

SPECTRUM

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

nano

nanoscience and nanotechnology
the power of small

FALL | 2011

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A LETTER FROM THE PRESIDENT

NANOSCALE INNOVATION

In the 19th and early 20th centuries, the elements of industrial progress were plain to see: Ore, steam, mass production. Applying their powers of discovery and innovation, MIT's scientists and engineers optimized such materials and processes, driving economic growth. In the century since, the ingredients of industrial progress have become so much more difficult to visualize that they can almost seem unreal. But today, the advances possible in the nearly invisible realm of nanotechnology hold very real promise for creating new knowledge, new answers to urgent problems, new industries and new jobs.

Nanotechnology refers to the exploration and creation of unprecedented new materials and devices by controlling matter at the scale of billionths of a meter. As we enhance our ability to assemble atoms into deliberately useful structures, we open the door to substances with a phenomenal spectrum of possible properties. Thanks to rapid advances in microscopy, lithography, and chemical and biological synthesis, engineers and scientists at MIT and other top institutions are orchestrating formidable feats of nanoscale innovation — from high-performance technologies for generating and storing energy, to medical devices and therapies that will enable “personalized medicine,” to strategies for making systems and substances, from computation to concrete, greener and more effective.

In this issue of *SPECTRVM*, you'll encounter MIT faculty who are pushing the boundaries of nanotechnology to develop transformative new ideas. Professor Michael Strano layers graphene — a form of pure carbon arranged in a lattice just one atom thick — to enable the material's use in novel electronics. He also creates self-assembling molecules that can turn sunlight into electricity. Professor Krystyn Van Vliet combines minuscule mechanical and chemical forces to rapidly map the behavior of engineered materials, and measures interactions between molecules on the surface of a cell. And Professor Feng Zhang engineers extraordinarily precise tools for manipulating genes to understand the role they play in neurological disorders.

These examples offer only a glimpse of nanotechnology research at MIT — but they illustrate the field's broad interdisciplinary foundation. Not surprisingly, given the Institute's deep strength in systems engineering; process design; electronics and computer science; materials science and engineering; mechanical engineering; chemistry; physics; and biology, and its thriving culture of collaboration, MIT is helping to shape the future of nanoscale innovation. Our researchers not only draw together collaborators from varied fields but often bridge different areas of expertise themselves; an ongoing challenge will be for nanotechnologists to unite the many contributing disciplines with a common language of exploration and invention.

Ultimately, as our nanoscale research generates new scientific understanding, it will also give rise to novel materials with sharply improved or entirely new properties — materials that could substantially reshape fields from biomedical imaging to solar power to building materials. And in an era of universal interest in creating good, lasting jobs, nanotechnology will also be essential to accelerating progress in advanced manufacturing — an area of intense and growing focus at MIT. This past summer, Dow Chemical Co. CEO Andrew Liveris and I were asked to co-chair the new federal initiative called the Advanced Manufacturing Partnership (AMP). By bringing together leading US manufacturers, top research universities and the federal agencies that fund innovation, AMP will develop an action plan to help the nation seize the opportunities of advanced manufacturing. Capitalizing on the new materials and processes of nanotechnology will figure centrally in that work.

By investing in our nanotechnology-related infrastructure and intellectual ecosystem, MIT is already laying the groundwork for new manufacturing paradigms — a world in which desktop machines compete with billion-dollar fabrication facilities, and in which an array of nanomanufactured materials far beyond silicon wafers become the backbone of a new generation of sensing, computation, and communication devices. By opening up vast new applications and markets, such new paradigms offer the surest path to renewed economic growth while providing new tools to confront some of society's most daunting challenges.

More than 50 years ago, describing the potential of nanotechnology before the field yet had a name, physicist Richard Feynman '39 famously observed that “There is plenty of room at the bottom.” And there still is: making clean energy feasible; improving health care through personalization; strengthening and greening our infrastructure; redesigning information technology to deliver more power with less energy. In all these areas and more, nanotechnology holds the very tiny but immeasurably powerful keys. I am delighted that MIT will also use them to help restart our economic engine.

Sincerely,

Susan Hockfield

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“... The comparative size of a nanometer to a meter is the same as that of a marble to the size of Earth.”



“To do anything outstanding in this field, you need people who really understand chemistry, physics, and engineering... Few institutions in the world have the breadth and depth of expertise that MIT has in these areas.”

Marc Kastner
Dean of the School of Science



“I’m excited about the prospects for the ‘world of the small.’”

Ian Waitz
Dean of the School of Engineering

Nanotechnology’s impact will one day rival that of electricity, transistors, antibiotics, and the Internet — thanks in part to MIT research.

“There is increasing recognition that we can apply our knowledge of the very small to solve some of the world’s very big problems,” says Ian Waitz, Dean of MIT’s School of Engineering.

“Very important engineering challenges and domains — such as energy, the environment, and health care — will benefit from nano-science and -technology.”

Nanotechnology is enabling MIT researchers to develop, for example, substantially more effective and inexpensive solar cells; greener, more sustainable materials for infrastructure; tiny biomedical sensors that can monitor health in real time; and electronic devices that could greatly increase computing power using minimal energy. And a great adventure is now under way at the David H. Koch Institute for Integrative Cancer Research at MIT as the science of cancer is joined with the engineering of nanoparticles and new materials to help create new knowledge about cancer and new treatments.

Since it emerged as a field roughly 25 years ago, nanotechnology — which harnesses the remarkable properties of matter at the scale of billionths of a meter — has been heralded for its potential to revolutionize materials, manufacturing, energy, security, and health care. Nano-enhanced materials are already used in hundreds of products — sunscreen, sports equipment, and surface coatings for vehicles, among others. And semiconductor manufacturers have fabricated nanoscale components to push the boundaries of chip efficiency for over a decade.

But the truly transformative advances that nanotechnology promises — from large-scale storage and conversion of renewable energy, to staggeringly powerful quantum computers, to sophisticated biomedical implants that monitor and treat disease — are still years if not decades away.

Those types of advances require the ability to precisely assemble and manipulate matter at the atomic level — in other words, “from the bottom up. And that remains very difficult,” says Marc Kastner, Dean of MIT’s School of Science. To grasp the challenges posed by the nanoscale, consider that the comparative size of a nanometer to a meter is the same as that of a marble to the size of Earth. The researchers profiled in this issue are leading science’s effort to overcome those challenges.

“To do anything outstanding in this field, you need people who really understand chemistry, physics, and engineering,” says Kastner. “There are very few institutions in the world that have the breadth and depth of expertise that MIT has in these areas.”

Kastner and Waitz say that nanotechnology will be key to a new era in manufacturing that could fuel a 21st-century industrial revolution. With MIT President Susan Hockfield, whom the Obama administration recently appointed co-chair of its Advanced Manufacturing Partnership, they are positioning MIT to lead this new era.

Waitz says he is awed by the pace of nanotechnological innovation at MIT. “I find it amazing that we’re engineering things at that scale, and then using them to solve very challenging problems. I’m excited about the prospects for the ‘world of the small.’”

— LAUREN CLARK

the power of small

Minuscule medical monitors

When Joel Dawson was 12, he was fascinated by MIT Professor Emeritus Rodney Brooks' insect robots that were then in the news. "I thought, 'I've got to go to the place where they would work on things like that,'" he says.

Now Dawson, who earned an MIT bachelor's degree in 1996 and a master's in 1997, both in electrical engineering, is an associate professor in the same department Brooks called home. And he's putting his own stamp on the field of electrical engineering and computer science. Among his projects is an inexpensive sensor the size of a grain of rice that could be implanted in patients with Parkinson's disease to monitor their tremors. Individual components in such a sensor are on the nanoscale, or billionths of a meter.

Patients with Parkinson's visit a doctor regularly to report on the general state of their tremors. Clinicians, however, "would love to complement that kind of feedback with the more objective data possible by wearing some kind of monitoring device," Dawson says. Such data could allow better tracking, say, of disease progression, or the

efficacy of drugs.

The technology for such monitoring exists, but the resulting device would be relatively large — roughly the size of a man's watch. "The downside is that now this person has to wear a big medical device all the time. And it's a reminder that they're ill," says Dawson, the Mark Hyman, Jr. Associate Professor of Electrical Engineering. As a result, unless such a monitor is critical to their health, a patient often won't wear it. Similarly, the device must also be easy to use.

"Our work in nanotechnology is to build medical monitors that are user-friendly and won't have a major impact on a person's life," Dawson says. Depending on what needs monitoring, the device could, for example, be implanted in the body with an outpatient procedure, attached to a fashionable watch, or even sewn into clothing.

The sensor would be powered by an energy storage device known as an ultracapacitor. Because it can be charged over and over without wearing out, it wouldn't have to be replaced, in contrast to even the best rechargeable batteries. Further, a device powered this way could be almost instantly recharged with a simple tap to a charging unit.

