I. Summary
   a) Peritoneum: a thin membrane that encloses the contents of the abdomen. Some structures in the abdomen are within the peritoneum, and some are behind it and called retroperitoneal.
   b) Digestion: the breakdown of food into molecules small enough to pass through the plasma membranes of cells.
   c) Absorption: the passage of these molecules through the cells and into the blood.
   d) Gastrointestinal (GI) Tract: A long, continuous tube that travels from the mouth to the anus.
      i) Mouth, Pharynx, Esophagus, Stomach, Small Intestine (Duodenum, Jejunum, Ileum), Large Intestine (Cecum, Ascending Colon, Transverse Colon, Descending Colon, Sigmoid Colon), Rectum, & Anus.
   e) Accessory Digestive organs: organs that aid in digestion, but are not part of the GI Tract.
      i) Teeth, tongue, salivary glands, liver, gallbladder, and pancreas.
   f) Basic functions of the digestive system:
      i) Ingestion: Taking foods and liquids into the mouth (eating and drinking)
      ii) Secretion: Cells within the walls of the GI Tract secrete about 7 Liters of Water, Acid, Buffers, and Enzymes into the GI lumen.
      iii) Mixing and Propulsion: contraction and relaxation of the smooth muscles of the GI Tract mixes the food and secretions in the lumen and propels them toward the anus. The ability to move material throughout its length is called motility.
      iv) Digestion: mechanical and chemical process of breaking down ingested food into small molecules.
         (1) Mechanical digestion: teeth cut and chew food before it is swallowed and the stomach & small intestine churn food, dissolving and thoroughly mixing the food with digestive enzymes
         (2) Chemical Digestion: Chemicals split the large molecules of carbohydrates, protein, fat, and nucleic acids are split into smaller molecules. Digestive enzymes produced by the salivary glands, tongue, stomach, pancreas, and small intestine help to catalyze these reactions.
   v) Absorption: Secreted fluids and the small molecules and ions that are products of digestion enter the lining of the lumen in the GI Tract. They pass into the blood or lymph and circulate to the cells throughout the body.
   vi) Defecation: Wastes, indigestible substances, bacteria, dead cells from the GI Lining, and digested materials that were not absorbed leave the body through the anus as feces.
   g) Saliva
      i) Chemically composed of 99.5% water and .5% solutes
      ii) Solutes include ions and organic substances (including two digestive enzymes):
         (1) Salivary Amylase helps in the breakdown of carbohydrates (starch)
         (2) Lingual Lipase helps in the breakdown of triglycerides (fat)
      iii) Salivation is promoted by the parasympathetic nervous system
      iv) During stress and sympathetic dominance, you might notice a dryness in the mouth.
      v) Saliva helps to lubricate the lips and tongue for speech and moistens the esophagus when swallowed.
      vi) Saliva is usually reabsorbed after being swallowed to prevent fluid loss
      vii) During times of dehydration, saliva production slows to conserve water, again causing a dry mouth, contributing to the sensation of thirst.
      viii) The smell, sight, taste, and thought of food might also stimulate the secretion of saliva psychologically through learned behavior.

II. Digestion: Digestion begins as soon as food enters the mouth
   a) Mechanical digestion begins with chewing (aka mastication).
   b) Food is manipulated by the tongue and ground by the teeth as it is mixed with saliva.
   c) The food is converted into an easily swallowed mass called the bolus.
d) During chewing, the saliva mixes with the food enacting salivary amylase and lingual lipase to begin chemically digesting starch into monosaccharides (glucose, etc.) and triglycerides into fatty acids.

e) Once the bolus is ready to swallowed, the mouth voluntarily pushes the bolus toward the pharynx. This is the voluntary stage of swallowing.

f) When the bolus reaches the pharynx, a swallowing reflex takes over and funnels the food down the pharynx toward the esophagus while breathing is suspended and the trachea is closed off by the epiglottis.

g) This reflex is initiated by the deglutition (swallowing) center of the medulla oblongata and lower pons of the brainstem.

h) Esophagus: a long, collapsible, muscular tube that runs from the inferior end of the pharynx, posterior to the trachea and anterior to the spinal column, through the mediastinum, down to the superior portion of the stomach (piercing the diaphragm at the esophageal hiatus).

