CHAPTER 51: FUELING BODY ACTIVITIES: DIGESTION

CHAPTER SYNOPSIS

Animals obtain metabolic energy by eating other organisms. They are not collections of simple molecules, but are composed of macromolecules including proteins, fats, and starches. The degradation of these organic molecules is the process of digestion. Very simple organisms, protists and sponges, exhibit intracellular digest ion. All other organisms have extracellular digestion where digestive enzymes are released into an internal body cavity. The most primitive invertebrates have a gastrovascular cavity with one opening that serves as mouth and anus. Higher invertebrates and vertebrates possess a one-way digestive tract with separate mouth and anus. Food is often fragmented before it is digested, some animals store ingested food in specialized organs prior to digestion.

Digestion begins in the mouth where teeth aid in the acquisition of food. They are variously shaped for capture, cutting, and grinding. Saliva from three pairs of glands moistens the food and initiates digestion of starches. The process of swallowing begins when food passes into the back of the mouth. It is propelled through the esophagus by peristaltic waves and enters the stomach. A muscular sphincter generally prevents food from reentering the esophagus once it is in the stomach. The inner surface of the stomach is convoluted to accommodate the sporadic ingestion of food, especially by carnivores. The walls of the stomach produce a protective mucus in addition to hydrochloric acid and pepsinogen. The production of acid is carefully regulated by gastric hormones to ensure that it can be neutralized sufficiently. Parietal cells produce HCl that provide an acidic-environment to keep pepsin active, help denature proteins, and kill ingested bacteria. Passage of chyme into the small intestine is controlled by the pyloric sphincter in response to changes in pH at the beginning of the small intestine.

Most digestion occurs within the first part of the small intestine, the duodenum, as a result of the action of intestinal and pancreatic enzymes. The intestine also produces bicarbonate to neutralize the acid from the stomach. The liver produces bile salts to solubilize fats prior to their digestion. Bile is stored in the gallbladder until it is needed. The remaining divisions of the small intestine, the jejunum, and the ileum, are specialized for absorption. The surface area is increased by finger-like projections called villi. The epithelium of each villus is covered with cytoplasmic extensions, the microvilli. Amino acids and sugars cross the intestinal cell membranes into blood capillaries at the brush border. Lipids are broken down into fatty acids and collected in the lymphatic system. Nutrients absorbed from the small intestine are directed to the liver, which acts as a metabolic reservoir. It absorbs glucose when there is too much in the blood and releases it when there is too little. Glucose is not stored as is, but is converted to glycogen. Ruminants house cellulose-digesting bacteria in the rumen and essentially digest their food twice. Horses have symbiotic bacteria in the caecum, but digestion of cellulose is less efficient because they only digest their food once.

The daily volume of food and water that passes through the gut equals nearly 9 liters, almost all is absorbed in the small intestine. A small amount of liquid is reabsorbed in the large intestine, leaving 50 grams of solids and 100 milliliters of liquid to be excreted. The inner surface of the large intestine lacks villi as its main function is to compact the wastes. Some sodium, vitamin K, and other products of bacterial metabolism are also absorbed here. Exit of wastes from the rectum is regulated by two sphincters; the first is involuntary, the second is voluntarily controlled. The digestive system is under a combination of nervous and hormonal control. Sight and smell of food stimulates salivary and gastric secretions. Food in the stomach stimulates secretion of gastrin, causing production of pepsinogen and HCl Passage of chyme from the stomach to the intestine inhibits stomach contractions. Cholecystokinin is secreted in response to fat in chyme and secretin is released in response to the acidity of chyme. Vertebrates obtain several vitamins from the food they eat as they are unable to synthesize them. Humans require 13 vitamins, 8 essential amino acids, essential minerals, and various other trace elements.

