Biochemistry and Microbiology

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Biochemistry and Microbiology

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Objective Sheet

SPECIFIC OBJECTIVES

After completing this module, you should be able to:

1. Define the terms **biochemistry** and **microbiology.**
2. Discuss the role of chemistry in human health.
3. Define the term **homeostasis.**
4. Define the term **element.**
5. Define the term **atom.**
6. Label the parts of an atom.
7. Define the term **molecule.**
8. Distinguish among the terms **compound, mixture,** and **solution.**
9. Describe the primary role of each of the principal elements and compounds in the body.
10. Complete statements that describe the chemical reactions that take place in the body.
11. State the functions of the major types of organic compounds in the body.
12. Match components of the major types of organic compounds in the body to their characteristics.
13. Complete statements that describe the major elements and compounds that compose the body.
14. Define types of solutions.
15. Define the major types of fluid in the body.
16. Define the term **electrolyte.**
17. Discuss the role of electrolytes in human health.
18. Select true statements concerning the role of acids and bases in human health.
19. Define the term **metabolism.**
20. Complete statements that describe the use of energy by the body.
21. Complete statements that describe the characteristics of body temperature.
22. State definitions of the basic activities that define life.

23. State the cell theory.
24. Match the compounds found in protoplasm to their functions.
25. Define the principal types of protoplasm.
26. Label the major parts of a cell.
27. Match the major parts of a cell to their functions.
28. Describe the major parts of a cell nucleus.
29. Describe the specialized structures in cells.
30. State the functions of the specialized structures in cells.
31. List the functions of a cell.
32. Define the term **transport.**
33. Distinguish between the terms **active transport** and **passive transport.**
34. Match types of passive transport to their descriptions.
35. Match types of active transport to their descriptions.
36. Complete statements that describe the process of cell growth.
37. Distinguish between the types of cell reproduction.
38. Describe the process in which the genetic makeup of a cell can be changed.
39. List the sources of mutation-causing conditions.
40. Match the types of cellular respiration to their descriptions.
41. Arrange in order the levels in the taxonomy system used to classify organisms.
42. Match the types of relationships between organisms to their descriptions.
43. Match classes of microorganisms to their descriptions.
44. Label the classes of microorganisms as classified by their shape.
45. Define the terms **resident flora** and **transient flora.**
46. Describe the purpose of a gram stain.
47. Complete statements that describe the characteristics of bacteria.
48. Complete statements that describe the characteristics of rickettsiae.
49. Complete statements that describe the characteristics of viruses.

50. Complete statements that describe the characteristics of protozoa.

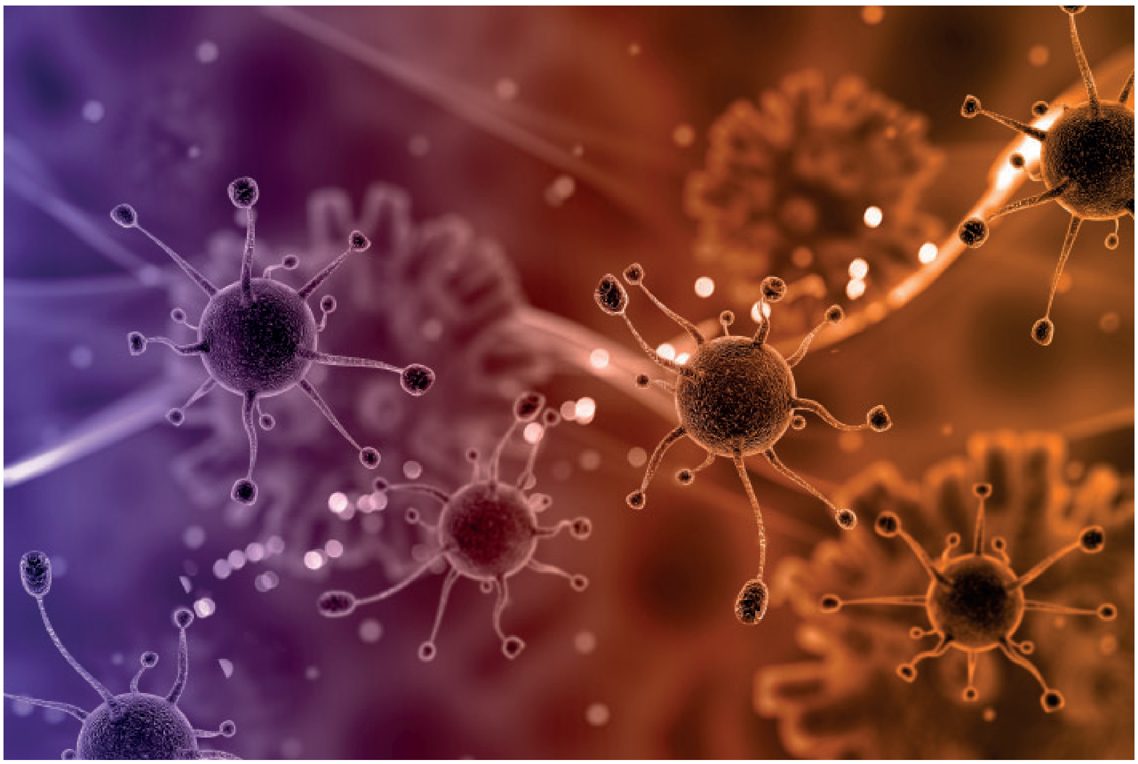
51. Distinguish between fungi and algae.

52. Complete statements that describe common parasites that afflict humans.

53. Construct a model of a typical cell. (Assignment Sheet 1)

54. Develop a presentation on bacteria, viruses, fungi, or parasites. (Assignment Sheet 2)

55. Practice critical thinking: complete biochemistry and microbiology case studies. (Assignment Sheet 3)



Information Sheet

OBJECTIVE 1 **The terms biochemistry and microbiology**

KEY TERMS

Energy (en´-uhr-je)—The capacity to do work

✔ **Note:** The definition presented here is the classic scientific definition of the term **energy.** Work can be understood as a force that can bring about change in matter or other types of energy. That force may change the shape or the state of the matter, such as bending a bar or melting ice. Energy is classed as kinetic (energy in motion) or potential (stored energy). There are also several forms of energy, including light, sound, heat, mechanical, chemical, electrical, and radiation. All of these forms are involved in the functioning of the body and its care through medical practices. For example, there is stored chemical energy in the food we eat. The body converts that stored energy into heat energy, which can help the functioning of the body.

Matter (mat´-uhr)—That portion of the universe that has shape and substance

a. Biochemistry—The study of chemistry as it relates to life

✔ **Note:** Everything in the universe exists as either **matter** or **energy**. Another name for matter is **chemicals,** and the study of what matter is made of is called **chemistry.** The study of chemistry as it relates to life is referred to as **biological chemistry** or simply **biochemistry.** The two basic functions of chemicals in the body are to provide structure to the body and to provide a source of energy to support life.

b. Microbiology—The study of extremely small life

✔ **Note:** **Bio-** is a prefix that means **life,** and **biology** is the study of life. Another prefix is **micro-,** which means **extremely small.** Thus, **microbiology** is the study of extremely small life. In this module, you will study the chemical nature of life and will consider the smallest building blocks of life—from chemicals to the cells that those chemicals form and support.

OBJECTIVE 2 **Role of chemistry in human health**

KEY TERMS

Chemical reaction (kem´-i-kuhl re-ak´-shuhn)—A process in which one or more chemicals that are exposed to other chemicals or sources of energy such as heat change their chemical composition to produce other chemicals and often other forms of energy

Gas (gas´)—A state of matter in which the substance will take on the shape of any container in which it is placed and will expand to fill the container

Liquid (lik´-wuhd)—A state of matter in which the substance will take on the shape of a container but will not expand to fill a container with greater volume than the substance

Nutrient (nu´-tre-uhnt)—A substance that can be processed by the digestive system and used by the cells to produce energy or build tissue

Respiration (res-puh-ra´-shuhn)—The physical and chemical processes by which an organism supplies its cells and tissues with oxygen and removes carbon dioxide

Solid (sawl´-uhd)—A state of matter in which the substance has a definite shape that is maintained unless acted upon by a force that is capable of changing that shape

a. The body consists of various chemicals.

✔ **Note:** The major chemicals of the body are oxygen (65 percent), carbon (19 percent), hydrogen (10 percent), and nitrogen (3 percent). Water, which makes up almost three-fourths of a person's body weight, consists of oxygen and hydrogen. Matter exists in three primary forms: **liquids**, **gases**, and **solids**. Chemicals are found in the body in all three forms. Bones and muscle are primarily solids. Blood and saliva are liquids. The air in the lungs and throughout the cavities in the body consists of gases.

b. Most body activities involve **chemical reactions.**

✔ **Note:** The basic chemical reaction in the body is referred to as **cell respiration.** In cell respiration, the chemical glucose, a sugar found in many foods, combines with oxygen that has been breathed into the lungs and carried to the cells by the blood system. The reaction between these two chemicals produces the chemicals carbon dioxide, water, and adenosine triphosphate (ATP), as well as heat. Carbon dioxide is carried in the bloodstream to the lungs and breathed out, while the water is used in various ways, including to help maintain the structure and chemical balance of the cells. ATP provides energy for other chemical reactions within the cell. The heat helps to warm the body and improves the efficiency of some chemical reactions.

c. For a person to remain healthy, the chemicals within the body must remain properly balanced.

- **Note:** Chemical imbalances can occur for a number of reasons related to the chemicals we take into the body or how those chemicals are processed internally. We obtain vitamins and minerals from the foods we eat. If a person's diet does not contain sufficient amounts of these vitamins and minerals, his or her health can be affected. For example, a person may not get enough iron in the diet. Iron is essential to healthy blood, and iron deficiency can lead to a condition in which the blood is not able to carry oxygen and **nutrients** effectively. On the other hand, a person who has sufficient iron intake may suffer the same condition if the iron cannot be digested and absorbed through the walls of the stomach and intestines.

d. The body also produces special chemicals that regulate body functions.

- **Note:** The organs and glands of the body produce various chemicals used to carry out body functions. Some specialized chemicals called **hormones** have specific roles in controlling growth, reproduction, and overall health. In some instances, the body may produce too much of a chemical, such as excessive digestive-fluid production, which can lead to holes called **ulcers** in the digestive tract.

e. Chemicals entering the body from the external environment can affect the balance of chemicals within the body and can disrupt normal physiological chemical reactions.

- **Note:** Chemicals enter the body through the nose, mouth, and other openings; through breaks in the skin; and through the skin itself. In some cases, it is important to have chemicals enter the body, such as when oxygen enters the body during breathing. However, a person may also breathe in harmful chemicals. The harm that such chemicals cause is generally the result of disrupting normal functions. For example, a person may inhale carbon monoxide if sitting in a parked car while it is running. Carbon monoxide readily attaches to the red blood cells that normally carry oxygen throughout the body. If the red blood cells are loaded with carbon monoxide, they cannot accept oxygen as they pass through the lungs. If enough carbon monoxide enters the bloodstream so that there is not adequate oxygen getting to the brain and other vital organs, eventually the person affected will lose consciousness and even die if not removed from the source of the carbon monoxide. Another way in which a person can be adversely affected by chemicals occurs when organisms such as harmful viruses enter the body. These organisms may produce chemicals called **toxins** that disrupt body functions.

f. Injuries and diseases can change the chemical balance within the body and can disrupt chemical reactions.

- **Note:** Injuries and diseases can affect the body's abilities to produce chemicals internally or to process chemicals taken in from external sources. For example, diabetes is a family of conditions that affect the body's ability to convert glucose to energy and other chemicals.

Objective 3 **The term homeostasis**

Homeostasis (ho-me-o-sta´-suhs)—The state of the body in which conditions remain relatively stable despite changes in the environment

- **Note:** Basically, the human body is a chemical engine. Humans place chemicals (food) in the body and subject those substances to chemicals within the body to create chemical reactions. One's health depends on providing the body with the proper amounts and types of chemical and the body's ability to properly process those chemicals. One aspect of chemical processing within the body is responding to changes in the environment in order to maintain health. For example, the human body functions best at a temperature between approximately 97°F and 99°F (36°C and 38°C). If the temperature of the outside environment drops, the body will increase its production of energy and reduce blood circulation in the extremities to ensure adequate warmth for the vital organs. On a hot day, the body will sweat more, which removes heat from the body and increases cooling of the skin due to the evaporation of the perspiration. These and other reactions to changes in the external and internal environment of the body help to maintain homeostasis.

Objective 4 **The term element**

Element—One of more than 100 primary, simple substances that cannot be broken down by chemical means into any other substance

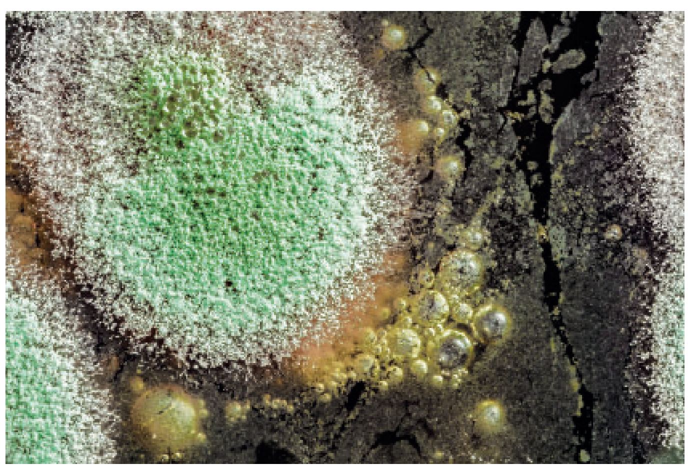
Objective 5 **The term atom**

Key Term

Atomic (uh-tawm´-ik) **number**—The number of protons, or positive charges, in the nucleus of an atom of a particular element

Atom—The smallest division of an element that exhibits all the properties and characteristics of the element

- **Note:** All matter is made up of three smaller particles: neutrons, electrons, and protons (see Objective 6). The number of protons in the nucleus of an atom determines the **atomic number** of the element.



