Physiology of Digestive System

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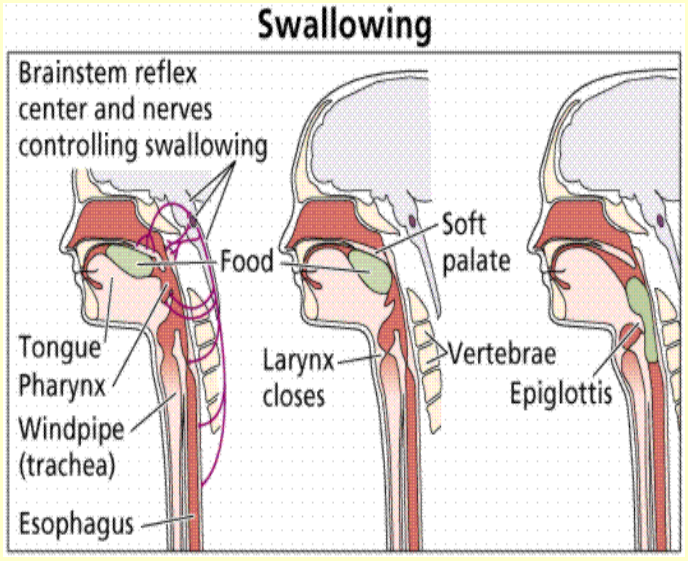
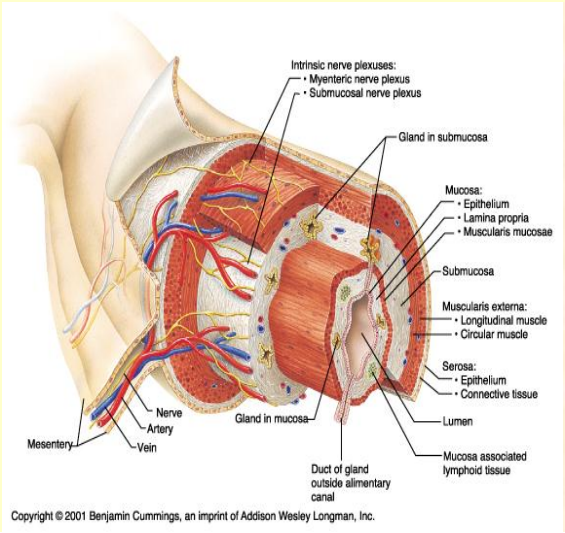
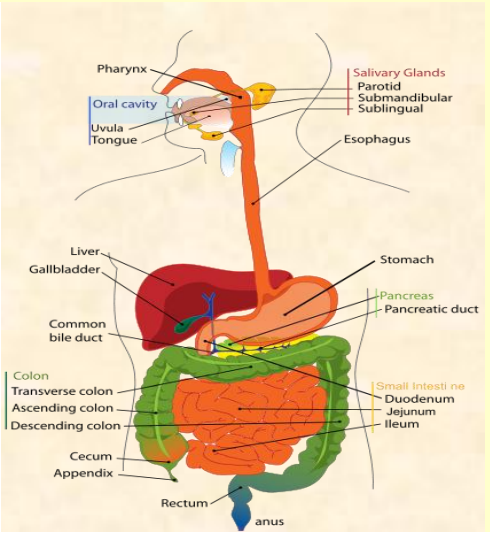






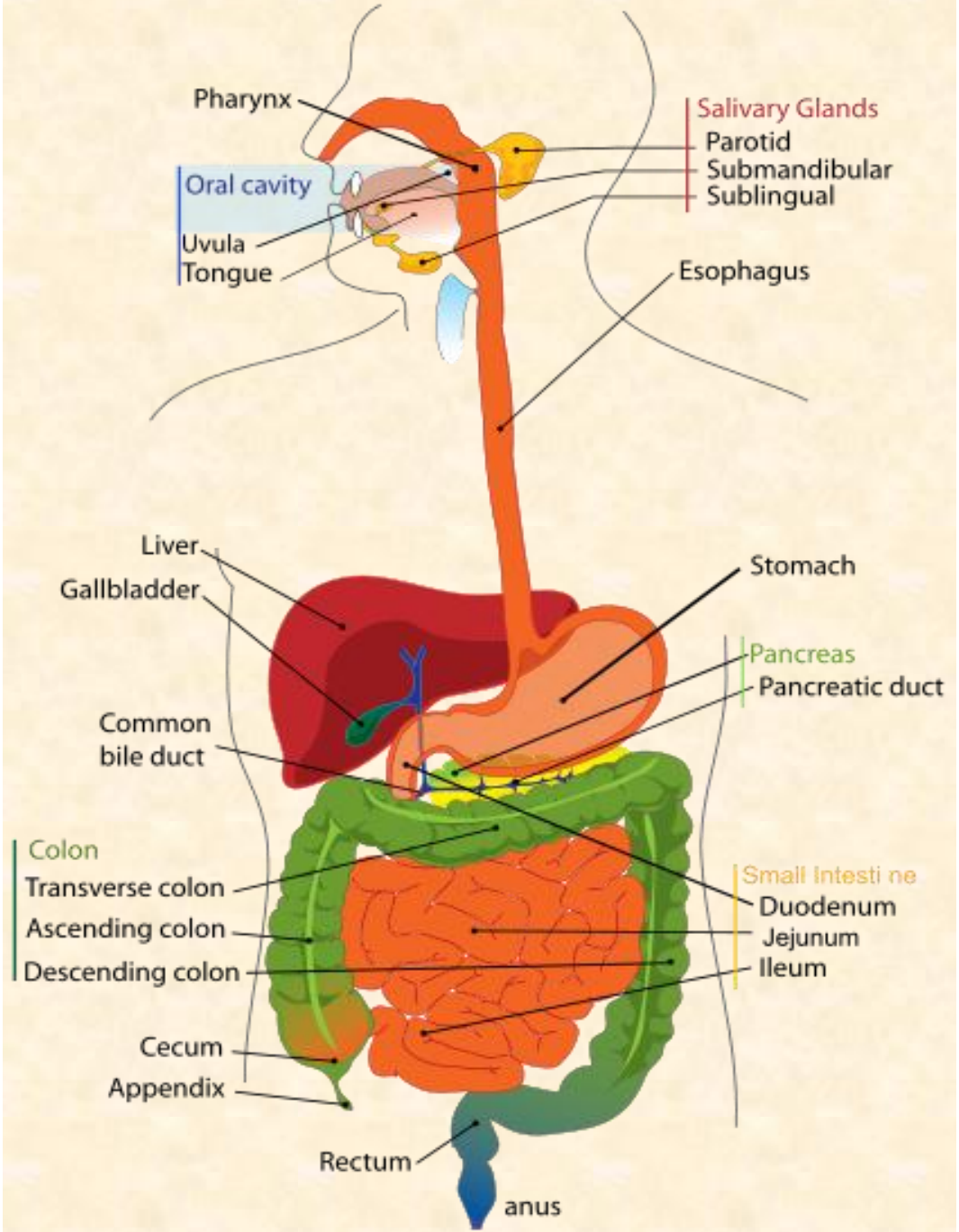
General Anatomy of Digestive System

A. Gastrointestinal Tract

1. also known as "alimentary canal"
2. all organs through which food passes (mouth to anus)

B. Accessory Structures

1. assist in digestion
2. includes teeth, tongue, salivary glands, liver, gall bladder and pancreas


Pharynx
Salivary Glands
Parotid
Submandibular
Sublingual
Oral cavity
Uvula
Tongue
Esophagus
Liver
Gallbladder
Stomach
Pancreas
Pancreatic duct
Common
bile duct
Colon
Transverse colon
Ascending colon
Descending colon
Small Intesti ne
Duodenum
Jejunum
Ileum
Cecum
Appendix
Rectum
anus

Histologically, the GI tract consists of 4 layers which are, from inside to outside:

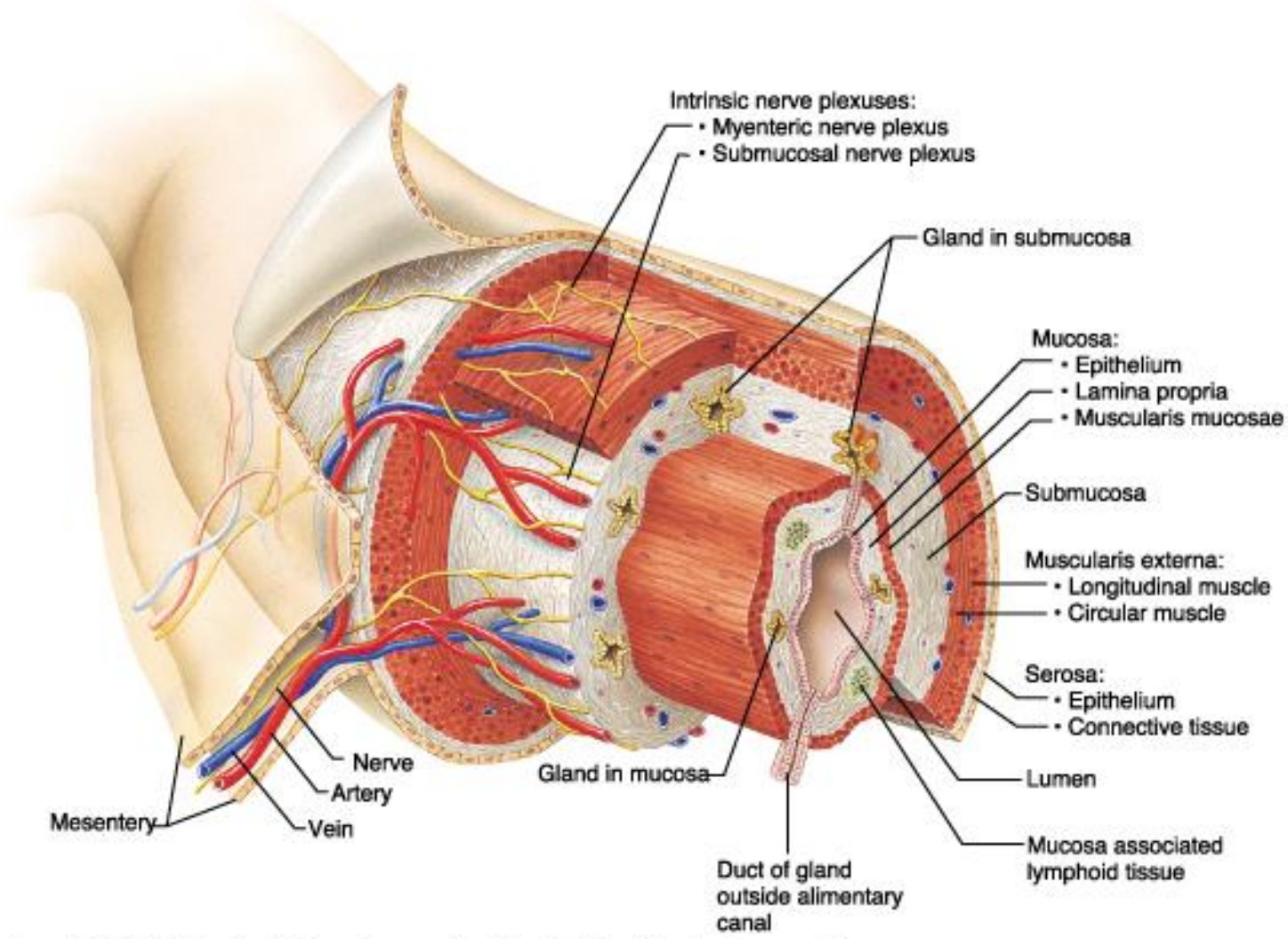
mucosa,

submucosa

muscularis (circular and longitudinal muscle layers) and

serosa

Structures of the Alimentary Canal



Digestive System Organization

- Gastrointestinal (GI) tract (Alimentary canal) is 9 meters long.
  - Tube in which food passes
  - Structures
    - **Mouth**
    - **Oral Cavity**
    - **Pharynx**
    - **Esophagus**
    - **Stomach**
    - **Duodenum**
    - **Jejunum**
    - **ileum**
    - **Caecum**
    - **Ascending colon**
    - **Transverse colon**

