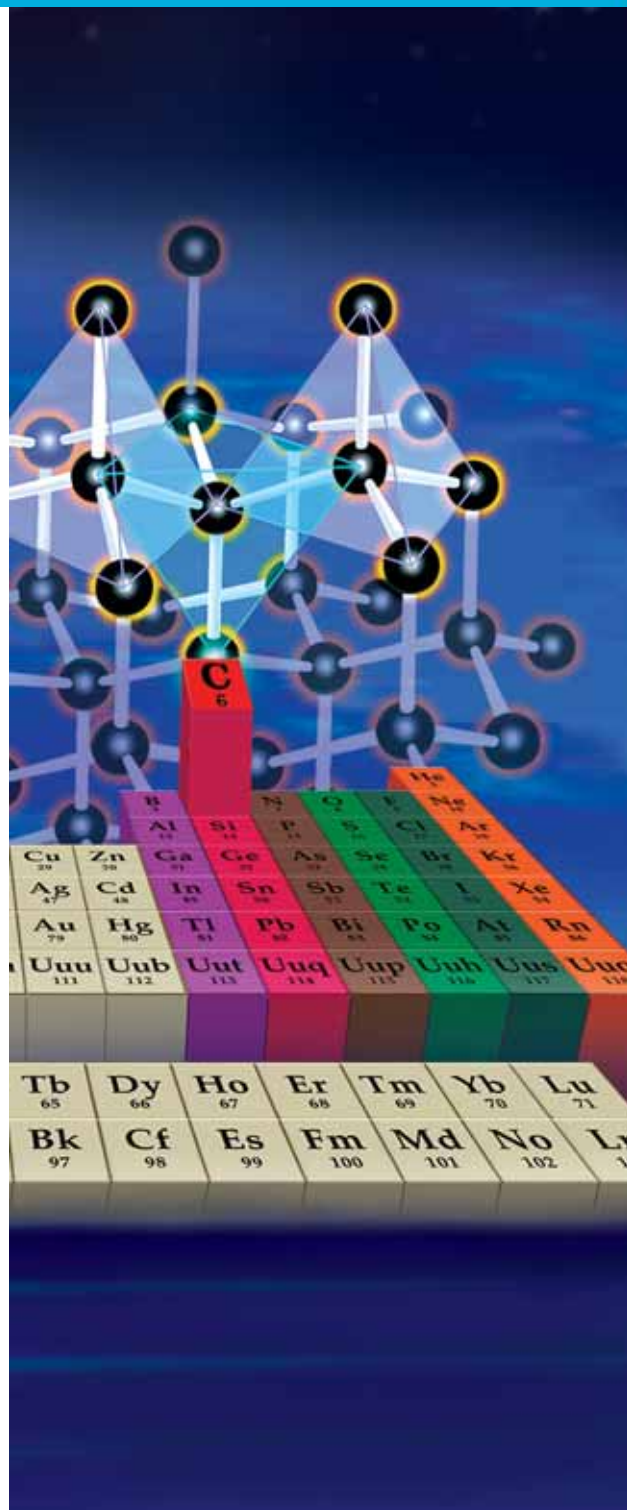
Chapter 11

The Chemistry of Living Systems



What is chemistry? If the image that comes to your mind is of a complicated array of tubes and smoking beakers, factories and stinky fumes, this chapter will paint quite a different picture. Chemistry is *you*. Like all living organisms, your body is an incredibly complex chemical machine taking in chemicals from food and causing countless chemical reactions to occur every second. In so many ways, the fundamental processes of life are chemistry.

If you take away the water, the rest of the human body is 53 percent carbon by weight. The chemistry of living things is the chemistry of carbon and its compounds. Carbon is the basic building block in the complex molecules that make up all living things. This chapter is your introduction to a branch of chemistry — organic chemistry — that is devoted solely to carbon and carbon compounds.

Key Questions

1. ***Why is carbon so important to living things?***
2. ***What are carbohydrates, fats, proteins, and DNA?***
3. ***How does a living creature control its chemistry?***

11.1 The Chemistry of Carbon

The chemistry of life is largely the chemistry of the element carbon. About 65 percent of the human body is water. Of the remainder, 91 percent is only four elements: carbon, oxygen, nitrogen, and hydrogen (Figure 11.1). Of those four, carbon is the largest fraction at 53 percent. Carbon atoms often serve as the backbone to which oxygen, nitrogen and hydrogen are connected. Carbon is so important because it is the lightest element that can make up to four bonds at the same time, including bonds with itself.

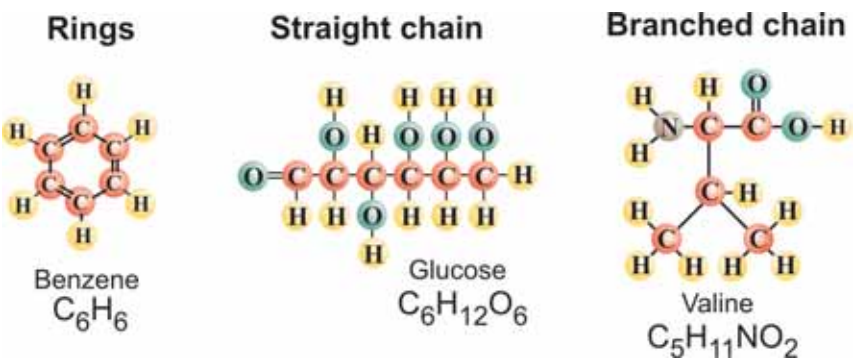
VOCABULARY

organic chemistry - the chemistry of carbon and carbon compounds.

Carbon molecules

Carbon forms ring and chain molecules

Carbon has four electrons in its outer energy level, and therefore four valence electrons. Carbon can share one or more electrons to make covalent bonds with itself or as many as four other elements. Carbon molecules come in three basic forms: straight chains, branching chains, and rings. All three forms are found in important biological molecules. For example, glucose is a sugar made by plants and valine is an amino acid found in proteins — and both are built on carbon.



Organic chemistry is the chemistry of carbon

The three basic shapes are often combined (chains and rings) in the same molecule. **Organic chemistry** is the branch of chemistry that specializes in carbon and carbon compounds. Organic molecules are found in all living things and also in many nonliving substances such as candle wax and polyethylene plastic.

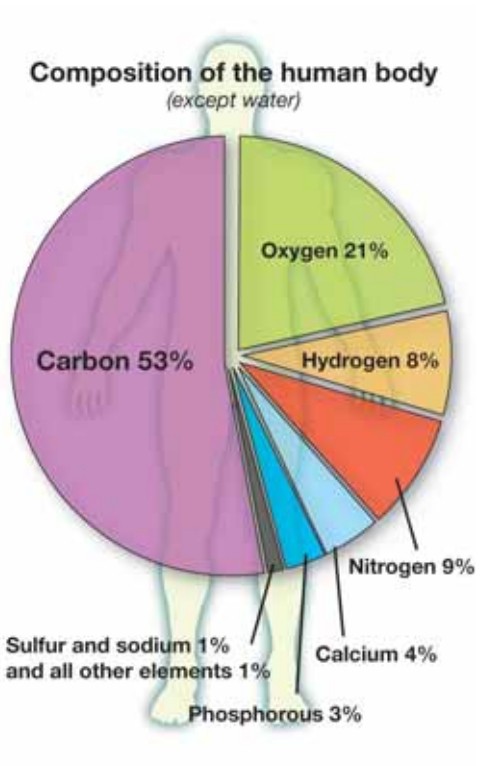


Figure 11.1: *After water, carbon is the most abundant element in the human body.*

Molecules in plants and animals

The four types of biological molecules

Living creatures are such complex organisms that even today we have much to learn about the chemical reactions that take place inside us. Scientists classify the organic molecules in living things into four basic groups: carbohydrates, fats, proteins, and nucleic acids. All living things contain *all four types* of molecules. And each type of molecule includes thousands of different chemicals, some specific to plants, some to animals. It is only in the past few decades that biotechnology has been able to reveal the rich chemistry of living things.

