Digestive System
Overview

- Basic digestive and functional processes
- The digestive organs
- Chemical digestion
- Absorption
- Elimination
Basic digestive and functional processes

- Ingestion – food intake
- Propulsion – moves food along tract
- Digestion – break down of food
- Absorption – into blood or lymph
- Defecation – eliminate residue
Propulsion

- Swallowing
  - voluntary
- Peristalsis
  - involuntary
Digestion

- Mechanical – increase surface area of food particles
  - Teeth and tongue
  - Stomach churning
  - Segmentation

- Chemical – breakdown of large molecules into smaller ones
Macromolecules and what they break down into

- Polysaccharides
  - Monosaccharides
- Lipids
  - Glycerol
  - Fatty acids
- Proteins
  - Amino acids
- Nucleic acids
  - Nucleotides
The Digestive Tract Organs

Mouth

Pharynx

Esophagus

Large Intestine

Stomach

Small Intestine

Anus

Rectum

Gastrointestinal tract
The Digestive Tract Accessory Organs

- Teeth, tongue, Salivary glands
- Liver
- Gall bladder
- Pancreas
Peritoneal relationships

Peritoneum – slippery membranes that line the body cavity
- Visceral
- Parietal
- Mesentery – double layer of peritoneum
  - Path for blood vessels and nerves
  - Fat stored here
Structural plan of digestive tract

- **Mucosa**
  - Epithelial lining
    - Secretes mucus, enzymes, hormones
  - Lamina propria
    - Connective tissue
    - Blood supply to epithelium
    - Absorbtion
  - Muscularis mucosae
    - Twitches
    - Causes folding
Structural plan of digestive tract

Submucosa
- Loose connective tissue
- Blood vessels
- Lymph vessels
- Nerves
- Extremely elastic
Structural plan of digestive tract

- **Muscularis**
  - **Functions**
    - Peristalsis
    - Segmentation
  - Inner layer
    - Circular
    - Forms sphincters
      - Prevents backflow
      - Controls passage
  - Outer layer
    - Longitudinal
Serosa
- Visceral peritoneum
- Loose connective tissue
- Blood vessels
- Produce serous fluid
Enteric nervous system

- Submucosal nerve plexus
- Glands and muscle in mucosa
- Myenteric nerve plexus
- Muscularis
- Secretion of accessory organs
Digestion starts in the Mouth

- Mastication
  - Teeth
  - Tongue
  - Cheeks
  - Lips
  - Hard palate
Salivary Glands

- Intrinsic salivary glands
  - Dispersed within oral cavity
    - Tongue
    - Lips
    - Cheeks
  - Keeps mouth moist
- Extrinsic salivary glands
  - Large, discrete organs
    - Parotid
    - Submandibular
    - Sublingual
  - Secrete upon salivation

Secrete 1-1.5L of saliva each day!
Saliva

- **Water (98%)**
- **Electrolytes**
  - Sodium, potassium, chloride, phosphate, bicarbonate
  - pH – 6.8-7.0
- **Salivary amylase**
  - Begins starch digestion
  - most active in lower pH
- **Lingual lipase**
  - Activated by stomach acid
  - Digests fat
- **Mucus**
  - Lubricates food
  - Binds food into a bolus
Lysozyme
  - Kills bacteria

Immunoglobulin A (IgA)
  - Inhibits bacterial growth

a cyanide compound
  - Inhibit bacteria

defensins
  - Antimicrobial proteins
  - Cytokine - draws white blood cells into the mouth
Pharynx

- Pharyngeal constrictors
  - Swallowing
- Epiglottis
  - Prevents food entering trachea
Swallowing (or Deglutition)

- Requires 22 muscles!
- Tongue blocks oral cavity
- Soft palate blocks nasopharynx
- Epiglottis blocks trachea
Swallowing (or Deglutition)

- Tongue blocks oral cavity
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Esophagus

- Straight, muscular tube
- about 10"
- Peristalsis
  - collapsed when empty
- Esophageal glands
  - Secrete mucus
Esophagus

- Esophageal hiatus
  - Penetration of diaphragm
  - Helps restrict backflow
- Lower esophageal sphincter
  - Not a separate muscle
  - Constriction of the esophagus
- Cardiac orifice
  - Entry into stomach
  - surrounded by a thickening of the muscles - cardiac sphincter
Stomach

