We're closing in on consciousness in the brain

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Brain "observatories" may solve the puzzle of how material brains create an intangible world of love, colour, taste and fantasy

A QUICK glance at the thousands of books that purport to explain consciousness makes the real understanding of it look like a Herculean task. There is, after all, a profound explanatory gap between neural activity of any sort and subjective feelings. The first belongs to the realm of physics, to space and time, energy and mass, the second to experience. And while experiences are ephemeral, they are the very stuff of life. The only way we know about the world, about space and time, about energy and mass, about anything in fact is by seeing, hearing and smelling, by lusting and hating, by remembering and imagining.

That these two realms are closely related is revealed by the effects of a stroke, a strong blow to the head, or by a neurosurgeon stimulating electrically some part of a person's brain and evoking a childhood memory. Yet consciousness does not appear in the equations of physics, nor in chemistry's periodic table, nor in the A-T-G-C molecular chatter of our genes. Somehow it emerges from the nervous system.

I have spent 25 years - the first 16 years working with my mentor, colleague and friend Francis Crick - linking specific aspects of consciousness to the mammalian brain. We popularised the idea of the neuronal correlates of consciousness (NCC): the minimal neuronal mechanisms - the synapses, neurons and brain regions - that are jointly sufficient for any one conscious percept.

Since then, much progress has been made. We now know that some sectors of the cerebral cortex making up the bulk of the brain (for its size the most complex organ in the universe) have a privileged relationship to consciousness, that not all of its many regions participate equally in generating the content of a conscious experience. Micro-electrodes and magnetic scanners have also shown us the neocortex can be active without necessarily giving rise to a conscious experience. This is the domain of the non-conscious.

Yet Crick and I looked deeper. Why did a particular NCC give rise to one specific conscious experience? Why should particular vibrations of highly organised matter trigger conscious feelings? It seems as magical as rubbing a lamp and having a genie emerge.

What is needed is a fundamental account of how activity in any system can give rise to consciousness. We therefore turned to the ideas of Giulio Tononi at the University of Wisconsin-Madison. He advocates a sophisticated information theory account of consciousness, called integrated information. The theory introduces a precise measure, called phi, which captures the extent of consciousness. Expressed in bits, phi quantifies the extent to which any system of interacting parts is both differentiated and integrated when that system enters a particular state.

This is the heart of phenomenal experience: any one conscious experience is both highly differentiated from any other one but also unitary, holistic. The larger the phi, the richer the conscious experience of that system. Furthermore, the theory assigns any state of any network of causally interacting parts (these neurons are firing, those ones are quiet) to a shape in a high-dimensional space. The shape (think of it as a crystal in a fantastically high-dimensional space) accounts for the peculiar feel of any one conscious experience. If the network

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