SPRING 10

ENG

CORNELL ENGINEERING MAGAZINE

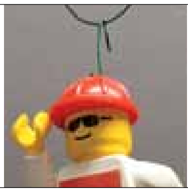
LIVING MACHINES:

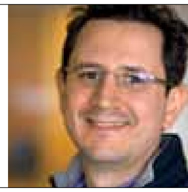
GENETICALLY ENGINEERING SOLUTIONS TO WIN

contents

DEPARTMENTS

CORNELL ENGINEERING MAGAZINE/SPRING 2010





Features

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NIH funds $13 million cancer center

The National Cancer Institute has funded the new Center on the Microenvironment and Metastasis, which will be headquartered at Cornell. The center will focus on using nanobiotechnology and other related physical science approaches to advance research on cancer.

"Our center will be organized to unravel cancer's complexity—using methods derived from the physical sciences and engineering — to further understand how cancer travels through the human body," said Harold Craighead, Cornell's C.W. Lake Professor of Engineering, director of Cornell's Nanobiotechnology Center, and the principal investigator and director of the new center. "The research may help identify new drug possibilities to inhibit metastasis and tumor growth."

The new center is one of 12 new research centers across the nation announced Oct. 26 by the institute. Cornell's grant is for $13 million over five years.

Cornell will serve as the lead institution in a partnership with Weill Cornell Medical College in New York City and the University at Buffalo. Barbara Hempstead, professor of medicine and co-chief of the Division of Hematology and Medical Oncology at Weill Cornell Medical College, will serve as the senior co-investigator.

Nationally, the 12 centers will bring a new cadre of theoretical physicists, mathematicians, chemists, and engineers to the study of cancer. During the initiative, the Physical Sciences–Oncology Centers will take new, nontraditional approaches to cancer research by studying the physical laws and principles of cancer; evolution and evolutionary theory of cancer; information coding, decoding, transfer and translation in cancer; and ways to de-convolute cancer's complexity.

Cornell's center will focus on three key projects:

Examining physio-chemical transducers and their role in tumor angiogenesis, led by Claudia Fischbach-Teschl, Cornell assistant professor of biomedical engineering, and Vivek Mittal, associate professor of cardiothoracic surgery at Weill Cornell;

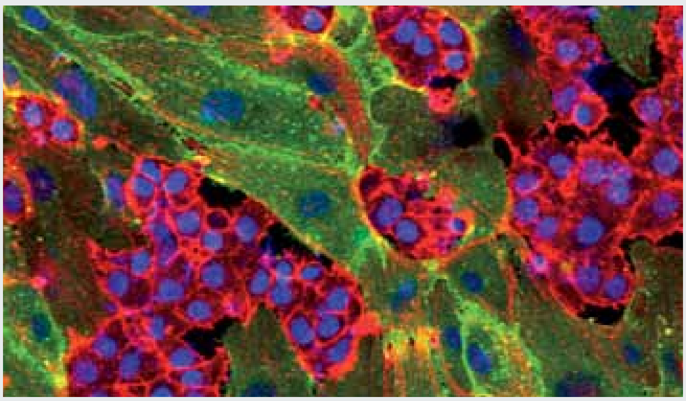
Physical and chemical cues in tumor cell migration, led by Cynthia Reinhart-King, Cornell assistant professor of biomedical engineering, and Paraskevi Giannakakou, associate professor of pharmacology in medicine at Weill Cornell; and

Adhesion of tumor cells in the vascular microenvironment, led by Michael King, Cornell associate professor of biomedical engineering, and David Nanus, professor of medicine and urology and co-chief of hematology and medical oncology at Weill Cornell.

Ultimately, through coordinated development and testing of novel approaches to studying cancer processes, the network of centers is expected to generate new bodies of knowledge, and identify and define critical aspects of physics, chemistry, and engineering that operate at all levels in cancer processes.

—*Blaine P. Friedlander Jr.*

Team investigates how to starve tumors


PROVIDED/SCOTT S. VERBRIDGE

Endothelial cells—a thin layer of cells that lines the interior surface of blood vessels—seeded on the surface of an engineered 3-D tumor model (proliferating tumor cells in red, endothelial cells in green, cell nuclei in blue).

For years, researchers have struggled to understand how tumors create the blood vessels that facilitate tumor growth, so that one day, they can learn to block the development of these vessels and starve the tumor.

Now, with federal stimulus funding from the American Recovery and Reinvestment Act, Cornell researchers will create tiny 3-D models of tumors to mimic conditions necessary for tumor angiogenesis—the development of vascular systems by tumors. Using such models, the researchers will specifically study characteristics of blood vessels that feed tumors and transport stem cells, which, in turn, play a role in developing a tumor's vascular system.

The research team—including Claudia Fischbach-Teschl, assistant professor of biomedical engineering; Abe Stroock and Jeff Varner, assistant professors of chemical and biomolecular engineering; and Vivek Mittal, associate professor of cardiothoracic surgery at Weill Cornell Medical College—will receive $633,000 over two years.

The funding will support three graduate students and a postdoctoral researcher to work on the project.

Among other things, the researchers hope that developing a microfluidic 3-D tumor model will allow them to examine how such essential soluble elements as dissolved oxygen are transported in blood to tumors. The researchers will also flood the system with bone marrow-derived stem cells that play a role in tumor vascularization.

"We will look at how and where they incorporate and be able to study these cells qualitatively and quantitatively," said Fischbach-Teschl.

The researchers will also use mathematical modeling to study underlying molecular signaling pathways involved in tumor angiogenesis.

—*Krishna Ramanujan*

Beetle-inspired device could let humans walk on walls

Could humans one day walk on walls, like Spider-Man? A palm-sized device invented at Cornell that uses water-surface tension as an adhesive bond just might make it possible.

The rapid adhesion mechanism could lead to such applications as shoes or gloves that stick and unstick to walls, or Post-it-like notes that can bear loads, according to Paul Steen, professor of chemical and biomolecular engineering, who invented the device with Michael Vogel, a former postdoctoral associate.

The device is the result of inspiration drawn from a beetle native to Florida, that can adhere to a leaf with a force 100 times its own weight, yet also instantly unstick itself. Research behind the device was published online Feb. 1 in *Proceedings of the National Academy of Sciences*.

The device consists of a flat plate patterned with holes, each on the order of microns (one-millionth of a meter). A bottom plate holds a liquid reservoir, and in the middle is another porous layer. An electric field applied by a common 9-volt battery pumps water through the device and causes droplets to squeeze through the top layer. The surface tension of the exposed droplets makes the device grip another surface—much the way two wet glass slides stick together.

"In our everyday experience, these forces are relatively weak," Steen said. "But if you make a lot of them and can control them, like the beetle does, you can get strong adhesion forces."

For example, one of the researchers' prototypes was made with about 1,000 300-micron-sized holes, and it can hold about 30 grams—more than 70 paper clips. They found that as they scaled down the holes and packed more of them onto the device, the adhesion got stronger. They estimate, then, that a one-square-inch device with millions of 1-micron-sized holes could hold more than 15 pounds.

To turn the adhesion off, the electric field is simply reversed, and the water is pulled back through the pores, breaking the tiny "bridges" created between the device and the other surface by the individual droplets.

The research builds on previously published work that demonstrated the efficacy of what's called electro-osmotic pumping between surface tension-held interfaces, first by using just two larger water droplets.

One of the biggest challenges in making these devices work, Steen said, was keeping the droplets from coalescing, as water droplets tend to do when they get close together. To solve this, they designed their pump to resist water flow while it's turned off.

Steen envisions future prototypes on a grander scale, once the pump mechanism is perfected, and the adhesive bond can be made even stronger. He also imagines covering the droplets with thin membranes—thin enough to be controlled by the pump but thick enough to eliminate wetting. The encapsulated liquid could exert simultaneous forces, like tiny punches.

PROVIDED/MICHAEL VOGEL

Paul Steen and Michael Vogel's surface tension-based adhesive device with a Lego man payload. A video of a larger version of the device is at www.engineering.cornell.edu/cem.

"You can think about making a credit card-sized device that you can put in a rock fissure or a door, and break it open with very little voltage," Steen said. "It's a fun thing to think about."

The research was funded primarily by the Defense Advanced Research Projects Agency, and also by the National Science Foundation.

—*Anne Ju*

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news

PROVIDED

Thorsten Joachims

Stimulus funding to help search engines learn on the job

New research by Thorsten Joachims and Robert Kleinberg, associate and assistant professors of computer science, respectively, aims to create search-engine software that can learn from users by noticing which links they click on in a list of search responses, and how they reformulate their queries when the first results don't pay off.

The work is funded by a four-year, $1 million grant from the National Science Foundation under federal stimulus funding, formally known as the American Recovery and Reinvestment Act. The research will lead to methods that improve search quality without human guidance, especially on specialized Web sites such as scientific or legal collections or corporate intranets.

Joachims believes the work will have long-term benefits for the economy, invigorating the market for high-quality and focused search software. "I think there is a potential for commercial impact, improving quality and productivity," he said. In the short term, the project will fund at least two Ph.D. students for four years, and provide research positions for undergraduate students.

As a demonstration, the researchers plan to create a new search engine for the physics arXiv Web site at Cornell, which contains thousands of papers in physics, mathematics, and computer science, and possibly for other specialized collections.

"In several ways, providing search for small collections is more difficult than for the whole Internet. Google, Yahoo!, and Microsoft can spend a lot of manpower on engineering a good ranking function for the Internet. For small collections, this has to happen automatically via machine learning to be economical," Joachims explained.

Search is not a one-size-fits-all business: People searching specialized collections might use the same words in very different ways. Is "uncertainty," for example, about the location of subatomic particles, career choices, investment opportunities, or romance?

"The key idea is have a search engine that gets better just by people using it," Joachims said. He and his collaborators have already created a search engine called Osmot—the name is a play on "learning by osmosis"—that draws on extensive research by computer scientists in machine learning. The problem the new research will address is that what the machine learns may be biased by the way it displays results.

Eye-tracking studies done in cooperation with Geri Gay, the Kenneth J. Bissett Professor and chair of Cornell's Department of Communication, have shown that absence of a click on a result at, say, the 11th position on the list of returns may mean that the result did not fit the user's information need, but it may also mean that the user had given up scanning the list that far down. To get reliable feedback from clicks, the search engine needs to shuffle the order in which results are returned.

"There is a trade-off. On the one hand, you want to present the best ranking you know so far," Joachims explained. "On the other hand, the search engine has to do a bit of experimentation to be able to learn even better rankings in the long run. The key is to balance the tradeoff between presentation and experimentation in an optimal way."

This trade-off is similar to what a gambler faces in a casino and is called a "multi-armed bandit" problem. When playing a row of slot machines, each play gives you new information about how much that machine pays, but also costs you a quarter. The trick is to eliminate some machines when you're sure they won't pay off without spending more than necessary. Kleinberg's work on algorithms for solving such trade-off problems will be key to making search engines learn effectively.

—*Bill Steele*

Society of Women Engineers takes home national award

PROVIDED/JENNIFER DOUGHTY

SWE Co-presidents Emily Swarr '10 ChE (left) and Kristie Resetco '10 ORE (right) holding the award at the SWE National Conference.

The Cornell Society of Women Engineers received the Gold Level Award for Outstanding Collegiate Section at the national SWE conference held Oct. 15–17 in Long Beach, Calif.

The top national honor for SWE collegiate chapters, the award recognized Cornell SWE's outstanding achievements in a wide range of areas, including planning and administration, communication and member recruitment, regional/national participation, education and outreach, inclusiveness and diversity, and alignment with the national SWE mission.

Cornell SWE is led by co-presidents Kristie Resetco '10 ORE and Emily Swarr '10 ChE.

The college's freshman class is 37 percent female, an all-time high.

—*Anne Ju*

PROVIDED/JENNIFER DOUGHTY

Alexandra Woldman '10 CE helps children make a putty-like elastic polymer as part of a SWE event at the Ithaca Sciencecenter in November.

MAGIC robots make cut Down Under

In early November, Cornell was named one of 10 semifinalists in the first Multi-Autonomous Ground-robotic International Challenge (MAGIC), co-sponsored by the U.S. Department of Defense and the Australian Defense Science and Technology Organization. The competition requires teams to build various robots that can accomplish a series of tasks like scanning for dangerous objects, protecting civilians, and mapping for obstructions—all with minimal human supervision.

As a semifinalist, Cornell received $50,000 to continue developing its robots and preparing for another round of cuts in June. Five finalists will compete in Australia in November 2010.

Assistant Professor Hadas Kress-Gazit and Associate Professor Mark Campbell, both in mechanical and aerospace engineering, co-lead the project as part of the Autonomous Systems Lab, which produced Cornell's DARPA Challenge autonomous vehicles.

