

**FIGURE 14.11 Schematic summary of gastrointestinal tract activities.** Gastrointestinal tract activities include ingestion, mechanical digestion, chemical (enzymatic) digestion, propulsion, absorption, and defecation. Sites of chemical digestion are also sites that produce enzymes or that receive enzymes or other secretions made by accessory organs outside the alimentary canal. The mucosa of virtually the entire GI tract secretes mucus, which protects and lubricates.

Most of the pancreas lies posterior to the parietal peritoneum; hence its location is referred to as *retroperitoneal*.

The pancreas produces enzymes (described later) that break down all categories of digestible foods. The pancreatic enzymes are secreted into the duodenum in an alkaline fluid, which neutral-

izes the acidic chyme coming in from the stomach. The pancreas also has an endocrine function; it produces the hormones insulin and glucagon, as explained in Chapter 9.

## Liver and Gallbladder

The **liver** is the largest gland in the body. It is located under the diaphragm, more to the right side of the body (see Figures 14.1 and 14.5). As described earlier, the liver overlies and almost completely covers the stomach. The liver has four lobes and is suspended from the diaphragm and abdominal wall by a delicate mesentery cord, the **falciform** (fal'si-form) **ligament**.

There is no question that the liver is one of the body's most important organs. It has many metabolic and regulatory roles; however, its digestive function is to produce **bile**. Bile leaves the liver through the **common hepatic duct** and enters the duodenum through the *bile duct* (see Figure 14.6).

Bile is a yellow-to-green, watery solution containing bile salts, bile pigments (chiefly bilirubin, a breakdown product of hemoglobin), cholesterol, phospholipids, and a variety of electrolytes. Of these components, only the bile salts (derived from cholesterol) and phospholipids aid the digestive process. Bile does not contain enzymes, but its bile salts *emulsify* fats by physically breaking large fat globules into smaller ones, thus providing more surface area for the fat-digesting enzymes to work on.

The **gallbladder** is a small, thin-walled green sac that snuggles in a shallow fossa in the inferior surface of the liver (see Figures 14.1 and 14.6). When food digestion is not occurring, bile backs up the **cystic duct** and enters the gallbladder to be stored. While being stored in the gallbladder, bile is concentrated by the removal of water. Later, when fatty food enters the duodenum, a hormonal stimulus prompts the gallbladder to contract and spurt out stored bile, making it available to the duodenum.

## Homeostatic Imbalance

If bile is stored in the gallbladder for too long or too much water is removed, the cholesterol it contains may crystallize, forming *gallstones*. Since gallstones tend to be quite sharp, agonizing pain may occur when the gallbladder contracts (the typical *gallbladder attack*).

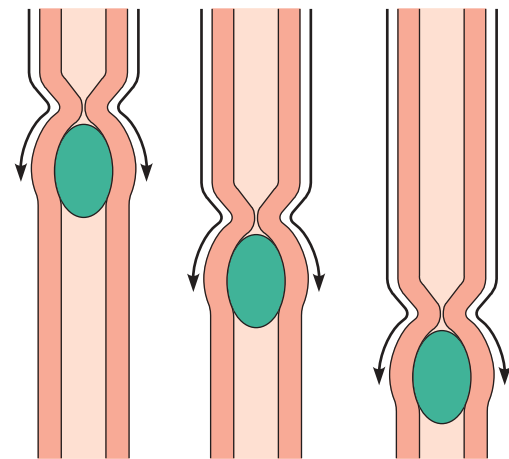
Blockage of the common hepatic or bile ducts (for example, by wedged gallstones) prevents bile from entering the small intestine, and it begins to accumulate and eventually backs up into the liver. This exerts pressure on the liver cells, and bile salts and bile pigments begin to enter the bloodstream. As the bile pigments circulate through the body, the tissues become yellow, or *jaundiced*. Blockage of the ducts is just one cause of jaundice. More often it results from actual liver problems such as *hepatitis* (an inflammation of the liver) or *cirrhosis* (sir-ro'sis), a chronic inflammatory condition in which the liver is severely damaged and becomes hard and fibrous. Hepatitis is most often due to viral infection resulting from drinking contaminated water or transmitted in blood via transfusion or contaminated needles. Cirrhosis is almost guaranteed when one drinks alcoholic beverages in excess for many years, and it is a common consequence of severe hepatitis. ▲

## Functions of the Digestive System

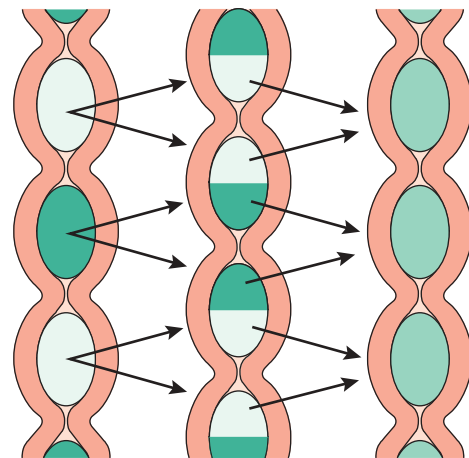
### Overview of Gastrointestinal Processes and Controls

The major functions of the digestive tract are usually summarized in two words—*digestion* and *absorption*. However, many of its specific activities (such as smooth muscle activity) and certain regulatory events are not really covered by either term. To describe digestive system processes a little more accurately, we really have to consider a few more functional terms. The essential activities of the GI tract include the following six processes, summarized in Figure 14.11.

