The Digestive System

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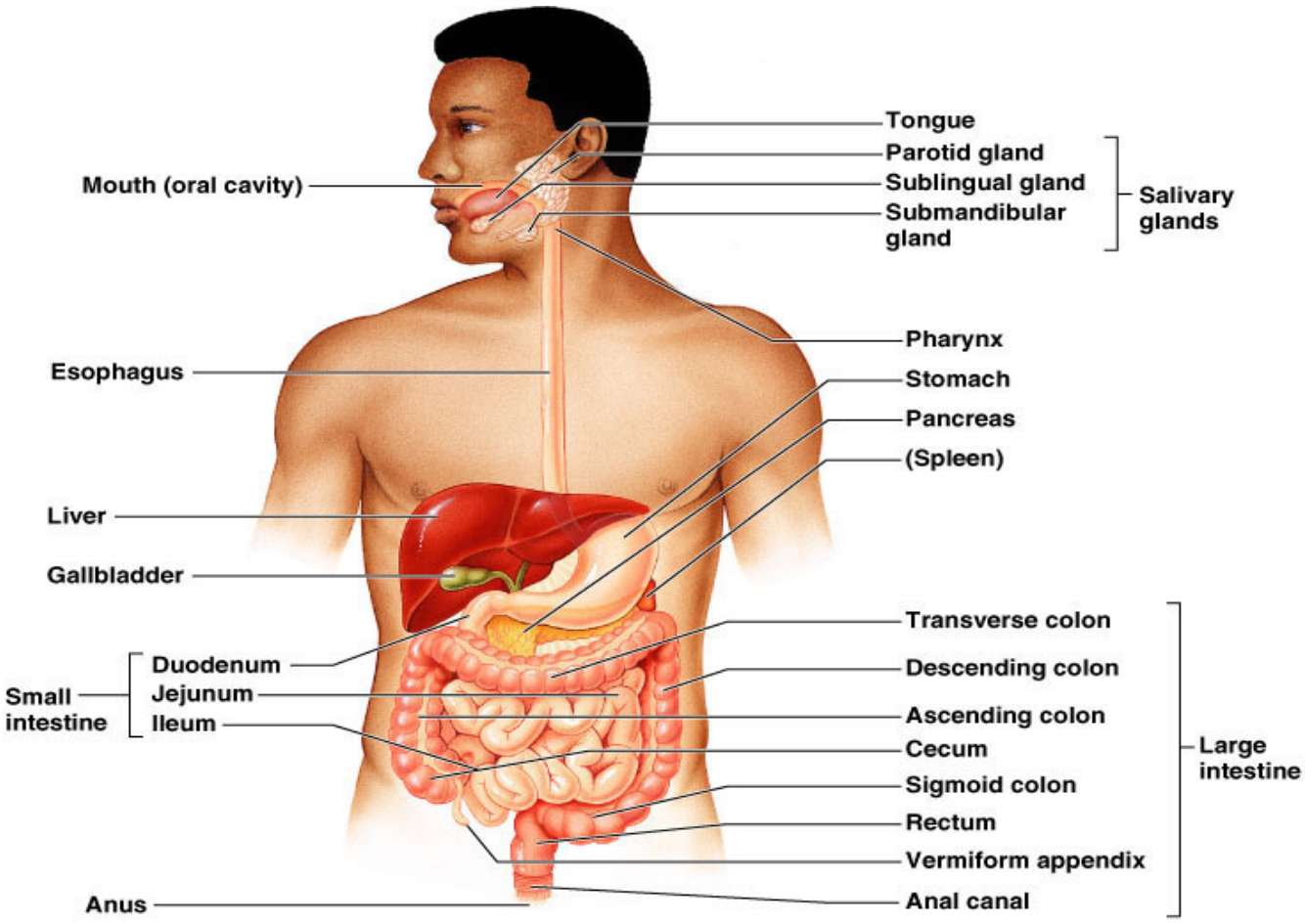


Digestive System: Overview

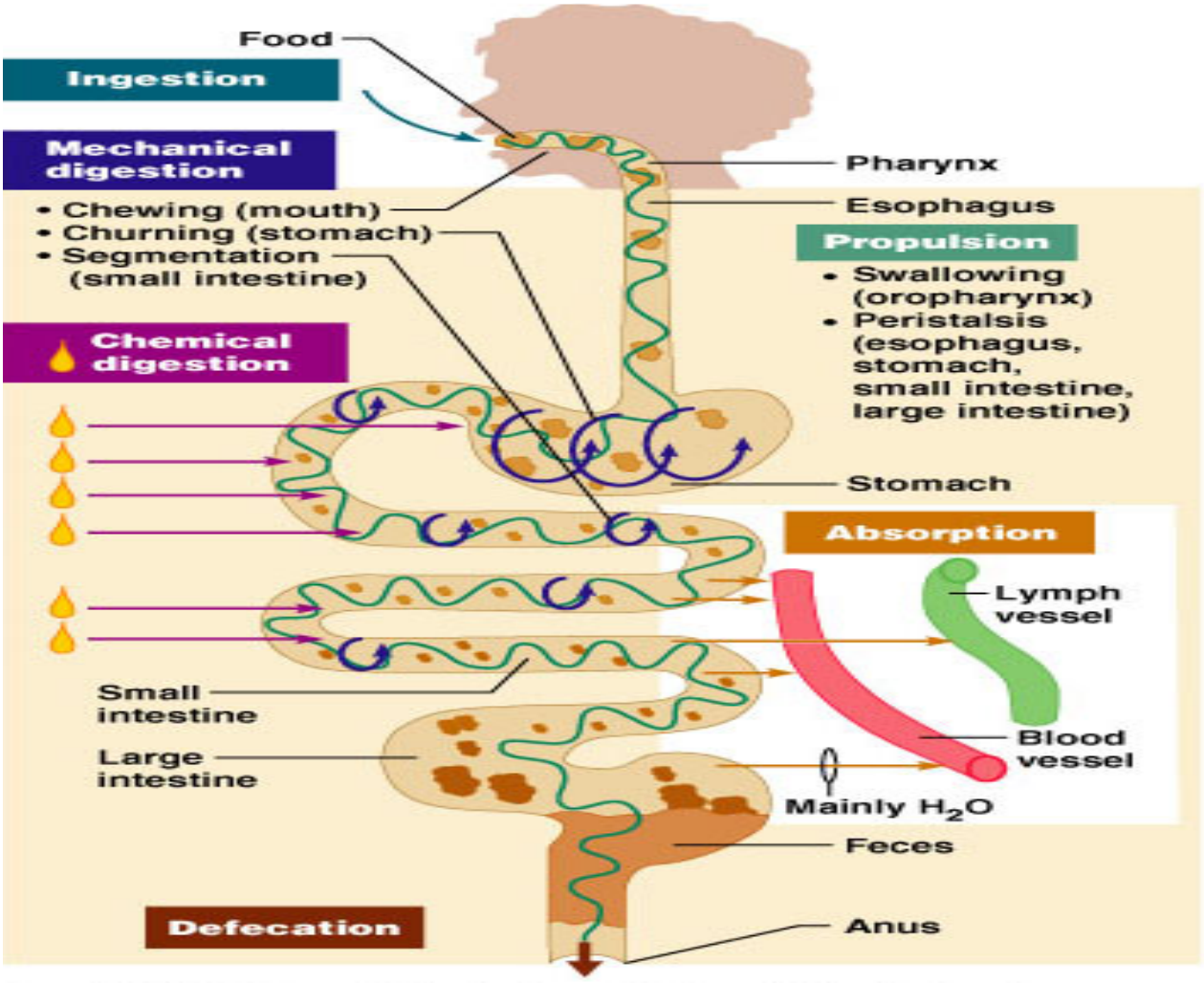
- The alimentary canal or gastrointestinal (GI) tract digests and absorbs food
- Alimentary canal – mouth, pharynx, esophagus, stomach, small intestine, and large intestine
  - Adult 30 feet long
  - Child 20 feet long
  - At birth 11 feet long
  - At 25 weeks 5 feet long
- Accessory digestive organs – teeth, tongue, gallbladder, salivary glands, liver, and pancreas

Digestive Process

- The GI tract is a “disassembly” line
  - Nutrients become more available to the body in each step
- There are six essential activities:
  - Ingestion, propulsion, and mechanical digestion
  - Chemical digestion, absorption, and defecation

Gastrointestinal Tract Activities

- Ingestion – taking food into the digestive tract
- Propulsion – swallowing and peristalsis
  - Peristalsis – waves of contraction and relaxation of muscles in the organ walls
  - Segmentation – rhythmic local contractions of intestine
- Mechanical digestion – chewing, mixing, and churning food
- Chemical digestion – catabolic breakdown of food
- Absorption – movement of nutrients from the GI tract to the blood or lymph
- Defecation – elimination of indigestible solid wastes



