DIGESTIVE SYSTEM

DIGESTIVE SYSTEM

COMPONENTS OF THE GI TRACT

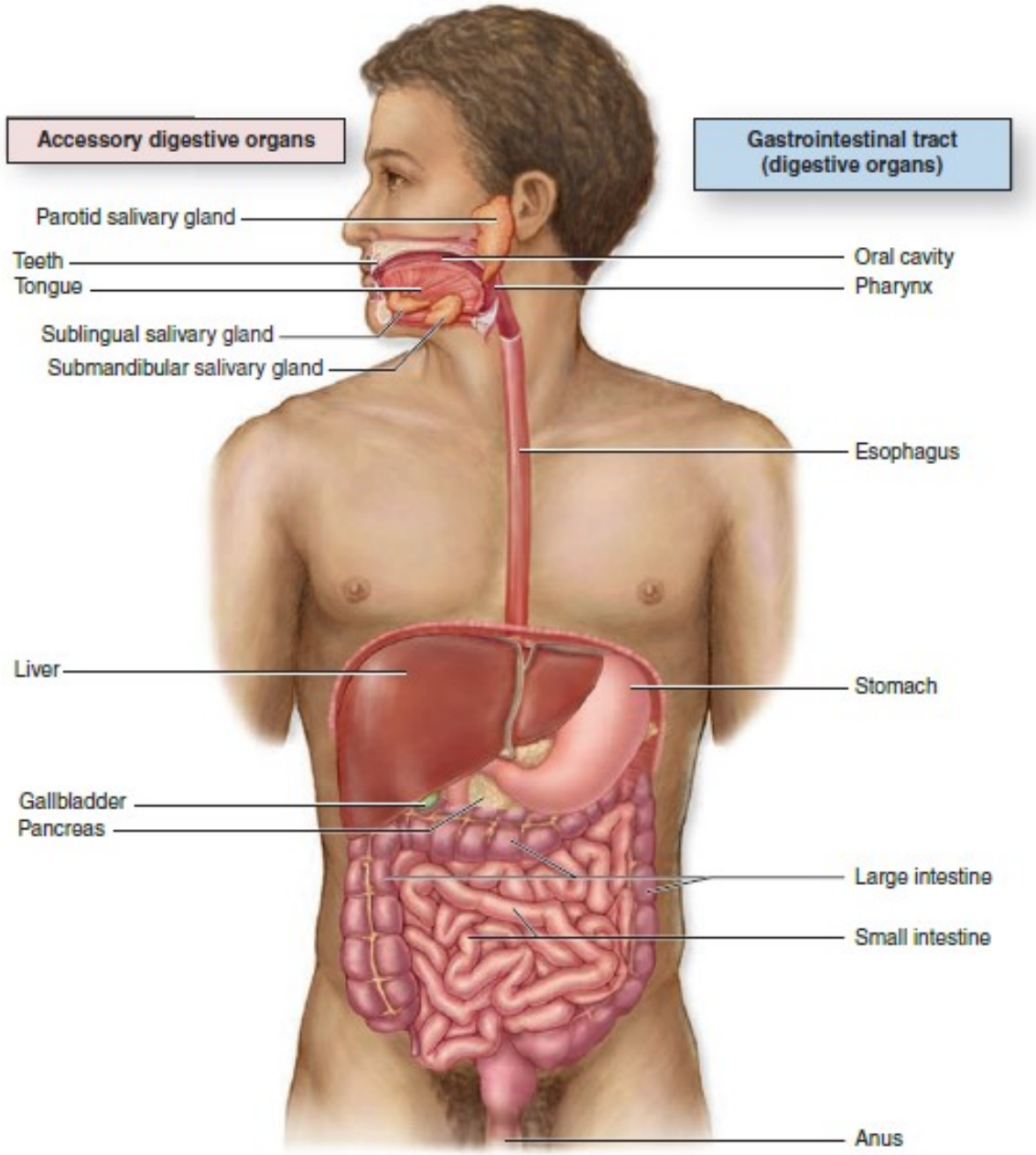
The digestive tract consist of:

- Oral cavity
- Esophagus
- Stomach
- Small and large intestines

Organs associated with the digestive tract:

- Salivary glands
- Pancreas
- Liver
- Gallbladder

- FUNCTION of the GI tract:
- To obtain from ingested food nutrients and energy
- Ingestion, fragmentation, digestion, absorption, elimination fo waste products
- Protective barrier



DIGESTIVE SYSTEM

BASIC HISTOLOGICAL ORGANIZATION

Glands

- *Exocrine glands*, aiding in digestion and/or lubrication, are located in:
  - Epithelium (e.g., goblet cells throughout the intestines)
  - Lamina propria (e.g., gastric glands)
  - Submucosa (e.g., Brunner's glands in the duodenum)
  - Glands located external to the digestive tract that open into the system (e.g., liver and pancreas)

- *Endocrine and paracrine cells*, belonging to the diffuse neuroendocrine system (DNES), are located throughout the mucosa of the gastrointestinal tract, influencing the secretion of glands and the motility of the gut

DIGESTIVE SYSTEM

ORAL CAVITY

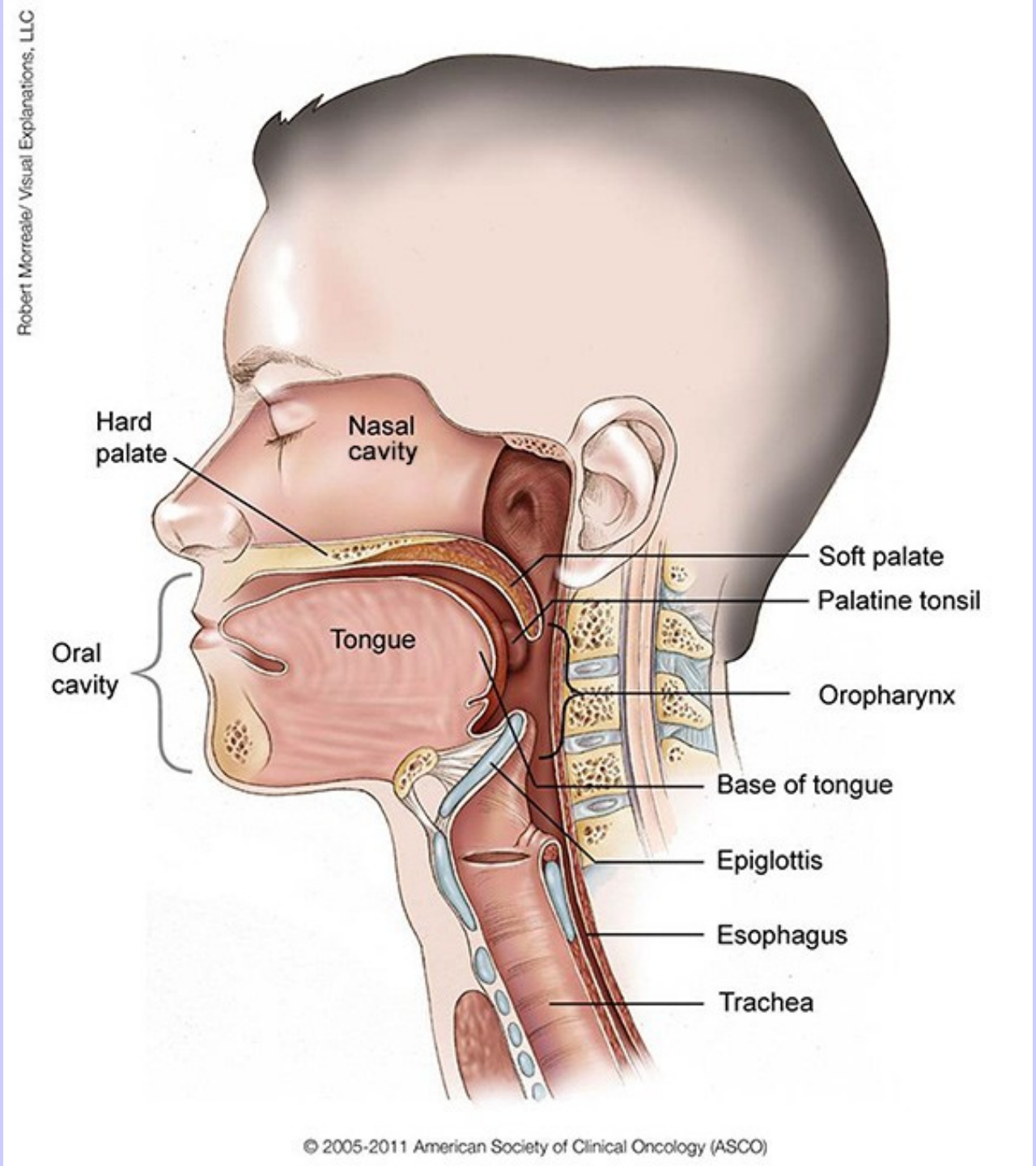
- In the oral cavity starts the digestive process with ingestion, fragmentation and moistening of food.
- Oral cavity is involved in speech, facial expression, sensory reception and breathing.

- **Major structures:**
  - lips
  - teeth
  - tongue
  - oral mucosa
  - hard and soft palate
  - associated salivary glands

Oral mucosa

- Oral mucosa, the protective mucous membrane (mucosa) lining the oral cavity, is continuous with external skin and with the mucous membrane of the pharynx.

- Composition:
  - *Epithelium*. Stratified squamous keratinized or nonkeratinized depending on location
  - *Lamina propria.* Collagenous tissue
  - *Muscularis mucosae* is not present.
  - Although not part of the oral mucosa, a submucosa of dense connective tissue, containing the minor salivary glands, underlies much of the oral mucosa.


