UNIT 4

Human Systems

General Outcomes

In this unit, you will

- explain how the human digestive and respiratory systems exchange energy and matter with the environment
- explain the role of the circulatory and defense systems in maintaining homeostasis
- explain the role of the excretory system in maintaining homeostasis through the exchange of energy and matter with the environment
- explain the role of the motor (muscular) system in the function of other body systems

Unit Contents

Focussing Questions

1. What factors influence the healthy functioning of the body?
2. How can technology assist the healthy functioning of the body?

Unit PreQuiz ?

www.albertabiology.ca

Don't tell Sarah Reinertsen it can't be done, unless you want to be proven wrong. In the world of running, she has just about done it all: 100 m, 200 m, 400 m, 5 km, 10 km, marathon, and triathlon. Compared with an athlete with two legs, Sarah Reinertsen must use 40 percent more oxygen and twice as much energy to accomplish the same basic feats. All of her organ systems—circulatory, respiratory, digestive, and muscular systems, to name only a few—are finely tuned through training to work together in the most effective and efficient manner. In this regard, however, she is no different from you or anyone else. Everyone's organ systems have the same vital function of providing and using matter and energy for all life-sustaining activities of the body. In this unit, you will explore the means by which your body obtains necessary materials from the environment, rids itself of materials it does not need, and transforms matter into energy. These processes are closely unified and regulated in a way that even the finest medical technologies cannot replicate.

UNIT 4 Preparation

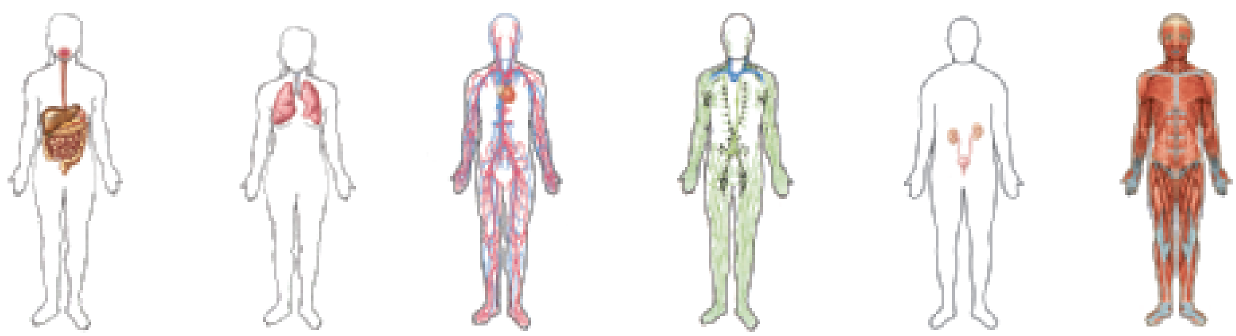
Prerequisite Concepts

This unit builds on your knowledge of the structure and function of animal cells (Unit 3 Preparation), the cell membrane (Unit 3 Preparation), and cellular respiration (Chapter 5).

Human Systems

Each of the cells of the human body is a living unit that performs a specific function. Cells of the same type interact both structurally and functionally to form specialized tissues, such as those that line your stomach. One or more tissues interact to form more complex structures known as organs, such as your stomach. Several organs—for example, your stomach, small and large intestines, liver, and pancreas—are linked either physically or functionally as organ systems, such as the digestive system.

Figure P4.1 Organ systems of the human body



Digestive system
- breaks down food into chemical components that are small enough to enter circulation
- eliminates undigested food

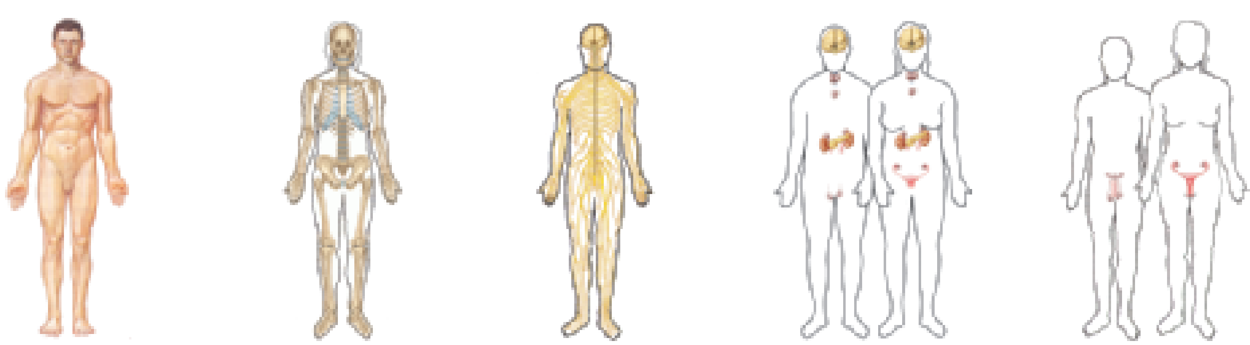
Respiratory system
- delivers oxygen to blood
- removes carbon dioxide from cells
- helps to control blood pH

Circulatory system
- transports blood, nutrients, gases, and metabolic wastes
- defends body against disease
- helps to control temperature, fluid balance, and pH balance

Lymphatic and immune systems
- help to control fluid balance
- defend against disease
- absorb fats (lymphatic)

Excretory system
- removes metabolic wastes
- helps to control fluid balance
- helps to control pH balance

Muscular system
- maintains posture
- moves body and organs
- produces heat



Integumentary system
- protects body from infection
- receives sensory input
- helps to control body temperature
- synthesizes vitamin D

Skeletal system
- provides framework for muscles to attach to, making movement possible
- produces blood cells
- stores minerals
- protects soft organs

Nervous system
- detects, interprets, and responds to stimuli from outside and within body
- with endocrine system, coordinates all organ-system functions

Endocrine system
- produces hormones
- helps to coordinate organ systems
- responds to stress
- helps to regulate fluid and pH balance
- helps to regulate metabolism

Reproductive system
- produces gametes (sperm or ova)
- transports gametes
- produces sex hormones
- nourishes, nurtures, and gives birth to offspring in females

The first six organ systems shown and summarized in Figure P4.1 are the subject of this unit. You will study other organ systems in your next biology course.

Homeostasis and Negative Feedback

Whether you are resting or working out, your body temperature will stay near a set point of 37 °C. The pH of your blood will stay near 7.4. Your blood glucose level will stay around 100 mg/mL. Regardless of external conditions, the internal environment of your body remains stable or relatively constant. The tendency of the body to maintain a relatively constant internal environment is known as *homeostasis*.

Body systems maintain homeostasis through a mechanism that has three components: a *sensor*, which detects a change in the internal environment; an *effector*, which brings internal conditions back into a normal range; and a *control centre*, which activates the effector based on information received from the sensor.

The main homeostatic mechanism that works in the body to keep a variable, such as body temperature, stable is *negative feedback*. Figure P4.2A compares negative feedback to the way a seesaw moves. A seesaw is level when the forces acting on it are balanced. If a change occurs to disrupt this balance, the seesaw can be made level again by applying a force to reverse the change.

In terms of negative feedback, a sensor detects a change that disrupts a balanced state and signals a control centre. The control centre then activates an effector, which reverses the change and restores the balanced state. Figure P4.2B shows how this idea applies to the control of body temperature.

Prerequisite Concepts

This unit provides opportunities to practice and further develop your skills in the use of the microscope and in the illustrating of scientific drawings.

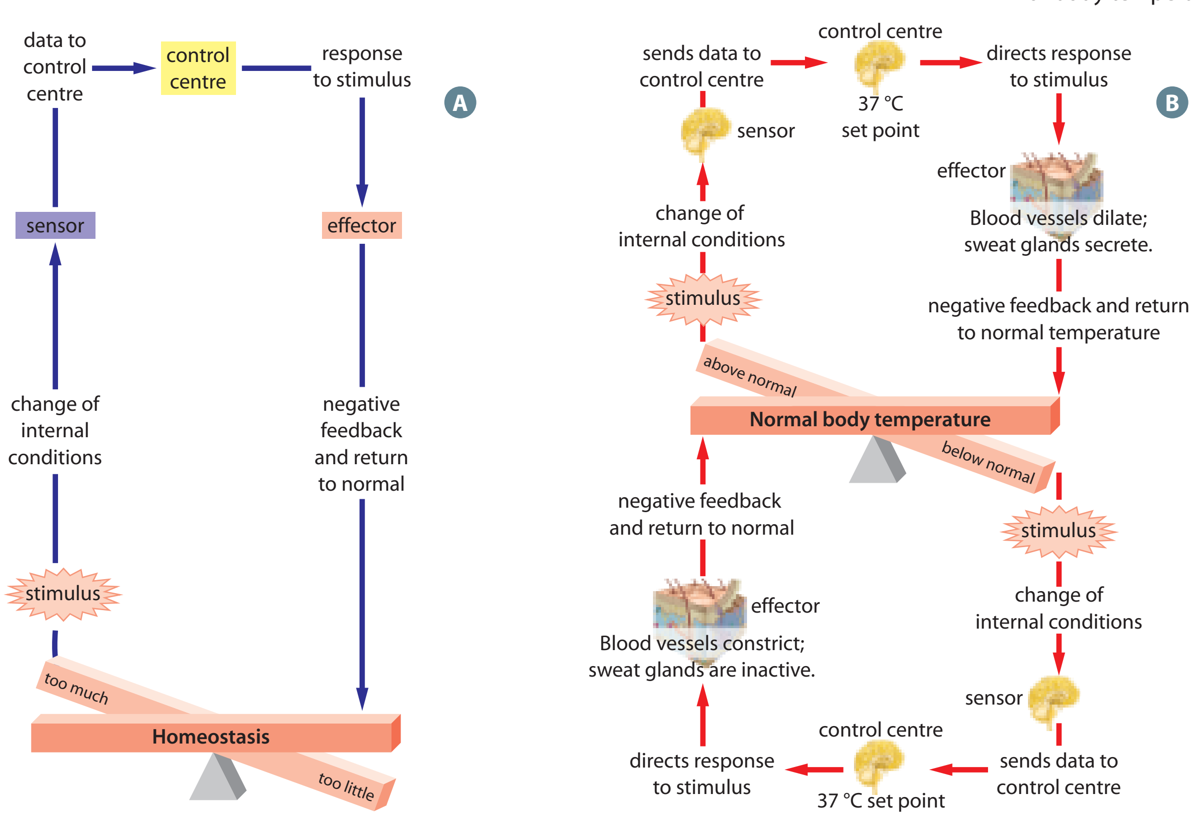
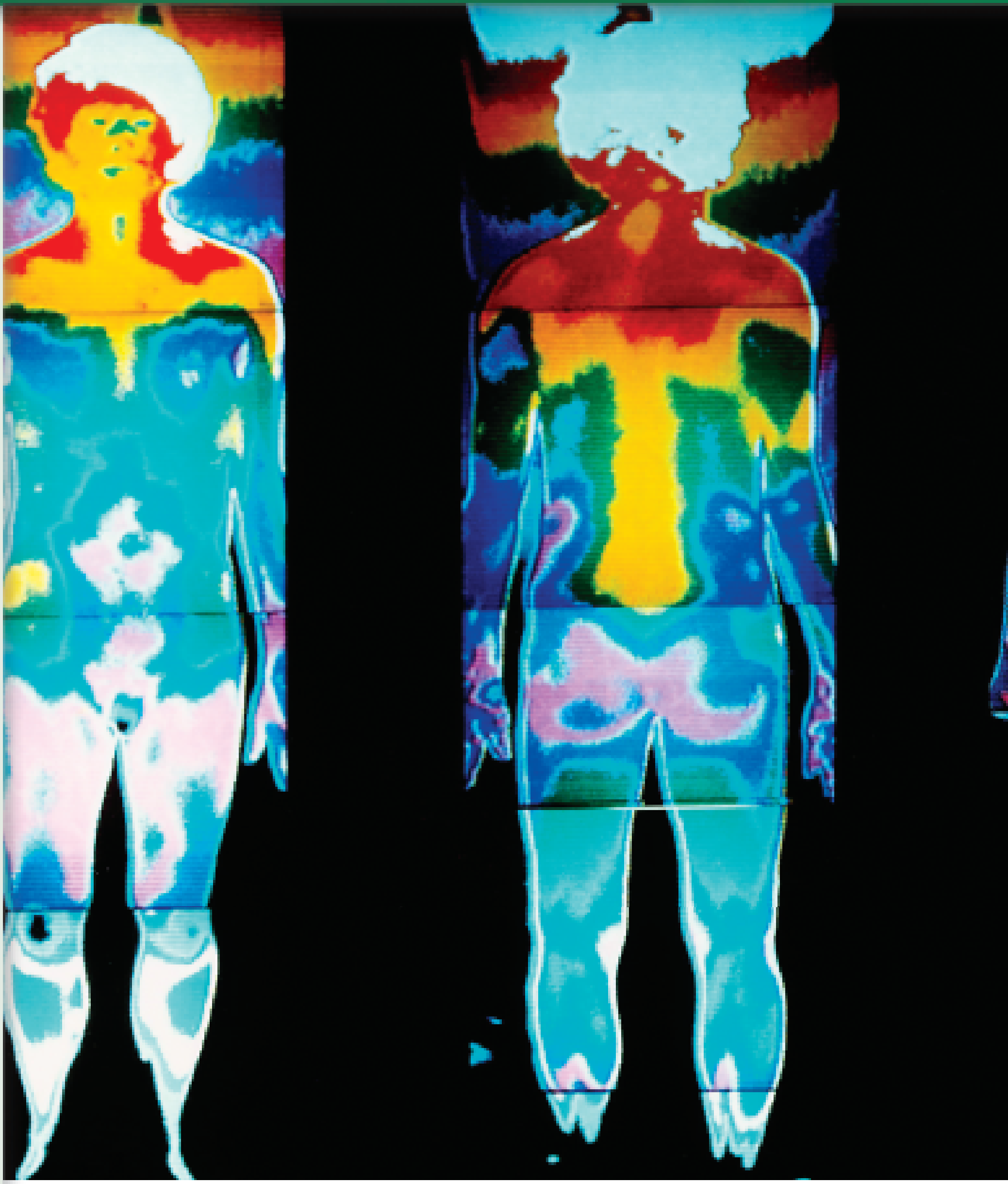


Figure P4.2 Negative feedback in general **(A)** and in a biological example—maintenance of body temperature **(B)**.

CHAPTER 6

Digestion and Human Health



Chapter Concepts

6.1 The Molecules of Living Systems

- Macromolecules such as carbohydrates, lipids, proteins, and nucleic acids are made up of smaller subunits that are chemically separated through hydrolysis.
- Enzymes are biological catalysts.

6.2 The Human Digestive System

- The digestive tract is a tube extending from the mouth to the anus through which food is broken down, nutrient molecules absorbed, and undigested material eliminated.
- Food is processed mechanically and chemically to reduce macromolecules to a form in which they may be absorbed into the bloodstream.

6.3 Health and the Digestive System

- An excess or deficiency of nutrients can lead to disorders that can be diagnosed and treated but not necessarily cured.

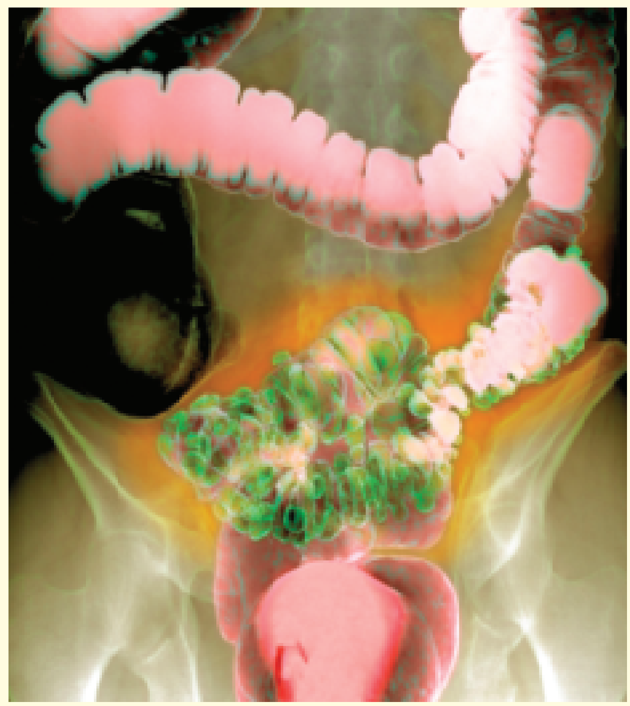
Modern technology provides us with new insights into how the human body works. An infrared camera took the pictures above, called thermograms, mapping the heat given off by the human body. The colours correspond to a range of temperatures, from light blue (coolest) through pink, yellow, red, and white (warmest). This heat is generated by ATP, and fuelled by oxygen from the air and nutrient molecules from food. It is evidence of the constant transformation of food into matter and energy that takes place within the trillions of specialized cells that make up each of the body's diverse, interconnected organ systems. In this chapter, you will find out how food is transformed into the matter and energy that enable you to survive.

Capsule endoscopy is a technology that uses a camera-containing pill to capture video footage of the same path that food takes through the digestive system. This photo shows the pylorus—the opening from the stomach to the small intestine.

Launch Lab

Visualizing the Human Body

Thermograms permit a view of the body that otherwise would be beyond the range of our human senses. Capsule endoscopy and similar internal-camera technologies provide views of the body from the inside out, in a manner of speaking. These technologies are powerful aids for diagnosis as well as for developing new understandings of the body and how it works. One of the oldest and still most often-used technologies for peering inside and imaging the body is the X-ray machine.



Procedure

1. Examine the coloured X-ray image. Sketch all the organs and body parts that you can see or recognize.
2. On your sketch, add any other organs and body parts that you know or recall.

Analysis

1. Compare your sketches with others in the class. Modify your sketch or labels as necessary.
2. Based on memory or personal knowledge, briefly describe the function of all the organs on your sketch. Write "unsure" for those you do not know or recall. Return to your sketch throughout the unit to assess and modify your sketch.

SECTION
6.1

The Molecules of Living Systems

Section Outcomes

In this section, you will
- **describe** the chemical nature of carbohydrates, lipids, and proteins
- **explain**, in general terms, how carbohydrates, lipids, and proteins are synthesized and how they are broken down (hydrolyzed)
- **perform** standard tests to identify macromolecules

Key Terms

macromolecules
dehydration synthesis
hydrolysis
carbohydrates
lipids
proteins
peptide bond
nucleic acids
vitamins
minerals
catalyst
enzyme

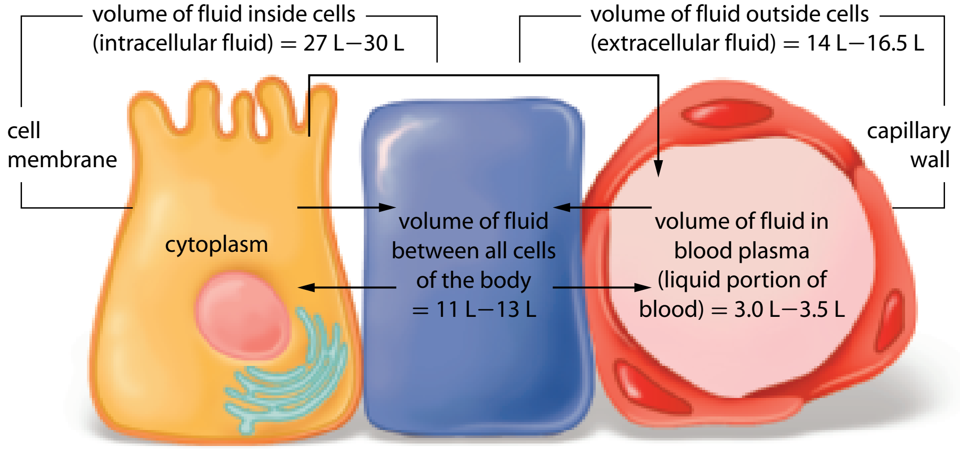


Figure 6.1 Distribution of body fluids in the adult human. These fluids are mostly water and move freely in both directions from inside to outside the cells.

