CHAPTER 21

Nutrition and Digestion

Objectives

Introduction Describe the nature of humpback whale feeding.

Obtaining and Processing Food

21.1 Define and distinguish between carnivores, herbivores, omnivores, suspension feeders, fluid feeders, and bulk feeders.
21.2 Describe the four stages of food processing.
21.3 Compare the structure and function of a gastrovascular cavity and an alimentary canal. Describe the specialized digestive systems of an earthworm, grasshopper, and bird.

Human Digestive System

21.4 Describe the main components of the human alimentary canal and the associated digestive glands.
21.5 Describe the functions of the molecules in saliva and the roles of the tongue and teeth in digestion.
21.6 Explain how swallowing occurs and how food is directed away from the trachea.
21.7 Explain how the structure of the esophagus functions to propel food.
21.8 Relate the structure of the stomach to its functions. Describe the functions of the secretions of the stomach. Finally, explain the causes of heartburn and why the stomach does not digest itself.
21.9 Describe the most common cause of stomach ulcers and the primary forms of treatment.
21.10 Describe the different types of chemical digestion that occur in the small intestine. Explain how the structure of the small intestine promotes nutrient absorption.
21.11 Describe the structure and functions of the large intestine and rectum. Note the causes of constipation and diarrhea.

Diets and Digestive Adaptations

21.12 Compare the digestive tracts of carnivores and herbivores. Describe the cellulose-digesting specializations of the digestive tracts of a koala and a cow.

Nutrition

21.13 Describe the three common nutritional needs of all animals.
21.14 Define "basal metabolic rate," explain how it is measured, and note how energy is obtained and stored in the body.
21.15 Explain why exercise and a balanced diet of 1200 kcal or more is the best way to lose weight.
21.16 Define essential amino acids and explain the complexities associated with a vegetarian diet.
21.17 Define a vitamin and distinguish between water-soluble and fat-soluble vitamins.
21.18 Define dietary minerals and explain why they are important in the diet.
21.19 Describe the types of information found on food labels.
21.20 Explain how diet can influence the risks of cardiovascular disease and cancer.

Key Terms

omnivore
herbivore
carnivore
suspension feeder
substrate feeder
fluid feeder
bulk feeder
ingestion
digestion
absorption
elimination
gastrovascular cavity
mouth
alimentary canal
pharynx
esophagus
crop
stomach
gizzard
intestine
anus
peristalsis
pyloric sphincter
trachea
gastric gland
gastrin
acid chyme
gastric ulcer
small intestine
pancreas
liver
bile
gallbladder
duodenum
villus
microvillus
large intestine
colon
cecum
appendix
feces
rectum
ruminant mammal
kilocalorie (kcal)
basal metabolic rate (BMR)
essential fatty acid
Recommended Dietary Allowances (RDA)
essential amino acid
vitamin
mineral
low-density lipoprotein (LDL)
high-density lipoprotein (HDL)

Lecture Outline

Introduction *Getting Their Fill of Krill*

A. *Review:* Feeding (ingesting food) is a distinctive characteristic of the animal kingdom.

B. The humpback whale, from an unusual habitat, shows how an animal's structure and behavior are directly tied to feeding and food processing.

1. Humpback whales are suspension feeders that strain small fish and crustaceans from the ocean. A 72-ton whale processes as much as 2 tons of food a day.
2. These whales use "bubble nets" to help concentrate their food at the surface. The mouth has a tremendous volume when expanded and uses the comblike baleen to sift the food from the water. The stomach can hold up to half a ton of food at a time.
3. For four months in the summer, these whales feed in the rich, cold oceans of polar regions and store up vast fat reserves. In the winter, they migrate to warm, southern oceans to breed. They eat little for eight months until they return to the polar regions.

I. Obtaining and Processing Food

Module 21.1 Animals ingest their food in a variety of ways.

A. Feeding can be by absorption (as in a few parasitic worms) or by ingestion.

B. Ingestive feeding can be categorized by type of food. **Omnivores** (such as humans and crows) eat both plants and animals. **Herbivores** (such as deer or sea urchins) eat plants or algae. **Carnivores** (such as lions and spiders) eat only other animals (Figure 21.1A).

