The Digestive System

Gastroenterology: study of digestive tract

Hepatologists study the liver

General surgeons operate on most parts of the GI tract

Digestive System

Gastroenterology:

- study of digestive tract

Hepatologists:

- study the liver

General surgeons:

- operate on most parts of the GI tract

Functions of Digestive System

- Protection
  - Corrosive effects of digestive acids and enzymes
  - Mechanical stresses such as abrasion
  - Bacteria

- Ingestion

- Digestive processes

- Absorption

- Compaction

- Defecation

Digestive Processes

- Ingestion - taking food into the mouth
- Mechanical processing – increasing surface area, mixing and propulsion by smooth muscles in GI tract walls
  - Mastication, Peristalsis, Segmentation, Haustral churning
- Digestion – chemical breakdown
- Secretion - release of water, acid, buffers, and enzymes into the lumen tract
- Absorption - passage of end products of digestion from GI tract into blood or lymph
- Excretion – removal of waste products
  - Defecation - emptying the rectum

Anatomy

Layers of the GI tract
Layers of the GI Tract

**Mucosa**
- Epithelium
  - Stratified squamous (in mouth, pharynx, esophagus & anus)
  - Simple columnar in the rest
    • Specialized goblet cells secrete mucus onto cell surfaces
    • Enteroendocrine cells secrete hormones controlling organ functions
- Lamina propria
  - Thin layer of areolar tissue
  - Contains BV, sensory nerve endings, smooth muscle cells, and lymphatic tissue
- Muscularis mucosae—thin layer of smooth muscle
  - Circular and longitudinal muscle fibers
  - Causes folds to form in mucosal layer
  - Increases local movements increasing absorption with exposure to “new” nutrients

**Submucosa**
- Dense irregular connective tissue
  - Containing BV, exocrine glands and lymphatic tissue
- Submucosal plexus (plexus of Meissner)
  - Sensory neurons
  - Autonomic neurons
  - Innervation
    • Vasoconstriction
    • Local movement by muscularis mucosa smooth muscle

**Muscularis Externa**
- Skeletal muscle = voluntary control
  - In mouth, pharynx, upper esophagus and anus
  - Control over swallowing and defecation
- Smooth muscle = involuntary control
  - Circular, longitudinal and oblique fibers
  - Mixes, crushes & propels food along by peristalsis
- Myenteric plexus (Auerbach’s plexus)
  - Sensory innervation
  - Both parasympathetic & sympathetic innervation of smooth muscle layers
Serosa or Adventitia

- **Serosa**
  - An example of a serous membrane
  - Covers all organs and walls of cavities not open to the outside of the body
  - Secretes slippery fluid
  - Areolar connective tissue covered with simple squamous epithelium

- **Adventitia**
  - Fibrous connective tissue

**Anatomy**

**GI Tract**

- **Peritoneal cavity**
  - Peritoneum
    - Visceral peritoneum
    - Parietal peritoneum
    - Peritoneal fluid
      - ~7 liters per day

- **Retroperitoneal organs**
  - Duodenum
  - Most of pancreas
  - Parts of large intestines
  - Kidneys
  - Adrenal glands
  - Superior region of bladder
Digestive System

Retroperitoneal organs
Kidneys
Adrenal glands
Superior region of bladder

Peritonitis - acute inflammation of the peritoneum

Trauma
Rupture of GI tract
Appendicitis
Perforated ulcer

Mesenteries
- Mesocolon
- Falciform ligament
- Greater omentum
- Lesser omentum
- Mesentery proper

Lesser omentum
Greater omentum
Mesocolon
Mesentery proper
Can you identify these structures (A-B)?

Falciform ligament
• Oral (buccal) cavity
  – Lips (labia)
  – Vestibule
  – Labial frenulum
  – Hard palate
  – Soft palate
  – Uvula
  – Pharyngeal arches (faucial pillars)
  – Palatine tonsils
  – Fauces

• Tongue
  – Body
  – Root
  – Lingual frenulum
  – Papillae
- Salivary glands
  - Parotid glands and ducts
  - Submandibular glands and ducts
  - Sublingual glands and lesser sublingual ducts
Mumps

