

An Overview of Differentiation and Morphogenesis

Slide 2 Take a moment and think of any type of organism...What did you think of? A human? A tree? A fish? A bacterium? Whatever type of organism you thought of, when you visualized it in your head it had a particular shape, correct? Virtually all types of organisms have a particular shape, or morphology. This is true whether you are considering different types of mammals, plants, algae, or even prokaryotes. As organisms develop, their shape, or morphology, also develops, in a process called morphogenesis. Morphogenesis shapes multicellular organisms, their tissues and organs, and even the individual cells of single-celled organisms.

Morphogenesis is a highly regulated process, although it is more flexible, or 'plastic', in some types of organisms than others (compare plants to humans, for example). Even with plasticity, however, there are basic developmental processes in different organisms that hold true pretty much all of the time. Humans, for instance, always develop with two eyes and a nose in the middle of their face, two arms connected to their shoulders, and two legs connected to their hips. Even many bacteria, though single-celled, always develop the same way – *E. coli* always develop as rod-shaped cells, *Leptospira* always develop as spiral-shaped, or coiled, cells.

But what are the mechanisms that are responsible for morphogenesis? What processes do we have to thank for not being born with eyes on the bottoms of our feet?

Slide 3 Morphogenesis is controlled at the cellular level, in large part due to a process called cell differentiation. Cell differentiation refers to a cell taking on its mature form and role for an organism. A cell becomes differentiated by producing specific proteins from the DNA template that allow it to develop into its mature form. Further, in their mature form cells produce proteins that are specific to the cell's role in the organism. As an example, compare your kidney cells, your liver cells, your muscle cells and your blood cells. All of these cells ultimately came from the same zygote that you started out as, yet through the process of differentiation they have developed to perform very specific functions inside of your body. They perform their functions by producing and using specific proteins coded for in your DNA.

Slide 4 At this point you might be wondering...if morphogenesis controls the development of the shape of organisms, and cell differentiation greatly affects morphogenesis, what processes control cell differentiation? As we will see in the following lessons, cells receive signals from their internal and external environment that affect what genes in their DNA are turned on and what genes are turned off at specific times. A cell's communication with its environment, followed by the selective transcription of genes, allows cells to differentiate, and organisms to develop.

Cell signaling involves a multitude of chemical reactions and cell differentiation is only one possible outcome of these reactions. There are completely differentiated cells in our bodies that constantly receive and respond to signals. For example, fully-differentiated pancreatic cells still respond to the signal of increased levels of sugar in the blood. This

signal sets off a number of other signaling pathways that lead to the production of enzymes that help you metabolize the sugar you are ingesting.

Slide 5 In many organisms, the genes involved in development are organized in a hierarchy. Certain genes act early in development, and are responsible for turning on other genes that act slightly later in development. Those genes, in turn, are in part responsible for turning on yet other developmental genes that act yet later in development. This hierarchical organization of genes is referred to as a *regulatory cascade*.

Slide 6 As we move through the following lessons on cell differentiation and morphogenesis, our focus will largely be on the cell differentiation and morphogenesis processes as they occur specifically in several types of organisms, such as humans, the fruit fly, *Drosophila melanogaster*, and the mouse-ear cress, *Arabidopsis thaliana*. These organisms represent both classic and contemporary examples of differentiation and morphogenesis. As research progresses, however, it is also becoming clear that the pathways present in these organisms are found in large numbers of related organisms, and can give important insight into the evolutionary histories and patterns of many forms of life.