Bioengineers like Antje Baeumner are developing new tools to quickly identify deadly pathogens.
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Taking the Helm
Fuchs named dean of the College of Engineering

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It is a great honor to lead one of the world’s finest colleges of engineering.

r. Kent Fuchs, head of the School of Electrical and Computer Engineering and the Michael J. and Catherine R. Birck Distinguished Professor at Purdue University, has been named the Joseph Silbert Dean of the College of Engineering at Cornell University.

Fuchs, who has been a student of divinity as well as electrical engineering, succeeds interim dean Harold Craighead, the Charles W. Lake Jr. Professor of Engineering and professor of applied and engineering physics. Craighead assumed the interim post in July 2001, succeeding Dean John Hopcroft.

Making the announcement, Cornell Provost Biddy Martin said that she and Cornell President Hunter Rawlings were “delighted that Kent Fuchs has agreed to lead our College of Engineering.” She continued, “Professor Fuchs has considerable administrative experience, and he brings foresight, thoughtfulness and an impressive ability to communicate with a range of audiences to this important position. He will have the support of outstanding faculty, staff and students in the college and will play a crucial role in the development of the university’s cross-college scientific initiatives.”

Said Rawlings, “Cornell’s College of Engineering has been a pillar of strength for this university since its inception. The appointment of Kent Fuchs to lead the college’s world-class faculty will ensure the college’s continuing leadership in research and instruction well into the 21st century.” Fuchs, who is a specialist in dependable computing, testing, and failure diagnosis, will serve a five-year, renewable term beginning July 1, 2002. Commenting on his appointment, he said: “It is a great honor to lead one of the world’s finest colleges of engineering. I look forward to serving the Cornell faculty, students, and alumni with dedication, energy, and enthusiasm.”

Prior to being named head of Purdue’s electrical and computer engineering school in 1996, Fuchs was a professor at the University of Illinois in the Coordinated Science Laboratory and the Department of Electrical and Computer Engineering. He joined the University of Illinois faculty in 1985 as an assistant professor. He was named a full professor in 1993.

The new Cornell engineering dean, who is 47, obtained his bachelor of science engineering degree at Duke University in 1977, his master of science degree at the University of Illinois in 1982, his master of divinity degree at Trinity Evangelical Divinity School in 1984, and his doctorate in electrical engineering at the University of Illinois in 1985.

Fuchs’s current research interests include dependable computing, testing, and failure diagnosis. He leads two research groups at Purdue: computer-aided design tools for testing and failure analysis in integrated circuits; and dependable mobile computing, active networks, and high-performance computing.

His research awards include, from the University of Illinois, the Senior Xerox Faculty Award for Excellence in Research, selection as a University Scholar, appointment as fellow in the Center for Advanced Studies and the Xerox Faculty Award for Excellence in Research. He also has received the Best Paper Award from the Institute of Electrical and Electronic Engineers (IEEE) and the Association for Computing Machinery (ACM) Design Automation Conference; and the Best Paper Award from the IEEE VLSI (very large scale integration) Test Symposium. He is a fellow of both the IEEE and the ACM.

—David Brand, Cornell News Service

SITE FOR LIFE SCIENCES

In January, the Cornell University Board of Trustees approved a recommendation to place the proposed $110 million Life Sciences Technology facility on the west end of Alumni Field, on the university’s central campus. The approval sets in
motion preparation of site criteria and the project budget, which will be presented to the board, perhaps in early summer.

Design work by Cornell alumnus Richard Meier ’56, the eminent architect who designed the Getty Museum in Los Angeles, will begin shortly. The scientific engineers for the project are CPR Lab Planners of Philadelphia and Bard Roe Athenus, Boston.

The building, which according to Peter Karp, university architect, is the Cornell administration’s top building priority on campus, will be a focal point of the Cornell Genomics Initiative (CGI), the campuswide, faculty-driven research, development and educational program. The new building potentially will house research programs in biomedical and biological engineering, computational biology, biophysics, structural genomics, plant functional genomics, and social, legal, ethical and business aspects of genomics.

“Connectivity, both physically and intellectually, is essential,” said Stephen Kresovich, who is the director of the university’s Institute for Biotechnology and Life Science Technologies and chairs the building’s planning committee.

“We want to build a facility that will act as a magnet to attract the best faculty, students, and visitors to join us in the opportunity of a generation,” said Kresovich. He added, “The facility has to be top-notch for science and education, but it also has to be aesthetically attractive.”

Among the scientific magnets will be the Biomedical Engineering Program. Faculty in the new program will be drawn from departments across the university. In addition, the creation of the Department of Biological Statistics and Computational Biology is being proposed in the College of Agriculture and Life Sciences and also is planned to be located in the building. Also, said Kresovich, “people from biophysics will be in and out of the building, as will people in structural genomics, mouse genetics, and plant functional genomics.”

The question is, why bring all these diverse researchers together under one roof?

“Because we recognize a unity to biology and the need to build on Cornell’s excellence in computational, engineering, and physical sciences,” said Kresovich. “We want to move aggressively into the 21st century through integrating basic disciplines to generate fundamental insights, solve problems, and train the next generation of life scientists.

Kraig Adler, Cornell vice provost for life sciences, believes that the way biology is taught is going to change and that the new building will foster and lead this change.

“The building will focus our attention more and more on interdisciplinary areas where many of the most important discoveries will be made,” he said. “If you have biologists working with engineers and physicists, it makes it more likely that courses will come out of these interactions between colleagues in different departments. And we will be exposing our students to their excitement.”

—David Brand,
Cornell News Service

NO EASY RIDE
THIS YEAR

Cornell engineering students streamed into the Memorial Room in Willard Straight Hall on Feb. 6 to find jobs in the toughest employment market in years. Mike Ng, a junior engineering student (operations research ’03), spoke for many of the 1,500 students at the fair when he said, “I don’t think it’s going to be an easy ride, getting a job.”

The occasion was the first student-organized engineering spring career fair, hosted by the Engineering Student Council. The aim was to get a jump on the market for co-ops and internships, which most Cornell students don’t get a chance to apply for until the Cornell Career Services university-wide career fair in the fall. This year, getting a jump on a job opening is more important than ever. According to the Associated Press, a survey by the National Association of Colleges and Employers shows that employers expect to hire about 20 percent fewer graduates this year than last.

“Recruiters are in the driver’s seat for the first time in eight years,” confirms Mark Savage, director of Engineering Cooperative Education and Career Services. His office started spring-semester recruiting at the beginning of February and had only 10 recruiters show up in the first week. “We should typically have 12 or 15 recruiters scheduled each day,” said Savage.

He added: “There are jobs out there, and that’s what we have to keep reminding students. But they need to really do their homework, do research, and spend a lot of time on the process of getting a co-op or internship.”

From the comments of recruiters from many of the 29 companies present, the students had, indeed, done their homework. “I’ve absolutely seen good candidates here, and we’ve got the best,” said Chandrasekaran Srin from Texas Instruments. Said Chad Hansen with Praxair/Global Engineering, “It’s tough,
Duffield Construction Update

This photograph of the construction site, taken in February, shows the structural foundation that will support Duffield Hall. As a result of the natural slope of the bedrock at the site and the design of the foundation, some supports rest directly on the bedrock; others are set on caissons reaching down to the bedrock layer.

The square columns at left are sitting on concrete caissons. The caissons were created by drilling holes in the earth to a depth of about 14 feet, where the natural bedrock layer was encountered. Steel reinforcing cages were installed in the open holes, which were then filled with concrete to a predetermined elevation. Forms measuring 20 inches by 20 inches by about 18 feet were set on the concrete caissons, and following installation of reinforcing steel, were filled with concrete to create the square columns. After removal of the forms, the columns will support the next floor level above. The perimeter concrete foundation walls and interior columns at center and at right were constructed directly off the exposed bedrock on spread concrete footings. In some areas, up to eight inches of the bedrock was removed with dynamite to achieve the required elevation. The nanotechnology teaching and research facility is scheduled for completion in 2004.

but we’re definitely hiring co-ops and interns. Next week we’ll be interviewing 13 of the students I’ve seen here today.”

Graduate student Regina Clewlow, president of the Engineering Student Council, explained that co-ops and internships are absolutely vital for young engineers because “to get a full-time job, you have to offer a company previous experience, and this is the only way to get it.”

In one area, civil engineering, the jobs seemed to be going begging. Colleen Veltri with Vollmer Associates said that “the hardest part of hiring this year is in filling co-op positions.” She has two co-op positions available and is having a hard time filling both, she said.

Savage confirmed that both civil engineers and chemical engineers seem currently most in demand. The reason, he said, is probably that the economic downturn began with and continues to affect high technology industries, whereas the basic industries are holding their own.

For students aiming at high-tech, the competition is likely to remain tough through this year. As student Ng noted, “There are lots of smart people out there looking for the same jobs.”

—David Brand, Cornell News Service

Engineer of the Year

Kevin Kornegay, associate professor of electrical and computer engineering at Cornell University, was selected Black Engineer of the Year for 2002 in the category of Promotion of Higher Education. The award is sponsored by Career Communications Group, publisher of U.S. Black Engineer and Information Technology; the Council of Engineering Deans of Historically Black Colleges and Universities; Lockheed Martin; and DaimlerChrysler.

