U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE AND TECHNOLOGY
SUBCOMMITTEE ON RESEARCH AND SCIENCE EDUCATION

HEARING CHARTER

21st Century Biology

June 29, 2010
2:00 p.m. – 4:00 p.m.
2318 Rayburn House Office Building

1. Purpose:

The purpose of the hearing is to examine the future of the biological sciences, including research occurring at the intersection of the physical sciences, engineering, and biological sciences, and to examine the potential these emerging fields of interdisciplinary research hold for addressing grand challenges in energy, the environment, agriculture, materials, and manufacturing.

2. Witnesses:

- Dr. Keith Yamamoto, Chair, National Academy of Sciences, Board on Life Sciences and Professor, Cellular and Molecular Pharmacology, University of California, San Francisco
- Dr. James Collins, Virginia M. Ullman Professor of Natural History and the Environment, Department of Ecology, Evolution, & Environmental Science, Arizona State University
- Dr. Reinhard Laubenbacher, Professor, Virginia Bioinformatics Institute and Department of Mathematics, Virginia Tech
- Dr. Joshua N. Leonard, Assistant Professor, Department of Chemical and Biological Engineering, Northwestern University
- Dr. Karl Sanford, Vice President, Technology Development, Genencor

3. Overarching Questions:

- What is the future of research in the biological sciences? What potential does research at the intersection of the biological sciences, physical sciences, and engineering hold for addressing grand research challenges in energy, the environment, agriculture, materials, and manufacturing? What new technologies and methodologies, including computational tools, are enabling advances in biological research? Are there promising research opportunities that are not being adequately addressed?

- What is the nature of the interactions and collaborations between physical scientists, engineers, and biological scientists? How might these disparate research communities be better integrated? Is the National Science Foundation playing an effective role in fostering research at the intersection of the physical sciences, engineering, and the biological sciences? Is research in the biological sciences, including research at the intersection of the biological sciences, the physical sciences, and engineering being effectively coordinated across the Federal agencies? If not, what changes are needed?

- What changes, if any, are needed in the education and training of undergraduate and graduate students to enable them to work effectively across the boundaries of the physical sciences, engineering, and the biological sciences without compromising core disciplinary depth and understanding? How do you achieve that balance?

- How are advances in the biological sciences affecting the biotechnology industry? What are the research needs of the biotechnology sector and are they being adequately addressed? Are science and engineering students being adequately trained by colleges and universities to be successful in the biotechnology industry? Is the National Science Foundation playing an effective role in fostering university-industry collaborations?

4. Background:

Research in the biological sciences is the largest area of research supported by the Federal government, representing 27 percent of federal research obligations in 2007. Currently over 20 Federal agencies support biological sciences research ranging from bioterrorism-related research at the Department of Homeland Security to stream ecology at the National Science Foundation. Over the last 30 years there have been rapid advances in DNA sequencing technologies, the real-time imaging of cells and organisms, and computational power. These technical advances, among others, have enabled significant accomplishments in biological research, including the sequencing of the human genome in 2003 and more recently, the creation of a synthesized genome by the J. Craig Venter Institute[1]. Many believe biological research is on the verge of a revolution, moving from a field that has focused primarily on "identifying parts" (i.e. plant species, cells, genes, and proteins) and defining complex systems to one that can design, manipulate, and predict the function of biological systems at all levels of organization from the individual cell to an entire ecosystem. Many experts predict that just as the 20th century was the golden era for physics the 21st century will be the "age of biology", and advances and discoveries in the biological sciences will transform society.

A deeper understanding of biological systems and the ability to address biology-based societal problems such as the production of a sufficient amount food to sustain the growing human population or the generation of clean energy are increasingly being tackled through interdisciplinary research. The trend toward interdisciplinary research, specifically, research at the intersection of the biological sciences, engineering, mathematics, and the physical sciences has been termed the "new biology"[2]. Within the "new biology" three areas are emerging as foundational fields: computational biology, systems biology, and synthetic biology.

