The Digestive System

Digestive Structures
- Mouth including teeth and tongue
- Esophagus
- Stomach
- Small intestine
- Large intestine
- Accessory structures - salivary glands, liver, gallbladder, & pancreas

Digestive Processes
- Digestion - the steps required to break down food to the molecular level and absorb the molecules across the digestive surface
- Digestion includes:
  - Ingestion
  - Mechanical digestion
  - Chemical digestion
  - Absorption
  - Defecation

Layers of the GI Tract
- Mucosa
  - Epithelium - simple columnar in stomach and intestines for secretion and absorption; also exocrine (mucus and fluid) and enteroendocrine (hormones) cells
  - Lamina propria - areolar connective and MALT tissue
  - Muscularis mucosae - establishes folded surface
- Submucosa
  - Areolar connective tissue
  - Vascularized
  - Submucosal plexus - mucosal muscle, vasoconstriction and secretion
- Muscularis
  - Two layers of smooth muscle (3 in portions of stomach) from lower esophagus through anus, skeletal muscle above and below (external anal sphincter)
  - Myenteric plexus - motility
- Serosa (below diaphragm - visceral peritoneum)

Extensions of Peritoneum
- Mesentery - holds small intestine
- Mesocolon - suspends large intestine
- Falciform ligament - attaches liver
- Lesser omentum - suspends stomach and upper small intestine
• Greater omentum - drapes anteriorly & contains lymph nodes and fat

**Mouth**

• Mastication
  – Biting, cutting and chewing action of the teeth
  – Use of tongue for manipulation of food during chewing & swallowing
    • Composed of skeletal muscle (intrinsic and extrinsic) covered by mucous membrane
    • Surface covered with papillae, some with taste buds
  – Saliva lubricates, dissolves & begins digestion of carbohydrates
    • Also important in keeping mucous membranes moist and for speech
    • Saliva mostly from three pairs of salivary glands (parotids, submandibulars, & sublinguals)
    • Saliva 99.5% water, remaining portion: salts, urea/uric acid, immunoglobulin A/lysozyme, enzymes (amylase, lipase) & other organic substances
      – Amylase catabolizes starches (polysaccharides) to disaccharides and other products - activated by Cl⁻
      – Lingual lipase - triglycerides to fatty acids and monoglycerides (becomes active in stomach acidic environment)
    • Mumps - inflammation of the parotids caused by virus

• Deglutition (swallowing)
  – Voluntary stage - movement of bolus to oropharynx with tongue
  – Involuntary stages - pharyngeal and esophageal stages

**Esophagus**

• Transports bolus to stomach via peristalsis
• Contains both upper & lower esophageal sphincters
  – When gastroesophageal sphincter leaks - heartburn

**Stomach**

• Valves at both ends - gastroesophageal and pyloric sphincters
• Subdivisions - cardia, fundus, body, pylorus
• Secretions - mucus from mucus cells, HCl & intrinsic factor (for Vit B₁₂ absorption) from parietal cells, pepsinogen (precursor of pepsin) from chief cells, and gastrin from enteroendocrine (G) cells

**Chyme production**

• Mechanical - smooth muscle contraction
• Chemical - largely protein to peptide digestion by pepsin in acidic environment
  – Continued amylase digestion of starch (in fundus)
  – Gastric lipase (also chief cells) breaks up small chained triglycerides
    • Important in infants - aids digestion of milk
  – Lingual lipase (secreted by surface cells on the tongue) attack fats
  – Low pH denatures proteins, and kills many microbes

**Gastric Regulation**
Both nervous and hormonal regulation

Three phases - cephalic, gastric, intestinal
  – Peristalsis and gastric emptying stimulated except during intestinal phase
  – During gastric phase, distention, partially digested proteins, alcohol, and caffeine stimulate production of gastrin, which in turn stimulates gastric juice production and peristalsis
  – Gastrin production inhibited by intestinal phase and low pH (below 2)
  – Histamine released by mast cells in lamina propria (histamine receptors on parietal cells) enhances effects of ACh from parasympathetic system & gastrin on HCl production
  – Intestinal phase is inhibitory due to hormones produced by enteroendocrine cells & NS reflex
    • Cholecystokinin (CCK) in response to amino acids and fatty acids, inhibits stomach emptying
    • Secretin in response to low pH, inhibits gastric secretions
    • Enterogastric reflex stimulates sympathetic NS (inhibits parasympathetic) to reduce stomach activity

