Cell Division

Reflect

Over the past several years, a debate has been brewing over the use of **stem cells**. Stem cells can be used to treat certain diseases and conditions such as spinal cord injuries, diabetes, arthritis, and heart disease. The sources of stem cells include umbilical blood, bone marrow, specially treated peripheral blood, and **embryos**. The use of embryos as a source of stem cells has stirred controversies over the past several years. Interestingly, stem cells are unique because, while not specialized, they have the potential to specialize into a variety of cell types. Since stem cells are undifferentiated, meaning they have not yet developed specific structures or functions, they can be used to replace unhealthy cells.

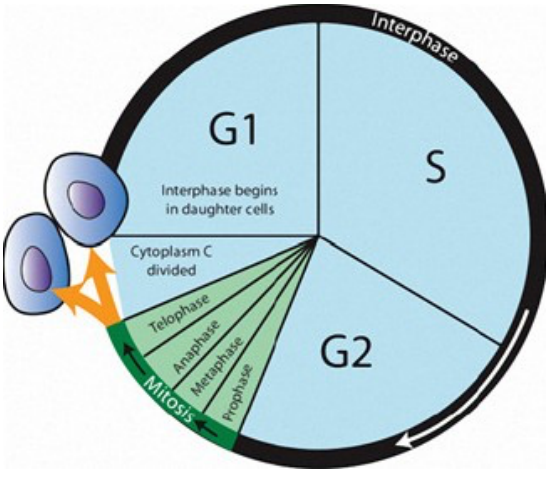
embryo: an early stage of development in organisms

As cells grow in an embryo, they differentiate and become a distinct type of cell. For example, muscle cells and nerve cells in animals, and root cells and leaf cells in plants are differentiated. Cell differentiation allows each type of cell to perform its necessary function. To better understand what makes cells special, we will explore the answers to these questions: How do cells divide and grow? How do they become differentiated? What factors affect cell differentiation, and what happens if cell differentiation is disrupted?

eukaryotic: having a membrane bound nucleus and other organelles

The Cell Cycle

Eukaryotic cells grow and divide through a series of events called the **cell cycle**. The cell cycle consists of two main stages: interphase and mitosis. During the cell cycle, a cell grows, prepares to divide, and then divides into two daughter cells. A cell spends 90 percent of its life in **interphase**, which includes G1, synthesis, and G2. These are growth and development stages.



G1: This phase is characterized by cell growth. In G1, which stands for Gap 1, the cell grows larger, makes new proteins, and develops organelles.

Synthesis: From G1, cells move into the S phase, or synthesis. This phase is characterized by the replication of the genetic material held within a cell, **DNA** (deoxyribonucleic acid).

Reflect

DNA replication makes an exact copy of the genetic material, which will be passed on to each daughter cell during mitosis. DNA replication begins when enzymes unzip the DNA molecule and form two strands. Then, nucleotides are added to each of the strands following the rules of base pairing. There are four nucleotides in DNA, adenine (A), thymine (T), guanine (G), and cytosine (C). Adenine always pairs with thymine, and guanine always pairs with cytosine. For example, a section of the template DNA strand reading TGATC would be paired with the nucleotides ACTAG. At the end of the S phase, the cell contains double of its original amount of DNA.

To start DNA replication, the molecule unzips along the base pairs, creating two single strands.

G2: This is the last phase before the cell enters mitosis. During G2, the cell continues to grow and prepares for mitosis by producing the structures needed for the upcoming division.

Mitosis: Although it is the shortest phase of the cell cycle, mitosis is a time of great activity, ending with **diploid cells**, such body cells. This is in contrast to the end product of meiosis which produces haploid cells, such as sperm and egg. **Mitosis** divides the nucleus, distributing DNA to each daughter cell. It is completed by **cytokinesis**, which divides the cytoplasm and separates the cell into two individual diploid cells. Mitosis is divided into four phases, which are described in the table on the following page.

What Do You Think?

Why do you think the strict rules of base pairing are important to DNA replication?

Look Out!

Only eukaryotic cells go through the stages of the cell cycle, including mitosis. **Prokaryotic** cells undergo a simpler form of cell division called **binary fission**. It is a form of asexual reproduction that results in two identical cells. It begins when a prokaryote replicates its DNA and attaches the copy to one part of the cell membrane and the original DNA to another. The cell pulls apart, separating the copy of DNA from the original genetic material and forming two identical cells.

