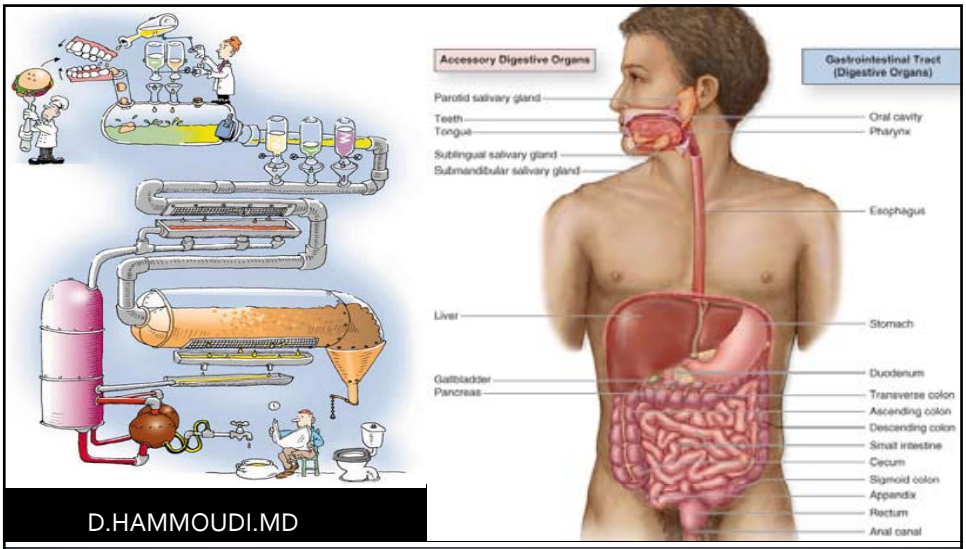
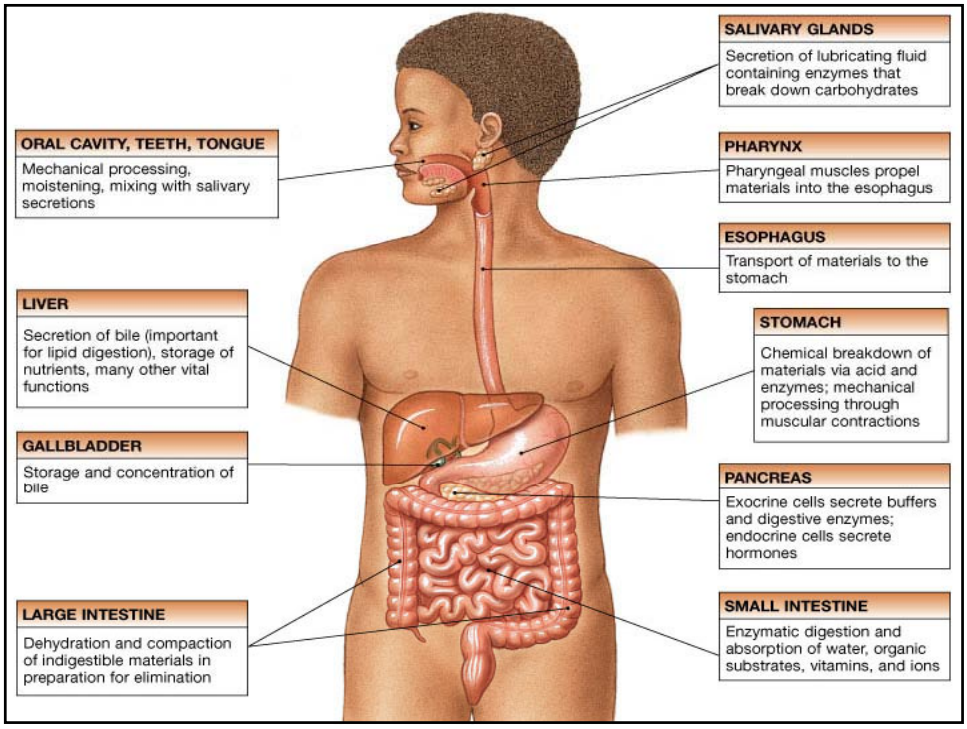


D.HAMMOUDI.MD

GI ANATOMY LAB

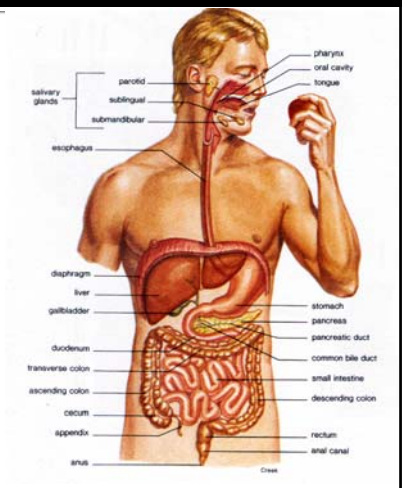


FUNCTION

- **General Structure and Functions of the Digestive System**
- Ingest the food.
- Transport the food.
- Digest the food into smaller usable components.
- Absorb the necessary nutrients into the bloodstream.
- Expel the waste products from the body.

Composed of two separate categories of organs:

- digestive organs
- accessory digestive organs.



- **1. Ingestion or the taking of food into the body**
- **2. Peristalsis or the physical movement or** pushing of food along the digestive tract
- **3. Digestion or the breakdown of food by both** mechanical and chemical mechanisms
- **4. Absorption or the passage of digested food** from the digestive tract into the cardiovascular and lymphatic systems for distribution to the body's cells
- **5. Defecation or the elimination from the body** of those substances that are indigestible and cannot be absorbed.

General Structure and Functions of the Digestive System

The GI tract organs:

- oral cavity
- pharynx
- esophagus
- stomach
- small intestine
- large intestine

Form a continuous tube that extends about 30 feet (9–10 meters) from the mouth to the anus.

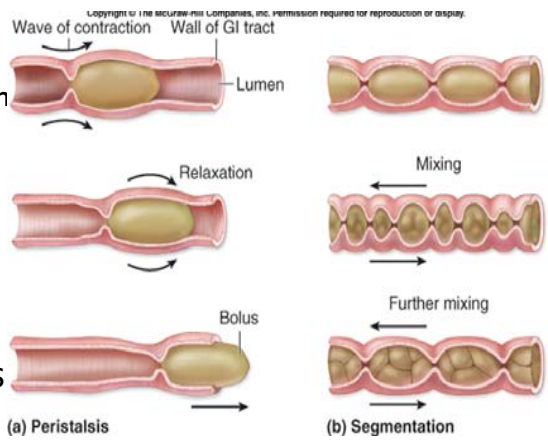
- Smooth muscle in the GI tract wall pushes materials from one end to the other.

Accessory digestive organs:

- do not form the long GI tube, but often develop as outgrowths from and are connected to the GI tract
- Assist the GI tract in the digestion of food.
- teeth, tongue, salivary glands, liver, gallbladder, and pancreas

Digestive System Functions

- Ingestion
- Digestion
  - **mechanical digestion**
    - **chemical digestion**
- Propulsion
  - peristalsis
  - segmentation
- Secretion
- Absorption
- Elimination of wastes (defecation)



GENERAL STRUCTURE

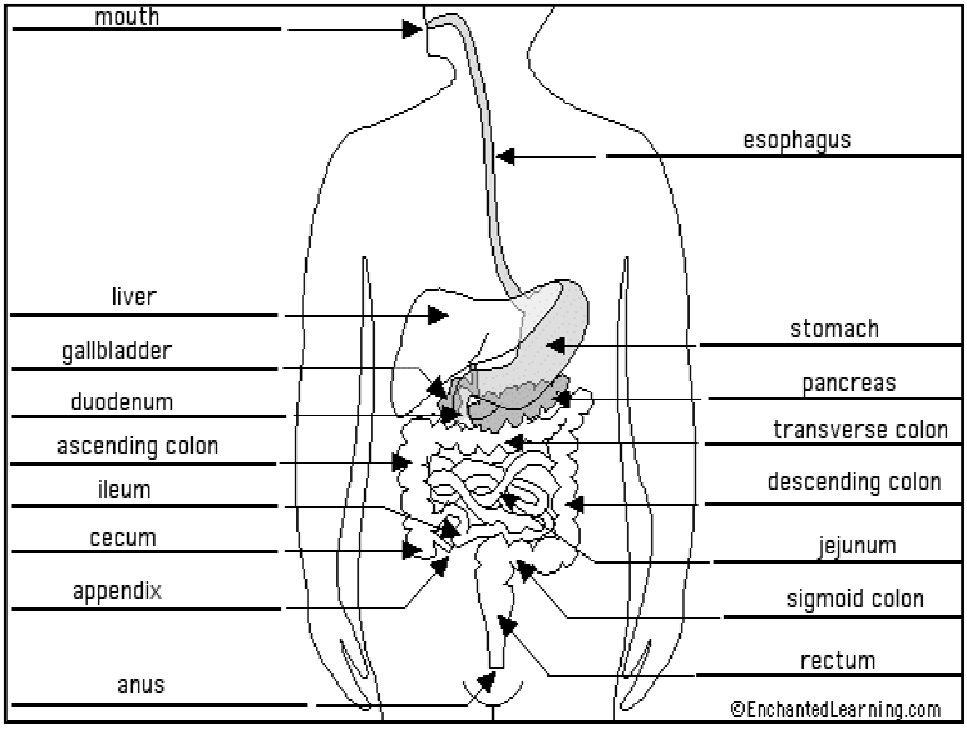
- **Mouth** - the first part of the digestive system, where food enters the body. Chewing and salivary enzymes in the mouth are the beginning of the digestive process (breaking down the food).
- **Salivary glands** - glands located in the mouth that produce saliva. Saliva contains enzymes that break down carbohydrates (starch) into smaller molecules.
- **Esophageus** - the long tube between the mouth and the stomach. It uses rhythmic muscle movements (called peristalsis) to force food from the throat into the stomach.
- **Peristalsis** - rhythmic muscle movements that force food in the esophagus from the throat into the stomach. Peristalsis is involuntary - you cannot control it. It is also what allows you to eat and drink while upside-down.
- **Liver** - a large organ located above and in front of the stomach. It filters toxins from the blood, and makes bile (which breaks down fats) and some blood proteins.
- **Stomach** - a sack-like, muscular organ that is attached to the esophagus. Both chemical and mechanical digestion takes place in the stomach. When food enters the stomach, it is churned in a bath of acids and enzymes.

GENERAL STRUCTURE 2

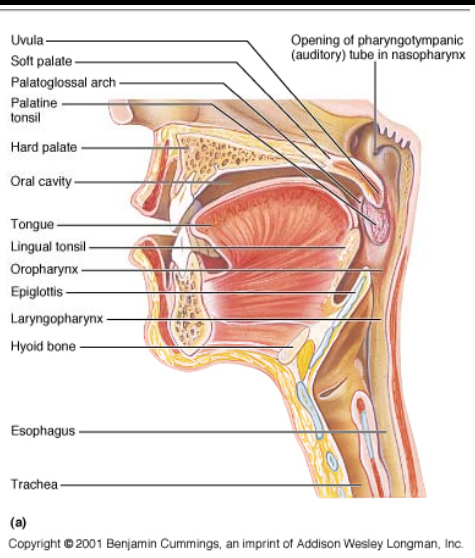
- **Chyme** - food in the stomach that is partly digested and mixed with stomach acids. Chyme goes on to the small intestine for further digestion.
- **Gall bladder** - a small, sac-like organ located by the duodenum. It stores and releases bile (a digestive chemical which is produced in the liver) into the small intestine.
- **Bile** - a digestive chemical that is produced in the liver, stored in the gall bladder, and secreted into the small intestine.
- **Pancreas** - an enzyme-producing gland located below the stomach and above the intestines. Enzymes from the pancreas help in the digestion of carbohydrates, fats and proteins in the small intestine.
- **Duodenum** - the first part of the small intestine; it is C-shaped and runs from the stomach to the jejunum.
- **Jejunum** - the long, coiled mid-section of the small intestine; it is between the duodenum and the ileum.

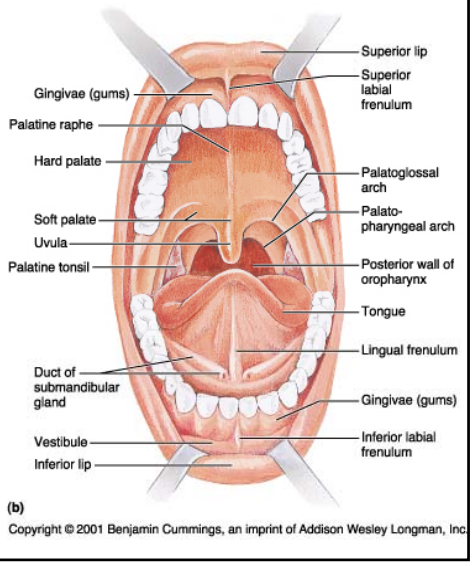
GENERAL STRUCTURE 3

- **Ileum** - the last part of the small intestine before the large intestine begins.
- **Cecum** - the first part of the large intestine; the appendix is connected to the cecum.
- **Appendix** - a small sac located on the cecum.
- **Ascending colon** - the part of the large intestine that run upwards; it is located after the cecum.
- **Transverse colon** - the part of the large intestine that runs horizontally across the abdomen.
- **Descending colon** - the part of the large intestine that run downwards after the transverse colon and before the sigmoid colon.
- **Sigmoid colon** - the part of the large intestine between the descending colon and the rectum.
- **Rectum** - the lower part of the large intestine, where faeces are stored before they are excreted.
- **Anus** - the opening at the end of the digestive system from which faeces (waste) exits the body



Anatomy of the Mouth and Throat





Oral Cavity (mouth)

Entrance to the GI tract.

Initial site of mechanical digestion (via mastication) and chemical digestion (via enzymes in saliva).

Bounded anteriorly by the teeth and lips and posteriorly by the oropharynx.

Superior boundary is formed by the hard and soft palates.

Floor, or inferior surface, of the oral cavity contains the tongue as well as the mylohyoid muscle covered with mucosa.

Vestibule is the space between the cheeks or lips and the gums.

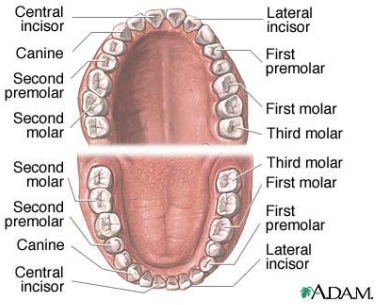
Oral cavity proper.

The lateral walls are formed by the cheeks.

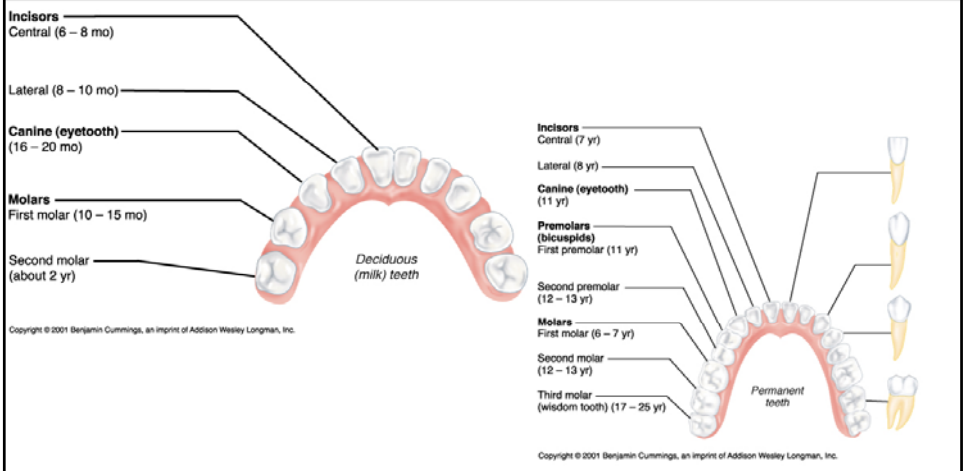
Lips (labia).

Gingivae, or gums.

Labial frenulum.



Human Deciduous and Permanent Teeth



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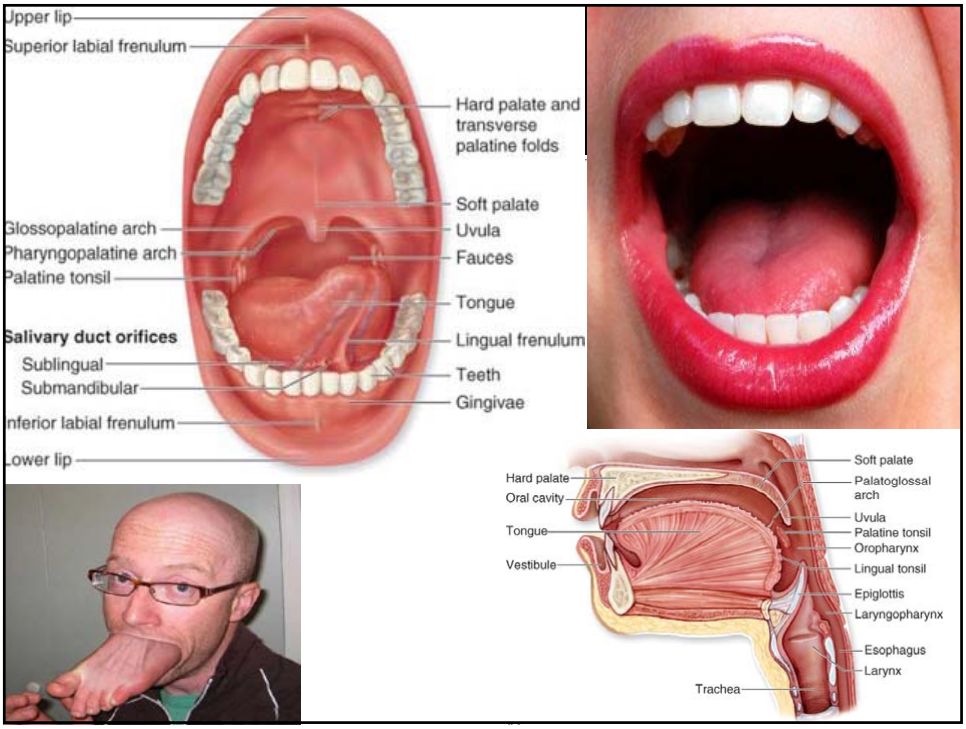
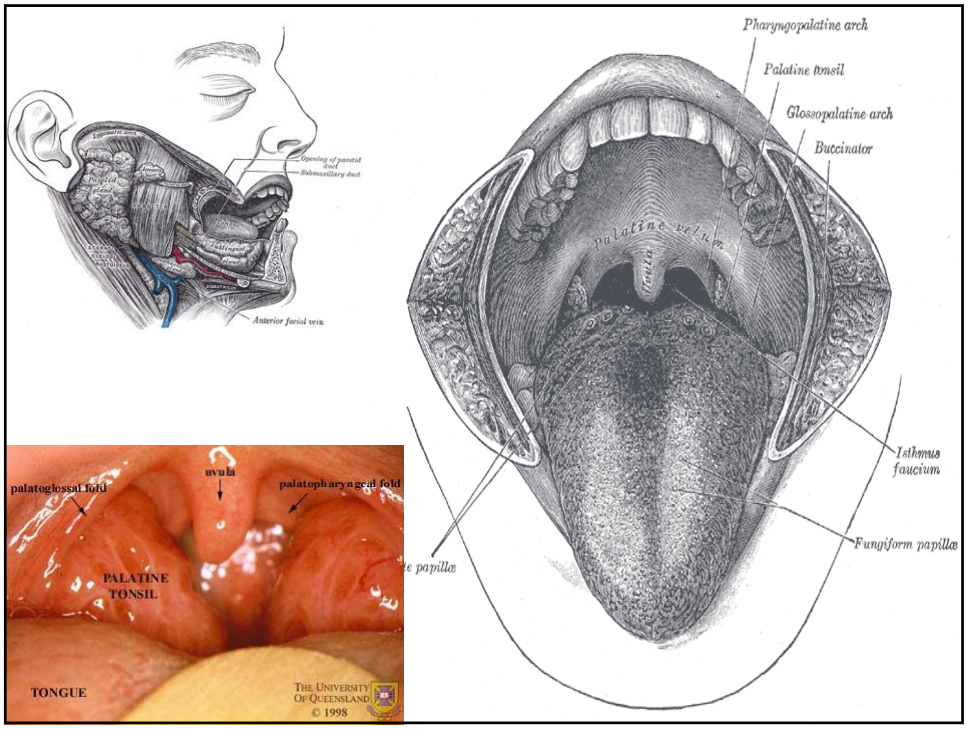
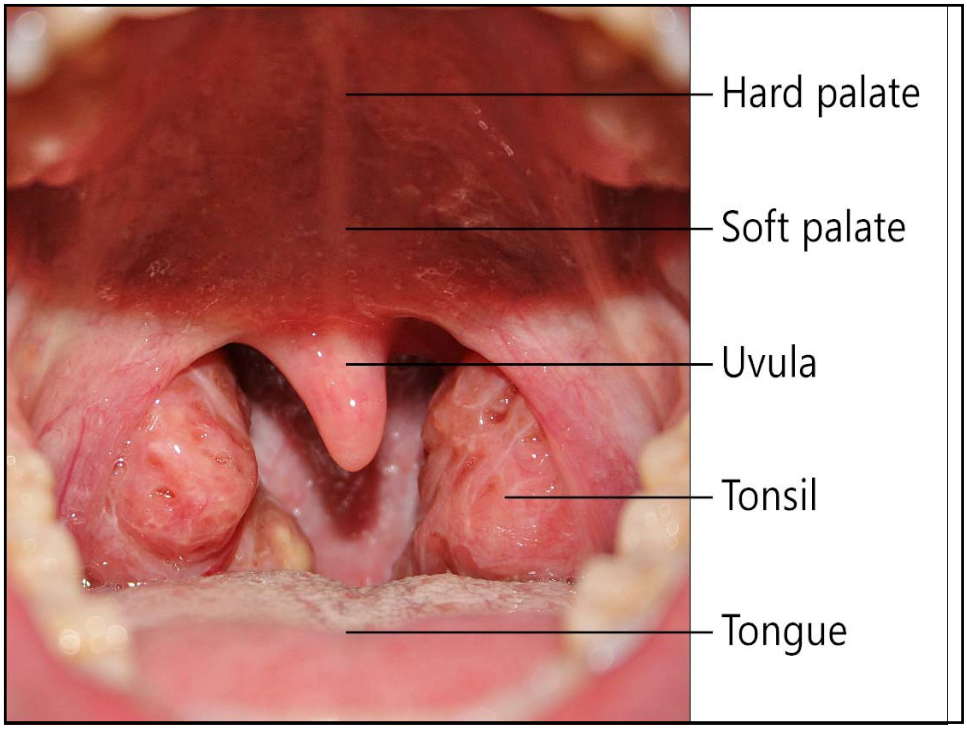
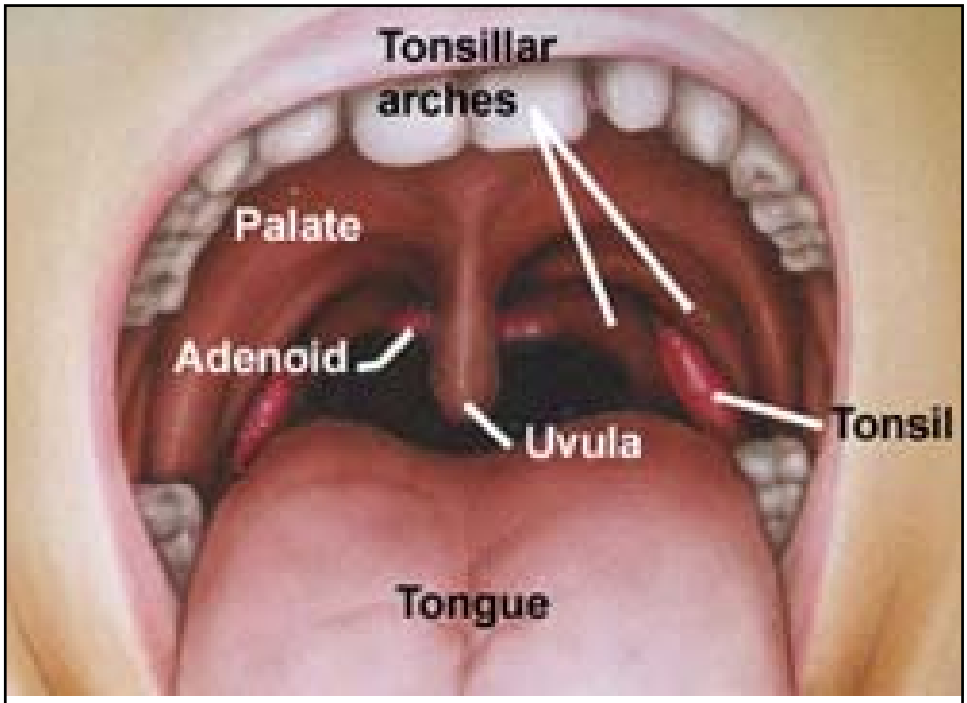
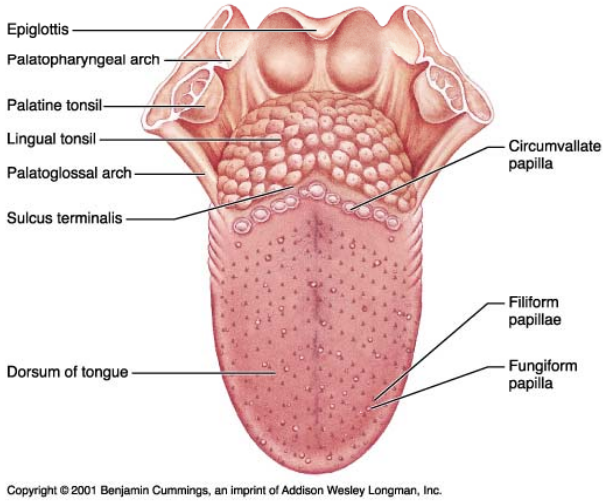