Kornegay received the award at the 16th annual Black Engineer of the Year Conference, in Baltimore, Feb. 14-16. The award is presented in more than a dozen categories, including professional achievement, technical contribution, and overall leadership.

Announcing the award to Kornegay, Tyrone D. Taborn, publisher and chief executive of Career Communications Group, spoke of the difficulty of selecting this year’s winners. “Over 40 percent of this year’s winners are directors, managers, or vice presidents of major organizations. Never before in the history of these awards was the competition so fierce,” he said.

Kornegay, who joined the Cornell faculty in 1998, was recognized for his research in developing the first CMOS (for complementary metal-oxide semiconductor) circuits in silicon carbide. This semiconductor remains functional at extreme temperatures. One of Kornegay’s research interests is developing integrated electronics for harsh environments.

He also was cited for his work in creating a Cornell center for mixed analog/digital electronics based on high-speed silicon-germanium alloys (SiGe), important semiconductor materials for many applications, including high-frequency devices. Kornegay is director of the Advanced Integrated Microsystems Research Group at Cornell, which performs basic research and develops innovative applications in integrated microsystems that have sensing, computing, and communications capabilities. He also is director of the Cornell Broadband Communications Research Center.
ASSESSING THE DAMAGE

Despite the huge loss of life and the massive damage caused by the destruction of the twin towers of the World Trade Center on Sept. 11, the utility systems beneath the buildings “held up remarkably well,” a Cornell University engineer with wide experience in investigating disasters reports.

Indeed, says Thomas O’Rourke, damage to the gas, steam, electrical, potable water, and waste water systems was largely confined to the immediate vicinity of ground zero where the towers collapsed.

“In many other cities, the way the electrical systems are configured would have resulted in a cascade effect as one substation shut down the next. But in New York City there is a system of local networks allowing one network to operate independently of another,” he says. “The rapid restoration of electric power after the event owes much to the commitment and skill of utility crews.”

These and other findings from an ongoing study of the infrastructure below the World Trade Center were reported by O’Rourke at a National Science Foundation (NSF) workshop in New York University on Dec. 12 and 13.

The workshop, “Learning from Urban Disasters,” was organized for the NSF by the Institute for Civil Infrastructure Systems (ICIS) at NYU, of which Cornell is a member and O’Rourke is co-chair of the executive committee. O’Rourke and Arthur Lembo, a senior research associate at Cornell, have been studying the infrastructure effects of the Sept. 11 destruction for ICIS and have applied for a NSF grant to further their research into understanding “how critical utility systems interact in extreme events,” in O’Rourke’s words.

In interviews with utility managers, the two Cornell researchers have started to collect information on the complex network of lines and pipes that intersected under the Trade Center. “We are trying to apply the data from the World Trade Center destruction on a more global, or generic basis,” says O’Rourke. They plan to compare utility response during September 11 with the distributed damage and behavior of utility systems after natural disasters, such as earthquakes.

Says O’Rourke, “The lessons from extreme events, like the World Trade Center destruction, can help create more resilient networks of resources and services.”

—David Brand, Cornell News Service
Sensing
Antje Baeumner is developing field-portable biosensors to detect pathogens such as anthrax in a fraction of the time it takes now.
The idea behind biosensors is that you can take them wherever you want to analyze something. It is portable, field usable. If you’re using it for clinical diagnostics, a patient might use it at home.

...
the water you treat, it still ends up in the water you drink.”

A startlingly small number of oocysts of *C. parvum* is necessary to infect a human—some believe just one is sufficient—and while the effect on healthy adults is insignificant, the results can be fatal for individuals whose immune systems are generally not as strong—infants, for instance, and the elderly—because no treatment for the illness exists. This is what happened in Milwaukee, when an estimated 1.6 million people were exposed. Some 400,000 of those were made ill, and over 100 lost their lives.

“Only the largest treatment plants analyze *C. parvum* because it’s expensive to do so,” says Baeumner. “This is why we chose it as our first model analyte. We wanted to develop a biosensor, and we picked *C. parvum* because it’s such an important and interesting analyte to try to detect.”

Current testing methods for *C. parvum*, like those used for anthrax, require sending samples away to labs and can take seven days. “When you’re getting results back seven days later,” says Baeumner, “it’s kind of late.” The biosensor that Baeumner has developed would not only give nearly instant results; it would do so at a charge of just a few dollars per test. The sorts of lab tests currently employed, estimates Baeumner, run in the ballpark of $350 for a single sample. She likens the mechanism of her *C. parvum* biosensor to a pregnancy test. It actually looks like a pregnancy test strip, and, similarly, its results come out as either clear or red—clear for no organism, red for contamination. That’s really what you want a biosensor to be like.”

A similar project designed to identify the Dengue virus is in the works. The Dengue virus causes Dengue Fever, which occurs primarily in the tropics and can be deadly. The vector for the virus is *Aedes aegypti*, a day-biting mosquito with a taste for humans. In recent times, the virus, native to Asia, has been on the move, showing up in Texas three times in the last few decades and in Hawaii in the fall of 2001. As with *C. parvum*, detection is difficult because of its expense, a particularly true fact in the places hardest hit by Dengue: third world countries.

“If this were available,” says Baeumner, holding up the prototype for the...
Dengue test in her office, “it would be very simple. To make it, including everything you need to run it, will maybe cost a few dollars. That is something very attractive for third world countries. You could do the test and analyze it right there and you could know.”

One of Baeumner’s graduate students, Sylvia Kwakye, who comes from Ghana, West Africa, says working on biosensors was appealing to her because of the opportunity of helping to develop technology she might then take home, including the detection of environmental and food pathogens. “As a result of my research experience,” she says, “I hope to work when I’m done as a research engineer designing miniaturized analytical systems that can be used anywhere in the world.”

The types of devices that Baeumner and her students develop are reliant on a number of different technologies. We might think of them—crudely, to be sure—as having a front-end, which does the biochemistry, and a back-end, which does the accounting.

Biologically, the device must have some way of recognizing the organism—a fingerprint, so to speak. This is obtained through a nucleic acid amplification technique, which, says Baeumner, “makes out of one RNA molecule a million, like a molecular copy machine.” She uses a particular technique called nucleic acid sequence-based amplification (NASBA). The point of this is not to amplify the entire strand of genetic material, but to merely amplify the part of it that is distinct to that organism, the part that cannot be mistaken for even a close relative.

Bacillus anthracis, for instance, has a staggering number of non-pathogenic relatives, one of which is Bacillus subtilis, a ubiquitous substance in the soil that, like B. anthracis, also forms spores. Unlike B. anthracis, though, it is harmless. “Some very high percentage of the genome of the two species is the same,” she says. “So it is really difficult to decide if you have this one or that one. You need to detect something that is very specific to the organism, and this is very difficult.”

With the biological identifier in place, the test is then run by combining a suspect sample—for the sake of argument, let’s say a mysterious powdery substance—with a membrane that has been treated with the DNA of Bacillus anthracis (through the use of NASBA). If it is indeed anthrax in the sample, the
DNA on the membrane will bond with the *B. anthracis* RNA in the sample.

The next step is to then send the RNA concentration through a contraption called an interdigitated ultramicroelectrode array, which determines the presence and number of cells in the sample. And, thirty minutes to an hour later—depending on what your poison is—voilà: identification.

These processes, of course, are extraordinarily complex, and becoming more complex all the time, as microchips are brought in to expedite the process.

“Whatever sequences you want,” Baeumner explains of the generic device, “you can just plug them in. Only the part that bears the biological information will change; the second part is always the same.”

A side, though related, project Baeumner has been working on lately is a biosensor for *Vibrio parahaemolyticus*, a bacterium that causes foodborne illness and is often found in seawater. Like other pathogens, a number of days is currently required to identify *V. parahaemolyticus*—far too much time when you are talking about whether or not to close a fishing area that might be infected.

The device that Baeumner is creating for this project is quite different from her other biosensor approaches. It can be used as a toxicity biosensor, in which a mammalian cell is exposed to the sample. If something in the sample is harmful, the cell will respond. The identity of the harmful agent can be obtained by coupling the toxicity-biosensor element to an immunomagnetic capture module, in which highly specific antibodies bind to the analyte of interest.

Though the project is in the very early stages, Baeumner thinks restaurants and food processing plants might be able to use this sort of technology in the future. “She’s got her foot in both worlds,” says her colleague on this project, Kathryn Boor, associate professor in the Department of Food Science. “Dr. Baeumner brings an extraordinary technical sophistication to this task. Others can have biological ideas, but without someone like her to create the biosensor, you’re nowhere.”

Jerry Gabriel teaches writing in Cornell University’s Writing Workshop, in addition to writing about science for a number of publications.
Immunofluorescence image of *Listeria monocytogenes* (green/yellow) infecting animal cells (animal cell actin is shown in red). *Listeria monocytogenes* forms actin tails when infecting cells to facilitate its movements inside cells (Kelly Horton and Martin Wiedmann, Cornell University).

