In 1822, a man named Alexis St. Martin was wounded in the stomach. Dr. William Beaumont saved St. Martin's life. The wound, however, left an opening in St. Martin's stomach that never healed completely. Beaumont realized that by looking through the opening in St. Martin's abdomen, he could observe what was happening inside the stomach.

Beaumont observed that food changed chemically inside the stomach. He hypothesized that chemical reactions in the stomach broke down foods into smaller particles. Beaumont removed liquid from St. Martin's stomach and analyzed it. The stomach liquid contained an acid that played a role in the breakdown of foods into simpler substances.

Functions of the Digestive System

Beaumont's observations helped scientists understand the role of the stomach in the digestive system. **The digestive system has three main functions. First, it breaks down food into molecules the body can use. Then, the molecules are absorbed into the blood and carried throughout the body. Finally, wastes are eliminated from the body.** Figure 12 shows the organs of the digestive system, which is about 9 meters long from beginning to end.

Digestion The process by which your body breaks down food into small nutrient molecules is called digestion. There are two kinds of digestion—mechanical and chemical. In mechanical digestion, foods are physically broken down into smaller pieces. Mechanical digestion occurs when you bite into a sandwich and chew it into small pieces.

In chemical digestion, chemicals produced by the body break foods into their smaller chemical building blocks. For example, the starch in bread is broken down into individual sugar molecules.

Absorption and Elimination After your food is digested, the molecules are ready to be transported throughout your body. Absorption (ab SAWRP shun) is the process by which nutrient molecules pass through the wall of your digestive system into your blood. Materials that are not absorbed, such as fiber, are eliminated from the body as wastes.

