The Digestive System

Specific Expectations
In this chapter, you will learn how to . . .

• E1.1 evaluate the importance of various technologies to our understanding of internal body systems

• E1.2 assess how societal needs lead to scientific and technological developments related to internal systems

• E2.1 use appropriate terminology related to animal anatomy

• E3.2 explain the anatomy of the digestive system and the importance of digestion in providing nutrients needed for energy and growth

• E3.4 describe some disorders related to the digestive system.

In the spring of 2008, Sebastien Sasseville was on top of the world—literally. On that day, he became the first Canadian with diabetes to reach the top of Mount Everest. Diabetes is a common disease that affects the proper functioning of a key organ of the digestive system, the pancreas. The pancreas releases a chemical called insulin that enables cells to take in the glucose released from food during digestion. Cells require glucose for energy. If diabetes is not carefully monitored and treated, it can cause irreversible organ damage or even death.

Until the early 1990s, people with diabetes had to monitor the amount of glucose in their blood constantly and manage their disease by injecting themselves daily with insulin. Today, thanks to technological advances, many people like Sebastien can replace daily injections with a more convenient and reliable insulin pump that releases the chemical directly into their bloodstream. You will learn more about this technology as you read this chapter.
I Can See Right through You

One of the oldest, least expensive, and still most often-used technologies for peering inside and imaging the body is the X-ray machine. X-ray technology is a fast and non-invasive tool that enables doctors to view and diagnose abnormalities in body tissues, organs, teeth and bones, and even blood flow. Standard X rays do not require any special preparation of the patient. For X rays of the digestive system, the person is normally given a barium sulfate solution to drink. Barium sulfate shows up white on the X-ray image and outlines the digestive tract, showing the shapes of the esophagus, stomach, and intestines. The barium solution collects in the abnormal areas, revealing ulcers, tumours, and other abnormalities such as enlarged organs. In this activity, you will test how many organs you can identify from an X-ray image.

Procedure

1. Examine the coloured X-ray image. Sketch and label 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 can recall.

Questions

1. Compare your sketch with those of 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 this unit to assess your understanding and modify your sketch.
**Macromolecules and Living Systems**

Figure 10.1 shows the three main fluid compartments of the body: the cytoplasm inside the cells, the fluid between the cells (the *interstitial* fluid), and the fluid in the blood. The fluid in these compartments is mostly water, which makes up more than 60 percent of the 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 also known as nutrients. These nutrients are the raw materials that our bodies need to provide energy, to regulate cellular activities, and to build and repair tissues. Regardless of their size or complexity, all organisms require nutrients to perform their life functions and to obtain energy for survival.

Macromolecules are often grouped into four major categories: carbohydrates, lipids (such as fats), proteins, and nucleic acids. Energy released from these macromolecules, and matter supplied by them, is used to maintain the body’s **metabolism**—all the chemical processes carried out by cells to maintain life.

Together, the four major categories of macromolecules are known as **essential nutrients.** Table 10.1 summarizes the four categories of macromolecules and their main functions in the body. Read on to learn more about macromolecules and how the human digestive system breaks down the macromolecules in the food we eat into forms that our bodies can use.

**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.
Table 10.1 Four Major Categories of Macromolecules

<table>
<thead>
<tr>
<th>Macromolecule</th>
<th>Main Functions</th>
<th>Examples</th>
</tr>
</thead>
</table>
| Carbohydrates | • provide materials to build cell membranes  
• provide quick energy for use by cells | glucose, fructose, lactose, maltose, starch, glycogen, cellulose |
| Lipids | • store energy reserves for later use by cells  
• cushion and insulate internal organs  
• provide materials to build cell membranes | fats, oils, waxes |
| Proteins | • provide structure and support for blood cells, body tissues, and muscles  
• aid in muscle movements, such as contraction  
• act as catalysts to speed up chemical reactions in the cells  
• provide immunity against infection and disease  
• transport ions in cell membranes | insulin, hemoglobin, collagen, antibodies, enzymes |
| Nucleic acids | • contain the organism’s genetic information  
• direct the organism’s growth | deoxyribonucleic acid (DNA), ribonucleic acid (RNA) |

Monosaccharides
Simple sugars, or monosaccharides (mono means one; sacchar means sugar), are carbohydrate molecules with three to seven carbon atoms (and the corresponding number of hydrogen and oxygen atoms). Examples of monosaccharides are glucose (the sugar found in blood) and fructose (the sugar found in fruit). Disaccharides, or double sugars, are made up of two simple sugars (di means two). Some common disaccharides are sucrose (table sugar), maltose (the sugar found in germinating grain), and lactose (the sugar found in dairy products).

Polysaccharides
Complex carbohydrates that consist of many linked simple sugars are called polysaccharides (poly means many). Examples are starch, cellulose, and glycogen, a polysaccharide made up of glucose sub-units. Starch performs the important function of storing energy in plants. Glycogen performs the same function in animals.

Lipids
Lipids are a group of macromolecules that have one important property in common: they are insoluble in water. The basic structure of lipids is a molecule of glycerol (an alcohol) consisting of three carbon atoms, each attached to a fatty acid chain (an acid with a long tail of carbon and hydrogen atoms). Lipids store 2.25 times more energy per gram than other biological molecules; therefore, some lipids function as energy-storage molecules. Other lipids, called phospholipids, form the membrane that separates a cell from its external environment. Examples of lipids are fats, such as butter and lard, and oils, such as olive oil and safflower oil.

Proteins
Proteins are assembled from small sub-units that are known as amino acids. Most protein molecules are made up of hundreds of amino acids joined together by peptide bonds into one or more chains. These chains are called polypeptides. Most enzymes are proteins, and so are antibodies, which combat disease. Proteins help build and repair muscles and cell membranes.

Nucleic Acids
Nucleic acids direct growth and development of all organisms using a chemical code. The two types of nucleic acids are ribonucleic acid (RNA) and deoxyribonucleic acid (DNA).
Breaking Down Macromolecules: Enzymes

Before the body can use carbohydrates, lipids, and proteins, these large macromolecules must be chemically broken down into molecules small enough to be absorbed by the cells lining the small intestine. The process that carries out this chemical breakdown is called **hydrolysis** (hydro is Greek for water, and lysis means to loosen). During hydrolysis, a water molecule is added to the macromolecule (the carbohydrate, protein, or lipid); this breaks the chemical bonds that hold together the smaller molecules from which the macromolecule is made. This breakdown of the chemical bonds involves a special class of protein molecules called **enzymes**, which are secreted by cells in the digestive tract. Enzymes act as catalysts, which are substances that increase the rate of chemical reactions without being used up in the reactions. There are three main types of digestive enzymes, each of which breaks down one type of macromolecule, as shown in **Table 10.2**.

**Table 10.2** Types of Digestive Enzymes

<table>
<thead>
<tr>
<th>Type of Enzyme</th>
<th>Macromolecule It Breaks Down</th>
<th>Product of Breakdown</th>
<th>Example of Enzyme and Where It Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrase</td>
<td>Carbohydrate</td>
<td>Simple sugars</td>
<td>Amylase: produced in the salivary glands and functions in the mouth</td>
</tr>
<tr>
<td>Lipase</td>
<td>Lipid</td>
<td>Glycerol (an alcohol) and fatty acids</td>
<td>Pancreatic lipase: produced in the pancreas and functions in the small intestine</td>
</tr>
<tr>
<td>Protease</td>
<td>Protein</td>
<td>Amino acids</td>
<td>Pepsin: produced by stomach glands and functions in the stomach</td>
</tr>
<tr>
<td>Nuclease</td>
<td>Nucleic acid</td>
<td>Nucleotides</td>
<td>Pancreatic nuclease: produced in the pancreas and functions in the small intestine</td>
</tr>
</tbody>
</table>

Digestive enzymes help to speed up the process of hydrolysis, which is shown in **Figure 10.2**. You will learn more about enzymes and their roles in digestion later in this chapter.
The Vital Roles of Minerals and Vitamins

Other substances that are vital to life, in varying amounts, are minerals and vitamins. Minerals and vitamins are inorganic and organic substances that enable chemical reactions to occur and aid in tissue development, growth, and immunity. All of these substances are needed by a healthy, functional human body. Table 10.3 shows some minerals and vitamins, and their functions in the human body.

### Table 10.3 Functions and Possible Sources of Selected Vitamins and Minerals

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Key Functions in the Body</th>
<th>Possible Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>• forming bone</td>
<td>magnesium: dark, leafy greens</td>
</tr>
<tr>
<td></td>
<td>• conducting nerve signals</td>
<td>calcium: dairy products</td>
</tr>
<tr>
<td></td>
<td>• contracting muscle</td>
<td>potassium: grains</td>
</tr>
<tr>
<td></td>
<td>• clotting blood</td>
<td>vitamin B1: beans</td>
</tr>
<tr>
<td>Iron</td>
<td>• producing hemoglobin</td>
<td>vitamin D: fish</td>
</tr>
<tr>
<td>Magnesium</td>
<td>• supporting enzyme functions</td>
<td>vitamins A, C, and E: fruit</td>
</tr>
<tr>
<td></td>
<td>• producing protein</td>
<td>vitamin E: strengthening red blood cell membranes</td>
</tr>
<tr>
<td>Potassium</td>
<td>• conducting nerve signals</td>
<td>sodium: salt</td>
</tr>
<tr>
<td></td>
<td>• contracting muscle</td>
<td></td>
</tr>
<tr>
<td>Sodium</td>
<td>• conducting nerve signals</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• balancing body fluid</td>
<td></td>
</tr>
<tr>
<td>Vitamin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A (Carotene)</td>
<td>• good vision</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• healthy skin and bones</td>
<td></td>
</tr>
<tr>
<td>B1 (Thiamine)</td>
<td>• metabolizing carbohydrates</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• growth and muscle tone</td>
<td></td>
</tr>
<tr>
<td>C (Ascorbic acid)</td>
<td>• healthy bones, teeth, gums, and blood vessels</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• boosting immune system</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>• absorbing calcium</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• forming bone</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>• strengthening red blood cell membranes</td>
<td></td>
</tr>
</tbody>
</table>

The Many Roles of Water in the Body

Water makes up about two thirds of the body’s mass and is needed for the proper functioning of all cells and organs. Its many roles include

- transporting dissolved nutrients into the cells that line the small intestine
- flushing toxins from cells
- lubricating tissues and joints
- forming essential body fluids, such as blood and mucus
- regulating body temperature (by sweating)
- eliminating waste materials (in urine and sweat)

Water is vital for maintaining the body’s fluid balance, the condition in which the amount of fluid lost from the body equals the amount of fluid taken in. A constant supply of water is needed to replenish the fluids lost to normal, daily bodily functions. An average adult produces 1.5 litres (6.3 cups) of urine per day and loses about 1 litre of water through the breath, perspiration, urine, and bowel movements.
There are two main reasons why food spoils: the growth of microorganisms (mostly bacteria and fungi) and the breakdown of fats, which makes foods rancid. Bacteria need water to grow in, and the earliest food preservation technologies involved drying and smoking 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. No technique is perfect, but 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.

