

\*\*\* 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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**Steven R. Hirsch, Daniel R. Weinberger**



## **Chapter 4 Neuronal Arborizations Spatial Innervation And:**

*The Computing Dendrite* Hermann Cuntz, Michiel W.H. Remme, Benjamin Torben-Nielsen, 2013-11-23 Neuronal dendritic trees are complex structures that endow the cell with powerful computing capabilities and allow for high neural interconnectivity Studying the function of dendritic structures has a long tradition in theoretical neuroscience starting with the pioneering work by Wilfrid Rall in the 1950s Recent advances in experimental techniques allow us to study dendrites with a new perspective and in greater detail The goal of this volume is to provide a r sum of the state of the art in experimental computational and mathematical investigations into the functions of dendrites in a variety of neural systems The book first looks at morphological properties of dendrites and summarizes the approaches to measure dendrite morphology quantitatively and to actually generate synthetic dendrite morphologies in computer models This morphological characterization ranges from the study of fractal principles to describe dendrite topologies to the consequences of optimization principles for dendrite shape Individual approaches are collected to study the aspects of dendrite shape that relate directly to underlying circuit constraints and computation The second main theme focuses on how dendrites contribute to the computations that neurons perform What role do dendritic morphology and the distributions of synapses and membrane properties over the dendritic tree have in determining the output of a neuron in response to its input A wide range of studies is brought together with topics ranging from general to system specific phenomena some having a strong experimental component and others being fully theoretical The studies come from many different neural systems and animal species ranging from invertebrates to mammals With this broad focus an overview is given of the diversity of mechanisms that dendrites can employ to shape neural computations

**Self-organizing Neural Maps: The Retinotectal Map and Mechanisms of Neural Development** John T. Schmidt, 2019-10-15 Self organizing Neural Maps From Retina to Tectum describes the underlying processes that determine how retinal fibers self organize into an orderly visual map The formation of neural maps is a fundamental organizing concept in neurodevelopment that can shed light on developmental mechanisms and the functions of genes elsewhere The book presents a summary of research in the retinotectal field with an ultimate goal of synthesizing how underlying mechanisms in neural development harmoniously come together to create life A broad spectrum of neuroscientists and biomedical scientists with differing backgrounds and varied expertise will find this book useful Describes the mechanisms relating to the developmental wiring of the retinotectal system Brings together the state of the art research in axon guidance and neuronal activity mechanisms in map formation Focuses on topographical maps and inclusion of multiple animal models from fish to mammals Explores the molecular guidance and activity dependent cue components involved in neurodevelopment

*Handbook of Brain Microcircuits* Gordon M. Shepherd, Sten Grillner, 2018 In order to focus on principles each chapter in this work is brief organized around 1 3 wiring diagrams of the key circuits with several pages of text that distil the functional significance of each microcircuit

**Society for Neuroscience Abstracts**

Society for Neuroscience. Annual Meeting, 1995      Schizophrenia Steven R. Hirsch, Daniel R. Weinberger, 2008-04-15

Schizophrenia is one of the most complex and puzzling diseases to affect mankind. It is the most common of the severe mental illnesses, psychoses, with an estimated prevalence of 0.5-1% in the general population and accounts for a very large portion of the day-to-day workload of the average psychiatrist. 50% of long-term psychiatric patients in mental hospitals are schizophrenic. There is a great deal of controversy about the causes, diagnosis, and treatment of schizophrenia, with the consequence that a huge amount of research is carried out in the field by psychiatrists, psychologists, neuroscientists, and pharmacologists. For the average practising psychiatrist seeing schizophrenics on a regular basis, making sense of the vast body of information on the subject and filtering out what is of clinical relevance can be very difficult. There is a constant stream of new drugs emerging and the new generation of drugs, the so-called atypicals, is very effective but often expensive. The Editors, one American and one British, are both highly respected clinical psychiatrists who are probably the leading experts on schizophrenia from their respective countries and jointly have published almost 150 papers on the subject. They have brought together a strong group of contributors from the USA, UK, and Europe to produce what will be an essential reference for the trainee and practising psychiatrist. The book consists of four sections: descriptive aspects, causative aspects, physical treatments, and psychological/behavioural/social treatments. There will be discussion of the theoretical controversies over symptomatology, classification, and aetiology; the relationship of schizophrenia to the other psychoses; the significance of positive and negative symptoms and pre-morbid personality. There will be chapters on organic models of schizophrenia, neurodevelopmental, genetic, and structural studies, and the role of high expressed emotion. The final section will cover social and environmental treatment, the role of the families of schizophrenics, and the psychoanalytical therapies. There is a new chapter on the patient's perspective, written by a former patient.

**Abstracts - Society for Neuroscience** Society for Neuroscience, 1994      **Society for Neuroscience Abstracts** Society for Neuroscience (U.S.). Annual Meeting, 1999

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