Food has different names depending on location

- When in mouth it is called **food**
- Once it mixes with saliva, it is called a **bolus**
- Once the bolus goes to the stomach, it mixes with HCl and is then called **chyme**
- The chyme enters the small intestine and the nutrients are absorbed
- Once all the nutrients are absorbed and it is in the large intestine, there is very little nutritional value left.
- From this point on it is called the **end products of digestion.**

Regulation of digestion involves:

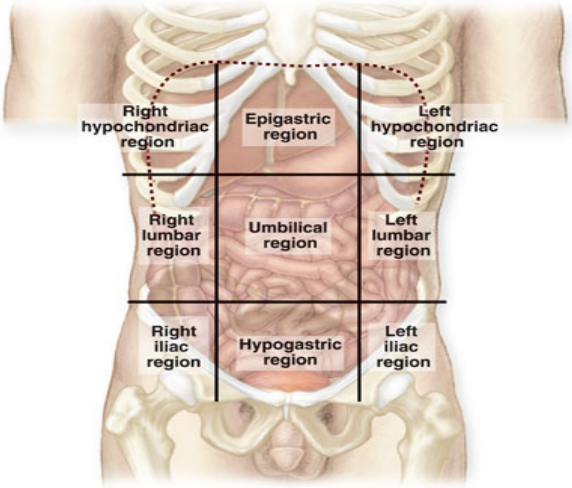
- Mechanical stretch receptors
    - Stretches with food in lumen
    - They initiate reflexes that mix lumen contents and move them along

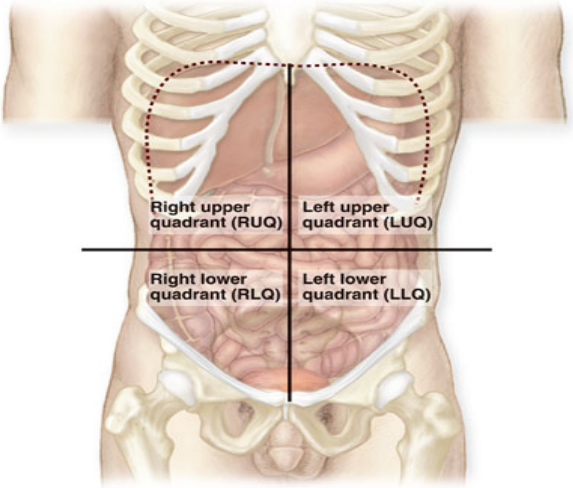
Receptors of the GI Tract

- Mechano- and chemoreceptors respond to:
    - Stretch by the presence of food
    - Osmolarity – solute concentration
    - pH of contents
    - Presence of end products of digestion
- They initiate reflexes that:
    - Activate or inhibit digestive glands to secrete digestive juices
    - Mix lumen contents and move them along

Nervous Control of the GI Tract

- Intrinsic controls
    - This gut-brain axis is often referred to as the ENS – enteric nervous system
    - Over 100 million nerves
- Extrinsic controls
    - Long reflexes arising within or outside the GI tract
    - Involve CNS centers and extrinsic autonomic nerves





Peritoneum and Peritoneal Cavity

- Lines the abdominopelvic cavity and invests the viscera.
- The parietal peritoneum, which lines the internal surface of the abdominopelvic wall
- The visceral peritoneum, which invests viscera such as the stomach and intestines.
- Both layers of peritoneum consist of mesothelium, a layer of simple squamous epithelial cells.

Parietal Peritoneum

- Served by the same blood and lymphatic vasculature and the same somatic nerve supply, as is the region of the wall it lines.
- Sensitive to pressure, pain, heat and cold, and laceration.
    - Pain from the parietal peritoneum is generally well localized due to nociceptive fibers.

Visceral Peritoneum

- Served by the same blood and lymphatic vasculature and visceral nerve supply.
- Insensitive to touch, heat and cold, and laceration; it is stimulated primarily by stretching and chemical irritation.
    - The pain produced is poorly localized, being referred to the dermatomes.
    - Consequently, pain is often in different locations
        - Foregut → epigastric pain
        - Midgut → umbilical region
        - Hindgut → pubic region.

The relationship of the viscera to the peritoneum is as follows:

- Intraperitoneal organs are almost completely covered with visceral peritoneum.
    - Intraperitoneal does not mean inside the peritoneal cavity (although the term is used clinically for substances injected into this cavity).
    - Intraperitoneal organs have literally invaginated into the closed sac.

Intraperitoneal organs

- Stomach
- Half of the first part of the duodenum
- Jejunum
- Ileum
- Cecum
- Appendix
- Transverse colon
- Sigmoid colon
- Rectum (upper 1/3)

Extraperitoneal organs

- Second half of the duodenum
- Ascending colon
- Descending colon
- Rectum (middle 1/3)

Extraperitoneal, retroperitoneal, and subperitoneal organs

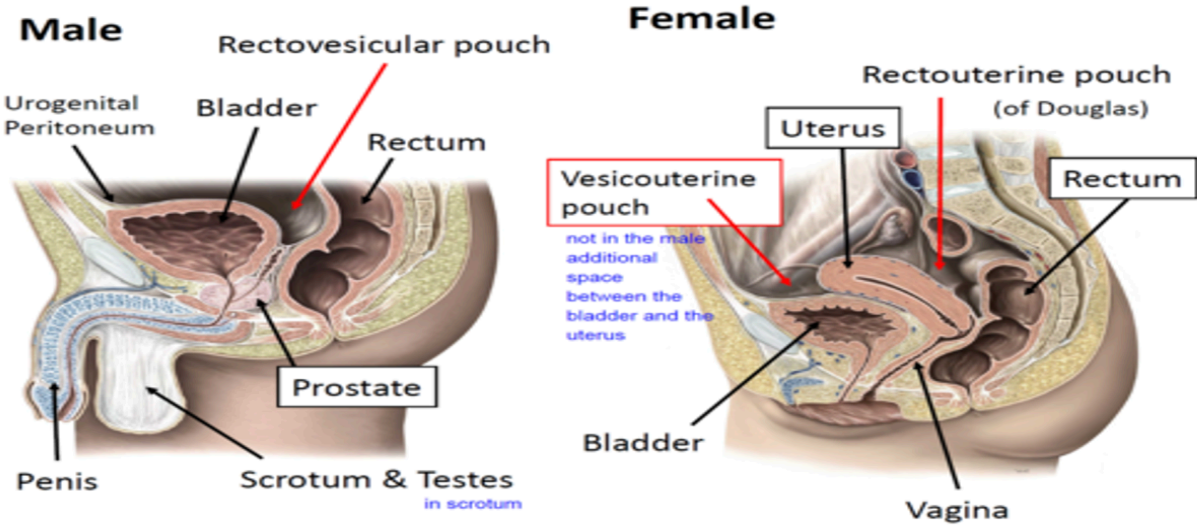
- Are only partially covered with peritoneum (usually on just one surface).
- Sandwiched between the organs and the parietal peritoneum
- There is often a variable amount of intervening fat

Peritoneal Cavity

- The peritoneal cavity is within the abdominal cavity and continues inferiorly into the pelvic cavity.
- Is a potential space of capillary thinness between the parietal and visceral layers of peritoneum.
- Contains no organs but contains a thin film of peritoneal fluid, which is composed of water, electrolytes, and other substances derived from interstitial fluid in adjacent tissues.

Peritoneal Fluid

- Lubricates the peritoneal surfaces
- Enables the viscera to move over each other without friction
- Allowing for the movements of digestion
- Contains leukocytes and antibodies that resist infection
- Lymphatic vessels, particularly on the inferior surface of the constantly active diaphragm, absorb the peritoneal fluid.
- In males, the peritoneal cavity is a completely closed sac system.
- In females, the peritoneal cavity is an open sac system with the fallopian tubes, ovaries and vagina.
- This communication constitutes a potential pathway of infection from the exterior.



