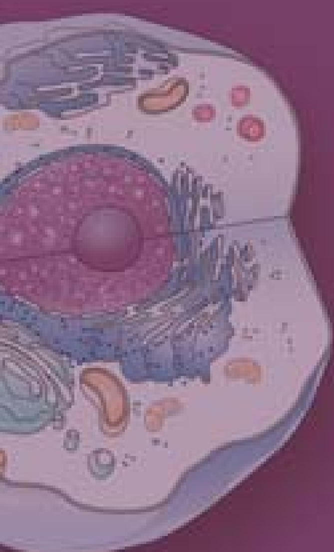
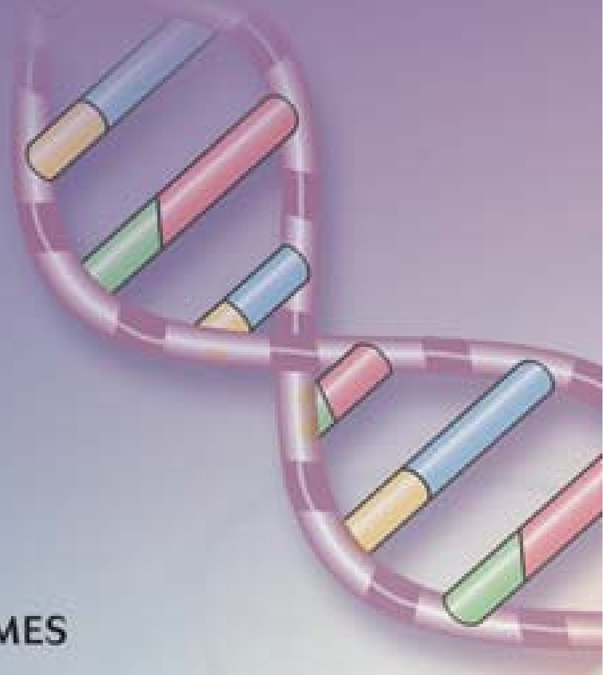


Selected Key Terms

The following terms and other boldface terms in the chapter are defined in the Glossary

active transport
cancer
chromosome
cytology
cytoplasm
diffusion
DNA
endocytosis
gene
interphase
isotonic
micrometer
mitocondria
mitosis
mutation
nucleotide
nucleus
organelle
osmosis
phagocytosis
plasma membrane
ribosome
RNA



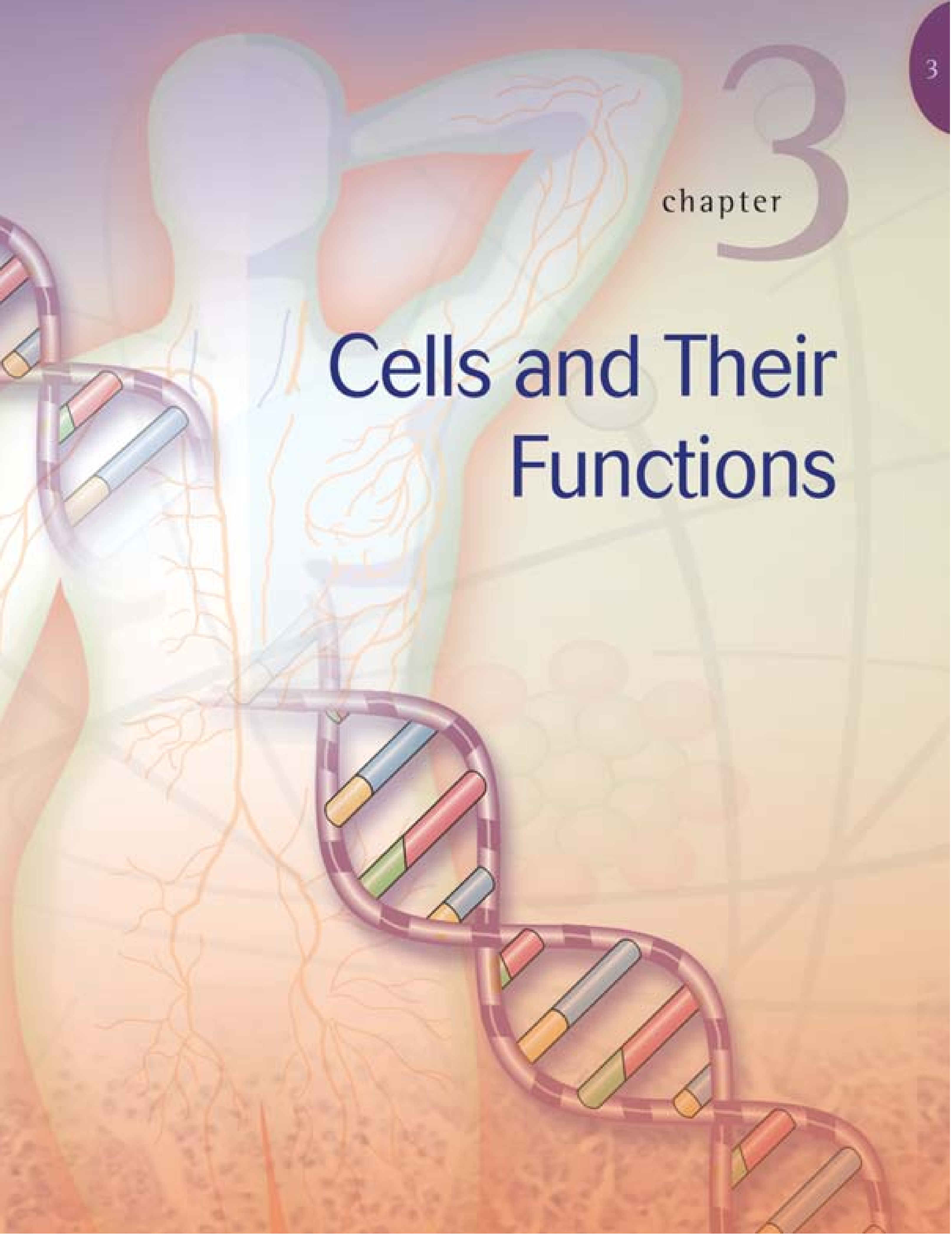
Learning Outcomes

After careful study of this chapter, you should be able to:

1. List three types of microscopes used to study cells
2. Describe the function and composition of the plasma membrane
3. Describe the cytoplasm of the cell, including the name and function of the main organelles
4. Describe the composition, location, and function of the DNA in the cell
5. Compare the function of three types of RNA in the cells
6. Explain briefly how cells make proteins
7. Name and briefly describe the stages in mitosis
8. Define eight methods by which substances enter and leave cells
9. Explain what will happen if cells are placed in solutions with concentrations the same as or different from those of the cell fluids
10. Define *cancer*
11. List several risk factors for cancer
12. Show how word parts are used to build words related to cells and their functions (see Word Anatomy at the end of the chapter)

chapter 3

Cells and Their Functions



The Role of Cells

The **cell** (sel) is the basic unit of all life. It is the simplest structure that shows all the characteristics of life, including organization, metabolism, responsiveness, homeostasis, growth, and reproduction. In fact, it is possible for a single cell to live independently of other cells. Examples of some free-living cells are microscopic organisms such as protozoa and bacteria, some of which produce disease. In a multicellular organism, cells make up all tissues. All the activities of the human body, which is composed of trillions of cells, result from the activities of individual cells. Cells produce all the materials manufactured within the body. The study of cells is **cytology** (si-TOL-o-je).

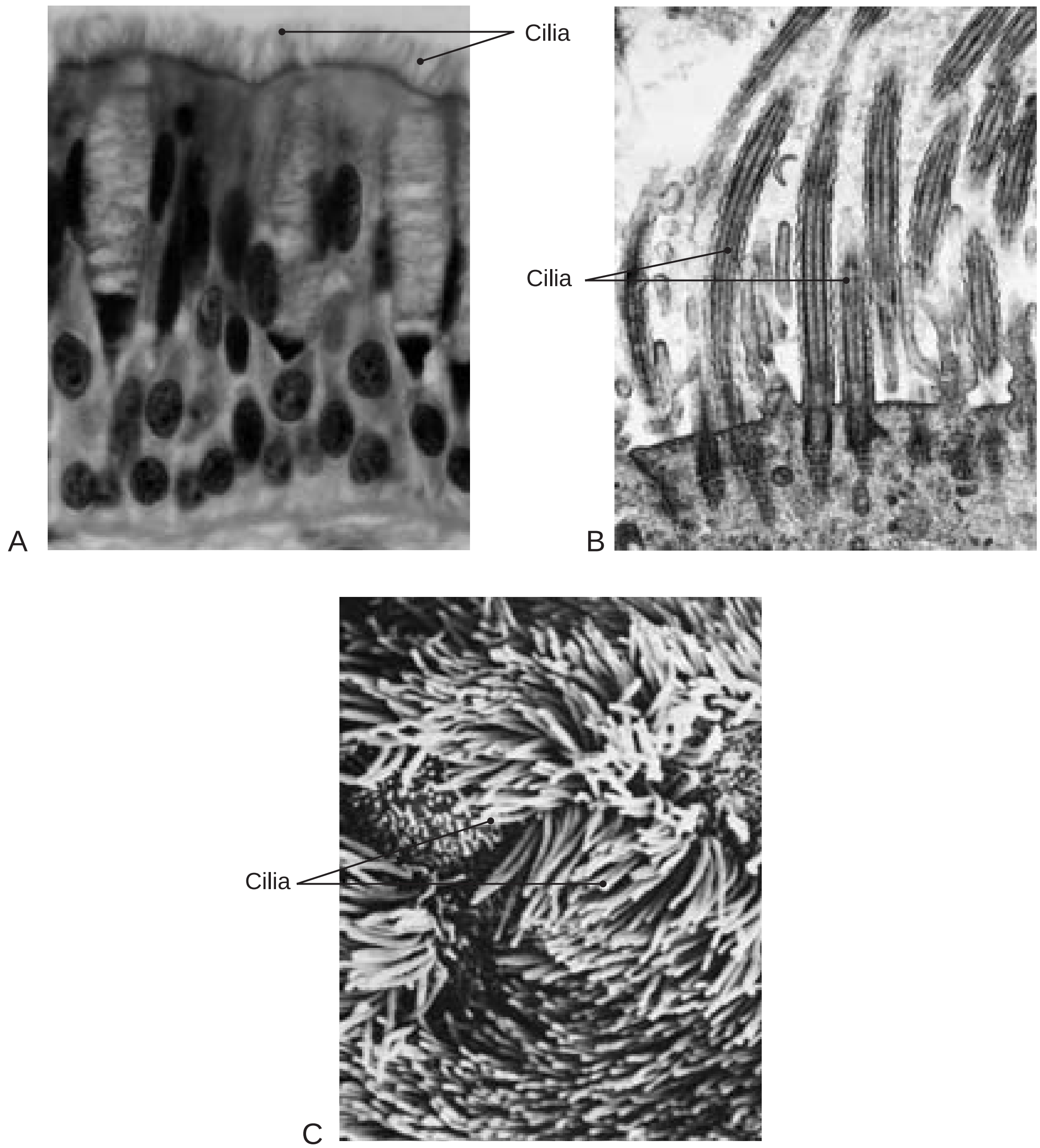


Figure 3-1 **Cilia photographed under three different microscopes. (A)** Cilia (hairlike projections) in cells lining the trachea under the highest magnification of a compound light microscope (1000×) **(B)** Cilia in the bronchial lining viewed with a transmission electron microscope (TEM). Internal components are visible at this much higher magnification. **(C)** Cilia on cells lining an oviduct as seen with a scanning electron microscope (SEM) (7000×). A three dimensional view can be seen. (A, Reprinted with permission from Cormack DH. Essential histology. 2nd ed. Philadelphia: Lippincott Williams & Wilkins, 2001. B, Reprinted with permission from Quinton P, Martinez R, eds. Fluid and electrolyte transport in exocrine glands in cystic fibrosis. San Francisco: San Francisco Press, 1982. C, Reprinted with permission from Hafez ESE, ed. Scanning electron microscopic atlas of mammalian reproduction. Tokyo: Igaku Shoin, 1975.) *ZOOMING IN ❖ Which microscope shows the most internal structure of the cilia? Which shows the cilia in three dimensions?*

Microscopes

The outlines of cells were first seen in dried plant tissue almost 350 years ago. Study of their internal structure, however, depended on improvements in the design of the **microscope**, a magnifying instrument needed to examine structures not visible with the naked eye. The single-lens microscope used in the late 17th century was later replaced by the **compound light microscope** most commonly used in laboratories today. This instrument, which can magnify an object up to 1000 times, has two lenses and uses visible light for illumination. A much more powerful microscope, the **transmission electron microscope** (TEM), uses an electron beam in place of visible light and can magnify an image up to 1 million times. Another type of microscope, the **scanning electron microscope** (SEM), does not magnify as much (100,000×) and shows only surface features, but gives a three-dimensional view of an object. Figure 3-1 shows some cell structures viewed with each of these types of microscopes. The structures are cilia, short, hairlike projections from the cell that move nearby fluids. The metric unit used for microscopic measurements is the **micrometer** (MI-kro-me-ter), formerly called a micron. This unit is 1/1000 of a millimeter and is symbolized with the Greek letter mu (μ), as μm.

