CHAPTER 5
Cell Growth and Division

GETTING READY TO LEARN

Preview Key Concepts

5.1 The Cell Cycle
Cells have distinct phases of growth, reproduction, and normal functions.

5.2 Mitosis and Cytokinesis
Cells divide during mitosis and cytokinesis.

5.3 Regulation of the Cell Cycle
Cell cycle regulation is necessary for healthy growth.

5.4 Asexual Reproduction
Many organisms reproduce by cell division.

5.5 Multicellular Life
Cells work together to carry out complex functions.

Review Academic Vocabulary

Write the correct word for each definition.

homeostasis  nucleus  centrosome  cell membrane

1. ____________ : forms spindle fibers
2. ____________ : described by the fluid mosaic model
3. ____________ : maintaining constant internal conditions
4. ____________ : largest organelle in a cell

Preview Biology Vocabulary

See how many key terms from this chapter you already know. Rewrite each phrase, using a different word or words for the words in bold.

<table>
<thead>
<tr>
<th>PHRASE</th>
<th>REWRITTEN WITH DIFFERENT WORDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The formation of skin and nerves and muscles in a developing embryo is an example of cell differentiation.</td>
<td>The formation of skin and nerves and muscles in a developing embryo is an example of __________________.</td>
</tr>
<tr>
<td>2. Bacteria reproduce asexually through binary fission.</td>
<td>Bacteria reproduce asexually through __________________.</td>
</tr>
<tr>
<td>3. Organisms that reproduce sexually use mitosis for growth, development, and repair.</td>
<td>Organisms that reproduce sexually use __________________ for growth, development, and repair.</td>
</tr>
</tbody>
</table>
The cell cycle has four main stages.

Cells grow and divide in a regular pattern, or cycle*. If you cut your finger, your cells grow and divide to make more cells. This is how your finger heals.

The cell cycle is a regular pattern of growth, DNA duplication*, and cell division* that occurs in eukaryotic cells. Recall that your cells are eukaryotic cells, and they have a nucleus. There are four main stages of the cell cycle:

- gap 1—normal growth
- synthesis—DNA is copied
- gap 2—more growth
- mitosis—nuclear division

Each stage is described below.

**Gap 1 (G1)** In G₁ cells do their normal functions. For example, your muscle cells contract, and intestinal cells absorb nutrients.

**Synthesis (S)** Synthesis means “the combining of parts to make a whole.” During the S stage, a cell puts together, or synthesizes, a whole copy of its nuclear DNA. In eukaryotes, DNA is in the nucleus. At the end of this stage, there are two complete sets of DNA in a cell’s nucleus.

**Gap 2 (G2)** In G₂ cells grow and continue their normal functions. If the cell is healthy, it will continue to the next stage.

**Mitosis (M)** There are two parts of this stage: mitosis and cytokinesis. Mitosis (my-TOH-sihs) is the division of the cell nucleus and the DNA inside it. Cytokinesis (sy-toh-kuh-NEE-sihs) is the division of the contents of the rest of the cell—the cytoplasm.

These four main stages are shown in the graph at the top of page 75.

**ACADEMIC VOCABULARY**

- cycle: a pattern of events that is repeated
- duplication: the process of doubling, or copying
- division: separating

**VISUAL VOCAB**

- Mitosis: the division of the cell nucleus and its contents.
- Cytokinesis: divides the cell cytoplasm.

* ACADEMIC VOCABULARY

* ACADEMIC VOCABULARY

* ACADEMIC VOCABULARY
On the figure above, circle the terms for the four stages of the cell cycle.

**Cells divide at different rates.**

Different types of eukaryotic cells take different amounts of time to go through the cell cycle. The table at right lists the life span—or how long until a cell dies—for different types of human cells. Also, cells divide at different rates depending on a person’s age. Children’s cells divide faster than do cells in adults. In adults, many cells divide only if there is an injury or cell death.

How long does it take for a cell to go through the cell cycle?

