2.5 Carbohydrates

Carbohydrates first and foremost function for quick fuel and short-term energy storage in all organisms, including humans. Carbohydrates play a structural role in woody plants, bacteria, and animals such as insects. In addition, carbohydrates on cell surfaces are involved in cell-to-cell recognition, as we learn in Chapter 3.

Carbohydrate molecules are characterized by the presence of the atomic grouping H—C—OH, in which the ratio of hydrogen atoms (H) to oxygen atoms (O) is approximately 2:1. Since this ratio is the same as the ratio in water, the name "hydrates of carbon" seems appropriate.

Simple Carbohydrates

If the number of carbon atoms in a molecule is low (from three to seven), then the carbohydrate is a simple sugar, or **monosaccharide.** The designation **pentose** means a 5-carbon sugar, and the designation **hexose** means a 6-carbon sugar. **Glucose,** a hexose, is blood sugar (Fig. 2.15); our bodies use glucose as an immediate source of energy. Other common hexoses are fructose, found in fruits, and galactose, a constituent of milk. These three hexoses (glucose, fructose, and galactose) all occur as ring structures with the molecular formula $C_6H_{12}O_6$. The exact shape of the ring differs, as does the arrangement of the hydrogen (—H) and hydroxyl (—OH) groups attached to the ring.

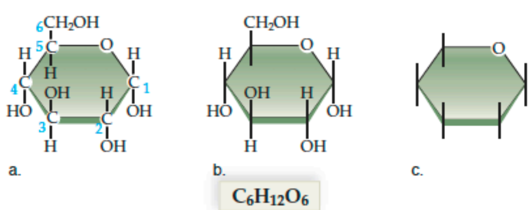


Figure 2.15 Three ways to represent the structure of glucose.
$C_6H_{12}O_6$ is the molecular formula for glucose. The *far left* structure (**a**) shows the carbon atoms, but the middle structure (**b**) does not show the carbon atoms. The *far right* structure (**c**) is the simplest way to represent glucose.

A **disaccharide** (*di*, two; *saccharide*, sugar) contains two monosaccharides that have joined during a dehydration reaction. Figure 2.16 shows how the disaccharide maltose forms when two glucose molecules bond together. Note the position of this bond; our hydrolytic digestive juices can break this bond, and the result is two glucose molecules. When glucose and fructose join, the disaccharide sucrose forms. Sucrose is another disaccharide of special interest because we use it at the table to sweeten our food. We acquire the sugar from plants such as sugarcane and sugar beets. You may also have heard of lactose, a disaccharide found in milk. Lactose is glucose combined with galactose. Some people are lactose intolerant because they cannot break down lactose. This leads to unpleasant gastrointestinal symptoms when they drink milk. Lactose-free milk is available in stores.

Polysaccharides

Long polymers such as starch, glycogen, and cellulose are **polysaccharides** that contain many glucose subunits.

Starch and Glycogen

Starch and **glycogen** are ready storage forms of glucose in plants and animals, respectively. Some of the polymers in starch are long chains of up to 4,000 glucose units. Starch has fewer side branches, or chains of glucose that branch off from the main chain, than does glycogen, as shown in Figures 2.17 and 2.18. Flour, which we use for baking and usually acquire by grinding wheat, is high in starch, and so are potatoes.

After we eat starchy foods such as potatoes, bread, and cake, glucose enters the bloodstream, and the liver stores glucose as glycogen. In between eating, the liver releases glucose so that the blood glucose concentration is always about 0.1%.

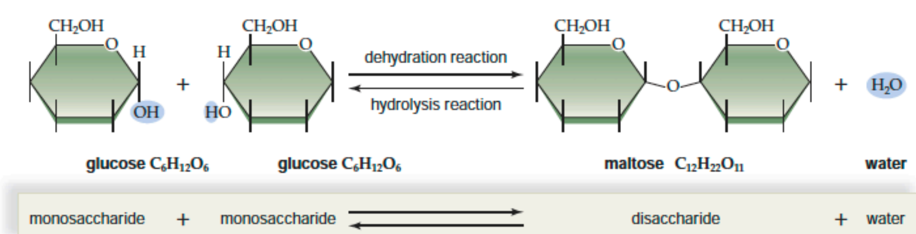


Figure 2.16 Synthesis and degradation of maltose, a disaccharide.
Synthesis of maltose occurs following a dehydration reaction when a bond forms between two glucose molecules and water is removed. Degradation of maltose occurs following a hydrolysis reaction when this bond is broken by the addition of water.

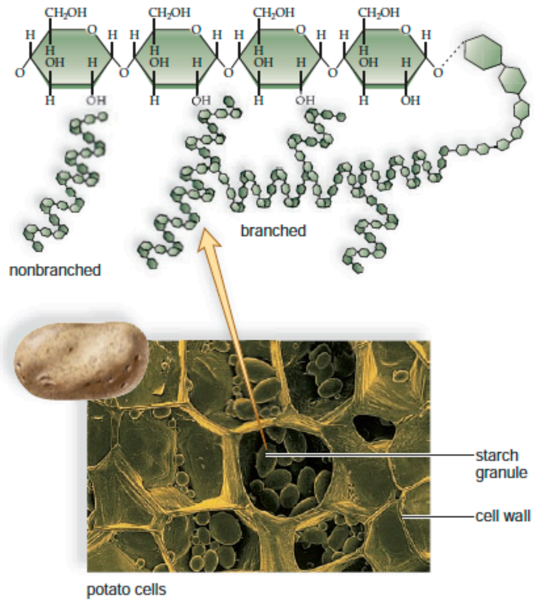


Figure 2.17 Starch structure and function. Starch is composed of straight chains of glucose molecules. Some chains are branched, as indicated. Starch is the storage form of glucose in plants. The electron micrograph shows starch granules in potato cells. When we eat starch-containing foods such as corn, potatoes, bread, white rice, and pasta, much glucose enters our bloodstream.