Reading Checkpoint **What is chemical digestion?**

Go Online NSTA SCILINKS

For: Links on digestion
Visit: www.SciLinks.org
Web Code: scn-0423

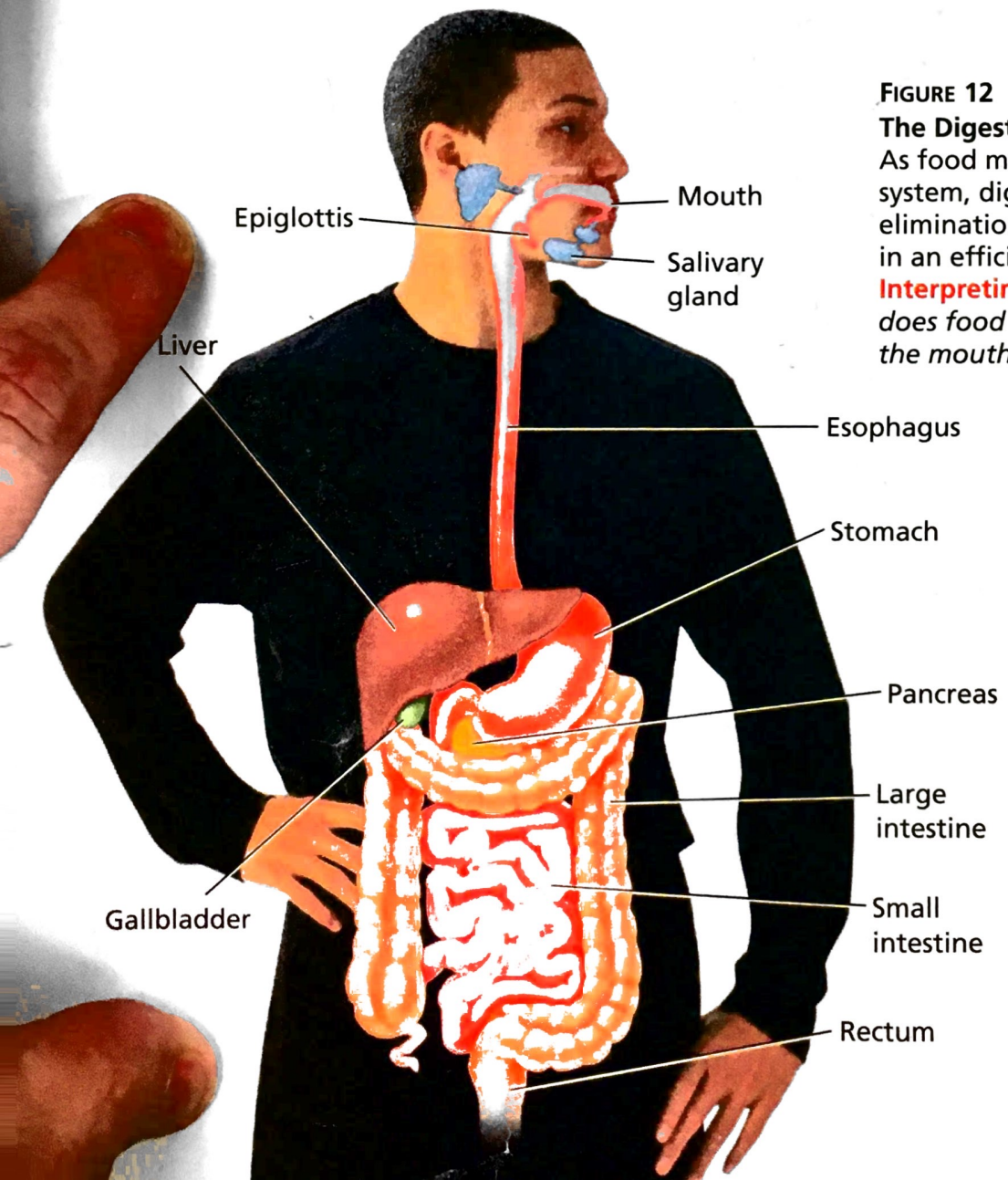


FIGURE 12
The Digestive System
As food moves through the digestive system, digestion, absorption, and elimination occur one after the other in an efficient, continuous process.
Interpreting Diagrams *Which organs does food pass through after leaving the mouth?*

The Mouth

Have you ever walked past a bakery or restaurant and noticed your mouth watering? Smelling or even just thinking about food when you're hungry is enough to start your mouth watering. This response isn't accidental. When your mouth waters, your body is preparing for the delicious meal it expects. **Both mechanical and chemical digestion begin in the mouth.** The fluid released when your mouth waters is saliva (suh LY vuh). Saliva plays an important role in both kinds of digestion.

Mechanical Digestion in the Mouth Your teeth carry out the first stage of mechanical digestion. Your center teeth, or incisors (in SY zurz), cut the food into bite-sized pieces. On either side of the incisors there are sharp, pointy teeth called canines (KAY nynz). These teeth tear and slash the food into smaller pieces. Behind the canines are the premolars and molars, which crush and grind the food. As the teeth do their work, saliva moistens the pieces of food into one slippery mass.

Chemical Digestion in the Mouth As mechanical digestion begins, so does chemical digestion. If you take a bite of a cracker and suck on it, the cracker begins to taste sweet. It tastes sweet because a chemical in the saliva has broken down the starch molecules in the cracker into sugar molecules.