- **Volume**
  - 50ml empty
  - 1-1.5L full
  - Can extend to 4L

- **Mechanical digestion**
  - Due to churning action

- **Chemical digestion**
  - Fats
  - Proteins

- **Chyme**
  - Pasty soup of semidigested food
Stomach regions

- Esophagus
- Cardiac orifice
- Cardiac region
- Fundic region
- Superior to cardiac orifice
- Pylorus
- Narrow passage
- Body – largest region
- Pyloric region
  - Antrum – funnel like area
  - Canal – narrower area
Stomach musculature

- Oblique
- Circular
- Longitudinal

- Gastric rugae
  - Not muscles!
  - allow stomach to expand
Stomach lining

- entirely mucus cells
  - 2 layers of mucus
    - both alkaline
    - top is viscous, insoluble
- Gastric pits
  - Open into 2-3 glands
Gastric glands

- Mucous cells
  - thin acidic mucus
- Regenerative (stem) cells
  - Lining is replaced every 3-6 days
- Parietal cells
  - Secrete HCl and intrinsic factor
- Chief cells
  - Secrete pepsinogen
- Enteroendocrine cells
  - Secrete hormones
  - (G cell here)

Produce 2-3L of gastric juice each day!
Gastric secretions

- **HCl**
  - Activates lingual lipase and pepsin
  - Softens connective tissues and plant cell walls
  - Denatures proteins
  - Destroys ingested pathogens
  - Converts ferric (Fe$^{3+}$) ions to ferrous (Fe$^{2+}$) ions
    - More absorbable

- **Pepsinogen**
  - Converted to pepsin
    - Digests proteins

- **Intrinsic factor**
  - Binds with B$_{12}$ to make it absorbable
  - Only indespensable function of the stomach!
Digestion and absorption in the stomach

- SMALL amounts of digestion
  - Starch
  - Fats
  - Proteins
- SMALL amounts of absorption
  - Aspirin
  - Some lipid-soluble drugs
  - alcohol
- Body’s largest gland (3 lbs)
- Many functions - only one important for digestion
  - Secretes bile
Liver

- composed of lobules
  - sesame sized
  - hexagonal structures
Liver microanatomy - Hepatic lobules

- Branch of hepatic portal vein
- Bile ductule - receives bile from bile canaliculi – narrow channels between hepatocytes
- Sinusoids - Blood filled
- Central vein
- Liver cells (hepatocytes)
- Hepatic triad - artery - vein - bile duct
- Branch of hepatic artery
Liver microanatomy - Hepatic lobules

- filtration unit
- blood from arteriole and venule move through sinusoids
- blood moves toward central vein
Liver microanatomy - Hepatic lobules

- Kupffer cells
  - macrophages that remove bacteria, old blood cells and other debris
Liver microanatomy- Hepatic lobules

- hepatocytes
  - store glucose as glycogen
  - make plasma proteins
  - store fat soluble vitamins
  - convert ammonia to urea
  - detoxifies blood
  - regenerate if injured
  - create bile

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Liver microanatomy - Hepatic lobules

- Bile moves into bile canaliculi to bile duct
- Note blood and bile move countercurrent

Key structures:
- Portal triad
- Portal arteriole
- Portal venule
- Bile duct
- Bile canaliculi
- Kupffer cells
- Hepatic sinusoids
- Hepatocytes
Bile ducts

- Bile flows from bile ductules
- to right and left hepatic ducts
- To common hepatic duct
- To common bile duct
- to hepatopancreatic duct
- To gallbladder
Gallbladder

- 4" long; size of kiwi
- Stores and concentrates bile
- Releases bile into the cystic duct
- To the common bile duct
- To the hepatopancreatic duct
Bile

- Yellowish green fluid
- Contains
  - bile salts
    - cholesterol derivatives
    - emulsify fats
    - help keep cholesterol in solution
    - facilitate fat and cholesterol absorption
    - not excreted - are reabsorbed in the ileum
  - Cholesterol
  - triglycerides
  - Phospholipids
  - Bile pigments
    - Bilirubin – decomposed hemoglobin
      - processed by bacteria to give feces their color
Pancreas

- Both an endocrine and exocrine gland
- Exocrine function relates to digestion
Pancreas

- Secretes 1.2-1.5L of pancreatic juice each day
  - Thru pancreatic duct
  - To both the hepatopancreatic duct and the accessory pancreatic duct
Pancreas

- Acini
  - secrete digestive enzymes
- Islets of Langerhans
  - secrete insulin and glucagon
Pancreatic juice

- Sodium bicarbonate
  - Buffers the HCl (exactly!)

