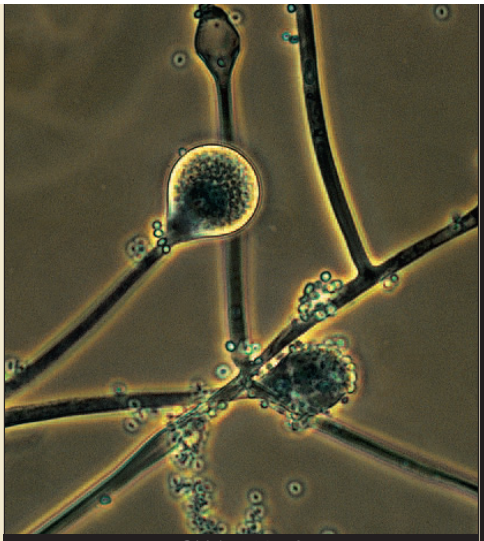
8 Mitosis
The Cell-Copying Process



CHAPTER 8

Chapter Outline

Key Concepts	Applications
Know the purpose of cell division.	• Identify the importance of cell division.
Diagram the events of cell division.	• Understand genes are passed on to the next generation of cells. • Explain how animals and plants differ in how they carry out this process.
Know the events that occur during interphase.	• Explain how the DNA molecules are sorted and arranged so that they can be passed on to a new cell during reproduction.

8.1 The Importance of Cell Division

The process of cell division replaces dead cells with new ones, repairs damaged tissues, and allows living organisms to grow. For example, you began as a single cell that resulted from the union of a sperm and an egg. One of the *first* activities of this single cell was to divide. As this process continued, the number of cells in your body increased, so that as an adult your body consists of several trillion cells. The *second* function of cell division is to maintain the body. Certain cells in your body, such as red blood cells and cells of the gut lining and skin, wear out. As they do, they must be replaced with new cells. Altogether, you lose about 50 million cells per second; this means that millions of cells are dividing in your body at any given time. A *third* purpose of cell division is repair. When a bone is broken, the break heals because cells divide, increasing the number of cells available to knit the broken pieces together. If some skin cells are destroyed by a cut or abrasion, cell division produces new cells to repair the damage.

During cell division, two events occur. The replicated genetic information of a cell is equally distributed to two daughter nuclei in a process called **mitosis.** As the nucleus goes through its division, the cytoplasm also divides into two new cells. This division of the cell's cytoplasm is called **cytokinesis**—cell splitting. Each new cell gets one of the two daughter nuclei so that both have a complete set of genetic information.

8.2 The Cell Cycle

All cells go through the same basic life cycle, but they vary in the amount of time they spend in the different stages. A generalized picture of a cell's life cycle may help you understand it better (figure 8.1). Once begun, cell division is a continuous process without a beginning or an end. It is a cycle in which cells continue to grow and divide. There are five stages to the life cycle of a eukaryotic cell: (1) G_1, gap (growth)—phase one; (2) S, synthesis; (3) G_2, gap (growth)—phase two; (4) cell division (mitosis and cytokinesis); and (5) G_0, gap (growth)—mitotic dormancy or differentiated.

During the G_0 phase, cells are not considered to be in the cycle of division but become differentiated or specialized in their function. It is at this time that they "mature" to play the role specified by their genetic makeup. Whereas some cells entering the G_0 phase remain there more-or-less permanently (e.g., nerve cells), others have the ability to move back into the cell cycle of mitosis—G_1, S, and G_2—with ease (e.g., skin cells).

The first three phases of the cell cycle—G_1, S, and G_2—occur during a period of time known as *interphase.* **Interphase** is the stage between cell divisions. During the G_1 stage, the cell grows in volume as it produces tRNA, mRNA, ribosomes, enzymes, and other cell components. During the S stage, DNA replication occurs in preparation for the distribution of genes to daughter cells. During the G_2 stage that follows, final preparations are made for mitosis with the synthesis of spindle-fiber proteins.

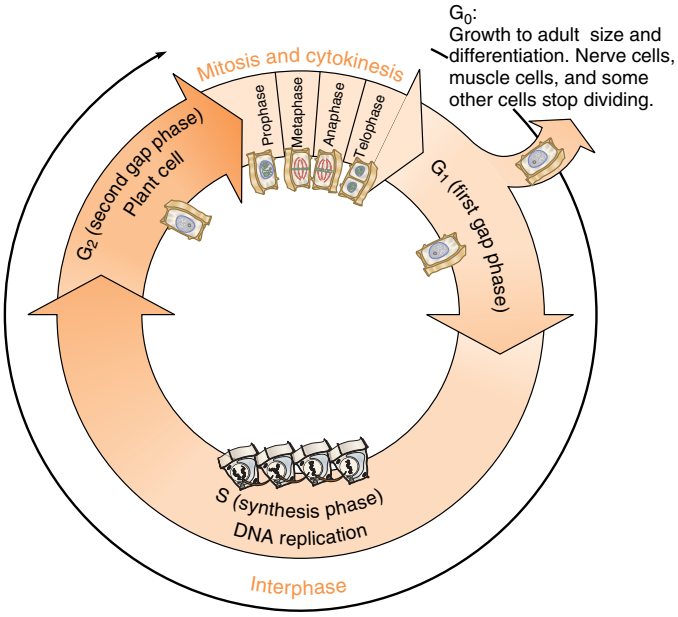


Figure 8.1

The Cell Cycle
During the cell cycle, tRNA, mRNA, ribosomes, and enzymes are produced in the G_1 stage. DNA replication occurs in the S stage. Proteins required for the spindles are synthesized in the G_2 stage. The nucleus is replicated in mitosis and two cells are formed by cytokinesis. Once some organs, such as the brain, have completely developed, certain types of cells, such as nerve cells, enter the G_0 stage. The time periods indicated are relative and vary depending on the type of cell and the age of the organism.

