputee, described how the 'whole is greater than the sum of its parts' in her talk. She shared her 'wardrobe' of prosthetics and showed video screen images of herself running on 'cheetah legs.'

PHOTO / **DONNA COVENEY**

Architect Michael Graves, left, shares one of many light moments in the Media Lab symposium with John Hockenberry, journalist, author and Media Lab Distinguished Fellow, during their talk, 'Solutions.'

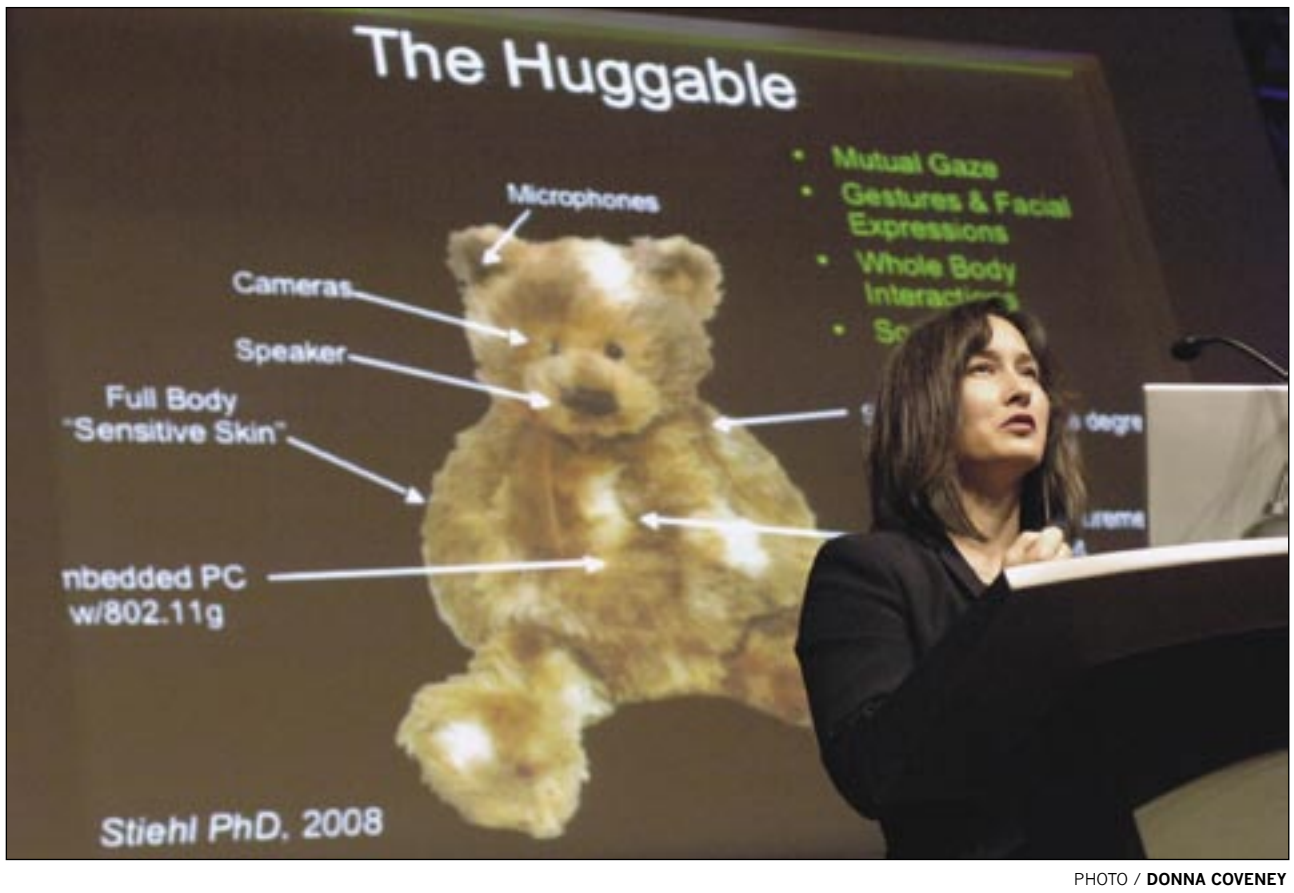

PHOTO / **DONNA COVENEY**

Cynthia Breazeal, associate professor of media arts and sciences, used images of the cuddly Huggable to illustrate her talk, 'The Next Best Thing to Being There: Increasing the Emotional Bandwidth of Mediated Communication Using Robotic Avatars.'