Robert Morreale/ Visual Explanations, LLC
Hard palate
Nasal cavity
Soft palate
Palatine tonsil
Tongue
Oral cavity
Oropharynx
Base of tongue
Epiglottis
Esophagus
Trachea
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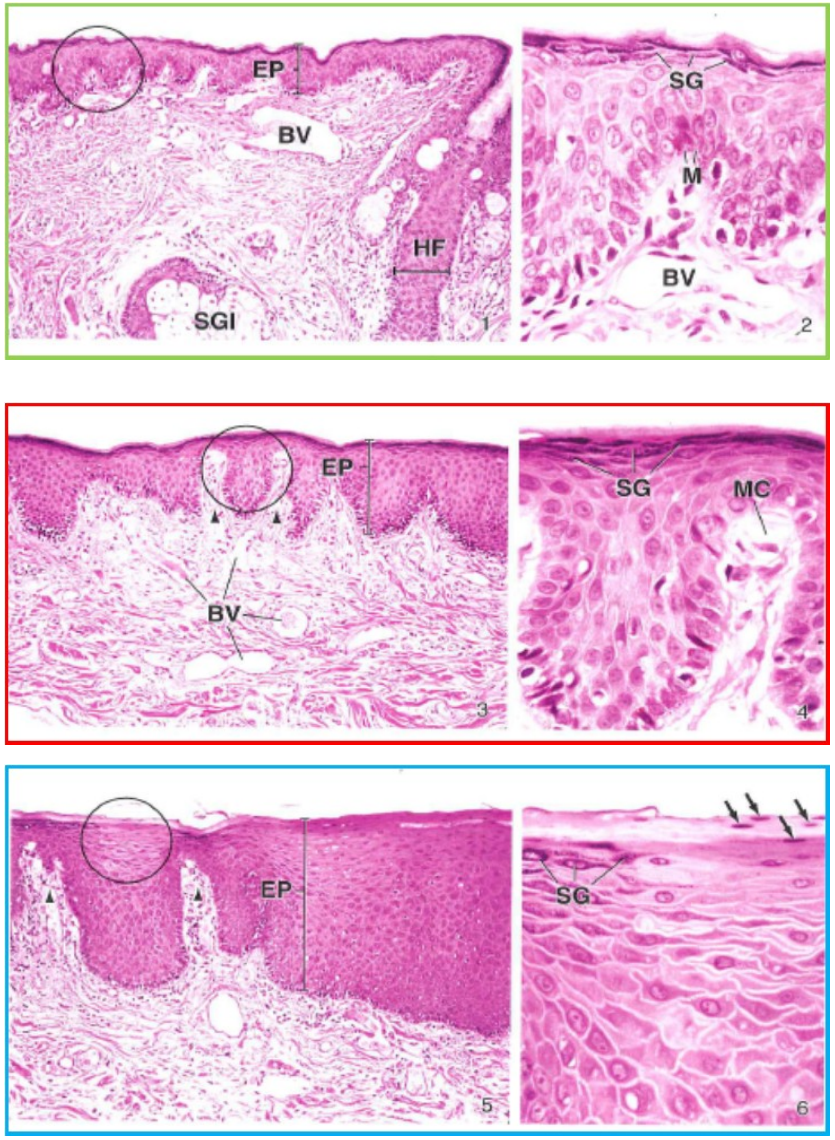
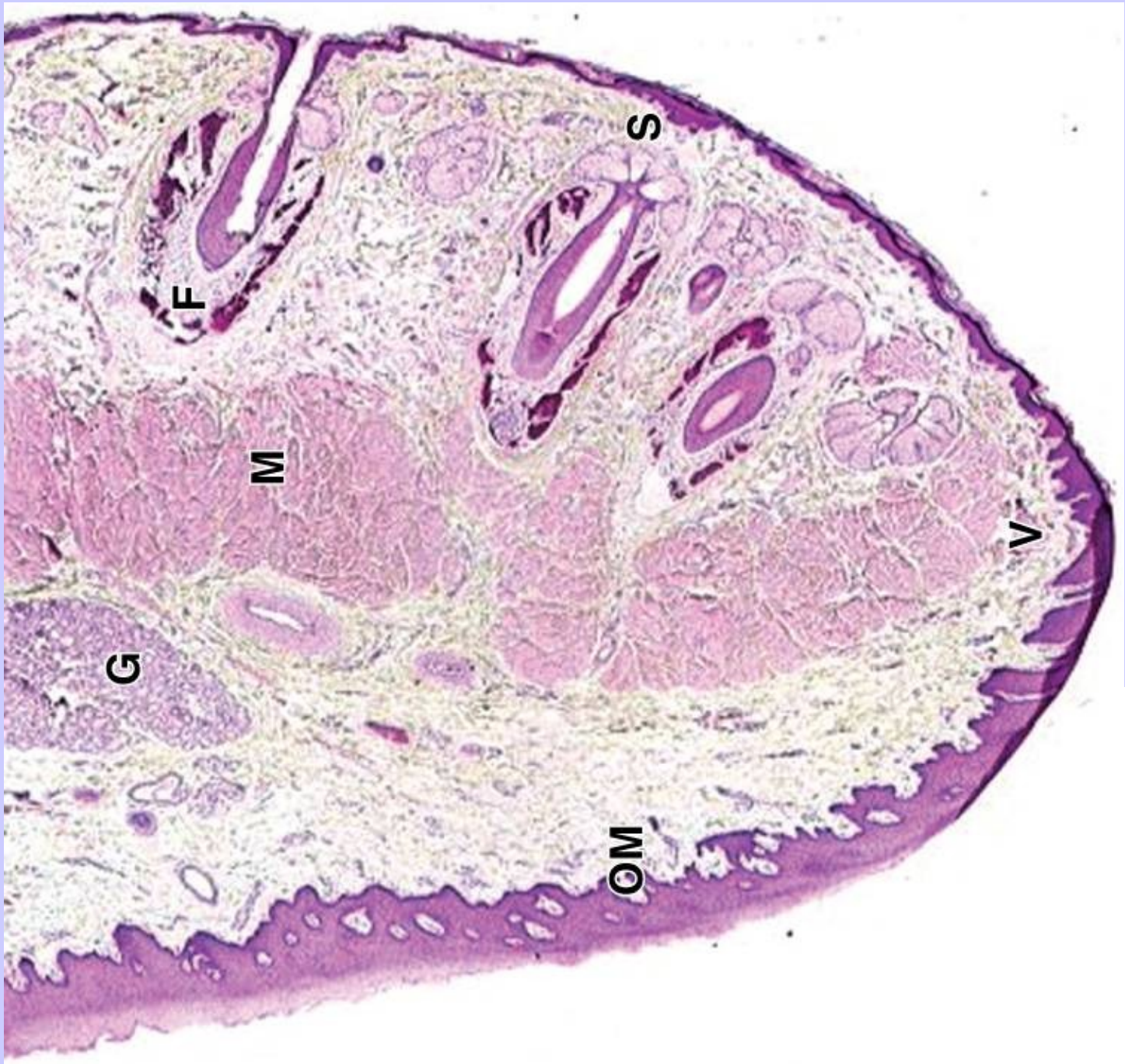
DIGESTIVE SYSTEM

LIPS

- Forms the anterior boundary of the oral cavity, the space between the inner surfaces of the lips and cheeks and the outer surface of the teeth and gingiva
- Regions:
  - **Exterior surface**
    - Covered by thin skin
    - Hair follicles and sebaceous glands are present
  - **Vermilion zone**
    - Forms the red-colored portion of the lip
      - Covered by a thin, stratified squamous keratinized epithelium
      - Mucosa contains numerous, densely packed dermal papillae
      - Papillae allow blood vessels close access to the surface
    - Lacks hair follicles
  - **Inner surface**
    - Lined by oral mucosa, stratified squamous moist epithelium
    - Minor salivary glands (labial glands) in the submucosa secrete both mucous and serous products.





Low-magnification micrograph of a lip section showing one side covered by typical oral mucosa (**OM**), the opposite side covered by skin (**S**) containing hair follicles (**F**) and associated glands. Between the oral portion of the lips and normal skin is the vermilion zone (**V**), where epidermis is very thin, lightly keratinized, and transparent to blood in the rich microvasculature of the underlying connective tissue. Because this region lacks the glands for oil and sweat, it is prone to excessive dryness and chapping in cold, dry weather. Internally, the lips contain much striated muscle (**M**) and many minor salivary glands (**G**). (X10; H&E)

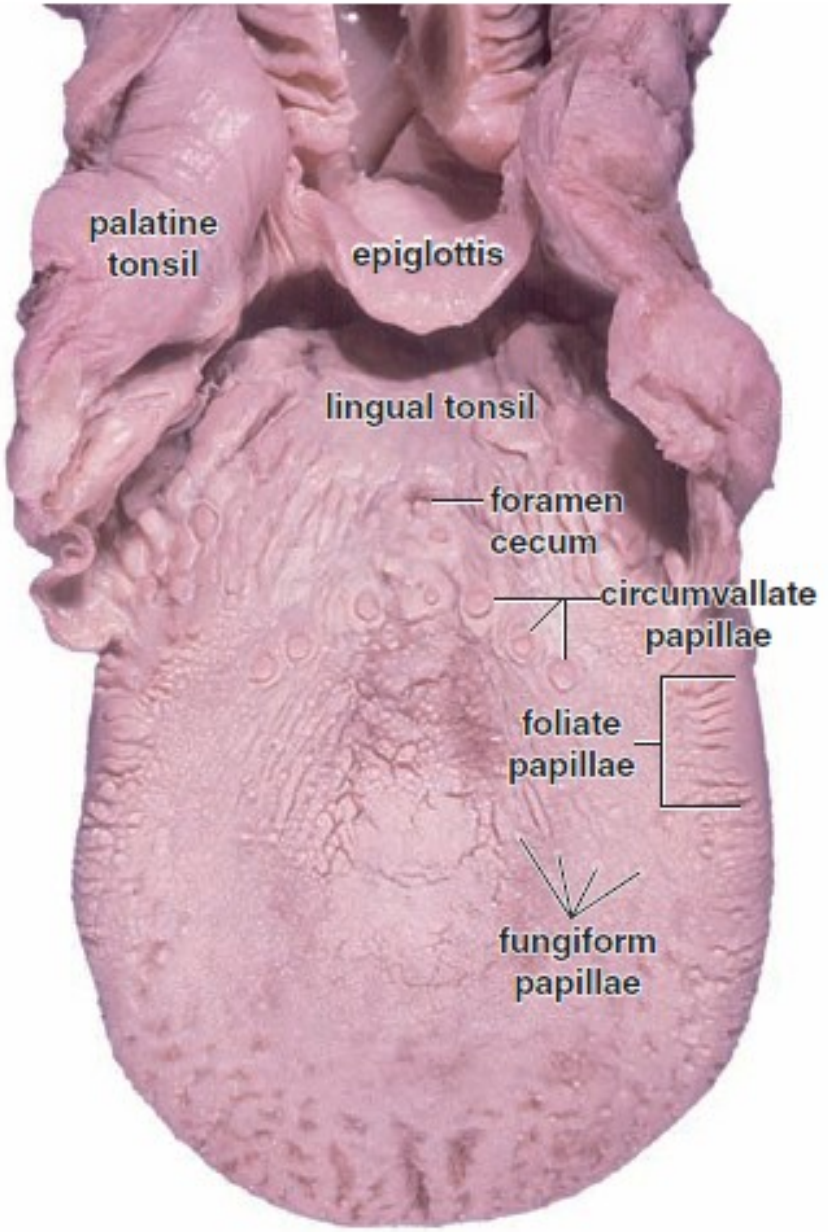
TONGUE

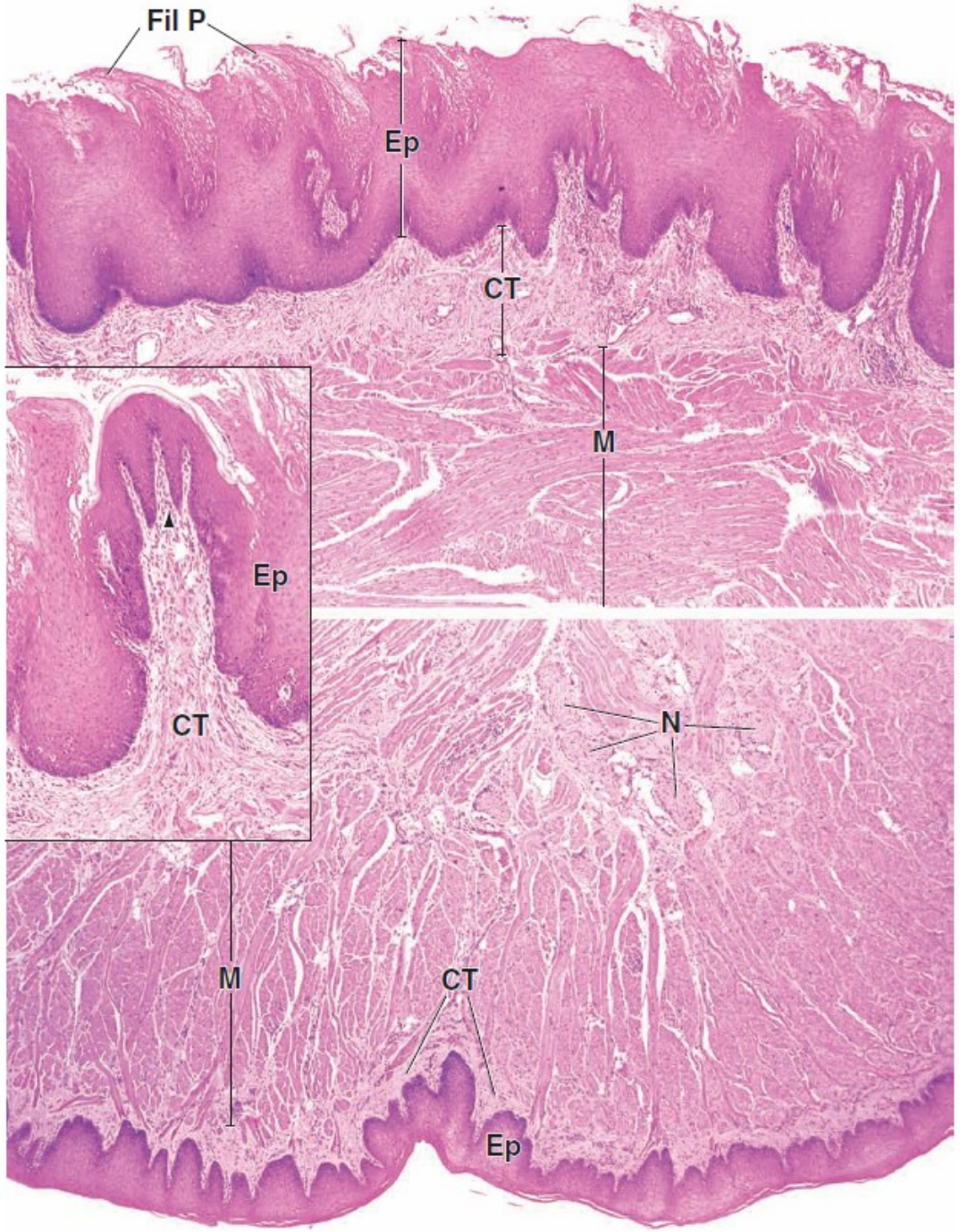
Composition:

- *Mucosa:*
  - Dorsum of the tongue is covered by a specialized oral mucosa, modified to form *papillae*.
  - The ventral surface of the tongue is covered by a lining mucosa.

- The *submucosa* possesses minor salivary glands that are mucus-secreting except for those associated with the circumvallate papillae, which are serous-secreting.

- *Intrinsic tongue muscles*. Skeletal muscle bundles are arranged in three separate planes, with connective tissue bands from the lamina propria separating the bundles and firmly anchoring the muscle to the mucous membrane.

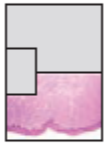




Dorsal surface, tongue, monkey, H&E ×65; inset ×130.

This figure shows the dorsal surface of the tongue with the **filiform papillae** *(Fil P)*. They are the most numerous of the three types of papillae. Structurally, they are bent, conical projections of the epithelium, with the point of the projection directed posteriorly. These papillae do not possess taste buds and are composed of stratified squamous keratinized epithelium.

The **fungiform papillae** are scattered about as isolated, slightly rounded, elevated structures situated among the filiform papillae. A fungiform papilla is shown in the *inset*. A large connective tissue core (primary connective tissue papilla) forms the center of the fungiform papilla, and smaller connective tissue papillae (secondary connective tissue papillae) project into the base of the surface epithelium *(arrowhead)*. The connective tissue of the papillae is highly vascularized. Because of the deep penetration of connective tissue into the epithelium, combined with a very thin keratinized surface, the fungiform papillae appear as small red dots when the dorsal surface of the tongue is examined by gross inspection.



Ventral surface, tongue, monkey, H&E ×65.

The ventral surface of the tongue is shown in this figure. The smooth surface of the **stratified squamous epithelium** *(Ep)* contrasts with the irregular surface of the dorsum of the tongue. Moreover, the epithelial surface on the ventral surface of the tongue is usually not keratinized. The connective tissue *(CT)* is immediately deep to the epithelium; deeper still is the striated muscle *(M)*. The numerous connective tissue papillae that project into the base of the epithelium of both ventral and dorsal surfaces give the epithelial–connective tissue junction an irregular profile. Often, these connective tissue papillae are cut obliquely and then appear as small islands of connective tissue within the epithelial layer (see figure above).

The connective tissue extends as far as the muscle without changing character, and no submucosa is recognized. The muscle *(M)* is striated and is unique in its organization, that is, the fibers travel in three planes. Therefore, most sections will show bundles of muscle fibers cut longitudinally, at right angles to each other, and in cross-section. Nerves *(N)* that innervate the muscle are also frequently observed in the connective tissue septa between the muscle bundles.

The surface of the tongue behind the vallate papillae (the root of the tongue) contains lingual tonsils (not shown). These are similar in structure and appearance to the palatine tonsils illustrated in Plate 36.

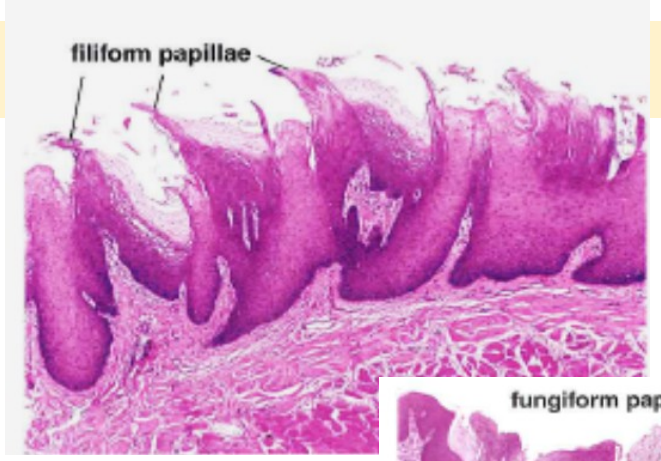
CT, connective tissue
Ep, epithelium
Fil P, filiform papillae
M, striated muscle bundles
N, nerves
arrowhead (inset), secondary connective tissue papilla

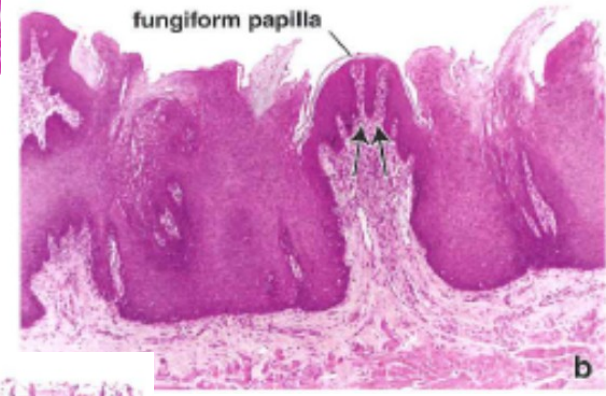
TONGUE

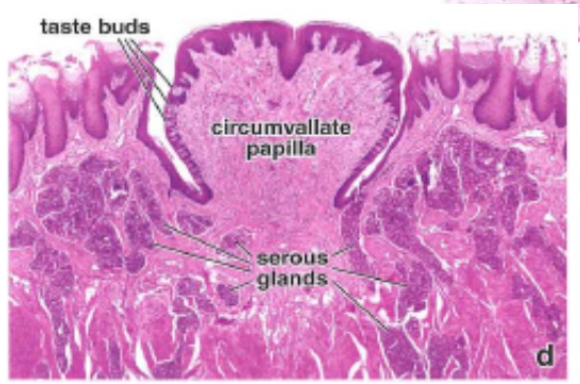
- **Papillae**

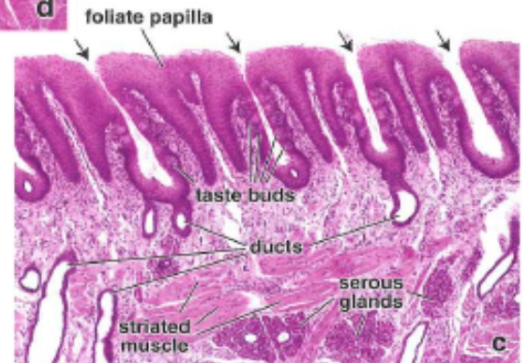
Each consists of a connective tissue core covered by a stratified squamous epithelium.

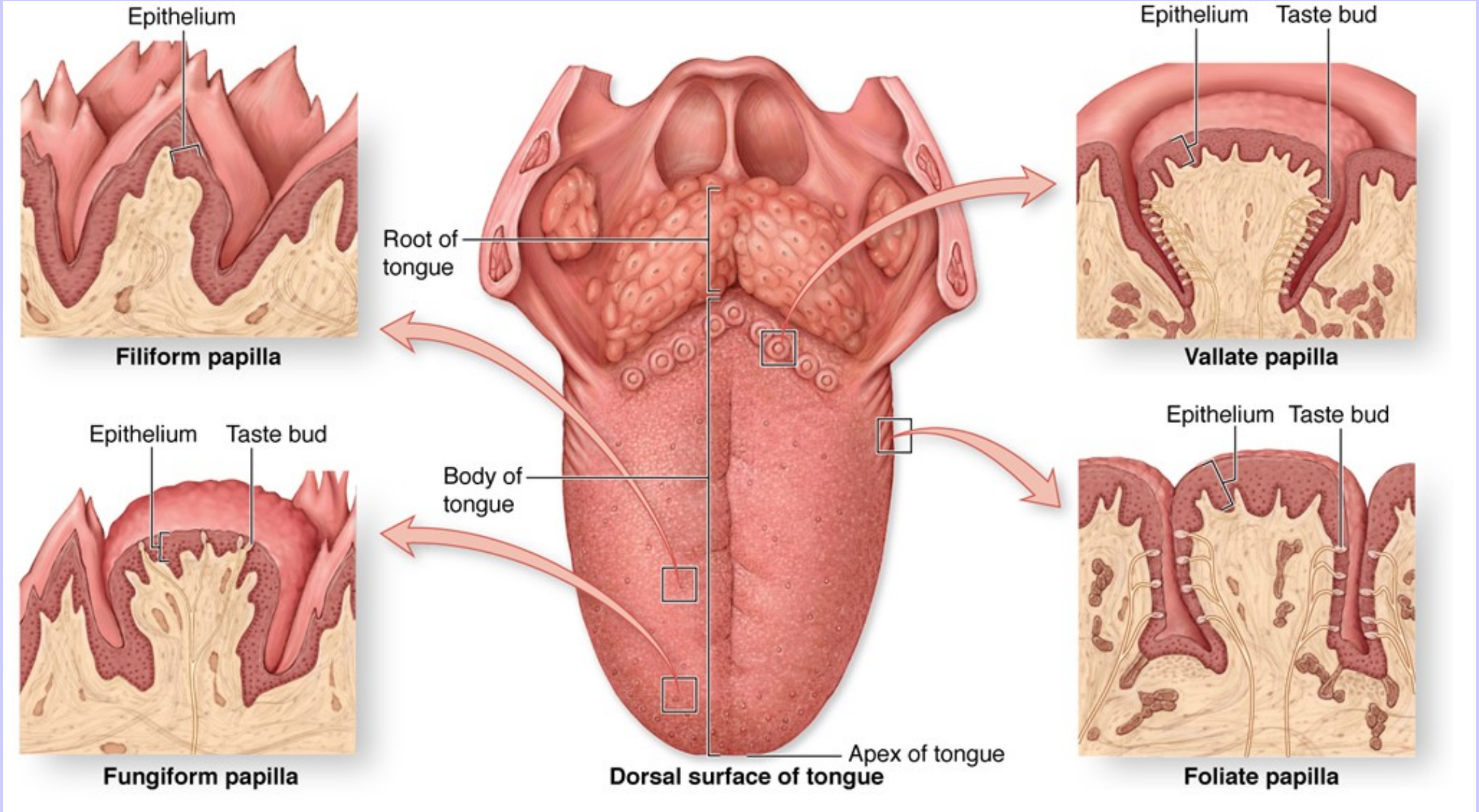
- *Filiform*
  - Most numerous; cover body of tongue
  - Cone-shaped protrusions angled so that they aid in movement of food toward the pharynx
- *Fungiform*
  - Less numerous than filiform but also located on anterior two-thirds of tongue
  - Mushroom shaped, possess taste buds on superior surface
- *Circumvallate*
  - Eight to twelve papillae located just anterior to the sulcus terminalis
  - Mushroom shaped and surrounded by a narrow moat; lateral wall of each papilla possesses taste buds
  - Serous glands of von Ebner open into the base of the moat and flush the moat for reception of new tastes.
- *Foliate*
  - Parallel folds on the posterolateral surface of the tongue; not well developed in humans