- *Myxovirus* that attacks the parotid gland
• Teeth (dentition)
  – Crown
  – Neck
  – Root
  – Pulp cavity
  – Root canal
  – Apical foramen
  – Gingiva
  – Enamel
  – Dentin
  – Cementum
  – Periodontal ligament
  – Incisors
  – Cuspids or canines
  – Bicuspids or premolars
  – Molars
  – Deciduous teeth (children’s teeth, primary teeth)
  – Secondary dentition (permanent teeth)

Dental Succession

• Deciduous teeth
  – Primary teeth, milk teeth, baby teeth
  – Most children have 20

• Secondary teeth
  – Permanent dentition
  – ~32 teeth

• Eruption: emergence of the secondary teeth
  – Impacted teeth: teeth that develop in locations that do not allow eruption
• Pharynx
  – Nasopharynx
  – Oropharynx
  – Laryngopharynx

• Esophagus
  – Upper and lower esophageal sphincters
  – Hiatus
    • Hiatal hernia

Why do you have an upper esophageal sphincter?
Why do you have an lower esophageal sphincter?

Esophagus

• Histology
  – Mucosa
    • Stratified squamous epithelium
    • Lamina propria
    • Muscularis mucosa
  – Submucosa
  – Muscularis
    • Circular muscle fibers
    • Longitudinal muscle fibers
  – Adventitia
Mucosa
Stratified squamous epithelium
Lamina propria
Muscularis mucosa
Submucosa
Muscularis
Circular muscle fibers
Longitudinal muscle fibers
Adventitia

• Stomach
  – Cardia
  – Fundus
  – Body
  – Pylorus
    • Pyloric antrum
    • Pyloric canal
    • Pyloric sphincter
  – Rugae

Cardia
Fundus
Body
Pylorus
Stomach

- Histology
  - Mucosa
    - Simple columnar epithelium
    - Goblet cells
    - Gastric pits
    - Gastric glands
      - Chief cells
      - Parietal cells
    - Lamina propria
    - Muscularis mucosa
  - Submucosa
  - Muscularis – oblique, circular, longitudinal smooth muscle
  - Serosa
• Small intestine
  – Duodenum (*10 inches*)
  – Jejunum (*8 feet*)
  – Ileum (*12 feet*)
  – Ileocecal valve (sphincter)
  – Plica circulares (circular folds)
Histology of the Small Intestine

- Structures that increase surface area
  - Plica circulares
    - ~½ inch tall, permanent
    - Not present in lower ileum
    - ~800 in small intestine
  - Villi
    - ~1 mm high
  - Microvilli
    - Brush border
    - Absorption and digestion

Histology of Small Intestine

- Intestine
  - Villi
  - Microvilli – brush border
  - Payers patch
  - Muscosa
    - Simple columnar epithelium
      - Goblet cells
    - Lamina propria
      - Arteriole
      - Venule
      - Blood capillary
      - Lacteal
    - Intestinal glands – secrete enzymes
  - Submucosa
    - Duodenal glands – secrete alkaline mucous
- Pancreas
  - Pancreatic duct (duct of Wirsung)
  - Accessory pancreatic duct (accessory duct, duct of Santorini)

- Histology
  - Acini
  - Pancreatic islet (islet of langerhans)
Digestive System

Liver and gallbladder
- Falciform ligament
- Right and left lobe
- Caudate lobe
- Quadrade lobe
- Hilus
- Right and left hepatic ducts
- Common hepatic duct
- Cystic duct
- Common bile duct
Liver

- **Histology**
  - Lobules
  - Central vein
  - Hepatocytes
  - Sinusoids
    - Hepatic macrophages
  - Portal triad
    - Hepatic portal vein
    - Hepatic artery
    - Bile canaliculus
- Large Intestine
  - Cecum
    - Appendix (vermiform appendix)
  - Colon
    - Ascending, transverse, descending, and sigmoid colon
    - Right colic flexure (hepatic flexure), left colic flexure (splenic flexure), and sigmoid flexure
  - Rectum
    - Anal canal
    - Anal columns
    - Anus (anal orifice)
    - Internal anal sphincter
    - External anal sphincter
  - Teniae coli
  - Haustra
Digestive System

Melissa Gonzales McNeal

Rectum

Anal canal
Anal columns
Anus (anal orifice)
Internal anal sphincter
External anal sphincter

Hemorrhoids

Cushions of tissue and varicose veins located in and around the rectal area

Hemorrhoids bother about 89% of all Americans at some time in their lives
Histology of Large Intestine

Histology of Large Intestine

Why are these important?

