CHAPTER 41: ANIMAL NUTRITION

AP BIOLOGY 2013

1

DIETARY CATEGORIES

- Herbivores - eat autotrophs (plants and algae)
- Carnivores - Eat other animals
- Omnivores - consume animals as well as plants
- Diet must satisfy three needs:
  - Fuel cellular work
  - Provide organic raw materials for biosynthesis
  - Essential nutrients (vitamins and minerals animals cannot make themselves)

FIG. 41.1

2

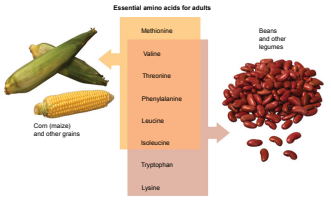
DIET MUST SUPPLY ESSENTIAL NUTRIENTS

- To build complex molecules required for growth, maintenance, and reproduction, and animal must obtain the precursors (carbon skeletons) from food.
- Diet must also supply essential nutrients in preassembled form
- Animal that is missing one or more essential nutrients in its diet are malnourished
  - Herbivores may suffer mineral deficiencies if they graze on plants in soil that lacks key minerals
  - Malnutrition is more common than undernutrition

3

ESSENTIAL AMINO ACIDS

- Animals require 20 amino acids and can synthesize about half of them from molecules they obtain in their diet
  - The remaining 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
- Most plant proteins are incomplete in amino acid makeup so individuals who must eat only plant proteins need to eat a variety to ensure they get all essential amino acids.
- Some animals adapt to help through periods when their bodies demand extraordinary proteins



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ESSENTIAL FATTY ACIDS, VITAMINS, AND MINERALS

- Animals can synthesize most fatty acids they need
  - Some unsaturated fatty acids are essential, but deficiencies are rare.
- Vitamins are organic molecules required in the diet in small amounts (13 essential vitamins have been identified)
  - Two categories: fat-soluble and water-soluble
- Minerals are simple inorganic nutrients usually required in small amounts

Table 41.1 Vitamin Requirements of Humans

Vitamin	Major Dietary Sources	Major Functions in the Body	Symptoms of Deficiency
Water-Soluble Vitamins			
B_1 (thiamine)	Pork, legumes, peanuts, whole grains	Coenzyme used in removing CO_2 from organic compounds	Beriberi (tingling, poor coordination, reduced heart function)
B_2 (riboflavin)	Dairy products, meats, enriched grains, vegetables	Component of coenzymes FAD and FMN	Skin lesions, such as cracks at corners of mouth
B_3 (niacin)	Nuts, meats, grains	Component of coenzymes NAD^+ and $NADP^+$	Skin and gastrointestinal lesions, delusions, confusion
B_5 (pantothenic acid)	Meats, dairy products, whole grains, fruits, vegetables	Component of coenzyme A	Fatigue, numbness, tingling of hands and feet
B_6 (pyridoxine)	Meats, vegetables, whole grains	Coenzyme used in amino acid metabolism	Irritability, convulsions, muscular twitching, anemia
B_7 (biotin)	Legumes, other vegetables, meats	Coenzyme in synthesis of fat, glycogen, and amino acids	Scaly skin inflammation, neuromuscular disorders
B_9 (folic acid)	Green vegetables, oranges, nuts, legumes, whole grains	Coenzyme in nucleic acid and amino acid metabolism	Anemia, birth defects
B_{12} (cobalamin)	Meats, eggs, dairy products	Production of nucleic acids and red blood cells	Anemia, numbness, loss of balance
C (ascorbic acid)	Citrus fruits, broccoli, tomatoes	Used in collagen synthesis; antioxidant	Scurvy (degeneration of skin and teeth), delayed wound healing
Fat-Soluble Vitamins			
A (retinol)	Dark green and orange vegetables and fruits, dairy products	Component of visual pigments; maintenance of epithelial tissues	Blindness, skin disorders, impaired immunity
D	Dairy products, egg yolk	Aids in absorption and use of calcium and phosphorus	Rickets (bone deformities) in children; bone softening in adults
E (tocopherol)	Vegetable oils, nuts, seeds	Antioxidant; helps prevent damage to cell membranes	Nervous system degeneration
K (phylloquinone)	Green vegetables, tea; also made by colon bacteria	Important in blood clotting	Defective blood clotting

