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Engineering the Brain

New tools are allowing neuroscientists to precisely control neurons.

By Edward Boyden

The last century has seen great progress in our understanding of those aspects of neural computation that can be studied through experimentation on one or a few cells--for example, how synapses enable a neuron to talk to one of its neighbors. But the phenomena that got many neuroscientists interested in the brain in the first place--learning, emotion, consciousness, and mysterious disorders such as depression and schizophrenia--remain difficult to explain through experiments on just one or even a few cells. Thousands or millions of cells, computing as an ensemble, are responsible for practically all of our behaviors, as well as the derangements thereof.

Due to the complexity of neural circuits, the practice of systems neuroscience remains a fine art. Beyond the single neuron, computational details remain hazy for most of the neural circuits in the brain.

Before becoming a neuroscientist, I trained as a physicist and an engineer. So I decided to try to invent tools to help solve the old, unyielding problems of the normal and pathological brain. I have launched a new research group at the MIT Media Lab to develop technologies for controlling neuronal activity and to use them to find and engineer the circuit elements mediating specific states and behaviors. We will also apply these technologies to devising more-targeted and noninvasive strategies for correcting brain disorders. These efforts may enable neuroscientists to understand better the links between neural-circuit activity and conditions such as depression (see "Neuron Control (http://www.technologyreview.com/Biotech/18289/) ").

In 2005, I was able, along with my colleagues at the Max Planck Institute of Biophysics and Stanford University, to cause specific neurons to fire spikes precisely in response to brief pulses of blue light, by expressing in the neurons a unique membrane protein from green algae (see "Artificially Firing Neurons (http://www.technologyreview.com/tr35/Profile.aspx?Cand=T&TRID=454) ," September/October 2006). My lab is developing automated protocols for using this technique and other neural-control tools we're inventing to systematically reveal the patterns of circuit activity and behavior that are mediated by a specific neuron or set of neurons. We are also exploring the systematic use of neural-control technologies to correct neurological and psychiatric deficits and to improve cognition.

Our brains are the ultimate interface between us and the world. Directly engineering this interface may give us new insights into how we feel sensations, decide upon actions, and become aware of ourselves--and enable new modes of communication, neural prosthesis, and cognitive augmentation. The question of how we subjectively experience reality is one of the great unsolved problems of all time and will require new tools, and collaboration across disciplines, to answer. I believe that in this quest,

the skills and efforts of neuroengineers will be essential.

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