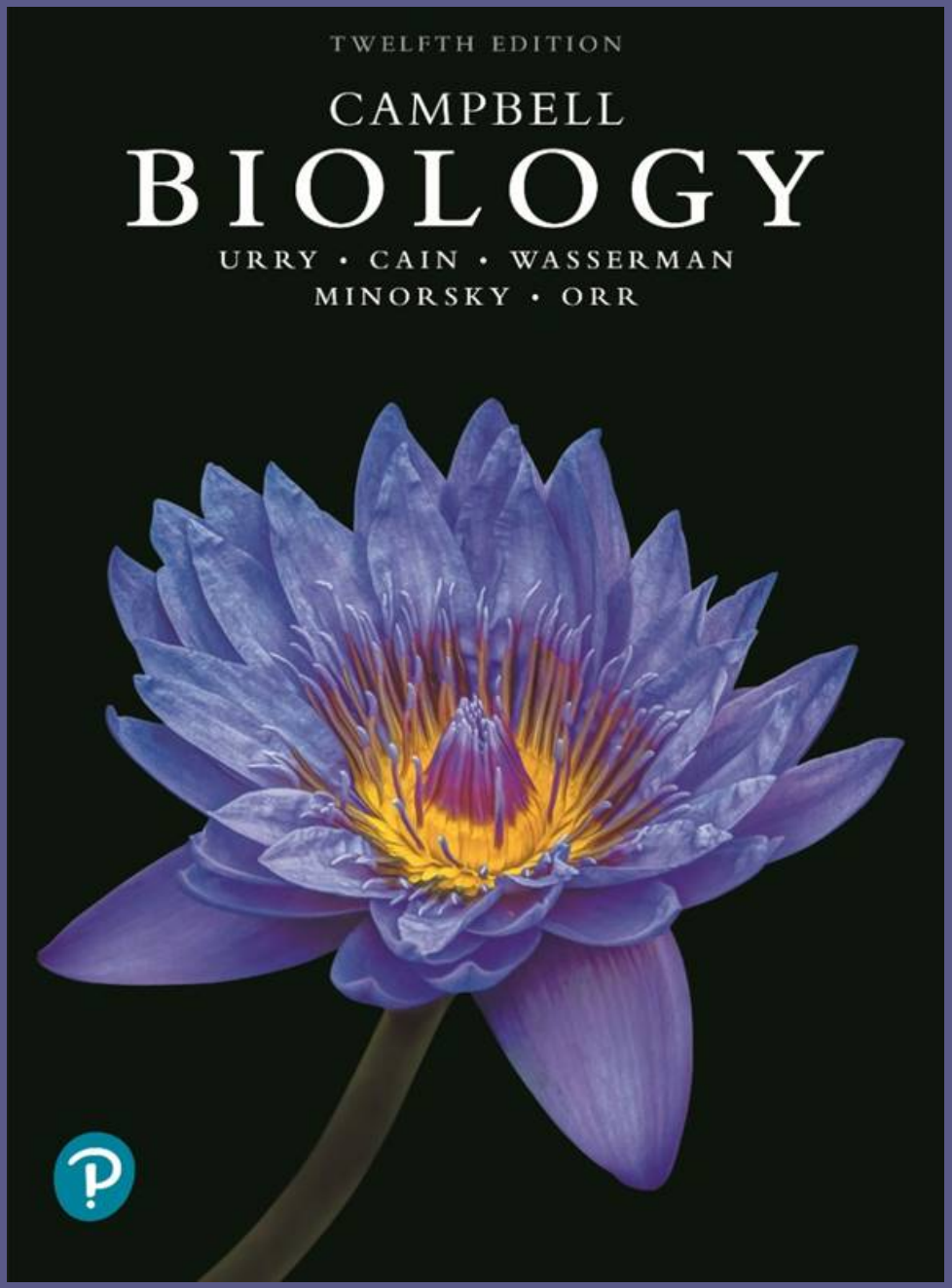


Chapter 41

Animal Nutrition

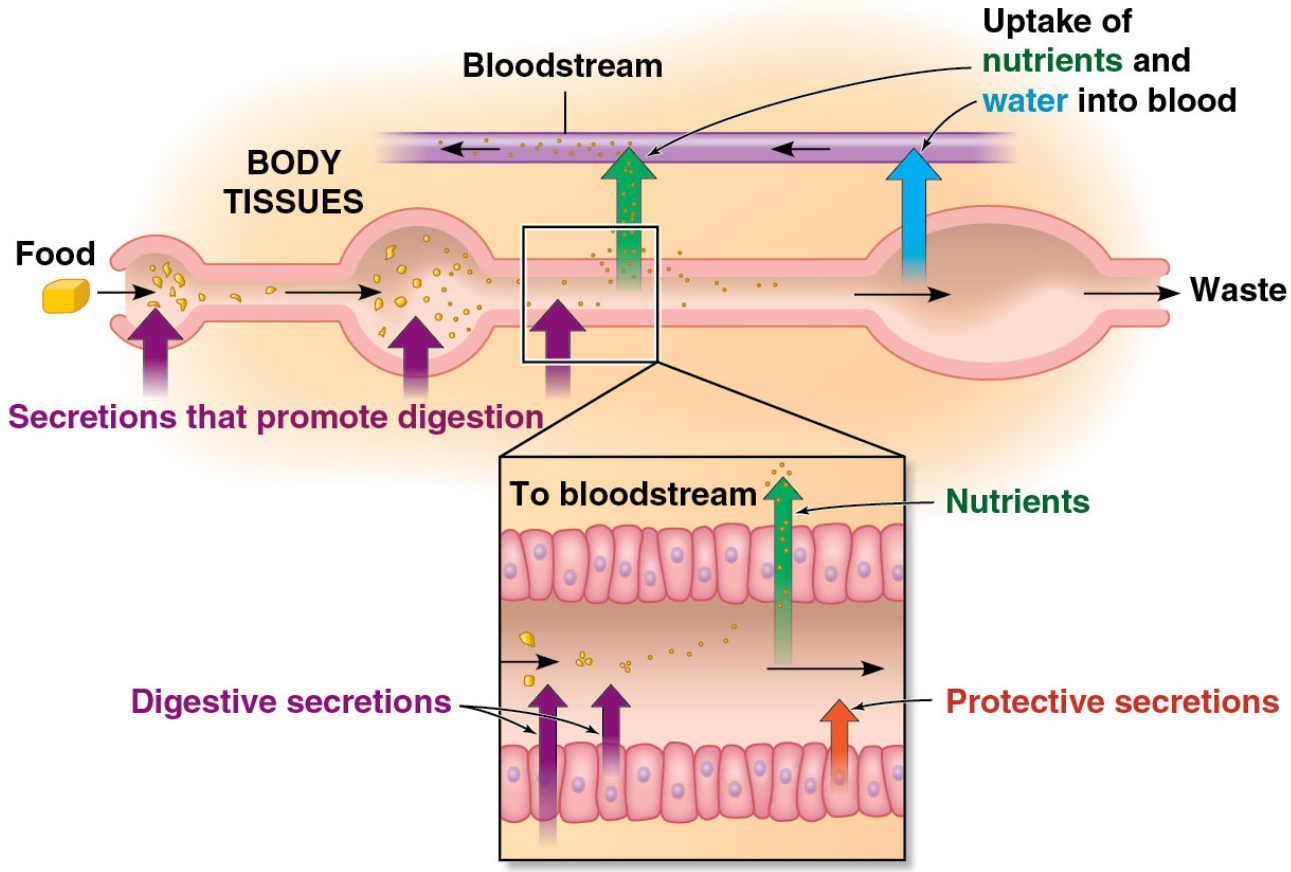
Lecture Presentations by
Nicole Tunbridge and
Kathleen Fitzpatrick

Figure 41.1a

Figure 41.1b

How can animals extract the nutrients they need from food while not digesting their own tissues?

Compartmentalized processing protects body tissues while allowing enzymes and acids to break down nutrients.



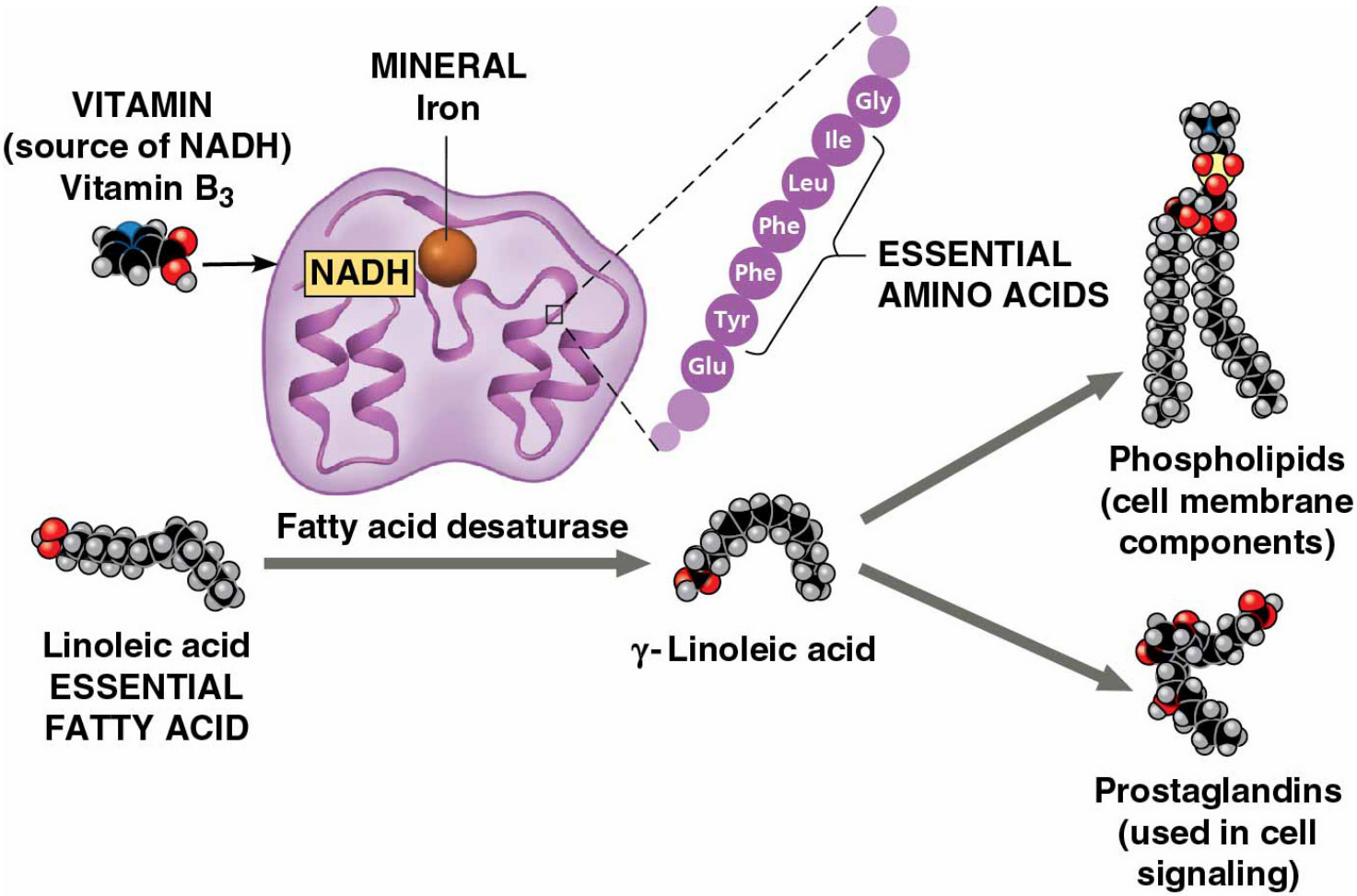
Concept 41.1: An animal's diet must supply chemical energy, organic building blocks, and essential nutrients

- An adequate diet must satisfy three needs:
  - Chemical energy for cellular processes
  - Organic building blocks for macromolecules
  - Essential nutrients

Essential Nutrients

- Required materials that an animal requires, but cannot assemble from simple organic molecules are called **essential nutrients**
- These must be obtained from an animal's diet
- There are four classes:
  - Essential amino acids
  - Essential fatty acids
  - Vitamins
  - Minerals

Figure 41.2


VITAMIN
(source of NADH)
Vitamin B_3
MINERAL
Iron
NADH
Gly
Ile
Leu
Phe
Phe
Tyr
Glu
ESSENTIAL
AMINO ACIDS
Phospholipids
(cell membrane
components)
Fatty acid desaturase
Linoleic acid
ESSENTIAL
FATTY ACID
γ- Linoleic acid
Prostaglandins
(used in cell
signaling)

Essential Amino Acids

- All organisms require 20 amino acids
- Plants and microorganisms can normally produce all 20
- Animals can synthesize about half from molecules in their diet
- The remaining amino acids, the **essential amino acids**, must be obtained from food in prefabricated form
- Meat, eggs, and cheese provide all the essential amino acids and are thus “complete” proteins

- Most plant proteins are incomplete in amino acid composition
- Vegetarians can easily obtain all essential amino acids by eating a varied diet of plant proteins

Essential Fatty Acids

- Animals can synthesize many of the fatty acids they need
- The **essential fatty acids** must be obtained from the diet and include certain unsaturated fatty acids (i.e., fatty acids with one or more double bonds)
- Animals typically obtain ample amounts of essential fatty acids from seeds, grains, and vegetables their diet

Vitamins

- **Vitamins** are organic molecules required in the diet in very small amounts
- Thirteen vitamins are essential for humans
- Vitamins are grouped into two categories: fat-soluble and water-soluble

