In previous issues of this magazine, we’ve indicated that a key guiding principle for charting new directions in research is one of thinking strategically and acting collaboratively. That is, we endeavor to focus on important areas of technology and, in each area, to establish a critical mass of intellectual and physical resources that enable us to have a significant impact on the field. This approach has served us well in areas such as nanotechnology, wireless communications, high-performance computing, and the mitigation of natural hazards. In all but one case, we were fortunate to have been able to launch our efforts from an existing base of excellent faculty. The one exception is in bioengineering.

The term bioengineering encompasses many activities, ranging from the development of medical devices and processes to the remediation of organic wastes. Five years ago, we recognized the need to establish a presence in the field, but to do so, we would have to begin from a virtually nonexistent base. One of the issues that had to be addressed was whether to move in the direction of establishing a separate department, or to integrate activities within existing departments. For two reasons, we adopted the second approach.

One reason was related to the reality of limited resources and the fact that establishment of a new department would adversely affect existing departments. The second reason related to our belief that a bioengineer is first and foremost an engineer. Accordingly, it was felt that our students would be better served by becoming well grounded in one of the traditional engineering disciplines and by appropriately integrating biological/medical issues. For many years this premise has been affirmed by corporations rooted in biomedical technologies through their preference for recruiting graduates with strong backgrounds in fields such as chemical, electrical, or mechanical engineering, with the understanding that they, the corporations, would provide the requisite biomedical background. The same inputs are received today from a range of corporate sectors, such as medical electronics, orthopedics, and pharmaceuticals.

Thus far our strategy has worked well. Within three of our departments (Aerospace and Mechanical Engineering, Chemical and Biomolecular Engineering, and Civil Engineering and Geological Sciences), bioengineering has emerged as a major thrust. Significant activities are also under way in our other departments, Electrical and Computer Science and Engineering. Collectively, research encompasses a broad range of topics such as orthopedic implants, biomaterials, reconstruction of medical images, and development of a host of diagnostic tools linked to microfabrication technologies. Many of these activities were described in a previous issue of this magazine (Vol. 4, No. 1, pp. 18-39, 2002), and in this issue we are pleased to report on more recent endeavors relating to research at the intersection of bio and nano technologies, devices for the rapid detection of biotoxins, improvements in radiation therapy, and establishment of a new Center for Microfluidics and Medical Diagnostics. Consistent with our commitment to excellence in both education and research, all of these activities involve extensive participation of undergraduate and, in some cases, high school students.

In this issue of Signatures, we also describe a major change to our first-year chemistry sequence, one that recognizes the importance of advances in molecular and cellular biology to technologies of the 21st century. Effective this past academic year, all of our first-year engineering intents must take a second-semester chemistry course that is strongly linked to molecular biology. We believe this change will better prepare our students for the future, and we are only the second college of engineering in the United States to have implemented such a requirement.

We hope you find the contents of this issue informative, and as always, we welcome your comments.

Frank P. Incropera
Matthew H. McCloskey Dean of Engineering
H. Clifford and Evelyn A. Brosey Professor of Mechanical Engineering
Evidence of Things Not Seen
Nanobiotechnology at the University of Notre Dame

It’s a Small World
Integrating Biology into the Engineering Curriculum
The worthiness of a field of study

or the benefit of combining technologies

— such as the integration of nanoscience and biotechnology —

becomes most apparent when engineers explore

how it can be applied across many disciplines

to improve the quality of life.
In the first volume of his journal *The Writings of Henry David Thoreau*, in the letter describing “A Week on the Concord and Merrimack Rivers,” the philosopher, author, and naturalist said, “The newest is but the oldest made visible to our senses.” His reflection is as true now as it was in 1849. People perceive truth from what they see, and from what they cannot see they extrapolate, reason, trust, or fabricate. When they are finally able to visualize an item or idea, it is not necessarily “new.” More than likely it was there all along. Perhaps this is why researchers continually look for ways to see beyond the immediately visible. They explore, observe, and record the “invisible,” so that they can better understand what they are able to see and then begin to use that knowledge.

Such is the case with the nano- and biosensor research being conducted at the University of Notre Dame, as some of the “invisibles” that faculty in the College of Engineering have been exploring involve activities on the nano scale. Nanotechnology describes the process of creating new structures or systems atom by atom. It focuses on materials whose components exhibit novel properties — physical, chemical, and biological — due to their size: from a single nanometer to 100 nanometers. And, its potential is enormous. According to the June 2004 issue of *Physics Today*, “Scientists predict that applications of nanotechnology will go far beyond their current uses — in sunblock, stain-resistant clothing, and catalysts — to, for example, environmental remediation, power transmission, and disease diagnosis and treatment.” Because researchers and investors continue to envision a world with molecule-sized clot-breaking machines and drug-delivery devices, the annual worldwide investment in nanotechnology has exceeded $3.5 billion.

Another “invisible” that’s gained impetus in the last few years is biotechnology, which uses living organisms and their by-products to develop or improve plants, animals, and products for specific purposes. Early “biotechnology” included plant and animal breeding techniques and the use of yeast in making beer, bread, and wine. Today, biotechnology includes manipulating genes to tailor new types of living cells for emerging environmental and industrial needs.

Researchers suggest that the potential of the interface of these two key technologies, which has proven to be truly multidisciplinary, lies in the fact that nanotechnology operates at the same level — the molecular or subcellular scale — as biological processes. This new field, which some call nanobiotechnology, integrates elements of nanotechnology and biotechnology in order to develop solutions for some of the problems facing society today, including challenges in the medical, information technology, security, and aerospace industries, as well as in environmental protection.
One of the hottest topics in nanobiotechnology is its potential for medical applications, especially in the areas of drug delivery and diagnostic devices. Agnes E. Ostafin, assistant professor of chemical and biomolecular engineering, believes that living cells themselves may provide the best clues for developing materials suitable for use as biosensors or drug-delivery vehicles. “One of the projects we’ve been working on,” she says, “involves red blood cells.” These cells are attractive for research because they have a specific function: They transport oxygen through capillaries to cells. To do this, they have to be flexible enough to change shape, fitting within different sized capillaries as they travel through the body.

According to Ostafin, the red blood cells of diabetics or people with sickle cell anemia are unusually rigid. They can’t bend or change their shape easily, which can lead to blood clots or strokes. “In our studies,” she says, “we’ve been paying special attention to the proteins within cells. What gives some cells their shape — red blood cells in this case — is a meshwork of proteins.” Ostafin explains that this meshwork responds differently to different biochemical signals. Under certain circumstances, the mesh opens, allowing interaction with the triggering chemical. At other times, the mesh remains closed.

“Once we understand the situations which make this mesh open and close,” says Ostafin, “we can begin to apply that knowledge to create synthetic meshes. Or perhaps we could deliver a drug that would help a cell regulate its sensing of chemicals, so it would begin to function more normally. We could develop synthetic cells (or bags) that could carry a drug to a selected site in the body and then, using the concept of opening and closing the meshwork, design it to interact with the chemical conditions of a specific disease. These are all possibilities, but first we must understand the physical biochemical reactions that are taking place.”

Another project directed by Ostafin involves the self-assembly of nanoshells. These shells, whose hollow cores are approximately 100 nanometers in diameter (the size of one human gene), are so small that they do not behave as expected: Semiconductor materials a few nanometers large begin to emit light, metals become catalytic, and interfacial chemistry dominates kinetics and particle dynamics. “Our goal is to find out how we can learn to control molecular assembly,” says Ostafin, “to make a molecule brighter or to control a chemical reaction, possibly preserving it within a solvent-filled core — so it occurs more efficiently.”
Ostafin and her team have many questions to answer, but the first step, she contends, always involves basic studies. Working with several graduate and undergraduate students, Ostafin has shown that dye molecules placed inside nanoshells glow brightly. “We’ve been working on this project for some time and have developed many different recipes to make a variety of particles,” she says. “We believe they could prove to be useful mobile sensors, perhaps even tracking cancer in the body.”

