

**National Academy of Sciences
Annual Symposium on Frontiers of Science**

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Final Report

This final report summarizes activities conducted for the National Academy of Sciences' Annual Symposium on Frontiers of Science with support from the US Department of Energy for the period July 1, 1993 through May 31, 1998.

During the report period, five Frontiers of Science symposia were held at the Arnold and Mabel Beckman Center of the National Academies of Sciences and Engineering. For each Symposium, an organizing committee appointed by the NAS President selected and planned the eight sessions for the Symposium and identified general participants for invitation by the NAS President.

These Symposia accomplished their goal of bringing together outstanding younger (age 45 or less) scientists to hear presentations in disciplines outside their own and to discuss exciting advances and opportunities in their fields in a format that encourages, and allows adequate time for, informal one-on-one discussions among participants. Of the 458 younger scientists who participated, over a quarter (124) were women. Participant lists for all symposia (1993-1997) are attached.

The scientific participants were leaders in basic research from academic, industrial, and federal laboratories in such disciplines as astronomy, astrophysics, atmospheric science, biochemistry, cell biology, chemistry, computer science, earth sciences, engineering, genetics, material sciences, mathematics, microbiology, neuroscience, physics, and physiology. For each symposia, the 24 speakers and discussants on the program were urged to focus their presentations on current cutting-edge research in their field for a scientifically sophisticated but *non-specialist* audience, and to provide a sense of the experimental data--what is actually measured and seen in the various fields. They were also asked to address questions such as: What are the major research problems and unique tools in their field? What are the current limitations on advances as well as the frontiers? Speakers were asked to provide a 2500- to 3000-word synopsis of their speech in advance, so that participants, particularly those in other fields, could familiarize themselves with the topic.

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In addition to the younger scientists the invited audience included distinguished senior colleagues, science journalists and foreign scientists (German, Japanese and Chinese observers for future bi-national Frontiers symposia). Expenses for these attendees were not paid with contract funds.

A copy of the 1993-1997 programs and lists of participants are attached. Starting with the report of the November 1996 Frontiers of Science Symposium, the *Proceedings of the National Academy of Sciences* has published collected summaries of the Frontiers sessions. The summary papers from the 1996 and 1997 Frontiers symposia are also attached.

Perhaps the most salient measure of the success of the Frontiers is that it has spawned several similar programs. In September 1995, the National Academy of Engineering sponsored the first in a planned series of symposia on Frontiers of Engineering. The German American Academic Council, in conjunction with NAS, the Alexander von Humboldt Foundation, and the Max Planck Society has sponsored three symposia on German-American Frontiers of Science. The first annual Japanese-American Frontiers of Science symposium took place August 21-23, 1998 and the Chinese-American Frontiers of Science symposium followed on August 28-30, 1998 as well. Thus, the Frontiers of Science symposia have been and continue to be a major instrument for disseminating the value of interdisciplinary research to the best researchers in the natural sciences and engineering, both in the United States and increasingly in other countries.

National Academy of Sciences
Fifth Annual Symposium on Frontiers of Science
Sponsored by the U.S. Department of Energy
November 4-6, 1993

PROGRAM

(Sessions listed in alphabetical order.)

ASTROPHYSICS: "The Universe at Radio and Infra-red Wavelengths"

Organizer: Shrinivas Kulkarni, California Institute of Technology

Talk title: **The Microwave Sky As Seen By the Cosmic Background Explorer (COBE)**
Speaker: Charles I. Bennett, NASA/Goddard Space Flight Center
Talk title: **Measuring Absolute Velocity**
Speaker: Andrew E. Lange, University of California-Berkeley

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BIOLOGY: "The Human Genome"

Organizer: Gerald Rubin, University of California-Berkeley

Talk title: **The Human Genome Project and the Secret of Life**
Speaker: David Page, Howard Hughes Medical Institute & The Whitehead Institute
Talk title: **The Dog Genome Initiative: Towards A Genetics of Body and Mind**
Speaker: Jasper Rine, University of California-Berkeley & Lawrence Berkeley Laboratory