Table 41.1 Vitamin Requirements of Humans

Vitamin	Major Dietary Sources	Major Functions in the Body	Symptoms of Deficiency
Water-Soluble Vitamins			
B_1 (thiamine)	Pork, legumes, peanuts, whole grains	Coenzyme used in removing CO_2 from organic compounds	Beriberi (tingling, poor coordination, reduced heart function)
B_2 (riboflavin)	Dairy products, meats, enriched grains, vegetables	Component of coenzymes FAD and FMN	Skin lesions, such as cracks at corners of mouth
B_3 (niacin)	Nuts, meats, grains	Component of coenzymes NAD^+ and $NADP^+$	Skin and gastrointestinal lesions, delusions, confusion
B_5 (pantothenic acid)	Meats, dairy products, whole grains, fruits, vegetables	Component of coenzyme A	Fatigue, numbness, tingling of hands and feet
B_6 (pyridoxine)	Meats, vegetables, whole grains	Coenzyme used in amino acid metabolism	Irritability, convulsions, muscular twitching, anemia
B_7 (biotin)	Legumes, other vegetables, meats	Coenzyme in synthesis of fat, glycogen, and amino acids	Scaly skin inflammation, neuromuscular disorders
B_9 (folic acid)	Green vegetables, oranges, nuts, legumes, whole grains	Coenzyme in nucleic acid and amino acid metabolism	Anemia, neural tube malformation in fetus
B_{12} (cobalamin)	Meats, eggs, dairy products	Production of nucleic acids and red blood cells	Anemia, numbness, loss of balance
C (ascorbic acid)	Citrus fruits, broccoli, tomatoes	Used in collagen synthesis; antioxidant	Scurvy (degeneration of skin and teeth), delayed wound healing
Fat-Soluble Vitamins			
A (retinol)	Dark green and orange vegetables and fruits, dairy products	Component of visual pigments; maintenance of epithelial tissues	Blindness, skin disorders, impaired immunity
D	Dairy products, egg yolk	Aids in absorption and use of calcium and phosphorus	Rickets (bone deformities) in children, bone softening in adults
E (tocopherol)	Vegetable oils, nuts, seeds	Antioxidant; helps prevent damage to cell membranes	Nervous system degeneration
K (phylloquinone)	Green vegetables, tea; also made by colon bacteria	Important in blood clotting	Defective blood clotting

Minerals

- **Minerals** are simple inorganic nutrients, usually required in small amounts
- Ingesting large amounts of some minerals can upset homeostatic balance

Table 41.2 Mineral Requirements of Humans*

	Mineral	Major Dietary Sources	Major Functions in the Body	Symptoms of Deficiency
More than 200 mg per day required	Calcium (Ca)	Dairy products, dark green vegetables, legumes	Bone and tooth formation, blood clotting, nerve and muscle function	Impaired growth, loss of bone mass
	Phosphorus (P)	Dairy products, meats, grains	Bone and tooth formation, acid-base balance, nucleotide synthesis	Weakness, loss of minerals from bone, calcium loss
	Sulfur (S)	Proteins from many sources	Component of certain amino acids	Impaired growth, fatigue, swelling
	Potassium (K)	Meats, dairy products, many fruits and vegetables, grains	Acid-base balance, water balance, nerve function	Muscular weakness, paralysis, nausea, heart failure
	Chlorine (Cl)	Table salt	Acid-base balance, formation of gastric juice, nerve function, osmotic balance	Muscle cramps, reduced appetite
	Sodium (Na)	Table salt	Acid-base balance, water balance, nerve function	Muscle cramps, reduced appetite
	Magnesium (Mg)	Whole grains, green leafy vegetables	Enzyme cofactor; ATP bioenergetics	Nervous system disturbances
	Iron (Fe)	Meats, eggs, legumes, whole grains, green leafy vegetables	Component of hemoglobin and of electron carriers; enzyme cofactor	Iron-deficiency anemia, weakness, impaired immunity
	Fluorine (F)	Drinking water, tea, seafood	Maintenance of tooth structure	Higher frequency of tooth decay
	Iodine (I)	Seafood, iodized salt	Component of thyroid hormones	Goiter (enlarged thyroid gland)

*Additional minerals required in trace amounts include cobalt (Co), copper (Cu), manganese (Mn), molybdenum (Mo), selenium (Se), and zinc (Zn). All of these minerals, as well as those in the table, can be harmful in excess.

Variation in Diet

- Animals have diverse diets
- **Herbivores** dine mainly on plants or algae
- **Carnivores** mostly eat other animals
- **Omnivores** regularly consume animals as well as plants or algae
- These terms represent the usual diets of the animals
- Most animals are opportunistic feeders, and broaden their diet when necessary

Dietary Deficiencies

- Malnutrition is a failure to obtain adequate nutrition
- Malnutrition can have negative impacts on health and survival

Deficiencies in Essential Nutrients

- Deficiencies in essential nutrients can cause deformities, disease, and death
- Some grazing animals can obtain missing nutrients by consuming concentrated sources of salt or other minerals
- In children, protein deficiency may arise when their diet shifts from breast milk to foods containing very little protein

Figure 41.3

Undernourishment

- Undernourishment results when a diet does not provide enough chemical energy
- An undernourished individual will
  - Use up stored fat and carbohydrates
  - Break down its own proteins
  - Lose muscle mass
  - Suffer protein deficiency of the brain
  - Die or suffer irreversible damage

Assessing Nutritional Needs

- Many insights into human nutrition have come from epidemiology, the study of human health and disease in populations
- Neural tube defects were found to be the result of a deficiency in folic acid in pregnant mothers
- Based on this evidence, the United States in 1998 began to require that folic acid be added to enriched grain products

Figure 41.4

Results

Group	Number of Infants/Fetuses Studied	Infants/Fetuses with a Neural Tube Defect
Vitamin supplements (experimental group)	141	1
No vitamin supplements (control group)	204	12

Data from R. W. Smithells et al., Possible prevention of neural-tube defects by periconceptional vitamin supplementation, *Lancet* 315:339–340 (1980).

Concept 41.2: Food processing involves ingestion, digestion, absorption, and elimination

- **Ingestion** is the act of eating or feeding
- Four quite different categories describe the feeding mechanisms of most animal species

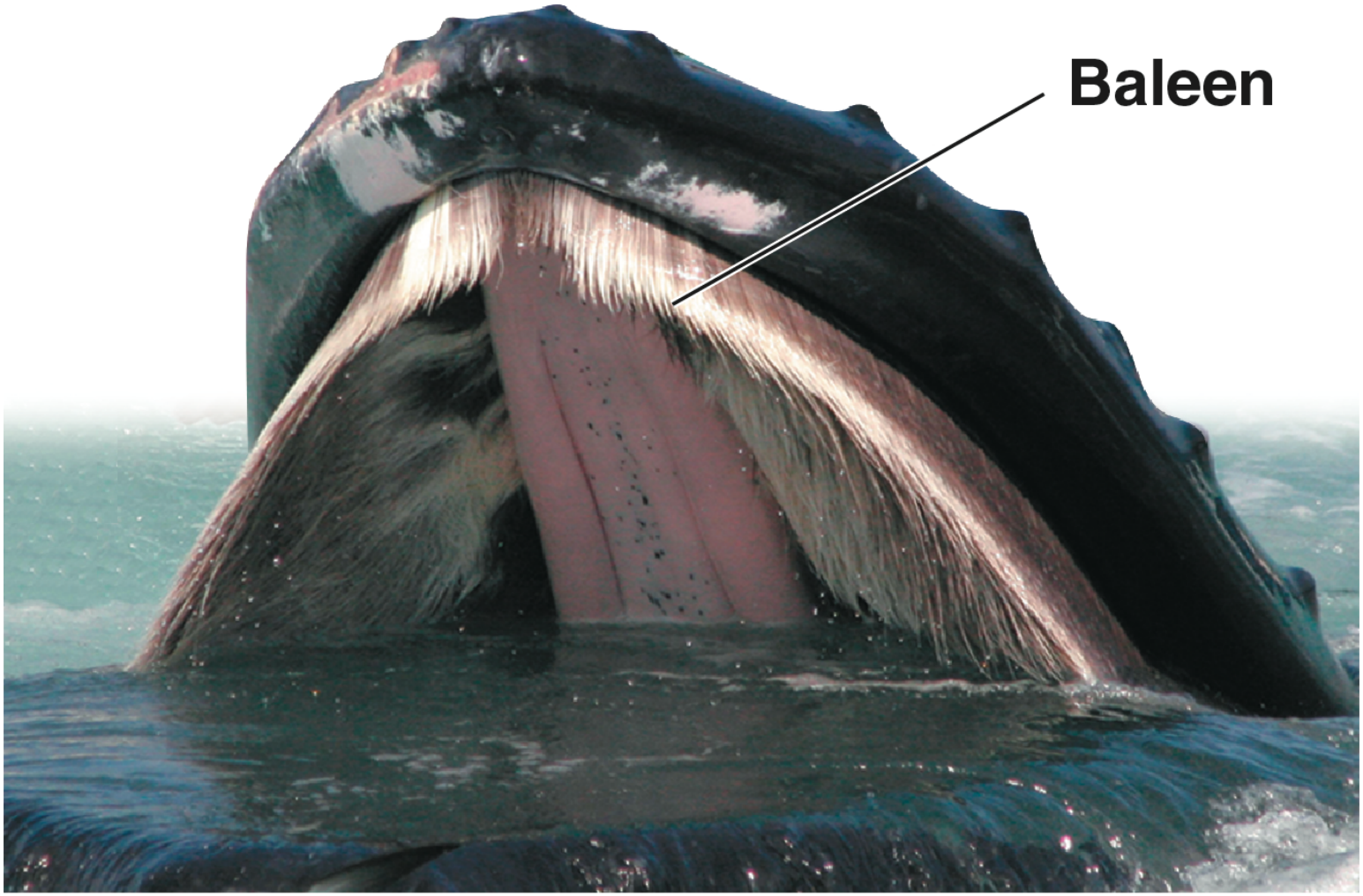
Figure 41.5 Exploring four main feeding mechanisms of animals

Filter Feeders

- Many aquatic animals are **filter feeders**, which sift small food particles from the surrounding medium

Figure 41.5

Filter Feeding

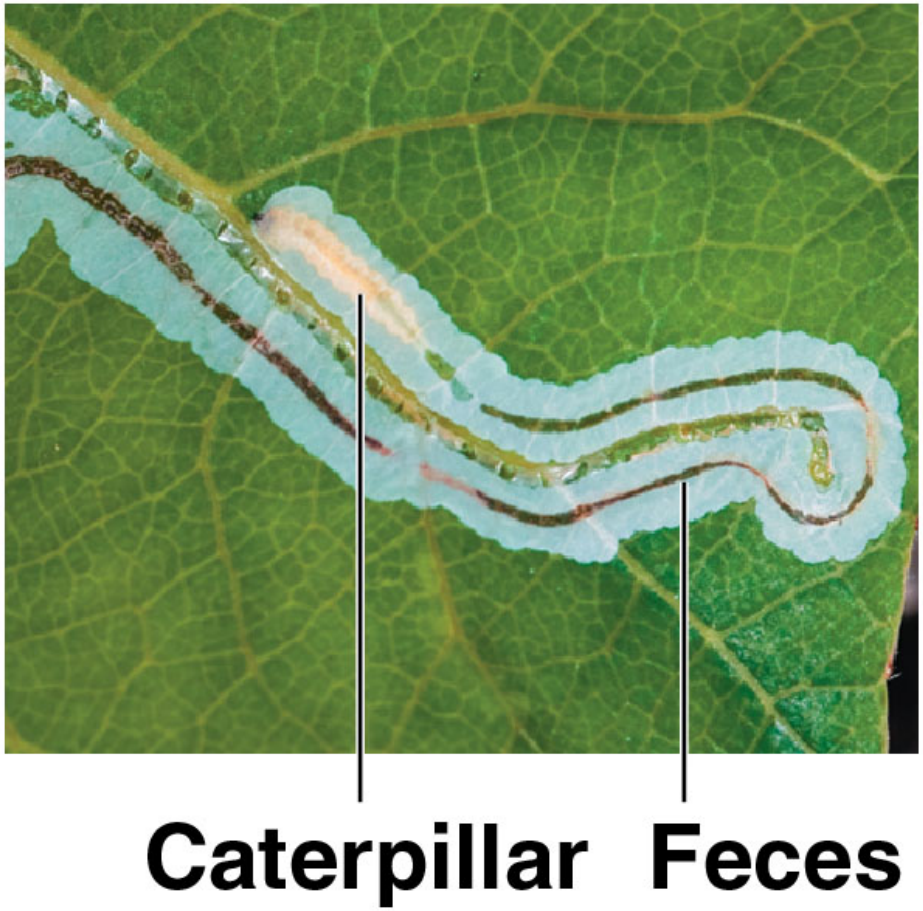


Substrate Feeders

- **Substrate feeders** are animals that live in or on their food source

Figure 41.5

Substrate Feeding



Fluid Feeders

- **Fluid feeders** suck nutrient-rich fluid from a living host

Figure 41.5

Fluid Feeding

Bulk Feeders

- **Bulk feeders** eat relatively large pieces of food
- Most animals, including humans, feed this way

Figure 41.5

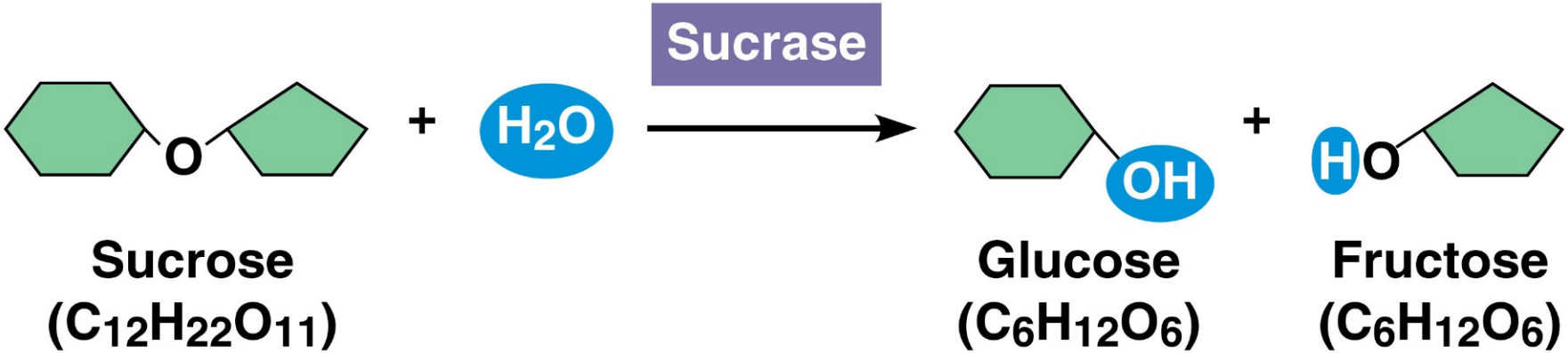
Bulk Feeding

Video: Shark Eating a Seal

Video: Lobster Mouth Parts

- **Digestion** is the process of breaking food down into molecules small enough to absorb
- Mechanical digestion, chewing or grinding, increases the surface area of food
- Chemical digestion splits food into small molecules that can pass through membranes; these are used to build larger molecules
- In chemical digestion, the process of enzymatic hydrolysis splits bonds in molecules with the addition of water

Figure 41.UN01



Enzymatic hydrolysis of a disaccharide

- **Absorption** is uptake of small molecules by body cells
- **Elimination** is the passage of undigested material out of the digestive system

