CHAPTER 2

Chemical Basics of Life

OUTLINE

OBJECTIVES

After studying this chapter, readers should be able to:

1. Describe the relationships between atoms and molecules.
2. Explain chemical bonds.
3. Describe how an atomic number is determined.
4. List the major groups of inorganic chemicals common in cells.
5. Explain acids, bases, and buffers.
6. Define the characteristics of lipids and proteins.
7. Define *pH*.
8. Describe the functions of various types of organic chemicals in cells.
9. List four examples of steroid molecules.
10. Explain nucleic acids.

KEY TERMS

Acids: Electrolytes that release hydrogen ions in water.
Activation energy: The amount of energy required to start a reaction.
Anions: Ions with a negative charge.
Atomic number: A whole number representing the number of positively charged protons in the nucleus of an atom.
Atomic weight: The total number of protons and neutrons in the nucleus of an atom.
Atoms: The smallest complete units of an element, varying in size, weight, and interaction with other atoms.
Bases: Electrolytes that release ions that bond with hydrogen ions.
Carbohydrates: Substances (including sugars) that provide much of the energy required by the body's cells, as well as helping to build cell structures.
Catalysts: Atoms or molecules that can change the rate of a reaction without being consumed during the process.
Cations: Ions with a positive charge.
Chemistry: The study of the composition of matter and changes in its composition.
Compounds: Molecules made up of different bonded atoms.
Decomposition: A reaction that occurs when bonds with a reactant molecule break, forming simpler atoms, molecules, or ions.
Electrolytes: Substances that release ions in water.
Electrons: Single, negatively charged particles that revolve around the nucleus of an atom.
Elements: Fundamental substances that compose matter, such as carbon, hydrogen, and oxygen.

KEY TERMS CONTINUED

Hydrogen bond: The attraction of the positive hydrogen end of a polar molecule to the negative nitrogen or oxygen end of another polar molecule.
Inorganic: Not having both carbon and hydrogen atoms.
Ions: Atoms that either gain or lose electrons.
Isotope: One of two (or more) forms of an element having the same number of protons and electrons, but different numbers of neutrons; they may or may not be radioactive.
Lipids: Substances that do not dissolve in water and include a variety of compounds with vital cell functions, including fats, phospholipids, and steroids.
Matter: Liquids, gases, and solids both inside and outside of the human body; it takes up space and has weight.
Molecule: The formation of two or more atoms.
Neutrons: Uncharged or "neutral" particles in the nucleus of an atom.
Nucleic acids: Macromolecules that carry genetic information or form structures within cells, and include DNA and RNA.
Nucleus: The central portion of an atom that contains protons and neutrons.
Organic: Having both carbon and hydrogen atoms.
pH: A value by which hydrogen ion concentrations may be measured.
Polar: A molecule that uses a covalent bond in which electrons are not shared equally; this results in a shape that has an uneven distribution of charges.
Proteins: Substances made up of amino acids that are vital for many body functions, including structures and their functions, energy, and hormonal requirements.
Protons: Single, positively charged particles inside the nucleus of an atom.
Radioisotopes: Also known as radioactive isotopes or radionuclides, they are atoms with unstable nuclei.
Steroid: Molecules with four connected rings of carbon atoms, including cholesterol, estrogen, progesterone, testosterone, cortisol, and estradiol.
Synthesis: A reaction that occurs when two or more reactants (atoms) bond to form a more complex product or structure.

Chemistry is the science that deals with the structure of matter, and the study of the human body begins with chemistry. It is essential for other sciences, including physiology, pathology, pharmacology, and microbiology. Life is based on atomic, molecular, and chemical interactions. Each cell of the body contains organelles made up of macromolecules. The cells then compose tissues and organs. The chemical basics of life require the interactions of all of these components.

Atoms, Molecules, and Chemical Bonds

The composition of matter and changes in its composition are the focuses of the study of chemistry. If you understand chemistry, your understanding of anatomy and physiology will be improved. Chemical changes within cells influence body functions and the status of the body's structures. Chemicals of the body include water, proteins, carbohydrates, lipids, nucleic acids, and salts, as well as foods, drinks, and medications.

Matter is defined as anything that takes up space and has mass. Mass is a physical property that determines an object's weight, based on the Earth's gravitational pull. Matter includes liquids, gases, and solids both inside and outside of the human body. **Elements** are fundamental substances that compose matter. Copper, iron, gold, silver, aluminum, carbon, hydrogen, and oxygen are all examples of elements. Most living organisms need about 20 elements to survive. **Table 2–1** lists the major and trace elements required by the human body.

Atoms are tiny particles that compose elements. Atoms are the smallest complete units of an element,

Table 2–1 Elements of the Human Body

Major Elements (totaling 99.9%)	Percentage in the Body
Oxygen (O)	65%
Carbon (C)	18.5%
Hydrogen (H)	9.5%
Nitrogen (N)	3.2%
Calcium (Ca)	1.5%
Phosphorus (P)	1%
Potassium (K)	0.4%
Sulfur (S)	0.3%
Chlorine (Cl)	0.2%
Sodium (Na)	0.2%
Magnesium (Mg)	0.1%
Trace Elements (totaling 0.1%)	
Chromium (Cr)	—
Cobalt (Co)	—
Copper (Cu)	—
Fluorine (F)	—
Iodine (I)	—
Iron (Fe)	—
Manganese (Mn)	—
Zinc (Zn)	—

and vary in size, weight, and interaction with other atoms. The characteristics of living and nonliving objects result from the atoms that they contain, as well as how those atoms combine and interact. Thus, by forming chemical bonds, atoms can combine with other atoms that are not similar to them.

