

# BTI 2000

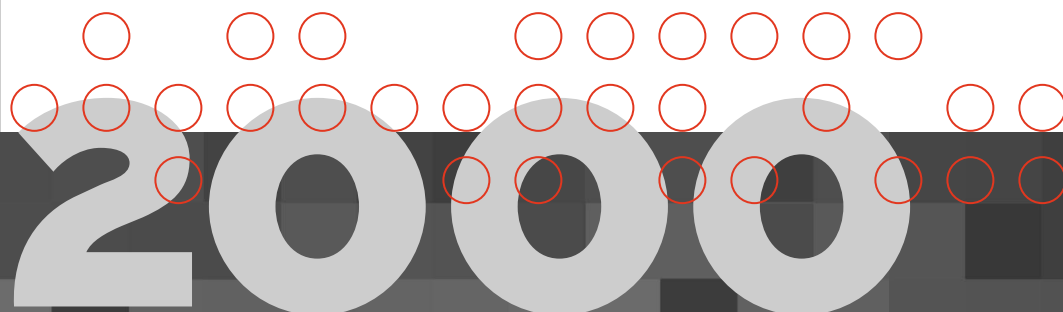
Boyce Thompson Institute for Plant Research

The 77th Annual Report



# Boyce Thompson Institute for Plant Research

The Boyce Thompson Institute conducts research to expand the frontiers of plant biology and related areas of science while continuing a tradition of using science and technology to protect the environment and improve human health and well-being.



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## President's Report

The past year has brought many changes to the Boyce Thompson Institute for Plant Research (BTI). On September 1, 2000, I took over the responsibilities of president and CEO from Charles J. Arntzen. Under his able leadership, the BTI made great strides toward streamlining its operations and enhancing its research programs; during Arntzen's five-year tenure, sponsored research funding more than doubled to \$6 million per year. With the addition of several new faculty members, research in the areas of plant development, plant pathology, and plants for human health was significantly enhanced.

In October 2000, Charles Arntzen assumed an endowed chair and distinguished professorship at Arizona State University; he remains, however, a project leader at the BTI where he continues to direct an active research group with Hugh Mason. Their pioneering work with plant-based edible vaccines brings hope to millions of people in developing countries who do not have access to traditional vaccines that could protect them against several deadly diseases. The work of this innovative research group receives increasing attention in print and broadcast media. Considerable television coverage by several major networks, including ABC, CBS, and PBS, and print outlets such as the *New York Times*, *Washington Post*, and *Scientific American* attest to the expanding public interest in the use of plants to improve health and prevent and treat disease.

The BTI is proud of its senior scientists who move on to pursue new opportunities. Stephen H. Howell, vice president for research during Charles Arntzen's tenure, has accepted a new position as director of Iowa State University's new Plant Science Institute. Steve initiated the first plant molecular biology research group at the BTI upon his arrival in 1988; his research focused on the study of several plant viruses and plant development. We thank Steve for his many contributions to the institute. The BTI takes pride in his "reflected glory"; we wish him much success as he assumes this prestigious position at a major agricultural university.

The institute is in an exciting but challenging period of transition in leadership, faculty recruitment, and research direction. The board is expected to approve the nomination of David B. Stern as vice president for research following Steve Howell's departure. Current research at the BTI can be grouped under four themes: forest biology, insect biology, plant molecular genetics, and plants for human health, with many research projects spanning two themes. With the retirement of several senior



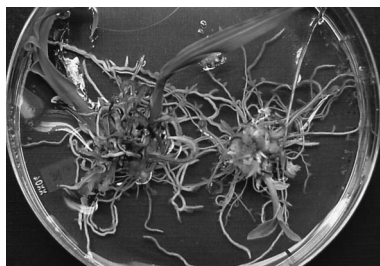
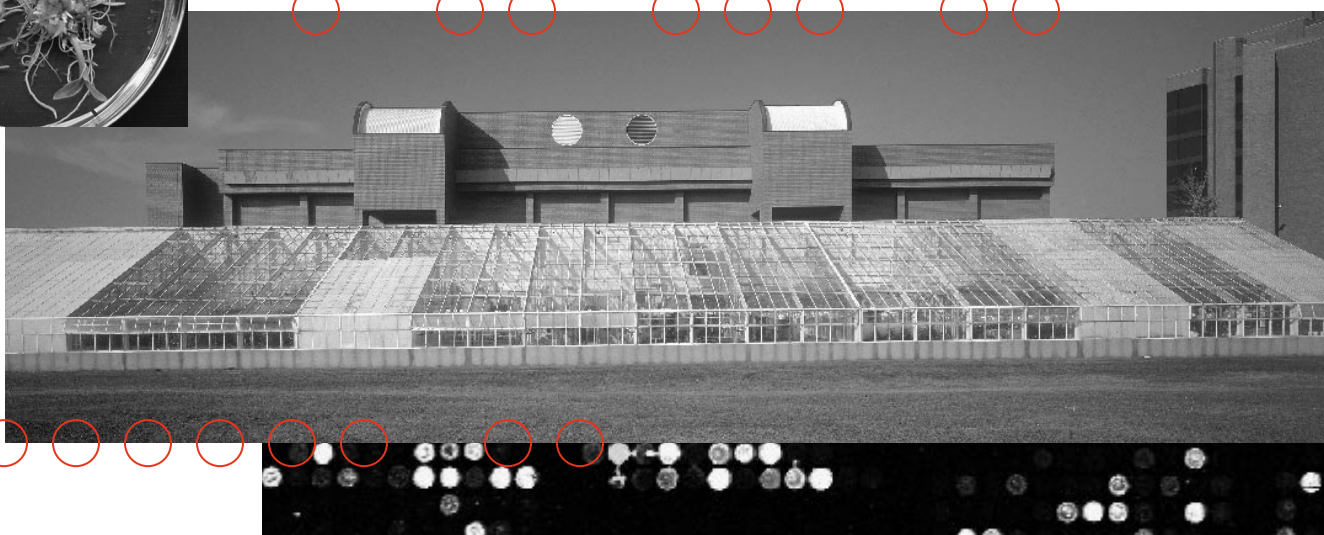


photo: Murielle Boisson



faculty members in the next five years, the institute will be positioned to redirect some of its programs. As part of the BTI's efforts to enhance the quality and impact of its research in plant science, new research areas will be added.

In keeping with the BTI's long history of accomplishments in ecology and environmental biology and drawing on its collaboration with Cornell University, the institute will reemphasize its research theme of plants and the environment: the study of their interactions. To carry out the BTI's mission successfully given its limited size and resources, its research programs will focus on three key areas: plant pathology, plant development, and plant molecular ecology. Plant pathology and plant development take advantage of current strengths in the institute and are part of Colonel William Boyce Thompson's vision to create "a scientific institution dealing with definite things, like germination, parasites, and plant potentialities."

In the area of plant pathology, work at the institute on how plants protect themselves against microbial pathogens such as viruses, bacteria, and fungi has resulted in the identification of critical components of signal transduction pathways that enable a plant to recognize that it is being attacked and then rapidly mount defenses against the invading microbe. These studies have helped establish that plants and animals, including humans, share an ancient immune system.

Researchers in plant development seek to understand how plants grow and develop into

mature organisms; these studies are crucial to improving food and fiber production to feed, clothe, and house the rapidly multiplying human population (estimated to reach 10 billion by 2050) without further destroying the world's limited wilderness areas, which serve as essential reservoirs of biodiversity. Current work at the institute uses molecular genetics and functional genomics to understand how plants sense light to alter their growth and development or regulate the expression of genes in the two principal organelles of the plant cell that are responsible for photosynthesis and energy production.

The recent addition to our plant development faculty of James Giovannoni and his research team from Texas A&M University expands our program and affirms the BTI's relationship with the USDA. Jim and his team study how tomato fruits form and mature into ripe, edible produce. The goal of their research is to improve the appeal and nutritional quality of tomato fruit. Although Jim is a project leader at the BTI where he conducts his research, he is an employee of the USDA Agricultural Research Service. His colleague, Leon Kochian, who is research leader at the U.S. Plant, Soil, and Nutrition Laboratory on Tower Road, became an adjunct project leader at the BTI this year. Thus, the close relationship between the BTI and the USDA continues to grow.

In keeping with the institute's collaborative research goals and with an eye toward developing a research program in plant molecular ecology, the BTI hosted a panel of experts from Cornell



BTI's management team (left to right): Lucy Pola, director of human resources; David Stern, vice president for research; Daniel Klessig, president and CEO; Joyce Frank, director of licensing and intellectual property; Laurance Russell, director of operations; John Dentes, vice president for finance, treasurer.