Embryology of Peritoneal Cavity

- When it is initially formed, the gut (embryonic digestive tube) is the same length as the developing body.
- The gastrointestinal (GI) system involves three germinal layers: mesoderm, endoderm, ectoderm.
- Mesoderm gives rise to the connective tissue, including the wall of the gut tube and the smooth muscle.
- All three layers involved
    - Endoderm is the source of the epithelial lining of the gastrointestinal tract, liver, gallbladder, pancreas.
    - Ectoderm is the source of the peripheral nervous system, including the neurons of the GI tract (also called the enteric nervous system).
- The gastrointestinal system has the divisions: the foregut, midgut, and hindgut.
    - The foregut (or anterior gut) is from the oral cavity to the initial part of the duodenum.
    - The midgut is from the mid-duodenum to the initial two-thirds of the transverse colon.
    - The hindgut is from the later one-third transverse colon to the upper portion of the anus.
- The three sections of the GI tract have different blood supplies.
    - The foregut receives vascular supply by the celiac artery.
    - The superior mesentery artery supplies the midgut.
    - The hindgut gets its supply from the inferior mesentery artery.
- Organogenesis occurs from weeks three to eight. Avoiding teratogens especially during these weeks is crucial.

Embryology of Peritoneal Cavity - Timeline

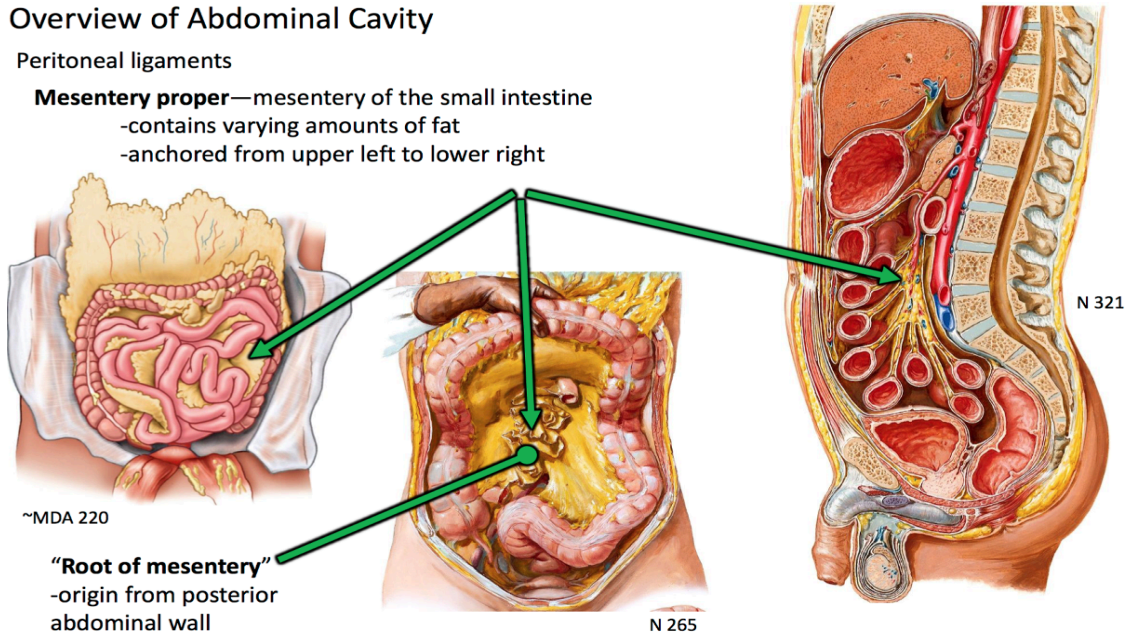
- Week 3: Digestive tube starts differentiating. The endoderm sheet elongates.
- Week 4: Resorption of the buccopharyngeal membrane occurs, which closes the cranial end of the digestive tube.
- Week 6-10: Midgut herniates throughout the umbilical ring, where it develops almost entirely outside the peritoneal cavity.
- Week 11: Longitudinal and circular muscle layers are present through the intestines
- Week 12: Crypt development begins.
- Week 14: muscularis mucosae develops
- Week 24: fetal intestinal absorption function develops
- Week 32: fetal intestinal absorption reaches adult level.

Peritoneal Formations

- The peritoneal cavity has a complex shape. Some of the facts relating to this include the following:
    - The peritoneal cavity houses a great length of gut, most of which is covered with peritoneum.
    - Extensive attachments are required between the parietal and visceral peritoneum to convey the necessary neurovascular structures from the body wall to the viscera.
    - The surface area of the peritoneum is greater than the surface area of the skin even though the peritoneum is only a fraction of the size of the skin
    - It can only accomplish this much surface area with the extensive convolutions.

Mesentery

- Double layer fold of the peritoneum, which attaches the stomach, small intestine, pancreas, spleen, and other organs to the posterior wall of the abdomen.
- Mesenteries have a core of connective tissue containing blood and lymphatic vessels, nerves, lymph nodes, and fat.
- It provides a means for neurovascular communications between the organ and the body wall.

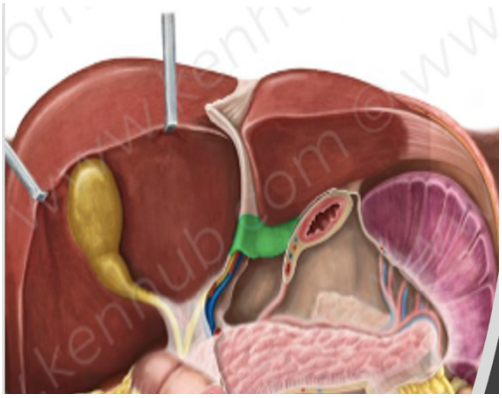


Omentum

- Omentum refers to a fold of peritoneum, connecting the stomach with other abdominal organs.
- The lesser omentum attaches the stomach to the liver.
- The greater omentum covers the small intestine like an apron.

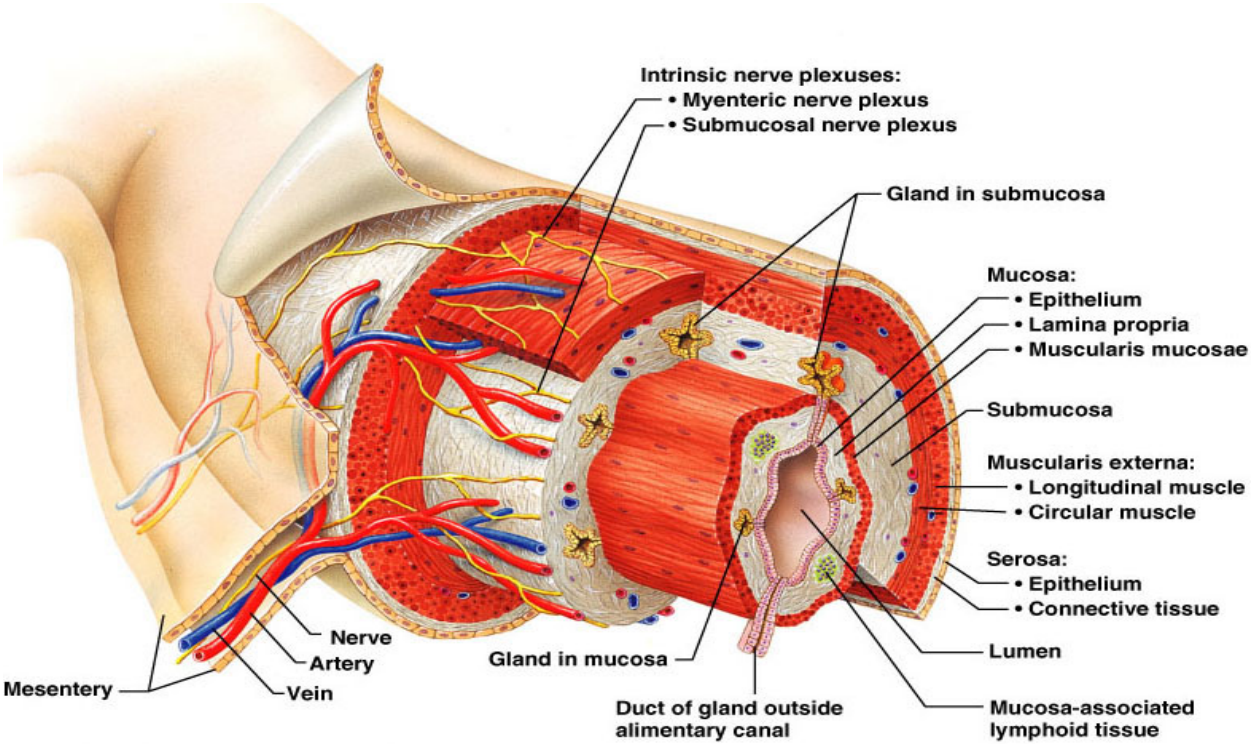
Peritoneal ligaments

- A peritoneal ligament consists of a double layer of peritoneum that connects an organ with another organ or to the abdominal wall.
- They have two main functions:
  - To attach organs to the abdominal wall and/or to other abdominal organs and hold them in position
  - To carry neurovascular structures which supply abdominal organs
- Based on from which they originate, peritoneal ligaments are classified as splenic, gastric or hepatic ligaments.
- Splenic ligaments
  - Phrenicocolic ligament
  - Gastrosplenic ligament
  - Splenorenal ligament
- Gastric ligaments
  - Gastrophrenic ligament
  - Gastrocolic ligament
- Hepatic ligaments
  - Falciform ligament
  - Hepatogastric ligament
  - Hepatoduendenal ligament
- Make up the lesser omentum
- Makes up the greater omentum