The downside, though, is that unlike a battery, which will hold its energy output at a steady rate until it dies, an ultracapacitor's energy output drops continuously as it is used. "And that behavior makes it difficult to design the electronic circuits that use that energy to store and transmit sensor data," Dawson says.

To circumvent the problem, he and his team developed a novel system. "Rather than rely on a single ultracapacitor, we take an array of them stacked strategically so that as the energy is drained out of [each] capacitor bank, we keep the voltage high," he says. He and his team have created a prototype chip containing the electronic circuits that can interface with that system. Ultimately they would like to integrate ultracapacitors and circuits on the same chip, making the system much more compact.

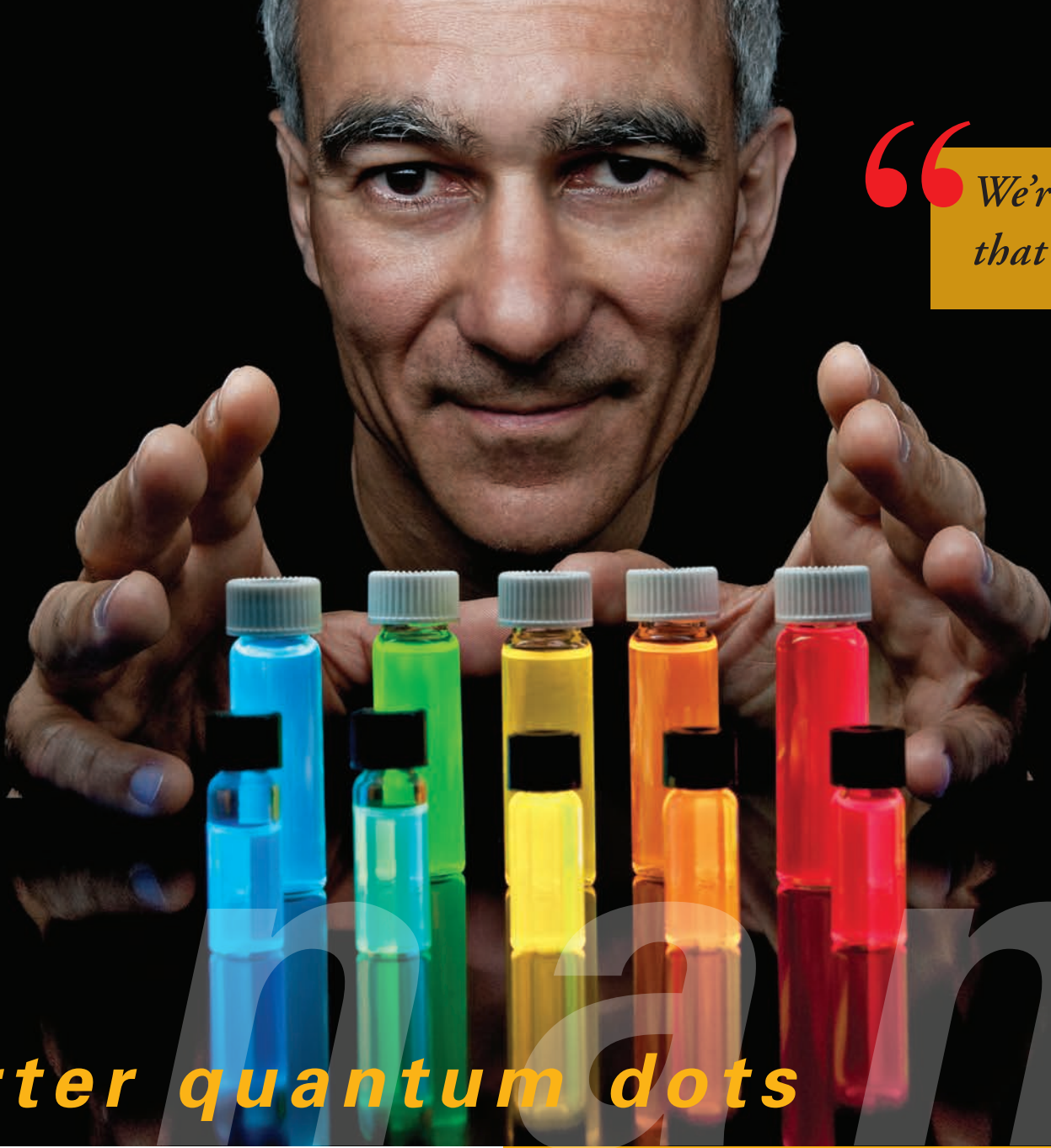
Dawson says that his top goal is to create a medical device that's easy for a patient to use. That, he says, "is emerging as the critical thing about medical electronics."

— ELIZABETH THOMSON

Joel Dawson is working on an inexpensive sensor the size of a grain of rice that could be implanted in patients with Parkinson's disease to monitor their tremors.

"Our work in nanotechnology is to build medical monitors that are user-friendly and won't have a major impact on a person's life."

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“We’re making dots that are smarter.”

Mounqi G. Bawendi envisions uses for quantum dots as alternatives to fluorescent organic dyes and proteins for labeling, imaging, and monitoring biological systems and for better understanding and battling cancer.

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Smarter quantum dots

For the past two decades, researchers have been manipulating tiny clumps of atoms to exploit their quantum mechanical properties in computing, optics, and electronics. Now Mounqi G. Bawendi envisions uses for these quantum dots as alternatives to fluorescent organic dyes and proteins for labeling, imaging, and monitoring biological systems and for better understanding and battling cancer.

Also called artificial atoms, quantum dots are nanometer-scale “boxes” containing a few hundred to a few thousand atoms that selectively hold or release electrons. Depending on their size, quantum dots can be “tuned” to emit any color in the rainbow, with the added bonus that the light they produce is much more saturated than that of other sources.

Quantum dots can be engineered to interact with biological tissue and to report back on what they encounter. Bawendi, Lester Wolfe Professor in Chemistry, measures the dynamics of these tiny semiconductor particles as they interact with cells and tissues at the level of individual molecules. Working with researchers at Massachusetts General Hospital, Beth Israel Deaconess Medical Center and chemists at MIT, Bawendi is injecting these dots into laboratory animals to shed light on the microbiology of tumors.

“We’re making dots that are smarter. They report not only where they are in the tumor to help image the tumor spatially and chemically, but also report on the microbiology within the cells,” Bawendi said. This gives researchers a read on what is going on at cancer’s ground zero, illuminating the effects of chemotherapy and how to tweak the timing of a dose for maximum effect.

Bawendi is using quantum dots to tag and image single stem cells, and to fluoresce in different colors when exposed to different biological substances, indicating certain concentrations of oxygen and glucose and acidity. Quantum dots can provide a pathway for a potential workaround to drug particles too big to permeate a cell wall: they can serve to help design nanoparticle systems that transport a payload to the outside of a tumor and then fall apart in the presence of enzymes, depositing the drugs where they can diffuse into the tumor. Researchers also are experimenting with quantum dots shaped like rods and spheres to see which are best at permeating tissues and cell walls.

Bawendi finds tumors formidable foes. “They’re complicated on so many fronts,” he said. “Every tumor is different. Biologically and morphologically, they are incredibly complicated, so any tool we can use to uncover their microbiology and promote the delivery of existing therapeutics may prove invaluable. This is an area where quantum dots can contribute something significant.”

— DEBORAH HALBER

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New material may revolutionize electronics

Pablo Jarillo-Herrero’s investigation of the basic properties of an amazing new material called graphene may help fulfill its touted role in revolutionizing electronics and other industries.

Jarillo-Herrero, Mitsui Career Development Assistant Professor of Physics, studies how electrons are influenced by quantum mechanical principles as they are transported through low-dimensional nanomaterials such as graphene, topological insulators, and carbon nanotubes. Among these, graphene, the single-atom thick, two-dimensional version of the form of carbon called graphite, became the best-known since the 2010 Nobel Prize was awarded to two UK physicists for groundbreaking experiments that shed initial light on graphene’s extraordinary electrical properties.

Jarillo-Herrero is looking at how and why this exceptionally thin, strong material conducts electricity better than any material known to man. Graphene’s unique properties, which allow electrons to propagate through it for long distances without bouncing off obstacles, may make it a serious candidate to replace silicon and other conventional semiconductors in a variety of nanoelectronic applications. In addition, graphene’s optoelectronic properties could make it useful in a new generation of solar cells, ultra-high speed photodetectors, and other energy-harvesting devices.

“We fabricate graphene nanodevices and measure quantum electronic transport within them,” Jarillo-Herrero said. “We send a current through the devices to observe how electrons propagate through the material and how they react to obstacles in their path, as well as how light and electrons interact within it.” He subjects the material to the ultra low temperatures and the very high magnetic fields in which its most interesting quantum properties become apparent.

