LECTURE PRESENTATIONS

For CAMPBELL BIOLOGY, NINTH EDITION

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Chapter 41

Animal Nutrition

Lectures by
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Concept 41.3: Organs specialized for sequential stages of food processing form the mammalian digestive system

- The mammalian digestive system consists of an alimentary canal and accessory glands that secrete digestive juices through ducts
- Mammalian accessory glands are the salivary glands, the pancreas, the liver, and the gallbladder

- Food is pushed along by **peristalsis**, rhythmic contractions of muscles in the wall of the canal
- Valves called **sphincters** regulate the movement of material between compartments

Figure 41.9

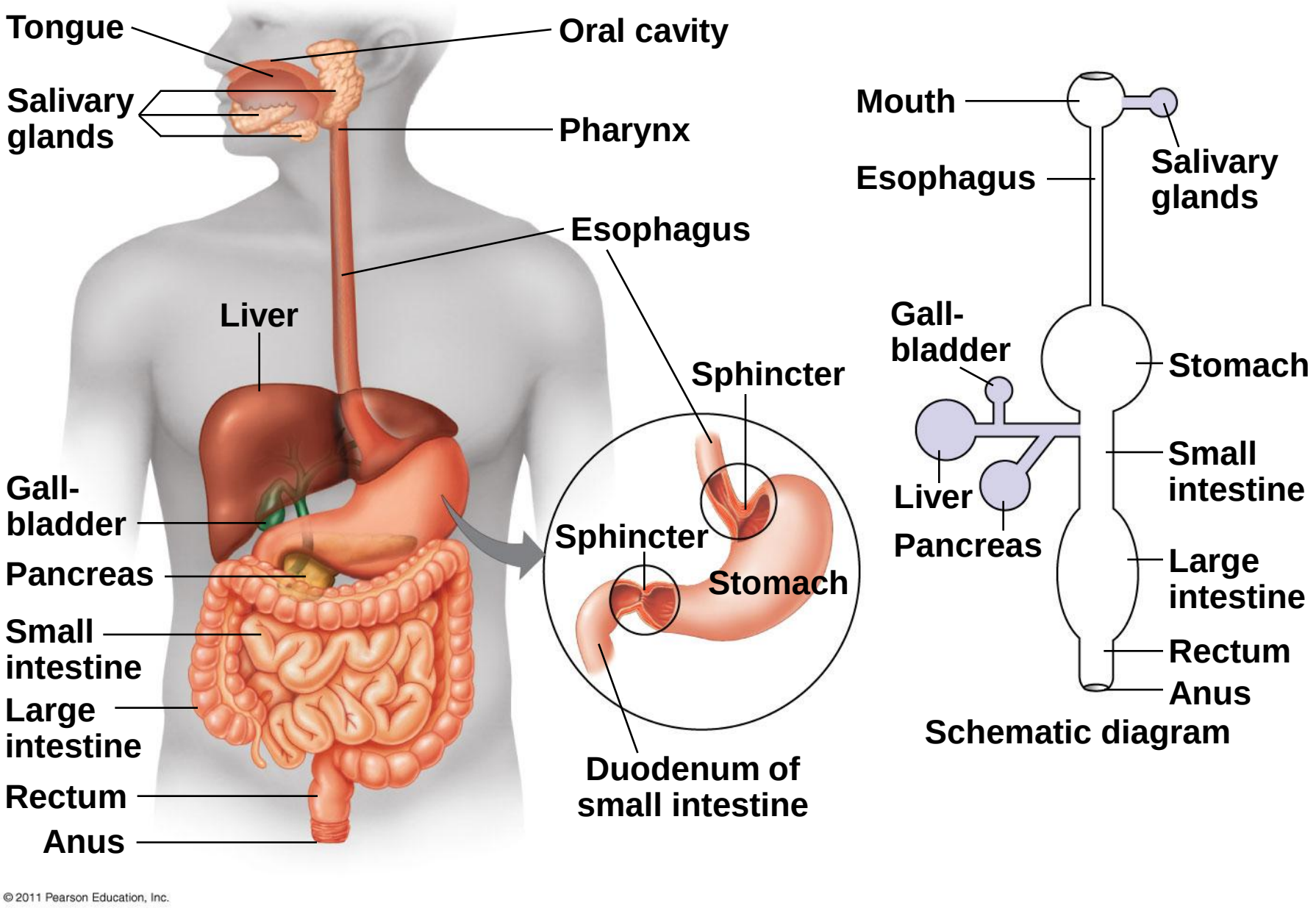

Figure 41.9a

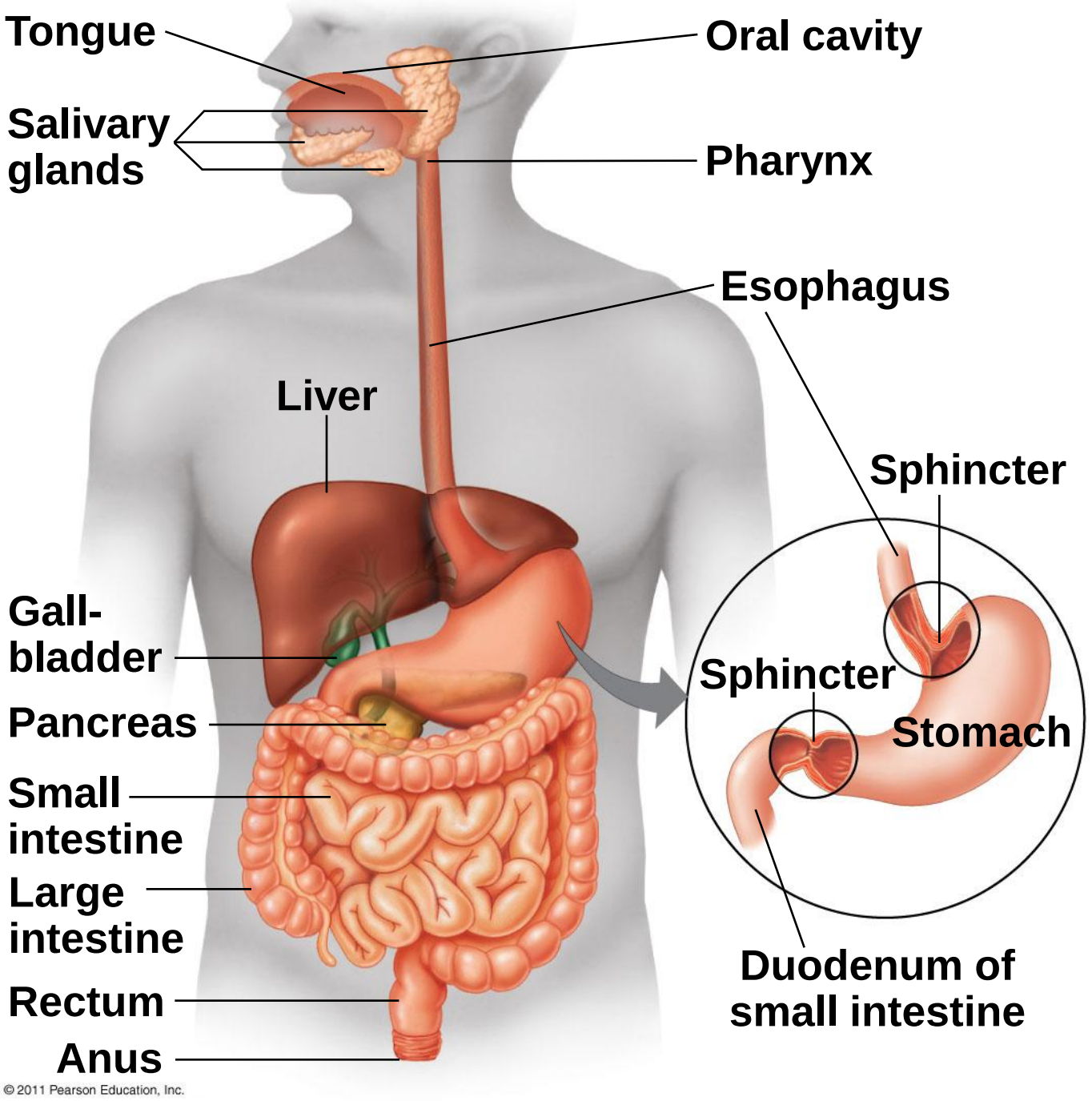
Tongue
Oral cavity
Salivary glands
Pharynx
Esophagus
Liver
Sphincter
Gall-bladder
Sphincter
Pancreas
Stomach
Small intestine
Large intestine
Duodenum of small intestine
Rectum
Anus
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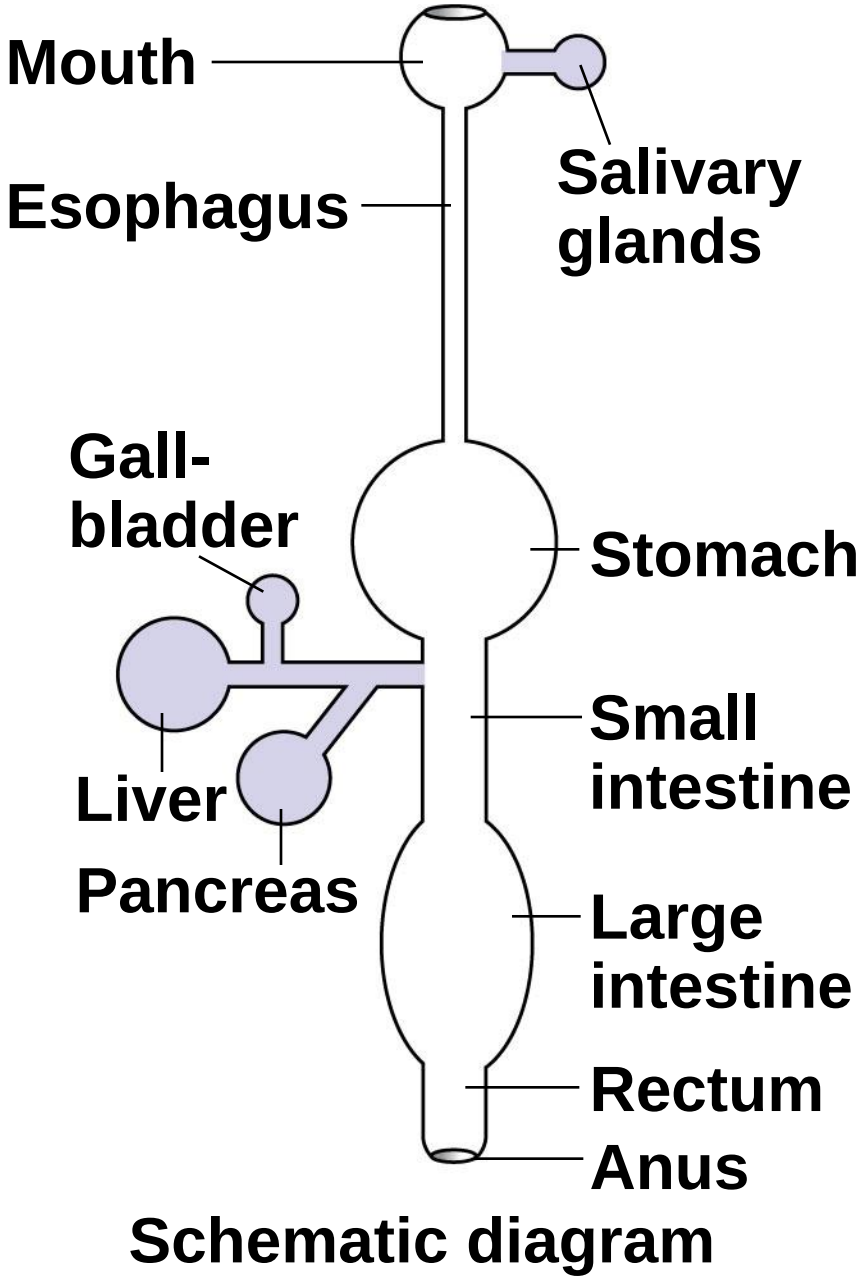
Figure 41.9b



The Oral Cavity, Pharynx, and Esophagus

- The first stage of digestion is mechanical and takes place in the **oral cavity**
- **Salivary glands** deliver saliva to lubricate food
- Teeth chew food into smaller particles that are exposed to salivary **amylase**, initiating breakdown of glucose polymers
- Saliva also contains **mucus**, a viscous mixture of water, salts, cells, and glycoproteins

- The tongue shapes food into a **bolus** and provides help with swallowing
- The throat, or **pharynx**, is the junction that opens to both the esophagus and the trachea
- The **esophagus** connects to the stomach
- The trachea (windpipe) leads to the lungs

- The esophagus conducts food from the pharynx down to the stomach by peristalsis
- Swallowing causes the epiglottis to block entry to the trachea, and the bolus is guided by the larynx, the upper part of the respiratory tract
- Coughing occurs when the swallowing reflex fails and food or liquids reach the windpipe