C. Ingestive feeding can be categorized by the size and location of the food.
   1. **Suspension feeders** ingest small animals such as microscopic protists, plants, and animals (clams and other bivalves, Figure 21.1B).
   2. **Substrate feeders** ingest by burrowing into their food (earthworms and caterpillars, Figure 21.1C).
   3. **Fluid feeders** obtain nutrients from plant sap (aphids) or animal fluids (mosquitoes, Figure 21.1D).
   4. **Bulk feeders** are those that consume larger prey whole or in pieces (most animals, Figure 21.1E).

Module 21.2 Overview: Food processing occurs in four stages.

A. Food processing can be divided into four stages (Figure 21.2):
   1. **Ingestion** is the act of eating.
   2. **Digestion** is the breakdown of food into small enough molecules to absorb. Digestion occurs in two steps: mechanical and chemical breakdown. The products of digestion are then used for either cellular respiration or biosynthesis (Modules 6.16 and 6.17).
   3. **Absorption** is the taking up of these small nutrient molecules.
      NOTE: Food does not actually enter the body until it is absorbed. Prior to absorption, food is in a tube (in the case of animals with an alimentary canal) that runs through the body.
   4. **Elimination** is the release of undigested material.

B. Food consists of large polymeric fats, carbohydrates, proteins, and nucleic acids that animals cannot absorb directly. All animals need the same monomeric components: fatty acids, simple sugars, amino acids, and nucleotides.

C. During digestion, larger polymers are chemically digested into smaller components by hydrolysis (Module 3.3; Figure 3.3A, B). Specific enzymes catalyze each step of digestion.

Module 21.3 Digestion occurs in specialized compartments.

A. These compartments provide environments that favor the action of the specific digestive enzymes and ensure that the enzymes will not attack an animal's own macromolecules.

B. Even a single-celled organism, such as an amoeba, has specialized compartments for digestion. Sponges, like these single-celled organisms, carry out all of their digestive functions within their cells (Module 18.3).

C. Simple animals, such as cnidarians and flatworms, have a single digestive compartment, a **gastrovascular cavity** in which digestion and absorption occur, with a single opening for ingestion and elimination (Figure 21.3A).

D. Other animals have a series of compartments (organs) arranged along a tube **(alimentary canal)** that extends between the **mouth** and **anus** (Figure 21.3B).

E. Ingested food passes to the first cavity via a muscular **pharynx** and **esophagus.**

F. The first cavity may be a **crop** (a pouchlike organ for temporary storage and food softening), a **gizzard** (a muscular pouch that contains teeth or grit), or a **stomach** (a muscular pouch without grinding structures).

G. Chemical digestion and nutrient absorption occur mainly in the **intestine.** Intestines typically have modifications that increase their inner surface area and thus increase the absorptive surface.

H. Undigested materials are expelled through the anus.

I. The exact nature of an animal's alimentary canal reflects its diet. An earthworm is an omnivorous substrate feeder with an intestine that has an inner, dorsal fold to increase its absorptive area. A grasshopper is an herbivore with a number of adaptations for the efficient processing of plant material. Different birds eat different foods, but most store food in a crop and use a gravel-containing gizzard to grind food swallowed whole.

II. Human Digestive System

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

A. The main parts of the alimentary canal are the mouth, oral cavity, tongue, pharynx, esophagus, stomach, small intestine, large intestine, rectum, and anus (Figure 21.4).

B. Digestive glands—the salivary glands, pancreas, and liver—secrete digestive enzymes into the cavities with which they are associated.
NOTE: These glands secrete into a duct; this makes them exocrine glands. In contrast, endocrine glands secrete into the blood (Module 20.9).

C. Food is propelled through the alimentary canal by wavelike contractions **(peristalsis)** of smooth muscle.

D. Sphincter muscles control the passage of food from one cavity to the next. The **pyloric sphincter** regulates movement of food from the stomach to the small intestine.

E. The total digestive process takes about 5–6 hours.
NOTE: Lipids take longer and require less energy to digest than carbohydrates and proteins.