<table>
<thead>
<tr>
<th>CELL LIFE SPAN</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CELL TYPE</strong></td>
</tr>
<tr>
<td>Skin cell</td>
</tr>
<tr>
<td>Red blood cell</td>
</tr>
<tr>
<td>Liver cell</td>
</tr>
<tr>
<td>Intestine—internal lining</td>
</tr>
<tr>
<td>Intestine—muscle and other tissues</td>
</tr>
</tbody>
</table>

This chart shows the life span of five different types of human cells. Each type of cell divides at a different rate.

**Cell size is limited.**

A cell must be big enough to fit all of the molecules and organelles it needs to live. A cell also must be small enough to quickly transport nutrients and wastes into and out of the cell across the cell membrane. As a cell gets bigger, its volume* increases faster than its surface area*. If a cell gets too big, there is not enough surface area of the cell membrane to transport nutrients and wastes for such a big volume. The upper limit on cell size depends on its surface area-to-volume ratio. The surface area-to-volume ratio is the size of the surface area compared to the size of the volume.

* **ACADEMIC VOCABULARY**
  - **volume**: the amount of space in a three-dimensional object
  - **surface area**: the total amount of area on the surfaces of an object
RATIO OF SURFACE AREA TO VOLUME IN CELLS

As a cell grows, its volume increases more rapidly than does its surface area.

<table>
<thead>
<tr>
<th>Relative size</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Surface area</strong> (length × width × number of sides)</td>
<td>6</td>
<td>24</td>
<td>54</td>
</tr>
<tr>
<td><strong>Volume</strong> (length × width × height)</td>
<td>1</td>
<td>8</td>
<td>27</td>
</tr>
<tr>
<td><strong>Ratio of surface area to volume</strong></td>
<td>( \frac{6}{1} = 6:1 )</td>
<td>( \frac{24}{8} = 3:1 )</td>
<td>( \frac{54}{27} = 2:1 )</td>
</tr>
</tbody>
</table>

Can a cell get too big? Explain.

1. __________ is the division of the nucleus and its contents.
2. The __________ is a pattern of growth, DNA duplication, and division.
3. The division of the cell cytoplasm is called __________.

**5.1 Vocabulary Check**

**Mark It Up**

Go back and highlight each sentence that has a vocabulary word in **bold**.

**5.1 The Big Picture**

4. During which stage of the cell cycle is DNA copied? __________
5. Do all cells take the same amount of time to divide? Explain. __________
6. How does the surface area-to-volume ratio limit cell size? __________
Chromosomes condense* at the start of mitosis.

DNA is a double-stranded molecule, like a twisted ladder. A chromosome is one long piece of DNA. Every one of your body cells has 46 chromosomes. The DNA in each chromosome has many genes.

During interphase, when the cell is not dividing, the chromosomes are loose—kind of like 46 pieces of spaghetti. During mitosis, the DNA is condensed* and organized. This helps the chromosomes to stay untangled while the cell divides.

The figure below shows how the DNA strand turns into the very condensed form of a chromosome during mitosis.

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CHROMOSOME STRUCTURE

DNA condenses tightly during the early stages of mitosis.

DNA double helix
Each continuous, double-stranded DNA molecule makes one chromosome.

DNA and histones
DNA wraps around proteins called histones, forming chromatin.

Chromatin
Interactions between parts of the histones further compact the DNA.

Supercoiled DNA
The chromatin coils more and more tightly around organizing proteins.

Condensed, duplicated chromosome
The condensed, duplicated chromosomes can be lined up and separated during mitosis.

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Look at the picture of the condensed, duplicated chromosome. Recall that the chromosomes are copied during the S stage that happens before mitosis. This condensed, duplicated chromosome looks like an “X.” The right half of the X and the left half are copies of each other.

* ACADEMIC VOCABULARY

condense to make something smaller or more compact
They are identical. Each half of a duplicated chromosome is called a **chromatid** (KROH-muh-tihd). Together, the two identical chromatids are called sister chromatids. The sister chromatids are held together at a place called the **centromere** (SEHN-truh-MEER).

Explain how a chromatid and a duplicated chromosome are related.

Mitosis and cytokinesis produce two genetically identical daughter cells.

By the end of interphase, a cell is ready to divide. Mitosis divides the DNA, and cytokinesis divides the rest of the cell. The result is two identical cells. Mitosis happens in all of your body cells—except cells that form eggs or sperm. Your cells divide for growth, development, and repair. Single-celled organisms use cell division to reproduce.