CHAPTER OBJECTIVES

- Compare the digestive strategies of single cells, primitive invertebrates, and higher animals.
- Compare the general structure of teeth of herbivores, carnivores, and omnivores.
- Describe the digestive activities that occur in the mouth and indicate how food passes from the mouth to the stomach.
- Describe the digestive activities of and secretions produced by the stomach.
- Describe the digestive and absorptive activities of the small intestine, including its secretions.
- Explain the importance of convolutions in the digestive tract; identify the regions that are highly convoluted and the regions that are not convoluted.
- Explain the digestive activities associated with the large intestine.
- Understand the symbiotic relationships that enhance digestive activities in the vertebrates.
- Know the two kinds of exocrine cells present in the pancreas and the function(s) of each of their secretions.
- Describe the metabolic and digestive activities of the liver.
- Understand the neural and hormonal regulation of digestion.
- Explain the importance of regulating food intake.
- Understand the importance of essential nutrients including vitamins and amino acids.

KEY TERMS

cœcum
carnivore
coprophagy
duodenum
essential mineral
essential nutrient
gluconeogenesis
herbivore
ileum
islets of Langerhans
jejunum
obesity
omnivore

CHAPTER OUTLINE

51.0 Introduction

I. NO VERTEBRATE CELLS ARE SPECIALIZED FOR PHOTOSYNTHESIS

A. Plants Are Self-Sustaining Autotrophs

B. Animals Are Heterotrophs fig 51.1
1. Cells must be nourished by food obtained from outside the body
2. Many major organ systems are associated with acquisition of food energy

51.1 Animals employ a digestive system to prepare food for assimilation by cells

I. TYPES OF DIGESTIVE SYSTEMS

A. Three Types of Digestive Systems Based on Food Sources
1. Herbivores
   a. Exclusively eat plants
   b. Examples: Cows, horses, rabbits, sparrows

2. Carnivores
   a. Eat primarily meat
   b. Examples: Cats, eagles, trout, frogs
3. Omnivores
   a. Eat both plants and other animals
   b. Examples: Humans, pigs, bears, crows

B. Digestive Strategies
1. Intracellular digestion exhibited by single-celled organisms and sponges
2. Other animals digest food extracellularly, enzymes released into digestive cavity
3. Cavity has one opening in coelenterates and flatworms fig 51.2
   a. Called gastrovascular cavity
   b. Mouth and anus in same opening
   c. No specialization, cells exposed to all stages of digestion
4. Other animals possess true one-way digestive tract fig 51.3
   a. Digestive tract has separate mouth and anus
   b. Specialization can occur since transport is one-way
   c. Nematodes possess most primitive system
      1) Tubular gut
      2) Lined by epithelial membrane
   d. Earthworms show specialization
      1) Separate regions for ingestion, storage, fragmentation, digestion, absorption
      2) Similar specialization in all higher animals
5. Characteristics of a generalized digestive system
   a. Ingested food may be stored in specialized region
   b. Food may undergo fragmentation first
      1) Grinding action of teeth as in many vertebrates
      2) Grinding action of pebbles, as in gizzard of earthworms and birds
   c. Chemical digestion breaks larger food molecules into smaller subunits
      1) Involves hydrolysis reactions
      2) Small units absorbed through gut epithelial lining into blood
      3) Molecules not absorbed are waste products
      4) Excreted or defecated through anus

II. VERTEBRATE DIGESTIVE SYSTEMS

A. General Organization of the Vertebrate Digestive System
1. Consists of a tubular gastrointestinal tract and accessory digestive organs fig 51.4
   a. Initial components are mouth and pharynx
      1) Common passage of oral and nasal cavities
      2) Pharynx leads to esophagus
   b. Esophagus is a muscular tube leading to stomach
   c. Preliminary digestion occurs in stomach
   d. Food passes into duodenum, upper part of small intestine
      1) Battery of digestive enzymes continue digestion
      2) Products pass across small intestine wall into bloodstream
   e. Products of small intestine empty into large intestine
      1) Water and minerals reabsorbed
      2) Waste products emerge from body
   f. Most vertebrates, not mammals, have a cloaca fig 51.3
      1) Also receives products of urinary and reproductive tracts
      2) Urogenital products and fecal materials separated in mammals
2. Carnivores have shorter intestines than herbivores
   a. Plant cellulose resists digestion, intestine may be convoluted

b. Ruminants have stomachs with multiple chambers
   1) Include cows
   2) Bacteria aid in digesting cellulose
c. Other herbivores have a simpler system
   1) Include rabbits and horses
   2) Blind pouch, caecum, located at beginning of large intestine
   3) Also contains digestive bacteria