Pharyngopalatine arch
Palatine tonsil
Glossopalatine arch
Buccinator
palatine velum
uvula
Isthmus faucium
Fungiform papillæ
Anterior facial vein
palatoglossal fold
uvula
palatopharyngeal fold
PALATINE TONSIL
TONGUE
THE UNIVERSITY OF QUEENSLAND
© 1998


Hard palate
Soft palate
Uvula
Tonsil
Tongue



Dorsal Surface of the Tongue



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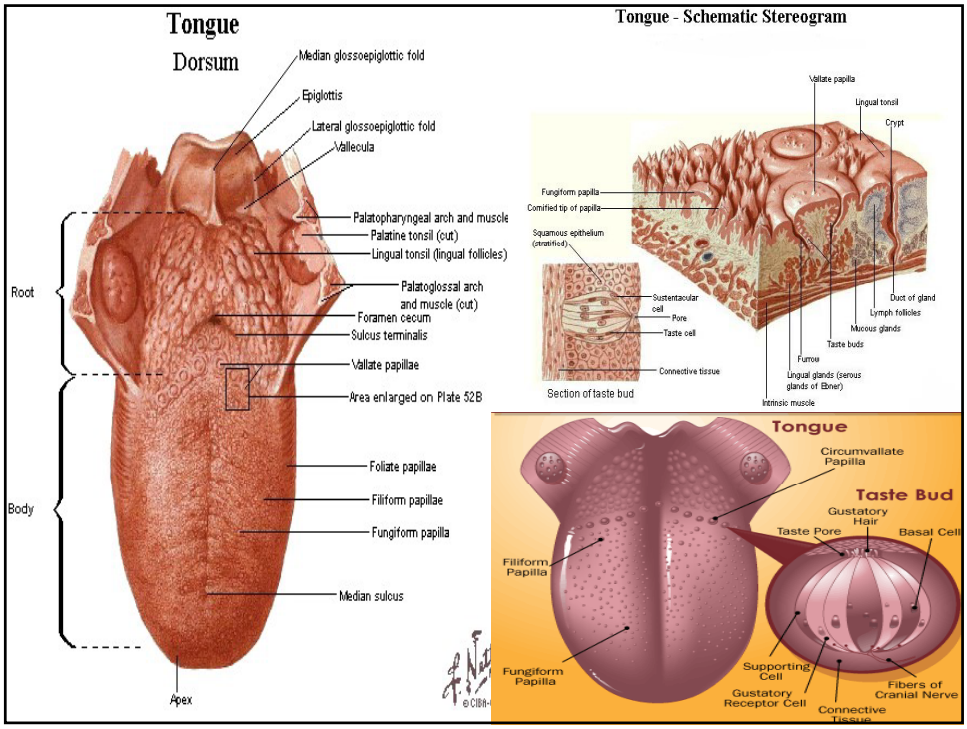
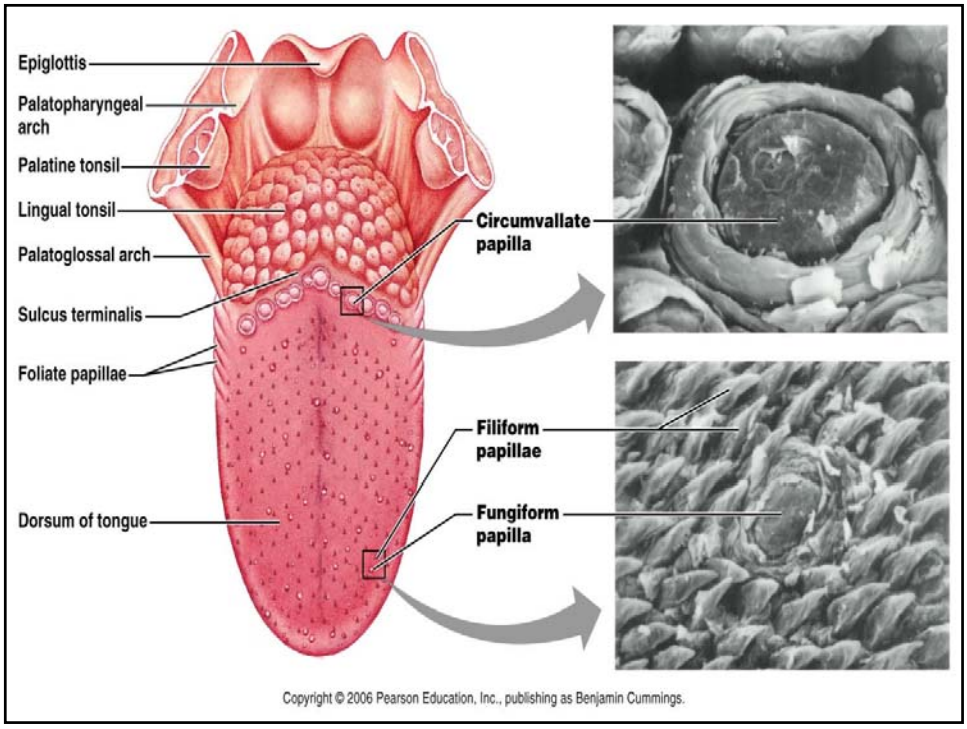

Tongue
Dorsum
Median glossoepiglottic fold
Epiglottis
Lateral glossoepiglottic fold
Vallecula
Palatopharyngeal arch and muscle
Palatine tonsil (cut)
Lingual tonsil (lingual follicles)
Palatoglossal arch and muscle (cut)
Foramen cecum
Sulcus terminalis
Vallate papillae
Area enlarged on Plate 52B
Foliate papillae
Filiform papillae
Fungiform papilla
Median sulcus
Root
Body
Apex
Tongue - Schematic Stereogram
Vallate papilla
Lingual tonsil
Crypt
Fungiform papilla
Cornified tip of papilla
Squamous epithelium (stratified)
Sustentacular cell
Pore
Taste cell
Connective tissue
Section of taste bud
Duct of gland
Lymph follicles
Mucous glands
Taste buds
Furrow
Lingual glands (serous glands of Ebner)
Intrinsic muscle
Tongue
Circumvallate Papilla
Taste Bud
Gustatory Hair
Taste Pore
Basal Cell
Filiform Papilla
Fungiform Papilla
Supporting Cell
Gustatory Receptor Cell
Fibers of Cranial Nerve
Connective Tissue


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

Anterior two-thirds of the palate is hard and bony (called the hard palate), while the

Posterior one-third is soft and muscular (called the soft palate).

primarily composed of skeletal muscle.

Extending inferiorly from the posterior part of the soft palate is the uvula.

When swallowing, the soft palate and the uvula elevate to close
off the opening of the nasopharynx.

Fauces represent the opening between the oral cavity and the oropharynx.

Fauces are bounded by paired muscular folds:

glossopalatine arch (anterior fold)

pharyngopalatine arch (posterior fold)

Palatine tonsils are housed between the arches.

Tongue

An accessory digestive organ that is formed from skeletal muscle and covered with lightly keratinized stratified squamous epithelium.

Manipulates and mixes ingested materials during chewing and

Helps compress the partially digested materials against the
palate to turn these materials into a bolus.

a globular mass of partially digested material

Performs important functions in swallowing.

Inferior surface of the tongue attaches to the floor of the oral cavity by a thin vertical mucous membrane, the lingual frenulum.

Numerous small projections (papillae) cover the superior (dorsal) surface.

Posterior surface contains lingual tonsils.

Skeletal muscles move the tongue.

Lingual papillae - projections of the lamina propria on the dorsum of tongue. There are three types of these projections:

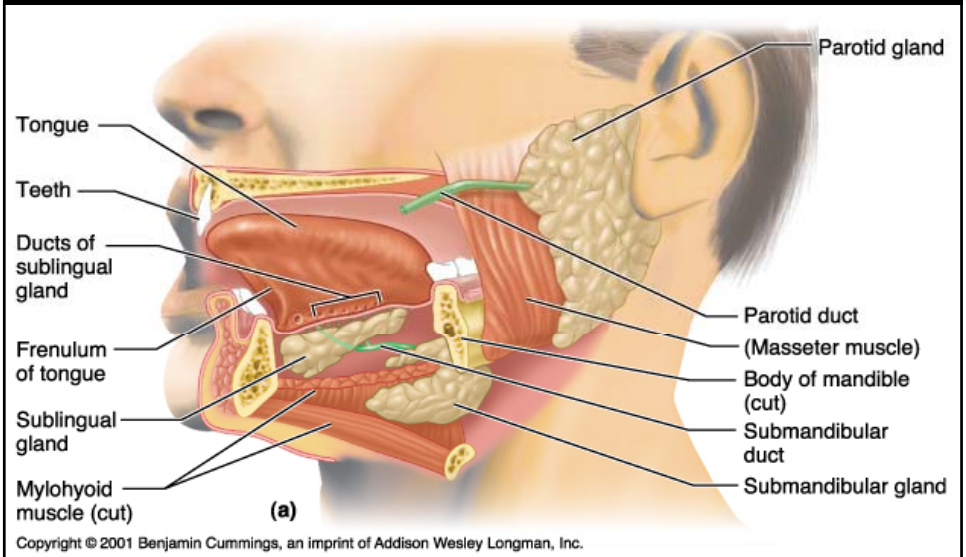
1. Filiform papillae - the most numerous they cover the anterior 2/3 of the dorsum. They give the tongue a roughness needed in licking semisolid foods. Heavily keratinized, they give the tongue a "coated" appearance.

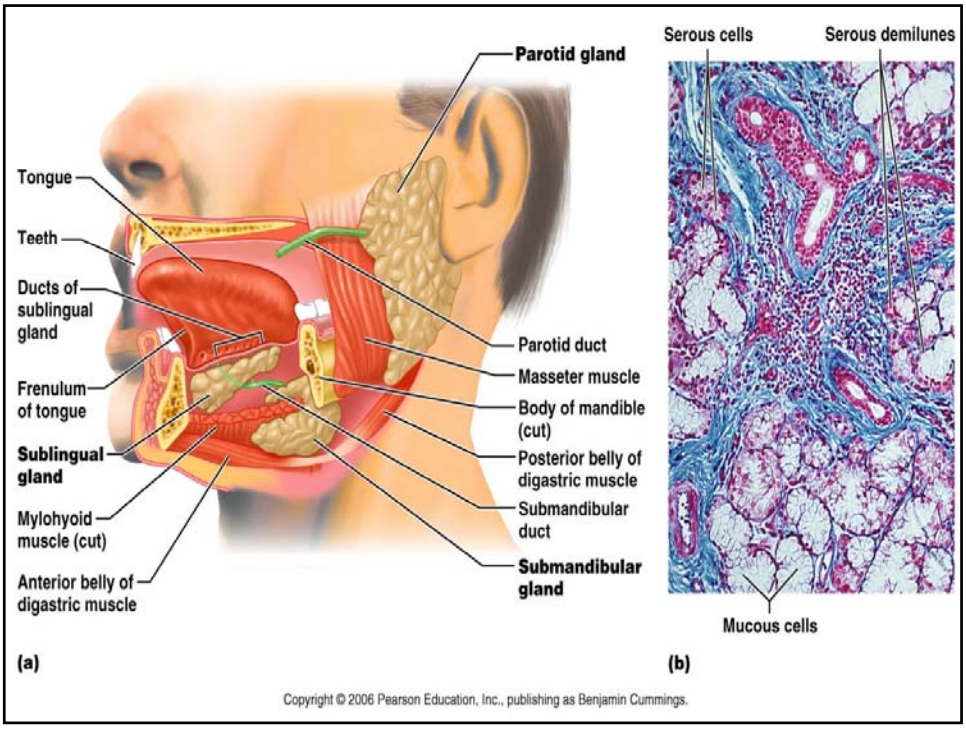
2. Fungiform Papillae - located on the sides of tongue interspersed among the filiform papillae. Taste buds are found around these papillae.

3. Circumvallate Papillae - form a V - shaped formation near the posterior margin of the tongue. The largest number of taste buds are associated with these papillae.
The Lingual Tonsil - an unencapsulated cluster of lymphoid tissue located at the base of the tongue.

•Most people mistake the bumpy structures that cover the tongue's surface for **taste buds**. These are actually **papillae**: goblet-shaped elevations that sometimes contain taste buds and help create friction between the tongue and food.
•Taste buds are smaller structures, tucked away in the folds between papillae.
• Every taste bud is made up of basal and supporting cells that help maintain about 50 **gustatory receptor cells**.
•These specialized receptors are stimulated by the chemical makeup of solutions.
•They respond to several primary tastes: sweet, salty, bitter, sour, **umami** (savory) and fat, which some scientists claim might be a sixth taste.
• When a stimulus activates a gustatory cell, the receptor will synapse with neurons and send an electrical impulse to the gustatory region of the cerebral cortex.
•The brain interprets the sensation as taste.
•Each gustatory receptor cell has a long, spindlelike protrusion called a **gustatory hair** that comes into contact with the outside environment.
•The hair extends from a small opening, or **taste pore**, and mingles with molecules of food introduced by saliva. The saliva solution contains digestive enzymes that help break down foods chemically. Saliva is secreted by three major salivary glands -- the **parotid, submandibular** and **sublingual glands** -- as well as other small salivary glands contained within the tongue and mouth.
•Aside from the tongue's ability to detect gustatory stimuli, it also perceives temperature and the complex tactile sensations that food scientists call **mouth feel**.
•The tongue, along with the rest of the mouth, helps determine a food's texture, oiliness, chewiness, viscosity and density

The Major Salivary Glands





The Salivary Glands - Ducted exocrine glands producing saliva. Two types of secretory cells are found in the glandular tissue:

1. Serous cells producing a watery secretion containing amylase.
2. Mucous cells producing a viscous liquid containing the glycoprotein mucin.

Submandibular Glands - are bilaterally located at the median aspect of the mandibular angle. Their ducts bring saliva to the oral cavity at the base of the frenulum. They are mixed glands, containing approximately equal numbers of serous and mucous cells.

Sublingual Glands - are anterior to the submandibular glands under the tongue. Cells of these glands are mostly mucous producing. Very little amylase is found in this saliva.

Parotid Glands - are anterior and inferior to the external ears lying in a connective tissue capsule. Parotid ducts bring saliva into the vestibule along side of the second upper molar.

The glandular cells are mostly serous.

The Fauces - are the passageway from the mouth to the pharynx. This short corridor is guarded by four pillars; the two palatoglossal arches are more anterior followed by the two palatopharyngeal arches. In between the two sets of arches on either side are the palatine tonsils. During swallowing, contraction of the muscles in these arches constricts the pillars preventing food from reentering the mouth.

Salivary Glands

Collectively produce and secrete saliva.
- a fluid that assists in the initial activities of digestion

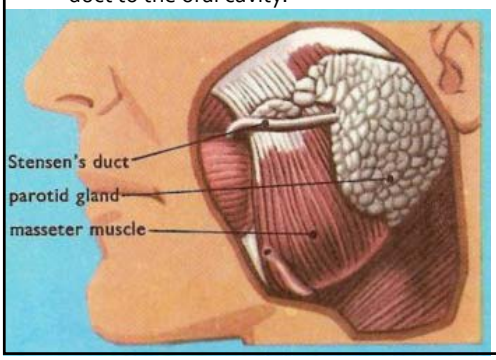
Volume of saliva secreted daily ranges between 1.0 and 1.5 L.
Most is produced during mealtime, but
Smaller amounts are produced continuously to ensure that the oral cavity remains moist.
Water makes up 99% of the volume of saliva.
Also contains a mixture of other components.
Three pairs of large, multicellular salivary glands:
- parotid glands
- submandibular glands
- sublingual glands

The Parotid Glands

Largest salivary glands.

Each parotid gland is located anterior and inferior to the ear, partially overlying the masseter muscle.

Produce about 25–30% of the saliva, which is conducted through the parotid duct to the oral cavity.



The Submandibular Glands

Inferior to the body of the mandible.

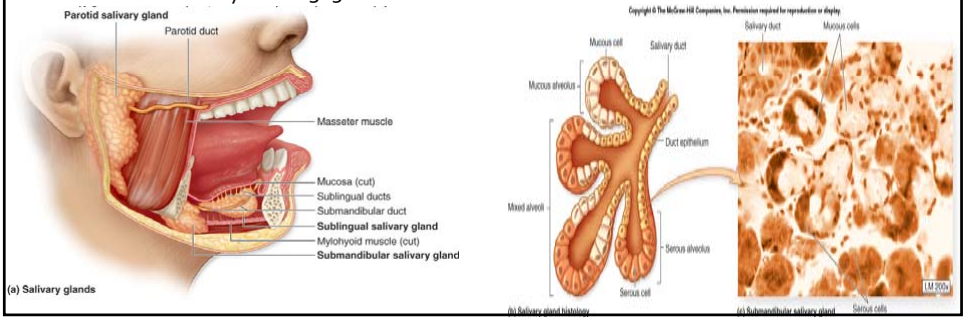
Produce most of the saliva (about 60–70%).

