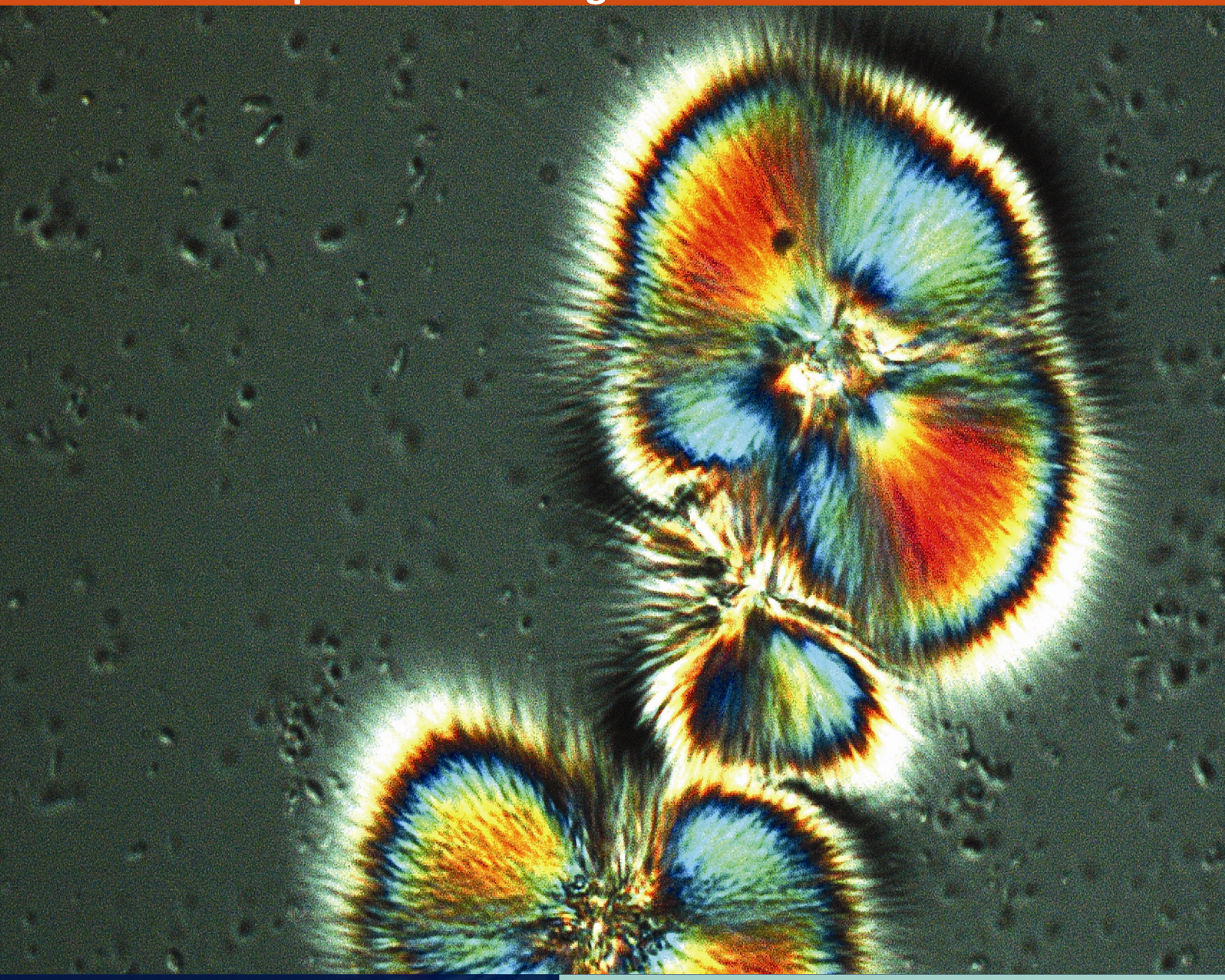
UNITED STATES

National Science Foundation

Excerpts for the Biological Sciences Directorate



FY 2012

BUDGET REQUEST TO CONGRESS

NATIONAL SCIENCE FOUNDATION

FY 2012 Budget Request to Congress

February 14, 2011

About the Cover
Microbe vs., Mineral – Life and Death Struggle in the Desert
Credit: Michael P. Zach, University of Wisconsin-Stevens Point

Although the bursts of rainbow colors in this photograph are mesmerizing, microbes fight for their lives in the background. Chemist Michael P. Zach of the University of Wisconsin-Stevens Point, snapped this image of a salt sample he collected in a hot, arid valley near Death Valley National Park in California. He crushed the salt, placed it under a microscope slide and added a drop of water. Suddenly, a slew of microbes came to life as the salt crystals dissolved. Then when the water started evaporating, he took a picture. The colors come from light passing through the growing crystals, which act like prisms. This image received an Honorable Mention in the 2009 Science and Engineering Visualization Challenge sponsored by NSF and the journal *Science.*

For more information see: www.nsf.gov/news/special_reports/scivis/winners_2009.jsp

NSF Funding by Account

(Dollars in Millions)

	FY 2010 Omnibus Actual	FY 2010 ARRA Actual	FY 2010 Enacted/ Annualized FY 2011 CR[2]	FY 2012 Request	Change Over FY 2010 Enacted Amount	Change Over FY 2010 Enacted Percent
Research & Related Activities[1]	$5,615.33	$439.17	$5,563.92	$6,253.54	$689.62	12.4%
Education & Human Resources	872.77	15.00	872.76	911.20	38.44	4.4%
Major Research Equipment & Facilities Construction	165.90	146.00	117.29	224.68	107.39	91.6%
Agency Operations & Award Management	299.85	-	300.00	357.74	57.74	19.2%
National Science Board	4.38	-	4.54	4.84	0.30	6.6%
Office of Inspector General	13.97	0.05	14.00	15.00	1.00	7.1%
Total, NSF	**$6,972.20**	**$600.22**	**$6,872.51**	**$7,767.00**	**$894.49**	**13.0%**

Totals may not add due to rounding.

[1] Funding for FY 2010 excludes a one-time appropriation transfer of $54.0 million to U.S. Coast Guard per P.L. 111-117.

[2] A full-year 2011 appropriation was not enacted at the time the budget was prepared; therefore, NSF is operating under a continuing resolution (P.L. 111–242, as amended). The amounts included for 2011 reflect the annualized level by account provided by the continuing resolution.

RESEARCH AND RELATED ACTIVITIES (R&RA) $6,253,540,000
+$689,620,000 / 12.4%

The FY 2012 Budget Request for the Research and Related Activities (R&RA) Appropriation is $6,253.54 million, an increase of $689.62 million, or 12.4 percent, above the FY 2010 Enacted level of $5,563.92 million. Support from the R&RA Appropriation enables U.S. leadership and progress across the frontiers of scientific and engineering research and education.

Sustained, targeted investment by NSF in fundamental science and engineering advances discovery and learning and spurs innovation. In addition to the amounts shown above, NSF would also receive $1.0 billion over five years for research on improving access to wireless broadband through the Wireless Innovation (WIN) Fund proposed under the Administration's *Wireless Innovation and Infrastructure Initiative* (WI3). Such transformational work holds great promise for meeting the myriad social, economic, and environmental challenges faced by both the Nation and the world.

In FY 2012, funding within the broad and flexible R&RA portfolio highlights the Administration's priorities for investing in the building blocks of American innovation. It also includes a push to better integrate interdisciplinary research and education and an investment in research in clean energy technology, nanotechnology, and advanced manufacturing.

R&RA Funding

(Dollars in Millions)

	FY 2010 Omnibus Actual	FY 2010 ARRA Actual	FY 2010 Enacted/ Annualized FY 2011 CR[1]	FY 2012 Request	Change over FY 2010 Enacted Amount	Percent
Biological Sciences	$714.77	$0.35	$714.54	$794.49	$79.95	11.2%
Computer & Information Science & Engineering	618.71	-	618.83	728.42	109.59	17.7%
Engineering	775.92	-	743.93	908.30	164.37	22.1%
Geosciences	891.87	0.40	889.64	979.16	89.52	10.1%
Mathematical & Physical Sciences	1,367.95	15.70	1,351.84	1,432.73	80.89	6.0%
Social, Behavioral & Economic Sciences	255.31	0.25	255.25	301.13	45.88	18.0%
Office of Cyberinfrastructure	214.72	-	214.28	236.02	21.74	10.1%
Office of International Science & Engineering	47.84	0.10	47.83	58.03	10.20	21.3%
Office of Polar Programs[2]	451.77	2.23	451.16	477.41	26.25	5.8%
Integrative Activities	274.89	420.15	275.04	336.25	61.21	22.3%
U.S. Arctic Research Commission	1.58	-	1.58	1.60	0.02	1.3%
Total, R&RA	**$5,615.33**	**$439.17**	**$5,563.92**	**$6,253.54**	**$689.62**	**12.4%**

Totals may not add due to rounding.

[1] A full-year 2011 appropriation for this account was not enacted at the time the budget was prepared; therefore, this account is operating under a continuing resolution (P.L. 111-242, as amended). The amounts included for 2011 reflect the annualized level provided by the continuing resolution.

[2] Funding for FY 2010 Enacted excludes a one-time appropriation transfer of $54.0 million to U.S. Coast Guard per P.L. 111-117.

DIRECTORATE FOR BIOLOGICAL SCIENCES (BIO) $794,490,000
+$79,950,000 / 11.2%

BIO Funding
(Dollars in Millions)

	FY 2010 Omnibus Actual	FY 2010 ARRA Actual	FY 2010 Enacted/ Annualized FY 2011 CR	FY 2012 Request	Change Over FY 2010 Enacted Amount	Change Over FY 2010 Enacted Percent
Molecular & Cellular Biosciences (MCB)	$125.90	-	$125.59	$145.72	$20.13	16.0%
Integrative Organismal Systems (IOS)	216.32	-	216.25	231.65	15.40	7.1%
Environmental Biology (DEB)	142.50	-	142.55	156.40	13.85	9.7%
Biological Infrastructure (DBI)	127.19	0.35	126.86	135.95	9.09	7.2%
Emerging Frontiers (EF)	102.85	-	103.29	124.77	21.48	20.8%
Total, BIO	**$714.77**	**$0.35**	**$714.54**	**$794.49**	**$79.95**	**11.2%**

Totals may not add due to rounding.

About BIO

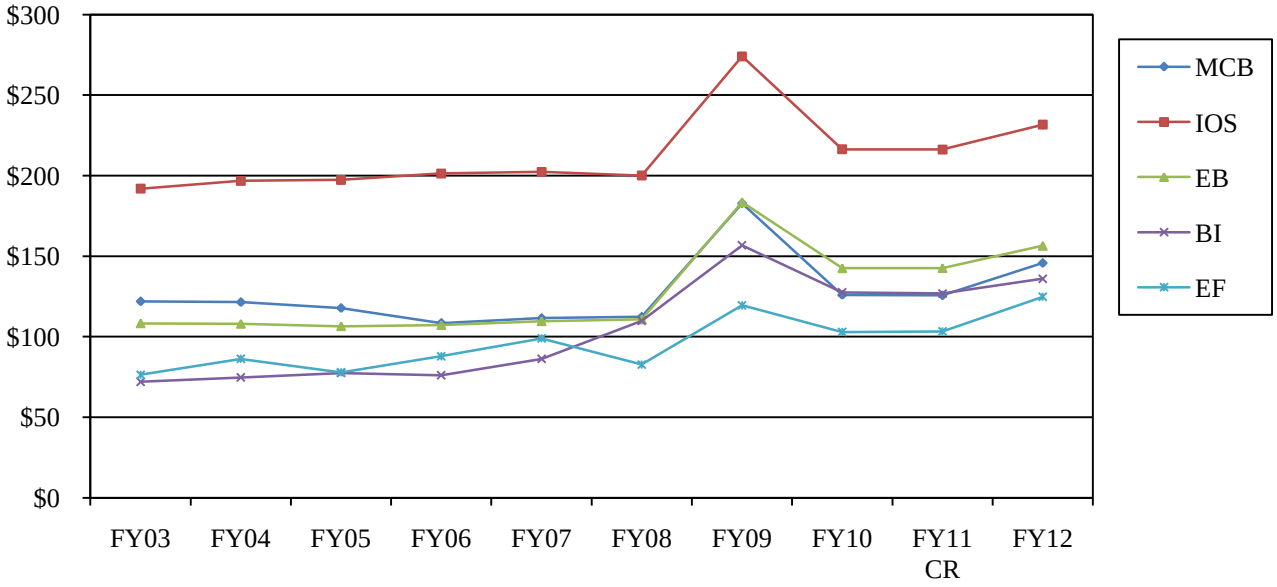
BIO's mission is to enable discoveries for understanding life. Through investments in innovative and transformative research, BIO advances the frontiers of knowledge in the life sciences by increasing our understanding of complex living systems. BIO-supported projects also provide the theory, data, and other research resources that advance research in other science and engineering fields. These fields are adapting and employing principles and processes derived from biological systems to answer fundamental questions, develop practical applications, and solve problems.

Issues of national importance related to the environment, economy, agriculture, and human welfare require an understanding of how complex living systems function and interact with each other and with non-living systems. Research supported by BIO enhances this understanding. As the physical, computational, mathematical, and engineering fields increasingly use living systems to address their major questions, NSF's robust investment in the non-medical biological sciences becomes increasingly relevant to tackling these multidisciplinary challenges.

Biological concepts are integral to wide-ranging areas of science essential to human welfare and the bio-economy, including national priorities such as climate science, biotechnology, and bioengineering. Over the last 3.5 billion years, living organisms have evolved mechanisms for efficiently using energy, producing an endless array of novel compounds, and storing information in a highly compact, adaptable format. Fundamental biological research makes these innovations available to inform the next generation of nano-, bio-, and information technologies. For example, research funded through a BIO CAREER award recently showed that simple and efficient algorithms can be developed using insights derived from discoveries about how a nervous system develops. BIO's investment portfolio includes projects on understanding the changing dynamics of the biosphere, research on the fundamental characteristics of biological energy systems, and efforts to broaden participation and develop the next generation of biological researchers.

BIO provides about 68 percent of federal funding for non-medical, basic research at academic institutions in the life sciences, including environmental biology, a research area critical for addressing questions related to climate science.

BIO Subactivity Funding
(Dollars in Millions)



FY 2012 Summary by Division

- Across all BIO divisions, the FY 2012 Request reflects enhanced support for Science, Engineering, and Education for Sustainability (SEES), including a priority investment in clean energy and support for the Research at The Interface of the Biological, Mathematical, and Physical Sciences (BioMaPS) program. In addition, MCB, IOS, DEB, and DBI support the CAREER program.

- MCB's FY 2012 requested increase of $20.13 million, or 16.0 percent, reflects enhanced support for fundamental research to understand the dynamics and complexity of living systems at the biochemical, molecular, and cellular level. Within this increase, MCB will contribute to advanced manufacturing research via BioMaPS and the National Nanotechnology Initiative. MCB will also participate in the BioMaPS and SEES activities by supporting fundamental research on the components and processes that comprise and control biological systems at the nano to cellular scales. These interdisciplinary efforts will result in accelerated understanding of biological systems, leading to innovations in manufacturing in such areas as renewable fuels, bio-based materials, bio-imaging, and bio-inspired sensors.

- IOS's FY 2012 requested increase of $15.40 million, or 7.1 percent, is aimed at fundamental research on organisms as complex integrated systems, and their interactions with their social and physical environments especially as they adapt to climate variability and other environmental factors. IOS also maintains its commitment to support for fundamental plant genome research. The activities of the Plant Genome Research Program (PGRP) support genome-scale research to accelerate discoveries about basic plant biology, as well as downstream applications of societal benefit such as crop improvement, new sources of bio-based energy, and development of novel bio-based materials. IOS will also participate in BioMaPS and SEES by supporting research on novel energy capture and transduction systems.

- DEB's FY 2012 requested increase of $13.85 million, or 9.7 percent, will provide support for research on complex ecological and evolutionary dynamics to improve our ability to understand the reciprocal interactions between living systems and the environment, and inform essential considerations of environmental sustainability. The increase also reflects the Administration's focus on climate science research and support for the NSF-wide investment in SEES, including programs that enhance our understanding of the diversity of life on Earth and basic research and related activities that enhance fundamental understanding of the complex interactions within and among natural and human systems, with special emphasis placed on the coupling between human and natural systems.

- DBI's FY 2012 requested increase of $9.09 million, or 7.2 percent, empowers biological discovery by supporting the development and enhancement of biological research resources, human capital, and centers. It also reflects funding for the new NSF investment, Cyberinfrastructure Framework for 21st Century Science and Engineering (CIF21). Within this increase, DBI will contribute to clean energy research via support for the SEES Sustainability Research Networks, which link together networks of researchers exploring the intersection of environmental, energy, and economic understanding needed for long term sustainability.

- EF's FY 2012 requested increase of $21.48 million, or 20.8 percent, enhances support for developing priorities. In FY 2012, these are: focused activities within SEES; oversight and management of NEON, including the start of NEON operations; and coordination of cross-directorate innovation activities. It also reflects support for NSF's CIF21 investment. EF will also contribute to clean energy and advanced manufacturing research through support for BioMaPS.

Major Investments

BIO Major Investments

(Dollars in Millions)

Area of Investment	FY 2010 Omnibus Actual	FY 2010 Enacted/ Annualized FY 2011 CR	FY 2012 Request	Change Over FY 2010 Enacted Amount	Change Over FY 2010 Enacted Percent
SEES Portfolio	$121.00	$121.00	$146.00	$25.00	20.7%
Clean Energy	28.20	28.20	55.10	26.90	95.4%
CAREER	30.60	29.06	33.01	3.95	13.6%
BioMaPS	-	-	32.57	32.57	N/A
Advanced Manufacturing	-	-	10.00	10.00	N/A
CIF21	-	-	6.00	6.00	N/A

Major investments may have funding overlap, and thus should not be summed.