In Figure 6.1, you see the three main fluid compartments of your body: the cytoplasm inside your cells, the fluid between your cells, and the fluid in your blood. The fluid in these compartments is mostly water, which makes up more than 60 percent of your body. These compartments also contain and are composed of thousands of different kinds of molecules and ions. Some of these molecules and ions—such as water, phosphates, hydrogen ions, and sodium ions—are small and simple. They are inorganic (non-living) matter. Other molecules, called organic molecules, contain carbon bonded to hydrogen, as well as to other atoms, such as oxygen, sulfur, and nitrogen. Larger, more complex assemblies of organic molecules, called **macromolecules**, are often grouped into four major categories: carbohydrates, lipids (such as fats), proteins, and nucleic acids. Many macromolecules are polymers—long molecules formed by linking many small, similar chemical subunits, much like linking railroad cars to form a train. Table 6.1 outlines the four categories of macromolecules and their subunits. You will learn about these macromolecules in this section, as well as in Section 6.2.

Table 6.1 The Macromolecules of Life

Macromolecule	Example(s) of subunits	Main functions	Examples of macromolecules
carbohydrates	sugars (such as glucose) and polymers of glucose	energy storage	sugars, starches, and glycogen
lipids	glycerol and three fatty acids or glycerol and two fatty acids	energy storage and cell membranes	fats, oils, and phospholipids
proteins	polymers of amino acids	transport, blood clotting, support, immunity, catalysis, and muscle action	hemoglobin, fibrin, collagen, antibodies, enzymes, actin, and myosin
nucleic acids	polymers of nucleotides	transfer and expression of genetic information	DNA and RNA

Assembling Macromolecules

Although the four categories of macromolecules contain different kinds of subunits, they are all assembled in cells in the same basic way. To form a covalent bond between two subunit molecules, an –OH (hydroxyl) group is removed from one subunit and a hydrogen atom is removed from the other subunit (see Figure 6.2A). This chemical reaction is known as **dehydration synthesis**, because removing the –OH group and H atom during the synthesis of a new biological molecule essentially removes a molecule of water (H_2O). (Dehydration means "without water.") Dehydration synthesis, like many other reactions that occur in the body, requires the correct chemical bonds to be broken at the right time. The process of positioning and breaking the chemical bonds is carried out in cells by a special class of proteins called enzymes. You will learn more about enzymes later in this section.

Disassembling Macromolecules

Cells disassemble macromolecules into their component subunits by performing a chemical reaction that basically reverses dehydration. In this reaction, called **hydrolysis**, a molecule of water is added instead of removed. (*Hydrolysis* comes from two Greek words for "water" and "break.") During a hydrolysis reaction (see Figure 6.2B), a hydrogen atom from water is attached to one subunit and the hydroxyl group is bonded to another subunit, effectively breaking a covalent bond in a macromolecule. As in dehydration, hydrolysis involves enzymes.

1. Identify the four categories of macromolecules that make up living systems, such as your body.
2. Name and describe the process that builds macromolecules.
3. Name and describe the process that breaks down macromolecules.

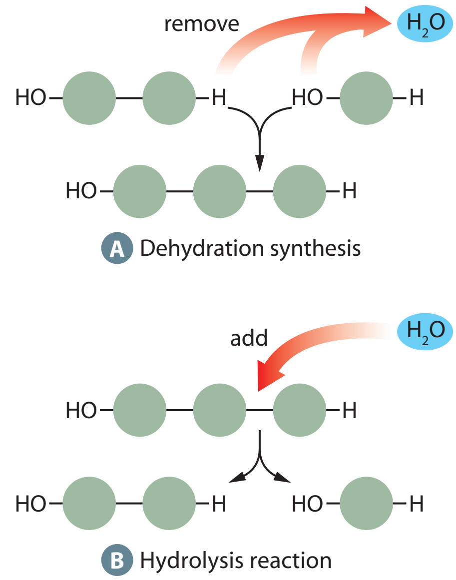


Figure 6.2 This simplified diagram shows how molecular subunits are put together (synthesized) to form macromolecules and broken apart through hydrolysis.

Carbohydrates

Carbohydrates are macromolecules that always contain carbon, hydrogen, and oxygen—and almost always in the same proportion: two atoms of hydrogen and one atom of oxygen for every atom of carbon. Carbohydrates provide short-term or long-term energy storage for organisms. There are two main types of carbohydrates: simple sugars and polysaccharides.

Simple Sugars

A carbohydrate molecule with three to seven carbon atoms (and the corresponding number of hydrogen and oxygen atoms) is called a monosaccharide, or a simple sugar (*mono* means one; *saccharide* comes from a Sanskrit word that means "sugar"). A disaccharide, or double sugar, is made up of two simple sugars (*di* means "two"). Figure 6.3 illustrates the synthesis and hydrolysis of maltose, which is a disaccharide.

Polysaccharides

A polysaccharide is a complex carbohydrate that consists of many linked simple sugars (*poly* means "many"). Figure 6.4 shows the structure of the polysaccharides starch, glycogen, and cellulose. Starch performs the important function of energy storage in plants. Glycogen performs the same function in

BiologyFile

FYI

Plants produce another type of polysaccharide, called cellulose, which makes up their cell walls. As a polysaccharide made up of glucose units, cellulose also stores a great deal of energy. Only a few bacterial species, however, produce the chemicals that are needed to break down cellulose into glucose. To obtain nourishment from plants, herbivores such as rabbits and goats must host these bacteria in their guts. Humans do not host these bacteria, so the stored energy in cellulose is not accessible to us.

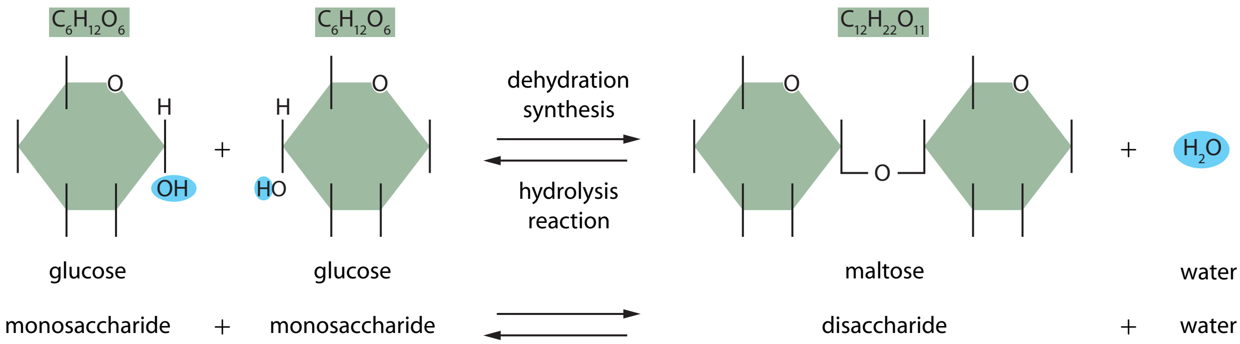


Figure 6.3 During the synthesis of maltose, a chemical bond forms between two glucose molecules, and the components of one water molecule are removed. During the hydrolysis of maltose, the components of one water molecule are added and the bond is broken, yielding two glucose molecules. (The double arrow indicates that the chemical reaction, represented by the chemical equation, can proceed in both directions—from left to right and from right to left.)

animals. Compare the structure of the starch and glycogen molecules, and note the many "branches" on the glycogen molecule. The larger amount of branching on the glycogen molecule means that it packs more glucose units into a single cell than a starch molecule does.

> **Q 4** Identify two types of carbohydrates, and name the subunits that make up each type.

Lipids

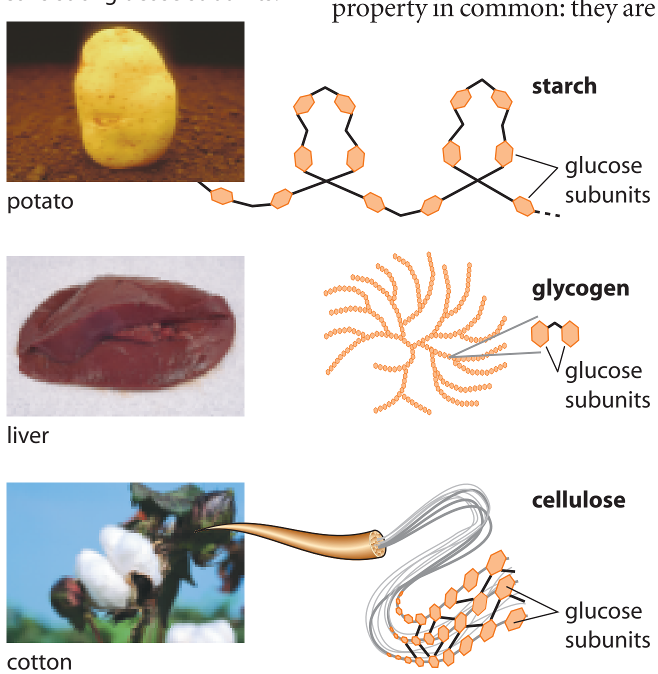
Lipids are a diverse group of macromolecules that have one important property in common: they are insoluble in water. Lipids store 2.25 times more energy per gram than other biological molecules. Not surprisingly, therefore, some lipids function as energy-storage molecules. Other lipids, called phospholipids, form a membrane that separates a cell from its internal environment. Still others, called steroids, form the sex hormones estrogen and testosterone.

The lipids that you are probably most familiar with are those found in fats and oils. Fats, such as butter and lard, are usually of animal origin and are solid at room temperature. Oils, such as olive oil and safflower oil, are of plant origin and are liquid at room temperature.

Fats and oils form when one glycerol molecule reacts with three fatty acid molecules (see Figure 6.5). A fat is sometimes called a *triglyceride* because of its three-part structure. You might also hear the term "neutral fat," referring to the fact that a fat molecule is non-polar.

In a triglyceride, the glycerol always has the same composition, but the composition of the three fatty acids may differ. (You can see an example of this in Figure 6.5.) The three fatty acids may be identical or different, short or long, and saturated or unsaturated. A saturated fatty acid does not have double covalent bonds between its carbon atoms, so it contains all the hydrogen atoms it can bond with. An unsaturated fatty acid has double bonds between some of its carbon atoms, leaving room for additional

Figure 6.4 Compare the structural differences among starch, glycogen, and cellulose. Notice that all three polysaccharides consist of glucose subunits.



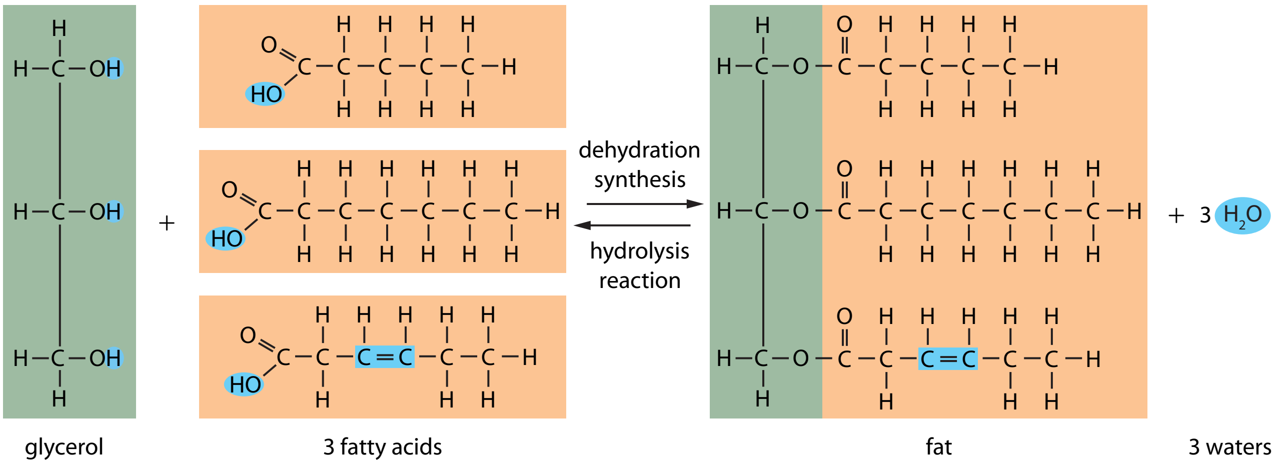


Figure 6.5 During the synthesis of a fat molecule, three fatty acid molecules bond with one glycerol molecule, and three water molecules are produced. What happens during the hydrolysis of a fat molecule?

hydrogen atoms. Unsaturated fatty acids cause the resulting fat to be liquid at room temperature. Saturated fatty acids usually cause the resulting fat to be solid at room temperature.

Q 5 Identify the subunits that make up fats.

Q 6 List the key differences between a saturated and an unsaturated fat.

Proteins

Most cellular structures are made of different types of **proteins**. Proteins serve many functions in cells and display greater structural complexity and functional diversity than either lipids or carbohydrates. Both your hair and fingernails are made of the same type of protein, keratin, but each has its own distinctive properties. The bones and muscles inside your hand and the ligaments and tendons that connect them contain very different proteins.

Like other macromolecules, proteins are assembled from smaller subunits. The subunits in proteins are amino acids. An amino acid has a central carbon atom bonded to a hydrogen atom and three other groups of atoms—amino group, acid group, and *R* group—as shown in Figure 6.6. The *R* group is a group of one or more atoms that determines identity and is what distinguishes the 20 types of amino acids from one another. The body can synthesize 11 of these 20 amino acids. The other nine must come from the diet, so they are termed essential amino acids.

Amino acids bond together in strands to form proteins. Individual amino acids are connected by a type of bond called a **peptide bond**. Figure 6.7 on the next page shows how a peptide bond between two amino acids is formed and broken. Regardless of which *R* group is present, amino acids always bond to each other as shown in Figure 6.7. A chain of several amino acids bonded together is called a peptide. If amino acids are bonded, the chain is called a polypeptide.

A strand of amino acids must undergo additional changes before it becomes a protein. Different amino acids along the strand attract and repel each other, and this causes the strand to coil and twist as the amino acids are drawn toward or pushed away from one another. The end result is a complex three-dimensional structure, such as the one shown in Figure 6.8. The final shape of a protein's three-dimensional structure determines its properties and functions.

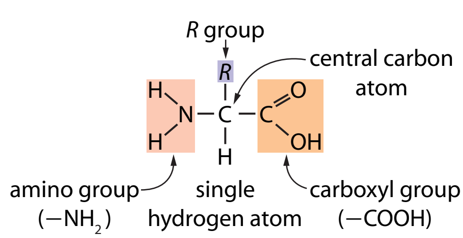


Figure 6.6 An amino acid is the subunit of proteins. An amino acid is composed of an amino group, an acid (carboxyl) group, and one of 20 *R* groups attached to a central carbon atom.

Thought Lab 6.1 How Do You Take Your Macromolecules?

Target Skills

Evaluating technologies designed to provide solutions to the problem of food preservation and long-term storage

Showing how food preservation technologies may solve one problem but create others

Most foods, especially in raw form, spoil quickly. It has been a challenge to preserve foods for later consumption since the earliest times, and, almost since then, people in all cultures have been devising ways to alter raw food so it will last longer. In this part of the world, food can only be grown during certain months, and then it has to be stored for use through the winter and spring. In earlier generations food had to be carefully preserved and stored to ensure survival. Now it must be carefully preserved for handling and transportation to distant markets.

There are two main reasons why food spoils: the growth of microorganisms (mostly bacteria and fungi) and/or the breakdown of fats, which makes foods rancid. Bacteria, which can cause life-threatening illnesses, need water to grow in, and the earliest technologies involved drying and smoking the foods to remove the water and kill any potential bacteria or parasites.

A variety of techniques to preserve foods are used today; some are improvements on old technologies, some are best suited to particular types of foods, and a combination of techniques is often used. Most techniques simply prolong the "shelf life" of the food, and no technique is perfect. Some are better than others at preserving the nutrients in food. Salt, one of the earliest food preservatives, is still in use and is currently being targeted by physicians as a cause of high blood pressure. A more modern technology—the use of trans fats—was thought to solve the problem of food going rancid, but it is being re-evaluated amid charges that it causes heart disease.

Other techniques fall into broad categories of lowering the pH, raising the temperature, lowering the temperature, using preservative spices or chemicals as additives, and sealing the food from air. One of the newer and more controversial techniques is known as irradiation and involves treating the food with ionizing radiation.

Procedure

1. Choose one example each of a food that is mostly carbohydrate, fat, or protein that you have on hand at home.

2. Examine the items, their ingredient lists, and the packaging for clues to how each has been preserved for long-term storage.

Analysis

1. Create a chart and list each of the foods and the technologies used to preserve them.

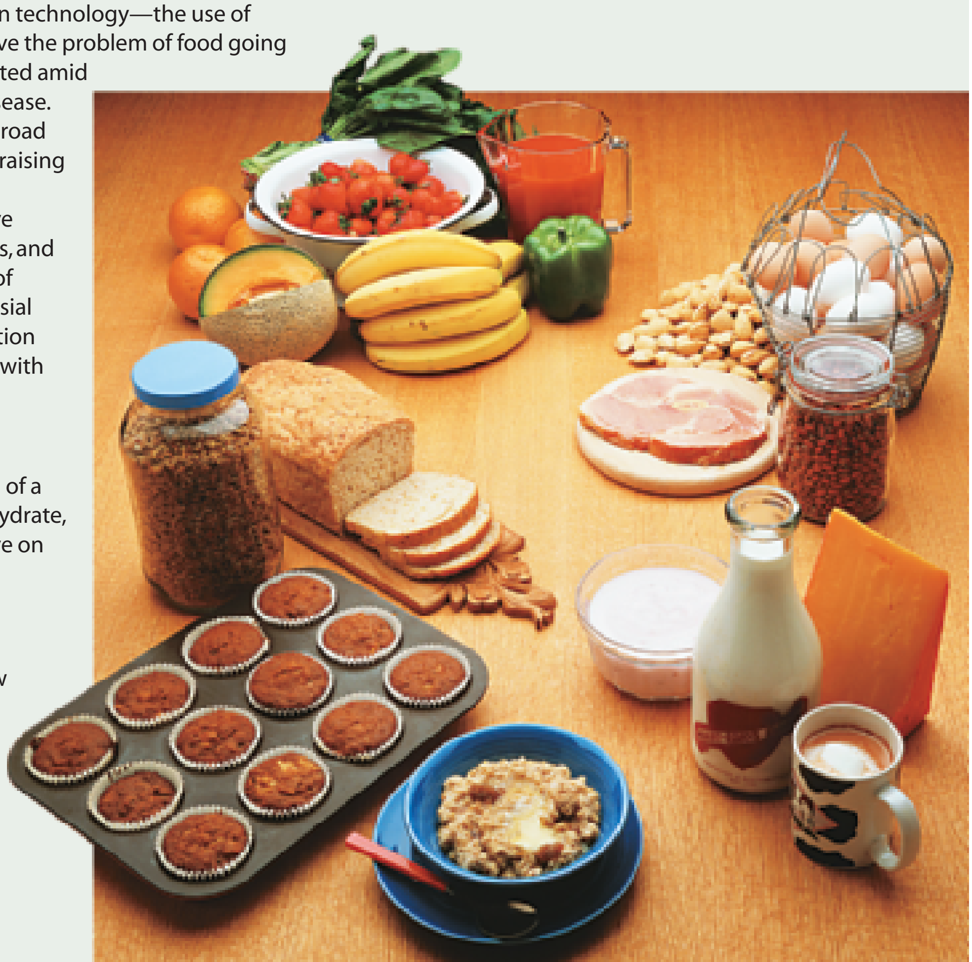
2. Choose one of the foods and use library resources or the Internet to research the method behind the technology or combination of technologies used to preserve the food and why it works.

