38–2 The Process of Digestion

Guide for Reading

Key Concepts

- What are the organs of the digestive system?
- What is the function of the digestive system?

Vocabulary

amylase
esophagus
peristalsis
stomach
chyme
small intestine
pancreas
liver
villus
large intestine

Reading Strategy: Asking Questions Before you read, rewrite the seven blue heads in the section as *how*, *why*, or *what* questions. As you read, write brief answers to your questions.

Food presents every chordate with at least two challenges. The first is how to obtain it. Once a chordate has caught, or gathered its food, it faces a new challenge—how to break that food down into small molecules that can be passed to the cells that need them. In humans and many other chordates, this is the job of the digestive system. As food passes through the digestive system, it gets disassembled, distributing its nutrient value to the body along the way.

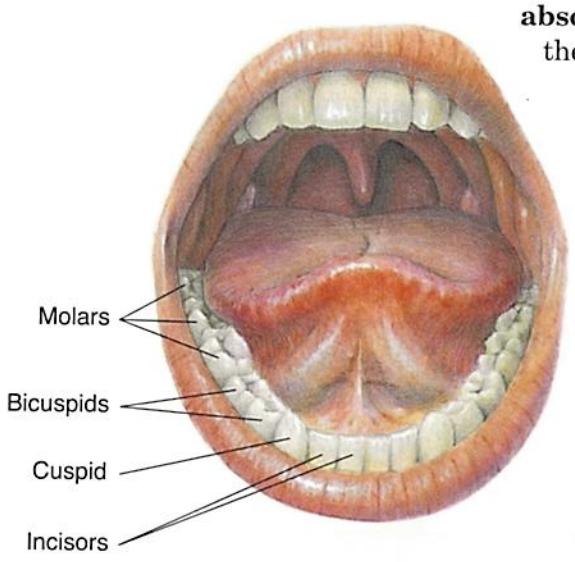
The human digestive system, like those of other chordates, is built around an alimentary canal—a one-way tube that passes through the body. **The digestive system includes the mouth, pharynx, esophagus, stomach, small intestine, and large intestine. Several major accessory structures, including the salivary glands, the pancreas, and the liver, add secretions to the digestive system.**

The Mouth

As you take a forkful of food into your mouth, the work of the digestive system begins. The teeth, shown in **Figure 38–9,** tear and crush the food into a fine paste until it is ready to be swallowed. Chewing begins the process of mechanical digestion. Mechanical digestion is the physical breakdown of large pieces of food into smaller pieces. But there is a great deal more to it than that. As you chew your food, digestive enzymes begin the breakdown of carbohydrates into smaller molecules. This process is called chemical digestion. During chemical digestion, large food molecules are broken down into smaller food molecules. **The function of the digestive system is to help convert foods into simpler molecules that can be absorbed and used by the cells of the body.** The organs of the digestive system are shown in **Figure 38–10.**

Teeth The teeth are anchored in the bones of the jaw. The surfaces of the teeth are protected by a coating of mineralized enamel. Teeth do much of the mechanical work of digestion by cutting, tearing, and crushing food into small fragments.