- BIO will participate in SEES by funding activities that will generate discoveries, advances, and capabilities in climate and energy science, engineering, and education to inform societal decisions needed for future environmental and economic sustainability and sustainable human well-being. Increased funding will be directed across all BIO divisions, reflecting a broad portfolio of support for Sustainability Research Networks, research on Sustainable Energy Pathways, Postdoctoral Fellowships in Sustainable Solutions, Dynamics of Coupled Natural Systems and the Dimensions of Biodiversity program.

- BIO will support Foundation-wide clean energy activities by funding research projects and Sustainability Research Networks that increase fundamental knowledge about how organisms capture and convert energy, which can form the basis to: imagine, invent, and deploy novel energy systems; explore alternative energy sources and technologies that can sustain a high quality of life on Earth; and investigate novel pathways for human energy futures built on a comprehensive understanding of risks and stressors related to environmental, biospheric, and societal responses associated with new energy pathways. Funding is split between MCB, IOS, EF, and DBI for this priority in FY 2012.

- BIO supports the CAREER program, an Administration priority. BIO's CAREER awards support young investigators who exemplify the role of teacher-scholars through outstanding research, excellent education, and the integration of education and research within the context of the mission of their organizations.

- In FY 2012, BIO will support the BioMaPS program, which seeks to integrate research at the intersections of the biological, mathematical and physical sciences, and engineering in order to discover, understand, and harness new knowledge to improve the human condition and our ability to adapt to a changing world. Research foci include discovering new physical, chemical, and mathematical principles driven by biological interactions; applying chemical and engineering principals to design and construct novel molecular and cellular systems for more efficient computational devices, complex circuits and networks, and new biomaterials; and developing novel nano-scale technologies that sense, collect, measure, and analyze information in real time. Enhanced support spans all BIO divisions.

- In FY 2012, BIO will support NSF's advanced manufacturing activities through funding in IOS, MCB, and EF. A portion of the new investment will be through BioMaPS. These interdisciplinary efforts will result in accelerated understanding of biological systems, leading to innovations in manufacturing in areas such as bio-based materials and bio-inspired sensors.

- BIO's funding for the new NSF-wide investment, Cyberinfrastructure Framework for 21st Century Science and Engineering (CIF21), will support each of the new programmatic components of CIF21: data enabled science, community research networks, new computational infrastructure, and access and connections to cyberinfrastructure facilities. FY 2012 funding will be split between EF and DBI.

Summary and Funding Profile

BIO supports investment in research and education as well as research infrastructure through support for centers and research resources such as databases and collections. BIO supports one major facility, the National Ecological Observatory Network (NEON), which begins construction in FY 2011; operations will commence late in FY 2012.

In FY 2012, the number of research grant proposals is expected to increase by approximately 20 percent compared to FY 2010 Enacted. BIO expects to award approximately 1,130 research grants in FY 2012. Average annualized award size will increase to reflect increasing costs of research, while duration will be held level with the FY 2010 Enacted.

In FY 2012, funding for Centers represents 5.3 percent of the BIO portfolio. Centers funding will increase with both the establishment in FY 2010 of a new Science and Technology Center (STC), the Bio/computational Evolution in Action Consortium, also known as the BEACON Center for the Study of Evolution, as well as increased support for a new environmental synthesis center to be established in FY 2011.

Funding for facilities, including initiating support for the maintenance and operations of NEON, represents 3.1 percent of the BIO portfolio in FY 2012.

BIO Funding Profile

	FY 2010 Actual Estimate	FY 2010 Enacted/ Annualized FY 2011 CR Estimate	FY 2012 Estimate
Statistics for Competitive Awards:			
Number of Proposals	8,060	7,150	8,580
Number of New Awards	1,557	1,370	1,557
Regular Appropriation	1,477	1,370	1,557
ARRA	80		
Funding Rate	19%	19%	18%
Statistics for Research Grants:			
Number of Research Grant Proposals	6,690	6,080	7,359
Number of Research Grants	1,130	930	1,130
Regular Appropriation	1,129	930	1,130
ARRA	1		
Funding Rate	17%	15%	15%
Median Annualized Award Size	$171,723	$165,500	$192,330
Average Annualized Award Size	$221,637	$206,500	$248,233
Average Award Duration, in years	3.1	3.1	3.1

BIO Funding for Centers Programs and Facilities

BIO Funding for Centers Programs

(Dollars in Millions)

	FY 2010 Omnibus Actual	FY 2010 Enacted/ Annualized FY 2011 CR	FY 2012 Request	Change Over FY 2010 Enacted Amount	Change Over FY 2010 Enacted Percent
Centers Programs	$33.63	$33.62	$41.71	$8.09	24.1%
Centers for Analysis & Synthesis	22.52	22.52	25.61	3.09	13.7%
Nano Centers	5.11	5.10	5.10	-	-
Science & Technology Centers	4.00	4.00	9.00	5.00	125.0%
Science of Learning Centers	2.00	2.00	2.00	-	-

No FY 2010 obligations for centers were made with funds provided by the ARRA.

Detailed information on individual centers can be found in the NSF-Wide Investments chapter.

Centers Programs

- Funding for the Centers for Analysis and Synthesis increases by $3.09 million over the FY 2010 Enacted level, to a total of $25.61 million. The program will support four centers in FY 2012, two of which are supported jointly with the Directorate for Mathematical and Physical Sciences (MPS). The increased support includes annual increments and a planned ramp up for the new environmental synthesis center that will be established in FY 2011.

- In addition to the Science and Technology Center for Microbial Oceanography: Research and Education (C-MORE), BIO will support the BEACON Center for the Study of Evolution in Action. BEACON is a consortium of universities led by Michigan State University, with partner institutions of North Carolina A&T State University, the University of Idaho, the University of Texas at Austin, and the University of Washington. BEACON's mission is to illuminate the power of evolution in action to advance science and technology, benefit society, and unite biologists, computer scientists, and engineers in joint study.

BIO Funding for Facilities

(Dollars in Millions)

	FY 2010 Omnibus Actual	FY 2010 Enacted/ Annualized FY 2011 CR	FY 2012 Request	Change Over FY 2010 Enacted Amount	Change Over FY 2010 Enacted Percent
Facilities	$34.71	$25.80	$23.28	-$2.52	-9.8%
Nanofabrication (NNIN)	0.35	0.35	0.35	-	-
National Ecological Observatory Network (NEON)	34.36	25.45	22.93	-$2.52	-9.9%

No FY 2010 obligations for facilities were made with funds provided by the ARRA.

For detailed information on individual facilities, please see the Facilities chapter.

Facilities

- Construction on NEON begins in FY 2011, with funding from the Major Research Equipment and Facilities (MREFC) account. In FY 2012, NEON operations will begin for the first NEON domain, the calibration and validation laboratory, and the data center.

Program Evaluation and Performance Improvement

The Performance Information chapter provides details regarding the periodic reviews of programs and portfolios of programs by external Committees of Visitors and directorate Advisory Committees. Please see this chapter for additional information.

In FY 2010, BIO held two COVs: one for DBI, and one for the Plant Genome Research Program within IOS. In FY 2011, BIO will hold COV reviews for IOS and MCB. All BIO divisions are responding to and implementing recommendations from recent COVs. The BIO Advisory Committee (BIO AC) met twice in 2010, in April and October. The second meeting was held at NEON headquarters in Boulder, CO, and included a site review of facilities and discussions with scientific staff. FY 2012 COVs are planned for DEB and EF.

A recent workshop and two recently released reports have been of interest with respect to programmatic portfolio development. The workshop, held on January 6 and 7, 2011, "Research Frontiers in Bioinspired Energy: Molecular-level Learning from Natural Systems," was sponsored by NSF and the Department of Energy (DOE), and was jointly organized by the National Academies of Science (NAS) Boards on Life Sciences and Chemical Sciences and Technology. Its focus was to explore the molecular-level frontiers of energy processes in nature. BIO's senior management is reviewing the recommendations from the Presidential Commission for the Study of Bioethics report, *NEW DIRECTIONS: The Ethics of Synthetic Biology and Emerging Technologies*, as well as the NAS workshop report, *Implementing the New Biology: Decadal Challenges Linking Food, Energy, and the Environment*. These reports will also be evaluated at the spring 2011 BIO AC meeting for potential implementation of recommendations and incorporation into future fiscal year program planning. In addition, the 2010 NAS report, *Research at the Intersection of the Physical and Life Science*, has informed the development of the BioMaPS program in FY 2012.

In FY 2010, BIO initiated a Science and Technology Policy Institute (STPI) study to assess the scientific, technological, economic and societal impacts of NSF/BIO's investments in plant biology research. Final results from this study are expected during FY 2011.

Number of People Involved in BIO Activities

	FY 2010 Actual Estimate	FY 2010 ARRA Estimate	FY 2010 Enacted/ Annualized FY 2011 CR Estimate	FY 2012 Estimate
Senior Researchers	5,791	452	4,547	4,530
Other Professionals	1,727	60	1,838	1,830
Postdoctorates	1,474	4	1,561	1,550
Graduate Students	2,947	9	3,123	3,330
Undergraduate Students	4,641	38	3,995	4,290
Total Number of People	**16,580**	**563**	**15,064**	**15,530**

DIVISION OF MOLECULAR AND CELLULAR BIOSCIENCES (MCB)

$145,720,000
+$20,130,000 / 16.0%

MCB Funding
(Dollars in Millions)

	FY 2010 Omnibus Actual	FY 2010 Enacted/ Annualized FY 2011 CR	FY 2012 Request	Change Over FY 2010 Enacted Amount	Percent
MCB Funding	**$125.90**	**$125.59**	**$145.72**	**20.13**	**16.0%**
Research	**124.78**	**124.89**	**145.02**	**20.13**	**16.1%**
CAREER	*14.12*	*14.06*	*15.86*	*1.80*	*12.8%*
Education	**1.12**	**0.70**	**0.70**	**-**	**-**

MCB supports fundamental research and educational activities that promote understanding of complex living systems at the molecular, subcellular, and cellular levels. Research supported by MCB typically combines integrated theoretical and experimental approaches with technologies derived from biological, physical, mathematical, computational, and engineering sciences. Projects are particularly encouraged in emerging areas such as single molecule or single cell studies, RNA biology, and synthetic biology. The MCB research portfolio also emphasizes projects aimed at understanding and predicting the molecular and cellular foundation of adaptation to environmental change. MCB continues to forge partnerships to support research that intersects biology and fields such as physical sciences and engineering, to introduce new analytical and conceptual tools for biological research, and to provide unique education and training opportunities for the next generation of researchers, scientific educators, and scientifically literate citizens.

In general, 44 percent of the MCB portfolio is available for new research grants. The remaining 56 percent funds continuing grants made in previous years.

FY 2012 Summary

Research

- Maintaining the health of its disciplinary knowledge base is one of BIO's top priorities, which is reflected in requested increases for all divisions. Increased support for basic biological research will yield insights that can be used to produce the next generation of nano-, bio-, and information technologies (+$2.87 million to a total of $144.60 million).
  - The blueprint for the form and function of an organism lies in its DNA and in the way that DNA is expressed as it interacts with its environment. MCB will support research to link the distinctive properties of organisms – from form to physiology to behavior – to the selective expression of their genetic information.
  - As with all BIO divisions, MCB will support BioMaPS in partnership with the Engineering and Mathematical and Physical Sciences Directorates (+$5.40 million to a total of $5.40 million).
- MCB will contribute $5.0 million to advanced manufacturing research via BioMaPS and the National Nanotechnology Initiative by supporting fundamental research on the components and processes that comprise and control biological systems at the nano to cellular scales.
  - Synthetic Biology employs an unconventional approach to understanding living systems by using chemical and engineering principles to design and construct (or reconstruct) functional molecular and cellular systems. MCB will encourage support of interdisciplinary research

employing Synthetic Biology approaches to advance our understanding of living systems and to enhance the quality of life on Earth.

- MCB will also contribute $5.0 million to clean energy research through the BioMaPS and SEES activities to support research on novel processes used by living organisms to capture and transduce energy.
  - MCB will prioritize research of societal importance, particularly related to energy, environment, and the diversity of life on Earth. Fundamental knowledge about how organisms capture and convert energy will help us develop sources of clean energy. For example, research funded by MCB has provided the basis for engineering of a nanoscale biocatalyst that uses light energy to generate hydrogen, a clean energy source. In addition, understanding the molecular and cellular basis for the adaptation of organisms to their environment is essential to understanding the central role of the diversity of life on Earth in adapting to or bringing about environmental change.
- MCB will increase support for CAREER (+$1.80 million to a total of $15.92 million) in accordance with Administration priorities.

Education

- All BIO divisions include support for Research Experiences for Teachers (RET) and Research Experiences for Undergraduates (REU) activities.

DIVISION OF INTEGRATIVE ORGANISMAL SYSTEMS (IOS) $231,650,000 +$15,400,000 / 7.1%

IOS Funding
(Dollars in Millions)

	FY 2010 Omnibus Actual	FY 2010 Enacted/ Annualized FY 2011 CR	FY 2012 Request	Change Over FY 2010 Enacted Amount	Change Over FY 2010 Enacted Percent
IOS Funding	**$216.32**	**$216.25**	**$231.65**	**$15.40**	**7.1%**
Research	**172.04**	**170.25**	**185.65**	**15.40**	**9.0%**
CAREER	*7.83*	*7.00*	*8.00*	*1.00*	*14.3%*
Education	**8.81**	**6.00**	**6.00**	**-**	**-**
Infrastructure	**35.47**	**40.00**	**40.00**	**-**	**-**

IOS supports research and education aimed at understanding the diversity of plants, animals, and microorganisms as complex systems interacting with their environments. Reaching a systems level understanding of organisms will require a new emphasis on interdisciplinary approaches and development of new tools. These approaches span computational, molecular, cellular, individual organism and population levels of inquiry. Many activities supported by IOS focus on biological processes that affect organismal development, structure, performance, and interactions under varying environmental conditions. IOS-supported research focuses on investigating organismal performance in an environmental context, which is significant for understanding reciprocal interactions between living systems and the environment.

The activities of the Plant Genome Research Program (PGRP) support genome-scale research to accelerate discoveries about basic plant biology as well as downstream applications of potential societal benefit such as crop improvement, development of new sources of bio-based energy, development of sources of novel bio-based materials, and adaptation to global climate variability.

The Basic Research to Enable Agricultural Development (BREAD) Program will continue support for basic research to test innovative, early-concept approaches and technologies for sustainable, science-based solution to problems of agriculture in developing countries. BREAD in FY 2012 is supported by NSF ($6.0 million) and the Bill & Melinda Gates Foundation ($6.0 million) through funding provided to NSF.

In general, 55 percent of the IOS portfolio is available for new research grants. The remaining 45 percent funds continuing grants made in previous years.

FY 2012 Summary

Research

- Maintaining the health of its disciplinary knowledge base is one of BIO's top priorities, which is reflected in requested increases for all divisions. In IOS (+$4.95 million to a total of $185.95 million) there is an emphasis on cross-disciplinary, integrated approaches, from the genome to the organism, to understanding complex living systems, especially as they interact with, and adapt to, a changing environment. Enabling research at the interfaces of organismal biology, environmental biology, and molecular and cellular biology, to address major questions in organismal biology and climate science, will be a priority. These studies are expected to extend the understanding of organismal structure and

function at all scales, from the individual to populations. For example, research funded by IOS has shown that tree resins collected by honey bees to fight microbes in the hive aids their immune systems. Local differences in the availability of resin producing trees and genetic behavioral differences in how much resin is collected provide insight into the interaction between these economically important pollinators and their environment at multiple scales.

  - New genomic technologies and computational tools are critical to gaining a mechanistic understanding of such diverse processes as plant development and animal development from elaboration of the nervous system to behavior processes. IOS will support development of critical tools and resources to enable a systems-level understanding of these processes.
  - IOS will continue to support basic research with the potential to yield societal benefits, in such areas as bio-inspired materials, industrial raw materials and new sources of energy. Ongoing genome-scale research within PGRP and BREAD will continue to accelerate basic discoveries with potential downstream applications.

- IOS will support BioMaPS, especially in areas relevant to bio-inspired design (+$4.39 million to a total of $4.39 million in IOS).
- IOS will contribute $5.0 million to clean energy research through BioMaPS and SEES to support research on novel energy capture and transduction systems.
- Responding to the national priority of supporting young investigators, IOS support for CAREER increases (+$1.0 million to a total of $8.00 million).

Education

- All BIO divisions include support for Research Experiences for Teachers (RET) and Research Experiences for Undergraduates (REU) activities.

Infrastructure

- Within infrastructure, the IOS Request includes investments in research resources essential to the plant genome research program.

DIVISION OF ENVIRONMENTAL BIOLOGY (DEB) $156,400,000 +$13,850,000 / 9.7%

DEB Funding
(Dollars in Millions)

	FY 2010 Omnibus Actual	FY 2010 Enacted/ Annualized FY 2011 CR	FY 2012 Request	Change Over FY 2010 Enacted Amount	Change Over FY 2010 Enacted Percent
DEB Funding	**$142.50**	**$142.55**	**$156.40**	**$13.85**	**9.7%**
Research	**139.15**	**140.55**	**154.40**	**13.85**	**9.9%**
CAREER	*4.92*	*4.50*	*5.14*	*0.64*	*14.2%*
Education	**3.35**	**2.00**	**2.00**	**-**	**-**

DEB supports catalytic and transformative research to inventory life on earth, to discover life's origins and evolutionary history, and to understand the dynamics of ecological systems. Ecological systems, in turn, provide goods and services upon which human health and welfare depend (e.g., breathable air, potable water, food and fiber, crop pollination, disease control). Long-term DEB research is critical to understanding the feedbacks between natural and human systems. Scientific foci in DEB address the process of evolution; describe the genealogical relationships of all life; elucidate the spatial and temporal interactions of species interactions that lead functional communities; and determine the flux of energy and materials through ecosystems. This theoretical and empirical research in ecology, evolution, and the diversity of life is enhanced by dynamic interactions with the fields of genomics, computer science, and mathematics.