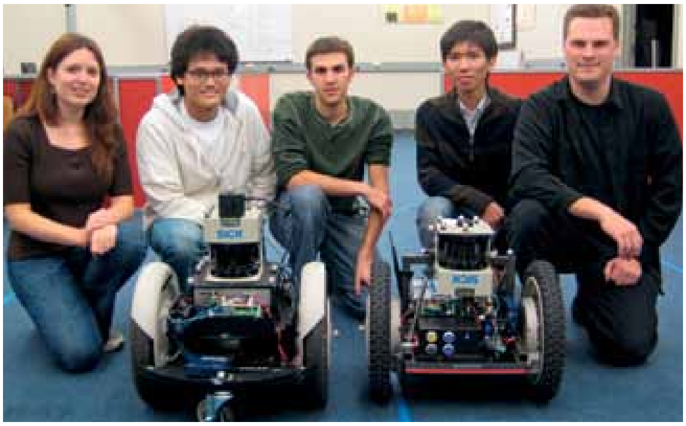
"We took an interest in the research—not just the competition," Kress-Gazit said of MAGIC. "Of course we want to win, but that's not the main drive."

The Cornell MAGIC team, consisting of about 20 people including faculty, graduate students, staff, and some undergraduates, has four robot prototypes with more possible in the future. They are built on Segway platforms, and each will eventually be equipped with GPS units, laser range finders, cameras, and inertial measurement units, which detect acceleration.

For the competition, the robots will operate in an "urban environment," both indoors and outdoors. In each environment, the robots must find, identify, and correctly respond to stationary and moving "objects of interest." They will also be required to have mapping capabilities to create a record of the area.

MAGIC aims to find ways in which "one to two operators can control 50 robots to magnify their effectiveness," said graduate student Mark McClelland. "The swarm of robots can do their thing, while the humans do the high-level stuff that humans are good at."

—*Anne Ju*



ANNE JU/CORNELL CHRONICLE

Members of Cornell's Multi-Autonomous Ground-robotic International Challenge team in the Autonomous Systems Lab with two of their robot prototypes. From left: graduate student Danelle Shah; Daniel Lee '10 ChE; lab manager Aaron Nathan '06, M.Eng. '09 CS; Chuck Yang M.Eng. '10 ECE; and graduate student Mark McClelland.

CEAA creates endowment

The Cornell Engineering Alumni Association recently created the CEAA Legacy Endowment Fund with a donation to the college of more than $180,000. Income from the fund will be used for awards recognizing outstanding achievement by faculty and students. It also will sponsor grants to student teams.

"We have long rewarded faculty and students for outstanding achievement," said CEAA President Bill Bruno '69 CE, M.Eng. '71. "The fund will allow us to further that goal."

Bruno said a grant the CEAA provided to the Cornell Solar Decathlon team, which competed last October in Washington, D.C., was an example of the kind of team sponsorship the fund would support. Several additional grants are planned for this year, he said.

The donated money came from fees collected for lifetime membership in the association, formerly known as the Cornell Society of Engineers. In 2007, the CEAA board of directors voted unanimously to eliminate membership dues, making all alumni members free of charge. "The CEAA wants to increase alumni involvement," explained Bruno. "Participating in CEAA activities will enhance your connection to Cornell, its students and faculty, and other alumni."

CEAA-sponsored conferences are one way to get involved, said Bruno. In November, the association helped organize a conference in Philadelphia titled "At the Leading Edge: Improving Lives Through Biomedical Engineering." Speakers included Claudia Fischbach-Teschl, assistant professor of biomedical engineering, and C.C. Chu, the Rebecca Q. Morgan '60 Professor of Fiber Science and Apparel Design in the College of Human Ecology. They were joined by Cornell alumnus and trustee David R. Fischell '75 EP, M.S. '78 AP, Ph.D. '80, founder of nine biomedical device companies.

"All who attended had a great time exploring new thoughts, meeting old friends, and making new friends," said Bruno. "Participants said that reconnecting with other engineering alumni was as wonderful as the program itself."

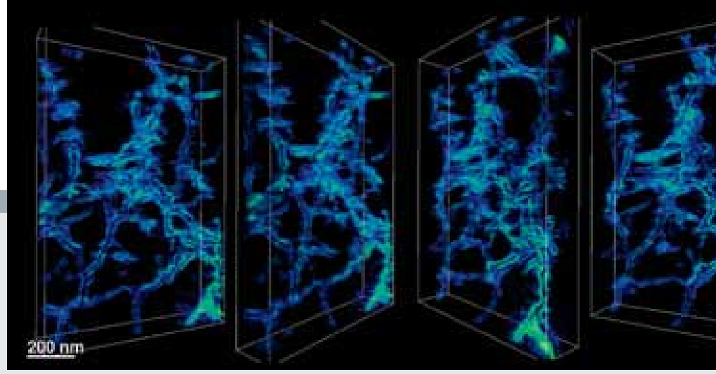
CEAA and the Cornell Entrepreneur Network are co-sponsoring the next conference, "Sustainable Energy: Investing in Our Future," which will take place in Boston on June 17.

Besides giving alumni a way to get together, the CEAA provides many ways to connect with Cornell engineering students, Bruno said, such as speaking on campus, mentoring students, assisting job seekers, and sponsoring Master of Engineering projects. "We also host dinners for Cornell co-op students in locations away from Ithaca so that they may meet alumni and their fellow students," he said.

News updates, details of future conferences, and information on how to become involved in the CEAA can be found at www.engineering.cornell.edu/ceaa.

—*Robert Emro*

Research offers clues to how shells grow



ESTROFF/MULLER LABS

This image shows the 3-D nanoscale structure of the inside of a synthetic calcite crystal, which was grown in an agarose gel. In this environment, the crystal grows around the polymeric fibers. The structure gives insight into the formation of single crystals by biological organisms.

Lara Estroff, assistant professor of materials science and engineering, and colleagues have taken a detailed look at the way manmade calcite crystals, similar to those found in limestone, grow in tandem with proteins and other large molecules, as they do in biological structures like shells.

Lara Estroff

They reported their findings in the Nov. 27 issue of the journal *Science*.

"We knew the organics were in there, but what no one had been able to do up until now was actually see what that organic-inorganic interface looked like," said Estroff, whose lab focuses on the synthesis and characterization of bio-inspired materials.

Estroff and graduate student Hanying Li grew samples of calcite in a hydrogel called agarose that mimics the way calcite grows in living things. In previously published work, Li and Estroff had determined that this gel environment made the crystals grow very differently than in solution.

In collaboration with associate professor of applied and engineering physics David Muller and physics graduate student Huolin Xin, the researchers prepared their crystals with Focused Ion Beam technology, which uses high-energy ions to slice samples thin enough for an electron beam to pass through for imaging.

Scanning transmission electron microscopy methods developed by Xin and Muller revealed detailed, three-dimensional pictures of the internal structure of calcite crystals grown in the gel. They found that the crystals trap large molecules by growing around them.

Studying this complex natural process may be a key step toward giving materials scientists like Estroff clues on how to make and manipulate nature-inspired composite materials. Applications could range from electronics to photovoltaics to completely new classes of materials.

—*Anne Ju*

Small optical force can budge nanoscale objects

With a bit of leverage, Cornell researchers have used a very tiny beam of light with as little as one milliwatt of power to move a silicon structure up to 12 nanometers. That's enough to completely switch the optical properties of the structure from opaque to transparent, they reported.

The technology could have applications in the design of micro-electromechanical systems (MEMS)—nanoscale devices with moving parts—and micro-optomechanical systems (MOMS) that combine moving parts with photonic circuits, said Michal Lipson, associate professor of electrical and computer engineering.

The research by postdoctoral researcher Gustavo Wiederhecker, Long Chen M.S. '08 ECE, Ph.D. '09, Alexander Gondarenko, M.S. '09 AP, Ph.D. '10, and Lipson appeared in the journal *Nature*.

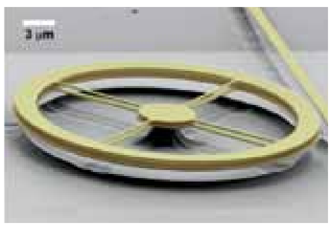
Light can be thought of as a stream of particles that can exert a force on whatever they strike. The sun doesn't knock you off your feet because the force is very small, but at the nanoscale it can be significant. "The challenge is that large optical forces are required to change the geometry of photonic structures," Lipson explained.

But the researchers were able to reduce the force required by creating two ring resonators—circular waveguides whose circumference is matched to a multiple of the wavelength of the light used—and exploiting the coupling between beams of light traveling through the two rings.

A beam of light consists of oscillating electric and magnetic fields, and these fields can pull nearby objects toward the center of the beam, a microscopic equivalent of the way static electricity on clothes attracts lint. This phenomenon is exploited in "optical tweezers" used by physicists to trap tiny objects.

When light travels through a waveguide whose cross-section is smaller than its wavelength, some of the light spills over and, with it, the attractive force. So parallel waveguides close together, each carrying

Michal Lipson



CORNELL NANOPHOTONICS GROUP

Scanning electron micrograph of two thin, flat rings of silicon nitride, each 190 nanometers thick and mounted a millionth of a meter apart. Light is fed into the ring resonators from the straight waveguide at the right.

a light beam, are drawn even closer, rather like two streams of rainwater on a windowpane that touch and are pulled together by surface tension.

The researchers created a structure consisting of two thin, flat silicon nitride rings about 30 microns in diameter mounted one above the other and connected to a pedestal by thin spokes. The ring waveguides are three microns wide and 190 nanometers thick, and the rings are spaced one micron apart.

When light at a resonant frequency of the rings, in this case infrared light at 1533.5 nm, is fed into the rings, the force between the rings is enough to deform the rings by up to 12 nm, which the researchers showed was enough to change other resonances and switch other light beams traveling through the rings on and off. When light in both rings is in phase—the peaks and valleys of the wave match—the two rings are pulled together. When it is out of phase, they are repelled. The latter phenomenon might be useful in MEMS, where an ongoing problem is that silicon parts tend to stick together, Lipson said.

An application in photonic circuits might be to create a tunable filter to pass one particular optical wavelength, Wiederhecker suggested.

—*Bill Steele*

100+ MPG CAR HITS THE ROAD FOR A TEST-DRIVE


PROVIDED

At the end of October, the Cornell 100+ MPG Team learned it had made the short list of teams competing in next year's $10 million Progressive Insurance Automotive X Prize, an international competition in which cars that get 100 miles to the gallon or more will go head-to-head in a series of races. Cornell is the only university team represented in the mainstream vehicles class. The next phase of the competition is the technical qualifiers, which begin this spring.

When the team got the good news, the car was starting to come together—its red paint was emblazoned with a list of sponsors on the side; the guts of the car were talking to each other; the electrical drive train was spinning the wheels, and the braking system was functioning fully.

The 100-mpg goal will be met when the car's generator, the backup power for the lithium-iron batteries, is installed. A British company, Evo Electric, has donated a $20,000 generator that's being programmed for the car, replacing a bulkier, less powerful one the team had been using. The new, "pancake-style" generator is only about 6 inches long as opposed to the old 20-inch generator.

The team has been helped along the way by other sponsors, including the lithium-ion battery pack from Chang's Ascending Co., a Taiwanese company, and a $20,000 cash donation from its parent company, Formosa Inc.

The team conducted their first drive test behind Rhodes Hall before moving to B Lot for more real-world testing conditions.

Until next May, when the cars will be complete and the races begin, the team will need to submit to competition judges several detailed technical reports on the car, including information on the fuel system, the safety of the battery packs and the crash-worthiness of the vehicle.

—Anne Ju

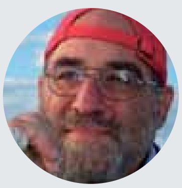
CEM GOES PAPERLESS

Alumni and friends of the college can now sign up to receive an electronic version of *Cornell Engineering Magazine* instead of a printed copy.

The college is providing this paperless option to reduce its impact on the environment and save money spent on printing and mailing costs.

Anyone who would like to receive an e-mail notification when we publish a new issue of *Cornell Engineering Magazine* online can do so at www.engineering.cornell.edu/paperless.

brainteaser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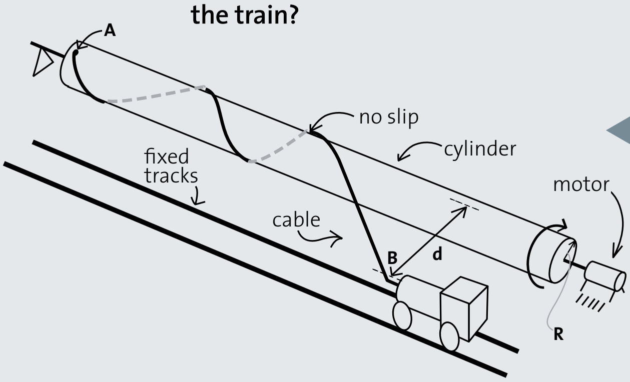
How far does the train go?

Professor Andy Ruina, Mechanical and Aerospace Engineering

A train is pulled by a cable that wraps around a cylinder that is parallel to the tracks. How far can the cylinder pull the train?



SOLVE THIS TO WIN CORNELL ENGINEERING GEAR

Enter your answers to both (a) and (b) by Aug. 1 at www.engineering.cornell.edu/brainteaser. We will draw 12 winners from the correct entries. They will receive a Champion sweatshirt (We'll contact you for sizing.), a Garland gift pen, a stainless steel water bottle, or one of nine Cornell Engineering car decals. We will announce the winners in the Fall 2010 issue. The full line of Cornell Engineering gear can be found at www.cornell.engineering.edu/gear.