Digestive System Organization

  - Descending colon
  - Sigmoid colon
  - Rectum
  - Anus
- Accessory structures
  - Not in tube path
  - Organs
    - Teeth
    - Tongue
    - Salivary glands
    - Liver
    - Gall bladder
    - Pancreas

Digestion

- Processing of food
- Types
  - Mechanical (physical)
    - Cutting
    - Tearing
    - Chewing (mastication)
    - Grinding
    - Mixing
  - Chemical
    - Enzymatic hydrolysis
      - Carbohydrate
      - Protein
      - Lipid
      - Nucleic acids

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

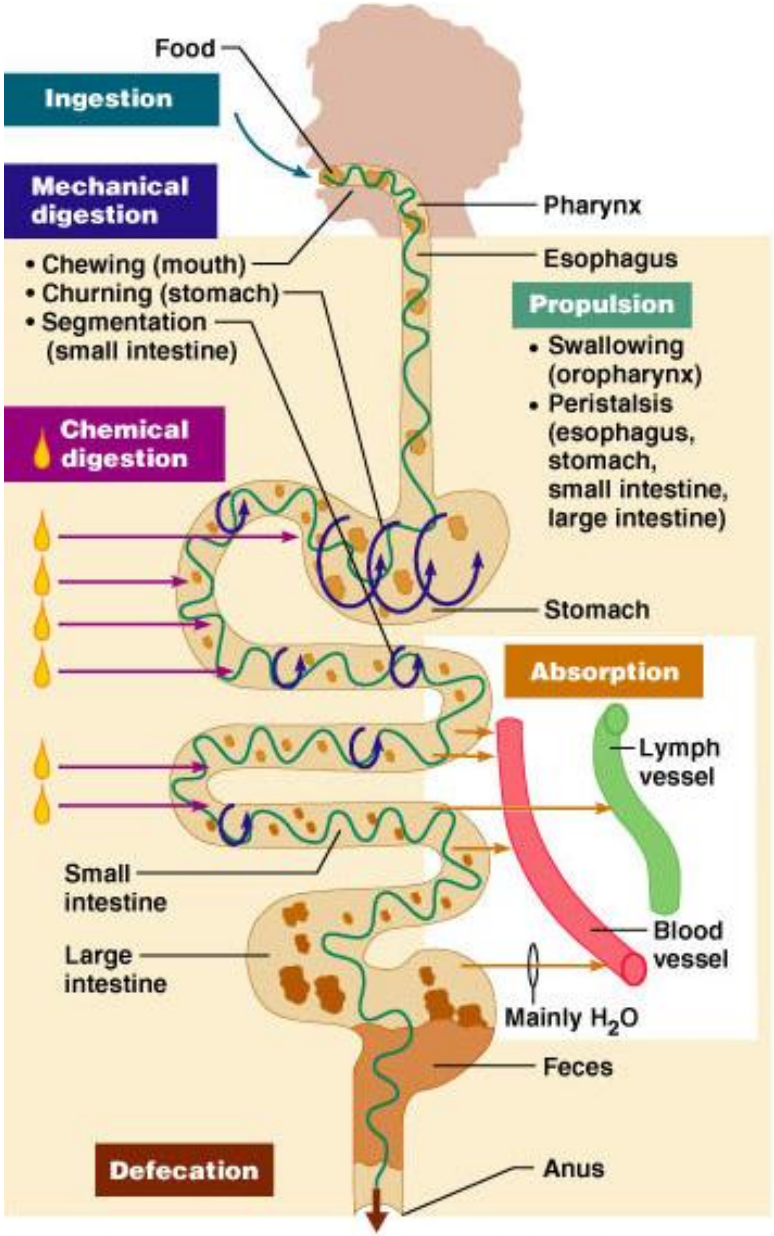

Food
Ingestion
Mechanical digestion
• Chewing (mouth)
• Churning (stomach)
• Segmentation (small intestine)
Chemical digestion
Pharynx
Esophagus
Propulsion
• Swallowing (oropharynx)
• Peristalsis (esophagus, stomach, small intestine, large intestine)
Stomach
Absorption
Lymph vessel
Small intestine
Large intestine
Blood vessel
Mainly H_2O
Feces
Defecation
Anus

Figure 3

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
- Mechanical digestion – chewing, mixing, and churning food

Gastrointestinal Tract Activities

- 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

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

Oral Cavity and Pharynx:

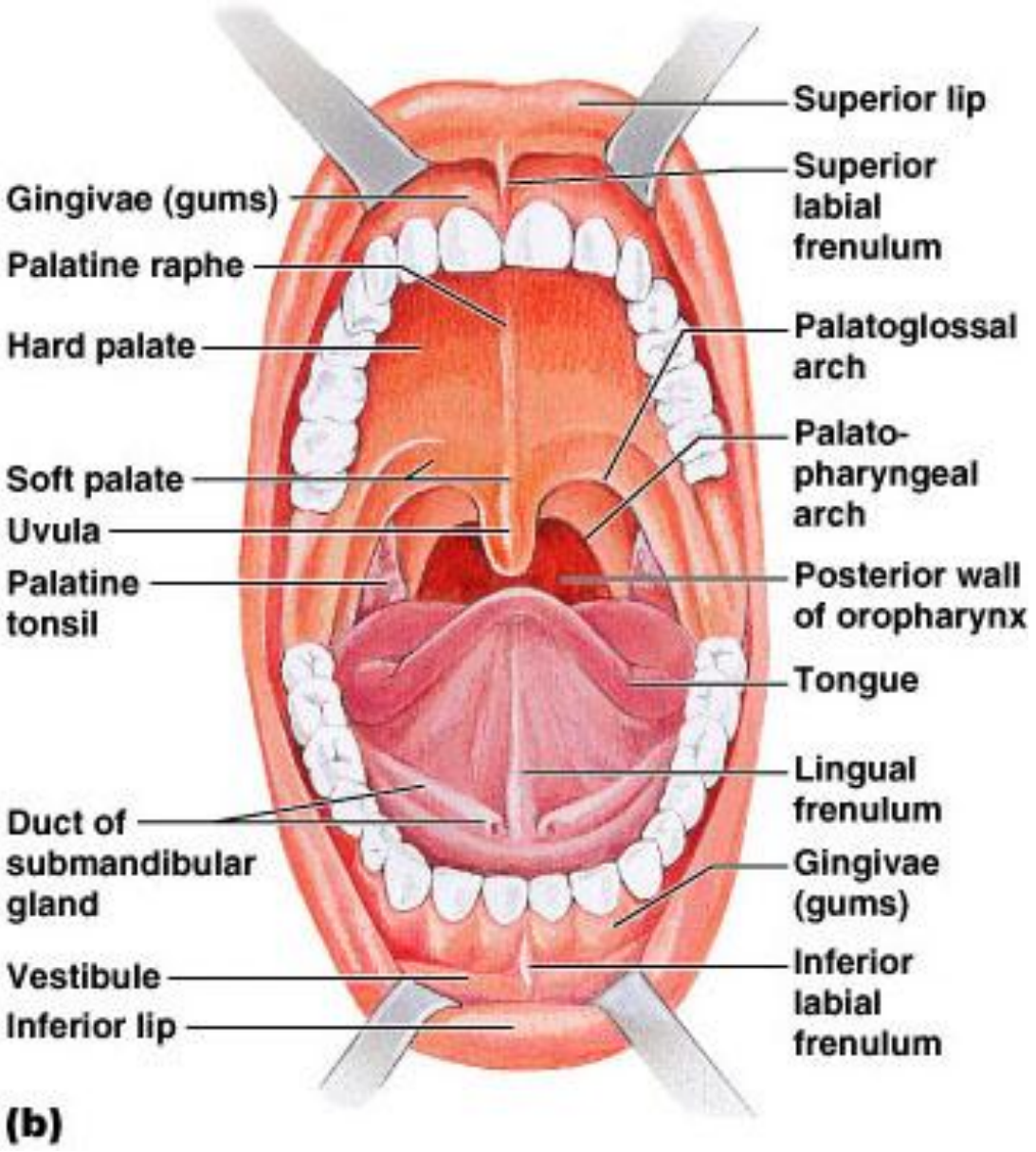
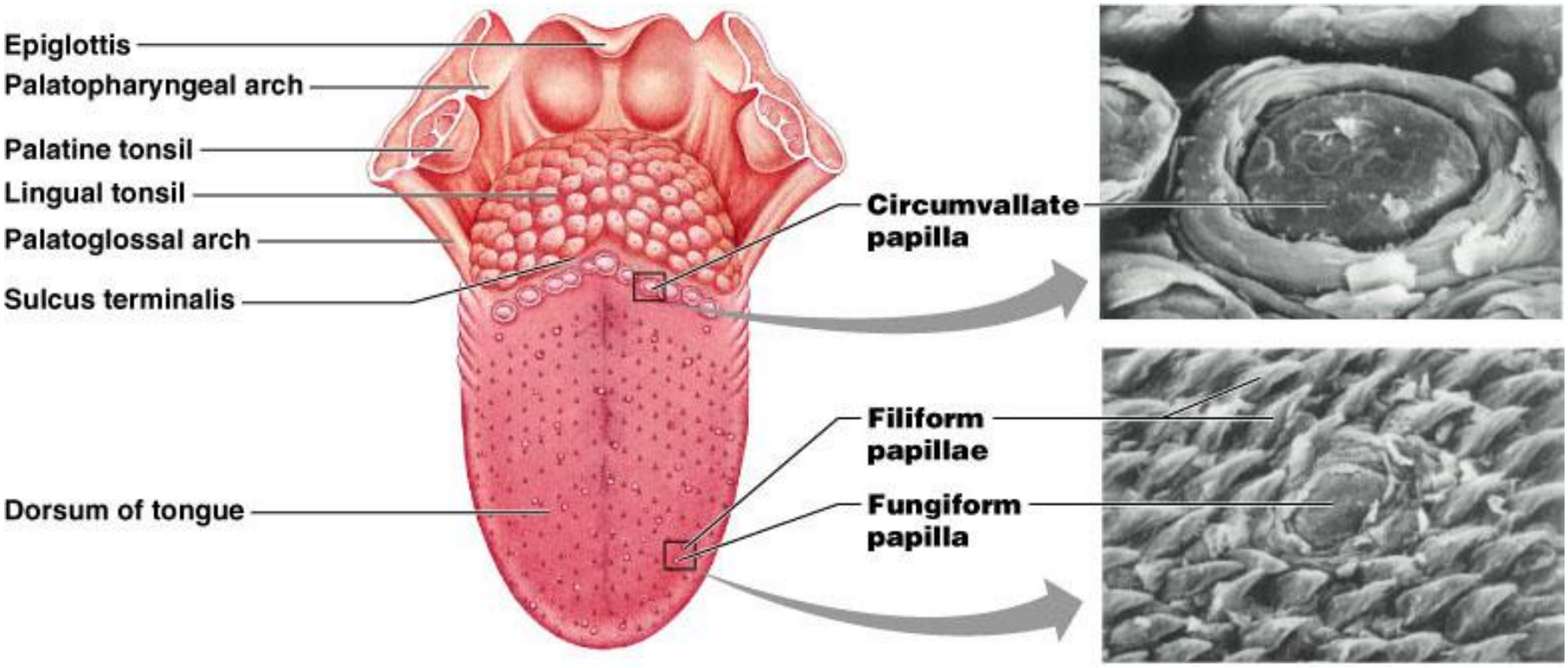