Objective 6

Parts of an atom

Key Term

Bond (bawnd´)—The mechanism by which atoms link to one another to form molecules involving the loss of, gaining of, or sharing of electrons in the outer shell

✔ **Note:** There are three types of chemical bonds among atoms. In an **ionic bond**, an atom gives up one or more electrons to another atom. This results in the atom having more protons than electrons, giving it a positive charge. The atom that gains electrons has more electrons than protons, meaning that the atom has a negative charge. The difference in charges holds the atoms together. In what is called **covalent bonding**, an atom that does not have an outer shell that is filled to its full capacity with electrons can share electrons with one or more other atoms. Finally, hydrogen is the smallest atom with only one proton and one electron. When hydrogen shares its electron with another atom, it causes a slightly positive charge in the atom, making it particularly attractive to oxygen and nitrogen atoms, which are slightly negative. This special attraction is referred to as **hydrogen bonding**. Hydrogen bonds are especially important in the human body because hydrogen bonds help hold water molecules together, as well as many of the proteins that are essential to body structure and functioning.

✔ **Note:** All matter is made of particles called **atoms.** Atoms, in turn, consist of three smaller particles (see Figure 1). In the center of the atom, termed the **nucleus**, are **protons** and **neutrons**. The third particle is called an **electron.** Electrons go around the nucleus in orbits, with each electron following a separate path. The atoms of different materials differ in the number of each type of particle they contain. Generally, there is an equal number of electrons, protons, and neutrons in an atom. For example, a hydrogen atom contains one of each of the particles, while an oxygen atom consists of eight electrons, protons, and neutrons each. As the number of electrons increases, the additional groups of orbits that are required are found at greater distances from the nucleus. All the orbits that are at an equal distance from the nucleus are referred to as a **shell.** Each shell is capable of supporting a specific number of electrons. The electrons in the outer shell can be shared with other atoms to form **bonds**. Atoms that bond to each other form structures called **molecules** (see Objective 7).

a. Electron (i-lek´-trawn)—A negatively charged elementary particle of an atom

b. Neutron (nu´-trawn)—An elementary particle that is a fundamental component of the nucleus of atoms; it has no electric charge

c. Nucleus (nu´-kle-uhs)—The structure in the center of an atom consisting of protons and neutrons and about which electrons orbit

✔ **Note:** The nucleus of each element is unique to that substance. Hydrogen is the smallest atom, with one neutron and one proton in its nucleus. Helium has two neutrons and two protons. This progression continues through the natural elements up to uranium with 92 neutrons and protons. The number of protons and neutrons is used to identify each element and is called its **atomic number**. Two of the more-common elements in the body, along with hydrogen, are carbon, with an atomic number of 6, and oxygen, with an atomic number of 8.

d. Proton (pro´-tawn)—A positively charged particle that is a fundamental component of the nucleus of atoms

e. Shell (shel´)—The set of electron orbits in an atom that have the same energy level

✔ **Note:** The innermost shell of atoms can hold up to two electrons. Thus, hydrogen and helium have one shell. The second shell or energy level consists of electrons with orbits that are farther from the nucleus than the innermost shell. The second shell can have as many as eight electrons, which means that the elements up to atomic number 10 (neon) have only two shells. Additional shells hold eight electrons or up to a multiple of eight electrons.

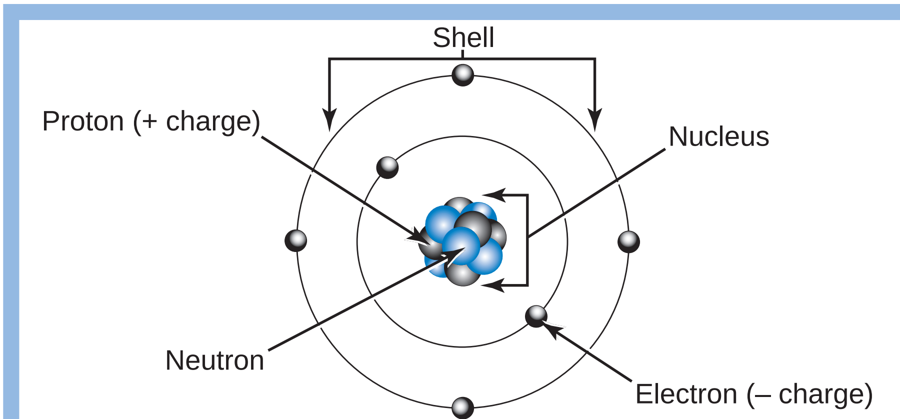


Figure 1
Parts of an atom

Objective 7

The term molecule

Molecule—A structure consisting of two or more atoms

✔ **Note:** A molecule may consist of atoms of the same element or atoms of two or more different elements. For example, oxygen in the air is often present as molecules of two atoms, which is written using the symbol for oxygen (O) and a subscript 2 to show that there are two atoms: O_2. Water is a compound, and its molecules consist of two hydrogen (H) atoms and one oxygen atom, represented symbolically as H_2O.

Objective 8 The terms compound, mixture, and solution

Key Terms

Catalyst (kat´-uhl-uhst)—A substance that affects the rate of change in a chemical reaction without being changed chemically

- **Note:** Generally, a catalyst will cause a reaction to begin or will cause the reaction to proceed at a faster rate. However, the catalyst itself is not affected by the reaction. As stated in the previous note, energy can have a catalytic effect, such as stirring sugar into a solution or heating the solution to increase the amount of sugar that will dissolve. Time, pressure, light, and other factors may also affect the efficiency of a chemical reaction.

Centrifuge (sen´-truh-fyuj)—A device that is used to separate the components of a solution or liquid mixture by spinning the substance

- **Note:** One of the laws of physics deals with centrifugal force. Basically, this law is a variation on the law of inertia, which states, in part, that an object in motion tends to continue in motion in a straight line unless acted upon by another force. When an object is spun in a circle, it tries to move in a straight line, but it is forced to follow a curved path. If the object is spinning fast enough, any substance that is free to move within the object will move toward the outside of the circular path. This explains why water will remain in a bucket if you swing the bucket over your head. The heavier the freely moving substance is, the quicker it will move toward the outside of the circular path. This principle can be used in medicine to separate the substances in a liquid, such as the cells in blood. A centrifuge is used to accomplish this separation.

Concentration (kawn-sen-tra´-shuhn)—The ratio of the components of a solution or mixture

- **Note:** Assume that a certain medication is to be mixed with an equal amount of water before being provided to the patient, using 0.5 liter of medicine and 0.5 liter of water. The resulting solution would be half water and half medicine. It could then be referred to as a 50 percent solution of medicine (or water). Solutions are often referred to as **percentages**. Thus, a 1 percent saline solution would be 99 percent water and 1 percent salt. Generally, these percentages refer to the volume of the substances in solution though occasionally measurements are made as weight. Also, concentrations are sometimes given as ratios rather than as percentages. The 50 percent solution of medicine described earlier can also be referred to as a 1:1 ratio, meaning that for one measure of medicine there is one measure of water.

Saturation point (sach-uh-ra´-shuhn point´)—The concentration level of a solution above which no more of a substance will dissolve

- **Note:** If one continues to add a **solute**—the substance being dissolved—to a liquid, at some point there will be more solute than the liquid can dissolve. This is called the **saturation point**. The saturation point can be changed through the use of catalysts, heat, stirring, and in other ways. One can also add more **solvent**—the liquid—but this does not actually change the saturation point if all other conditions remain the same. It simply lowers the concentration of solute, allowing more to be added if desired.

✔ **Note:** When substances are put together, they form relationships that may or may not involve a chemical reaction between them. A chemical reaction (see Objective 10) results in a change in the reacting chemicals. For example, in a reaction between two compounds, the atoms may be rearranged to form one or more other compounds or they may simply break into the elements that make up the original compounds. In other instances, nothing chemical happens between substances that are mixed together. Whether a reaction takes place depends on a number of factors—most importantly, the chemicals involved and the presence or absence of **catalysts**.

a. Compound—A substance that consists of atoms of two or more different elements bonded together as molecules; to separate its components into other compounds and elements requires a chemical reaction

b. Mixture—A substance that consists of two or more combined components that do not interact chemically; to separate its components requires either a mechanical method or the application of energy

   ✔ **Note:** Numerous methods exist for separating mixtures, many of which are applied to medical procedures. One method of separating mixtures in which the substances are different sizes is filtration in which the mixture is forced through a material that allows smaller substances to pass through while preventing the passage of larger particles. Blood, urine, and other body fluids are sometimes filtered to remove impurities or certain components. In some cases, energy is used to separate the substances. For example, a mixture may be spun in a **centrifuge** to separate substances based on their mass (weight). An electrical charge can be used to remove negative or positive ions.

c. Solution—A substance that consists of one or more components dissolved in a liquid; to separate its components, the energy of the substance must change so that the energy balance between the components prevents the liquid from being able to hold the dissolved material

   ✔ **Note:** Whether a substance will dissolve in a liquid depends on a number of factors. Consider placing sugar in water. If one places a teaspoon of sugar in a glass of water, some of the sugar will dissolve and some will settle to the bottom. The chemical relationship between water and sugar allows the sugar to dissolve, but at a relatively slow rate. If the solution is stirred, more of the sugar will dissolve because the stirring adds mechanical energy to the solution. Similarly, if the solution is heated, more sugar will dissolve because of the heat energy. However, if one keeps increasing the **concentration** of sugar, eventually the solution will reach its **saturation point** and no more sugar will dissolve even with additional stirring or heat.

OBJECTIVE 9 **Primary role of each of the principal elements and compounds in the body**

KEY TERMS

Exhalation (eks-huh-la´-shuhn)—The act of breathing out or exhaling

- **Note:** Breathing consists of two steps. Taking air into the lungs is called **inhalation** or **inspiration**. Breathing out is called **exhalation** or **expiration**.

Lubricate (lu´-bruh-kat)—To improve the ease of movement between two objects by applying a substance that reduces friction

- **Note:** Friction is the resistance to movement of objects that are in contact with each other. For example, if you press your hands against each other and try to move them, it takes some effort. If you cover your hands with soap and water and rub them against each other it takes less effort because the soap and water have reduced the friction. You may also notice that when you rub your dry hands together, they get warm. This is a result of friction. While you cannot see it, you also rub cells and parts of dead tissue off your hands. Inside the body, where structures rub against each other, such as at the joints between bones, there is friction. Water and fluids largely composed of water in the body help reduce that friction, which allows the body structures to last longer.

Organic compound (or-gan´-ik kawm-paund´)—A compound that contains carbon and hydrogen

- **Note:** Life on earth is referred to as being **carbon-based** because the physical structures of all organisms are made principally of compounds that contain carbon and hydrogen. Compounds that do not contain carbon and hydrogen, such as water, are referred to as *inorganic compounds***.**

a. Oxygen (awk´-si-juhn)—Required for the chemical reaction that releases energy from nutrients; one of the atoms in a water molecule; a key element in other compounds of importance to the body

- **Note:** The earth's atmosphere is approximately 21 percent oxygen, which we take into the body by breathing and, to a much lesser degree, through the breakdown of oxygen-containing compounds in nutrients. Oxygen is required for the release of energy within the cells. Oxygen is also an important part of water (H_2O). The body is approximately 60 to 75 percent water. Much of the rest of the body is composed of **organic compounds**, which often contain oxygen in their structure.

b. Carbon dioxide (kar´-buhn di-awk´-sid)—Given off as a waste product of cell respiration

- **Note:** Carbon dioxide is a compound consisting of molecules with one carbon atom and two oxygen atoms (CO_2). When nutrients are converted to energy, excess atoms of carbon and oxygen combine to form carbon dioxide. Carbon dioxide is carried to the lungs, from which it is returned to the atmosphere through **exhalation**. If the body is unable to remove CO_2 at a sufficient rate so that the gas builds up in the body, acids form and may lead to a condition called **acidosis**, which can interfere with normal functioning of the body. Diseases such as pneumonia may impair normal elimination of carbon dioxide.

c. Water (wawt´-uhr)—Dissolves substances to make them more usable to the body; provides fluid to **lubricate** moving parts of the body; helps to maintain body temperature

✔ **Note:** The process of moving nutrients and chemicals through the body is highly dependent on water because most of these substances must be dissolved in order to pass through the body and into cells. Water is an effective solvent and dissolves directly or indirectly (as the liquid part of blood, for example) most of the chemicals that must be transported through the body. The process actually begins with saliva in the mouth. This water begins dissolving nutrients. It also lubricates the food to make it easier to chew and to swallow. In the digestive tract, water helps to carry nutrient chemicals through membranes and to the cells. Finally, water heats and cools slowly. Because most of the volume of the body is saturated with water, body temperature does not change quickly with changes in environmental temperature, helping to maintain homeostasis.

d. Glucose (glu´-kos)—Serves as the primary energy source for the cells

✔ **Note:** Glucose is a complex compound that consists of 6 carbon atoms, 12 hydrogen atoms, and 6 oxygen atoms ($C_6H_{12}O_6$). It belongs to a class of chemicals called **monosaccharides** (mawn-uh-sak´-uh-rids) or **simple sugars.** Glucose may be taken into the body in nutrients, or it may be produced by the liver from other sugars.

OBJECTIVE 10

Chemical reactions that take place in the body

KEY TERMS

Fever (fe´-vuhr)—An abnormally high body temperature

✔ **Note:** Fever often accompanies a number of diseases. Body temperature is discussed in more detail in Objective 21.

Theory (the´-uh-re)—A statement that provides an explanation based on evidence without final proof being obtained

✔ **Note:** Like the active site theory, there are many ideas about how the body functions that cannot be proved. Many of these will probably be proved or disproved as science continues to make advances, such as new methods for examining processes inside the body. The explanations offered by theories are not guesses. Theories are based on known facts and attempt to take those facts into consideration in their explanations.

a. A chemical reaction involves an interaction between two or more chemicals that results in matter with a different chemical composition from the chemicals that were originally introduced into the reaction.