According to Ostafin, coating the outer surface of the nanoshells with other chemicals helps the structures evade the body’s immune system while targeting specific tissues. “Once the shells have attached to the target,” she says, “they ‘glow,’ making the targeted molecule or cell much easier to see for diagnostic purposes. At that point we can consider tailoring the disassembly of the nanoshells, so that they can either deliver a therapeutic payload to the site or signal physicians when the biochemical environment near the targeted tissue is abnormal. This additional information would improve a physician’s ability to design a treatment regime or track a patient’s progress.”

Ostafin stresses that her team is not developing “a cure for cancer,” although she is excited about the potential medical applications of this research. “The most important thing to remember about the nano- and bioengineering efforts at Notre Dame is that there’s scientific merit in the work that’s occurring throughout the college,” she says. “When we understand a system, and why and how it works, that’s when we’ve really opened the door for discovery and innovation.”

In fact, a basic understanding of biotechnology is the focus of a laboratory course elective for seniors that Ostafin will be introducing this fall within the Department of Chemical and Biomolecular Engineering. Ostafin believes the lab experience will give students hands-on opportunities to use the tools of biotechnology, allowing them to contribute more meaningfully to this growing field.

As part of a project aimed at creating an early cancer detection nanoprobe, Susan Fath, a rising junior in the Department of Chemical and Biomolecular Engineering, studies the kinetics of the chemiluminescent reaction between luminol and peroxide. She is working with Agnes E. Ostafin, assistant professor of chemical and biomolecular engineering, and graduate student Philip A. Wingert.
Nanoscience research was not new to the College of Engineering when the Center for Nano Science and Technology was established in 1999. In fact, the creation of the center culminated 15 years of faculty research and development in this area. Led by the Department of Electrical Engineering since its inception, the center continues to explore the fundamental concepts of nanoscience in order to develop unique engineering applications. It integrates research in biological, molecular, and semiconductor-based nano-structures; device concepts and modeling; nanofabrication and characterization; and information processing architectures and design.

Activities in the center include multidisciplinary projects in Quantum-dot Cellular Automata, a paradigm for transistorless computing pioneered at the University; resonant-tunneling devices and circuits; photonic integrated circuits; quantum transport and hot carrier effects in nanodevices; optical and high-speed nano-based materials, devices, and circuits; the role of non-equilibrium thermodynamics in influencing the properties of nanodevices; and the interaction of biological systems with semiconductors.

“One of the current projects,” says Wolfgang Porod, center director and Freimann Professor of Electrical Engineering, “focuses on developing a new generation of parallel processing chips that can capture both visible and invisible — infrared — light. It’s very exciting because we’re using the mammalian retina, specifically the way the sensors in an eye are connected, as a model for the vision sensors which will be placed on these chips.”

The project is one of only 16 to have received a grant in 2003 from the Multidisciplinary University Research Initiative (MURI) program. Sponsored by the Department of Defense, the MURI program is designed to encourage the development of multidisciplinary teams from several universities whose efforts address more than one traditional science and engineering discipline critical to national defense. Partnering with the University’s Center for Nano Science and Technology on the MURI project are the Vision Research Laboratory and the Nonlinear Electronics Laboratory of the University of California at Berkeley, the Molecular Vision Laboratory at Harvard University, the Signal Processing System Design Laboratory at Notre Dame, and Pázmány Péter Catholic University in Budapest, Hungary.

Porod and the MURI team are clear; they are not “inventing” a parallel processing chip. “That’s been done,” says Porod. “By employing the concept of cellular neural/nonlinear networks, image acquisition and data processing on the same chip at the same time has already been accomplished by researchers other than those at Notre Dame. The challenge with the most recent generation of parallel processing chips, and the problem we are addressing, is that it is difficult for the current chips to ‘see’ different colors at high speeds. Another concern is that they can’t detect infrared light, which is useful in a variety of applications.”

According to Yih-Fang Huang, professor and chair of the Department of Electrical Engineering, a number of systems — including target detection, navigation, tracking, and robotics — rely upon information beyond the visible spectrum, such as ultraviolet rays, infrared rays, and radio waves. “The military certainly has a great interest in detecting infrared light,” says Huang, “but there are many civilian uses for this research as well, including law enforcement and medical applications.”
The team describes the project as an example of the convergence of nanotechnology, biotechnology, and information technology, but it is more importantly a project designed to solve a vision problem: developing sensors for parallel processing chips that will detect infrared light, which is why the team is modeling the connections within the eye.

A mammalian retina contains millions of light-sensitive cells called rods and cones. Rods are sensitive to dim light but cannot distinguish wavelengths. Cones come in three types, which respond to short, middle, and long wavelengths, respectively. All of the cones are used to capture light, after which electrical signals are sent to the brain, where they are organized and interpreted as images. “Obviously, the eye cannot sense infrared light,” says Patrick J. Fay, associate professor of electrical engineering, “but because of the way it works, it makes great sense to use the eye as a model for the development of vision chips with nanoscale multispectral sensors.”

“Using nanotechnologies such as electron beam lithography, atomic force microscopy, and scanning-tunneling microscopy,” says Gary H. Bernstein, “we can fabricate these bio-inspired sensors so that they function comparably to the cones in a retina.” Then the sensors, tens of thousands of nanoscale antennae, will be placed on a silicon chip to assist in the acquisition and processing of infrared images.

A multidisciplinary effort, the Center for Nano Science and Technology brings together faculty from many departments across campus. They include:

**Department of Electrical Engineering**
Gary H. Bernstein, professor
Arpad Csurgay, visiting faculty
Patrick J. Fay, associate professor
Douglas C. Hall, associate professor
Debdeep Jena, assistant professor
Thomas H. Kosel, associate professor
Craig S. Lent, professor
James L. Merz, professor
Alexander Mintairov, research faculty
Alexei Orlov, research faculty
Wolfgang Porod, center director and Freimann Professor
Alan C. Seabaugh, associate director of the center and professor
Gregory L. Snyder, associate director of the center and professor
Huili (Grace) Xing, assistant professor

**Department of Chemical and Biomolecular Engineering**
Agnes E. Ostafin, assistant professor

**Department of Chemistry and Biochemistry**
Thomas P. Fehlner, Grace-Rupley Professor
Holly V. Goodson, assistant professor
Gregory V. Hartland, associate professor
Paul W. Huber, professor
Marya Lieberman, associate professor
Olaf Wiest, associate professor

**Department of Computer Science and Engineering**
Jay B. Brockman, associate professor
Jesus A. Izaguirre, assistant professor
Peter M. Kogge, Ted H. McCourtney Professor

**Department of Physics**
Malgorzata Dobrowolska-Furdyna, professor
Jacek Furdyna, professor
Boldizsar Janko, assistant professor

For more information on the center, its facilities, personnel, and research initiatives, visit [www.nd.edu/~ndnano](http://www.nd.edu/~ndnano).
Although hundreds of security efforts have risen in the wake of 9-11, this particular project of Alan C. Seabaugh, professor of electrical engineering and associate director of the Center for Nano Science and Technology, began with a call for proposals in 1999, when the United Engineering Foundation requested papers on the development of anti-terrorist technology. Seabaugh’s idea was one of the four selected from a total of 920 proposals. His concept focused on the creation of a handheld biotoxin analyzer that could be used at potentially contaminated sites, such as the aftermath of a terrorist attack or an industrial accident.