Figure 23.7b

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

Tongue


Epiglottis
Palatopharyngeal arch
Palatine tonsil
Lingual tonsil
Palatoglossal arch
Sulcus terminalis
Dorsum of tongue
Circumvallate papilla
Filiform papillae
Fungiform papilla

Deciduous Teeth

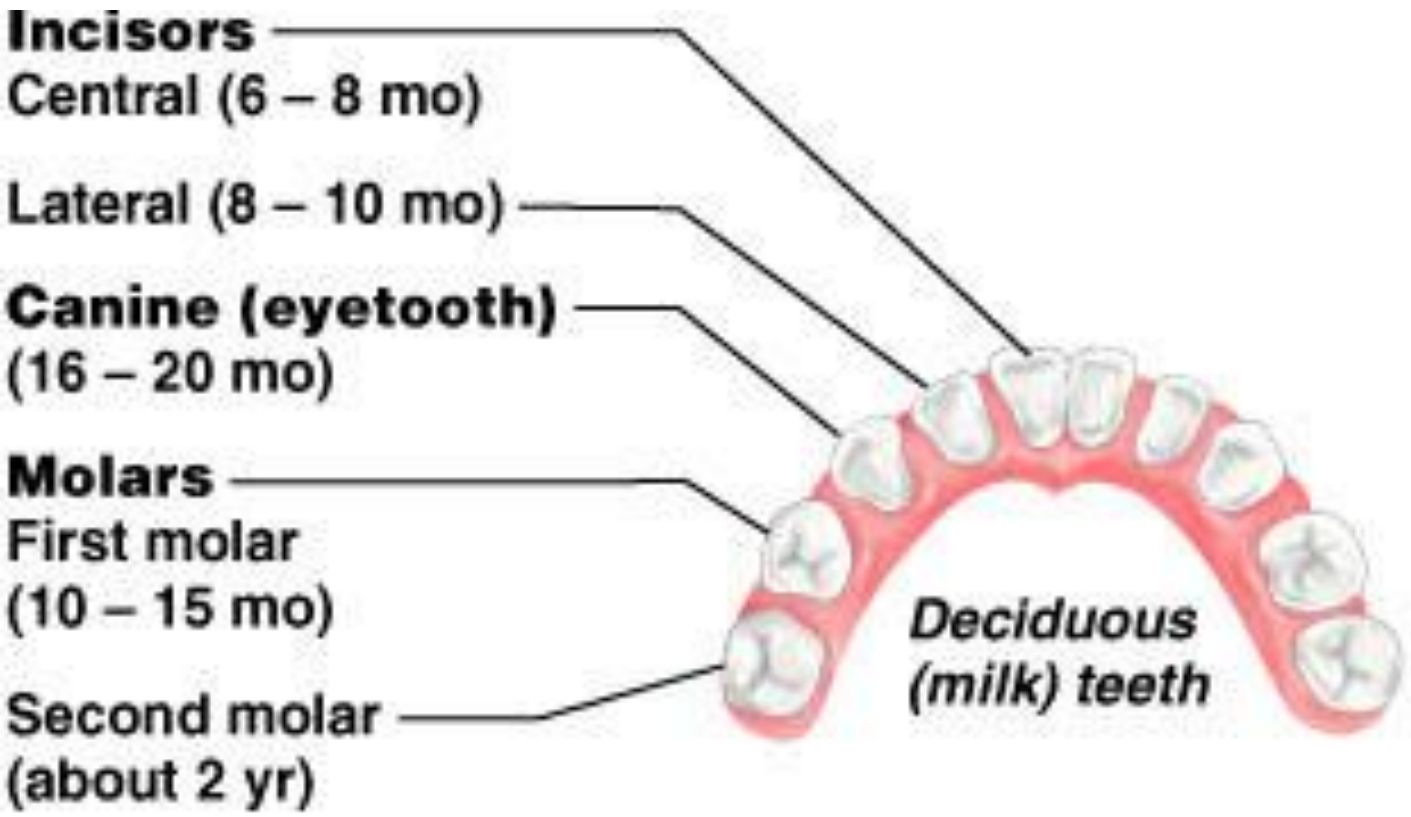


Figure 23.10.1

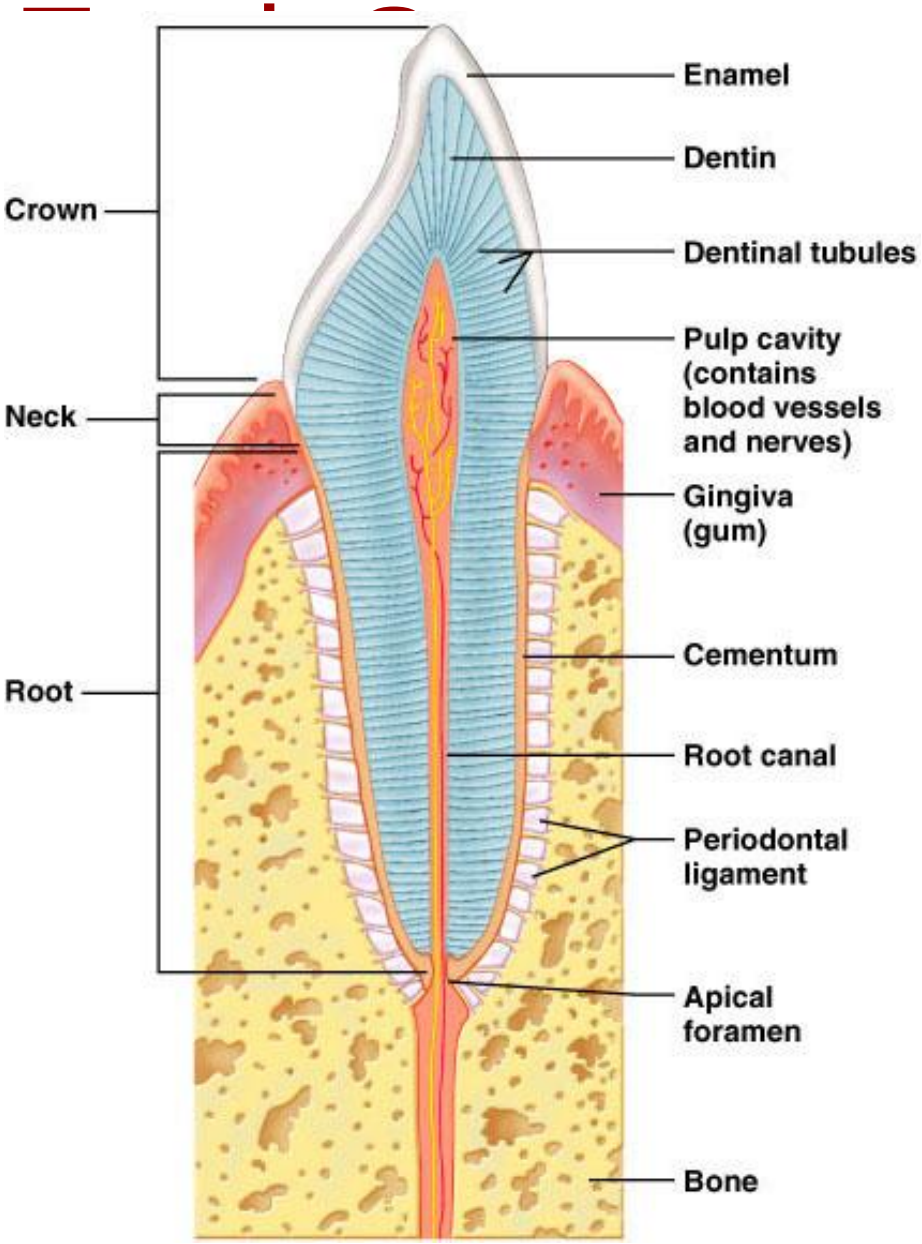
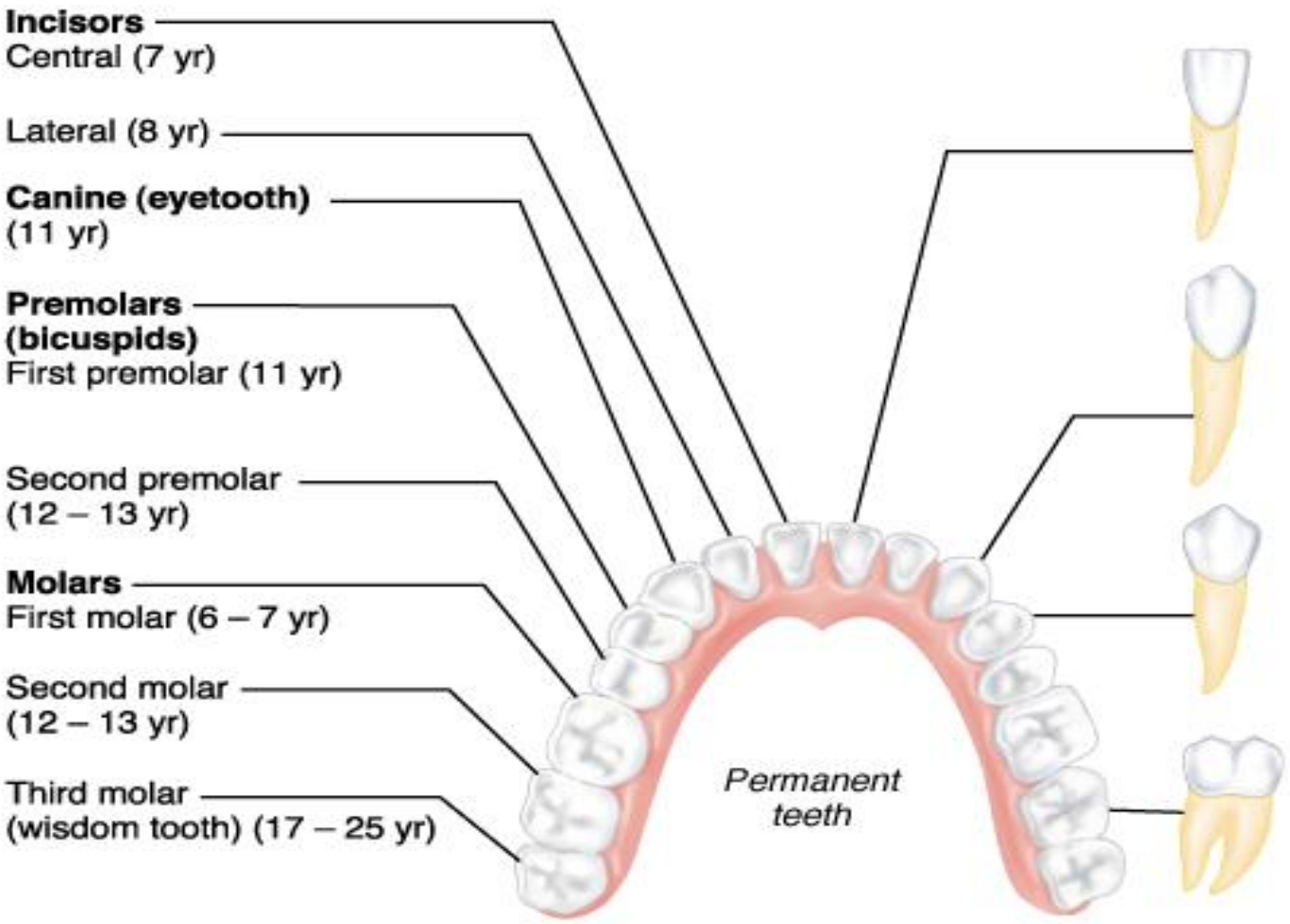

