Breaking the Biological Barriers to Cellulosic Ethanol: A Joint Research Agenda

A Research Roadmap Resulting from the Biomass to Biofuels Workshop Sponsored by the U.S. Department of Energy

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Appendix C. Workshop Participant Biosketches

Eric Ackerman

Eric Ackerman is a molecular biologist at Pacific Northwest National Laboratory, having earned a doctorate in biophysics from the University of Chicago in 1979. He was a Helen Hay Whitney Fellow at the Laboratory of Molecular Biology in Cambridge, England, for 3 years and then a staff scientist at NIH National Institute of Diabetes and Digestive and Kidney Diseases until 1996. He has been involved in developmental biology projects with *Xenopus laevis*, the methods by which toxins kill cells, mechanisms of nucleases, biochemistry of nucleotide excision DNA repair, and an extremely sensitive and quantitative assay to measure radiation effects on multiple kinds of DNA repair using as few as 3000 cells and 0.1-ng DNA.

Most relevant for the Biomass to Biofuels workshop have been Ackerman's studies of novel mechanisms for immobilizing enzymes in functionalized nanoporous materials for enhanced activity and stability. Recently, he began implementing high-throughput, cell-free production of proteins and their characterizations in hopes that this approach might yield optimized, stable protein complexes that could contribute to energy generation. He also was involved in strategic planning for Genomics: GTL production facilities, particularly for the Facility for Production and Characterization of Proteins and Affinity Reagents.

Justin Adams

Justin Adams joined BP PLC in 2003 and currently is director of long-term technology strategy in BP's Office of the Chief Scientist. In this role he helps build and shape the strategic agenda, coordinates all long-term activities across the company to ensure alignment and balance, and oversees specific programs managed by the central technology function.

Before joining BP, Adams was founder and CEO of High Power Lithium, a Swiss company developing next-generation battery materials for hybrid electric vehicles in collaboration with Toyota. He also was an advisor to Konarka Technologies, a Massachusetts-based startup developing next-generation solar cells using conducting polymers and nanostructured materials. He previously worked as a consultant with Arthur D. Little, ultimately leading its Advanced Energy Systems practice in Europe. Arthur D. Little delivers strategic and technoeconomic consulting on emerging energy technologies to many of the world's leading energy majors.

Adams holds joint honors in management and technology from the University of Bath (England) and the University of Richmond (Virginia).

Katherine Armstrong

Katherine Armstrong is global leader for trait genetics and technologies R&D at Dow AgroSciences in Indianapolis, Indiana. She earned her bachelor's degree from the University of Virginia and master's in molecular and population genetics from the University of Georgia. She has been an R&D scientist with Dow for 25 years and has studied plant gene expression at the molecular and cellular levels. Currently she oversees the development of corn traits through product launch. She holds seven U.S. patents in the area of plant gene expression and has written numerous publications. Relevant areas of research include optimization of corn genetics for ethanol extraction from both grain and cellulosic feedstocks.

Rajai H. Atalla

Rajai Atalla received his bachelor's degree from Rensselaer Polytechnic Institute in 1955 and master's and doctorate in chemical engineering and physics from the University of Delaware by 1960; his work focused on spectroscopic studies of flames. During 8 years at Hercules Research Center, he studied phase transitions in semicrystalline polymers and evaluated anomalous spectra of many compounds. He was first to recognize that anomalous proton nuclear magnetic resonance (NMR) spectra of (alkyl phosphito) hydrides of cobalt and iron indicated the occurrence of fluxional molecules. He also developed the first theoretical model for photodegradation of inorganic pigment.

As professor of chemical physics and engineering at the Institute of Paper Chemistry, Atalla pioneered the application of Raman spectroscopy to studies of celluloses. Finding accepted crystal structures inconsistent with Raman spectra, he investigated the ^{13}C solid-state NMR spectra of native celluloses with David VanderHart of the National Institute of Standards and Technology. They determined that all native celluloses are composites of two forms—I_α and I_β (1984). With Umesh Agarwal, using a Raman microprobe, Atalla developed the first direct evidence of lignin orientation in secondary walls (1984).

In 1989, as head of chemistry and pulping research at the U.S. Department of Agriculture (USDA) Forest Service and adjunct professor in chemical and biological engineering at the University of Wisconsin, Madison, Atalla led development of inorganic analogs of lignin peroxidases for use in liquid-effluent–free pulping and bleaching systems. The processes were feasible economically, but the industry's economic condition led to suspension of the program. Freed of administrative responsibilities in 1999 and elevated to senior and pioneering research scientist in 2005, he returned to studies of molecular architecture in plant cell walls, with emphasis on secondary walls and native celluloses.

Atalla has published more than 150 papers, edited a book on cellulose structures, and is a fellow of the International Academy of Wood Science and of the Technical Association of the Pulp and Paper Industry. He received the Anselme Payen Award of the American Chemical Society's Cellulose Division as well as

multiple USDA awards, including the Forest Service Chief's Distinguished Scientist Award.

Ed Bayer

Ed Bayer is a professor in the Department of Biological Chemistry at the Weizmann Institute of Science, Rehovot, Israel. He was awarded a bachelor's degree in liberal arts from the University of Michigan in 1969, a master's in biology from Wayne State University in 1971, and a doctorate in biophysics from the Weizmann Institute of Science in 1976. Since the early 1970s, he has been involved in developing the avidin-biotin system as a general tool in the biological sciences. He was first to use biotinylation procedures for antibodies and other proteins and carbohydrates as well as avidin-conjugation and complexation techniques. The work initially was published in the mid-1970s, and many of the procedures are still in routine use today. He received the Sarstedt Award for his contributions to the avidin-biotin system for biomedical analysis.

Together with Raphael Lamed, Bayer introduced the cellulosome concept in the early 1980s. In 1999, he was organizer and cochair of the first Gordon Research Conference on Cellulases and Cellulosomes, and he served as chairman of the same conference in 2001. In 1994, he proposed the use of "designer cellulosomes" for biomass degradation and waste management and as a general tool in the biological sciences. Since then, he has worked systematically toward the controlled construction of such artificial cellulosomes via self-assembly and has produced a growing repertoire of divergent cellulosomal components for this purpose.

During his career, he has collaborated with groups in the United States, Canada, Holland, Belgium, Germany, Great Britain, France, Spain, Finland, Denmark, Guatemala, and the Republic of Georgia, and he has authored more than 250 articles and reviews in both fields. He coedited Vol. 184 on avidin-biotin technology in the *Methods in Enzymology* series and since 1999 has served as editor of the review journal *Biotechnology Advances*. In 2002, he was elected a fellow of the American Academy of Microbiology. He continues his work in both the avidin-biotin and cellulosome fields, and his interests still focus on protein engineering, nanobiotechnology, and the structural and functional consequences of protein-protein and protein-ligand interactions.

John Brady

John Brady is a professor in the Department of Food Science at Cornell University. He received a bachelor's degree in chemistry from the University of North Carolina, Chapel Hill, in 1975 and a doctorate in chemistry from the State University of New York at Stony Brook in 1980. During much of his graduate study, he was a visiting staff member at Los Alamos National Laboratory in New Mexico. He received his postdoctoral training in chemistry at Harvard University, working with Martin Karplus.

His research primarily involves biopolymer dynamics and hydration and the relationships among structure, conformation, and function in biological systems. Specific examples include the solution behavior of biopolymers, factors that determine secondary and tertiary structure in polymers, enzymatic reaction mechanisms, rational drug design, effects of point mutations in proteins, and the possibility of engineering desirable modifications in the function of wild-type proteins. His work uses techniques of computational theoretical chemistry to model properties of biopolymers and solutions numerically. These techniques, often called molecular mechanics, include computer graphics–based molecular docking, energy minimization and conformational energy calculations, and molecular dynamics simulations.

A principal focus of Brady's research is on carbohydrate structure, dynamics, and hydration. He has contributed to advances in carbohydrate modeling, including the first molecular dynamics simulations on a sugar, the first relaxed conformational energy map for a disaccharide, the first free-energy simulations of sugar energy differences in solution, and the first potential of mean-force or conformational free-energy map for a disaccharide. As an outgrowth of his primary interests in carbohydrates, he is studying carbohydrate interactions with proteins. In a current project, Brady is using molecular mechanics simulations to study the catalytic mechanism and mode of substrate binding in various cellulases, including E2 from *Thermomonospora fusca*, in the hope of designing a more active enzyme that could be produced by site-directed mutagenesis.