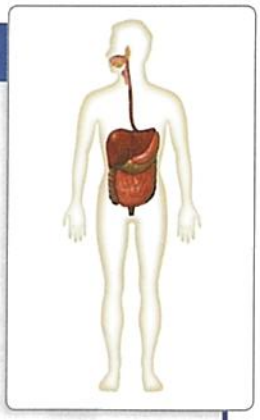
CHECKPOINT *What do the teeth do?*

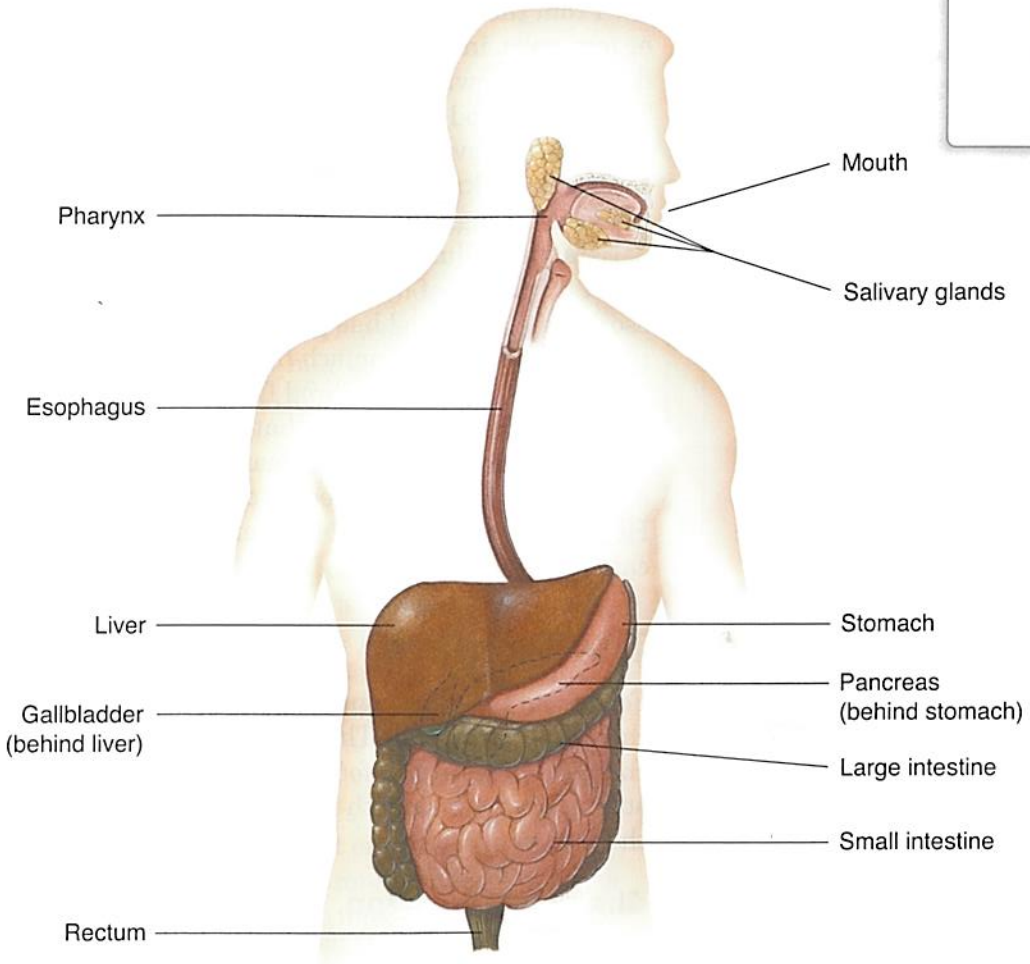


◀ **Figure 38–9** Human teeth include sharp incisors; cuspids and bicuspids, which grasp and tear food; and large, flat molars. **Inferring** *How do human teeth reflect an omnivorous diet?*

FIGURE 38–10 THE DIGESTIVE SYSTEM

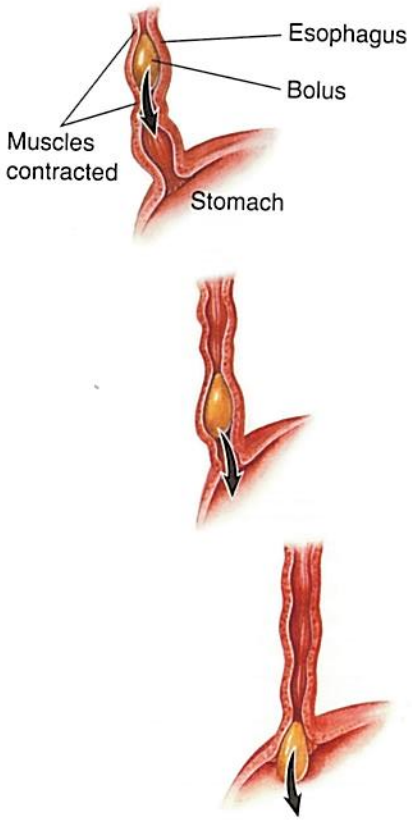
The digestive system includes the mouth, pharynx, esophagus, stomach, small intestine, and large intestine. Because the pancreas and most of the gallbladder are behind other organs, their locations are indicated by dotted lines.





Saliva As the teeth cut and grind the food, the salivary glands secrete saliva, which helps to moisten the food and make it easier to chew. The release of saliva is under the control of the nervous system and can be triggered by the scent of food—especially when you are hungry!