In general, 51 percent of the DEB portfolio is available for new research grants. The remaining 49 percent funds continuing grants made in previous years.

FY 2012 Summary

Research

- Maintaining the health of its disciplinary knowledge base is one of BIO's top priorities, which is reflected in requested increases for all divisions. Support increases in DEB (+$3.26 million to a total of $153.05 million) for fundamental research on ecological and evolutionary patterns and processes at all spatial and temporal scales in the context of climate science and other environmental factors.
- BioMaPS (+$3.39 million to a total of $3.39 million) supports interdisciplinary research at the intersection of the life and physical sciences, such as theories underlying the interactions at various levels of biological organization, from gene to population to ecosystem.
- Funding for SEES (+$5.0 million to a total of $5.0 million) supports the Dimensions of Biodiversity program and the Dynamics of Coupled Natural and Human Systems.
  - The Dimensions of Biodiversity program will use integrative, innovative approaches to transform how we describe and understand the role and scope of life on Earth. Previous research funded by DEB has demonstrated that species losses in ecosystems due to fragmentation of natural habitats can result in increases in the transmission of infectious diseases such as West Nile virus, Lyme disease, and Hantavirus. Supporting studies to elucidate the functional role of biological diversity, a major knowledge gap, is a central focus of the Dimensions program.
- Responding to the national priority of supporting young investigators, DEB support for CAREER increases (+$640,000 to a total of $5.14 million).

- DEB supports research for which long-term data are critical to address some of our most pressing environmental challenges. Increased support for the Long Term Ecological Research (LTER) program will cover planned annual increments for LTER sites (+$1.5 million to a total of $23.11 million).

Education

- All BIO divisions include support for Research Experiences for Teachers (RET) and Research Experiences for Undergraduates (REU) activities.

DIVISION OF BIOLOGICAL INFRASTRUCTURE (DBI)

$135,950,000
+$9,090,000 / 7.2%

DBI Funding
(Dollars in Millions)

	FY 2010 Omnibus Actual	FY 2010 ARRA Actual	FY 2010 Enacted/ Annualized FY 2011 CR	FY 2012 Request	Change Over FY 2010 Enacted Amount	Change Over FY 2010 Enacted Percent
DBI Funding	**$127.19**	**$0.35**	**$126.86**	**$135.95**	**$9.09**	**7.2%**
Research	**41.68**		**40.80**	**58.35**	**17.55**	**43.0%**
CAREER	*3.72*	-	*3.50*	*4.01*	*0.51*	*14.6%*
Centers Funding (total)	*33.63*	-	*33.62*	*41.71*	*8.09*	*24.1%*
Natl. Ctr for Ecol. Analysis & Synthesis	*3.70*	-			-	*N/A*
Natl. Environmental Synthesis Center		-	*3.70*	*6.00*	*2.30*	*62.2%*
Natl. Evolutionary Synthesis Center	*5.50*	-	*5.50*	*5.35*	*-0.15*	*-2.7%*
Natl. Institute for Math and Bio Synthesis	*2.35*	-	*2.35*	*2.35*	-	-
iPlant	*10.97*	-	*10.97*	*11.91*	*0.94*	*8.6%*
Cntrs. for Enviro. Implications of Nanotech.	*5.11*	-	*5.10*	*5.10*	-	-
STC: Microbial Oceanography: Res. & Ed.	*4.00*	-	*4.00*	*4.00*	-	-
STC: BEACON		-		*5.00*	*5.00*	*N/A*
SLC: Temporal Dynamics of Learning	*2.00*	-	*2.00*	*2.00*	-	-
Education	**27.77**	**0.35**	**26.06**	**17.60**	**-8.46**	**-32.5%**
Infrastructure	**57.74**	-	**60.00**	**60.00**	-	-
NNIN	*0.35*	-	*0.35*	*0.35*	-	-
Research Resources	*57.39*	-	*56.75*	*56.75*	-	-

DBI empowers biological discovery by supporting the development and enhancement of biological research resources, human capital, and centers. In particular, DBI supports the development of, or improvements to, research infrastructure, including instruments, software, and databases; and the improvements to biological research collections, living stock collections, and field stations and marine labs. In addition, DBI funds the development of human capital through support of undergraduate, graduate, and postdoctoral research experiences. Support of center and center-like activities creates opportunities to address targeted but deep biological questions that have major societal impact.

DBI supports research resources that include the development of research tools, acquisition of instrumentation, and infrastructure improvements; human resource activities; and centers. Approximately 45 percent of the DBI budget is available for new awards each year, with approximately 36 percent available for new research grants. Approximately 30 percent supports Centers, while the remainder is distributed through grants for various DBI and BIO priorities and continuing funds for grants made in previous years.

FY 2012 Summary

Research

- DBI will support BioMaPS (+$4.39 million to a total of $4.39 million), focusing on areas such as bio-inspired information technologies and nano-scale bio-sensors.

- BIO will be actively involved in all aspects of the new CIF21 investment, as its components are important to advancement across all of the biological sciences. Support will focus on Data-Enabled Science, but will also be directed to Community Research Networks and Access and Connections to Cyberinfrastructure Facilities (+$3.0 million to a total of $3.0 million).
- CAREER funding in DBI increases by $510,000 to a total of $4.01 million in FY 2012. This increase is consistent with DBI's emphasis on supporting early career researchers.
- The Research Improvement Grants (RIG) program will end in DBI (-$2.0 million), as the program did not receive the increased numbers of proposals from underrepresented groups, as was intended. RIG will be absorbed and supported across the other BIO divisions.
- DBI contributes $5.0 million to clean energy research through support for SEES Sustainability Research Networks to link together networks of researchers exploring the intersection of environmental-energy and economic understanding needed for long term sustainability.

Centers

- As planned, FY 2010 was the final year of funding for the National Center for Ecological Analysis and Synthesis. Support for the new environmental synthesis center that will be established in FY 2011 increases to a total of $6.0 million in FY 2012. The center will stimulate research, education, and outreach at the interface of the biological, geological, and social sciences, and foster synthetic, collaborative, cross-disciplinary efforts.
- Small adjustments are provided for the National Evolutionary Synthesis Center (-$150,000 to a total of $5.35 million) and iPlant (+$940,000 to a total of $11.91 million) as part of existing cooperative agreement annual increments.
- BIO will initiate support (+$5.0 million) for a new STC, the BEACON Center for the Study of Evolution in Action. BEACON unites biologists, computer scientists and engineers in joint study.

Education

- Support for a number of BIO programs, Undergraduate Research Mentoring (URM) and Interdisciplinary Training for Undergraduates in Biological and Mathematical Sciences (UBM) will be eliminated (-$4.10 million), and support is decreased for IGERT (-$3.25 million to a total of $3.25 million). Funding from these reductions will be used to support new biology undergraduate education activities resulting from the recommendations of the "Vision and Change: A Call to Action" conference and report: http://visionandchange.org/files/2010/03/VC_report.pdf. In addition, some new activities will be developed by partnering with the Education and Human Resources Directorate (EHR) on new pilot programs aimed at improving undergraduate STEM education.
- ADVANCE increases (+$70,000 to a total of $2.57 million) in accordance with NSF priorities.

Infrastructure

- DBI investments in infrastructure further advances in all areas of biological research as well as databases, resources, and tools for the entire biology community. For example, historically the amount of animal vocalization and associated species data has been limited, due to the enormous human effort and cost required for field collecting. DBI has funded the development of permanent and portable recording devices and accompanying software to automate species identification, which has made major contributions to the spatial and temporal coverage of animal biodiversity data. These technological advances have allowed for improved collection of biodiversity data that is aiding land managers in assessing ecosystem health and making informed conservation decisions.

DIVISION OF EMERGING FRONTIERS (EF) $124,770,000
+$21,480,000 / 20.8%

EF Funding
(Dollars in Millions)

	FY 2010 Omnibus Actual	FY 2010 Enacted/ Annualized FY 2011 CR	FY 2012 Request	Change Over FY 2010 Enacted Amount	Change Over FY 2010 Enacted Percent
EF Funding	**$102.85**	**$103.29**	**$124.77**	**$21.48**	**20.8%**
Research	**58.52**	**66.94**	**76.94**	**10.00**	**14.9%**
Education	**9.97**	**10.90**	**14.90**	**4.00**	**36.7%**
Infrastructure	**34.36**	**35.45**	**32.93**	**-2.52**	**-7.1%**
NEON	*34.36*	*25.45*	*22.93*	*-2.52*	*-9.9%*

EF identifies, incubates, and supports infrastructure and research areas that transcend scientific disciplines and/or advance the conceptual foundations of biology. For example, research supported by EF found that cockroaches scrambling over rough terrain do not change the neural signals to their leg muscles; instead, control is built into the mechanics of their legs that requires no active adjustments from a brain. This ability to self-stabilize like an extraordinary passive suspension system was predicted by project mathematicians and built into a robot to improve maneuverability. Using a novel model approach, this research team "rewrote" the neural code from the spinal cord to the leg muscles in running cockroaches to tease apart the complex neural and muscular networks, information which was used to revise the mathematical models that were applied to the robot. This fundamental research to understand how animals control legged locomotion is advancing the design of the first search-and-rescue robot that has performance truly comparable to animals.

Typically, developing programs and priority areas begin in EF and then shift to other BIO divisions to become part of the disciplinary knowledge base. Examples include the Assembling the Tree of Life and Ecology of Infectious Diseases programs. Supporting biological research that crosses scales of organization and involves multiple disciplines continues to be a high priority, and is particularly relevant for research questions related to global change. EF also facilitates the development and implementation of new forms of merit review and mechanisms to support transformative research and stimulate creativity. These goals are accomplished by promoting cultural change within and across scientific disciplines to increase and strengthen multidisciplinary collaborations, encourage curiosity and exploration through novel mechanisms and investments, and facilitate support of research areas relevant to all of biology by targeted co-funding throughout the directorate.

In general, 90 percent of the EF portfolio is available for new research grants. The remaining 10 percent funds continuing grants made in previous years.

FY 2012 Summary

Research

- The Advancing Theory in Biology program (-$5.0 million) and the Life in Transition focus (-$10.0 million), after development and growth in EF, now shift to be supported as a mainstream activity across all other BIO divisions.
- The CDI program will end in BIO (-$1.0 million) as support refocuses on CIF21.
- Investment increases include:

- Active involvement in all aspects of the new CIF21 emphasis, as components are important to advancement across all of the biological sciences. Support will focus on Data-Enabled Science, but will also be directed to Community Research Networks and Access and Connections to Cyberinfrastructure Facilities (+$3.0 million to a total of $3.0 million)
- EF will support SEES (+$5.0 million to a total of $5.0 million) through sustainability research networks and the Dimensions of Biodiversity program, which is designed to provide an enhanced and integrated understanding of the key natural variation and function of life on Earth, across genetic, taxonomic, and functional dimensions.
- Continued funding ($10.0 million total) will be provided for an activity in support of digitization of scientific information associated with biological specimens held in U.S. research collections. This program was begun in FY 2009 with funding from ARRA. A strategic plan developed by the community and released in FY 2010 will guide investments in FY 2012.
- Continued support of research activities relevant to NEON, including macrosystems biology, as construction continues on NEON.
- EF contributes $5.0 million to clean energy research via BioMaPS, by supporting research on novel processes used by living organisms to capture and transduce energy.
- EF contributes $10.0 million to advanced manufacturing research via BioMaPS, by supporting research that aims to understand the components and processes that comprise and control biological systems from the nano to cellular scales.

Education

- In FY 2012, BIO is focusing on support for new biology undergraduate education activities, including selected Transforming Undergraduate Biology Education (TUBE) activities with well-developed metrics (+$4.0 million to a total of $14.90 million). This is based on the recommendations of the 2009 "Vision and Change: A Call to Action" conference and report (http://visionandchange.org/files/2010/03/VC_report.pdf). In addition, some new activities will be developed, including partnering with EHR on new pilot programs aimed at improving undergraduate STEM education.

Infrastructure

- In FY 2012, management and operations funding for NEON will commence, assuming a construction start by July 2011. The request for $22.93 million will enable operations of the first two domains constructed, including related management and technical support, seasonal biological sampling, and domain facility costs. Project planning costs conclude as the NEON project transitions into construction and operations.

The National Ecological Observatory Network $87,920,000

The FY 2012 Budget Request for the National Ecological Observatory Network (NEON) is $87.92 million, which represents the second year of a 5-year project that spans six fiscal years and totals an estimated $433.72 million.

Appropriated and Requested Funding for the National Ecological Observatory

(Dollars in Millions)

Prior Years[1]	FY 2010	FY 2010 Enacted/ Annualized FY 2011 CR[2]	FY 2012 Request	FY 2013 Estimate	FY 2014 Estimate	FY 2015 Estimate	FY 2016 Estimate	Total Project Cost[2]
$3.00	-	-	$87.92	$101.07	$103.43	$86.23	$32.07	$433.72

[1] Per P.L. 110-161, $4.0 million was rescinded from prior year unobligated balances.

[2] A full-year 2011 appropriation was not enacted at the time the budget was prepared; therefore, this project is operating under a continuing resolution (P.L. 111-242, as amended). The amounts shown above for 2011 reflect the annualized level provided by the continuing resolution. The FY 2011 Request based on the project's funding profile is $20.0 million. Any FY 2011 funding shortfall might need to be addressed in future budgets and could impact the total project cost and schedule baseline.

NEON will consist of geographically distributed field and lab infrastructure networked via cybertechnology into an integrated research platform for regional to continental scale ecological research. Cutting-edge sensor networks, instrumentation, experimental infrastructure, natural history archive facilities, and remote sensing will be linked via the internet to computational, analytical, and modeling capabilities to create NEON's integrated infrastructure.

Baseline History

In 2004 the National Research Council (NRC) evaluated the original NEON design of loosely confederated observatories and recommended that it be reshaped into a single integrated platform for regional to continental scale ecological research. Congress appropriated a total of $7.0 million through the MREFC account for NEON in FY 2007 and FY 2008, $4.0 million of which was rescinded in FY 2008. A Preliminary Design Review (PDR) was completed in June 2009 and a Final Design Review (FDR) was completed in November 2009. Project planning continues through the first three quarters of FY 2011 until construction start in the fourth quarter of FY 2011. A formal construction baseline review and cost review occurred as part of the FDR, and an additional baseline review will be conducted in April 2011 prior to initiation of construction, to ensure there are no significant changes to cost and the estimated schedule baselines.

Total Obligations for NEON

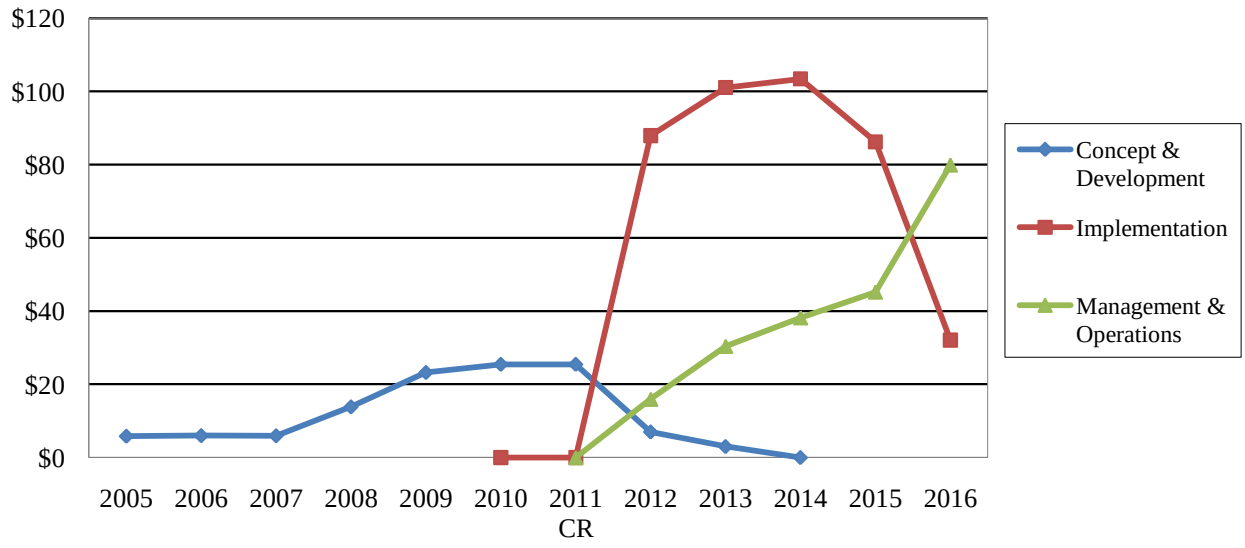
(Dollars in Millions)

	Prior Years	FY 2010 Enacted/ Annualized FY 2011 CR[1]	FY 2012 Request	ESTIMATES FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
R&RA Obligations:								
Concept & Development	$44.84	$25.45	$7.00	$3.00	-	-	-	-
Management and Operations	-	-	15.93	30.39	38.18	45.51	79.91	83.10
ARRA	9.96	-	-	-	-	-	-	-
Subtotal, R&RA Obligations	$54.80	$25.45	$22.93	$33.39	$38.18	$45.51	$79.91	$83.10
MREFC Obligations:								
Implementation	-	-	87.92	101.07	103.43	86.23	32.07	-
Subtotal, MREFC Obligations	-	-	$87.92	$101.07	$103.43	$86.23	$32.07	-
TOTAL Obligations	**$54.80**	**$25.45**	**$110.85**	**$134.46**	**$141.61**	**$131.74**	**$111.98**	**$83.10**

Totals may not add due to rounding.

