See 119

OVERVIEW

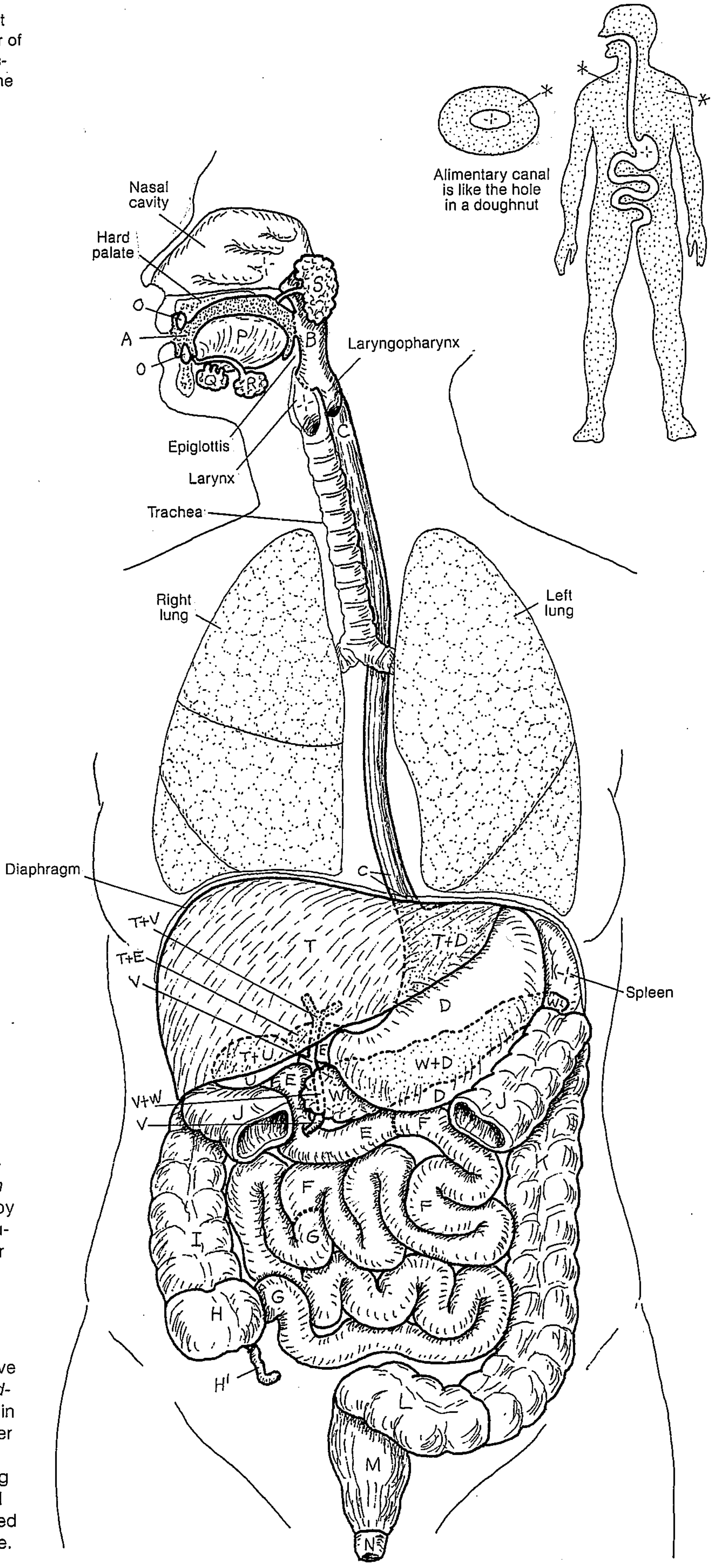
CN: When coloring the organs that overlap each other, use your lightest colors for D, E, T, V, and W. Each overlapping portion receives the color of both structures. (1) After coloring the alimentary canal, review the structures before completing the accessory organs. The central section of the transverse colon (J) has been removed to show deeper structures.

ALIMENTARY CANAL ✢

- ORAL CAVITY A
- PHARYNX B
- ESOPHAGUS C
- STOMACH D
- SMALL INTESTINE ✢
  - DUODENUM E
  - JEJUNUM F
  - ILEUM G
- LARGE INTESTINE ✢
  - CECUM H
    - VERMIFORM APPENDIX H'
  - COLON ✢
    - ASCENDING COLON I
    - TRANSVERSE COLON J
    - DESCENDING COLON K
    - SIGMOID COLON L
  - RECTUM M
  - ANAL CANAL N

ACCESSORY ORGANS ✢

- TEETH O
- TONGUE P
- SALIVARY GLANDS ✢
  - SUBLINGUAL Q
  - SUBMANDIBULAR R
  - PAROTID S
- LIVER T
- GALL BLADDER U
- BILE DUCT V
- PANCREAS W



The digestive system consists of an alimentary canal with accessory organs. The canal begins with the *oral cavity.* Here the *teeth* pulverize ingested food while it is softened and partly digested by *salivary gland* secretions. The *tongue* aids in mechanical manipulation of the food and literally flips the food into the fibromuscular *pharynx* during swallowing.

The esophagus moves the bolus along to the *stomach* by peristaltic muscular contractions. Here the bolus is treated to mechanical and chemical digestion, then passed into the highly coiled *small intestine* for more enzymatic and mechanical digestive processes. Bile, produced by the *liver* and stored in the *gall bladder,* is discharged into the *duodenum* by a *bile duct.* Bile assists in the breakdown of fats. Digestive enzymes from the *pancreas* enter the duodenum as well. Nutrients of molecular size are extracted primarily from the lumen of the small intestine, absorbed by lining cells, and transferred to blood and lymph capillaries for eventual delivery to the liver for processing. The large intestine is concerned with absorption of minerals and water (proximal half) and storage. Undigested, unabsorbed material continues to the rectum for discharge through the anal canal and anus.

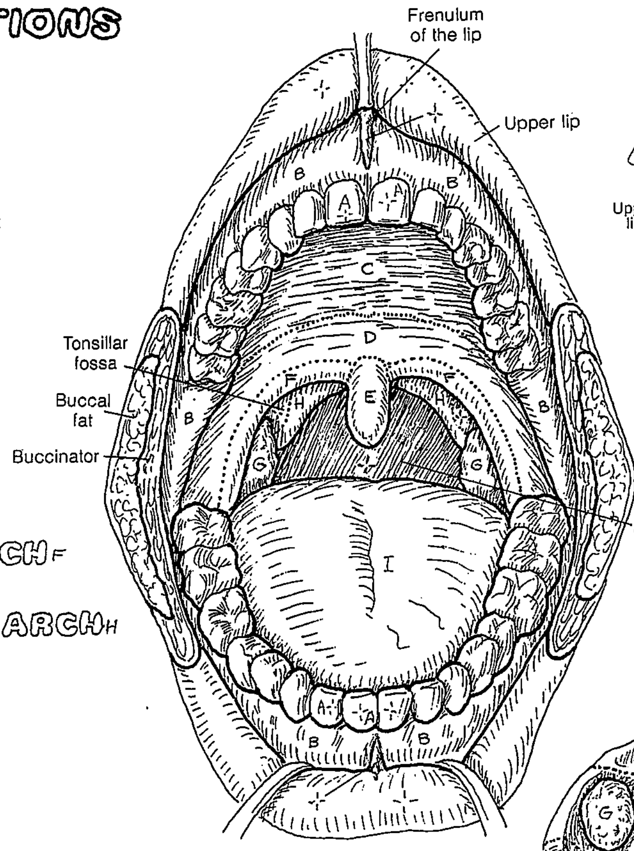
See 26, 47, 127, 132

ORAL CAVITY & RELATIONS

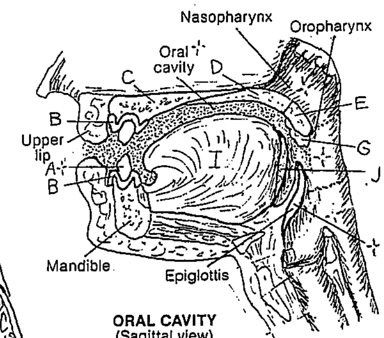
CN: Use pink or red for I and very light colors for N, O, and P. The asterisks preceding titles F, G, and H refer to the footnote under the list of titles, and not the color gray. (1) Color the two upper views of the oral cavity simultaneously. (2) Color the papillae of the tongue with the color of the tongue (I) but not the tongue itself. (3) Color the three salivary glands and the cellular diagram to their right. Note that the lumen, which receives glandular secretions, is not colored as it passes through the various colored structures.

ORAL CAVITY
- TEETH A
- GINGIVA (GUM) B
- HARD PALATE C
- SOFT PALATE D
  - UVULA E
  - * PALATOGLOSSAL ARCH F
  - * PALATINE TONSIL G
  - * PALATOPHARYNGEAL ARCH H
- TONGUE I
  - LINGUAL TONSIL J
  - VALLATE PAPILLAE I^1
  - FOLIATE P. I^2
  - FUNGIFORM P. I^3
  - FILIFORM P. I^4

*These structures are considered as part of the oropharynx in Plates 132 and 139; as a practical mattter, they are part of the oral cavity bordering the oropharynx.