3. Describe the advantages of this technology.

4. Describe the disadvantages of this technology.

Extension

5. Identify any chemical preservatives and use the Internet to research the role of the preservatives and any possible side effects. ICT



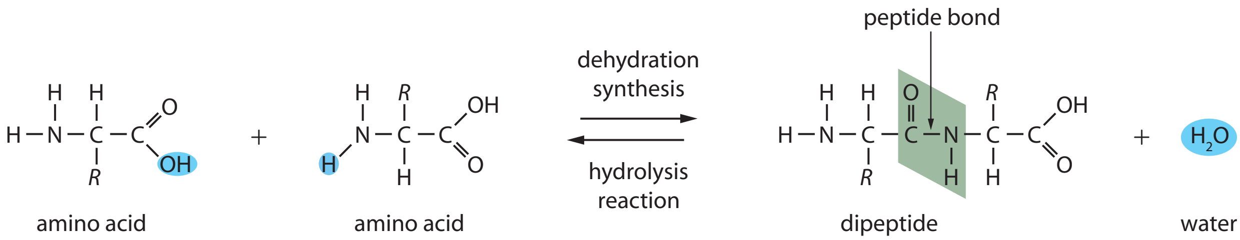


Figure 6.7 In dehydration synthesis, two amino acids bond to form a two-subunit molecule called a dipeptide. Hydrolysis breaks the peptide bond that links the amino acids. The *R* groups are shown here only as "*R*," because they do not take part in the reactions that make or break peptide bonds.

The *R* group also affects the structure of a protein. Some *R* groups are electrically charged, making them attracted to water. As a result, they end up on the outside of the final protein structure. Proteins with these *R* groups, such as enzymes and hemoglobin, are soluble in water. Other *R* groups are not electrically charged and are repelled by water. Thus, they appear on the inside of the protein structure, away from the water in the body's internal environment. Proteins with these *R* groups, such as the keratin in your fingernails, are not soluble in water.

Q7 Name the subunits that make up proteins.

Q8 Explain why proteins are more structurally and functionally diverse than carbohydrates and lipids.

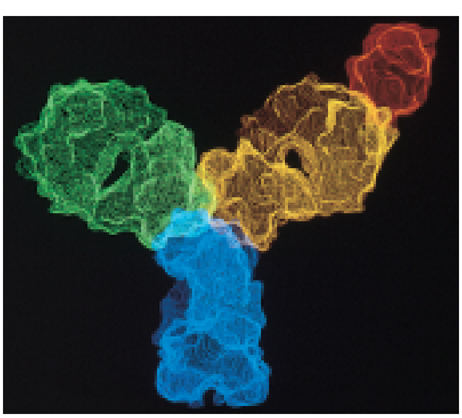


Figure 6.8 This computer-generated image of a protein molecule makes the protein's complex, three-dimensional structure easier to visualize.

Nucleic Acids

Nucleic acids direct the growth and development of all organisms using a chemical code. Nucleic acids determine how a cell functions and what characteristics it has. There are two types of nucleic acids: RNA (ribonucleic acid) and DNA (deoxyribonucleic acid). Recall that DNA contains genes, which hold the information needed to build the cell. When needed, a gene is first copied into RNA, which then is involved in making a protein.

Like proteins and carbohydrates, nucleic acids consist of long chains of linked subunits. These subunits are called nucleotides, as shown in Figure 6.9. Both DNA and RNA are made up of just four different nucleotides.

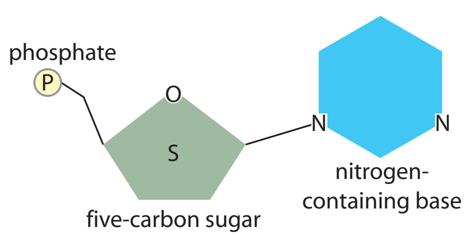


Figure 6.9 This model shows a generalized nucleotide. All nucleotides consist of a five-carbon simple sugar (ribose in RNA and deoxyribose in DNA), a nitrogen-containing base, and a phosphate group.

Vitamins and Minerals

Vitamins and **minerals** are not macromolecules, but they are essential to the structure and function of all cells. They are key components of many of the chemical reactions that yield energy, synthesize compounds, and break down compounds.

INVESTIGATION 6.A

Target Skills

Performing qualitative tests to detect and identify the presence of carbohydrates, proteins, and lipids

Working cooperatively within a group and with the whole class to collect and communicate results

Testing for Macromolecules

Biochemists have developed standard tests to determine the presence of the most abundant macromolecules made by cells: carbohydrates (sugars, starches), lipids (fats), and proteins. In this investigation, your group will conduct one or more of the standard tests to identify the presence of sugars, starch, lipid, and protein in known samples. Some of these tests involve the use of an indicator—a chemical that changes colour when it reacts with a specific substance. You will share the results of your tests with the class.

Question

How can you recognize and identify the presence of macromolecules in various samples?

Safety Precautions

Be careful when handling iodine, Benedict's solution, and Biuret reagent because they are toxic and can stain skin and surfaces. To prevent test tubes from breaking, do not allow the hot-water bath to boil vigorously. Clean up all spills immediately, with plenty of water, and inform your teacher immediately if a spill occurs.

Materials

- distilled water
- Biuret reagent
- albumin solution
- pepsin solution
- starch suspension
- iodine solution in dropper bottle
- Benedict's solution
- glucose solution
- onion juice
- large beaker (500 mL or larger) for hot-water bath
- potato juice
- vegetable oil
- butter or margarine
- 11 test tubes
- 3 test-tube racks
- 3 small squares of brown paper
- millimetre ruler
- wax pencil
- hot plate
- tongs

Procedure

Part 1: Test for Proteins

Biuret reagent has a blue colour that changes to violet in the presence of proteins or to pink in the presence of peptides.

1. Use a millimetre ruler and a wax pencil to mark and label four clean test tubes at the 2 cm and 4 cm levels. Fill each test tube as follows:
   - Test tube 1: Fill to the 2 cm mark with distilled water, and then add Biuret reagent to the 4 cm mark.
   - Test tube 2: Fill to the 2 cm mark with albumin solution, and then add Biuret reagent to the 4 cm mark. (Albumin is a protein.)
   - Test tube 3: Fill to the 2 cm mark with pepsin solution, and then add Biuret reagent to the 4 cm mark. (Pepsin is an enzyme.)
   - Test tube 4: Fill to the 2 cm mark with starch suspension, and then add Biuret reagent to the 4 cm mark.
2. Record the final colour of the contents of all four test tubes in a table like the one below.

Biuret Test for Protein

Test tube	Contents	Colour change	Conclusions
1	distilled water		
2	albumin		
3	pepsin		
4	starch		

3. Dispose of the contents of the test tubes as directed by your teacher. Clean and dry the test tubes.

Part 2: Test for Starch

Iodine solution turns from a brownish colour to blue-black in the presence of starch.

1. Use a millimetre ruler and a wax pencil to mark and label two clean test tubes at the 1 cm level. Fill each test tube as follows:
   - Test tube 1: Fill to the 1 cm mark with starch suspension, and then add five drops of iodine solution. (Be sure to shake the starch suspension well before taking your sample.)
   - Test tube 2: Fill to the 1 cm mark with distilled water, and then add five drops of iodine solution.

2. Note the final colour change. Record your results in a table like the one below.

Iodine Test for Starch

Test tube	Contents	Colour change	Conclusions
1	starch		
2	distilled water		

3. Dispose of the contents of the test tubes as directed by your teacher. Clean and dry the test tubes.

Part 3: Test for Sugars

Sugars react with Benedict's solution after being heated in a boiling-water bath. Increasing concentrations of sugar give a continuum of colours, as shown in the table below.

Typical Reactions for Benedict's Solution

Chemical	Chemical category	Benedict's solution (after heating)
distilled water	inorganic	blue (no change)
glucose	monosaccharide (carbohydrate)	varies with concentration: • very low: green • low: yellow • moderate: yellow-orange • high: orange • very high: orange-red
maltose	disaccharide (carbohydrate)	varies with concentration (See results for glucose.)
starch	polysaccharide (carbohydrate)	blue (no change)

1. Use a millimetre ruler and a wax pencil to mark and label five clean test tubes at the 1 cm and 3 cm levels.
   - Test tube 1: Fill to the 1 cm mark with distilled water, and then add Benedict's solution to the 3 cm mark. Heat in a boiling-water bath for about 5 min.
   - Test tube 2: Fill to the 1 cm mark with glucose solution; add Benedict's solution to the 3 cm mark. Heat in a boiling-water bath for about 5 min.
   - Test tube 3: Put a few drops of onion juice in the test tube. Fill to the 1 cm mark with distilled water, and then add Benedict's solution to the 3 cm mark. Heat in a boiling-water bath for about 5 min.
   - Test tube 4: Put a few drops of potato juice in the test tube. Fill to the 1 cm mark with distilled water, and then add Benedict's solution to the 3 cm mark. Heat in a boiling-water bath for about 5 min.
   - Test tube 5: Fill to the 1 cm mark with starch suspension; add Benedict's solution to the 3 cm mark. Heat in a boiling-water bath for about 5 min.

2. Note the final colour change. Record your results in a table like the one below.

Benedict's Test for Sugars

Test tube	Contents	Colour (after heating)	Conclusions
1	distilled water		
2	glucose solution		
3	onion juice		
4	potato juice		
5	starch suspension		

3. Dispose of the contents of the test tubes as directed by your teacher. Clean and dry the test tubes.

Part 4: Test for Fats

Fats leave a translucent, oily spot on paper. Liquid fats penetrate paper, while solid fats rest predominantly on top.

1. Place a small drop of water on a square of brown paper. Describe the immediate effect.
2. Place a small drop of vegetable oil on a square of brown paper. Describe the immediate effect.
3. Place a small quantity of butter or margarine on a square of brown paper. Describe the immediate effect.
4. Wait about 5 min. Examine each piece of paper to determine which test material penetrates the paper. Record your results in a table like the one below.

Paper Test for Fats

Sample	Results
distilled water	
oil (liquid fat)	
butter or margarine (solid fat)	

Analysis

1. Identify the control sample in each test you conducted. Explain how you know that it is the control and why it is included.
2. If the results of any of your tests were not as you expected, offer a possible explanation.

Conclusions

3. Describe a positive test for
   a) protein
   b) starch
   c) sugars
   d) fats (lipids)

Biology File

FYI

During the 1960s, stone-washed jeans—denim pants laundered with stones to wear away some of the blue dye—became very popular. The stones, however, damaged the cotton fibres of the fabric, giving the jeans a fairly short "life." The same effect is now created using enzymes that hydrolyze the blue dye. Because the enzyme is substrate (dye)-specific, the cotton fibres are left undamaged.

Vitamins are organic compounds. Only small amounts of vitamins are typically required by the body. Among other functions, vitamins serve as *coenzymes*—chemicals needed to make enzymes function. As well, they are involved in tissue development, tissue growth, and resistance to disease.

Minerals are inorganic compounds. Like vitamins, only small amounts of most minerals are required by the body. Minerals enable certain chemical reactions to occur and help to build bones and cartilage. Minerals are readily absorbed into the bloodstream. They are essential components of molecules such as hemoglobin, hormones, enzymes, and vitamins.

Enzymes

One of the chemical reactions that occurs in the red blood cells in your body is the reaction of carbon dioxide with water to form carbonic acid. If you performed this reaction in the laboratory, you would find that it proceeds quite slowly. Perhaps 200 molecules of carbonic acid would form in about one hour. Reactions this slow are of little use to a cell. One way to increase the rate of any chemical reaction is to increase the temperature of the reactants. In living things, however, this approach to speeding up reactions has a major drawback. The temperatures at which chemical reactions would normally occur to sustain life are so high that they would permanently *denature* body proteins. (They would lose their three-dimensional shape). This has very real implications for people when they have a fever. If the fever stays too high for too long, major disruptions to cellular biochemical reactions occur, and in some cases they can be fatal.

Another way to increase the rate of chemical reactions without increasing temperature is to use a catalyst. A **catalyst** is a chemical that speeds up a chemical reaction but is not used up in the reaction. It can be recovered unchanged when the reaction is complete. Catalysts function by lowering the amount of energy needed to initiate a reaction. Cells manufacture specific proteins that act as catalysts. A protein molecule that acts as a catalyst to increase the rate of a reaction is called an **enzyme**. In red blood cells, for example, an enzyme (called carbonic anhydrase) enables carbon dioxide and water to react to form about 600 000 molecules of carbonic acid each second!

How Enzymes Speed Chemical Reaction Rates

Each enzyme in the body has a precise three-dimensional shape that is specific to the kind of reactant molecule with which it can combine. The enzyme physically fits with a specific *substrate*—its reactant molecule. The enzyme is specific because it has a particular shape that can combine only with its substrate molecule. The part of the enzyme that binds to the substrate is called the active site. When the substrate binds to the active site, its bonds become less stable and, thus, more likely to be altered and to form new bonds.

You can think of an enzyme as a tool that makes a task easier and faster. For example, using an open-end crescent wrench can make the job of removing or attaching a nut and bolt go much faster than doing that same job with your fingers. To accomplish this task, the proper wrench must be used. Another type of tool (a screwdriver or a hammer, for example) won't work. Similarly, an enzyme must also physically attach itself to the substrate in a specific place and in a specific way (see Figure 6.10). Note that the fit between the wrench and nut is very specific, just like the fit between active site and substrate. Note also that a wrench and an enzyme are recovered unchanged after they have been used. Thus, they can be used over and over

Q 9 Explain what an enzyme is.

Q 10 Describe how an enzyme speeds up the rate of a chemical reaction.

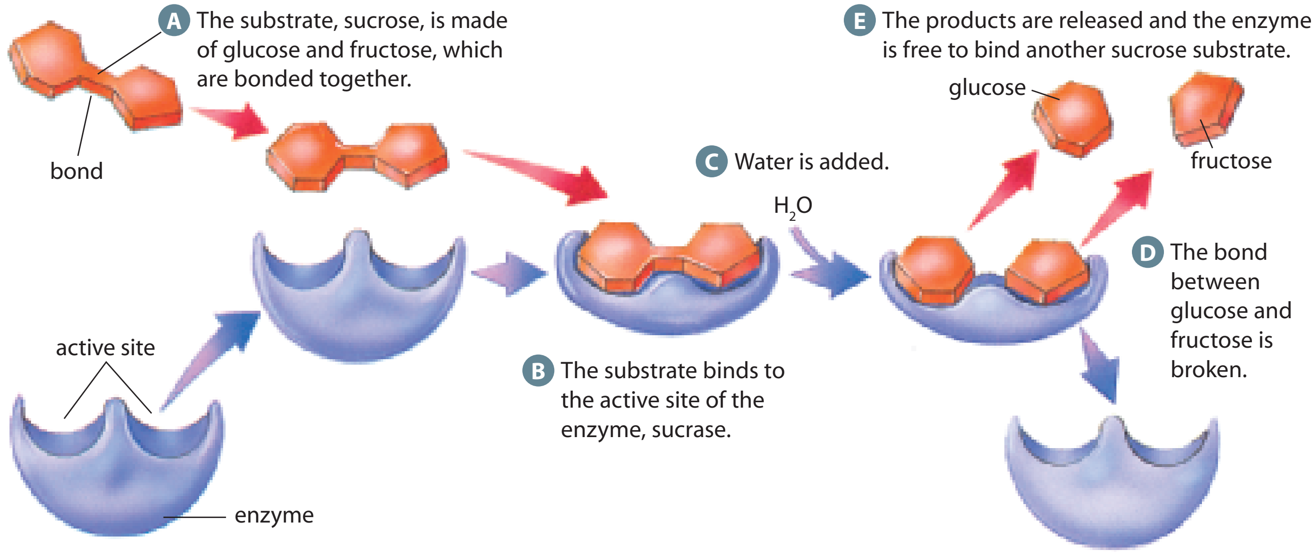


Figure 6.10 In this enzymatic reaction, the disaccharide sucrose is hydrolyzed to form its component simpler sugars, glucose and fructose.

again for the same task. Eventually, however, like wrenches, enzymes wear out, so cells must synthesize replacements.

Factors Affecting Enzyme Action

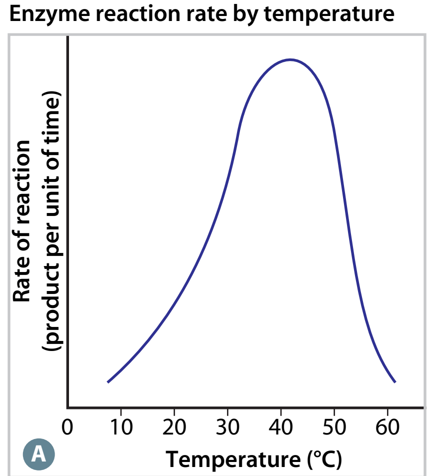
Temperature and pH can affect the action of enzymes. Enzyme activity is affected by any change in condition that alters the enzyme's three-dimensional shape. When the temperature becomes too low, the bonds that determine enzyme shape are not flexible enough to enable substrate molecules to fit properly. At higher temperatures, the bonds are too weak to maintain the enzyme's shape. It becomes denatured, meaning that its molecular shape and structure (and, thus, its properties) are changed. (Think of the changes that occur to egg white—a protein—when it is heated.) Therefore, enzymes function best within an optimal temperature range, as shown in Figure 6.11A. This range is fairly narrow for most human enzymes.

Enzymes also function within an optimal pH range (Figure 6.11B). Most human enzymes work best within the range of pH 6 to 8. Some enzymes, however, function best in very acidic environments, such as is found in the stomach.

Inhibitors can also affect enzyme activity. *Inhibitors* are molecules that attach to the enzyme and reduce its ability to bind substrate. There are two classes of inhibitors: competitive inhibitors and non-competitive inhibitors. *Competitive inhibitors* attach to the enzyme in its active site. When both inhibitor and substrate are present, the two compete to occupy the active site. If the inhibitor is plentiful, it will occupy the active site, blocking the substrate from binding and stopping enzyme activity. In biological systems, the competitive inhibitor is often the end product of the enzymatic reaction. As more end product is created and binds to the active site, enzyme activity is inhibited. That's a negative feedback loop.

> **Q 11** Describe how temperature and pH can affect the action of enzymes.

Enzyme reaction rate by temperature



Enzyme reaction rate by pH

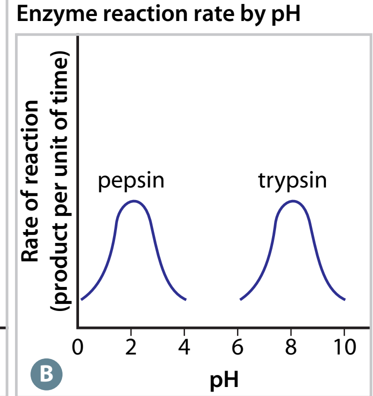


Figure 6.11 The activity of an enzyme is affected by **(A)** temperature and **(B)** pH. Most enzymes in humans, such as trypsin, which helps break down protein in the small intestine, work best at a temperature of about 40 °C and within a pH range of 6 to 8.

Non-competitive inhibitors attach elsewhere on the enzyme, not on the active site. Their attachment changes the three-dimensional shape of the enzyme, including the active site. Since the fit between active site and substrate is specific, the change in the shape of the active site makes the enzyme less able to bind substrate and carry out the reaction. Enzyme activity is inhibited.

Section 6.1 Summary

- Carbohydrates, lipids, proteins, and nucleic acids are macromolecules that are made up of smaller, chemically simpler subunits.
- The macromolecules are assembled by dehydration synthesis and disassembled by hydrolysis reaction, which are processes involving the removing or adding of a molecule of water.
- A monosaccharide, such as glucose, is a carbohydrate that consists of three to seven carbon atoms. A disaccharide, such as maltose, is made up of two monosaccharides. A polysaccharide, such as starch (cellulose), is made up of many monosaccharides linked together.
- Lipids, such as fats, do not dissolve in water. All fats have a three-branched structure made up of a glycerol and three fatty acid molecules. Fats are also called triglycerides.
- Proteins make up most cellular structures. They consist of amino acids joined by peptide bonds and then twisted into three-dimensional structures.
- The nucleic acids RNA and DNA direct an organism's growth and development by a chemical code. DNA carries genetic information, and RNA copies the genetic information so a cell can synthesize proteins.
- Vitamins are organic compounds; minerals are inorganic compounds. Neither are macromolecules, but they are key components of many of the chemical reactions that synthesize and break down compounds and yield energy in cells.
- Enzymes are proteins that increase the rate of biochemical reactions.

