BIOLOGICAL SCIENCES

BIOLOGICAL SCIENCES $599,930,000

The FY 2005 Budget Request for the Biological Sciences Activity (BIO) is $599.93 million, an increase of $13.04 million over the FY 2004 Estimate of $586.89 million.

Biological Sciences Funding
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Change over FY 2004 Percent
Molecular & Cellular Biosciences	121.89	121.77	124.98	3.21	2.6%
Integrative Biology & Neuroscience	107.47	107.41	110.63	3.22	3.0%
Environmental Biology	108.28	108.26	111.48	3.22	3.0%
Biological Infrastructure	75.03	80.22	85.47	5.25	6.5%
Emerging Frontiers	73.37	79.76	77.90	-1.86	-2.3%
Plant Genome	84.45	89.47	89.47	0.00	0.0%
Total, BIO	$570.49	$586.89	$599.93	$13.04	2.2%

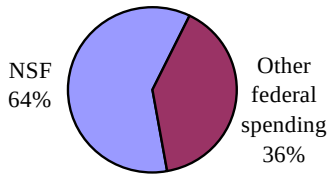
Totals may not add due to rounding.

The mission of the Biological Sciences Activity (BIO) is to support the vitality of the biological sciences at U.S. colleges and universities, especially in those areas where NSF has a major responsibility. BIO supports research, infrastructure, and education.

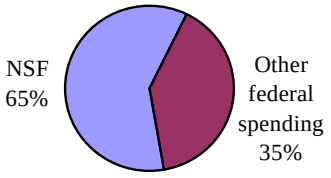
RELEVANCE

BIO is the dominant federal supporter of basic research in non-medical aspects of the biological sciences at academic institutions – providing over 65 percent of the support for these activities. Because most federal support for the life sciences – over 85 percent – goes to health-related research funded by the National Institutes of Health, NSF's contribution to the broader array of the biological sciences is significant and strategically focused – particularly in such areas as environmental biology and plant sciences.

Federal Support for Basic Research in Environmental Biology at Academic Institutions



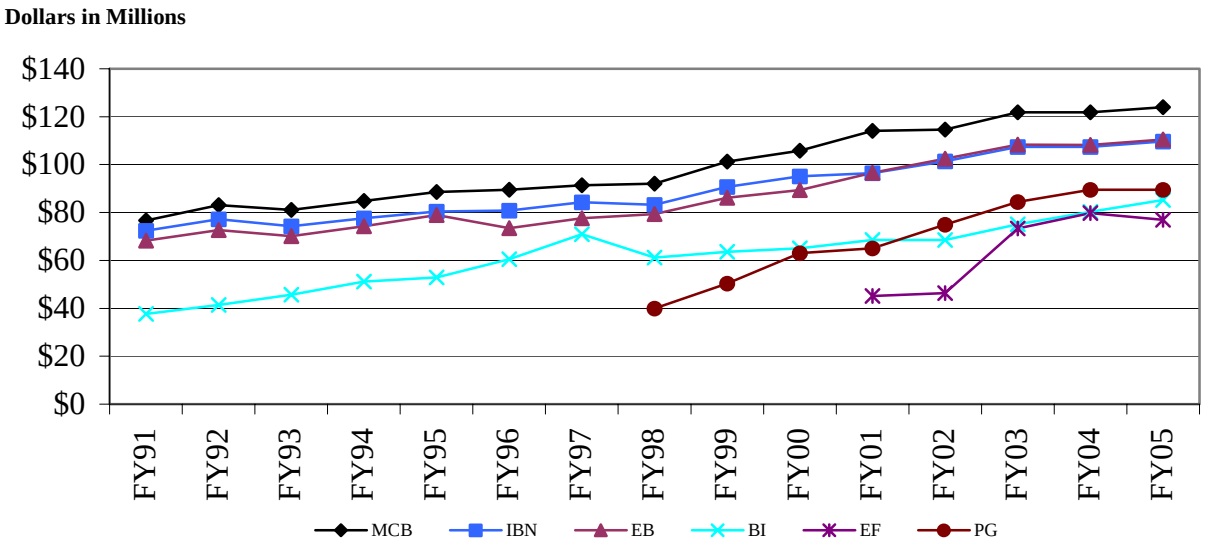
Federal Support for Basic Research in Non-Medical Biological Sciences at Academic Institutions



Fundamental research on understanding all aspects of "life" – from the cell to whole ecosystems is supported within NSF – where the ability to integrate the range of biological sub-disciplines is unique. BIO support represents 64 percent of all federal funding for basic research in environmental biology and

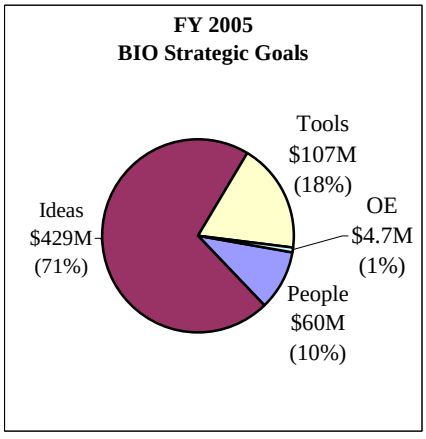
an estimated 55 percent of support in plant biology at academic institutions. Additionally, NSF plays a special role in supporting interdisciplinary biological research, since collaborations among disciplines represented by the various R&RA Activities are possible. Issues of national importance related to the environment, economy and human welfare require an understanding of how living organisms function and interact with non-living systems. BIO supported research enhances this understanding.

BIO Subactivity Funding
(Dollars in Millions)



STRATEGIC GOALS

Four aims guide BIO's activities:



- PEOPLE: Improvement of the quality of biological sciences education and training and enhancement of diversity in all the fields of biology. BIO will continue to advance education and training for current biological scientists, increase the diversity of the biological sciences community, facilitate education and training for future generations of biological scientists, and enhance the general public's knowledge about biology.

- IDEAS: Advancement of understanding of major biological questions from a multidisciplinary view, including both maintaining adequate base support across all biological fields and identifying opportunities where more focused support can play a catalytic role in advancing scientific progress. 21st Century Biology is multidimensional, multidisciplinary, integrative, data-driven, education-oriented and global, encompassing conceptual and experimental approaches broader than those of the last Century.

- TOOLS: Enhancement of the infrastructure for the conduct of biological research. BIO will invest in instrumentation and facilities, including cyberinfrastructure; biological research resources; and genomics technologies.

- ORGANIZATIONAL EXCELLENCE: Organizational Excellence provides for administrative activities necessary to enable NSF to achieve its strategic goals. This includes the cost of Intergovernmental Personnel Act appointments and contractors performing administrative functions.

Funding by Strategic Goal: Summary
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Change over FY 2004 Percent
People	57.65	57.18	59.68	2.50	4.4%
Ideas	406.98	419.15	428.82	9.67	2.3%
Tools	101.74	106.44	106.71	0.27	0.3%
OE	4.12	4.12	4.72	0.60	14.6%
Total, BIO	$570.49	$586.89	$599.93	$13.04	2.2%

Totals may not add due to rounding.