Carbohydrates

Carbohydrates are mainly composed of carbon, hydrogen, and oxygen in a ratio of about 1:2:1. Carbohydrates exist as small molecules, like glucose, and long-chain molecules, like starches. Table sugar is a carbohydrate called sucrose. Sucrose is composed of two simple sugars, glucose and fructose, which are chained together (Figure 11.2).

Proteins

Proteins are large molecules composed of carbon, hydrogen, oxygen, nitrogen, and trace elements. Skin and muscle tissue are composed primarily of protein. A single protein may contain several thousand atoms in a complex structure.

Fats

Fats are medium-to-large nonpolar molecules that do not dissolve in water. Structurally, fats are long chains of carbon and hydrogen with different elements added every so often. Cholesterol is a fat that makes up part of the outer membrane of cells. Cholesterol is naturally essential to cells, but unnaturally high cholesterol may lead to heart disease.

Nucleic acids

Nucleic acids such as DNA store the genetic code that allows organisms to reproduce. DNA is a huge molecule with millions of individual atoms. All the information that makes you a human is stored as a coded sequence of component molecules within DNA.

VOCABULARY

carbohydrates - energy-rich sugars and starches.

proteins - large molecules found in animal and plant tissue.

fats - energy-rich hydrocarbon chain molecules.

nucleic acids - biological molecules such as DNA that have the ability to store the genetic code.

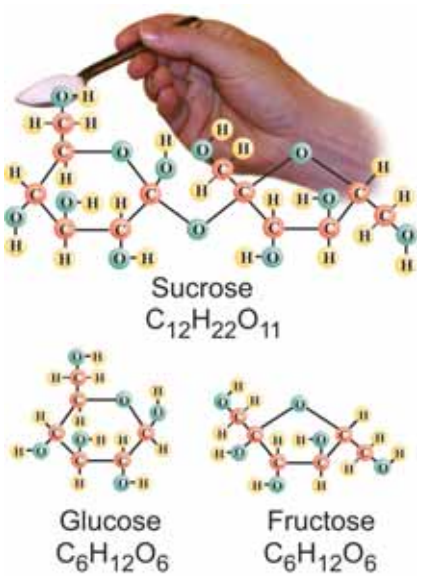


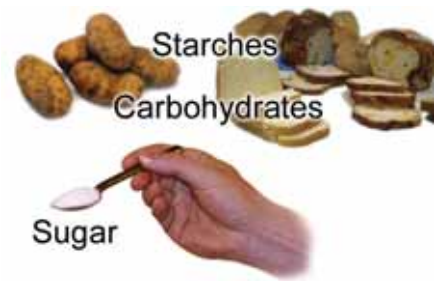
Figure 11.2: *Table sugar is sucrose, a carbohydrate made of two simple sugars: glucose and fructose.*

Carbohydrates

How carbohydrates are used

Carbohydrates are relatively small molecules used to store and transfer energy in living systems. Plant cells use energy from the sun to build carbohydrates from carbon dioxide and water. Animal cells consume carbohydrates and extract the energy by breaking the carbohydrates into smaller molecules again.

Starches and sugars



Carbohydrates are classified as either sugars or starches. Sugars are the smaller of the two types. Sugars break down relatively quickly in the body, releasing energy within a short time of being eaten. Glucose is the simplest sugar and is dissolved directly into the bloodstream.

Glucose is the simplest sugar

Glucose is the primary energy source for cells. When dissolved in water, the chain structure of a glucose molecule curls around on itself to become a ring (Figure 11.3). The glucose molecule can have several variations in the order of the OH - H - OH groups on either side of the carbon backbone. Some animals are so specialized that they can only digest one form of glucose and not the others.

Starches are chains of sugar

Starches are long chains of simple sugars joined together to make natural polymers. Because starches are larger molecules, they are slower to break down in the body and therefore can provide energy for a longer period than sugars. Corn, potatoes, and wheat contain substantial amounts of starches (Figure 11.4).

Cellulose

Cellulose is the primary molecule in plant fibers, including wood. The long-chain molecules of cellulose are what give wood its strength. Like starch, cellulose is made from chains of thousands of glucose molecules. However, in starch all the glucose units are the same orientation. In cellulose, alternate glucose units are inverted. This difference makes cellulose difficult for animals to digest. Trees grow so large partly because so few animals can digest wood.

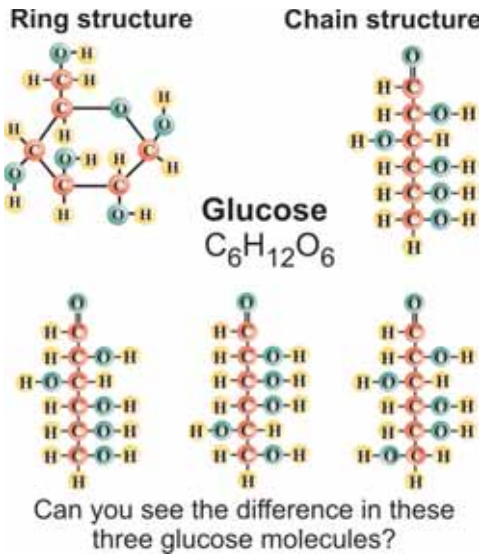


Figure 11.3: *Different structures of the glucose molecule.*

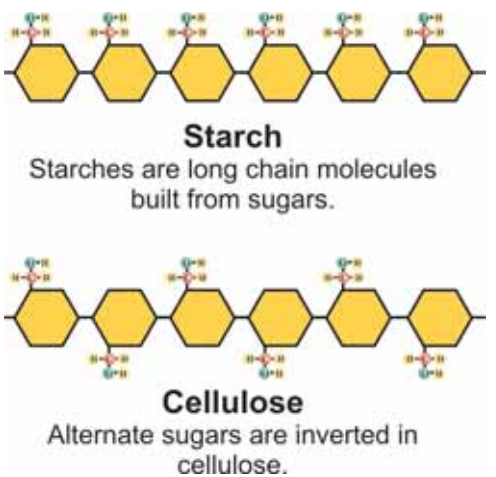


Figure 11.4: *Starch and cellulose.*

Photosynthesis

The importance of photosynthesis

The energy that supports life on Earth starts with a reaction that takes energy from sunlight and stores it as chemical bonds in molecules of glucose and other simple sugars. This reaction is called **photosynthesis**. Photosynthesis occurs mostly in plants and in some types of bacteria.

The food chain

Photosynthesis is the foundation of the food chain on Earth. At the bottom of the food chain are producers, plants that take energy from the sun and convert it to chemical energy in glucose and other organic molecules. Animals (including ourselves) ultimately get energy from photosynthesis, because we eat plants or other animals that eat plants. Nearly all the energy in living things can be traced to this important reaction.