[1] http://www.sciencemag.org/cgi/rapidpdf/science.1190719v1.pdf
[2] http://www.nap.edu/catalog.php?record_id=12764

Computational biology is the use of mathematical tools and techniques in the examination of biological processes and systems; for example the use of math to describe and understand heart physiology. Systems biology is the study and predictive modeling of biological processes through a holistic examination of the dynamic interaction of the individual components of a system; for example the study of an organism, viewed as an integrated and interacting network of genes, proteins and biochemical reactions. Synthetic biology is an emerging field that applies the principles of engineering to the basic components of biology. The aim of synthetic biology is to make predictable and easy to use genetically-engineered cells, organisms, or biologically-inspired systems for industrial applications like the production of biofuels or therapeutic applications to treat disease.

A number of issues need to be considered as these new trends in biological sciences research develop. Specifically, the type of education and training necessary for undergraduate and graduate students to work effectively across traditional disciplines, the effectiveness of Federal support for interdisciplinary research and education, and the increasing need for interagency coordination of biological sciences research.

The Role of NSF in Biological Sciences Research

The Directorate for Biological Sciences (BIO) at the National Science Foundation supports 68 percent of the non-medical, basic biological sciences research performed at academic institutions, including plant biology, environmental biology and biodiversity research. The fiscal year 2011 budget request for BIO is $767.8 million, an increase of 7.5 percent over fiscal year 2010 (see table below). BIO is separated into 5 divisions and supports research to advance understanding of the underlying principles and mechanisms governing life. Research supported by BIO ranges from the examination of the structure and dynamics of biological molecules to more complex systems and scales, including organisms, communities, ecosystems, and the global biosphere.

BIO Funding

(Dollars in Millions)

	FY 2009 Omnibus Actual	FY 2009 ARRA Actual	FY 2010 Estimate	FY 2011 Request	Change Over FY 2010 Estimate	
					Amount	Percent
Molecular & Cellular Biosciences (MCB)	$121.28	$61.53	$125.59	$133.69	$8.10	6.4%
Integrative Organismal Systems (IOS)	212.34	61.71	216.25	226.70	10.45	4.8%
Environmental Biology (DEB)	120.37	63.23	142.55	155.59	13.04	9.1%
Biological Infrastructure (DBI)	117.95	38.74	126.86	145.63	18.77	14.8%
Emerging Frontiers (EF)	84.68	34.80	103.29	106.20	2.91	2.8%
Total, BIO	**$656.62**	**$260.00**	**$714.54**	**$767.81**	**$53.27**	**7.5%**

Source: National Science Foundation FY 2011 Budget Request to Congress
http://www.nsf.gov/about/budget/fy2011/toc.jsp

The Division of Molecular and Cellular Biosciences (MCB) supports research to understand the dynamics and complexity of living systems at the molecular, biochemical and cellular levels.

Projects funded through MCB often focus on the regulation of genes and genomes, properties of biomolecules, and the structure of subcellular systems. Activities supported by MCB are increasingly interdisciplinary with the use of tools and technologies developed in the physical sciences, mathematics, and engineering becoming routine.

The Division of Integrative Organismal Systems (IOS) supports a systems-level approach to the understanding of plants, animals, and microorganism; this holistic approach includes the study of an organism's development, function, behavior, and evolution. The Plant Genome Research Program (PGRP), which is part of the National Plant Genome Initiative, is supported through IOS. The PGRP, with a budget request of $105.4 million in fiscal year 2011, supports basic research to improve crop production, and to identify and develop new sources for bio-based fuels and materials.

The Division of Environmental Biology (DEB) supports fundamental research on the origins, functions, relationships, interactions, and evolutionary history of populations, species, communities, and ecosystems. Research on the complexity and dynamics of ecosystems and evolution are essential to improving our ability to understand and mitigate environmental change.

The Division of Biological Infrastructure (DBI) supports a variety of activities from the development of instruments, software, and databases to the improvement and maintenance of biological research collections and field stations to the transformation of undergraduate biology education. DBI provides the infrastructure, including the human capital, necessary for contemporary research in biology. DBI oversees BIO's participation in cross-cutting programs at NSF including, the Graduate Research Fellowships program, the Integrative Graduate Education and Research Traineeship (IGERT) program (described in detail later) and the Major Research Instrumentation program.

Developing programs and priority areas often start in the Emerging Frontiers (EF) Division and then are integrated into BIO's core programs. EF supports novel partnerships across disciplines and enables the development of new conceptual frameworks. Additionally, EF develops and implements new forms of merit review and mechanisms to support high-risk, high-reward research.