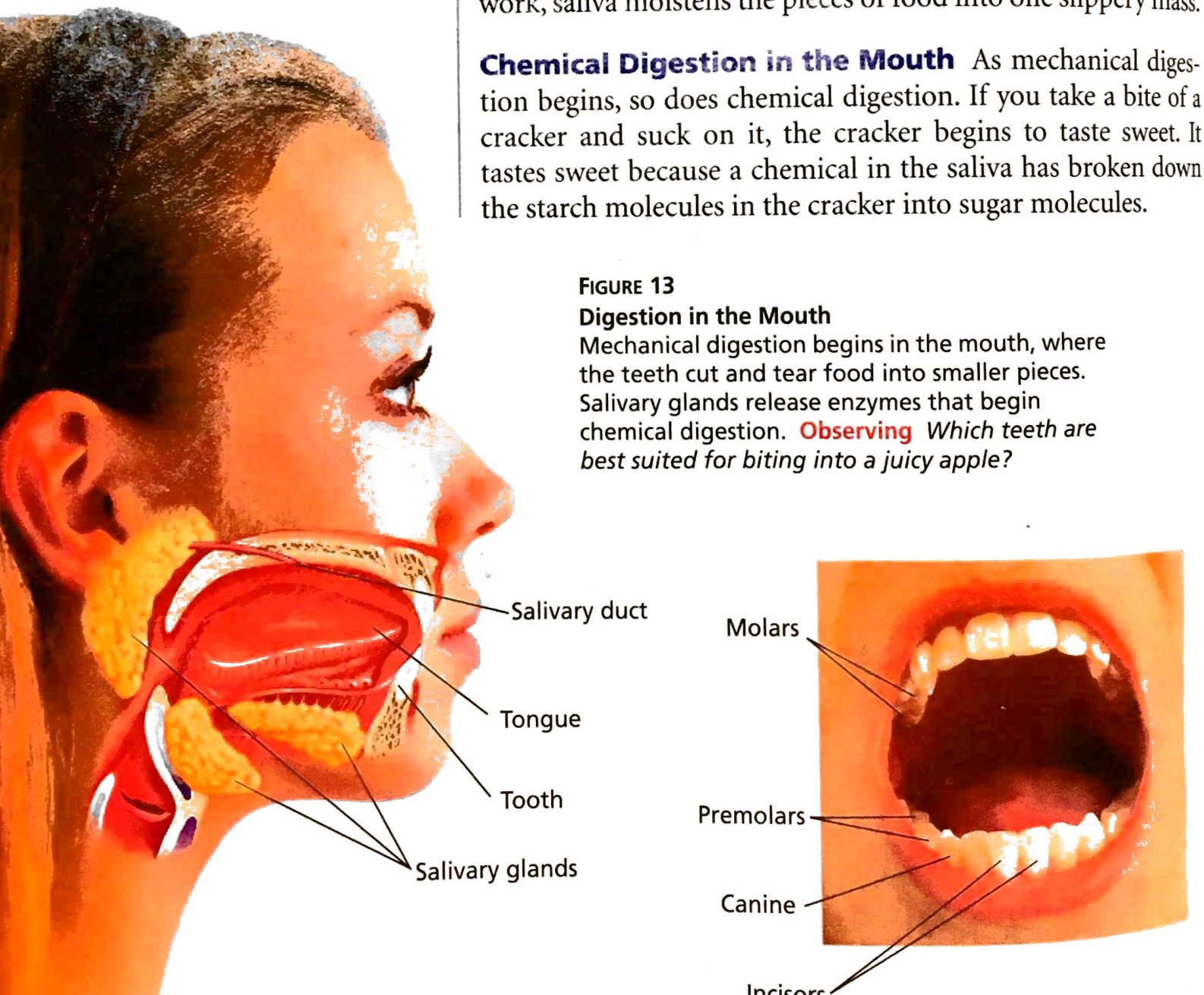
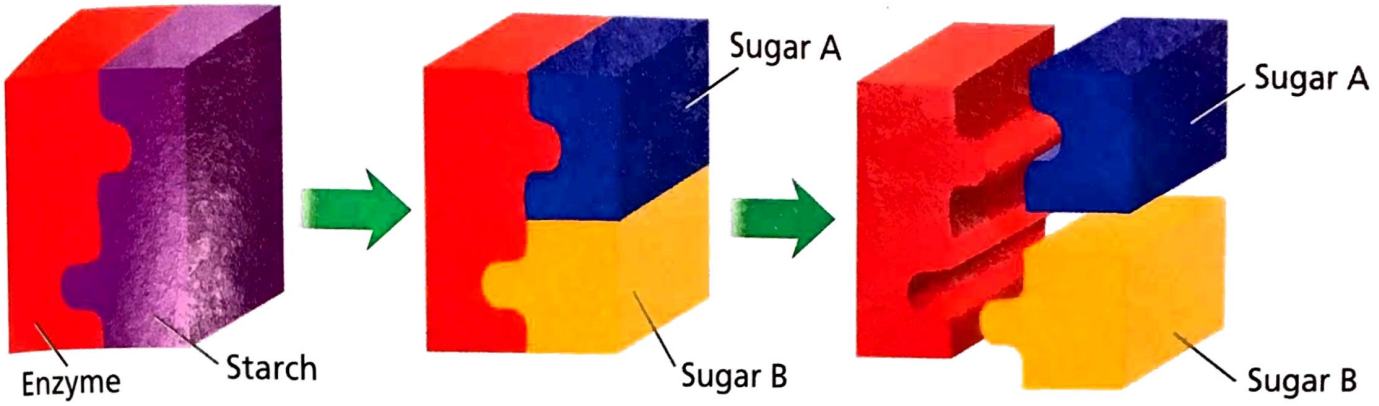