Hepatogastric ligament - Forms the portal triad with the hepatic portal vein and artery and the common bile duct

Histology of the Alimentary Canal



Layers of the Alimentary Canal

- Mucosa
  - Secretes mucus, enzymes and hormones
  - Absorption of end products of digestion into blood
  - Protection against disease
- Submucosa
  - Dense connective tissue with blood, lymph and nerves
- Muscularis externa or muscularis
  - Responsible for peristalsis and segmentation
- Serosa - Actually the visceral peritoneum

Smooth Muscle

- Contraction is slow and sustained
  - Takes 30x longer to contract and relax
  - Resistant to fatigue
  - Energy requirements are low
  - Mitochondria are not abundant
- Primarily found in walls of viscera
- Fibers elongated
- Grouped into sheets
  - Longitudinal layer—parallel to long axis of organ
  - Circular layer—deeper layer, fibers run around circumference of organ

Innervation of Smooth Muscle

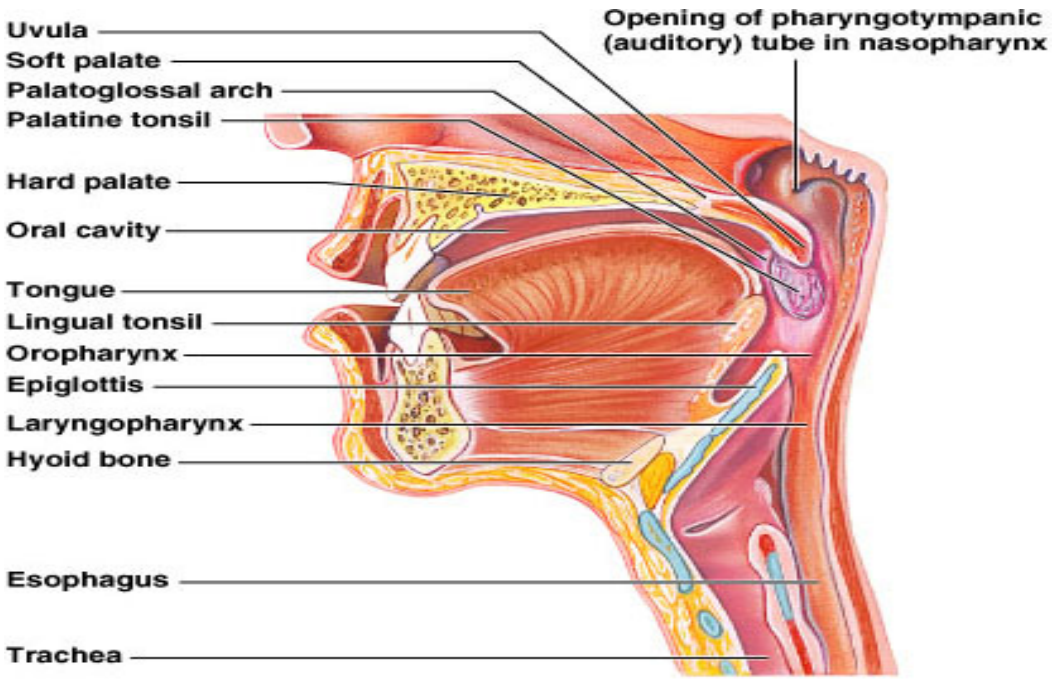
- Innervated by ANS
  - Few fibers per sheet innervated
- Sheet of smooth muscle contracts as a unit
- Sympathetic and parasympathetic motor fibers
- Visceral sensory fibers
- Myenteric nerve plexus controls peristalsis and segmentation
- Submucosal nerve plexus signals glands to secrete

Mouth

- Oral or buccal cavity:
  - Is bounded by lips, cheeks, palate, and tongue
  - Has the oral orifice as its anterior opening
  - Is continuous with the oropharynx posteriorly
- To withstand abrasions:
  - The mouth is lined with stratified squamous epithelium
  - The gums, hard palate, and dorsum of the tongue are slightly keratinized

Lips and Cheeks

- Have a core of skeletal muscles
  - Lips: orbicularis oris
  - Cheeks: buccinators
- Vestibule – bounded by the lips and cheeks externally, and teeth and gums internally
- Oral cavity proper – area that lies within the teeth and gums
- Labial frenulum – median fold that joins the internal aspect of each lip to the gum