Instead of using a light source to illuminate a toxin, which is a traditional way of “seeing” dangerous substances, Seabaugh’s expertise in nanoelectronics led him to suggest using microwave reflection. The use of microwaves would provide the same accurate measurements as the typical optical method but allow the finished device to be much smaller than other devices, possibly the size of a credit card.

Working with graduate students Wei Zhao, Srivatsan Srinivasan, and Qing Liu, Seabaugh designed a semiconductor chip that featured micromachined silicon waveguides through which fluids would travel. The same channels that conducted the fluid would guide the electromagnetic waves.

Completing the requirements for the original proposal in June 2004, Seabaugh and his team demonstrated a prototype of the concept. “The next step ... whether planning to use this device as an attack detector or as a medical diagnostic device,” says Seabaugh, “is to develop microwave tags for specific toxins or chemicals and create a database on the chip for each of those toxins. This type of device could eventually assist in the safe and targeted deployment of personnel and resources to specific sites with detailed information about the type and level of toxin involved. It could make emergency efforts much more effective.”

For more information on the biotoxin analyzer, visit www.nd.edu/~nano/projects/chembio.html.
Aerospace engineers track the wind and measure its velocity as it whips through cities. In today’s environment, city officials and emergency teams also need this type of information to predict the path of pollutants and assess their toxicity.

An ultrasonic anemometer is a device that is currently used to provide three-dimensional wind measurements. But the anemometers available today are too large to obtain the small-scale measurements of velocity and temperature that would be required for many fluid dynamics and security applications. For this reason Scott C. Morris, assistant professor of aerospace and mechanical engineering, is developing the first microsonic anemometer.

Morris’ microsonic anemometer, proposed to be less than 1/30 the size of current devices, will record turbulent flows with up to 60 times the resolution of other anemometers. This will provide better information for the modeling of air flows and chemical dispersion throughout a city. “For example,” says Morris, “a chemical detector on a rooftop may alert officials to danger, but alone it cannot provide information on where a toxin came from or predict where it’s going. The effective modeling of cityscapes, using the information provided by a series of microsonic anemometers, would offer the predictive capability necessary to ensure the safety of a city’s inhabitants.”

Morris is working with Gary H. Bernstein, professor of electrical engineering and expert in nanolithography, who will fabricate the capacitor micro-machined ultrasonic transducer (CMUT) portion of the anemometer with a 30-micron diameter, the width of a human hair. He has also developed a relationship with a dispersion modeling team from the University of Utah that will assist in the testing phase of the project.

Once produced, Morris envisions testing the anemometer with its CMUT probe in places like Oklahoma City, where officials have already instrumented the city with ultrasonic anemometers. According to Morris, “Oklahoma City is an ideal location because it’s flat. We can measure the approach of the wind, its velocity, and its path very easily. And, because of their smaller size, officials could economically place more of the microsonic devices throughout the city to obtain more data.”

The microsonic anemometer proposed by Scott C. Morris, assistant professor of aerospace and mechanical engineering, will be 1/30 the size of currently available ultrasonic devices.
In addition to working on drug-delivery and diagnostic devices, Ostafin is collaborating with Jeffrey W. Talley, assistant professor of civil engineering and geological sciences; Michael D. Lemmon, professor of electrical engineering; Patricia A. Maurice, professor of civil engineering and geological sciences and director of the Center for Environmental Science and Technology; and Lloyd H. Ketchum, associate professor of civil engineering and geological sciences, on an environmental sewage treatment project.

"In most major cities in the midwest and northeastern parts of the country, and on the west coast," says Talley, "combined sewer overflow (CSO) is an important challenge. In these cities storm and sanitary sewers are often connected, so when there’s a storm, raw sewage and storm runoff can mix together. Cities usually divert the excess sewage into an open stream or river, but because it is untreated, this poses a threat to public health. The team has proposed using an embedded wireless sensor network to detect and control the CSO problem.

As part of a recently funded recommendation to the Indiana 21st Century Research & Technology Fund, Talley and team will develop the network of embedded microprocessors using off-the-shelf components, EmNet. The network would supply data in real-time to a main base which would monitor the sewer infrastructure in municipalities and provide data that could be used to design additional remediation strategies.

Ostafin’s role in the project is to help the team design sensors that would attach to the microprocessors. "It's a challenge," says Ostafin, "because it offers a different scale of detection. In many of the other projects we’re working on, we are concerned with detecting one chemical or type of bacteria. In this case, there will be many types of bacteria ... good and bad ... floating through the system. Our challenge is to be able to detect specific types of bacteria without swamping the sensor." Other challenges include the fact that the sensors must be strong, yet almost disposable, and able to withstand six to 12 months in a sewer. They must also be lightweight and very sensitive.
They may not be as humorous as David Letterman’s Top 10, but these engineering achievements have literally changed the world. According to the National Academy of Engineering, the 20 most significant accomplishments of the last century were:

1. Electrification
2. Automobile
3. Airplane
4. Water supply and distribution
5. Electronics
6. Radio and television
7. Agricultural mechanization
8. Computers
9. Telephone
10. Air conditioning and refrigeration
11. Highways
12. Spacecraft
13. Internet
14. Imaging
15. Household appliances
16. Health technologies
17. Petroleum and petrochemical technologies
18. Laser and fiber optics
19. Nuclear technologies
20. High-performance materials

As far-reaching as past achievements have proven to be, the integration of nano- and biotechnologies holds even greater promise in the way it will affect life in the 21st century.
it's a small world
integrating engineering and biology
When Walt Disney introduced “it’s a small world,” it was part of the Pepsi-Cola exhibit at the 1964 World’s Fair. Located at Flushing Meadows Park in Queens, New York, the fair featured more than 140 pavilions on 646 acres and offered dual themes: “Peace through Understanding” and “Man’s Achievements on a Shrinking Globe in an Expanding Universe.” Anyone who attended the 1964 fair and everyone who’s ever taken a child to a Disney park knows the “small world” song. One of its most memorable phrases is, “There’s so much that we share that it’s time we’re aware; it’s a small world after all.” In those words songwriters Richard M. and Robert B. Sherman captured the essence of Disney’s vision for the exhibit and one of the fair’s themes. Forty years later, “it’s a small world” still emphasizes the similarities that people around the world share, the things that make individuals from diverse countries and cultures more alike than different.

To the faculty in the College of Engineering, there is an even more basic denominator, one commonality that must be explored and taught at the undergraduate level if the world is to continue to see the kind of technological progress in the 21st century that it witnessed throughout the 20th: life. Every living organism employs similar biological processes to create and sustain life. Better understanding the molecular biology of those processes, being able to track them, model them, and some day duplicate them, will enhance the quality of life for all the inhabitants of this “shrinking globe.”
What James D. Watson and Francis H.C. Crick found as they researched, and eventually solved, the structure of deoxyribonucleic acid (DNA) was that “the secret of life is complementarity.” Ironically, it was as true of their collaboration as it was of the double helix design they unveiled in 1953. Their teamwork, as one colleague put it, was “that of resonance between two minds — that high state in which 1 plus 1 does not equal 2 but more like 10.”

They shared, as Crick said, “a mad keen to solve the problem (the DNA structure).” The complementarity they discovered between the adenine-thymine pair and guanine-cytosine pair in the DNA ladder echoed the synergy of their partnership. For example, although Crick championed the complementarity concept, it was Watson who fit the final pieces of the puzzle together. When outlining their findings in the journal *Nature*, they were also in agreement as to whose name would come first — a flip of a coin was to determine the order. Finally, in closing that first groundbreaking article, Watson and Crick served up a British understatement that was complementary to their well-known brashness. They wrote, “It has not escaped our notice that the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material.”