Oddly, electrons propagate through graphene more like photons, which have no mass, than typical electrons, which do. Electrons do not move through graphene at the speed of light but they move with a velocity that is independent of their energy. “This doesn’t happen in normal materials,” Jarillo-Herrero said. Another key feature is that electrons moving through graphene can go through any obstacle

Applications abound for nano field

“If you ask 10 people what I study, you may get 10 answers,” says Krystyn Van Vliet. That’s because the general phenomenon she explores —how a material’s mechanical properties, such as stiffness, can affect its chemistry, and vice versa — is applicable to so many disciplines. Van Vliet’s work has already, for example, led to important insights on everything from the formation of blood vessels to the structural dynamics of cement.

Key to her approach: studying these chemomechanical interactions at the nanoscale, or billionths of a meter.

Van Vliet, the Paul M. Cook Career Development Associate Professor of Materials Science and Engineering and Biological Engineering, is at

the forefront of a relatively new field called chemomechanics. The tools that can probe materials’ mechanical properties at the most basic level of atomic features have been around only since the early 1990s.

Van Vliet recalls needing to travel to Lawrence Livermore National Lab to run experiments for her MIT doctorate because the Institute didn’t have the equipment. Now, she’s faculty director of the Department of Materials Science and Engineering’s NanoMechanical Technology Laboratory, “which is filled with these machines.”

Van Vliet first used these tools, coupled with computer simulations, to show how a stress or force can initiate a defect in an otherwise perfect crystal of metal. Such work is important as devices get smaller and smaller — a seemingly minuscule flaw can compromise their performance.

She’d always had a strong interest in biology, however, so before joining the MIT faculty she spent her postdoc years in a lab at Children’s Hospital. “I felt that there were measurements I could take down at the



“Her work has already... led to important insights on everything from the formation of blood vessels to the structural dynamics of cement.”

Krystyn Van Vliet is at the forefront of a relatively new field called chemomechanics.



Pablo Jarillo-Herrero says: “We fabricate graphene nanodevices and measure quantum electronic transport within them.”

without being reflected, while electrons moving through other materials are scattered when they encounter impurities. This phenomenon, never measured before, is ultimately responsible for the exceptional “bounce-free” propagation of electrons through graphene.

“Graphene’s properties are so unusual that they may lead to totally unexpected applications, such as a new generation of computation and processing, cheaper display screens in mobile devices, flexible displays, storing hydrogen for fuel cell powered cars, sensors to diagnose disease, and high-performance batteries. Ultimately, far down the road, my research could be used in those applications,” Jarillo-Herrero said. In the meantime, knowledge gleaned from his experiments will help fuel the imaginations of the many MIT researchers and others who envision new real-world devices and applications based on graphene and other materials spawned by basic science.

nanoscale to explore how mechanics might affect cancer biology and vascular biology,” she says. “I don’t pretend that I knew how I was going to do that, but it seemed like it should be possible.”

She succeeded, and biology is now a major focus of Van Vliet’s lab. “Small changes in the chemistry of the interface [between a cell and the material it is next to] can affect the mechanical adhesion of the cell to that material, for example,” says Van Vliet. Similarly, “small changes in the mechanics, like the fact that the periphery of a tumor is stiffer, can change the biochemistry — how quickly, for example, enzymes can affect the speed of certain reactions.

“It’s that back-and-forth between chemistry and mechanics that interests me,” she says.

Among other advances, she and colleagues have shown how certain cells surrounding capillaries may use mechanical forces — contractions — to initiate angiogenesis, or the growth of new blood vessels, a process key to wound healing and the growth of cancerous tumors. The team is currently exploring how these contractions affect the growth rate, shape, and chemical secretions of the cells key to angiogenesis.

Van Vliet emphasizes, however, the range of projects in her lab. These include not only studies of cells, but of inorganic materials like new scratch-resistant coatings for cars, and even polymer nanocomposites that replicate the mechanical response of real human tissues. So, for example, the Army could develop a new protective garment without testing on a live body.

“So many amazing discoveries have been made at MIT,” says Van Vliet. “It’s inspiring just to be around all that history of great thinking and enthusiasm for learning.”

— ELIZABETH THOMSON



the power of small

Faster, more energy efficient digital electronics

Electronics have come a long way since cell phones were the size of Maxwell Smart's shoe phone. The advances in nanoelectronics that enable smart phones to record video and surf the web may one day account for wearable or implantable medical devices and sensors that detect metal fatigue on airplanes or pollutants in the atmosphere.

The compression of all that technology is based on the scaling of the transistor, and Judy L. Hoyt, professor of electrical engineering and computer science, is pioneering new ways to make these building blocks even smaller and more powerful. Technically speaking, she said the goal is faster and more energy efficient digital electronics that could impact a wide range of applications, such as increasingly jaw-dropping capabilities for consumer electronics and high-performance supercomputers able to tackle complex problems in fluid dynamics, for instance, and weather forecasting.

Engineers had chugged along fulfilling Moore's Law — doubling the number of transistors on a chip every two years — until they ran up against the laws of physics, said Hoyt, associate director of the Microsystems Technology Laboratories (MTL). In the 1990s she spearheaded the atomic-level tinkering that now is used in digital integrated circuits, AKA chips. She and her colleagues at Stanford pioneered methods to improve transistor performance. They adapted a process developed by materials scientists to “strain” silicon by depositing it on top of a substrate whose atoms are spaced farther apart, causing the silicon atoms to line up wider and its electrons to flow faster.

With manufacturers' ability to provide increased electron velocity and performance again running out of steam, Hoyt, who holds six patents, continues to explore ways to change the nanostructured architecture of transistors and experiment with new candidates that might one day displace silicon as the favored material of microchips.

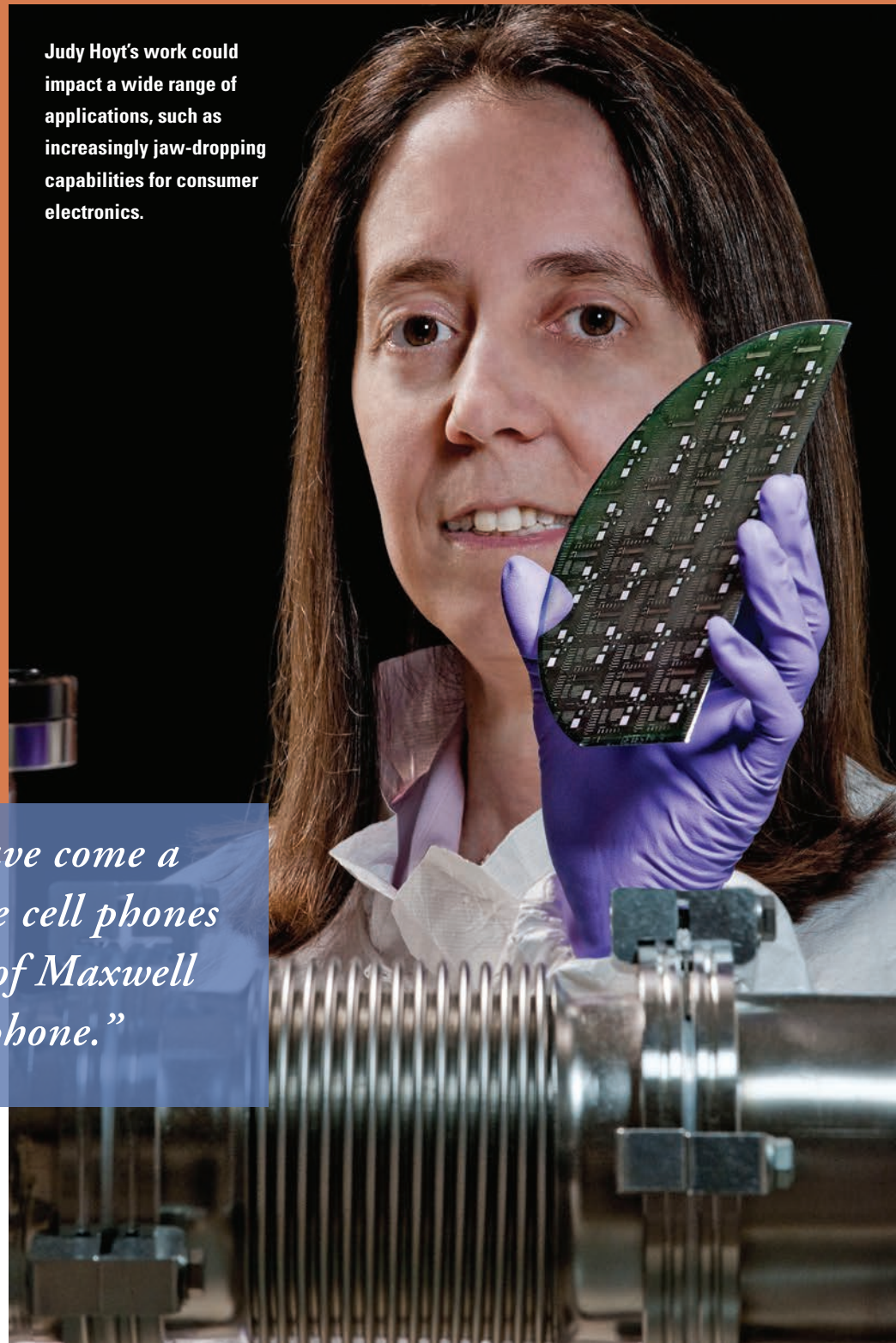
Hoyt and others are scouring the periodic table for “strainable” semiconductors that might rival silicon's excellent properties; lustrous germanium is in the running, as well as indium arsenide. They are also exploring ways to improve transistor architecture: basically switches, transistors have a gate like the tap on a faucet, turning electrical flow

off and on. Instead of a discrete gate, Hoyt and others are looking into having the gate wrap entirely around the conducting channel: this “gate all around” or nanowire geometry permits less leakage when the switch is off (important for energy efficiency), and the use of strain or alternate channel materials, such as those noted above, provides enhanced electrical current when the switch is on. The double-whammy of a new material and a new transistor architecture may potentially lead to another quantum leap in speed and performance, she said.