Figure 41.10-1

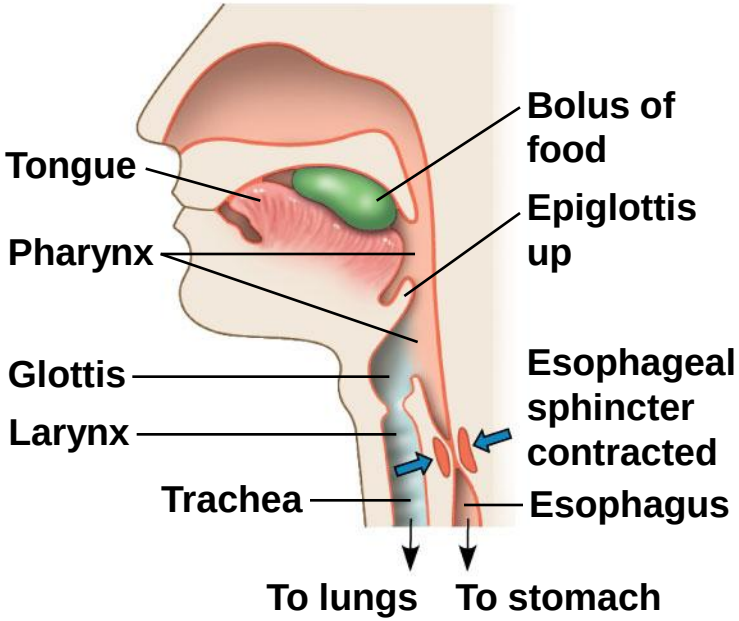


Figure 41.10-2

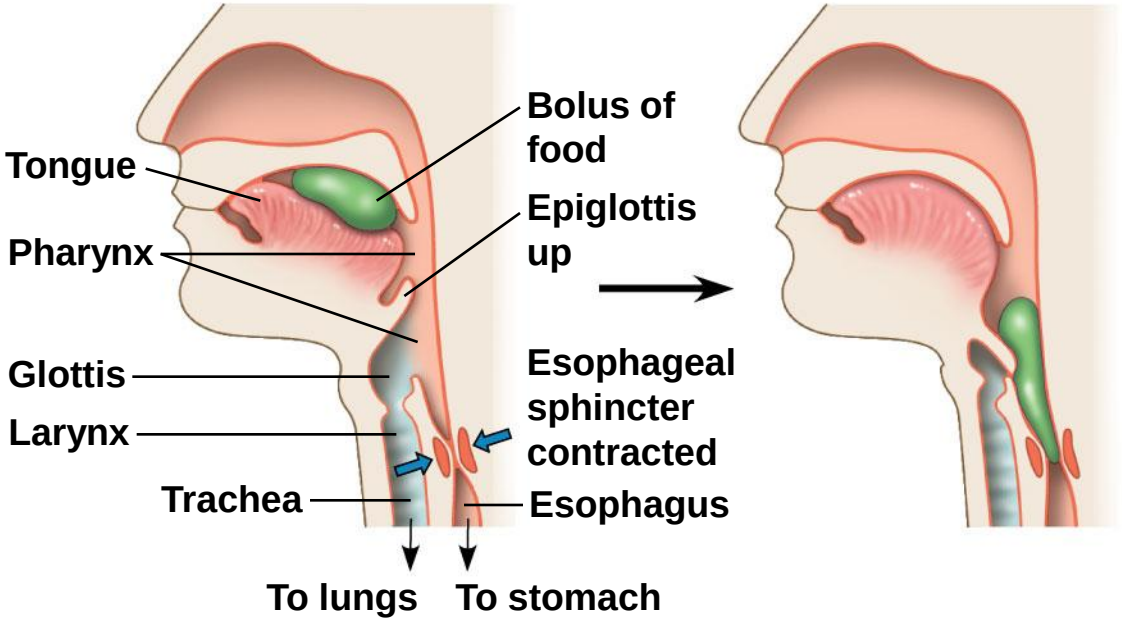
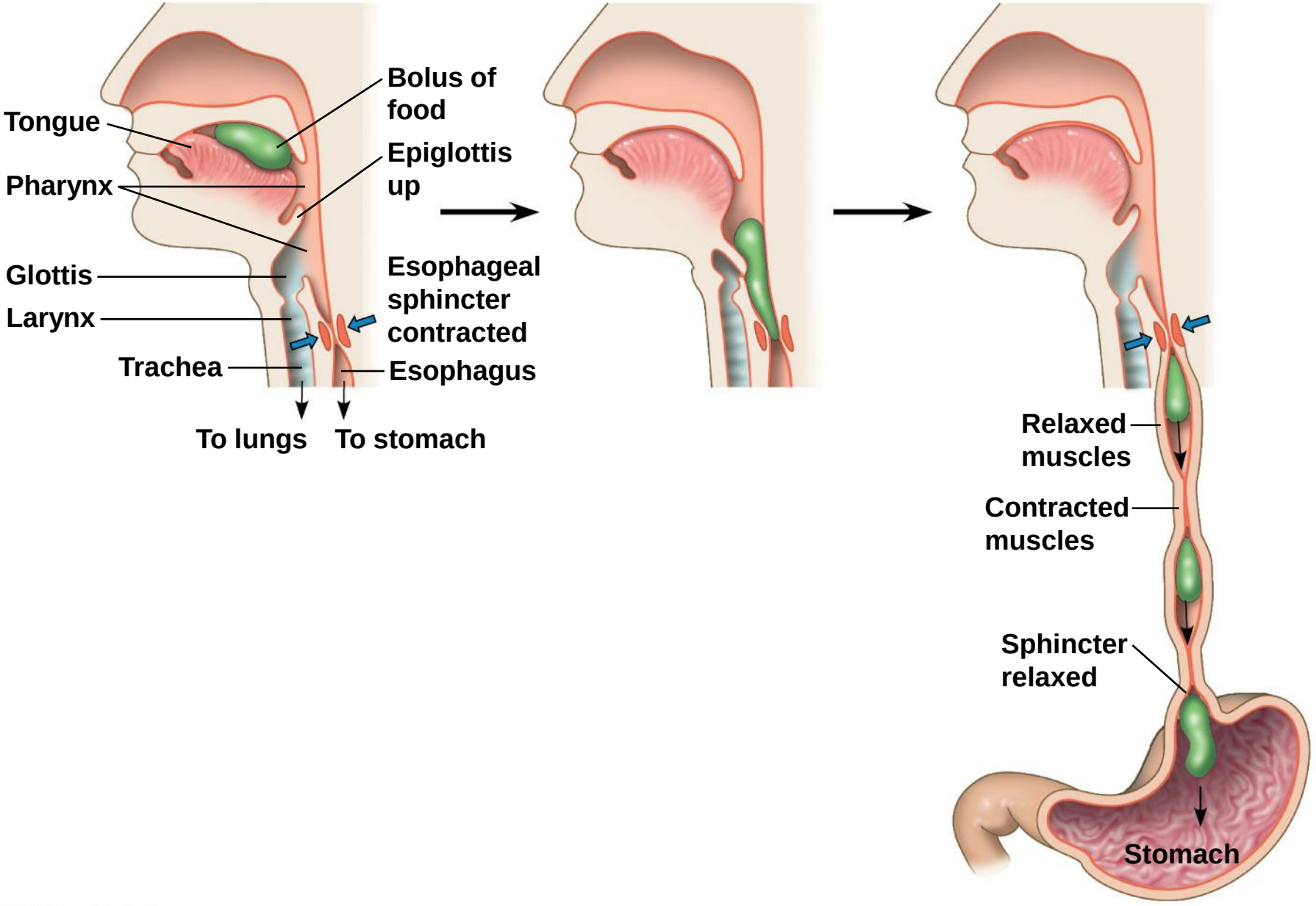


Figure 41.10-3



Digestion in the Stomach

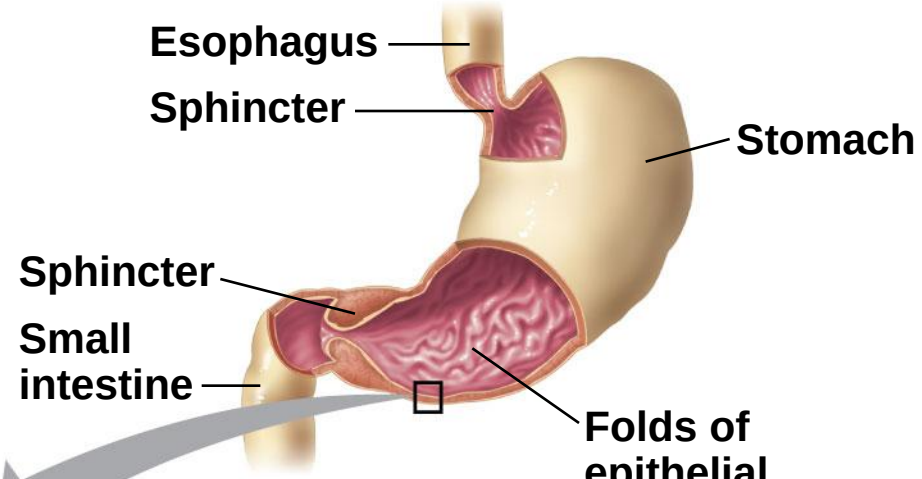
- The **stomach** stores food and secretes **gastric juice**, which converts a meal to acid **chyme**

Chemical Digestion in the Stomach

- Gastric juice has a low pH of about 2, which kills bacteria and denatures proteins
- Gastric juice is made up of hydrochloric acid (HCl) and **pepsin**
- Pepsin is a **protease**, or protein-digesting enzyme, that cleaves proteins into smaller peptides

- Parietal cells secrete hydrogen and chloride ions separately into the lumen (cavity) of the stomach
- Chief cells secrete inactive **pepsinogen**, which is activated to pepsin when mixed with hydrochloric acid in the stomach
- Mucus protects the stomach lining from gastric juice