Doug Cameron

Doug Cameron received a bachelor's degree in biomedical engineering in 1979 from Duke University and a doctorate in biochemical engineering from MIT in 1986. He serves as director of biotechnology for Cargill Research, with an adjunct professorship in the Department of Chemical and Biological Engineering at the University of Wisconsin, Madison (UWM). From 1986 to 1998, Cameron was a professor in the Department of Chemical Engineering and an affiliate in the Molecular Biology Program at UWM. In 1996 he was a guest professor in the Institute for Biotechnology at the Swiss Federal Institute of Technology in Zurich. From 1979 to 1981, he held the position of biochemical engineer at Advanced Harvesting Systems, a plant biotechnology company funded by International Harvester.

Cameron is a fellow of the American Institute of Medical and Biological Engineering and is on the editorial boards of *Metabolic Engineering* and *Biomacromolecules*. He serves on the Minnesota Governor's Bioscience Council and the board of directors of Minnesota Biotechnology Industry Organization. He is a member of the MIT Biological Engineering visiting

committee and on the managing board of the newly formed Society for Biological Engineering. Cameron also is a consulting professor in the Department of Chemical Engineering at Stanford University.

Clint Chapple

Clint Chapple received his doctorate in chemistry from the University of Guelph in 1989. After doing postdoctoral work with Chris Somerville at Michigan State University, he joined the faculty of Purdue University in the Biochemistry Department. Chapple's research in the area of lignin biosynthesis and plant secondary metabolism, using *Arabidopsis* as a model system, has earned him the title of Purdue University Scholar and a fellowship in the American Academy for the Advancement of Science. Research by the Chapple group helped to change the traditional paradigm of the role of ferulic and sinapic acids in building plant cell walls. Rather than contributing to the production of lignin, the group found that these two acids serve as end products in an essential biochemical pathway for cell-wall construction.

The phenylpropanoid pathway gives rise to a wide array of soluble metabolites in plants. These compounds participate in many plant defense responses and absorb potentially damaging UVB radiation. The pathway also generates the monomers required for lignin biosynthesis—ferulic acid and sinapic acid. Lignin is integrated into the plant secondary cell wall, where it provides structural rigidity to plant tissues and enables tracheary elements to withstand the tension generated during transpiration.

Chapple received the 2001 Agricultural Researcher Award from the Purdue School of Agriculture for his patented work in engineering plants to store and stabilize plastic monomer precursors in vacuoles.

Helena L. Chum

Trained in physical and industrial chemistry, Helena Chum has worked in bioenergy and renewable energy since 1979 at the Solar Energy Research Institute, now National Renewable Energy Laboratory (NREL), and has led R&D branches, divisions, and centers at NREL since 1992. Her general research involves technology development for conversion of biomass and a variety of organic wastes into biofuels, chemicals, electricity, and high-value materials. She has coauthored a book, 85 peer-reviewed publications, and 150 meeting papers. She has presented 100 invited lectures worldwide and jointly holds 18 patents.

Her specific research areas are biomass chemical analyses, standards development, and rapid spectrometric analysis methodologies; biomass and urban and plastic residue conversion to chemicals and biofuels; thermochemical conversion to multiple products; biomass fractionation; electrochemistry applied to biomass and derived compounds; environmental technologies; thermally regenerative electrochemical systems and fuel cells; technology development and government-industry-academia partnerships in R&D; and analyses of U.S. governmental biomass and hydrogen programs and their impact on commercial tools and systems to support recommendations for future programs.

Chum is a fellow of the American Association for the Advancement of Science for integrating industry-academia-government research partnerships in biomass and biobased materials and also of the International Academy of Wood Science for demonstrated leadership of biomass analysis and standards activities worldwide. She received a certificate of appreciation from the U.S. DOE Assistant Secretary of the Office of Energy Efficiency and Renewable Energy (EERE) for contributions and leadership in departmental, presidential, and congressional environmental initiatives, including the National Environmental Technology Strategy, and for dedication to EERE programs (1995).

Mike Cleary

Joseph Michael Cleary is Executive Division Director of Sciences R&D at the San Diego Supercomputer Center (SDSC), University of California, San Diego. He received his bachelor's degree in biology from Stanford University in 1970 and his doctorate in molecular biology from the University of California, Los Angeles, in 1980. At SDSC, he directs groups that support the cyber infrastructure needs of researchers by producing data systems and computational tools to facilitate discoveries in the natural sciences. His responsibilities include the initiation of interdisciplinary research projects for life science programs with biomedical and biology researchers at university, government, and independent research institutions.

Before joining SDSC in 2003, Cleary held biotechnology research and management positions for over 20 years at Merck and Monsanto, where he worked in fermentation and microbial-strain development, with emphasis on biosynthetic pathways for producing commercially valuable bacterial polysaccharides. He is an adjunct professor of biology at San Diego State University and serves as a consultant to several biotechnology businesses on matters related to industrial microbiology.

Frank Collart

Frank Collart is manager of the Robotic Molecular Biology Facility in the Biosciences Division at Argonne National Laboratory and Cloning and Expression group leader of the Midwest Center for Structural Genomics (MCSG). He received his doctorate in medical sciences from the Medical College of Ohio and master's degree in chemistry from Bowling Green State University. He has used cultured cell models to delineate critical signal transduction events involved in differentiation of hematopoietic, melanoma, and breast cell lineages and has over 50 scientific publications and 4 patents.

Collart manages a research program for DOE that focuses on the development of genome-scale methods for cloning and expression of proteins from the genomes of *Shewanella oneidensis* and *Geobacter sulfurreducens.* These organisms have potential for degrading organic pollutants and bioremediating metals. The program uses in vivo and cell-free approaches to address protein classes that represent a challenge for current cellular expression systems but are essential experimental targets for DOE research programs. With colleagues at MCSG, he has developed automated protocols for high-throughput generation and analysis of bacterial expression clones.

Steve Colson

Steve Colson received his bachelor's in chemistry from Utah State University in 1963 and his doctorate from the California Institute of Technology in 1968. He became associate laboratory director of the Fundamental Science Directorate in 2003 when he joined the leadership team at Pacific Northwest National Laboratory. Directorate divisions include Atmospheric Sciences and Global Change, Chemical Sciences, and Biological Sciences.

Colson has published more than 130 papers in peer-reviewed journals and has one patent. Before moving to PNNL, he spent 21 years at Yale University as a professor of chemistry. He research focused on the combination of optical and mass spectrometric methods to address fundamental problems in physical and analytical chemistry. General research interests include high-sensitivity spectroscopy and microscopy, photochemistry, photophysics, molecular dynamics, electronic structures of molecules, radical and molecular ions, process at the molecule-surface interface, and intermolecular interactions in molecular solids.

Before leaving Yale, he built up a strong collaborative team of faculty from the chemistry, physics, and engineering departments and industry. The power and excitement of interdisciplinary, collaborative research led him naturally to join the team created to establish the W. R. Wiley Environmental Molecular Sciences Laboratory, with a focus on the integration of modern physical, biological, and computational sciences.

Michael Cotta

Michael Cotta is research leader for the Fermentation Biotechnology Research Unit (FBT), U.S. Department of Agriculture (USDA) Agricultural Research Service (ARS), National Center for Agricultural Utilization Research, in Peoria, Illinois. FBT conducts a broad-based program of microbial, biochemical, genetic, and engineering research to develop bioproducts and bioprocesses for conversion of agricultural commodities into biofuels and chemicals, enzymes, and polymers.

Cotta obtained his bachelor's and master's degrees in animal science in 1977 and 1979, respectively, from the University of California, Davis, where he worked under the direction of R. L. Baldwin. Upon completion of these studies, he continued his education at the University of Illinois in the laboratories of R. B. Hespell and M. P. Bryant. Cotta earned a doctorate in dairy science in 1985 and joined USDA ARS as a research microbiologist in October 1984. His research interests include microbial ecology of gastrointestinal environments and animal waste–handling systems, ecophysiology of ruminal microorganisms, and microorganism interactions in the bioconversion of complex polysaccharides.

