Testimony of

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on

"Understanding the Brain – In Context, In Action"

NSF's Role in the BRAIN Initiative

February 27, 2014

Chairman Wolf, Ranking Member Fattah, and Members of the Subcommittee, it is my privilege to be here today with you and with Dr. Holdren to discuss the National Science Foundation's role in The BRAIN Initiative.

Introduction

Understanding the brain is one of humanity's greatest scientific challenges and achieving this understanding will clearly have great societal benefits. This imperative has been recognized by advisory bodies including the National Academies,[1] and has moved forward with the guidance of Congress and by the President's announcement of The BRAIN Initiative.

With its broad support for science, engineering and STEM education, NSF is well positioned to advance research on understanding the brain – by bringing together a wide-range of scientific

[1] A National Research Council report entitled, "*Research at the Intersection of the Physical and Life Sciences*" (2010) identified "Understanding the Brain" as one of five foremost grand challenges, at the interface of the life and physical sciences. The National Academy of Engineering has also recognized "*Reverse-Engineering the Brain*" as a Grand Challenge for Engineering (2008).

and engineering disciplines to reveal the basic physical (e.g. biophysical, biochemical), neuronal, networking, and computational principles underlying brain organization and reorganization that govern learning, cognition, and behavior.

For over thirty years, the scientific investments of NSF core programs has catalyzed transformative breakthroughs in brain research and related enabling technologies. Fundamental discoveries that began with NSF support led to the development of the optogenetics technique for experimentally manipulating brain neurons in living organisms, the CLARITY transparent brain preservation and mapping technique, brain-machine interface systems designed to restore lost function from disease or injury, and the first FDA-approved artificial retina. NSF funding for research that compares similar neural circuits and mechanisms in different animals, including humans, is both unique and critical and has led to conceptual breakthroughs in basic principles of brain structure and function.

Furthermore, NSF's capacity for driving integrative research across multiple disciplines – a key to accelerating progress in understanding the brain – is exemplified by the highly successful BioMaPS program, a multi-directorate collaboration focused on supporting research teams at the interfaces of the biological, mathematical, physical and chemical sciences and engineering. Future efforts under BioMaPS will support the development of the neurotechnologies needed for new molecular and cellular neuroscience research. Similarly, the Collaborative Research in Computational Neuroscience (CRCNS) program is a multi-directorate effort to build on the theories and findings of computer science, cognitive science, neuroscience and other related fields to advance understanding of nervous system structure and function. NSF is also a leader in supporting key developments in advanced cyberinfrastructure that enable processing, analysis and storage of large cross-disciplinary data sets like those that will be generated under The BRAIN Initiative. Finally, NSF's importance in enabling coordination of neuroscience research at the global scale is exemplified by NSF's long history of support for the International Neuroinformatics Coordinating Facility.

Recent Investments Relating to Understanding the Brain

In FY 2012, Congress encouraged NSF to establish a **"cognitive science and neuroscience crosscutting theme"** to sustain and expand investments in "the non-medical aspects of cognitive sciences and neurosciences, particularly through interdisciplinary science, computational models, visualization techniques, innovative technologies, and the underlying data and data infrastructure needed to transform our understanding of these areas." NSF responded in FY 2013 by encouraging the submission of transformative new proposals across disciplines for research aimed at understanding the brain and cognition. In its FY 2014 Budget Request, NSF proposed new investments of nearly $14 million to catalyze new research at the frontiers of neuroscience, neuroengineering, and cognitive science.

The President announced The BRAIN Initiative on April 2, 2013 and identified NSF, NIH, and DARPA as the lead agencies. NSF's $20 million support for The BRAIN Initiative in FY 2014 leverages existing investments in research across a wide range of topics and disciplines related to The BRAIN Initiative.

