The brain engineer: Shining a light on consciousness

Updated 09:52 07 March 2011 by **Rowan Hooper**
For similar stories, visit the **Interviews** and **The Human Brain** Topic Guides

*Neuroengineer **Ed Boyden** is best known for his pioneering work on optogenetics, which allows brain cells to be controlled using light. A speaker at the TED2011 conference this week, his vision, he tells Rowan Hooper, is nothing less than to understand the brain, treat neural conditions and figure out the basis of human existence.*

Mining the genomes of the world (Image: Jeff Kubina/CC BY-SA 2.0)

Give us your elevator pitch.
I run the synthetic neurobiology group. We develop software, electrical and optical tools to allow people to analyse brain dynamics.

Unlike a computer, the brain is made of thousands of different types of cell, and we don't know how they work. We need to be able to turn the cells on and off to see how they cooperate to implement brain computations, and how they go awry in brain disorders. What we're doing is making genetically encoded neurons that we can turn on and off with light. By shining light on these cells we can activate them and see what they do.

What brain functions will this allow you to study?
Scientists now have unprecedented abilities to perturb and record from the brain, and that's allowing us to go after complex ideas like thought and memory. Our tools will help us parse out emotion, memory, attention and consciousness. Put psychology and neuroscience together with neuroengineering, and some of the biggest questions in neuroscience become tractable.

Tell us about your tools.
The core idea is to take molecules that sense light and convert it into electrical energy, and put them in neurons. We can take a given class of brain cells and develop a virus to deliver genes to these cells. Then we can shine light on these cells and activate them and see what they do.

Where do you get the light-sensitive molecules?
We mine the genomes of the world – fungi, plants, archaea, bacteria – looking for molecules that convert light into different kinds of energy. We're finding stuff already that you could never have dreamed up. We've found several classes of molecules that can pump negative charge in or positive charge out of cells. That's really powerful in terms of what it allows us to do.

Can this approach treat disease?
Imagine we have an epileptic brain and we want to quiet it down. We can put these molecules into cells, shine light on them and turn them off, using a technique called neural silencing. Turning off seizures is a "killer app" for this sort of thing because there's no other way to turn off brain circuits transiently.

We can also, potentially, install light sensors onto the spare neurons in blind people, converting the spare neurons into a camera so they can send info to the brain. We've done this in mice.

Another condition we're working on in mice is post-traumatic stress disorder. We use implants to stimulate brain regions with light and causally assess which cells are associated with which emotions and memories. This way we can find true clinical targets to treat the condition.

It sounds quite invasive.

If we want to drive light very precisely in the central nervous system then we need some kind of implant. We are working on an array of optical devices that can beam light into the brain itself in three dimensions. The width of one of these devices is something like one-eighth that of the deep brain stimulation electrodes used to treat Parkinson's. We're also working hard to try and do this wirelessly.

What other problems do you need to overcome?

We're using molecules from other species – from algae, from archaebacteria and fungi – and we need to put these into human cells. One thing that could happen is that the cells could die if the immune system detects them as foreign.

So we've done the first preclinical study, working with primates (*Neuron*, DOI: 10.1016/j.neuron.2009.03.011). There doesn't seem to be cell death or an active immune response, there don't seem to be immune cells infiltrating the brain. All the classical responses we looked for, we couldn't find.

I would be the first to admit this is early days, but given the potential power of ultra-precise activation and silencing of neurons in the very complex neural circuits of the brain, we're very eager to pursue the science.

You majored in physics. What drew you to neuroscience?

We've got all these rules from physics about how the universe works, but how do we perceive? How do we think? How do we feel? We haven't exactly got a lot of insight into that from knowing about quarks and leptons. We know about the building blocks of the universe, but knowing a lot about physics doesn't help us understand the brain as a complex physical system – and that's one of the outstanding problems of the 21st century.

You work a lot with mouse models. How are you going to get at problems like consciousness by working on animals?

Consciousness and free will are always going to be tricky to analyse in anything but a human, and it's even tricky to analyse in humans. But there are people who are doing very clever things.

Scientists have recorded neurons in the motor regions of the human brain, and it turns out that there are neurons that fire almost a second before people are aware they want to make a decision. So maybe we can't analyse free will and consciousness in the animal brain per se, but if people find neural signatures of free will or consciousness then we can go into the animal brain and perturb them and see what happens. Then we can start to get at causality.

Where do you see this going, long term?

There are two ways of looking at this. One, in the medium term, is the kind of synthetic neurobiology we work on now, in the sense of taking an intact human brain and fixing it. The other would be building brains from scratch, and that's something we haven't even really thought about. We don't know enough about the brain to build one completely from scratch. But it's good to reevaluate every five or 10 years.

Profile

Ed Boyden leads the Synthetic Neurobiology Group at the Media Lab at the Massachusetts Institute of Technology. His group develops software and technologies for controlling neural circuits in order to understand how cognition and emotion arise, and to try and treat intractable brain disorders.

Back to article

PRINT SEND SHARE