**Fresh Tracks:**

**Getting the Jump on Bad Bugs**
Bacteria can be nasty, insidious little creatures. They have been around for millions of years and in their more virulent forms have learned how to make life miserable for humankind. Their pathogenic power was dramatically demonstrated last year when five people died after inhaling airborne anthrax (*Bacillus anthracis*) spores sent through the mail. But while exposure to anthrax is extremely rare, ingesting food-borne virulent bacteria such as *Salmonella* and *Listeria monocytogenes* is all too common, causing severe sickness or death in scores of people each year.

Which is why quickly pinpointing the sources of diseases caused by such microbes is critical to controlling outbreaks and protecting public health. To speed investigative process, engineering and computer science students at Cornell, working with food science specialists at the university, have created an innovative database that tracks the spread of virulent bacteria using the Web.

The brainchild of Martin Wiedmann, assistant professor of food science, PathogenTracker stores the individual genetic fingerprints of bacteria, enabling scientists to trace and compare isolates, or strains, in a manner of minutes instead of hours or days. It is among the first projects undertaken by the Computational Biology Service Unit (CBSU) of the Cornell Theory Center (CTC), and is supported by research grants from Dairy Management Inc. (through Kathryn Boor, associate professor of food science at Cornell) and the U.S. Department of Agriculture.

By enabling real-time, Internet-based comparisons of strain characteristics and images of DNA fingerprints, it not only helps compile strain subtype data from a number of separate laboratories for analyzing outbreaks and epidemics of infectious diseases but also serves as a database for evaluating the biodiversity of bacteria and how they interact with the environment.

“We DNA fingerprint the bacteria to detect disease outbreaks and prevent further cases,” Wiedmann explains. “Our interest is in food-borne diseases, but the anthrax problem illustrates the same thing; you can get disease cases all over the country that are linked to one source, but how do you determine if those cases are related?”

Like detectives tracking down a serial killer who leaves clues at the scenes of the crimes, Wiedmann says, scientists and health officials can fingerprint all bacteria that cause a specific disease and find, for example, that there are five people throughout the country who became ill from a strain, or subtype, of bacteria with the same DNA. “Once the cases are linked,” he says, “the question is, where did it come from?”

The trick is to catalog the information gathered from different sources, and that’s where the database proves its worth. “You can take the bacteria from a person who is sick with a disease and send it to a central laboratory to have it fingerprinted, which is very time consuming. Or [you can] have every state or local health department fingerprint bacteria and exchange the visual DNA scans through a common database to immediately see where else in the country there are people infected with the same fingerprint,” Wiedmann explains.

The seeds for PathogenTracker were sown in 1999, when Wiedmann and food science undergrad student Steven Cai developed an elementary database using an Excel spreadsheet that was used to identify the source of a nationwide...
outbreak of the food-borne disease listeriosis in 1998-99 that caused severe illness in 100 individuals and 100 deaths. “The isolated bacteria from cases in New York state were sent by the state health department to our laboratory, where we sub-typed it and found that five of seven cases had bacteria with the same DNA fingerprint,” Wiedmann recalls. “We communicated this to the Centers for Disease Control and it turned out there were three or four other states which also saw a slight increase in listeria cases but had not identified the specific strain. With the New York state cases and half of the cases in other states having the same fingerprint, we discovered a nationwide outbreak.”

Upon further investigation, all of the victims with the specific subtype of the listeria bacteria reported a common link to deli meats and hot dogs produced by a packing plant in Michigan that shipped foods throughout the country. The result was one of the largest-ever food recalls. “The key in detecting this was that we had long-term data. We had learned that one or two types of food had the same bacteria subtype,” Wiedmann says.

Buoyed by that success, and realizing the potential of an improved database, Wiedmann and Cai enlisted the help of computer science students to improve it. PathogenTracker became a project for a CS 501 class that accepted the challenge of writing the software, using computer science to interpret biological ideas.

“In the beginning, we had to pool the resources for both fields — biology and computer science,” says Michael Chung ’02 CS, who worked with the CS 501 class who did the mainstream Java programming and de-bugging of the database. “Initially, we were looking for a way to organize the data with the long-term goal of putting the information online for more people to access it and contribute to it,” Chung says.

The primary goals, he said, were to standardize the data for entry from multiple sources and to enable expected expansion of the database. Bacteria subtype characteristics such as DNA patterns, ribotypes, and phenotypes were added by Chung and a team of CS students that set up the PathogenTracker server and added image-recognition software with the help of a member of the Cornell RoboCup team.

“We are changing to an active server from Javascript and taking it to the Theory Center, where it is being installed on a .net Web server that can handle greater amounts of information that will be added,” Chung said.

Mike Bohlander ’03 CS said redesigning the database to enable expansion of its capabilities kept the budding engineers busy. “The previous implementation worked well for what it was designed for, but it couldn’t handle some of the new things we wanted it to do,” he says. As an example he cited the addition of more species-specific information. “In the first iteration of PathogenTracker that [type of] data was hacked in, so it kind of worked, but in our latest version we have explicit support for this type of data,” Bohlander says.

After putting the database through its paces to check its performance, Bohlander says, the CS team tweaked the methods for storing image data to enable faster searches and matching. “We’re still working on it, and one improvement on the horizon is to implement different kinds of searches that compare isolates in the database statistically,” Bohlander said. Wiedmann confirms that such data mining capabilities are in the development stages to get a handle on which subtypes are more common, and which are particularly virulent. Learning to speak a common language was key, participants in the project agree, since the biologists knew little about the skills involved in writing software and the CS students had to get up to speed on the microbial world. “We have worked on this for more than a year, and I think we spent the first three months trying to figure out how to communicate with each other,” says Chung.

Cai, who describes himself as the liaison between the biological data and software development teams, says, “We had to teach the CS 501 students basic biology and how biological data is used. We got into molecular biology and understanding a DNA sequence, and they picked it up pretty quickly.”

As with any multi-faceted database, protecting the information from unauthorized prying eyes was a consideration, although Wiedmann concedes it was an aspect of PathogenTracker he had not initially considered. “You may not want to share all the fingerprints if you have an ongoing outbreak. With the anthrax outbreak, for example, you don’t want the whole world to know what the fingerprint is and alert the perpetrator,” he said. “You want to allow various levels of security, and there was a lot of database engineering that went into this.”

A form of discretionary access control was developed, assigning security levels for each aspect of the data, with different clearance levels for the public, for laboratories, and for engineers working on the system, says David Wang, M.Eng. ’01 CS, who also participated in the project and is now using his database security skills at software giant Oracle.

Image recognition was another primary facet of the database since many of the DNA fingerprinting methods use banding patterns. While more work is needed to improve the method of matching these patterns through image recognition, Wiedmann cites the software-writing contributions of RoboCup team member Thibet Rungrotkitiyot M.Eng. ’01 CS as crucial to the initial effort.

Beyond tracking outbreaks of virulent bacteria, the database is an important clearinghouse for researchers, Wiedmann says. “We are collecting DNA fingerprints from all over the United States—and eventually throughout the world—in a real-time, interactive database.” The idea is to understand all of the different subtypes of bacteria, some of which cause animal diseases, others that cause human diseases, and yet others that are present in the environment but don’t cause disease.

Understanding these subtypes can have significant ramifications, Wiedmann says, offering another example from the food industry. “Listeria is a very common organism, and people who ingest it don’t always get sick. We don’t know why, but we think that certain subtypes don’t have the ability to cause human disease,” he says.
“But because we don’t know which ones they are, every time a food is found with one listeria cell in 25 grams of a product, that company has to recall all of that food,” he explains. One such business had to recall 30 million pounds of deli meats and hot dogs, but there was not a single human case linked to these products. “The company went bankrupt—and we don’t even know if the listeria found in that specific food has the ability to cause human disease,” says Wiedmann.

As it expands, PathogenTracker could help determine that a subtype of bacteria found in 20 percent of tested food samples is not a health hazard and eliminate the need to recall vast amounts of food.

The database currently holds some 6,000 bacteria DNA fingerprints, Wiedmann says, mostly of food-borne pathogens, and he envisions it including all types of bacteria through the contributions of future collaborators. Anthrax isn’t included, at least for now, because the Centers for Disease Control closely monitors the bacteria and tracks outbreaks, Wiedmann says. Their database, however, is proprietary.

Their information is mainly for tracking outbreaks. Ours is very broad, including multiple fingerprinting methods and containing data on multiple organisms. Our interest is in long-term research,” says Wiedmann.

How the database will evolve is of great interest to the professor and the students who put it together. “I want to see how many people will use it; how many different organisms will be included,” Wiedmann says. “Will we be able to maintain it, or is the interest limited to a few specific organisms?”

Weaving together engineering, computer science, and biology is a significant development, says Cai. “In the past researchers were not able to use DNA sequencing technology in a database, but we now have a vast connection enabling scientists worldwide to store and share information on all types of bacteria. There is a lot of interest in tracking pathogens, as well as other organisms with biological characteristics.”

Wang, who continues to monitor the progress of the project although he’s now removed from it, contends PathogenTracker will prove popular among bacteriologists. “It allows hospitals, clinics, and researchers to pull data together on bacteria. Research sharing is more feasible now that it was before,” he says. But even if interest is limited, or it takes a while for PathogenTracker to get on track, the process of creating the database and setting up the server was valuable in and of itself.