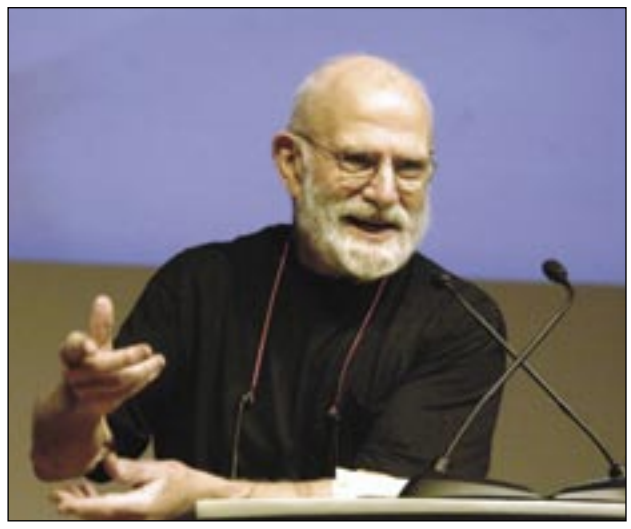

PHOTO / **DONNA COVENEY**

Celebrated author and neurologist Oliver Sacks gave the keynote address at the Media Lab's H2.0 conference on May 9.

MEDIA LAB

Continued from Page 1

lems and is keenly interested in new eye research.

Speaking diffidently, in the self-effacing style of a bookish don, Sacks described how Parkinson's patients, frozen into human statues, could be led into dancing and singing with the right stimuli. Perhaps, he speculated, the Media Lab will come up with a device that will provide the right stimulation. But "the most wonderful power resides in music," he said. Music "will facilitate movement and action in a Parkinsonian as nothing can."

Sacks also spoke of "phantom limbs," a phenomenon in which amputees retain sensation in missing limbs. Once thought to be a "nostalgic construct like the memory of departed parents," such sensations represent the brain's ability to map out senses and motor skills, Sacks said. A famous pianist who lost his right arm could still create fingering on a new piece for students.

Citing 19th-century doctor Silas Weir Mitchell, who identified the phenomenon in the Civil War, Sacks noted, "A phantom is longing, as it were, to be re-embodied."

South African poet David Wright lost his hearing at age 9, but he didn't realize he was deaf because he would continue to hear phantom voices, Sacks said. "If they turned away, he couldn't hear them." In the blind, the sensory cortex of the brain becomes hypersensitive, producing experience or images that are "quasi visual," something the rest of us cannot imagine, he said.

Sacks turned from natural to artificial adaptations, describing how a grid of electrodes can be placed on the tongues of the blind and connected to a video camera.

"This sounds absurd, if not obscene, but in fact people who have this can not only rapidly learn to interpret it and derive information, but they can start to experience it as if visual. You don't have to have eyes to have a visual experience."

But "one needs some caution in this brave new world." Sacks also told of "Virgil," a congenitally blind man, contented with his life, who was talked into an operation that would restore his sight. When the bandages were taken off, there was "a long confused silence." The shifting mass of colors and textures meant nothing to him and only worsened his disabilities. Virgil "was never able to make

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PHOTO / **DONNA COVENEY**

Deb Roy, AT&T Career Development Professor of Media Arts and Sciences, discussed memory augmentation.

Fiber bridge connects Incan, student engineers

PHOTO / **DAN BERSAK**

Junior Allison Brown works on an Incan bridge built at MIT on Saturday, May 12. The Chaka Stata is an all-fiber suspension bridge of the type the Incas built to ford deep ravines in the high and rugged Andean mountains.

PHOTO / **DAN BERSAK**

Freshman Alice Chang works on Chaka Stata.

Ruth Walker
News Office Correspondent

A technology that once brought the bold conquistadores of Spain to their knees in fear in the jungles of South America has come to the dry moat behind the Stata Center.

Students in Course 3.094 (Materials in Human Experience) have built a fiber bridge in the style of the Incan Empire. They call it Chaka Stata—chaka being the word for bridge in Quechua, the native language of Peru.

The Incas had no wheel, no arch and no system of writing. But they knew how to twist and braid countless miles of grasses and slender branches into ropes—sometimes as thick as a wrestler's waist.

From these ropes they built a system of long-span fiber suspension bridges that connected 15,000 miles of road across a distance greater than the width of the Roman Empire. The bridges, appropriate to the vertical landscape of the Andes, made possible a system of messenger service unmatched until the 19th century.

But the bridges swayed under the weight of traffic—and that's what terrified the Spanish and their horses, even though, as one Spaniard observed, they were almost as "sturdy as the street of Seville."

John Ochsendorf, assistant professor of architecture, has been studying these rope bridges since his undergraduate days at Cornell. This semester, Heather Lechtman, professor of archaeology and ancient technology, and Linn Hobbs, professor of materials science, have been guiding their students in Course 3.094 in the construction of the 70-foot Chaka Stata.

The project made a few concessions to modernity, however: They used sisal twine from the Yucatan Peninsula instead of the grasses the Incas used. And whereas the Incas chiseled into stone to anchor their bridges, the MIT students anchored Chaka Stata by wrapping it around some massive concrete blocks contributed by A.J. Welch Corporation of Brighton.

