

\*\*\* Preprint \*\*\*

## Chapter 4

# Neuronal Arborizations, Spatial Innervation and Emergent Network Connectivity

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### Abstract

Neurons innervate space by their axonal and dendritic arborizations. Synapses can form when axons and dendrites are in close proximity. The geometry of neurons and their numerical densities in space are thus primary factors in the formation of synaptic connectivity of neuronal networks. A simulator of neuronal morphology based on principles of neural development (NETMORPH) has been used to show that realistic network connectivities emerge from realistic neuronal morphologies and simple proximity-based synapse formation rules.

### Key Words

neuronal morphology, network connectivity, presynaptic distances, postsynaptic distances, pathdistances, Euclidean distances, synapse multiplicity, network simulator, NETMORPH

## 4.1 Introduction

Activity dynamics underlying cognition depends crucially on the patterns and strengths of synaptic connections between neurons. Neurons innervate space by their axonal and dendritic arborizations as determined by their geometries. Axonal and dendritic arborizations are complex and show large variations in all their shape characteristics, such as in the number of segments and segment lengths, branching angles, tortuosity of branches, orientation of branches, thickness of branches, topology of their tree patterns, and their global 3D embedding, which may show some spherical symmetry or axial symmetry or even flat 2D patterns such as in Purkinje cells. Synapses can form only at those locations where axons and dendrites come sufficiently close to each other (Peters 1979). The geometry of neuronal arborisations and the numerical densities of neurons are therefore important determinants of synaptic connectivity of neuronal networks.

How neuronal morphology shapes neuronal network connectivity is, however, still poorly understood. From a computational point of view this question can be addressed by creating neuronal networks of computer generated or experimentally reconstructed neurons along with their axonal and dendritic arborizations in a given space and studying the emergent connectivity by applying Peters' rule (Peters 1979). The use of experimentally reconstructed

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