



Pattern formation during development of the embryonic cerebellum

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The patterning of the embryonic cerebellum is vital to establish the elaborate zone and stripe architecture of the adult. This review considers early stages in cerebellar Purkinje cell patterning, from the organization of the ventricular zone to the development of Purkinje cell clusters—the precursors of the adult stripes.

Keywords: Purkinje cell, ventricular zone, zebrin, EBF2, neurogenin, stripe

INTRODUCTION—PATTERNING OF THE ADULT CEREBELLUM

The adult mouse cerebellum houses a complex topographical map (e.g., **Figure 1**). The map probably involves all cell types in the cerebellar cortex (e.g., Purkinje cells—Hawkes et al., 1985; granule cells—Hawkes and Turner, 1994; Hawkes et al., 1998; Golgi cells—Sillitoe et al., 2008; basket cells—Dermilly et al., 2011; glia—Scott, 1963); this review is focused on the Purkinje cells. The mapping of Purkinje cell antigens (e.g., zebrin II/aldolase C—Brochu et al., 1990; phospholipase (PL)CB4—Sarna et al., 2006; heat shock protein (HSP)25—Armstrong et al., 2000; CART—Reeber and Sillitoe, 2011 etc.), gene transcripts (reviewed in Sillitoe and Joyner, 2007) and transgenes (e.g., L7/pcp2-lacZ—Vandaele et al., 1991; Oberdick et al., 1993; OMP-lacZ—Nunzi et al., 1999; IP3R1-nb-lacZ—Furutani et al., 2010 etc.), has revealed multiple Purkinje cell subtypes. Each subtype has a characteristic distribution, but it seems plausible that these are all reflections of a common underlying architecture (Apps and Hawkes, 2009). First, the cerebellar cortex is divided from anterior to posterior into transverse zones: the anterior zone (AZ; ~lobules I–V), the central zone (CZ; ~lobules VI–VII; possibly further subdivided—Marchan et al., 2008), the posterior zone (PZ; ~lobules VIII–dorsal IX) and the nodular zone (NZ; ~lobules IX ventral and X; Osoi et al., 1999; Sillitoe and Hawkes, 2002). Next, each transverse zone is divided mediolaterally into parasagittal stripes. The most broadly studied marker of adult stripes is the Purkinje cell antigen zebrin II/aldolase C (e.g., Brochu et al., 1990; Ahn et al., 1994). The opposite pattern is revealed by other markers, for example PLCB4 (Sarna et al., 2006) and EBF2 (Croci et al., 2006; Chung et al., 2008). The zone-and-stripe pattern is highly reproducible between individuals and conserved across mammals and birds: zebrin II is expressed by many vertebrates (e.g., fish—Lannoo et al., 1991a,b;

Meek et al., 1992), as is EBF2 (Malgaretti et al., 1997; Bally-Cuif et al., 1998; Dubois and Vincent, 2001), but arrays of stripes are only seen in birds (e.g., pigeon—Pakan et al., 2007; chicken—Marchan et al., 2010) and mammals (reviewed in Sillitoe et al., 2005; Marchan and Hawkes, 2011). Many molecular markers are co-localized with either the zebrin II+ or zebrin II– Purkinje cells (e.g., PLCB3—Sarna et al., 2006; sphingosine kinase 1a—Terada et al., 2004 etc.). However, this is not the extent of the stripe compartmentation—other markers reveal subdivisions within stripes, subsets of stripes within the zebrin II+/– sets, and stripes in the CZ and NZ (e.g., P-path—Leclerc et al., 1992; heat shock protein (HSP)25—Armstrong et al., 2000; human natural killer cell antigen 1 (HNK1)—Eisenman and Hawkes, 1993; Marchan et al., 2004). In sum, the adult cerebellar cortex is highly reproducibly subdivided into several hundred distinct modules with >10 distinct Purkinje cell phenotypes (e.g., reviewed in Hawkes and Gravel, 1991; Hawkes, 1997; Apps and Hawkes, 2009). In the mouse, a typical stripe/module comprises fewer than a thousand Purkinje cells.

Zones and stripes are important because cerebellar patterning influences all aspects of cerebellar organization and function. Here is not the place to expound this at length, but simply to note that the Purkinje cell map serves as a scaffold around which many other cerebellar structures are organized:

1. *Afferent projections* use Purkinje cells to target their terminal fields.
2. *Interneurons* are restricted at stripe boundaries and are thought to use Purkinje cell cues to establish their own topography.
3. *Functional boundaries* align with stripe boundaries (e.g., Chockkan and Hawkes, 1994; Chen et al., 1996; Haller et al., 1999; Apps and Garwicz, 2005; Wädiche and Jahr, 2005).

Pattern Formation During Development

Gerd B. Muller, Stuart A. Newman



Pattern Formation During Development:

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studied by comparative anatomists but only recently has new light been thrown on such subjects as segmentation of the head proposed in the 18th century by Goethe and now a live issue for developmental biologists. Somites are simple when they first appear but very complex structures arise from them. These include the vertebrae and the axial and other muscles and consequently there is a wealth of morphogenetic problems to be explored. Sometimes their morphogenesis is disturbed by genetic or environmental factors and there are many clinical conditions which arise as a result. Genetics of Pattern Formation and Growth Control

Society for Developmental Biology. Symposium, 1990-10. Topics covered in this volume intended for geneticists and developmental biologists include the origin of polarity, establishment of cell fate, the role of growth factors in development, genetic control of pattern formation and use of transgenic organisms in the study of development. **Comparative Anatomy and Developmental Biology of Vertebrates** Mr. Rohit Manglik, 2024-03-04. EduGorilla Publication is a trusted name in the education sector committed to empowering learners with high quality study materials and resources. Specializing in competitive exams and academic support, EduGorilla provides comprehensive and well structured content tailored to meet the needs of students across various streams and levels. Biomedical Index to PHS-supported Research, 1990. **Plant Biology and Biotechnology Volume - I** Mr. Rohit Manglik, 2024-01-23.