[1]A full-year 2011 appropriation was not enacted at the time the budget was prepared; therefore, this project is operating under a continuing resolution (P.L. 111-242, as amended). The amounts shown above for 2011 reflect the annualized level provided by the continuing resolution. The total funding presented in the FY 2011 Request is $38.0 million. This includes $23.0 million for construction implementation and $15 million for concept and development. Of the $23.0 million, $20.0 is requested in FY 2011 and $3.0 is available from prior year appropriations. Any FY 2011 funding shortfall might need to be addressed in future budgets and could impact the total project cost and schedule baseline.

NEON Funding, by Stage
(Dollars in Millions)

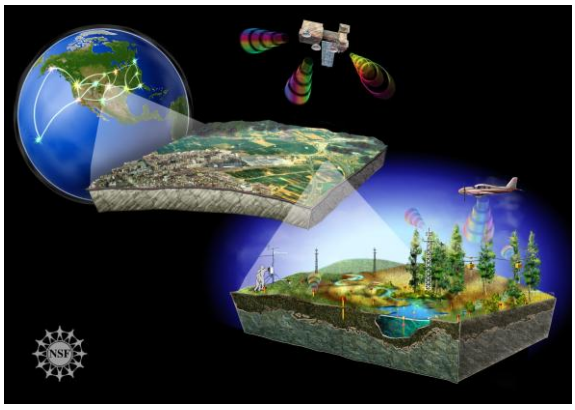


Since NSF supports 63 percent of the fundamental environmental biology research at U.S. academic institutions, advances in the field of ecology and the infrastructure to enable those advances depend largely on support from NSF. Current research infrastructure does not enable studies to address the

complex phenomena driving ecological change in real time and at the scales appropriate for studying many grand challenge questions in ecology. NEON will build upon previous NSF investments through the Long Term Ecological Research (LTER) program, an ecosystem-based research program. NEON is a research facility that will enable research at regional to continental scales. NEON infrastructure will be co-located at eleven LTER sites. When operational, NEON will allow LTER researchers to expand the scale of their research to understand larger scale dynamics affecting their ecosystems. As a continent-wide research instrument, NEON will support a large and diverse group of organizations and individuals; foremost are the scientists, educators, and engineers who will use NEON infrastructure in their research and educational programs. A NEON cyberinfrastructure gateway will provide resources to support formal and informal public education and provide opportunities for citizens to participate in scientific investigations. Data from standard measurements made using NEON will be available in "near real time". The basic NEON datastreams will be open-access via web portals and available as soon as possible, once basic quality assurance and quality control procedures have been applied.

Recent United States Global Change Research Program (USGCRP) assessments indicate that U.S. ecosystems will experience abrupt and unpredictable changes from a suite of human-driven processes in the near future. The Administration has identified these environmental issues as among the most important, demanding, and urgent global problems of our time, and scientific discovery and science-based decision making are critical to selecting mitigation and adaptation policies and strategies. NEON is the ideal platform to provide the scientific foundation needed to address these environmental challenges, and the urgency of these issues to our national resources, economic vitality, health, quality of life, and national security justified beginning to build NEON in FY 2011. NEON will provide an unprecedented opportunity to detect environmental signals as early as FY 2013.

NEON will enable research on the impacts of climate and land use change, water use, and invasive species on the Nation's living ecosystems at temporal and spatial scales that are relevant to human well-being. NEON will be the first research platform and the only national experimental facility specifically designed to enable basic research in these areas. All prior basic research infrastructure was designed and deployed on an *ad hoc*, question-, mission-, or site basis. NEON is unique. Its statistically-determined, continental-scale design, with data products, data management, and standardization will support research on the dynamics of complex coupled systems needed for modeling and understanding rates of change on regional and continental scales. No other standalone system – federal or private – can provide the scientifically validated suite of data measurements that NEON anticipates providing. For example, federal operational agencies, such as the Environmental Protection Agency (EPA), provide comprehensive, sustained, and dependable observations in real time on a broad geographic basis, similar to the observations supporting the forecasts of the National Weather Service; these observations support information needs and forecasts for resource management. In contrast, NEON will provide infrastructure to enable hypothesis-driven basic biological and ecological research, with data and high-level data products available in close to real-time. NEON scientists will develop and use the latest technologies and sensors to push the envelope of knowledge. Just as NEON researchers will benefit from access to data from Federal Agency networks that provide spatial and temporal coverage of the U.S., so will federal agencies benefit as the techniques, sensors and knowledge gained through NEON-enabled



NEON will be a collaborative research platform of geographically distributed infrastructure connected via the latest information technology. By combining in-situ sensing with remote sensing observations, NEON will address pressing environmental questions on regional to continental scales. *Credit: NSF.*

activities migrate from research to societal applications and inform management decisions.

NSF and NEON, Inc. coordinate with other federal agencies through the NEON Federal Agency Coordinating Committee, Memoranda of Understanding (MOU), Memoranda of Agreements, and Cooperating Agency Agreements. Areas of coordination include planning, design, construction, deployment, environmental assessment, data management, geospatial data exchange, cyberinfrastructure, research, and modeling. In addition, NSF will continue to seek opportunities for new interagency and international partnerships. Examples of current partnerships include:

- Design: The Jet Propulsion Laboratory (JPL) at the National Aeronautics and Space Agency (NASA) designed and is building the hyperspectral sensor for the NEON airborne observation platform
- NEON infrastructure deployment sites: U.S. Department of Agriculture Forest Service, USDA Agricultural Research Service, Bureau of Land Management, Department of Energy (DOE), and National Park Service
- Sharing of geospatial data, in-situ verification, and archival of NEON aerial remote sensing data with the U.S. Geological Survey (USGS)
- Partners in research, modeling, data exchange, standards, and protocols: NASA, the National Oceanic and Atmospheric Administration (NOAA), USGS, and EPA
- International: Discussions have begun between NEON, Inc. and Mexican and Canadian scientists to broaden linkages with NEON and expand the research capability to the North American continent

Private organizations including the Heinz Center, Nature Serve, and the Science and Engineering Alliance, participated in NEON design and development activities. The Science and Engineering Alliance and the Ecological Society of America are assisting NEON, Inc. with education and inclusion of minority serving institutions in NEON science and education. Building enhanced accessibility for all institutions into the design will broaden the impact of NEON science and education to the next generation of scientists and educators. While the bulk of NEON's infrastructure and instrumentation will be "commercial off-the-shelf", NEON's scientific and networking design required certain technological innovations. Consequently, the Directorate for Biological Sciences (BIO) has provided Research and Related Activities (R&RA) funds for advanced research and development (R&D) activities in the areas of sensors and cyberinfrastructure.

Project Report

Management and Oversight

NSF Structure: The NEON program is managed in the BIO Office of the Assistant Director (OAD/BIO) as part of Emerging Frontiers. OAD/BIO provides overall policy guidance and oversight, and the location of the NEON program in the Emerging Frontiers Division (EF) within BIO fosters its interdisciplinary science connections. The NEON program is managed by a dedicated program officer, and an NSF/NEON project manager was added in FY 2011 to oversee construction and participate in planning, development and oversight of management and operations. A business oversight team chaired by the NEON program officer advises and assists with the business framework of the project. A BIO-NEON committee, which includes the Deputy Director for Large Facility Projects in the Office of Budget, Finance and Award Management (BFA) and a cross-NSF Program Advisory Team (PAT), formulates program planning for NEON. The NEON program officer served as the contracting officer's technical representative (COTR) for the NEON environmental assessment completed in FY 2010. A NEON Environmental Assessment Team (EA) provides ongoing technical advice on the National Environmental Policy Act (NEPA) compliance and NSF environmental policy.

External Structure: The NEON project is funded through cooperative agreements with NEON, Inc., a non-profit, membership-governed consortium, established to oversee the design, construction, management and operation of NEON for the scientific community. Within that organization, the CEO provides overall leadership and management; the project manager oversees all aspects of the project design, review, construction, and deployment; and the director of computing is responsible for oversight of the cyberinfrastructure and embedded sensor development. A Board of Directors, a Science, Technology, and Education Advisory Committee (STEAC) and a Program Advisory Committee (PAC), composed of members of the NEON user community, each provide oversight and guidance to the project and help ensure that NEON will enable frontier research and education.

Reviews:

- Technical reviews: The NEON Observatory Design Review (including site selection and deployment design) was successfully completed in February 2009.
- Management, Cost, and Schedule reviews:
  - The Conceptual Design Review was held in November 2006.
  - A combined PDR/FDR of the airborne observation platform was successfully completed in February 2009.
  - A PDR for the entire project was successfully completed in June 2009.
  - An FDR was successfully completed in November 2009, including construction and cost reviews.
  - National Science Board (NSB) Review: The Board reviewed and authorized NEON construction subject to final appropriation of funds in May 2010.
  - An additional baseline review, to ascertain readiness to begin construction, is scheduled for April 2011 prior to construction.
  - An operations review of the project's operating plan and anticipated budget is scheduled for August 2011.

Current Project Status

In November 2009, the final design, scope, schedule, and risk-adjusted costs were reviewed and the project's baseline scope, budget, and schedule were found to be credible. The review panel endorsed the remaining pre-construction planning activities slated for 2011 that will enable the project to commence construction in FY 2011. Contingency was increased to cover known risks, per panel recommendations. The NEON, Inc. Project Office has completed the final design, NEON project execution plan (PEP), and maintenance and operations plan. The site selection and associated deployment plan is complete and was merit reviewed during the preliminary design review. The NEPA environmental assessment was completed in November 2009 and a "Finding of No Significant Impact" was signed by NSF in December 2009. The U.S. Fish and Wildlife Service has concurred with the "Finding of No Significant Impact" and NSF's compliance with the Endangered Species Act. This compliance action will allow construction to commence in July 2011. A NEON-led operations review was completed in April 2010; NSF staff participated as observers. The first NSF-led operations review, covering the operating plan and associated budget, is scheduled for August 2011.

Support was provided through the R&RA account for final NEON Project planning. Funds came specifically through Emerging Frontiers (EF) in FY 2011. R&RA funds were used to retire risk, complete detailed construction-ready design documents, and scale up final project activities, including: establishment of the NEON Calibration/Validation Laboratory for sensors and instrumentation; advanced design for the first six NEON domains and all NEON core sites; and biological assessment and permitting for the first six domains.

Cost and Schedule
The projected length of the project is five years, covering six fiscal years, with a six-month schedule contingency. The risk-adjusted cost of $433.72 million includes a contingency budget of 19 percent.

In 2011, NEON requested $20.0 million in MREFC funds to initiate construction. These funds will: establish the NEON Data Center and two domain offices, initiate construction of two domains, procure instruments for the two domains, support the engineering technical facility, and provide for contracts and procurements for long-lead instruments, communications, and field equipment.

In FY 2012, $87.92 million is requested for construction. These funds will support: civil and facilities construction in 9 domains; instrument procurement and calibration for 11 domains, with deployment in 6 domains; biological site characterization in 6 domains; and aquatic site characterization in all domains. Construction activities include production engineering and ongoing equipment procurement for the associated calibration/validation and instrument integration laboratories. These funds also include support for the Data Center infrastructure and will initiate the data products application implementation. Construction will begin on the NEON Airborne Observatory, including spectrometer and LIDAR procurements.

In FY 2012, management and operations funding will commence, with an initial request for $15.93 million. The funds will enable operations of the first two domains constructed, including related management and technical support, seasonal biological sampling, and domain facility costs.

Risks
Technical: Dependence on commercial off-the-shelf technology will be mitigated by long-lead purchase orders and alternative vendors. Production quality, embedded and system-level cyberinfrastructure will be addressed by a combination of "in-house" design, commercial, contracts, and targeted research (e.g., cyber-dashboard).

Deployment: Environmental assessment and permitting may impact schedule and costs. These risks have been and continue to be addressed through multiple means, including: the direct contracting of the environmental assessment by NSF; the hiring of two national firms by NEON, Inc. for engineering and permitting; the identification of alternative sites if the primary sites are determined to have significant risk; and the allocation of two full-time equivalents (FTE) by the U.S. Forest Service to assist with environmental compliance issues on Forest Service lands.

Geospatial Data Acquisition: A potential risk is the long-term availability of satellite (e.g., LANDSAT and MODIS) borne sensors. This risk is mitigated through a partnership with the USGS EROS Data Center, which has the federal responsibility for curation and management of LANDSAT and MODIS images and having alternative satellite sensor sources to purchase images (e.g., SPOT - France, AWIFS – India, Terra and Aqua - US). The proposed NEON airborne observatory platform (AOP) sensor system design and aircraft availability are also sources of technical and implementation risk. To minimize this risk, the AOP is being developed by JPL; similar instrument packages are being prototyped by NASA and Carnegie Institution at Stanford University. The sensor system fits multiple aircraft, including commercial aircraft. Experienced flight design engineers were contracted by NEON, Inc. to provide the baseline operations plans, aircraft analysis, and assessment of commercial companies that could potentially support NEON flight operations, and experienced research aircraft pilots serve on the design team.

Future Operations Costs
Operations costs will ramp up to $83.10 million in FY 2017. Preliminary management and operations costs were reviewed at the NEON FDR in November 2009. A NEON-led operations review, with NSF as

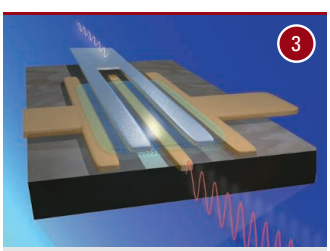
observer, was held in April 2010. An NSF-led operations cost review is scheduled for August 2011 and cost reviews will be conducted throughout the operations phase to assess the project and inform future budget requests. NEON is reliant on sensors and cyberinfrastructure that have a defined lifecycle, so operations costs include scheduled replacement and refreshing of sensor, instrumentation, and cyberinfrastructure technology. NEON operations also include significant labor costs due to the labor-intensive processes required as part of the Fundamental Sentinel Unit (FSU), which is a major component of each domain.

The Year in News

2010 was a busy year for science and science policy. Here are some developments that tested the limits of our knowledge and influenced thinking about the global research enterprise

January: A magnitude-7.0 earthquake in a long-recognized seismic zone kills more than 200,000 people in a highly vulnerable population.

February: A magnitude-8.8 quake results in fewer than 500 deaths thanks to quake-resistant building construction and an offshore epicenter.



February: IBM researchers create graphene transistors that switch on and off at 100 billion times per second.

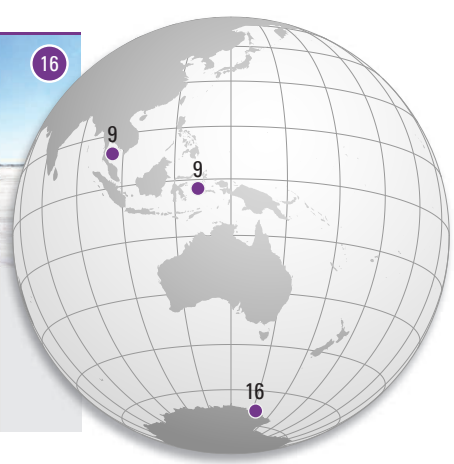
April: Arizona State University agrees to return DNA samples to the Havasupai tribe following questions about informed consent.

April: Explosion of *Deepwater Horizon* drilling platform triggers release of 205 million gallons of oil in the Gulf of Mexico—and research on effects that could last for decades.

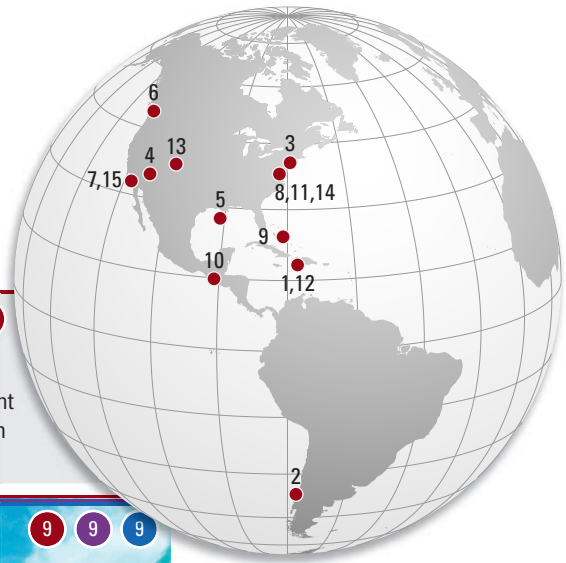
April: Researchers evaluate the first data from the NEPTUNE project, an undersea cable network of sensors.

May: J. Craig Venter's group incorporates a synthetic genome into a microbe.

October: Four people die in helicopter crash involving employees at the French Polar Institute Paul Émile Victor.



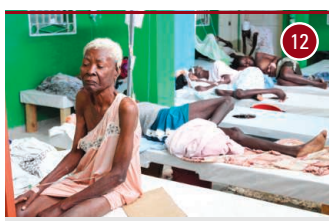
August: Federal judge blocks U.S. government funding of stem cell research.



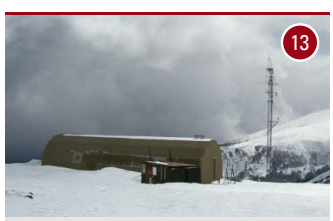
Summer/Fall: What may prove to be the worst coral bleaching on record devastates reefs in the Caribbean, the Indian Ocean, and the tropical Pacific.

September: Historian uncovers a syphilis study in Guatemala from the 1940s, and the U.S. government apologizes for its ethical lapses.

September: The U.S. and European governments sharply restrict use of the diabetes drug Avandia because of safety concerns, capping a long controversy.



October: Explosive cholera outbreak erupts and spirals out of control.



October: Construction completed on prototype site for NEON, an ecological observatory network to monitor long-term change on continental scales.

November: Study finds that CT exams cut death from lung cancer 20% among smokers—but screening has major costs.