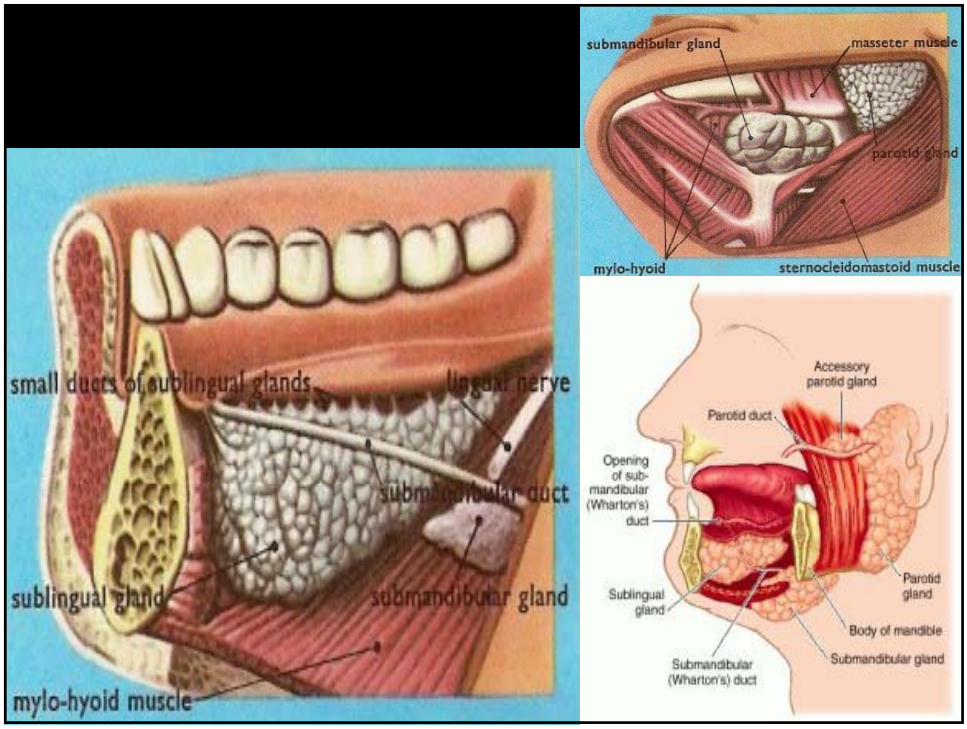
A duct opens from each gland through a papilla in the floor of the mouth on the lateral sides of the lingual frenulum.

Inferior to the tongue and internal to the oral cavity mucosa.

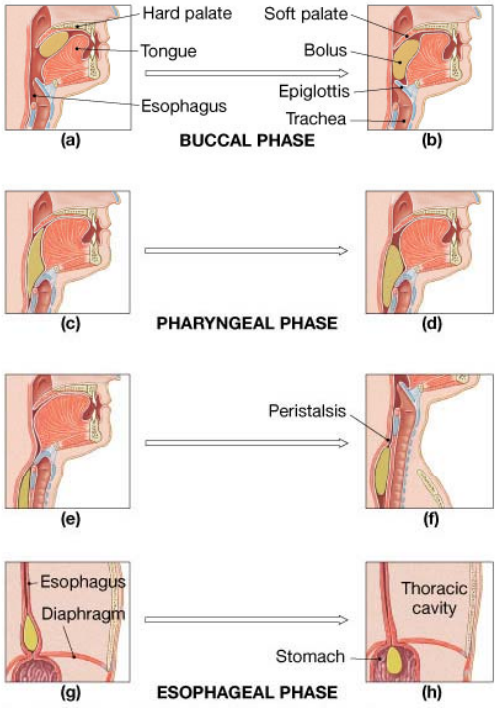
Each gland extends multiple tiny sublingual ducts that open onto the inferior surface of the oral cavity, posterior to the submandibular duct papilla.

Contribute only about 3–5% of the total saliva.





The Swallowing Process



Functions of Saliva

Moistens ingested food and helps turn it into a semisolid bolus that is more easily swallowed.

Moistens and cleanses the oral cavity structures.

First step in chemical digestion occurs when amylase in saliva begins to break down carbohydrates.

Contains antibodies and an antibacterial element called lysozyme that help inhibit bacterial growth in the oral cavity.

Watery medium into which food molecules are dissolved so taste receptors can be stimulated.

Esophagus

A muscular tube about ten inches long.

It receives food from the pharynx as a result of swallowing.

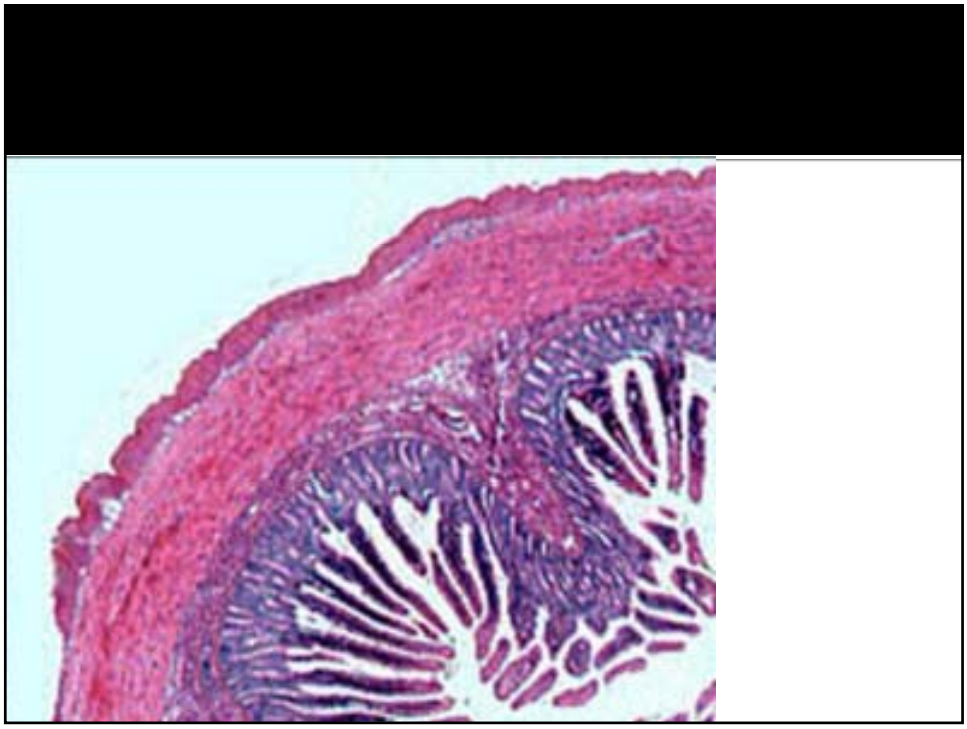
The esophagus passes through the mediastinum and penetrates the diaphragm at the esophageal hiatus.
Trauma in this area may allow the upper portion of the stomach to protrude above the diaphragm (hiatal hernia). This will produce regurgitation and ulceration of the esophageal wall. Normally, food passes through the esophagus by muscular contractions of the wall called peristalsis. The food enters the stomach through the cardiac orifice. This opening is guarded by a sling of muscle from the diaphragm called the cardiac sphincter (skeletal muscle).
Basic Design of the Wall of the Digestive Tract
From the esophagus to the anus, the wall of the digestive tract shows a basic plan or design. However, each region of the tract modifies this basic architecture for its own purposes. The overall design is as follows:

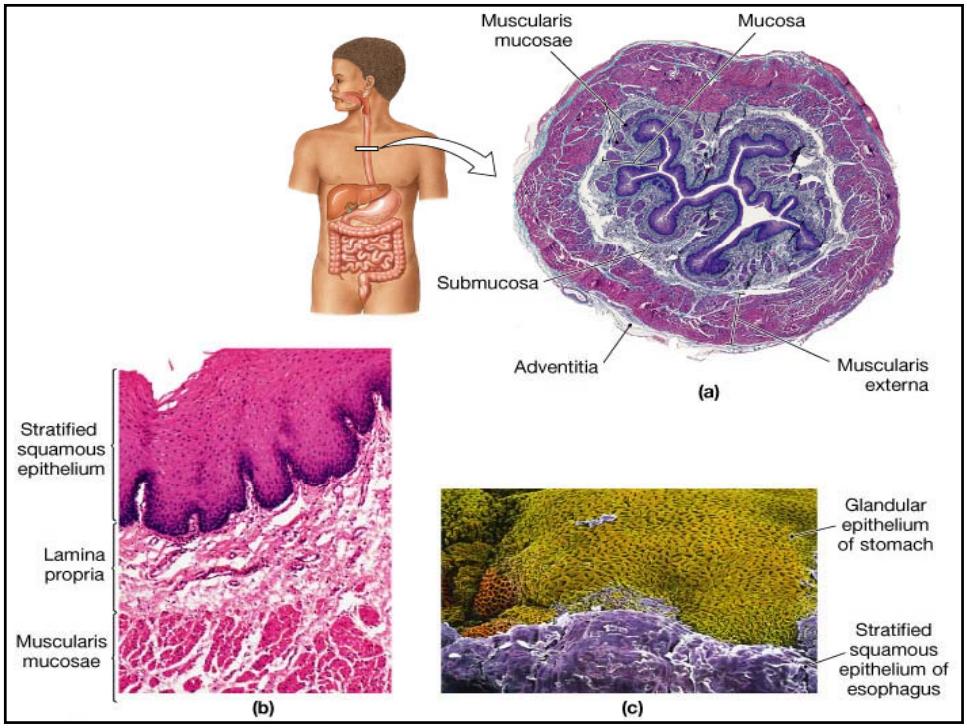
1. **Adventitia - the outermost portion of the gut wall consists of a layer of tough collagenous connective tissue.**
2. **This covering protects and anchors that portion of the tract to surrounding structures.**
3. **Digestive organs located below the diaphragm usually have an outer wrapping of peritoneum called the Serosa.**

2. Just inside the adventitia is the muscularis externa.
Generally, this is a double layer of smooth muscle consisting of an outer longitudinal layer and an inner circular layer. It is the combined action of these two layers that produces the muscular contractions of peristalsis. Skeletal muscle may replace smooth in certain areas of the tract, e.g.. esophagus.

3. The Submucosa is a layer of loose connective tissue inside the thick muscularis. Blood vessels, lymphatics, nerves and nerve plexi are located here, as well as, glandular tissue and nodules of lymphoid tissue.

4. The inner lining or Mucosa of the tract is essentially a mucous membrane. Overall its functions are:
- **a. Secretion - mucous, digestive enzymes and hormones.**
- **b. Absorption - end products of digestion, water, minerals.**
- **c. Protection from infection.**




Muscularis mucosae
Mucosa
Submucosa
Adventitia
Muscularis externa
(a)
Stratified squamous epithelium
Lamina propria
Muscularis mucosae
(b)
Glandular epithelium of stomach
Stratified squamous epithelium of esophagus
(c)

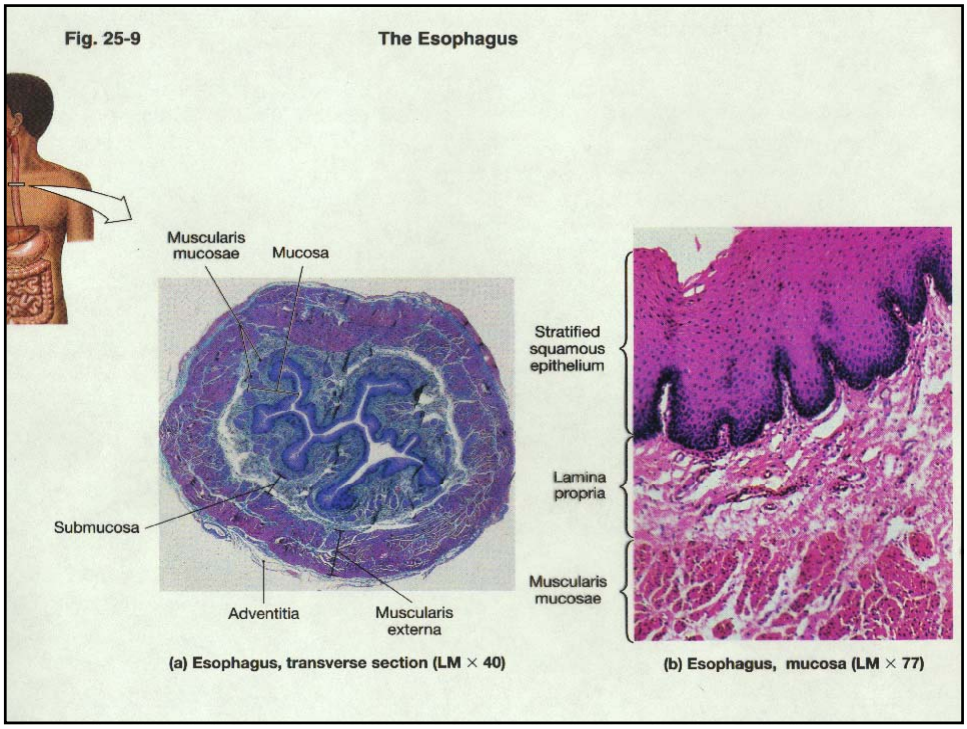
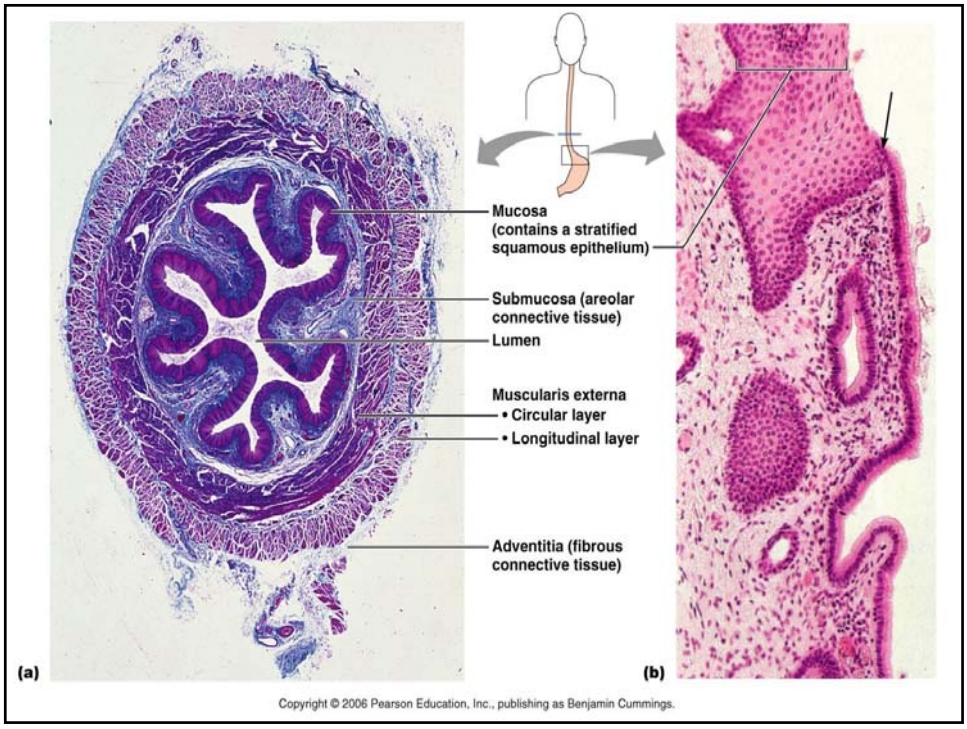


Fig. 25-9
The Esophagus
Muscularis mucosae
Mucosa
Submucosa
Adventitia
Muscularis externa
Stratified squamous epithelium
Lamina propria
Muscularis mucosae
(a) Esophagus, transverse section (LM × 40)
(b) Esophagus, mucosa (LM × 77)


Mucosa (contains a stratified squamous epithelium)
Submucosa (areolar connective tissue)
Lumen
Muscularis externa
• Circular layer
• Longitudinal layer
Adventitia (fibrous connective tissue)
(a)
(b)
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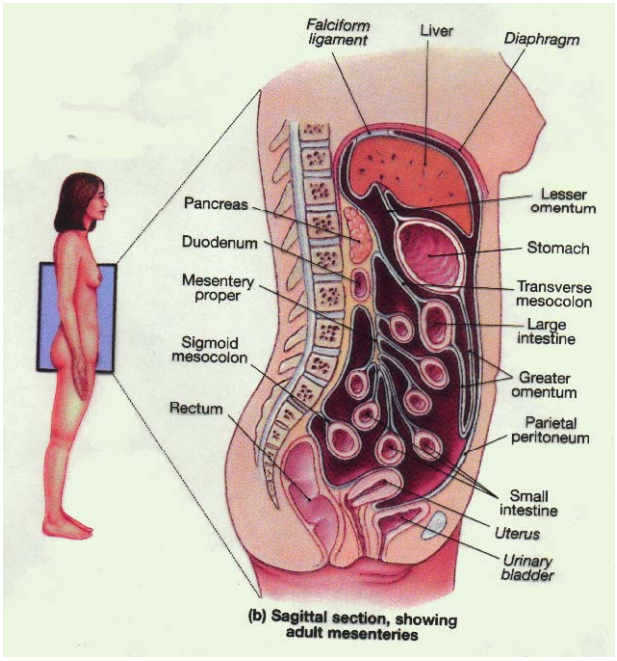
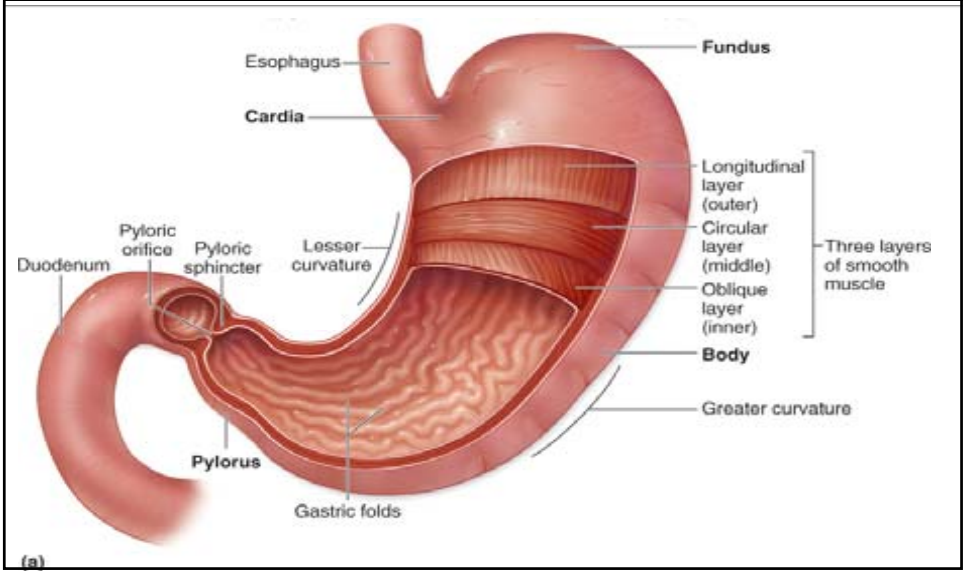

Falciform ligament
Liver
Diaphragm
Pancreas
Duodenum
Mesentery proper
Sigmoid mesocolon
Rectum
Lesser omentum
Stomach
Transverse mesocolon
Large intestine
Greater omentum
Parietal peritoneum
Small intestine
Uterus
Urinary bladder
(b) Sagittal section, showing adult mesenteries

stomach

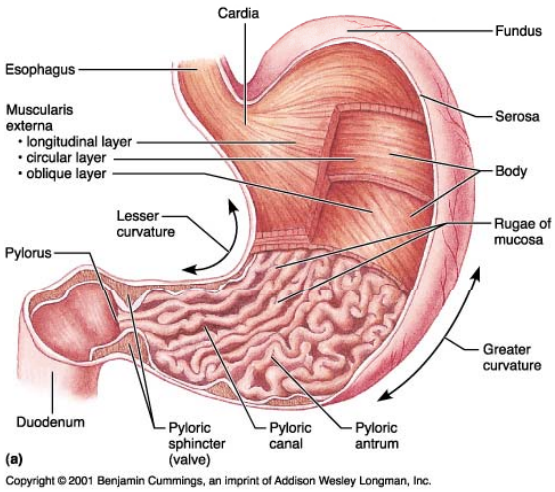

Esophagus
Cardia
Fundus
Longitudinal layer (outer)
Circular layer (middle)
Oblique layer (inner)
Three layers of smooth muscle
Body
Greater curvature
Duodenum
Pyloric orifice
Pyloric sphincter
Lesser curvature
Pylorus
Gastric folds
(a)

Stomach

- Usually "J" shaped
- Left side, anterior to the spleen
- Mucous membrane
  - G cells – make gastrin
  - Goblet cells – make mucous
  - Gastric pit – Oxyntic gland – Parietal cells – Make HCl
  - Chief cells – Zymogenic cells
    - Pepsin
    - Gastric lipase