The weekend's burst of activity was preceded by what the students estimated was 360 hours of rope-twisting as the 50 miles of sisal twine was turned into rope.

Working together as a group was part of the exercise. "A third of the time was spent learning to work together," one of the students said. "But after a while, we were banging those cables out."

PHOTO / **DAN BERSAK**

The Incan bridge builders are, background to foreground: left, off bridge, senior Daniel Arlow; right, off bridge, sophomore Zachary Jackowski; on bridge—junior Shane Treadway, junior Allison Brown, junior Megan Firko, sophomore Luke Johnson and junior Darren Verploegen.

Team discovers hottest planet

Zenaida Gonzalez Kotala
University of Central Florida
and
Elizabeth Thomson
MIT News Office

A team of scientists including one from MIT has measured the hottest planet ever at 3,700 degrees Fahrenheit, or 2,300 Kelvin.

Using Spitzer, NASA's infrared space telescope, the scientists observed the tiny planet disappear behind its star and reappear. Although the planet, known as HD 149026b, cannot be seen separately from the star, the dimming of the light that reached Spitzer told the scientists how much light the planet emits. From this they deduced the temperature on the side of the planet facing its star.

"This planet is so intriguing that it is changing the way we think about planet atmospheres," said Sara Seager, an MIT associate professor with appointments in the Department of Earth, Atmospheric and Planetary Sciences and the Department of Physics.

The team's findings were published in the May 9 advance online issue of Nature.

"HD 149026b is simply the most exotic, bizarre planet," said Joseph Harrington (S.B. 1988, Ph.D. 1995), a professor at the University of Central Florida and leader of the work. "It's pretty small, really dense, and now we find that it's extremely hot."

Discovered in 2005, HD 149026b is a bit smaller than Saturn, making it the smallest extrasolar planet with a measured size. However, it is more massive than Saturn and is suspected of having a core 70-90 times the mass of the entire Earth. It has a comparable amount of heavy elements (material other than hydrogen and helium) to that contained in our whole solar system, outside the sun.

There are more than 230 known extrasolar planets, but this is only the fourth to have its temperature measured directly. It is simple to explain the temperatures of the other three planets. However, for HD 149026b to reach 3,700 degrees, it must absorb essentially all the starlight that reaches it. This means the atmosphere must be blacker than charcoal, which is unprecedented for planets. The planet would also have to re-radiate all that energy in the infrared spectrum.

"The high heat would make the planet glow slightly, so it would look like an ember in space, absorbing all incoming light but glowing a dull red," said Harrington.

Drake Deming, of NASA's Goddard Space Flight Center in Greenbelt, Md., and a co-author of the Nature paper, thinks theorists are going to be scratching their heads over this one.

"This planet is off the temperature scale that we expect for planets, so we don't really understand what's going on," Deming said. "There may be more big surprises in the future."

Other members of the team include Statia Luszcz of the University of California at Berkeley and Jeremy Richardson of NASA Goddard.

PHOTO / **NASA/JPL-CALTECH**

This artist's concept illustrates the hottest planet yet observed in the universe. The scorching ball of gas, a "hot Jupiter" called HD 149026b, is a sweltering 3,700 degrees Fahrenheit (2,040 degrees Celsius)—about three times hotter than the rocky surface of Venus, the hottest planet in our solar system.

NMR advance relies on microscopic detector

Technology could vastly improve diagnostics

Anne Trafton
News Office

Detecting the molecular structure of a tiny protein using nuclear magnetic resonance (NMR) currently requires two things: a million-dollar machine the size of a massive SUV, and a large sample of the protein under study.

Now, researchers from MIT's Center for Bits and Atoms report the development of a radically different approach to NMR. The highly sensitive technique, which makes use of a microscopic detector, decreases by several orders of magnitude the amount of protein needed to measure molecular structure.

Yael Maguire

The new technology could ultimately lead to the proliferation of tabletop NMR devices in every research laboratory and medical office. Among other things, such devices could prove invaluable in diagnosing a variety of diseases.

"It's revolutionary," said Shuguang Zhang, one of the authors and associate director of MIT's Center for Biological Engineering. "It's not just incremental progress."

The research team reports the work in the online and print editions of the Proceedings of the National Academy of Sciences this week. Lead author Yael Maguire, who earned his MIT Ph.D. for this work, will give a talk on it today at the VII European Protein Symposium in Stockholm.

NMR, along with X-ray crystallography, is commonly used to determine the structure of proteins and other molecules. NMR probes normally consist of a coil that surrounds the sample being studied. The coil creates a magnetic field that interacts with the nuclear spin of atoms in the sample, and those interactions reveal how the atoms are connected.