Module 21.5 Digestion begins in the oral cavity.

A. Salivary juices contain lubricants, buffers, antibacterial agents, and a digestive enzyme (salivary amylase) that hydrolyzes starch. The release of salivary juices is triggered by meal time and the sight or smell of food.
NOTE: Oral stimulation and the thought of food also trigger the secretion of saliva. Other functions of saliva include helping keep teeth clean, dissolving food so that it can be tasted, and aiding in the formation of the bolus.

B. Mechanical and chemical digestion begins in the oral cavity as food is chewed (Figure 21.5).

C. Humans have four kinds of teeth (arranged in four sets, right and left in the upper and lower jaw): two bladelike incisors for biting, one pointed canine for tearing, two premolars, and three molars for grinding and crushing food.
NOTE: Only animals with a palate and cheeks chew their food; the palate prevents food from entering the nasal cavity while chewing, and the cheeks prevent food from falling out of the mouth. Compare how a crocodile gulps its food with how a human chews its food. Vertebrates vary greatly in their complement of teeth. A pattern of dentition is related to an animal's diet. For example, horses have incisors to shear off, and molars to grind, the grass they eat, but they have no canines. Rodents have strong, continually growing incisors for gnawing on cellulose-rich plant materials. Lions and other carnivores have prominent canines with which they tear large hunks of flesh from their prey.

D. The tongue tastes the food, manipulates the food, and shapes the food into a bolus, which it then pushes to the back of the oral cavity and into the pharynx (where it is swallowed).
NOTE: The tongue also secretes lingual lipase, an enzyme that acts in the stomach and plays a minor role in lipid digestion.

Module 21.6 The food and breathing passages both open into the pharynx.

A. Most of the time, when not eating, the human pharynx opens into the windpipe **(trachea)** for breathing and speaking (as air vibrates vocal cords in the voice box, or larynx).

B. When a bolus of food passes into the pharynx, the swallowing reflex is triggered. The esophageal sphincter muscle relaxes, the tracheal opening closes off by the epiglottis, and the food passes into the esophagus (Figure 21.6).

Module 21.7 The esophagus squeezes food along to the stomach.

A. Esophageal muscles are arranged in two layers of smooth muscle, one circular and the other longitudinal.

B. Peristalsis moves the bolus down the esophagus toward the stomach (Figure 21.7).
NOTE: The esophagus itself has no digestive function. However, salivary amylase continues to act on the food during its passage through the esophagus. Carbohydrate digestion stops upon entering the stomach, which is very acidic. Digestion then continues in the small intestine.

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

A. The stomach can store up to 2 liters of food. It empties its contents slowly (after 2–6 hours) by opening the pyloric sphincter.

B. The inner surface of the stomach is highly folded and has pits that terminate in **gastric glands** (Figure 21.8).

C. Chemical digestion continues in the stomach and is aided by contractions of smooth muscle in the stomach wall. The digestion of proteins into smaller polypeptides occurs by the action of the enzyme pepsin.

D. Gastric juice also includes mucus, which protects the stomach lining and also lubricates, and hydrochloric acid, which converts pepsinogen to pepsin and provides the proper pH for the action of pepsin.
NOTE: The HCl secreted by the stomach has a pH of ≈1. HCl is also important in denaturing proteins that allow greater exposure of peptide bonds to pepsin, deactivating hormones present in food, and killing bacteria. Further, HCl is important for the absorption of nutrients such as vitamin B_{12} and iron.

E. Gastric activity is initiated by a nervous signal from the brain (after seeing, tasting, or smelling the food) and is continued by the secretion of **gastrin,** a gastric gland hormone, when food is actually present in the stomach.