Section 6.1 Review

1. Explain how macromolecules, such as carbohydrates, differ from inorganic substances, such as water and sodium ions.
2. Use graphics software to sketch a representation of the dehydration synthesis and the hydrolysis of each macromolecule listed below. Design symbols to represent the molecules involved. Explain your reasoning for distinguishing each symbol as you did. ICT
   a) a disaccharide from two molecules of glucose
   b) a triglyceride from one molecule of glycerol and three fatty acid molecules
   c) a dipeptide from two amino acid molecules
3. Compare a fat with an oil, and explain why both are examples of lipids.
4. Use word processing or spreadsheet software to design a table that compares the structure and function of the following macromolecules: sugars, polysaccharides, lipids, proteins, and nucleic acids. ICT
5. A dessert topping for ice cream contains maltose, hydrogenated soybean oil, salt, and cellulose. Identify the macromolecules in this dessert topping.
6. Use word processing or spreadsheet software to design a table summarizing the standard tests for identifying the presence of starch, sugar, proteins, and fats in a food source. Include the colour change that indicates the presence of that macromolecule in each case. ICT
7. Explain the significance of this statement: An enzyme is a biological catalyst.
8. Explain how an enzyme can take part in a reaction involving sucrose, but not in a reaction involving maltose.
9. Relate the importance of shape to an enzyme's function.
10. Use spreadsheet software to sketch a graph that illustrates how the rate of an enzyme-controlled reaction is affected by temperature. Identify the optimum temperature for this enzyme-controlled reaction and explain why the rate of the reaction is slower when the temperature is colder and warmer than this point. ICT

SECTION 6.2

The Digestive System

Section Outcomes

In this section, you will
- **identify** the main structures and functions of the digestive system
- **describe** the physical and chemical processing of food through the digestive system and into the bloodstream
- **explain** the action of enzymes in chemical digestion
- **identify** and **describe**, in general terms, how digested molecules enter the bloodstream

Key Terms

digestive system
mouth
amylase
esophagus
peristalsis
esophageal sphincter
stomach
pyloric sphincter
pepsin
small intestine
segmentation
duodenum
villi
microvilli
pancreas
liver
gall bladder
carbohydrases
lipases
proteases
nucleases
gastrin
secretin
CCK
GIP
large intestine

Every cell in your body needs nourishment in the form of water, carbohydrates, fats, proteins, vitamins, and minerals. Most cells, however, cannot leave their location in the body and move into the external environment to find food. Thus, food must be delivered to the cells, in a form they can use. This task belongs to the digestive system, with the assistance of the circulatory system. The **digestive system** is specialized to ingest food, move it through a tube approximately 8 m long (the digestive tract), and break it down into smaller components (digest it). Digestion involves both physical breakdown, through motions such as chewing, churning and segmenting, and chemical breakdown, through hydrolysis. The resulting substances are absorbed into the bloodstream and delivered to all the body cells by the circulatory system. Solid wastes that cannot be broken down for use by the cells are eliminated to the external environment via the anus.

Figure 6.12 shows the organs associated with the human digestive system and their main functions. Figure 6.13 presents a modified view of the digestive system to emphasize the length of the continuous tube that makes up the digestive tract. (Note that the digestive tract is commonly referred to as the gastrointestinal or GI tract, as well. It is also referred to as the alimentary canal. The term *alimentary* comes from a Latin word that means “nourishment.”)

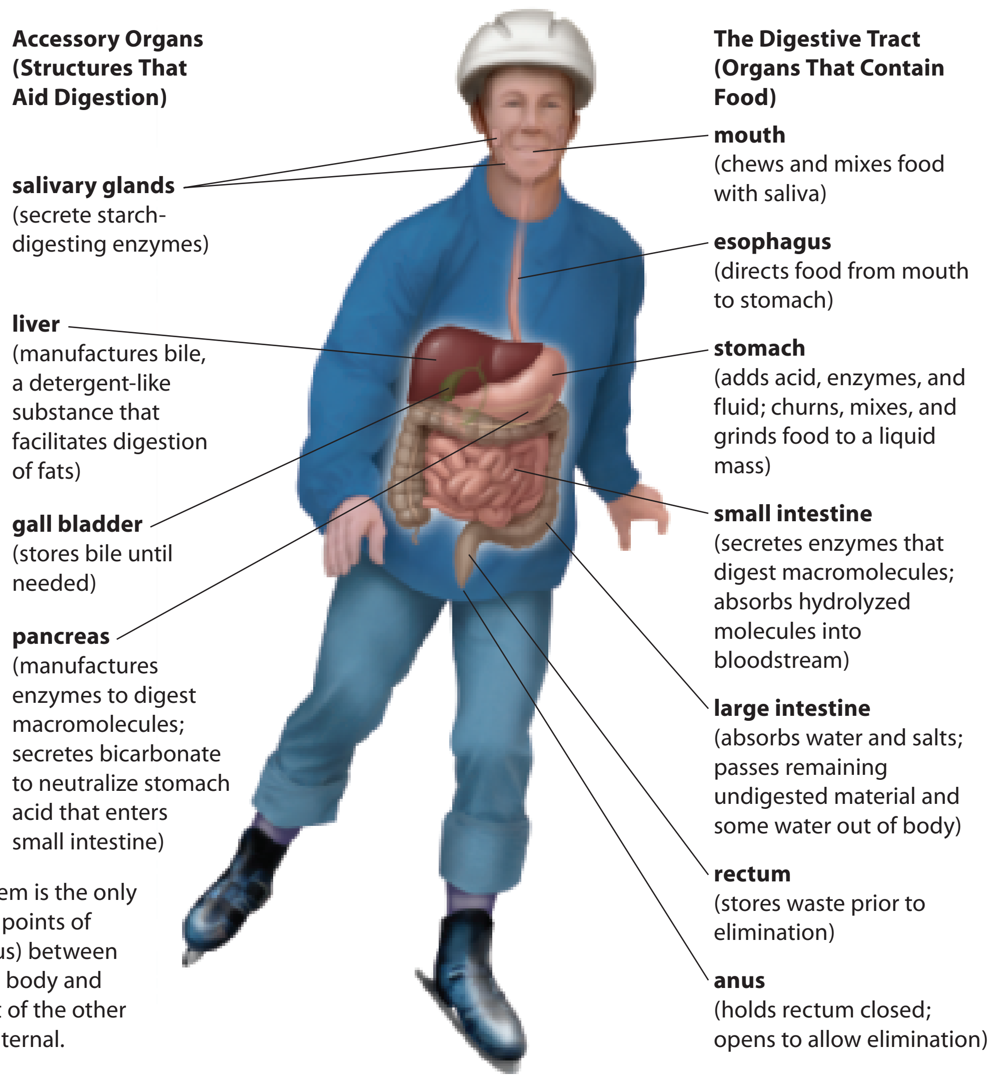


Figure 6.12 The digestive system is the only body system that provides two points of contact (the mouth and the anus) between the internal environment of the body and the external environment. Most of the other body systems are completely internal.

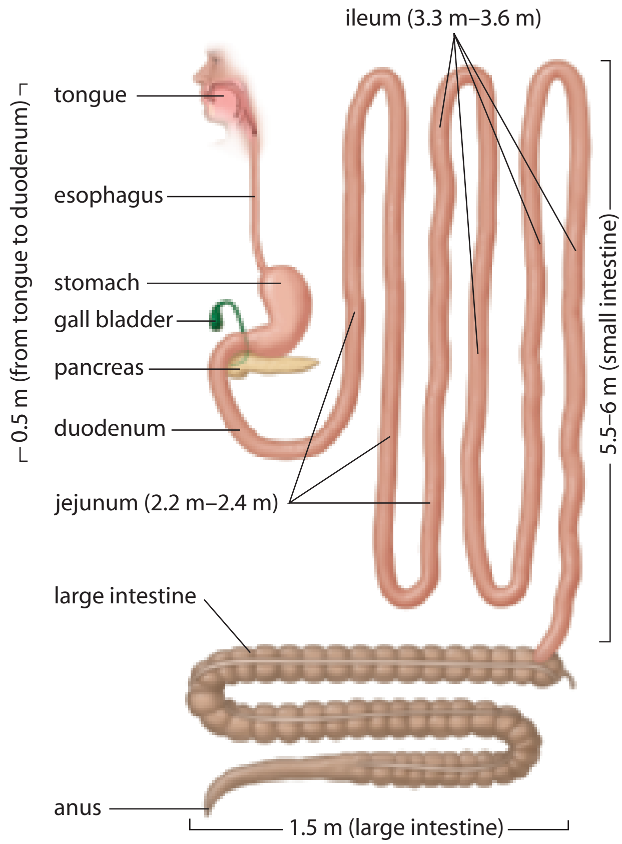


Figure 6.13 An average-sized digestive tract is approximately 8 m long in an adult human.

Q 12 Identify the organs that make up the human digestive tract.

Q 13 Identify the accessory organs that assist the digestive system in performing its function.

BiologyFile

Try This

The digestive tract is essentially a modified, hollow tube. The *interior* of the digestive tract is *external* to the body. Does this sound strange? After all, the digestive tract is inside the body, isn't it? Use a sketch or a brief paragraph to clarify these meanings of *internal* and *external* as they relate to the digestive tract and the body. Suggest one possible advantage of segregating the food you eat until it is sufficiently digested to enter the body cells.

Digestion Begins: The Mouth and the Esophagus

The idea, smell, or taste of food triggers three pairs of salivary glands near the **mouth** to secrete a watery fluid, called saliva. Saliva is one of many fluids and substances that are secreted by the digestive tract to aid digestion. Table 6.2 lists the major secretions of the digestive tract. Refer to this table as you continue your study of the digestive system.

Chemical digestion (hydrolysis) starts in the mouth, when an enzyme in saliva, called salivary **amylase**, begins to break down starch into simpler sugars (disaccharides). You can test this yourself at home. Slowly chew a polysaccharide-containing food, such as a cracker, a piece of boiled potato, or a piece of bread, until you notice the starchy food tastes sweet. The sweet taste results from the hydrolysis reaction of starch, catalyzed by salivary amylase.

The physical digestion of food also begins in the mouth as you use your teeth to chew your food. Water and mucus in saliva aid the teeth as they tear and grind food into smaller pieces, increasing the surface area available for the chemical digestion of any starch that has been ingested.

As you chew, your tongue rolls the food into a smooth lump-like mass, called a *bolus*, and pushes it to the back of your mouth for swallowing. The bolus enters the esophagus, passing the covered opening of the trachea (windpipe) on the way. If you place your fingers on your "Adam's apple" and swallow, as shown in Figure 6.14, you will notice that both it and your trachea move up. This movement closes the trachea against a flap of tissue (the epiglottis) and prevents food from passing through the trachea into your lungs.

Figure 6.14 The digestive and respiratory systems share a common pathway for bringing food and air into the body. Use this photo to help you find your Adam's apple, which is the front part of the voice box (larynx). When you swallow, food enters the esophagus, rather than the trachea, because the passage to the trachea becomes blocked. You do not breathe when you swallow.

Table 6.2 Important Secretions of the Digestive Tract

Secretion	Site of production	Function
saliva	mouth	contributes to starch digestion via salivary amylase; lubricates the inside of the mouth to assist in swallowing
mucus	mouth, stomach, small intestine, and large intestine	protects the cells lining the innermost portion of the digestive tract; lubricates food as it travels through the digestive tract
enzymes	mouth, stomach, small intestine, and pancreas	promote digestion of food masses into particles small enough for absorption into the bloodstream
acid	stomach	promotes digestion of protein
bile	liver (stored in gall bladder)	suspends fat in water, using bile salts, cholesterol, and lecithin to aid digestion of fats in small intestine
bicarbonate	pancreas and small intestine	neutralizes stomach acid when it reaches the small intestine
hormones	stomach, small intestine, and pancreas	stimulate production and/or release of acid, enzymes, bile, and bicarbonate; help to regulate peristalsis

The **esophagus** is a muscular portion of the digestive tract that directs food from the mouth to the stomach. The bolus moves through the esophagus partly by gravity, but mainly through a wavelike series of muscular contractions and relaxations called **peristalsis** (see Figure 6.15). As peristalsis continues, food is propelled through the esophagus toward the stomach, where the next stage of digestion occurs. Entry to the stomach is controlled by a ringlike muscular structure, called the **esophageal sphincter**. Relaxation of the esophageal sphincter allows the bolus to pass into the stomach. Contraction of this sphincter usually prevents the acidic contents of the stomach from backing up into the esophagus. (If the acidic contents of your stomach escape into your esophagus, you may feel a burning pain rising up your throat. This experience is commonly known as heartburn.)

Q 14 Identify and describe the digestive processes that begin in the mouth.

Q 15 Describe how food moves through the esophagus.

Q 16 Name the structure that controls the movement of food from the esophagus into the stomach.

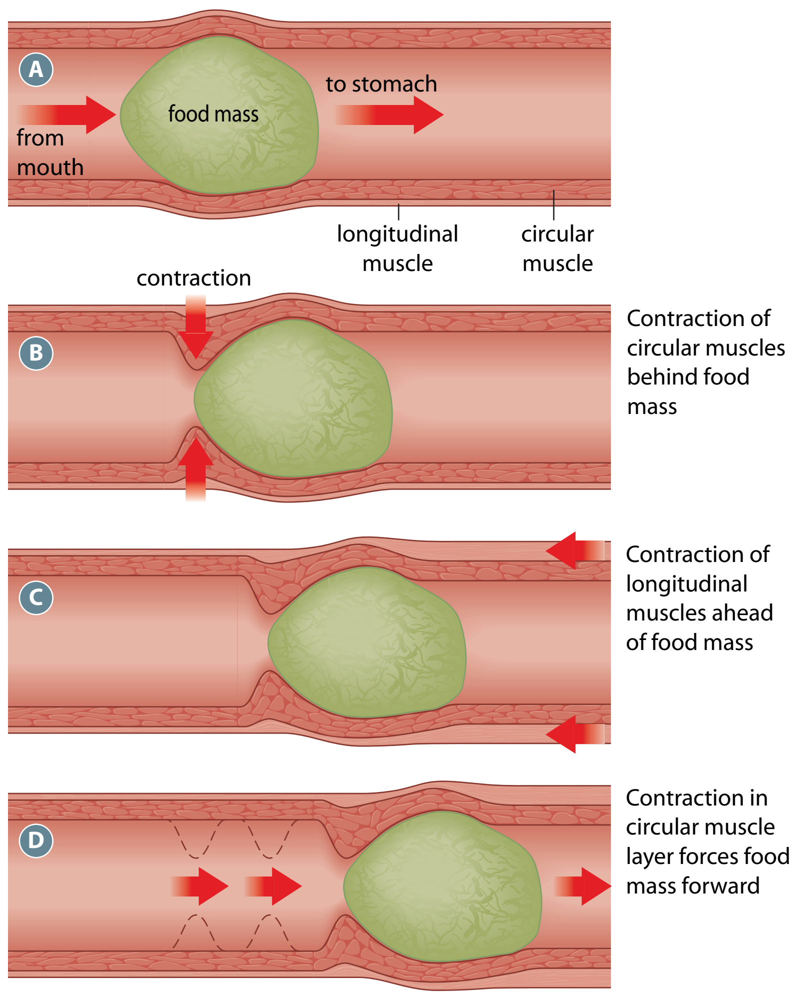


Figure 6.15 Peristalsis moves food through the esophagus. Peristalsis involves two layers of muscles that line the digestive tract. One layer of longitudinal muscles runs parallel to the length of the tract. Beneath these muscles, and perpendicular to them, is a circular layer of muscles. To move food, the circular muscles over a bolus relax, while the longitudinal muscles in front of the bolus contract. The circular muscles behind the bolus then contract, while the longitudinal muscles over it relax. Repetition of these movements pushes the bolus along.

Biology File

FYI

The word sphincter comes from a Greek word that means "bind tightly." The esophageal sphincter is not a true sphincter, because it does not completely seal the esophagus from the stomach. This is an advantage, since it allows for the regurgitation of food—vomiting—when you are sick or have ingested spoiled food. Some animals, such as mice, horses, and goats, have a true esophageal sphincter, so they are unable to vomit.

Storing, Digesting, and Pushing Food: The Stomach

The **stomach**, shown in Figure 6.16, is a J-shaped, muscular, sac-like organ with three important functions: storage, some digestion, and pushing food into the small intestine. When empty, the stomach is the size of a large sausage with a capacity of about 50 mL. It can, however, expand to hold 2 L to 4 L of food! Folds in the stomach's lining unfurl like the pleats of an accordion to accommodate a large meal. A true sphincter, called the **pyloric sphincter**, controls the exit of the stomach's contents into the small intestine. (The word *pyloric* comes from a Greek word that means "gatekeeper.")

Physical and chemical digestion occur in the stomach. Waves of peristalsis push food against the bottom of the stomach, churning it backward, breaking it into smaller pieces, and mixing it with gastric juice to produce a thick liquid called *chyme*. About 40 million cells that line the interior of the stomach secrete 2 L to 3 L of gastric juice each day. Gastric juice is responsible for chemical digestion in the stomach. It is made up of water, mucus, salts, hydrochloric acid, and enzymes. The strong hydrochloric acid has a pH of 1 to 3. It provides a highly acidic environment that begins to soften and break down proteins in the chyme. The low pH also serves to kill most bacteria that are ingested along with the food we eat. (Some disease-causing bacteria escape this fate, however, because they have an outer coating that resists stomach acid.)

The stomach usually does not digest the proteins that make up its own cells, because it has three methods of protection. First, the stomach secretes little gastric juice until food is present. Second, some stomach cells secrete mucus, which prevents gastric juice from harming the cells of the stomach lining. Third, the stomach produces its protein-digesting enzyme, **pepsin**, in a form that remains inactive until hydrochloric acid is present. Once active, pepsin hydrolyzes proteins to yield polypeptides—a first step in protein digestion in the digestive tract.

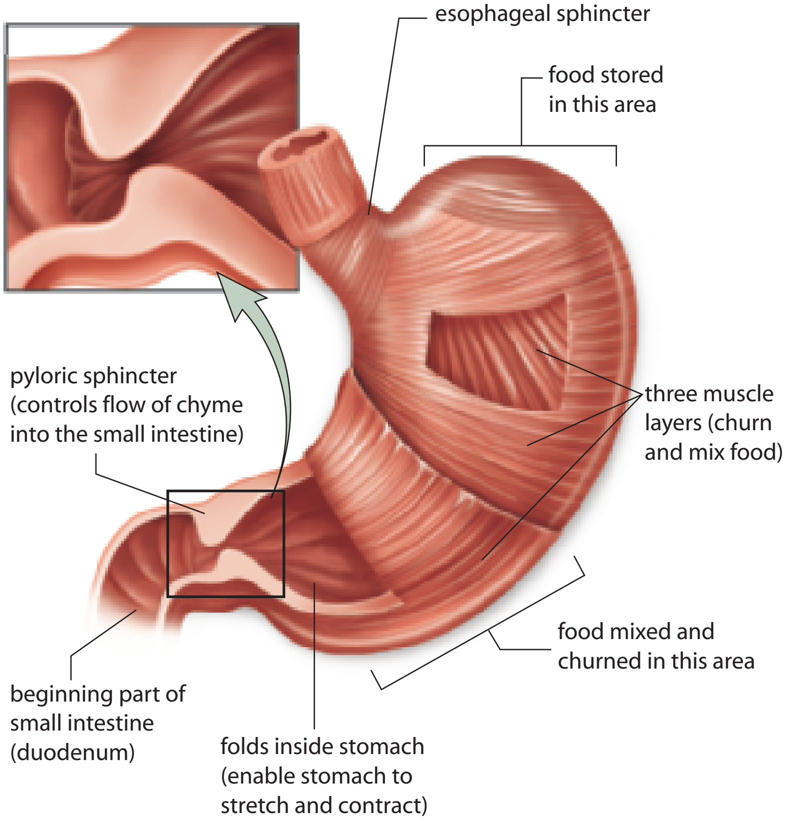


Figure 6.16 The folds in the interior of the stomach are called *rugae*—a Latin word that means "creased" or "wrinkled."