During interphase, the cell is not dividing but is engaged in metabolic activities such as muscle-cell contractions, photosynthesis, or glandular-cell secretion. During interphase, the nuclear membrane is intact and the individual chromosomes are not visible (figure 8.2). The individual chromatin strands are too thin and tangled to be seen. Remember that **chromosomes** include various kinds of histone proteins as well as DNA, the cell's genetic information. The double helix of DNA and the nucleosomes are arranged as a chromatid, and there are two attached chromatids for each replicated chromosome. It is these chromatids (chromosomes) that will be distributed during mitosis.

8.3 The Stages of Mitosis

All stages in the life cycle of a cell are continuous; there is no precise point when the G_1 stage ends and the S stage begins, or when the interphase period ends and mitosis begins. Likewise, in the individual stages of mitosis there is a gradual tran-

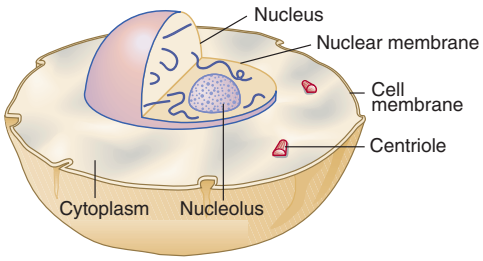


Figure 8.2

Interphase
Growth and the production of necessary organic compounds occur during this phase. If the cell is going to divide, DNA replication also occurs during interphase. The individual chromosomes are not visible, but a distinct nuclear membrane and nucleolus are present. (Some cells have more than one nucleolus.)

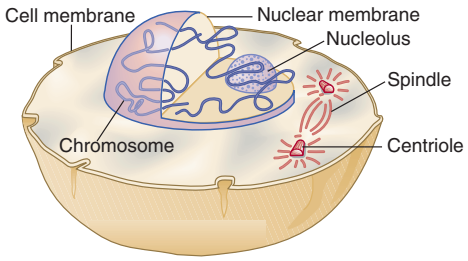


Figure 8.3

Early Prophase
Chromosomes begin to appear as thin tangled threads and the nucleolus and nuclear membrane are present. The two sets of microtubules known as the centrioles begin to separate and move to opposite poles of the cell. A series of fibers known as the spindle will shortly begin to form.

sition from one stage to the next. However, for purposes of study and communication, scientists have divided the process into four stages based on recognizable events. These four phases are prophase, metaphase, anaphase, and telophase.

Prophase

As the G_2 stage of interphase ends, mitosis begins. **Prophase** is the first stage of mitosis. One of the first noticeable changes is that the individual chromosomes become visible (figure 8.3). The thin, tangled chromatin present during interphase gradually coils and thickens, becoming visible as separate chromosomes. The DNA portion of the chromosome has genes that are arranged in a specific order. Each chromosome carries its own set of genes that is different from the sets of genes on other chromosomes.

As prophase proceeds, and as the chromosomes become more visible, we recognize that each chromosome is made of two parallel, threadlike parts lying side by side. Each parallel thread is called a **chromatid** (figure 8.4). These chromatids were formed during the S stage of interphase, when DNA synthesis occurred. The two identical chromatids are attached at a genetic region called the **centromere.** This portion of the DNA is not replicated during prophase, but remains base-paired as in the original double-stranded DNA. The centromere is vital to the cell division process. Without the centromere, cells will not complete mitosis and will die.

In the diagrams in this text, a few genes are shown as they might occur on human chromosomes. The diagrams show fewer chromosomes and fewer genes on each chromosome than are actually present. Normal human cells have 10 billion nucleotides arranged into 46 chromosomes, each chromosome with thousands of genes. In this book, smaller numbers of genes and chromosomes are used to make it easier to follow the events that happen in mitosis.

Several other events occur as the cell proceeds to the late prophase stage (figure 8.5). One of these events is

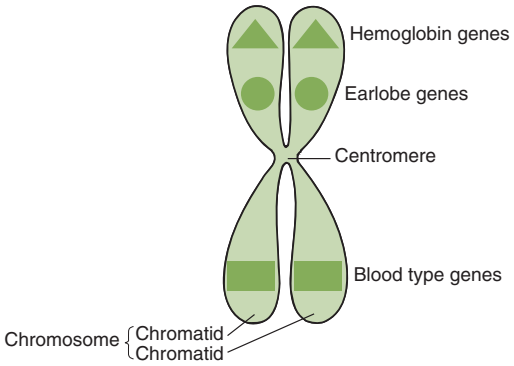


Figure 8.4

Chromosomes
During interphase, when chromosome replication occurs, the original double-stranded DNA unzips to form two identical double strands that are attached at the centromere. Each of these double strands is a chromatid. The two identical chromatids of the chromosome are sometimes termed a dyad, to reflect that there are two double-stranded DNA molecules, one in each chromatid. The DNA contains the genetic data. (The examples presented here are for illustrative purposes only. Do not assume that the traits listed are actually located in the positions shown on these hypothetical chromosomes.)

the duplication of the **centrioles.** Remember that human and many other eukaryotic cells contain centrioles, microtubule-containing organelles located just outside the nucleus. As they duplicate, they move to the poles of the cell. As the centrioles move to the poles, the microtubules are assembled into the *spindle*. The **spindle** is an array of microtubules extending from pole to pole that is used in the movement of chromosomes.