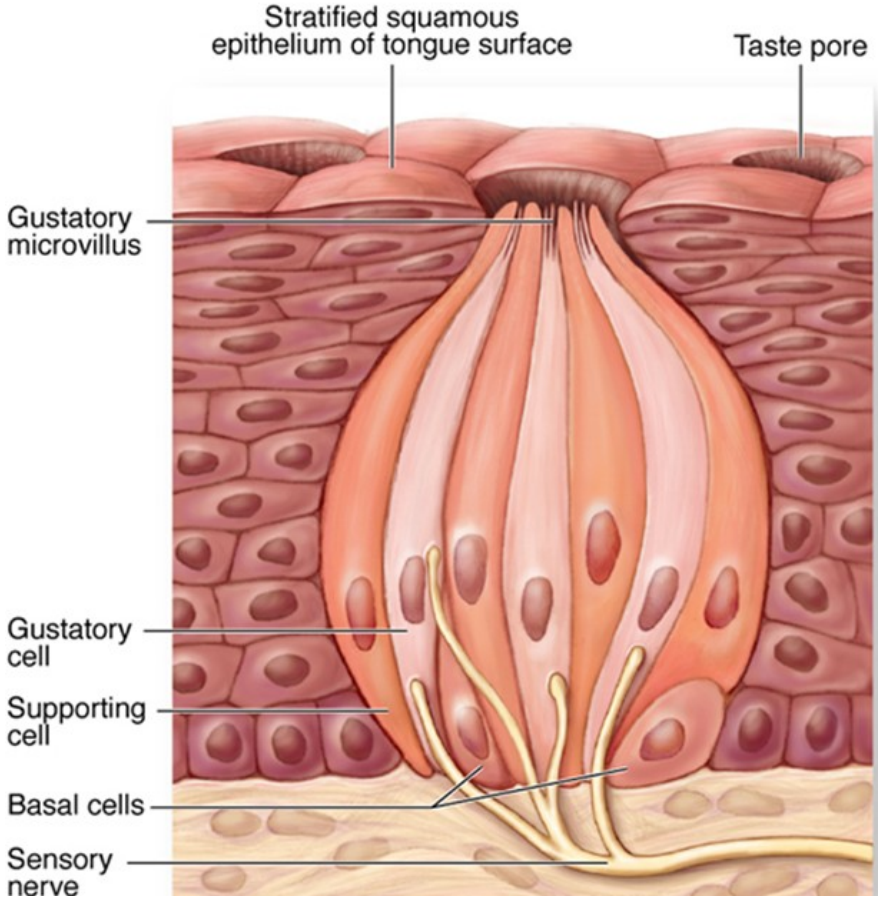


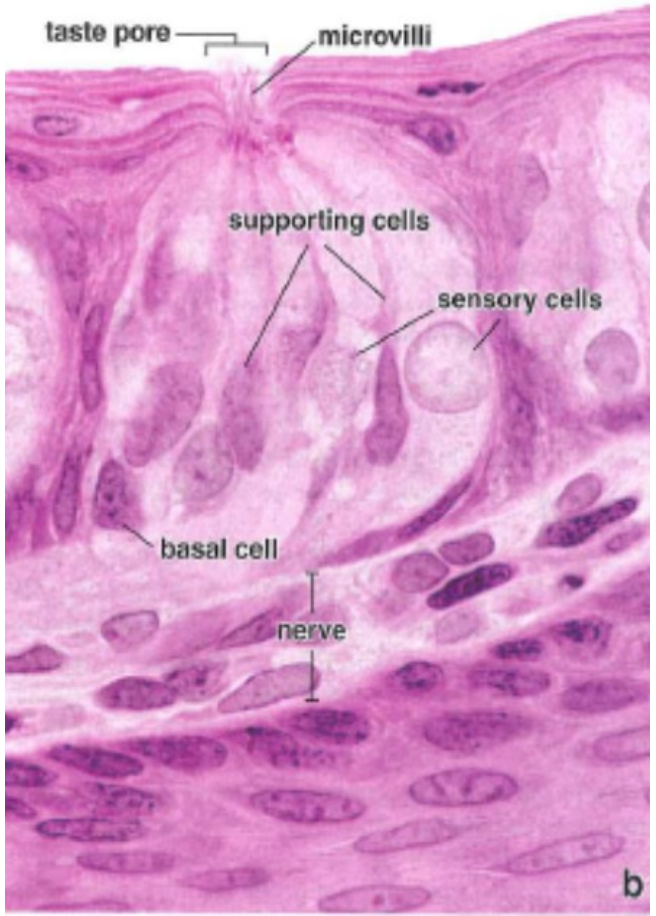

Epithelium
Filiform papilla
Epithelium
Taste bud
Vallate papilla
Root of tongue
Body of tongue
Epithelium
Taste bud
Fungiform papilla
Epithelium
Taste bud
Foliate papilla
Apex of tongue
Dorsal surface of tongue

DIGESTIVE SYSTEM

TONGUE

- Taste buds are onion-shaped structures embedded in the surface of the fungiform and circumvallate papillae. Taste buds contain **taste-receptor cells** (gustatory) that communicate with the surface of the papilla through a **taste pore.** Other cells are **supportive cells** and **basal stem cells**. Depolarization of the taste cells leads to the stimulation of **gustatory nerve fibers** and the discrimination of sweet, salty, bitter, and sour sensations.



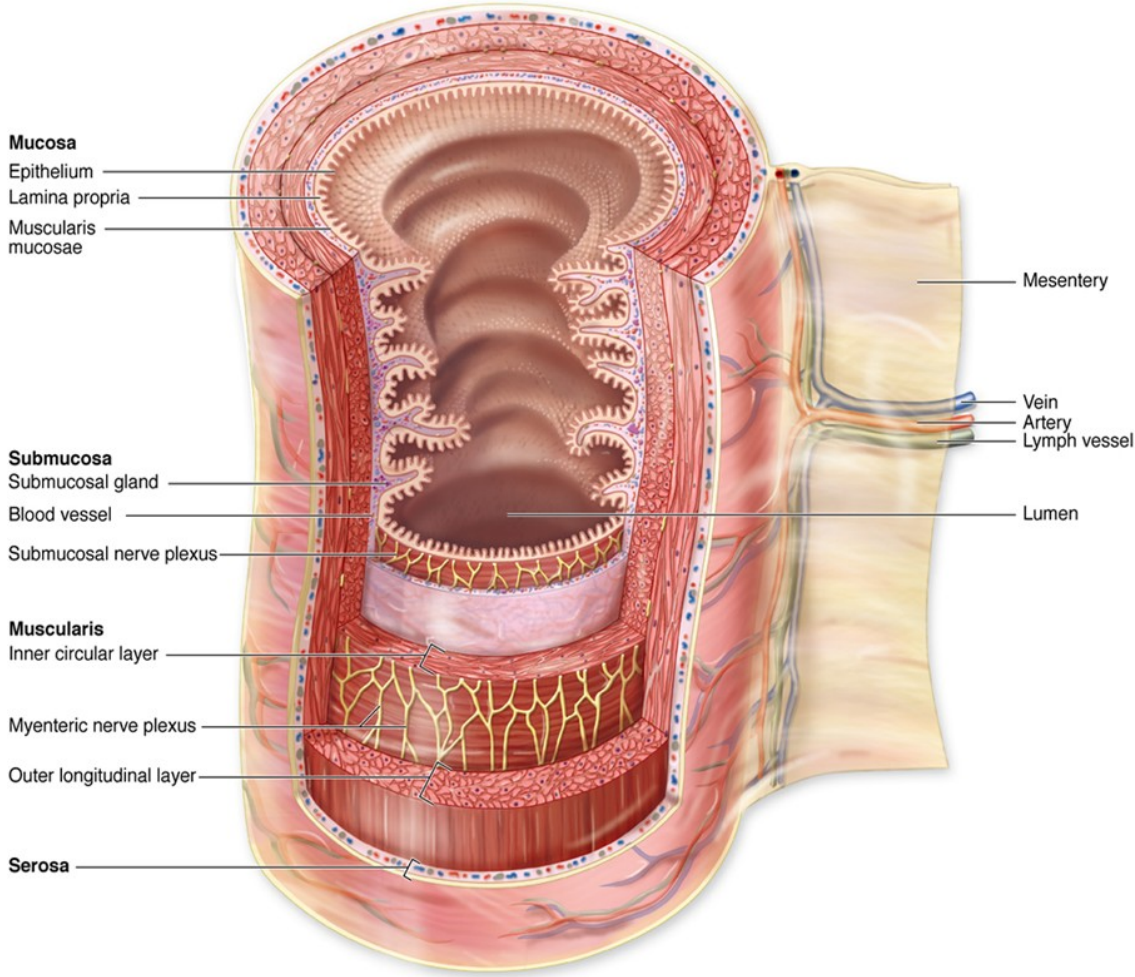


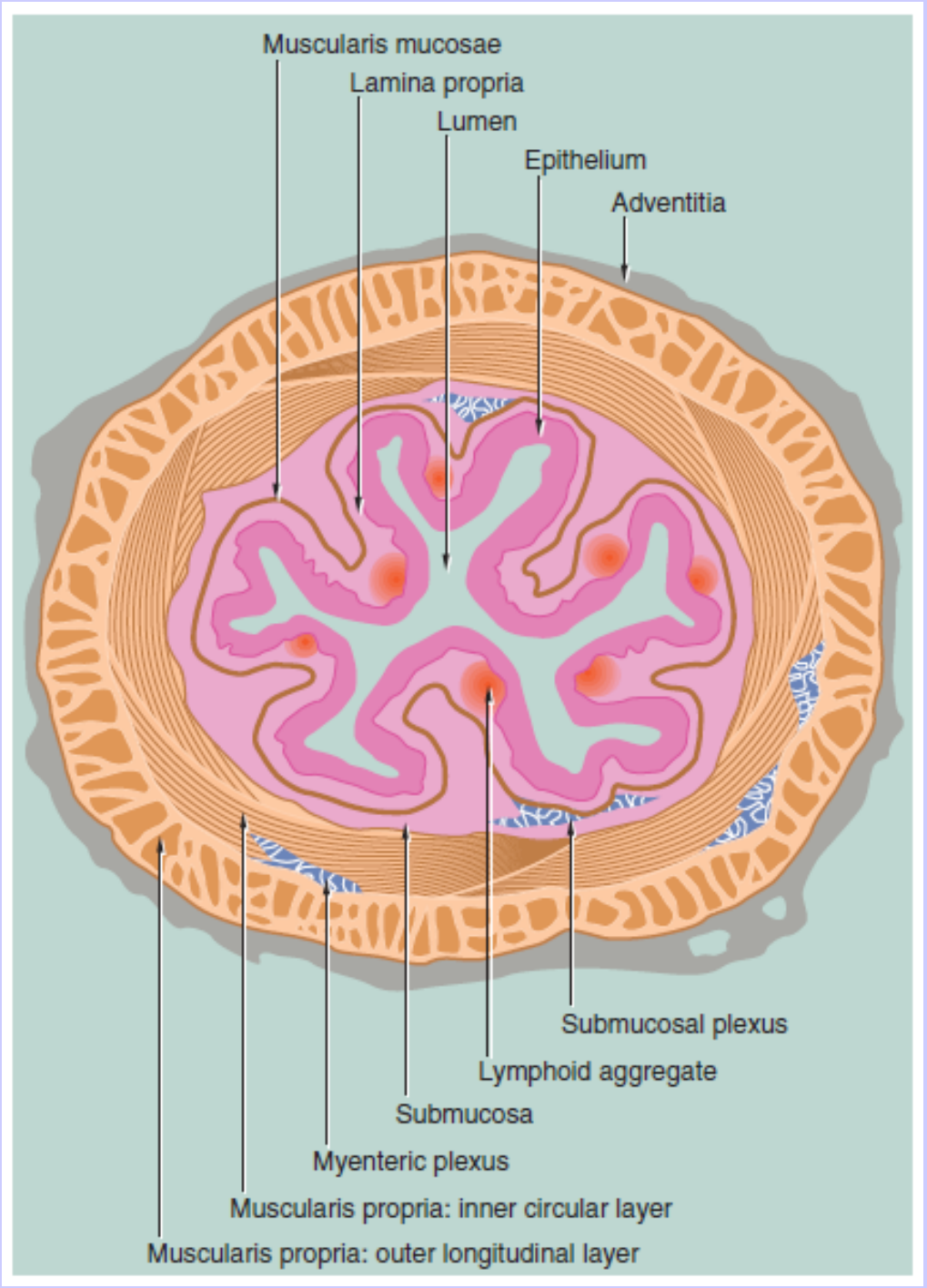
DIGESTIVE SYSTEM

BASIC HISTOLOGICAL ORGANIZATION

Muscular tube with a lumen of variable diameter and wall made up of four main layers:

- **Mucosa** (mucous membrane). Innermost layer facing the lumen
  - *Epithelium*. Either a stratified squamous moist or a simple columnar epithelium
  - *Lamina propria*. Loose connective tissue; usually possesses digestive glands
  - *Muscularis mucosae* of smooth muscle is usually present.
- **Submucosa**. Denser connective tissue than the lamina propria. The submucosa possesses *Meissner's nerve plexus* that supplies innervation to the muscularis mucosae and to digestive glands in the mucosa and submucosa. The submucosa possesses glands in the esophagus and duodenum.
- **Muscularis externa** of smooth muscle is usually arranged into inner circular and outer longitudinal layers. *Auerbach's nerve plexus* is located between the two muscle layers and provides innervation to this smooth muscle.
- **Serosa** (serous membrane) is present if the organ protrudes into the peritoneal cavity, or an **adventitia** (only the connective tissue portion of the serosa) is present if the organ is retroperitoneal.




Muscularis mucosae
Lamina propria
Lumen
Epithelium
Adventitia
Submucosal plexus
Lymphoid aggregate
Submucosa
Myenteric plexus
Muscularis propria: inner circular layer
Muscularis propria: outer longitudinal layer

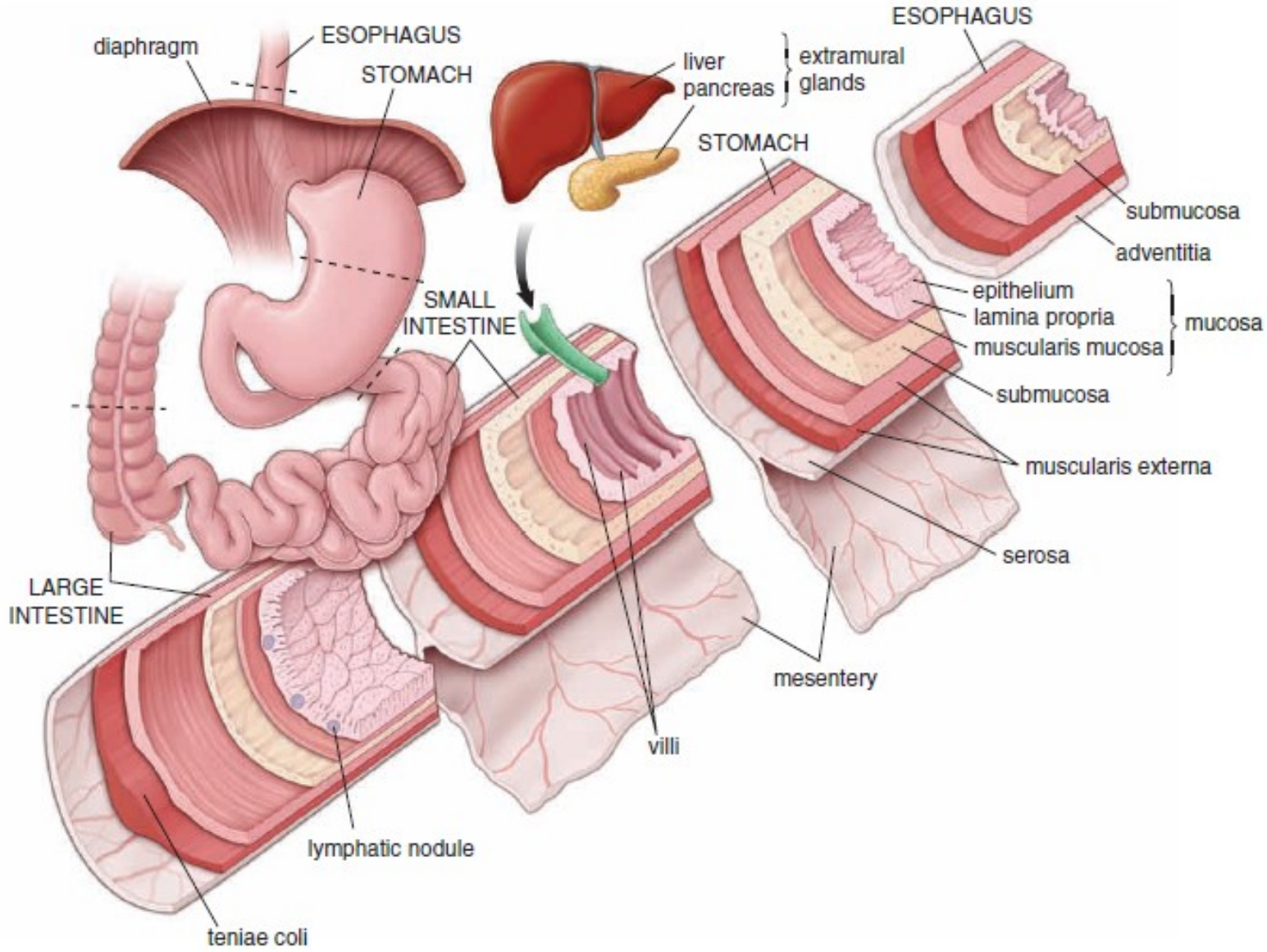


FIGURE 17.1 ▲ Diagram of general organization of the alimentary canal. This composite diagram shows the wall structure of the alimentary canal in four representative organs: esophagus, stomach, small intestine, and large intestine. Note that villi, a characteristic feature of the small intestine, are not present in other parts of the alimentary canal. Mucosal glands are present throughout the length of the alimentary canal but sparingly in the esophagus and oral cavity. Submucosal glands are present in the esophagus and duodenum. The extramural glands (liver and pancreas) empty into the duodenum (first part of the small intestine). Diffuse lymphatic tissues and nodules are found in the lamina propria throughout the entire length of the alimentary canal (shown here only in the large intestine). Nerves, blood vessels, and lymphatic vessels reach the alimentary canal via the mesenteries or via adjacent connective tissue (tunica adventitia as in the retroperitoneal organs).

DIGESTIVE SYSTEM

ESOPHAGUS

- **Mucosa:**
  - *Epithelium*. Stratified squamous nonkeratinized epithelium
  - *Lamina propria* possesses esophageal cardiac glands that resemble the mucus-secreting glands of the cardiac portion of the stomach. These glands are particularly prominent near the junction of the esophagus with the stomach and are sometimes located in the beginning of the esophagus.
  - *Lamina muscularis mucosae*.
- **Submucosa** has mucus-secreting, esophageal glands proper.
- **Muscularis externa** is composed of striated muscle in the upper portion of the esophagus, skeletal, and smooth muscle in the middle portion, and smooth muscle in the lower portion.
- **Adventitia.** Composed of loose connective tissue.

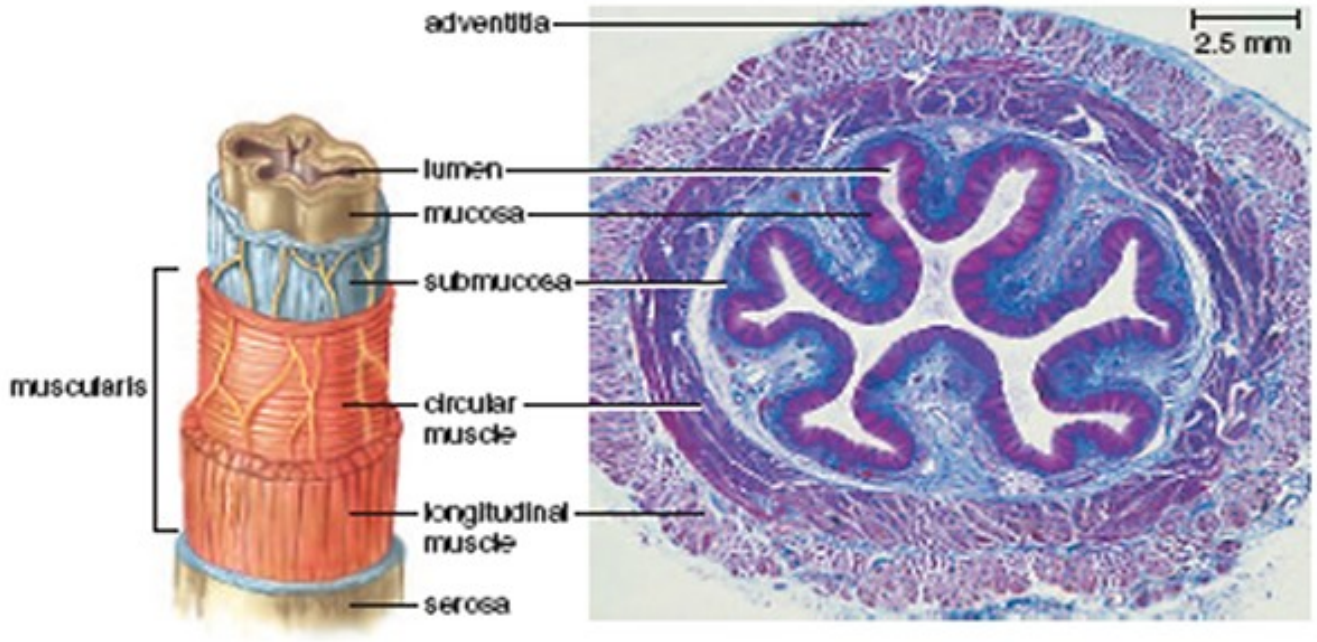
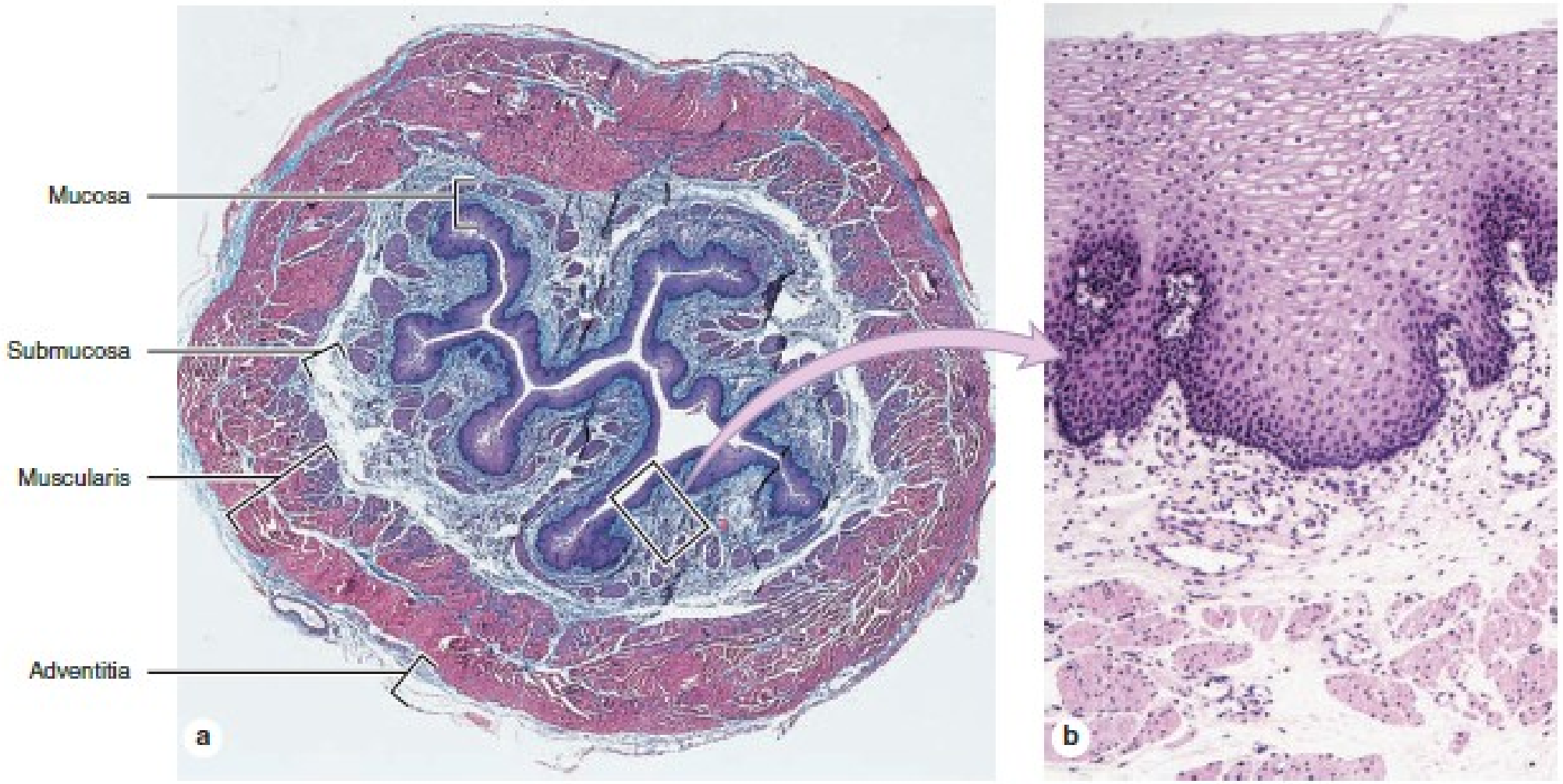