Absorption in the Stomach

Very few substances are absorbed from the chyme in the stomach because most substances in the chyme have not yet been broken down sufficiently. The stomach does absorb some water and salts, however, as well as certain anti-inflammatory medications such as Aspirin™, and alcohol. (This explains why Aspirin™ can irritate the lining of the stomach and why many people feel alcohol's intoxicating effects so quickly.)

17 Describe what happens to food, physically and chemically, to transform it into chyme.

18 What is the function of pepsin in the stomach?

19 Explain why few substances are absorbed in the stomach.

Thought Lab 6.2 An Accident and an Opportunity

Target Skills

Analyzing and **interpreting** historical events and information

Assessing the validity of historical information

On June 6, 1822, an army surgeon at Mackinac Island, on Lake Huron, recognized a unique opportunity to learn how the stomach works. A French-Canadian trapper, Alexis St. Martin, arrived with a shotgun wound to his stomach. The surgeon, William Beaumont, pushed back protruding parts of the lung and stomach, and cleaned the wound. Upon healing, the stomach lining had fused to the outer body wall, leaving an opening directly to the stomach. Beaumont found that he could look directly through this "window" and observe and perform tests on the stomach in action. Beaumont's discoveries marked the start of a new understanding of human digestion. In this Thought Lab, you will infer some of what Beaumont discovered based on excerpts from the journal he kept.

Procedure

During a period of several years, Beaumont gathered gastric juice, had its components identified, introduced food into the hole in Alexis St. Martin's stomach with a string attached so he could retrieve the food particles that were partially digested, and observed the effect of emotion on digestion. Much of what Beaumont discovered was new to science—and contrary to the accepted teachings of the time. He recounted many of his observations and experiments in his journal. The following are selections from that journal.

Note: You might be wondering how Alexis St. Martin felt about serving as a human guinea pig in these experiments. For awhile, he submitted to them. He was, after all, receiving free room and board. Boredom eventually took its toll, and St. Martin returned to Canada, where he married and resumed his former life as a trapper. He lived until the age of 83, having spent over 60 years of his life with a hole in his stomach.

Excerpt A: I consider myself but a humble inquirer after truths—a simple experimenter. And if I have been led to conclusions opposite to the opinions of many who have been considered luminaries of physiology, and in some instances, from all the professors of this science, I hope the claim of sincerity will be conceded to me, when I say that such difference of opinion has been forced upon me by the convictions of experiment, and the fair deductions of reasoning.

Excerpt B: But from the result of a great number of experiments and examinations, made with a view to asserting the truth of this opinion, in the empty and full state of the organ,…I am convinced that there is no alteration of temperature.

Excerpt C: I think I am warranted, from the result of all the experiments, in saying, that the gastric juice, so far from being "inert as water," as some authors assert, is the most general solvent in nature of alimentary [food-related] matter—even the hardest bone cannot withstand its action.

Excerpt D: The gastric juice does not accumulate in the cavity of the stomach until alimentary matter is received and excites its vessels to discharge their contents for the immediate purpose of digestion.

Excerpt E: At 2 o'clock P.M.—twenty minutes after having eaten an ordinary dinner of boiled, salted beef, bread, potatoes, and turnips, and drank a gill [about 142 mL] of water, I took from stomach, through the artificial opening, a gill of the contents… Digestion had evidently commenced, and was perceptually progressing, at the time.

Excerpt F: To ascertain whether the sense of hunger would be allayed without food being passed through the oesophagus, he fasted from breakfast time, til 4 o'clock, P.M., and became quite hungry. I then put in at the aperture, three and a half drachms [about 13 mL] of lean, boiled beef. The sense of hunger immediately subsided, and stopped the borborygmus, or croaking noise, caused by the motion of the air in the stomach and intestines, peculiar to him since the wound, and almost always observed when the stomach is empty.

Analysis

1. The prevailing view of Beaumont's time was that the stomach heated up when people ate. Beaumont discovered this was not the case. Identify the excerpt in which he makes this statement.
2. It was believed that once food had been ingested the stomach remained idle for an hour or more before digestion began. Identify the excerpt in which Beaumont found otherwise.
3. Many scientists before Beaumont's time asserted that stomach fluid is essentially water. Although some evidence had been produced to disprove this assertion, the belief proved strong enough to persist to the 1800s. What evidence did Beaumont cite in response to this belief?
4. In which excerpt did Beaumont suggest that gastric juice is not stored in the stomach, as was believed to be the case?
5. Summarize the significance of the discoveries Beaumont describes in Excerpt F.
6. Based on what you have learned about the stomach and its actions, how accurate do you think Beaumont's observations and conclusions were? Quote passages from this textbook or your own research to support your answer.
7. Beaumont was a surgeon by profession. In what ways was he also a research scientist? Justify your answer.

Biology File

FYI

The sound of your "stomach growling" actually comes from your intestines and is the sound of gas and fluid moving through them. The scientific name for these sounds is *borborygmi* (bore-bore-IG-mee), which comes from a Greek word meaning "rumble." The scientific names for two other common digestive-system sounds are *eructation* (from a Latin word meaning "to belch") and *flatulence* (from a Latin word meaning "a blowing" or "a breaking wind").

Digesting and Absorbing Nutrients: The Small Intestine

The **small intestine** is small only in terms of its diameter, compared with that of the large intestine. In terms of length, the small intestine is poorly named, because it is more than four times the length of the large intestine. It is, in fact, the longest part of the digestive tract. Some physical digestion occurs in the small intestine as a result of a process called **segmentation**. During this process, the chyme sloshes back and forth between segments of the small intestine that form when bands of circular muscle briefly contract. Meanwhile, peristalsis pushes the food along the intestine.

The main function of the small intestine is to complete the digestion of macromolecules and to absorb their component subunits. Although both digestion and absorption occur simultaneously throughout the small intestine, these processes and the structures associated with them will be discussed separately to help you understand how and where macromolecules are hydrolyzed so they can be absorbed into the bloodstream.

Regions and Structures of the Small Intestine

The small intestine can be subdivided into three regions. The first 25 cm of the small intestine is called the **duodenum**. The duodenum is generally U-shaped and is the shortest and widest of the three regions. Ducts (channels) from the liver and pancreas join to form one duct that enters the duodenum. Thus, the duodenum is an important site for the chemical digestion of the chyme received from the stomach.

As you can see in Figure 6.17, the innermost surface of the duodenum, like the rest of the small intestine, is corrugated with circular ridges about 1.3 cm high. The surface of every "hill" and "valley" of these ridges has a velvety appearance due to additional folds—about 6 million tiny finger-like projections called **villi** (see Figure 6.18A). The surface of the villi bristle with thousands of microscopic extensions called **microvilli**. Because the microvilli give the villi a fuzzy, brush-like appearance in electron photomicrographs, they are often referred to as the "brush border" of the cells that line the intestinal wall.

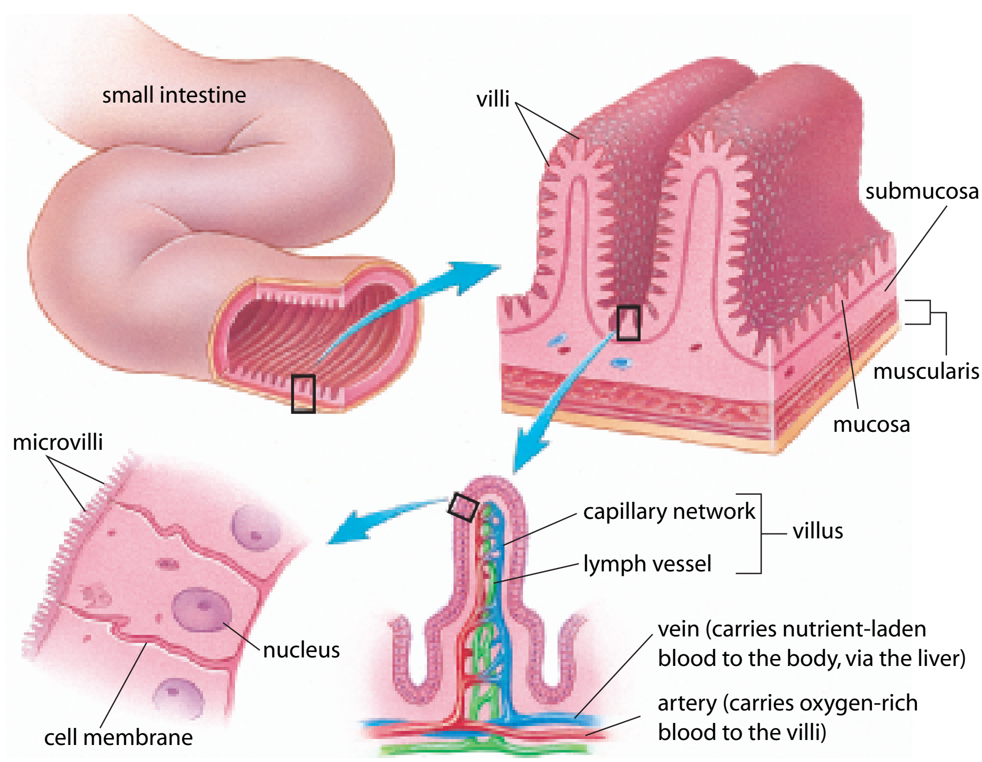


Figure 6.17 The ridges in the inner lining of the small intestine are covered in tiny projections called villi, which, in turn, are covered in microvilli. Together, the ridges, villi, and microvilli vastly increase the absorptive surface area of the small intestine.

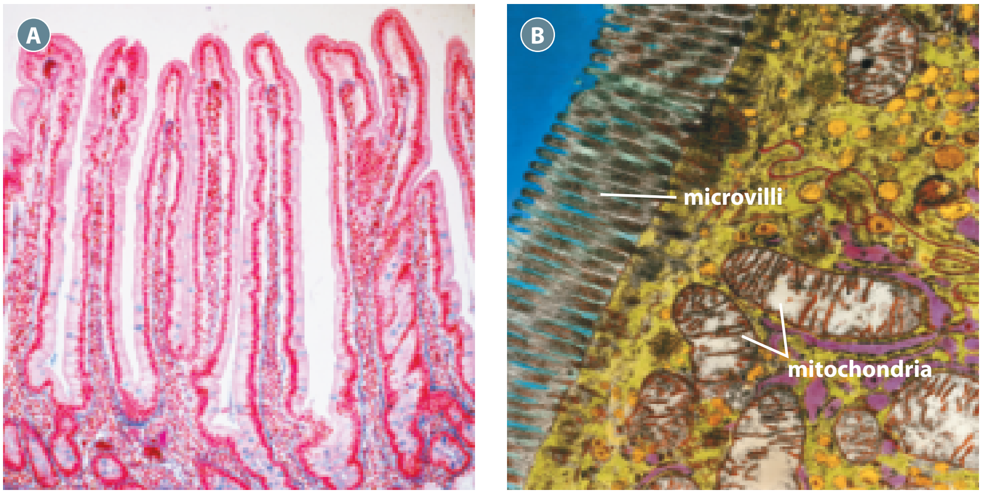


Figure 6.18 Villi **(A)** and microvilli **(B)** in the small intestine: Note the number of mitochondria near the innermost surface of the small intestine, just below the microvilli. Infer the significance of their presence. Each villus is about 1 mm long and is covered by thousands of microvilli. Microvilli are measured in μm.

In Figure 6.17, you can see that each villus contains tiny structures called capillary networks and lymph vessels. These structures are part of the circulatory system. They conduct absorbed substances from the small intestine into the bloodstream and the lymphatic system. (You will learn more about capillaries and lymph vessels in Chapter 8.)

The other regions of the small intestine are the jejunum and the ileum, and they are quite similar to the duodenum. The jejunum, which is about 2.5 m long, contains more folds and secretory glands than the duodenum. It continues to break down food so that the end products can be absorbed. The ileum, which is about 3 m long, contains fewer and smaller villi. Its function is to absorb nutrients and to push the remaining undigested material into the large intestine.

20 Describe how the physical movements of the small intestine aid in the physical digestion of food. Include the name of this process.

21 Explain how surface area is maximized in the small intestine.

Accessory Organs

To digest the macromolecules that are still present in chyme, the small intestine has its own arsenal of enzymes that are secreted from its microvilli. Digestive assistance is provided by substances that are secreted by three organs located near the stomach and small intestine: the pancreas, liver, and gall bladder. These organs, shown in Figure 6.19, are often referred to as *accessory organs* of the digestive system, because their role in the process of digestion is vital, but they are not physically part of the digestive tract.

Pancreas The **pancreas** delivers about 1 L of pancreatic fluid to the duodenum each day. Pancreatic fluid contains a multitude of enzymes, including the following:

- trypsin and chymotrypsin, which are proteases that digest proteins
- pancreatic amylase, which is a carbohydrase that digests starch in the small intestine
- lipase, which digests fat

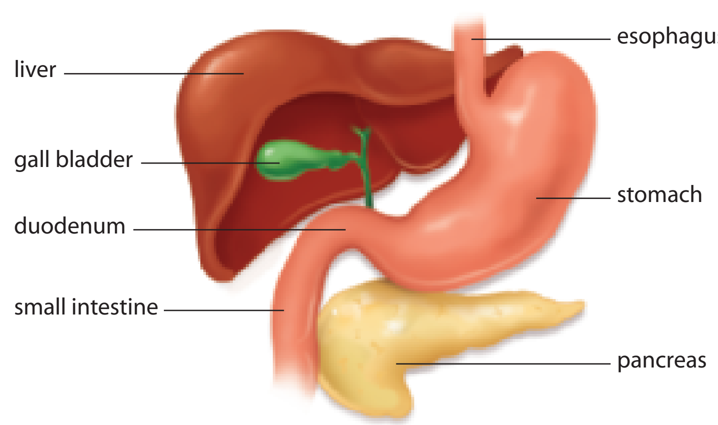


Figure 6.19 The pancreas, liver, and gall bladder produce and/or store secretions necessary for digestion of macromolecules.

BiologyFile

Try This

The ridges in the lining of the small intestine increase its surface area about three times. The villi increase its surface area another 30 times, and the microvilli increase its surface area another 600 times. Calculate the surface area of a small section of smooth tubing that is 280 cm long and 4 cm in diameter. How does this compare with the surface area of a section of the small intestine, with the same length and diameter, but including the ridges, villi, and microvilli?

Biology File

FYI
The colour of bile is responsible for the brown colour of feces and the pale yellow colour of blood plasma and urine. If the liver's removal of bile pigments becomes impaired, the bile pigments can accumulate in the blood and cause a yellow staining of skin. This condition is called jaundice.

These enzymes are released into the duodenum, mainly in an inactive form. They are then activated by enzymes secreted by the brush border of the duodenal lining. The pancreatic enzymes digest proteins into smaller polypeptides, polysaccharides into shorter chains of simpler sugars, and fats into free fatty acids and other products. Further digestion of these molecules is completed by the brush border enzymes.

Pancreatic fluid also contains bicarbonate, which neutralizes the hydrochloric acid from the stomach and gives the chyme in the duodenum a slightly alkaline pH of about 8.

Liver The **liver** is the largest internal organ of the human body. In an adult, it is the size of a football, with a mass of about 1.5 kg . The main digestion-related secretion of the liver is bile, a greenish-yellow fluid mixture that is made up of bile pigments and bile salts. Bile pigments do not take part in digestion. They are waste products from the liver's destruction of old red blood cells, and they are eventually eliminated with the feces.

Bile salts, on the other hand, play a crucial role in the digestion of fats. Because fats are insoluble in water, they enter the intestine as drops within the watery chyme. Lipases, however, are water soluble, so they can only act at the surface of a fat droplet where it is in contact with water. Bile salts assist lipases in accessing fats because they are partly soluble in water and partly soluble in fats. As shown in Figure 6.20, bile salts work like a detergent, dispersing large fat droplets into a fine suspension of smaller droplets in the chyme. This emulsification process produces a greater surface area of fats on which the lipases can act. As a result, the digestion of fats can occur more quickly.

Gall Bladder After bile is produced in the liver, it is sent to the **gall bladder**, which stores the bile between meals. The arrival of fat-containing chyme in the duodenum stimulates the gall bladder to contract. This causes bile to be transported through a duct (shared by both the gall bladder and the liver) and injected into the duodenum.

Q 22 How do secretions of the pancreas, liver, and gallbladder aid digestion?

Digestion and Absorption in the Small Intestine

The digestive secretions from the brush border of the small intestine, the liver, and the pancreas contribute mucus, water, bile, and enzymes. Most of the chemical digestion in the small intestine occurs in the duodenum and acts on all four categories of macromolecules and their components. Enzymatic digestion

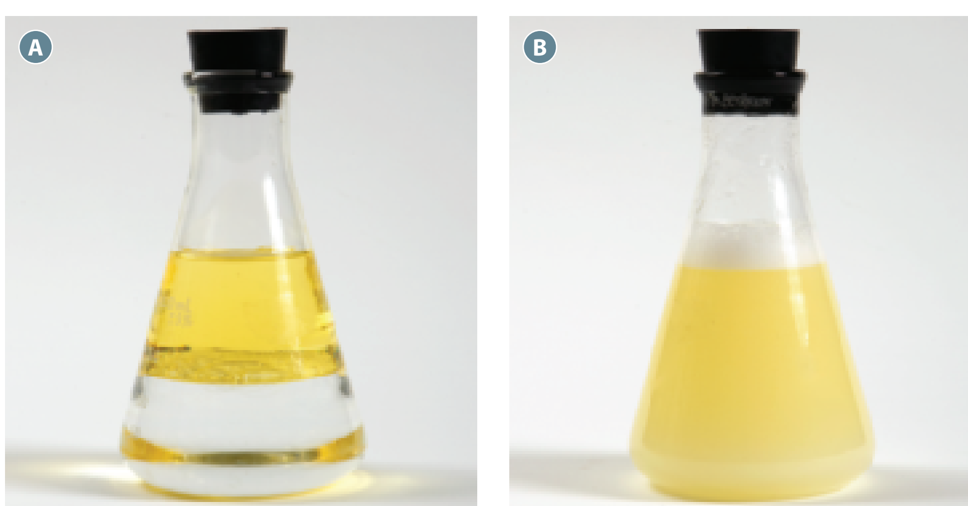


Figure 6.20 Emulsifiers, such as detergents, cause fats to mix with water. They contain molecules with a non-polar end and a polar end. These molecules position themselves around a fat droplet so that their non-polar ends project. The fat droplet disperses into a fine suspension of smaller fat droplets in the water.