Oral Cavity

Functions

- Analysis of material
- Mechanical processing
- Lubrication
- Limited digestion
  - carbohydrates
  - lipids

Physiology

Function
Digestion:
  - Mechanical
  - Chemical
Absorption
Regulation
Oral Cavity Functions

**Tongue**
- Mechanical processing
- Manipulation to assist in chewing and swallowing
- Sensory analysis
- Secretion
  - lingual lipase
  - Mucins – glycoproteins for lubrication

**Saliva**
- Wet food for easier swallowing
  - 99% water
  - Mucins — lubricating glycoproteins
- Dissolves food for tasting
- Bicarbonate ions buffer acidic foods
  — *Bulemia*??
- Chemical digestion of starch begins with enzyme (salivary amylase)
- Enzyme (lysozyme) — helps destroy bacteria
- Protects mouth from infection with its rinsing action — 1 to 1½ qts per day

Regulation: Salivation

- Increase salivation
  — Sight, smell, sounds, memory of food, tongue stimulation — rock in mouth
  — Primarily parasympathetic innervation
- Stop salivation
  — Dry mouth when you are afraid
  — Sympathetic nerves

**Teeth**
- Incisors — clipping, cutting (*carrots*)
- Cuspids (canines) — tearing, slashing (*celery*)
- Bicusps (premolars) — crush, mash, grind (*nuts*)
- Molars — crush, grind (*nuts*)
**Digestion: Oral Cavity**

- Mechanical digestion (mastication or chewing)
  - Increases surface area
  - 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

**Pharynx and Esophagus Functions**

- Pharynx
  - Common passageway
    - Solid foods
    - Liquids
    - air
- Esophagus
  - Carry solid foods and liquid to stomach
  - Sphincters
    - Air versus stomach acid

**Deglutition - Swallowing**

- Buccal phase
  - Compression of bolus against hard palate
  - Voluntary
- Pharyngeal phase
  - Bolus comes in contact with pharyngeal arches
  - Swallowing reflex initiated via swallowing center
  - Involuntary
- Esophageal phase
  - Bolus enters esophagus
  - Parastals
- Abnormalities
  - Dysphagia
  - Gastroesophageal reflux disease (GERD)

**Stomach Functions**

- Bulk storage of ingested food
  - Pylorospasm
  - Pyloric stenosis
- Mechanical breakdown
- Disruption of chemical bonds
  - Using acids and enzymes
- Production of intrinsic factor
Mucosa & Gastric Glands

- Chief cells
  - Pepsinogen
  - Gastric lipase
- Parietal cells
  - Intrinsic factor for absorption of vitamin B₁₂
  - RBC production
  - Hydrochloric acid (HCl)
    - H ions via CO₂ and carbonic anhydrase
    - Bicarbonate exchanged for chloride
    - **Alkaline tide**: increase in pH due to sudden influx of bicarbonate
    - Breaks down plant cell walls and connective tissue in meat
    - **H₂ blockers**: tagamet, zantac, pepcid

Pyloric Glands

- Enteroendocrine glands
  - G cells: gastrin
    - Stimulates secretion of parietal and chief cells
    - Stimulates contraction of gastric wall
    - Constricts esophageal sphincter
    - **Release stimulated by stretch receptors in stomach, protein and caffeine**
  - D cells: somatostatin
    - Inhibits gastrin
- Mucous cells
  - Mucus
  - Alcohol dehydrogenase
  - **Life span**: ~3-7 days
**Digestion: Stomach**

- **Mechanical Digestion** - peristalsis
- **Chemical Digestion**
  - Protein digestion begins
    - HCl denatures (unfolds) protein molecules
      - Including enzymes from mouth (amylase and lipase)
    - HCl transforms pepsinogen into pepsin that breaks peptides bonds between certain amino acids
  - Fat digestion continues
    - Gastric lipase and lingual lipase digest ~ 10-15% of dietary fat
    - HCl kills microbes in food

**Absorption: Stomach**

- **Some electrolytes**
- **Some drugs**
  - 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
    - Converts some alcohol to acetaldehyde
    - More of this enzyme found in males than females