University and other American and European scientific institutions in November 2000. Given the BTI's outstanding reputation in ecology and environmental biology, the superb chemical ecology program at Cornell University and the panel's strong recommendation to proceed, the institute has initiated a search for faculty in this area. Research in plant molecular ecology will focus on the molecular basis of the interrelationship between plants and their environment. Through a complex array of compounds, plants respond to their environment, including beneficial and harmful microorganisms, insects, and abiotic stresses such as air pollution. Using the latest tools of functional genomics to simultaneously analyze the expression of hundreds to thousands of genes, researchers will strive to unravel the mysteries of these complex molecular interrelationships for the improvement of human and environmental health.

The BTI now stands poised to enhance its important role in the plant sciences. Over the past few years, generous support from individuals and foundations, in particular the Park Foundation, has made possible the recruitment of world-renowned scientists. Recruiting new faculty and staffing new programs such as plant molecular ecology present major challenges as well as opportunities. As we move through this critical transitional phase, identifying financial resources that enable us to continue attracting the best and brightest researchers remains a priority.

In closing, I want to acknowledge the support and assistance I have received from members of

management, faculty, and staff at the BTI. They have contributed greatly to a relatively smooth transition between presidents. Special thanks go to Charles Arntzen and Steve Howell for their invaluable guidance and unselfish assistance. I owe a debt of gratitude to management, staff, and all the individuals who have patiently guided me through the intricacies inherent in transitions. Too often credit is concentrated at the top when it ought to be distributed throughout an organization.

The year 2000 was a year of transition for the BTI. The institute has entered a period of great change, whose dimensions and significance may be paralleled only by the relocation of the BTI from Yonkers to Ithaca (Cornell) in the mid-1970s. Together with the BTI's bright, imaginative scientists and talented, dedicated staff, I look forward to guiding this fine institution in the new millennium.

*Daniel Klessig*

# Outreach



photo: Murielle Boisson



photo: Joyce Van Eck



The **Educational Outreach Committee (EOC)** promotes science, educates the public about the BTI and its research, and helps students explore careers in science and plant biology. EOC's efforts included the New Visions program for local high school students and the Expanding Your Horizons program for middle school girls, both in conjunction with Cornell University. The establishment of the new public display Tomato Biodiversity Garden at Cornell Plantations highlighted EOC's accomplishments this year.

The **New Visions Program** gives selected Tompkins County high school seniors the opportunity to spend their senior year on the Cornell campus, studying various special topics in biology including laboratory visits at the BTI. This year Greg Martin introduced his research program in plant disease resistance, followed by a tour of his lab and the Center for Gene Expression Profiling (see page 6). Lokesh Joshi talked to the students about drug production in insects and the effect of space flight on protein synthesis. Sara Abend gave a tour of the Plant Transformation Facility, and Tom Brutnell introduced the students to maize genetics. Three of the fourteen New Visions students participated in the program's four-week independent research projects in BTI laboratories.

Junior high school girls and their parents participated in the **Expanding Your Horizons Program** to learn about careers that use mathematics and science. The BTI presented two of the twenty-three workshops that were given at numerous locations on the Cornell University campus. Joyce Van Eck explained plant tissue culture and gene transfer techniques; Brian Gollands and Denise Costich demonstrated educational software developed by BTI's Plant Modeling Group. Students evaluated their success at achieving high biodiversity and sustainability of the land using a simulation model based on ecological data provided by the Tropical Forestry Initiative in Costa Rica.

The BTI and Cornell Plantations established their first **Tomato Biodiversity Garden** as a multiyear collaboration for educational outreach to demonstrate the diversity in tomatoes and to make the public aware of how natural mutation, selection, and crop improvement through the centuries have taken the tomato from its wild species to today's grocery store varieties. The tomatoes were grouped as wild, heirloom, and modern cultivated species to demonstrate the progression from ancestral plants to the tomato of today. Various fruit shapes, colors, and plant habits were chosen as evidenced by the names Orange Banana, Black from Tulla, Prudens Purple, Yellow Pear, Green Zebra, White Tomato, Golden Sunray, and Silvery Fir Tree.

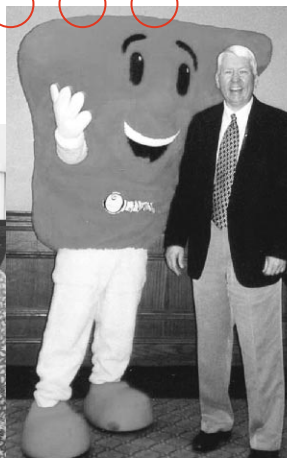
The development office, with help from the EOC, hosted exhibit booths at Cornell's Reunion Weekend and at a Tompkins County Chamber of Commerce event. Charles Arntzen and Joyce Frank gave lectures at Kendal at Ithaca, a senior living community. Development hosted an informal forum with BTI scientists and Ithacans resistant to genetically modified foods; the Ithaca Garden Club's annual meeting during which Charles Arntzen presented a talk, "Nature's Bounties, Pharmaceuticals from Plants," and Joyce Frank arranged tours of the greenhouses; a tour of the BTI by Maurice Hinchey including a round table discussion with senior scientists; and a welcome reception for the BTI's new president Dan Klessig to meet community members and friends of the institute.

**Mary Alyce Kobler** and **Brian Bell** jointly received the 2000 New York State Integrated Pest Management (IPM) Award for Excellence, Innovation, and Education. This award recognizes the novel and successful ways in which the BTI greenhouse staff integrates cultural, chemical, and biological tools to produce healthy research plants. Brian has figured out ways to use beneficial insects in our research growing environment. Mary Alyce has given educational seminars at "sister" institutions and helped them develop IPM programs.

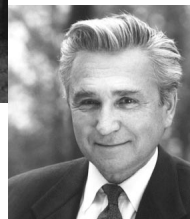




photo: Sheryl D. Sinkow Photography



Charles Arntzen spoke at the Eastern American Society of Microbiology Hepatitis B Foundation Conference in Philadelphia where he received the "Distinguished Service Award" in recognition of his groundbreaking work in the advancement of hepatitis virus vaccines. He is seen here with Mr. O'Liver, the mascot of the Hepatitis B Foundation.



Congressman Maurice Hinchey toured the BTI and discussed agricultural issues with BTI scientists.

photo: Jocelyn Augustino, 1997

BTI staff (left to right) Jamie Lyman, Joyce Frank, and Brian Gollands staffed the BTI's booth at Tompkins County Chamber of Commerce, Business After Hours.

BTI research, particularly on plant-based edible vaccines, was publicized in media worldwide, including the *New York Times*, *The New Yorker*, *Discover*, *USA Today*, *Scientific American*, and on ABC and CBS evening news programs.

More than 200 visitors attended the grand opening of the Center for Gene Expression Profiling (CGEP) on January 20. CGEP promotes the use of microarrays and genomics in basic research; graduate, undergraduate, and high school classes have visited this lab to learn about the array-making process and understand its usefulness to scientists.

The institute's Distinguished Lecture Series hosted renowned scientists, including Tom Hinckley from the University of Washington, Seattle; Margaret Lowman from Marie Selby Botanical Gardens, Sarasota, Fla.; David Baulcombe from the Sainsbury Laboratory, Norwich, UK; Harry Smith from the University of Leicester, UK; and Jack Schultz from Penn State University.

Institute scientists gave presentations at national and international meetings of professional societies, conferences, workshops, and symposia in the United States and abroad, several in conjunction with Cornell University. Other presentations were made to foundations and corporations.

Institute scientists also reviewed many grant proposals, including those submitted to the National Institutes of Health Small Business Innovative Research Grants Panel, United States Department of Agriculture, National Science Foundation, Binational Agricultural Research and Development Foundation, and Department of Energy. They also reviewed articles in plant science publications, including *Nature Biotechnology*, *Cell*, *Journal of Virology*, *Virology*, *Genetics*, *Nature Genetics*, *The Plant Cell*, *Tree Physiology*, *Plant Physiology*, *Oecologia*, *Plant Molecular Biology*, *New Phytologist*, *Seed Science Research*, *Gravitational and Space Science Biology*, *The Plant Journal*, and *Proceedings of the National Academy of Sciences*.

**Charles J. Arntzen** served on the boards of the Cornell Center for the Environment, the Cornell Research Center Directors, and the Boyce Thompson Southwestern Arboretum. He was on the editorial boards of *AgBiotechNet* (an online service for agricultural biotechnology) and *CRC Critical Reviews in Plant Sciences* and was a member of the scientific advisory or editorial boards for five private companies. In 2000 he became the Florence Ely Nelson Presidential Chair, Arizona State University, while continuing as a BTI project leader.

**Gary W. Blissard** was coordinator for the Cornell Virology Journal Club and served on the executive committee of the Cornell NIH Training Grant in Virology. He was a member of the Baculovirus Study Group of the Invertebrate Virus Subcommittee of the International Committee on Taxonomy of Viruses and was on the editorial boards of the *Journal of Virology* and *Virology*. He was a member of the NSERC (Natural Sciences and Engineering Research Council) of Canada Site Review Panel and chair of the BTI Library Committee.

