Tata Institute of Fundamental Research

Survey No. 36/P, Gopanpally Village, Serilingampally, Ranga Reddy Dist., Hyderabad – 500 046

Seminar

Emergence of structure in cortical circuits through bottom-up dynamical principles

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Modularity and hierarchical organisation are fundamental features in biology, but the mechanisms underlying their emergence during development remain elusive. While some information is likely genetically coded, development must unfurl through the dynamics of self-organisation that obeys fundamental physics principles. In this talk, I will demonstrate how simple bottom-up dynamical rules can give rise to rich structure in the form of functional modularity and hierarchy.

I will focus on two key examples: grid cell modules in the entorhinal cortex, and the hierarchical organisation of the visual cortex. For grid cells, I introduce the novel principle of peak selection, whereby local interactions organise module boundaries from a global gradient, unifying the positional hypothesis and the Turing pattern formation hypothesis for morphogenesis. I will show that peak selection in the entorhinal cortex results in the formation of robust grid modules independent of all microscopic details. Further, we make robust predictions for the relationship between grid cell modules, yielding the most accurate match to grid cell data to date. In the visual system, I will show how a synaptic growth rule driven by spontaneous retinal waves and heterosynaptic competition can lead to the emergence of a spatially arranged visual cortical hierarchy with primate-like retinotopy. Our proposed model remarkably requires only a small number of parameters and robustly reproduces several additional features of sensory cortices, such as the formation of mirrored maps, local convolutional-like connectivity and variation in receptive field size and structure through the visual field.

Through the formulation of such simple principles governing the development of cortical circuits, our models produce multiple testable hypotheses for future developmental, connectomics and physiology studies for sensory cortices and the entorhinal cortex.

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4:00 PM (Tea / Coffee 03.45 PM)

Auditorium, TIFR-H