Chapter 41

Animal Nutrition

PowerPoint Lectures for
***Biology*, Seventh Edition**
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- Overview: The Need to Feed
- Every mealtime is a reminder that we are heterotrophs
  - Dependent on a regular supply of food

Figure 41.1

- In general, animals fall into one of three dietary categories
  - Herbivores eat mainly autotrophs (plants and algae)
  - Carnivores eat other animals
  - Omnivores regularly consume animals as well as plants or algal matter

- Regardless of what an animal eats, an adequate diet must satisfy three nutritional needs
  - Fuel for all cellular work
  - The organic raw materials for biosynthesis
  - Essential nutrients, substances such as vitamins that the animal cannot make for itself

- Animals feed by four main mechanisms

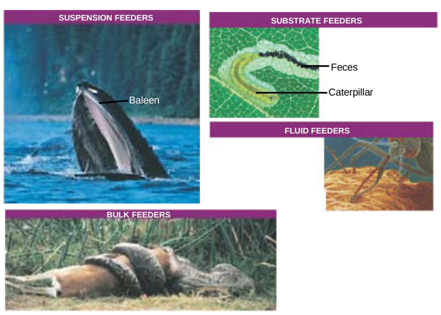


Figure 41.2

- Concept 41.1: Homeostatic mechanisms manage an animal's energy budget
- Nearly all of an animal's ATP generation
  - Is based on the oxidation of energy-rich molecules: carbohydrates, proteins, and fats

Glucose Regulation as an Example of Homeostasis

- Animals store excess calories
  - As glycogen in the liver and muscles and as fat

- Glucose is a major fuel for cells
- Its metabolism, regulated by hormone action, is an important example of homeostasis

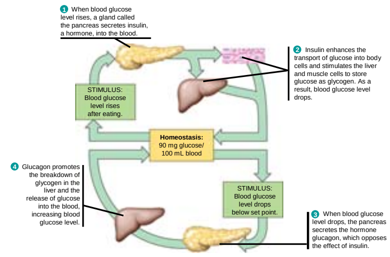


Figure 41.3

- When fewer calories are taken in than are expended
  - Fuel is taken out of storage and oxidized

Caloric Imbalance

- Undernourishment
  - Occurs in animals when their diets are chronically deficient in calories
  - Can have detrimental effects on an animal

- Overnourishment
  - Results from excessive food intake
  - Leads to the storage of excess calories as fat

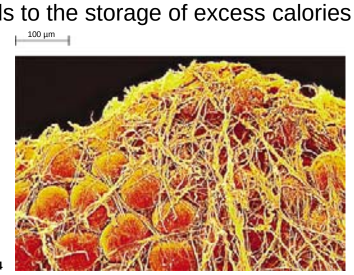


Figure 41.4

Obesity as a Human Health Problem

- The World Health Organization
  - Now recognizes obesity as a major global health problem
- Obesity contributes to a number of health problems, including
  - Diabetes, cardiovascular disease, and colon and breast cancer

- Researchers have discovered
  - Several of the mechanisms that help regulate body weight
- Over the long term, homeostatic mechanisms
  - Are feedback circuits that control the body's storage and metabolism of fat

- Several chemical signals called hormones
  - Regulate both long term and short term appetite by affecting a "satiety center" in the brain

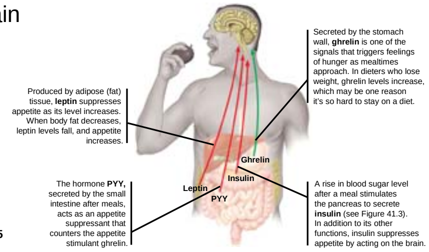


Figure 41.5

- 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

Figure 41.6

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 due to the need to consume more calories than they burn

Figure 41.7

- Concept 41.2: An animal's diet must supply carbon skeletons and essential nutrients
- To build the complex molecules it needs to grow, maintain itself, and reproduce
  - An animal must obtain organic precursors (carbon skeletons) from its food

- Besides fuel and carbon skeletons
  - An animal's diet must also supply essential nutrients in preassembled form
- An animal that is malnourished
  - Is missing one or more essential nutrients in its diet

- Herbivorous animals
  - May suffer mineral deficiencies if they graze on plants in soil lacking key minerals

Figure 41.8

- Malnutrition
  - Is much more common than undernutrition in human populations

Essential Amino Acids

- Animals require 20 amino acids
  - And can synthesize about half of them from the other molecules they obtain from their diet
- The remaining amino acids, the essential amino acids
  - Must be obtained from food in preassembled form