1. **Ingestion**—Food must be placed into the mouth before it can be acted on. This is an active, voluntary process called ingestion.
2. **Propulsion**—If foods are to be processed by more than one digestive organ (and indeed they are), they must be propelled from one organ to the next. Swallowing is one example of food movement that depends largely on the propulsive process called **peristalsis**. Peristalsis is involuntary and involves alternating waves of contraction and relaxation of the muscles in the organ wall (Figure 14.12a). The net effect is to squeeze the food along the tract. Although **segmentation** (Figure 14.12b) may help to



(a)



(b)

**FIGURE 14.12 Peristaltic and segmental movements of the digestive tract.** (a) In

peristalsis, adjacent or neighboring segments of the intestine (or other alimentary canal organs) alternately contract and relax, which moves food distally along the tract. (b) In segmentation, single segments of the intestine alternately contract and relax. Because active segments are separated by inactive ones, the food is moved forward and then backward. Thus the food is mixed rather than simply propelled along the tract.

propel foodstuffs through the small intestine, it normally only moves food back and forth across the internal wall of the organ, serving to mix it with the digestive juices. Thus, segmentation is more an example of mechanical digestion than of propulsion.

### 3. Food breakdown: mechanical digestion—

Mixing of food in the mouth by the tongue, churning of food in the stomach, and segmentation in the small intestine are all examples of processes contributing to mechanical digestion. Mechanical digestion prepares food for further degradation by enzymes by physically fragmenting the foods into smaller particles.

### 4. Food breakdown: chemical digestion—

The sequence of steps in which large food molecules are broken down to their building blocks by enzymes (protein molecules that act as catalysts) is called chemical digestion. Recall from Chapter 2 that these reactions are called *hydrolysis* reactions, because a water molecule is added to each bond to be broken. Water is also necessary as a dissolving medium and a softening agent for food digestion.

Since each of the major food groups has very different building blocks, it is worth taking a little time to review these chemical units, which were first introduced in Chapter 2. The building blocks, or units, of *carbohydrate* foods are *monosaccharides* (mon"o-sak'ah-rīdz), or simple sugars. We need to remember only three of these that are common in our diet—*glucose*, *fructose*, and *galactose*. Glucose is by far the most important, and when we talk about blood sugar levels, glucose is the “sugar” being referred to. Fructose is the most abundant sugar in fruits, and galactose is found in milk. Essentially, the only carbohydrates that our digestive system digests, or breaks down to simple sugars, are *sucrose* (table sugar), *lactose* (milk sugar), *maltose* (malt sugar), and *starch*. Sucrose, maltose, and lactose are referred to as *disaccharides*, or double sugars, because each consists of two simple sugars linked together. Starch is a *polysaccharide* (literally, “many sugars”) formed of hundreds of glucose units. Although we eat foods containing other polysaccharides, such as *cellulose*, we do not have enzymes capable of breaking them down. The indigestible polysaccharides do not provide us with any nutrients, but they help move the foodstuffs along the gastrointestinal tract by providing bulk, or *fiber*, in our diet.

Proteins are digested to their building blocks, which are amino (ah-me'no) acids. Intermediate products of protein digestion are polypeptides and peptides. When lipids (fats) are digested, they yield two different types of building blocks—fatty acids and an alcohol called glycerol (glis'er-ol).

The chemical breakdown of carbohydrates, proteins, and fats is summarized in Figure 14.13 and is described in more detail shortly.