Mitosis and cytokinesis are continuous processes. They do not happen in steps. However, scientists have divided the processes into steps to make them easier to understand and discuss. The four main phases of mitosis are prophase, metaphase, anaphase, and telophase. Cytokinesis begins at the end of anaphase or in telophase. These steps are shown in the figure to the right.

What is one reason your body cells need to divide?
1. Label the diagram below with the terms chromosome, chromatid, centromere, and telomere.

2. Draw and label each phase of mitosis—prophase, metaphase, anaphase, and telophase—in the circles below:

3. On the diagram above, in question 2, circle the part of the process in which cytokinesis occurs.

4. The word part telo- means “end.” How does this word part relate to the meaning of the terms telomere and telophase? ________________

5.2 The Big Picture

1. During which stage of the cell cycle is DNA copied? ________________

2. How many chromatids are there in one duplicated chromosome? ____

3. Two identical daughter cells result from mitosis and cytokinesis. In what ways are they “identical”? __________________________
Internal and external factors regulate cell division.

If the cell cycle goes out of control, cancer can result. Cancer is uncontrolled cell division. To regulate means “to control.” Regulation of the cell cycle is important for healthy cell growth. Internal means “inside” and external means “outside.” Information from both inside and outside the cell—internal and external factors—help regulate the cell cycle.

External Factors

There are external physical and chemical signals that help regulate the cell cycle. For example, a cell that is surrounded by other cells stops dividing. Many cells also release chemical signals that tell other cells to grow. Growth factors are proteins that stimulate cell division. If you are bleeding, some of your blood cells release a growth factor to help start the healing process.

Internal Factors

External factors bind to a receptor on the cell membrane. This starts a response inside the cell. These internal factors include enzymes and proteins that help a cell move through the cell cycle.

Apoptosis

Just as cells need to grow and divide, other cells need to die. Internal or external signals can start an orderly process of cell death. The cell is broken down and its parts are reused in building other molecules. This process of programmed cell death is called apoptosis (AP-uhp-TOH-sihs).

Why is regulation of the cell cycle important?

* ACADEMIC VOCABULARY

stimulate to cause something to happen
Cell division is uncontrolled in cancer.

Cancer is the common name for a group of diseases that involve uncontrolled cell division. Cancer cells keep dividing and form clumps called tumors. A **benign** tumor is relatively harmless because the cells stay clumped together and it can be removed. A **malignant** tumor has cancer cells that break away from the tumor. These cells **metastasize** (mih-TAS-tuh-syz), which means they travel to other parts of the body and can form more tumors. When a cancer metastasizes, it is much harder to get rid of.

Cancer cells come from normal cells that have damaged genes. Substances that are known to cause or lead to cancer are called **carcinogens** (kahr-SIHN-uh-juhnz). Tobacco smoke and certain air pollutants are carcinogens.

What is the difference between a benign tumor and a malignant tumor?

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**Vocabulary Check**

<table>
<thead>
<tr>
<th>growth factor</th>
<th>malignant</th>
</tr>
</thead>
<tbody>
<tr>
<td>apoptosis</td>
<td>metastasize</td>
</tr>
<tr>
<td>cancer</td>
<td>carcinogen</td>
</tr>
<tr>
<td>benign</td>
<td></td>
</tr>
</tbody>
</table>

Choose the correct term from the list for each description.

1. substance that causes cancer ____________________________
2. programmed cell death _________________________________
3. a tumor that does not metastasize ________________________

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**The Big Picture**

1. What are two ways that cell division is regulated in healthy cells?
   ____________________________
   ____________________________

2. What is one main difference between a normal cell and a cancer cell?
   ____________________________

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Cancer cells break away from malignant tumors. They can then be carried in the bloodstream to other parts of the body where they form new tumors.
Binary fission is similar in function to mitosis.

Reproduction is a process of making new organisms from one or more parent organisms. It happens in two ways, sexually and asexually. Sexual reproduction involves the joining of egg and sperm, and results in unique* offspring. Asexual reproduction is the production of offspring from a single parent. The offspring are, for the most part, genetically identical to each other and to the parent.