Before a scientist can examine cells and tissues under a microscope, he or she must usually color them with special dyes called **stains** to aid in viewing. These stains produce the variety of colors seen in pictures of cells and tissues taken under a microscope.

> **Checkpoint 3-1** The cell is the basic unit of life. What characteristics of life does it show?

> **Checkpoint 3-2** Name three types of microscopes.

Cell Structure

Just as people may look different but still have certain features in common—two eyes, a nose, and a mouth, for example—all cells share certain characteristics. Refer to Figure 3-2 as we describe some of the parts that are common to most animal cells. Table 3-1 summarizes information about the main cell parts.

Plasma Membrane

The outer limit of the cell is the **plasma membrane,** formerly called the *cell membrane* (Fig. 3-3). The plasma membrane not only encloses the cell contents but also participates in many cellular activities, such as growth, reproduction, and interactions between cells, and is especially important in regulating what can enter and leave the cell. The main substance of this membrane is a double layer of lipid molecules, described as a bilayer. Because these lipids contain the element phosphorus, they are called **phospholipids.** Some molecules of cholesterol, another type of lipid, are located between the phospholipids. Cholesterol strengthens the membrane.

A variety of different proteins float within the lipid bilayer. Some of these proteins extend all the way through the membrane, and some are located near the inner or outer surfaces of the membrane. The importance of these proteins will be revealed in later chapters, but they are listed here along with their functions (Table 3-2):

- Channels—pores in the membrane that allow specific substances to enter or leave. Certain ions travel through channels in the membrane.

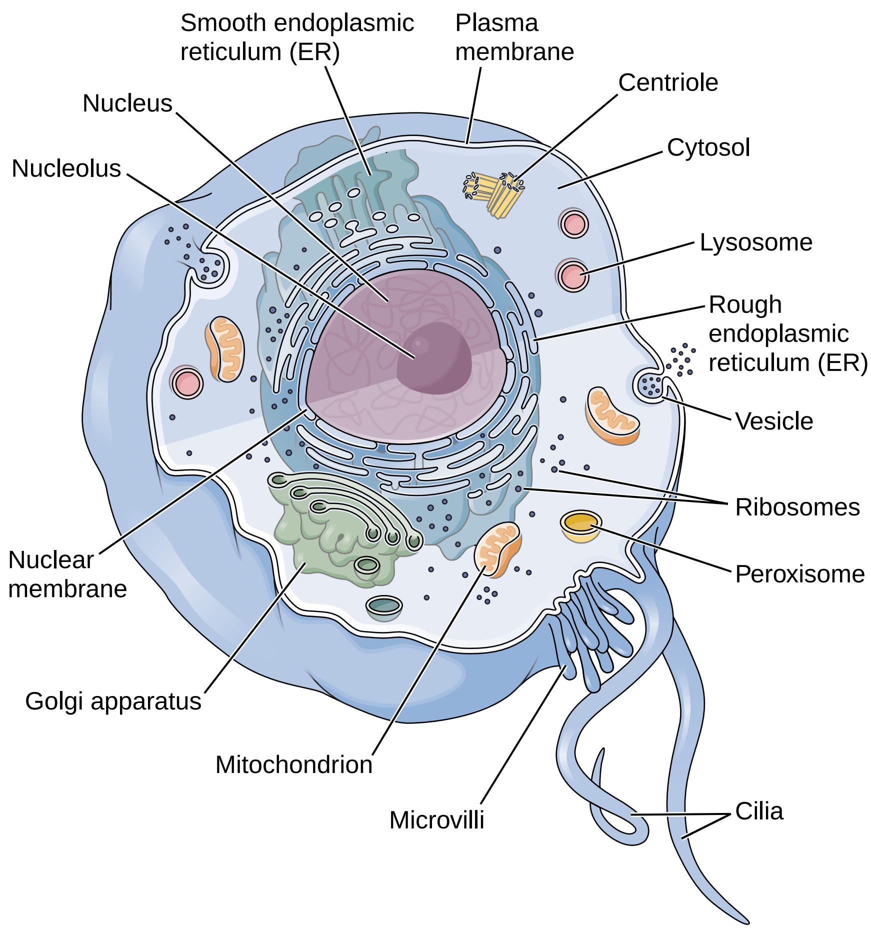


Figure 3-2 **A generalized animal cell, sectional view.** *ZOOMING IN ✦ What is attached to the ER to make it look rough? What is the liquid part of the cytoplasm called?*

Table 3•1 Cell Parts

NAME	DESCRIPTION	FUNCTION
Plasma membrane	Outer layer of the cell; composed mainly of lipids and proteins	Encloses the cell contents; regulates what enters and leaves the cell; participates in many activities, such as growth, reproduction, and interactions between cells
Microvilli	Short extensions of the cell membrane	Absorb materials into the cell
Nucleus	Large, dark-staining organelle near the center of the cell, composed of DNA and proteins	Contains the chromosomes, the hereditary units that direct all cellular activities
Nucleolus	Small body in the nucleus; composed of RNA, DNA, and protein	Makes ribosomes
Cytoplasm	Colloidal suspension that fills the cell from the nuclear membrane to the plasma membrane	Site of many cellular activities, consists of cytosol and organelles
Cytosol	The fluid portion of the cytoplasm	Surrounds the organelles
Endoplasmic reticulum (ER)	Network of membranes within the cytoplasm. Rough ER has ribosomes attached to it; smooth ER does not.	Rough ER sorts proteins and forms them into more complex compounds; smooth ER is involved with lipid synthesis
Ribosomes	Small bodies free in the cytoplasm or attached to the ER; composed of RNA and protein	Manufacture proteins
Mitochondria	Large organelles with folded membranes inside	Convert energy from nutrients into ATP
Golgi apparatus	Layers of membranes	Makes compounds containing proteins; sorts and prepares these compounds for transport to other parts of the cell or out of the cell
Saclike bodies	Small, membrane-enclosed bodies	Store materials, transport materials through the plasma membrane, or destroy waste material
Lysosomes	Small sacs of digestive enzymes	Digest substances within the cell
Peroxisomes	Membrane-enclosed organelles containing enzymes	Break down harmful substances
Vesicles	Small membrane-bound bubbles in the cytoplasm	Store materials and move materials into or out of the cell in bulk
Centrioles	Rod-shaped bodies (usually two) near the nucleus	Help separate the chromosomes during cell division
Surface projections	Structures that extend from the cell	Move the cell or the fluids around the cell
Cilia	Short, hairlike projections from the cell	Move the fluids around the cell
Flagellum	Long, whiplike extension from the cell	Moves the cell

- Transporters—shuttle substances from one side of the membrane to the other. Glucose, for example, is carried into cells using transporters.
- Receptors—points of attachment for materials coming to the cell in the blood or tissue fluid. Some hormones, for example, must attach to receptors on the cell surface before they can act upon the cell, as described in Chapter 12 on the endocrine system.
- Enzymes—participate in reactions occurring at the plasma membrane.
- Linkers—give structure to the membrane and help attach cells to other cells.
- Cell identity markers—proteins unique to an individual's cells. These are important in the immune system and are also a factor in transplantation of tissue from one person to another.

Carbohydrates are present in small amounts in the plasma membrane, combined either with proteins (glycoproteins) or with lipids (glycolipids). These carbohydrates help cells to recognize each other and to stick together.

In some cells, the plasma membrane is folded out into multiple small projections called **microvilli** (mi-kro-VIL-li). Microvilli increase the surface area of the membrane, allowing for greater absorption of materials from the cell's environment, just as a sponge absorbs water. Microvilli are found on cells that line the small intestine, where they promote absorption of digested foods into the circulation. They are also found on kidney cells, where they reabsorb materials that have been filtered out of the blood.

Checkpoint 3-3 The outer limit of the cell is a complex membrane. What is the main substance of this membrane and what are three types of materials found within the membrane?

The Nucleus

Just as the body has different organs to carry out special functions, the cell contains specialized structures that perform different tasks. These structures are called **or-**

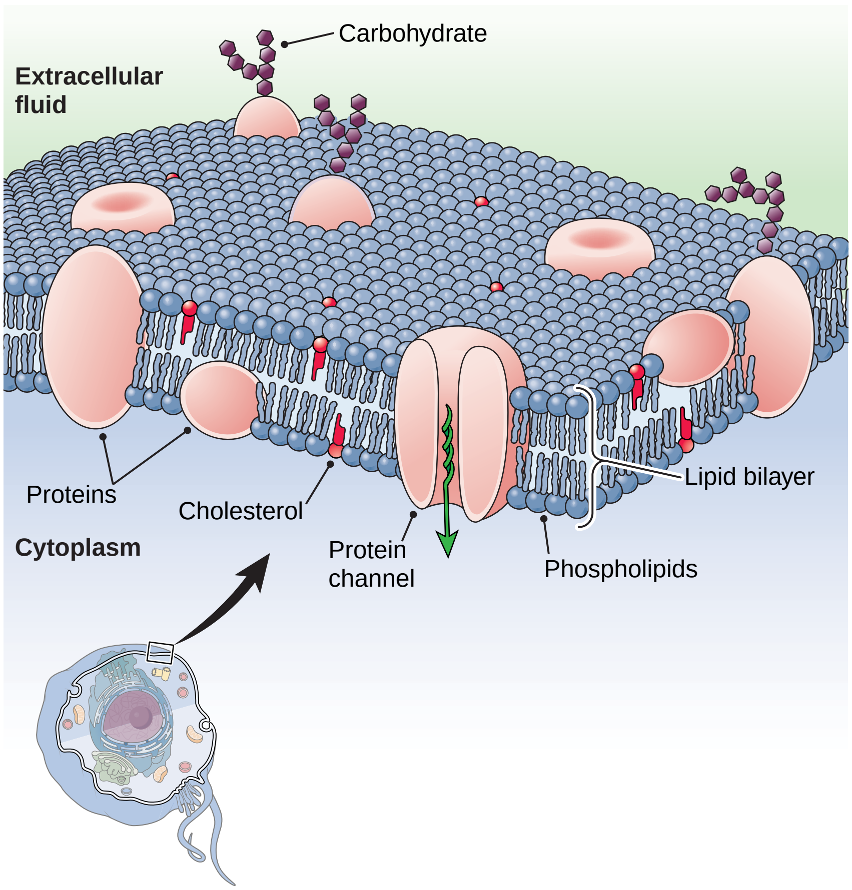


Figure 3-3 **The plasma membrane.** This drawing shows the current concept of its structure. *ZOOMING IN ✦ How many layers make up the main substance of the plasma membrane?*

ganelles, which means "little organs." The largest of the organelles is the **nucleus** (NU-kle-us).

The nucleus is often called the *control center* of the cell because it contains the chromosomes, the threadlike units of heredity that are passed on from parents to their offspring. It is information contained in the **chromosomes** (KRO-mo-somes) that governs all cellular activities, as described later in this chapter. Most of the time, the chromosomes are loosely distributed throughout the nucleus, giving that organelle a uniform, dark appearance when stained and examined under a microscope (see Fig. 3-2). When the cell is dividing, however, the chromosomes tighten into their visible threadlike forms.

Within the nucleus is a smaller globule called the **nucleolus** (nu-KLE-o-lus), which means "little nucleus." The job of the nucleolus is to assemble ribosomes, small bodies outside the nucleus that are involved in the manufacture of proteins.

Checkpoint 3-4 What are cell organelles?

Checkpoint 3-5 Why is the nucleus called the control center of the cell?