- A diet that provides insufficient amounts of one or more essential amino acids
  - Causes a form of malnutrition called protein deficiency

Figure 41.9

- Most plant proteins are incomplete in amino acid makeup
  - So individuals who must eat only plant proteins need to eat a variety to ensure that they get all the essential amino acids

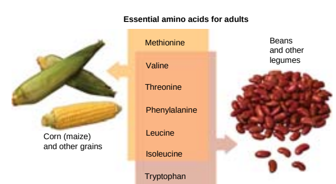


Figure 41.10

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

Figure 41.11

Essential Fatty Acids

- Animals can synthesize most of the fatty acids they need
- The essential fatty acids
  - Are certain unsaturated fatty acids
- Deficiencies in fatty acids are rare

Vitamins

- Vitamins are organic molecules
  - Required in the diet in small amounts
- To date, 13 vitamins essential to humans
  - Have been identified

- Vitamins are grouped into two categories
  - Fat-soluble and water-soluble

Table 41.1 Vitamin Requirements of Humans

Vitamin	Major Dietary Sources	Some Major Functions in the Body	Possible Symptoms of Deficiency or Extreme Excess
Water-Soluble Vitamins			
Fat-Soluble Vitamins			

Table 41.1

Minerals

- Minerals are simple inorganic nutrients
  - Usually required in small amounts

- Mineral requirements of humans

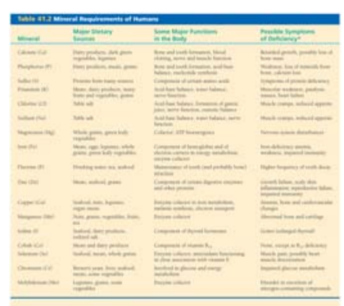


Table 41.2 Mineral Requirements of Humans

Mineral	Major Dietary Sources	Some Major Functions in the Body	Possible Symptoms of Deficiency*

Table 41.2

- Concept 41.3: The main stages of food processing are ingestion, digestion, absorption, and elimination
- Ingestion, the act of eating
  - Is the first stage of food processing

- Digestion, the second stage of food processing
  - Is the process of breaking food down into molecules small enough to absorb
  - Involves enzymatic hydrolysis of polymers into their monomers

- Absorption, the third stage of food processing
  - Is the uptake of nutrients by body cells
- Elimination, the fourth stage of food processing
  - Occurs as undigested material passes out of the digestive compartment

- The four stages of food processing

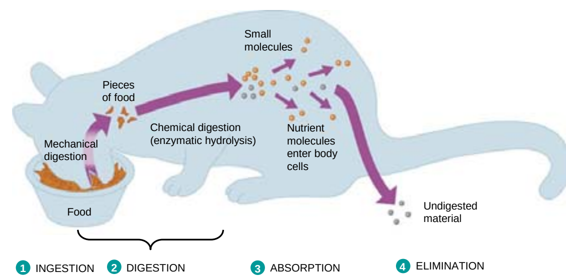


Figure 41.12

Digestive Compartments

- Most animals process food
  - In specialized compartments

Intracellular Digestion

- In intracellular digestion
  - Food particles are engulfed by endocytosis and digested within food vacuoles

Extracellular Digestion

- Extracellular digestion
  - Is the breakdown of food particles outside cells

- Animals with simple body plans
  - Have a gastrovascular cavity that functions in both digestion and distribution of nutrients

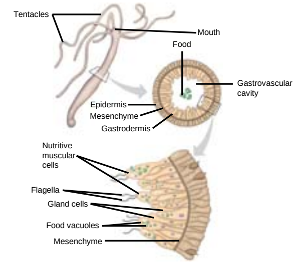
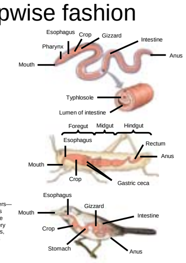


Figure 41.13

- Animals with a more complex body plan
  - 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

- The digestive tube can be organized into specialized regions
  - That carry out digestion and nutrient absorption in a stepwise fashion



(a) Earthworm. The digestive tract of an earthworm includes a muscular pharynx that sucks food in through the mouth. Food passes through the esophagus and is stored and moistened in the crop. The muscular gizzard, which contains small bits of sand and gravel, pulverizes the food. Digestion and absorption occur in the intestine, which has a dorsal fold, the typhlosole, that increases the surface area for nutrient absorption.

