Digestive System

Introduction

• Every cell requires a constant energy source
  – Ingested food is complex
  • Modification is needed to utilize

Introduction

• Digestive system is a tube
  – Gastrointestinal tract
  • Specialized regions
    – Mouth
    – Pharynx
    – Esophagus
    – Stomach
    – Small intestine
    – Large intestine

Introduction

• Digestive processes
  1. Ingestion
  2. Propulsion
  3. Mechanical digestion
  4. Chemical digestion
  5. Absorption
  6. Defecation
Introduction

- Histology of the alimentary canal
  - Four basic layers (tunics)
    - Tunica mucosa – innermost layer
      - Protection and absorption
      - Epithelium and connective tissue
    - Tunica submucosa
      - Connective tissue
      - Binds tube together
    - Tunica muscularis (externa)
      - Double layer of muscle
    - Tunica serosa
      - Single layer of epithelium and connective tissue
      - Forms the visceral peritoneum

- Peritoneum
  - Membrane that lines abdominal cavity
  - Serous membrane – remember, that means 2 layers!
    - Parietal peritoneum = outer layer (attached to abdominal wall)
    - Visceral peritoneum = inner layer (wrapped around visceral organs)
    - Space in between = peritoneal cavity

- Mesentery
  - Folds in the peritoneum
  - Attached to intestinal tract
  - Encapsulate blood vessels, nerves, fat stores that

- Omenta
  - Folds in peritoneum
  - Connect stomach to another organ
    - Examples:
      - Lesser omentum connects stomach to liver
      - Greater omentum connects stomach to colon
Digestive System

- Mouth
  - Cheek, palate, tongue
  - Opens into oropharynx
  - Salivary glands

Salivary glands secrete about 1250 ml of saliva per day!

Digestive System

- Teeth
  - Held in place by periodontal ligaments
  - Gingiva covers bone
  - 2 dentitions
    - Deciduous
    - Permanent
Teeth

- **20 deciduous**
  - Incisors (Central) (6–8 mo)
  - Laterals (8–10 mo)
  - Canines (Eye teeth) (16–20 mo)
  - Premolars (bicuspids) (2–3 yr)
  - Second molars (11 yr)
  - Third molars (17–25 yr)

- **32 permanent**
  - Incisors (Central) (7 yr)
  - Canines (Eye teeth) (11 yr)
  - First premolars (bicuspids) (12–13 yr)
  - Second molars (12–13 yr)
  - Third molars (wisdom teeth) (18–20 yr)

**Digestive System**

- **Teeth**
  - **Anatomy**
    - Crown
      - Covered by enamel
  - **Dentin**
  - **Pulp cavity**
  - **Roots**
  - **Function**
    - Break down food
    - Mixed with saliva to form bolus

**Digestive System**

- **Esophagus**
  - **Pharynx to stomach**
    - Moves bolus to stomach
  - **Peristalsis**

- **Cardiac (gastroesophageal) sphincter**
  - **Heartburn**

- **Histology**
  - **Mucosa**
    - Stratified squamous epithelium
    - Abundant mucous glands
  - **Serosa**
    - Entirely connective tissue

**Digestive System**

- **Mouth (oral cavity)**
  - Tongue
  - Salivary glands
  - Parotid gland
  - Submandibular gland

- **Gastroesophageal sphincter closed**
  - Food is moved through the esophagus to the stomach by peristalsis.
The gastroesophageal sphincter opens, and food enters the stomach.

Relaxed muscles

Gastroesophageal sphincter opens

Digestive System

- Stomach
  - From cardiac orifice to pyloric sphincter
  - Rugae (flatten as stomach fills)
  - Greater curvature
    - Convex lateral surface
    - Greater omentum
  - Lesser curvature
    - Concave medial surface
    - Lesser omentum
Digestive System

- Stomach
  - Four tunics
    - Muscularis
      - Additional layer of muscle in an oblique orientation
      - Three layers of smooth muscle

Digestive System

- Stomach
  - Four tunics
    - Mucosa
      - Gastric glands
        - Mucous cells = Mucus
        - Parietal cells = Intrinsic factor and HCl
        - Zymogenic (chief) cells = Pepsinogen
        - Enteroendocrine cells = Gastrin and cholecystokinin

Mucosa contains gastric glands

(a) Layers of the stomach wall (l.s.)

