

# Defining and Advancing the Conceptual Basis of Biological Science for the 21st Century

## Committee

### David J. Galas

#### Chair

David Galas is the vice president and chief scientific officer of biological and life sciences at Battelle Memorial Institute and a professor at the Institute for Systems Biology. Prior to joining Battelle, he held a number of key positions including Chancellor, Chief Scientific Officer and Norris Professor of Applied Life Sciences, Keck Graduate Institute of Life Sciences (Claremont, California); President and Chief Scientific Officer of Darwin Molecular and Chiroscience R&D Inc.; Director for Health and Environmental Research, U.S. Department of Energy; Professor of Molecular Biology, University of Southern California; Senior Staff Scientist, Biomedical Division, Lawrence Livermore National Laboratory; and Scientific Adviser to the Defense Science Board. Galas was among the early leaders in the U.S. Human Genome Program and, from 1990 to 1993, he led the DOE component of this project. In recent years, his focus has included the application of a variety of scientific disciplines to addressing challenging biological and medical problems -- including Alzheimer's disease, osteoporosis, and improving diagnostic technologies. Dr. Galas received his PhD in physics from the University of California, Davis-Livermore, and his undergraduate degree in physics from the University of California, Berkeley. He is the recipient of several awards including the Smithsonian Institution-Computer World Pioneer award in 1999. He has served on many federal, university and corporate boards and advisory committees, including a number of NRC committees and the Board on Life Science. He is a lifetime National Associate of the National Academy of Sciences.

## **Carl T. Bergstrom**

### **Member**

Carl T. Bergstrom is an Associate Professor in the Department of Biology at the University of Washington. As an evolutionary biologist, Dr. Bergstrom studies the role of information in biological systems at scales from intracellular control of gene expression to population wide linguistic communication. Working in close collaboration with empirical and experimental researchers, Dr. Bergstrom's group approaches these problem using mathematical models and computer simulations. Dr. Bergstrom's recent projects include contributions to the game theory of communication, models of intracellular information processing, and work on how immune systems avoid subversion by pathogens. In a set of more applied endeavors, Bergstrom uses ecological and evolutionary theory to understand and control emerging infectious diseases, including antibiotic resistant bacteria in hospitals, and novel emerging pathogen such as SARS and avian influenza. A national leader in promoting public education about evolutionary biology, Dr. Bergstrom received his Ph.D. in theoretical population genetics from Stanford University in 1998. After a two year postdoctoral fellowship at Emory University, where he studied the ecology and evolution of infectious diseases, Dr. Bergstrom joined the faculty at the University of Washington in 2001.

## **Vicki L. Chandler**

### **Member**

Vicki Chandler is the Carl E. and Patricia Weiler Endowed Chair for Excellence in Agriculture and Life Sciences, Regents' Professor in the Department of Plant Sciences and Molecular & Cellular Biology and the director of the BIO5 Institute. She received her B.S. from the University of California, Berkeley and her Ph.D. from the University of California, San Francisco. Her research program investigates the regulation of gene expression. The anthocyanin biosynthetic pathway in maize is the focus of their work, as it provides an exceptionally tractable system for genetic, biochemical and molecular approaches. A major emphasis in their research is to investigate how the regulatory genes of this pathway are controlled. Dr. Chandler received the College of Agriculture and Life Sciences Faculty Researchers of the Year Award in 2001 and was elected to the National Academy of Sciences in 2002.

## **Carlos M. del Rio**

### **Member**

Carlos Martinez del Rio is an associate professor in the Department of Zoology and Physiology at the University of Wyoming. He received his B.Sc. from the Universidad Nacional Autonoma de México and his Ph.D. from the University of Florida. He is a functional ecologist who tries hard to establish connections across disciplines. He studies mutualistic interactions like pollination and seed dispersal and approaches research problems from a variety of perspectives. He and members of his laboratory investigate three broad areas: the ecological and evolutionary physiology of nectar and fruit eating animals, stable isotopes as tracers in animal-plant interactions, and the spatial ecology of mistletoes. He is the recipient of the USDA-APHIS best publication award in 1988 and the NSF Young Investigator Award in 1992-1998.

