Chapter 24: The Digestive System

2 groups of organs compose the digestive system
- Gastrointestinal (GI) tract or alimentary canal – mouth, most of pharynx, esophagus, stomach, small intestine, and large intestine
- Accessory digestive organs – teeth, tongue, salivary glands, liver, gallbladder, and pancreas

6 functions of the digestive system
1. Ingestion
2. Secretion of water, acid, buffers, and enzymes into lumen
3. Mixing and propulsion
4. Digestion
   - Mechanical digestion churns food
   - Chemical digestion – hydrolysis
5. Absorption – passing into blood or lymph
6. Defecation – elimination of feces

Layers of the GI tract
- Wall of GI tract from lower esophagus to anal canal has same basic 4 layers
  1. Mucosa – inner lining
     - Epithelium protection, secretion, absorption
     - Lamina propria – connective tissue with blood and lymphatic vessels and mucosa-associated lymphatic tissue (MALT)
     - Muscularis mucosae – thin layer of smooth muscle making folds to increase surface area
  2. Submucosa
     - Connective tissue binding mucosa to muscularis
     - Contains many blood and lymphatic vessels
     - Submucosal plexus

Layers of the GI tract
- Muscularis
  - Voluntary skeletal muscle found in mouth, pharynx, upper 2/3 of esophagus, and anal sphincter
  - Involuntary smooth muscle elsewhere
    - Arranged in inner circular fibers and outer longitudinal fibers
    - Myenteric plexus between muscle layers
- Serosa
  - Outermost covering of organs suspended in abdominopelvic cavity
  - Also called visceral peritoneum
  - Esophagus lacks serosa – has adventitia
Layers of the gastrointestinal tract

Neural innervation

- Enteric nervous system (ENS)
  - Intrinsic set of nerves – “brain of gut”
  - Neurons extending from esophagus to anus
  - 2 plexuses
    - Myenteric plexus – GI tract motility
    - Submucosal plexus – controlling secretions
- Autonomic nervous system
  - Extrinsic set of nerves
  - Parasympathetic stimulation increases secretion and activity by stimulating ENS
  - Sympathetic stimulation decreases secretion and activity by inhibiting ENS

Organization of the enteric nervous system

Peritoneum

- Largest serous membrane of the body
- Divided into
  - Parietal peritoneum – lines wall of cavity
  - Visceral peritoneum – covers some organs
    - Also called serosa
  - Space between is peritoneal cavity
  - 5 major peritoneal folds
    - Greater omentum, falciform ligament, lesser omentum, mesentery, and mesocolon
    - Weave between viscera binding organs together

Peritoneal Folds
Mouth

- Oral or buccal cavity
- Formed by cheeks, hard and soft palates, and tongue
- Oral cavity proper is a space that extends from gums and teeth to fauces (opening between oral cavity and oropharynx)
- Salivary glands release saliva
  - Ordinarily, just enough is secreted to keep mouth and pharynx moist and clean
  - When food enters mouth, secretion increases to lubricate, dissolve and begin chemical digestion
  - 3 pairs of major salivary glands secrete most of the saliva
    - Parotid, submandibular, and sublingual

Saliva

- Mostly water 99.5%
- 0.5% solutes – ions, dissolved gases, urea, uric acid, mucus, immunoglobulin A, lysozyme, and salivary amylase (acts on starch)
- Not all salivary glands produce the same saliva
- Salivation
  - Controlled by autonomic nervous system
  - Parasympathetic stimulation promotes secretion of moderate amount of saliva
  - Sympathetic stimulation decreases salivation

Tongue and Teeth

- Tongue
  - Accessory digestive organ
  - Skeletal muscle covered by mucous membrane
  - Maneuvers food for chewing, shapes mass, forces food back for swallowing
  - Lingual glands secrete salivary lipase
- Teeth or dentes
  - Accessory digestive organ
  - 3 major regions – crown, root, and neck
  - Dentin of crown covered by enamel
  - 2 dentitions – deciduous and permanent teeth

