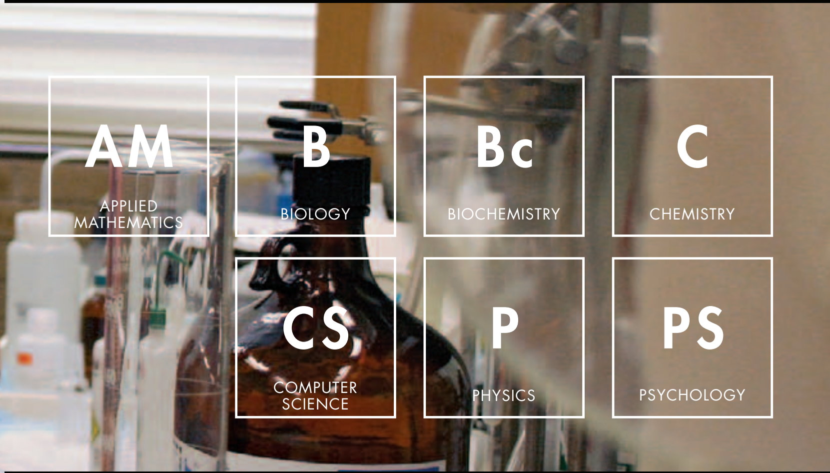
Ryan McClure assists Professor Chong with her NIH-funded cancer research.

2009 UNDERGRADUATE SUMMER RESEARCH STIPEND

This report presents the research of CSL undergraduates and their faculty mentors during Summer 2009.



