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Columbia-led Team Receives $16.75M from BRAIN Initiative in Effort to Build Blueprint of Brain's Visual System

~ Award unites different fields of brain research to foster an innovative, interdisciplinary approach to deciphering the brain ~

News Release
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Contact: Anne Holden, anne.holden@columbia.edu, 212.853.0171

NEW YORK — The BRAIN Initiative has awarded $16.75 million to a team of neuroscientists charged with deciphering the primary visual cortex, a few hundred million brain cells that play a key role in making sense of what the eye sees. This region is part of the brain's cerebral cortex, the wrinkly outer layer of the mammalian brain responsible for our most sophisticated activities — our faculty of thought. Understanding the brain's visual system thus represents a crucial step toward understanding how the brain itself gives rise to its most complex capabilities.

This five-year award, administered by the National Institutes of Health, will support a cross-disciplinary effort that brings together theoretical neuroscientists, who develop mathematical models of the brain, and experimental neuroscientists, who study the brain directly. This world-class consortium of scientists from labs across Columbia and the United States hopes their work can serve as a paradigm for mapping other brain structures, thus bringing us closer to a true, detailed understanding of the brain.

"One of the key questions in neuroscience is: How does the brain take in information from the eyes and use it to interpret and navigate the outside world?" said Kenneth Miller, PhD, a theoretical neuroscientist at Columbia's Zuckerman Institute and the co-lead investigator on the project. "With the BRAIN Initiative's enthusiastic support, we can now begin to answer this powerful question, while also setting the stage for future investigations into the brain."

This new funding is one of just 11 awards to universities nationwide given by the BRAIN Initiative's Team-Research BRAIN Circuit U19 program, created to fund exceptional teams addressing major questions in neuroscience.

Dr. Miller will codirect, along with Massimo Scanziani, PhD, from the University of California, San Francisco (UCSF), a stellar group of scientists with expertise in fields ranging from physics and statistics to molecular biology and cellular imaging.

Zuckerman Institute Principal Investigators Larry Abbott, PhD, and Liam Paninski, PhD, as well as Brent Doiron, PhD, from the University of Pittsburgh, and Misha Tsodyks, PhD, from the Weizmann Institute of Science and a regular visitor to Columbia, will join Dr. Miller as the team's theoretical neuroscientists. They will work closely with Dr. Scanziani; Hillel Adesnik, PhD, and Na Ji, PhD, from the University of California, Berkeley; and Long Cai, PhD, from

Caltech. As experimental neuroscientists, this second set of researchers will bring expertise in electrophysiology, imaging and molecular biology.

Together, the team will focus on a region of the cerebral cortex in mice called the primary visual cortex, or V1. The primary visual cortex is the first stage of cerebral cortical processing of visual information. It kickstarts the process of interpreting information sent from the eyes.

Often considered to be a model system for understanding the rest of the cerebral cortex, V1 is one of the most-studied cortical regions. But while previous work has revealed much about how V1 processes simple images, such as lines or dashes, far less is known about how it interprets the complex scenes we see every day in the world around us.

Overcoming this gap in knowledge requires a true partnership between theoretical and experimental neuroscience, says Dr. Miller. The last five years have seen an explosion in abilities of experimentalists and data analysts alike. For example, it is now possible to classify V1 cells based on differing molecular signatures. Researchers can also observe how these cells connect to each other, as well as how large numbers of cells respond to visual stimuli.

And while theorists have made significant progress in understanding how brain circuits produce the responses observed in the brain, they have yet to tackle these mechanisms in rich detail. This team grant will allow them to do so.

“Our progress will be iterative; we will develop models to make sense of the newest data, and our experimentalists will then test those models,” said Dr. Miller, who is also professor of neuroscience at Columbia University Irving Medical Center. “Over time, we should be able to rapidly improve V1 models so that they more closely resemble the biological brain.

“Today we can use cutting-edge technologies, unthinkable even a few years ago, to probe and perturb the brain with unsurpassed precision,” said project codirector Dr. Scanziani, who is a professor of physiology and Howard Hughes Medical Institute investigator at UCSF. “With the data obtained from our experiments, theoretical neuroscientists can constrain their models and make predictions that will motivate and guide future experiments. Ultimately, we hope to develop models so realistic that they will not only reproduce what we see in the lab, but will also provide explanatory power beyond what we can currently test experimentally.”

This combined research approach also has implications beyond V1, due to similarities between V1 and other parts of the cerebral cortex.

“The cerebral cortex, the central hub of mammalian intelligence, developed from a basic circuit that appears to have been replicated, with some modifications, again and again to create different cortical regions devoted to different things, from vision and hearing to language and working memory,” said Dr. Miller. “After deciphering V1, or even segments of V1, scientists should be able to use that knowledge as a model for mapping the rest of the cerebral cortex — gaining insight into the underlying mechanisms behind the brain’s most impressive abilities.”

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The Brain Research through Advancing Innovative Neurotechnologies, or BRAIN Initiative, was announced in 2013 by President Barack Obama to accelerate and revolutionize the understanding of the human brain. The BRAIN Initiative has supported scientists from across the United States to develop innovative tools and technologies that explore the brain's inner-workings.

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Award details are as follows:

"Understanding V1 circuit dynamics and computations" (1U19NS107613-01)
Total award: $16,749,076 million over five years.

Investigators:

- Kenneth Miller, PhD (Project co-PI), Professor of Neuroscience at Columbia University Irving Medical Center; Principal Investigator at Columbia's Zuckerman Institute
- Massimo Scanziani, PhD (Project co-PI), Professor of Physiology and Howard Hughes Medical Institute Investigator at the University of California, San Francisco School of Medicine
- Larry Abbott, PhD, William Bloor Professor of Theoretical Neuroscience and Professor of Physiology and Cellular Biophysics (in Biological Sciences) at Columbia University Irving Medical Center; Principal Investigator at Columbia's Zuckerman Institute
- Hillel Adesnik, PhD, Assistant Professor of Neurobiology at the University of California, Berkeley
- Long Cai, PhD, Professor of Biology and Biological Engineering, Caltech
- Brent Doiron, PhD, Professor of Mathematics at the University of Pittsburgh
- Na Ji, PhD, Associate Professor of Physics at the University of California, Berkeley
- Liam Paninski, PhD, Professor of Statistics and Neuroscience; Principal Investigator at Columbia's Zuckerman Institute
- Misha Tsodyks, PhD, Professor of Theoretical Physics, Weizmann Institute of Science and regular visitor to Columbia's Zuckerman Institute
- Rajendra Bose, PhD, Director of Research Computing at Columbia's Zuckerman Institute

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