**Tom Brutnell** was a member of the Cornell Plant Biology Faculty Search Committee and authored tutorials in developmental and molecular genetics at the University of Oxford.

**Alice Churchill** was a member of the proposed Sustainable Agriculturally Based Bioindustries Center at Cornell University.

**Jonathan Comstock** is director of the Cornell and Boyce Thompson Stable Isotope Laboratory (CoBSIL).

**Patricia Conklin** led a laboratory titled "Ascorbic Acid" for the Cornell Institute for Biology Teachers and led a workshop at "Biology as an Information Science—A Workshop for Engineers," held in Cornell's College of Engineering. She became a visiting assistant professor of genetics at the State University of New York College at Cortland.



**Denise E. Costich** co-chaired the BTI's Educational Outreach Committee and directed a New Visions high school student in the lab. She co-organized monthly meetings of research associates, postdoctoral associates, and graduate students.

**James Giovannoni** joined USDA from Texas A&M and became a BTI project leader. He was a monitoring editor for *Plant Physiology*.

**Robert Granados** presented a plenary lecture at the Mexican National Biological Control Congress in Guanajuato, Mexico, titled "Baculovirus Pathogenesis: Viral and Insect Transgenes." Bob also served on the BTI's Benefit Plan Committee and the Cornell Relations Committee.

**Leon V. Kochian** became a BTI adjunct project leader, was a member of the Cornell Genomics Task Force, was monitoring editor for *Plant Physiology*, and served on the editorial boards of *Annual Reviews of Plant Physiology* and *Plant Molecular Biology*.

**Robert Kohut** organized and chaired the session "Effects of Elevated CO<sub>2</sub> on Plants and the Environment" at the Air Pollution Workshop at Auburn University.

**John Laurence** served on the editorial board for *New Phytologist* and was a member of the Commercial Forestry Benefits Team for the Regulatory Impact Analysis in support of "Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements," a rule issued by EPA in December 2000.

**A. Carl Leopold**, BTI emeritus scientist, served on the editorial boards of *Seed Science Research* and *Gravitational and Space Science Biology*. He was chairman of the Tropical Forestry Initiative, became vice president of the Aldo Leopold Foundation, and was a member of three advisory boards. Carl received the prestigious Academico Honore of the Royal Galician Academy of Science in Spain.

## The Center for Gene Expression Profiling

This state-of-the-art facility provides DNA microarraying and analysis services to BTI researchers as well as those at Cornell University, the Geneva Agricultural Experiment Station, and the USDA Federal Plant, Soil, and Nutrition Laboratory. The center is equipped to analyze genome-wide gene expression changes in plants, mammals, insects, microbes, and other organisms. Equipment includes two robotic arrayers to develop high-density custom arrays of PCR products or oligonucleotides onto glass slides, a confocal laser scanner for capturing hybridization images, and computer and software support analysis of large data files. The center is directed by Gregory

Martin and is managed by a full-time research specialist engaged in array-based projects. CGEP is supported in part by the BTI and a National Science Foundation Major Research Infrastructure grant.

### What Is Gene Expression Profiling?

Changes in gene expression underlie many biological phenomena. Advances in molecular biology have permitted detailed analysis of the expression of individual genes by using hybridization of gene probes to RNA blots, providing insight into tissue-specific expression of genes and the response of gene expression to external stimuli. In the past few years,





**Gregory Martin** established and is currently director of the Center for Gene Expression Profiling. He is co-principal investigator on an NSF-funded project that is developing a large, publicly available tomato express sequence tags (EST) database, administered by The Institute for Genomic Research (TIGR). Greg also co-directed BTI's collaboration with Cornell Plantations to develop the Tomato Biodiversity Garden.

**Hugh Mason** was interviewed twelve times by the popular press regarding his work on plant-based edible vaccines.

**David Stern** was co-editor of *The Plant Cell* and associate editor of *Plant Molecular Biology*. He was a member of the National Science Foundation (NSF) Plant Genome Site Review Committee and a panel member of the Winston Churchill Fellowship National Nomination Committee. David was committee chair of the Boyce Thompson Institute Internal Promotion Committee and acting chair of Cornell's Plant Cell and Molecular Biology Graduate Program.

**Mary Topa** was chair of the International Union of Forestry Research Organizations (IUFRO) Root Physiology and Symbiosis working party.

**Joyce Van Eck** was co-chair of the BTI Educational Outreach Committee, coordinator of the BTI-Cornell Plantations Tomato Biodiversity Garden, workshop leader for Cornell's Expanding Your Horizons at BTI, and participated in a forum about genetically modified foods.

**David Weinstein** chaired the Cornell Plantations Advisory Board, was a member of the Dryden Town Planning Board and the Finger Lakes Land Trust, and an associate member of the Tompkins County Environmental Management Council.

**H. Alan Wood** presented an invited symposium lecture at the 2000 World Congress on In Vitro Biology titled "On Earth and in Space: The Insect N-linked Glycosylation Pathway" in San Diego, Calif. He joined Mississippi State University as director of its new Life Sciences and Biotechnology Institute.

## Media Interactions

Newspapers, Magazines, and Print media: *The New York Times*, *Wired*, *Cornell Magazine*, *Discover*, *The New Yorker*, *Nature Medicine*, *Rochester (NY) Democrat and Chronicle*, *Prevention magazine*, *Cleveland Plain Dealer*, *USA Today*, *Vision*, *Cambio magazine*, *the Lancet*, *the Ithaca Journal*, *the Ithaca Times*, *the New Republic*, *Red Herring magazine*, *the (Syracuse) Post-Standard*, *Science News*, *the Dallas Morning News*, *Scientific American*, *Reuters News Service*.

Internet publications included: AgWeb.com, HMS Beagle, Bioresearch OnLine, BioMed Central, the Washington Post Online, Food Biotechnology Communications Network (Canadian Newswire), Forbes.com, BioWorld Today (a biotechnology newspaper).

Television and Radio Interactions: *NOVA/FRONTLINE*, PBS, Fox Health News, Time-Warner Channel 7, City TVn3v (in Canada), CBS Evening News with Dan Rather, ABC World News Tonight with Peter Jennings.

large collections of cDNAs from many organisms have been sequenced and have made possible the analysis of the fluorescent probe from mRNA isolated from an organism responding to a specific external stimulus (e.g., pathogen attack) or from an organ at a specific developmental stage (e.g., ripening fruit). The probe is then hybridized to many thousands of cDNA inserts that have been individually spotted onto a glass slide. Genes that are expressed in the tissue being studied will hybridize to the corresponding cDNA, and the fluorescence is detected by a confocal laser scanner. The resulting image is analyzed using software that was specially developed for the purpose.

# History and Philosophy



Founder William Boyce Thompson (above) and the Montana home he was born and raised in (left).



William Boyce Thompson (1869–1930) was born in the rough mining towns of Montana; he left to attend Phillips Exeter Academy and the Columbia School of Mines and ultimately built a fortune from copper-mining stocks on Wall Street.

Thompson was a shrewd man of business and a philanthropist who wanted to contribute something of lasting value to humanity. After seeing the devastation and hunger in Russia following World War I as a volunteer “colonel” during an American Red Cross relief mission, Thompson decided to create a scientific research institute dedicated to ensuring adequate food supplies for a growing population and to expanding fundamental knowledge of plants. He was convinced that “any principles concerning the nature of life that you can establish for plants will help you to understand man, in health and in disease.”

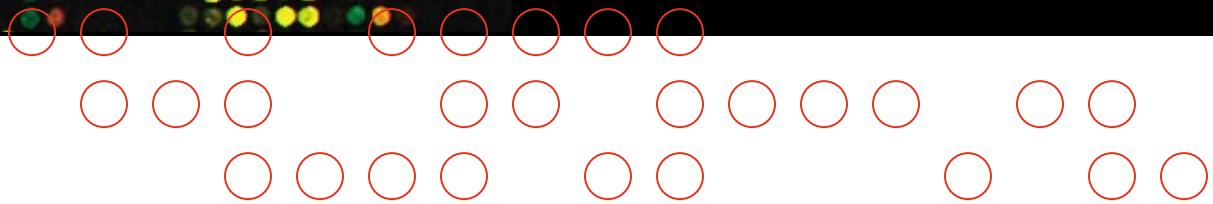
In 1924 Boyce Thompson Institute for Plant Research was established in Yonkers, New York, to study “why and how plants grow, why they languish or thrive, how their diseases may be conquered, how their development may be stimulated by the regulation of the elements which contribute to their life.” The institute was built directly across from Thompson’s house so that he could participate in its management. The founder named his institute in honor of his parents, Anne Boyce and William Thompson.