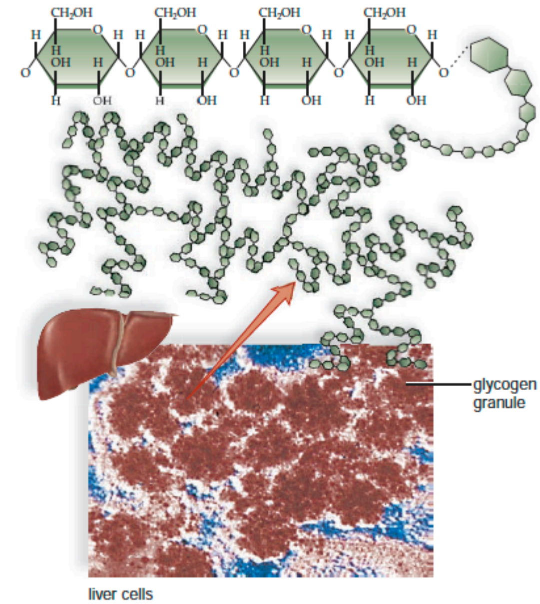


Figure 2.18 Glycogen structure and function. Glycogen is a highly branched polymer of glucose molecules. Glycogen is the storage form of glucose in animals. The electron micrograph shows glycogen granules in liver cells. Muscle cells also store glycogen.

Cellulose

Some types of polysaccharides function as structural components of cells. The polysaccharide **cellulose** is found in plant cell walls, and this accounts, in part, for the strong nature of these walls.

In cellulose (Fig. 2.19), the glucose units are joined by a slightly different type of linkage than that in starch or glycogen. (Observe the alternating position of the oxygen atoms in the linked glucose units.) While this might seem to be a technicality, it is significant because we are unable to digest foods containing this type of linkage; therefore, cellulose largely passes through our digestive tract as fiber, or roughage. Medical scientists believe that fiber in the diet is necessary to good health, and some have suggested it may even help prevent colon cancer.

Chitin, which is found in the exoskeleton (shell) of crabs and related animals, is another structural polysaccharide. Scientists have discovered that chitin can be made into a thread and used as a suture material.

Cells typically use the monosaccharide glucose as an energy source. The polysaccharides starch and glycogen are storage compounds in plant and animal cells, respectively, and the polysaccharide cellulose is found in plant cell walls.

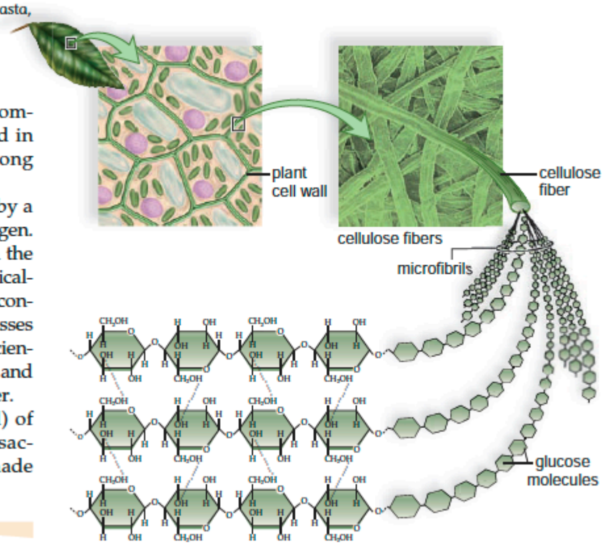


Figure 2.19 Cellulose structure and function. In cellulose, the linkage between glucose molecules is slightly different from that in starch or glycogen. Plant cell walls contain cellulose, and the rigidity of these cell walls permits nonwoody plants to stand upright as long as they receive an adequate supply of water.

2.6 Lipids

Lipids contain more energy per gram than other biological molecules, and fats and oils function as energy storage molecules in organisms. Phospholipids form a membrane that separates the cell from its environment and forms its inner compartments as well. The steroids are a large class of lipids that includes, among others, the sex hormones.

Lipids are diverse in structure and function, but they have a common characteristic: they do not dissolve in water. This is because lipids are neutral—they lack polar groups. Therefore, lipids do not undergo electrical attraction to other groups.

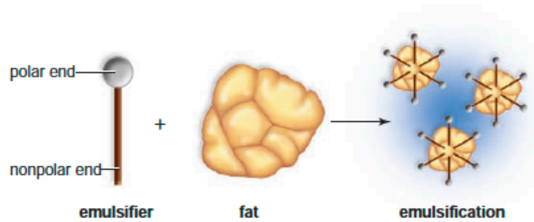
Fats and Oils

The most familiar lipids are those found in fats and oils. **Fats,** which are usually of animal origin (e.g., lard and butter), are solid at room temperature. **Oils,** which are usually of plant origin (e.g., corn oil and soybean oil), are liquid at room temperature. Fat has several functions in the body: it is used for long-term energy storage, it insulates against heat loss, and it forms a protective cushion around major organs.