Atomic Structure

Atoms are composed of subatomic particles. Each atom consists of protons, neutrons, and electrons. Protons and neutrons are similar in size and mass; however, **protons** bear a positive electrical charge whereas **neutrons** are electrically neutral (uncharged). **Electrons** bear a negative electrical charge. An atom's mass is determined mostly by the number of protons and neutrons in its **nucleus**. The mass of a larger object, such as the human body, is the sum of the masses of all of its atoms. **Figure 2–1** shows the components of an atom and its nucleus.

Electrons orbit an atom's nucleus at high speed, forming a spherical electron cloud. Atoms normally contain equal numbers of protons and electrons. The number of protons in an atom is known as its **atomic number**. Thus, hydrogen (H), the simplest atom, has one proton, giving it the atomic number 1, while magnesium, with 12 protons, has the atomic number 12.

The **atomic weight** of an element's atom equals the number of protons and neutrons in its nucleus. For example, oxygen has eight protons and eight neutrons, so its atomic weight is 16. An **isotope** is defined as when an element's atoms have nuclei containing the same number of protons, but different numbers of neutrons. Isotopes may or may not be radioactive. Radioactivity is the emission of energetic particles known as *radiation*, which occurs because of instability of the atomic nuclei.

The nuclei of certain isotopes (**radioisotopes**) spontaneously emit subatomic particles or radiation in measurable amounts. The process of emitting radiation is called *radioactive decay.* Strongly radioactive isotopes are dangerous because their emissions can destroy molecules, cells, and living tissue. For diagnostic procedures, weaker radioactive isotopes are used to diagnose structural and functional characteristics of internal organs. Radiation is basically identified as one of three common forms: alpha (α), beta (β), or gamma (γ). Gamma radiation is the most penetrating type, and is similar to X-ray radiation.

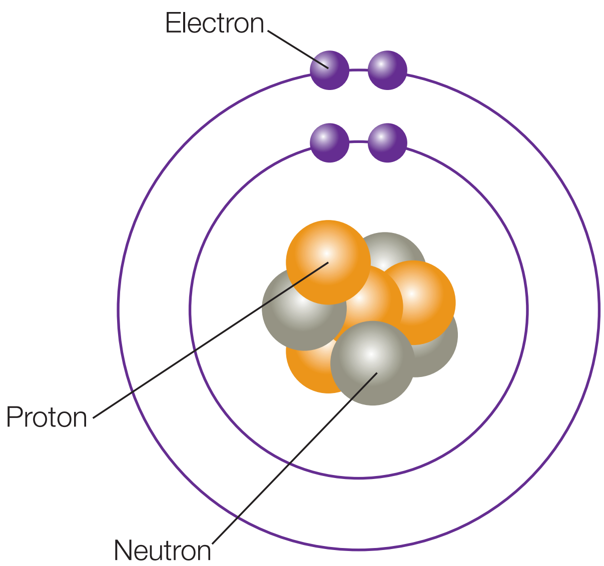


FIGURE 2–1 The components of an atom

✓ CHECK YOUR KNOWLEDGE

1. Differentiate between atomic weight and atomic number.
2. Describe the locations of electrons, protons, and neutrons.

Molecules

The term **molecule** is defined as any chemical structure that consists of atoms held together by covalent bonds (involving the sharing of electrons between atoms). When two atoms of the same element bond, they produce molecules of that element, such as hydrogen, oxygen, or nitrogen molecules.

Chemical Bonds

Atoms can bond with other atoms by using chemical bonds that result from interactions between their electrons. During this process, the atoms may either gain, lose, or share electrons. Chemically inactive atoms are known as *inert* atoms. An example of a chemical that is made up of inert atoms is helium. Atoms that either gain or lose electrons are called **ions**. These atoms are electrically charged. An example of an electrically charged atom, or ion, is sodium.

Ionic Bonds

Ionic bonds form between ions. Ions with a positive charge (+) are called **cations**, and those with a negative charge (−) are called **anions**. Oppositely charged ions attract each other to form an *ionic bond*. This is a chemical bond that forms arrays (indiscreet molecules) such as crystals. An example

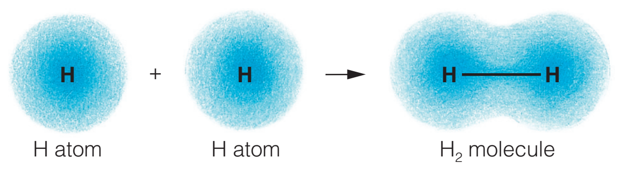


FIGURE 2–2 Covalent bond

is when sodium forms an ionic bond with chloride to create sodium chloride (table salt).

Covalent Bonds

Some atoms can complete their outer electron shells by sharing electrons to create a covalent bond. They do not gain or lose electrons. In a covalent bond, each atom achieves a stable form. An example of a covalent bond is when two hydrogen atoms bond to form a hydrogen molecule (see **Figure 2–2**).

If a single pair of electrons is shared, the result is a single covalent bond. If two pairs are shared, the result is a double covalent bond. Some atoms can even form triple covalent bonds. Some covalent bonds do not share electrons equally, resulting in a **polar** molecule—one that has an uneven distribution of charges. Polar molecules have equal numbers of protons and electrons, but one end of the molecule is slightly negative while the other end is slightly positive. An example of a polar molecule is water, created by hydrogen and oxygen atoms.

When the positive hydrogen end of a polar molecule is attracted to the negative nitrogen or oxygen end of another polar molecule, the attraction is called a **hydrogen bond** (see **Figure 2–3**). These bonds are weak at body temperature, and may change form, from water to ice and back again. Hydrogen bonds are important in protein and nucleic acid structure, forming between polar regions of different parts of a single, large molecule.

Molecules made up of different bonded atoms are called **compounds**. Examples of compounds include water (a compound of hydrogen and oxygen), table sugar, baking soda, alcohol as used in beverages, natural gas, and most medicinal drugs. A molecule of a compound has specific types and amounts of atoms. For example, water consists of two hydrogen atoms and one oxygen atom. When two hydrogen atoms bind with two oxygen atoms, they form hydrogen peroxide instead of water.