Table 41.2 Mineral Requirements of Humans

Mineral	Major Dietary Sources	Major Functions in the Body	Symptoms of Deficiency
Required in Daily Amounts Greater than 200 mg per Day			
Calcium (Ca)	Dairy products, dark green vegetables, legumes	Bone and tooth formation, blood clotting, nerve and muscle function	Impaired growth, 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	Impaired growth, fatigue, swelling
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	Enzyme cofactor, ATP bioenergetics	Nervous system disturbances
Iron (Fe)	Meats, eggs, legumes, whole-grains, green leafy vegetables	Component of hemoglobin and of electron carriers; enzyme cofactor	Iron-deficiency anemia, weakness, impaired immunity
Fluorine (F)	Drinking water, tea, seafood	Maintenance of tooth structure	Higher frequency of tooth decay
Iodine (I)	Seafood, iodized salt	Component of thyroid hormones	Goiter (enlarged thyroid gland)

[a]Additional minerals required in trace amounts are chromium (Cr), cobalt (Co), copper (Cu), manganese (Mn), molybdenum (Mo), selenium (Se), and zinc (Zn). All of these minerals, as well as those in the table, are harmful when consumed in excess.

5

CALORIC IMBALANCE

- Undernourishment - diet chronically deficient in calories
- Overnourishment - results from excessive food intake (leads to storage of calories as fat)
- WHO (World Health Organization) now recognizes obesity as a major global health problem that contributes to diabetes, cardiovascular disease, colon and breast cancer, and many more.
- There are several mechanisms that regulate body weight (control how fat is stored and metabolized)

6

FOOD PROCESSING

- Ingestion - act of eating
- Digestion - process of breaking down food into molecules small enough to absorb using enzymatic hydrolysis of polymers into their monomers
- Absorption - uptake of nutrients by body cells
- Elimination - occurs as undigested material passes out of the digestive compartment

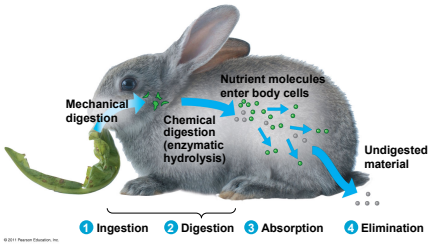


FIG. 41.5

7

FEEDING MECHANISMS

- Suspension Feeders - sift small food particles from the water
- Substrate Feeders - live on or in their food source
- Fluid feeders - suck nutrient-rich fluid from a living host
- Bulk feeders - eat relatively large pieces of food

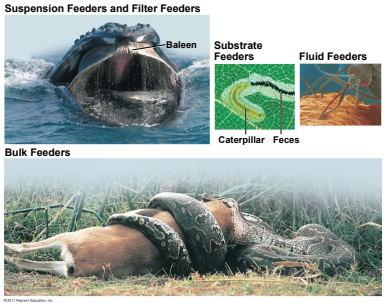
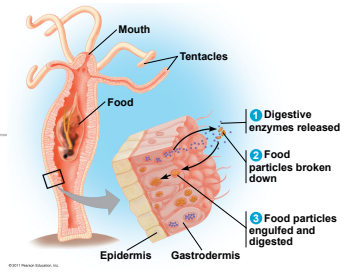


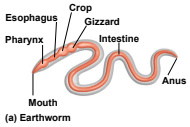
FIG. 41.6

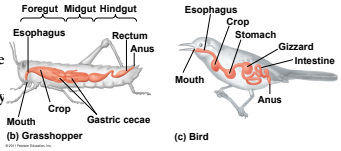
8

DIGESTION

- Most animals process food in specialized compartments
- Intracellular digestion - food particles are engulfed by endocytosis are digested with food vacuoles
- Extracellular digestion - breakdown of food particles outside of the cells
- Animals with simple body plans have a gastrovascular cavity that functions in both digestion and distribution of nutrients
- Animals with more complex body plans have digestive tubes with two openings (mouth and anus)
  - Digestive tube is called a complete digestive tract or an alimentary canal; tubes can be organized into specialized regions that carry out digestion and nutrient absorption in a stepwise fashion