Crown
Neck
Root
Enamel
Dentin
Dentinal tubules
Pulp cavity (contains blood vessels and nerves)
Gingiva (gum)
Cementum
Root canal
Periodontal ligament
Apical foramen
Bone

Figure 23.11

Permanent teeth

- Teeth are responsible for cutting, breaking, tearing and grinding of food



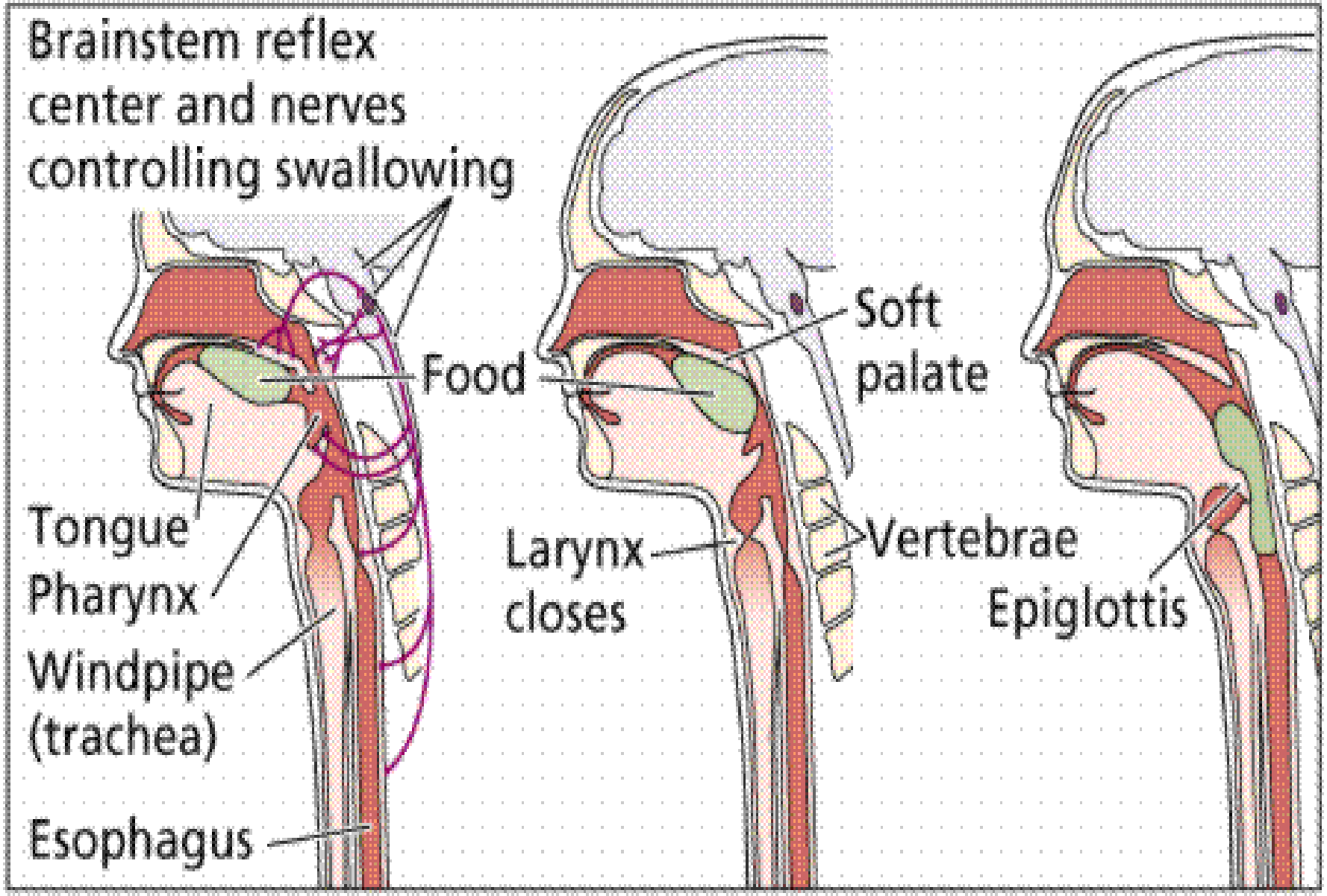
Deglutition (swallowing)

- It is a process of passage of food from the oral cavity to the stomach through the esophagus
- Sequence
  - Voluntary stage (Buccal stage)
    - Push food to back of mouth. The tongue rolls food into a mass (bolus) and forces it into pharynx.
  - Pharyngeal stage
    - Raise
      - Soft palate to prevent food from entering nasal cavity
      - Larynx + hyoid and epiglottis closes the larynx
      - Tongue to soft palate
  - Esophageal stage
    - Contract pharyngeal muscles
    - Open esophagus
    - Start peristalsis

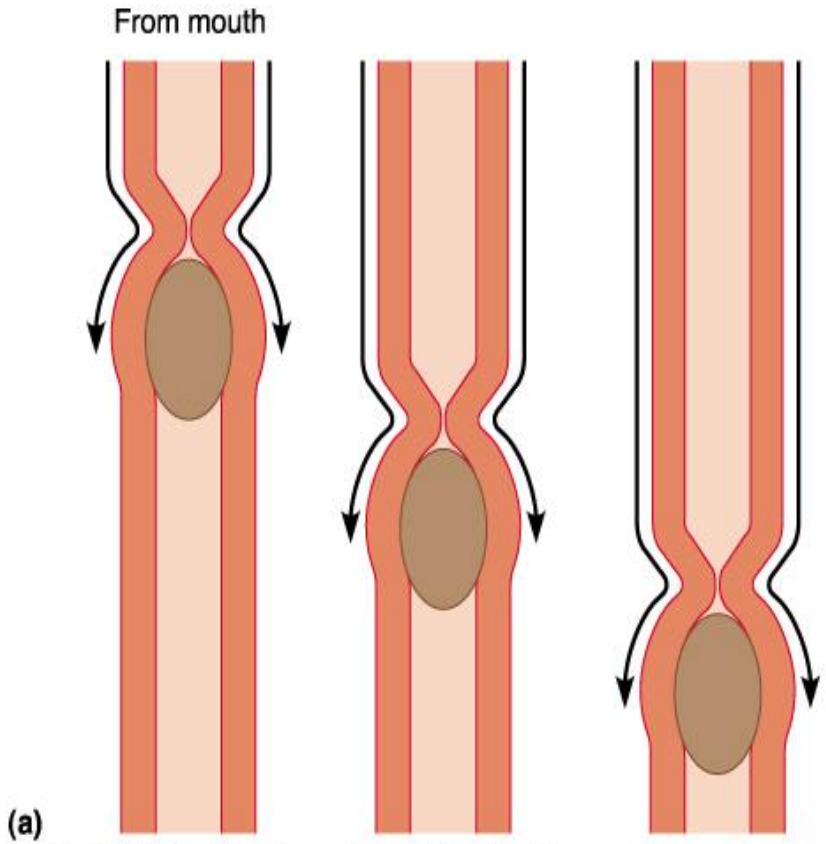
Deglutition (swallowing)

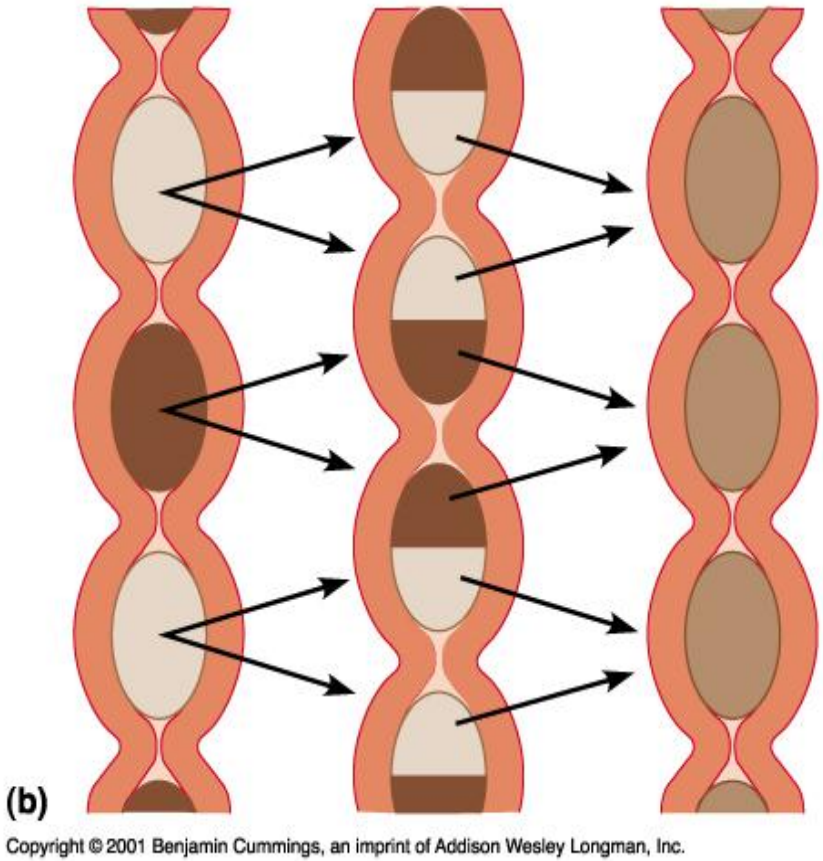
- Control
  - Nerves
    - Glossopharyngeal
    - Vagus
    - Accessory
  - Brain stem
    - Deglutition center
      - Medulla oblongata
      - Pons

Swallowing


Brainstem reflex center and nerves controlling swallowing
Food
Tongue
Pharynx
Windpipe (trachea)
Esophagus
Soft palate
Larynx closes
Vertebrae
Epiglottis