✔ **Note:** Chemists record chemical reactions with symbols similar to math equations. For example, the basic reaction in the cells that converts glucose into energy can be written:

$$C_6H_{12}O_6 + 6O_2 \blacktriangleright 6CO_2 + 6H_2O + \text{heat}$$

This formula shows that when a molecule of glucose ($C_6H_{12}O_6$) is combined with 6 molecules of oxygen (O_2) it is converted into (▶) 6 molecules of carbon dioxide (CO_2), 6 molecules of water (H_2O), and heat. The glucose comes from digested food, while the oxygen is taken into the lungs during respiration. Both glucose and oxygen are delivered to the cells by the circulatory system. The carbon dioxide is returned to the bloodstream and breathed out from the lungs. The water is used to maintain the health of the cells and to transport substances in and out of the cells, while the heat produced is the energy that allows the cells to do work. Note that there are 6 carbon atoms, 12 hydrogen, and 18 oxygen atoms on each side of the equation.

b. A reaction that causes atoms or molecules to bond, thus producing different chemicals, is called a **synthesis reaction.**

✔ **Note:** An example of a synthesis reaction would be the formation of water:

$$2H_2 + O_2 \blacktriangleright 2H_2O$$

In this formula, free hydrogen and free oxygen molecules bind through hydrogen bonds to form or **synthesize** water.

c. A reaction that causes molecule bonds to break is called a **decomposition reaction**.

✔ **Note:** The conversion of glucose and oxygen into carbon dioxide, water, and heat is a decomposition reaction. While it is true that new compounds are formed, the reaction begins by decomposing existing molecules by breaking their bonds.

d. Synthesis reactions are necessary to allow the body to build proteins and other building blocks of cells and tissue.

e. Decomposition reactions are necessary to allow the body to break down the large, complex molecules of nutrients into small, easily transported molecules that the cells can use to sustain life.

✔ **Note:** While it is true that there are proteins in the foods we eat, most of them are not directly usable by the body. Most proteins are broken into their carbon, hydrogen, oxygen, and nitrogen components so that the body can build the proteins that it needs, such as hemoglobin and collagen.

f. Catalysts or energy can be added to a chemical reaction to increase the rate of reaction.

✔ **Note:** Enzymes are perhaps the most-important catalysts in the body because they are responsible for assisting in thousands of kinds of reactions. According to the active site **theory**, enzymes perform their catalytic function because of their shapes. Each enzyme has receptor sites on the outer surfaces. The chemical that a particular enzyme catalyzes has a shape that exactly fits the enzyme's receptor site, much like the pieces of a jigsaw puzzle fit together. Each enzyme receptor site exactly matches one chemical molecule, referred to as a **substrate**. For example, the digestive enzyme involved in the breakdown of the muscle protein of ingested meat will not catalyze the starch in potatoes. Generally, the enzyme can be envisioned to attach to a chemical and pull it away from a molecule. Another receptor site then attaches to a second chemical and pulls it from its molecule. The chemicals in the receptor sites then form bonds with each other and release from the enzyme. Thus, a new substance is produced and the enzyme is left unchanged.

g. The failure to provide the reactive chemicals in the proper proportions, the introduction of additional chemicals, or the failure to provide a required catalyst or energy source can prevent the reaction from happening.

✔ **Note:** A poor diet can lead to not having the proper chemicals in the body, and disease may interfere with normal chemical reactions. For example, with certain illnesses, the body may develop acidosis, or an excess of acid, and the accompanying positive hydrogen ions (H+). In some instances, these hydrogen ions may attach to enzyme receptor sites that would normally break down carbohydrates and other chemicals or the ions may change the shape of the enzyme, making it impossible for the enzyme to perform its function. The **fever** that accompanies some illnesses may increase the temperature to a point that the internal bonds of the enzyme break down and are unable to perform their function. Enzymes that have changed shapes are said to be **denatured.**

OBJECTIVE 11

Functions of the major types of organic compounds in the body

KEY TERM

Genetic code (juh-net´-ik kod´)—The sequence of bases in DNA that determines how the organism will be structured

✔ **Note:** The segments of DNA called **genes** each have a specific purpose in determining the characteristics of the organism. Some traits are common to a given type of organism. For example, genes for the number of fingers and toes, eyes, and ears, and their locations are pretty much the same from person to person. However, the gene sequence that determines the color of the eyes and the shape of the ears will vary from person to person. Genetic code is especially important to health professionals because the code helps to determine whether a particular person is likely to become afflicted with certain illnesses or conditions. For example, a person may be more likely to have high blood pressure, liver cancer, or a heart condition because of that person's genetic code.

a. Carbohydrates (kar-bo-hi´-drats)—Serve as the major source of energy

b. Lipids (lip´-uhds)—Serve as a means of storing energy, providing structure to cell membranes, and influencing some hormone functions

c. Proteins (pro´-tens)—Serve many roles in the human body that can be generally classed as **functional,** in which the protein regulates a chemical reaction, or **structural,** in which the protein is a component in cells and tissues

   ✔ **Note:** All proteins are large molecules called **macromolecules** and are the most-abundant organic chemical in the body.

d. Nucleic (nu-kle´-ik) acids—Serve to encode and decode information required for the production of structural protein

   ✔ **Note:** The nucleic acids provide a coded plan for how an individual organism is supposed to be assembled. This coded plan is referred to as the **genetic code.**

Objective 12 **Components of the major types of organic compounds in the body**

Key Terms

Antibody (ant´-i-bawd-e)—A protein molecule that will bind to foreign substances in the body

✔ **Note:** Antibodies are part of the immune system that protects the body against invasion by foreign organisms. Every cell—those in the body and those that may enter the body from outside—have markers, proteins called **antigens** in their cell walls. The body recognizes the antigens of its own cells, but when a foreign antigen is encountered, the body produces antibodies that can attach to the foreign antigen. The antibodies are produced by plasma cells in the blood. The receptor sites on the antibody are specific to the foreign antigen.

Enzyme (en´-zim)—A protein that acts as a catalyst in a chemical reaction

✔ **Note:** Enzymes are sometimes referred to as **organic catalysts**. Enzymes are located throughout the body. For example, the saliva, gastric juices, and secretions of the intestine contain enzymes to help digest food.

Inflammatory response (in-flam´-uh-tor-e ri-spawns´)—The way the body reacts to an injury

✔ **Note:** The inflammatory response may include redness, swelling, and heat due to increased blood flow and pain due to the chemicals released by injured and dying cells. The response is ordered and normal.

Pore (por´)—An opening in a surface that allows materials to pass through

✔ **Note:** Pores are found in the skin, in organs, and in the cells themselves to allow the flow of materials that support life. For example, pores in the skin allow the release of perspiration, body oils, and other secretions that help to maintain homeostasis and health. Pores at the cellular level allow nutrients to penetrate the cell and allow the elimination of wastes.

Sexual maturation (sek´-shuhl mach-uh-ra´-shuhn)—The process of developing secondary sexual characteristics and becoming able to reproduce

a. Carbohydrates

- Consist primarily of sugars or saccharides (sak´-uh-rids)
- Include monosaccharides (mawn-uh-sak´-uh-rids), which are simple sugars that provide nutrient energy and form other compounds

  ✔ **Note:** Simple sugars contain five carbon atoms and are called **pentose** or contain six carbon atoms and are referred to as **hexose.** There are three principal hexose saccharides that are important to the body: glucose (glu´-kos), fructose (fruhk´-tos), and galactose (guh-lak´-tos). Glucose is the major source of energy. The liver can convert fructose and galactose into glucose when extra energy is needed.

- Include ribose (ri´-bos) and deoxyribose (de-awk´-si-ri-bos), which are part of the nucleic acids that form the genetic code in cells

  - ✔ **Note:** The two most-important pentose monosaccharides are ribose and deoxyribose. Their primary importance is in the formation of nucleic acids—proteins that carry the chemical "blueprint" of how the body is to be formed and the code for traits such as hair color, handedness, eye color, etc.

- Include oligosaccharides (awl-i-go-sak´-uh-rids), which serve as antigens on the outer surface of cell membranes

  - ✔ **Note:** There are other sugars that are more complex than mono-saccharides. Disaccharides are two monosaccharides joined by covalent bonds. Sucrose, common table sugar, is a disaccharide consisting of glucose and fructose. Oligosaccharides, or **few sugars**, are chains of 3 to 20 monosaccharides.

- Include cellulose (sel´-yuh-los), an indigestible substance that provides bulk to the contents of the digestive tract and promotes healthy movement through the intestines

  - ✔ **Note:** Polysaccharides, or **many sugars**, may consist of several thousand monosaccharide molecules. Cellulose is a nearly straight polysaccharide found in the cell walls of plants. Other polysaccharides include glycogen (gli´-kuh-juhn) and starches, which are described below.

- Include glycogen, which consists of a very-complex chain of glucose molecules that can be stored in the liver and skeletal muscles until converted back into glucose

- Include starches, which consist of chains of glucose that are split apart during digestion

b. Lipids

- Consist of carbon, hydrogen, and sometimes phosphorus (faws´-fruhs), often in the form of fatty acids

- Include triglycerides (tri-glis´-uh-rids), which store energy primarily in the form of body fat

  - ✔ **Note:** True fats consist of a molecule of glycerol and one, two, or three molecules of fatty acids. Triglycerides have three fatty-acid molecules. These lipids are stored between the skin and muscles and around certain organs. When the intake of nutrients does not supply enough energy, the fat can be converted into glucose and used to produce energy.

- Include phospholipids (faws-fo-lip´-uhds), which are one constituent of cell membranes

  - ✔ **Note:** Lipids with two fatty acids and a phosphate group (a phosphorus atom with four atoms of oxygen, PO_4) are referred to as **phospholipids.** They help to form walls and sheaths around cells in various structural configurations of molecules.

- Include steroids (stir´-oids), which are one constituent of cell membranes and assist with hormone synthesis

- ✔ **Note:** Steroids differ in structure from other lipids in that they do not consist of glycerol and fatty acids. Instead, they contain four rings of carbon with hydrogen and other molecules attached. Steroids include cholesterol (kuh-les´-tuh-rol) and certain hormones.

- Include prostaglandins (praws-tuh-glan´-duhns), which regulate hormone action, enhance the immune system, and affect the **inflammatory response**

  ✔ **Note:** There are several types of prostaglandins, each of which is a structural variation of a 20-carbon fatty acid with a 5-carbon ring. Prostaglandins originate in virtually every type of tissue. They perform a specific purpose—usually causing a certain chemical reaction, such as aiding in the clotting of blood, increasing the body's response to disease, influencing blood pressure, and various other roles.

c. Proteins

- Consist of amino (uh-me´-no) acids, which are made of carbon, hydrogen, oxygen, nitrogen, and in some cases, sulfur

  ✔ **Note:** Amino acids are chemical structures that include an amine group (NH_2) and a carboxyl group (COOH). There are 20 different amino acids. Amino acids bind to each other through what is called **peptide bonds**. Short chains of amino acids are referred to as **polypeptides** (pawl-i-pep´-tids).

- Include keratin, collagen, hemoglobin, myosin, and other structural proteins that form receptor sites in cell membranes

  ✔ **Note:** One of the more-important structural functions of proteins is to create receptor sites and **pores** in the cell walls. The receptor sites allow certain molecules and other chemical structures to attach to the cell wall. For example, red blood cells have receptor sites for oxygen in the hemoglobin (he´-muh-glo-buhn) protein in their walls. Keratin (ker´-uht-uhn) is found in the skin and hair, while collagen (kawl´-uh-juhn) is part of the tendons and ligaments. Myosin (mi´-uh-suhn) is found in muscles and aid in the contraction or drawing up of working muscles.

- Include hormones, which regulate body functions including growth, **sexual maturation**, and cell functions

- Include **antibodies**, which tag harmful substances in the body so that they will be destroyed

- Include **enzymes**, which serve as catalysts in chemical reactions

d. Nucleic acids

- Consist of nucleotides, which are made of a pentose sugar, a phosphate group, and one of five base chemicals that include nitrogen

  ✔ **Note:** The base chemicals included in nucleotides (nu´-kle-uh-tids) are adenine (ad´-uhn-en), cytosine (sit´-uh-sen), guanine (gwawn´-en), thymine (thi´-men), and uracil (yur´-uh-sil). The pentose sugars are either ribose or deoxyribose.

- Include deoxyribonucleic (de-awk´-si-ri-bo-nu-kle-ik) acid, which is a double strand of nucleotides with a structure that defines the code of inherited traits

  ✔ **Note:** Deoxyribonucleic acid (DNA) consists of two strands of nucleotides that are twisted in a double helix, somewhat like a ladder that has been rotated while one end was held in place. The strands of nucleotides are alternating molecules of phosphate and deoxyribose sugar. The "rungs" of the ladder are pairs of the base chemicals adenine, thymine, cytosine, and guanine. Adenine is always paired with thymine and cytozine is always paired with guanine. The sequence of the base pairs in a strand of DNA is what creates the coded information for assembling the organism. The sequence of code for one protein is called a **gene**.

- Include ribonucleic (ri-bo-nu-kle´-ik) acid, which is a single strand of nucleotides that synthesizes protein

  ✔ **Note:** Ribose combines with a phosphate group and four bases (adenine, cytosine, guanine, and uracil) to form ribonucleic acid (RNA). The nucleotides are joined in a single strand. RNA is formed from DNA in the cells. There are two functional types of RNA. Messenger RNA (mRNA) is a copy of the genetic code from the DNA, while transfer RNA (tRNA) builds proteins by aligning the amino acids correctly.

OBJECTIVE 13

Major elements and compounds that compose the body

a. More than 20 elements are found in the human body.

b. Oxygen is the most-common element in the body by total weight, at approximately 65 percent.

✔ **Note:** Because oxygen is a major part of water molecules and 60 to 75 percent of body weight is water, plus the fact that many other compounds contain oxygen, this element is the most common.

c. Carbon, at nearly 19 percent, and hydrogen, at nearly 10 percent, are the other large constituents.

✔ **Note:** Carbon and hydrogen are large constituents of the body's composition because they are found in carbohydrates.

d. There are also minor quantities of nitrogen, calcium, and phosphorus.

✔ **Note:** Elements such as sodium, magnesium, sulfur, chlorine, and potassium make up less than 1 percent each.

e. There are trace amounts—less than 0.1 percent—of a number of minerals, including manganese, iron, cobalt, copper, zinc, and others, as well as iodine and chlorine.