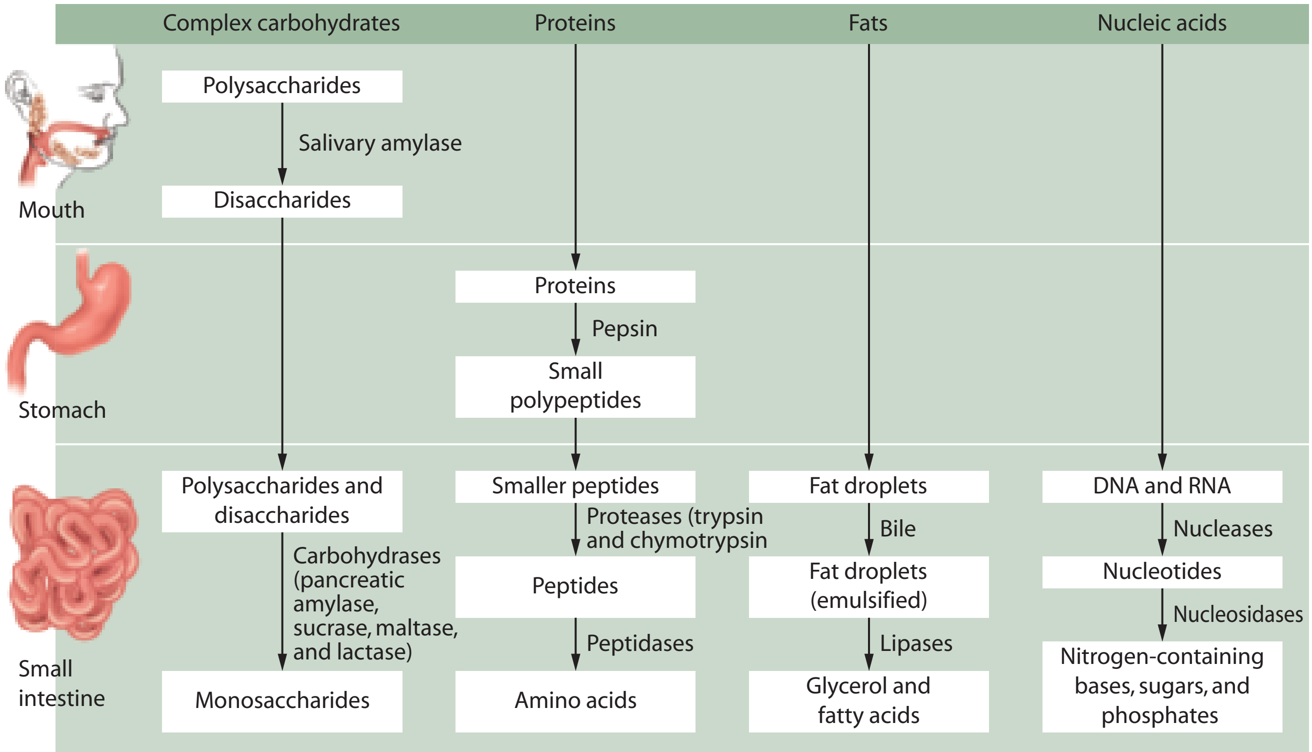


Figure 6.21 An overview of chemical digestion and absorption in the small intestine

of macromolecules is performed by **carbohydrases** (which digest carbohydrates), **lipases** (which digest fats), **proteases** (which digest larger polypeptides), and **nucleases** (which digest nucleic acids). Figure 6.21 provides an overview of the sites of digestion for the four categories of macromolecules and their stepwise "dismantling" by enzymes. Table 6.3 outlines some of the digestive enzymes and their activities. You may find it helpful to refer to Table 6.3 and Figure 6.21 as you read about the digestion and absorption of carbohydrates, proteins, lipids, and nucleic acids on the next few pages.

Table 6.3 Selected Enzymes of the Digestive System

Enzyme	Where enzyme acts/pH	Substrate (food) digested	Products of digestion	Origin of enzymes
salivary amylase	mouth/7	starch, glycogen	maltose (disaccharide)	salivary glands
pancreatic amylase	small intestine/8	starch, glycogen	maltose	pancreas
carbohydrases • sucrase • maltase • lactase	small intestine/8	 sucrose maltose lactose	 glucose + fructose glucose glucose + galactose	small intestine
pancreatic lipase	small intestine/8	lipids	fatty acids and glycerol	pancreas
proteases • pepsin • trypsin • chymotrypsin	 stomach/1–2 small intestine/8 small intestine/8	 protein peptides peptides	 peptides smaller peptides smaller peptides	 stomach pancreas pancreas
peptidases	small intestine/8	peptides	smaller peptides and amino acids	pancreas and small intestine
nucleases	small intestine/8	nucleic acids	nucleotides and components	pancreas
nucleosidases	small intestine/8	nucleotides	bases, sugars, and phosphates	small intestine

BiologyFile

Web Link
Deficiency of a particular carbohydrase can cause digestive distress when a person eats certain foods. For example, lack of the enzyme lactase prevents a large proportion of the human population from digesting the monosaccharide lactose, which is a common component of dairy products. What are the symptoms of lactose intolerance? Which segments of the population are most likely to experience it, and why?

www.albertabiology.ca
WWW

Carbohydrate Digestion and Absorption The digestion of starch begins in the mouth with the action of salivary amylase. Since food stays in the mouth for only a short time, however, carbohydrate digestion is usually minimal there. When undigested starch enters the stomach, the hydrochloric acid interrupts its digestion. Salivary amylase is most active at a pH of about 7, but the pH in the stomach is about 2 because of the hydrochloric acid. Thus, the digestion of starch and other carbohydrates does not continue until the chyme enters the small intestine, where the pH is about 8. In the small intestine, pancreatic amylase completes the digestion of starch into disaccharides. Other carbohydrases hydrolyze the disaccharides into monosaccharides, such as glucose, galactose and fructose.

As shown in Figure 6.22, monosaccharides are absorbed by active transport into the cells of the intestinal villi. (Recall the mitochondria in Figure 6.18B. The active transport of glucose and other monosaccharides requires ATP, which is produced in the mitochondria of cells.) From the cells of the intestinal lining, the monosaccharides enter the bloodstream and are transported directly to the liver. Monosaccharides other than glucose are converted into glucose by the liver. Glucose is circulated from the liver by the bloodstream to all the body cells, where it is used as a source of energy. Excess glucose is converted by the liver into glycogen, which is temporarily stored in the liver and muscles. Later, when blood glucose levels fall, glycogen is converted back into glucose and used by the cells.

Q 23 Outline in words, a sketch, or a flowchart the processes by which carbohydrates are digested in the small intestine and absorbed into the bloodstream.

Protein Digestion and Absorption
The polypeptides that are produced in the stomach by the action of pepsin are further digested in the small intestine by two proteases secreted by the pancreas. These proteases, trypsin and chymotrypsin, are secreted as inactive enzymes and then activated by a different enzyme secreted in the small intestine. Both trypsin and chymotrypsin hydrolyze the peptide bonds between specific but different amino acids, resulting in the formation of short peptide chains. The short peptide chains vary in length from 2 to 10 amino acids. During the hydrolysis of these peptide

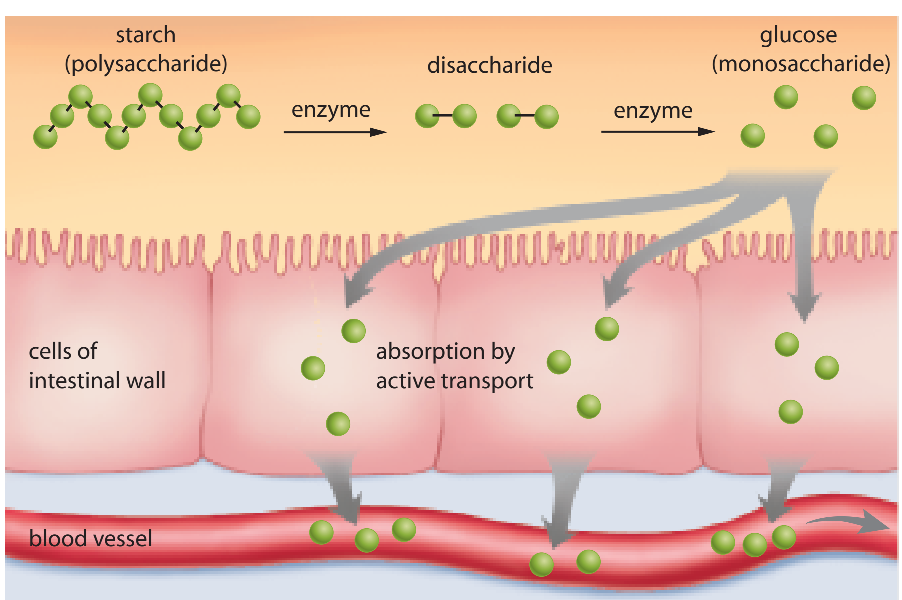


Figure 6.22 The monosaccharide glucose is actively transported into cells of the intestinal wall in order to move into the bloodstream.

chains, a few single amino acids are separated from their ends.

All that is left to complete the digestion of protein is for the short peptide segments to be split into single amino acids. This is done by different peptidase enzymes secreted by the pancreas and the small intestine. The amino acids are then absorbed by active transport into the villi in the small intestine (see Figure 6.23). From there, the amino acids diffuse into the blood capillaries and are carried, like the sugars, directly to the liver. In the liver, the amino acids may undergo a variety of reactions. Some have their amino group removed (a process called deamination) before they are used in energy-releasing reactions or converted into sugars. These amino groups combine with carbon dioxide in a series of reactions that lead to the formation of the nitrogenous waste urea, which is excreted in the urine. Other amino acids are released into the bloodstream from the liver, for distribution to the body cells. In the body cells, they are used to make proteins for a variety of functions, such as enzymes and cellular structures.

Fat Digestion and Absorption The salivary glands and stomach of an infant produce lipases, so fat digestion can begin quickly in the infant's digestive system. In adults, however, this

24 Outline in words, a sketch, or a flowchart the processes by which proteins are digested in the small intestine and absorbed into the bloodstream.

production is greatly reduced, and so very little fat digestion occurs early on.

The arrival of fats in the duodenum stimulates the secretion of bile, which emulsifies the fat droplets, as described earlier. Note that emulsification is a physical process, not a chemical process. The bonds that join the glycerol and fatty acids in fats are not hydrolyzed by emulsification. The breakdown of fats by hydrolysis is carried out by lipase secreted in the duodenum. The resulting glycerol and fatty acids are absorbed into the cells of the villi by simple diffusion (see Figure 6.24). Inside the cells of the intestinal lining, the fat subunits are reassembled into triglycerides and then coated with proteins to make them soluble before they enter the lymph vessels in the villi. The lymph vessels carry the coated triglycerides to the chest region, where they join the bloodstream. Once in the bloodstream, the protein coating is removed by lipase in the lining of the blood vessels. Lipase hydrolyzes the

BiologyFile

FYI

Protein molecules are normally too large to pass through the cell membranes of the cells that make up the intestinal lining. Occasionally, however, whole proteins are absorbed by these cells. When this happens, the undigested proteins are recognized as "foreign" by the body's immune system, leading to unpleasant allergic reactions. This is why some people must avoid certain protein-rich foods, such as eggs, fish, and nuts.

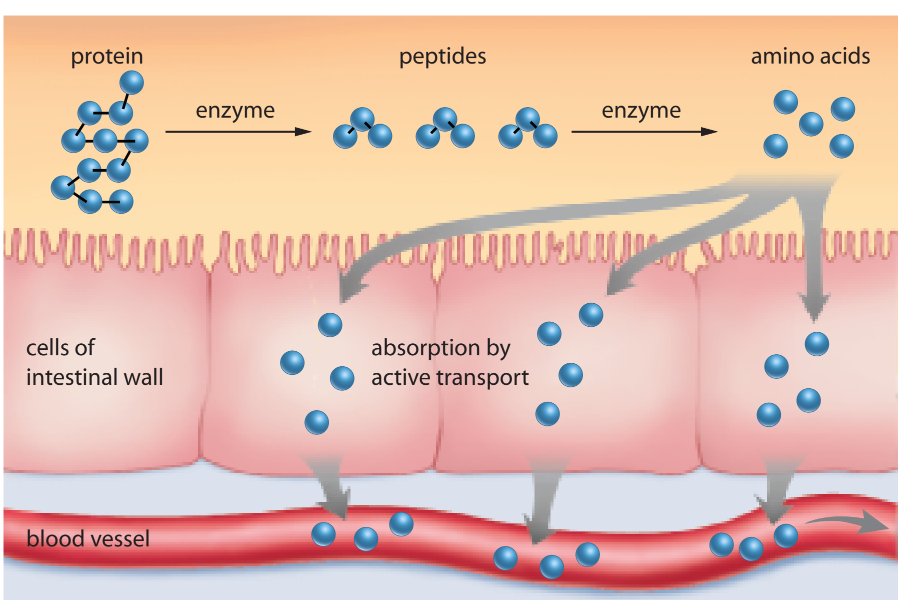


Figure 6.23 Amino acids are actively transported into the cells of the intestinal wall in order to move into the bloodstream.

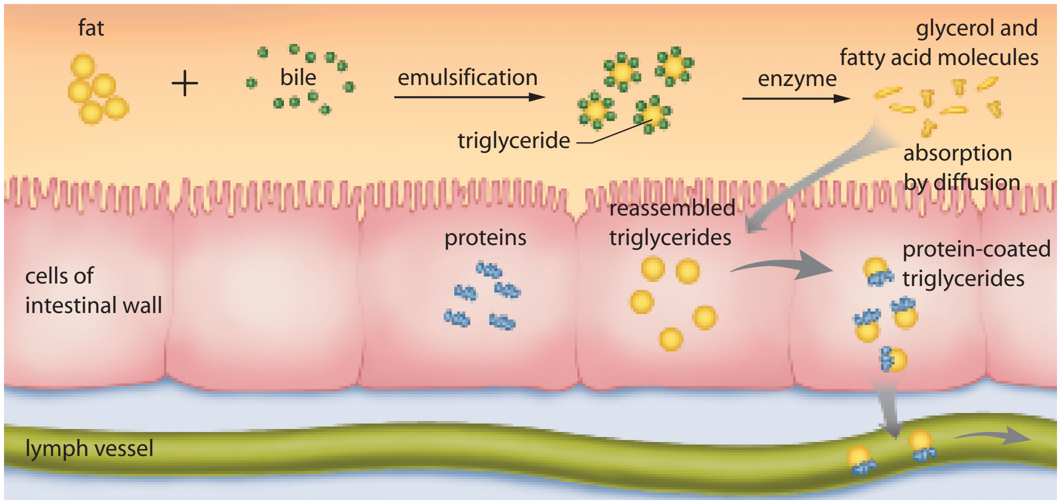


Figure 6.24 Glycerol and fatty acid molecules diffuse into the cells of the intestinal wall where they are resynthesized into fats, coated with proteins, and move into lymph vessels for eventual transport into the bloodstream.

triglycerides, making free fatty acids and glycerol available for use by the body cells.

Nucleic Acid Digestion and Absorption Nucleic acids are not abundant enough to be considered a major nutrient that must be ingested in the diet. The food you eat contains sufficient quantities of these macromolecules for the body to use. In the small intestine, nucleic acids are digested by enzymes called nucleases to yield nucleotides. Nucleosidases hydrolyze the nucleotides to their constituent bases, sugars, and phosphates. These molecules are then absorbed, like glucose and amino acids, into the bloodstream by active transport.

25 Describe how fats are digested in the small intestine and absorbed into lymph vessels.

26 Describe how nucleic acids are digested and absorbed.

INVESTIGATION 6.B

Target Skills

Performing an experiment to investigate the influence of pH on the activity of pepsin and trypsin

Designing an experiment to investigate the influence of other variables on the activity of pepsin and trypsin

Assessing the validity of collected data and observations, as well as conclusions drawn from them

Optimum pH for Two Protease Enzymes

Two proteases, pepsin and trypsin, are secreted at different stages and at different sites during digestion. Each protease works best at an optimum pH. The stomach has a pH of about 2, while the small intestine has a pH of between 7 and 8. In this investigation, you will observe evidence to verify historically obtained results related to the optimum pH at which these two proteases work.

Question

How can you use pH to determine which protease, pepsin or trypsin, is secreted into the stomach and which protease is secreted into the small intestine?

Hypothesis

State a suitable hypothesis for this investigation.

Safety Precautions

- Hydrochloric acid is a strong acid, and sodium hydroxide is a strong base. Both are very corrosive and must not be mixed together.
- Other chemicals used in this investigation may be toxic. Take extra care to avoid getting them in your eyes, on your skin, or on your clothes. Flush spills immediately with plenty of cool water, and inform your teacher.

Materials

- 18 cubes of boiled egg white (protein samples)
- 10 mL distilled water
- 10 mL 2% pepsin solution
- 10 mL 5% trypsin solution
- 15 mL dilute hydrochloric acid (0.01 mol/L)
- 15 mL dilute sodium hydroxide (0.01 mol/L)
- wax pencil
- metric ruler
- 6 test tubes
- 10-mL graduated cylinder
- test-tube rack
- test-tube holder
- water bath or incubator at 37 °C

Procedure

1. Use a wax pencil to label the test tubes as follows: C-2, C-8, P-2, P-8, T-2, and T-8. The test tubes labelled C are your controls. The test tubes labelled P will contain pepsin, and the test tubes labelled T will contain trypsin. The numerals indicate the pH of the contents of the test tubes.
2. Put three cubes of boiled egg white into each test tube. Observe the size and appearance of the cubes in each test tube. Record your observations in a data table like the one below.

Size and Appearance of Egg White Before and After Digestion by Pepsin and Trypsin

Test tube	Before digestion		After digestion	
	Size of cubes	Appearance of cubes	Size of cubes	Appearance of cubes
C-2				
C-8				
P-2				
P-8				
T-2				
T-8				

3. Add 5 mL of distilled water to each test tube labelled C. Add 5 mL of pepsin solution to each test tube labelled P. Add 5 mL of trypsin solution to each test tube labelled T.
4. Add 5 mL of dilute hydrochloric acid to each test tube labelled 2. Add 5 mL of dilute sodium hydroxide solution to each test tube labelled 8.
5. Place the test tubes in a water bath or incubator at 37 °C, and leave them overnight. The temperature must be maintained between 35 °C and 39 °C during this time.
6. Observe the contents of the heated test tubes. Note any changes in the size and appearance of the cubes of egg white in each test tube. Record your observations in your data table.
7. Dispose of the contents of the test tubes as directed by your teacher, and clean up your work area.

Analysis

1. How did the contents of the test tubes with protease differ from the control test tubes?
2. **a)** At what pH did pepsin break down protein more completely?
   b) At what pH did trypsin break down protein more completely?

Conclusions

3. Based on your results, which protease would break down protein in the small intestine? Justify your answer.
4. Based on your results, which protease would break down protein in the stomach? Justify your answer.

Extensions

5. **a)** What is the significance of maintaining the temperature of the test tubes between 35 °C and 39 °C?
   b) Based on the experimental design, describe the degree of certainty you have in the conclusions you stated in questions 3 and 4. (**Hint:** Think carefully about all the conditions and variables you tested in this investigation. Identify any possible sources of error, both in the experimental design and the way you conducted it.)
6. What, if any, difference do you think there would be if you manipulated a different variable, rather than pH? Design a procedure to investigate the possible impact of manipulating a different variable. With your teacher's permission, and with careful attention to safety, carry out your procedure.

Table 6.4 Characteristics of hormones that regulate digestion

Hormone	Source	Stimulus	Target	Response
Gastrin	Stomach	Entry of food into stomach	Stomach	Increased acid production
Secretin	Duodenum	Entry of chyme into duodenum	Stomach	Decreased stomach motility
CCK	Duodenum	Entry of chyme into duodenum	Stomach	Decreased stomach motility

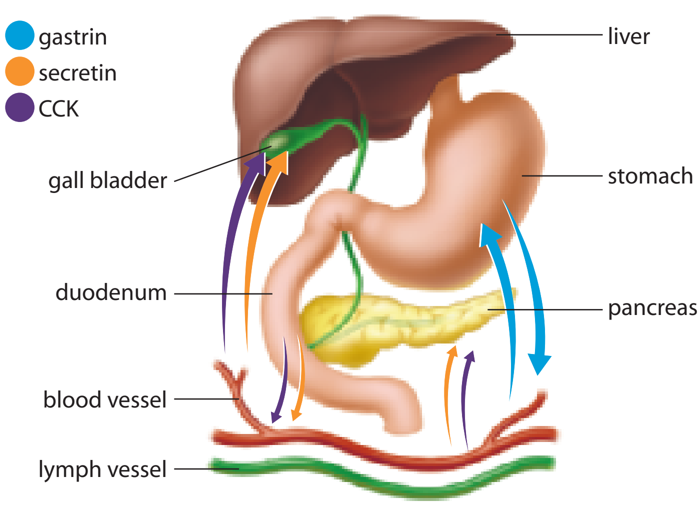
Regulation of Processes in the Small Intestine

The activities of the digestive tract are coordinated by the nervous system and the endocrine system. The nervous system, for example, stimulates salivary and gastric secretions in response to the sight, smell, and consumption of food. When food arrives in the stomach, proteins in the food stimulate the secretion of a stomach hormone called **gastrin**. Gastrin then stimulates the secretion of hydrochloric acid and the inactive precursor molecule of pepsin from glands in the stomach. The secreted hydrochloric acid lowers the pH of the gastric juice, which acts to inhibit further secretion of gastrin. Because the inhibition of gastrin secretion reduces the amount of hydrochloric acid that is released into the gastric juice, a negative feedback mechanism is completed. In this way, the secretion and concentration of gastric fluid is kept under tight control.

