Digestive system

I. Consists of:
   A. digestive tract - tube running from mouth to anus
   B. Accessory organs - gall bladder, liver, pancreas etc.

II. Anatomy Overview
   A. Oral cavity
      1. Lips, cheeks, tongue, teeth
      2. Accessory glands - salivary glands, tonsils
   B. Pharynx - with simple mucous glands
   C. Esophagus - with simple mucous glands
   D. Stomach
      1. Contains tube like glands
         a. Produce acid and enzymes
   E. Duodenum
      1. Accessory structures: Liver, gall bladder and pancreas
   F. Jejunum - empty
      1. Major site of absorption
      2. Contains mucous glands (goblet cells)
   G. Ileum - twisted
      1. Similar to jejunum but few digestive enzymes and more mucous secreted
      2. Less absorption occurs
   H. Large intestine
      1. Function:
         a. Accessory organs secrete mucous
         b. Absorption of water and salts
         c. Concentrates food into feces
      2. Cecum - blind
         a. Vermiform (wormlike) appendix
      3. Ascending, transverse, descending and sigmoid colons
      4. Rectum (straight)
      5. Anal canal
         a. ends at anus.

III. Histology Overview
   A. Digestive tube has four major layer (tunics): (internal) mucosa, submucosa, muscularis, (external) serosa.
   B. Gland types associated with intestinal tract
      1. Unicellular mucous glands (goblet cells) in mucosa
2. Multicellular glands in mucosa and submucosa
3. Multicellular glands (accessory glands) outside of intestinal tract.

C. Mucosa
1. Innermost tunic
2. Three layers:
   a. Mucous epithelium
      (1) Strat. Squam. Epi - oral and rectum
      (2) Simple columnar epithelium - remainder of digestive tract
   b. Lamina propria - loose C.T.
   c. Muscularis mucosae - thin muscular layer.

D. Submucosa,
1. Thick C.T. layer
2. Contains:
   a. blood vessels, small glands, and...
   b. nerves
      (1) **submucosal (Meisner’s) plexus**
      (2) parasympathetic ganglionic plexus

E. Muscularis
1. Inner circular layer - smooth muscle
2. Outer longitudinal layer - smooth muscle
3. Skeletal - striated voluntary muscle is found in the upper esophagus
4. stomach has 3 layers
5. Nerves - **myenteric (Auerbach’s) plexus**
   a. Parasympathetic nerve fibers and cell bodies between layers
   b. **Intramural plexus** - made up of myenteric and submucosal plexi

F. Serosa. - Adventicia (**foreign, from outside**)
1. Serosa - visceral peritoneum
2. Adventicia - derived from surrounding C. T. (esophagus)
IV. Physiology Overview

A. Functions of the Digestive System

1. Ingestion *(pouring in)*
   a. Introduction of food and liquid into the stomach via oral cavity

2. Mastication (chewing)
   a. Food is taken in and chewed by the teeth
   b. Breaks food into smaller particles so enzymes can act on it.
      (1) smaller particle have a larger surface area

3. Propulsion
   a. Movement of food from one end of the digestive tract to the other
      (1) Food travels full length in 24-36 hours
   b. Deglutination - swallowing
      (1) *bolus* of food moves from mouth to stomach
      (2) **Peristalsis** - muscular contraction and relaxation in waves

4. Mixing
   a. Muscular contractions that mix food with digestive secretions

5. Secretion
   a. Secretions are added to food to: *lubricate, liquify and digest food.*
   b. Musous - lubricates, coats and protects passageway from mechanical abrasion
   c. Liquify - secretions contain large amounts of water that makes it easier to digest and absorb
   d. Enzymes -
      (1) secreted from oral cavity, stomach, intestine, liver, pancreas
      (2) function to break food down into small absorbable molecules

6. Digestion
   a. Breakdown of complex molecules into parts
      (1) carbohydrates into monosaccharides
      (2) proteins into amino acids
      (3) triacylglycerols into fatty acids and glycerol.
   b. Two forms:
      (1) **mechanical** - mastication, mixing
      (2) **chemical** - digestive enzymes.

7. Absorption
   a. Movement of molecules out of digestive tract and into circulation or lymphatic system

8. Transportation
   a. Process by which absorbed molecules are distributed throughout the body
(1) Direct - through circulation
(2) Indirect - lymphatic system to circulation

9. Elimination
   a. Process by which waste products are removed from the body
   b. Water and salts must be removed
   c. Change from liquid to semisolid state
   d. Feces removed by defecation

10. Regulation
   a. Processes of propulsion, secretion, absorption and elimination are controlled by a
      complex and elaborate system of nerves and hormones
   b. Primarily regulated by the Vegas cranial nerve.