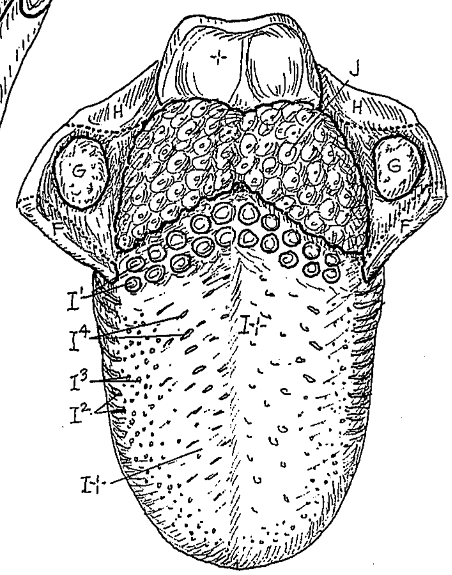


ORAL CAVITY



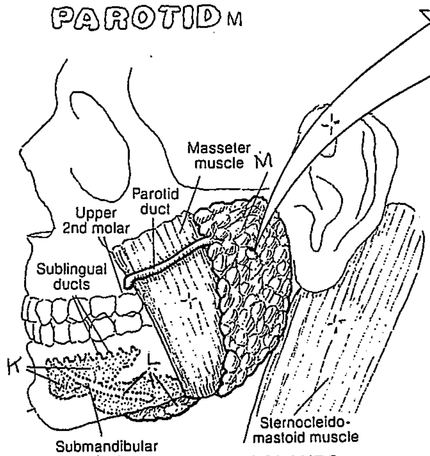
ORAL CAVITY (Sagittal view)

The oral cavity (mouth) is essentially concerned with preparation of food for swallowing. Food is pulverized with *teeth* (presented in next plate), which act on food through chewing (mechanical digestion), made possible by the muscles of mastication and the temporomandibular joint, which permits mouth opening to an interincisor distance of 35–50 mm. Wetting the food is a function of the thousands of mucous and serous glands in the tongue and the mucosa lining the oral cavity. Wetting and enzymatic action also are functions of the salivary glands (discussed below). Mechanical digestion is enhanced by the *papillae* on the surface (dorsum) of the tongue. These provide a site for taste receptors (except filiform papillae) and an abrasive surface, for breaking down food.

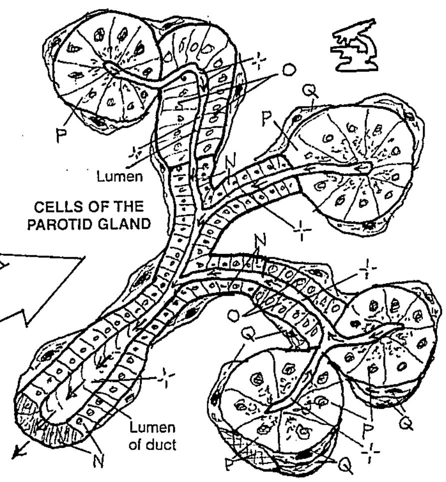


TONGUE

SALIVARY GLANDS
- SUBLINGUAL K
- SUBMANDIBULAR L
- PAROTID M



SALIVARY GLANDS



- DUCT N
- MUCOUS TUBULE O
- SEROUS ACINUS P
- MYOEPITHELIAL CELL Q

Salivary glands secrete an enzyme-rich fluid into the mouth during periods of eating or anticipated eating. The largest is the *parotid gland,* situated bilaterally in front of and below each external auditory canal, partly overlying the masseter muscle. Its duct arches over the masseter, penetrating the cheek mucosa to enter the oral cavity opposite the upper 2nd molar. Its glandular cells are serous. The smallest of the salivary glands, the mucus-type *sublingual glands,* lie under the tongue below the oral mucosa. The *submandibular glands* are U-shaped and wrap around the mylohyoid muscle (Plate 48). They consist of ducts and mixed glands, primarily mucous.

An example of a mixed (muco-serous) gland is shown here. The serous glands consist of cells that are pyramid-shaped. The cells form rounded, grape-shaped alveoli or acini, whose center forms the *duct.* The more *tubular glands* are mucous-secreting; they are cylinder-shaped, with a central duct. Collections of *serous cells* capping a mucous gland are called serous demilunes (half-moon shaped). Contractile *myoepithelial cells* within the basal laminae of both duct and gland cells are responsible for forcing the secretions into the ducts and out of the glands.

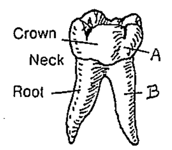
ANATOMY OF A TOOTH

See 24, 137

CN: Use yellow for F, red for G, blue for H, and light colors for A, B, and L. (1) Begin with the anatomy of a tooth. Color gray the titles and arrows/bands arranged vertically. (2) Use only light colors on the teeth below. Note that the identifying letter and number labels are those used by the dental profession.

TOOTH-|-

ENAMEL A DENTIN B
PULP CAVITY C PULP E
ROOT CANAL D
NERVE F ARTERY G VEIN H
CEMENTUM I
PERIODONTAL LIGAMENT J
GINGIVA K ALVEOLAR BONE L



Note the longitudinal section of a molar; two roots are shown. The core substance of the tooth is *dentin*. Composed of packed microscopic tubules, pain-sensitive, avascular dentin is composed like bone, though more mineralized (70% by weight). Dentin is capped by a 1.5 mm layer of insensitive *enamel*, 95% mineral by weight, less than 1% organic. Enamel consists of microscopic circular rods filled with hydroxyapatite (bone) crystals, and it is the hardest material in the body. The dentin of each tooth has a hollow *pulp cavity*; it extends into each root of the tooth as the root canal. At the apex of each root, an opening (apical or root foramen) permits the passage of *blood vessels and nerves* into/from the alveolar bone. *Pulp* is a well-innervated and vascular loose connective tissue, continuous with the periodontal ligament through the root foramen.

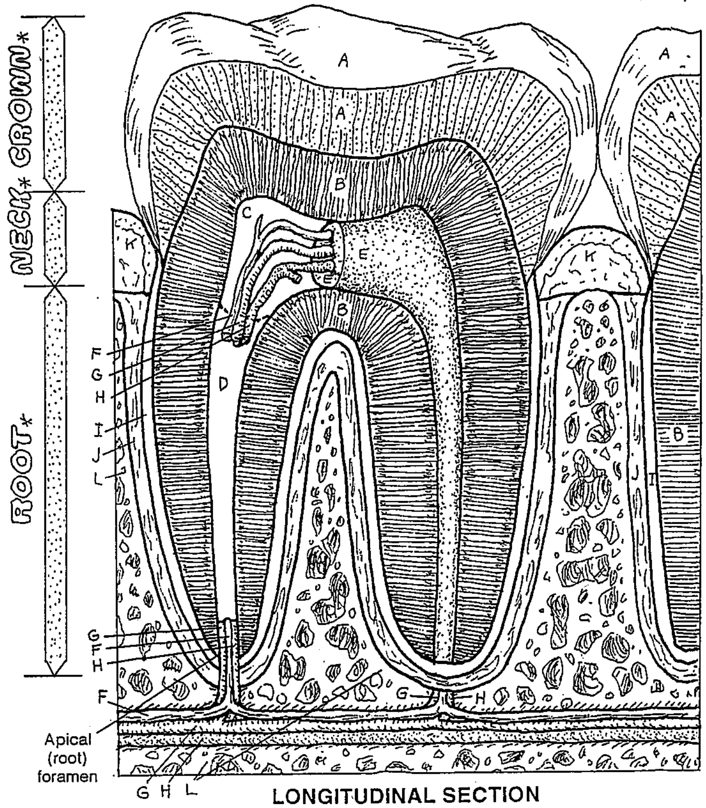
Each tooth has a crown, extending above the *gingiva* (gum line), a *neck* (at the level of the gum; here the enamel ends and abuts the cementum), and one or more *roots* buried in *alveolar bone* of the maxilla (upper teeth) or mandible (lower teeth). Incisors and canine teeth each have a single root canal; premolars and molars may have 1–3 roots. The surface of the crown is characterized by tubercle-like cusps separated by fissures, except for incisiors, which have only a cutting edge. Canines have one cusp (cuspid); premolars have two (bicuspids), and molars have 4 or 5 cusps. Multiple cusps enhance the grinding and abrasive functions of the teeth.

The fibrous *periodontal ligament*, about 0.2 mm thick, interfaces the *cementum* (lining the root of the tooth) and the alveolar bone. The cementum is a highly mineralized substance. Collagen fibers stuck in the cementum penetrate the ligament to insert into the alveolar bone. The gingiva (gum) is a mucous membrane with stratified squamous epithelia that attaches to the enamel by a thickened basal lamina; the lamina propria of the membrane is strongly anchored to the underlying alveolar bone.

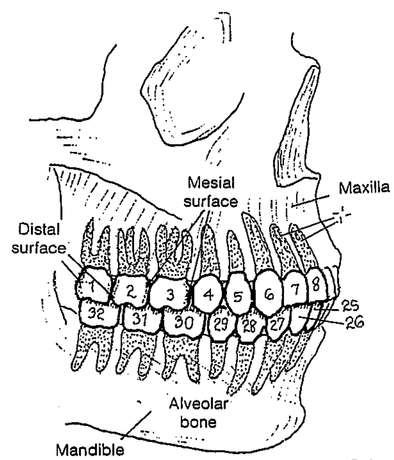
ADULT/CHILD DENTITION-|-

CENTRAL INCISOR 8, 9, 24, 25, E, F, O, P
LATERAL INCISOR 7, 10, 23, 26, D, G, N, Q
CANINE 6, 11, 22, 27, C, H, M, R
1ST PREMOLAR 5, 12, 21, 28
2ND PREMOLAR 4, 13, 20, 29
1ST MOLAR 3, 14, 19, 30, B, I, L, S
2ND MOLAR 2, 15, 18, 31, A, J, K, T
3RD MOLAR (WISDOM) 1, 16, 17, 32

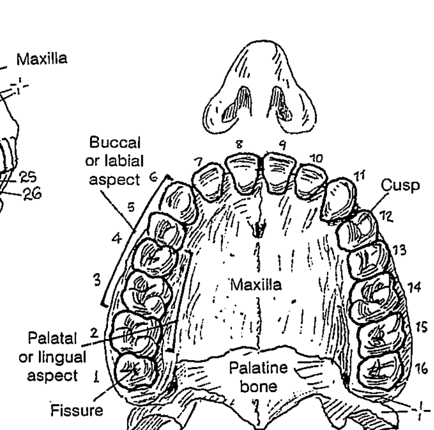
There are naturally 32 teeth in an adult—8 in each of four quadrants (right and left, in both upper and lower dental arches). Two sets of teeth (dentition) develop in a lifetime: deciduous and permanent. The deciduous set (20) are absorbed/shed in early life; the permanent set (32) is not naturally shed. Babies are born with the deciduous dentition submerged under the gingiva, for which breast-feeding mothers are grateful. In general, the deciduous incisors are the first to erupt, at 6 months. The entire deciduous dentition (see boxed area at right) has erupted by 18 months; it is gone by 12 years. The first permanent tooth (1st molar) appears at about 6 years; the last (3rd molar) appears at about 18 years ("wisdom tooth").



