Chapter 24
Digestive System

1. **Ingestion**: introduction of food into stomach

2. **Mastication**: chewing. Chemical digestion requires large surface area so breaking down large particles mechanically facilitates chemical digestion.

3. **Propulsion**
   - **Deglutition**: swallowing
   - **Peristalsis**: moves material through digestive tract. A wave of circular smooth muscle relaxation moves ahead of the bolus of food or chyme allowing the digestive tract to expand. Then a wave of contraction of the circular smooth muscles behind the bolus of food or chyme propels it through the digestive tract.
     - **Mass movements** in large intestine

**Functions**
4. Mixing: Segmental contraction

Functions, cont.

5. **Secretion**: lubricate, liquefy, digest
   Mucus: secreted along entire digestive tract, lubricates food and lining, coats lining and protects from mechanical digestion, from acid and from digestive enzymes.
   Water: liquefaction makes food easier to digest and absorb
   **Bile**: emulsifies fats
   **Enzymes**: chemical digestion

6. **Digestion**: Mechanical and chemical

7. **Absorption**: Movement from tract into circulation or lymph

8. **Elimination**: Waste products removed from body; feces. **Defecation**
Digestive Tract Histology: The Tunics

**Mucosa.** Innermost layer, consisting of mucous epithelium (stratified squamous in mouth, oropharynx, esophagus and anal canal), simple columnar epithelium in the rest of the tract.
- Loose connective tissue: *lamina propria*
  Note: Muscularis mucosae: smooth muscle
**Submucosa.** Thick C.T. layer with nerves, blood vessels, small glands. Parasympathetic submucosal plexus.

Digestive System Regulation

- **Nervous** regulation
  - Local: *enteric nervous system*
    - Coordinates peristalsis and regulates local reflexes
  - General: coordination with the CNS. May initiate reflexes because of sight, smell, or taste of food. **Parasympathetic primarily.** Sympathetic input inhibits muscle contraction, secretion, and decrease of blood flow to the digestive tract.
- **Chemical** regulation
  - Production of hormones to be discussed later
    - Gastrin, secretin
  - Production of paracrine chemicals like histamine
    - Help local reflexes in ENS control the conditions of the internal environment of the digestive tract such as pH levels.
### Peritoneum and Mesenteries

- **Peritoneum**
  - **Visceral**: Covers organs
  - **Parietal**: Covers interior surface of body wall
  - **Retroperitoneal**: Certain organs covered by peritoneum on only one surface and are considered behind the peritoneum; e.g., kidneys, pancreas, duodenum

- **Mesenteries**: two layers of peritoneum with thin layer of loose C.T. between
  - Routes by which vessels and nerves pass from body wall to organs
  - **Greater omentum**: connects greater curvature of the stomach to the transverse colon.
  - **Lesser omentum**: connects lesser curvature of the stomach and the proximal part of the duodenum to the liver and diaphragm.
  - **Transverse mesocolon, sigmoid mesocolon, mesoappendix.**

- **Ligaments**

### Oral Cavity

- Bounded by lips anteriorly, **fauces** (opening into pharynx) posteriorly
  - **Vestibule**: space between lip/cheeks and alveolar processes with teeth
  - **Oral cavity proper**: medial to alveolar processes
  - Lined with moist stratified squamous epithelium
Tongue

• Muscular with free anterior surface and attached posterior surface. Covered with moist stratified squamous epithelium.
  – **Intrinsic muscles**: change shape
  – **Extrinsic muscles**: protrude or retract tongue, move side to side
• **Lingual frenulum** attaches tongue inferiorly to floor of oral cavity
• Anterior part: **papillae**, some of which have taste buds
• Posterior part: no papillae and a few scattered taste buds. Lymphoid tissue embedded in posterior surface: **lingual tonsil**
• Moves food in mouth,参与speech and swallowing

Teeth

• Two sets
  – **Primary, deciduous, milk**: Childhood
  – **Permanent or secondary**: Adult (32)
• Types
  – **Incisors, canines, premolars and molars**
Saliva

- EXOCRINE Compound alveolar salivary glands. Produce saliva
  - Prevents bacterial infection
  - Lubrication
  - Contains salivary amylase that breaks down starch into disaccharides maltose and isomaltose.
  - Helps to form bolus for swallowing
  - Parasympathetic input causes salivary production

Salivary Glands

- Three pairs of multicellular glands
  - Parotid: largest. Serous. Just anterior to the ear. Parotid duct crosses over masseter, penetrates buccinator, and enters the oral cavity adjacent to the 2nd upper molar
  - Submandibular: mixed, but more serous than mucous. Posterior half of inferior border of mandible. Duct enters oral cavity on either side of lingual frenulum
  - Sublingual: smallest. Mixed, but primarily mucous. Each has 10-12 ducts that enter the floor of the oral cavity.
- Lingual glands. Small, coiled tubular glands on surface of tongue.
Pharynx and Esophagus

