Cargill Building for Microbial and Plant Genomics
University of Minnesota

Building Facts

- First public research university building dedicated to microbial and plant genomics in the nation.
- First building in the university's biotechnology precinct on the St. Paul campus.
- Unites 15 research groups from the Center for Microbial and Plant Genomics, from the University's Academic Health Center units; the College of Agricultural, Food and Environmental Sciences; the College of Biological Sciences; the Institute of Technology; and others.
- Researchers in the building conduct basic research that could lead to disease- and drought-resistant crops, create new ways to treat and prevent human and animal health problems, and develop methods to improve the environment.
- The facility accommodates research "hoteling" by visiting faculty and researchers to foster national and international collaboration.

Highlights

The $20 million, 64,000-square-feet building includes:

- Genomics and bioinformatics research laboratories
- Bioinformatics workshop and tutorial area
- Microbial fermentation lab space and plant growth chambers
- Robotic high throughput center for screening new biological compounds
- Atrium for special events, and an auditorium for seminars, workshops and meetings
- Conference and meeting areas with writeable walls or countertops to foster collaboration

Funding

- Minneapolis-based Cargill Foundation donated a gift of $10 million toward the project. It is the largest single donation in Cargill's history. A matching $10 million was appropriated by the state of Minnesota.

Other Biosciences programs and initiatives

- Biodale, the one-stop shopping center for biological and biochemical lab support
- The future biotechnology incubator, which will nurture new businesses based on genomic sciences
- The biotechnology research alliance of the University of Minnesota, Mayo Clinic and the state of Minnesota
- The Molecular and Cellular Biology building that opened in October 2002

Building Research

Genomics

- Genomics is the process of determining the location, sequence, function and interrelationships of all genes in organisms, including, in this case, the genes in microbes and plants. It is among the fastest-growing fields in science.

- The Center for Microbial and Plant Genomics housed in the Cargill Building focuses on basic genomics research. Genomic researchers work to unlock the genetic code determines how plants and microbes (e.g. bacteria) live and function. Scientists are genomic detectives uncovering the genetic blueprint of plants and microbes. No one can predict exactly where that new knowledge and undiscovered science will lead.

Areas of Investigation

Genomics of plants, animals and pathogens:

- Investigate how plants develop means to fight off infection.
- Identify the specific genetic makeup of diseases that attack livestock.
- Focus on the genomics involved in the interaction between mosquitoes, the pathogens that cause malaria and the animal host for the disease.
- Knowledge discovered in these areas could be used to develop treatments for costly diseases or develop techniques to equip plants with natural disease resistance.

Harnessing friendly microbes:

- Friendly microbes help legume plants produce their own nitrogen, work in human intestines to break down food and eliminate toxins in soil.
- Genomic research will provide tools to make use of these abilities.
- This could lead to maximizing the healthy benefits of the bacteria in yogurt, reducing the need for plant fertilizers or developing methods for cleaning up contaminated soil.
- In addition, other researchers are looking at genomic information that could lead to producing antibiotics, biodegradable plastics, natural product chemicals and other useful products.

Developing basic research tools:

- Each DNA strand stores millions of pieces of data, and analyzing that requires a lot of computer power and sophisticated programs. Researchers use DNA chips, or microarray technology (slides that show activity of all genes within a genome), to study the activity of a large number of genes (when genes are switched on or off).
- Gene shuffling assembles groups of genes to produce novel compounds that could be used in medicine or industry.
- High throughput screening technology will sort through large numbers of cells, genes, plants, microbes or compounds to find those that have useful characteristics or properties that can be applied to crop improvement, environmental clean-up, or human health.

Ethics and economic impact:

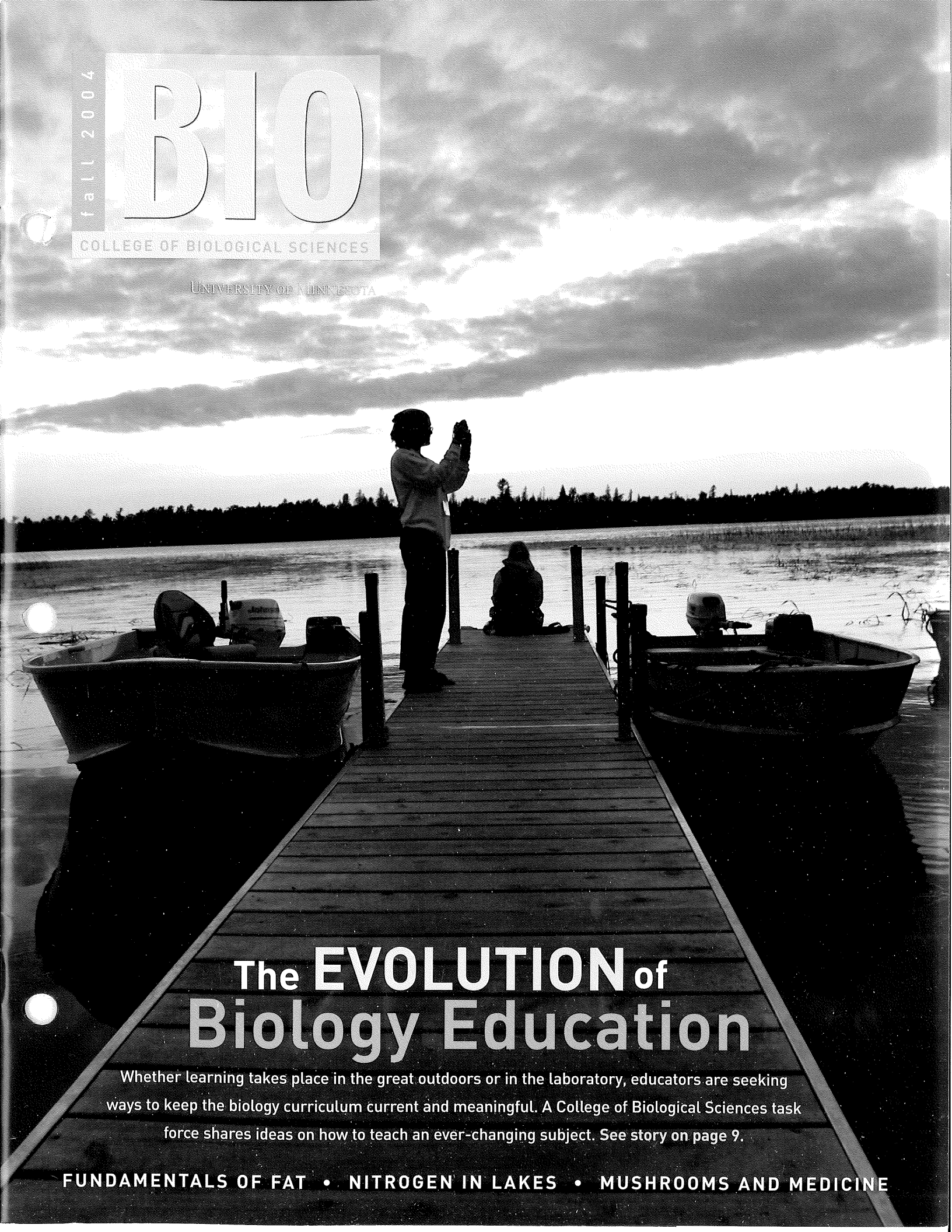
- Impacts of new genomic discoveries on society.
- Agricultural and environmental ethics and policy issues.
- Economics of science and technology.
- Impacts of biotechnology on public policy.

fall 2004

BIO

COLLEGE OF BIOLOGICAL SCIENCES

UNIVERSITY OF MINNESOTA



The EVOLUTION of Biology Education

Whether learning takes place in the great outdoors or in the laboratory, educators are seeking ways to keep the biology curriculum current and meaningful. A College of Biological Sciences task force shares ideas on how to teach an ever-changing subject. See story on page 9.

FUNDAMENTALS OF FAT • NITROGEN IN LAKES • MUSHROOMS AND MEDICINE

BIO

FALL 2004 ▮ Vol. 3 No. 3

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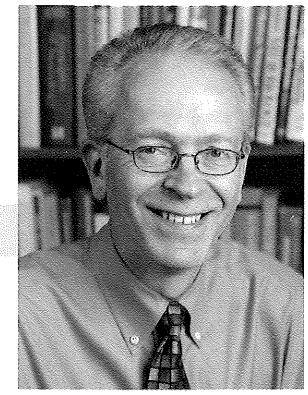
Robert Elde, Dean

FROM THE DEAN

Education at a Public Research University

Most people know that the University of Minnesota is a public research university, which sets it apart from state colleges and private liberal arts colleges. But what does that really mean?

At face value, it means our that our faculty brings in $500 million a year in federal research grants to carry out research on human health, the environment, renewable energy, and food, among other areas. They also contribute intellectual property and train a highly skilled and creative workforce for industries such as health care, agribusiness, and biotechnology. The University's research enterprise is the fuel that powers the state's economy.

It also means that we provide a different set of educational opportunities, particularly for students interested in the sciences. They take classes from faculty who conduct federally sponsored research and write textbooks. They work with real scientists in real labs on research that addresses problems such as cancer and diabetes, global warming, and dependence on foreign oil. These opportunities are not typically available at MnSCU and private colleges.

When Nobel Laureate and alumnus Ed Lewis (B.S. '39) passed away in July, I was reminded that undergraduate research has a long tradition at the University of Minnesota. Lewis came here from Pennsylvania as an undergraduate to do research on fruit fly genetics with Professor Clarence Oliver, a former student of genetics pioneer Thomas Hunt Morgan. Oliver provided space for Lewis in his own laboratory and freedom to conduct research outside of his scheduled classes. Lewis said his experience at the U was pivotal to his development as a scientist.

Today, the National Research Council recommends that undergraduate students begin research as early as possible in their education. And as we undergo a review of our own curriculum we are stressing the value of learning by doing. You can read more about this in our cover story, "The Evolution of Biology Education," which begins on page 9.

I particularly enjoyed reading a student's perspective on biology education from recent CBS graduate Chuck Hernick (B.S. Ecology, Evolution, and Behavior, 2003.) He says, "Science is a dynamic field. What you get from lectures and textbooks is history, which gives you the language to be a scientist. But science is problem solving. The only way you can really learn how to be a scientist is by doing research. Most of what I know about biology I learned from working in a research lab."

That's another thing that distinguishes a large, public research university: the quality of our students. The educational opportunities we provide bring the best and brightest students to our doorstep. It's a privilege to welcome these talented young people and to guide their transformation into scientists.

Robert Elde, Dean
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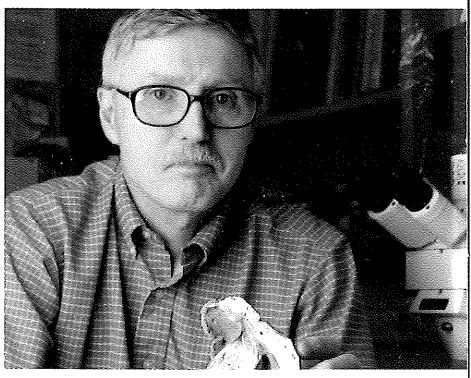
IN THIS ISSUE

IN EVERY ISSUE

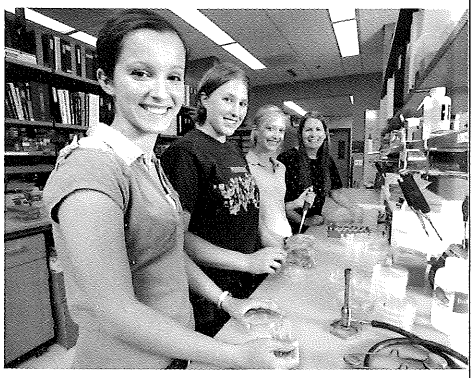
COVER STORY

FEATURES



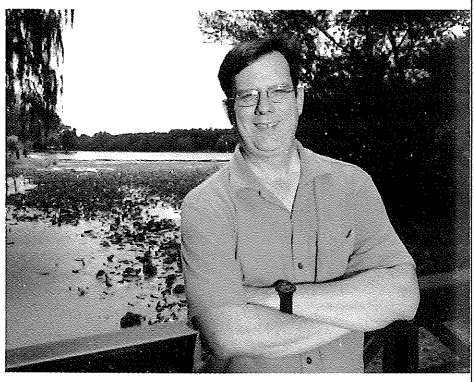
PAGE 7

David McLaughlin, mushroom aficionado



PAGE 9

Undergraduates in the lab



PAGE 14

Ecologist Bob Sterner

On the Cover Sun sets at the Lake Itasca Biological Station and Laboratories where incoming freshmen attend the annual "Nature of Life" program. *Photo by Jonathan Chapman*

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IRE

Initiative for Renewable Energy and the Environment

Leaders Named to Steer Renewable Energy Initiative

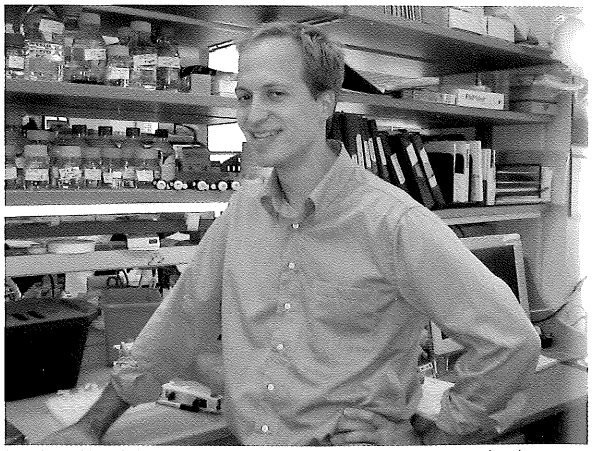
The University of Minnesota's Initiative for Renewable Energy and the Environment (IREE), funded with $20 million from the state and Xcel Energy, has named 24 leaders from the business, nonprofit, government, and higher education sectors to serve as its advisory council.

The advisory council will determine strategy and priorities for developing renewable fuel sources—such as biomass, hydrogen, wind, and solar energy—based on Minnesota's resources and needs.

"They are a very diverse group of individuals who bring different perspectives on renewable energy to the table," said Robert Elde, IREE chair and dean of the College of Biological Sciences. "They share a commitment to helping us bring renewable energy to Minnesota and to sustaining IREE for the long haul." Members of the advisory council range from 3M and Cargill executives to heads of large state growers' associations to leaders of smaller rural and environmental organizations.

IREE was created to address the urgent need to reduce dependence on nonrenewable, fossil fuel-based energy sources, and to sustain global ecosystems. For details about the advisory council, research projects, and other information about IREE, go to www1.umn.edu/iree/. ■

CBS Researcher Discovers HIV Search and Destroy Protein



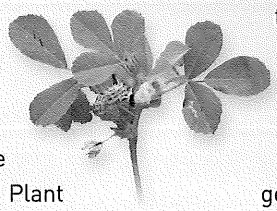
Reuben Harris' research team has discovered a protein that may contribute to HIV resistance.

A human protein that mutates the AIDS virus (HIV) and holds potential for keeping the disease at bay has been discovered and its function described by a team led by Reuben Harris, assistant professor of biochemistry, molecular biology, and biophysics. The new protein, called APOBEC3F, and one described previously called APOBEC3G can directly mutate HIV. Such proteins, called retroviral restrictors, may contribute to HIV resistance in some people. Harris and colleagues at the university reported the discovery in the June 24 issue of the journal *Current Biology.*

HIV mounts its own defense against proteins in the APOBEC family. But APOBEC3F seems especially adept at getting around this defense. "APOBECs are a 'search and destroy' defense," Harris explains. "It's different from the defense found in some HIV-resistant people, in which the outer surfaces of their cells no longer offer footholds for the virus to attach and begin the process of infection." ■

RESEARCH GRANTS & AWARDS

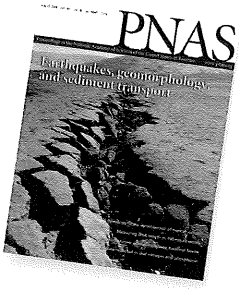
Steve Gantt (Plant Biology) and colleagues **Kate VandenBosch** (Plant Biology), **Carroll Vance** (Agronomy and Plant Genetics), **Ernie Retzel** (Microbiology), **Debby Samac** (Plant Pathology) at the University of Minnesota and Maria Harrison at the Boyce Thompson Institute in New York have received $2.1 million from the National Science Foundation (NSF) Plant Genome program for a four-year study entitled "Use of Interfering RNAs to Identify Gene Function in *Medicago truncatula*." They will silence the expression of about 1,500 individual genes in transgenic roots and examine the roots for altered development and symbiotic associations.



Fumi Katagiri (Plant Biology) received funding from the U.S. Department of Agriculture and the Natural Resources Institute for a project entitled "Efficient Discovery of Plant Regulatory Genes by Exploitation of Natural Variation." The project, which was funded for three years for a total award of $400,000, has longterm implications for crop improvement, Katagiri says, "Naturally occurring genetic variation is a great genetic resource for crop improvement."

Jeff Simon (Genetics, Cell Biology, and Development) received $1.2 million from the National Institutes of Health (NIH), for a four-year continuation of an ongoing project entitled "Transcriptional Repression by Polycomb Group Products." The project aims to study chromatin mechanisms that control gene expression and development in

Tilman Presents New Theory of Species Diversity



David Tilman, Regents Professor and McKnight Presidential Chair in Ecology, presented a new theory of species diversity and abundance within ecosystems in the July 27 issue of *Proceedings of the National Academy of Sciences.* The theory was inspired, in part, by data he gathered over the past two decades at the Cedar Creek Natural History Area. Through his new stochastic niche theory, Tilman offers an explanation for the patterns seen during the assembly of species into ecosystems, including what controls the number of species and their abundances, and why some ecosystems are more readily invaded by exotic species than others. The article suggests that stochastic niche theory offers a resolution to the controversy between whether it is "neutral" or "niche" processes that determine the diversity and composition of ecosystems. A biography of Tilman was published in the same issue. The two articles recognize his inauguration into the National Academy of Sciences. ■

U Explores Partnership with Norway

"The Environmental Impact of Agriculture and Energy Use" was the focus of a research and technology seminar connecting the University of Minnesota and the Agricultural University of Norway. It took place in Staur, Norway, in August. The conference was the first in a joint effort to find the ways in which the U.S. and Norway can capitalize on the each other's strengths, specifically in the areas of genomics and biomass/bioenergy. Bob Elde and Kate VandenBosch represented the College of Biological Sciences. Faculty from the College of Agriculture, Food and Environmental Sciences, the Institute of Technology, the College of Veterinary Medicine, the College of Natural Resources, and the Medical School also attended. ■

Drosophila. One rationale for the research is to better understand basic molecular mechanisms that contribute to prostate and breast cancers.

Steve Ekker (Genetics, Cell Biology, and Development) received renewed funding from NIH for his research, "Systematic Vertebrate Functional Genomics." This grant supports a collaborative effort at several universities with Ekker as the principal investigator.

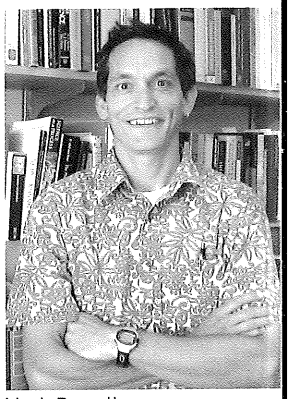
Carolyn Silflow (Plant Biology) has obtained a four-year, $730,000 award from NSF for a project entitled "Segregation and Positioning of Basal Bodies." This is a "gene discovery" project to identify and elucidate the function of genes involved in positioning of basal bodies in *Chlamydomonas*.

Kate VandenBosch (Plant Biology) received a three-year $360,000 grant from the U.S. Department of Energy. The project is entitled "Nodulation Genes of *Medicago truncatula* Governing Early Responses to Rhizobia." This project complements genomic analysis projects in Medicago by focusing on particular genetic loci.

Akhouri A. Sinha (Genetics, Cell Biology, and Development) received $471,421 from the U.S. Department of Defense for "Prediction of Aggressive Human Prostate Cancer by Cathespin B."

Nathan Springer (Plant Biology) received $327,757 from NSF for "Assessment of the Use of Oligonucleotide Microarrays for Single Nucleotide Polymorphism Mutation Detection in Maize." ■

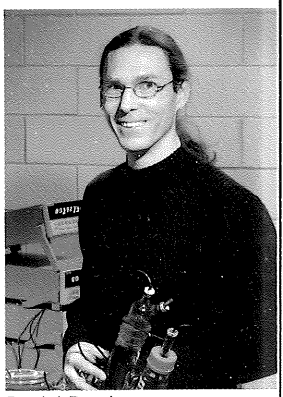
MEET THE NEW FACULTY


Mark Borrello

Mark Borrello, (Ecology, Evolution, and Behavior) is a historian of biology with a particular interest in evolutionary theory, genetics, behavior, and the environment. His work explores the varied interpretations and applications of evolutionary theory from the late 19th century to the present.


Helene Muller-Landau

Helene Muller-Landau (Ecology, Evolution, and Behavior) has research interests that include plant community ecology, especially of tropical forests; ecological and evolutionary theory; and anthropogenic influences on plant community structure and dynamics.


Daniel Bond

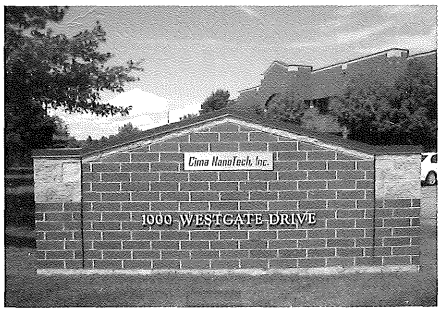
Daniel Bond, (Microbiology and Biotechnology Institute) focuses his research on renewable energy. He helped create a battery that uses common bacteria to turn organic matter from the ocean floor into electricity.

University Enterprise Laboratories Renovation Gets Underway

Renovation of the University Enterprises Laboratories (UEL) incubator began this summer, after board members completed fundraising.

Contributors include Xcel Energy ($2 million), 3M ($1 million), Boston Scientific, Dorsey & Whitney, Ecolab, Guidant, Medtronic, and Surmodics ($500,000 each), the City of St. Paul ($6.75 million), and the University of Minnesota ($2 million).

UEL is a nonprofit, public-private partnership created to advance Minnesota's biotechnology industry by providing lab space and support services for biotech start-up companies. Offices move in this fall; laboratories in July, 2005.



Companies have started moving into the UEL incubator.

The facility is located within the St. Paul Bioscience Zone and between the University's Twin Cities campuses. It will also house the University's Office of Business Development and Carlson Venture Enterprises. ■

Freshmen get a head start with CBS "Nature of Life" program

The incoming freshmen class got a preview of life at CBS during the second annual "Nature of Life" program, which was held at Itasca Biological Station and Laboratories from July 18-30. Students attended one of four three-day sessions. Each session offered mini-courses on topics ranging from bog biology to molecular biology, opportunities for students to get to know each other, returning students, faculty, staff, and administrators and to learn "Hail Minnesota" and the "Minnesota Rouser," thanks to biochemistry professor John Anderson, who served as singing coach. ■

CBS Says Goodbye t Edward B. Lewis

The College of Biological Sciences lost a good friend and distinguished alumnus when No Laureate Ed Lewis (B.S. '39) died in July in Pasadena, California, after a long battle with cancer. He was 86.

Lewis won a flute scholarship to Bucknell University, but after a year there, he gave up his scholarship and transferred to the University of Minnesota because Minnesota offered the opportunity to pursue genetics research. He received a B.S. in biostatistics from Minnesota.

With his 1950s experiments in fruit fly genetics, Lewis became the first to explain how genes control the development of organs during the early growth of an embryo. His work had particular usefulness in the study of children's cancers such as brain tumors and leukemia, which develop differently in children than in adults, says Bob Elde dean of the College of Biological Sciences.

Lewis was a professor at Caltech, a smaller with fewer hiring opportunities. So he helped Minnesota recruit young star scientists for its labs, among them Michael O'Connor (Genetics, Cell Biology, and Development) who is a Howard Hughes Medical Institute professor and holder of the Ordway Chair in Genetics. Lewis was a generous contributor to the college, and received an

PEOPLE

Kathy Ball, education specialist, has retired afte more than 30 years with the College of Biological Sciences. Ball was instrumental in the developmer of courses including General Biology laboratory, General Botany lecture, and various seminars. She contributed to a summer workshop on botany for elementary school teachers and she develop taught Kids' University courses in biology.

Robert Megard, professor of ecology, evolution and behavior, retired in December after making numerous contributions to limnology. He joined the University of Minnesota as a research fellow i 1962 and became one of the first EEB faculty

Nobel Laureate

HAROLD SWEET

Edward B. Lewis

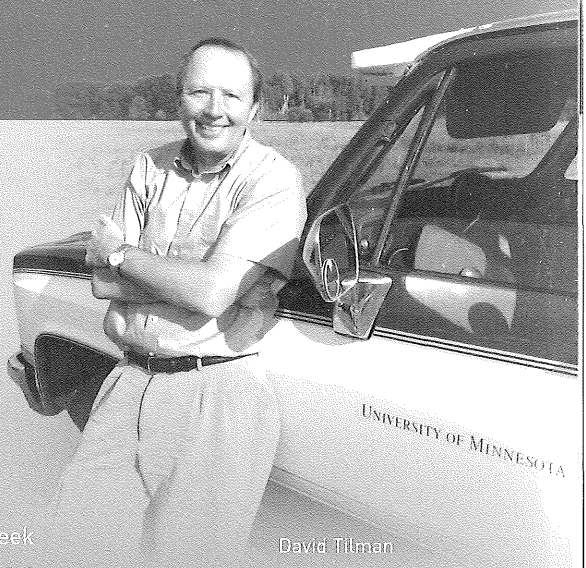
honorary doctor of science degree from the University in 1993, two years before he received the Nobel Prize in Physiology or Medicine. Known for his sense of humor, Lewis often dressed as a mutant fruit fly on Halloween.

"In science, given how competitive it has become, he stood out as a generous person," said Jeff Simon, associate professor in the Department of Genetics, Cell Biology, and Development. ■

members in 1967. He is recognized for his research on *Paleocladocera* of Iran, kinetics of oxygen generation in algae, and transmission of light through water columns. In recent years, he refined the understanding of fine-scale spatial distribution in zooplankton in lakes.

David Sheridan, associate dean for research and international programs, stepped down September 1, 2004. An associate dean since 1999, he will continue his research as a faculty member in the Department of Genetics, Cell Biology, and Development and oversee international programs part-time. ■

Improvements for Cedar Creek Natural History Area



UNIVERSITY OF MINNESOTA

David Tilman

David Tilman, Regents Professor and McKnight Presidential Professor of Ecology, is on a mission to make major improvements at Cedar Creek Natural History Area. He is leading a campaign to raise $4.1 million through grants, individual contributions, and funding from the state of Minnesota.

Cedar Creek Natural History Area is a 5,400-acre ecological research site near Isanti, with natural habitats that represent the entire state. The funds will allow Cedar Creek to restore 950 acres to savanna and prairie, create interpretive trails for year-round access for walkers and cross country skiers, and construct a 7,000-square-foot Science and Interpretive Center that will demonstrate cost effective technologies for energy efficiency, highlight how society can sustain the supply of vital services provided by ecosystems, and provide space essential for both outreach and research.

The Big Back Yard Showcases CBS Science

The Big Back Yard opened in June at the Science Museum of Minnesota with the help of the University of Minnesota. The Big Back Yard serves as the museum's "outdoor exhibit hall." It includes a miniature golf course, a hands-on demonstration of landscape processes, and a prairie maze. The Museum worked closely with CBS faculty to develop the prairie maze and biomass from that portion of the exhibit will be used by an adjacent heat and power plant.

The collaboration is part of a formal partnership between the University and the Science Museum which provides the University with a venue to communicate its research to the public and enhance the public's science literacy. The museum contributed $3 million and the University contributed $1 million to the exhibit.

Thomas S. Reid

In Memoriam: Thomas S. Reid

Thomas S. Reid (Ph.D.'43) died in May at age 92. During his 50-year career at 3M, he developed patented products that include Scotchgard™ stain repellent and the low-adhesion coating that makes it possible to unwind and dispense Scotch tape. Reid gave a substantial gift to CBS to establish the Thomas Reid Graduate Fellowship in Biochemistry, Molecular Biology, and Biophysics. He received the University's Outstanding Achievement Award in 1988.

Figuring Out Fat

Behind the bulge, there's a lot of activity.

TIM RUMMELHOFF

David Bernlohr and Ann Hertzel are part of a research group gaining a new understanding of fat and how it behaves in the body.

"Humans evolved under conditions of nutrient limitation. Now, with industrialization, we live in an environment of nutrient excess, and our bodies don't know how to respond."

—David Bernlohr

When scientists start talking about what molecules do inside cells, listeners' eyes often start to glaze over. But when David Bernlohr, head of the Department of Biochemistry, Molecular Biology, and Biophysics, mentions his sub-cellular research, people prick up their ears instead.

Bernlohr studies adipocytes, the cells that suck fat from our bloodstream and stash it away in our hips, stomachs, and thighs. In today's overweight world, plenty of folks would like to know how these cells do what they do—and how we can keep them from doing it so darn well.

Adipocytes were literally lifesavers for past generations, helping keep our ancestors from starving by providing a backup energy source when food was scarce. But in a food-saturated environment, their fat-hoarding tends to cause trouble instead. Thanks to their diligence, two-thirds of Americans are overweight. Moreover, obesity directly leads to other diseases such as type II diabetes, hypertension, and cardiovascular disease, making it the nation's number one health issue.

"Humans evolved under conditions of nutrient limitation," says Bernlohr. "Now, with industrialization, we live in an environment of nutrient excess, and our bodies don't know how to respond."