Fats and oils form when one glycerol molecule reacts with three fatty acid molecules (Fig. 2.20). A fat molecule is sometimes called a **triglyceride** because of its three-part structure, and the term *neutral fat* is sometimes used because the molecule is nonpolar.

Emulsification

Emulsifiers can cause fats to mix with water. They contain molecules with a nonpolar end and a polar end. The molecules position themselves about an oil droplet so that their nonpolar ends project inward and their polar ends project outward. Now the droplet disperses in water, which means that **emulsification** has occurred:



Emulsification takes place when dirty clothes are washed with soaps or detergents. It explains why some salad dressings are uniform in consistency (emulsified) while others separate into two layers. Also, prior to the digestion of fatty foods, fats are emulsified by bile. The gallbladder stores bile for use when a meal is eaten, and a person who has had the gallbladder removed may have trouble digesting fatty foods.

Saturated and Unsaturated Fatty Acids

A **fatty acid** is a hydrocarbon chain that ends with the acidic group —COOH (Fig. 2.20). Most of the fatty acids in cells contain 16 or 18 carbon atoms per molecule, although smaller ones with fewer carbons are also known.

Fatty acids are either saturated or unsaturated. **Saturated fatty acids** have no double covalent bonds between carbon atoms. The carbon chain is saturated, so to speak, with all the hydrogens it can hold. Saturated fatty acids account for the solid nature at room temperature of fats such as lard

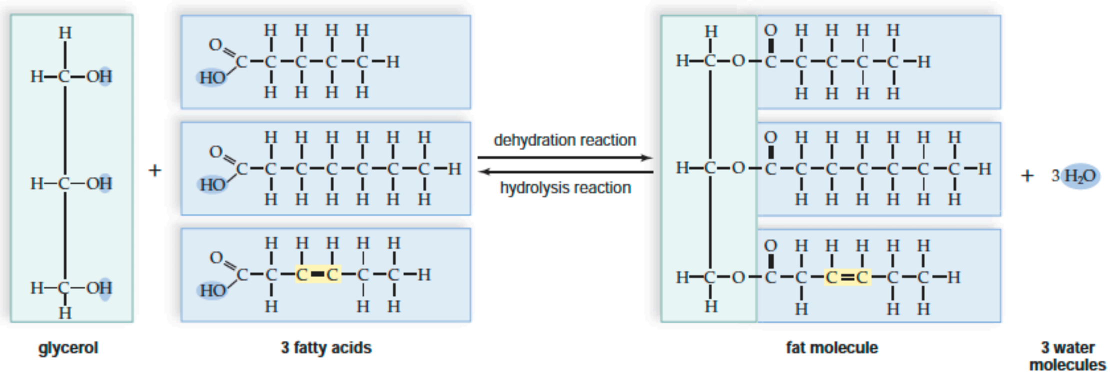


Figure 2.20 Synthesis and degradation of a fat molecule.
Fatty acids can be saturated or unsaturated. Saturated fatty acids have no double bonds between carbon atoms, whereas unsaturated fatty acids have some double bonds (colored yellow) between carbon atoms. When a fat molecule (triglyceride) forms, three fatty acids combine with glycerol, and three water molecules are produced.

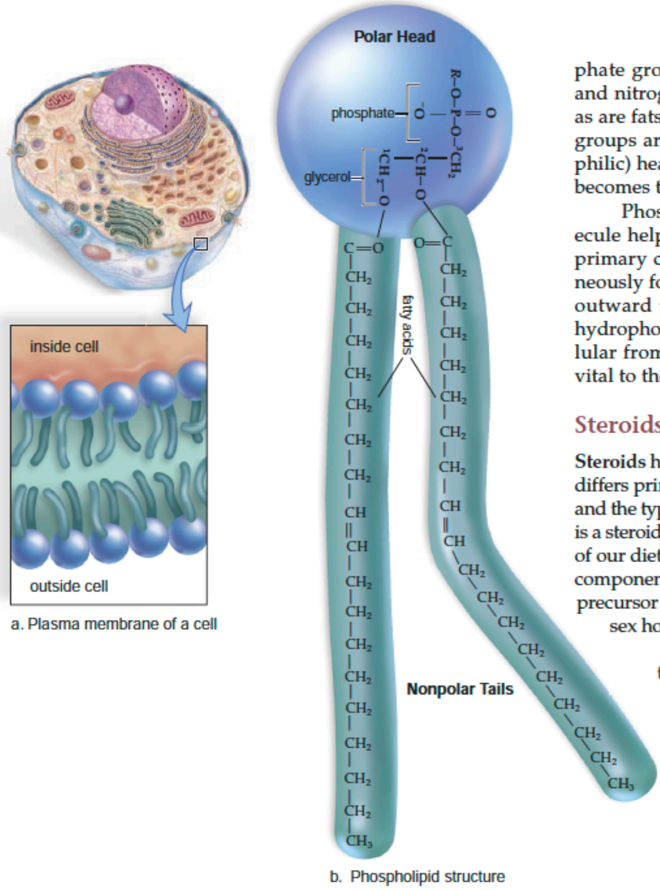


Figure 2.21 Phospholipids form membranes.
a. Phospholipids arrange themselves as a bilayer in the plasma membrane that surrounds cells. **b.** Phospholipids are constructed like fats, except that in place of the third fatty acid, they have a polar phosphate group. The bilayer structure forms because the polar (hydrophilic) head is soluble in water, whereas the two nonpolar (hydrophobic) tails are not.

and butter. **Unsaturated fatty acids** have double bonds between carbon atoms wherever the number of hydrogens is less than two per carbon atom. Unsaturated fatty acids account for the liquid nature of vegetable oils at room temperature. Hydrogenation, the chemical addition of hydrogen to vegetable oils, converts them into a solid. This type of fat, called *trans fat*, is often found in processed foods.