The Cytoplasm

The remaining organelles are part of the **cytoplasm** (SI-to-plazm), the material that fills the cell from the nuclear membrane to the plasma membrane. The liquid part of the cytoplasm is the **cytosol**, a suspension of nutrients, minerals, enzymes, and other specialized materials in water. The main organelles are described here (see Table 3-1).

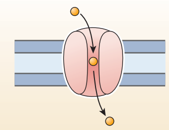
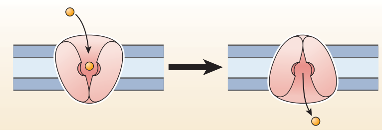
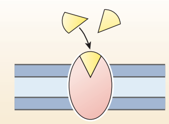
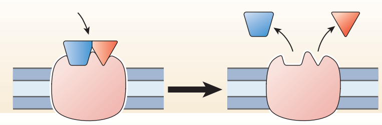
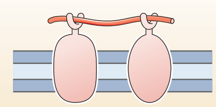
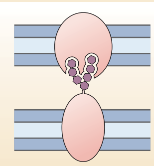
The **endoplasmic reticulum** (en-do-PLAS-mik re-TIK-u-lum) is a network of membranes located between the nuclear membrane and the plasma membrane. Its name literally means "network" (reticulum) "within the cytoplasm" (endoplasmic), but for ease, it is almost always called simply the **ER**. In some areas, the ER appears to have an even surface, and is described as *smooth ER*. This type of ER is involved with the synthesis of lipids. In other areas, the ER has a gritty, uneven surface, causing it to be described as *rough ER*. The texture of rough ER comes from small bodies, called **ribosomes** (RI-bo-somz), attached to its surface. Ribosomes are necessary for the manufacture of proteins, as described later. They may be attached to the ER or be free in the cytoplasm.

The **mitochondria** (mi-to-KON-dre-ah) are large organelles that are round or bean-shaped with folded membranes on the inside. Within the mitochondria, the energy from nutrients is converted to energy for the cell in the form of ATP. Mitochondria are the "power plants" of the cell. Active cells, such as muscle cells or sperm cells, need lots of energy and thus have large numbers of mitochondria.

Another organelle in a typical cell is the **Golgi** (GOL-je) **apparatus** (also called Golgi complex), a stack of membranous sacs involved in sorting and modifying proteins and then packaging them for export from the cell.

Several types of organelles appear as small sacs in the cytoplasm. These include **lysosomes** (LI-so-somz), which contain digestive enzymes. Lysosomes remove waste and foreign materials from the cell. They are also involved in destroying old and damaged cells as needed for repair and remodeling of tissue. **Peroxisomes** (per-OK-sih-somz) have enzymes that destroy harmful substances produced in metabolism (see Box 3-1, Lysosomes and Peroxisomes: Cellular Recycling). **Vesicles** (VES-ih-klz) are small, membrane-bound bubbles used for storage. They can be used to move materials into or out of the cell, as described later.

Table 3•2 Proteins in the Plasma Membrane and Their Functions

TYPE OF PROTEIN	FUNCTION	ILLUSTRATION
Channels	Pores in the membrane that allow passage of specific substances, such as ions	
Transporters	Shuttle substances, such as glucose, across the membrane	
Receptors	Allow for attachment of substances, such as hormones, to the membrane	
Enzymes	Participate in reactions at the surface of the membrane	
Linkers	Give structure to the membrane and attach cells to other cells	
Cell identity markers	Proteins unique to a person's cells; important in the immune system and in transplantation of tissue from one person to another	

Box 3-1 **Clinical Perspectives**

Lysosomes and Peroxisomes: Cellular Recycling

Two organelles that play a vital role in cellular disposal and recycling are lysosomes and peroxisomes. **Lysosomes** contain enzymes that break down carbohydrates, lipids, proteins, and nucleic acids. These powerful enzymes must be kept within the lysosome because they would digest the cell if they escaped. In a process called **autophagy** (aw-TOF-ah-je), the cell uses lysosomes to safely recycle cellular structures, fusing with and digesting worn out organelles. The digested components then return to the cytoplasm for reuse. Lysosomes also break down foreign material, as when cells known as **phagocytes** *(FAG-o-sites)* engulf bacteria and then use lysosomes to destroy them. The cell may also use lysosomes to digest itself during **autolysis** (aw-TOL-ih-sis), a normal part of development. Cells that are no longer needed "self-destruct" by releasing lysosomal enzymes into their own cytoplasm.

Peroxisomes are small membranous sacs that resemble lysosomes but contain different kinds of enzymes. They break down toxic substances that may enter the cell, such as drugs and alcohol, but their most important function is to break down free radicals. These substances are byproducts of normal metabolic reactions but can kill the cell if not neutralized by peroxisomes.

Disease may result if either lysosomes or peroxisomes are unable to function. In Tay-Sachs disease, nerve cells' lysosomes lack an enzyme that breaks down certain kinds of lipids. These lipids build up inside the cells, causing malfunction that leads to brain injury, blindness, and death. Disease may also result if lysosomes or peroxisomes function when they should not. Some investigators believe this is the case in autoimmune diseases, in which the body develops an immune response to its own cells. Phagocytes engulf the cells and lysosomes destroy them. In addition, body cells themselves may self-destruct through autolysis. The joint disease rheumatoid arthritis is one such example.

Centrioles (SEN-tre-olz) are rod-shaped bodies near the nucleus that function in cell division. They help to organize the cell and divide the cell contents during this process.

Surface Organelles

Some cells have structures projecting from their surface that are used for motion. **Cilia** (SIL-e-ah) are small, hairlike projections that wave, creating movement of the fluids around the cell. For example, cells that line the passageways of the respiratory tract have cilia that move impurities out of the system. Ciliated cells in the female reproductive tract move the egg cell along the oviduct toward the uterus.

A long, whiplike extension from the cell is a **flagellum** (flah-JEL-lum). The only type of cell in the human body that has a flagellum is the sperm cell of the male. Each human sperm cell has a flagellum that is used to propel the sperm cell toward the egg in the female reproductive tract.

Cellular Diversity

Although all body cells have some fundamental similarities, individual cells may vary widely in size, shape, and composition according to the function of each. The average cell size is 10 to 15 μm, but cells may range in size from the 7 μm of a red blood cell to the 200 μm or more in the length of a muscle cell.

Cell shape is related to cell function (Fig. 3-4). A neuron (nerve cell) has long fibers that transmit electrical energy from place to place in the nervous system. Cells in surface layers have a modified shape that covers and protects the tissue beneath. Red blood cells are small and round, which lets them slide through tiny blood vessels. They also have a thin outer membrane to allow for passage of gases into and out of the cell. As red blood cells mature, they lose the nucleus and most of the other organelles, making the greatest possible amount of space available to carry oxygen.

Aside from cilia and flagella, most human cells have all the organelles described above. These may vary in number, however. For example, cells producing lipids have lots of smooth ER. Cells that secrete proteins have lots of ribosomes and a prominent Golgi apparatus. All active cells have lots of mitochondria to manufacture the ATP needed for energy.

Checkpoint 3-6 What are the two types of organelles used for movement, and what do they look like?

Protein Synthesis

Because protein molecules play an indispensable part in the structure and function of the body, we need to identify the cellular substances that direct the production of proteins. As noted, the hereditary units that govern the cell are the chromosomes in the nucleus. Each chromosome in turn is divided into multiple subunits, called **genes** (Fig. 3-5). It is the genes that carry the messages for the development of particular inherited characteristics, such as brown eyes, curly hair, or blood type, and they do so by directing the manufacture of proteins in the cell.

Nucleic Acids: DNA and RNA

The genes are distinct segments of the complex organic chemical that makes up the chromosomes, a substance called **deoxyribonucleic** (de-ok-se-RI-bo-nu-kle-ik) **acid,** or **DNA**. DNA is composed of subunits called **nucleotides** (NU-kle-o-tides) (see Fig. 3-5). A related compound, **ribonucleic** (RI-bo-nu-kle-ik) **acid,** or **RNA**, which also

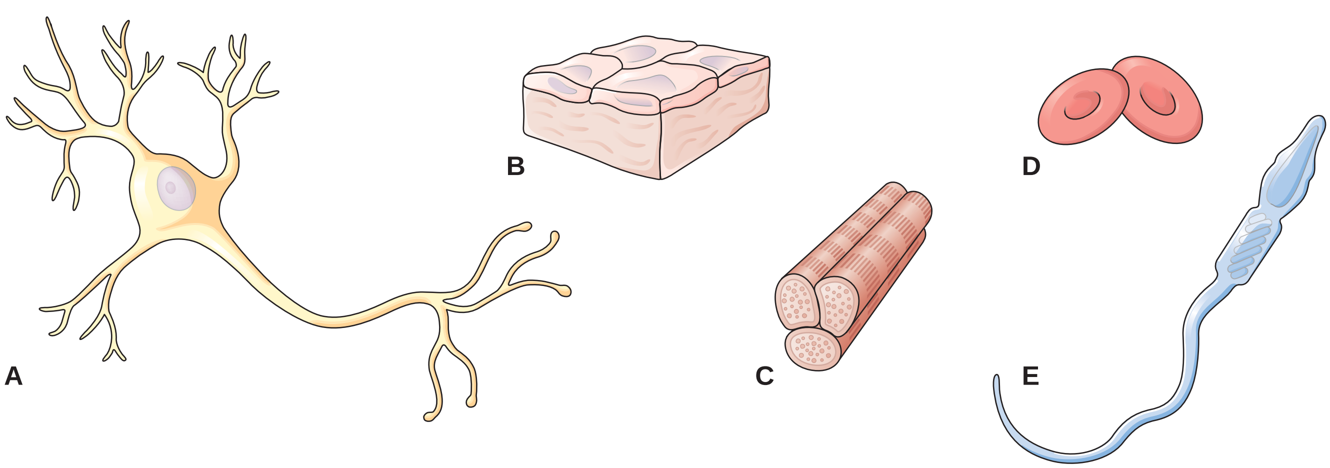


Figure 3-4 Cellular diversity. Cells vary in structure according to their functions. **(A)** A neuron has long extensions that pick up and transmit electrical impulses. **(B)** Epithelial cells cover and protect underlying tissue. **(C)** Muscle cells have fibers that produce contraction. **(D)** Red blood cells lose most organelles, which maximizes their oxygen-carrying capacity, and have a small, round shape that lets them slide through blood vessels. **(E)** A sperm cell is small and light and swims with a flagellum. *ZOOMING IN ✦ Which of the cells shown would best cover a large surface area?*

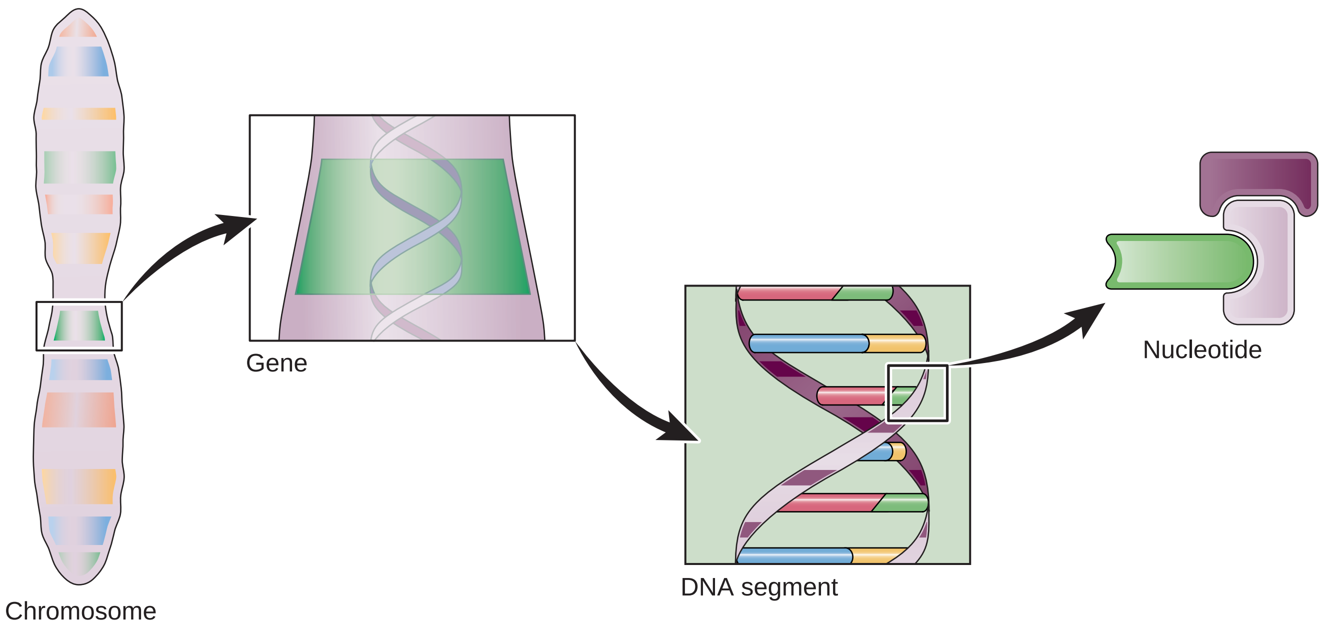


Figure 3-5 **Subdivisions of a chromosome.** A gene is a distinct region of a chromosome. The entire chromosome is made of DNA. Nucleotides are the building blocks of DNA.

participates in protein synthesis but is not part of the chromosomes, is also composed of nucleotides. There are four different nucleotides in DNA and four in RNA, but only three of these are common to both. Both DNA and RNA have the nucleotides adenine (A), guanine (G), and cytosine (C), but DNA has thymine (T), whereas RNA has uracil (U). Table 3-3 compares the structure and function of DNA and RNA.