The numbers and types of atoms in a molecule are represented by a *molecular formula*. The molecular formula for water is H_2O, signifying the two atoms of hydrogen and the one atom of oxygen. *Structural formulas* are used to signify how atoms are joined and arranged inside molecules. Single bonds are represented by single lines, and double bonds are represented by double lines. When structural formulas are represented in three-dimensional models, different colors are used to show different types of atoms.

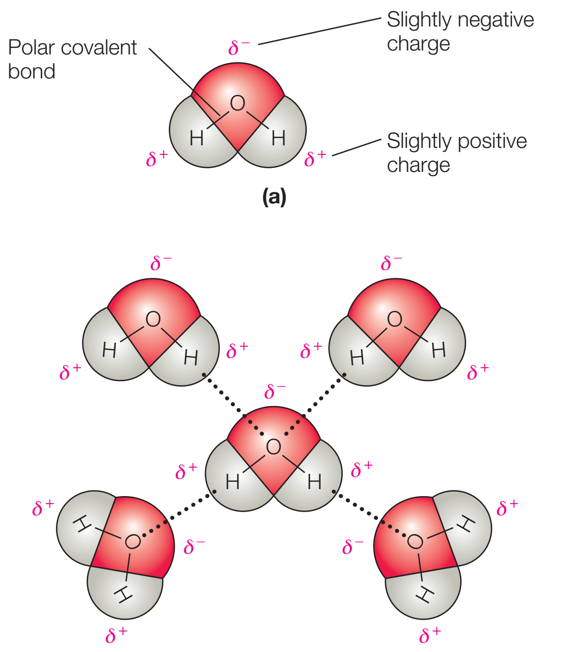


FIGURE 2–3 Hydrogen bond

✓ CHECK YOUR KNOWLEDGE

1. Distinguish between ionic bonds and covalent bonds.
2. Which kind of bond holds together atoms in a water molecule?

Types of Chemical Reactions

Four types of chemical reactions are important to the study of physiology: synthesis reactions, decomposition reactions, exchange reactions, and reversible reactions.

Synthesis Reactions

Chemical reactions change the bonds between atoms, molecules, and ions to generate new chemical combinations. **Synthesis** is a reaction that occurs when two or more reactants (atoms) bond to form a more complex product or structure. The formation of water from hydrogen and oxygen molecules is a synthesis reaction. Synthesis always involves the formation of new chemical bonds, whether the reactants are atoms or molecules. Synthesis requires energy, and it is important for growth and the repair of tissues.

Synthesis is symbolized as follows: $A + B \rightarrow AB$

Decomposition Reactions

Decomposition is a reaction that occurs when bonds within a reactant molecule break, forming simpler atoms, molecules, or ions. For example, a typical meal contains molecules of sugars, proteins, and fats that are too large and too complex to be absorbed and used by the body. Decomposition reactions in the digestive tract break these molecules down into smaller fragments before absorption begins.

Decomposition is symbolized as follows: $AB \rightarrow A + B$

Exchange Reactions

In an *exchange reaction*, parts of the reacting molecules are shuffled around to produce new products. An example of an exchange reaction is the reaction of an acid with a base, which forms water and a salt.

Exchange reactions are symbolized as follows: $AB + CD \rightarrow AD + CB$

Reversible Reactions

A *reversible reaction* is one wherein the products of the reaction can change back into the reactants they originally were. These reactions can proceed in opposite directions, depending on the relative proportions of reactants and products, as well as how much energy is available.

So, if $A + B \rightarrow AB$, then $AB \rightarrow A + B$. Many important biological reactions are freely reversible. Such reactions can be represented as the equation:

$$A + B \rightarrow AB$$

✓ CHECK YOUR KNOWLEDGE

1. Describe four kinds of chemical reactions.
2. What are the structural formulas for synthesis reactions and exchange reactions?

Enzymes

Enzymes promote chemical reactions by lowering the **activation energy** requirements. Activation energy is the energy that must be overcome in order for a chemical reaction to occur. Therefore, they make chemical reactions possible. Enzymes belong to a class of substances called **catalysts** (compounds that accelerate chemical reactions without themselves being permanently changed or consumed). A cell makes an enzyme molecule to promote a specific reaction. Enzymatic reactions, which are reversible, can be written as:

$$A + B \overset{\text{enzyme}}{\rightleftarrows} AB$$

Acids, Bases, and the pH Scale

Electrolytes are substances that release ions in water. When they dissolve in water, the negative and positive ends of water molecules cause ions to separate and interact with water molecules instead of each other. The resulting solution contains electrically charged particles (ions) that will conduct electricity. **Acids** are electrolytes that release hydrogen ions in water. An example of an acid is hydrochloric acid, made up of hydrogen and chloride ions. **Bases** are electrolytes that release ions that bond with hydrogen ions. An example of a base is sodium hydroxide, made up of sodium, oxygen, and hydrogen ions. In body fluids, the concentrations of hydrogen and hydroxide ions greatly affects chemical reactions. These reactions control certain physiological functions such as blood pressure and breathing rates.

Hydrogen ion concentrations can be measured by a value called **pH**. The hydrogen ion concentration in body fluids is vital. It is expressed in a type of mathematical shorthand based on concentrations calculated in moles per liter (with a mole representing an amount of solute in a solution). The pH of a solution is defined as the level of acidity or basicity. The pH scale ranges from 0 to 14, with 7 being the midpoint (meaning it has equal numbers of hydrogen and hydroxide ions). Pure water has a pH of 7, and this midpoint is considered to be neutral (neither acidic nor basic). Measurements of less than 7 pH are considered acidic, meaning that there are more hydrogen ions than hydroxide ions. Measurements of more than 7 pH are considered basic, also known as alkaline, meaning that there are more hydroxide ions than hydrogen ions.