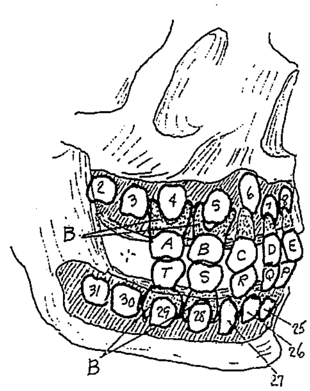
LONGITUDINAL SECTION
(1st molar in bone)



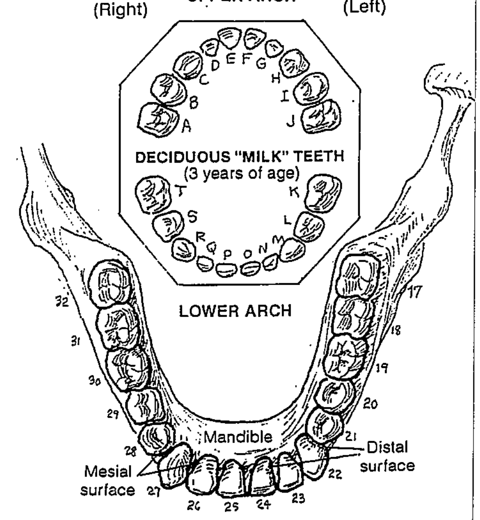
PERMANENT TEETH IN OCCLUSION
(21 years of age)



UPPER ARCH



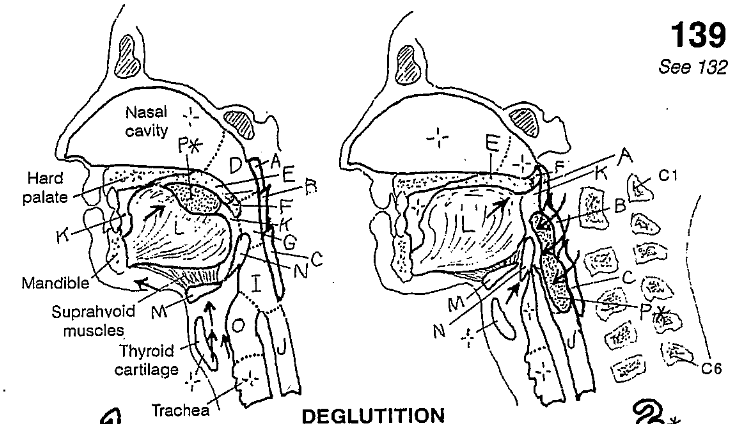
DECIDUOUS AND PERMANENT TEETH
(5 years of age/alveolar walls removed)



See 132

PHARYNX & SWALLOWING

CN: Use pink for K. (1) Color the three lower illustrations simultaneously. In the posterior view of the interior of the pharynx, the posterior pharyngeal wall is divided and retracted so you can note the relationship of internal pharyngeal structure to the constrictor muscles (A, B, C) and the subdivisions of the pharynx (D, G, I). Color gray the boluses of food in all views. In the two outer views (below), add the color of the overlying structure to the representation of bolus movement. (2) Follow the text when coloring the deglutition diagrams.



DEGLUTITION
(Swallowing)

MUSCULAR WALL OF PHARYNX -:-
- SUPERIOR CONSTRICTOR A
- MIDDLE CONSTRICTOR B
- INFERIOR CONSTRICTOR C

INTERIOR OF PHARYNX -:-
- NASOPHARYNX D
- SOFT PALATE E
  - UVULA F
- OROPHARYNX G
- PALATOPHARYNGEAL M. H
- LARYNGOPHARYNX I

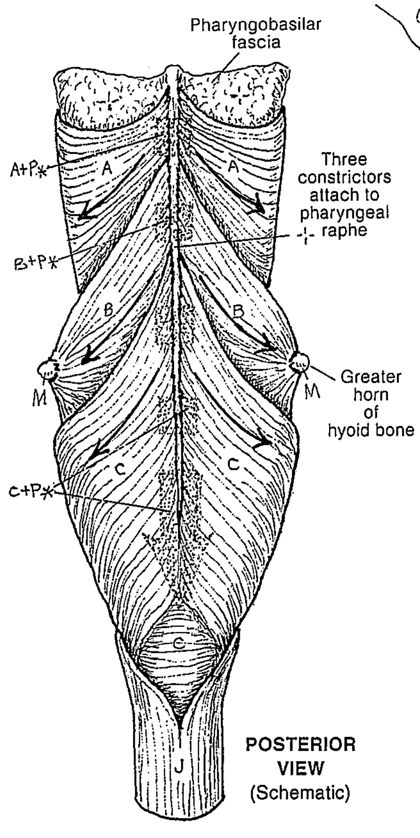
ESOPHAGUS J

RELATED STRUCTURES -:-
- ORAL CAVITY K
- TONGUE L
- HYOID BONE M
- EPIGLOTTIS N
- LARYNX O

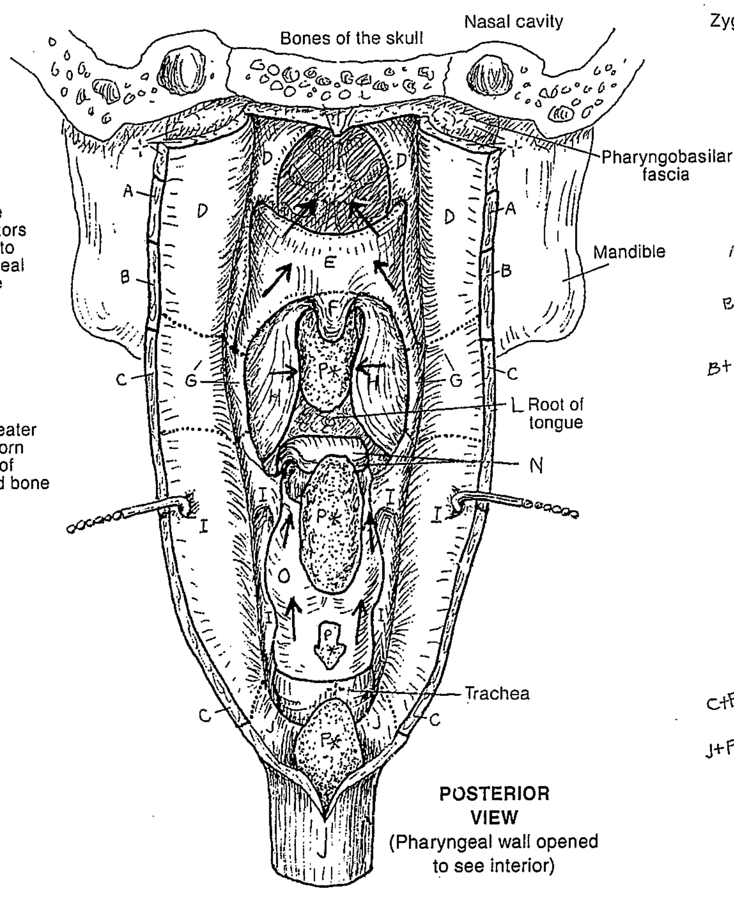
BOLUS OF FOOD P*

Swallowing (deglutition) begins with food in the oral cavity. (1) The *food bolus* is voluntarily pushed upward and backward into the *oropharynx* by the *tongue*. The suprahyoid muscles lift and shorten or lengthen the floor of the mouth by pulling the *hyoid bone* up and forward or backward to one degree or another, depending on the material being moved into the pharynx. You can feel the ascent and descent of the hyoid bone. Place your thumb and index finger around the front of your mid-neck at the level of the palpable hyoid bone; swallow and feel the bone move upward and downward. The bilateral *palatopharyngeal muscles*/folds partially close off the oral cavity from the pharynx, selectively permitting appropriately sized boluses to enter the pharynx and resisting regurgitation into the mouth. Once the bolus is in the oropharynx, the following mechanism is involuntary.

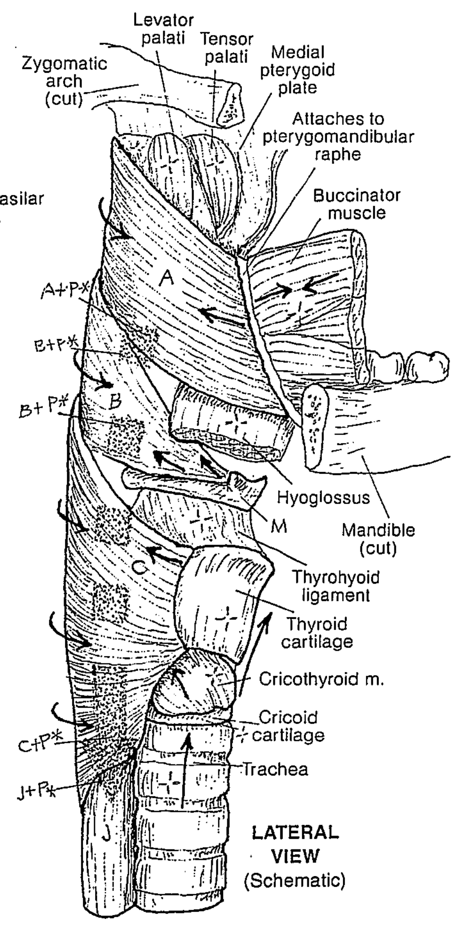
The soft palate is elevated (2), blocking the *nasopharynx* and preventing regurgitation into the nasal cavity. Indeed, the entire pharynx is elevated by the pharyngeal elevator muscles. Simultaneously, the larynx is elevated by infrahyoid and other muscles, and the laryngeal opening is closed by intrinsic laryngeal muscles. During the lifting of the larynx, the epiglottis moves over the laryngeal opening. The *superior and middle constrictor muscles* of the pharynx, assisted by gravity, sequentially contract from above downward, driving the bolus into the laryngopharynx. The contractions of the palatopharyngeal muscles orient the descent of the bolus downward and slightly backward. Contractions of the *inferior constrictor muscle* force the bolus into the esophagus.