F. The release of gastric juice by the gastric glands, under the control of gastrin, is a negative-feedback mechanism.

G. Occasional backflow of the stomach contents **(acid chyme)** into the esophagus causes heartburn (what the commercials like to call acid reflux). During vomiting, the stomach contents are eliminated by reverse peristalsis back up the esophagus and out of the oral cavity.
NOTE: Chronic exposure of the esophagus to the acid contents of the stomach can cause several problems. The acid can back up the esophagus and cause hoarseness, or get to the lungs and affect respiration. The buildup of scar tissue at the base of the esophagus can decrease the diameter of this region of the esophagus (peptic stricture). Ironically, the discomfort of chronic heartburn is relieved with the development of Barrett's esophagus (the growth of abnormal tissue in the esophagus), which increases the risk of esophageal cancer.

H. The pyloric sphincter regulates the passage of chyme from the stomach to the small intestine, allowing the passage of only a small amount at a time.

Module 21.9 Connection: Bacterial infections can cause ulcers.

A. A **gastric ulcer** is an open sore on the stomach lining. The major symptom is pain in the upper abdomen associated with eating.

B. At one time ulcers were thought to be due to the overproduction of pepsin and/or acid. However, evidence now indicates that a major cause of ulcers is the bacterium *Helicobacter pylori.*
NOTE: This applies to the small intestine as well as to the stomach. In addition to *H. pylori,* the other major cause of ulcers is the (over) use of nonsteroidal anti-inflammatory drugs (NSAID) such as aspirin and ibuprofen. NSAID reduce inflammation by inhibiting prostaglandin synthesis. Prostaglandins play a major role in cytoprotection (protecting the cells lining the stomach from damage by HCl).

C. The body's response to a *H. pylori* infection results in stomach inflammation (gastritis). Gastritis may progress to an ulcer.

D. *H. pylori* infection is also associated with an increased cancer risk.

E. Gastric ulcers usually respond to an antibiotic regime in combination with drugs such as bismuth (the active ingredient in Pepto Bismol).
NOTE: Not only is this treatment regime more effective than the older regime; it is also less expensive.

F. Duodenal ulcers occur in the first portion of the small intestine.

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

A. All remaining chemical digestion and most absorption of nutrients occur in the **small intestine.** This organ is about 6 meters long and 2.5 cm in diameter. Peristalsis moves the mixture.
NOTE: The chyme that enters the small intestine from the stomach has a pH of ≈2–3.

B. Digestion continues in the first 25 cm (the duodenum).

C. Glandular secretions are released into the **duodenum** from the liver, the **gallbladder** (the **liver** produces **bile** that contains salts to make fats more soluble; bile is stored in the gallbladder until it is needed in the small intestine), the duodenum wall, and the **pancreas** (which produces enzymes and bicarbonate ions to neutralize the acid chyme and raise its pH) (Figure 21.10A).
Preview: The role of the liver in homeostasis is discussed in more detail in Module 25.13.
NOTE: Folic acid (a B vitamin that is of great importance during pregnancy; Table 21.17) is secreted along with bile and is reabsorbed in the small intestine. Anything that inhibits this reabsorption can result in a folate deficiency.

D. Each type of macromolecule (carbohydrates, proteins, fats, and nucleic acids) is digested sequentially by specific enzymes. The digestion of carbohydrates and proteins continues on fragments produced by previous chemical breakdown. The digestion of fats and nucleic acids starts here (Table 21.10).

E. The surface area of the lower part of the small intestine is huge, with several levels of folding. The wall is folded into circular pleats. These pleats contain projections **(villi)** of cells, and the cells have further projections **(microvilli).** The total surface area is about 300 m^2 (Figure 21.10B).

F. The core of each villus contains capillaries and lymph ducts. Nutrients diffuse from intestine chamber to blood, or they are moved across microvillous membranes by an ATP-requiring transport mechanism.
NOTE: Water-soluble nutrients pass into the capillaries, lipid-soluble nutrients into the lacteals.

G. Nutrient-laden blood from the small intestine passes to the liver, which gets the first chance to process or store the nutrients, particularly storing excess glucose as animal starch (glycogen).

Module 21.11 The large intestine reclaims water.

A. The **large intestine (colon)** is about 1.5 m long and 5 cm in diameter (Figure 21.11).

B. About 7 liters of digestive contents pass into the large intestine each day. About 90% of the water is absorbed back into the blood.