With current NMR machines, you need about 10^{17} (more than a million billion) molecules of a protein to determine its molecular structure. Some researchers have tried to make tiny coils to study smaller samples, but it has proven very difficult to scale these to small sizes to analyze tiny samples and to create high throughput methods.

Instead, research originally aimed at improving quantum computing led the MIT researchers to a completely different approach based on guiding waves.

"We were trying to get away from coils and see if we could find a new way to look at it," said Maguire, now a visiting researcher at MIT and chief technology officer of Cambridge-based ThingMagic.

How it works

The new approach starts with technology similar to the Wi-Fi antennas found in laptop computers. These antennas consist of a flat strip of metal. Using a laser, the MIT team made a microscopic defect (a slot) in such a conducting structure, known as a strip line. In that location a

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PHOTO / **DONNA COVENEY**

Rosalind Picard, professor of media arts and sciences, discussed 'Technology-Sense and People-Sensibility.'

PHOTO / **DONNA COVENEY**

Author Michael Chorost, who is deaf, describes his cochlear implant.

PHOTO / **DONNA COVENEY**

President Susan Hockfield and MIT Media Lab director Frank Moss opened the May 9 symposium, 'H2.0: New Minds, New Bodies, New Identities.'

MEDIA LAB

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sense of the visual world," Sacks said. "You have to learn to see."

Other speakers described MIT research initiatives for augmenting mental and physical capabilities to improve human life. Many gave deeply personal accounts. Writer Michael Chorost ("Rebuilt: How Becoming Part Computer Made Me More Human") explained—and showed—what he could hear with his cochlear implant. Deb Roy, AT&T Career Development Professor of Media Arts and Sciences, who is videotaping every waking moment in his home, demonstrated ways to cull specific information from the "ultra dense" data of recording, including his son's vocal progress from saying "ga-ga" to "water."

During a talk by Hugh Herr, NEC Career Development Professor of Media Arts and Sciences, about breakthroughs in building adaptive gait prostheses, Herr reached down and rolled up his pant leg to show the latest prototype, adding that he often forgets to mention he is an amputee himself. "This is the strongest ankle in the world—when I walk up steps it pushes me up," he said, provoking an Arnold Schwartzenegger imitation from Hockenberry. (Herr lost his legs in a climbing accident as a teenager.)

Another symposium high point came when Aimee Mullins, a Paralympic athlete and model, strutted on stage with her prosthetic legs tucked into four-inch stiletto heels. Not only does she compete in sports events, often on unusual, curved "cheetah legs," Mullins, a stunning, slender blonde, has modeled her "legs" as fashion accessories. "People say I have no legs, but, in fact, I have 10 pairs," she remarked.

Rosalind Picard, professor of media arts and sciences, demonstrated software that recognizes human emotions (which may help those with autism), while Cynthia Breazeal, LG Career Development Professor of Media Arts and Sciences, introduced the robot Leonardo, which can work through classic "false belief" scenarios.

The symposium also was punctuated by short films in which Hockenberry—in deadpan, Stephen Colbert fashion—visits various MIT luminaries to demand an "upgrade." The clips showed images of MIT's research from robots to voting screens to spray-on clothing.

Famed architect and designer Michael Graves, who suffered a mysterious illness in 2003 that paralyzed his legs, discussed new home product designs, such as adjustable tub rails, easy-grip shower heads and reversible walker/wheelchairs—all increasingly attractive to an aging baby boomer population, as well as the disabled. "This is a business opportunity," Hockenberry noted. Indeed, "There are things that are simple to do and they don't cost more; you just have to use your mind and your convictions," Graves said.

Receiving a standing ovation was a performance of "My Eagle Song," by Dan Ellsey, who has cerebral palsy, on a computer designed by Tod Machover and Adam Boulanger that allows him to both compose and play. Machover, professor of media arts and sciences, heads the Opera of the Future group, currently examining the use of music in therapy.

The symposium ended with a flourish as Herr nimbly scaled a climbing wall erected on stage (he said he had been told he would never climb again) and Hockenberry showed off his "upgrade," a "hacked" Segway wheelchair.

"You see how we're changed. How have you changed?" he asked the audience.

MIT urged to educate 'geeks' and 'chiefs'

Lois Slavin
ESD Communications Director

Resilience is important to Professor Yossi Sheffi, best-selling author of "The Resilient Enterprise: Overcoming Vulnerability for Competitive Advantage." An international expert in supply chain management, Sheffi recently turned his attention to resilience in engineering education at MIT and its impact on U.S. competitiveness.

"Southeast Asia produces 10 times more engineers annually than the U.S., many comparable to our highest quality professionals. If MIT and other U.S. schools continue to generate a large number of 'traditional' engineers, trained for a manufacturing economy, then engineering will become a commodity," Sheffi warned a standing-room-only audience at the sixth annual Charles L. Miller lecture.