FIGURE 13
Digestion in the Mouth
Mechanical digestion begins in the mouth, where the teeth cut and tear food into smaller pieces. Salivary glands release enzymes that begin chemical digestion. **Observing** *Which teeth are best suited for biting into a juicy apple?*

FIGURE 14
How Enzymes Work
The shape of an enzyme molecule is specific to the shape of the food molecule it breaks down. Here, an enzyme breaks down a starch into sugars.



1 The shape of the enzyme fits the starch molecule.

2 A chemical reaction occurs between the enzyme and starch molecule.

3 The starch molecule has been broken down into sugar molecules.

The chemical in saliva that digests starch is an enzyme. Enzymes are proteins that speed up chemical reactions in the body. Your body produces many different enzymes. Each enzyme has a specific chemical shape. Its shape enables it to take part in only one kind of chemical reaction. An example of enzyme action is shown in Figure 14.

The Esophagus

If you've ever choked on food, your food may have "gone down the wrong way." That's because there are two openings at the back of your mouth. One opening leads to your windpipe, which carries air into your lungs. As you swallow, a flap of tissue called the **epiglottis** (ep uh GLAHT is) seals off your windpipe, preventing the food from entering. The food goes into the **esophagus** (ih SAHF uh gus), a muscular tube that connects the mouth to the stomach. The esophagus is lined with **mucus,** a thick, slippery substance produced by the body. Mucus makes food easier to swallow and move along.

Food remains in the esophagus for only about 10 seconds. **After food enters the esophagus, contractions of smooth muscles push the food toward the stomach.** These involuntary waves of muscle contraction are called **peristalsis** (pehr ih STAWL sis). Peristalsis also occurs in the stomach and farther down the digestive system. These muscular waves keep food moving in one direction.

Reading Checkpoint How is food prevented from entering the windpipe?

Lab zone Try This Activity

Modeling Peristalsis

1. Obtain a clear, flexible plastic straw.
2. Hold the straw vertically and insert a small bead into the top of the straw. The bead should fit snugly into the straw. **CAUTION:** *Do not put the straw in your mouth or blow into the straw.*
3. Pinch the straw above the bead so the bead begins to move down the length of the tubing.
4. Repeat Step 3 until the bead exits the straw.

Making Models How does this action compare with peristalsis? What do the bead and the straw represent?