In addition to the research and education activities supported by BIO, the National Ecological Observatory Network (NEON) was included in NSF's fiscal year 2011 budget request for the Major Research Equipment and Facilities Construction (MREFC) account. NEON, a continental-scale research platform for discovering and understanding the impacts of climate change, land-use change, and invasive species on ecosystems, is the first biological sciences related project funded through the MREFC process.

The Role of NSF in Interdisciplinary Education and Training

NSF supports interdisciplinary education primarily through the IGERT program. Since 1998 the IGERT program has made 215 awards to over 100 universities and has provided funding for nearly 5,000 doctoral-level graduate students. IGERT awards average $3.0 million over 5 years with the major portion of the funds being used for graduate student stipends and training expenses. While each IGERT award is unique, the overall goal of the program is to develop scientists and engineers who will pursue careers in research and education from a strong interdisciplinary background and catalyze a cultural change in graduate education, for students, faculty, and institutions, by establishing innovative models that transcend traditional disciplinary boundaries. For example, there are currently 15 IGERT awards in the area of bioinformatics all seeking to create professionals who can translate scientific problems in biology into mathematics and computations.

NSF also supports a number of research centers that are interdisciplinary in nature and undergraduate and graduate students working in the context of those research centers are exposed to interdisciplinary research, education, and training. For example, through the Centers for Analysis and Synthesis Program, the iPlant Center led by the University of Arizona integrates biologists, computer scientists, and engineers to address grand challenges in the plant sciences, and through the Engineering Research Centers program, the Center for Biorenewable Chemicals led by Iowa State University seeks to transform the chemical industry by integrating biologists and chemists to produce sustainable biochemicals. However, centers are not required to be interdisciplinary and the degree of formal graduate and undergraduate education programs associated with the centers varies.

Interagency Biological Sciences Research Programs

The National Plant Genome Initiative (NGPI) was established in 1998 and includes the U.S. Department of Agriculture (USDA), the Department of Energy (DOE), the National Institutes of Health (NIH), and NSF. According the initiative's strategic plan[3], the goal of the initiative is translate basic research and understanding of economically important plants and plant processes, including a deeper understanding of the structures and functions of plant genomes into the enhanced management of agriculture, natural resources, and the environment to meet societal needs.

The U.S. Global Change Research Program (USGCRP), which began as a presidential initiative in 1989 and includes 13 federal agencies, was formally established by Congress through the Global Change Research Act of 1990 (P.L. 101-606). The USGCRP coordinates and integrates federal research on global climate change. While the USGCRP extends beyond biological sciences research one of the program's strategic goals is to "understand the sensitivity and adaptability of different natural and managed ecosystems and human systems to climate and related global changes."[4]

On a smaller scale, NSF and NIH are jointly funding grants in mathematical biology and the ecology of infectious diseases. Specifically, NSF and NIH sponsor a collaborative research program in computational neuroscience that could lead to significant advances in the understanding of nervous system function and the underlying mechanisms of nervous system disorders such as Alzheimer's disease.

---

[3] http://www.csrees.usda.gov/business/reporting/stakeholder/pdfs/pl_iwg_plant_genome_yearPlan.pdf
[4] http://www.climatescience.gov/Library/stratplan2008/CCSP-RRP-FINAL.pdf

5. Questions for Witnesses:

Dr. Keith Yamamoto

- Please summarize the findings and recommendations of the National Research Council's report, A *New Biology for the 21st Century*.

- Are there promising research opportunities at the intersection of the biological sciences, the physical sciences, and engineering that are not being adequately addressed? Are federal agencies, in particularly NSF, playing an effective role in fostering research at this intersection? If not, what recommendations would you offer?

- Is research in the biological sciences, including research at the intersection of the biological sciences, the physical sciences, and engineering being effectively coordinated across the Federal agencies? If not, what changes are needed?

- What changes, if any, are needed in the education and training of undergraduate and graduate students to enable them to work effectively across the boundaries of the physical sciences, engineering, and the biological sciences without compromising core disciplinary depth and understanding? Specifically, what recommendations or changes, if any, would you offer regarding the portfolio of education and training programs supported by NSF?