**Binary Fission and Mitosis**

Recall that prokaryotes include organisms such as bacteria. Most prokaryotes reproduce through binary fission. **Binary fission** (BY-nuh-reh FIHSH-uhn) is asexual reproduction of a single-celled organism by division into two parts. Binary fission does not follow the same steps as mitosis; the processes are different. But binary fission and mitosis have similar results—two daughter cells that are genetically identical to the parent cell.

**Advantages of Asexual Reproduction**

Asexual reproduction can quickly result in large numbers of offspring. All cells can have offspring. In contrast, sexual reproduction is slower. Only females can have offspring, and many sexually reproducing organisms must find a mate.

**Disadvantages of Asexual Reproduction**

Asexually reproduced offspring are genetically identical—so they will respond to their environment in the same way. If conditions stay the same, this is not a problem. If the environment changes, and the organisms cannot live with the changes, the entire population could die off. In contrast, offspring from sexual reproduction are genetically different from the parents. Genetic diversity increases the chance that some individuals will survive even in changing conditions.

* ACADEMIC VOCABULARY

**unique** unlike any other

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**What types of organisms reproduce by binary fission?**

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**BACTERIA GROWTH**

One bacterium can result in a total of 1024 cells after only 10 rounds of cell division.
Some eukaryotes reproduce through mitosis.

Growing a new plant from a cutting is an example of asexual reproduction through mitosis. Sea stars, flatworms, strawberries, potatoes, sea anemones, yeast, and many other eukaryotic organisms can also reproduce asexually, through mitosis. Many organisms can reproduce both sexually and asexually. The form of reproduction may depend on the conditions around the organism.

How do eukaryotes reproduce asexually?

5.4 Vocabulary Check

asexual reproduction
binary fission

Circle the correct word to complete each sentence.

1. Asexual reproduction results in genetically different / identical daughter cells.
2. Binary fission is when a single-celled organism divides into two / four daughter cells.

5.4 The Big Picture

1. Through what process do most prokaryotes reproduce asexually?

2. Through what process do eukaryotes reproduce asexually?

3. List one advantage and one disadvantage of asexual reproduction.
Multicellular Life

KEY CONCEPT

Cells work together to carry out complex functions.

SECTION 5.5

Multicellular organisms depend on interactions among different cell types.

In multicellular organisms like you, different types of cells communicate and work together. There are different levels of organization.

- **Tissues** are groups of cells that work together to perform a similar function. For example, plants have photosynthetic tissue made of cells that contain chlorophyll.
- **Organs** are groups of tissues that work together to perform specific functions. For example, different tissues work together to form a plant leaf, the plant’s food-producing organ.
- **Organ systems** are groups of organs that work together. For example, the shoot system of a plant is the part of the plant that is above ground. The stems support the plant, the leaves capture sunlight, and flowers help in reproduction.

LEVELS OF ORGANIZATION

Cells work together in groups that form larger, specialized structures.

<table>
<thead>
<tr>
<th>CELL</th>
<th>TISSUE</th>
<th>ORGAN</th>
<th>SYSTEMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A multicellular organism has different types of cells.</td>
<td>Similar types of cells that work together form different types of tissues.</td>
<td>Different types of tissues work together in an organ.</td>
<td>Organs work together in organ systems. Here, you can see the plant’s root system and shoot system, each made of different organs, which are made of different tissues.</td>
</tr>
</tbody>
</table>

What is an example of an organ and an organ system from the human body?
Specialized cells perform specific functions.

Your body began as a single fertilized egg. If that egg cell simply divided to make lots of identical cells, it would not form a baby. To form all of the different tissues that make up your body, cells need to specialize, or develop specific functions. For example, some cells become skin cells and others become stomach cells. Cell differentiation is the process by which cells that are not specialized develop into their specialized forms.

So why do stomach cells function differently than skin cells? They do not have different DNA. Almost all cells in your body have the same full set of DNA. Different types of cells simply use different genes contained in the DNA. Skin cells use one part of the DNA information—for skin cells—and stomach cells use a different part of the DNA information—for stomach cells.

If all cells in your body have the same DNA, how can you have different types of cells?

Stem cells can develop into different cell types.