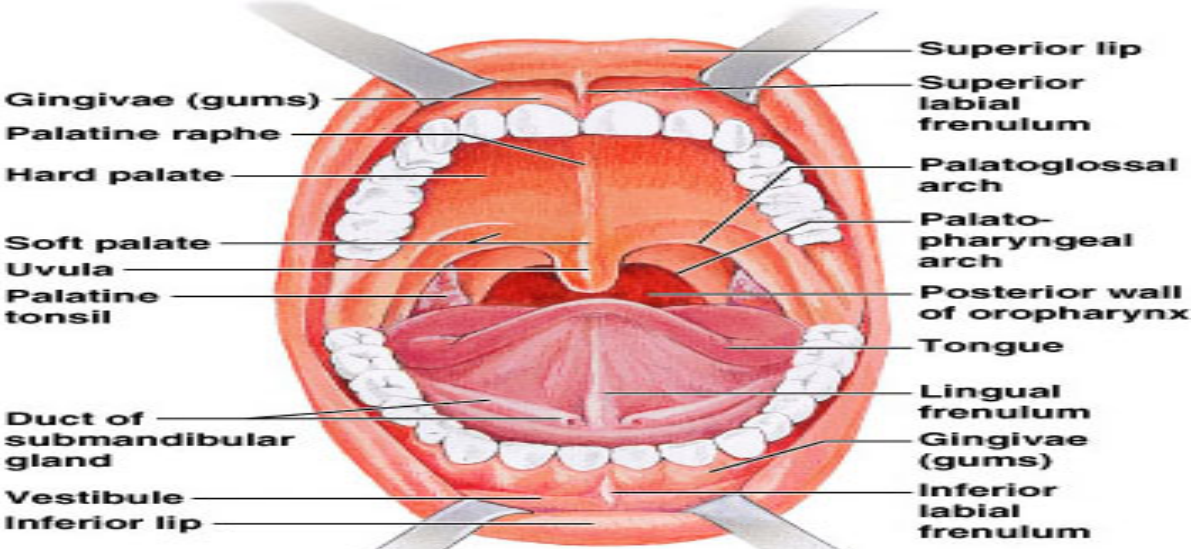


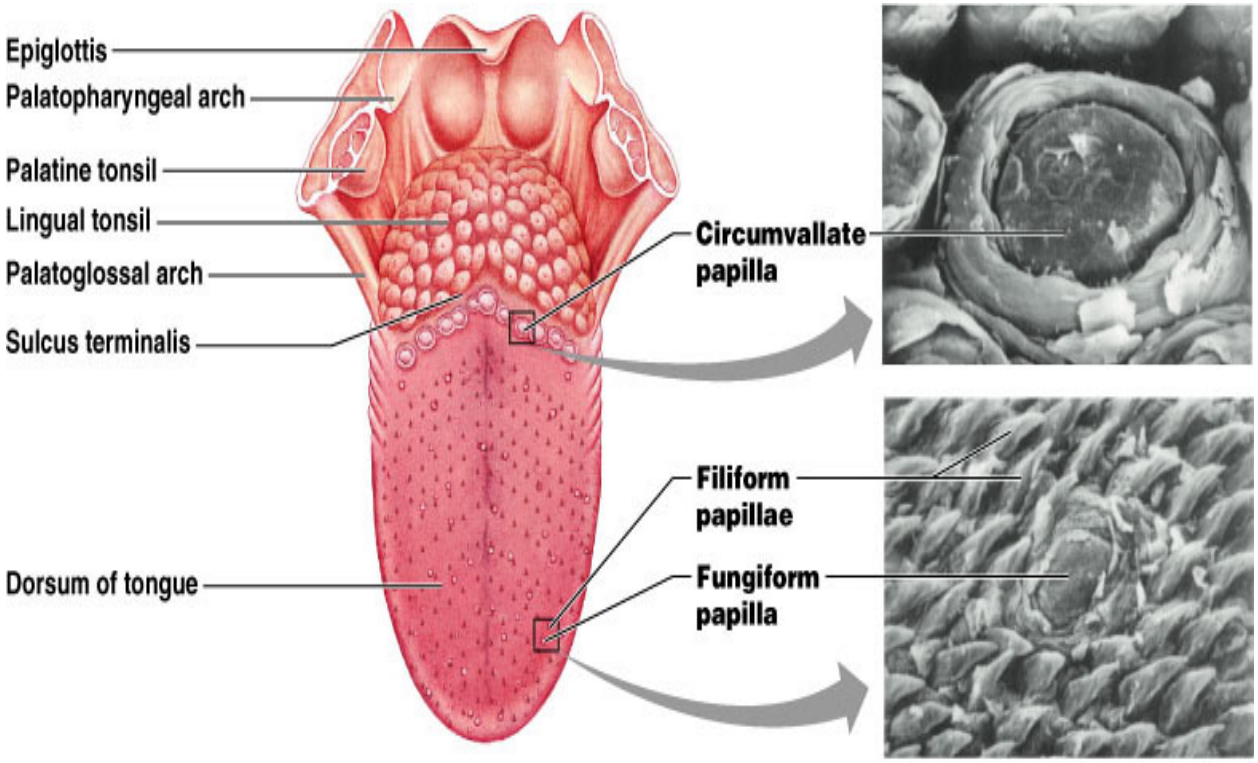
Palate

- Hard palate
  - Assists the tongue in chewing
  - Slightly corrugated on either side of the raphe (midline ridge) which helps to create friction
- Soft palate – mobile fold formed mostly of skeletal muscle
  - Closes off the nasopharynx during swallowing

Tongue

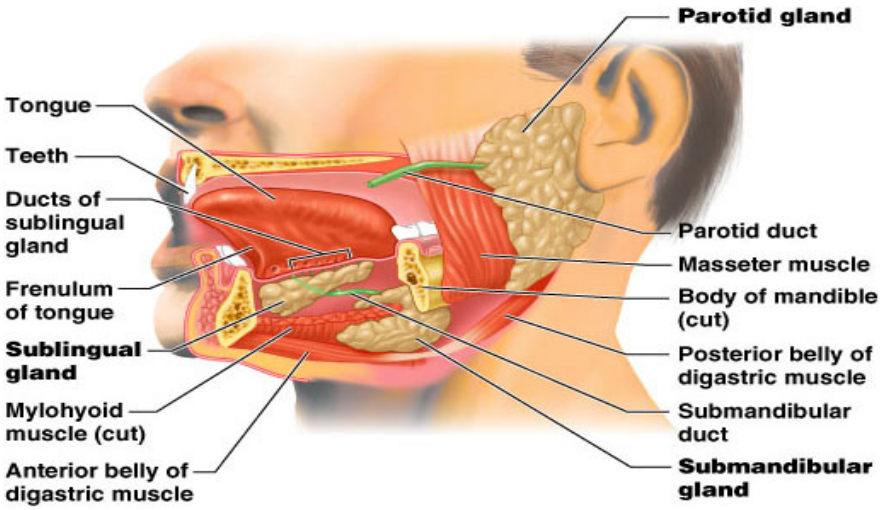
- Occupies the floor of the mouth and fills the oral cavity when mouth is closed
- Functions include:
  - Gripping and repositioning food during chewing
  - Mixing food with saliva and forming the bolus
  - Initiation of swallowing, and speech
- Intrinsic muscles change the shape of the tongue
- Extrinsic muscles alter the tongue's position
- Lingual frenulum secures the tongue to the floor of the mouth





Salivary Glands

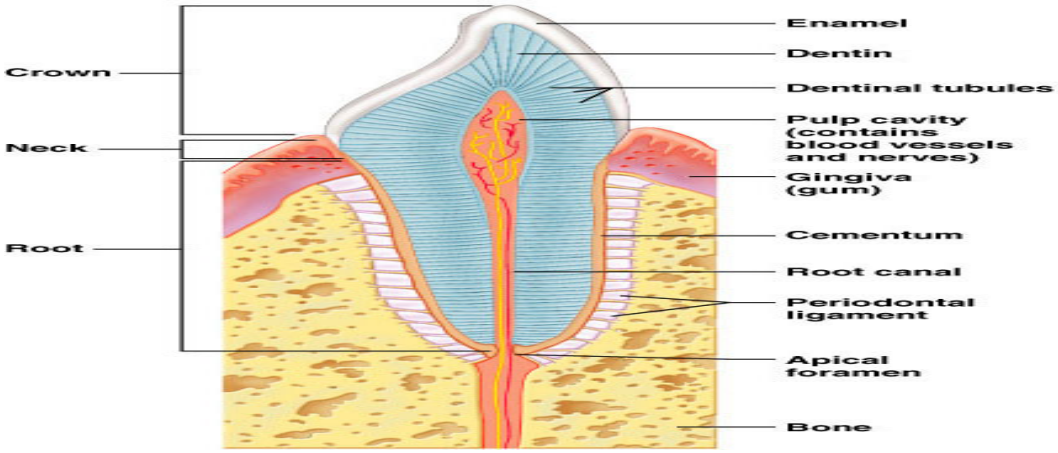
- Produce and secrete saliva that:
  - Cleanses the mouth
  - Moistens and dissolves food chemicals
  - Aids in bolus formation
  - Contains enzymes that break down starch
- Three pairs of extrinsic glands – parotid, submandibular, and sublingual
- Intrinsic salivary glands (buccal glands) – scattered throughout the oral mucosa
- Parotid – lies anterior to the ear between the masseter muscle and skin
  - Parotid duct – opens into the vestibule next to the second upper molar
- Submandibular – lies along the medial aspect of the mandibular body
  - Its ducts open at the base of the lingual frenulum
- Sublingual – lies anterior to the submandibular gland under the tongue
  - It opens via 10-12 ducts into the floor of the mouth



Teeth

- Primary and permanent dentitions have formed by age 21
- Primary – 20 deciduous teeth that erupt at intervals between 6 and 24 months
- Permanent – enlarge and develop causing the root of deciduous teeth to be resorbed and fall out between the ages of 6 and 12 years
  - All but the third molars have erupted by the end of adolescence
  - There are usually 32 permanent teeth
- Teeth are classified according to their shape and function
  - Incisors – chisel-shaped teeth adapted for cutting or nipping
  - Canines – conical or fanglike teeth that tear or pierce
  - Premolars (bicuspids) and molars – have broad crowns with rounded tips and are best suited for grinding or crushing
- During chewing, upper and lower molars lock together generating crushing force

- Tooth Structure
  - Two main regions – crown and the root
    - Crown – exposed part of the tooth above the gingiva (gum)
    - Enamel – acellular, brittle material composed of calcium salts and hydroxyapatite crystals is the hardest substance in the body
      - Encapsules the crown of the tooth
    - Root – portion of the tooth embedded in the jawbone



Pharynx

- From the mouth, the oro- and laryngopharynx allow passage of:
  - Food and fluids to the esophagus
  - Air to the trachea
- Lined with stratified squamous epithelium and mucus glands
- Has two skeletal muscle layers
  - Inner longitudinal
  - Outer pharyngeal constrictors

Esophagus

- Muscular 10” tube going from the laryngopharynx to the stomach (C6 to T11)
- Travels through the mediastinum and pierces the diaphragm
- Joins the stomach at the cardiac orifice
- The empty esophagus is folded longitudinally and flattens when food is present
- Glands secrete mucus as a bolus moves through the esophagus
- The esophagus has three constrictions where adjacent structures produce impressions:
- Cervical constriction (upper esophageal sphincter) at its beginning at the pharyngo-esophageal junction.
- Thoracic (broncho-aortic) constriction where it is first crossed by the arch of the aorta.
- Diaphragmatic constriction where it passes through the esophageal hiatus of the diaphragm.
- Follows the curve of the vertebral column as it descends through the neck and mediastinum.

Esophagus

- Has internal circular and external longitudinal layers of muscle.
- Top 1/3 is skeletal muscle / middle 1/3 is skeletal and smooth / bottom 1/3 is smooth muscle
- Passes through the esophageal hiatus in the of the diaphragm.
- Terminates by entering the stomach at the cardiac orifice of the stomach.
- The lower esophageal sphincter is called the cardiac sphincter and it is in the esophagogastric junction.
- Is innervated by the esophageal plexus, formed by the vagal trunks and the thoracic sympathetic trunks.