i) Histological Layers of the Esophagus (superficial to deep)
   (1) Serosa: outermost epithelial layer (most superficial)
   (2) Muscularis: two layers of muscle that contract to push food toward the stomach. 
      (a) Longitudinal esophageal muscle: outermost muscle
      (b) Circular esophageal muscle: innermost muscle
   (3) Submucosa: layer of connective tissue between the muscularis and the mucosa. Blood vessels are embedded in the mucosa and extend into the mucosa.
   (4) Mucosa: innermost layer. Made of a combination of epithelial tissue, connective tissue, and a thin layer of muscle.
      (a) The internal portion is called the mucous membrane and secretes mucus providing a lubricated surface for food to travel through.

ii) The esophageal phase of swallowing is facilitated by a progression of coordinated muscular contractions called peristalsis. Peristalsis pushes the bolus down the esophagus toward the stomach.

iii) Sphincter: a circular band or ring of muscle that is normally contracted to act as a valve or barrier between two spaces that can be opened to allow passage.
   (1) The esophagus is closed at either end by a sphincter.
   (2) At the superior end is the upper esophageal sphincter separating the esophagus from pharynx and at the inferior end is the lower esophageal sphincter separating the esophagus from the stomach.
      (a) Failure of the lower esophageal sphincter to close can cause acid from the stomach to back up into the esophagus causing burning of the esophageal tissue. This is called gastroesophageal reflux disease (GERD).
      (b) These sphincters open when they relax in a response to swallowing.

III. Stomach: j-shaped enlargement of the GI Tract inferior to the diaphragm and in the upper left portion of the abdomen. Runs from the end of the esophagus to the pyloric sphincter, which separates the stomach from the duodenum (first part of the small intestine).

   a) The stomach is divided into 4 sections:
      i) Cardiac: the section that connects to the esophagus
      ii) Fundus: the part that projects superiorly and laterally
      iii) Body: the largest part of the stomach
      iv) Pyloris: The part of the stomach that bottlenecks toward the duodenum.
         (1) Pyloric Sphincter: a circular band of muscle that acts as a valve to the duodenum, opening and closing to regulate the movement of substances from the stomach to the small intestine.

   b) Lesser Curvature: the concave curve of the stomach on the medial side
   c) Greater curvature: the convex curve of the stomach on the lateral side
   d) Histological Layers of the stomach wall
      i) Serosa: external most layer
      ii) Muscularis: Three muscular layers in the middle (more muscles for mixing and churning of food)
         (1) Longintudinal muscle: external muscle layer
         (2) Circular muscle layer: the middle layer
iii) **Submucosa**: layer of connective tissue between the muscularis and the mucosa. Blood vessels are embedded in the submucosa and extend into the mucosa.

iv) **Mucosa**: the innermost, wrinkled mucous membrane layer that secretes mucous, digestive enzymes and acids and absorbs some water and other substances (ions, alcohol, aspirin and some other drugs).

(1) Comprised of a layer of epithelium, connective tissue, and a thin layer of muscle.

(2) The epithelial cells of the stomach wall secrete mucous, hydrochloric acid, pepsinogen, and gastric lipase.

(a) Together known as **gastric juice**

(b) As food enters the stomach, it can either be stored for a while or peristaltic contractions of smooth muscle called **mixing waves** begin in the stomach, churning food and mixing it with the gastric juice until it becomes a soupy liquid called **chyme**.

(c) Protein digestion begins in the stomach with an enzyme called **pepsin** (active form of pepsinogen). When the stomach cells secrete pepsinogen, it is inactive so it cannot digest the cells of the stomach itself. Then, when it comes in contact with HCl or active Pepsin in the stomach lumen, it is activated. By this time, the stomach wall is protected by a layer of mucous.

(d) **Gastric Lipase**: has a limited role in the adult stomach, in babies it aids in the digestion of fat molecules found in milk, breaking them down into fatty acids and monoglycerides.

(e) Very little absorption takes place in the stomach except for some **water, ions, short-chain fatty acids, and certain drugs (aspirin) and alcohol**.

(f) **Gastric Emptying** – periodic release of chyme from the stomach to the duodenum.

(i) Regulated by neural and hormonal reflexes by these steps:

(ii) Stimuli such as distention of the stomach and partially digested proteins, alcohol, and caffeine initiate gastric emptying.

(iii) Secretion of gastrin is increases and parasympathetic stimulation by the vagus nerve (X) is initiated.

(iv) Gastrin and nerve impulses stimulate the contraction of the lower esophageal sphincter, increase motility of the stomach, and relax the pyloric sphincter. 1. Therefore, the chyme can begin to move from the stomach into the duodenum.

(v) Distention of the duodenum as well as the presence of fatty acids, glucose, and partially digested proteins inhibit gastric emptying to avoid too much chyme from being moved from the stomach to the duodenum at once.