Movements in the alimentary tract Peristalsis and Segmentation

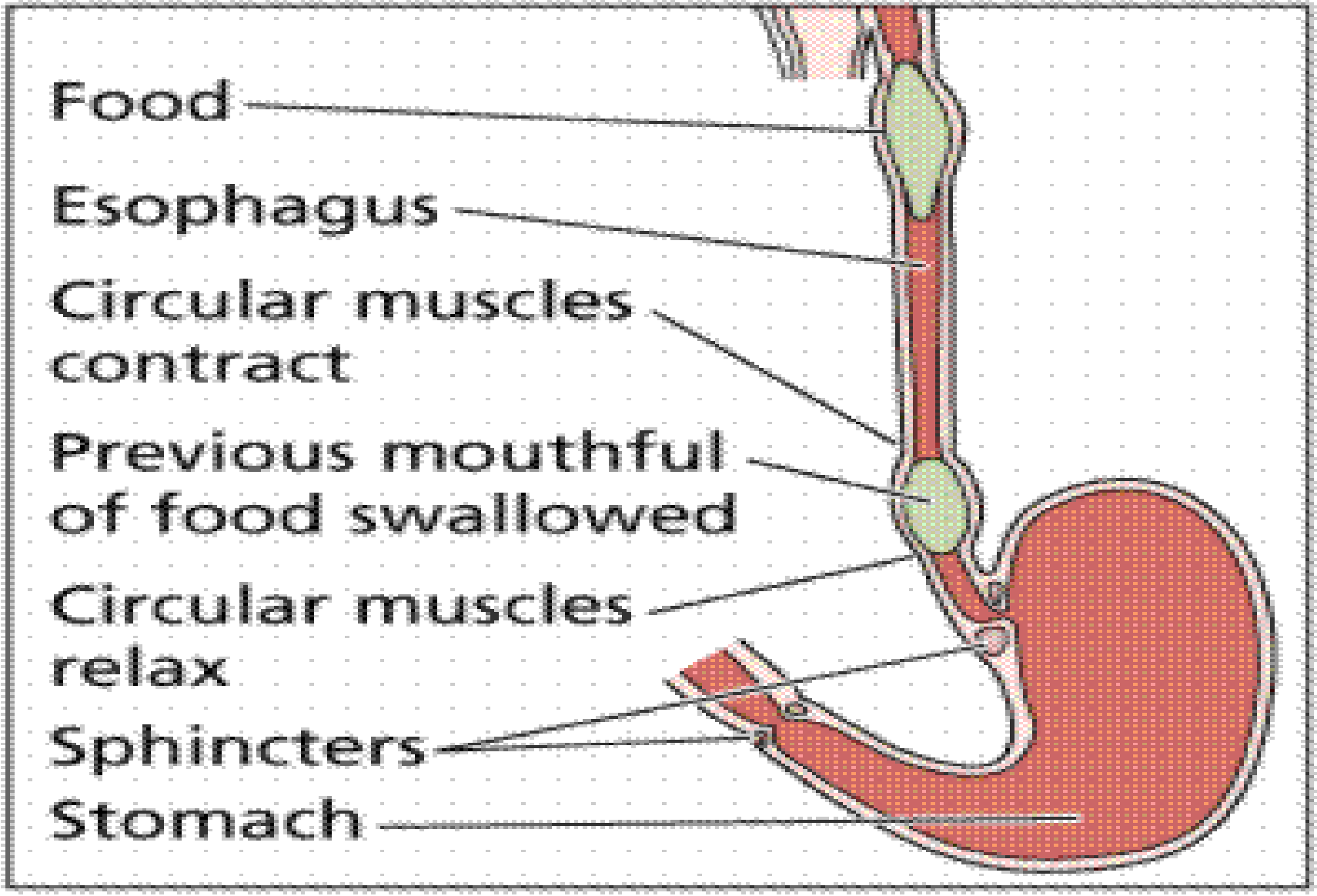




Peristalsis is a wave of contraction that propel food to backward in GI tract

Segmentation in which small parts of GI tract goes in a series of contractions and relaxations alternating. It helps in mixing of food with the digestive enzymes

Peristalsis



Nervous Control of the GI Tract

- Intrinsic controls
  - Nerve plexuses near the GI tract initiate short reflexes
  - Short reflexes are mediated by local enteric plexuses (gut brain)
- Extrinsic controls
  - Long reflexes arising within or outside the GI tract
  - Involve CNS centers and extrinsic autonomic nerves

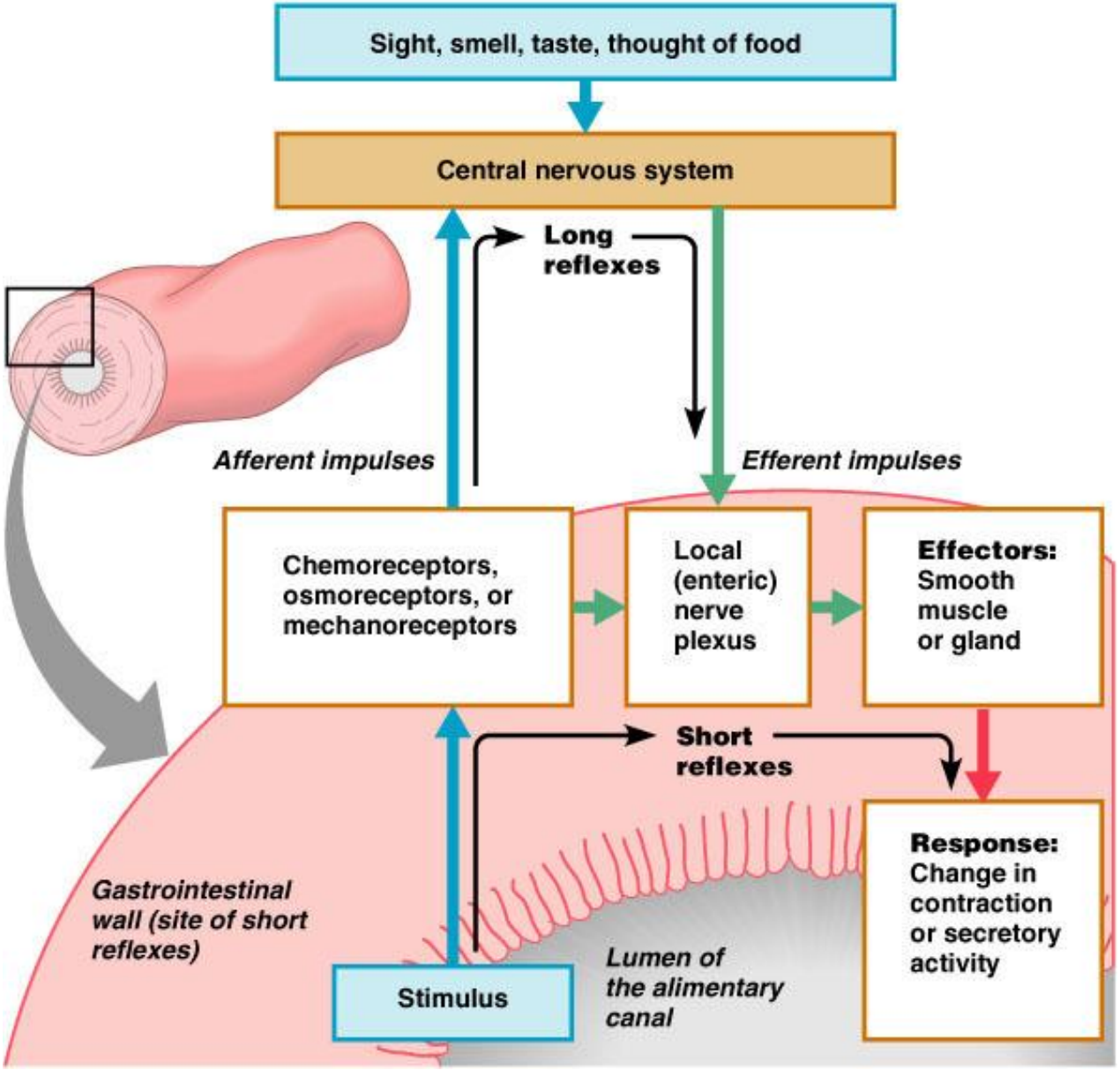

Sight, smell, taste, thought of food
Central nervous system
Long reflexes
Afferent impulses
Efferent impulses
Chemoreceptors, osmoreceptors, or mechanoreceptors
Local (enteric) nerve plexus
Effectors: Smooth muscle or gland
Short reflexes
Response: Change in contraction or secretory activity
Gastrointestinal wall (site of short reflexes)
Stimulus
Lumen of the alimentary canal

Figure 23.4

Innervations of the gastrointestinal tract (Neural control of the gastrointestinal function)

The GIT has a nervous system all its own called the enteric nervous system. It lies entirely in the wall of the gut, beginning in the esophagus and extending all the way to the anus. It consists of a network of neurons (about 100 million) and nerve fibres. The enteric system is composed of two plexuses

1- Myenteric (Auerbach's) plexus lying between longitudinal and circular muscle layers. It controls mainly the GIT movements.

2- Submucosal (Meissner's) plexus is found in the submucosa. It controls mainly GIT secretions and local blood flow.

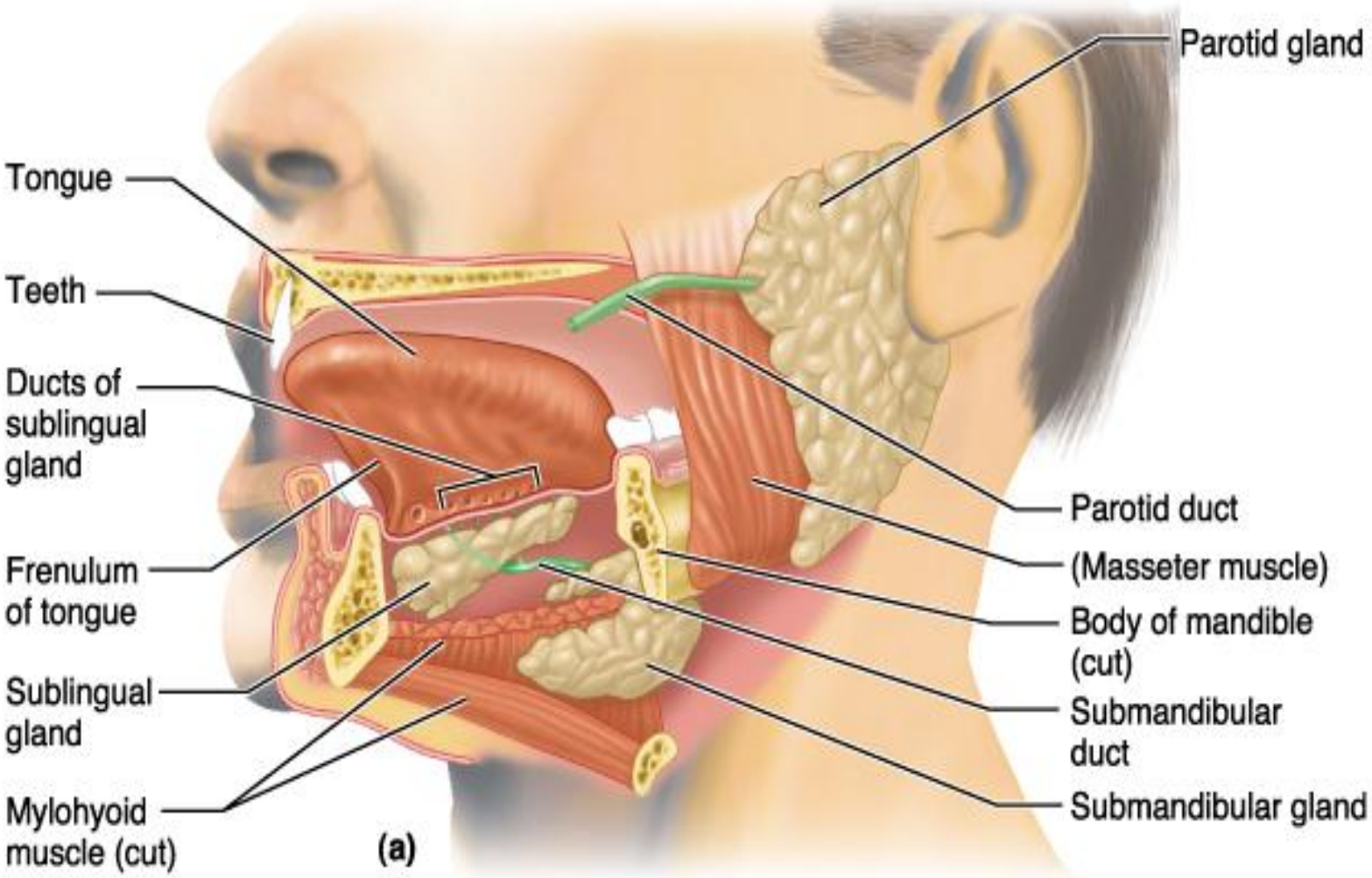
The sympathetic and parasympatheic nerve fibres connect both myenteric and submucosal plexuses. Although the enteric nervous system can function on its own, independently of these extrinsic nerves, stimulation by sympathetic and parasympatheic nerve fibres can further activate or inhibit GIT functions.

