Animal nutrition

• All living organisms require food for energy
• Animals are heterotrophs
  – Food broken down
    • Nutrients used to build cells, tissues and other molecules needed for functioning
    • Provide vitamins and minerals to meet cell needs
    • Energy in molecular bonds of food used to provide the energy needed for all metabolism (=sum of all cellular reactions)
Feeding Process

• Ingestion
  – Taking food into mouth

• Digestion
  – Breaks down food to molecules small enough to be absorbed by intestine

• Absorption
  – Molecules transported across lining of intestine into bloodstream

• Egestion (=elimination)
  – Removal of everything that wasn’t used from the digestive system (feces)
Sources of Organic Nutrients

- **Herbivores**
  - Eat mostly plants
- **Carnivores**
  - Eat mostly other animals
  - Often referred to as predators
- **Omnivores**
  - Eat large amounts of plants and animals
Mammalian Dentition

Generalized mammalian dentition

Carnivore

Herbivore

Human

KEY
- Molars
- Canines
- Premolars
- Incisors

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Digestion

• Intracellular digestion (used by protists, sponges and some cnidarians)
  – Occurs inside cells after endocytosis
  – Lysosomes fuse with food vacuole
    • Food broken down chemically

• Extracellular digestion (used by most animals)
  – Occurs outside the cells
    • Usually in gut cavity
    • Sometimes in outside environment
  – Resulting molecules can be absorbed
Digestive Organs

• Platyhelminthes and Cnidaria have sac-like gastrovascular cavity (incomplete gut)
Digestive Organs

• Most invertebrates and all vertebrates have digestive tract (=tube from mouth to anus)
  – Several organs in sequence
Digestive Organs

- More complex digestive tract is assisted by accessory glands
  - Secrete chemicals to help in process of digestion
  - Molluscs, arthropods, etc.
- Food is broken down in specific regions of tract and moved to another region for absorption
- Anything not absorbed is eliminated
Mammalian Digestive System
Human as Example
Glands in lining of stomach and intestine
Digestion in Mouth

• Mouth
  – Ingestion
  – Mechanical digestion
    • Food is chewed
    • **Bolus** is formed by tongue, teeth, cheeks
  – Chemical digestion
    • Taste buds detect sweet, sour, salty, bitter
    • Smell, sight, taste of food prepares stomach
Digestion in Mouth

• Mouth
  – Chemical digestion
    • Salivary glands secrete saliva
      – Parotid glands
      – Sublingual glands
      – Submandibular glands
    • Saliva
      – 99% water
      – 1% salts and proteins
        » Mucins produce mucus
        » Amylase breaks down starch
Digestion

• Peristalsis moves material through digestive tract
  – Waves of involuntary muscle contractions
  – Different rates in different regions of tract
  – Triggered by stretch of muscular walls as material moves into each region

• Sphincter valves regulate passage from one region to another
Individual not swallowing

The pharyngoesophageal sphincter muscle is contracted, closing the esophagus, the epiglottis is up, and the glottis is open to let air enter the lungs.
Swallowing reflex begins when bolus reaches the pharynx.

- Elevation of soft palate prevents food bolus from entering nasal passages.
- Pressure of tongue seals back of mouth and prevents bolus from backing up.
- Larynx moves upward, pushing glottis against epiglottis to prevent bolus from entering airway.
- Pharyngoesophageal sphincter muscle relaxes, permitting bolus to enter the esophagus.
Peristalsis in esophagus

7 Once food is in the esophagus, the structures of the mouth and pharynx reset to the nonswallowing state.

8 Circular muscles of the esophagus contract behind the food, constricting the esophagus and blocking upward movement.

9 Longitudinal muscles of the esophagus contract, opening up the esophagus. In concert with the constricting circular muscles, this pushes the bolus down the esophagus. A series of alternating contractions and relaxations of the circular and longitudinal muscles produces peristaltic waves that move the bolus to the stomach.

