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TR35 2006 Young Innovator

Edward Boyden, 27

Stanford University
Artificially firing neurons

Even in the hypertechie milieux of MIT and Stanford science departments, Edward Boyden stands out, bubbling with brilliance, energy, infectious enthusiasms, imaginative approaches to impossibly ambitious projects--and through it all, at his most earnest, with a vibrant sense of play. At MIT, he got a bachelor's in physics and bachelor's and master's in electrical engineering and computer science, all with a perfect grade-point average--and by the age of 19. Fascination with computing led him to neurobiology. "The brain is a three-dimensional mass of densely wired tissue," he says. "It's kind of the ultimate computer."

He landed at Stanford, where he got his doctorate in 2005, aged 26. There he created an ingenious new technology for analyzing and even controlling any neural circuit, including those in the cerebral cortex--important in sensation, action, thought, emotion, memory. In the science of the cortex, perhaps the toughest problem is to determine how neurons interact with their near neighbors. The cortex has some 20 billion neurons, which have many different functions. For years, neuro-biologists have known various ways to measure the outputs of individual neurons when they fire. Yet no method had been found to control inputs, to find and deliberately activate cells of one particular type.

Boyden's technology--an elegant, tricky piece of genetic engineering--gives scientists exactly that. It begins with a curious protein called Channel-rhodopsin-2, or ChR2. This protein normally sits in the cell membrane of a green algae, and when exposed to blue light it changes the cell's electrical state. Working with Stanford colleagues and the German researchers who isolated the protein and the gene that encodes it, Boyden linked the gene for ChR2 to the gene for a protein that fluoresces when hit by green light, creating a single, novel protein. The researchers inserted the gene for this new protein into rat neurons. Under green light, the cells that made the combination protein glowed; blue light caused the neurons to fire.

Boyden had thus invented a precise, reliable neural switching system operating at thousandths

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Technology Review's Emerging Technologies Conference at MIT brings together world-renowned innovators and leaders to discuss the technological innovations destined to better our lives and fuel economic growth.

of a second--the speed at which neurons naturally interact. He has since added genetic elements that control just which type of neuron makes the new protein. Introduced into, say, a mouse's brain, the protein could highlight individual types of neurons and allow researchers to study their functions. One possible use, Boyden says, is to analyze the neural circuits that perform particular types of "computation," such as decision-making. Clinical applications are potentially huge: delivered to the brain and activated by implanted optical fibers, the protein could give doctors the power to activate neurons with selected functions. That could give rise to radical new medical technologies to treat brain disorders such as Parkinson's disease or even some types of blindness, Boyden says. He believes that activating the right neurons could change mental and emotional states--perhaps curing prolonged, profound depression. More grandly, he projects enhancements of human mental capabilities, even the control of behavior.

"We can maybe apply some simple versions of the technology to solving urgent questions of today," Boyden says. "There's a lot of synergy between that and the technology that we use to do very, very hard things, such as addressing psychiatric disorders, confronting questions of consciousness, making brain-machine interfaces--and on the way to climbing those mountains, we can have a lot of little picnics!"

--*Horace Freeland Judson*

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