FIGURE 15–12 Esophagus.



(a) In cross section the four major layers of the GI tract are clearly seen. The esophageal mucosa is folded longitudinally, with the lumen largely closed. (X10; H&E)

(b) Higher magnification of the mucosa shows the stratified squamous epithelium (**E**), the lamina propria (**LP**) with scattered lymphocytes, and strands of smooth muscle in the muscularis mucosae (**MM**). (X65; H&E)

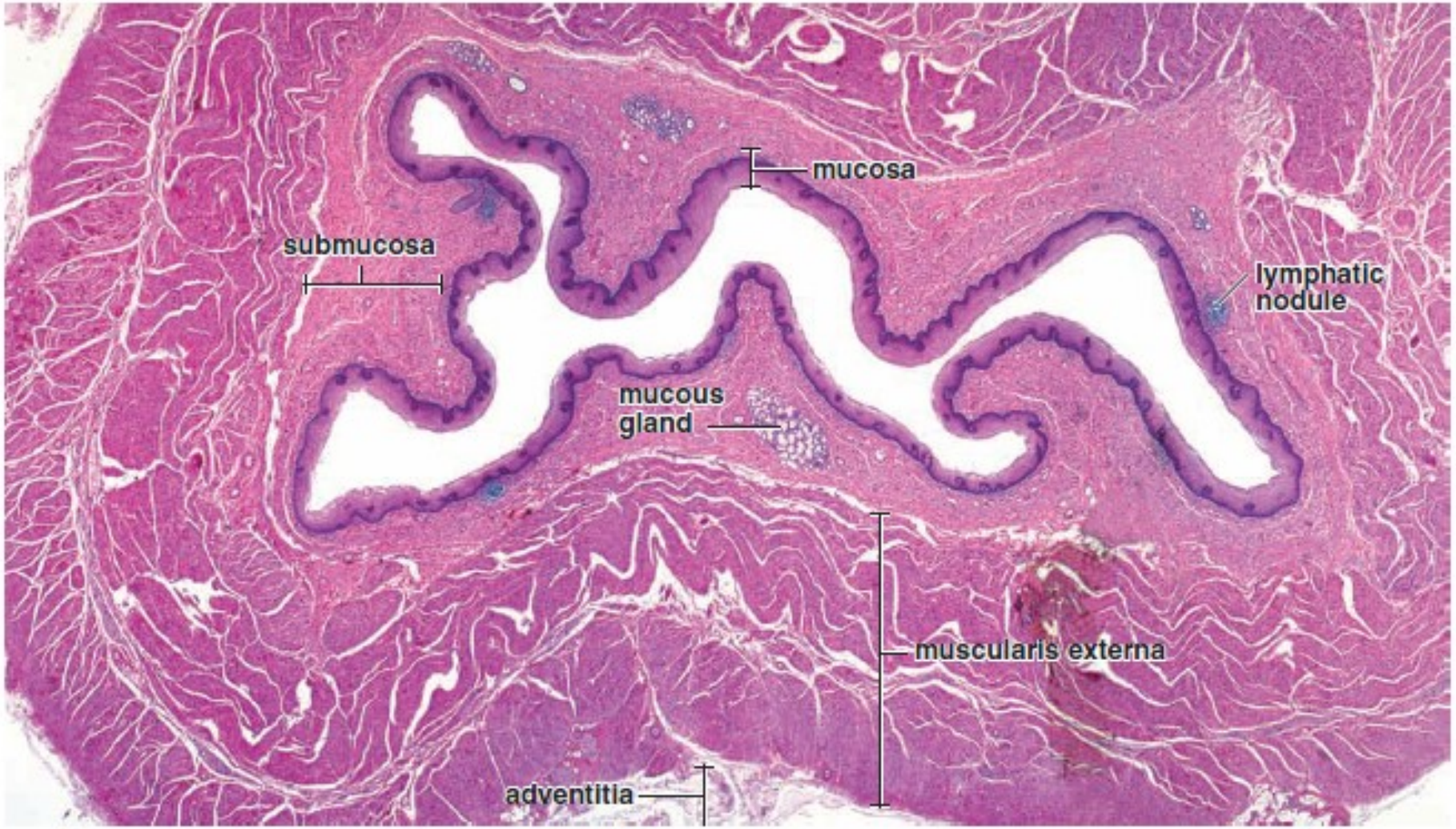


FIGURE 17.2 ▲ Photomicrograph of the esophagus. This low-magnification photomicrograph shows an H&E–stained section of the esophagus with its characteristically folded wall, giving the lumen an irregular appearance. The mucosa consists of a relatively thick stratified squamous epithelium, a thin layer of lamina propria containing occasional lymphatic nodules, and muscularis mucosae. Mucous glands are present in the submucosa; their ducts, which empty into the lumen of the esophagus, are not evident in this section. External to the submucosa in this part of the esophagus is a thick muscularis externa made up of an inner layer of circularly arranged smooth muscle and an outer layer of longitudinally arranged smooth muscle. The adventitia is seen just external to the muscularis externa. ×8.

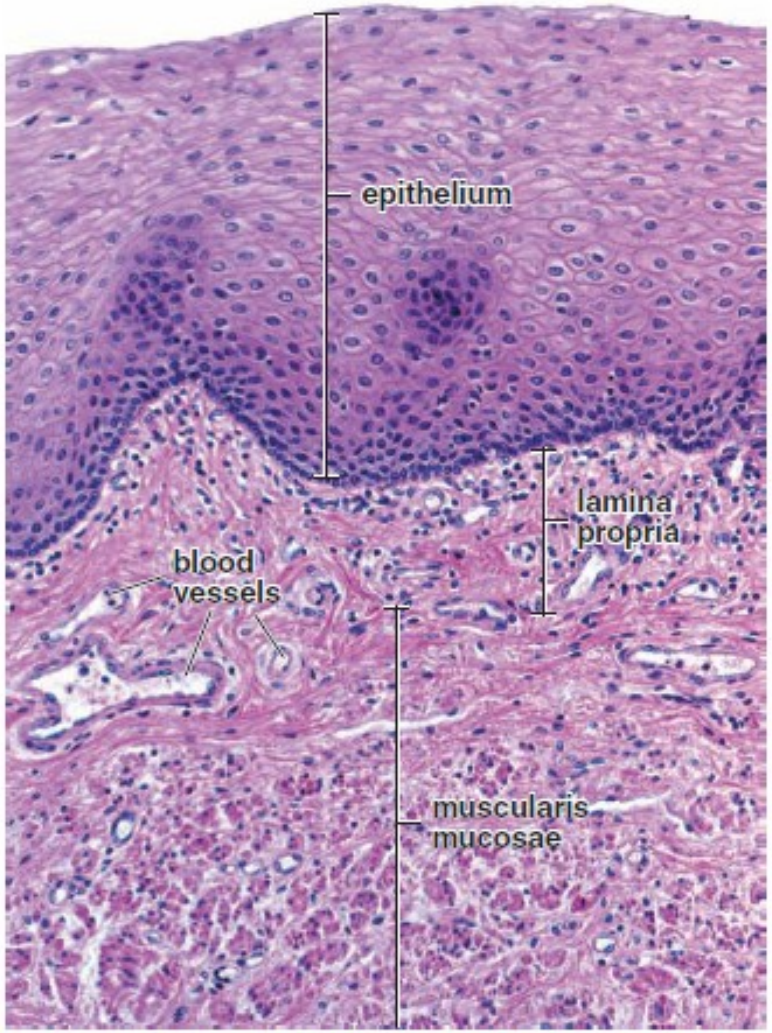


FIGURE 17.3 ▲ Photomicrograph of the esophageal mucosa. This higher magnification photomicrograph shows the mucosa of the wall of the esophagus in an H&E preparation. It consists of a stratified squamous epithelium, lamina propria, and muscularis mucosae. The boundary between the epithelium and lamina propria is distinct, although uneven, because of the connective tissue papillae. The basal layer of the epithelium stains intensely, appearing as a dark band because the basal cells are smaller and have a high nucleus-to-cytoplasm ratio. Note that the loose connective tissue of the lamina propria is very cellular, containing many lymphocytes. The deepest part of the mucosa is the muscularis mucosae, which is arranged in two layers (inner circular and outer longitudinal) similar in orientation to the muscularis externa. ×240.