The cable can pull no more once it is orthogonal to the top line of the cylinder. The top of the cylinder is level with the cable attachment point on the train and a distance d from it. The cable is inextensible, always taut and does not slip once it is on the cylinder. The cylinder has radius R. (a) At the start of the process the cable AB makes a 30 degree angle with the top of the cylinder. (b) Limiting case: at the start of the process A is infinitely forward of the train. *Hint:* the answers have a simple form. Question unclear? Ask Andy: ruina@cornell.edu.

PROBLEM SOLVER

By Lauren Cahoon

The path less traveled leads to science superstardom for a once struggling ChemE.

PROVIDED/DONNA COVENEY/MIT

MIT Professor Robert Langer '70 ChE and fellow faculty member Jeffrey Karp display an adhesive they developed that was inspired by the gecko and may have medical and surgical applications.

Within the scientific community, and even outside of it, Robert Langer '70 ChE is something of a celebrity. Colleagues toss around the word "genius" when referring to him. Entire fields of research are considered his brainchildren. Life-saving technologies are on the market due to his ingenuity. Yet, if you time-traveled back to 1967 to get a glimpse of Langer as a Cornell undergrad and expected to see a science prodigy acing his prelims, you'd be surprised. "My first three terms were pretty bad," says Langer. "I don't think my average was above a B minus."

This disarming revelation may bring hope to those Cornell engineering students who find their coursework less than breezy. Despite the rocky start, Langer went on to get his Sc.D. at the Massachusetts Institute of Technology where he would later become a professor in bioengineering, running the largest academic biotechnology lab in the world. He would also garner more than 170 major awards, including the 2008 Millennium Prize, (the world's largest technology prize), the 2006 United States National Medal of Science, and the Charles Stark Draper Prize (the equivalent of the Nobel Prize for engineers). And he has returned to Cornell many times as a guest lecturer—most recently, he spoke to engineering students last fall about biomaterials and biotechnology, focusing on the two fields he revolutionized: tissue engineering and drug delivery systems.

How did he turn a dismal first three semesters into a science superstar career? "After a year and a half of falling asleep in large lecture classes and not getting anything out of it, I thought, 'Why am I even bothering to go?'" Langer says. He realized he needed to change his hands-off approach and began attending office hours and pushing himself in labs—and focused on solving lots of problem sets. For Langer, this was the key to success. "It was a self-observation after three terms of doing crummy, I realized I was good at solving problems," he says.

His problem-solving skills soon shot him to straight-A status, and he thrived as a TA in chemical engineering classes. What lay in store after graduation, however, "was a big blank," says Langer. Even his choice of majors was a whimsical decision. "In my first year the only thing I did well in was chemistry, and I was in the engineering school, so I picked it. I don't think I even knew what a chemical engineer actually did."

As it turned out, most chemical engineers in his class were taking jobs in the oil industry—an idea that held little appeal for Langer. "I always had the idea that I wanted to do something good for the world," he says. It was this noble, yet vague desire that led Langer to the unusual decision that would jumpstart his career—applying for and winning a post-doctoral position in the lab of Harvard Medical School vascular biology researcher Judah

Folkman. It was an unusual move for an engineer, Langer admits, but a fortuitous one. There, Langer and Folkman tackled the issue of drug delivery.

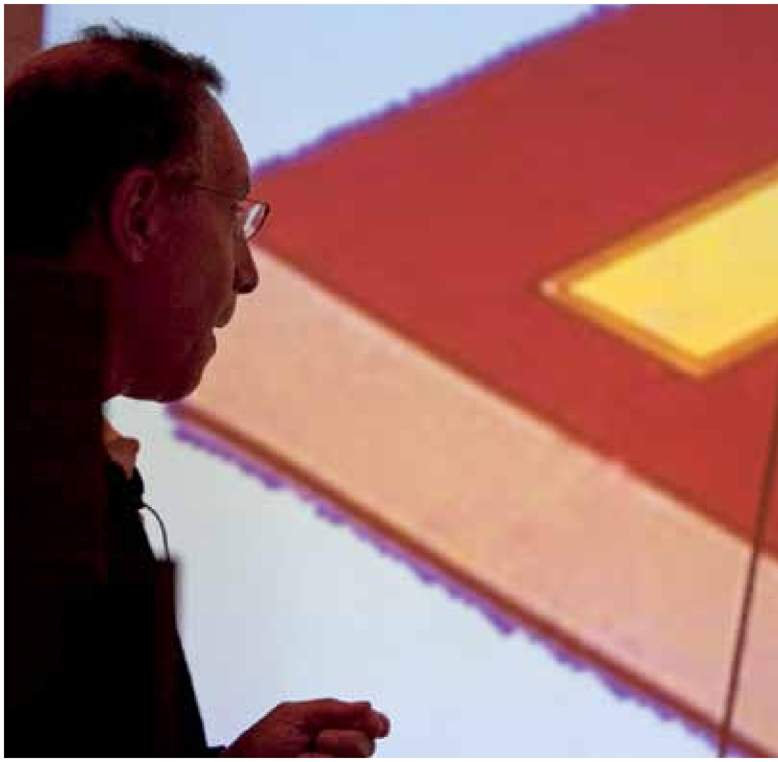
Folkman wanted to develop a type of drug known as an angiogenesis inhibitor, which blocks the growth of blood vessels that nourish tumors. However, these drugs cannot be taken orally and are ineffective when injected. They needed a new way to get these drugs to tumors—and Langer believed this could be done using porous polymer microspheres that would slowly release the drugs directly at the tumor site after being injected. Yet the idea of a porous polymer that would allow the medication's large molecules to pass through it was deemed impossible by the scientific community. This didn't faze Langer, who was determined to find a solution, despite the odds. "Judah Folkman and I found about 200 ways to get it to NOT work," Langer says with a smile. Yet persistence paid off. Now drug delivery systems, based in large part on his work, are used to treat cancer, schizophrenia, and alcoholism. Clinical trials are under way to use such systems for diabetes and substance abuse.

Since then, Langer has continued to forge meaningful medical advances, including tissue engineering, a field that he actively created by discovering the use of polymer-based scaffolds on which human cells could be placed and encouraged to replicate and flourish. Langer's research in this field has since developed exponentially, with scientists now having successfully grown human skin, corneas, bladders, cartilage, bone, and blood vessels, while spinal cord, liver, pancreas, intestine, and ureters have been successfully grown in animal studies.

For all the accomplishments, Langer is remarkably down to earth. Speaking with him face to face during his visit to Cornell last September, the scientist was unassuming, answering interview questions as if for the first time, rather than the five-hundredth. He's happy to recall memories from his Cornell undergrad days, from sledding down Libe Slope on cafeteria trays ("Do they still do that anymore?") to a now long-gone dining establishment Langer and his friends would call "The Barf Bar."

"Some people are generally successful in their career, but they're not very easy to get along with, but Bob's not like that," says Mike Shuler, the James M. and Marsha McCormick Chair of the Department of Biomedical Engineering, who's known Langer for decades. Alex Klibanov, MIT Novartis Professor of Chemistry and Bioengineering, who met Langer 30 years ago when they both joined the faculty at MIT, agrees. "We have been good friends for years, so I'm not sure I'm objective," says Klibanov, "but there is a wide consensus in the field that he's a very nice person."

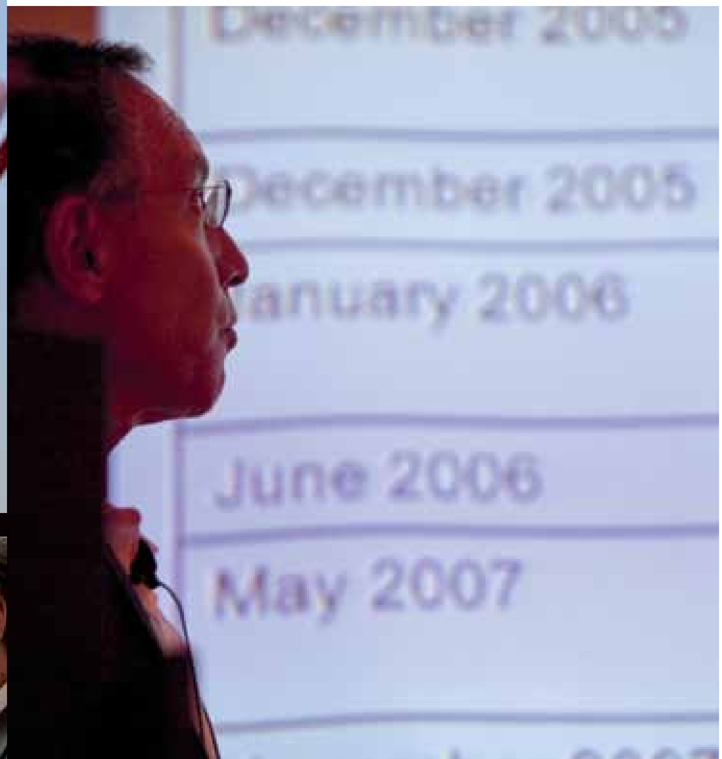
Both Shuler and Klibanov claim this has worked greatly to Langer's advantage—it fosters a highly successful lab of graduate students and post-docs that create first-rate research. With close to 1,100 scientific papers and 750 issued and pending patents to their credit, Langer lab members have a laundry list of discoveries that aim to change the face of medicine. Some of the more recent ones include work on creating long-term delivery systems for insulin, growth factors, gene therapy agents, vaccines, and anti-cancer drugs. Other work focuses on drug delivery systems that can move proteins or genes across anatomical barriers such as the intestine, lungs, blood-brain barrier, and the skin. And, as mentioned before, tissue engineering is another key focus in the lab—with the famed ex-songbird Julie Andrews as a potential beneficiary of their efforts. By injecting a synthetic, gel-like material into scarred or damaged vocal cords, Langer and his team believe they may someday be able to restore the voices of singers like Andrews.



Langer described his work to Cornell faculty and students at a seminar last September.

While Langer has done a lot for the medical field, his work hasn't stopped there. He recently teamed up with a hair product company known as Living Proof to tackle the omnipresent problem of frizzy hair. The result was No Frizz, a product composed of a compound known as polyflourester that coats hair follicles and prevents moisture from getting at the hair strand and creating a "frizz" response. Beauty magazines and frizz-haired customers have raved about the product since its release earlier this year.

One particularly faithful customer happens to be Langer's daughter, Susan '13, who got to work at Living Proof during its early stages doing both science and marketing. Susan, a chemistry major at Cornell who hopes to work in science and business one day, seems to be a chip off the Langer block. Yet she says her father never pushed her into science—and that dinnertime conversations at the Langer household don't



"WHATEVER ELSE YOU DO, THINK ABOUT WHAT IMPACT IS GREATEST—IS IT THE ROAD EVERYONE ELSE IS TAKING? A LOT OF PEOPLE MAY TELL YOU IT'S IMPOSSIBLE. BUT THERE'S NOT THAT MUCH THAT'S IMPOSSIBLE. IT'S WORTH TRYING IT IF YOU BELIEVE."

—ROBERT LANGER

necessarily focus on her father's high-profile science work but on "every-day stuff," says Susan. "We talk about everybody's lives at the dinner table." She also mentions fond memories of attending weekly summertime Langer lab softball games—a well-loved tradition among Langer group members.

"He's very, very good at working with a variety of people," adds Shuler, "he elicits a lot of loyalty, and people feel they're doing something important." This may in part be due to Langer's unfailing policy to make time for whoever requests to see or talk to him—somewhat unusual for a scientist of Langer's stature. However, "that's just showing people respect," says Langer. "If someone wants to talk to me, I will make time for them." That sense of respect seems to have an empowering effect. Of the roughly 500 students and post docs to come through the Langer lab, 200 of them are executives at pharmaceutical and biotech companies, and 200 of them are now professors, including David Putnam, an associate professor of chemical and biomolecular engineering at Cornell. Putnam was a postdoc in the Langer lab from 1996 to 2000 and vows the experience was instrumental in his success. "I was in an environment where you could dream big—Bob didn't micro-manage," says Putnam. "It was an academic candy store." Langer says it is these successful careers, like Putnam's—and not the countless prizes, papers, and patents—that he is most proud of.

As for those who aspire to follow Langer's footsteps, "consider not going down a conventional path," says Langer. "Whatever else you do, think about what impact is the greatest—is it the road everyone else is taking?" And, after years of going down the path less traveled, Langer now knows better than to listen to naysayers. "A lot of people may tell you it's impossible," he says. "But there's not that much that's impossible. It's worth trying it if you believe."

LIVING MACHINES

GENETICALLY ENGINEERING SOLUTIONS TO WIN

Ben Cammarata '11 BE and Malinka Walaliyadde '12 MSE creating "BioBricks" for the competition.

By Dan Tuohy

A screen flashed an image of an impoverished man, hunched over and suffering from prolonged exposure to toxic heavy metals. Malinka Walaliyadde '12 MSE stepped up to the front of the hall at the Massachusetts Institute of Technology in Cambridge, Mass., to identify the culprit: cadmium poisoning.

Ingestion of cadmium-contaminated water, whether from industrial and mining operations, sewage, or poor irrigation practices, can cause any number of life-threatening conditions and lead to bone fractures and severe brain and kidney damage.