PEOPLE (+ $2.50 million, for a total of $59.68 million)

BIO programs promote a diverse, internationally competitive workforce of scientists, engineers, educators and knowledgeable citizens. These programs also seek to achieve participation in biology that reflects the diversity of the U.S. population.

BIO People Investments
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Change over FY 2004 Percent
Individuals	46.82	46.26	48.26	2.00	4.3%
Institutions	2.49	2.71	2.71	0.00	0.0%
Collaborations	8.34	8.21	8.71	0.50	6.1%
Total, BIO	$57.65	$57.18	$59.68	$2.50	4.4%

Totals may not add due to rounding.

Enhancement of multidisciplinary education, teaching, and training activities including:

INDIVIDUALS

- A total of $13.20 million, a $2.0 million increase, is provided to enhance support for the Integrative Graduate Education and Research Training (IGERT) program. NSF developed this agency-wide program to enhance the development of innovative, research-based graduate education and training programs in Ph.D.-granting institutions and to meet the need for a cadre of broadly prepared Ph.D.s with the technical, professional, and personal skills essential to address the varied career demands of the future. The IGERT program will support projects based on multidisciplinary research themes and organized by diverse groups of investigators with appropriate research and teaching expertise. The use of a multidisciplinary research theme provides a framework for the integration of research and educational activities, and for collaborative efforts in training that span many disciplinary areas.

- A total of $35.06 million is provided for other support to individuals, which includes Faculty Early Career Development (CAREER) Awards, Postdoctoral Research Fellowships, Research Experience for Undergraduates (REU) Supplements, Undergraduate Mentoring in Environmental Biology (UMEB), Cross-disciplinary Research at Undergraduate Institutions (CRUI), and Research Experiences for Teachers (RET).

INSTITUTIONS

- Support for the ADVANCE program, designed to help institutions increase the participation and advancement of women in academic sciences and engineering careers, will continue at $2.71 million.

COLLABORATIONS

- A total of $1.64 million, a $500,000 increase, is provided for the NSF Graduate Teaching Fellows in K-12 Education (GK-12). This program supports fellowships and associated training that enable graduate students and advanced undergraduates in science, technology, engineering, and mathematics to serve as knowledgeable resources in K-12 schools.

- A total of $7.07 million is provided for other collaborative programs such as Research Experiences for Undergraduates (REU) Sites, and Minority Institutions of Excellence.

IDEAS (+ $9.67 million, for a total of $428.82 million)

BIO Ideas Investments
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Change over FY 2004 Percent
Fundamental Science and Engineering	331.84	339.48	346.53	7.05	2.1%
Centers Programs	57.54	61.85	64.47	2.62	4.2%
Capability Enhancement	17.60	17.82	17.82	0.00	0.0%
Total, BIO Ideas	$406.98	$419.15	$428.82	$9.67	2.3%

Totals may not add due to rounding.

The Biological Sciences Activity provides support for research to advance understanding of the underlying principles and mechanisms governing life; it provides research support for enhancement of multidisciplinary research activities, interagency partnerships, and international activities. BIO's support for discovery spans all the biological disciplines. BIO-supported research effectively builds the knowledge base needed to address societal interests in areas as diverse as food, nutrition, agriculture, and the environment.

FUNDAMENTAL SCIENCE AND ENGINEERING

- A total of $346.53 million, a $7.05 million increase, will support awards central to 21st Century Biology. As research breakthroughs are realized from recent advances in genomics, proteomics, informatics, computer science, mathematics, physics, chemistry, engineering and the earth and social

sciences, a new biology has emerged that is multidimensional, multidisciplinary, information-driven, education-oriented, and internationally engaged.

- Frontiers in Biological Research (FIBR) is a key component of the Subactivity, Emerging Frontiers, a division established in FY 2003 to serve as an incubator for 21st Century Biology activities. FIBR is designed to support ideas and approaches that do not fit within the boundaries of the subdisciplinary areas. Through FIBR, BIO intends to support groups of researchers to capitalize on synergistic interactions and to employ diverse tools to achieve an integrative understanding of clearly defined, important biological questions.
- BIO will support projects to utilize the latest genomics tools and techniques to gain an understanding of the biological diversity and functioning of complex environmental systems.
- Molecular-Level Understanding of Life Processes: BIO will continue to identify new opportunities, for example comparative or trans-kingdom genomics, that take full advantage of current molecular, computational and bioinformatics technologies to better understand plants, animals and microorganisms.
- Support for cyberinfrastructure will increase by $7.0 million to focus on domain-specific cyberinfrastructure and services enabling biological research and education. Support across BIO will focus on: access to information networks linking researchers worldwide; hardening software; software portability; enabling software development for the National Ecological Observatory Network (NEON); and data integration.

CENTERS PROGRAMS

BIO Centers
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Change over FY 2004 Percent
Science and Technology Centers	3.99	4.00	4.00	0.00	0.0%
Centers for Analysis and Synthesis	2.86	6.15	6.47	0.32	5.2%
Long Term Ecological Research Program	14.69	15.70	18.00	2.30	14.6%
Plant Genome Virtual Centers	36.00	36.00	36.00	0.00	0.0%
Total, BIO Centers	$57.54	$61.85	$64.47	$2.62	4.2%

Support for the BIO Centers and Center-like programs, totaling $64.47 million, an increase of $2.62 million over the FY 2004 Estimate, includes: the Center for Ecological Analysis and Synthesis (CEAS); Plant Genome Virtual Centers; the Center for Synthesis in Biological Evolution; the Center for Behavioral Neuroscience; and the Long Term Ecological Research program (LTER).

- Following recommendations from the "Twenty-Year Review of the NSF LTER Program," LTER will be increased by $2.30 million in FY 2005 to provide incentives for interdisciplinary collaborations at LTER sites.
- The Center for Ecological Analysis and Synthesis (CEAS) promotes integrative studies of complex ecological questions and serves as a locus for the synthesis of large data sets. A small scheduled increase of $320,000, for a total of $3.47 million, is included in the FY 2005 Request.
- Plant Genome Virtual Centers (centers without walls) are collaboratories where coordinated, multi-investigator teams pursue comprehensive plant genome research programs relevant to

economically important plants or plant processes. In the FY 2005 Request, Plant Genome Virtual Centers will be funded at $36.0 million, equal to the FY 2004 Estimate.

CAPABILITY ENHANCEMENT

- Support for Capability Enhancement activities such as Research Opportunity Awards (ROA) and Research at Undergraduate Institutions (RUI) will continue at $17.82 million in FY 2005.

TOOLS (+$270,000, for a total of $106.71 million)

BIO Tools Investments
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Change over FY 2004 Percent
Facilities	1.20	5.20	5.20	0.00	0.0%
Infrastructure and Instrumentation	100.54	101.24	101.51	0.27	0.3%
Total, BIO Tools	$101.74	$106.44	$106.71	$0.27	0.3%

FACILITIES

- In FY 2004, the NEON Coordinating Consortium (NCC) and Project Office development is proposed to be initiated. These units will refine the NEON project, scope, budget, and schedule for research infrastructure. In FY 2005, $4.0 million in R&RA will provide support for finalizing development of the NCC and Project Office, and for funding research on enabling technologies.

