

ENGINEERING BRAIN CIRCUITS

Professor Edward Boyden, who first came to MIT as a teen prodigy and is now a neuroengineer, has developed a first-of-its-kind control system for the brain. Combining genetic and optical engineering, the technology is so precise that it can switch electrical activity on and off in individual neurons, or brain cells. It represents a potentially transformative leap, both in understanding brain function and in treating disorders involving faulty circuitry: Parkinson's disease, depression, epilepsy, and others. And in the near term, it may serve as a clever tool for reversing certain types of blindness.

"We have a lot of questions about how the brain works," says Boyden, who earned a master's in electrical engineering and computer science from MIT when he was just 19 and now works in the MIT Media Lab. "How do people make decisions? What is an emotion? These are deep questions you can't really answer with existing technologies. But with these new technologies, people feel like they can make some inroads. And the hope is that (these technologies) can allow us to put a big dent in neurological and psychiatric disorders."

Boyden's technology involves two unusual light-activated proteins produced by microorganisms. One of those proteins, found in green algae, creates a positive charge inside a cell when exposed to blue light. The other, from a bacterium that grows in extremely salty water, creates a negative charge when exposed to yellow light. Boyden, who is also a principal investigator in the McGovern Institute for Brain Research, delivers the genes that encode these proteins to target neurons via harmless viruses. He then exposes those neurons to blue or yellow light in millisecond pulses approximating the speed at which neurons naturally interact. The result? A reliable way to activate and silence specific neural circuits.

This optogenetic system, as it is called, could one day be a dramatically fine-tuned improvement on the implanted electrodes used in a therapy called deep-brain stimulation (DBS). DBS controls the tremors caused by advanced Parkinson's disease and is being tested in some extreme cases of depression. While the therapy targets very small areas of brain tissue, those areas still contain millions of neurons, not all of which are associated with the condition being treated. Optogenetics would target only those neurons relevant to the disease. Boyden's laboratory has already achieved promising results using the method to control epileptic seizures in mice.

And, in a revelation of the tool's versatility, Boyden recently showed in mice that it can reverse blindness caused by non-functioning photoreceptors — cells in the retina that process light. He implanted his proteins in retinal neurons, which connect to photoreceptors but don't process light — thereby rendering them light-sensitive. In essence, he converted the neurons to photoreceptors and thus enabled the mice to see.

Years of testing will be required before optogenetics can be used in humans, Boyden notes. Yet researchers in the Media Lab's new Neuroengineering and Neuromedia Group, which Boyden spearheads, are working quickly. They recently showed that the genes encoding the light-activated proteins can function safely in mammals, without triggering an immune response. They are also developing optical-fiber arrays that can beam pulses of light at specific groups of neurons deep within the brain.



Neuroengineer Edward Boyden developed a first-of-its-kind control system for the brain. Photo: Len Rubenstein

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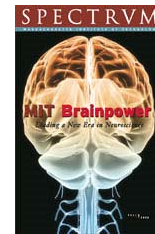
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Through his research and teaching, Boyden is on a mission to advance neuroengineering as a full-fledged discipline. MIT, he believes, is the place to achieve this goal. "I really like the palpable energy of being here, and the adventurous spirit of 'Let's solve these intractable problems.' That, I think, is really powerful."

by [Lauren Clark](#)

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