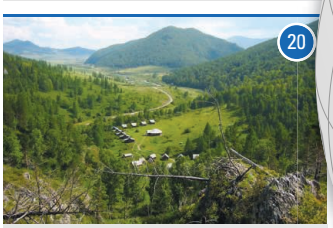
November: Long-delayed NASA Stratospheric Observatory for Infrared Astronomy (SOFIA) completes first science flight.

Published by AAAS

January: The Intergovernmental Panel on Climate Change offers "regrets" about overstating the rate of glacier melting in the Himalayas. 17

February: Government rejects commercial release of genetically modified brinjal (eggplant). 18

March: Eruption of Eyjafjallajökull volcano leads to the greatest disruption to air travel since World War II.



March: New species of human discovered from ancient DNA.

March: Science ministers declare 2011–2020 as the "Decade of Science in Africa." 21

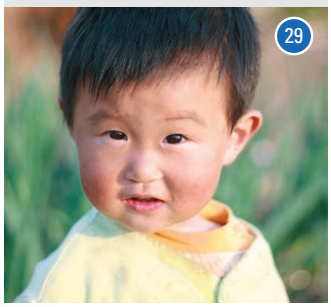
April: Research center opens to develop technologies for a post-ITER fusion reactor. 22

April: Chinese Family Panel Studies survey, the largest long-term social science study in the developing world, begins. 23

May: Neandertal genome sequenced.

June: The Hayabusa spacecraft capsule lands in Australia with dust from asteroid Itokawa.

September: China's one-child policy turns 30.



July: Funding profile approved for ITER fusion reactor project. 26

July: First positive HIV microbicide results from South Africa announced at international AIDS meeting. 27

August: Wildfires across Russia reach the region heavily affected by the Chornobyl nuclear disaster, raising fears that they could spread radiation.

October: Parties to the Convention on Biological Diversity adopt new targets to protect biodiversity and urge caution on geoengineering. 30

October: Plan to honor presidency of Teodoro Obiang with UNESCO science prize is put on ice after human rights protests.

October: Results of the first Census of Marine Life presented.

October: U.K. science avoids sharp cuts in government research spending. 33

October: The U.N. Food and Agriculture Organization proclaims end to rinderpest, a deadly cattle disease.

November: China unveils world's fastest supercomputer.

December: Launch of new, affordable meningitis vaccine to protect 450 million people. 36

Ongoing: BGI-Shenzhen enhances its reputation as world's largest sequencing center, deciphering an ant, a paleo-Eskimo, the human methylome, and a gene catalog of the human gut microbiome. 37

–JEFFREY MERVIS

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Advancing Digitization of Biological Collections (ADBC)

10/19/10

This program encourages new collaborations to develop thematic networks and an innovative national resource coordinating organization.

Please note the recently published Dear Colleague Letter available at http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf11007 announcing a **new WIKI** to facilitate and increase the number of collaborations among potential principal investigators in developing their proposals for this competition.

Frequently Asked Questions related to Advancing Digitization of Biological Collections (ADBC) solicitation have also been posted at http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf11005

We strongly encourage those interested to utilize both these resources to facilitate understanding of the program and to aid in collaborative efforts.

CONTACTS

Name	Email	Phone	Room
Rafael O. de Sa	biodigit@nsf.gov	(703) 292-8400	
Anne M. Maglia	amaglia@nsf.gov	(703) 292-8470	
Susan L. Perkins	biodigit@nsf.gov	(703) 292-8400	
Judith E. Skog	biodigit@nsf.gov	(703) 292-8400	
William C. Taylor	biodigit@nsf.gov	(703) 292-8470	

PROGRAM GUIDELINES

Solicitation 10-603

Please be advised that the NSF Proposal & Award Policies & Procedures Guide (PAPPG) includes guidelines implementing the mentoring provisions of the America COMPETES Act (ACA) (Pub. L. No. 110-69, Aug. 9, 2007.) As specified in the ACA, each proposal that requests funding to support postdoctoral researchers must include a description of the mentoring activities that will be provided for such individuals. Proposals that do not comply with this requirement will be returned without review (see the PAPP Guide Part I: Grant Proposal Guide Chapter II for further information about the implementation of this requirement).

DUE DATES

Current but no Longer Receiving Proposals

SYNOPSIS

This program seeks to create a national resource of digital data documenting existing biological collections and to advance scientific knowledge by improving access to digitized information (including images) residing in vouchered scientific collections across the United States. The information associated with various

collections of organisms, such as geographic distribution, environmental habitat data, phenology, information about associated organisms, collector field notes, tissues and molecular data extracted from the specimens, etc. is a rich resource for providing the baseline from which to further biodiversity research and provide critical information about existing gaps in our knowledge of life on earth. The national resource will be structured at three levels: a national hub, thematic networks based on collaborative groups of collections, and the physical collections. This resource will build upon a sizable existing national investment in curation of the physical objects in scientific collections and contribute vitally to scientific research and technology interests in the United States. It will be an invaluable tool in understanding the biodiversity and societal consequences of climate change, species invasions, natural disasters, the spread of disease vectors and agricultural pests, and other biological issues.

RELATED PROGRAMS

Dimensions of Biodiversity

Improvements to Biological Research Collections

RELATED URLS

A Strategic Plan for Establishing a Network Integrated Biocollections Alliance

THIS PROGRAM IS PART OF

Additional Funding Opportunities for the DBI Community

Additional Funding Opportunities for the DEB Community

Current Activities: no longer receiving proposals

What Has Been Funded (Recent Awards Made Through This Program, with Abstracts)

Map of Recent Awards Made Through This Program

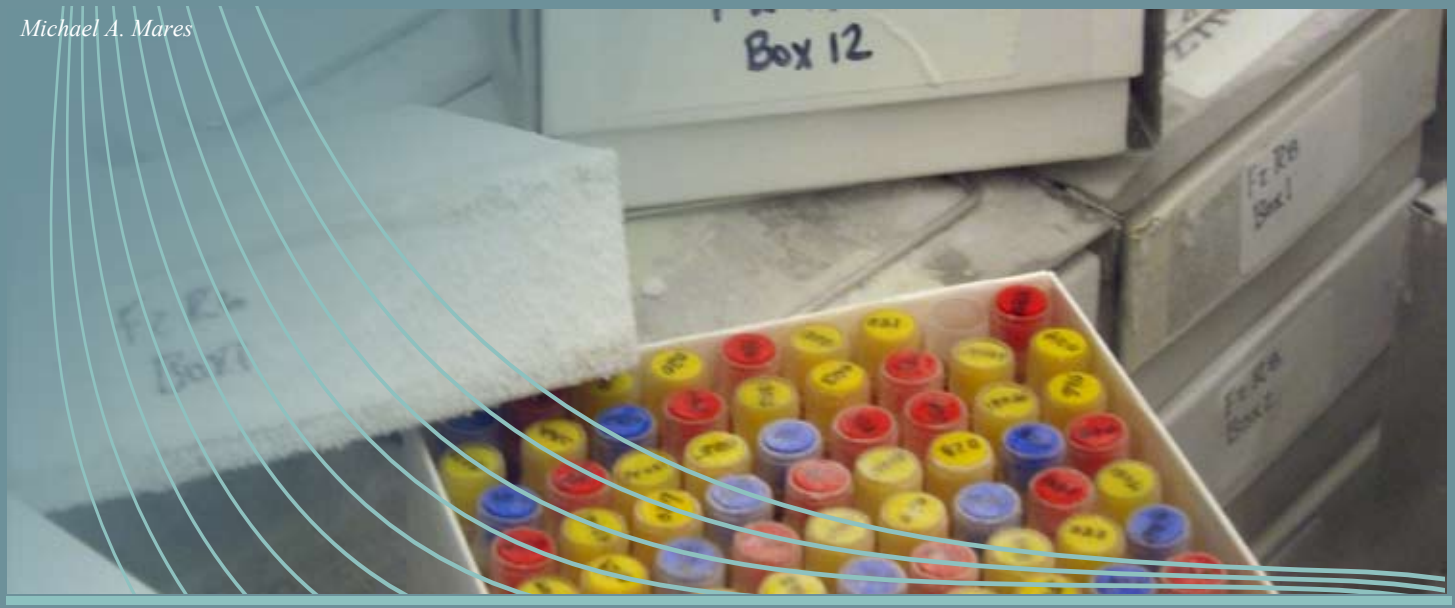
A Strategic Plan for Establishing a Network Integrated Biocollections Alliance

Executive Summary

This report is a strategic plan for a 10-year effort to digitize and mobilize the scientific information associated with biological specimens held in U.S. research collections. The primary objective of the initiative is to create a national collections resource that will contribute critical information to U.S. scientific research and technology interests, and will aid in understanding the biodiversity dimensions and societal consequences of climate change, species invasions, natural disasters, the spread of disease vectors and agricultural pests and pollinators, and other environmental issues. Network Integrated Biocollections Alliance (NIBA) resources such as databases, network portals, and analytical tools will synthesize information contained in the nation's collections and place them into national service for stakeholders in government, academia, business, K-12 education, informal science education, and the public.

Biological collections across the U.S. are united by over two centuries of common purpose in research vision, curatorial methods, and field protocols. Digitizing the nation's collections represents a grand challenge that will require development of technical and human resources, such as automated workflows, a robust data publishing and error-checking infrastructure and professionals networked to support the creation of an enduring digital alliance of collections institutions. These challenges can be addressed, in partnership with federal agency and other stakeholders, in order to create an organizational structure and processes that reflect the long-standing biological collection community values of inclusiveness, scientific empowerment and open data access, while allocating credit to data owners and editors.

Digitization of biological specimens will take place within the nation's collections facilities, which will be organized into networks having shared interests in geographic scope, taxonomic research domain, or specimen preservation type. These collaborations will be supported by a national digitization hub, whose responsibility will be to assure the successful implementation of the collaborative and inclusive digitization vision. The digitization hub will: establish collaboration protocols for consensus-based decision making among



Michael A. Mares

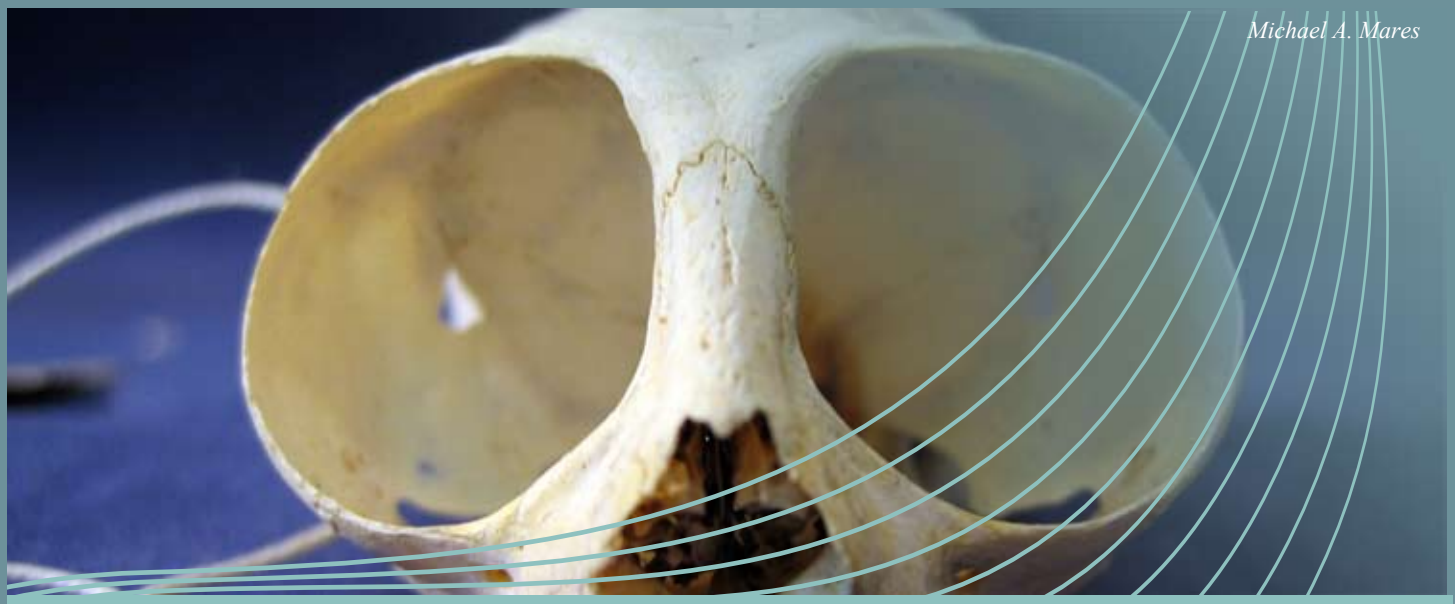
collections; proactively form working relationships and synergies with U.S. and international partners; grow scientific and collection institutional engagement; oversee new digitization technology development; establish protocols for ensuring data quality and proper crediting of data owners and editors; prioritize digitization efforts based on advice from stakeholders, oversight committees, and collections professionals; and define metrics for measuring progress against explicit goals while also reporting progress to all stakeholders.

This strategic plan is the outcome of a deliberative community process that has included surveys of 291 federal and ~600 federally supported collections (see reports referenced in Appendix II), along with multiple workshops. These have recently included community engagement meetings on "Future Directions in Biodiversity and Systematics Research", and an NSF-funded Research Coordination Network meeting entitled "Collections Data Integration." Directed planning activities began with a workshop held at the National Evolutionary Synthesis Center (NESCent) on February 5-7, 2010. The product of that first meeting was an outline for the digitization plan. Input from the community further shaped the vision, and a second workshop at NESCent on 28-30 April provided the input and guidance for this strategic plan.

> **VISION STATEMENT:** *The Network Integrated Biocollections Alliance will develop an inclusive, vibrant, partnership of U.S. biological collections that collectively will document the nation's biodiversity resources and create a dynamic electronic resource that will serve the country's needs in answering critical questions about the environment, human health, biosecurity, commerce, and the biological sciences.*

Call to Action

Collections of biological specimens gathered over two centuries of field exploration document the nation's biological diversity and represent a monumental societal investment for research and applied environmental sci-



ence. Identification of new species and documentation of the properties and distribution of life forms is possible only through research involving curated biological specimens. The knowledge derived from specimens contribute vitally to studies of invasive species, biological conservation, land management, pollination, biotic responses to climate change, spread of pathogenic organisms, and research and management activities of many kinds.

NIBA Use Scenario 1: *A massive oil spill occurs off the coast of Louisiana. Critical information is needed on the potential impact of the oil on living systems. With the national biological database completed, EPA, Coast Guard, Louisiana environmental responders, oil executives, marine fisheries personnel, fishing boat companies, estuary researchers, public health personnel, and others have instantaneous (millisecond) access to all life forms that have been recorded from the region actually or potentially threatened by the spill. Included are data on natural history, geographic distributions, protected and endangered status, position in food chains, and physiological limits of the species. Such data are vital to act quickly to mitigate damage. Without the digitized national database in place, it will take months or even years to gather the same data.*

Large-scale digitizing of the nation's biological collections and mobilizing their images and data through the Internet has never been more urgent or achievable. Technological advances with scanning and research information management systems, decades of experience managing collections data in electronic form, and recent collection data standards have positioned the collections community to address the challenge in a coherent and efficient way. Further, the community has committed to the mission of open access to those data in networked environments. A national focus on collection digitization will transform the practice of collections-based biological research, and international research collaboration by implementing electronic protocols and information channels for real-time communications of all collection data.

The C. V. Starr Virtual Herbarium of The New York Botanical Garden

The Scope of Collections Digitization

U.S. biological collections are an incomparable national treasure and source of knowledge. The collections contain a cross-section of the world's biodiversity including fossils, invertebrates, vertebrates, protists, fungi, plants, and human cultures. This immense knowledge base is underutilized due to the difficulty of obtaining and analyzing data within and across collections. Digitization and mobilization of specimen and associated data (e. g., field notes, illustrations, gene sequences) removes this impediment, but presents technical and organizational challenges. The largest of these is how to capture specimen data fast enough to achieve digitization of entire collections while maintaining sufficient data quality (*Overcoming the Digitization Bottleneck in Natural History Collections Workshop*, September 2006).

The community of natural history research collections has already developed the social and technological infrastructures to provide open access to species occurrence data through broad community participation. Projects such as VertNet (http://vertnet.org; Constable 2010), which already provides access to over 50 million species occurrence records from more than 70 institutions, accessed at a rate of nearly 2.5 million records per week, make clear that such national endeavors can succeed.

Collections digitization is defined broadly to include transcription into electronic format of various types of data associated with specimens, the capture of digital images of specimens, and the georeferencing of specimen-collection localities. To assess the scope of undertaking to digitize the nation's collections, the collections community continues to conduct surveys to document the number and diversity of specimens contained in U.S. collections. Additionally, the community has held three workshops on "Future Directions in Biodiversity and Systematics Research". These, in addition to two recent reports (see Appendix II for references), highlight the scale of the challenge, the need to address the integration of digitized biological data, the need to coordinate the capture of specimen data and images, and the necessity of providing broad accessibility to specimen data by scientists worldwide. Estimates of collection size range as high as three billion specimens globally, with as many as one billion preserved and cared for by U.S. institutions, most of which (~ 90%) are not accessible online.

Doug Anderson, http://www.flickr.com/photos/douga/2176966329/

Prior to this initiative, there has been no nationwide coordination of the effort to digitize and electronically mobilize data from biological research collections. Episodic and incremental funding has yielded limited success with digitization, addressing mainly specific, localized projects. Such past efforts were not designed to have an impact across collection types or institutions in any efficient or supportable way.

This strategic plan emerges at a critical period of accelerated environmental change. Understanding the impact of this change creates new research challenges that must draw upon the massive store of knowledge of life on earth, past and present, that is held in our nation's biological collections. This digitization initiative will be a unified campaign involving a coordinated funding program and well defined strategy for execution. In addition to improving the physical care of collections and supporting collections-based research (see references, Appendix II), it is vital to increase online accessibility of U.S. biological collections through an integrative and focused digitization effort.