- **Pharynx**
  - Posterior walls of oropharynx and laryngopharynx contains group of muscles called pharyngeal constrictors that contribute to swallowing

- **Esophagus**
  - Transports food from pharynx to stomach
  - Passes through *esophageal hiatus* (opening) Hiatal hernia: widening of hiatus
  - **Sphincters**
    - Upper. Striated
    - Lower. Smooth
  - Mucosa is moist stratified squamous epithelium. Produces thick layer of mucus.

Three Phases of Swallowing
**Stomach Anatomy**

- **Openings**
  - Gastroesophageal (cardiac): to esophagus
  - Pyloric: to duodenum
- **Regions**
  - Cardiac
  - Fundus
  - Body
  - Pyloric: antrum and canal
- **Greater and lesser curvatures:** attachment sites for omenta
- **Sphincters**
  - Cardiac (lower esophageal)
  - Pyloric

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**Stomach Histology**

- **Layers**
  - Serosa or visceral peritoneum: outermost
  - Muscularis: three layers
    - Outer longitudinal
    - Middle circular
    - (Inner oblique)
  - Submucosa
  - Mucosa
- **Rugae:** folds in stomach when empty.
Gastric Phase

- Distention of the stomach activates a parasympathetic reflex. Action potentials are carried by the vagus nerves to the medulla oblongata.
- Medulla oblongata stimulates further secretions of the stomach.
- Distention also stimulates local reflexes that amplify stomach secretions.
Movements in Stomach

- Combination of mixing waves (80%) and peristaltic waves (20%)
- Both esophageal and pyloric sphincters are closed.

Small Intestine

- Site of greatest amount of digestion and absorption of nutrients and water
- Divisions
  - Duodenum- first 25 cm beyond the pyloric sphincter.
  - Jejunum- 2.5 m
  - Ileum- 3.5 m. Peyer’s patches or lymph nodules
Duodenum

- Curves to the left; head of pancreas in the curve
- Major and minor duodenal papillae: openings to ducts from liver and/or pancreas.

 Modifications to Increase Surface Area

- Increase surface area 600 fold
  - Plicae circulares (circular folds)
  - Villi that contain capillaries and lacteals. Folds of the mucosa
  - Microvilli: folds of cell membranes of absorptive cells
Jejunum and Ileum

- Gradual decrease in diameter, thickness of intestinal wall, number of circular fold, and number of villi the farther away from the stomach
- Major site of nutrient absorption
- **Peyer’s patches**: lymphatic nodules numerous in mucosa and submucosa
- **Ileocecal junction**: where ilium meets large intestine. **Ileocecal sphincter** and **ileocecal valve**

Liver

- **Lobes**
  - **Major**: Left and right
  - **Minor**: Caudate and quadrate
- **Porta**: on inferior surface. Vessels, ducts, nerves, exit/enter liver
- **Ducts**
  - **Right and left hepatics** unite to form
  - **Common hepatic**
  - **Cystic**: from gallbladder
  - **Common bile**: union of cystic duct and common hepatic duct
Liver, Gallbladder, Pancreas and Ducts

Histology of the Liver

- C.T. Divides liver into lobules
- Nerves, vessels and ducts follow the septa
  - Lobules: portal triad at each corner
    - Three vessels: hepatic portal vein, hepatic artery, hepatic duct
    - Central vein in center of lobule
  - Central veins unite to form hepatic veins that exit liver and empty into inferior vena cava
Functions of the Liver

• **Bile production**: 600-1000 mL/day. Bile salts (bilirubin), cholesterol, fats, fat-soluble hormones, lecithin
  - Neutralizes and dilutes stomach acid
  - Bile salts emulsify fats. Most are reabsorbed in the ileum.
  - Secretin (from the duodenum) stimulates bile secretions, increasing water and bicarbonate ion content of the bile

• **Storage**
  - Glycogen, fat, vitamins, copper and iron. Hepatic portal blood comes to liver from small intestine.