Up until 10 years ago or so, the prevailing view was that adipocytes were little more than expandable containers where our bodies stocked up supplies for hard times. "Over the last decade, that view has changed dramatically," Bernlohr says. In addition to collecting calories, he says, we now know that adipocytes "secrete a raft of hormones that regulates a number of processes" related to the fate of fat within our bodies. The more we learn about how they do this, Bernlohr says, the better able we will be to direct their activity so they help rather than harm us.

Bernlohr is currently working to understand how fats enter adipocytes, how they move once inside, and how they regulate genes that might influence the onset of obesity-related health problems. In one set of studies he's looking at the class of molecules, known as FATPs, that ferry fat across the cell membranes. He has cloned the gene that makes one such ferry. He has also discovered that a helper molecule known as Coenzyme A plays a key role in their ability to do so.

Within cells, Bernlohr is focusing on fatty acid binding proteins (FABPs), which shuttle fatty acids from one place to another. By studying animals that lack FABP genes, he's learning a lot about the role these proteins play in not only making fat cells fatter, but also in sending messages to other parts of the body that may result in obesity-related disease.

Bernlohr has not only been studying adipocytes, he also has applied what he's learned to develop an innovative eating regimen he calls the Northwoods Diet. "Miami has its South Beach, I figure we could have our Northwoods," he says. The plan allows carbohydrates in the morning (to get insulin flowing), but switches to proteins and fats in the afternoon, with no food at all after 7:30 p.m. Bernlohr has dropped 45 pounds following his own advice, and says others in his lab who have tried the plan have lost weight as well.

—Mary K. Hoff

Mushrooms and Medicine

What does deciphering the family tree of fungi have to do with cancer? Potentially plenty.

A gourmet food item that prevents cancer? In a world where it sometimes seems that anything that pleases the palate is automatically bad for you, that may sound too good to be true. But David McLaughlin, professor of plant biology and curator of fungi in the James Ford Bell Museum of Natural History, thinks otherwise. Following leads laid by folk wisdom and science, McLaughlin and Joel Slaton, assistant professor in the Medical School, have teamed together to test whether certain edible mushrooms boost the body's ability to fend off cancer.

The unusual collaboration began just over a year ago, when the College of Agricultural, Food, and Environmental Sciences' new Center for Plants and Human Health put out a call for proposals for projects linking plant biologists and medical researchers. McLaughlin suggested a study exploring claims that porcini, a mushroom found throughout much of the northern hemisphere, has anticancer effects. Center staff helped him connect with Slaton, who was already studying the anticancer attributes of another type of mushroom known as reishi.

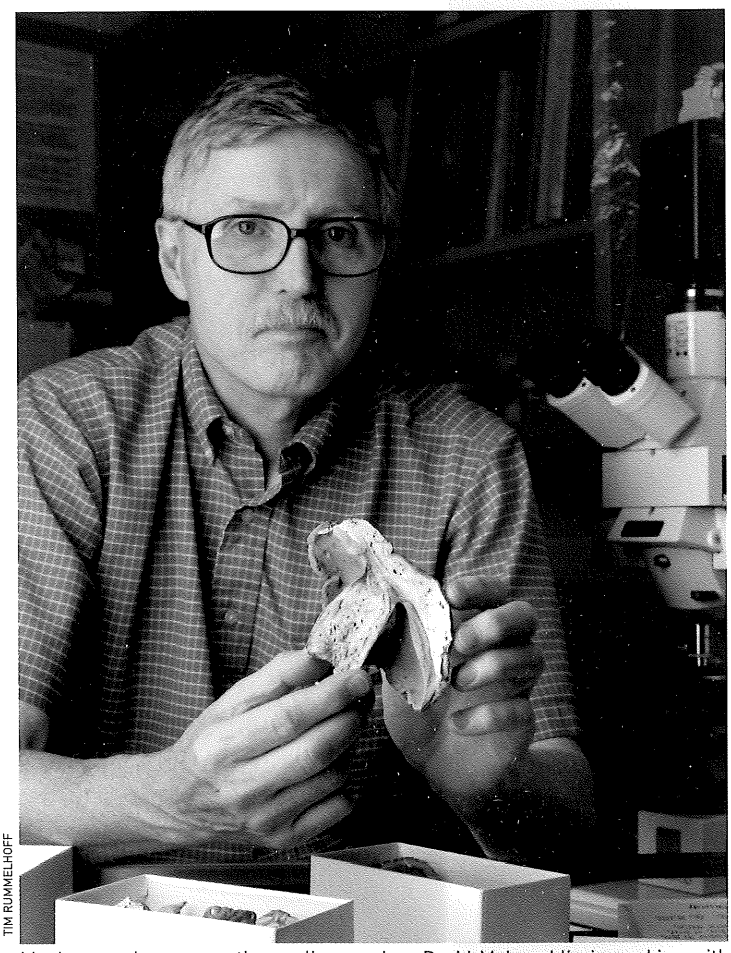
Slaton agreed to test samples of porcini to see if they affect the growth of cancer cells in culture. McLaughlin, for his part, is working to clarify porcini's phylogeny—to identify relationships among the various branches in the fungus's family tree—to help enhance the usefulness of Slaton's efforts.

A key player in the systematics work is Bryn Dentinger, a graduate student in McLaughlin's lab. Dentinger became a fungus fanatic as a teen when his mother handed him a field guide one day and challenged him to identify the mushrooms growing in his yard. Now he's applying that fascination to help clarify relationships among porcini specimens.

"We talk about porcini as though it's one mushroom, when it's really about 30 species," Dentinger says. By collecting a variety of samples and sequencing key genes in each, he hopes to create a picture of the degree of relationship among them. The information he gathers will help Slaton and McLaughlin design their studies in a way that maximizes the reliability and usefulness of the results. It will also help the researchers figure out which types of porcini are most likely to have anticancer activity.

Dentinger's work is part of a National Science Foundation–funded effort by McLaughlin and mycologists at several other universities to clarify the phylogeny of all known fungi using structural and genetic information. That project, in turn, is part of a larger NSF undertaking called Assembling the Tree of Life, which aims to clarify relationships among all living things. The mycological studies should be helpful in another cooperative effort underway by McLaughlin and Slaton to identify anticancer activity of shiitake mushrooms. It will also provide valuable information for conservation biologists, ecologists, and others seeking to clarify how various fungi fit into the overall picture of life on this planet.

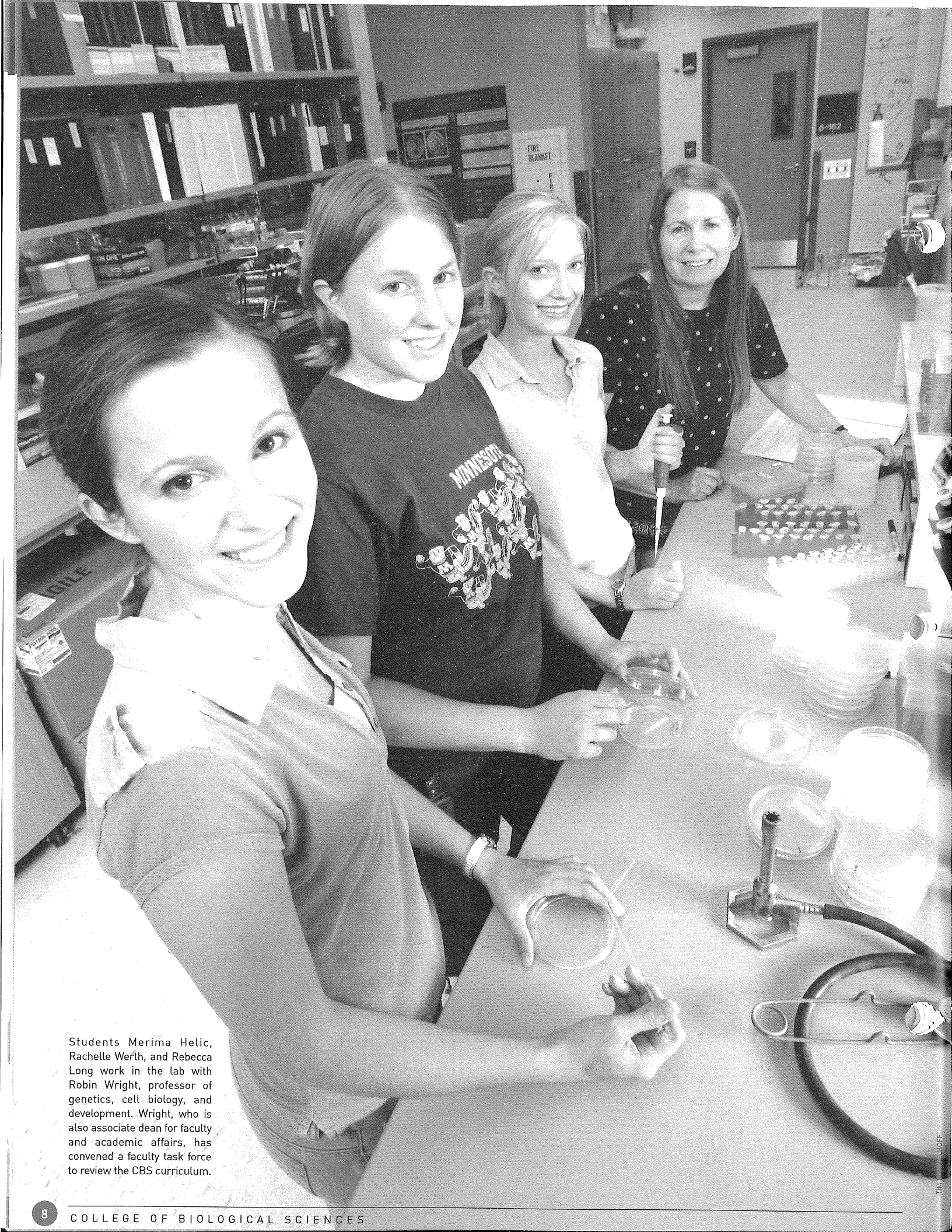
—Mary K. Hoff



TIM RUMMELHOFF

Mushrooms have more than culinary value. David McLaughlin is working with Medical School faculty to determine their potential for preventing cancer.

They have teamed together to test whether certain edible mushrooms boost the body's ability to fend off cancer.



Students Merima Helic, Rachelle Werth, and Rebecca Long work in the lab with Robin Wright, professor of genetics, cell biology, and development. Wright, who is also associate dean for faculty and academic affairs, has convened a faculty task force to review the CBS curriculum.

The EVOLUTION of Biology Education

Curriculum task force members share ideas on how to teach an ever-changing subject.

Biology has advanced more in the last 20 years than in the previous 200, and the next 20 years promise to be just as fast-paced.

Given this rapid rate of progress, how can educators keep up and prepare their students for jobs that may not even exist yet?

Publishers help by updating textbooks with the latest discoveries. Yet the issue goes deeper than facts: biology itself is evolving. The volume of data generated by genomics and other areas is making biology a more quantitative science. And at the molecular level, boundaries between biology, chemistry, and physics are blurring.

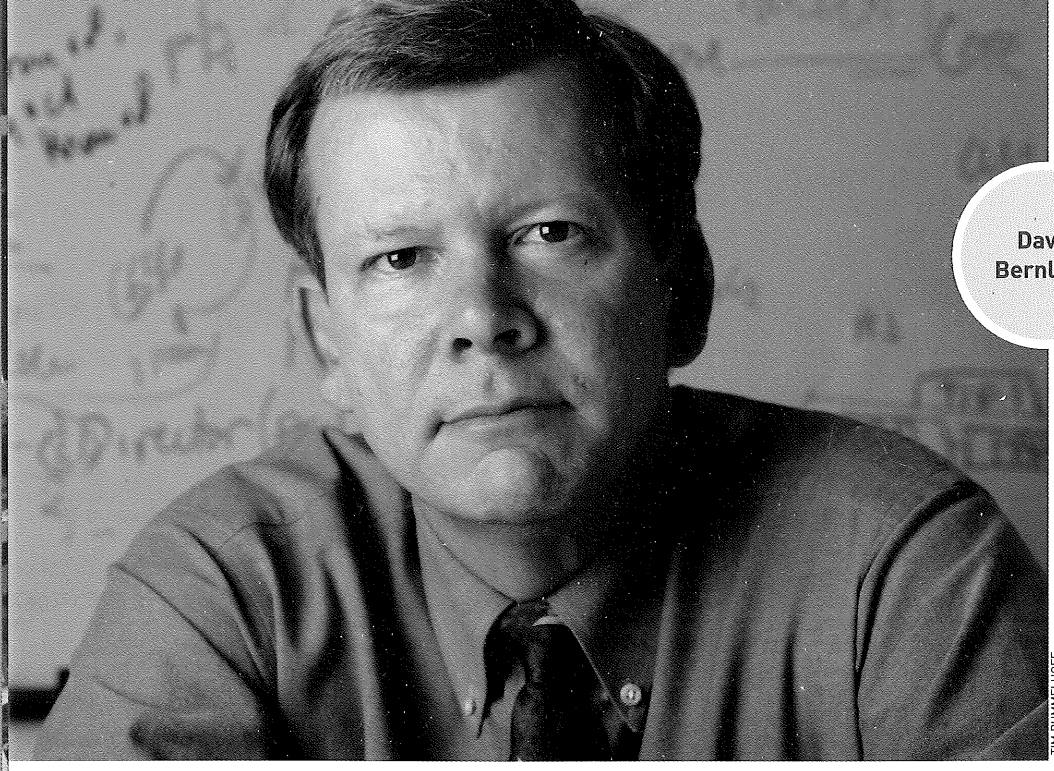
The National Research Council launched a discussion on the subject with the January, 2003 publication of "BIO 2010: Transforming Undergraduate Education for Future Research Biologists," which was sponsored by the National Institutes of Health and Howard Hughes Medical Institute. In essence, "BIO 2010" says that biology education should emphasize math, physics, chemistry, and information sciences and integrate them into biology courses, train students in interdisciplinary groups, and get all students into research labs early on.

Last fall, Robin Wright, associate dean for faculty and academic affairs, convened a faculty task force to review CBS' curriculum. The group reviewed curricula at peer colleges, consulted with leaders in biology education, referred to scholarly analyses, and sought input from CBS students and faculty as well as people from other colleges and departments and University administrators. Agendas and minutes are posted at http://cbs.umn.edu/main/ctf/.

> "We're still adding ingredients to the batter. But I think we have all the ingredients to be truly outstanding—talented students and faculty, committed leadership."
>
> *—Robin Wright*

They agreed that their top priority is to consider creating different general biology courses for different groups of students: CBS undergraduates, students majoring in engineering, agriculture or health sciences, and those in non-science majors, such as liberal arts, education, and business. Currently, most students choose from the same general biology courses.

By the end of the school year, a subgroup drafted a proposal for a new year-long core biology course for CBS students to be offered during the sophomore rather than freshman year, after students have taken calculus, some chemistry, physics, and possibly some biochemistry. Currently, most students take a year of inorganic chemistry and a



Dave Bernlohr

TIM RUMMELHOFF

year of organic chemistry before taking biochemistry. But since biochemistry permeates much of biology, the task force hopes to offer it before the core biology course. The new core course, which would integrate lectures and labs, would require students to use facts to solve problems rather than simply memorize facts.

This year, the task force is continuing its work. While the group as a whole continues to develop the core course for biology majors, sub-groups will consider courses for other science students and for non-science majors.

Following are some perspectives on curriculum reform from task force members and others.

Robin Wright

Associate Dean for Faculty and Academic Affairs, Professor of Genetics, Cell Biology, and Development

Wright says she first saw problems with biology curriculum when surveys at the University of Washington, where she was a faculty member, showed that graduates weren't using what they learned in her classes, either professionally or personally.

It was a wake-up call that led her to question the way she and most of her colleagues teach biology—through lectures, textbooks, and tests, she says. "Like most teachers, I invest an enormous amount of time preparing for classes, and I want it to have a long-term value for students."

After some research, Wright concluded that critical thinking skills rather than facts would better prepare students to use biology. Her teaching changed dramatically, from lectures and tests to asking students to use facts to solve problems.

"It's much more fun, but much harder—for teachers and students," she says. "I knew I didn't have a choice if I wanted to make a difference in their lives. In biology, the facts will change. That's why it's important to teach students to think like scientists, so they can delve into the rich amount of information that's available, evaluate it, and make decisions."

As Wright further explored the issue, she discovered she was not alone. There was a growing wave of concern among biologists nationwide—from federal agencies to small liberal arts colleges—that undergraduate biology education needed reform.

Wright came to CBS in January, 2003 to seize an opportunity to advance that reform and perhaps even create a model curriculum. CBS is one of few schools in the U.S. devoted to biological sciences and the University of Minnesota is one of few large public universities that require all undergraduates to take biology. As associate dean for faculty and academic affairs, Wright is responsible for undergraduate education and the University's General Biology Program.

The process is taking longer than she had hoped, but she believes that her goal of creating an integrated, inquiry-based core curriculum is gaining support among faculty. "The cake is definitely not in the oven yet," Wright says. "We're still adding ingredients to the batter. But I think we have all the ingredients to be truly outstanding – talented students and faculty, committed leadership. I think we can make a multi-layer chocolate torte with raspberry filling, not just an ordinary cake. I hope I'm helping people to realize that."

Dave Bernlohr

Distinguished McKnight University Professor and Head of the Department of Biochemistry, Molecular Biology, and Biophysics

Although Dave Bernlohr helped develop the proposal for a new biology curriculum, he is quick to point out that it's a first draft and suggestions are welcome.

"There are different opinions among faculty about how much change is needed," he says. "Do we really need to overhaul the

"Everyone agrees magic happens when you create interdisciplinary teams."

curriculum or just tweak it? If it's not broken, should we fix it?"

"Everyone agrees magic happens when you create interdisciplinary teams," Bernlohr says. "But there are different schools of thought about how to generate that magic." Some people think the integrated approach advocated in "BIO 2010" may go too far.

Proponents of another approach, called "Ways of Knowing," contend that interdisciplinary research produces results because scientists from different disciplines learn differently and approach problems differently. If you train everyone together, you may risk losing this advantage.

"BIO 2010 launched a national discussion on how to educate the next generation of biologists. We're now looking at integrated education versus ways of knowing. It's really not clear at this point how to reconcile the two," Bernlohr says. He adds that there appears to be consensus on some aspects of the proposal, such as increasing math rigor and getting students involved in research earlier.

In the 1970s, Bernlohr was looking at the CBS curriculum from a student's point of view. He earned a B.S. degree in biochemistry at CBS in 1978. Even then, faculty and students recognized the value of laboratory-based learning. Bernlohr worked in the lab of Finn Wold, who was head of biochemistry.

"The best educational experiences I had occurred in his lab," Bernlohr recalls. "He provided students with outstanding opportunities to learn and think critically. As we think about curriculum reform today, experience-based education is still the key."

Claudia Neuhauser

Professor and Head of the Department of Ecology, Evolution, and Behavior, Director of Graduate Studies for EEB

Claudia Neuhauser took an unusual road to ecology, evolution, and behavior. After earning a Ph.D. in math at Cornell University, she spent a year at Princeton studying ecology. Then she served on faculties of math and biology departments at several universities, including USC, UW Madison, and UC Davis, before settling on the ecology, evolution, and behavior department at CBS.

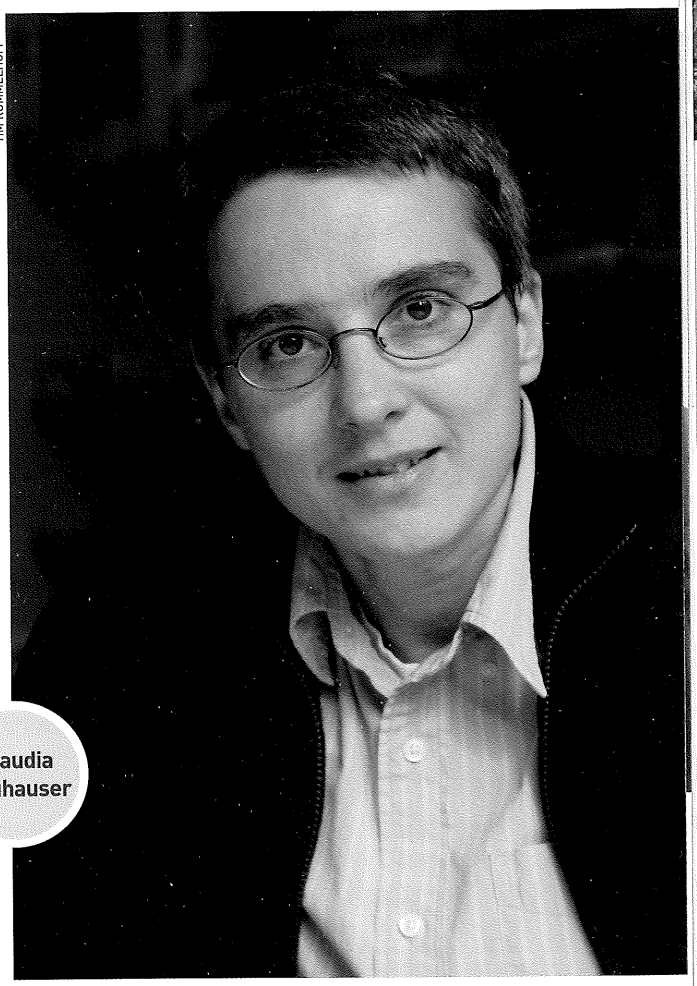
She says the highest compliment a student can pay her at the end of a term is, 'You know, that really wasn't so bad.'

An applied mathematician, Neuhauser uses "spatial stochastic processes" (an area of probability) to create models that address questions in biodiversity and population genetics. As a mathematician and biologist, she brings an extremely valuable vantage point to CBS. Not surprisingly, she strongly supports integrating math into biology courses. She also thinks biology majors need to take a statistics course in addition to a year of calculus, currently the only math requirement for most CBS majors.

Neuhauser understands that biology students tend to think of math as something you have to swallow because it's good for you. With this in mind, she created a class called "Calculus for Biology and Medicine" and wrote a textbook with the same name to show students how to apply calculus in the life sciences. She says the highest compliment a student can pay her at the end of a term is, 'You know, that really wasn't so bad.'

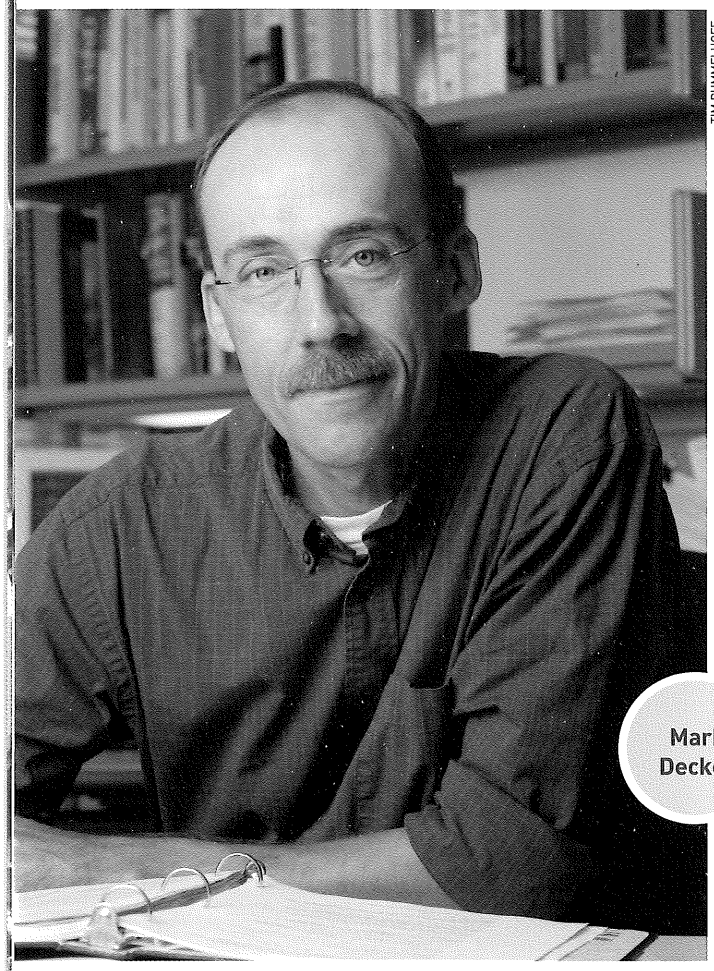
Since she got her Ph.D. in math in 1990 and began dabbling in biology, Neuhauser has witnessed a sharp increase in the use of quantitative skills in life sciences. All areas of biology, not just genomics and proteomics, are generating streams of numerical data, she says. More and more biologists will use this data to construct models on computers.

"We need to prepare them for the opportunities this will create for them," she says. "A curriculum that lacks quantitative elements doesn't serve the students well. Required math classes aren't enough. We need to show them how to use math in biology.



TIM RUMMELHOFF

Claudia Neuhauser


TIM RUMMELHOFF

Mark Decker

"The proposed class is an experiment, but that's okay," she adds. "If it works, good. If not, we go back to the drawing board, just like research."

Mark Decker

Associate Education Specialist General Biology Program

Mark Decker is on the front lines of general biology education. As one of three full-time instructors in the University's General Biology Program, he helps teach the subject to approximately 4,000 majors and non-majors every year.

Currently, the General Biology Program offers a one-semester survey course and a two-semester sequence for majors. Both cover the gamut of biology from molecules to ecosystems and include lab sessions. CBS majors are required to take a full year of introductory biology. Those who enter with a qualifying score on the AP biology exam get credit for the one-semester survey course and take another semester of organismal biology. Others take the two-semester sequence. Non-majors may take the one-semester course or the first semester of the year-long course.

Decker supports creating separate classes for majors and non-majors, but hopes that both will continue to cover all of general biology. "All students, even biology majors, need to be exposed to the full spectrum of biology," he says, adding that lectures are the most efficient way to cover lots of material. "Inquiry-based modules are more effective but slower."

Decker also has some concern that "BIO 2010" is geared for research biologists, particularly in biomedical sciences. While this may work for many CBS students, many others will work in environmental sciences, health care, the biotechnology industry, education, and other areas.

And, Decker says that while he sees the wisdom of planning the new biology course for majors for the sophomore year he wonders what students will think. "It may be a grind for freshmen to spend a year on prerequisites," he says. "I don't know if the "Nature of Life" and "Breadth of Biology" courses would be enough to keep their interest."

He also sees an important opportunity to create a very different course for non-majors. It would focus on showing them the role of biology in their lives, from global warming to renewable energy to health care, and preparing them to be informed consumers and citizens.

Ultimately, Decker says, creating separate biology courses for majors and non-majors is best.

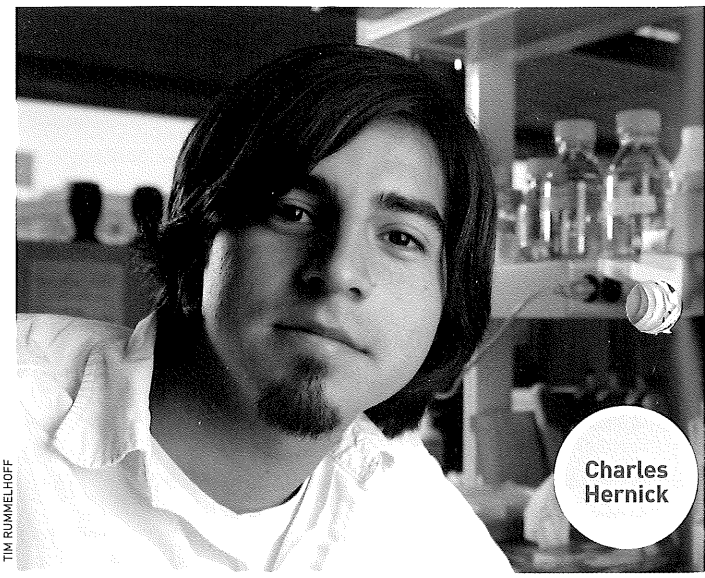
"But it's going to be messy," he says. "It will require lots of time, money, and trade-offs. Tension between the teaching model and breadth of content is inevitable."

Charles Hernick

Recent CBS graduate

A 2003 graduate with a B.S. degree in ecology, evolution, and behavior, Chuck Hernick worked as a junior scientist in a CBS plant genomics research lab in 2003-2004. He recently began a graduate program in international relations and environmental policy at Boston University.

Hernick says he's very happy with the education he got at CBS and thinks most students feel the same way. "I feel that I am better prepared for the future than friends who went to other schools says Hernick, who went to high school


TIM RUMMELHOFF

Charles Hernick

at the School of Environmental Studies in Apple Valley. But he does think it's important to use the lecture format judiciously, in combination with other ways of teaching biology.

"It's very motivating to do research yourself. It makes the calculus, physics, and chemistry classes worthwhile."

"Science is a dynamic field. What you get from lectures and textbooks is history. This gives you the language to be a scientist, but science is problem solving. The only way you can really learn how to be a scientist is by doing independent research in a lab. I think most students share this feeling."

Hernick says the instructional labs that accompany lecture classes are helpful, but not nearly as valuable as solving real problems in a real research lab. "When you just duplicate an experiment in an instructional lab, you miss the critical thinking component," he says. "Most of what I know about biology I learned from working in a research lab."

He adds that while students will always need lectures, they're just not the best way to teach students how to be scientists. "It's very motivating to do research yourself," he says. "It makes the calculus, physics, and chemistry classes worthwhile."

Hernick agrees with the plan to offer the core biology course during the sophomore year, after students take calculus and chemistry. He also agrees with Neuhauser that biology students could use a course in statistics designed for them. "It's a practical skill that most biology students will need," he says.