Their discovery, one of the most significant scientific breakthroughs of the 20th century, opened the door for a better understanding of the interactions between molecules in living systems and, thus, a better understanding of life. In 1962 Watson and Crick received the Nobel Prize in Physiology or Medicine “for their discoveries concerning the molecular structure of nucleic acids and its significance for information transfer in living material.” They shared the honor with Maurice Wilkins of London University.

After their discovery, Watson joined the faculty of Harvard University and then accepted a position first as associate director and then as director of the National Institute of Health’s fledgling Human Genome Project. In 1992 he joined the Cold Harbor Laboratory in Cold Harbor Spring, N.Y. Today, he is chancellor of the Watson School of Biological Sciences at the laboratory. Crick focused his efforts on the synthesis of proteins and the genetic code as a fellow at the Salk Institute for Biological Studies in San Diego, Calif. He served as the Distinguished Professor and President Emeritus of the Kieckhefer Center for Theoretical Biology at the institute until his death on July 28, 2004.

Almost all aspects of life are engineered at the molecular level, and without understanding molecules we can only have a very sketchy understanding of life itself.

— Francis H.C. Crick
The integration of engineering with life sciences ... from molecular to ecosystem levels ... is a natural process. As society's innovators engineers have always been the “builders,” the ones who say “what if” and then work to make a product, service, or situation better. At times that means advancing existing technologies to better meet a need. Often it means pioneering new technologies.

Some may argue that with the cracking of the structure of deoxyribonucleic acid (DNA) in 1953 by James D. Watson and Francis H.C. Crick, the field of molecular (or cellular) biology is hardly new. Others would counter that the most dramatic benefits of that particular achievement are yet to come and that the leaders of the next technological revolution will be today's engineering undergraduates as they explore and define the field of bioengineering.

“Molecular biology,” says Mark J. McCready, chair of the Department of Chemical and Biomolecular Engineering, “is one of the most profound revolutions in science and technology in the last 20 years. Two decades ago you couldn’t effectively engineer the life sciences, because you couldn’t write equations to accurately describe the fundamental processes of living systems. It’s only been in the last 20 years that engineers and biologists have been able to quantify events at the cellular level.”

This understanding of living organisms and the chemical operations that sustain life is pivotal to being able to engineer biological solutions for a variety of applications, including medical diagnostics; pharmaceuticals and drug-delivery methods; “biological” tissue for organ implants; natural resource conservation; water quality and treatment; soil enrichment; forest management; food growth, safety, and preservation; and biodegradable products. The number and scope of possible applications are as varied as the spectrum of life.

Yet, most engineering programs do not require its students to take biology courses. In fact, the Massachusetts Institute of Technology may be the only other university in the country that requires all of its engineering students to take a chemical biology course.

“Before researching ways to integrate biology into our engineering curriculum, we formed a faculty committee,” says McCready. The curriculum committee — Jesus A. Izaguirre, assistant professor of computer science and engineering; Agnes E. Ostafin, assistant professor of chemical and biomolecular engineering; Glen L. Niebur, assistant professor of aerospace and mechanical engineering; Ken D. Sauer, associate professor of electrical engineering; and Jeffrey W. Talley, assistant professor of civil engineering and geological sciences — found that a few institutions had been modifying their chemistry courses to include aspects of chemical biology, but only for chemical and biomedical engineering majors.

“We didn’t want to cut chemistry completely; it’s a fundamental aspect of engineering,” says McCready. “On the other hand, we believed there was a distinct advantage in requiring all engineering undergraduates to experience a course in molecular biology. And, we’re confident that the chemistry-molecular biology sequence we have designed, like our engineering business program, will differentiate our graduates from students at other institutions.”

The new year-long sequence requires undergraduates to take a traditional course in chemistry during the first semester of the freshman year. The molecular biology course is offered during second semester. Working closely with McCready to develop the second course in the sequence were A. Graham Lappin, professor of chemistry and biochemistry, and Francis J. Castellino, the Kleiderer-Pezold Professor of Chemistry and Biochemistry and Director of the W.M. Keck Center for Transgene Research. “Faculty in chemistry and biochemistry were instrumental in helping us achieve our goals,” says McCready. “Frank Castellino, in particular, developed an incredible course for our students that will give them a solid grounding in
the biological sciences."

"Because the basic biological processes in all organisms are pretty much identical," says Castellino, "I structured the class to emphasize the unity of chemical, physical, and biological sciences." In the course the evolution and assembly of macromolecules into cellular structures, as well as the interactions among cells, is stressed. Throughout the semester, students study the origins of matter. They learn the basic structure of the nucleus, as well as nucleosynthesis. They follow the synthesis of heavy elements and are introduced to stable and unstable nuclei and nuclear processes in various radioactive emissions.

Students review human pathologies, from the natural radioactivity of potassium to the variety of synthetic nuclides and how they are prepared and used in the diagnostic and therapeutic applications of nuclear medicine. They track the evolution of simple biologically relevant compounds and carbon bonding.

Castellino also introduces protein, DNA, and membrane structures to students. They review protein folding and discuss the roles of simple sugars and polysaccharides in the transport, structure, and storage of carbohydrates. Energy storage and the structure and functions of lipids are also studied.

As the course progresses, students learn the principles of pathogenesis and host-defense mechanisms, including chemical intervention for the elimination of pathogens and the development of antibiotic resistance. They study membrane fusion, as well as passive and active diffusion — mechanisms for the transport of materials into and out of cells. The transduction of sensory signals and the properties of the synapse are also covered, as are the characteristics of enzymes, enzyme inhibitors, and the properties of chromosomes.

Largely a lecture course, students have ample opportunity to debate the social and ethical issues that have followed the Human Genome Project and DNA replication. "What's most important," says McCready, "is that through this course, our students begin to understand life science fundamentals in terms of living systems. Engineering has always been effective at describing and designing systems. By establishing this link early in our curriculum, our students can build on it throughout their time at Notre Dame and see how the life sciences connect with the full range of subjects that they study."

McCready believes that this "bio" revolution, especially in the field of health care, is where the next wave of engineering undergraduates will make the largest contributions. "Engineers have created many products and processes that have had a profound impact on health care — such as drug-delivery patches and insulin pumps — but many of the developments did not rely on molecular biology. What if someone said, 'We want an artificial pancreas'? Engineers would need to develop ways to sense glucose levels, create a reservoir — with a means of filling it, and release insulin into the body without killing the patient. Or what about an artificial liver? Or a new heart, not just a mechanical pump but actual biological tissue? The point is that engineers will significantly drive the 'bio' revolution, but they cannot do so without first understanding biology. This course sequence is their introduction."

The College of Engineering also offers additional courses as electives, as well as a variety of opportunities for undergraduate research in bioengineering activities.

According to McCready, the goal of the chemistry-molecular biology course sequence is not to lay the foundation for a degree program in "bioengineering" at Notre Dame. Its purpose is to better prepare engineering undergraduates to be the leaders and innovators of tomorrow, so that they can build a better world ... big or small.
Students in the Class of 2007 were the first engineering undergraduates required to take the new course, Molecular Biology for Engineers. Nathan Stober, a chemical engineering student from Granger, Ind., says, “The course gave me insight into how biological and even nuclear processes are related to chemical reactions. It also gave me an introduction to the everyday functions of cells.”

Stober describes the course as fast-paced but very interesting. “The most important thing I learned from the course and Dr. Castellino [the course instructor],” he says, “was that a basic knowledge of chemistry is crucial to the study of almost all engineering, scientific, or medical fields.”