NIBA Use Scenario 2: *The Yosemite National Park mammal survey (Moritz et al., 2008) is a valuable example of how biological collections data can be mobilized to evaluate the threat of climate change on living animal populations. Samples collected on the Joseph Grinnell expeditions of 1914-1920 and deposited in the Museum of Vertebrate Zoology, UC Berkeley, served as the baseline data to compare with recent surveys. The results showed that over the intervening 90+ years temperatures for the park had risen by as much as 7° F and several key mammal species ranges had changed dramatically. Some were in danger of extirpation from the park due to a narrowing of their habitat. Comparable data gathered across a century of time throughout the western US show how global climate change is affecting U.S. national and state parks. The collections will enable effective new conservation strategies to be developed to provide additional management of threatened species and other organisms found in the national parks.*

Biodiversity Institute, University of Kansas

The Challenge of Collection Digitization

The nation's biological collections have developed over more than two and a half centuries, and standards for collection acquisition, preservation, and documentation are well formalized and consistent. However, different types of organisms require different methods of preservation to ensure that key biological traits will be preserved. Below, some of the similarities and differences across collections types are highlighted.

Plants and fungi are usually prepared as dried, flattened specimens attached to archival quality paper or are stored in archival envelopes or boxes. All collecting information about such specimens is printed on a label attached to the specimen. These preservation methods pre-adapt plants and fungi specimens for rapid digitization, since they can be handled and digitized individually with all data attached. Herbaria have organized themselves into regional networks, such as the California Consortium of Herbaria (http://ucjeps.berkeley.edu/consortium/), the Consortium of Pacific Northwest Herbaria (http://www.pnwherbaria.org/) and the Southeast Regional Network of Expertise and Collections (SERNEC, http://www.sernec.org/). These regional networks will be united under the nascent U.S. Virtual Her-

NIBA Use Scenario 3: *An airliner encounters a bird strike while taking off from Reagan National Airport. Both engines are damaged but the plane makes a safe emergency landing. How can the serious problem of bird strikes be solved? Upon examination, the motors are found to contain bits of feathers and tissues. The feathers are compared with bird specimens in a museum and identified, while DNA from tissues is compared with the museum's collection of genomic resources. Within a short time it is determined that the birds were not from a nearby resident flock of Canada geese, which might require removal or mitigation, or even delay of air travel, but were in fact a flock of large migratory birds that had strayed from their normal migratory route. This fictional account has actual antecedents in bird strike studies that have utilized collections to help redesign jet engines for commercial and military use, and to plan safer air travel (e.g., Dove 1999).*

John Bates

barium initiative which will serve as an information and technology conduit for the regional networks.

Mammals and birds are prepared differently. Most are skinned, preserving the exterior appearance of the animal. Some are stored in alcohol as whole specimens. Mammals, both modern and fossil, often have their skulls and skeletons prepared and stored separately. The size of birds and mammals varies from hummingbirds and insect-sized bats to large specimens of ostriches and whales. This physical scaling requires heterogeneous storage and preparation techniques, which can make specimen imaging challenging and time consuming. Historically, data from mammals and birds were individually recorded in leather-bound museum master catalogues. Today, those catalogues can be used as primary sources and starting points for digitizing data from the collection. Ancillary data such as vocalizations, habitats, food habits, field notes, climatic data associated with specimens, age and reproductive data, and other observations of each specimen are often available and will be digitized. Specimen data from at least 30 U.S. collections has been published through both the Mammal Network Information System (MaNIS, http://manisnet.org) and Ornithological Information System (ORNIS, http://ornisnet.org).

Reptiles and amphibians are typically catalogued as individual fluid preserved specimens, but historically large series of specimens of a single species were preserved as a "lot" and stored in jars of alcohol without reference to individual animals. Other collections, such as fish and many invertebrates, are also preserved and cataloged as lots. Although plants, birds, reptiles, amphibians, and mammals are often identified to species, fish—the largest vertebrate group when numbers of species is considered—are often identified only to family or genus. In contrast, fossils may have multiple identifications associated with a single sample of rock. Data sharing networks for herpetological, fish and fossil data have been developed (HerpNET, http://herpnet.org; FishNet 2, http://fishnet2.net; PaleoPortal, http://paleoportal.org).

Insects (the most numerous organisms in collections) are curated primarily by pinning individuals and printing the basic information on tiny tags beneath the specimens. Until recently, individual catalog numbers were typically not assigned to insect specimens. Identification is often only to the level of order or family, although the better curated collections are known to genus or even species. Cataloguing the nation's insect collections will likely require the development of hardware and software to speed digitization while assuring specimen safety. As a group, the insects (and

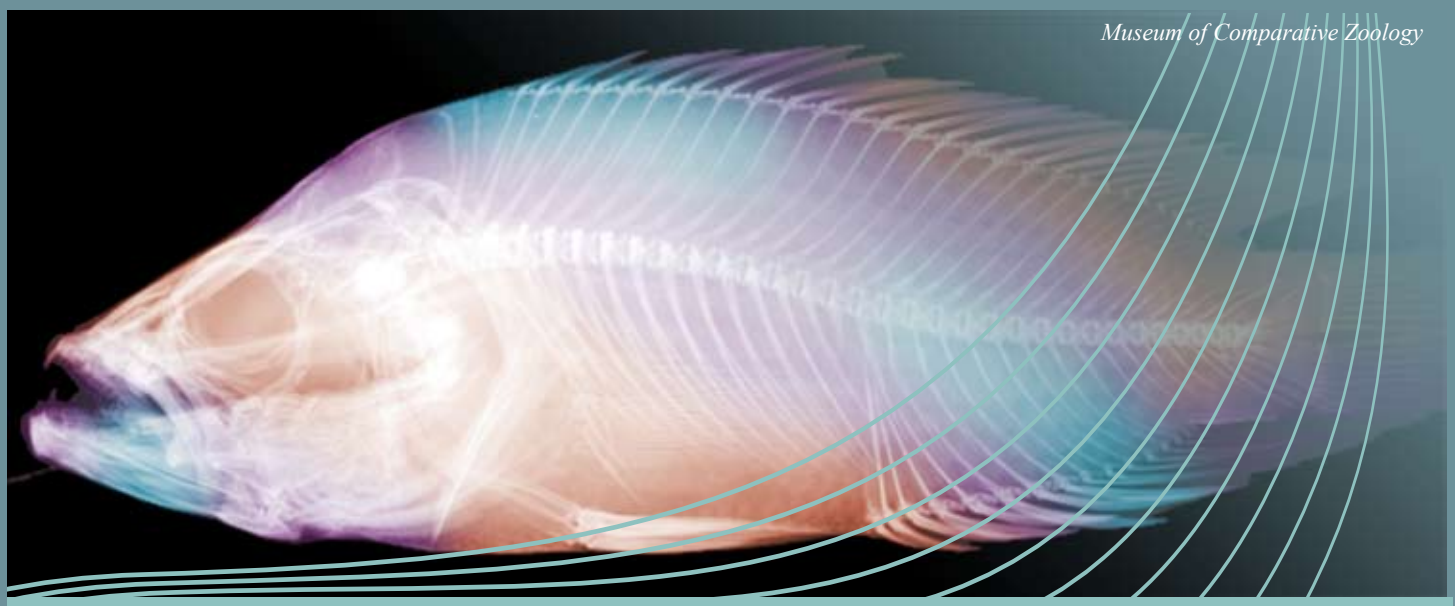
Bruce Patterson

other small invertebrates) involve hundreds of millions of specimens and present an enormous digitization challenge.

Special specimen preparations, such as marine species (e.g., jellyfish, giant squid), or thin sections generated from modern and fossil specimens, also require special digitization techniques, as do microbes and extremely small invertebrates and protists (e.g., unicellular organisms such as diatoms, yeasts, prokaryotes, microinvertebrates).

NIBA Use Scenario 4: *A deadly virus suddenly appears in the southwestern United States, infecting hundreds of people, at least half of them fatally. It is quickly identified as a new Hantavirus. Field biologists quickly determine that it is carried by several species of rodents. By utilizing the digitized database, public health officials and zoologists are able to delineate the geographic area in which the virus is likely to occur, the habitats of the rodent species, associated species, and other parameters of their life cycle that will influence the spread of the virus. The disease is contained. This scenario occurred with the Sin Nombre Hantavirus in New Mexico in 1993 and the disease was understood rather quickly because of extensive mammal collections from the region, as well as ongoing field research with the species involved (Yates et al., 2002). Today, the extensive collections of genomic resources, mammals, and viruses would provide a ready resource for identifying viruses associated with any of thousands of species.*

Across the major taxonomic groups, innovations in digitizing hardware, software, process engineering, workflows and networked data interactions will be needed. Such innovations will lead to collaborative community approaches sensitive to local needs but able to leverage efficiencies and synergies of industrial-scale collection data processing and publishing.



Museum of Comparative Zoology

Strategic Plan For Collections Digitization: Objectives

The key objectives of this strategic plan are:

• Digitize data from all U.S. biological collections, large and small, and integrate these in a web accessible interface using shared standards and formats.

Estimates suggest that there are on the order of 1 billion specimens held in U.S. biological collections, residing in thousands of institutions. A significant number of these institutions have embarked on the digitization of some specimens, but very few of the smaller and none of the larger collections have a complete digital accounting of their specimen holdings and associated ancillary information (e.g. field notes). Although some institutions share data through a common web portal, such collaborative projects are limited to particular regions (e.g., SEINET, http://swbiodiversity.org/seinet/index.php) or a particular taxonomic or thematic group (e.g., VertNet, http://vertnet.org; PaleoPortal, http://paleoportal.org).

• Develop new web interfaces, visualization and analysis tools, data mining, georeferencing processes and make all available for using and improving NIBA resources.

In order to hasten completion of the digitization of U.S. collections in a timely and efficient manner, the development of new techniques will be essential to develop new web interfaces, visualization and analysis tools, data mining tools, and georeferencing processes and make all available for using and improving the NIBA resources. As the body of digitized specimen data grows, so will the types of questions that this data pool can be used to answer. New tools for analyses of these data will permit a deeper knowledge of species distribution, biological interactions, and response to environmental change and crises management. The Network Integrated Biocollections Alliance will be a platform on which to build innovative applications that support data improvement such as collaborative georeferencing tools, species identification, data visualization, and data and image analysis. For example, a simple application on a mobile cellular device could access NIBA resources and provide information about local biodiversity. Auto-updating analysis and modeling tools that link NIBA resources to physical and chemical environmental layers derived from in situ sensor networks or remote sensing products provide an unparalleled opportunity to generate a process-oriented view on biodiversity change over space and time.

• Create real-time upgrades of biological data and prevent the future occurrence of non-accessible collection data through the use of tools, training, and infrastructure.

Specimen collection for scientific study continues because many species remain undocumented and large gaps remain in our knowledge of the earth's biodiver-

Dr. Michael Engel

sity, especially in marine and tropical regions. Reference to the digitized collections repository will help to target future collecting efforts by providing an excellent baseline of inventory completeness. The tools developed for efficient data and image collection will be designed to accept data from field sites, to ensure that data from field collections, including specimen images and genomics data, stream directly into digital archives.

Elements of the Plan

An estimated one billion specimens are held in more than 1600 collection institutions in the United States. As discussed above, the physical preparations of these modern and fossil specimens include skins and hides, wet and dry skeletons, pinned insects, taxidermied mounts, fluid-preserved organisms in vials, bottles or tanks, dried in packets or boxes, pressed on sheets or mounted on microscope slides. The core elements of the plan to accomplish this monumental task are discussed below.

Organization, Leadership, Governance and Collaboration

The organizational and leadership structure will have as its highest priorities:

Accessibility. Enable new science and provide more effective monitoring and regulatory activities by networking collections and mobilizing specimen data to the Internet in order to interconnect and integrate specimen information across laboratory, institutional and governmental boundaries.

Inclusiveness. Maximize the number of collaborating biological collections by creating value for institutional participation and engaging broader stakeholders by addressing their needs for specimen data and their integration.

Efficiency. Recognize and address issues of technology, scale, error-checking, and staging of data computerization activities to maximize quantity and quality of collection data produced and published.

Accuracy. The participation of expert biologists and collections professionals in combination with new technology for image acquisition, data capture, and error-checking routines is critical in order to make the digital resources scientifically accurate and reliable.

National Digitization Hub (NDH): The national hub will serve as the administrative home for the digitization effort, fostering partnerships and innovations, facilitating best practice standards and workflows, serving as a repository for data and techniques, and establishing cohesion and interconnectivity among digitization projects. Through collaborative and inclusive processes, the NDH will: determine the scope and staging of technology development priorities; promote the development of collections-level metadata at all

Doug Anderson, http://www.flickr.com/photos/douga/4530932696/

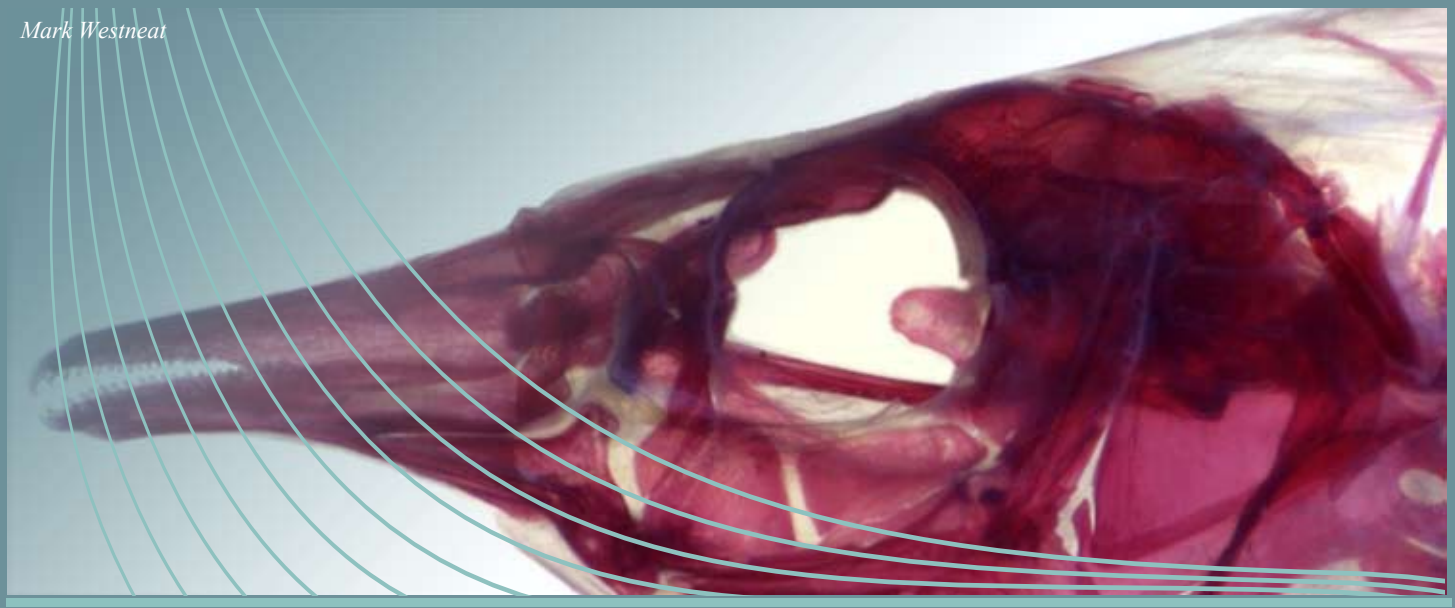
institutions; ascertain priorities for collections institution engagement and collaboration; identify key external partners; measure progress against explicit goals; establish and promote credit for data publishers and editors and; develop a plan for long-term sustainability and report on progress to all stakeholders. It is likely that the NDH will consist of a small number of full-time staff, including an Administrative Director, Cyberinfrastructure Director and Director of Engagement and Outreach. A governing advisory board will have authority for decision making, oversight, and guidance.

Regional and Thematic Collections Networks: Translating the vision of the *National Digitization Hub* and its advisors and collaborators will be Regional and Thematic Collections Networks which will directly organize and support the digitization effort at a group of institutions. Regional collaborations may consist of institutions housing both large and small collections that are united to focus on digitization and mobilization of collections data from the same geographic area. They may also address scientific or environmental questions pertinent to that region and may share resources and expertise among collections located in proximity to one another. Thematic collaborations may be driven by the specific needs of collections of a particular clade or preservation type, or motivated by a particular scientific question to be addressed by the use of collections images and data. These thematic networks will: define and delineate subprojects for technology development or content generation; identify deliverable goals, metrics for assessment, and specific needs for community support; provide technical support; and strengthen communications and outreach to other collections.

Collections Institutions: Within biological collections themselves, where the information associated with specimens is sequestered, collections researchers and curatorial staff will be incentivized and supported with state-of-the-art technologies and workflows, and with benefits for participation, to value and undertake the kinds of baseline-level digitization activities of the initiative. The heart of this effort will reside in the galleries and among the cabinets and drawers of the thousands of collections that comprise this national enterprise. Collections personnel will prioritize their specimen holdings for digitization, select the technological solutions that are most effective for their collections, and share their data and digitization experiences. They will define the functions and capabilities that add value to the collections and present them to the collection networks and Hub administrators as requirements for the initiative, provide feedback on workflows, and suggest best practices for the project.

Technology Development

In order to achieve the goal of digitizing U.S. biologi-



Mark Westneat

cal collections, this initiative must foster the creation of technological innovations to increase the rate of data capture (while maintaining data quality). Such efforts can dramatically lower both the time and cost of specimen digitization. The community must seize the moment to develop specific best practices, standard methodologies for data capture and workflow technologies that can likely achieve orders of magnitude increases in the rate of digitization processes.