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CHEMISTRY: "Chemical Reaction Dynamics"

Organizers: Nathan Lewis, California Institute of Technology
Sylvia Ceyer, Massachusetts Institute of Technology

Talk title: **Bouncing Gases Off Liquids**
Speaker: Gilbert M. Nathanson, University of Wisconsin-Madison
Talk title: **The World Beyond Arrhenius**
Speaker: James J. Valentini, Columbia University
Discussion leader: Steven Sibener, University of Chicago

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MATHEMATICS: "Groups and Quantum Groups"

Organizer: Vaughan Jones, University of California-Berkeley

Talk title: **Elementary Geometry and Quantum Logic**
Speaker: John Conway, Princeton University
Talk title: **Quantum Groups**
Speaker: Adrian Ocneanu, Pennsylvania State University

NEUROSCIENCE: "Is Homosexuality Biological?"

Organizer: Geraldine Richmond, University of Oregon

Talk title: **Molecular Genetics of Sexual Orientation**
Speaker: Dean Hamer, National Cancer Institutes
Talk title: **Population Genetics of Human Sexual Orientation**
Speaker: Michael Bailey, Northwestern University
Discussion leader: Laura Allen, UCLA School of Medicine

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NEUROSCIENCE: "Neurological Bases of Learning and Memory"

Organizer: Geraldine Richmond, University of Oregon

Talk title: **Probing Brain Development**
Speaker: Scott Fraser, California Institute of Technology
Talk title: **Plasticity and Commitment in Brain Development**
Speaker: Sue McConnell, Stanford University
Discussion leader: Marianne Bronner-Fraser, University of California-Irvine

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OCEANOGRAPHY: "Paleoceanography—Milankovitch and Beyond"

Organizer: Marcia McNutt, Massachusetts Institute of Technology

Talk title: **Paleoceanography—Milankovitch and Beyond**
Speakers: Maureen Raymo, Massachusetts Institute of Technology
Scott Lehman, Woods Hole Oceanographic Institution
Edouard Bard, Université de Marseille

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PHYSICS: "Baryogenesis—or Why the Universe is Matter and Not Anti-matter"

Organizer: Jim Siegrist, Superconducting Super Collider Laboratory

Session Chair: To be determined

Talk title: **Baryon Number Violation via Quantum Tunneling: How (Otherwise) Intelligent Theoretical Physicists Can Differ by 180 Orders of Magnitude**
Speaker: Michael Mattis, Los Alamos National Laboratory
Talk title: **Baryogenesis—The Origin of Matter**
Speaker: Ann Nelson, University of California-San Diego

National Academy of Sciences'
SYMPOSIUM ON FRONTIERS OF SCIENCE
Supported by the US Department of Energy
November 3-5, 1994

Program

(Sessions are listed in alphabetical order)

Biology & Engineering: Animal Locomotion and Robot Design

Organizer: Deborah Penry

Diversity Enables Discovery: Lessons from Legged Locomotion

Robert Full, University of California-Berkeley

Dynamic Legged Robots

Marc Raibert, Massachusetts Institute of Technology

Discussion leader:

Mimi Koehl, University of California-Berkeley

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Biology & Paleontology: The Cambrian Explosion in Biological Diversification
(two parts):

session 1:

"Rates and Directions of Cambrian Evolution"

Organizer: Marcia McNutt

Understanding the Cambrian Explosion

Simon Conway Morris, Cambridge University

The Context of Early Animal Evolution

Andrew Knoll, Harvard University

Discussants:

John Grotzinger, Massachusetts Institute of Technology

Sam Bowring, Massachusetts Institute of Technology

session 2:

"Biological Mechanisms and Consequences of the Cambrian Explosion"

Organizer: Deborah Penry

The Origin of Ecological and Developmental Space During the Cambrian Radiation

Douglas Erwin, National Museum of Natural History/Smithsonian Institution

**Using Molecular Data to Understand Inter-Phylum Relationships and
the Morphological Transformations that Led to the Origin of the Phyla**

Charles Marshall, University of California-Los Angeles

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Chemistry: Solid State Chemistry: Turning Down the Heat

Organizer: Geri Richmond

**Controlling Kinetics and Mechanisms of Solid State Reactions
by Design of Superlattice Reactants**

David Johnson, University of Oregon

Chemistry (cont.)