41

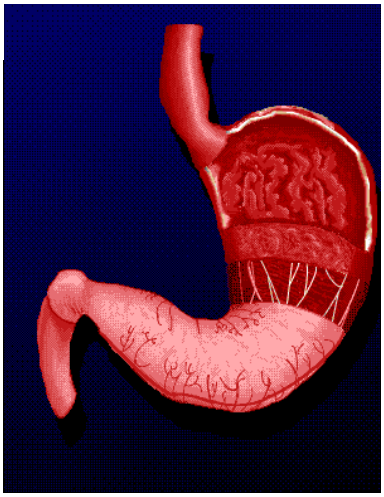
Anatomy of the Stomach



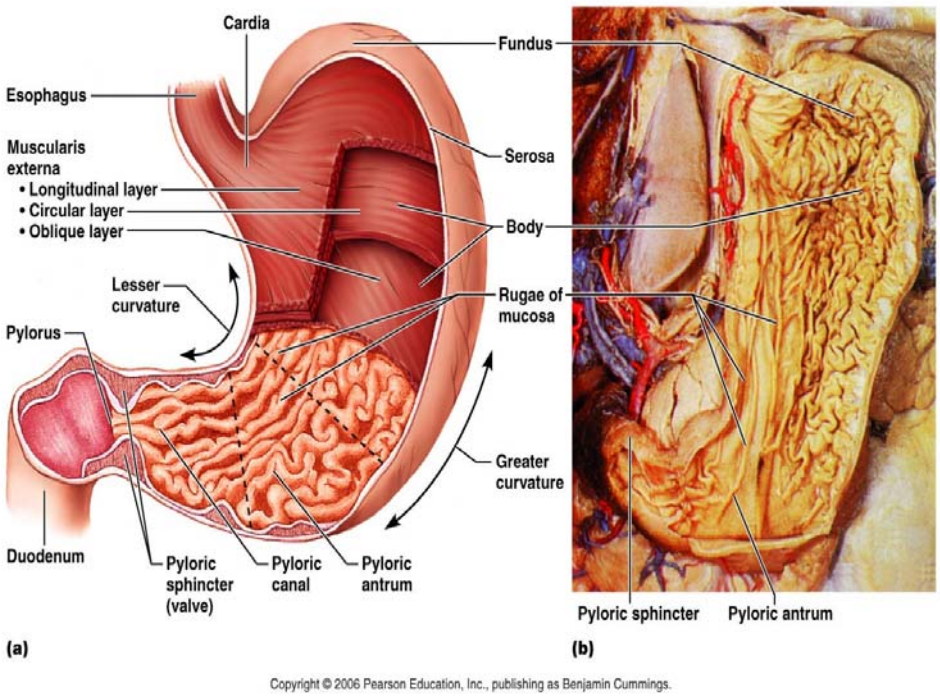
42

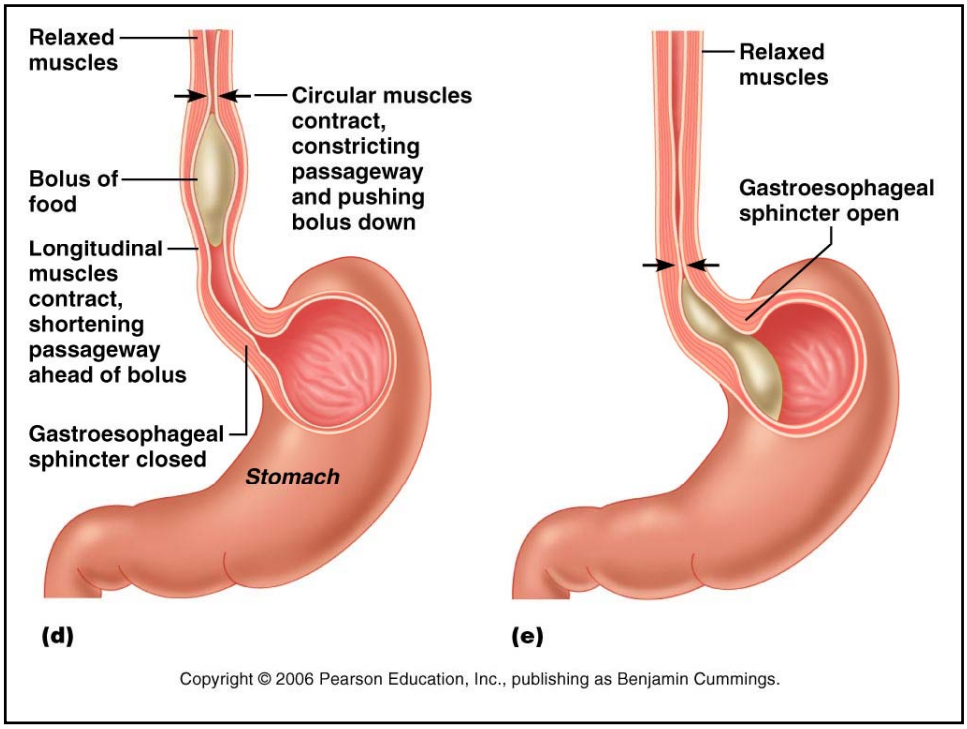
Stomach

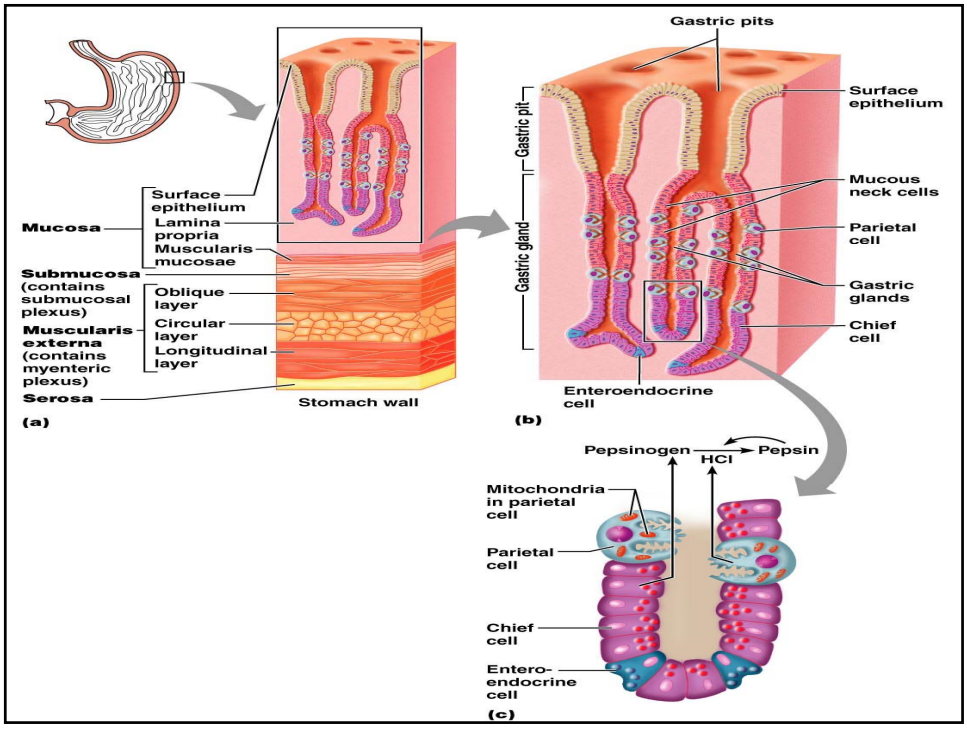
- 3 muscle layers
  - Oblique
  - Circular
  - Longitudinal
- Regions
  - Cardiac sphincter
  - Fundus
  - Antrum (pylorus)
  - Pyloric sphincter
- Vascular
- Inner surface thrown into folds – Rugae
- Contains enzymes that work best at pH 1-2



43



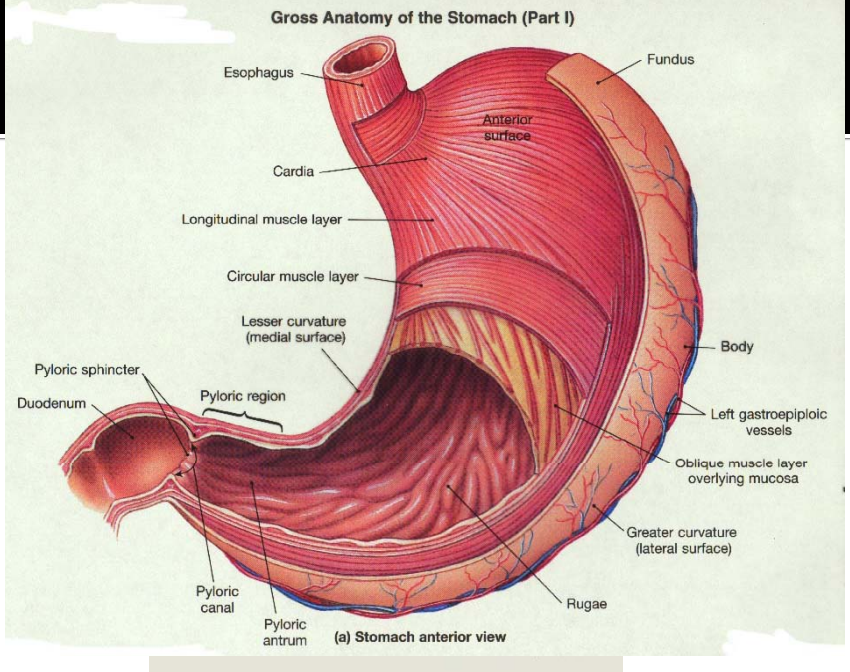




Stomach

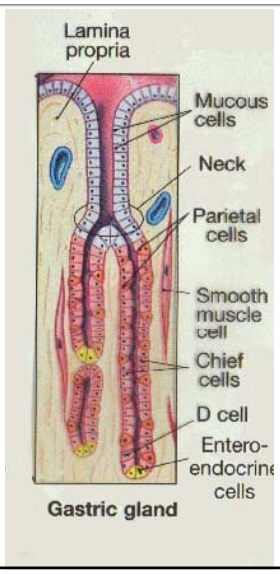
- Functions
  - Mix food
  - Reservoir
  - Start digestion of
    - Protein
    - Nucleic acids
    - Fats
  - Activates some enzymes
  - Destroy some bacteria
  - Makes intrinsic factor – B 12 absorption
  - Destroys some bacteria
- Absorbs
  - Alcohol
  - Water
  - Lipophilic acid
  - B 12

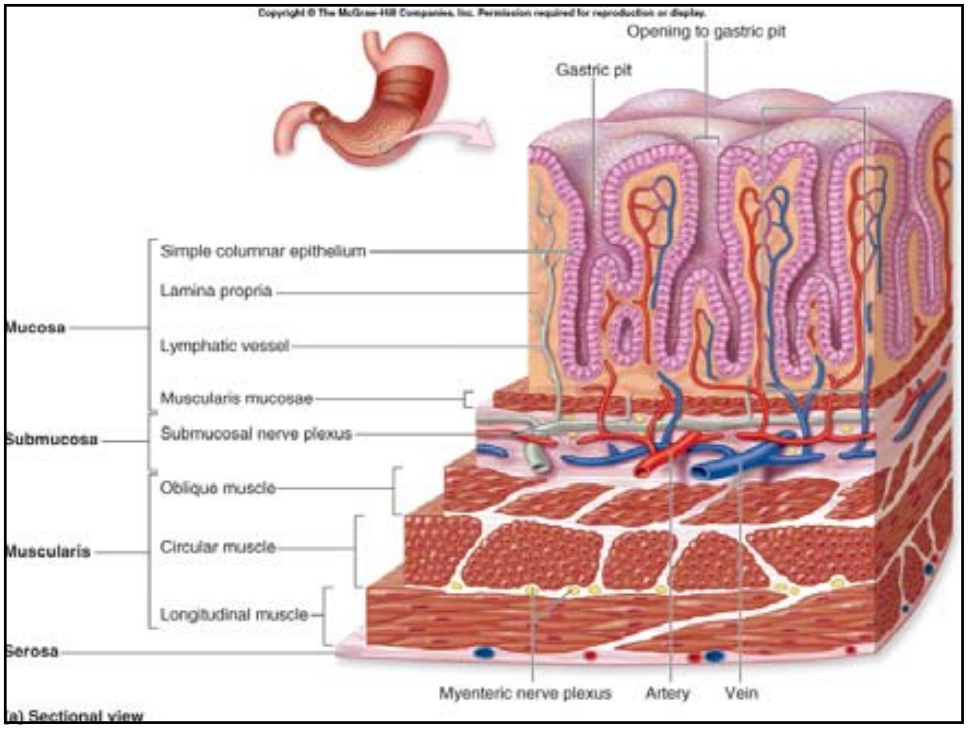
47

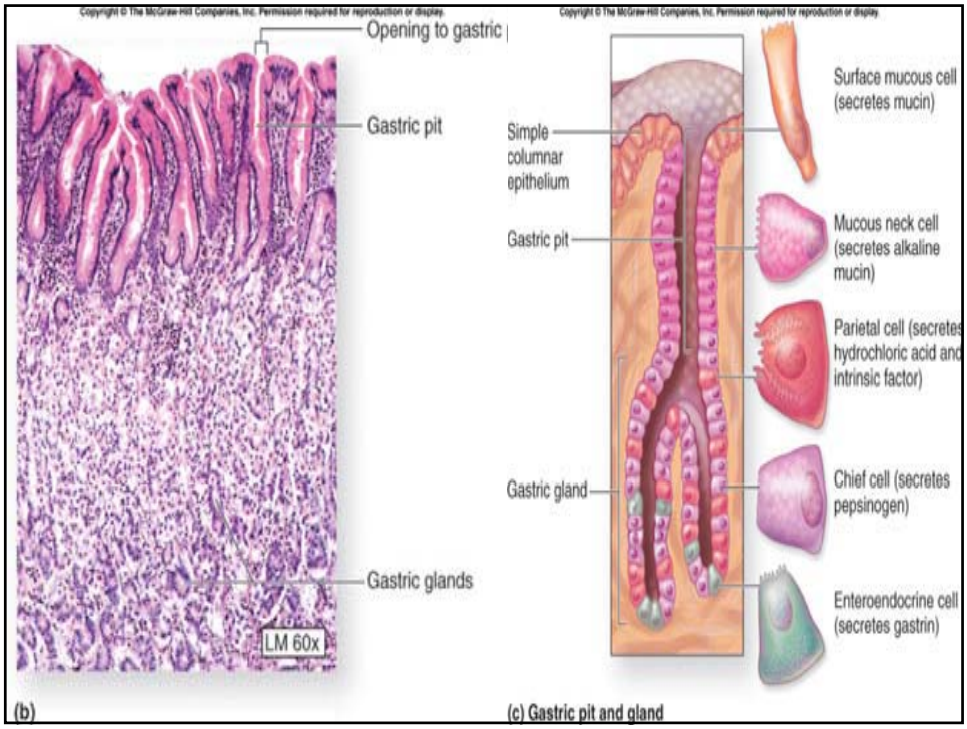


- Stomach Histology
  - mucosa: location of gastric glands

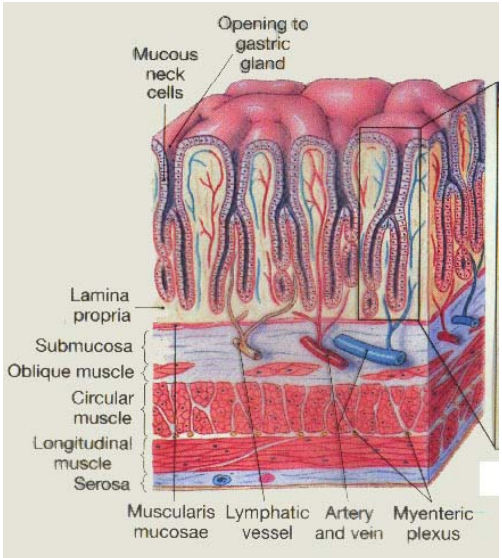
- gastric gland cells
  - mucous cells
  - parietal cells
  - chief cells
  - endocrine cells



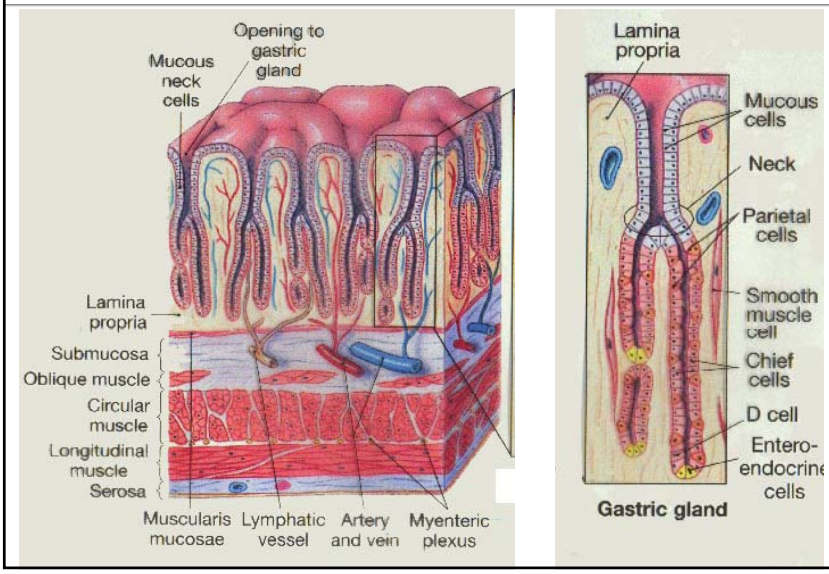


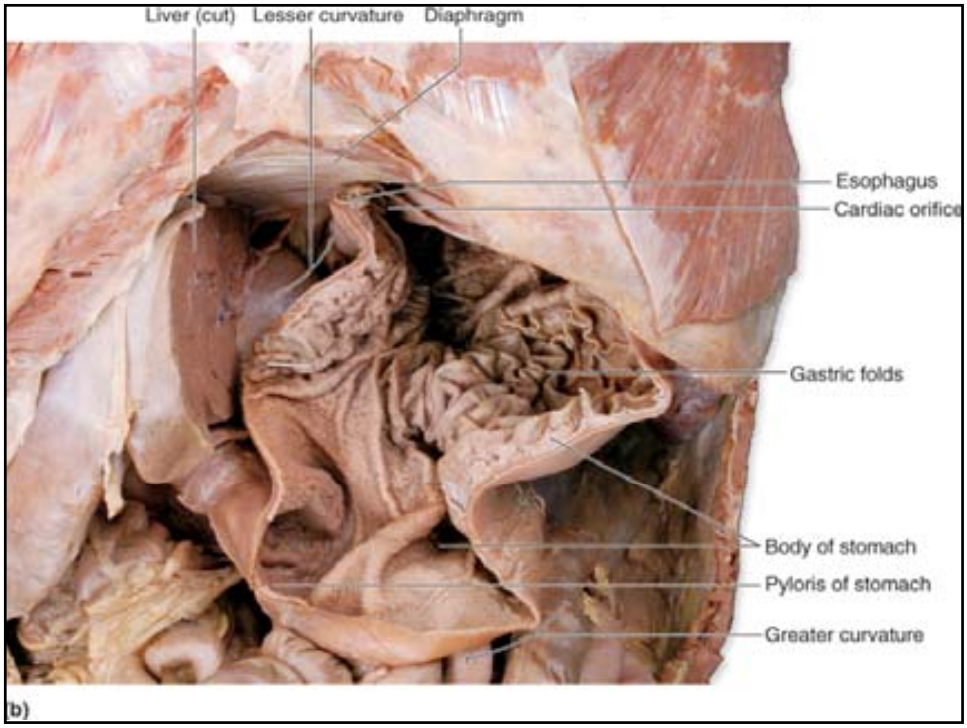


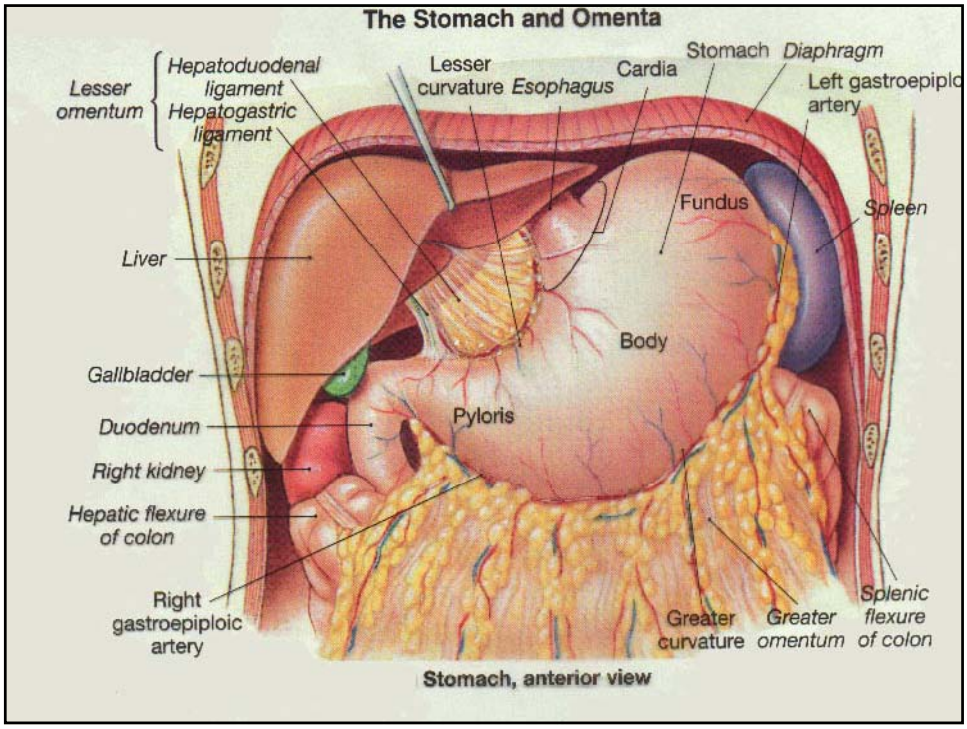
- **Stomach Histology**
  - **mucosa: location of gastric glands**



- Stomach Histology
  - mucosa: location of gastric glands

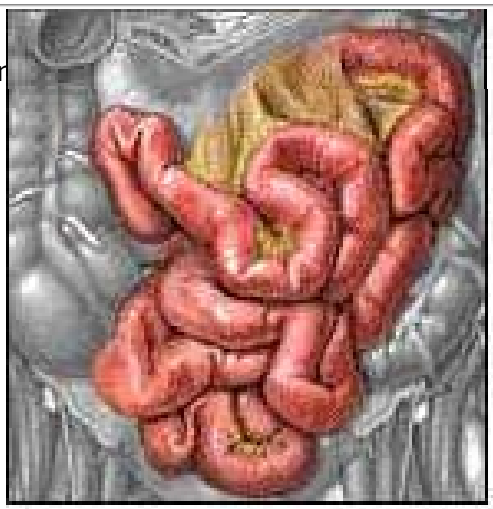




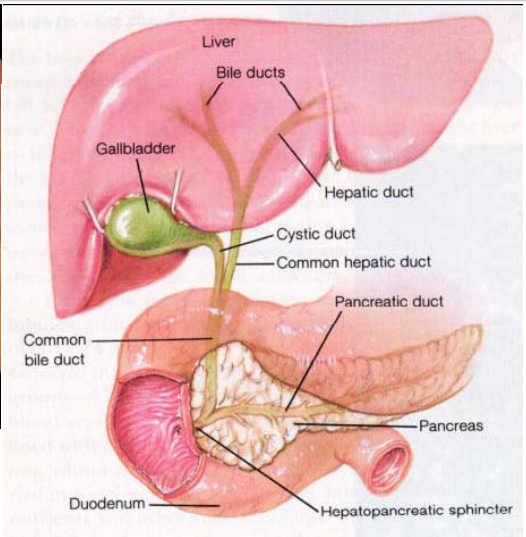

The Stomach and Omenta
Lesser omentum
Hepatoduodenal ligament
Hepatogastric ligament
Lesser curvature
Esophagus
Cardia
Stomach
Diaphragm
Left gastroepiplo artery
Fundus
Spleen
Liver
Body
Gallbladder
Pyloris
Duodenum
Right kidney
Hepatic flexure of colon
Right gastroepiploic artery
Greater curvature
Greater omentum
Splenic flexure of colon
Stomach, anterior view

