Introduction to development

Reading: Chp 1: 1-16

Welcome to Developmental Biology! In this first class period, we will talk only briefly about development. Mostly, we'll address how this class will work, practice using clickers, and take a short assessment. If you haven't yet done so, you should make sure to look at the Introductory Information link from the main web page, which describes all the different components of this course.

The following notes just help you get oriented to some of the terms and ideas we will discuss during this course.

Learning goals: Be able to:

Give a general description of what development is all about.

Define life cycles, stages of embryonic development, determination and differentiation.

Life Cycles

Development is the series of changes that take place in an organism during its life cycle. The simplest cycles consist of growth plus mitosis. This is the basic cell cycle: G1, S, G2, and M. The more complex life cycles of some single-celled organisms and all multicellular organisms include two other processes: differentiation and sexual reproduction.

Differentiation can be defined as the display of different phenotypes by cells of the same genotype—for example, skin cells and muscle cells in the human body produce different proteins and have different functions.

Sexual reproduction involves an alternation of haploid and diploid phases, involving fusion of haploid cells to form diploid cells, which can undergo genetic recombination and give rise to haploid cells with new combinations of genes. Recall the processes involved in a sexual reproductive cycle: fertilization, recombination and meiosis, as well as mitosis.

Germ cells and somatic cells: In higher organisms, germ cells are those that will undergo meiosis to form haploid gametes and give rise to the next generation. Somatic cells are all the rest. The germ cells are part of the immortal chain of life that passes from generation to generation. The fate of the somatic cells is aging and death.

The process of animal development

This course is primarily about development of multicellular animals (metazoans). Most of what we will be talking about is development of the soma during embryogenesis, from the fertilized egg (zygote) to the newly hatched or newborn animal. The embryo first consists of one cell, then two, then four, then later becomes a ball of many cells, which may look and behave differently from each other. Then large groups of cells begin to move, shape changes begin to take place (morphogenesis), and pretty soon, the embryo becomes a fetus that starts to look more and more like the newborn animal.

Until quite recently, this process was a mystery. How are cells at particular positions in an embryo directed at specific times to express different sets of genes to become the correct types of cells? How are particular cells directed to change their shapes or move to new locations to form specific morphological patterns? Cells in an embryo behave as though they "know" what time it is during development, where they are relative to other cells, and what they are supposed to be doing. What kind of the temporal and spatial information they are receiving? How do they "know" what to

do when they get that information? Although there are still plenty of mysteries, we now know many of the answers to these questions, and soon, so will you!

Cell determination, cell differentiation, and differential gene expression

The zygote is totipotent, capable of giving rise to every type of cell in the organism. In mammals, early embryonic cells are also totipotent, or at least pluripotent, capable of giving rise to many cell types (these are the well-known embryonic stem cells). During embryonic development, cells become progressively more restricted in their developmental potential. We say that a cell is determined when it has become committed to a certain developmental fate, say, to become a muscle cell (note: the terms committed and determined are often used interchangeably.) It may be some time before this cell actually undergoes differentiation, that is, begins to synthesize muscle proteins like actin and myosin that allow it to take on the characteristic features and roles of an actual muscle cell. In mammals, there are about 200 different recognized types of differentiated cells.

The distinction between determination and differentiation is useful for discussion. However, it is a little fuzzy, because both processes involve the activation of genes that were not previously expressed, as we shall see shortly. Different types of cells express different genes, in other words, development results from differential gene expression.

Molecular and cellular mechanisms and the evolution of development

One of the revelations of the last 20 years in developmental biology has been the extent to which all animals, from worms to humans, use similar sets of structural genes and proteins, mechanisms for controlling gene expression, signaling molecules, and entire signaling pathways. Although animals of different phyla may differ somewhat in the way these components are programmed to function in development, the similarities are much more striking than the differences. That's why we have been able to learn so much about human development (and human biology in general) from the study of simpler model organisms that are more convenient to study in the laboratory. We begin this course by reviewing the general mechanisms of gene expression and cell signaling in the context of development, as essential background to much of what we will discuss throughout the semester.

Review questions

1) How would you define the soma and the germ line of an animal, and what are the major differences between them?

2) How would you define determination/commitment and cell differentiation? How are these processes different, and how are they similar?

3) What is the evidence that processes of development are highly conserved throughout all animal phyla? What are some consequences of this relatedness for research in developmental biology?