A Modular Approach to New Solids and Surfaces

Thomas Mallouk, Pennsylvania State University

Discussion leader:

Mercouri Kanatzidis, Michigan State University

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Mathematics: Non-linear Inverse Problems

Organizer: Ingrid Daubechies

Finding Properties of Vibrating Systems from Nodes and/or Nodal Lines

Joyce McLaughlin, Rensselaer Polytechnic Institute

Electrical Impedance Tomography

Michael Vogelius, Rutgers University

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Physics: Electronics with a Single Electron

Organizer: John Price

Transfer of Single Electrons in Metallic Nanostructures

Michel Devoret, CEA-Saclay (France)

Applications of Single Electron Tunneling:

Is Digital Logic on a Nanometer Scale Possible?

John Martinis, National Institute of Standards and Technology

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Physics & Materials Science:

Optical Microscopy: Technological Advances and Future Potential

Organizer: Tim Harris

Soft X-ray Microscopy: Technology and Applications

Chris Jacobsen, State University of New York-Stony Brook

Seeing Single Molecules

Jay Trautman, AT&T Bell Laboratories

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Sociology & Demography: How Long Will We Live?

Organizers: Beth Soldo/Barbara Torrey

The Experimental Demography of Genotypes and Genes:

Findings on Longevity and Aging

James Curtsinger, University of Minnesota

Beyond Gompertz and Buffon:

Trajectories of Mortality at Advanced Ages

James Vaupel, Duke University/Odense (Denmark) University Medical School

Discussion leaders:

Jay Olshansky, University of Chicago

John Wilmoth, University of California-Berkeley

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National Academy of Sciences
Seventh Annual Symposium on Frontiers of Science
November 2-4, 1995
Irvine, CA

Program

The Age of the Universe

Organizer: David Spergel, Princeton University Observatory

Speakers:

"Red Dwarfs and Einstein's Biggest Mistake"

Michael Bolte, University of California-Santa Cruz

"Measuring the Expansion Age of the Universe"

Wendy Freedman, Carnegie Observatories

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Mathematical Approaches to Comparative Linguistics

Organizer: Tandy Warnow, University of Pennsylvania

Speakers:

"Tracing the Origin and Dispersal of Human Language"

Johanna Nichols, University of California-Berkeley

"Determining the Evolutionary History of Languages"

Ann Taylor, University of Pennsylvania

Discussion leader:

Don Ringe, University of Pennsylvania

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Life in the RNA World (and Evolution in the Test Tube)

Organizer: Diane Hawley, University of Oregon

Speakers:

"Bringing Evolutionary Biology, Organic Chemistry, and Geology Together"

Steven Benner, Swiss Federal Institute of Technology

Andrew Ellington, Indiana University

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Micromachining

Organizers: Timothy Harris, AT&T Bell Laboratories

John Price, University of Colorado

Speakers:

"MicroElectroMechanical Systems (MEMS):

It's the Little Things in Life that Keep You Going"

Susanne Arney, AT&T Bell Laboratories

"Micromachines - Technology Transfer or Conceptual Transfer?"

Jeff Sampsel, Digital Optics International Corporation

"MEMS Vision for the Future"

Tom Kenny, Stanford University

Neurobiology of Mood and Behavior

Organizer: James Valentini, Columbia University

Speakers:

"The Neurobiology of Emotion and Behavior Illustrated by Addiction"

Steven Hyman, Massachusetts General Hospital

"Emotion, Memory, and the Brain"

Joseph LeDoux, New York University

"Molecular Basis of Addictive States"

Eric Nestler, Yale University School of Medicine

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Quantum Chaos

Organizer: Charles Marcus, Stanford University

Speakers:

"Quantum Chaos: From Atoms to Solid State Devices"

Rodrick Jensen, Wesleyan University

"Chaos in Quantum Billiards"

Carlo Beenakker, Leiden University

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Linked sessions:

The Missing Sink: Whither Anthropogenic CO₂?