FIGS. 41.7 & 41.8

9

DIGESTIVE SYSTEM

- Mammalian digestive system consists of the alimentary canal and various glads that secrete digestive juices through ducts
- Food is pushed along the digestive tract by peristalsis (rhythmic waves of contraction of smooth muscles in the wall of the canal)
- Oral cavity - food is lubricated and digestion begins (teeth chew food into smaller particles that are exposed to amylase that starts the breakdown of glucose)
- Pharynx (throat) - opens to both esophagus and trachea
  - Esophagus conducts food from the pharynx down to the stomach by peristalsis

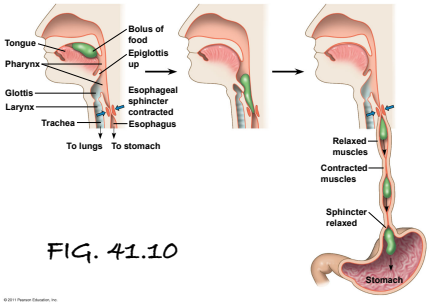
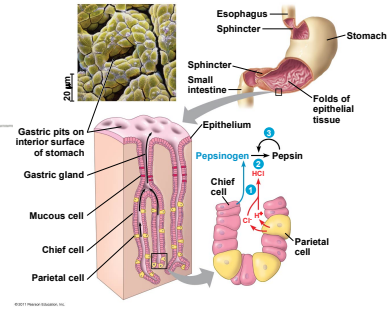


FIG. 41.10

DIGESTIVE SYSTEM

- Stomach - stores food and secretes gastric juices (converts food into acid chyme)
  - Gastric juice - made up of hydrochloric acid and the enzyme pepsin
  - Lining is coated with mucus which prevents gastric juice from destroying cells
  - Gastric ulcers (lesions in the lining) are caused by a bacteria (*Helicobacter pylori*)



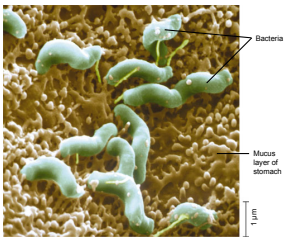


FIG. 41.11

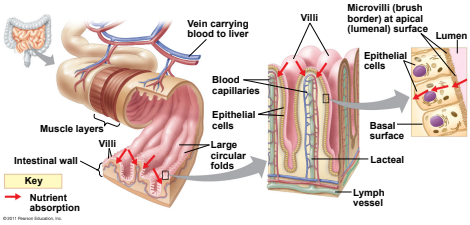
DIGESTIVE SYSTEM

- Small intestine - longest section of the alimentary canal and major organ of digestion and absorption
  - First portion is the duodenum - where acid chyme from the stomach mixes with digestive juices from the pancreas, liver, gallbladder, and intestine
  - Pancreas produces proteases (protein digesting enzymes) that are activated once they enter the duodenum
  - Hormones help coordinate the secretion of digestive juices into the alimentary canal

DIGESTIVE SYSTEM

- Small intestine (continued)
  - Have a high surface area due to the presence of villi and microvilli that are exposed to the intestinal lumen
  - Greatly increases the rate of absorption
  - 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 to enter the bloodstream
  - Glycerol and fatty acids are absorbed and recombined into fats within these cells

FIG. 41.13



DIGESTIVE SYSTEM

- Fats are mixed with cholesterol and coated with proteins forming small molecules called chylomicrons which are transported into lacteals

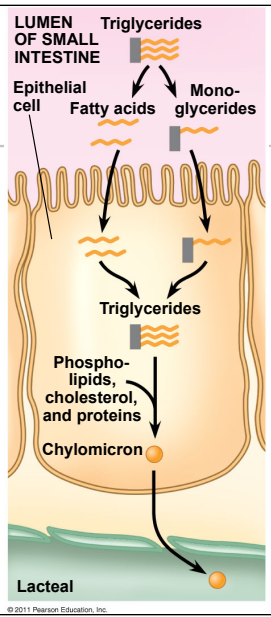


FIG. 41.14

DIGESTIVE SYSTEM

- Large intestine - connected to the small intestine
  - Major function of the colon is to recover water that has entered the alimentary canal
  - Wastes become more solid as they move through the colon and pass through the rectum and exit via the anus
  - Colon contains strains of *Escherichia coli* (some produce vitamins)