Structures of the mouth (oral cavity)

The three major salivary glands - parotid, sublingual, and submandibular

A typical tooth and surrounding structures
**Digestion in the mouth**

- Mechanical digestion in the mouth
  - Chewing or mastication
  - Food manipulated by tongue, ground by teeth, and mixed with saliva
  - Forms bolus
- Chemical digestion in the mouth
  - Salivary amylase secreted by salivary glands acts on starches
    - Only monosaccharides can be absorbed
    - Continues to act until inactivated by stomach acid
  - Lingual lipase secreted by lingual glands of tongue acts on triglycerides
    - Becomes activated in acidic environment of stomach

**Pharynx**

- Passes from mouth into pharynx
- 3 parts
  - Nasopharynx
    - Functions only in respiration
  - Oropharynx
    - Digestive and respiratory functions
  - Laryngopharynx
    - Digestive and respiratory functions

**Esophagus**

- Secretes mucous, transports food – no enzymes produced, no absorption
- Mucosa – protection against wear and tear
- Submucosa
- Muscularis divided in thirds
  - Superior 1/3 skeletal muscle
  - Middle 1/3 skeletal and smooth muscle
  - Inferior 1/3 smooth muscle
- 2 sphincters – upper esophageal sphincter (UES) regulates movement into esophagus, lower esophageal sphincter (LES) regulates movement into stomach
- Adventitia – no serosa – attaches to surroundings

**Histology of the esophagus**

**Deglutition**

- Act of swallowing
- Facilitated by secretions of saliva and mucus
- Involves mouth, pharynx, and esophagus
- 3 stages
  - Voluntary – bolus passed to oropharynx
  - Pharyngeal – involuntary passage through pharynx into esophagus
  - Esophageal – involuntary passage through esophagus to stomach
  - Peristalsis pushes bolus forward

**Deglutition (swallowing)**
**Stomach**
- Serves as mixing chamber and holding reservoir
- 4 main regions: Cardia, fundus, body, pylorus
- Same 4 layers:
  - Mucosa – gastric glands open into gastric pits
    - 3 types of exocrine gland cells – mucous neck cells (mucus), parietal cells (intrinsic factor and HCl), and chief cells (pepsinogen and gastric lipase)
  - G cell – endocrine cell
  - Submucosa
  - Muscularis – additional 3rd inner oblique layer
  - Serosa – part of visceral peritoneum

**External and internal anatomy of the stomach**

**Histology of the stomach**

**Mechanical and Chemical Digestion**
- Mechanical digestion
  - Mixing waves – gentle, rippling peristaltic movements – creates chyme
- Chemical digestion
  - Digestion by salivary amylase continues until inactivated by acidic gastric juice
  - Acidic gastric juice activates lingual lipase
    - Digest triglycerides into fatty acids and diglycerides
  - Parietal cells secrete H+ and Cl- separately but net effect is HCl
    - Kills many microbes, denatures proteins

**Chemical Digestion**
- Chemical digestion (cont.)
  - Pepsin secreted by chief cells digest proteins
    - Secreted as pepsinogen
  - Gastric lipase splits triglycerides into fatty acids and monoglycerides
- Small amount of nutrient absorption
  - Some water, ions, short chain fatty acids, certain drugs (aspirin) and alcohol

**Pancreas**
- Lies posterior to greater curvature of stomach
- Pancreatic juice secreted into pancreatic duct and accessory duct and to small intestine
  - Pancreatic duct joins common bile duct and enters duodenum at hepatopancreatic ampulla
- Histology
  - 99% of cells are acini
    - Exocrine
    - Secrete pancreatic juice – mixture of fluid and digestive enzymes
  - 1% of cells are pancreatic islets (islets of Langerhans)
    - Endocrine
    - Secrete hormones glucagon, insulin, somatostatin, and pancreatic polypeptide
Relation of the pancreas to the liver, gallbladder, and duodenum