John R. Jungck

CBS alumnus and Mead Chair of Sciences at Beloit College.

Robin Wright first learned about John Jungck while exploring undergraduate biology curriculum at the national level. Jungck is co-founder of BioQUEST, a national consortium dedicated to reforming biology curriculum and a contributor to "BIO 2010."

Then she met him at a Howard Hughes Medical Institute (HHMI) gathering for undergraduate education directors in Maryland and discovered that he was a CBS alumnus.

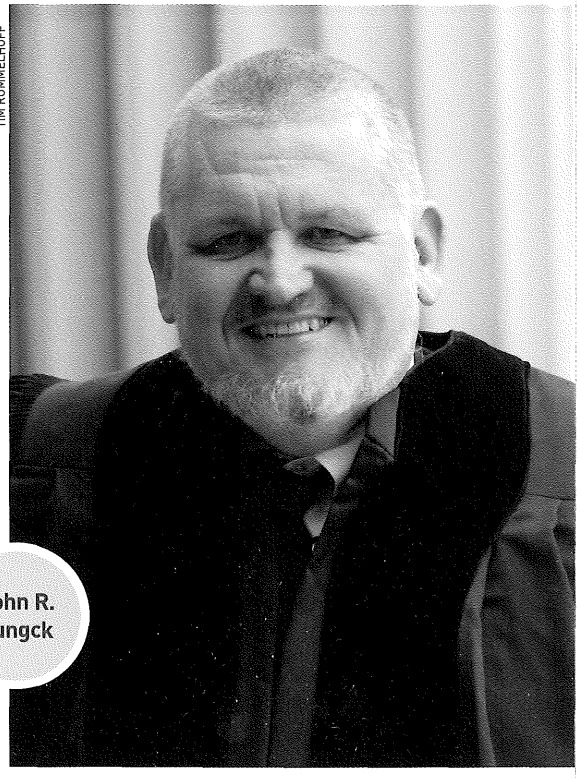
"When I told him I was moving to the College of Biological Sciences at the University of Minnesota, he told me he was a double alumnus. It made me feel very good about my decision because I knew a place that trained John Jungck simply had to be terrific," Wright says.

Jungck earned a B.S. degree in biochemistry from CBS in 1966 and an M.S. degree in genetics and microbiology in 1968. He became interested in undergraduate biology education at CBS when he shared an office with Donald Dean, a visiting professor who was involved with national science education organizations. Jungck helped Dean write a book on science education and talked to graduate students nationwide about teaching careers. After earning a doctorate at the University of Miami, Florida he joined the faculty of Beloit College in Wisconsin, where he is now Mead Chair of Sciences.

Jungck uses computer simulations, databases, and other tools (as well as toys) to create learning environments that give students a sense of what it's like to be a scientist working in a lab. Through BioQUEST he shares these materials and helps educators create their own. An expert in mathematical molecular evolution, he emphasizes the importance of math as a tool for future biologists.

This spring, Jungck returned to the University of Minnesota to receive an honorary doctorate for his contributions to undergraduate biology education. He says he was deeply honored and very proud to be an ambassador for his alma mater.

"While all the new facilities are remarkable, I was even more impressed with the



TIM RUMMELHOFF

John R. Jungck

leadership, the commitment to undergraduate biology education, and the friendliness of the academic community," he says. "

Jungck is also impressed that CBS encourages undergraduates to do independent research in faculty labs. He supports extending that opportunity to all students and faculty. The University's fundamental challenge, he says, is how to convert large lecture classes into interactive, collaborative, and investigative learning experiences.

"If the University of Minnesota can provide large numbers of students with these opportunities it could become a major national presence in undergraduate biology education. "

—Peggy Rinard

For the Love of Lakes

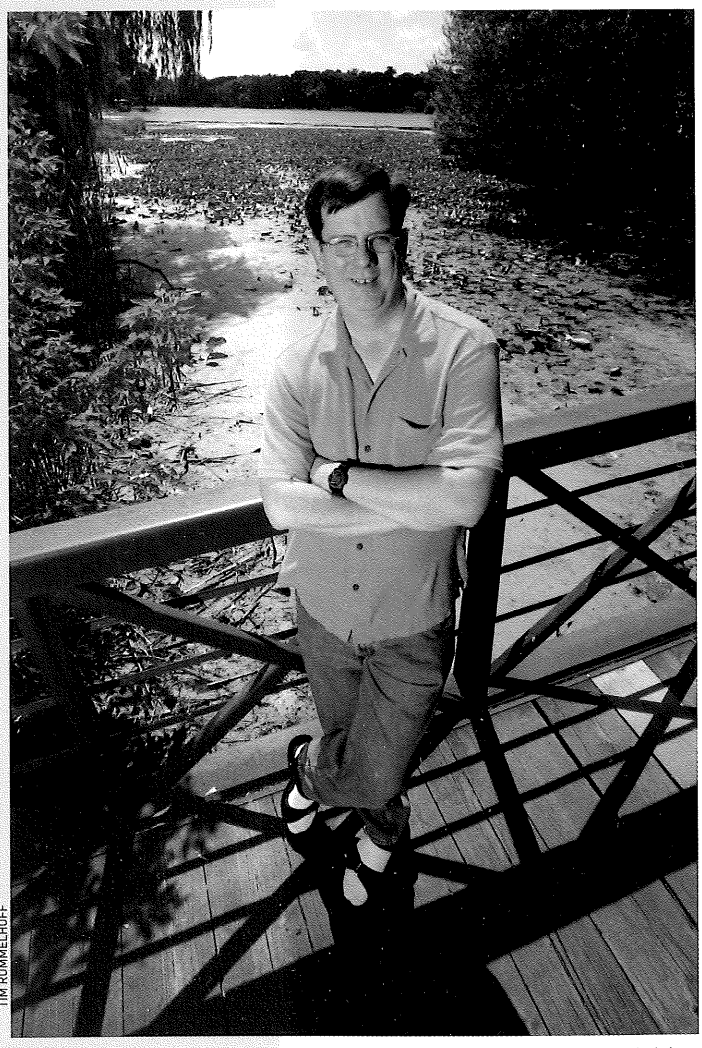
Nitrogen pollution is reaching even the pristine "big lake."

Lake Superior is like the canary in a coal mine, sending a strong signal about the condition of *all* the world's lakes.

—Bob Sterner

It's larger than the Czech Republic. It holds ten percent of the planet's fresh water. And, it's right in our back yard. Yet, says Professor Bob Sterner (Ecology, Evolution, and Behavior), "We know more about the large, remote lakes of Africa and Asia than we do about Lake Superior. It's a scandal that we don't know more about it."

That's one reason much of his current research focuses on Superior, yet what he's learning isn't such good news. Superior is "still fairly pristine by most measures," says Sterner. "Unlike the lower Great Lakes, there are no large urban centers around it and there is virtually no agriculture to provide chemical runoff." So, he was surprised when his research showed that nitrates are building up in the lake at an inexplicably fast rate. The nitrogen level has increased six-fold in the last 100 years, he says.



TIM RUMMELHOFF

Bob Sterner is studying the effects of rising nitrogen levels in Lake Superior.

If not from farms or factories, how is nitrogen reaching the lake? High temperature combustion in factories and cars releases certain forms of nitrogen that waft through the atmosphere and fall into Superior and other bodies of water when it rains or snows. As a result of human activities, the lake now receives an extra four million kilograms, or eight to ten million pounds, of this form of nitrogen per year.

Sterner stresses that Superior's nitrogen levels are still well below the EPA's limits for safe drinking water. Yet, nitrogen is a major cause of oxygen depletion in other bodies of water. The symptoms include blooms of algae (both toxic and non-toxic), declines in the health of fish and shellfish, loss of sea grass beds and coral reefs in oceans, and ecological changes in food webs. Now, with funding from the National Science Foundation, he's studying the "bio-geo-chemistry" that is taking place in Superior as a result of the increasing nitrogen levels.

Sterner became a limnologist because of his wide-ranging scientific interests. "It allows me a huge amount of freedom to study intriguing things, be they chemical, physical or biological, and I may utilize many different approaches to solving questions."

That perspective led to the publication of his book *Ecological Stoichiometry: The Biology of Elements from Molecules to the Biosphere* (Princeton University Press, 2002), coauthored by his long-time colleague from Arizona State University, James Elser. The book, about the balance of chemical elements in ecological interactions, has received high praise in the most prestigious journals such as *Nature* and *Science*. "I believe that this is one of the most important books written on ecology in the last 10 years," said a reviewer in *Ecology*. The book has been adopted as a textbook at some universities and, Sterner jokingly points out that it has reached the status of number 5,000 on Amazon.

Sterner's research and his book offer greater understanding of how human behavior affects the environment and he hopes we'll take some corrective action. "Lake Superior is like the canary in a coal mine, sending a strong signal about the condition of all the world's lakes. It's a treasure and we need to take care of it."

—Terri Peterson Smith

It Doesn't Seem Like Work

Truman Scholar lives life at breakneck speed.

Maya Babu spent a month this summer in India seeing some sights, catching up with relatives, and even garnering advice on staying active from her 97-year-old grandfather. There was but one pitfall to her journey: she couldn't keep busy enough. "I would have liked to have been working on a laptop, working on grant proposals," says Babu. "It was hard for me to just sit and know I couldn't be doing something."

"Doing something" for Babu has meant extensive community work—enough to fill a resumé many times over. But it's that commitment to public service, along with her leadership potential and communication skills, that helped earn her a distinguished honor.

Babu was one of 77 students nationally chosen as 2004 Truman Scholars. Each scholar receives $26,000—$2,000 for the student's senior year and $24,000 for graduate study. That's sure to come in handy for Babu, who has ambitious plans beyond her undergraduate years. The dual-degree (neuroscience and psychology) honors student from Eagan plans to pursue both medical and law degrees in preparation for a career in mental health policy.

Much of Babu's passion, as well as her interest in neuroscience, stems from her long-term involvement with America's Promise, the national organization dedicated to supporting youth. She has been a part of two trips to the juvenile detention center in Red Wing, Minn., to promote peacemaking and conflict resolution. It was there she discovered that juvenile offenders "were very similar to me, and that the difference was that something along our paths made us diverge." She also learned that 50 to 75 percent of juvenile offenders suffer from mental illness and half of those also have a substance abuse problem.

Since there is "so much yet to be discovered about the brain," Babu decided to study neuroscience, and she tacked on psychology "because it has more of the social aspect of mental health and substance abuse." Within the field of mental health policy, she plans to focus on youth in corrections and women's mental health.

Babu is now back in her comfort zone of computers, grant proposals, and breakneck pace. Late in the summer, she was teaching debate at a camp at Yale University and finishing the launch of a new scholarly publication called *The Bridge*. It focuses on "exploring—through case studies, research articles, and reflections—community work, youth work, and community mobilization," she says. And she's on the America's Promise board of directors with the likes of Alma Powell (wife of Colin), Cal Ripken, Jr., Tim Russert, and Jean Case.

How does she keep up? "I don't feel like it's work a lot of the time," Babu says. "I really feel like I'm spoiled. It's fun for me; I get to hang out with some really great people."

—Rick Moore

Editor's note: Maya was recently named one of Glamour Magazine's "Top Ten College Women" of 2004. She and her fellow honorees will be featured in the October, 2004 issue of the magazine.

DOUG KNUTSON

Truman Scholar Maya Babu plans to pursue both medical and law degrees.

"Doing something" for Babu has meant extensive community work—enough to fill a resumé many times over.

ALUMNI PROFILE

Bacchus and Biotech

Making every year a great year for wine.

Steven Lund is helping put a high-tech spin on an ancient industry.

"When you know what's going on inside the plants, you can use that knowledge to improve wine production."

—Steven Lund

Steven Lund (M.S. in plant biology, '90; Ph.D., '95) is no wine snob but what he knows about the genomics and biochemistry of wine grapes would make Robert Mondavi's head spin.

So, while he swirls the wine in his glass, he's not just enjoying the color, aroma, and flavor, but rather, he's thinking about the genetic mechanisms controlling those qualities during berry ripening.

In 2002, Lund joined the University of British Columbia's Wine Research Centre in Vancouver as an assistant professor in the faculty of agricultural sciences. Before his current position, Lund worked as a post-doctoral research fellow at the University of Florida and then as a senior staff scientist with Genesis Research and Development in New Zealand. There aren't a lot of genomics experts in the field of viticulture compared to other crops such as maize and tomato. That's why UBC recruited someone from outside the industry to work at the Wine Research Centre.

Canada may not be the first place that comes to mind when one thinks of wine. However, the country has two major wine-making regions—the Okanagan Valley in British Columbia and the Niagara area in the east—and Canada is fostering this research to assist its growing wine industry.

The Centre recently received a $3.1 million funding award from Genome Canada, an organization that provides financial resources for genomics and proteomics research, for an integrated genomics project in grape berries, on which Lund is project leader for Canada. They will conduct the research in collaboration with researchers at the University of Madrid and other Spanish universities with funding from Genome Spain. So, one of the world's oldest wine producing countries is collaborating with one of the newest.

Vineyards have always been at the mercy of soil conditions, climate, and disease. When Mother Nature works in the growers' favor, however, the result is a "great year" for the wine. Now, genomics may assist in this centuries-old process by minimizing the need for luck and guesswork in the growing process. Says Lund, "Growers do their best, but it's like typing into a computer and not knowing what goes on in the hard drive. They don't know why things turn out the way they do. When you know what's going on inside the plants, you can use that knowledge to improve wine production."

Lund stresses that this work is not aimed at commercializing genetically modified grapevines and wines. "Genomics doesn't mean GMOs," he says. Instead, it allows growers to understand how the plants operate. They may respond in the way they breed the plants and the way they treat the plants in the vineyard.

For example, growers may more selectively grow grapes with more concentrated flavor, or a particular skin thickness and seed size. They may also learn when the genes that initiate ripening and control quality "switch on." At that point they may, for example, withhold water from the plants to intensify flavor before harvesting.

While Lund's work involves extremely complex science, the results will be simple to understand—more consistent "great years" and better wine in our glasses.

—Terri Peterson Smith

Class Notes

John Jungck (M.S. in Genetics and Microbiology, 1968) received the University of Minnesota's honorary doctor of science degree at the College of Biological Sciences Commencement ceremony for the Class of 2004. He is currently Mead Chair of Sciences and Professor of Biology at Beloit College in Wisconsin.

Paul Kalina (B.S. in Biology, 1983) and his family moved back to Minnesota this past spring after living in Arizona.

Mary Jo Lockbaum (B.S. in Biology, 1990) joined Corporate Express at the company's North American headquarters in Broomfield, Colorado. Mary Jo oversees environmental initiatives such as environmentally friendly office product sales, energy conservation, and alternative fuel implementation.

Paul Savereide (Ph. D. in Cell and Developmental Biology and J.D. in 1991) left Cargill, Inc. and is now working for Patterson, Thuente, Skaar and Christensen, P.A. in Minneapolis.

Stacy Sjoberg (B.S. in Microbiology, 1993) moved to Iowa City to begin a fellowship in ophthalmology at the University of Iowa.

Cynthia Mattan (M.S. in Microbial Engineering, 1998) and **Benjamin Stading** (B.S. in Ecology, Evolution, and Behavior, 2003) were among 80 students chosen to begin the doctor of veterinary medicine program at the University of Wisconsin – Madison.

Kelly Pawlenty (B.S. in Biology, 1998) received her doctor of veterinary medicine degree from the University of Minnesota College of Veterinary Medicine in May. Kelly will be practicing small animal medicine, surgery, and dentistry at Apache Animal Hospital in Minneapolis.

Leiha Johnson (B.S. in Genetics and Cell Biology, 1999) is in her third year of teaching science in Tracy, California. Leiha recently received the "Teacher of Character" award for the Sacramento area. She enjoys teaching biology, physics, art, and senior seminar.

Tara Kirby (Ph.D. in Biochemistry, Molecular Biology, and Biophysics, 2002) started her post-doctoral fellowship at the National Institutes of Health in November, 2003. She works with Dr. Susan Buchanan on X-ray crystallography of bacterial outer membrane iron transporters.

Arman H. Nadershahi (M.S. in Biology and J.D., 2002) is practicing patent law in Los Angeles and is the executive director for the Biotech Education Center, Inc. which is a nonprofit organization dedicated to teaching college students about various aspects of biotechnology.

Dan Wepplo (B.S. in Biochemistry, 2004) is a research assistant in the Department of Cell Biology in the Center for Integrative Molecular Biosciences at Scripps Research Institute in La Jolla, California. His move to the west coast has allowed him to take advantage of the warm climate and become a proficient surfer.

Send your news to Emily Johnston, ejohnsto@cbs.umn.edu.

—Emily Johnston

Fall Fest

Join College of Biological Sciences alumni, faculty, staff, students, and friends at *Fall Fest 2004: Connecting U.* On Sunday, October 17 we'll gather on the St. Paul campus for a day filled with fun activities for all ages. This event is free and open to the public. You'll be able to tour the new Cargill building, learn how researchers can generate electricity from mud and how they can turn microbial cells into chemical factories. Attendees may also enjoy the Harvest Bowl Brunch for 50 cents, tour the large and small animal hospitals and the Raptor Center, and enjoy wagon rides around campus. For more information on Fall Fest visit www.umn.edu/fallfest/index.html

CBS Needs You

Volunteers are needed to help support alumni programs that benefit students such as the Mentor Program, Speakers Bureau, and Career Network. Time commitment varies and depends on the program. If you have not volunteered for a CBS program this year, please consider giving some of your time to our current students. You can volunteer online at www.cbs.umn.edu/volunteer or by calling Emily at 612-624-4770.

BSAS Has a New President

Jane Johnson is the new Biological Sciences Alumni Society board president. She received her degree in biology from CBS in 1976 and a degree in nursing from the University of Wisconsin-Madison in 1986. She is now in the Transcultural Nursing and Community Health masters program at Augsburg, which she hopes to complete in May 2005. Johnson currently serves as the care coordinator at HealthPartners Medical Group & Clinics where her primary focus is working with Somali, Oromo, Latino, and Vietnamese patients. She is also a nursing supervisor for First Minnesota Care, Inc., an agency that provides personal care assistance for elderly and disabled people in their homes.

Her vision for the Alumni Society is to identify more opportunities for alumni to connect with undergraduate students, to continue to refine and strengthen the mentor program, to explore alumni participation in the "Nature of Life" course for freshmen, and provide alumni input in relation to the curriculum review that's currently taking place. She urges alumni to contact her at alumni@cbs.umn.edu.

Ames Sheldon Joins CBS

Ames Sheldon joined the College of Biological Sciences in July as director of development. In this role, she will work closely with the U of M Foundation and CBS executive staff to strategically position the college for acquiring major gifts and building prospects for future donor relationships with individuals and corporations. Most recently, she served in a similar role for the Minnesota Historical Society.

GIVING Making Greatness . . .

The College of Biological Sciences gratefully acknowledges the following donors, who have generously provided support for student scholarships and fellowships, research, and a variety of special initiatives during fiscal year 2004. Every gift makes a difference.

If your name is missing or listed incorrectly, please call 612-625-7705 or e-mail lindq011@umn.edu.

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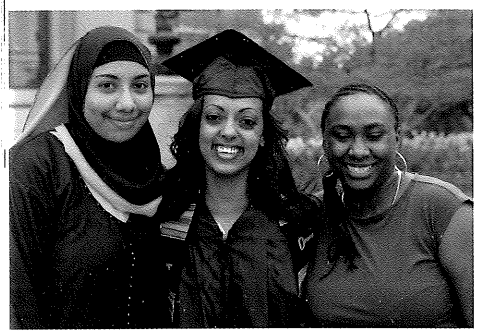
TIM RUMMELHOFF

Commencement, 2004

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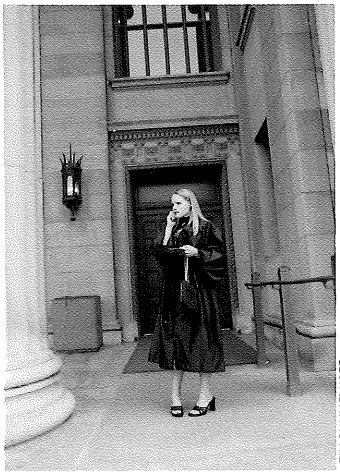
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Carrell J. and Grenaviere Kucera
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Pamela J. Lachowitzer
Kathryn R. Lamar **M**
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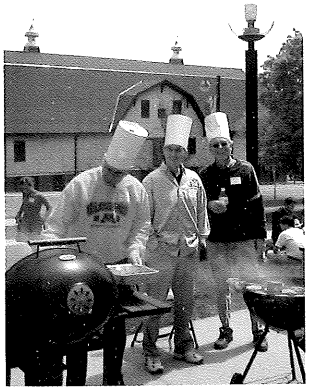

CBS Year-end Picnic

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Scott C. and Kathleen A. Rowe **M**
Doris S. Rubenstein **M**
Mary V. Santelmann and George A. King
Paul D. and Tamara J. Saunders **M**
Paul J. Savaryn **M**
Sidna M. Scheital
Lolly J. Schiffman
Robert D. Schmid
Mark A. Schoenbeck
Mark T. and Jean E. Schroepfer
Fang-Miin Sheen
Robert and Elsie Shoemaker
Gary B. Silberstein **M**
Thomas C. Skalbeck **M**
Jennifer L. St Sauver
John G. Steiert **M**
Shelley A. Steva
Lawrence G. Strate **M**
Melvin P. and Dorothy B. Stulberg
Douglas and Selene Swanson
Jean E. Takekawa
Jeffrey E. Tam
Steven W. and Jeanne M. Tanamachi
Rasa M. Tautvydas
Brent and Amy Theisen **M**
Robert E. Thompson
Mark A. Tomai
Peter M. Torgerson **M**
David J. and Mary Tosteson
Cheng-Hsien Tsai **M**
Mark J. and Ann E. Vellek
Gregory A. Viglianti
Joseph S. Villa **M**
Thomas A. Vogelpohl **M**
Terence C. Wagenknecht **M**
William R. Wallauer
Agnes M. Walz
Kenneth F. Walz
A. Vincent Weber
William P. Wenstrom
Janice A. Westerling
Robert C. Wild
Linda L. Williams
Janice M. and Curtis M. Wilson **M**
Jeanette A. Wiltse
Michael P. Winegar
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May C. Yang
Adrienne Zihlman

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Gregory J. Abler
Craig N. Adelmann **M**
Richard D. Allen **M**
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Dawn C. A. Anderson **M**
Lorraine B. Anderson **M**
Paula J. and Thomas Andrzejewski
Patrick J. Antonelli
Carolyn W. Arndt
Atofina Chemicals Inc. Foundation
Laura M. Auron **M**
Carolyn L. Bagne **M**
Leonard J. Banaszak **M**

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Jill M. and Stephen D. Barry
Barbara Ann Barzen
Leah R. Becicka
Kellie A. Benzow
Cynthia L. Bergsbaken
Paul C. Billings
Kalli-Ann L. Binkowski
Marie Blanchard
David Scott Blehert
Simba L. Blood
Janet S. Boe and Thomson P. Soule
Gennie Bolling
Tara R. Bonde
Steven R. Boyer **M**
Terrie L. and John E. Brandt
Rebecca A. Brenner
Gwenda L. Brewer
Louanne S. Brooks **M**
Kirk M. and Ione V. Brown
Maclean R. Brown Jr. **M**
Lakshmi R. Buddhavarapu
Diane E. Bundlie **M**
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Gregory A. Burtman

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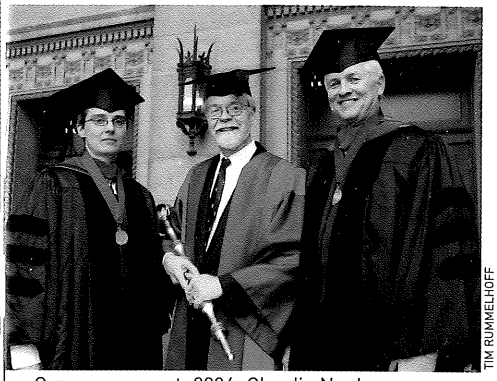
TIM RUMMELHOFF

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Mukul C. and Aparna Ganguli M
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Paul D. Lampe M
Lawrence J. Landherr
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Steven R. Larson M

Phillip A. Lawonn M
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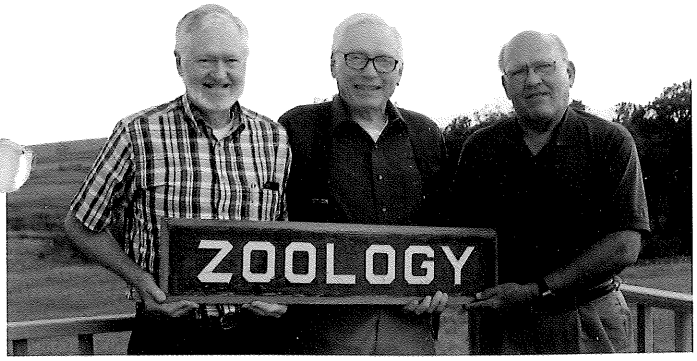
Deborah A. Nelson M
Douglas A. Nelson


TIM RUMMELHOFF

M membership in the University of Minnesota Alumni Association/Biological Sciences Alumni Society



Omer Larson, Robert McKinnell, and Thomas Collins, zoology grad students at the U in the late 1950s, enjoyed a reunion this summer. All are now retired -- Larson from University of North Dakota, Grand Forks; McKinnell from CBS; and Collins from Moorehead State. McKinnell salvaged the sign when Zoology became part of Ecology, Evolution, and Behavior in 1976.

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Marcy C. Salzer
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Thomas E. Sauber **M**
Scott Saunders
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Christine C. Schoenbauer
Christopher L. and Janet L. Schottel
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Martin W. and Rhoda J. Schularick
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Marcia K. Schuyler **M**
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Tina Seeland **M**
Allen V. and Sandra H. Seilheimer
Michelle I. and Dale Setterholm
Lisa L. Shafer
Michael J. and Debra J. Shane **M**
Robert A. Sharrock
Bianca Williamson Shaw and Joe Shaw
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Gregg D. Simonson
Sara M. Simpson
Satinder K. Singh
Lesli R. Smith
Lynda K. Smith
Val and Marilyn Smith **M**
Arnold W. Sodergren
James V. Soldin II **M**
Lindsay M. Sovil
Sandra L. Spier
St. Jude Medical Inc.
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Bret M. Steiner **M**
Cynthia A. Steinke
Linda Stenzel
Shelley A. Steva **M**
Linda K. Stevenson
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May T. Stewart
Michael K. Stock
Jay A. Stoerker
Steven M. Stone
Diane R. Storvick
John T. Stout
Gary A. Strand
Jami R. Stromberg
Constance S. Stueland
Larry B. Sundberg
Paul N. and Beverly Swenson
Violet E. Swenson
Brett M. Tanttu
Paul E. Tavernier
Michael and Kathleen Tekautz **M**
Dennis N. Thaden
Marcia M. Tholen **M**
Margaret L. Thomas
Mari C. Thomas
Michael G. and Joan E. Thomas
Randall M. Thompson
Scott R. Thulien
R. Thomas Tilbury
William A. Tisel **M**
Peter D. Tomascak
John D. Trawick **M**
Elizabeth J. Tuohy
Genevieve M. Tvrdik
Robert M. Valente **M**
Todd M. and Jill M. Vannelli
Robert S. Veit **M**
Scott Q. and Brigitte Vidas **M**
Carolyn R. Vitek
James Walker and Randi Nordstrom **M**
Margaret M. Walker
Mary F. and C. Stewart Walker
Patricia M. Walsh and Dale Hoover
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David C. Watrous-McCabe
Jane M. Wattrus
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Jane I. Wenger **M**
Bruce A. Werness **M**
Deborah A. Whitcomb
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C. Robert Wikel
Brian W. Woo
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Daniel S. Wovcha
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Jerry F. Zelesnikar
Jill L. Zullo
Thomas H. Zytkovicz

CBS Year-end Picnic, Senior Class photo

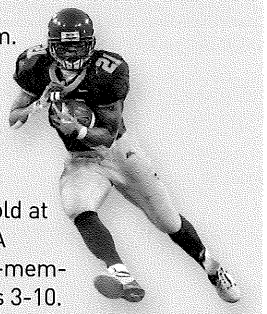
BOLD Membership in University of Minnesota Presidents Club

CBS Calendar

Annual Awards and Recognition Dinner
October 7, 2004
5:30 - 8:30 p.m.
McNamara Alumni Center, Minneapolis

Fall Fest
October 17, 2004
11:00 – 5:00
St. Paul Campus
www.umn.edu/fallfest/index.html

UMAA Homecoming Breakfast and Parade
October 23, 2004
Breakfast: 7:30-10 a.m.
Parade: 9:30 a.m.
Sports Pavilion (adjacent to Williams Arena), University Avenue
Food tickets will be sold at the door: $6 for UMAA members; $8 for non-members; $3 for kids, ages 3-10.



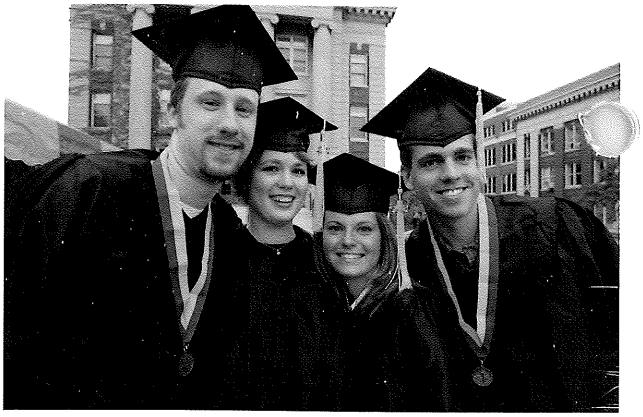
The Gophers will play Illinois later on Saturday at the Metrodome, time TBD. Go to http://www.alumni.umn.edu/ for Homecoming details.