POSTERIOR VIEW
(Schematic)

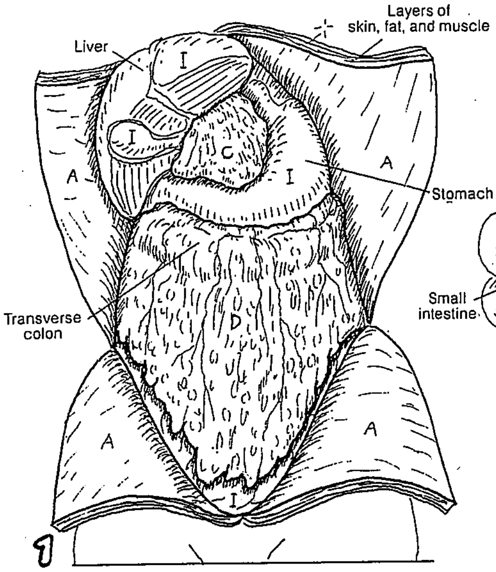


POSTERIOR VIEW
(Pharyngeal wall opened to see interior)

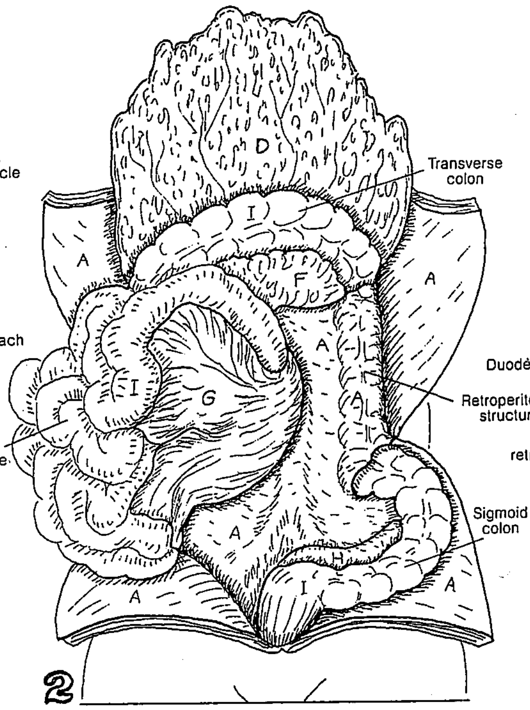


LATERAL VIEW
(Schematic)

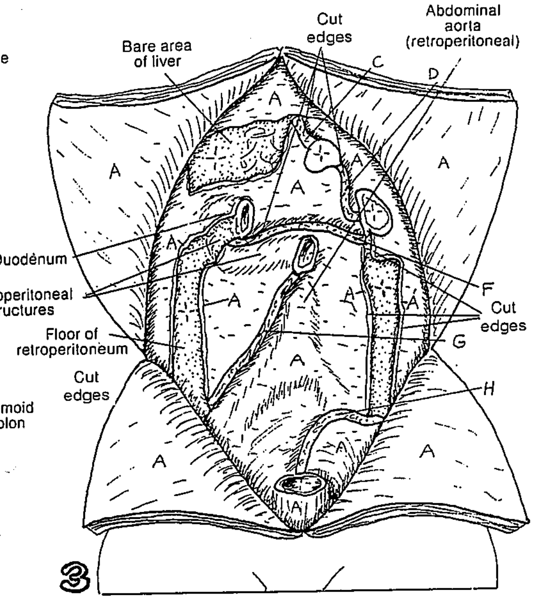
PERITONEUM



With the anterior abdominal wall opened through its deepest (*parietal peritoneal*) layer, the liver, the stomach, and the fatty *greater omentum* are generally all that can be seen with the contents undisturbed. Lifting the liver exposes the *lesser omentum*, a double peritoneal layer between the stomach and liver. It is the anterior wall of the *omental bursa* (E). The greater omentum connects the transverse colon to the stomach.



With the greater omentum lifted, the double-layered, *transverse mesocolon* between the transverse colon and parietal peritoneum can be seen. Retracting the intestines to one side reveals the *common mesentery* between most of the small intestine and the parietal peritoneum on the posterior body wall. The sigmoid colon has a mesentery (*sigmoid mesocolon*) as well. Abdominal structures posterior to these mesenteries/omenta are retroperitoneal.



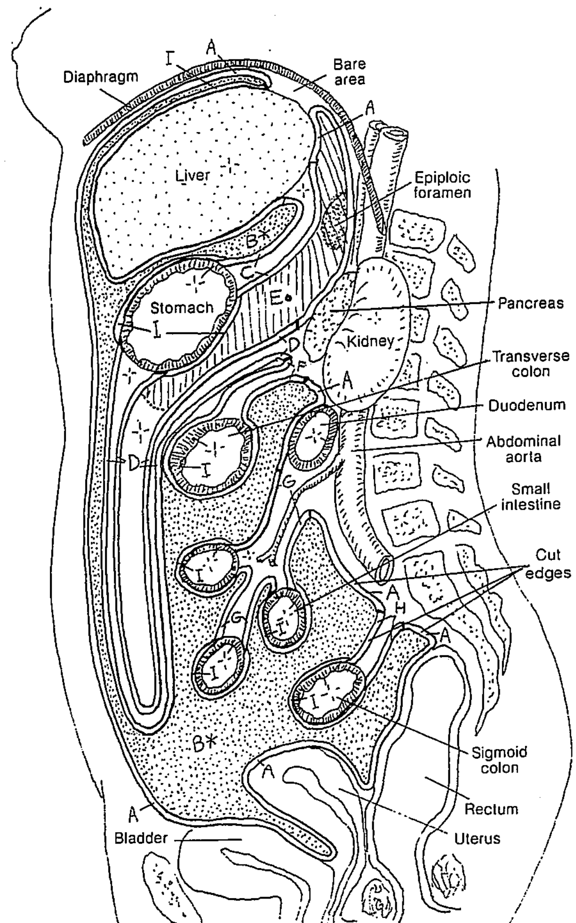
The parietal peritoneum of the posterior body wall is seen when all structures except retroperitoneal ones (aorta, inferior vena cava, kidneys, ureters, pancreas, duodenum, ascending/descending colon) are removed. Many nerves and vessels travel in this retroperitoneal space. As organs emerge from the peritoneum, they develop a mesentery to suspend them. The cut layers of several of them can be seen (C, D, F, G, and H).

CN: Use a very light color for A and I. (1) Color the upper three diagrams in numerical order. Note that the digestive organs are covered with visceral peritoneum (I). (2) Color the sagittal view. Use a darker gray or black for the omental bursa (E). The space of the peritoneal cavity (B) has been greatly exaggerated for clarity of peritoneal membranes.

PERITONEAL STRUCTURES

- PARIETAL PERITONEUM A
  - PERITONEAL CAVITY B*
- LESSER OMENTUM C
  - OMENTAL BURSA E•
- GREATER OMENTUM D
- TRANSVERSE MESOCOLON F
- COMMON MESENTERY G
- SIGMOID MESOCOLON H
- VISCERAL PERITONEUM I

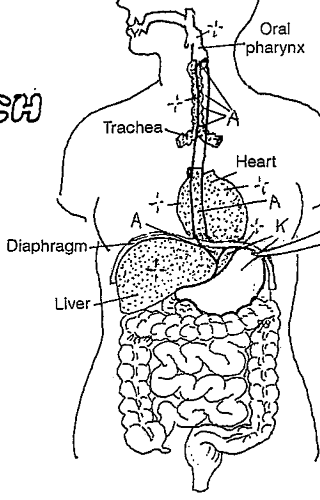
Peritoneum is a serosal membrane of the abdominal cavity. The disposition of the peritoneum is similar to that of the serosal layers around heart (pericardium) and lungs (pleura): peritoneum attached to the body wall is *parietal*; peritoneum attached to the outer visceral wall is *visceral*. Structures deep to the posterior parietal peritoneum are retroperitoneal. Peritoneal layers suspending organs are called *mesenteries*; those suspending an organ from another organ are called *omenta* or ligaments. When coloring the sagittal view, the continuity of these peritoneal membranes can be appreciated. The cavity of the peritoneum is empty; it can fill with fluid in disease and trauma. The view at right shows intestines separated from one another; in life, they are as close together as strands of coiled wet rope. Vessels/nerves to the intestines and stomach travel in the mesenteries/omenta; they do not penetrate peritoneal layers. The source vessels are retroperitoneal. The *omental bursa* is a peritoneal-lined sac created by rotation of the stomach during fetal life. It is open on the right at the epiploic foramen between the lesser omentum and the parietal peritoneum. Here the omental bursa (lesser sac) communicates with the collapsed, empty peritoneal cavity (greater sac).

