Chapter 41

Animal Nutrition

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

Neil Campbell and Jane Reece

Lectures by Chris Romero, updated by Erin Barley with contributions from Joan Sharp

Key concepts

Nutrients and food processing

Homeostasis (balance): energy

Overview: The Need to Feed

- Food is taken in, taken apart, and taken up in the process of animal **nutrition**
- In general, animals fall into three categories:
  - **Herbivores** eat mainly autotrophs (plants and algae)
  - **Carnivores** eat other animals
  - **Omnivores** regularly consume animals as well as plants or algal matter

Fig. 41-1

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

- An animal's diet provides chemical energy, which is converted into ATP and powers processes in the body
- Animals need a source of organic carbon and organic nitrogen in order to construct organic molecules
- **Essential nutrients** are required by cells and must be obtained from dietary sources

Essential Nutrients

- There are four classes of essential nutrients:
  - Essential amino acids
  - Essential fatty acids
  - Vitamins
  - Minerals

Fig. 41-2

Essential amino acids for adults

Corn (maize) and other grains

Methionine

Valine

Threonine

Phenylalanine

Leucine

Isoleucine

Tryptophan

Lysine

Beans and other legumes

Some animals have adaptations that help them through periods when their bodies demand extraordinary amounts of protein

Fig. 41-3

Table 41-1

Table 41.1 Vitamin Requirements of Humans

Vitamin	Major Dietary Sources	Major Functions in the Body	Symptoms of Deficiency or Extreme Excess
Water-Soluble Vitamins			
Vitamin B_1 (thiamine)	Pork, legumes, peanuts, whole grains	Coenzyme used in removing CO_2 from organic compounds	Beriberi (nerve disorders, emaciation, anemia)
Vitamin B_2 (riboflavin)	Dairy products, meats, enriched grains, vegetables	Component of coenzymes FAD and FMN	Skin lesions such as cracks at corners of mouth
Niacin (B_3)	Nuts, meats, grains	Component of coenzymes NAD^+ and $NADP^+$	Skin and gastrointestinal lesions, nervous disorders **Liver damage**
Vitamin B_6 (pyridoxine)	Meats, vegetables, whole grains	Coenzyme used in amino acid metabolism	Irritability, convulsions, muscular twitching, anemia **Unstable gait, numb feet, poor coordination**
Pantothenic acid (B_5)	Most foods: meats, dairy products, whole grains, etc.	Component of coenzyme A	Fatigue, numbness, tingling of hands and feet
Folic acid (folacin) (B_9)	Green vegetables, oranges, nuts, legumes, whole grains	Coenzyme in nucleic acid and amino acid metabolism	Anemia, birth defects **May mask deficiency of vitamin B_{12}**
Vitamin B_{12}	Meats, eggs, dairy products	Coenzyme in nucleic acid metabolism; maturation of red blood cells	Anemia, nervous system disorders
Biotin	Legumes, other vegetables, meats	Coenzyme in synthesis of fat, glycogen, and amino acids	Scaly skin inflammation, neuromuscular disorders
Vitamin C (ascorbic acid)	Fruits and vegetables, especially citrus fruits, broccoli, cabbage, tomatoes, green peppers	Used in collagen synthesis (such as for bone, cartilage, gums); antioxidant; aids in detoxification; improves iron absorption	Scurvy (degeneration of skin, teeth, blood vessels), weakness, delayed wound healing, impaired immunity **Gastrointestinal upset**
Fat-Soluble Vitamins			
Vitamin A (retinol)	Provitamin A (beta-carotene) in deep green and orange vegetables and fruits; retinal in dairy products	Component of visual pigments; maintenance of epithelial tissues; antioxidant; helps prevent damage to cell membranes	Blindness and increased death rate **Headache, irritability, vomiting, hair loss, blurred vision, liver and bone damage**
Vitamin D	Dairy products, egg yolk; also made in human skin in presence of sunlight	Aids in absorption and use of calcium and phosphorus; promotes bone growth	Rickets (bone deformities) in children, bone softening in adults **Brain, cardiovascular, and kidney damage**
Vitamin E (tocopherol)	Vegetable oils, nuts, seeds	Antioxidant; helps prevent damage to cell membranes	Degeneration of the nervous system
Vitamin K (phylloquinone)	Green vegetables, tea; also made by colon bacteria	Important in blood clotting	Defective blood clotting **Liver damage and anemia**

Table 41-2

Table 41.2 Mineral Requirements of Humans

	Mineral	Major Dietary Sources	Major Functions in the Body	Symptoms of Deficiency*
Greater than 200 mg per day required	Calcium (Ca)	Dairy products, dark green vegetables, legumes	Bone and tooth formation, blood clotting, nerve and muscle function	Retarded growth, possibly 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	Symptoms of protein deficiency
	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	Cofactor; ATP bioenergetics	Nervous system disturbances
	Iron (Fe)	Meats, eggs, legumes, whole grains, green leafy vegetables	Component of hemoglobin and of electron carriers in energy metabolism; enzyme cofactor	Iron-deficiency anemia, weakness, impaired immunity
	Fluorine (F)	Drinking water, tea, seafood	Maintenance of tooth (and probably bone) structure	Higher frequency of tooth decay
	Zinc (Zn)	Meats, seafood, grains	Component of certain digestive enzymes and other proteins	Growth failure, skin abnormalities, reproductive failure, impaired immunity
	Copper (Cu)	Seafood, nuts, legumes, organ meats	Enzyme cofactor in iron metabolism, melanin synthesis, electron transport	Anemia, cardiovascular abnormalities
	Manganese (Mn)	Nuts, grains, vegetables, fruits, tea	Enzyme cofactor	Abnormal bone and cartilage
	Iodine (I)	Seafood, dairy products, iodized salt	Component of thyroid hormones	Goiter (enlarged thyroid)
	Cobalt (Co)	Meats and dairy products	Component of vitamin B_{12}	None, except as B_{12} deficiency
	Selenium (Se)	Seafood, meats, whole grains	Enzyme cofactor; antioxidant functioning in close association with vitamin E	Muscle pain, possibly heart muscle deterioration
	Chromium (Cr)	Brewer's yeast, liver, seafood, meats, some vegetables	Involved in glucose and energy metabolism	Impaired glucose metabolism
	Molybdenum (Mo)	Legumes, grains, some vegetables	Enzyme cofactor	Disorder in excretion of nitrogen-containing compounds

*All of these minerals are also harmful when consumed in excess.

Dietary Deficiencies

- **Undernourishment** is the result of a diet that consistently supplies less chemical energy than the body requires
- **Malnourishment** is the long-term absence from the diet of one or more essential nutrients

Fig. 41-4

Assessing Nutritional Needs

- 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

Fig. 41-5

RESULTS

Group	Number of infants/fetuses studied	Infants/fetuses with a neural tube defect
Vitamin supplements (experimental group)	141	1 (0.7%)
No vitamin supplements (control group)	204	12 (5.9%)

Concept 41.2: The main stages of food processing are ingestion, digestion, absorption, and elimination