Figure 41.11



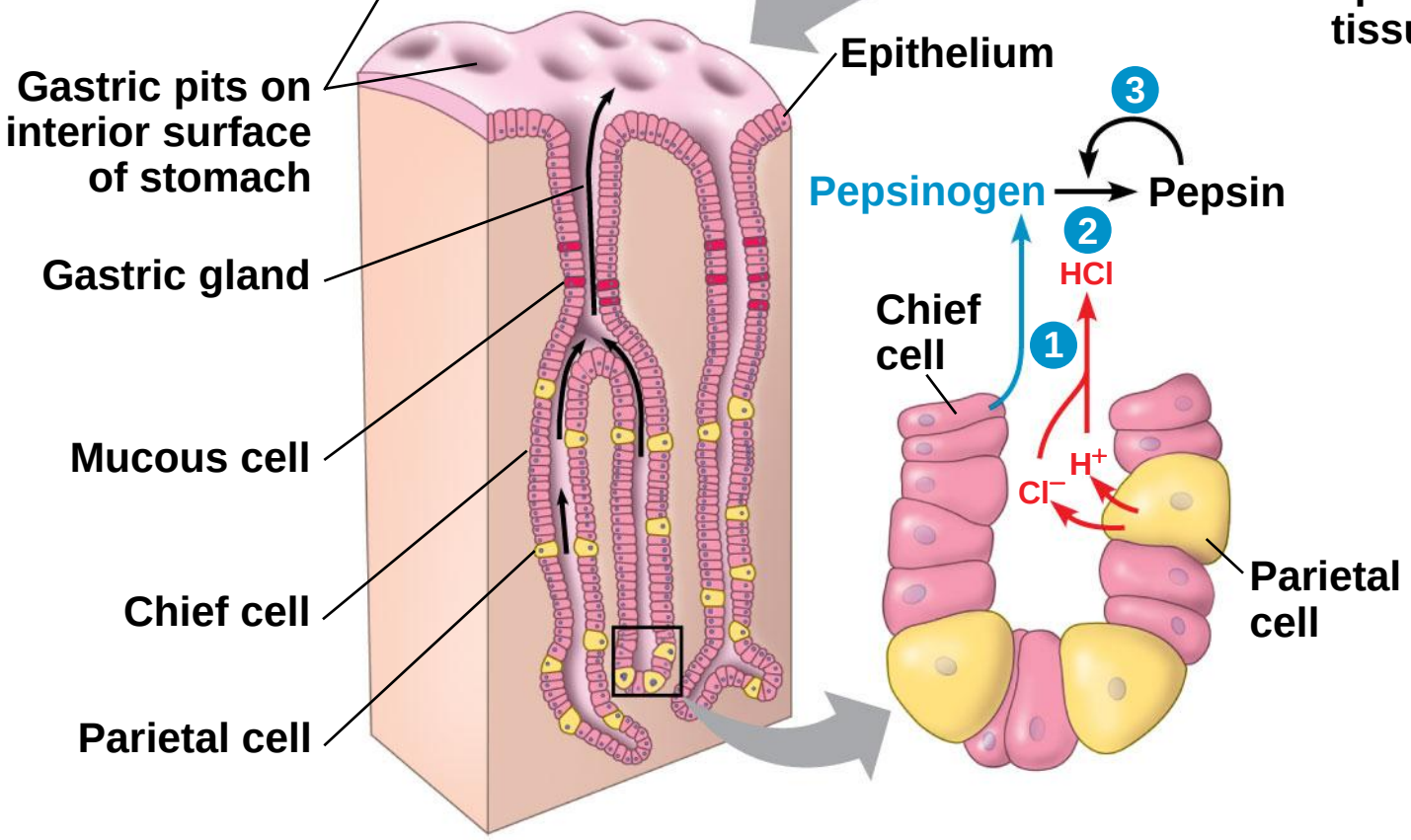
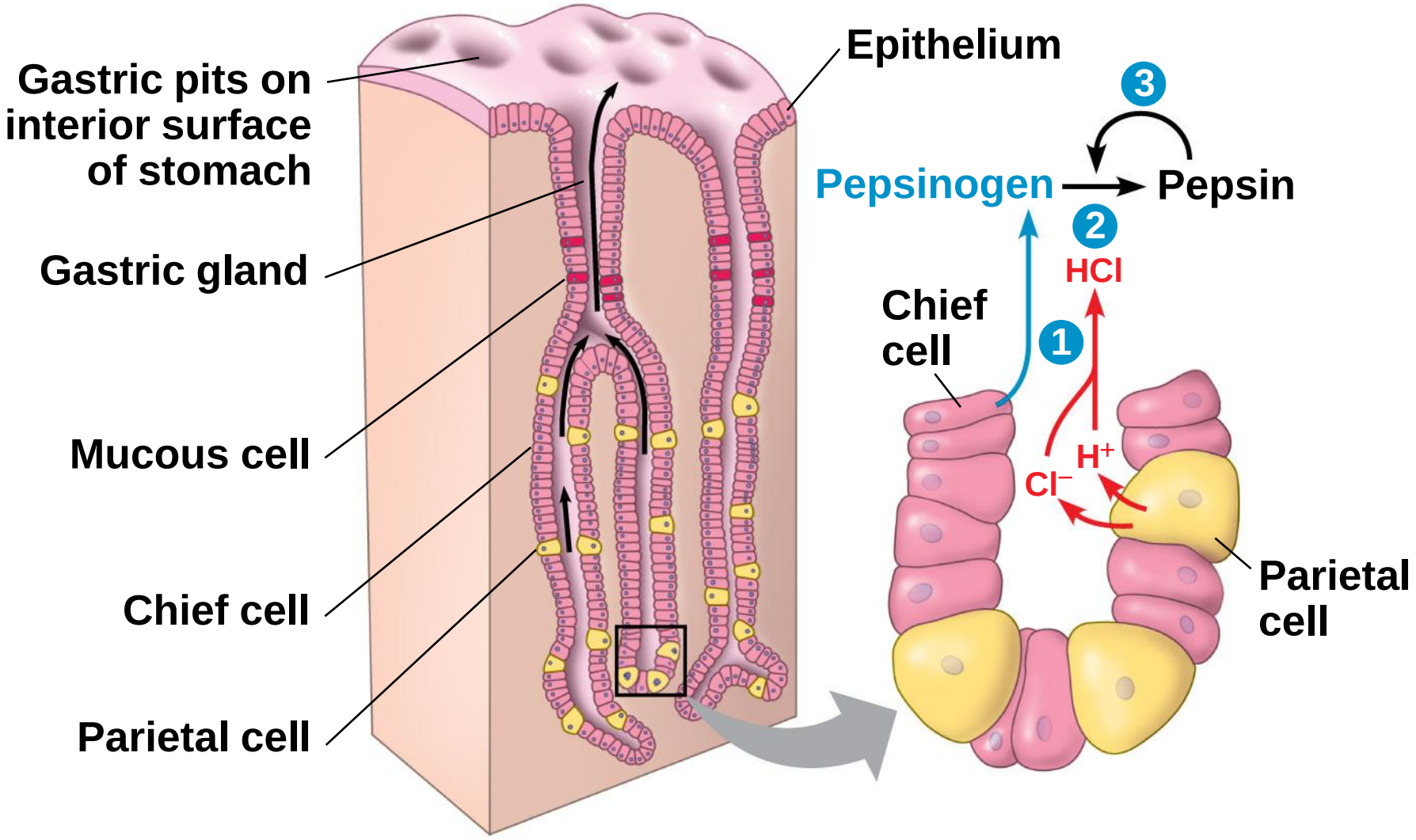


Figure 41.11a

Figure 41.11b



- Gastric ulcers, lesions in the lining, are caused mainly by the bacterium *Heliobacter pylori*

Stomach Dynamics

- Coordinated contraction and relaxation of stomach muscle churn the stomach's contents
- Sphincters prevent chyme from entering the esophagus and regulate its entry into the small intestine

Digestion in the Small Intestine

- The **small intestine** is the longest section of the alimentary canal
- It is the major organ of digestion and absorption

Figure 41.12-1

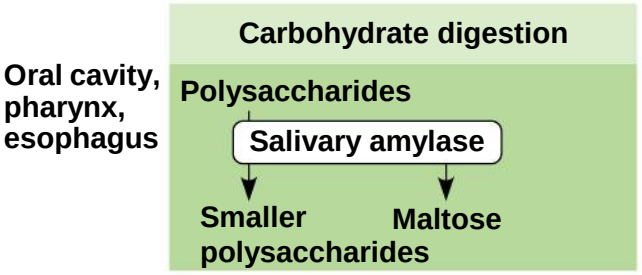


Figure 41.12-2

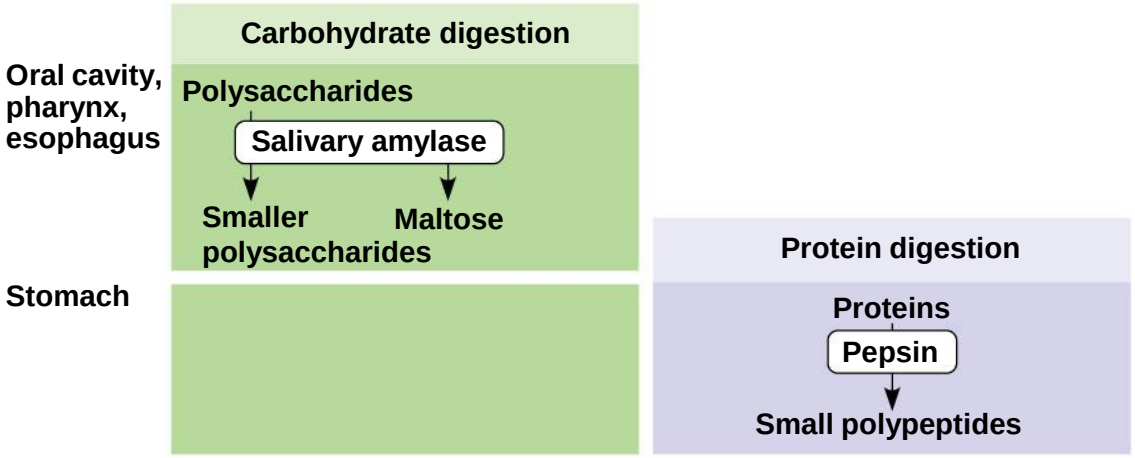


Figure 41.12-3

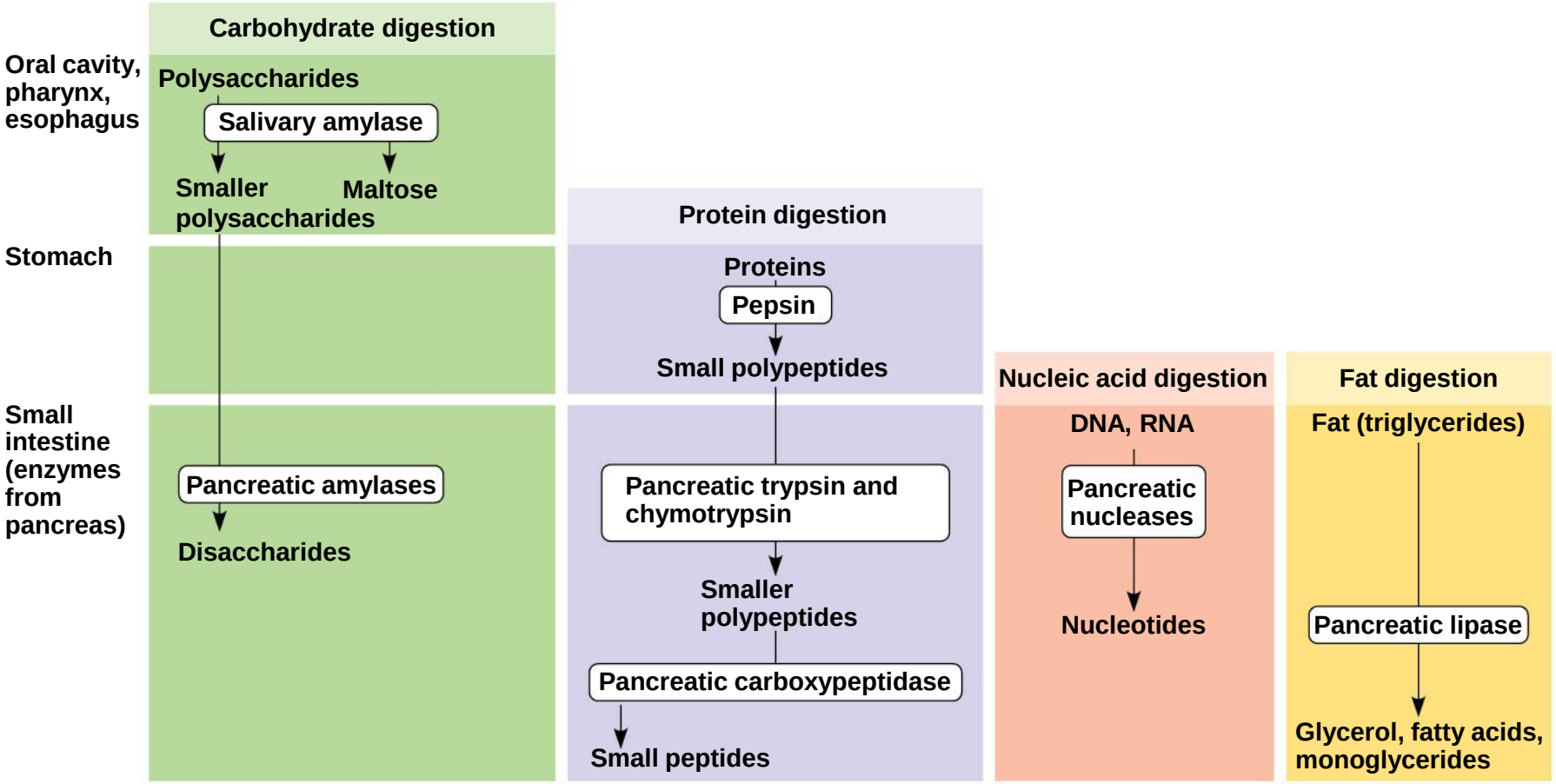
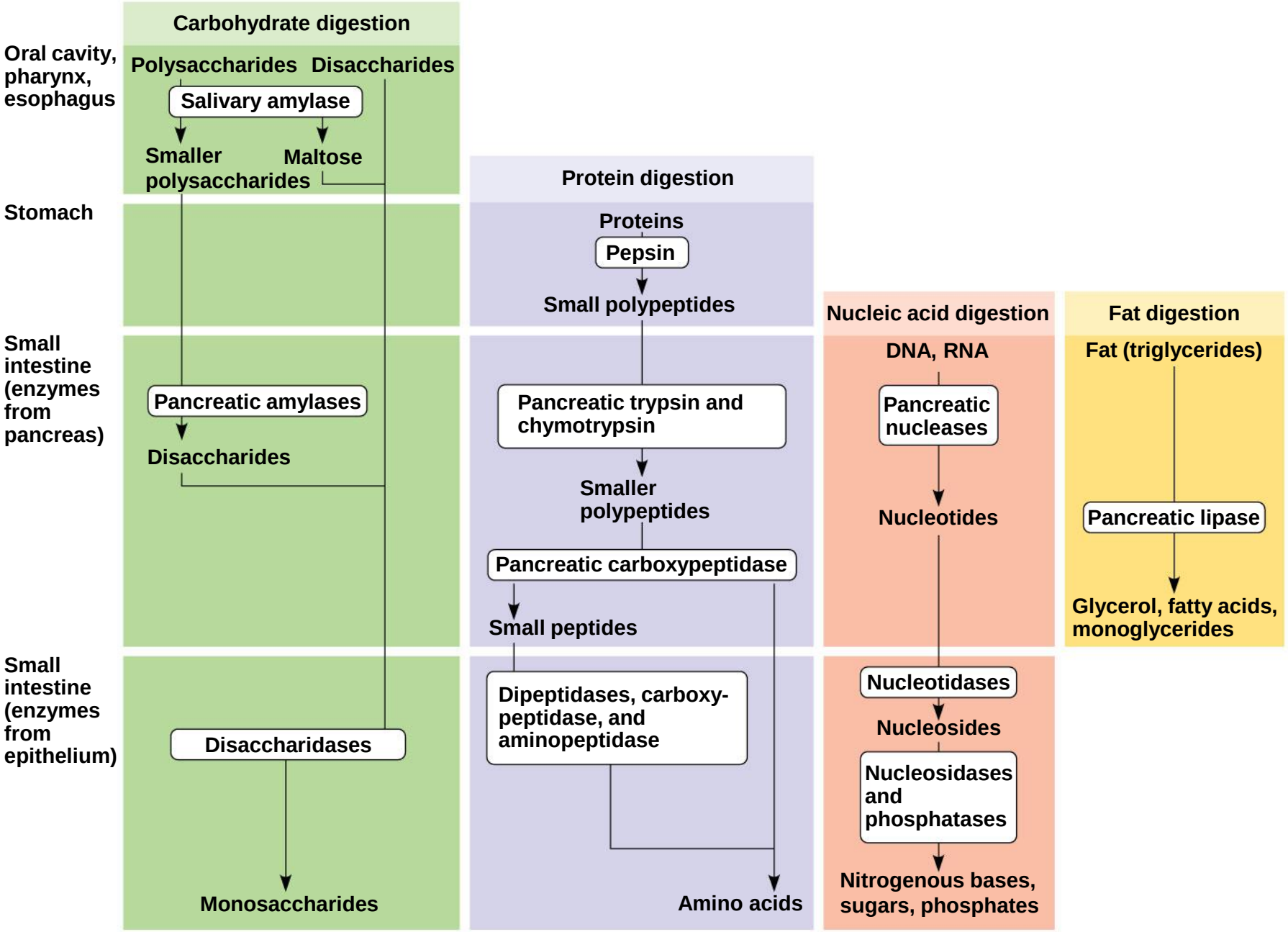