Saliva not only helps ease the passage of food through the digestive system but also begins the process of chemical digestion. Saliva contains an enzyme called **amylase** that breaks the chemical bonds in starches and releases sugars. If you chew on a starchy food like a cracker long enough, it will begin to taste sweet. This sweet taste is a sign that sugar has been released from starch by the action of amylase. Saliva also contains lysozyme, an enzyme that fights infection by digesting the cell walls of many bacteria that may enter the mouth with food.



▲ **Figure 38–11** Muscles in the walls of the esophagus contract in waves. Each wave pushes the chewed clump of food, or bolus, in front of it. Eventually, the bolus is pushed into the stomach.
Applying Concepts *What kind of muscle surrounds the esophagus?*

The Esophagus

During swallowing, the combined actions of the tongue and throat muscles push the chewed clump of food, called a bolus, down the throat. Recall that as you swallow, a flap of connective tissue called the epiglottis closes over the opening to the trachea. This action prevents food from blocking the air passageways to the lungs.

From the throat, the bolus passes through the **esophagus,** or food tube, into the stomach. You might think that gravity draws food down through the esophagus, but this is not correct. The reason food travels through the esophagus into the stomach is that it is moved along by contractions of smooth muscle. These contractions, known as **peristalsis** (pehr-uh-STAL-sis), squeeze the food through the esophagus into the stomach. The process of peristalsis is illustrated in **Figure 38–11.**

A thick ring of muscle, called the cardiac sphincter, closes the esophagus after food has passed into the stomach and prevents the contents of the stomach from moving back up into the esophagus. Have you ever suffered from "heartburn"? Heartburn is a painful, burning sensation that feels as if it is coming from the center of the chest (by your heart), just above the stomach. The sensation is usually caused by a backflow of stomach acid. Heartburn can be caused by overeating or drinking an excess of caffeinated drinks.

The Stomach

Food from the esophagus empties into a large muscular sac called the **stomach.** The stomach continues the mechanical and chemical digestion of food. Alternating contractions of the stomach's three smooth muscle layers thoroughly churn and mix the food you swallow.

Chemical Digestion The lining of the stomach contains millions of microscopic gastric glands that release a number of substances into the stomach. Some of these glands produce mucus, a fluid that lubricates and protects the stomach wall. Other glands produce hydrochloric acid, which makes the contents of the stomach very acidic. The acid activates pepsin, an enzyme that begins the digestion of protein and is secreted by a third set of stomach glands. Pepsin works best under the acidic conditions present in the stomach. The combination of pepsin and hydrochloric acid begins the complex process of protein digestion. Pepsin breaks proteins into smaller polypeptide fragments. While pepsin requires the acidic environment of the stomach in order to function, other enzymes such as amalyse are denatured by the stomach acid. As a result, chemical digestion of carbohydrates stops when food enters the stomach and does not resume until the food passes into the small intestine. Not all enzymes that aid in digestion are released by the stomach. Other enzymes that help in digestion are shown in **Figure 38–12.**

CHECKPOINT *What is the role of pepsin?*

Mechanical Digestion As digestion proceeds, stomach muscles contract to churn and mix stomach fluids and food, gradually producing a mixture known as **chyme** (KYM). After an hour or two, the pyloric valve, which is located between the stomach and small intestine, opens and chyme begins to flow into the small intestine.