- **Ingestion** is the act of eating

Fig. 41-6a

Humpback whale, a suspension feeder

Fig. 41-6b

Leaf miner caterpillar, a substrate feeder

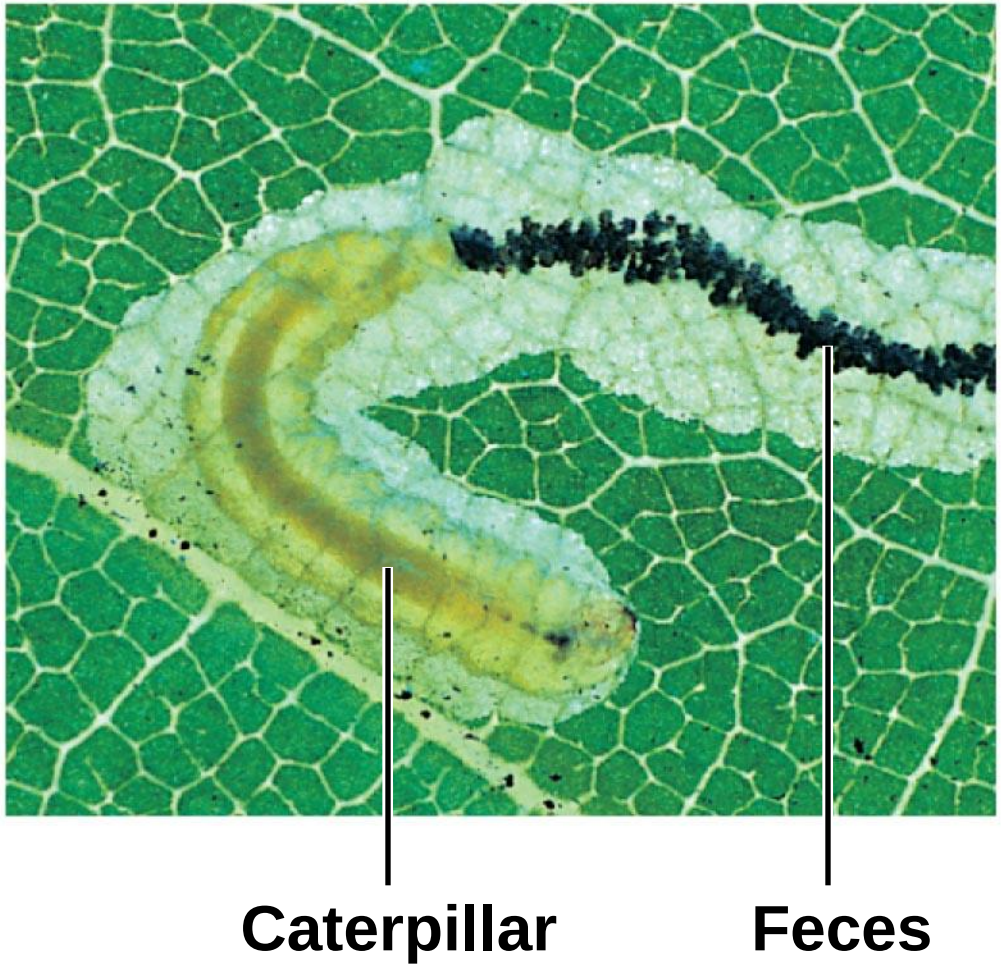
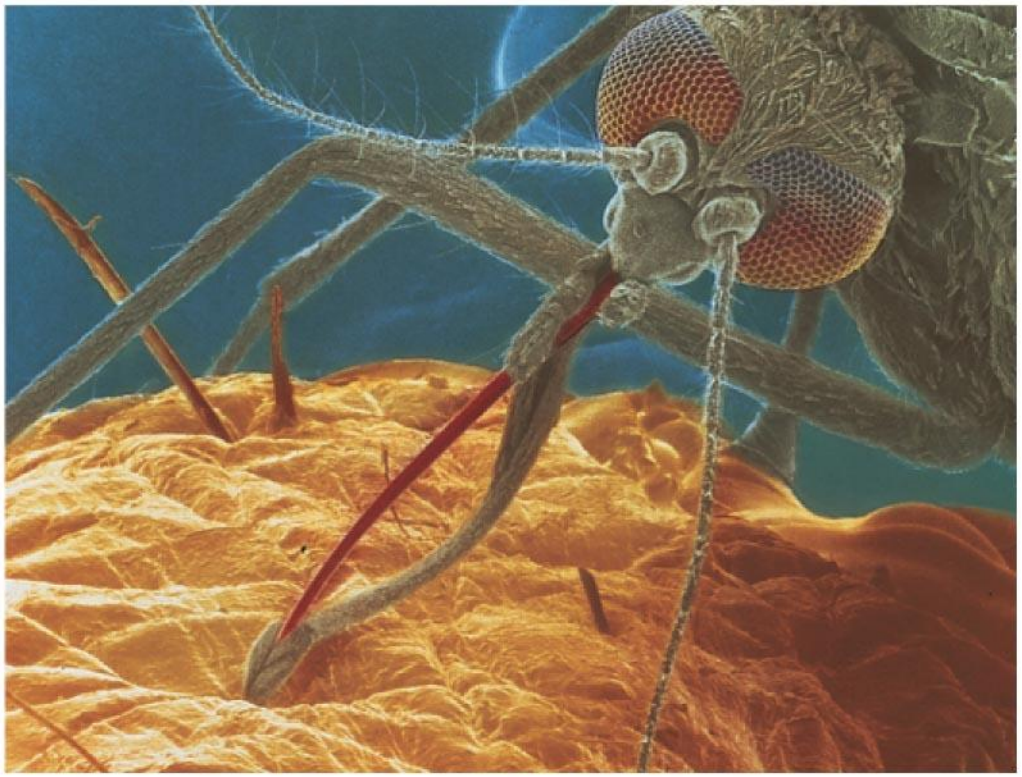


Fig. 41-6c



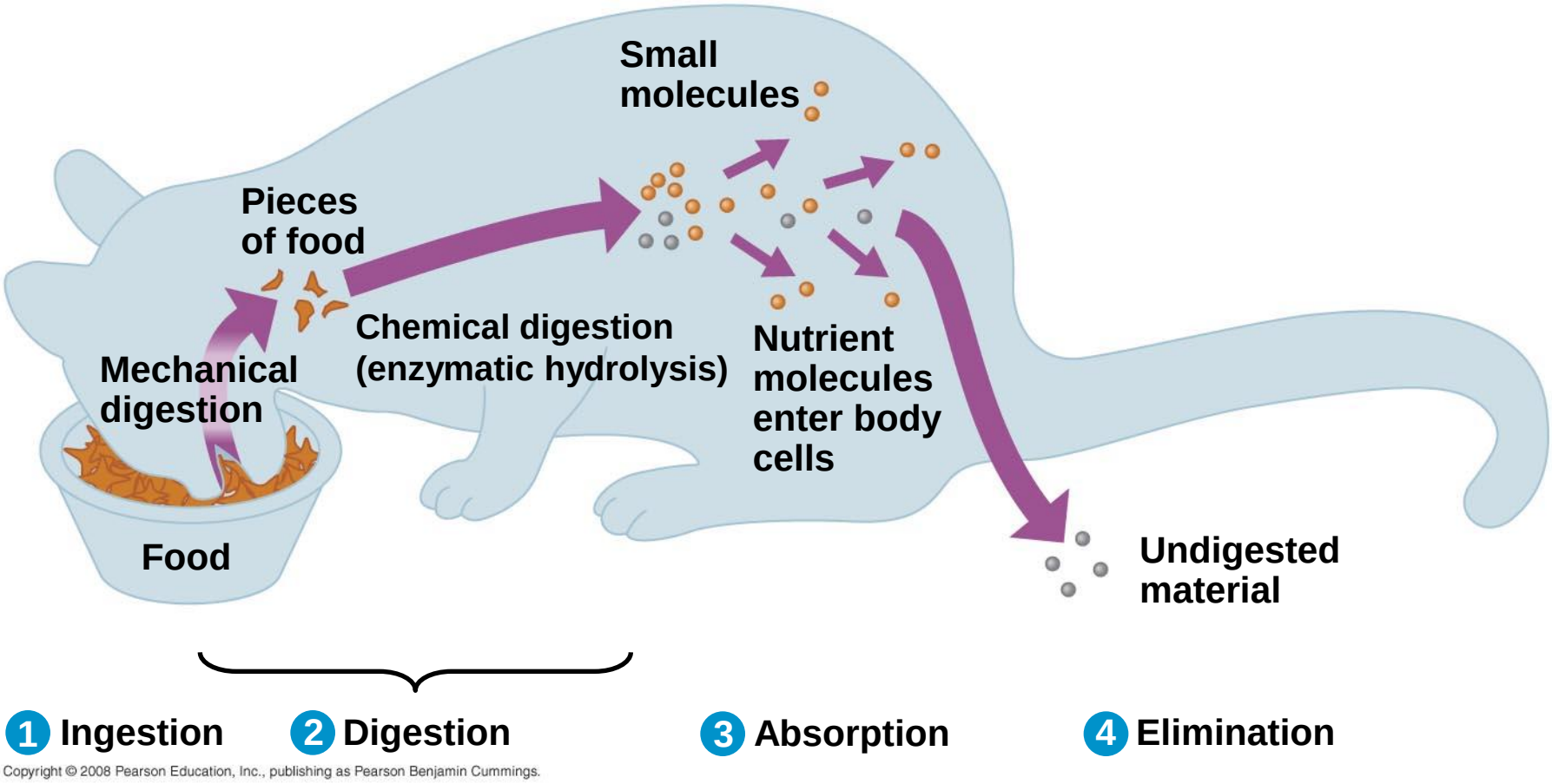
Mosquito, a fluid feeder

Fig. 41-6d

Rock python, a bulk feeder

- **Digestion** is the process of breaking food down into molecules small enough to absorb
  - In chemical digestion, the process of **enzymatic hydrolysis** splits bonds in molecules with the addition of water
- **Absorption** is uptake of nutrients by body cells
- **Elimination** is the passage of undigested material out of the digestive compartment

Fig. 41-7



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**
- **Extracellular digestion**