The Stomach

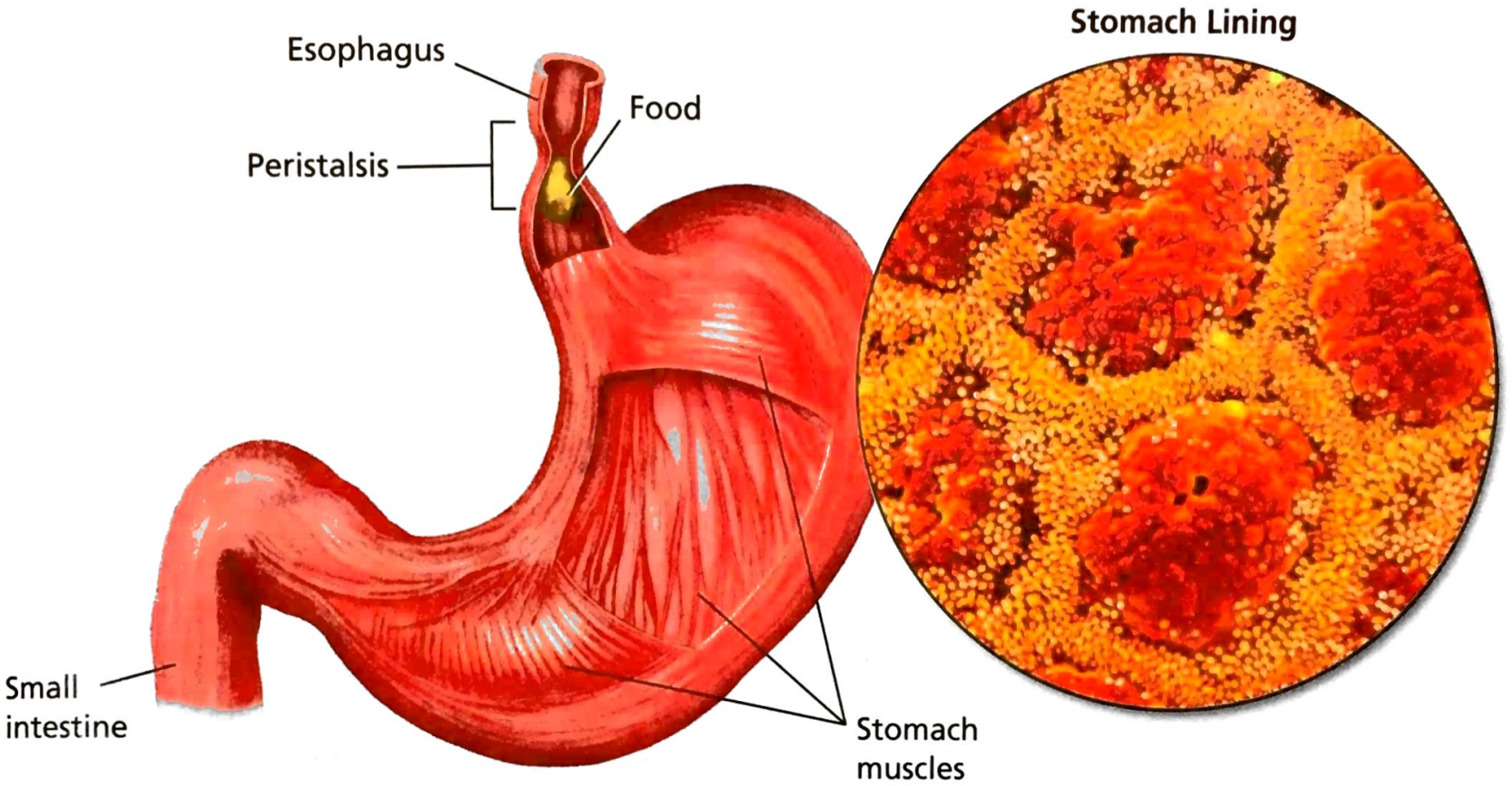
When food leaves the esophagus, it enters the stomach, a J-shaped, muscular pouch located in the abdomen. As you eat, your stomach expands to hold all of the food that you swallow. **Most mechanical digestion and some chemical digestion occur in the stomach.**

Mechanical Digestion in the Stomach The process of mechanical digestion occurs as three strong layers of smooth muscle contract to produce a churning motion. This action mixes the food with fluids in somewhat the same way that clothes and soapy water are mixed in a washing machine.

Chemical Digestion in the Stomach Chemical digestion occurs as the churning food makes contact with digestive juice, a fluid produced by cells in the lining of the stomach. Digestive juice contains the enzyme pepsin. Pepsin chemically digests the proteins in your food, breaking them down into short chains of amino acids.

Digestive juice also contains hydrochloric acid, a very strong acid. Without this strong acid, your stomach could not function properly. First, pepsin works best in an acid environment. Second, the acid kills many bacteria that you swallow with your food.

Why doesn't stomach acid burn a hole in your stomach? The reason is that cells in the stomach lining produce a thick coating of mucus, which protects the stomach lining. Also, the cells that line the stomach are quickly replaced as they are damaged or worn out.



Food remains in the stomach until all of the solid material has been broken down into liquid form. A few hours after you finish eating, the stomach completes mechanical digestion of the food. By that time, most of the proteins have been chemically digested into shorter chains of amino acids. The food, now a thick liquid, is released into the next part of the digestive system. That is where final chemical digestion and absorption will take place.

Reading Checkpoint **What is pepsin?**

FIGURE 15
The Stomach
The stomach has three layers of muscle that help to break down foods mechanically. The inset photo shows a microscopic view of the stomach lining. The yellow dots are mucus.
Relating Cause and Effect *What role does mucus play inside the stomach?*

Have you ever been part of a huge crowd attending a concert or sports event? Barriers and passageways often guide people in the right direction. Ticket takers make sure that people enter in an orderly fashion.