INFRASTRUCTURE AND INSTRUMENTATION

- Funding for Research Resources, totaling $101.51 million, provides essential support for the core infrastructure needs of the community supported by the BIO Activity. This support includes: multi-user instrumentation, development of instrumentation and new techniques, living stock centers, marine laboratories and terrestrial field stations, databases and support for development of informatics tools and techniques.

ORGANIZATIONAL EXCELLENCE (+$600,000, for a total of $4.72 million)

Organizational Excellence provides for administrative activities necessary to enable NSF to achieve its strategic goals. Requested funding for FY 2005 is $4.72 compared to $4.12 for FY 2004. This includes support for Intergovernmental Personnel Act appointments (IPAs), IPA's travel and the administrative contracts necessary to conduct program activities.

PRIORITY AREAS

In FY 2005, BIO will support research and education efforts related to broad, Foundation-wide priority areas in Biocomplexity in the Environment, Nanoscale Science and Engineering, Mathematical Sciences, and Human and Social Dynamics.

Biological Sciences Investments in NSF Priority Areas
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Change over FY 2004 Percent
Biocomplexity in the Environment	26.00	39.86	39.86	0.00	0.0%
Nanoscale Science and Engineering	2.98	5.31	5.85	0.54	10.2%
Mathematical Sciences	0.91	2.21	2.21	0.00	0.0%
Human and Social Dynamics	N/A	0.50	0.50	0.00	0.0%

Information Technology Research as an NSF Priority Area will be terminated in FY 2004. In keeping with the incubating mission of Emerging Frontiers (EF), resources formerly associated with ITR will be distributed across all BIO divisions and used to support cyberinfrastructure activities such as database development and management and information networking. The remaining NSF Priority Areas will be enhanced by $540,000 for a total of $48.42 million.

Biocomplexity in the Environment: A total of $39.86 million will continue support for the Ecology of Infectious Disease, Microbial Genome Sequencing, Tree of Life, and the NSF-wide joint competition.

Nanoscale Science and Engineering: The increase of $540,000, for a total of $5.85 million, will continue support to emphasize development of nano-sensors.

Mathematical Sciences: A total of $2.21 million will continue support for interdisciplinary science and engineering through research on mathematical and statistical challenges posed by large data sets, managing and modeling uncertainty, and modeling complex nonlinear systems; and to foster curriculum development to incorporate mathematics into the study of biology.

Human and Social Dynamics: A total of $500,000 will be provided to support a focus on Modeling Human and Social Dynamics.

QUALITY

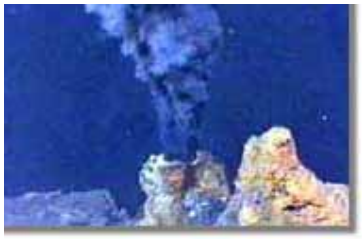
BIO maximizes the quality of the R&D it supports through the use of a competitive, merit-based review process. The percent of research funds that were allocated to projects that undergo external merit review was 97 percent in FY 2003, the last year for which complete data exist.

To ensure the highest quality in processing and recommending proposals for awards, BIO convenes Committees of Visitors, composed of qualified external evaluators, to review each program every three years. These experts assess the integrity and efficiency of the processes for proposal review and provide a retrospective assessment of the quality of results of NSF's investments.

The Directorate also receives advice from the Advisory Committee for Biological Sciences (BIOAC) on such issues as: the mission, programs, and goals that can best serve the scientific community; how BIO can promote quality graduate and undergraduate education in the biological sciences; and priority investment areas in biological research. The BIOAC meets twice a year. Members represent a cross section of biology and include members from institutions and industry. The Committee includes a balanced representation of women, under-represented minorities and geographic regions.

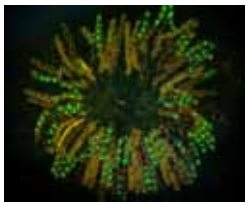
PERFORMANCE

Recent Research Highlights



BIO researchers pushed back the boundary for the existence of life in extreme environments by discovering a **single-celled microbe from a deep-sea hydrothermal vent** in the Pacific Ocean, which survives at temperatures previously thought impossible. The organism thrives at 121° Celsius, or about 250° Fahrenheit, which is well above the 100° C boiling point of water. This discovery provides a clue as to when and where life may have first appeared on Earth and portends a new generation of heat stabile enzymes for industry.

Using advanced infrared and Doppler radar imaging, BIO-supported researchers modeled the population density and foraging behavior of **Brazilian free-tailed bats** in south-central Texas. These aerial predators feed on insects in both natural and managed eco-systems. Using these combined methods, researchers determined that bats from two Texas caves provide pest control service for a number of crops, including cotton and corn. The estimated value of the protection afforded the cotton crop by bats from the two caves amounts to as much as 500 tons of cotton, or $258.0 million dollars annually. This suggests that protecting bat diversity and habitat is not only biologically but also economically desirable.



Neurospora spore cases

Fungi – slime molds and mushrooms among them – are used for food and for the production of industrial chemicals and enzymes. They also rot wood, damage fabric, obscure optics and, as pathogens, injure animals and plants. The recent completion of the **sequencing of the first filamentous fungus (*Neurospora crassa)* genome**, through the cooperative efforts of more than 70 scientists, will facilitate new insights into fungal growth and the production of compounds such as pigments, antibiotics and toxins.

An LTER site used computer modeling and long-term field observations to predict the effect of wildlife management decisions on northern temperate lakes in Wisconsin. The **model integrates long-term field observations and management decision-making** using a simulated lake that can switch between alternate states of lake productivity. Managers used two different models and as they observed variations from year-to-year, estimated how well each of the models was supported by observed data and then developed policies that responded to environmental conditions to maximize the expected economic value of the lakes.

When a chewing bug bites into a potato, the plant not only produces chemicals that deter the bug from further feeding but also produces volatile compounds that waft to nearby plants and trigger their anti-bug

defenses. Chewing triggers this process by stimulating release of a protein called systemin from the chewed tissues. Researchers recently isolated **the sensor protein that detects systemin from damaged tissue**. Furthermore, the gene for the sensor protein from potato was similar to genes in *Arabidopsis*, even though *Arabidopsis* appeared to lack the systemin response. This suggests that systemin-type defenses are more widespread in plants than thought previously. This finding is a key advance in understanding how plants defend against insect attack, and holds immediate promise for reducing pesticide use in agriculture.

A BIO-supported CAREER researcher developed a model to predict multi-scale interactions and ecological consequences of human activities and then used it to **model the loss of panda habitat in China**. A significant finding was that human population growth alone was not a good index of local resource consumption. Rather, changing demographic and socioeconomic factors contribute disproportionately to environmental degradation. These results can guide biodiversity management with regard to the impact of human social dynamics.