Photosynthesis releases oxygen

Photosynthesis also produces the oxygen in our atmosphere. Without photosynthetic organisms, Earth could not support life. Although oxygen is a common element on Earth, it is usually trapped by rocks and minerals in compounds like calcium carbonate ($CaCO_3$).

Photosynthesis removes CO_2

Photosynthesis removes carbon dioxide from the atmosphere. For every glucose molecule produced, six molecules of carbon dioxide are removed from the air, and six molecules of oxygen are produced. Carbon dioxide absorbs infrared radiation and therefore traps heat in the atmosphere. If too much carbon dioxide is present, the planet cannot cool itself by radiating energy into space. Higher levels of carbon dioxide may be responsible for the warming of Earth by several degrees over the past 200 years. Can you think of ways to stabilize carbon dioxide levels?

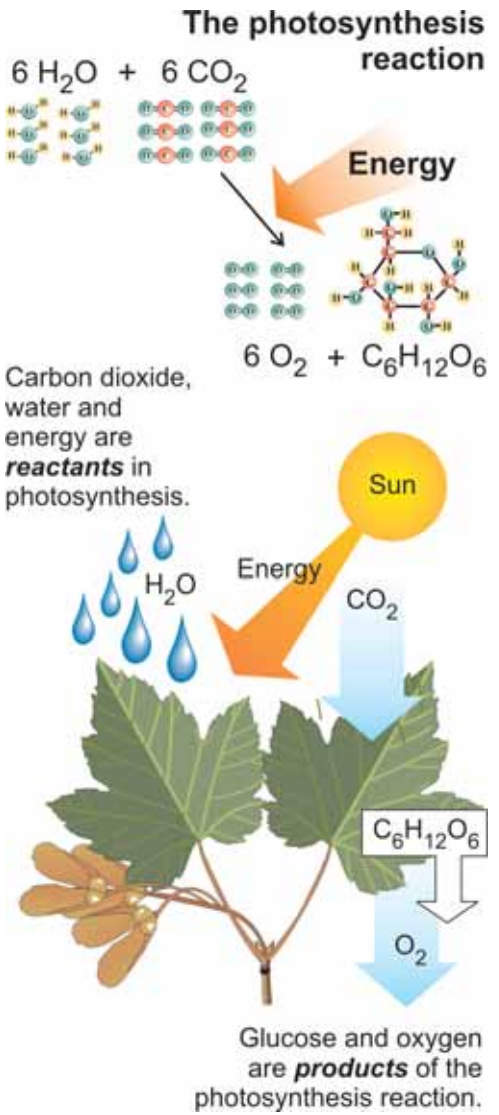
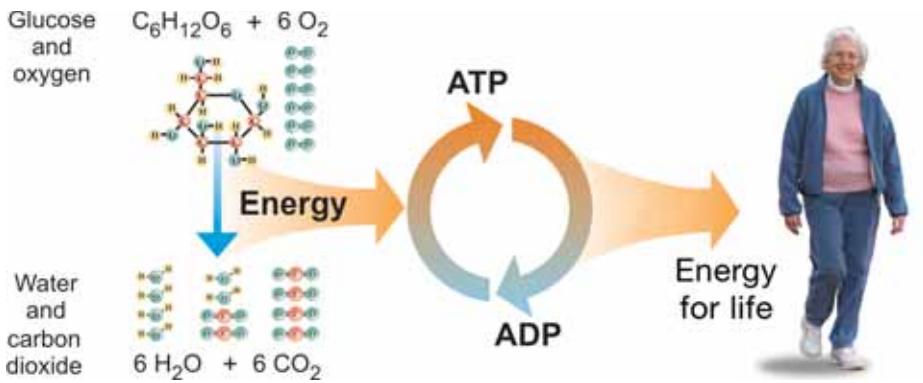


Figure 11.5: *Photosynthesis is a chemical reaction that is the basis for the food chain on Earth.*

Respiration

Digestion Animals get energy and nutrients by breaking up glucose, starch, and other organic molecules. The digestive system breaks food down into molecules the body can use. Proteins are split into amino acids. Carbohydrates are reduced to simple sugars. Fats are split into glycerol and fatty acids. These nutrients are then absorbed into the blood and transported to all the cells of the body.

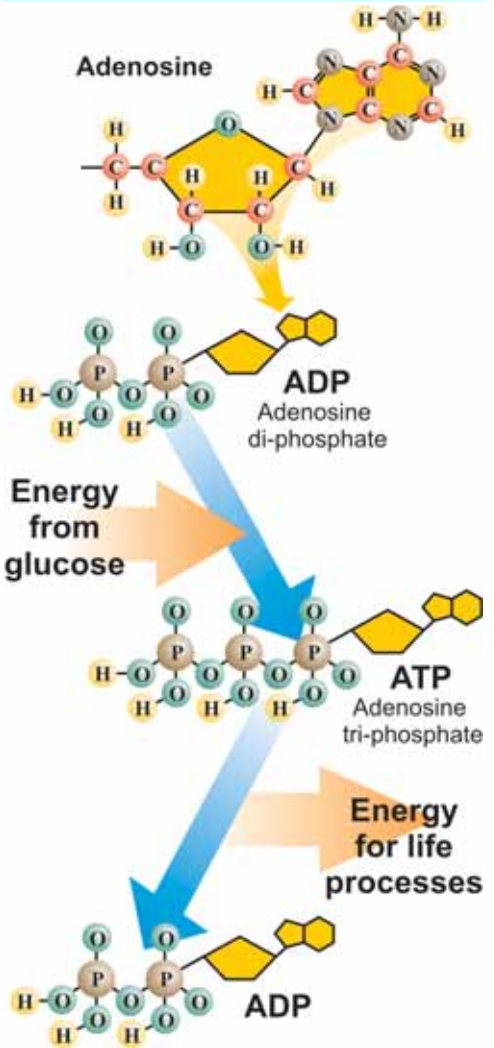
Cellular respiration On the molecular level, **cellular respiration** breaks down glucose into water and carbon dioxide again, extracting energy in the process. The reactions of respiration proceed in many steps, but the end result is that glucose and oxygen are used up and carbon dioxide and water are produced. Respiration is almost the reverse of photosynthesis, releasing energy that originally came from the sun.



The ATP cycle Each cell converts the energy in glucose into chemical energy stored in molecules of ATP. A cycle between ADP and ATP is the energy source of cells. In a series of complex reactions that also require oxygen, one molecule of glucose is used to convert a maximum of 36 to 38 molecules of ADP to ATP. The ATP molecule is like a battery that distributes energy to where it is needed. Cells use the energy by converting the ATP back into ADP and the cycle starts over. Phosphorus is a critical part of the ADP-ATP cycle and one reason this element is an important nutrient.

VOCABULARY

cellular respiration - the reactions in cells that release energy from glucose.



The importance of water

Why water is necessary

Liquid water is essential to life as we know it. The human body is typically between 60 and 65 percent water by weight. Most of the chemical reactions that sustain life *only work in solution*. Therefore, when scientists look for life on other planets, the first thing they look for is water. We believe Mars either had or has water on its surface or beneath its surface. That raises the tantalizing possibility that life may exist there.

There are three important characteristics of water that make it essential for life.

