The Digestive System
Overview of GI tract Functions

- **Mouth**---bite, chew, swallow
- **Pharynx and esophagus**---transport
- **Stomach**---mechanical disruption; absorption of water & alcohol
- **Small intestine**--chemical & mechanical digestion & absorption
- **Large intestine**---absorb electrolytes & vitamins (B and K)
- **Rectum and anus**---defecation
Salivary Glands

- **Parotid** below your ear and over the masseter
- **Submandibular** is under lower edge of mandible
- **Sublingual** is deep to the tongue in floor of mouth
- All have ducts that empty into the oral cavity
Composition and Functions of Saliva

- Wet food for easier swallowing
- Dissolves food for tasting
- Bicarbonate ions buffer acidic foods
- Chemical digestion of starch begins with enzyme (salivary amylase)
- Enzyme (lysozyme) --- helps destroy bacteria
- Protects mouth from infection with its rinsing action --- 1 qt/day
Digestion in the Mouth

• Mechanical digestion (mastication or chewing)
  • breaks into pieces
  • mixes with saliva so it forms a bolus

• Chemical digestion
  – amylase
    • begins starch digestion at pH of 6.5 or 7.0 found in mouth
    • when bolus & enzyme hit the pH 2.5 gastric juices
      hydrolysis ceases
  – lingual lipase
    • secreted by glands in tongue
    • begins breakdown of triglycerides into fatty acids and glycerol
Esophagus

- Collapsed muscular tube
- In front of vertebrae
- Posterior to trachea
- Posterior to the heart
- Pierces the diaphragm at hiatus
Physiology of the Esophagus - Swallowing

- Voluntary phase---tongue pushes food to back of oral cavity
- Involuntary phase----pharyngeal stage
  - breathing stops & airways are closed
  - soft palate & uvula are lifted to close off nasopharynx
  - vocal cords close
  - epiglottis is bent over airway as larynx is lifted
Swallowing

- Upper sphincter relaxes when larynx is lifted
- Peristalsis pushes food down
  - circular fibers behind bolus
  - longitudinal fibers in front of bolus shorten the distance of travel
- Travel time is 4-8 seconds for solids and 1 sec for liquids
- Lower sphincter relaxes as food approaches
Anatomy of Stomach

• Size varies
  – large sausage when empty
  – stretches due to rugae (folds of mucosa)

• Parts of stomach
  – cardia
  – fundus
  – body
  – pylorus

• Empties as small squirts of chyme leave the stomach through the pyloric valve
Muscularis

- Three layers of smooth muscle--outer longitudinal, circular & inner oblique
- Permits greater churning & mixing of food with gastric juice
Physiology--Mechanical Digestion

• Gentle mixing waves
  – every 15 to 25 seconds
  – mixes bolus with 2 quarts/day of gastric juice to turn it into chyme (a thin liquid)

• More vigorous waves
  – travel from body of stomach to pyloric region

• Intense waves near the pylorus
  – open it and squirt out 1-2 teaspoons full with each wave
Physiology--Chemical Digestion

• Protein digestion begins
  – HCl denatures (unfolds) protein molecules
  – HCl transforms pepsinogen into pepsin that breaks peptides bonds between certain amino acids

• Fat digestion continues
  – gastric lipase breakdown triglycerides

• HCl kills microbes in food

• Mucous cells protect stomach walls from being digested with 1-3mm thick layer of mucous
Absorption of Nutrients by the Stomach

- Water especially if it is cold
- Electrolytes
- Some drugs (especially aspirin) & alcohol
- Fat content in the stomach slows the passage of alcohol to the intestine where absorption is more rapid
- Gastric mucosal cells contain alcohol dehydrogenase that converts some alcohol to acetaldehyde—more of this enzyme found in males than females
- Females have less total body fluid than same size male so end up with higher blood alcohol levels with same intake of alcohol
Anatomy of the Pancreas

- 5" long by 1" thick
- Head close to curve in C-shaped duodenum
- Main duct (duct of Wirsung) joins common bile duct from liver
- Sphincter of Oddi is 4" below pyloric sphincter
Composition and Functions of Pancreatic Juice

• .5 Quarts/day
• Contains water, enzymes & sodium bicarbonate
• Digestive enzymes
  – pancreatic amylase digests carbohydrates
  – pancreatic lipase digests lipids
  – proteases digest proteins
Anatomy of the Liver and Gallbladder

- **Liver**
  - weighs 3 lbs.
  - below diaphragm
  - right lobe larger
  - gallbladder on right lobe
  - size causes right kidney to be lower than left

- **Gallbladder**
  - fundus, body & neck
Bile Production

• One quart of bile/day is secreted by the hepatocytes of the liver
  – yellow-green in color

• Components
  – water & cholesterol
  – bile salts = Na & K salts of bile acids
    Break down (emulsify) large lipid globules
  – bile pigments (bilirubin) from hemoglobin molecule
    Bilirubin is broken down in the intestine
    Sterocobilin-gives brown color to feces
Liver Functions

- Carbohydrate metabolism - glucose production
- Lipid metabolism
- Protein metabolism
- Detoxifies the blood by removing or altering drugs & hormones
- Removes the waste product -- bilirubin
- Releases bile salts help digestion by emulsification
- Phagocytizes worn out blood cells & bacteria
Anatomy of the Small Intestine