(b) Grasshopper. A grasshopper has several digestive chambers grouped into three main regions: a foregut, with an esophagus and crop; a midgut; and a hindgut. Food is moistened and stored in the crop, but most digestion occurs in the midgut. Gastric ceca, pouches extending from the midgut, absorb nutrients.

(c) Bird. Many birds have three separate chambers—the crop, stomach, and gizzard—where food is pulverized and churned before passing into the intestine. A bird's crop and gizzard function very much like those of an earthworm. In most birds, chemical digestion and absorption of nutrients occur in the intestine.

Figure 41.14a–c

- Concept 41.4: Each organ of the mammalian digestive system has specialized food-processing functions

- The mammalian digestive system consists of the alimentary canal
  - And various accessory glands that secrete digestive juices through ducts

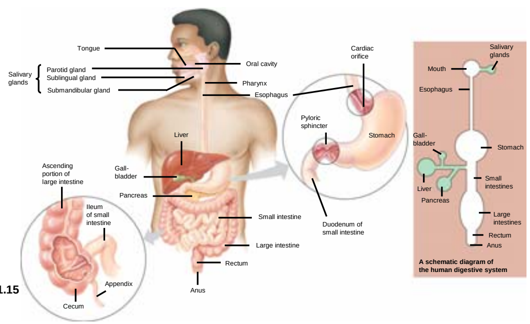


Figure 41.15

- Food is pushed along the digestive tract by peristalsis
  - Rhythmic waves of contraction of smooth muscles in the wall of the canal

The Oral Cavity, Pharynx, and Esophagus

- In the oral cavity, food is lubricated and digestion begins
  - And teeth chew food into smaller particles that are exposed to salivary amylase, initiating the breakdown of glucose polymers

- The region we call our throat is the pharynx
  - A junction that opens to both the esophagus and the windpipe (trachea)
- The esophagus
  - Conducts food from the pharynx down to the stomach by peristalsis

- From mouth to stomach

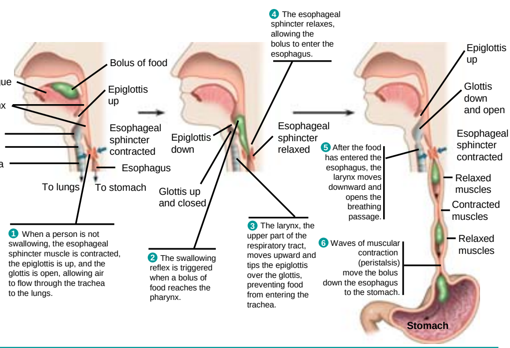


Figure 41.16

The Stomach

- The stomach stores food
  - And secretes gastric juice, which converts a meal to acid chyme
- Gastric juice
  - Is made up of hydrochloric acid and the enzyme pepsin

- The lining of the stomach
  - Is coated with mucus, which prevents the gastric juice from destroying the cells

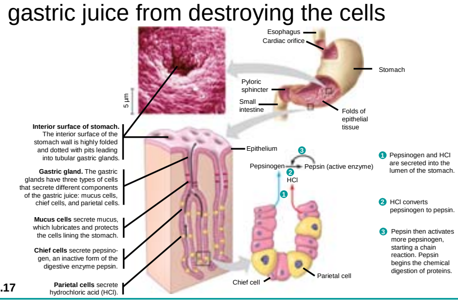


Figure 41.17

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

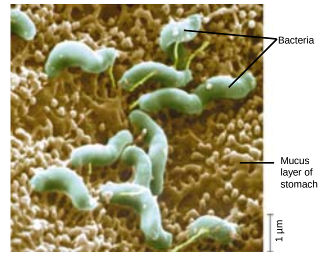


Figure 41.18

The Small Intestine

- The small intestine
  - Is the longest section of the alimentary canal
  - Is the major organ of digestion and absorption

Enzymatic Action in the Small Intestine

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

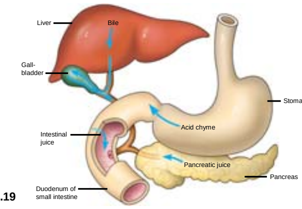


Figure 41.19

- The pancreas produces proteases, protein-digesting enzymes
  - That are activated once they enter the duodenum

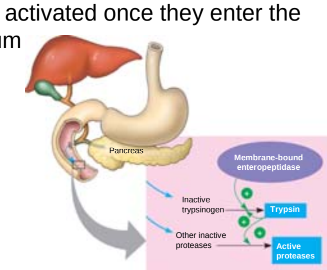


Figure 41.20

- Enzymatic digestion is completed
  - As peristalsis moves the mixture of chyme and digestive juices along the small intestine