In addition to providing a strong base in biology for undergraduates, Molecular Biology for Engineers is proving to be a stepping stone to the wide range of bioengineering research opportunities offered throughout the College of Engineering for these first-year students, who would not normally have the opportunity to participate in hands-on research until the end of their sophomore year.

Ailis Tweed-Kent, a classmate of Stober’s and native of Pittsfield, Mass., is applying the knowledge she gained in the course to her work in the Tissue Culture Laboratory. Under the direction of Agnes E. Ostafin, assistant professor of chemical and biomolecular engineering, Tweed-Kent is studying osteoblasts, the bone cells responsible for producing calcium. “The work I’m doing here is the first step in the research process,” she says. “By observing the morphology of the cells and using chemical assays, we can gather information on their activity. When we have a basic understanding of how the cells function, then we can move to the next step in the process.”
Consider the impact they have had to date. Engineers are the dreamers and the doers. They apply the “what ifs” and make them practical and effective for commercialization. For example, at the dawn of the Industrial Revolution, engineers took the concept of power-driven machinery and set it into motion for manufacturing. In the race for space, they employed their ingenuity not only to send men and machines to the moon, but they also extended space technology to the development of hundreds of products — from wireless phones and heart pumps to the creation of new metal alloys and lightweight composite materials. It’s called technology transfer, and it’s the process through which the impact of research and development on the marketplace is maximized.

While organizations like the National Academy of Engineering (NAE), Honeywell International, NEC Foundation of America, National Science Foundation (NSF), and SBC Foundation believe that the engineers of tomorrow will continue to identify problems and find solutions — many of which will be commercialized — they are also...
The NAE, NSF, Honeywell, NEC, and SBC are not the only participants in the discussion about the future of engineering education. According to Arthur T. Johnson, professor of biological resources engineering at the University of Maryland and author of a book and several papers on biology for engineers, “the frantic rush to establish and enhance academic bioengineering programs in the United States ... may also have kept bioengineering from emerging in an orderly and thoughtful way.”

What exactly is “bioengineering”? It’s been defined by a number of people in a variety of ways. Some view it as specifically applying to medicine and health care. Others describe it as anything affecting the human organism. The National Institutes of Health defines bioengineering as “an integration of the physical, chemical, or mathematical sciences and engineering principles for the study of biology, medicine, behavior, or health. It advances fundamental concepts, creating knowledge from the molecular to the organ systems level. It develops innovative biologies, materials, processes, implants, devices, and informatics approaches for the prevention, diagnosis, and treatment of disease; for patient rehabilitation; and for improving health.” But biology also affects ecology and the environment. In fact, it is the impetus for a multitude of bio-inspired research projects across numerous fields.

Johnson believes that “all engineers these days should know something about biology.” They should have a broad understanding of biological principles, be able to apply the information known about “familiar living systems” to those of less familiar or unknown systems. They also need to be willing to work in collaborative teams, whose members offer a variety of skills and approaches.

His recommendation for a successful undergraduate engineering curriculum is one that offers “basic instruction in physics, mathematics, chemistry, biology, and engineering. Students should be able to view the full horizon of potential biological applications, from subcellular to ecological levels.” This corresponds to the approach the College of Engineering has taken in developing its new chemistry-molecular biology course sequence for undergraduates.

Sarah Bergler is a senior development engineer at Zimmer, Inc. A Double Domer, Bergler received a bachelor’s degree in mechanical engineering in 1994 and a master’s degree, also in mechanical engineering, in 2001. A leader in the design, manufacture, and distribution of orthopedic implants and fracture management products, Zimmer is located in Warsaw, Ind., less than an hour from Notre Dame.

The pace of technological innovation will continue to be rapid (most likely accelerating). The world in which technology will be deployed will be intensely globally interconnected. The population of individuals who are involved with or affected by technology (e.g., designers, manufacturers, distributors, and users) will be increasingly diverse and multidisciplinary. Social, cultural, political, and economic forces will continue to shape and affect the success of technological innovation. The presence of technology in our everyday lives will be seamless, transparent, and more significant than ever.”

As a senior Jonathan Nickels, far left, worked with Andre Palmer, assistant professor of chemical and biomolecular engineering, to develop a mechanically stable liposome, a hollow structure similar to a biological cell. Researchers believe that liposomes may offer a less toxic method of drug delivery, as they are able to target infected cells while leaving healthy tissue intact. Nickels, now a graduate student at the University of Texas, demonstrated that the shape and size of liposomes can be engineered to make them more resilient to the shear forces in the bloodstream. He published a paper on his undergraduate work with Palmer in both the Biophysical Journal and Langmuir.
College of Engineering Sponsors International Conferences

Many aspects of “academics” make living or working on or near a campus unique. In addition to the special speakers and performing arts programs that are offered, universities are places where researchers and other professionals can gather to garner new ideas for their investigations, as well as share their findings, in an effort to improve the overall state of a particular field. The University of Notre Dame and College of Engineering are proud to be part of such efforts and to serve as host for many events, including the following most recent conferences:

International Symposium on Flow Visualization

According to Roth-Gibson Professor of Aerospace and Mechanical Engineering Thomas J. Mueller, chairman of the 11th International Symposium on Flow Visualization (ISFV-11), the event — held on the Notre Dame campus from August 9 through August 12, 2004 — went very well. “The symposium originated in 1977,” says Mueller. “In fact, I went to the first symposium and then became a member of the international organizing board, working on following symposia. Our goal was to foster a global forum for communication and information exchange in the field of flow visualization.”

Recalling the years since the first symposium, Mueller stresses that flow visualization has undergone huge changes. The use of lasers for illumination and the increased use of computers for data processing and computations has led to rapid development in a number of areas. “For example,” says Mueller, “during the first symposium, there were no papers on the use of particle image velocimetry and only one or two that featured numerical solutions. Our most recent gathering featured more papers on these two techniques than all of the other techniques combined.”

Flow visualization can be applied to a variety of fields such as experimental and computational fluid dynamics, aerodynamics, mechanical engineering, chemical engineering, civil engineering, metallurgy, meteorology, oceanography, biomedical, and food and agricultural technology.

The symposium was first hosted by the Institute of Space and Aeronautical Science at the University of Tokyo. Over the years, it has been held in Germany, France, the Czech Republic, Italy, England, and the United States. “This is only the third time it has been held in the U.S.,” says Mueller, “and the first time it’s been at Notre Dame, even though the University has a long history in flow visualization.”

For more information on ISFV-11, visit www.ode-web.demon.co.uk/11isfv. For information on the history of flow visualization at Notre Dame, visit www.nd.edu/~ame.

LaVision, Inc., is an international company specializing in imaging solutions, specifically CCD-based camera and integrated optical diagnostics systems in the field of fluid dynamics. It was one of the exhibitors at the 11th International Symposium on Flow Visualization, held at the University of Notre Dame in August 2004. Representatives from LaVision’s North American subsidiary in Ypsilanti, Mich., above, demonstrate a particle image velocimetry system using a free jet.
Sponsored by the University of Notre Dame and Carnegie Mellon University, the first conference on Ethics and Changing Energy Markets: Issues for Engineers, Managers, and Regulators (EnergyEthics 2004) is scheduled for October 28 - 29, approximately 14 months after the largest blackout in the history of North America. According to the Michigan Public Service Commission’s Report, “The August 14th blackout was a wake-up call concerning the reliability of our nation’s electric grid.”

But the fact is that consumer confidence was already shaky long before approximately 50 million people — from southeastern Michigan through Ontario and northern Ohio, all the way east to New York City — found themselves without electricity. People around the country had questions about Enron, they were worried about the California energy crisis, and they were concerned about the future of the energy industry.

