National Academy of Sciences
Annual Symposium on Frontiers of Science

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Washington, DC 20418
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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.)  

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<tr>
<th>SESSION</th>
<th>SPEAKER</th>
<th>TOPIC</th>
<th>ORGANIZER</th>
<th>INSTITUTE</th>
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<tbody>
<tr>
<td><strong>ASTROPHYSICS:</strong> &quot;The Universe at Radio and Infrared Wavelengths&quot;</td>
<td></td>
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<td>Shrinivas Kulkarni, California Institute of Technology</td>
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<tr>
<td><strong>Talk title:</strong> The Microwave Sky As Seen By the Cosmic Background Explorer (COBE)</td>
<td><strong>Speaker:</strong> Charles I. Bennett, NASA/Goddard Space Flight Center</td>
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<tr>
<td><strong>Talk title:</strong> Measuring Absolute Velocity</td>
<td><strong>Speaker:</strong> Andrew E. Lange, University of California-Berkeley</td>
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<tr>
<td><strong>BIOLOGY:</strong> &quot;The Human Genome&quot;</td>
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<td>Gerald Rubin, University of California-Berkeley</td>
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<tr>
<td><strong>Talk title:</strong> The Human Genome Project and the Secret of Life</td>
<td><strong>Speaker:</strong> David Page, Howard Hughes Medical Institute &amp; The Whitehead Institute</td>
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<tr>
<td><strong>Talk title:</strong> The Dog Genome Initiative: Towards A Genetics of Body and Mind</td>
<td><strong>Speaker:</strong> Jasper Rine, University of California-Berkeley &amp; Lawrence Berkeley Laboratory</td>
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<td><strong>CHEMISTRY:</strong> &quot;Chemical Reaction Dynamics&quot;</td>
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<td>Nathan Lewis, California Institute of Technology</td>
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<tr>
<td><strong>Talk title:</strong> Bouncing Gases Off Liquids</td>
<td><strong>Speaker:</strong> Gilbert M. Nathanson, University of Wisconsin-Madison</td>
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<tr>
<td><strong>Talk title:</strong> The World Beyond Arrhenius</td>
<td><strong>Speaker:</strong> James J. Valentini, Columbia University</td>
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<tr>
<td><strong>MATHEMATICS:</strong> &quot;Groups and Quantum Groups&quot;</td>
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<td>Vaughan Jones, University of California-Berkeley</td>
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<tr>
<td><strong>Talk title:</strong> Elementary Geometry and Quantum Logic</td>
<td><strong>Speaker:</strong> John Conway, Princeton University</td>
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<tr>
<td><strong>Talk title:</strong> Quantum Groups</td>
<td><strong>Speaker:</strong> Adrian Ocneanu, Pennsylvania State University</td>
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</table>
**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

As of October 28th 1993
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

* *

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

* *

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
A Modular Approach to New Solids and Surfaces
Thomas Mallouk, Pennsylvania State University
Discussion leader:
Mercouri Kanatzidis, Michigan State University

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

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

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

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
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

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

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

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 Sampsell, 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

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

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

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

As of October 26th 1995
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 Rapidityof 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”
FINAL ATTENDANCE

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