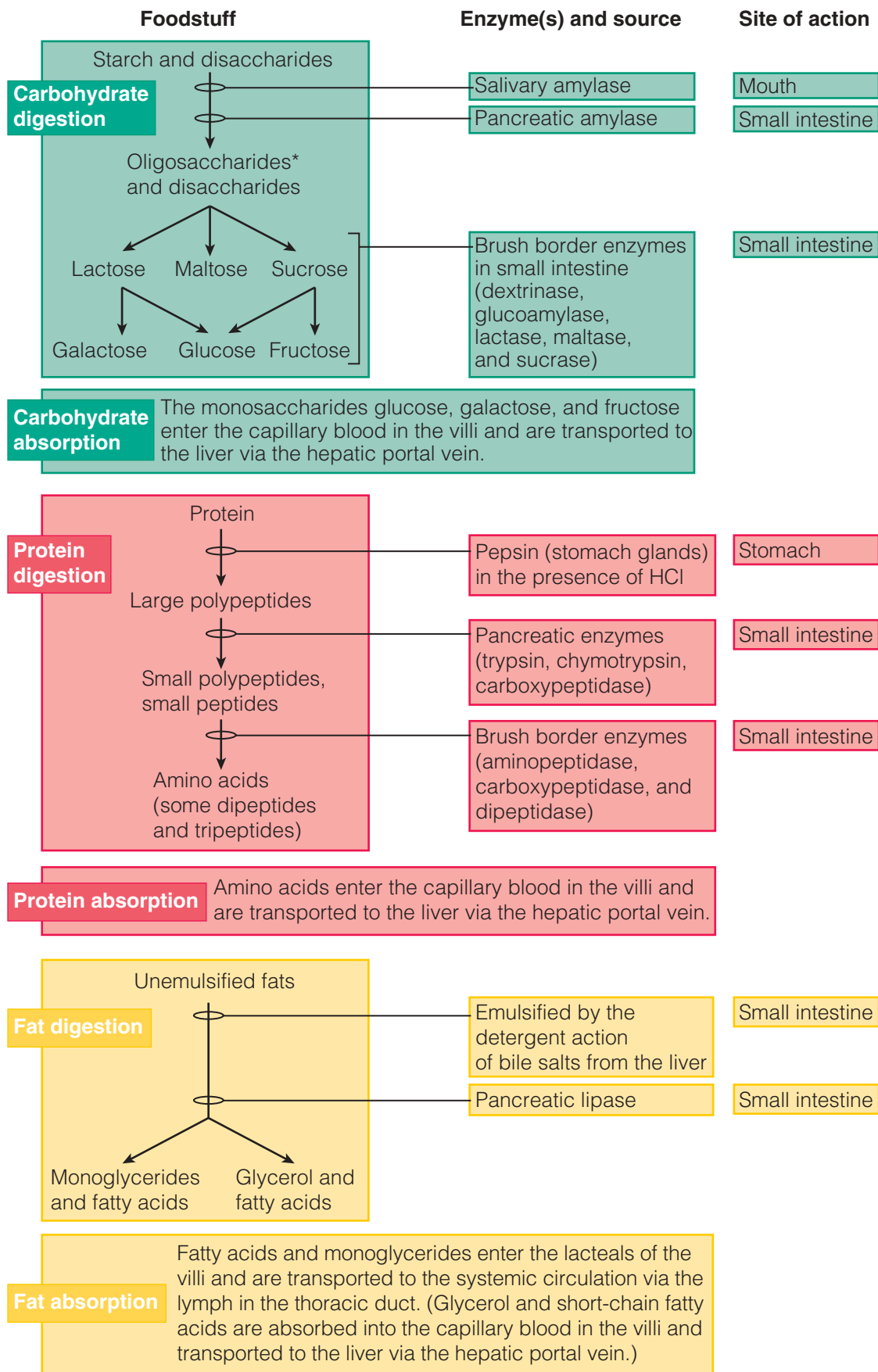
**5. Absorption**—Transport of digested end products from the lumen of the GI tract to the blood or lymph is absorption. For absorption to occur, the digested foods must first enter the mucosal cells by active or passive transport processes. The small intestine is the major absorptive site.

**6. Defecation**—Defecation is the elimination of indigestible residues from the GI tract via the anus in the form of feces (fe'sēz).

Some of these processes are the job of a single organ. For example, only the mouth ingests, and only the large intestine defecates. But most digestive system activities occur bit by bit as food is moved along the tract. Thus, in one sense, the digestive tract can be viewed as a “disassembly line” in which food is carried from one stage of its processing to the next, and its nutrients are made available to the cells in the body en route.

A point that has been stressed throughout this book has been the drive of the body to maintain a constant internal environment, particularly in terms of homeostasis of the blood, which comes into intimate contact with all body cells. The digestive system, however, creates an optimal environment for itself to function in the lumen (cavity) of the alimentary canal, an area that is actually *outside* the body. Conditions in that lumen are controlled so that digestive processes occur efficiently. Digestive activity is mostly controlled by reflexes via the parasympathetic division of the autonomic nervous system. (Recall from Chapter 7 that this is the “resting-and-digesting” arm.) The sensors (mechanoreceptors, chemoreceptors) involved in these reflexes are located in the walls of the alimentary canal organs and respond to a number of stimuli, the most important being stretch of the organ by food in its lumen, pH of the contents, and presence of certain breakdown products of digestion. When these receptors are activated, they start reflexes that activate or inhibit (1) the glands that secrete digestive juices into the lumen or hormones into the blood, and (2) the smooth muscles of the muscularis that mix and propel the foods along the tract.

Now that we have summarized some points that apply to the function of the digestive organs as a group, we are ready to look at their special capabilities.



\*Oligosaccharides consist of a few linked monosaccharides.

**FIGURE 14.13** Flow chart of chemical digestion and absorption of foodstuffs.