3. Accessory digestive organs produce a variety of secretions
   a. Liver produces bile
   b. Gallbladder stores and concentrates bile
   c. Pancreas produces pancreatic juices that contain digestive enzymes and bicarbonate
   d. Secretions enter first region of small intestine, aid digestion

B. Tubular gastrointestinal tract has a layered structure fig 51.5
1. Mucosa is innermost layer
   a. Epithelial layer
   b. Lines interior (lumen)
2. Submucosa is next layer made of connective tissue
3. Next outermost layer is the muscularis
   a. Double layer of smooth muscle
   b. Inner muscles have circular orientation
   c. Outer layer are arranged longitudinally
4. Serosa connective tissue layer covers external surface
5. Nerve plexuses in submucosa regulate activities of gastrointestinal tract

51.2 Food is ingested, swallowed, and transported to the stomach

I. THE MOUTH AND TEETH

A. Specializations of Digestive Systems Indicate Different Ways of Living
1. Fish have large pharynx with gill slits
2. Air-breathing vertebrates have reduced pharynx
3. Many vertebrates have teeth and chew food particles fig 51.6
4. Birds lack teeth, break up food in two-chambered stomach fig 51.7
   a. Gizzard grinds material with small pebbles
   b. Seeds and hard materials ground up for digestion in second chamber

B. Vertebrate Teeth
1. Carnivores possess pointed teeth for capture, cutting, and shearing
   a. Tear off pieces, do little chewing
   b. Digestive enzymes readily act on animal cells
2. Herbivores have large, flat teeth suited for grinding plant materials
3. Omnivores have both types, front like carnivores, back like herbivores fig 51.8
   a. Incisors: Four front teeth, used for biting
   b. Cuspids (canines): One on each side of incisors, used for tearing food
   c. Premolars: Two on either side behind cuspids, chewing teeth
   d. Molars: Three on either side behind cuspids, chewing teeth
   e. Human children have 20 teeth replaced by 32 adult teeth

C. The Mouth
1. Tongue mixes food with saliva
   a. Saliva secreted by three pairs of salivary glands
   b. Empty through mucosal lining of mouth
   c. Contains salivary amylase to initiate breakdown of starch

2. Secretion of saliva controlled by the nervous system
   a. Continuous secretion to keep the mouth moist
   b. Secretion stimulated by presence of food
3. Food passes beyond the teeth to the back of the mouth
4. Palate elevates, pushes against back wall of pharynx fig 51.9
   a. Seals off nasal cavity
   b. Prevents entry of food into nasal cavity
5. Pressure on pharynx stimulates receptors to signal swallowing center
6. Swallowing center signals respiratory tract
   a. Inhibits respiration
   b. Seals trachea by raising larynx and closing glottis with epiglottis

II. ESOPHAGUS AND STOMACH

A. Structure and Function of the Esophagus

1. Upper portion of esophagus enveloped in voluntary skeletal muscle
2. Lower two-thirds enveloped in involuntary smooth muscle
3. Food propelled to stomach by peristaltic waves fig 51.10
4. Exit of food from esophagus to stomach controlled by a sphincter
   a. Muscular constriction at junction of two organs
   b. Prevents food in stomach from re-entering esophagus
   c. Rodents and horses have true sphincter, cannot regurgitate, humans can

B. Structure and Function of the Stomach fig 51.11

1. Saclike portion of digestive tract
2. Interior of stomach is highly convoluted
   a. Folds up when empty, expands when full of food
   b. Carnivores that gorge sporadically can distend stomachs greatly