C. Prokaryotes that normally live in the colon, including *E. coli,* live in the undigested material. They produce and release important vitamins (biotin, folic acid, B vitamins, and vitamin K) that humans cannot make themselves.
NOTE: The amount of a vitamin synthesized by the intestinal fauna that is available for absorption is not the same for each vitamin. For example, intestinal bacteria can meet ≈50% of an adult's need for vitamin K, whereas it is not yet known how much of the biotin synthesized by intestinal prokaryotes is absorbed.

D. The remaining, undigested material (fiber) is compacted by peristalsis and stored in the **rectum** until it is defecated as **feces.**

E. The **appendix** is a gland at the top of the large intestine (above the **cecum**) that has a minor immune system function. Appendicitis occurs if the appendix becomes infected following irritation, or when its opening is jammed by undigested food.
NOTE: A lack of fiber in the diet can also cause outpouchings (diverticula) in the wall of the colon. If the diverticula become inflamed the result is diverticulitis.

III. Diets and Digestive Adaptations

Module 21.12 Adaptations of vertebrate digestive systems reflect diet.

A. Herbivores and omnivores have longer alimentary canals than carnivores, to allow more time and surface area for digesting plant material (Figure 21.12A).

B. Dietary needs change from the larval stage to the adult stage in amphibians. The alimentary canal of the larva is proportionally longer relative to body size than that of the adult.

C. Most herbivores rely on the cellulose-digesting enzymes of prokaryotes and protists. Populations of these organisms are housed in parts of the animals' alimentary canals.

D. Rabbits, and some rodents, produce soft fecal pellets first, which include microorganisms that have digested the cellulose in the cecum (a pouchlike region where small and large intestine meet). They reingest these pellets and absorb the digested cellulose (glucose molecules) through their small intestines, and then defecate hard fecal pellets.

E. **Ruminant mammals,** such as cattle, sheep, and deer, have an elaborate, four-chambered stomach, part of which houses the microorganisms. Ingested grass enters the rumen and reticulum, where prokaryotes and protists begin to digest the cellulose. Periodically, a cow regurgitates some of this material and helps mechanically digest it by "chewing the cud." It is then swallowed into the omasum, where water is absorbed, passing to the abomasum, where the cow's own enzymes complete the digestion process (Figure 21.12B).

IV. Nutrition

Module 21.13 Overview: A healthful diet satisfies three needs.

A. Fuel to power all body activities

B. Raw materials needed to make an animal's own molecules

C. Essential nutrients (substances the animal cannot make itself)

Module 21.14 Chemical energy powers the body.

Review: Cellular respiration in Chapter 6.
NOTE: Ongoing studies of nonhuman animals are showing that undernutrition, without malnutrition, has health benefits and can increase maximum lifespans.

A. The energy content of food (carbohydrates, fats, and, when these are in short supply, proteins) is measured in **kilocalories (kcal),** the accurate form of the popular word "calories."
NOTE: A kilocalorie is the amount of energy required to raise one kilogram of water one degree Celsius.

B. The **basal metabolic rate (BMR)** is the amount of energy required to maintain cellular metabolism in a resting animal. The average BMR for adult humans is 1300–1800 kcal per day.

C. Various levels of activity add to a human's caloric requirements, and various foods supply these requirements (Table 21.14).

D. Metabolic rates are determined by measuring the rate of oxygen consumption. Each liter of O_2 consumed liberates 4.83 kcal from food (Figure 21.14).

E. Liver and muscle store energy in the form of glycogen, a complex carbohydrate.

F. Excess energy is also stored as fat. The liver can make fat from carbohydrates and proteins even if there is little fat in the diet.

Module 21.15 Connection: Body fat and fad diets.

A. *Review:* Lipids (Modules 3.8–3.10).

B. Fat is an essential component of the human body. It insulates the body against cold, and a moderate amount is correlated with a healthy immune system. Below-normal amounts of fat interfere with vitamin A formation and may make people susceptible to some cancers.