In most eukaryotic cells, as prophase is occurring, the nuclear membrane is gradually disassembled. It is present at the beginning of prophase but disappears by the time this stage is completed. In addition to the disassembled nuclear

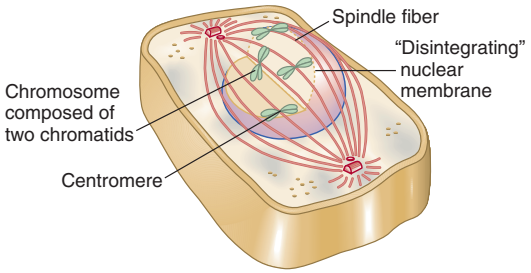


Figure 8.5

Late Prophase
In late prophase, the chromosomes appear as two chromatids (a dyad) connected at a centromere. The nucleolus and the nuclear membrane have disassembled. The centrioles have moved farther apart, and the spindle is produced.

membrane, the nucleoli within the nucleus disappear. Because of the disassembly of the nuclear membrane, the chromosomes are free to move anywhere within the cytoplasm of the cell. As prophase progresses, the chromosomes become attached to the spindle fibers at their centromeres. Initially they are distributed randomly throughout the cytoplasm. As this movement occurs, the cell enters the next stage of mitosis.

Metaphase

During **metaphase,** the second stage in mitosis, the chromosomes align at the equatorial plane. There is no nucleus present during metaphase, and the spindle, which started to form during prophase, is completed. The centrioles are at the poles, and the microtubules extend between them to form the spindle. Then the chromosomes are their most tightly coiled and continue to move until all their centromeres align themselves along the equatorial plane at the equator of the cell (figure 8.6). At this stage in mitosis, each chromosome still consists of two chromatids attached at a centromere. In a human cell, there are 46 chromosomes, or 92 chromatids, aligned at the cell's equatorial plane during metaphase.

If we view a cell in the metaphase stage from the side (figure 8.6), it is an equatorial view. In this view, the chromosomes appear as if they were in a line. If we view the cell from the pole, it is a polar view. The chromosomes are seen on the equatorial plane (figure 8.7). Chromosomes viewed from this direction look like hot dogs scattered on a plate. In late metaphase, each chromosome splits as the centromeres replicate and the cell enters the next phase, anaphase.

Anaphase

Anaphase is the third stage of mitosis. The nuclear membrane is still absent and the spindle extends from pole to pole. The two chromatids within the chromosome separate as they move along the spindle fibers toward opposite ends of the poles (figure 8.8). Although this movement has been observed repeatedly, no one knows the exact mechanism of its action. As this separation of chromatids occurs, the chromatids are called **daughter chromosomes.** Daughter chromosomes contain identical genetic information.

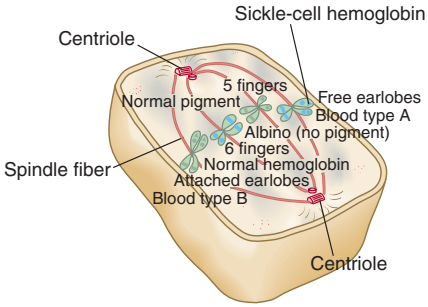


Figure 8.6

Metaphase
During metaphase the chromosomes travel along the spindle and align at the equatorial plane. Notice that each chromosome still consists of two chromatids.

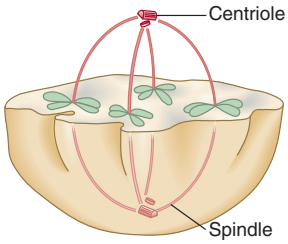


Figure 8.7

The Equatorial Plane of Metaphase
This view shows how the chromosomes spread out on the equatorial plane.

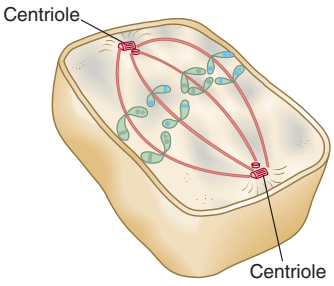


Figure 8.8

Anaphase
The pairs of chromatids separate after the centromeres replicate. The chromatids, now called daughter chromosomes, are separating and moving toward the poles and the cell will begin cytokinesis.

Examine figure 8.8 closely and notice that the four chromosomes moving to one pole have exactly the same genetic information as the four moving to the opposite pole. It is the alignment of the chromosomes in metaphase, and their separation in anaphase, that causes this type of distribution. It is during anaphase that a second important event occurs, cytokinesis. Cytokinesis (cytoplasm splitting) divides the cytoplasm of the original cell so that two smaller, separate daughter cells result. **Daughter cells** are two cells formed by cell division that have identical genetic information. At the end of anaphase, there are two identical groups of chromosomes, one group at each pole. The next stage completes the mitosis process.

Telophase

Telophase is the last stage in mitosis. It is during telophase that daughter nuclei are re-formed. Each set of chromosomes becomes enclosed by a nuclear membrane and the nucleoli reappear. Now the cell has two identical **daughter nuclei** (figure 8.9). In addition, the microtubules are disassembled, so the spindle disappears. With the formation of the daughter nuclei, mitosis, the first process in cell division, is completed, and the second process, cytokinesis, can occur, from which two smaller daughter cells are formed. Each of the newly formed daughter cells then enters the G_1 stage of interphase. These cells can grow, replicate their DNA, and enter another round of mitosis and cytokinesis to continue the cell cycle (table 8.1).