KEY

- Circular muscles
- Longitudinal muscles
Tissue Layers of Digestive Tract

- 4 layers, from inside to outside
  - Mucosa
    - Lines lumen
    - Epithelial cells
      - Regulate entrance into cells of body
      - Absorb nutrients
    - Gland cells
      - Secrete enzymes, mucus, chemicals to adjust pH
  - Submucosa
    - Connective tissue
      - Provides elasticity
    - Nervous tissue
    - Blood vessels
    - Lymphatic vessels
      - Carry lipids away from intestine
Tissue Layers of Digestive Tract

- 4 layers, from inside to outside
  - Mucosa
  - Submucosa
  - Muscularis – used in peristalsis
    - 2 layers smooth muscle (involuntary)
    - Circular muscle
    - Longitudinal muscle
    - Stomach has 3rd oblique muscle layer
  - Serosa
    - Outer layer
    - Connective tissue
    - Secretes fluid lubricant to reduce friction between organs
    - Continuous with mesentery
Stomach

- Sphincters keep food and gastric juices in stomach until desired release
  - Cardiac (gastroesophageal) sphincter
    - Prevents backflow into esophagus
  - Pyloric sphincter
    - Controls movement into small intestine
Stomach -- Digestion

• Serves for:
  – Food storage
  – Formation of chyme
    • Slurry of food, mucus, gastric enzymes
  – Initiation of protein digestion
Stomach -- Digestion

• Muscles of stomach wall contract to mix the chyme
Stomach -- Digestion

- Stretch of stomach triggers release of hormone gastrin
- Gastrin triggers gastric glands to secrete pepsinogen & acid (mucus also secreted)
  - Very acidic (pH≤2)
  - Deactivates salivary amylase
  - Acid + pepsinogen → pepsin
  - Pepsin breaks down proteins → amino acid chains
  - Mucus protects epithelial lining of stomach
Small Intestine

- Peristalsis in stomach and relaxation of pyloric sphincter
- Chyme enters small intestine a little bit at a time
Small Intestine

• 3 sections
  – Duodenum -- first 10 inches
  – Jejunum -- 8 feet
  – Ileum -- 12 feet
Small Intestine -- Digestion

• Chyme
  – Carbs have barely started digestive process
  – Protein segments from stomach digestion
  – Fats not yet digested
Small Intestine -- Digestion

- **Role of liver**
  - Produces bile to assist in fat digestion
- **Role of gall bladder**
  - Stores bile from liver
- **Role of pancreas**
  - Produces bicarbonate
  - Produces digestive enzymes
Small Intestine -- Digestion

- Duodenum receives
  - Chyme
  - Mucus from intestinal cells
- Secretin from glands in intestinal lining
  - Inhibits release of chyme
  - Stimulates bicarbonate production from pancreas
    - Neutralizes acid
- CCK from glands in intestinal lining
  - Stimulate gallbladder to release bile
  - Stimulates pancreas to release enzymes
- GIP stimulated pancreas to release insulin
  - Aids absorption of sugars in small intestine
Small Intestine -- Digestion

• Bile emulsifies fats
  – Increases surface area for digestive enzymes
Small Intestine -- Digestion

• Pancreatic enzymes work once pH neutralized
  – Pancreatic amylase
    • Digests carbohydrates to disaccharides (sugars)
      – Digested to monosaccharides as they cross intestinal cell membranes
  – Proteases
    • Digest proteins to peptides (small amino acid chains)
      – Digested to amino acids as they cross intestinal cell membranes
  – Lipases
    • Digest fats to fatty acid + glycerol
Small Intestine -- Digestion

Carbohydrate digestion

H$_2$O

Enzyme (amylase)

Sugar
Small Intestine -- Digestion

Protein digestion

Enzyme (protease)
Small Intestine -- Digestion

Fat digestion

\[
\text{Enzyme (lipase)} \rightarrow \text{Glycerol} \rightarrow \text{Fatty acid}
\]

\[
\text{H}_2\text{O} \rightarrow \text{H}_2\text{O} \rightarrow \text{H}_2\text{O}
\]
Small Intestine

• Most of absorption occurs here

• Maximizes surface area
  – Folds, folds, more folds
  – Villi and microvilli most abundant in duodenum and jejunum, also present in ileum
Section of small intestine

Folds of small intestine

Villus

Capillaries

Lymphatic vessel

Brush border

Micro-villi

Intestinal epithelial cell

Animal Nutrition

Figure 47-12 p1056
Absorption

• Most of water
• Amino acids & sugars
  – actively transported into cells and then to ECF and blood capillaries
Absorption

- Fats
  - Diffuse into cells
  - Built back into triglycerides
  - Attached to proteins (lipoproteins)
  - Expelled via exocytosis
  - Absorbed into lymphatic vessel and carried to blood
Ulcer-causing Bacteria

Stomach mucus

*Helicobacter pylori* bacteria

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What’s left?