OBJECTIVE 14

Types of solutions

a. Isotonic (i-suh-tawn´-ik)—A solution that has the same concentration of dissolved particles as the solution to which it is compared

✔ **Note:** The prefix **iso-** means "the same." Isotonic solutions are sometimes referred to as **normal solutions** because they are in a state of balance with the compared solution. A fundamental law of physics is that if two solutions are placed in a relationship in which they can exchange material with each other, they will tend to end up with the same concentrations of dissolved materials. The two solutions would be isotonic with each other. This is the condition of blood cells and plasma with regard to the dissolved substances in both. The concentration of dissolved minerals inside the cells is normally the same as that in the plasma, thus there is no flow between the internal and external solutions (see Figure 2 below).

b. Hypertonic (hi-puhr-tawn´-ik)—A solution that has a higher concentration of dissolved particles than the solution to which it is compared

✔ **Note:** If there is a difference in the concentrations of two solutions that have a relationship in which they can exchange material with each other, the solvent will flow toward the higher concentration of solute so that the concentration is reduced in the hypertonic solution. Therefore, if the concentration of the solution surrounding the cells is greater than that of the cells, material will flow out of the cell to the surrounding solution causing the cell to shrink and be destroyed (crenation). See Figure 3 below.

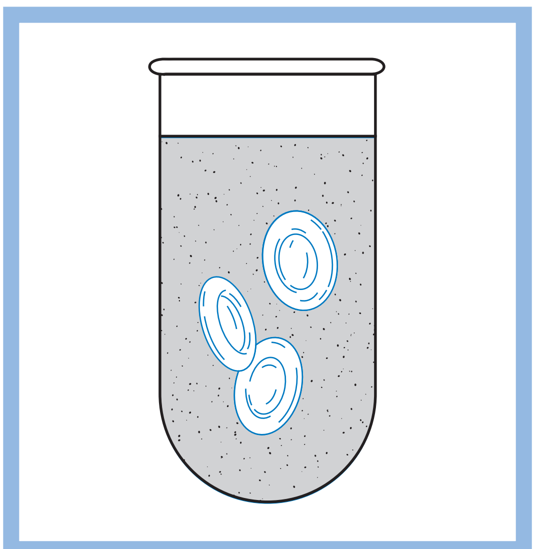


Figure 2
Types of solutions: Isotonic

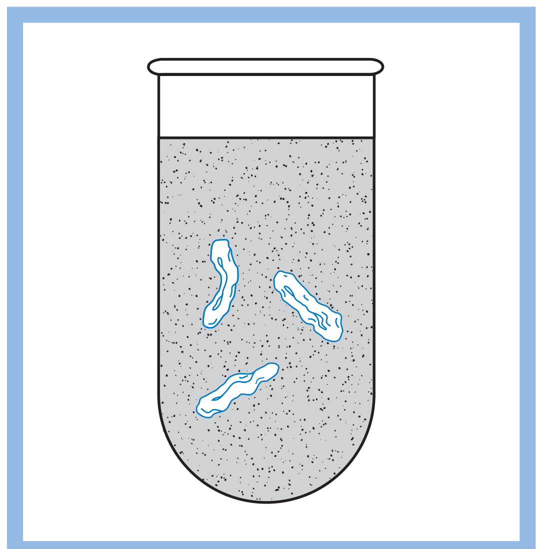


Figure 3
Types of solutions: Hypertonic

c. Hypotonic (hi-po-tawn´-ik)—A solution that has a lower concentration of dissolved particles than the solution to which it is compared

✔ **Note:** If there is a difference in the concentrations of two solutions that have a relationship in which they can exchange material with each other, the solvent will flow toward the higher concentration of solute so that the concentration is increased in the hypotonic solution. Therefore, if the concentration in the cells is greater than that in the surrounding solution, the material in the cells ruptures the cells to create an equilibrium in the surrounding solution (see Figure 4 below).

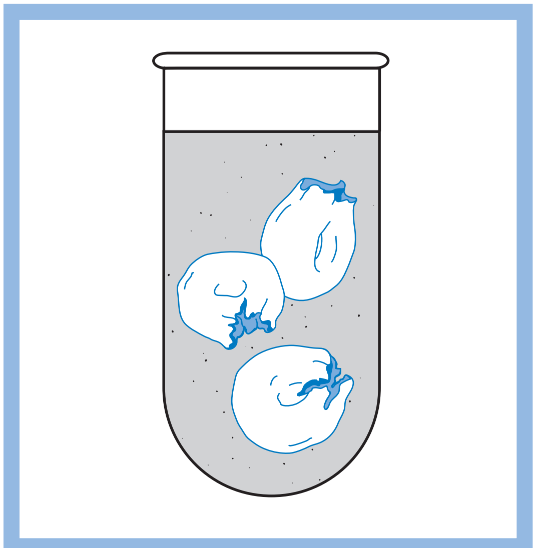


Figure 4
Types of solutions: Hypotonic

OBJECTIVE 15

Major types of fluids in the body

a. Intracellular fluid (in-truh-sel´-yuh-luhr flu´-uhd)—Fluid contained within the cells

b. Interstitial (int-uhr-stish´-uhl) fluid—Fluid between the cells and in special cavities, such as in the cranium

c. Plasma (plaz´-muh)—The fluid portion of blood

✔ **Note:** Plasma composes nearly 60 percent of the volume of blood.

Objective 16 **The term electrolyte**

Key Terms

Acid (as´-uhd)—A substance that releases a hydrogen ion when dissolved

Base (bas´)—A substance that releases a hydroxide ion when dissolved

- ✔ **Note:** Base substances are also referred to as **alkaline** (al´-kuh-luhn).

Hydroxyl (hi-drawk´-suhl)—An anion consisting of one hydrogen atom and one oxygen atom

- ✔ **Note:** Hydroxyls can be considered to be the most-basic compound, while a hydrogen cation is the most-acidic. Note that combining the hydrogen cation (H^+) with a hydroxyl anion or **hydroxide ion** (OH^-) forms water (H_2O). In fact, in the body, many chemical reactions involving water are reversible breakdowns of water into H^+ and OH^- and conversion back again into water.

Ion (i´-awn)—An atom or group of atoms with either a positive or a negative electrical charge

- ✔ **Note:** An atom that has fewer electrons than protons has a positive charge and is called a **positive ion** or **cation** (kat´-i-uhn). an atom that has more electrons than protons has a negative charge and is called a **negative ion** or **anion** (an´-i-uhn). The charge of an ion can play an important role in the transport of chemicals throughout the body.

Salt (sawlt´)—A class of chemicals that have a positive ion other than hydrogen and a negative ion that is not a **hydroxyl**

- ✔ **Note:** Table salt is sodium chloride and consists of a sodium cation and an anion of chlorine. Numerous other salts exist, many of which play a role in body functioning.

Electrolyte—A substance that forms **ions** when it dissolves

- ✔ **Note:** Electrolytes include **salts**, **acids**, and **bases** found throughout the body. The fact that the ions have a positive or negative charge provides the body with a mechanism for moving these substances from one place to another, as ions with similar charges tend to move away from each other while those with different charges tend to move toward each other.

Objective 17 **Role of electrolytes in human health**

a. Dissolved electrolytes have an excess or shortage of electrons, giving them a negative or a positive charge respectively.

   - ✔ **Note:** Some of the more-common positive electrolytes in the body are sodium (Na^+), potassium (K^+), manganese (Mg^{+2}), and calcium (Ca^{+2}). The most-common negative electrolytes are chloride (Cl^-), phosphate (HPO_4^{-2}), protein anions, and sulfate (SO_4^{-2}). These substances are present in plasma and tissue fluids, though their normal concentration varies from fluid to fluid.

b. Body functions are most efficient when the concentrations of the electrolytes are within specific ranges.

✔ **Note:** Tissue fluid and plasma normally have high concentrations of sodium and chloride and low concentrations of potassium, manganese, and phosphate and protein ions with low concentrations of sodium and chloride. These concentration levels are vital to the functions that are performed by tissues and organs.

c. Electrolytes are lost through sweating and through the elimination of urine and feces.

Objective 18 **Role of acids and bases in human health**

a. Acids and bases are classed as strong, using a value called pH, with the most-acidic substances having a value toward 0 and the most-basic substances having a value toward 14.

✔ **Note:** The pH scale represents the potential hydrogen that a substance can accommodate. Thus, the 0 end of the scale shows that a hydrogen ion shows no reaction with another hydrogen ion, while a hydroxide ion at the 14 end of the scale will easily react with a hydrogen ion to form water. At the midpoint of the scale is pure water with a value of 7, showing that it is neither acidic nor alkaline.

b. Body fluids have a normal pH value with a narrow range above and below that value.

✔ **Note:** The normal pH of blood is 7.35 to 7.45, meaning that it is slightly alkaline. Intracellular fluid has a pH of approximately 6.8 or slightly more-acidic than pure water.

c. If the pH value of a fluid goes above or below its ideal range, chemical reactions will be affected.

d. Normal human activities can lead to major shifts in pH.

✔ **Note:** Changes in diet, changes in exercise, environmental exposures, and illness can affect the pH balance in the body. However, normal cell respiration would also lead to an increase in acidity if the body did not have mechanisms to compensate for such changes.

e. To compensate for these potential changes in pH, the body contains buffer systems.

✔ **Note:** There are three major buffer systems: the bicarbonate system associated with respiration, the phosphate system associated with the kidneys, and the protein system associated with intracellular fluid.

f. Buffer systems contain a weak acid and a weak base that react with strong acids and strong bases to produce substances that do not change the normal pH excessively.

Objective 19

The term metabolism

Key Terms

Anabolism (uh-nab´-uh-liz-uhm)—The process of chemical synthesis in which smaller molecules are combined to produce larger molecules

Catabolism (kuh-tab´-uh-liz-uhm)—The process of reducing large molecules into smaller molecules

- **Note:** Anabolism requires energy to create the bonds and generally a catalyst such as an enzyme. Catabolism generally releases energy but also requires catalysts. Together, the two processes make up metabolism.

Metabolism—The processes that lead to chemical reactions in the body

- **Note:** Chemical reactions take place because of the natural interactions of specific substances, due to the addition of energy such as heat, or because of the presence of catalysts. A chemical reaction may either break chemicals down into other substances and energy or bond substances together. Metabolism can result either in **catabolism** or **anabolism**. Both types of reactions are required for good health. For example, anabolism can lead to the formation of muscle and bone. Catabolism can result in the release of energy from nutrients.

Objective 20

Use of energy by the body

- **Note:** One of the laws of physics is that energy and matter cannot be created or destroyed. They can only be converted between different forms. This is a key concept in understanding metabolism. Matter is converted into other types of matter and into energy. The energy is converted into matter—cells and other components of the body—and into other types of energy, such as the contraction of muscles so that a person can move.

a. The primary source of energy in the body is adenosine triphosphate (uh-den´-uh-sen tri´-faws-fat) (ATP).

   - **Note:** ATP is composed of ribose, adenine, and three phosphate molecules. Adenine (ad´-un-en) is a molecule with five nitrogen and three hydrogen atoms. A molecule with the same structure as ATP except with one less phosphate group occurs naturally in cells and is called **adenosine diphosphate** (uh-den´-uh-sen di´-faws-fat) (ADP).

b. During cell metabolism in which glucose and oxygen are converted into carbon dioxide and water, some of the energy released creates a bond between ADP and a phosphate group to produce ATP.

c. Energy is stored in the phosphate bonds of ATP until it is needed for cell functions.

d. All cells contain enzymes that allow them to break the phosphate bonds in ATP.

   - **Note:** The phosphate bonds are known as **high-energy bonds**. When they are broken, a relatively large amount of energy is released in the cell.

e. Energy released from ATP fuels cell functions, including cell division to produce new cells.

f. Some of the energy is applied to moving substances in and out of the cell and in carrying out chemical reactions, as well as providing the cell with a stable temperature.

Objective 21

Characteristics of body temperature

a. Normal body temperature ranges from 96.5° F to 99.5° F (36° C to 38° C).

✔ **Note:** Body temperature normally varies 1 to 2 degrees during a 24-hour period.

b. Normal temperature is considered to be 98.6° F (37° C).

✔ **Note:** Body-temperature regulation in infants is not as precise due to their small amount of skin-surface area. Body-temperature regulation in older adults is not as precise due to reduced efficiency in the mechanisms that regulate body temperature.

c. Temperature is normally lower during sleep.

d. Body temperature is regulated by the hypothalamus.

e. Blood vessels near the surface of the skin constrict to reduce heat loss.

f. Blood vessels near the surface of the skin dilate to increase heat loss.

✔ **Note:** Although most heat loss occurs through the skin, heat loss also occurs through exhaling breath (respiration). There is also a slight amount of heat loss through the elimination of body wastes through urination and defecation.

g. Heat is removed from the body by sweating.

h. Fever is an abnormally high body temperature.

✔ **Note:** Fever is generally the result of a disruption of the body-temperature regulation mechanisms due to injury or illness.

i. Hypothermia is an abnormally low body temperature.

✔ **Note:** Hypothermia is generally the result of exposure to low environmental temperatures such as exposure to cold air or water.

OBJECTIVE 22 **Basic activities that define life**

KEY TERMS

Asexual (a-sek´-shuhl)—Relating to reproduction that does not involve the union of individual organisms or separate cells

- **Note:** Asexual reproduction occurs in the simplest life forms, such as one-celled organisms, and at the cellular level in higher life forms when internal cells divide to reproduce.