Vote for the U!
November 2, 2004
Your local polling place

For information about any of these events, contact: Emily Johnston, (612) 624-4770 or ejohnsto@cbs.umn.edu

When You Invest in Scholarships...

You help keep the U of M affordable.



TIM RUMMELHOFF

Annual undergraduate expenses at the U of M are about $17,000 for Minnesota residents. A student would have to work more than 60 hours a week to cover these costs. Compare this with 1970, when students needed to work only 24 hours to cover expenses at an average public university.

You keep talented students in Minnesota.

More than half of our students stay in the state after they graduate. They become our teachers, physicians, company founders, and community leaders. Scholarships are an investment in Minnesota.

You encourage students to do their best.

U of M students with scholarships maintain good grades, become involved in activities, and graduate on time at a rate up to 35 percent higher than other students.

The U of M Scholarship Drive, which seeks to raise $150 million to increase the number of scholarships by 50 percent, is the largest in Minnesota history. Make a $50 gift to the Annual Fund or double the impact of your gift by contributing $25,000 or more for an endowed scholarship through the President's Scholarship Match.

To make a gift, use the envelope inside BIO, go to www.giving.umn.edu, or contact Ames Sheldon, CBS Development Director, at 612-624-9460 or sheldo57@umn.edu.

COLLEGE OF Biological Sciences
UNIVERSITY OF MINNESOTA

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UNIVERSITY OF MINNESOTA

Initiative for Renewable Energy and the Environment

ANNUAL REPORT 2004

IREE

Mission

The mission of the Initiative for Renewable Energy and the Environment is to promote statewide economic development; sustainable, healthy, and diverse ecosystems; and national energy security through development of bio-based and other renewable resources and processes.

History

Perhaps the most critical global challenge for the 21st Century is maintaining a healthy, productive environment that will continue to support human and biological communities and allow economies to prosper. Integrating all we know—from scientific, economic, and social perspectives—is key to understanding this challenge.

Beginning in the fall of 2002, informal discussions leading to the development of this initiative began to coalesce from several areas. Within the University of Minnesota, a growing number of faculty and administrators discussed the need for a coordinating mechanism to raise the profile of renewable energy research and development within the University and within the state of Minnesota. These discussions soon merged with those of key representatives of state government who shared a similar goal.

By early 2003, the decision was made to form the University of Minnesota Initiative for Renewable Energy and the Environment (IREE). Later that year, the Minnesota Legislature directed a portion of Xcel Energy rate-payer funds for renewable development and conservation improvements to the University for renewable energy research and demonstration. University of Minnesota President Bob Bruininks, as part of a commitment to sustaining and growing the University as a top public research institution, designated the Environment and Renewable Energy as one of the primary academic initiatives for the University. Under the guidance of IREE, the funds are being used by multidisciplinary teams to conduct cutting-edge basic and applied research and to develop demonstration projects. They are also supporting efforts to identify strategic issues associated with renewable energy systems.

Initiative for **Renewable Energy** and the **Environment**

Goals and Values

Core Values

Collaboration

Scholars and researchers involved with IREE include chemists, engineers, ecologists, biologists, agronomists, economists, architects, and policy experts. We share common interests in finding environmentally and economically friendly alternatives to energy and products made from fossil fuels.

Partnership

We actively seek and support the expertise and resources of private business and industry, state public agencies, and the non-profit sectors. The University of Minnesota has diverse intellectual strengths and is uniquely positioned to lead and facilitate these partnerships.

Leveraging Resources

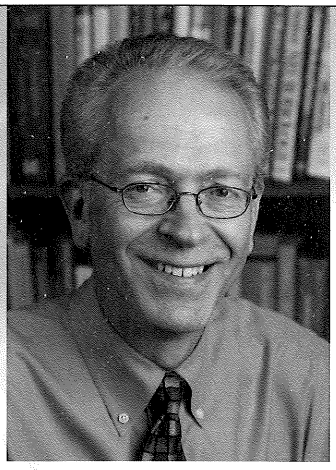
We attract support from state and federal government and private industry. We forge strong external partnerships to leverage financial resources to their best advantage and to position Minnesota as a leader in the renewable energy economy.

Impact

Our focus is on research and technology development that carry the potential for significant, long-term environmental and economic benefits for Minnesota. We also emphasize commercializing short-term solutions to immediately use renewable energy options like wind and solar energy.

Goals and Objectives

- **Provide leadership in research and development of environmentally sound production, distribution and use of energy, chemicals, and materials from renewable resources.**
- **Create jobs by transferring technologies into practical outcomes for industry and communities.**
- **Support the goal of moving toward an economy based on hydrogen and renewables.**
- **Utilize bio-based and other renewable sources as a substitute for fossil fuel-based energy, chemicals, and materials.**
- **Facilitate communication, coordination, and collaboration.**



All the elements at hand

It's rare for advances in basic science to align with society's most critical needs. But that's what's happening with renewable energy and materials. Scientists are acquiring the tools to use hydrogen, enzymes, and biomass to create renewable fuel and biodegradable plastics just as the world's built-in gas tank is dropping to empty and the environment is reaching the limit of petroleum waste products that it can assimilate.

"Our intention was to use our resources to attract a broad spectrum of expertise within and outside of the University to address the problems and potential of renewable energy. That has succeeded beyond our expectations."

Here in Minnesota we have all the elements at hand to make the most of this opportunity: world-class experts in chemical engineering, biochemistry, agriculture, environmental sciences, and other key disciplines; an abundance of natural resources; and enthusiastic partners in state agencies, industry, and non-profit organizations. Thus it's not surprising that we have accomplished so much in the year since the University's Initiative for Renewable Energy and the Environment (IREE) was formed and funded with $20 million from the state and Xcel Energy. Nor is it surprising that we feel so optimistic about the future.

When we organized IREE, our intention was to use our resources to attract a broad spectrum of expertise within and outside of the University to address the problems and potential of renewable energy. That has succeeded beyond our expectations. Within the University, we have been joined by scientists of all kinds, engineers, ecologists, architects, and public policy experts. Our partners outside of the University include the Department of Agriculture, the Science Museum of Minnesota, major corporations such as Xcel Energy, Cargill, and 3M, Energy Alley and the Minnesota Environmental Initiative, heads of large state growers' associations, and leaders of smaller rural and environmental organizations.

The creative energy generated by such a diverse and committed group will lead us to new and unimagined places. You can get a glimpse of that among the research projects funded by IREE to date: the use of common bacteria to generate electricity and hydrogen; a softball-sized hydrogen reactor that could supply power for a home; and a solar-powered stove, to name a few.

In every sense, IREE is a "win-win-win" situation. It's good for energy security, the environment, and the economy. It has attracted supporters with very different political views. And it is very much aligned with the interests of our students at the University of Minnesota. Our efforts now will create a better world and jobs for them, and for future generations. There's something in IREE that everyone can feel good about.

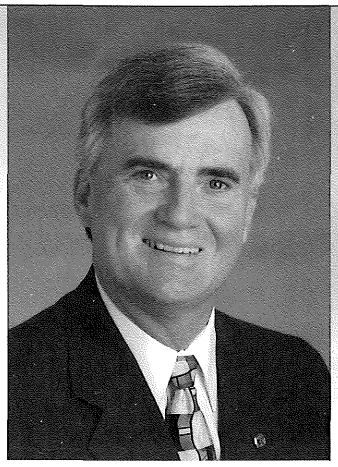
I would like to thank everyone who contributed to IREE during this first year. We can achieve so much more by working together than we can individually. We are off to a strong start. And our future is bright.

Robert Elde

Chair, Initiative for Renewable Energy and the Environment

Dean, College of Biological Sciences

Bringing together the best and brightest minds



Wow! What an incredible journey! That pretty much summarizes my thoughts as I write this preface to IREE's first annual report. The development of IREE has been a significant event in the history of the University of Minnesota and I hope, the state of Minnesota. I'm reminded of the advice my dad gave while facing endless rows of corn still awaiting the two-row manual-lift cultivator on our Super H Farmall tractor… "Don't just look at the rows that are left. Look back once in a while, and see what you've gotten done." So, while it's tempting for me to focus on the issues and challenges that remain ahead of us, it is important to pause and reflect on some significant accomplishments for the first year of IREE's existence.

"I've found this effort to be a magnet, both for new converts to these issues and for many people who have been tirelessly pursuing these goals for decades."

This annual report highlights some of the research efforts underway, but I should point out the significant efforts and discussions that have gone into the development of the IREE mission statement, principles that guide our funding processes, and the mechanisms by which we solicit and award funding. We've invested significant efforts to bring to life the core values which guide our work: COLLABORATION, PARTNERSHIPS, LEVERAGING our resources, and having an IMPACT on Minnesota's renewable energy future. Our clusters of activity focus not only on technological advancements, but also on incorporating economics, policy, and environmental considerations. We've worked hard to reach out, both within the University and to the broader community to bring together the best and brightest minds to advance our goals of reducing our dependence on nonrenewable, fossil fuel-based sources of energy and products, promoting economic development, and improving the health and sustainability of our global ecosystem.

I've found this effort to be a magnet, both for new converts to these issues, and for many people who have been tirelessly pursuing these goals for decades. As I've often stated, this renewable energy business is an idea whose time has come—again.

One of our major objectives is to put Minnesota on the map as a place where these ideas, technologies, and advances take root and flourish. We have made good progress in our first year, but significant challenges and opportunities lie ahead. We need to continue to develop our partnering and collaborative efforts. We need to strive towards sustainable funding for this important initiative. We must press forward on communicating our results. And most importantly, we must ensure our efforts lead to a brighter renewable energy future, not just for Minnesota, but for the nation and the world.

Finally, I'd be remiss if I didn't thank many colleagues here at the University; members of the Working Group, the Executive Committee, the IREE staff, and numerous faculty who've engaged in this work. Also, my thanks to countless numbers of individuals across this state who have helped in many ways to shape this initiative.

Richard (Dick) Hemmingsen

Director, Initiative for Renewable Energy and the Environment

Exploring applied research questions *and* optimizing the technologies involved

IREE is committed to demonstrating the applicability of new and emerging renewable energy technologies. As these technologies, practices, and approaches are being developed, demonstration projects in both the public and private sectors are underway. These projects are necessary to explore applied research questions and optimize the technologies involved.

The University of Minnesota Renewable Energy Research and Demonstration Center at Morris is a collaborative project of the West Central Research and Outreach Center (WCROC), the University of Minnesota-Morris (UMM), and IREE. The project has two primary objectives: 1) to provide a model for rural communities and agricultural producers to integrate renewable energy systems into their economies, and 2) to establish systems research that provides information to stimulate the renewable energy industry.

The first phase of a hybrid wind energy system at WCROC is the construction of a 1.65 megawatt wind turbine, which will be completed in March of 2005. This has created the possibility of developing a unique wind-to-hydrogen demonstration and research platform with leveraged funds from the Legislative Commission on Minnesota Resources. Additional partners include the Upper Midwest Hydrogen Initiative and its member companies, Windustry and the National Renewable Energy Laboratory.

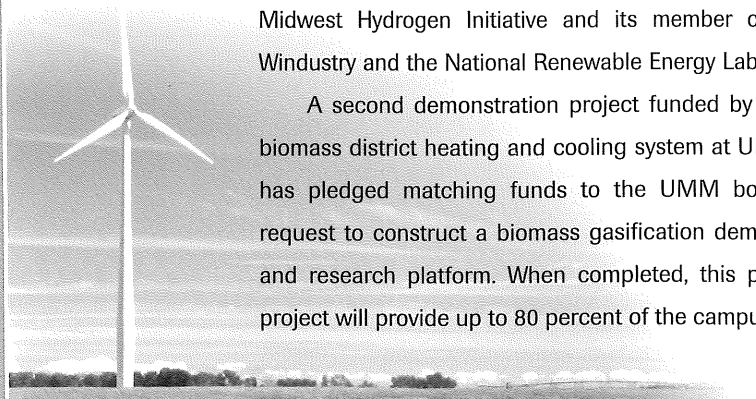
A second demonstration project funded by IREE is a biomass district heating and cooling system at UMM. IREE has pledged matching funds to the UMM bonding bill request to construct a biomass gasification demonstration and research platform. When completed, this plant-scale project will provide up to 80 percent of the campus' heating and cooling needs. In addition to being a model for commercial application of biomass in heating and cooling systems, the facility will also enable University of Minnesota research to address important collection, processing, and storage issues, enable improved permitting, establish best management practices to ensure environmental sustainability of biomass systems, and provide valuable information on the economic impact of using biofuels on rural economies. The Agricultural Utilization and Research Institute and Minnesota Corn Growers Association are partners in this project.

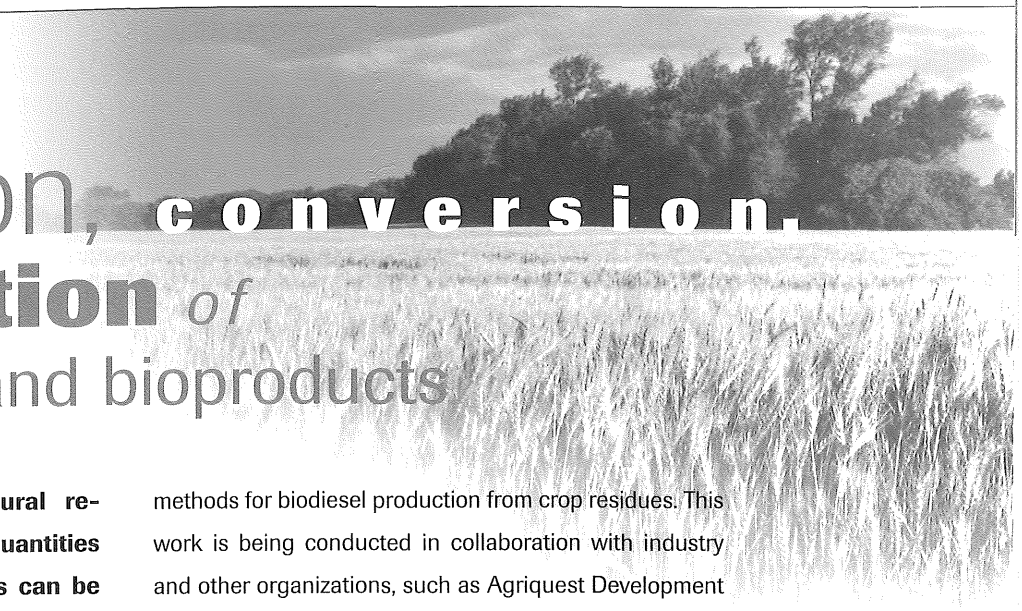
Additionally, IREE supported the development of the Prairie Maze project at the Science Museum of Minnesota. This project is focused on demonstrating the principles related to obtaining renewable energy from biomass.

When completed, this plant-scale project will provide up to 80 percent of the campus' heating and cooling needs.

IREE also supported the completion of a unique solar–hydrogen fuel cell demonstration at Rapson Hall in the College of Architecture and Landscape Architecture on the University's Twin Cities Campus. Partners on this project include Xcel Energy and the Minnesota Office of Environmental Assistance.

Work on demonstration projects is being conducted by Greg Cuomo, West Central Research and Outreach Center; Lowell Rasmussen, University of Minnesota–Morris; Vance Morey, Department of Biosystems and Agricultural Engineering; and Louise Goldberg and John Carmody, Sustainable Building Research Center.





Production, conversion, and utilization of bioenergy and bioproducts

Minnesota possesses significant natural resources for the production of both large quantities and a wide variety of biomass. Biomass can be converted into energy or products using a variety of means, including biocatalysis, biorefining, and fermentation. Scientific and technological advances are needed in order for biobased renewable sources to replace fossil fuel-based sources.

This cluster is designed to bring together researchers along the farm- or forest-to-product continuum and promote multidisciplinary work. Upstream research in this continuum includes work on crop improvement. Professors Sue Gibson, Department of Plant Biology, and David Somers, Department of Agronomy and Plant Genetics, are using genomic tools to manipulate carbon partitioning in model plant systems such as *Arabidopsis thaliana,* with the ultimate goal of increasing crop yields for biofuels and bioproducts. Other cluster projects focus on the optimization of biomass production from hybrid poplar, alfalfa, and willow—all potential regional resources for bioenergy and bioproducts. Cluster leaders are partnering with numerous government, non-profit, and industry organizations on this work.

The next stage in the continuum involves processing, separation, and isolation steps. Professor Roger Ruan in the Department of Biosystems and Agricultural Engineering is working on the biorefining concept for the corn industry. The model will utilize corn to produce ethanol fuels, energy to run the plant, and value-added byproducts such as protein isolates, lipids, and biopolymers. Professor Ruan is also working with Professor David Kittelson in the Institute of Technology to improve methods for biodiesel production from crop residues. This work is being conducted in collaboration with industry and other organizations, such as Agriquest Development Co., Inc., the Agricultural Utilization Research Institute (AURI), and TME Industries Limited.

The model will utilize corn to produce ethanol fuels, energy to run the plant, and value-added byproducts.

Finally, University of Minnesota researchers are working at the end of the continuum, focusing on the properties of bioproducts and their uses. These projects include the use of biomass-derived oils in gas turbine engines, the kinetics of poly-lactic acid degradation in the environment, and the synthesis and properties of polyesters using bio-based building blocks. These projects are also being done in collaboration with external groups, such as AURI, Cargill, Inc., and Cargill-Dow.

This cluster continues to devise and conduct research at the cutting edge of science, while anchoring such work through partnerships to bring bioenergy and bioproducts to the market.

This cluster is co-led by Roger Ruan, Department of Biosystems and Agricultural Engineering; Donald Wyse, Department of Agronomy and Plant Genetics; Donald Fosnacht, Natural Resources Research Institute; David Kittelson, Department of Mechanical Engineering; and Larry Wackett, Department of Biochemistry, Molecular Biology, and Biophysics.

Hydrogen from domestically available renewable resources

Minnesota is exploring the increased utilization of hydrogen—the simplest and most abundant element in the universe—as a carrier of energy for electric, heating, and transportation needs. The generation, storage, transport, and utilization of hydrogen are all research challenges. Research opportunities include conversion of wind resources to hydrogen, conversion of biomass feedstocks grown specifically for conversion to energy and products, and improvements in scalable fuel cell technologies. The goal is to be able to produce hydrogen cleanly, efficiently, and affordably from domestically available renewable resources.

A research group led by Regents Professor Lanny Schmidt in the Department of Chemical Engineering and Materials Science has found a way to convert ethanol-water mixtures directly into hydrogen with high efficiency in small, compact chemical reactors. Professor Schmidt's results suggest that ethanol may be a suitable liquid for electricity generation. Ethanol is easily produced from corn, is safe and transportable, and is non-toxic. It can be used in portable and distributed applications with little infrastructure change. The system produced is capable of generating sufficient hydrogen for a one kilowatt fuel cell and is about the size of a person's hand. The results were published in the February 13, 2004 issue of *Science* magazine. Research related to this process is being supported by IREE and the Minnesota Corn Growers Association.

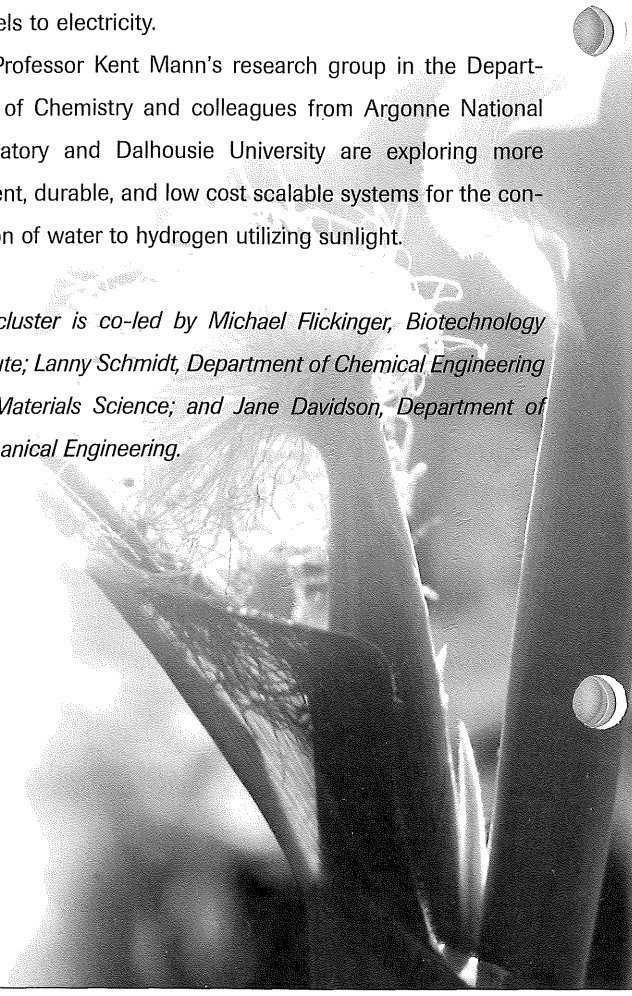
The goal is to be able to produce hydrogen cleanly, efficiently, and affordably from domestically available renewable resources.

Professor Michael Flickinger in the Biotechnology Institute, and colleagues in the Department of Chemical Engineering and Materials Science, the University of Iowa, and the National Renewable Energy Laboratory in Golden, Colorado are experimenting with encapsulating phototrophic bacteria in latex films. The cells produce hydrogen when they are exposed to light. The goal of this research is to develop bacterial fuel cells that convert organic waste and sunlight into hydrogen and electricity.

Professor Bill Smyrl in the Department of Chemical Engineering and Materials Science is developing improved catalysts and electrode structures to improve the performance of fuel cells for the conversion of hydrogen and other biofuels to electricity.

Professor Kent Mann's research group in the Department of Chemistry and colleagues from Argonne National Laboratory and Dalhousie University are exploring more efficient, durable, and low cost scalable systems for the conversion of water to hydrogen utilizing sunlight.

This cluster is co-led by Michael Flickinger, Biotechnology Institute; Lanny Schmidt, Department of Chemical Engineering and Materials Science; and Jane Davidson, Department of Mechanical Engineering.



Creating more efficient buildings, materials and systems

Conservation and efficient utilization of energy in buildings, industry, and transportation are important. Research efforts are currently focusing on developing and integrating efficient systems for energy generation and conservation. Further development of efficient and cost-effective wind and solar-based energy systems are also part of this effort.

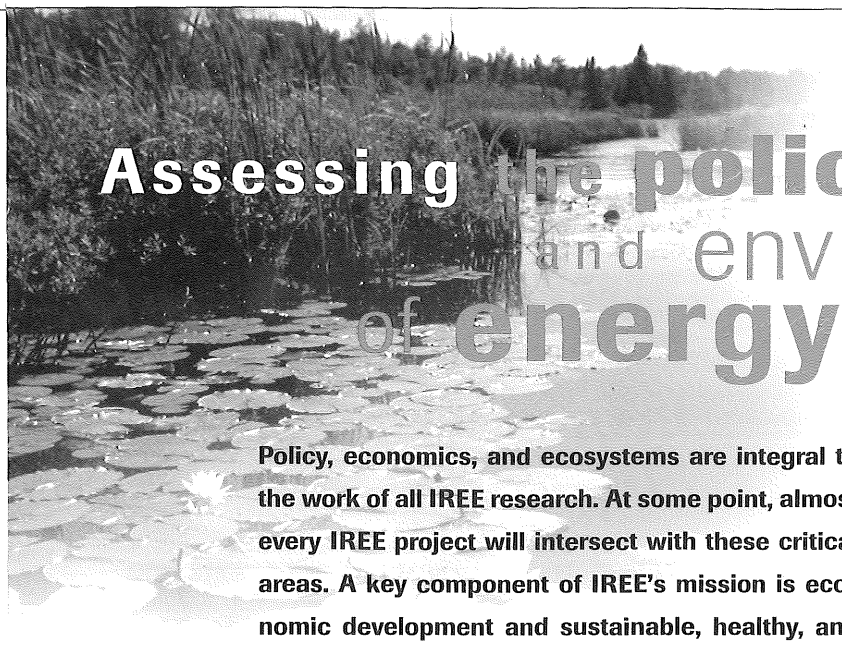
A team of University researchers and external partners was recently awarded a three-year, $1.5 million grant from the Department of Energy (DOE) to develop an innovative residential roof. The primary objective of the work is to create a more energy-efficient building envelope. The one-piece modular roof panel will be self-supporting and will have a number of improvements over existing technology. These improvements include an R-value 20% greater than that required by the 2003 International Energy Conservation Code; reduced infiltration and moisture condensation; and integrated heat recovery, photovoltaics and solar hot water collectors. This innovative approach to roof construction will eliminate the need for additional roof support and will provide conditioned space for HVAC equipment and storage.

The project was initially supported by IREE as a seed grant to Professors Jane Davidson and Susan Mantell in the Department of Mechanical Engineering, and Director John Carmody and Senior Research Associate Louise Goldberg of the Sustainable Building Research Center. The seed grant allowed the team to work with Pulte Home Sciences and General Electric Advanced Materials to conduct preliminary analyses of various concepts. In turn, this work led to a short-term feasibility project funded by IREE and the Oak Ridge National Laboratory. The newly awarded DOE grant, which is cost-shared by IREE, the Institute of Technology and the College of Architecture and Landscape Architecture, has just begun.

A team of University researchers and external partners was recently awarded a three-year, $1.5 million grant from the Department of Energy to develop an innovative residential roof.

In another project led by Professor Davidson, a team of University faculty and students is collaborating with scientists at the National Renewable Energy Laboratory (NREL), two U.S. solar manufacturers, and several polymer manufacturers to develop a new type of solar water heating system made primarily of polymeric materials. The replacement of glass and metal components with plastic is expected to reduce the costs of hardware, shipping and installation, and make solar water heating more affordable. This research addresses some of the key challenges in using polymers in solar systems. It is aimed at assuring high thermal efficiency and appropriate selection and testing of candidate polymer materials. IREE has provided matching funds for this project, which is also supported by a grant from NREL.

This cluster is co-led by John Carmody, Sustainable Building Research Center; Greg Cuomo, West Central Research and Outreach Center; Ned Mohan, Department of Electrical and Computer Engineering; and Jane Davidson, Department of Mechanical Engineering.



Assessing the policy and environmental costs of energy

Policy, economics, and ecosystems are integral to the work of all IREE research. At some point, almost every IREE project will intersect with these critical areas. A key component of IREE's mission is economic development and sustainable, healthy, and diverse ecosystems. Policy considerations and incentives for development are central to movement toward an economy based on renewables.

While many alternative sources of energy are technologically possible, whether or not they are economically and environmentally desirable requires consideration of the full cost of energy use. Environmental costs are not reflected in market prices. These costs include the human health and welfare impacts caused by residual air, water, and solid waste emissions; the impacts of climate change tied to emissions of greenhouse gases; and ecological changes from land use and nutrient cycles. One IREE project investigates methods to calculate the full cost of energy use, variously called full cost accounting or life-cycle cost analysis. Professors David Tilman of the Department of Ecology, Evolution, and Behavior and Steve Polasky of the Department of Applied Economics are leading this effort.

Policy considerations and incentives for development are central to the application of renewable energy technologies and movement toward an economy based on renewables.

Projects in this cluster reflect IREE's core values of partnership and are by nature interdisciplinary. In one project, University students and researchers, in collaboration with the Great Plains Institute for Sustainable Development, are investigating the economic and policy issues associated with obtaining ethanol from native grasses. In another, professors and students in the Carlson School of Management are working with researchers in the Institute of Technology to understand the business and public policy dimensions of bringing alternative vehicles to the market.

The University is partnering with Minnesota Environmental Initiative's Energy Alley to identify research priorities for the state and region. One of these priorities lies in biomass research and development. The University of Minnesota has great strengths in agriculture, biocatalysis, and bioprocessing. In this context, investigators from many colleges and departments are teaming up with external organizations, such as state government, industry groups, and non-profit organizations, to design and develop systems for the use of sustainable fuels from biomass. Through this cluster, IREE research and development is grounded, leading to real-world applications of science and technology.

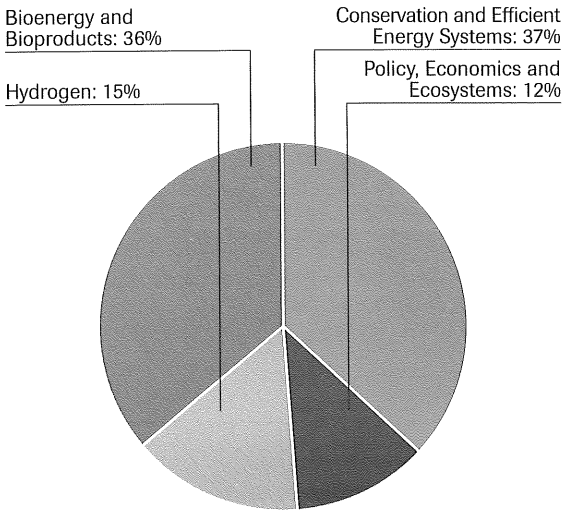
This cluster is co-lead by Kenneth H. Keller, Center for Science, Technology, and Public Policy; David Tilman, Department of Ecology, Evolution, and Behavior; and Steve Polasky, Department of Applied Economics.