Digestive Compartments

- Most animals process food in specialized compartments
- These compartments reduce the risk of an animal digesting its own cells and tissues

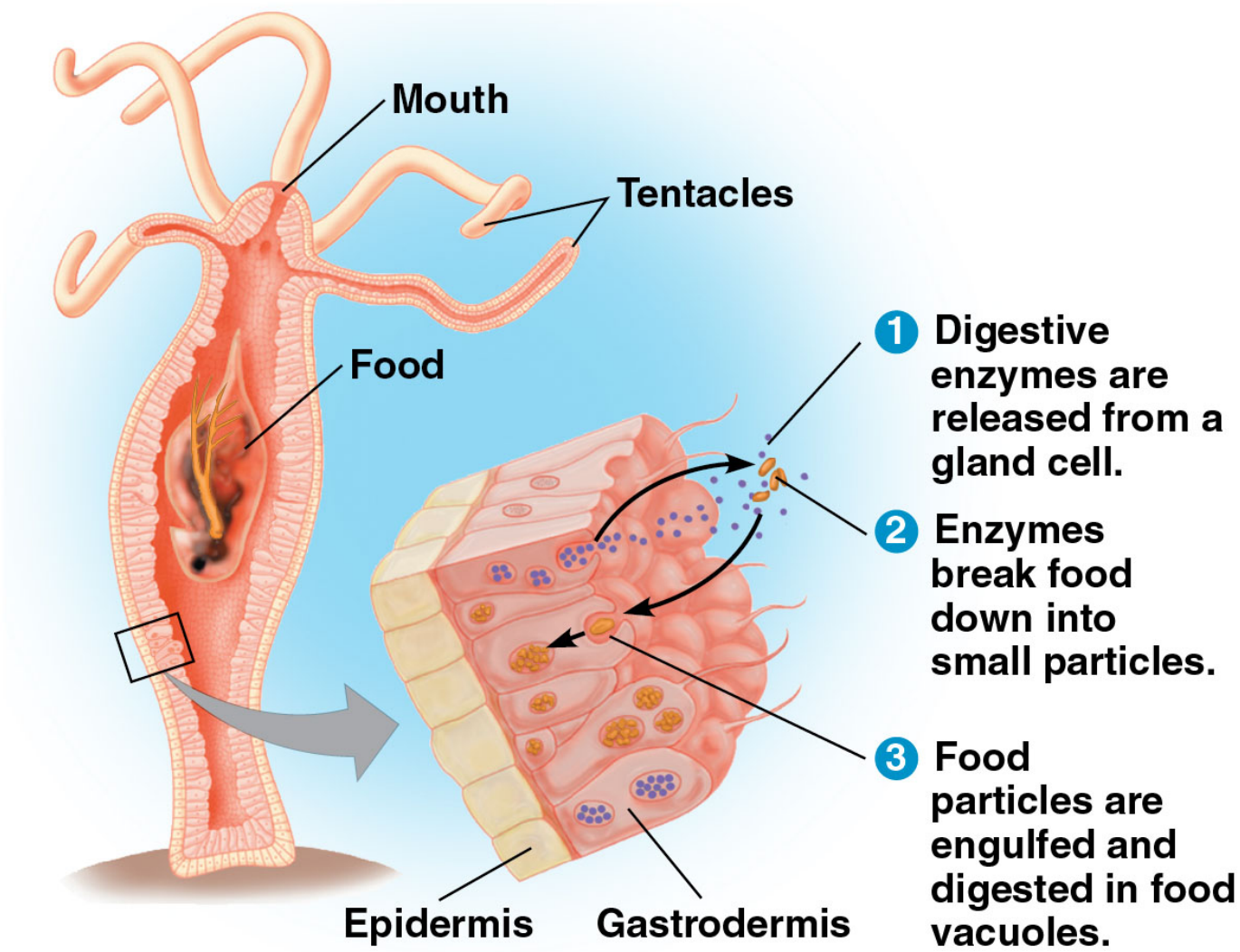
Intracellular Digestion

- In intracellular digestion, food particles are engulfed by phagocytosis and liquids by pinocytosis
- Food vacuoles, containing food, fuse with lysosomes containing hydrolytic enzymes
- A few animals, such as sponges, digest all their food in this way

Extracellular Digestion

- In most animal species, hydrolysis occurs by extracellular digestion
- Extracellular digestion is the breakdown of food particles outside of cells
- It occurs in compartments that are continuous with the outside of the animal's body
- Animals with simple body plans have a **gastrovascular cavity** that functions in both digestion and distribution of nutrients

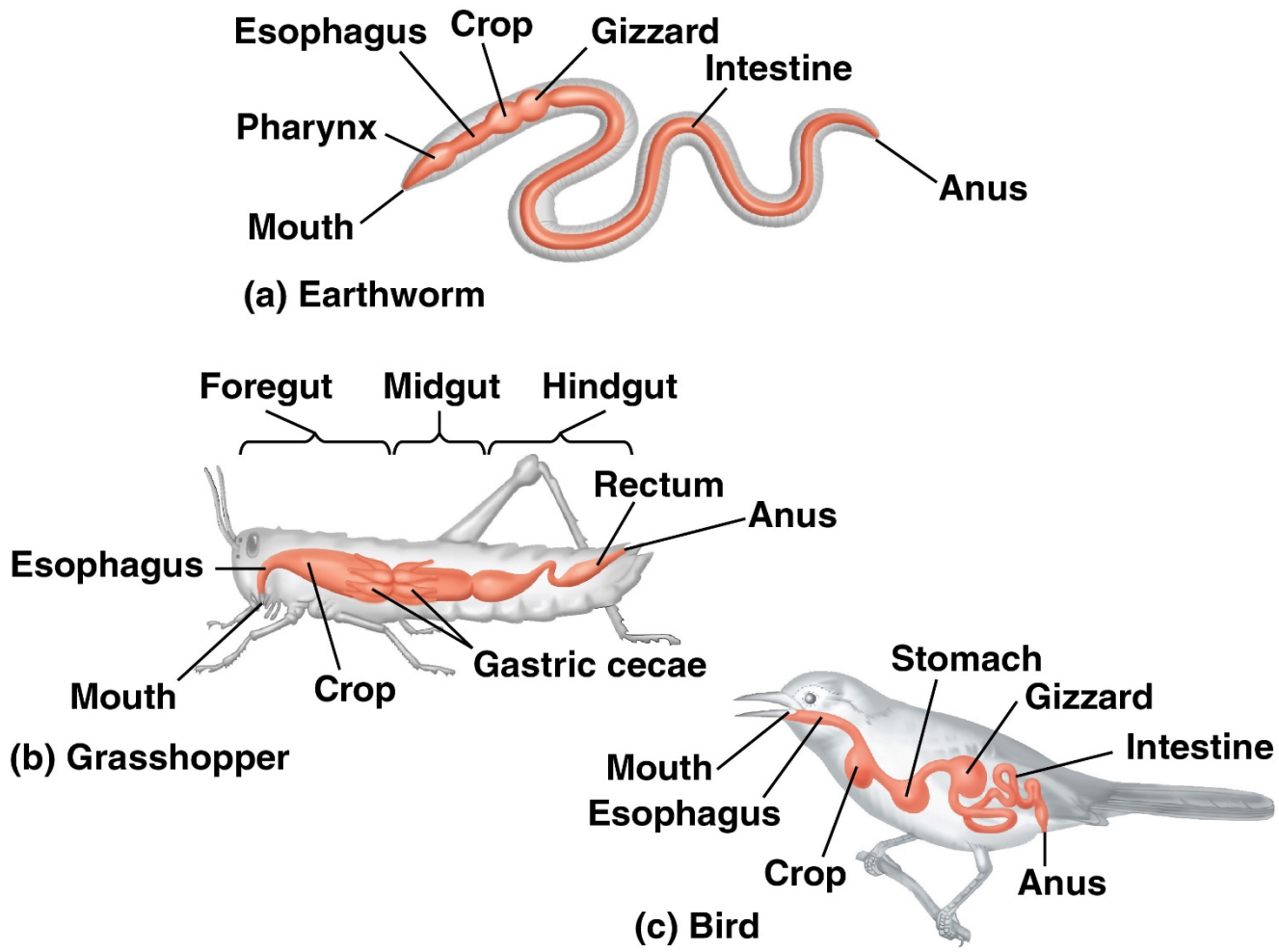
Figure 41.6


Mouth
Tentacles
Food
1 Digestive enzymes are released from a gland cell.
2 Enzymes break food down into small particles.
3 Food particles are engulfed and digested in food vacuoles.
Epidermis
Gastrodermis

Video: Hydra Eating *Daphnia*

- More complex animals have a digestive tube with two openings, a mouth and an anus
- This digestive tube is called a complete digestive tract, or an **alimentary canal**
- It can have specialized regions that carry out digestion and absorption in a stepwise fashion

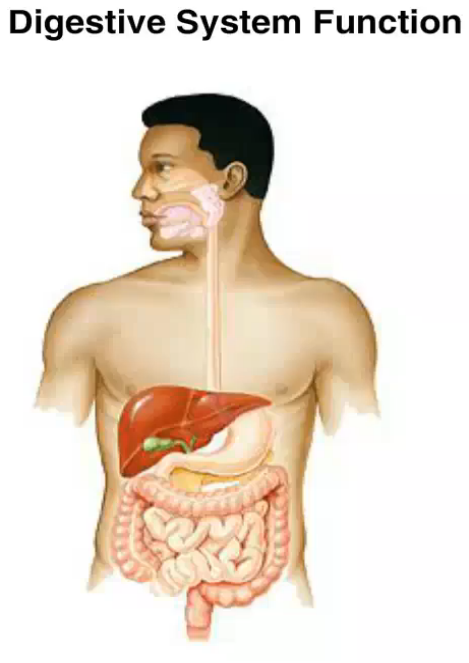
Figure 41.7


Esophagus
Crop
Gizzard
Intestine
Pharynx
Anus
Mouth
(a) Earthworm
Foregut
Midgut
Hindgut
Rectum
Anus
Esophagus
Gastric cecae
Mouth
Crop
(b) Grasshopper
Stomach
Gizzard
Intestine
Mouth
Esophagus
Crop
Anus
(c) Bird

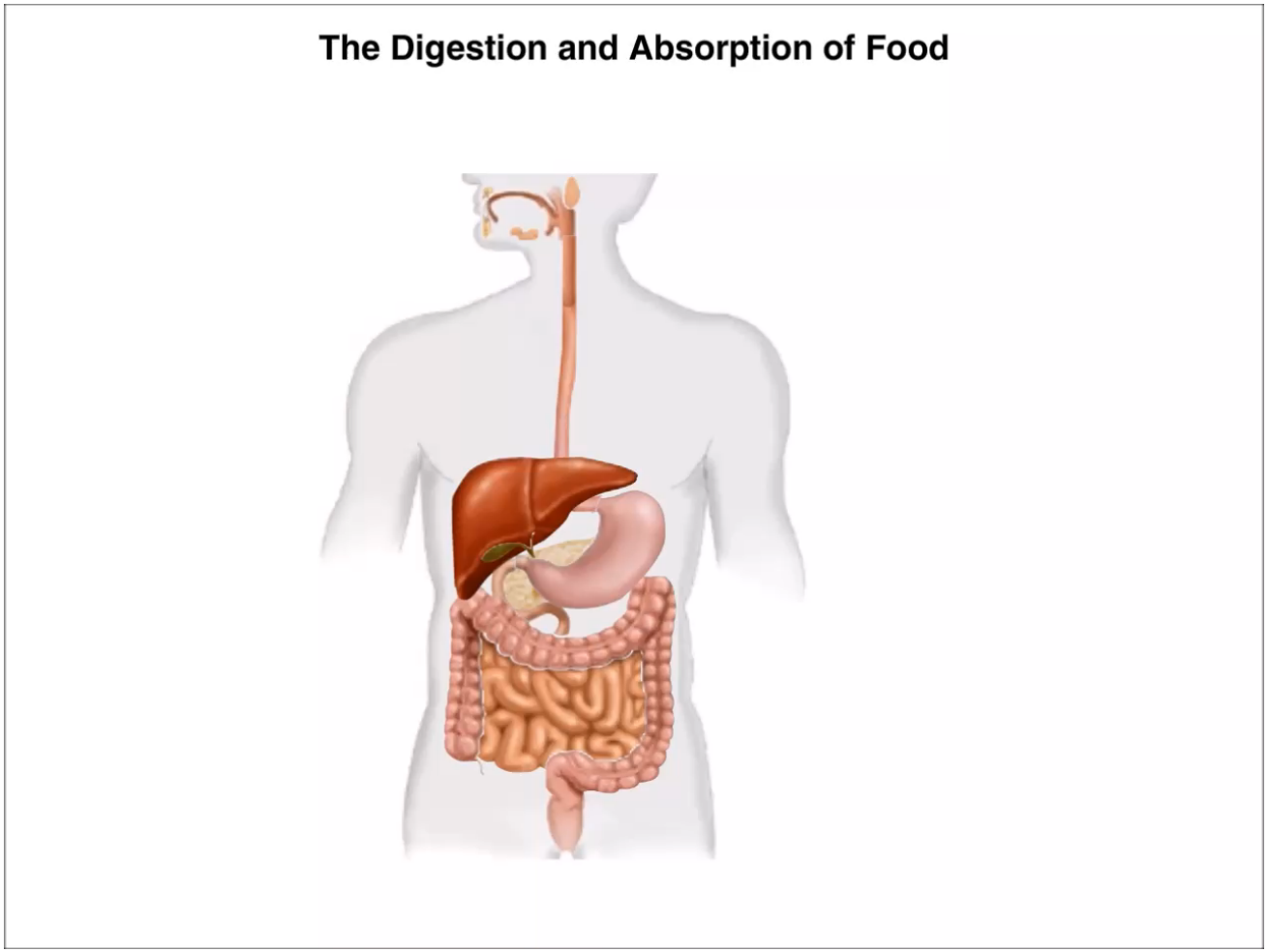
Concept 41.3: Organs specialized for sequential stages of food processing form the mammalian digestive system

- In mammals, a number of accessory glands secrete digestive juices through ducts into the alimentary canal
- Mammalian accessory glands are the salivary glands, the pancreas, the liver, and the gallbladder