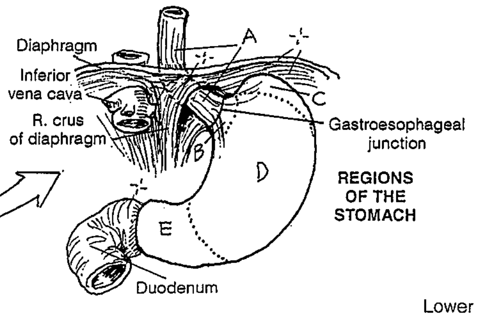


SAGITTAL VIEW OF ABDOMEN
(Schematic)

ESOPHAGUS & STOMACH

CN: Use only light colors. (1) Color the esophagus (A) as it descends through the chest. Color over the dotted parts of the trachea and heart that lie anterior to the esophagus. Color the stomach and the dotted part of the liver anterior to it. (2) Color the names of the digestive products secreted by tile cells shown below.





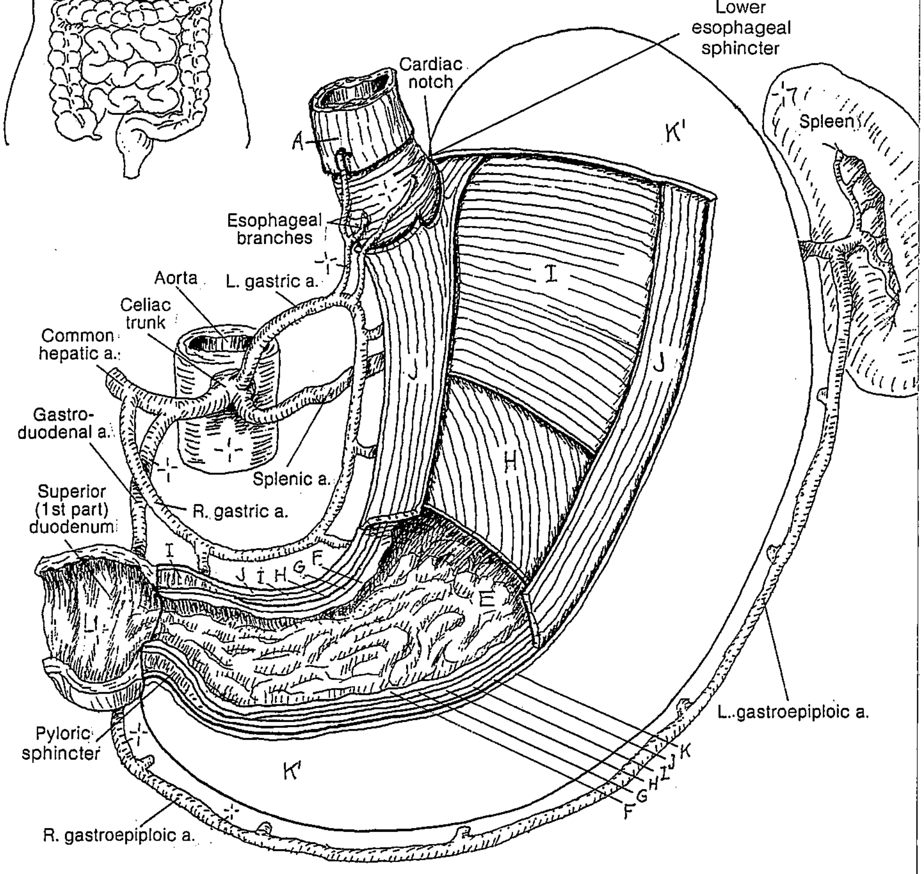
ESOPHAGUS A

STOMACH REGIONS -:-

- CARDIA B
- FUNDUS C
- BODY D
- PYLORUS E

STOMACH WALL K

- MUCOSAL SURFACE (RUGAE) F
- SUBMUCOSA G
- MUSCULARIS EXTERNA -:-
  - OBLIQUE M. H
  - CIRCULAR M. I
  - LONGITUDINAL M. J
- SEROSA K'

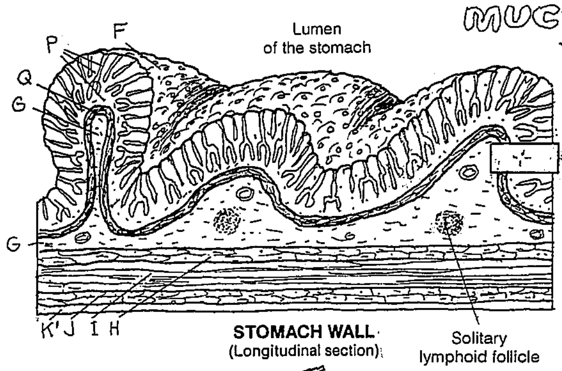


The esophagus connects the laryngo pharynx and the *cardia* of the stomach. It is a muscular tube whose mucosa is lined with non-keratinized stratified squamous epithelium. At the gastroesophageal junction, the epithelia transition abruptly to simple columnar. The muscle layer is arranged in both longitudinal and circular orientations. In the proximal part of the esophagus, the muscle is striated; in the midesophagus, it is both striated and smooth; in the lower third, the muscle is entirely smooth. The glands of the submucosa secrete mucus, enhancing flow. The esophagus conducts its contents by sequential, rhythmic muscular contractions.

The gastroesophageal junction has an area of specialized circular muscle (lower esophageal sphincter) that permits passage of a food bolus by muscle relaxation during swallowing. The right crus of the diaphragm also contributes fibers to the esophagus (external sphincter) and functions to resist gastroesophageal reflux (reverse flow) during inspiration.

The stomach is the first part of the gastrointestinal tract. The stomach is generally located in the upper left quadrant of the abdomen, although a full stomach can droop into the pelvis. Suspended by peritoneal layers, it receives the esophagus just below the diaphragm. At the duodenal end, the stomach narrows to a muscular pyloric sphincter. The stomach classically has four regions whose shape varies with the quantity of contents. The stomach mechanically manipulates ingested material, acidifies it to enhance protein digestion, secretes proteolytic enzymes (pepsin), and induces secretion of bile from the gall bladder and enzymes from the pancreas, both of which enter the duodenum. Microorganisms do not generally survive these activities.

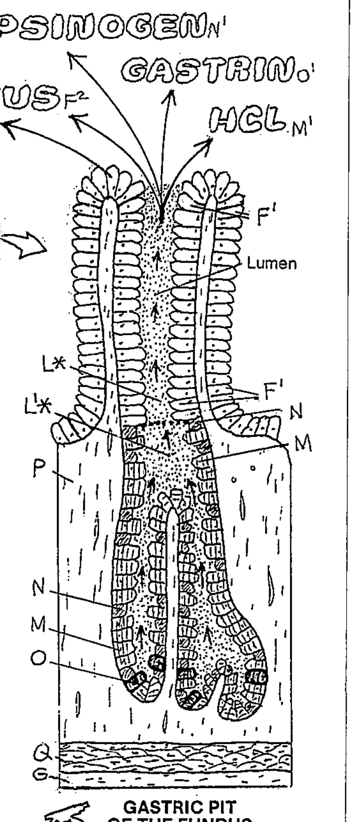
Note the arrangement of the stomach wall and the various cells that make up the epithelial layer of the mucosa. The epithelial cells are the working cells, providing a cocktail of digestive products, whose main target is protein. The *lamina propria* provides vascular and mechanical support for the *gastric pits*. The muscle layer of the *mucosa* and the external muscle layers produce peristaltic contractions to assist in mechanical digestion and moving the residue of digestion along the tract. The fibrous submucosa supports lymphoid follicles, vessels, and nerves.



STOMACH WALL (Longitudinal section)

MUCOSA -:-

- EPITHELIAL LAYER -:-
  - GASTRIC PIT L*
    - MUCOUS CELL F'
  - GASTRIC GLAND L*
    - PARIETAL CELL M
    - CHIEF CELL N
    - ENDOCRINE CELL O
- LAMINA PROPRIA P
- MUSCULARIS MUCOSAE Q

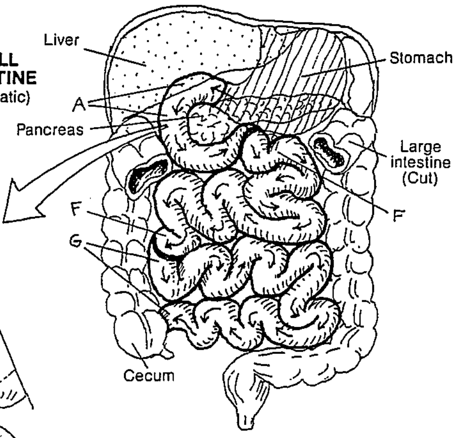


GASTRIC PIT OF THE FUNDUS (Diagrammatic)

See 145

SMALL INTESTINE

CN: Use green for N, red for Q, purple for R, blue for S, yellow for T, and a very light color for H. (1) Begin with the three divisions of the small intestine. (2) Color the parts of the duodenum and the section of duodenal wall. The lamina propria (L) is identified and colored only in the enlarged view of the villi below.

