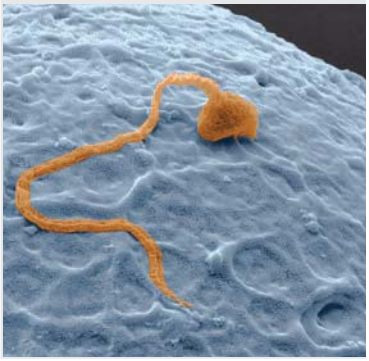
Cell Differentiation

A skin cell can divide to make a new skin cell, or a single bacterium can generate another bacterium. But how does a complex organism like you develop? Your body began as a single fertilized egg, or zygote. If the egg simply divided to make lots of identical cells, it would not form a baby.

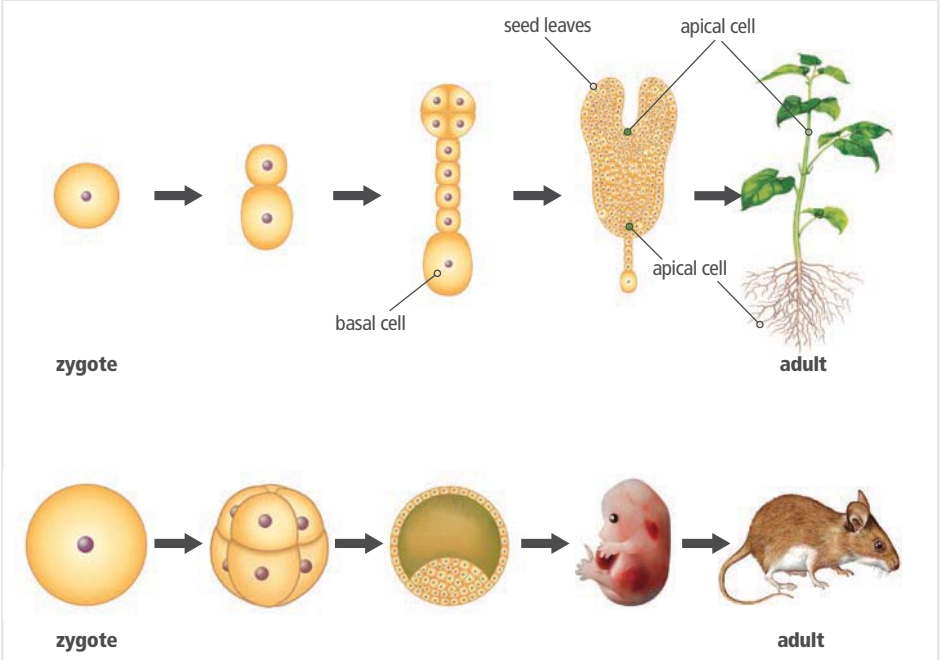
FIGURE 12: A sperm and egg fuse during fertilization, and a zygote is formed.



Development of Multicellular Organisms

Embryonic development begins with the fertilization of an egg by a sperm, producing a zygote. The zygote undergoes a series of divisions to produce a mass of cells that then become specialized. Cell differentiation is the process by which a cell becomes specialized for a specific structure and function during the development of a multicellular organism.

FIGURE 13: Cell differentiation in a plant and an animal



A cell's location within an embryo helps determine how it will differentiate. In plant cells, the first division of a fertilized egg is unequal, or asymmetric, as shown above. The apical, or topmost, cell forms most of the embryo, including the growth point for stems and leaves. The basal cell provides nutrients to the embryo and serves as the growth point for the roots. Plant cells cannot easily migrate because of their cell walls, but they adapt to changing conditions and continue to develop throughout their lifetime. As the plant grows, new cells continue to differentiate based on their location in the plant.

Analyze Compare the model of cell differentiation in plants to the model of cell differentiation in animals. What are the differences, and what are the similarities?

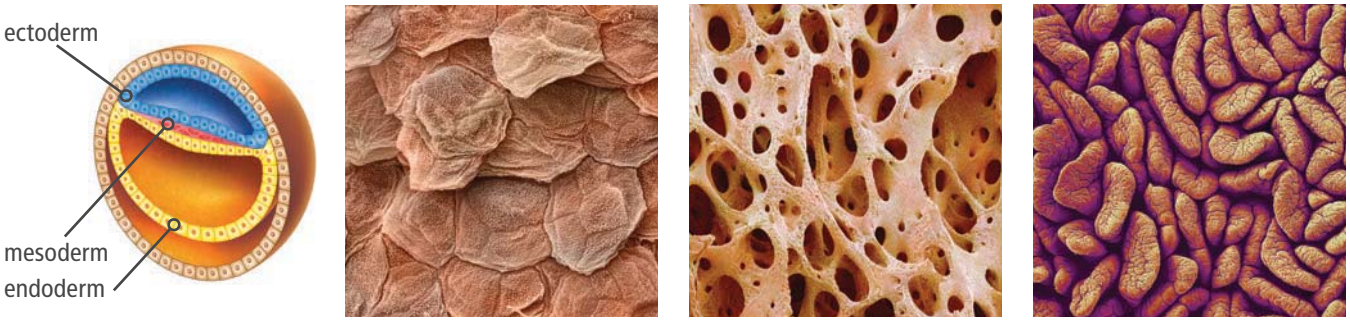
Explore Online

Hands-On Lab

Modeling Induction in Embryos Design a model to show how inducing chemicals trigger cell differentiation in a developing embryo.