Water is a good solvent

Water is a good solvent. In order to have a chemical reaction, molecules must be able to move around and contact each other. In a solid, this is just not possible. However, in a solution, molecules can move relatively large distances carrying energy and nutrients throughout a cell. Water also allows transport through the body on a larger scale. For example, oxygen is required by cells throughout the body, but it comes into the body in a centralized place: your lungs. Red blood cells absorb oxygen in the lungs and are carried throughout the body so they can distribute the oxygen.

Liquid over a wide temperature range

Water exists as a liquid over a large range of temperatures. In fact, virtually all living organisms on Earth are most active between the freezing and boiling point of water. The wide range over which water remains liquid allows most of Earth to be habitable most of the time. Very few biological processes can proceed when completely frozen because molecules: (a) cannot reach each other, and (b) have less thermal energy for activating reactions.

High specific heat

Water has a high specific heat — one of the highest of any substance known. Water's high specific heat means it takes a lot of energy to raise the temperature a small amount. This property of water helps living organisms maintain a stable body temperature even though outside temperatures may fluctuate a great deal.

Figure 11.6: *Water is essential to our planet and to living things, including you.*

11.1 Section Review

1. About 80 percent of all chemical compounds on Earth contain carbon. Why is carbon found in so many compounds?
2. Complete the table by filling in the missing information:

Biological molecule	Composed of what atoms?	Example	Importance
carbohydrate		sugar	store and transfer energy
fat			
protein	C, H, N, O and trace elements	found in skin and muscle tissue	
nucleic acid		makes up DNA	protein synthesis and heredity

3. Photosynthesis is a critically important process. Why?
4. Does photosynthesis involve a physical change or a chemical change?
5. List the reactants and products for:
   a. Photosynthesis.
   b. Cellular respiration.
6. Why is water essential to life?
7. What are the characteristics of water that make it life-sustaining?

CHALLENGE

Termites are insects that eat wood. Do a little research on termites to answer the following:

a. What biological molecule can termites digest that most animals have great difficulty digesting?
b. What are some signs that a building may be infested with termites?
c. What parts of the world have the greatest problems with termites?

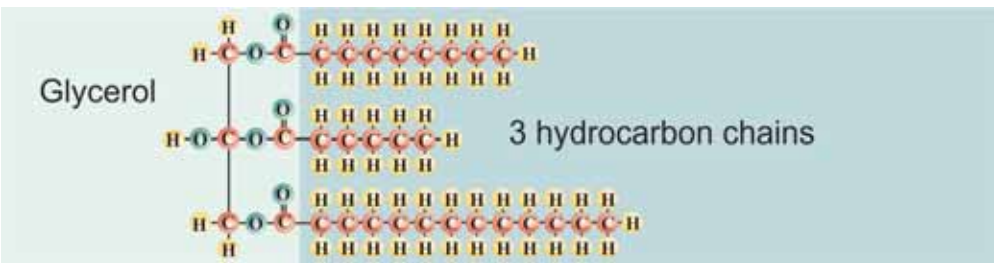
11.2 Proteins, Fats, and Nucleic Acids

Carbohydrates are the simplest of the important biological molecules. Proteins, fats, and nucleic acids are more complex molecules, including thousands of individual atoms in a single molecule. Nucleic acids found in DNA are at the core of genetics, an active area of scientific research. The creation and functions of proteins are another area of active research. While we know a tremendous amount, we still have much to learn.

Fats

Fats provide long-term energy storage

Fats are high-energy molecules that plants and animals use to store energy in reserve for longer periods. Sugars break down too quickly to store energy reserves in a body. Fats are more complex molecules that take much longer to break down. Chemically, fats and oils are similar. Oils are fats that are liquid at room temperature.



Saturated fats

A fat molecule has a two-part structure. The first part is called *glycerol*. Attached to the glycerol are 3 hydrocarbon chains. In a **saturated fat** the carbon atoms are surrounded by as many hydrogens as possible (Figure 11.8).

Unsaturated fats

An **unsaturated fat** has fewer hydrogen atoms than it could have, meaning some of the carbon molecules have double bonds with each other instead of with hydrogen. Chemical processing of food adds some hydrogen to unsaturated fats in a process called *hydrogenation*. Because they are harder to digest, *partially hydrogenated* fats have have a longer shelf life however, research is showing that partially hydrogenated fats may be unhealthy.

VOCABULARY

saturated fat - a fat molecule in which each carbon is bonded with two hydrogen atoms.

unsaturated fat - a fat molecule that has less hydrogen atoms than a saturated fat.

Figure 11.7: *Fats and oils are high-energy molecules organisms use to store energy reserves.*

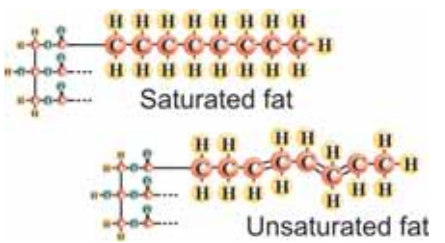
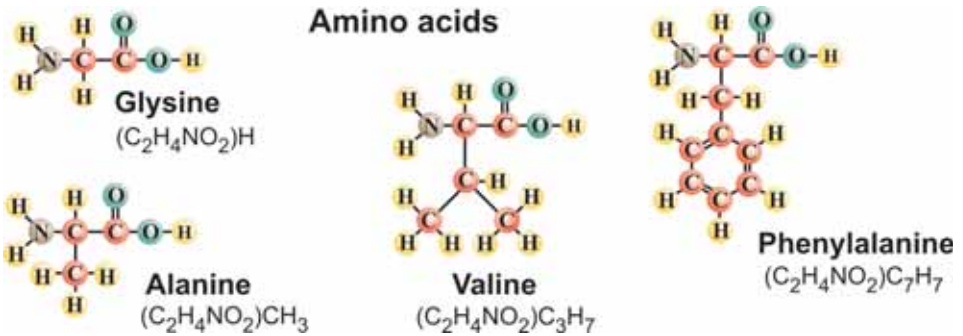


Figure 11.8: *The hydrocarbon chains in saturated and unsaturated fats.*

Proteins

Proteins are large molecules

Proteins are basic molecular building blocks of cells and all parts of animals. Muscle, skin, blood, and internal organs contain proteins. Second only to DNA, proteins are among the largest organic molecules. A relatively small protein is shown in Figure 11.9.



Proteins are made of amino acids

Amino acids are the building blocks of proteins. Virtually all proteins found in animals are made from only 20 different **amino acids**. The amino acids in a protein form multiple chains that fold around each other in complex structures (Figure 11.10).

Shape and function

Only certain parts of a protein are chemically active. The shape of a protein determines which active sites are exposed. Many proteins work together by fitting into each other like a lock and key. This is one reason proteins that do the same function in one organism do not work in another organism. For example, a skin protein from an animal cannot replace a skin protein from a human.

Amino acids from food are used to build proteins

Food supplies new proteins that a body needs to live and grow. However, proteins from one organism cannot be used by another. Fortunately, the same 20 amino acids are found in proteins from almost all living things. In your body, digestion breaks down food protein into its component amino acids. Cells reassemble the amino acids into new proteins suitable for your body's needs.

VOCABULARY

amino acids - organic molecules that are the building blocks of proteins.