## **Paul G. Falkowski**

### **Member**

Paul G. Falkowski is a professor of biochemistry and biophysics in the Insititute of Marine and Coastal Sciences at Rutgers University. Some of his research interests include biogeochemical cycles, photosynthesis, biological oceanography, molecular biology, biochemistry and biophysics, physiological adaptation, plant physiology, evolution, mathematical modeling, and symbiosis. Dr. Falkowski is also the lead principal investigator in the Environmental Biophysics and Molecular Ecology (EBME) Program. That program focuses on molecular biology and biophysics to address key questions in biological oceanography and marine biology. The EBME program provides a laboratory in the Institute of Marine and Coastal Sciences at Rutgers University that addresses the application of similar techniques to primary production, nitrogen fixation, and other rate determining processes in aquatic as well as terrestrial ecosystems. Dr. Falkowski has received many awards; his most recent include the Board of Trustees Award for Excellence in Research, Rutgers University (2000), Vernadsky Medal, European Geosciences Union (2005), and Board of Governors Professor, Rutgers University (2005). He has also received numerous grants, some from NASA, NSF, DOD, DOE, and the Moore Foundation. Dr. Falkowski received his Ph.D. in Biology at the University of British Columbia.

## **Douglas J. Futuyma**

### **Member**

Douglas Futuyma is a distinguished professor of ecology and evolution at the State University of New York at Stony Brook. He received his M.S. and Ph.D. from the University of Michigan. His research interests in evolution focus primarily on speciation and the evolution of ecological interactions among species. He has been a Guggenheim and a Fulbright Fellow, the President of the Society for the Study of Evolution and the American Society of Naturalists, the editor of *Evolution*, and was elected to the National Academy of Sciences in 2006. He is the author of the successful textbook *Evolutionary Biology*. Most of his work has centered on the population biology of herbivorous insects and the evolution of their affiliation with host plants. Research on several species centered on genotypic differences conferring adaptation to different host plants, and cast light on the evolution of host specificity. Recent work has focused on whether or not constraints on genetic variation are likely to have influenced the phylogenetic history of host associations in a group of leaf beetles, and on the pattern of speciation in this group. Futuyma's students have worked on diverse evolutionary and ecological studies of insect-plant interactions and of speciation in insects.

## **James R. Griesemer**

### **Member**

James Griesemer is a professor and Chair of the Department of Philosophy at the University of California, Davis and a member of the Center for Population Biology, the Science and Technology Studies Program, and of the Konrad Lorenz Institute for Evolution and Cognition Research in Australia. He received his A.B. in genetics from the University of California, Berkeley, and his M.S. in biology and Ph.D. in Conceptual Foundations of Biology from the University of Chicago. His research interests include the history, conceptual foundations, and social organization of genetics, ecology, development and evolutionary biology. He teaches about scientific reasoning and understanding scientific change. He is writing a book titled *Reproduction in the Evolutionary Process*, which provides an alternative to Richard Dawkins' popularization of the "replicator" or "selfish gene." He has also published on topics related to genetics that include reproduction and the reduction of genetics, the case for epigenetic inheritance in evolution, and human nature and the interpretation of genetic information. Dr. Griesemer is the president-elect of the International Society for History, Philosophy and Social Studies of Biology.

## Leroy E. Hood

### Member

Leroy Hood is president of the Institute of Systems Biology. He received his M.D. from John's Hopkins School of Medicine and Ph.D. in Chemistry from the California Institute of Technology. His research has focused on the study of molecular immunology, biotechnology, and genomics. His professional career began at Caltech where he and his colleagues pioneered four instruments—the DNA gene sequencer and synthesizer, and the protein synthesizer and sequencer—which comprise the technological foundation for contemporary molecular biology. In particular, the DNA sequencer has revolutionized genomics by allowing the rapid automated sequencing of DNA, which played a crucial role in contributing to the successful mapping of the human genome during the 1990s. In 1992, Dr. Hood moved to the University of Washington as founder and Chairman of the cross-disciplinary Department of Molecular Biotechnology. In 2000, he co-founded the Institute for Systems Biology in Seattle, Washington to pioneer systems approaches to biology and medicine. Most recently, Dr. Hood's lifelong contributions to biotechnology have earned him the prestigious 2004 Association for Molecular Pathology (AMP) Award for Excellence in Molecular Diagnostics. He was also awarded the 2003 Lemelson—MIT Prize for Innovation and Invention, the 2002 Kyoto Prize in Advanced Technology and the 1987 Lasker Prize for his studies on the mechanism of immune diversity. He has published more than 500 peer-reviewed papers, received 14 patents, has co-authored textbooks in biochemistry, immunology, molecular biology, and genetics, and is a member of the National Academy of Sciences, the American Philosophical Society, the American Association of Arts and Sciences, and the Institute of Medicine. Dr. Hood has also played a role in founding numerous biotechnology companies, including Amgen, Applied Biosystems, Systemix, Darwin and Rosetta.