NSF Goals and Plans for The BRAIN Initiative

Following the President's announcement, NSF immediately began engaging leaders across the relevant scientific and engineering disciplines in discussions to identify priority research areas for meeting the goals of The BRAIN Initiative. Over the past year, NSF has supported the following planning and prioritization workshops across many of the disciplines and thematic areas of The BRAIN Initiative:

- *Physical and Mathematical Principles of Brain Structure and Function*, May 2013
  Sponsored by the Directorates of Mathematical and Physical Sciences and Biological Sciences, this workshop brought together research leaders to identify key gaps in conceptual, experimental, computational, theoretical and data handling methodologies and tools needed to advance understanding of the brain.
- *Linking Language and Cognition to Neuroscience via Computation*, May 2013
  Sponsored by the Directorates of Social, Behavioral, and Economic Sciences and Computer and Information Science and Engineering, this workshop comprised experts across computer science, linguistics, cognition, neuroscience and genetics to identify how principles elucidated and techniques employed in these disciplines could inform collaborations and advance discovery.
- *Integrating Approaches to Computational Cognition*, May 2013
  Sponsored by the Directorates of Social, Behavioral, and Economic Sciences and Computer and Information Science and Engineering, this workshop brought key research leaders together to identify the conceptual frameworks, technologies and research tools needed to integrate cognitive science and machine learning disciplines and open new vistas on brain research.
- *Mapping and Engineering the Brain*, August 2013
  Sponsored by the Directorate of Engineering, this workshop comprised experts in bioengineering, neuroscience and research infrastructure development, and focused on the needs for improved capabilities and techniques in advanced neuroimaging, multi-scale modelling, and experimentation in naturalistic environments.
- *Phylogenetic Principles of Brain Structure and Function*, October 2013
  Sponsored by the Directorate of Biological Sciences and the Howard Hughes Medical Institute/Janelia Farms, experts in fundamental biology at this workshop looked specifically at the need for reference species to accelerate comparative brain mapping research, and the associated cross-disciplinary coordination and workforce training.
- *Quantitative Theories of Learning, Memory, and Prediction*, planned for May 2014
  Sponsored by the Directorates of Mathematical and Physical Sciences and Social, Behavioral and Economic Sciences, this workshop will comprise leaders in the fields of computational neuroscience, cognition and behavior to identify needs for conceptual frameworks that guide research into the relationship between brain and behavior.

This broad-based NSF engagement with the scientific community – which has included Nobel laureates, leading domestic and international scientists, as well as members of the NIH Advisory

Committee to the Director on The BRAIN Initiative – has served to identify the technological and conceptual advances in neuroscience, neuroengineering, and cognitive science that are most important for understanding the brain, which in turn guide NSF investments in these areas.

This review by the scientific community has shown that we have gained much knowledge of the individual genetic, molecular, cellular, and biochemical elements of the brain and nervous system. Recent research enabled by new methodologies and tools has also revealed some of the relationships between these elements and simple cognitive processes and behaviors. However, science must move beyond investigating simple linear relationships to discover how complex systems emerge from their individual elements. The causal connection of multi-directional interactions among these elements with normal brain function, cognition and behavior, within a broad environmental context, will continue to engage the efforts of the scientific community for the foreseeable future

To attain a fundamental scientific understanding of the full complexity of the brain, in context and in action, **NSF investments in The BRAIN Initiative are focused on generating an array of physical and conceptual tools** needed to determine how healthy brains function over the lifespan of an organism, including humans; and on deployment and utilization of these tools to produce a comprehensive understanding of how thoughts, memories and actions emerge from the dynamic activities of the brain. NSF is leveraging and expanding its investments in high-risk/high reward exploratory and transformational scientific and engineering research in three areas where it is uniquely strong:

First, NSF is increasing its already strong emphasis on **integrative and interdisciplinary fundamental research** using new collaborations among the science and engineering disciplines to expand and improve our understanding of the brain, and to develop the scientific workforce.

Second, NSF is investing in development of **new theories, computational models and analytical tools** that will guide research questions and synthesize experimental data.

And third, NSF is placing more emphasis on the **development of innovative technologies and data infrastructure** that are required to handle the expected large scale data sets resulting from this research, and enable new experimental recording and neuro-control capabilities required for recovery of normal function.

Expertise in science, engineering and education at NSF is being brought together to accelerate relevant fields of research across these priority investment areas. Examples of such new investments include:

- New NSF-funded Research Coordination Networks (RCNs) to organize the scientific community and increase collaborative efforts in neuroscience
- A new $25 million Science and Technology Center (STC) on "Brains, Minds, and Machines" at the Massachusetts Institute of Technology.
- $5 million in interdisciplinary awards to stimulate potentially transformative research, including basic experimentation, theory development, computation, and technology development related to understanding the brain.