In some ways, the stomach can be thought of as the "ticket taker" of the digestive system. Once the food has been changed into a thick liquid, the stomach releases a little of the liquid at a time into the next part of the digestive system. This slow, smooth passage of food through the digestive system ensures that digestion and absorption can take place efficiently.

The Small Intestine

After the thick liquid leaves the stomach, it enters the small intestine. The **small intestine** is the part of the digestive system where most chemical digestion takes place. You may wonder how the small intestine got its name. After all, at about 6 meters—longer than some full-sized cars—it makes up two thirds of the length of the digestive system. The small intestine was named for its small diameter. It is from 2 to 3 centimeters wide, about half the diameter of the large intestine.

When food reaches the small intestine, it has already been mechanically digested into a thick liquid. But chemical digestion has just begun. Starches and proteins have been partially broken down, but fats haven't been digested at all. **Almost all chemical digestion and absorption of nutrients takes place in the small intestine.** As the liquid moves into the small intestine, it mixes with enzymes and secretions that are produced by the small intestine, the liver, and the pancreas. The liver and the pancreas deliver their substances to the small intestine through small tubes.

The Liver As you can see in Figure 16, the liver is located in the upper right portion of the abdomen. It is the largest organ inside the body. The liver is like an extremely busy chemical factory and plays a role in many body processes. For example, it breaks down medicines, and it helps eliminate nitrogen from the body. **The role of the liver in the digestive system is to produce bile.**

Bile is a substance that breaks up fat particles. Bile flows from the liver into the gallbladder, the organ that stores bile. After you eat, bile passes through a tube from the gallbladder into the small intestine.

Bile is not an enzyme. It does not chemically digest foods. It does, however, physically break up large fat particles into smaller fat droplets. You can compare the action of bile on fats with the action of soap on a greasy frying pan. Soap physically breaks up the grease into small droplets that can mix with the soapy water and be washed away. Bile mixes with the fats in food to form small fat droplets. The droplets can then be chemically broken down by enzymes produced in the pancreas.

Lab zone **Try This Activity**

Break Up!

You can model the breakup of fat particles in the small intestine.

1. Fill two plastic jars half full of water. Add a few drops of oil to each jar.
2. Add about $\frac{1}{4}$ spoonful of baking soda to one jar.
3. Stir the contents of both jars. Record your observations.

Observing In which jar did the oil begin to break up? What substance does the baking soda represent?