Bruce E. Dale

Bruce Dale is professor of chemical engineering and former chair of the Department of Chemical Engineering and Materials Science at Michigan State University (MSU). He earned his bachelor's degree (summa cum laude) in chemical engineering from the University of Arizona, Tucson, in 1974 and master's degree from the same university in 1976. He then studied under George T. Tsao at Purdue University, receiving his doctorate in 1979. His first academic position was in the Department of Agricultural and Chemical Engineering at Colorado State University, where he rose to professor in 1988. In that same year, he joined Texas A&M University, where he was professor of chemical engineering and of agricultural engineering. He also directed two multimillion-dollar interdisciplinary research centers at Texas A&M: Engineering Biosciences Research Center and the Food Protein Research and Development Center.

In 1996 Dale became professor and chair of the Department of Chemical Engineering at MSU, where he also holds an appointment in the Michigan Agricultural Experiment Station. In 1996 he won the Charles D. Scott Award for contributions to the use of biotechnology to produce fuels and chemical and other industrial products from renewable plant resources. In 2001 he stepped down as department chair to return to full-time research and teaching.

His research and professional interests lie at the intersection of chemical engineering and the life sciences. Specifically, he is interested in the environmentally sustainable conversion of plant matter to industrial products—fuels, chemicals, and materials—while meeting human and animal needs for food and feed. Dale expects to devote the rest of his MSU career to teaching and research aimed at developing such resources while the Hydrocarbon Age is winding down during the current century. His concern with sustainable resources was influenced by growing up in the copper-mining town of Ruth in eastern Nevada—a vibrant small community that became a ghost town when the mine ran out. Dale has distrusted societies that rely on mining natural resources (petroleum, for example) ever since.

He led production of the May 2000 National Research Council report, *Biobased Industrial Products: Research and Commercialization Priorities*. He has authored more than 100 refereed journal papers and is an active consultant to industry and an expert witness. He also holds 13 U.S. and foreign patents.

Brian H. Davison

Brian H. Davison is chief scientist for systems biology and biotechnology at Oak Ridge National Laboratory (ORNL), where for 2 years he was director of the Life Sciences Division. He previously was a distinguished researcher and leader of the Biochemical Engineering Research Group. In his 20 years at ORNL, he has conducted biotechnology research in a variety of areas, including bioconversion of renewable resources (ethanol, organic acids, and solvents); nonaqueous biocatalysis; systems analysis of microbes (cultivation and proteomics); biofiltration of volatile organic compounds; mixed cultures; immobilization of microbes and enzymes; metal biosorption; and extractive fermentations. His research has resulted in more than 80 publications and 6 patents.

Davison received his doctorate in chemical engineering from the California Institute of Technology and his bachelor's in chemical engineering from the University of Rochester. He chaired the 15th to 26th Symposia on Biotechnology for Fuels and Chemicals and served as proceedings editor in *Applied Biochemistry and Biotechnology* from 1994 to 2005. The symposium grew from 150 to 400 attendees during his 12 years as chair. Davison received an R&D 100 Award in 1977 for "Production of Chemicals from Biologically Derived Succinic Acid." He also is an adjunct professor of chemical engineering at the University of Tennessee, Knoxville.

Bill Dean

Bill Dean received his doctorate in biochemistry from Syracuse University. He is vice president of development and process sciences at Danisco Genencor International, Inc.; previously, he held the positions of vice president of technology programs and vice president of manufacturing development. Before joining Genencor, he was in the Research Division of Corning Glass Works, where he worked on enzyme immobilization techniques and bioreactor design and was responsible for overseeing the enzyme subcontract with the National Renewable Energy Laboratory to develop cost-effective biomass cellulases. Currently, he is responsible for grain-processing technology at Genencor.

Tim Donohue

Tim Donohue is professor of bacteriology at the University of Wisconsin, Madison. He earned his doctorate from Pennsylvania State University in 1980. He studies photosynthetic bacteria that convert solar energy into alternative fuels (hydrogen) or remove greenhouse gases and other environmental pollutants. He has used molecular genetic, biochemical, and systems biology techniques to study global signal-transduction pathways, alternative sigma factors, and signals that control expression of well-studied components of the respiratory and photosynthetic electron-transport chains.

Donohue's most recent work includes identification of cellular pathways used by photosynthetic microbes to sense the presence of singlet oxygen and defend themselves from this toxic substance. This knowledge may lead to the ability to fine tune the design of microbial and plant photosynthetic systems to minimize the harmful effects of singlet oxygen and to enhance energy production. Photosynthesis provides >90% of net energy input into the biosphere. Therefore, light-driven processes within photosynthetic organisms have enormous capacity for the production of sustainable, carbon-neutral, solar-powered technologies that reduce the global dependency on fossil fuels.

The long-range goals of Donohue's projects are to identify important metabolic and regulatory activities; obtain a thorough understanding of energy-generating pathways of agricultural, environmental and medical importance; and generate computational models to help design microbial machines with increased capacity to use solar energy, generate renewable sources of energy, remove toxic compounds, or synthesize biodegradable polymers.

Tom Foust

Tom Foust joined the National Renewable Energy Laboratory (NREL) in 2004 as director of biomass research. He has a doctorate from the University of Idaho, master's from Johns Hopkins University, and bachelor's from Pennsylvania State University, all in mechanical engineering. He also is a licensed professional engineer.

In his current role, he guides and directs NREL's research efforts to develop biomass conversion technology via both bioconversion and thermoconversion. This research is focused on developing the necessary science and technology for converting biomass to biofuels in an economical manner and covers the gamut of fundamental to applied science. His particular area of expertise is in complex flow and chemical-reaction modeling as it relates to biomass-conversion processes and in-process separations.

Before joining NREL, Foust spent 7 years with the Idaho National Laboratory where he was the research lead for the biomass feedstocks program. His primary area of research was in complex multiphase flow analysis as it related to physical fractionation of biomass. He has over 20 years of experience in research and research management, specializing in biomass feedstocks and conversion research. He has written more than 15 peer-reviewed publications related to biomass fractionation and technology-development issues.

Jim Fredrickson

Jim Fredrickson obtained a bachelor's in soil science from the University of Wisconsin, Stevens Point, and advanced degrees in soil chemistry and soil microbiology from Washington State University. He is a chief scientist within the Biological Sciences Division at Pacific Northwest National Laboratory, specializing

in microbial ecology and environmental microbiology. With his research focused on subsurface microbiology and biogeochemistry, he has been responsible for laboratory and field research programs investigating the microbial ecology and biogeochemistry of geologically diverse subsurface environments and is recognized nationally and internationally for these studies.

Fredrickson also has served as subprogram coordinator for DOE's Subsurface Science Program from 1991 to present. In this role, he coordinated the technical aspects of DOE's Deep Subsurface Microbiology Subprogram at the national level and assisted the program manager in setting programmatic research directions. This subprogram involved more than 15 projects at universities and national laboratories nationwide and focused on multidisciplinary field-scale research. At the request of DOE, he currently is national coordinator for the *Shewanella* Microbial Cell Project, part of the Genomics:GTL program. He was appointed chief scientist in 2005 to serve as spokesperson to the science community for the GTL program and facilities.

Ramon Gonzalez

Ramon Gonzalez is the William W. Akers Professor in the Department of Chemical and Biomolecular Engineering at Rice University. He holds degrees in chemical engineering from the University of Chile and the Central University of Las Villas, Cuba, and also is a licensed professional engineer. His research addresses such challenging issues in microbial catalysis as understanding and manipulating vitamins and cofactor biosynthesis, anaerobic fermentation of nontraditional carbon sources, simultaneous metabolism of sugars in sugar mixtures, and understanding and modifying respiratory and fermentative systems for synthesis of reduced products. Specific research areas include metabolic engineering and inverse (metabolic) engineering, functional genomics and systems biology, microbial fermentation, molecular modeling, and high-performance liquid chromatography optimization.