- An Engineering Research Center (ERC) at the University of Washington on Sensorimotor Neural Engineering, which is developing engineering models and neural interfaces that correct or compensate for neural deficits and augment neural capabilities.
- Recently established partnerships with other agencies and non-governmental organizations to leverage support for workshops, training, and collaborative opportunities in targeted areas of mutual interest for understanding the brain.

NSF Interagency and International Coordination

NSF's plans for The BRAIN Initiative are informed by its extensive engagement with interagency and international neuroscience activities. In FY 2013, NSF began co-chairing the Interagency Working Group on Neuroscience (IWGN), chartered under the National Science and Technology Council by the Office of Science and Technology Policy to coordinate neuroscience research efforts across the federal government. NSF representation on the IWGN spans all relevant science and engineering directorates. NSF also participates as an *ex-officio* member of the NIH Advisory Committee to the Director on The BRAIN Initiative, and maintains regular high-level contact with NIH, DARPA and OSTP to ensure that agency plans and activities for The BRAIN Initiative are coordinated and distinct. At the scientific level, NSF and NIH have partnered for many years to support computational neuroscience research through the Collaborative Research in Computational Neuroscience Program, which also increasingly includes international participation, currently by France, Germany, and Israel. Finally, as mentioned earlier, NSF has been a sustaining supporter of the International Neuroinformatics Coordinating Facility.

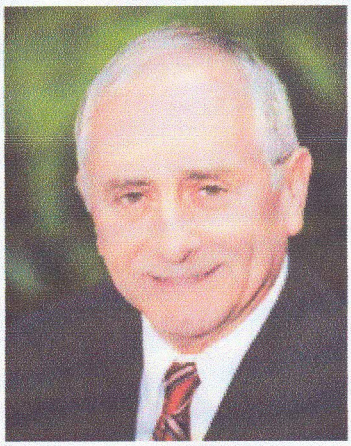
Summary

Mr. Chairman, first and foremost, NSF is focused on support for *basic research and education* in science and engineering. Our investments in neuroscience, cognitive science and The BRAIN Initiative are building upon this focus to provide the foundation for development of neurotechnologies and concepts that ultimately form the basis for future translational results.

The results of our new cross-foundation activities are aimed at accelerating scientific discovery and innovation, promoting advances in technology, and ultimately, improving the competitiveness of the American scientific workforce and enhancing the lives of Americans. Improved understanding of the brain will promote better brain health; enable engineered solutions that enhance, replace or compensate for lost function; improve the effectiveness of formal and informal educational approaches; and lead to brain-inspired smarter technologies for improved quality of life. Basic research in these areas will also offer novel insights into how cognitive abilities develop and can be maintained and improved throughout the lifespan.

Thank you, Mr. Chairman for this opportunity to highlight NSF's contributions to the nation's quest to understand the brain. I will be pleased to answer any questions you may have.

Dr. John C. Wingfield, Assistant Director, Biological Sciences (BIO)



Dr. John C. Wingfield is the assistant director for Biological Sciences (BIO) at the National Science Foundation (NSF). Wingfield's research has covered a wide spectrum of biology from molecular and organismal to environmental and ecological scales. He joined NSF as division director for Integrative Organismal Systems in September 2010 from the University of California, Davis.

Wingfield is a distinguished scientist and active researcher with a strong record of scholarly scientific publication and leadership experience. His research focuses on neural pathways for environmental signals affecting seasonality in birds and their mechanisms of coping with environmental stress. His research also interfaces with how animals deal with global climate change, endocrine disruption and conservation biology.

Wingfield has delivered numerous invited lectures, served on several editorial boards, and held positions as associate editor and/or editor-in-chief for major journals in his fields. He has received many honors from his peers and served as president of the Society for Integrative and Comparative Biology. He also has an extensive record of service to NSF and scientific advisory boards. Prior to joining NSF in 2010, Wingfield was the chair for the department of zoology at the University of Washington from 1999 to 2003, and has held an Endowed Chair in Physiology at UC-Davis since 2007.

Wingfield received his Bachelor of Science degree in zoology from the University of Sheffield and a Ph.D. in zoology and comparative endocrinology from the University College of North Wales.

Credit: *NSF/Photo by Sandy Schaeffer*