AM — APPLIED MATHEMATICS

B — BIOLOGY

Bc — BIOCHEMISTRY

C — CHEMISTRY

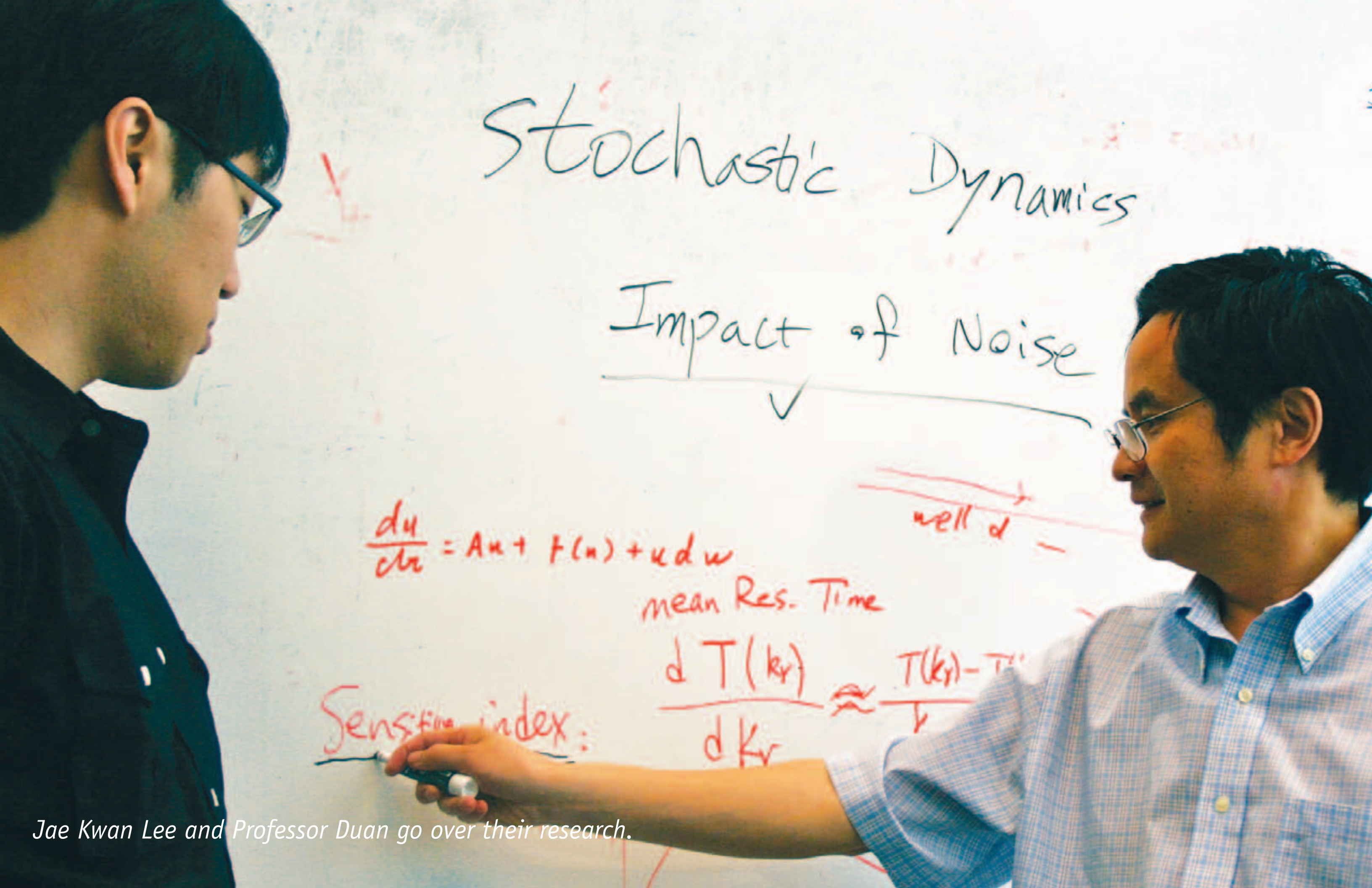
CS — COMPUTER SCIENCE

P — PHYSICS

PS — PSYCHOLOGY

IIT College of Science and Letters

ILLINOIS INSTITUTE OF TECHNOLOGY



Jae Kwan Lee and Professor Duan go over their research.

Jae Kwan Lee
Fourth-year applied mathematics

Jeffrey Duan
Professor of applied mathematics

Perturbation on the manifolds with application to biomedical modeling

As the life sciences have exploded, with a flood of new information and data, so has the interdisciplinary area of mathematical biology. Mathematical models can help scientists understand why something is happening and what might happen next – such as how molecules in a cell interact, or how a tumor develops – in areas from ecology to epidemiology and more.

Professor Duan is the director of the Laboratory for Stochastics and Dynamics at IIT and a guest faculty fellow at Argonne National Laboratory. His expertise is mathematics to help describe random, dynamic systems, including biomedical systems.

"There are not many first principles in biomedicine that can be put in familiar mathematics models," he said. "We only know a small part of the typical biomedical system or process."

A student from South Korea who transferred to IIT from Ajour University in 2008, Jae Kwan has learned many kinds of mathematics in the classroom. But he never before had the chance to put his knowledge to work in research. This summer, he worked on a model in MATLAB studying the impact of small perturbation on the invariant manifolds for application to biomedical modeling. Perturbations help find an approximate solution based on a solution to a related problem, and invariant manifolds are geometric structures that help us understand dynamical behaviors of complex systems.

"I changed the perturbation so it showed a change in the model," said Jae Kwan. Ultimately, the idea is to help the scientist understand how the biological process changes when some system parameters change.

Besides the software, Jae Kwan also will write a paper and create a poster about his work, and probably present the research at a conference. The experience should help him get into graduate school, and it gave him a different view of his field. "This kind of work is very new," he said. "It makes me creative to try to figure out things no one has before."

AM
APPLIED MATHEMATICS

Jesse Reinhardt
Fourth-year biochemistry

Ben Stark
Professor of biology

Engineering bacterium to utilize DBT in crude oil

Just a few years ago, Jesse was working at Wrigley Field, washing dishes and preparing food, trying to figure out what to do next. He initially enrolled in Truman College for biotechnology, and then transferred to IIT in Fall 2006.

After ranking first in Professor Stark's genetics class, Jesse was soon working in Stark's lab on a two-year research project for Saudi Aramco with IIT Research Professor John Kilbane.

Their goal is to engineer bacteria that can utilize dibenzothiophene (DBT), the major sulfur component in crude oil, so that when refined to gasoline it releases less sulfur into the atmosphere. In one process, three genes linked together as an operon (dszABC) can catalyze reactions to do this; but no bacteria can do this at a rate feasible for industry and at high (≥60° C) temperatures, so one must be made. "Saudi Aramco wants a bacterium that can survive at higher than 60°C and use DBT like a banshee," explained Stark.