V. Anatomy and Histology of the Digestive Tract
   A. Covered in the lab

VI. Functions Associated with Anatomical structures
   A. Oral cavity - functions
      1. Teeth
         a. mastication - cutting and grinding of food
         b. Speech
      2. Lips and cheeks
         a. manipulation of food,
         b. hold food in position for mastication
         c. Communication
      3. Tongue
         a. Manipulation of food
         b. Cleaning teeth,
         c. Taste
         d. Communication
      4. Secretions of the oral cavity -
         a. Saliva
            (1) Serous (watery secretion)
                (a) moistens food and mucous membrane
            (2) Salivary amylase -
                (a) produced by serous glands of parotid salivary gland
                (b) breaks down carbohydrates into disaccharides (maltose)
                (c) 3-5% of all carbs are broken down in mouth.
Lysozyme -
(a) weak antibacterial action - kills bacteria
(b) prevents bacterial infection

Mucin (mucous)-
(a) produced by submandibular and sublingual salivary gland
(b) contains a proteoglycan that lubricates passageway

b. Secretion is triggered by:
(1) Parasympathetic stimulation (facial VII and glossopharyngeal IX)
(2) tactile stimuli
(3) taste - especially sour tastes
(4) odors -
(5) Thoughts of food
(6) sensations of hunger.

5. Mastication
a. Incisors and canines - cut and tear food
b. Premolars and molars, crush and grind food
c. Mastication is a subconscious act
   (1) reflex modulated by the medulla oblongata
   (2) can be initiated or stopped consciously

6. Deglutination (swallowing)
a. 3 parts: voluntary, pharyngeal, esophageal
b. Voluntary Phase
   (1) formation of bolus
   (2) pushed by tongue against hard palate and into oropharynx
c. Pharyngeal
   (1) Soft palate is elevated closing the nasopharynx
   (2) Pharynx is elevated
   (3) tactile receptors activate the swallowing center in medulla oblongata
   (4) Bolus is forced into the esophagus.
   (5) epiglottis is bent down to cover the larynx
d. Esophageal phase
   (1) Esophageal sphincter relaxes to allow food to enter
   (2) Peristaltic wave begin to move food toward stomach
   (3) Reinforced by medulla oblongata stimulation of smooth muscle in esophagus via vagus nerve

B. Stomach
1. Functions
a. Store food,
b. initiate digestion of proteins,
c. move food to small intestine.

2. Histology of Stomach
   a. Rugae of stomach allow stomach mucosa of stomach to bend and stretch
   b. Stomach is lined by simple columnar epithelium
      (1) forms gastric pits which are openings for gastric glands
   c. Cell types:
      (1) mucous cells - line gastric pits
      (2) mucous neck cells - deep in pits produce mucus
      (3) parietal cells - HCl and intrinsic factor
      (4) chief cells - pepsinogen
      (5) endocrine cells - regulatory hormones

3. Chyme - (juice)
   a. Food and stomach secretions

4. Stomach secretions:
   a. 2-3 L produced each day composed of the following secretions.
   b. Mucus
      (1) produced by mucous neck cells
      (2) viscous and alkaline substance
      (3) thick (1.5 mm thick)
      (4) Protects lining of stomach from acids
   c. Intrinsic factor
      (1) glycoprotein
      (2) secreted by parietal cells
      (3) binds vitamin B12 (necessary for DNA synthesis)
      (4) makes B12 more readily absorbed in ileum.
   d. HCl
      (1) Secreted by parietal cells in gastric glands.
      (2) produces low pH of stomach pH 1-3.
1. Produced from CO$_2$ and H$_2$O. CO$_2$ is taken into the cell.
2. CO$_2$ is combined with water to form carbonic acid.
3. Carbonic acid dissociates into bicarbonate ion and H$^+$. 
4. Bicarbonate moves back into the bloodstream.
5. Anion exchange molecule changes HCO$_3^-$ for Cl$^-$.
6. H$^+$ is actively transported into the stomach.
7. Cl$^-$ diffuses with the charged H$^+$ ions.
8. K$^+$ is transported into the cell in exchange for H$^+$.