Phospholipids

Phospholipids, as their name implies, contain a phosphate group. Essentially, they are constructed like fats, except that in place of the third fatty acid, there is a polar phosphate group or a grouping that contains both phosphate and nitrogen. These molecules are not electrically neutral, as are fats, because the phosphate and nitrogen-containing groups are ionized. They form the so-called polar (hydrophilic) head of the molecule, while the rest of the molecule becomes the nonpolar (hydrophobic) tails (Fig. 2.21).

Phospholipids illustrate that the chemistry of a molecule helps determine its function. Phospholipids are the primary components of cellular membranes; they spontaneously form a bilayer in which the hydrophilic heads face outward toward watery solutions and the tails form the hydrophobic interior. Plasma membranes separate extracellular from intracellular materials and thus are absolutely vital to the form and function of a cell.

Steroids

Steroids have a backbone of four fused carbon rings. Each one differs primarily by the arrangement of the atoms in the rings and the type of functional groups attached to them. Cholesterol is a steroid formed by the body that also enters the body as part of our diet. Cholesterol has several important functions. It is a component of an animal cell's plasma membrane and is the precursor of several other steroids, such as bile salts and the sex hormones testosterone and estrogen (Fig. 2.22).

Now we know that a diet high in saturated fats, trans fats, and cholesterol can cause fatty material to accumulate inside the lining of blood vessels thereby reducing blood flow. The Health Focus on page 36 discusses which sources of carbohydrates, fats, and proteins are recommended for inclusion in the diet.

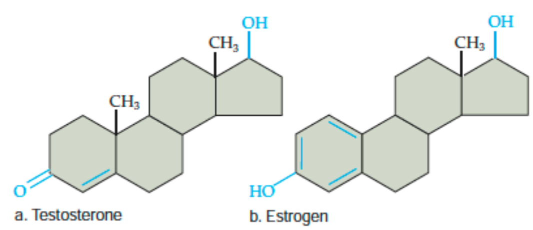


Figure 2.22 Steroids.
All steroids have four adjacent rings, but their attached groups differ. The effects of (**a**) testosterone and (**b**) estrogen on the body largely depend on the difference in the attached groups (shown in blue).

Lipids include fats and oils (for long-term energy storage), phospholipids, and steroids. Phospholipids, unlike other lipids, are soluble in water because they have a hydrophilic group. The steroid cholesterol performs several important functions in the body.

Health Focus

A Balanced Diet

Everyone agrees that we should eat a balanced diet, but just what is a balanced diet? The U.S. Department of Agriculture (USDA) released a new food pyramid in April of 2005 (Fig. 2B). The new pyramid contains vertical bands showing that all types of foods are needed for a balanced diet. Some bands are wider than others because you need more of some foods and less of others in your daily diet.

Progressing up the pyramid, the bands get smaller. The bands at the base represent food with little or no added fat or sugar. The narrower top area stands for foods with more added sugars and fats—which should be eaten more sparingly. For example, apple pie may contain fruit, but it also contains fat and sugar and should be eaten in smaller quantities than raw apples.

Carbohydrates

Carbohydrates (sugars and polysaccharides) are the quickest, most readily available source of energy for the body. Complex carbohydrates, such as those in whole-grain breads and cereals, are preferable to simple carbohydrates, such as candy and ice cream, because they contain dietary fiber (nondigestible plant material), plus vitamins and minerals. Insoluble fiber has a laxative effect, and soluble fiber combines with the cholesterol in food and prevents cholesterol from exiting the intestinal tract and entering the blood. However, researchers have found that the starch in potatoes and processed foods, such as white bread and white rice, leads to a high blood glucose level just as simple carbohydrates do. Researchers ask, Is this why many adults are now coming down with adult-onset diabetes?

Fats

We have known for many years that saturated fats in animal products contribute to the formation of deposits called plaque, which clog arteries and lead to high blood pressure and heart attacks.

Today, processed foods often contain trans fatty acids, which are especially capable of causing cardiovascular disease. So-called "trans fats" are oils that have been hydrogenated to solidify them.

Notice that the new food pyramid advocates an intake of certain liquid oils. These oils contain monounsaturated and polyunsaturated fatty acids, which researchers have found are protective against the development of cardiovascular disease.

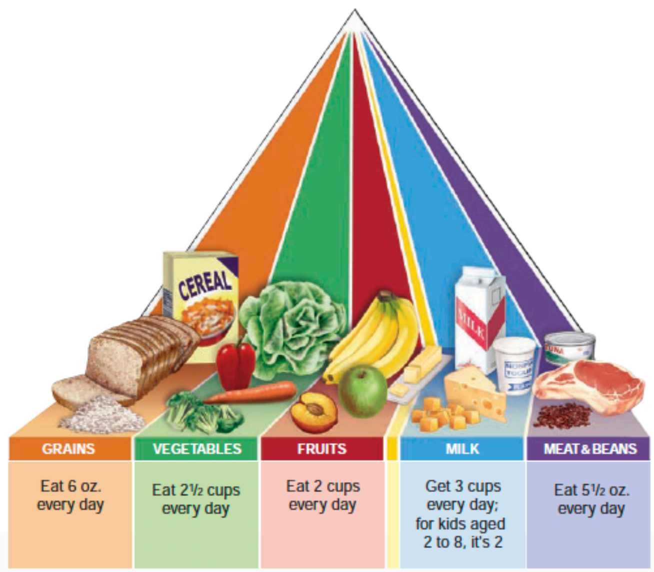
Other Nutrients

Red meat is rich in protein, but it is usually also high in saturated fat; therefore, fish and chicken are preferred sources of protein. Also, a combination of rice and *legumes* (a group of plants that includes peas and beans) can provide all of the amino acids the body needs to build cellular proteins.