The Small Intestine

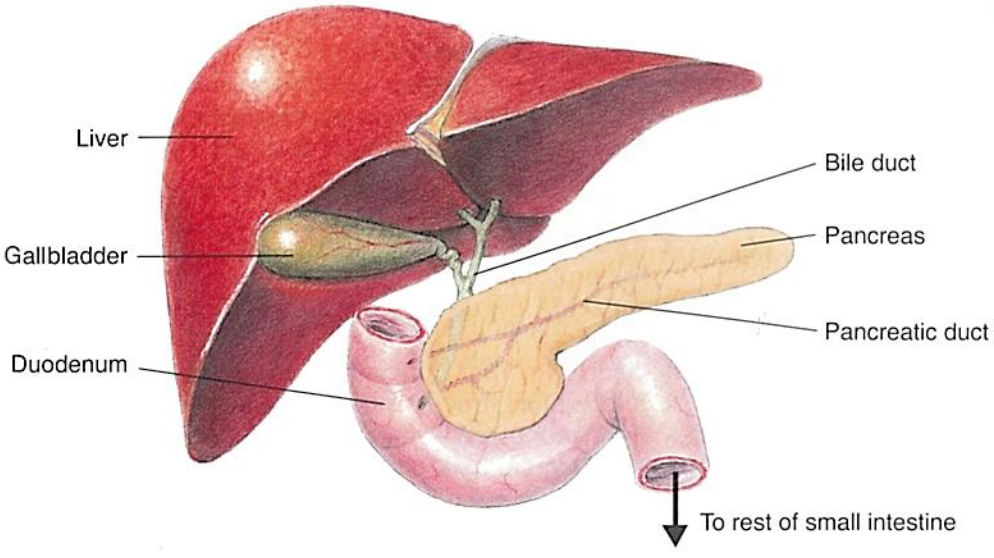
As chyme is pushed through the pyloric valve, it enters the duodenum (doo-oh-DEE-num). The duodenum is the first of three parts of the **small intestine,** and it is where almost all of the digestive enzymes enter the intestine. Most of the chemical digestion and absorption of the food you eat occurs in the small intestine. As chyme enters the duodenum from the stomach, it mixes with enzymes and digestive fluids from the pancreas, the liver, and even the lining of the duodenum itself. The pancreas and liver are shown in **Figure 38–13.**

Effects of Digestive Enzymes

Active Site	Enzyme	Effect on Food
Mouth	Salivary amylase	Breaks down starches into disaccharides
Stomach	Pepsin	Breaks down proteins into large peptides
Small intestine (from pancreas)	Amylase	Continues the breakdown of starch
	Trypsin	Continues the breakdown of protein
	Lipase	Breaks down fat
Small intestine	Maltase, sucrase, lactase	Breaks down remaining disaccharides into monosaccharides
	Peptidase	Breaks down dipeptides into amino acids

▲ **Figure 38–12** Digestive enzymes break down foods and make nutrients available to the body. **Using Tables and Graphs** *Where in the body does the digestion of carbohydrates begin?*

Accessory Structures of Digestion Just behind the stomach is the **pancreas.** The pancreas is a gland that serves three important functions. One function is to produce hormones that regulate blood sugar levels. Within the digestive system, the pancreas plays two key roles. It produces enzymes that break down carbohydrates, proteins, lipids, and nucleic acids. The pancreas also produces sodium bicarbonate, a base that neutralizes stomach acid so that these enzymes can be effective. Why is this neutralization necessary? Recall that enzymes are proteins. Stomach acid can change the shapes of protein molecules. If the shape of an enzyme's active site does not match the shape of its substrate, the enzyme will not be effective.



◀ **Figure 38–13** Accessory structures, including the liver and pancreas, add secretions to the digestive system. The pancreas secretes enzymes that help break down carbohydrates, proteins, and fats.

Assisting the pancreas is the **liver,** a large organ located just above and to the right of the stomach. The liver produces bile, a fluid loaded with lipids and salts. Bile acts like a detergent, dissolving and dispersing the droplets of fat found in fatty foods. This action makes it possible for enzymes to reach the smaller fat molecules and break them down. Bile is stored in a small, pouchlike organ called the gallbladder.

CHECKPOINT *What is bile?*

Absorption in the Small Intestine

The duodenum is much shorter than the remaining parts of the small intestine—the jejunum and the ileum, which together average about 6 meters long. By the time chyme enters these parts of the small intestine, much of the chemical digestion has been completed. The chyme is now a rich mixture of medium and small nutrient molecules.

The small intestine is specially adapted for the absorption of nutrients. The folded surfaces of the small intestine are covered with fingerlike projections called **villi** (VIL-eye; singular: villus).

Quick Lab

How do villi help the small intestine absorb nutrients?

Materials 2 paper towel sheets, scissors, 3 cardboard tubes, metric ruler, 30-mL graduated cylinder, 2 plastic cups

Procedure

1. Cut cardboard tube 1 lengthwise, and flatten it. **CAUTION:** *Scissors are sharp.* Lay paper towel sheet 1 over the flattened cardboard. Cut sheet 1 to the same size as the cardboard tube.
2. Determine the area of the flattened sheet with a ruler (area = width x length). Record the measurements.
3. Roll sheet 1 lengthwise until the sides meet but do not overlap. Insert rolled sheet 1 inside tube 2. The tube represents the small intestine, and the sheet represents an intestinal lining without villi.
4. Fold uncut sheet 2 back and forth in a zigzag pattern, as for a fan. Determine the area of sheet 2 and record the measurement. Roll sheet 2 until the sides meet, and insert it in tube 3. The folds represent an intestinal lining with villi.
5. **Predicting** Predict which model will absorb more water.
6. Stand each tube in a plastic cup. Slowly pour 30 mL of water down the inside of each tube. Remove the tubes. Then, measure and record the quantity of water in each cup.