Organizer: Scott Lehman, Woods Hole Oceanographic Institute

Speakers:

"An Update on the 'Missing Sink' for Atmospheric CO₂"

Ralph Keeling, Scripps Institution of Oceanography

"Anthropogenic CO₂: The Natural Carbon Cycle Reclaims Center Stage"

J. Robert Toggweiler, Princeton University

Discussion leader:

James White, INSTAAR, University of Colorado

and

Biological Invasions: Irreversible Aspects of Global Change

Organizer: Deborah Penry, University of California - Berkeley

Speakers:

"Historical Perspectives on Biological Invasions"

David Burney, Fordham University

"Biological Invasions as Agents of Change to the World's Ecosystems"

Carla D'Antonio, University of California-Berkeley

National Academy of Sciences

Eighth Annual Symposium on Frontiers of Science

November 7-9, 1996

FINAL PROGRAM*

Bose-Einstein Condensation

Organizer: Steve Chu

CHAIR:

John Doyle, Harvard University

SPEAKERS:

Wolfgang Ketterle, Massachusetts Institute of Technology
How to Reach and Observe Bose-Einstein Condensation

Eric Cornell, University of Colorado
Bose-Einstein Condensation: Present and Future

The Cell Cycle and Cancer

Organizers: Tom Alber and Alanna Schepartz

CHAIR:

Kathleen Collins, University of California, Berkeley

SPEAKERS:

Tyler Jacks, Massachusetts Institute of Technology
Tumor Suppressor Gene Function: Cellular Brakes and Suicide Pills

Nikola Pavletich, Memorial Sloan-Kettering Cancer Center
Crystallographic Studies of Cell Cycle Regulatory Proteins

Combinatorial Thinking in Chemistry and Biology

Organizer: Tom Alber

CHAIR:

Barry Stoddard, Fred Hutchinson Cancer Research Institute

SPEAKERS:

Jonathan Ellman, University of California, Berkeley
Synthetic Chemical Libraries

Jim Wells, Genentech Inc.

Minimizing Proteins

Epoch of Galaxy Formation

Organizer: David Spergel

CHAIR:

David Spergel, Princeton University

SPEAKERS:

Charles Steidel, California Institute of Technology
The Epoch of Galaxy Formation: Found?

Simon Lilly, University of Toronto
The Evolution of Galaxies and the History of the Universe

* Sessions listed in alphabetical order

Genetics of Complex Behavioral Disorder

Organizer: Nora Volkow

CHAIR:

George Uhl, National Institute on Drug Abuse

SPEAKERS:

Lisa Gold, Scripps Research Institute

*Integration of Molecular and Genetic Analysis of Complex Behavioral Disorders in Mice:
Focus on Drug Abuse and Dementia*

Neil Risch, Stanford University School of Medicine

The Future of Genetic Analysis of Complex Human Diseases

Imaging the Living Human Brain

Organizer: Nora Volkow

CHAIR:

Nora Volkow, Brookhaven National Laboratory
Imaging of Neurotransmission in the Human Brain

SPEAKERS:

Bruce Rosen, Massachusetts General Hospital

Lars Farde, Karolinska Institute

Security and Privacy in the Information Economy

Organizer: Joan Feigenbaum

CHAIR:

Joan Feigenbaum

SPEAKERS:

Matt Blaze, AT&T Research

Steven Rudich, Carnegie Mellon University

The Science of Modern Cryptography

DISCUSSANT:

Kevin McCurley, Sandia National Laboratories

Signals in Plants

Organizer: Tom Alber

CHAIR:

Michael Mulligan, University of California, Irvine

SPEAKERS:

Joanne Chory, The Salk Institute

Joseph Ecker, University of Pennsylvania

Hormone Signaling in Plants

National Academy of Sciences

Ninth Annual Symposium on Frontiers of Science

November 6-8, 1997

FINAL PROGRAM

(Sessions in alphabetical order)