Stomach

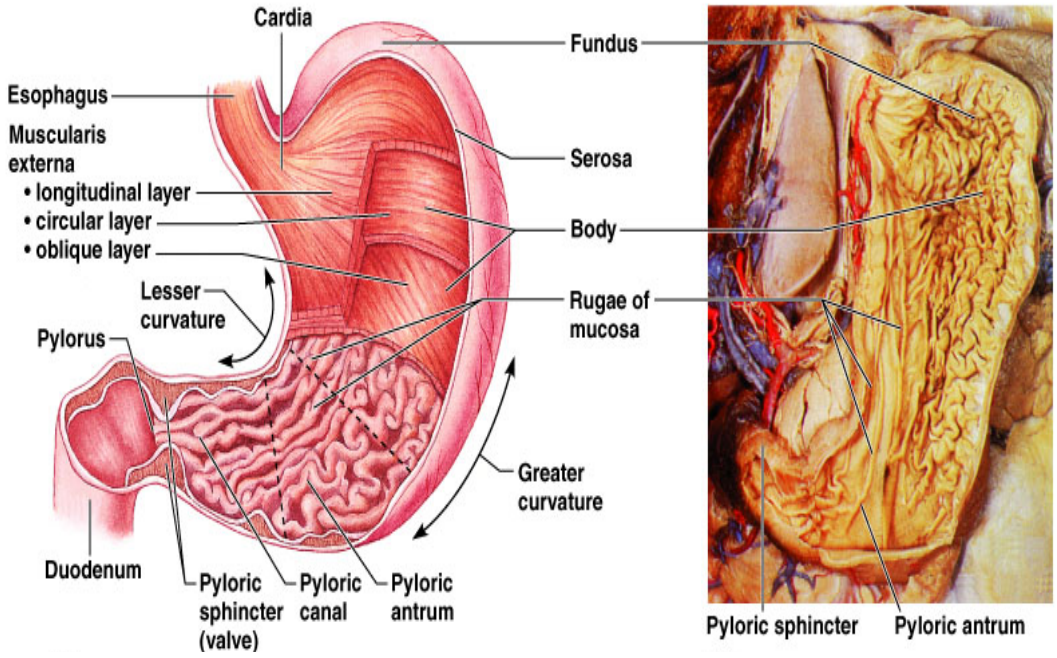
- Specialized for the accumulation of ingested food with chemical and mechanical digestion.
- The stomach acts as a food blender and reservoir.
- Its chief function is enzymatic digestion.
- 5/6 of the stomach lies to the left of the midline under the liver.
- Stomach position
    - The size, shape, and position of the stomach can vary markedly in persons of different body types (bodily habitus).
    - May change due to
        - diaphragmatic movements during respiration
        - empty or after a heavy meal
        - body position
    - In the erect position, the stomach moves inferiorly.
    - In asthenic (thin, weak) individuals, the body of the stomach may extend into the pelvis.

Stomach – Gross Anatomy

- Chemical breakdown of proteins begins and food is converted to chyme
- Cardiac region – surrounds the cardiac orifice
- Fundus – dome-shaped region beneath the diaphragm
- Body – mid portion of the stomach
- Pyloric region – made up of the antrum and canal which terminates at the pylorus
- The pylorus is continuous with the duodenum through the pyloric sphincter

Stomach – Gross Anatomy

- Greater curvature – entire extent of the convex lateral surface
- Lesser curvature – concave medial surface
- Lesser omentum – runs from the liver to the lesser curvature
- Greater omentum – drapes inferiorly from the greater curvature to the small intestine



Vessels and Nerves of Stomach

- The rich arterial supply of the stomach arises from the celiac trunk and its branches of the gastric arteries.
- The gastric veins drain into the hepatic portal vein.
- The gastric veins drain into the splenic vein, which joins the superior mesenteric vein (SMV) to form the hepatic portal vein.
- The parasympathetic nerve supply of the stomach is from the anterior and posterior vagal trunks and their branches.
- The anterior vagal trunk, derived mainly from the left vagus nerve (CN X), usually enters the abdomen as a single branch that lies on the anterior surface of the esophagus .

Microscopic Anatomy of the Stomach

- Muscularis – has three muscular layers (circular, longitudinal, oblique) that:
  - Allows the stomach to churn, mix, and pummel food physically
  - Breaks down food into smaller fragments
- Mucosa dotted with **gastric pits**
  - There are 100 gastric pits in every mm3 of mucosa (that is a little bigger than a grain of sand)
  - Gastric pits contain gastric glands that secrete gastric juice, mucus, and gastrin
- Gastric glands of the fundus and body have a variety of secretory cells
  - Mucous neck cells – secrete acid mucus
  - Parietal cells – secretes HCl and intrinsic factor
  - These gastric glands in the pits makes over 3 quarts of secretions per day

Stomach Lining

- The stomach is exposed to the harshest conditions in the digestive tract
- To keep from digesting itself, the stomach has a mucosal barrier with:
  - A thick coat of bicarbonate-rich mucus on the stomach wall
  - Epithelial cells that are joined by tight junctions
  - Gastric glands that have cells impermeable to HCl
- Damaged epithelial cells are quickly replaced

Small Intestine

- Gross Anatomy
  - Is twenty feet long and about 1" – 1 ½" wide.
  - Runs from pyloric sphincter (end of stomach) to the ileocecal valve (start of large intestine)
- Has three subdivisions: duodenum, jejunum, and ileum
  - Duodenum is the first and shortest section
    - Latin for "12 finger widths"
    - Main pancreatic duct and common bile duct enter duodenum
    - Sphincters control entry of bile and pancreatic juices
  - The jejunum extends from the duodenum to the ileum
    - Latin is "empty"
    - Is 8-10 feet long
  - The ileum joins the large intestine at the ileocecal valve
    - Latin is "twisted"
    - Is 12 feet long

Duodenum

- The duodenum pursues a C-shaped course around the head of the pancreas.
- It begins at the pylorus and ends at the duodenojejunal flexure (junction) on the.
- Most of the duodenum is fixed by peritoneum to structures on the posterior abdominal wall and is considered partially retroperitoneal.
- The duodenum is divided into four parts :
  - Superior (first) part - Short about 2" long
  - Descending (second) part - Descends about 4" long
  - Inferior (third) part - Crosses about 4" long
  - Ascending (fourth) part short - Rises superiorly about 2" long

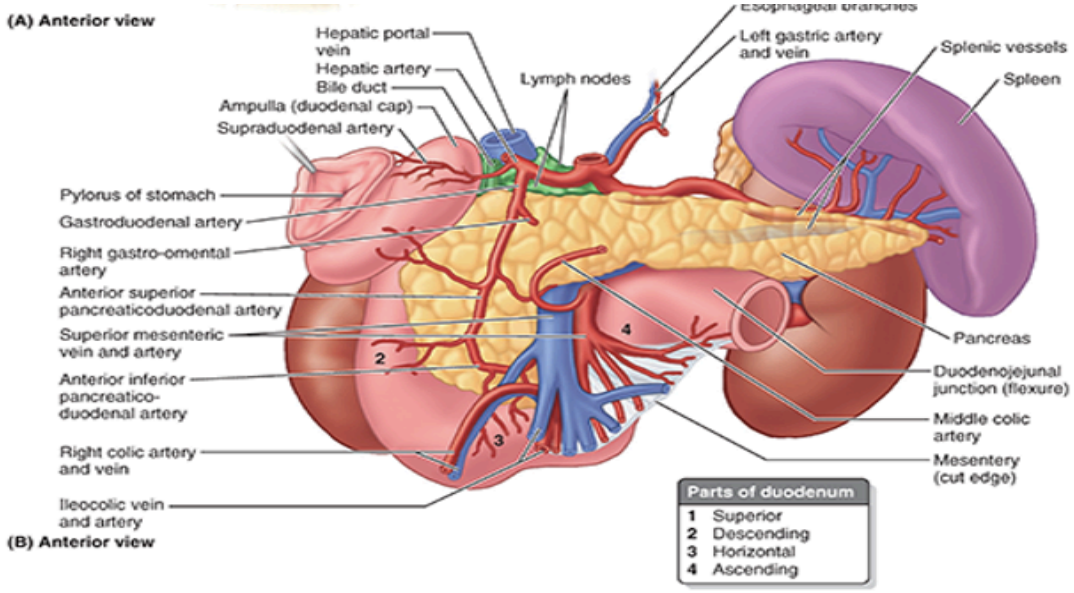
Relationships of the duodenum to other organs

- The superior part of the duodenum ascends from the pylorus and is overlapped by the liver and gallbladder.
- Peritoneum covers its anterior aspect, but it is bare of peritoneum posteriorly, except for the ampulla.
- The proximal part has the hepatoduodenal ligament (part of the lesser omentum) attached superiorly and the greater omentum attached inferiorly.