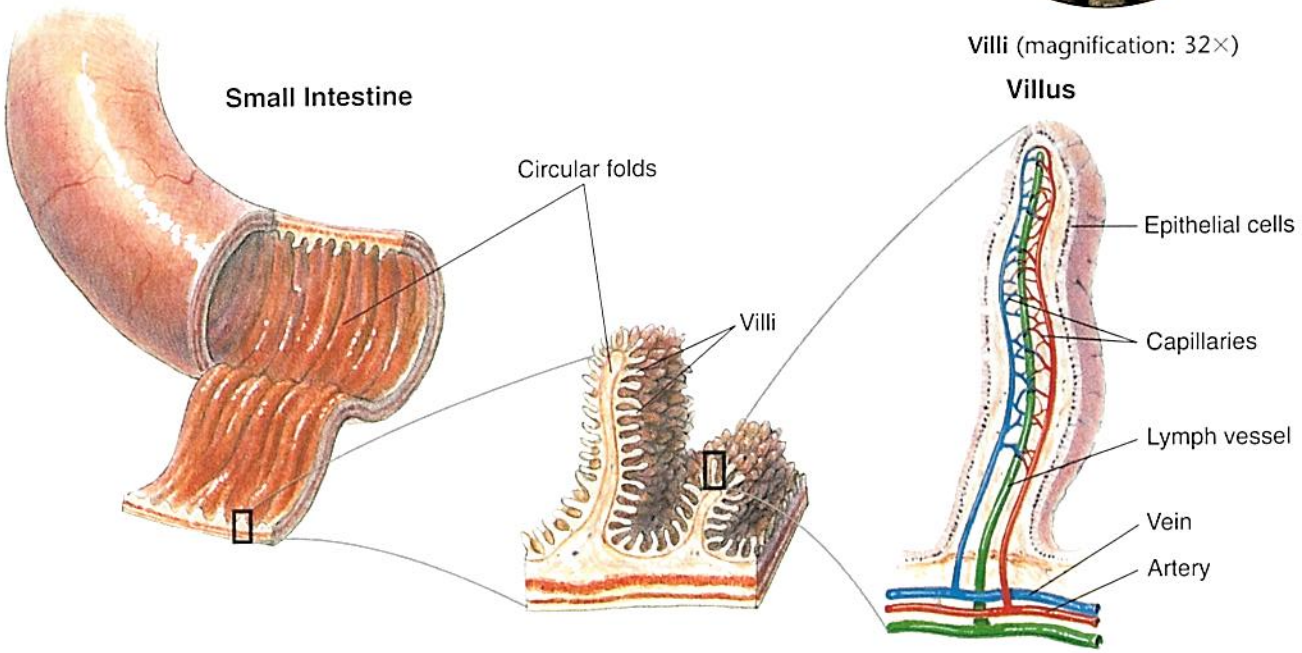
Analyze and Conclude

1. **Calculating** Use your calculations in steps 2 and 4 to show which model had more surface area.
2. **Applying Concepts** How does surface area affect the ability to absorb substances? Was your prediction in step 5 correct?
3. **Applying Concepts** How do folds and fingerlike projections affect the area of an absorbing surface? How do villi help the intestine absorb nutrients?
4. **Inferring** Your kidneys contain about 1 million microscopic structures that filter waste products from your blood. What advantage does this arrangement have over filtering the waste products out of one large blood vessel?