Video: Functions of The Digestive System



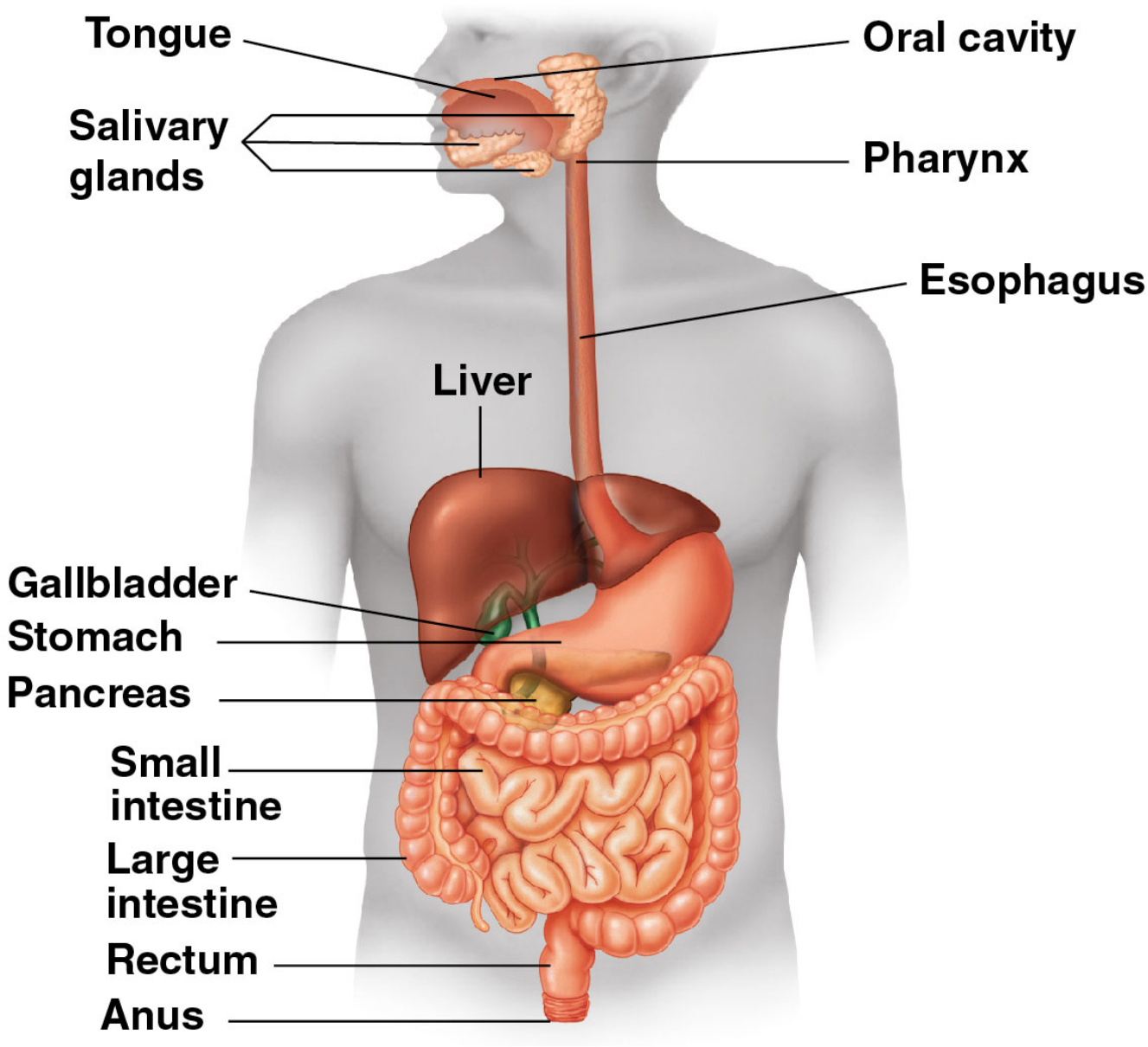
Video: Overview of The Human Digestive System



The Oral Cavity, Pharynx, and Esophagus

- Food processing begins in the **oral cavity**
- Teeth with specialized shapes cut, mash, and grind, breaking the food into smaller pieces
- **Salivary glands** deliver saliva to lubricate food
- Saliva contains **mucus**, a viscous mixture of water, salts, cells, and glycoproteins
- Saliva also contains **amylase**, which breaks down starch

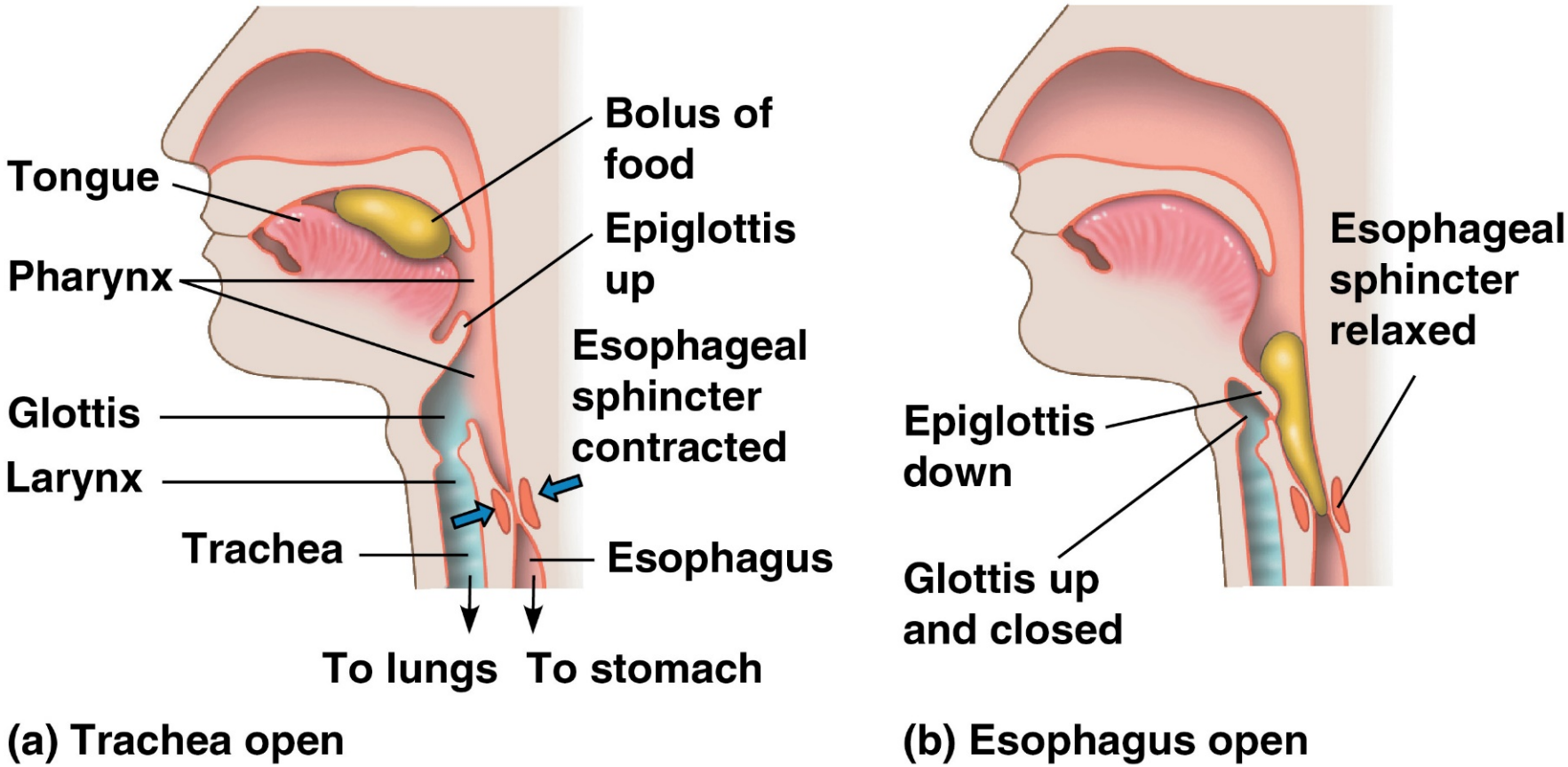
Figure 41.8


Tongue
Oral cavity
Salivary glands
Pharynx
Esophagus
Liver
Gallbladder
Stomach
Pancreas
Small intestine
Large intestine
Rectum
Anus

- The tongue movements shape food into a bolus and 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

- 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 41.9


Tongue
Pharynx
Glottis
Larynx
Trachea
Bolus of food
Epiglottis up
Esophageal sphincter contracted
Esophagus
To lungs
To stomach
(a) Trachea open
Esophageal sphincter relaxed
Epiglottis down
Glottis up and closed
(b) Esophagus open

- Within the esophagus, food is pushed along from the pharynx to the stomach by **peristalsis**, alternating waves of smooth muscle contraction and relaxation
- Valves called **sphincters** regulate the movement of material between compartments

Digestion in the Stomach

- The **stomach** stores food and processes it into a liquid suspension
- The stomach secretes **gastric juice** and mixes it with food through a churning action
- The mixture of ingested food and gastric juice is called **chyme**

Chemical Digestion in the Stomach

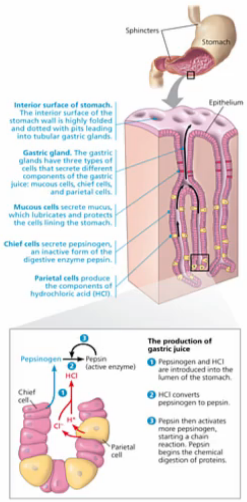
- Gastric juice has a low pH of about 2, which kills bacteria and denatures proteins
- Gastric juice is made up of hydrochloric acid (HCl) and **pepsin**
- Pepsin is a **protease**, which breaks peptide bonds to cleave proteins into smaller polypeptides

- 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
- Cell division adds a new epithelial layer every three days

Video: Digestion in the Stomach

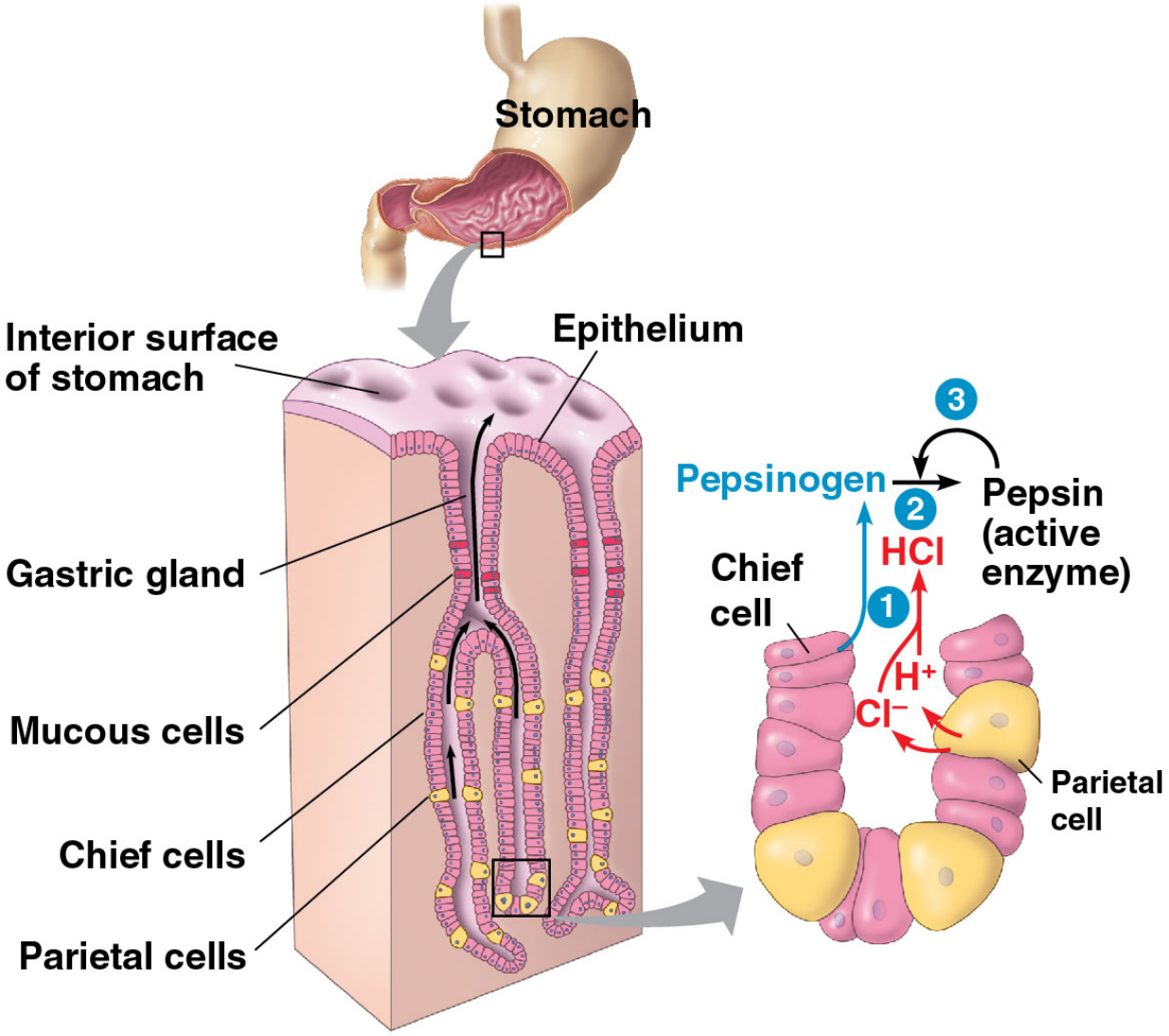
CAMPBELL FIGURE WALKTHROUGH

The stomach and its secretions



Pearson

Figure 41.10


Stomach
Interior surface of stomach
Epithelium
Gastric gland
Mucous cells
Chief cells
Parietal cells
Pepsinogen
Pepsin (active enzyme)
HCl
Chief cell
H+
Cl−
Parietal cell
1
2
3