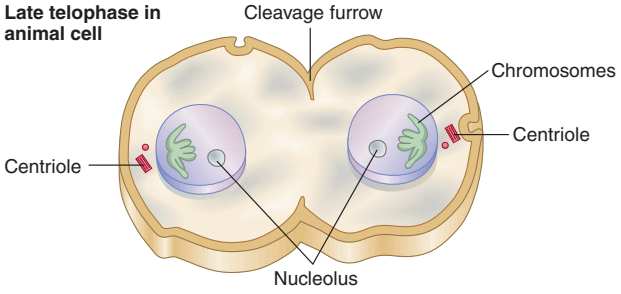
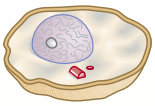
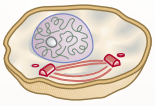
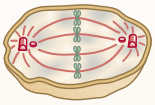
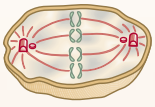
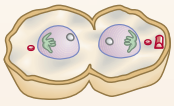


Figure 8.9

Telophase
During telophase the spindle disassembles and the nucleolus and nuclear membrane form. Daughter cells are formed as a result of the division of the cytoplasm.

Table 8.1

REVIEW OF THE STAGES OF MITOSIS

Interphase		As the cell moves from G_0 into meiosis, the chromosomes replicate during the S phase of interphase.
Prophase		The replicated chromatin begins to coil into recognizable chromosomes; the nuclear membrane fragments; centrioles move to form the cell's poles; spindle fibers form.
Metaphase		Chromosomes move to the equator of the cell and attach to the spindle fibers at the centromeres.
Anaphase		Centromeres complete DNA replication allowing the chromatids to separate toward the poles.
Telophase		Two daughter cells are formed from the division cells; the nuclear membranes and nucleoli re-form; spindle fibers fragment; the chromosomes unwind and change from chromosomes to chromatin.

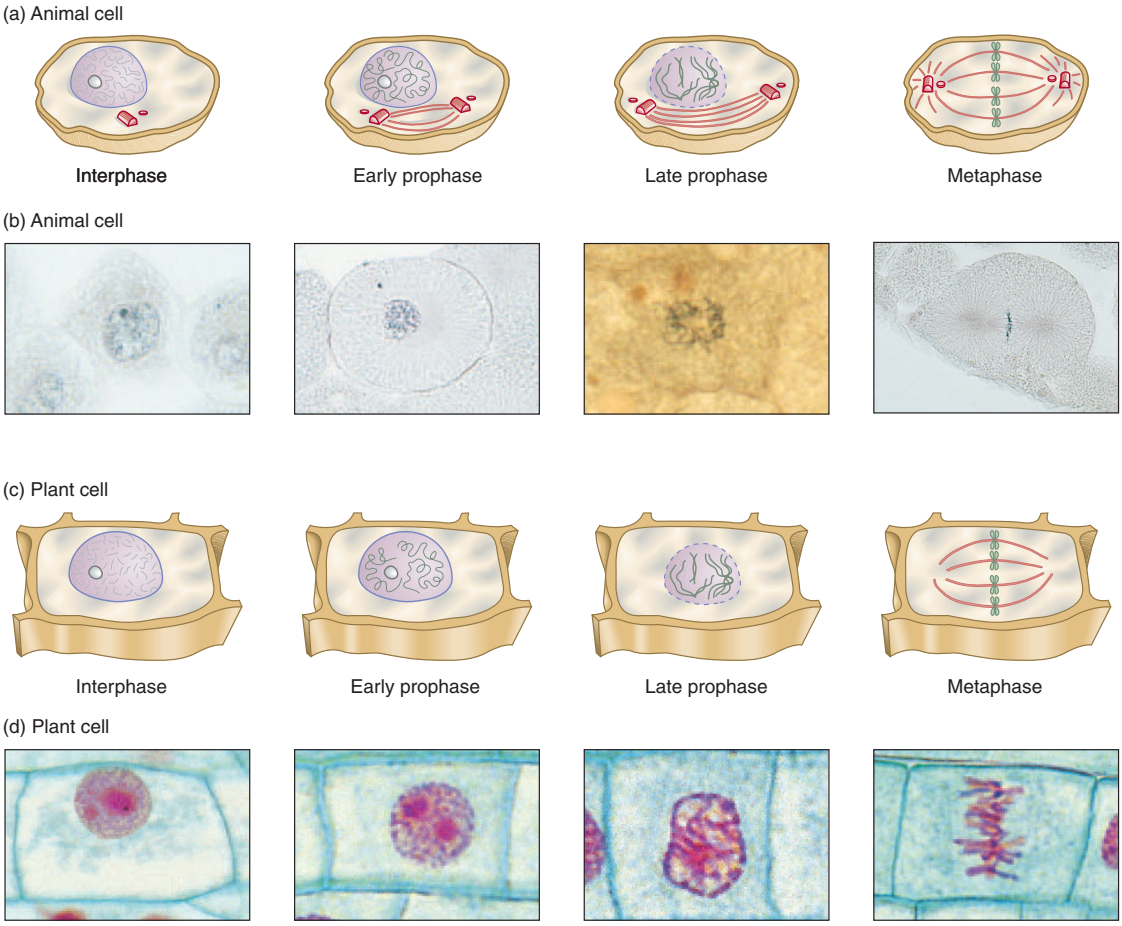


Figure 8.10

A Comparison of Plant and Animal Mitosis
(*a*) Drawing of mitosis in an animal cell. (*b*) Photographs of mitosis in a whitefish blastula. (*c*) Drawing of mitosis in a plant cell. (*d*) Photographs of mitosis in an onion root tip.

