Brain waves

Above the 'big neuroscience' commotion, literature plays its part.

"Literature was not born the day when a boy crying 'wolf, wolf' came running out of the Neanderthal valley with a big grey wolf at his heels," wrote novelist Vladimir Nabokov. Instead, he argued, it was born "on the day when a boy came crying 'wolf, wolf' and there was no wolf behind him".

The French consciousness-research pioneer Stanislav Dehaene uses this quote in his new book, *Consciousness and the Brain*, in which he describes his 'global neuronal workspace' theory, elaborated together with Jean-Pierre Changeux through modelling a 20-year series of daring experiments probing conscious and unconscious perception in humans. Only since brain imaging and other tools have allowed us to view the human brain at work has it become 'respectable' to try to pin down consciousness, and to debate how the human mind has allowed the development of intellectual pursuits as sophisticated as literature.

The Dehaene–Changeux theory holds that awareness moves from subconscious to conscious only when we pay attention to specific sets of information in our brains: images, memory, emotional state. These briefly come together in a limited-capacity workspace, ready to broadcast to all brain regions through axons. This theoretical workspace is where consciousness emerges; where, for example, a storyteller may invent a fictitious scene of deceit, such as the boy who cried wolf.

Dehaene quotes Nabokov often in his books, with good reason. The poetic, multilingual novelist and entomologist often pondered eloquently on the state of being conscious. Understanding consciousness and the mind may take a century, but it stands as an irresistible beacon. Other goals, such as understanding, fixing or ameliorating neurodegenerative or psychiatric diseases, may be 'only' decades away.

Many regret, but few doubt, that the long haul towards these goals requires a cultural shift in neuroscience research, from small to big science. Indeed, 'big neuroscience' has already begun. Last year, Europe formally launched its highly ambitious Human Brain Project (HBP), which aims to simulate the human brain in a supercomputer. It already has 32 partners across 13 countries. And the Brain Research through Advancing Innovative Neurotechnologies (BRAIN) Initiative, announced by US President Barack Obama on 2 April last year, will soon begin distributing money.

The privately funded Allen Institute for Brain Science in Seattle, Washington, has been doing big neuroscience for more than a decade, producing systematic anatomical and brain maps, mostly in the mouse, and is now starting to map functions of the component neurons. All of its maps are publicly available. It is a happy coincidence that *Nature* has published two brain-mapping papers from Allen scientists on the anniversary of Obama's announcement (see http://dx.doi.org/10.1038/nature13185; http://dx.doi.org/10.1038/nature13186; 2014). One of the maps is the first gene-expression atlas of the entire developing human brain. The other is a mouse 'connectome' — the first brain-wide neuronal-connectivity map for a mammalian species — that will guide the initial modelling of the HBP, which is beginning with the mouse brain.

But the path to generating and modelling the data needed to crack the codes of the brain will not be smooth. Already, the HBP has annoyed researchers by not funding the generation of data in non-human primates in its first phase, perhaps fearing a political backlash. But monkey data will be needed as a bridge between the mouse and human brain.

As big neuroscience advances, the Dehaene–Changeux theory may be proved wrong. So, too, may the more abstractly mathematical 'integrated information theory' of consciousness preferred by the Allen Institute's chief scientific officer Christof Koch. That is the process of science. Koch complains in his review of Dehaene's new book in *Science* that the workspace theory limits itself too much

to the waves of electrical activity in the brain that experiments pick up, and fails to explain the 'why' of consciousness (see http://doi.org/r5q; 2014). Koch counter-quotes Nabokov: "The breaking of a wave cannot explain the whole sea."

As big-brain programmes navigate their thorny early years, it is good to be so neatly reminded of their ultimate goal.