Small Intestine

- Extends from pyloric sphincter → ileocecal valve
- Regions
  - Duodenum
  - Jejenum
  - Ileum
- Movements
  - Segmentation
  - Peristalsis



Duodenum



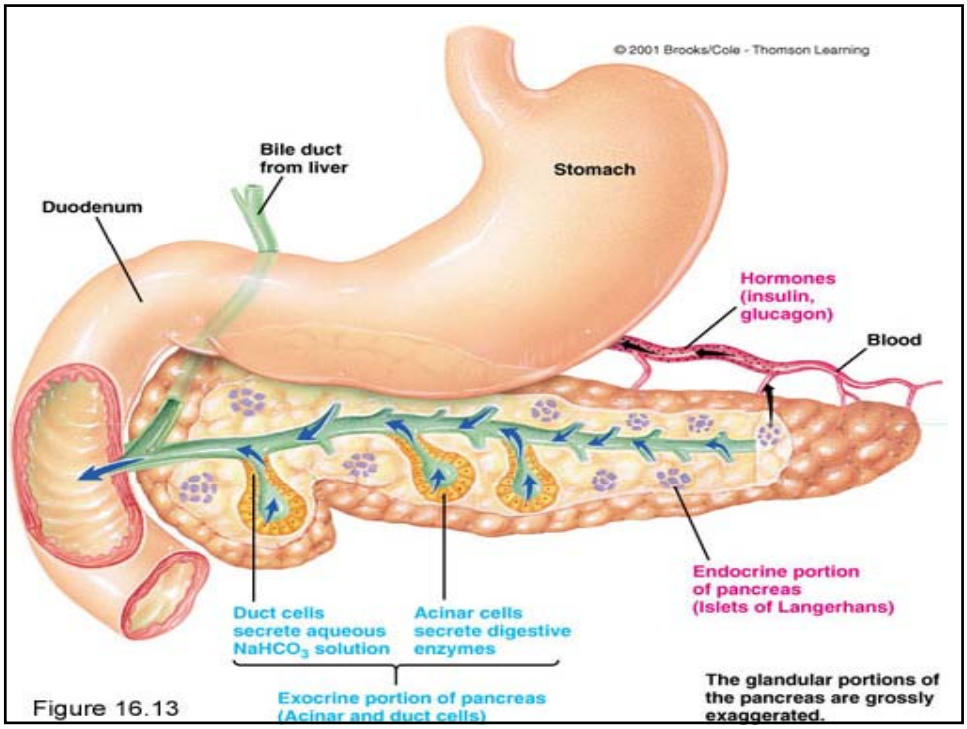
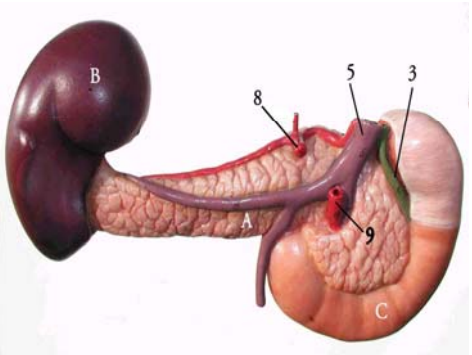
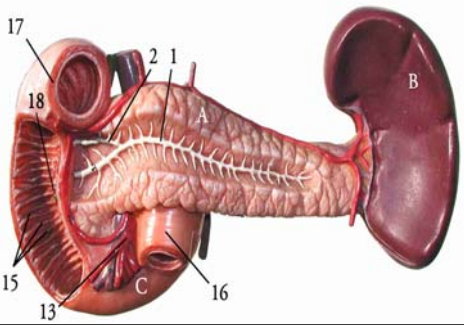


Figure 16.13

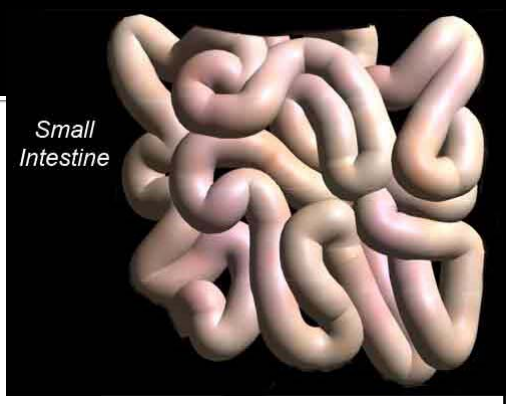
The duodenum forms the first segment of the small intestine.
Approximately 25 centimeters (10 inches) long and originates at the pyloric sphincter.
The jejunum is the middle region of the small intestine.
Extending approximately 2.5 meters (7.5 feet), it makes up approximately two-fifths of the small intestine's total length.
primary region for chemical digestion and nutrient absorption
The ileum is the last region of the small intestine.
At about 3.6 meters (10.8 feet) in length, the ileum forms approximately three-fifths of the small intestine.
Its distal end terminates at the ileocecal valve, a sphincter that controls the entry of materials into the large intestine.

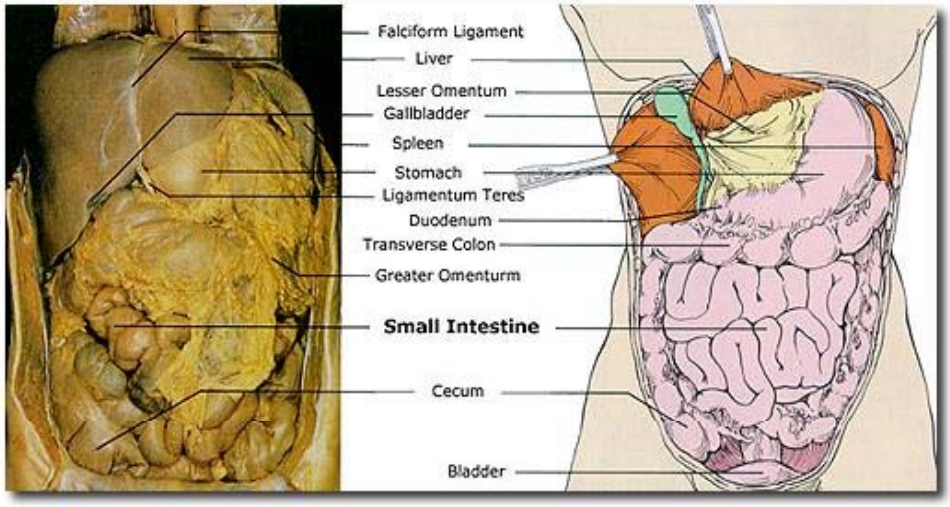


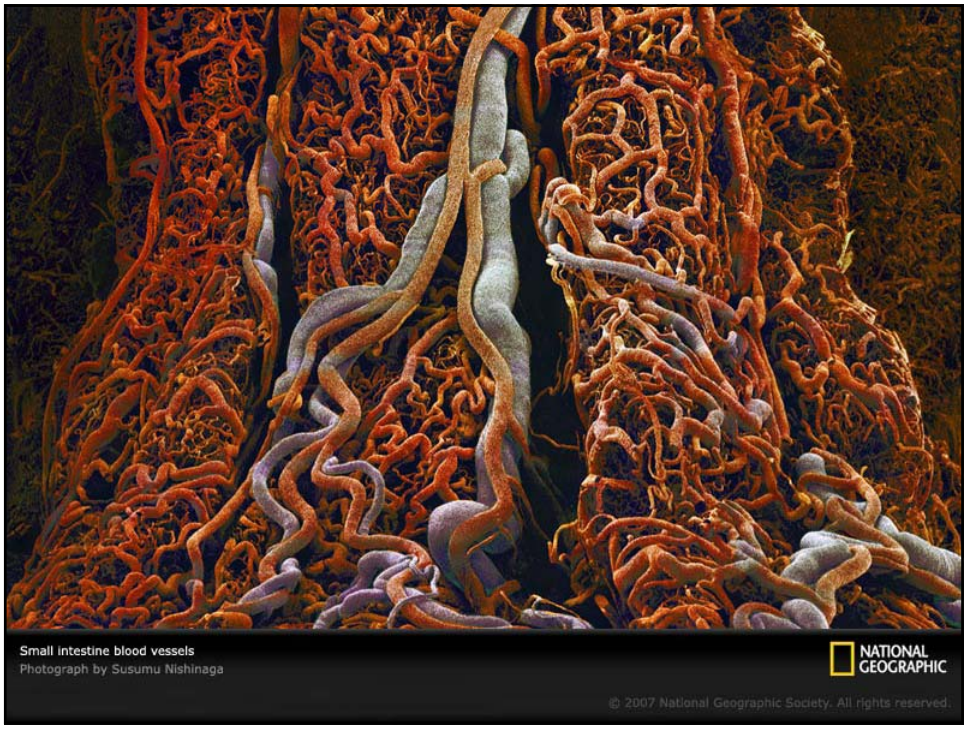


Small Intestine

- Finishes the chemical digestion process and is responsible for absorbing most of the nutrients.
- Ingested nutrients spend at least 12 hours in the small intestine as chemical digestion and absorption are completed.
- Coiled, thin-walled tube about 6 meters (20 feet) in length.
- Extends from the pylorus of the stomach to the cecum of the large intestine, and thus occupies a significant portion of the abdominal cavity.

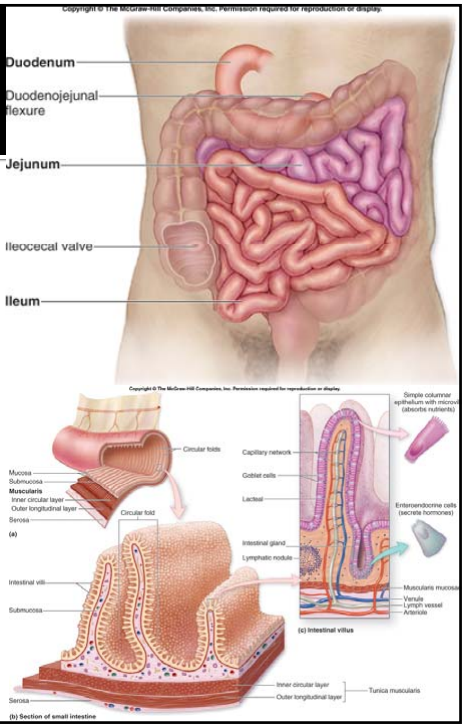


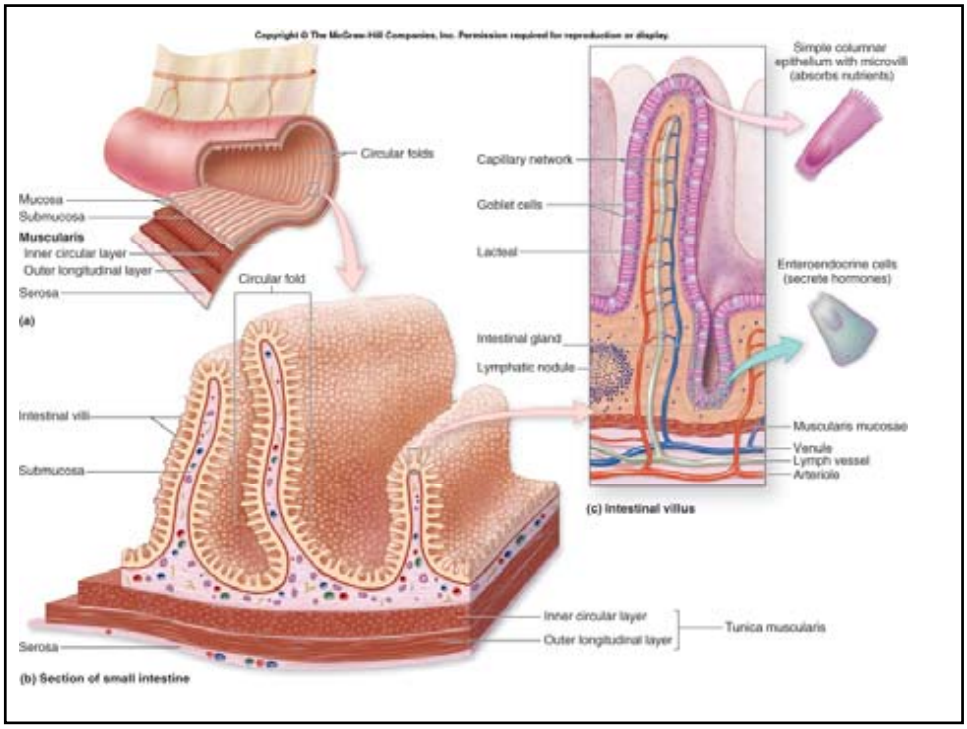




Small Intestine

- Histology
  - Intestinal glands – Intestinal enzymes
  - Duodenal glands – Alkaline mucous
  - Paneth cells – Lysozyme
  - Microvilli
  - Lacteals
  - Plica circularis
  - Smooth muscle
  - Lymphatic tissue – GALT
  - Vascular

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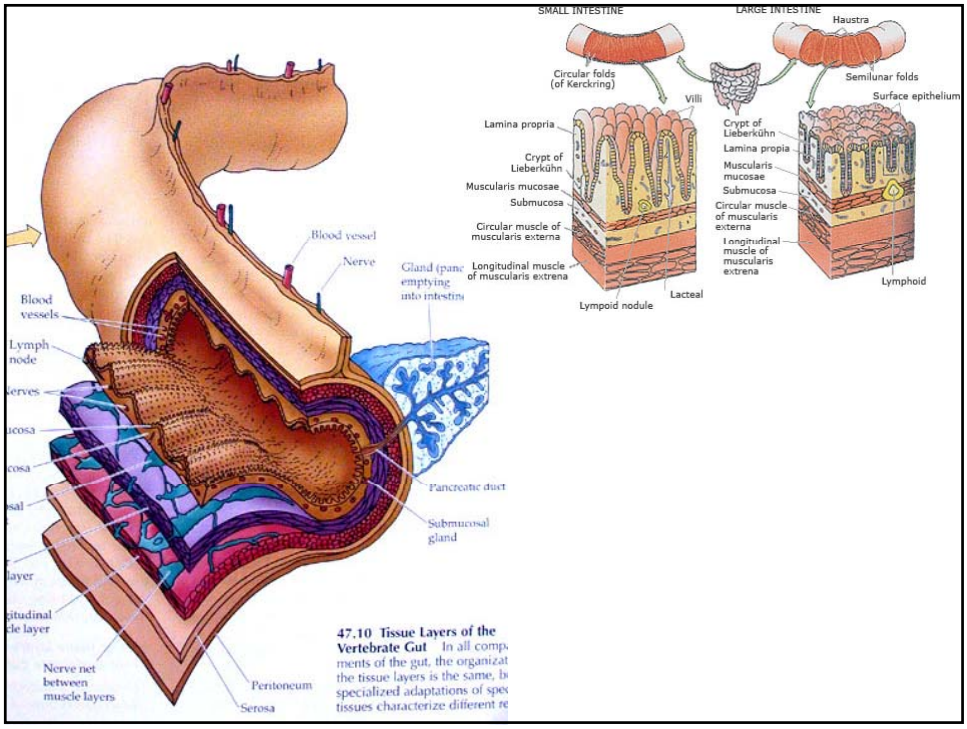
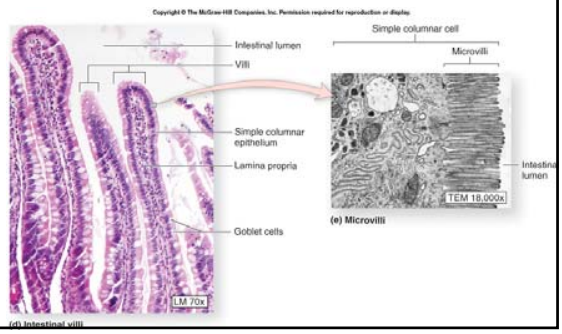
Circular folds
Mucosa
Submucosa
Muscularis
Inner circular layer
Outer longitudinal layer
Serosa
(a)
Circular fold
Intestinal villi
Submucosa
Serosa
(b) Section of small intestine
Simple columnar epithelium with microvilli (absorbs nutrients)
Capillary network
Goblet cells
Lacteal
Enteroendocrine cells (secrete hormones)
Intestinal gland
Lymphatic nodule
Muscularis mucosae
Venule
Lymph vessel
Arteriole
(c) Intestinal villus
Inner circular layer
Outer longitudinal layer
Tunica muscularis

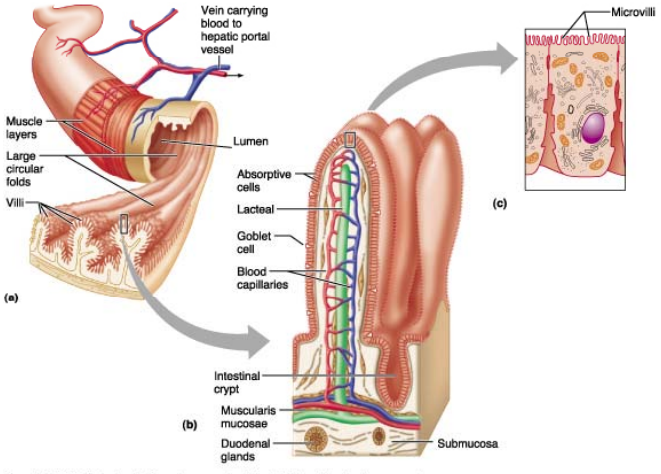

SMALL INTESTINE
LARGE INTESTINE
Haustra
Circular folds (of Kerckring)
Villi
Semilunar folds
Surface epithelium
Lamina propria
Crypt of Lieberkühn
Muscularis mucosae
Submucosa
Circular muscle of muscularis externa
Longitudinal muscle of muscularis extrena
Lympoid nodule
Lacteal
Lymphoid
Blood vessel
Nerve
Blood vessels
Lymph node
Pancreatic duct
Submucosal gland
Nerve net between muscle layers
Peritoneum
Serosa
47.10 Tissue Layers of the Vertebrate Gut

Small Intestine

- Absorbs
  - 80% ingested water
  - Electrolytes
  - Vitamins
  - Minerals
  - Carbonates
    - Active/facilitated transport
    - Monosaccharides
  - Proteins
    - Di-/tripeptides
    - Amino acids
- Lipids
  - Monoglycerides
  - Fatty acids
  - Micelles
  - Chylomicrons



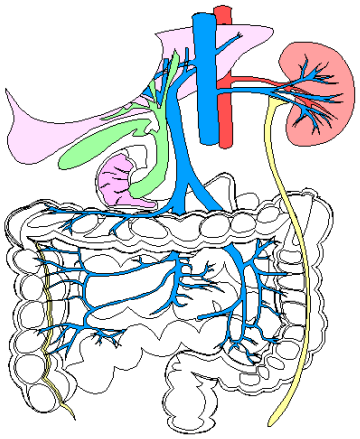
Structure of the Villi in the Small Intestine



68

Small Intestine

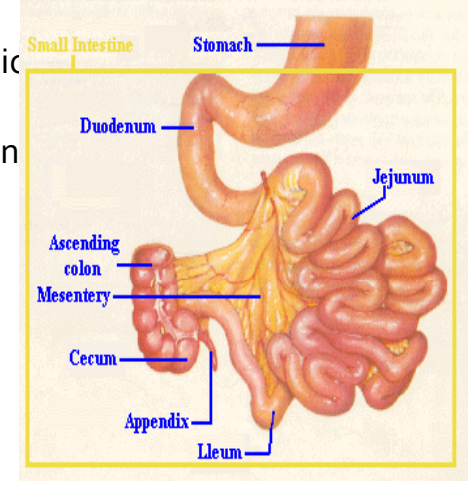
- Secretes digestive enzymes
  - Peptidases
    - Amino-
    - Di-
    - Tri-
  - Sucrases
  - Maltase
  - Lactase
  - Saccharidases
    - Di-
    - Tri-
  - Lipase
  - Nucleases



69

Small Intestine

- Control
- Requires pancreatic enzymes & bile to complete digestion



70

Large Intestine

- Extends from ileocecal valve to anus
- Regions
  - Cecum – Appendix
  - Colon
    - Ascending
    - Transverse
    - Descending
  - Rectum
  - Anal canal

Has an approximate length of 1.5 meters (5 feet) and a diameter of 6.5 centimeters (2.5 inches).

Absorbs most of the water and electrolytes from the remaining digested material.

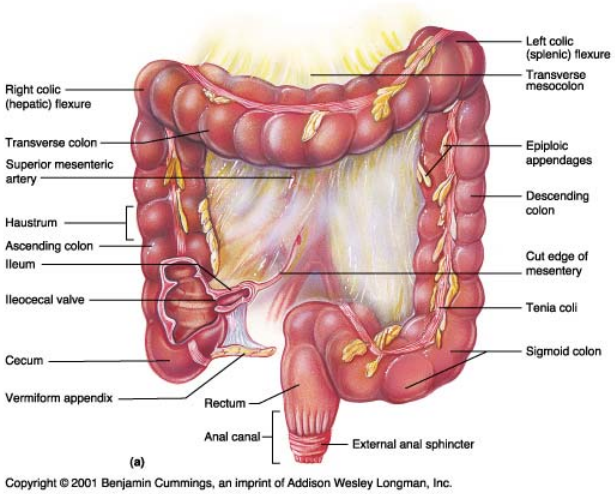
Watery material that first enters the large intestine soon solidifies and becomes feces.

Stores this fecal material until the body is ready to defecate.