“There is a lot of information to deal with in the 21st century and what we learned about bioinformatics — combining information technology and biology using pattern matching — through this project was important,” says Chung.

“In this case the data were scattered and we were able to bring the science up to date with new technology. I think we will see a lot more fusion between CS and basic science,” he says.

Wiedmann concurs. “Putting biology and engineering together is a significant development. If we can teach people in different disciplines to communicate, we can do things that we didn’t dream of doing 10 years ago,” he says.

Jay Wrolstad is a freelance writer/editor living in Ithaca.
The leading cause of death in the U.S. and in the world is heart disease. Why should the heart, that humble pump, be the main reason people die?

It was in 1968 at a table in Joe’s Restaurant that Arthur Kantrowitz suggested to David Lederman he might be able to do something great. Thirty-three years later, Lederman did. On July 3, 2001, surgeons implanted the first self-contained artificial heart in 59-year-old Robert Tools. Lederman’s company, Danvers, Mass.-based Abiomed Inc., invented the heart. “I always dreamt of the day,” Lederman says. “I dreamt what it would be like to shake the hands of a patient and say, ‘How are you doing?’ whose [dysfunctional] heart was in a bottle” on a shelf.

But in 1968, Lederman was a Cornell graduate student in aerospace engineering, only a few years removed from his native Colombia. He was president of the local chapter of the American Institute of Aeronautics and Astronautics, he had $1,000 to obtain a speaker, and he didn’t know whom, if anybody, he could bring to town on that sum.

Matters of
Dr. Arthur Kantrowitz—the man whose work stretched from beyond the earth, having proved re-entry from outer space was possible, to beneath the skin, having invented the first successful heart-assist device —knew Lederman’s adviser and agreed to speak for free.

Earlier Kantrowitz had been an engineering professor at Cornell; he had since turned his attention to building an artificial heart at Avco Corp. Now he was looking for acolytes to join his quest, and after hearing him speak, Lederman wanted in.

“He came to Ithaca, and he gave a talk on what people who have studied fluid mechanics could do to advance the development of devices and technologies that help the failing heart and replace the failing heart,” Lederman recalls. The message: The heart, that humble pump, should not be the main reason that people die.

After the speech, Lederman took the visitor to Joe’s for dinner. He may have been awed to be seated alongside Kantrowitz, but he wasn’t too daunted to ask for a job at Avco.

“I asked him if he was interested in more than a job—I asked him if he was interested in a lifelong career,” says Kantrowitz, now a professor emeritus at Dartmouth College.

The answer must have been yes. When Lederman finished his doctorate in 1973, he signed on with Avco. And he started doing great things, which, in retrospect, doesn’t really surprise Kantrowitz.

“He was the best chance, by far,” Kantrowitz says. “You could see that he had a lot of drive, and you could see that he was a very intelligent person.”

Lederman grew up in Colombia and had never been to America before he arrived at Cornell. “I was given opportunities I never imagined,” he says. “I met people like Linus Pauling, Hans Bethe; I took lectures with Carl Sagan. It was just unbelievable.”

Lederman seems to cherish the opportunities he’s had and seeks ways to return the favor. Giving extra life to those facing the end is the most obvious manifestation. But he has also stocked his company with former Cornellians and every year opens its doors to current Cornell students looking for internships and co-ops.

The people who work at Abiomed can feel Lederman’s pulse coursing through it. “The character of the company is set by Dr. Lederman,” says Seana Richardson ’00 MSE, a Cornell graduate who has worked there since August 2000. “We are all motivated by our desire to save human lives, and are proud of our efforts to do so.”

Abiomed was established in 1981 and until releasing the AbioCor, the company had only one product: a heart pump that gives failing hearts a boost. The device, which is the company’s chief revenue source, has been used on more than 4,000 patients.

Six people thus far have been outfitted with an AbioCor. By the end of January, three were still alive. Four of them survived at least 60 days, the company’s goal for this first phase of human trials. One died after 57 days. One other person died on the operating table. Robert Tools, the first recipient, died after suffering a stroke and severe abdominal bleeding; he had his new heart 151 days.

Lederman has always been clear that all of the patients who received the artificial heart in this phase of testing would die. The qualifications to participate in the clinical trial practically assure it: To be accepted into the AbioCor program, patients must be within 30 days of death and have no other options. Yet all of them could glean more hope from the grapefruit-sized AbioCor than through their own failing hearts.

The patients, perhaps needless to say, are thrilled with their extra time. But Lederman and others at Abiomed are thrilled, too, with how well the tests have gone, despite having lost three patients. “It’s more than a success,” Lederman says. “It’s absolutely incredible. In the case of Bob Tools, we were able to give him minimal medication in the first four months.”

The statistics backing the need for such a device are sobering. Heart failure kills more than 700,000 Americans every year. Abiomed projects that up to 125,000 people a year would be candidates to receive its artificial heart. Congestive heart failure alone kills more than 50,000. Of the 4,200 people waiting for heart transplants, only about half ever get one.

To date, the Food and Drug Administration has approved 15 AbioCor implants; the company expects to finish those by the middle of the year. If those are successful, more could be authorized.

The notion of fashioning a man-made heart has been around for years. In fact, by the time Lederman had started his career at Avco, scientists had already been at work for nearly 20 years on the concept.

In 1953, a heart-lung machine was used to support open-heart surgery. In 1958, a dog lived 90 minutes with a man-made heart. In 1965, the federal government declared an all-out effort to develop an artificial heart fit for humans by 1970. Officials earmarked $40 million for the project over the next four years.

Indeed, in 1969, an artificial heart was implanted for two and a half days into Haskell Karp, a 47-year-old dying of heart disease. After 65 hours, he received a heart transplant and died shortly after.

But scandal tainted the Karp case. The doctor responsible for implanting Karp’s heart, Denton Cooley, did so without permission from regulators or the man who spearheaded the development of that heart. Cooley had actually commandeered a heart intended for animal trials and used it in Karp.

In the wake of the Karp episode, arodor for the artificial heart project cooled for several years. Then, in 1982,
Dr. William DeVries implanted the Jarvik-7 artificial heart in Barney Clark, a retired dentist. Lederman and the rest of Abiomed’s staff followed the case with great clinical interest but certain misgivings: the media frenzy surrounding the surgery seemed sure to give the public unrealistic expectations. Clark’s heart was air-driven and needed a dishwasher-sized pump to make it beat. A series of tubes would forever connect every Jarvik-7 patient to the 350-pound machine. And every spot where those tubes entered the patient’s body provided opportunity for infection, which indeed tormented Clark, who died after 112 days. The man who lived the longest with the Jarvik was William Schroeder. He lasted 620 days, and was decimated by strokes and infections that made his extra time very painful.

As Lederman’s group had anticipated, the public’s high expectations were dashed and pessimism set it. The New York Times dubbed artificial heart research the “Dracula of Medical Technology.”

“It set this field back at least 10 or 15 years,” Lederman says of the Jarvik-7 experiments. But not for any medical reason. “It was a public relations disaster,” Lederman says, “but it was a very important first step.”

He was so affected by the media circus surrounding the Jarvik-7 trials—one reporter went so far as to sneak inside the hospital in a laundry cart—that he tried to implant his first AbioCor under a near-total press blackout. His goal, Lederman says, was to keep a lid on public expectations. “We knew in 1982 that the expectations of the public at large were of a technology that was impossible to meet,” he says.

The Jarvik experiments taught Abiomed’s researchers other valuable lessons. Prime among them was that the heart needed to be entirely internal. They also needed to do more work to prevent clotting that occurs when platelets collect on foreign surfaces.

Even now, clotting remains an issue. Abiomed said at the end of January that two patients had strokes that may have been caused by the heart’s design, which the company will change.

But if the AbioCor succeeds, it will surely find a vast market. There are no bulky units a patient must tow around. The heart runs on electricity, not air. The pump that drives the heart gets its power from a battery pack worn by the patient. But instead of cords that puncture the skin, the electricity is transmitted across the skin via a coil.

That electricity passes to a computer module implanted near the abdomen. It keeps a constant watch on a patient’s physical activity, automatically adjusting how quickly the pump beats—and how much blood is circulated. While AbioCor recipients might not be able to play football, lower levels of exercise are entirely possible.

The heart itself shares some characteristics with its natural counterpart. Blood enters and exits both hearts through ventricles. A natural heart relies on muscular contractions to pump blood through the ventricles, however, while the AbioCor uses a tiny motor to pulse a gel against the ventricle walls, forcing it to close, pushing blood out.

When Lederman saw Tools after the surgery, the heart pulsing inside him, “It was the most extraordinary time in my professional life,” Lederman says. He called his wife. “I said it’s just incredible,” he recalls now. He tried to explain the euphoria he was feeling, but she already understood. “To her, it sounded like the equivalent of a woman who’s giving birth,” he says.

Over the next weeks, the Abiomed team became close with Tools and his family. “He really was a remarkable guy with a zest for life that was incredible,” Lederman says. “He was so happy. And he enjoyed life so much. He didn’t complain.”