Pancreatic juice
- 1200-1500ml daily
- Mostly water
  - Sodium bicarbonate — buffers acidic stomach chyme
  - Enzymes
    - Pancreatic amylase
    - Proteolytic enzymes — trypsin (secreted as trypsinogen), chymotrypsin (chymotrypsinogen), carboxypeptidase (procarboxypeptidase), elastase (proelastase)
    - Pancreatic lipase
    - Ribonuclease and deoxyribonuclease

Liver and gallbladder
- Liver is the heaviest gland of the body
- Liver is composed of
  - Hepatocytes — major functional cells of liver
    - Wide variety of metabolic, secretory, and endocrine functions — secrete bile (excretory product and digestive secretion)
  - Bile canaliculi — ducts between hepatocytes that collect bile
    - Exit livers as common hepatic duct, joins cystic duct from gallbladder to form common bile duct
  - Hepatic sinusoids — highly permeable blood capillaries receiving oxygenated blood from hepatic artery and deoxygenated nutrient-rich blood from hepatic portal vein
  - 3 different ways to organize units
    - Hepatic acinus — preferred method
      - Hepatocytes arranged in 3 zones around short axis with no sharp boundaries

Histology of the Liver

Gallbladder
- Contraction of smooth muscle fibers eject contents of gall bladder into cystic duct
- Functions to store and concentrate bile produced by the liver until it is needed in the small intestine
- Absorbs water and ions to concentrate bile up to ten-fold
Hepatic blood flow

- Liver receives blood from
- Hepatic artery carrying oxygenated blood
- Hepatic portal vein carrying deoxygenated blood with newly absorbed nutrients and possibly drugs, microbes or toxins from GI tract

Role and composition of bile

- Hepatocytes secrete 800-1000mL of bile daily
- Mostly water, bile salts, cholesterol, lecithin, bile pigments and several ions
- Partially excretory product/ partially digestive secretion
- Bilirubin – principal bile pigment
  - Derived from heme of recycled RBCs
  - Breakdown product stercobilin gives feces brown color
- Bile salts play role in emulsification
  - Also aid in absorption of lipids following digestion

Small intestine

- 3 regions – duodenum, jejunum, and ileum
- Same 4 layers
  1. Mucosa
     - Absorptive cells (digest and absorb), goblet cells (mucus), intestinal glands (intestinal juice), Paneth cells (lysozyme), and enteroendocrine cells
     - Abundance of MALT
  2. Submucosa
     - Duodenal glands secrete alkaline mucus
  3. Muscularis
  4. Serosa
     - Completely surrounds except for major portion of duodenum

Anatomy of the small intestine

Special structural features increase surface area for digestion and absorption

- Circular folds
  - Permanent ridges of mucosa and submucosa
  - Cause chyme to spiral
- Villi
  - Fingerlike projections of mucosa
  - Contains arteriole, venule, blood capillary, and lacteal
- Microvilli
  - Projects of apical membrane of absorptive cells
  - Brush border with brush border enzymes

Histology of the small intestine
Histology of the duodenum and ileum

Intestinal juice and brush-border enzymes

- Intestinal juice
  - 1-2L daily
  - Contains water and mucus, slightly alkaline
  - Provide liquid medium aiding absorption

- Brush border enzymes
  - Inserted into plasma membrane of absorptive cells
  - Some enzymatic digestion occurs at surface rather than just in lumen
  - α-dextrinase, maltase, sucrase, lactase, aminopeptidase, dipeptidase, nucleosidases and phosphatases

Mechanical Digestion

- Governed by myenteric plexus
- Segmentations
  - Localized, mixing contractions
  - Mix chyme and bring it in contact with mucosa for absorption
- Migrating motility complexes (MMC)
  - Type of peristalsis
  - Begins in lower portion of stomach and pushes food forward