Nutritionists agree that eating fruits and vegetables is beneficial. At the very least, they provide us with the vitamins we need in our diet.

Discussion Questions

1. List the number and types of fruits and vegetables you eat in a typical day. Are you getting the recommended amounts of these important foods? Do you have variety in the types of fruits and vegetables you consume?
2. Why are some fats "good" for you and some "bad" for you? What is the difference in these fats?
3. Chemically, what is the difference between a "whole-grain" carbohydrate and a simple carbohydrate?



Source: U.S. Dept. of Agriculture

Figure 2B Food guide pyramid.
The United States Department of Agriculture (USDA) developed this pyramid as a guide to better health. The different widths of the food group bands suggest how much food a person should choose from each group. The six different colors illustrate that foods from all groups are needed each day for good health. The yellow band represents oils; the USDA recommends consuming 1–2 tablespoons every day. The wider base is supposed to encourage the selection of foods containing little or no solid fats or added sugars.

2.7 Proteins

Proteins are polymers with amino acid monomers. An **amino acid** has a central carbon atom bonded to a hydrogen atom and three groups. The name of the molecule is appropriate because one of these groups is an amino group (—NH_2) and another is an acidic group (—COOH). The third group is called an *R* group, and amino acids differ from one another by their *R* group.

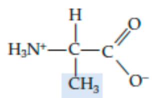
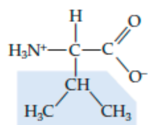
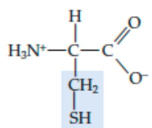
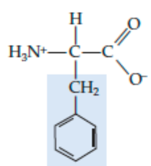
Name	Structural Formula	*R* Group
alanine (ala)		*R* group has a single carbon atom
valine (val)		*R* group has a branched carbon chain
cysteine (cys)		*R* group contains sulfur
phenylalanine (phe)		*R* group has a ring structure

Figure 2.23 Representative amino acids.
Amino acids differ from one another by their *R* group; the simplest *R* group is a single hydrogen atom (H). *R* groups (blue) containing carbon vary as shown.

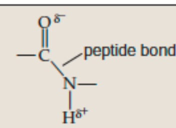
The *R* group varies from having a single carbon to being a complicated ring structure (Fig. 2.23).

Proteins perform many functions. Proteins such as keratin, which makes up hair and nails, and collagen, which lends support to ligaments, tendons, and skin, are structural proteins. Many hormones, messengers that influence cellular metabolism, are also proteins. The proteins actin and myosin account for the movement of cells and the ability of our muscles to contract. Some proteins transport molecules in the blood; hemoglobin is a complex protein in our blood that transports oxygen. Antibodies in blood and other body fluids are proteins that combine with foreign substances, preventing them from destroying cells and upsetting homeostasis.

Proteins in the plasma membrane of cells have various functions: some form channels that allow substances to enter and exit cells; some are carriers that transport molecules into and out of the cell; and some are enzymes. Enzymes are necessary contributors to the chemical workings of the cell, and therefore of the body. **Enzymes** speed chemical reactions; they work so quickly that a reaction that normally takes several hours or days without an enzyme takes only a fraction of a second with an enzyme.

Peptides

Figure 2.24 shows that a synthesis reaction between two amino acids results in a dipeptide and a molecule of water. A **polypeptide** is a single chain of amino acids. The bond that joins any two amino acids is called a **peptide bond.** The atoms associated with a peptide bond—oxygen (O), carbon (C), nitrogen (N), and hydrogen (H)—share electrons in such a way that the oxygen has a partial negative charge (δ^-) and the hydrogen has a partial positive charge (δ^+):



Therefore, the peptide bond is polar, and hydrogen bonding is possible between the C=O of one amino acid and the N—H of another amino acid in a polypeptide.

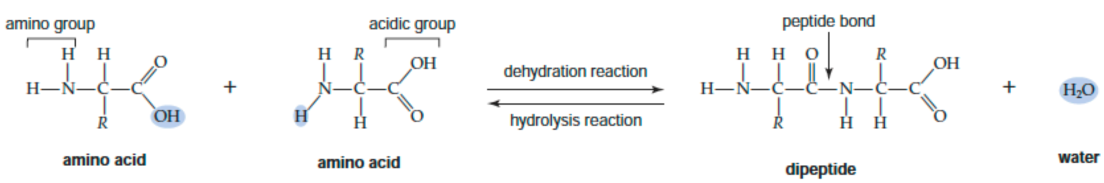


Figure 2.24 Synthesis and degradation of a dipeptide.
Following a dehydration reaction, a peptide bond joins two amino acids, and a water molecule is released. Following a hydrolysis reaction, the bond is broken with the addition of water.