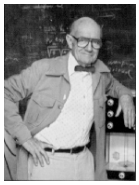
Two basic hypotheses have arisen to explain **forest biodiversity**. One theory holds that stabilizing forces are required for many species to coexist, i.e. if one species is limited by light, and another by moisture, they coexist because their competition is minimal. The alternative 'neutral model' hypothesizes that time is the critical factor in competition between similar species but eventually the better competitor would drive the other species to extinction. Direct observations to distinguish which model is correct would take centuries, so researchers used a clever blend of long-term data on tree pollen extracted from ancient lake sediments and statistical modeling to test the opposing hypotheses. Their findings indicate that stabilizing processes are more important than previously thought, and that the human-caused loss of species could upset that stability in ways that remain poorly understood.

How reptiles evolved into flying birds has been hotly debated since the 1800's. One theory holds that ground-dwelling animals developed feathered wings to allow them to become airborne while the opposing theory is that as tree-dwelling animals leapt from limb to limb they eventually developed gliding structures to soften their landings. Recently researchers discovered that the transition from ground travel to flight may have involved a “ramp-up” phase in which the rapid movement of the animals appendages was used to gain more foot traction as they ran up vertical slopes. The researchers observed hatchlings that could not yet fly used “wing-assisted incline running” (WAIR) to climb a 50-degree incline. Adult birds used their wings to defy gravity keeping their bodies secured to the underside surface of a 105-degree overhang. Thus, WAIR in modern-day birds may be a remnant from prehistoric ancestors and represent the intermediate stage in the development of flight-capable wings.

One ITR project of note is **SEEK (Science Environment for Ecological Knowledge),** a project involving an international multidisciplinary team of ecologists, computer scientists, and technologists focused on inventing and implementing a global computing infrastructure for environmental biology. This project is yielding fundamental improvements on how researchers can gain global access to data and information, rapidly locate and utilize distributed computational services, and exercise powerful new methods for capturing, reproducing, and extending the analysis process itself.

Awards to BIO researchers

MIT researcher, Dr. Angelika Amon, received the NSF Waterman Award in May 2003 for her groundbreaking research on cell cycling. Born in Austria in 1967, she earned her bachelor's and doctoral degrees at the University of Vienna. She first came to the U.S. in 1994 for postdoctoral studies. Her research helped to identify the means by which yeast cells precisely regulate the replication of chromosomes during cell division.



Dr. John Fenn, from the Virginia Commonwealth University, received the 2002 Nobel Prize for the development of methods for identification and structure analyses of biological macromolecules. BIO supported Dr. Fenn's research to develop and use mass spectroscopic methods for research on the conformation of protein molecules.

Dr. Carl R. Woese, professor of microbiology at the University of Illinois at Urbana-Champaign, won the 2003 Crafoord Prize for Biosciences for his discovery of the third domain of life, called Archaea. The traditional paradigm of life contained two domains, prokaryotes (e.g. bacteria) and eukaryotes (protests, fungi, plants and animals). Using comparative sequence analysis of ribosomal RNA, Dr. Woese was able to determine that within prokaryotes there existed an evolutionarily distinct group. Dr. Woese also won the National Medal of Science for this research.

Dr. Dick McCombie, Cold Spring Harbor Laboratory, right, received the award on behalf of IRGSP

On June 25, 2003 the World Technology Network (WTN), which is comprised of over 700 individuals and organizations from over 50 countries focused on the business or science of bringing emerging technologies into reality, selected the International Rice Genome Sequencing Project (IRGSP) as the winner of the 2003 World Technology Award in Biotechnology (Corporate Division). The IRGSP is a collaboration of 10 countries or regions, including BIO-supported U.S. researchers. In December 2002, this consortium announced the completion of a high-quality draft sequence of the rice genome. The sequence data, now freely available on the Internet, is expected to induce innovative research on rice, which serves as the staple food for over half the world's population.

Other Performance Indicators

The tables below show the change in the number of people benefiting from BIO funding, and trends in the award size, duration and number of awards.

Number of People Involved in BIO Activities

	FY 2003 Estimate	FY 2004 Estimate	FY 2005 Estimate
Senior Researchers	3,346	3,332	3,264
Other Professionals	1,729	1,722	1,676
Postdoctorates	1,455	1,469	1,469
Graduate Students	2,704	2,750	2,795
Undergraduate Students	2,854	2,687	2,690
K-12 Students			
K-12 Teachers	36	125	125
Total Number of People	12,124	12,085	12,019

BIO Funding Profile

	FY 2003 Estimate	FY 2004 Estimate	FY 2005 Estimate
Statistics for Competitive Awards:			
Number	1,448	1,443	1,404
Funding Rate	26.0%	25.9%	24.9%
Statistics for Research Grants:			
Number of Research Grants	871	868	845
Funding Rate	21.0%	20.0%	19.0%
Median Annualized Award Size	$126,900	$138,066	$140,250
Average Annualized Award Size	$177,392	$181,667	$190,750
Average Award Duration, in years	3.2	3.2	3.3

MOLECULAR AND CELLULAR BIOSCIENCES $124,980,000

The FY 2005 Request for the Molecular and Cellular Biosciences (MCB) Subactivity is $124.98 million, an increase of $3.21 million, or 2.6 percent, above the FY 2004 Estimate of $121.77 million.

Molecular and Cellular Biosciences Funding
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Change over FY 2004 Percent
Molecular & Cellular Biosciences Research Projects	121.89	121.77	124.98	3.21	2.6%
Total, Molecular & Cellular Biosciences	$121.89	$121.77	$124.98	$3.21	2.6%

The overarching goal of **21st Century Biology** is to understand life at both its most fundamental level and in all its complexity. MCB supports research on the fundamental properties and dynamics of living cells and their components and how those components work together to carry out the complex processes of life. The research supported by MCB addresses questions about how living cells are organized, communicate, and respond to internal and environmental signals, and explores subjects ranging from the diversity of microbes that populate every imaginable habitat on Earth, to the cells that make up the specialized tissues of multi-cellular plants and animals.

Exciting advances in genomics, informatics, computer science, mathematics, physics, chemistry, and engineering offer the tools that make it possible to realize these ambitious goals. MCB is forging partnerships across disciplines to introduce new analytical and conceptual tools, especially cyberinfrastructure tools, to the biological scientist, as well as to provide unique training environments for the scientists of the future.

Research and education at the interface of biology and the physical sciences: MCB core activities support research on the structure, mechanisms of action, and control of the molecules that represent the machinery of the living cell. Partnerships generated among the core activities of MCB and Mathematical and Physical Sciences (MPS) subactivities will emphasize support for beginning investigators whose integrated research and teaching activities bridge this interface.

Living Networks: Theoretical, computational, and mathematical modeling approaches are playing increasingly critical roles in all areas of the molecular and cellular biosciences - in formulating and testing physical and mathematical models of the structure and function of complex molecules and cellular processes; in analysis of genome data; and in addressing one of the greatest computational challenges facing 21st Century Biology, creating multi-scale models that can integrate our understanding of biological structure, function, and interactions at all levels into a predictive whole. MCB is partnering with programs in the Engineering Directorate to promote research and training in this area.

In FY 2005, core activities in the MCB Subactivity are increased by $3.21 million, or 2.6 percent. Within the constraints of this increase current emphases will be maintained.