Moving one step deeper into the structure of the nucleic acids, each nucleotide is composed of four units:

- A sugar, which in RNA is ribose and in DNA is a ribose that is missing one oxygen atom (that is, deoxyribose)
- A phosphorus-containing portion, or phosphate
- A nitrogen-containing portion known as a nitrogen base

The sugar and phosphate alternate to form a long chain to which the nitrogen bases are attached. It is variation in the nitrogen bases that accounts for the differences in the five different nucleotides.

DNA Most of the DNA in the cell is organized into chromosomes within the nucleus (a small amount of DNA is in the mitochondria located in the cytoplasm). Looking at Figure 3-6, which shows a section of a chromosome, you can see that the DNA exists as a double strand. Visualizing the complete molecule as a ladder, the sugar and phosphate units of the nucleotides make up the "side rails" of the ladder, and the nitrogen bases project from the side rails to make up the "steps" of the ladder. The two DNA strands are paired very specifically according to the identity of the nitrogen bases in the nucleotides. The adenine (A) nucleotide always pairs with the thymine (T) nucleotide; the guanine (G) nucleotide always pairs with the cytosine (C) nucleotide. The two strands of DNA are held together by weak bonds (hydrogen binds; see Box 2-

Table 3•3 Comparison of DNA and RNA

	DNA	RNA
Location	Almost entirely in the nucleus	Almost entirely in the cytoplasm
Composition	Nucleotides: adenine (A), guanine (G), cytosine (C), thymine (T) Sugar: deoxyribose	Nucleotides: adenine (A), guanine (G), cytosine (C), uracil (U) Sugar: ribose
Structure	Double-stranded helix formed by nucleotide pairing A-T; G-C	Single strand
Function	Makes up the chromosomes, hereditary units that control all cell activities; divided into genes that carry the nucleotide codes for the manufacture of proteins	Manufacture proteins according to the nucleotide codes carried in the DNA; three types: messenger RNA (mRNA), ribosomal RNA (rRNA), and transfer RNA (tRNA)

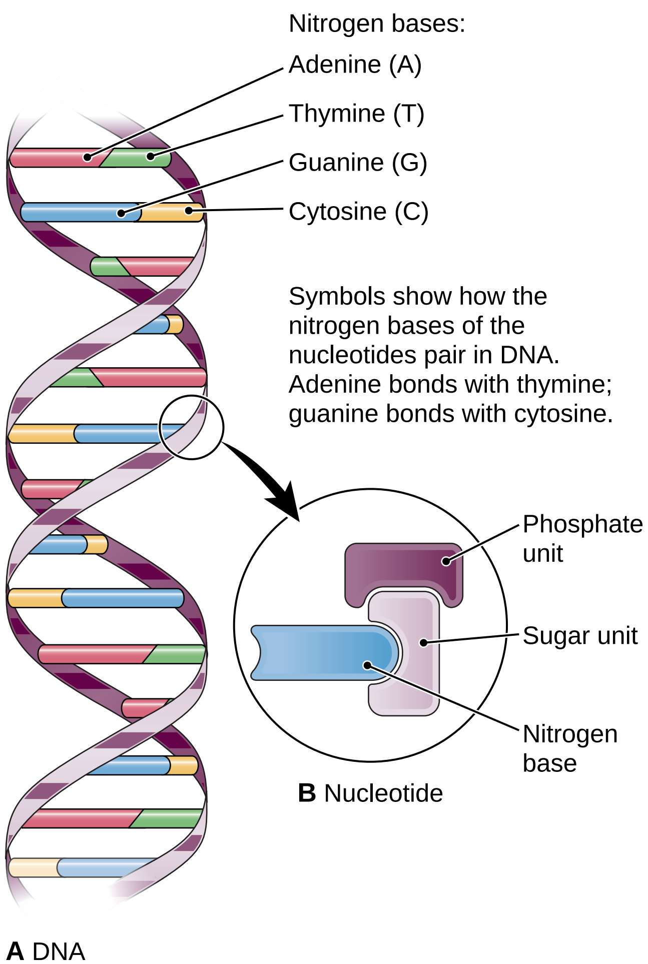


Figure 3-6 **Structure of DNA. (A)** This schematic representation of a chromosome segment shows the paired nucleic acid strands twisted into a double helix. **(B)** Each structural unit, or nucleotide, consists of a phosphate unit and a sugar unit attached to a nitrogen base. The sugar unit in DNA is deoxyribose. There are four different nucleotides in DNA. Their arrangement "spells out" the genetic instructions that control all activities of the cell. *ZOOMING IN ✦ Two of the DNA nucleotides (A and G) are larger in size than the other two (T and C). How do the nucleotides pair up with regard to size?*

1). The doubled strands then coil into a spiral, giving DNA the descriptive name *double helix.*

The message of the DNA that makes up the individual genes is actually contained in the varying pattern of the four nucleotides along the strand. The nucleotides are like four letters in an alphabet that can be combined in different ways to make a variety of words. The words represent the amino acids used to make proteins, and a long string of words makes up a gene. Each gene thus codes for the building of amino acids into a specific cellular protein. Remember that all enzymes are proteins, and enzymes are essential for all cellular reactions. DNA is thus the master blueprint for the cell.

In light of observations on cellular diversity, you may wonder how different cells in the body can vary in appearance and function if they all have the same amount and same kind of DNA. The answer to this question is that only portions of the DNA in a given cell are active at any one time. In some cells, regions of the DNA can be switched on and off, under the influence of hormones, for example. However, as cells differentiate during development and become more specialized, regions of the DNA are permanently shut down, leading to the variations in the different cell types. Scientists now realize that the control of DNA action throughout the life of the cell is a very complex matter involving not only the DNA itself but proteins as well.

Checkpoint 3-7 What are the building blocks of nucleic acids?

Checkpoint 3-8 What category of compounds does DNA code for in the cell?

The Role of RNA

A blueprint is only a guide. The information it contains must be interpreted by appropriate actions, and RNA is the substance needed for these steps. RNA is much like DNA except that it exists as a single strand of nucleotides and has the nucleotide uracil (U) instead of thymine (T). Thus, when RNA pairs up with another molecule of nucleic acid to manufacture proteins, as explained below, adenine (A) bonds with uracil (U) in the RNA instead of thymine (T).

A detailed account of protein synthesis is beyond the scope of this book, but a highly simplified description and illustrations of the process are presented. The process begins with the transfer of information from DNA to RNA in the nucleus, a process known as *transcription* (Fig. 3-7). Before transcription begins, the DNA breaks its weak bonds and uncoils into single strands. Then a matching strand of RNA forms along one of the DNA strands by the process of nucleotide pairing. (For example, if the DNA strand reads CGAT, the corresponding mRNA will read GCUA. Recall that RNA uses the nucleotide U instead of A.) When complete, this messenger RNA (mRNA) leaves the nucleus and travels to a ribosome in the cytoplasm (Fig. 3-8). Recall that ribosomes are the site of protein synthesis in the cell.

Ribosomes are composed of a type of RNA called ribosomal RNA (rRNA) and also protein. At the ribosomes, the genetic message now contained within mRNA is decoded to build amino acids into the long chains that form proteins, a process termed *translation*. This final step requires a third type of RNA, transfer RNA (tRNA), small molecules present in the cytoplasm (see Fig. 3-8). Each transfer RNA carries a specific amino acid that can be added to a protein chain. A nucleotide code on each tRNA determines whether or not its amino acid will be added. After the amino acid chain is formed, it must be coiled and folded into the proper shape for that protein, as noted in Chapter 2. Table 3-4 summarizes information on the

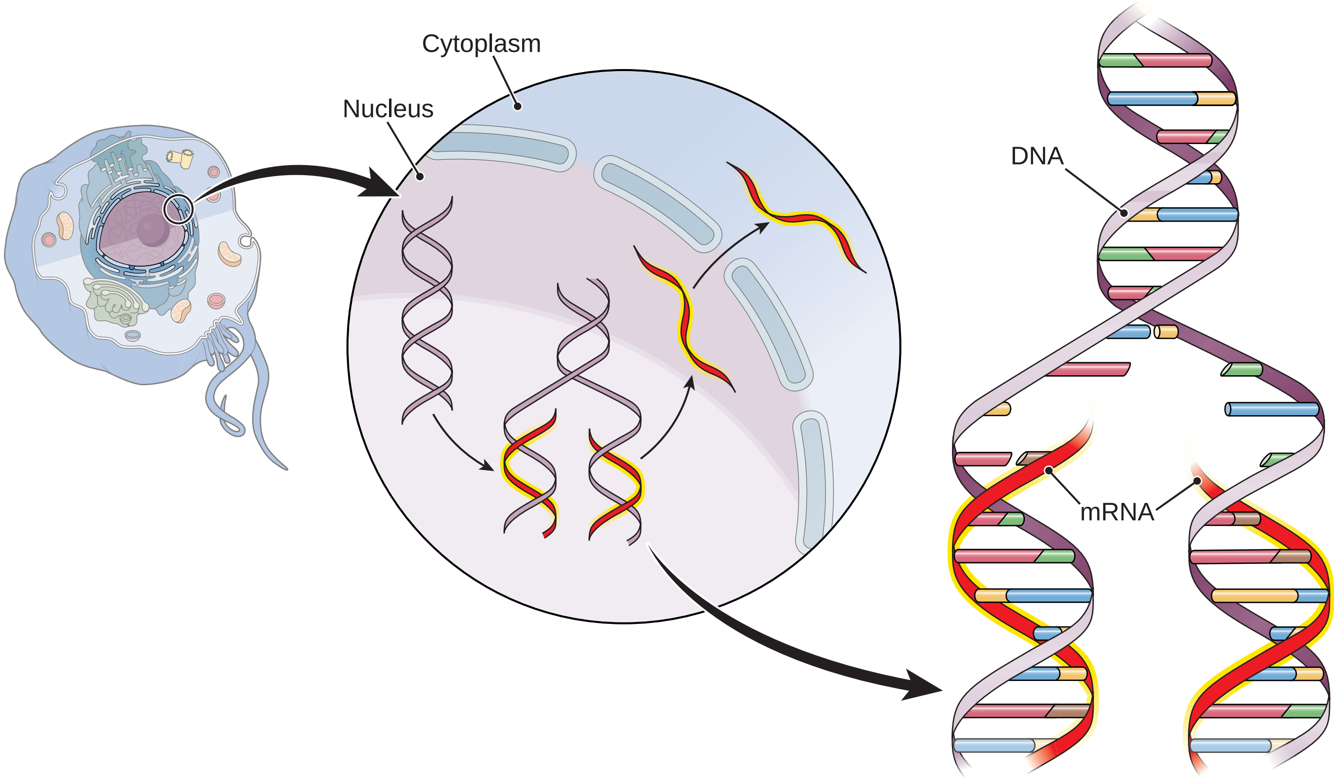


Figure 3-7 **Transcription.** In the first step of protein synthesis the DNA code is transcribed into messenger RNA (mRNA) by nucleotide base pairing. An enlarged view of the nucleic acids during transcription shows how mRNA forms according to the nucleotide pattern of the DNA. Note that adenine (A, red) in DNA bonds with uracil (U, brown) in RNA.