The pH of blood usually ranges from 7.35 to 7.45. Abnormal fluctuations in pH can damage calls and tissues, change the shapes of proteins, and alter cellular functions. *Acidosis* is an abnormal physiological state caused by blood pH that is lower than 7.35. If pH falls below 7, coma may occur. *Alkalosis* results from blood pH that is higher than 7.45. If pH rises above 7.8, it generally causes uncontrollable and sustained skeletal muscle contractions.

Chemicals that resist pH changes are called *buffers*. They combine with hydrogen ions when these ions are excessive and contribute hydrogen ions

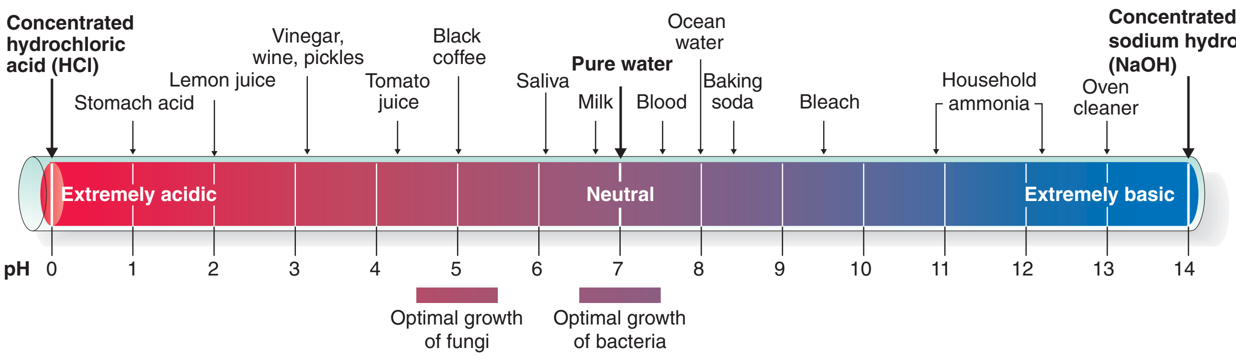


FIGURE 2–4 pH scale

when these ions are reduced. **Figure 2–4** shows the pH values of acids and bases.

CHECK YOUR KNOWLEDGE

1. Why are enzymes needed in our cells?
2. What does pH measure?

Chemical Constituents of Cells

Chemicals can basically be divided into two main groups: organic and inorganic. **Organic** chemicals are those that always contain the elements carbon and hydrogen, and generally oxygen as well. **Inorganic** chemicals are any chemicals that do not. Inorganic substances release ions in water and are also called electrolytes. Though many organic substances also dissolve in water, they dissolve to great effect in alcohol or ether. Organic substances that dissolve in water usually do not release ions and are known as *nonelectrolytes*.

Inorganic Substances

Inorganic substances in body cells include oxygen, carbon dioxide, compounds that are known as salts, and water. The most abundant compound in the human body is water, accounting for nearly two thirds of body weight. Any substance that dissolves in water is called a *solute*. Because solutes dissolved in water are more likely to react with each other as they break down into smaller particles, most metabolic reactions occur in water. In the blood, the watery (aqueous) portion carries vital substances such as oxygen, salts, sugars, and vitamins among the digestive tract, respiratory tract, and the cells.

Oxygen enters the body through the respiratory organs and is transported in the blood. The red blood cells bind and carry the largest amount of oxygen. Organelles inside the cells use oxygen for energy release from nutrients such as glucose (sugar) to drive cellular metabolic activities. Carbon dioxide is an inorganic compound produced as a waste product when some metabolic processes release energy. It is exhaled via the lungs.

Salts are compounds of oppositely charged ions that are abundant in tissues in fluids. Many ions required by the body are supplied in salts, including sodium, chloride, calcium, magnesium, phosphate, carbonate, bicarbonate, potassium, and sulfate. Salt ions are important for transporting substances to and from the cells, as well as for muscle contractions and nerve impulse conduction. Common inorganic molecules are summarized in **Table 2–2.**

Organic Substances

Organic substances include carbohydrates, lipids, proteins, and nucleic acids. Many organic molecules are made up of long chains of carbon atoms linked by covalent bonds. The carbon atoms usually form additional covalent bonds with hydrogen or oxygen atoms and, less commonly, covalent bonds with nitrogen, phosphorus, sulfur, or other elements.

CHECK YOUR KNOWLEDGE

1. Distinguish between organic and inorganic compounds.
2. Explain how the chemical properties of oxygen and water make life possible.

Carbohydrates

Carbohydrates provide much of the energy required by the body's cells, as well as helping to build cell structures. Carbohydrate molecules consist of carbon, hydrogen, and oxygen molecules. The carbon atoms they contain join in chains that vary with the type of carbohydrate. Carbohydrates with shorter chains are called *sugars*.