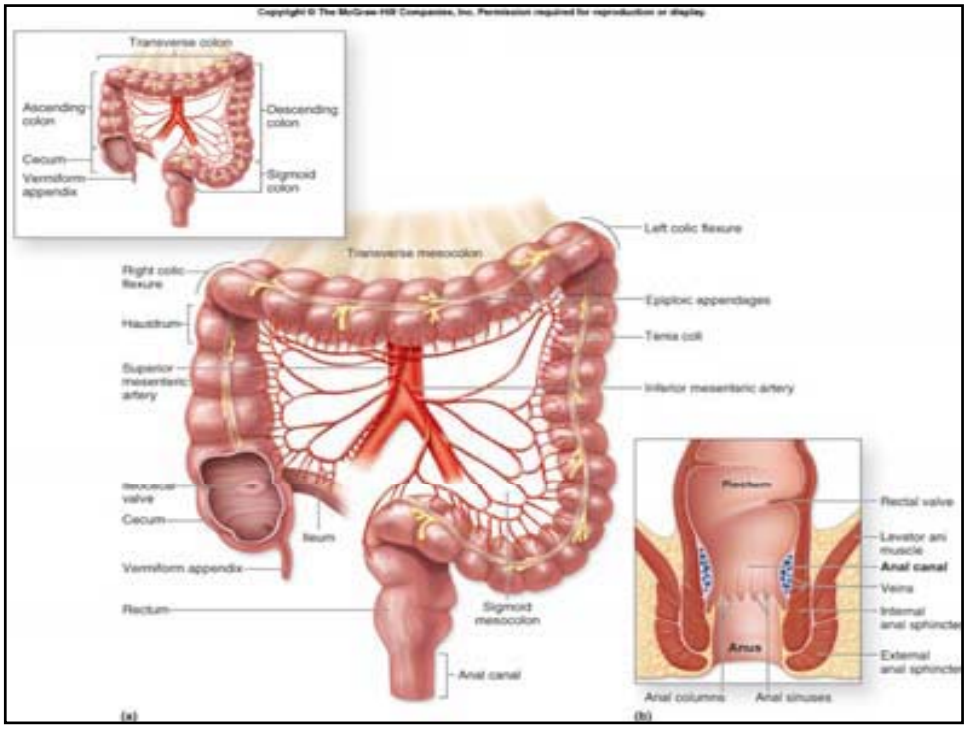
Absorbs a very small percentage of nutrients still remaining in the digested material.

71

Anatomy of the Large Intestine

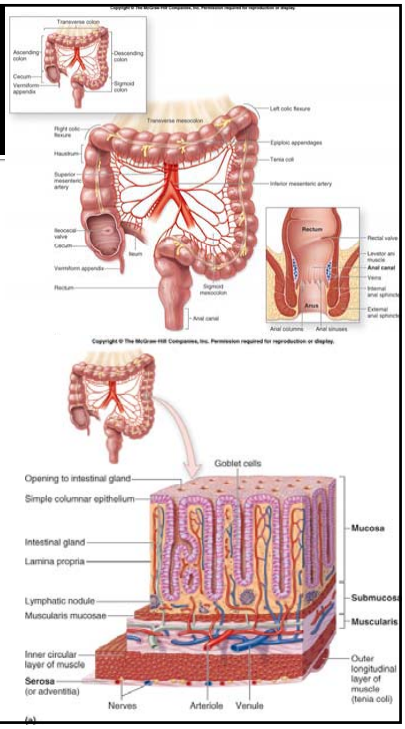


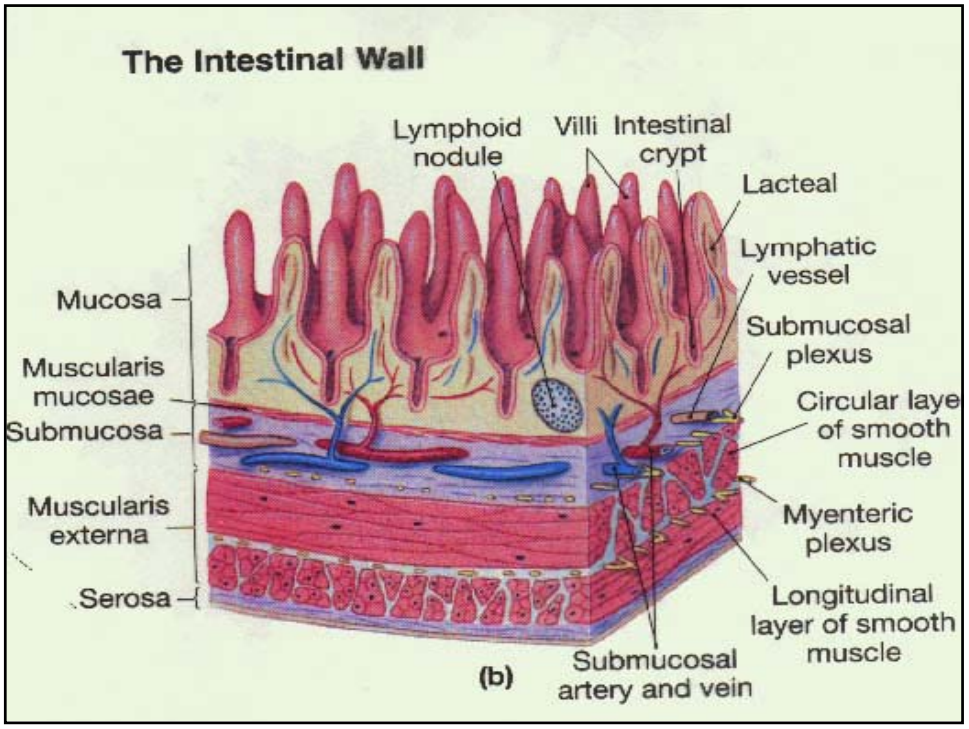
72

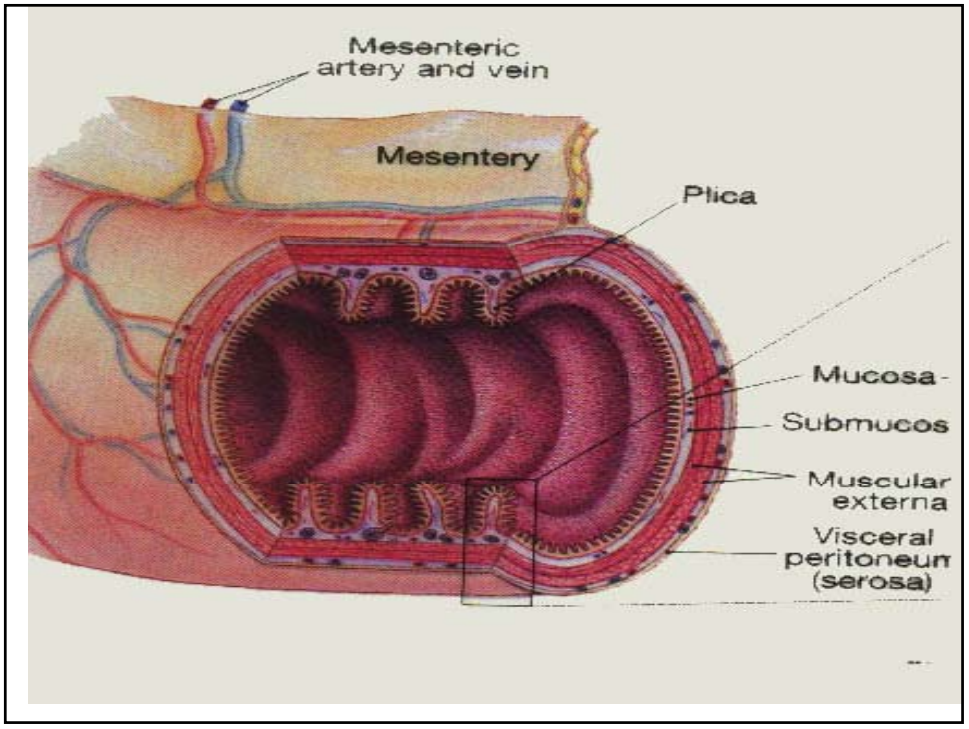


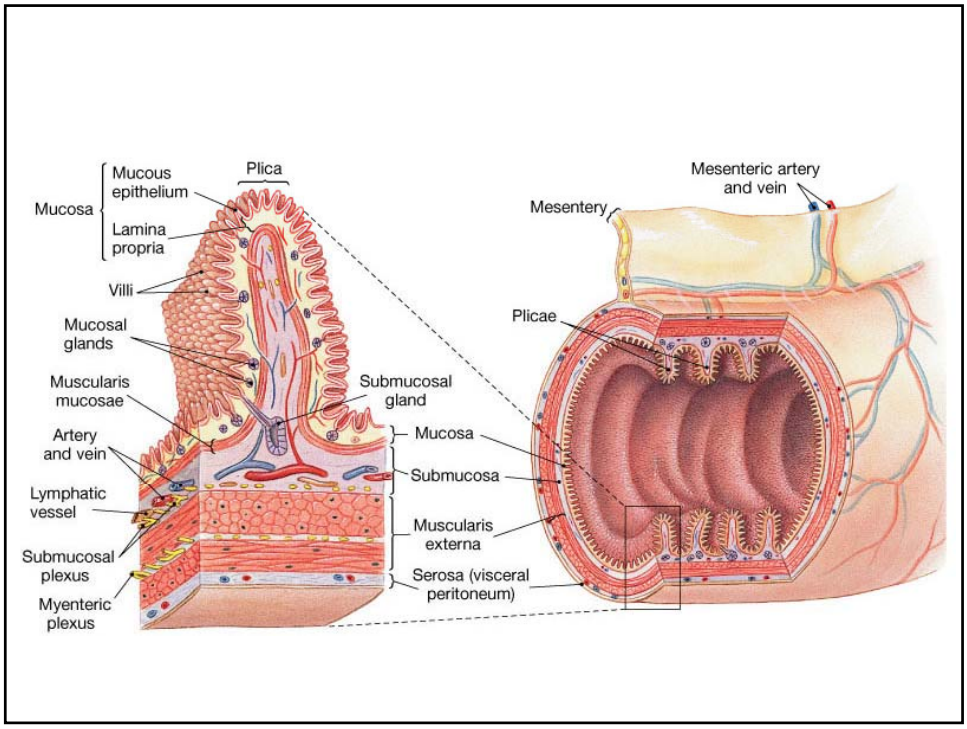
Large Intestine

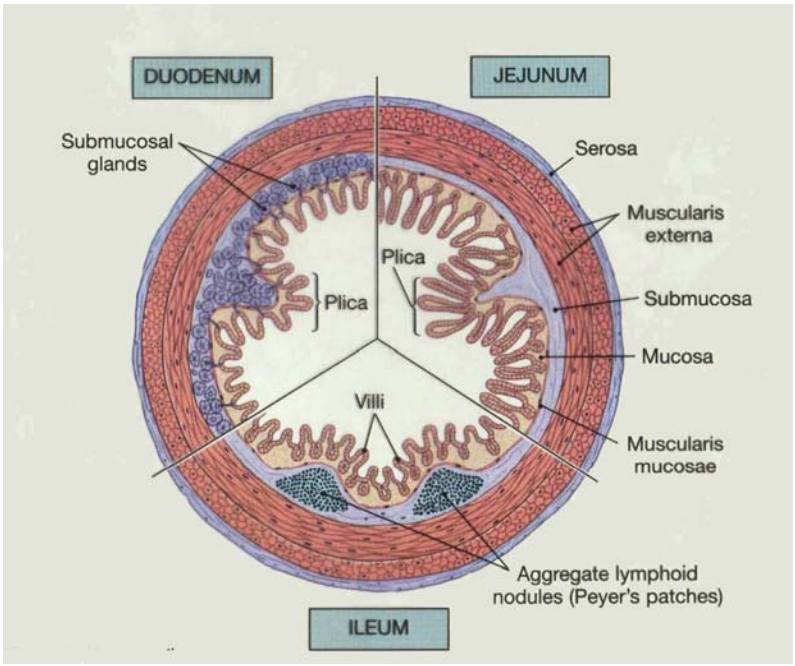
- Histology
  - No villi
  - No permanent circular folds
  - Smooth muscle
    - Taeniae coli
    - Haustra
  - Epiploic appendages
  - Otherwise like rest of GI tract

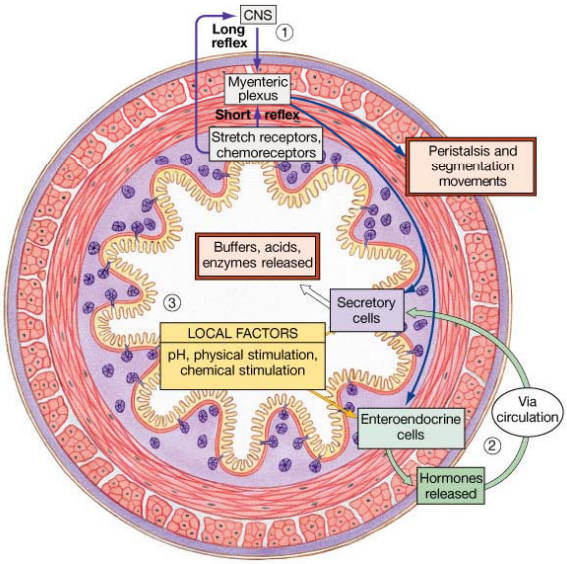


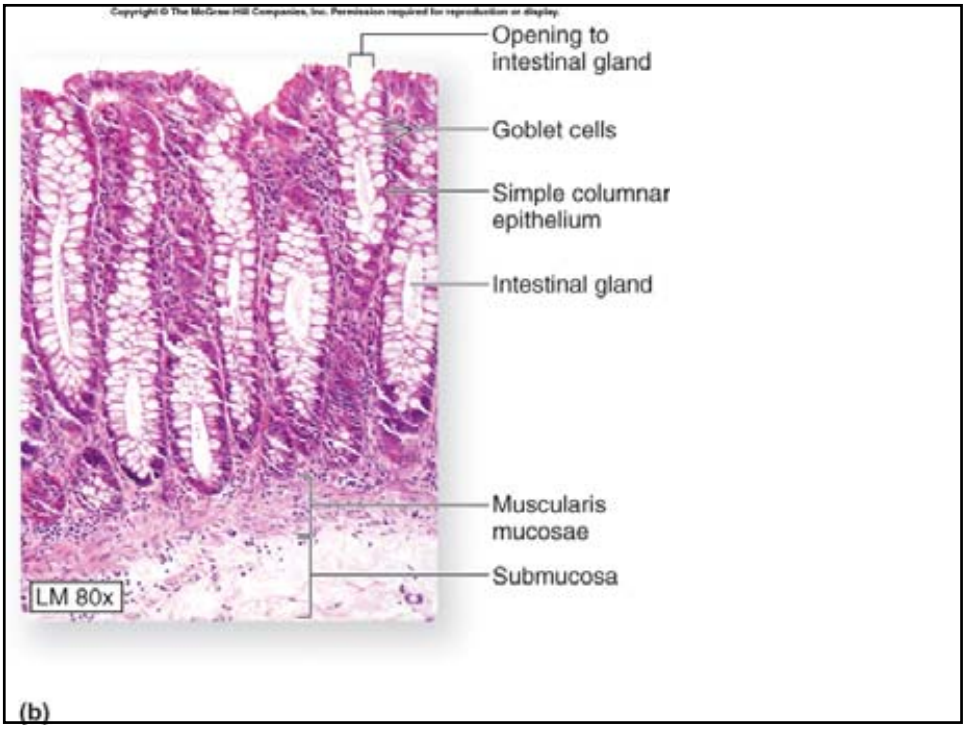

The Intestinal Wall
Lymphoid nodule
Villi
Intestinal crypt
Lacteal
Lymphatic vessel
Submucosal plexus
Circular laye of smooth muscle
Myenteric plexus
Longitudinal layer of smooth muscle
Submucosal artery and vein
Mucosa
Muscularis mucosae
Submucosa
Muscularis externa
Serosa
(b)


Mesenteric artery and vein
Mesentery
Plica
Mucosa
Submucos
Muscular externa
Visceral peritoneum (serosa)


Mucosa
Mucous epithelium
Lamina propria
Plica
Villi
Mucosal glands
Muscularis mucosae
Artery and vein
Lymphatic vessel
Submucosal plexus
Myenteric plexus
Submucosal gland
Mucosa
Submucosa
Muscularis externa
Serosa (visceral peritoneum)
Mesenteric artery and vein
Mesentery
Plicae


DUODENUM
JEJUNUM
ILEUM
Submucosal glands
Serosa
Muscularis externa
Plica
Plica
Submucosa
Mucosa
Villi
Muscularis mucosae
Aggregate lymphoid nodules (Peyer's patches)


CNS
Long reflex
1
Myenteric plexus
Short reflex
Stretch receptors, chemoreceptors
Peristalsis and segmentation movements
Buffers, acids, enzymes released
Secretory cells
3
LOCAL FACTORS
pH, physical stimulation, chemical stimulation
Via circulation
Enteroendocrine cells
2
Hormones released


Opening to intestinal gland
Goblet cells
Simple columnar epithelium
Intestinal gland
Muscularis mucosae
Submucosa
LM 80x
(b)

Large Intestine

- Functions
  - Mechanical digestion
    - Haustral churning
    - Peristalsis
    - Reflexes
      - Gastroileal
      - Gastrocolic
  - Chemical digestion – Bacterial digestion
    - Ferment carbohydrates
    - Protein/amino acid breakdown

– Absorbs
  - •More water
  - •Vitamins
    - – B
    - – K

– Concentrate/eliminate wastes

81

Feces Formation and Defecation

- Chyme dehydrated to form feces
- Feces composition
  - Water
  - Inorganic salts
  - Epithelial cells
  - Bacteria
  - Byproducts of digestion
- Defecation
  - Peristalsis pushes feces into rectum
  - Rectal walls stretch
- Control
  - Parasympathetic
  - Voluntary

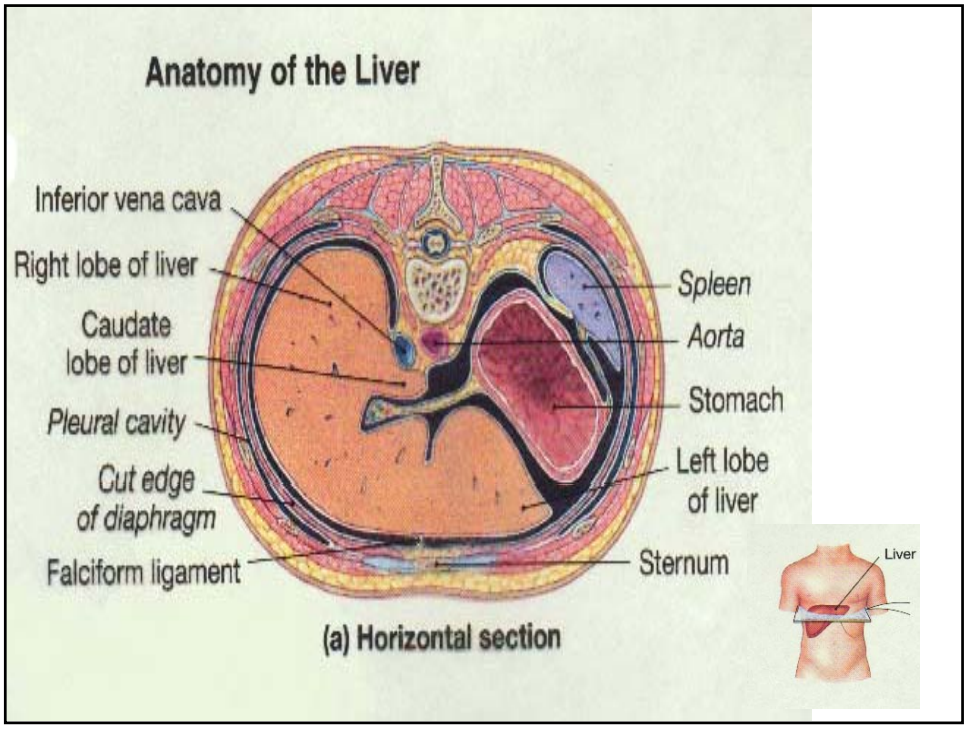
82

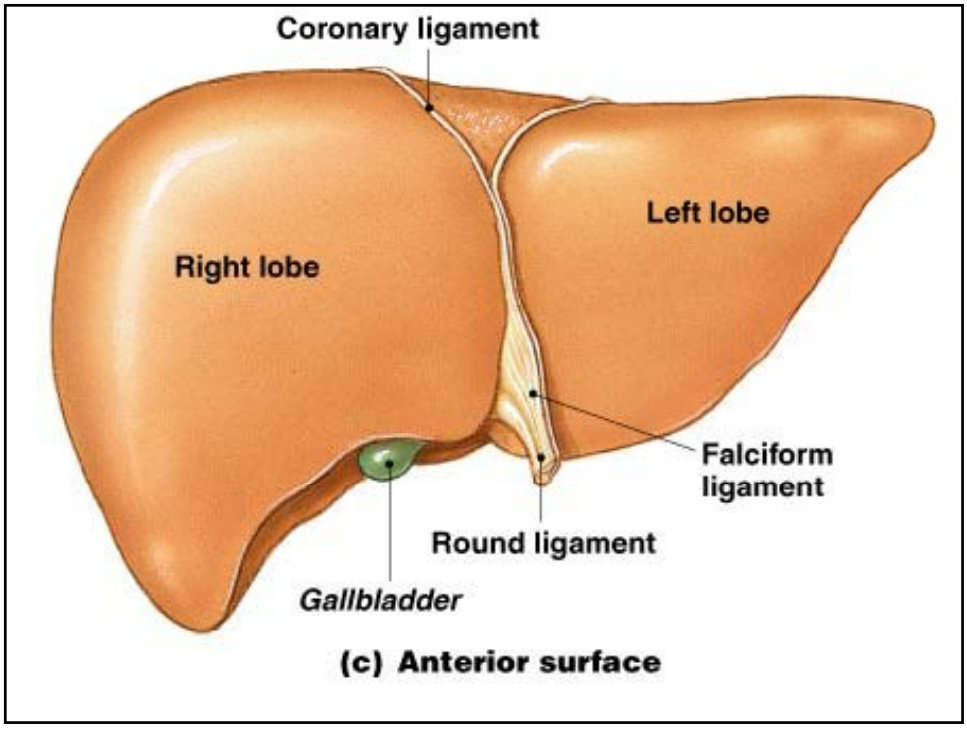
Liver

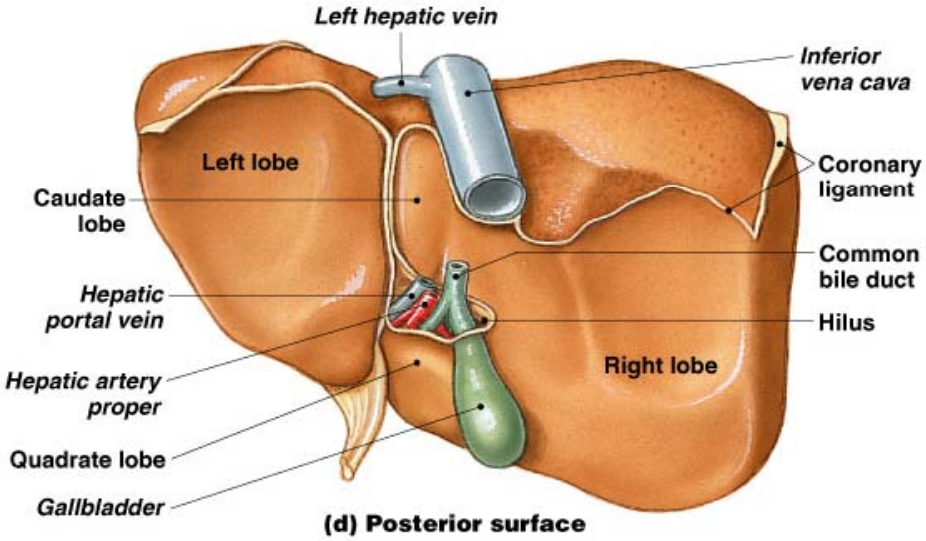
- Location
  - R. Hypochondrium
  - Epigastric region
- 4 Lobes
  - Left
  - Quadrate
  - Caudate
  - Right
- Each lobe has lobules – Contains hepatocytes – Surround sinusoids – Feed into central vein