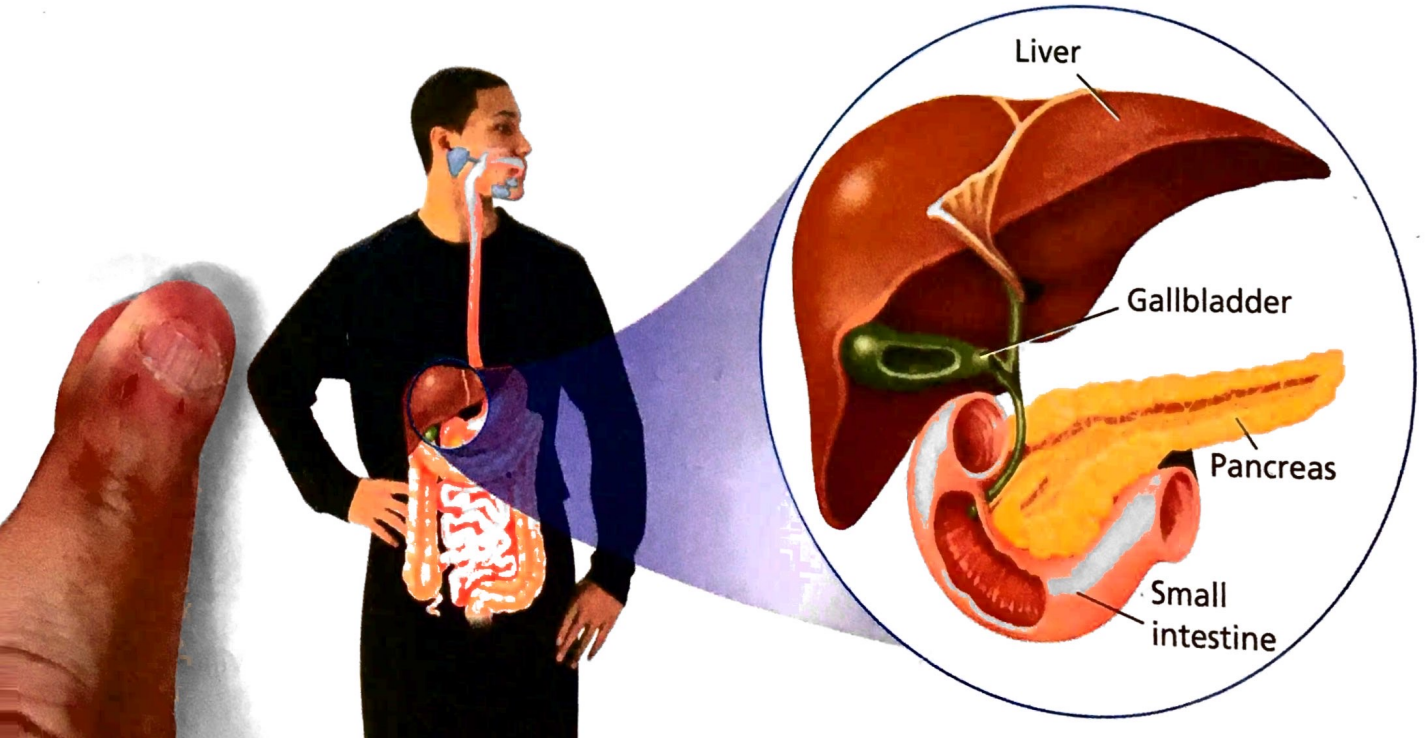


FIGURE 16
The Liver and Pancreas
Substances produced by the liver and pancreas aid in digestion.
Predicting *How would digestion be affected if the tube leading from the gallbladder to the small intestine became blocked?*

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The Pancreas The **pancreas** is a triangular organ that lies between the stomach and the first part of the small intestine. Like the liver, the pancreas plays a role in many body processes. **As part of the digestive system, the pancreas produces enzymes that flow into the small intestine and help break down starches, proteins, and fats.**