Sexual (sek´-shuhl)—Relating to reproduction that requires a union of two organisms or the union of separate cells

Theory of evolution (ev-uh-lu´-shuhn)—A theory that proposes that all life began as simple organic compounds that over time developed the characteristics of life and continued to become more complex in functioning and in coping with the environment

- **Note:** You have seen that our bodies consist of various assemblies of common chemicals and that most of what happens within our bodies are simply reactions among those chemicals. So what distinguishes us from other groups of chemicals, such as rocks? Scientists generally define life by the activities that are common in living organisms and are not normally found in nonliving things.

a. Reproduction (re-pruh-duhk´-shuhn)—The process by which organisms create more of their own kind

   - **Note:** Living organisms must have a way of renewing themselves because all living things break down or fall victim to injury so that they eventually die. Through reproduction, a cell can divide to make a replacement or a man and a woman can have children. Reproduction may be **sexual** or **asexual**.

b. Growth (groth´)—The orderly increase in size that an organism exhibits as it matures

   - **Note:** Living things tend to get bigger as they age to the point of maturity. Even single-celled organisms double in size from a divided cell or grow from a spore or cyst.

c. Metabolism (muh-tab´-uh-liz-uhm)—The process by which organisms convert matter and energy to sustain life functions

   - **Note:** It takes energy to sustain life. Organisms find this energy in nutritional matter or in the environment. For example, humans eat food and convert the food to energy and chemicals required to support the functions of life. Many plants are able to use the energy of sunlight to sustain life. Metabolism includes those internal processes that allow an organism to derive energy and the chemicals required to support life functions from external sources.

d. Movement (muv´-muhnt)—The ability to change the location of matter from one place to another

- **Note:** While it is fairly obvious that human beings and most animals travel from place to place, it may be less apparent that a tree exhibits movement or that a barnacle attached to a rock moves. Many plants turn their flowers or leaves toward the sun. Even in plants where such movement is absent, there is a flow of nutrients and water through the plant, just as blood flows through the human body. Thus, movement may be either external or internal.

e. Responsiveness (ri-spawn´-siv-nes)—The characteristic of an organism to react to changes in its environment

- **Note:** Even simple organisms are equipped with sense organs that provide the organism with an awareness of its environment. Often these environmental conditions will cause a reaction in the organism, as when you pull your hand away from a hot object. The response may be done either consciously, such as eating to relieve hunger, or automatically, such as the constriction of the pupil of the eye when exposed to bright light.

f. Adaptation (ad-ap-ta´-shuhn)—The process of modifying life processes to improve an organism's chances of survival

- **Note:** Adaptation may appear to be very similar to responsiveness, and the two are related. However, responsiveness generally refers to changes in the organism's behavior that cope immediately with a change in the environment, where adaptation often indicates a long-term change. Adaptation may occur for an individual, as when a snowshoe rabbit turns white in the winter, or for a species, as suggested by the **theory of evolution**.

OBJECTIVE 23

Cell theory

KEY TERM

Protoplasm (prot´-uh-plaz-uhm)—The complex mass of proteins and other organic and inorganic materials that is capable of exhibiting the characteristics of life

All organisms are made of small, enclosed bodies called cells and of the products of those cells.

- **Note:** Cells are small bits of organized **protoplasm** encased in a thickened membrane. In multicellular organisms, cells tend to have a specialized function that contributes to the overall functioning of the organism.

Objective 24 **Functions of the compounds found in protoplasm**

a. Water—Serves as the solvent in all cell chemistry

- ✔ **Note:** Water not only makes up most of the body, but it is also involved in virtually every chemical reaction that takes place in the body. About 65 percent of the water in the body is contained within cells. However, the water within the body is in constant motion, transporting molecules in and out of the cells and moving substances about the body through the bloodstream and lymphatic vessels. The transported chemicals are generally in solution.

b. Protein—Forms the structural framework of protoplasm

c. Carbohydrates—Serve as a source of energy during metabolism

d. Fats—Store excess energy

- ✔ **Note:** The energy provided by nutrients that is not required by the body immediately is converted to fat and stored between the skin and muscles.

e. Nucleic acids—Control the growth and reproduction of cells

f. Mineral salts—Serve as chemical buffers to maintain the chemical balance in cells

- ✔ **Note:** Salts serve as a source of trace elements and are needed in the cells in small quantities. For example, the formation of ATP requires that phosphate molecules be available in the cell. One source of phosphates is the mineral salt calcium phosphate.

Objective 25 **Principal types of protoplasm**

a. Nucleoplasm (nu´-kle-uh-plaz-uhm)—The protoplasm found in the nucleus of a cell

- ✔ **Note:** All human cells except mature red blood cells have a nucleus.

b. Cytoplasm (sit´-uh-plaz-uhm)—The protoplasm found outside the nucleus of a cell

OBJECTIVE 26

Major parts of a cell

- **Note:** Cells contain specialized structures that perform specific functions in maintaining the cell as a living body. The exact structures and their arrangements will vary from cell to cell depending on the type of parent organism, the cell's role within the parent organism, and the cell's stage of life. The cell shown in Figure 5 is representative of cells in general and is not intended to be a specific cell or to reflect the structure of all cells.

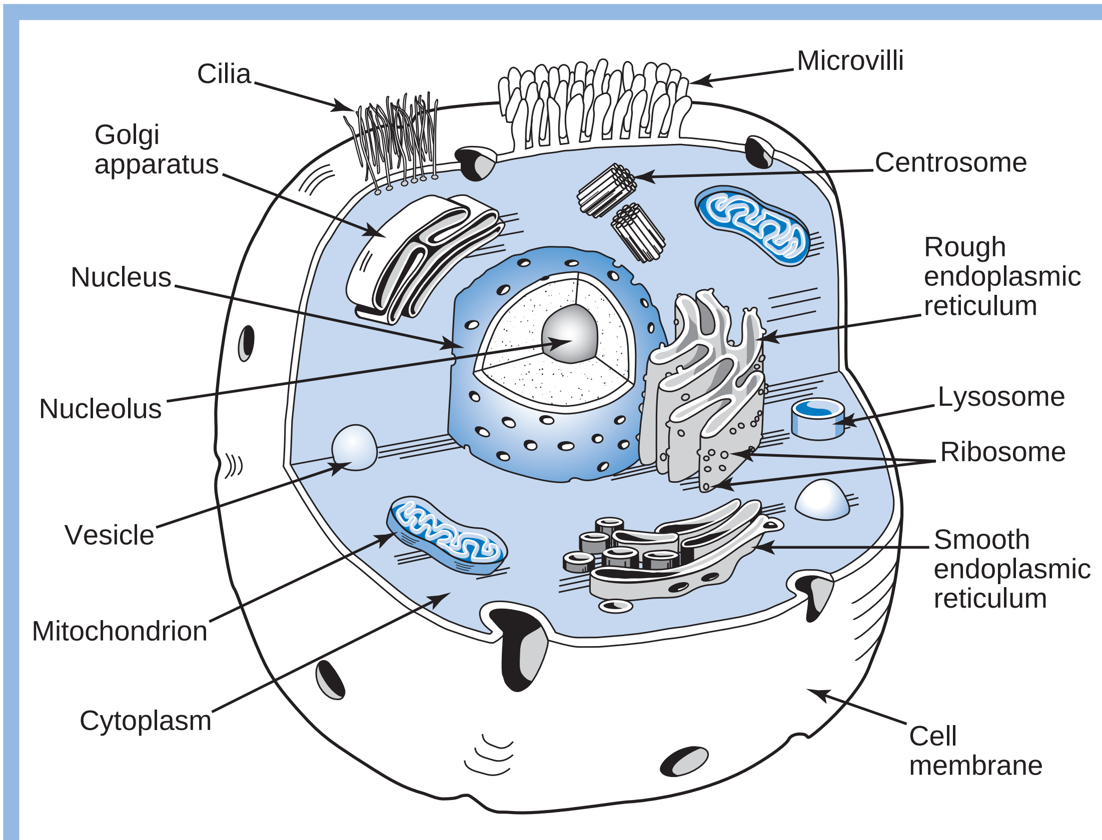


Figure 5
Major parts of a cell

OBJECTIVE 27

Functions of the major parts of a cell

KEY TERM

Permeability (puhr-me-uh-bil´-uht-e)—The characteristic of a material to allow other substances to pass through it

- **Note:** An important function of a cell is to take in substances such as oxygen and nutrients and to release substances such as carbon dioxides and enzymes. However, the membrane must prevent substances such as toxins from entering the cell. For this reason, the cell membrane is said to be **selectively permeable**.

a. Nucleus—Regulates cellular structure and activities, including reproduction of the cell (see Figure 5)

b. Cell membrane—Allows some molecules to enter the cell while preventing entry by other molecules (see Figure 5)

- **Note:** The cell membrane is sometimes referred to as the **plasma membrane**. The membrane exhibits selective **permeability**—it selects the chemicals that are allowed to pass through it, permitting some to pass in or out easily and keeping others out completely.

c. Cytoplasm—Provides structure to the cell and supports other parts of the cell (see Figure 5)

- **Note:** The cytoplasm contains a number of specialized structures referred to as **organelles** (or-guh-nels´). The remaining parts listed in this objective are organelles.

d. Endoplasmic reticulum (en´-duh-plaz-mik re-tik´-yu-luhm)—Provides a passageway for the transport of materials within the cell and synthesizes lipids

- **Note:** The endoplasmic reticulum winds through the cytoplasm, delivering proteins and other chemicals to various parts of the cell and to other organelles. There are two types of endoplasmic reticula: smooth and rough (see Figure 5 on page 33). The bumpy appearance of rough endoplasmic reticulum is created by the ribosomes—another type of organelle—that attach to it. Smooth endoplasmic reticulum lacks ribosomes.

e. Ribosome (ri´-buh-som)—Synthesizes protein

- **Note:** The ribosomes are attached to the endoplasmic reticula and are scattered throughout the cell (see Figure 5). The ribosomes contain RNA and play a key role in cell division.

f. Golgi apparatus (gol´-je ap-uh-rat´-uhs)—Synthesizes carbohydrates and packages materials to prepare them for secretion from the cell

- **Note:** The Golgi apparatus (see Figure 5) generally lie near the terminal ends of endoplasmic reticula and receive the proteins produced by the endoplasmic reticula and ribosomes. This protein material is delivered in small bubble-like packets called **vesicles** (ves´-i-kuhls) (see Figure 5). In the Golgi apparatus, the proteins are modified for special purposes, such as serving as pores in the cell membrane or as enzymes to be secreted from the cell. Once the proteins have been processed by the Golgi apparatus, they are released in vesicles for transport to their destination.

g. Mitochondrion (mit-uh-kawn´-dre-uhn)—Produces ATP and serves as the site of cell respiration

- **Note:** The mitochondria generate the energy required by the cell. They consist of a smooth outer sac that contains an inner sac partitioned by numerous folds called **cristae** (see Figure 5). The mitochondria are rich in fats, proteins, and enzymes. The more energy that a cell requires to perform its functions, the more mitochondria the cell is likely to have.

h. Lysosome (li´-suh-som)—Contains the enzymes used to digest ingested material and damaged tissue (see Figure 5)

i. Centrosome (sen´-truh-som)—Organizes special spindle fibers during cell division

- **Note:** Centrosomes consist of two cylinders called **centrioles** (see Figure 5)**.**

OBJECTIVE 28

Major parts of a cell nucleus

a. Nuclear membrane—A thickening of the outer surface of the nucleus protoplasm that regulates the movement of materials into and out of the nucleus

b. Chromosome (kro´-muh-som)—One of several strands of DNA that contains the genetic code that determines inherited traits

- **Note:** Human cells contain 23 pairs of chromosomes that carry the genetic code. When a cell is dividing to reproduce itself, the DNA molecules form tight coils so that they have the appearance of short rods. This is the chromosomal state. When the cells are not dividing, the DNA molecules have the appearance of granules or threads in the nucleoplasm and are referred to as **chromatin** (kro´-muht-uhn).

c. Nucleolus (nu-kle´-uh-luhs)—A dense spherical structure within the nucleus that is involved in protein synthesis and that forms ribosomal RNA (see Figure 5)

OBJECTIVE 29

Specialized structures in cells

a. Microvilli (mi-kro-vil´-e)—Extensions of the cell cytoplasm that line the intestines (see Figure 5)

b. Flagellum (fluh-jel´-uhm)—A single hair-like projection on a sperm cell

c. Cilia (sil´-e-uh)—Hair-like projections of the cells that form the mucous lining of the respiratory system and other passageways (see Figure 5)

OBJECTIVE 30 **Functions of the specialized structures in cells**

a. Microvilli—Serve to increase the surface area of cells

- **Note:** The purpose of the intestines is to absorb nutrients. The reason that the small intestines twist around and fold back on themselves is to increase their length so that food being digested and absorbed will have to travel a greater distance, thus increasing the amount of intestine to which the nutrients are exposed. Microvilli serve the same purpose by presenting "fingers" into the interior of the intestines. This too increases the surface area to which nutrients are exposed.

b. Flagellum—Helps to propel a sperm cell so that it can reach an ovum

- **Note:** The sperm, or spermatozoa (spuhr-mat-uh-zo´-uh), is the male reproductive cell, while the ovum is the female reproductive cell. When an ovum is released for fertilization in the female, it is still beyond the point where sperm is deposited. This means that the sperm must "swim" the rest of the way to reach the ovum. The flagellum wiggles back and forth and whips around to propel the sperm toward the ovum.

c. Cilia—Help to propel fluid in one direction over the surface of cells

- **Note:** The cilia act like the bristles of a broom on a microscopic scale. Their sweeping motion moves fluids and transported substances along a passageway. For example, when the ovaries release an egg cell, cilia extending from the cells that line the interior of the fallopian tubes move the ovum toward the uterus. This increases the chances of fertilization by presenting the ovum to sperm cells and then to the uterus to be implanted or to be discharged if not fertilized.

OBJECTIVE 31 **Functions of a cell**

a. To absorb materials to support cell functions

Examples: Oxygen, nutrients

b. To metabolize nutrients

c. To metabolize oxygen

d. To release energy

e. To synthesize protein

f. To excrete waste products

g. To reproduce itself

h. To support functions specific to that kind of cell

- **Note:** The body contains hundreds of types of cells that serve specialized functions to support the purposes of the organ system in which the cells originate. The set of objectives in this module concentrates on the structure and chemistry of cells in general. The details of specific cell functioning will be provided in the modules that deal with the individual organ systems.

Objective 32 **The term transport**

Transport—The movement of substances in and out of the cells

- **Note:** Depending on the type of cell, the substance, and the purpose of the movement, the method of transport can vary in a number of ways. However, the process can be generally divided into two categories: passive and active (see Objective 33).