The liver
composed of four incompletely separated lobes
supported by two ligaments
Right lobe
Left lobe
Falciform ligament
Round ligament
Caudate lobe
Quadrate lobe

83

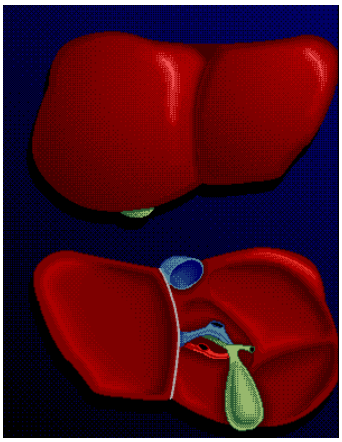

Anatomy of the Liver
Inferior vena cava
Right lobe of liver
Caudate lobe of liver
Pleural cavity
Cut edge of diaphragm
Falciform ligament
Spleen
Aorta
Stomach
Left lobe of liver
Sternum
Liver
(a) Horizontal section


Coronary ligament
Left lobe
Right lobe
Falciform ligament
Round ligament
Gallbladder
(c) Anterior surface



Liver

- Functions
  - Makes bile
    - Detergent – emulsifies fats
    - Release promoted by:
      - Vagus n.
      - CCK
      - Secretin
    - Contains
      - Water
      - Bile salts
      - Bile pigments
      - Electrolytes
      - Cholesterol
      - Lecithin



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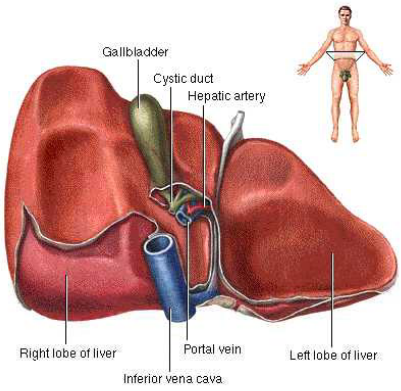
Liver

- Detoxifies/removes
  - Drugs
  - Alcohol
- Stores
  - Gycolgen
  - Vitamins (A, D, E, K)
  - Fe and other minerals
  - Cholesterol
- Activates vitamin D
- Fetal RBC production
- Phagocytosis
- Metabolizes absorbed food molecules
  - Carbohydrates
  - Proteins
  - Lipids



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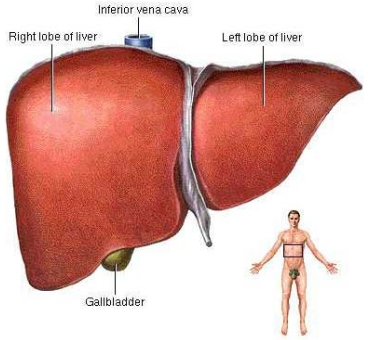
Liver

- Dual blood supply
  - Hepatic portal vein
    - Direct input from small intestine
  - Hepatic artery/vein
    - Direct links to heart



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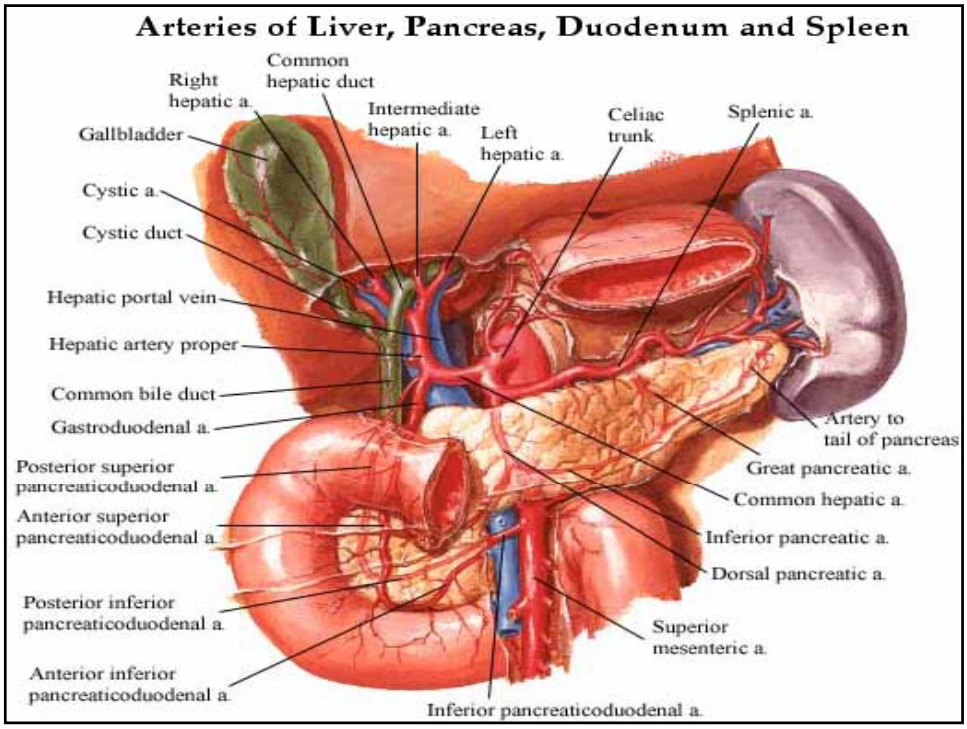
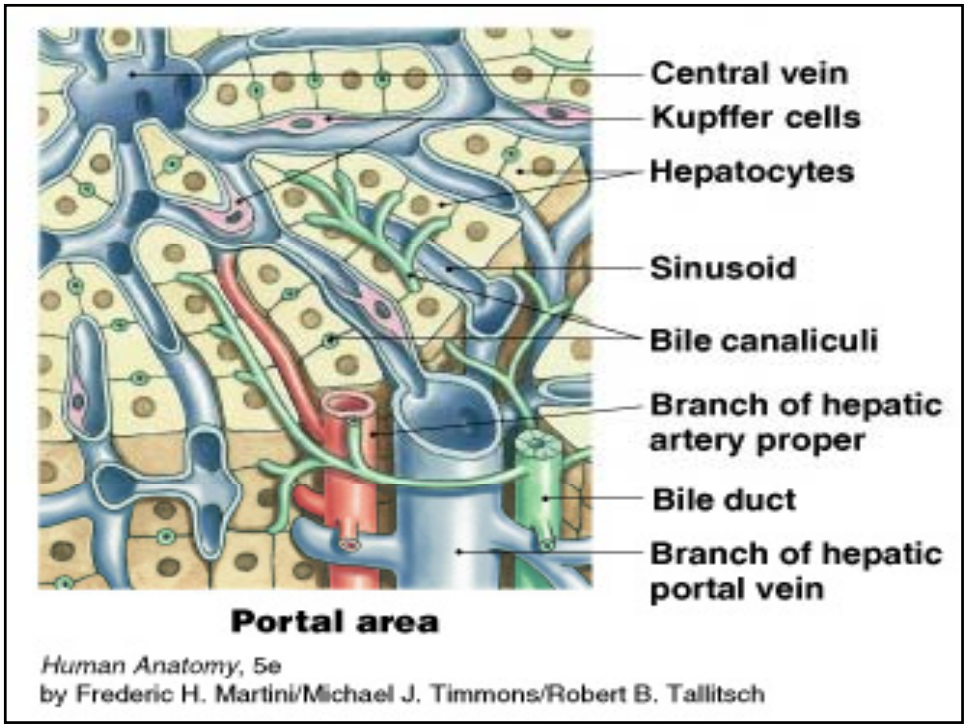
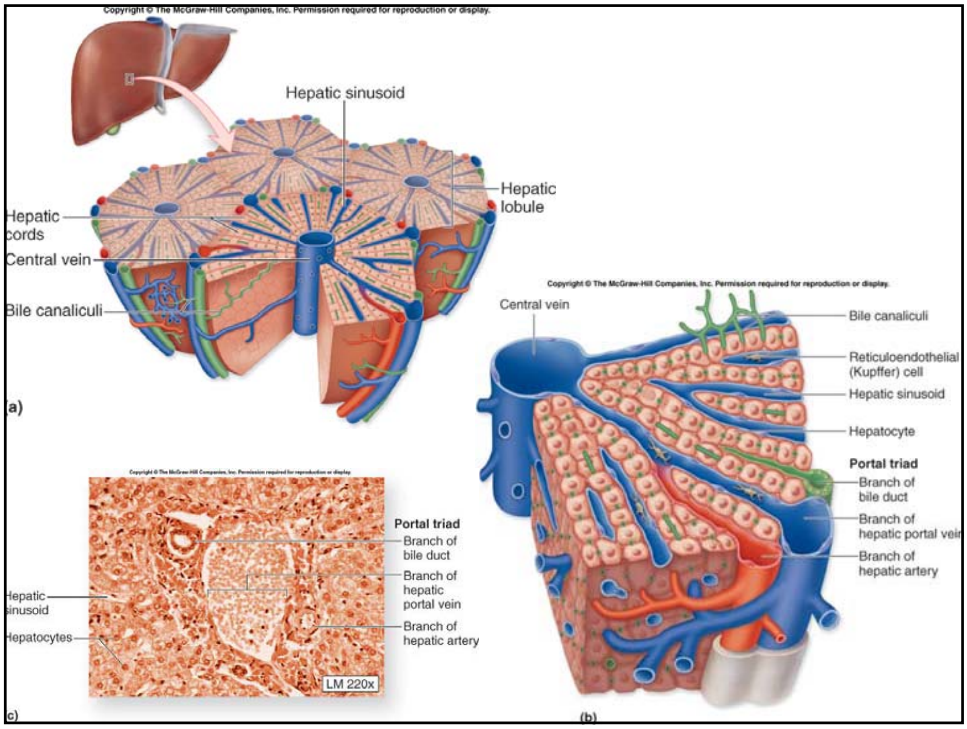
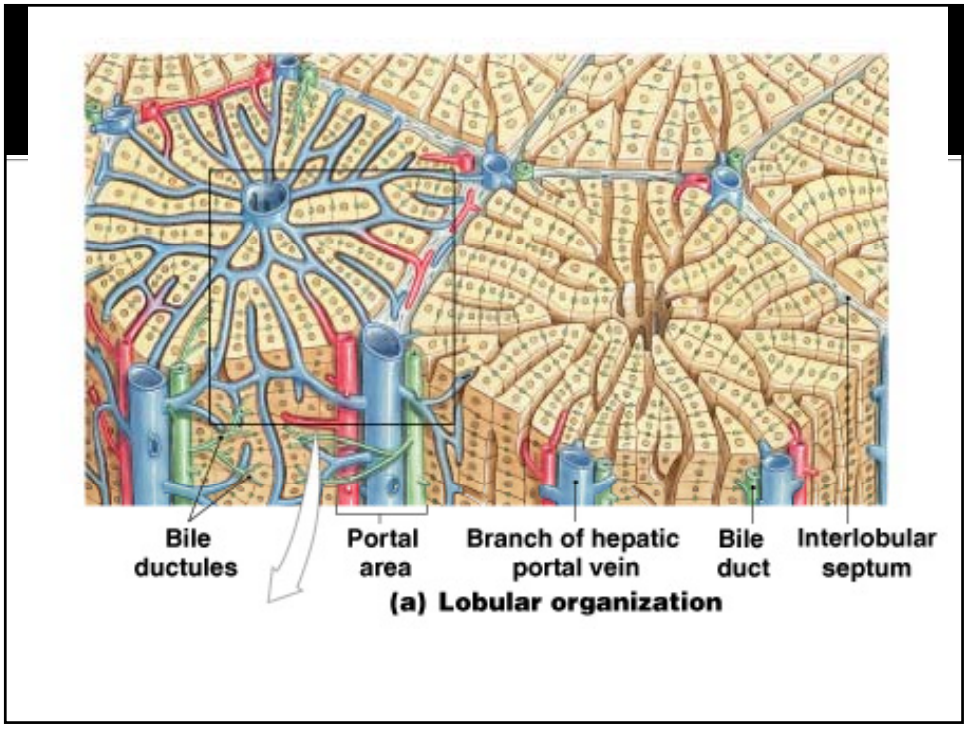
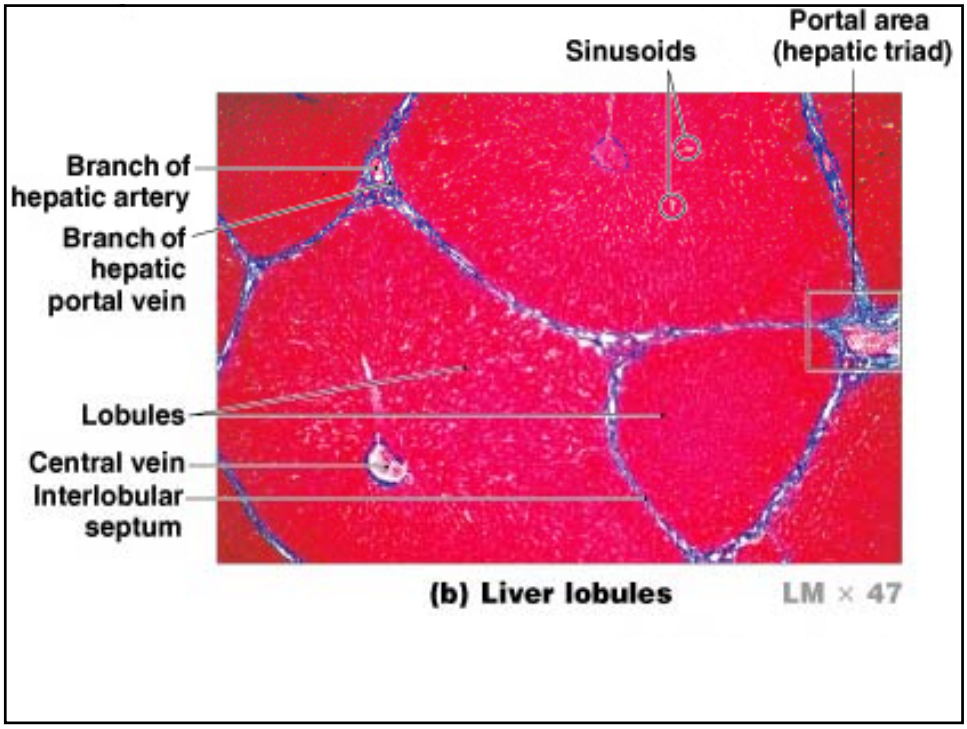
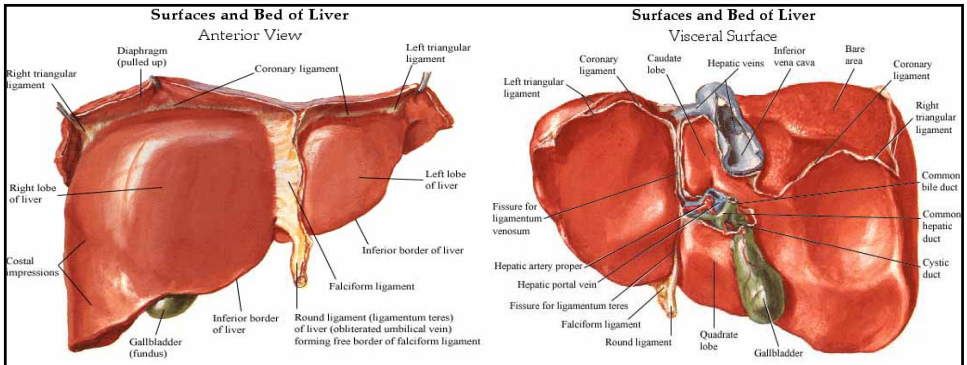

Arteries of Liver, Pancreas, Duodenum and Spleen
Right hepatic a.
Common hepatic duct
Intermediate hepatic a.
Left hepatic a.
Celiac trunk
Splenic a.
Gallbladder
Cystic a.
Cystic duct
Hepatic portal vein
Hepatic artery proper
Common bile duct
Gastroduodenal a.
Posterior superior pancreaticoduodenal a.
Anterior superior pancreaticoduodenal a.
Posterior inferior pancreaticoduodenal a.
Anterior inferior pancreaticoduodenal a.
Artery to tail of pancreas
Great pancreatic a.
Common hepatic a.
Inferior pancreatic a.
Dorsal pancreatic a.
Superior mesenteric a.
Inferior pancreaticoduodenal a.


Central vein
Kupffer cells
Hepatocytes
Sinusoid
Bile canaliculi
Branch of hepatic artery proper
Bile duct
Branch of hepatic portal vein
Portal area
Human Anatomy, 5e
by Frederic H. Martini/Michael J. Timmons/Robert B. Tallitsch


Hepatic sinusoid
Hepatic lobule
Hepatic cords
Central vein
Bile canaliculi
(a)
Central vein
Bile canaliculi
Reticuloendothelial (Kupffer) cell
Hepatic sinusoid
Hepatocyte
Portal triad
Branch of bile duct
Branch of hepatic portal vein
Branch of hepatic artery
(b)
Portal triad
Branch of bile duct
Branch of hepatic portal vein
Branch of hepatic artery
Hepatic sinusoid
Hepatocytes
LM 220x
(c)


Bile ductules
Portal area
Branch of hepatic portal vein
Bile duct
Interlobular septum
(a) Lobular organization



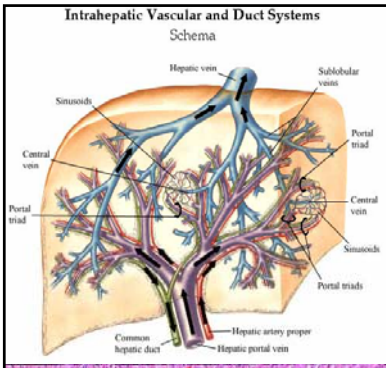


-The liver has **diaphragmatic** and **visceral surfaces** which contact the diaphragm and abdominal viscera, respectively. Note the **right triangular, left triangular,** and **coronary ligaments** that attach to the diaphragm. Note also the bare area not covered by peritoneum. Anteriorly, there is a fold of peritoneum connecting the liver to the umbilicus called the **falciform ligament,** which contains the **round ligament** or **ligamentum teres**. It is the remnant of the umbilical vein that brought oxygenated blood from the placenta to the fetus heart. The **ligamentum venosum** is the remnant of the fetal ductus venosus that shunted blood from the umbilical vein to the inferior vena cava to bypass the liver. In the adult liver, the **porta hepatis** includes the **hepatic arteries** from the **hepatic artery proper**, the **hepatic portal vein**, and the **hepatic** and **cystic ducts** joining to form the **common bile duct**.

- The portal vein brings nutrients and other compounds absorbed by the GI tract to be stored and/or processed.

- **Anatomical lobes**: Note how the inferior vena cava, gallbladder, ligamentum teres, ligamentum venosum, and porta hepatis form an "H" shape on the visceral surface. It divides the liver into 4 anatomical lobes based on outer appearance – the **right, left, caudate**, and **quadrate lobes**.

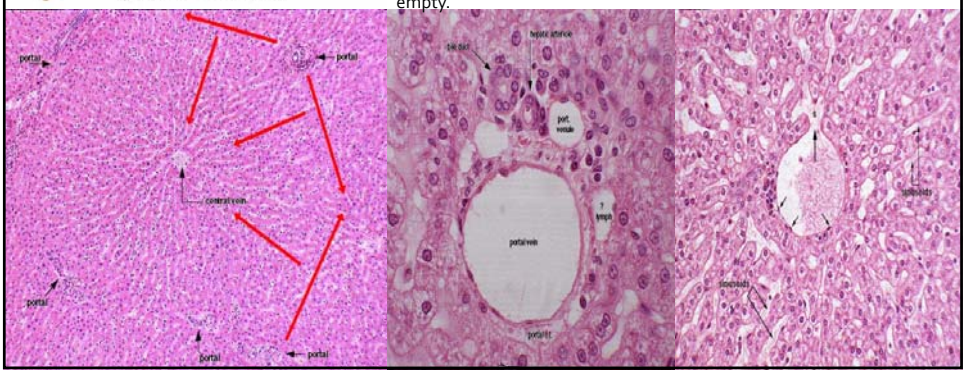
- **Functional lobes**: These are based on the distribution of the hepatic arteries, portal vein, and hepatic bile duct. The inferior vena cava and the gallbladder serve as the dividing line between the functional right and left lobes.