C. Those fatty acids that our body cannot make for itself and that are required in the diet are called essential fatty acids.
NOTE: The **essential fatty acids** are polyunsaturated fatty acids (PUFAs). Overconsumption of PUFAs increases the risk of cancer. Monounsaturated fatty acids (such as are found in olive oil and canola oil) can, in moderation, have cardiovascular benefits. Saturated fatty acids and trans fatty acids (formed when fatty acids are hydrogenated) increase the risk of developing cardiovascular disease and other illnesses.

D. Ideally, fat should be 20–25% and 15–19% of the body weights of women and men, respectively. "Overfat" levels should be regarded as those about 20% higher than ideal levels.

E. Too much body fat increases the chance of developing certain diseases, such as heart disease, and decreases life span.

F. When the consumption of carbohydrates (or proteins) increases, the rate at which it is metabolized increases. The body tends to readily convert dietary fat into body fat. Thus,

dietary fat has a more direct affect on weight (fat) gain than the consumption of carbohydrates (or proteins).
NOTE: Even the energy cost of processing fats is less than the energy costs of processing carbohydrates or proteins. This is not to say that fat stores cannot increase on a high-carbohydrate (or high-protein) diet. Calories consumed do matter, but the source of the calories is also important.

G. However, even with this tendency to store body fat, many people, even obese ones, tend to maintain a relatively stable body weight.

H. Fad diets not only are usually ineffective but also may be harmful (Table 21.15). A popular diet, the high-protein low-carbohydrate diet, may in fact increase the risk of heart disease.

I. Following the guidelines for the **Recommended Dietary Allowances (RDAs)** for nutrients, and getting regular aerobic exercise, can keep body fat at normal levels.
NOTE: Maintaining body fat at an appropriate level gets more difficult with age. With age, metabolic rate declines and unless there is some measure of compensation by adjusting the amount of food consumed and increasing the level of exercise, body fat will tend to accumulate.

Module 21.16 Connection: Vegetarians must be sure to obtain all eight essential amino acids.

A. The human body can make a great variety of organic molecules (including 11 amino acids) from basic sources of organic carbon and nitrogen provided in digested food.

B. Some substances (essential nutrients) cannot be made and must be obtained directly from food.

C. Meat and egg products provide all eight **essential amino acids.**

D. A combination of plant proteins can also provide all nine essential amino acids (Figure 21.16).

Module 21.17 Connection: A healthful diet includes 13 vitamins.

A. A **vitamin** is an organic nutrient that is essential but required in much smaller quantities than the essential amino acids.

B. Most vitamins serve as coenzymes or parts thereof, that are reused in metabolic reactions or in a variety of roles in maintaining cellular health.
Review: Enzyme function is discussed in Modules 5.5–5.9.

C. Vitamins are grouped into those that are water-soluble and those that are fat-soluble (Table 21.17). Unlike water-soluble vitamins, excess fat-soluble vitamins are not easily eliminated from the body and build up in body fat, where they may have toxic effects.

D. RDAs have been established for all vitamins, but many nutritionists recommend higher levels of certain vitamins.
NOTE: Folic acid is one such vitamin.

E. Extreme deficiencies of each vitamin cause specific sets of symptoms.

Module 21.18 Connection: Essential minerals are required for many body functions.

A. **Minerals** are chemical nutrients other than carbon, hydrogen, oxygen, and nitrogen.

B. All minerals are essential. Depending on their roles in structure and function, essential minerals are required in various amounts (Table 21.18).

C. Too much of some minerals can cause abnormal function; for example, too much sodium in salt promotes high blood pressure in humans.

NOTE: Recent studies are showing that only a subset of the population is sodium sensitive and that those individuals who are not sodium sensitive have less need to be concerned about their sodium intake (but shouldn't overdo it).

Module 21.19 Connection: What do food labels tell us?

A. Food labels provide two pieces of information for the consumer (Figure 21.19):
   1. A list of ingredients arranged according to weight, from the greatest amount to the least amount.
   2. The number of kilocalories, carbohydrates (total and dietary fiber and sugars), proteins, fats (total and saturated fats and cholesterol), and selected vitamins and minerals supplied in one serving appear on the label and are expressed as percentages of a daily value.