This summer, Jesse worked to find dszABC operons that will encode enzymes to function at high temperatures, and to obtain bacteria that will grow at high temperatures, in high salt concentrations, and in the presence of crude oil.

He put soil samples (from under the Chicago el, the Grand Canyon, and Hot Springs, AR) through growth regimens to select for the right characteristics. Ultimately, he created a library of strains that can be combined and tested to produce an engineered strain that can grow at high temperatures with DBT, and eventually crude oil, as their sole sulfur source.

"It was really a good experience," Jesse said. "I've been able to get in-depth, hands-on skills that are hard to get by just taking regular classes. I definitely like research." He plans to graduate this December, work for the next year and a half to save money, and then enter medical school in fall 2011 and specialize in infectious diseases.

Bc
BIOCHEMISTRY

B
BIOLOGY

[left to right] Jesse Reinhardt, Professor Stark, Ling Xu, Fan Wu, and Suni Lokesh in the lab.

Aram Apyan
Second-year physics

Yagmur Torun
Assistant professor of physics

Detecting field emission in superconducting cavities using Cerenkov radiation

Physicists build particle accelerators to accelerate elementary particles to the speed of light and study their collisions to advance the understanding of the small-scale structure of the universe. Professor Torun develops technologies to improve particle accelerators. This summer, he worked with Aram to test the use of Cerenkov radiation to detect field emission, which can reduce accelerator performance, in superconducting cavities.

The superconducting radio frequency (SRF) cavities of accelerators are electromagnetic resonators with exquisite precision operated at 2 Kelvin for maximum efficiency in generating electric fields for accelerating particles.

"Dark current" in terms of accelerators is the extra current of electrons stripped from the inner surface of accelerating cavities. It can interfere with the main accelerator beam.

As Torun and Aram wrote, "SRF cavities are made of thin metal shells in a metal liquid helium vessel. This system can be viewed as a Cerenkov radiator between a set of mirrors. Field emitted electrons can punch through the cavity wall and generate Cerenkov light in helium, which can be collected by appropriate photodetectors."

Aram used GEANT4, a C++based software framework used in most modern high-energy physics experiments, to create a simulation of electron and Cerenkov photon transport in a TESLA-type superconducting cavity to evaluate the feasibility of the method.

He presented "Cerenkov Light Diagnostics for Superconducting Cavities" at an American Physical Society meeting in Detroit, in July.

Aram co-wrote the article "Detecting Neutrino Magnetic Moments with Conducting Loops" published in *Physical Review D1* in February 2008. He is fascinated with gravity and astrophysics, plans to get a Ph.D. in physics, and wants to get as much research experience as possible while at IIT. He also is interested in other things, including ancient history. "It's important to be a well-developed person," he said. "Life is too interesting to focus on just one thing."

P

PHYSICS

Ryan McClure
Third-year chemistry

Hyun-Soon "Joy" Chong
Associate professor of chemistry

Synthesis of ligant for positron emission tomography imaging

For the third year, Professor Chong had a CSL Undergraduate Summer Research Stipend winner in her lab – the only faculty member to do so. She and her team specialize in interdisciplinary research to create safe, effective, and targeted therapeutic and imaging drugs for cancer and neurodegenerative diseases, making drugs for antibody-targeted radiation therapy, iron-depletion therapy, and magnetic resonance and positron emission tomography imaging. Last spring, Professor Chong filed an international patent for a series of bimodal macrocyclic synthetic ligands for these techniques.

Ryan is interested in organic chemistry, particularly the medicinal applications of organic chemistry. A student from West Chester, OH, he began working in Professor Chong's lab last winter, preparing and carrying out a synthetic route of precursor molecule for C-NETA, a bifunctional macrocyclic ligand designed for the targeted radiation therapy of cancer; and performing ^{1}H and ^{13}C NMR to determine the structure of compounds. This summer, he made progress in the synthesis of a macrocyclic bifunctional ligant for positron emission tomography imaging of gastrin-releasing peptide receptor expressing tumors.

When Ryan was in fifth grade, he was nominated to take a Saturday morning class called "Fun with Chemistry" at the local high school. From that point on, he said, he knew he wanted to be a scientist. But getting in the lab has been a revelation.