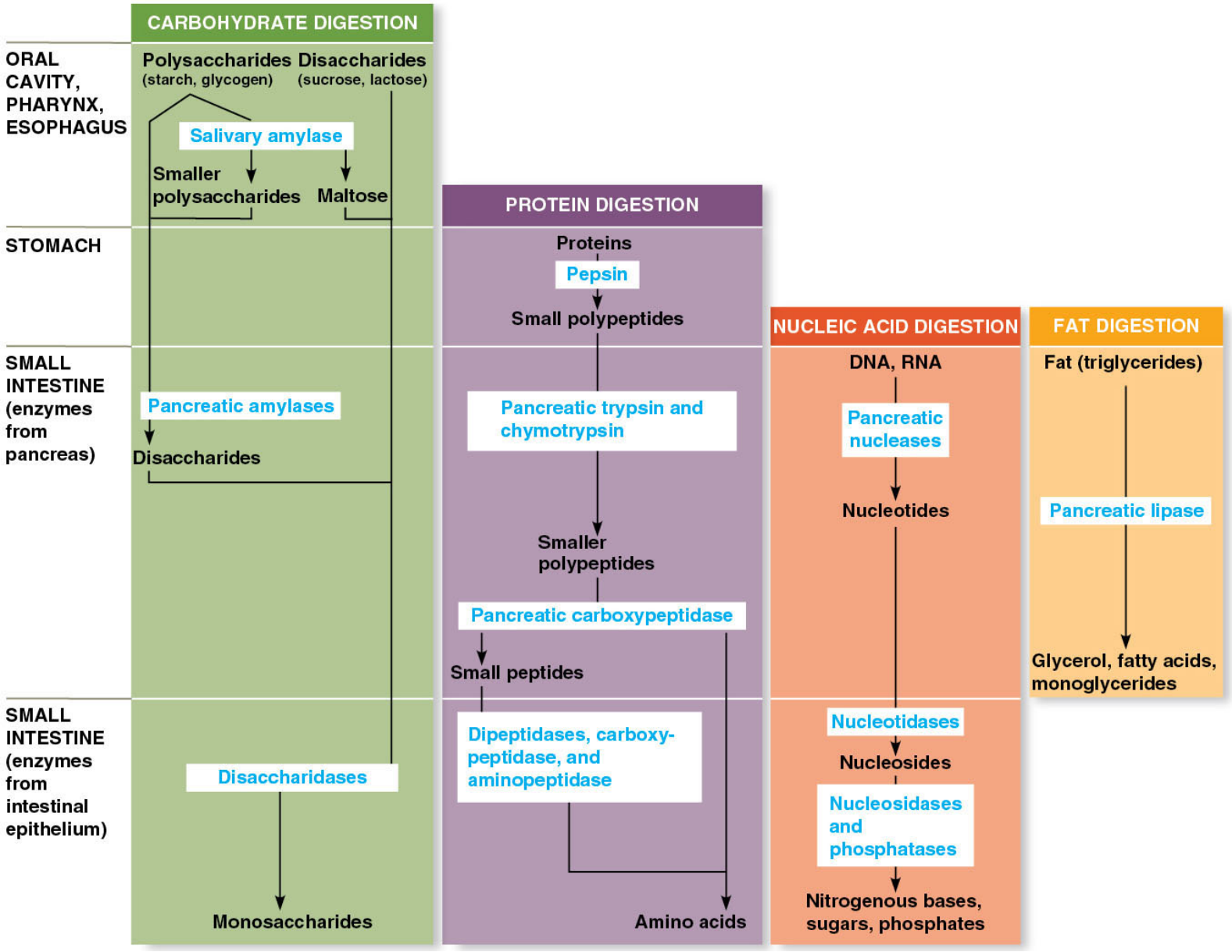
Stomach Dynamics

- Coordinated contraction and relaxation of stomach muscles churn the stomach's contents
- Sphincters prevent chyme from entering the esophagus and regulate its entry into the small intestine
- If the sphincter at the top of the stomach allows movement of chyme back to the lower end of the esophagus, the result is "heartburn"

Digestion in the Small Intestine

- The **small intestine** is the longest compartment of the alimentary canal
- Most enzymatic hydrolysis of macromolecules from food occurs here

Figure 41.11


CARBOHYDRATE DIGESTION
PROTEIN DIGESTION
NUCLEIC ACID DIGESTION
FAT DIGESTION
ORAL CAVITY, PHARYNX, ESOPHAGUS
Polysaccharides (starch, glycogen)
Disaccharides (sucrose, lactose)
Salivary amylase
Smaller polysaccharides
Maltose
STOMACH
Proteins
Pepsin
Small polypeptides
SMALL INTESTINE (enzymes from pancreas)
Pancreatic amylases
Disaccharides
Pancreatic trypsin and chymotrypsin
Smaller polypeptides
Pancreatic carboxypeptidase
Small peptides
DNA, RNA
Pancreatic nucleases
Nucleotides
Fat (triglycerides)
Pancreatic lipase
Glycerol, fatty acids, monoglycerides
SMALL INTESTINE (enzymes from intestinal epithelium)
Disaccharidases
Monosaccharides
Dipeptidases, carboxy-peptidase, and aminopeptidase
Amino acids
Nucleotidases
Nucleosides
Nucleosidases and phosphatases
Nitrogenous bases, sugars, phosphates

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

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

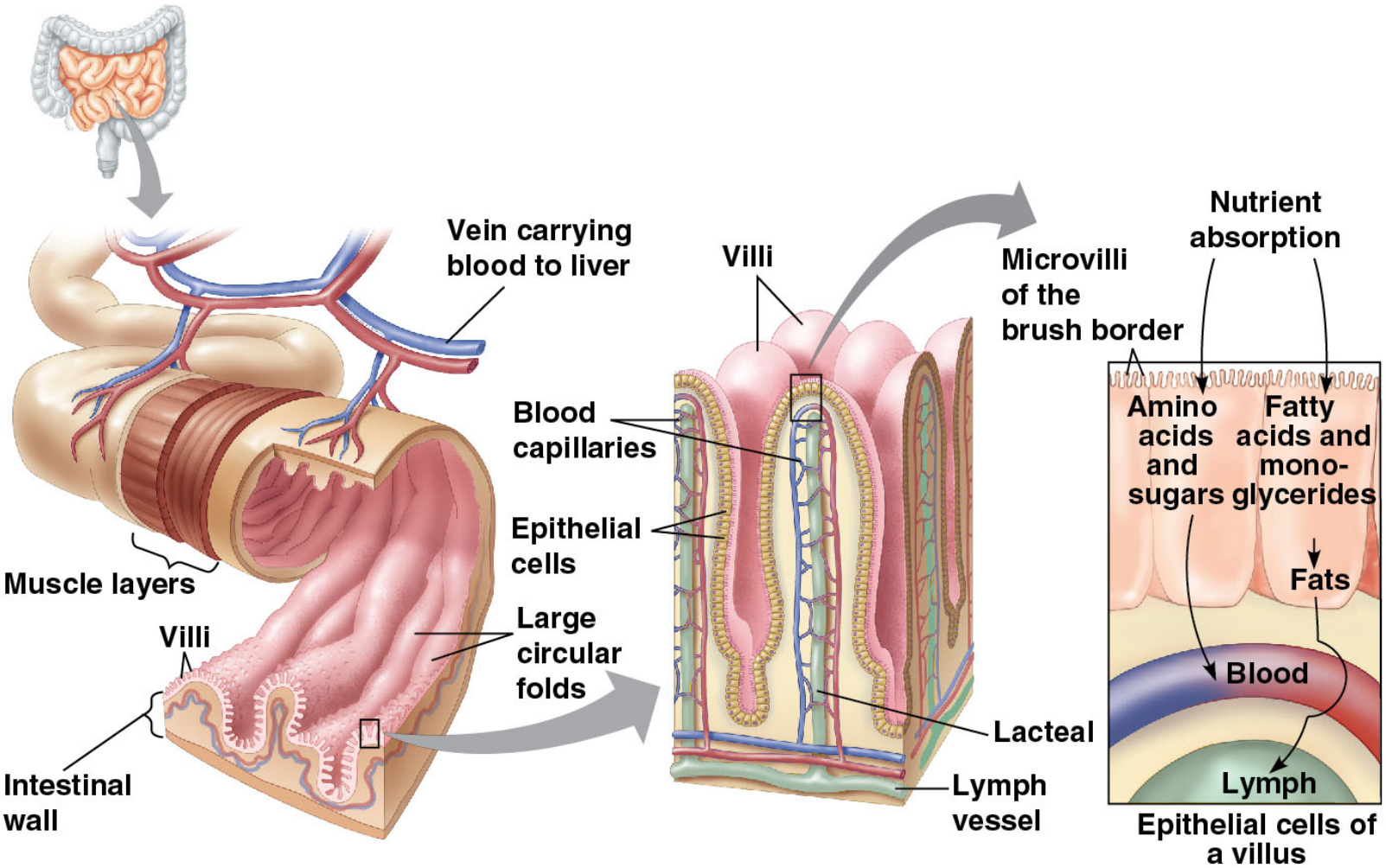
- Bile salts facilitate digestion of fats and are a major component of **bile**
- Bile is made in the **liver** and stored and concentrated in the **gallbladder**
- Bile also destroys nonfunctional red blood cells

Absorption in the Small Intestine

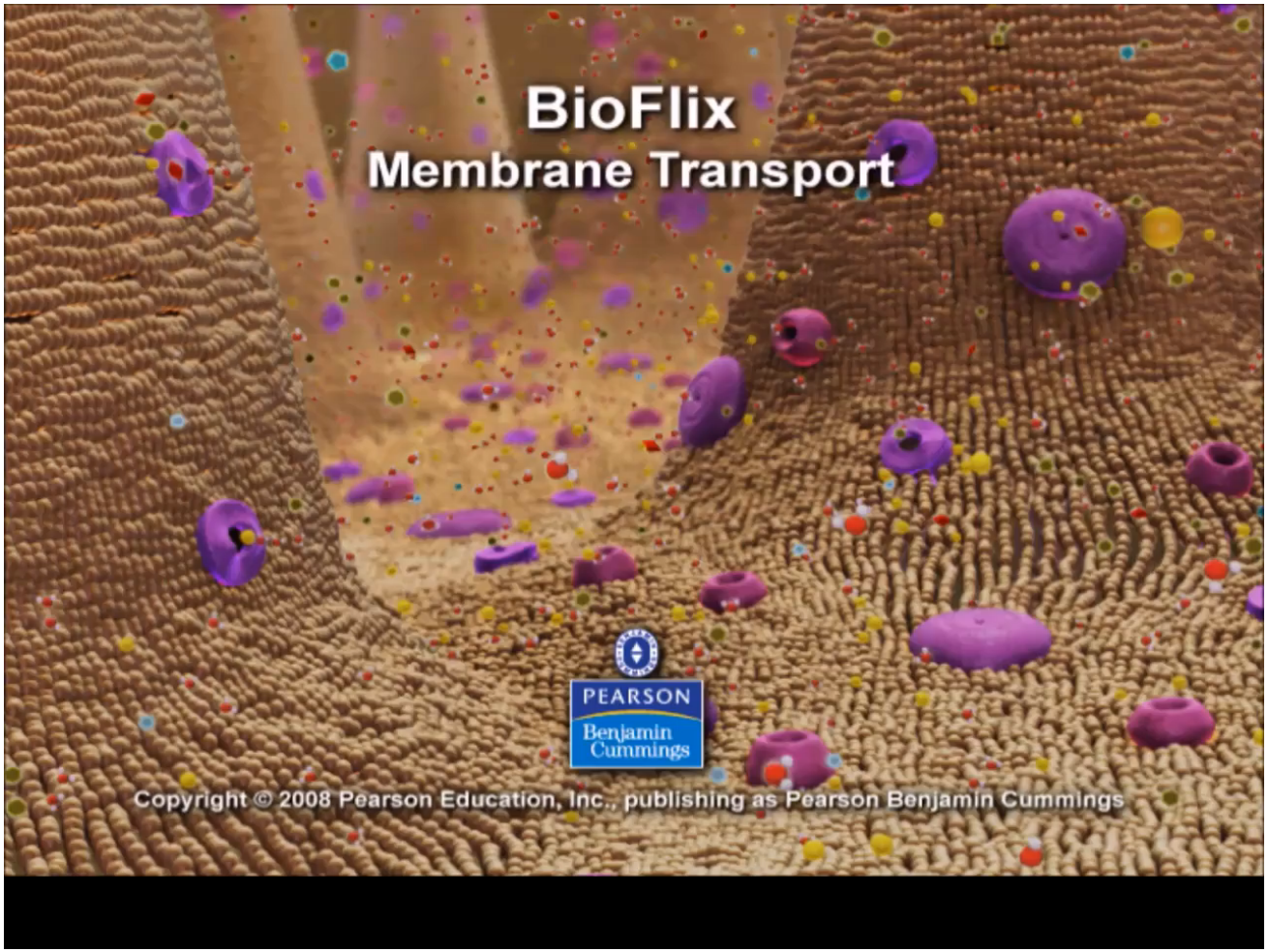
- Digestion is largely completed in the duodenum
- In the remaining regions of the small intestine, nutrient absorption occurs

- 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 41.12


Vein carrying blood to liver
Muscle layers
Villi
Intestinal wall
Large circular folds
Villi
Blood capillaries
Epithelial cells
Lacteal
Lymph vessel
Microvilli of the brush border
Nutrient absorption
Amino acids and sugars
Fatty acids and mono-glycerides
Fats
Blood
Lymph
Epithelial cells of a villus