EnergyEthics 2004 is the first conference to convene energy experts and industry leaders in order to engage them in discussions of ethical, market, and regulatory issues as they pertain to energy generation and use. Some of the topics to be covered at the conference include the roles of engineers, managers, and regulators in establishing an operational framework that is responsive to the market as well as to the needs of consumers.

Featured speakers — from the energy industry, regulatory agencies, and academia — will explore the issues arising in the shift from regulated to competitive markets and discuss the historical applications of energy in today’s market. They include the Honorable Patrick Wood III, chairman of the Federal Energy Regulatory Commission; Vernon L. Smith, a Nobel Laureate in Economics and professor of economics and law at George Mason University; Bethany McLean, a writer for Fortune Magazine and co-author of “The Smartest Guys in the Room”; and Vicky Bailey, a partner with Johnston & Associates and former assistant secretary of energy for Policy & Intergovernmental Affairs of the Department of Energy.

Frank P. Incropera, the McCloskey Dean of Engineering at Notre Dame; Indira Nair, the vice provost for education at Carnegie Mellon University; Patrick Murphy, professor of marketing at the University and the Smith Co-director of the Institute for Ethical Business WorldWide; and Notre Dame alum Anthony F. Earley Jr., chief executive officer of DTE Energy, will also be speaking.

For more information about this conference, visit energyethics2004.nd.edu.
College Selects Kaneb Honorees

The Kaneb Teaching Awards are bestowed annually on faculty who have been active in full-time undergraduate teaching for a minimum of five years. Nominees are chosen based upon the recommendations of current students, recent graduates, and fellow faculty. This year’s recipients were Danny Z. Chen, professor of computer science and engineering; David T. Leighton Jr., professor of chemical and biomolecular engineering; Robert C. Nelson, professor of aerospace and mechanical engineering; Stephen E. Silliman, professor of civil engineering and geological sciences and associate dean for educational programs; Gregory L. Snider, associate professor of electrical engineering; and Robert A. Howland, associate professor of aerospace and mechanical engineering.

Chen has developed a reputation for excellence in the classroom, and students consistently rate his Analysis of Algorithms course in the upper quartile of classes taught within the Department of Computer Science and Engineering. He joined the University in 1992.

According to students, Leighton offers “interesting and insightful class demonstrations, but he also makes himself available outside of class.” Leighton has been a faculty member since 1986.

Nelson has been recognized for his efforts in a number of courses since joining the University in 1975, but students comment most about his approach to Aerodynamics Laboratory, one of the most demanding in the aerospace engineering program.

Since 1986 undergraduates in both the environmental geosciences and civil engineering programs have experienced the enthusiasm and hands-on approach to engineering applications displayed by Silliman.

Snider has developed the Integrated Circuits laboratory course into a one-of-a-kind fabrication experience in silicon circuitry for undergraduates. They leave the course with a definite advantage over their electrical engineering peers at other institutions. Snider joined the University in 1994.

A faculty member since 1981, Howland has consistently been cited for his ability to explain difficult concepts and the enthusiasm with which he presents the material. As one student said, “He is the most challenging professor I have, but he also puts in the extra effort to make sure students have the opportunity to learn.”

Created in 1999 through a gift from University Trustee John A. Kaneb, the Kaneb Teaching Awards honor faculty for their “Outstanding Service as Educators.”

Teacher of the Year

Since joining the University in 1990, Joannes J. Westerink, associate professor in the Department of Civil Engineering and Geological Sciences and director of the Environmental Hydraulics Laboratory, has earned many accolades for his personable and approachable teaching style. Students describe him as a teacher who is “patient, laid-back, and easy to talk to.” They acknowledge that his classes are demanding, but they also say, “He is interested in getting to know us on a personal level and wants us to get the best out of his courses.”

Westerink’s passion for his field, something students also comment upon, honors a long-standing tradition within the College of Engineering, as a civil engineering program has been offered at Notre Dame since 1873.
Distinguished Engineering Lecture Series Begins Fifth Year

The Distinguished Engineering Lecture Series, established in 2000 by Dean Frank P. Incropera, is entering its fifth year of service to undergraduates. Its goal is to expose students, particularly first-year engineering intents, to professional engineers who have achieved at the highest levels in their fields, giving the new undergraduates an overview of the range of opportunities available in engineering and providing them with a deeper understanding of the role of engineering in society and the impact that they, as future engineers, can have. The two speakers who participated this past year represent different fields, but they both serve in high-profile industries where decisions and actions can have tremendous consequences.

William F. Readdy, associate administrator of NASA’s Office of Space Flight, delivered the first talk in the 2003-04 series. A former astronaut and veteran of three space shuttle missions — including commanding a docking mission to the MIR Space Station — he is responsible for the Johnson, Kennedy, Marshall, and Stennis space stations; the International Space Station; and space shuttle, space communications and space launch vehicles programs.

During his presentation, “Engineering Challenges in Human Space Flight: NASA’s Path from Columbia Recovery to Return to Flight,” Readdy discussed the engineering challenges of space flight as he highlighted the incredible successes and tragic failures of the space program. He also addressed the Columbia Accident Investigation Board report and the path that NASA has chartered for a stronger, smarter, and safer flight program.

Readdy earned a bachelor’s degree in aerospace engineering, with honors, from the U.S. Naval Academy and is a distinguished graduate of the U.S. Naval Test Pilot School.

The second speaker in the 2003-04 series was Michael O’Sullivan, senior vice president of development for FPL Energy, LLC. His talk, “Engineering Careers and the Energy Industry,” outlined the importance of energy in a global economy; wind energy, one of the most exciting developments in power generation today; and the benefits of an engineering education.

O’Sullivan, who was appointed to his current position in July 2001, is responsible for FPL Energy’s business development and asset acquisition activities. He previously held management positions at Commonwealth Edison, NRG Energy, and the AES Corporation.

A registered professional engineer, O’Sullivan earned his bachelor’s degree in civil engineering from Notre Dame in 1982 and a master’s of business administration degree from the University of Chicago in 1987.

FPL Energy is one of the largest providers of clean energy in the United States, operating facilities — natural gas, wind, solar, hydroelectric, and nuclear — in more than 20 states.

Speakers for the 2004-05 academic year will be announced on the College of Engineering home page, www.nd.edu/~engineer, later this year.

facultypromotions

To Professor
Patrick J. Flynn
Computer Science and Engineering

Michael D. Lemmon
Electrical Engineering

To Associate Professor
J. William Goodwine
Aerospace and Mechanical Engineering

To Emeritus
John W. Lucey
Aerospace and Mechanical Engineering

Recognized for 25 Years of Service
David J. Kirkner
Civil Engineering and Geological Sciences
Roger A. Schmitz
Chemical and Biomolecular Engineering
Seniors Test Their Wings

Each spring aerospace engineering seniors are required to participate in a capstone design course. According to instructor Thomas C. Corke, the Clark Equipment Professor of Aerospace and Mechanical Engineering, the purpose of the course is to give students a hands-on design experience. By working through the various steps of the design process, students learn the use of constraints; they come to understand the interactions between competing technologies; and they develop an appreciation for the roles of planning and communication. “Consequences are not as critical in a senior design course as they would be in the real world,” says Stephen M. Batill, professor and chair of the Department of Aerospace and Mechanical Engineering. “But the skill set our students gain from this experience is priceless. It makes a difference in their effectiveness as professional engineers.”