Fig. 41-8

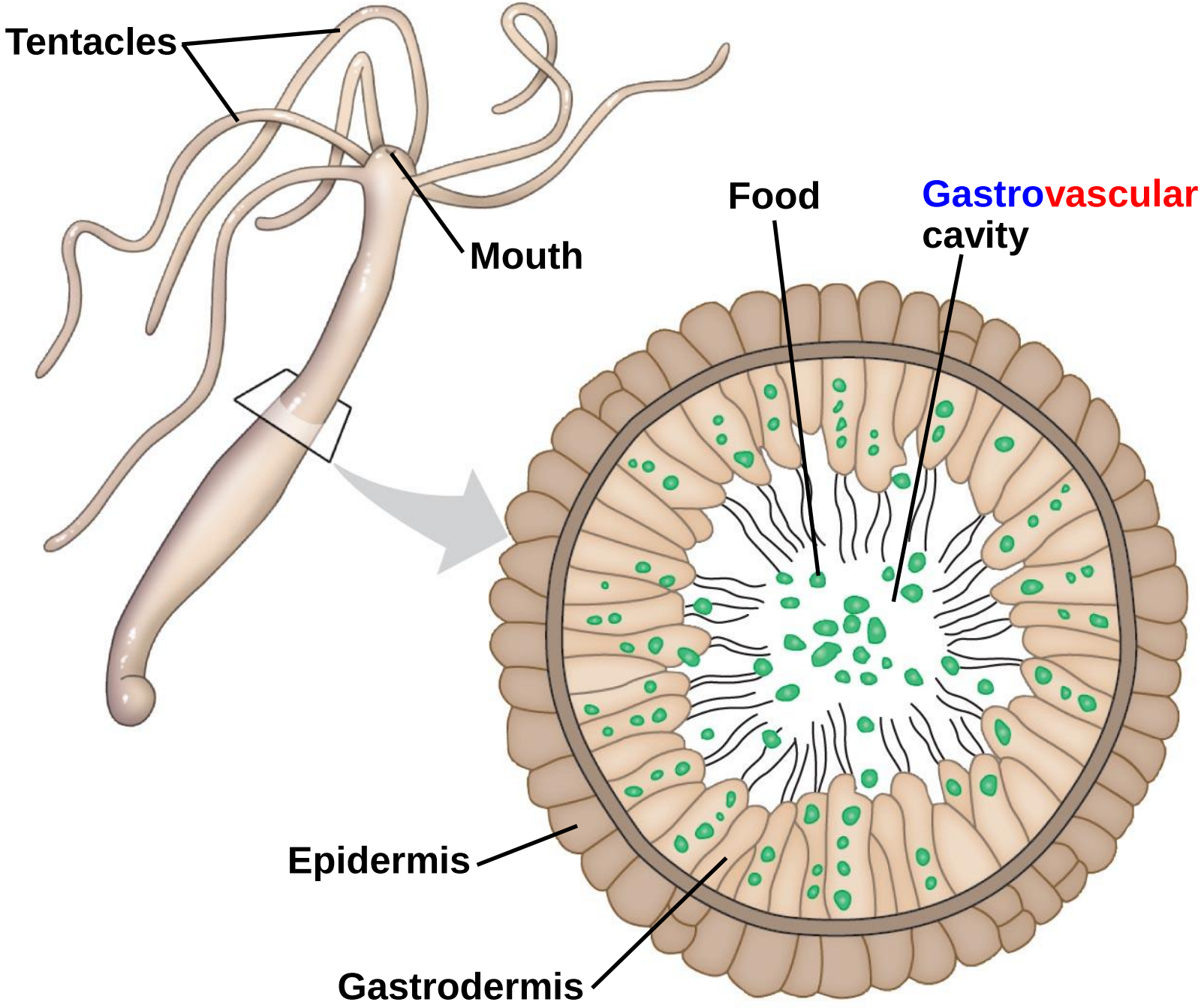
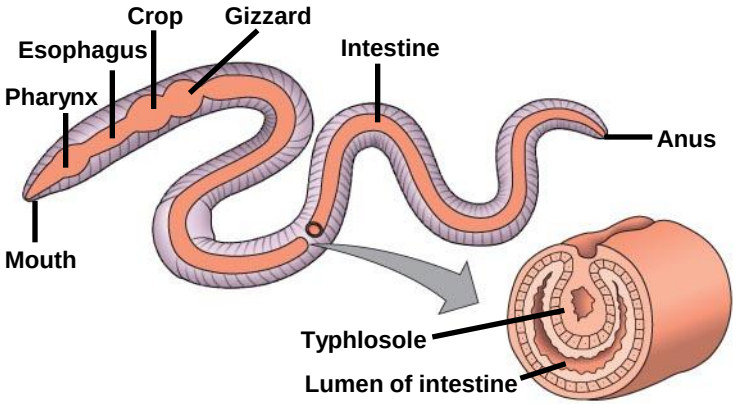
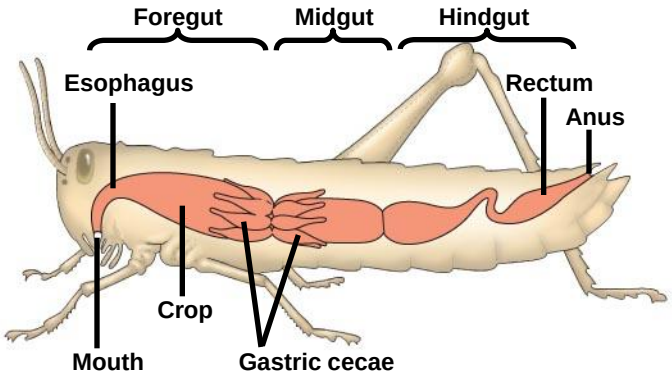


Fig. 41-9

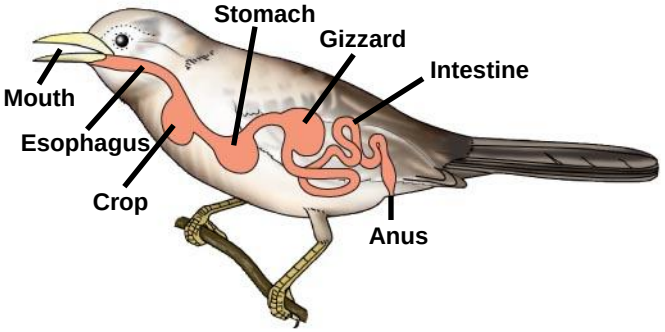
This digestive tube is called a **complete digestive tract** or an **alimentary canal**



(a) Earthworm



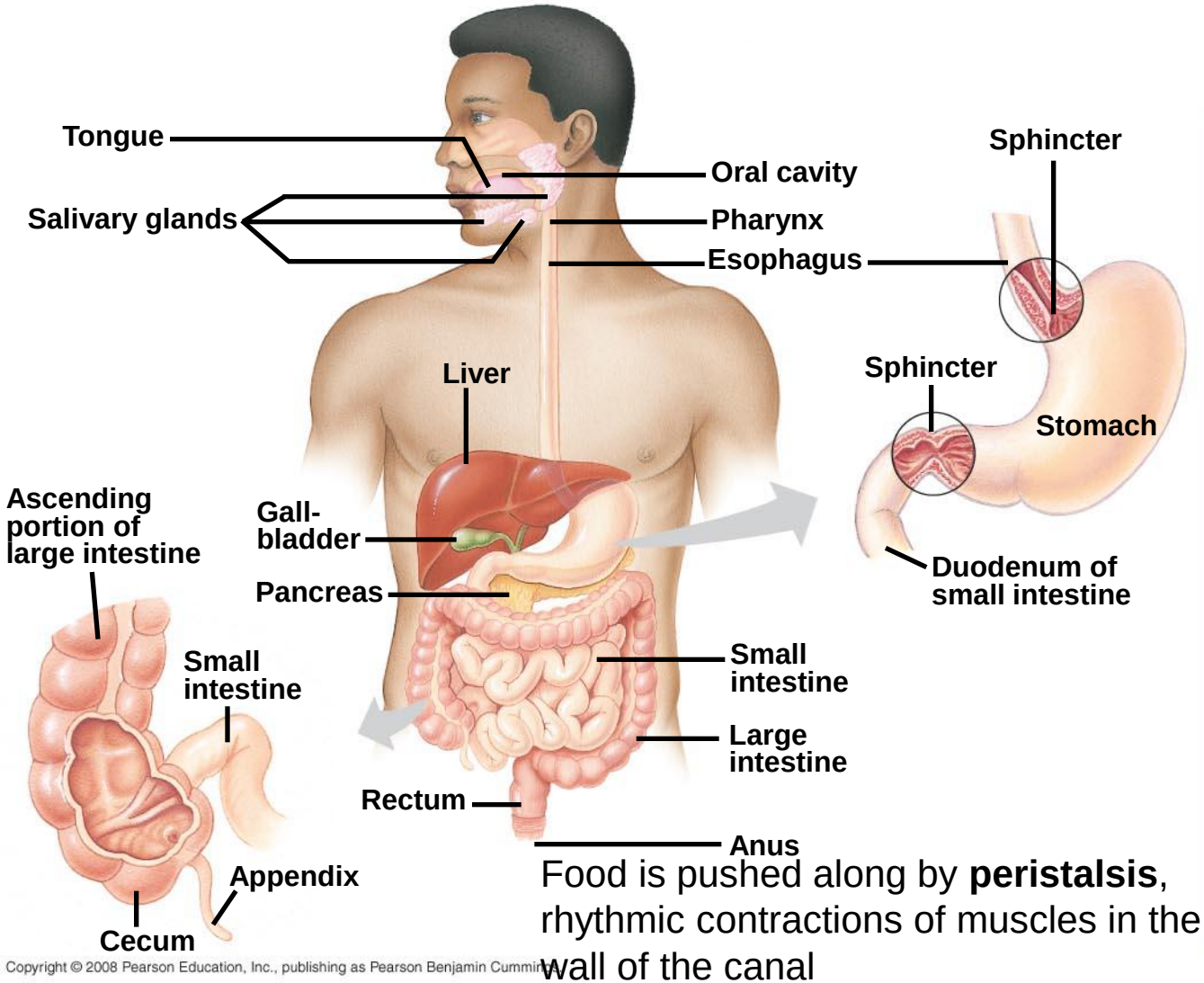
(b) Grasshopper

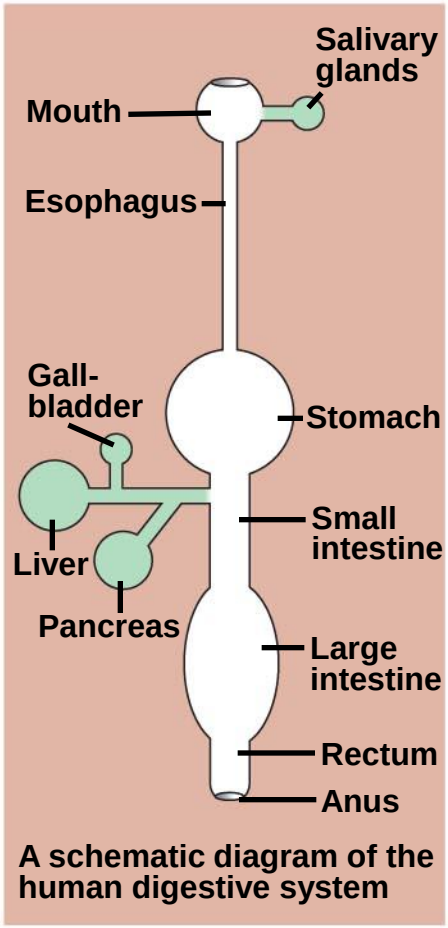


(c) Bird

Fig. 41-10

The mammalian digestive system consists of an alimentary canal and accessory glands that secrete digestive juices through ducts