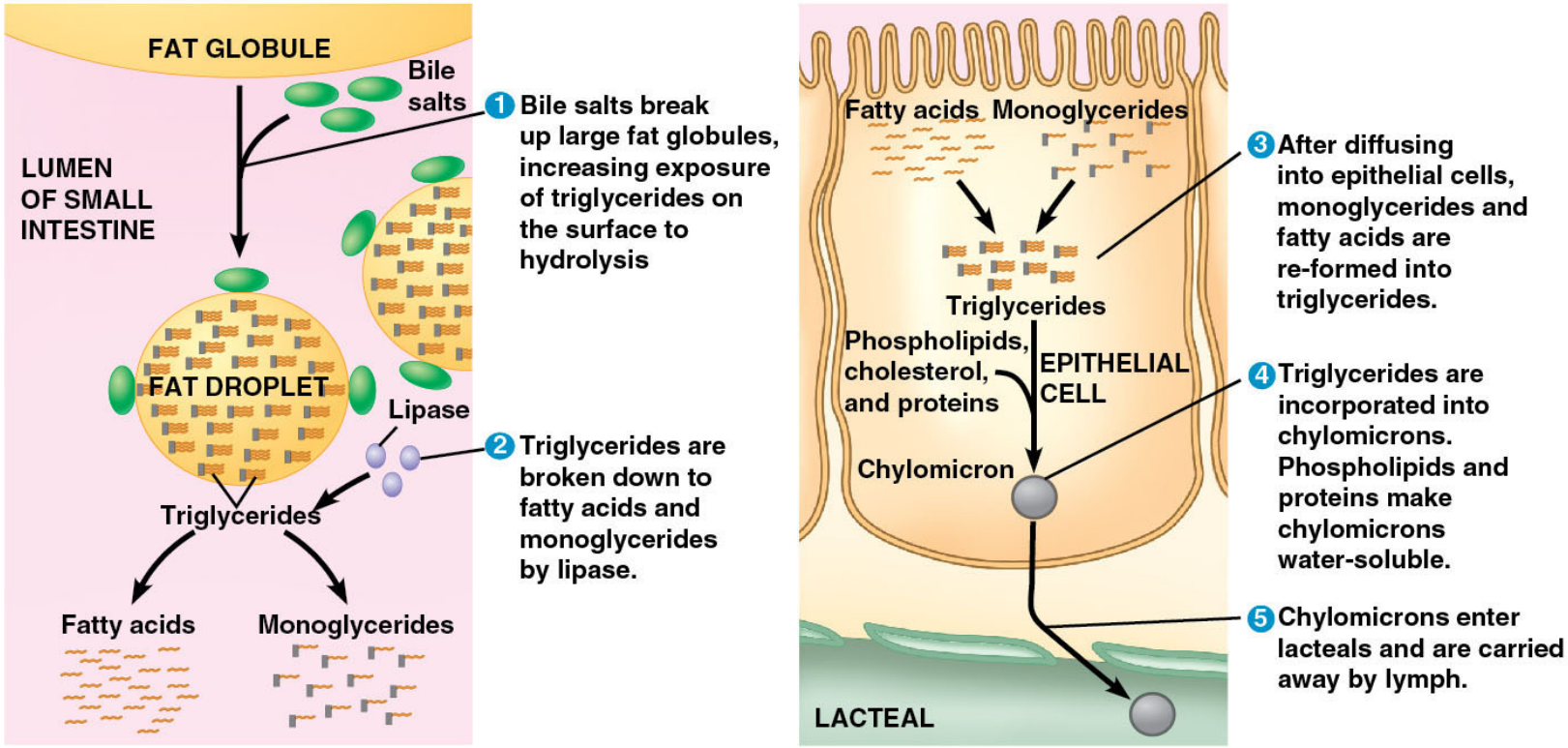
BioFlix® Animation: Membrane Transport



- 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 a monoglyceride (glycerol joined to a fatty acid) 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

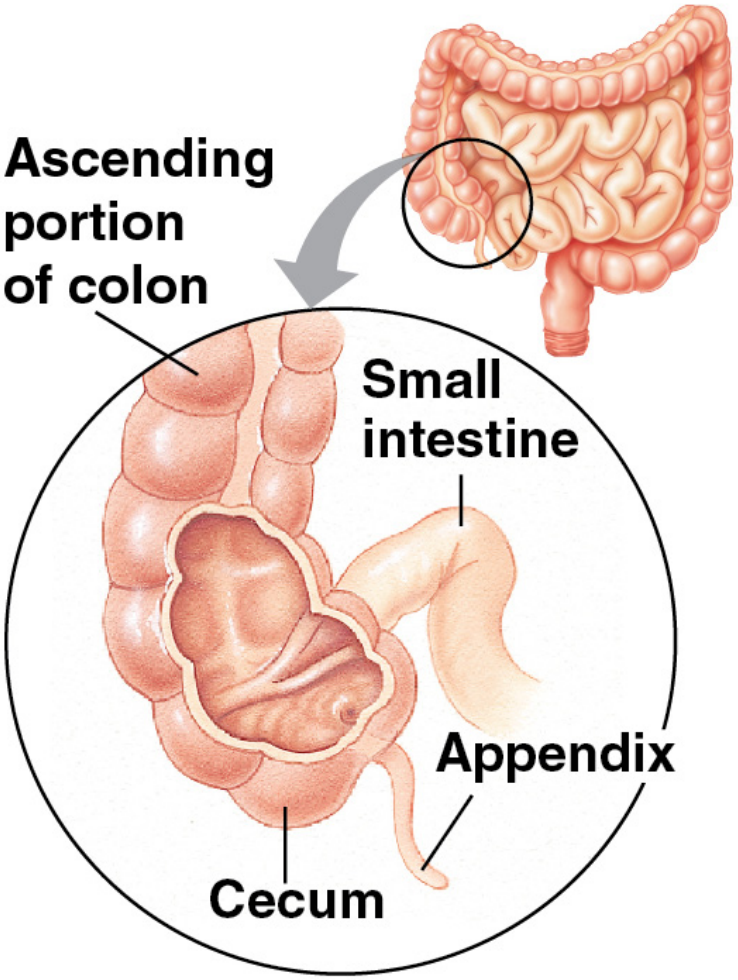
Figure 41.13


FAT GLOBULE
Bile salts
LUMEN OF SMALL INTESTINE
FAT DROPLET
Lipase
Triglycerides
Fatty acids
Monoglycerides
1 Bile salts break up large fat globules, increasing exposure of triglycerides on the surface to hydrolysis
2 Triglycerides are broken down to fatty acids and monoglycerides by lipase.
Fatty acids
Monoglycerides
Triglycerides
Phospholipids, cholesterol, and proteins
EPITHELIAL CELL
Chylomicron
LACTEAL
3 After diffusing into epithelial cells, monoglycerides and fatty acids are re-formed into triglycerides.
4 Triglycerides are incorporated into chylomicrons. Phospholipids and proteins make chylomicrons water-soluble.
5 Chylomicrons enter lacteals and are carried away by lymph.

Processing in the Large Intestine

- The alimentary canal ends with the **large intestine**
- It includes the colon, caecum, and rectum
- The **colon** leads to the rectum and anus
- 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 minor role in immunity

Figure 41.14


Ascending portion of colon
Small intestine
Appendix
Cecum

- The colon completes the recovery of water that began in the small intestine
- **Feces**, the wastes of the digestive system, become more solid as they move through the colon
- The community of bacteria living on unabsorbed organic material in the colon contributes about one-third of the dry weight of feces

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

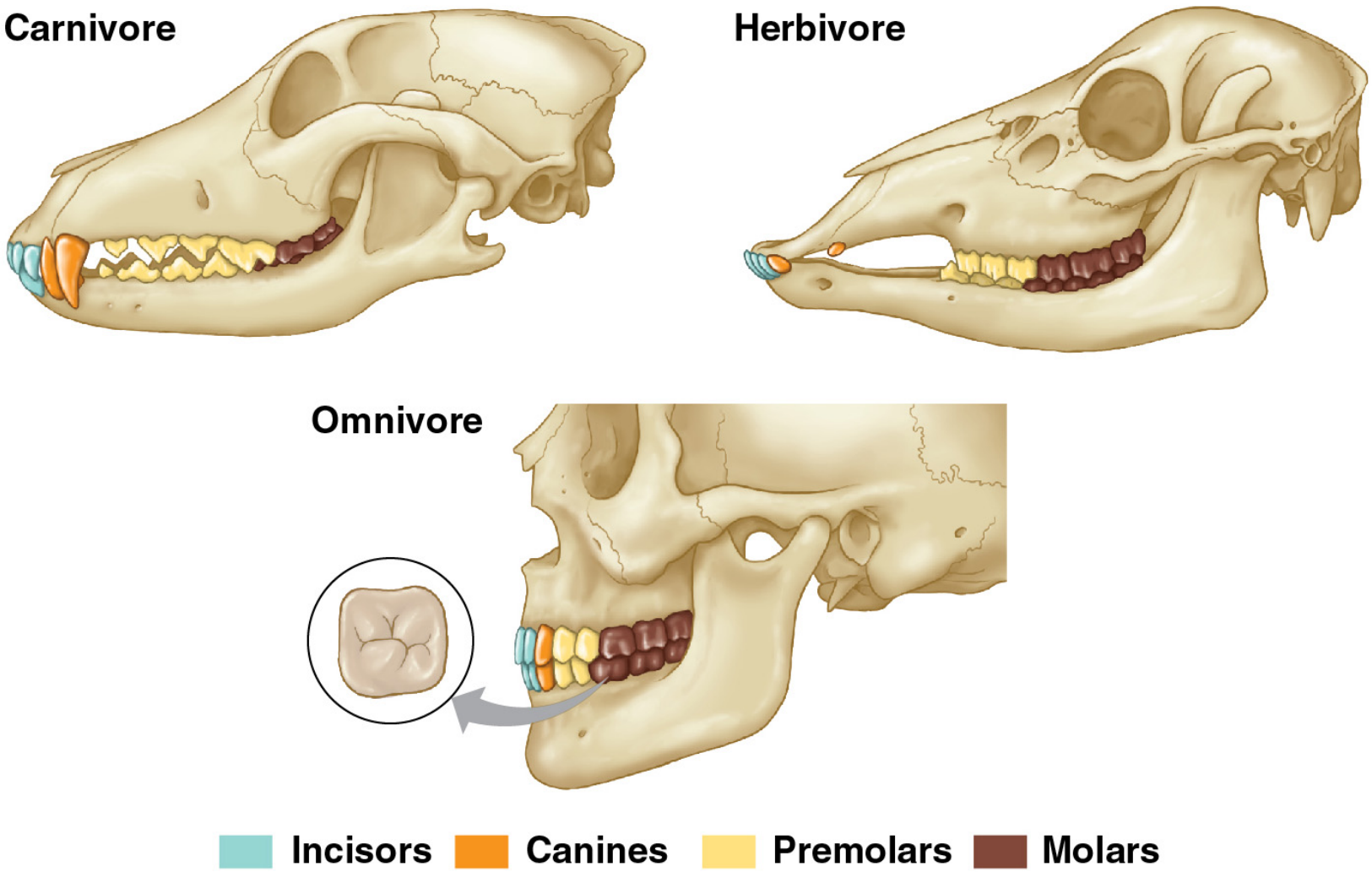
Concept 41.4: Evolutionary adaptations of vertebrate digestive systems correlate with diet

- Digestive systems of vertebrates are varied, with many adaptations linked to an animal's 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