Over the past 76 years BTI scientists have made contributions toward more nutritious food plants and disease- and pest-resistant crops that have added to an abundant supply of food in our country. They have been leaders in environmental research, working to provide the necessary knowledge for a balance between industry and the natural environment. They have demonstrated the importance of using plant biology in medical research, revealing that disease, fundamental physiological processes, and genetics are in some cases more easily studied in plants and insects than in mammals. BTI research has contributed unique insights into new experimental techniques and the development of plant-derived medicines and plant-based vaccines. The institute’s relocation to the Cornell campus in 1978 increased collaborations with Cornell colleagues while maintaining the BTI’s independent, not-for-profit status.

With its new leadership, Boyce Thompson Institute will see many changes in the coming years. It enters the millennium with numerous strengths, notably its staff and facilities. These same strengths also offer opportunities for the future as we refocus scientific direction and bring new scientists to the institute who will advance the BTI’s vision to be at the forefront of plant research and to benefit humankind.



# Research 2000





## Research at the Interface of Plant Biology and Human Medicine

**Charles J. Arntzen, Ph.D.**  
Scientist, Plant Molecular Biology  
President Emeritus

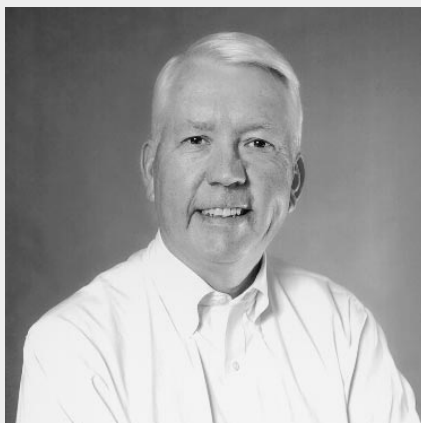


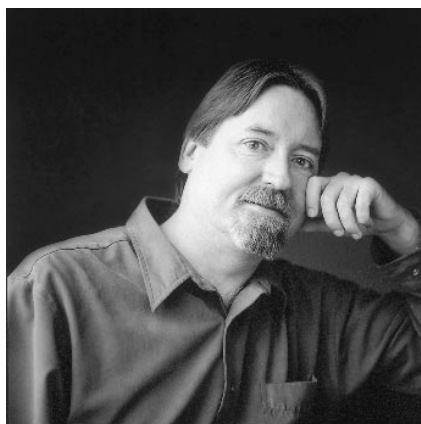
photo: Timothy Trimble

Two-thirds of the world's population use herbal medicines as their primary means for disease intervention. New tools for molecular biology, analytical chemistry, and biotechnology make it possible to build upon plant-based medical history to create or discover new pharmaceuticals. It is my goal to work at the interface of plant biology and human clinical medicine to prevent disease and provide new therapeutics.

Dr. Hugh Mason and I, using plant biotechnology to create new oral vaccines, have recorded several milestones in plant-based vaccine delivery. First, we found that specific, single genes from human or animal

## Molecular Biology of Baculoviruses

**Gary W. Blissard, Ph.D.**  
Scientist  
Molecular Biology



One of the most severe environmental insults to plants is insect attack. In nature, various insect diseases such as the viruses known as baculoviruses, hold insect populations in check. Baculoviruses can be highly lethal to insect hosts, yet cannot replicate in other insects, plants, or animals. Therefore baculoviruses have been studied extensively as an environmentally safe alternative to nonspecific chemical insecticides that must otherwise be used to control many insect pests in agriculture.

Our work aims to understand how baculoviruses enter host cells, spread infection, and express viral genes in the

## Light Responses in Corn

**Thomas P. Brutnell, Ph.D.**  
Assistant Scientist  
Plant Molecular Genetics



Plants "see" red, far-red, blue, and ultraviolet light through distinct photoreceptors. Phytochrome, the best-characterized photoreceptor, allows plants to perceive and respond to red and far-red light. When plants are emerging from the soil or are shaded by another plant, the light environment is enriched in far-red relative to red light. Through phytochrome, the plants are able to detect this change in environment and respond either by pushing through the soil or by growing away from a neighboring plant.

Recent studies in the small weed *Arabidopsis thaliana* have greatly advanced our understanding of the

pathogens (bacteria and viruses) can be transferred to plants, and when the correlated gene product accumulates in plant cells it retains immune-stimulating properties of the original pathogen. Second, we showed that the “vaccine” in the plant cells did not have to be purified but is orally active if the plant material containing it is simply consumed as food. Third, we showed that oral immunization by plant-delivered vaccines is effective in human clinical trials; we have completed three human trials with three different prototype vaccines and have observed both humoral and mucosal immune responses. Next we plan to select and

use a plant production system that will give reliable vaccine delivery, meeting all standards of “good manufacturing practice” and be suitable for production use in both developed and developing countries. We will continue our efforts to produce vaccines in ripening banana fruit, focusing on a pediatric vaccine (such as pureed banana) that could be produced and used in developing regions of the world.

I also participate in a multi-disciplinary team attempting to find novel anticancer chemicals in plants native to arid regions of the world. Dr. Jordan Gutterman of the M.D. Anderson Cancer Center in Houston helps identify

mode(s) of action of various chemicals that have been isolated and have the capacity to induce programmed cell death (apoptosis) in cultured human cancer cell lines. Recently we have extended these studies to animal skin cancer trials, using a preparation from a desert tree, *Acacia victoriae*. The results have been very encouraging, and I am now focusing on generating a large and reliable supply of the active chemical extract from this tree as a step toward human clinical trials of a potential preventive of cancer.

infected insect. One series of studies focuses on the role and function of the major envelope protein of a model baculovirus, *Autographa californica* multicapsid nucleopolyhedrovirus (AcMNPV). We have examined the role of this envelope protein (known as GP64) in virus binding to the surface of the host cell, the interactions necessary to release the virus into the cell, and its role in the production of new virus particles. Our laboratory developed a genetic “knockout” virus system that removes the gp64 gene from the AcMNPV genome and replaces that gene with modified forms of gp64, facilitating rapid analysis of the

functions and functional domains in this critical envelope protein.

Another interest is regulation of gene expression during the viral infection cycle. Baculoviruses are large DNA viruses with over 100 genes, and many viral genes are expressed immediately after the virus enters the host cell. Many “Early” genes encode regulatory proteins that control viral DNA replication and “Late” gene expression. We use the genetic “knockout” system to examine the roles of these early regulatory proteins, with a focus on genes and proteins that regulate late virus transcription. To use baculoviruses in biological control, we

will need to understand the mechanisms of virus entry and exit from the cell, as well as the complex regulation of viral gene expression that leads to a coordinated and successful conquest of the host cell. Through studies of virus envelope proteins and their roles in infection, and the functions of viral regulatory proteins, we are beginning to understand important details of the viral infection process. Such information improves our understanding of these important natural pathogens of insects and will lead to more specific, effective, and environmentally sound methods for plant protection.

molecular components plants use to perceive and respond to light. The genes encoding phytochrome have all been cloned, and rapid progress is being made at identifying proteins that are part of the phytochrome signaling pathway. Not surprisingly, these studies are revealing a complex network regulating a variety of plant processes such as seed germination, plant architecture, and flowering time.

Despite these advances in Arabidopsis, our understanding of light signaling in crop plants such as corn is surprisingly limited. Fortunately, through recent advances in genomics, we now have tools such as microarray

analysis and transposon mutagenesis that are enabling us to dissect these processes in corn. Through a comparative analysis of light signaling pathways in Arabidopsis and corn, we are beginning to see how evolution has tailored these pathways to meet the different environmental, physiological, and developmental needs of these two very different plant species.

## Fungal Natural Products as Plant Toxins and Medicinals

Alice C. L. Churchill, Ph.D.  
Center Scientist  
Molecular Mycology



Fungi create complex chemicals that exhibit diverse biological activities. Some of these natural products act as disease-causing toxins against plants and animals. Others (e.g., antibiotics) protect the fungus against predators or competing organisms. Fungal natural products, such as penicillin and cyclosporin, serve as medicines to treat human disease. Yet less than 5 percent of the 1.5 million fungal species predicted to populate the earth have been explored taxonomically, and an even smaller fraction has been characterized chemically. A common theme of our research is understanding the molecular genetic basis for the

## Dynamics of Nitrate Assimilation in Plants

Jonathan P. Comstock, Ph.D.  
Associate Research Scientist  
Plant Ecophysiology



This year we have focused on a variety of projects using stable isotope techniques to understand the physiological limitations of plants. Natural abundance stable isotope approaches take advantage of the fact that the essential atoms making up biological molecules, such as carbon, nitrogen, hydrogen, and oxygen, all exist in the natural environment in more than one isotopic form. The different isotopes of the same atom have similar chemistry but slightly different weights, and they can be identified using a mass spectrometer. Because biological processes discriminate against the heavier

## Free Radical Detoxification Using *Arabidopsis thaliana*

Patricia L. Conklin, Ph.D.  
Senior Research Associate  
Plant Molecular Biology



Because they grow in an environment that contains oxygen, plants can experience oxidative stress caused by the production of reactive oxygen species. Normal metabolic processes and numerous environmental factors including air pollutants, extreme temperatures, drought, and pathogens can produce this stress. Our long-term goal is to understand the genetic and biochemical mechanisms of free radical detoxification using the plant *Arabidopsis thaliana*. The current major focus of our research is understanding the biosynthesis of the antioxidant L-ascorbic acid (vitamin C).



synthesis of fungal bioactive natural products. We are also studying the roles these compounds play as plant toxins, as well as using fungi as a genetic resource for novel genes and natural products to be exploited for medicinal purposes.

