



Protrusion-Mediated Signaling Regulates Patterning of the Developing Nervous System

Rachel E. Moore¹, Jon Clarke^{1*} and Paula Alexandre^{2*}

¹ Department of Developmental Neurobiology, King's College London, London, United Kingdom, ² Developmental Biology and Cancer, UCL GOS Institute of Child Health, University College London, London, United Kingdom

During brain development, the tissue pattern and specification are the foundation of neuronal circuit formation. Contact-mediated lateral inhibition is well known to play an important role in determining cell fate decisions in the nervous system by either regulating tissue boundary formation or the classical salt-and-pepper pattern of differentiation that results from direct neighboring cell contacts. In many systems, however, such as the *Drosophila* notum, *Drosophila* wing, zebrafish pigmented cells, and zebrafish spinal cord, the differentiation pattern occurs at multiple-cell diameter distances. In this review, we discuss the evidence and characteristics of long-distance patterning mechanisms mediated by cellular protrusions. In the nervous system, cellular protrusions deliver the Notch ligand Delta at long range to prevent cells from differentiating in their vicinity. By temporal control of protrusive activity, this mechanism can pattern differentiation in both space and time.

Keywords: neuronal patterning, neuronal spacing, protrusion mediated signaling, long distance signaling, nervous system, neurogenesis

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*Correspondence:

Jon Clarke
jon.clarke@kcl.ac.uk
Paula Alexandre
p.alexandre@ucl.ac.uk

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INTRODUCTION

During morphogenesis, the differentiation of cells must be coordinated and patterned at both short (among immediate neighbors) and long range (across several or many-cell diameters). Short-range signaling can be achieved, for example, by cell-cell contact via ligands and receptors proteins inserted into cell membranes (such as Delta-Notch or ephrin-Eph signaling) (reviewed by Cayuso et al., 2015; Henrique and Schweisguth, 2019). Long-range signaling requires mechanisms that can operate over greater distances and is traditionally thought to employ secreted ligands [for example, hedgehog (Hh), wingless (Wnt), fibroblast growth factor (FGF), or bone morphogenic protein (BMP)] that diffuse through tissues to their distant target receiving cells (Briscoe and Small, 2015). More recently, it has become apparent that morphogen and cell-to-cell contact-dependent signaling can also be achieved between distant cells via long cellular protrusions (for example, Cohen et al., 2010; Eom et al., 2015; Oswald et al., 2015; and reviewed by González-Méndez et al., 2019). Cellular protrusions that may have signalling, organizational, or mechanical roles have been described in many systems and can have a variety of morphologies, cytoskeletal structure, and names (reviewed by Kornberg, 2014). Here, we will focus on protrusions called cytonemes, nanotubes, and filopodia that include actin-based projections, which together with more substantial protrusions can contain both microtubule and actin cytoskeletons. In this discussion, we will concentrate on protrusion-mediated signals in the nervous system (Table 1). Of course, in the nervous system, the most

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Jean M. Lauder



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Pattern Formation in the Developing Nervous System E. M. Carpenter, 2000-01-01 This special issue features a collection of papers examining multiple aspects of central and peripheral nervous system development. They address molecular genetic and cellular aspects of central and peripheral nervous system organization and regional development. These papers highlight recent work from laboratories and investigators using vertebrate models to study processes affecting the early development of the nervous system. Several areas of the nervous system such as the developing eye and spinal cord are used as models for examining molecular and cellular events contributing to neural development. Additional studies address genetic aspects of central nervous system development and identify novel genes implicated in CNS patterning. These papers present a diversity of approaches and model systems while retaining a central focus on the early events required to shape the nervous system. Researchers and instructors in developmental biology and developmental neuroscience will profit most from this publication.

Developmental Neuropsychobiology William T. Greenough, Janice M. Juraska, 2013-10-22 Developmental Neuropsychobiology is a compendium of papers that deals with developmental neuroscience and developmental psychology as well as the broad range of approaches toward brain behavior development. One paper reviews the embryonic mechanisms including the pattern formation that develops in a single fertilized egg, particularly focusing on limb innervation as a special case of pattern formation. Another paper discusses the regulation of nerve fiber elongation during embryogenesis. One author analyzes the pathways and changing connections in the nervous system of the insect; he shows that manipulating neural organization by grafting results in the ability of the transplanted sensory cells to find the proper central connections. Another paper reviews the sex differences in developmental plasticity of behavior and the brain. These differences point to the vulnerability of males during development to incidences of autism, dyslexia, or cerebral palsy compared to females. One paper also examines alternative perceptions of parent-offspring relationships. This collection can prove helpful for researchers, students, and academicians involved in the disciplines of biological or psychological sciences.

Gene Expression and Cell-Cell Interactions in the Developing Nervous System Jean M. Lauder, 2013-03-14 The dramatic advances in molecular genetics are becoming incorporated into neurobiological studies at an ever-increasing rate. In developmental neurobiology, the importance of cell-cell interactions for neurogenesis and gene expression is beginning to be understood in terms of the molecular bases for these interactions. This book seeks to emphasize the importance of molecular technology in the study of neurogenetic mechanisms and to explore the possible relationships between specific cell-cell interactions and regulated gene expression in the developing nervous system. This volume consists of nineteen chapters which address questions of gene expression and the importance of cell-cell interactions as key factors in the developing nervous system. Rather than viewing these two processes as separate mechanisms, as the organization of these chapters might suggest, we would like to emphasize the interplay of these genetic and epigenetic influences in all phases of neural ontogeny, a concept which is

made clear by the subject matter of the contributions themselves The authors of these chapters were participants in selected symposia from the Fourth Congress of the International Society of Developmental Neuroscience held in Salt Lake City Utah July 3-7 1983