Three broad challenges with technology development can be foreseen. The first is the need to develop hardware and software tools for automated data entry, quality control and publication workflows that are generalizable and extensible across different types and sizes of collections. This effort will require expertise from process engineers and from biological and curatorial domain experts to determine data entry process bottlenecks and efficiencies as recommendations for the technology solutions. Goals will be to minimize complexity, cost, and damage to specimens, while maximizing the quantity and quality of specimen data produced and mobilized.

To initiate and further develop technology and workflow optimization, the NDH will create a working group with collections experts and workflow process engineers. The working group will be charged with the rapid creation of a plan that describes where the greatest efficiences in specimen digitization and mobilization can be achieved for the least amount of overhead. The output of this working group report will be used to prioritize technology development that will occur within the first two years of the project.

A second technology challenge will be developing new systems or evaluating and deploying existing prototype systems that can move to production stage in a short time-frame. In order to digitize as many specimens as possible during the 10-year time frame of this initiative, it is essential that such technologies are ready for deployment within 2 years of the project start. Accommodating institutions that already have successful digitization programs will require careful coordination.

A third technology challenge will be the logistics surrounding deployment, training and helpdesk support of the data entry and publication workflow technologies. These components must have high levels of usability, low learning curves, and be robustly engineered to reflect physical collection and traditional local procedures and protocols for specimen handling.

With limited grant funding, a few biological collections have already designed data entry workflows with innovative technology. For example, the botanical community has developed prototype systems such as Herbis (http://www.herbis.org/) and Apiary (http://www.apiaryproject.org/content/apiary-home) that perform ‘one-button’ specimen imaging and data capture. Such ‘one-button’ systems automate all steps

The C. V. Starr Virtual Herbarium of The New York Botanical Garden

in the workflow so that positioning specimens and clicking a button to capture an image are the main human operations. The images and label data are automatically sent to a structured database. These systems show the promise of workflow automation that remove onerous and repetitive tasks often performed by humans, and better done by computers

Workforce development and training

The human resources required for this initiative include faculty and curators, collection managers, information technologists, and a diversity of staff, students, and volunteers who are involved with collections. The goal of the workforce development and training element of the plan is to have a corps of people who are enabled to perform efficient and accurate collections digitization and manage that process according to established standards so that data may be readily shared and integrated with that generated by other institutions. Some of these people may be based in regional centers.

In order to realize the vision of the Network Integrated Biocollections Alliance, a significant investment in training of collections personnel, ranging from digitizers to collections administrators will be needed. Training will also be required in the use of software and hardware tools that are currently available for collections digitization and mobilization projects, and for those that will be developed in the course of the project. Collections personnel must receive instruction in best practices for data capture, editing for conformance to established data standards, and how to store and share data. Collections administrators will need training in how to develop a workable plan to accomplish their digitization objectives, and how to plan for the long-term maintenance and updating of the digital resource created by their institution.

Scientists and students who generate new collections need training in how to create digital documentation of new specimens as they are collected so that these data immediately become part of the available collections data stream and not part of the backlog of collections to be digitized. Because the national NIBA resources created by this plan will be universally accessible, students at the high school and university level should be introduced to it during formal coursework; furthermore, students may represent a significant part of the digitization workforce in university collections, and thus should be trained to participate in this work and in how to use digital collections data to answer research questions. Finally, citizen scientists may contribute significantly to the digitization workforce and they too must have access to training in digitization and best practices.

Training will take place at designated facilities, such as the National Digitization Hub or in lead institutions comprising the Regional and Thematic Collections

Pierre_Pouliquin , http://www.flickr.com/photos/pierre_pouliquin/307223105/

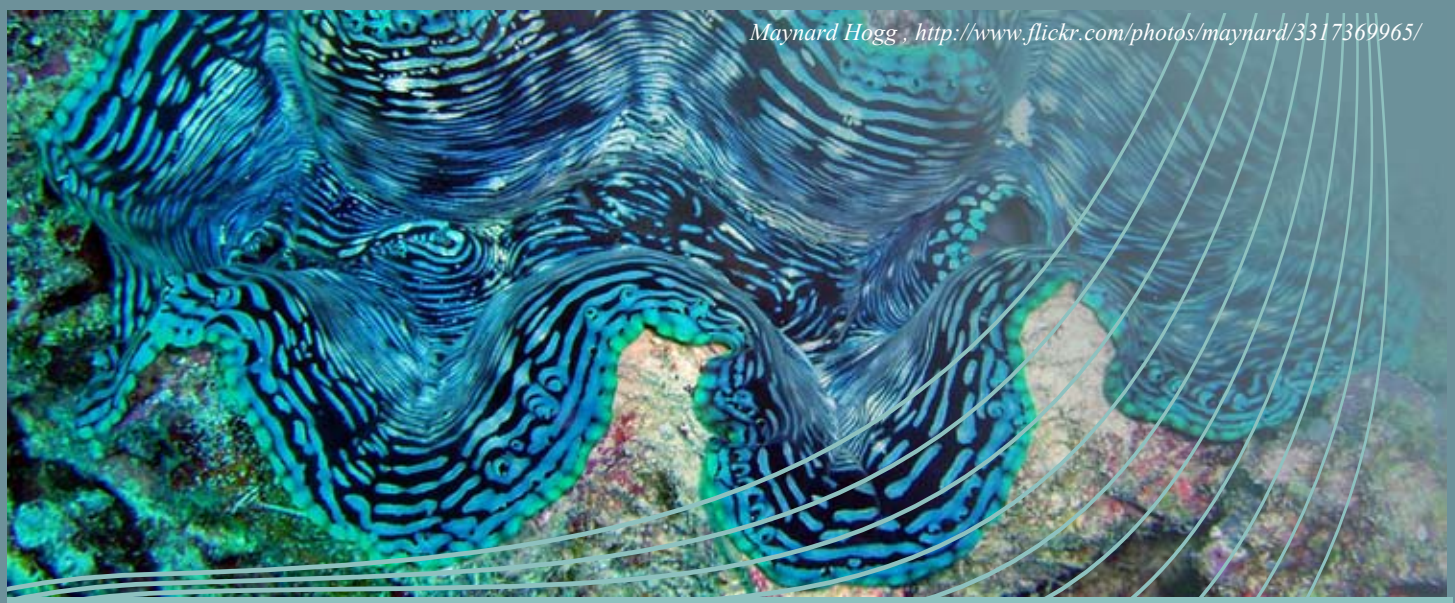
Networks, and may also be available as a distance-learning activity or offered in conjunction with national society meetings and workshops. Training must be followed up with on-going support, in the form of on-line instruction, document repositories, discussion or help resources using social media, and deployment of problem-solvers who can travel to collections as necessary.

Products

Digitized specimen data: The primary product of coordinated biological collections digitization initiative will be an openly accessible digital archive of the diversity and distribution of life on earth. Stewarded by the individual institutions that curate the specimens and their digital representation, these data will be available over the Internet through multiple interfaces—through institutional, regional, thematic, and national portals, and as content within international biodiversity caches, such as those run by the Global Biodiversity Information Facility (GBIF). Public web interfaces will serve as gateways for education, applied management, and research. The digital specimen data collections resulting from the initiative will be more than just repositories of archived information. Web services and peer-to-peer network communications through standardized application programming interfaces will facilitate cooperative data entry, duplicate specimen discovery, shared authority files, and a new level of interactivity to the desktops of collections researchers and data consumers. Machine-to-machine data transfer will port relevant data from collections to a broad range of applications from scientific to commercial to educational and recreational.

New Applications to Support Rapid Specimen Digitization and Data Mobilization: Hardware and software products to accomplish high throughput specimen digitization, as well as optimized workflows for all types of specimens, will be key products of this initiative. Equally as important will be tools for data editing and standardization, to ensure that data captured at different institutions will be compatible. In order to assure that a backlog of non-digitized specimens does not recur in the future, these products must be designed to be sustainable and scalable into the future. The community can leverage current innovations such as cloud-based data publishing networks. VertNet for example, has begun migrating to the cloud—a virtualized data center—in order to solve current impediments with fully distributed network architectures (see Constable, 2010 for details).

Network Integrated Biocollections Alliance (NIBA) Virtual Communities: An essential product of this plan is a vibrant, virtualized community that can effectively



Maynard Hogg , http://www.flickr.com/photos/maynard/3317369965/

share data and digitization experiences, while collectively developing requirements for new tools. By using the Internet as a research platform, existing and new social media and user/content management approaches will be utilized to allow for persistent collaboratoriums where members of the community can self organize to accomplish the goals of this product. An early example of such an approach is GEOLocate: Community Edition (http://www.museum.tulane.edu/coge/), a collaborative georeferencing application.

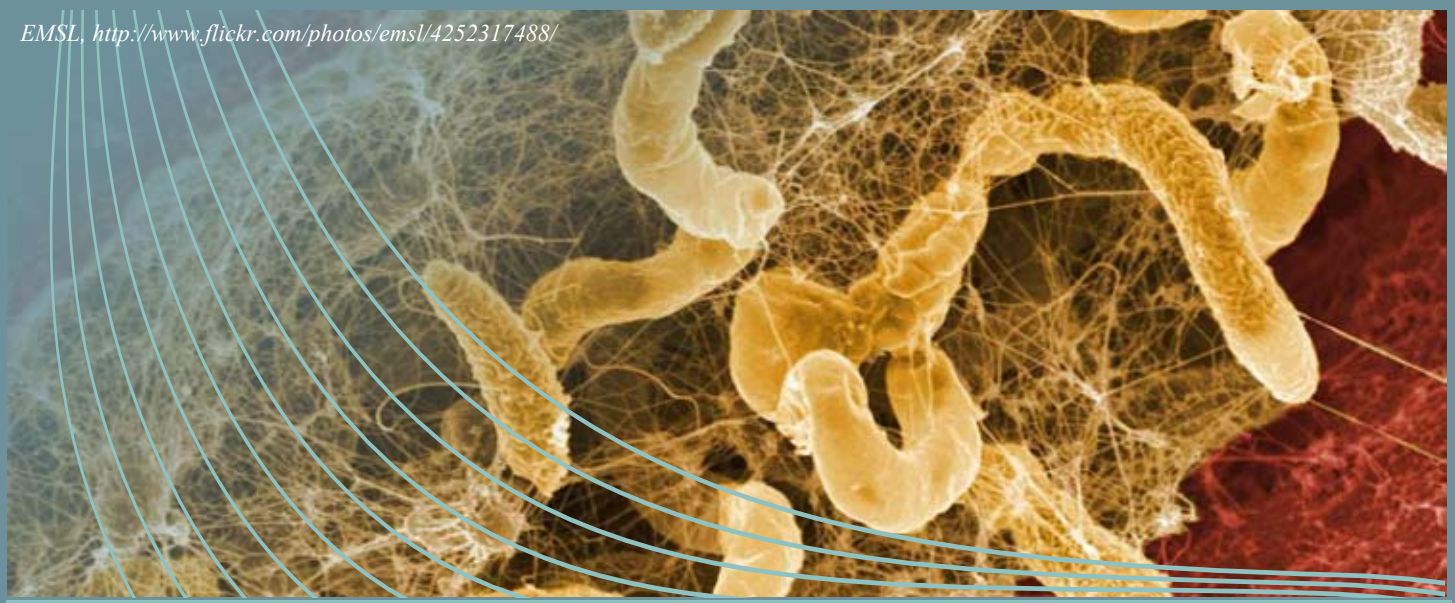
The Network Integrated Biocollections Alliance will build on a durable legacy of protocols and formalisms by which collections have always collaborated with one another in physical space, but NIBA will transform those historical methods of cooperation into a highly-interactive, network-based research enterprise.

A Workforce Enabled for 21st Century Life and Work: Digitizing the nation's biological collections will involve a large and diverse workforce ranging from volunteers to students to museum professionals to research faculty. Training in the use of technology for digitizing existing biological collections and for acquisition of new data that can seamlessly enter the digitized collections dataset will empower the workforce for life in a world with continual changes in technology. Through the training and practical experience gained through this project, the participants will be well-equipped for future challenges and will use the experience gained to train the next generation of biodiversity specialists and enthusiasts, as well as make the best possible uses of technology in their personal lives.

Partnerships

Digitizing the nation's natural history collections and managing the resulting digital collections network will be a monumental task that does not end when the specimens are digitized. New collections will continue to be added, new techniques for specimen and data analysis will surely lead to re-digitization of some specimens, and new questions will require new means of delivering collections information. Ensuring the long term success of this venture will require the development of a web of partnerships of the stakeholders for these data. NIBA will have a significant association with numerous partner organizations and agencies, discussed in detail below. The first focus is on federal agencies given the value of such data for national priority environmental, scientific, security, and related issues. Then, other stakeholders (e.g., NGOs, state and local governments, educational institutions) who will also dramatically benefit from this initiative are addressed.

The Department of Homeland Security (DHS) is responsible for dealing immediately with acts of



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terrorism, protection of the borders against the introduction of damaging or deadly pests or pathogens, interdicting shipments of forbidden items, and measuring the impact of security activities on the natural environment. Each of these operations, and many more, require accurate and rapid access to the nation's NIBA resources. DHS will utilize the data continuously to identify protected or endangered species and other contraband involving plants and animals. DHS scientists will be using the database to discern species distributions and associations of possible pathogenic species and their hosts. Access to data will be instantaneous so that quieries can be made in the field by officers on the line.

The Department of Defense already requires good and rapid data on species associated with operations that occur on military lands and may affect personnel. With the database in operation, military activities throughout the world would have instant and complete information of all specimens that occur in the area and that may impact operations.

The Department of Energy (DOE) requires accurate data on species identifications and distributions to assess the impact of any large energy generating operation, such as wind power, on organisms. DOE may have immediate need for information on species that migrate during particular times of year. Cross-taxa data are difficult to access at present. Should radiation, petroleum, or other accidents occur, models can be developed and predictions made about the effects, spread, and potential damage of such occurrences in the natural environment and in human populations. Should new sources of energy be considered, such as wind energy, possible conflicts with wildlife can be assessed readily.

The Department of Agriculture already maintains many biological collections, but like all such collections at present, the data are not easily obtained and cannot easily be accessed across taxonomic associations. The proposed NIBA resources will be used to locate potential biological control agents for pests, predict the spread and influence of damaging species, assist with pest and crop management, control damaging vertebrates, invertebrates, plants, and micro-organisms, and document the status of managed and unmanaged pollinators. The data will also be a primary resource for developing new foods, biocides, and biological control agents. As managers of Forest Service lands, knowledge of verifiable species occurrence is vital to informed decision making in our nation's forests and wilderness areas. Similarly, extension agents will have instant access to species identification for pests, competitors, and other organisms that impact agricultural lands.

The Department of Commerce will be a major user of these data, especially through NOAA activities re-

Raymond Panaligan/IRRI– Part of the image collection of the International Rice Research Institute (www.irri.org)

lated to global climate change research and marine sciences. The data to be made available through the Network Integrated Biocollections Alliance are the finest record of organisms across time in numerous climatic situations. The complete database will be an important record of species distributions associated with climate changes. The largest collections of marine organisms reside in the collections, so any attempts to describe oceanic biodiversity and identify trends will require access to the totality of the nation's collections, something not possible at this point in time.

The Department of Interior includes the Bureau of Indian Affairs, Bureau of Land Management, Bureau of Reclamation, Minerals Management Service, National Park Service, Office of Surface Mining, U.S. Fish and Wildlife Service, and the U.S. Geological Survey which hosts the Integrated Taxonomic Information System and the National Biological Information Infrastructure, which in turn is home to the U.S. node of GBIF. The DOI is a natural partner in terms of the large number of collections that it maintains, the integral part that collections data plays in its management of land and natural resources, and its mandate to provide infrastructure and leadership in the management of national biological information.

The Department of State is constantly monitoring threats to US citizens overseas or travelers returning to or entering the United States. Biological data provide a rapid assessment of the threat of the spread of disease or other contaminants in foreign countries and the likelihood that such organisms pose a danger to the nation.

The Department of Health and Human Services, which includes the Center for Disease Control and the National Institute of Health, will utilize natural history collections data in multiple ways. Specimen records can provide essential baseline information on zoonotic disease transmission, for example. Digitized specimen records will serve as essential vouchers for much of the organismal data available via NIH-supported Genbank. The many collections of genomic resources will be readily linked to provide access to frozen living tissues specimens from thousands of species worldwide, as well as any viral or pathogenic associates of those species.

The Department of Justice will utilize the data continuously to assist with forensic investigations (identifying insects, bacteria, fungi, and many other organisms associated with a crime scene), as well as the vast collections of genomic resources linked to NIBA resources which will provide genetic sequence data for research related to a crime.

The Department Transportation is often involved in the unexpected transport of pests across the nation. Efforts to control such possibly disastrous introductions or dispersals will require regular access to the collections database.

Alana Kirby , http://www.flickr.com/photos/67769880@N00/4473344307/

The Environmental Protection Agency is charged with protecting the environment which involves large efforts to monitor the effects of environmental change on all biota. From invasive species tracking to the characterization of ecosystem and biotic diversity change in response to pollution and climate change, there is a significant need for the Network Integrated Biocollections Alliance.

The Smithsonian Institution, the nation's national museum, is the largest collection repository in the United States. However, its collections, too, are not completely digitized and available. As the largest collection in the Network Integrated Biocollections Alliance, the Smithsonian would be expected to be a primary provider and user of collections data, directly benefitting the many federal and non-federal agencies, organizations, and individuals that require access to such data.

The possibility for partnerships that could support the digitization of national biological collections extends beyond the Federal government. For example, data from NIBA resources are required each day by almost all non-governmental organizations (NGOs) that deal with environmental issues. Whether one is planning or selecting new reserves to protect species or habitats, measuring the effects of habitat destruction on ecosystems and individual species, seeking indicator species for such vital issues as extinction, determining changes in distributional patterns, identifying keystone species for special protection efforts, assessing bellwethers of global climate change, or devising long-term conservation strategies, georeferenced and associated data of species past and present are required. Rapid access to such data allows timely responses to threats and greater precision when developing plans to conserve nature.

