Chapter 21 Nutrition and Digestion

Introduction

- The modern human diet in developed countries allows access to relatively cheap and available calorie-dense foods.
- This diet, combined with sedentary jobs and inactive lifestyles, has led to an obesity crisis in the United States leading to
  - 68% of people categorized as overweight and
  - 100 million people categorized as obese.
- Thus, the modern diet appears to be contributing to shorter, less healthy lives.
21.1 Animals obtain and ingest their food in a variety of ways

- Most animals have one of three kinds of diets.
  - **Herbivores** eat plants and include cattle, snails, and sea urchins.
  - **Carnivores** eat meat and include lions, hawks, and spiders.
  - **Omnivores** eat plants and other animals and include humans, roaches, raccoons, and crows.

21.2 Overview: Food processing occurs in four stages

- Food is processed in four stages.
  1. **Ingestion** is the act of eating.
  2. **Digestion** is the breaking down of food into molecules small enough for the body to absorb.
  3. **Absorption** is the take-up of the products of digestion, usually by the cells lining the digestive tract.
  4. **Elimination** is the removal of undigested materials out of the digestive tract.
Most animals have an alimentary canal with
- a mouth,
- an anus, and
- specialized regions associated with one-way flow of food.

The normal one-way flow moves food
- into the pharynx or throat,
- down the esophagus to a
  - crop where food is softened and stored, (birds, snails, earthworms)
  - gizzard, where food is ground and stored, and/or (birds, fish alligators)
  - stomach where food is ground and stored,****(humans)
- to the intestines, where chemical digestion and nutrient absorption occur, and finally
- undigested materials are expelled through the anus.

THE HUMAN DIGESTIVE SYSTEM
21.4 The human digestive system consists of an alimentary canal and accessory glands

- In humans, food is
  - ingested and chewed in the mouth or oral cavity,
  - pushed by the tongue into the pharynx,
  - moved along by alternating waves of contraction and relaxation by smooth muscle in the walls of the canal in a process called peristalsis, and
  - moved in and out of the stomach by sphincters.

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21.4 The human digestive system consists of an alimentary canal and accessory glands

- The final steps of digestion and nutrient absorption in humans occur in the small intestine.
- Undigested materials move through the large intestine, feces are stored in the rectum, and then expelled out the anus.

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A schematic diagram of the human digestive system

Key
- Alimentary canal
- Accessory digestive glands

- Oral cavity
- Esophagus
- Stomach
- Gall-bladder
- Liver
- Pancreas
- Small intestine
- Large intestine
- Rectum
- Anus
- Salivary glands

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21.5 Digestion begins in the oral cavity

- Mechanical digestion and chemical digestion begin in the mouth.
- Chewing cuts, smashes, and grinds food, making it easier to swallow.
- The tongue
  - tastes,
  - shapes the food into a ball called a bolus, and
  - moves it toward the pharynx.

- Salivary glands release
  - a slippery glycoprotein that moistens and lubricates food for easier swallowing,
  - buffers that neutralize acids,
  - salivary enzyme amylase that begins the hydrolysis of starch, and
  - antibacterial agents that kill some bacteria ingested with food.
21.6 After swallowing, peristalsis moves food through the esophagus to the stomach

- Swallowed food and drink move from the pharynx,
  - into the esophagus, and
  - into the stomach.

- During swallowing,
  - the tip of the larynx moves upward,
  - preventing the food from entering the trachea.
21.8 The stomach stores food and breaks it down with acid and enzymes

- The stomach can stretch and store up to 2 liters of food and drink.
- Some chemical digestion occurs in the stomach.
- The stomach secretes gastric juice, made up of
  - mucus,
  - a protein-digesting enzyme, and
  - strong acid with a pH of about 2 that
    - kills ingested bacteria,
    - breaks apart cells in food, and
    - denatures proteins.