Co-sponsored by MIT's Engineering Systems Division (ESD) and the Department of Civil and Environmental Engineering (CEE), the series is named for Miller, who was MIT CEE department head from 1962 to 1969. Miller died in 2000.

Sheffi, professor of engineering systems and civil and environmental engineering and director of the MIT Center for Transportation and Logistics, referenced recent reports by the National Academy of Science and the National Academy of Engineering to build his argument for how to address the "Sputnik challenge" of the 21st century. He identified the current challenge as the design and operation of complex systems aimed at health care provision, education, security and energy independence.

He said the important challenge is to educate engineers who can go beyond designing complicated technical systems (such as airplanes). They need to be able to design complex systems of which new technologies are part (like air transportation systems), where technology intertwines with environmental, political, economic, managerial and other systems. These engineers will lead complex systems design, whose objectives include flexibility, compatibility and safety.

Sheffi advocated a two-pronged approach for MIT: continuing to educate world-class technical experts—the geeks—to be practicing engineers who design complicated systems, while preparing world-class leaders—the chiefs—to design complex systems.

The new curriculum may include engineering and social science classes taught jointly by the School of Engineering (SOE) and the School of Humanities, Arts, and Social Sciences; engineering courses with embedded managerial concepts and case studies taught by SOE and the Sloan School of Management; mandatory studies abroad; and a leadership curriculum. (He referenced the leadership course offered by ESD's logistics program as an example.)

Sheffi acknowledged the many hurdles to implementing a new curriculum alongside "MIT Classic"; he asserted, however, that MIT presently has an unprecedented opportunity. A new president, new senior administration and new incoming deans may provide the opportunity for profound changes.

In concluding the event, ESD Professor Daniel Roos called on the audience to "work together to ensure that this issue gets exposure—and action—within MIT now."

Materials science contest starts

The Department of Materials Science and Engineering (DMSE) launched the MIT and Dow Materials Engineering Contest (MADMEC), co-sponsored by Dow Chemical Company and DMSE. The theme of MADMEC's first year is alternative energy: The contest invites groups of students to design and build devices that harness, store or exploit sources of alternative energy through principles of materials science. The top three teams will win $5,000, $3,000 and $2,000 prizes. Proposals for entry in MADMEC are due May 18. Semifinals are scheduled for Aug. 8, and the MADMEC finals will be held on Sept. 25.

For more information, go to dmse.mit.edu/madmec.

NMR

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little bit of the magnetic field leaks out of the line, creating a uniform, concentrated magnetic field. That field allows the slot to be used as an NMR probe, in place of a coil.

The detector described in the PNAS paper is a plastic card about one-third the size of a credit card and is easy and inexpensive to produce. To get structural information, the new detector must still be placed in a massive machine housing a superconducting magnet, just as the coil probes are. However, the MIT researchers anticipate that the microslot's small sample volume will allow much smaller tabletop spectrometers to be developed.

Zhang said such NMR devices could prove especially valuable in diagnosing diseases caused by misfolded proteins, such as Alzheimer's and Huntington's, or prion diseases like Cruetzfeld-Jakob disease. It could also allow early detection of glaucoma and cataracts, which could be diagnosed by testing a single teardrop. "You could detect it so early it will become treatable," Zhang said.

The new technology could dramatically improve the rate of biomedical research, because it can take up to a year to obtain enough material for an NMR study using the coil probes, said co-author Professor Neil Gershenfeld, director of MIT's Center for Bits and Atoms. That is "a major limiting step in drug discovery and studying biological pathways," he said.

The probes could also be used to make portable devices for diagnostics or soil analysis. And because the smaller devices are cheaper to make, they should be affordable even in developing countries where NMR machines are now rare, said Zhang.

Asking big questions

Maguire got the idea for the project after talking to Zhang and asking him what kind of new device would make the biggest impact in biology. For Zhang, the answer was immediate: improving NMR.

Elucidating structure is critically important for biologists because structure determines function, said Zhang. The goal for the project was to create an NMR detector sensitive enough to detect structural information using the amount of protein in a spot on a two-dimensional gel used for electrophoresis (about 10^{14} molecules).

The task was daunting. "Nobody in their right mind would try to take one spot from that gel and get a molecular structure from it," said Zhang.

However, Zhang said that he believes in the sentiment expressed by Francis Crick, the legendary biologist who determined the double helix structure of DNA along with James Watson: You need to ask big questions in order to get big answers.

Zhang adds that the project probably never would have happened without interdisciplinary collaboration: "Biologists would never have thought of this type of machine, but a physicist would never have asked the question," he said.