Lederman remembers how one day shortly after the surgery, he approached Tools with some questions. “We spent a lot of time trying to make sure that this heart would make a very good quality of life,” Lederman says. There were four valves in it, and engineers wanted to make sure the flaps didn’t click upon opening and closing. “It could drive a person crazy.”

So Lederman asked if Tools could feel the heart beating. No, Tools said.

“I was really happy,” Lederman says. “He kept saying, ‘No.’”


“You didn’t ask me if I hear a sound,” Tools replied. But it was OK with him. “Bob was glad it had the noise,” Lederman says, “because it told him it was working.”

By 2004, the company hopes to have a smaller heart ready for use in all adults; the current model fits about half the male population and 20 percent of the female population. It is expanding its trials internationally and plans to implant nine more AbioCor devices by midyear.

“We are proving what we expected we could do,” Lederman says of the current generation of AbioCor hearts. “Does that mean that we’re done? Nowhere near. This is the first good quality flight.” The next generation, Lederman promises, will last longer; someday, they’ll last for years.

Kantowitz, he of the lofty goals, has still loftier ones for the artificial heart, which he is convinced can be built even better than an organic one. He wants to see an AbioCor recipient run a mile in under four minutes. “Surely it’s possible,” he says.

Why not; he was right about Lederman.

Ken Aaron writes for the Albany Times Union and is a frequent contributor to CEM.
Cutting edge research in fields where engineering and biology meet is nothing new at the College of Engineering. But this academic year marks an initiative to make that research more visible nationally in a more unified fashion.

The Biomedical Engineering Program (BMEP), approved last summer, has been taking shape under the guidance of Michael Shuler, director of both the School of Chemical and Biomolecular Engineering and the current Bioengineering Program. A graduate field in biomedical engineering is already in place; BMEP will serve as the home for a new university-wide undergraduate minor and a master of engineering (M.Eng.) degree. The program will be responsible for coordination and delivery of educational programs in Biomedical Engineering and will facilitate interactions between biologists, physical scientists, and engineers.

Initial funding indicates strong interest from industry and foundations in the engineering/biology combination. The Whitaker Foundation provided grants to help develop the curriculum; Intel Corporation will provide support for creating a nanobiotechnology teaching lab.

“Biology and biotechnology will have an increased importance in the jobs that engineers hold in the future,” said Harold Craighead, professor of applied and engineering physics and interim dean of the College of Engineering. “The uses of engineering and physical sciences for biological purposes have been growing. This program will bridge basic biology, medicine, and engineering.”

About 100 faculty members across campus—including many in the colleges of Agriculture and Life Sciences, Arts and Sciences, Human Ecology, Veterinary Medicine, and Weill Medical—have self-identified as part of a broad bioengineering community and many of those faculty have interests in biomedical engineering. The BME core faculty will be drawn from this wide range of fields. “They will hold tenure in their ‘home’ departments,” Shuler says, “but have primary responsibilities, in teaching, toward BMEP and actively participate in graduate education in BME.”

The melding of biology, medicine, and engineering has been underway at Cornell for many years. Prof. Don Bartel, who joined the faculty in mechanical and aerospace engineering in 1969, began immediately to develop an active research and teaching program in biomechanics, working with the Hospital for Special Surgery in New York. This association has provided a firm foundation for building an increasingly strong relationship between engineering and the Weill Medical College.

Shuler joined the Cornell faculty in 1974 and was instrumental in moving forward a program of biotechnology based in his department, building on a strong existing concentration in biochemical engineering begun by Prof. Emeritus Bob Finn in 1955.

In the 1980s, the Department of Agricultural Engineering changed its name to Agricultural and Biological Engineering to reflect their increasing emphasis on biological processes and systems. Today the unit is called Biological and Environmental Engineering—creating, in the words of department chair, Prof. Michael Walter, “[an engineering] department with biology as our foundation.”

The School of Applied and Engineering Physics has a history of research and teaching in biophysics, and faculty members have significant research in biological applications of new technology. AEP’s Craighead was instrumental in the establishment of the Nanobiotechnology Center in 1999.

In each of the schools and departments of the college, faculty members have identified ongoing or potential bio-related teaching and research. “We’ve had many separate efforts,” Shuler said. “Now we’re trying to make them more connected and therefore more effective.”

The new program will continue to call upon long-standing partnerships with the Weill Medical College and the Hospital for Special Surgery (HSS), both in New York. Some engineering faculty members already split their time between Ithaca and Manhattan, advising graduate students in both locales.

Biomedical engineering students can work with such Weill and HSS faculty as Timothy Wright, who studies the performance of bone-implant systems, design of total joint replacements, and the properties of ultrahigh molecular weight polyethylene.

On campus, the program will provide an umbrella for collaboration in teaching and research across colleges and between departments. The challenge will be to integrate all of this under BMEP. “There’s a need for a group of faculty who would have resources and obligations to develop an organized, coherent curriculum,” Shuler said. “The sequence of courses would be from the molecular level to the tissue level, to physiological systems.”

Teaching in the interdisciplinary program appeals to Marjolein van der Meulen, associate professor of mechanical engineering, who researches the load-carrying abilities of “long bones,” specifically the arm and leg bones. She says that all faculty members who work in cross-cutting disciplines “end up straddling multiple communities.” The day she discussed this, van der Meulen was preparing to make a presentation to a conference on osteoporosis, where most of her audience would be endocrinologists—specialists whose work in bone structure from a biological perspective could complement van der Meulen’s engineering approach.

“Ultimately you need to think about students and student training,” said van der Meulen. “In biomedical engineering, we are working at the convergence where biology and engineering interface. By training students to be equally comfortable with the biological side and the engineering side, we believe the sum will be greater than the individual parts.”

—Scott Conroe
Shaking hands with Francisco Valero-Cuevas, assistant professor of mechanical and aerospace engineering is no simple hello. The hand is his research subject, and so beyond the social niceties that we all recognize, Valero-Cuevas can also evaluate how well that welcoming hand does its job. He can calculate the muscle forces that allow the hand to move and grasp and measure how each fingertip might press against the tip of the
A new research approach combines mechanical engineering, anatomy, and neurophysiology to explore what a hand is, how it works, and how to fix it.

thumb. He also knows that a versatile hand is fundamental—without the ability to grab and pinch, a person can’t hold a fork, braid a child’s hair, or type on a keyboard. And yet no one, not even Valero-Cuevas, knows exactly how the hand works. “Anatomists have studied the hand for thousands of years,” he points out. “We have named the tendons and muscles. But we know precious little about how a hand is, precious little about how the hand works. We know even less about how hands differ from each other, or how to restore hand function after disease or injury in a biomechanically optimal way.”

With a series of research projects conducted here at the Neuromuscular Biomechanics Laboratory, and in New York City in conjunction with the Hospital for Special Surgery, Valero-Cuevas is using computer models and real hands to understand exactly what makes a pinch, grasp, and grab. Beyond mapping the basic mechanics of the hand, his work also intends to improve current techniques for hand surgery and aid in treatment after injury such as stroke or nerve damage. More remarkable, Valero-Cuevas employs a holistic approach to hand function as he combines mechanical engineering, knowledge of anatomy, and explorations into how exactly the brain receives, processes, and sends signals to the hands. “No one person has the time look at all three levels—anatomy, biomechanics, and neurophysiology—at once and get them all right 100 percent of the time,” he claims. And so Valero-Cuevas has assembled a collaborative team of engineers, neurophysiologists, surgeons, therapists, and roboticists to contribute their perspective: “I am trying to bring together the three fields on a clinically important problem. You can address a clinical problem that is very important, but if you don’t have your mechanics right, or if you are not considering the nervous system, you may not come out as well.”

With that triangular approach he hopes to help people with hand impairment. He cites stroke, multiple sclerosis, spinal cord injury, arthritis, carpal tunnel syndrome, cut tendons, and broken bones as a few of the conditions that can severely impair the hand; in the United States, there are over eight million injuries a year that affect hand function. “We want to know what a hand is, how it works, and then, of course, how to fix it,” Valero-Cuevas says. The most obvious way to evaluate the hand is to see it in action. But this is no easy task. There are 27 bones in the hand moved by about 37 muscles, including some muscles located in the forearm with long tendons that attach to the wrist or fingers. (Why “about 37”? Because natural anatomical variation allows some people to have muscles others lack.) The thumb, with its superior mobility and strength, is especially important to manipulation. The whole hand is also highly dependent on the wrist, itself a complex mechanism with eight bones that act like a set of ball bearings, allowing the hand to pivot freely.

The human hand has specialized adaptations to which we owe its versatility. Most mammals—dogs and cats, for example—use their hands for walking, but some primates, including humans, have evolved to free the hands from the tasks of locomotion, adapting them instead for manipulation. Humans, in particular, devote an unusually large portion of our brains to hand control. Because the anatomy of the primate hand is so complex, it is often impossible to predict which muscles are involved in a particular manipulation task, or how much force each muscle must contribute to perform a given task. In an attempt to map hand function, Valero-Cuevas and his research group—Jonathan Pearlman, a graduate student; Michal Weisman, an undergraduate student; Stephanie Roach, a hand surgeon in Ithaca; and John Hermanson, Cornell muscle specialist—have developed a protocol using cadaver hands to calculate the details of thumb force production. Lest the idea of lifeless hands pinching and grasping is too ghoulish, Valero-Cuevas points to centuries of such work. “Mind you, the use of cadaver hands for surgical anatomical training has been the standard...
for over 700 years,” he claims. “All we are doing is bringing rigorous mathematics and engineering to the problem.”

