Cortical Computation

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Computation by digital computers is the only thoroughly studied model of symbolic information processing that we have, so it is not too surprising that computation is often defined within the conceptual framework of von Neumann machines. It is difficult to underestimate how this model of computation dominates our thinking. If one wanted to study language, for example, it would seem that measuring electrical and chemical signals inside the brain would be of as little use as measuring signals inside a digital computer if one wanted to study the programs that were running. This reasoning, however, may be profoundly misleading because digital computers were designed with very different constraints and for very different purposes.

Structural reasoning about biological systems can best be explained in a system that is already understood at a conceptual level. Take for example, the digestive system, which once was as obscure as the nervous system. How much can be learned about digestion if one examines only what goes in and what comes out? A great deal can be learned about the composition of food and the composition of waste; however, the transformation between them is highly under determined and will also depend on an unpredictable internal state. The problems of digestion were solved by looking into our bodies and discovering organs and functions for those organs. The concept of an enzyme, a key to the digestive process, followed from a detailed analysis of the internal fluids.

The architecture of the brain is much more closely tied to its function than is the architecture of general purpose digital computers. The anatomical connectivity, both within an area and between areas, is itself highly revealing about the type of computation that is performed. Many areas of the brain are dedicated to special tasks, such as photo-transduction in the retina and eye movements in the oculomotor nuclei, and the part of the brain that is most closely associated with cognition, cerebral cortex, is parceled into areas having different functions. From recent anatomical and physiological work in many cortical areas, a new view of cortical processing is emerging that is different from the von Neumann architecture. This view is based on parallel rather than serial processing, distributed rather than local representations and stochastic rather than deterministic algorithms, and may offer an alternative conceptual framework within which to think about our cognitive abilities.