Figure 41.12-4



- The first portion of the small intestine is the **duodenum**, where chyme from the stomach mixes with digestive juices from the pancreas, liver, gallbladder, and the small intestine itself

Pancreatic Secretions

- The **pancreas** produces proteases trypsin and chymotrypsin that are activated in the lumen of the duodenum
- Its solution is alkaline and neutralizes the acidic chyme

Bile Production by the Liver

- In the small intestine, **bile** aids in digestion and absorption of fats
- Bile is made in the **liver** and stored in the **gallbladder**
- Bile also destroys nonfunctional red blood cells

Secretions of the Small Intestine

- The epithelial lining of the duodenum produces several digestive enzymes
- Enzymatic digestion is completed as peristalsis moves the chyme and digestive juices along the small intestine
- Most digestion occurs in the duodenum; the jejunum and ileum function mainly in absorption of nutrients and water

Absorption in the Small Intestine

- The small intestine has a huge surface area, due to **villi** and **microvilli** that are exposed to the intestinal lumen
- The enormous microvillar surface creates a brush border that greatly increases the rate of nutrient absorption
- Transport across the epithelial cells can be passive or active depending on the nutrient

Figure 41.13

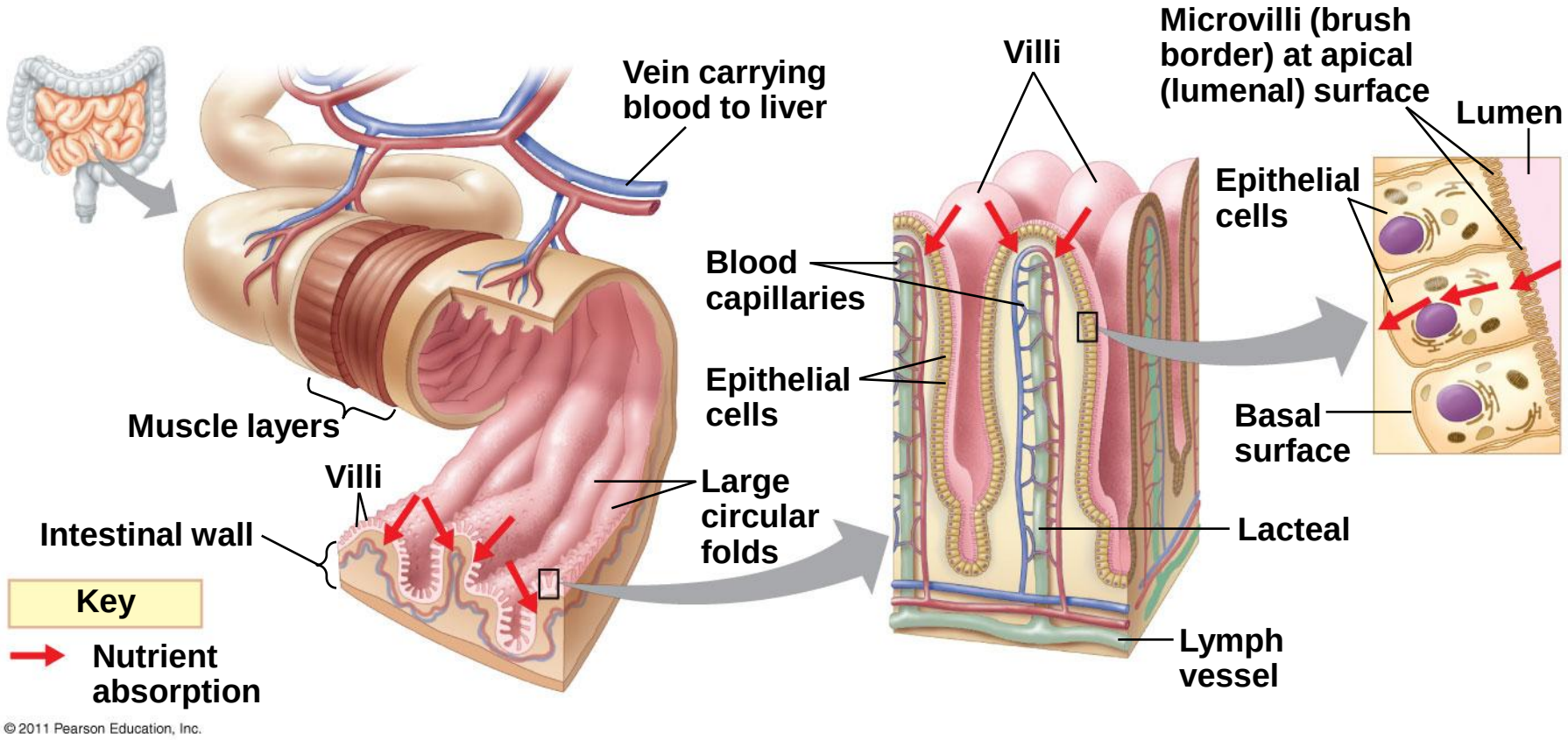


Figure 41.13a

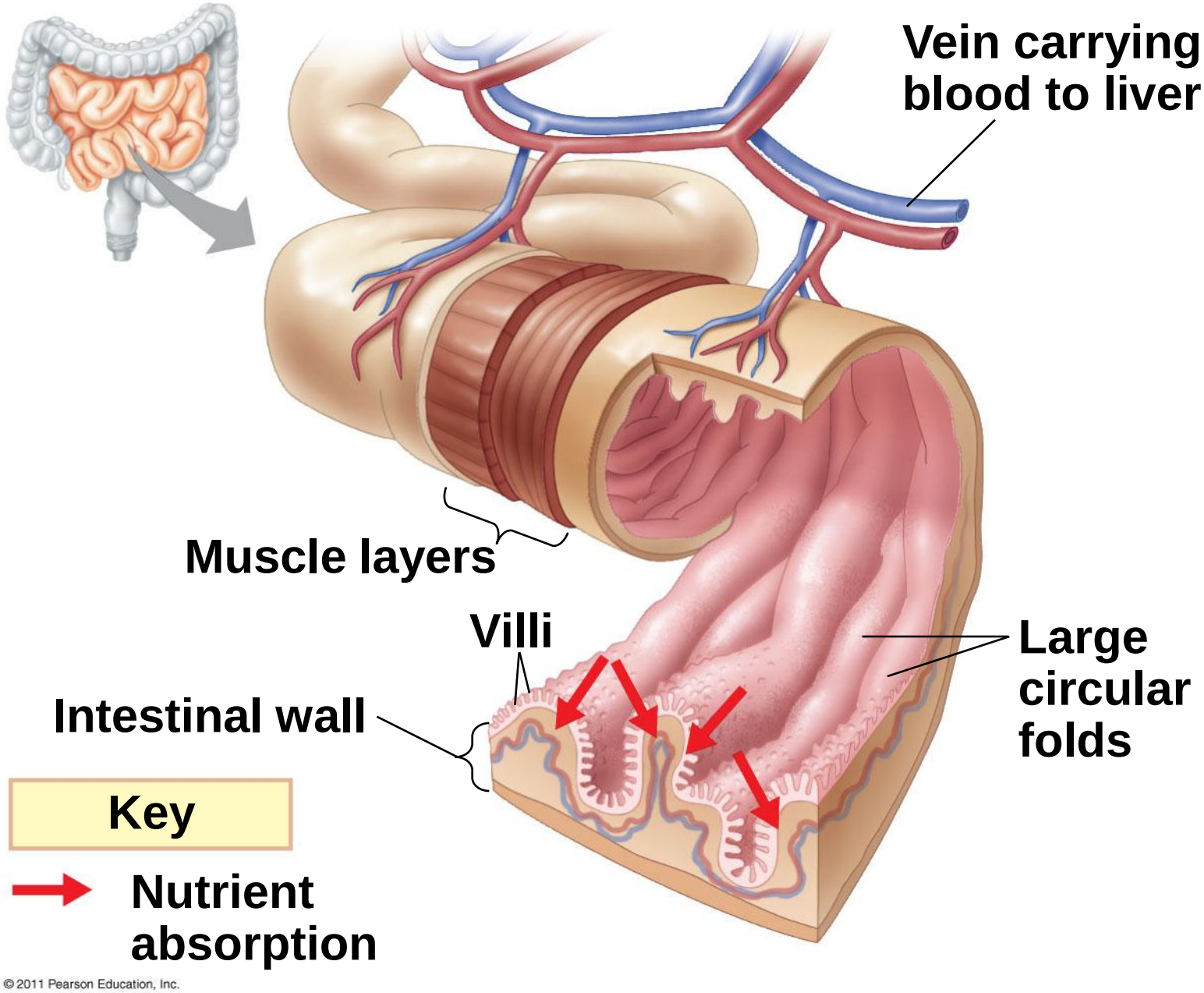
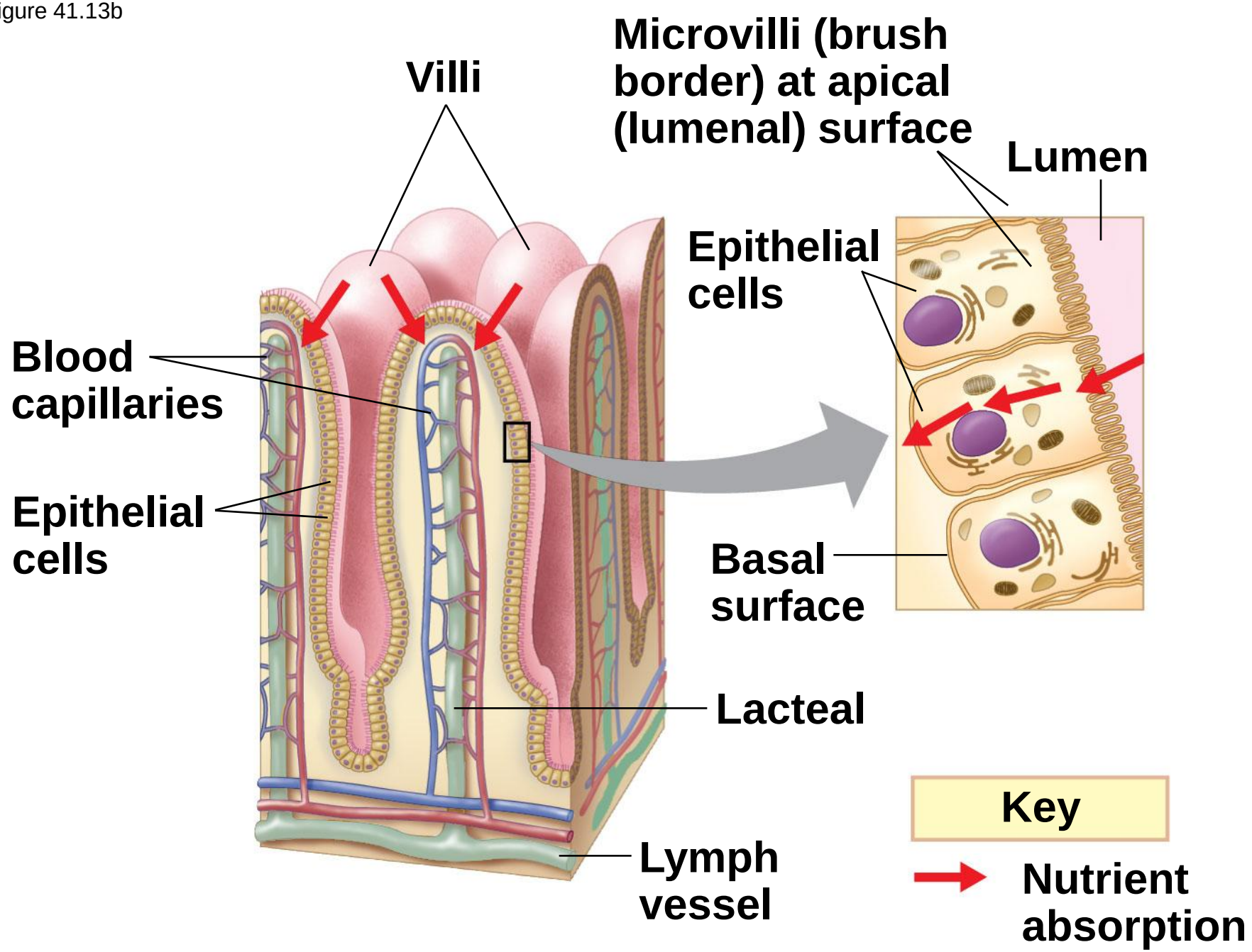