Gastric Absorption
• Some water
• Electrolytes
• Certain drugs (e.g. aspirin)
• Some alcohol (particularly when fatty foods prolong stomach emptying)

Small Intestine
• Majority of both digestion and absorption
• Valves on both ends - pyloric sphincter and ileocecal valve
• Subdivisions - duodenum, jejunum, ileum
  – Other structures include circular folds (plica), villi, microvilli (brush border) & length
    • All important to function
• Secretions - mucus from goblet cells, variety of enzymes from brush border (for carbohydrates, proteins & nucleic acids), variety of enzymes from pancreas, bile from liver/gallbladder

Pancreas
• Broad range of enzymes including:
  – Starch - pancreatic amylase
  – Protein - trypsin, chymotrypsin, & carboxypeptidase
  – Fat - pancreatic lipase
  – Nucleic acid - ribonuclease & deoxyribonuclease
• Sodium bicarbonate to neutralize stomach acid
• Secretions transported via pancreatic duct to common bile duct, or accessory duct direct

Pancreatic Regulation
• Parasympathetic NS stimulates pancreatic enzymes
• During intestinal phase
  – CCK stimulates pancreatic enzymes
  – Secretin stimulates bicarbonate secretion

Liver
• Complex structure supplied with two sources of blood - hepatic artery & hepatic portal vein (all leave via hepatic vein)
• Bile produced by hepatocytes
  – Consists of water, bile salts (of Na & K), cholesterol, lecithin (phospholipid), bile pigment (bilirubin from a waste product from hemoglobin)
    • Jaundice - inability to remove bilirubin
  – Released via common hepatic duct (stored in gallbladder for later use)
    • Gallbladder also concentrates bile
  – Bile salts emulsify fats (forming micelles due to polar & nonpolar nature)

Regulation of Bile Release
• Parasympathetic NS stimulates bile production
• CCK increase contraction of gallbladder
• Secretin enhances production of bicarbonate rich bile

Other Liver Function
• Carbohydrate, fat and protein metabolism
• Removal of drugs & hormones from blood
• Storage of vitamins and minerals
• Phagocytosis of worn-out blood cells and some bacteria
• Activation of Vit D

Digestion in the Small Intestine
• Mechanical - segmentation, peristalsis
• Chemical - intestinal juice, enzymes from pancreas and brush border
  – Intestinal juice mostly water and mucous with pH of 7.6
  – Enzymes - see Exhibit 24.5
    • Many enzymes held at surface of absorptive cells, digestion and absorption in close proximity
    • Lactose intolerance due to absence of lactase produced by brush boarder

Regulation of Secretion and Motility
• Largely due to localized reflex due to presence of chyme
• Parasympathetic NS increases motility
• Vasoactive intestinal polypeptide (VIP) increases intestinal juice

Absorption in Small Intestine
• 90% in small intestine including simple sugars, amino acids, peptides, fatty acids, water, electrolytes and vitamins
• Varied types - see figure 24.24
  – Diffusion
  – Facilitated Diffusion
  – Osmosis
  – Active transport
• Before leaving absorptive cells, triglycerides are reformed and coated in protein - chylomicron

**Large Intestine**
• Valves on both ends - ileocecal valve & internal anal sphincter
• Subdivisions - cecum (with appendix), colon (ascending, transverse, descending, & sigmoid), rectum and anal canal
  – Haustra of colon are series of pouches due to contraction of longitudinal muscles
• Secretions - mucus

**Digestion in Large Intestine**
• Mechanical - haustral churning, peristalsis, mass peristalsis (starting at transverse colon)
• Biological rather than enzymatic digestion
  – Fermentation of carbohydrates & catabolism of remaining proteins
  – Alteration of bilirubin to stercobilin
  – Manufacture of certain vitamins (K & some B)

**Absorption in Large Intestine**
• Water
• Electrolytes
• Some vitamins

**Defecation**
• Feces consist of water, inorganic salts, sloughed-off epithelial cells, bacteria and their products, undigested food
• Mass peristalsis pushes feces into rectum causing defecation reflex, when combined with pressure applied by diaphragm and abdominal wall, feces are expelled
• Internal anal sphincter (involuntary) and external anal sphincter (voluntary) control expulsion