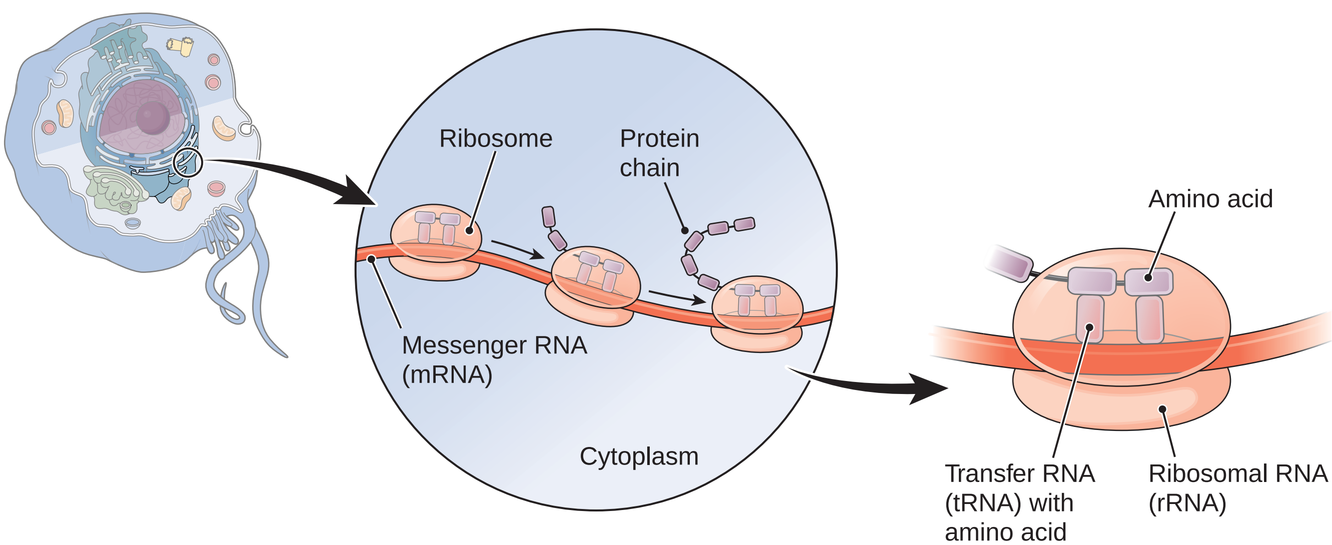


Figure 3-8 **Translation.** In protein synthesis, messenger RNA (mRNA) travels to the ribosomes in the cytoplasm. The information in the mRNA codes for the building of proteins from amino acids. Transfer RNA (tRNA) molecules bring amino acids to the ribosomes to build each protein.

Table 3•4 RNA

TYPES	FUNCTION
Messenger RNA (mRNA)	Is built on a strand of DNA in the nucleus and transcribes the nucleotide code; moves to cytoplasm and attaches to a ribosome
Ribosomal RNA (rRNA)	With protein makes up the ribosomes, the sites of protein synthesis in the cytoplasm; involved in the process of translating the genetic message into a protein
Transfer RNA (tRNA)	Works with other forms of RNA to translate the genetic code into protein; each molecule of tRNA carries an amino acid that can be used to build a protein at the ribosome

different types of RNA. Also see Box 3-2, Proteomics: So Many Proteins, So Few Genes.

Checkpoint 3-9 What three types of RNA are active in protein synthesis?

Cell Division

For growth, repair, and reproduction, cells must multiply to increase their numbers. The cells that form the sex cells (egg and sperm) divide by the process of *meiosis* (mi-O-sis), which cuts the chromosome number in half to prepare for union of the egg and sperm in fertilization. If not for this preliminary reduction, the number of chromosomes in the offspring would constantly double. The process of meiosis is discussed in Chapter 23. All other body cells, known as *somatic cells*, divide by the process of **mitosis** (mi-TO-sis). In this process, described below, each original parent cell becomes two identical daughter cells.

Before mitosis can occur, the genetic information (DNA) in the parent cell must be doubled, so that each of the two new daughter cells will receive a complete set of chromosomes. For example, a cell that divides by mitosis in the human body must produce two cells with 46 chromosomes each, the same number of chromosomes that was present in the original parent cell. DNA duplicates during **interphase**, the stage in the life of a cell between one mitosis and the next. During this phase, DNA uncoils from its double-stranded form, and each strand takes on a matching strand of nucleotides according to the pattern of A-T, G-C pairing. There are now two strands, each identical to the original double helix. The strands are held together at a region called the *centromere* (SEN-tro-mere) until they separate during mitosis. A typical cell lives in interphase for most of its cycle and spends only a relatively short period in mitosis. For example, a cell reproducing every 20 hours spends only about 1 hour in mitosis and the rest of the time in interphase.

Checkpoint 3-10 What must happen to the DNA in a cell before mitosis can occur? During what stage in the life of a cell does this occur?

Stages of Mitosis

Although mitosis is a continuous process, distinct changes can be seen in the dividing cell at four stages (Fig. 3-9).

- In **prophase** (PRO-faze), the doubled strands of DNA return to their tightly wound spiral organization and

Box 3-2 Hot Topics

Proteomics: So Many Proteins, So Few Genes

To build the many different proteins that make up the body, cells rely on instructions encoded in genes on chromosomes. Collectively, all the different genes on all the chromosomes make up the **genome**. Genes contain the instructions for making proteins, while the proteins themselves perform the body's functions.

Scientists are now studying the human **proteome**—all the proteins that can be expressed in a cell—to help them understand the proteins' structure and function. Unlike the genome, the proteome changes as the cell's activities and needs change. In 2003, after a decade of intense scientific activity, investigators mapped the entire human genome and realized that it contained only 35,000 genes, far fewer than initially expected. How could this relatively small number of genes code for several million proteins? They concluded that genes were not the whole story.

Gene transcription is only the beginning of protein synthesis. In response to cell conditions, enzymes can snip newly transcribed mRNA into several pieces, each of which a ribosome can use to build a different protein. After each protein is built, enzymes can further modify the amino acid strands to produce several more different proteins. Other molecules help the newly formed proteins to fold into precise shapes and interact with each other, resulting in even more variations. Thus, while a gene may code for a specific protein, modifications after gene transcription can produce many more unique proteins. There is much left to discover about the proteome, but scientists hope that future research will lead to new techniques for detecting and treating disease.

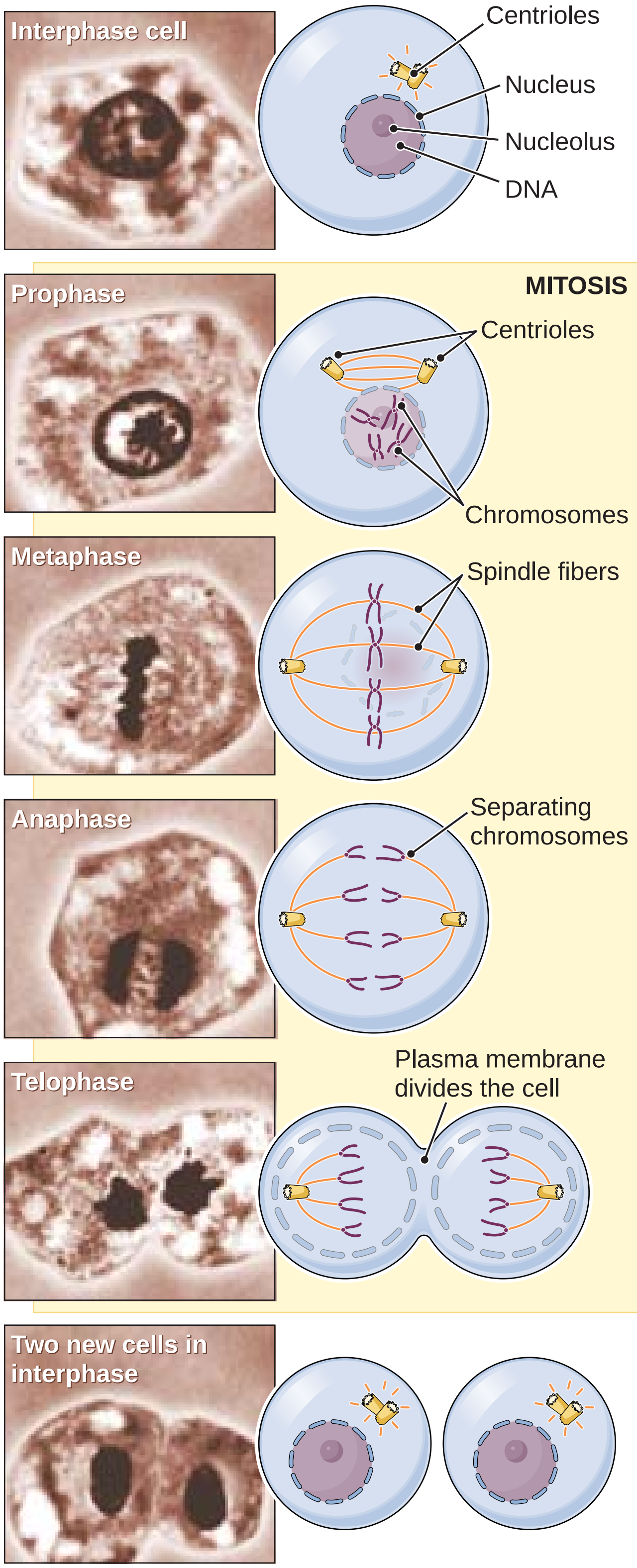


Figure 3-9 **The stages of mitosis.** When it is not dividing, the cell is in interphase. The cell shown is for illustration only. It is not a human cell, which has 46 chromosomes. (Photomicrographs reprinted with permission from Cormack DH. Essential Histology. 2nd ed. Philadelphia: Lippincott Williams & Wilkins, 2001.) *ZOOMING IN ◆ If the original cell shown has 46 chromosomes, how many chromosomes will each new daughter cell have?*

become visible under the microscope as dark, threadlike chromosomes. The nucleolus and the nuclear membrane begin to disappear. In the cytoplasm, the two centrioles move toward opposite ends of the cell and a spindle-shaped structure made of thin fibers begins to form between them.

- In **metaphase** (MET-ah-faze), the chromosomes line up across the center (equator) of the cell attached to the spindle fibers.
- In **anaphase** (AN-ah-faze), the centromere splits and the duplicated chromosomes separate and begin to move toward opposite ends of the cell.
- As mitosis continues into **telophase** (TEL-o-faze), a membrane appears around each group of separated chromosomes, forming two new nuclei.

Also during telophase, the plasma membrane pinches off to divide the cell. The midsection between the two areas becomes progressively smaller until, finally, the cell splits in two. There are now two new cells, or daughter cells, each with exactly the same kind and amount of DNA as was present in the parent cell. In just a few types of cells, skeletal muscle cells for example, the cell itself does not divide following nuclear division. The result, after multiple mitoses, is a giant single cell with multiple nuclei. This pattern is extremely rare in the human body.

During mitosis, all the organelles, except those needed for the division process, temporarily disappear. After the cell splits, these organelles reappear in each daughter cell. Also at this time, the centrioles usually duplicate in preparation for the next cell division.

Body cells differ in the rate at which they reproduce. Some, such as nerve cells and muscle cells, stop dividing at some point in development and are not replaced if they die. They remain in interphase. Others, such as blood cells, sperm cells, and skin cells, multiply rapidly to replace cells destroyed by injury, disease, or natural wear-and-tear. Cells that multiply slowly may be triggered to divide when tissue is injured, as in repair of a bone fracture.

Immature cells that retain the ability to divide and mature when necessary are known as **stem cells** (see Box 4-1 in Chapter 4). All blood cells, for example, are produced from stem cells in the red bone marrow. Research has been done on stimulating stem cells to divide into various cell types in the laboratory, but these studies have been controversial. Although it may be possible some day to use such cells to replace cells injured by disease, some people consider these studies to be unethical.

Checkpoint 3-11 What are the four stages of mitosis?

