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Brain connectomics: connectome, synaptome and the siliconcortex

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The brain is composed of millions of neurons which are interconnected through synapses in an ordered fashion, forming highly intricate neuronal networks. The cerebral cortex is the area chosen by numerous theorists and experimentalists for study since it is directly involved in many aspects of mammalian behavior. Moreover, it is the largest (85% of the brain) and most human part of the nervous system (i.e., it is the brain structure whose activity is directly related to the emergence of those capacities that distinguish humans from other mammals). The term “connectome” has recently been proposed to refer to the highly organized connection matrix of the human brain, in analogy to the human genome. However, defining how information flows through such a complex system represents so difficult a task that it would seem unlikely it could be achieved in the near future, or, for the most pessimistic, perhaps never. Circuit diagrams of the nervous system can be considered at different levels, although they are surely impossible to complete at the synaptic level. Despite the technical difficulties, by adopting appropriate strategies with the tools now available coupled with the development of huge international projects like the Human Connectome or Blue Brain Project, it should be possible to make spectacular advances in unraveling brain organization, even in humans. Indeed, advances in our capacity to marry macro- and microscopic data may help establish a realistic statistical model that could describe connectivity at the ultrastructural level, the “synaptome”, giving us cause for optimism. Computational models of neuronal networks based on real circuits have become useful tools to study aspects of the functional organization of the brain. It appears that as more detailed circuit diagrams become available, the more we will learn with computer simulations about the role of each element of the circuit. The common interest between theorists working on neural computation and experimentalists working on cortical microanatomy / physiology will ultimately allows us to reduce the microanatomical complexity to relatively simple diagrams. Such diagrams may be useful for both experimental and accurate theoretical neuroscience. Thus, why shouldn’t it be possible to construct a “siliconcortex”, a computer with an artificial cerebral cortex based on a realistic model of the complete anatomical, physiological and molecular design of the cortical circuit?