(vi) This is called the **enterogastric reflex**

IV. **Pancreas** – Acts as both and endocrine and an exocrine (for digestion) gland

a) The pancreas lies posterior and inferior to the stomach

b) There are two ducts that allow pancreatic secretions to enter the duodenum

i) **Pancreatic Duct** – the larger of the two, connects the pancreas to the common bile duct (from the liver & gall bladder), which leads to the duodenum.

ii) **Accessory Duct** – the smaller of the two, goes directly to the duodenum.

c) **Pancreatic juice** is the mixture of pancreatic enzymes that are used for digestion in the duodenum.

i) Secreted by the exocrine portion of the pancreas

ii) Consists of water, salts, enzymes, and sodium bicarbonate (a base) to balance out the acid in gastric juice.

iii) Main Pancreatic Digestive Enzymes and what they digest

iv) **Pancreatic Amylace**: carbohydrate

v) **Trypsin, & chymotrypsin**: protein

vi) **Pancreatic Lipase**: triglycerides (fat)

V. **Liver & Gallbladder**

a) **Liver**

i) The second largest organ in the body (1st is skin)
ii) Separated into right and left lobes connected by the **falciform ligament**

iii) Cells of the liver are called **hepatocytes**

   (1) Hepatocytes produce and secrete **bile**

   (a) Bile is an alkaline liquid made mostly of water, bile acids, salts, cholesterol, and lecithin.

   (b) Bile acts to help pancreatic lipase digest triglycerides more quickly by breaking down fat globules into small droplets.

   (c) This process is called **emulsification**

   (2) Hepatocytes secrete bile into tiny ducts that eventually all come together from the left & right lobes to exit the liver through the **common hepatic duct**.

   (3) The common hepatic duct will join the **cystic duct** from the gallbladder to become the **common bile duct**, where bile enters the cystic and is temporarily stored in the gallbladder.

iv) **Other functions of the liver:**

   (1) Carbohydrate metabolism – the liver stores glucose as glycogen and can therefore break it down or store it to regulate blood sugar if needed.

   (2) Lipid Metabolism – stores some triglycerides to synthesize cholesterol and make bile salts

   (3) Protein Metabolism – Synthesize most plasma proteins as well as breakdown protein to form amino acids, which can be used for energy production or stored as carbohydrate or fats.

   (4) Processes drugs and hormones – detoxifies alcohol and drugs as well as chemically alter thyroid and steroid hormones.

   (5) Vitamin Storage – stores A, B12, D, E, and K

   (6) Activation of Vitamin D – vitamin D must be converted from ingested form to active for utilization in the body.

VI. **Gallbladder**

   a) A small, pear-shaped sac located in a depression on the posterior surface of the liver.

   b) The gallbladder’s function is to store and concentrate bile until it is need in the small intestine.

   c) Bile Regulation

   i) Parasympathetic stimulus causes the liver to produce more bile.

   ii) The presence of fatty acids and amino acids in the chyme of the duodenum, stimulate the release of a hormone called **cholecystokinin (CCK)**.

   iii) CCK causes the contraction of the wall of the gallbladder squeezing bile into the cystic duct and through the common bile duct that leads to the duodenum.

   d) Gall Stones: aka cholelithiasis

   i) Excessive cholesterol in bile can crystallize into stones that sit in the gallbladder and block the cystic duct.

   ii) Treatments are drugs, shock-wave therapy to break them up, or surgery to remove the gallbladder (cholecystectomy)

VII. **The Small Intestine**

   a) Most digestion and absorption takes place in the small intestine.

   b) Separated into three parts

   i) **Duodenum** – about 10 inches, shortest part. Goes from stomach to Jejunum

   ii) **Jejunum** – second part, about 3 feet. From duodenum to ileum.

   iii) **Ileum** – about 6 feet. From jejunum to where it joins the large intestine at the **ileocecal sphincter**

   c) **Histological Layers of the small intestine:**

   i) **Serosa:** external most layer

   ii) **Muscularis:** Two muscular layers in the middle

   (1) Longitudinal muscle: external muscle layer

   (2) Circular muscle layer: the internal layer

   iii) **Submucosa:** connective tissue layer that anchors the mucosa and has blood vessels embedded within that extend to the mucosa.