Generally, stimulation of parasympathetic nerve fibres (vagus nerve) leads to activation of GIT motility and secretion while stimulation of sympathetic nerve fibres produces the reverse effect

Blood Supply: Splanchnic Circulation

- Arteries and the organs they serve include
  - The hepatic, splenic, and left gastric: spleen, liver, and stomach
  - Inferior and superior mesenteric: small and large intestines
- Hepatic portal circulation:
  - Collects nutrient-rich venous blood from the digestive viscera
  - Delivers this blood to the liver for metabolic processing and storage

The Major Salivary Glands



Salivary glands consists of three pairs

- Sublingual salivary glands
- Submandibular salivary glands
- Parotid salivary glands

Functions of the salivary glands

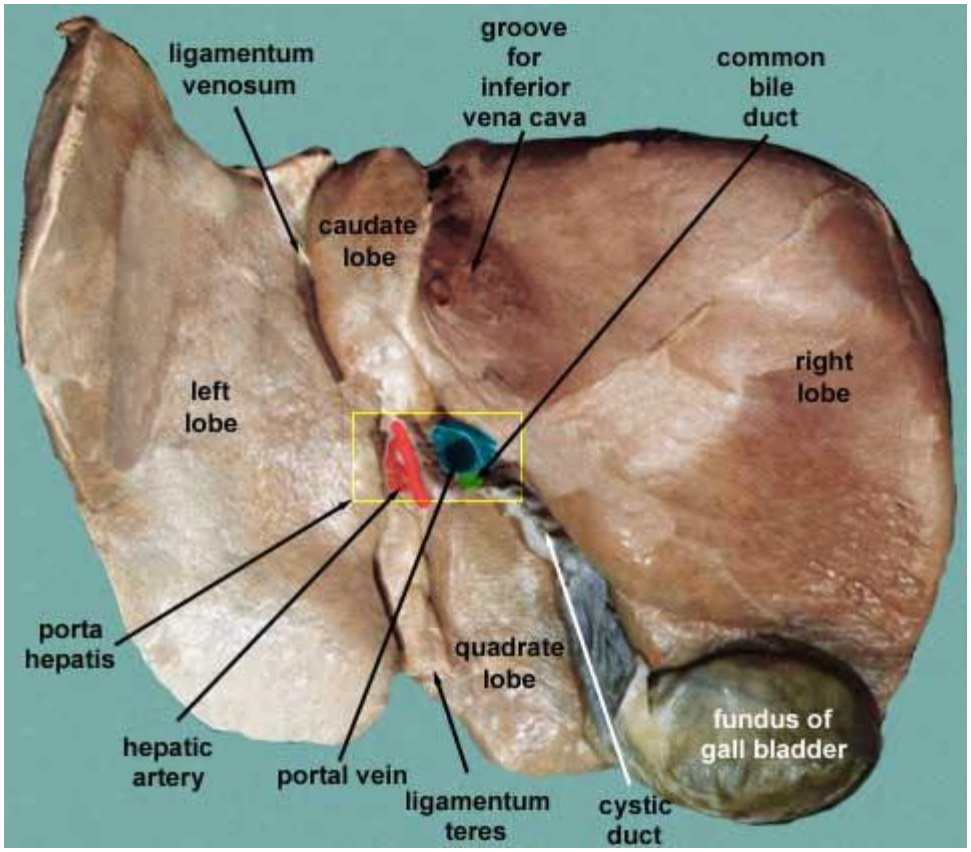
The functions of saliva are numerous.

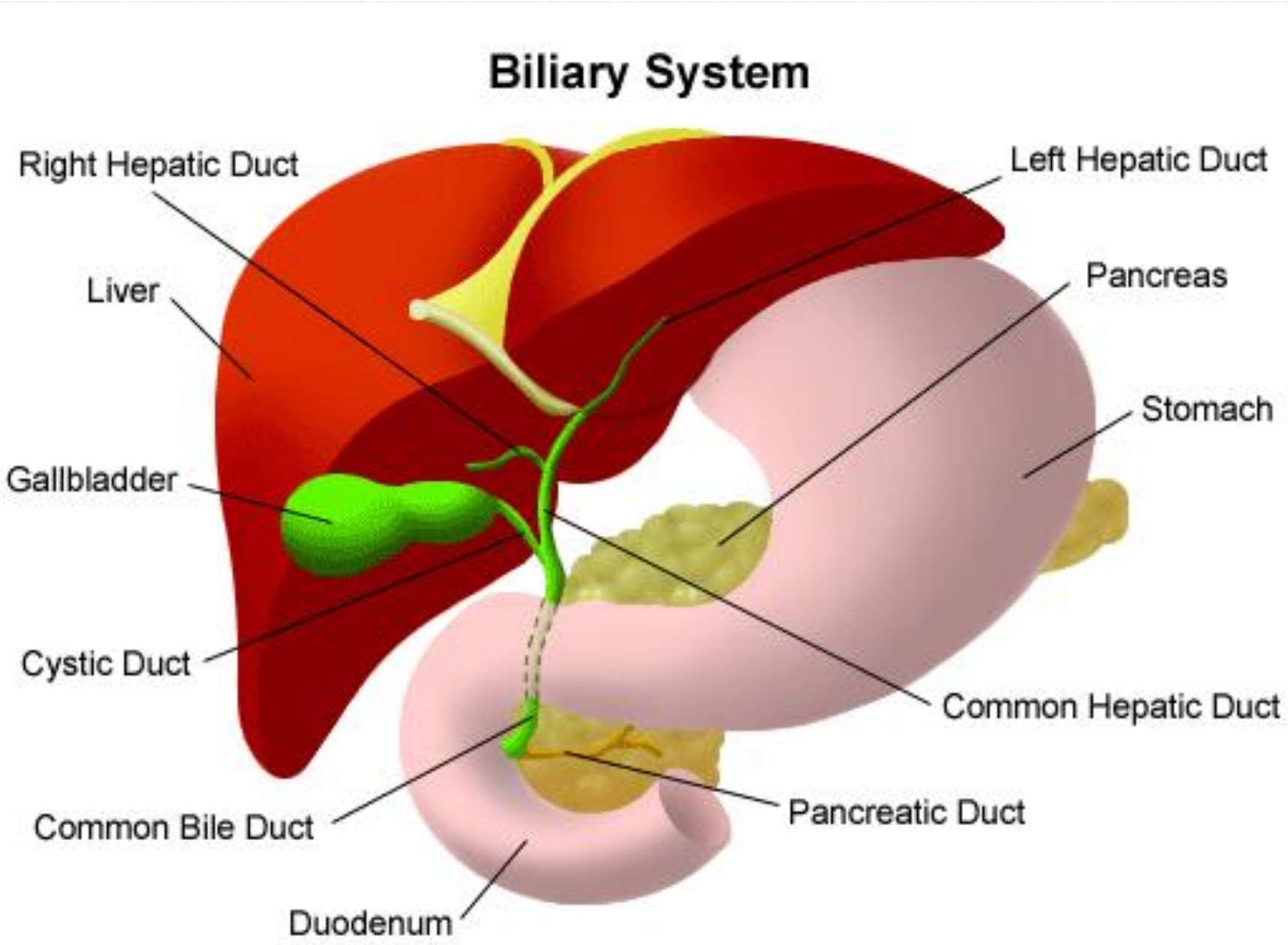
- It lubricates and moistens foods
- Keeps the oral cavity moist
- Decaying of teeth and oral infection are reduced to a large extent because saliva removes food debris, dead cells, bacteria and white blood cells. It contains lysozymes, which have bactericidal functions.
- Help to maintain water balance because when the body water content is reduced, rate of saliva secretion decreases, and hence the person feels the sensation of thirst.
- An enzyme present in saliva, called amylase chemically breaks down starch into simpler compounds.

Liver

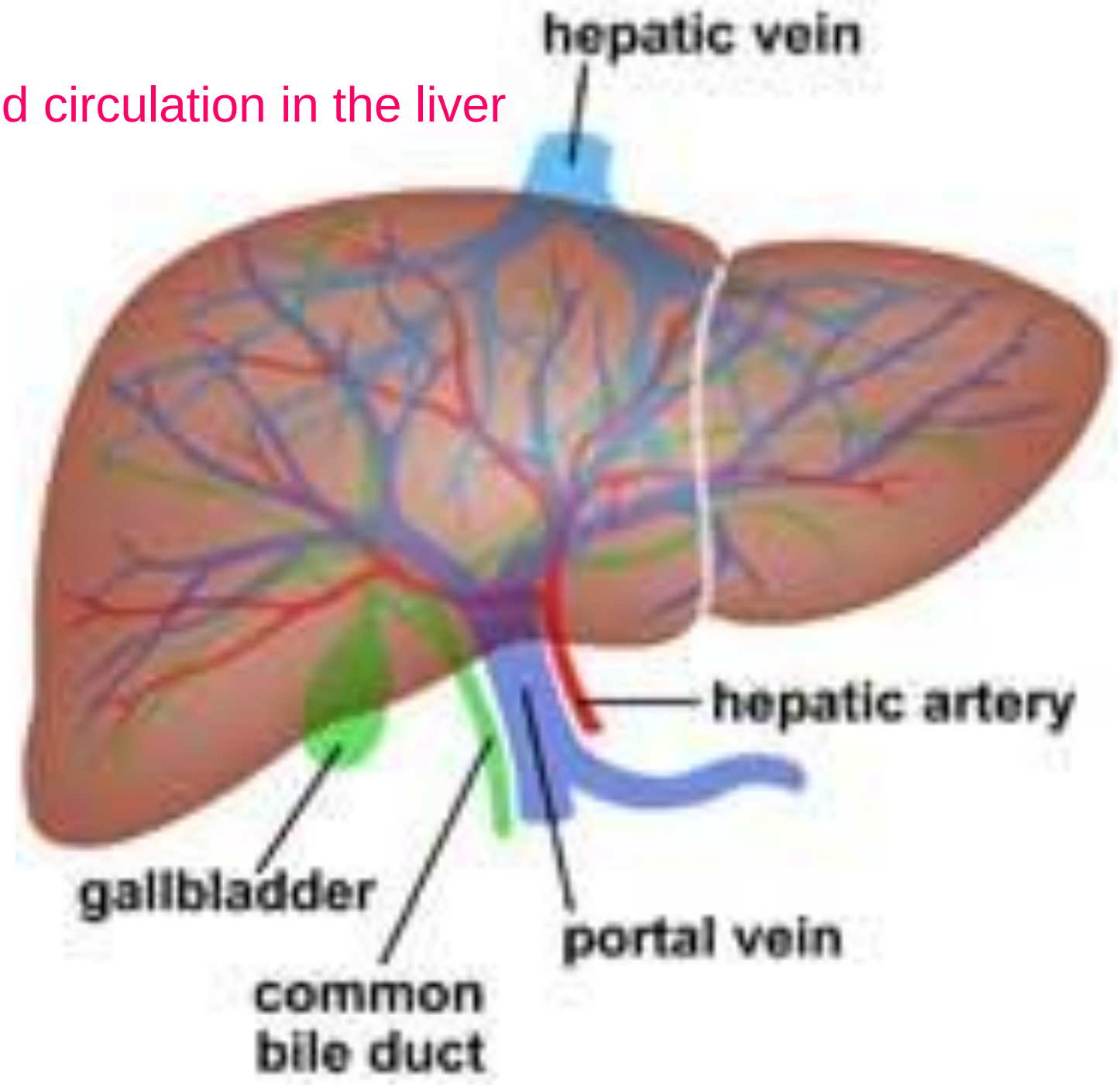
- Location
  - primarily in the upper right part of the abdomen, mostly under the ribs.
  - resting just below the diaphragm
  - Epigastric region
- 4 Lobes
  - Left
  - Quadrate
  - Caudate
  - Right
- Each lobe has lobules – Contains hepatocytes – Surround sinusoids – Feed into central vein