Dr. James Collins

- In your opinion, what is the future of research in the biological sciences and what potential does research at the intersection of the biological sciences, the physical sciences, and engineering hold for addressing grand challenges in the environment? What tools and methodologies need to be developed and what are the most promising research opportunities?

- As the most recent Assistant Director for Biological Sciences at the National Science Foundation,

    - How is NSF fostering research at the intersection of the biological sciences, the physical sciences, and engineering? What recommendations, if any, would you offer regarding NSF's current portfolio of programs supporting research at this intersection?

    - What education and training programs at NSF provide undergraduate students, graduate students, and postdocs with the skills necessary to work at the intersection of the biological sciences, the physical sciences, and engineering? What recommendations, if any, would you offer regarding NSF's education and training programs?

- How is NSF fostering university-industry research collaborations in the biological sciences? What recommendations, if any, would you offer regarding NSF's university-industry programs?

- Is research in the biological sciences, including research at the intersection of the biological sciences, the physical sciences, and engineering being effectively coordinated across the Federal agencies? If not, what changes are needed?

Dr. Reinhard Laubenbacher

- In your opinion, what is the future of research in the biological sciences and what role does research at the intersection of biology and mathematics hold for addressing grand challenges in energy, the environment, agriculture, materials, and manufacturing? What computational tools still need to be developed? Are there promising research opportunities that are not being adequately addressed? Is the National Science Foundation playing an effective role in fostering research at the intersection of the physical sciences, engineering, and the biological sciences? If not, what recommendations would you offer?

- What is the nature of the interactions and collaborations between mathematicians and biological scientists at the Virginia Bioinformatics Institute (VBI)? How is VBI facilitating these interdisciplinary collaborations and what lessons can we learn from VBI? Is research at the intersection of the biological sciences, the physical sciences, and engineering being effectively coordinated across the Federal agencies? If not, what changes are needed?

- What changes, if any, are needed in the education and training of undergraduate and graduate students to enable them to work effectively across the boundaries of the physical sciences, engineering, and the biological sciences without compromising core disciplinary depth and understanding? Specifically, what recommendations or changes, if any, would you offer regarding the portfolio of education and training programs supported by NSF?

Dr. Joshua N. Leonard

- In your opinion, what role does research at the intersection of biology and engineering hold for addressing grand challenges in energy, the environment, agriculture, materials, and manufacturing? Specifically, describe the emerging field of synthetic biology, including the work of your research group and your involvement in the recent NSF sponsored "sandpit" and National Academies Keck Futures Initiative on synthetic biology. Is the National Science Foundation playing an effective role in fostering research in synthetic biology? If not, what recommendations would you offer?

- Is research in the biological sciences, including research at the intersection of the biological sciences, the physical sciences, and engineering being effectively coordinated across the Federal agencies? If not, what changes are needed?

- What changes, if any, are needed in the education and training of undergraduate and graduate students to enable them to work effectively across the boundaries of the physical sciences, engineering, and the biological sciences without compromising core disciplinary depth and understanding? Specifically, describe the ongoing efforts of Northwestern University and the Department of Chemical and Biological Engineering to improve interdisciplinary graduate education. What recommendations or changes, if any, would you offer regarding the portfolio of education and training programs supported by NSF?

Dr. Karl Sanford

- Please provide a brief overview of Genencor, including a description of the development of new products and processes in the areas of bioenergy and biomaterials.

- In your opinion, what is the future of research in the biological sciences? How are research advances in the biological sciences driving industrial biotechnology? Does the current range of federally supported research adequately address the needs of the biotechnology industry? If not, what are the research gaps?

- Are science and engineering students being adequately trained by colleges and universities to be successful in the biotechnology industry? If not, what kind of education and training is needed and at what levels of education?

- What is the nature of Genencor's partnerships with U.S. universities, including Genencor's involvement in the Synthetic Biology Engineering Research Center at the University of California- Berkeley? Are the Federal agencies, including the National Science Foundation playing, an effective role in fostering university-industry collaboration? Are these research partnerships effective in the transfer of knowledge and technology from U.S. universities to industry? If not, are there best practices, training, or policies that should be put in place to facilitate the commercialization of federally funded research in the biological sciences?