Objective 33 **The terms active transport and passive transport**

a. Passive transport—Movement that occurs without any energy being expended by the cell

- **Note:** In passive transport, chemicals move through the cell wall due to the mechanics of solutions. You have previously studied a general principle of fluid mechanics that states if two solutions are placed in a relationship in which materials can move between them, then there will be a flow of solvent from the area of lower concentration to the area of higher concentration until an isotonic state is reached. The word **passive** means that an action takes place without resistance to outside forces.

b. Active transport—Movement that requires the use of energy for the cell to transport the material through the cell wall

- **Note:** Active transport goes counter to the normal mechanics of solution. In other words, the solvent flows from the area of higher concentration to the area of lower concentration, causing the higher concentration to become even greater and the lower concentration to decrease further. This is somewhat like water running uphill. For active transport to take place, the cell must expend energy.

Objective 34 **Types of passive transport**

a. Diffusion (dif-yu´-zhuhn)—The process by which particles in a fluid spread throughout the fluid to produce an equal concentration

- **Note:** Diffusion is the process that involves the flow of a substance from an area of higher concentration to one of lower concentration. Although this process is described as **passive**, all movement requires some form of energy. In this case, the energy is that of the atoms that make up the substance. The electrons that orbit the nucleus, the differences in electrical charges, and other forces cause atoms to be in continuous motion. In a solid, the movement is very slow. However, if a solid is dissolved in a liquid, many of the bonds that hold the substance in its solid shape are broken and the atoms and molecules of the substance move about with more freedom, bouncing off each other to further add to the motion. Substances in gaseous states are even more free to move about, which explains why an odor can so quickly fill a room.

b. Osmosis (awz-mo´-suhs)—The process by which solvent molecules pass through a semipermeable membrane to produce an equal concentration on each side of the membrane

- **Note:** Osmosis is actually a form of diffusion, one that involves a semi-permeable or selectively permeable membrane. With osmosis, the emphasis is on the substances that are allowed to pass through the membrane. Similarly, filtration (see below) can be a form of osmosis in which the emphasis is on the prevention of movement of select substances. An example of osmosis is the flow of fluid into a cell if the electrolyte concentration within the cell gets too high.

c. Filtration (fil-tra´-shuhn)—The process by which solvents or specific particles are able to move through a membrane that prevents the passage of other solvents or particles

- **Note:** There are several filter systems in the body besides the cell walls. For example, the spleen filters blood that passes through it. Filtration requires force to move the solution through the filter. That force may be normal fluid mechanics forces or it may be an active force such as the heart pumping blood through the spleen.

Objective 35

Types of active transport

a. Physiological pump—The process that moves molecules or ions through cell membranes against the pressure of natural forces

- **Note:** A physiological pump may be an organ like the heart. In active cell transport, the most-common form of physiological pump is a "carrier" molecule to which substances attach and are then carried in or out of the cell by movement of the carrier. An example is the sodium-potassium pump, which uses a molecule of sodium-potassium ATP to carry sodium ions out of the cells and potassium into the cells.

b. Phagocytosis (fag-uh-si-to´-suhs)—The process of a cell engulfing a solid particle with a portion of its membrane, which then breaks off from the membrane and migrates into the cell as a closed vesicle

- **Note:** During phagocytosis, the transported substance connects to receptor sites on the surface of the cell. The cell then draws in that portion of the cell wall and pinches it off to form a vesicle. The vesicle can then be moved about the cytoplasm as required. The same mechanism is used for pinocytosis (see below) except that the process involves a liquid rather than a solid. Phagocytosis and pinocytosis are sometimes collectively referred to as **endocytosis** (en-duh-si-to´-suhs) because materials are transported into the cell.

c. Pinocytosis (pin-uh-si-to´-suhs)—The process of a cell engulfing a liquid particle with a portion of its membrane, which then breaks off from the membrane and migrates into the cell as a closed vesicle

d. Exocytosis (ek-so-si-to´-suhs)—The process of a cell carrying substances in vesicles and secreting through the cell membrane

- **Note:** Exocytosis has previously been described in Objective 27 as part of the function of Golgi apparatus.

Objective 36

Process of cell growth

Key Term

Self-replication (self´ rep-luh-ka´-shuhn)—To produce a copy of oneself

- **Note:** Cells reproduce by replicating themselves and structures with the cells are also capable of dividing to make a copy of the structure. DNA replicates itself by splitting into two strands and then rejoining segments composed of new nucleotides joining each of the existing strands.

a. Once a cell forms, it must produce additional cytoplasm and cell membrane as the cell enlarges.

- **Note:** New cells are formed by the division of existing cells. This is followed by a growth period called the **interphase** (int´-uhr-faz).

b. Part of the growth process involves protein synthesis through anabolism.

c. During protein synthesis, amino acids are bonded in polypeptide chains.

d. To create the polypeptide chains, a ribosome attaches to a complementary set of RNA molecules—a transfer RNA (tRNA) molecule and a messenger RNA (mRNA) strand—and holds them together during protein synthesis.

- **Note:** The messenger RNA carries the genetic code that describes the type of protein to be constructed. The transfer RNA attracts amino acids based on the coding in the messenger RNA.

e. The amino acids are drawn to the ribosome.

f. The ribosome secretes an enzyme that promotes the formation of a peptide bond.

g. The ribosome moves along the RNA strand pair building polypeptides.

h. In some cases, after the ribosome travels the full length of the RNA strands and moves on, enzymes present in the cell connect the polypeptides to form proteins.

i. Other enzymes cause the proteins to form cell membrane and organelles.

j. Mitochondria increase by **self-replication**.

k. Just before the cell begins to reproduce, the DNA also replicates itself.

Objective 37 **Types of cell reproduction**

- **Note:** Human cells undergo two types of division in order to reproduce. Mitosis (mi-to´-suhs) is the process used by virtually all cells, while meiosis (mi-o´-suhs) occurs only in reproductive cells.

a. Mitosis

- Occurs in all human cells other than reproductive cells and nerve-tissue cells
- Gives rise to two daughter cells that are identical to the parent cell
- Consists of four distinct stages

  - **Note:** The four phases of mitosis are (1) prophase, (2) metaphase, (3) anaphase, and (4) telophase. During prophase (pro´-faz), the cell prepares for division. The chromatids curl into dense chromosomes, the centrioles move to opposite ends (poles) of the cell and spindle fibers extend between them, and the nucleus dissolves. In the metaphase (met´-uh-faz), the spindle fibers have stretched from one end of the cell to the other and the chromosomes align across the midline of the cell at right angles to the spindle fibers, to which they attach. As the anaphase (an´-uh-faz) begins, the chromosome pairs (called **centromeres** [sen´-truh-mirz]) split and migrate toward opposite poles. The split of the centromeres results in the cell having sets of identical chromosomes in each half with each half having the same number of chromosomes as the original cell, and the cell begins to pinch in at the midline between the two poles. The final phase, or telophase (tel´-uh-faz), completes reproductive division by reversing the processes of the prophase in each half of the parent cell. A nucleus develops in each half, the chromosomes revert back to chromatids, and the spindle fibers disappear. Once these structures are all in place, the two halves split and two daughter cells exist in place of the split parent cell.

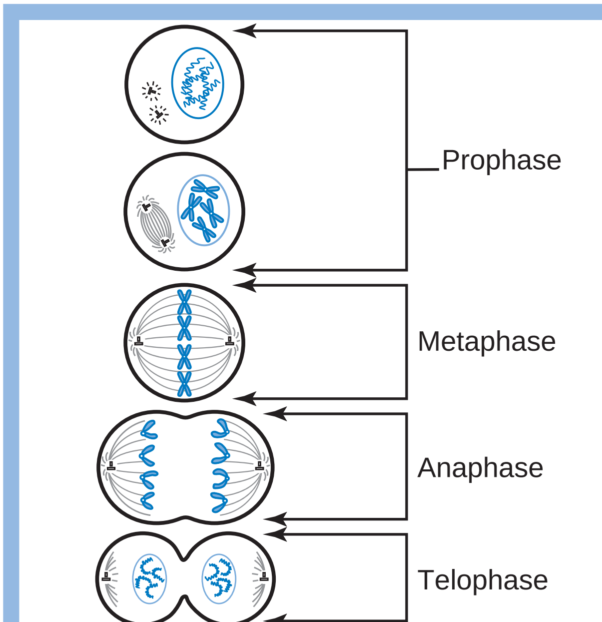


Figure 6
Types of cell reproduction: Mitosis

b. Meiosis

- Occurs in reproductive cells
- Gives rise to four daughter cells that each contain only half the number of chromosomes found in the parent cell
- Consists of two stages

✔ **Note:** The purpose of meiosis is to create reproductive cells that have only one half of the number of chromosomes normally found in the organism's cells. In this way, when the two reproductive cells unite, the resulting cell will have a full set of chromosomes. The first stage of meiosis is called **meiosis I** and begins with normal mitosis. In **meiosis II**, the process is repeated so that by the end of the second telophase, four cells have been produced. However, as the second stage begins, the two cells do not replicate their chromosomes as is done at the beginning of mitosis. Thus, the four cells produced have only half the number of chromosomes normally found in the organism's cells. The resulting cells are generally referred to as **gametes** (gam´-ets), though for male reproductive cells the process begins with spermatogonia (spuhr-mat-uh-go´-ne-uh) and produces spermatozoa and the process for female reproductive cells begins with oogonia (o-uh-go´-ne-uh) and produces one ootid and three polar bodies. The ootid has more cytoplasm than the polar bodies, which eventually disintegrate. This is something of a simplification of the two processes, but they will be discussed in more detail in later modules.

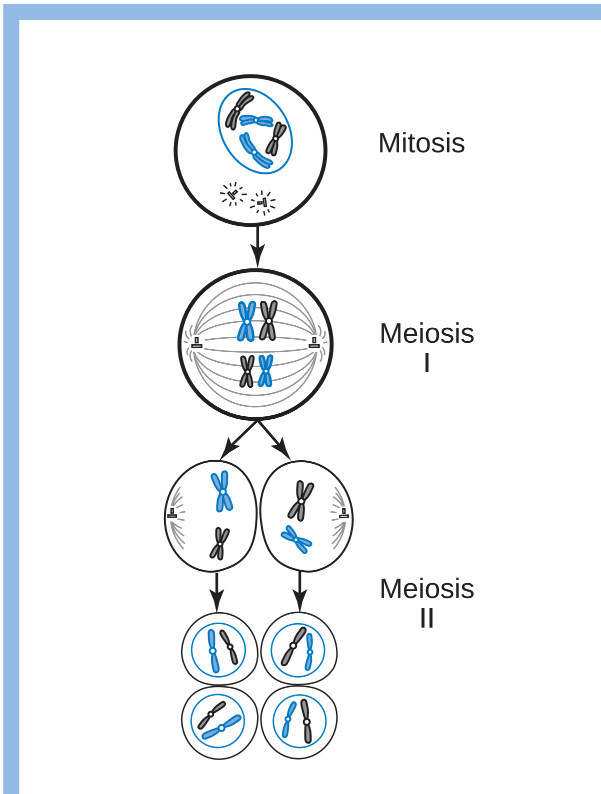


Figure 7
Types of cell reproduction: Meiosis

Objective 38 **Process in which the genetic makeup of a cell can be changed**

a. Exposure to certain conditions can disrupt the genetic makeup of a cell, resulting in a mutation.

- ✔ **Note:** Conditions that cause mutations are called **mutagens.** The world around us is full of mutagens, some natural and some produced by human activities. Some mutations may be beneficial, which is part of the basis of the theory of evolution, which suggests that mutations that help an organism to adapt and survive are likely to be passed on to the organism's offspring. However, some mutations harm the organism or lessen its chances of survival.

b. A mutation may lead to structural or functional disorders that are then passed on to daughter cells during mitosis.

- ✔ **Note:** Many mutations are not passed on because the afflicted organism does not survive to reproduce or the mutation itself may leave the organism unable to reproduce. A number of mutations have been assimilated into the genetic code of individuals. For example, some persons are unable to see colors or are unable to distinguish between certain colors such as red and green and are said to be **color-blind**. Color-blindness is an inherited trait that probably started as a mutation. The condition sickle-cell anemia is an inherited condition in which a person's red blood cells are misshapen. Sickle-cell anemia probably began as a mutation. Cancer is also a common outcome of changes in the genetic makeup of cells. Cancer, which includes more than 100 varieties in humans, is always characterized by abnormal cell functioning. Malignant cancers exhibit uncontrolled cell division.

Objective 39 **Sources of mutation-causing conditions**

a. Exposure to chemicals

Examples: Inhaling asbestos; inhaling the tar that enters the lungs from smoking cigarettes

- ✔ **Note:** You know by now that our bodies are basically chemical containers in which reactions are taking place continuously. It should come as no surprise then that the introduction of foreign chemicals into the body can disrupt those reactions, including the reactions that transfer the genetic code. Such exposures may lead to illnesses, but they may also directly affect the genetic makeup of the cells.

b. Exposure to energy sources

Examples: Exposure to radioactive materials; exposure to the ultraviolet light of the sun

- ✔ **Note:** Most skin cancers are the result of exposure to ultraviolet light. The energies emitted by radioactive materials can penetrate deep into the body and cause mutations in the genetic code. These energies can even reach the ova and sperm stored in the body and developing fetuses to cause mutations in offspring that did not result from the inheritance of those mutations through the genetic codes of the parents.

c. Infections by other organisms

Example: Viruses that disrupt cell reproduction

✔ **Note:** Illness and infectious organisms may create chemical imbalances or toxic conditions in the body that disrupt normal reproduction.

OBJECTIVE 40

Types of cellular respiration

✔ **Note:** Cell respiration is that part of metabolism that specifically deals with the conversion of glucose to produce energy in the cells (see Figure 8 on the next page). There are three types of cellular respiration: (1) glycolysis (gli-kawl´-uh-suhs), (2) aerobic oxidation (ar-o´-bik awk-suh-da´-shuhn), and (3) electron transport system.

a. Glycolysis (anaerobic oxidation)

- Uses enzymes located in the cytoplasm
- Does not require oxygen

  ✔ **Note: Anaerobic** means "without air or oxygen." Glycolysis does not use oxygen in its reaction. This is helpful to the cells if there is not enough oxygen available, as might occur with respiratory diseases or strenuous exercise.

