Preface

This book presents the basic concepts and facts relating to the developmental biology of animals. It is designed as a core text for undergraduate courses from the second to the fourth year, and also for first year graduate students. The first and second editions were "road tested" by myself and by many other instructors, and were found suitable for both biologically based and medically oriented courses. A basic knowledge of cell and molecular biology is assumed, but no prior knowledge of development, animal structure, or histology should be necessary.

The book is arranged in four sections and the order of topics is intended to represent a logical progression. The first section introduces the basic concepts and techniques. The second covers the six main "model organisms," *Xenopus*, zebrafish, chick, mouse, *Drosophila*, and *Caenorhabditis elegans*, describing their early development to the stage of the general body plan. The third deals with organ development, mostly of vertebrates but including also *Drosophila* imaginal discs. The fourth deals with some topics of high contemporary interest: growth and stem cells, regeneration, regenerative medicine, and evolution. To assist readers unfamiliar with the families of genes and molecules that are important in development, they are listed in the Appendix in the context of a short revision guide to basic molecular and cell biology.

Like the previous editions, the new version of *Essential Developmental Biology* differs from its main competitors in four important respects, all of which I feel are essential for effective education.

- It keeps the model organisms separate when early development is discussed. This avoids the muddle that arises all too often when students think that knockouts can be made in *Xenopus*, or that bindin is essential for mammalian fertilization.
- It avoids considerations of history and experimental priority because students do not care who did something first if it all happened 20 years ago.
- It does, however, explain *why* we believe what we do. Understanding does not come from simply memorizing long lists of gene names, so I continue to explain how to investigate developmental phenomena and what sorts of evidence are needed to prove a particular type of result.
- The work is highly focused. In order to keep the text short and concise I have not wandered off into areas such as the development of plants or lower eukaryotes, that may be very interesting but are really separate branches of biology.

The first two editions were very well received by both users and reviewers and I hope that the third edition will make this book an even more popular choice for undergraduate and graduate level teaching around the world.

The curse of detail

The principal challenge today is that of exponentially increasing detail. The molecular life sciences seem to double in workforce and output every 10 years or so, and developmental biology has grown at least this fast since its re-founding as a molecular subject in the 1980s. But students' brains do not double in size every 10 years, nor do their courses lengthen. So very serious thought has to be given to what to include and what to leave out.

I have taken the view that the value of model organisms is that they enable experiments to be performed whose results illuminate some general principle of development. However, a lot of recent research has diverged from this strategy and has focused on an ever more detailed molecular analysis of every possible process and organ system in every model organisms. Although the principles of development are common to all animals, it is inevitable that the harder you look, the more differences between organisms you will find. My view is that for a textbook at this level it is not appropriate to cover all the detailed differences between, say, myogenesis in mouse, chicken, *Xenopus*, and zebrafish, so I have focused on just the main themes. In the general field of organogenesis it is also not feasible to cover all of the organs in the vertebrate body. Accordingly, I have selected for inclusion those that are classic developmental biology topics, such as limb development, and those of the greatest medical importance, such as the nervous system, the heart, or the pancreas. Likewise, when considering regeneration, it is not possible to cover every structure in the living world that regenerates to some extent, so I have focused on three classic systems: the planarian, insect limbs, and vertebrate limbs.

New features

Two new chapters in the third edition are devoted to Techniques for Studying Organogenesis and Postnatal Development and Applications of Pluripotent Stem Cells. The Techniques chapter mostly deals with the very important genetic methods in the mouse used for conditional knockouts, induction of transgene activity, and labeling of specific cell lineages. The Applications chapter deals with human embryonic stem cells and induced pluripotent stem cells and their current and future applications. The two chapters on Tissue Organization and Stem Cells and on Growth, Aging, and Cancer, areas of enormous current interest, are both very substantially revised, and place tissue-specific stem cells firmly into the context of normal postembryonic development and cell turnover.

Otherwise, the text has all been rewritten and updated, the grouping of topics has been reorganized to some extent, the further reading has been updated, and errors have been removed. I have also taken the opportunity of the third edition to introduce many photographs. This helps to communicate the remarkable beauty of specimens, which is what motivates many developmental biologists to do their work.

Obstacles to learning

Students sometimes consider developmental biology to be a difficult subject, but this need not be the case so long as certain obstacles to understanding are identified at an early stage. The names and relationships of embryonic body parts are generally new to students so in this book the number of different parts mentioned is kept to the minimum required for understanding the experiments, and a consistent nomenclature is adopted (e.g. "anterior" is used throughout rather than "rostral" or "cranial").

The competitor texts mix up species and, for example, would typically consider sea urchin gastrulation, *Xenopus* mesoderm induction, and chick somitogenesis in quick succession. This leaves the student unsure about which processes occur in which organisms. In order to avoid confusion, I have kept separate the model organism species in Section 2, and for Sections 3 and 4 it is made clear to which organisms particular findings apply.

Although most students do understand genetics in its simple Mendelian form, they do not necessarily appreciate certain key features prominent in developmental genetics. Among these are the fact that one gene can have several mutant alleles with different properties (e.g. loss of function, constitutive, or dominant negative), or that the name of a gene often corresponds to its loss-of-function phenotype rather than its normal function (e.g. the normal function of the *dorsal* gene in *Drosophila* is to promote ventral development!). Furthermore, pathways with inhibitory steps, such as the Wnt pathway, cause considerable trouble because of the difficulty of representing the lack of something in a diagram. Here, these issues are fully explained in the early chapters, with appropriate reinforcement later on. I provide charts showing the state of each component of inhibitory pathways such that the consequences of altering a particular component can be seen at a glance. I also always distinguish clearly between loss-of-function, gain-of-function, and dominant negative mutations.

Gene nomenclature is an awkward problem for a textbook because there are different conventions in use for different model organisms and between those genes discovered through mutation as opposed to those discovered via biochemistry of the protein product. Here, the species-specific conventions are followed where the text relates to a particular species, but if the text relates a gene in more than one species, I use a generic convention with the name italicized and an initial capital letter.

Students usually fail to distinguish between genes and gene products, and should hopefully be encouraged to do so by the use of italics for gene symbols and regular type for proteins. It is also necessary to understand the difference between increasing the expression of a gene product and activating the biochemical function of a product that is already present. Here, I refer respectively to "upregulation" and "activation" for these two situations, and to "repression" and "inhibition" for the situation where expression or activity is reduced.

I am careful not to adopt the colloquial joining of name and function, as for example in "Notch receptor." This all too easily suggests a receptor *for* Notch rather than the Notch molecule itself, and is a style best avoided.

Finally, I have tried to keep the overall level of detail, in terms of the number of genes, signaling systems, and other molecular components, to the minimum required to explain the workings of a particular process. This often means that various parallel or redundant components are not mentioned, and the latest detail published in *Cell* is omitted.

Learning outcomes

When students have completed a course corresponding to the content of this book they should be able to understand the main principles and methods of the subject. If they wish to enter graduate school, they should be very well prepared for a graduate program in developmental biology. If they go to work in the pharmaceutical industry, they should be able to evaluate assays based on developmental systems where these are used for the purposes of drug screening or drug development. If they become high school teachers, they should be able to interpret the increasing flow of stories in the media dealing with developmental topics, which are sometimes inaccurate and often sensationalized. Whether the story deals with miracle stem cell cures, human cloning, four-legged chickens, or headless frogs, the teacher should be able to understand and explain the true nature of the results and the real motivation behind the work. It is in all our interests to ensure that the results of scientific research are disseminated widely, but also that they are a source of enlightenment and not of sensation.

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