Simple sugars have 6 carbon atoms, 12 hydrogen atoms, and 6 oxygen atoms ($C_6H_{12}O_6$). They are also known as *monosaccharides*. Simple sugars

Table 2–2 Inorganic Substances in Cells

Formula or Symbol	Molecule or Ion	Function
H_2O	Water molecule	Major component of body fluids, biochemical reactions, chemical transport, and temperature regulation
O_2	Oxygen molecule	Used for energy release from glucose molecules
CO_2	Carbon dioxide	Metabolic waste product; forms carbonic acid via reaction with water
HCO_3^-	Bicarbonate ions	Assists in acid–base balance
CA^{+2}	Calcium ions	Used in bone development, muscle contraction, and blood clotting
CO_3^{-2}	Carbonate ions	Important for formation of bone tissue
Cl^-	Chloride ions	Assists in maintaining water balance
Mg^{+2}	Magnesium ions	Important for formation of bone tissue and certain metabolic processes
PO_4^{-3}	Phosphate ions	Used in ATP, nucleic acid, and other vital substance synthesis; important for formation of bone tissue and to maintain cell membrane polarization
K^+	Potassium ions	Needed for cell membrane polarization
Na^+	Sodium ions	Needed for cell membrane polarization and to maintain water balance
SO_4^{-2}	Sulfate ions	Assists in cell membrane polarization

include glucose, fructose, galactose, ribose, and deoxyribose. Ribose and deoxyribose differ from the others in that they each contain five atoms of carbon. Complex carbohydrates include sucrose (table sugar) and lactose (milk sugar). Some of these carbohydrates are double sugars or *disaccharides*. Other types of complex carbohydrates contain many simple joined sugar units, such as plant starch, and are known as *polysaccharides*. Humans and other animals synthesize a polysaccharide called glycogen (see **Figure 2–5**).

Lipids

Lipids are not soluble in water. They may dissolve in other lipids, oils, ether, chloroform, or alcohol. Lipids include a variety of compounds with vital cell functions. These compounds include fats, phospholipids, and steroids. Fats are the most common type of lipids. Like carbohydrates, fat molecules also contain carbon, hydrogen, and oxygen, but they have far fewer oxygen atoms than do carbohydrates.

Fatty acids and glycerol are the building blocks of fat molecules. A single fat molecule consists of one