- Requires two molecules of ATP to start the reaction
- Converts glucose and two ATP molecules into four ATP molecules, hydrogen, and energy

  ✔ **Note:** Glycolysis produces pyruvic (pi-ru´-vik) acid and, in a continuing reaction in the absence of oxygen, lactic (lak´-tik) acid. The lactic acid can later be converted back into pyruvic acid or glucose.

- Requires the vitamin niacin
- May develop into aerobic oxidation once oxygen is available

  ✔ **Note:** Once glucose has been converted into pyruvic acid, glycolysis can follow one of two paths. If there is still a shortage of oxygen, the reaction will continue along the path to produce lactic acid. However, if oxygen is available, the pyruvic acid will move to the mitochondria to be used in aerobic oxidation.

b. Aerobic oxidation

✔ **Note:** Aerobic oxidation is also called **Krebs cycle** or **citric-acid cycle**.

- Uses enzymes located in the mitochondria
- Requires oxygen
- Converts pyruvic acid into one ATP molecule, hydrogen, carbon dioxide, and carbon molecules

- Requires the vitamins thiamine, riboflavin, and niacin
- May continue through additional cycles as carbon combines with acetyl coenzyme A (uh-set´-uhl ko-en´-zim a)

c. Electron transport system

✔ **Note:** The electron transport system is also referred to as the **cytochrome** (sit´-uh-krom) **transport system**.

- Uses proteins located in the mitochondria
- Allows the electrons released by hydrogen atoms to react with cytochromes to generate enough energy to produce 34 ATP molecules from each glucose molecule
- Combines hydrogen and oxygen released from other forms of respiration to produce water
- Requires the vitamins riboflavin and niacin and the minerals iron or copper

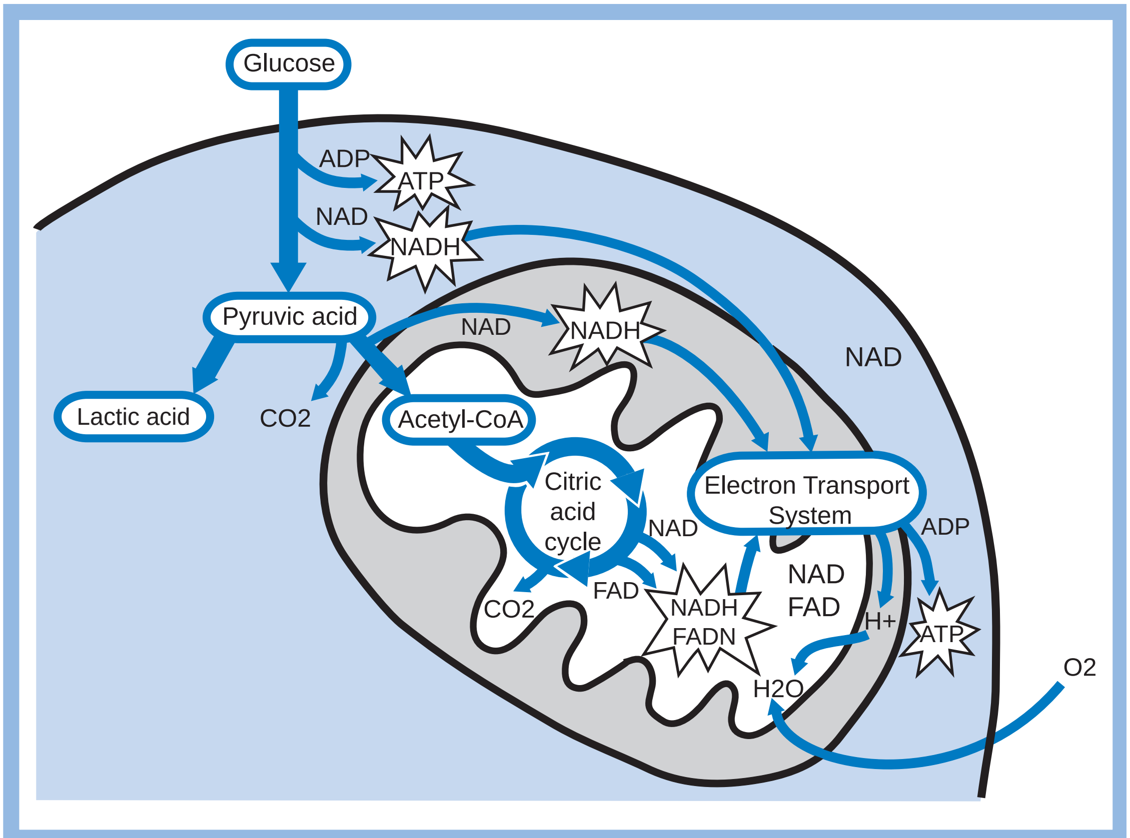


Figure 8
Cell respiration

Objective 41

Levels in the taxonomy system used to classify organisms

- **Note:** Scientists use a system called **taxonomy** to classify all organisms based on their similarities and differences. The system contains seven major levels, beginning with the very broadest similarities and getting more specific until a single kind of organism is identified.

a. Kingdom

- **Note:** There are two major kingdoms: plants and animals. As advances in technologies have enabled scientists to discover more about microbiology and biochemistry, other kingdoms have been added, including fungi, protists (including most algae), and monera (including bacteria). Humans are classed in the animal kingdom.

b. Phylum

Example: The human phylum is Chordata.

c. Class

Example: The human class is Mammalia.

d. Order

Example: The human order is Omnivora.

e. Family

Example: The human family is Primates.

f. Genus

Example: The human genus is Homo.

g. Species

Example: The human species is **Sapiens**.

Objective 42

Types of relationships between organisms

- **Note:** Because we share the planet with each other, organisms form relationships with each other. Generally, these relationships may be classed as beneficial, harmful, or neutral. For example, you know that certain organisms can cause illness in humans. On the other hand, there are organisms that live in our intestines that help us to digest food. Still other organisms seem to have little or no interaction with humans. The terms presented in this objective describe some of the more-important relationships that can exist between organisms.

a. Symbiosis (sim-bi-o´-suhs)—A relationship between two organisms that have close contact with each other

- **Note:** Symbiosis is a general term for any close relationship between organisms of different species, whether that relationship is beneficial or harmful or neither. The two organisms may simply live very near each other, the two organisms may have physical contact, or one organism may actually live on or within the other.

b. Mutualism (myuch´-uh-wuh-liz-uhm)—A relationship between two organisms that is beneficial to both

- **Note:** In a mutualistic relationship, the organisms maintain close contact with one another and both benefit from each other. For example, tick birds stay near herds of cattle or antelope. The birds feed on insects and other pests that bother the herd animals. Thus, both types of organisms benefit. The term **symbiosis** was once applied to this type of relationship but now has a broader meaning.

c. Commensalism (kuh-men´-suh-liz-uhm)—A relationship between two organisms in which one organism benefits and the other neither benefits nor is harmed

- **Note:** The remora fish that attach themselves to sharks, whales, and sea turtles provide no benefit to their hosts yet cause their hosts no real harm. However, the remora is able to eat bits of food that the host misses when feeding. In this way the remora benefits from the commensalistic relationship.

d. Neutralism (nu´-truh-liz-uhm)—A relationship between two organisms in which the organisms present no significant benefit or harm to each other

- **Note:** Squirrels and songbirds that live in the same tree share a neutralistic relationship. While there may be some competition for food and nest sites, the two species have little interaction. In parts of Africa, herds of animals, like zebras and wildebeests, travel and graze together. The increased herd size may allow a greater degree of alertness to danger from predators, but there is essentially no direct benefit to either type of organism.

e. Parasitism (par´-uh-suh-tiz-uhm)—A relationship between two organisms in which one organism is harmed by the presence of the other

- **Note:** Parasitism is an important concern to all health professionals. The organisms that cause diseases in humans are generally parasites. Additionally, disease-carrying organisms such as fleas and ticks are parasitic on humans.

f. Pathogenic (path´-uh-jen-ik)—A relationship between two organisms in which one organism is capable of causing a disease in the other organism

- **Note:** There are organisms that live inside humans in mutualistic relationships. They are nonpathogenic. However, other organisms that enter the body can cause a variety of diseases, generally through the production of toxins that disrupt normal cell functioning.

OBJECTIVE 43

Classes of microorganisms

KEY TERMS

Allergy (al´-uhr-je)—A condition of being highly sensitive to foreign substances that enter the body often because the person's immune system does not respond to the antigen of the substance

Amebic dysentery (uh-me´-bik dis-uhn´-ter-e)—A condition of severe diarrhea often accompanied by blood and mucus that results from an infection of protozoa

Cyst (sist´)—A capsule that forms around microorganisms before they enter dormant periods

- **Note:** Some microorganisms enter periods in which they are inactive, often because environment conditions may not be favorable to them, such as during a drought. Cysts are also used to protect the organism as it moves from host to host, especially for parasites that require multiple hosts.

Exoskeleton (ek-so-skel´-uht-uhn)—A characteristic of some organisms in which the outer tissue of parts of the body are hardened to the point that they support attached softer tissues

Giardiasis (je-ar-di´-uh-suhs)—A condition of diarrhea caused by drinking water containing giardia

Host (host´)—The organism that provides the resources required to sustain a parasitic relationship

Infestation (in-fes-ta´-shuhn)—The presence of parasites in the environment, on the skin, or in the hair of a host

Invertebrate (in-vuhrt´-uh-brat)—An organism that does not have an internal skeleton and, specifically, a spinal column

Malaria (muh-ler´-e-uh)—A parasitic infection of red blood cells by plasmodium virus transmitted by the bite of certain species of mosquito

Spore (spor´)—The dormant form of a bacterium or the reproductive form of a fungus

Unicellular (yu-ni-sel´-yuh-luhr)—Consisting of one cell

a. Bacterium (bak-tir´-e-uhm)—A widely distributed **unicellular** organism that may or may not cause disease

   - **Note:** The plural of bacterium is **bacteria.** There are three primary ways of classifying bacteria. They are classified by their shape (see Objective 44), by their arrangements, and by whether they require oxygen (aerobic) or not (anaerobic).

b. Virus (vi´-ruhs)—A subcellular organism that reproduces as a parasite within other organisms and, consequently, is pathogenic

   - **Note:** Viruses are smaller than bacteria. They consist of DNA or RNA within a protein shell; the protein shell of each virus has a distinct shape. During reproduction, the virus enters a cell in the **host** and uses the chromosomes and enzymes in the cell to replicate itself. The cell will then die. The severity of the disease depends on the kind of cell that is infected. Rabies, chicken pox, measles, influenza, cold sores, polio, and certain tumors are all the result of viruses.

c. Protozoan (prot-uh-zo´-uhn)—A unicellular organism that is adapted for life in water and forms **cysts** that pass from host to host

- **Note:** The plural of protozoan is **protozoa.** Many protozoa are pathogenic to humans. Some, such as those that cause **amebic dysentery** and **giardiasis**, are contracted by consuming infected food or water. Others, such as those that cause **malaria**, are spread by other organisms, such as mosquitoes.

d. Fungus (fuhn´-guhs)—A unicellular or multicellular organism that reproduces by means of spores and that may be pathogenic or nonpathogenic

- **Note:** The plural of fungus is **fungi.** Many fungi, such as molds and mushrooms, live on dead matter and help to decompose it. Unicellular fungi are called **yeast,** and many of them are pathogenic to humans, causing yeast infections in moist areas of the body, athlete's foot, ringworm, and other conditions. In some cases, persons with weakened immune systems may experience serious illness and even death from inhaling **spores** that infect the pulmonary regions. A yeast-induced illness is called a **mycosis** (mi-ko´-suhs).

e. Worm (wuhrm´)—A multicellular organism that in its parasitic form can be pathogenic to humans

- **Note:** Generally referred to as **helminths** (hel´-minths) in the medical profession, parasitic worms can produce very serious **infestations** because they live inside the body and feed on the host's blood and nutrients. Many go through several life stages only some of which are parasitic or that require different hosts for each stage. Flukes, tapeworms, pinworms, and hookworms are examples of helminths that infect humans.

f. Arthropod (ar´-thruh-pawd)—An **invertebrate** organism with six or more jointed legs and an **exoskeleton**

- **Note:** All insects, arachnids (such as spiders), and creatures such as lobsters and crabs are arthropods. Some arthropods are parasitic on humans, including ticks, lice, and mites. Many, such as bees, spiders, and scorpions, carry toxins that can be harmful to humans, especially persons with **allergies** to arthropod venom. Arthropods such as ticks, fleas, flies, and mosquitoes can present additional risks to humans by carrying infectious organisms that enter the bloodstream when the arthropod bites.

OBJECTIVE 44

Classes of microorganisms as classified by their shape

- **Note:** One of the means of classifying bacteria and some other unicellular organisms is by their shape. Three of the common microorganism shapes—bacillum (buh-sil´-uhm), coccus (kawk´-uhs), and spirillum (spi-ril´-uhm)—are illustrated in Figures 9 through 11 below. A bacillum is any rod-shaped bacterium; a coccus is any round, spherical, or oval bacterium; and a spirillum is any coiled bacterium.