• **Nutrient interconversion**
  - Amino acids to energy producing compounds
  - Hydroxylation of vitamin D. Vitamin D then travels to kidney where it is hydroxylated again into its active form

• **Detoxification**
  - Hepatocytes remove ammonia and convert to urea

• **Phagocytosis**
  - Kupffer cells phagocytize worn-out and dying red and white blood cells, some bacteria

• **Synthesis**
  - Albumins, fibrinogen, globulins, heparin, clotting factors

Control of Bile Secretion and Release
Pancreas

- Pancreas both endocrine and exocrine
- **Head, body** and **tail**
- Endocrine: **pancreatic islets**. Produce insulin, glucose, and somatostatin
- Exocrine: groups **acini** (grape-like cluster) form **lobules** separated by septa.
- Pancreatic duct joins common bile duct and enters duodenum at the **hepatopancreatic ampulla** controlled by the **hepatopancreatic ampullar sphincter**

Pancreatic Secretions: Pancreatic Juice

- Aqueous. Produced by columnar epithelium lining smaller ducts. Na⁺, K⁺, HCO₃⁻, water. Bicarbonate lowers pH inhibiting pepsin and providing proper pH for enzymes
- Enzymatic portion:
  - Interaction of duodenal and pancreatic enzymes.
    - **Enterokinase** from the duodenal mucosa and attached to the brush border activates trypsinogen to **trypsin**.
    - Trypsin activates chymotrypsinogen to **chymotrypsin**
    - Trypsin activates **procarboxypeptidase** to carboxypeptidase.
  - Trypsin, chymotrypsin and carboxypeptidase digest proteins: proteolytic.
  - Pancreatic amylase continues digestion of starch
  - Pancreatic lipase digests lipids
  - Deoxyribonucleases and ribonucleases digest DNA and ribonucleic acid, respectively
Large Intestine

- Extends from ileocecal junction to **anus**
- Consists of **cecum, colon, rectum, anal canal**
- Movements sluggish (18-24 hours); chyme converted to feces.
- Absorption of water and salts, secretion of mucus, extensive action of microorganisms.
- 1500 mL chyme enter the cecum, 90% of volume reabsorbed yielding 80-150 mL of feces

Anatomy of Large Intestine

- **Cecum**
  - Blind sac, **vermiform appendix** attached. Appendix’ walls contain numerous lymph nodules
- **Colon**
  - **Ascending, transverse, descending, sigmoid**
  - Circular muscle layer complete; longitudinal incomplete (three **teniae coli**). Contractions of teniae form pouches called **haustra**. Small fat filled pouches called **epiploic appendages**
  - Mucosa has numerous straight tubular glands called **crypts**. Goblet cells predominate, but there are also absorptive and granular cells as in the small intestine
Secretions of Large Intestine

- **Mucus** provides protection
  - Parasympathetic stimulation increases rate of goblet cell secretion
- **Pumps:** bacteria produce acid and the following remove acid from the epithelial cells that line the large intestine
  - Exchange of bicarbonate ions for chloride ions
  - Exchange of sodium ions for hydrogen ions
- **Bacterial actions** produce gases (flatus) from particular kinds of carbohydrates found in legumes and in artificial sugars like sorbitol
- **Bacteria** produce vitamin K which is then absorbed
- **Feces** consists of water, undigested food (cellulose), microorganisms, sloughed-off epithelial cells

Movement in Large Intestine

- **Mass movements**
  - Common after meals
  - Integrated by the enteric plexus
- **Local reflexes** instigated by the presence of food in the stomach and duodenum
  - **Gastrocolic:** initiated by stomach
  - **Duodenocolic:** initiated by duodenum
- **Defecation**
  - **Defecation reflex:** distension of the rectal wall by feces
  - Parasympathetic stimulation
  - Usually accompanied by voluntary movements to expel feces. Abdominal cavity pressure caused by inspiration and by contraction of muscles of abdominal wall.
Lipoproteins

- All lipids carried in the blood are done so in combination with protein to make them soluble in plasma.
- Cholesterol: 15% ingested; 85% manufactured in liver and intestinal mucosa.
- Lipids are lower density than water; proteins are higher density than water.
- Chylomicrons: 99% lipid and 1% protein (extremely low density); enter lymph.
- **VLDL**: 92% lipid, 8% protein
  - Form in which lipids leave the liver
  - Triglycerides removed from VLDL and stored in adipose cells. VLDL has been converted to LDL.
- **LDL**: 75% lipid, 25% protein
  - Transports cholesterol to cells
  - Cells have LDL receptors
  - # of LDL receptors become less once cell’s lipid/cholesterol needs are met.
- **HDL**: 55% lipid, 45% protein
  - Transports excess cholesterol from cells to liver.

Water and Ions

- Water: can move in either direction across wall of small intestine depending on osmotic gradients.
- Ions: sodium, potassium, calcium, magnesium, phosphate are actively transported.
Effects of Aging

• Decrease in mucus layer, connective tissue, muscles and secretions
• Increased susceptibility to infections and toxic agents, increase in incidences of ulcerations and cancers