Highlights of areas supported:

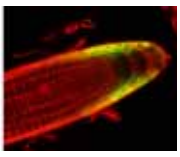
Research and education at the interface of molecular and environmental biology: Originally imported from Europe, the spotted knapweed has now become widely distributed over millions of acres of rangeland. Its advance is threatening ranches in the Midwest and the West. A plant biochemist and two ecologists worked together to unlock the secret of the mechanism behind the successful invasion of this weed. They found that this plant with beautiful purple flowers has a deadly effect on its neighbors by secreting a chemical, catechin, from its roots. Catechin is deadly to most plants, but not to the knapweed itself. The researchers found that the mechanism of catechin's toxicity is that in susceptible plants it activates a signaling pathway that produces toxic "reactive oxygen" that kills their roots. Turning to the tools of genomics the researchers found in the genome of the model plant, Arabidopsis, a gene that determines sensitivity to catechin. This work offers clues to strategies for interfering with the spread of this invasive species.

Spotted Knapweed

Microbial Biology: Core activities and the Microbial Observatories program encourage research on microbes at all levels of biological organization. Genome-enabled and biochemical approaches are being used to identify and characterize attributes of microbes, most of which have never before been described. Analysis of microbial genomes is leading to discovery of new organisms and to appreciation of the diversity of their metabolic functions that enable them to occupy diverse habitats and to interact in complex communities. These efforts are consistent with priorities of the interagency effort, "The Microbe Project."

It has long been assumed that in winter when the tundra is covered with snow the microbes living in the soil are dormant. Research from one of the Microbial Observatories has shown that the opposite is true. Populations of fungi covered by snow in the Colorado mountains are more active in winter. The metabolism of snow-covered microbes serves as an important "sink" for nitrogen. Release of nitrogen from the microbial sink in the spring may serve as ready fertilizer for the tundra-dwelling plants, which have a short growing season. In addition, the fungi discovered in this study belong to totally new groups, thus our appreciation for the diversity of fungi has been expanded by this project.

"2010 Project:" Unsolicited research led to the discovery of the value of *Arabidopsis thaliana* as a model flowering plant. Recently published research has provided a gene expression map of the Arabidopsis root. This map shows where and when about 22,000 of the estimated 28,000 total genes of Arabidopsis are active within the root. This level of resolution of gene expression on a global basis has not thus far been achieved for any other organism. The MCB Subactivity will continue to support research enabled by the availability of the complete genome sequence of *Arabidopsis* to determine the functions of all the genes of this model flowering plant by the year 2010.



Arabidopsis root tip

INTEGRATIVE BIOLOGY AND NEUROSCIENCE $110,630,000

The FY 2005 Budget Request for the Integrative Biology and Neuroscience (IBN) Subactivity is $110.63 million, an increase of $3.22 million, or 3.0 percent, above the FY 2004 Estimate of $107.41 million.

Integrative Biology and Neuroscience Funding
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Change over FY 2004 Percent
Integrative Biology & Neuroscience Research Projects	107.47	107.41	110.63	3.22	3.0%
Total, Integrative Biology & Neuroscience	$107.47	$107.41	$110.63	$3.22	3.0%

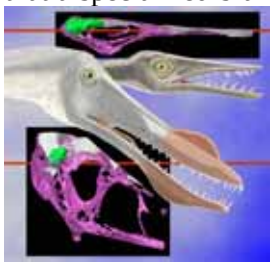
Totals may not add due to rounding.

Research supported by the Integrative Biology and Neuroscience Subactivity focuses on organisms, with particular emphasis on the mechanisms by which organisms develop, grow, reproduce, regulate their physiological activity, respond to their environment, and evolve. Understanding organisms requires integration of molecular, subcellular, cellular, and functional genomics information gathered in both laboratory and natural settings. It can also require advanced computational techniques and interdisciplinary perspectives from other areas of biology, the physical sciences, mathematics, engineering, and computer science. The development and use of a wide diversity of organisms contributes to both identifying unifying principles common to all organisms and documenting the variety of mechanisms that have evolved in specific organisms.

In FY 2005, core activities in the IBN Subactivity are increased by $3.22 million. IBN will emphasize 21st Century Biology projects that are multidimensional, multidisciplinary, and integrative, to understand the development, physiology, neurobiology, behavior, and evolution of living organisms. Because these projects will be data-driven, IBN will increase support for new ways to manage and analyze data.

Highlights of areas supported:

Brain scans of extinct reptiles. Pterosaurs, which emerged as the first flying vertebrates during the age of dinosaurs, could grow as large as an airplane but soared through the skies with ease. Research suggests that a specialized brain and inner ear structure helped these ancient reptiles to fly and target their prey, a finding that could give scientists insight into the evolution of the brain and visual system. Fossils of pterosaurs, which lived during the Mesozoic Era, are being examined by running fossil skulls through a high-resolution CT scanner and using sophisticated computer graphics software to reconstruct the brain cavity and inner ear canals. These scans can be compared with skulls of alligators and birds, which are the closest living relatives of pterosaurs, to test hypotheses on how evolutionarily similar, but still quite distinct, animals adapted to live in the air.

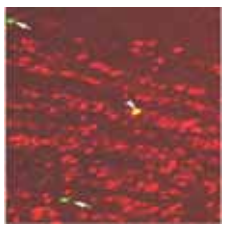


Paternal care as an ancient trait in primates: Behavior plays a pivotal role in survival and reproduction. Baboons in east Africa are providing a comprehensive picture of how behavior shapes fitness outcomes and population processes. Adult males and females do not form permanent bonds, and males have no easy way to tell which infants in the group are their own offspring. When biologists and anthropologists, jointly supported by BIO and SBE, performed DNA paternity tests, they surprisingly found that males provided far more care to their own offspring than to non relatives. This project also provides research and educational opportunities for American and Kenyan students and supports active collaborations between researchers in both countries.

Plants make their own aspirin to fight disease: Plant disease causes an estimated loss worldwide of $100 billion annually. A variety of strategies are being developed to protect plants against disease, including induction of the plant's own defense. Gaining an understanding of the mechanisms of acquired immunity against pathogens could reduce the effects of disease in agricultural systems and in managed forests. Research has established that acetylsalicylic acid (aspirin) is made inside Arabidopsis cells in response to viral attack and that it plays a critical role in providing immunity to the entire plant. This research breakthrough shows that plant immuno-response systems share traits with animal immuno-response systems. From a practical perspective, plant immunity has tremendous implications for the resistance of plants to pathogens. To control these pathogens we currently apply chemicals on our fields. Insight into how the immunity process works suggests ways to amplify this immune response, so that chemical use may be decreased.

Identifying the signal from mother to embryo that initiates pregnancy: Failure to implant is a major cause of doomed pregnancies in mammals. Research on basic reproductive physiology will improve our knowledge of embryo implantation. One characteristic of many carnivorous species is tight control of the timing of implantation. In the black bear and spotted skunk, for example, embryo implantation occurs months after fertilization, with the blastocyst in an inactive state in the interim, a phenomenon called delayed implantation. Because of their domestication and relative abundance, domestic ferrets provide an excellent model to study implantation in carnivores. Researchers have identified a protein called GPI, produced by the female, that triggers the implantation of the embryo into her uterus. In addition, this research is helping to train students in new methodologies by combining whole-organism and molecular approaches to answer important questions in reproductive endocrinology.