(b) Enlarged view of gastric pits and gastric glands
Digestive System

- Chemical digestion in the stomach
  - Protein catabolism → polypeptides
  - Secretions HCl
    - Pepsinogen → pepsin
    - HCl
      - pH 1.5–3.5
      - Denatures protein in food
      - Kills many bacteria
    - Intrinsic factor
      - Required for absorption of vitamin B₁₂ in small intestine

- Chemical digestion in the stomach
  - Chyme
  - Product of stomach digestion
  - Prevention of autodigestion
    - Mucous
    - Gastritis
    - Peptic ulcers
      - Gastric ulcers
      - Duodenal ulcers

- Control of gastric secretions
  - Neural control
    - Seeing, smelling, tasting, thinking about food stimulates gastric secretions via the vagus nerve
    - Enteric nervous system provides local control independently of brain and spinal cord
      - Spinal cord injury will not damage!
      - Ischemia can damage, but transplants have been performed since 2011
    - Also subject to ANS control
      - “Rest and digest”

- Control of gastric secretions
  - Hormonal control
    - Gastrin
      - Released reflexively by enteroendocrine cells in response to stomach distension, peptides, and low acidity
      - Release stimulated by caffeine
Digestive System

• Control of gastric secretions
  • Stimulatory and inhibitory events occur in three phases
  1. Cephalic
  2. Gastric
  3. Intestinal

- Hearing, seeing, smelling, tasting, thinking about food
  • Vagus nerve stimulated
  • Gastric secretion starts

- Arrival of food in stomach
  - Stomach distension, peptides, low acidity → gastrin released
    » Relaxes pyloric sphincter
    » Increases stomach motility

- Chyme reaches duodenum
  - Intestinal distension → enterogastric reflex
  - Release of secretin, CCK, VIP
    » Inhibit stomach motility and delay emptying
Figure 23.19

1. **Propulsion**: Peristaltic waves move from the fundus toward the pylorus.
2. **Grinding**: The most vigorous peristalsis and mixing action occur close to the pylorus.
3. **Retropulsion**: The pyloric end of the stomach acts as a pump that delivers small amounts of chyme into the duodenum, simultaneously forcing most of its contained material backward into the stomach.

Figure 23.20

- Presence of fatty, hypertonic, acidic chyme in duodenum
- Duodenal enteroendocrine cells
- Chemoreceptors and stretch receptors
- Enterogastrones (secretin, cholecystokinin, vasoactive intestinal peptide)
- Duodenal stimuli

<table>
<thead>
<tr>
<th>Initial stimulus</th>
<th>Physiological response</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contractile force and rate of stomach emptying decline</td>
<td>CNS centers: sympathetic activity; parasympathetic activity</td>
<td>Stimulate Inhibit</td>
</tr>
</tbody>
</table>

**Digestive System**

- **Small intestine**
  - Major organ of digestion and absorption
  - 2 - 4 m long; from pyloric sphincter to ileocecal valve
- **Subdivisions**
  - Duodenum
  - Jejunum
  - Ileum

- Located within the peritoneal cavity

**Digestive System**

- **Small intestine**
  - Structural modifications
    - Villi ("fingers")
    - Intestinal glands
      - Mucosa
      - Submucosa

- **Vein carrying blood to hepatic portal vessel**

- **Muscle layers**
- **Circular folds**
- **Villi**

(a)
Digestive System

- Chemical digestion in the small intestine
- Food entering SI = partially digested
- Intestinal juice
  - Water, mucous
  - Crypt cells produce lysozyme

Digestive System

- Chemical digestion in the small intestine
- Pancreatic juice
  - Enzymes
    - Amylase
    - Lipase
    - Pancreatic lipase
    - Trypsinogen, chymotrypsinogen, carboxypeptidase
      - Notice the "-ogen"
      - These must be activated to digest protein
  - Sodium bicarbonate
  - Neutralize stomach acid
Digestive System