As with governmental departments and NGOs, a digitized database of biological organisms is vital to a host of state and private organizations that require species distribution data, species associations, and other data related to plants, animals, and microbes. Private businesses—from large petroleum, logging, fishing, and real estate development corporations to private businesses and individual entrepreneurs concerned with such activities as tourism, sports fishing, farming, pollination services, and hunting—need rapid access to reliable information on nature's species and habitats.

State and local government (e.g., state and county wildlife, forestry, and health departments) constantly require extensive information on species distributions and habitat and landscape associations, whether dealing with issues of fishing and hunting, agricultural extension programs, water quality, state and county health department needs, and quality of life matters of importance to such groups as local chambers of commerce.

Leigh Anne McConnaughey

Providers of educational services have a direct interest in the data that will be made available through this project, as do landscapers, artists, television and film producers and historians. Nature lovers at all levels, from professional biologists to bird watchers, journalists, wildlife artists, and photographers would be regular users of and contributors to a digitized database of nature. Automated comparisons of images and observational records placed online by the public and validated through comparison with verified specimen records to be captured by this project will allow citizen science data to be mobilized to an unprecedented extent while maintaining professional standards of data quality. The NIBA resources envisioned here can be a powerful tool for increasing science literacy, which empowers Americans to make informed decisions in their personal lives and at the polls.

This new and powerful association of museums and collections that will develop in the United States will link seamlessly with efforts that are further advanced in Europe and Australia. Such organizations as the National Biological Information Infrastructure (NBII) and Encyclopedia of Life (EOL) in the United States, and the Global Biodiversity Information Facility (GBIF), will be continuous users of these data. GBIF in particular has paved the way for this initiative through the creation of its Data Portal (http://data.gbif.org), which demonstrated that large data sets from a range of collections institutions could be mobilized effectively. GBIF has also devoted a great deal of effort to developing and promulgating standards and best practices, and data editing techniques. GBIF's newly published "Global Strategies and Action Plan for the Digitization of Natural History Collections" will be very influential in the development of the Network Integrated Biocollections Alliance. Collaborations for these and other international organizations (e.g., the Atlas of Living of Australia; http://www.ala.org.au/) can be foreseen to support continued development of digitization and mobilization best practices.

Most profoundly affected by NIBA will be science itself, particularly science that is specimen based or that discerns patterns in nature to understand the past and predict future trends. Ecologists, marine biologists, botanists, crop scientists, pharmaceutical researchers, and wildlife biologists, among others, will benefit enormously as new patterns of species and habitat associations develop when investigators are able to formulate questions across taxa and across geographic boundaries to quickly seek new and unexpected patterns of species coexistence, interactions, evolutionary trends, distributional changes, or species associations. Evolutionary biology will be a great beneficiary of these data as vast amounts of associated morphological, ecological, and genetic data become available, in addition to information on present and past geographic

Doug Anderson, http://www.flickr.com/photos/douga/4449439457/

distributions. Medical researchers will examine distributions over time, as well as assess the possibility of the spread of a disease into new geographic areas and into new hosts. In summary, the Network Integrated Biocollections Alliance will have significant, positive impacts on biological science, since the data will be immediately applicable to everything from basic taxonomy to astrobiology, from contemporary understanding of nature to the history of the development of life's diversity.

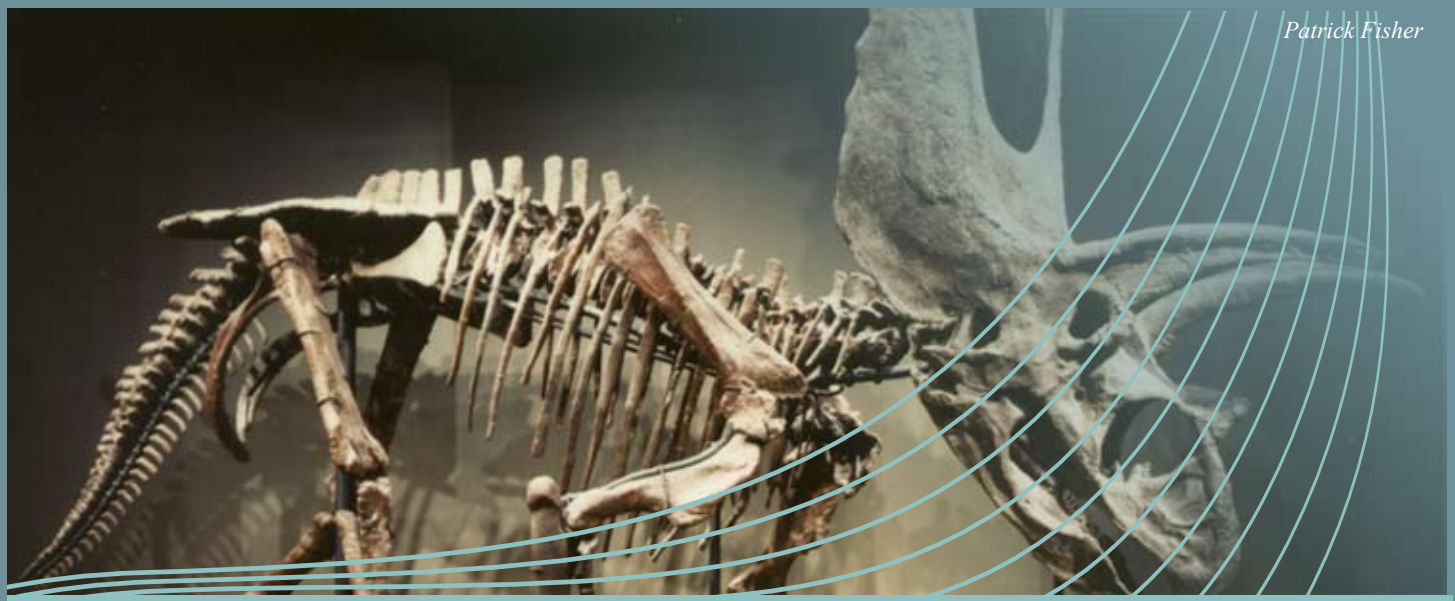
Long-Term Sustainability

It is essential that the U.S. Network Integrated Biocollections Alliance be maintained for society in perpetuity. Doing so requires a sustainability plan past the proposed ten-year time frame. One of the first priorities for the National Digitization Hub will be to develop a sustainability plan that will be comprehensive and adaptive, given a changing technological and social landscape.

Multiple avenues for sustainability can be considered. The National Science Foundation has made significant investments in DataNets to achieve long term digital presevation. One of the first funded DataNets, called DataOne (http://dataone.org), is explicitly focused on environmental data. A partnership with DataOne would be one obvious avenue for sustaining the technological infrastructure and data generated by this project. Forming strong partnerships with mission-oriented federal agencies, who already manage collections or serve as national nodes for sharing species data (e.g., National Biological Information Infrastructure), would be another natural collaboration.

A key component of this plan is developing technologies that increase the rate of digitization, and that provide simplified, scalable, and sustainable data publishing networks. Providing scalable and sustainable data publication methods may rely on commercial data centers (e.g., the cloud). Other commercial partnerships are possible that can leverage resources and expertise that may be limiting within our community or within the sciences more broadly.

Sustainability is greatly enhanced through continued development of data curation as an emerging discipline that links traditional library and information science with management of an explosion of new types of biological data (e.g., genomics and proteonomics data). Training and workforce development are initial and essential steps towards formal career opportunities that become integrated into the fabric of academic institutions.


Patrick Fisher

Community Involvement in this Planning Effort

Creating NIBA resources will require intellectual input from collections curators and researchers and an understanding of diverse perspectives and requirements from all collection data stakeholders. The initial draft of the digitization plan was shared with the community via wide distribution to individuals, institutions, agencies, and professional societies. A summary of the full community input process is below.

Feedback from the biological collections community was brisk and constructive, generating many discussions in 60+ responses posted to the project's blog (http://digbiocol.wordpress.com/). Detailed responses were received from a diversity of collections professionals and biologists, from both large and small institutions, and from representatives of societies, departments, and administrators across the nation. Collections community enthusiasm is high, with replies such as "this is a fantastic proposal that would have a tremendous impact on natural history collections in the U.S." and "a national collection resource like this will make new kinds of biodiversity science possible". Others saw the value to both scientific and public audiences: "this project would be of great value to multiple communities and many different kinds of users with disparate goals—from schoolchildren seeking to learn about species found in their geographic area to scholars investigating biodiversity". The Society for the Preservation of Natural History Collections (SPNHC), an international membership of over 600 professionals including collection curators, collection managers, conservators, and registrars, submitted a letter strongly endorsing the concept. They wrote "Our Society enthusiastically supports an initiative that increases access to collections and that promotes novel uses of specimens and specimen data". Strong letters of support for the final strategic draft plan were also received from the American Institute of Biological Sciences (AIBS) and the Natural Sciences Collections Alliance (NSCA).

Stakeholders have also provided perspective and caution. The primary concern voiced was that the logistics and electronic products of this digital initiative do no harm to the physical specimens. Other voices argued for identification and collections curation activities be supported within the context of the initiative, so as to maximize the quality of the resulting digital resource and to help with preservation of the actual specimens upon which the digital data are derived. An articulate blogger wrote that the plan "seems to reflect a vision

Ariel Javellana– Part of the image collection of the International Rice Research Institute (www.irri.org)

of one-way data mobilization: from the dusty shelves of museums to the eager hands of scientists. I would argue that this initiative should explicitly allow and encourage informatics research for the purpose of collections improvement, with the goal of positive feedback between specimen curation and taxonomy." This interaction between the digital resource and the physical specimens is clearly an important component of an accurate and vital collections data resource; it should be recognized as an important principle of the initiative.

The public comment period remains open; additional perspectives are cordially solicited and highly valued. They will contribute to the further development of this plan. Continued community feedback on the initiative outlined here is critical. Professional opinion can still be transmitted by adding a comment to the blog page (http://digbiocol.wordpress.com/). Perspectives on institutional priorities or taxon-based needs are welcomed. Specific feedback is needed to critique or amplify the proposed organizational model, to offer suggestions for revision, priorities for collection digitization, and to suggest ways to maximize collaboration across institutions and federal agencies, and at the international level. Ongoing discussion will continue to be aggregated as the effort to establish NIBA resources continue. The approach for broad involvement, across the biological collections community and among stakeholders that has been integral to the shaping of this strategic plan will continue to be a hallmark of the effort.

A draft final plan was distributed to all participants of both NESCent workshops for comment and feedback was received from multiple contributors. This feedback led to the development of this final plan, which is being delivered to federal agencies for further action. Once delivered, the community will continue to discuss and further develop efforts related to this plan in the form of additional workshops and meetings.

This outstanding transformational opportunity to digitize the specimens held by the nation's biological collections is matched in significance only by the massive societal, govermental, and research investment that has already been made with over two centuries of U.S. exploration and curation. The nation's biological collections institutions are prepared to contribute their knowledge to the most pressing science and environmental issues of our day.

Leveraging this national and monumental investment in the information contained in biological collections by digitizing and mobilizing specimen data to the Internet will renew the long-standing shared vision and purpose of biological collections institutions and take them to a new era of research communication, collaborative research, and societal engagement, while impacting science in all disciplines and at all levels.

Ian Hayhurst, http://www.flickr.com/photos/imh/1570916689/

Appendices

Appendix I: Terms

Specimen: an item of biological origin that is stored in a collection. A specimen is documented with information about the name of the species, where, when and by whom it was collected.

Collection: a set of specimens held by an institution. Institutions holding collections include museums, herbaria, universities, government agencies.

Collections Digitization: broadly defined to include transcription into electronic format various types of data associated with specimens, the capture of digital images of specimens, and the georeferencing of specimen collection localities,and other associated data quality enhancement activities.

Appendix II. Relevant Reports and Scientific Publications (in order cited in main text)

Report from the National Science Foundation based on a survey of collections which had received federal support for projects over the past twenty years http://www.nsf.gov/pubs/2009/nsf09044/nsf09044.pdf

Report from OSTP and the Interagency Working Group on Scientific Collections based on the survey of federally-held collections: http://www.nescent.org/wg/digitization/images/d/d1/Collections2.pdf

Stevenson, J. W. and D. W. Stevenson. 2003. Development of a national systematics infrastructure: a virtual instrument for the 21st century. Report to the National Science Foundation, Biodiversity Surveys and Inventories Program. New York, December, 2003.

Constable, H., R. P. Guralnick, J. Wieczorek, C. Spencer, A. T. Peterson and the VertNet Steering Committee. 2010. VertNet: A New Model for Biodiversity Data Sharing. PLoS Biology 8(2): e1000309

Moritz, C. et al. 2008. Impact of a Century of Climate Change on Small-Mammal Communities in Yosemite National Park, USA. Science 322: 261-264.

Dove, C. 1999. Feather identification and a new electronic system for reporting US Air Force bird strikes. Paper posted at DigitalCommons@University of Nebraska - Lincoln. http://digitalcommons.unl.edu/birdstrike1999/13.

Yates, T. E. et al., 2002. The ecology and evolutionary history of an emergent disease: Hantavirus pulmonary syndrome. BioScience 52: 989-998.

Mark Westneat

Page, L., Funk, V., Jeffords, M., Lipscomb, D., Mares, M., and A. Prather. 2004. Workshop to produce a decadal vision for taxonomy and natural history collections, Gainesville, November 2003. Report to the National Science Foundation, Biodiversity Survey and Inventories Program, Gainesville, November, 2003.

Page, L., et al. 2005. LINNE: Legacy Infrastructure Network for Natural Environments. Illinois Natural History Survey Publication, Pp. 1-16.

Appendix III. Workshop Participants and Funding Support

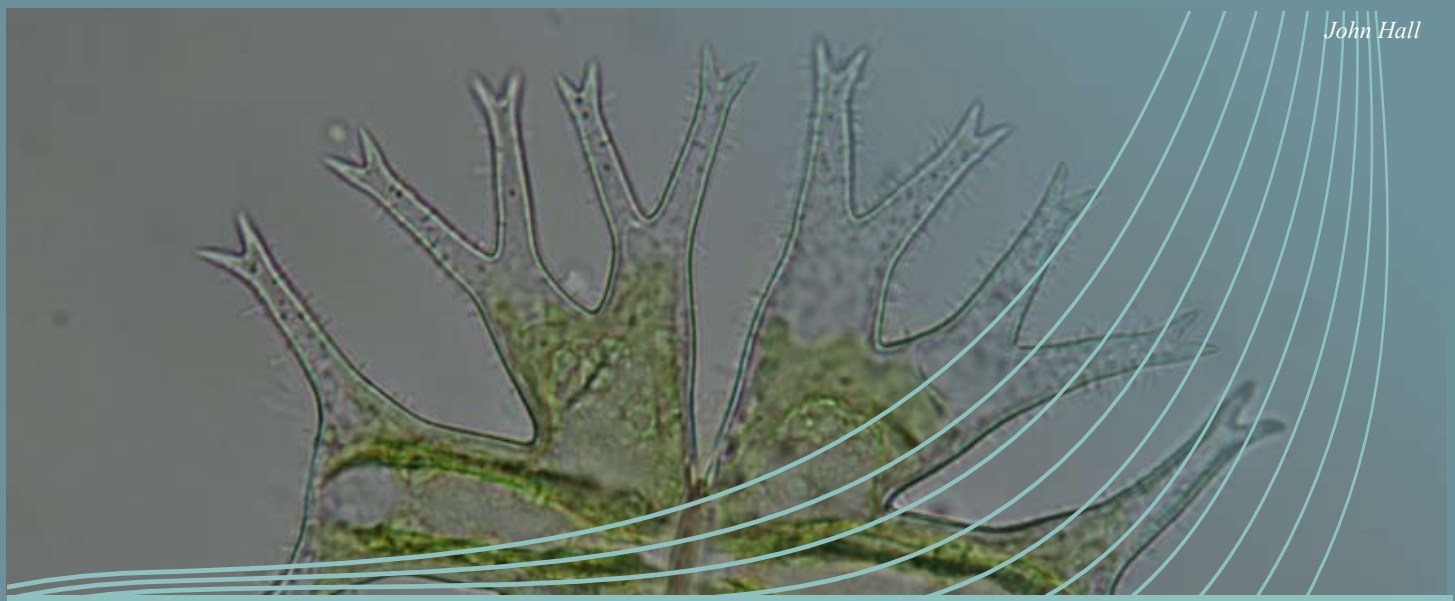
NESCent digitization workshop I (Feb 5-7th 2010) participants: Hank Bart, James Beach, Stan Blum+, Andy Deans, Michael Donoghue*+, Linda Ford+, Gerald Guala, Rob Guralnick+, Pat Holroyd, Jennifer Leopold, Michael Mares*+, Chuck Miller, Bob Morris, William Piel, Babara Thiers+, Todd Vision, Mark Westneat+, Quentin Wheeler+, Tim White, Brian Wiegmann.

* - Workshop leaders, + Initial strategic plan draft writing

NESCent digitization workshop II (April 28-30th 2010) participants: John Ascher, Mark Barkworth, Hank Bart, James Beach+, Joel Cracraft, Andy Deans, Linda Ford+, Gerald Guala, Rob Guralnick*+, Mari Kimura, Michelle Koo, John Long, Michael Mares+, Bob Morris, Paul Morris, Christopher Norris, William Piel, Alan Prather, Kate Rachwal, Randall Schuh, Barbara Thiers*+, Paul Tinerella, Mark Westneat+, Tim White, Brian Wiegmann*+, Jean Woods.

* - Workshop leaders, + Final strategic plan writing

Workshop funding support to: Allen Rodrigo (workshop I), and Andy Deans and Brian Wiegmann (workshop II).



John Hall