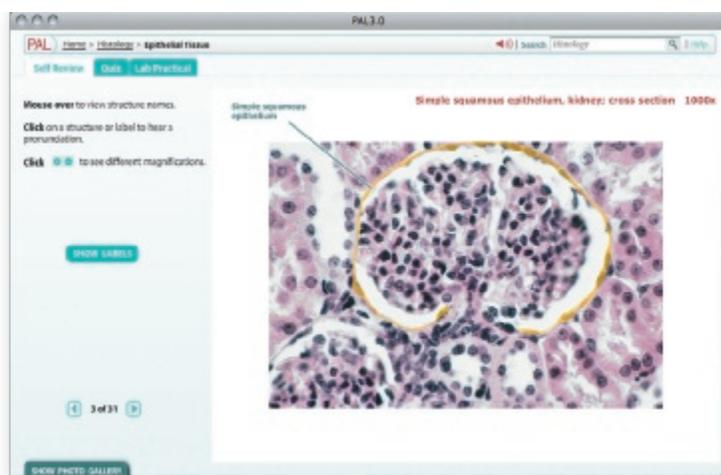


Anatomy of the Cell and Cell Division



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PAL™ For this lab exercise, follow this navigation path:

- PAL>Histology>Cytology (cell division)

Learning Outcomes

On completion of this exercise, you should be able to:

1. Identify cell organelles on charts, models, and other laboratory material.
2. Use the microscope to identify the nucleus and plasma membrane of cells.
3. State a function of each organelle.
4. Discuss a cell's life cycle, including the stages of interphase and mitosis.
5. Identify the stages of mitosis using a whitefish blastula slide.

Cells were first described in 1665 by a British scientist named Robert Hooke. Hooke examined a thin slice of tree cork with a microscope and observed that it contained many small open spaces, which he called **cells**. During the next two centuries, scientists examined cells from plants and animals and formulated the *cell theory*, which states that (1) all plants and animals are composed of cells, (2) all cells come from preexisting cells, (3) cells are the smallest living units that perform physiological functions, (4) each cell works to maintain itself at the cellular level, and (5) homeostasis is the result of the coordinated activities of all the cells in an organism.

Your cells are descendants of your parents' sperm and egg cells that combined to create your first cell, the zygote. You are now composed of approximately 75 trillion cells, more cells than you could count in your lifetime. These cells must coordinate their activities to maintain homeostasis for your entire body. If a population of cells becomes dysfunctional, disease may result. Some organisms, like amoebas, are composed of a single cell that performs all functions necessary to keep the organism alive. In humans and other multicellular organisms, cells are diversified, which means that different cells have different specific functions. This specialization leads to dependency among cells. For example, muscle cells are responsible for movement of the body. Because movement requires a large amount of energy, muscle cells rely on the cells of the cardiovascular system to distribute blood rich with oxygen and nutrients to them.

Lab Activities

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- 3 Cell Division 52

CLINICAL APPLICATION

Cell Division and Cancer 54

In this exercise you will examine the structure of the cell and how cells reproduce to create new cells that can be used for growth and repair of the body.