### Materials
- reference books
- computer with Internet access

### Activity 10.1 How Do You Take Your Macromolecules?

**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.

**Questions**

1. Create a table 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 the technique works.
3. Describe the advantages of this technology.
4. Describe the disadvantages of this technology.
5. Identify any chemical preservatives in the foods you have examined, and use the Internet to research the role of the preservatives and any possible side effects.

### Learning Check

1. What is the primary function of carbohydrates in the human body?
2. What is the difference between a monosaccharide and a disaccharide? Give an example of each.
3. Explain how macromolecules are broken down for use in the body, as shown in Figure 10.2.
4. If an athlete runs for 15 minutes, which macromolecules are likely to break down first in the athlete’s body?
5. Which macromolecules would provide the greatest benefit as a long-term energy storage molecule to a bird that migrates long distances?
6. Name three of the functions of proteins in the human body.
How Animals Obtain Their Food

As discussed in Chapter 1, some organisms, known as autotrophs, obtain energy by making their own food, usually using sunlight. Other organisms, known as heterotrophs, must consume other organisms to obtain energy-yielding food. Animals cannot produce their own food, so they use a wide variety of processes and behaviours to search for, obtain, and take in their food. Despite their many shapes, sizes, and food preferences, all animals obtain their food through one of four means, called feeding mechanisms. These feeding mechanisms include filter feeding, substrate feeding, fluid feeding, or (as humans do) bulk feeding. The four types of feeding mechanisms are shown in Table 10.4. By observing the mouth or other feeding device of an organism, it is usually possible to tell what type of feeder it is.

Table 10.4 Animal Feeding Mechanisms

<table>
<thead>
<tr>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filter feeders are aquatic animals that use a body structure similar to a filter basket to gather organisms, such as protists, bacteria, and the larvae of many aquatic animals, suspended in the surrounding water. The filter feeder siphons water into its mouth and then filters it to obtain small organisms to digest. The tube sponge is a filter feeder. Other examples include flamingoes, tube worms, clams, barnacles, and baleen whales.</td>
<td>![tube sponge]</td>
</tr>
<tr>
<td>Substrate feeders live in or on their food source and eat their way through it. Examples of substrate feeders include caterpillars and earthworms. Caterpillars eat their way through the green tissues of leaves. Earthworms eat their way through the soil, ingesting soil particles containing partially decayed organic material as they go.</td>
<td>![caterpillar]</td>
</tr>
<tr>
<td>Fluid feeders obtain food by sucking or licking nutrient-rich fluids from live plants or animals. Fluid feeders have mouth parts that are adapted to pierce or rip skin or leaf tissue. The same or other mouth parts are used to suck or lick the blood or sap that is their food. Examples of fluid feeders include mosquitoes, ticks, aphids, spiders, bees, butterflies, vampire bats, and hummingbirds.</td>
<td>![butterfly]</td>
</tr>
<tr>
<td>Bulk feeders include many animals and most vertebrates (including humans). Bulk feeders ingest fairly large pieces of food and some, like the great blue heron, swallow their food whole. Other bulk feeders use tentacles, pincers, claws, fangs, or jaws and teeth to kill prey, to tear off pieces of meat or vegetation, or to take in mouthfuls of animal or plant food.</td>
<td>![great blue heron]</td>
</tr>
</tbody>
</table>
The Four Stages of Food Processing

After an animal has obtained its food, the nutrients in the food must get into the individual cells of the animal’s body in a usable form. The essential function of an animal’s digestive system is to break food down into small, soluble units that can pass through cell membranes. The digestive system breaks down food into useful substances that can be absorbed into the circulatory system. The circulatory system (to be discussed in detail in Chapter 12) transports these substances to the individual cells of the body.

Whatever an animal’s source of food, type of food, or feeding method, digestion of food occurs in four stages:

1. ingestion—the taking in or eating of food
2. digestion—the breakdown of food by mechanical and chemical processes into molecules small enough for cells of the body to absorb
3. absorption—the transport of the products of digestion from the digestive system into the circulatory system, which distributes them to the rest of the body
4. elimination—the removal of undigested solid waste matter from the body

Digestion and the Alimentary Canal

To digest their food, most animals have a digestive tract that consists of a long open tube. This tube, called the alimentary canal, has a mouth at one end to ingest food and an anus at the other end to eliminate waste. As food moves along this tube, different organs of the digestive system process the food in different ways—rather like a production line in a factory.

One example of an open tube structure is the alimentary canal of the earthworm. In the earthworm, shown in Figure 10.3, food enters the mouth and passes into the pharynx, or throat. The esophagus then channels the food into the crop, a pouch-like organ in which food is softened and stored. The muscular gizzard churns and grinds the food, and the food is further digested in the intestine.

In more complex animals, food enters the mouth and is physically broken apart into smaller pieces by the teeth. The food is further broken apart as it moves along the digestive tract by the muscular contractions of the tube itself. This process of physical breakdown of the food into smaller bits is called mechanical digestion.

At the same time, various fluid-releasing glands in the mouth and further along the digestive tract add liquid and enzymes that help to break down the macromolecules of food into smaller molecules. This breakdown of macromolecules by enzymes is the process known as chemical digestion. Figure 10.4 shows a simple overview of the digestive process in a typical mammal.
The Length of the Digestive Tract
Although the function of the digestive system is the same in all animals, the length of the digestive tract varies according to the feeding habits of the species. Herbivores and omnivores (including humans) usually have longer digestive tracts, relative to their body size, than carnivores. For example, compare the digestive tracts of a rabbit (a herbivore) and a fox (a carnivore) in Figure 10.5. Because the cellulose walls in plant tissues are more difficult to digest than animal tissues, most herbivores have relatively longer digestive tracts, which allows the extra time needed for digestion. In Section 10.2, you will focus on the structure and function of the human digestive tract.

Figure 10.4 The four main stages of food processing in animals are: (1) ingestion, the intake of food; (2) digestion, the breakdown of food into small molecules; (3) absorption, the transport of nutrient molecules across cell membranes; and (4) elimination, the expulsion of undigested waste.

Figure 10.5 The digestive tract of a small herbivore, such as a rabbit, is longer than that of a small carnivore, such as a fox. In both digestive tracts you can see the cecum, a pouch at the beginning of the large intestine that receives waste material from the small intestine. Infer What might account for the relative difference in the size of the cecum between these two animals?
Section Summary

- There are four major categories of macromolecules that contain the essential nutrients needed to maintain life: carbohydrates, lipids, proteins, and nucleic acids.
- Macromolecules are chemically broken down by hydrolysis, a process that uses certain enzymes as catalysts.
- Water helps transport materials around the body, lubricate joints, form vital fluids such as blood, and regulate body temperature.
- To digest their food, most animals have a digestive tract that consists of a tube known as the alimentary canal.
- The four stages of food processing in animals are ingestion, digestion (mechanical and chemical), absorption, and elimination.

Review Questions

1. **K/U** What are the four major macromolecules that are needed by the body, and why are they important?
2. **K/U** Summarize the functions of lipids in the body.
3. **C** Use Tables 10.1 and 10.2 to create a graphic organizer, such as a spider map, to show the four major macromolecules. For each grouping, include a list of the characteristics that define the grouping, including structure, function, examples, and the digestive enzymes that make them usable by the body.
4. **C** Use what you have learned so far in this chapter to make a Venn diagram that compares and contrasts monosaccharides, disaccharides, and polysaccharides.
5. **C** Create an analogy to explain to another student why a polysaccharide is considered a long-term source of energy, while a monosaccharide is considered a short-term source of energy.
6. **T/I** A dessert topping for ice cream contains maltose, soybean oil, and salt. Identify the kinds of macromolecules and minerals that are in this topping.
7. **T/I** Why must macromolecules be broken down into smaller molecules during digestion?
8. **K/U** In your own words, describe the structure of a protein.
9. **T/I** Explain why humans cannot survive for more than a few days without drinking water.
10. **C** Copy the table below into your notebook and complete it. Refer to Figure 10.4 to help you. Give your table a title.