**Regulation: Gastric Activity**

**The Cephalic Phase**

- Function: Prepare stomach for arrival of food
- Duration: Minutes
- Mechanism: Neurons in prepyloric plexus cause release of pepsinogen in submucosal plexus
- Activity: Primary: stimulation of mucus, enzymes, and acid production, leading to increased volume of gastric juice
  - Secondary: stimulation of gastrin release by B cells

**The Gastric Phase**

- Function: Enzyme secretion starts in stomach
- Duration: Hours
- Mechanism: Neuronal: short reflexes triggered by:
  1. Stimulation of emetic reflexes as stomach fills
  2. Stimulation of chemoreceptors as pH increases
  3. Gastrin release by G cells through parasympathetic activity and presence of peptides
- Activity: Increased acid and pepsinogen production, increased motility and inhibition of mixing waves

**Regulation: Gastric Activity**

Intense waves near the pylorus squirt out 1-2 teaspoons full with each wave.
Regulation: Gastric Activity

Chyme moves from stomach into duodenum of the small intestine

- Secretions are added from
  - Pancreas
  - Liver and gallbladder

Pancreas

Functions

- Hormone production
- Digestive enzyme production
- Buffer production

Regulation: Pancreas

- Acidic chyme containing partially digested fats (fatty acids) and proteins (amino acids)
- Parasympathetic impulses along vagus (X) nerves
- Stimulates secretion of pancreatic juice rich in bicarbonate ions
- Stimulates secretion of pancreatic juice rich in digestive enzymes

GIP

CCK

Secretin

Blood

Pancreas

Hormone production
Digestive enzyme production
Buffer production

The Intestinal Phase

Function:
Control rate of chyme entry into duodenum

Duration:
Long (hours)

Mechanisms:
Neural short reflexes (entero gastric reflex triggered by distension of duodenum)

Hormonal:
Primary: stimulation of cholecystokinin (CCK), gastric inhibitory peptide (GIP), and secretin release by presence of acid, carbohydrates, and fat
Secondary: release of gastrin stimulated by presence of undigested proteins and peptides (not shown)

Actions:
Feedback inhibition of gastric acid and peptidogen production; reduction in gastric motility
Liver
*Functions*
- Metabolic regulation
  - Carbohydrate, lipid, and amino acid metabolism
  - Vitamin and mineral storage
  - Drug inactivation
  - Removal of waste products
- Hematological regulation
  - Phagocytosis and antigen presentation
  - Synthesis of plasma proteins
  - Removal of circulating hormones and antibodies
- Bile production

Gallbladder
*Functions*
- Bile storage
- Bile modification (concentration)

Small Intestine
*Functions*
- Chemical digestion completed
- Nutrient absorption

Hormones of Small Intestine
- Cholecystokinin (CCK)
  - Stimulated by arrival of lipids and proteins from stomach contents
  - Causes
    - *Pancreas* - Production of pancreatic enzymes
    - *Gallbladder* - Contraction of gallbladder
    - *Duodenum* - Relaxation of hepatopancreatic sphincter
    - *Stomach* - Inhibits gastric secretion and motion
    - *CNS* - May reduce hunger
- Enterocrinin
  - Stimulated by arrival of stomach contents in duodenum
  - *Duodenal glands* - causes production of alkaline mucus
Hormones of Small Intestine

- **Gastrin**
  - Stimulated by large amounts undigested proteins in stomach contents
  - *Stomach* – causes production of acids and enzymes, and increases stomach motility

- **Glucose-dependent insulinoetric peptide (Gastric Inhibitory Peptide)**
  - Stimulated by fat and glucose from stomach contents
  - Causes
    - *Pancreas* – release of insulin
    - *Adipose tissue* – stimulates lipid synthesis
    - *Skeletal muscle* – stimulates glucose use

- **Secretin**
  - Stimulated by arrival of stomach contents
  - Causes
    - *Pancreas* – production of alkaline buffers
    - *Stomach* – inhibits secretion and motility
    - *Liver* – increases bile secretion

- **Vasoactive Intestinal Peptide (VIP)**
  - Stimulated by arrival of stomach contents
  - Causes
    - *Duodenum* – buffer secretion, dilates intestinal capillaries
    - *Stomach* – inhibits acid production