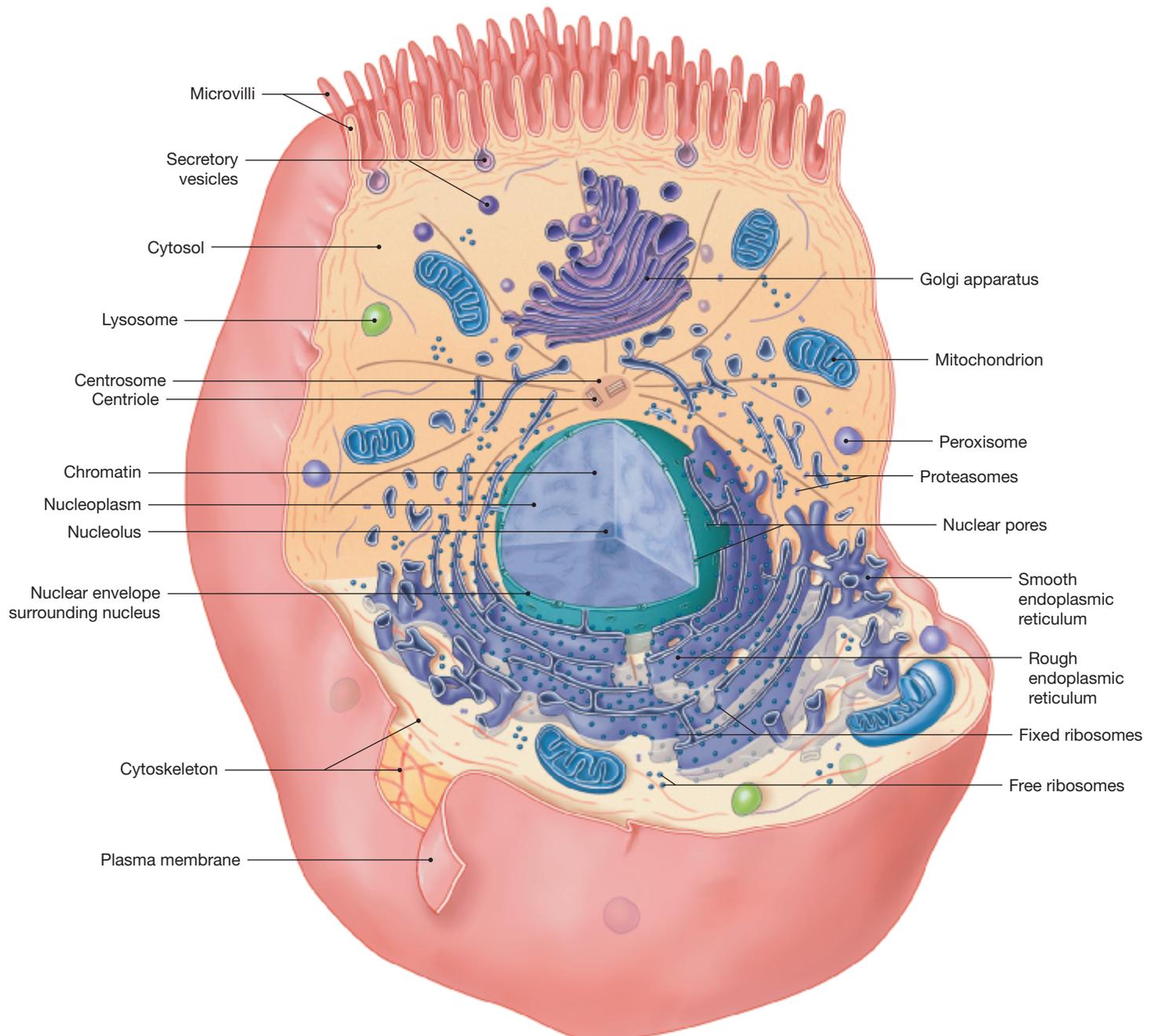
1 Anatomy of the Cell

Although the body is made of a variety of cell types, a generalized composite cell, as illustrated in **Figure 5.1**, is used to describe cell structure. All cells have an outer boundary, the **plasma membrane**, also called the *cell membrane*. This

physical boundary separates the **extracellular fluid** surrounding the cell from the cell interior. It regulates the movement of ions, molecules, and other substances into and out of the cell.

Inside the volume defined by the plasma membrane are a central structure called the **nucleus** of the cell and other internal structures. Collectively, these internal structures are called **organelles** (or-gan-ELZ). All the volume inside the plasma membrane but outside the nucleus is referred to as the **cytoplasm**. This region is made up of solid components (all the cell's organelles except the nucleus) suspended in a liquid called the **cytosol**.

Figure 5.1 The Anatomy of a Composite Cell



Each organelle has a distinct anatomical organization and is specialized for a specific function. Organelles are grouped into two broad classes: nonmembranous and membranous. **Nonmembranous organelles** lack an outer membrane and are directly exposed to the cytosol. Ribosomes, microvilli, centrioles, the cytoskeleton, cilia, and flagella are nonmembranous organelles. **Membranous organelles** are enclosed in a phospholipid membrane that isolates them from the cytosol. The nucleus, endoplasmic reticulum, Golgi apparatus, lysosomes, peroxisomes, and mitochondria are membranous organelles.

Keep in mind while studying cell models that most organelles are not visible with a light microscope. The nucleus typically is visible as a dark-stained oval. It encases and protects the **chromosomes**, which store genetic instructions for protein production by the cell.

Nonmembranous Organelles

- **Microvilli** are small folds in the plasma membrane that increase the surface area of the cell. With more membrane surface, the cell can absorb extracellular materials, such as nutrients, at a greater rate.
- **Centrioles** are paired organelles composed of **microtubules**, which are small hollow tubes made of the protein **tubulin**. The **centrosome** is the area surrounding the pair of centrioles in a cell. When a cell is not dividing, it contains one pair of centrioles. When it comes time for the cell to divide, one of the first steps is replication of the centriole pair, so that the cell contains two pairs. The two centrioles in one pair migrate to one pole of the nucleus, and the two centrioles in the other pair migrate to the opposite pole of the nucleus. As the two pairs migrate, a series of **spindle fibers** radiate from them. The spindle fibers pull the chromosomes of the nucleus apart to give each of the forming daughter cells a full complement of genetic instructions.
- Cells have a **cytoskeleton** for structural support and anchorage of organelles. Like the centrioles, the cytoskeleton is made of microtubules.
- Many cells of the respiratory and reproductive systems have nonmembranous organelles called **cilia**, which are short, hairlike projections that extend from the plasma membrane. One type of human cell, the spermatozoon, has a single, long **flagellum** (fla-JEL-um) for locomotion.
- **Ribosomes** direct protein synthesis. Instructions for making a protein are stored in deoxyribonucleic acid (DNA) molecules in the cell nucleus. The “recipe” for a protein is called a gene and is copied from a segment of DNA onto a molecule of messenger RNA. The messenger RNA then carries the instructions out of the nucleus and to the ribosome. Each ribosome consists of one large subunit and one small subunit. Both subunits clamp around the messenger RNA molecule to coordinate protein synthesis. Ribosomes occur either as **free ribosomes** in the cytoplasm or as **fixed ribosomes** attached to the endoplasmic reticulum (ER).

Membranous Organelles

- The **nucleus** controls the activities of the cell, such as protein synthesis, gene action, cell division, and metabolic rate. The material responsible for the dark appearance of the nucleus in a stained specimen is **chromatin**, uncoiled chromosomes consisting of DNA and protein molecules. A **nuclear envelope** surrounds the nuclear material and contains pores through which instruction molecules from the nucleus pass into the cytosol. A darker-stained region inside the nucleus, the **nucleolus**, produces ribosomal RNA molecules for the creation of ribosomes.
- Surrounding the nucleus is the **endoplasmic reticulum** (en-dō-PLAZ-mik re-TIK-yoo-lum). Two types of ER occur: **rough ER**, which has ribosomes attached to its surface; and **smooth ER**, which lacks ribosomes. Generally, the ER functions in the synthesis of organic molecules, transport of materials within the cell, and storage of molecules. Materials in the ER may pass into the Golgi apparatus for eventual transport out of the cell. Proteins produced by ribosomes on the rough ER surface enter the ER and assume the complex folded shape characteristic of the ER. Smooth ER is involved in the synthesis of many organic molecules, such as cholesterol and phospholipids. In reproductive cells, smooth ER produces sex hormones. In liver cells, it synthesizes and stores glycogen, while in muscle and nerve cells it stores calcium ions. Intracellular calcium ions are stored in the smooth ER in muscle, nerve, and other types of cells.
- The **Golgi (GÖL-jē) apparatus** is a series of flattened saccules adjoining the ER. The ER can pass protein molecules in transport vesicles to the Golgi apparatus for modification and secretion. Cell products such as mucin are synthesized, packaged, and secreted by the Golgi apparatus. In a process called **exocytosis**, small **secretory vesicles** pinch off the saccules, fuse with the plasma membrane, and