"We know cadmium is bad for us," Walaliyadde says. "In developing countries it remains an issue. One of the biggest problems in developing countries is the consumption of cadmium-contaminated crops."

He and five others on one of Cornell's newest student teams have created an answer: a biosensor to detect cadmium. The team of undergraduates put their research to the test at MIT in the 2009 International Genetically Engineered Machine competition, better known as iGEM, and earned a bronze medal.

PROVIDED/ALYSSA HENNING

In presenting their work, the teammates switched up, each describing part of the problem and their solution: attaching proteins that glow when activated to the cadmium response promoters found in the soil bacteria *Bacillus subtilis* to synthesize a whole cell cadmium biosensor.

A bacterial biosensor of cadmium can be much less expensive and therefore more readily available in third-world countries, says Xing Xiong '10 Chemistry, Cornell's team leader.

The opening presentation at MIT took approximately 30 minutes, but the team began training for the competition a year before. Xiong, Walaliyadde, Bernard Cammarata '11 BE, Alyssa Henning '11 BE, Matthew Hall '10 BE, and Kevin Cheng '10 Bio worked with advisers Carl Batt, Maki Inada, John D. Helmann, and Xiling Shen.

The expertise is indicative of the multidisciplinary approach. Batt is a professor of food science. Inada is an adjunct assistant professor of molecular biology and genetics. Helmann is a professor of microbiology. Shen is an assistant professor of electrical and computer engineering.

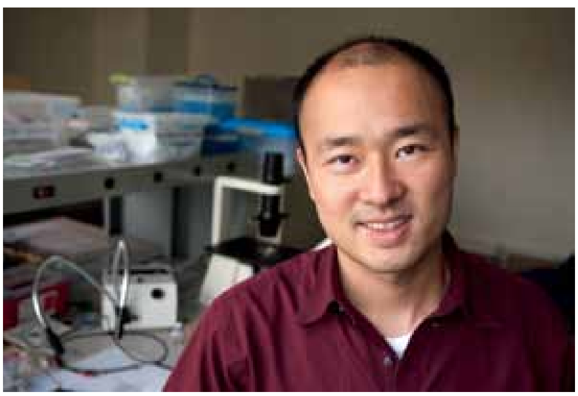
The premiere undergraduate synthetic biology competition, iGEM requires student teams to begin working with a standard kit of biological parts, known as "BioBricks," at the beginning of summer. They use the parts and parts of their own design to build biological systems and operate them in living cells.

It began in 2003, designed as an effective and motivational teaching method, with a month-long independent studies course at MIT. Students designed biological systems to make cells blink. The first competition, in 2004, was among five teams. It grew to 13 teams in 2005, 32 teams in 2006, 54 teams in 2007, and 84 teams in 2008.

Projects have ranged from banana and wintergreen-smelling bacteria to arsenic biosensors and buoyant bacteria.

The iGEM philosophy is "get and give," said iGEM director Randy Rettberg as he welcomed the record number of 2009 participants to MIT. They numbered 1,700 from 112 teams and came from 26 countries in pursuit of research glory and a chance to change the world.

iGEM points to the impressive



ECE Assistant Professor Xiling Shen advises the team.

PROVIDED/ALYSSA HENNING

Alyssa Henning '11 BE culturing *B. subtilis* in tubes. The bacteria grow overnight and can be used in experiments the next day.

"I know a lot about the techniques, how to do the cloning and things like that, but I don't think about circuits. ... So having the engineers with me, from that perspective, really enriches the whole project." —Maki Inada

student team accomplishments, often reached in a short span of time, which may lead to advances in medicine, energy, and the environment.

Sponsors in 2009 included Life Technologies, a global biotechnology tools company; GeneART, a world provider of synthetic genes; the National Science Foundation; The Mathworks; and the Federal Bureau of Investigation, through its Biological Sciences Outreach Program.

"It's just been growing like mad," says Meagan Lizarazo, assistant director of iGEM. "It's a new field, so that kind of attracts people."

Students say it is also fun, all this hands-on work and research and the professional interaction.

"They're the ones driving the whole project," Lizarazo says. "The students feel like they own the project."

The Cornell team was founded by Naweed Paya '09 BE ECE, M.Eng. His interest led to exploration in 2008. Students conferred and brainstormed, discussing with faculty how best to launch a team.

"I was already interested in this whole synthetic biology field, along with electrical engineering that I was doing," Paya says. After reading up on iGEM, he says he was motivated by the MineSweeper and autonomous underwater vehicle teams at Cornell, and the vacuum in the synthetic biology field.

"There was a lot of interest when we sent out the initial calls," says Paya. "There was a lot of interest and there was really nothing available. It was the perfect opportunity."

The biggest challenge? Finding lab space on campus, the students say during interviews after their initial presentation at MIT.

The multidisciplinary challenges remain an attractive component, says Henning. "Malinka and I didn't have experience in the genetic engineering," she says. "So there was a bit of a learning curve there."

Hall says the iGEM philosophy, that the competition advances each year based on all the teams' work, is compelling.

"I feel like now that I've done the projects, I can understand the lectures a lot better," he says. "Last time we split up, saw probably half of the lectures, and took all these notes. We really figured out a couple weeks later that we had no idea what had just happened."

After their performance at MIT, Xiong says the questions from judges were reasonable, centered as they were on design and purpose. "We wanted to do something that we could accomplish in a short period of time," he says. "We knew that it was our first year so we could have some trouble, so we tried to think of something simple and we had seen some people do some biosensors before."

Those biosensors were different, of course. Henning says the team's early brainstorming produced biomedical and environmental ideas. "Another reason why we chose to go with a cadmium biosensor is that *Bacillus subtilis*, the bacteria we work with, naturally took in metals that we've got," she says. "All the other teams use *E. coli*, the workhorse of bacteria." But *E. coli* does not naturally take in metals, so it would have to be manipulated more to produce the desired biosensor.

While biosensors are pretty well established, adviser Shen noted the Cornell concept is a cheap way to create them, something of paramount importance in developing nations. "These provide a very, very convenient way," he says.

Shen says the iGEM competition has several educational benefits, starting with its interdisciplinary scope. Because it requires different majors with complementary skills to work together, Shen and the other team advisers have created a special course, cross-listed in multiple departments, to recruit and prepare students for future iGEM competitions.

Shen says organizers try to make the competition as realistic as possible. In some course work, there can be a disconnect between studies and occupational reality, so it can be a unique experience for undergraduates.

"Also," he says, "the organizers try, in a way, to show that research is cool."

Cheng called Cornell progressive for its support of the new team. "It's really very forward-looking as education, especially biology," he says. "In 50 years, it'll be unrecognizable with what we see today."

Teams continue to draw talent from across the spectrum. Lizarazo pointed out that several teams had social science majors, including a couple of artists, among their members. One of those teams was Cambridge University, the grand winner in 2009.

Inada, the molecular biologist, spoke of the valuable collaboration in confronting a growing field and emerging technologies.

"I know a lot about the techniques, how to do the cloning and things like that, but I don't think about circuits," Inada says. "I don't think about how all the pathways connect together. So having the engineers with me, from that perspective, really enriches the whole project."

Interdisciplinary assets are visible on campus, as Inada explained. The engineering and biology departments are not really close to one another. But the new Weill Institute for Cell and Molecular Biology, a state-of-the-art center in newly constructed Weill Hall, is a kind of connective tissue.

"They have bio engineers in that building that are sort of helping to bridge and bring together the different disciplines," she says. "It's a really exciting time for that."

PROVIDED

Members of the CUGEM team stand in front of their poster at the 2009 international iGEM jamboree. From left: Alyssa Henning '11 BE, Matt Hall '10 BE, Xing Xiong '10 Chemistry, Malinka Walaliyadde '12 MSE, and Ben Cammarata '11 BE.

The same goes for iGEM, established to celebrate and strengthen the foundation of the scientific community: that today's advances arrive on yesterday's hard work.

Henning says she found the professional networking, with the sharing of experiences, an unexpected reward. Walaliyadde agreed. He noted that iGEM gold medals are only awarded when a team can demonstrate its work has helped another team. "They make it a collaborative community," he says.

The Wiki-inspired collaborative model is a big part of the weekend's contest, from presentations to a poster-board discussion of a team's solution.

As a result, Xiong says, the competition gets bigger, better, and more challenging every year. "Every year you have a build-up of more parts that other teams can use," he says.

Like so many construction bricks and mortar, the "BioBricks" stack up with each year. A team's success could be directly linked to a team's past work—next year, it could be thanks to the Cornell competitors.

To save a life, the environment, the world?

As the Cornell students assessed their work sitting around a table at MIT's Stata Center, where high-tech companies handed out fliers for potential future employees, Xiong grinned at the prospect. "Maybe."

The new Weill Institute for Cell and Molecular Biology, a state-of-the-art center in Weill Hall, is a kind of connective tissue for the interdisciplinary CU GEM team.

Q&A

By Robert Emro

A conversation with **Mark Spencer**, Director of Engineering Admissions

In the strategic plan laid out in 2005, the college set itself the goal of becoming a leader in the education of women and underrepresented minorities. In recent years, the college has passed significant milestones on the way to achieving this goal. We sat down in December with Mark Spencer, director of Engineering Admissions, to find out what's behind the numbers and talk about other recruitment trends.

Cornell Engineering Magazine:* *How is the college doing at recruitment?

Mark Spencer: We think the college is doing a great job. We just came out of a year in which we saw more applications than the College of Engineering has ever seen. We had just over 7,700 applicants and the enrolling freshmen class of 2013 was 37 percent female and 12 percent underrepresented minorities. All those stats are all-time highs for the college.

CEM:* *How are things looking this year?

MS: We have seen another increase in early-decision applications. In the last two cycles alone we have seen an increase in early applications of 33 percent. I don't know yet where we're going to be with regular decision applications, but we're expecting another increase. We may reach another all-time high in total applications to the college.

(Editor's note: As of March 1, 2010, Engineering applications did in fact reach an all new record high of just over 8,400 applications!)

CEM:* *What is the effect on our acceptance rate?

MS: We only have 735 slots each year, so as applications rise, our acceptance rate drops. Since 2005 our acceptance rate has dropped from 38 percent to 22 percent for last year. So, we're more selective, and the quality of our students continues to be excellent—for example, the mean SAT score (Critical Reading and Math composite) for accepted students is consistently between 1450 and 1460, out of 1600. Also, for students who have a high school rank, 96% of them fall in the top decile of their graduating class. Having so many applicants gives us even more options for diversifying the class in so many ways.

CEM:* *What's behind the increase in applicants?

MS: There are a lot of factors. We have a great staff and they work very hard. We logged something like 4,000 Engineering Admissions visits last year. And the Engineering Ambassadors, the students who give our tours, are great representatives of the college. Our faculty members help too by opening up some of their classes for visitors to sit in on, or by serving on panels for on-campus events like Cornell Days.

Another item that has helped is that the strategic communications of the college and the university as a whole have done a good job representing Cornell to high-school students. The university is definitely a partner in this. From an enhanced Web site to updated print communications, I believe we have reached out to these students in an informative and positive manner. We also went to the Common



Application about five years ago. Some of our increase may have come from that change, although not all of it. And perhaps with this economy, more parents and students are focusing on studying something with a clear path to a future profession where they can make a nice salary upon graduation.

CEM: What has led to the success in recruiting women and underrepresented minorities?

MS: Outreach programs that bring prospective students to our beautiful campus so they can experience the quality of our programs, faculty, and facilities first-hand. For example, last fall (2008) about 90 percent of the students that attended either our Women in Engineering Day or our fall underrepresented minority hosting events ended up applying. In the spring of 2009, with our Prospective Candidates Weekend program for admitted female students, 70 percent of those attendees chose to come to Cornell. These are amazing rates. Obviously the efforts of our Diversity Programs office and the involvement of faculty and student groups, like the Society of Women Engineers, are crucial to the success of these on-campus events.

The Diversity Programs office also has two summer outreach programs, CURIE for women and CATALYST for underrepresented minority students. These programs are stellar and their efforts in exposing high-school sophomores and juniors to engineering are paying off for us.

Lastly, I have to believe the recent dramatic changes in our financial aid packaging has helped us be more competitive with our peers and attracted more students towards Cornell.

CEM: What challenges do you face?

MS: Continuing to build on the success of this talented and diverse class. The college's goal is to have a total female undergraduate population of 35 percent. Right now we're at about 31 percent overall. For underrepresented minorities, the goal is 10 percent and we're at 8 percent overall. We still have work to do. And our competitors are out there trying to recruit the same students. They aren't going away.

It's an enormous challenge to select the class from a group of such accomplished and talented students. We expect more than 8,000 applications, and the quality of our applicants continues to rise. It is extremely difficult to deny admission to so many excellent students who could undoubtedly make a great contribution to the Cornell community.

CEM: What do you look for when reading applications?

MS: Academics is still the biggest deciding factor. It's important that students have challenged themselves academically in their high school and been successful. Beyond that, we look at how well they would match with Cornell. How do they speak about Cornell and engineering? What do they know about us? Have they done science or engineering research? Are they leaders? Do they work hard? What were their extracurricular activities? There is no exact formula here for admission. Each student has a story to tell; what is that story? For example, a successful applicant doesn't necessarily need to have participated in a lot of extracurricular activities—some are really committed and good in one or two things, like they're a licensed pilot or certified airplane mechanic. That is their story.