C. Secretory Systems

1. Stomach has extra layer of smooth muscle to churn food
2. Exocrine gastric glands of mucosa produce secretions fig 51.11
   a. Parietal cells secrete hydrochloric acid (HCl)
   b. Chief cells secrete pepsinogen, acid-loving ,weak protein-digesting enzyme
3. Activated pepsinogen molecules cleave fragment from each other, make pepsin
   a. Pepsin is more active molecule
   b. Production of inactive molecule, converted to active enzyme outside
   c. Prevents chief cells from self-digestion
4. Partial digestion of proteins, no digestion of carbohydrates or fats

D. Action of Acid

1. Stomach produces 2 liters of acid and gastric secretions per day
   a. Produces pH of 2, compared to blood pH of 7.4
   b. Low pH helps denature proteins, keeps pepsin active
   c. Proteins denatured into polypeptides
   d. Digestion to amino acids occurs in small intestine
2. Chyme: Mix of partly digested food and gastric juice
3. Acid solution also kills bacteria ingested with food
   a. Most vertebrates harbor colonies of bacteria
   b. Bacteria are major component of feces
   c. Necessary for digestion of cellulose in ruminants

E. Ulcers
1. Overproduction of acids may occur
   a. In stomach, cause gastric ulcers
      1) Are rare due to protective alkaline mucus produced by mucosa
      2) Mucosal cells readily replaced when damaged
   b. Duodenal ulcers are more common
      1) Produced when excessive amount of acidic chyme delivered into duodenum
      2) Alkaline secretions of pancreas cannot neutralize chyme
2. Susceptibility to ulcers increased by presence of *Helicobacter pylori*
   a. Bacterial infection weakens mucosal barriers
   b. Treatment with antibiotics reduces symptoms, may cure ulcers
3. Parietal cells also produce intrinsic factor
   a. Polypeptide needed for intestinal absorption of vitamin B_{12}
   b. B_{12} required for formation of red blood cells
   c. Deficiency causes pernicious anemia

F. Leaving the Stomach
1. Chyme leaves stomach through pyloric sphincter to small intestine fig 51.11
2. Terminal digestion occurs in small intestine
   a. Carbohydrates, lipids, proteins broken down
   b. Products absorbed into blood
3. Little absorption occurs in stomach
   a. A little water in chyme
   b. Substances like aspirin and alcohol

51.3 The small and large intestines have very different functions

I. THE SMALL INTESTINE

A. Digestion in the Small Intestine
1. Food passes from stomach to small intestine
2. Capacity of small intestine limited, digestion takes time
   a. Relatively small amounts of chyme can enter at a time
   b. Coordination regulated by neural and hormonal signals
3. Length is approximately 4.5 meters
   a. Duodenum comprises first 25 centimeters, or 4%
   b. Jejunum and ileum comprise rest of small intestine
4. Duodenum receives chyme, pancreatic enzymes, bile from liver and gallbladder
5. Most digestion occurs in duodenum and jejunum
6. Epithelial wall covered with small projections called villi fig 51.12
7. Epithelium of villi covered with microvilli, cytoplasmic projections fig 51.13
   a. Seen clearly with electron microscope
   b. Epithelial wall also called brush border
8. Both increase the absorptive surface of the small intestine
9. Microvilli also participate in digestion
   a. Digestive enzymes embedded in epithelial cell plasma membranes fig 51.14
   b. Brush border enzymes hydrolyze lactose, sucrose, and others tbl 51.1
      1) Adults lose ability to produce lactase that breaks down lactose (milk sugar)
      2) Condition called lactose intolerance

B. Absorption in the Small Intestine
1. Components of protein and carbohydrate digestion transported across brush border
   a. Amino acids and monosaccharides cross to intestinal epithelial cells fig 51.15a
   b. Transported across intestinal epithelium to capillaries in villi
   c. Blood carries digestion products to liver
   d. Travel via hepatic portal vein
2. Products of fat digestion absorbed by different mechanism fig 51.15b
   a. Fats hydrolyzed into fatty acids and monoglycerides
   b. Absorbed by intestinal epithelium
   c. Reassembled into triglycerides
   d. Combine with proteins to form water-soluble chylomicrons
   e. Absorbed into lymphatic capillaries, not hepatic portal system
   f. Contents of lymphatic system enter blood stream in veins near neck
3. Daily volume of food and water passing through small intestine equals 9 liters
4. Nearly all fluids and solids are absorbed
   a. 8.5 liters reabsorbed in the small intestine
   b. 350 milliliters reabsorbed in the large intestine
5. Only 50 grams of solids and 100 milliliters of liquid leave as feces
6. Fluid absorption efficiency = 99%

