P2.10.

Wiring Economy of Neocortical Axon Arbors

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Discovering the organizational principles of cerebral cortex represents a fundamental challenge in neuroscience. Rámon y Cajal proposed that general laws of conservation concerning cellular material (axon and dendritic ‘wire’) and conduction delay regulate neuronal morphology. Yet despite more than a century of research it is not known how well these laws apply to axon arbors in neocortex. Using a variety of graph optimization algorithms, we investigated Cajal’s proposed economy laws in relation to detailed 3D reconstructions of spiny and basket cell axon arbors obtained from in vivo labelling experiments in adult cat visual cortex. Our analysis of these data suggests that individual neocortical axon arbors are not minimized for axonal length (cellular material) but neither are they optimized for conduction delay. Instead neocortical axon arbors in contacting thousands of spatially distributed postsynaptic targets appear to trade-off saving axonal wire for more rapid communication. In particular, the branched structure of neocortical arbors seems to preserve the relationship between axonal propagation latency and cortical distance and ensures a low degree of temporal dispersion axonal latencies, which may be tighter for inhibitory basket cell than excitatory spiny cell axons. This work has implications for our understanding of neocortical organizing principles, coding, and communication.

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