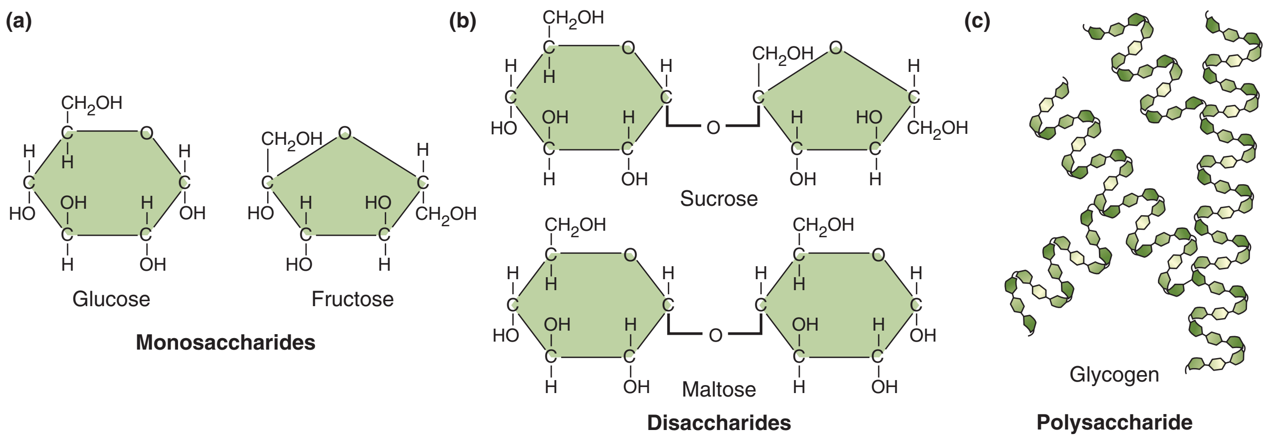


FIGURE 2–5 a) Monosaccharide, (b) Disaccharide, and (c) Polysaccharide

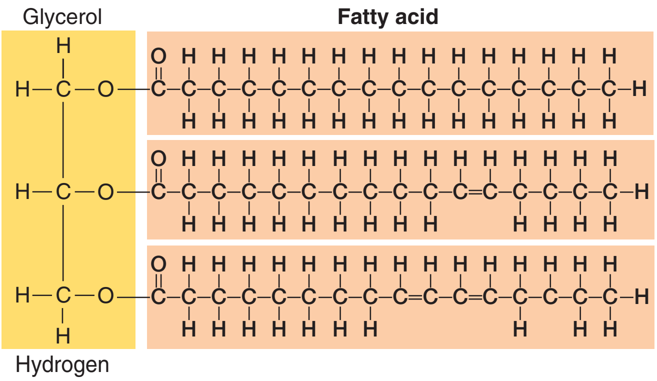


FIGURE 2–6 Saturated fats

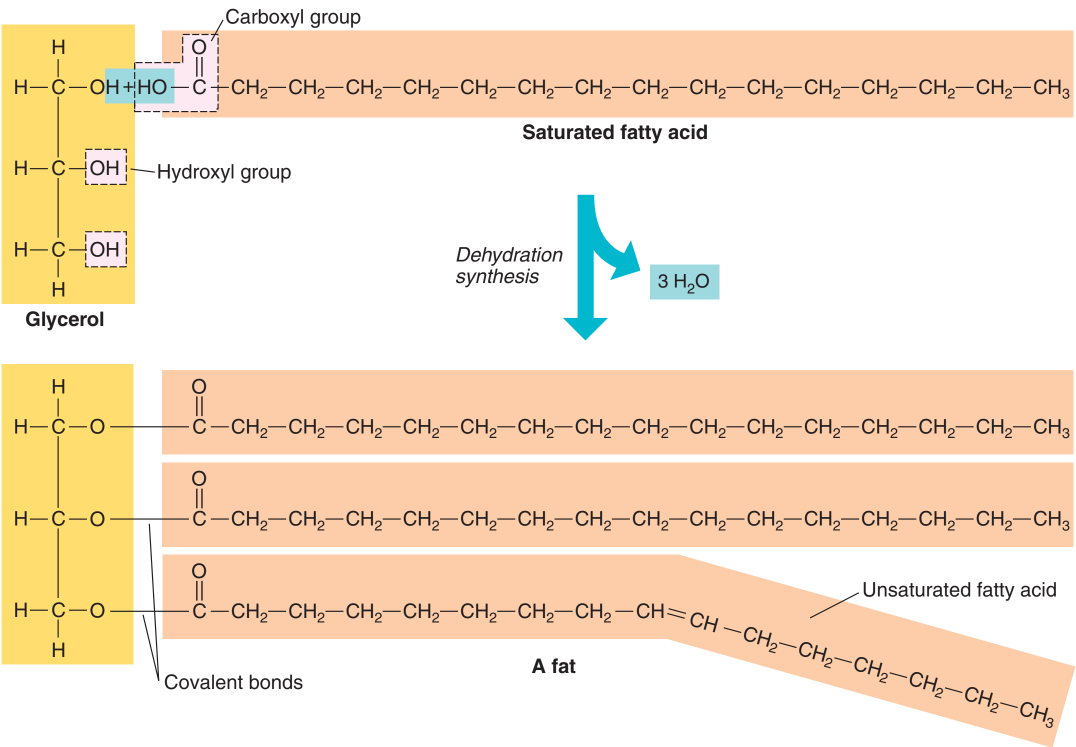


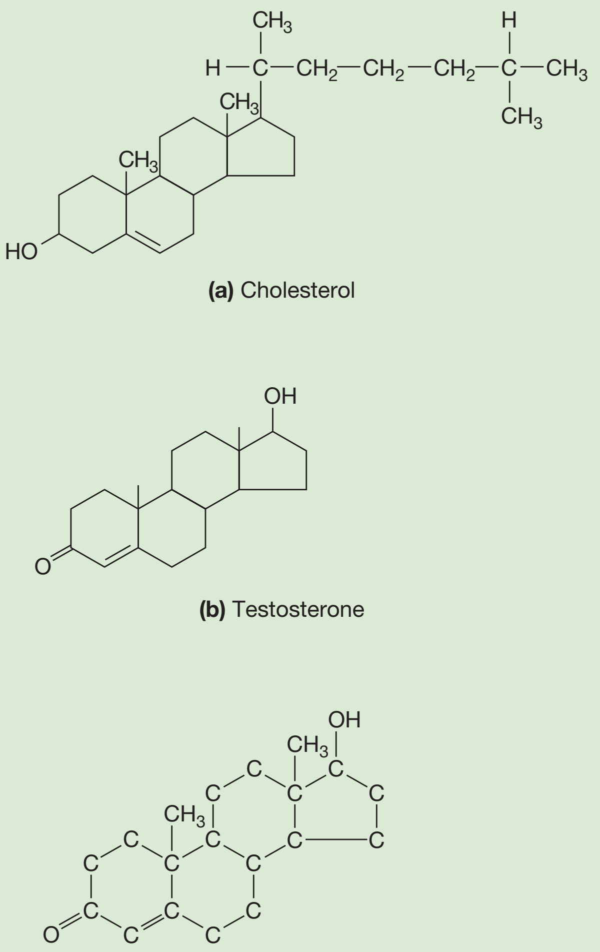
FIGURE 2–7 Saturated vs. unsaturated fats

glycerol molecule bonded to three fatty acid molecules. These fat molecules are known as *triglycerides*, a subcategory of lipids that includes fat and oil. These molecules are formed by the condensation of one molecule of glycerol, which is a three-carbon alcohol. Glycerol contains three fatty acid molecules. Triglycerides contain different saturated and unsaturated fatty acid combinations. Those with mostly saturated fatty acids are called *saturated fats* (see **Figure 2-6**). Those with mostly unsaturated fatty acids are called *unsaturated fats* (see **Figure 2–7**).

Saturated fat is defined as containing carbon atoms that are bound to as many hydrogen atoms as possible, becoming saturated with them. Fatty acid molecules with double bonds only are called *unsaturated*. Fatty acid molecules with many double-bonded carbon atoms are called *polyunsaturated*.

Similar to a fat molecule, a *phospholipid* consists of a glycerol portion with fatty acid chains. Phospholipids are structurally related to glycolipids. Human cells can synthesize both types of lipids, primarily from fatty acids. A phospholipid includes a phosphate group that is soluble in water and a fatty acid portion that is not. Phospholipids are an important part of cell structures.

Steroid molecules are large lipid molecules that share a distinctive carbon framework. Steroids have four connected rings of carbon atoms. All steroid



(a) Cholesterol

(b) Testosterone

(c) Structural formula of testosterone

FIGURE 2–8 Various types of steroid molecules

molecules have the same basic structure: three 6-carbon rings joined to one 5-carbon ring. They include cholesterol, estrogen, progesterone, testosterone, cortisol, and estradiol (see **Figure 2–8**).

Proteins

Proteins are the most abundant organic components of the human body, and in many ways the most important. Proteins are vital for many body functions, including structures and their functions, energy, enzymatic function, defense (antibodies), and hormonal requirements. On cell surfaces, some proteins combine with carbohydrates to become glycoproteins. They allow cells to respond to certain molecules that bind to them.

There are more than 200,000 types of proteins in the human body. Antibodies are proteins that detect and destroy foreign substances. All proteins contain carbon, hydrogen, oxygen, and nitrogen atoms, with small quantities of sulfur also present. Proteins always contain nitrogen atoms. Twenty-two different amino acids make up the proteins that exist in humans and most other living organisms. Protein molecules consisting of amino acids held together by peptide bonds are called *peptides*.

Other types of proteins include structural proteins such as collagen, which gives strength to ligaments and connective tissues, and keratin, which functions to prevent water loss through the skin. More active proteins include antibodies and enzymes. Cell membrane proteins may serve as receptors and carriers for specific molecules.