II. THE LARGE INTESTINE

A. Structure of the Large Intestine
1. Large intestine or colon comprises last meter of digestive tract
   a. Small intestine empties directly into large diameter tube
   b. Presence of vestigial appendix and cecum fig 51.16
2. Has no digestive function, absorbs 4% of fluids
3. Shorter in length than the small intestine
   a. Surface is not convoluted
   b. Inner surface lacks villi
   c. Significantly less surface area over which to absorb
4. Absorb sodium, vitamin K, other products of bacterial metabolism

B. Function of the Large Intestine
1. Primary function is to concentrate waste material
   a. Undigested material compacted and stored
   b. Bacteria live and reproduce and are incorporated into feces
   c. Bacterial fermentation produces gas within the colon
2. Human colon evolved to process food with high fiber content
   a. Low fiber diets result in slower passage of food through colon
   b. May be associated with high level of colon cancer in U. S.
3. The rectum is the terminal portion of the large intestine
   a. Feces pass into rectum by peristaltic contractions
   b. Material exits anus through two sphincters
      1) First sphincter is smooth muscle, opens involuntarily
      2) Second sphincter is striated muscle, under voluntary control
4. Almost all vertebrates possess common cavity, the cloaca
   a. Excludes placental mammals
   b. Location for three systems to empty
      1) Digestive system
      2) Reproductive system
      3) Urinary system
   c. Some birds and reptiles further reabsorb water in cloaca

III. VARIATIONS IN VERTEBRATE DIGESTIVE SYSTEMS

A. Bacterial Digestion of Cellulose within Animals
1. Vertebrates lack enzymes to digest plant material
2. Some bacteria can do so and are harbored by animals
   a. Plays relatively small role in human nutrition
   b. Essential nutrition for termites, cockroaches, and some herbivores
   c. Excellent example of symbiosis
3. Cows and related ruminants possess large, divided stomachs fig 51.17
   a. First stomach has two chambers, rumen and reticulum
   b. Second stomach has two chambers, omasum and abomasum
4. Capacity of rumen is 50 gallons
   a. Provides a fermentation vat for bacteria and protozoa to process cellulose
   b. Allows cows to regurgitate and rechew their food (cud)
5. Re-chewed food swallowed, goes into reticulum, omasum, and abomasum
   a. Abomasum releases gastric juices
   b. Is equivalent to human stomach
   c. Leads to a very efficient digestion of cellulose
6. Horses, rodents, and lagomorphs retain bacteria in the caecum fig 51.18
   a. Cannot regurgitate material from caecum
   b. Rats and rabbits redigest cellulose another way
      1) Eat feces and literally redigest them a second time
      2) Efficiency approaches that of ruminants
      3) Practice called coprophagy
      4) Necessary for health of animals

B. Additional Digestive Activity of Intestinal Bacteria
1. Wax digestion
   a. Occurs through action of bacteria in gut of honey guide birds
   b. Also occurs in marine fish and birds that eat copepods
2. Intestinal bacteria provide mammals with vitamin K
   a. Birds lack bacteria and must consume vitamin K in food
   b. Prolonged antibiotic treatment depletes bacteria
   c. Must supplement vitamin K until bacteria are re-established

51.4 Accessory organs, neural stimulation, and endocrine secretions assist in digestion

I. ACCESSORY ORGANS

A. Secretions of the Pancreas
1. Pancreas located at junction of stomach and small intestine fig 51.19
2. Fluid secreted into duodenum via pancreatic duct
   a. Pancreas is an exocrine organ
   b. Fluid contains
      1) Protein digesting trypsin and chymotrypsin
      2) Starch digesting pancreatic amylase
      3) Fat digesting lipase
   c. Enzymes released primarily as inactive zymogens, activated by brush border
      1) Proteins to polypeptides
      2) Polysaccharides to shorter chain sugars
      3) Fat into free fatty acids and other products
   d. Also contains bicarbonate to neutralize HCl from stomach
      1) Chyme in intestine is slightly alkaline
      2) Bicarbonate produced by acini, clusters of secretory cells