<table>
<thead>
<tr>
<th>Process</th>
<th>Definition</th>
<th>Part of digestive tract where process occurs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical digestion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mechanical digestion</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

11. **A** Use the information in Table 10.3 to answer the following questions.
   a. Which vitamin is involved in the absorption of calcium from foods?
   b. Identify a vitamin that would be useful to take for night blindness.
   c. What vitamin deficiency could lead to bone malformations?
12. **T/I** To prevent cramping during a soccer match, an athlete is advised to eat a banana and drink a glass of milk before the game. Explain why these foods might be helpful in preventing cramps.
13. **A** Classify the following organisms as filter feeders, fluid feeders, substrate feeders, or bulk feeders.
   a. An animal that feeds on plant sap has a long, beak-like mouthpart that can pierce plant tissues.
   b. An animal eats its way through the upper surface of a leaf.
   c. An animal captures its prey with its teeth and tears off pieces of meat.
   d. An aquatic animal has gills in which mucus traps food.
14. **T/I** A biologist studying the alimentary canal in animals notices that herbivores such as deer have an enlarged cecum, whereas carnivores like foxes have a small cecum or none at all. The researcher also finds that the cecum hosts a high concentration of bacteria. How might the concentration of bacteria be related to the size of the cecum in herbivores?
15. **C** Use a graphic organizer, such as a flowchart, to show clearly how the words digestion, elimination, absorption, and ingestion are related.
16. **A** Using your knowledge of evolution from Unit 3, explain why so there is so much diversity in feeding mechanisms in animals.
The human digestive system, like other body systems, is made up of a group of organs working together. The digestive tract and the organs associated with it are shown in Figure 10.6. In this section, you will learn about the structure and function of the digestive system, and how each part of this system plays a role in transforming food into the energy and materials the body needs to survive.

### Parts of the Human Digestive System

The specialized organs in the human digestive tract start with the first point of contact—the mouth. Even before you take your first bite of food, the smell or sight of food can trigger the salivary glands, shown in Figure 10.7, to secrete a watery fluid called saliva into the mouth. There are three pairs of salivary glands in the mouth.

Chemical digestion begins with saliva. Saliva contains an enzyme called amylase that starts to break down the starches in food into simpler sugars. Saliva dissolves water-soluble food particles. It stimulates the taste buds, making it possible to taste the flavours of the food. It also lubricates the food to make it easier to swallow. Mechanical digestion also begins in the mouth as your teeth bite, tear, and grind food into smaller pieces. This mechanical action also exposes more of the surface area of the food to the saliva, making it more accessible for chemical digestion.
The Esophagus
As you chew your food, your tongue helps mould and smooth it into a soft mass, called a bolus, that the tongue then pushes to the back of your mouth. When you swallow, the bolus enters the top of the esophagus to begin its passage to your stomach. The opening of the esophagus lies next to the opening of your windpipe, or trachea, which carries air to and from your lungs. To prevent food from going down the wrong tube and choking you when you swallow, the opening of the trachea is closed by a valve called the epiglottis when you swallow.

The esophagus is a hollow muscular tube that transports each bolus of food to the stomach in a series of wave-like muscular contractions called peristalsis, shown in Figure 10.8. Glands in the lining of the esophagus produce mucus, which keeps the passage moist and aids in swallowing. The entrance to the stomach is controlled by a ring of muscle called the esophageal sphincter. This sphincter is normally closed to prevent the acidic contents of the stomach from backing up into the esophagus, but it relaxes to allow each bolus of food to enter the stomach.

Figure 10.8 Peristalsis moves food through the esophagus by means of muscular contractions. When you vomit, or “throw up” your stomach contents, the contractions of the esophagus are reversed. Similarly, small amounts of acidic liquid can escape from the stomach and move up the esophagus into your throat. This is experienced as a burning sensation in the throat or chest, commonly called heartburn or acid reflux.

Activity 10.2 Modelling Peristalsis

In this activity, you will design and construct a working model to demonstrate how the esophagus uses muscular action to move food along from the throat to the stomach. Could someone swallow a mouthful of juice while upside down?

Safety Precautions

• Inform your teacher if you have any allergies to soaps or detergents.

Materials

• knee-high nylon stocking
• tennis ball
• water
• liquid soap or detergent
• hand lens
• scissors

Procedure

1. Examine the materials provided by your teacher.
2. Review the section on the esophagus, and refer to Figure 10.8 to help you with this activity.
3. As a group, discuss the possible ways you might use the materials to construct your model.
4. Construct your model and use it to demonstrate the process of peristalsis.
5. When you are finished your demonstration, clean the materials and leave them out to dry.

Questions

1. How are the textile fibres in the stocking analogous to the muscle fibres in the esophagus? Hint: Refer to Figure 10.8 to help you with your answer.
2. What was the function of the water and soap in this model? What two secretions serve the same function in the esophagus?
3. As an optional extension to this activity, create a flipbook to illustrate peristalsis so that a younger student could understand this process.
The Stomach

The stomach is a muscular, J-shaped organ in which food is temporarily stored while further chemical and mechanical digestion takes place. This organ lies on the left side of the abdominal cavity, just below the diaphragm [DIH-uh-fram], which is the sheet of muscle that separates the heart, lungs, and ribs from the abdominal cavity. The walls of the stomach are folded like an accordion, allowing the stomach to expand after a meal, as shown in Figure 10.9. The stomach is lined with millions of gastric glands that secrete gastric juice when stimulated by the presence of food. Gastric juice is made up of hydrochloric acid, salts, enzymes, water, and mucus. The mucus coats the walls of the stomach, protecting it from attack by the strongly acidic gastric juice. The rest of the gastric juice continues the chemical digestion of the food.

Figure 10.9 Folds in the stomach wall allow it to expand and contract as it fills with food and then empties its contents into the small intestine.

The stomach has three layers of muscle fibres that contract and then relax to churn and mechanically break up pieces of food and mix them with the gastric juice. The result of this churning and mixing is a thick liquid called chyme [kihm]. At the lower end of the stomach is a muscular valve called the pyloric sphincter. When closed, this valve keeps food in the stomach.

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.

The stomach is surrounded by a network of nerves that help regulate the activities of the digestive system. These nerves initiate the stomach contractions that release partially digested food into the small intestine. When the small intestine is full and still digesting food, the stomach temporarily stores the chyme. When processed food has moved out of the small intestine into the large intestine, the pyloric sphincter opens and the stomach pushes chyme into the first part of the small intestine—the duodenum.
Learning Check

7. Describe where the digestion of carbohydrates begins in the body, the major glands involved, and the digestive secretions produced.

8. Using Figure 10.8, explain how peristalsis works in the esophagus and its function in digestion.

9. Analyze whether the epiglottis is closed and covering the trachea or open in the following situations, and explain why:
   a. when the person is talking
   b. when the person is swallowing
   c. when the person is coughing
   d. when the person is chewing

10. If a person has the mumps, their submandibular glands are swollen. Analyze Figure 10.7, and decide which part of the body a doctor would examine to help diagnose the mumps.

11. A doctor orders a pH test of the esophagus for a patient who is complaining about having heartburn and a burning sensation in the chest. What do you expect the doctor to find and why? Use Figure 10.9 to identify the source of this problem.

12. Using your knowledge of basic chemistry from previous studies, how do over-the-counter antacids, such as calcium carbonate, help an individual with a gastroesophageal discomfort, such as stomach pain?

The Small Intestine

The small intestine is the part of the alimentary canal in which digestion is completed—that is, the nutrient macromolecules are finally broken down into their component molecules. The nutrients are then absorbed through the membranes of the cells that line the small intestine, and they pass from the digestive system into the circulatory system. The circulatory system carries the nutrients to cells and tissues throughout the rest of the body.

The Duodenum

The small intestine looks like a long, folded tube divided into three main regions. The first region after the stomach is the U-shaped duodenum. To speed up the process of absorption, the walls of the small intestine are lined by folds that greatly increase the surface area through which nutrients can be absorbed. The folds are covered by tiny, finger-like projections called villi (singular villus). Each villus, in turn, is covered with many fine brush-like microvilli, as shown in Figure 10.10. As food passes through the duodenum, it receives secretions from two organs that support the function of the digestive system: the pancreas and the gall bladder.

**Figure 10.10** The lining of the duodenum is arranged in circular folds. Each fold is covered in tiny villi and microvilli, through which the absorption of nutrients into the bloodstream takes place.
The Jejunum and Ileum
Following the duodenum is a structure called the **jejunum**, which is about 2.5 m long and contains more folds than the duodenum. The jejunum breaks down the remaining proteins and carbohydrates so the end products can be absorbed into the bloodstream. The **ileum**, which is about 3 m long, contains fewer and smaller villi than either the duodenum or the jejunum. Its function is also to absorb nutrients, as well as to push the remaining undigested material into the large intestine.

The Accessory Organs
The pancreas and gall bladder are not part of the alimentary canal itself, but they are connected to the canal by ducts, as shown in Figure 10.11. Because of this close association with the alimentary canal, the pancreas and gall bladder are referred to as accessory organs. (An accessory is something that aids or provides support to something else.) Fluids produced by the accessory organs are essential to the process of digestion.

![Diagram of the digestive system](image)

**Figure 10.11** The pancreas and gall bladder secrete enzymes necessary for digestion.

In an adult human, the **pancreas** secretes about 1 L of pancreatic fluid into the duodenum each day. Pancreatic fluid contains numerous enzymes that chemically digest carbohydrates, lipids, and proteins. The fluid also contains bicarbonate, which is very important to the function of the enzymes. The bicarbonate alters the pH of chyme from strongly acidic (pH 1) to weakly basic (pH 8), thereby producing conditions in which the enzymes in the pancreatic fluid can work most efficiently.

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.

After bile is produced in the liver, it is sent to the **gall bladder**, which stores the bile between meals. Bile contains bile salts that are essential for the digestion of fats. Because fats are insoluble (that is, they cannot be dissolved) in water, they are suspended in the chyme as small droplets—like the blobs of fats that float up if you put a greasy dish in a sink of hot water. Bile salts act like detergent, physically breaking up the fat droplets into smaller fat droplets, and suspending the smaller fat droplets so they can disperse throughout the chyme. The many smaller fat droplets create a greater surface area to be exposed for digestive enzymes to chemically break down the fats in the small intestine: this makes it easier for the intestinal cells to absorb the fats.
Chemical Digestion and Absorption

The bile and pancreatic fluid in the duodenum help break down carbohydrates, proteins, and lipids into smaller molecules that can be absorbed into cells that line the small intestine. Enzymatic digestion 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 10.12 provides an overview of the sites of digestion of the four categories of macromolecules and how enzymes break them down step by step.