   iv) **Mucosa:** the innermost, wrinkled mucous membrane layer that secretes mucous & digestive enzymes, absorbs most of the fluids and digested products in our foods.
d) Supporting structures of the small intestine
   i) Greater omentum: a fold of the peritoneum that hangs from the stomach and duodenum anterior to the intestines like a fatty apron. It is a double-sheet of peritoneum folded over on itself resulting in a four-layered structure.
   (1) Contains a considerable amount of fat tissue (adipose) that can expand with weight-gain, giving the ‘beer belly’ appearance.
   ii) Lesser omentum: two folds of the peritoneum that extend from the liver suspending the stomach and proximal duodenum.
   (1) Divided into two parts called ligaments
      (a) Hepatoduodenal ligament: from the liver to the duodenum
      (b) Hepatogastric ligament: from the liver to the stomach
   iii) Mesentery: a fold of peritoneum that attaches the small intestine to the posterior abdominal wall
   iv) Ligament of Treitz: connective tissue extension of the diaphragm near the esophagus that suspends the duodenum from the diaphragm.
e) The internal lining of the small intestine has small, fingerlike projections called villi to increase the surface area for greater absorption of digested materials.
   i) The lining of the small intestine secretes digestive enzymes called brush-border enzymes for digestion.
   ii) There are two types of movements of the small intestine
      (1) Segmentation: localized distention of the small intestine cause a contraction of the smooth muscle to mix chyme and bring more of it in contact with the surface of the intestinal wall for absorption. Chyme is not moved further down the line by segmentations.
      (2) Migrating Motility Complex: a peristaltic movement of smooth muscle to push chyme toward the large intestine when it’s become mostly absorbed and the volume is no longer enough to stimulate segmentation.
f) Carbohydrates, lipids, proteins, and nucleic acids are all digested (broken down by enzymes) in the small intestine into absorbable substances and absorbed.
   i) Carbohydrates absorbed as monosaccharides (fructose, glucose, galactose) for energy production
   ii) Proteins absorbed as Amino acids, dipeptides, and tripeptides for energy and tissue building and repair.
   iii) Lipids absorbed as fatty acids, triglycerides, & glycerol for energy, hormone production, and storage.
   iv) Electrolytes (ions, etc.), Vitamins, and Water are also absorbed.

VIII. Large Intestine
   a) About five feet long and runs from the ileocecal sphincter in the lower right quadrant of the abdomen to the anus.
   b) Distal to the ileocecal sphincter is the cecum, a small pouch about 2.5 inches long.
   c) Attached to the cecum is the appendix, a twisted finger-like projection about 3 inches long.
   d) The colon is retroperitoneal and starts at the opening of the cecum.
      i) It is a long tube divided into portions:
         (1) Ascending Colon: The first part runs superiorly to the liver.
         (2) Transverse colon: at the liver, the colon turns medially and runs across the midline to the spleen
         (3) Descending colon: at the spleen, the colon turns inferiorly and runs toward the hip.
         (4) Sigmoid Colon: At the level of the iliac crest (hip bone), the colon turns and runs toward the midline and terminates at the rectum around the S3 vertebra in the sacrum.
      ii) The colon is sectioned into a series of muscular pouches called haustra, which give it a puckered-like appearance.
   e) The Rectum: The last 8 inches of the GI Tract.
      i) Anterior to the sacrum and coccyx.
      ii) The terminal portion is called the anal canal, which opens to the exterior world as the anus, guarded by an involuntary internal sphincter and a voluntary external sphincter.
   f) Histological Layers of the Large Intestine
i) **Serosa**: external most epithelial layer

ii) **Muscularis**: Two muscular layers in the middle
   (1) Longitudinal muscle: external muscle layer
   (2) Circular muscle layer: the internal layer

iii) **Submucosa**: connective tissue layer that anchors the mucosa and has blood vessels embedded within that extend to the mucosa.

iv) **Mucosa**: the innermost mucous membrane layer that secretes mucous & absorbs most of the water that is left in colonic contents.

g) **Mesocolon**: the mesentery of the colon
   i) **Transverse mesocolon**: the superior mesocolon
   ii) **Sigmoid mesocolon**: the inferior mesocolon

h) **Digestion in the Large Intestine**
   i) The ileocecal sphincter normally remains closed to make sure passage of chyme from the ileum to the large intestine occurs slowly.

ii) Immediately after eating, a **gastroileal reflex** from stomach distension intensifies ileal peristalsis, forcing chyme through the ileocecal sphincter.

iii) Movements of the colon begin when substances pass through the ileocecal sphincter.