Investment principles and **how funds have been used**

IREE funding is utilized to produce cutting-edge integrative research and demonstrations leading to the advancement of the initiative's mission, goals, and objectives. We have framed the following investment principles. Funded activities will:

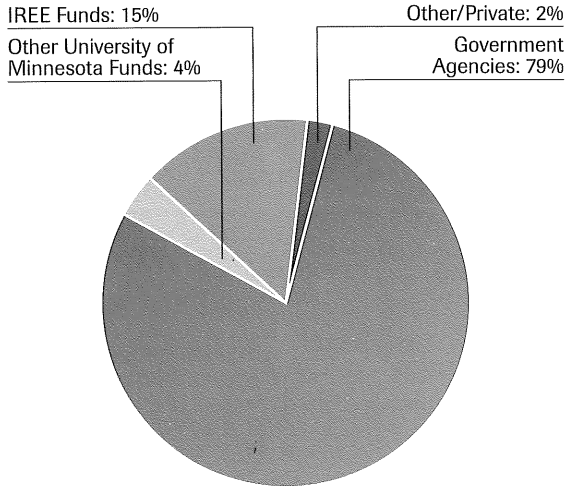
- be consistent with our mission;
- be multi-disciplinary;
- be highly leveraged;
- capitalize on unique or potential University strengths, opportunities and faculty expertise;
- address clear and compelling societal needs and opportunities;
- be balanced between proposals with short-term and long-term impacts.

Distribution of IREE Funds: $1.2 million
*By Area of Activity**



Does not include Demonstration Projects of $2.9 million

Matching Funds: $3.0 million
By Source



Projects

Project Title	Project Researcher	Department
Pre-design/Economic Modeling	Gregory Cuomo	West Central Research and Outreach Center
Solicit Construction Manager at Risk/UMM BioMassDistrict Heating Alternative	Lowell Rasmussen	UMM- Morris Plant Services Administration
Power Purchase Agreement/RFP for 2 Wind Turbines	Gregory Cuomo	West Central Research and Outreach Center
Turbine Purchase Submitted	Gregory Cuomo	West Central Research and Outreach Center
UMRER&DC-Morris Coordinator Position Pre-design/passive Solar Building Addition	Gregory Cuomo	West Central Research and Outreach Center
Biomass Feedstock Engineering-Densification and Moisture Management	Vance Morey	Biosystems and Agricultural Engineering
Solar/Hydrogen Fuel Cell Project	Louise Goldberg John Carmody	Center for Sustainable Building Research Center for Sustainable Building Research
Catalysts and Electrode Structures for Electrochemical Oxidation	William Smyrl	Chemical Engineering and Materials Science
Reforming Ethanol and Biodiesel to Produce Hydrogen	Lanny Schmidt	Chemical Engineering and Materials Science
Investigation of Composite Coatings for Photo Biochemical Generation of Hydrogen from Carbohydrates	Michael Flickinger L.E. Scriven Lanny Schmidt	Biotechnology Institute Chemical Engineering and Materials Science Chemical Engineering and Materials Science
The Study of Photoelectrochemical Processes for Hydrogen Production	Kent Mann	Chemistry
Production of Bio-energy and Bio-products from Alfalfa and Willow	Gregg Johnson Dean Current	Southern Research and Outreach Center Forest Resources
Development of a Biorefining Model for Corn Processing	Roger Ruan Gary Fulcher	Biosystems and Agricultural Engineering Food Science and Nutrition
Functional Genomics of Bacterial Energetics	Arkady Khodursky Jim Cotner	Biotechnology Institute Ecology, Evolution, and Behavior
Using Genomics Tools to Manipulate Carbon Partitioning to Increase Crop Yields of Biofuels and Biobased Products	Sue Gibson David Somers	Plant Biology Agronomy and Plant Genetics
Genetic Basis of Biomass Accumulation in the Model Plant *Arabodopsis thaliana* Grown in Ambient and Elevated CO2 Environments	Peter Tiffin Peter Reich Ruth Shaw	Plant Biology Forest Resources Ecology, Evolution, and Behavior
Making Biodiesel from Crop Residues	Roger Ruan David Kittelson	Biosystems and Agricultural Engineering Mechanical Engineering
Combustion Studies of Biomass-Derived Oil Sprays	Paul J. Strykowski Kenneth Bickel	Mechanical Engineering Mechanical Engineering
Moisture Degradation Kinetics of Poly Lactic Acid (PLA) Products	Shri Ramaswamy	Bio-based Products
Development of Research Infrastructure for Hybrid Poplar Biomass Production in Minnesota	Bill Berguson Don Riemenschneider Gregg Johnson	Natural Resources Research Institute Forest Resources Southern Research and Outreach Center
Synthesis and Properties of Polyesters Using 3-hydroxy Proprionic Acid (3HP)	Marc Hillmyer William Tolman	Chemistry Chemistry

Project Title	Project Researcher	Department
Renewable Roof for Residential Buildings	Jane Davidson John Carmody Susan Mantell	Mechanical Engineering Center for Sustainable Building Research Mechanical Engineering
Intelligent Building Control with Renewable Energy Sources and Distributive Passive Wireless MEMS Sensors	Rajesh Rajamani	Mechanical Engineering
Integrated Building Systems for Energy Efficiency and Renewables	Thomas Kuehn John Carmody Jane Davidson Louise Goldberg	Mechanical Engineering Center for Sustainable Building Research Mechanical Engineering Center for Sustainable Building Research
Application of Hybrid Wind-Solar Electricity Generation in Western Minnesota	Frank Kulacki	Mechanical Engineering
Sustainable Fast-Sourcing Systems for Biomass Energy Production: Two Minnesota Case Studies	Nicholas Jordan Dean Current	Agronomy and Plant Genetics Forest Resources
Energy From Grass: Summarizing and Disseminating Directed Class Research	Doug Tiffany Steve Taff	Applied Economics Applied Economics
Full Cost Accounting of Renewable Energy Systems	Steve Polasky David Tilman Jennifer Kuzma	Applied Economics Ecology, Evolution and Behavior Center for Science Technology and Public Policy
Clean Energy Research Teams (CERTS)	Lissa Pawlisch	Regional Partnerships
Bringing Energy Efficient Hybrid Vehicles to Market	Alfred A. Marcus David Kittelson	Carlson Strategic Management/Organization Mechanical Engineering
Value Added Technologies for Utilization of Crop Bio-products and Residues	Roger Ruan	Biosystems and Agricultural Engineering
Next Generation Solar Heating Systems	Jane Davidson Susan Mantel Lorraine Francis	Mechanical Engineering Mechanical Engineering Chemical Engineering and Materials Science
Energy Efficient Roof and Attic System	Jane Davidson Susan Mantel John Carmody	Mechanical Engineering Mechanical Engineering Center for Sustainable Building Research
Advanced Energy Efficient Roof System	Jane Davidson Susan Mantel John Carmody Louise Goldberg Patrick Huelman	Mechanical Engineering Mechanical Engineering Center for Sustainable Building Research Center for Sustainable Building Research Bio-based Products
Renewable Hydrogen and Chemicals from Ethanol **PHA–Large Scale Production of Polyhydroxalanoic Acid**	Lanny Schmidt Friedrich Srienc	Chemical Engineering and Materials Science Biotechnology Institute
Science Museum of Minnesota's Prairie Maze: A Demonstration Project on Renewable Energy and the Environment	David Tilman Donald Wyse	Ecology, Evolution and Behavior Agronomy and Plant Genetics
Investigation of a Thin-Multi-Layer Latex Coating Photobioreactor for Optimal Light Absorption and Hydrogen Evolution using Non-Growing *Rhodopsuedomonas palustris* Mutants	Michael Flickinger L.E. Scriven	Biotechnology Institute Chemical Engineering and Materials Science
Energy Alley Research Workgroup	Robert Elde Richard Hemmingsen	Biological Sciences IREE

Outreach and Partners

One of IREE's core values is collaboration. With this in mind, IREE hosted or co-hosted numerous outreach activities during the past year. The IREE workshop series is designed to promote interaction and learning among local, national, and international experts and stakeholders on issues and research in renewable energy. As an example of this series, Dr. Lynn Orr, head of Stanford's Global Climate and Energy Project, visited the University to give a seminar on global climate change and carbon sequestration. In IREE's formative stages, the University's Center for Science, Technology, and Public Policy hosted a public input meeting, during which leaders from industry, government, and the non-profit community discussed ideas for how IREE should be organized and operate.

IREE has co-hosted larger workshops with Minnesotans for an Energy Efficient Economy and the Minnesota Environmental Initiative's Energy Alley. One of these events was designed to inform legislators about Minnesota's renewable energy programs and discuss public policy challenges with them. Another event focused on research directions for the state of Minnesota.

IREE has organized visits with DOE, NREL and USDA officials and University faculty to exchange information and explore possible collaborations. IREE staff and researchers meet regularly with numerous community leaders, experts, and stakeholders.

IREE continues to reach out to the community and design workshops, seminars, and other activities to encourage bi-directional learning and communication.

Past and upcoming IREE events can be found on the IREE website: http://www.iree.umn.edu

Industry

Agriquest Development Co.
Blue Earth River Basin Initiative
Biorefining Inc.
Cargill
Cargill-Dow
Cardinal Glass Industries
Cummins Power Generation
Davis Energy Group, Inc.
Delphi Automotive Systems
District Energy, Saint Paul
DuPont
Entegris Fuel Cells
Fafco, Inc.
GE Plastics
Generation II Ethanol
Great River Energy
Honeywell
Institute for Agriculture and Trade Policy
Kraus Global
Land O' Lakes
Lindquist & Vennum
Moorhead Public Service Utility
Material Productivity, European Environment Agency
Minnesota Building Research Center
Minnesota Corn Growers Association
NGP Power-LFG Processing/NGP Power
Praxair
Pulte Home Sciences
Sebesta Blomberg & Associates, Inc
Solvay Advanced Polymers
Stuart Energy-Canada
Technology North
TME Industries Limited
Windustry
Xcel Energy
3M

Universities and Higher Education

Dalhousie University, Canada
Drexel University in Philadelphia, PA
Fond du Lac Tribal College, Cloquet, MN
Iowa State University, Ames, IA
South Dakota State University, Brookings, SD
State University of New York, NY
University of Iowa, Iowa City, IA
University of North Dakota, Grand Forks, ND
University of Wisconsin, Madison WI

External Organizations

Argonne National Laboratory
Agricultural Utilization Research Institute
Clean Energy Research Teams
Electric Power Research Institute
Great Plains Institute for Sustainable Development
Legislative Commission on Minnesota Resources
Minnesota Department of Agriculture
Minnesota Department of Commerce
Minnesota Department of Employment and Economic Development
Minnesota Department of Natural Resources
Minnesota Environmental Initiative
Minnesota Hydrogen Initiative
Minnesota Logger Education Program
Minnesota Office of Environmental Assistance
National Renewable Energy Laboratory
National Science Foundation
Oak Ridge National Laboratory
Science Museum of Minnesota
U.S. Department of Agriculture
U.S. Department of Defense
U.S. Department of Energy
Upper Midwest Hydrogen Initiative

External and Internal Leaders

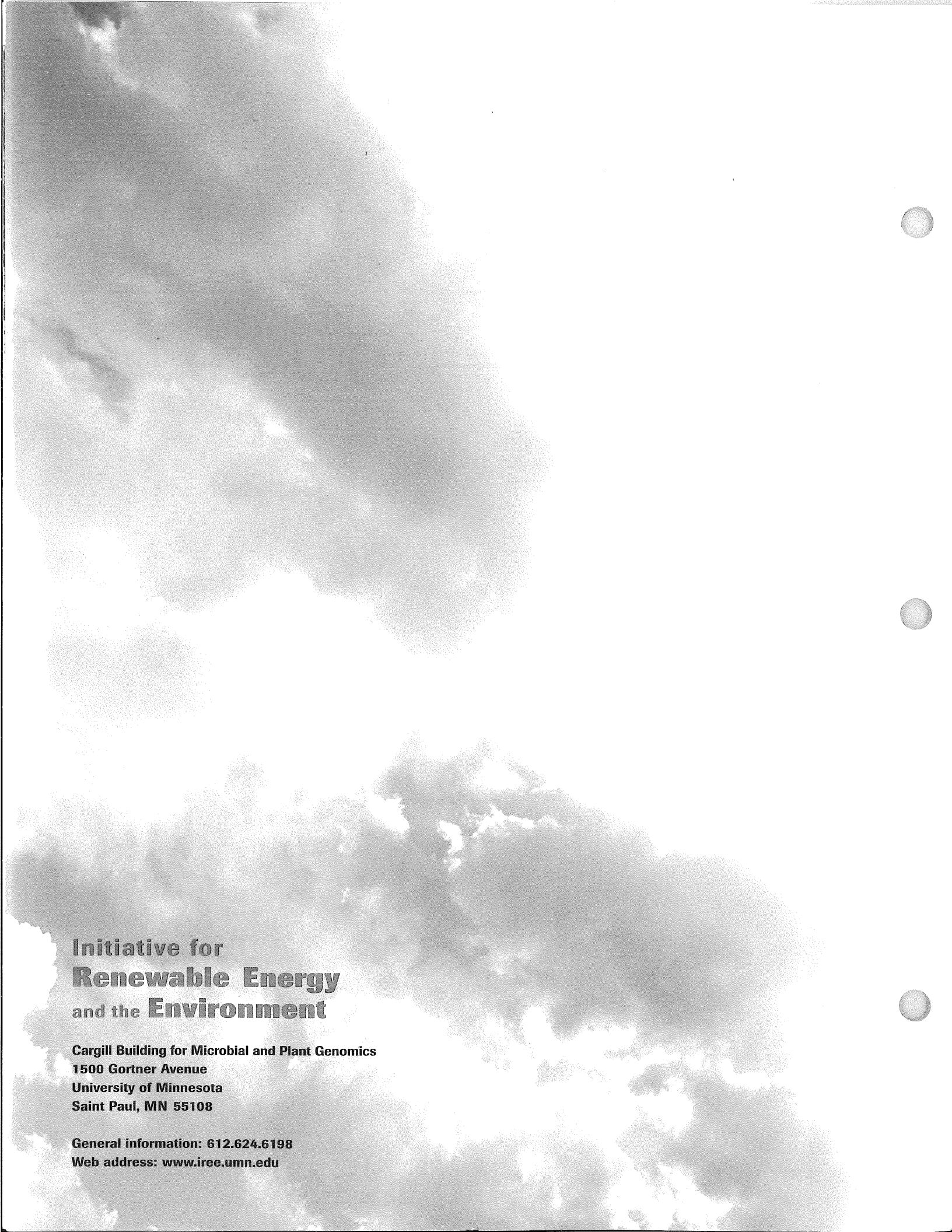
External Advisory Council
Duane Adams, Minnesota Corn Growers Association
Kenneth Brown, Minnesota Office of Environmental Assistance
Robert Brown, Iowa State University
Hongda Chen, U.S. Department of Agriculture
J. Drake Hamilton, Minnesota for an Energy Efficient Economy
James Dumesic, University of Wisconsin
Edward Garvey, Minnesota Department of Commerce
David Glassner, Cargill-Dow
John Goodman, Entegris
Wade Gordon, Fond du Lac Tribal and Community College
William B. Grant, The Izaak Walton League
Gene Hugoson, Minnesota Department of Agriculture
F. Terry Jaffoni, Cargill
Diane Jensen, Minnesota Project
Jack Keers, Pipestone County Commissioner
Kevin Kephardt, South Dakota State University
Rodney Larkins, 3M
Rolf Nordstrom, Upper Midwest Hydrogen Initiative
Erik Pratt, Energy Alley, Minnesota Environmental Initiative
Anders Rydaker, District Energy
David Sparby, Xcel Energy
Kristen Weeks-Duncanson, Minnesota Soybean Growers
Mark Willers, Minwind
David Zumeta, Minnesota Forest Resources Council

Executive Committee Members
Robert Elde, Dean, College of Biological Sciences
Kenneth H. Keller, Director, Center for Science, Technology and Public Policy
H. Ted Davis, Dean, Institute of Technology
Charles Muscoplat, Dean, College of Agricultural, Food and Environmental Sciences
Alfred Sullivan, Vice Provost, Office of the Executive Vice President

Working Group Members
Philip O. Larsen, Director of Operations, UMORE Park, Plant Pathology
Lanny D. Schmidt, Regents Professor, Chemical Engineering and Materials Science
Kenneth J. Valentas, Director, Biotechnology Institute
Shri Ramaswamy, Professor and Department Head, Department of Bio-based Products
Judson Sheridan, Associate Dean, College of Biological Sciences (CBS-DAES)
Richard Hemmingsen, Director, IREE
Jennifer Kuzma, Associate Director, IREE

Staff
Richard Hemmingsen, Director
Jennifer Kuzma, Associate Director
Laureen L. Ross McCalib, Interim Associate to the Director
Sue Lewis, Senior Office Assistant

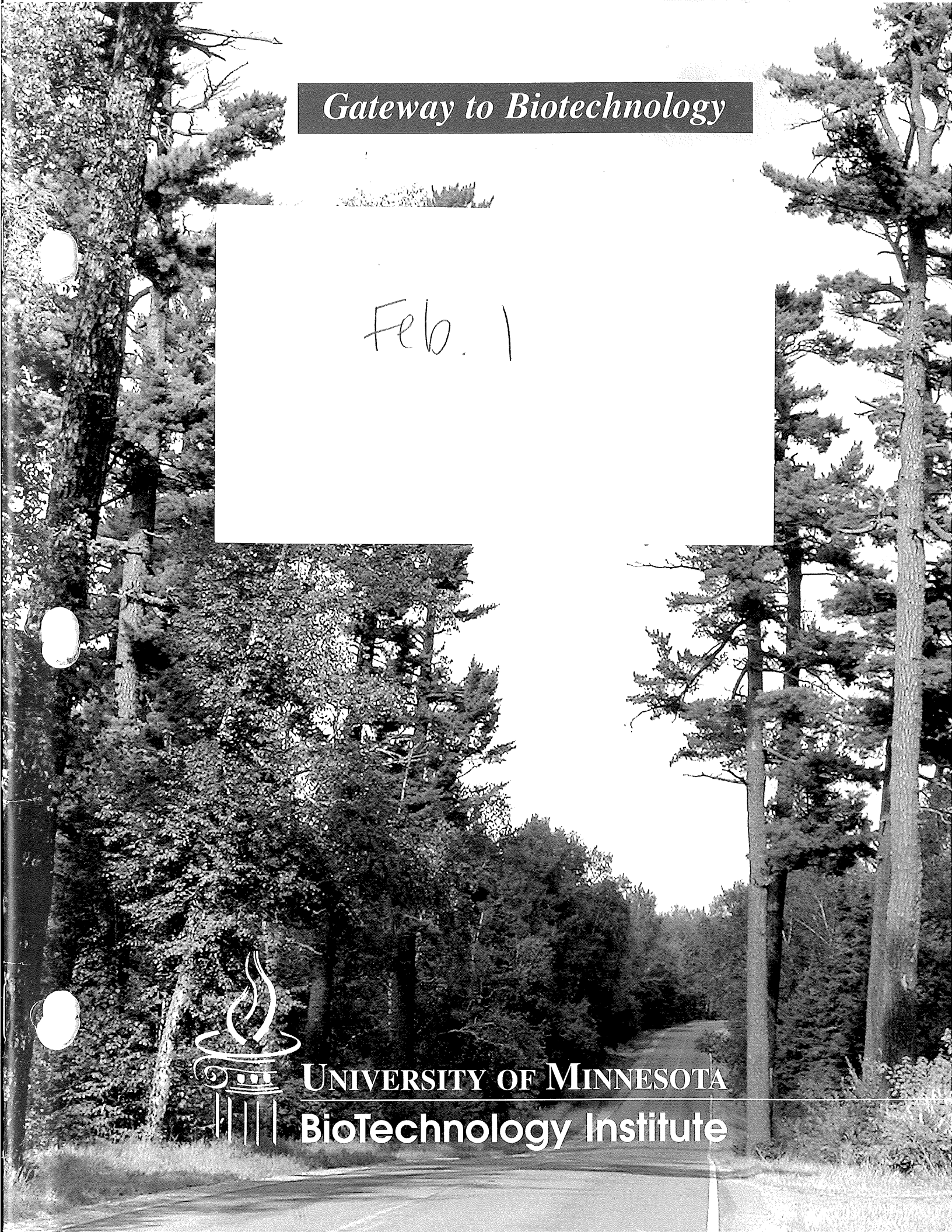
Design: Elizabeth Longhurst
Photography: David Hansen
Cover (field); Page 4 (wind turbine);
Page 5 (wheat field); Page 6 (corn);
Page 8 (lake):



Initiative for
Renewable Energy
and the Environment

Cargill Building for Microbial and Plant Genomics
1500 Gortner Avenue
University of Minnesota
Saint Paul, MN 55108

General information: 612.624.6198
Web address: www.iree.umn.edu


Gateway to Biotechnology
Feb. 1
UNIVERSITY OF MINNESOTA
BioTechnology Institute

On the cover

These majestic white pines are located along the historic Gunflint Trail in northeastern Minnesota and serve as a gateway to the pristine, one-million acre Boundary Waters Canoe Area Wilderness. This unique area of boreal forest and interconnected lakes and waterways has been preserved so that future generations might appreciate its magnificent natural beauty and experience the intricate relationship of natural systems within its complex ecosystem. The visual impact of the white pines is striking and helps one focus on what lies ahead. The BioTechnology Institute is a gateway to the world of biotechnology and all that it entails at the University of Minnesota.

Produced by the BioTechnology Institute. Design by Tim Montgomery / montytj@worldnet.att.net

LEADERSHIP IN

Biotechnology

From the director

Our name has changed from Biological Process Technology Institute (BPTI) to the BioTechnology Institute (BTI). The BPTI name served us well for 17 years, but the new name is more inclusive of our wide range of activity in areas such as metabolic engineering / microbial physiology, biocatalysis, biomaterials, bioremediation, biosensors, combinatorial biology, population dynamics, proteomics, and bioinformatics, which all fall under the broad umbrella of biotechnology.

The Institute's cross-disciplinary, intercollegiate structure positions it as a convenient gateway to biotechnology at the University of Minnesota. As reflected in our logo, our mission is to:

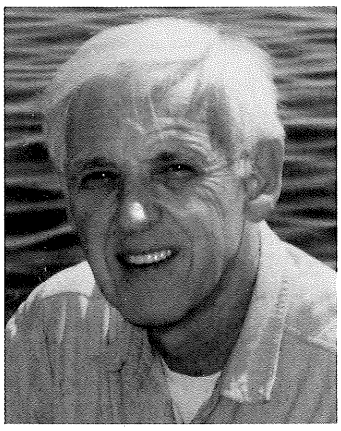
- Provide **Professional Training**
- Conduct **Innovative Research**
- Provide **Resources for Industry**

Since the last report in 1998, there has been significant positive change within the Institute that reflects, to some extent, the explosion of interest and activity in the various aspects of biotechnology as we enter the era of genomics and proteomics. In the past three years we have focused on improving our physical and personnel resources to better assist both faculty and industry in translating laboratory discoveries to feasibility and proof of principle stage at pilot plant scale. More detail is provided in the section titled **Outreach**.

Research activity continues at a significant level with each faculty member receiving an average of $364,000 per year in grants, and with the combined activity of Institute faculty generating $550,000 in indirect cost recovery this past year. A further indication of the high quality of faculty research is the second competitive renewal of the prestigious NIGMS grant. This grant provides $2.2 million over a 5-year period which translates to support for 16 Ph.D. candidates yearly.

Start-up biotechnology companies can now utilize the new Biotechnology Incubator Laboratories that provide physical space and access to services available in CBS' Biodale. Since inception in January 2001, the space has been fully subscribed by a mix of faculty and industrial entrepreneurs. Interaction between the biotechnology industry and faculty has been enhanced by the initiation of University of Minnesota Biotechnology Networking meetings. The expectation is that these efforts will stimulate growth of biotechnology in Minnesota.

In this report, you will see how we are progressing in our effort to provide the state of Minnesota with a strong and focused effort in education, research, and outreach in biotechnology. ■



Dr. Kenneth J. Valentas, who joined the Institute as Interim Director in 1992, was named the permanent Director in 1995.

UNIVERSITY OF MINNESOTA

BioTechnology Institute

• Professional Training • Research • Resources for Industry

Nurturing environment

A. G. FREDRICKSON

Osprey and fledglings nesting atop a white pine. The Biotechnology Resource Center provides a nurturing environment where ideas grow into new biotechnology businesses.

Partners in growth

Since 1985, the Biotechnology Resource Center has worked with the following businesses and other organizations:

- 3M
- Abbot Laboratories
- ABEC
- Agr. Utilization Research Inst.
- American Cyanamid
- Amoco
- Applied Membrane Technology
- Avidity
- Beckman Instruments
- Bioclastics Research
- Biolyph Inc.
- Bionega
- Biopolymer Engineering
- Biotrol
- Blandin Foundation
- Cargill
- Cellex Biosciences
- Charles Rivers Lab
- Ciba-Geigy
- Cytogen
- DCI
- Davisco Foods
- DeKalb
- DiaSorin
- DuPont
- Eastman Kodak

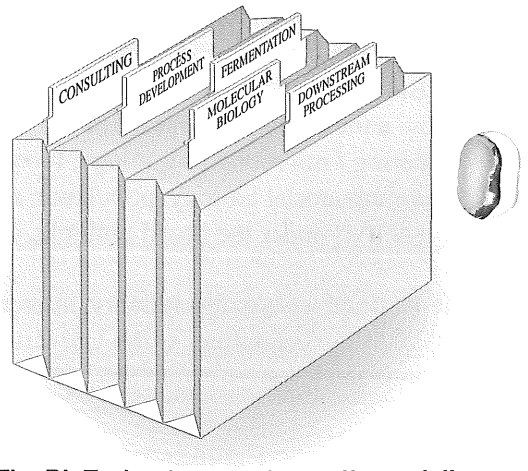
BIOTECHNOLOGY RESOURCE CENTER

Outreach

As a land-grant institution the University of Minnesota has a strong tradition of public service (outreach) along with education and research.

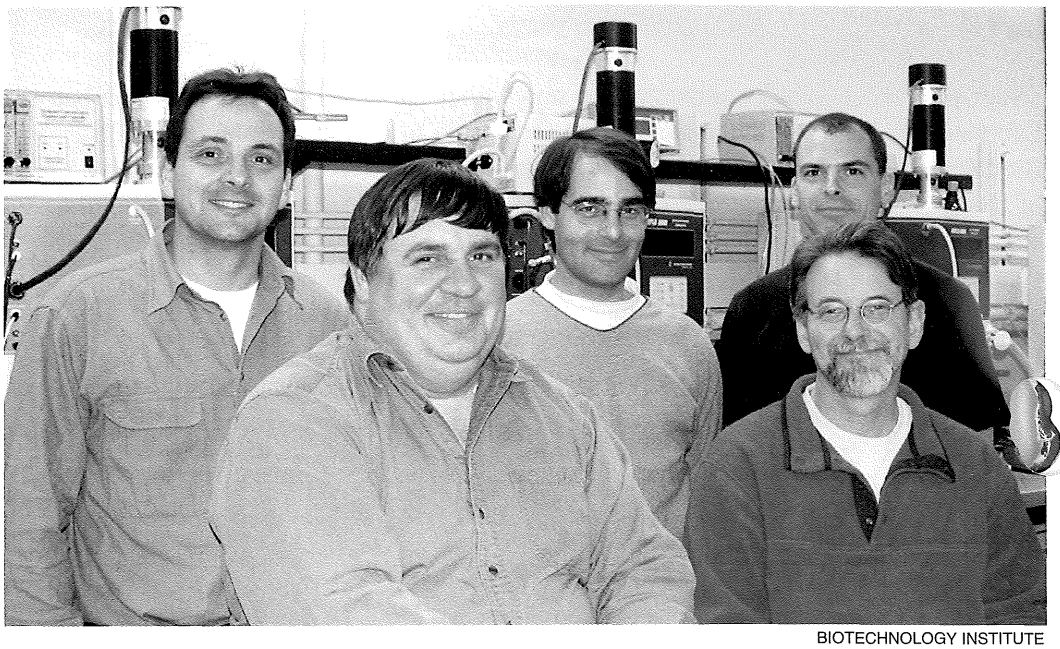
Public service is a major focus of the BioTechnology Institute. By providing critical resources for industry the Institute strives to encourage and nurture growth of the biotechnology industry in Minnesota, the United States, and around the world. The resources provided help start-up companies and established industries demonstrate the feasibility of scientific discoveries at the pilot scale and benefit students and faculty as well. The specialized equipment and personnel available in our Biotechnology Resource Center are utilized by faculty to support their research and are essential to provide hands-on training for students in fermentation, separation, purification, and molecular biology techniques.

The Biotechnology Resource Center has undergone major change during the past two years. The hiring of two molecular biologists, a biochemist, and an engineer, significantly expanded the portfolio of services offered.



The BioTechnology Institute offers a full portfolio of services to promote advances in technology.

In addition to fermentation process development and scale-up, a new area of expertise has been created around recombinant protein expression and purification. Starting with the cloning of the gene of interest into a range of possible expression systems, such as bacteria, yeast, or animal cells, the production of these recombinant proteins can be scaled up to a volume of up to 240 liters. The proteins are then recovered and purified using membrane filtration and liquid chromatography systems of a matching scale. The close cooperation of



BIOTECHNOLOGY INSTITUTE

BioTechnology Resource Center staff (left to right): Marc von Keitz, Fred Schendel, Mark Williams, Rod Felsheim and Rick Dillingham.

molecular biologists, fermentation technologists, and downstream processing experts has created an environment uniquely suited for integrated process development and process optimization.