- Enzymes precursors
  - Trypsinogen
  - Chymotrypsinogen
  - procarboxylase

- Enzymes
  - Pancreatic amylase
  - Pancreatic lipase
  - Ribonuclease
  - Deoxyribonuclease

- Electrolytes (ions)

1. Trypsinogen is converted to trypsin by enteropeptidase (secreted by small intestine)
2. Trypsin converts chymotrypsinogen into chymotrypsin
3. Trypsin converts procarboxyypeptidase into carboxypeptidase
Small Intestine - regions

- Duodenum – 10 inches
  - From pyloric valve to duodenojejunal flexure
  - Bile and pancreatic juice enter here
  - Glands produce alkaline mucus
    - Counteract HCl
Small Intestine - regions

- Jejunum
  - 8 feet
- Ileum
  - 12 feet
  - Ends at the ileocecal juncture
- Circular folds
  - 1 cm tall
  - Duodenum through middle of ileum
  - Force chyme in a spiral path
  - Slows movement of chyme
  - Increases contact of chyme with intestine
- **Villi**
  - about 1mm tall
  - Largest in duodenum, smallest in ileum
- 2 cell types
  - Absorptive cells
  - Goblet cells – secrete mucus
- **Villi**
  - Arteriole, capillary bed, venule
    - Absorb most nutrients
  - Lacteal
    - Lymphatic capillary
    - Absorbs fat
- smooth muscle
  - shortens and lengthens the villus
    - moves lymph
    - increases contact with chyme
- **Microvilli**
  - Increases surface area of small intestine
  - Contain brush border enzymes
    - Are not secreted – contact digestion only
    - carbohydrates and proteins only
  - Activate pancreatic enzymes
Intestinal gland (or crypt)

- Similar to gastric gland
- secrete intestinal juice
- Paneth cells
  - determine flora
  - Secrete lysozyme, phospholipase, defensins
    - All antibacterial

- 1-2 L of intestinal juice is secreted each day
- pH of 7.4-7.8
- Mostly water and mucus
- no enzymes!
Intestinal gland (or crypt)
- enteroendocrine cells
  - secretin and cholecystokinin
- T cells
  - bind with antigens and kill target cells
- Stem cells that resurface the villi
  - 2-4 days
Function of the small intestine

- Segmentation
  - occurs when "loaded"
  - massages the chyme back and forth
  - chyme moves very slowly along

- Peristalsis
  - occurs after most nutrients have been absorbed
  - first wave starts near duodenum
  - subsequent waves begin further along
  - all material (food, bacteria, debris) is moved out - critical to prevent bacterial overgrowth
  - takes about 2 hours
Function of the small intestine

- Carbohydrate digestion overview
  - In mouth, salivary amylase
    - Begins breakdown of starch
    - Continues in stomach until acid level reduces to pH 4.5
    - 50% of starch may be broken down
  - In duodenum, pancreatic amylase
    - Finishes starch digestion (mostly to maltose) within 10 minutes
  - Brush border, maltase, sucrase, lactase
    - dextrinase and glucoamylase - digest oligosaccharides
    - maltase, sucrase, lactose
    - Converts remaining carbs to glucose
Function of the small intestine

- Carbohydrate absorption
  - glucose and galactose: active transport (co-transport with Na+)
  - fructose: facilitated diffusion
Function of small intestine

- **Protein digestion**
  - 3 sources of proteins
    - Dietary
    - Digestive enzymes
    - Sloughed epithelial cells
  - In stomach, pepsin
    - Digests 10-15% into short polypeptides (some amino acids)
    - Inactivated in duodenum due to increase in pH
  - In duodenum, trypsin and chymotrypsin
    - Create short peptides
  - Brush border, carboxypeptidase, aminopeptidase, dipeptidase
    - Create amino acids
Function of small intestine