"I learned a ton of things working this summer," he said. "First of all, research is hard. A lot of time and effort go into every single step of a reaction. I also found that even after I had left the lab for the day, I would still be thinking about my research and considering ways I could improve. The research became a 24-hour job."

He will continue the research this school year – and, he said, "hopefully for the rest of my time at IIT" – before going to graduate school to pursue a Ph.D. in organic chemistry.

C
CHEMISTRY

The College of Science and Letters
at the Illinois Institute of Technology
believes strongly in research experience for undergraduates.

APPLIED MATHEMATICS

Research allows students to explore their interests, solve problems, advance knowledge, and prepare for the next step - whether graduate school, medical school, or the workplace.

BIOLOGICAL, CHEMICAL, AND PHYSICAL SCIENCES

Research opportunities for CSL undergraduates:

- Available as early as second semester of freshman year
- Guided by world-class faculty who have received national and international recognition in their respective fields

COMPUTER SCIENCE

CSL Undergraduate Summer Research Stipends provide students with $5,000 for 10 weeks of focused research under faculty guidance.

HUMANITIES

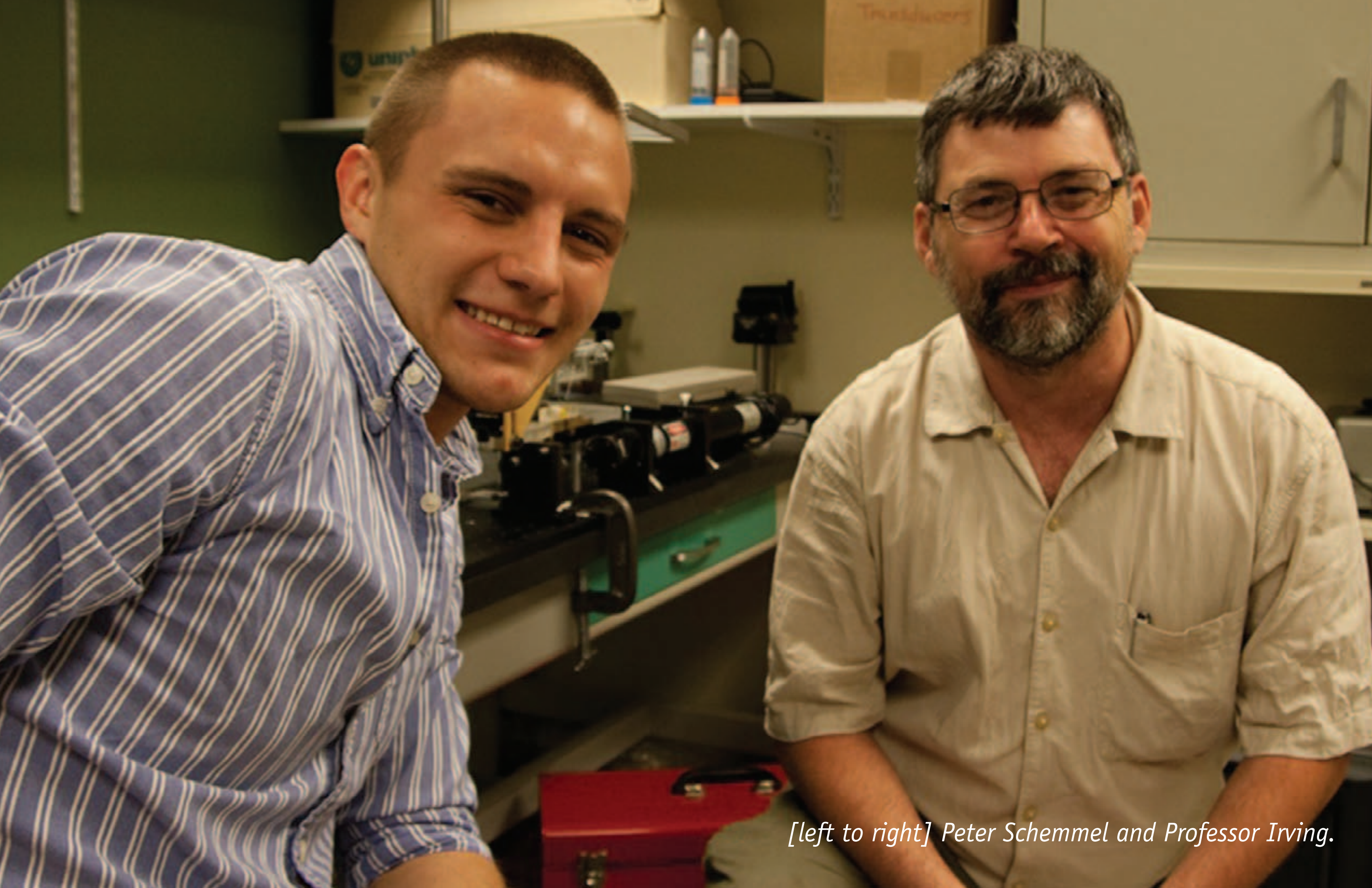
Research is critically important to advances in health, energy, security, information technology, and countless other areas. When you invest in student research, you give students the joy of inquiry and discovery, and enable them to learn how to ask and answer the questions that improve people's lives.