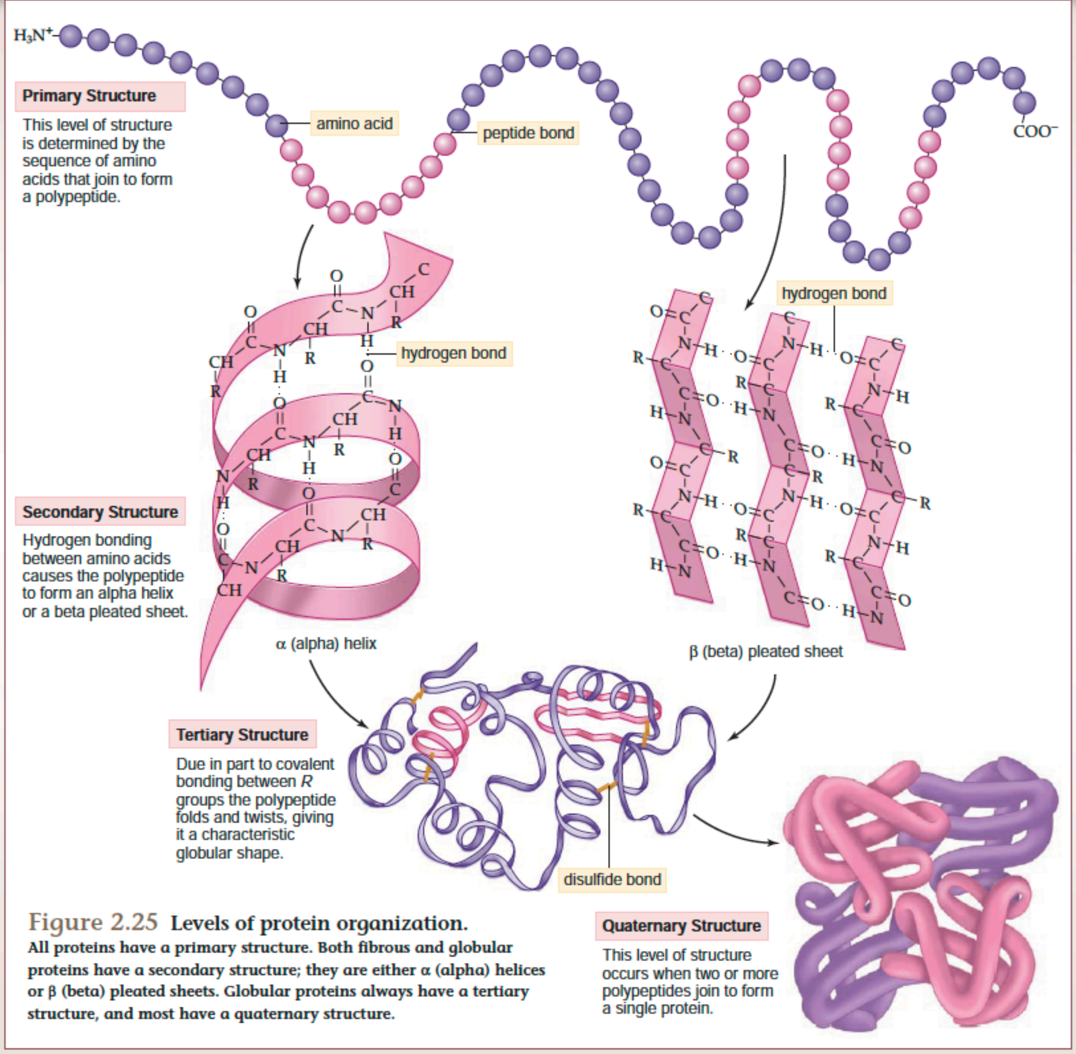


Figure 2.25 **Levels of protein organization.** **All proteins have a primary structure. Both fibrous and globular proteins have a secondary structure; they are either α (alpha) helices or β (beta) pleated sheets. Globular proteins always have a tertiary structure, and most have a quaternary structure.**

Levels of Protein Organization

The structure of a protein has at least three levels of organization and can have four levels (Fig. 2.25). The first level, called the *primary structure*, is the linear sequence of the amino acids joined by peptide bonds. Polypeptides can be quite different from one another. If a polysaccharide is like a necklace that contains a single type of "bead," namely glucose, then polypeptides make use of 20 different possible types of "beads," namely amino acids. Each particular polypeptide has its own sequence of amino acids. Therefore, each polypeptide differs by the sequence of its *R* groups.

The *secondary structure* of a protein comes about when the polypeptide takes on a certain orientation in space. A coiling of the chain results in an α (alpha) helix, or a right-handed spiral, and a folding of the chain results in a β (beta) pleated sheet. Hydrogen bonding between peptide bonds holds the shape in place.

The *tertiary structure* of a protein is its final three-dimensional shape. In muscles, myosin molecules have a rod shape ending in globular (globe-shaped) heads. In enzymes, the polypeptide bends and twists in different ways. Invariably, the hydrophobic portions are packed mostly on the inside, and the hydrophilic portions are on the outside where they can make contact with water. The tertiary shape of a polypeptide is maintained by various types of bonding between the *R* groups; covalent, ionic, and hydrogen bonding all occur. One common form of covalent bonding between *R* groups is a disulfide (S—S) linkage between two cysteine amino acids.

Some proteins have only one polypeptide, and others have more than one polypeptide, each with its own primary, secondary, and tertiary structures. These separate polypeptides are arranged to give some proteins a fourth level of structure, termed the *quaternary structure.* Hemoglobin is a complex protein having a quaternary structure; most enzymes also have a quaternary structure. Thus, proteins can differ in many ways, such as in length, sequence, and structure. Each individual protein is chemically unique.