Movement of Substances Across the Plasma Membrane

The plasma membrane serves as a barrier between the cell and its environment. Nevertheless, nutrients, oxygen, and many other substances needed by the cell must be

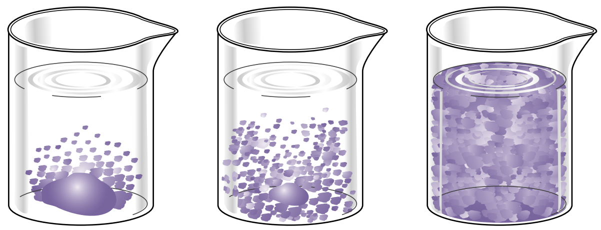


Figure 3-10 Diffusion of a solid in a liquid. The molecules of the solid tend to spread evenly throughout the liquid as they dissolve.

taken in and waste products must be eliminated. Clearly, some substances can be exchanged between the cell and its environment through the plasma membrane. For this reason, the plasma membrane is described at a simple level as **semipermeable** (sem-e-PER-me-ah-bl). It is permeable, or passable, to some molecules but impassable to others. Some particles, proteins for example, are too large to travel through the membrane unaided.

The ability of a substance to travel through the membrane is based on several factors. Molecular size is the main factor that determines passage through the membrane, but solubility and electrical charge are also considerations. Water, a tiny molecule, is usually able to penetrate the membrane with ease. Nutrients, however, must be split into small molecules by the process of digestion so that they can travel through the plasma membrane. Sucrose (table sugar), for example, is converted to glucose and fructose, smaller molecules that enter the cell and serve as sources of energy.

Various physical processes are involved in exchanges through the plasma membrane. One way of grouping these processes is according to whether they do or do not require cellular energy.

Movement That Does Not Require Cellular Energy

The adjective *passive* describes movement through the plasma membrane that does not require energy output by the cell. Passive mechanisms depend on the internal energy of the moving particles or the application of some outside source of energy. The methods include:

- **Diffusion** is the constant movement of particles from a region of relatively higher concentration to one of lower concentration. Just as couples on a crowded dance floor spread out into all the available space to avoid hitting other dancers, diffusing substances spread throughout their available space until their concentration everywhere is the same—that is, they reach equilibrium (Fig. 3-10). This movement from higher to lower concentrations uses the internal energy of the particles and does not require cellular energy, just as a sled will move from the top to the bottom of a snowy hill. The particles are said to follow their *concentration gradient* from higher concentration to lower concentration.

  When substances diffuse through a membrane, such as the intact plasma membrane, passage is limited to those particles small enough to pass through spaces between molecules in the membrane, as shown with a large-scale example in Figure 3-11. In the body, soluble materials, such as nutrients, electrolytes, gases, and waste materials, are constantly moving into or out of the cells by diffusion.
- **Osmosis** (os-MO-sis) is a special type of diffusion. The term applies specifically to the diffusion of water through a semipermeable membrane. The water molecules move, as expected, from an area where there are more of them to an area where there are fewer of them.

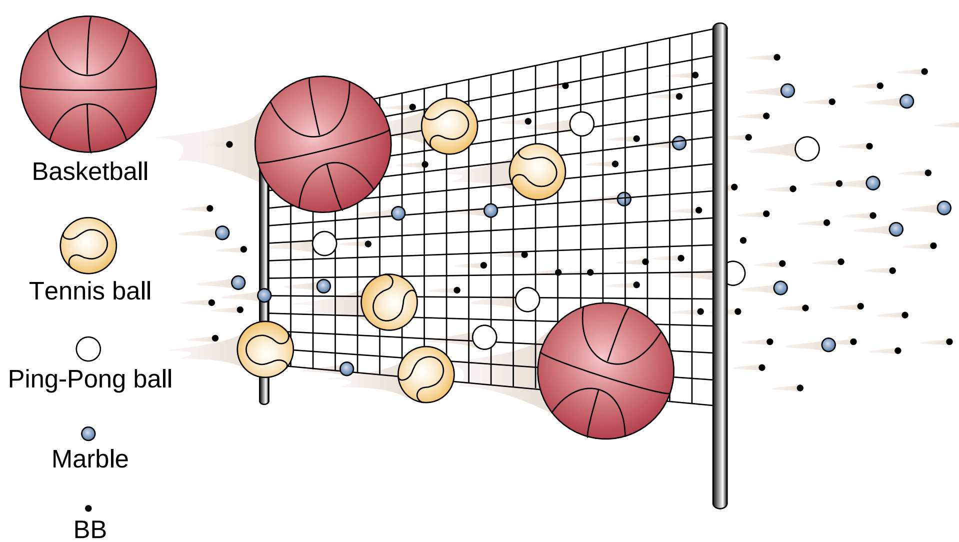


Figure 3-11 Diffusion through a semipermeable membrane. In this example, large objects (basketballs, tennis balls) cannot pass through the net, whereas the smaller ones (ping-pong balls, marbles, BBs) can. In the human body, large particles in the blood, such as proteins and blood cells, cannot pass through the walls of the capillaries, whereas small particles, such as nutrients, electrolytes, and gases can. *ZOOMING IN ❖ If this picture represented diffusion in the body, what would the net be?*

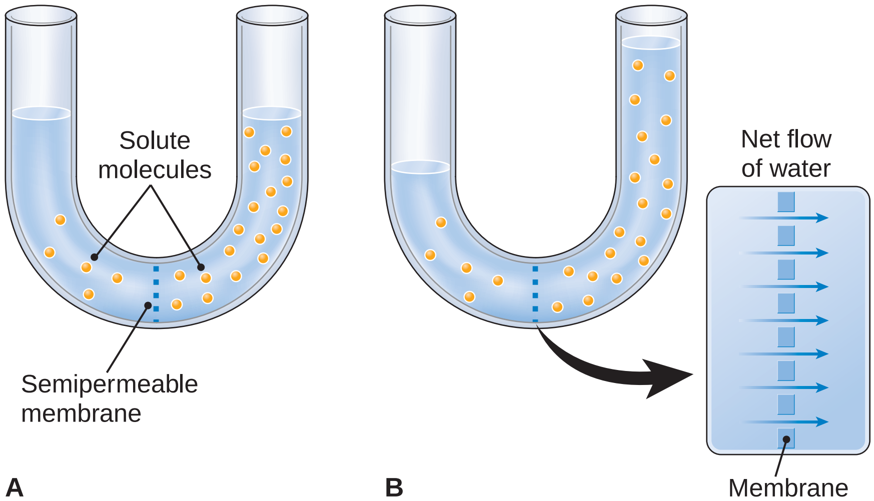


Figure 3-12 **A simple demonstration of osmosis.** Solute molecules are shown in yellow. All of the solvent (blue) is composed of water molecules. **(A)** Two solutions with different concentrations of solute are separated by a semipermeable membrane. Water can flow through the membrane, but the solute cannot. **(B)** Water flows into the more concentrated solution, raising the level of the liquid in that side. *ZOOMING IN ◆ What would happen in this system if the solute could pass through the membrane?*

That is, the solvent (the water molecules) moves from an area of lower *solute* concentration to an area of higher *solute* concentration (Fig. 3-12).

For a physiologist studying the flow of water across membranes, as in exchange of fluids through capillaries in the circulation, it is helpful to know the direction in which water will flow and at what rate it will move. A measure of the force driving osmosis is called the *osmotic pressure*. This force can be measured, as illustrated in Figure 3-13, by applying enough pressure to the surface of a liquid to stop the inward flow of water by osmosis. The pressure needed to counteract osmosis is the osmotic pressure. In practice, the term osmotic pressure is used to describe the tendency of a solution to draw water into it. This force is directly related to concentration: the higher the concentration of a solution, the greater is its tendency to draw water in.

- **Filtration** is the passage of water containing dissolved materials through a membrane as a result of a mechanical ("pushing") force on one side (Fig. 3-14). One example of filtration in the body is the movement of materials out of the capillaries and into the tissues under the force of blood pressure (see Chapter 15). Another example occurs in the kidneys as materials are filtered out of the blood in the first step of urine formation (see Chapter 22).
- **Facilitated diffusion** is the movement of materials across the plasma membrane in the direction of the concentration gradient (from higher to lower concentration) but using transporters to move the material at a faster rate (Fig. 3-15). Glucose, the sugar that is the main energy source for cells, moves through the plasma membrane by means of facilitated diffusion.

Movement That Requires Cellular Energy

Movement across the membrane that requires energy is describes as *active*. These methods include:

- **Active transport.** The plasma membrane has the ability to move small solute particles into or out of the cell opposite to the direction in which they would normally flow by diffusion. That is, the membrane moves them against the concentration gradient from an area where they are in relatively lower concentration to an area where they are in higher concentration. Because this

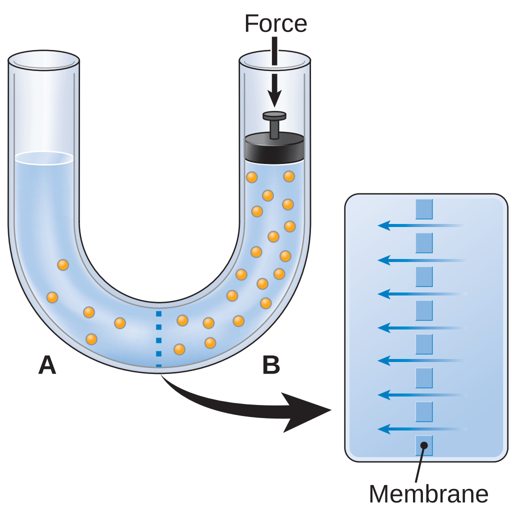


Figure 3-13 **Osmotic pressure.** Osmotic pressure is the force needed to stop the flow of water by osmosis. Pressure on the surface of the fluid in side B counteracts the osmotic flow of water from side A to side B. *ZOOMING IN ◆ What would happen to osmotic pressure if the concentration of solute were increased on side B of this system?*

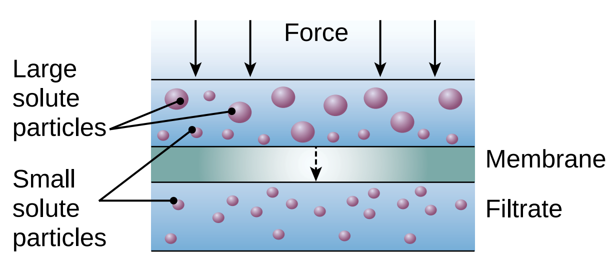


Figure 3-14 **Filtration.** A mechanical force pushes a substance through a membrane, although the membrane limits which particles can pass through based on size. The small particles go through the membrane and appear in the filtered solution (filtrate).

movement goes against the natural flow of particles, it requires energy, just as getting a sled to the top of a hill requires energy. It also requires proteins in the cell membrane that act as **transporters** for the particles.

This process of active transport is one important function of the living cell membrane. The nervous system and muscular system, for example, depend on the active transport of sodium, potassium, and calcium ions for proper function. The kidneys also carry out active transport in regulating the composition of urine. By means of active transport, the cell can take in what it needs from the surrounding fluids and remove materials from the cell. Because the cell membrane can carry on active transport, the membrane is most accurately described, not as simply semipermeable, but as **selectively permeable.** It regulates what can enter and leave based on the needs of the cell.

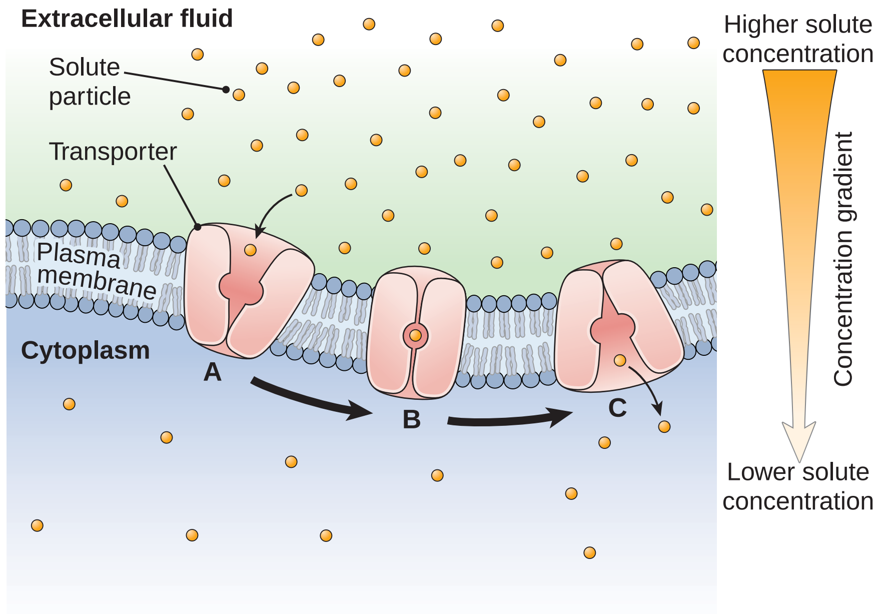


Figure 3-15 Facilitated diffusion. Transporters (proteins in the plasma membrane) move solute particles through a membrane from an area of higher concentration to an area of lower concentration. **(A)** A solute particle enters the transporter. **(B)** The transporter changes shape. **(C)** The transporter releases the solute particle on the other side of the membrane. *ZOOMING IN ✦ How would a change in the number of transporters affect the movement of a solute by facilitated diffusion?*

There are several active methods for moving large quantities of material into or out of the cell. These methods are grouped together as **bulk transport**, because of the amounts of material moved, or **vesicular transport**, because small bubbles, or vesicles, are needed for the processes.

