Nanotechnology for Mapping, Controlling, and Building Brain Circuits and Other Complex Systems

Abstract

To enable the understanding, repair, and building of complex systems such as the brain, we are creating novel nanotechnological tools that enable molecular-resolution maps of large scale systems, as well as technologies for observing and controlling high-speed physiological dynamics in such systems. First, we have developed a method for imaging large 3-D specimens with nanoscale precision, by embedding them in a swellable polymer, homogenizing their mechanical properties, and exposing them to water – which causes them to expand isotropically manyfold. This method, which we call expansion microscopy [ExM; see Science (2015) 347(6221): 543-548], enables scalable, inexpensive diffraction-limited microscopes to do large-volume nanoscopy, in a multiplexed fashion – important, for example, for brain mapping. Running this process in reverse – which we call implosion fabrication [ImpFab; Science (2018) 362(6420):1281-1285] enables the direct assembly of 3D nanomaterials consisting of metals, semiconductors, and biomolecules arranged in virtually any 3D geometry. Second, we have developed a set of genetically-encoded reagents, known as optogenetic tools, that when expressed in specific neurons, serve as single-protein devices that enable their electrical activities to be precisely driven or silenced in response to millisecond timescale pulses of light. These templates, appropriately evolved, can be transformed into reagents that serve as fluorescent voltage indicators, enabling the imaging of fast physiological processes in 3D with millisecond precision. In this way we aim to enable the systematic mapping, control, and dynamical observation of complex biosystems.

Biography

Prof. Edward S. Boyden, is the Y. Eva Tan Professor in Neurotechnology, a faculty member in the MIT Media Lab and an associate member of the McGovern Institute for Brain Research. In 2018 he was named a Howard Hughes Medical Institute Investigator. His group invents, and applies, technologies that enable the systematic mapping and repair of the brain and other complex biological systems. Their philosophy is to try to bring the observation and fixing of such complex systems to a “ground truth” level, so that we can understand and address the fundamental mechanisms of operation of these systems. They are developing tools that enable molecular mapping of large 3D biological systems with nanoscale precision, recording of the high-speed dynamics of brain circuits and other 3D biological systems, and control of the activity of brain cells using new synthetic biology tools engaged by pulses of light. Ultimately they hope to create technologies that enable the correction of brain disorders and other complex diseases that affect almost everyone, and to provide insights into how the brain generates thoughts and feelings, to understand the human condition.