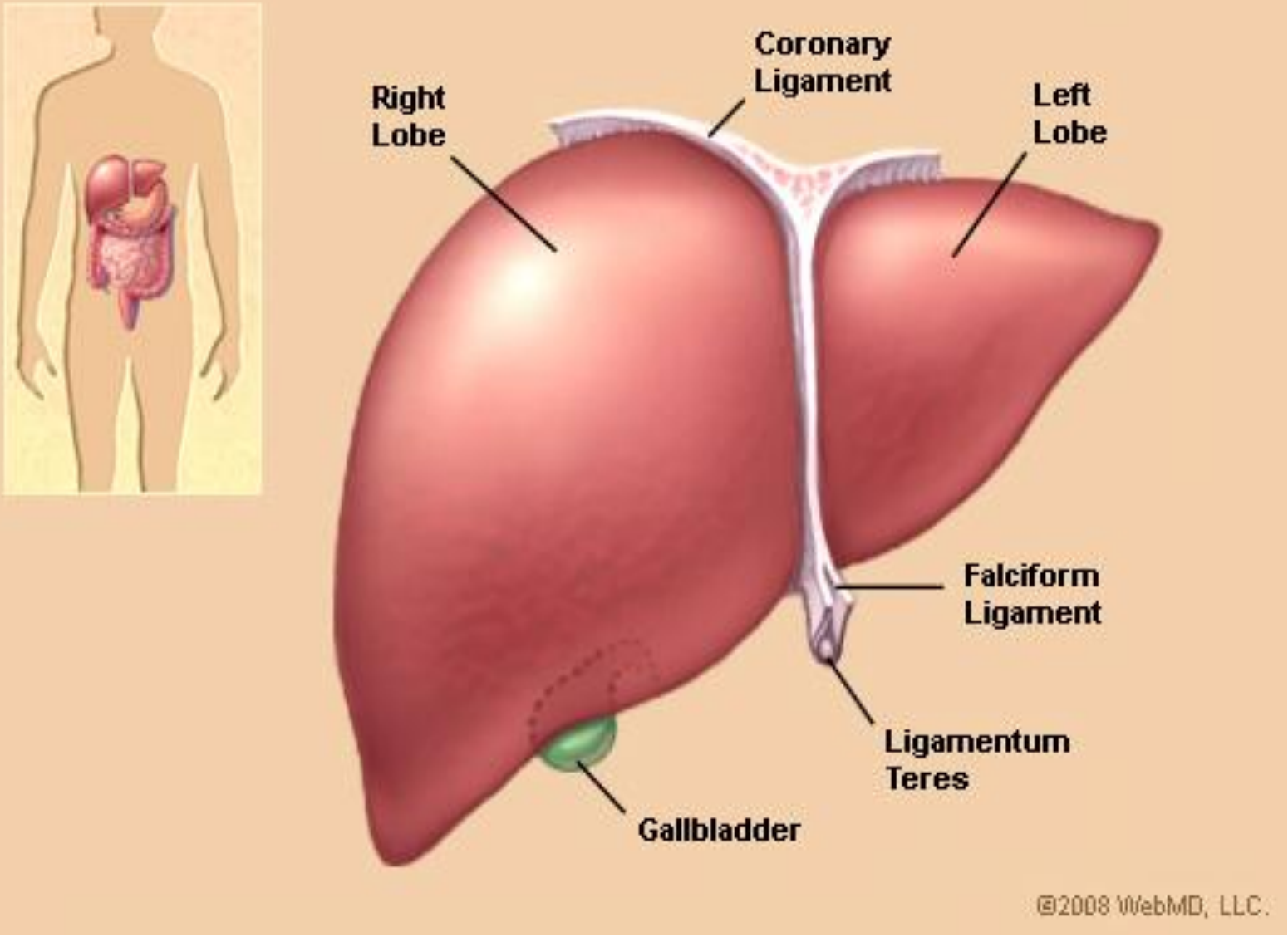
Liver lobes


ligamentum venosum
groove for inferior vena cava
common bile duct
caudate lobe
left lobe
right lobe
porta hepatis
quadrate lobe
fundus of gall bladder
hepatic artery
portal vein
ligamentum teres
cystic duct


Biliary System
Right Hepatic Duct
Left Hepatic Duct
Liver
Pancreas
Stomach
Gallbladder
Cystic Duct
Common Hepatic Duct
Common Bile Duct
Pancreatic Duct
Duodenum

Blood circulation in the liver




Coronary Ligament
Right Lobe
Left Lobe
Falciform Ligament
Ligamentum Teres
Gallbladder
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Functions of liver

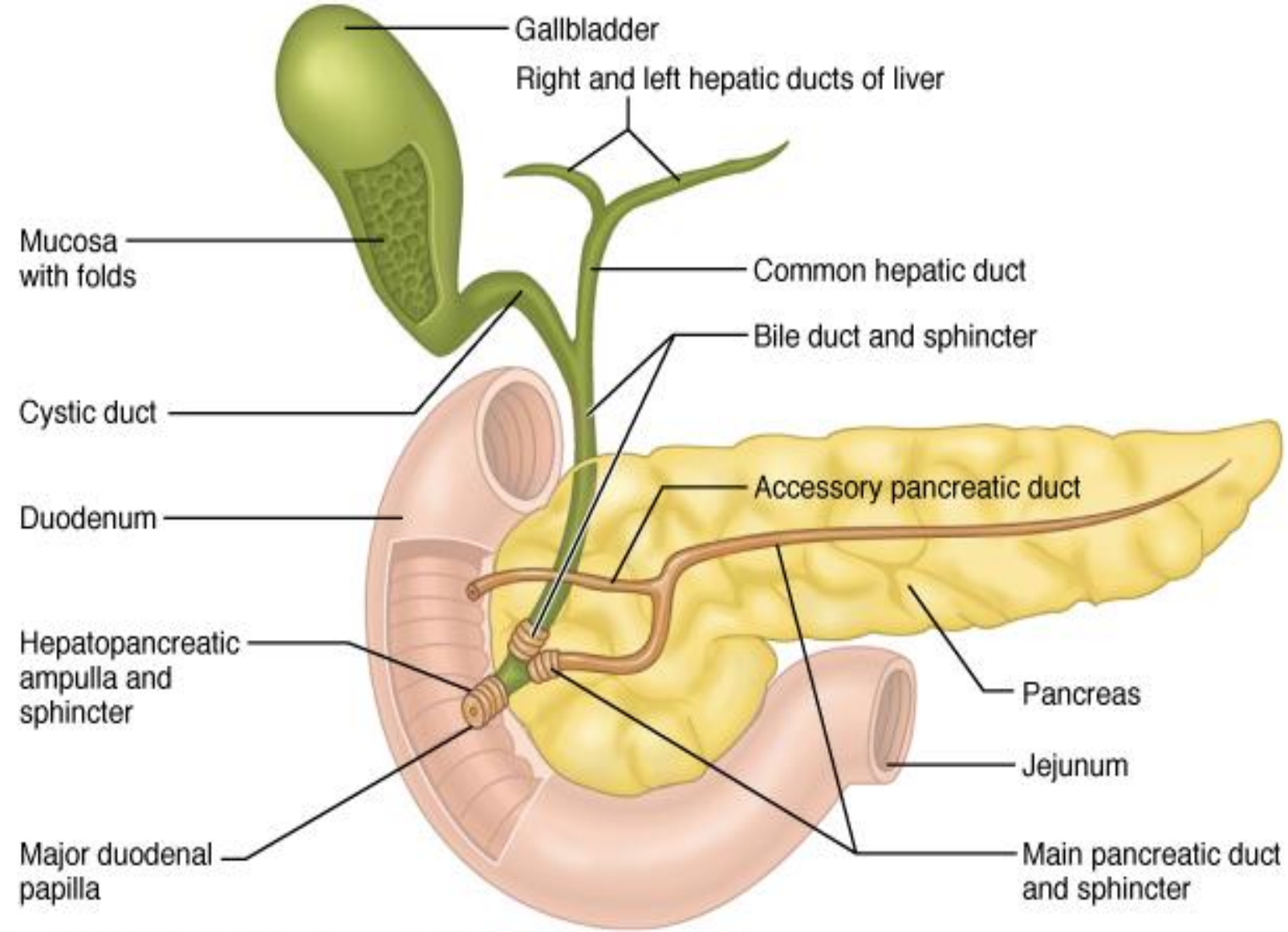
- Makes bile
  - emulsifies fats by bile salts
  - Helps to carry away waste products (bile pigments) from the liver.
  - Release promoted by:
    - Vagus n.
    - Cholecystokinin (CCK)
    - Secretin
- Detoxifies/removes
  - Drugs
  - Alcohol
- Stores
  - Gycolgen
  - Vitamins (A, D, E, K)
  - Fe (in the form of ferritin) and other minerals
  - Cholesterol

Functions of liver continued ----

- Fetal RBC production
- Phagocytosis
- The liver also makes proteins important for blood clotting and other functions.
- Metabolizes absorbed food molecules
  - Carbohydrates
  - Proteins
  - Lipids

Pancreas

- It is both an endocrine gland producing several important hormones, including insulin, glucagon, and somatostatin, as well as an exocrine gland, secreting pancreatic juice containing digestive enzymes that pass to the small intestine. These enzymes help in the further breakdown of the carbohydrates, protein, and fat in the chyme.
- Pancreatitis means inflammation of the pancreas leading to lack of pancreatic secretion.

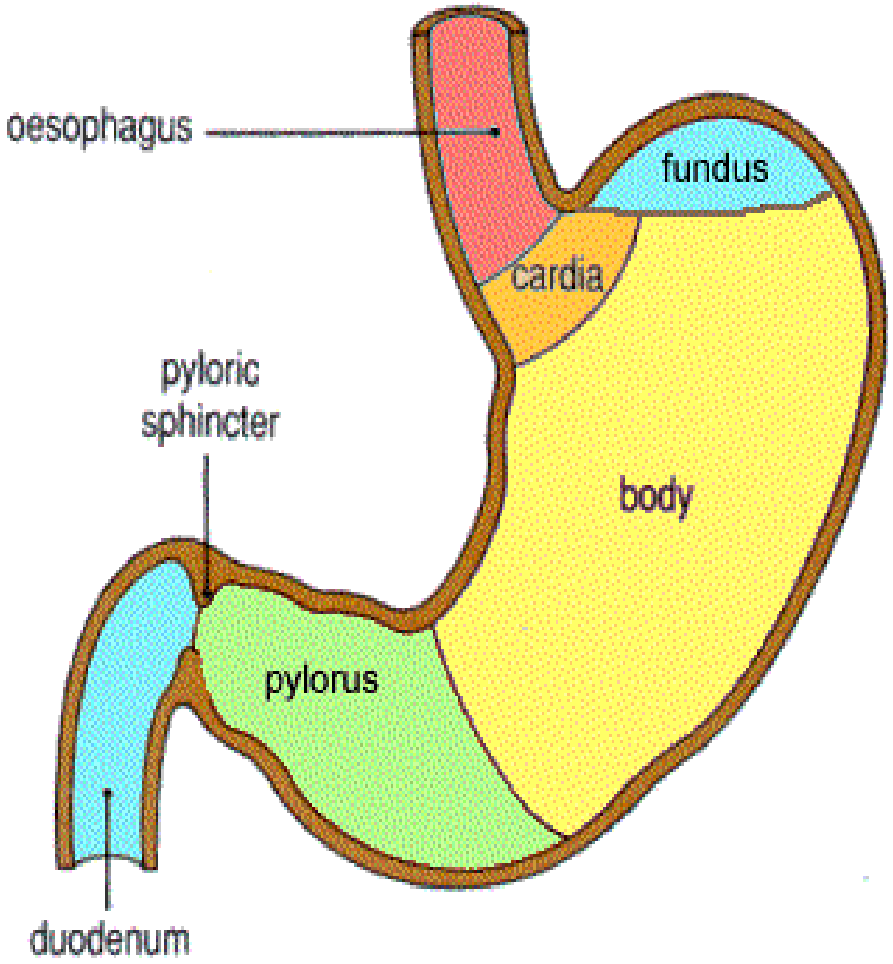


Esophagus

- Usually collapsed (closed)
- It 25 cm long
- 3 constrictions
  - Aortic arch
  - Left primary bronchus
  - Diaphragm
- Sphincters
  - Upper
  - Lower
- Functions
  - Secrete mucous
  - Transport food by peristaltic movement