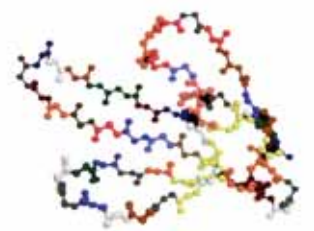


Figure 11.9: *This small protein called erabutoxin B is the active ingredient in sea snake venon.*

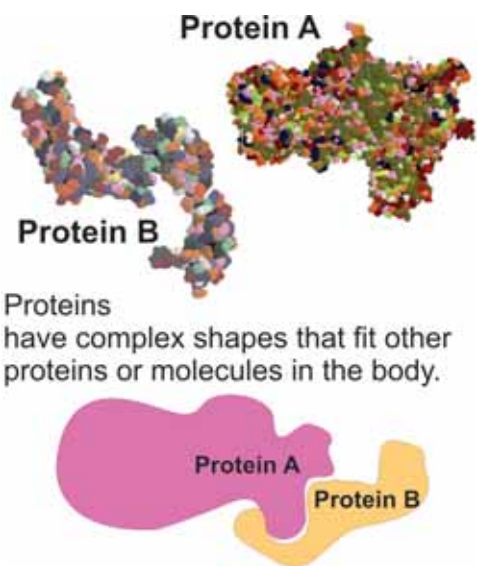


Figure 11.10: *The shape of a protein determines how it functions.*

Enzymes

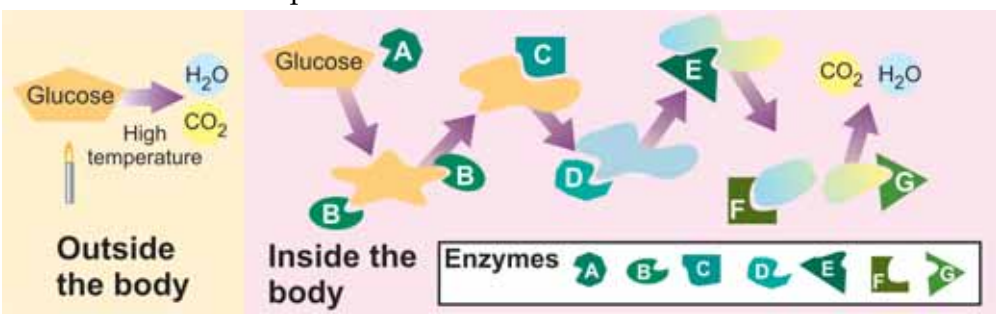
The control problem

Thousands of chemical reactions are going on in your body each *second,* involving thousands of chemicals. The reactions proceed at just the right rate to produce energy as it is needed. When you exercise, the reaction rate increases because your body needs more energy. How does your body control its chemical reactions?

The temperature problem

Sugar (glucose) does not turn into water and carbon dioxide by itself. Outside the body, this reaction needs the intense heat of a flame. Yet your body causes this reaction to occur at only 37°C. How does the body cause reactions like this to occur at low temperature?

The answer is that *enzymes* allow your body to initiate chemical reactions at low temperature and to control the rate of reactions.



How enzymes solve the temperature problem

Enzymes are special proteins that are **catalysts** for chemical reactions. A *catalyst* is a chemical that allows a reaction to have a much lower activation energy than it normally would. You can think of catalysts like *helper molecules* that allow a reaction to proceed in many small steps instead of all at once. Each step uses only the thermal energy provided by ordinary body temperature.

How enzymes solve the control problem

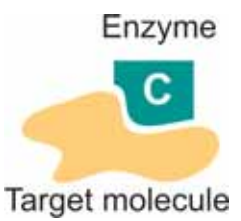
The body controls the rate of reactions by regulating the amount of enzymes produced. For example, when a cell needs more energy, it produces more enzymes to break down glucose. Without those enzymes, glucose molecules stay together and store their energy for when it is needed.

VOCABULARY

catalyst - a chemical that allows a reaction to have a much lower activation energy than it normally would have.

enzymes - special proteins that are catalysts for chemical reactions in living things.

How do enzymes work?



Enzyme molecules have special shapes that allow them to bind to their target molecule. The body has thousands of different enzymes because each one is highly specific and only works on its target molecule.

Enzymes are quite sensitive to temperature and pH. Most will not work outside a narrow range of temperature and pH.

DNA and nucleic acids

Protein synthesis

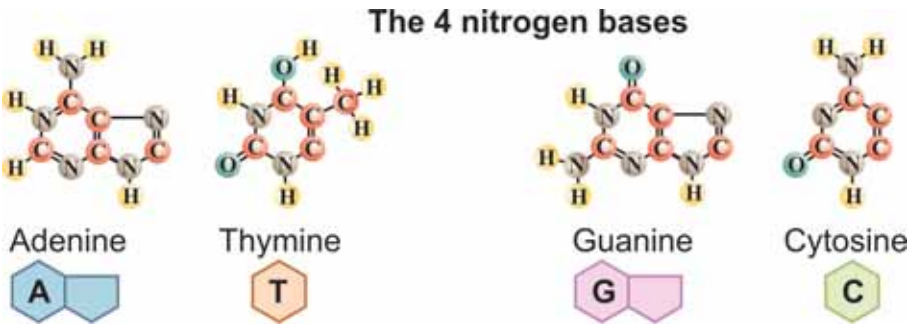
Cells must continually create the proteins they need from amino acids. This process is called **protein synthesis** and it occurs inside every cell of your body. How does protein synthesis work? How are the instructions for building proteins remembered and carried out?

VOCABULARY

protein synthesis - using the information in DNA to assemble proteins from amino acids.

DNA

The answer involves DNA, a nucleic acid. A DNA molecule is put together like a twisted ladder, or *double helix* (Figure 11.11). Each side of the ladder is made of 5-carbon sugars called deoxyribose and phosphate groups. The nitrogen bases are paired in the center of the ladder. DNA is among the largest molecules known. A single DNA molecule contains more than one million atoms.



The four nitrogen bases

There are four nitrogen bases in two matched pairs, adenine (A) with cytosine (C) and thymine (T) with guanine (G). The assembly instructions for building a protein are coded in the sequence of nitrogen bases on one side of the ladder. For example, TAA-GCT-AGG-GCT-GGC-GGC-TAA tells the cell: start-alanine-argenine-alanine-glycine-glycine-stop. This code would result in a protein with that sequence of five amino acids..