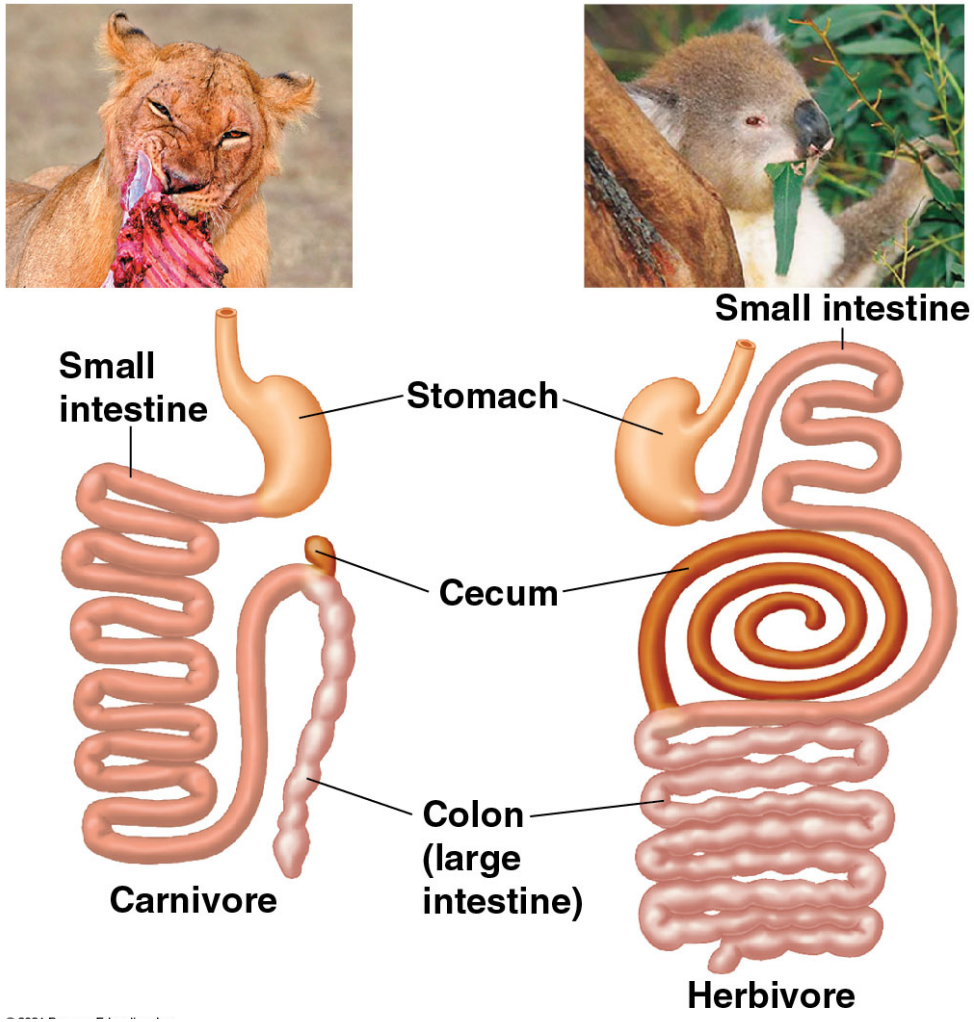
Figure 41.15


Carnivore
Herbivore
Omnivore
Incisors
Canines
Premolars
Molars

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 41.16

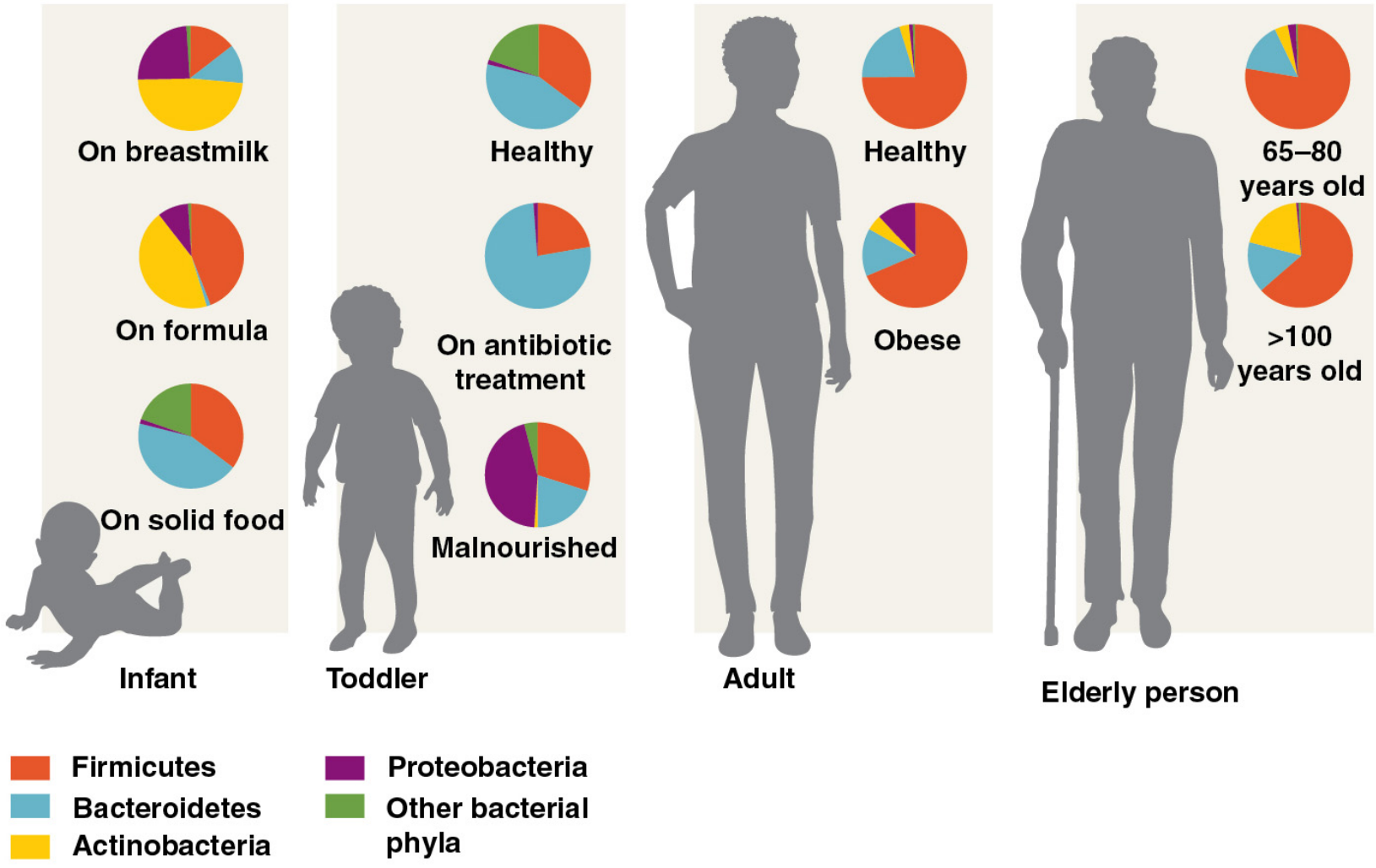

Small intestine
Stomach
Cecum
Colon (large intestine)
Carnivore
Small intestine
Herbivore

Mutualistic Adaptations

- The coexistence of humans and many bacteria involves mutualistic symbiosis
- Some intestinal bacteria produce vitamins
- They also regulate the development of the intestinal epithelium and the function of the innate immune system

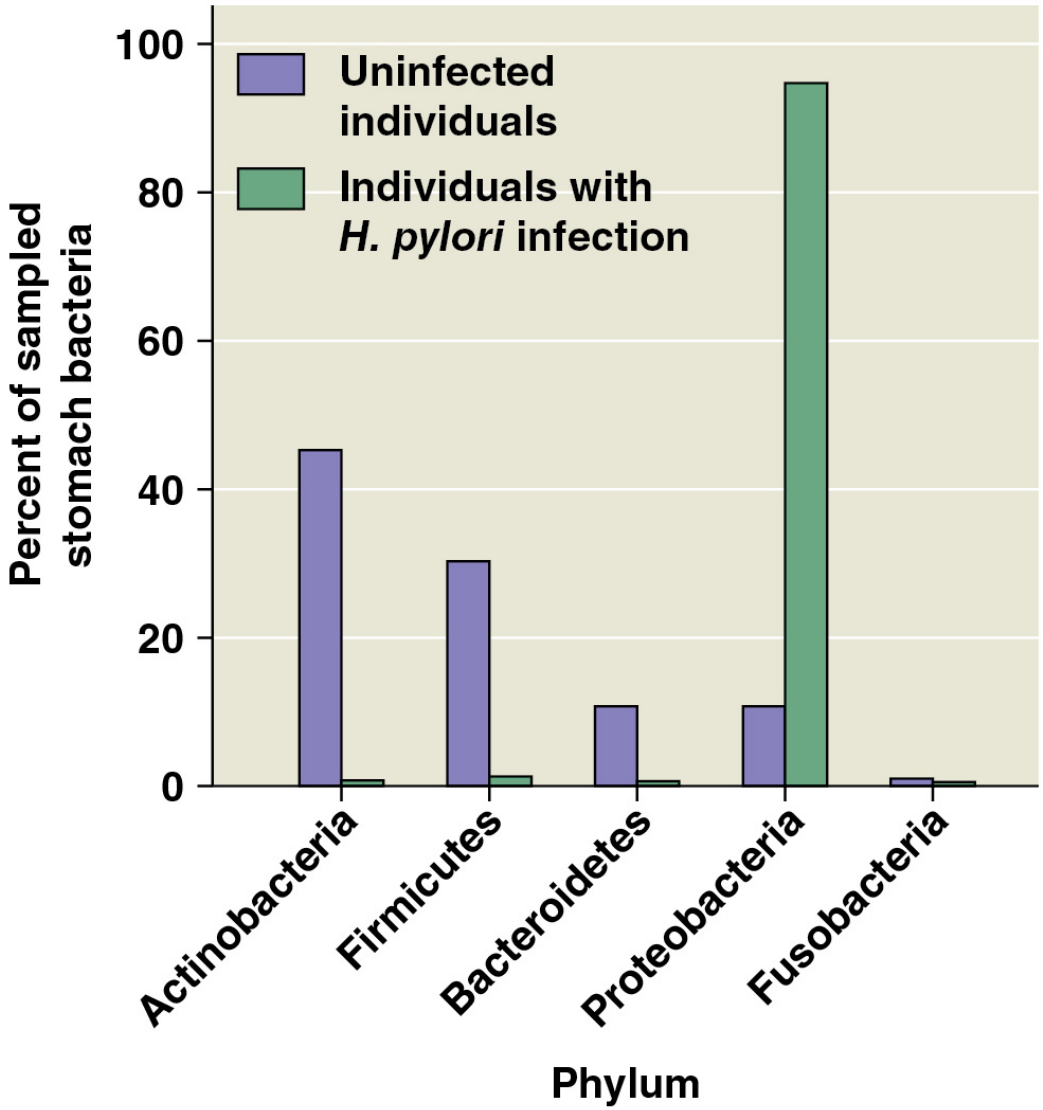
- The **microbiome** is the collection of the microorganisms living in and on the body
- Scientists use a DNA sequencing approach based on the polymerase chain reaction to study the microbiome
- More than 400 bacterial species have been found in the human digestive system using this method
- There are differences in the microbiome associated with diet, disease, and age

Figure 41.17


On breastmilk
On formula
On solid food
Infant
Healthy
On antibiotic treatment
Malnourished
Toddler
Healthy
Obese
Adult
65–80 years old
>100 years old
Elderly person
Firmicutes
Bacteroidetes
Actinobacteria
Proteobacteria
Other bacterial phyla

- *Helicobacter pylori* is an acid-tolerant bacterium that has been found to cause stomach ulcers
- *H. pylori* can disrupt stomach health by eliminating other bacterial species from the stomach

Figure 41.18


Percent of sampled stomach bacteria
100
80
60
40
20
0
Uninfected individuals
Individuals with *H. pylori* infection
Actinobacteria
Firmicutes
Bacteroidetes
Proteobacteria
Fusobacteria
Phylum

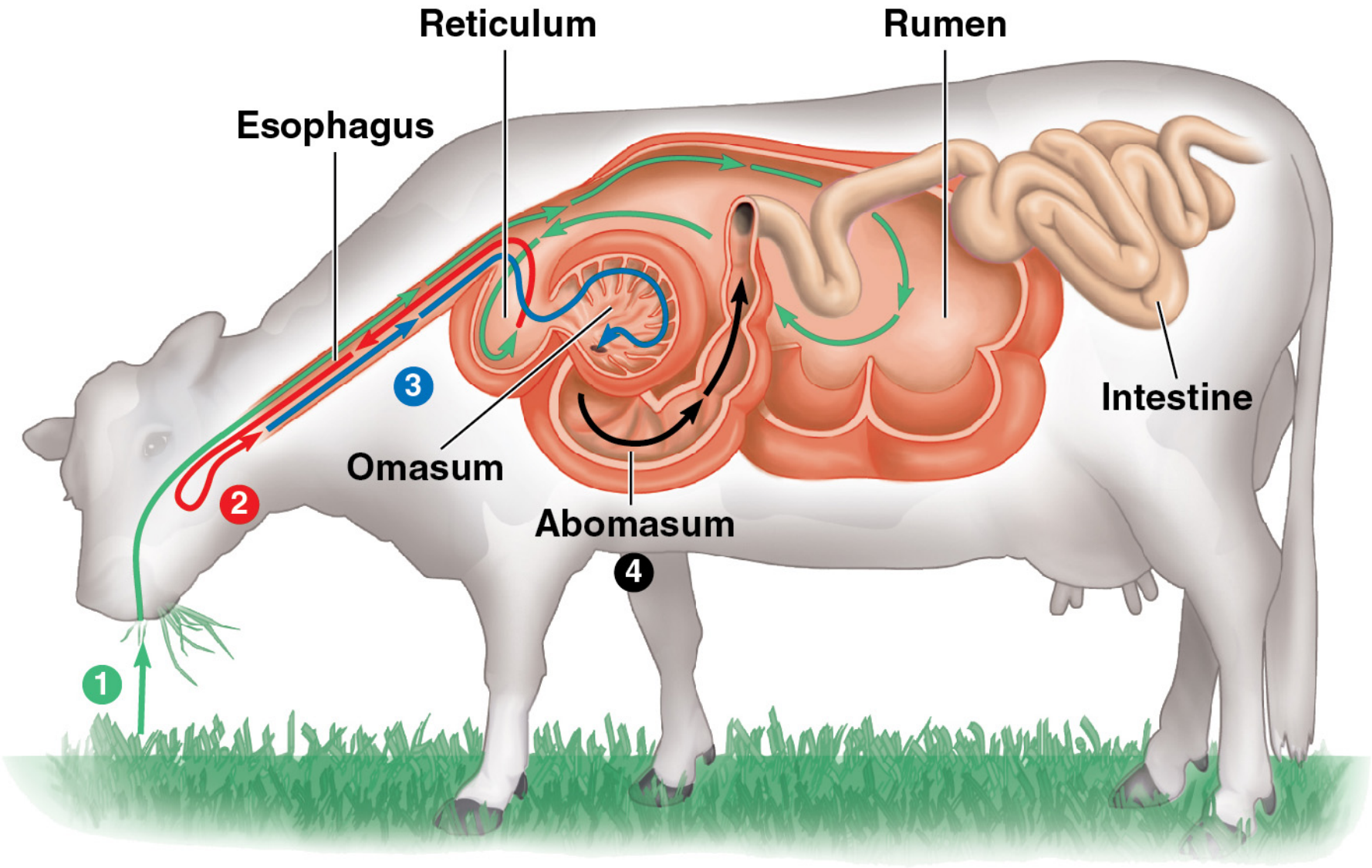
- Studies on the microbiome have led to therapies for intestinal infections; one is fecal microbial transplantation
- The microbiome of a healthy individual is introduced into the patient's intestine
- This approach has been used to treat diarrhea caused by the bacterium *Clostridium difficile*
- Another treatment against antibiotic-resistant pathogens makes use of bacteriophages, viruses that infect bacteria but not human cells

Figure 41.19

Mutualistic Adaptations in Herbivores

- Many organisms whose diet consists largely of cellulose have fermentation chambers
- Here, mutualistic microorganisms digest cellulose
- Rabbits and rodents pass food through their alimentary canal twice to recover important nutrients
- The most elaborate adaptations for an herbivorous diet have evolved in the animals called ruminants

Figure 41.20


Reticulum
Rumen
Esophagus
Intestine
Omasum
Abomasum
1
2
3
4

- Giant tubeworms have no digestive system and instead obtain nutrients from mutualistic bacteria within their bodies

Figure 41.21

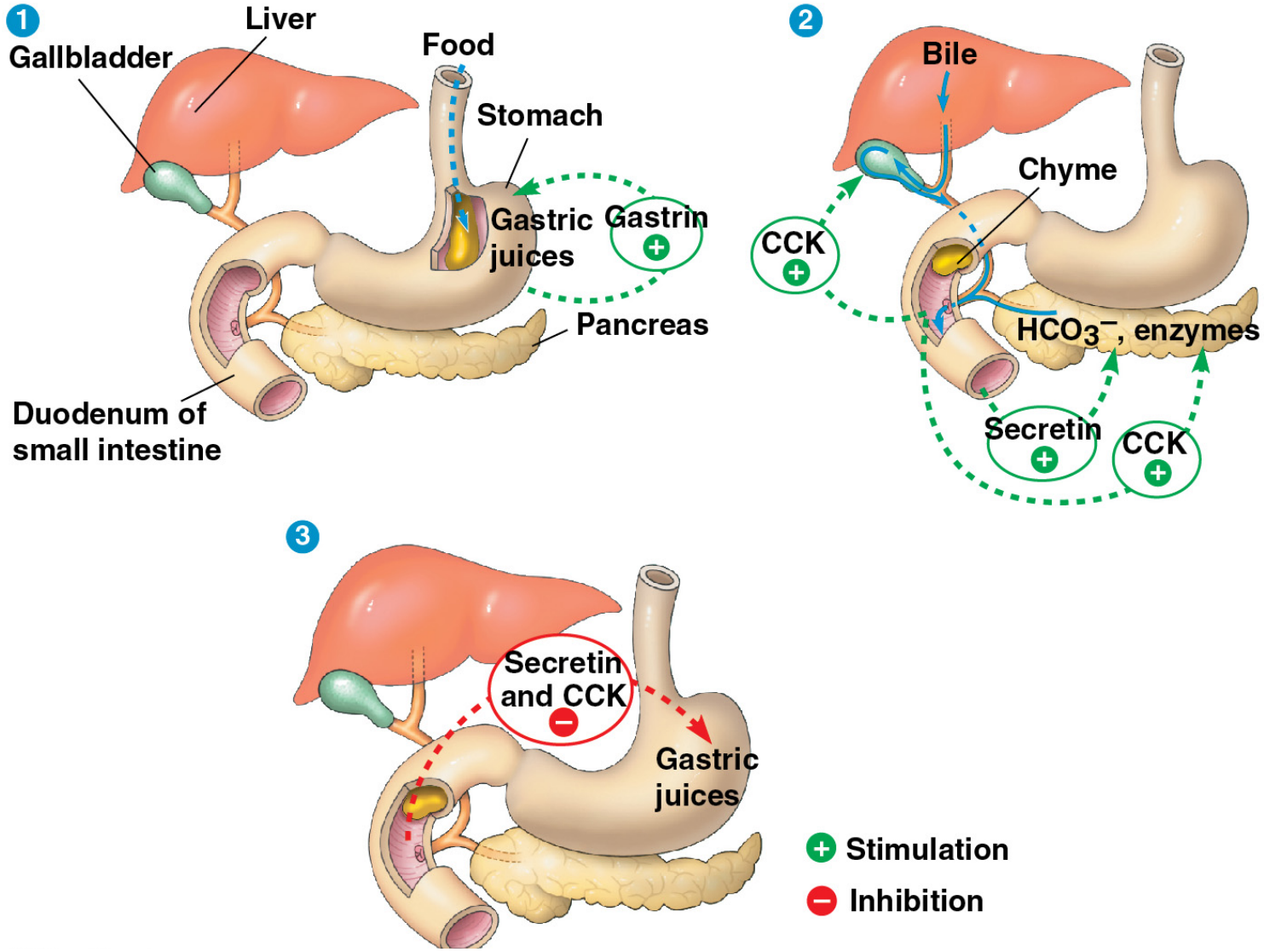
Concept 41.5: Feedback circuits regulate digestion, energy storage, and appetite