Table 10.5 outlines some of the digestive enzymes and their digestive activities. You may find it helpful to refer to Table 10.5 as you read about the digestion and absorption of carbohydrates, proteins, lipids, and nucleic acids on the next few pages.

Table 10.5 Selected Enzymes of the Digestive System

<table>
<thead>
<tr>
<th>Enzyme</th>
<th>Origin of Enzyme</th>
<th>Where Enzyme Acts/pH</th>
<th>Nutrient Molecule Digested</th>
<th>Products of Digestion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salivary amylase</td>
<td>Salivary glands</td>
<td>Mouth/7</td>
<td>Starch, glycogen</td>
<td>Maltose (disaccharide)</td>
</tr>
<tr>
<td>Pancreatic amylase</td>
<td>Pancreas</td>
<td>Small intestine/8</td>
<td>Starch, glycogen</td>
<td>Maltose</td>
</tr>
<tr>
<td>Carbohydrases</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• sucrase</td>
<td>Small intestine</td>
<td>Small intestine/8</td>
<td>Sucrose</td>
<td>Glucose + fructose</td>
</tr>
<tr>
<td>• maltase</td>
<td></td>
<td></td>
<td>Maltose</td>
<td>Glucose</td>
</tr>
<tr>
<td>• lactase</td>
<td></td>
<td></td>
<td>Lactose</td>
<td>Glucose + galactose</td>
</tr>
<tr>
<td>Pancreatic lipase</td>
<td>Pancreas</td>
<td>Small intestine/8</td>
<td>Lipids</td>
<td>Fatty acids and glycerol</td>
</tr>
<tr>
<td>Proteases</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• pepsin</td>
<td>Stomach</td>
<td>Stomach/1–2</td>
<td>Protein</td>
<td>Peptides</td>
</tr>
<tr>
<td>• trypsin</td>
<td>Pancreas</td>
<td>Small intestine/8</td>
<td>Small polypeptides</td>
<td>Smaller peptides</td>
</tr>
<tr>
<td>• chymotrypsin</td>
<td>Pancreas</td>
<td>Small intestine/8</td>
<td>Small polypeptides</td>
<td>Smaller peptides</td>
</tr>
<tr>
<td>Peptidases</td>
<td>Pancreas and small intestine</td>
<td>Small intestine/8</td>
<td>Peptides</td>
<td>Smaller peptides and amino acids</td>
</tr>
</tbody>
</table>
Factors That Affect Enzyme Action
Two factors, temperature and pH, can affect the rate at which an enzyme functions to break down complex molecules. More energy is added at higher temperatures, so the enzyme activity increases. The chemical bonds become too weak to maintain the enzyme’s shape. The enzyme 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.) For most human enzymes, the optimal temperature range is fairly narrow, peaking at about 37°C, as shown in Figure 10.13 (A).

Enzymes also function best within an optimal pH range. Some human enzymes such as pepsin, shown in Figure 10.13 (B), function best at a low pH. Pepsin is found in the acidic environment inside the stomach. However, most human enzymes, such as trypsin, function best in pH environments of about pH 6 to 8. Trypsin is found in the more neutral environment of the small intestine.

Absorption in the Small Intestine
Monosaccharides are absorbed into the bloodstream through the lining of the small intestine as shown in Figure 10.12. They are transported to the liver, where monosaccharides (other than glucose) are converted into glucose. Glucose is carried from the liver to all parts of the body by the circulatory system, and is used by cells as a source of energy. The liver converts excess glucose into glycogen, which can be temporarily stored in the liver and, in much smaller amounts, in muscles. When the body needs additional energy, some of the stored glycogen is converted back to glucose.

Like monosaccharides, amino acids are carried by the bloodstream from the small intestine directly to the liver. In the liver, amino acids are processed by various reactions and are either converted into sugars or used in energy-releasing chemical reactions. Some of the amino acids resulting from these reactions undergo a series of further transformations in the liver, and become part of a nitrogen-rich waste called *urea*. Urea is filtered by the excretory system and expelled from the body in urine. Other amino acids are carried by the circulatory system to the cells of the body, where they are used to make enzymes and other proteins such as keratin, which forms skin and hair.

Glycerol and fatty acid molecules are absorbed into the cells of the small intestine, where they are reassembled to form triglycerides. The triglycerides are coated with proteins to make them water-soluble. Protein-coated triglycerides pass from the cells of the small intestine into a network of vessels that transfer them into the bloodstream. In the blood, the protein coating is removed and the triglycerides are broken down by lipase enzymes back to glycerol and fatty acids. These smaller molecules provide energy to the cells.

Learning Check

13. Explain two functions of pancreatic fluid.
14. What happens to fats before they are digested and absorbed by the intestinal cells? Explain why this occurs.
15. Make a graphic organizer to show what happens to partially digested food after it leaves the stomach, up to the stage where it leaves the small intestine.
16. What is the role of the gall bladder in digestion?
17. A family member has recently had a cholecystectomy, a surgical procedure to remove his gall bladder. Now he must take medication to prevent diarrhea. Why would the removal of the gall bladder cause diarrhea?
18. A baby is born with a mutation that results in an unusually smooth small intestine that has far fewer villi than a normal small intestine. Describe one possible consequence of this mutation.

Figure 10.13  The proper functioning 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.

Suggested Investigation

Inquiry Investigation 10-B, Optimum pH for Two Protease Enzymes
**The Large Intestine**

After the nutrients in digested food have been absorbed from the small intestine into the bloodstream, the remaining material moves into the large intestine, or *colon*, shown in **Figure 10.14**. This part of the digestive system is much shorter and wider than the small intestine.

The main function of the large intestine is to absorb water from the alimentary canal. About 90 percent of the water is absorbed back into the blood and extra-cellular fluids. The volume of the indigestible food matter (mostly indigestible plant matter) is therefore reduced by about two thirds.

![Image of colon](image)

**Figure 10.14** This view of a healthy colon shows its high number of blood vessels and its ring-like muscular wall. This image is of the final part of the large intestine, where it joins to the rectum.

Billions of anaerobic bacteria (bacteria that do not live or grow in the presence of oxygen) in the colon break down undigested matter further. Some of these bacteria produce important vitamins, including folic acid, several B vitamins, and vitamin K, which are absorbed into the bloodstream through the colon. The leftover matter forms feces, which are pushed by muscular contractions of the colon into the *rectum*.

The typical brown colour of feces is due to the bacterial breakdown of *bilirubin*. Bilirubin is a by-product of the breakdown of hemoglobin (the protein that carries oxygen in the blood). Bilirubin gets secreted into the bile in the liver.

Fecal odour comes from gases produced by bacterial activity. The rectum stores the feces until they are eliminated at the anus. **Table 10.6** summarizes the primary function of each structure in the digestive system and how long food usually remains in each structure as it is being digested.

**Table 10.6** Time Required for Human Digestion

<table>
<thead>
<tr>
<th>Digestive Structure</th>
<th>Primary Function</th>
<th>Time Food Spends in Each Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mouth</td>
<td>Mechanical and chemical digestion</td>
<td>5–30 s</td>
</tr>
<tr>
<td>Esophagus</td>
<td>Transport (swallowing)</td>
<td>10 s</td>
</tr>
<tr>
<td>Stomach</td>
<td>Mechanical and chemical digestion</td>
<td>2–24 h</td>
</tr>
<tr>
<td>Small intestine</td>
<td>Mechanical and chemical digestion</td>
<td>3–4 h</td>
</tr>
<tr>
<td>Large intestine</td>
<td>Water absorption</td>
<td>18 h–2 days</td>
</tr>
</tbody>
</table>
Section Summary

- The human digestive system is made up of the alimentary canal and three accessory organs: the liver, the pancreas, and the gall bladder.
- Food is transported from the esophagus to the stomach by wave-like muscular contractions known as peristalsis.
- Although chemical digestion begins in the mouth and continues in the stomach, most chemical digestion occurs in the small intestine.
- The large intestine absorbs water from the alimentary canal and forms feces, which are eliminated as solid waste.
- Different types of enzymes are involved in the chemical digestion of carbohydrates, proteins, and fats.
- The levels of pH differ throughout the digestive system, to allow optimum enzyme function.

Review Questions

1. **K/U** Use the diagram below to answer the following questions.
   a. Identify the body part(s) where digestion of carbohydrates occurs.
   b. Identify where digestion of proteins occurs.
   c. Which is the longest section of the alimentary canal?
   d. Where does most absorption in the digestive system take place?

2. **C** Create a graphic organizer, such as a flowchart or a table, that compares the chemical digestion of the four types of macromolecules as they move through the following body parts: oral cavity, esophagus, small intestine, and large intestine. Include any enzymatic digestion that occurs along the way.

3. **K/U** The small intestine is divided into three different regions. Describe the structure and function of each of these regions.

4. **K/U** Your friend is convinced that digestion begins in the stomach. Is this true or false? Explain your answer.

5. **T/I** Infer how the food reaches an astronaut's stomach when he or she is floating in zero gravity.

6. **K/U** Why does the acid in gastric juice not damage the wall of the stomach?

7. **K/U** Which structural features of the small intestine increase surface area? Why is this important?

8. **T/I** Why are most digestive enzymes not found in the stomach?

9. **A** In what ways would a digestive system that did not use mechanical digestion differ from one that does?

10. **A** After playing in the dirt, a child sticks her fingers in her mouth and ingests a significant number of bacteria but does not get sick. Explain how this child's digestive system protected her from these potentially toxic bacteria.

11. **K/U** What would an individual need to do to replace the function of their pancreas if their pancreas was removed?

12. **T/I** A new species of animal is found to have a digestive system that uses very little mechanical digestion. Describe its digestive tract.

13. **T/I** A nutritionist recommends drinking water before or after a meal, but not during a meal. Why might this be good advice?