A recent grant from the Whitaker Foundation will fund using this approach to study the biomechanics of the thumb. “The thumb has about ten individual muscles, and some of these muscles are innervated by the median nerve that goes through the carpal canal,” Valero-Cuevas explains. “If you have an injury to the median nerve, it paralyzes these muscles and your hand doesn’t work that well.” The thumb, in other words, loses much of its ability to oppose the other fingers, which will compromise hand dexterity and versatility.

“If you look at the surgery books, you’ll find at least a dozen procedures proposed for restoring thumb opposition. But how do muscles coordinate their actions to produce opposition? There are very many ways to control your thumb muscles to oppose the thumb to the fingers,” he continues, complicating the picture. Think of the hand as a marionette. The doll has a shape and size and the strings are routed in some way. The path of the string obviously makes a difference in how the marionette moves. Other strings that are being pulled at the same time also affect how the puppet moves.

“Now, imagine a marionette that has too many strings. Thus you can pull on different strings in different ways to achieve the same action of the marionette,” Valero-Cuevas explains. “If you then lose some strings, the question becomes: Which strings were the critical ones, and how should we replace their actions with the available strings? Seen in this way, it is not surprising that there are different proposed surgical procedures. In this project, we would simply like to find out what are the biomechanical consequences of each of these procedures.”

In this particular project, the cadaver hands are mounted on a frame, and tendons are attached to nylon cords that in turn are attached to computer-controlled motors that simulate muscle forces. Meanwhile, a dynamometer measures the three-dimensional forces the thumb produces. In this way, Valero-Cuevas and his colleagues are able to outline the blueprint for the worst case scenario following the paralysis of some thumb muscles (like in severe carpal tunnel syndrome). They then examine the biomechanical merits of alternative possibilities for repair to decide how to best bring back the most important functions. For example, in a previous study of the partially paralyzed index finger, Valero-Cuevas discovered that a slight modification to a tendon to shift its insertion point by only a few millimeters could restore normal function for some finger pinches. These results show how complex even the simple task of pinching can be.

“There is also a duality in how well we can move the digits and what forces the digits can produce,” explains Valero-Cuevas. “In fact, they are the inverse
of each other. We have a digit that can move very quickly—like the index finger—but the force it can produce cannot be very large. In the same way, we have a digit that can’t move very quickly—like the thumb—but can produce high forces. Try trilling [on the piano] with your thumb instead of with your fingers for a change!” he suggests.

Combining this cadaver work and other biomechanical approaches, Valero-Cuevas and colleagues at the Neuromuscular Biomechanics Laboratory have also been able to construct computer models of how the thumb works, how it moves and pinches with the other digits. These computer models take into account every possible combination of muscle actions and will help clinicians predict finger motion and force in the intact and impaired hand. The ultimate goal of the team is to combine this model with a previous model of the index finger to develop a comprehensive computer model of the whole hand.

To experience the complex interactions among finger muscles, visit the Neuromuscular Biomechanics Laboratory website (www.mae.cornell.edu/edu/nmbl/) and click on the thumb of the hand, or “Projects,” and then find the link to the interactive explorations of the hand. Drawn on a black background are the bones of the hand with various force vectors that can be rotated for viewing. “At the website you can actually see where the force is going in three dimensions and all the muscles that are involved, from all angles,” Valero-Cuevas describes.

As the data show, there are complex interactions among muscles of the hand that are not always obvious; no single muscle alone is responsible for producing force in a particular direction. “It takes a little bit of this and a little bit of that,” he says, moving each of his own fingers up and down in demonstration.

The three-dimensional visualization of these complex biomechanical interactions can influence how hand specialists treat a case. For example, there are extensor muscles of the fingers that are typically considered “release” muscles, but the computer model shows that these muscles also contribute to strength during a pinch. A hand surgeon or physical therapist studying this model online would note that a patient could improve their pinch strength by exercising the extensor muscles that also move the fingers away from objects. Valero-Cuevas says, “Our work has begun to reveal the problems that arise when the anatomical description of a muscle, typically based on how the muscle moves a joint, is assumed to apply when force production is involved.”

Valero-Cuevas is also concerned with another major piece of the hand measuring what we think we are measuring, the ability of the hand,” Valero-Cuevas asks, “or are we only measuring learning?”

To examine these issues, Valero-Cuevas and colleague Joy Hirsch from Memorial Sloan-Kettering in New York City are associating specific requirements for manipulation to parts of the brain, using Magnetic Resonate Imaging (MRI) to spot places in the brain that are activated when the thumb produces dexterous manipulation or simple pinch.

“Our results show that fine-tuned finger tasks are regulated by cerebral networks that vary depending on the availability and quality of visual and tactile information,” he says. The obvious goal is to integrate the central nervous system’s role in hand surgery and therapy. In the case of stroke, for example, if someone has injury in a brain area that is tied to dexterous manipulation, it may be unrealistic to expect the patient to regain dexterity quickly. But if those areas are not affected, surgery or therapy might restore mobility more easily. Brain images can help marry nervous system function with biomechanical function and come up with a compromise solution for the patient. “Our goal is to make engineering principles part of clinical care,” he says. “After all, we’re bio-mechanical beings. And where the rubber hits the road is at the interface of your fingertips and an object.

“There are thousands of things the hand can do,” Valero-Cuevas sums up, smiling in admiration of this human appendage. “It’s so versatile.” With that, he moves his fingertips from the keyboard, where they have been typing furiously, to gently pick up a pen, demonstrating again the complicated, but sublime, mechanical gymnastics of four fingers and a thumb. And then he shakes hands to say goodbye.

Meredith Small is a professor of anthropology at Cornell University.
Life as a Table

The question becomes not so much does the art appeal to us; rather, do we appeal to the art?

It looks like a plain metal table. Sitting inside a bare white gallery, it’s got four sturdy legs, a long, smooth top, and nothing to distract you from its perfect ordinariness. But as soon as you walk into the room, it starts rolling towards you, trying to grab your attention. It wiggles a little greeting and waits for you to respond. If you don’t, it’ll wiggle again. If you do, it’ll keep playing, following you around the room until you lose patience and move onto the next gallery. When you do, the table will just sit there, alone again, waiting for some more human contact.

“We wanted this inanimate, everyday object to try to engage in a conversation with a human being,” says Raffaello D’Andrea, associate professor of mechanical and aerospace engineering, who designed the intelligence that controls The Table: Childhood. The piece was on display at the Biennale di Venezia in Venice, Italy, in the summer and fall of 2001 and will be shown at the National Gallery of Canada in Ottawa in the fall of 2002. “Some people are charmed by it; some people get very scared. Some people, once they figure it out, try to monopolize The Table. And other people, once The Table picks them for a conversation, they get very shy. They either leave the room, or try to move close to another person, so The Table will shift its attention to somebody else. Which in a sense is how we all behave, right?”

D’Andrea, who specializes in the mathematics of controlling complex systems, began working on The Table in 1999. Artist Max Dean had begun developing the concept in the 1980s, but the price tag was prohibitively expensive: By the early nineties, when the project became technologically possible, the hardware alone would have cost $300,000. But as the decade moved forward, industry started applying the new technology, and by the time D’Andrea came on board, he could supply the control system for less than a tenth of what it had cost ten years earlier.

“It’s much more sophisticated than I had ever anticipated,” says Dean, who created the concept of The Table, and oversaw the design and construction of the entire project. “You start off with the idea that you’re going to take a table and give it a human presence. Human characteristics. So you have to take these abstract emotions, like fear or excitement, translate them into a mathematical formula, and then turn that formula into behavior. That’s the thing that blew me away, and still blows me away: That Raff can take these true abstractions and turn them into movement.”

The Table is controlled by two computers, one custom-made by Galil, which introduced the first industrial microprocessor-based motion controller in 1983, and the other an ordinary Pentium III computer running the standard Windows NT. Inside the ceiling of the gallery, a hidden camera shoots 30 pictures every second, feeding data to a computer that analyzes movement over time and calculates the control algorithms that determine The Table’s direction. From there it sends the
results to a computer hidden inside The Table, controlling its eight high-performance motors, arranged in pairs on each leg, one for drive and one for orientation.

Reaching for an analogy, D’Andrea rises out of his chair, describing what happens to his body as he pretends to chase an object around the room. On the highest level, his brain sees the object moving from Point A to Point B. It takes that information, performs an algorithm to determine exactly where he wants to go, and passes that data to lower level controls, which coordinate the movement of his arms and legs to finally reach their goal.

That’s how The Table knows when to run away from danger, or when to approach a friendly visitor. By analyzing movements within the room, the system’s global control can send its instructions to the local control, which can move The Table anywhere inside the gallery. The design is very similar to the one used in Cornell’s RoboCup project, in which a student team builds soccer-playing robots with D’Andrea as faculty advisor. But here, the control algorithms are completely different, and D’Andrea’s greatest challenge—besides trying to fit weekend trips to Toronto into his teaching and research schedule—was in trying to make all the parts of the system work together, so The Table can move smoothly and smartly from one point to another.