## David Julius

### Member

David Julius is a Professor in the Department of Cellular & Molecular Pharmacology at the University of California, San Francisco. He is interested in the molecular biology of sensory transduction and neurotransmitter action in the mammalian nervous system. Dr. Julius is a leading neuropharmacologist whose group has cloned and characterized a number of neurotransmitter receptors and ion channels from the mammalian nervous system. These include temperature-activated channels that also serve as receptors for capsaicin, the pungent ingredient of chili peppers, or for menthol. One of his goals is to understand the molecular basis of somatosensation - the process whereby we experience touch and temperature - with an emphasis on identifying molecules that detect noxious (pain-producing) stimuli. He is also interested in understanding how somatosensation is altered in response to tissue or nerve injury. David received his Ph.D. in Biochemistry from the University of California, Berkeley, and his Bachelor's at MIT. He is a member of the National Academy of Sciences.

## **Junhyong Kim**

### **Member**

Junhyong Kim is a professor of biology at the University of Pennsylvania. He received his B.S. from Seoul National University and his Ph.D. from the State University of New York. His current focus is on developing new statistical approaches to analysis of biological information. Current projects include identification of transmembrane proteins from genomic databases, analysis of estimation methods for evolutionary trees, and analysis of gene expression array data. His work includes analyzing the macroevolution and mutational dynamics of the transcriptome in *Drosophila*. He has developed computational tools to study and visualize the timing of transcription in yeast in order to learn about how various transcripts are coordinated to drive the cell cycle. He works on improving the underlying mathematics used for phylogenetic prediction, and how to mine the haphazard phylogenetic information from GenBank. Dr. Kim is a former faculty of Ecology and Evolutionary Biology, Yale University, with a joint appointment in the Department of Statistics, the Department of Molecular, Cellular, and Developmental Biology, and the Biomedical Engineering program. He has 17 years experience in computational biology. He is an Associate Editor for Systematic Biology, Editorial Board of Molecular Development Evolution, and co-Director of National Center for Computational Phylogenetics. He was a recipient of the Sloan Foundation Young Investigator Award.

## **Karla A. Kirkegaard**

### **Member**

Karla Kirkegaard is a professor and chair of the Department of Microbiology and Immunology at Stanford. She received her Ph.D. in Biochemistry from Harvard University, and has been investigating the genetics, biochemistry and cell biology of poliovirus and other positive-strand RNA viruses since her postdoctoral work with David Baltimore from 1983-1986 at the Massachusetts Institute of Technology. Dr. Kirkegaard was a faculty member in the "RNA World" of University of Colorado, Boulder from 1986 to 1996, where she was an assistant investigator of the Howard Hughes Medical Institute, a Searle and a Packard Scholar. Upon moving to Stanford in 1996, her laboratory's interests have included the biochemistry of RNA-dependent RNA polymerases as well as immune evasion mechanisms used by positive-strand RNA viruses.

## Jane Maienschein

### Member

Jane Maienschein is Regents' Professor and Parents Association Professor in the School of Life Sciences and the director of the Center for Biology and Society at the Arizona State University. She received her Ph.D. from Indiana University. Dr. Maienschein specializes in the history and philosophy of biology and the way that biology, bioethics, and biopolicy play out in society. Focusing on research in embryology, genetics, and cytology, she combines detailed analysis of the epistemological standards, theories, laboratory practices and experimental approaches with study of the people, institutions, and changing social, political, and legal context in which science thrives. She enjoys teaching and is committed to public education about biology and its human dimensions. Dr. Maienschein has received numerous faculty and teaching awards, including the 2000 Parents Association Professor of the Year Chair and a Regents' Professorship in 2002.

## Eve Marder

### Member

Eve E. Marder is the Victor and Gwendolyn Beinfeld Professor of Neuroscience in the Biology Department and Volen Center for Complex Systems at Brandeis University. She received her Ph.D. in 1974 from the University of California, San Diego. Dr. Marder has studied the dynamics of small neuronal networks using the crustacean stomatogastric nervous system. Her work was instrumental in demonstrating that neuronal circuits are not "hard-wired" but can be reconfigured by neuromodulatory neurons and substances to produce a variety of outputs. Together with Larry Abbott, her laboratory pioneered the "dynamic clamp." Marder was one of the first experimentalists to forge long-standing collaborations with theorists and has for almost 15 years combined experimental work with insights from modeling and theoretical studies. Her work today focuses on understanding how stability in networks arises despite ongoing channel and receptor turnover and modulation, both in developing and adult animals. Dr. Marder is a Fellow of the American Association for the Advancement of Science, a Fellow of the American Academy of Arts and Sciences, and a trustee of the Grass Foundation. She was the Forbes Lecturer at the MBL in 2000 and the Einer Hille Lecturer at the University of Washington in 2002.

