Interview: Ed Boyden, the neurotechnologist who hopes 'to cure all disease'

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Professor Ed Boyden leads the Synthetic Neurobiology Group at Massachusetts Institute of Technology. He is best known for the invention of optogenetics: a technique that allows neurons to be controlled with light. Before an IET lecture in Central London, E&T met Boyden to discuss his imaginative and ambitious plans to understand the human brain.

How did working in electrical engineering, chemistry, and physics affect your approach to neurotechnology?

Hugely. I think most neuroscientists at the time were thinking about biology in a certain way, and if you think about the same problems from a physics or chemistry or engineering standpoint, you think about them differently. The really big problems are network problems. They have a lot of moving parts and lots of ways to interact, and they're immensely complex. What you have to do is basically engineer your path to become lucky by connecting dots between different fields and thinking backwards from big problems. We're trying to apply this thinking to lots of problems.

Why is it that brain disorders remain poorly understood, and with limited treatments?

The brain is just really, really complicated. You could take a human brain and image all the molecules in it, store that data on hard drives and make a stack of those hard drives so it reached from the surface of the Earth into outer space. A lot of biological systems you can study at a slow pace; cancer is spreading and the immune system reacting over minutes to hours to days or even longer, but events in the brain are very short. You could have a thought or a feeling within a second and the electrical pulses within the brain are one thousandth of a second long.

Could you explain how optogenetics works?

Brain cells compute using electrical pulses, and if you want to understand what the neurons do you have to be able to control those electrical pulses. We invented a technology called optogenetics. What we do is take the natural molecules from bacteria, plants, and fungi, and these molecules are basically little solar panels which convert light into electricity. If we transplant them into brain cells and shine light on them these molecules convert light into electricity. We speak the language of the brain with light.

How have researchers been using optogenetics to understand the brain?

My group does not apply optogenetics very much, we focus on inventing the tools. But a group in the US, for example, has used these tools to try to figure out where in the brain aggression or violence is initiated. They found cells that you can put our molecule in, and shine light and activate them. When you do that it triggers a mouse to attack whatever is next to it, even a rubber globe; it's able to pinpoint the site in the brain that triggers aggression. Another example is other groups are using our tools to discover patterns of connectivity that when activated can overcome disease. You can cancel out the immobility [associated with] Parkinson's disease. One of my colleagues used our technology to discover a pattern of activity that can overcome Alzheimer's disease in mice.

You describe optogenetics as a tool for "debugging" the brain. Is it helpful to use the logical language of computers to talk about brains?

Computers are not always logical and predictable. I mean, my laptop struggles to get through the day without crashing, right? Alan Turing and others showed that computers are fundamentally unpredictable. I think everything is unpredictable.

What other tools will be game-changers for understanding and treating brain disorders?

There are three things. You need a way to control the brain: optogenetics. Secondly, you need a way to watch the brain in action and that's something we're working on right now. We're trying to develop voltage indicators which are basically the opposite of optogenetics; rather than control the brain with light can you watch the brain with light, so the neurons blink at you when they're active. Thirdly, can we make a map of the brain. We developed a way to do that where you take a piece of brain tissue (preserved, not alive) and you infuse it with a chemical that's a lot like the stuff in baby diapers, a swellable polymer. You chemically process the tissue, add water, the polymer swells and you can blow the brain up a hundred times or even ten thousand times bigger. So then you can use cheap optics like ordinary microscopes to make very accurate maps of the brain.

My dream is to combine these three tools, watch the brain in action with voltage imaging, perturb it with optogenetics and then map it out with the diaper expansion process, and then combine these three data sets in a computer. The goal for the next ten years is can we actually simulate a brain in a computer, starting with a small one. If we could do that, this could revolutionise fields like artificial intelligence (AI).

What would be the implications for AI of combining these three tools?

AI has been very good at certain things like recognising faces or classifying pictures, but they haven't yet been able to, say, invent a radical new invention or propose a new form of art, or do things that we consider as humans to be part of the creative arts. They are also not known for ethical judgements. In fact, a lot of the backlash right now is about the automation and machine learning behind websites and social media; they are not ethical forces. If we can simulate brain computations, could you make something that you would want to simulate: maybe an AI with ethical values.

What motivated you to do research across these areas?

Ever since I was a kid, I was obsessed with the idea that we need to understand the human condition more. Why is there suffering, what is the meaning of happiness, what is the meaning of meaning? If you think about what societies and religions and cultures and so forth are about, a lot of it is devoted to these questions. But look at the state of the world today.

I really wanted to see if we could understand and improve the human condition through something like science where we can have a bit more of a firm grasp on what we're doing. I started college really young, when I was only 14, and I worked in an origins of life group where they were trying to create life from scratch. I was obsessed from a young age with this idea that I should work on ideas at the border of philosophy and science.

What are you most excited about working on in the future?

In the long term, returning to my roots and being interested in philosophy, I hope to understand the nature of the human condition and maybe as a species achieve a more enlightened state. Maybe we'll understand the nature of happiness and suffering and why we do what we do; I think my biggest hope is we'll be more enlightened beings and know what the meaning of life is and what we should all do to be happy. As a byproduct though, I also hope we can cure all disease.

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