Before starting this project, Maguire and Gershenfeld, with co-author Isaac Chuang, had already used NMR to create early quantum computers. Their effort to improve the computing capabilities turned out to be surprisingly relevant to detecting molecular structures, an "unexpected spin-off," said Gershenfeld.

"We were not at all thinking about biology, but this turned out to be exactly what was needed to improve biological sensitivity," Gershenfeld said.

The research was funded by the National Science Foundation.

TECHNOLOGY

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quent visit that locals had improved the design and were teaching it to other communities.

However, such innovations, Smith insisted, do not eliminate the need for governments to provide clean water. Why, she asked, should those who make $1 to $2 a day be required to purify their own water? The water purification bags are, she acknowledged, a "transition technology."

Smith also overturned the old saw about "teaching a man to fish" by adding these caveats: "Unless there's no river nearby"; "Until the fishing pole breaks"; and "Maybe you should ask if he likes fish."

Interactive 'Scratch' program empowers young media artists

Stephanie Schorow
News Office Correspondent

A new programming language developed at the MIT Media Lab turns the web into a two-way street for kids, enabling them to become interactive media producers, not just media consumers.

Scratch, designed for ages 8 and up and available by free download, lets kids create games, interactive stories or dynamic greeting cards by snapping together graphical blocks, unhampered by the obscure punctuation and syntax of traditional programming languages.

Kids can share their interactive Scratch creations on the Web, the same way they share videos on YouTube or photos on MySpace. Scratch runs on both PCs and Macs.

"This is the next step in user-generated content," says Mitchel Resnick, professor of learning research at the MIT Media Lab and head of the Scratch development effort. "Our goal is to expand the range of what kids can create, share and learn. As kids work on Scratch projects, they learn to think creatively and solve problems systematically—skills that are critical to success in the 21st century."

Resnick's Lifelong Kindergarten research group previously developed the "programmable bricks" that inspired the award-winning Lego® Mindstorms® robotics kits. Just as Mindstorms allows kids to control Lego creations in the physical world, Scratch allows them to control media-rich creations on the Web.

The name Scratch comes from the technique used by hip-hop disc jockeys, who spin vinyl records to mix music clips together in creative ways. Similarly, Scratch lets kids mix graphics, photos, music and sounds. A glance at the Scratch web site (scratch.mit.edu) reveals a kaleidoscope of projects created by kids: a polar bear school, space attack games, a break-dancing performance and drawing exercises. Some creations are goofy and fun, some reveal serious social themes.

Resnick, whose research group has been working on Scratch for more than four years, is pleased at how kids often cogently explain on the site what they're trying to accomplish and how they seem to learn from each other. "It's exciting to wake up each day and see what's new on the site," he said.

Scratch was developed by the Lifelong Kindergarten group at the MIT Media Lab, in collaboration with UCLA educational researchers and with financial support from the National Science Foundation and the Intel Foundation. Throughout the development process, the design team received feedback from children and teens at Intel Computer Clubhouses and selected school classrooms.

"There is a buzz in the room when the kids get going on Scratch projects," says Karen Randall, a teacher at the Expo Elementary School in St. Paul, Minn. "Students set design goals for their projects and problem-solve to fix program bugs. They collaborate, cooperate, co-teach. They appreciate the power that Scratch gives them to create their own versions of games and animations."

The MIT Media Lab is now collaborating with other organizations, including Microsoft, Samsung, Intel, BT, the Lego Group, Motorola and One Laptop Per Child on additional versions of Scratch.

PHOTO / **L. BARRY HETHERINGTON**

Students at the Umana Barnes Middle School in East Boston (left to right: Bonnie Ramos, Roberto Paredes and Kayla Bishop) participated in Scratch software workshops held at the MIT Media Lab.

Expo showcases TechTV video site

Kelly Dobson, a graduate student in the MIT Media Lab, invented an odd device—the ScreamBody, a "wearable space for screaming," as she describes it. "When you need to scream but feel unable to because of environmental pressures—you're in the classroom or at work or watching children—you can scream into ScreamBody. ScreamBody silences the scream but also records it for later release."

You have to see it to believe it. Luckily, that's easy—Dobson uploaded a short video of herself demonstrating ScreamBody on MIT TechTV.

"ScreamBody" and other videos that members of the MIT community have uploaded to the beta version of MIT TechTV will be on display at the MIT TechTV Expo on May 17. The event begins with an open house in the student lounge near Lobby 10 from 11 a.m. to 4 p.m. People can also learn the basics of using MIT TechTV, a YouTube-like video-sharing web site that launched last month.

The interactive web site enables students, faculty, staff, alumni and others at the Institute to easily publish multimedia content and, if desired, embed those video clips in their own web sites and blogs. Users can rate videos, organize content and create tags or descriptive words so viewers can search for a particular video. Anyone can view videos on MIT TechTV, but only members of the MIT community may upload, rate and comment on videos.