Vertebrate Pattern Formation, 2024-05-13 Vertebrate Pattern Formation Volume 159 in the Current Topics in Developmental Biology series highlights advances in the field with this volume presenting interesting chapters on timely topics including Hox genes patterning the vertebrate body Endodermal patterning The use of organoids gastruloids to understand development Cell shape and movements controlling development Neural crest and placodes in vertebrate development Patterning of the neural tube Non canonical Wnt signaling in axial extension The control of transitions along the main body axis Emergence of a left right symmetric body plan in vertebrate embryos Formation of the vascular system Generation of patterns in the paraxial mesoderm and more Provides the authority and expertise of leading contributors from an international board of authors Presents the latest release in the Current Topics in Developmental Biology series Updated release includes the latest information on the Vertebrate Pattern Formation

Development of the Nervous System Dan H. Sanes, Thomas A. Reh, William A. Harris, Matthias Landgraf, 2019-06-13 Development of the Nervous System Fourth Edition provides an informative and up to date account of our present understanding of the basic principles of neural development as exemplified by key experiments and observations from past and recent times This book reflects the advances made over the last few years demonstrating their promise for both therapy and molecular understanding of one of the most complex processes in animal development This information is critical for neuroscientists developmental biologists educators and students at various stages of their career providing a clear presentation of the frontiers of this exciting and medically important area of developmental biology The book includes a basic introduction to the relevant aspects of neural development covering all the major topics that form the basis of a comprehensive advanced undergraduate and graduate curriculum including the patterning and growth of the nervous system neuronal determination axonal navigation and targeting neuron survival and death synapse formation and plasticity Provides broad coverage of concepts and experimental strategies Includes full color schematics and photographs of critical experiments Outlines the molecular and genetic basis for most developmental events Written at a level that is appropriate for advanced undergraduates and beyond Includes designs of critical experiments that are easy to understand

Receptors in the Developing Nervous System Ian S. Zagon, Patricia J. McLaughlin, 2012-12-06 Receptors for cell hormones growth factors Fourth alterations in the development of neu and neurotransmitters are involved in the neural receptors may have profound implications control and modulation of an enormous array for the structure and function of the of biological processes The development of organism As much as possible the receptor these receptors has distinct spatial and temporal functions of disrupting the orchestration of neural arrangements and alterations in this receptor development in the nervous system pattern during embryogenesis can have significant consequences for the well being of the we are just beginning to learn about some

fetus infant child and adult The developing receptors and the authors may not be in a nervous system is particularly dependent on position to discuss the consequences of recep receptors because its period of structural and tor dysfunction functional organization extends through both In designing these two volumes we have prenatal and postnatal phases Moreover asked major figures in each field to review the receptors are a key element in neural com literature to apprise the audience of their munication in both the developing and adult latest findings and to provide a perspective on organism so that the ontogeny of receptors is the role of receptors in the developing nervous crucial in determining the myriad connections system These books are intended to sum forming the circuitry of the nervous system **Fundamental**

Neuroscience Larry Squire,Darwin Berg,Floyd E. Bloom,Sascha du Lac,Anirvan Ghosh,Nicholas C. Spitzer,Larry R. Squire,2008-04-02 Fundamental Neuroscience Third Edition introduces graduate and upper level undergraduate students to the full range of contemporary neuroscience Addressing instructor and student feedback on the previous edition all of the chapters are rewritten to make this book more concise and student friendly than ever before Each chapter is once again heavily illustrated and provides clinical boxes describing experiments disorders and methodological approaches and concepts Capturing the promise and excitement of this fast moving field Fundamental Neuroscience 3rd Edition is the text that students will be able to reference throughout their neuroscience careers 30% new material including new chapters on Dendritic Development and Spine Morphogenesis Chemical Senses Cerebellum Eye Movements Circadian Timing Sleep and Dreaming and Consciousness Additional text boxes describing key experiments disorders methods and concepts Multiple model system coverage beyond rats mice and monkeys Extensively expanded index for easier referencing **Human**

Molecular Genetics Tom Strachan,Andrew Read,2018-03-29 Human Molecular Genetics is an established and class proven textbook for upper level undergraduates and graduate students which provides an authoritative and integrated approach to the molecular aspects of human genetics While maintaining the hallmark features of previous editions the Fourth Edition has been completely updated It includes new Key Concepts at the beginning of each chapter and annotated further reading at the conclusion of each chapter to help readers navigate the wealth of information in this subject The text has been restructured so genomic technologies are integrated throughout and next generation sequencing is included Genetic testing screening approaches to therapy personalized medicine and disease models have been brought together in one section Coverage of cell biology including stem cells and cell therapy studying gene function and structure comparative genomics model organisms noncoding RNAs and their functions and epigenetics have all been expanded **Postimplantation Development in the**

Mouse Derek J. Chadwick,Joan Marsh,2008-04-30 Examines the establishment of the germ layers and other cell lineages in the early embryo including details of cell movements during the beginning stages of primitive streak formation Discusses patterns of gene expression during the development of such tissues as the limb bud skeletal muscle and the central nervous systems placing special emphasis on commitment to particular cell types Although it concentrates on the mouse as an

example of mammalian development chick amphibian and Drosophila embryogenesis are employed whenever these organisms are more applicable to the study of a particular problem

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

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