14. **C** Use a graphic organizer to illustrate the interaction between the digestive system and the circulatory system.

15. **K/U** Explain how your body absorbs water.

16. **C** Use a graphic organizer, such as a main idea web or a fishbone organizer, to summarize the structure and functions of the large intestine in humans.
SECTION 10.3

Digestive System Disorders

Key Terms
peptic ulcer
inflammatory bowel disease
Crohn’s disease
ulcerative colitis
hepatitis
cirrhosis
diabetes

Digestive system disorders can occur when any part of the system is not working properly during the digestive process. In this section you will learn about these disorders, and how technological advances help doctors diagnose and treat them.

Peptic Ulcers
Abdominal pain, bloating, nausea, and loss of appetite can all be symptoms of a peptic ulcer. A peptic ulcer is a sore in the lining of the stomach or duodenum, where hydrochloric acid and pepsin are present. Ulcers form when the tissues become inflamed because the protective mucus that covers the lining has weakened, as shown in Figure 10.15. Ulcers are very painful because exposed, unprotected tissue comes into contact with acidic gastric juice. They can occur in people of all ages. Most ulcers begin when populations of an acid-resistant bacterium, Helicobacter pylori, attach themselves to the wall of the digestive tract and prevent that area from producing the protective mucus. Because ulcers are caused by a bacterium, they can be treated with antibiotics that kill the bacteria. Along with antibiotics, doctors also often prescribe medications that reduce acidity in the stomach. Treatment may also include lifestyle changes, such as losing weight if overweight, avoiding alcohol, and not smoking.

Inflammatory Bowel Disease
Often referred to as IBD, inflammatory bowel disease is a general name for a group of diseases that cause inflammation in the intestines. The incidence of inflammatory bowel disease is increasing in Canada—over 200,000 people (1 in 160) are living with the disease. IBD is a chronic disease, meaning that it is long lasting or recurrent. IBD can only be treated—not cured—by a special diet and by taking medication to reduce pain and inflammation. The main forms of IBD are Crohn’s disease and ulcerative colitis.

Crohn’s disease is a form of IBD that can affect any part of the alimentary canal from the mouth to the anus. Children with Crohn’s disease generally do not grow properly during puberty. They develop thinner bones that increase the future risk of fractures, and they experience poor muscle development. Ulcerative colitis is a form that attacks the colon. Symptoms of colitis include loose and bloody stools, cramps, and abdominal pain. In severe cases of IBD, it may be necessary for surgeons to remove the affected part of the colon and create a new external opening for digestive waste. Research scientists are trying to find out why these diseases of the digestive tract have been increasing among children, and why rates are much higher in western nations than in other countries.
Constipation

Constipation is a common disorder of the digestive system in which bowel movements are reduced to three per week or less and stools are dry, small, and difficult to eliminate. Constipation can be caused by inadequate water intake (which leaves the stools dry) and lack of good nerve and muscle function in the bowel. An unhealthy diet and lack of physical activity can also cause constipation.

Although fibre is not a nutrient and is not digested, it is essential for maintaining a healthy digestive system. Fibre refers to parts of fruits, vegetables, and grains that are not broken down in the digestive system— they pass through the body almost unchanged. Foods rich in fibre include whole grain bread, brown rice, whole grain pasta, oats, beans, peas, lentils, grains, seeds such as flax, some fruits, and vegetables. Most dietary fibre is made up of cellulose, which humans are unable to digest. The bulk and soft texture of fibre helps to prevent constipation.

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 but there is a vaccine to protect against it. Hepatitis C is usually contracted by contact with infected blood. There is no vaccine for hepatitis C.

Figure 10.16 shows part of the liver of someone who has 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 has the 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.

Another common disorder that affects the accessory organs 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 (a fat-like substance found in the blood and cells) in the bile can precipitate out of the bile and form crystals. The crystals grow and become gallstones. 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 omega-3 fatty acids (unsaturated fats that are found in fish and nut oils), and decreasing the size of meals. If the gallstone problem is serious, the entire gall bladder may need to be surgically removed.
19. How do *Helicobacter pylori* cause the condition shown in Figure 10.15? Explain your answer.

20. Identify some lifestyle changes that can reduce the risk of developing a gallstone.

21. Why might Crohn’s disease be difficult to diagnose?

22. Distinguish between inflammatory bowel disease, Crohn’s disease, and ulcerative colitis, and describe in which part of the digestive tract each disease occurs.

23. Define the following disorders of the digestive system, and identify the causes of each.
   a. constipation
   b. hepatitis
   c. cirrhosis

24. Why are coffee and citrus fruits, such as oranges and grapefruits, not recommended for patients with ulcers?

---

**Learning Check**

---

**The Endoscope and Digestive System Disorders**

Modern technology allows surgeons to locate, diagnose, and remove ulcers, tumours, and other problems of the digestive tract without having to cut into the body of the patient. Recall that the alimentary canal is a tube running from the mouth to the anus. Therefore, physicians can get access to it through these natural openings at either end. A device used for this purpose is the endoscope.

The endoscope often helps to confirm medical problems that are hard to observe using other methods, such as X rays. It allows a surgeon to visually inspect the lining of any part of the alimentary canal, including the stomach as shown in Figure 10.17 (A). Other attachments that can be fitted to the endoscope include a camera to photograph and record portions of the alimentary canal for further study; a laser that can be used to cut through tissue and seal blood vessels; and tiny forceps that can be used to extract samples of tissue for laboratory examination.

A more recent development is the capsule endoscope, shown in Figure 10.17 (B)—a tiny camera placed inside a capsule that can be swallowed. The capsule endoscope is especially useful for seeing inside the small intestine, which is too long and coiled to allow an endoscope tube to be pushed through its entire length.

---

*Figure 10.17 (A) Doctors perform an endoscopy to examine a woman’s stomach and take a tissue sample (a biopsy). (B) The patient swallows a tiny capsule endoscope. Over the next eight hours, it travels down the digestive tract, where it takes about 30 pictures per second.*

---

Technologies such as endoscopy are known as non-invasive surgery, in contrast to traditional surgery in which a physician must cut into the body to repair or remove tissues and organs. Non-invasive surgery is relatively painless and allows patients to recover much faster than they do from traditional surgery. Complications from non-invasive surgery are rare. It can be carried out with only a local anesthetic, and it reduces the risk of infection.
Diabetes

Diabetes is a chronic disease in which body cells are unable to use glucose to provide energy for muscles and tissues. Normally, the pancreas releases insulin into the bloodstream after the individual has eaten. Insulin allows glucose from the digested food to enter the body’s cells, and this lowers the amount of glucose circulating in the bloodstream throughout the body. As the glucose level in the bloodstream drops, so does the release of insulin from the pancreas. As you learned earlier in the chapter, glycogen can be temporarily stored in the liver so that when the insulin level gets low—for example, when you have not eaten for a while—some of that stored glycogen is converted back to glucose to keep the blood glucose at a normal level.

Diabetes develops when there is not enough insulin in the bloodstream or when the body cannot properly use the insulin that the pancreas makes. Without insulin, glucose cannot get into the cells and the glucose level in the blood can increase to life-threatening levels.

The Three Types of Diabetes

The three types of diabetes are type 1, type 2, and gestational diabetes. Type 1 diabetes occurs when the insulin-producing cells of the pancreas are destroyed by the immune system and therefore no longer produce insulin. Type 1 diabetes is most often diagnosed in children, teens, and young adults. Type 2 diabetes occurs when either the body does not make enough insulin or it is unable to properly use the insulin it makes. Although Type 2 diabetes is most often diagnosed in people over the age of 40, it is becoming increasingly common in children and adolescents.

Gestational diabetes can develop during pregnancy. Even though this type of diabetes often ends when the baby is born, women who have had gestational diabetes are more likely to develop type 2 diabetes later in life. Gestational diabetes is often the result of pregnancy hormones or inadequate levels of insulin production.

Canadian Contributions to Diabetes Research

In 1922, Canadian scientists Frederick Banting and Charles Best, seen in Figure 10.18, discovered the connection between insulin and diabetes. Before then, diabetes usually resulted in early death.

After Banting and Best demonstrated that insulin injections could help people with diabetes, the University of Toronto’s Connaught Laboratories developed ways to produce the hormone in large quantities. Some of these methods are described on the following page. The production of insulin in such large quantities has prolonged the lives of millions of people around the world.

Figure 10.18 Charles Best (left) and Frederick Banting (right) discovered that people suffering from diabetes could be saved from an early death by taking injections of the pancreatic hormone insulin.
Technological Advances in Treating Diabetes

Diabetes is becoming a more common medical condition in Canada as a result of increasingly sedentary lifestyles and an ageing population. Figure 10.19 shows a steady increase in the number of Canadians with diabetes over a seven-year period. According to Statistics Canada, from the period 2001 through 2008, men were more likely than women to report that they had diabetes. In 2008, the incidence of diabetes ranged from 0.3% at ages 12 to 19 to 16.0% for seniors (65 or older). At ages 20 to 34, women were more likely than men to have diabetes (1.1% versus 0.6%), but by age 55 men were more likely than women to be diabetic.

![Figure 10.19](image)

**Figure 10.19** Survey respondents were asked to report diabetes that had been diagnosed by a doctor, so type 1, type 2, and gestational diabetes are all included in these percentages.

According to the Public Health Agency of Canada, the risk factors for diabetes also include being of advanced age, having a family history of the disease, and belonging to certain high-risk ethnic groups (Aboriginal peoples and people of African, Asian, Hispanic, and Pacific Island descent). To meet a growing demand for improved treatment for diabetes, scientists have developed several new technologies, described below.

Manufacturing Human Insulin

Until the early 1980s, insulin used to treat diabetes was extracted from pigs or cattle. However, the human body treats these kinds of insulin as a “foreign” contaminant, and injections of this type of insulin eventually trigger an immune response. The immune response is how the body recognizes and defends itself against bacteria and other harmful substances.