iv) There are three methods of movement in the colon:
   (1) **Haustral Churning** – when a haustra distends from filling with chyme, the walls contract and squeeze the chyme into the next haustra.
   (2) **Peristalsis** – some peristalsis (periodic contractions of smooth muscle) also occur, pushing chyme along the way.
   (3) **Mass Peristalsis**: about half way through the transverse colon, a mass peristalsis occurs moving colonic contents quickly into the rectum.
      (a) Usually takes place 3-4 times/day due to the **gastrocolic reflex** initiated by the presence of food in the stomach.

v) Bacteria that inhabit the lumen of the colon are responsible for the final stages of digestion.
   (1) Chyme is prepared for elimination by the bacteria
   (2) Bacteria ferment the remaining carbohydrates and release hydrogen, carbon dioxide, and methane gas.
      (a) Combination of gasses called **flatus**

vi) A significant amount of water absorption takes place in the colon, turning the chyme into a solid to semisolid mass called **feces**.
   (1) Feces consists of water, inorganic salts, dead epithelial tissue from the GI Tract, bacteria, products of bacterial decomposition, unabsorbed digested material, and indigestible parts of food.
   (2) Chyme usually remains in the colon for about 3-10 hours before it is converted to feces.

i) **The Defecation Reflex**
   i) **Defecation** – removal of waste products (feces) through the anus
   (1) Mass peristalsis pushes feces from the sigmoid colon into the rectum
   (2) Distension of the rectal walls stimulates stretch receptors, which initiate the defecation reflex.
   (3) The muscles of the rectum contract, shortening it and increasing the pressure within.
   (4) The pressure, along with voluntary contractions of the diaphragm and abdominal muscles, as well as parasympathetic stimulation, relax and open the internal anal sphincter.
   (5) The external sphincter is voluntarily controlled. If it is relaxed, defecation can occur. If it is contracted, defecation can be postponed.

IX. **Blood Supply of the bowel**

   a) **Celiac Trunk**: large anterior branch just inferior to the diaphragm and branches into 3 main arteries:
   i) **Common Hepatic artery**: medium-sized, right-sided branch of the celiac trunk and branches into three arteries of it’s own:
      (1) **Proper hepatic artery**: liver, gallbladder, and stomach.
      (2) **Hepatic arteries**: liver
      (3) **Right gastric artery**: stomach
(4) **Gastroduodenal artery**: stomach, duodenum, pancreas, greater omentum
(5) **Right gastro-omental artery**: stomach and greater omentum

ii) **Left gastric artery**: small, left-sided branch of the celiac trunk
   (1) Left & right Gastric arteries anastomose with each other and branch out all over the stomach in combination with other arteries.

iii) **Splenic artery**: also left-sided branch of celiac trunk
   (1) **Left gastro-omental**: stomach and greater omentum

b) **Superior Mesenteric artery**: anterior branch of abdominal aorta inferior to the celiac trunk.
   i) Travels inferiorly and branches into several arteries that anastomose with each other and supply the pancreas, duodenum, ascending colon, transverse colon, cecum, ilium, jejunum, and the mesentery of the small intestine:
      (1) **Middle colic artery**: transverse colon
      (2) **Inferior pancreaticoduodenal artery**: pancreas and duodenum
      (3) **Right colic artery**: ascending colon
      (4) **Ileocolic arteries**: ileum and ascending colon
      (5) **Ileoepatic arteries**: ileum
      (6) **Ileal arteries**: jejunum

c) **Inferior mesenteric**: large anterior branch at about the 3rd lumbar vertebra. Travels leftward and branches into arteries that anastomose with each other and the branches of the superior mesenteric artery to supply the transverse colon, descending colon, sigmoid colon, rectum, and the mesocolon:
   i) **Left Colic artery**: transverse and descending colon
   ii) **Sigmoid arteries**: descending and sigmoid colon
   iii) **Superior rectal artery**: rectum

X. **Veins and blood return**

a) **Hepatic Portal Vein**: a large vein that brings blood returning from the digestive system to the liver for detoxification and processing of nutrients, vitamins, minerals, and other molecules absorbed from digestion.
   i) All blood returning from the digestive tract eventually leads to the hepatic portal vein and then the liver.
   ii) After the liver is finished processing contents, the blood makes it to the hepatic veins and then the inferior vena cava to return to the heart.

b) **Gastric veins**: stomach

c) **Superior Mesenteric vein** returns blood from the right side of the large intestine and all of small intestine to the hepatic portal.
   i) **Spleenic vein**: returns blood from the spleen to the hepatic portal

d) **Inferior mesenteric vein**: returns blood from the left side of the large intestine to the hepatic portal.