New cells in adult mammalian brain can make functional connections: Previously, researchers had made the startling discovery that the adult brain can produce new cells and that cells made in particular regions of the brain migrated within the forebrain and differentiated into neurons. But did the new cells make functional connections and respond to environmental factors? Using adult male hamsters, researchers recently discovered that new brain cells made functional connections and were activated when females were placed near the males. Apparently, testosterone produced in response to the proximity of the females was important for activation and survival of the new cells. These discoveries significantly enhance our understanding of neuron production, migration and death.



Arrows indicate new cells in adult hamster brain

ENVIRONMENTAL BIOLOGY $111,480,000

The FY 2005 Request for the Environmental Biology (DEB) Subactivity is $111.48 million, an increase of $3.22 million, or 3.0 percent, above the FY 2004 Estimate of $108.26 million.

Environmental Biology Funding
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Change over FY 2004 Percent
Environmental Biology Research Projects	108.28	108.26	111.48	3.22	3.0%
Total, Environmental Biology	$108.28	$108.26	$111.48	$3.22	3.0%

The Environmental Biology Subactivity supports fundamental research to inventory life in the biosphere, comprehend its origins and evolutionary history, and understand the interactions and dynamics of biological communities and ecosystems. Studies can address the species of or genealogical relationships among plants, animals, fungi, and microbes; the flux of energy and materials in ecosystems; and the principles or rules by which species function in communities and evolve through time.

In FY 2005, core activities in the DEB Subactivity are increased by $3.22 million to enhance support for research that addresses the continuum of questions from evolutionary processes to ecosystem services, consistent with present community strengths and future science and cyberinfrastructure needs. Priority will be given to leveraging new cyberinfrastructure capabilities and bringing innovative tools into the toolkits of environmental biologists. In order to take the information generated by these investigations and transform it into knowledge – within the scientific community and throughout the citizenry – a high priority will be placed on integrating education with research through activities that engage students at all levels from "K to gray."

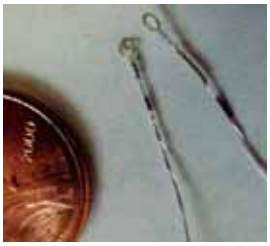
Twenty-first century biology is by its nature anticipatory. Pioneering studies often identify biological questions that later — in the short or long term — become compelling research areas that attract talented investigators across many fields of inquiry. In this context, DEB-supported activities will continue to balance disciplinary and multidisciplinary research needs; focus on what NSF supports uniquely, or uniquely well; provide for ecological and evolutionary synthesis; and diversify and educate the next generation of environmental biologists.

Highlights of areas supported:

Biodiversity Discovery at a Global Scale. With at most one in ten living species known to science, biodiversity inventories are a time-critical research endeavor. A project funded by the new Planetary Biodiversity Inventory (PBI) activity in 2003 brings together more than 200 scientists from 31 countries to inventory the world's catfishes. Results will enhance fundamental knowledge about the earth's biota and help decision makers prioritize areas for protection and make informed freshwater management decisions. PBI grants will transform how scientists discover and document the diversity of entire branches of the tree of life.

CAREER awardee and team develop an Extinction Modeling Toolkit (EMT). This computational modeling toolkit identifies the types of wildlife species and populations at greatest risk of extinction. This allows researchers to investigate the risks of habitat fragmentation, harvest, and deleterious mutations on wildlife populations. Wildlife managers cannot use vast amounts of biodiversity data directly. They require specialized computing tools such as the EMT to focus the data on questions of interest.

Endangered Checkerspot Butterfly



Glucose Sensors

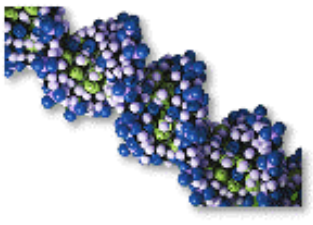
New Tool for Soil Carbon Analysis. Ecologists seek to understand the patterns observed in nature. The addition of molecular and genomics tools, new sensors, broad new informatics capabilities and other advanced techniques are helping investigators explain much variation that exists in ecological processes over space and time. For example, one investigator adapted miniaturized glucose sensors (originally designed for diabetics) for use in non-invasive carbon studies in root zones (rhizospheres).

Studies that cross multiple spatial scales as well as disciplines are increasing. One study of how fish and fisheries depend on watershed inputs and human impacts has linked biology with nuclear physics to apply proton-induced x-ray emission analysis to the study of movements and environmental events in a fish's life. This research is addressing whether incremental economic activities at the watershed level can alter the stability of an ecosystem. Unexpectedly, researchers discovered the heavy metal, selenium, in fish from Onondaga Lake in New York. This lake is known for its severe mercury contamination, and the discovery of selenium in the fish suggests that there may be a second element of concern.

Bursera fagaroides

Molecular tools help researchers tease apart plant/insect interactions. For hundreds of millions of years, there has been a coevolutionary "arms race" between plants and the animals that eat them. Recent work on the coevolution of the plant *Bursera* and its herbivores combines chemical, ecological and phylogenetic techniques. Not only is this work the first to use rigorous molecular analyses for highly diverse, subtropical tree and insect lineages, but it also has led to new insights about adaptation and counteradaptations.

Evolution at the molecular level. Genomics is bringing together molecular and evolutionary biologists to tackle big questions in comparative evolution. The technological advances made in DNA sequencing coupled with the development of algorithms for analyzing gene order rearrangements have allowed construction of new family trees for a broad range of organisms. These new analysis tools will be important for making the best use of the large data sets produced by comparative sequencing projects. Studies of organismal relationships are critical to comparative studies of animal evolution, and provide useful models for understanding plant, fungal, and microbial evolution.



BIOLOGICAL INFRASTRUCTURE $85,470,000

The FY 2005 Budget Request for the Biological Infrastructure (DBI) Subactivity is $85.47 million, an increase of $5.25 million, or 6.5 percent, above the FY 2004 Estimate of $80.22 million.

Biological Infrastructure Funding
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Change over FY 2004 Percent
Research Resources	42.41	48.63	51.38	2.75	5.6%
Human Resources	32.62	31.59	34.09	2.50	7.9%
Total, Biological Infrastructure	$75.03	$80.22	$85.47	$5.25	6.5%

Totals may not add due to rounding.

The goal of the Biological Infrastructure Subactivity is to ensure that essential infrastructure for contemporary research is available to scientists in all areas of biological science for both disciplinary and interdisciplinary efforts. Innovations in infrastructure support, including cyberinfrastructure, are vital to the advancement of 21st Century Biology across the BIO Activity. Resources supported range from physical infrastructure, such as multi-user instrumentation, to research training for students at all levels. In addition, teams of scientists including biologists, mathematicians, physicists, chemists, computer scientists, and engineers are supported to develop new research tools such as software, new algorithms, and novel instrumentation.