(3) HCl kills bacteria (some bacteria have a special coating making them impervious to HCl)
(4) inactivates salivary amylase (stops digestion of carbs)
(5) denatures proteins
(6) provides proper pH for pepsin to act.

**e. pepsinogen**
(1) precursor to the active pepsin
(2) secreted by chief cells in glands of stomach
(3) packaged and released in as zymogen granules
(4) converted to pepsin by HCl
(5) most active at pH below 3.
(6) catalyzes the cleavage of proteins into smaller peptide chains

**f. gastrin,**
(1) produced by endocrine cells of gastric pits.
(2) stimulates additional HCl and pepsinogen secretion.
(3) secreted in response to stomach filling, caffeine, alcohol consumption

5. Regulation of stomach secretion
a. Cephalic phase: Taste and smell of food during and after eating causes activation of medulla oblongata causing vagal stimulation of stomach
b. Gastric phase: Stomach distention causes local neurons to be activated and acetylcholine is released.
   (1) ACh from parasympathetic neurons stimulates the release of HCl, pepsinogen, gastrin and mucous.
   (2) Gastrin release causes further release of HCl and pepsinogen release
   (3) Histamine also stimulates production of HCl
      (a) Tagamet and Zantac block the action of histamine on parietal cells and stop the production of HCl.
c. Intestinal Phase:
   (1) Food enters duodenum
      (a) pH above 3 causes stimulation of secretion in stomach
      (b) pH below 2 inhibits secretion in stomach
         i) Acid causes release of the hormone secretin from duodenum
         ii) Secretin inhibits secretion from parietal and chief cells.
      (c) lipids in duodenum cause the release of two hormones that also inhibit secretion.
         i) gastric inhibitory hormone -
         ii) CCK

6. Stomach Filling
   a. As food enters the stomach the rugae flatten and medulla oblongata stimulation allows smooth muscle distention

7. Mixing of stomach contents.
   a. mixing waves (1/20 sec.)
   b. Peristaltic waves force chyme in periphery into duodenum

8. Stomach Emptying
   a. Time food spends in stomach depends on type and amount of food
   b. Liquids clear stomach in 1.5 - 2.5 hrs
   c. Full meal will pass in 3-4 hours.
   d. Pyloric sphincter remains partially closed and food is forced through it.

VII. Functions of the Small Intestine
A. Anatomy
   1. Small intestine is divided into the duodenum, jejunum and ileum
   2. Specialized for increased surface area.
      a. Circular folds (perpendicular to long axis),
b. villi (finger like projections) covered by simple cuboidal epi.
c. microvilli - form the brush border
3. Intestinal gland cell types:
   a. Absorptive cells - produce digestive enzymes and absorb food
   b. Goblet cells - mucus
   c. Granular cells - bacterial protection
   d. Endocrine cells - regulatory hormones.
B. Site of the greatest amount of digestion and absorption.
C. Secretions of the small intestine
   1. Secretions form the Intestinal mucosa
      a. Mucus - from goblet and intestinal mucosal glands
         (1) Lubricate and protect small intestine from
              (a) acidic environment
              (b) digestive enzymes
              (c) abrasion
      b. Electrolytes and Water
         (1) Keep the chyme in a liquid form.
      c. Hormones:
         (1) Secretin and CCK
            (a) from intestinal mucosa
            (b) stimulate the liver, gall bladder and pancreas.
      d. Surface bound Enzymes -
         (1) not released into lumen, found on plasma membrane of mucosal cells
         (2) Disaccharidases - break down disaccharides
         (3) Peptidases - break down peptide chains
         (4) Nucleases - break down amino acids.
D. Movement of the small intestine
   1. Segmental contractions mix intestinal contents
   2. Peristaltic contractions move materials distally along intestine
   3. Regulation of movement (constriction causes by):
      a. Stretch of smooth muscle,
      b. local reflexes (changes in pH, osmolarity, food products trigger constriction).
      c. Parasympathetic stimulation
E. Absorption form the small intestine
   1. 9 L a day enters the small intestine
   2. 8 - 8.5 L is absorbed
   3. 0.5 - 1 L passed on to large intestine.
VIII. Liver Anatomy and Functions

A. Anatomy
   1. 4 lobes
   2. porta (entry of blood vessels, ducts, nerves to liver)
      a. Hepatic portal vein and artery
      b. Common hepatic duct