21.8 The stomach stores food and breaks it down with acid and enzymes

- Pepsinogen and HCl produce active pepsin.
  - Pepsinogen, H⁺, and Cl⁻ are secreted into the lumen of the stomach.
  - HCl converts some pepsinogen to pepsin.
  - Pepsin helps activate more pepsinogen, starting a chain reaction.
  - Pepsin begins the chemical digestion of proteins.
What prevents the gastric juices from digesting the walls of the stomach?

- The secretion of pepsin in the inactive form of pepsinogen helps protect the cells of the gastric glands.
- Mucus helps protect the stomach lining against HCl and pepsin.
- New cells lining the stomach are produced about every three days to those that have been damaged.
21.9 CONNECTION: Digestive ailments include acid reflux and gastric ulcers

- Acid reflux of chyme in the stomach back into the esophagus causes the feeling of heartburn.
- Gastroesophageal reflux disease (GERD) results from frequent and severe acid reflux that harms the lining of the esophagus.
- Open sores in the lining of the stomach, called ulcers, may form.
- Bacterial infections (*Helicobacter pylori*) in the stomach and duodenum can produce ulcers.

21.10 The small intestine is the major organ of chemical digestion and nutrient absorption

- The small intestine is
  - named for its smaller diameter,
  - about 6 meters long,
  - the site of much chemical digestion, and
  - where most nutrients are absorbed.
21.10 The small intestine is the major organ of chemical digestion and nutrient absorption

- The first 25 cm of the small intestine is the **duodenum**, where chyme squirted from the stomach mixes with digestive juices from the pancreas, liver, gallbladder, and gland cells in the intestinal wall.
  - The **pancreas** produces pancreatic juice containing a mixture of digestive enzymes and an alkaline solution rich in bicarbonate.
  - The **liver** produces bile, which is stored in the **gallbladder** until it is needed. Bile breaks up fats into small droplets that are more susceptible to attack by digestive enzymes.
  - The intestinal wall produces digestive enzymes.
21.10 The small intestine is the major organ of chemical digestion and nutrient absorption

- The surface area for absorption in the small intestine is greatly increased by
  - folds of the intestinal lining,
  - fingerlike projections called villi, and
  - tiny projections of the surface of intestinal cells called microvilli.
Nutrients pass into epithelial cells by diffusion and against concentration gradients.

Fatty acids and glycerol are recombined into fats, coated with proteins, and transported into lymph vessels.

Other absorbed nutrients such as amino acids and sugars pass out of the intestinal epithelium, across the thin walls of the capillaries into blood, and finally to the liver.
21.11 One of the liver’s many functions is processing nutrient-laden blood from the intestines

- The liver performs many functions. The liver
  - converts glucose in blood to glycogen,
  - stores glycogen and releases sugars back into the blood as needed,
  - synthesizes many proteins including blood-clotting proteins and lipoproteins that transport fats and cholesterol to body cells,
  - modifies substances absorbed in the digestive tract into less toxic forms, and
  - produces bile.

21.12 The large intestine reclaims water and compacts the feces

- The large intestine, or colon,
  - is about 1.5 m long and 5 cm in diameter,
  - has a pouch called the cecum near its junction with the small intestine, which bears a small fingerlike extension, the appendix,
  - contains large populations of E. coli, which produce important vitamins,
  - absorbs these vitamins and water into the bloodstream, and
  - helps form firm feces, which are stored in the rectum until elimination.
21.12 The large intestine reclaims water and compacts the feces

- Diarrhea occurs when too little water is reclaimed from the contents of the large intestine.
- Constipation occurs when too much water is reclaimed.

21.13 EVOLUTION CONNECTION: Evolutionary adaptations of vertebrate digestive systems relate to diet

- The length of the digestive tract often correlates with diet. In general, the alimentary canals relative to their body size are
  - longer in herbivores and omnivores and
  - shorter in carnivores.
Many herbivores have specializations of the gut that promote the growth of cellulose-digesting bacteria and protists because these animals lack the enzymes needed to digest cellulose in plants.

These mutualistic organisms may be housed in
- the cecum, in a coyote or koala,
- the large intestine and the cecum in rabbits and some rodents, or
- the stomach of ruminants such as cattle, sheep, and deer.