Research Resources supports a range of activities including support for the proposed National Ecological Observatory Network (NEON); multi-user instrumentation; the development of instruments with new capabilities, improved resolution or sensitivity; upgrades to biological field stations and marine laboratories; support of living stock collections ranging from microbes to plants and animals; development of biological databases and informatics tools; and research collections in biological sciences. These various research resources provide the essential platforms and tools for effective research in modern biology.

Research Resources will provide infrastructure support of $51.38 million, an increase of $2.75 million above FY 2004, for:

- Support for research resources, totals $51.38 million, an increase of $2.75 million over FY 2004. BIO will expand support for research tools development for the 21st Century Biology, expanding the instrument development activities to include research technique/method development that has the potential to revolutionize biological research.

- Support for NEON totals $4.0 million, equal to the FY 2004 Estimate. Funding will be used for the NEON Coordinating Consortium and Project Office (proposed to begin in FY 2004), NEON project execution planning, and enabling technologies. Construction and instrumentation costs for NEON are discussed in the Major Research Equipment and Facilities Construction chapter.

Human Resources supports a range of activities centered on ensuring adequately and appropriately trained scientists for the future, broadening participation, and fostering the integration of research and education. A total of $34.09 will be provided in FY 2005, an increase of $2.50 million above the FY 2004 Estimate.

- An increase of $2.50 million will be provided for the Integrative Graduate Education and Research Training (IGERT) program, Graduate Teaching Fellows in K-12 Education (GK-12), and Research Experience for Teachers (RET).

- Support will continue for NSF-wide activities such as Research Experiences for Undergraduates (REU) Sites projects and ADVANCE, and for the Undergraduate Mentorship in Environmental Biology (UMEB), and the Cross-disciplinary Research at Undergraduate Institutions (C-RUI) programs, designed to encourage interdisciplinary research experiences for faculty and students at predominantly undergraduate institutions.

Highlights of areas supported:

Federated Distributed Databases. Several crucial database infrastructure communities are being developed within the biological sciences. One is the DiGIR distributed database community. The DiGIR software and community is now the engine behind such broad reaching federated database resources as HerpNet and Manis. The program has also funded similar systems for the genomics/proteomics community such as MOBY. Taken together these projects have been the major force in biology both in making enormous amounts of essential data available to researchers and in supplying an alternative to large, expensive centralized databases by providing broad access through federation and interoperability.

Unique Site for Field Research and Education. The Archbold Biological Station in Central Florida, according to Archbold's director, is "Florida's attic, where we have this assemblage of species and communities found really nowhere else on Earth." In this scrub of nearly 9,000 acres are more than 40 rare species of plants and animals. Biologists now manage the environment these plants and animals inhabit. Understanding of the habitats and the organisms ranges from extracting DNA to identify the plants and animals, tracking diseases such as West Nile Virus, and investigating the processes that created the habitats. Facilities such as this field station allow biologists to offer programs for public education.

Research Experiences Expose Diverse Students to Science. An example of investment in students under the REU program is a project that targets children of migrant farm workers to encourage them to consider a career in scientific research. During the past summer, ten 1st generation college students who are children of migrant farm worker families successfully completed an intensive summer research in plant science. Students who have never been exposed to research have benefited from the program and view plants from a different perspective.

Students Discover Fish Habits While Learning Scientific Process. The Cross-disciplinary Research at Undergraduate Institutions (C-RUI) program supports a project designed to demonstrate the applicability of using fish otoliths ("ear stones") to determine the environments in which freshwater brown trout have lived. Otoliths "record" the life histories in fish through deposition of minerals, just as tree rings provide information on the life history of trees. The study can have major implications both as a useful scientific tool and in the management of freshwater fish. In the process, students are exposed to principles of biology, hydrology, and chemistry.

EMERGING FRONTIERS $77,900,000

The FY 2005 Budget Request for the Emerging Frontiers (EF) Subactivity is $77.9 million, a decrease of $1.86 million, or 2.3 percent, from the FY 2004 Estimate of $79.76 million.

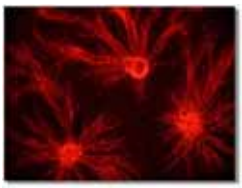
Emerging Frontiers Funding
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Change over FY 2004 Percent
Emerging Frontiers	73.37	79.76	77.90	-1.86	-2.3%
Total, Emerging Frontiers	$73.37	$79.76	$77.90	-$1.86	-2.3%

The Emerging Frontiers Subactivity is an incubator for 21st Century Biology. EF supports multidisciplinary research opportunities and networking activities that arise from advances in disciplinary research. By encouraging synergy between disciplines, Emerging Frontiers provides a mechanism by which new initiatives will be fostered and subsequently integrated into core programs.

Reduced funding in EF is a result of the termination of Information Technology Research (ITR) as an NSF Priority Area. In keeping with the incubating mission of EF, $7.0 million from ITR will be distributed to all BIO divisions in FY 2005 and used to support cyberinfrastructure activities such database development and management and information networking.

In FY 2005 BIO will increase support for Frontiers in Integrated Biological Research (FIBR). FIBR invites new ideas for integrative research on major biological questions from a multidisciplinary point of view. Questions addressed in the first FIBR awards in 2003 include: How do species arise? Do species matter among microbes? Why do some individual cells in the community of slime molds pictured here give up their chance to reproduce so others can? The projects employ boldly creative approaches and draw upon recent breakthroughs in genomics, information technology, high-throughput instrumentation, imaging and wireless technologies, sophisticated sensors, improved GIS systems and other recent advances.



BIO continues support for Research Coordination Networks (RCN), which supports groups of investigators to coordinate their research efforts across disciplinary, organizational, institutional and geographical boundaries. Networks are formed around a focal theme and can involve a broad research question, group of organisms, or particular technologies or approaches.

NSF-wide Priority Areas will be supported out of EF in order to introduce new ideas into these model 21st Century Biology activities and to provide a mechanism through which the priority areas can be integrated with disciplinary activities. Support includes:

Biocomplexity in the Environment (BE) supports research on the dynamics that occur within biological systems and between these systems and the physical environment. Support will continue at the FY 2004 Estimate of $39.86 million for the NSF-wide BE competition as well as for the Tree of Life Project, and two interagency programs, Ecology of Infectious Disease and Microbial Genome Sequencing.

Nanoscale Science and Engineering (NSE) research, focused on studying the structure and regulation of macromolecular machines and macromolecular complexes that are capable of self-replication and self-assembly, will increase by $540,000 to $5.85 million in FY 2005. The increase will specifically support

research on nanoscale biosensors and information processors that could provide new tools for understanding cellular communication and detection of environmentally important signals.

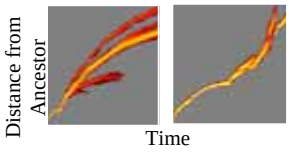
Mathematical Sciences (MSI) will continue to support interdisciplinary research involving mathematics, science and engineering, and focus on mathematical and statistical challenges posed by large data sets, managing and modeling uncertainty, and modeling complex, non-linear systems. Funding will remain at the FY 2004 Estimate of $2.21 million.