Study Tip Information Linking

Practice connecting information together rather than memorizing facts and terms. An effective and fun approach for learning about cells is to compare a cell to a mass-production factory. Each organelle in a cell, like each station in a factory, has a specific task that integrates into the overall function of the cell. As you identify organelles on cell models, consider their function. Once you are familiar with all the organelles, begin to associate them with one another as functional teams. For example, molecules made in the organelles called the endoplasmic reticulum are transported to a neighboring organelle known as the Golgi apparatus, and so you should associate these two organelles with each other. Assimilating information in this way improves your ability to apply knowledge in a working context. ■

then rupture to release their contents into the extracellular fluid. The phospholipid membranes of the empty vesicles contribute to the renewal of the plasma membrane.

- **Lysosomes** (LĪ-sō-sōms; *lyso-*, dissolution + *soma*, body) are vesicles produced by the Golgi apparatus. They are filled with powerful enzymes that digest worn-out cell components and destroy microbes. As certain organelles become worn out, lysosomes dissolve them, and some of the materials are used to rebuild the organelles. White blood cells trap bacteria with plasma membrane extensions and pinch the membrane inward to release a vesicle inside the cell. Lysosomes fuse with the vesicle and release enzymes to digest the bacteria. Injury to a cell may result in the rupture of lysosomes, followed by destruction or autolysis of the cell. Autolysis is implicated in the aging of cells owing to the accumulation of lysosomal enzymes in the cytosol.
- **Peroxisomes** are vesicles filled with enzymes that break down fatty acids and other organic molecules. Metabolism of organic molecules can produce free-radical molecules, such as hydrogen peroxide (H_2O_2), that damage the cell. Peroxisomes protect cell structure by metabolizing hydrogen peroxide to oxygen and water.
- **Mitochondria** (mī-tō-KON-drē-uh) produce useful energy for the cell. Each mitochondrion is wrapped in a double-layered phospholipid membrane. The inner membrane is folded into fingerlike projections called **cristae** (the singular is *crista*). The region of the inner membrane between cristae is the **matrix**. To provide the cell with energy, molecules from nutrients are passed along a series of **metabolic enzymes** in the cristae to produce a molecule called *adenosine triphosphate (ATP)*, the energy currency of the cell. The abundance of mitochondria varies greatly among cell types. Muscle and nerve cells have large numbers of mitochondria that supply energy for contraction and generation of nerve impulses, respectively. Mature red blood cells lack mitochondria and subsequently have a low metabolic rate.

QuickCheck Questions

- 1.1 What are the two major categories of organelles?
- 1.2 Which organelles are involved in the production of protein molecules?

1 IN THE LAB

Materials

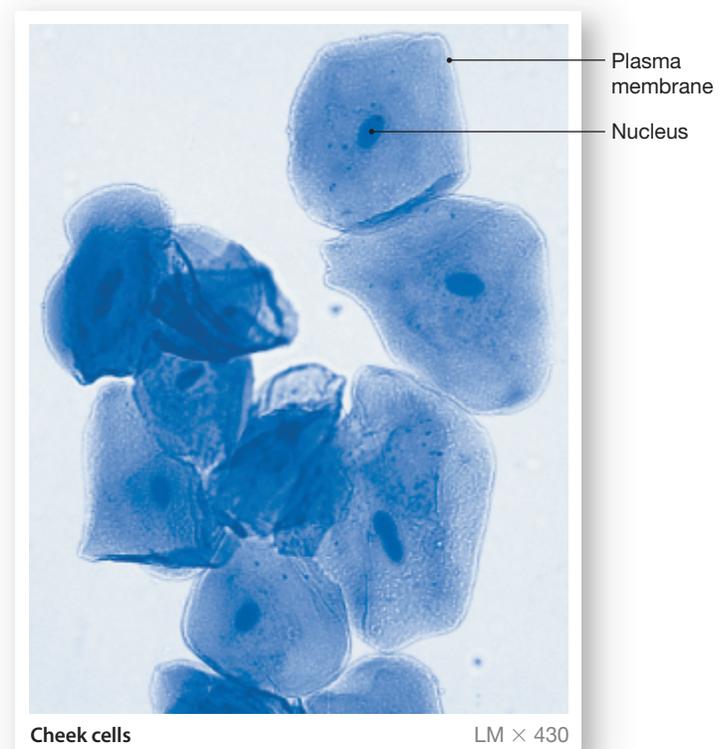
- Cell models and charts
- Toothpicks
- Microscope slide and coverslip
- Physiological saline in dropper bottle

- Iodine stain or methylene blue stain
- Compound microscope

Procedures

1. Review the nonmembranous and membranous organelles in Figure 5.1.
2. Identify each organelle on a cell model.
3. Prepare a wet-mount slide from cells of the inner lining of your cheek.
 - a. Place a drop of saline on a microscope slide.
 - b. Gently scrape the inside of your cheek with the blunt end of a toothpick.
 - c. Stir the scraping into the drop of saline on the slide.
 - d. Add 1 drop of stain, carefully stir again with the same toothpick, and add a coverslip.
 - e. Dispose of your used toothpick in a biohazard bag as indicated by your instructor.
4. Examine your cheek cell slide with the scanning lens and note the many flattened epithelial cells. These cells are thin and often become folded by the coverslip.
5. Observe individual cells at low and high magnifications (Figure 5.2). Identify the nucleus, cytoplasm, and plasma membrane of a cell.