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Developmental Genetics Gurbachan S. Miglani, 2013-12-30. Development is behind what one looks like. It is directed by genes, the units of heredity which are made up of deoxyribonucleic acid (DNA) in all animals including man, plants, microorganisms and most of the viruses except in some viruses where ribonucleic acid (RNA) is the genetic material. Developmental Genetics integrates the two disciplines of development and genetics into one. Key Features: Each chapter

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Brain abnormalities due to genetic alterations or developmental exposure to environmental factors Kazuhiko Sawada, Atsushi Yoshiki, Shigeyoshi Saito, 2022-08-31

Physiological Systems in Insects Marc J. Klowden, Subba Reddy Palli, 2022-09-24 Physiological Systems in Insects Fourth Edition explores why insects have become the dominant animals on the planet Sections describe the historical investigations that have led us to our current understanding of insect systems Integrated within a basic physiological framework are modern molecular approaches that provide a glimpse of the genetic and evolutionary frameworks that testify to the unity of life on earth This updated edition describes advances that have occurred in our understanding of hormone action metamorphosis and reproduction along with new sections on the role of microbiomes insecticide action and its metabolism and a chapter on genetics genomics and epigenetic systems The book represents a collaborative effort by two internationally known insect physiologists who have instructed graduate courses in insect physiology As such it is the ideal resource for entomologists and those in other fields who may require knowledge of insect systems Presents updated information on key physiological principles Covers detailed and instructive figures for visual enhancement Provides flowing text without the interruption of citations Includes evolutionary considerations throughout also providing a discussion on the implications of molecular techniques and discoveries Encourages further reading with a complete bibliography at end of each chapter *Biological Regulation and Development* Robert F. Goldberger, 2013-11-11 The motivation for us to conceive this work on regulation was mainly our belief that it would be fun and at the same time productive to approach the subject in a way that differs from that of other

treatises We thought it might be interesting and instructive for both author and reader to examine a particular area of investigation in a framework of many different problems Cutting across the traditional boundaries that have separated the subjects in past volumes on regulation is not an easy thing to do not because it is difficult to think of what interesting topics should replace the old ones but because it is difficult to find authors who are willing to write about areas outside those pursued in their own laboratories Anyone who takes on the task of reviewing a broad area of interest must weave together its various parts by picking up the threads from many different laboratories and attempt to produce a fabric with a meaningful design Finding persons who are likely to succeed in such tasks was the most difficult part of our job In the first volume of this treatise most of the chapters dealt with the mechanisms of regulation of gene expression in microorganisms This second volume involves a somewhat broader area spanning the prokaryotic eukaryotic border

Origination of Organismal Form Gerd B. Muller, Stuart A. Newman, 2003-01-03 A more comprehensive version of evolutionary theory that focuses as much on the origin of biological form as on its diversification The field of evolutionary biology arose from the desire to understand the origin and diversity of biological forms In recent years however evolutionary genetics with its focus on the modification and inheritance of presumed genetic programs has all but overwhelmed other aspects of evolutionary biology This has led to the neglect of the study of the generative origins of biological form Drawing on work from developmental biology paleontology developmental and population genetics cancer research physics and theoretical biology this book explores the multiple factors responsible for the origination of biological form It examines the essential problems of morphological evolution why for example the basic body plans of nearly all metazoans arose within a relatively short time span why similar morphological design motifs appear in phylogenetically independent lineages and how new structural elements are added to the body plan of a given phylogenetic lineage It also examines discordances between genetic and phenotypic change the physical determinants of morphogenesis and the role of epigenetic processes in evolution The book discusses these and other topics within the framework of evolutionary developmental biology a new research agenda that concerns the interaction of development and evolution in the generation of biological form By placing epigenetic processes rather than gene sequence and gene expression changes at the center of morphological origination this book points the way to a more comprehensive theory of evolution

The Shaping of Life Lionel G. Harrison, 2010-12-23 Biological development how organisms acquire their form is one of the great frontiers in science While a vast knowledge of the molecules involved in development has been gained in recent decades big questions remain on the molecular organization and physics that shape cells tissues and organisms Physical scientists and biologists traditionally have very different backgrounds and perspectives yet some of the fundamental questions in developmental biology will only be answered by combining expertise from a range of disciplines This book is a personal account by Professor Lionel Harrison of an interdisciplinary approach to studying biological pattern formation It articulates the power of studying dynamics in development that to understand how an

organism is made we must not only know the structure of its molecules we must also understand how they interact and how fast they do so *Epigenetics* Benedikt Hallgrímsson, Brian K. Hall, 2011-04-11 If you want to understand evolution you need to understand the murky world of epigenetics A hearty congratulations should be paid to Hallgrímsson and Hall who provide reliable and steady illumination Bernard Wood Center for the Advanced Study of Hominid Paleobiology George Washington University

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