Furthermore, the space itself has been renovated to alleviate structural deficiencies, provide for better workflow, and make room for new, updated equipment. Equipment additions include; six 5-liter NBS Bioflo 3000 fermenters equipped with a networked computer control system (four of these have closed loop methanol controllers for protein expression in methylotrophic yeast, e.g. Pichia pastoris), two 10-liter Braun Biostat fermenters, which are set-up for flow-cytometry experiments, a Bellco animal cell culture system with a 8-liter and a 36-liter vessel, a ThermoOnix mass spectrometer for off-gas analysis which can collect data from any of the 16 fermenters in the facility, a process-scale liquid chromatography system from NCSRT, and a BIOCAD perfusion chromatography system.

Biotechnology Incubator Laboratories that provide physical space and access to Biodale services for biotechnology start-up companies have been available since January 2001. The space has been fully utilized by both faculty and industrial entrepreneurs. Development laboratories in very close proximity to the services and expertise available at the University are an essential ingredient to nurture the growth of a strong biotechnology industry in Minnesota.

The Biotechnology Resource Center is now one of the corner stones of Biodale, a recently formed coalition of biotechnology service facilities that are co-located in Gortner Laboratory and Snyder Hall on the St. Paul campus. Other Biodale facilities include the Advanced Genetic Analysis Center, Mass Spectrometry for the Lifesciences, the High-Throughput Screening Facility, and the Imaging Center. The close cooperation between these units enables the Biotechnology Resource Center to tackle even the most complex biotechnology projects. ■

The BioTechnology Resouce Center houses a 300-liter fermenter donated by DCI of St. Cloud, Minnesota.

Partners in growth

- Ecolab
- Eli-Lilly
- Encore Technologies
- Endotronics
- Eucroware
- GalaGen
- Genemed Biotechnologies
- General Mills
- Hercules, Inc.
- Hewlett-Packard
- Hosokawa-Bepex
- ICI
- ImmunoTheraputics
- INCSTAR
- Kyowa Hakko Kogyo
- Lactogen
- Land O' Lakes
- Mayo Clinic
- Merck
- Microbiologics
- Micro Motion
- Microcide Pharmaceuticals
- Midwest Molecular
- Minnesota Dairy Assoc.
- Minnesota Technology
- Mitotix
- Molecular Genetics
- National Dairy Association
- Natural Biologics
- New Brunswick Scientific
- Northrup King
- Novartis
- Pfizer
- Pillsbury
- Proctor & Gamble
- QMI
- R & D Systems
- Rosemount
- SAF Products
- SarTec
- Scherring-Plough
- Sci-Med Life Systems
- Sigma Chemical
- SmithKline Beechum
- Solvay Animal Health
- TerraMax
- Waters Div. of Millipore
- Willmar Poultry

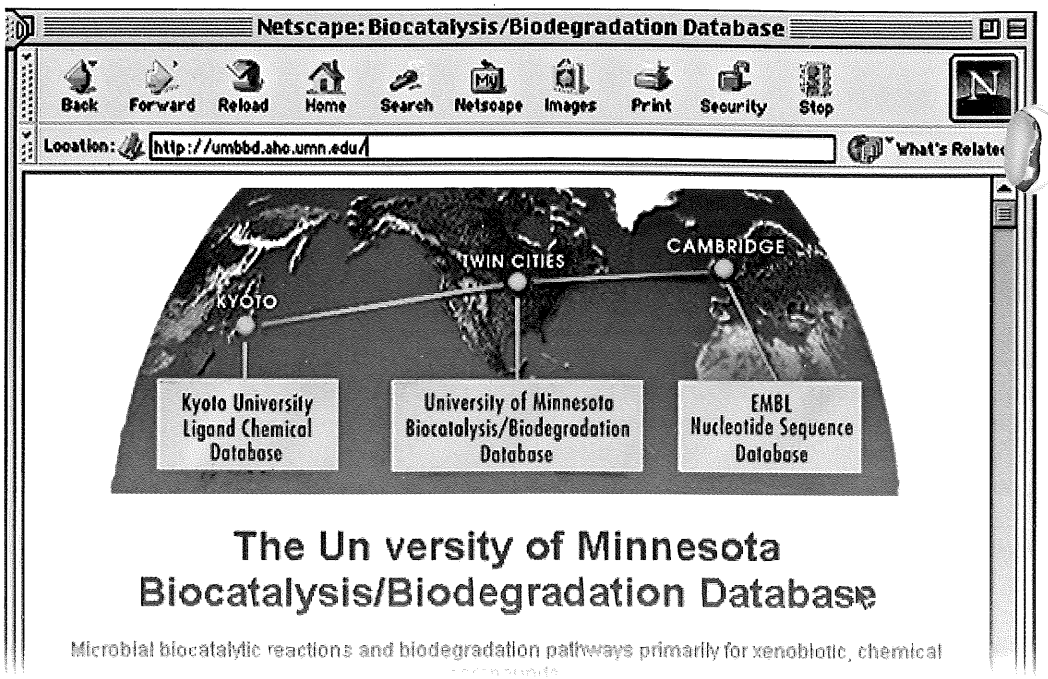
Innovation and adaptation

© D. BRENEMAN

The Pitcher Plant is an innovative plant found in bogs and sedgy marshes in Northern Minnesota. Aside from the beautiful purple flowers, it's functional part is the rosette of pitcher shaped leaves that collect and hold water. Insects descending into the leaves cannot exit because of downward pointing hairs lining the inside of the leaves. The insects are eventually converted to plant nutrients by bacteria and enzymes.

INTELLECTUAL PROPERTY

Innovation



Ideas in the form of technical papers, patents, books and the like are some of the measureable results of an academic institution. Enumeration is often the primary vehicle of communication, but simply stating that BTI faculty had 10 patents issued and 11 more pending actions in the past 3 years does not convey the value of such intellectual property.

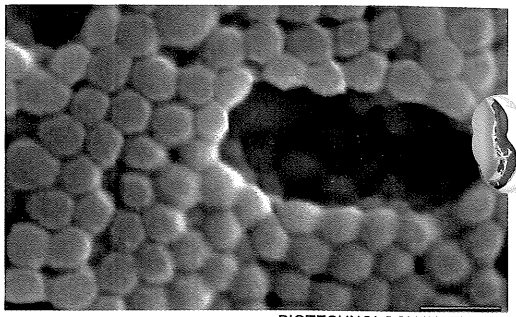
The BioTechnology Institute's faculty have broad interests and are involved in significant interdisciplinary collaborations that have generated clusters of important and potentially valuable scientific discovery. Because of the nature of the BioTechnology Institute, entrepreneurship is encouraged and supported by facilities such as a full-service pilot plant for protein expression, fermentation, and purification as well as incubator labs in close proximity to support services such as DNA sequencing, mass spectrometers, high throughput screening and imaging technology located in the college's Biodale biotechnology mall.

Natural product drug discovery

Two new companies have been formed by Institute faculty. Acera Biosciences was founded by Prof. David Sherman to play a key role in natural product drug discovery and development. Acera also strives to be a preferred supplier of fin chemical biocatalysts to service an existing worldwide market.

Biosensors/biocatalytic membranes

Veos, Inc. was founded by Prof. Michael Flickinger and Dr. Ron Anderson to commercialize technology based on a new concept for fabricating porous nanostructures of latex coatings containing microorganisms as functional components. Veos plans to develop, produce and market a wide range of revolutionary composite biological products in applications such as biosensors and biocatalytic membrances.



BIOTECHNOLOGY INSTITUTE

High magnification cryo-sem image of the impression formed in the SF091 polymer matrix by Escherichia coli ZK211.

Value added to ethanol fermentation

Biodegradeable plastics have been of interest for sometime and were initially directed primarily at the potentially large market of "green" packaging materials. What began as an attempt to develop environmentally friendly plastics has expanded to value these new biomaterials for their unique physical properties, versatility, and biodegradability.

Prof. Friedrich Srienc is taking a new approach to the development of polyhydroxyalkanoates (PHA's), which are biopolymers that can be converted into biodegradeable plastic articles of commercial interest. Srienc's research group has developed proprietary yeast strains, through genetic engineering, that can produce PHA's inexpensively during the normal ethanol fermentation process. Minnesota, which has a large ethanol industry, is an obvious potential beneficiary of this new technology.

Biocatalysis/ biodegradation database

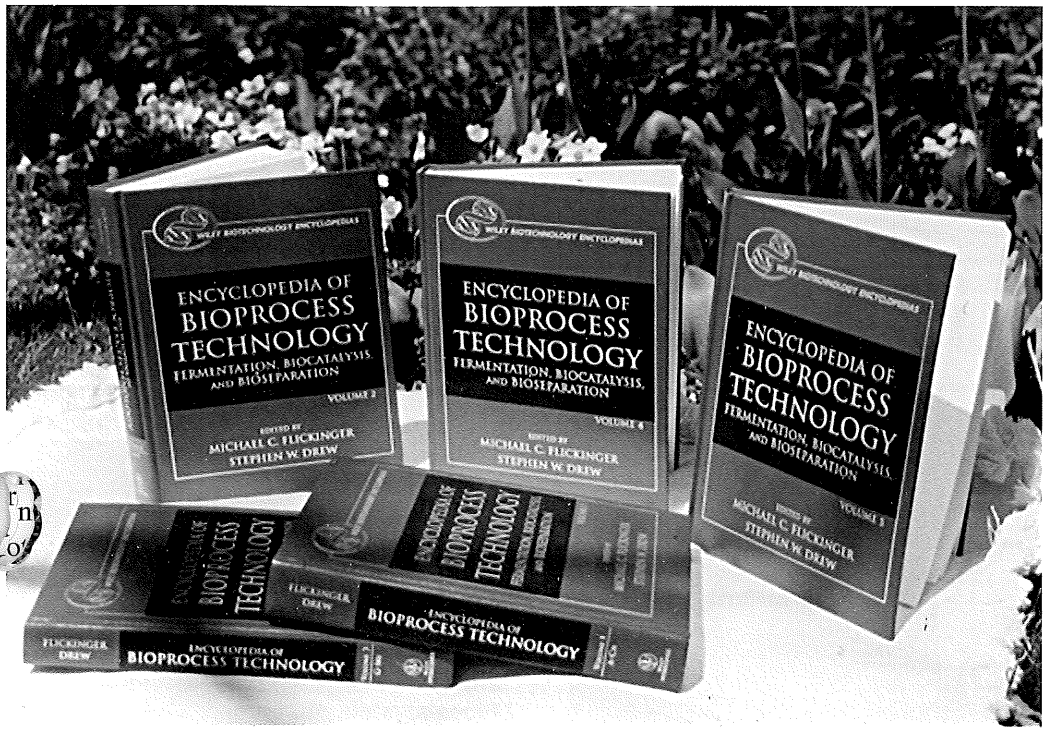
Within BTI, Prof. Lawrence Wackett is the catalyst for efforts in bioinformatics and digital learning. In particular, along with Prof. Lynda Ellis, he developed a web-based biocatalysis / biodegradation database by linking the University of Minnesota's database with those at Kyoto University and EMBL (European Molecular Biology Lab). This has been widely utilized on a worldwide basis by industrial and academic scientists.

Bioremediation

Profs. Lawrence Wackett's and Michael Sadowsky's experimental efforts in bioremediation have resulted in a genetically modified organism that greatly accelerates the degradation of atrazine, a widely used agricultural herbicide. This has been successfully tested in field trials in soil and is currently being evaluated for water treatment.

New books

BTI faculty have been very active in book publication. Prof. Robert Brooker has published "Genetics: Analysis and Principles." Prof. Lawrence Wackett and Dr. Doug Hershberger (Dow Biotechnology) have published "Biocatalysis and Biodegradation." In a monumental effort Prof. Michael Flickinger and Prof. Steven Drew (Princeton University) edited the 5 volume "Encyclopedia of Bioprocess Technology." ■



BIOTECHNOLOGY INSTITUTE

The Encyclopedia of Bioprocess Technology: Fermentation, Biocatalysis, and Bioseparation. Published March, 1999.

Patented technologies

- **Production of amino acids from methanol.**
- **Zirconia based chromatography packing.**
- **Porous latex nanostructures containing microorganisms as functional biocatalysts.**
- **Biodegradeable biopolymers (PHA).**
- **Biodegradation of Atrazine.**

Mutual dependence

A. G. FREDRICKSON

The Pink Ladyslipper is an orchid found in the wild in certain parts of Minnesota. To thrive in a difficult environment, this plant has developed a symbiotic relationship with Myocohizal fungus in the boggy soils of northern Minnesota. The cross-disciplinary emphasis of the Biotechnology Institute has been symbiotic in many instances.

PROFESSIONAL

Training

BIOTECHNOLOGY INSTITUTE

Professor Michael Sadowsky (center) advises Mic. E. students I. Fruchy and C. Solheid.

A multi-disciplinary approach to biotechnology

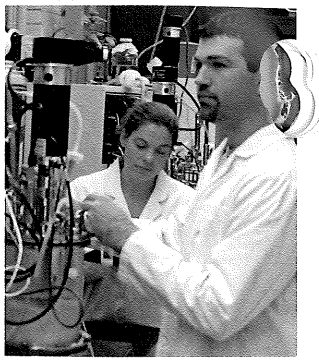
The BioTechnology Institute provides an environment that solidifies and enhances the interface between biology and engineering in today's rapidly expanding biotechnology enterprise. Cross training students between the biological sciences and engineering is the foundation of two distinct graduate programs in the Institute.

+ NIGMS (National Institute of General Medical Sciences) training grant in biotechnology originated in 1990 and has since been renewed twice at the level of 16 students per year. Since its inception the grant has supported 76 graduate students. They are drawn from the departments of Biochemistry, Microbiology, Chemistry, Agronomy and Plant Genetics, Plant Biology, Veterinary Pathobiology, Medicinal Chemistry, Food Science and Nutrition, and Chemical Engineering. The majority of graduates have gone on to industrial careers with established companies such as Cargill, Merck, Abbott Labs, R&D Systems, Kodak, Dow, Smith Kline Beecham as well as start-up biotechnology companies. Others have gone on to academic careers.

+ Microbial Engineering (Mic. E.) Master of Science Program accepts students with undergraduate degrees in the Biological Sciences or Engineering and trains them in the complementary field. This program has been active since 1985 and has graduated 54 students. About half the graduating students go to industrial careers and half continue with graduate study leading to their Ph.D. Often, the Ph.D. is earned in the complementary field.

Special Course

In addition to these graduate programs, the Institute offers a unique opportunity for our students and industrial colleagues to gain "hands-on" experience in



BIOTECHNOLOGY INSTITUTE

Students Amy Suiter and Erik Pederson at work in the fermentation lab for the "Advanced Fermentation and Biocatalysis Laboratory" course.

As a bridge between cultures, the exchange program with NAIST in Japan has allowed 17 students to experience each others culture during the past 5 years.

KEN VALENTAS

Learning new cultures

Biocatalysis in an intensive and comprehensive course, "Advanced Fermentation and Biocatalysis Laboratory," taught by Prof. Michael Flickinger during the summer intersession. In its first year this course has been recognized as providing valuable training in the practical and industrially important aspects of Biocatalysis.

Symposia/Networking

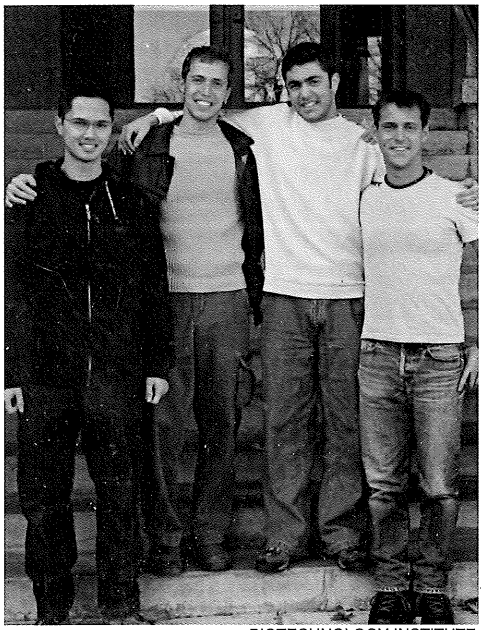
Professional development is not limited to academia. The Institute provides opportunities for the industrial and academic communities to come together at symposia focused on important topics of current interest. Over the past three years the Institute has hosted one day symposiums on Genomics, Bioinformatics and Biomaterials. These have been well received and provide the added benefit of a networking opportunity for industry and academia. The Institute also hosts University-Industry Networking dinners on a regular basis.

Exchange Programs

Biotechnology is clearly an international enterprise with significant technical breakthroughs occurring on a global basis. As part of their professional development, our students have the opportunity to interact with colleagues from Japan and Switzerland as part of the Institute's formal exchange program. The programs are currently focused on student exchange of ideas and information which is important to our students and faculty. The Institute also sponsored a joint symposium with NAIST (Nara Advanced Institute of Science and Technology) in Japan which was focused on Novel Plants and Microorganisms for Environmental Biotechnology. The exchange program will continue to expand in a focused manner most beneficial to our students and faculty. ■

J. JOHNSON

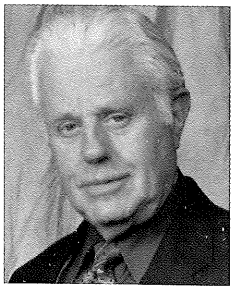
■ **ABOVE: BTI students on visit to NAIST in Nara, Japan (left to right): Nick Abu-Absi, Susan Fuget Abu-Absi, Jerry Johnson and Ben Hause.**

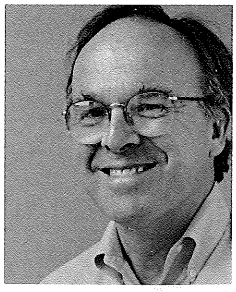


BIOTECHNOLOGY INSTITUTE

■ **LEFT: Exchange students from Hochshule, Wadenswill, Switzerland (left to right): David Strupler, Otmar Baenziger, Michael Schoeb and Patrik Ottinger.**

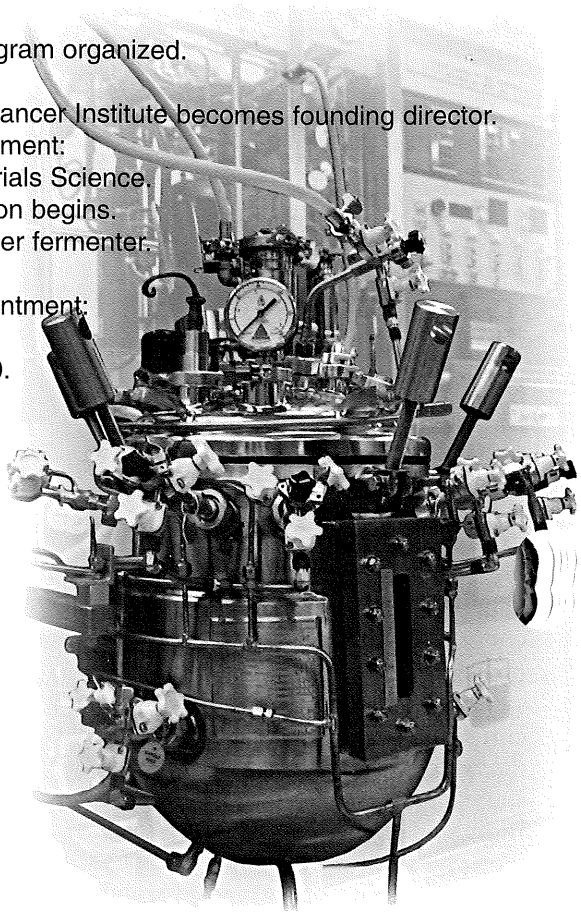
MAKING
History


Caldecott


Bloomfield

1983
- Concept for BPTI proposed by Prof. Victor Bloomfield and Dean Richard Caldecott.
- $300,000 annual funding provided by Minnesota state legislature.

1984
- Space allocated within College of Biological Sciences for laboratories, pilot plant, and Institute offices.
- Search for director and faculty.
- Microbial Engineering Masters Degree program organized.



1985
- Prof. Michael C. Flickinger from National Cancer Institute becomes founding director.
- Prof. Friedrich Srienc hired as joint appointment: BPTI and Chemical Engineering and Materials Science.
- Central Research Facility (CRF) construction begins.
- DCI, Inc., of St. Cloud, MN, donates 300-liter fermenter.

1986
- Prof. Robert J. Brooker hired as joint appointment: BPTI and Genetics and Cell Biology.
- State increases annual budget to $900,000.
- CRF opens for business.

1987
- ABEC, Inc., (Allentown, PA) donates animal cell culture reactor.

1988
- First published research annual report.
- Renovation of lab space.

1989
- Prof. Gary M. Dunny hired as joint appointment: BPTI and Microbiology.
- Dr. Jeffrey Tate hired as industrial liason.
- BPTI hosts first Midwest Biotechnology Symposium with U of Wisc., U of Iowa and Iowa State.

1990
- Prof. David H. Sherman hired as joint appointment: BPTI and Microbiology.
- BPTI hosts International Streptococcal Genetics Symposium.
- National Institute of General Medical Sciences (NIGMS) Training Grant awarded.

1991
- Fisher Rosemount, Inc. (Eden Prairie, MN), donates state-of-the-art process control system.
- BPTI catalyzes formation of Minnesota Biotechnology Association (MNBIO).

1992
- Prof. Lawrence P. Wackett joins BPTI from Gray Freshwater Institute as joint appointment: BPTI and Biochemistry.
- Dr. Kenneth J. Valentas, retired V.P. of Engineering, Pillsbury Co., becomes interim director.

1993
- External review ranks BPTI among the top 5 biotechnology centers in the U.S.
- First seed money grants established.

1994
- Profs. L. Wackett, L. Ellis begin development of biocatalysis/bioremediation web database

1995
- Dr. Kenneth J. Valentas named permanent director.
- NIGMS graduate training grant renewed and expanded.

A. G. FREDRICKSON
Tori at Itsukushima shrine at Miyajima (Temple Island) in Hiroshima Bay.

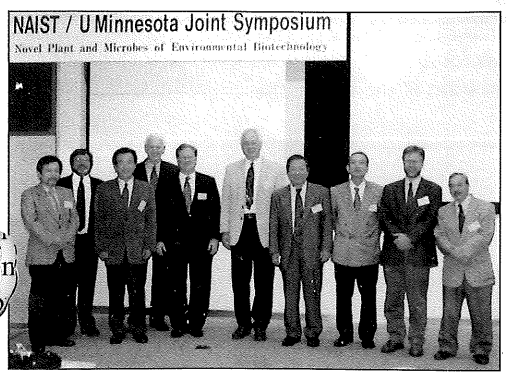
1996
- Japanese exchange program established with Nara Advanced Institute of Science and Technology (NAIST).
- BPTI hosts Biorefinery Conference.
- BPTI hosts Mathematical Modeling in Biochemical Engineering International Conference, honoring Prof. A. G. Fredrickson.

1997
- Prof. Dan W. Urry hired as joint appointment: BPTI and Chemical Engineering and Material Science.
- BPTI students visit NAIST/Japan.

1998
- Prof. Michael J. Sadowsky joins as joint appointment: BPTI and Soil, Water and Climate.
- Students and faculty from NAIST visit BPTI.
- Assistant Prof. Antony Dean hired as joint appointment: BPTI and Ecology, Evolution and Behavior.

1999
- BPTI hosts Genomics Conference.

2000
- BPTI hosts Bioinformatics Conference.
- Major renovation of pilot plant.
- NIGMS training grant - second renewal and expansion.
- NAIST/BPTI Symposium in Japan on "Novel Plants and Microbes of Environmental Biotechnology."

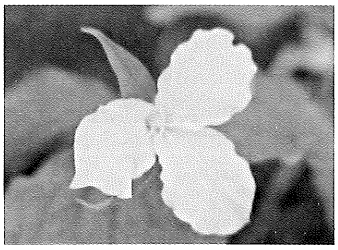


NAIST
The joint NAIST-BPTI Symposium features speakers from NAIST, OSAKA University, Hiroshima University, the University of Tennessee and the University of Minnesota.

2001
- Exchange program established with Hochschule, Wadenswil, Switzerland.
- Assistant Prof. Arkady Khodursky joins as joint appointment: BPTI and Biochemistry, Molecular Biology and Biophysics.
- BPTI hosts Biomaterials Conference / Industry Networking Event.
- **Name changed to BioTechnology Institute (BTI).**
- Technology Development Laboratories (incubator labs) opened.
- Cargill donates $10 million for Microbial and Plant Genomics Building.

2002
- Board of Regents designates Biotechnology Precinct area of St. Paul campus adjacent to BTI.

Financial leverage



KEN VALENTAS

■ Trillium Grandiflorum- a beautiful three-petaled, woodland wildflower found throughout Minnesota in the spring. One petal does not a Trillium make. The BioTechnology Institute could not survive on the budget provided by the state (1 petal). BTI faculty, through competitive grant awards, provide 2/3 (2 petals) of the budget necessary to keep the Institute viable.

LEVERAGING THE STATE'S INVESTMENTS

Financials

The infrastructure provided by the BioTechnology Institute (BTI) is important support for the basic and applied research conducted by faculty and students. Services range from access to specialized equipment to accounting and secretarial support. The research interests of the Institute faculty are very broad and the Institute can spread the expense of special apparatus and services over a wide user base to minimize cost. This leaves more for the researcher to use for critical personnel support.

This year the Institute's budget was $4.2 million. Of this total, the state of Minnesota provided $1.4 million with the remaining $2.8 million being raised by the faculty in competitive grant activity coming from federal granting agencies such as the NIH and NSF as well as industrial grants.

On average, each faculty member receives $346,000 per year in outside grant awards. From these dollars the Institute faculty turn back $555,000 per year (indirect cost recovery) to the University or about 40% of the monies provided by the state.

The state's investment is highly leveraged and it is our intention to surpass even these excellent results. Our ability to do so is totally dependent on the faculty's success in competitive grant activity. BTI seed money grants allow the researcher to do enough work up-front to submit a well-documented grant application and increases the odds of success for competitive proposals.

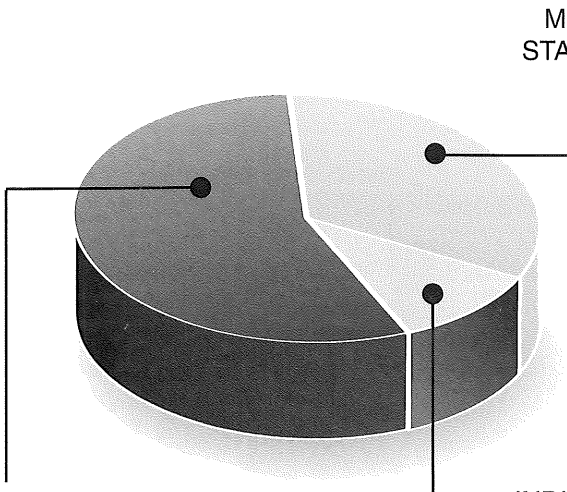
The Institute's stewardship of funds is based on two principles: first, attract the very best faculty in areas of strategic importance and secondly, manage our resources in a way that maximizes the amount of seed money available to the faculty. This strategy has, and will continue to serve us well. ■

Funding sources

Seed grants give BTI faculty a competitive edge through stronger grant proposals.

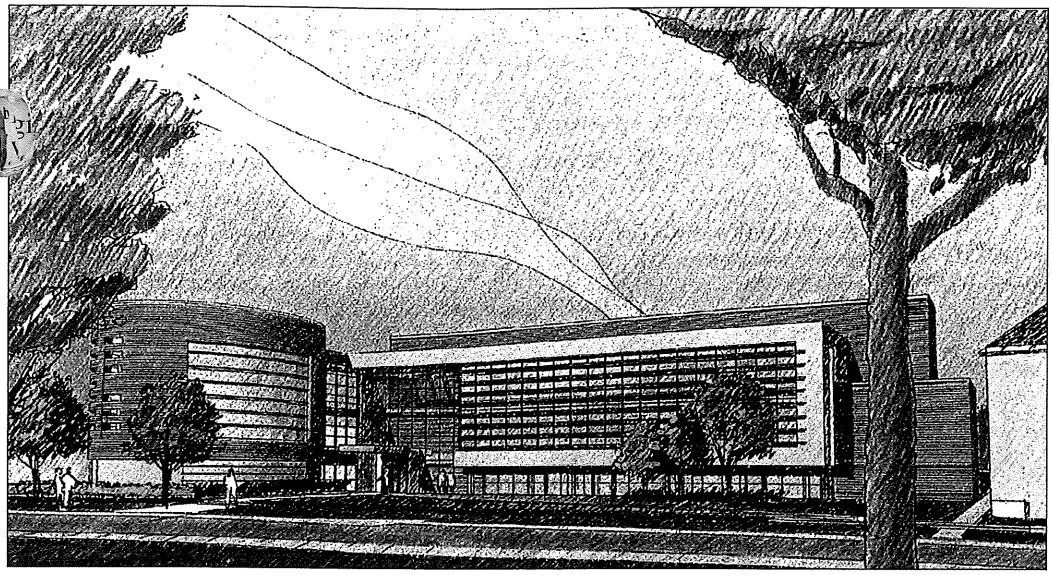
Currently, indirect cost dollars from BTI faculty research grants pay back 40 percent of state-provided budget.

Research grants bring in two dollars for each state dollar.



BUILDING FOR THE

Future



ARCHITECTURAL ALLIANCE

The Microbial and Plant Genomics Building, specifically dedicated to genome research, is scheduled for occupancy in early 2003.

The future is bright for biotechnology at the University of Minnesota. Since our last report there has been major investment in improving the biotechnology infrastructure on the St. Paul campus. Dean Robert Elde has spearheaded the drive to move the University into a competitive position in biotechnology research. Snyder Hall has been remodeled and turned into useful research space including Biodale, the biotechnology mall that consolidates services such as genomics technology, proteomics technology, protein expression, fermentation and protein purification equipment in one convenient location. Incubator labs have been made available, on a temporary basis, and it is obvious that there is a strong demand for such facilities on campus near the support services of Biodale.