B. Functions of liver
   1. Bile production
      a. 600 - 1000L produced each day
      b. Neutralizes the acid pH of chyme leaving the stomach
      c. Emulsification of fat - to increase surface area and solubility of lipids to increase absorption
      d. Contains waste products from the liver to be excreted in feces/urine
   2. Storage
      a. Glucose is stored as glycogen
      (1) glucose removed from the blood rapidly -
      (2) control of blood glucose levels
      b. Fat and vitamins (A, B12, D, E and K)
   3. Nutrient interconversion
      a. Fats are converted into phospholipids for cell membranes
      b. Amino acids converted to ATP, lipids, glucose.
4. Detoxification
   a. Toxic substances from metabolism and ingestion
   b. Detoxifies by breaking down toxins or making their elimination easier.
      (1) ie, ammonia from amino acids metabolism is converted to urea and
           eliminated in kidney.
5. Phagocytosis
   a. Old Red and white blood cells, bacteria, debri
6. Synthesis
   a. Blood components - albumin, globulins, heparin, clotting factors

IX. Functions of the Gall bladder
   A. Anatomy
      1. Sac under liver (~ 8cm long)
      2. Wall contains muscular layer
      3. Connected to the liver by the cystic duct
   B. Function
      1. Stores and concentrates bile (5-10x)
      2. Contracts to release bile following a meal in response to :
         a. CCK released from duodenum or
         b. vagal stimulation.

X. Functions of the Pancreas
   A. Anatomy
      1.
   B. Both an endocrine and exocrine gland
      1. Endocrine:
         a. pancreatic islets (islets of Langerhans) - insulin and
            glucagon
      2. Exocrine
         a. Divided into lobules that contain acini
         b. Acini drain into a duct system that drains into the
            pancreatic duct
         c. empties into the duodenum
C. Function: produce Pancreatic enzymes
   1. watery bicarbonate solution
      a. Neutralizes acidic chyme
      b. $H_2O + CO_2 \rightarrow H_2CO_3 \rightarrow HCO_3^- + H^+
         (1) $HCO_3^-$ actively transported to the pancreatic duct
         (2) $H^+$ goes into bloodstream.
   2. Digestive Enzymes
      a. Produced by acinar cells
      b. Important for digestion of lipids, proteins and carbohydrates
         (1) Proteins - trypsin, chymotrypsin and carboxypeptidase
             (a) secreted in their inactive forms and activated by enzymes in duodenum.
         (2) Carbs - amylase
         (3) Lipids - pancreatic lipase
         (4) DNA and RNA - deoxyribonuclease and ribonuclease

D. Control of pancreatic secretion
   1. Controlled by both hormonal and endocrine mechanisms.
   2. Secretin stimulates the release of aqueous component (bicarbonate)
      a. Secretin release is stimulated by acid in duodenum
      b. Neutralizes the acidic chime coming from the stomach
   3. CCK stimulates release of bile from liver and digestive enzymes from pancreas
      a. Release initiated by lipid and protein in duodenum
   4. Vagus nerve (parasympathetic) stimulation
      a. Causes the release of digestive enzymes from the pancreas.

XI. Functions of the large intestine
A. Anatomy
   1. - cecum, ascending, transverse, descending, sigmoid, rectum
   2. Mucosal lining with mucous producing crypts
   3. Anal canal -
      a. internal anal sphincter (smooth muscle)
      b. External anal sphincter (skeletal muscle)

B. Function of the large intestine
   1. 18 - 24 hours to pass large intest. (compared to 3-5 h for small)
   2. 1500 ml enters / day,
      a. 90% reabsorbed, 80 - 150 ml of feces defecated
C. Secretions of the large intestine
   1. Little enzymatic activity
   2. Mostly mucus
a. Lubricates
b. Helps fecal matter stick together

3. Bicarbonate, sodium, and water are reabsorbed
   a. Inflammation of bowel due to bacterial infection can the release of large amounts of mucus, bicarb, electrolytes and water causing diarrhea -
      (1) infected feces is moved out quickly to aid healing.

4. Bacteria
   a. Produce vitamin K
   b. Gases (flatus) gk. Blowing
      (1) amount depends on bacterial type and food type

D. Movement in the large intestine
   1. Peristaltic waves move chyme
   2. Mass movements -
      a. triggered by gastric and duodenocolonic reflexes
   3. Defecation reflex due to distention of rectal wall.
      a. Causes relaxation of the internal anal sphincter (involuntary)
      b. external anal sphincter is voluntary