BIOCOMPLEXITY IN THE ENVIRONMENT

The world is facing significant scientific and societal challenges, including the prospect of rapid environmental and climate change, the threat of biological warfare, and the complicated question of long-term environmental security. The integrity of local, regional and global ecosystems is inextricably linked to human well-being, and environmental and human health often intertwine. While exploration of complex environmental systems poses significant research challenges, it is a necessary element of local, national, and global security and critical to the development of new scientific and technological capabilities that will significantly advance our ability to anticipate environmental conditions and thus improve environmental decision-making. Thus, both scientific and practical needs for clear, quantitative understanding of the world motivate continued focus on the investigation of complex environmental systems.

The *Biocomplexity in the Environment* (BE) priority area is designed to give NSF the capability to respond to the demand for new approaches to investigating complex environmental systems in which the dynamic behavior of biota is linked to the physical and chemical processes of the environment. Investigations must be highly interdisciplinary, consider non-human biota and/or humans explicitly, and examine challenging systems that have high potential for exhibiting nonlinear or highly coupled behavior. Advanced computational and mathematical modeling strategies are intrinsic to this research. The term "biocomplexity" is used to stress the requirement that research questions must address the dynamic web of interrelationships that arise when living things at all levels – from their molecular structures to genes to organisms to ecosystems to urban centers – interact with their environment. This priority area will result in more complete and synthetic understanding of natural processes, of human behaviors and decisions in the natural world, and ways to use new technology effectively to sustain life on earth.

In future years, as part of the planned phasing down of the priority area, NSF will refer to this research portfolio as Complexity in Environmental Systems (CES).

Biocomplexity in the Environment Funding

(Dollars in Millions)

	FY 2004 Actual	FY 2005 Current Plan	FY 2006 Request	Change over FY 2005 Amount	Change over FY 2005 Percent
Biological Sciences	39.86	39.86	30.43	-9.43	-23.7%
Computer and Information Science and Engineering	8.01	8.00	3.00	-5.00	-62.5%
Engineering	6.00	6.00	6.00	0.00	0.0%
Geosciences	37.22	37.22	37.22	0.00	0.0%
Mathematical and Physical Sciences	4.70	4.03	3.36	-0.67	-16.6%
Social, Behavioral and Economic Sciences	6.27	2.00	2.00	0.00	0.0%
Office of International Science and Engineering	0.50	0.50	0.25	-0.25	-50.0%
Office of Polar Programs	1.55	1.55	1.55	0.00	0.0%
Subtotal, Research and Related Activities	104.11	99.16	83.81	-15.35	-15.5%
Education and Human Resources	0.00	0.00	0.00	0.00	NA
Total, Biocomplexity in the Environment	$104.11	$99.16	$83.81	-$15.35	-15.5%

Long-term Goals: NSF will continue to emphasize research and education on the role of *Biocomplexity in the Environment*. This priority area is part of investments and accomplishments within NSF's FY 2006

environmental investment portfolio of approximately $892 million. The intellectual goals of the effort are to:

- Synthesize environmental knowledge across disciplines, subsystems, time and space;
- Discover new methods, models, theories, and conceptual and computational strategies for understanding complex environmental systems;
- Develop new tools and innovative applications of new and existing technologies for cross-disciplinary environmental research;
- Integrate human and societal and ecological factors into investigations of the physical environment and environmental engineering;
- Improve science-based forecasting capabilities and enhance research on decision-making and human environmental behaviors; and
- Advance a broad range of infrastructure to support interdisciplinary environmental activities: collaboratory networks, information systems, research platforms, international partnerships, and education activities that enhance and diversify the future environmental workforce.

Long-term Funding for Biocomplexity in the Environment
(Dollars in Millions)

FY 2000	FY 2001	FY 2002	FY 2003	FY 2004 Actual	FY 2005 Plan	FY 2006 Request	FY 2007
$50.00	$54.88	$58.10	$70.12	$104.11	$99.16	$83.81	$83.81

Estimates for 2007 and beyond do not reflect policy decisions and are presented for planning purposes only.

FY 2006 Topical Areas: In FY 2006, NSF plans to invest $83.81 million in the interdisciplinary Biocomplexity in the Environment activities described below. Five primary areas will be supported. The first three stress the interactions of humans and biota with the chemical and physical environment. The latter two areas contribute enhanced fundamental understanding of the role of microorganisms in the environment.

- **Earth Systems, Cycles, and Pathways: Biogeochemical, chemical and physical pathways linking the atmosphere, ocean and solid Earth** – This involves the interrelation of biological, geochemical, geological, and physical processes at all temporal and spatial scales, with particular emphasis on understanding linkages between biologically important chemical and physical cycles (for example, the cycles of carbon, oxygen, nitrogen, phosphorus, sulfur and essential minerals) and the influence of human and other biotic factors on those cycles. This includes research on biotic mediation of the distribution, transformation and transport of significant biogeochemical constituents, such as carbon, among terrestrial, atmospheric, and ocean and seafloor environments. Also included is research on the complex processes, both abiotic and biotic, that affect water cycle variability, time-dependence in the distribution of freshwater resources, and feedbacks between the water cycle and other physical, geochemical and biological processes, for example, climate processes, the carbon cycle, or terrestrial ecosystems.

A panda at the China Research and Conservation Center for the Giant Panda in the Wolong Nature Reserve in Sinchuan Province in southern China.

- **Dynamics of Coupled Natural and Human Systems** – This involves quantitative, interdisciplinary analyses of relevant human and natural system processes and the complex interactions among human systems and natural systems at diverse scales. Example areas of study include land use, the role of institutions in decision-making, and social valuation of biodiversity.