"The idea is to distribute science, engineering and other MIT-created videos on the web. Content can be serious or fun. I hope MIT TechTV will also encourage members of the MIT community to create web video," said Dean of Engineering Thomas L. Magnanti. He is leading the development of the first web "channel" on MIT TechTV, focused on generating interest in science and engineering among middle school students.

Concluding the MIT TechTV Expo on May 17, Magnanti will award prizes to the video contest winners in the Bush Room at 4 p.m.

Shane Colton, a senior in mechanical engineering, is participating in the video contest. "I was excited to hear about TechTV. I take video of everything—2.007 competitions, FIRST Robotics events, the Sodium Drop—and having a place to put it all is great. I can see it becoming a hybrid of YouTube and Makezine.com (a web site on hacker culture) where people can search for interesting engineering, science and technology video clips."

The School of Engineering, in partnership with Academic Media Production Services, is sponsoring MIT TechTV. To view TechTV videos, go to http://techtv.mit.edu/posts/?topic_name=tvscontest.

Ancient arches guide modern work

Robin H. Ray
News Office Correspondent

"As hangs the flexible line, so but inverted will stand the rigid arch." This dictum on structural forces, formulated by Robert Hooke in 1675, remains the basis for understanding both suspension bridges and masonry buildings. But as John Ochsendorf, assistant professor of architecture at MIT, explained in his Program in Science, Technology and Society colloquium, "Medieval Architectural Technology: New Lessons from Master Builders," on April 30, we can learn a lot from studying exactly why and under what loads the flexible line will keep hanging and the rigid arch will keep standing.

Ochsendorf studies historical design procedures in traditional structures, creates tools to analyze and assess the safety of masonry buildings and looks at what traditional building methods can teach modern architects and engineers about sustainability. He studied civil and environmental engineering under David Billington at Princeton and was able to study the work of medieval masons firsthand while completing his doctorate at King's College, Cambridge (United Kingdom).

His colloquium presentation opened with an image of the magnificent fan-vaulting on the ceiling of King's College Chapel (completed in 1515), which spans 42 feet and hovers 84 feet above the pavement, yet its constituent blocks are only four inches thick. "You'd be hard-pressed to find someone in the world (today) who could sign off on this and say this is a safe structure," he said. "If some architect, maybe an MIT graduate, proposed this geometry…almost no building code in the world would allow it to be built. And yet it's been standing for 500 years."

But such buildings do sometimes come down, as did the 13th-century Upper Church of Saint Francis in Assisi, Italy. It had stood for 700 years before September 1997, when its vault, weakened by an earthquake, was brought down by an aftershock. The collapse killed four people and destroyed priceless frescoes by Giotto and Cimabue. With the example of Assisi in mind, Ochsendorf said, "One of the questions of our research group is, 'Which one is next?'"

Along with his graduate students, Ochsendorf has been developing interactive tools to explore the geometries of different arches—work that he plans to continue next year as a fellow at the American Academy in Rome. Using these tools, you can move building elements around virtually, imitating the ravages of gravity, and show at what point a particular configuration becomes unstable. As part of his work in this area, he has collaborated in a Columbia University survey of Romanesque churches of the 10th and 11th centuries in the Bourbonnais region of central France, led by Professor Stephen Murray (see www.learn.columbia.edu/bourbonnais/). He looks for patterns in the churches' original layouts, noting which of these have failed over their millennium of existence.

PHOTO / **DONNA COVENEY**

Architecture professor John Ochsendorf with wooden arch (above) and chain (making arch) below. He will be a fellow at the American Academy in Rome next year.

History has a lot to teach us about technology transfer and the lack thereof, Ochsendorf noted. In 1532, Spanish conquistadors in Peru first encountered the long-span suspension bridges, built entirely out of vegetable fiber, that the Incas used to tie together their vast empire—"Hooke's chain," as Ochsendorf put it. The Spanish were so terrified of these bridges that, according to contemporary accounts, they crawled over them on hands and knees even as their horses and cannons passed across in safety.

Ochsendorf believes that their fear sprang from incomprehension: This technology, based on tension rather than compression, was utterly at odds with their understanding of how the world worked. Spanish colonial attempts to use their familiar compression technology to span these deep Peruvian river valleys were failures, costly in materials and lives, while the Incan feat of suspension engineering would not be matched in the European sphere until the 19th century. (At MIT this semester, an undergraduate class in materials science is reproducing a small Incan suspension bridge near the Stata Center. See story on page 5.)

Ochsendorf believes that the masters responsible for these buildings have a lot to teach modern architects and engineers about sustainability in building design. It is no accident that older masonry buildings, built with traditional techniques and materials, survive earthquakes far better than modern ones, or that often the only buildings left standing in European cities bombed during World War II were the Gothic cathedrals.