Chemical digestion

- Carbohydrates
  - Pancreatic amylase
  - α-dextrinase, sucrase, lactase, maltase in brush border
  - Ends with monosaccharides which can be absorbed

- Proteins
  - Trypsin, chymotrypsin, carboxypeptidase, and elastase from pancreas
  - Aminopeptidase and dipeptidase in brush border

Lipids and Nucleic Acids

- Lipids
  - Pancreatic lipase most important in triglyceride digestion
  - Emulsification by bile salts increases surface area
    - Amphipathic – hydrophobic and hydrophilic regions
- Nucleic acids
  - Ribonuclease and deoxyribonuclease in pancreatic juice
  - Nucleosidases and phosphatases in brush border

Absorption of:

- Monosaccharides
  - All dietary carbohydrates digested are absorbed
  - Only indigestible cellulose and fibers left in feces
  - Absorbed by facilitated diffusion or active transport into blood

- Amino acids, dipeptides and tripeptides
  - Most absorbed as amino acids via active transport into blood
  - ½ of absorbed amino acids come from proteins in digestive juice and dead mucosal cells
Lipids

- All dietary lipids absorbed by simple diffusion
- Short-chain fatty acids go into blood for transport
- Long-chain fatty acids and monoglycerides
  - Large and hydrophobic
  - Bile salts form micelles to ferry them to absorptive cell surface
  - Reform into triglycerides forming chylomicrons
  - Leave cell by exocytosis
  - Enter lacteals to eventually enter blood with protein coat of chylomicron keeping them suspended and separate

Absorption of digested nutrients in the small intestine

Absorption of:

- Electrolytes
  - From GI secretions or food
  - Sodium ions (Na+) reclaimed by active transport
  - Other ions also absorbed by active transport
- Vitamins
  - Fat-soluble vitamins A, D, E, and K absorbed by simple diffusion and transported with lipids in micelles
  - Most water-soluble vitamins also absorbed by simple diffusion
- Water
  - 9.3L comes from ingestion (2.3L) and GI secretions (7.0L)
  - Most absorbed in small intestine, some in large intestine
  - Only 100mL excreted in feces
  - All water absorption by osmosis

Daily volumes of fluid ingested, secreted, absorbed, and excreted from the GI tract

Large intestine

- Overall function to complete absorption, produce certain vitamins, and form and expel feces
- 4 major regions – cecum, colon, rectum, and anal canal
- Ileocecal sphincter between small and large intestine
- Colon divided into ascending, transverse, descending and sigmoid
- Opening of anal canal (anus) guarded by internal anal sphincter of smooth muscle and external anal sphincter of skeletal muscle

Anatomy of the large intestine
**Large Intestine**

- Same 4 layers
- Mucosa – mostly absorptive and goblet cells
  - No circular folds or villi
  - Does have microvilli
- Submucosa
- Muscularis
  - Longitudinal muscle modified to form teniae coli
  - Forms haustra – pouches
- Serosa

**Digestion of the Large Intestine**

- Mechanical digestion
  - Haustral churning
  - Peristalsis
  - Mass peristalsis – drives contents of colon toward rectum
- Chemical digestion
  - Final stage of digestion through bacterial action
    - Ferment carbohydrates, produce some B vitamins and vitamin K
    - Mucus but no enzymes secreted
- Remaining water absorbed along with ions and some vitamins

**Histology of the large intestine**

- Phases of digestion
  - Cephalic phase
    - Smell, sight, thought or initial taste of food activates neural centers – prepares mouth and stomach for food to be eaten
  - Gastric phase
    - Neural and hormonal mechanisms promote gastric secretion and motility
  - Intestinal phase
    - Begins when food enter small intestine
    - Slows exit of chyme from stomach
    - Stimulates flow of bile and pancreatic juice

**The gastric phase of digestion**
End of Chapter 24

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