Figure 5.2 Cheek Epithelial Cells



Cheek cells

LM × 430

2 Observing Cells

The cells within the body are very diverse, so it is useful to classify each type according to the kind of tissue it inhabits. The four major tissue groups are epithelia, connective tissue, muscle tissue, and nerve tissue (**Figure 5.3**). Each tissue group has specific types of cells with certain characteristics. Recognizing these basic tissue groups during observations of slides will assist in the identification of histological structures.

QuickCheck Question

2.1 What are the four major tissue types in the body?

2 IN THE LAB

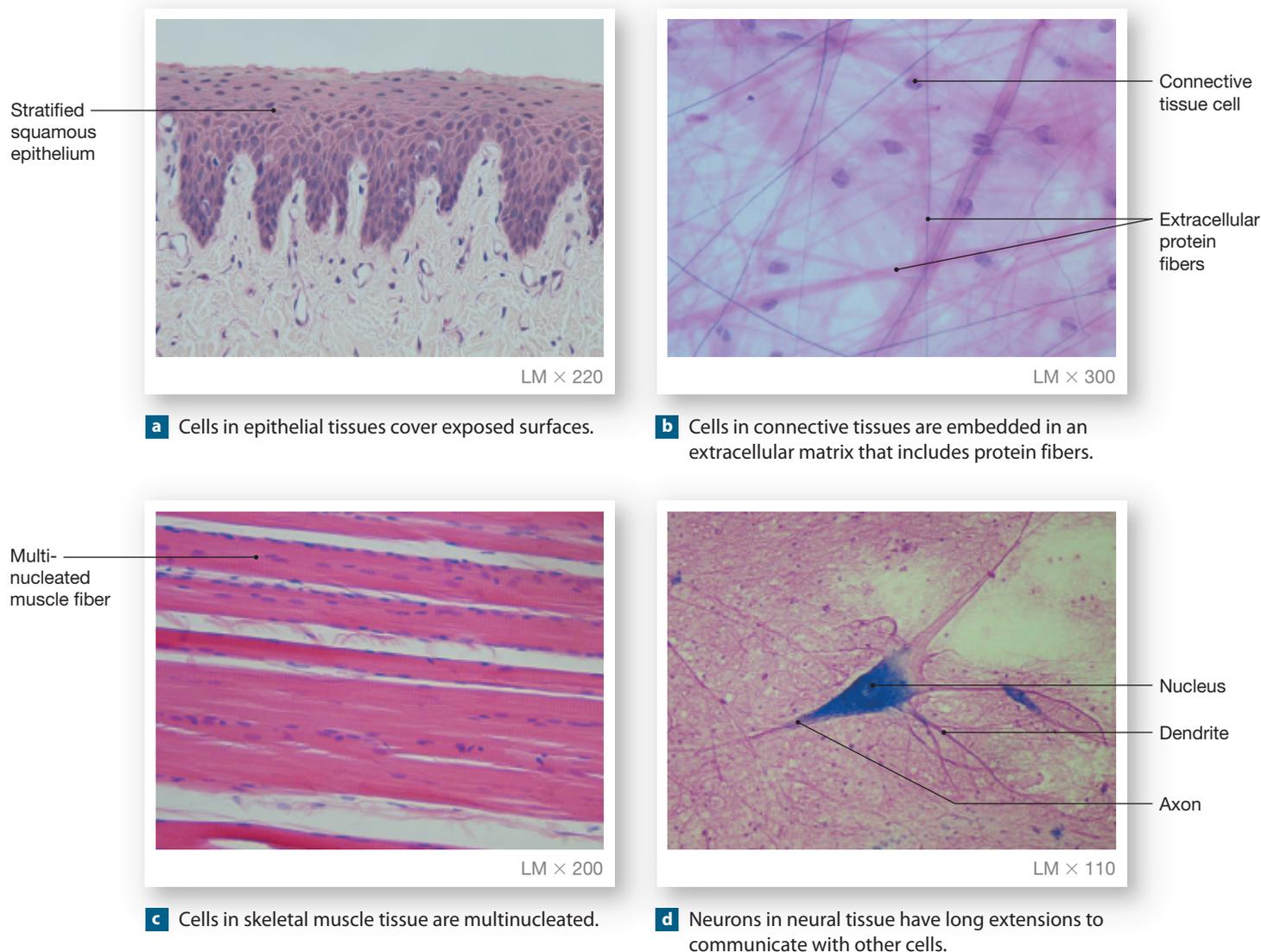
Materials

- Microscope slides: stratified squamous epithelium, areolar tissue, skeletal muscle tissue, neural tissue
- Compound microscope

Procedures

1. Observe the stratified squamous epithelium slide with the scanning lens and locate the dark stained cells on the top edge of the specimen. Notice how these cells are organized into a thick layer. Also note how the cell shape

Figure 5.3 Organization of Cells Cells are organized into four major tissue groups.



changes from the bottom to the top of the tissue. View the cells at low and high magnification and observe the nucleus and cytoplasm. Examine the plasma membrane and note its proximity to other cells.