Stability is one consideration; resources are another. Architecture, he notes, is "waste in transit," and in our heavily built world, flimsy construction projects are burning through natural resources as never before. But the trend may be moving in the other direction.

Ochsendorf recently consulted on a new conference center in southern England. The client wanted a building that would last for 500 years, one that could be made with nontoxic local materials and have zero energy consumption. Ochsendorf's team brought in Spanish masons to make lightweight timbrel vaulting, made of tile and light mortar, that would support a "green" roof. The building was made with blocks of rammed local chalk. "We were concerned about our vaults, that if they put a modern riding mower on top it would be a nasty point load on our thin tile shell—they're only six inches thick," said Ochsendorf, "and the client said, 'Oh, that's not a problem. I'll use sheep.'"

Arts awards honor student musicians and actors

MIT students were recognized for their accomplishments in the arts at two ceremonies in May.

Lori Huberman, a senior majoring in biology from Raleigh, N.C., received the Louis Sudler Prize in the Arts, presented to a graduating senior who has demonstrated excellence or the highest standards of proficiency in the performing or fine arts. Huberman was presented the award for her "skill and brilliance" as a performing flutist as well as for her work as a composer, at the Awards Convocation on May 9.

Also on May 9, Christine Yu, a senior in chemical engineering from Laurel, Md., was recognized for her musical ability and tireless service to many of MIT's music groups. She won one of three Laya and Jerome B. Wiesner Awards, presented for achievements in the creative and performing arts.

On Tuesday, May 15, the music and theater arts section recognized students who have made outstanding contributions to the cultural life of MIT. The students included Yuri Podpaly, a physics major from Sharon, Mass., who received one of two Edward S. Darna Awards, presented to a graduating student who has demonstrated excellence in theater arts and made a substantial contribution to the health of theater life on the MIT campus.

Elizabeth V. (Elvie) Stephanopoulos, an economics major from Winchester, Mass., received one of two Joseph D. Everingham Awards, which recognize a single creative outstanding performance or notable creative accomplishments in theater arts by a graduating senior.

PHOTO / **THOMAS MAXISCH**

Christine Yu, left, and Lori Huberman, right, rehearsed with the MIT Wind Ensemble. Both won arts awards in May.

PHOTO / **HAYDEN TAYLOR**

PHOTO / **HAYDEN TAYLOR**

Yuri Podpaly, shown above in a November 2006 performance of 'As You Like It,' will graduate on June 8 with an S.B. degree in physics and a Darna Award for his acting. Elizabeth V. (Elvie) Stephanopoulos, left, will walk to the stage on Killian Court with an Everingham award for her theater work and an S.B. in economics.

The annual Tech Talk Awards issue, presenting all Institute awards, will be published on June 6.

Lori Gross will become director of arts initiatives at MIT

Associate Provost Philip S. Khoury announced that Lori Gross, director of the Museum Loan Network at MIT since 1995, will become director of arts initiatives and advisor to the associate provost, effective July 1, 2007.

Gross will work with Khoury to advance the arts at MIT, specifically in the areas of strategic planning, communications policy, resource development and facilities planning. Working alongside the associate provost and with the Creative Arts Council members, faculty, staff and students, Gross will create and implement strategic plans to further the arts agenda, manage noncurricular arts initiatives across disciplines and facilitate ongoing dialogue concerning the role of the arts at the Institute.

"Lori Gross has long been active in the arts community at MIT and she brings a wealth of professional experience to her new position," said Khoury. "I am excited about working closely with Lori to further the interests of the arts, which are already such a vital contributor to the world of creativity at the Institute."

Philip Khoury

Gross has served as the founding director of the Museum Loan Network (MLN) since its establishment in 1995, encouraging interdisciplinary collaborations among U.S. institutions and enabling them to better serve their communities. As an international lecturer, she promoted multifaceted partnerships among institutions and an appreciation and understanding of the value of collections-based community-focused programming.

Under her leadership, the MLN has awarded nearly 400 grants to U.S. museums, established an illustrated online database of more than 20,000 objects from more than 1,000 global cultures and facilitated cultural policy dialogue on the role of museums.

During her tenure at the MLN, Gross has been an active participant in the MIT community. She has served on a number of search committees for the MIT Museum and the List Visual Arts Center and has been a member of the Creative Arts Council for 12 years. An energetic member of the wider Cambridge community, Gross is interim co-chair of the citywide Cambridge Arts Advisory Council for the public schools and a board member of the Underground Railway Theater.

In her more than 30 years working in the arts and museum fields in the United States, Canada and Spain, Gross has developed extensive experience in directing complex arts initiatives and in building partnerships among various constituencies. A Getty Museum Management Institute alumna, she holds master's degrees in art history and library science from Case Western Reserve University and a bachelor's degree in art history from Colgate University.