- The liver is divided into many **hepatic lobules**. Inflow to the liver involves hepatic arteries, which bring oxygenated blood to hepatic tissue, and portal veins, which bring nutrients and other compounds absorbed by the GI tract to be processed and/or stored in the liver. Outflow also involves two routes – hepatic veins which drain into the inferior vena cava and the common hepatic duct which joins the cystic duct and empties bile into the duodenum.

- Major characteristics of the liver are **portal triads** (labeled "portal" in bottom left and shown in the middle) and **central veins** (labeled in bottom left and shown in the right). Red arrows indicate direction of blood flow within **blood sinusoids** flanking **cords** of liver cells.

- Note the portal triad contains 1) the **portal vein**, 2) the **hepatic artery**, and 3) the **bile duct**. Each has its typical appearance. The central vein is lined with endothelial cells, with perforations into which the sinusoids empty.

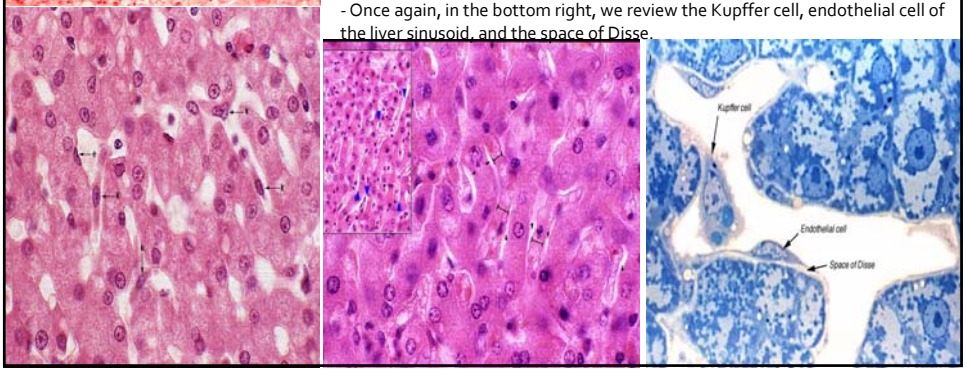


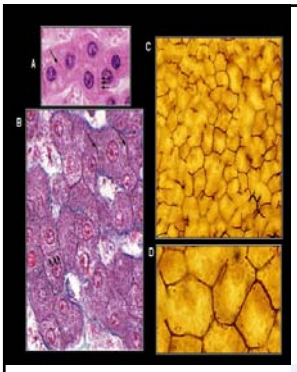
- The central veins lead to sublobular veins, which reach collecting veins, hepatic veins, and finally the inferior vena cava. **The venous outflow of the liver has no regard to the organization of the lobules.**

- The liver sinusoids are shown in higher magnification in the bottom left. They are dilated, capillary-like vessels lined by fenestrated, discontinuous epithelium (labeled "e"). Interspersed among the endothelial cells are **Kupffer cells** (labeled "k"), which are fixed macrophages within the hepatic tissue. They have distinct cytoplasm that may enter the sinusoidal lumen and function like other macrophages within the body. They also break down damaged red blood cell hemoglobin.

- In the bottom middle panel, there are many spaces between the hepatocytes and sinusoidal epithelial cells marked by arrowheads. They are referred to the **space of Disse** where exchange between hepatocytes and blood flow takes place.

- Once again, in the bottom right, we review the Kupffer cell, endothelial cell of the liver sinusoid, and the space of Disse.





- The liver lobules can be defined in 3 ways:

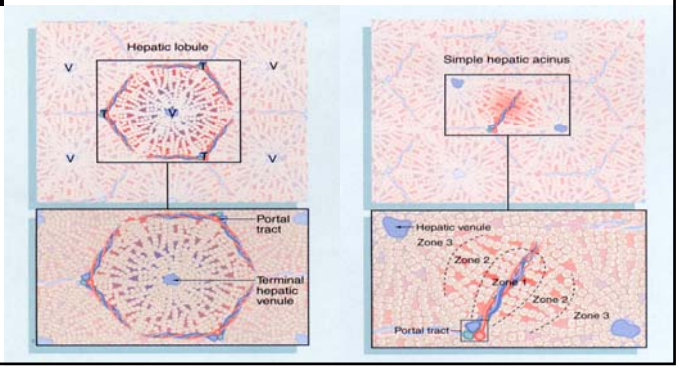
- 1) **Classic lobule** – centered around the central vein with the portal triads at each corner. Shown below on the left, the classic lobule may not always be hexagonal in shape.

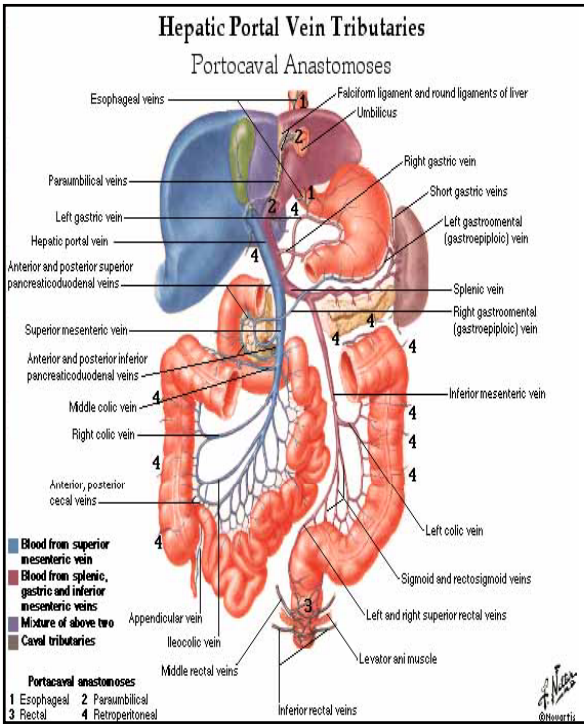
- 2) **Portal lobule** (not shown) – centered on the portal triad, based on bile secretion, and approximately triangular in shape.

- 3) **Liver acinus of Rappaport** – this is the most functionally important classification. Shown below on the right, the acinus is roughly oval in shape with 2 central veins and 2 portal triads on opposite ends. Based on the blood flow within hepatic tissue, the acinus is divided into 3 zones. Cells in different zones are specialized for different activity. Zone 1 cells, being closest to the portal triads and hence most oxygenated blood, have the most drug-metabolizing enzymatic activity. Following that same reasoning, zone 3 hepatocytes near the central veins are most susceptible to ischemia.

- As mentioned earlier, the liver has both endocrine and exocrine functions. The various proteins that hepatocytes secrete enter the bloodstream via the liver sinusoids. The liver also secretes bile in the conventional exocrine fashion.

- The hepatocytes secrete bile into sealed extracellular spaces called **bile canaliculi**. The typical "chicken-wire" appearance is more easily visualized with silver stain.





- Once again, inflow to the liver involves oxygenated blood via hepatic arteries and absorbed nutrients and compounds from the GI tract via the hepatic portal veins.

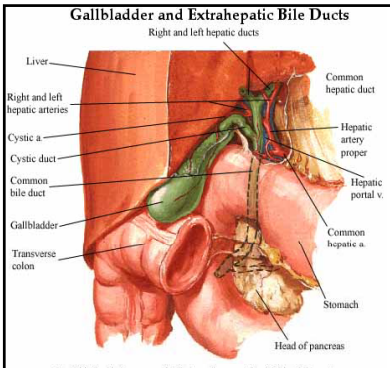
- All venous drainage from the GI tract and abdominal visceral organs enters the **portal system** back to the liver. The overall order is as following: arteries → capillaries → veins → portal vein → hepatic sinusoids → veins → vena cava → heart.

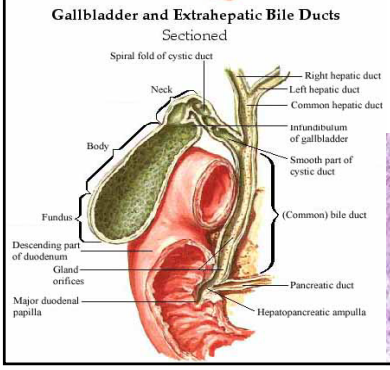
- In contrast, the **caval system** is as following: arteries → capillaries → veins → vena cava → heart. Obviously, this is the circulatory system within the rest of the body.

- The portal and caval system are not exclusive from each other. There are 4 sites of **portocaval anastomoses**:

  - 1) esophageal veins
  - 2) paraumbilical veins
  - 3) rectal veins
  - 4) retroperitoneal veins

- If there is liver damage or **cirrhosis** – accumulation of fibrous tissue that constricts the sinusoids – there may be **portal hypertension**. This may lead to varicose veins at the 4 sites of anastomoses.



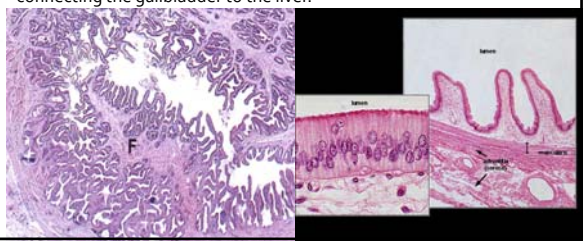


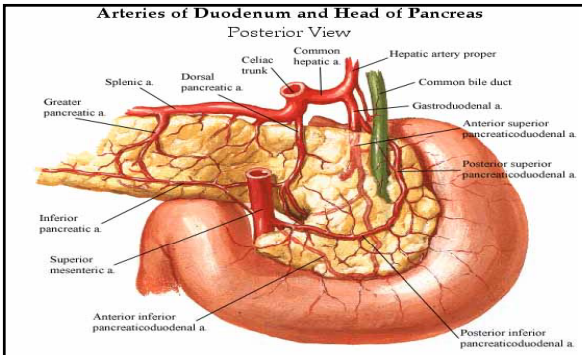
- The **gallbladder** is found under the right lobe of the liver. Its function is to store bile produced by the liver, which leaves via the **cystic duct**. It also enters the gallbladder in the cystic duct, traveling retrograde when the bile is not needed for digestion. Note the **fundus**, **body**, **neck**, and **infundibulum** of the gallbladder.

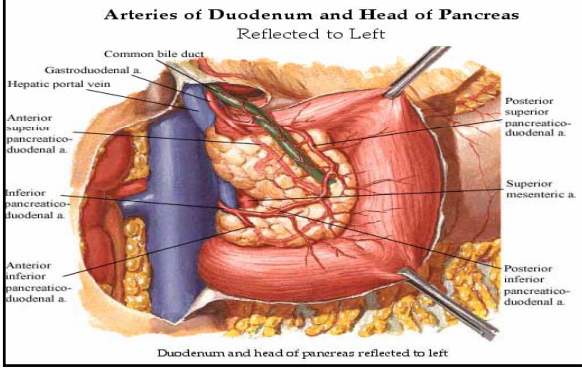
- Note the **right** and **left hepatic ducts** coming together as the **common hepatic duct**, joining the **cystic duct** to form the **common bile duct**. This descends to the 2nd part of the duodenum, is joined by the **pancreatic duct**, and empties its contents into the duodenal lumen via the **major duodenal papilla**.

- The gallbladder is supplied by the **cystic artery**, which is extremely important to find during a cholecystectomy. In most people it branches off the right hepatic artery, but could also come off the left hepatic, proper hepatic, or gastroduodenal arteries.

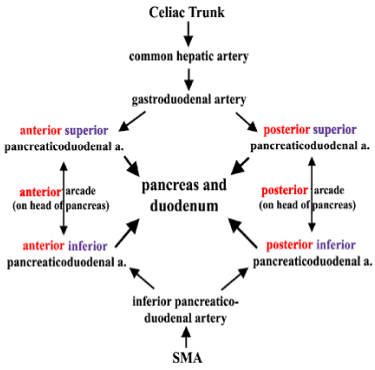
- Note the extensive folds of mucosa extending into the lumen, consisting of **tall, simple columnar epithelium**. The underlying connective tissue is comprised of lamina propria, with no distinctly defined submucosa. There are scattered bundles of smooth muscle in the muscularis. The adventitia has rather dense connective tissue connecting the gallbladder to the liver.





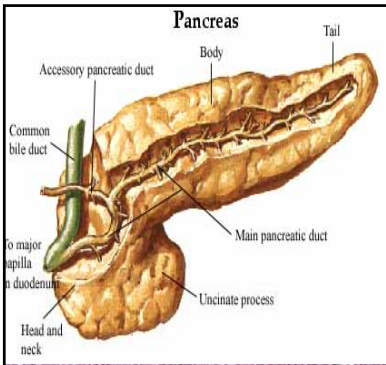


- Finally, we will look at the **pancreas**. To review: The head of the pancreas and duodenum are supplied from both the celiac trunk and the superior mesenteric artery.



- The body and tail of the pancreas are mostly supplied by branches of the splenic artery, namely the dorsal, greater, and inferior pancreatic arteries.

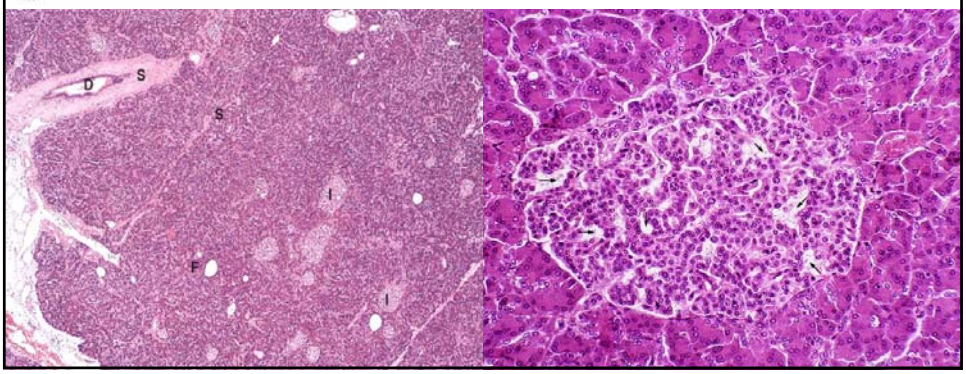
- Piece of advice: It can be very confusing when identifying these arteries. First orient yourself, note whether the duodenum is in anatomical position or reflected (as it is on the bottom left), and identify where the arteries branch from and where they lead.



- The pancreas contains multiple ducts, but the **main pancreatic duct** runs from the tail to the head of the pancreas. There may be a smaller **accessory pancreatic duct**. They join the common bile duct to empty into the duodenum. The pancreas is retroperitoneal.

- Histologically, we can see the **septa** (S) between pancreatic lobules with **interlobular ducts** (D). As mentioned above, the pancreas also has both exocrine and endocrine functions. Most of the bottom left panel is filled with exocrine pancreatic tissue. Secretory portions are called **acini**. The scattered endocrine **islets of Langerhans** (I) are paler staining.

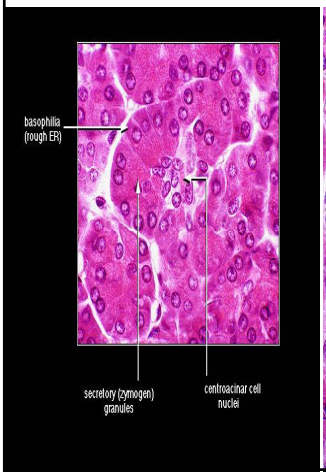
- An islet is magnified in the bottom right. It is a compact mass of epithelial cells that receive rich vascular supply (arrows). It is typically very difficult to identify the different cell types in the islets. Briefly, the alpha cells secrete glucagon, the beta cells secrete insulin, and the delta cells secrete somatostatin.

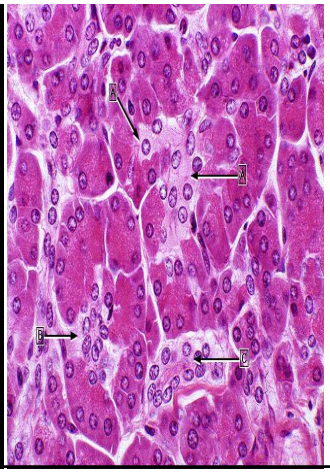


-Once again, most of the pancreas contains **exocrine acini**. Pancreatic enzymes are very diverse, including extremely efficient proteases, lipases, and amylases.

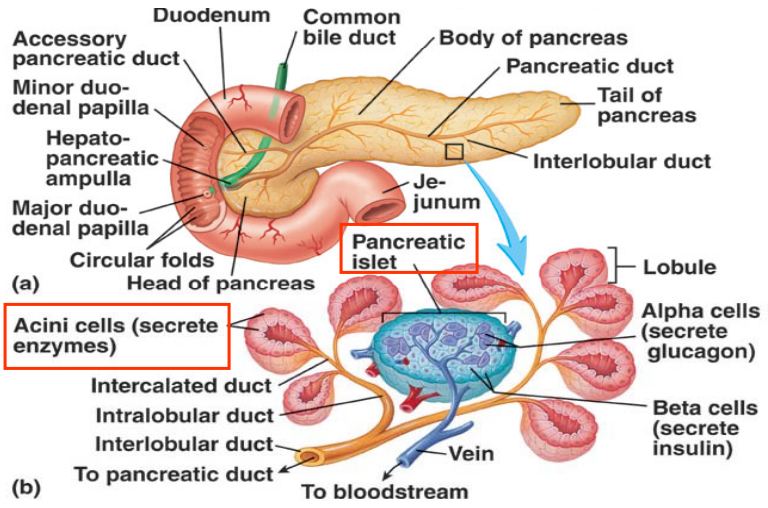
- Separate acini are shown in the left. The pancreatic **acinar** or **secretory cells** are polarized, meaning the **basal** portions are filled with **basophilic rough ER**. The **apical** regions are filled with **zymogen granules** that contain many stored pro-enzymes.

- **Centroacinar cells,** with paler staining, can be seen in the middle of some acini and mark the beginning of the duct system (marked "A" in the middle panel). They converge at "B" to form **intercalated ducts,** marked as "C". The intercalated duct cells may be hard to identify, but they actively pump water and bicarbonate into the duct lumen. Intercalated ducts empty into interlobular ducts, marked as "small duct" in the bottom right, which lead to the main pancreatic duct.

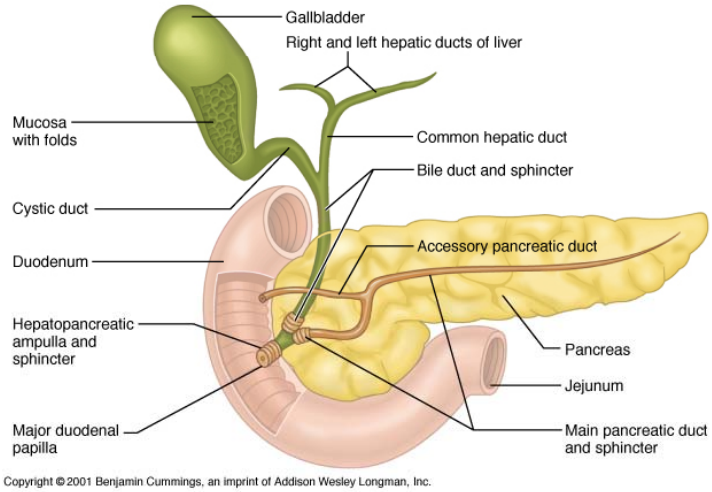




PANCREAS ANATOMY



The Duodenum and Related Organs



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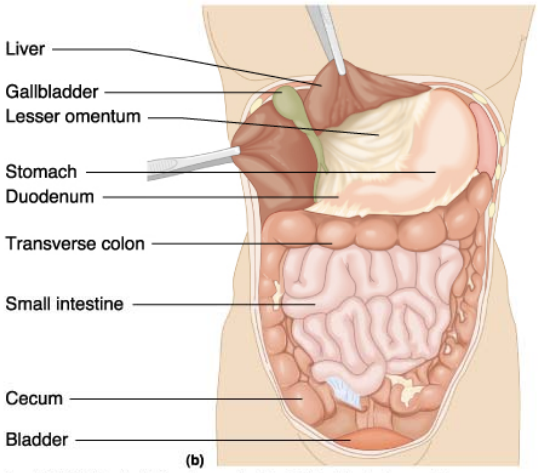
The Organs and Positions in the Abdominal Cavity



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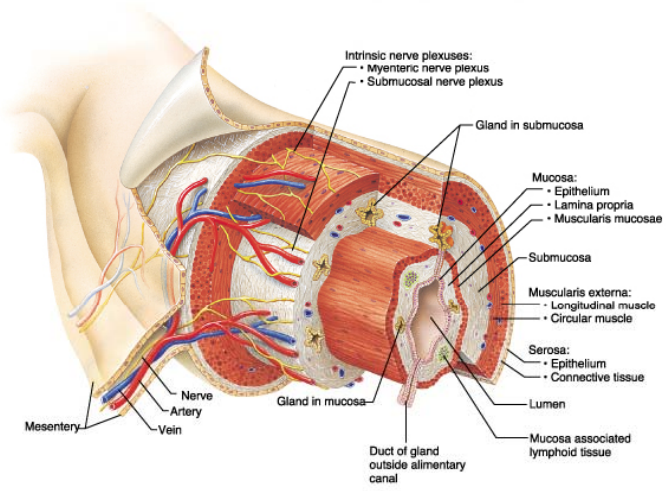
Structures of the Alimentary Canal



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