Our research is focused in three main areas. The first is fungal toxins as plant pathogenicity or virulence factors. We are studying the genetic factors used by the fungus *Mycosphaerella fijiensis* to cause black Sigatoka disease, the most destructive leaf disease of bananas and plantains (*Musa* sp.) worldwide. Fungal toxins are predicted to be important in this host-pathogen interaction. We have

collaborated with other BTI researchers to develop a DNA-mediated transformation system for *Mycosphaerella* pathogens of *Musa* sp. This is a first step toward applying molecular approaches to understand the mechanisms used by *M. fijiensis* to cause disease in bananas.

A second project uses molecular techniques to screen fungi for the genetic potential to produce novel natural products. Many fungi encode genes for the synthesis of unknown natural products, some of which may have value for targeting mammalian receptors controlling animal diseases. We are collaborating with international

researchers to identify unique natural product sources from which anti-cancer agents can be developed and are using fungi as a resource for novel anti-cancer activities.

Finally, we are characterizing fungal metabolic pathways of medicinal interest that are also found in plants. Ultimately, we want to understand whether plants and fungi have similar or divergent pathways for the biosynthesis of identical metabolites.

isotopes to varying degrees, measuring the isotopic ratios of living plants and comparing them to those in soil, air, and water can tell us a great deal about the physiology of individual plants or even whole plant communities.

One new project is a study of the dynamics of nitrate assimilation in plants. Nitrogen is the most common nutrient limiting growth in terrestrial ecosystems, and nitrate is the most common form of nitrogen taken up by plants, especially in agricultural contexts. The understanding of carbon metabolism in plants and the environmental physiology of photosynthesis has been advanced

tremendously during the past 15 years by studying variation in the naturally occurring stable carbon isotopes in plant tissues. We are currently testing the application of similar techniques to nutritional studies by evaluating a new theoretical model of how different plant strategies of nitrate assimilation affect the isotopic behavior of nitrogen in the soil-plant system.

On a larger scale, we are also using natural abundance stable isotope techniques to evaluate the impact of pollution on forest ecosystems. We are studying similar forest systems along a gradient of pollutant deposition in national parks of the western United

States. This approach allows us to evaluate the relationships between altered plant physiology and ecosystem cycling of nutrients, water, and carbon. We wish to know the extent to which the physiological characteristics of dominant tree species control ecosystem processes and how anthropogenically altered ecosystem chemistry affects forest health.

Ascorbic acid is a crucial antioxidant and cellular reductant in both plants and animals, as well as an essential component of the human diet. Despite the importance of this small molecule in plant physiology and animal health, only very recently has significant progress been made toward understanding how plants synthesize ascorbic acid. To identify genes involved in this biosynthetic pathway we have isolated *Arabidopsis thaliana* mutants that are deficient in ascorbic acid. One of these mutants was isolated by virtue of its sensitivity to ozone and has led to the isolation of a gene that

encodes an ascorbic acid biosynthetic enzyme. We are currently cloning two additional genes involved in the synthesis of ascorbic acid and are generating transgenic plants that have the potential to overproduce this antioxidant.

In addition to our work on ascorbic acid, we are beginning to analyze additional ozone-sensitive *Arabidopsis* mutants in the hopes that these mutants will reveal additional antioxidant protective mechanisms. Currently, we are cloning the gene *SO22*. Plants harboring a mutation in this gene become "bleached" when

exposed to conditions that are known to generate oxidative stress.

Our research on plant antioxidants has potential for applications in the area of plant environmental stress tolerance.

## Plant Evolutionary Ecology

**Denise E. Costich, Ph.D.**  
Environmental Biology



The environment presents an infinite number of problems that plants must solve to survive and reproduce. Survival alone is insufficient; to be evolutionarily successful a plant must pass its genes to the next generation. Sexually reproducing plants do this through their flowers, fruits, and seeds. The traits that underlie a plant's reproductive biology interact with and are molded by the environment as integral components of pollination and seed dispersal systems. The amazing diversity in flowers and fruits can be attributed to variation in all aspects of the environments in which plants are found and the myriad ways that plants have evolved to adapt to

## Nutrient Genomics of Plant Species

**James J. Giovannoni, Ph.D.**  
Scientist, Plant Molecular Biology, USDA  
Plant, Soil and Nutrition Laboratory



Our lab develops and uses molecular tools for analyzing and elucidating genetic mechanisms that underlie the nutrient quality of plant species used as human foods, with emphasis on fruits and vegetables. We define "nutrient quality" to include analysis of genetic regulation of specific compounds (e.g., vitamins, minerals, phytonutrients) that may affect human health and nutrition in addition to broader-quality traits (e.g., flavor, texture, pigmentation, shelf life) that may influence human consumption of fruit and vegetables.

Specific research activities include analysis of the molecular basis of fruit development and ripening using tomato

## Molecular Pathology and Insect Control

**Robert R. Granados, Ph.D.**  
**Charles E. Palm Scientist**  
Virology



My laboratory has identified novel molecular and biochemical strategies for insect control. These new control methods will reduce our reliance on the use of synthetic chemicals, many of which are known to be detrimental to the environment and human health. By examining chitin-targeting genes present in insect baculoviruses or insect tissues, we have identified genes that express proteins that may alter insect development and eventually result in their death.

My lab has discovered chitin-binding proteins and peptides that can interfere with the normal function of an essential structure of the insect intestinal tract,

them. Factors such as the assemblage of insects that might pollinate or destroy pollen, the proximity of suitable mates, the climate, and the presence of seed dispersers and seed predators, all define the complex nature of selection and adaptation that I, as an evolutionary ecologist, seek to understand.

In a recent study of sexual dimorphism in flower size, Thomas Meagher and I investigated how male and female flowers have evolved in the two subspecies of a wild Mediterranean cucumber plant (*Ecballium elaterium*) that have different breeding systems. One subspecies is monoecious, meaning that all plants bear both male and

female flowers, whereas the other is dioecious, in which plants are either male or female. The patterns revealed indicated that the evolution of unisexuality in *Ecballium* resulted in larger flowers in both sexes, a phenomenon called “reproductive compensation,” but the degree of the size difference between male and female flowers did not change. Female flowers, which bear no reward for pollinating insects, “mimic” male flowers so as to maintain a level of visitation by insects that will result in sufficient pollen transfer and, ultimately, seed set.

My current projects include a growth chamber study of populations of mustard

plants grown under the selection pressure of gradually increasing levels of carbon dioxide, an investigation of whether fragmented populations of wind-pollinated pine trees lose genetic diversity, and a field and laboratory study of the ecology and evolution of heteromorphic fruits that vary in dispersal strategy.

as a model system. Tomato was selected because of the wealth of available information and germplasm resources as well as fruit development and ripening. Relevant mutants (natural, induced, and transgenic) affecting overall ripening or specific to distinct aspects of fruit maturation such as carotenoid metabolism, hormonal and environmental signal transduction systems, abound in tomato. Many molecular and genomics tools are available, resulting from the recent NSF–Plant Genome investment, in addition to activities of geneticists, breeders, and other plant biologists working on tomato fruit development and ripening.

Research activities include (1) use of genomics tools for identifying candidate genes and gene networks that may be related to the regulation of tomato fruit nutrient composition, carotenoid and related flavor volatile accumulation, and primary ripening regulation; (2) employment of molecular, physiological, and biochemical strategies toward characterizing nutrient/ripening traits so that they can best be correlated with gene expression data; (3) implementation of transgenic strategies for testing specific hypotheses related to putative gene and gene-network function.

We also characterize recently isolated genes influencing primary regulatory

control over fruit ripening. The *RIN* (*RIPENING-INHIBITOR*) gene was recently cloned in the laboratory. The corresponding *rin* mutant is widely used in commercial tomato hybrids for increased fruit firmness and shelf life. The isolated gene represents a molecular tool for texture modification and shelf life enhancement in additional fruit species.

the peritrophic membrane. Earlier work in our laboratory had identified this membrane as an essential intestinal mucosal immune system that protects insects from microbial infection and mediates insect digestion. Furthermore, we demonstrated that chitin-binding agents could completely inhibit the formation of this membrane in insect larvae. Treatment with chitin-binding peptides may interfere with the normal physiology of the mid-intestine and make the insect more vulnerable to microbial infection. These insect-specific genes will be engineered and used to develop transgenic plants that may be tolerant to insect attack.