- View the slide of areolar tissue, a connective tissue with widely scattered cells that are embedded in protein fibers. Focus on the specimen with the scanning lens and then observe the cells at low and high magnification. Note the dark-stained cells and the hairlike fibers in the tissue. Observe individual cells at low and high magnifications (see Figure 5.3). Identify the nucleus, cytoplasm, and plasma membrane of a cell.
- Examine the cells on the skeletal muscle tissue slide at scanning power. These muscle cells are large and multinucleated. Increase the magnification to low and then high power. At high magnification, use the fine focus knob to observe light and dark bands in the cells. The cells appear striped (striated) because of the arrangement of protein molecules that interact during contraction.
- Locate the nerve cells on the neural tissue slide using the scanning lens. Increase the magnification and note the branches of a neuron. The largest is most likely the axon, the branch that communicates to other cells. The smaller branches are dendrites and they connect with other cells to receive information.

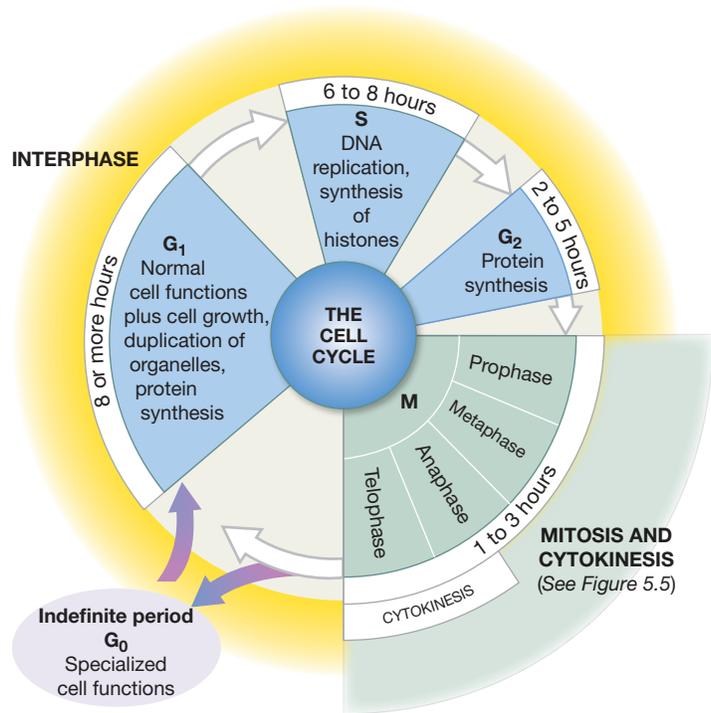
3 Cell Division

Cells must reproduce if an organism is to grow and repair damaged tissue. During cell reproduction, a cell divides its genes equally and then splits into two identical cells. The division involves two major events: mitosis and cytokinesis. During **mitosis** (mĭ-TŌ-sis), the chromatin in the nucleus condenses into chromosomes and is equally divided between the two forming cells. Toward the end of mitosis, **cytokinesis** (sĭ-tō-ki-NĒ-sis; *cyto-*, cell + *kinesis*, motion) separates the cytoplasm to produce the two daughter cells. The daughter cells have the same number of chromosomes as the parent cell. Human cells have 23 pairs of chromosomes that carry the genetic code of approximately 20,000 to 25,000 genes.

Interphase

Examine the cell life cycle in **Figure 5.4**. Most of the time, a cell is not dividing and is in **interphase**. This is not a resting period for the cell, however, because during this phase the cell carries out various functions and prepares for the next cell division. Distinct phases occur during interphase, each related to cell activity. At this time, the nucleus is visible, as is the darker

Figure 5.4 The Cell Life Cycle



nucleolus. During the **G₀ phase** of interphase, the cell performs its specialized functions and is not preparing to divide. The **G₁ phase** is a time for protein synthesis, growth, and replication of organelles, including the centriole pair. Replication of DNA occurs during the **S phase**. After DNA replication, each chromosome is double stranded and consists of two **chromatids**; one chromatid is the original strand and the other is an identical copy. The chromatids are held together by a **centromere**. The **G₂ phase** is another time for protein synthesis; at this time, replication of the centriole pair is completed.