**Digestion:** *Small Intestine*

**Mechanical Digestion**
- Weak peristalsis in comparison to the stomach
- Segmentation---local mixing of chyme with intestinal juices---sloshing back & forth

**Chemical Digestion via ** **Brush Border Enzymes**
- Carbohydrases: breakdown maltose, sucrose and lactose into monosaccharides
  - Maltase, sucrase, lactase, dextrinase, glucoamylase
- Dipeptidases and peptidases: breakdown dipeptides and tripeptides into amino acids
- Enterokinase: trypsinogen to trypsin
  - For digestion of proteins
  - Activates pancreatic enzymes
Chemical Digestion via **Pancreatic Juice**
- Contains water, enzymes & sodium bicarbonate
- Digestive enzymes
  - Pancreatic amylase
  - Pancreatic lipase
  - Pancreatic nucleases
    - Ribonuclease
    - Deoxyribonuclease
  - Proteases and peptidases: break down proteins
    - Released as proenzymes and the proenzymes are activated by trypsin
      - Trypsinogen
      - Chymotrypsinogen
      - Procarboxypeptidase
    - trypsinogen—activated by enterokinase (a brush border enzyme)
    - trypsin inhibitor—combines with any trypsin produced inside pancreas

Digestion via bile from Liver and Gallbladder
- Yellow-green in color & pH 7.6 to 8.6
- Components
  - Water & cholesterol
  - Bile salts = Na & K salts of bile acids
  - Bile pigments (bilirubin) from hemoglobin molecule
- Emulsification
- Promote absorption of digested lipids

**Absorption: Small Intestine**
- Lipids
  - Mostly through lacteals
- Amino acids
- Water
- Ions
  - sodium, calcium, potassium, magnesium, iron
  - Chloride, iodide, bicarbonate, nitrate
  - Phosphate, sulfate
- Vitamins
  - Fat soluble: A, D, and E
  - Water soluble: B vitamins and C
  - Vitamin B₁₂ requires intrinsic factor released by gastric glands
- Monosaccharides
Regulation: Small Intestine

- Parasympathetic stimulation
- Myenteric reflexes
  - Local motility
- Gastroileal reflex
  - Triggered by stretch receptors
  - Enhanced by gastrin from stomach
  - Causes ileocecal valve relaxation

Large Intestine Functions

- Reabsorption of water and compaction of intestinal contents into feces
- Absorption of vitamins produced by bacteria
- Storage of fecal material prior to defecation

Digestion: Large Intestine

- Mechanical digestion
  - Peristaltic waves
    - Hastral churning = relaxed pouches are filled from below by muscular contractions (elevator)
- Chemical Digestion
  - No enzymes are secreted
  - Bacteria ferment
    - Undigested carbohydrates into carbon dioxide & methane gas
    - Undigested proteins into simpler substances
      - Ammonia, Indole and skatole (fecal odor), Hydrogen sulfide (rotten eggs)
    - Bilirubin into simpler substances
  - Bacteria produce vitamin K and B in colon

Absorption: Large Intestine

- Some electrolytes - Na⁺ and Cl⁻
- After 3 to 10 hours, 90% of H₂O has been removed from chyme
- Bile salts
- Vitamins: vitamin K, biotin, vitamin B₅ (pantothenic acid)
- Organic wastes: urobilinogen

Feces = dead epithelial cells, undigested food such as cellulose, bacteria (live & dead)
Regulation: Large Intestine

- Gastroileal reflex moves contents from small intestine into large intestine
- Gastrocolic and duodenocolic reflexes move feces into rectum
- Stretch receptors signal sacral spinal cord
- Nerves contract muscles of rectum & relax internal anal sphincter
- External sphincter is voluntarily controlled

Defecation Problems

- Diarrhea = chyme passes too quickly through intestine
  - $H_2O$ not reabsorbed
- Constipation—decreased intestinal motility
  - Too much water is reabsorbed
  - Remedy = fiber, exercise and water
Dietary Fiber

• Insoluble fiber
  – Woody parts of plants (wheat bran, veggie skins)
  – Speeds up transit time & reduces colon cancer

• Soluble fiber
  – Gel-like consistency = beans, oats, citrus white parts, apples
  – Lowers blood cholesterol by preventing reabsorption of bile salts so liver has to use cholesterol to make more