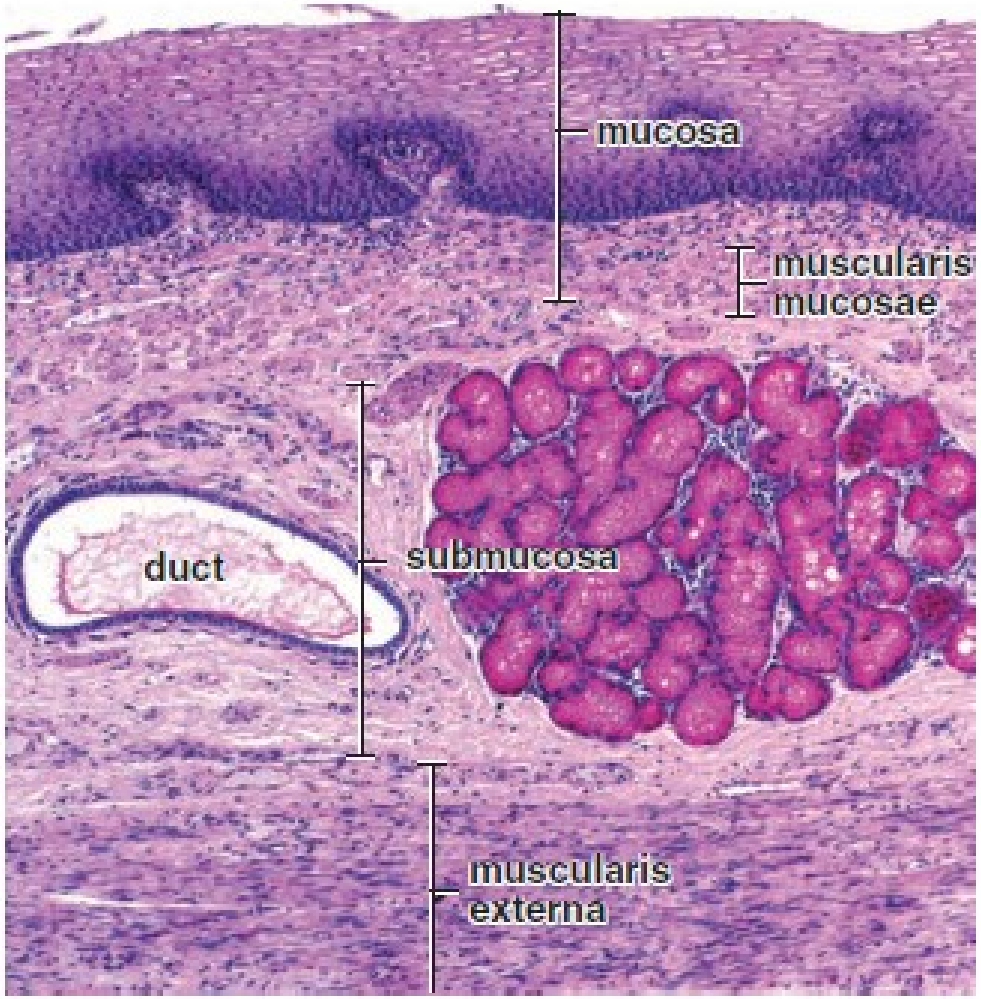


FIGURE 17.4 ▲ Photomicrograph of an esophageal submucosal gland. This photomicrograph shows a mucicarmine-stained section of the esophagus. An esophageal gland, deeply stained red by the carmine, and an adjacent excretory duct are seen in the submucosa. These small, compound, tubuloalveolar glands produce mucus that lubricates the epithelial surface of the esophagus. Note the stained mucus within the excretory duct. The remaining submucosa consists of dense irregular connective tissue. The inner layer of the muscularis externa (*bottom*) is composed of circularly arranged smooth muscle. ×110.

DIGESTIVE SYSTEM

STOMACH

- **Function of the stomach**
  - Mixed exocrine (digestion) and endocrine organ (hormones secretion)
  - To continue the digestion of carbohydrates initiated in the mouth, add an acidic fluid to the ingested food, mixes food to produce *chyme*
  - Initial digestion of proteins with enzyme *pepsin*
  - Gastric lipase – digestion of triglycerides
  - Produces intrinsic factor for absorption of vitamin B12
  - Absorbs a few nutrients
- **Four regions:**
  - Cardia
  - Fundus
  - Body
  - Pylorus
- **Wall of the stomach:**
  - Tunica mucosa (epithelium, lamina propria, lamina muscularis mucosae)
  - Tunica submucosa
  - Tunica muscularis
  - Tunica serosa
- **Rugae**. Longitudinal folds of the mucosa and submucosa in the undistended stomach allow for expansion.

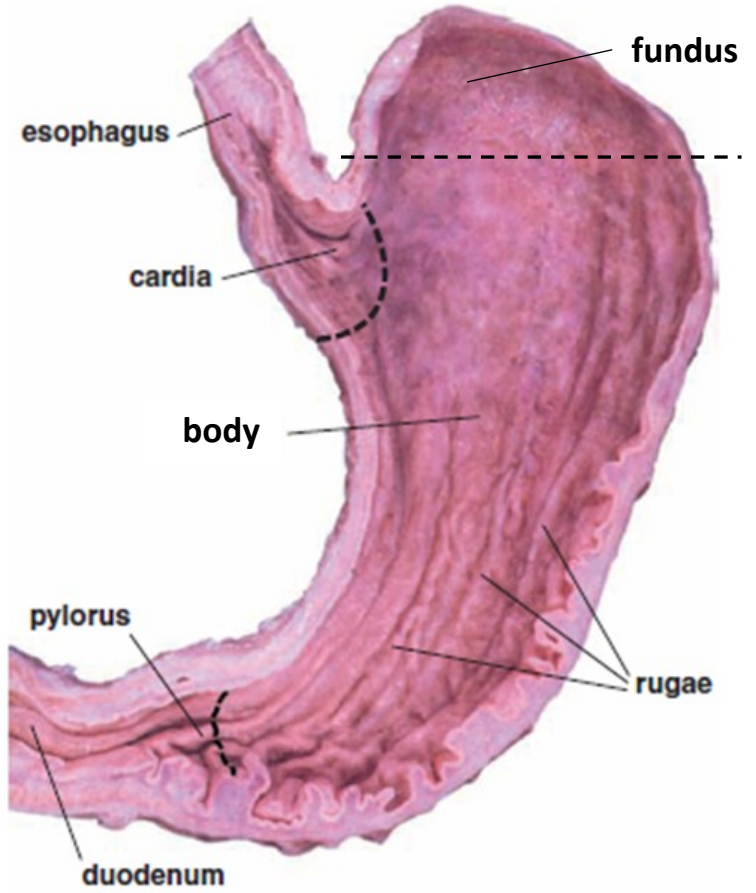
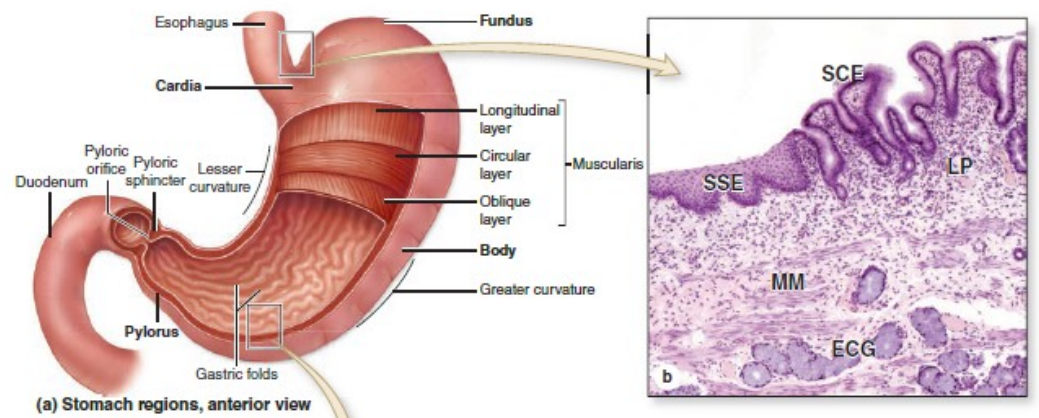
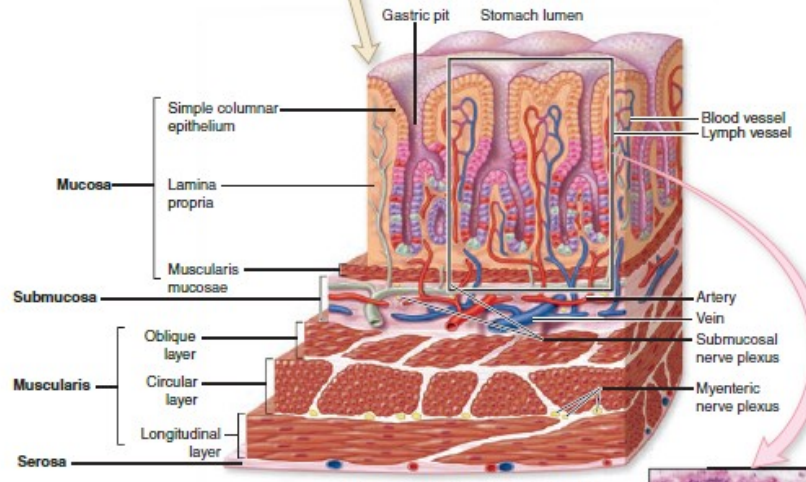


FIGURE 17.5 ▲ Photograph of a hemisected human stomach. This photograph shows the mucosal surface of the posterior wall of the stomach. Numerous longitudinal gastric folds are evident. These folds or rugae allow the stomach to distend as it fills. The histologic divisions of the stomach differ from the anatomic division. The former is based on the types of glands found in the mucosa. Histologically, the portion of the stomach adjacent to the entrance of the esophagus is the cardiac region (*cardia*) in which cardiac glands are located. A *dashed line* approximates its boundary. A slightly larger region leading toward the pyloric sphincter, the pyloric region (*pylorus*), contains the pyloric glands. Another *dashed line* approximates its boundary. The remainder of the stomach, the fundic region (*fundus*), is located between the two *dashed lines* and contains the fundic (gastric) glands.

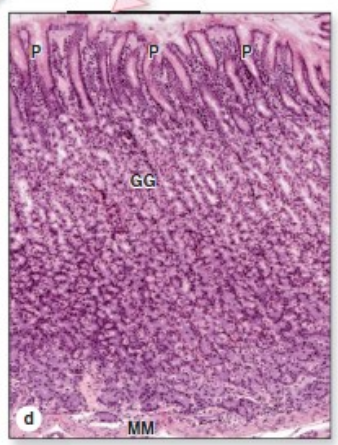
FIGURE 15–14 Stomach.



