Abstract View

WHY IS THERE A UNIVERSAL SCALING LAW BETWEEN THE GRAY MATTER AND WHITE MATTER OF CEREBRAL CORTEX?

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Neocortex, a brain structure unique to mammals, has a similar layered architecture in species over a wide range of brain sizes. Larger brains require longer fibers to communicate between distant cortical areas---the volume of the white matter that contains long axons increases disproportionally faster than the volume of the gray matter that contains cell bodies, dendrites, and axons for local information processing, according to a power law. Inspired by Allman and coworkers' recent demonstration of power law scaling of white matter volume against gray matter volume, we have combined data from various sources together with our own measurements to find the power law exponent of 1.23 ± 0.01 (r=0.998) over 5 orders of magnitude in brain sizes for various mammalian species including human and non-human primates. This remarkable anatomical regularity might arise as a consequence of the local uniformity of the cortex and the requirement for compact arrangement of long axonal fibers. We propose that these fibers occupy a constant fraction of a unit cortical surface area crossing the gray/white matter boundary; the data suggest that this constant fraction is only about 8%. This theory links various anatomical variables and predicts that gray and white matter volumes follow a power law with an exponent of 4/3 minus a small correction (0.10 ± 0.02) for the scaling of cortical thickness, in precise agreement with the data. It also predicts that the average length of white matter fibers scales as the 1/3 power of the gray matter volume, consistent with the empirical value (0.30 ± 0.02).

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