3. Pancreas also serves as an endocrine gland
   a. Produces hormones that regulate levels of blood sugar and other nutrients
   b. Produced in islets of Langerhans clustered throughout pancreas
   c. Most important hormones are insulin and glucagon

B. The Liver and Gallbladder
1. Liver is largest internal organ of body fig 51.4
2. Main secretion of liver is bile
   a. Mixture of bile pigments and bile salts delivered into duodenum
   b. Bile pigments do not participate in digestion
      1) Are waste products from liver's destruction of old red blood cells
      2) Eliminated with feces
      3) Accumulation of pigments result in jaundice
   c. Bile salts are lipid and water soluble
      1) Disperse fat droplets in chyme into emulsion of smaller droplets
      2) Emulsification increases surface area for lipase to work on
      3) Allows fat digestion to proceed more rapidly
3. Bile is stored and concentrated in gall bladder
4. Fatty food in duodenum triggers contraction of gallbladder to release bile
      1) Bile duct may become blocked by gallstone (hardened cholesterol)
      2) Contraction of gallbladder results in pain under right shoulder blade

C. Regulatory Functions of the Liver
1. Hepatic portal vein carries blood from stomach and intestine to liver
2. Liver absorbs or chemically modifies substances before they reach rest of body
   a. Ingested alcohol and drugs metabolized by liver cells
   b. Toxins, pesticides, carcinogens, poisons detoxified
   c. Ammonia from intestinal bacteria converted into urea
3. Controls level of substances produced in body
   a. Steroid hormones converted into less active water-soluble forms
   b. Molecules included in bile, eliminated in feces or through kidneys
4. Produces proteins found in blood plasma
   a. Includes most blood-clotting factors
   b. Maintains blood protein concentration within narrow limits
   c. Imbalance can cause edema

D. Regulation of Blood Glucose Concentration fig 51.20
1. Constant concentration of blood glucose must be maintained
   a. Cannot fall too low as during fasting or prolonged exercise
   b. Cannot stay too high as in diabetes mellitus, causes tissue damage
2. Maintaining level requires active control by various body organs
   a. Liver and skeletal muscles remove glucose from blood, convert it into glycogen
   b. Process stimulated by pancreatic hormone, insulin
   c. Secreted by β cells in islets of Langerhans
3. If blood glucose level is low, liver secretes glucose into blood
   a. Occurs between meals, during fasting or exercise
   b. Glucose partly obtained from breakdown of glycogen
   c. Only liver can secrete glucose into blood, not skeletal muscles
4. Conversion stimulated by glucagon
   a. Other pancreatic hormone
   b. Produced in α islet cells
5. For greater fasting, liver converts amino acids, lactic acid into glucose
   a. Process called gluconeogenesis
   b. Amino acids come from muscle protein

II. NEURAL AND HORMONAL REGULATION OF DIGESTION

A. Coordination by Nervous System
1. Stimulates salivary and gastric secretions
2. Occurs in response to sight and smell of food

B. Coordination by Hormones
1. Food in stomach stimulates secretion of gastrin by stomach tbl 51.2
   a. In turn stimulates secretion of pepsinogen and HCl in stomach fig 51.21
   b. Decreased stomach pH reduces secretion of gastrin
   c. Decrease in gastrin decreases HCl production
2. Passage of chyme from stomach inhibits stomach contractions
   a. No more chyme enters intestine until previous amount processed
   b. Process mediated by neural impulses and enterogastrone enzymes
      1) Gastric inhibitory peptide (GIP) is one enterogastrone
      2) GIP released by duodenum
      3) Production stimulated most strongly by fat in chyme
      4) Fatty meals take longer to process
3. Cholecystokinin (CCK) is secreted in response to fat in chyme
   a. Stimulates contraction of gallbladder to release bile
   b. Bile emulsifies fats, increases efficiency of digestion
4. Secretin released in response to acidity of chyme
   a. Stimulates pancreas to release bicarbonate
   b. Neutralizes acidity of chyme
   c. First hormone ever discovered

