COGNITIVE SCIENCE AND NEUROSCIENCE

Overview

Cognitive Science and Neuroscience is a multi-year effort that includes NSF's participation in the Administration's Brain Research through Advancing Innovative Neurotechnologies (BRAIN) Initiative. The overall objective of the Cognitive Science and Neuroscience activity is to enable scientific understanding of the full complexity of the brain through targeted, cross-disciplinary investments in research, technology, and workforce development.

For over three decades, NSF has supported neuroscience and cognitive science research and technology development through many disciplinary programs spread across the Foundation. With this cross-foundation activity, NSF aims to leverage its existing investments and foster greater internal collaboration among these programs – in order to revolutionize our understanding of the brain by changing the way science and engineering disciplines collaborate. This activity supports the NSF Strategic and Performance Goals to "Transform the Frontiers of Science and Engineering" and "Stimulate Innovation and Address Societal Needs through Research and Education."

Cognitive Science & Neuroscience Funding

(Dollars in Millions)

FY 2013 Actual	FY 2014 Estimate	FY 2015 Request
$1.00	**$13.85**	**$29.00**

Goals

Goal 1: *Develop innovative neurotechnologies to monitor and analyze brain activity, and new tools, experimental approaches, theories, and models to integrate neuroscience information across scales and scientific disciplines.* This goal represents the objectives of NSF's investments under the BRAIN Initiative. These objectives are focused on development of innovative technologies, tools, computational infrastructure, theory, and models that will accelerate the integration of knowledge across experimental scales from atomic to behavioral; across multiple science, engineering, and computational disciplines; and across species and lifespans. Expected outcomes include the appearance of new neurotechnologies, predictive models, and theories of brain and nervous system function that can guide follow-on experimental research and foster further technical and theoretical achievements. One long-term success measure will be the level of adoption of these innovations by the scientific community.

Goal 2: *Identify the fundamental relationships among neural activity, cognition, and behavior.* This goal aims to foster increased understanding of the causal relationships between neuronal activity in the brain, cognitive processes, and behavior. Advancements in this area require greater collaboration among the neuroscience, cognitive science, and behavioral disciplines; and adoption of innovative technologies and methods to monitor and manipulate brain activity – such as the recent development of optogenetics, and the utilization of cyber-infrastructure platforms and computational tools for performing multi-scale analysis of neuroscientific and behavioral data. NSF planned investments are designed to provide an agile means for research teams to form around specific behavioral paradigms and adapt and/or develop technologies and models. Expected outcomes include an increase in the number of such teams working together on specific neural-behavioral paradigms utilizing advanced methods and models.

Goal 3: *Transform our understanding of how the brain responds and adapts to changing environments and recovers from lost functionality.* This goal aims to expand support for exploring the links among the environment, behavior, and brain function, as well as the enhancing and restorative neurotechnologies

that can be brought to bear in these areas. NSF research investments are aimed to catalyze the formation of new teams to elucidate basic brain mechanisms and their relationships to social and physical environments, cognition and behavior, and related neuroengineering. The expected outcome is measurable progress in developing specific mappings between brain functional/structural changes and identified changes in psychosocial, external physical, and technological environments; and acceptance of those mappings wider in the community via citation and reuse.

Goal 4: *Train a new generation of scientists, engineers, and educators for a transdisciplinary, globally competitive workforce in neuroscience and neuroengineering.* This goal has the objective of developing a scientific workforce for understanding the brain that is better prepared for interdisciplinary and global collaboration, data sharing, and adopting new and innovative technologies, tools, and models. Furthermore, NSF and the neuroscience community have recognized that a specialized technical workforce is needed to manage, analyze, curate, and enable sharing of large-scale neuroscience data to accomplish the integrative goals of understanding the brain. In order to transform the workforce, the activities funded under goals 1-3 will require special training and professional development for multi-disciplinary research and international collaboration. NSF will also provide separate funding opportunities for training and professional development in data management and analysis, as described further below.

Approach

The critical scientific challenge for understanding the brain is to integrate research and innovation across multiple scales of space and time, from molecular, physical (e.g. biophysical and biochemical), physiological, and genetic to cognitive and behavioral, with the ultimate goals of establishing integrative, quantitative, and predictive theories of brain structure and function, and applying the new knowledge to maintaining and restoring the healthy brain.

Through existing mechanisms including workshops and summer schools, Research Coordination Networks (RCNs), and Ideas Labs, NSF will bring together the diverse relevant scientific communities in biology, chemistry, behavior, cognition, computer science, engineering, physics, and mathematics to identify scientific priorities and needed research infrastructure, establish cross-disciplinary standards, integrate data and methods, and catalyze the development of conceptual and theoretical frameworks.

New activities and funding opportunities described below are designed to directly address the multi-year scientific, technical, and workforce goals and to accelerate discovery at the frontiers of cognitive science and neuroscience.

To ensure coordination of the Cognitive Science and Neuroscience activity and the BRAIN Initiative, NSF established a high-level Steering Committee to coordinate and oversee the cross-foundation activity, and several programmatic-level working groups that are dedicated to the individual multi-year goals. Multiple divisions of five NSF science and engineering directorates will participate.

Investment Framework

Cognitive Science & Neuroscience Funding by Directorate

(Dollars in Millions)

Directorate/Office	FY 2013 Actual	FY 2014 Estimate	FY 2015 Request
Biological Sciences	-	$5.00	$9.50
Computer and Information Science and Engineering	-	3.50	5.65
Engineering	-	0.75	4.95
Mathematical and Physical Sciences	-	1.60	3.90
Social, Behavioral and Economic Sciences	1.00	3.00	5.00
Total	**$1.00**	**$13.85**	**$29.00**

Totals may not add due to rounding.