Frankly, probably 80 percent of the applicant pool could do the work here. But do they fit academically and will they contribute something to the Cornell community? One way in which we try to determine that fit is with our Cornell supplemental essay question. A few years back we changed the question to be more engineering-specific. We're looking to see if they have an engineering idea or interest and how they think they can develop that at Cornell. It's basically asking, "Why engineering?" and "Why Cornell?" We're not looking for anything in particular, but how they are thinking about it and whether it makes sense. It doesn't necessarily need to be a Nathaniel Hawthorne piece of writing, but it is a good way for students to differentiate themselves.

CEM: What majors are applicants most interested in?

MS: Mechanical and electrical engineering continue to be the most popular, but there is growing interest in fields that are biology or sustainability related, such as chemical and biomolecular, biomedical, and environmental engineering. The students applying today were alive when gas hit $5 a gallon. They saw *An Inconvenient Truth*. Now they want to make an impact on the world. We're seeing more altruism expressed now in students' applications. Students want to develop sustainable water systems in developing countries, design the next-generation gas-efficient automobile, and cure disease, to name a few. These are the people we want to be leading the world into the future. They see that engineering will not only give them a secure living but it will also make the world a better place. They're going to be difference-makers out there. I can see and feel the excitement between the lines of their applications. This is my sixteenth cycle in the admissions world and this altruism trend is something I am seeing currently more than any other time in my career. It's uplifting.

EDUCATING INNOVATORS

Thomas Murray '10 ME (left) got his hands dirty on the EcoRock production line.

By Bridget Meeds

Kessler Fellows Program offers unique entrepreneurial instruction to engineering students.

PROVIDED

When Andrew J. Kessler left Cornell in 1980, B.S. in electrical engineering in hand, he was at the beginning of an untraditional but very successful career. For the first 10 years, he learned the ropes at big corporations—AT&T, PaineWebber, and Morgan Stanley. But then he struck out on his own, hitting the sweet spot of the '90s tech boom with Velocity Capital Management, a venture capital fund. Now he writes books and frequently appears in the media commenting on tech entrepreneurship. It's been a great ride, but he had to learn everything about running his own business on his own.

Kessler has decided to train a new generation of entrepreneurial engineers, but in a way that gets them out of the gate quicker, by providing them significant support to learn the business side of entrepreneurship as undergraduates. In 2009, he gave the College of Engineering $2 million to fully fund the first five years of the Kessler Fellows Program. It's an innovative combination of coursework and internships that teaches 10 juniors each year the know-how to go out and do it on their own.

"Andy wanted to develop a comprehensive program that had to do with education and experience surrounding what he has termed 'the business wrapper of entrepreneurism,'" says program director Tracey Brant. Each student attends a course in the spring of their junior year about the essentials of entrepreneurism, in which they hear war stories from alumni entrepreneurs and learn real business skills. They spend the summer interning with a start-up. And in the fall of their senior year, they present a symposium series, sharing what they learned with the engineering community. In return, they receive a salary for their internship, travel expenses, a cash prize, and, if needed, a portion of their senior year financial aid package is paid by the program.

In summer 2009, Kessler Fellows did traditional engineering—measured nanoparticles, tested the fire resistance of building materials, wrote computer code—but those same fellows also did market research, wrote business plans, and researched patents.

"IT WAS A GREAT LEARNING EXPERIENCE. IT WAS EXACTLY WHAT I WANTED TO BE ABLE TO DO, TO EXPERIENCE MANY ASPECTS OF THE ENTREPRENEURIAL ENVIRONMENT."

—PETER BAI '10 MSE

PROVIDED

Peter Bai '10 MSE did everything from measuring nanoparticles to writing a business plan at Hybrid Silica Technologies.

Not enough hands

"Everything I have is pretty darn important and I don't have enough hands," says Ken Wang '77 ChE, president of Hybrid Silica Technologies Inc. "We actually need help more than larger companies."

Peter Bai '10 MSE soon discovered this with his internship at the start-up, born in the lab of Ulrich Wiesner, Spencer T. Olin Professor of Materials Science and Engineering. HST develops fluorescent core-shell nanoparticles with biomedical, energy, and electronics applications at its labs in Ithaca, N.Y., and Cambridge, Mass.

At HST, Peter measured nanoparticles and analyzed data in the lab. He made training videos on lab techniques and created a private YouTube account to host them. He researched patents. He helped plan the company's expansion to Cambridge, learning about permits and vetting potential lab spaces. And in his free moments he wrote a 25-page business plan about a spin-off product that HST hopes to market, one that will help identify conditions to which diabetics are prone.

"It was a great learning experience," says Bai. "It was exactly what I wanted to be able to do, to experience many aspects of the entrepreneurial environment."

"The Kessler Fellows Program is absolutely brilliant," says Wiesner. "It provides the intellectual environment that particularly talented students thrive on. We need to not only educate the best technical engineers, but also individuals that are ready and hungry to bring the most promising engineering solutions to the market. That is exactly what the Kessler Fellows Program helps to do."

"Peter's very versatile," says Wang. "In a start-up, you need people who can help pack a truck one day, and another day, do the highest level thinking on the IP."

Beautiful engineering

Thevaki Thambirajah '97 (Applied Economics and Management), who owns Thevi Cosmetics and hosted Kessler Fellow Amy Chen '10 ORE, agrees. "We have so much work to do and we have limited resources!" Thambirajah says.

Thevi Cosmetics in New York, N.Y., is a high-end, boldly colored, all-natural line inspired by the Indian lifestyle and based on the Ayurvedic philosophy. How did an engineer end up interning at a cosmetics company? Amy is an unusual engineer, one who openly celebrates her "girly" side. She found a way to mesh her passion for cosmetics with business development through the Kessler program.

As soon as Chen arrived, she dove enthusiastically into doing hands-on market research at department store counters, planning and executing a social media marketing plan including a splashy blog, and creating the "mood boards" that demonstrate the feel of the brand for Thambirajah's investor presentations. In the process, Chen helped change the very direction of the company from being a brand targeted to Indian women to an "Indian lifestyle-inspired" brand that appeals to more consumers.

"Initially, before Amy came on board, we were very focused toward the minority market," says Thambirajah. "But we found that retailers as well as consumers want to have a broader reach. So through my and Amy's research, we found that the Indian-inspired concept had a wider appeal."

PROVIDED

Amy Chen '10 ORE helped Thevaki Thambirajah '97 reorient Thevi Cosmetics toward a broader market.

PROVIDED

Thomas Murray '10 ME worked on technical development of EcoRock in the lab at Serious Materials.

2009 Kessler Fellows

Peter Bai '10 MSE
Hybrid Silica Technologies
Ithaca, N.Y.

Amy Chen '10 ORE
Thevi Cosmetics
New York, N.Y.

Bhaskar Garg '10 ME
Palo Alto Research Center
Palo Alto, Calif.

Tucker Moffat '10 ME
Bug Labs
New York, N.Y.

Thomas Murray '10 ME
Serious Materials
Sunnyvale, Calif.

Scott Purdy '10 CS
Numenta
Redwood City, Calif.

Mike Ryan '10 EP
V.i. Labs
Waltham, Mass.

Joey Zwicker '10 ME
AN.Y.bots
Mountain View, Calif.

Casey Worthington '10 ECE
Marketcetera
San Francisco, Calif.

Jeff Will '10 ChE
The Water Initiative
New York, N.Y.

"THIS PROGRAM REALLY SAVED ME IN A LOT OF WAYS. I WAS GRASPING FOR ANYTHING TO HELP ME WITH MY CAREER, AND THEN I FOUND THIS PROGRAM AND IT OPENED UP THIS WHOLE NEW WORLD FOR ME."

—AMY CHEN '10 ORE

"I felt really honored," says Chen, "because I'm still in college, and she trusted me enough to really tell her my opinions about the direction she should take her company. It was a really great experience and I got to accomplish a lot of things that I honestly never dreamed I'd be able to do just as an intern."

A new Field needs new ideas

"Entrepreneurs benefit from interns because interns don't have any preconceptions about how things are done," says Dan Boss, vice president of engineering for Serious Materials in Sunnyvale, Calif. Serious Materials is riding the zeitgeist of green building by manufacturing building products that help reduce the embodied energy of a building—including energy used for raw material extraction, transport, manufacture, construction, and deconstruction —as well the energy usage in its operation. They offer highly-efficient windows and EcoRock, the low embodied energy drywall on which Thomas Murray '10 ME focused. "Interns come in open-minded," continues Boss. "When you're an entrepreneur, that's one of the key aspects that makes you successful, to look at problems from a different perspective."

Murray says he was really pleased to offer his different perspective to Serious Materials during his internship. During the summer, says Boss, "Tom was focused on EcoRock. We had him do both some technical development for us, looking at some chemistry of the system, but also looking at the value proposition of EcoRock versus competitive products. He had the chance to get his hands dirty in the lab and work on the production line as well as look at how EcoRock fits in, particularly for LEED construction in the commercial space."

Traditional drywall has been made in the same way for more than 100 years using gypsum, a limited natural resource, with an energy-consuming, carbon dioxide-producing drying process. EcoRock is air-dried, using 80 percent less energy; is made from 80 percent recycled waste from steel and cement plants; can end its life cycle as a soil amendment; resists mold better; emits no mercury; and looks great. Builders earn LEED credits when they use it.

"One big thing that I learned from the Essentials of Entrepreneurism class and then saw in practice was that bringing a product to market is one-third engineering," says Murray. "The other two-thirds are business and marketing. Working for a larger company, you are just going to be able to see your engineering part of the process. But working in a start-up, you'll see the entire process."

"Thomas is developing a very valuable perspective in that he's looking at both the technical problem and the business aspect of it," says Boss, "which I think it is a great focus for the Kessler Program, because that's often missing. A lot of the technical internships focus just on the technology and it is the synergy of the business and the technology that makes something successful. If you don't have both aspects, you only have half the answer."

The entrepreneurs of the future

Each Kessler Fellow has taken the skills and opportunities of the program and used them to plan the future. Bai is applying to graduate programs with good technology transfer support, envisioning developing his own company before he finishes his Ph.D. Chen plans to enter the cosmetics industry to learn its intricacies and hopes to eventually open her own company. Murray is spending the spring having conversations with members of the Kessler advisory board, bouncing around ideas about the sustainable building business he'd like to start.

"This program really saved me in a lot of ways," says Chen, who took a long time to find her niche in engineering school. "I was grasping for anything to help me with my career, and then I found this program and it opened up this whole new world for me. Honestly, without Andy Kessler and the help he's given me, I don't know where I would be right now."

"In the lab, a lot of people have very good ideas," says Bai. "But a lot of those ideas are being buried in notebooks because not a lot of people are taking the next step to develop them into products that have commercial value. It is important to bring these ideas into the marketplace because it not only benefits the people who invent and sell these products; it also generates value for everybody."

"The Kessler Fellows is an awesome experience," says Murray. "There's really no other time in your life when you're going to be able to just go and pick the start-up you want to work for and go see that culture and have it be a wonderful learning experience."

KILLER ROB

The promise and perils of artificial intelligence

By Michael Gillis

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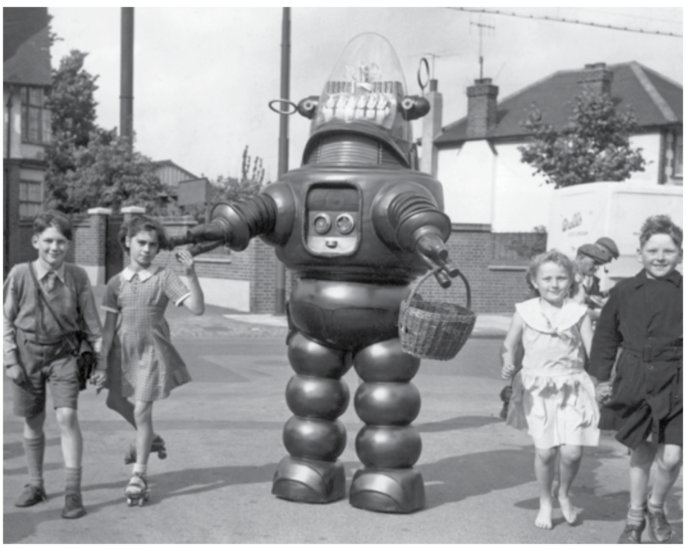

Built-in safeguards prevented Robby the Robot, from the 1956 film *Forbidden Planet,* from obeying Dr. Morbius when he ordered the robot to destroy an invisible menace that was an extension of himself.

In the final act of the 1956 film *Forbidden Planet*, Robby the Robot is ordered by his creator, Dr. Morbius (Walter Pidgeon) to destroy an invisible monster descending upon the doctor's laboratory. As the creature hammers the steel walls that shield the lab, Robby shakes, rocks, heats up, and shuts down. The robot's inaction is not insubordination but a built-in safeguard that prevents Robby from harming his master: although Morbius has not yet admitted it, the invisible beast outside is an extension of himself, which Robby already knows.