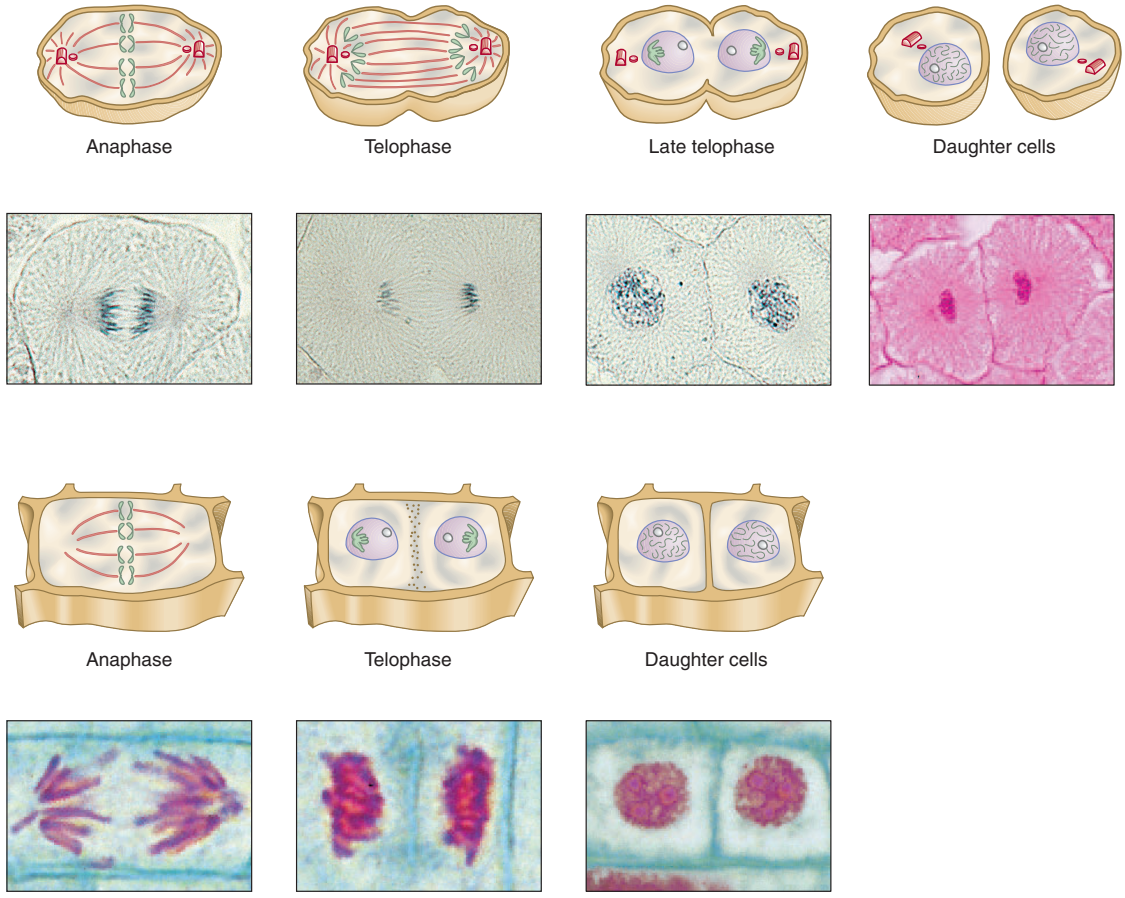
8.4 Plant and Animal Cell Differences

Cell division is similar in plant and animal cells. However, there are some minor differences. One difference concerns the centrioles (figure 8.10). Centrioles are essential in animal cells, but they are not usually found in plant cells. However, by some process, plant cells do produce a spindle. There is also a difference in the process of cytokinesis (figure 8.11). In animal cells, cytokinesis results from a **cleavage furrow.** This is an indentation of the cell membrane of an animal cell that pinches the cytoplasm into two parts as if a string were tightened about its middle. In an animal cell, cytokinesis begins at the cell membrane and proceeds to the center. In plant cells, a **cell plate** begins at the center and proceeds to the cell membrane, resulting in a cell wall that separates the two daughter cells.

8.5 Differentiation

Because of the two processes in cell division, mitosis and cytokinesis, the daughter cells have the same genetic composition. You received a set of genes from your father in his sperm, and a set of genes from your mother in her egg. By cell division, this cell formed two daughter cells. This process was repeated, and there were four cells, all of which had the same genes. All the trillions of cells in your body were formed by the process of cell division. This means that, except for mutations, all the cells in your body have the same genes.

All the cells in your body are not the same, however. There are nerve cells, muscle cells, bone cells, skin cells, and many other types. How is it possible that cells with the same genes can be different? Think of the genes in a cell as indi-



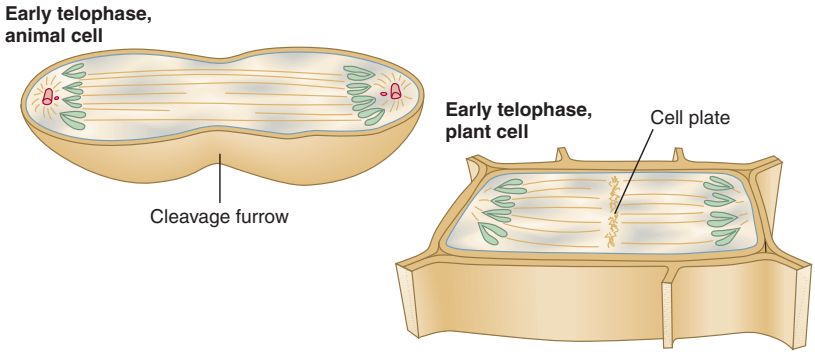


Figure 8.11

Cytokinesis
In animal cells there is a pinching in of the cytoplasm that eventually forms two daughter cells. Daughter cells in plants are formed when a cell plate separates the cell into two cells.

vidual recipes in a cookbook. You could give a copy of the same cookbook to 100 people and, though they all have the same book, each person could prepare a different dish. If you use the recipe to make a chocolate cake, you ignore the directions for making salads, fried chicken, and soups, although these recipes are in the book.