The Table has to be robust enough to survive the stress of performing every day, safe enough to play with small children, and flexible enough to compensate for changing conditions within the gallery. Most important, it needs to be personable.

“The Table is actually quite shy,” says Dean, talking from his studio. “It’s introverted, and it takes quite a bit of effort by the viewer to bring out its character. Like Raff, there’s a great deal of energy and ambitiousness in it. It’s very intense, and very focused in a way that particularly reminds me of Raff. And the look of it—its humbleness, its lack of ornamentation, its use of generic, everyday materials—is more like me.”

In a collaboration that has exceeded their expectations, Dean talks about D’Andrea moving “at the speed of light—no, just below the speed of light, because you can still see him moving.” Meanwhile D’Andrea, who credits the vision system to Thibet Rungrotkitiyot, M.Eng. ’01 CS, calls Dean “a pure artist,” and looks forward to their continuing collaboration on The Table: Adolescence, and ultimately The Table: Adulthood. Both artist and engineer occasionally slip into Table speak, talking from the artwork’s point of view, and D’Andrea, who has two cats (one bold and one shy), insists The Table already has more personality and less bad breath than many household pets.

“Everyone’s perception is different,” says D’Andrea, who thinks that anything people interact with is going to be seen as having a personality. “When I look at this machine, I’m thinking exactly what line of code is running right now, and what’s it going to do next? Maybe there is no black and white between people and robots; maybe it’s all shades of gray, and people are just running a more sophisticated program.

“I’ll never be able to experience The Table like everyone else does, because I created the intelligence. But I know that other people see it as something that actually has a life.”

—Kenny Berkowitz ’81

RED ROVER, RED ROVER

The Mars Exploration Rover, one of the two vehicles scheduled to explore the surface of Mars in 2004, is built and seemingly ready for its trip, complete with a full payload of scientific instruments—about two years in advance.

But this is not the real rover. It is a finely detailed, full-scale model made out of wood, plastic, and aluminum that will be put on display in science museums throughout central New York state. It has been built by eight university and two high school students working with Steven Squyres, Cornell University professor of astronomy, who is the principal investigator on the Athena science payload to be carried by the long-range rovers.

Since last summer the students have been designing, machining, and constructing the rover replica. Its folding solar-panel “deck” has a span of nearly 8 feet by more than 5 feet, and
ME; Matt Siegler ’03
Heather Arneson ’02
Miles Johnson ’02 ME; team leader
’02 ME; Renee Hillaire from Cornell, Phil Chu
freshman Emily Dean; (left) Ithaca College
student builders (from
model are some of its
blades—an assembly machined
on Mars aboard the rovers. Once the spacecraft has
the sun’s shadow. Then the
sundial lines can be put into
the correct position and super-
posed over the image of the
sundial as it appears on the web.
The Mars Exploration Rover
mission, scheduled for launch
in 2003, is managed for NASA
by JPL.
Athena: http://athena.cornell.edu/
—David Brand
Cornell News Service

LEADERS OF
THE FUTURE

Three Cornell faculty members
are among this year’s recipients of National Science
Foundation (NSF) Faculty Early Career Development (CAREER)
Awards for new faculty members. The career program rec-
ognizes and supports the early-career development activities
of those teacher-scholars who are considered most likely to
become the academic leaders of the 21st century.
Johannes Gehrke and
Andrew Myers, assistant profes-
sors of computer science, and
Anna Scaglione, assistant pro-
fessor of electrical and com-
puter engineering, each will
receive five-year grants of about
$350,000 to support their research.
Johannes Gehrke, who
joined the Cornell faculty in August 1999, has focused his
research on “data mining,” the
mechanisms by which computers can scan through large
databases to note trends or odd-
ities and present statistics about
them, or collect data on specific
subcategories. In the project
funded by the NSF award, he
will be extending this idea
to data collected from large
arrays of sensors. His grant is
titled “Towards Sensor Database Systems.”
Andrew Myers joined the
Cornell faculty in January 1999.
His research aims to give com-
puter users more security when
running programs supplied by
an outside source. Increasingly,
users must allow “visiting” pro-
grams access to confidential
data, but need to prevent that
data from being corrupted and
to control what is sent back to
the visitor’s home base. Myers’s
approach is to build safeguards
into the programs in ways that
the local computer can verify
at run time. The system, called
Java Information Flow (JIF),
requires that programs be writ-
ten in a special version of
the Java programming lan-
guage that builds in security
features. The NSF grant sup-
ports his project called “Practi-
cal Language-Based End-to-End
Security.”
Anna Scaglione, who joined
the faculty at Cornell in July
2001, works on the design of
modems for wireless telephone
and computer communications.
In a wireless device, the modem
is the hardware that converts
digital data into a radio-fre-
quency signal. Her goal is to find
better ways of “multiplexing,”
so that many digital signals
can occupy a single frequency,
and to prevent or correct for
errors caused by interference in
a busy urban environment. The
NSF grant will support contin-
ued development of those ideas
in her project titled “Linear Pre-
coding Methods for High Bit
Rate Wireless Transmission.”
—Bill Steele,
Cornell News Service

D’ANDREA WINS
PECASE

Raffaello D’Andrea, associate
professor in the Sibley
School of Mechanical and Aero-
space Engineering at Cornell,
has been awarded a Presidential
Early Career Award for Science
and Engineering (PECASE), the
White House has announced.
The award carries a five-year, $500,000 research grant to explore the control of interconnected systems. Matching grants from the U.S. Air Force Office of Scientific Research bring the total project funding to $1 million.

The award is the highest honor bestowed by the U.S. government on outstanding scientists and engineers who are in the early stages of establishing their independent research careers.

PECASE winners are nominated by eight federal agencies from among researchers already being funded by those agencies. D’Andrea’s award was one of six sponsored by the Department of Defense.

D’Andrea’s specialty is control of complex systems, which he approaches by building a mathematical model of the system, in which outputs such as sensor readings and inputs such as forces are represented by mathematical equations. From this, he says, one can derive “laws” about the relationship between inputs and outputs, and these form the basis of the control system, which then can be applied to the physical world.

The project being funded by PECASE concerns the control of systems in which many machines or devices must work together to achieve a common objective. Examples range from aircraft flying in formation to automated highway systems to mirrors in space telescopes that can be deformed by hundreds of actuators to focus an image. The underlying mathematics can even be applied to the group behavior of animals and humans.

D’Andrea’s research group is highly interdisciplinary, including graduate and postgraduate researchers in applied mathematics, computer science, electrical and computer engineering, mechanical and aerospace engineering, and theoretical and applied mechanics. “We believe that a multidisciplinary approach is the only viable method for exploiting the ever-accelerating advances in technology to create the next generation of autonomous, high-performance and intelligent systems,” D’Andrea said.

—Bill Steele, Cornell News Service

NEW CHAIRMAN IN TOWN

Peter C. Meinig, a 1962 graduate of Cornell University in mechanical engineering and chairman and chief executive officer of HM International Inc. of Tulsa, Okla., was unani-

mously elected chairman of the Cornell Board of Trustees at its first meeting of 2002 in New York City, Jan. 25.

Meinig’s one-year term begins July 1. He will succeed Harold Tanner, a 1952 Cornell graduate who has served as chairman since 1997.

“I consider it an honor and privilege to be asked to serve as chairman ... succeeding Harold Tanner, who has distinguished himself in this role for the past five years,” Meinig said. “We are fortunate to have a dedicated and hard working board, which provides thoughtful policy guidance to the university. I look forward to working with President Hunter Rawlings, who is a visionary and an innovative leader. We have a world-class faculty and 19,000 of our nation’s best students. With the assistance of our alumni and the other members of the Cornell community, we will work together to enhance our mission of teaching, research and service, thereby ensuring Cornell’s position as one of the world’s truly outstanding universities.”

“It has been a great pleasure for me to work with Pete during these past seven years, and I look forward to his chairmanship of our board of trustees,” Cornell President Hunter Rawlings said. “He is a capable and experienced board member with a great love for Cornell and an ability to get things done.”

HM International is a privately held management/holding company of various manufacturing and service businesses. Meinig also serves as chairman of PGI International Ltd., of Houston; chairman of Ninth House Inc., of San Francisco; chairman of eCornell Inc.; and director of Williams Communications Group Inc., of Tulsa. As trustee-at-large, Meinig currently chairs the board’s executive committee and serves on the board membership and alumni affairs and development committees.

Meinig has served as the regional vice president of the Cornell Society of Engineers for the Southwest/Mountain Region and served as vice chair of the Engineering College Campaign that concluded in 1995. He sat on the administrative board of the Cornell University Council from 1990 to 1992 and continues to be a member of the council. Meinig and his wife, Nancy Schlegel, a 1962 graduate of the College of Human Ecology, helped revitalize the Parent’s Fund and served as co-chairs in 1987–88. They were the National Tower Club co-chairs for fiscal years 1993 and 1994. The Meinigs remain active on the Cornell campus through their support of the Meinig Family National Scholars Program.