- The processes that enable an animal to obtain nutrients are matched to the organism's circumstances and need for energy

Regulation of Digestion

- The digestive system is activated step-wise as needed
- The steps are regulated by the enteric nervous system, a network of neurons dedicated to the digestive organs
- The endocrine system also regulates digestion through the release and transport of hormonessd

Figure 41.22


1
Liver
Gallbladder
Food
Stomach
Gastric juices
Gastrin
Pancreas
Duodenum of small intestine
2
Bile
Chyme
CCK
HCO_3^-, enzymes
Secretin
CCK
3
Secretin and CCK
Gastric juices
Stimulation
Inhibition

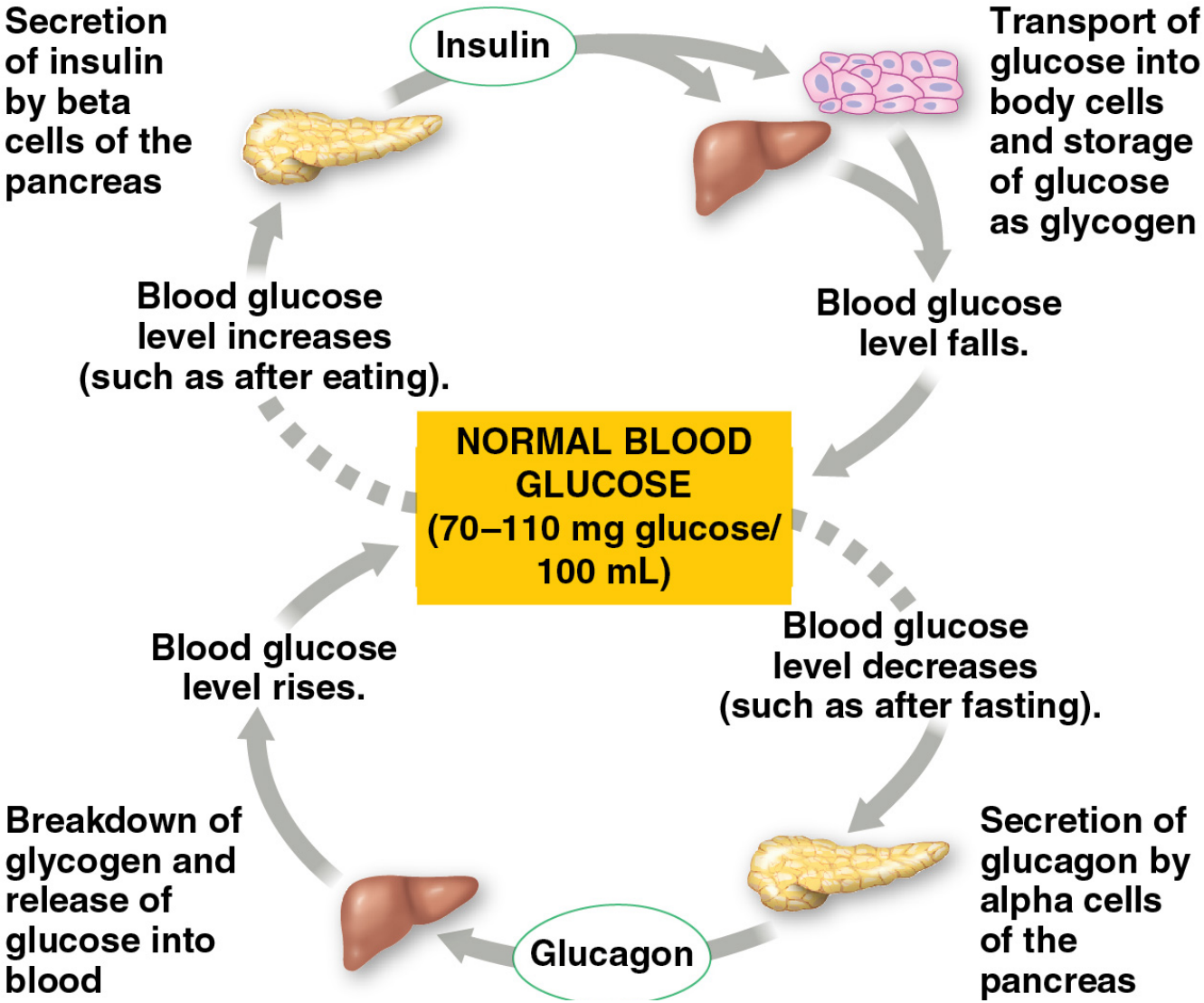
Regulation of Energy Storage

- The body stores energy-rich molecules that are not needed for metabolism right away
- In humans, energy is stored first in the liver and muscle cells in the form of glycogen
- Excess energy is stored in fat in adipose cells
- When fewer calories are taken in than expended, the human body expends liver glycogen first, then muscle glycogen and fat

Glucose Homeostasis

- Glucose homeostasis relies predominantly on the opposing effects of two hormones, **insulin** and **glucagon**
- These 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 41.23


Secretion of insulin by beta cells of the pancreas
Insulin
Transport of glucose into body cells and storage of glucose as glycogen
Blood glucose level falls.
Blood glucose level increases (such as after eating).
NORMAL BLOOD GLUCOSE (70–110 mg glucose/ 100 mL)
Blood glucose level decreases (such as after fasting).
Blood glucose level rises.
Breakdown of glycogen and release of glucose into blood
Glucagon
Secretion of glucagon by alpha cells of the pancreas

Animation BioFlix®: Homeostasis: Regulating Blood Sugar

- Insulin acts on nearly all body cells to stimulate glucose uptake from blood
- Brain cells are an exception; they can take up glucose whether or not insulin is present
- Glucagon and insulin are both produced in the islets of the pancreas
- Alpha cells make glucagon, and beta cells make insulin

Diabetes Mellitus

- The disease **diabetes mellitus** is caused by a deficiency of insulin or a decreased response to insulin in target tissues
- Cells are unable to take up enough glucose to meet metabolic needs
- The level of glucose in the blood may exceed the capacity of kidneys to reabsorb it
- Sugar in the urine is one test for diabetes

Type 1 Diabetes

- Type 1 diabetes is an autoimmune disorder in which the immune system destroys the beta cells of the pancreas
- It usually appears during childhood
- Treatment consists of insulin injections, typically several times per day
- Currently, genetically engineered bacteria produce human insulin at a reasonable cost

Type 2 Diabetes

- Type 1 diabetes is an autoimmune disorder in which the immune system destroys the beta cells of the pancreas
- It usually appears during childhood
- Treatment consists of insulin injections, typically several times per day
- Currently, genetically engineered bacteria produce human insulin at a reasonable cost

BioFlix® Animation: Diabetes

Regulation of Appetite and Consumption

- Overnourishment can lead to obesity, the excess accumulation of fat
- Obesity contributes to type 2 diabetes, cancer of the colon and breasts, and cardiovascular disease
- Researchers have discovered several of the mechanisms that help regulate body weight

- Hormones regulate long-term and short-term appetite by affecting a “satiety center” in the brain
- Ghrelin, a hormone secreted by the stomach wall, triggers feelings of hunger before meals
- Insulin and PYY, a hormone secreted by the small intestine after meals, both suppress appetite
- Leptin, produced by adipose (fat) tissue, also suppresses appetite and plays a role in regulating body fat levels

Figure 41.24

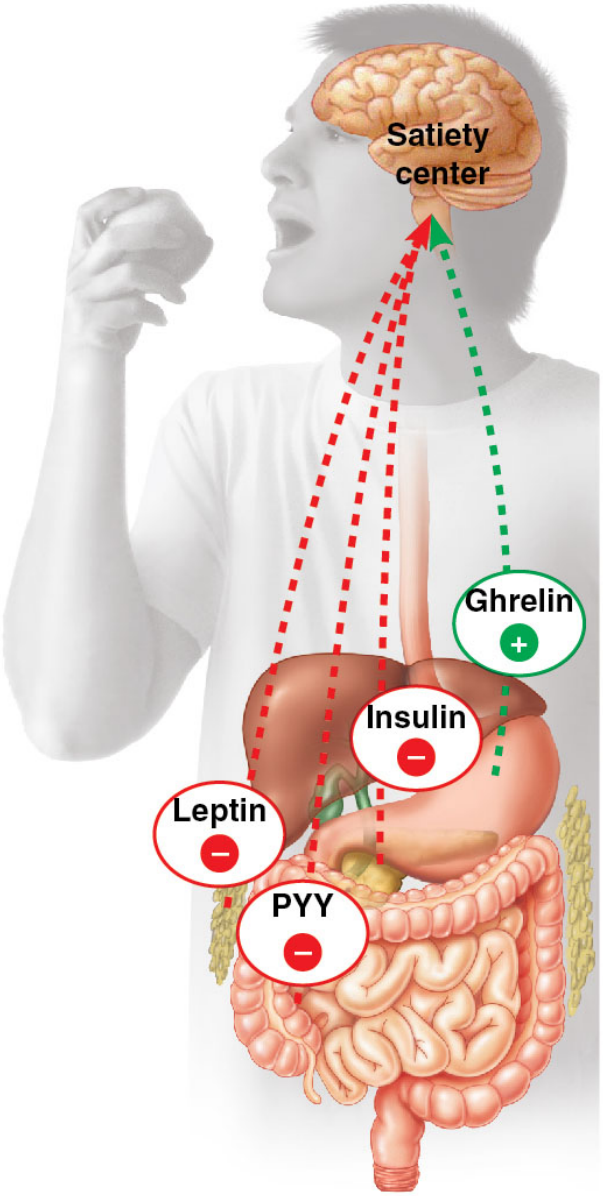


Figure 41.UN02

Figure 41.UN03

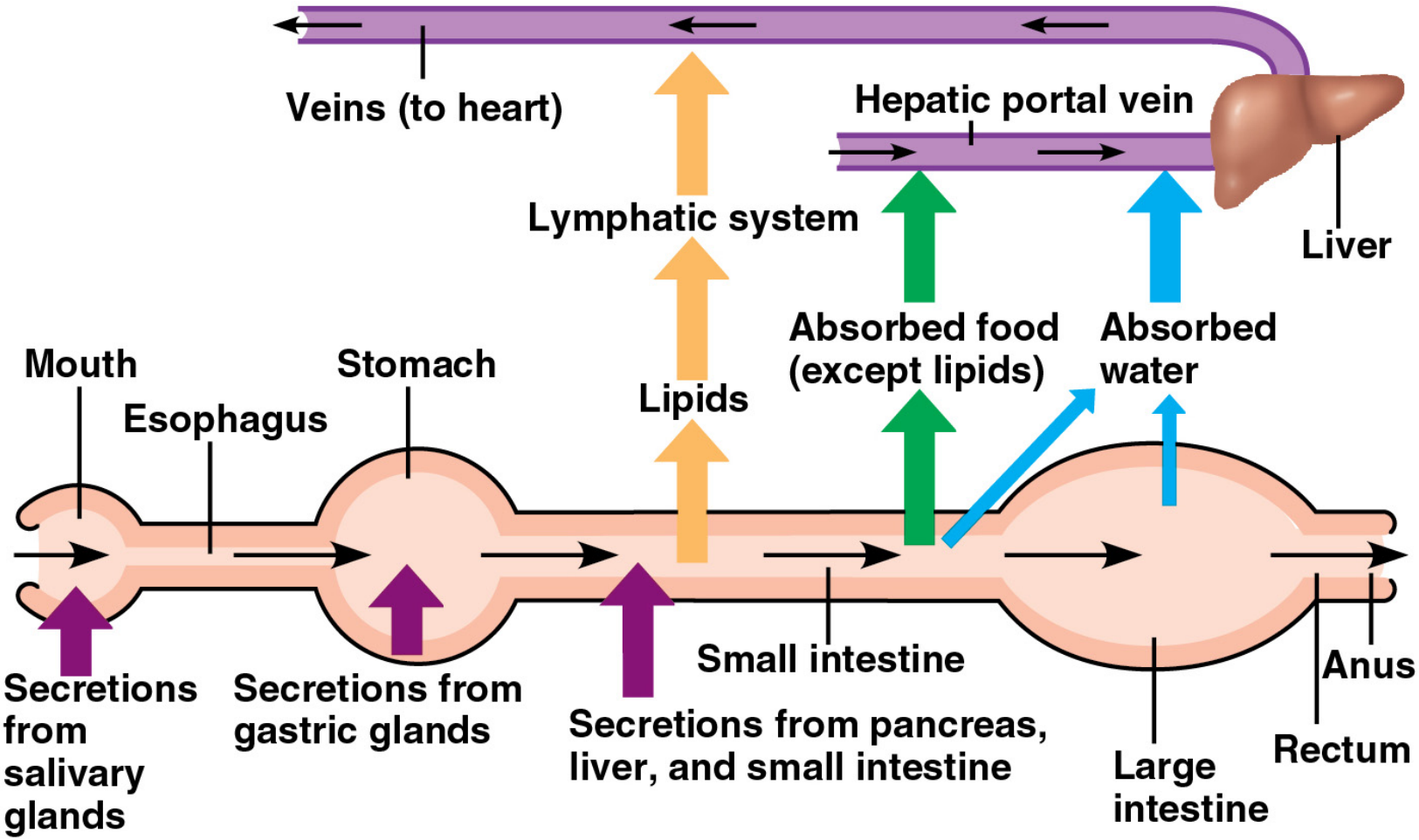


Figure 41.UN04