A generous $10 million donation from Cargill with matching funds from the state, will finance the Microbial and Plant Genomics Building to be ready for occupancy by 2003. This forms the cornerstone of the Biotechnology Precinct plan that was recently presented by Dean Elde to the Board of Regents. The regents have voted to include the Biotechnology Precinct in the University's six-year capital plan. The precinct will be located on the northeast quadrant of the St. Paul Campus and includes buildings for a biotechnology incubator, biocatalysis and biosensors. In addition, the plan calls for renovation of the landmark cattle barn on Gortner and Buford to maintain its historical exterior presence but transform the interior into meeting, office and dining services space.

The BioTechnology Institute will continue its investment in the Bioprocessing Resource center to add up-to-date

Dean Robert Elde, College of Biological Sciences, is moving Minnesota into a competitive position in Biotechnology.

- **Microbial and Plant Genomics Building – 2003.**
- **Biotechnology Precinct Plan approved by regents.**
- **Strategic new faculty positions.**
- **More investment in Bioprocessing Resource Center.**

process control, extended capabilities in on-line process monitoring (mass spec. flow cytometry, etc.), versatile downstream processing, and additional space. We generally will continue on the path of integrating molecular biology developments and bioprocess technology. But, perhaps most importantly, we will continue to develop our staff capabilities through continued education and timely and appropriate addition to provide critical services to researchers.

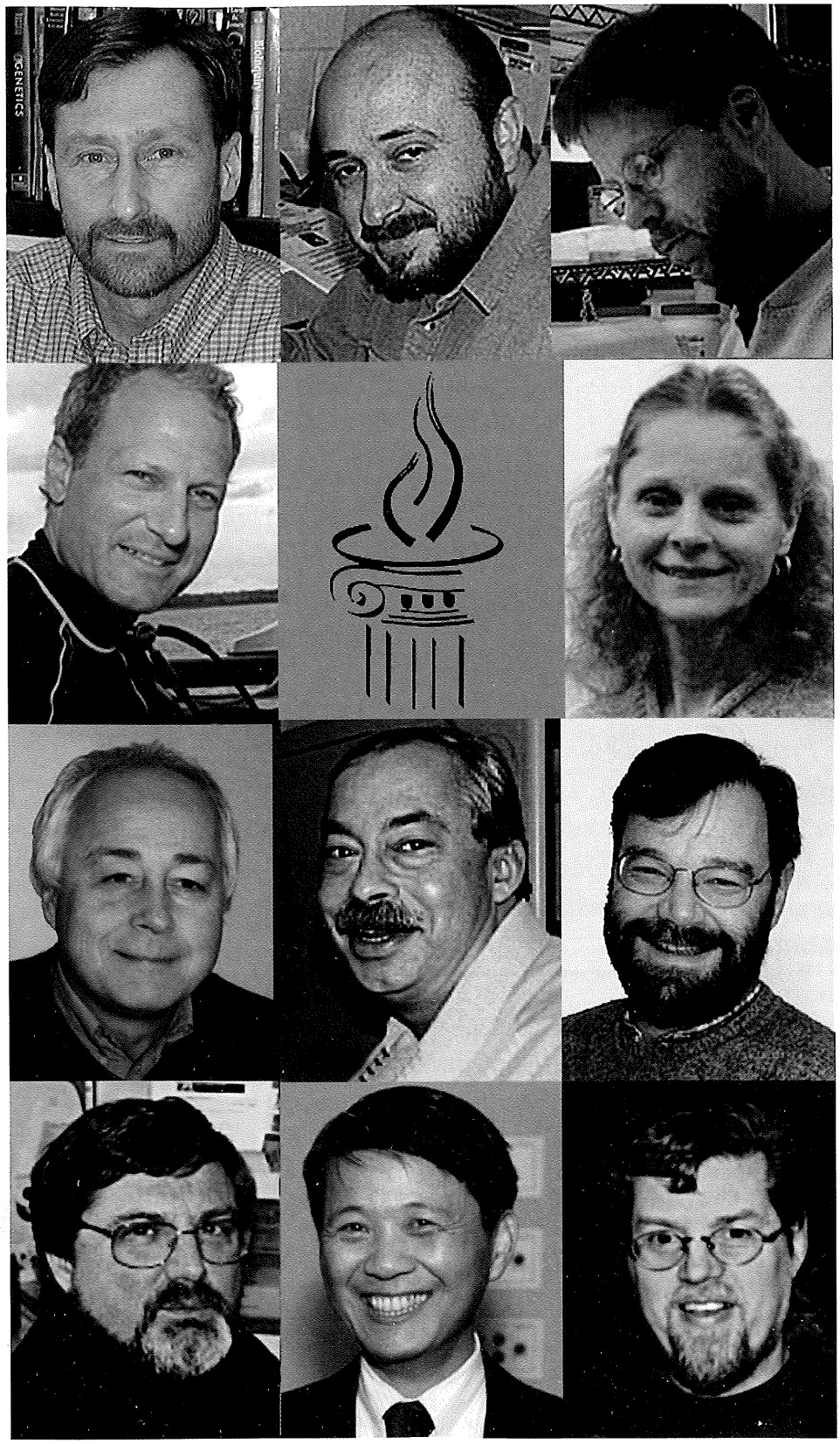
As is apparent in the faculty profiles section of this report, the research interests of BioTechnology Institute affiliated faculty are very broad. However, biotechnology is an evolving area of research, and to maintain a position on the cutting edge, the Institute must evolve as well. Just as there have been timely, strategic faculty additions in the past three years, there will be some in the next few years. Our attention now is on the areas of biomaterials, bioinformatics and biological chemistry. Admittedly, these are very broad categories, and that is as it should be for the Institute to be strategically opportunistic and to continually strengthen the research base of the Institute and of the University. ■

KEN VALENTAS

A golden sunset is reflected in this wilderness lake located in northeastern Minnesota. Biotechnology in Minnesota is moving to a bright future. The BioTechnology Institute will be a major resource in this effort.

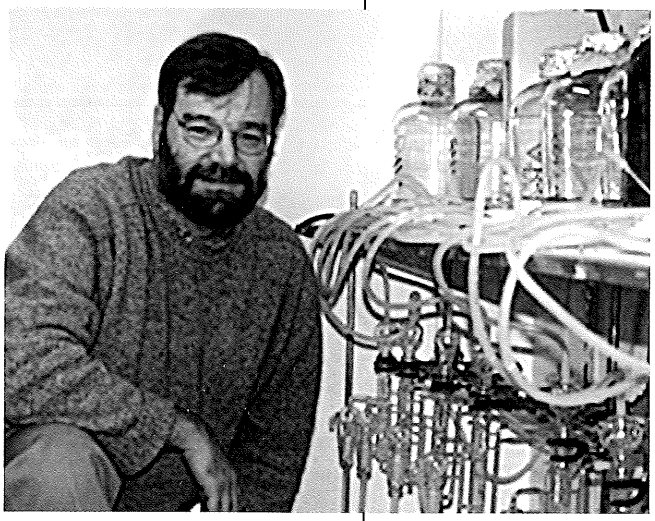
BIOTECHNOLOGY INSTITUTE

Faculty



ANTONY M.

Dean



ANTONY DEAN
Ph.D., Washington University School of Medicine, St. Louis, 1987.

- **Associate Professor, Ecology, Evolution, and Behavior.**

Prof. Dean's research centers on understanding the biochemical basis of adaptive evolution. His studies are not only fundamental to an understanding of the evolution, but also to the many evolutionary processes that occur in industrial fermenters and which commonly frustrate industrial bioproduction. His work is highly multidisciplinary and includes areas of molecular biology, enzymology, metabolic flux studies, population genetics, and evolutionary theory.

Work on the lac genes of E. coli focuses on the relations between enzyme activity, metabolic flux and Darwinian fitness. A new method to monitor competitions using flow cytometry enables the detection of the frequency-dependent selection predicted when lac operons compete on mixtures of galactosides. Analysis predicts that frequency-dependent selection can not maintain genetic variation at lac because it is evolutionarily highly unstable. Yet balanced polymorphisms of specialists, each consuming a preferred galactoside, regularly evolve starting with a single clone growing on a mixture of galactosides. Current work, funded by the NIH, aims at uncovering the genetic, biochemical and ecological mechanisms that drive evolution into such a tiny region of the available parameter space.

So few amino acid replacements are necessary to switch function in enzymes that it is now a practical proposition to reconstruct all genetic intermediates, to recombine them into the E. coli chromosome, and to determine fitness in chemostats. By such means it will be possible to explore the mechanisms that constrain all isopropylmalate dehydrogenases to use NAD and that have allowed isocitrate dehydrogenases to switch from NAD to NADP use. This work, recently initiated and funded by the NIH, will allow the evolution of enzymes in their adaptive landscapes to be investigated f the first time.

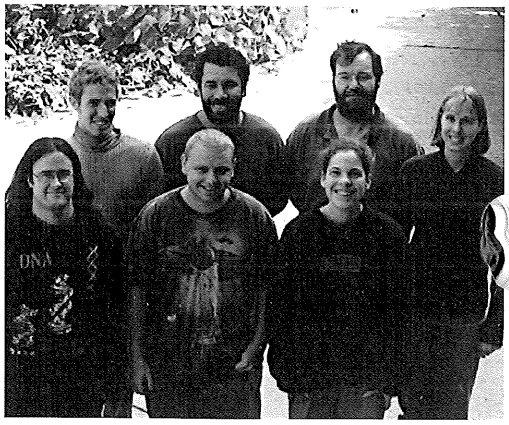
Current work with the arginine operon (Arg) of E. coli centers on developing a tractable experimental system with which to investigate the evolution of gene regulation in temporally variable environments. Recently, we have not only demonstrated that different naturally occuring alleles of the ArgR regulator are selectively favored under different ecological conditions but that the direction and intensity of selection also depends on the temporal frequency of switching between two ecological conditions.

Recent publications

- Dean, A. M. and G. B. Golding. 2000. Enzyme evolution explained (sort of). In: Pacific Symposium on Bioinformatics 2000, Edited by R. B. Altman, A. K. Dunker, L. Hunter K. Lauderdale, and T. E. Klein. Worl Scientific, Singapore.

- Miller, S. P., R. Chen, E. J. Karshina, A. M. Dean and D. C. LaPorte. 2000. Locations of the regulatory sites for isocitrate dehydrogenase kinase/phosphatase. J. Biol. Chem. 275:833-839.

- Bishop, J. G., A. M. Dean and T. Mitchell-Olds. 2000. Rapid adaptive evolution in the active site of plant class I chitinases. Proc. Natl. Acad. Sci. USA. 97:5322-5327.



BIOTECHNOLOGY INSTITUTE

Mark Lunzer, Otmar Baengiger, Jason Belter, Ricardo Medeiros, Amy Suiter, Prof. Tony Dean, Lauren Merlo.

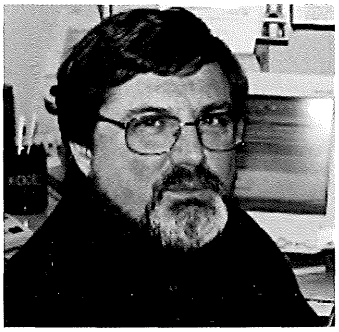
MICHAEL C.
Flickinger

Chris Solheid, Edward Crabbe, Sridevi Nagarajan, Ron Anderson, Paul Orwin, Prof. Michael Flickinger, and Trygve Brautaset.

BIOTECHNOLOGY INSTITUTE

My laboratory investigates novel microbes as biocatalysts and whole-cell biocatalysis on coated surfaces, within membranes, or composite microstructures. This combines expertise in materials science, coating technology, microbial biochemistry, industrial microbiology, and protein engineering. The major themes are 1. Whole-cell biocatalysis in extreme environments (elevated temperature, salt tolerant), 2. Gene expression and in vivo protein stability in biocatalytic coatings, and 3. Surface-modified ceramic particles for use in large volume protein purification processes. Biocatalytic coatings are porous, multilayer acrylate/vinyl acetate latex coatings containing 50% (vol/vol) of living bacteria. They are 10μm to 100μm thick, they have a porous polymer sealant top layer which entraps the cells, and the coating composition is optimized so that the embedded microorganisms survive film formation and partial desiccation during coat drying. We investigate the biological state of entrapped metabolically active bacteria such as E. coli as well as how to arrest latex polymer particle coalescence to generate porosity. Drawdown and piezoelectric (ink jet) coating methods are used to generate multi-layer patches, microstructures, or coated filaments. Gene expression in the coatings is studied with Prof. Schottel's laboratory using E. coli containing mercury II-inducible mer-lux or mer-gfp constructs. Laser scanning confocal microscopy (LSCM) is used to determine cell viability and spatial gene expression in the coatings. Coating permeability, perfusive films (composite membranes), and methods to arrest polymer particle coalescence to generate porosity are evaluated in diffusion cells. With Prof. Scriven's group we study coating microstructure using cryogenic scanning electron microscopy (cryo-SEM). Core-shell and polymer-blend coatings stable at elevated temperatures (in excess of 80°C) are studied using Thermotoga maritima, as an anaerobic, halotolerant model biocatalysts. Partial oxidations of sugars are studied using latex-entrapped Gluconobacter oxydans. Latex biocatalytic coatings may change the way microorganisms are stored, transported, and used on surfaces as sensors, in bioelectronic devices, or in membranes and composite microstructures as industrial biocatalysts.

A second project is metabolic engineering of the restrictive, thermotolerant methylotroph Bacillus methanolicus for production of L-lysine and other amino acids from methanol at 50°C. The demand for L-lysine, an essential amino acid in human, non-ruminant animal and fish nutrition, increases annually in proportion to global population growth. L-Lysine is currently produced by microbial fermentation from carbohydrates at 30°C in excess of 500,000t/yr. In the future, additional carbon sources will be needed to meet increasing demand. Microbes that grow at temperatures from 50°C to 60°C on methanol are useful biocatalysts to manufacture L-lysine because at these temperatures there is a signifi-



MICHAEL C. FLICKINGER
Ph.D., Pharmaceutical Biochemistry (University of Wisconsin, 1977)

- **Professor, Biochemistry, Molecular Biology, and Biophysics.**
- **Editor-in-Chief, Encyclopedia of Bioprocess Technology: Fermentation, Biocatalysis and Bioseparation, Wiley-Interscience.**

cant reduction in cooling costs for very large bioreactors (400m3 to 1,000m3 liquid volumes). We investigate genetic manipulation of B. methanolicus including characterization of the major restriction and methylation systems, sequencing of native plasmids, development of expression plasmids, transformation methods, and promoters. The pathways of methanol carbon assimilation and dissimilation are studied using 13C NMR and isotope ratio mass spectroscopy. The regulation of carbon flux to L-lysine or glutamate is investigated in mutant strains by cloning of the genes which encode enzymes at key branch points of metabolism such as aspartokinase, citrate synthase, diaminopimelate decarboxylase, and others. Protein engineering methods are used to alter enzyme structure and regulation to increase the yield of L-lysine, reduce formaldehyde toxicity, and to reduce carbon dissimilation as CO2. Bacillus methanolicus may become the first high temperature microbial L-lysine manufacturing technology from a non-carbohydrate substrate.

A third project is investigation of porous zirconia particles for protein adsorption and desorption. The use of robust, cleanable porous ceramic particles will reduce purification costs for proteins manufactured on the kilogram to hundreds of kg scale. The density, thermal, and chemical stability of zirconia make it an ideal material for use in processes where the porous particles need to be cleaned with harsh reagents (for example strong base), depyrogenated, steam sterilized,or fluidized in expanded bed adsorbers. Porous zirconia particles of 35µm to 75µm in diameter are being investigated modified for ligand exchange (fluoride-modified zirconia, FmZr) and immobilized metal affinity chromatography (IMAC). These will be useful for separation of proteins expressed in bacteria, yeast, or in the milk of transgenic animals. The fluid-filled density of porous zirconia particles is high, approximately 3g/cm3; these particles are ideal for expanded bed protein adsorption (EBA). EBA of human serum albumin (HSA) has been demonstrated in the presence of 100 g dry wt/l of Saccharomyces cerevisiae using FmZr particles. Porous zirconia particles are also being investigated as immobilization supports for thermal stable enzymes. These dense ceramic particles may be useful as supports for industrial biocatalysis at very high temperature.

In addition, we study the permeability of bacteria and the regulation of folding and secretion of antibodies and antibody fragments in myelomas, hybridomas, and transfected lymphoid cells.

Recent publications

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- Mullick, A., C.M. Griffith and M.C. Flickinger. Expanded and Packed Bed Albumin Adsorption on Fluoride Modified Zirconia. Biotechnol. Bioeng. 60: 333-340 (1998).
- Martinez, M.B., M.C. Flickinger and G.L. Nelsestuen. Steady State Enzyme Kinetics in the Escherichia coli Periplasm: A Model of a Whole-Cell Biocatalyst. J. Biotechnol. 71: 59-66 (1999).
- Lyngberg, O.K., V. Thiagarajan, D. Stemke, J. Schottel and M.C. Flickinger. A Patch Coating Method for Preparing Biocatalytic Films of Escherichia coli. Biotechnol. Bioeng. 62: 44-55 (1999).
- Lyngberg, O.K., D. J. Stemke, J.L. Schottel and M.C. Flickinger. A Simple Single use Luciferase Based Mercury Biosensor using Latex-Film Immobilized Escherichia coli HB101. J.Ind. Microbiol. Biotechnol. 23: 668-676 (1999).
- Thiagarajan, V.S., Z. Huang, L.E. Scriven, J.L. Schottel and M.C. Flickinger. Microstructure of an E. coli Biocatalytic Latex Coating Elucidated by Cryogenic Scanning Electron Microscopy. J. Coll. Interfac. Sci. 215: 244-257 (1999).
- Mullick, A. and M.C. Flickinger. AExpanded Bed Adsorption of Human Serum Albumin from Very Dense Saccharomyces cerevisae Suspensions on Fluoride Modified Zirconia. Biotechnol. Bioeng. 65: 282-290 (1999).
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- Martinez, M.B., M.C. Flickinger, L.A. Higgins, T. Krick and G.L Nelsestuen. Reduced Outer Membrane Permeability of Escherichia coli O157:H7: Role of Modified Outer Membrane Porins and Theoretical Function in Resistance to Antimicrobial Agents. Biochemistry 40: 11965-11974 (2001).

ARKADY

Khodursky

My laboratory uses and develops tools for functional genomics that we feel will further our understanding of the molecular principles behind complex biological phenomena. Parallel probing of multiple structural and regulatory sequences representing almost entire genomes has opened enormous opportunities for genetic screening and molecular phenotypic analysis. It has also presented us with new challenges that were not common in the field of molecular biology such as interpretation of highly complex data sets, statistical inference and multiparametric modeling and optimization. In our work on Escherichia coli and Saccaromyces cerevisiae we will generate and use whole genome DNA microarrays to advance research on these organisms in several directions:

Development of microarray technologies

We have demonstrated that it is possible to trace the progression of bacterial replication fork in vivo in real time at about 1 kb resolution using DNA microarrays, as well as to localize DNA deletions and amplifications. In my laboratory we plan to expand the high-resolution potential of microarray analysis by developing parallel transposon positioning technology in conjunction with saturation genome-wide mutagenesis.

Transcriptional dynamics of complex transitions

Growing cells cycle through overlapping stages of responses to internal and external cues. Some responses require concerted switching from the cycling routine. We have shown that microarray analysis of mRNA levels can be very useful in delineating such responses by determining transient changes in mRNA abundances, as well as transcripts' composition and levels corresponding to new steady-states. However, even for well-established processes the exact sequence of transcriptional events accompanying the process is not known. Temporal sequencing of such events is needed to understand the basis of regulation, pathway connectivity, intracellular flow of information, and "logic" behind it.

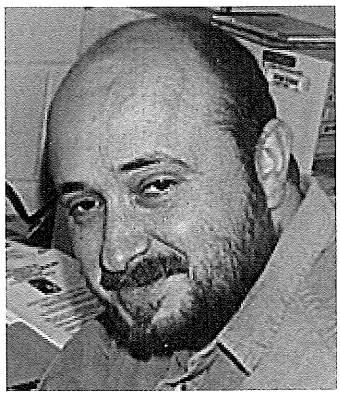
Bacterial chromosome dynamics and organization

Global analysis of transcripts' abundances revealed spatial periodicity in transcriptional activity of the E. coli chromosome. The period was found to coincide with the size of a supercoil domain in the bacterial chromosome. These findings prompt us to investigate organization of the bacterial chromosome in more detail. The first step in these studies will involve determining the periodicity of transcriptional activity in mutant strains that are known to be defective in chromosomal DNA maintenance, condensation and packaging, e.g., muk-, fis-, hu-, gyr-. Mapping of the proteins encoded by these genes on a "static" chromosome at different growth phases, as well as their mapping relative to the moving replication fork, will provide insights into how protein-DNA interactions contribute to the chromosome architecture.

Additional information about the accessibility of different regions of the bacterial chromosome will be obtained by using Tn10-based parallel transposon positioning.

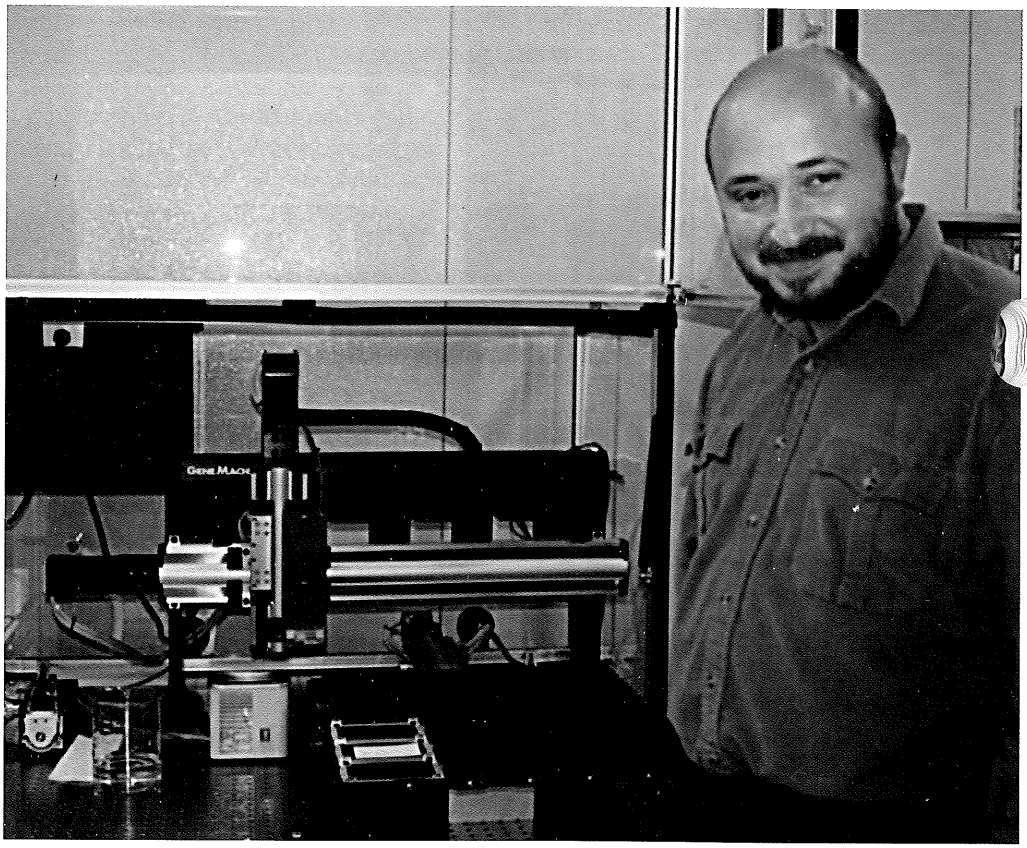
Transcriptional networks and the data analysis

Using previously accumulated information about transcriptional activity of the E. coli living genome along with the newly generated data from multiple transient and steady-state comparisons, my lab will focus on comprehensive decoding of transcriptional regulatory networks in the E. coli cell. Multiple replications,



ARKADY KHODURSKY
Ph.D., Biophysics (UC Berkeley 1997).

- **Assistant Professor, Biochemistry, Molecular Biology and Biophysics.**



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Prof. Khodursky with DNA Microarrayer.

high experimental dimensionality, and various integrated sampling techniques will be employed to provide high quality dynamic picture of the transcriptional regulation and transcriptional connectivity in bacteria.

Selected publications

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- Daniel P. Zimmer, Eric Soupene, Haidy L. Lee, Volker F. Wendisch, Arkady B. Khodursky, Brian J. Peter, Robert A. Bender, and Sydney Kustu. (2000) NtrC-controlled genes of Escherichia coli: scavenging as a defense against nitrogen limitation, Proc. Natl. Acad. Sci. USA 97(26): 14674-9.

- Arkady B. Khodursky, Brian J. Peter, David Botstein, Patrick O. Brown, and Charles Yanofsky. (2000) DNA microarray analysis of physiological conditions and genetic changes that affect tryptophan metabolism in Escherichia coli. Proc. Natl. Acad. Sci. USA 97: 12170-12175.

- Arkady B. Khodursky, Brian J. Peter, Molly B. Schmid, Joseph DeRisi, David Botstein, Patrick O. Brown, and Nicholas R. Cozzarelli. (2000) Analysis of topoisomerase function in bacterial replication fork movement: Use of DNA microarrays. Proc. Natl. Acad. Sci. USA 97: 9419-9424.

MICHAEL J.

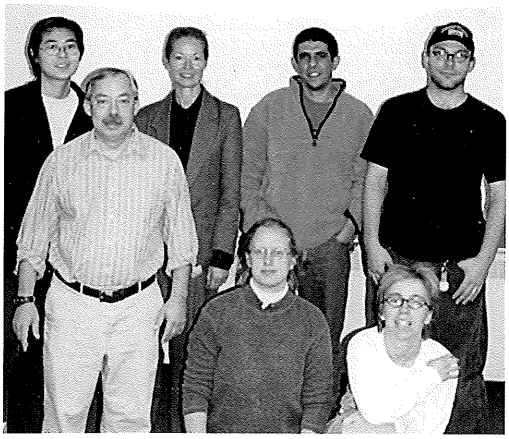
Sadowsky

Research interests

One of the major research efforts in Prof. Sadowsky's laboratory is directed towards the identification and characterization of bacterial genes and metabolic pathways involved in the biodegradation of chlorinated herbicides. His laboratory (in collaboration with Prof. Larry Wackett) is using genomics and recombinant DNA methodologies to examine the genes and enzymes involved in the mineralization of the broadleaf herbicide atrazine by soil bacteria. They have cloned, sequenced, and expressed all genes in the atrazine biodegradation pathway; and isolated, purified, and characterized several of the enzymes that are involved in atrazine degradation. They are currently examining the evolution of bacterial genes and pathways involved in the degradation of recalcitrant chemicals in the environment, and using genomic and genetic approaches to examine how these genes are regulated in a global manner.

Research in his laboratory is also directed towards the identification and characterization of bacterial genes involved in the earlier periods of legume-microbe symbioses. His is specifically interested in studying Rhizobium/Bradyhizobium genes which play a prominent role in host/microbe recognition and in the establishment of symbiotic, nitrogen-fixing nodules on the roots of soybean. Most recently, he has taken a whole genome approach in order to more fully understand the symbiotic interaction between rhizobia and the host legume. He (in collaboration with Profs. Gary Stacey and Ross Overbeek) has generated the complete genomic sequence of Bradyrhizobium japonicum, one of the most agriculturally important microorganisms. He is currently using macro-array and functional genomic approaches to examine how host plant and soil environment variables regulate the expression of bacterial nodulation, survival, and persistence genes.

Prof. Sadowsky also has a relatively large research group involved in the development of DNA fingerprinting methodologies to determine sources of fecal pollutants in water and soils. His laboratory has established a large library of DNA fingerprints from E.coli isolated from 15 animal sources and has shown that there is a relationship between host origin and DNA fingerprints. He is currently using rep-PCR fingerprinting methods and pattern recognition analyses on E.coli isolates from three watershed areas to identify the sources of fecal pollution and target appropriate water pollution abatement efforts.



BIOTECHNOLOGY INSTITUTE

Konnika Saffaphan, Prof. Michael Sadowsky, Carol Gross, Lisa Strong, Nir Shapir, Charlotte Pedersen, Isaac Fruchey.

Selected publications

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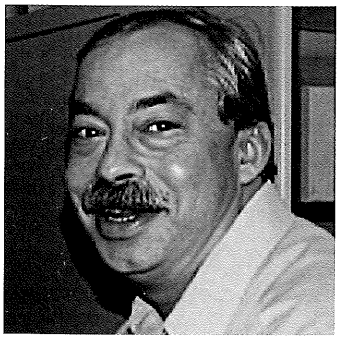
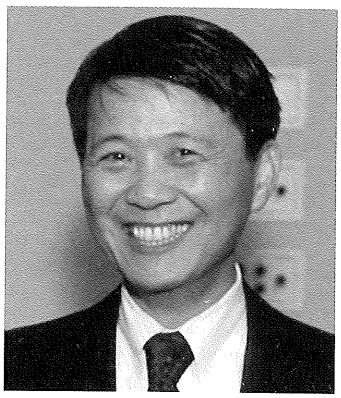


MICHAEL J. SADOWSKY

- **Ph.D., Microbiology, University of Hawaii, 1983.**
- **Professor, Soil Water & Climate.**

WEI-SHOU

Hu



WEI-SHOU HU

- **Ph.D., Biochemical Engineering, Massachusetts Institute of Technology, 1983.**

- **Professor, Chemical Engineering and Material Sciences.**

Back Row/left to right: Wei lian, Marcela De Leon Gatti, Mughda Gadgil, Gargi Seth, Rashmi Korke, Pam Lai, Shen Dong, Mary Anderson, Ziomara Gerdtzen, Sarika Mehra, Quin Meng, Rugh Patton, Prof. Wei-Shou Hu. Front Row/left to right: Jongchan Lee, R. A. Narayanan, Chetan Gadgil, Ming-Chien Yang, Yun Kyung, Patrick Hossler, Yongquan Li
BIOTECHNOLOGY INSTITUTE

Research interests

Dr. Hu's primary research area is biochemical engineering, with emphasis on experimental studies and development of kinetic models. The systems employed include mammalian cells, differentiated tissues and microorganisms.