It is the same with cells. Although some genes are used by all cells, some cells activate only certain genes. Muscle cells produce proteins capable of contraction. Most other cells do not use these genes. Pancreas cells use genes that result in the formation of digestive enzymes, but they never produce contractile proteins. **Differentiation** is the

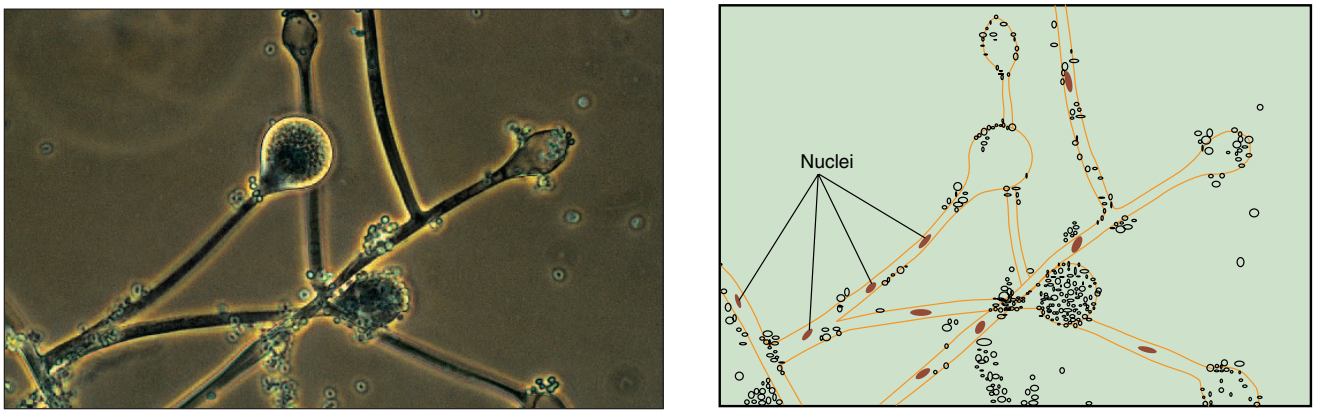


Figure 8.12

Multinucleated Cells
Many types of fungi, including bread molds, water molds, *Penicillium,* and *Aspergillus* are composed of multinucleated cells. As the organism grows, nuclei undergo mitosis, but cytokinesis does not occur. As a result, each cell contains tens of nuclei.

process of forming specialized cells within a multicellular organism.

Some cells, such as muscle and nerve cells, lose their ability to divide; they remain in the G_0 phase of interphase. Other cells retain their ability to divide as their form of specialization. Cells that line the digestive tract or form the surface of your skin are examples of dividing cells. In growing organisms such as infants or embryos, most cells are capable of division and divide at a rapid rate. In older organisms, many cells lose their ability to divide as a result of differentiation, and the frequency of cell division decreases. As the organism ages, the lower frequency of cell division may affect many bodily processes, including healing. In some older people, there may be so few cells capable of dividing that a broken bone may never heal. Recall from chapter 7 that the loss of telomeres is associated with cell aging. It is also possible for a cell to undergo mitosis but not cytokinesis. In many types of fungi the cells undergo mitosis but not cytokinesis, which results in multinucleated cells (figure 8.12).

8.6 Abnormal Cell Division

As we have seen, cells become specialized for a particular function. Each cell type has its cell-division process regulated so that it does not interfere with the activities of other cells or the whole organism. Some cells, however, may begin to divide as if they were "newborn" or undifferentiated cells. Sometimes this division occurs in an uncontrolled fashion.

For example, when human white blood cells are grown outside the body under special conditions, they develop a regular cell-division cycle. The cycle is determined by the DNA of the cells. However, white blood cells in the human body may increase their rate of mitosis as a result of other influences. Disease organisms entering the body, tissue damage, and changes in cell DNA all may alter the rate at which white blood cells divide. An increase in white blood cells in response to the invasion of disease organisms is valuable because these white blood cells are capable of destroying the disease-causing organisms.

On the other hand, an uncontrolled mitosis in white blood cells causes *leukemia*. In some forms, this condition causes a general weakening of the body because the excess number of white blood cells diverts necessary nutrients from other cells of the body and interferes with their normal activities. It takes a lot of energy to keep these abnormal cells alive.

When such uncontrolled mitotic division occurs, a group of cells forms what is known as a *tumor*. A **tumor** is a mass of undifferentiated cells not normally found in a certain portion of the body. A **benign tumor** is a cell mass that does not fragment and spread beyond its original area of growth. A benign tumor can become harmful by growing large enough to interfere with normal body functions. Some tumors are malignant. **Malignant tumors** are nonencapsulated growths of tumor cells that are harmful; they may spread or invade other parts of the body. Cells of these tumors move from the original site (**metastasize**) and establish new colonies in other regions of the body (figure 8.13). Cells break off from the original tumor and enter the bloodstream. When they get stuck to the inside of a capillary, these cells move through the wall of the blood vessel and invade the tissue, where they begin to reproduce by mitosis. This tumor causes new blood vessels to grow into this new site, which will carry nutrients to this growing mass. These vessels can also bring even more spreading cells to the new tumor site. **Cancer** is the term used to refer to any abnormal growth of cells that has a malignant potential. Agents responsible for causing cancer are called **carcinogens** (table 8.2).