TTT	Phenylalanine	GCT	Alanine	GGT	Glycine
TTA	Leucine	CCC	Proline	GGC	Glycine
ATG	Methionine	GTT	Valine	AGG	Argenine
TAA	stop	ACA	Threonine	AGT	Serine

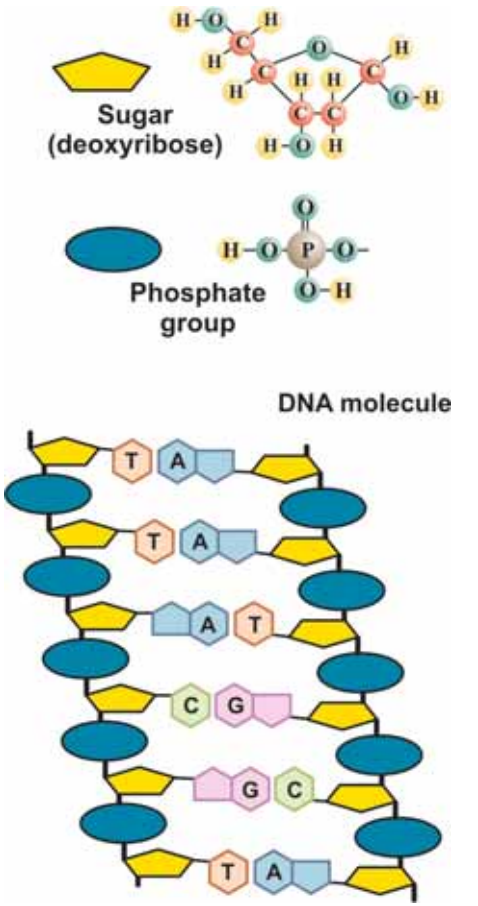


Figure 11.11: *The DNA molecule.*

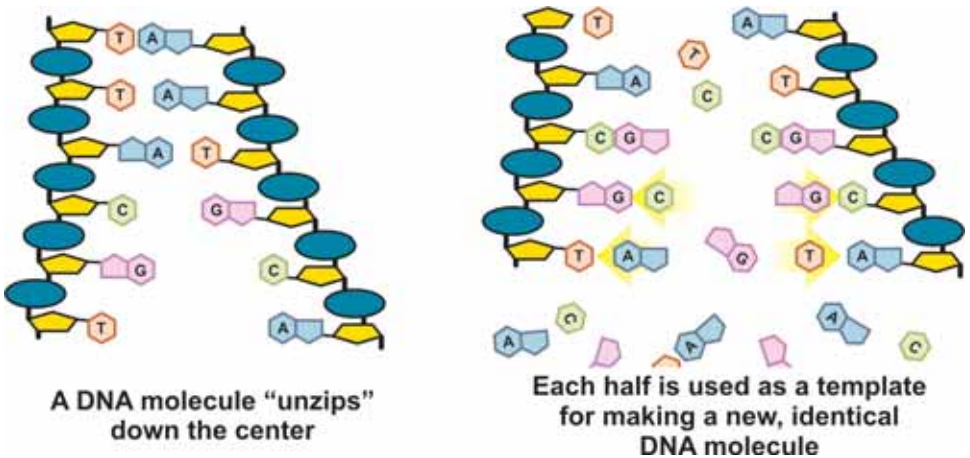
DNA and reproduction

What reproduction does

When an organism reproduces, it must pass on the chemical information for how to create every single protein in the organism. This is an incredible amount of information considering how many proteins there are and how complex a protein is.

Splitting the DNA molecule

Fortunately, the DNA molecule is able to make exact replicas of itself. When a cell reproduces, enzymes split the DNA molecule down the center. Each half of the molecule contains a complementary code of nitrogen bases. Since guanine only pairs with cytosine and adenine only pairs with thymine, each half of the molecule contains the complete genetic information for how to make proteins.



A DNA molecule "unzips" down the center

Each half is used as a template for making a new, identical DNA molecule

Rebuilding identical DNA molecules

Other enzymes called *polymerases* move along the unzipped DNA molecule rebuilding the nitrogen bases on each side. Still more enzymes rebuild the sugar and phosphate backbone on top of the completed nitrogen base pairs. At the end of the process, there are two identical DNA molecules.

Error checking

Another set of enzymes compares the old and new DNA strands for errors and corrects them by replacing nitrogen bases where necessary. We believe DNA replication occurs with less than one error out of every *billion* base pairs.

VOCABULARY

mutation - change in the sequence of base pairs in DNA that may be passed on to successive generations.

Mutations and evolution

Even with odds of 1 in a billion, over time, the sequence of bases in a DNA molecule does change through random replication errors. Radiation from the environment and other processes also change DNA. Changes in DNA are called **mutations**. Changes in DNA lead to new proteins, and changes in living organisms that are passed on in successive generations. This is the chemical basis for evolution.

Vitamins

Vitamins Most of the chemicals required for life can be synthesized by your own body, like proteins. However, there are certain chemicals necessary for the chemistry of life that the human body does not make. Collectively, these are called vitamins and minerals. In addition to carbohydrates, fats, and proteins, your body must get vitamins and minerals from food.

Vitamin C Ascorbic acid (Figure 11.12), also known as vitamin C, is required for synthesis of several important chemicals in your brain and nervous system. Vitamin C is also needed to synthesise compounds used in the transfer of energy within cells (ADP/ATP). Vitamin C must be supplied daily through food.

Vitamin D Vitamin D includes several fat-soluble compounds known chemically as *calciferols*. Vitamin D is not a true vitamin since it can be synthesized by your skin when cholesterol reacts with ultraviolet light. However, sunscreens and clothes block UV rays from reaching the skin and can result in vitamin D deficiency. To help prevent this possibility, foods such as milk are being fortified with vitamin D2 or vitamin D3. A severe deficiency of vitamin D leads to softening of the bones called *rickets* in children and *osteomalacia* in adults.

The B vitamins The B vitamins include several compounds that must be obtained from food. The B vitamins often work together to bolster metabolism, maintain healthy skin and muscle tone, enhance immune and nervous system function, and promote cell growth and division, including that of the red blood cells that help prevent anemia. All B vitamins are water soluble, and are dispersed throughout the body and must be replenished daily, with any excess excreted in the urine.

Folate Folate is another vitamin especially important during periods of rapid cell division and growth such as infancy and pregnancy. Folate is needed to make DNA and RNA. Both adults and children need folate to make normal red blood cells and prevent anemia.

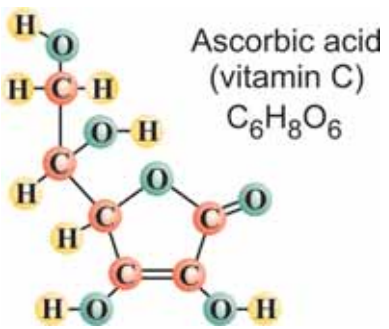


Figure 11.12: Ascorbic acid, also known as vitamin C.

B vitamins

Vitamin B-1 (thiamine)

Vitamin B-2, also vitamin G (riboflavin)

Vitamin B-3, also vitamin P or vitamin PP (niacin)

Vitamin B-5 (pantothenic acid)

Vitamin B-6 (pyridoxine and pyridoxamine)

Vitamin B-7, also vitamin H (biotin)

Vitamin B-9, also vitamin M (folic acid)

Vitamin B-12 (cyanocobalamin)

11.2 Section Review

1. What is the difference between a saturated and unsaturated fat? Why are *partially hydrogenated fats* useful when making potato chips — and not particularly healthy for humans to eat?
2. Simple sugars are the building blocks of carbohydrates. What are the simple units that make up proteins?
3. All of the amino acids share something in common. What is it?
4. What type of biological molecule is an *enzyme*, and why are enzymes so important to living things?
5. Why is DNA important to the process of protein synthesis?
6. How does an organism pass on the chemical information for making proteins to the next generation?
7. Complete the table by filling in the missing information. You will have to do some research to fill in the last column.

Vitamin	Examples of why it is important	Foods that supply this vitamin
C		
D	strong bones	
B		
folate	needed to make RNA, DNA, and red blood cells	

8. One of the DNA sequences in Figure 11.13 is impossible. Which one is wrong and why is it wrong?
9. Which of the DNA sequences in Figure 11.14 contains a mutation?
10. A vitamin is a chemical
    a. in food that is needed but not produced in the body.
    b. that is produced in the body and not needed from food.
    c. that is found in food but not used by the body.
    d. that is found in the body but not found in food.