The passage of chyme from the stomach into the duodenum inhibits the contractions of the stomach, so that no additional chyme can enter the duodenum until the previous amount has been processed. This inhibition of stomach contractions is guided, in part, by hormones that are secreted into the bloodstream by the duodenum (see Table 6.4). These hormones include **secretin**, **CCK** (cholecystokinin), and **GIP** (gastric inhibitory peptide). Chyme with a high fat content is the strongest stimulus for the secretion of CCK and GIP. Chyme with a high acidity is the strongest stimulus for the release of secretin. All three hormones inhibit stomach movements and secretions, enabling fatty meals to remain in the stomach longer than non-fatty meals. Figure 6.25 summarizes the relationship among the enzyme-secreting activities in the accessory organs, the stomach, and the duodenum.

CCK and secretin also have other regulatory functions in digestion. CCK stimulates increased pancreatic secretions of digestive enzymes and gall bladder contractions. Gall bladder contractions inject more bile into the duodenum, which enhances the emulsifying and digestion of fats. Secretin also stimulates the pancreas to release more bicarbonate to neutralize acidic chyme.

Figure 6.25 Gastrin, secretin, and CCK are hormones that must be transported by the bloodstream from their place of origin to the place where they act to stimulate the release of digestive secretions. Lymph vessels carry absorbed fats.



> **Q 27** Describe briefly how the actions of the accessory organs are orchestrated with the digestive functions of the stomach and gall bladder.

Completing Nutrient Absorption and Elimination: The Large Intestine

The material that remains in the small intestine after nutrients are absorbed enters the final part of the digestive tract: the **large intestine**. The large intestine is much shorter than the small intestine, measuring only about 1.5 m long, but it has a larger diameter of about 2.5 cm.

Digestion does not occur in the large intestine. Its main function is to concentrate and eliminate waste materials. Each day, the large intestine receives about 500 mL of indigestible food residue, reduces it to about 150 mL of feces by absorbing water and salts, and eliminates the feces.

Undigested chyme that enters the large intestine passes up, along, and down the colon, which is the main portion of the large intestine. In the colon, water and salts are absorbed from any undigested food, while billions of anaerobic intestinal bacteria break it down further. As well, these bacteria produce vitamins B-12 and K, and some amino acids. At the end of this process, any remaining indigestible materials, along with the colon bacteria, form the feces. The feces pass into the rectum and anal canal, which comprise the last 20 cm of the large intestine. From there, the feces pass out of the body through the anus. The function of the rectum is to store the feces until they are eliminated. The rectum has three folds that enable it to retain the feces while passing gas.

The opening to the anus is usually controlled by two sets of sphincters. You are able to control contraction and relaxation of one of these sets of sphincters. The other set is under the control of the nervous system. When the rectum is full, receptor cells trigger a reflex that moves the feces out of the body by peristalsis.

Section 6.2 Summary

- Digestion begins in the mouth. By the time food leaves the small intestine digestion and absorption are nearly complete.
- The digestive tract is a tube that extends from the mouth to the anus. Food passes through the digestive tract and is broken down into its molecules through physical and chemical processing.
- The stomach secretes acidic gastric juices, which chemically break down food. The stomach physically breaks down food through muscular contractions.
- The small intestine is where most macromolecule digestion and absorption occur, and where nutrients pass out of the digestive tract and into the bloodstream.
- The accessory organs of digestion are the liver, the pancreas, and the gall bladder. The liver performs many functions, such as removing toxins and maintaining a constant level of glucose in the blood.
- The pancreas produces enzymes and hormones. The gall bladder stores bile that is produced in the liver.
- The large intestine absorbs most of the water and salts from chyme, leaving semi-solid feces that are eliminated from the body through the anus.

BiologyFile

FYI

People pass about 500 mL of intestinal gas each day. Most of it is swallowed air. The anaerobic respiration of intestinal bacteria accounts for the rest. Intestinal gas is composed mainly of nitrogen, carbon dioxide, hydrogen, methane, hydrogen sulfide, and organic molecules called amines, which are structurally related to ammonia. The amines, hydrogen sulfide, and methane contribute the distinctive odour of the gas and the feces.

Section 6.2 Review

1. Use word processing software to create a flow chart that lists, in order, the organs of the digestive tract through which food passes. ICT
2. Identify the accessory organs of the digestive system. Explain why these organs are considered to be accessories to the system.
3. Explain the impact on the digestive system if mechanical digestion did not take place.
4. Most of the digestive enzymes are secreted into the small intestine. Suggest two reasons why these enzymes are secreted into this organ, rather than into the stomach.
5. Explain how the secretions of the pancreas, liver, and gall bladder aid digestion.
6. Based on the structure of its internal lining, explain why you could infer that absorption of most nutrients occurs in the small intestine.

Sorting Out Nutritional Supplements

Many Canadians regularly take vitamin and mineral pills. Are such food supplements necessary for good health? Can they help increase your energy, strengthen your immune system, or reduce the risks of some illnesses? How do scientists assess these different claims? Why are there so many different opinions about the value of supplements?

The Case of Calcium

Consider the question, "How much calcium do I need each day?" Calcium is the most abundant mineral in your body. It forms your bones and teeth, and plays roles in several activities such as blood clotting and enzyme activation. The amount of calcium a person needs, however, depends on age, sex, level of activity, diet, and state of health. For example, women after the age of 30 lose bone mass each year and are at greater risk of developing osteoporosis—a disease in which bones become more porous, break more easily, and heal more slowly. For this reason, healthcare professionals often recommend calcium supplements to older women.

What is Bioavailability?

Calcium is found in milk and other dairy products, dark, leafy vegetables, and a variety of supplements. But your body may not use all the calcium you ingest. The source of the calcium is just as important as the quantity. *Bioavailability* refers to the amount of calcium that a person absorbs from a source, rather than the total amount of calcium actually in the source. For example, 1 g of calcium carbonate contains more elemental calcium than 1 g of calcium citrate, but it is not as readily available to the body. As a result, a smaller quantity of calcium citrate gives the body more calcium than a larger quantity of calcium carbonate.

Other nutrients that you eat with calcium also affect how efficiently the body is able to use the mineral. For example, magnesium and vitamin D increase calcium absorption.

Designing Nutrition Tests

Suppose you are a researcher and want to compare the bioavailability of calcium present in: a) milk, b) calcium carbonate tablets, and c) calcium carbonate plus vitamin D.

• • •

1. List the variables in your test.
2. 50 people volunteer to take part in the test. They include men and women ranging in age from 28 to 59. Explain why this is not a good sample for testing and suggest a better sample.
3. The calcium uptake of volunteers can be measured by changes in the levels of calcium excreted in their urine. How will you set up a fair test of the variables you wish to study?
4. Follow up your study of supplements by an informal survey at your local pharmacy or health food store. Pick a supplement such as calcium, vitamin C, or glucosamine hydrochloride. How many different forms of the supplement are available? How does one form differ from another? Why do you think the cost of supplements varies?

Weight-bearing exercise is as important in the prevention of osteoporosis as adequate calcium intake—especially in women.

SECTION 6.3

Health and the Digestive System

Section Outcomes

In this section, you will

- **recognize** and **appreciate** the relationship between health and nutritional decisions
- **identify** conditions that adversely affect the health of the digestive system and the technologies that are available to treat them

Key Terms

ulcer
inflammatory bowel disease
hepatitis
cirrhosis
gallstones
anorexia nervosa
obesity

Figure 6.26 Good nutrition is essential for high-performance athletes.

Competitive athletes, like those shown in Figure 6.26, are careful about the food they eat because they know that their performance is related to nutrition. This link is not immediately obvious to non-athletes, however. The effects of poor dietary and lifestyle habits may take weeks, months, or even years to show up. Good nutrition is the only way to provide the energy our bodies need to carry out their many activities, such as nerve transmission, muscle contraction, and cell repair and replacement. As well, good nutrition provides the raw materials our bodies need as building blocks but are unable to manufacture themselves.

What we eat is influenced by our lifestyles and attitudes. For example, we live in a society that often promotes unrealistic body images as the desired norm. The societal pressure to be thin can lead to unhealthy personal decisions. So can the confusing array of dietary plans, some of which are endorsed by medical professionals and some of which are not. The truth is that all individuals are unique, and it is impossible for everyone to fit an "ideal" body image. Maintaining a healthy body mass and feeling energized and healthy results from eating a well-balanced diet, getting regular rest and exercise, and adopting positive, self-enriching attitudes. Deficiencies in any of these areas can severely affect our ability to function.

Since the end result of digestion is the absorption of nutrients, salts, and water, most disorders of the digestive system affect either the nutritional state of the body or its salt and water content. Examples of digestive system disorders include ulcers, inflammatory bowel disease, hepatitis, cirrhosis, and gallstones.

Q 28 What is the connection between healthy dietary practices and a healthy functioning body?

BiologyFile

FYI
With one exception, water-soluble vitamins (vitamins B and C) are absorbed passively in the small intestine. Vitamin B-12 is a very large molecule. To be absorbed, it must first bond to a protein called intrinsic factor, which is secreted in the stomach. Intrinsic factor with bound vitamin B-12 is then absorbed at specific sites in the ileum by endocytosis (a process in which the cell membrane actively engulfs molecules or particles).

Ulcers

An **ulcer** forms when the thick layer of mucus that protects the lining of the stomach from the acids in the digestive juices is eroded. Research has shown that most ulcers are caused by acid-resistant bacteria, *Helicobacter pylori*, which attach to the stomach wall. The sites of

Biology File

Web Link
The discovery of *Helicobacter pylori* and its role in ulcers is an outstanding example of scientific inquiry and investigation. Why was the bacterium's existence in the stomach hypothesized? How was it discovered? And what astounding adaptations enable it to survive in the hostile environment of the stomach?

www.albertabiology.ca
WWW

attachment stop producing the protective mucus, and the stomach acid eats away at the stomach wall (see Figure 6.27). Other factors, such as smoking, caffeine and alcohol intake, and stress, can contribute to the formation of ulcers. Treatments for ulcers include medications that reduce the amount of acid in the stomach or strengthen the layer of mucus, antibiotics, and sometimes lifestyle adjustments. If these treatments do not work, surgery to block nerve signals or even to remove part of the stomach is possible.

Inflammatory Bowel Disease

Inflammatory bowel disease is the general name for diseases that cause inflammation in the intestines (bowels). Crohn's disease (also called ileitis or enteritis) is a serious inflammatory bowel disease that usually affects the ileum of the small intestine, but it can affect any part of the digestive tract from the mouth to the anus. The inflammation extends deep into the lining of the affected organ, causing the intestines to empty frequently. This results in diarrhea and sometimes rectal bleeding. Thus, Crohn's disease is very painful. Crohn's disease can be difficult to diagnose because its symptoms are similar to the symptoms of other intestinal disorders, such as irritable bowel syndrome and ulcerative colitis. Research into Crohn's disease shows that it may be an autoimmune disorder, in which the body recognizes part of its own digestive tract as a foreign substance. (You will explore the immune system and autoimmune disorders in more detail in Chapter 8.) Crohn's disease is chronic and may be inherited. There is no cure, so treatments focus on medications to reduce pain, suppress the inflammation, reduce the immune response, and allow time for the tissue to heal. If medications do not control the symptoms, surgery is sometimes performed to remove the diseased portions of the digestive tract.

Colitis is another inflammatory bowel disease. It is the inflammation and ulceration of the lining of the colon. While Crohn's disease affects the entire thickness of the colon, colitis is restricted to the innermost lining of the colon. The symptoms are similar to Crohn's disease and include loose and bloody stool, cramps, and abdominal pain. There may be skin lesions, joint pain, and (in children) a failure to grow properly. Treatments include medications that are similar to those given for Crohn's disease. Surgery is a final option. The entire bowel and rectum are removed, and an external opening is created for waste. Less drastic procedures are still being developed.

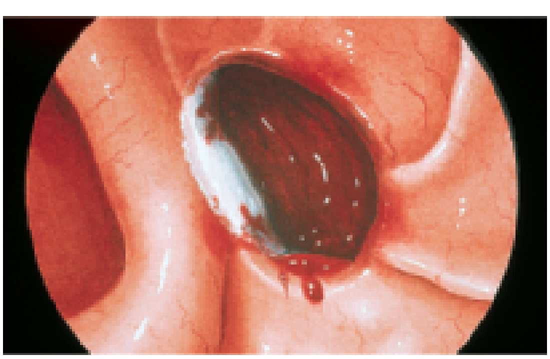
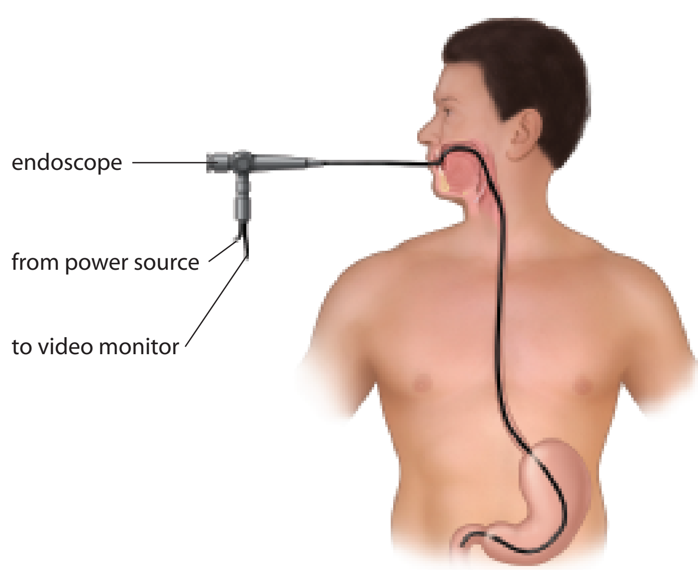


Figure 6.27 This photo of a bleeding ulcer in the stomach was taken with an endoscope, a tube-shaped instrument with a tiny lens and light source that is inserted into the abdominal cavity. Capsule endoscopy—the technology you saw in the opening to this chapter—now enhances the range of diagnostic tools available to health professionals.



Disorders of the Accessory Organs

Two of the most serious disorders of the liver are hepatitis and cirrhosis, and both are life-threatening. **Hepatitis** is an inflammation of the liver. There are three types of hepatitis: A, B, and C. Hepatitis A is usually contracted from drinking contaminated water. Hepatitis B is spread by sexual contact and is more contagious than the AIDS virus, but a vaccine has been developed to protect against it. Hepatitis C is usually contracted by contact with infected blood. There is no vaccine for hepatitis C.

Figure 6.28 shows **cirrhosis**—a chronic disease of the liver that occurs when scar tissue replaces healthy liver tissue and prevents the liver from functioning properly. Chronic alcoholism and hepatitis C are the most common causes of cirrhosis of the liver. There are few symptoms in the early stages of the disease. Blood tests, however, can determine if the liver is becoming fatty—an early warning sign that cirrhosis is developing. The liver is amazing in its ability to heal itself, but, in many cases, there is not enough regeneration to avoid liver failure. A liver transplant is the primary treatment for liver failure. There is active research on a bioartifical liver, which uses pig cells to perform the functions that are normally carried out by the human liver. Experimental trials have been successful, but more research is necessary to develop this treatment fully.

Another common disorder of the digestive system is **gallstones**, which are small hard masses that form in the gall bladder. Remember that the gall bladder stores bile from the liver. Sometimes, cholesterol in the bile can precipitate out of the bile and form crystals. The crystals continue to grow in size and become gallstones. Three factors that are related to the formation of gallstones are obesity, alcohol intake, and heredity. Gallstones are usually treated with medications or with ultrasound shock waves to disintegrate the stones so that they can be passed out in the urine. Since gallstones often reoccur, it is important to reduce the causal factors. Cholesterol in the gall bladder can be lowered by losing weight, increasing the intake of the omega-3 fatty acids that are present in fish, and decreasing the size of meals. If the gallstone problem is serious, the entire gall bladder may need to be surgically removed.

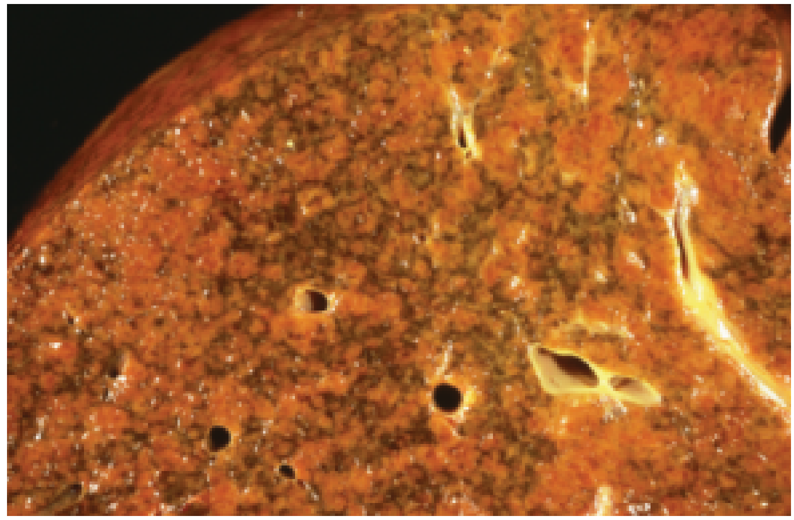


Figure 6.28 A liver affected by cirrhosis. The word cirrhosis comes from a Greek word that means tawny, referring to the brownish-orange colour of the diseased liver.

29 What is an ulcer?

30 Briefly describe inflammatory bowel disease.

31 Explain why disorders of the liver are so threatening to the health of the body.

Psychological, Social, and Cultural Dimensions of Digestion-Related Conditions

Current ideas of physical attractiveness have sent many people in search of a quick way to lose weight and keep it off. Some people may become obsessed with their weight and deprive their bodies of basic nutrients in order to become or stay thin. For example, **anorexia nervosa** is an eating disorder that is characterized by a morbid fear of gaining weight. People with this disorder starve themselves and typically have a body mass that is less than 85 percent of what

BiologyFile

Web Link
Inflammation of the pancreas is called pancreatitis. Being a disease of the digestive tract, perhaps it's not surprising that it is linked to many other aspects of digestion and metabolism. For example, which of its most common causes is a disease of another accessory organ? What enzyme you've just learned about is used in diagnosis of pancreatitis? And what role does nutrition play in managing the condition?

www.albertabiology.ca
WWW

BiologyFile

Web Link

Gastric bypass surgery is a procedure that alters the digestive tract and reduces the size of the stomach. Under what circumstances is this procedure usually performed? How successful is it, statistically?

www.albertabiology.ca
WWW

is considered to be their normal body mass. They have a distorted self-image, seeing themselves as fat even when they are dangerously thin. All of the symptoms of starvation are present in this serious disorder, including low blood pressure, irregular heartbeat, and constipation. As the disorder progresses, the body begins to shut down. Menstruation in females stops, internal organs have trouble functioning, and the skin dries out. As the digestive tract stops working, even fewer nutrients can be absorbed. At this point, death is imminent.

The initial stage of any treatment begins by stabilizing the life-threatening complications of starvation. Once the person is out of immediate physical danger, the distorted perceptions that have caused the eating disorder must be treated. Psychological therapy, including behavioural and family therapy, can be used to treat this disorder successfully.