Gonzalez uses a wide spectrum of approaches and state-of-the-art techniques typically viewed under such different scientific and engineering disciplines as molecular biology, biochemistry, and chemical engineering. He currently is using transcriptomics and proteomic tools in conjunction with fluxomic tools to elucidate biological function of individual genes at cellular levels. He advocates the systemic method for its integration of mathematical and computational tools and is using this global and integrative approach to understand complex metabolic and regulatory networks in bacterial systems, the basis for understanding similar processes in more complex organisms. The ultimate goal of his research is the design of specific genotypes based on the desired phenotype.

Bonnie Hames

Bonnie Hames leads the biomass chemical characterization teams within the National Bioenergy Center at the National Renewable Energy Laboratory (NREL). She earned a bachelor's degree in chemistry from Regis University and a doctorate in organic chemistry from the University of Denver. Working in the group of Bernard Monties, she also completed a postdoctoral assignment in lignin chemistry at the Centre National de la Recherche Scientifique, Institute National de la Recherche Agronomique, Laboratoire de Chimie Biologique, Thiverval-Grignon-Paris, France.

Her extensive experience in biomass chemistry includes more than 18 years of developing standard wet chemical methods for characterizing biomass feedstock and biomass-derived materials, preparing standard reference materials for quality assurance and quality control, and applying standard methods to fuel and chemical production from biomass. She currently leads the NREL Biomass Program to develop new, rapid, and inexpensive methods for biomass compositional analysis. These methods include advanced tools for chemical characterization of biomass feedstocks and biomass-derived materials based on infrared spectroscopy and advanced multivariate analysis techniques first developed in the Agenda 2020 program sponsored jointly by DOE Office of Industrial Technologies and the forest products industry. In 2000, her program's real-time biomass analysis won an R&D 100 award and was honored by DOE as a Best of Agenda 2020 Project.

Hames also developed patented techniques for biomass fractionation and lignin isolation. She has extensive experience in lignin chemistry including structural characterization, synthesis of lignin model compounds, and development of methods for the selective oxidation of lignin using organ metallic catalysts and biomimetic systems. She holds 3 U.S. patents, has authored 3 book chapters and more than 25 papers in peer-reviewed journals, and has made more than 80 presentations at technical meetings. She currently chairs the American Society for Testing and Materials committee E48 on standards for biotechnology and subcommittee E48.05 on standards of biomass conversion.

Maria Harrison

Maria Harrison earned her bachelor's degree with honors in microbiology from the University of Newcastle Upon Tyne, England, and her doctorate in 1987 from the Institute of Science and Technology, University of Manchester. She conducted postdoctoral research at the Samuel Roberts Noble Foundation in Ardmore, Oklahoma, under the direction of R. A. Dixon. She has served as an adjunct professor at Oklahoma State University and Texas A&M University; in 2003, she joined the staff at the Boyce Thompson Institute for Plant Research, with an adjunct appointment in the Department of Plant Pathology at Cornell University.

Most vascular flowering plants are able to form symbiotic associations with arbuscular mycorrhizal (AM) fungi. These associations develop in the roots, where the fungus colonizes cortical

cells to access carbon supplied by the plant. The fungal contribution to symbiosis includes transfer of mineral nutrients, particularly phosphorus, from the soil to the plant. In many soils, phosphate levels are limiting to plant growth. Consequently, additional phosphate supplied via AM fungi can have a significant impact on plant development, and this symbiosis influences the structure of plant communities in ecosystems worldwide.

The long-term goals of Harrison's research are to understand the mechanisms underlying development of AM symbiosis and phosphate transfer among symbionts. She uses a model legume *Medicago truncatula* and AM fungi *Glomus versiforme*, *G. intraradices,* and *Gigaspora gigantea* for these analyses. Currently, a combination of molecular, cell biology, genetic, and genomic approaches is being used to obtain insights into symbiosis development, communication among plant and fungal symbionts, and symbiotic phosphate transport.

Susan Hennessey

In almost 20 years at DuPont, Susan Hennessey has applied her expertise as a chemical engineer to a number of improved chemical production processes. Her team of scientists has used immobilized bacterial cells and other encapsulation techniques to increase enzyme durability and concentration for continuous production. Her work on the introduction of the herbicide Milestone for crop protection earned her team the 2002 Industrial Innovation Award from the Mid-Atlantic Region of the American Chemical Society. Other work combining the synergy of biology with new chemical synthesis technologies continues to result in new high-value products using environmentally preferred processes.

Mike Himmel

During his 23-year term at DOE's National Renewable Energy Laboratory (NREL, formerly SERI) in Golden, Colorado, Mike Himmel has worked to support many technical aspects of DOE's Biomass Program. More recently, he has been responsible for establishing the facilities and staff necessary to pursue projects in protein engineering, specifically cellulases. Today, he manages the award-winning Enzyme Technology Team and the major industrial and academic subcontracts that support this work. The team has assembled world-class protein purification and characterization facilities at NREL, with special emphasis on robotic systems for screening libraries derived from directed evolution technology. Himmel has contributed 300 peer-reviewed papers and meeting abstracts, 4 books, and 16 patents to the literature. He also chaired or cochaired 15 international meetings in the field of biochemistry and biotechnology, including the 2003 Gordon Research Conference on Cellulases and Cellulosomes.

Maurice Hladik

Maurice Hladik is director of marketing for Iogen Corporation, which specializes in developing, manufacturing, and marketing enzymes to modify and improve the processing of natural fibers within the textile, animal-feed, and pulp and paper industries. One of Iogen's major activities is research on cellulosic ethanol. Hladik has extensive international business experience, particularly in the United States, Germany, and the United Kingdom as well as several Asian countries including China (also Hong Kong), South Korea, and Thailand. A particular strength is his ability to locate business contacts and commercial intelligence in a foreign setting.

Before joining Iogen, from 1978 to 1998 he served in the Canadian Foreign Service. His assignments included senior Canadian trade officer posted to Bangkok (3 years), Hong Kong (3 years), Beijing (1 year), Seoul (2 years), and Munich as consul general (3 years); and director general of the Grain Marketing Bureau at Agriculture Canada. In this position, Hladik was chief advisor to the Canadian government on international grain policy and marketing issues. He also served the Canadian International Development Agency as director for Asia, Industrial Cooperation Division.

Lonnie Ingram

Lonnie Ingram is a distinguished professor of microbiology and director of the Florida Center for Renewable Chemicals and Fuels at the University of Florida. Elected to the National Academy of Sciences in 2001, Ingram and his coworkers were the first in the world to develop genetically engineered *E. coli* bacteria capable of converting all sugar types found in plant cell walls into fuel ethanol. Ingram's organism produces a high yield of ethanol from such biomass as sugarcane residues, rice hulls, forestry and wood wastes, and other organic materials.

Ingram's breakthrough bioconversion technology was selected to become Landmark Patent No. 5,000,000 by the U.S. Department of Commerce. More than 30 additional patents are pending or have been issued for this technology, which is being commercialized with assistance from the U.S. Department of Energy. BC International Corp., based in Dedham, Mass., holds exclusive rights to use and license the engineered bacteria, dubbed "K011" by Ingram. In 1993, Ingram received a U.S. Department of Agriculture Distinguished Service Award for his breakthrough research. The agency's highest honor, the award recognized his outstanding contributions to research and the consumer.

Jay Keasling

Jay Keasling earned a bachelor's degree in chemistry and biology in 1986 from the University of Nebraska, Lincoln, and a doctorate in chemical engineering from the University of Michigan in1991. He is professor of chemical engineering and bioengineering at the University of California, Berkeley. He also serves as director of the Physical Biosciences Division and heads the new Synthetic Biology Department at Lawrence Berkeley National Laboratory. The idea behind this department is to design and construct novel organisms and biologically inspired

systems to solve problems unsolvable by natural biological systems and also provide new information about living cells. Keasling's many honors include election as fellow of the American Institute of Medical and Biological Engineering and recipient of the AIChE Award for Chemical Engineering Excellence in Academic Teaching. He also is founder of two companies, Amyris Biotechnologies and Codon Devices, which have grown from discoveries at his laboratory.