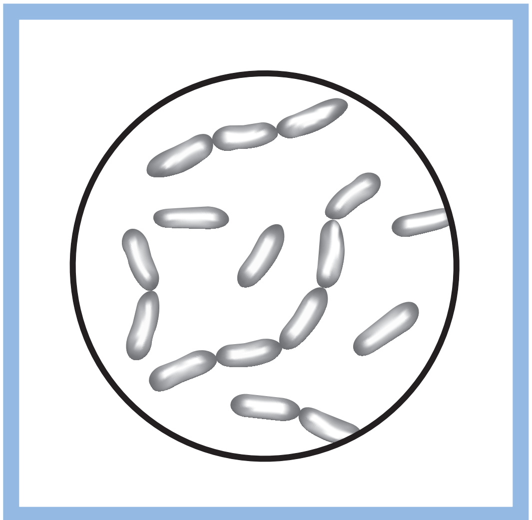


Figure 9
Bacillum

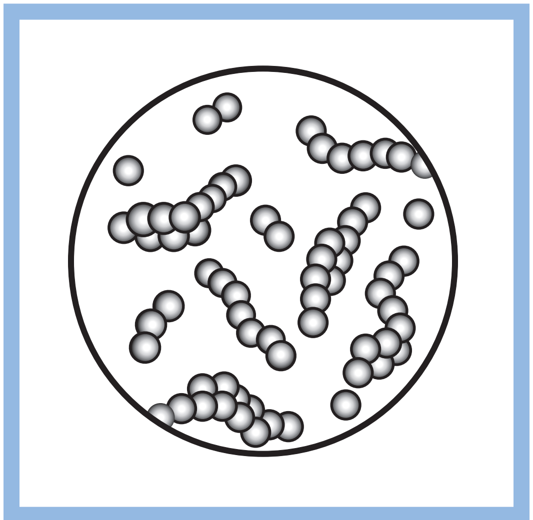


Figure 10
Coccus

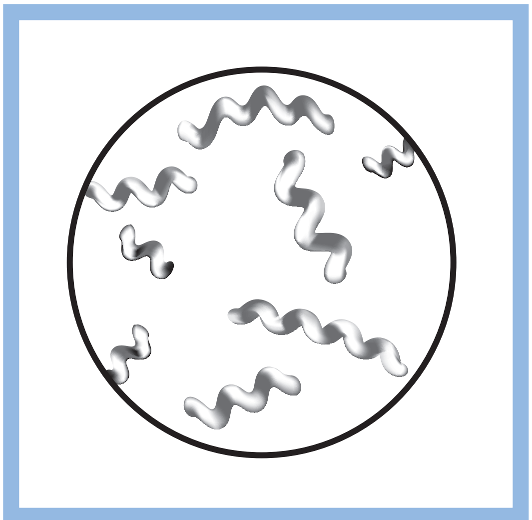


Figure 11
Spirillum

OBJECTIVE 45 **The terms resident flora and transient flora**

- **Note:** While some organisms are pathogenic to humans, many live in the body or on its surface in mutualistic or commensalistic relationships. These organisms are referred to as **resident flora**. Those organisms that inhabit the body temporarily are referred to as **transient flora**. In some cases, a resident flora will become pathogenic. Typically, this happens when the population of some other resident flora has declined, allowing the organism that becomes pathogenic to multiply well beyond its normal number. An organism that takes advantage of a temporary situation to spread is called an **opportunist.**

a. Resident flora (rez´-uh-dent flor´-uh)—Organisms that normally live in and on the bodies of healthy persons without causing harm when located in specific sites

b. Transient flora (tranz´-e-uhnt flor´-uh)—Organisms that take up residence in or on the body temporarily in a location where they are not normally found

OBJECTIVE 46 **Purpose of a gram stain**

A gram stain identifies the shape of a pathogen and indicates a positive or negative characteristic of the pathogen that allows preliminary identification of the organism as an aid to diagnosis.

- **Note:** The identification and treatment of a disease often depends on interpreting a limited number of clues, such as a person's symptoms. Another clue is the identification of the pathogenic organism involved. One method of identifying bacteria is the gram stain, in which an infected sample, such as saliva, is treated with a dye and examined under a microscope. The shape and color of the organism is apparent under the microscope. Depending on whether the bacteria turn a bluish color or a reddish color, the bacteria can be classed as either gram negative or gram positive. Since a genus will react as either positive or negative and a shape may be particular to a genus or species, the gram-stain test is often enough to specifically identify an organism.

OBJECTIVE 47 **Characteristics of bacteria**

KEY TERM

Facultative (fak´-uhl-tat-iv)—Having the ability to adapt to more than one condition

a. The tough outer cell wall gives a bacterium its shape.

b. Cocci and bacilli often colonize with each other so that another way of identifying bacteria is by the shape of their colonies.

    - **Note:** The shape of the bacterial groups is added as a prefix to the shape of the organism. Thus, cocci that forms clusters are called **staphylococcus** (staf-uh-lo-kawk´-uhs), those that form chains are called **streptococcus** (strep-tuh-kawk´-uhs), and those that form pairs are called **diplococcus** (dip-lo-kawk´-uhs). There are also strepto- and diplo- forms of bacilli.

c. Bacteria reproduce by binary fission, in which the chromosome duplicates itself and then the cell divides into two identical cells.

d. Aerobic species require that oxygen be present in order to reproduce.

e. Anaerobic species require that no oxygen be present in order to reproduce.

f. **Facultative** anaerobic species can reproduce with or without oxygen.

Objective 48 **Characteristics of rickettsiae**

a. Rickettsiae (rik-et´-se-uh) are bacteria that can reproduce only within the cells of a living host.

b. Rickettsiae infect mammals and are often spread by arthropods.

✔ **Note:** Two rickettsial diseases include Rocky Mountain spotted fever and typhus, spread by ticks and lice respectively.

c. Rickettsiae infections can be treated with antibiotics.

Objective 49 **Characteristics of viruses**

a. Viruses are nucleic acids within shells of protein.

b. Each virus exhibits a shape that is characteristic of that virus.

c. Viruses can only reproduce when they are within the living cells of a host organism.

d. A virus will use the nucleic acid and enzymes of an infected cell to produce other viruses, often multiplying to the point that the host cell ruptures and dies.

e. The severity of a viral disease depends on the type of cells that are infected.

f. Some viruses can become dormant so that they present no signs of infection and then become active again after a period of time, even years later.

g. Some viruses can be transmitted from a pregnant woman to her fetus.

h. Antiviral medications are difficult to develop because viruses reside inside cells, use the cell's chemicals to reproduce, and offer few functions that can be attacked without harming the host organism.

Objective 50 **Characteristics of protozoa**

a. Protozoa are unicellular.

b. Protozoa live in water and soil.

c. Protozoa can form cysts and become dormant.

d. Protozoa generally spread from food or water contaminated with cysts.

OBJECTIVE 51

Characteristics of fungi and algae

✔ **Note:** Fungi (fuhn´-ji; singular **fungus,** fuhn´-guhs) and algae (al´-je) are two types of plants. They are distinct from each other primarily in that alga has chlorophyll in its cells and can produce its own nourishment in the presence of light. Fungi do not have chlorophyll and must extract their nutrition from an external source, such as decaying organic matter or a live host. Both types of organisms are simple plants and are not differentiated into complex structures such as root systems and leaves. Many types of fungi are capable of infecting humans. Infections with algae are extremely rare with fewer than 100 cases reported in humans.

a. Fungi

- Fungi may be unicellular or multicellular.
- Some fungi are normally found in and on the body.
- Fungi infections may result from the use of antibiotics or reduced resistance due to injuries or diseases.
- Most fungi infections are superficial but can spread to the inside of the body through spores.

b. Algae

- Algae may be unicellular or multicellular.
- Infestation generally occurs as a result of a break in the skin or a trauma, including surgery, and is generally limited to the skin or bursa.
- The most-common symptom is skin lesions that resemble many other conditions so that the diagnosis must be confirmed through laboratory analysis.

OBJECTIVE 52

Common parasites that afflict humans

KEY TERM

Vectors (vek´-tuhrs) **of disease**—The conditions that tend to promote the spread of a disease, such as when the bite of an arthropod allows pathogens to enter a person's bloodstream

a. Parasitic worms live off nutrients in the host's body, in the host's blood, or on the host itself.

b. Many parasitic worms have several stages of life involving eggs, larvae, and adult stages.

c. Parasitic worms generally inhabit specific body sites.

d. For some species of parasitic worms, the inhabited site varies with the stage of development and may even involve more than one host species.

e. Mites and lice generally afflict the surface of a host's body and present little direct risk to the host.

f. Parasites such as lice, fleas, mosquitoes, and ticks may be **vectors of disease.**

Objective 53

Assignment Sheet 1—Construct a Model of a Typical Cell

Name ______________________________ Date ______________

Evaluation criteria **Rating**

- Model reflects research findings related to size, shape, and structure ________
- Presentation is clear and concise and includes the functions of each part of the cell, and the functions of specialized structures found in cells ________
- Teamwork demonstrated throughout completion of assignment ________

Overall rating ________

Evaluator's comments ____

____

____

Part 1 Directions

Research cells of the human body using resources available on the Internet or provided by your instructor. Work with teammates to collect the following information to help you in constructing your model and preparing your group presentation about the selected cell.

Size ______________________________

Shape ______________________________

Major parts of a cell ______________________________

Explain the functions of each part of a cell. ______________________________

____

____

____

____

Explain the functions of specialized structures found in cells. ______________________________

____

____

____

Part 2 Directions

Construct a 3-D model of a typical cell showing the major parts of the cell using the findings collected through your research.

Part 3 Directions

Present findings to class members using your model as a visual aid. Point out each part of a cell and explain their functions and the functions of the specialized structures found in cells.

Objective 54

Assignment Sheet 2—Develop a Presentation on Bacteria, Viruses, Fungi, or Parasites

Name ______________________________ Date ______________

Evaluation criteria
Rating

- Presentation reflects research findings as to how bacteria, viruses, fungi, or parasites affect the human body ______
- Presentation is clear and concise and includes: ______

  — classes of microorganisms and bacteria, or
  — characteristics of viruses, or
  — characteristics of fungi, or
  — common parasites that afflict humans
  — examples of when a surgical technologist may come into contact with bacteria, viruses, fungi, or parasites
  — explanation of how a surgical technologist should deal with the microorganism

Overall rating ______

Evaluator's comments ______________________________

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Part 1 Directions

Divide the class into teams to complete research and develop a presentation on bacteria, viruses, fungi, or parasites. All topics should be covered by at least one team.

Research bacteria, viruses, fungi, or parasites using resources available on the Internet or provided by your instructor. Work with your team and write your findings below. This information will help you in constructing your outline and preparing your presentation about bacteria, viruses, fungi, or parasites.

Classes of microorganisms ______________________________

Shape and characteristics of bacteria, or ______________________________

Characteristics of viruses, or ____________________

Characteristics of fungi, or ____________________

Common parasites that afflict humans ____________________

Explain the effects of bacteria, viruses, fungi, or parasites on the human body.

____

____

Describe when a surgical technologist may come into contact with bacteria, viruses, fungi, or parasites and how the surgical technologist should deal with the organisms.

____

____

Part 2 Directions

Using PowerPoint® software, develop a presentation using the findings collected through your research on bacteria, viruses, fungi, or parasites. Where access to PowerPoint is not possible, use flip charts, posters or other means of media to develop the presentation. Practice the presentation with the team. Give your PowerPoint presentation and provide explanation of the subject matter and answer any questions from your classmates or instructor.

OBJECTIVE 55

Assignment Sheet 3—Practice Critical Thinking: Complete Biochemistry and Microbiology Case Studies

Name ______________________________ Date ______________

Evaluation criteria **Rating**

- Directions were followed ________
- Answers demonstrate an understanding of the information presented in the Information Sheet ________
- Complete sentences were used in answering each case study ________

Overall rating ________

Evaluator's comments ______________________________

____

____

INTRODUCTION

Biochemistry and microbiology play important roles in health care. As you have learned in this module, our bodies are containers for a number of chemicals. The performance of these chemical engines is easily affected by chemicals that enter the body and by invasions by microorganisms. For these reasons, it is as important that you have an understanding of how chemical reactions within the body react to these outside influences as it is that you have an understanding of the body's normal activities.

CASE STUDY 1

Patients often receive solutions intravenously while in the hospital. These solutions may include nutrients or medications in water. The solution generally has salts dissolved in the water. Why is this done?

CASE STUDY 2

Mr. Rodriguez has a respiratory infection. Tests have been made of his oxygen capacity. The tests show that Mr. Rodriguez's lungs are not taking in enough oxygen nor are they getting rid of carbon dioxide efficiently. Considering this situation, what do you expect to happen to the pH value of the patient's blood and why?

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Case Study 3

Many people today consume "sports drinks" when they exercise. These drinks contain electrolytes and are intended to replace those lost during exercise. Does this seem like a good practice? Why or why not?

Case Study 4

Mrs. Cunningham has been diagnosed with osteoporosis. What chemical is the patient's body lacking or failing to process adequately? How does this lead to Mrs. Cunningham's condition?

CASE STUDY 5

Judy Phan is a 14-year-old girl who has been diagnosed with anemia. What could be some of the contributing factors and what mineral is Miss Phan's doctor likely to prescribe?

CASE STUDY 6

Arthropods can be vectors of disease. Are there organisms in your area that present a risk as vectors of disease? What is the organism and what is the associated disease that pose a threat in your area?

Answers to Assignment Sheets

Assignment Sheet 1—Construct a Model of a Typical Cell

This assignment should be evaluated by the instructor using the evaluation criteria stated on the assignment sheet.

Assignment Sheet 2—Develop a Presentation on Bacteria, Viruses, Fungi, or Parasites

This assignment should be evaluated by the instructor using the evaluation criteria stated on the assignment sheet.

Assignment Sheet 3—Practice Critical Thinking: Complete Biochemistry and Microbiology Case Studies

Suggested answers

Case Study 1 Salts are dissolved in the water to make the solution comparable to the concentration of blood plasma and body fluids. If the IV solutions were lower concentrations than the surrounding cells, then minerals, nutrients, and other chemicals would flow from the cells into the solution-diluted blood.

Case Study 2 The pH will decrease in the blood. The increased CO_2 will result in more hydrogen ions in the blood, causing the blood to be more acidic.

Case Study 3 While sports drinks can help to replace electrolytes, they can actually slow the absorption of fluid. Most fluid absorption occurs in the small intestine. If the fluid has a high solute concentration, absorption will be slower.

Case Study 4 Calcium is the chemical. Inadequate intake of calcium leads to the body resorbing calcium from the bones to supply other systems with the required calcium. This process reduces bone mass.

Case Study 5 Anemia can be caused by kidney or liver disorders or a low intake of dietary iron. Iron supplements may be prescribed.

Case Study 6 Answers will vary and must be evaluated to the satisfaction of the instructor.