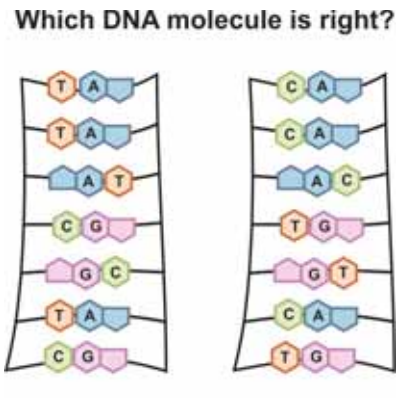


Figure 11.13: *Only one of the DNA molecules shown is correct. Which one is it (question 8)?*

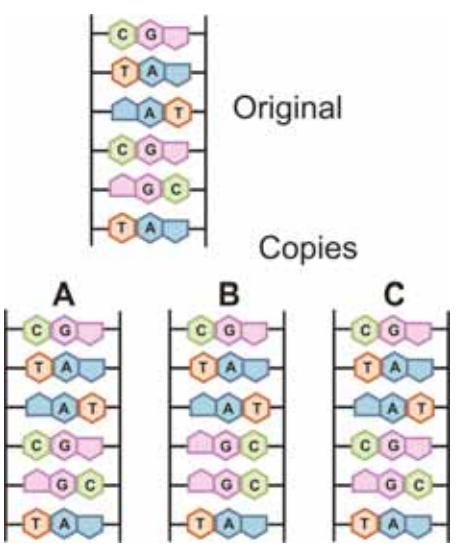


Figure 11.14: *A DNA molecule and three copies of the same molecule.*

HEALTH CONNECTION

Good Fats vs. Bad Fats

What is your favorite food? French fries, ice cream, cookies, maybe, or candy? Does just reading that make your mouth water? Many of us eat these tasty treats every now and then, but eating too much of high-fat foods can be bad for our health. What does "high-fat" actually mean, and are all fats bad for us?

The lowdown on fats

We need a reasonable amount of fat in our diets. Fat helps support cell function and helps our bodies absorb vitamins. But a diet too high in certain fats can lead to many health problems, including obesity, diabetes, and heart disease.

High cholesterol is a leading risk factor for heart disease. It can cause the deposit of fatty buildups in our arteries called plaques. Plaques narrow the arteries and so reduce blood flow, a condition called atherosclerosis.

Cholesterol-carrying compounds called lipoproteins play a key role in the development of atherosclerosis and heart disease. Low-density lipoproteins (LDL) transport cholesterol from the liver to the rest of our body. When there is too much LDL cholesterol in the blood, it can begin to build up on the walls of the arteries. LDL cholesterol is called "bad cholesterol" because of this buildup. High-density lipoproteins (HDL) transport cholesterol from the blood back to the liver for removal. HDL cholesterol is less likely to be deposited in the arteries, and so is referred to as the "good cholesterol."

A low-fat diet will help to reduce the risk for heart disease. But what truly affects our health is the type of fat and the total amount we eat.

Unsaturated, saturated, and trans fats

Based on their chemical structure, fats are either unsaturated or saturated. An unsaturated fat has two or more carbon atoms that are not bonded to hydrogen. In a saturated fat, all the carbon atoms have the maximum number of hydrogen atoms attached.

Unsaturated fats, known as "good fats," lower LDL and reduce the risk for heart disease. Unsaturated fats are liquid at room temperature and are found in olive and canola oils, avocados, and some nuts. Fatty fishes, such as salmon and tuna, are good sources of unsaturated fat.

Saturated fats are referred to as "bad fats." Our livers easily convert them to LDL cholesterol, which increases the risk for heart disease.

Saturated fats are solid at room temperature and are found in whole-milk dairy products like cheese, cream, and butter, and also in meat and poultry. Coconut and palm oils are among plant foods that are high in saturated fats.

Trans fatty acids, or trans fats, are included in the "bad fats" that raise LDL cholesterol levels. Food manufacturers produce trans fats by adding hydrogen to liquid vegetable oils, a process known as hydrogenation. The more hydrogenated the oil, the harder it is at room temperature. For example, a tub of spreadable margarine is less hydrogenated than a stick of margarine. Trans fats are found in most fried foods and in many processed foods, such as cakes and cookies.

The new food pyramid

For over 100 years, the U.S. Department of Agriculture (USDA) has made recommendations on the types and amounts of food we should eat. Recently, the USDA developed "MyPyramid," an interactive food guidance system. MyPyramid incorporates recommendations from the USDA's 2005 Dietary Guidelines for Americans. Using the USDA website (www.MyPyramid.gov), and entering their age, gender, and activity level, consumers can design their own healthy food plans.

The MyPyramid symbol encourages people to personalize their food choices and to incorporate daily physical activity in their lives. In terms of fat intake, the USDA recommends low-fat or fat-free milk products, that less than 10 percent of calories come from saturated fats, and that trans fats be kept to a minimum. Most fats we eat should come from unsaturated sources, such as fish, nuts, and vegetable oils.

Changes on food labels

Nutrition Facts

Serving Size 28g Tortilla chips

Amount Per Serving	
Calories 138	Calories from Fat 58
	% Daily Value*
Total Fat 7g	10%
Saturated Fat 1g	3%
Trans Fat	
Cholesterol 0mg	0%
Sodium 119mg	5%
Total Carbohydrate 18g	6%
Dietary Fiber 1g	6%
Sugars 0g	
Protein 2g	
Vitamin A 0% • Vitamin C 0%	
Calcium 5% • Iron 4%	

*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs.

NutritionData.com

By Jan. 1, 2006, the Food and Drug Administration (FDA) is requiring that food labels list trans fats. This will be in addition to the listing of overall fat, saturated fat, and cholesterol. The FDA hopes that the more detailed label will give consumers a complete picture of the foods they buy - and help them make healthier food choices and ultimately live healthier lives.

Questions:

1. Why are low-density lipoproteins (LDL) called "bad cholesterol" and high-density lipoproteins (HDL) called "good cholesterol"?
2. How do unsaturated, saturated, and trans fats affect LDL and HDL levels?
3. What changes are being made to food labels by Jan. 1, 2006, and why?

CHAPTER ACTIVITY

The Scoop on Nutrition Labels

All packaged foods are required to contain nutrition labels to help consumers choose healthy foods. A nutrition label shows the amount of calories, fat, cholesterol, carbohydrates, protein, and several vitamins and minerals in one serving of the food.

The exact amount of each nutrient a person needs depends on gender, age, activity level, and weight. An average female teenager should consume approximately 2200 calories and not more than 73 grams of fat per day. A male should consume 2800 calories and not more than 93 grams of fat. Protein requirements depend on body mass and amount of physical activity. Teenagers need between 1 and 1.5 grams of protein per kilogram of body mass.