Keasling and collaborators were awarded a Gates Foundation grant that will seek to create in the laboratory an inexpensive antimalarial drug, artemisinin. This drug could be sold for one-tenth of today's price and compete with the formerly front-line antimalarial now confronted by disease-resistant strains around the world. Keasling and his team at Berkeley already have worked out methods for extracting the genes responsible for making artemisinin and have transplanted them into a harmless strain of *E. coli*.

Research in the Keasling laboratory focuses on the metabolic engineering of microorganisms for degradation of environmental contaminants or for environmentally friendly synthesis. To that end, he has developed a number of new genetic and mathematical tools to allow more precise and reproducible control of metabolism. These tools are being used in such applications as synthesis of terpene drugs and biodegradable polymers, accumulation of phosphate and heavy metals, degradation of chlorinated and aromatic hydrocarbons, biodesulfurization of fossil fuels, and complete mineralization of organophosphate nerve agents and pesticides. Genomics, proteomics, and metabolomics are being employed to investigate effects of these changes on cellular physiology and to optimize cellular redesign.

Ken Keegstra

Ken Keegstra is director of the Plant Research Laboratory and a University Distinguished Professor in the departments of Biochemistry and Plant Biology at Michigan State University (MSU). He received his doctorate in chemistry at the University of Colorado, where he investigated the structure of plant cell-wall components and their interactions within the wall. For more than 20 years he studied other biological problems, mainly chloroplast biogenesis and the targeting of nuclear-encoded protein into chloroplasts. At the time of his move to MSU in 1993, he reinitiated work on plant cell walls. The major focus of his current research is the biosynthesis of plant cell-wall polysaccharides produced in the Golgi before delivery to the cell wall. The greatest amount of effort has centered on xyloglucan biosynthesis, but his research group also has investigated the biosynthesis of mannans, glucomannans, and arabinoxylans as well as a few other wall components.

Michael Ladisch

Michael Ladisch is director of the Laboratory of Renewable Resources Engineering and Distinguished Professor of Agricultural and Biological Engineering at Purdue University, with a joint appointment in biomedical engineering and a courtesy appointment in food science. In 1973 he earned his bachelor's degree from Drexel University and in 1974 and 1977, respectively, his master's and doctorate from Purdue University, all in chemical engineering.

He has a broad background in bioscience and bioengineering and has authored a textbook, *Bioseparations Engineering: Principles, Practice and Economics* (Wiley, 2001) and 150 journal and proceedings papers. He has 14 patents (issued and applied for) and has presented over 100 papers. He received the Marvin J. Johnson Award in Biochemical Technology of the American Chemical Society in 2002 and the Food, Pharmaceutical, and Bioengineering Division Award of the American Institute of Chemical Engineers in 2001. He was elected to the National Academy of Engineering in 1999.

Ladisch served as a member of U.S. delegations and advisory panels to Russia, Thailand, China, and Japan to review the status of biotechnology programs. In 1991 and 1992, he chaired the National Research Council's Committee on Bioprocess Engineering, which studied research priorities and policy issues related to commercialization of biotechnology and published the report *Putting Biotechnology to Work: Bioprocess Engineering* (National Academy Press, 1992).

His research addresses fundamental topics in bioprocess engineering as they apply to bioenergy, bioproducts, biorecovery, and bionanotechnology. The research addresses transformation of renewable resources into bioproducts, properties of proteins and living organisms at surfaces, rapid prototyping of microfluidic biosensors, and bioseparations. This work has resulted in new industrial bioenergy processes and systematic approaches and correlations for scaleup of laboratory chromatographic purification techniques to process-scale manufacturing systems; it also has resulted in scaledown of bioseparations and the rapid prototyping of microfluidic biochips for quick detection of pathogenic microorganisms. Ladisch teaches bioseparations, bioprocess engineering, and biotechnology at both the graduate and undergraduate levels.

Lee Lynd

Lee Rybeck Lynd is a professor of engineering and adjunct professor of biological sciences at Dartmouth College and a professor extraordinary of microbiology at the University of Stellenbosch in South Africa. He received a bachelor's degree in biology from Bates College; master's in bacteriology from the University of Wisconsin, Madison; and master's and doctorate from the Thayer School of Engineering.

Lynd leads a research group in biochemical engineering and applied biology relevant to processing cellulosic biomass. His laboratory's research topics are chosen to address a primary technical impediment to realizing a "carbohydrate economy":

Overcoming the recalcitrance of cellulosic materials to biological conversion. Specific topics include, in order of increasing scale, metabolic engineering to improve product yields in thermophilic bacteria, microbial physiology of anaerobic cellulolytic microorganisms, kinetics and reactor design for enzymatic and microbial hydrolysis of cellulosic materials, and conversion of "real-world" cellulosic materials such as waste sludge produced from paper mills. A particular focus of the Lynd group is "consolidated bioprocessing," a widely applicable potential breakthrough in which production of cellulase enzymes, hydrolysis of biomass fiber, and fermentation of resulting sugars are accomplished in one process step by a single microbial community.

Lynd is a recipient of the National Science Foundation's Presidential Young Investigator Award and a two-time recipient of the Charles A. Lindbergh Award for his efforts to promote balance between technological progress and preservation of natural and human environments. Professional activities include service as associate editor for *Biotechnology and Bioengineering*, member of a presidential advisory committee on reducing greenhouse gas emissions from personal vehicles, and organizing committee member for the Annual Symposium on Biotechnology for Fuels and Chemicals. Lynd has authored more than 60 peer-reviewed manuscripts and holds 5 patents.

George Michaels

In May 2004, George Michaels was named associate laboratory director of the newly formed Computational and Information Sciences Directorate at Pacific Northwest National Laboratory (PNNL). This new directorate delivers innovative solutions to address national and global problems by enabling large-scale scientific discoveries through R&D in science-driven computing. He holds a doctorate in biochemistry and molecular biology and a bachelor's degree (1974) in microbiology, all from the University of Florida.

He joined PNNL in April 2003 as director of bioinformatics for the Biomolecular Systems Initiative. He is an internationally recognized pioneer in bioinformatics and in the practical development of biotechnological approaches for discovery. During his career spanning nearly 30 years, he has provided increasingly significant technical and leadership contributions to his field. He holds patents in methods for designing DNA-binding proteins and for morphological reconstruction.

Most recently, Michaels held leadership positions at Monsanto in St. Louis, Missouri, where he designed an integrated expression-profiling program. He also cofounded and served as vice-president and chief scientist of Genome Dynamics, a Maryland biotechnology startup company. While an associate professor at George Mason University in Fairfax, Virginia, he initiated one of the nation's first doctoral programs in bioinformatics and computational biology. He also has served as a special expert to the office of the director of the National Institutes of Health.

Colin Mitchinson

Colin Mitchinson earned his bachelor's degree in biochemistry from the University of Edinburgh and doctorate in biochemistry from the University of Newcastle. He has extensive research experience in the study of structure-function relationships in proteins ranging from (Ca++/Mg+) ATPase of muscle sarcoplasmic reticulum, ribonuclease, and subtilisin. He also has performed protein engineering on starch-processing enzymes and cellulases and was project leader and principal investigator for a multidisciplinary effort to develop a new cellulase. He currently serves as senior staff scientist at Danisco Genencor, where his research focuses on development of new cellulase products for biomass conversion. His publications include reviews on protein folding, substrate binding, and active site characterization using molecular genetic, biochemical, and biophysical techniques. A representative recent publication is M. Sandgren, J. Stahlberg, and C. Mitchinson, "Structural and Biochemical Studies of GH Family 12 Cellulases: Improved Thermal Stability, and Ligand Complexes," *Progress in Biophysics and Molecular Biology* **89**, 246–91 (2005).

Mark Morrison

Mark Morrison is a professor in the Department of Animal Science at Ohio State University and also holds a nonsalaried appointment in the Department of Microbiology. He has a long-standing interest in gastrointestinal microbiology and bacterial physiology. Much of his research has focused on the ecophysiology of plant biomass degradation in herbivores and the molecular biology underpinning cellulose degradation and bacterial adhesion to plant structural polysaccharides. He serves as project leader for the North American Consortium for Genomics of Fibrolytic Bacteria, involving scientists from The Institute for Genomic Research, Cornell, University of Illinois, and University of Guelph. The consortium's activities include sequencing of four rumen bacterial genomes (*Fibrobacter succinogenes*, *Prevotella bryantii*, *Prevotella ruminicola*, and *Ruminococcus albus*) as well as comparative and functional genomic studies with these bacteria.