The research on mammalian cell technology focuses on applying genomic tools to elucidate the regulation of various physiological events and on the development of quantitative description of the system. The insight obtained from this combined experimental and modeling approach is applied to the development of strategies for enhancing the productivity.

Another project involves cultivation of hepatocytes (liver cells) in a hollow fiber bioreactor as a potential artificial liver. Hepatocytes cultivated in the bioreactor developed by Dr. Hu's group have been shown to retain some key liver functions. Current emphasis is on the invitro formation of liver tissue-like spheroids from cultured hepatocytes and on the differentiation of stem cells into liver cells.

A microbial project concerns the engineering of the pathway for antibiotic biosynthesis in Streptomyces. Of particular interest is the control of spatial distribution and temporal profile of regulatory and structural genes.

Gene expression profiling using DNA microarray is combined with a theoretical modeling approach to decipher the regulatory hierarchy of antibiotic biosynthesis.

Selected publications

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- Kyung, Y.S., Sherman, D. Hu, W.-S. (2001) Simultaneous Analysis of Spatio-Temporal Gene Expression for Cephamycin Biosynthesis in Streptomyces clavuligerus. Biotechnol. Prog., 17, 1000-1007.
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- Seow, T.K., Korke, R., Liang, M.E., Ong, S. E., Ou, K, Wong, K., Hu, W-S. and Chung, M. C. (2001) Proteomic investigation of metabolic shift in mammalian cell culture. Biotechnol. Prog., 17, 1137-1144.
- Abu-Absi, S.F., Friend, J.R., Hansen, L.K., and Hu, W.-S. Structural Polarity and Functional Bile Canaliculi in Rat Hepatocyte Spheroids. Exp. Cell Res. (accepted).
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FRIEDRICH

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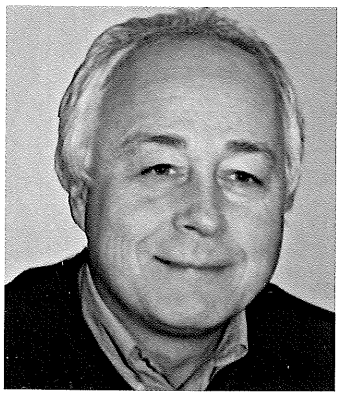


FRIEDRICH SRIENC
Ph.D., Biotechnology, Technical University in Graz, Austria, 1980.

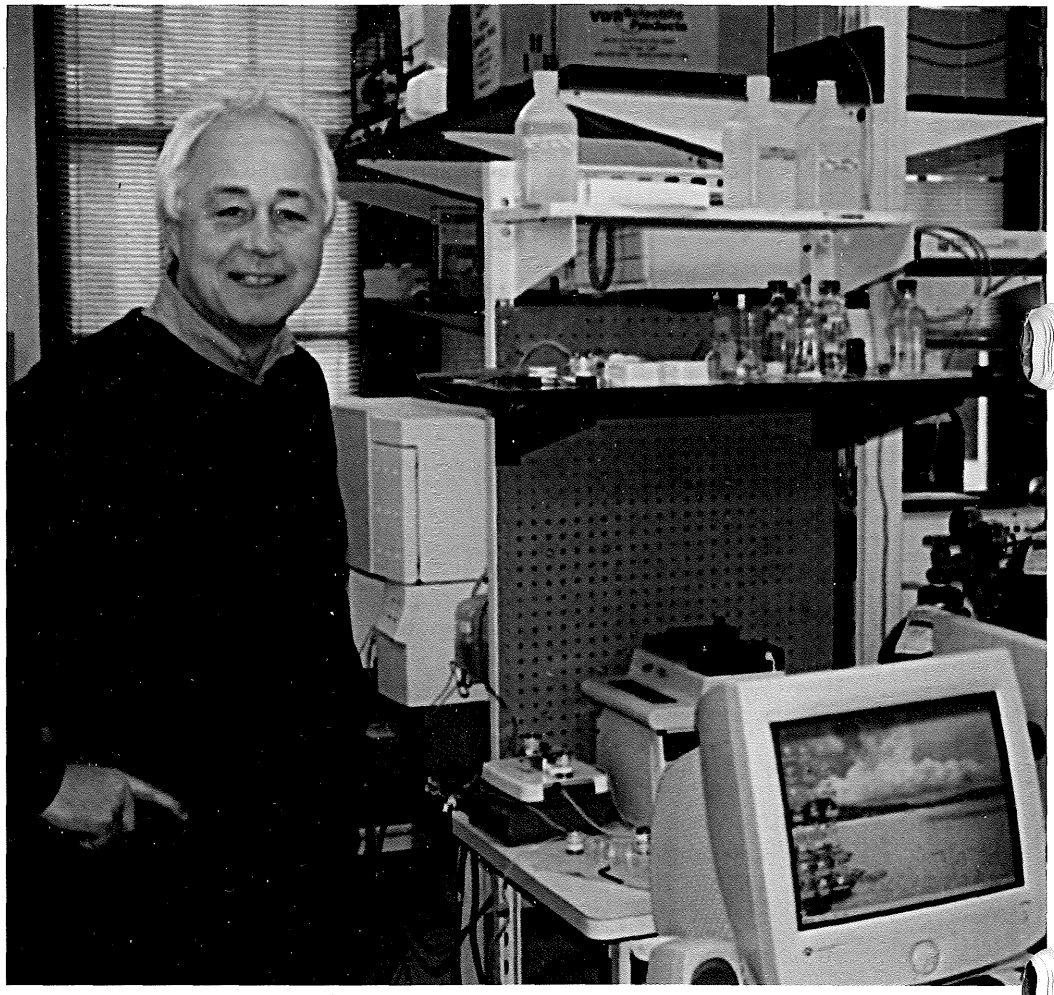
- **Professor, Chemical Engineering and Material Sciences.**

Research summary

Prof. Srienc works in the general area of biochemical engineering. In his work all aspects of biotechnology and bioengineering ranging from molecular biology, metabolic engineering and mathematical modeling are employed to study fundamental processes of gene expression, protein synthesis and metabolic networks and how these relate to the growth physiology of cells.

A fundamental problem in biochemical engineering is the dynamics of cell populations and how it is related to the formation of useful products. This problem is complicated by the fact that cell populations are heterogeneous, i.e they consist of cells that differ from each other in age, chemical composition and functional properties. The operation of the cell cycle and its regulation contributes much to this heterogeneity. Experimental as well as theoretical tools are little developed to investigate the variability of cell cultures at the single cell level. However, automation of flow cytometry analysis operations and new methods for solving so-called population balance equations that have recently been developed by his group, provide unique methods to approach this problem in a rigorous way in bacterial, yeast and mammalian cell populations.

A further component in his work is the study of the biosynthesis of polyhydroxyalkanoic acids (PHA). These biopolymers represent biodegradable thermoplastics that could replace certain petrochemically derived plastics that are not biodegradable and they contribute, therefore, considerably to the pollution of our environment. In this work, new reaction pathways are engineered into host cells using genetic engineering tools with the purpose of economically synthesizing new types of PHA polymers with useful



BIOTECHNOLOGY INSTITU

Prof. Friedrich Srienc with BD – Facscalibur flow cytometer.

properties. The PHA pathway in the context of overall cellular metabolism represents a unique model to study the limits of metabolic networks. This work extends into aspects of materials science and nanotechnology. Using specific bioprocessing strategies cells can be made to synthesize microstructured architectures of this polymer that confer to the final product desirable physical properties. Moreover, control of cellular biosynthesis can be extended to the molecular level resulting in the formation of block-copolymers that self assemble into defined structures.

Selected publications

- Frykman S, Srienc F "Cell cycledependent protein secretion by Saccharomyces cerevisiae," Biotechnol. Bioeng. 76 (3): 259268, 2001.
- Natarajan A, Srienc F "Glucose uptake rates of single E. coli cells grown in glucose-limited chemostat cultures," J. Microbiol. Meth. 42 (1): 8796, 2000.
- Mantzaris NV, Kelley AS, Srienc F, Daoutidis P "Optimal carbon source switching strategy for the production of PHA copolymers," AIChE J. 47 (3): 727743, 2001.
- Kelley AS, Mantzaris NV, Daoutidis P, and Srienc F "Controlled Synthesis of Polyhydroxyalkanoic (PHA) Nanostructures in R. eutropha," Nano Lett. 1 (9): 481-485, 2001 Selection of past students.

DAVID
Sherman

BIOTECHNOLOGY INSTITUTE

BACK: Alex Xue, Joon Yoon, Clem Fortman, Dafana Ableson, Daniel Wilson; FRONT: Prof. David Sherman, Brian Beck, Han Yun Kang.

DAVID SHERMAN
Ph.D., Organic Chemistry, Columbia University, 1981.

- **Professor, Microbiology.**

Research interests

My research effort at the University of Minnesota has evolved into several programs that are distinct in focus, yet coalesce into an overriding theme; metabolic engineering and genomic analysis of microbial secondary metabolism. Metabolic engineering is a powerful approach for harnessing the tremendous biosynthetic capabilities of microorganisms, including primary and secondary pathways. New genomic-based technologies are enhancing considerably our ability to understand and manipulate complex biosynthetic pathways and will enable vast new opportunities in medicine and industry.

■ Molecular genetic analysis of terrestrial and marine natural products biosynthesis.

A large number of novel natural products are being discovered from terrestrial and novel marine microbes. These exciting sources of new chemical entities will provide a wealth of unique information about the organization, structure, and regulation of genes involved in secondary metabolism. The focus over the past five decades has been entirely on secondary metabolite pathways of terrestrial microorganisms. Since novel classes of microorganisms that produce important secondary metabolites are being discovered from marine sources, it is clear that there will be exciting new information to be learned from these

novel organisms at the genetic level. Our focus will include marine cyanobacteria, actinomycetes and myxobacteria.

■ **Biochemistry and enzymology of proteins involved in biosynthesis of terrestrial and marine natural products.** The unique chemistry operating to construct complex terrestrial and marine natural products provides a certain and virtually limitless source of novel enzymes and resistance proteins. The genes that specify the biosynthesis of these compounds will provide a readily accessible source of novel biocatalysts that perform interesting and potentially novel chemical reactions. As new classes of marine natural products are elucidated, the corresponding organisms identified and the gene clusters characterized, it will be possible to use the versatile tools of genetic engineering to overexpress, purify and characterize fully the unique chemical catalysts that have evolved in the terrestrial and marine environments.

■ **Combinatorial biology of marine natural product biosynthetic genes.** Over the past few years it has become evident that powerful new molecular methods exist for the reconfiguration and expression of genes involved in natural product biosynthesis. There is huge potential to create novel organic molecules through deliberate in vivo and in vitro engineering of these pathways for production of human and veterinary pharmaceuticals, specialty chemicals, and high value biomaterials. Relatively few systems exist that can be readily tapped to provide the needed metabolic diversity for the creation of new pathways. Perhaps the single most important new source of this metabolic potential will be provided by natural product biosynthetic gene derived from marine microorganisms. We will continue to pursue aggressively novel metabolic pathways from micro- and macro-organisms, including sponge symbionts.

Selected publications

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- Sang-Jung Kim, Han-Young Kang, and David H. Sherman. 2001. Synthesis of trike[illegible]tide delta-lactones. Synthesis 12:1790-1793.
- Zhang, Q. and D. H. Sherman. 2001. Isolation and structure determination of novamethymycin, a new bioactive metabolite of the methymycin biosynthetic pathway in Streptomyces venezuelae. J. Nat. Prod. 64:1447-1450.
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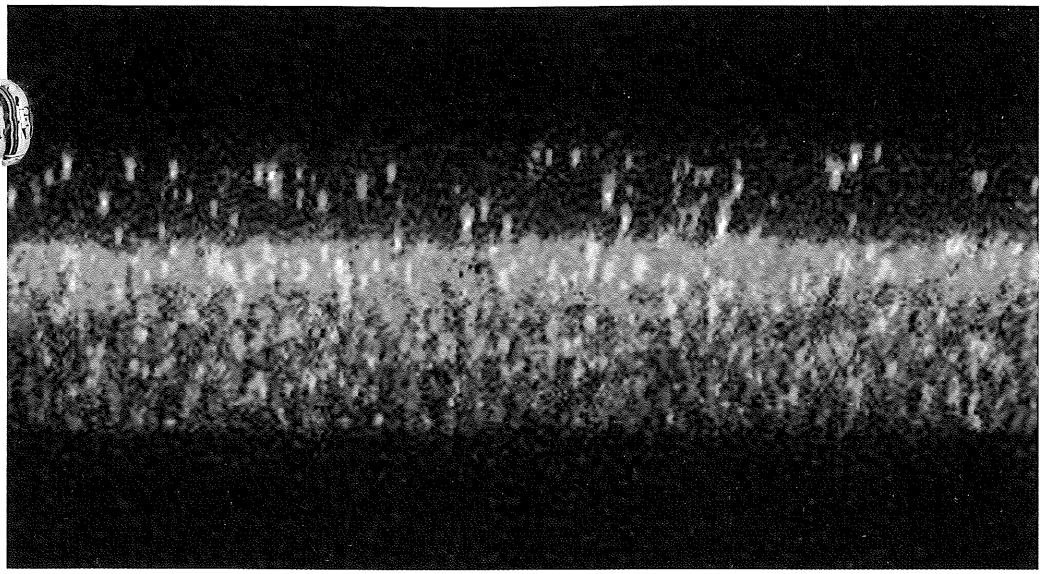
- Baumann, R. P., W. F. Hodnick, H. A. Seow, M. F. Belcourt, S. Rockwell, D. H. Sherman and A. C. Sartorelli. 2001. Reversal of mitomycin C resistance by overexpression of bioreductive enzymes in Chinese hamster ovary cells. Cancer Research 61:7770-7776.
- Kyung, Yung Sun, W.-S. Hu and D.H. Sherman. 2001. Analysis of temporal and spatial expression of the CcaR regulatory el[illegible]ment in the cephamycin C biosynthetic pathway using green fluorescent protein. Mol. Microbiol. 40: 530-541.
- Kyung, Y. S., D. H. Sherman and W.-S. Hu. 2001. Simultaneous analysis of spatio-temporal gene expression for cephamycin biosynthesis in Streptomyces clavuligerus. Biotechnol. Prog. 17: 1000-1007.

JANET

Schottel



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Spatial expression of GFP in e-coli (green) trapped in latex biocatalytic coatings (blue) with latex top-coat sealant (red).

JANET L. SCHOTTEL

Ph.D., Biology, Washington University, St. Louis, MO, 1977.

- **Professor, Associate Department Head, and Director of Undergraduate Studies Department of Biochemistry, Molecular Biology and Biophysics**

Research interests

Professor Schottel works primarily in the area of microbial biochemistry and molecular biology. One research interest focuses on the regulation of gene expression in response to stresses such as nutrient deprivation, culture density, osmotic stress, heat shock, mechanical stress, and desiccation stress. Approaches used in these studies include measurements of transcription, mRNA degradation and protein synthesis rates in cells grown under a variety of culture conditions. Of particular interest is the physiology of cells immobilized in thin porous latex copolymer coatings, and a collaborative project with Professor Michael Flickinger and Professor Skip Scriven investigates the development of these coatings as biocatalysts and biosensors. These cells are metabolically active and non-dividing and exposed to desiccation stress and perhaps mechanical stress during immobilization among the partially coalesced latex particles. Expression of the green fluorescent protein, detected by fluorescence confocal microscopy, has been used to analyze the spatial pattern of inducible gene expression within the coatings. Permeability of the coating, diffusion of inducer, availability of oxygen and viability of the cells are important parameters for optimization. Additional studies will focus on identifying genes expressed specifically in the latex-trapped cells that are important for maintaining viability.

In another research program, Dr. Schottel is studying the interaction between pathogenic streptomycetes and their host plants. Streptomyces scabies causes scab disease on a variety of underground vegetables. In this system, phytotoxins produced by the pathogen that are involved in eliciting lesion formation on the plant have been isolated and characterized. The biosynthetic pathway and regulation of expression of these phytotoxins are being elucidated. Also, a genomic analysis will be used to identify additional pathogenicity genes. Developing new approaches for disease control is a very important issue for this plant disease, and biological control has shown some recent promise. Naturally scab disease-suppressive soil has been

identified in Minnesota, and this soil has been a source of nonpathogenic streptomycetes that inhibit the pathogen. With Dr. Linda Kinkel and Dr. Michael Sadowsky, the suppressive strains have been characterized by genomic, metabolic, and morphological analyses, and these strains are being further investigated for their potential use as biocontrol organisms.

Selected publications

- Schottel, J.L., K. Shimizu, and L.L. Kinkel. 2001. Relationships of in vitro pathogen inhibition and soil colonization to potato scab biocontrol by antagonistic Streptomyces spp. Biol. Control 20:102-112.

- Neeno-Eckwall, E.C., L.L. Kinkel, and J.L. Schottel. 2001. Competition and antibiosis in the biological control of potato scab. Can. J. Microbiol. 47:332-340.

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- Thiagarajan, V.S., Z. Huang, L.E. Scriven, J.L. Schottel, and M.C. Flickinger. 1999. Microstructure of a biocatalytic latex coating containing viable Escherichia coli cells. J. Coll. Inter. Sci. 215:244-257.

- Lyngberg, O.K., V. Thiagarajan, D.J. Stemke, J.L. Schottel, L.E. Scriven and M.C. Flickinger. 1999. A patch coating method for preparing biocatalytic films of Escherichia coli. Biotechnol. Bioeng. 62:44-55.

- Neeno-Eckwall, E.C. and J.L. Schottel. 1999. Occurrence of antibiotic resistance in the biological control of potato scab disease. Biol. Control 16:199-208.

DAVID A.

Somers

Research interests

Research interests are in applications of molecular genetics and genomics to crop netics, physiology and improvement. th crop plants and model systems are ed in my research. Crop responsibilities are focused on soybean and oat. Research activities are directed toward development, investigation and utilization of plant genetic engineering systems for basic and applied research. Basic research emphasis is on investigating mechanisms controlling integration of DNA into plant genomes and formation of transgene loci. We have improved transformation systems in both soybean and oat. These systems are used to investigate gene/enzyme relationships controlling protein and carbohydrate quality and fatty acid synthesis in the seed of both species. We are investigating production of biodegradable materials including biopolymers in soybean ed. We are currently involved in col- orative projects to investigate novel ease resistance mechanisms in oat.

Selected publications

- Stombaugh, S.K., H.G. Jung, J.H. Orf, and D.A. Somers. 2000. Genotypic and environmental variation in soybean seed cell wall polysaccharides. Crop Sci. 40:408-412.

- Pritsch, C., G.J. Muehlbauer, W.R. Bushnell, D.A. Somers, and C.P. Vance. 2000. Fungal development and induction of defense response genes during early infection of wheat spikes by Fusarium graminearum. Molec. Plant-Microb. Interact. 13(2):159-169.

- Svitashev, S., E. Ananiev, W.P. Pawlowski, and D.A. Somers. 2000. Association of transgene integration sites with chromosome rearrangements in hexaploid oat. Theor. pl. Genet. 100:872-880.

- Pritsch, C., C.P. Vance, W.R. Bushnell, .A. Somers, T.M. Hohn, and G.J. Muehlbauer. 2001. Systemic expression of defense response genes in wheat spikes as a response to Fusarium graminearum infection. Physiol. Mol. Plant Path. 58:1-12.

- Ke, J., R. Khan, T. Johnson, D.A. Somers, and A. Das. 2001. High efficiency gene transfer to recalcitrant plants by Agrobacterium tumefaciens. Plant Cell Rep. 20:150-156.

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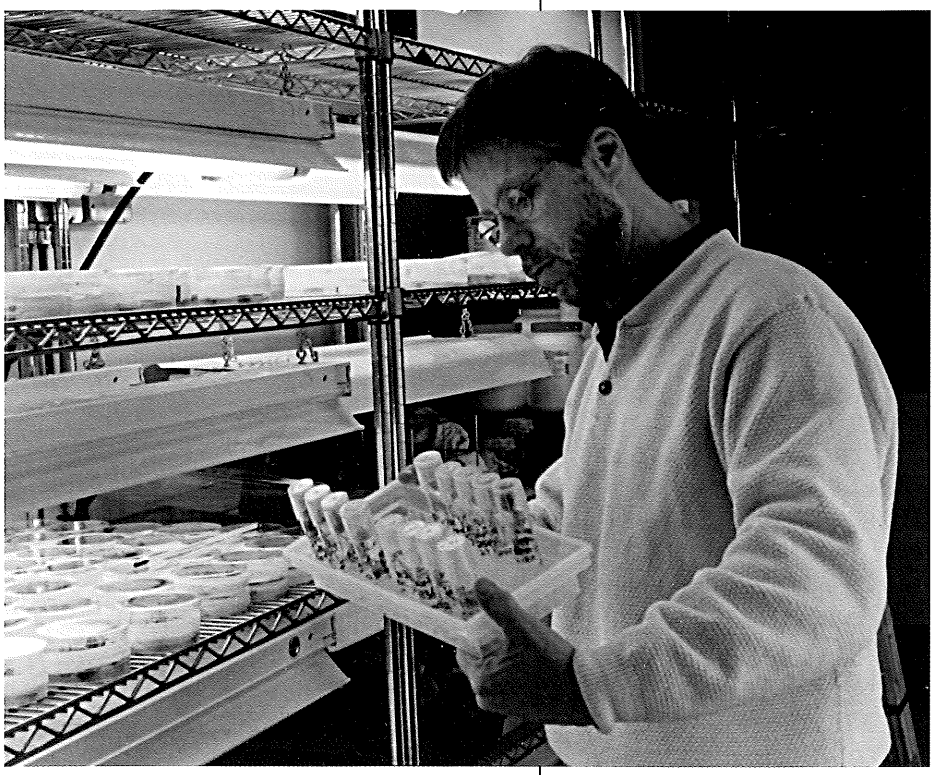

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- Saruul, P., D.A. Somers, and D.A. Samac. Production of a biodegradable plastic polymer, poly—hydroxybutyrate, in alfalfa (Medicago sativa L.). Crop Sci. (in press).

DAVID A. SOMERS

Ph.D.: Washington State University (1983).

- **Professor and Endowed Chair in the Department of Agronomy and Plant Genetics.**

LAWRENCE P. Wackett

LAWRENCE P. WACKETT
Ph.D., Microbiology, University of Texas, 1989.

- **Professor, Biochemistry, Molecular Biology and Biophysics.**
- **Head Microbial Biochemistry and Biotechnology, Division of Biochemistry.**

BIOTECHNOLOGY INSTITUTE

Back Row/Left-Richt: Patrick Ottinger, Charlotta Pederson, Anna Negrete, Nir Shapir, Gilbert Johnson, Jennifer Seffernick, Michael Schoeb, Prof. Larry Wackett, Jack Richman. Front Row/Left-Right: Kannika Saijaphan, Jeff Osborne, Isaac Fruchey, Tony Dodge, Lisa Strong.

Research interests

Bioinformatics

Professor Wackett, in collaboration with Bioinformatics Professor Lynda Ellis, has constructed a World Wide Web database (UM-BBD) focused on microbial biocatalytic and biodegradative reactions (Ellis, Hershberger and Wackett, 2001). This effort presages a time when anyone can sit at a desktop computer and theoretically design efficient biochemical pathways for purposes of biosynthesis or biodegradation and find out rapidly if the genes and organisms are available to carry out the plan experimentally. Research is underway to develop heuristic models of microbial biocatalytic pathways.

Functional Genomics and Biocatalysis

It is the overall objective of this research to explore the breadth of Earth's biochemical diversity and help uncover the function of unknown genes in the widespread microbial genome sequencing projects. The enormous taxonomic and genomic diversity of microbes provides corresponding metabolic diversity, of which only a narrow slice has been discovered for a basic understanding of microbial metabolism and exploited for biocatalytic production of commercial chemicals.

Biodegradation

The Wackett laboratory investigates bacterial degradation of organic, organometallic, and metalloid compounds. For example, bacteria initiate metabolism of atrazine via the enzyme atrazine chlorohydrolase (deSouza, et al., 1998), which renders the herbicide nontoxic. The enzyme is being studied as a model to better understand dechlorinati biocatalysts and for its applicability to treat soil and water contaminated with atrazine. We have recently completed an environmental cleanup of 1000 pounds of atrazine spilled in a soil in South Dakota (Strong, et al., 2000). This research is conducted in collaboration with Professor Michael Sadowsky.

Metabolic Engineering and Genomics

Deinococcus radiodurans is extremely resistant to ionizing radiation, making it a primary candidate to use for the remediation of mix waste sites containing organic pollutants and radionucleides. The complete DNA sequence of Deinococcus radiodurans has been determined. Metabolic reconstruction has shown that D. radiodurans has a very narrow range of catabolic pathways, limiting its usefulness in remediation. However, our collaborator, Professor Michael Daly at the Uniformed Services University of the Health Sciences, has developed methods for efficient introduction of foreign DNA into D. radiodurans. This has been used to clone and express toluene oxidation genes (Lange, et al., 1998) and the mercury resistance operon (Brim, et al, 2000) in D. radiodurans. The recombinant strains are able to metabolize toluene and mercury, respectively, in the presence of strong ionizing radiation.

Catabolic Enzyme Evolution

The Wackett laboratory studies protein ancestry and modulation via evolutionary processes. Research has shown that microbes and their enzymes and pathways are extremely plastic. For example, in conjunction with Professor Michael Sadowsky, we have shown that virtually identical atrazine-catabolism genes have spread globally with the aid of catabolic plasmids and transposons (Martinez, et al., 2001). Other research is identifying enzymes catalyzing different reactions but having nearly identical sequences, thus allowing the opportunity to emulate natural evolutionary transition of catalytic function in the laboratory (Seffernick and Wackett, 2001). We have also used DNA shuffling in collaboration with Jeremy Minshull and his coworkers at Maxygen, Inc. to generate catalytic diversity in the amidohydrolase protein family (Raillard, et al., 2001).

Selected publications

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- Lange, C.C., L.P. Wackett, K. Minton, and M. Daly (1998) Engineering a recombinant Deinococcus radiodurans for organopollutant degradation in radioactive mixed waste environments. Nature Biotechnology 16:929-933.

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- Strong, L.C., H. McTavish, M. J. Sadowsky, L. P. Wackett (2000) Field-scale remediation of atrazine-contaminated soil using recombinantEscherichia coli expressing atrazine chlorohydrolase. Environ. Microbiol. 2:91-98.

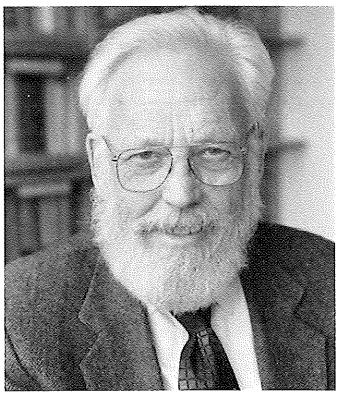
- Seffernick, J.L. and L.P. Wackett (2001) Rapid evolution of bacterial catabolic enzymes: A case study with atrazine chlorohydrolase. Biochemistry 40:12747-12753.

- Raillard, S-A., A. Krebber, Y. Chen, J.E. Ness, E. Bermudez, R. Trinidad, R. Fullem, C. Davis, M. Welch, J. Seffernick, L.P. Wackett, W.P.C. Stemmer and J. Minshull (2001) Novel enzyme activities and functional plasticity revealed by recombining homologous enzymes. Chem. Biol. 125:1-9.

- Martinez, B., J. Tomkins, L.P. Wackett, R. Wing, and M.J. Sadowsky (2001) Complete nucleotide sequence and organization of the atrazine catabolic plasmid pADP-1 from Pseudomonas sp. ADP. J. Bacteriol. 183:5684-5697.

ARNOLD G.

Fredrickson



A. G. FREDRICKSON

- **Professor Emeritus, Chemical Engineering and Material Science.**

A. G. FREDRICKSON

Tundra swans during migration through Minnesota.

Prof. Arnie Fredrickson was one of the founding faculty of BPTI. In his early collaborative work with Prof. H.M. Tsuchiya, who was a microbiologist, he experienced the benefits of interdisciplinary research between engineers and biologists. This is the touchstone of BTI to conduct research at the interface of engineering and biology. Prof. Fredrickson's early work in mathematical modelling of cell populations was seminal for much of today's work in cell population dynamics.

Arnie is passionate about his research and teaching. Now emeritus, he continues to teach in Chemical Engineering.He is equally passionate about photography and has , over the years, travelled far and wide seeking worthy subjects for his artistic eye. A few of Arnie's Minnesota photographs have been reproduced in this report. It is an opportunity to share the beauty of Minnesota, as recorded by Prof. Fredrickson, with our constituents.

A. G. FREDRICKSON

Bloodroot (Sanguinaria Canadensis) is a harbinger of spring in Minnesota.

ABOVE: Arnie travels to interesting and sometimes remote sites for photographic material.

A. G. FREDRICKSON

ABOVE: Yes, pelicans in Minnesota!

A. G. FREDRICKSON

LEFT: North Shore of Lake Superior – Mountain Ash in fall color.

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