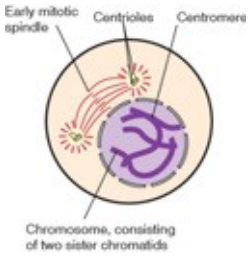
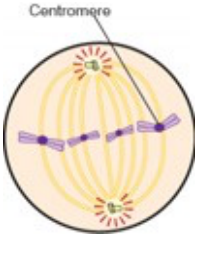
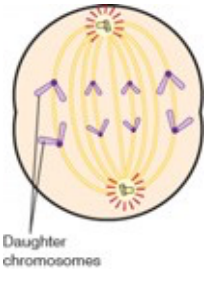
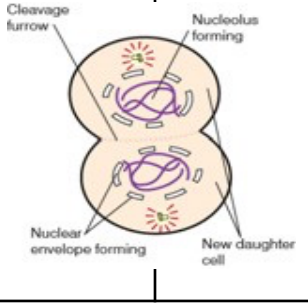
prokaryotic: lacking a membrane bound nucleus and other organelles

Try Now

Look at the chart below. If you were to examine a plant or animal cell under a microscope, what phase of the cell cycle would you most likely see? Explain your reasoning.

_____

_____

Prophase	Metaphase →	Anaphase →	Telophase →	Cytokinesis
• DNA condenses into chromosomes made up of two sister **chromatids** connected at the **centromere**. • The spindle fiber forms, radiating from the centrioles. • The centrioles move toward opposite ends of the cell.	• The nuclear envelope breaks down. • The centromeres attach to the spindle fibers. • Chromosomes are lined up at the center of the cell.	• Sister chromatids separate at the centromere and are now called chromosomes. • The chromosomes move to opposite ends of the cell along the spindle fibers. • The cell begins to elongate at the ends.	• Chromosomes uncoil. The mass of the uncoiled chromosomes is called **chromatin**. • Nuclear envelopes form around each cluster of chromosomes. • The spindle fiber breaks down and disappears.	• The cytoplasm divides in two. • In animals, the cytoplasm is drawn in until it is pinched in two, creating two new daughter cells. • In plants, a cell plate forms between the daughter cells. It gradually forms a membrane and cell wall, separating the two cells.
				

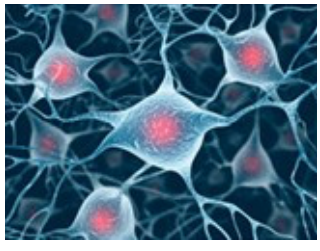
What Do You Think?

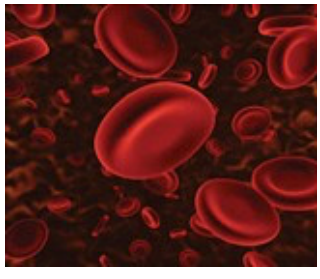
Cell Specialization

Although every eukaryotic cell contains similar structures, including a complete set of DNA, cells are specialized to perform specific functions. In a cell, DNA is the set of instructions that control all aspects of an organism. DNA is transcribed into another nucleic acid called **ribonucleic acid**, or **RNA**. RNA is important because, unlike DNA, it can travel outside of the nucleus to the cytoplasm where proteins are made. Organelles in the cell "read" the RNA and synthesize the proteins it encodes for. This is called gene expression. The proteins then build certain cell structures and perform specific cellular functions.

However, not the entire strand of DNA is read and synthesized. Only the necessary parts for each type of cell are expressed.

Transcription factors determine which sequences of the DNA will be transcribed into RNA, which establishes what type of cell it will be. This process, called **cellular differentiation**, changes an unspecialized cell, a stem cell, into a specialized one. As certain genes in somatic, or body, cells are expressed, the cells become specialized to perform specific tasks the organism needs. For example, the cells found in the roots of plants differ from those found in their stems or leaves. This is because different parts of a plant perform different functions.





Nerve cells (top) and red blood cells (bottom) differ in shape, structure, and function because of cell differentiation.