Human and Social Dynamics (HSD) will support research in behavior, cognition, development and neuroscience. Funding will remain at the FY 2004 Estimate of $500,000.

Highlights of areas supported:

Multidisciplinary team tackles how plant cell walls form. WallBioNet is a RCN that fosters interactions among biologists, chemists, physicists, and informaticists to understand the biosynthesis of the plant cell wall, an extremely complicated matrix of carbohydrates and proteins. This coordinated effort to address cell wall biosynthesis will lead to fundamental discoveries about plant development and to improvements of cell-wall based products such as fiber, paper, and wood.

Evolution in silico. A team of microbiologists, computer scientists and a philosopher, used an artificial life computer program to create a road map detailing the evolution of complex organisms, an old problem in biology. They found that the path to complex functions is built up from simpler functions, each unremarkable if viewed in isolation. The computer program called Avida, not only reproduces but also performs mathematical calculations to obtain rewards; more computer time that they use for making copies of themselves. Avida is a way to watch evolution, which for living organisms would require thousands of years, in real time. Many computer scientists and engineers are now using processes based on principles of genetics and evolution to solve complex problems, design robots, and more.

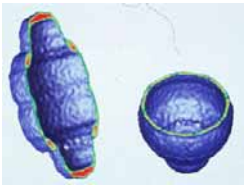


Evolution of Digital Life

Overturning a Paradigm. Humans rely on green plants for food, shelter, clothing, and even the oxygen we breathe. As one of the oldest and most diverse branches of the Tree of Life, green plants provide an unparalleled system in which to approach questions concerning the diversification of life on earth. Tree of Life supported research revealed that the traditional belief that the so-called "land-plant invasion" was led by seawater plants is wrong. Instead, primitive freshwater plants were the ancestors of all green land plants, whether extant or extinct.

Freshwater Elodea plants

One NSE project has studied vaults, small, intracellular particles made of RNA and protein that were discovered almost 20 years ago, but whose cellular function is still a mystery. Recent work has clarified that the structure of these unique, naturally occurring nano-capsules is a hollow cage, with a very thin (about 2 nanometer) shell (see image). The interior volume is large enough to enclose hundreds of proteins. This work points the way to controlled assembly of vaults loaded with small molecules or enzymes useful for measuring or altering metabolism within specific cells. Such modified vaults could be targeted to specific cell types or even to specific sites within cells, and may prove useful both in basic studies of cellular function, and in applications such as biosensing and drug delivery.



PLANT GENOME RESEARCH $89,470,000

The FY 2005 Budget Request for the Plant Genome Research (PGR) Subactivity is $89.47 million, equal to the FY 2004 Estimate.

Plant Genome Research Funding
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Change over FY 2004 Percent
Plant Genome Research Projects	84.45	89.47	89.47	0.00	0.0%
Total, Plant Genome Research	$84.45	$89.47	$89.47	$0.00	0.0%

The Plant Genome Research Subactivity was initiated in FY 1998, building upon an existing base of genome research supported throughout the BIO Activity. PGR supports projects that make significant contributions to our understanding of plant genome structure and function. Emphasis is placed on plants of economic importance, as well as plant processes of potential economic value. Long-term benefits of this research include fundamental breakthroughs in our understanding of plant biology and practical applications to crop improvement, and the development of novel, plant-based products.

The program was established as part of the National Plant Genome Initiative (NPGI). NSF plays a major role in the NPGI. Other participating agencies are USDA, DOE, USAID, and NIH. The NSF program is managed according to the guidelines and objectives of the NPGI, and it works closely with the other agencies in coordinating funding activities.

The National Plant Genome Initiative has issued its new five-year plan for 2003-2008. The FY 2005 Budget Request for PGR will support activities to meet the goals of the new NPGI plan, including:

- **Functional Genomics including Rice Functional Genomics**: Taking advantage of the recently completed sequence of the rice genome by an international consortium, PGR will support efforts to identify the function of all the rice genes and to develop functional genomics tools for rice. These efforts will be coordinated across agencies as well as internationally. Functional genomics research in other plant systems will continue to be supported.

- **Large-scale Sequencing of Genomes of Economically Important Plants**: The recent success in using new methods to concentrate gene-rich regions of large genome species, like maize, for sequencing will likely lead to increased efforts to sequence gene-rich regions of several other economically important plant species.

- **Informatics Tools Development**: Enormous amounts of data on many different aspects of plant genomics are rapidly accumulating. It is critical that seamless ways to access and make use of them by biologists be developed. Training that integrates informatics technologies and plant genomics research is also needed.

- **Interagency Activity on Research Collaboration with Scientists in Developing Countries:** As an important outreach activity for the NPGI, PGR plans to participate in the interagency program to support research collaboration between U.S. scientists and scientists in developing countries with a focus on plant genomics and plant biotechnology. Research will focus on crops important to developing countries such as banana and cassava, and traits critical to developing countries such as drought tolerance and disease resistance.

Highlights of areas supported:

An integrated physical and genetic map of the maize genome. Research resources and research tools have been developed that now make it possible for scientists located anywhere in the U.S. to participate in plant genome research. For example, a five-year project to develop a detailed integrated physical and genetic map for maize has been completed and the map is allowing basic researchers to rapidly locate and clone genes of interest.

Variants of Maize

Sequencing the maize gene space. Maize is the most economically important crop in the US and knowledge of its genome sequence can help improve crop yield and nutritional quality, and expand its uses. The maize genome is large (about the same size as the human genome at almost 3 billion base pairs) and complex, containing islands of genes among the sea of repetitive DNA sequences. Genes account for 1/4 to 1/3 of the genome.

Two Virtual Center projects funded in 2002 are trying several methods to isolate and sequence regions of the maize genome containing genes. Those projects have already released over a million sequences. Many new genes have been discovered in this collection, including genes involved in economically important processes such as flowering and disease resistance. The maize sequencing effort is also pioneering a novel method to sequence large genomes more efficiently.

Studying gene expression in individual cells. A new method, laser capture microdissection, is being used by two projects to select individual cells from specific plant tissues. This method allows for more precise analysis of gene expression than had previously been possible. The data from these studies will be used to develop a gene-expression atlas for rice plants, and to dissect the expression patterns of genes regulating the development of maize shoot meristems, the part of the plant that gives rise to the leaves.

International collaboration in legume genomics. PGR has supported large-scale genome projects that will enable scientists to address major biological questions in plants, such as plant responses to environmental and biological stresses. Many of the projects are conducted by Virtual Centers each of which involves scientists from multiple institutions and disciplines. NSF's investment in plant genome research has stimulated international collaboration, including the international wheat genome research group, the international rice functional genomics consortium, the international tomato sequencing consortium, and the international *Medicago trancatula* (a model legume) research consortium. An international project to sequence the gene-rich portions of the Medicago genome was initiated in FY 2003 with support from PGR and the European Union (EU).

Bringing the excitement of genomics to the classroom. High school teachers are being trained in genomics as part of a project studying the rice pathogen Magnaporthe. Teachers gain hands-on experience in cutting edge genomics research and develop new classroom materials to take back to their schools. The curricular materials are developed in line with state standards.