The final shape of a protein is very important to its function. As we will discuss in Chapter 6, for example, enzymes cannot function unless they have their usual shape. When proteins are exposed to extremes in heat and pH, they undergo an irreversible change in shape called **denaturation.** For example, we are all aware that adding acid to milk causes curdling and that heating causes egg white, which contains a protein called albumin, to coagulate. Denaturation occurs because the normal bonding between the *R* groups has been disturbed. Once a protein loses its normal shape, it is no longer able to perform its usual function. Researchers hypothesize that an alteration in protein organization is related to the development of Alzheimer disease and Creutzfeldt-Jakob disease (the human form of "mad cow disease").

A polypeptide is a chain of amino acids joined by peptide bonds. Proteins are important in the structure and the function of cells. Some proteins are enzymes, which speed chemical reactions. A protein can be composed of one or more polypeptides, each with levels of organization. The three-dimensional shape of a polypeptide/protein is important to its function in the body.

2.8 Nucleic Acids

The two types of nucleic acids are **DNA (deoxyribonucleic acid)** and **RNA (ribonucleic acid).** The discovery of the structure of DNA has had an enormous influence on biology and on society in general. DNA stores genetic information in the cell and in the organism. Further, it replicates and transmits this information when a cell reproduces and when an organism reproduces. We now not only know how genes work, but we can manipulate them. The science of biotechnology is largely devoted to altering the genes in living organisms.

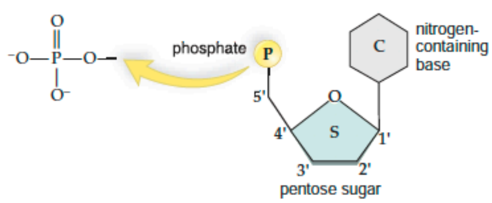
DNA codes for the order in which amino acids are to be joined to form a protein. RNA is an intermediary that conveys DNA's instructions regarding the amino acid sequence of a protein.

TABLE 2.1 DNA Structure Compared to RNA Structure

	DNA	RNA
Sugar	Deoxyribose	Ribose
Bases	Adenine, guanine, thymine, cytosine	Adenine, guanine, uracil, cytosine
Strands	Double stranded with base pairing	Single stranded
Helix	Yes	No

Structure of DNA and RNA

Both DNA and RNA are polymers of nucleotides. Every **nucleotide** is a molecular complex of three types of subunit molecules—phosphate (phosphoric acid), a pentose sugar, and a nitrogen-containing base:



Nucleotide structure

The nucleotides in DNA contain the sugar deoxyribose and the nucleotides in RNA contain the sugar ribose; this difference accounts for their respective names (Table 2.1). There are four different types of bases in DNA: **adenine (A), thymine (T), guanine (G),** and **cytosine (C).** The base can have two rings (adenine or guanine) or one ring (thymine or cytosine). In RNA, the base **uracil (U)** replaces the base thymine. These structures are called bases because their presence raises the pH of a solution.

The nucleotides form a linear molecule called a strand, which has a backbone made up of phosphate-sugar-phosphate-sugar, with the bases projecting to one side of the backbone. The nucleotides and their bases occur in a definite order. After many years of work, researchers now know the sequence of all the bases in human DNA—the human genome. This breakthrough is expected to lead to improved genetic counseling, gene therapy, and medicines to treat the causes of many human illnesses.

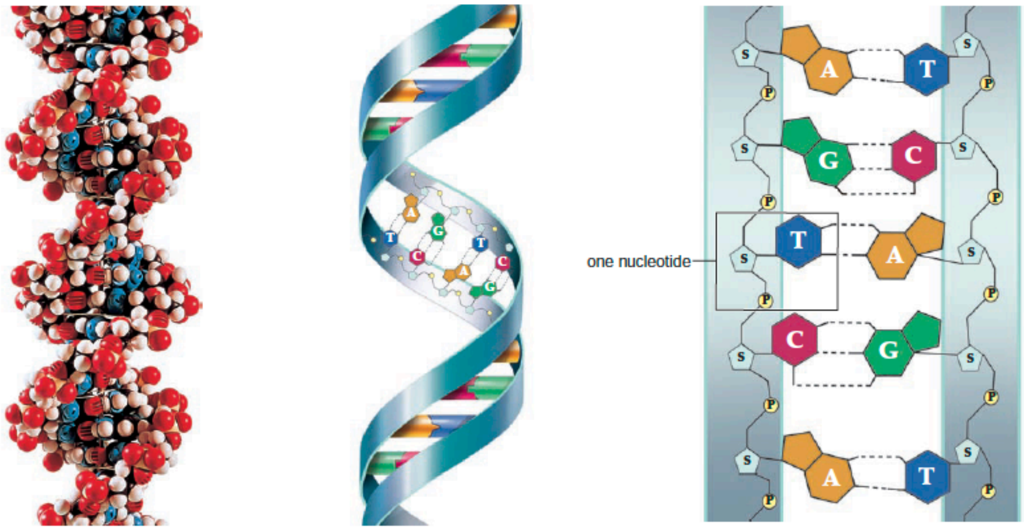


Figure 2.26 Overview of DNA structure.
The structure of DNA is absolutely essential to its ability to replicate and to serve as the genetic material. **a.** Space-filling model of DNA's double helix. **b.** Complementary base pairing between strands. **c.** Ladder configuration. Notice that the uprights are composed of phosphate and sugar molecules and that the rungs are complementary nitrogen-containing paired bases. The heredity information stored by DNA is the sequence of its bases, which determines the primary structure of the cell's proteins.