- **Endocytosis** (en-do-si-TO-sis) is a term that describes the bulk movement of materials into the cell. There are two examples:

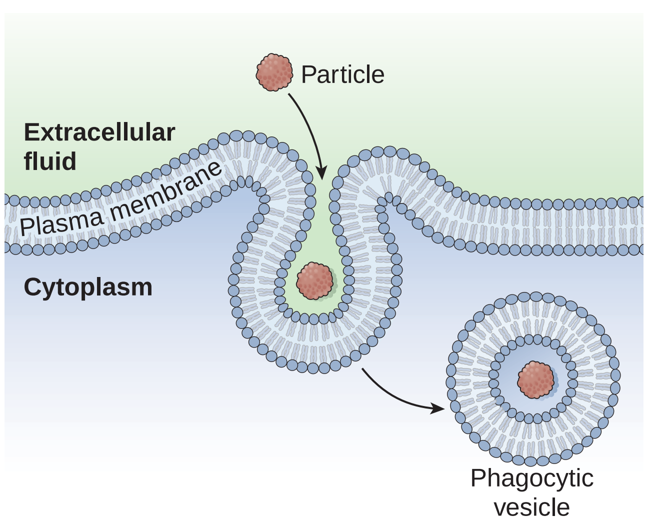


Figure 3-16 Phagocytosis. The plasma membrane encloses a particle from the extracellular fluid. The membrane then pinches off, forming a vesicle that carries the particle into the cytoplasm. *ZOOMING IN ✦ What organelle would likely help to destroy a particle taken in by phagocytosis?*

  - In **phagocytosis** (fag-o-si-TO-sis), relatively large particles are engulfed by the plasma membrane and moved into the cell (Fig. 3-16). Certain white blood cells carry out phagocytosis to rid the body of foreign material and dead cells. Material taken into a cell by phagocytosis is first enclosed in a vesicle made from the plasma membrane and is later destroyed by lysosomes.
  - In **pinocytosis** (pi-no-si-TO-sis), the cell membrane engulfs droplets of fluid. This is a way for large protein molecules in suspension to travel into the cell. The word *pinocytosis* means “cell drinking.”
- In **exocytosis**, the cell moves materials out in vesicles (Fig. 3-17). One example of exocytosis is the export of neurotransmitters from neurons (neurotransmitters are chemicals that control the activity of the nervous system).

The transport methods described above are summarized in Table 3-5.

Checkpoint 3-12 Substances are constantly moving into and out of cells through the plasma membrane. What types of movement do not require cellular energy and what types of movement do require cellular energy?

How Osmosis Affects Cells

As stated earlier, water usually moves easily through the cell membrane. Therefore, for a normal fluid balance to be maintained, the fluid outside all cells must have the

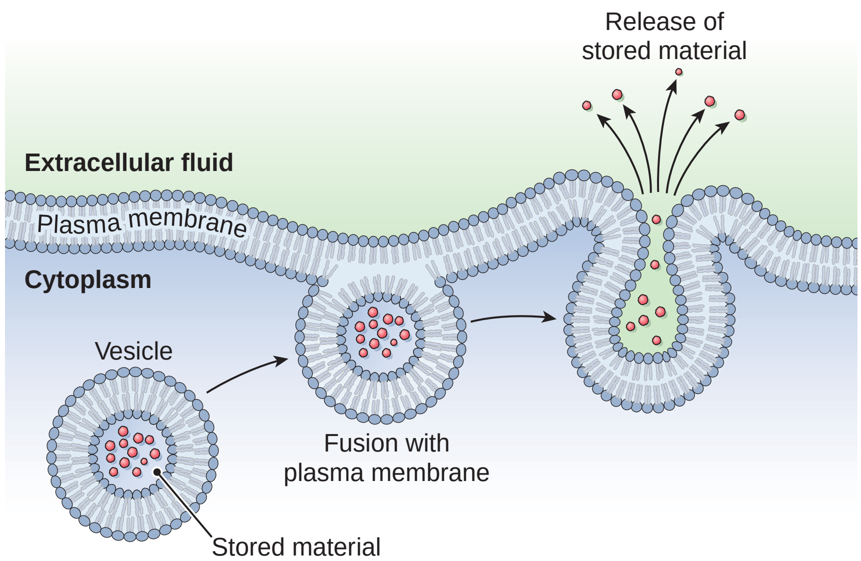


Figure 3-17 **Exocytosis.** A vesicle fuses with the plasma membrane then ruptures and releases its contents.

same concentration of dissolved substances (solutes) as the fluids inside the cells (Fig. 3-18). If not, water will move rapidly into or out of the cell by osmosis. Solutions with concentrations equal to the concentration of the cytoplasm are described as **isotonic** (i-so-TON-ik). Tissue fluids and blood plasma are isotonic for body cells. Manufactured solutions that are isotonic for the cells and can thus be used to replace body fluids include 0.9% salt, or **normal saline**, and 5% dextrose (glucose).

A solution that is less concentrated than the intracellular fluid is described as **hypotonic.** Based on the principles of osmosis already explained, a cell placed in a hypotonic solution draws water in, swells, and may burst. When a red blood cell draws in water and bursts in this way, the cell is said to undergo **hemolysis** (he-MOL-ih-sis). If a cell is placed in a **hypertonic** solution, which is more concentrated than the cellular fluid, it loses water to the surrounding fluids and shrinks, a process termed **crenation** (kre-NA-shun) (see Fig. 3-18).

Fluid balance is an important facet of homeostasis and must be properly regulated for health. You can figure out in which direction water will move through the plasma membrane if you remember the saying "water follows salt," salt meaning any dissolved material (solute). The total amount and distribution of body fluids is discussed in Chapter 21. Table 3-6 summarizes the effects of different solution concentrations on cells.

Checkpoint 3-13 The concentration of fluids in and around the cell is important in homeostasis. What term describes a fluid that is the same concentration as the fluid within the cell (intracellular fluid)? What type of fluid is less concentrated? More concentrated?

Table 3•5 Membrane Transport

PROCESS	DEFINITION	EXAMPLE
Do not require cellular energy (passive)		
Diffusion	Random movement of particles with the concentration gradient (from higher concentration to lower concentration) until they reach equilibrium	Movement of nutrients, electrolytes, gases, wastes, and other soluble materials into and out of the cell
Osmosis	Diffusion of water through a semipermeable membrane	Movement of water across the plasma membrane
Filtration	Movement of materials through a membrane under mechanical force	Movement of materials out of the blood under the force of blood pressure
Facilitated diffusion	Movement of materials across the plasma membrane along the concentration gradient using transporters to speed the process	Movement of glucose into the cells
Require cellular energy		
Active transport	Movement of materials through the plasma membrane against the concentration gradient using transporters	Transport of ions (*e.g.*, Na^+, K^+, Ca^{2+}) in the nervous system and muscular system
Endocytosis	Transport of bulk amounts of materials into the cell using vesicles	Phagocytosis, intake of large particles, as when white blood cells take in waste materials; also pinocytosis—intake of fluid
Exocytosis	Transport of bulk amounts of materials out of the cell using vesicles	Release of neurotransmitters from neurons

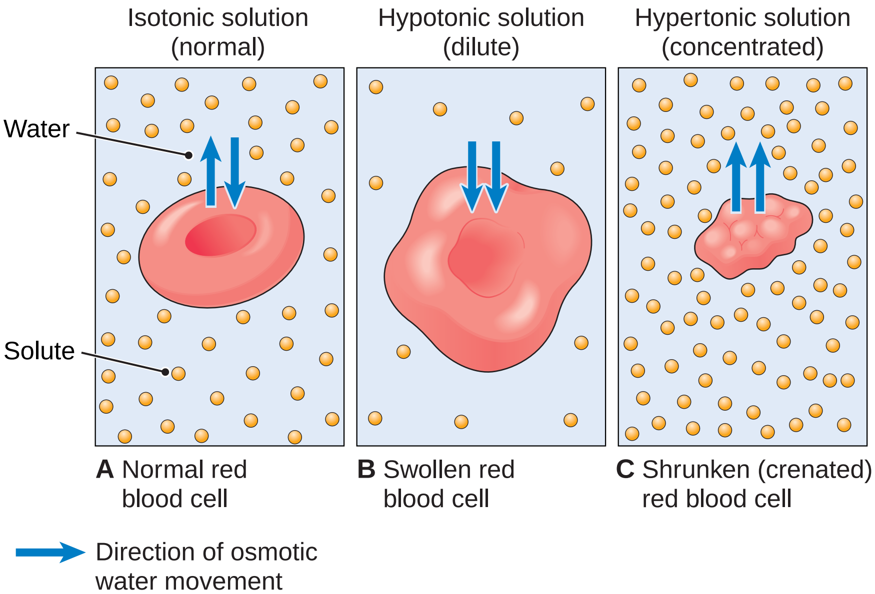


Figure 3-18 **The effect of osmosis on cells.** Water moves through a red blood cell membrane in solutions with three different concentrations of solute. **(A)** The isotonic (normal) solution has the same concentration as the cell fluid, and water moves into and out of the cell at the same rate. **(B)** A cell placed in a hypotonic (more dilute) solution draws water in, causing the cell to swell and perhaps undergo hemolysis (bursting). **(C)** The hypertonic (more concentrated) solution draws water out of the cell, causing it to shrink, an effect known as crenation. *ZOOMING IN ✦ What would happen to red blood cells if blood lost through injury were replaced with pure water?*

Cell Aging

As cells multiply throughout life, changes occur that may lead to their damage and death. Harmful substances known as *free radicals*, produced in the course of normal metabolism, can injure cells unless these materials are destroyed. Chapter 20 covers free radicals in more detail. Lysosomes may deteriorate as they age, releasing enzymes that can harm the cell. Alteration of the genes, or **mutations**, are a natural occurrence in the process of cell division and are increased by exposure to harmful substances and radiation in the environment. Mutations usually harm cells and may lead to cancer.

As a person ages, the overall activity of the body cells slows. One example of this change is the slowing down of repair processes. A bone fracture, for example, takes considerably longer to heal in an old person than in a young person.

One theory on aging holds that cells are preprogrammed to divide only a certain number of times before they die. Support for this idea comes from the fact that cells taken from a young person divide more times when grown in the laboratory than similar cells taken from an older individual. This programmed cell death, known as *apoptosis* (ah-pop-TO-sis), is a natural part of growth and remodeling before birth in the developing embryo and in repair and remodeling of tissue throughout life (see Box 3-3, Necrosis and Apoptosis: Cellular Homicide and Suicide).

Cells and Cancer

Certain mutations (changes) in the genetic material of a cell may cause that cell to reproduce without control. Cells that normally multiply at a fast rate, such as epithelial cells, are more likely than slower-growing cells to undergo such transformations. If these altered cells do not die naturally or get destroyed by the immune system, they will continue to multiply and may spread (metastasize) to

Table 3•6 Solutions and Their Effects on Cells

TYPE OF SOLUTION	DESCRIPTION	EXAMPLES	EFFECT ON CELLS
Isotonic	Has the same concentration of dissolved substances as the fluid in the cell	0.9% salt (normal saline); 5% dextrose (glucose)	None; cell in equilibrium with its environment
Hypotonic	Has a lower concentration of dissolved substances than the fluid in the cell	Less than 0.9% salt or 5% dextrose	Cell takes in water, swells, and may burst; red blood cell undergoes hemolysis
Hypertonic	Has a higher concentration of dissolved substances than the fluid in the cell	Higher than 0.9% salt or 5% dextrose	Cell will lose water and shrink; cell undergoes crenation

Box 3-3 A Closer Look

Necrosis and Apoptosis: Cellular Homicide and Suicide

Cell death happens in two ways: by necrosis, because the cell is injured; or by apoptosis, because the cell is programmed to die. One way of remembering the difference is to think of necrosis as "cellular homicide" and apoptosis as "cellular suicide."