- Amino acids are absorbed
  - active transport (co-transport with Na+)
- dipeptides and tripeptides
  - active transport (H+ dependent)
  - these are digested to amino acids within the epithelial cells
Function of small intestine

- Lipid digestion
  - In mouth, lingual lipase
    - Activated by acid in stomach
    - Digests 10% of ingested fat
  - In duodenum, bile salts
    - Emulsifies fat to increase surface area
  - In duodenum, pancreatic lipase
    - Digests fat in 1-2 minutes
    - Result of digestion is 2 fatty acids and a monoglyceride
Function of small intestine

- Fatty acids and monoglycerides associate with bile salts and lecithin to create micelles.
- At epithelium, fatty acids and monoglycerides are absorbed via simple diffusion.
- Inside epithelium, triglycerides reform.
- Chylomicrons form: triglycerides + phospholipids, lecithin, cholesterol.
- Exocytosis of chylomicrons to lacteals.
- Once in blood stream: triglycerides are digested to fatty acids and glycerol.
  - Remaining substances are processed by the liver.
Function of small intestine

- Nucleic acid digestion
  - In duodenum, pancreatic nucleases
    - Create nucleotides
  - Brush border, nucleosidases and phosphatases
    - Create phosphate, ribose or deoxyribose, nitrogenous bases
- Phosphate, sugar and bases are absorbed
  - all active transport
Function of small intestine

- Vitamin absorption
  - fat soluble (A, D, E, and K)
    - incorporate into micelles
  - water soluble (B and C)
    - diffusion or active transport
  - B12 - very large
    - intrinsic factor binds to it
    - complex binds to mucosal receptors (in terminal ileum)
    - uptake is via endocytosis
Function of small intestine

- Electrolyte absorption
  - most ions actively absorbed
  - Na+ - coupled to glucose and amino acid absorption
  - K+ - facilitated diffusion
- Iron
  - active transport into mucosa where it binds to ferritin: this is a local iron storage
    - women have 4x as much as men
  - If iron is needed, iron is transferred to transferrin - a plasma protein
- Calcium
  - regulated by vitamin D dependent calcium binding protein
Function of small intestine

- Water is absorbed
  - Intestine receives 9L of water a day!
    - 0.7L in food
    - 1.6L in drink
    - 6.7L in gastrointestinal secretions
  - 9L is absorbed
  - 95% is absorbed via osmosis in small intestine (remainder (all but 0.1L) is absorbed in large intestine)
Large Intestine

- 1.5m long
- Functions
  - absorption
  - formation of feces
- Haustra
  - puckers due to muscle tone
Large Intestine

- Cecum
  - Blind pouch
  - Appendix
    - Significant source of immune cells (lymphocytes)
Large Intestine

- Colon
  - Ascending colon
  - Transverse colon
  - Descending colon
  - Sigmoid colon
Large Intestine

- Rectum
  - 3 Rectal valves
    - Transverse folds
    - Retain feces
    - Pass gas
Large Intestine

- Anal columns
- Rectal sinuses
  - Secrete mucus when feces pass
- Hemorrhoidal veins
  - Lack valves
  - Subject to distension and venous pooling
Large Intestine

- Internal sphincter
  - involuntary
- External sphincter
  - voluntary
Functions of the colon

- Passage takes 12-24 hours
- Haustral contractions
  - Segmental movement that last 1 min. and occur every 30 min.
- Mass movements
  - Peristalsis over large areas that occur 3-4x daily
- Diverticula: breaks in the mucosa
  - If diet lacks bulk, colon narrows and these form (usually in sigmoid colon)
  - Diverticulitis = inflamed diverticula
Functions of the colon

- Bacterial flora
  - Ferment cellulose, xylan and other carbs (from food)
  - metabolize mucin, heparin, hyaluronic acid (produced by our body)
  - Synthesize B vitamins
  - Synthesize vitamin K (necessary for blood clotting proteins)
- Absorbs vitamins
- Reabsorbs water and electrolytes (NaCl)
  - 0.8L water is absorbed
Feces

- 75% water
- 25% solids
  - 30% bacteria
  - 30% undigested fiber
  - 10-20% fat (from broken down epithelial cells- NOT diet)
  - Protein
  - Sloughed epithelial cells
  - Salts
  - Mucus
  - Digestive secretions