Forbidden Planet is one of the earliest films to explore safeguards hardwired into robots built to serve man. It's a concept in full bloom in the "robot" novels by Isaac Asimov, in which robots are programmed with three laws intended to protect mankind from runaway robots. For the last half-century, popular entertainment has explored the possibilities and consequences of robotics and artificial intelligence, from the sublimely sinister in Stanley Kubrick's *2001: A Space Odyssey* and its cunning self-aware computer HAL 9000, to the emotional in Steven Spielberg's *A.I.*

But as science fiction runs amok with tales of artificial intelligence leveraged for evil and greed, scientific advances in

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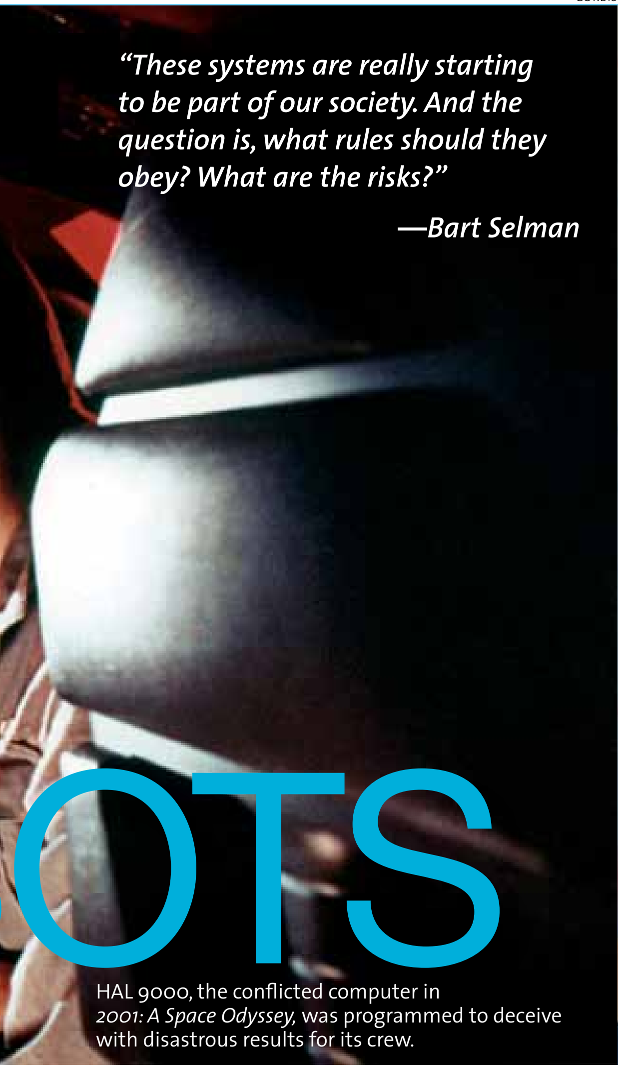
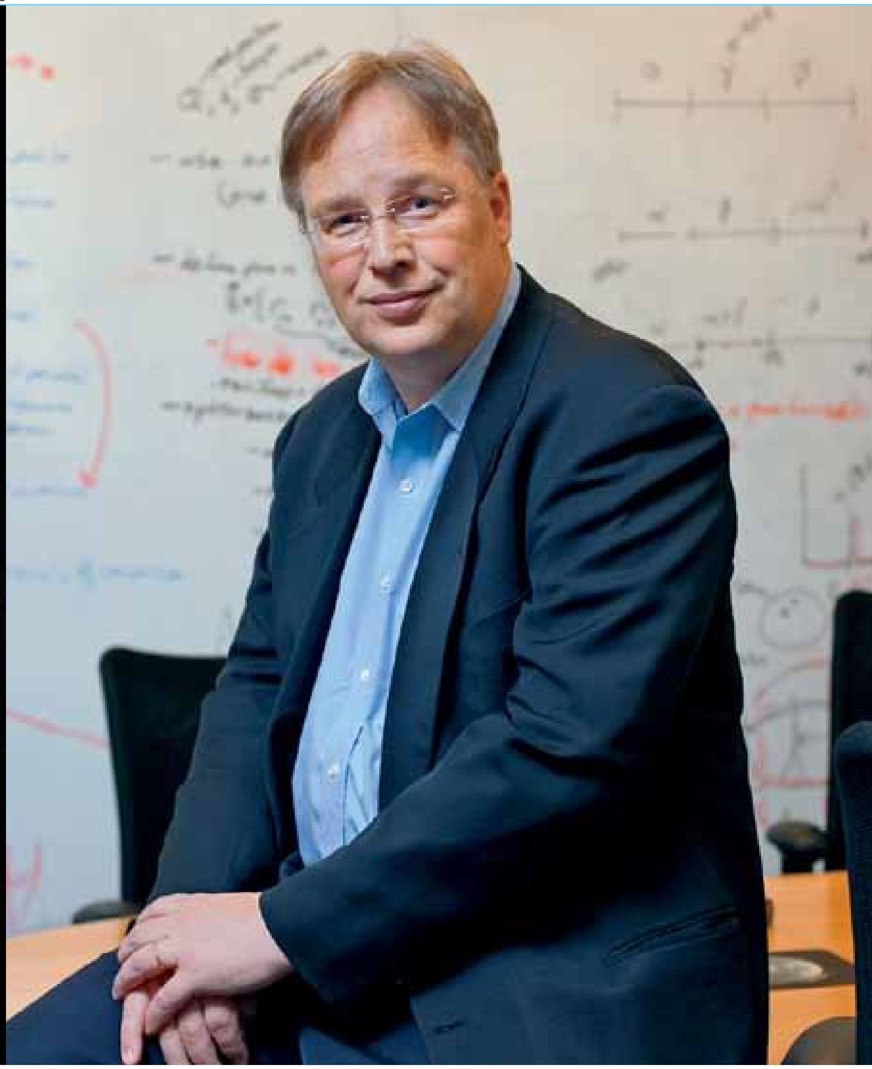


"These systems are really starting to be part of our society. And the question is, what rules should they obey? What are the risks?"

—Bart Selman

HAL 9000, the conflicted computer in *2001: A Space Odyssey*, was programmed to deceive with disastrous results for its crew.



Bart Selman, Cornell professor of computer science and co-chair of a yearlong study into AI and society by the Association for the Advancement of Artificial Intelligence.

the real world have quietly and significantly expanded the boundaries of AI, and it looks a lot different from pulp fiction.

Many of these advances—and questions—are evident at the intersection of AI and robotics. Semi-autonomous machines are already at work in factories and airplanes, and on the battlefield, where unmanned drones fulfill missions over Iraq and Afghanistan. As that technology advances and migrates to more systems, and as those systems become more autonomous and sidestep human control, the possibilities are spectacular—and potentially frightening.

"We have paid very little attention to the societal impacts or the ethical issues, because up until now, these systems were not very feasible," says Bart Selman, Cornell professor of computer science. Selman co-chairs a yearlong study into AI and society by the Association for the Advancement of Artificial Intelligence. The study comes at a critical time, Selman says, because advances over the next 15 to 20 years will bridge science fiction with science fact.

"These systems are really starting to be part of our society," he says. "And the question is, what rules should they obey? What are the risks?"

The AI explosion

The mystery of intelligence remains a tough nut to crack, but computer scientists have made important advances in several fields, including machine learning, which teaches computers how to behave based on data and complex algorithms.

Progress may be slower than expected decades ago, but Eric Horvitz, president of AAAI and a senior artificial intelligence researcher at Microsoft, says the last 25 years have yielded insight into key aspects of intelligence, including perception, representation, learning, and reasoning.

"In the last decade, there has been an acceleration in our understanding, our prowess in both principles and applications on multiple fronts based on a coalescence of several factors," Horvitz says.

Banks lean on AI to manage investments, hospitals use AI to diagnose illness and manage work schedules, and the government leverages AI in the form of speech and gesture recognition and data mining to help curb cybercrime and track down terror suspects.

One ubiquitous AI application is the aviation autopilot, used

Tsuhan Chen

Hadas Kress-Gazit

The New Roboticists

By Robert Emro

More than 20 Cornell faculty members are solving problems in robotics and artificial intelligence. Their research spans various subareas, including perception, control, learning, planning, and human-robot interaction. They work with aerial robots, home and office assistant robots, autonomous cars, humanoids, evolutionary robots, legged robots, snake robots, and more. Here are three recent additions to this group.

Tsuhan Chen's work puts him at the nexus of several disciplines with one thing in common—visual data. His projects involve everything from capturing and enhancing the signal sent from a digital camera, to analyzing it for pattern recognition, to using it to render digital images of what the camera did not see.

One project Chen's group is working on could provide surveillance with fewer cameras and faster reaction times. The goal is to program groups of networked "robocams" to patrol buildings and historical sites. Simple image analysis tells them where there's movement, but it takes more sophisticated algorithms to identify suspicious activity. "We need to know what our target is," says Chen, director of the School of Electrical and Computer Engineering. "We want them to know when something is interesting enough to record, and second, we want them to work together to get the best image."

If a couple of the robocams break down, for example, the others need to adjust to cover the gaps. Each robocam has its own computer, so deciding who goes where is a joint decision between parallel programs. "The group decision is made in a very distributed manner," says Chen. "Just like humans."

Hadas Kress-Gazit wants to know how to make robots do what they are supposed to.

Once a robot understands the meaning of a command given in natural language, it must be translated into motor and velocity commands. That's where Kress-Gazit comes in. "You want to say, 'Search the rooms.' You don't want to say, 'Move five meters forward. Turn 30 degrees to the right,' and things like that," she explains. "You want to keep it at the high level."

To be useful, a robot must be reliable. "I want to have some kind of guarantees for the robot behavior, because anything can be hacked together," she says. "I want a systematic way of going from a high-level description to a correct behavior. And if I can't, I want to know why I cannot."

There's no shortage of ways to tell a robot to simply go from point A to point B. What Kress-Gazit is interested in are tasks that require robots to react to their environment. "There is not a lot of research out there to deal with if I want to say, 'OK. I want you to go through the rooms. If you see my daughter, just stop there and call me,'" she says. "The behavior of the robot is going to change based on if my daughter is anywhere in there or if she is moving around or if she's just not there. If she's not there, the robot is just going to continue searching. The behavior is reactive.

"For example," she continues, "if I tell the robot, 'Go search all the rooms and make sure you get into every single room,' and there are doors. I want the robot to tell me, 'Listen, I can't open doors. This is the reason I cannot do what you asked me to do.'"

So far, Kress-Gazit has got her robots to tell her when they cannot perform a command, but not why. There are many other questions she would also like to answer. "Right now I'm assuming that if the robot is searching for my daughter and my daughter is there, it will see her," she says. "If it doesn't see her at all because of its point of view and tells me she's not here, what does that mean? Is that correct behavior? Is that incorrect behavior? There's a lot of uncertainty in the sensing that has to be incorporated."

Ashutosh Saxena teaches robots to operate autonomously in new, uncertain environments.

Most existing robots can be "scripted" to perform difficult tasks in highly constrained, known environments.


Ashutosh Saxena

"That works most of the time, but it doesn't apply to actual environments where there is uncertaintity and that's a big problem," says Saxena. "One of my goals is to enable robots to perceive the environment, even if it's completely new, so that they can operate in that environment. It has not only to infer the 3-D structure of the environment and recognize objects, but also to figure out what to do with the objects. A robot is not just a passive observer; it is meant to perform desired tasks by acting upon the environment."

Saxena uses machine learning algorithms to teach his robots. "We don't have to program the computer explicitly; you let them learn from the data," he says. "Just like when you are training a dog." By showing robots sample problems and their correct answers, Saxena can train robots to do all sorts of tasks. At Stanford, where he studied for his Ph.D., Saxena used machine learning to solve several robotics problems, including how to create a three-dimensional model from a two-dimensional image.

"We showed the computer about 500 images and the correct 3-D models for the images," says Saxena. "So it learned the functional mapping from the image to the depths. Then when given a new image it could make a 3-D model."

With this technology, Saxena turned a remote control car into a robot that could drive itself through unfamiliar surroundings full of obstacles, like a forest. "It's a small robot, so it cannot have big sensors on it, but it can use camera images to find out where it should go," he says. "And it could really drive fast avoiding the obstacles, even ones that were not seen before."

Saxena is now teaching robotic helicopters how to fly without the aid of positioning systems. "It's really hard to make aerial robots fly in GPS-denied environments, or in cluttered environments," he says. "There's no robot that can fly inside a building in constrained spaces."

Saxena has trained a robot to unload items from a dishwasher and wants to build a general purpose home and office assistant robot that can do household chores like tidy up a room, fetch or deliver items, or prepare simple kitchen meals.

extensively on commercial flights. The technology's benefits are obvious, but it also provides an example of potential dangers in an automated society.

"Ten years ago you could just turn off the system," Selman says. However, he explains that switching off autopilot may not be the right choice today. He points to a recent incident in New York where a pilot turned off his plane's automated controls and crashed. "It's very hard for a pilot to take over in a difficult situation. Because they have been flying autopilot so much, they may not actually have the training anymore to recover from difficult situations."