While taking in too few nutrients is dangerous, eating too many can lead to **obesity**—a body mass that is 20 percent or more above what is considered to be an ideal body mass for a person's height. In Canada, more than half of Canadians are classified as overweight or obese. Obesity is most likely caused by a combination of hormonal, genetic, lifestyle, and social factors. Research scientists have shown that people who are obese have more fat cells than people who are not obese. When weight is lost, the fat cells simply get smaller; they do not disappear. Social factors that influence obesity include the eating habits of other family members. Lifestyle choices, such as the consistent eating of fatty foods, sedentary activities, and inadequate aerobic exercise, also contribute to the development of excess body fat.

Surgery to remove body fat may be considered for people who are severely obese and at risk for associated conditions, such as high blood pressure and joint and bone impairment. When the cause is related more to lifestyle choices, the most successful approach is a commitment to more balanced and moderate dietary choices and to increase physical activity.

Q 32 Are anorexia nervosa and obesity conditions related only to the digestive system? Explain why or why not.

Figure 6.29 The Inuit of Canada's north are healthier when they eat the traditional diet of their ancestors, which includes foods such as the caribou shown here, as well as Arctic char, seal, and whale meat. What did your ancestors eat?

Traditional vs. Modern Diets

Some peoples who have abandoned their traditional foods in favour of modern convenience foods are returning to the old ways (Figure 6.29). In 1985, a study involving native Hawaiians compared their modern dietary practices with those of their ancestors. As shown in Figure 6.30, the traditional diet included only 3 percent protein from animal

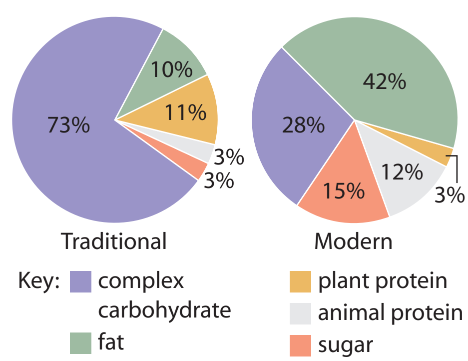


Figure 6.30 The incidence of cardiovascular disease, cancers, and diabetes has dropped in native Hawaiians who have returned to their traditional diet. The switch to the traditional diet has been accompanied by a return to more traditional cultural and social values and practices.

HUNTING AND FISHING FOR A HEALTHY LIFESTYLE!

Getting out on the land is part of our way of life. It is a great way to be active. Hunting, fishing and eating traditional foods will help keep us healthy. Traditional foods give us the nutrients we need to be healthy.

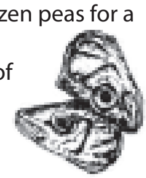
FOR MORE INFORMATION CONTACT:

- Your local Health Centre
- Your Regional Nutritionist

or refer to the Nutrition Fact sheet Series on Nutrients found in the **Contaminants and Your Health: NWT Fact Sheets** binder.

HEALTHY EATING!

Boil fish heads in broth and add rice, onion, carrots and frozen peas for a tasty soup. Serve with bannock and a glass of milk or unsweetened juice. Enjoy a piece of fruit for dessert.



Produced by Baffin, Inuvik, Keewatin and Kitikmeot Health Boards, in conjunction with the Community Health Programs, Department of Health and Social Services, GNWT. Prototype developed by Dene Nation and Mackenzie Regional Health Services. Funded by Arctic Environmental Strategy. March 1996

Figure 6.31 The Health and Social Services department of the Northwest Territories publishes a comprehensive series of fact sheets (a portion of one page is shown here) to help Aboriginal peoples in northern provinces and territories in their food choices.

sources, compared with 12 percent in the modern diet. The differences in fat, sugar, and complex carbohydrate intake were even more dramatic. A statistical study showed that the rate of cardiovascular (heart and circulatory system-related) disease and cancer was higher than average among Hawaiians who followed the modern diet. Diabetes was also common in Hawaiians who followed the modern diet. Follow-up studies showed that their health greatly improved when they returned to the ancestral diet.

Some non-native Hawaiians have used this study to promote the recommendation that a diet emphasizing plant proteins and low to moderate fat intake should be adopted as a healthy diet for others. This would surprise many Aboriginal peoples, especially Inuit people who strive to follow a traditional diet and lifestyle. Aboriginal peoples of the Far North have traditional diets that are the lowest in carbohydrates and the highest in fats and protein of any other diets in the world. For millennia, with minimal and often no access to plant-based foods for months at a time, Inuit and other northern Aboriginal peoples obtained all the nutrients that are essential for healthy functioning. Today, with the increased encroachment of foods from non-Aboriginal society in the south and the erosion of traditional practices, northern Aboriginal peoples are experiencing the same unhealthy conditions as those faced by modern native Hawaiians. In response to this situation, many Aboriginal peoples—not only in the Far North, but throughout North America—are returning to their dietary traditions, as well as to their cultural and social traditions (see Figure 6.31).

Q 33 Describe the effect of returning to a traditional diet on the health of Aboriginal peoples.

Section 6.3 Summary

- Ulcers are caused when the walls of the digestive tract, usually in the stomach, are irritated by gastric secretions.
- Inflammatory bowel disease is the general name for a painful group of digestive disorders that can affect the digestive tract anywhere from the mouth to the anus.
- Hepatitis and cirrhosis are two major disorders of the associated digestive organs.
- Anorexia nervosa is a serious eating disorder, in which people starve themselves. Obesity which is also dangerous, results when people take in too much food and exceed a healthy weight.

BiologyFile

Web Link

Processed foods, a common feature of modern diets, often contain additives. These chemicals are put into food to preserve it, enhance its flavour, or improve its colour. The national government ensures the safety of these products. However, there is still much controversy over whether they can harm people.

www.albertabiology.ca
WWW

Thought Lab 6.3 Enzymes and Diet

Target Skills

Evaluating the role of technology to solve problems that involve dietary choices

Identifying and **evaluating** enzyme-related technologies and the problems they are developed to solve

In the 1960s, an American named Ann Wigmore spearheaded a dietary movement called "Living Foods." She based her ideas on her belief that cooked foods cause most mental and physical illnesses, because many proteins and enzymes are destroyed during the cooking process. The diet she recommended was a vegetarian, raw-food diet.

Wigmore's philosophy found an appreciative audience in North America. Bookstores carry many raw-food diet cookbooks, restaurateurs have set up cafes serving raw foods, and many alternative health-care practitioners recommend raw-food diets to help patients lose weight and prevent disease. The raw-food diet has also been extended to pets. Some veterinarians, noting the frequency of certain diseases in domestic animals—especially cats and dogs—suggest that ill health is the result of insufficient access to raw foods. As a result, some people have switched their pets to the BARF diet. (BARF stands for "Biologically Appropriate Raw Food" or "Bones and Raw Food," depending on who you consult.) The reasoning is that dogs and cats eat raw foods in the wild, and only raw foods produce the anti-bacterial enzymes in the gut and mouth that domestic animals need to be healthy.

Skeptics point out that people in many cultures have been eating cooked foods for centuries. They further suggest that although people do need enzymes to digest food, the cells make enzymes for this purpose. Some veterinarians also dismiss the need for pets to eat raw foods, saying that pets have become accustomed to a "domestic" diet and would not function well on a "wild" diet.

Procedure

1. Find out more about the Living Foods diet. Research Web archives and dietary journals. If possible, interview dietitians or health-care providers. Summarize the main concepts behind this diet. ICT
2. Investigate a specific food and the enzymes it contains to determine whether there would be any benefits and dangers associated with eating this food raw rather than cooked. Possible foods to investigate include pineapples, tomatoes, soybeans, broccoli, and raw meats and fish.

Analysis

1. Using your understanding of the properties and functions of enzymes and the process of digestion, review what you learned in your research. Prepare a report to answer these questions:
   - Is a diet of raw foods healthy?
   - Is such a diet healthy for all people?
   - Is such a diet healthy for dogs and cats?

Extension

2. Research enzymes that have medical and industrial applications. Choose one application that interests you, and research it further. Some examples include the treatment of Alzheimer's disease and Chronic Fatigue Syndrome with NADH, DNA fingerprinting, prodrugs, nutraceuticals, and synthetic oligosaccharides.

Section 6.3 Review

1. **a)** List at least two factors that can cause the formation of an ulcer.

   b) Describe what an ulcer is, and identify two technologies that may be used to treat it.
2. Compare and contrast Crohn's disease and colitis. Identify at least three treatments for these inflammatory bowel diseases.
3. Explain why diseases that affect the liver pose serious health risks.
4. Explain why anorexia nervosa and obesity are more than simple physiological conditions. Discuss the impact of this on options for treatment.

Use the following information to answer the next question.

Pancreatitis

Pancreatitis is an inflammation of the pancreas. The pancreas is a large gland behind the stomach and close to the duodenum. Normally, digestive enzymes produced in the pancreas do not become active until they reach the small intestine, where they begin digesting food. Pancreatitis develops when the digestive enzymes become active inside the pancreas. Chronic pancreatitis occurs when digestive enzymes attack and destroy the pancreas and nearby tissues, causing scarring and pain.

5. Explain why a person with pancreatitis would have difficulty digesting carbohydrates, lipids, and proteins.

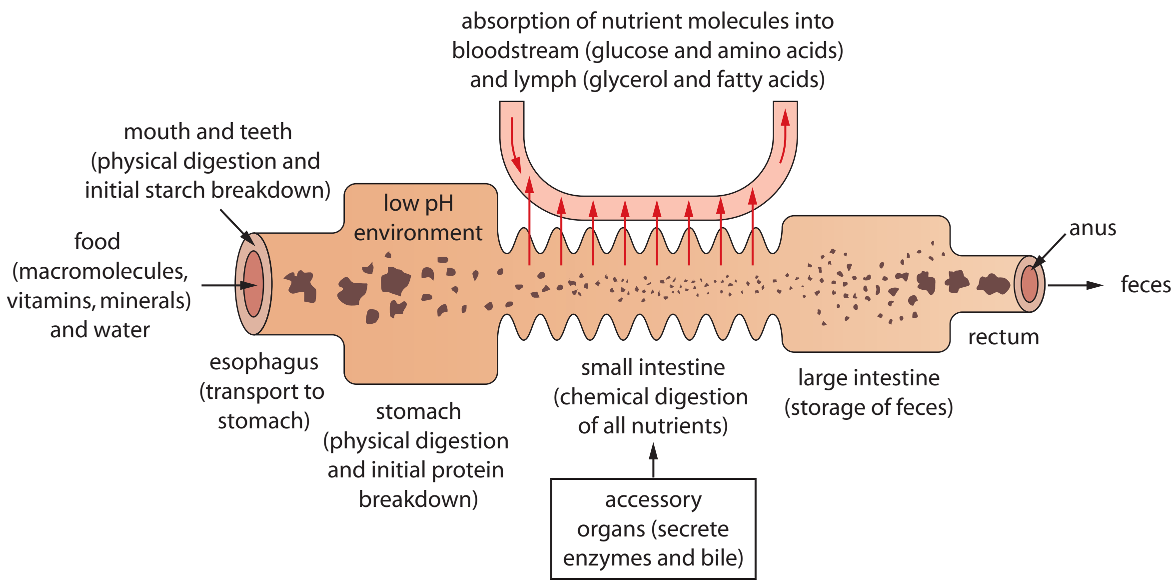
The human body takes in matter from the environment in the form of food and water. The human digestive system processes the food and water in order to obtain the macromolecules it needs for survival.

Food passes through the digestive tract—the mouth, pharynx, esophagus, stomach, small intestine, and large intestine—during physical digestion. The accessory organs—the salivary glands, liver, gall bladder, and pancreas—supply chemicals that also contribute to the digestion of food as it passes through the digestive tract. The stomach supplies chemicals to aid digestion as well as generating physical contractions to physically break down food. The food is eventually liquefied into soluble units that can pass through cell membranes for transport via the circulatory system to all the cells in the body. The waste materials from the digestive process leave the body via the large intestine.

The nutrients that food supplies include carbohydrates, lipids (fats), protein, and nucleic acids. Carbohydrates and lipids are broken down to supply energy; lipids also supply material for the cell membranes. Proteins are more structurally and functionally diverse than carbohydrates and lipids. They assist in transport, immunity, and muscle action and are used to make up most cellular structures. Nucleic acids direct growth and development. Enzymes speed up chemical reactions, particularly for the production of energy. Vitamins and minerals are organic and inorganic substances that enable chemical reactions to occur and aid in tissue development and growth and immunity. All of these substances are needed by a healthy, functional human body.

Disorders of the digestive system and its accessory organs include ulcers, inflammatory bowel disease, hepatitis, cirrhosis, and gallstones. All disorders that affect digestion, including eating disorders, can seriously damage overall health by depriving the body cells of the nutrients they need to survive.

Chapter 6 Graphic Organizer



Chapter 6 REVIEW

Understanding Concepts

1. Compare the dehydration synthesis of maltose to the hydrolysis reaction of this macromolecule.

2. What is a peptide bond? Use a diagram to illustrate the dehydration synthesis for the formation of a dipeptide.

3. Describe why some amino acids are classed as essential amino acids.

4. Use examples to distinguish a monosaccharide from a disaccharide and a polysaccharide.

5. Describe the function of proteins in the human body.

6. Explain the following statement. "The stomach is an organ in which both physical digestion and chemical digestion takes place."

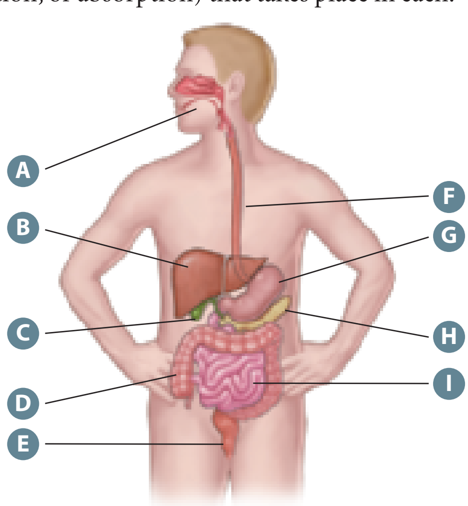
7. Use a flow chart to summarize the chemical digestion of the following macromolecules. Include the enzymes (or group of enzymes) that would be involved in this process.
a) starch
b) protein
c) fat

8. Explain the role of the liver in the physical digestion of fats and describe the importance of this process.

9. Identify the approximate pH of fluids in the stomach and explain the importance of having this pH level as far as chemical digestion is concerned.

10. Use a flow chart to illustrate the negative feedback mechanism that controls the secretion of the hormone gastrin.

11. Identify each organ shown in the diagram below and list the digestive process(es) (physical digestion, chemical digestion, or absorption) that takes place in each.



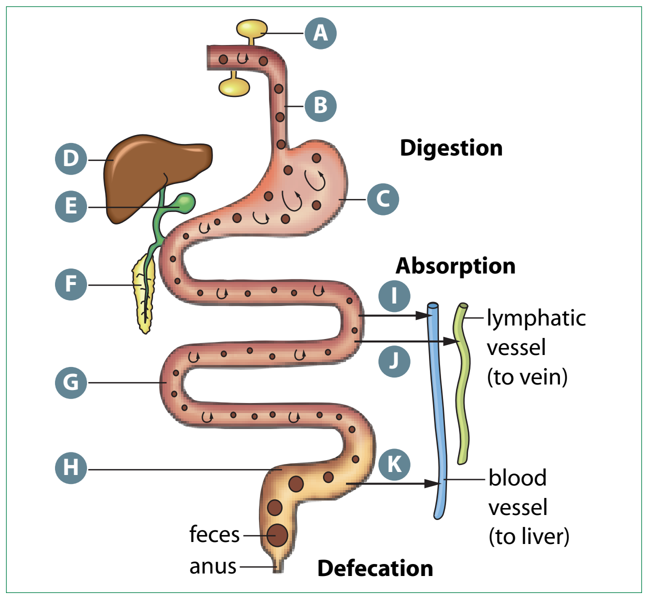
12. Summarize the following disorders of the digestive system.
a) inflammatory bowel disease
b) cirrhosis
c) ulcer

Applying Concepts

13. After playing in the dirt, a child sticks her fingers in her mouth and ingests a significant number of bacteria but doesn't get sick. Explain how the digestive system protected this youngster from these potentially toxic bacteria.

14. Draw a concept map or other graphic organizer that summarizes the relationship between the organs of the digestive tract and the accessory organs.

Use the following diagram to answer the next two questions.



15. Copy the following chart into your notebook and fill in the blanks. The first one has been done for you.

Label	Structure	Secretion(s)	Function of each Secretion
A	salivary glands	• salivary amylase • saliva	• enzyme that contributes to the digestion of starch • lubricates the inside of the mouth to assist in swallowing
B			
C			
D			
F			
G			

16. Identify the substances on the diagram indicated by the arrows labelled (i), (j), and (k).

17. Sketch and label a line graph (including labels for the axes) that compares the optimal environmental pH for the digestive action of the enzymes pepsin and trypsin. Based on this information, infer the organs where each enzyme functions.

Use the following information to answer the next two questions.

Statistics Canada collected data on the obesity rates of Canadians in 1978 and again in 2004. The obesity rates were calculated using the body mass index (BMI), which is calculated by dividing mass in kilograms by height in metres squared. The table below shows representative data from these two studies.

Age Group	Obesity Rate 1978 (%)	Obesity Rate 2004 (%)
12–17	3	9
25–34	9	21
75+	11	24

18. Use spreadsheet software and a computer to create a bar graph of this data. ICT

19. a) Interpret what is happening to the obesity rate for each age group.

b) Infer three possible reasons for the changing obesity rates for each age group in this sample.

Making Connections

Use the following information to answer the next two questions.

Alcoholism is a disease marked by, among other things, the inability to control drinking. Excessive consumption of alcoholic beverages can lead to other diseases such as cirrhosis of the liver. If the cirrhosis progresses too far, the only treatment is a costly liver transplant. Livers for transplant are in very short supply and may also be damaged if the recipients continue to drink alcohol. Many individuals believe that these potential recipients should not be eligible for a liver transplant.

20. List the ethical concerns of offering organ transplants to people who have an underlying medical condition that jeopardizes the chance of a successful outcome.

21. You have been asked to respond to the point of view provided in the textbox above. What are your recommendations?

Use the following information to answer the next two questions.

Acute cholecystitis is a sudden inflammation of the gallbladder that causes severe abdominal pain. In 90 percent of cases, acute cholecystitis is caused by gallstones, which obstruct the duct leading from the gallbladder to the common bile duct (which drains into the intestine). The trapped bile becomes concentrated and causes irritation and pressure buildup in the gallbladder. This can lead to bacterial infection and perforation. Gall bladder attacks may follow a large or fatty meal. The main symptom is abdominal pain—particularly after a fatty meal—that is located on the upper right side of the abdomen. Occasionally, nausea and vomiting or fever may occur. Although cholecystitis may clear up on its own, surgery to remove the gallbladder (cholecystectomy) is usually needed when inflammation persists or recurs.

22. Explain why gall bladder attacks usually follow a large or fatty meal.

23. How would having a cholecystectomy change your diet? Explain.

24. Meal X consists mainly of simple carbohydrates with some proteins. Meal Y consists mainly of complex carbohydrates with some proteins. Predict the blood glucose levels you would expect to find right after eating each meal. Explain your prediction.

Use the following information to answer the next question.

Gastric bypass surgery is the treatment of last resort for those who suffer from severe obesity. Gastrointestinal surgery is probably the best option for those who have been unable to lose weight by the traditional methods of dieting and exercise and can have great results. People who can be considered for surgery are those who are severely obese (i.e., with a body mass index of 40 or more) or people who are obese (with a BMI of between 35–40) who also have a significant disease (such as diabetes or high blood pressure) that could be improved if they lost weight.

There are two main types of digestive tract surgery: restrictive surgery (stomach stapling) in which the stomach walls are stapled together to create a small stomach pouch, and malabsorptive surgery, which involves shortening the overall length of the digestive tract.

25. Explain, in terms of specific digestive organs and processes, how:

a) restrictive surgery (stomach stapling) would help an obese person lose weight

b) malabsorptive surgery would help an obese person lose weight