Stomach

- Usually “J” shaped
- Left side, anterior to the spleen
- It is 25-30cm long
- Mucous membrane
  - G cells – make gastrin
  - Goblet cells – make mucous
  - Gastric pit – Oxyntic cells (Parietal cells) secretes HCl
  - Chief cells – Zymogenic cells
    - Pepsin
    - Gastric lipase
- Pepsin act on peptide bonds of proteins to give proteoses and peptones. (Its optimum pH is 1.8)
- Gastric lipase is not of significant importance in stomach because pH is not suitable for its action.
- In children, renin (optimum pH 6-7; HCl in not yet secreted) is secreted in the stomach to convert casein protein of milk to paracasein that react with calcium to form calcium paracaseinate (milk curd).


oesophagus
fundus
cardia
pyloric
sphincter
body
pylorus
duodenum

Stomach

- Functions
  - Mix food
  - Reservoir
  - Start digestion of
    - Protein
    - Fats
  - Activates some enzymes
  - Destroys some bacteria
  - Makes intrinsic factor – B 12 absorption
  - Absorbs
    - Alcohol
    - Water
    - Lipophilic acid
    - B 12

Rgulation of secretion of gastric juice

- Cephalic phase. It accounts for 30% of the gastric secretory response. It begins before food reaches the stomach. In this stage, parasympathetic reflexes operating through vagus nerve stimulate gastric secretion whenever the person tastes, sees, smells or even thinks about food.

- Gastric phase. It accounts for 50% of the gastric secretory response. It starts when food enters the stomach leading to distension of its wall. It is mediated by both neural (vagus nerve) and hormonal (by gastrin) mechanisms.

- Intestinal phase. It accounts for 5% of the gastric secretory response. It occurs when food enters the duodenum. Enterogastrone, secretin and cholecystokinin-pancreozymin (CCK-PZ) secreted from duodenum enter circulation and act on stomach to decrease secretion and motility of the stomach.

Movements in the stomach

- Segmentation (mixing).
- Mild peristaltic wave at rate of 3/minute toward the antrum (mixing).
- Strong propulsive peristaltic contractions to press on pyloric sphincter and push food to the duodenum.

Peptic ulcers. Peptic ulcer is produced in stomach and some parts of small intestine that are exposed to gastric juice.

Causes

- high acid and peptic content of gastric juice
- irritation
- poor blood supply
- poor secretion of mucus
- infection

Small Intestine

- Extends from pyloric sphincter → ileocecal valve
- It is 5.5 - 6 meters long
- Regions
  - Duodenum. It is 25 cm long and it C-shaped.
  - Jejenum
  - Ileum
- Movements
  - Segmentation
  - Peristalsis

Small Intestine

- Secretes digestive enzymes
  - Peptidases (proteolytic enzymes)
    Aminopeptidase
    Dipeptidase
    Tripeptidase

  - Disaccharidases (amylolytic enzymes)
    Sucrases to form glucose and fructose
    Maltase form 2 glucose
    Lactase form glucose and galactose
  - Lipase (lipolytic enzyme)
  - Nucleases

Small Intestine

- Absorbs
  - 80% ingested water
  - Electrolytes
  - Vitamins
  - Minerals
  - Carbohydrates
    - Active/facilitated transport
    - Monosaccharides
  - Proteins
    - Di-/tripeptides
    - Amino acids
  - Lipids
    - Monoglycerides
    - Fatty acids
    - To be absorbed by villi, the bile salts form with lipids what is known, Micelles.
    - In the mucosal cell, the fatty acids recombine with glycerol to form triglycerides which are surrounded with protein envelop to form chylomicrons that are transported to lymph and blood.

Small Intestine

- Control: Its secretion and motility are regulated by hormonal and neural signals.
- Requires pancreatic enzymes & bile to complete digestion.
- The bile consists of bile pigments (bilirubin and biliverdin) which are excretory products and bile acids or salts (glycocholic acid and taurocholic acid) which emulsify fats in the intestine.
- Pancreatic juice consists of sodium bicarbonate and digestive enzymes which includes amylase, trypsin, chemotrypsin, carboxypeptidase, lipase, cholestrol estrase and nucleases.
- Trypsin and chemotrypsin are secreted in the form of trypsinogen and chemotrypsinogen which are activated by enterokinase (enteropeptidase) and then by autoactivation.

Summary of chemical digestion

- **Salivary amylase converts starch and glycogen into maltose.**
- **Pepsin in gastric juice converts proteins into proteoses, peptons and peptides.**
- **Gastric lipase is not of significant importance because of unsuitable pH.**
- **Renin in stomach of children converts casein of milk into calcium paracaseinate (milk curd) to facilitate its digestion by peptidases.**
- **Bile from liver and gall bladder contains bile pigments (bilirubin and biliverdin) as excretory products and bile salts (acids) that causes emulsification of fats.**
- **Sodium bicarbonate in pancreatic juice converts medium to neutral to mild alkaline suitable for actions of enzymes in small intestine.**
- **Pancreatic amylase converts starch and glycogen as well as dextrins into maltose.**
- **Pancreatic lipase converts triglycerides, diglycerides and monglycerides into fatty acids and glycerol.**
- **Cholesterol esterase in pancreatic juice converts cholesterol ester into cholesterol and fatty acids.**
- **Phospholipase in pancreatic juice causes release of fatty acids from phospholipids.**
- **Trypsin, chemotrypsin and carboxypeptidase in pancreatic juice convert proteins into proteoses, peptons, peptides and amino acids.**

Continued ----
Summary of chemical digestion

- **Aminopeptidases, tripeptidase and dipeptidase in intestinal juice convert peptides into amino acids.**
- **Intestinal lipase in intestinal juice converts triglycerides, diglycerides and monglycerides into fatty acids and glycerol.**
- **Sucrase in in intestinal juice converts disaccharide sucrose into monosaccharides glucose and fructose.**
- **Maltase in in intestinal juice converts disaccharide maltose into monosaccharide glucose.**
- **Lactase in intestinal juice converts disaccharide lactose into monosaccharides glucose and galactose.**
- **Cellulase secreted from beneficial bacteria in vermiform appendix and large intestine digest cellulose found in herbs.**

Absorption

- **End products of digestion which includes monosaccharides (glucose, fructose and galactose), fatty acids, cholesterol and amino acids are absorbed into blood or lymph by small intestine.**
- **Jejenum is redder and has richer blood supply than ileum.**
- **Fat soluble end products of digestion are transported into lymph vessels while water soluble end products are transported into blood capillaries to enter liver through hepatic portal vein.**
- **Glucose is absorbed by active transport**
- **Fructose and amino acids are absorbed by facilitated diffusion**
- **Fatty acids are absorbed with the aid of bile salts.**

Hormonal control GI secretion

- Gastrin. It increases secretion of gastric juice
- Enterogastrone. It inhibits secretion and motility of stomach.
- Secretin. It increases secretion of pancreatic juice rich in bicarbonates and low in enzymes.
- Cholecystokinin-pancreozymin. It increases secretion of pancreatic juice rich in enzymes and low in bicarbonates. It also causes discharge of bile into small intestine.
- Enterocrinin. It stimulates the secretion of intestinal juice.

Large intestine

It is 1.5 meter long.
It has little or no digestive function.
In the large intestine, there are haustra or pouches due presence of teniae coli (fibres) that exert tension on the wall.
It consists of caecum, ascending colon, transverse colon, descending colon, sigmoid colon, rectum (5 cm) and anal tube (2.5-4 cm) leading to anus.

Movements

- Segmentation
- Mass peristalsis (bowel movements). It occurs around the time of defecation.

Functions

- Absorption of water and sodium.
- Temporary storage organ for faeces
- Excretion of fecal matter.
- Secretion of mucous that helps the fecal matter to remain bound to each other as mass and helps in smooth passage through rectum and anal canal.
- Synthesis of certain vitamins such as some vitamins of B complex (B12, thiamine and riboflavin) and vitamin K by bacteria or intestinal microflorae.

- Cellulose is also digested by bacterial microflorae.

Defecation

- **Defecation** is the process of emptying of fecal matter from the large intestine through the anal canal and anus. Mechanisms of defecation.
- The primary center for defecation is found in the sacral segment of the spinal cord.
- The higher center is present in cerebral cortex. Hence, after 2 years of birth, these involuntary reflexes can be inhibited by inhibitory voluntary impulses from the cerebral cortex.

Mechanism of Defecation

- It looks like mechanism of micturition.
- Distension of the wall of the rectum leads to the stimulation of the mechanoreceptors present in the wall of the rectum.
- Pelvic fibres carry afferent impulses.
- On reaching the spinal cord, they stimulate the motor neurons present in the sacral segments.
- Efferent impulses come along the pelvic nerve (S_2, $_3$ and $_4$) and stimulate the contraction of smooth muscles in the wall of rectum and relaxation of the internal sphincter.
- As a result, the fecal matter gets pushed into the anal canal.
- The mechanoreceptors in the anal tube are stimulated and afferent impulses are carried by pudic nerve fibres to the sacral segments.
- Efferent nerve impulses of pudic nerve causes contraction of anal canal and relaxation of external sphincter expelling fecal matter to exterior
- These two reflexes can be inhibited by signals from higher center in the cerebral cortex.

Diarrhea

- **Diarrhea** results from rapid movement of fecal matter through the large intestine.

Causes of diarrhea

- **Enteritis** caused either by infection of intestinal tract with virus or bacteria. The intestinal mucosal cells are extensively irritated and its rate of secretion becomes greatly enhanced. The motility of the intestinal wall increases manyfolds.
- **Psychogenic diarrhea:** It is caused by excessive activity of the parasympathetic nervous system which in turn excites the motility and secretion of mucus from the distal colon.
- **Ulcerative colitis.** In which the large intestine is inflamed and ulcerative. The motility of the ulcerated intestine is often so great that the mass movements occur most of the time.

Constipation

- It means slow movement of faeces through the large intestine; it is often associated with large quantity of dry and hard faeces in the descending colon. It may result from a defect in defecation reflexes or may result from spasm of small segment of a sigmoid colon.
- The long term constipation and long time persistent constipation lead to a condition known as megacolon (Hirschsprung's disease; which may be due to lack of myenteric fibres in a segment of the sigmoid colon).

Vomiting

- It is a process by which the contents of the upper parts of GI tract are thrown out of the body through the oral cavity.

- It results when the upper part of the GIT becomes excessively irritated, over distended or over excitable.
- It is controlled by reflex mechanism and center present in the floor of the fourth ventricle of medulla oblongata.

During vomiting, there are nausea, increased salivation, reverse peristalsis, lower esophageal sphincter relaxation, contraction of abdominal muscles, closure of glottis, lifting soft palate to close the posterior nares and breathing is temporary held.
- Certain drugs like morphine, apomorphine can stimulate this area and initiate the process of vomiting.