Nucleic Acids

Nucleic acids are large organic molecules (macromolecules) that carry genetic information or form structures within cells. They are composed of carbon, hydrogen, oxygen, nitrogen, and phosphorus. Nucleic acids store and process information at the molecular level, inside the cells. The two classes of nucleic acids are deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). Nucleic acids are found in all living things, cells, and viruses.

The DNA in our cells determine our inherited characteristics, including hair color, eye color, and blood type. DNA affects all aspects of body structure and function. DNA molecules encode the information needed to build proteins. By directing structural protein synthesis, DNA controls the shape and physical characteristics of the human body.

Several forms of RNA cooperate to manufacture specific proteins by using the information provided by DNA. Important structural differences distinguish RNA from DNA. An RNA molecule consists of a single chain of nucleotides.

Human cells have three types of RNA:

1. Messenger RNA (mRNA)
2. Transfer RNA (tRNA)
3. Ribosomal RNA (rRNA)

A DNA molecule consists of a pair of nucleotide chains (see **Figure 2–9**). The two DNA strands twist around each other in a double helix that resembles a spiral staircase.

CHECK YOUR KNOWLEDGE

1. Distinguish between saturated and unsatrated fats.
2. Distinguish between DNA and RNA.

Summary

Chemistry describes the composition of substances and how chemicals react with each other. The human

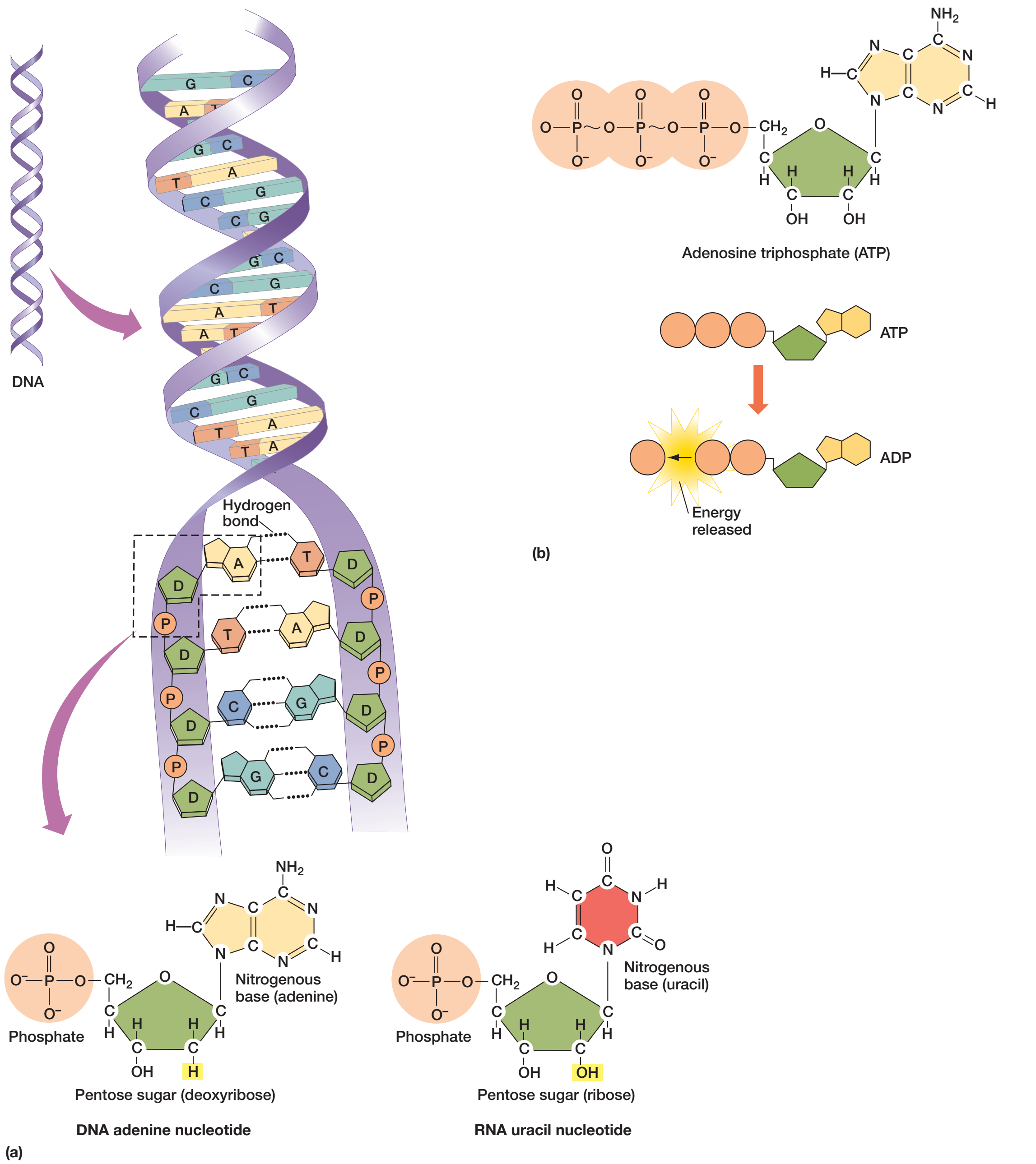


FIGURE 2–9 Nucleic acids, DNA, a DNA nucleotide, and an RNA nucleotide are shown in (a). Adenosine triphosphate (ATP) is shown in (b).

body is made up of chemicals. Matter is composed of elements, some of which occur in a pure form. Many elements are combined with other elements. Elements are composed of atoms, which are the smallest complete units of elements. Atoms of different elements have characteristic sizes, weights, and ways of interacting. An atom consists of one or more electrons surrounding a nucleus, which contains one or more protons and usually one or more neutrons. Electrons are negative, protons are positive, and neutrons are uncharged. When atoms combine, they either gain, lose, or share electrons. Atoms of the same element may bond to form a molecule of that element. Compounds that release ions when they dissolve in water are known as electrolytes. Inorganic substances include water, oxygen, carbon dioxide, and salts. Organic substances include carbohydrates, lipids, proteins, and nucleic acids.