The development of genetic engineering during the 1990s allowed pharmaceutical companies to manufacture human insulin using bacteria and modified bacterial **plasmids**, as shown in Figure 10.20. A plasmid is a circular molecule of DNA that is commonly found in bacteria. Large vats of genetically engineered bacteria produce human insulin in the lab, and this is now the main source of insulin for people with diabetes in Canada.

![Figure 10.20](image)
Timing Insulin Delivery

Until the 1980s, people with diabetes had to monitor their blood glucose levels regularly using a glucose meter in order to know when to inject insulin into their bloodstream at times when it was most needed. To replace this form of monitoring, researchers developed computerized insulin pumps, as shown in Figure 10.21. The device includes the pump itself (the processing module, controls, and batteries) and a disposable internal insulin reservoir. It also comes with a disposable infusion set, consisting of a cannula (a soft plastic needle) and the tubing that runs from the insulin reservoir to the cannula.

An advantage of this technology is that it provides better control over blood glucose levels, reducing the risk of long-term complications that can affect the eyes, kidneys, and blood vessels. A disadvantage is that pumps are far more expensive than the syringes used for insulin injection. Because a pump must be attached most of the time, users may find it uncomfortable and must avoid jarring activities that might damage it.

Figure 10.21 This small insulin pump is an alternative to multiple daily self-administered insulin shots.

---

Activity 10.3 Digestive System Cancers

Aside from lung cancer, digestive system cancers kill more Canadians than any other type of cancer. Every year, about 15,000 Canadians die of cancers of the digestive tract, including the accessory organs. According to the Canadian Cancer Society, about half of all cancers can be prevented by maintaining a healthy lifestyle. In this activity, you will research and report on one type of digestive system cancer, and evaluate the importance of technological advances in detection, diagnosis, and treatment of the disease.

Materials
- reference books
- computer with Internet access

Procedure
1. Choose one type of digestive system cancer that you would like to research, such as cancer of the esophagus, colon, rectum, stomach, pancreas, liver, or gall bladder.
2. Using print or on-line resources, research your chosen disease to find out the causes, symptoms, diagnostic technologies, treatments, and prognosis. Include in your research any screening tests that can aid in early detection of the disease.
3. Summarize your findings in an appropriate format and present them to the class.

Questions
1. What are some lifestyle factors that increase the risk of developing digestive system cancers? What lifestyle changes can help minimize this risk?
2. What are some of the social and economic costs associated with cancer? Explain your answer.
3. Evaluate the importance of technological advances in diagnosing and treating digestive system cancers.
**Do You Really Need Your Appendix?**

Today, every known human body process is at least partly understood by doctors and scientists. Many of the mysteries of circulation, respiration, and digestion have been solved. One organ, however, still has biologists stumped: the appendix. Humans have this small pouch at the intersection of the small and large intestines. What is it for?

Dr. William Parker, a professor of surgery at Duke University in North Carolina, USA, and his colleagues think they have solved the mystery, and Bob McDonald interviewed him on Quirks and Quarks to hear their theory.

**Is the Appendix a Safe Haven?**

Dr. Parker admitted that he and his colleagues were not all that interested in the appendix when they began their research. They were trying to find out how the immune system interacts with the normal (“good”) bacteria found in the intestines. The intestines contain more than 100 different species of bacteria, with numbers in the billions. The bacteria aid in digestion and absorption of food. They also help keep out “bad” bacteria that make people sick.

If the bad bacteria are present in the intestines in large numbers, the immune system triggers a reaction that cleans out the intestines—taking out the lining and everything else in an effort to flush out the bad bacteria. (We call this diarrhea.) This approach is very effective, but once the bad bacteria are gone, how do we get the good bacteria back in there?

Dr. Parker and his colleagues found evidence of large populations of good bacteria around the appendix. They think that this little pouch is ideally situated—out of the way of intestinal clean-outs—to provide a place for good bacteria to stay until the bad bacteria have been cleaned out. Parker says when it is safe, the good bacteria can emerge from the appendix to re-populate the intestines.

**Related Career**

**Nutritional counsellors** create personalized food, supplement, and lifestyle plans to help their clients achieve optimum health. Clients can range from children to seniors to professional athletes. Training to become a nutritional counsellor includes studies in anatomy, basic biochemistry, nutritional support of body systems, and environmental influences on health and disease.

**QUESTIONS**

1. Why is the function of the appendix, as proposed by Dr. Parker and his colleagues, particularly important for people living in developing countries?

2. Use the Internet or print resources to research careers in the field of natural and holistic nutrition.
Section Summary

- Ulcers in the alimentary canal are primarily caused by the bacteria *Helicobacter pylori*.
- Inflammatory bowel disease is a group of chronic diseases that cause inflammation in the intestines.
- Technological advances such as medical imaging technology and endoscopy enable doctors to diagnose and treat many diseases of the alimentary canal without the need for invasive surgery.
- The pancreas secretes insulin that regulates the absorption of glucose from the small intestine; diabetes results when there is insufficient insulin to regulate blood glucose levels.
- Genetically engineered human insulin and computerized insulin pumps are some of the technological innovations used in the control and maintenance of blood glucose levels.

Review Questions

1. **K/U** What is a peptic ulcer?
2. **K/U** Use the figure below to answer the following questions.
   - a. Identify the body part(s) where an ulcer can occur.
   - b. Identify where Crohn's disease occurs in the body.
   - c. Which body part(s) does colitis affect?
   - d. What organ does hepatitis target?

3. **C** Create a table that compares the causes of, symptoms of, and treatments for the following digestive system disorders: ulcers, inflammatory bowel disease, cirrhosis, and gallstones.
4. **A** Your friend may have a stomach virus and she vomits violently in class. She is concerned because she sees a green tint in her vomit. What do you suppose that is? Explain your answer.
5. **A** List five important questions that a gastroenterologist (a medical doctor who specializes in digestive disorders) should ask every new patient prior to diagnosis or treatment.
6. **T/I** Diseases of the liver can be fatal. Why is the liver such an important organ?
7. **K/U** Summarize the differences between a traditional endoscope and a capsule endoscope.
8. **K/U** Why might an endoscope be used for retrieving foreign objects in the alimentary canal?
9. **C** Create a Venn diagram that compares the costs and benefits of using capsule endoscopy as compared to traditional endoscopy for detecting gastrointestinal disorders.
10. **K/U** What are the three types of hepatitis, and how is each type contracted?
11. **A** For health reasons, particularly to fight cancer, certain organs of the digestive system may be removed or altered. Which organs are vital to digestion and, thus, could not be removed?
12. **C** Make a table to compare and contrast the advantages and disadvantages of using self-delivery insulin injections compared with using a computerized insulin pump.
13. **A** Would a capsule endoscope be useful for viewing the interior of the pancreas? Explain.
14. **T/I** Your friend complains about having hard stools, infrequent bowel movements, and difficulty having bowel movements. What diagnosis would your friend's doctor probably make based on these symptoms? What advice would the doctor likely provide to relieve these symptoms?
15. **A** An older friend of the family has just had her gall bladder removed. Describe the kind of diet you think she would be wise to follow.
16. **T/I** Why do you think the incidence of diabetes is generally higher among elderly people than in younger people?
An Accident and an Opportunity

On June 6, 1822, an army surgeon at Mackinac Island, on Lake Huron, recognized a unique opportunity to learn how the stomach works. A 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 ThoughtLab, you will infer some of what Beaumont discovered based on excerpts from the journal he kept.

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.

Pre-Lab Questions

1. What is the source of data for this activity?
2. What substances is gastric juice made up of?
3. Why might people in Beaumont’s time have believed the stomach heated up when people ate?

Question

What important contributions did William Beaumont make to our current understanding of the digestive process?

Organize the Data

1. Read the excerpts from William Beaumont’s journal on the following page.
2. As you read, make notes to help you organize and summarize the information.
Excerpts from William Beaumont’s Journal

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 [sic] a gill [about 142 mL] of water, I took from his 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 esophagus, 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.

Analyze and Interpret
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 the case?

Conclude and Communicate
5. Summarize the significance of the discoveries Beaumont described in Excerpt F.

Extend Further
6. INQUIRY Beaumont was a surgeon by profession. In what ways was he also a research scientist? Justify your answer.
7. RESEARCH 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.
Optimum pH for Two Protease Enzymes

Two protease enzymes, pepsin and trypsin, are secreted at different stages and at different sites during human digestion. Each of the two protease enzymes works best at an optimum pH. The stomach has a pH of about 2 and the small intestine has a pH of between 7 and 8. In this investigation, you will compare the optimum pH at which these two enzymes work.

Pre-Lab Questions
1. Why do you have to wear safety glasses and protective clothing while conducting this investigation?
2. What does the test tube label P-8 signify?
3. What do you expect the two protease enzymes to do?

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

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 C tubes are controls, the P tubes will contain pepsin, and the T tubes will contain trypsin. The numbers indicate the pH of the contents of the test tubes. Place the test tubes in the test tube rack.
2. Put three cubes of boiled egg white into each test tube. Prepare a data table like the one below. Record the size and appearance of the cubes in each tube in the table.

### Appearance of Egg Cubes Before and After Digestion

<table>
<thead>
<tr>
<th>Test Tube</th>
<th>Before Digestion</th>
<th>After Digestion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Size of Cubes</td>
<td>Appearance of Cubes</td>
</tr>
<tr>
<td>C-2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P-2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P-8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T-2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T-8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. Add 5 mL distilled water to each test tube labelled C. Add 5 mL pepsin solution to each test tube labelled P. Add 5 mL trypsin solution to each test tube labelled T.

4. Add 5 mL dilute hydrochloric acid to each test tube labelled 2. Add 5 mL dilute sodium hydroxide to each test tube labelled 8.