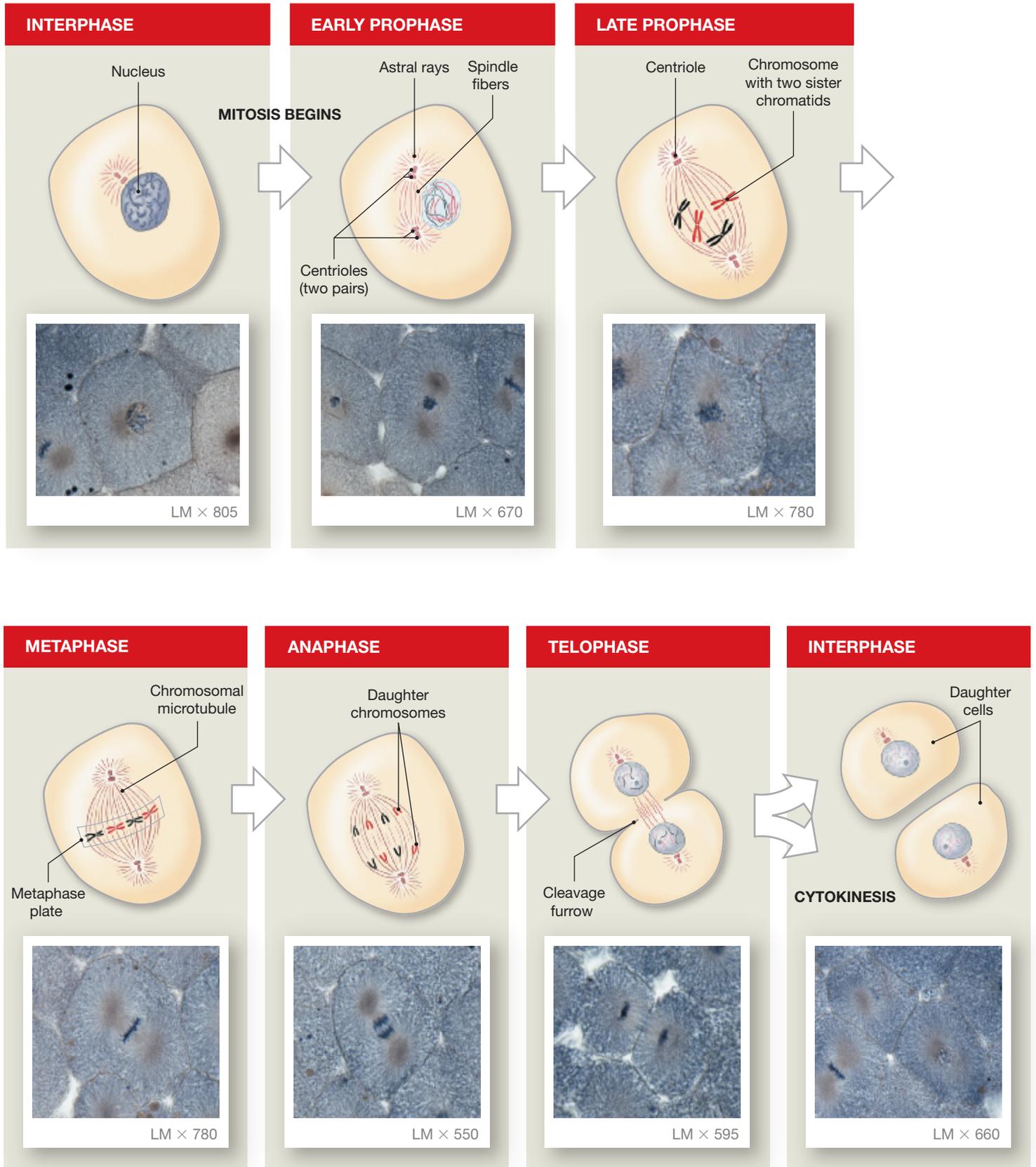
Make a Prediction

Which cells would you expect to spend most of their time in the **G₀** phase: cells lining the inside of your mouth or nerve cells in the brain?

Mitosis

The **M phase** of the cell cycle is the time of mitosis, during which the nuclear material divides (**Figure 5.5**). After chromosomes are duplicated in the S phase of interphase, the double-stranded chromosomes migrate to the middle of the cell, and spindle fibers attach to each chromatid. Chromosomes are divided when the spindle fibers drag sister chromatids to opposite ends of the cell. The division is complete when the

Figure 5.5 Interphase, Mitosis, and Cytokinesis Diagrammatic and microscopic views of representative cells undergoing cell division.



CLINICAL APPLICATION

Cell Division and Cancer

A tumor is a mass of cells produced by uncontrolled cell division. The mass replaces normal cells, and cellular and tissue functions are compromised. If **metastasis** (me-TAS-ta-sis), which means spreading of the abnormal cells, occurs, secondary tumors may develop. Cells that metastasize are often cancerous. ■

cell undergoes cytokinesis and pinches inward to distribute the cytosol and chromosomes into two new daughter cells.

The four stages of mitosis are prophase, metaphase, anaphase, and telophase. Telophase and the latter part of anaphase are together referred to as cytokinesis.

- **Prophase:** Mitosis starts with prophase (PRO-fāz; *pro-*, before), when chromosomes become visible in the nucleus (see Figure 5.5). In early prophase, the chromosomes are long and disorganized, but as prophase continues the nuclear envelope breaks down, and the chromosomes shorten and move toward the middle of the cell. In the cytosol, the two centriole pairs begin moving to opposite sides of the cell. Between the centrioles, microtubules fan out as spindle fibers and extend across the cell.
- **Metaphase:** Metaphase (MET-a-fāz; *meta-*, change) occurs when the chromosomes line up in the middle of the cell at the **metaphase plate**. Spindle fibers extend across the cell from one pole to the other and attach to the centromeres of the chromosomes. The cell is now prepared to partition the genetic material and give rise to two new cells.
- **Anaphase:** Separation of the chromosomes is the event that defines anaphase (AN-a-fāz; *ana-*, apart). Spindle fibers pull apart the chromatids of a chromosome and drag them toward opposite poles of the cell. Once apart, individual chromatids are considered chromosomes. Cytokinesis marks the end of anaphase as a **cleavage furrow** develops along the metaphase plate and the plasma membrane pinches. Cytokinesis continues into the next stage of mitosis, telophase.
- **Telophase:** In telophase (TEL-ō-fāz; *telo-*, end), cytokinesis partitions the cytoplasm of the cell and mitosis nears completion as each batch of chromosomes unwinds inside a newly formed nuclear envelope. Each daughter cell has a set of organelles and a nucleus containing a complete set of

genes. Telophase ends as the cleavage furrow deepens along the metaphase plate and separates the cell into two identical daughter cells. These daughter cells are in interphase and, depending on their cell type, may divide again.

QuickCheck Questions

- 3.1 What must the cell do with the genetic material in the nucleus before mitosis?
- 3.2 Name the four stages of mitosis and list what happens during each stage.