That growing dependence on automated technologies is why Selman and the AAAI are taking a hard look at the societal effects of AI.

"AI research is at the front edge of a larger computational revolution in our midst—a technical revolution that has been introducing new kinds of tools, automation, services, and new access to information communication," reads the interim report of the AAAI Presidential Panel on Long-Term AI Futures.

Ghost rider

Some of the most obvious advances in AI are found in the field of robotics, in part, because it's easier for people to see these machines as physical beings, Selman says. Robots are already widely used in manufacturing and the medical profession, and now robotics stands at the dawn of a new age.

In 2005, Team Cornell participated in the Defense Advanced Research Projects Agency's second Grand Challenge, one of a series of contests launched by the U.S. military in 2002 that offers millions of dollars to groups that build vehicles that can navigate themselves across a finish line.

In 2007, Cornell was one of six teams to finish the DARPA Urban Challenge at a former military base in California. Its driverless Chevy Tahoe, dubbed Skynet after the AI in *The Terminator* movies, traveled 55 miles across a variety of terrain, obeying traffic lights, merging with traffic, and parking itself.

Selman, who sits on the advisory board for the Cornell team, says the contest and its achievements are proof that AI is "grown up."

Those accomplishments also help paint a more vivid picture of the potential societal benefits of driverless vehicles.

"Such robotic systems will first come to the fore as collision avoidance systems that will sense dangerous situations and take over driving briefly," Horvitz says. "Even early versions of robotic automobile systems promise to reduce traffic injuries. We have had over 40,000 people killed each year in the United States—and I believe that most of these deaths will one day be prevented by robotic vehicles."

That kind of technology will likely be commonplace in 20 years, says Selman, which is why the AAAI is raising the questions of responsibility—and quelling fear—as robots rise.

The 2009 CUAUV, Nova, dodged barbed wire, fired torpedoes and retrieved a pinging briefcase.

Big Red Robots

Cornell student teams have been at the forefront of robotics for more than a decade. Cornell won its first RoboCup championship in 1999. Before disbanding, the robot soccer team took the trophy three more times, most recently in 2003. That same year, Cornell's robotic airplane and submarine teams also won their competitions. In 2005 and 2007, Cornell competed in DARPA challenges, designing autonomous robotic SUVs capable of navigating themselves through desert and urban environments. CUAUV, the robotic submarine team, won again in August 2009 with a flawless performance. And in November, Cornell was named one of 10 semifinalists in the first Multi-Autonomous Ground-robotic International Challenge, co-sponsored by the U.S. Department of Defense and the Australian Defense Science and Technology Organization (see page 5).

The Cornell RoboCup team won the championship four times.

Skynet, Cornell's entry in the DARPA Urban Challenge, drove itself through 55 miles of simulated city driving.

Bad robot

The AAAI's interim report takes unabashed aim at science fiction.

It points out that much of the lay perception of robots and artificial intelligence is fueled by pulp fiction visions of the "technological singularity," when humanity creates an intelligence greater than its own that can then design even smarter machines. The result is either a world overrun by killer machines, as in *The Terminator* movies, or a utopian future where AI solves all our problems.

"The panel of experts was, overall, skeptical of the radical views expressed by futurists and science-fiction authors," the report reads.

The interim report specifically mentions science fiction author Isaac Asimov and his robot novels. Robots and popular culture are much informed by Asimov's writings, the ideas of which populate an ever-expanding mythology in movies and books.

Asimov's laws of robotics are well known throughout the science-fiction community, and many readers believe they are sensible rules to follow: "1. A robot may not injure a human being or, through inaction, allow a human being to come to harm. 2. A robot must obey any orders given to it by human beings, except where such orders would conflict with the First Law. 3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law."

But scientists can easily poke holes in this code.

Selman offers an example of a home robot given money and told to take the family vehicle to the car wash.

"At the end of the day, you come back, the car is not washed, and you ask the robot 'Why?'" Selman says. "The robot says, 'I donated your money to hunger relief because that will save human lives.'" The answer is consistent with Asimov's laws of robotics, but isn't what the owner wanted.

Still, Selman sees a place for Asimov's laws. "We believe new research is actually needed to see how we implement something like Asimov's laws but in a more effective way with these robotic systems," he says.

"We feel these technologies can be developed as long as safeguards are built in and as long as the systems can reflect on the consequences of their actions," Selman says.

Those questions are timely. Robotics is advancing quickly, as shown by developments in the labs of Hod Lipson, associate professor of mechanical and aerospace engineering. Lipson has created a robot that can replicate itself, a robot that can adapt to injury, and a rapid prototyping system that may one day give machines the tools to self-assemble. Lipson has also created an AI that can derive natural laws of motion from physical observations. He is now working on getting the robot scientist, named Eureqa, to automatically plan and execute biological experiments.

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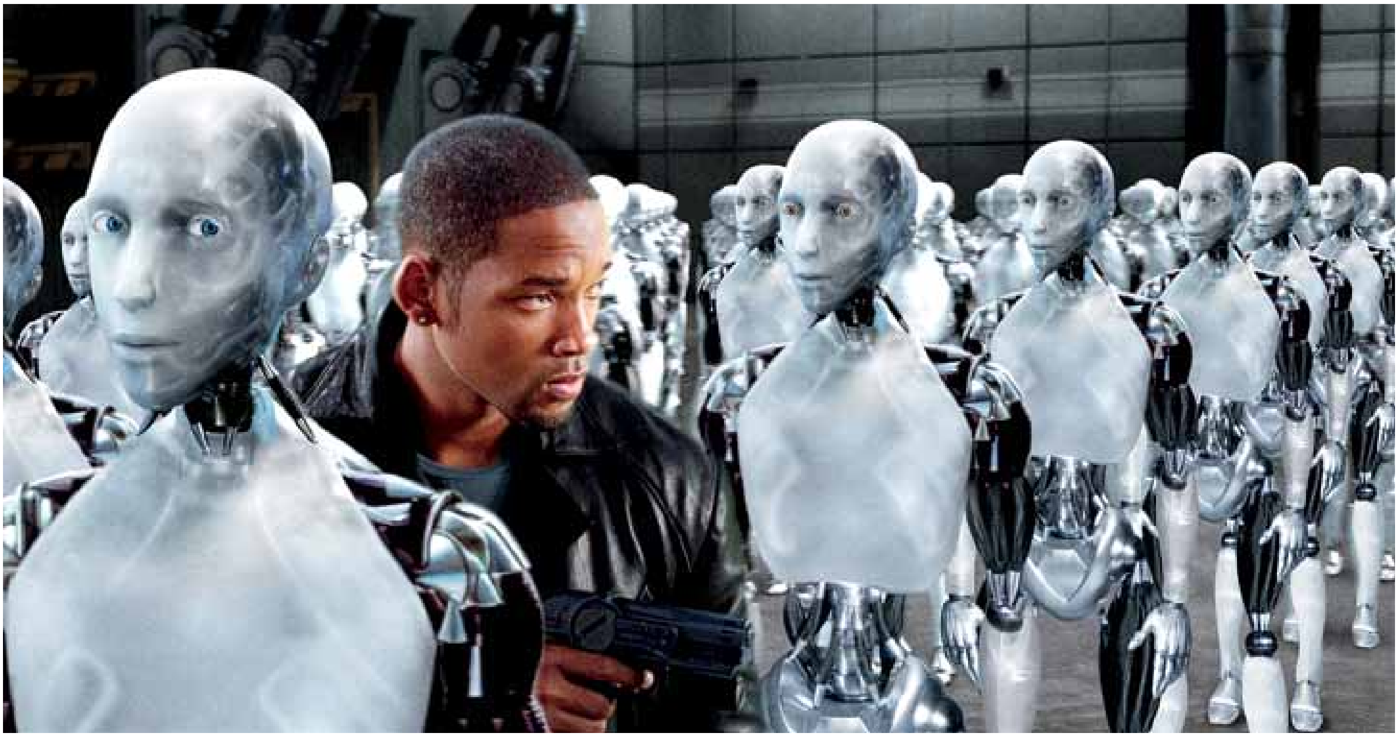

Detective Del "Gary" Spooner (Will Smith) searches for Sonny, an experimental NS-5 he believes has killed its creator in *I, Robot*.

Bad boys

The threat of AI being tapped for criminal activity is more immediate, and likely, than a machine-induced apocalypse, according to the AAAI. A subgroup is charged with assessing such short-term challenges, or "rough edges."

"We explored the possibility that one day smart AI systems might be used in a 'criminal manner'—where ill-intentioned people design new kinds of very smart computer viruses that examine people's email, Facebook accounts, iPhones, and learn enough about people that they can do a variety of malevolent things, such as steal their identity or do other things that are much more concerning than today's computer viruses," Horvitz says. "We have no evidence that this kind of thing has happened yet, but see this as a real potential threat of the future."

The group is also considering the ethics of AI, raising questions that range from the implications of robots able to display emotion to military applications used to make recommendations based on "friend or foe" observations.

The future's so bright …

As the AAAI continues to gauge the impact of AI on society, research continues and the science progresses. Selman sees computers that can converse with people within 20 years. Joseph Halpern, a fellow Cornell computer science professor says it's what cannot be predicted that is most exciting.

"I'm sure we will see more of the same, only better, that is, better search, better machine learning, better robots, with the AI seamlessly integrated so that you won't even realize it's there," he says. "But my guess is that, in addition, something will come out of the blue that I couldn't possibly predict."

Clearly, AI has the potential to transform society, enhancing everyone's quality of life. "I foresee that robotic systems will enable people who are elderly or ill to stay at home and be more independent with the help of nursing robots that will take care of them and watch out for their health," Horvitz says. "AI systems will help teachers to educate students. AI systems will have tremendous benefits in medical diagnosis and treatment. We are already seeing robotic systems assisting surgeons to perform complex surgeries. AI systems will one day serve as automated scientists, working as collaborators on gleaning of insights from large data sets."

For Selman, the coming years will be an important and dramatic phase for AI. "It's an exciting time, that's for sure," Selman says.

people

Defense man

The Department of Defense has announced the appointment of Fred Schneider, the Samuel B. Eckert Professor of Computer Science, to its Defense Science Board.

Established in 1956 as a standing committee to advise top Pentagon leadership on "the needs and opportunities presented by new scientific knowledge for radically new weapons systems," the board has evolved to develop and strengthen the department's research and development strategies for the 21st century through its reports.

Schneider, an expert on computer security, is chief scientist of the National Science Foundation-funded TRUST Science and Technology Center, a collaboration involving researchers at five universities, including Cornell. He serves on the Department of Commerce Information Security and Privacy Advisory Board, as a member of the Computing Research Association's board of directors, and as a council member of the Computing Community Consortium. He co-chairs Microsoft's external advisory board on trustworthy computing.

"Secretary of Defense Gates believes the DSB needs to be a professional board representing the best scientific and expert advice available to the Department of Defense," said Ashton B. Carter, undersecretary of defense for acquisition, technology and logistics. "We are grateful to these superb individuals for their willingness to serve."

Most of the 39 new appointees are from industry and government. Schneider is one of only seven with a university affiliation.

–Cornell Chronicle

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Fred Schneider

Climate modelers

A husband and wife team of Cornell climate researchers is helping one of 20 groups around the world developing new models to submit for review under the auspices of the Intergovernmental Panel on Climate Change (IPCC).

Natalie Mahowald, associate professor of earth and atmospheric sciences, and Peter Hess, associate professor of biological and environmental engineering, are members of a large group of scientists nationwide working on the Community Climate System Model (CCSM), managed by the National Center for Atmospheric Research, with funding from the National Science Foundation and the U.S. Department of Energy. Mahowald is co-chair of the CCSM Biogeochemistry working group; Hess is co-chair of the climate/chemistry working group.

Eventually, all the models and their output will be submitted to a vast online archive hosted by the U.S. Department of Energy for all scientists to review and use, and the results of that work will become part of the next IPCC report, due around 2013.

The basic predictions of climate change are based on very simple models, but we need to develop and refine these more elaborate models to make the predictions more precise, Hess says.

"This is the first or second generation for these models. In five or 10 years we'll have models we can trust much more," Mahowald concludes. "That will show us how much we have to cut emissions, but in the meantime, we have to be coming up with new energy technologies and cutting as much as possible."

–Bill Steele

Natalie Mahowald

Intel fellows

Cornell graduate students Shuang Zhao and Mark Cianchetti have each received a Ph.D. Fellowship Award from Intel Corp. The award, which recognizes the recipients' potential as future technology leaders, includes tuition for one year, a stipend, an opportunity to connect with an Intel mentor, and a travel grant.

Zhao, a second-year Ph.D. student in the Department of Computer Science, works with associate professor of computer science Kavita Bala on synthesizing photo-realistic images. He interned for two years with the Internet Graphics Group of Microsoft Research Asia, where he worked on appearance modeling and realistic rendering.

Cianchetti is a fourth-year Ph.D. student in Cornell's Computer Systems Laboratory. Working with David Albonesi, associate professor of electrical and computer engineering, Cianchetti examines how integrated photonics can be used in future generation multi-core processors. Cianchetti hopes to address the development of cost-effective technologies in developing countries and for those underserved by modern technology.

