NEURAL ENGINEERING SEMINAR SERIES

Tools for Analyzing and Controlling the Brain

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ABSTRACT: Understanding and repairing complex biological systems, such as the brain, requires technologies for systematically observing and controlling these systems. We are discovering new molecular principles that enable such technologies. For example, we discovered that one can physically magnify biological specimens by synthesizing dense networks of swellable polymer throughout them, and then chemically processing the specimens to isotropically swell them. This method, which we call expansion microscopy, enables ordinary microscopes to do nanoimaging – important for mapping the brain across scales. Expansion of biomolecules away from each other also decrowds them, enabling previously invisible nanostructures to be labeled and seen. As a second example, we discovered that microbial opsins, genetically expressed in neurons, could enable their electrical activities to be precisely controlled in response to light. These molecules, now called optogenetic tools, enable causal assessment of how neurons contribute to behaviors and pathological states, and are yielding insights into new treatment strategies for brain diseases. Finally, we are developing, using new strategies such as robotic directed evolution, fluorescent reporters that enable the precision measurement of signals such as voltage and calcium. By fusing such reporters to self-assembling peptides, they can be stably clustered within cells at random points, distant enough to be resolved by a microscope, but close enough to spatially sample the relevant biology. Such clusters, which we call signaling reporter islands (SiRIs), permit many fluorescent reporters to be used within a single cell, to simultaneously reveal relationships between different signals. We share all these tools freely, and aim to integrate the use of these tools so as to enable comprehensive understandings of neural circuits.

BIOGRAPHY: Ed Boyden is Y. Eva Tan Professor in Neurotechnology at MIT, an investigator of the Howard Hughes Medical Institute and the MIT McGovern Institute, and professor of Brain and Cognitive Sciences, Media Arts and Sciences, and Biological Engineering at MIT. He leads the Synthetic Neurobiology Group, which develops tools for analyzing and repairing complex biological systems, such as the brain, and applies them systematically to reveal ground truth principles of biological function and to repair these systems. These inventions include optogenetic tools, which enable control of neural activity with light; expansion microscopy, which enables ordinary microscopes to do nanoimaging; new tools for high-speed imaging of living biological signals and networks; noninvasive brain stimulation strategies that may help with conditions ranging from Alzheimer's to blindness; and new strategies for inexpensively creating 3-D nanotechnology. He co-directs the MIT Center for Neurobiological Engineering, which aims to develop new tools to accelerate neuroscience progress, and is a faculty member of the MIT Center for Environmental Health Sciences, Computational & Systems Biology Initiative, and Koch Institute.