Chemical Physics of Protein Folding

Organizer: Peter Wolynes, University of Illinois

CHAIR:

Peter Wolynes, University of Illinois

SPEAKERS:

José Onuchic, University of California, San Diego
Exploring the Energy Landscape of Protein Folding

Martin Gruebele, University of Illinois
Proteins: Efficient Folders

Charles Brooks, Scripps Research Institute
Exploring Protein Folding Free Energy Landscape at Atomic Resolution with Molecular Simulations

Cretaceous-Tertiary (dinosaur) Extinction

Organizer: Mary Lou Zoback, U.S. Geological Survey

CHAIR:

Kevin Pope, Geo Eco Arc Research
New Environmental And Biological Evidence For A Meteorite Impact Cause

SPEAKERS:

Steven D'Hondt, University of Rhode Island
Environmental And Evolutionary Consequences Of The Impact On Time Scales Of Seconds To Millions Of Years

Charles Marshall, University of California, Los Angeles
Overcoming An Incomplete Fossil Record To Assess The Magnitude And Rapidity of The End-Cretaceous Extinctions

Lifespan and Senescence

Organizer: Joanne Chory, The Salk Institute

CHAIR:

Leonard P. Guarente, Massachusetts Institute of Technology
Identification of a Molecular Cause of Aging

SPEAKERS:

Richard Amasino, University of Wisconsin

Gary Ruvkun, Massachusetts General Hospital
Neuroendocrine Control Of Metabolism And Longevity

Nanochemistry

Organizer: Nora Volkow, Brookhaven National Laboratory

CHAIR:

Robert L. Whetten, Georgia Institute of Technology

SPEAKERS:

Michael J. Natan, Pennsylvania State University
Architecture Using Nanoparticles

Paul Alivisatos, University of California, Berkeley
Nanocrystals: Building Blocks for Modern Materials Design

The Frontiers of Science symposium series is sponsored by the National Academy of Sciences and supported, in part, with funding from the U.S. Department of Energy, and the National Science Foundation.

New Developments in the Biology and Treatment of HIV

Organizer: Tyler Jacks, Massachusetts Institute of Technology

CHAIR:

Frederic Bushman, The Salk Institute

SPEAKERS:

Ned Landau, Aaron Diamond Center

Genetic Resistance to AIDS: What Does It Tell Us?

Emilio Emini, Merck Research Labs

A New Paradigm for the Treatment of AIDS

Prions and Prion Diseases

Organizer: Peter Wolynes, University of Illinois

CHAIR:

David Westaway, University of Toronto

SPEAKERS:

Glenn Telling, Imperial College of Science, Technology and Medicine at St Mary's
Transgenic Mouse Models of Prion Diseases

Suzette Priola, National Institute of Allergy and Infectious Disease
Prions and Prion Diseases

Quantum Cryptography and Quantum Computing

Organizer: Steve Chu, Stanford University

CHAIR:

Steve Chu, Stanford University

SPEAKERS:

Chris Monroe, National Institute of Standards and Technology
Quantum Computing with Individual Atoms

Isaac Chuang, Los Alamos National Laboratory
Bulk Quantum Computation

Seth Lloyd, Massachusetts Institute of Technology
Quantum Computers
What? Why? How?

Gilles Brassard, University of Montreal
Quantum Information Processing

String Theory

Organizer: Jennifer Chayes, Princeton University

CHAIR:

David Morrison, Duke University

SPEAKERS:

Brian Greene, Columbia University
String Theory and the Fabric of Spacetime

Joseph Polchinski, University of California, Santa Barbara
"What is String Theory"

NATIONAL ACADEMY OF SCIENCES
FIFTH ANNUAL SYMPOSIUM
ON
FRONTIERS OF SCIENCE
Sponsored by the U.S. Department of Energy
November 4-6, 1993

FINAL ATTENDANCE

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ON

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Eighth Annual Symposium on Frontiers of Science

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Irvine, California
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Participant Roster

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