Figure 41.13b



- The **hepatic portal vein** carries nutrient-rich blood from the capillaries of the villi to the liver, then to the heart
- The liver regulates nutrient distribution, interconverts many organic molecules, and detoxifies many organic molecules

- Epithelial cells absorb fatty acids and monoglycerides and recombine them into triglycerides
- These fats are coated with phospholipids, cholesterol, and proteins to form water-soluble **chylomicrons**
- Chylomicrons are transported into a lacteal, a lymphatic vessel in each villus
- Lymphatic vessels deliver chylomicron-containing lymph to large veins that return blood to the heart

Figure 41.14

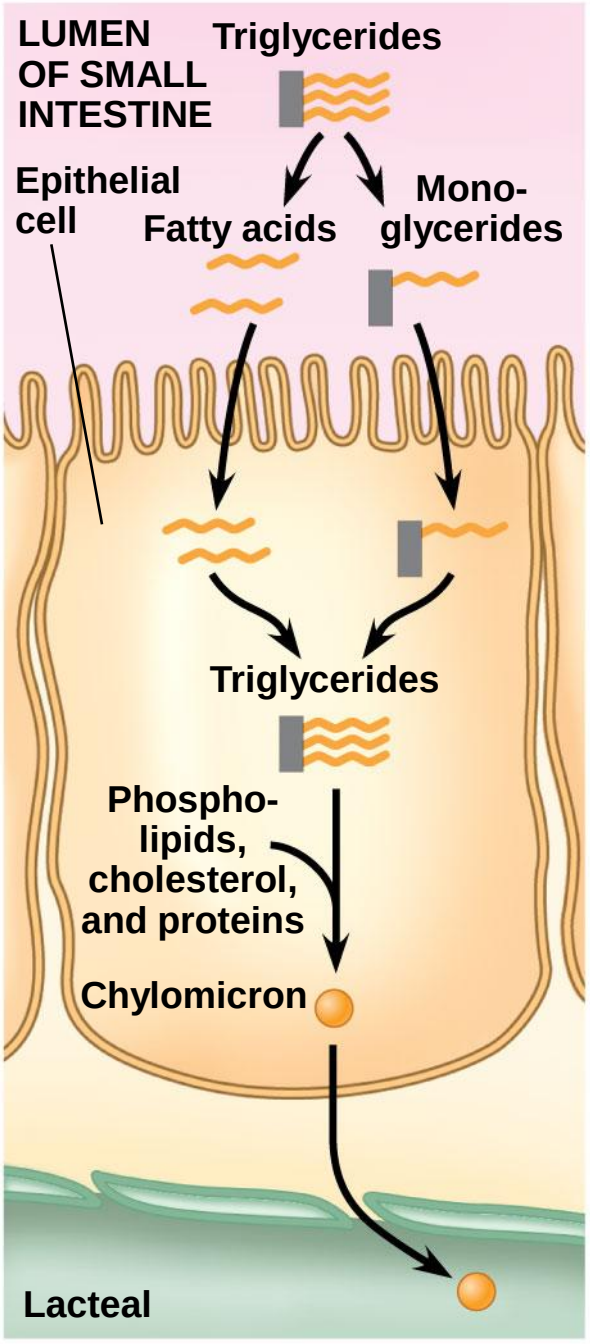


Figure 41.14a

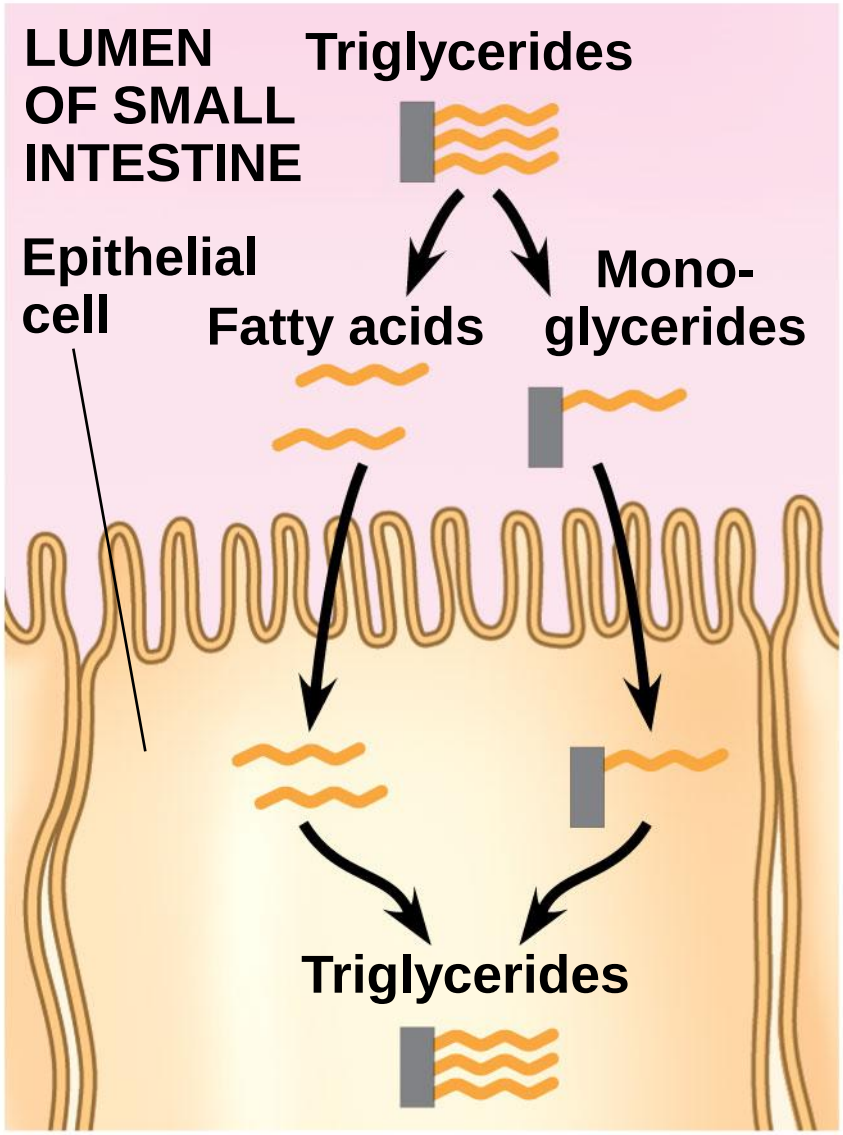
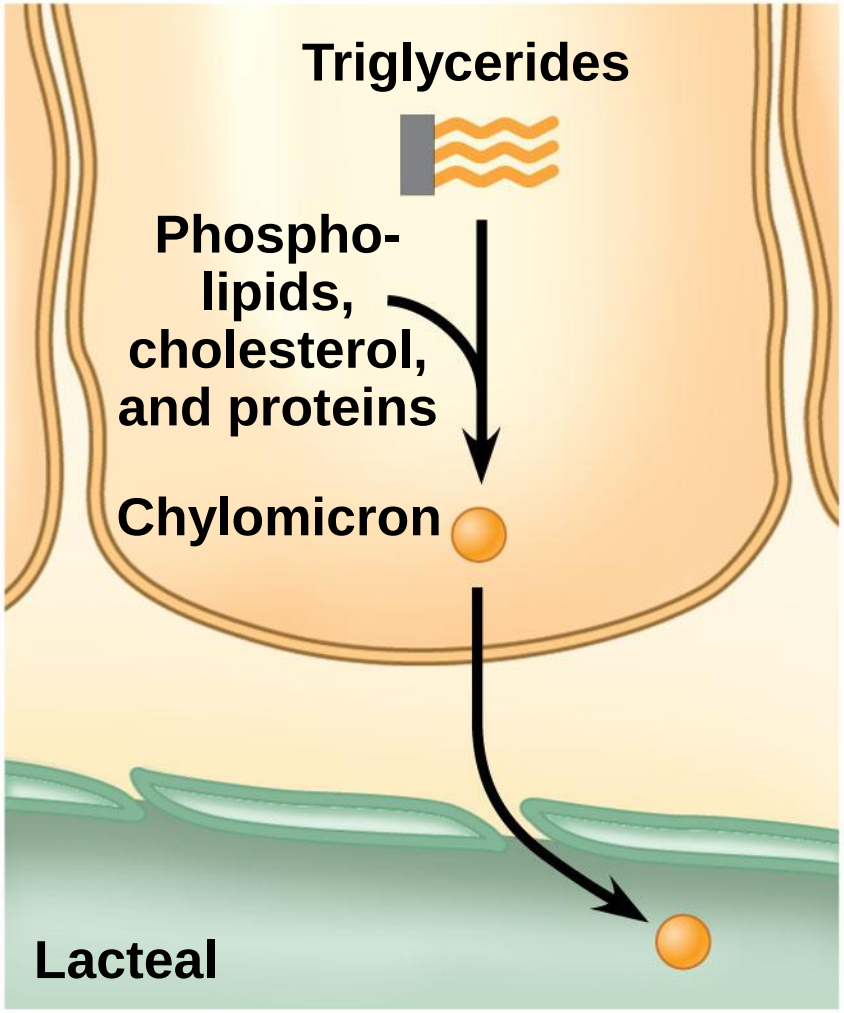


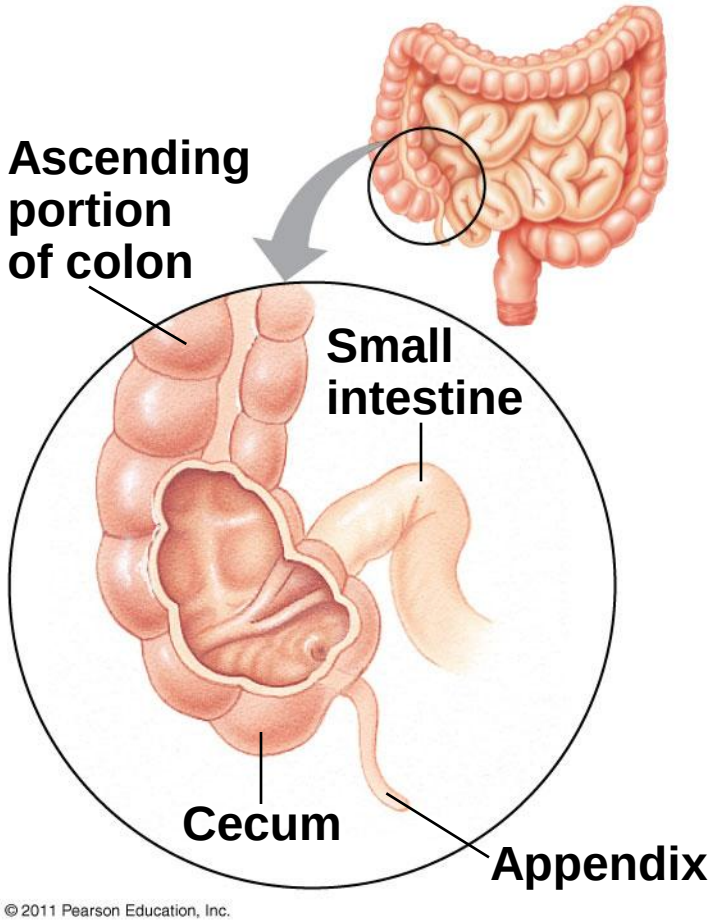
Figure 41.14b



Absorption in the Large Intestine

- The **colon** of the l**arge intestine** is connected to the small intestine
- The **cecum** aids in the fermentation of plant material and connects where the small and large intestines meet
- The human cecum has an extension called the **appendix**, which plays a very minor role in immunity

Figure 41.15


Ascending portion of colon
Small intestine
Cecum
Appendix
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- A major function of the colon is to recover water that has entered the alimentary canal
- The colon houses bacteria (e.g., *Escherichia coli*) which live on unabsorbed organic material; some produce vitamins
- **Feces**, including undigested material and bacteria, become more solid as they move through the colon

- Feces are stored in the **rectum** until they can be eliminated through the anus
- Two sphincters between the rectum and anus control bowel movements