Materials:

Nutrition labels from food packages or from the internet
Poster board

What you will do

1. Look at a variety of nutrition labels, including those for foods considered to be healthy and those that are unhealthy. You can use the internet to find information on foods that don't come in packages, such as fruits and vegetables.
2. Suppose your doctor recommends a diet of 2400-2600 calories, fewer than 80 grams of fat, and at least 65 grams of protein. Use nutrition labels to select an assortment of food to eat in one day that meets these requirements and includes 100% of the daily requirement of vitamins A, vitamin C, vitamin D, calcium, and iron.
3. Make a poster describing your menu for the day. List the number of calories, grams of fat and protein, and percentage of each nutrient.

Applying your Knowledge

a. The term "empty calories" is used to describe foods that have a high number of calories but little nutritional value. List three foods that contain empty calories.
b. Which of the foods you selected for your menu contains the greatest amount of protein?
c. Which of the foods contains the greatest amount of fat?
d. Which three of your selected foods would you consider to be the most healthy? Explain why you chose these foods and what you think it means to say that a food is healthy.

Nutrition Facts

Serving Size 1 fruit 27/8 (140g)

Amount Per Serving	
Calories 69	Calories from Fat 2
	% Daily Value*
Total Fat 0g	0%
Saturated Fat 0g	0%
Trans Fat	
Cholesterol 0mg	0%
Sodium 1mg	0%
Total Carbohydrate 18g	6%
Dietary Fiber 3g	12%
Sugars 12g	
Protein 1g	

Vitamin A	7%	• Vitamin C	138%
Calcium	6%	• Iron	1%

*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

	Calories	2,000	2,500
Total Fat	Less than	65g	80g
Sat Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Fiber		25g	30g

Calories per gram:
Fat 9 • Carbohydrate 4 • Protein 4

NutritionData.com

Vocabulary

Select the correct term to complete the sentences.

nucleic acid	fat	carbohydrates
photosynthesis	unsaturated	proteins
cellular respiration	organic chemistry	partially hydrogenated
catalyst	protein synthesis	nitrogen bases
amino acids	mutations	enzymes

Section 11.1

1. The branch of chemistry that specializes in carbon and carbon compounds is called ____.
2. The chemical energy that supports the food chain on Earth comes from a reaction called ____.
3. The reaction that breaks down glucose and releases its stored energy is called ____.
4. Sugars and starches are classified as ____.
5. DNA is an example of a(n) ____.

Section 11.2

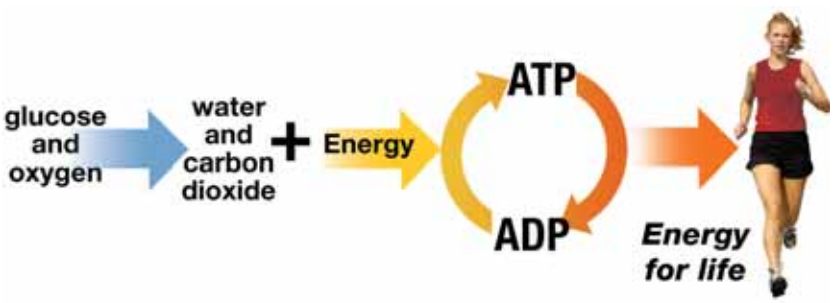
6. High-energy ____ molecules are used to store energy in reserve.
7. ____ are made up of amino acids.
8. When a fat molecule has two hydrogen atoms bonded to each carbon atom, it is called a ____ fat.
9. When a fat molecule has some carbon atoms double bonded to each other, along with hydrogen atoms, it is called a(n) ____ fat.
10. ____ are organic molecules that are the building blocks of proteins.
11. ____ allow your body to initiate chemical reactions and control the reaction rates.
12. Changes in DNA are called ____.
13. Enzymes are a type of ____ for chemical reactions.
14. The process the cells in your body use to build proteins from amino acids is called ____.
15. The molecular components within DNA that contain the code for building proteins from amino acids are ____.

Concepts

Section 11.1

1. What do all organic molecules have in common?
2. What makes carbon uniquely suited to being the basis for biological molecules?
3. Describe the four types of biological molecules. Give an example for each type:
   a. carbohydrate
   b. fat
   c. protein
   d. nucleic acid
4. What elements are carbohydrates made of?
5. Why do sugars break down so quickly in your body?
6. What is the difference between a starch molecule and a cellulose molecule?
7. Why does the high specific heat of water make it essential to life?
8. Explain how photosynthesis and respiration are related carbon reactions.

9. Which process adds oxygen (O_2) to Earth's atmosphere?
   a. photosynthesis
   b. cellular respiration
   c. protein synthesis
10. What process removes carbon dioxide (CO_2) from the atmosphere?
   a. photosynthesis
   b. cellular respiration
   c. protein synthesis
11. What process does the diagram illustrate?



12. Digestion breaks down food into molecules the body can use. What type of molecules are each of the following broken down into?
   a. proteins
   b. carbohydrates
   c. fats

Section 11.2

13. Describe how your body allows chemical reactions to occur at low temperature?
14. What is the function of fats in the human body?
15. What is the role of a catalyst in a chemical reaction? Describe how enzymes act as catalysts.
16. What is the structure of DNA called?
   a. Nitrogen bases
   b. Protein synthesis
   c. Double helix
17. How are mutations the chemical basis for evolution?
18. In the process of DNA reproduction, how are errors fixed?
19. Nitrogen bases:
   a. are amino acids.
   b. hold the codes for building proteins.
   c. initiate chemical reactions.
20. Which function does DNA perform?
   a. It reproduces itself exactly.
   b. It controls chemical reactions in the body.
   c. It provides energy for cells.

Problems

Section 11.1

1. Classify each of the following carbohydrates as containing mostly sugar, starch, or cellulose:
   a. a stack of firewood
   b. rice
   c. jelly beans
   d. a shirt made of cotton
   e. an apple
2. The human body is made mostly of:
   a. carbon, oxygen, nitrogen, and hydrogen.
   b. oxygen, calcium, carbon, and hydrogen.
   c. hydrogen, iron, nitrogen, and oxygen.

3. All plants use the process of photosynthesis. However, this process wasn't always understood. In one classic experiment, a small plant and its soil were weighed. The plant was given only water for a solid year. At the end of the year, the plant weighed much more than it did at the end of the first of the year. The soil weighed the same amount. Where did the extra weight of the plant come from?

4. A product of cellular respiration is energy. What is this energy used for?

5. Which of the following compounds are organic?
   a. nucleic acid
   b. CH_4
   c. H_2O
   d. hydrochloric acid
   e. table salt
   f. sugar

Section 11.2

6. Identify each of the following as a carbohydrate, fat, protein, or nucleic acid.
   a. glucose
   b. DNA
   c. cholesterol
   d. cellulose
   e. olive oil

7. An organic compound contains carbon, hydrogen, oxygen, and nitrogen. Could this compound be a fat? Could it be a nucleic acid? Explain.

8. What is the relationship between proteins and nucleic acids?

9. About how many different amino acids are found in animal proteins?
   a. 2
   b. 4
   c. 20

10. Which of the following is NOT part of the process for the body to get the essential proteins it needs?
    a. protein synthesis
    b. digestion of food protein into amino acids
    c. the manufacturing of amino acids from fats

11. Of the four nitrogen base pairs, adenine always pairs with:
    a. adenine
    b. guanine
    c. thymine
    d. cytosine

12. Your body produces proteins it needs through the process of protein synthesis. How does your body obtain the vitamins it needs?

13. The diagram shows an enzyme and three different molecules. Which of the three molecules would this enzyme target for a reaction?