51.5 All animals require food energy and essential nutrients

I. FOOD ENERGY AND ENERGY EXPENDITURE

A. Ingestion of Food Has Dual Purpose
1. Provides source of energy
2. Provides raw materials the animal cannot manufacture for itself
   a. Basal metabolic rate (BMR): Rate energy is consumed at complete rest
   b. Food energy – (energy used at rest + exercise energy) = energy in glycogen and fat
   c. BMR is relatively constant within an individual
3. Intake of food required to maintain glycogen stores in the liver
   a. Excess glucose metabolized by muscles or converted to fat
   b. Balance between food energy and exercise energy determines energy storage in fat
   c. Measured in kilocalories (Calorie), determined by amount of heat generated
4. Wealthy countries exhibit obesity from overeating and imbalanced diet
   a. Accumulate fat if kilocalories ingested exceed metabolic rate
   b. Obese = 20% more than normal weight for a certain height

B. Regulation of Food Intake
1. Adipose tissue releases hormonal satiety factor
   a. Considered as a weight loss chemical
   b. Determined by surgical joining of obese and normal mice
   c. Obese mice lost weight
2. Factor identified, found in *ob*/*ob* (homozygous) strain of mice
   a. Gene expressed only in adipocytes
   b. Protein product of gene called leptin
   c. Obese *ob* mice produce mutated, ineffective form of leptin
   d. Mice stop eating and lose weight when injected with normal leptin fig 51.22

3. Activity of *ob* gene and levels of leptin are higher in obese humans
   a. Leptin produced by obese individuals is normal
   b. Human obesity may result from reduced sensitivity to leptin in brain
4. Concerns regarding eating disorders
   a. Anorexia nervosa: Afflicted individuals starve selves
   b. Bulimia: Individual gorges then vomits
   c. Most individuals are female

II. ESSENTIAL NUTRIENTS

A. Specific Substances Critical for Proper Health
1. Over time many vertebrates have lost ability to synthesize substances
2. Essential nutrients cannot be manufactured, must be obtained from diet
3. Vitamins: Essential organic substances required in trace amounts tbl 51.3
   a. Humans, apes, monkeys, guinea pigs cannot make vitamin C
   b. Vitamin K produced by symbiotic bacteria in mammals, ingested by birds
   c. Humans require at least 13 vitamins
4. Essential amino acids: Eight of the total 20
   a. Must be obtained from proteins in food fig 51.24
   b. Vegetarian diets must include full complement of amino acids
5. Vertebrates cannot synthesize certain unsaturated fatty acids
6. Vertebrates synthesize cholesterol, carnivorous insects cannot

B. Essential Minerals
1. Include calcium, phosphorus, and other trace elements tbl 2.1
2. Must be obtained from plants or herbivorous animals

INSTRUCTIONAL STRATEGY

PRESENTATION ASSISTANCE:

Although no food products are absorbed in the stomach, alcohol and some drugs are absorbed. Alcohol can also be absorbed through the lining of the mouth if it remains there long enough. The presence of small amounts of it in the stomach improves the digestive process by slowing the exit of materials into the small intestine.

Discuss the activity of the liver as a detoxifying organ. The liver is frequently the first body organ damaged by toxins, including alcohol. This is readily evidenced by the damage to the liver of alcoholics due to fatty deposits and cirrhosis.

Discuss the various feeding strategies of herbivores versus carnivores, endotherms versus ectotherms, and how these strategies affect the anatomy of the skull, jaws, and digestive tract.

VISUAL RESOURCES:

Obtain photos or scanning electron micrographs showing the various convolutions of the digestive tract, include the stomach, duodenum, lower small intestine, and the large intestine.