## Joseph H. Nadeau

### Member

Joseph Nadeau received his Ph.D. in population biology from Boston University in 1978. He was a postdoctoral fellow with Jan Klein in the Immunogenetics Department, Max Planck Institute for Biology, Tübingen (1978-1980) and with Eva Eicher at the Jackson Laboratory (1980-1981). He was appointed Associate Staff Scientist (1981-1985), Staff Scientist (1985-1991) and Senior Staff Scientist (1991-1994) at the Jackson Laboratory, and then Professor, Department of Human Genetics, McGill University, and Medical Scientist, Department of Medicine, Montreal General Hospital (1994-1996). He is currently James H. Jewel Professor and Chair of Genetics Department at Case Western Reserve University School of Medicine and Co-Director for the Center for Computational Genomics and Systems Biology. He has over 200 research publications. He was a founding member of the International Mammalian Genome Society and a founding editor of Mammalian Genome. He was founder and director of the Mouse Genome Informatics Project (1989-1994), founder of the Mouse Gene Expression Database Project (1992-1994), founding editor of Systems Biology Reviews, and founder and first director of the Ohio GI Cancer Consortium. He has served on review panels and advisory groups at the National Institutes of Health, the National Science Foundation and the Human Genome Database. He has organized nearly 40 courses, workshops and conferences. He has consulted for GlaxoSmithKline, Pharmacia, Celera Genomics, Exelixis, NineSigma and CellTech Chiroscience, and is on the Scientific Advisory Board of Galileo Genomics.

## Joan Roughgarden

### Member

Joan Roughgarden is a professor in the Department of Biological Sciences where she has taught since 1972. She founded and directed the Earth Systems Program at Stanford, and was awarded for service to undergraduate education. Dr. Roughgarden studied coevolutionary models that combine ecology with population genetics and her current research focuses on the mathematical theory of reproductive social behavior and is applying the cooperative game theory of bargaining and side payments to explain animal social dynamics, especially mating behavior. In addition to a seminal ecology textbook written with Paul R. Ehrlich, Roughgarden published a 2004 challenge to certain tenets of sexual selection titled *Evolution's Rainbow*. Roughgarden received a Bachelor of Science in biology and a Bachelor of Arts in Philosophy from University of Rochester in 1968, and a Ph.D. in biology from Harvard University in 1971. She is the author of 5 books and over 120 articles.



## **Julie A. Theriot**

### **Member**

Julie Theriot is an associate professor of biochemistry and of microbiology and immunology at the Stanford University School of Medicine. She received her Ph.D. from the University of California, San Francisco. Dr. Theriot studies the transformation of chemical energy to mechanical energy in cell movement. Her work focuses on understanding the mechanisms of actin-based movement of the intracytoplasmic pathogenic bacteria *Listeria monocytogenes* and *Shigella flexneri*. She is investigating these systems at the molecular level, to yield insights into the mechanisms of whole-cell actin-based motility, as well as bacterial pathogenesis. Other research interests include establishment and maintenance of bacterial polarity, quantitative videomicroscopy, and image and motion analysis. She was on the National Academies committees on antivirals against smallpox and Bridges to Independence. Honors include a Whitehead Fellowship and a Packard Fellowship for Science and Engineering. Dr. Theriot recently received The School of Medicine Award for Graduate Teaching and was named a 2004 MacArthur Fellow. She served on the NRC Committee on Bridges to Independence: Identifying Opportunities for and Challenges to Fostering the Independence of Young Investigators in the Life Sciences and Committee on Transforming Biological Information into New Therapies: A Strategy for Developing Antiviral Drugs for Smallpox.

## **Gunter P. Wagner**

### **Member**

Gunter Wagner, the Alison Richard Professor of Ecology and Evolutionary Biology at Yale University, is a noted researcher and theorist of developmental genetics and evolution. He was chair of the department of ecology and evolutionary biology in 1997-2001. Prior to joining Yale, he was an associate professor at the University of Vienna. Wagner and other researchers in his laboratory use mathematical modeling to understand the complex adaptations of organisms, with a focus on the molecular evolution of Hox genes and their role in the origin and early evolution of tetrapod limbs. For example, he has compared the expression of Hox genes between the primitive limbs of salamander and the highly derived limbs of frogs to understand the morphological evolution of these organisms. In another project, his lab studies the evolutionary history of Hox genes in primitive vertebrates and their correlation with the emergence of the developmental body plan of higher vertebrates. Wagner and his team have also developed new mathematical techniques in order to better understand gene interactions and evolutionary biology. Dr. Wagner received his Ph.D. from the University of Vienna. He was awarded a MacArthur Fellowship in 1992 and is a fellow of the American Association for the Advancement of Science and a corresponding member of the Austrian Academy of Sciences.