This year the challenge was to design and build a remote piloted aircraft which could carry a specified payload, take-off on grass in less than 300 ft., and land safely. Although students who had experience building model aircraft or working with electronics may have held a slight advantage, each team was required to use the same equipment and follow specific design parameters: Planes were required to feature a fixed main wing, house an electric motor and battery power pack, and carry an internal cargo which included a “sport” propeller, an on-board microprocessor, and a digital radio control system that featured a minimum of seven channels.

Student teams worked throughout the semester, first creating the “paper” design of the plane and then making a formal presentation to the rest of the class on their vehicles and their predicted performance. Next, teams developed a full set of CAD-CAM drawings, including details of individual components. Parts they could not purchase were manufactured by the students in the aerospace engineering laboratories.

Flight tests were held at the South Bend Model Aircraft Club flying field, approximately 30 minutes from the Notre Dame campus. Each team’s aircraft was required to maintain a specific velocity at a constant altitude and also achieve a change in altitude through a minimum of a 100-ft. climb. During the flight test, the microprocessor aboard each plane transmitted information regarding the velocity and altitude of the aircraft to a laptop computer located on the ground.

Students analyzed this information and included it in their final presentations, which were made to classmates and an industry panel. Panel participants were Daniel T. Jensen, a senior project engineer for the Rolls-Royce Corporation who received a master’s degree in mechanical engineering from Notre Dame in 1990; Gregory Addington, a research aerospace engineer at the Air Force Research Laboratory who received a master’s degree in mechanical engineering from the University in 1996 and a doctorate in 1998; Frank C. Berrier and Christian V. Rice of the Boeing Corporation; and Steven Eno of the Honeywell Corporation.

Mechanical engineering students are also required to participate in a senior design course. It is typically offered during the fall semester.

For more information on the senior aircraft design course and to view flights of each team’s aircraft, visit http://www.nd.edu/~engineer/ame441.

http://www.nd.edu/~ame
Center for Microfluidics and Medical Diagnostics Teams with Industry Partners

In the September 2004 issue of Business 2.0, an article titled “Seven New Technologies That Change Everything” by G. Pascal Zachary identifies microfluidics as one of the hottest emerging technologies because it offers the potential of eliminating expensive laboratory tests and the lengthy wait for results. According to Zachary, sales of currently available microfluidic test kits are projected to reach $300 million by the end of the year. In fact, says Zachary, the U.S. Postal Service has already installed microfluidic detection systems at major processing centers in an effort to identify anthrax laced mail.

These actions are not surprising to Andrew Downard, product development manager for the Center for Microfluidics and Medical Diagnostics at Notre Dame. “Microfluidics research has been going on for quite awhile,” says Downard. “It’s just a matter of time before it makes the full-fledged jump from university laboratories to commercial applications, where small, cost-effective test kits could be sold over-the-counter. Bacteria, viral infections, and diseases such as tuberculosis or SARS ... could be identified quickly and more cost-effectively.”

One of the goals of the center, which was established in 2003, is to facilitate the type of technology transfer Downard describes. In fact, the center is working with Scientific Methods, Inc., of Granger, Ind., on the development of a portable beach-monitoring sensor that can detect dangerous E. Coli in a matter of minutes. Currently, the decision to close public beaches is driven by laboratory tests, which take up to two days to process. Researchers are incorporating a bacteria trap into the handheld sensor. The trap uses A/C electro-osmotic flow to force bacteria into highly concentrated lines, giving municipal officials real-time information about the water quality to better safeguard public health.

“We’ve been working with Scientific Methods since April 2004,” says Downard, “and it’s been a good match. We have the expertise in fluid mechanics, and they have the expertise in microbiology and business applications.”

According to Downard, the company has also been instrumental in helping the center with research and development space for Microfluidic Applications (MFA), a separate company founded by faculty within the center. The company serves as an incubator for research projects that offer the best possibilities for commercialization. Personnel in the company are working with researchers to develop viable products. They are also applying for Small Business Innovative Research grants and seeking private-equity investments to fund these efforts.

One of the devices MFA is developing is a Zetafilter, which will be used for the electrophoretic separation and concentration of bacteria, viruses, and proteins. Separation is based on the size and charge of the molecule, providing faster processing times and more selectivity than currently available products. Its principal applications will be for medical, proteomic, and environmental researchers. Downard recently completed a working prototype of the Zetafilter and is currently working to commercialize the technology.

The center director is Hsueh-Chia Chang, the Bayer Professor of Chemical and Biomolecular Engineering. David T. Leighton Jr., professor of chemical and biomolecular engineering, is associate director.

For more information about the center, its faculty, and current projects, visit http://www.nd.edu/~chegdept/CMMD.html.

http://www.nd.edu/~chegdept
Talley Named to Joint Chiefs

In July 2003 Jeffrey W. Talley, assistant professor of civil engineering and geological sciences and colonel in the U.S. Army Reserve, returned from extended service in Operation Iraqi Freedom. He had spent six months there serving as chief of operations for the U.S. Army’s 416th Engineering Command. Talley earned the Bronze Star for his service in Iraq.

Since January 2004 he has been serving as a strategic planner for the War on Terrorism Directorate of the Joint Chiefs of Staff (JCS), one of a handful of reserve officers who have been appointed to the JCS.

A full-time faculty member, Talley’s work for the Joint Chiefs is conducted during semester breaks and summer reserve service. In fact, a good part of this summer has been spent helping prepare Joint Staff Action Packages, white papers suggesting terrorism policies to JCS Chairman Gen. Richard Meyers, Secretary of Defense Donald Rumsfeld, and President Bush.

Talley joined the Notre Dame faculty in 2001 after earning a doctorate in civil and environmental engineering from Carnegie Mellon University. He holds three master’s degrees — in environmental engineering and science from The Johns Hopkins University, in history and philosophy from Washington University in St. Louis, and in religious studies from Assumption College. He specializes in the environmentally friendly remediation of contaminated groundwater, soils, and sediments.

EMSI Offers Outreach Programs

One of the goals of the Environmental Molecular Science Institute (EMSI) at Notre Dame is to bring engineers and scientists together to investigate the interaction between microparticles and heavy metals in the environment.

In addition to its research efforts, EMSI is involved in a variety of educational and outreach programs, one of which is the Research Experiences for Undergraduates (REU) program. A 10-week summer initiative, students participating in the REU program receive hands-on experience in geomicrobiology, environmental mineralogy and geochemistry, and hydrology under the supervision of Notre Dame faculty.

During the 2004 session, which ended on August 7, the following students participated, each focusing on a particular area of research:

Brian Bucher, junior
Valparaiso University
“Determining the Abundance of Platinum Group Elements along Urban Roadsides”

Elizabeth Hernadon, freshman
Washington University
“Determining the Reversibility of Bacillus Subtilis Adsorption to Mineral Surfaces”

Todd Hoppe, sophomore
Tulsa University
“Mercury Speciation and Availability in Tidal Waters, Suspended Solids, and Sediments from the San Francisco Bay”

Terri Huynh, sophomore
University of California at Berkeley
“Metal Adsorption onto Bacterial Consortia from Uncontaminated Geologic Settings: Building Predictive Models”

Nathan Porter, sophomore
Utah State University
“Synthesis and Characterization of Uranyl Oxalate Compounds”

Ginger Sigmon, junior
North Carolina State University
“Uranyl Peroxides”

Rachel Thompson, junior
Rockford College
“The Effects of Nickel on the Growth of the Aerobic Bacterium Pseudomonas Mendocina”

Petia Tontcheva, junior
University of Illinois at Chicago
“The Effects of Water-retention Parameters on Air Entrainment below the Water Table”
At the close of the program, REU students were required to participate in a research forum by presenting a 15-minute seminar on their project followed by a question-and-answer period.