- Chemical digestion in the small intestine
  - Intestinal juice
    - Alkaline, mucous rich watery secretion
    - Lysosozymes – why are these defensive enzymes so important here?
  - Brush border enzymes
    - Enzymes for carbohydrates and proteins
  - Pancreatic secretions
    - Bicarbonate rich watery secretion
    - Amylases, lipases, proteases, and nucleases
  - Bile
    - Bile salts emulsify lipids

Digestive System

- Accessory digestive organs
  - Liver
    - Gallbladder
  - Pancreas

Digestive System

- Accessory digestive organs
  - Liver
    - Largest internal surface area of any body organ
  - Blood supply
    - Hepatic artery – oxygenated blood to the liver
    - Hepatic-portal vein – venous blood to the liver
    - Hepatic vein – all blood exiting the liver
Digestive System

- Accessory digestive organs
  - Liver
    - Hepatocyte functions
      - Process blood borne nutrients
      - Store fat-soluble vitamins and minerals
      - Glucose is stored as glycogen
      - Perform detoxification
      - Stores fat soluble toxins
      - Produce ~900 ml bile per day
      - Note: gall bladder does not MAKE bile, only stores excess
      - Makes heparin and other plasma proteins
      - Catabolizes nitrogenous wastes

- Bile
  - Yellow-green, alkaline solution
  - Bile salts
    - Cholesterol derivatives that function in fat emulsification & absorption
    - Lack of bile = grayish stools with fatty streaks (acholic feces)

- Bilirubin
  - Pigment formed from heme
  - Metabolized to form urobilinogen → stercobilin
digestive system

- accessory digestive organs
  - liver
    - gallbladder
  - pancreas
    - function: delivers digestive fluids and NaHCO₃ to duodenum via pancreatic duct
    - tissue types:
      - endocrine: islets of Langerhans → insulin and glucagon
      - exocrine: acinar tissue → pancreatic juice

- accessory digestive organs
  - liver
  - gallbladder: thin-walled muscular sac on the ventral surface of the liver
  - stores and concentrates bile by absorbing its water and ions
  - releases bile via the cystic duct
    - flows into the bile duct

miscellaneous

- mouth (oral cavity)
- tongue
- esophagus
- liver
- gallbladder
- anus
- duodenum
- jejunum
- ileum
- small intestine
- parotid gland
- sublingual gland
- submandibular gland
- salivary glands
- pharynx
- stomach
- pancreas
- (spleen)
- transverse colon
- descending colon
- ascending colon
- cecum
- sigmoid colon
- rectum
- vermiform appendix
- anus
- large intestine

- mucosa with folds
- gallbladder
- major duodenal papilla
- hepatopancreatic ampulla and sphincter
- duodenum
- tail of pancreas
- jejunum
- main pancreatic duct and sphincter
- head of pancreas

- acinar cells
- basement membrane
- zymogen granules
- rough endoplasmic reticulum
Digestive System

- Accessory digestive organs
  - Pancreas
    - Secretion mediated by hormones (where were these hormones made?)
    - Secretin
      - Released in response to acid
      - Stimulates release of base from pancreas
      - Also stimulates release of pancreatic secretions and bile
    - Cholecystokinin
      - Released when protein and fat enter intestine
      - Stimulates the release of pancreatic secretions and bile

Digestive System

- Large intestine
  - About 1.5 meters in length in a cadaver (SI about 6m long)
- Functions
  - Vitamins, water, and electrolytes are reclaimed
  - Propulsion of feces toward the anus
  - Colon is not essential for life

Digestive System

- Regions
  - Cecum
  - Colon
  - Rectum
  - Anal canal

Digestive System

- Regions
  - Cecum
    - Blind pouch
    - Appendix attaches to this area
    - Bacteria
    - Immune function
    - Fermentation chamber in some other species
    - Examples: horse, rabbit, koala
Digestive System

- **Regions**
  - Colon
    - Ascending
    - Retroperitoneal
    - Transverse
      - Anchored via mesocolons (mesenteries)
    - Descending
      - Retroperitoneal
    - Sigmoid
      - Anchored via mesocolons (mesenteries)

Digestive System

- **Regions**
  - Rectum
    - Rectal valves stop feces from being passed with gas
  - Anal canal
    - Last segment of the large intestine
      - Internal anal sphincter
      - Smooth muscle (involuntary)
      - Spinal reflex arcs
    - External anal sphincter
      - Skeletal muscle (voluntary)