“We can generate fundamental advances in a laboratory and then share those ideas with the world,” Hoyt said. “It's during this process of shared discovery that things get really exciting.”

— DEBORAH HALBER

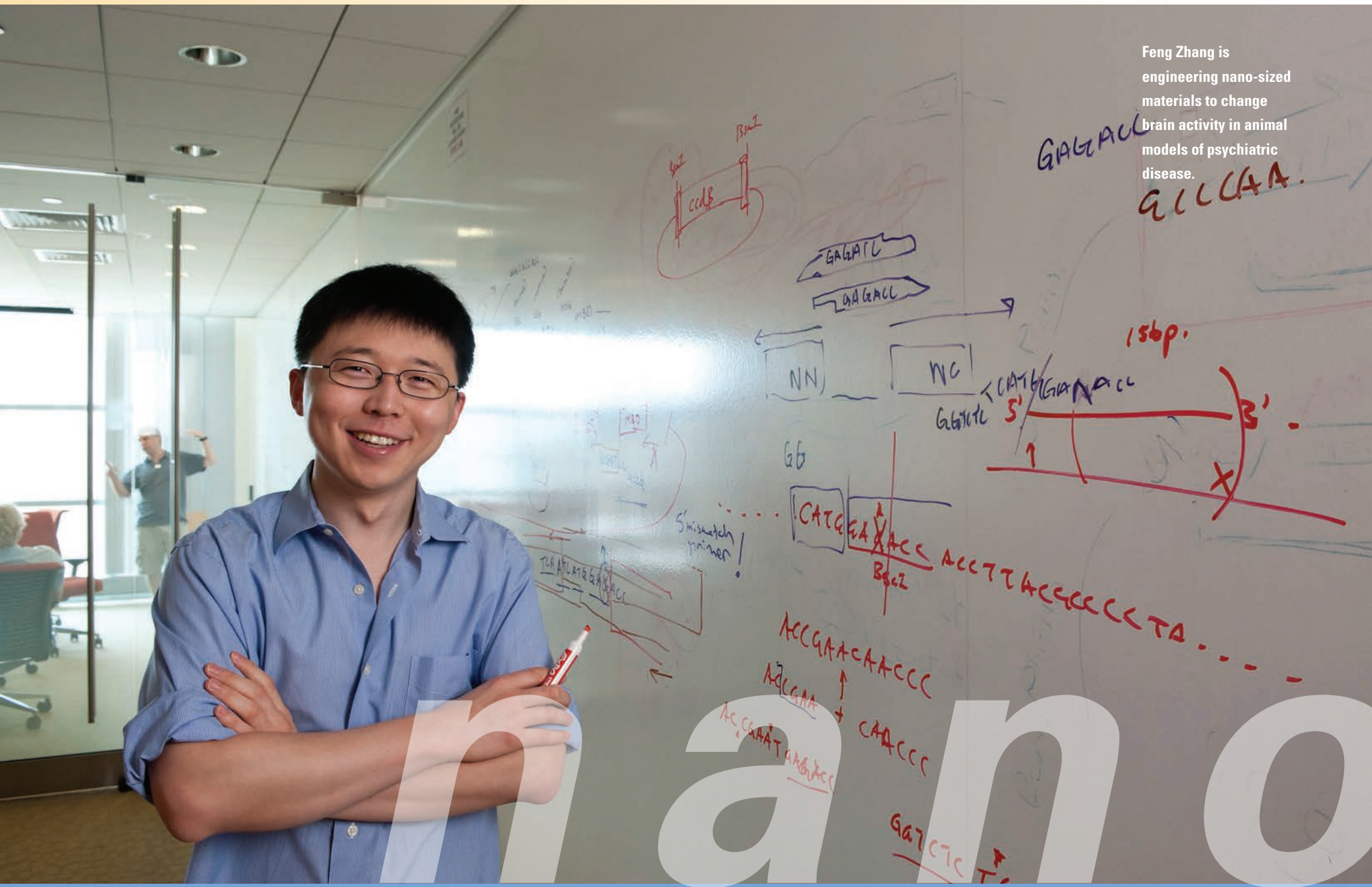
Judy Hoyt's work could impact a wide range of applications, such as increasingly jaw-dropping capabilities for consumer electronics.



“Electronics have come a long way since cell phones were the size of Maxwell Smart's shoe phone.”



Feng Zhang is engineering nano-sized materials to change brain activity in animal models of psychiatric disease.



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Nanotools to examine the brain

Feng Zhang used to think biology was all about animals and anatomy, but a seventh-grade enrichment program in molecular biology changed his mind. “I saw that biology is also about little molecular parts you can play with and put together in engineering ways,” he says. Now as a new member of the Department of Brain and Cognitive Sciences, the McGovern Institute for Brain Research, and the Broad Institute, Zhang is engineering nano-sized materials to change brain activity in animal models of psychiatric disease. “I’m using these tools to discover what goes wrong in brain circuits in these diseases, and to learn how to fix it,” he says.

If that sounds ambitious, consider that he co-developed a revolutionary technology called optogenetics, now used by neuroscientists worldwide, in his first lab rotation as a new Stanford graduate student with Karl Deisseroth in 2004. They decided to see if they could use the newly discovered channelrhodopsin, a protein made by green algae that opens a pore in cell membranes in response to light, to control the activity of neurons. As an undergraduate at Harvard, Zhang had studied how viruses enter cells, so he now engineered a virus to deliver the light-activated protein into specific sets of neurons in transgenic animals. Working with fellow graduate student Ed Boyden (now a fellow member of the McGovern Institute), he developed a mini-hardware system using lasers and fiber optics to precisely control the neurons expressing these proteins in living animals, turning them on and off with colored lights to study neural patterns involved in sleep and reward conditioning. “We can use this tool to see what the many different types of cells in the brain do and how they correlate with behavior,” Zhang says. “It’s a way to take apart a very complex brain.”

Then, as a junior fellow at Harvard, Zhang created another tool using other newly discovered proteins, TAL (transcription activator-like) effector proteins made by *Xanthomonas* bacteria. “These proteins manipulate the genome of the plants the bacteria live on,” he explains, “and we can engineer them to bind to any DNA sequence we want and modulate the expression of genes in specific types of neurons.”

Now at MIT, Zhang is using these tools in animal models of depression and schizophrenia to discover what changes result in psychiatric disease. For example, he wants to understand how environmental influences change the way genes are expressed in neural circuits in people genetically predisposed to depression. “We’re working with the Broad Institute to map the changes in the genome, and we’re applying optogenetics and gene transcription modulation to correct the errant patterns of gene activity to see if we can rescue the behavioral deficit. That could lead us to new targets for developing new treatments or cures.”

Zhang says he was attracted to MIT because of its sense of practicality. “The school wants to make something that translates into people’s lives,” he says. “It’s also very collaborative, and those interactions are important – because psychiatric diseases are not small problems.”

“We can use this tool to see what the many different types of cells in the brain do and how they correlate with behavior.”

— CATHRYN DELUDE



Yang Shao-Horn is tackling the world's energy problems.

“Her work could lead to everything from better fuel cells — environmentally friendly energy storage devices — to state-of-the-art batteries.”

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Exploring surfaces of nanomaterials

Yang Shao-Horn is tackling the world's energy problem by exploring — and manipulating — the surfaces of particles only billionths of a meter in diameter. Hundreds of thousands of these particles could fit on the period at the end of this sentence.

“We are working to understand the surface chemistry and atomic structure of nanoparticles that help control key reactions relevant to clean and sustainable energy conversion and storage,” says the Gail E. Kendall Professor of Mechanical Engineering and Materials Science and Engineering. Her work could lead to everything from better fuel cells — environmentally friendly energy storage devices — to state-of-the-art batteries.

Over the nine years Shao-Horn has been at MIT, the Electrochemical Energy Laboratory she directs has grown “to one with a research team of 20 students and postdocs,” she says.