The EMSI also hosts a high school outreach program for area students. This year students from three area high schools — Marian, Clay, and Adams — participated in hands-on projects which were presented at the annual Indiana Regional Science Fair. In fact, four of the students involved, all from Marian High School, won prizes at the fair for their efforts: For her project on "Monitoring High Nitrate Levels in Benin, West Africa," Claire Shearer, a rising senior, won first place in behavioral and social science. She also received the Kodak Photographic Award and the American Society for Quality Award. Another student, rising senior Caleb Laux, received a second place award in biochemistry. His project, "The Effects of Aluminum on the Formation of Natural Organic Matter Aggregate," also received the second place Environmental Management Association Award. Deanna Lind, a rising freshman, presented "The Effects of Copper Ions on UV254 Measurement for DOC in Water." She received a first place in chemistry, as well as the Stockholm Junior Water Prize and the American Society for Quality Award.

Deanna Lind, a rising freshman, presented "The Effects of Copper Ions on UV254 Measurement for DOC in Water." She received a first place in chemistry, as well as the Stockholm Junior Water Prize and the American Society for Quality Award.

Margaret Garascia, rising senior, received a first place in chemistry for her project, "Hydrothermal Alteration of Cement and Its Application to Nuclear Waste Disposal.

Although not as formal as the REU and high school outreach programs, EMSI also sponsors tours and special events for local middle schools. For example, in November 2003, the EMSI and Center for Environmental Science and Technology co-hosted a tour and lecture for 40 students from The Montessori Academy at Edison Lakes, located in Mishawaka, Ind. Discussions with students included the mission of the institute and how the environmental research occurring in the EMSI relates to their lives.

For more information about the research initiatives and outreach programs in the EMSI, visit http://www.nd.edu/~emsi.
Computational Medicine Group Helps Improve Radiation Therapy Treatment Time

The goal of researchers and physicians in radiation therapy is to deliver high doses of radiation to a targeted area while minimizing the damage to surrounding normal tissue and critical organs. One of the current techniques is called intensity-modulated radiation therapy (IMRT), which requires the ability to generate non-uniform dosages.

Steps taken during a typical IMRT treatment include scanning the area to provide a tomographic image of the tumor and surrounding tissue, calculating the dosage based on the tomography of the tumor, setting the “movements” of the cylinder — a computer-controlled multileaf collimator (MLC) which delivers the beams of radiation, and then delivering the radiation. The challenge is in generating a plan for the movements of the MLC, because it consists of up to 80 pairs of tungsten leaves which must each be adjusted to accurately shape the beam. This is called leaf-sequencing, and it is a vital part of the treatment plan as the maximum dose required must be delivered in the minimum amount of time.

Using new algorithms and computational geometry techniques, the Computational Medicine Group at Notre Dame has been developing solutions to this leaf-sequencing challenge. The team, led by Danny Z. Chen, professor of computer science and engineering, includes Sharon X. Hu, associate professor of computer science and engineering, and former Ph.D. candidate Xiaodong Wu. The Notre Dame team has been collaborating with researchers in the Department of Radiation Oncology at the University of Maryland School of Medicine, who are performing extensive experimental studies using the new algorithms and software developed at Notre Dame.

This software, called SLS, produces IMRT plans that compare favorably with the currently available IMRT software, while reducing the time required to establish the plan by approximately two-thirds. As a result, the SLS software is now being used in the University of Maryland Medical Center and the Helen P. Denit Cancer Center in Montgomery General Hospital. Journal papers on the work have been accepted for publication in the Journal of Physics in Medicine and Biology and the Journal of Medical Physics. Research results were also presented at the 45th Annual Meeting and Technical Exhibition of the American Association of Physicists in Medicine and the 19th ACM (Association for Computing Machinery) Symposium on Computational Geometry.
Striegel Receives NSF CAREER Award

Assistant Professor Aaron Striegel has been named a recipient of the National Science Foundation’s Early Career Development (CAREER) Award. This is the highest honor given by the U.S. government to junior faculty in engineering and science.

Established in 1995, the CAREER program recognizes and supports “exceptionally promising college and university junior faculty who are committed to the integration of research and education,” says NSF Director Rita R. Colwell. “Its goal is to help top-performing scientists and engineers early in their careers to simultaneously develop their contributions and commitment to research and education.”

Striegel joined the Department of Computer Science and Engineering in 2003. He received both his bachelor’s and doctoral degrees in computer engineering from Iowa State University. He is receiving the CAREER award for his work on stealth multicast techniques, titled “Transparent Bandwidth Conservation Techniques.”

Fuja Named IEEE Fellow

Thomas E. Fuja, professor of electrical engineering, has been named a Fellow of the Institute for Electrical and Electronics Engineers (IEEE). The world’s largest technical professional society, the IEEE is composed of more than 320,000 members who focus on advancing the theory and practice of electrical, electronics, and computer engineering. Fuja is the 11th faculty member to receive this honor. His work addresses coding for wireless applications and the interface between source coding (compression) and channel coding (error control). He joined the University in 1998.

Fuja received bachelor’s degrees in electrical and in computer engineering in 1981 from the University of Michigan. From Cornell University he received a master’s degree in 1983 and a doctorate in 1987, both in electrical engineering.

Graduate Student Receives Indiana Governor’s Award

Dane Wheeler, a Ph.D. candidate and Semiconductor Research Corporation fellow working under the direction of Alan C. Seabaugh, professor of electrical engineering, and Douglas C. Hall, associate professor of electrical engineering, has received the 2004 Indiana Governor’s Award for Tomorrow’s Leaders. Wheeler received his bachelor’s degree from the University in 2003. As an undergraduate he won first-place in the Intel Student Research Contest and received the award for Best Undergraduate Plan from the Gigot Center for Entrepreneurial Studies at Notre Dame. As a high school student, Wheeler co-developed a software package called mightybrain.com, which enables teachers to record and distribute grades and relevant information to students and parents. The program is currently in use at a large local school system, the Penn-Harris-Madison Corporation, in Mishawaka, Ind.
Scanning a photograph or slide on a desktop computer and then printing it on a laser or ink-jet printer produces a two-dimensional image. It’s flat. Even though it may still show a stunning subject, there are nuances to the image that have been lost. These nuances are extremely important to photographers who wish to capture the beauty of nature or a particular object. They are more vital in computer vision research, where three-dimensional (3D) images are providing data that can be used in a variety of applications, including biometric identification for homeland security, virtual reality, historical preservation, and archaeology.

For example, faculty and students in the Computer Vision Research Laboratory are applying 3D scanning, modeling, and rapid prototyping to the fabrication of missing bones in Peck’s Rex, one of the highest-quality T.Rex skeletons ever discovered. While an undergraduate in the Department of Computer Science and Engineering, Chris Boehnen wrote a software program that automatically converted digital photographs into files which described the dimensional geometry of a shape for modeling processes. As a graduate student, he is now applying rapid prototyping techniques to configure the missing bones of the T.Rex.

Boehnen, Patrick J. Flynn, professor of computer science and engineering; and J. Keith Rigby, associate professor of civil engineering and geological sciences, scanned the shape of the existing bones and duplicated them at the correct scale and position to complete the dinosaur. Replicas of their work are currently on display in Notre Dame’s Eck Visitors’ Center.

Work in the Computer Vision Research Laboratory is directed by Flynn and Kevin W. Bowyer, the Schubmehl-Prein Chair in Computer Science and Engineering, and supported by the National Science Foundation, Sandia National Laboratories, and the Defense Advanced Research Projects Agency.

For more information on 3D scanning, modeling, and fabrication within the Department of Computer Science and Engineering, visit http://www.cse.nd.edu/research/labs.php.