- 20 feet long----1 inch in diameter
- Large surface area for majority of absorption
- 3 parts
  - duodenum---10 inches
  - jejunum---8 feet
  - ileum---12 feet
    - ends at ileocecal valve
Histology of the Small Intestine

- Structures that increase surface area
  - plica circularis (circular folds)
    - permanent .4 inch tall folds that contain part of submucosal layer
    - not found in lower ileum
    - can not stretch out like rugae in stomach

  - villi
    - 1 Millimeter tall
    - Core is lamina propria of mucosal layer
    - Contains vascular capillaries and lacteals (lymphatic capillaries)

  - microvilli
    - cell surface feature known as brush border
Functions of Microvilli

• Absorption and digestion
• Digestive enzymes found at cell surface on microvilli
• Digestion occurs at cell surfaces
• Significant cell division within intestinal glands produces new cells that move up
Cells of Intestinal Glands

- Absorptive cell
- Goblet cell
- Enteroendocrine
  - secretin
  - cholecystokinin
- Paneth cells
  - secretes lysozyme
Mechanical Digestion in the Small Intestine

• Weak peristalsis in comparison to the stomach---chyme remains for 3 to 5 hours

• Segmentation---local mixing of chyme with intestinal juices---sloshing back & forth
Digestion of Carbohydrates

- **Mouth**---salivary amylase
- **Esophagus & stomach**---nothing happens
- **Duodenum**----pancreatic amylase
- **Enzymes** (maltase, sucrase & lactose) act on disaccharides
  - produces monosaccharides---fructose, glucose & galactose
Digestion of Proteins

• Stomach
  – HCl denatures or unfolds proteins
  – pepsin turns proteins into peptides

• Pancreas
  – digestive enzymes---split peptide bonds between different amino acids
  – enzymes (small intestine)-----aminopeptidase or dipeptidase------split off amino acid at amino end of molecule or split dipeptide
Digestion of Lipids

• Mouth----lingual lipase

• Small intestine
  – emulsification by bile
  – pancreatic lipase---splits into fatty acids & monoglyceride
Digestion of Nucleic Acids

• Pancreatic juice contains 2 nucleases
  – ribonuclease which digests RNA
  – deoxyribonuclease which digests DNA
• Nucleotides produced are further digested by small intestine enzymes (nucleosidease and phosphatase)
  – pentose, phosphate & nitrogenous bases
Absorption in Small Intestine

- Glucose and galactose: Secondary active transport with Na⁺
- Fructose: Facilitated diffusion
- Amino acids: Active transport or secondary active transport with Na⁺
- Dipeptides and Tripeptides: Secondary active transport with H⁺
- Short-chain fatty acids: Simple diffusion
- Long-chain fatty acids: Monoglycerides
- Micelle

From the lumen of the small intestine, materials are absorbed through:
- Microvilli (brush border) on apical surface
- Epithelial cells of villus

The absorbed materials are transported to the blood capillary of a villus and the lacteal of a villus via:
- Monosaccharides: Facilitated diffusion
- Amino acids: Diffusion
- Triglyceride
- Chylomicron
- Basolateral surface
Absorption of Water

- 9 liters of fluid dumped into GI tract each day
- Small intestine reabsorbs 8 liters
- Large intestine reabsorbs 90% of that last liter
- Absorption is by osmosis through cell walls into vascular capillaries inside villi
Anatomy of Large Intestine

- 5 feet long by 2.5 inches in diameter
- Ileocecal sphincter
- Cecum & appendix
- Rectum = last 8 inches of GI tract
- Anal canal = last 1 inch of GI tract
  - internal sphincter----smooth muscle & involuntary
  - external sphincter----skeletal muscle & voluntary control
Mechanical Digestion in Large Intestine

- Smooth muscle = mechanical digestion
- Peristaltic waves (3 to 12 contractions/minute)
  - haustral churning—relaxed pouches are filled from below by muscular contractions (elevator)
  - gastroilial reflex = when stomach is full, gastrin hormone relaxes ileocecal sphincter so small intestine will empty and make room
  - gastrocolic reflex = when stomach fills, a strong peristaltic wave (mass peristalsis) moves contents of transverse colon into rectum
Chemical Digestion in Large Intestine

- No enzymes are secreted only mucous
- Bacteria ferment
  - undigested carbohydrates into carbon dioxide & methane gas
  - undigested proteins into simpler substances (indoles)----odor
  - turn bilirubin into simpler substances (sterocobilin) that produce color
- Bacteria produce vitamin K and B in colon
Absorption & Feces Formation in the Large Intestine

• Some electrolytes---Na\(^+\) and Cl\(^-\)
• 90% of H\(_2\)O has been removed from chyme in small intestine, large intestine also absorbs water
• Feces are semisolid by time reaches transverse colon
• Feces = dead epithelial cells, undigested food such as cellulose, bacteria (live & dead)
Defecation

- Gastrocolic reflex moves feces into rectum
- Stretch receptors signal sacral spinal cord
- Parasympathetic nerves contract muscles of rectum & relax internal anal sphincter
- External sphincter is voluntarily controlled