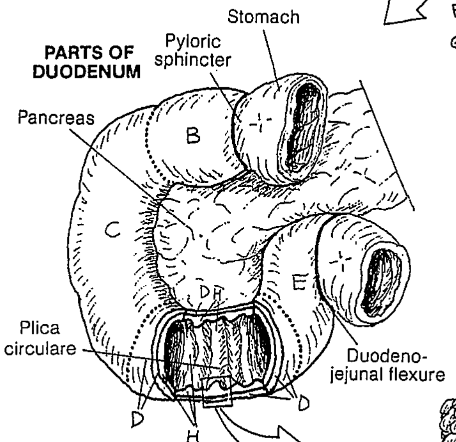


SMALL INTESTINE (Schematic)

DUODENUM A
- SUPERIOR (1ST) PART B
- DESCENDING (2ND) PART C
- HORIZONTAL (3RD) PART D
- ASCENDING (4TH) PART E

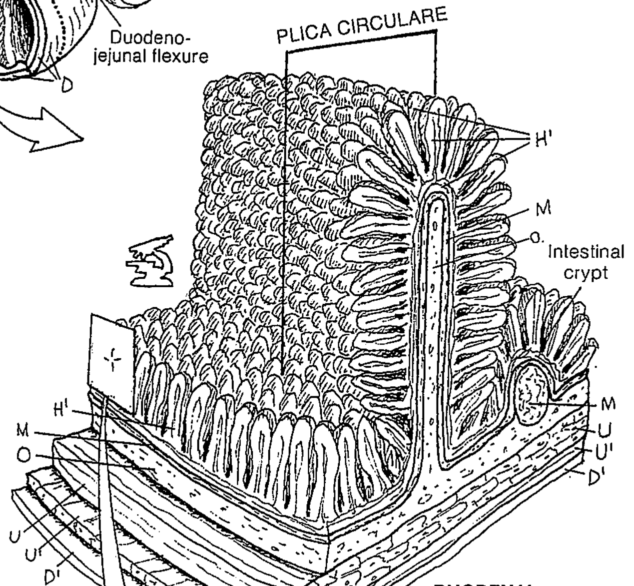
JEJUNUM F

ILEUM G



PARTS OF DUODENUM

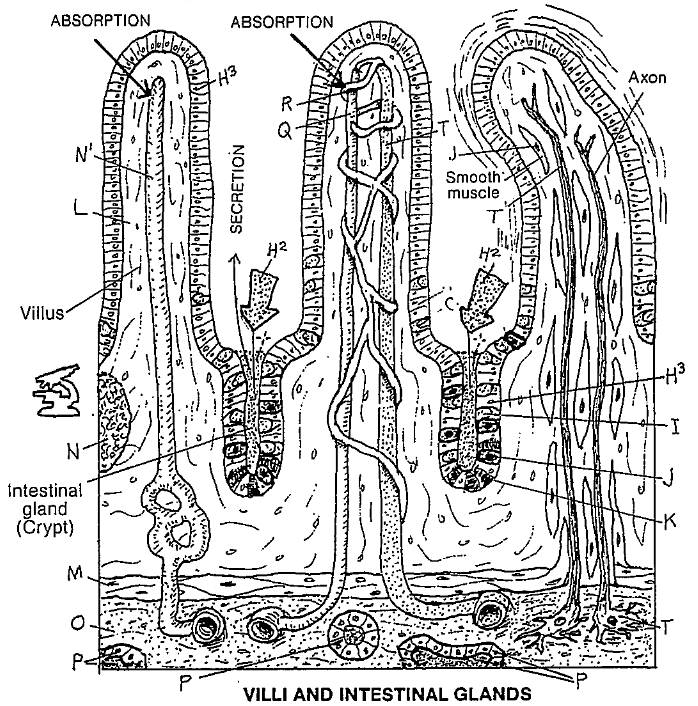
INTESTINAL WALL ✣
- PLICA CIRCULARE H
  - MUCOSA ✣
    - VILLUS H' / CRYPT H²
      - EPITHELIUM ✣
        - ABSORPTIVE CELL H³
        - MUCOUS (GOBLET) CELL I
        - ENTEROENDOCRINE CELL J
        - PANETH CELL K
      - LAMINA PROPRIA L
      - MUSCULARIS MUCOSAE M
      - LYMPHOID NODULE N
  - SUBMUCOSA O
    - DUODENAL GLAND P
  - ARTERY Q CAPILLARY R VEIN S LACTEAL N'
  - PARASYMP. POSTGANG. NEURON T
- MUSCULARIS EXTERNA: CIRC. DU / LONG. DU'
- SEROSA D'



DUODENAL WALL
(Longitudinal section through plica circulare)

The small intestine is a highly convoluted, thin-walled tube that undertakes much of the chemical and mechanical digestive process and almost the whole of the absorptive process of the entire gastrointestinal tract. The first part of the *duodenum* is suspended by the lesser omentum. The second and third parts are retroperitoneal. The fourth part emerges anteriorly to become embraced by the common mesentery, pulled upward/suspended by a band of smooth muscle at the duodenojejunal junction. The *jejunum* is highly coiled, suspended by the common mesentery between the peritoneal layers through which travel its blood and nerve supply and draining veins. The thinner but longer *ileum* also is suspended by the common mesentery. It opens into the cecum of the large intestine.

The internal or luminal surface of the small intestine, especially the jejunum, consists of a continuous series of circumferential (ring-like) folds (*plicae circulares*) composed of *mucosal* and *submucosal tissue.* Myriad conical, finger-like projections (*villi*) and deep tubular glands (*intestinal crypts*) characterize the mucosal surface. Simple columnar epithelia, mostly goblet-shaped mucous cells and absorptive cells, line the villi and crypts. In the crypts, the cells are secretory and produce a watery medium, enhancing uptake of minerals and nutrients. *Enteroendocrine* cells secrete a number of hormones that encourage glandular secretion (e.g., cholecystokinin and secretin). Potentially phagocytic *paneth cells* secrete lysozymes into the broth in the deep crypts. This digestive enzyme destroys bacterial cell walls. The loose fibrous, vascular *lamina propria* supports the lacteal-, blood vessel-, and axon-containing villi and the glands of the crypts. The *submucosa* supports large blood/lymph vessels and the cell bodies/axons of *parasympathetic neurons.* Both submucosa and lamina propria contain masses of lyphoid nodules (Peyer's patches; recall Plate 127). Specialized epithelial M or membranous cells at the epithelium-lymphoid nodule interface play a role in taking antigen to immune-reactive lymphocytes. In the duodenum, the glands of Brünner of the submucosa secrete a bicarbonate-containing mucus that neutralizes the hydrochloric acid entering from the stomach.



VILLI AND INTESTINAL GLANDS
(Structures common to all villi are shown separately)

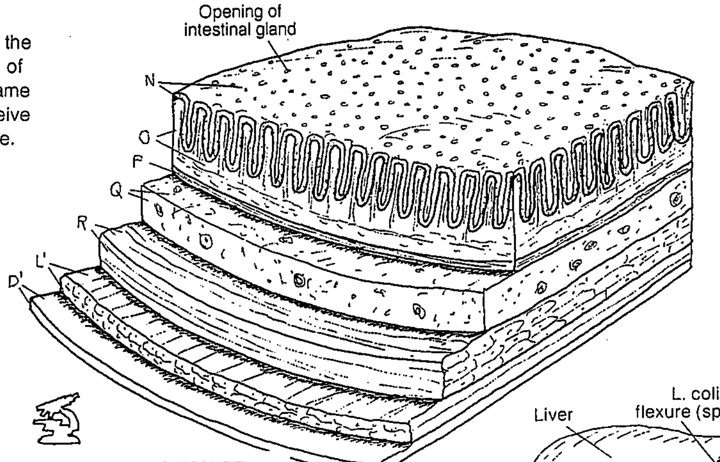
See 119

LARGE INTESTINE

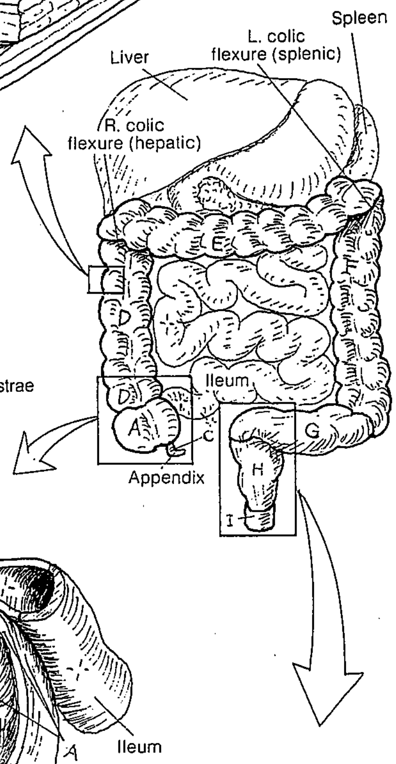
CN: By using the same colors for the parts of the intestinal wall you used on the preceding plate, you can demonstrate the similarity between the structures of the two intestines. The epithelium/mucous glands (N) should receive the same color as the villi (H[1]) of Plate 142, and the serosa in both plates should receive the same color. Use a very light color for B. (1) Begin with the section above.

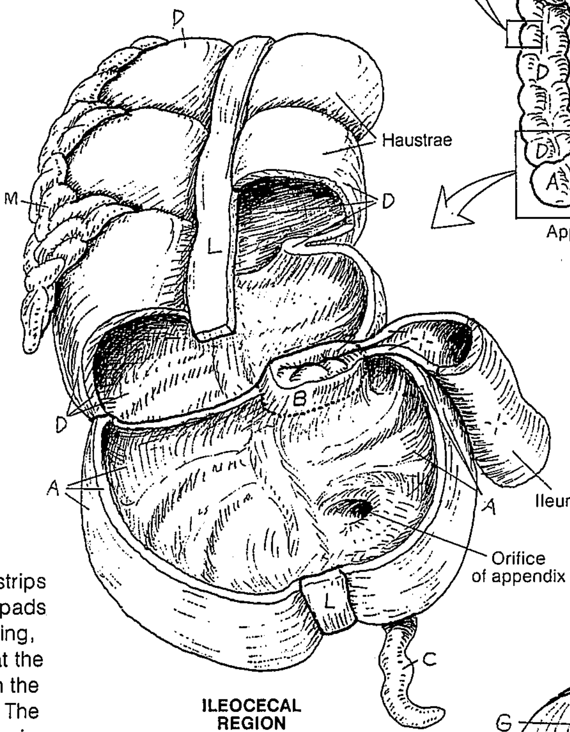
LARGE INTESTINE ✣
- CECUM A
  - ILEOCECAL VALVE B
  - VERMIFORM APPENDIX C
- ASCENDING COLON D
- TRANSVERSE COLON E
- DESCENDING COLON F
- SIGMOID (PELVIC) COLON G
- RECTUM H
  - ANAL CANAL I
  - INTERNAL ANAL SPHINCTER J
  - EXTERNAL ANAL SPHINCTER K
- TAENIA COLI L
- OMENTAL APPENDICES M