MATHEMATICS AND SCIENCE EDUCATION

"A university like IIT is a place for the creation, sharing and application of knowledge. Here, students have the opportunity to learn from people who not only **have** knowledge but who also know how to **create** knowledge. Education in the environment of knowledge creation is extremely powerful."

--Dr. Russell Betts, Dean, College of Science and Letters

SOCIAL SCIENCES



[left to right] Peter Schemmel and Professor Irving.

Peter Schemmel
Second-year physics

Thomas Irving
Professor of biology and physics

Experimental X-ray diffraction equipment design, machining, and fabrication

Peter is from Brandon, SD, where he worked on the Supernova Survey at Badlands Observatory (and independently discovered Supernova SN2008A, NGC634) and among other things built motorcycles and airplanes as a hobby.

His science orientation and mechanical aptitude were perfect for Professor Irving, who needed a student to design and fabricate muscle physiology setups for Irving's work.

He also noticed Peter's commitment. "I have come along only a small handful of students that compare to Peter," said Irving. "He has a passion for science that is truly remarkable."

Irving is internationally known for his use of small-angle x-ray diffraction to study the ordered structure of muscles on the nm length scale (one billionth of a meter), work that helps us better understand things like heart disease. He directs the Biophysics Collaborative Access Team (BioCAT) x-ray diffraction, scattering, and spectroscopy facility at the Advanced Photon Source at Argonne National Laboratory. This National Institutes of Health-funded facility is probably one of the best in the world for muscle studies of non-crystalline biological systems such as muscle and proteins in solution.

This summer, Peter finished building a laser diffraction system for combined X-ray diffraction and physiological measurements from intact cardiac muscle. "We are still testing and making tweaks to the setup, but we intend to use it at the synchrotron," said Irving. Peter also helped to build a rig for combined laser light diffraction and muscle mechanics for the flight muscles of the Hawkmoth Manduca sexta, with a prototype setup assembled and used in an experiment at Argonne (where, said Peter, "I always feel like James Bond").

"Working with Professor Irving has dramatically increased my desire to become a scientist," noted Peter, who wants to earn a Ph.D. in physics and teach. "There is no longer any doubt as to where I want my future to end up."

P PHYSICS

B BIOLOGY

Andrew Yates
Second-year computer science

Wai Gen Yee
Assistant professor of computer science

Creating an educational video annotation and indexing system

Professor Yee's research is in mobile and distributed system performance; data warehousing, analysis, and mining; and information retrieval. Last year, in a project that grew out of some consulting work, he decided to develop a system that allows users who are watching a video to leave comments that can be searched by other users.

"I thought it could have application in the classroom," he said, for online and videotaped classes, as well as other fine-grained video searches from Hulu to London's surveillance video.

"Right now, systems like YouTube don't let you search the comments," only title, description, and keywords, he added.

Last winter, Andrew helped Professor Yee to collect and analyze more than one million YouTube comments to see if they were worth searching and would help improve searches – determining yes on both counts. He co-authored a paper about the work given at the 2009 ACM SIGIR conference workshop. This summer, he wrote a program for recording the video annotations and searching them. He also did a survey of related work and systems, and wrote documentation for the research and results. Yee plans to use this work as a basis for an IPRO.