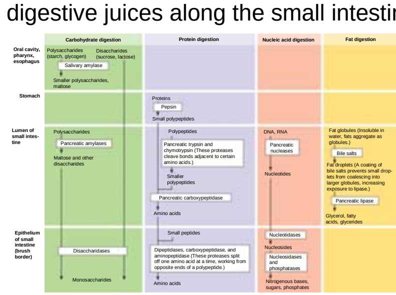


Figure 41.21

- Hormones help coordinate the secretion of digestive juices into the alimentary canal

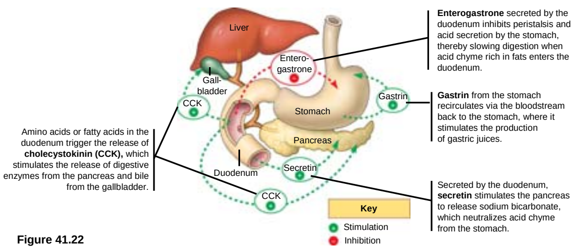


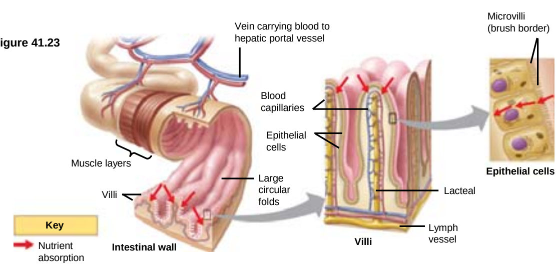
Figure 41.22

Absorption of Nutrients

- The small intestine has a huge surface area
  - Due to the presence of villi and microvilli that are exposed to the intestinal lumen

- The enormous microvillar surface
  - Is an adaptation that greatly increases the rate of nutrient absorption

Figure 41.23



- The core of each villus
  - Contains a network of blood vessels and a small vessel of the lymphatic system called a lacteal

- Amino acids and sugars
  - Pass through the epithelium of the small intestine and enter the bloodstream
- After glycerol and fatty acids are absorbed by epithelial cells
  - They are recombined into fats within these cells

- These fats are then mixed with cholesterol and coated with proteins
  - Forming small molecules called chylomicrons, which are transported into lacteals

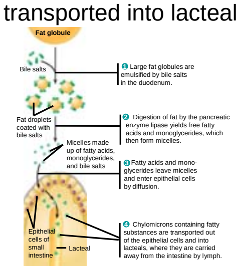


Figure 41.24

The Large Intestine

- The large intestine, or colon
  - Is connected to the small intestine

Figure 41.25

- A major function of the colon
  - Is to recover water that has entered the alimentary canal
- The wastes of the digestive tract, the feces
  - Become more solid as they move through the colon
  - Pass through the rectum and exit via the anus

- The colon houses various strains of the bacterium *Escherichia coli*
  - Some of which produce various vitamins

- Concept 41.5: Evolutionary adaptations of vertebrate digestive systems are often associated with diet

Some Dental Adaptations

- Dentition, an animal's assortment of teeth
  - Is one example of structural variation reflecting diet

- Mammals have specialized dentition
  - That best enables them to ingest their usual diet

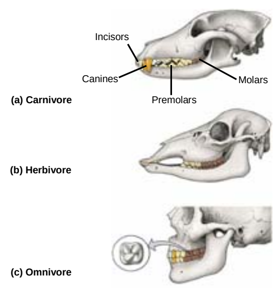


Figure 41.26a–c

Stomach and Intestinal Adaptations

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

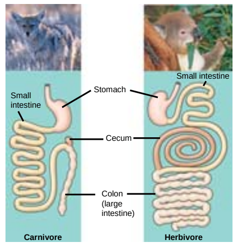


Figure 41.27

Symbiotic Adaptations

- Many herbivorous animals have fermentation chambers
  - Where symbiotic microorganisms digest cellulose

- The most elaborate adaptations for an herbivorous diet
  - Have evolved in the animals called ruminants

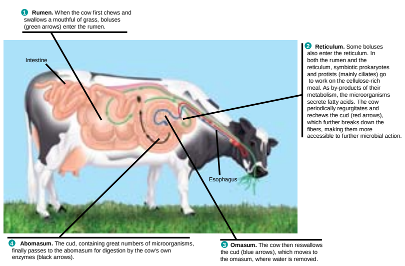


Figure 41.28