INTESTINAL WALL ✣
- MUCOSA ✣
  - EPITHELIUM/MUCUS GLANDS N
  - LAMINA PROPRIA O
  - MUSCULARIS MUCOSAE P
- SUBMUCOSA Q
- MUSCULARIS EXTERNA
  - CIRCULAR M. R
  - LONGITUDINAL M. L'
- SEROSA D'



SECTION OF LARGE INTESTINE

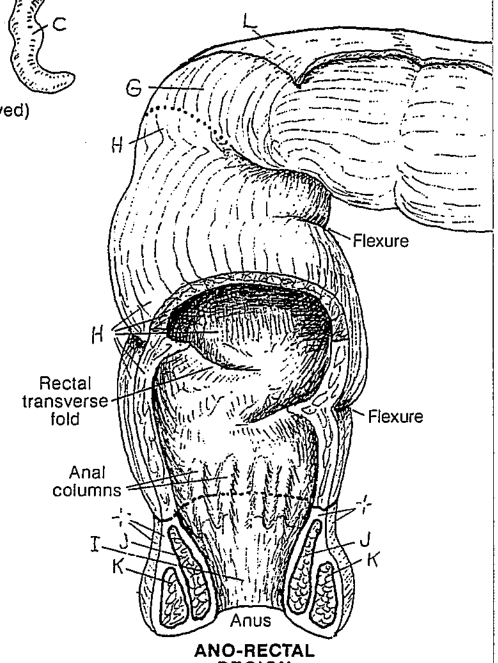




ILEOCECAL REGION
(Anterior portion of cecum removed)

The large intestine is characterized by large sacculations (haustrae), strips of *longitudinal muscle* in the muscularis externa (*taenia coli*), and fat pads (*appendices epiploica*) attached to the serosal surface of the ascending, transverse, and descending colon (only). The large intestine begins at the *ileocecal valve* with the *cecum*, usually suspended by a mesentery, in the right lower abdominal quadrant. The function of the valve is not clear. The *vermiform appendix* varies in length (2–20 cm); it may lie anterior, posterior, or inferior to the cecum. The *ascending* and *descending colons* are retroperitoneal; the *transverse colon* is suspended by a mesentery (transverse mesocolon). Note the colic flexures and their relationships. At the pelvic inlet (not shown), the colon turns medially, gains a mesentery (sigmoid mesocolon), and is named the *sigmoid colon*. Variable in its extent and shape, it becomes the *rectum* at the level of the S3 vertebra. Here the haustrae, the appendices epiploica, and the taenia are no longer seen. About 12 cm long, the rectum has a dilated lower part (ampulla). Feces entering the rectum stimulate the desire for defecation; thus, the rectum is not a long-term storage site. As the rectum narrows inferiorly, it becomes the *anal canal* surrounded by *sphincter muscles*.

The wall of the large intestine is characteristic: *mucosal* surface without villi or plicae, underlying vascular *submucosa*, and two-layered *muscularis externa* lined with peritoneal *serosa*. The epithelial lining is simple columnar except in the anal canal where it becomes stratified squamous. The glands are tubular and mucus-secreting. Lymphoid nodules are seen in the lamina propria. At the anorectal junction, about 2 cm above the anus, a remarkably large number of veins can be seen in the lamina propria (not shown). Varicose dilatations of these veins (rectal or hemorrhoidal plexus) are called hemorrhoids. The large intestine functions in absorption of water, vitamins, and minerals as well as the secretion of mucus.



ANO-RECTAL REGION

See 119, 136, 140, 145

LIVER

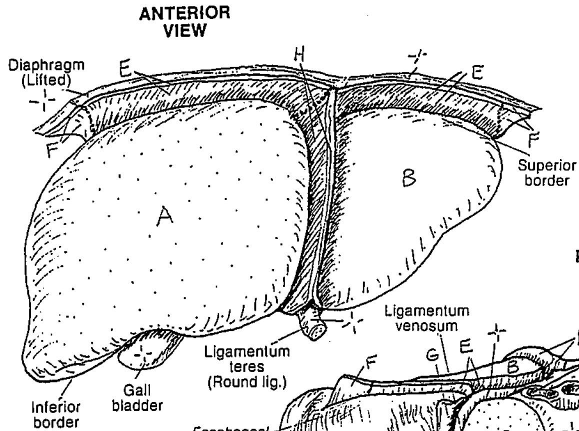
CN: Use blue for I, red for J, and yellow for K. Use very light colors for A, B, and L. (1) Color the two upper views simultaneously. (2) Color the group of lobules, and then the enlargement. Begin with the branches of the portal vein (I^1) at the bottom of the section. (3) Begin the overview of blood and bile with the arterial flow.

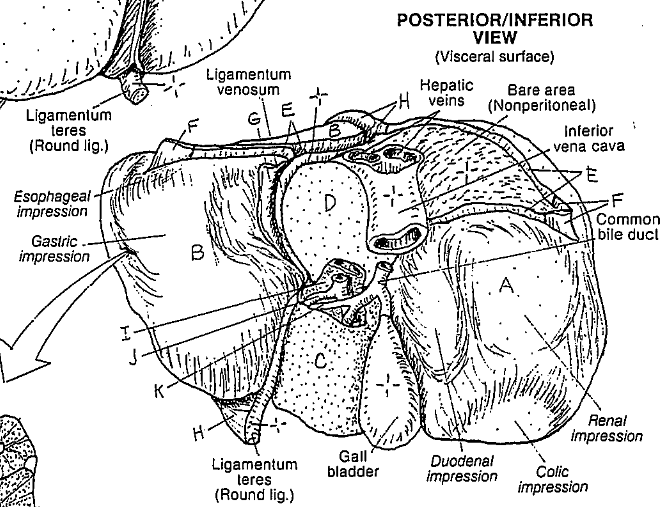
LOBES -:-
- RIGHT LOBE A
- LEFT LOBE B
- QUADRATE LOBE C
- CAUDATE LOBE D

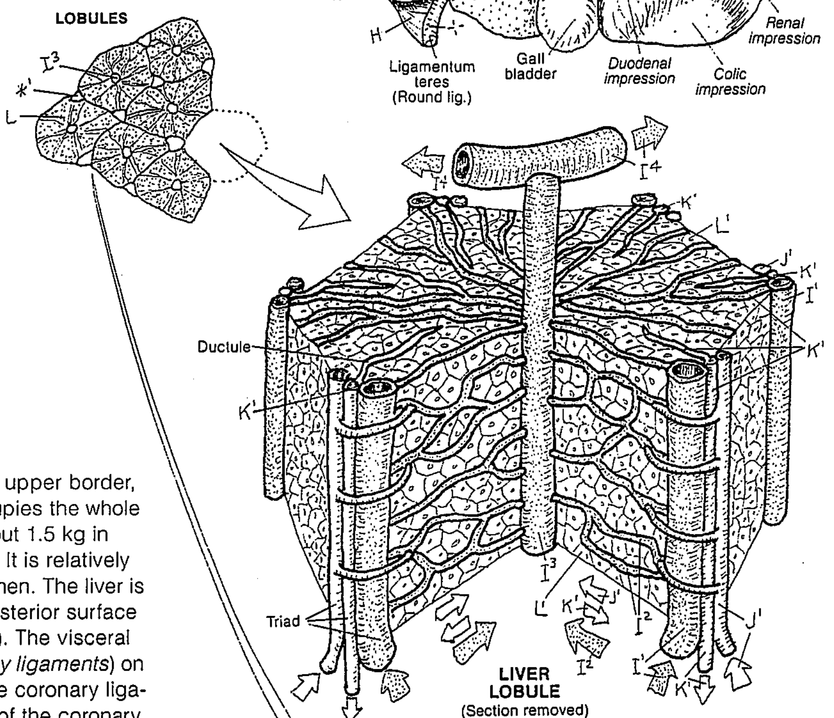
LIGAMENTS -:-
- CORONARY L. E
- TRIANGULAR L. F
- LESSER OMENTUM G
- FALCIFORM L. H

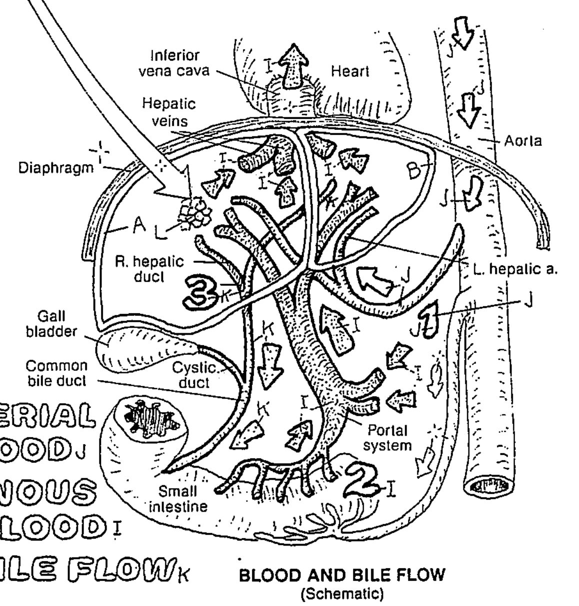
PORTA -:-
- PORTAL VEIN I
- HEPATIC ARTERY J
- BILE DUCT K

LIVER LOBULE L
- TRIAD *'
  - BRANCH OF PORTAL V. I'
  - BRANCH OF HEPATIC A. J'
  - BILE DUCT K'
- SINUSOID I^2
- HEPATIC CELL L'
- CENTRAL VEIN I^3
- TRIBUTARY OF HEPATIC V. I^4









1 ARTERIAL BLOOD J
2 VENOUS BLOOD I
3 BILE FLOW K

BLOOD AND BILE FLOW
(Schematic)