Art Ragauskas

Art Ragauskas received his doctorate in chemistry from the University of Western Ontario in 1986, with subsequent postdoctoral research at the University of Alberta and Colorado State University. He is a fellow of the International Academy of Wood Science and the Technical Association of the Pulp and Paper Industry (known as TAPPI). His research program at Georgia Institute of Technology is seeking to understand and exploit innovative sustainable lignocellulosic materials and develop new and improved applications for nature's premiere renewable biopolymers including cellulose, hemicellulose, and lignin.

Ragauskas's research is directed toward innovative processes for converting lignocellulosic biomass into innovative biomaterials and biofuels. Achieving this goal requires research in

several fields of study, including lignocellulosic fiber chemistry and physical properties; carbohydrate, lignin, and extractive chemistry; nanobiomaterials; biotechnology; and material and polymer science. These studies are supported by expertise in advanced spectroscopy, imaging, nanotechnology, chemoenzymatic biotechnology, cold plasma, composites, bleaching, and pulping technologies. His research is sponsored by a consortium of industrial partners, Defense Advanced Research Projects Agency, National Science Foundation, U.S. Department of Agriculture, Department of Energy, and Georgia Traditional Industries Program (TIP3).

Ragauskus has been a Luso-American Foundation Teaching Fellow at the Universidade da Beira Interior, Portugal; an invited guest teaching professor at Chalmers University of Technology, Sweden and South China University of Technology; and an invited research professor at Royal Institute of Technology, Stockholm. He has published 185 papers, patents, and conference proceedings. He is an associate editor for the *Journal of Pulp and Paper Science*, Holzforschung, and the *Journal of Chemistry and Technology* and has served on several advisory boards and review panels.

John Ralph

John Ralph received his bachelor's degree with honors in chemistry in 1976 from the University of Canterbury, New Zealand, and his doctorate in chemistry and forestry in 1985 from the University of Wisconsin, Madison (UWM). He is a research chemist at the U.S. Dairy Forage Research Center and a professor in the UWM Department of Forest Ecology and Management.

An organic chemist and nuclear magnetic resonance (NMR) spectroscopist specializing in cell-wall model compound syntheses and monolignol polymerization reactions, Ralph is involved principally in studies aimed at detailing the mechanisms of lignin-polysaccharide cross-linking and their effect on limiting cell-wall degradability. He developed NMR methods for cell-wall structural analysis, including an NMR database of model compounds for lignin and related wall components, as well as methods for analyzing lignin structure and nondegradatively solubilizing the entire cell-wall faction of finely divided plant cell walls. He has additional expertise in synthetic organic chemistry, specifically in the synthesis of cell-wall model compounds, lignin oligomers, enzyme precursors, and products.

Simo Sarkanen

Simo Sarkanen is a professor in lignin chemistry and biochemistry at the Department of Biobased Products, University of Minnesota. He received his undergraduate training at King's College, Cambridge (England), and was awarded a doctorate in chemistry from the University of Washington, Seattle. His first publications were in theoretical (computational) chemistry, but his doctoral dissertation was in bioorganic chemistry (enzyme kinetics). At the postdoctoral level in the Department of Chemical Engineering at the University of Washington, he embarked on a journey into various controversial aspects of lignin chemistry. Currently, his research interests range from lignin biosynthesis and biodegradation to new formulations for lignin-based thermoplastics.

Most lignin chemists and biochemists have thought that configurations of lignin macromolecules are random (or combinatorial), but Sarkanen's group is trying to develop an explicit working hypothesis for replicating specific lignin primary structures during lignin biosynthesis. The first step in lignin biodegradation generally has been considered under the control of lignin peroxidase, manganese-dependent peroxidase, or laccase-mediator systems. Sakanen and his coworkers actively promote the view that a completely different kind of lignin depolymerase may be responsible for cleaving lignin macromolecules in vivo. Finally, they have produced the first series of thermoplastics with promising mechanical properties composed predominantly or entirely (85 to 100%) of simple lignin derivatives. Previous work in the field typically had encountered incorporation limits of 25 to 40% for lignins in potentially useful polymeric materials.

Christophe Schilling

Christophe Schilling is a cofounder of Genomatica, Inc. He received his doctoral degree in bioengineering under Bernhard Palsson at the University of California, San Diego, where he was a Powell Foundation and Whitaker Foundation Fellow. He also holds a bachelor's degree in bomedical engineering from Duke University, where he was a Howard Hughes Undergraduate Research Fellow.

As president and chief scientific officer of Genomatica, he currently directs all the company's business and scientific efforts toward applying advanced modeling and simulation technologies to a number of metabolism-driven products. This includes overseeing development of Genomatica's integrated computation and experimental platform to drive the metabolic engineering of microbes to support next-generation bioprocesses being developed by the company's industrial partners.

He is coauthor of numerous scientific articles in systems biology and metabolic modeling, and he is an inventor on a number of patent filings surrounding Genomatica's core technologies. He was featured in the February 2001 edition of *Genome Technology* as one of 16 "up and comers" who have the talent and drive to make great strides in science, technology, and business. In 2003 he was named one of the top 100 young innovators under 35 whose innovative work in technology will have a profound impact on the world, as selected by MIT's *Technology Review* magazine.

John Shanklin

John Shanklin is a senior biochemist in the Biology Department at Brookhaven National Laboratory and an adjunct professor in the Biochemistry Department at the State University of New

York at Stony Brook. He received his bachelor's degree in physiology from the University of Lancaster, United Kingdom, in 1981 and his master's in forestry from the University of Wisconsin, Madison (UWM), in 1984. He was awarded a doctorate in horticulture from UMW in 1988, working on the ubiquitin system.

Shanklin's current interests focus on plant lipid biochemistry and developing plant oils as renewable industrial feedstocks. Specifically he studies structure and function in lipid modification enzymes. This class of enzymes performs high-energy chemistry on a wide variety of substrates with various chemical outcomes. In addition to studying how specific fatty acids are synthesized, he also conducts metabolic engineering experiments on how modulations in pathway components affect storage oil accumulation for both usual and unusual fatty acids.

Shanklin is the winner of several awards, including the Office of Energy Research Young Scientist Award, a Presidential Early Career Award, and the Terry Galliard Medal for Plant Lipid Biochemistry. He was chair of the Scientific Program Committee for the National Plant Lipid Cooperative meetings from 2001 to present. He has served on panels for the Department of Energy and the National Science Foundation and is on the Scientific Advisory Board for *Genetic Engineering, Principles and Methods* and *Advances in Plant Biochemistry and Molecular Biology*. He currently is a member of the Council for Energy Biosciences on the Basic Energy Sciences Committee of Visitors (2005).

Sharon Shoemaker

Sharon Shoemaker joined the University of California, Davis (UCD), in 1991 as founder and executive director of the California Institute of Food and Agricultural Research (known as CIFAR). She also is research leader at the UC Forest Products Laboratory and site director of the National Science Foundation–UCD Center for Advanced Processing and Packaging. Shoemaker holds a bachelor's degree in chemistry, master's in food science, and doctorate in biochemistry and nutrition from Virginia Tech. After postdoctoral training in biochemical engineering, she joined Cetus Corporation in Berkeley, California, the first U.S. biotechnology company. After 7 years, she left Cetus to join Genencor, a company more aligned with her interests in applying fermentation and enzymology to problems in food and agriculture.

Shoemaker's industrial experience led to patents on novel yeast strains to convert biomass to ethanol and on novel bacterial strains to produce new forms of cellulose. She also led team efforts to improve enzyme systems for converting biomass to sugars and subsequently fermenting them to chemicals and to characterize and develop ligninase systems for use in the pulp and paper industry. Her research interests focus on cellulose applications in biomass conversion (e.g., rice straw, wood, and mixed waste paper); integration of various unit operations in biomass-conversion processes (membrane filtration and enzymes); and development of new analytical methods for quantifying specific cellulase activities. Shoemaker is active in regional, national, and international task forces, review panels, and programming on new and emerging biobased processing technologies, carbon sequestration, and cellulase R&D.