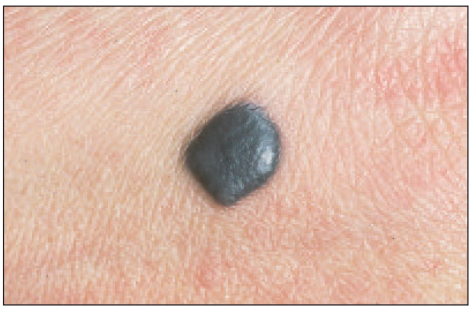


Figure 8.13

Skin Cancer
Malignant melanoma is a type of skin cancer. It forms as a result of a mutation in pigmented skin cells. These cells divide repeatedly giving rise to an abnormal mass of pigmented skin cells. Only the dark area in the photograph is the cancer; the surrounding cells have the genetic information to develop into normal, healthy skin. This kind of cancer is particularly dangerous because the cells break off and spread to other parts of the body (metastasize).

Once cancer has been detected, the tumor might be eliminated. If the cancer is confined to a few specific locations, it may be possible to surgically remove it. Many cancers of the skin or breast are dealt with in this manner. However, in some cases surgery is impractical. If the tumor is located where it can't be removed without destroying healthy tissue, surgery may not be used. For example, removing certain brain cancers can severely damage the brain. In such cases, other methods may be used to treat cancer such as chemotherapy and radiation.

Chemotherapy uses various types of chemicals to destroy mitotically dividing cancer cells. This treatment may be used even when physicians do not know exactly where the cancer cells are located. Many types of leukemia, testicular cancer, and lymphoma are successfully treated with chemotherapy. There are four generally recognized types of chemotherapeutic drugs. *Antimetabolites* appear to the cancer cell as normal nutrients, but in reality they are compounds that will fatally interfere with the cell's metabolic pathways. Methotrexate appears to be the normal substrate for an enzymatic reaction required to produce the nitrogenous bases adenine and guanine. When this medication is given, cancer cells are prevented from synthesizing new DNA. *Topoisomerase inhibitors* are drugs that prevent the DNA of cancer cells from "unzipping" so that DNA replication can occur. Doxorubicin is such a medication. *Alkylating agents* such as cyclophosphamide and chlorambucil form chemical bonds within the DNA of cancer cells resulting in breaks and other damage not easily repaired. The *plant alkaloids* such as vinblastine disrupt the spindle apparatus, thus disrupting the normal separation of chromatids at the time of anaphase.

However, most common cancers are not able to be controlled with chemotherapy alone and must be used in combination with radiation. Chemotherapy also has negative effects on normal cells. It lowers the body's immune reaction because it decreases the body's ability to reproduce new white blood cells by mitosis. Chemotherapy interferes with the body's normal defense mechanisms. Therefore cancer patients undergoing chemotherapy must be given antibiotics.

Table 8.2

FACTORS ASSOCIATED WITH CANCER

Radiation
X rays and gamma rays
Ultraviolet light (UV-B, the cause of sunburn)
Sources of Carcinogens
Tobacco
Nickel
Arsenic
Benzene
Dioxin
Asbestos
Uranium
Tar
Cadmium
Chromium
Polyvinyl chloride (PVC)
Diet
Alcohol
Smoked meats and fish
Food containing nitrates (e.g., bacon)
Viruses
Hepatitis B virus (HBV) and liver cancer
Herpes simplex virus (HSV) type II and uterine cancer
Epstein-Barr virus and Burkitt's lymphoma
Human T-cell lymphotropic virus (HTLV-1) and lymphomas and leukemias
Papillomavirus
Hormonal Imbalances
Diethylstilbestrol (DES)
Oral contraceptives
Types of Genetic and Familial Cancers
Chronic myelogenous leukemia
Acute leukemias
Retinoblastomas
Certain skin cancers
Breast
Endometrial
Colorectal
Stomach
Prostate
Lung

HOW SCIENCE WORKS 8.1

Total Body Radiation to Control Leukemia

Leukemia is a kind of cancer caused by uncontrolled growth of white blood cells. Patients with leukemia have cancer of blood-forming cells located in their bone marrow; however, not all of these cells are cancerous. It is possible to separate the cancerous from the noncancerous bone marrow cells. A radiation therapy method prescribed for some patients involves the removal of some of their bone marrow and isolation of the noncancerous cells for laboratory growth. After these healthy cells have been cultured and increased in number, the patient's whole body is exposed to high doses of radiation sufficient to kill all the cancerous cells remaining in the bone marrow. Because this treatment is potentially deadly, the patient is kept isolated from all harmful substances and infectious microbes. They are fed sterile food, drink sterile water, and breathe sterile air while being closely monitored and treated with antibiotics. The cultured noncancerous cells are injected back into the patient. As if they had a memory of their own, they migrate back to their origins in the bone marrow, establish residence, and begin cell division all over again.

The antibiotics help them defend against dangerous bacteria that might invade their bodies. Other side effects include intestinal disorders and loss of hair, which are caused by damage to healthy cells in the intestinal tract and the skin that divide by mitosis.

Radiation therapy uses powerful X rays or gamma rays. This therapy may be applied from the outside or by implanting radioactive "seeds" into the tumor. Because this treatment damages surrounding healthy cells, it is used very cautiously especially when surgery is impractical (How Science Works 8.1).

It was commonly thought that radiation therapy is effective because cancer cells divide more rapidly than other cells. This is not true. In fact, some cancer cells divide more slowly than normal. What most likely prevents normal cells from becoming tumor cells is the fact that genetic damage or errors are repaired. This appears to happen just before the cell enters the S phase. Damaged cells are put into the repair cycle with the assistance of the "guardian of the genome," the tumor-suppressor p53 gene. There is evidence that p53 stops a damaged cell just before the S phase so that it can be repaired and, in fact, p53 may be directly involved with the DNA repair process. p53 gives a cell the ability to be genetically "healthy." Individuals with mutations of the p53 gene are more susceptible to many cancers including retinoblastoma, breast cancer, and leukemia. Over a thousand different mutations have been identified in p53.