Shao-Horn has made several key contributions to the field. These include the first images of atoms on and near the surface of nanoparticles key to the catalytic activity of oxygen chemistry that limits the efficiency of fuel cells. Chemical reactions catalyzed by these nanoparticles, composed of platinum and cobalt, run up to four times faster than reactions catalyzed by particles of platinum alone. Why?

Shao-Horn's images show that the platinum and cobalt atoms form a sandwich-like structure, with platinum on the top followed by a layer of cobalt. Successive layers contain mixtures of the two. She and

her team explain that the resulting nanoparticles are so active because the platinum ions on the surface are constrained by the cobalt atoms underneath.

Later, she showed that the nanoparticle surface is also important to its performance. By creating tiny stair steps on the surface of platinum nanoparticles, the team increased catalytic activity by 200 times over particles with smooth surfaces. “We find that the reaction happens at the step site,” Shao-Horn says.

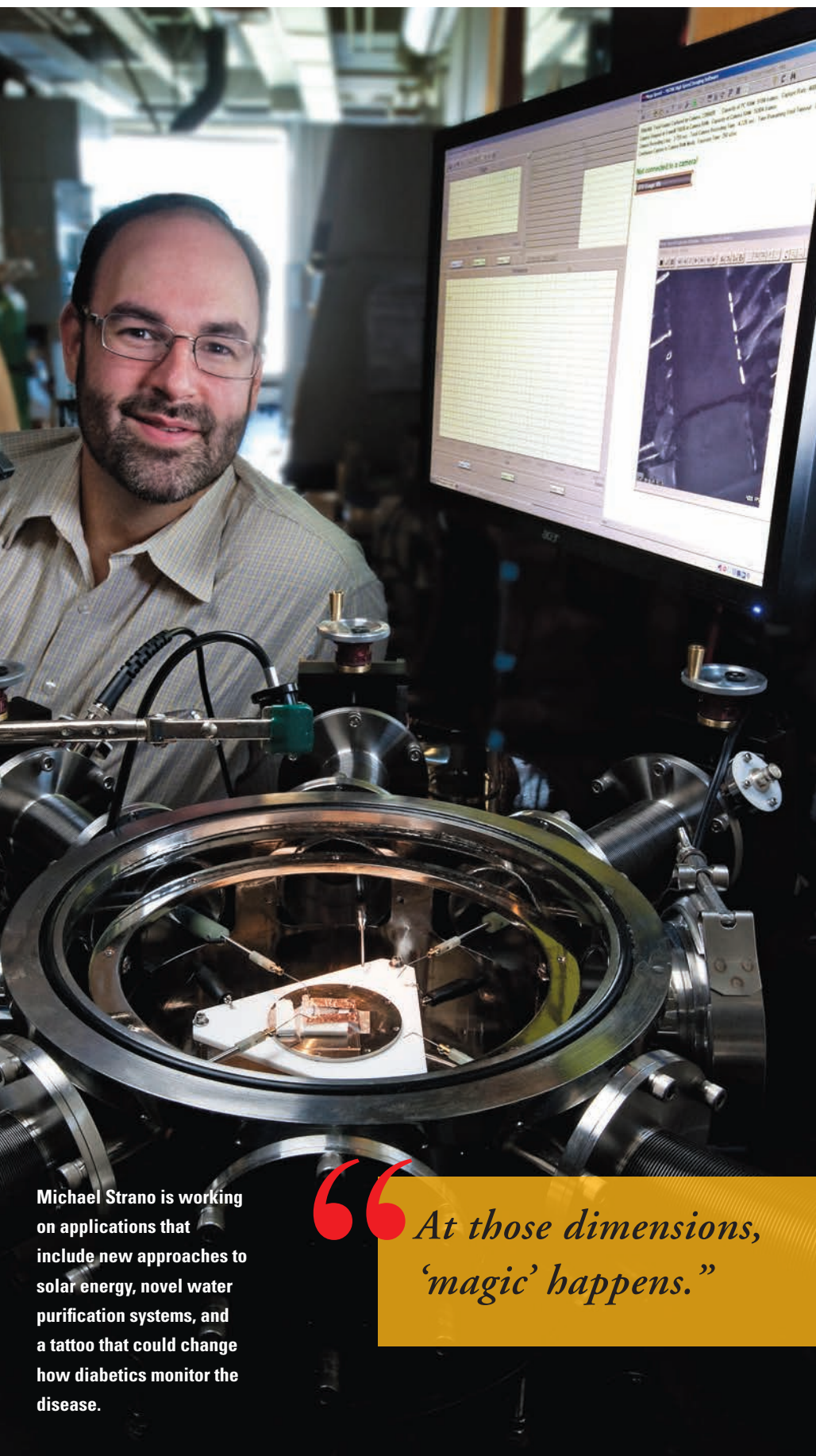
Working with Paula Hammond, a professor of chemical engineering, Shao-Horn recently created a novel lithium battery composed only of carbon nanotubes, or cylinders of carbon only one atom thick. The battery produced up to 10 times the amount of power possible with a conventional lithium battery. The technology has been licensed to a company that aims to commercialize it, Shao-Horn says.

Much of her work is done with her “brilliant, committed” students, she says. “Over the years, I'm very much inspired by them to work here.”

— ELIZABETH THOMSON

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Tinkering on the atomic scale



Michael Strano is working on applications that include new approaches to solar energy, novel water purification systems, and a tattoo that could change how diabetics monitor the disease.

“At those dimensions, ‘magic’ happens.”



Michael Strano has always been a tinkerer. As kids, he and his brothers fiddled with the old radios and electronic parts that filled their basement. “My dad owned his own electronics shop, so he saw value in any broken piece of electronics and would harvest it for parts,” he says.

Strano is still tinkering, but now on the atomic scale. His ideas for research projects seem nearly endless. Currently, he is working on applications that include new approaches to solar energy, novel water purification systems, and a tattoo that could change how diabetics monitor the disease.

Strano, the Charles and Hilda Roddey Associate Professor of Chemical Engineering, works with graphene, a form of carbon with dimensions on the nanoscale. A sheet of the material, which resembles chicken wire, is only one atom thick. Graphene, in turn, can be made into different shapes, from particles to the tiny cylinders about 10,000 times thinner than a human hair known as carbon nanotubes.

At those dimensions, “magic” happens, Strano says. Graphene and its nanoparticles and nanotubes are so small that they confine and restrict the movement of electrons. “If you start to put electrons in spaces commensurate with their size, you get new and unusual properties.”

“And really, that’s all an engineer needs — new properties. Then we try to apply them to global challenges.”

In one theme of his research, Strano is looking at new approaches to solar energy, work that is funded in part by the MIT Energy Initiative (MITEI). For example, he and his team have developed minuscule antennae that can concentrate 100 times more solar energy than the conventional photovoltaic cell used in solar panels.

Key to the work are two different nanotubes, one nested within the other. Each antenna contains about 30 million of the composite nanotubes. It then absorbs solar energy, concentrates it, and funnels it to a small spot, roughly like rain from a roof pouring through a downspout into a water barrel. As a result, today’s large solar panels could be replaced by much smaller ones. Among other advantages, this would lower the capital investment for such panels, he said.

Strano is also developing novel sensors. He is especially excited about a tattoo of nanoparticles that could become “a new paradigm for monitoring diabetes,” he says. The tattoo takes advantage of nanoparticles’ ability to fluoresce under infrared light. In this case, they are engineered to be sensitive to glucose, or blood sugar. A watch-like wearable monitor can then detect the amount of fluorescence, which is proportional to the amount of glucose.

Such a tattoo could allow the continuous monitoring of a person’s blood sugar, which would help prevent the wide swings in blood-sugar concentration that over time cause the complications associated with diabetes. Strano believes the tattoo could last for a decade. Most existing continuous glucose sensors operate for a few days at best.

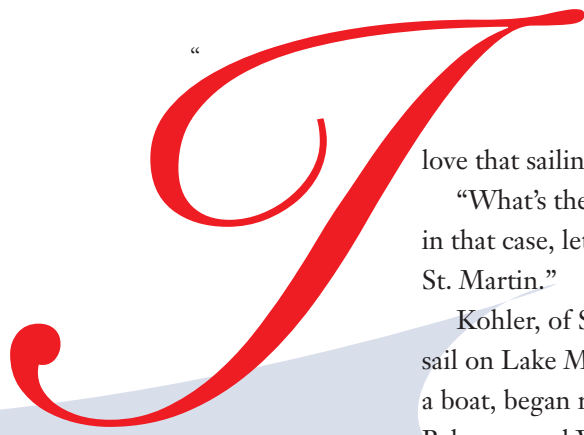
Strano has many more ideas for research on and applications of nanomaterials. “I feel like I’m limited only by the number of people in my lab to help me work on them,” he says.

— ELIZABETH THOMSON



SMOOTH SAILING

Major gift to restore MIT sailing dock



love that sailing is so casual,” says Terry Kohler.

“What’s the direction of the wind? Well, in that case, let’s go over to St. Croix instead of St. Martin.”