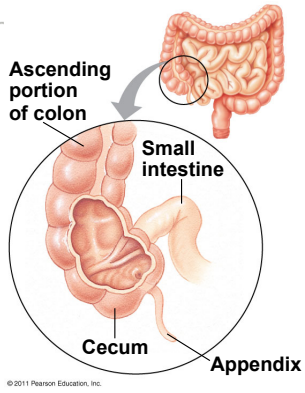
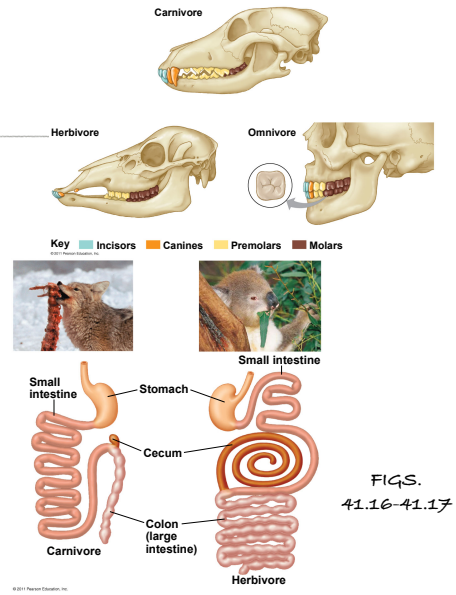


FIG. 41.15

EVOLUTIONARY ADAPTATIONS

- Digestive system in vertebrates associated with diet
- Dentition (assortment of teeth)
  - Based off of diet
- Herbivores have longer alimentary canals than carnivores (takes longer to digest vegetation)
  - Many have fermentation chambers (symbiotic organisms digest the cellulose)



FIGS. 41.16–41.17

16

HOMEOSTATIC MECHANISMS

- Nearly all animal's ATP generation is based on the oxidation of energy-rich molecules: Carbohydrates, proteins, and fats
  - Store excess calories as glycogen in the liver and muscles as well as in fat
  - Glucose is a major fuel for cells
    - Metabolism of glucose is regulated by hormones (EXAMPLE OF HOMEOSTASIS)
  - When fewer calories are taken in than are expended (fuel is taken out of storage and oxidized)

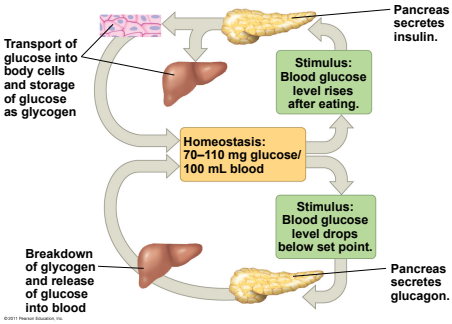


FIG. 41.20

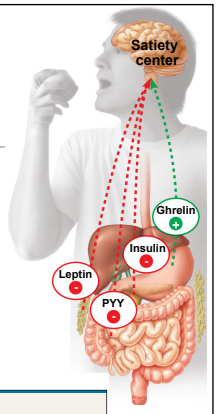
17

CALORIC IMBALANCE

FIGS. 41.21 & 41.22

- Hormones regulate both long-term and short-term appetite by affecting the "satiety center" in the brain
- Shows the complexity of weight control
- Mice that inherit a defect in the gene for leptin become very obese
- Weight problems stem from evolutionary past when hoarding fat was needed for survival

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



RESULTS

Genotype pairing (red type indicates mutant genes)		Average change in body mass (g) of subject
Subject	Paired with	
*ob**ob*, *db**db**	*ob**ob**, *db**db**	8.3
ob ob, *db**db**	*ob ob*, *db**db**	38.7
ob ob, *db**db**	*ob**ob**, *db**db**	8.2
ob ob, *db**db**	*ob**ob**, *db db*	-14.9*

*Due to pronounced weight loss and weakening, subjects in this pairing were reweighed after less than eight weeks.

18