In animals, an egg undergoes many divisions after it is fertilized. The resulting cells migrate to a specific area and begin to differentiate, forming a hollow ball. As the embryo develops, part of the ball folds inward, forming an inner layer called the endoderm. An opening is formed in the outer layer, called the ectoderm. Some animals, such as jellyfish, develop from only two cell layers. Vertebrates, including humans, develop a third layer of cells, called the mesoderm, between the inner and outer layers. This standard model of development varies from species to species.

FIGURE 14: Each cell layer in the gastrula of a human embryo produces cells that will form different tissues and organs.



a The gastrula is the embryo stage that develops three layers of cells: the ectoderm, mesoderm, and endoderm.

b The ectoderm develops into the skin and the nervous system. It also forms the lining of organs such as the mouth.

c The mesoderm develops into bone, muscle, blood, and connective tissue. It also forms organs such as the kidneys.

d The endoderm forms the lining of organs in the digestive, respiratory, and excretory systems. It also forms some glands.

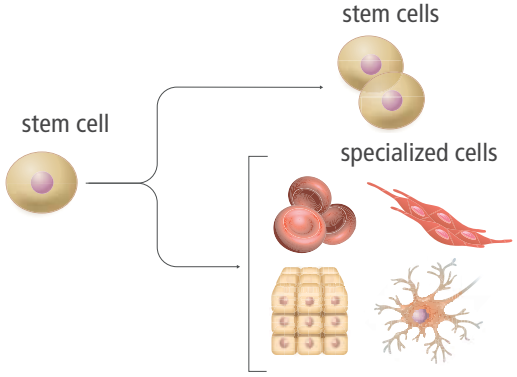
Explain Like the cell cycle, the process of cell differentiation is highly regulated. Write an argument for why regulation of the cell differentiation process would be especially important during the early stages of development.

Stem Cells

Specialized cells develop from a type of cell known as a stem cell. Stem cells are a unique type of body cell that can develop into a variety of specialized cells through differentiation. Stem cells are able to divide and renew themselves by mitosis for long periods of time, remaining undifferentiated until they are needed. When needed, they divide to form one new stem cell and one specialized cell.

Predict Describe a scenario in the human body in which a stem cell would need to divide into a new stem cell and a specialized cell.

FIGURE 15: Stem cells can develop into any type of cell.



Stem cells are classified by their potential to develop into differentiated cell types of different tissues. In general, the more differentiated a stem cell already is, the fewer the types of cells it can form. Stem cells are also classified by their origin, as either adult or embryonic. Adult stem cells are partially undifferentiated cells located near the specialized cells of many organs and tissues. Their primary role is to maintain and repair the specialized cells in tissues and organs, and the variety of specialized cell types they can produce are limited. Adult stem cells are found in small numbers all over the body in adults and children, as well as in umbilical cord blood.

Embryonic stem cells can form any of the 200 cell types of the body. They may be obtained from donated three-to-five-day-old embryos that result from in vitro fertilization. In vitro fertilization is a process in which eggs are fertilized outside a woman's body and go through several divisions in a culture. Scientists have also developed methods for converting differentiated cells, such as human skin cells, to embryonic stem cells.

Analyze Scientists are now able to convert human skin cells to embryonic stem cells. How might this technology influence science and society?

Researchers are studying ways to use stem cells to treat many different medical conditions. Because stems cells can differentiate into other types of cells, they offer the potential to repair or replace damaged tissues or organs. For example, stem cells in bone marrow produce red and white blood cells. Bone marrow transplants have been used for many years to treat leukemia and lymphoma, cancers that affect white blood cells. Scientists are also studying the use of stem cells to repair the pancreas of people with type I diabetes so that they will produce normal amounts of insulin. A patient with a damaged heart could potentially have stem cells injected into the tissue to repair the damage and grow new capillaries, thus restoring normal heart function. However, there are many technical problems with these treatments that future research needs to solve.

Collaborate Write a list of the tradeoffs you might consider when deciding whether to use stem cell treatments or traditional treatments to treat a disease like diabetes. Compare your list to a partner's list and mark the common items.

Gene Expression and Cell Differentiation

Virtually every cell in your body contains the same set of DNA, but every cell is not the same. How is this possible? A gene is a segment of DNA that stores genetic information. While almost every cell in your body has a full set of genes, each type of cell expresses only the specific genes it needs to carry out its function.

When a gene is expressed, or "switched on," the instructions within that segment of DNA are used to make proteins that carry out specific functions within the cell. When a gene is "switched off," or not expressed, its instructions are not used to make proteins. During development, genes are expressed differently in different types of cells. The set of genes expressed is determined by the type of cell and its location in the embryo or organism. By expressing some genes and not others, each cell generates the proteins it needs to take on its specific structure and function within the organism.

Model Make a model to illustrate how an organism develops from a zygote to a fully grown adult. In your model, include media and text to explain fertilization, cell division, and cell differentiation.