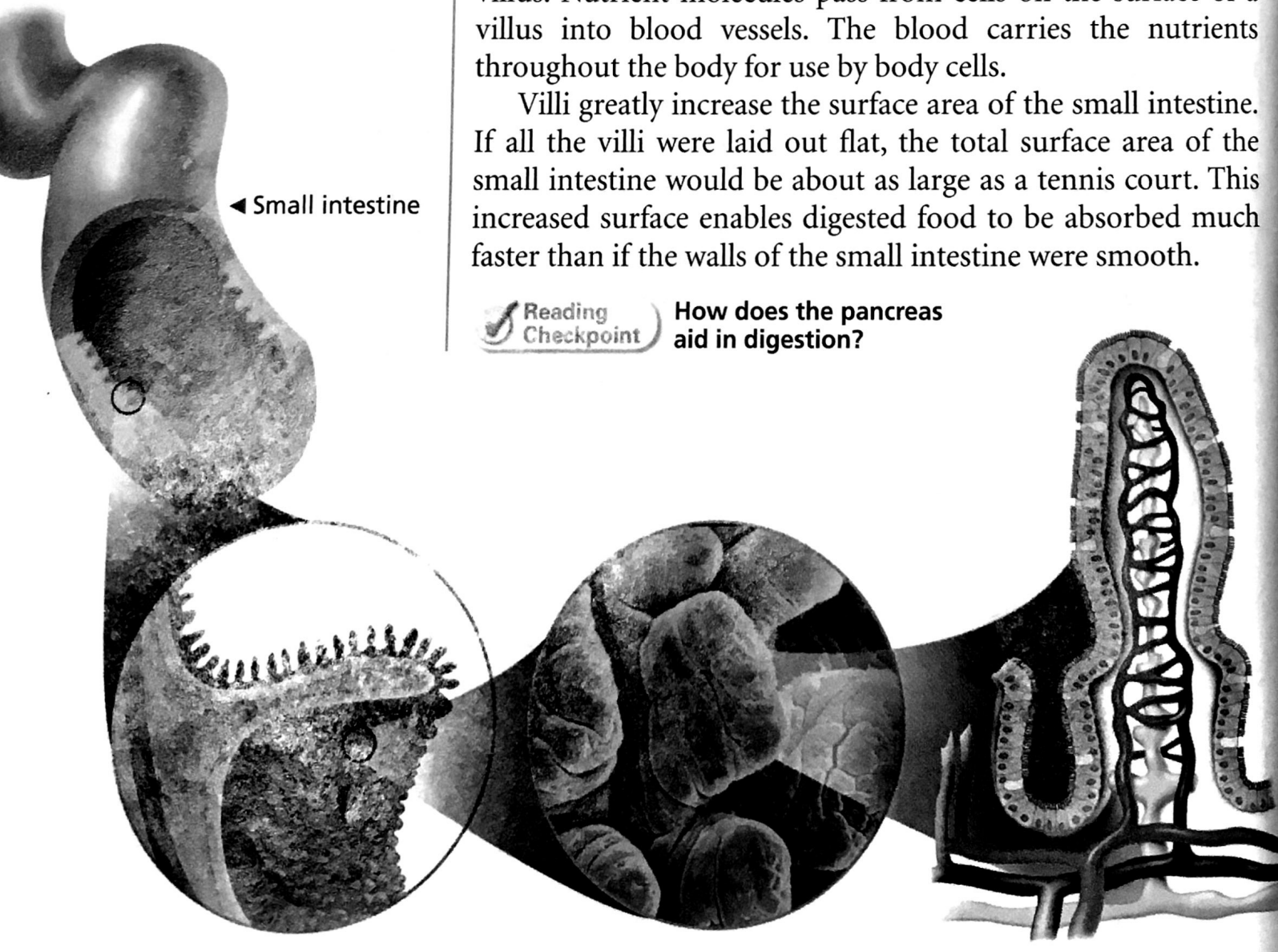
Digestive enzymes do not break down all food substances. Recall that the fiber in food isn't broken down. Instead, fiber thickens the liquid material in the intestine. This thickening makes it easier for peristalsis to push the material forward.

Absorption in the Small Intestine After chemical digestion takes place, the small nutrient molecules are ready to be absorbed by the body. The structure of the small intestine makes it well suited for absorption. The inner surface, or lining, of the small intestine looks bumpy. Millions of tiny finger-shaped structures called **villi** (VIL eye) (singular *villus*) cover the surface. The villi absorb nutrient molecules. Notice in Figure 17 that tiny blood vessels run through the center of each villus. Nutrient molecules pass from cells on the surface of a villus into blood vessels. The blood carries the nutrients throughout the body for use by body cells.

Villi greatly increase the surface area of the small intestine. If all the villi were laid out flat, the total surface area of the small intestine would be about as large as a tennis court. This increased surface enables digested food to be absorbed much faster than if the walls of the small intestine were smooth.

Reading Checkpoint **How does the pancreas aid in digestion?**

FIGURE 17
The Small Intestine
Tiny finger-shaped projections called villi line the inside of the small intestine. Blood vessels in the villi are covered by a single layer of cells.
Relating Cause and Effect *How does the structure of the villi help them carry out their function?*



The Large Intestine

By the time material reaches the end of the small intestine, most nutrients have been absorbed. The remaining material moves from the small intestine into the large intestine. The **large intestine** is the last section of the digestive system. It is about 1.5 meters long—about as long as the average bathtub. It runs up the right-hand side of the abdomen, across the upper abdomen, and then down the left-hand side. The large intestine contains bacteria that feed on the material passing through. These bacteria normally do not cause disease. In fact, they are helpful because they make certain vitamins, including vitamin K.

The material entering the large intestine contains water and undigested food. **As the material moves through the large intestine, water is absorbed into the bloodstream. The remaining material is readied for elimination from the body.**

The large intestine ends in a short tube called the **rectum.** Here, waste material is compressed into a solid form. This waste material is eliminated from the body through the **anus,** a muscular opening at the end of the rectum.

FIGURE 18
The Large Intestine
As material passes through the large intestine, most of the water is absorbed by the body. The remaining material will be eliminated from the body.

Reading Checkpoint **What role do bacteria play in the large intestine?**