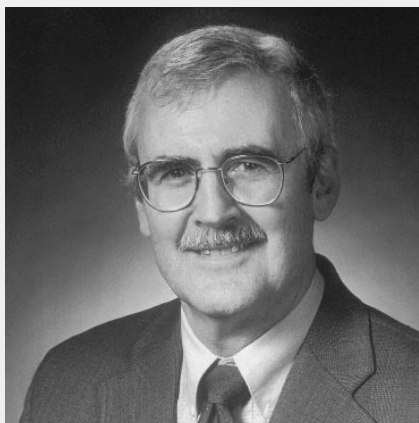
We have also demonstrated that antibodies made against insect-specific proteins found on the peritrophic membrane, when fed to larvae, can affect the permeability of the membrane and alter the microvillar structure of the intestinal cell. This in turn can alter the development of insect larvae and make them more susceptible to microbial infection and possibly other agents. We are studying the use of these antibodies for the development of transgenic plants that express “plantibodies” that would be detrimental to insect pests.



## Search for Genes in Arabidopsis That Confer Tolerance to Toxic Aluminum

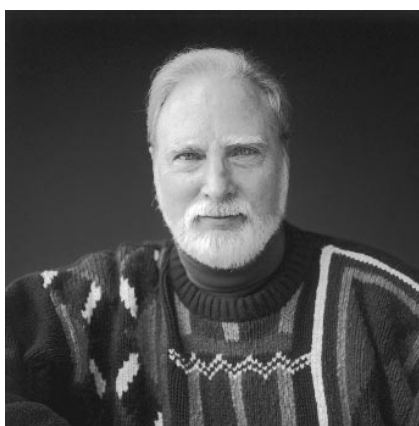
**Stephen H. Howell, Ph.D.**  
Boyce Schulze Downey Scientist  
Plant Molecular Biology

**Leon V. Kochian, Ph.D.**  
Adjunct Scientist, Plant Molecular Biology, USDA  
Plant, Soil and Nutrition Laboratory



## Isolation and Establishment of Stem Cell Lines

**Patrick R. Hughes, Ph.D.**  
Scientist  
Insect Physiology



Insects constitute one of the greatest environmental stresses on plants, causing millions of dollars of damage and loss in food, fiber, and ornamental plants annually. Traditional methods of reducing this stress are not meeting the changing needs and expectations of farmers, foresters, and others involved in plant protection. To open new, creative avenues of addressing this problem, we have begun to isolate and establish stem cell lines from insects. These cells have the unique capability of becoming any of the many types of cells present in the organism while maintaining their own population of undifferentiated cells. When subjected

## Signal Transduction in Plant Disease Resistance

**Daniel F. Klessig, Ph.D.**  
Scientist, Plant Pathology  
President and CEO



The overall goal of our research is to help understand, at molecular and cellular levels, how plants protect themselves against microbial pathogens. We are studying two systems, the response of tobacco to infection by tobacco mosaic virus (TMV) and the interaction of Arabidopsis with turnip crinkle virus (TCV). Our major objective is to identify components of the signal transduction pathways that enable a plant to recognize that it is being attacked and then rapidly mount defenses against the invading pathogen.

Our studies have helped establish that plants and animals, including humans, share an ancient immune

Aluminum (Al) toxicity is one of the most widespread agronomic problems in the world. Al is the third most abundant element in the earth's crust and is toxic to plants when solubilized in acidic soils. Al toxicity in acidic soils affects 50 percent of the potentially arable land in the world. Although the majority of acidic soils are in developing countries, Al toxicity is increasing in developed countries because intensive agricultural practices that use ammonia fertilizers are causing further soil acidification.

Our aim is to isolate genes that confer Al tolerance in Arabidopsis with the long-term goal of better

understanding the mechanisms of Al tolerance in economically important plants. Through the analysis of Al-tolerant mutants, we found evidence of different molecular mechanisms for Al tolerance in Arabidopsis, both of which involve the exclusion of Al from root tips. In one category of mutants, organic acids are released from root tips tying up the toxic form of Al,  $Al^{+3}$ , in the immediate vicinity of the root. In another category, the availability of Al to the root tip is reduced due to root-mediated increases in rhizosphere pH.

Arabidopsis ecotypes differ in their sensitivity to aluminum and we used these differences to identify two

regions of the Arabidopsis genome associated with increased Al tolerance. Microarray analysis was used to scan the Arabidopsis genome for changing patterns of gene expression following exposure to  $Al^{+3}$ , and we found that about 300 out of the 11,500 cDNAs surveyed are induced by greater than 1.5-fold during the Al stress response in roots. We are currently analyzing the induced genes further and are focusing on those involved in signaling or regulating gene expression.

to the right conditions, a population of stem cells can be induced to differentiate into a specific cell type, such as a nerve cell or a muscle cell, providing large, relatively uniform populations for detailed study. These cell lines also could be useful in producing transgenic insects for physiological and behavioral studies. This work has been initiated using the cabbage looper, which is an important agricultural pest, and the monarch butterfly, which is of considerable ecological and behavioral interest.

Establishment of these lines could enable the frontiers of insect physiology to be pushed forward in

many new ways and would provide very valuable tools for the study of genes and gene products essential to the interaction of insects with their host plants. We expect that such lines could open new ways of understanding the physiological underpinnings of insect behavior and pave the way for new, innovative approaches to limiting the detrimental effects of insects on plants important to human welfare.

system. Salicylic acid (SA), a derivative of which is aspirin, is an important defense signal involved in activating plant defenses, including the expression of genes related to pathogen attack. Likely components in the SA-mediated signaling pathway(s) are (1) several antioxidant enzymes such as catalase and ascorbate peroxidase; (2) several SA binding proteins found in the cytoplasm, chloroplasts, and mitochondria; (3) an SA- and tobacco mosaic virus-activated member of the mitogen-activated protein kinase family; (4) a protein, which has homology to an inhibitor of a key transcription factor in innate and acquired immunity in

animals; and (5) members of a family of plant transcription factors involved in activation of SA-inducible genes.

Recently, we demonstrated the involvement of nitric oxide in plant defense against pathogens. Nitric oxide performs key roles in innate immune and inflammatory responses in animals. Several critical players in animal nitric oxide signaling are also operative in plants, including secondary messengers and enzymes.

Thus, it appears that plants respond to their environment, which includes disease-causing microbes, using sophisticated signal perception and transmission systems that often

resemble those employed in animals. Deciphering these defense pathways may therefore not only improve plant health but may also benefit human health.

## Environmental Genetics

Robert J. Kohut, Ph.D.  
Scientist  
Plant Pathology



Genetic diversity in species and populations of native plants is both complex and valuable—complex because it comprises the mechanism by which plants adapt and evolve in response to changes in their environments and valuable because plants are the cornerstone upon which each ecosystem has developed, and their genetic diversity helps preserve ecosystem structure and function. The loss of this genetic resource is significant, wherever and however it occurs. Though habitat destruction is the most significant and obvious means by which genetic diversity is affected, stresses that are subtle, but widespread and persistent, may also be important.

## Assessing Ecosystem Response to Stress Across Temporal and Spatial Scales

John A. Laurence, Ph.D.  
Scientist  
Plant Pathology



How are we to know, based on studies of basic plant processes conducted in the laboratory, how plants will grow in a natural environment, under varying weather conditions, in competition with their neighbors, under attack by pests and pathogens, and in the chemical milieu that is our atmosphere? I believe an answer to this question is key to providing sufficient food, fiber, and water to a rapidly expanding human population.

My research addresses issues of scale, from individual plants to communities, forest stands, landscapes, and regions. Using studies conducted under controlled environmental conditions, in

## Plants and Their Interactions with Pathogens in the Environment

Gregory B. Martin, Ph.D.  
Scientist  
Plant Molecular Biology



The long-term goal of our research is to understand how plants recognize specific disease-causing organisms and activate their defense responses to inhibit pathogen growth and minimize disease symptoms. We focus on the interaction between tomato and the causative agent of bacterial speck disease, *Pseudomonas syringae* pv. *tomato*. However, we also rely on other plant species (e.g., potato, tobacco, and Arabidopsis) to investigate the universality of specific defense mechanisms.