LEARNING GOALS

The following learning goals correspond to the objectives at the beginning of this chapter:

1. Atoms are tiny particles that compose elements. A molecule is formed when two or more atoms bond. When two atoms of the

same element bond, they produce molecules of that element, such as hydrogen, oxygen, or nitrogen molecules.

2. Atoms can bond with other atoms by using chemical bonds that result from interactions between their electrons. The atoms may either gain, lose, or share electrons. Atoms that either gain or lose electrons are called ions.
3. Each atom consists of a central nucleus and one or more electrons continually moving around it. Inside the nucleus are one or more protons and neutrons. The number of protons in an atom is known as its atomic number.
4. The major groups of inorganic chemicals common in cells include oxygen, carbon dioxide, salts, and water. Other inorganic substances in cells include the ions of bicarbonate, calcium, carbonate, chloride, magnesium, phosphate, potassium, sodium, and sulfate.
5. Acids are electrolytes that release hydrogen ions in water (such as hydrochloric acid). Bases are electrolytes that release ions that bond with hydrogen ions (such as sodium hydroxide). Buffers are chemicals that resist pH changes. They combine with hydrogen ions when these ions are excessive and contribute hydrogen ions when these ions are reduced.
6. Lipids are not soluble in water; they may dissolve in other lipids, oils, ether, chloroform, or alcohol. Proteins are vital for many body functions. They can combine with carbohydrates or lipids, and always contain carbon, hydrogen, oxygen, and nitrogen atoms.
7. The term *pH* is defined as the measurement of hydrogen ion concentration. The pH scale ranges from 0 to 14, with 7 being the midpoint (an equal number of hydrogen and hydroxide ions) or "neutral"—neither acidic nor basic.
8. Organic substances in cells include carbohydrates, lipids, proteins, and nucleic acids. Carbohydrates provide much of the energy required by the body's cells, as well as helping to build cell structures. Lipids are vital for many cell functions such as the building of the cell membrane, and include fats, phospholipids, and steroids. Proteins are vital for body structures, functions, energy, enzymatic functions, defense (antibodies), and hormonal requirements. Nucleic acids carry genetic information or form structures within cells, and include DNA and RNA.
9. Steroid molecules include cholesterol, estrogen, progesterone, testosterone, cortisol, and estradiol.
10. Nucleic acids are macromolecules that carry genetic information or form structures within cells. They are composed of carbon, hydrogen, oxygen, nitrogen, and phosphorus. Nucleic acids are found in all living things, cells, and viruses.

CRITICAL THINKING QUESTIONS

1. How would you explain the importance of amino acids and proteins to a person whose diet is composed primarily of carbohydrates?
2. Explain why the symptoms of many inherited diseases result from abnormal protein function.

WEBSITES

http://biology.clc.uc.edu/Courses/bio104/lipids.htm

http://hyperphysics.phy-astr.gsu.edu/hbase/chemical/bond.html

http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/P/Proteins.html

http://www.biology.arizona.edu/molecular_bio/problem_sets/nucleic_acids/nucleic_acids_1.html

http://www.emc.maricopa.edu/faculty/farabee/BIOBK/BioBookCHEM1.html

http://www.madsci.org/posts/archives/2000-12/975719013.Ch.r.html

http://www.nlm.nih.gov/medlineplus/carbohydrates.html

http://www.shodor.org/unchem/basic/atom/index.html

http://www.visionlearning.com/library/module_viewer.php?mid=58

REVIEW QUESTIONS

1. Which of the following represents an atomic number?
   A. protons in an atom
   B. protons and neutrons

C. electrons in an ion
D. neutrons in an atom

2. Which of the following is an important buffer in body fluids?
A. hydrochloric acid
B. sodium bicarbonate
C. sodium chloride
D. water

3. A solution containing an equal number of hydrogen ions and hydroxide ions is:
A. basic
B. alkaline
C. acidic
D. neutral

4. Which of the following statements about water is false?
A. It has a relatively low heat capacity.
B. It contains hydrogen bonds.
C. It dissolves many compounds.
D. It is responsible for about two thirds of the mass of the human body.

5. Which of the following is the most important high-energy compound in cells?
A. glucose
B. protein
C. fructose
D. adenosine triphosphate

6. The molecules that store and process information at the molecular level are the:
A. steroids
B. carbohydrates
C. nucleic acids
D. lipids

7. An unstable isotope that emits subatomic particles spontaneously is referred to as:
A. a proton
B. an atom
C. a radioisotope
D. a neutron

8. Which of the following is the smallest particle of an element that has the properties of that element?
A. an electron
B. an atom
C. a neutron
D. a proton

9. The building blocks of fat molecules are:
A. fatty acids
B. triglycerides
C. glycerols
D. fatty acids and glycerols

10. Nucleic acids are composed of units called:
A. fatty acids
B. nucleotides
C. amino acids
D. adenosines

11. Which of the following is a true statement about lipids?
A. They provide roughly twice the energy of carbohydrates.
B. They provide roughly twice the energy of proteins.
C. They help to cushion delicate organs from damage.
D. All of the above.

12. A fatty acid that contains three double covalent bonds in its carbon chain is said to be:
A. polyunsaturated
B. monounsaturated
C. hydrogenated
D. saturated

13. Which of the following is the most important metabolic fuel molecule in the body?
A. starch
B. protein
C. glucose
D. sucrose

14. Ions with a negative charge are called:
A. cations
B. anions
C. polyatomic ions
D. radicals

15. The atomic weight of an element includes which of the following?
A. protons and neutrons in the nucleus
B. protons and electrons in an atom
C. electrons in the outer shells
D. neutrons in the nucleus