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

Fig. 41-11-3

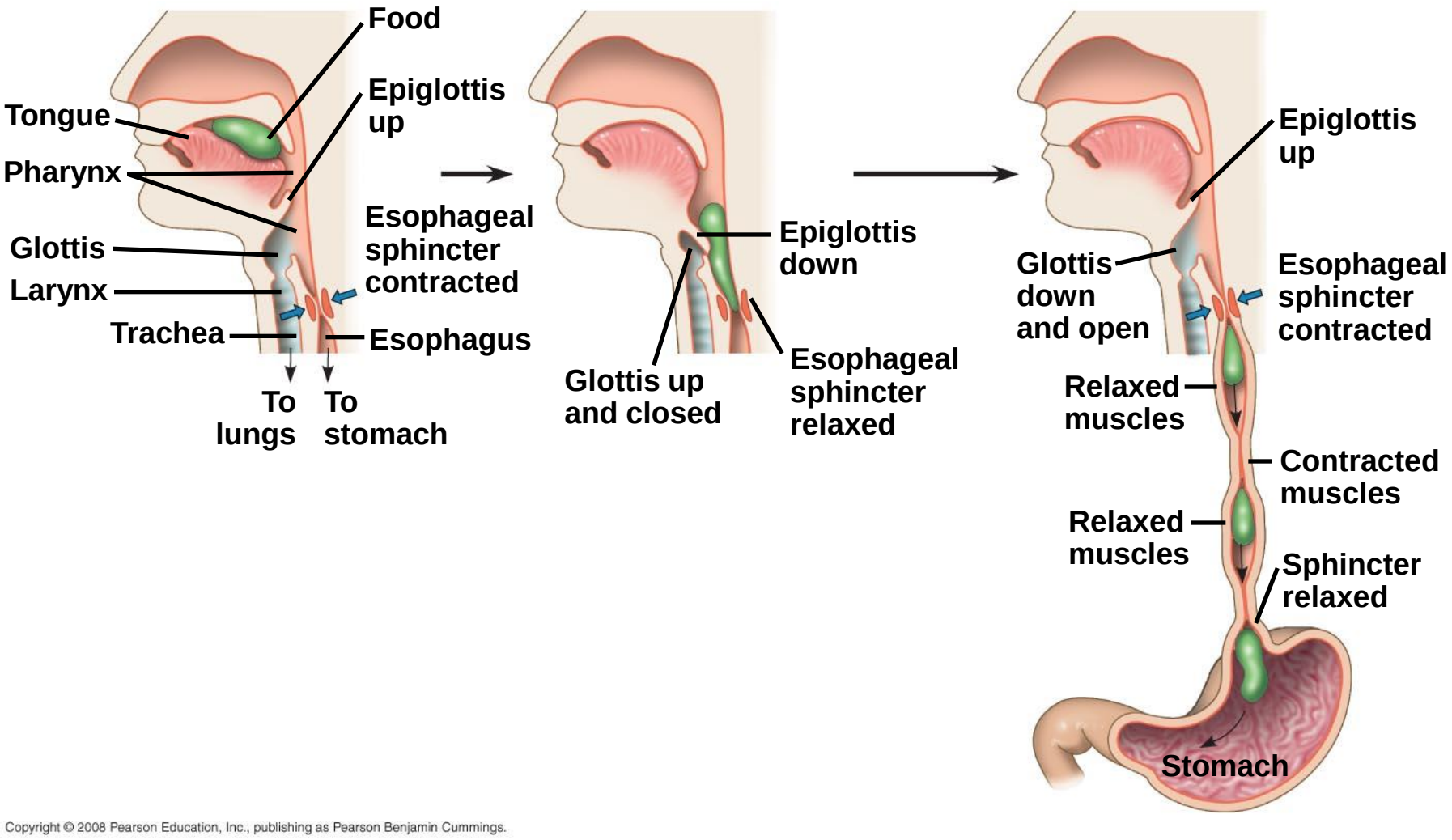
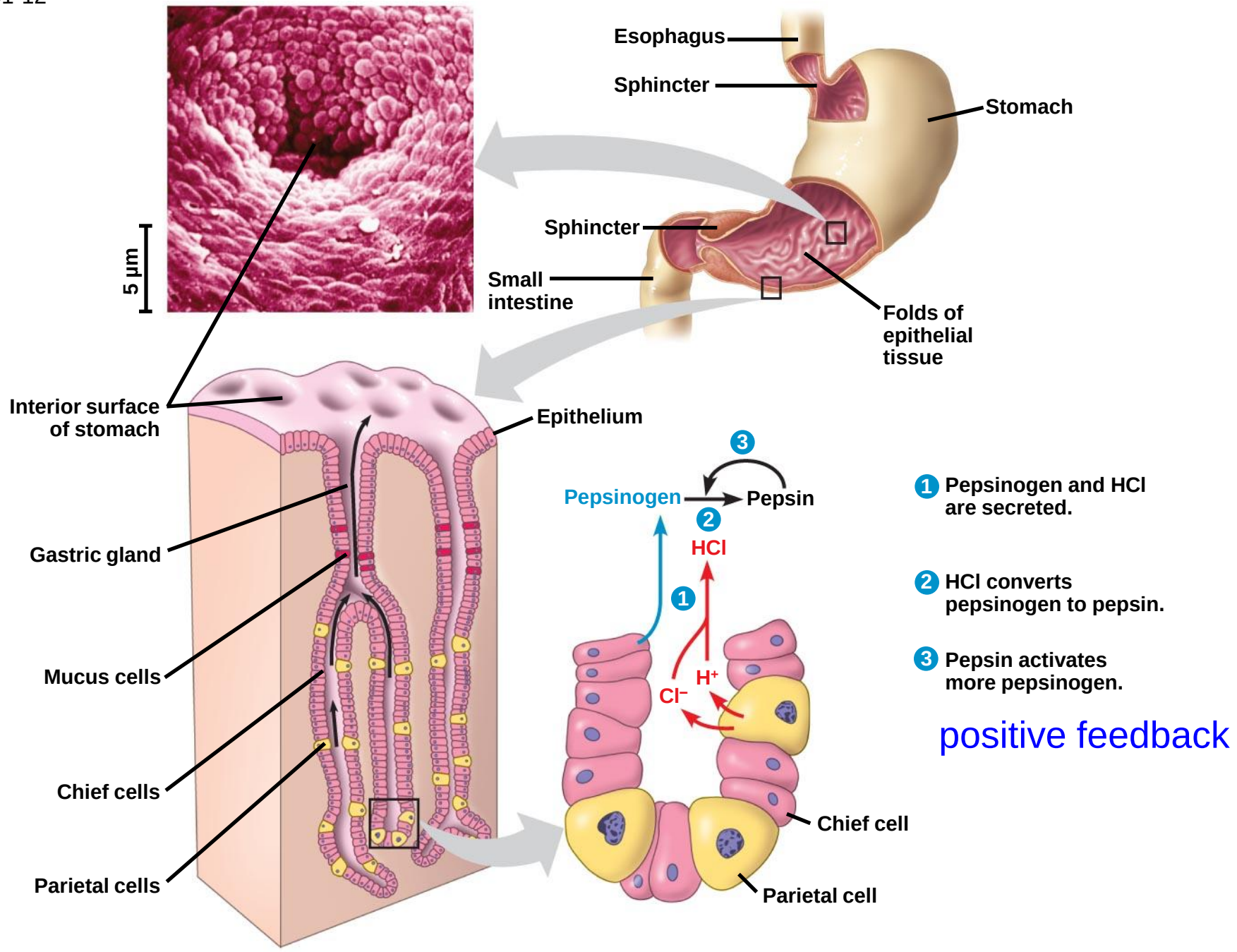


Fig. 41-12

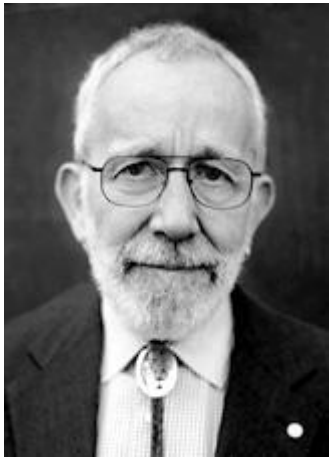


- Gastric ulcers, lesions in the lining, are caused mainly by the bacterium *Helicobacter pylori*

The Nobel Prize in Physiology or Medicine 2005

"for their discovery of the bacterium *Helicobacter pylori* and its role in gastritis and peptic ulcer disease"