A student from Orlando, FL, Andrew came to IIT in part because of the information retrieval research done here. He is an assistant in the Information Retrieval Lab. This summer, he often worked through the night – "It's easier to work at night!" he said – often multitasking, including working on this research and taking care of Linux servers for a company in England, a side job.

"It's nice to have such a mature undergraduate," said Yee. "We're lucky to have Andrew. At some point, the student is generating his own ideas and taking a lot of open-ended requests. That is what Andrew is doing now, and it makes my life so much easier."

CS
COMPUTER SCIENCE

Evan Estola
Third-year computer science

Doug Cork
Professor of biology

Developing W-curve tools and techniques for studying molecular biology

Professor Cork researches such things as antibiotic resistance, the toxicity of *Salmonella*, and – most recently – the HIV-1 virus and its resistance to a vaccine. He developed the W-Curve algorithm to visualize and analyze long genomic sequences and infer the phylogenetic (evolutionary) history of a species. Instead of a string, the W-Curve describes DNA as a three-dimensional curve, making it easier to see patterns.

This summer, Evan built a live CD of the W-Curve so biologists can use it on any PC (which most prefer to Linux). Cork will give the CDs to researchers working on the HIV-1 virus at Walter Reed Army Research Hospital, where he is doing a sabbatical year with the U.S. Military HIV Research Program, Henry Jackson Foundation.

Evan also wrote a program to examine HIV strings by randomly mutating them and comparing them to a value set, drawing on knowledge from his advanced CS classes and work in the Information Retrieval Laboratory, and with help from graduate students. "The difference in speed for the W-Curve algorithm is ridiculous, absurdly useful," Evan noted.

The HIV virus replicates in so many different ways, it is difficult to find the patterns, and difficult to find the viral "ancestor"; being able to look at the trees in 3D might offer up new information.

"With HIV-1, the envelope gene of the virus hypermutates, leading to rapid changes in the envelope protein," said Cork. "Hopefully, with the W-Curve, we can correlate its 3D patterns with clinical symptoms that one monitors in the patient, related to neutralization of the virus."

A student from Grand Rapids, MI, Evan switched from biomedical engineering to computer science by his third semester, because he discovered he loved programming. Part of IIT's a capella singing community, he will graduate in December and may join Cork at Walter Reed, helping the biologists make the most of their computer tools.

CS COMPUTER SCIENCE

B BIOLOGY

[left to right] Matthew Bauer and Erik Harpstead

Erik Harpstead
Third-year psychology and computer science

Matthew Bauer
Senior lecturer, computer science

Researching and redesigning IIT's CS general education requirement (CS105/ARCH125/CS115)

What should CS 105, Introduction to Computer Programming, accomplish?

Award-winning teacher Mr. Bauer is interested in the answer. Director of CS undergraduate programs and undergraduate academic advising, he is known for answering student emails in record-breaking time – even in the middle of the night – as he helps them explore their options.

Erik came to his attention in CS201, an accelerated introductory class. (Both also shaved their heads for St. Baldrick's Day to raise money for cancer.) A student from Auden Hills, MN, Erik is interested in research, human-technology interaction, and how best to teach people to use computers. He also is treasurer for his fraternity and a disc jockey for radio station WIIT, and he will study in Japan next year.

In CS201, Erik said, "Students are presented with problems and asked to find ways to solve them with minimal handholding and more of a focus on good programming practice than proper syntax." Would some of that approach work better in CS105? With Bauer, he spent the summer researching the question.

They interviewed other departments about computational thinking and problem-solving required for different majors, what upper-level major courses expect from CS general education, "best practices" in each major, and more, and catalogued the results. Working with Bauer's CS495 class, they analyzed the data from the perspective of computer scientists looking for what computational concepts were hidden behind the engineering and mathematics concepts. They also surveyed previous CS105 students and researched introductory classes at other universities and alternative ways to teach computer science to non-majors.

"We concluded that what was in order was a new set of objectives for the course," said Erik, and they plan to roll out a beta version of a new course in Spring 2010, with appropriate data collection to test its effectiveness. They hope their changes will improve the educational experience, support interdisciplinary work, and concentrate on computational thinking and problem-solving, rather than just programming – while also improving the major-specific programming skills.

PS
PSYCHOLOGY

CS
COMPUTER SCIENCE

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