5. Place the tubes in a water bath and leave them overnight at a temperature set between 35°C and 39°C.

6. Observe the contents of each test tube and record your observations in the table.

7. Dispose of the contents of the tubes as directed by your teacher, and clean up your work area.

### Analyze and Interpret

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

### Conclude and Communicate

4. Based on your results, which enzyme would be most effective in the small intestine? Explain your answer.
5. Based on your results, which enzyme would be most effective in the stomach? Explain your answer.

### Extend Further

6. **INQUIRY** What conditions may slow down the level of activity of these proteases, or even destroy them?

7. **RESEARCH** Conduct research on enzymes that function in extreme conditions, and why many modern industries are interested in these extreme enzymes.
The administrators at your school have proposed a ban on the sale of conventional snack foods in the school cafeteria. They want to replace these foods with functional foods such as low-calorie junk food—for example, low-fat, low-salt popcorn instead of potato chips, high fibre grain and nut bars, fortified beverages, and yogurt with probiotics. (Probiotics are the “good” bacteria that live in your digestive tract. They are often added to food to boost digestive health.) The school administrators’ goal is to promote healthier eating habits for everyone in the school. They are concerned about recent statistics showing a steady increase in obesity, as well as increased risk for heart disease, type 2 diabetes, and some types of cancer, even among young people.

Some students support the administration’s proposal and view this change in snack food choices as a positive one. However, other students oppose the change. They insist that no research solidly demonstrates that functional foods are more beneficial to health and well-being than conventional foods. They also say that the school should not impose decisions about food choices on students. The student council has called an after-school meeting to let both sides state their points of view and to try to resolve the issue.

What Are Functional Foods?

All types of foods provide the nutrients that your body needs, to varying degrees. But some foods, known as functional foods, apparently do more for your body than just provide essential nutrients. Some nutritionists and manufacturers of functional foods claim that these foods perform specific beneficial functions in the body. These functions include strengthening the immune system, preventing and treating disease, controlling certain physical or mental conditions, or slowing the ageing process.

There are several different categories of functional foods. Whole foods contain a natural level of a functional component, such as the antioxidant beta-carotene in carrots, or the dietary fibre in wheat bran, oats, and barley. (Antioxidants are substances that protect the body’s cells from damage caused by environmental stressors such as air pollution, radiation, and cigarette smoke.) Fortified foods contain added ingredients, such as calcium-fortified fruit juice. Enhanced foods contain a functional component that has been introduced into the organism from which the food comes—through breeding, feeding, or genetic engineering. For example, chickens are fed fish oil, which naturally contains omega-3 fatty acids. Thus, the chickens produce omega-3-enhanced eggs. Some examples of functional foods and their potential health benefits, are shown in the table.
Research and Analyze

1. Multifunctional foods are foods that serve more than one function, such as satisfying a snack craving while claiming to provide a specific health benefit. What types of products have resulted from society’s demand for multifunctional foods, such as low-calorie snack foods? Research some popular snack foods that claim to be healthy snacks, and compare these foods to the conventional version of that snack food. Summarize the similarities and differences between the two versions of the food. As part of your analysis, include whether you think the manufacturers’ claims related to the “healthy” version are valid.

2. Lifestyle-related chronic disorders are a major factor in Canada’s increasing health-care costs. Heart disease, diabetes, cancer, obesity, arthritis, and osteoporosis are all linked in part to poor nutrition and lifestyle habits. Research Health Canada’s current initiatives related to manufacturers’ health claims for functional foods. Write a paragraph to summarize your findings. State whether you believe consumers are adequately protected against potentially false health claims by food manufacturers.

3. Consumer demand for functional foods has grown rapidly since 2000 as people respond to advertisements claiming that these foods can improve their health and well-being. Based on your research, evaluate whether eating functional foods is a valid means to improve health and well-being.

Take Action

1. In a group, discuss the pros and cons of choosing functional foods over the conventional versions of these foods. What are the differing points of view within your group? What other questions might you ask about functional foods before you choose which type of food is right for you? Share with your group the results of your research and analysis from questions 1 to 3 above. Determine whether your group will support or challenge the school administrators’ proposal to substitute functional snack foods for conventional snack foods.

2. Within your group, prepare a draft of a presentation that you will make at the student council meeting. State your position on whether the school administration’s proposal should be challenged. Support your point of view with information from current and credible sources.
### Section 10.1 The Function of Digestion

Digestion is the process by which essential nutrients are broken down to provide the raw materials for energy, cellular activities, and to build and repair tissues.

**KEY TERMS**
- alimentary canal
- amino acid
- chemical digestion
- disaccharide
- enzyme
- essential nutrient
- glycogen
- hydrolysis

**KEY CONCEPTS**
- There are four major categories of macromolecules that contain the essential nutrients needed to maintain life: carbohydrates, lipids, proteins, and nucleic acids.
- Macromolecules are chemically broken down by hydrolysis, a process that uses certain enzymes as catalysts.
- Water helps transport materials around the body, lubricate joints, form vital fluids such as blood, and regulate body temperature.
- To digest their food, most animals have a digestive tract that consists of a tube known as the alimentary canal.
- The four stages of food processing in animals are ingestion, digestion (mechanical and chemical), absorption, and elimination.

### Section 10.2 The Human Digestive System

The human digestive system is made up of a tube-like alimentary canal with the specialized organs and chemical environments needed to digest and absorb nutrients and eliminate undigested waste.

**KEY TERMS**
- bile
- chyme
- duodenum
- esophagus
- gastric juice
- ileum
- jejunum
- pepsin
- peristalsis
- saliva
- salivary glands
- villi

**KEY CONCEPTS**
- The human digestive system is made up of the alimentary canal and three accessory organs: the liver, the pancreas, and the gall bladder.
- Food is transported from the esophagus to the stomach by wave-like muscular contractions known as peristalsis.
- Although chemical digestion begins in the mouth and continues in the stomach, most chemical digestion occurs in the small intestine.
- The large intestine absorbs water from the alimentary canal and forms feces, which are eliminated as solid waste.
- Different types of enzymes are involved in the chemical digestion of carbohydrates, proteins, and fats.
- The levels of pH differ throughout the digestive system, to allow optimum enzyme function.

### Section 10.3 Digestive System Disorders

Technological advances enable doctors to diagnose and treat digestive system disorders such as ulcers, inflammatory bowel disease, cancer, diabetes, and diseases of the accessory organs.

**KEY TERMS**
- cirrhosis
- Crohn's disease
- diabetes
- hepatitis

**KEY CONCEPTS**
- Ulcers in the alimentary canal are primarily caused by the bacteria *Helicobacter pylori*.
- Inflammatory bowel disease is a group of chronic diseases that cause inflammation in the intestines.
- Technological advances such as medical imaging technology and endoscopy enable doctors to diagnose and treat many diseases of the alimentary canal without the need for invasive surgery.
- The pancreas secretes insulin that regulates the absorption of glucose from the small intestine; diabetes results when there is insufficient insulin to regulate blood glucose levels.
- Genetically engineered human insulin and computerized insulin pumps are some of the technological innovations used in the control and maintenance of blood glucose levels.
Knowledge and Understanding

Select the letter of the best answer below.

1. To leave the digestive tract, a substance must cross a cell membrane. During which stage of food processing does this take place?
   a. ingestion
   b. digestion
   c. elimination
   d. absorption
   e. hydrolysis

2. What is the first type of macromolecule that is broken down by enzymes in the human digestive tract?
   a. carbohydrates
   b. lipids
   c. nucleic acids
   d. fats
   e. proteins

3. Which of the following is a monosaccharide?
   a. glycogen
   b. starch
   c. carbohydrase
   d. glucose
   e. sucrose

4. Which of the following statements is true of digestion in humans?
   a. All foods begin their enzymatic digestion in the mouth.
   b. After leaving the oral cavity, the bolus enters the larynx.
   c. The epiglottis prevents food from entering the trachea.
   d. Enzyme production continues in the esophagus.
   e. The trachea leads to the esophagus and then to the stomach.

5. What part of the digestive system has secretions with a pH as low as 2?
   a. small intestine
   b. stomach
   c. pancreas
   d. liver
   e. mouth

6. Which of the following pairs of organs and functions is incorrect?
   a. stomach, protein digestion
   b. oral cavity, starch digestion
   c. large intestine, bile production
   d. small intestine, nutrient absorption
   e. pancreas, insulin production

7. Which is the correct order of the four main stages of food processing?
   a. ingestion → digestion → absorption → elimination
   b. digestion → ingestion → absorption → elimination
   c. absorption → elimination → ingestion → digestion
   d. elimination → ingestion → digestion → absorption
   e. ingestion → elimination → absorption → digestion

8. How do we refer to animals that sift small food particles from the water?
   a. filter feeders
   b. substrate feeders
   c. fluid feeders
   d. bulk feeders
   e. leaf miners

Answer the questions below.

9. Chyme, bolus, and feces are all undigested food materials in the digestive tract. Which of these enables nutrients to be absorbed during digestion? Explain your answer.

10. In your notebook, state whether each of the following statements is true or false. If the statement is false, rewrite it so that it is true.
    a. After surgical removal of an infected gall bladder, a person must be especially careful to minimize protein intake.
    b. You can expect to see a large cecum in rabbits, horses, and herbivorous bears.
    c. A substance that increases water reabsorption in the large intestine can contribute to constipation.

11. The pH of the stomach is fairly acidic, and the rate of protein digestion is high enough that the cells of the stomach are at risk of self-digestion. Explain what prevents this from happening.

12. Why is it important to chew your food when you eat?

13. Explain the function of the esophagus.

14. Explain the role of the liver in the digestion of fats, and describe the importance of this process.

15. Identify each statement about what happens in the large intestine as true or false. Explain why each false statement is false.
    a. Waste materials are concentrated and eliminated.
    b. Digestible food matter passes through the colon.
    c. The removal of water and salts reduces volume.
    d. Undigested remains form feces.
    e. Feces are stored in the rectum.