• Mostly wastes
  – Never absorbed into cells of body
    • Exception is bile, made from breakdown products of red blood cells

• Some water
  – Will be absorbed in large intestine
Ileocecal Sphincter

- Peristalsis moves materials into large intestine
- Small intestine joins large intestine at ileocecal sphincter
Large Intestine

- Large intestine
  - Colon
    - Ascending colon
    - Transverse colon
    - Descending colon
    - Sigmoid colon
  - Rectum
  - Anus
    - 2 sphincters
      - Voluntary & involuntary
Large Intestine -- Absorption

• Large anaerobic bacteria population (E. coli)
  – Breaks down remaining nutrients
  – Synthesize some B vitamins (folic acid and biotin) and vitamin K
    • absorbed in large intestine
Large Intestine -- Absorption

• Most remaining water absorbed
  – Prevents dehydration
  – Peristalsis too fast
    • Diarrhea
  – Peristalsis too slow
    • constipation
Egestion

- Peristalsis moves wastes into rectum
- Stretch of rectal walls triggers urge to defecate
- Wastes removed from body through anus
  - 2 sphincters
    - Internal anal sphincter -- involuntary
    - External anal sphincter -- voluntary
Mammalian Adaptations

Carnivore (a dog) and Herbivore (a rabbit)

- Esophagus
- Stomach
- Small intestine
- Large intestine
- Cecum
- Anus
Mammalian Adaptations

Chewing, swallowing, regurgitation, rechewing, and reswallowing of food through esophagus
Mammalian Adaptations

Swallowed boluses go to rumen and reticulum where fermentation reactions by symbiotic microorganisms begin digesting the plant matter.

The animal chews its cud by regurgitating material, rechewing it, and swallowing it again.

Reswallowed cud goes to the omasum where water is absorbed.

Matter then moves to the abomasum where typical gastric digestion occurs.
Animal Nutrition

• Organic molecules in diet
  – Source of building blocks for biomolecules
    • Carbohydrates
    • Proteins
    • Lipids
    • Nucleic acids
  – Cells break apart organic molecules and rebuild the molecules they use
    • Use sugars to build sugars and starches
    • Use amino acids to build proteins
    • Use fatty acids to build fats
    • Use nucleotides to build nucleic acids
Animal Nutrition

– If not eating the basic organic molecules, can build most of them
– Some molecules cannot be built
  • Must be eaten
  • Essential
    – Essential fatty acids
      » Omega-3 fatty acids
        • alpha-linolenic acid, or ALA
      » Omega-6 fatty acids
        • linoleic acid
      » Oily fish, nuts, plant based oils
    – Essential amino acids
Protein Complimentarity

Eight essential amino acids

Methionine

Tryptophan

Leucine

Phenylalanine

Threonine

Valine

Isoleucine

Lysine

Rice, corn, or other grains

Lentils, soybeans (for example, tofu), or other legumes
Minerals

- Na, Cl, K, Mg, Ca, P, I, Fe, Cu, Mn, Zn, Co
  - Calcium, magnesium, phosphorus necessary for bone and tooth formation
  - Iron necessary for hemoglobin
  - Iodine necessary for thyroid function
  - NaCl necessary for proper osmotic balance
Vitamins

• Substance the body needs in very small amounts and cannot make (or makes in insufficient amounts)
• “Something that will make you sick if you don't get enough”
• Many function as coenzymes
• Not all organisms require same vitamins
Vitamins

• Vitamins required for humans
  – Water soluble vitamins
    • $B_1$ (thiamin), $B_2$ (riboflavin) $B_6$, $B_{12}$, nicotinic acid, *C, folic acid, pantothenic acid
  – Fat soluble vitamins
    • *A, *D, E, *K
    • Can be toxic if too much

*Know names of these vitamins and diseases/symptoms associated with a lack of them
THE END
Digestion

• Mechanical digestion
  – Chewing, tearing, churning food into smaller particles
    • ↑ surface area for enzymes to work on

• Chemical digestion
  – Release of enzymes and other substances to assist in breakdown process
  – Complex food molecules broken into simple molecules small enough to be absorbed
    • Hydrolysis breaks down molecules while splitting water in the process
Feeding Methods -- Ingestion

A. Fluid feeder

B. Suspension feeder

C. Deposit feeder

D. Bulk feeder