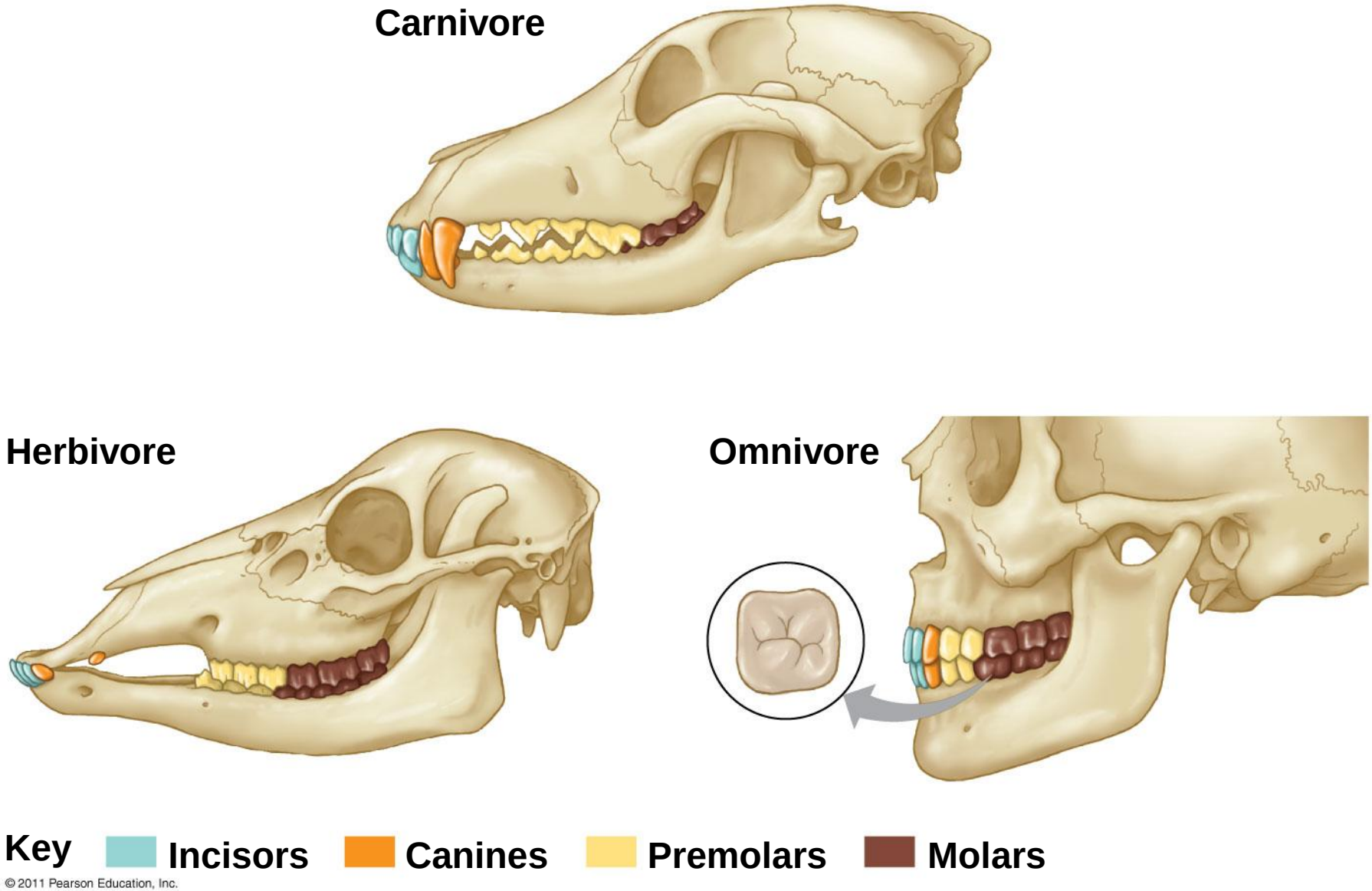
Concept 41.4: Evolutionary adaptations of vertebrate digestive systems correlate with diet

- Digestive systems of vertebrates are variations on a common plan
- However, there are intriguing adaptations, often related to diet

Dental Adaptations

- Dentition, an animal's assortment of teeth, is one example of structural variation reflecting diet
- The success of mammals is due in part to their dentition, which is specialized for different diets
- Nonmammalian vertebrates have less specialized teeth, though exceptions exist
  - For example, the teeth of poisonous snakes are modified as fangs for injecting venom

Figure 41.16



Stomach and Intestinal Adaptations

- Many carnivores have large, expandable stomachs
- Herbivores and omnivores generally have longer alimentary canals than carnivores, reflecting the longer time needed to digest vegetation

Figure 41.17

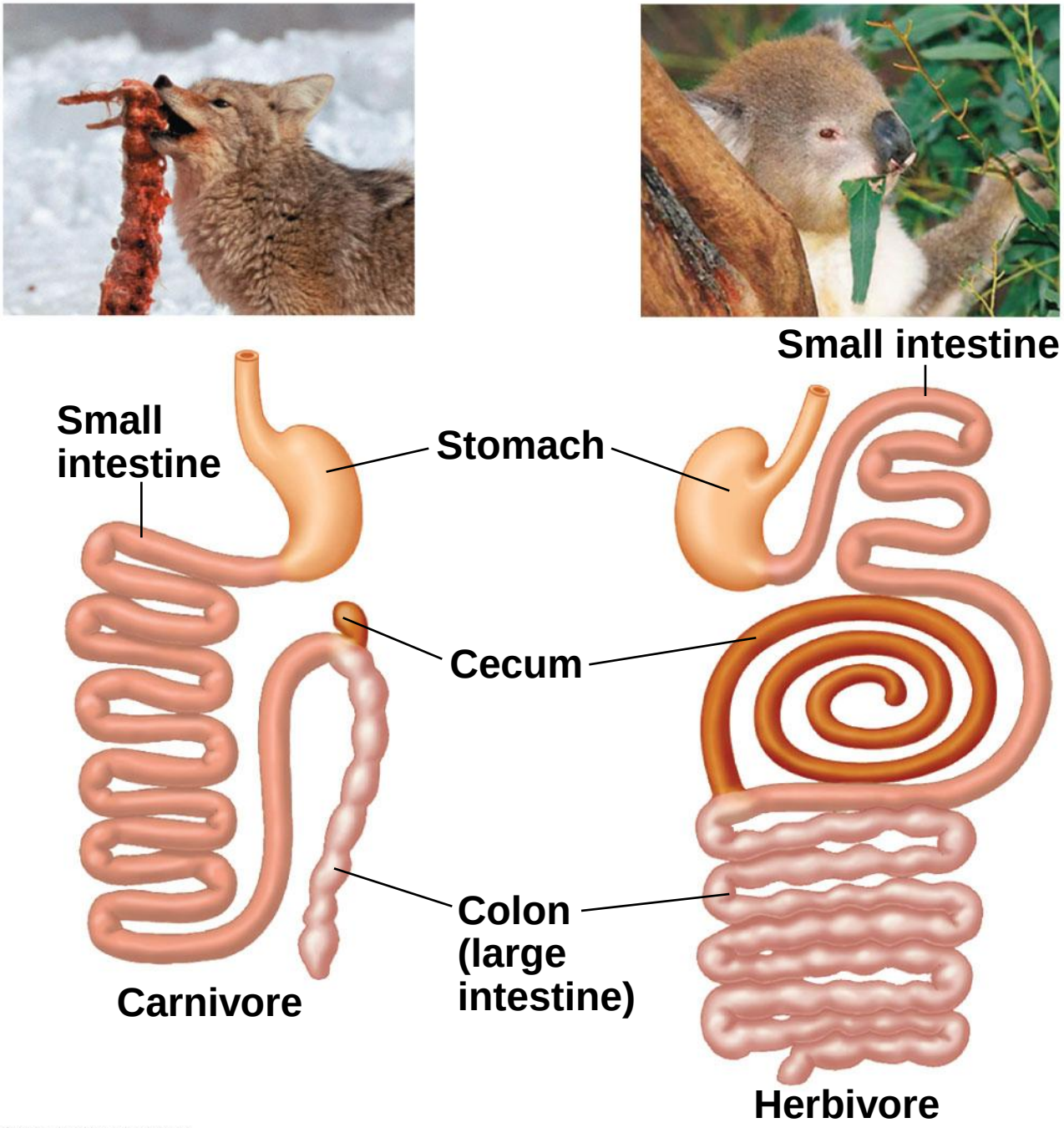


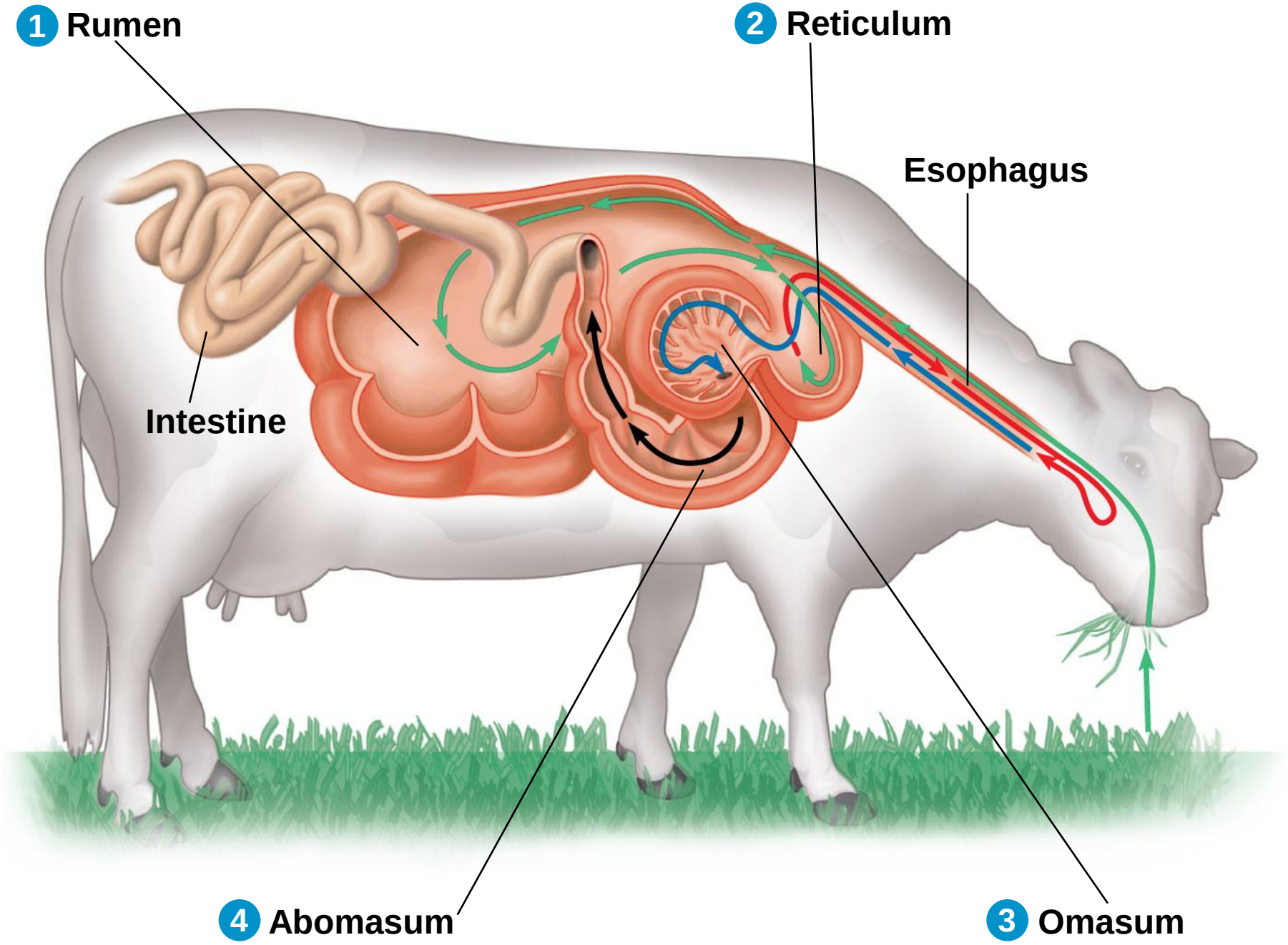
Figure 41.17a

Figure 41.17b

Mutualistic Adaptations

- Many herbivores have fermentation chambers, where mutualistic microorganisms digest cellulose
- The most elaborate adaptations for an herbivorous diet have evolved in the animals called **ruminants**

Figure 41.18



Concept 41.5: Feedback circuits regulate digestion, energy storage, and appetite

- The intake of food and the use of nutrients varies with an animal's diet and environment

Regulation of Digestion

- Each step in the digestive system is activated as needed
- The enteric division of the nervous system helps to regulate the digestive process
- The endocrine system also regulates digestion through the release and transport of hormones