Once a cell differentiates, it stays in its specialized form. For example, once a cell becomes a stomach cell, it cannot turn into another type of cell. Stem cells are a special type of body cell that can develop into different types of cells. Stem cells can:

- divide and renew themselves for a long period of time,
- remain undifferentiated, and
- develop into many different types of specialized cells.

When a stem cell divides, it forms either two stem cells or one stem cell and one specialized cell.

*ACADEMIC VOCABULARY*

differentiate to make different
**Stem Cell Classification**

Stem cells can be classified, or grouped, by their ability to differentiate into cell types of different tissues. Some kinds of stem cells can differentiate into any cell, and others can only differentiate into a few different kinds of cells. In general, the more differentiated a stem cell already is, the fewer types of cells it can form. Stem cells can also be classified by where they come from—either adult cells or embryonic* cells.

<table>
<thead>
<tr>
<th>Type of cell</th>
<th>fertilized egg</th>
<th>embryonic stem cell</th>
<th>adult stem cell (example from blood)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can give rise to</td>
<td>all cells</td>
<td>almost any cell</td>
<td>closely related cells</td>
</tr>
<tr>
<td>Example</td>
<td>new organism</td>
<td>neurons, skin, muscle, kidney, cartilage, bone, liver, pancreas</td>
<td>red blood cells, platelets, white blood cells</td>
</tr>
</tbody>
</table>

**Adult Stem Cells**

Adult stem cells are found all over the body—in the brain, liver, bone marrow, skeletal muscle, dental pulp, and even fat. These cells are partly undifferentiated. For years, much evidence suggested that adult stem cells could only make closely related cells. Newer research suggests that adult stem cells may be able to make many different types of cells.

**Embryonic Stem Cells**

Most embryonic stem cells come from donated stem cells grown in a lab. These embryos are grown from eggs that are fertilized outside a woman's body. The stem cells come from a three-to-five-day-old cluster of cells. These cells are entirely undifferentiated and can form any type of cell in the human body.

* ACADEMIC VOCABULARY

**embryonic** related to an embryo

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In the figure, circle the embryonic stem cells.

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First, an egg is fertilized by a sperm cell in a petri dish. The egg divides, forming an inner cell mass. These cells are then removed and grown with nutrients. Scientists try to control how the cells specialize by adding or removing certain molecules.
Research and Treatment Hope

Stem cells have been used to treat patients with various types of cancer for many years. They offer hope for treating many more diseases. For example, stem cells could potentially be used to replace nonworking cells in organs. This could help cure diabetes or repair heart damage. In addition, stem cells offer a new way to develop drugs. The current process for drug development is very expensive and takes a long time. Testing new products on specific cell types grown from stem cells could make the process faster and cheaper.

**5.5 Vocabulary Check**

tissue cell differentiation
organ stem cell
organ system

1. Underline the word in the list above that means “a group of similar cells that work together to perform a similar function.”

2. Circle the word in the list above that means “a cell that is undifferentiated, and can turn into different types of cells.”

3. Make a box around the word that means “the process by which cells that are unspecialized turn into their specialized forms.”

**5.5 The Big Picture**

1. Fill in the boxes below to show the different levels of organization in multicellular organisms.

   - cells
   - work together in groups to form
   - which work together to form
   - which work together to form

2. Are there differences in the DNA in different types of human body cells? Explain. 

   ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________
Chapter 5 Review

1. In a multicellular organism, what makes cells different—for example, what makes a muscle cell different from a brain cell? 

2. What process is shown in the diagram below? 
   - cell differentiation
   - mitosis
   - apoptosis
   - sexual reproduction

3. Write the terms tissue, organ, and organ system onto the diagram in order of largest level of organization to smallest level of organization. The biggest circle should be labeled with the biggest level of organization and the smallest circle with the smallest level.

4. Circle the correct words to complete the sentence below.
   Asexual reproduction results in offspring that are genetically different / identical and sexual reproduction results in offspring that are genetically different / identical.

5. A stem cell is a cell that is 
   - undifferentiated
   - differentiated
   - only found in embryos
   - only found in the brain stem

6. In which body cells does mitosis not occur?

7. Draw a duplicated chromosome, and label the drawing with the following terms: centromere, telomere, and chromatid.

8. What are the four stages of the cell cycle?