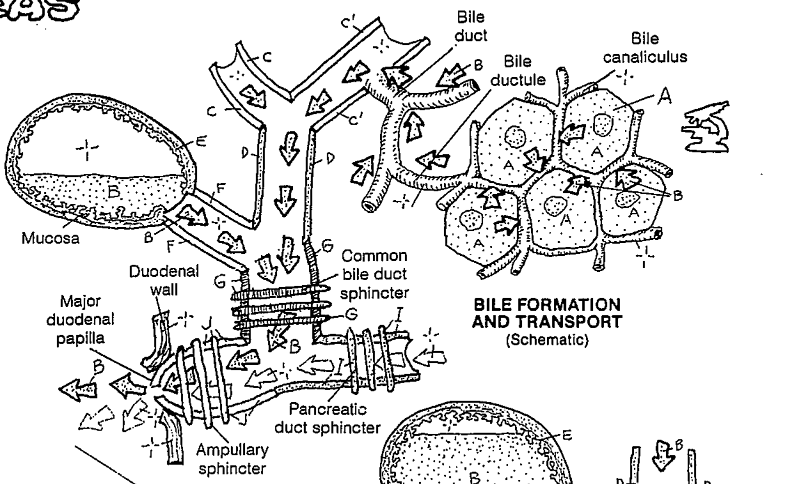
The liver is the largest gland in the body. Wedge-shaped (rounded upper border, thin, sharp inferior border) when seen from the side, the liver occupies the whole of the upper right quadrant of the abdominal cavity. Weighing about 1.5 kg in health, it can weigh over 10 kg when diseased (chronic cirrhosis). It is relatively large in young children, causing protuberance of the upper abdomen. The liver is enveloped in visceral peritoneum, except for a part of the right posterior surface that is flush against the fascia covering the diaphragm (bare area). The visceral peritoneum around the bare area turns or reflects upward (*coronary ligaments*) on to the diaphragm to become parietal peritoneum. The edges of the coronary ligaments are called the *triangular ligaments*. The two anterior leaves of the coronary ligaments join to become the *falciform ligament*; the two posterior leaves become the *lesser omentum*, which encircles the *porta*, of the liver. Here the hepatic *portal vein* and the *hepatic artery* approach the visceral surface of the liver and branch, and the common bile duct receives the common hepatic duct and cystic duct. The two-layered lesser omentum descends to support the pyloric end of the stomach and the first part of the duodenum. The falciform ligament is continuous with the parietal peritoneum of the anterior abdominal wall.

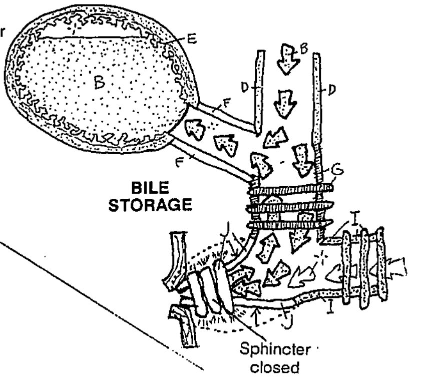
Connective tissue septa divide the liver cells/tissue (parenchyma) into irregular polyhedral *lobules*. Within each lobule, the cells form radially arranged cords; on two surfaces of these cords are sinusoids that converge onto a more or less *central vein*. At the corners of the lobules are the hepatic artery and portal vein branches, and bile ducts (called a *triad*). The portal vein branches feed into the sinusoids; the hepatic artery branches supply the cells; the *bile ducts* drain the bile ductules formed from tiny canaliculi (not shown) surrounding the cells. The liver cells discharge their products into the sinusoids (except bile) and absorb from the same sinusoids various nutrients and non-nutrients as well. Liver cells store and release proteins, carbohydrates, lipids, iron, and certain vitamins (A, D, E, K); they manufacture urea from amino acids, and bile from pigments and salts; they detoxify many harmful ingested substances. Bile is released from the cells into tributaries of bile ducts. The central veins are tributaries of larger veins that merge to form three *hepatic veins* at the posterior, superior aspect of the liver. These veins join the inferior vena cava just inferior to the diaphragm.

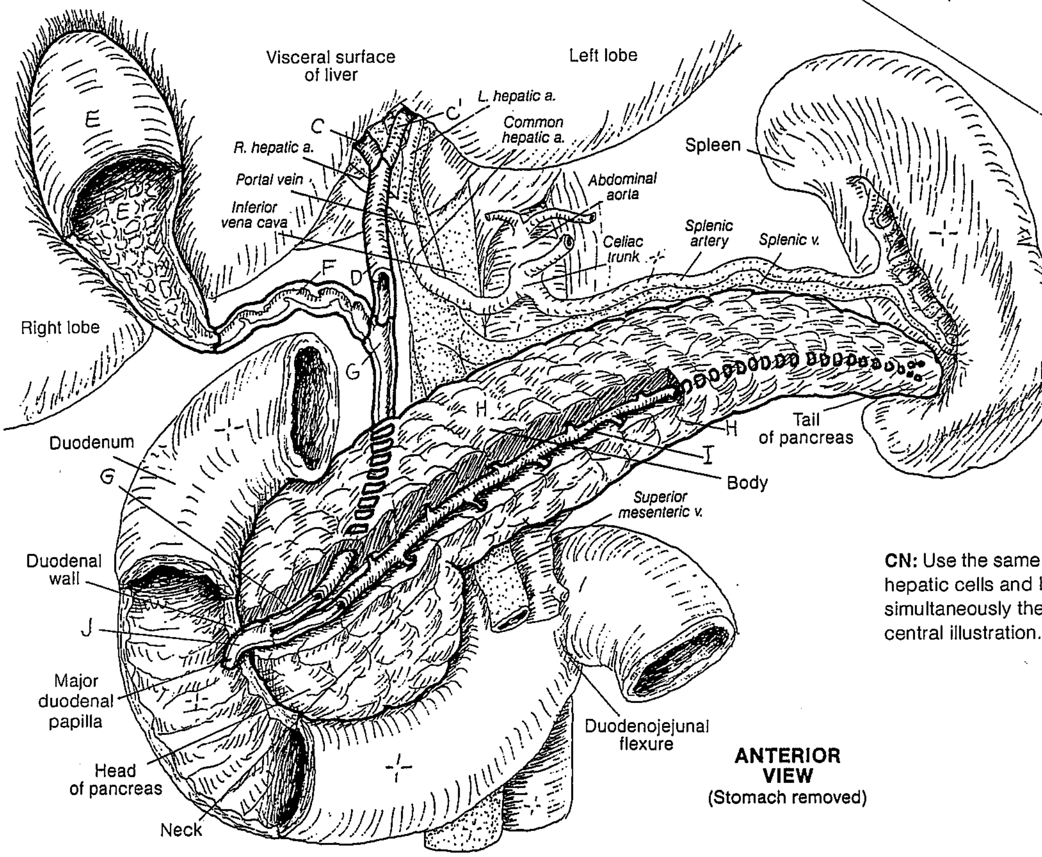
See 136, 144, 156

BILIARY SYSTEM & PANCREAS

LIVER (HEPATIC) CELL A
BILE B
R. C & L. HEPATIC DUCT C'
COMMON HEPATIC DUCT D
GALL BLADDER E
CYSTIC DUCT F
COMMON BILE DUCT G
PANCREAS H
PANCREATIC DUCT I
HEPATO-DUODENAL AMPULLA J







CN: Use the same colors as were used on the preceding plate for the hepatic cells and bile ducts, and a very light color for H. (1) Color simultaneously the diagram of bile formation/transport and the large central illustration. (2) Color the diagram describing bile storage.

The biliary system consists of an arrangement of *ducts* transporting *bile* from the *liver cells* that manufacture it to the *gall bladder* and to the second part of the duodenum.

It is worth repeating: bile is formed in the liver (not the gall bladder). It is a fluid consisting largely of water (97%), with bile salts and pigments (from the breakdown products of hemoglobin in the spleen). Once formed, bile is discharged from liver cells into surrounding *bile canaliculi.* These small canals merge to form bile ductules that join the bile ducts, which travel in company with the branches of the portal vein and hepatic artery. The bile is brought out of the liver by the *right and left hepatic ducts,* which merge at the porta to form the *common hepatic duct.* That duct descends between the layers of the lesser omentum and receives the 4-cm-long *cystic duct* from the *gall bladder.* The gall bladder is pressed against the visceral surface of the right lobe of the liver, covered with visceral peritoneum. The *common bile duct* (or just bile duct) is formed by the cystic and common hepatic duct. About 8 cm long, it descends behind the first part of the duodenum, deep to or through the head of the pancreas. It usually joins with the main *pancreatic duct,* forming an *ampulla* in the wall of the second part of the duodenum. Here the duct opens into the lumen of the duodenum. There can be variations in the union of these two ducts.

The gall bladder serves as a storage chamber for bile discharged from the liver. Bile is concentrated here several times, a fact reflected in the multiple microvilli on the luminal surfaces of the simple columnar epithelial cells that absorb water from the dilute bile. In response to the gastric or duodenal presence of fat, secretion of cholecystokinin is induced, which stimulates the gall bladder to discharge its contents into the cystic duct. Peristaltic contractions of the duct musculature squirt bile into the duodenal lumen through the ampullary sphincter. Bile saponifies and emulsifies fats, making them water soluble and amenable to digestion by enzymes (lipases).

The pancreas is a gland in the retroperitoneum, consisting of a head, neck, body, and tail. Most of the pancreas consists of exocrine glands that secrete enzymes into the pancreatic duct tributaries and on into the duodenum at a rate of about 2000 ml per day. These enzymes are responsible for a major part of chemical digestion in the small intestine (lipases for fat, peptidases for protein, amylases for carbohydrates, and others). Pancreatic secretion is regulated by hormones (primarily cholecystokinin and secretin) from entero-endocrine cells and by the vagus nerves (acetylcholine). The endocrine portion of the pancreas is covered in Plate 156.