Barry J. Marshall



J. Robin Warren

Fig. 41-13

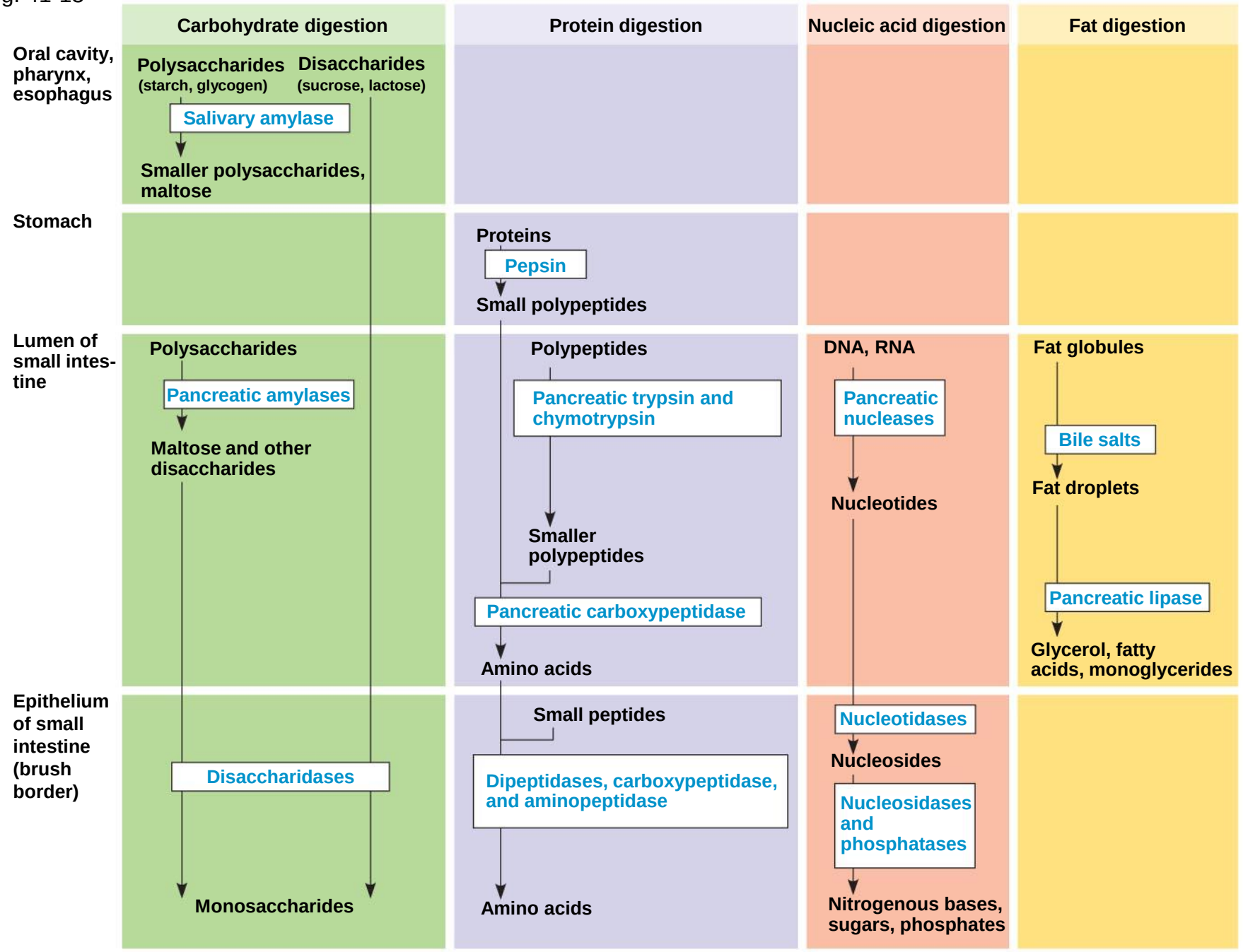
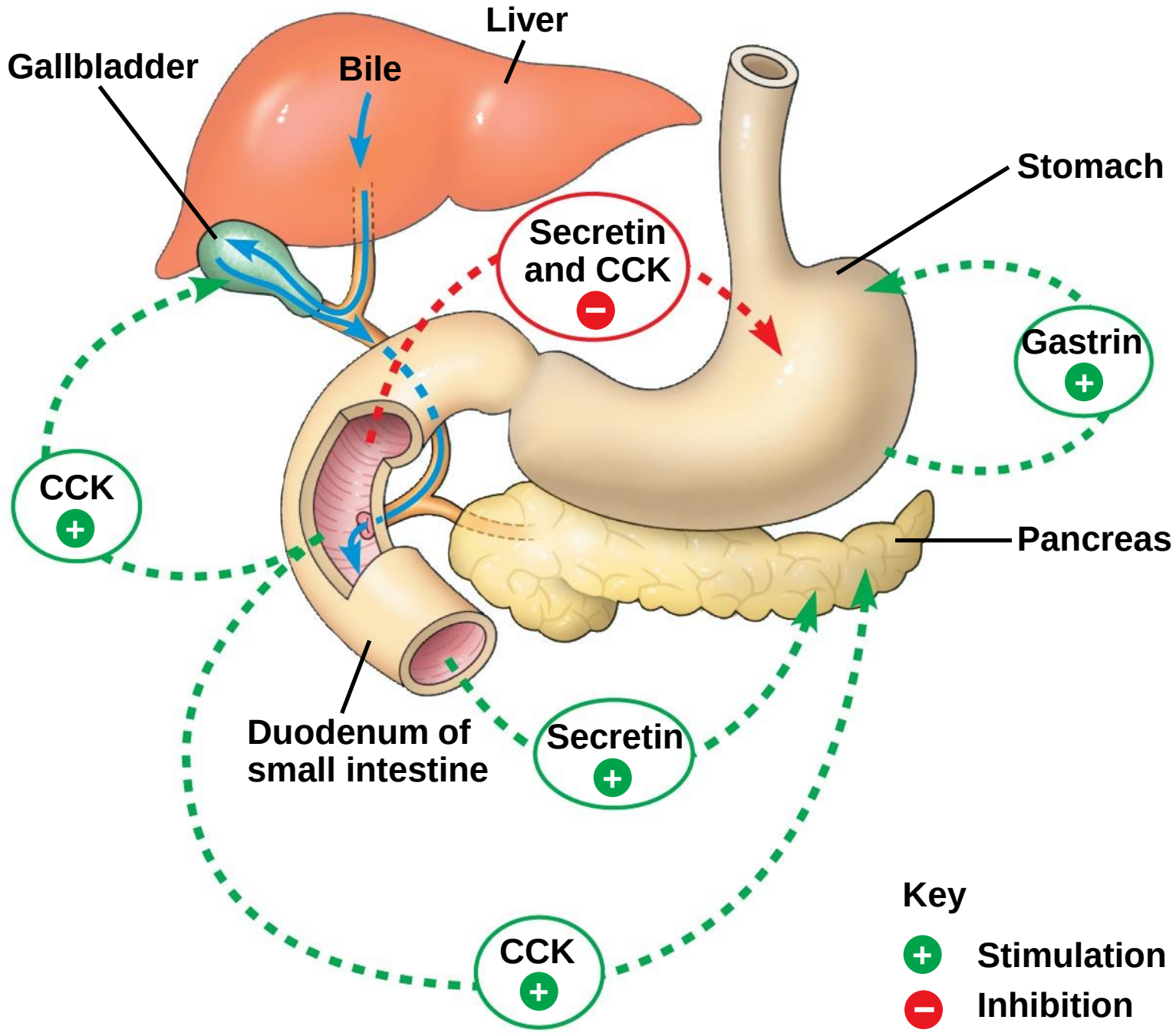


Fig. 41-14



Pancreatic Secretions

- The **pancreas** produces proteases trypsin and chymotrypsin, protein-digesting enzymes that are activated after entering the duodenum
- Its solution is alkaline and neutralizes the acidic chyme