Kohler, of Sheboygan, Wisconsin, learned to sail on Lake Michigan at age five. Soon he soloed a boat, began racing, and as a teen sailed the Bahamas and Virgin Islands. Now, the 77-year-old businessman has spent his life moving with the wind and has sailed more than 100,000 miles around the world.

“Sailing is incredibly aesthetic, athletic, and intellectual all at the same time,” he says. “It’s been an extensive part of my life. When you sail 70 days in a row in the summers, it just becomes second nature.”

CELEBRATES 75TH

It will be smooth sailing this spring when the Institute celebrates the 75th anniversary of MIT Sailing. The Sailing Pavilion, built in 1936, was the first facility ever built for college sailing in the United States. Walter Wood ’17 and a few professors felt that since MIT was on the Charles River, why not bring a sport of the rich to non-millionaires.

In 1984, when the company was for sale, Barrett called Kohler to say: “You should buy it. You know a lot about sailing. You’ve sailed every sailboat from a dinghy to an 87-footer. You have a sterling reputation as a Wisconsin businessman. And you have the money.”

It sounded good.

“Now, I’ve been having great fun for the last 27 years,” says Kohler, who at the helm, grew that company to 20 times its former size. North Sails — which designs and manufactures high-tech sails, sail cloth, and masts for sailing vessels — has long been the world’s leading sailmaker.

NORTH SAILS

After high school, Kohler spent five years in the Air Force. Married and a father, he entered MIT as a freshman at age 25. He earned a bachelor’s in 1962 and a master’s in 1963, both from the Sloan School of Management.

Kohler then joined the Vollrath Company, a family firm that made pots and pans for commercial cooking. He is now president and CEO of Windway Capital, the parent company of both Vollrath and North Technology Group,

“At the helm, Kohler grew the company to 20 times its former size.”



It will be smooth sailing this spring for the 75th anniversary of MIT Sailing, thanks to a major gift from Terry Kohler.

Jerry Turba

Recently, Terry Kohler made a major gift to MIT to celebrate that anniversary and to honor American sailor Lowell North, an engineer, sailmaker, and Olympic gold medalist.

“The people at MIT had a need,” Kohler says of the 2,000 students, faculty, alumni, and staff who are taught to sail at the Institute each year. “People love to sail, and I feel you should make it easy for them. Otherwise, they’ll just lay on a couch and watch TV.”

Kohler’s gift will provide MIT with floating docks that will increase the space and capacity to store more boats at the same time. “It’s going to be a radical change in the whole environment down there,” he says, adding that he hopes that the gift not only will help MIT but also will honor Lowell North. North — who along with Peter Barrett won a gold medal in the 1968 Summer Olympics in Mexico City — in 1957 founded North Sails, a company that produced sailing equipment.

a family of nine companies that advances innovation and superior technologies through many companies, including water sports. One of those companies is North Sails.

“The people at North Technology are just as souped up about this whole business as I am,” Kohler says. “In a room full of North folks, the dynamics, just the raw power of intelligence and commitment, is incredible. I mean, you walk in there and the next thing you know, you feel like you’re floating two feet off the floor.”

Kohler says sailing has defined his life. It’s a mental and physical challenge. It’s adventure. And there’s no greater sense of teamwork than literally being in the same boat with someone. He says he loves it all — the wind, waves, gleaming sun, brilliant sky.

“Sailing is my passion,” he says. “It’s almost everything.”

— LIZ KARAGIANIS

FREEING THE MIND

MIT professor empowers inmates to earn college degrees

Prof. Craig Wilder is teaching history to inmates.



Richard Howard

You wouldn't think that men sentenced to a maximum-security prison would be interested in studying American Colonial History, now would you?

But for the past three years, MIT's Craig Wilder has been working with inmates at medium- and maximum-security prisons in upstate New York through the privately funded Bard Prison Initiative. And the "street-smart, funny, sarcastic men," he says, are extraordinary students.

"One thing I love is that the guys show up to class really prepared and enjoy wrestling with you intellectually. The lectures I give are as intense as any lecture I give at MIT."

WHY STUDY?

For some prisoners, studying is something to do. For others, it's an intellectual escape.

One inmate reportedly said that he wanted a college education because just learning a trade would give him skills to get a job but not skills to have a life. Another said he wanted his son to have a father figure who was more than a prisoner; while another added that he was eager for a chance to start over in life. "Everyone has a different reason for participating," says Wilder, who was raised in New York's inner city and "absolutely" identifies with the men.

"These are the guys from my (former) neighborhood in Bedford-Stuyvesant. 'I've

GOOD INVESTMENT

Inmates who earn degrees are much less likely to commit crimes when they are released, Wilder says.

"The recidivism rates decimate. They go down from about 70 percent to less than 10 percent. It's an extraordinarily good investment.

"If there's anything socially dangerous about American prisons, it's that the distance between the people who are incarcerated in the United States and the rest of us has grown far too broad," he says.

"These are real people. These are men with extraordinarily varied life experiences and backgrounds, but the one thing they have in

"The day inmates began discussing Modern European Christian Philosophy," Wilder says, laughing, "I'm thinking, 'Where is this coming from?'"

Inmates are earning associate and bachelor degrees through New York's elite Bard College, whose liberal arts curriculum is being taught inside five New York prisons. Two hundred men and women participate in this program, where only one in 10 is accepted on the basis of essays, test scores, transcripts, and GEDs, if they didn't finish high school.

Prisoners study English literature, sociology, philosophy, or theology. Maybe they'll read a book by W.E.B. DuBois or perhaps a biography of Albert Einstein. The day inmates began discussing Modern European Christian Philosophy, Wilder says, laughing, "I'm thinking, 'Where is this coming from?' But it was coming from the classes they were taking, and the books they were reading.

"Their studies don't end when the class ends," he says of the inmates who spend up to six hours a night studying. "They go back to their cells, to the cafeteria, to the yard, and talk about ideas. They become a community of scholars within the prison."

actually seen men in the prisons, who I know, or who I've seen before in New York.

"I was a first-generation college student," he says. "I walked into college from a low-income inner-city family with a single Mom who worked two jobs. For me, college was the one chance to change that narrative. And I think it's the same for many of them."

One of the most extraordinary moments of his life as an academic, Wilder says, was in 2008 when he gave the commencement address at Eastern State Penitentiary, a maximum-security facility.

"I walked to the podium and looked down at the men with caps and gowns over their prison uniforms, and looked into their faces, and into the faces of their families, and felt these guys are actually trying to change their lives. And it's not about reform. It's not about proving anything to anyone. It's just for them. And for their families. And it was so empowering."

common, and certainly have in common with me, is an interest in a set of ideas. They had the courage to actually reach out and say, 'Could you help us pursue this?' And my answer had to be yes."

"To actually see these guys rediscover that love of learning, that trust in education, and that passion for ideas is great."

— LIZ KARAGIANIS



Daniela Yuschenkoff — who has worked at the San Francisco Zoo for six years — has a chance to fulfill a dream, thanks to donors Jacque and John Jarve. Yuschenkoff is shown here with a Harris Hawk.

SAVING WILDLIFE

Donors help make dream possible

Marc Longwood

Daniela Yuschenkoff — who has seen *The Lion King* more than 100 times — was raised two blocks from the San Francisco Zoo and visited every Saturday.

“My Dad would say: ‘I’m taking you on a safari,’ and I loved it.”

Now, the 18-year-old sophomore — who has worked at that zoo for six years and logged more than 2,000 hours — plans to earn a Ph.D. and become a veterinarian.

“I really want to learn more about animals in the wild to save them from extinction. I want to collide my love of animals with my love of research because if I’m researching endangered species, or finding ways to genetically keep species alive, that will, in turn, help our ecosystem, which will also help the world.”

It would not be possible, though, she says, without the Jarve Scholarship — a gift of John ’78 and Jacque Jarve.

“There’s no way we could afford MIT tuition, room and board, books, or travel fees without this gift. There would be absolutely no way,” she says, adding that her Dad recently lost his teaching job and found work 400 miles south of their home, visiting now just once a month.

“The scholarship has brought me and my family financial freedom, and freedom from worry, and it made it possible for me to focus not only on my studies but also on my outside work,” she says.

At MIT, Yuschenkoff now has the freedom to intern every Saturday at the Live Animal Center at Boston’s Museum of Science. She also is service chair of Kappa Alpha Theta, where she plans service events and encourages her sorority sisters to get involved in the community.

This year, the sorority won MIT’s Killian Community Service Award.

Yuschenkoff began volunteering at the San Francisco Zoo at age 12. She handled hawks, tortoises, and legless lizards. Soon, she became an animal handler and presented shows for more than 500 visitors a day. She presented to the crowd alligators, porcupines, and iguanas, and later camels, elk, and bison. She fast became the zoo’s top volunteer and represented the facility on an expedition to New Mexico and Colorado, where she worked with a team of geologists analyzing igneous rocks.