3 IN THE LAB

Materials

- Compound microscope
- Whitefish blastula slide

Procedures

1. Obtain a slide of a whitefish blastula.
A **blastula** is formed during the early stage of development when an embryo is a rapidly dividing mass of cells that is growing in size and, eventually, in complexity. For microscopic observation of the cells, the whitefish embryo is sectioned and stained. A typical slide preparation usually has several sections of a blastula, each showing cells in various stages of mitosis.
2. Preview the slide with the scanning lens and observe the numerous cells of the blastula.
3. Slowly scan a group of cells with the low-magnification lens and locate a nucleus, centrioles, and spindle fibers. The chromosomes appear as dark, thick structures.
4. Using Figure 5.5 as a reference, locate cells in the following phases:
 - Interphase with a distinct nucleus
 - Prophase with disorganized chromosomes
 - Metaphase with equatorial chromosomes attached to spindle fibers
 - Anaphase with chromosomes separating toward opposite poles
 - Telophase with a nuclear envelope forming around each set of genetic material
 - Cytokinesis in late anaphase and telophase.

Draw It!



VIDEO TUTOR

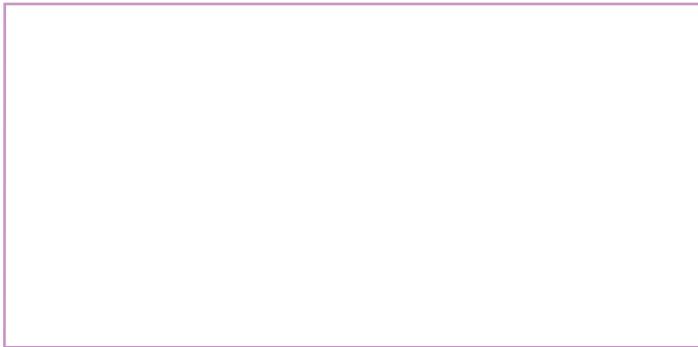
5. **Draw It!** Draw and label cells in each stage of mitosis in the space provided.



Interphase



Prophase



Metaphase



Anaphase



Telophase



Daughter Cells



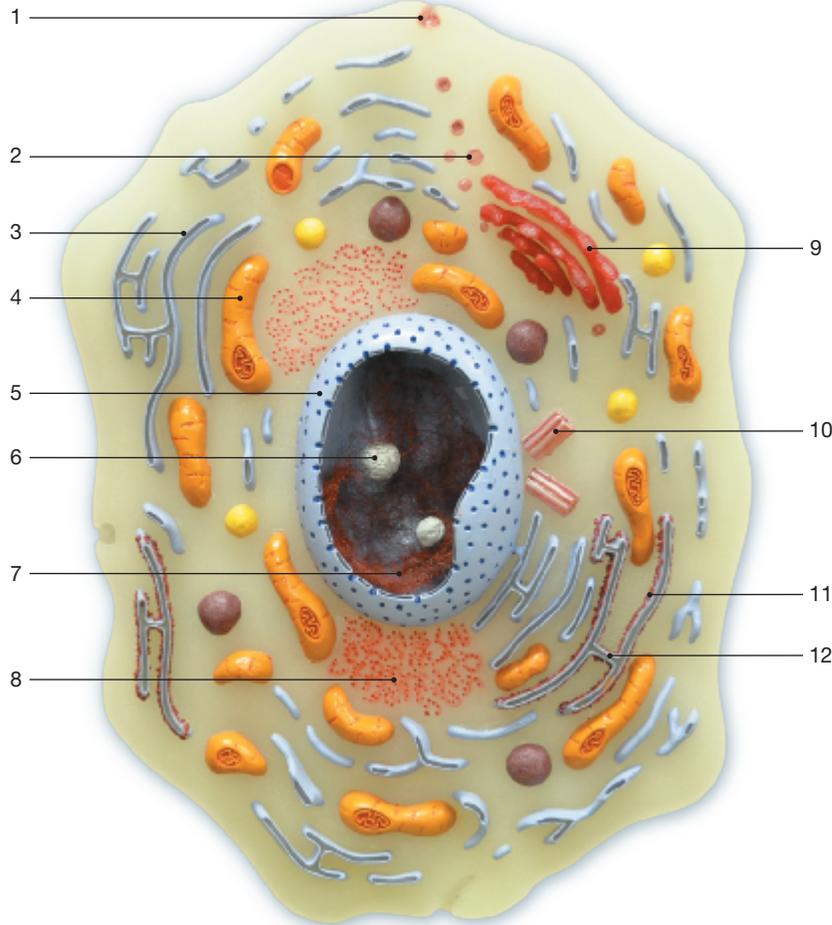
Name _____

Date _____ Section _____

Anatomy of the Cell and Cell Division

A. Labeling

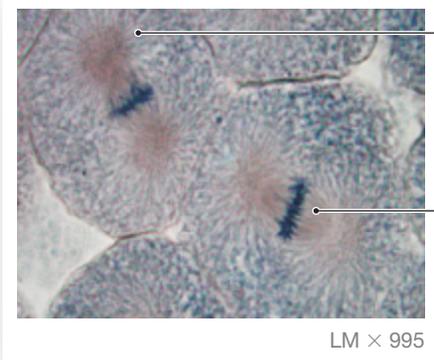
1. Label the organelles.



- 1. _____
- 2. _____
- 3. _____
- 4. _____
- 5. _____
- 6. _____
- 7. _____
- 8. _____
- 9. _____
- 10. _____
- 11. _____
- 12. _____

Exercise 5

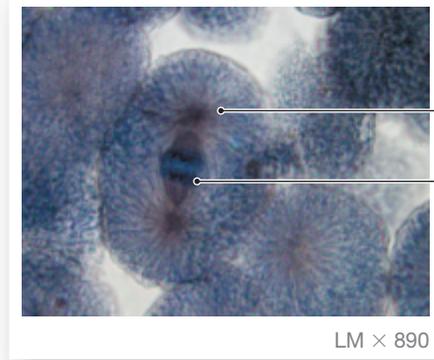
2. Label the cell division photos.



