Cortical Columnar Circuits and Canonical Computations

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The common notion that the brain is the "most complex system in the universe" can be daunting, especially for neuroscientists eager to see advancements within their lifetimes. However, there's promising evidence suggesting that the brain's complexity arises from relatively simple building blocks, much like an intricate construction made from a limited set of LEGO bricks. This implies that a deeper understanding of brain function may not require unraveling the full complexity of the entire system. Instead, we might learn much about the brain by examining simple, but fundamental components that recur throughout the brain. For instance, the neocortex is known for its linear (columnar) spatial organization of neurons. The axonal inputs and outputs of these cortical columns exhibit common features across cortex, leading to a consistent motif or microcircuit. This uniform "canonical columnar microcircuit" in the cortical structure could facilitate uniform "canonical computations". In other words, cortical computations might follow a common blueprint. Uncovering this blueprint could revolutionize the study of cortical function by enabling unified understanding rather than piecemeal insights. Here, we will delve into several studies from our and other laboratories that speak to the existence of uniform (canonical) features in cortical columnar organization. We will contrast these findings with an exploration of counterexamples. We will then evaluate the possibility of canonical computations given these insights and consider candidate theories. Finally, we will examine remaining challenges for a mathematical understanding of neuronal computations and explore their potential impact.