

The product of our neurons

Can mapping the connections inside our brain reveal our true selves, asks **Terrence Sejnowski**

Connectome: How the brain's wiring makes us who we are by Sebastian Seung, Houghton Mifflin Harcourt, \$27



BIOLOGY is in the midst of a revolution that is changing what we know and can know. The large-scale studies of genes and

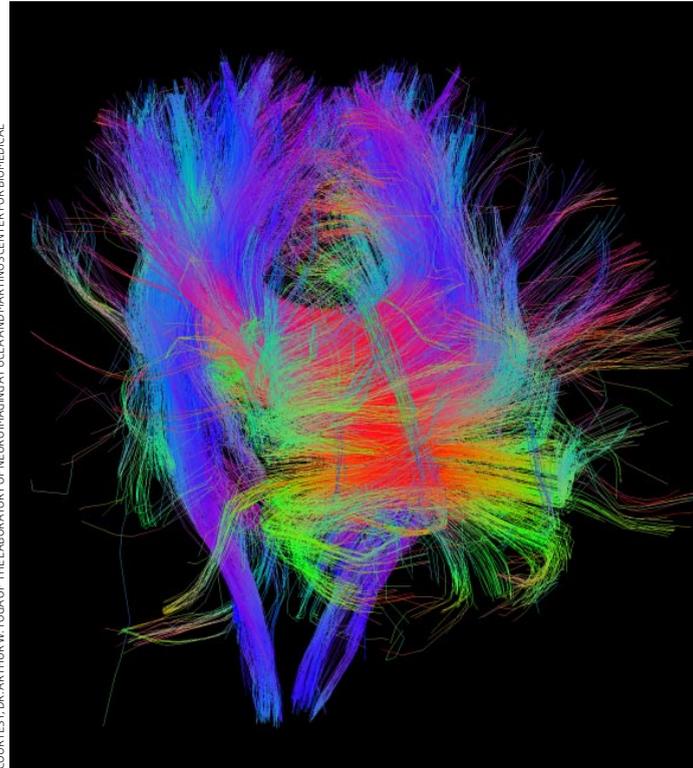
proteins, known as genomics and proteomics, have been joined in neuroscience by connectomics, the endeavour to find the complete wiring diagram of the brain – the connectome.

It is a feat so far achieved just once, for the roundworm *C. elegans*, which has 302 neurons to our 100 billion. What has made the “omic” sciences possible is the exponentially increasing amount of data that computers can collect and analyse. Once a certain threshold has been achieved, something that seemed impossible becomes possible, and soon becomes routine. This has already happened with genomics.

In *Connectome*, Sebastian Seung, a computational neuroscientist at the Massachusetts Institute of Technology, sets the stage with an able introduction to neuroscience and genetics. He then explores, with passion, how he and others are figuring out the way neurons are connected up in big brains.

With the first-person flavour of James Watson's *Double Helix* – an account of how DNA's structure was discovered – *Connectome* gives a sense of the excitement on the cutting edge of neuroscience.

Ingenious devices have been constructed to serially slice up larger and larger brains so thinly



COURTESY, DR. ARTHUR W. TOGA OF THE LABORATORY OF NEUROIMAGING AT UCLA AND MARTINOS CENTER FOR BIOMEDICAL

that they can be studied with an electron microscope. But then all the thin “wires” and tiny connections in the fuzzy micrographs need to be traced, and the intricately interlocking three-dimensional shape of every neuron reconstructed. Seung

❑ If experiences are coded into brain connections, could a wiring diagram simulate your mind?”

estimates that if we stick to the manual methods used for the roundworm, it would take a million person-years to reconstruct the wiring in a cubic millimetre of the brain's cortex. He is on the forefront of using

machine learning – a type of artificial intelligence – to reduce, though not eliminate, the human effort required. This book is the story of how this grand vision came about and the consequences for our future.

Sydney Brenner, who led the project to map the connectome of *C. elegans*, pointed out in a recent editorial we wrote together for *Science* (DOI: 10.1126/science.1215674) that the connectome was essential, but not sufficient, for explaining the worm's behaviour. Techniques for simultaneously recording activity from many neurons and synapses are also needed to achieve understanding.

Anatomy is indeed the bedrock

We must know how the brain fires, as well as its wires, to grasp behaviour

of the brain, but if the mind is the music that neural networks play, then we will also need to bring the wiring diagram to life by simulating its electrochemical signals, and take into account the properties of the synapses and neurons at the diagram's intersections. It is a daunting task.

The final part of the book explores what might be possible once we have deciphered a wiring of the human brain, and explores the hypothesis that “you are your connectome”.

If all your life experiences are coded into your brain's connections, could we someday reconstruct your wiring diagram inside a computer and simulate your mind? There are, of course, certain practical problems with this proposal, not least in stopping the information in your brain decaying after death. If “connectome death” can be halted, then at some future date a sufficiently advanced technology might allow your brain to be reconstructed and some version of you resurrected. This is the modern version of the brain in a vat, though it is not clear what could take the place of a body.

Seung once gave a talk at the Salk Institute in which he played the Vangelis theme music from the cult science *Blade Runner*, in which survival is a battle to secure more time. I didn't understand why at the time, but I do now.

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