FY 2013 – FY 2014

In recent years, NSF has expanded cross-cutting investments in cognitive science and neuroscience. In FY 2013, NSF released a Dear Colleague Letter to encourage the scientific community to submit transformative proposals across disciplines for research aimed at understanding the brain and cognition. In FY 2014, NSF will invest $13.85 million to catalyze fundamental research and new collaborations across neuroscience, neuroengineering, and cognitive science. In addition, beginning in FY 2014, NSF is playing a leading role in the BRAIN Initiative, which was announced in April 2013. An additional investment of $20.0 million above the $13.85 million will fund ongoing activities focused on accelerating fundamental research and associated development of new technologies for neuroscience and neuroengineering. NSF has also recently made new investments in RCNs, a new Science and Technology Center on "Brains, Minds and Machines," and new interdisciplinary awards through INSPIRE, all focused on understanding the brain.

Over the past year, NSF has engaged leaders across the scientific and engineering disciplines through a series of cross-disciplinary workshops that have identified a number of key gaps in scientific understanding of the brain and needed technologies. This input guides NSF's investment strategies for FY 2015 and beyond.

FY 2015 Request

In FY 2015, NSF proposes investments of $29.0 million for the Cognitive Science and Neuroscience activity, with $20.0 million of these funds devoted to projects related to the BRAIN Initiative. These investments will drive integration of research at multiple scales of analysis, and accelerate the development of new experimental and analytical approaches, including computational and data-enabled modeling, and new neural engineering and technology research and development. These investments will enable transformative scientific progress toward understanding of the functional dynamics of the brain and complex neural systems, and their responses and adaptation to changing physical, technological, and social environments throughout the lifespan.

To achieve this scientific and technical progress to understand the full complexity of the brain, its response to inputs from the environment, and the relationship of brain structure and function to behavior, it will be crucial to increase collaborations among relevant scientific communities which have been traditionally focused on narrower discipline-specific experimental questions. Consequently, FY 2015 investments will also fund new interdisciplinary and transdisciplinary team formation and workforce development. Also important will be increases in interagency collaboration, coordination, and communication through the BRAIN Initiative and the efforts of the Interagency Working Group on Neuroscience.

In FY 2015, NSF will employ new investment strategies designed to enable the transformational research, engineering, infrastructure development, and training required to accomplish the four multi-year goals:

- **Integrative and transdisciplinary team-based brain research.** NSF will seek proposals from interdisciplinary and multi-institutional teams of researchers poised to promptly address targeted issues in innovative experimentation; neurotechnology development; computational modeling; and quantitative theory development. Such teams will also contribute to defining requirements for cyberinfrastructure and analytic tools required to address the expected data surge from these experimental, modeling, and theoretical efforts. One major objective of these investments is to establish truly transdisciplinary team-based brain research: integrated collaborative research environments that rise above existing disciplines. NSF will use an array of existing funding mechanisms potentially including traditional grants, RCNs, centers, and NSF's EAGER and INSPIRE programs, with the goal of enabling major progress on problems specific to understanding the brain.

- **Data science, infrastructure and tool development for understanding the brain.** NSF will provide new opportunities for building infrastructure and analytic capabilities for data integration and interpretation across scales and disciplines, with the objectives of transforming data to knowledge for neuroscience, neuroengineering, education, and research. Proposals will also be sought to address outcome goals of establishing policies and community practices for data management, open access, data sharing, and methods for exploiting large-scale neuroscience and behavioral data. A major NSF objective will be to encourage stronger connections with other NSF-funded communities which are dealing with similar Big Data issues and multi-modal data integration, such as in earth, ocean and climate observing, high energy physics, astronomy, and related large-scale computing. NSF will fund planning workshops and other community engagement activities, including via NSF's current supporting role in the International Neuroinformatics Coordinating Facility (INCF), to identify and clarify specific needs for infrastructure and analytic tools.

- **Specialized training and professional development in multi-disciplinary and international research and large-scale data management and analysis.** To develop a scientific workforce that is better prepared for interdisciplinary and global collaboration in understanding the brain, NSF will provide supplementary awards to principal investigators of Cognitive Science and Neuroscience projects. These supplementary awards will be required to be used for training and professional development of supported participants (students and PIs) in areas of multi-disciplinary research and international collaboration, that is, beyond the anticipated student and postdoctoral support for research activities included in the budgets of the original awards. Opportunities for multi-disciplinary training will require mentoring and professional activity in collaboration and co-located collaborations with experts from at least two or three intellectually distinct disciplines, and the emphasis will be on the postdoctoral level. For international training, opportunities must be provided for students and professionals to train and/or collaborate abroad for a defined period of time. The award supplements will be tracked separately for evaluation purposes.

  NSF will also provide funding opportunities for training and professional development to annotate, curate, and manage large-scale neuroscience datasets. Via existing funding mechanisms, co-funded awards for workforce training and professional development will be made through collaborations with programs in EHR and other NSF directorates.

FY 2016 – FY 2017

Multi-year collaboration and workforce development awards will continue to be made and funded according to the criteria established for these individual activities.

Evaluation Framework

The Steering Committee will oversee evaluation of the scientific and programmatic multi-year goals. Assays of success of each multi-year goal will be compared against the expected outcomes described above, using measures including: level of deployment and adoption of innovative technologies by the scientific community via reuse and citations (Goal 1); increases in the number of transdisciplinary teams working and publishing in this area (Goal 2); acceptance by the research community of new mappings between brain functional/structural changes and identified changes in psychosocial, external physical, and technological environments (Goal 3); and number of participants, and demographics of collaborations in publications before and after the investment period (Goal 4). Furthermore, NSF will perform an internal review of its own success in fostering more coordination, collaboration, and co-funding among the relevant programs within the Foundation.