Yuval Shoham

Yuval Shoham has been head since 2004 of the Department of Biotechnology and Food Engineering at the Israel Institute of Technology (Technion) in Haifa. He received his bachelor's degree in biology from Tel Aviv University in 1980, his master's in microbiology in 1982, and his doctorate in biochemical engineering from MIT in 1987. In 1988 he joined the Technion, where he is director of the Otto Meyerhoff Minerva Center for Biotechnology and holds the Erwin and Rosl Pollak Chair in Biotechnology. He is a fellow of the American Academy of Microbiology.

Shoham's research focuses on the catalytic mechanisms and structure-function relationships of industrial enzymes, especially glycoside hydrolases, and on gene regulation of the hemicellulolytic system in *Geobacillus stearothermophilus* and cellulosome-related genes in *Clostridium thermocellum*. He has been involved in several industrial projects, including the development of a large-scale process for bleaching paper pulp with alkaline thermostable xylanases and an enzymatic process for making complex lipids with novel SN-2 lipases. He has authored more than 120 articles and book chapters and holds several patents.

Lloyd M. Smith

Lloyd M. Smith is John D. MacArthur Professor of Chemistry and director of the Genome Center at the University of Wisconsin, Madison (UWM), where he has been since 1988. He received a bachelor's degree in biochemistry from the University of California, Berkeley, in 1977 and a doctorate in biophysics from Stanford University in 1981. In 1982 he moved to the California Institute of Technology, where he developed the first fluorescence-based automated DNA sequencing instrument.

Smith has been named one of *Science Digest*'s Top 100 Innovators and has received the Presidential Young Investigator Award, Eli Lilly Analytical Chemistry Award, Association of Biomolecular Resource Facilities Award for the development of automated DNA sequencing, and the American Chemical Society Award in Chemical Instrumentation. He has served on the NIH National Human Genome Research Institute Advisory Council and the NIH Human Genome Study Section, has authored more than 165 scientific papers, and is inventor on 20 issued U.S. patents. He is a cofounder of the biotechnology company, Third Wave Technologies, and is a member of the board of directors of GWC Technologies, Inc., and GenTel Biosurfaces,Inc., where he also is chair of the Scientific Advisory Board. His primary area of research is the development of new technologies for analysis and manipulation of biomolecules.

Chris Somerville

Chris Somerville is director of the Carnegie Institution Department of Plant Biology and professor in the Department of Biological Sciences at Stanford University. He has published more than 170 scientific papers and received patents in plant and microbial genetics, genomics, biochemistry, and biotechnology. His current research interests are focused on the characterization of proteins such as cellulose synthase, which is implicated in plant cell-wall synthesis and modification. He is a member of the senior editorial committee of *Science* magazine and of the scientific advisory boards of numerous academic institutions and private foundations in Europe and North America. He is a member of the U.S. National Academy of Sciences, Royal Society of London, and Royal Society of Canada. He has received numerous scientific awards and several honorary degrees. He is chairman of the board of Mendel Biotechnology, a private plant biotechnology company in the San Francisco Bay area.

Gregory Stephanopoulos

Since 1985, Gregory Stephanopoulos has been a professor of chemical engineering at Massachusetts Institute of Technology (MIT). He received his bachelor's degree from the National Technical University of Athens, master's from the University of Florida, and doctorate from the University of Minnesota, all in chemical engineering. Upon finishing his doctorate in 1978, he joined the faculty of the California Institute of Technology, where he served as assistant and associate professor until 1985. He was associate director of the Biotechnology Process Engineering Center between 1990 and 1997 and was appointed Bayer Professor of Chemical Engineering and Biotechnology. He also is the Taplin Professor of Health Sciences and Technology (2001–), instructor of bioengineering at Harvard Medical School (1997–), member of the international faculty of the Technical University of Denmark (2001–), and fellow of the Singapore–MIT Alliance (2000–).

Stephanopoulos's current research focuses on metabolic engineering and its applications to the production of biochemicals and specialty chemicals, the rigorous evaluation of cell physiology using advanced isotopic methods, the metabolism and physiology of mammalian cells with emphasis on obesity and diabetes, and bioinformatics and functional genomics whereby new genomics-based technologies are applied to the elucidation of cell physiology and metabolic engineering. He has coauthored or coedited 5 books and published some 250 papers and 19 patents.

Stephanopoulos currently is editor-in-chief of the journal *Metabolic Engineering* and serves on the editorial boards of seven scientific journals. In 1992 he chaired the Food, Pharmaceutical, and Bioengineering Division of the American Institute of Chemical Engineers (AIChE) and was elected a founding fellow of the American Institute for Medical and Biological Engineering. In 2002 he received the Merck Award in Metabolic Engineering and was elected to the board of directors of AIChE. In 2003, he was elected to the National Academy of Engineering and in 2005 was awarded an honorary doctorate (doctor technices honoris causa) by the Technical University of Denmark.

He has taught a variety of undergraduate and graduate courses in the chemical engineering curricula at California Institute of Technology and MIT. He also has developed a number of new courses, including Metabolic Engineering, Metabolic and Cell Engineering, and, more recently, Bioinformatics. He coauthored the first textbook on metabolic engineering and has taught a number of biotechnology courses in the summer sessions since 1985. He introduced and directed two such courses, Metabolic Engineering (1995–99) and Bioinformatics (2000–).

Bruce Stone

Bruce Stone received his bachelor's degree from the University of Melbourne in 1948 after majoring in chemistry and biochemistry. In 1951 he was seconded for training in mycology to the Commonwealth Mycological Institute, Kew, England. In 1952 he commenced doctoral studies in the Department of Biochemistry at University College, London. After graduating in 1954, he held postdoctoral appointments in Ottawa (National Research Council Fellow) and London (Imperial Chemical Industries Fellow). He returned to the Russell Grimwade School of Biochemistry, University of Melbourne, as a lecturer in 1958 and was appointed reader in agricultural biochemistry in 1966. From 1972 until his official retirement in 1995, he served as foundation professor of biochemistry at La Trobe University.

Stone twice held the position of dean of the School of Biological Sciences at La Trobe (1976–78, 1987-91), was president of the Australian Biochemical Society (1988–90), and was chairman of the Royal Australian Chemical Institute, Cereal Chemistry Division (1978–79). He currently is editor-in-chief of the *Journal of Cereal Science* and assistant director of the Australian Academy of Science and Technology's Crawford Fund, an organization supporting international agricultural research.

His major research interest in the chemistry and biochemistry of plant polysaccharides arose during his first appointment through an investigation of cellulose-breakdown enzymology. His specific studies on polysaccharide components of the cell walls of cereals and grasses encompassed their structure, biosynthesis, depolymerization, and their interactions with lignins and proteins. Their outcomes have been applied to the solution of agricultural and horticultural problems, especially in relation to cereal-grain quality and processing behavior and in human and ruminant nutrition. Stone has a special interest in the biology and chemistry of callose and related(1→3)-ß-D-glucans, and, with Adrienne Clarke, published a treatise on the subject in 1993. Currently he is investigating the biology and biosynthesis of a bacterial (1→3)-ß-D-glucan, curdlan.

Bob Tabita

Bob Tabita is professor of microbiology and plant biology and an Ohio Eminent Scholar at Ohio State University. His doctoral work in the late Don Lundgren's laboratory at Syracuse University introduced him to the metabolism and biochemistry of autotrophic bacteria; his postdoctoral research was in Bruce McFadden's group in the Chemistry Department at Washington State University. A key experiment, in which he discovered that growth with a reduced electron donor upregulates Rubisco synthesis, has been the foundation for his entire career with photosynthetic bacteria, enabling studies on the enzymology of Rubisco and other pathway enzymes. His laboratory continues this strong interest in molecular regulation, biochemistry, and enzymology of carbon dioxide assimilation and the control of Rubisco synthesis.