Figure 41.19

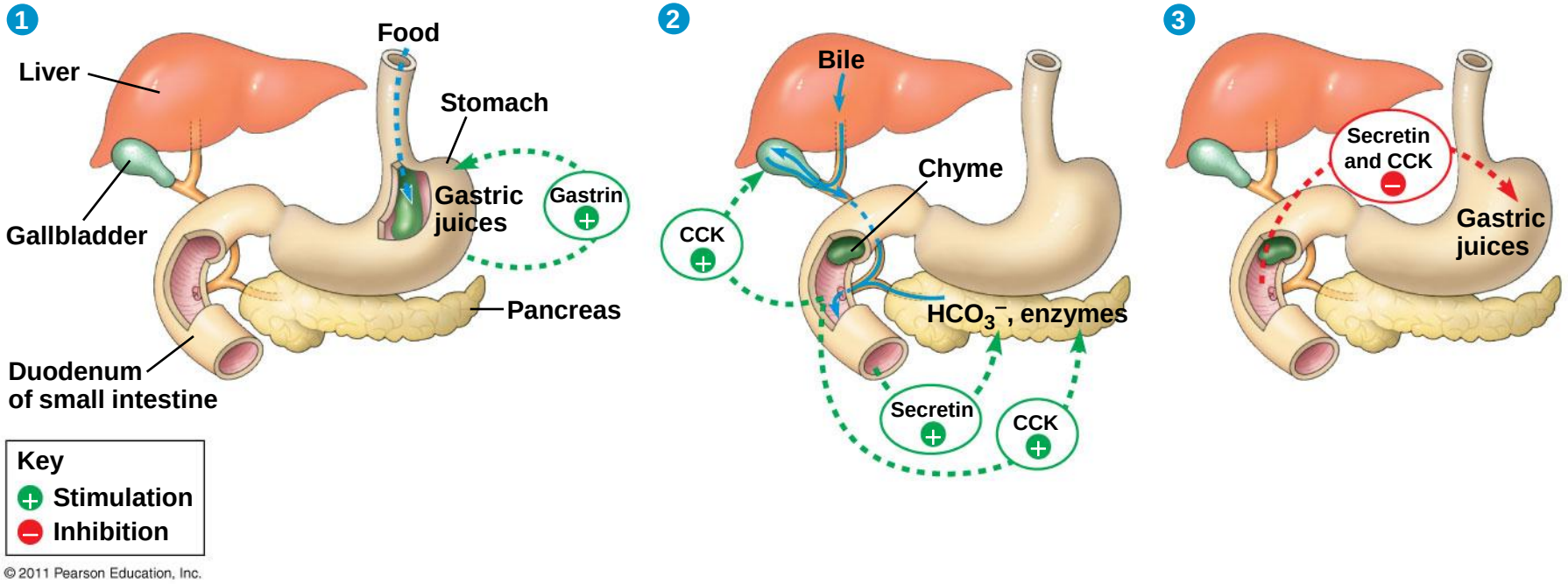


Figure 41.19a

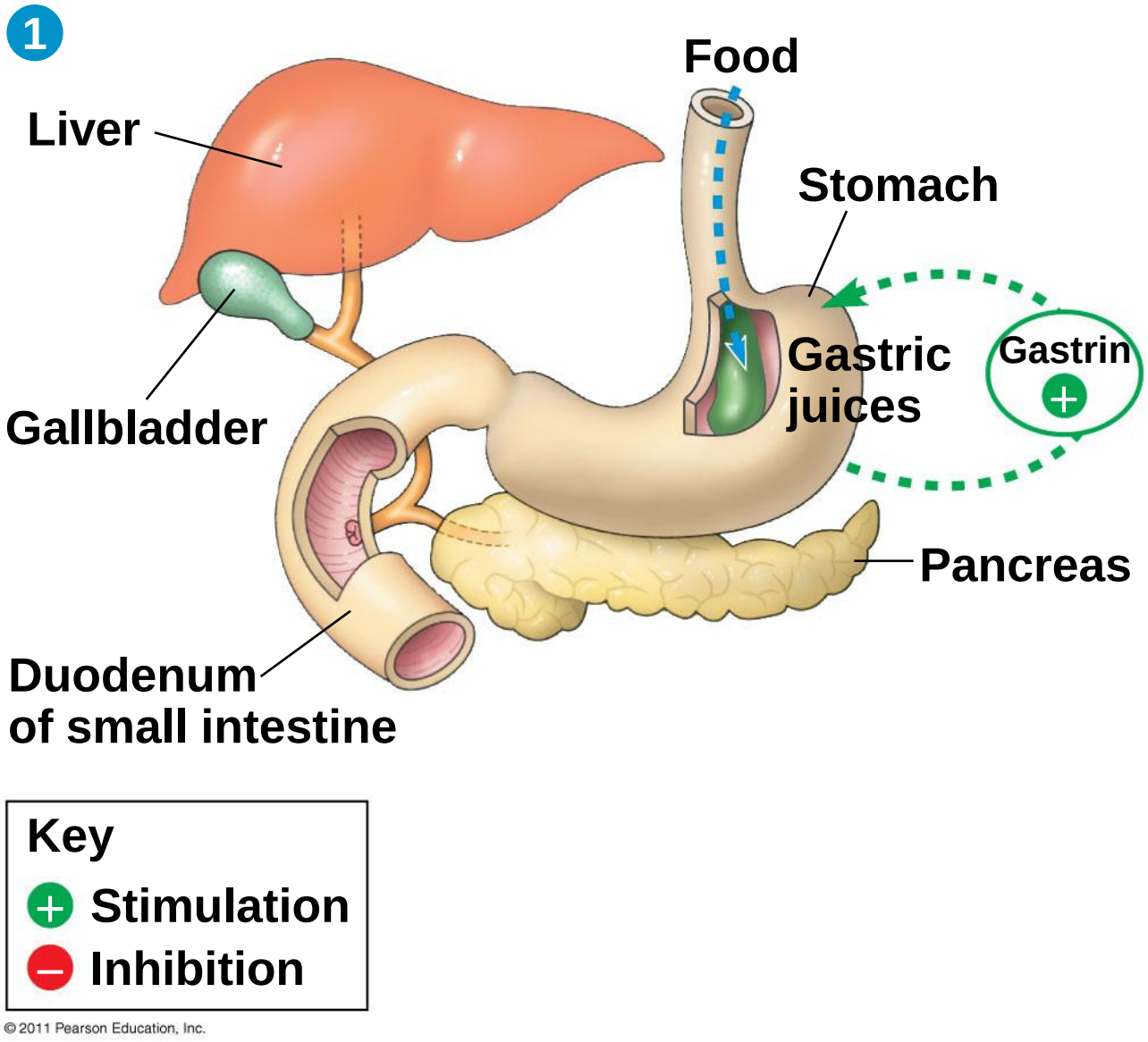


Figure 41.19b

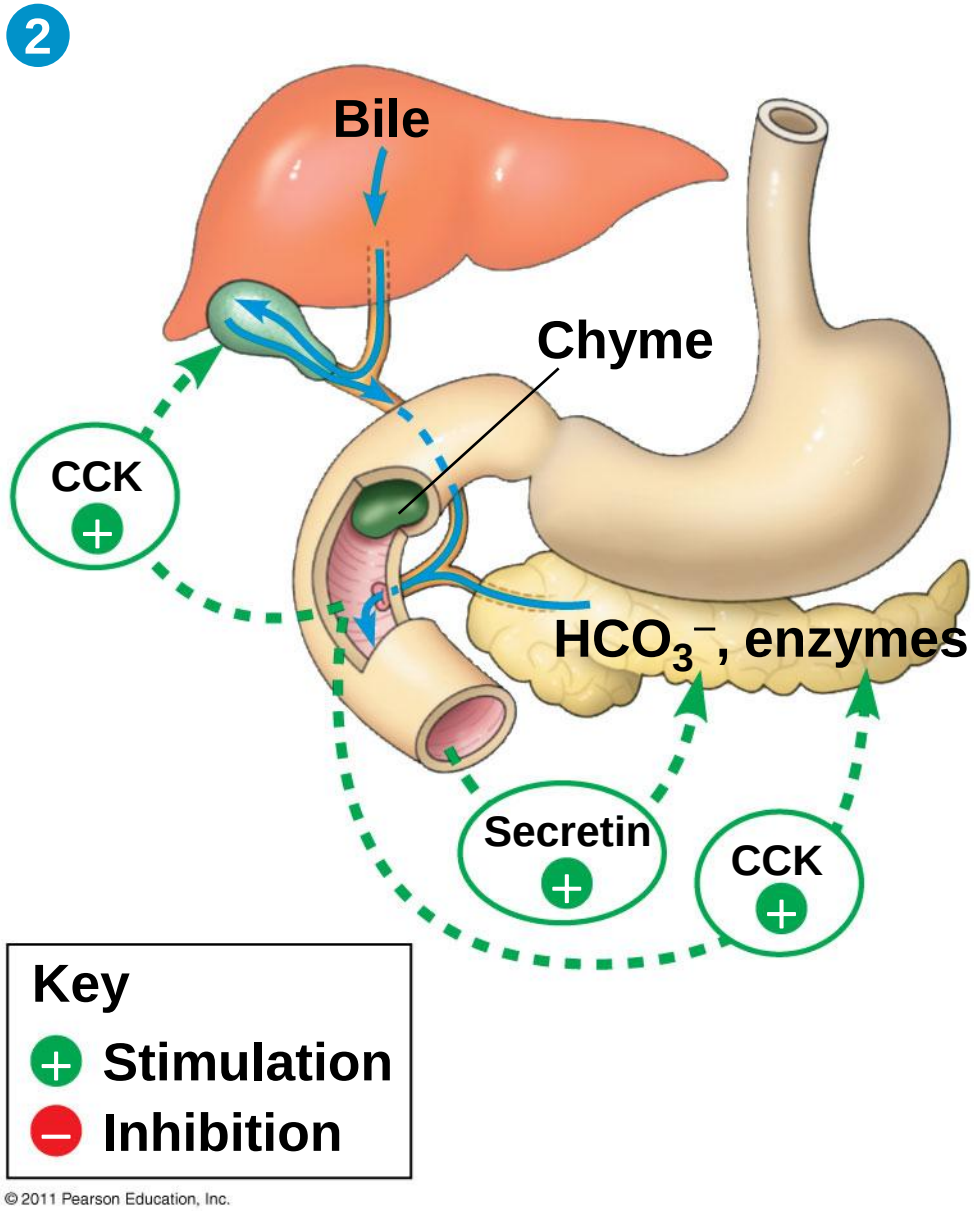
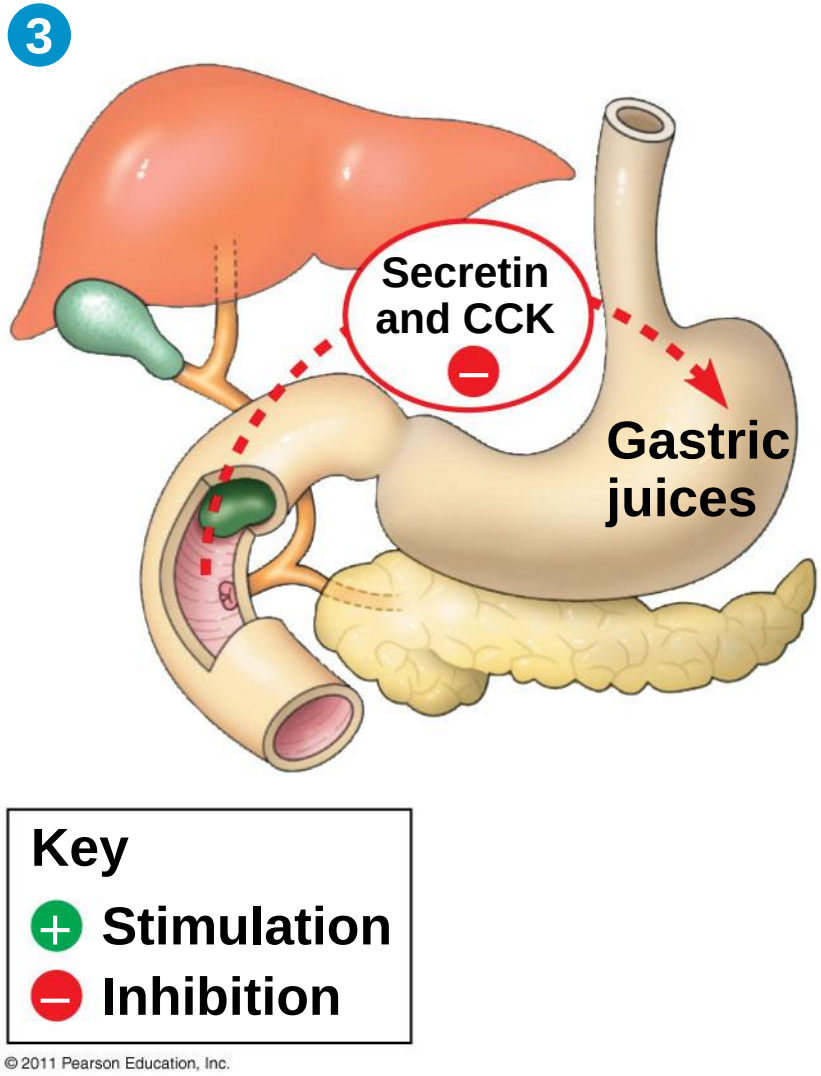