Our research uses many experimental approaches, including molecular



My research investigates the effects that changes in atmospheric ozone or carbon dioxide have on the genetic diversity of plant populations. The ability of ozone to act as a selection pressure on plant populations has been demonstrated in research with *Plantago major* in England where after several years of exposure to increasing levels of ozone, wild populations exhibited increased resistance to ozone and reduced genetic diversity. Whether the genetic diversity of native species in the United States is being similarly affected is unknown but is likely to be taking place. Similar selective effects on genetic diversity may also be

occurring as a result of exposure to gradually increasing levels of atmospheric carbon dioxide. To explore this possibility, my current research uses controlled exposures and a model plant system to examine the effects of escalating levels of carbon dioxide on the phenotypic, physiological, and genetic properties of plant populations over several generations of exposure.

The scope and long-term significance of the impacts of air quality on the genetic diversity of wild plants are not known. However, reductions in genetic diversity resulting from selection owing to changes in air quality may have important consequences if they alter

the ability of plant populations to cope with stresses from insects, diseases, and climate change.

mesocosms, in forest stands, and with computer models, I try to understand how trees interact with their environment over long time spans as they provide ecosystem services such as clean air, abundant water, wildlife habitat, lumber, fiber, food, and recreation.

I attempt to identify the basic mechanisms that operate at each scale—individual, community, and stand—that lead to success for the ecosystem, landscape, and region. Once these mechanisms are identified and understood, probabilistic models of ecosystem function under stress will facilitate the assessment of risk and the

subsequent development of environmental policy and regulation.

E. C. Stakman said more than five decades ago that “plant pathogens are shifty enemies.” To understand how communities of plants function in the natural world—and it is essential to understand that—we must work across scales, applying and testing what we learn in the lab to fields and forests where our food, water, and air come from. That is what I try to do.

biology, cellular biology, microbiology, protein biochemistry, and genetics. We study plant disease resistance by subdividing the process into four stages: delivery of “effector” proteins from the pathogen; recognition events involving pathogen effector proteins and plant target proteins; plant signal transduction; and plant defense responses.

In related work we are using genomics approaches to identify and study new genes that play a role in disease resistance. In collaboration with researchers at Cornell, USDA, and The Institute for Genomics Research (TIGR), we are developing a large database of

expressed sequence tags (ESTs) from tomato. Ultimately, more than 150,000 ESTs will be developed as a result of this collaboration. The sequenced cDNAs and the EST database are being used to examine genome-wide gene expression changes that occur in tomato leaves being attacked by various pathogens. We use several different experimental approaches to investigate this problem, including cDNA subtraction, cDNA microarray technology, serial analysis of gene expression (SAGE), and bioinformatics. This work also encompasses a large effort to develop and use “functional

genomics” approaches to examine the role(s) of newly discovered genes.

Toward this goal we are optimizing the use of potato virus X for gene silencing, an *Agrobacterium* transient assay, mutagenesis, and activation tagging.

Our work on gene expression profiling benefits from the Center for Gene Expression Profiling (CGEP). The center, located at the BTI, is equipped to analyze genome-wide gene expression changes in a variety of organisms, including plants, insects, and microbes.

## **"Bio-Pharming"**

**Hugh S. Mason, Ph.D.**  
Associate Research Scientist  
Plant Molecular Biology

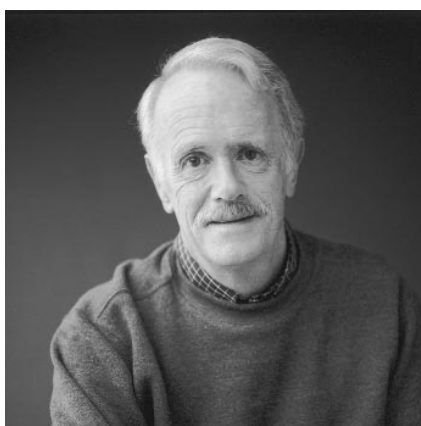


"Bio-pharming" is an exciting area of research that uses living organisms to produce valuable organic molecules. Plants are the natural source of many therapeutic drugs, compounds that are produced to protect the plant against pathogens, herbivores, or environmentally stressful conditions. Plants can also be used to produce recombinant proteins using transgenic technologies wedded with the molecular and cellular biology of plants.

My research focuses on protein expression systems for plants, with special emphasis on vaccine antigens. Subunit vaccines are proteins derived from pathogenic bacteria or viruses,

## **Plant-Insect Associations**

**J. Alan A. Renwick, Ph.D.**  
Scientist  
Chemical Ecology



Attack by insects is one of the most serious stresses encountered by plants in their natural environments. Although most plants are chemically defended in some way, many insects have adapted to these natural defenses and may actually use them for their own benefit. Our research has focused on the chemistry responsible for the close associations that occur between specialist insects and particular plants. We have found that several crucifer specialists depend on the taste of characteristic compounds at the leaf surface to recognize suitable food. However, some members of the crucifer family are avoided because of negative

## **Responses of Plant Genes to Environmental Signals**

**David B. Stern, Ph.D.**  
Scientist  
Plant Molecular Biology



One of the principal environmental signals that plants react to is the quality and quantity of light. Since green plants use photosynthesis to fix carbon dioxide into sugars and carbohydrates, they have designed sophisticated light-dependent regulatory pathways. Our laboratory studies the responses of plant genes to environmental signals, including light. We focus especially on genes that encode proteins destined for the chloroplast, a subcellular compartment where carbon is fixed and oxygen is produced, and for mitochondria, which produce chemical energy through a light-independent pathway.

and they can stimulate immune responses in host animals to protect against infectious disease. Because these vaccines contain only one or a few proteins from the pathogen, they are much safer than live or killed whole-cell vaccines, which can frequently cause side reactions or even the disease itself. One goal is to use plants as “edible vaccines,” which could provide less expensive and more convenient orally delivered immunization. Working with clinical collaborators, we have tested three edible plant vaccines in humans, including hepatitis B surface antigen (HBsAg), with very promising results.

Expression of foreign proteins in plants often requires substantial “engineering” of the DNA to obtain optimal levels of expression. The DNA coding sequence must be optimized to provide efficient transcription to produce stable mRNA and then to decode the mRNA for synthesis of the protein. Gene regulatory elements must be tailored to control expression, especially when strong constitutive expression has growth-stunting effects. Further, targeting the protein to the appropriate cellular compartment allows the most abundant accumulation and yield. My goal is to develop an understanding of the processes that

control protein expression and accumulation in plants, which can ultimately be applied to production of recombinant proteins. We are also experimenting with a plant virus-based gene amplification system that can enhance expression of foreign proteins in a tightly regulated way.

chemical messages perceived by the insect taste receptors. In particular, introduced plants are well defended against native insect species, and many of the novel chemicals that help to explain the invasive nature of these plants have now been identified.

Studies of two insects that specialize on solanaceous plants have revealed the fact that these insects use different chemistry for recognition of the same host. The tobacco hornworm is stimulated to feed by a steroidal glycoside, and becomes dependent on this compound for continued feeding. The Colorado potato beetle, however, tunes in on one or more non-steroidal

glycosides for host recognition. Efforts are now under way to determine whether the same compounds are responsible for feeding by these insects on a wide range of solanaceous plants, which include potato, tomato, and eggplant.

Taking advantage of the new resources generated through the Cornell Genomics Initiative and national programs, we have two genomics projects that focus on the chloroplasts of maize and the green alga *Chlamydomonas reinhardtii*, respectively. The maize project is a collaborative genetic screen for nuclear mutants affecting chloroplast RNA metabolism. The *Chlamydomonas* project has identified new genes in the chloroplast and has also included a broad screen for other environmental responses of the chloroplast, for example, to nutrient deprivation and temperature stress. Additional projects are focused more closely on response

mechanisms at the level of individual components that regulate chloroplast protein synthesis or RNA processing.

Mitochondrial work focuses on a nucleus-encoded RNA polymerase that is being studied both biochemically and through genetics. Maize mutants lacking this polymerase show a complex developmental phenotype, suggesting that mitochondria also respond to the environment. The mutants are able to develop embryos but are unable to survive as seedlings in spite of having normal chloroplasts. Details of these defects are currently being elucidated.



## Tree Root Function

**Mary A. Topa, Ph.D.**  
Associate Scientist  
Plant Physiology



Interactions between roots and the soil environment are easily the most complex and least understood interactions in plants. Questions concerning various global climate change scenarios have increased our interest in elucidating the role below-ground ecosystems play in carbon sequestration and carbon-nutrient cycling. Fine root systems play a critical role in forest ecosystem function; more than 50 percent of annual carbon fixed is allocated below ground. Yet fine root system demography and function is little understood because of its complex biodiversity and dynamic nature and the technological difficulty in monitoring in

## Plant Biotechnology

**Joyce M. Van Eck, Ph.D.**  
Senior Research Associate  
Plant Biotechnology



Plant biotechnology has revolutionized the area of crop improvement because it provides researchers with the tools to identify and isolate genes of interest, allowing for more precise genetic manipulation of important crop traits. The development of biotechnological techniques has made it possible to design and introduce gene constructs into plant cells with the subsequent recovery of plants that express various genes of interest. We have employed and refined these techniques to introduce genes into three major food crops: potato, tomato, and banana. The various genes we introduce have the potential to strengthen a plant's

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situ root function in an opaque soil medium.