FIGURE 38–14 THE SMALL INTESTINE

The lining of the small intestine consists of folds that are covered with tiny projections called villi. Within each villus there is a network of blood capillaries and lymph vessels that absorb and carry away nutrients.
Applying Concepts *How do the folds in the small intestine help in absorption?*

Villi (magnification: 32×)

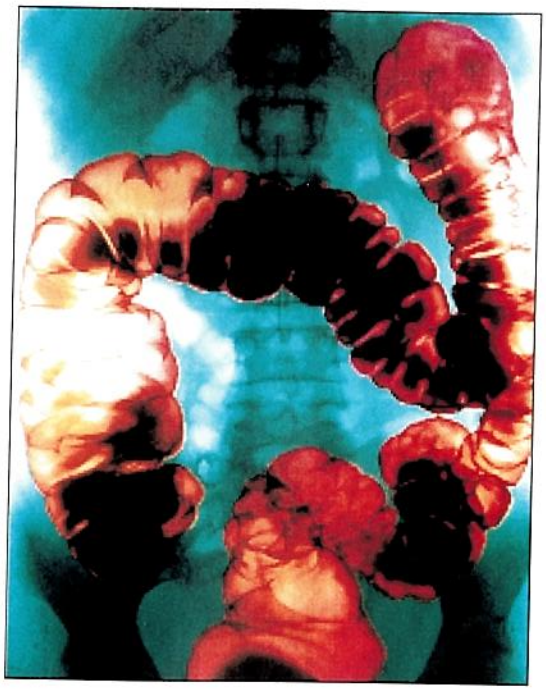


The villi are illustrated in **Figure 38–14.** The surfaces of the cells of the villi are covered with thousands of fingerlike projections known as microvilli. These folds and projections provide an enormous surface area for the absorption of nutrient molecules. Slow, wavelike contractions of smooth muscles move the chyme along this surface.

Nutrient molecules are rapidly absorbed into the cells lining the small intestine. Most of the products of carbohydrate and protein digestion are absorbed into the capillaries in the villi. Molecules of undigested fat and some fatty acids are absorbed by lymph vessels.

By the time food is ready to leave the small intestine, it is basically nutrient-free. The complex organic molecules have been digested and absorbed, leaving only water, cellulose, and other undigestible substances behind.

As the water, cellulose, and other undigestible substances leave the small intestine and enter the large intestine, they pass by a small saclike organ called the appendix. In humans, the appendix appears to do little to promote digestion. In other mammals, the appendix is used to store cellulose and other materials that the digestive enzymes cannot break down. The only time you may pay attention to the appendix is when it becomes clogged and inflamed, causing appendicitis. The only remedy for appendicitis is to remove the infected organ by surgery—as quickly as possible.



▲ **Figure 38–15** This barium X-ray shows the large intestine. **Applying Concepts** *What is the role of the large intestine?*

The Large Intestine

When the chyme leaves the small intestine, it enters the large intestine, or colon. The large intestine is shown in **Figure 38–15.** The primary function of the **large intestine** is to remove water from the undigested material that is left. Water is absorbed quickly across the wall of the large intestine, leaving behind the undigested materials. Rich colonies of bacteria present in the large intestine produce compounds that the body is able to use, including vitamin K. When large doses of antibiotics are given to fight an infection, they can destroy these bacteria and a vitamin K deficiency can occur. The concentrated waste material that remains after the water has been removed passes through the rectum and is eliminated from the body.

Digestive System Disorders

The powerful acids released into the stomach sometimes damage the organ's own lining, producing a hole in the stomach wall known as a peptic ulcer. For years, physicians hypothesized that the primary cause of ulcers was too much stomach acid. They prescribed drugs that suppressed acid production and recommended bland, easily digested diets. Scientists have since discovered that most peptic ulcers are caused by the bacterium *Helicobacter pylori*. Doctors now know that many peptic ulcers are caused by an infectious disease that can be cured. Thanks to powerful antibiotics, cure rates for peptic ulcers are as high as 90 percent.

Other digestive system disorders include diarrhea and constipation. When something happens that interferes with the removal of water by the large intestine, you usually become aware of it right away. If not enough water is absorbed, a condition known as diarrhea occurs. If too much water is absorbed from the undigested materials, a condition known as constipation occurs.

38–2 Section Assessment

1. **Key Concept** List the organs of the digestive system and give the function of each.
2. **Key Concept** Explain the function of the digestive system.
3. How do mechanical and chemical digestion work together to break down foods?
4. How does bile help in the digestion of fats?
5. **Critical Thinking Inferring** What can you infer about the diet of an animal that has a large appendix?

Focus on the BIG Idea

Matter and Energy
How would the rate of digestion be affected if enzymes were not released by the various organs and glands? You may wish to refer to Chapter 2 for a review of enzyme action.