—David Brand, Cornell News Service

We will work together to enhance our mission of teaching, research and service, thereby ensuring Cornell’s position as one of the world’s truly outstanding universities.

Peter Meinig (left), new chair of the Cornell Board of Trustees, spent a day in March touring the College of Engineering and meeting with faculty, staff, and students.
Rhythm of the Moons
What makes Jupiter’s tiny moons orbit the way they do?

In what could be the ultimate in fast-forward, Cornell University planetary scientists have used one of the world’s most powerful computing clusters to simulate motions of the small moons of Jupiter over a one billion-year epoch. From this, the researchers have learned how the tugs and pulls of the sun and planets—even from hundreds of millions of miles away—shake out the permanent moons of the giant planets from those that get tossed away.

In a three-month computing marathon, the Velocity I cluster at the Cornell Theory Center was able to mimic cosmic conditions over eons that would cause physical perturbations in the moons of Jupiter. The 256-processor cluster consists of 64 Dell PowerEdge servers, each with four Intel Pentium III Xeon 500 Mhz processors and running Microsoft Windows 2000 operating system. The astronomers “installed” hypothetical moons around Jupiter, programmed in the physical perturbations that would likely occur in a simulated scenario, and mimicked cosmic conditions for a period of one billion years.

In addition to finding how the sun’s gravity pulls the moons from their orbits, the researchers are studying why the orbits of the tiny moons are tightly clumped together. The astronomers have deduced that the moons were once larger objects broken apart by cometary or asteroidal collisions.

Burns says this research is an early step to understanding how the giant planets were formed. “This research is similar to how archaeologists—by investigating what remains—reconstruct the birth and death of civilizations,” says Burns. “As planetary scientists, we have a comparable opportunity to decipher the origin of giant planets by interpreting the orbital distribution structure of irregular satellites that still orbit their planets. We hope to use the observed distribution to start to unravel the formations of the planets themselves.”

http://www.news.cornell.edu/releases/Nov01/Burns.bpf.html

—Blaine P. Friedlander Jr., Cornell News Service

PHOTON-POWER FOR THE FUTURE

Bacteria-sized, photon-powered nanodevices someday will operate inside cells in the human body as well as almost anywhere in the outside world, said Carlo D. Montemagno, associate professor of biological and environmental engineering, at the annual meeting of the American Association for the Advancement of Science (AAAS) in February.

But please don’t call the tiny things “nano-choppers,” pleaded Montemagno, who currently is on leave from Cornell at the University of California, Los Angeles.

Montemagno’s presentation, “Biomolecular Motors: Engines for Nanofabricated Systems,” was the final and most futuristic in a daylong nanotechnology seminar, “From Computer Elec-
During the AAAS seminar, Montemagno played a microscope video clip demonstrating the first biomolecular motors with rapidly spinning metal propellers, a landmark achievement that was made in his Cornell lab and reported in November 2000. The devices’ resemblance to helicopters has haunted Montemagno ever since, he said, showing a cartoon from a European publication that depicted a medical helicopter bombing a cancer cell with tiny packets of medicine. “This is not about nanochoppers,” Montemagno insisted.

http://www.bee.cornell.edu/faculty/faculty-bio.cdm11.htm

— Roger Segelken, Cornell News Service

PLUMBER’S NIGHTMARE

Using nanoscale chemistry, researchers at Cornell University have developed a new class of hybrid materials that they describe as flexible ceramics. The new materials appear to have wide applications, from microelectronics to separating macromolecules, such as proteins.

What is particularly striking, even to the researchers themselves, is that under the transmission electron microscope (TEM) the molecular structure of the new material—known as a cubic bicontinuous structure—conforms to century-old mathematical predictions. “We in polymer research are now finding structures that mathematicians theorized long ago should exist,” says Ulrich Wiesner, associate professor of materials science and engineering at Cornell. The structure of the new material appears so convoluted that it has been dubbed “the plumber’s nightmare.”

Wiesner’s research group was attracted to chemistry on the nanoscale (a nanometer is equal to the width of three silicon atoms) by the perfect, symmetrical shapes that are found in nature. An often-cited example is the elegant structure of diatoms—unicellular algae whose shell walls are made of perfectly replicated silica pores. Nature’s key to this replication, says Wiesner, “is perfect shape control governed by self-assembly of organic components directing inorganic materials’ growth.”

The Cornell researchers can do this by controlling the “phases,” or molecular architectures, of the material just by controlling the mix of the polymer and the ceramic. The material goes through several shifts in shape, from cubic to hexagonal to lamellar—thin and plate-like—to inverse hexagonal and inverse cubic.

“The resulting material has properties that are not just the simple sum of polymers plus ceramic, but maybe something quite new,” says Wiesner. It is transparent and bendable but with considerable strength, and unlike pure ceramic will not shatter. In one form the hybrid material is an ion conductor (an ion is an electrically charged atom), with great promise as highly efficient battery electrolytes. There also is the possibility that the new material could be used in fuel cells.

Because the material has pores only 10 to 20 nanometers across, Wiesner is collaborating with Larry Walker, Cornell professor of biological and environmental engineering, to see if the material can be used to separate live proteins.

http://www.ccmr.cornell.edu/~uli/

— David Brand, Cornell News Service

Read more on these and other research projects at www.engineering.cornell.edu/news.

Just don’t call them nano-choppers.
The Science of Snow

There’s a new way to predict avalanches in the Rockies, and it all started with a hamburger press in Ithaca.

The first avalanche Michel Louge ever saw came barreling out of the Rockies near Bozeman, Montana, rushed over a small shack that was affording him some protection, and stopped right at his feet, burying him to his knees.

“It was astounding,” he said. “It looked like the mountain had melted.”

A professor of mechanical and aerospace engineering at Cornell, Louge was in the Bridger Bowl ski area, where snow scientists Jimmie Dent and Ed Adams from Montana State University keep an avalanche observation post. Their shack, consequently, contains computers, amplifiers, binoculars, shovels, sun block, and ski wax. It also contains scientists, most of them wearing portable transmitters in case they get buried in their work.

In the avalanche corridor of the ski resort’s back forty, Louge was testing a new capacitance sensor that he’d designed—partly in his own garage and partly in the alcove of Cornell’s Rhodes Hall, where he sheltered from the wind while pressing wads of snow together with a store-bought hamburger press.

He’d been approached in June 1993 at a conference in Charlotte, Va., by a colleague with an interesting idea. Prof. Rand Decker had heard of Louge’s work using sensors to measure particle concentration in gas-fluidized beds, not to mention his expertise in granular flows (concrete or sand, for example), which behave like liquid when poured down a chute.

A civil engineer at the University of Utah, Decker was thinking of snow packs, high in the mountains, tearing loose from their foundations. Tons of snow rush out of the high ground and bury skiers, snowmobile riders, and occasionally scientists—not to mention railroad tracks and highways. Salt Lake City’s stretch of the Rockies, close to the site of the winter Olympics in the Wasatch Mountains, is among the most avalanche-prone in the world.

Decker’s question: could Louge develop a sensor to measure the density of snow and help detect the possibility of an avalanche?

“I’m glad he didn’t approach me in the winter,” Louge admitted. That gave him a chance, before snow fell in Ithaca, to consider the idea. By the time winter arrived in Central New York, he was convinced that he could do it, but Louge realized he would need to create instruments to measure the white stuff accurately. The hamburger press was a good starting point, but he then assigned Cornell technician Stephen C. Keast the task of creating the first ever, scientific snow-press. Louge focused on developing instrumentation that would record the properties of a snow sample in the press.

To test the device on Western-style snow—twelve feet deep, high, dry, and dangerous—Louge found himself traveling to Montana, Utah, and Switzerland, where snow scientists strap on skis to go to work, and the tools of the trade include howitzers and hand grenades. These specialists, Louge explained, ski above an avalanche ridge and lob an avalanche trigger downhill. If a large chunk of the snow pack is dislodged, that’s a good day at the office.

For much of history, their work has included the use of a shovel. A series of “academic pits,” sometimes ten feet deep, are dug into avalanche areas to provide an observable bank of snow. Scientists look for the “weak layer,” where metamorphosed snow crystals have lost an ability to support the weight of snow above. This is where a snow pack will sheer and release, creating an avalanche.

Shoveling may never become obsolete, but the capacitance sensor might help lower the risks for snow and ice scientists. The sensor, mounted on a long pole and attached to a handheld computer, can measure depth, temperature, and density of snow in a fraction of the time it takes to dig an observation pit. “Because it’s quicker, it’s also safer,” Louge explained. “People will not have to stay on an avalanche ridge longer than they need to.”

Bob Foster, president of Capacitec Inc., the Massachusetts company that will produce and market the device thanks to a Small Business Innovation Research Grant from the Army Research Office, was impressed by the combination of skills the professor brought to the project. “He blows me away as a theorist,” said Foster, “but then, he’s an outdoorsman, too. I think that’s very rare.”

Louge, however, reserves his awe for his colleagues in the field. “These guys go up to 9,000 or 10,000 feet,” he says of scientists and patrolmen who ski the high ridges just to get to work. “It’s freezing and the wind is howling and they carry explosive charges and ski right into the danger zones.”

Now, thanks to Louge, they can spend a little less time there.

—Tony Hall