The focus of my research is to better understand how root systems respond to natural and anthropogenic stresses in their naturally complex and dynamic soil environment and how these responses may account for the wide variation in aboveground growth among tree populations. Because root demography (e.g., root births, deaths, growth, colonization by symbiotic fungi) and function are integrally linked, it seems reasonable that faster-growing trees might have more efficient rooting strategies than slower-growing ones (i.e., a lower carbon cost per

nutrient return), but this may be true only in optimal soil environments.

In a current study examining why some families of loblolly pine grow faster under specific environmental conditions than others, we are using minirhizotron and stable isotope technologies to determine the carbon cost per nutrient or water return of the various root systems and to determine which strategy is most efficient under optimal and stressed soil environments.

resistance to disease and insects, improve fruit characteristics, enhance nutritional quality, and induce plant cells to produce macromolecular (protein) pharmaceuticals.

Using a major disease of potato as an example, collaborative research activities are in place among BTI, Cornell, and industry scientists to use plant biotechnology to develop potato lines that are resistant to late blight, the disease whose causal agent, the fungus *Phytophthora infestans*, brought about the Irish potato famine in the 1840s. Despite efforts to develop resistant varieties through conventional plant breeding, the disease is still

prevalent throughout the world. Control of the disease is primarily achieved through numerous applications of costly fungicides. In addition to the negative effects of the fungicides on the environment, the prohibitive cost of the most effective fungicides does not allow for their use in developing countries.

Our goal is to develop potato lines that contain an inherent resistance to *P. infestans* by exploiting the biodiversity of wild ancestors to search for new genes. Once identified, we will use the tools of plant biotechnology to transfer these genes into lines of cultivated potatoes and evaluate them for their level of resistance against the disease.

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# Plant Modeling

David A. Weinstein, Ph.D.  
Associate Research Scientist  
Plant Ecology



The Plant Modeling Group is conducting several investigations of the effects of pollutants on ecosystems. We are exploring the problem of why trees in the Southern Appalachian Mountains are being damaged and are dying at accelerated rates. Increased prosperity in the United States has raised the exposure of natural ecosystems to toxic air pollutants. Because change in forests normally occurs at a very slow pace, damaging effects of pollutants can be detected only by using advanced computing techniques to simulate forest growth over long time periods. Using sophisticated computer models, we are simulating forest growth in

# Molecular "Pharming" in Space

H. Alan Wood, Ph.D.  
Scientist  
Insect Virology



Space biology research has shown that many biological processes can be altered under conditions of microgravity. My laboratory has been studying the changes in the processing of sugars attached to glycoproteins produced in insect cells growing in NASA-developed, simulated microgravity bioreactors. We know from recent discoveries that sugar molecules attached to proteins play a central role in determining both the physical and biological properties of glycoproteins, and the processing of sugar structures on glycoproteins can be altered by many environmental factors. Under conditions of microgravity, my lab has

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thirteen regions of the Southern Appalachians, which currently receive high levels of ozone. We are predicting the extent to which car exhaust and smokestack emissions must be controlled to eliminate the damaging effects of ozone on these forests.

Nitrogen oxides, produced by car exhaust and industrial activity and deposited in dust and rainfall, are also affecting forests throughout the United States. While nitrogen is needed for plant growth, it can also be a pollutant when excess quantities enter our drinking water systems. Forests are capable of filtering out most of this nitrogen, preventing it from moving

downstream into reservoirs and coastal ecosystems. However, recent evidence suggests that some forests may be saturated with nitrogen, which means they will no longer act as good filters. We are developing and using a new spatial modeling tool to follow the flow of nitrogen from polluted air to forests, through the soil, and into streams in an attempt to identify when and where forests may stop functioning as water filters and start leaking nitrogen into rivers and streams.

As forests are increasingly fragmented by human activities, the viability of tree populations is being influenced. The genetic diversity (i.e.,

the variety of genes found in the population) may be reduced in a stand of trees that has been cut into small islands, decreasing the long-term survival of the population. The effect is to foreclose future opportunities for society to find new uses for these genes. We are tracing the movement of genes within the threatened tree population of table mountain pine to identify the size of populations necessary for healthy maintenance of the gene pool of this species.

shown that insect cells are capable of producing human proteins that have the same sugar structures as attached by human cells. Accordingly, it is now possible to use insect expression systems to produce pharmaceutically important human proteins whose properties are identical to glycoproteins produced in human cells. In addition, our research program is being used as a model system to investigate the possible effects of microgravity on glycosylation by astronauts.

The importance of post-translational processing of proteins, such as glycosylation, has recently been emphasized with the results from the

Human Genome Project. Because of the complexity of the human organism, it was estimated that the human genome must code for 125,000 to 150,000 proteins. The discovery that the human genome codes for only about 30,000 proteins means that the same protein can have several functions based on the type of post-translational processing that has occurred and underscores the importance of the highly variable nature of glycosylation.

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Marc D. Andersen, Ph.D. North Dakota State University					
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# National Agricultural Biotechnology Council

The 2000 Annual Meeting of the National Agricultural Biotechnology Council (NABC), organized in conjunction with the University of Gainesville, was held in Orlando, Florida. The topic of the meeting, "The Biobased Economy of the Twenty-First Century: Agriculture Expanding into Health, Energy, Chemicals, and Materials," was timely in that many people believe that movement toward a biobased economy is the most significant opportunity for agriculture in more than a century.

Several national activities in 1999 and 2000, including the Presidential Executive Order for a biobased initiative, the National Research Council Report on Biobased Industrial Products, and the Epcot Millennium Exhibit (a visit to which was a scheduled activity at the 2000 NABC Annual Meeting), evidence increasing enthusiasm for a change to a biobased economy in the United States. The use of renewable resources as raw materials for manufacturing holds potential utility for many industries, including liquid fuels, organic chemicals, polymers, fabrics, and

health-related products. Significant use of biobased resources for energy production would reduce national reliance on fossil fuels, thus affecting national and international security concerns with major implications for access to energy, balance-of-trade issues, jobs, and military expenditure.

The economic, environmental, and societal issues, locally and nationally, that will develop from industrial uses of plant and animal resources were subjects for discussion at the NABC 2000 Annual



photo: Thomas Wright

Meeting. New uses for underused productive land not required for food, feed, and fiber production were also discussed. Related bioethics questions of global food supply and distribution, along with the use of genetically modified crops and animals in the health, materials, chemical, and related fields were debated. Concerns were raised over possible loss of crop diversity through contract farming and the equitable treatment of farmers in their interaction with biobased companies.

NABC developed from a meeting in 1987 at the BTI at which the issues underpinning the introduction of genetically altered crops were discussed. Following that successful experience in organizing an open forum to address difficult issues, Ralph W. F. Hardy, then president and CEO of the BTI, invited Cornell University, Iowa State University, and the University of California to join the BTI as founding members of NABC. Since then, twelve annual reports have been published, resulting from yearly open-forum meetings that address major issues relating to agricultural biotechnology, including novel products and new partnerships, resource management in challenged environments, gene escape and pest resistance, and world food security and sustainability. These, the 2000 Annual Report, and other recent NABC publications may be accessed at [www.cals.cornell.edu/extension/nabc](http://www.cals.cornell.edu/extension/nabc).

The membership of NABC continues to grow, comprising thirty-three institutions in Canada and the United States and three affiliate members.

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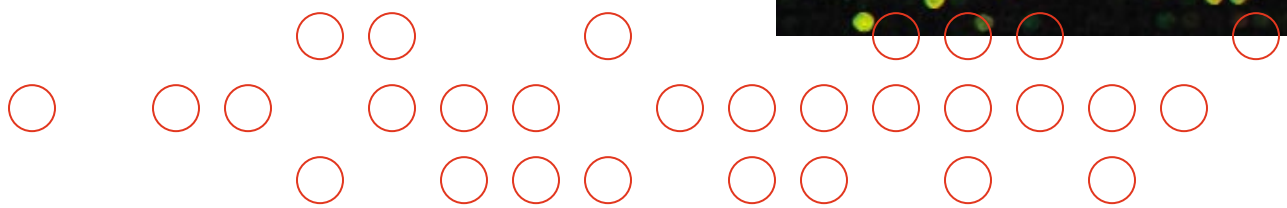
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### On the cover

Tomatoes are an important research tool at the BTI. Greg Martin and Jim Giovannoni (along with Cornell colleague Steve Tanksley) work on fruit development and ripening, disease resistance, nutritional genomics, and a tomato genome project. Greg studies disease resistance and, with other BTI colleagues, collaborated with the Cornell Plantations to create a public Tomato Biodiversity Garden, displaying a large number of exotic tomato varieties and several wild tomato species.



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