Fig. 41-15

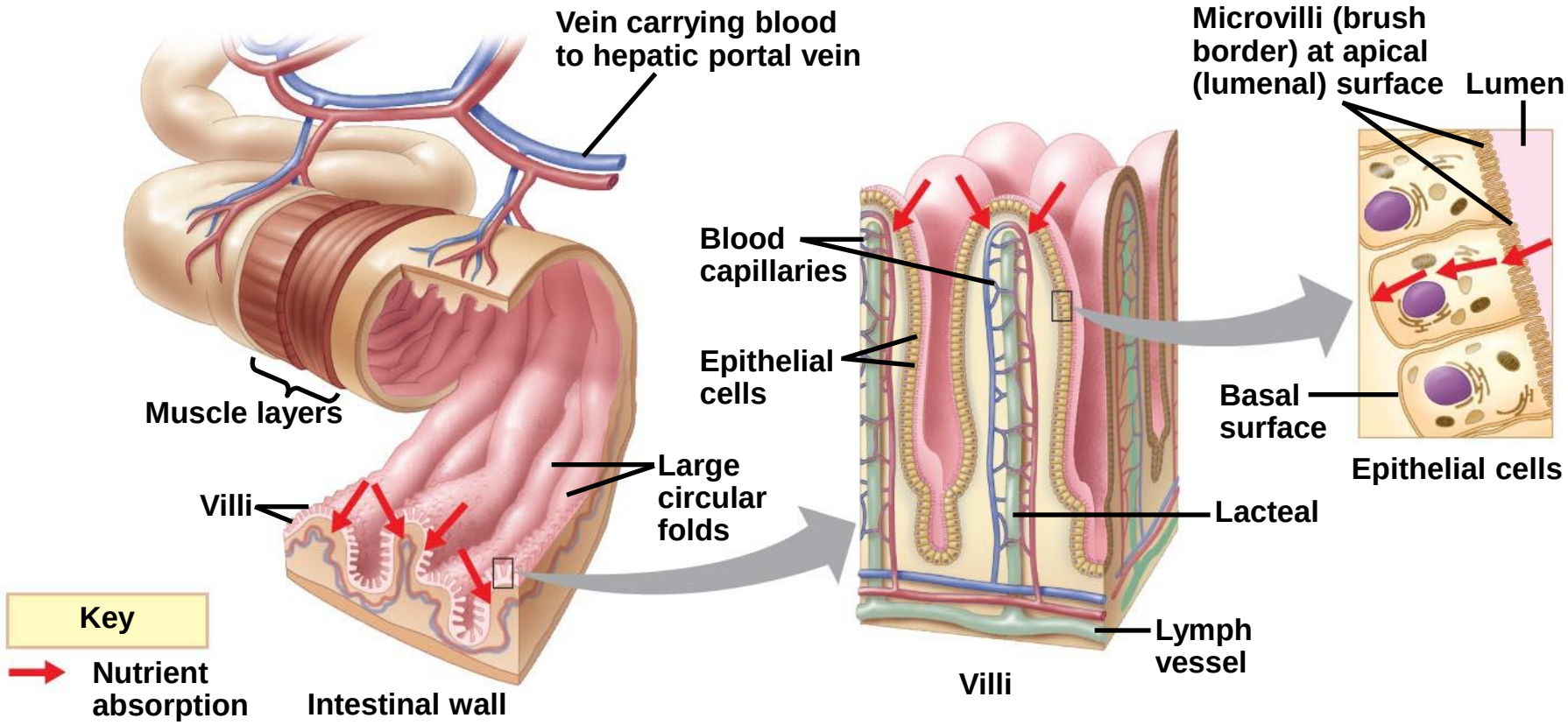


Fig. 41-16

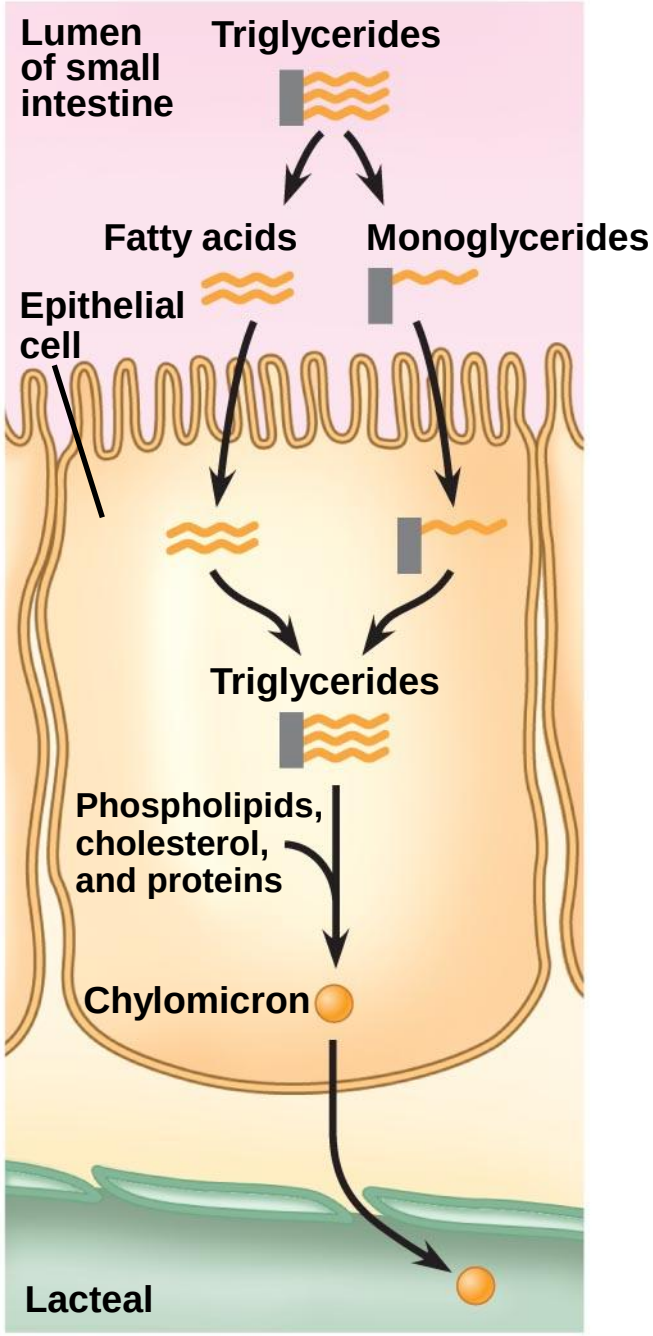
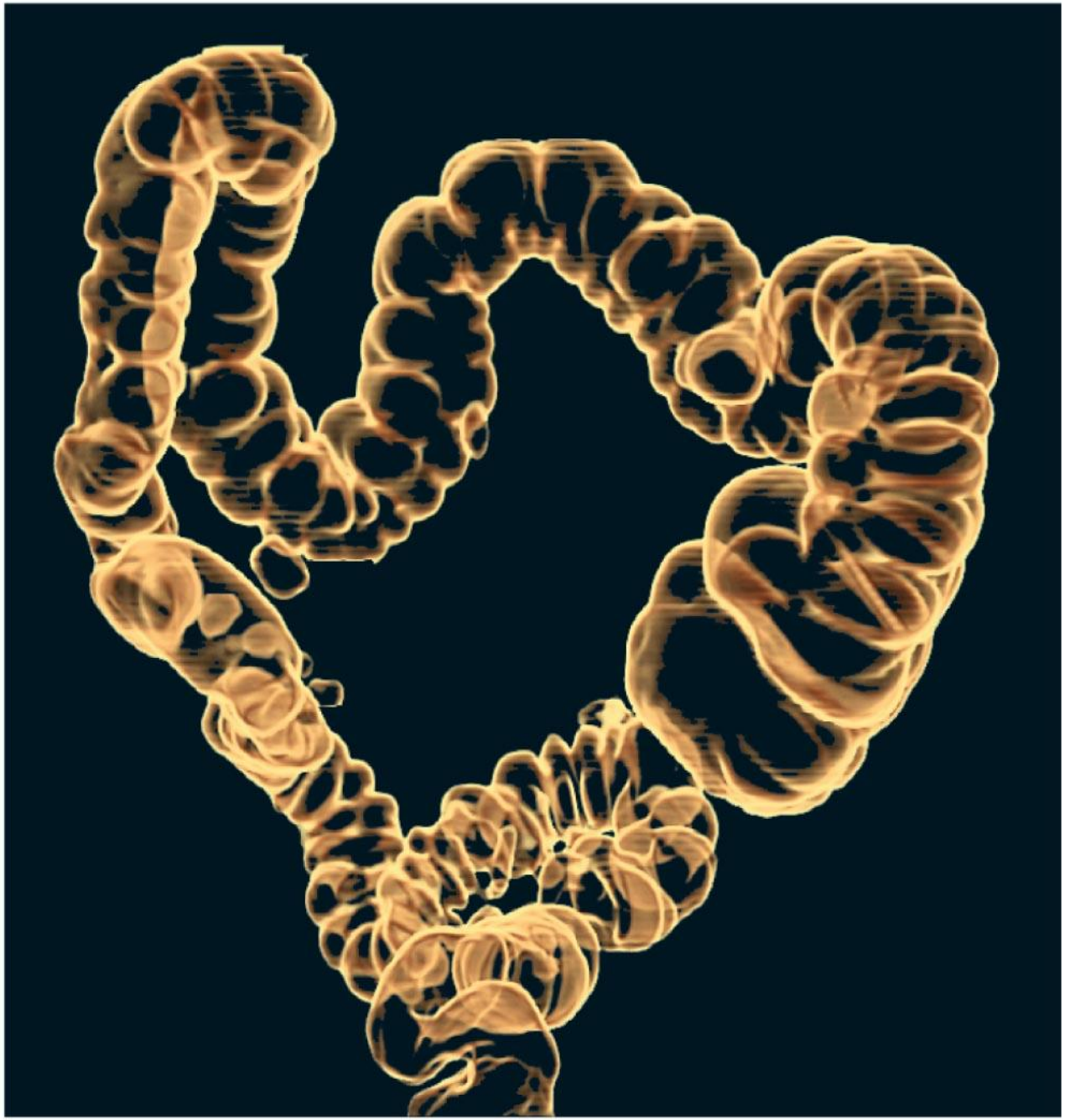
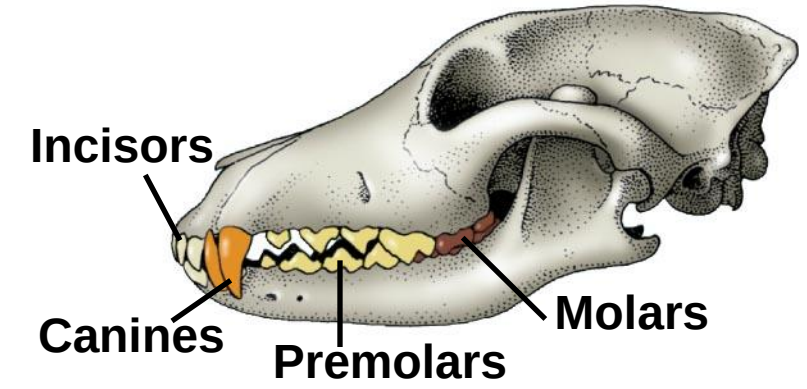


Fig. 41-17

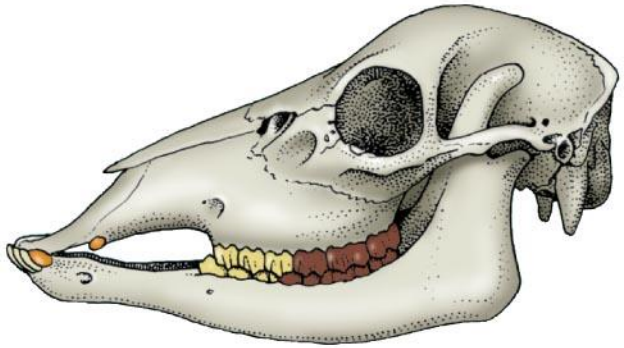


- The colon houses strains of the bacterium *Escherichia coli*, some of which produce vitamins
- Feces are stored in the **rectum** until they can be eliminated
- Two sphincters between the rectum and anus control bowel movements