- The descending part runs inferiorly, curving around the head of the pancreas.
- Initially, it lies to the right of and parallel to the IVC.

Relationships of the duodenum to other organs

- The bile and main pancreatic ducts enter its posteromedial wall.
- These ducts usually unite to form the hepatopancreatic ampulla.



Arteries of the Duodenum

- The proximal segment of the duodenum is supplied by the gastroduodenal artery and its branches which include the superior pancreaticoduodenal artery.
- The distal segment of the duodenum is supplied by the superior mesenteric artery and the inferior pancreaticoduodenal artery.

Veins of the Duodenum

- The duodenal veins drain directly from the duodenum into the pancreaticoduodenal veins.
- From here they merge back into the two largest vessels which are the superior mesenteric vein and the common hepatic vein.

Lymphatic Vessels of the Duodenum

- The lymphatic vessels of the duodenum follow the arteries.
- The anterior lymphatic vessels drain into the pancreaticoduodenal lymph nodes.
- The posterior lymphatic vessels pass posterior to the head of the pancreas and drain into the superior mesenteric lymph nodes.
- Efferent lymphatic vessels from the duodenal lymph nodes drain into the celiac lymph nodes.

Nerves of the Duodenum

- The nerves of the duodenum come from the vagus and greater and lesser splanchnic nerves by way of the celiac and superior mesenteric plexuses.
- The nerves are next conveyed to the duodenum via peri-arterial plexuses extending to the pancreaticoduodenal arteries.

Jejunum

- The second part of the small intestine, the jejunum, begins at the duodenojejunal flexure where the gastrointestinal tract resumes an intraperitoneal course.
- Latin is “empty”
- Is 8-10 feet long
- Is in the right upper quadrant

Ileum

- The third part of the small intestine, the ileum, ends at the ileocecal junction, the union of the terminal ileum and the cecum.
- Latin is “twisted”
- Is 12 feet long
- Most is in the left upper quadrant

Small Intestine Mesenteries

- Mesenteries are found dorsally and adhere the viscera to the posterior wall.
- Function of mesenteries
    - To store fat, vessels and nerves
    - To attach the intestine to the abdominal wall
- There are three mesenteries, all named after their organ attachments in the abdominal cavity.
    - The Mesentery Proper
        - From small intestine (jejunum and ileum) to posterior abdominal wall
        - Contains superior mesenteric artery, autonomic nerve plexuses, lymphatics,
    - The Transverse Mesocolon
        - Connects to the posterior abdominal wall Contains middle colic artery
        - Sigmoid Mesocolon
        - Connects sigmoid mesocolon to the pelvic wall
        - Contains sigmoid arteries and superior rectal artery
    - Mesoappendix
        - Mesentery of ileum that connects to the appendix
        - Contains the appendicular artery
    - The fact that the mesentery is intraperitoneal is important in surgery.
    - If the organ can already move around because of its mesentery, then it does not need to be "mobilized", it is already movable.
    - If the organ (jejunum or ileum) have adhesions that limit their mobility within the abdominal cavity, the surgeon may have to perform an adhesiolysis to restore their mobility.

Specialized Lymphatic Vessels

- The vessels in the intestinal villi that absorb fat are called lacteals.
- They empty their milk-like fluid into the lymphatic plexuses in the walls of the jejunum and ileum.
- The lacteals drain in turn into lymphatic vessels between the layers of the mesentery.
- Within the mesentery, the lymph passes sequentially through three groups of lymph nodes:
    - Juxta-intestinal lymph nodes: located close to the intestinal wall
    - Mesenteric lymph nodes: scattered among the arterial arcades
    - Superior central nodes: located along the proximal part of the SMA
- Efferent lymphatic vessels from the mesenteric lymph nodes drain to the superior mesenteric lymph nodes.
- Lymphatic vessels from the terminal ileum follow the ileal branch of the ileocolic artery to the ileocolic lymph nodes.

Nerve Supply of Small Intestine

- Duodenum
    - Nerves come from sympathetic (T6-T9) and parasympathetic (Vagus) nerves from the celiac and superior mesentery plexus
- Jejunum and Ileum
    - Sympathetic and parasympathetic(Vagus) nerves come from the superior mesenteric plexus
- Sympathetic stimulation reduces peristaltic and secretory activity of the intestine and causes vasoconstriction.
- Sympathetic stimulation reduces or stops gastrointestinal activity and makes blood (and energy) available for “fleeing or fighting.”
- Parasympathetic stimulation increases peristalsis and secretion activity of the intestine.
- Parasympathetic stimulation restores gastrointestinal activity following a sympathetic reaction.
- Cessation of sympathetic stimulation allows vasodilation, restoring blood flow to the active bowel.
- The small intestine also has extrinsic and intrinsic sensory (visceral afferent) fibers.
- The small intestine is insensitive to most pain stimuli, including cutting and burning.
- It is sensitive to distension that is perceived as colic (spasmodic abdominal pains or “intestinal cramps”).
- Visceral pain from the small intestine may be referred to dermatomes supplied by somatic afferent fibers sharing by the same spinal sensory ganglia and spinal cord segments.

Microscopic Anatomy of Small Intestine

- Structural modifications of the small intestine wall increase surface area
    - Plicae circulares: deep circular folds of the mucosa and submucosa
    - Villi – fingerlike extensions of the mucosa
    - Microvilli – tiny projections of absorptive mucosal cells' plasma membranes
- Histology of the Intestinal Wall
    - Goblet cells
        - Secrete mucus that lubricates chyme
    - Enteroendocrine cells – Secretes hormones
        - The gastrointestinal tract is the largest endocrine organ in the body and the endocrine cells within it are referred to collectively as the *enteric endocrine system*. Three enteric hormones are:
        - **Gastrin:** Secreted from the stomach and plays an important role in control of gastric acid secretion.
        - **Cholecystokinin:** A small intestinal hormone that stimulates secretion of pancreatic enzymes and bile.
        - **Secretin:** Another hormone secreted from small intestinal epithelial cells; stimulates secretion of a bicarbonate-rich fluids from the pancreas and liver.
    - Intestinal crypts of Lieberkuhn
        - Epithelial cells secrete intestinal juice
        - These cells are like a conveyer belt and are regenerating and replacing themselves every 3-4 days
    - Brunner Glands or Duodenal Glands
        - The stomach acids can be as low as pH 1 and these glands neutralize the stomach acid to a pH of 7.6 for absorption

Intestinal Secretions

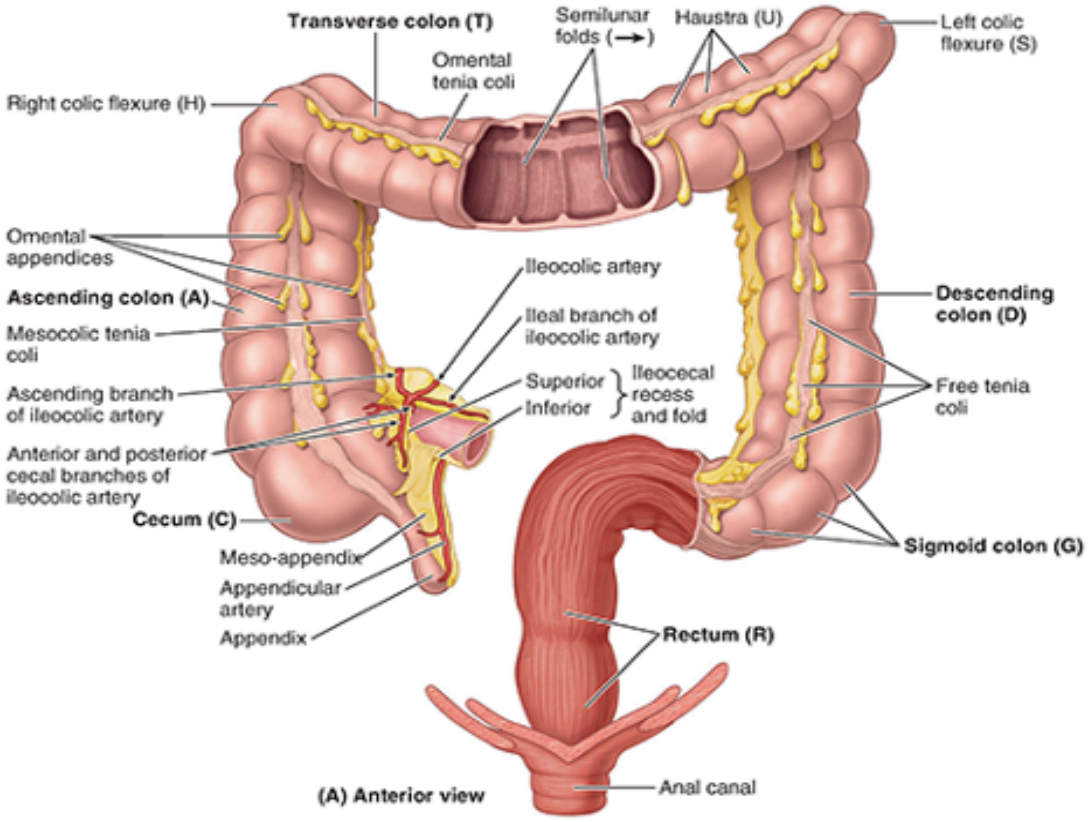
- Secretes 1-2liters per day
- Secreted by intestinal glands in response to distension or irritation of the mucosa
- Slightly alkaline and isotonic with blood plasma
- Largely water, enzyme-poor, but contains mucus