B. Some labels will also list the amount of PUFA and monounsaturated fat. If these are listed and their amounts are added to the amount of saturated fat, the sum may not be equal to the total amount of fat listed; the difference will be the amount of trans fat in a serving of that food item.

Module 21.20 Connection: Diet can influence cardiovascular disease and cancer.

A. Linked to cardiovascular disease are diets low in fruits and vegetables and rich in saturated fats, which in turn correlates with high levels of blood cholesterol. Cardiovascular disease is linked to high levels of **low-density lipoproteins (LDLs),** while increased concentrations of **high-density lipoproteins (HDLs)** are correlated with lower risk of cardiovascular disease. Exercise tends to increase—and smoking to decrease—HDL levels (Figure 21.20).
   NOTE: Inherited (familial) hypercholesterolemia is discussed in Modules 5.20 and 9.9. However, as discussed here, lifestyle (lack of exercise, a high-fat diet) will also result in hypercholesterolemia.

B. Linked to some forms of cancer are high levels of dietary fat and low levels of dietary fiber (Table 21.20).
   Review: See Modules 11.15–11.19 for a discussion of the cellular basis of cancer and lifestyle and cancer risk.
   NOTE: The benefits of fiber include slowing glucose absorption and lowering blood cholesterol levels. In addition, foods high in fiber tend to be lower in fats. Until the body adapts to a high-fiber diet, the result can be diarrhea or constipation, gas, and abdominal discomfort. A diet can also be too high in fiber; the result can be insufficient consumption of energy or nutrients, inhibition of nutrient absorption, and formation of phytobezoars (fiber balls that can obstruct the GI tract).

Class Activities

1. Have your students create a model of the human digestive system illustrating the major functions of each component of the system.
2. Have your students choose two different vertebrate species and explore how differences in their diet are reflected in differences in the structure of their digestive systems.
3. There is a great deal of misinformation/misrepresentation concerning nutrition in the popular press. Have students bring in articles to critique.
4. Have students analyze and critique the diets they consume (there are many good diet analysis programs available) and discuss ways to improve their diet.

Transparency Acetates

Figure 21.2	The four main stages of food processing
Figure 21.3A	Digestion in the gastrovascular cavity of a hydra
Figure 21.3B	Alimentary canals of an earthworm, a grasshopper, and a bird
Figure 21.4	The human digestive tract
Figure 21.5	The human oral cavity
Figure 21.6	The swallowing reflex (Layer 1)
Figure 21.6	The swallowing reflex (Layer 2)
Figure 21.6	The swallowing reflex (Layer 3)
Figure 21.7	Muscle layers of the esophagus and their roles in peristalsis
Figure 21.8	The cells of the gastric glands in the stomach
Figure 21.10A	The small intestine and related digestive organs
Figure 21.10B	Structure of the small intestine
Table 21.10	Enzymatic digestion in the small intestine
Figure 21.11	The relationship of the small and large intestine
Figure 21.12A	The alimentary canal in a carnivore (coyote) and an herbivore (koala)
Figure 21.12B	The digestive system of a ruminant mammal
Table 21.14	Food-exercise energy equivalents
Table 21.15	Diet types and their health effects and potential problems
Figure 21.16	Essential amino acids
Table 21.17	Vitamins (Layer 1)
Table 21.17	Vitamins (Layer 2)
Table 21.18	Minerals
Figure 21.19	Wheat bread label
Figure 21.20	Risk factors associated with cardiovascular disease
Table 21.20	Dietary guidelines for reducing cancer risk

Media

See the beginning of this book for a complete description of all media available for instructors and students. Animations and videos are available in the Campbell Image Presentation Library. Media Activities and Thinking as a Scientist investigations are available on the student CD-ROM and web site.

Animations and Videos	File Name
Whale Eating a Seal Video	21-01E-WhaleEatSealVideo-B.mov
Whale Eating a Seal Video	21-01E-WhaleEatSealVideo-S.mov

Activities and Thinking as a Scientist	Module Number
Web/CD Activity 21A: *Digestive System Function*	21.10
Web/CD Thinking as a Scientist: *What Role Does Amylase Play in Digestion?*	21.10