Root cells absorb minerals and water from the soil, while cells that make up the stem provide structure and height for a plant to hold up its leaves to sunlight. Leaf cells must express the genes that build structures for photosynthesis.

The same is true in animals. Differentiated cells perform different functions, so they express different genes. Red blood cells, for example, express the gene for the protein hemoglobin because it is necessary for transporting oxygen. Muscle cells are differentiated to build many mitochondria, which produce energy in a cell, because muscles are responsible for movement and physical activity. Bone cells provide strength, support, and protection to the body. Nerve cells are quite unique in their structure. Their shape is differentiated to receive signals from stimuli and pass them between the brain and the rest of the body. Epithelial cells are differentiated to control absorption and secretion.

Look Out!

External factors in the environment can affect cellular differentiation by disrupting gene expression. Certain genes may become activated or inactivated in response to such triggers as temperature changes, injury, exposure to chemicals, and lack of nutrients.

For example, when the body is infected with a disease, white blood cells of the immune system will express genes that produce antibodies. Injuries, such as cuts and wounds, will initiate the expression of genes in the cells of the injured tissues for clotting factors.

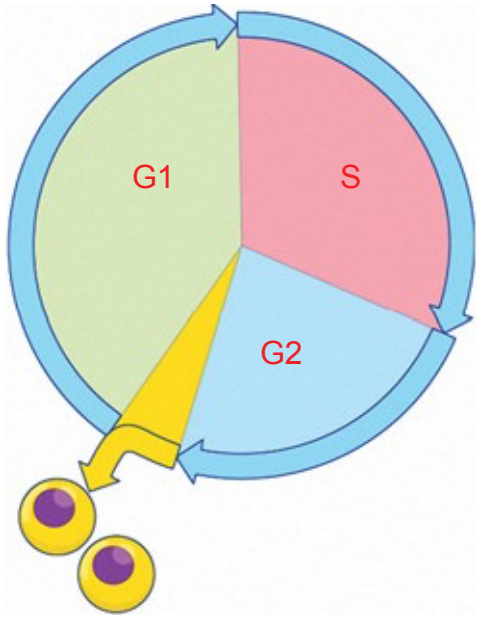
Temperature even determines male or female differentiation in some organisms. In certain species of alligators, eggs incubated at temperatures below 30 degrees Celsius will typically develop into females, while eggs incubated above 34 degrees Celsius will typically develop into males.

What Do You Think?

What are the advantages of cell differentiation? (Hint: Think about how an organism would be changed if all of its DNA were expressed in every cell.) What is a disadvantage of cell differentiation?

What do you know?

Use what you have learned to label the diagram of the cell cycle below. Begin by labeling the stages. Write your answers inside the sections of the circle. Then, on the outside of the circle, write the main processes that occur in each stage.



What Do You Think?

Now complete the Venn diagram below. Write in the correct section of the diagram each characteristic of the cell listed below. If the characteristic applies to all cells, write it in the middle section of the diagram.

Cell Characteristics

• Transports oxygen and nutrients through blood • Sends messages from the brain to the body • Differentiated • Receives stimulus signals • Contains protein hemoglobin for oxygen transport	• Round, thick, concave shape • Surrounded by a cell membrane • Long, narrow shape • Generated through the cell cycle • Passes electric signals between nerve cells

Nerve Cell **All Cells** **Red Blood Cell**

Connecting With Your Child

Stem Cells

To help your child learn more about cell differentiation, have your child research stem cells and create a PowerPoint presentation or poster that highlights the findings.

Encourage your child to compare stem cells with differentiated cells such as plant leaf cells or animal muscle cells. If possible, have your child observe different types of cells under a microscope. Prepared slides can be obtained from science supply companies. Your child can also find images of each cell type on the Internet.

Have your child include in the research the diseases that can be treated with stem cells and why only undifferentiated cells work in this type of therapy. Encourage your child to read about the controversy surrounding stem cells and explain the arguments for each side.

Here are some questions to discuss with your child:

- What are the stages of the cell cycle? Why are these stages necessary for organisms to grow and develop?
- What are the consequences of disruptions to the cell cycle and differentiation? How can some of these disruptions be avoided?
- Do you think cell differentiation is a trait that has evolved over time? Why is cell differentiation beneficial to organisms?