Digestive System

- **Defecation**
  - Mass movements force feces into rectum
  - Distension initiates spinal defecation reflex
  - Parasympathetic signals
    - Stimulate contraction of the sigmoid colon and rectum
  - Relax the internal anal sphincter
  - Conscious control allows relaxation of external anal sphincter
  - Valsalva’s maneuver
**Digestion**

- Ingested materials must be broken down for absorption
- Majority of absorption in small intestine
  - Water and alcohol in stomach mucosa
  - Water, some salts and water-soluble vitamins in large intestine
- Non-absorbable materials removed by defecation

**Fate of Digested Materials**

**Carbohydrates**
- Glucose, fructose, and galactose are directly absorbed
  - Glucose: metabolized by nearly all cells
  - Fructose: metabolized almost entirely by the liver
    - Converted to glucose → stored as glycogen
    - Converted to glycerol → triglycerides
  - Galactose: metabolized to glucose, mostly in the liver

**Proteins**
- Amino acids, dipeptides, and some tripeptides
  - Absorbed by active transport
  - Further metabolism in cells → free amino acids → bloodstream

**Vitamins**
- K and B12 are byproducts (very small amounts)
Protein digestion

- Amino acids are absorbed by cotransport with sodium ions.
- Some dipeptides and tripeptides are absorbed via cotransport with $H^+$ and hydrolyzed to amino acids within the cells.
- Amino acids leave the epithelial cells by facilitated diffusion, enter the capillary blood in the villi, and are transported to the liver via the hepatic portal vein.

Fate of Digested Materials

- Lipids
  - Emulsified by bile salts and digested by lipase into monoglycerides and FFAs
  - Micelles formed (lipid and bile salts) and move between microvilli
  - Lipids diffuse into intestinal epithelium (bile salts later reabsorbed in ileum)

Fate of Digested Materials

- Lipids
  - Within intestinal cells
    - Triglycerides are formed
      - Combined with proteins and cholesterol in the cell
      - Chylomicrons
      - Enter lymphatics through lacteal
      - Enter blood vascular system

Fate of Digested Materials

- Lipids
  - Plasma enzymes generate FFAs and glycerol
  - Pass thru capillary wall to serve tissues
  - The remaining protein-cholesterol combo returns to liver
  - Additional proteins added
    - HDL and LDL created (carriers for lipids)
Fat digestion

- Foodstuff
- Enzymes(s) and source
- Site of action
- Path of absorption

Unemulsified fats
- Emulsification by the detergent action of bile ducts from the liver
- Small intestine
- Pancreatic lipases
- Water

- Monoglycerides
- Glycerol and fatty acids
- Small intestine
- Path of absorption

- Fatty acids and monoglycerides enter the intestinal cells via diffusion.
- Fatty acids and monoglycerides are recombined to form triglycerides and then combined with other lipids and proteins within the cells, and the resulting chylomicrons are extruded by exocytosis.
- The chylomicrons enter the lacteals of the villi and are transported to the systemic circulation via the lymph in the thoracic duct.
- Some short-chain fatty acids are absorbed, move into the capillary blood in the villi by diffusion, and are transported to the liver via the hepatic portal vein.

Fate of Digested Materials

- Water
  - After digested nutrients removed, large volumes of salt and water remain in LI
  - Active Na+ uptake → passive Cl- and water uptake
    - Undigested materials (cellulose) cause water to be retained in LI
    - Antibiotics may kill bacteria → digestion impaired

Disorders of the Digestive System

- Colon cancer
  - Second most common cause of cancer death in U.S. in men
    - 98,000 new cases annually
    - 48,000 deaths/year
  - Diagnosis
    - Colonoscopy

Disorders of the Digestive System

- Gallstones
  - A.K.A. cholelithiasis
  - Bile salts precipitate
    - Block bile ducts
    - Jaundice due to bilirubin
  - Treatment
    - Lithotripsy
    - Medications
    - Cholecystectomy

Disorders of the Digestive System

- Celiac disease
  - Autoimmune disease
  - Immune system destroys intestinal villi in response to gluten
  - No villi = no nutrient absorption