The highly competitive fellowship program requires students first to be selected by their universities to apply. This year, a total of 26 fellowships were awarded to outstanding Ph.D. students across the country.

Student inventors

Two student-developed inventions won finalist status in the 2009 Collegiate Inventors Competition in Chicago, Oct. 18–20.

Leon Bellan, a former graduate student and postdoctoral associate in applied and engineering physics, conceived the idea for using a cotton candy machine to make artificial tissues while he was a graduate student in Professor Harold Craighead's lab and after hearing Weill Cornell Medical College surgeon Jason Spector speak at a symposium about the challenges of producing materials that mimic capillaries in living tissue.

Bellan made the artificial tissues by spinning a wad of cotton candy, covering it with a liquid polymer, letting the polymer solidify, then soaking it in water to dissolve the sugar. What was left was a material containing an interconnected network of tiny, capillary-size tubes.

Mark Levatich, a senior majoring in biological engineering and biology with a concentration in neurobiology, was recognized for his skull base sealer. Advised by David Lipson, senior lecturer in biomedical engineering, he invented the device after watching neurosurgeons at Weill Cornell Medical College perform endoscopic procedures through

David Erickson

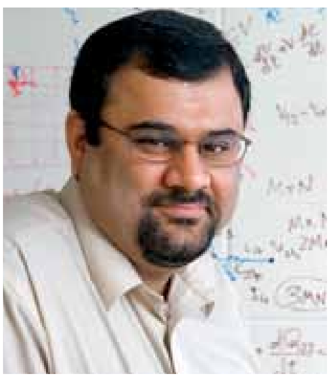
holes drilled in the base of the skull.

Doctors used forceps to place pieces of fat grafted from the patient and surgical foam into the hole in the skull. With luck, soft tissue grew over this foam and formed a seal. But often, the seal was imperfect, and cerebrospinal fluid leaked out, requiring later surgical repair.

Levatich's skull base sealer works with a trigger action that pushes pre-mixed bone cement into the hole. The cement is inserted directly into the skull to ensure a solid seal. Bone cement is pushed by a threaded screw-like plunger.

His prototype consists of a single tube packed to deploy a protective pad of foam against the brain, followed by a plastic self-sealing sheet as a mold. Bone cement is then injected between the pad and the mold. The mold holds the bone cement in place while it cures and also acts as a waterproof barrier to insulate the cement so that while it cures, cooling water can be circulated through the nasal area, thus protecting the brain and nasal tissues from heat produced during the curing process.

–Anne Ju



Ehsan Afshari

Salman Avestimehr

Early achievers

Six Cornell Engineering faculty members have each received a Faculty Early Career Development Award from the National Science Foundation for demonstrating "excellent research and teaching early in their careers."

Ehsan Afshari, assistant professor of electrical and computer engineering, will use his five-year, $400,000 award for his ongoing research into circuits that can generate signals at terahertz frequencies and process information at very high speeds with low power consumption and using standard silicon processes.

The research, Afshari says, hopefully will lead to new methods of circuit design in which devices can operate close to or even beyond their maximum power levels. He will attempt to demonstrate novel high-frequency signal generation and processing systems, with orders of magnitude better performance in terms of maximum output power, operating frequency, power efficiency, and bandwidth, compared with existing models.

Chris Schaffer

Salman Avestimehr, assistant professor of electrical and computer engineering, will use his five-year, $441,876 grant to develop models for advancing wireless-network technologies.

The project will involve a new approach to theory behind information flow over large-scale communication networks. Avestimehr plans to develop simple channel models that capture the main features of the wireless medium and utilize them to approximate more complex models.

Peter Diamessis, assistant professor of civil and environmental engineering, will use his five-year, $646,700 award to continue his work on nonlinear internal waves (NLIWs), which are high-amplitude wave motions, invisible to the eye, in the interior of coastal oceans and lakes. He will use numerical modeling techniques to study the propagation of NLIWs up gently sloping seafloors and will work closely with physical oceanographers at the University of Washington. Understanding the physics of turbulent dissipation of NLIWs is a crucial missing link in understanding the fate of energy input by the winds and tides into the oceans and lakes, he says.

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Peter Diamessis

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Jeffrey Varner

David Erickson, assistant professor of mechanical and aerospace engineering, will use his five-year $400,000 grant to develop a research area called optofluidics, which combines the study of microfluidics and optics. The work will involve a new class of microfluidic devices to transport, switch, and modify light. He also plans to create a "FluidicsWiki" organized around the theme of micro- and nanofluidics to allow user-edited content that can help evolve the field.

Chris Schaffer, assistant professor of biomedical engineering, received $400,000 over five years to develop tools to introduce genes into specifically targeted brain cells, opening the door to cell-targeted genetic manipulation. The work will involve in vivo experiments that use tightly focused laser pulses to create small, transient holes in the cell membrane, allowing DNA to enter the cell. This work could provide a unique means to study the functional connectivity of cortical neuronal circuits.

Jeffrey Varner, assistant professor of chemical and biomolecular engineering, has received a five-year, $400,000 grant to develop mathematical modeling tools that will help us better understand the behavior of large protein-protein

people

Paul Kintner

Harold Craighead

Kevin Tang

Jonathan Butcher

and protein-DNA interaction networks. These tools, which will be applied to the problem of decoding the behavior of stem cells, will advance the state-of-the-art of mechanistic modeling of molecular networks and possibly open the door to new treatments for an array of human diseases, including cancer.

–Anne Ju

Jefferson fellow

Paul Kintner, professor of electrical and computer engineering, will advise the U.S. government on global positioning systems, space weather, navigation satellite systems, and other defense-related topics this year as a U.S. Department of State Jefferson Science Fellow.

Kintner, who heads Cornell's Global Positioning System Laboratory, is spending this academic year in Washington, D.C., working in the State Department's Office of Space and Advanced Technology and Office of International Communications and Information Policy. He is one of 10 Jefferson fellows selected from more than 50 applicants.

In particular, he will advise on the technical impacts of the European Galileo and Chinese Global Navigation Satellite Systems on GPS. He also will advise the department on the potential dangers of purposeful interference of GPS and navigation satellite systems signals.

Kintner also will work to better coordinate space weather predictions with other countries and integrate space weather awareness into the work of civilian and Department of Defense satellite operators.

–Anne Ju

Nano excellence

The University of Pennsylvania's Nano/BioInterface Center has presented its annual Award for Research Excellence in Nanotechnology to Harold Craighead, Cornell's C.W. Lake Professor of Engineering.

A professor of applied and engineering physics since 1989, Craighead has served as director of Cornell's National Nanofabrication Facility (now the Cornell NanoScale Science and Technology Facility), director of the School of Applied and Engineering Physics, and founding director of the Nanobiotechnology Center.

Craighead has been a pioneer in nanofabrication methods and the application of engineered nanosystems for research and device applications. His most recent research includes the use of nanofabricated devices for biological applications. His research continues to involve the study and development of new methods for nanostructure formation, integrated fluidic/optical devices, nanoelectromechanical systems and single-molecule analysis.

IBMers

José Martínez and Kevin Tang, both Cornell electrical and computer engineering faculty members, have each received a 2009 IBM Faculty Award.

The Faculty Award Program is a worldwide competition intended to foster collaboration between researchers at leading universities and those in IBM research, development, and service organizations. It also promotes courseware and curriculum innovation to stimulate growth in disciplines and geographies that are strategic to IBM, according to the company.

Martínez, associate professor of electrical and computer engineering, leads the Microprocessor, Multicore, and

PROVIDED

José Martínez

Multiprocessor Research Group, part of Cornell's Computer Systems Laboratory.

Tang, assistant professor of electrical and computer engineering, leads the Networks Group.

–Anne Ju

Young investigator

The Biomedical Engineering Society honored Jonathan Butcher, assistant professor of biomedical engineering, with the Rita Schaffer Memorial Young Investigator Award in October.

In recognition of the award, Butcher was invited to give the Rita Schaffer Memorial Lecture Oct. 10 during the society's annual meeting in Pittsburgh.

Butcher talked about engineering breakthroughs that could complement genetic programs for combating cardiovascular disease through the study of embryonic tissues.

Butcher's research at Cornell focuses on mechanisms of embryonic heart and valve development, with the goal of implementing an embryonic "blueprint" to control heart and valve tissue assembly and remodeling.

–Anne Ju

hometown hero

Engineering Evangelist: Sheila Hemami

Sheila Hemami was only two years old when she tackled her first engineering problem. After watching several televised NASA launches, she decided to construct her own rocket. Although Hemami's model was made of couch pillows and chairs, it was clear that she had a passion for engineering. Four decades later, Hemami, a professor of electrical and computer engineering at Cornell University, is a self-proclaimed engineering evangelist. "The difference between an engineer and a non-engineer is this: When Kennedy said 'Let's go to the moon,' the non-engineer says 'Oh my God, that's impossible,'" she says. "The engineer goes 'Oh my God, that's impossible' then thinks and says, 'Okay the first step to it would be this.'"

Hemami's projects have evolved from pretend rockets to high-fidelity visual communication systems, a field she chose for its potential impacts on daily life, especially in the context of the cellular revolution.

"As long as you are within reach of a cell tower, anywhere in the world, you can call anyone," she says. "Hearing someone's voice is a very valuable, personal thing. But the deaf have been left out of this revolution."

She and Ph.D. student Frank Ciaramello want to make cell phone communication available, and convenient, for American Sign Language speakers.

This requires a cell phone with the camera and the screen on the same side—a feature that has recently hit the market. However, Hemami says that when they proposed the idea, "That type of phone didn't even exist."

The next challenge was power. Hemami explains that while video conferencing is no problem to do between two computers, cell phones have a limited power supply.

"You don't want a two-minute phone conversation and then have to recharge," she says.

The issue also comes down to bandwidth. "How do we fit the amount of water in a fire hose through a straw?" she asks.

Hemami's team and their co-investigators at the University of Washington have tackled this problem by focusing the phone's resources on the things that matter the most. While one might assume that would be the signer's hands, Hemami explains that the signer's face is much more important, imparting more information to the listener than the hands.

"It makes sense," Hemami says. "Deaf people go to parties; they have drinks in their hands—they still need to be able to talk."

Hemami's technology ensures that the speaker's hands and face are in sharp detail while background activity may be fuzzier.

Hemami is just as passionate about helping students learn.

"Teaching is simultaneously the most difficult and rewarding part of my job," she says. "My goal is not only for students to learn technical content, but for them to be able to explain the highly technical things in English—to be able to explain it to their grandmas."

Ciaramello says Hemami's enthusiasm was a primary reason he decided on her as a graduate adviser. Additionally, "She's good about catering to different students' needs," he says.

For Hemami, it's the success of her students that makes her most proud. "It's wonderful to sit in the audience at a major international conference and to watch them deliver a polished technical talk which is well received by the audience."

Another source of pride is her efforts to engage women in science and engineering. In 2005, Hemami and Marjolein van der Meulen, Cornell professor of mechanical and aerospace engineering, secured a $3.3 million National Science Foundation Advance grant to recruit, retain, and promote women in these fields. Hemami lists this as one of the biggest challenges of her career.

Richard Allmendinger, associate dean for diversity, faculty recruiting, and mentoring in Cornell's College of Engineering, notes the importance of the achievement. "This is a project which touches the highest levels of the university," he says. "It actually molds the future policies. Sheila and Marjolein are to be commended on bringing this grant to Cornell."

Still, the percentage of women in engineering is much lower than that of men. According to 2001 Current Population Survey data, one out of 10 employed engineers was a woman, and only 11 percent of electrical engineers were women.

Hemami suspects this disparity may be due the fact that women want to see a social impact from their work, and that the impacts from engineering may not be as immediately apparent as that from other fields.

"But engineers are bad at marketing that," she says. She notes that everyday life activities such as viewing digital photos or listening to mp3s were made possible by electrical engineers, as were experiences as profound as hearing a baby's heartbeat in utero.

However, Hemami doesn't necessarily have an agenda focused on women. "The U.S. really needs more engineers, and recruiting women is an obvious point of growth," she says.

Plus, the more problem-solvers on a team, the more different perspectives there are on the problem, making for a better design process, Hemami explains. Having more women there simply means more diversity.

"It's a win for everybody," says Hemami. "I really think the world would be a better place if everyone was an engineer."

—*By Lauren Cahoon*

Joint Effort

A mechanical engineer who wants to help people, Yingxin Gao works in biomechanics. Gao's research revolves around the shoulder joint, or glenoid. About 23,000 Americans receive total shoulder joint replacement surgery each year, compared with more than 700,000 who receive knee or hip replacements. Shoulder research is where the knee was 30 years ago, says Gao.

From an engineer's perspective, a shoulder is more complicated than a knee because it can move in more ways, explains Gao.

In a project with the Hospital for Special Surgery in New York City, Gao is developing a model to show how stress is distributed in shoulder implants and the surrounding bone through a range of motions. "The purpose of this project is to determine how the geometry, anatomy, and design factors affect glenoid loosening in total shoulder replacement," she says.

That information will help manufacturers design better shoulder implants and also provide insights for surgeons. "The doctors in the hospital are very excited about this project," says Gao. "They know there are things during surgery they have to be careful about, but they don't know why. They want us to find out."

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