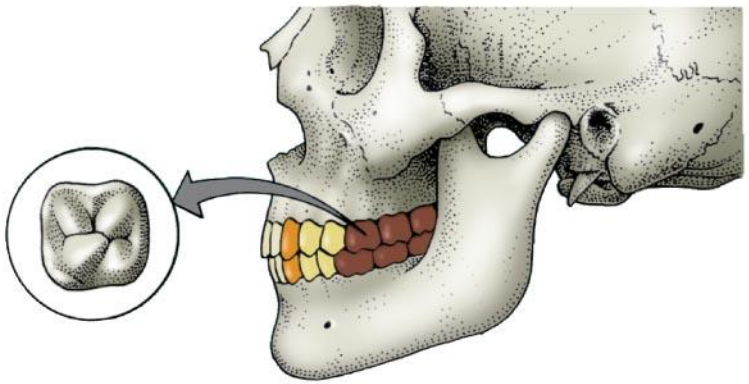
Fig. 41-18



(a) Carnivore



(b) Herbivore

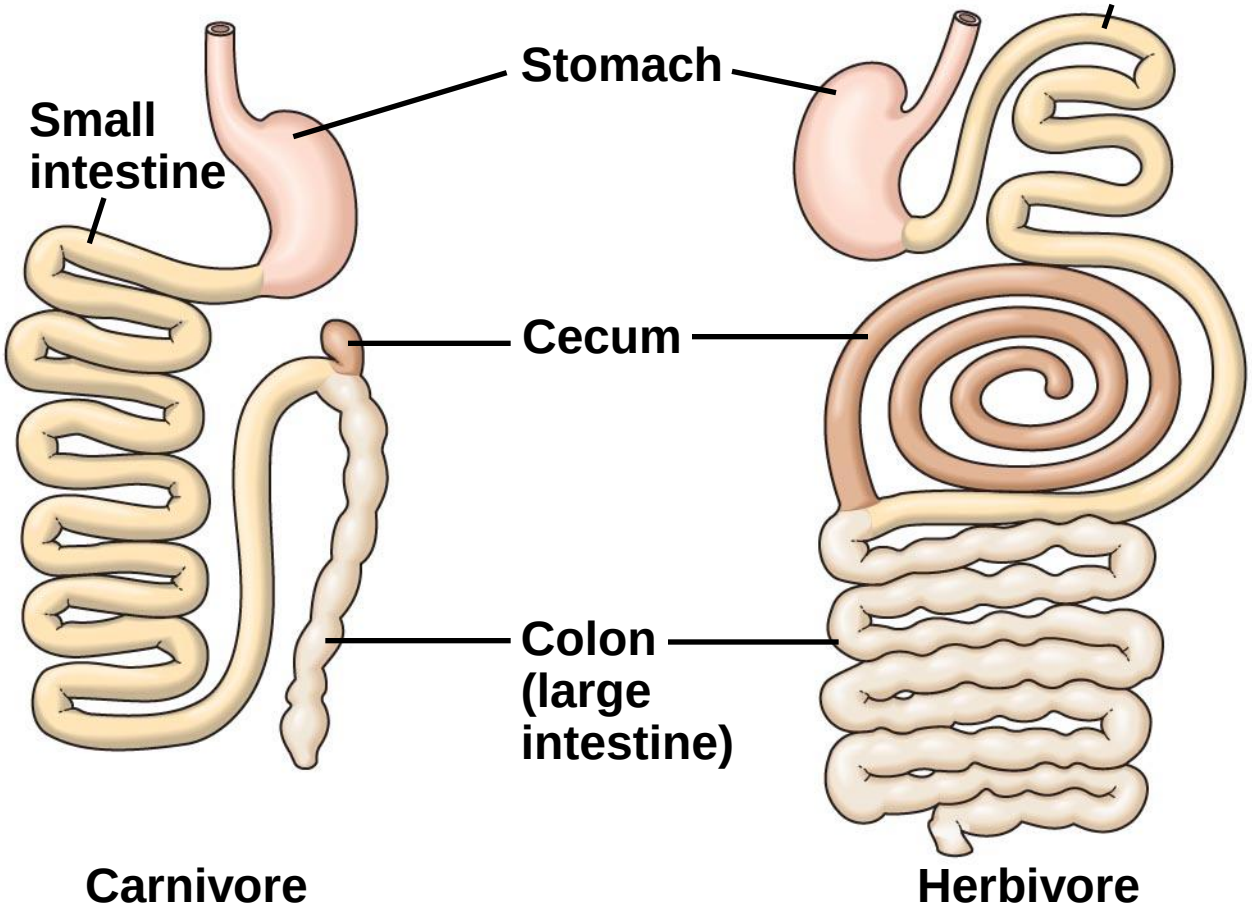


(c) Omnivore

Stomach and Intestinal Adaptations

- Herbivores generally have longer alimentary canals than carnivores, reflecting the longer time needed to digest vegetation