“I’m in a crazy amount of debt to the Jarves,” she says. “My MIT education is completely because of them. I think the best I can do is use it to its fullest extent and really use it to fuel the future.”

“I’m absolutely amazed that strangers would want to pay my tuition. There’s plenty of people who can’t afford MIT, but the Jarves are giving me an opportunity, and it’s fantastic.”

— LIZ KARAGIANIS

“IF I’M RESEARCHING ENDANGERED SPECIES, OR FINDING WAYS TO GENETICALLY KEEP SPECIES ALIVE, THAT WILL, IN TURN, HELP OUR ECOSYSTEM, WHICH WILL ALSO HELP THE WORLD.”



“When you go through what I went through, you do develop a certain amount of toughness and resiliency. You grow up a lot faster and really want to succeed.”



Marc Longwood

“My Mom was an incredible optimist,” says John Jarve. “It was a blessing to live in a household where your mother is always positive, the glass is always half full, and things are going to get better no matter how bad they are.”

Jarve’s father, an alcoholic, died when he was 12. His mother died when he was 16. He began receiving \$110 a month in Social Security benefits and \$40 a month from the Veterans Administration, and soon after, left Martin’s Ferry, Ohio, a coal mining and steel town where he was raised, for Northern Ohio to live with his older sister, a newlywed.

“As a kid, I was like a sponge. I had an incredible hunger for knowledge and was willing to work very hard to get ahead,” says Jarve, a great student who loved calculus. When a guidance counselor encouraged him to apply to MIT, he says: “I never had even heard of MIT.” He flipped open a volume of the *Encyclopedia Britannica* and looked it up. Soon after, he was accepted to the Institute.

TOUGH AND RESILIENT

“I felt extremely fortunate to get a great financial package that enabled me to attend MIT,” he says. “When you go through what I went through, you do develop a certain amount of toughness and resiliency. You grow up a lot faster and really want to succeed. At MIT, I wanted to get a great education that could make a difference in my life. I learned to work hard and become resourceful.”

Jarve — along with his wife Jacque — established a scholarship at MIT. “Our goal is to enable students to have the same great experience that I had and to provide funds for them. There are lots of kids just like me, who cannot attend MIT without financial support,” he says, adding that their dream is for those students to one day support scholarships themselves so even more students can study at the Institute.

“MIT students have a tremendous ability to greatly influence the world — whether it’s developing projects or inventions that change the world or raising great kids who change the world. I do feel that every MIT student can make a difference,” he says.

GIFT TO OTHERS

A scholarship to change lives

John and Jacque Jarve live in Atherton, California, a long distance from Northern Ohio and the life John long ago left behind.

A venture capitalist for the past 26 years, Jarve earned bachelor’s and master’s degrees in electrical engineering from MIT in 1978. Then he earned an MBA from Stanford.

Early on, he worked as an engineer at Draper Labs before a stint in a laser lab at Massachusetts General Hospital. In 1983, he joined Intel, working on marketing for software products and development tools. Two years later, he joined Menlo Ventures as an associate, then a partner, and is now a managing director, leading the company’s investments in more than 50 portfolio companies in the areas of communications, storage, and Internet technologies.

An MIT Corporation member, Jarve is also a member of the Institute’s Corporation Development Committee and serves on two MIT Visiting Committees.

A CHANGED LIFE

“MIT changed my life in many ways,” he says. “It gave me unbelievable career options, ones I never would have had otherwise. And it enabled me to reach my full potential. We hope our support can help other students reach their full potential.”

The couple is eager to support MIT’s need-blind admissions program, which makes it possible for qualified students to attend the Institute regardless of their ability to pay. “MIT aims to get the best and brightest students, give them a fantastic education, and enable them to have better lives. I’d be devastated if the need-blind admissions policy at MIT ever changed.”

In many ways, Jarve is now a long distance from Northern Ohio and the life he long ago left behind.

He lives in Atherton, California, with his wife, whom he met when both worked at Intel, and they have two children, both students at Stanford. “I am a joyful person,” he says. “I have a great marriage, wonderful kids, I love my job, and love the people I work with.”

Another thing makes him happy, too. “The greatest pleasure of being a donor is meeting the students who receive our scholarship,” he says. “To me, that’s just one of the most enjoyable things about giving. Making the personal connection and hearing the benefits of our support is a wonderful experience.”

— LIZ KARAGIANIS



Kristin Forbes, a founder of Deworm the World, has seen firsthand “the power of good economics to improve the lives of millions.”

DEWORMING THE WORLD

Boosting school populations in developing countries



MIT Professor Kristin Forbes admits she once wondered if economics was “all about doing proofs in an ivory tower.” Now, as a founder of Deworm the World, she has seen firsthand “the power of good economics to improve the lives of millions.”

A nonprofit organization, Deworm the World provides school-based programs to treat children for parasitic worms. Worldwide, more than 400 million children suffer from intestinal worms, which can make them too sick to attend school.

“People rarely die from worms. It’s not as dramatic as AIDS,” Forbes says. But treating for worms is incredibly cost-effective. A child can be dewormed for 50 cents or less a year — and is more likely to attend school, learn more, and have higher earnings later in life than infected children, according to research conducted by MIT’s Abdul Latif Jameel Poverty Action Lab.

Incorporated in 2008, Deworm the World tackles the worldwide problem of chronic, widespread infection with helminth or schistosome worms. Transmitted through contaminated soil or water, these worms live in the intestines and cause stomach pain, fever, vomiting, diarrhea, loss of appetite, blood in stools or urine, and fatigue.

Treatment is simple: a deworming tablet given just once a year will safely eradicate infection. In fact, Forbes says Deworm the World focuses on treating whole school populations, rather than testing and treating affected individuals, because testing is significantly more expensive than mass treatment, which has no side effects.

It’s a perfect example of good economic policy in action. To date, Deworm the World has reached more than 20 million people in 27 countries and is continuing to expand.

“

“PEOPLE OFTEN DON’T UNDERSTAND THE CONNECTION OF ECONOMICS TO THEIR DAY-TO-DAY LIVES.”

MANY PROJECTS

For Forbes, however, it is just one of many projects in which she works to make the world better through economics. “I have given briefings to the president, the vice president, and members of the Cabinet,” says Forbes, who is the Jerome and Dorothy Lemelson Professor of Management and Global Economics at MIT. “It has been incredibly rewarding to see how explaining facts can change what they do.”

As a newly minted college graduate, however, Forbes initially did what most economics majors did: she went to work on Wall Street. There she quickly discovered the “thrill of the deal” wasn’t enough for her, so when she was offered a job at the World Bank, she leaped at the chance.

She spent much of her year there trying to explain the so-called “Asian miracle” — the rapid growth of China and several other Asian economies that had pulled so many people out of poverty — and what lessons to apply to other countries. The experience demonstrated for her the power of sound economic policies to better the world, and drove her to pursue a doctorate. “That’s when I fell in love with economics.”

Even after getting a Ph.D., however, Forbes considered leaving the academic path. “I wanted to effect things immediately,” she says — and she had a job offer from the International Monetary Fund. But then she got a call from the late MIT Professor Rudiger Dornbusch, a man she describes as an “amazing teacher, friend, mentor, and inspiration.” Dornbusch refused to hang up the phone until she agreed to take the job she’d been offered at the MIT Sloan School of Management.

“He convinced me that it’s very hard to make an impact on policy; first you have to establish credibility as an economist,” she says — and working at MIT and doing research would give her that edge.

“He was right,” Forbes says. A few years later, she took a leave of absence from MIT to become the youngest person ever to serve on the White House Council of Economic Advisers (in 2003-2005).

“I valued the independence that came from being the MIT economist on leave at the White House,” she says, explaining that she could argue with the president fearlessly because she had “a great MIT job to come back to.”

FOUNDING OF ORGANIZATION

Then, in 2007, Forbes had the chance to participate in the Forum of Young Global Leaders, “a group of amazing people” (as Forbes describes it) named by the World Economic Forum to serve as a catalyst for improving the world. A meeting of this group at Davos, Switzerland, led to the founding of Deworm the World by Forbes, Rachel Glennerster, Esther Duflo of MIT, and Michael Kremer of Harvard. “We saw this as a way we could make a concrete difference, by improving education in the developing world,” Forbes says.

Now that Deworm the World is up and running, Forbes is spending more time on other projects — notably conducting research on repatriation tax holidays and leading a major effort to explain the global financial meltdown — but she continues to spread the word that sound economic practices can make the world a better place.

“People often don’t understand the connection of economics to their day-to-day lives,” she says. “Explaining it clearly to people can make a powerful difference.”

— KATHRYN M. O’NEILL

SENSING THE UNSEEN

Seminar explores the invisible world

Our goal was to join the material world and the symbolic world,” says Heather Paxson.

“The tendency in our field had been to neglect the body and the senses. It’s all in the head. It was exciting to bring these two together.”