16. Refer to Figure 10.11 showing the gall bladder and surrounding organs. Assess how and where gallstones can cause serious problems if they are not removed.
Thinking and Investigation

17. A new diet pill claims that it can help a person lose weight by turning off enzyme production in the stomach. Why do people think this will help them reduce weight? What are some possible side effects?

18. Gastroesophageal reflux disease (GERD) is a chronic disease in which gastric juice flows up into the esophagus. What could be some of the complications of this disease if it is left untreated?

19. Diseases such as pancreatic cancer and human immunodeficiency virus (HIV) can interfere with the healthy functioning of the pancreas. What would happen to the digestion of carbohydrates, proteins, and fats when the pancreas is dysfunctional?

20. Groups of organs with specific structures and functions work together as systems, which interact with other systems in the body. Copy the table below into your notebook, and fill in the missing rows to analyze how the digestive system interacts with other systems in the body. Give your table a title.

<table>
<thead>
<tr>
<th>System</th>
<th>Interconnection with Digestive System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integumentary</td>
<td>Vitamin D in the skin plays a role in the absorption of calcium.</td>
</tr>
<tr>
<td>Skeletal</td>
<td></td>
</tr>
<tr>
<td>Muscular</td>
<td></td>
</tr>
<tr>
<td>Nervous</td>
<td>This influences digestive system activity.</td>
</tr>
<tr>
<td>Lymphatic</td>
<td></td>
</tr>
<tr>
<td>Cardiovascular</td>
<td></td>
</tr>
<tr>
<td>Respiratory</td>
<td></td>
</tr>
</tbody>
</table>

21. The following questions relate to the graph below.
   a. Describe what is happening in the graph, and why.
   b. Suggest a reason why blood insulin levels peak after blood glucose levels do, rather than at exactly the same time. How might this explain why people sometimes experience a sugar craving a few hours after a sizeable carbohydrate-rich meal?

22. The time food stays in the various parts of the human digestive tract under normal conditions is as follows:
   - stomach: 4 to 6 hours
   - small intestine: 2 to 4 hours
   - large intestine: 24 to 48 hours

   Use the above information to answer the following questions:
   a. Why do many people get hungry at mealtime?
   b. Why do you have a bowel movement every day or every two days?

23. Someone helps out at the scene of a car accident. Based on what you have learned about disorders of the accessory organs, what disease could this person be at risk of contracting if they were to make contact with the blood of an infected person?

24. You are studying birds and you notice that they do not have teeth. What do you predict about digestion in the mouth of birds?

Communication

25. Write a brief essay about how the esophageal and pyloric sphincters increase the efficiency of digestion in humans.

26. You are asked to write a script for a digital animation showing digestion in the body. Write an outline of the script that summarizes how you will show different macromolecules breaking down in the body.

27. Create a Venn diagram that compares and contrasts how sugars and lipids move from the small intestine to body cells. Use the image below to help you.

28. Create a main idea web of a few examples of technology related to the human digestive system. Put “the needs of society” in the centre, and include what each piece of technology is used for.
29. Conduct research on one disorder of the digestive system. Look into the causes and symptoms of the disorder, how it is diagnosed and treated, and any new advances in the treatment of the disorder. Create a pamphlet based on your findings.

30. Create a Venn diagram that shows the relationships among inflammatory bowel disease, Crohn's disease, and colitis.

31. The development and uses of technology to maintain human health are based, in part, on the changing needs of society. Self-administered insulin injections are being replaced by insulin pump therapy because it is more convenient and more reliable. But consider the technical issues that arise if the insulin pump malfunctions. Create a handout to compare and contrast the costs and benefits of insulin injections and insulin pump therapy.

32. Summarize your learning in this chapter using a graphic organizer. To help you, the Chapter 10 Summary lists the Key Terms and Key Concepts. Go to Using Graphic Organizers in Appendix A for help with deciding which type of graphic organizer to use.

Application

33. Pizza is considered to be a fairly nutritious food compared to other fast foods. Analyze the nutritional value of pizza based on what you learned in the chapter.

<table>
<thead>
<tr>
<th>Food in Pizza</th>
<th>Nutrients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheese</td>
<td></td>
</tr>
<tr>
<td>Meat</td>
<td></td>
</tr>
<tr>
<td>Crust</td>
<td></td>
</tr>
<tr>
<td>Broccoli</td>
<td></td>
</tr>
<tr>
<td>Tomato sauce</td>
<td></td>
</tr>
</tbody>
</table>

34. Stem cells have the potential to develop into nearly any kind of cell when they mature. How might advances in stem cell research contribute to new treatments for diabetes?

35. Identify whether each of the following factors can or cannot contribute to type 2 diabetes. Explain your answers.
   a. gestational diabetes
   b. obesity
   c. immune system-mediated destruction of insulin-producing cells
   d. a diet that includes a high proportion of carbohydrate-rich convenience foods
   e. a situation in which insulin does not bind to the surface of cells

36. Diabetes occurs when the special cells in the pancreas do not make enough insulin. As a result, the person's blood glucose rises. The body cells are being starved for glucose because the glucose stays in the blood rather than moving into the cells. Using what you have learned in previous studies about osmosis, explain why excess blood glucose also dehydrates cells in people with diabetes.

37. Some people have a band surgically inserted near the top of the stomach to help them control their weight. What impact would this have on their digestion?

38. Identify the organs below and write a summary of what happens in each.

39. What gastrointestinal disorders might stimulate the contraction of the diaphragm and the abdominal muscles, which can cause you to vomit? Based on your knowledge of the body, is there anything else that might initiate vomiting?

40. Through genetic engineering, scientists can manufacture large quantities of the protein insulin for treating diabetes. This is done by inserting human DNA with genes for making insulin into bacterial plasmids. Based on basic principles of genetics and evolution, why is it possible to insert a gene from a human into the DNA of bacteria to make insulin?
Select the letter of the best answer below.

1. K/U Which is an example of a fluid feeder?
   a. a sponge that filters food particles from the water
   b. a butterfly that drinks nectar from a flower
   c. a lion that tears apart its caught prey
   d. a rabbit that chews on tough leaves
   e. a dog that licks water from a bowl

2. K/U During which stage of food processing do enzymes help break apart large macromolecules into smaller molecules?
   a. ingestion
   b. filtration
   c. digestion
   d. absorption
   e. elimination

3. K/U Which macromolecule is first broken down by digestive enzymes in the stomach?
   a. protein
   b. carbohydrate
   c. cholesterol
   d. glycogen
   e. glucose

4. K/U In what organs and/or body structures do you find enzymes that break down carbohydrates?
   a. pancreas, small intestine, and large intestine
   b. liver and gall bladder
   c. stomach, liver, and small intestine
   d. mouth, pancreas, and small intestines
   e. esophagus, stomach, and pancreas

5. K/U Which two types of molecules make up the macromolecules known as lipids?
   a. glycerol and phospholipids
   b. triglycerides and phospholipids
   c. glycerol and fatty acids
   d. triglycerides and glycerol
   e. phospholipids and fatty acids

6. K/U In which part of the digestive system does trypsin work?
   a. mouth
   b. esophagus
   c. stomach
   d. small intestine
   e. large intestine

7. K/U Which of the following organs is correctly paired with one of its functions?
   a. pancreas, starch digestion
   b. liver, protein digestion
   c. large intestine, bile production
   d. oral cavity, nutrient absorption
   e. liver, bile storage

8. K/U Which are two major sources of energy in the human body?
   a. carbohydrates and proteins
   b. lipids and carbohydrates
   c. nucleic acids and lipids
   d. water and lipids
   e. proteins and minerals

9. K/U Which is an example of mechanical digestion?
   a. digestion of sugars in the small intestine
   b. bile salts combining with fat droplets
   c. bile production by the liver
   d. chewing food in the mouth
   e. proteins that transport ions in cell membranes

10. K/U Which compound is important for storing energy in plants?
    a. starch
    b. phospholipids
    c. glycogen
    d. maltose
    e. insulin

Use sentences and diagrams as appropriate to answer the questions below.

11. K/U Fish is a good source of protein. Describe some of the major functions that proteins have in your body.

12. C Examine the molecule in the diagram below.

   a. Draw a hydrolysis reaction of the disaccharide shown.
   b. List the type of end products formed.
   c. State which enzymes are involved in this process.
   d. Identify the origin of the enzymes.
13. **A** Which class of molecule is shared by all of the food items shown below, and how are they broken down in the body?

![Food Items](image)

14. **T/I** Explain why macromolecules are also known as essential nutrients.

15. **A** Sketch the diagram below into your notebook and use a coloured pencil to map out the path that food takes through the body. Shade in the important accessory organs using a different colour.

![Digestive System Diagram](image)

16. **T/I** How is food still able to propel down the esophagus when a person is hanging upside down?

17. **K/U** What are ulcers and how do they form?

18. **C** Create a handout to compare and contrast type 1 and type 2 diabetes. If you were teaching this material to students in a lower grade, what information would you use to teach them the basic differences between the two types?

19. **A** A patient has loose and bloody stools, cramps, and abdominal pain. Make a possible diagnosis.

20. **T/I** The graph below shows the effect of pH on the activity of an unknown digestive enzyme. Answer the questions that follow.

![Enzyme Activity Graph](image)

a. From your knowledge of digestive enzymes, explain the above graph. Give the graph a title.
b. What digestive enzyme may be involved in the activity shown in the graph?
c. Where is this digestive enzyme likely to be active in the body?
d. Suggest why enzyme activity is affected by pH.

21. **K/U** Why does the stomach not digest its own lining?

22. **A** Why does Crohn’s disease result in poor muscle development?

23. **T/I** Why do you think it is dangerous to take more than the recommended quantity of fat-soluble vitamins, such as vitamin A and vitamin E?

24. **C** Frederick Banting and Charles Best made an important discovery in 1922. Describe and explain the significance of their discovery to a class of grade 4 students.

25. **A** You find an organism with a large cecum that is filled with specialized bacteria. What can you infer about the organism’s diet?