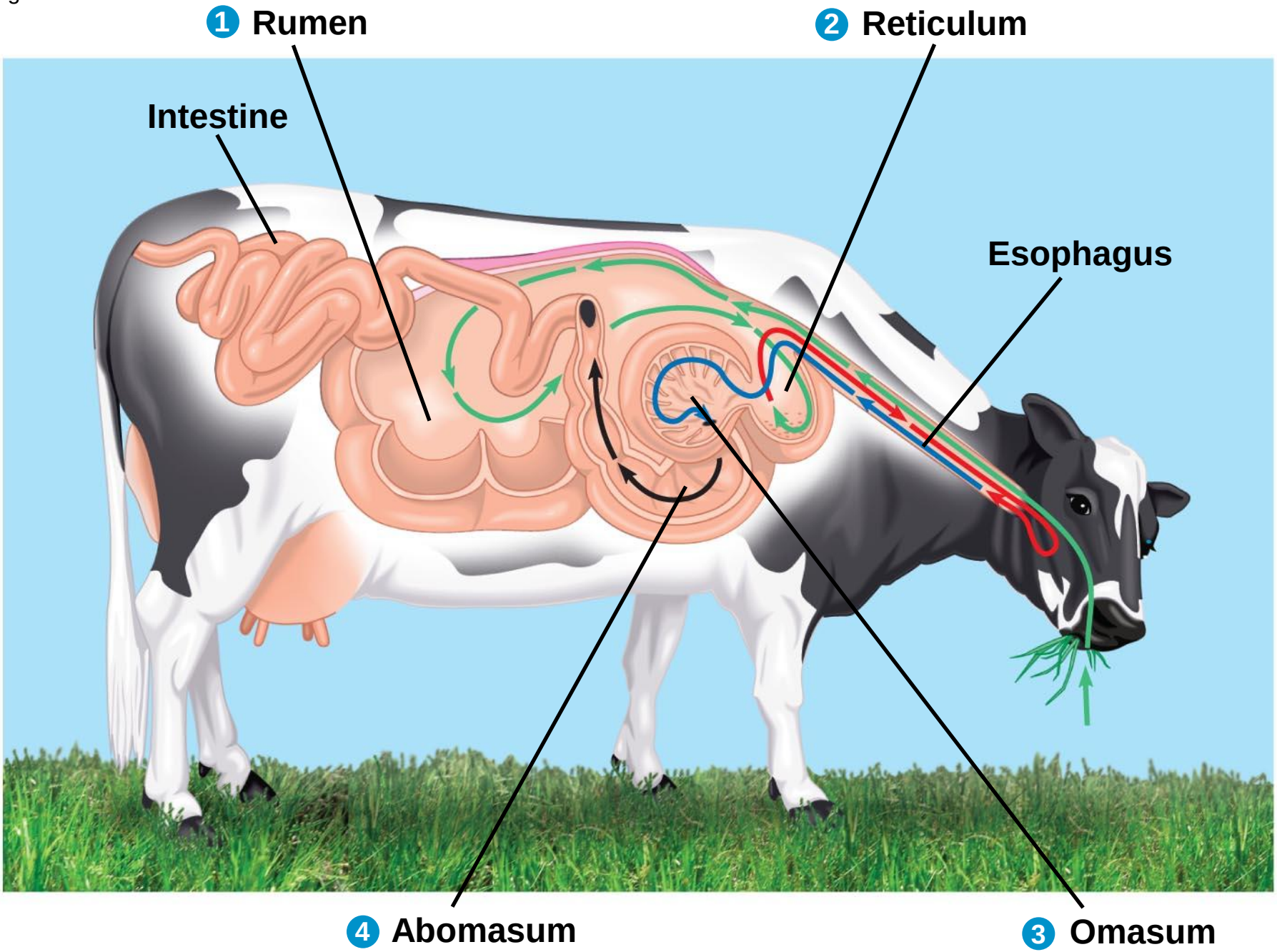
Fig. 41-19



Mutualistic Adaptations

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

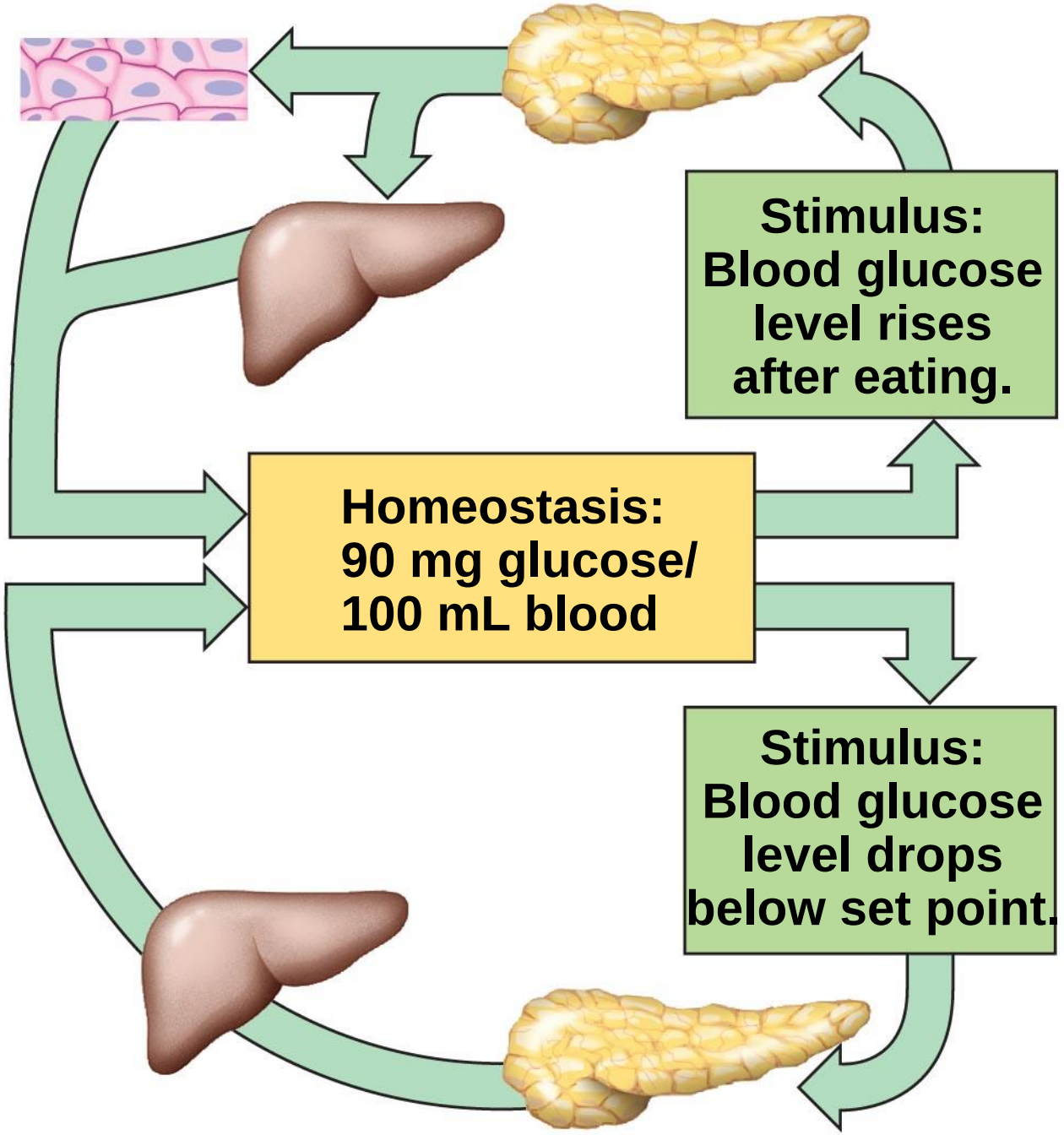
Fig. 41-20



Concept 41.5: Homeostatic mechanisms contribute to an animal's energy balance

- Nearly all of an animal's ATP generation is based on oxidation of energy-rich molecules: carbohydrates, proteins, and fats
- Animals store excess calories primarily as glycogen in the liver and muscles
- Energy is secondarily stored as adipose, or fat, cells
- When fewer calories are taken in than are expended, fuel is taken from storage and oxidized

Fig. 41-21



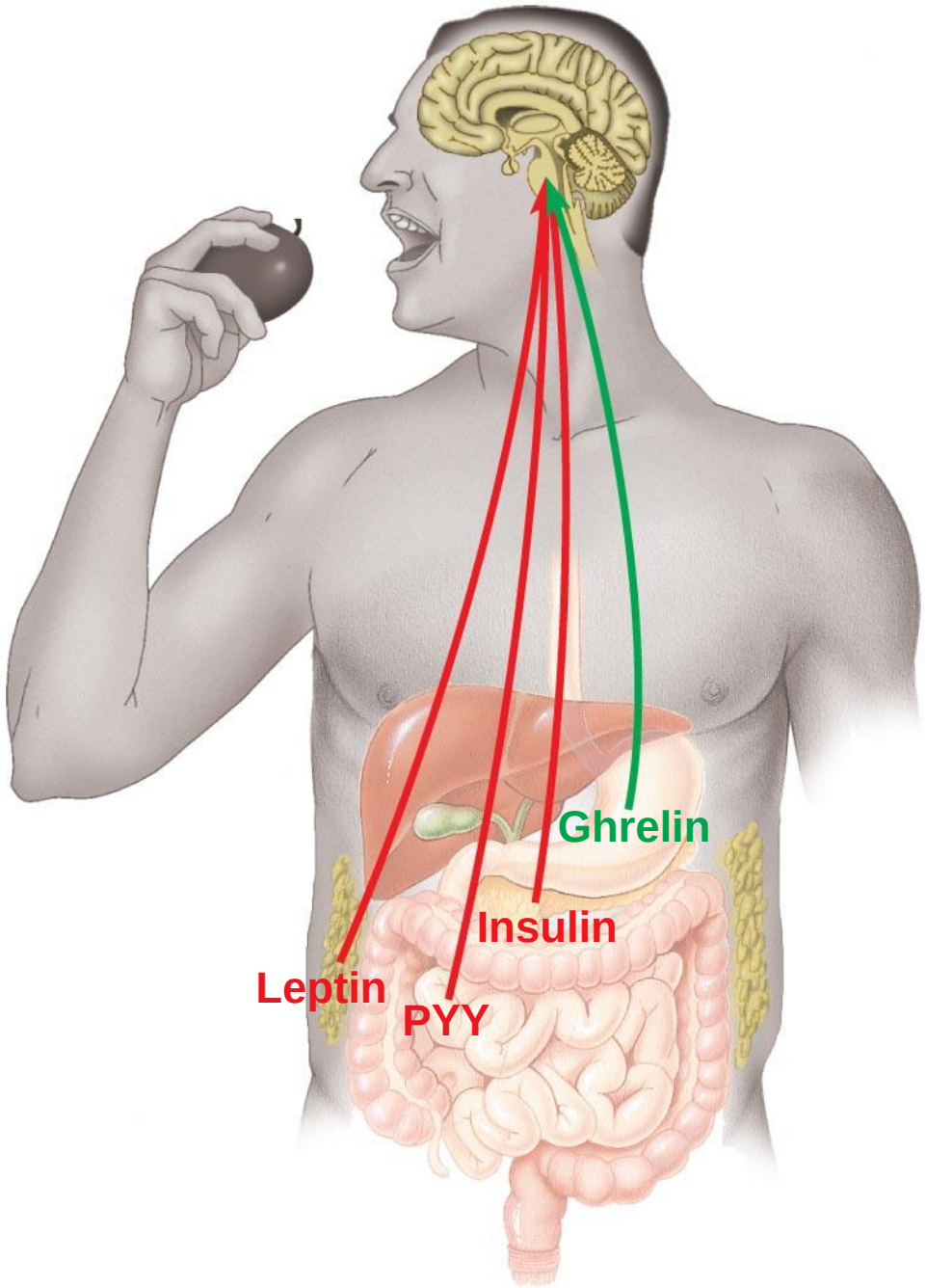
Overnourishment and Obesity

- **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

Fig. 41-22

- Researchers have discovered several of the mechanisms that help regulate body weight
- Homeostatic mechanisms are feedback circuits that control the body's storage and metabolism of fat over the long-term
- Hormones regulate long-term and short-term appetite by affecting a "satiety center" in the brain

Fig. 41-23



- The complexity of weight control in humans is evident from studies of the hormone leptin
- Mice that inherit a defect in the gene for leptin become very obese

Fig. 41-24

EXPERIMENT

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

RESULTS

Genotype pairing (red type indicates mutant genes; bar indicates pairing)	Average body mass (g)	
	Starting	Ending
ob^+, db^+	20.3	23.6
|		
ob^+, db^+	20.8	21.4
ob, db^+	27.6	47.0
|		
ob, db^+	26.6	44.0
ob, db^+	29.4	39.8
|		
ob^+, db^+	22.5	25.5
ob, db^+	33.7	18.8
|		
ob^+, db	30.3	33.2

Obesity and Evolution

- The problem of maintaining weight partly stems from our evolutionary past, when fat hoarding was a means of survival
- 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

Fig. 41-25

You should now be able to:

1. Name the three nutritional needs that must be met by an animal's diet
2. Describe the four classes of essential nutrients
3. Distinguish among undernourishment, overnourishment, and malnourishment
4. Describe the four main stages of food processing
5. Distinguish between a complete digestive tract and a gastrovascular cavity

6. Follow a meal through the mammalian digestive system:
   - List important enzymes and describe their roles
   - Compare *where* and *how* the major types of macromolecules are digested and absorbed
7. Relate variations in dentition with different diets
8. Explain *where* and *in what form* energy-rich molecules may be stored in the human body