Figure 41.19c



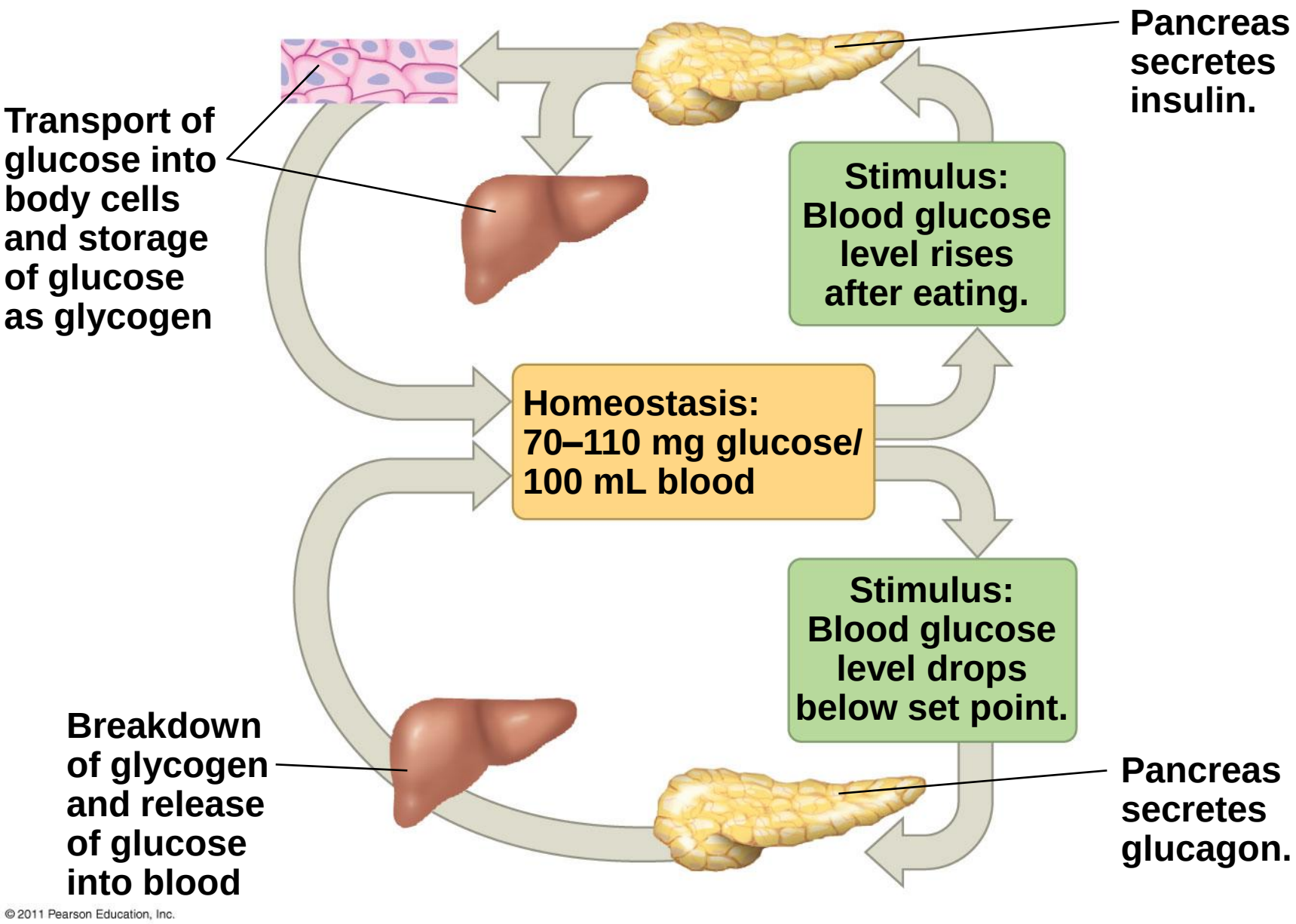
Regulation of Energy Storage

- The body stores energy-rich molecules that are not needed right away for metabolism
- In humans, energy is stored first in the liver and muscle cells in the polymer glycogen
- Excess energy is stored in adipose tissue, the most space-efficient storage tissue

Glucose Homeostasis

- Oxidation of glucose generates ATP to fuel cellular processes
- The hormones insulin and glucagon regulate the breakdown of glycogen into glucose
- The liver is the site for glucose homeostasis
  - A carbohydrate-rich meal raises insulin levels, which triggers the synthesis of glycogen
  - Low blood sugar causes glucagon to stimulate the breakdown of glycogen and release glucose

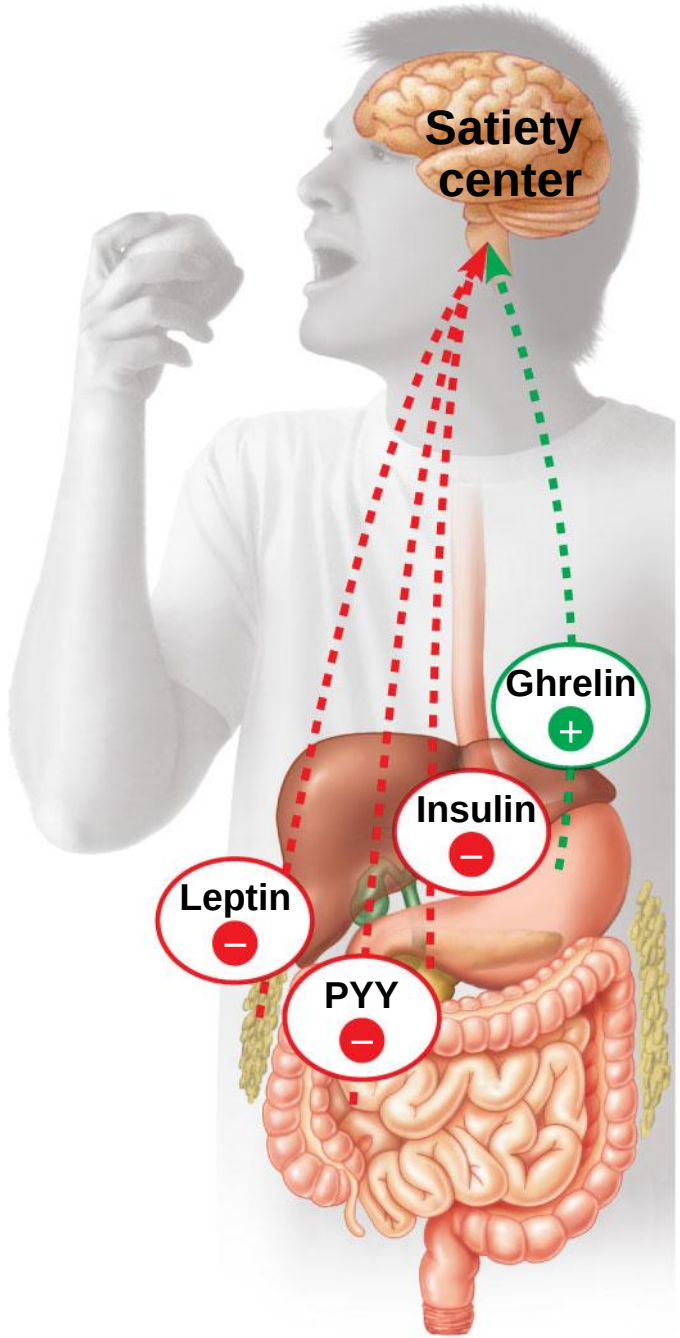
Figure 41.20



Regulation of Appetite and Consumption

- Overnourishment causes obesity, which results from excessive intake of food energy with the excess stored as fat
- Obesity contributes to diabetes (type 2), cancer of the colon and breasts, heart attacks, and strokes
- Researchers have discovered several of the mechanisms that help regulate body weight

Figure 41.21



- Hormones regulate long-term and short-term appetite by affecting a “satiety center” in the brain
- Studies on mice revealed that the hormone **leptin** plays an important role in regulating obesity
- Leptin is produced by adipose tissue and can help to suppress appetite

Figure 41.22

EXPERIMENT

Obese mouse with mutant *ob* gene (left) next to wild-type mouse

RESULTS

Genotype pairing (red type indicates mutant genes)		Average change in body mass (g) of subject
Subject	Paired with	
ob^+ob^+ , db^+db^+	ob^+ob^+ , db^+db^+	8.3
ob ob, db^+db^+	*ob ob*, db^+db^+	38.7
ob ob, db^+db^+	ob^+ob^+, db^+db^+	8.2
ob ob, db^+db^+	ob^+ob^+, *db db*	–14.9*

*Due to pronounced weight loss and weakening, subjects in this pairing were reweighed after less than eight weeks.

Figure 41.22a

Obese mouse with mutant *ob* gene (left) next to wild-type mouse

Figure 41.22b

RESULTS

Genotype pairing (red type indicates mutant genes)		Average change in body mass (g) of subject
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ob ob, db^+db^+	ob^+ob^+, *db db*	–14.9*

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Obesity and Evolution

- A species of birds called petrels become obese as chicks; in order to consume enough protein from high-fat food, chicks need to consume more calories than they burn

Figure 41.23

- The problem of maintaining weight partly stems from our evolutionary past, when fat hoarding was a means of survival
- Individuals who were more likely to eat fatty food and store energy as adipose tissue may have been more likely to survive famines

Figure 41.UN01

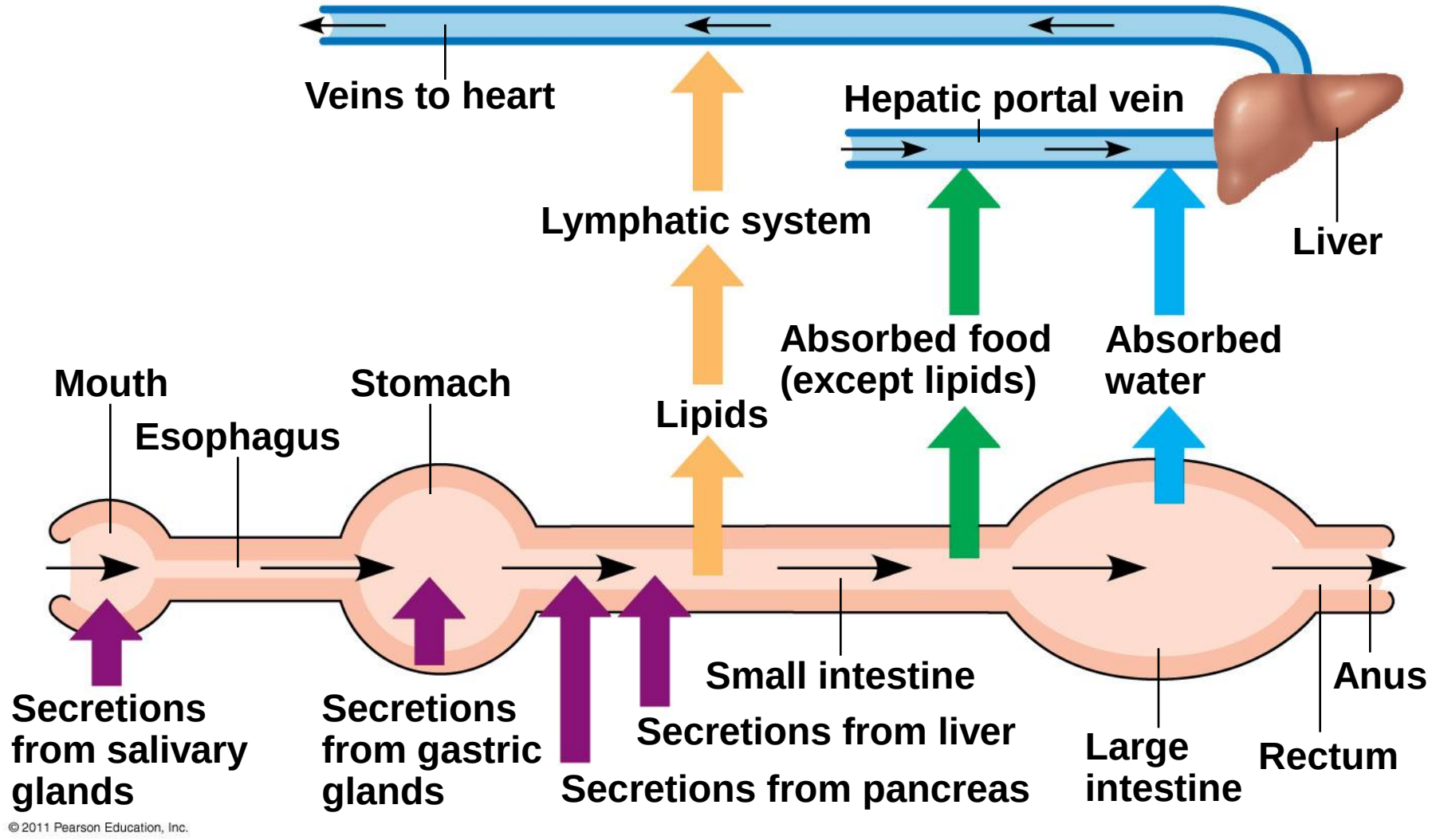

Figure 41.UN02