Large Intestine

- The large intestine is where water is absorbed from the indigestible residues of the liquid chyme.
- It converts it into semisolid stool or feces that is stored temporarily and allows to accumulate until defecation occurs.
- Is subdivided into the cecum, appendix, colon, rectum, and anal canal
- The saclike cecum:
    - Lies below the ileocecal valve in the right iliac fossa
    - Contains a wormlike vermiform appendix

Large Intestine vs. Small Intestine

- Unique features:
  - Teniae coli – three bands of smooth muscle
  - Haustra – pocketlike sacs caused by muscle tone
  - Epiploic appendages – fat-filled pouches of visceral peritoneum
  - A much wider lumen



Vessels and Nerves of the Large Intestine

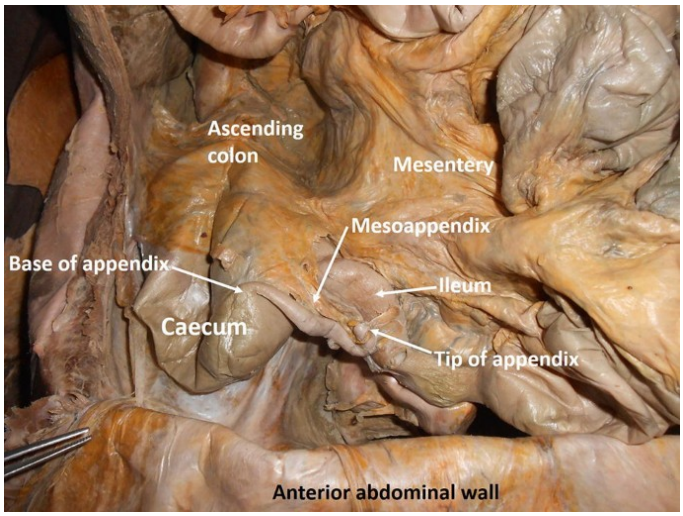
- First half of large intestine
  - Arterial supply is superior mesenteric artery
  - Innervation
    - Sympathetic innervation **-** Superior Mesenteric and celiac ganglia
    - Parasympathetic innervation **-** Vagus nerve
- Distal half of large intestine
  - Arterial supply is Inferior Mesenteric artery
  - Innervation
    - Sympathetic innervation - Inferior Mesenteric and hypogastric plexuses
    - Parasympathetic innervation - Pelvic splanchnic nerves

Cecum

- The cecum is the first part of the large intestine
- It is continuous with the ascending colon.
- The cecum is a blind intestinal pouch, approximately 3” in both length and breadth.
- It lies in the iliac fossa of the right lower quadrant of the abdomen.
- If distended with feces or gas, the cecum may be palpable through the anterolateral abdominal wall.
- The cecum usually lies within 1” of the inguinal ligament
- It is almost entirely enveloped by peritoneum and can be lifted freely.
- The cecum has no mesentery.
- Because of its relative freedom, it may be displaced from the iliac fossa, but it is commonly bound to the lateral abdominal wall by one or more cecal folds of peritoneum.
- The terminal ileum enters the cecum obliquely and partly invaginates into it.

Appendix

- The vermiform appendix is a finger-like, blind-ended tube connected to the cecum.
    - The term vermiform means "worm-shaped."
- Averages 3.5” in length but can range from 2” to 13”.
    - Longest appendix ever removed was 10” long.
- The appendix is usually located in the lower right quadrant near the anterior iliac spine.
- The base of the appendix is located ¾” beneath the ileocecal valve that separates the large intestine from the small intestine.
- Its position within the abdomen corresponds to a point on the surface known as McBurney’s point.



- Appendix variations
    - Some identical twins are known as mirror image twins.
        - They have a congenital condition known as mirror image anatomy.
        - In this condition the appendix is located in the left lower quadrant.
        - In intestinal malrotation, the appendix can be displaced to the left lower quadrant.
- Functions of the appendix
    - Immune system function as a MALT - mucosal associated lymphatic tissue
    - It was always thought to be a vestigial organ because of the strange shape and location.
    - Research at Duke in 2007 found that the appendix serves as a reservoir of useful bacteria when illness flushes the flora from the colon.

Colon

- The colon has four parts—ascending, transverse, descending, and sigmoid—that succeed one another in an arch.
- The colon encircles the small intestine, the ascending colon lying to the right of the small intestine, the transverse colon superior and/or anterior to it, the descending colon to the left of it, and the sigmoid colon inferior to it.
- Ascending Colon
    - The ascending colon is the second part of the large intestine.
    - It passes superiorly on the right side of the abdominal cavity from the cecum to the right lobe of the liver.
    - It turns to the left at the right colic flexure or hepatic flexure.
    - This flexure lies deep to the 9th and 10th ribs and is overlapped by the inferior part of the liver.
    - The ascending colon is narrower than the cecum.
    - Is retroperitoneal along the right side of the posterior abdominal wall.
    - The ascending colon is usually covered by peritoneum anteriorly and on its sides.
    - The ascending colon is separated from the anterolateral abdominal wall by the greater omentum.
        - A deep vertical groove lined with parietal peritoneum, the right paracolic gutter, lies between the lateral aspect of the ascending colon and the adjacent abdominal wall.
- Transverse colon
    - The transverse colon is the third, longest, and most mobile part of the large intestine.
    - It crosses the abdomen from the right colic flexure to the left colic flexure.
    - It turns inferiorly to become the descending colon.
    - The left colic flexure or splenic flexure is usually more superior and less mobile than the right colic flexure.
    - It lies anterior to the inferior part of the left kidney and attaches to the diaphragm through the phrenicocolic ligament.
    - The transverse colon and its mesentery, the transverse mesocolon, loop down, often inferior to the level of the iliac crests.
    - The mesentery is adherent to or fused with the posterior wall of the omental bursa. The root of the transverse mesocolon lies along the inferior border of the pancreas.
    - Being freely movable, the transverse colon is variable in position.
    - It usually hangs to the level of the umbilicus (L3 vertebral level).
    - In tall thin people, the transverse colon may extend into the pelvis.

Valves and Sphincters of the Rectum and Anus

- Three valves of the rectum stop feces from being passed with gas
- The anus has two sphincters:
  - Internal anal sphincter of smooth muscle
  - External anal sphincter of skeletal muscle
  - These sphincters are closed except during defecation
- The rectum and anal canal are the most terminal parts of the lower GI tract.
- They form a functional unit and control defecation.
  - Fecal incontinence can occur if this function is disturbed.
  - Fecal continence is maintained by several important anatomic structures including rectal folds, anal valves, the sling-like puborectalis muscle, and internal and external anal sphincters.
- How defecation occurs:
  - Peristaltic waves within the rectal muscles
  - Involuntary relaxation of the internal anal sphincter which is controlled by the ANS.
  - Voluntary relaxation of the external anal sphincter controlled by the cerebral cortex.
- The rich plexus of veins surrounding the anal canal can develop hemorrhoids if dilated.

Functions of the Large Intestine

- Other than digestion of enteric bacteria, no further digestion takes place.
- Vitamins, water, and electrolytes are reclaimed
- Its major function is propulsion of fecal material toward the anus
- Though essential for comfort, the colon is not essential for life

Developmental Aspects

- During fetal life, nutrition is via the placenta, but the GI tract is stimulated toward maturity by amniotic fluid swallowed in utero.
- At birth, feeding is an infant's most important function and is enhanced by
- Rooting reflex (helps infant find the nipple) and sucking reflex (aids in swallowing)
- Digestive system has few problems until the onset of old age
- During old age the GI tract activity declines, absorption is less efficient, and peristalsis is slowed