DNA is double stranded, with the two strands twisted about each other in the form of a **double helix** (Fig. 26*a, b*). In DNA, the two strands are held together by hydrogen bonds between the bases. When unwound, DNA resembles a ladder. The uprights (sides) of the ladder are made entirely of phosphate and sugar molecules, and the rungs of the ladder are made only of complementary paired bases. Thymine (T) always pairs with adenine (A), and guanine (G) always pairs with cytosine (C). Complementary bases have shapes that fit together (Fig. 2.26*c*).

Complementary base pairing allows DNA to replicate in a way that ensures the sequence of bases will remain the same. This sequence of the DNA bases contains a code that specifies the sequence of amino acids in the proteins of the cell.

RNA is single stranded and is formed by complementary base pairing with one DNA strand. One type of RNA, mRNA or messenger RNA, carries the information from the DNA strand to the ribosome where it is translated into the sequence of amino acids specified by the DNA.

DNA has a structure like a twisted ladder: sugar and phosphate molecules make up the uprights of the ladder, and hydrogen-bonded bases make up the rungs. The sequence of bases contains the DNA code.

ATP (Adenosine Triphosphate)

In addition to being the monomers of nucleic acids, nucleotides have other metabolic functions in cells. When adenosine (adenine plus ribose) is modified by the addition of three phosphate groups instead of one, it becomes **ATP (adenosine triphosphate),** an energy carrier in cells. Glucose is broken down in a step-wise fashion so that the energy of glucose is converted to that of ATP molecules. ATP molecules serve as small "energy packets" suitable for supplying energy to a wide variety of a cell's chemical reactions.

ATP is a high-energy molecule because the last two phosphate bonds are unstable and easily broken. In cells, the terminal phosphate bond usually is hydrolyzed, leaving the molecule **ADP (adenosine diphosphate)** and a molecule of inorganic phosphate Ⓟ (Fig. 2.27). The cell uses the energy released by ATP breakdown to synthesize macromolecules such as carbohydrates and proteins. Muscle cells use the energy for muscle contraction, and nerve cells use it for the conduction of nerve impulses. After ATP breaks down, it is rebuilt by the addition of Ⓟ to ADP. Notice in Figure 2.27 that an input of energy is required to re-form ATP.

ATP is a high-energy molecule. ATP breaks down to ADP + Ⓟ, releasing energy, which is used for all the metabolic work done in a cell.

Bioethical Focus

Blue Gold

Environmentalists believe that the world is running out of clean drinking water. Over 97% of the world's water is salt water found in the oceans. Salt water is unsuitable for drinking without expensive desalination. Of the fresh water in the world, most is locked in frozen form in the polar ice caps and glaciers and therefore unavailable. This leaves only a small percentage in groundwater, lakes, and rivers that could be available for drinking, industry, and irrigation. However, some of that water is polluted and unsuitable.

Water has always been the most valuable commodity in the Middle East, even more valuable than oil. But as fresh water becomes limited and the world's population grows, the lack of sufficient clean water is becoming a worldwide problem.

The combination of increasing demand and dwindling supply has attracted global corporations who want to sell water. Water is being called the "blue gold" of the twenty-first century, and an issue has arisen regarding whether the water industry should be privatized. That is, could water rights be turned over to private companies to deliver clean water and treat wastewater at a profit, similar to the way oil and electricity are handled? Private companies have the resources to upgrade and modernize water delivery and treatment systems, thereby conserving more water. However, opponents of this plan claim that water is a basic human right required for life, not a need to be supplied by the private sector. In addition, a corporation can certainly own the pipelines and treatment facilities, but who owns the rights to the water? For example, North America's largest underground aquifer, the Ogallala, covers 175,000 square miles under several states in the southern Great Plains. If water becomes a commodity, do we allow water to be taken away from people who cannot pay in order to give it to those who can?

Form Your Own Opinion

1. Do you agree that the water industry should be privatized? Why or why not?
2. Is access to clean water a "need" or a "right"? If it is a right, who pays for that right?
3. Since water is a shared resource, everyone believes they can use water, but few people feel responsible for conserving it. What can you do to conserve water?

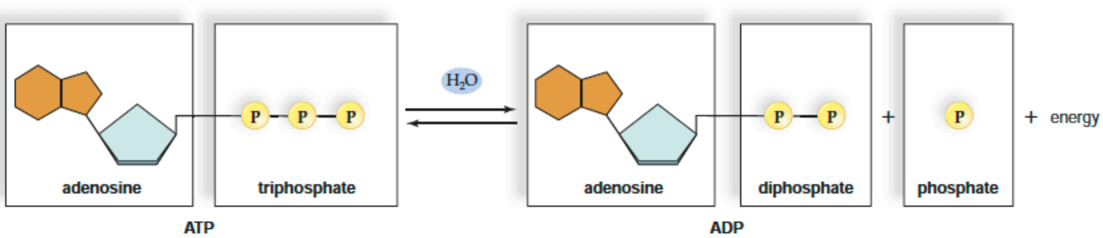


Figure 2.27 **ATP reaction.**
ATP, the universal energy currency of cells, is composed of adenosine and three phosphate groups (called a triphosphate). When cells require energy, ATP undergoes hydrolysis, producing ADP + Ⓟ, with the release of energy.