Radiation most likely destroys cancer cells by inducing a process called *apoptosis*. **Apoptosis** is also known as "programmed cell death," that is, death that has a genetic basis and is not the result of injury. Apoptosis normally occurs in many cells of the body because they might be harmful or it takes too much energy to maintain them. During menstruation, cells lining the uterus undergo apoptosis, thus enabling the uterus to be renewed for a possible pregnancy. Cells damaged as a result of viral infection regularly kill themselves, thus helping prevent the spread of the virus to other healthy cells of that tissue. (Tumor cells can prevent apoptosis from occurring by interfering with the activity of gene p53.) Radiation simulates a variety of cellular events that can activate apoptosis in cells with severe genetic damage, or that might undergo uncontrolled mitosis leading to the formation of a tumor. When p53 initiates apoptosis, the cell's DNA is cut into pieces and the cytoplasm and nucleus shrink. This is followed by its engulfment by phagocytes. In this manner, cells that are potentially dangerous to the entire body (tumor cells) are killed before they cause serious harm.

As a treatment for cancer, radiation is dangerous for the same reasons that it is beneficial. In cases of extreme exposure to radiation, people develop what is called *radiation sickness*. The symptoms of this disease include loss of hair, bloody vomiting and diarrhea, and a reduced white blood cell count. These symptoms occur in parts of the body where mitosis is common. The lining of the intestine is constantly being lost as food travels through and it must be replaced by the process of mitosis. Hair growth is the result of the continuous division of cells at the roots. White blood cells are also continuously reproduced in the bone marrow and lymph nodes. When radiation strikes these rapidly dividing cells and kills them, the lining of the intestine wears away and bleeds, hair falls out, and few new white blood cells are produced to defend the body against infection.

SUMMARY

Cell division is necessary for growth, repair, and reproduction. Cells go through a cell cycle that includes cell division (mitosis and cytokinesis) and interphase. Interphase is the period of growth and preparation for division. Mitosis is divided into four stages: prophase, metaphase, anaphase, and telophase. During mitosis, two daughter nuclei are formed from one parent nucleus. These nuclei have identical sets of chromosomes and genes that are exact copies of those of the parent. Although the process of mitosis has been presented as a series of phases, you should realize that it is a continuous, flowing process from prophase through telophase. Following mitosis, cytokinesis divides the cytoplasm, and the cell returns to interphase.

The regulation of mitosis is important if organisms are to remain healthy. Regular divisions are necessary to replace lost cells and allow for growth. However, uncontrolled cell division may result in cancer and disruption of the total organism's well-being.

THINKING CRITICALLY

One "experimental" cancer therapy utilizes laboratory-generated antibodies to an individual's own unique cancer cells. Radioisotopes such as alpha-emitting radium 223 are placed in "cages" and attached to the antibodies. When these immunotherapy medications are given to a patient, the short-lived killer isotopes attach to only the cancer cells. They release small amounts of radiation and for short distances; therefore they cause little harm to healthy cells and tissues before their destructive powers are dissipated. Review the material on cell membranes, antibodies, cancer, and radiation and explain the details of this treatment to a friend. (You might explore the Internet for further information.)

CONCEPT MAP TERMINOLOGY

Construct a concept map to show relationships among the following concepts.

apoptosis
benign
cell cycle
differentiation
interphase
malignant
mitosis
tumor

KEY TERMS

anaphase
apoptosis
benign tumor
cancer
carcinogens
cell plate
centrioles
centromere
chromatid
chromosomes
cleavage furrow
cytokinesis
daughter cells
daughter chromosomes
daughter nuclei
differentiation
interphase
malignant tumors
metaphase
metastasize
mitosis
prophase
spindle
telophase
tumor

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Topics	Questions	Media Resources
8.1 The Importance of Cell Division	1. What is the purpose of mitosis?	**Quick Overview** • Growth, repair, and replacement **Key Points** • The importance of cell division **Animations and Review** • Introduction • Prokaryotes • Chromosomes
8.2 The Cell Cycle	2. What is meant by the cell cycle? 3. What types of activities occur during interphase?	**Quick Overview** • Mostly interphase **Key Points** • The cell cycle
8.3 The Stages of Mitosis	4. Name the four stages of mitosis and describe what occurs in each stage. 5. During which stage of a cell's cycle does DNA replication occur?	**Quick Overview** • iPMAT **Key Points** • The stages of mitosis **Animations and Review** • Mitosis/Cell cycle

(*continued*)

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Topics	Questions	Media Resources
8.3 The Stages of Mitosis (*continued*)	6. At what phase of mitosis does the DNA become most visible? 7. List five differences between an interphase cell and a cell in mitosis.	**Labeling Exercises** • Mitosis overview I • Mitosis overview II • Plant cell mitosis **Interactive Concept Maps** • Events during mitosis
8.4 Plant and Animal Cell Differences	8. What are the differences between plant and animal mitosis? 9. What is the difference between cytokinesis in plants and animals?	**Quick Overview** • Centrioles, spindle fibers, and cleavage furrows **Key Points** • Plant and animal cell differences **Interactive Concept Maps** • Mitotic differences between plants and animals
8.5 Differentiation	10. How is it possible that cells with the same genes can be different? 11. What does cell specialization mean? 12. Identify some cells that lose the ability to undergo mitosis as they differentiate, as well as some cells that retain this ability.	**Quick Overview** • Specialization through selected gene expression **Key Points** • Differentiation
8.6 Abnormal Cell Division	13. Why can radiation be used to control cancer?	**Quick Overview** • Cancer **Key Points** • Abnormal cell division **Interactive Concept Maps** • Text concept map **Experience This!** • Learning about cancer **Review Questions** • Mitosis: The cell-copying process