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CytoNet: A Foundation Model for the Human Cerebral Cortex - Applications in BigBrain and Beyond

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Microscopic analysis of cytoarchitecture in the human cerebral cortex is essential for understanding the anatomical basis of brain function. We present CytoNet, a foundation model that encodes high-resolution microscopic image patches into expressive feature representations suitable for whole-brain analysis. CytoNet leverages the spatial relationship between anatomical proximity and microstructural similarity to learn biologically meaningful features using self-supervised learning, without the need for manual annotations. The learned features are consistent across regions and subjects, can be computed at arbitrarily dense sampling locations, and support a wide range of neuroscientific analyses. We demonstrate state-of-the-art performance for brain area classification, cortical layer segmentation, morphological parameter estimation, and unsupervised parcellation. As a foundation model, CytoNet provides a unified representation of cortical microarchitecture and establishes a basis for comprehensive analyses of cytoarchitecture and its relationship to other structural and functional principles at the whole-brain level.

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