1. Identify the stage of mitosis.
2. Identify small lines.

LM × 995

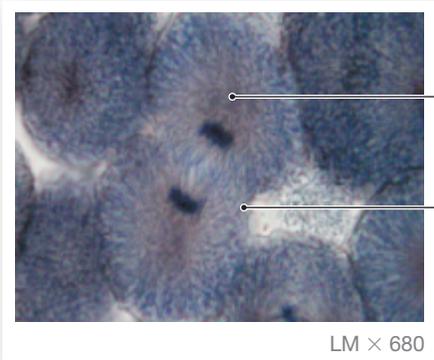
a



3. Identify the stage of mitosis.
4. Identify the dark-stained structures.

LM × 890

b



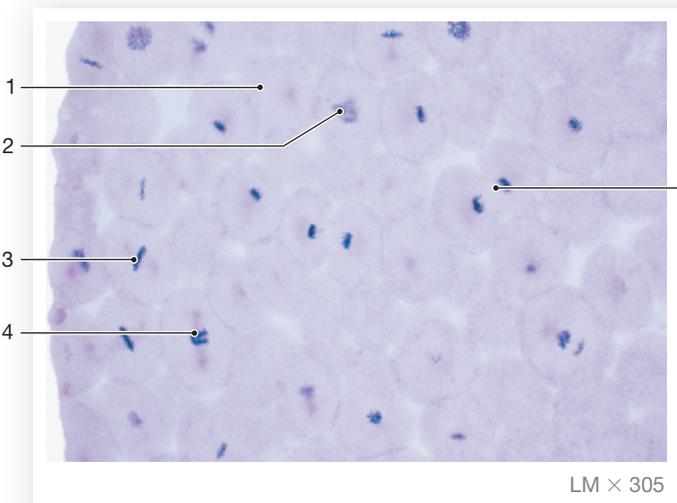
5. Identify the stage of mitosis.
6. Identify the process that is occurring here.

LM × 680

c

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____

3. Label the stages of mitosis.



LM × 305

1. _____
2. _____
3. _____
4. _____
5. _____

B. Matching

Match each cellular structure listed on the left with the correct description on the right.

- | | | |
|-------|--------------------|--|
| _____ | 1. plasma membrane | A. copy of a chromosome |
| _____ | 2. centrioles | B. short, hairlike cellular extensions |
| _____ | 3. ribosome | C. intracellular fluid |
| _____ | 4. smooth ER | D. involved in mitosis |
| _____ | 5. chromatid | E. folds of the inner mitochondrial membrane |
| _____ | 6. lysosomes | F. composed of a phospholipid bilayer |
| _____ | 7. cytoplasm | G. stores calcium ions in muscle cells |
| _____ | 8. cristae | H. site for protein synthesis |
| _____ | 9. cytosol | I. vesicles with powerful digestive enzymes |
| _____ | 10. cilia | J. intracellular fluid and the organelles |

C. Fill in the Blanks

Complete the following statements.

1. Replication of genetic material results in chromosomes consisting of two _____.
2. A cell in metaphase has chromosomes located in the _____ of the cell.
3. Division of the cytoplasm to produce two daughter cells is called _____.
4. Double-stranded chromosomes separate during the _____ stage of mitosis.
5. During interphase, DNA replication occurs in the _____ phase.
6. Microtubules called _____ attach to chromatids and pull them apart.
7. Chromosomes become visible during the _____ stage of mitosis.
8. The last stage of mitosis is _____.
9. Division of the nuclear material is called _____.
10. Matching chromatids are held together by a _____.

D. Short-Answer Questions

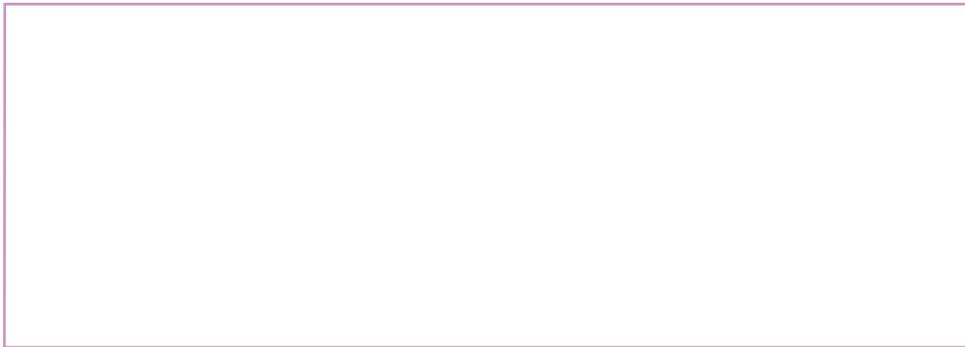
1. What is the function of cell division?
2. Describe a phospholipid molecule and its interaction with water.
3. What is the function of the spindle fibers during mitosis?
4. What structures in the plasma membrane regulate ion passage?

E. Drawing

1. **Draw It!** Draw and label a cell with the following organelles: nucleus, rough ER, Golgi apparatus, mitochondria, and centrioles.



2. **Draw It!** Draw and label a cell with four chromosomes in interphase and each stage of mitosis.

**F. Application and Analysis**

1. Describe how the nucleus, ribosomes, rough ER, Golgi apparatus, and plasma membrane interact to produce and release a protein molecule from the cell.
2. What happens in a cell during the S portion of interphase?
3. Describe how chromosomes are evenly divided during mitosis.
4. Identify where in a cell the production of protein, carbohydrate, and lipid molecules occurs.

G. Clinical Challenge

1. Lysosomes are sometimes referred to as "suicide bags." Describe what would happen to a cell if its lysosomes ruptured.