Necrosis disrupts the cell's normal water-balancing mechanisms and stimulates autolysis (see Box 3-1). As a result, the cell swells and its organelles break down. Finally, the cell ruptures, releasing its contents into the surrounding tissue. These contents contain digestive enzymes that damage adjacent cells, producing more injury and necrosis.

Apoptosis is an orderly, genetically programmed cell death triggered by the cell's own genes. Under the right circumstances, these "suicide genes" produce enzymes called capsases that destroy the cell swiftly and neatly. The cell shrinks, and phagocytes quickly digest it. In contrast to necrosis, apoptotic cells do not cause further chaos when they die.

Apoptosis is a normal bodily process. It is especially important during embryonic development because it removes unneeded cells, such as those from limb buds to form fingers and toes. Apoptosis also occurs after birth, as when cells subject to extreme wear and tear regularly undergo apoptosis and are replaced. For example, the cells lining the digestive tract are removed and replaced every 2 to 3 days.

other tissues, producing **cancer.** Cancer cells form tumors, which interfere with normal functions, crowding out normal cells and robbing them of nutrients. There is more information on the various types of tumors in Chapter 4.

Cancer Risk Factors

The causes of cancer are complex, involving interactions between cellular factors and the environment. Because cancer may take a long time to develop, it is often difficult to identify its cause or causes. Certain forces increase the chances of developing the disease and are considered risk factors. These include the following:

- **Heredity.** Certain types of cancer occur more frequently in some families than in others, indicating that there is some inherited predisposition to the development of cancer.
- **Chemicals.** Certain industrial and environmental chemicals are known to increase the risk of cancer. Any chemical that causes cancer is called a **carcinogen** (kar-SIN-o-jen). The most common carcinogens in our society are those present in cigarette smoke. Carcinogens are also present, both naturally and as additives, in foods. Certain drugs also may be carcinogenic.
- **Ionizing radiation.** Certain types of radiation can produce damage to cellular DNA that may lead to cancer. These include x-rays, rays from radioactive substances, and ultraviolet rays. For example, the ultraviolet rays received from exposure to the sun are very harmful to the skin.
- **Physical irritation.** Continued irritation, such as the contact of a hot pipe stem on the lip, increases cell division and thus increases the chance of mutation.
- **Diet.** It has been shown that diets high in fats and total calories are associated with an increased occurrence of certain forms of cancer. A general lack of fiber and insufficient amounts of certain fruits and vegetables in the diet can leave one susceptible to cancers of the digestive tract.
- **Viruses** have been implicated in cancers of the liver, the blood (leukemias), and lymphatic tissues (lymphomas).

Word Anatomy

Medical terms are built from standardized word parts (prefixes, roots, and suffixes). Learning the meanings of these parts can help you remember words and interpret unfamiliar terms.

WORD PART	MEANING	EXAMPLE
The Role of Cells		
cyt/o	cell	*Cytology* is the study of cells.
Microscopes		
micr/o	small	*Microscopes* are used to view structures too small to see with the naked eye.
Cell Structure		
bi-	two	The lipid *bilayer* is a double layer of lipid molecules.
-some	body	*Ribosomes* are small bodies outside the cell's nucleus that help make proteins.
chrom/o-	color	*Chromosomes* are small, threadlike bodies that stain darkly with basic dyes.

WORD PART	MEANING	EXAMPLE
Cell Structure		
end/o-	in, within	The *endoplasmic* reticulum is a network of membranes within the cytoplasm.
lys/o	loosening, dissolving, separating	*Lysosomes* are small bodies (organelles) with enzymes that dissolve materials (see also *hemolysis*).
Cell Functions		
inter-	between	*Interphase* is the stage between one cell division (mitosis) and the next.
pro-	before, in front of	*Prophase* is the first stage of mitosis.
meta-	change	*Metaphase* is the second stage of mitosis when the chromosomes change position and line up across the equator.
ana-	upward, back, again	In the *anaphase* stage of mitosis, chromosomes move to opposite sides of the cell.
tel/o-	end	*Telophase* is the last stage of mitosis.
semi-	partial, half	A *semipermeable* membrane lets some molecules pass through but not others.
phag/o	to eat, ingest	In *phagocytosis* the cell membrane engulfs large particles and moves them into the cell.
pino	to drink	In *pinocytosis* the cell membrane "drinks" (engulfs) droplets of fluid.
ex/o-	outside, out of, away from	In *exocytosis* the cell moves material out in vesicles.
iso-	same, equal	An *isotonic* solution has the same concentration as that of the cytoplasm.
hypo-	deficient, below, beneath	A *hypotonic* solution's concentration is lower than that of the cytoplasm.
hem/o	blood	*Hemolysis* is the destruction of red blood cells.
hyper-	above, over, excessive	A *hypertonic* solution's concentration is higher than that of the cytoplasm.
Cells and Cancer		
carcin/o	cancer, carcinoma	A *carcinogen* is a chemical that causes cancer.
-gen	agent that produces or originates	See preceding example.

Summary

I. The Role of Cells

1. Basic unit of life
2. Show all characteristics of life—organization, metabolism, responsiveness, homeostasis, growth, reproduction

II. Microscopes

A. Types
  1. Compound light microscope
  2. Transmission electron microscope—magnifies up to 1 million times
  3. Scanning electron microscope—gives three-dimensional image

B. Micrometer—metric unit commonly used for microscopic measurements

C. Stains—dyes used to aid in viewing cells under the microscope

III. Cell Structure

A. Plasma membrane—regulates what enters and leaves cell
  1. Phospholipid bilayer with proteins, carbohydrates, cholesterol
    a. Proteins—channels, transporters, receptors, enzymes, linkers, cell identity markers

B. Nucleus
  1. Control center of the cell
  2. Contains the chromosomes (units of heredity)
  3. Contains the nucleolus, which manufactures ribosomes

C. Cytoplasm—colloidal suspension that holds organelles
  1. Cytosol—liquid portion
  2. Organelles—structures that carry out special functions
    a. ER (endoplasmic reticulum), ribosomes, mitochondria, Golgi apparatus, lysosomes, peroxisomes, vesicles, centrioles
    b. Cilia, flagellum—surface organelles used for movement

IV. Protein synthesis

A. Nucleic acids—DNA and RNA
  1. Composed of nucleotides
    a. Each nucleotide has sugar, phosphate, nitrogen base
    b. Nitrogen bases vary, giving five nucleotides
  2. DNA
    a. Carries the genetic message
    b. Located almost entirely in the nucleus
    c. Composed of nucleotides adenine (A), guanine (G), cytosine (C), thymine (T)
    d. Double stranded by pairing of A-T, G-C, and wound into helix
  3. The role of RNA
    a. Single strand of nucleotides—A, G, C, and uracil (U)
    b. Located in the cytoplasm
    c. Translates DNA message into proteins
    d. Three types
      (1) Messenger RNA (mRNA)—transcribes the message of the DNA
      (2) Ribosomal RNA (rRNA)—makes up the ribosomes, the site of protein synthesis
      (3) Transfer RNA (tRNA)—brings amino acids to be made into proteins

V. Cell division

1. Meiosis—forms the sex cells (egg and sperm)
   a. Divides the chromosome number in half
2. Mitosis—division of somatic (body) cells
   a. Chromosomes first duplicate during interphase
   b. Division of cell into two identical daughter cells

A. Stages of mitosis—prophase, metaphase, anaphase, telophase

VI. Movement of substances across plasma membrane

A. Movement that does not require cellular energy (passive)
1. Diffusion—molecules move from area of higher concentration to area of lower concentration
2. Osmosis—diffusion of water through semipermeable membrane
   a. Osmotic pressure—measure of tendency of a solution to draw in water
3. Filtration—movement of materials through plasma membrane under mechanical force
4. Facilitated diffusion—movement of materials with aid of transporters in plasma membrane

B. Movement that requires cellular energy (active)
1. Active transport
   a. Movement of solute particles from area of lower concentration to area of higher concentration
   b. Requires transporters
2. Endocytosis—movement of bulk amounts of material into the cell in vesicles
   a. Phagocytosis—engulfing of large particles
   b. Pinocytosis—intake of droplets of fluid
3. Exocytosis—movement of bulk amounts of materials out of the cell in vesicles

C. How osmosis affects cells
1. Isotonic solution—same concentration as cell fluids; cell remains the same
2. Hypotonic solution—lower concentration than cell fluids; cell swells and may undergo hemolysis (bursting)
3. Hypertonic solution—higher concentration than cell fluids; cell undergoes crenation (shrinking)

VII. Cell aging

1. Mutations (changes) occur in genes
2. Slowing of cellular activity
3. Apoptosis—programmed cell death

VIII. Cells and cancer

1. Cancer
   a. Uncontrolled growth of cells
   b. Spread (metastasize) to other tissues

A. Cancer risk factors
1. Heredity
2. Chemicals—carcinogens
3. Ionizing radiation
4. Physical irritation
5. Diet
6. Viruses

Questions for Study and Review

Building Understanding

Fill in the blanks

1. The part of the cell that regulates what can enter or leave is the _____.
2. Distinct segments of DNA that code for specific proteins are called _____.
3. The cytosol and organelles make up the _____.
4. If Solution A has more solute and less water than Solution B, then Solution A is _____ to Solution B.
5. Mechanisms that require energy to move substances across the plasma membrane are called _____ transport mechanisms.

Matching

Match each numbered item with the most closely related lettered item.

___6. DNA duplication takes place
___7. DNA is tightly wound into chromosomes
___8. Chromosomes line up along the cell's equator
___9. Chromosomes separate and move toward opposite ends of the cell
___10. Cell membrane pinches off, dividing the cell into two new daughter cells

a. metaphase
b. anaphase
c. telophase
d. interphase
e. prophase

Multiple choice

___ 11. The main component of the plasma membrane is
   a. phospholipid
   b. cholesterol
   c. carbohydrate
   d. protein

___ 12. ATP is synthesized in the
a. nucleus
b. Golgi apparatus
c. endoplasmic reticulum
d. mitochondria

___ 13. Transcription of the DNA strand TGAAC would produce an mRNA strand with the sequence
a. CAGGU
b. ACTTG
c. CAGGT
d. ACUUG

___ 14. Somatic cells divide by the process called
a. mitosis
b. meiosis
c. crenation
d. hemolysis

___ 15. Movement of solute from a region of high concentration to one of lower concentration is called
a. exocytosis
b. diffusion
c. endocytosis
d. osmosis

Understanding Concepts

16. List the components of the plasma membrane and state a function for each.

17. Compare and contrast the following cellular components:
a. microvilli and cilia
b. nucleus and nucleolus
c. rough ER and smooth ER
d. lysosome and peroxisome
e. DNA and RNA
f. chromosome and gene

18. Describe the role of each of the following in protein synthesis: DNA, nucleotide, RNA, ribosomes, rough ER, and Golgi apparatus.

19. List and define six methods by which materials cross the cell membrane. Which of these requires cellular energy?

20. Why is the cell membrane described as selectively permeable?

21. What will happen to a red blood cell placed in a 5.0% salt solution? In distilled water?

22. Discuss the link between genetic mutation and cancer. List six risk factors associated with cancer.

Conceptual Thinking

23. Cigarette smoke paralyzes the cilia of cells lining the respiratory tract. Explain the effects of this on respiratory system function.

24. A particular type of cell manufactures a protein needed elsewhere in the body. Beginning with events in the nucleus, describe the process of making that protein and exporting it out of the cell.

25. Kidney failure causes a buildup of waste and water in the blood. A procedure called hemodialysis removes these substances from the blood. During this procedure, the patient's blood passes by a semipermeable membrane within the dialysis machine. Waste and water from the blood diffuses across the membrane into dialysis fluid on the other side. Based on this information, compare the osmotic concentration of the blood with that of the dialysis fluid.