All organisms require CO_2. It is used in many enzyme-catalyzed reactions in processes as important and varied as carbohydrate metabolism, lipid biosynthesis, and production of vital metabolic intermediates for the cell. With the realization that many microorganisms use CO_2 to elicit pathogenesis, CO_2 metabolism and its control are recognized as having great health relevance. Carbon dioxide also may be employed as the sole source of carbon by a large and diverse group of organisms. For this reason, CO_2 fixation is associated with global issues of agricultural productivity, carbon cycling, and industrial productivity. Carbon dioxide also is recognized as the chief greenhouse gas and has been implicated in general warming of the earth's biosphere. For all these reasons, research on various aspects of CO_2 fixation control, biochemistry, and ecology have attracted wide interest. Microbial systems studied in the Tabita laboratory include *R. palustris*, *C. tepidum*, and *R. sphaeroides*.

Steve Thomas

Steve Thomas's research expertise spans work on insect hormones at the University of California, Los Angeles, to plant biotechnology research at the ARCO Plant Cell Research Institute in Dublin, California. Through the National Renewable Energy Laboratory, Thomas was manager for the DOE Office of Fuel Development project entitled, "Production of Cellulases in Tobacco and Potato Plant Bioreactors." He has worked on the Sugar Processing Integration Task, surveying the compositional variability of geographically and genetically diverse corn stover residues to minimize risk associated with commercialization of biomass-conversion technology. He recently joined Ceres, Inc., as a principal scientist.

Jerry Tuskan

Gerald A. Tuskan, a distinguished scientist in Oak Ridge National Laboratory (ORNL) Environmental Sciences Division, holds a bachelor's degree in forest management from Northern Arizona University; a master's in forest genetics from Mississippi State University; and a doctorate in genetics from Texas A&M University. He also is a research professor in the University of Tennessee's departments of Entomology, Plant Pathology, Plant Sciences, and Genome Sciences and Technology where he advises graduate students, interacts with departmental faculty, and provides guest lectures and graduate seminars. Before joining ORNL, he served as associate professor of horticulture and forestry at North Dakota State University and was an instructor in the Forest Science Department at Texas A&M University.

At ORNL, Tuskan is responsible for coordinating the DOE effort to sequence the *Populus* genome. This includes projects with carbon allocation and partitioning in woody plants as a means to enhance bioenergy conversion and carbon sequestration, genome-enabled discovery of carbon sequestration genes in poplar, environmental influences on wood chemistry and density of *Populus* and loblolly pine, formation of an international *Populus* genome consortium, and creation of a *Populus* postsequence science plan. His research helps identify genes associated with cell-wall chemistry, genetic mapping in *Populus*, particularly related to carbon allocation and partitioning, and the use of genomics information to accelerate domestication of *Populus*.

Ed Uberbacher

Ed Uberbacher is lead scientist for computational biology in the Life Sciences Division at Oak Ridge National Laboratory. He received a bachelor's degree from Johns Hopkins University in 1974 and a doctorate in chemistry from the University of Pennsylvania in 1979. He is the codeveloper of GRAIL, the first of many gene-finding programs created during the Human Genome Project. Next-generation algorithms such as Grail-Exp, which can use both EST and complete cDNA data, provide another level to the analysis of draft data.

As a member of the Computational Biology Institute, Uberbacher works within a collaborative environment that combines the expertise of biologists, computer scientists, and mathematicians with high-performance computing to create and provide tools and infrastructure to advance systems and computational biology. He is CEO of Genomix Corporation, a provider of analysis systems, information resources, and partnering opportunities to guide R&D teams through critical steps in pharmaceutical discovery and development. He also serves as a faculty member in computational biology and bioinformatics at the University of Tennessee–ORNL Graduate School of Genome Science and Technology.

Fernando Valle

Fernando Valle is staff scientist for process science at Danisco Genencor International, with expertise in microbial pathway engineering for the biological production of enzymes, therapeutic proteins, peptides, antibiotics, vitamins, amino acids, and organic acids. His significant research accomplishments include the optimization and pathway engineering of an *E. coli* strain

to transform glucose into 1, 3-propanediol, a monomer used in producing polyester fibers.

John Vogel

John Vogel's research program is focused on applying molecular biology to improve herbaceous energy crops. Major projects include using dsRNA-mediated gene silencing to reduce lignin content in switchgrass and studying the model grass *Brachypodium distachyon* to identify genes controlling cell-wall composition. Recent accomplishments include creation of transgenic switchgrass plants with silenced lignin biosynthetic genes, development of an *Agrobacterium*-mediated transformation method for *Brachypodium*, and sequencing of >20,000 *Brachypodium* ESTs.

He is a USDA Agricultural Research Service molecular biologist at the Western Regional Research Center in Albany, California. His experience includes extensive research in plant pathology as both an assistant professor at the University of California, Riverside, and postdoctoral fellow at the Carnegie Institution of Washington in Stanford, California. His graduate work focused on cytokinin and ethylene signaling in *Arabidopsis*.

Ken Vogel

Kenneth Vogel is a research geneticist at the USDA Agricultural Research Service Wheat, Sorghum, and Forage Research Unit in Lincoln, Nebraska. He received his bachelor's and master's degrees from Colorado State University in 1965 and 1967 and a doctorate from the University of Nebraska in 1974.

His responsibilities are in research management and perennial grass breeding and genetics. His specific research interest is to develop improved perennial grasses, switchgrass in particular, for use on marginal lands of the Central Great Plains and midwestern states along with associated management practices. This research involves germplasm evaluation and characterization of native and introduced grasses and basic and applied genetic research in addition to applied breeding work. Since 1990, he has been conducting research to develop switchgrass into a biomass energy crop for these areas.

Nicholas Wheeler

Nicholas Wheeler received an undergraduate degree in forest sciences from the University of Washington in 1973, a master's in forest genetics from Michigan State University in 1974, and a doctorate in plant breeding and genetics from Wisconsin in 1981. He has worked as a tree breeder for the government of British Columbia for 4 yrs, as a scientist in the forest products industry for 22 yrs, and, more recently, as a private consultant in his own business (Molecular Tree Breeding Services).

Wheeler's research includes projects in physiological and quantitative genetics, genecology, and molecular genetics. He currently is an adjunct faculty member in the Department of Forestry and Environmental Resources at North Carolina State University, working on a National Science Foundation grant focused on association genetics in loblolly pine. He also is an affiliate faculty member at Oregon State University Department of Forest Sciences. He most recently completed a project investigating a novel approach to breeding in poplars.

David Wilson

David Wilson is a professor of biochemistry and molecular and cell biology at Cornell University. He received his bachelor's degree from Harvard in 1961 and his doctorate in biochemistry from Stanford Medical School in 1966. He did postdoctoral work at the Department of Biophysics at Johns Hopkins Medical School from 1966 to 1967 before going to Cornell as an assistant professor in 1967. Wilson is a member of the American Society of Biological Chemists, American Society of Microbiologists, and American Association for the Advancement of Science. He also is a member of the Johns Hopkins Society of Scholars and director of the Cornell Institute for Comparative and Environmental Toxicology.

Wilson's laboratory uses a combination of genomics, protein engineering, and molecular biology to study the enzymology of plant cell-wall degradation, with a major focus on cellulases. Enzymes that degrade insoluble substrates have significant differences from most enzymes whose substrates are small soluble molecules. In addition, cellulases are important industrial enzymes and have potential in the production of renewable, nonpolluting fuels and chemicals. His group has been studying the high G-C gram variable soil bacterium *Thermobifida fusca*, a moderate thermophile, for more than 20 years. *T. fusca* is a major microorganism degrading plant cell walls in heated plant wastes such as compost piles. He also is using a genomic approach to compare aerobic and anaerobic organisms to discover novel mechanisms for degrading cellulose.

Research projects involve the biochemistry and chemistry of the cell walls of higher plants, with special reference to cereals and grasses and the structure-function relationships of wall polysaccharides and proteins: chemistry of lignin-carbohydrate and lignin-protein associations in walls of forage plants, with special reference to their impact on ruminant digestion; enzymology of ß-glucan hydrolases–active site chemistry in relation to specificity and to the design of specific hydrolase inhibitors; molecular mechanisms of biosynthesis of ß-glucans in plant cell walls and by bacteria; and development of monoclonal antibodies for the specific detection of cell-wall polysaccharides.