- **Materials Use: Science, Engineering and Society** – This involves studies directed toward reducing adverse human impact on the total, interactive system of resource use; the design and synthesis of new materials with environmentally benign impacts on complex environmental systems; as well as maximizing the efficient use of individual materials throughout their life cycles.

- **Microbial Genome Sequencing** – This involves use of high throughput sequencing of microorganisms of fundamental biological interest, importance to agriculture, forestry, food and water quality, or value in understanding potential agents of bioterrorism. Genome sequence information will provide the basis for understanding the physiology, pathology, and ecology of these organisms. This knowledge can be applied to detection and economic uses of organisms and to understanding microbial adaptation to extreme environments. Emphasis will also be placed on sequencing microbes of interest because of their associations with other organisms—plants, animals, or other microbes. This is an interagency activity in partnership with the U.S. Department of Agriculture.

- **Ecology of Infectious Diseases** – This involves development of predictive models and discovery of principles for relationships between environmental factors and transmission of infectious agents. Potential benefits include the development of disease transmission models, understanding of unintended health effects of environmental change, and improved prediction of disease outbreaks, emergence, and re-emergence. Examples of environmental factors include habitat transformation, biological invasion, biodiversity loss, and contamination. This activity involves an interagency partnership with the National Institutes of Health.

In addition to these primary areas, additional multidisciplinary research and education activities that use a synthetic approach to understanding complex environmental systems will be supported. These include:

- Environmental Genomics – the integrated use of genomic and information technology approaches to gain novel insights into environmental questions and problems.
- Integration Activities for Sensor Networks and Observing Systems – development of data management tools and partnerships to improve data coordination and access, as well as addressing computational challenges in ecosystem dynamics.
- Molecular Scale Studies – development of benign materials and elucidation of molecular scale environmental processes.
- Educational Activities – projects that integrate education and research on complex environmental systems that promote workforce development, including increased participation of underrepresented minorities, and the professional development of science teachers.
- International Partnerships – collaborations with research partners in other countries that expand the scope of research activities on complex environmental systems and broaden the experience of U.S. students.

PERFORMANCE ASSESSMENT RATING TOOL

PART Assessment of Biocomplexity in the Environment. A PART assessment of the Biocomplexity in the Environment (BE) program was completed to inform the FY 2006 budget decision-making process. Overall, BE earned an "effective" PART rating.

Annual Efficiency Goal: Percent of award decisions made available to applicants within six months of proposal receipt or deadline date, while maintaining a credible and efficient competitive merit review system, as evaluated by external experts. Timely availability of proposal decisions allows the research community to more effectively plan activities. Considering the increasing complexity and numbers of proposals coming into NSF, the goal of keeping decision time for 70 percent of proposals down to six months is ambitious.

Biocomplexity in the Environment Purpose and Design: The Biocomplexity in the Environment (BE) priority area is a multidisciplinary effort with the purpose of synthesizing knowledge across disciplines; improving science-based forecasting for complex environmental systems; and advancing a broad range of methods, tools, and infrastructure to support interdisciplinary activities. BE specifically responds to the demand for new, interdisciplinary approaches for investigating the interactivity of the environment and both human and non-human biota, and program activities address the need for new training, organizations and funding to bring together multidisciplinary research teams as identified by the National Research Council.

NSF's activities through its investments in BE address unique interdisciplinary research questions and needs for multidisciplinary research teams that are not under the purview of mission-oriented federal, state or local agencies. NSF partners with other agencies to avoid duplication (e.g., the Microbial Genome Sequencing activity is administered jointly with USDA and other agencies, the Ecology of Infectious Diseases activity is with NIH, and research activities at the William R. Wiley Environmental Molecular Sciences Laboratory with DOE).

Strategic Planning: Specific long-term performance measures for NSF's investments in Biocomplexity in the Environment are drawn from the objectives set forth in the NSF Strategic Plan FY 2003-2008, and they encompass NSF's commitment to promoting interdisciplinary research to enhance scientific understanding of complex environmental systems and processes for the benefit of society.

The Advisory Committee for Environmental Research and Education (AC/ERE) reviews and oversees the BE program. The AC/ERE meets semi-annually to evaluate program activities and progress and make recommendations that direct program planning and effect program improvements. The AC/ERE also authors reports and occasional papers to provide program guidance.

For NSF's investments in Biocomplexity in the Environment (BE), the Committee of Visitors (COV) process provides a valuable mechanism for identifying and addressing planning-related issues. Through the COV, NSF receives feedback on the activity's goals and overall effectiveness. Steps to address weaknesses are identified, when applicable. In the FY 2004 COV review of the BE program, one of the recommendations was to expand social science methodology to include rigorous qualitative research methods. The 2005 solicitation for BE will be revised to reflect this recommendation. The BE program has successfully emphasized NSF's broader impacts criterion, as acknowledged by the National Research Council as "one of the few programs to require that applicants explicitly include an education or outreach component."

BE Management: Performance information is collected from NSF grant recipients via interim, annual and final project reports. Site visits to larger projects are also used to collect performance information.

Committee of Visitors (COV) reviews and recommendations are utilized to improve program performance. Process-related or quantitative goals such as dwell time are monitored via the agency's Enterprise Information System (EIS). All of these assessments impact management practices.

BE Results/Accountability: NSF relies on external evaluation to determine whether it is achieving its long-term objectives. Input is derived from the Committees of Visitors (COVs), Principal Investigator annual and final project reports, and summaries of substantial outcomes ("nuggets") from funded research. The Advisory Committee for GRPA Performance Assessment has determined that the accomplishments under the Ideas goal have demonstrated "significant achievement" toward annual and long-term performance.