A year ago, she and Stefan Helmreich, both professors of anthropology, launched *Sensing the Unseen*, a one year seminar that focused on the unseen world — from invisible toxic chemicals to echoes to fleeting tastes — and showed how the intangible world is as real and significant as that which we can see and touch.

“You can’t, for example, fully explain the social world without taking ghosts, saints, or gods into account,” Paxson says. “It’s similar to thinking about how we feel pain, or how we hear things, or how we taste with our tongues. Our usual social theory doesn’t account for everything. We need another language.”

The idea for the event — a John E. Sawyer Seminar on the Comparative Study of Cultures, funded by the Andrew W. Mellon Foundation — arose when Paxson and Helmreich, who holds the Elting E. Morison Chair, realized that many faculty members in their department were working in sensory studies.

Open to the public, the seminar met once a month for eight months and drew crowds from across New England, including faculty and students from Harvard, Brandeis, Boston University, Mount Holyoke, and Brown. Each session featured research presentations by scholars from across the country and discussions by local scholars.

The seminar focused on six aspects of the unseen:

The Elusive: Listening

Sound can access that which is out of sight, generating new ways of understanding spaces and places.

The Unaccounted: Measuring

Whether at the nano, atomic, or molecular scale, or at the scale of global accounting — as with climate change or global finance — measurement is a way to bring the unseen into the open.

The Occult: Governing

If governing depends on making social relations legible, what about the realms of ghosts, gods, angels, or spirits?

The Invisible: Feeling

Feeling points to unseen activity inside the body, including pain, trauma, and suffering, and has different meanings across contexts.

The Evanescent: Tasting

Taste is at once physiological and a subjective aesthetic experience.

The Obscure: Photographing

From spirit photography to microcinematography to strobed high-speed snapshots, photography and film make visible that which is unseen.

ACQUIRING TASTE

“How do we understand the way we taste things? How do we learn new tastes?” Helmreich asks. “When I was a kid here in Boston, for example, there was no sushi. And I was taught you couldn’t eat raw food. But tastes transform. How are our senses tuned to new flavors?” He notes that Boston’s New England Aquarium now has an exhibit showcasing the beauty of jellyfish and that this may just be the beginning of these creatures’ appearance in our everyday lives; some scientists speculate that in 20 years many of us will be eating jellyfish because of overfishing of the ocean. How will this previously untasted taste be assimilated by those unfamiliar with it?

Speaking about the invisible, Paxson says, is difficult. “That’s why the seminar was challenging and fun.”

“*Sensing the Unseen* addressed the many ways we know what we know. But it was not only about grappling with existential questions. Sometimes you could just be trying to figure out why this cheese tastes better than that cheese.”

LISTENING

How do we hear the world? Steven Feld, an anthropologist of music, spoke at the seminar on Listening. He helped the audience understand that music might mean many things cross-culturally. For some, music must be composed. For others, ambient sounds, like flowing rivers, may be musical. During a visit to Ghana, Feld asked local musicians to play instruments along with an audio recording he had made of frogs that live in the sewers of Accra; tuning in to frogs croaking might be a way of hearing the previously unheard.

“It’s not that people can’t physically hear the frogs, it’s just that they can’t understand *how* to hear them yet,” Helmreich says. “Music keeps changing. And the question is how do people apprehend that? The boundary between music and noise depends on who is listening.”

The benefit of work in the anthropology of the unseen, Helmreich says, is that we can understand how people make the invisible real, and even create new realities in the material world. For example, he says, “the subvisible realm of nanotechnology produces new possibilities for engineering. Novel beliefs in spiritual phenomena can produce new worship practices and new communities of people.”

Paxson adds: “People have long talked about science and religion as ways of making sense of the inexplicable or of the natural world, but one of the things the seminar did was talk about this in terms of people’s everyday lives, and it was great.”

— LIZ KARAGIANIS

Richard Howard

Prof. Heather Paxson and Stefan Helmreich launched *Sensing the Unseen* — a yearlong seminar that explores the invisible world. Not obvious to the eye is that they are married.



“The boundary between music and noise depends on who is listening.”

A WISH TO HEAL THE WORLD

Empowering others to become self-reliant, healthy, and whole

Elisha Goodman has always believed in healing the world.

Now, she is enabling people to grow their own food, not only fostering a sense of community, but also allowing them to become more self-reliant, healthy, and whole.

“There’s an idea in Judaism called *Tikkun Olam*, which means ‘repairing the world,’” she says. “That was part of what I always did and thought that I should do.”

This strong code of personal ethics, coupled with an adolescence in a declining steel town where she witnessed friends’ parents losing their jobs as business moved overseas, has influenced Goodman’s life in significant ways. She has already formed two non-profits and recently won an MIT award for an innovative solution to agricultural issues in struggling communities.

For their work developing a novel “water farm” that could benefit regions with infertile soil, increase food security, and provide jobs, Goodman and teammates won the 2011 Muhammad Yunus Innovation Challenge, part of the MIT Global Challenge. It’s an annual competition that awards student teams for innovative solutions to world problems. The team’s aquaponics system, originally designed for use in the Niger Delta, combines hydroponics (growing vegetables in water) and aquaculture (growing fish for food), resulting in a self-contained, sustainable system that can provide food to areas with infertile or polluted soil.

The growing fish can be fed kitchen scraps. Fish waste is filtered, leaving behind nutrients to fertilize the plants. Clean water flows back to the fish tank to start the cycle again. The system utilizes approximately one-tenth the amount of water required for traditional agriculture, and also protects natural bodies of water from pollution often associated with fish farming.

GROW ANYWHERE

“The goal of our sustainable agricultural model is to allow people to grow their own healthy fresh fish and vegetables in almost any location,” explains Goodman. “You can use it in hot areas, cold areas, areas where it doesn’t rain much, and it produces a lot of food.”

Last fall, Goodman implemented a pilot of the system in Lynn, MA. The 50-gallon system built with members of the Lynn community is already producing vegetables, and plans are under way to construct a 750-gallon system.



Elisha Goodman is enabling people to grow their own food, not only fostering a sense of community, but also allowing them to become more self-reliant, healthy, and whole.

“The goal of our sustainable agricultural model is to allow people to grow their own healthy fresh fish and vegetables in almost any location.”

Richard Howard

She says of the project: “It’s amazing how much people want to help. We have engineers and lawyers and others who offer good advice, who want to see this succeed.”

The team is now exploring other places to test the system, most likely in Nigeria and Kenya. “We’re trying to figure out how to optimize the system to get the energy requirements lower, because we’re hoping to deploy it in the least developed countries.” Goodman envisions other implementations for the system, too, such as an aquaponics community center, similar to traditional community garden plots.

After completing her undergraduate studies, she spent time in Arizona and Hawaii learning about organic farming and community organizing. During that time, she formed two non-profits that advocate for Hawaii’s farmers and promote food sovereignty, and served as president of the Hawaii Organic Farmers

Association. “I did a lot of community organizing, a lot of lobbying, and really learned how to build communities, manage projects, and implement programs.”

Goodman received a master’s in city planning last June. Selecting a graduate school was an easy choice. MIT immediately stood out as the place for her. “The brochure from MIT said, ‘How will you make the world a better place?’”

Looks like she is figuring it out.

— STEPHANIE EICH

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FRONT RUNNER

Portia Jones is the most talented athlete in the history of MIT Women's Track and Field. "I have so much energy, it's physically hard for me to sit still," she says.

The 21-year-old senior is a 14-time All-American. She was named the New England Women's Track Athlete of the Year four consecutive times. This year she helped lead MIT to its second New England Division III Championship in the past three years in Outdoor Track and Field. At this year's National Collegiate Athletic Association (NCAA) Division III Championship, she ranked third in the nation in the Indoor Track and Field 55-Meter High Hurdles and second in the Outdoor Track and Field 100-Meter High Hurdles.

Growing up in Queens, N.Y., Jones climbed fences and trees, roller skated, played tag and hide-and-seek. "I never was tired and always wanted to *do* something." In high school, she danced hip hop and began running track. "I run to release all this energy.

"The challenge of track is mental," she says. "In a difficult race, you're dying to slow down and give up. But you have to realize that the pain in your legs is just in your head, and push through."

"She's a great athlete," says her coach Halston Taylor. "She's great because of her genes. She was born with natural talent, but her hard work brings it out."

Seldom does Jones celebrate after a win. Rather, she consoles opponents with a hug and honey words. "I hate to lose," she says, "but I'm friends with many of my competitors and hate to see *them* lose."

Jones, who volunteers at a Boston homeless shelter, dreams one day that her work will merge biology and electrical engineering and computer science to improve human health. She hopes to develop an invention, like a pacemaker or health monitor, that will one day save a life.

Meanwhile, she says, she will go snowboarding, rock climbing, and white water rafting. "I'm such a fidgeter," she says. "I really need to *do* something."

— LIZ KARAGIANIS

Portia Jones grew up in Queens, N.Y., climbing fences and trees, roller skating, playing tag and hide-and-seek, dancing hip hop, and running track.