(a) Stomach regions, anterior view



(c) Stomach wall, sectional view



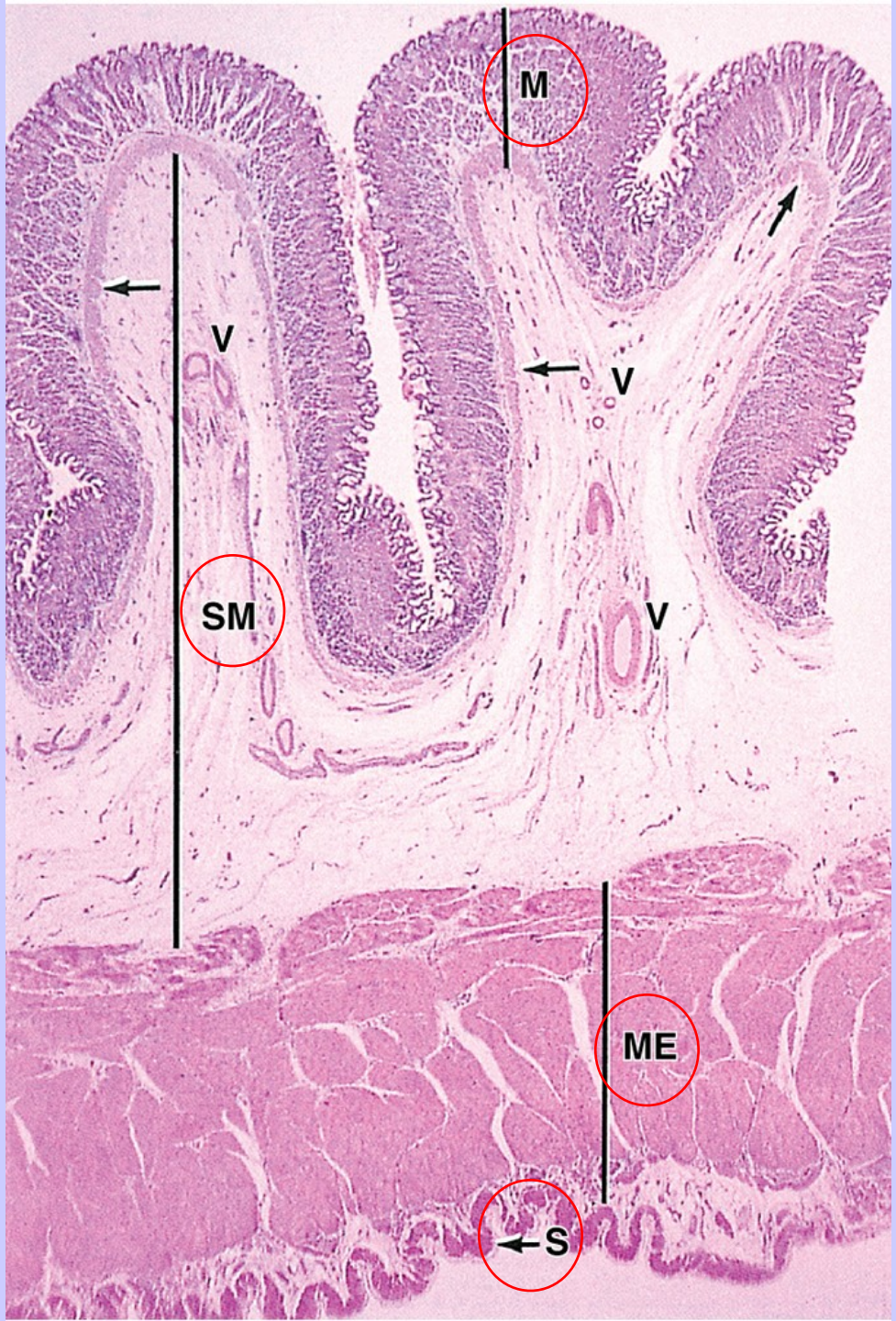
The stomach is a muscular dilation of the digestive tract where mechanical and chemical digestion occurs.

(a) The major stomach regions are the **cardia**, **fundus**, **body**, and **pylorus**, all with longitudinal gastric folds, or rugae. The muscularis has three layers.

(b) At the esophagogastric junction, stratified squamous epithelium (**SSE**) lining the esophagus is abruptly replaced by simple columnar epithelium (**SCE**) of the stomach. Also seen here are the mucous esophageal cardiac glands (**ECG**) beneath the lamina propria (**LP**) and muscularis mucosae (**MM**). (X60; H&E)

(c) The mucosa of the stomach wall contains invaginations called **gastric pits** that lead into **gastric glands**. These structures are lined by simple columnar epithelium containing five functional cell types.

(d) A histologic section of the gastric mucosa shows the gastric pits (**P**) and glands (**GG**) surrounded by cells of the lamina propria. The underlying muscularis mucosae (**MM**) is also seen. (X60; H&E)

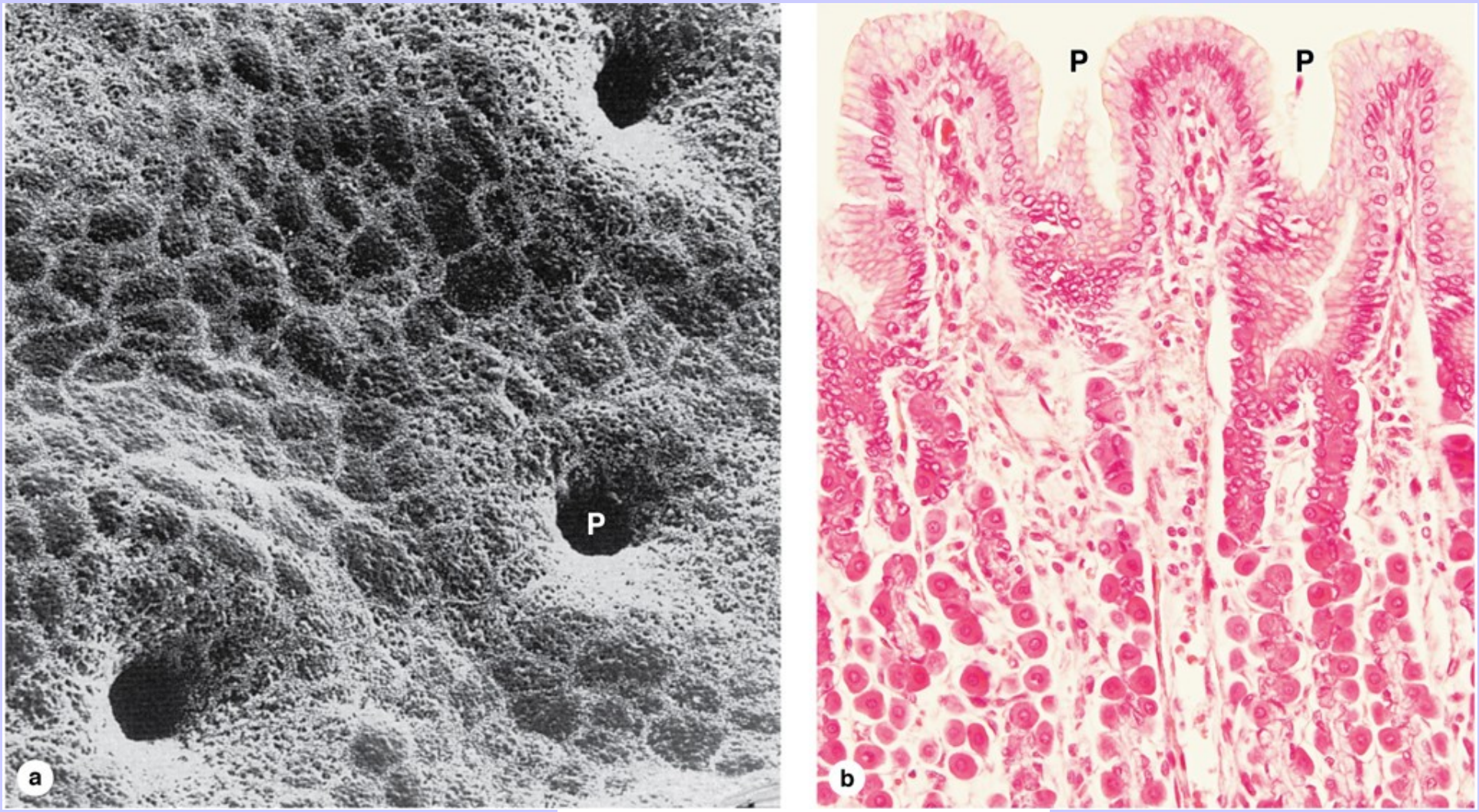


A low-magnification micrograph of the stomach wall at the fundus shows the relative thickness of the four major layers: the mucosa (**M**), the submucosa (**SM**), the muscularis externa (**ME**), and the serosa (**S**). Two rugae (folds) cut transversely and consisting of mucosa and submucosa are included. The mucosa is packed with branched tubular glands penetrating the full thickness of the lamina propria so that this sublayer cannot be distinguished at this magnification. The **muscularis mucosae** (arrows), immediately beneath the basal ends of the gastric glands, is shown. The submucosa is largely loose connective tissue, with blood vessels (**V**) and lymphatics. (X12; H&E)

DIGESTIVE SYSTEM

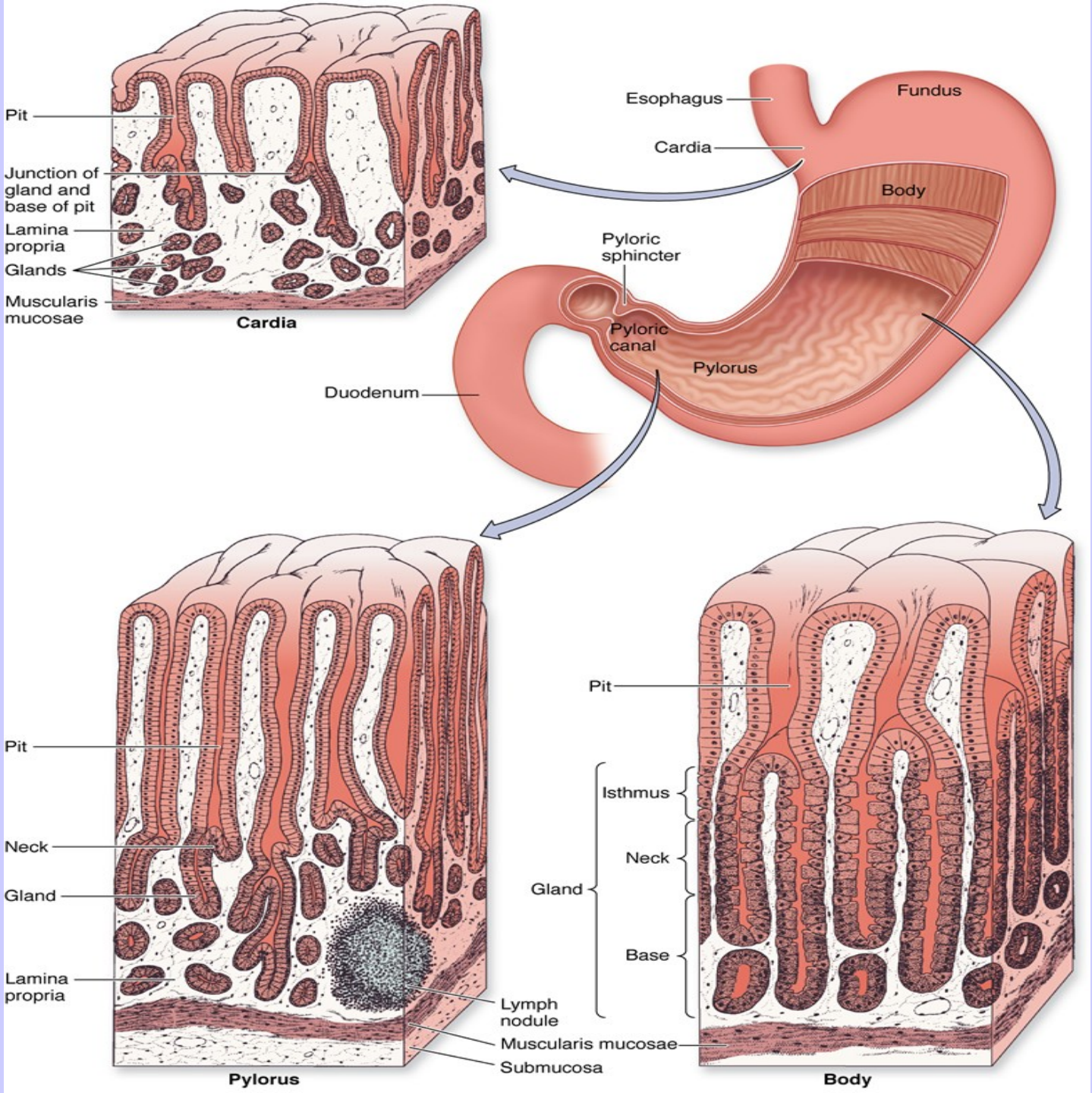
STOMACH

- **Structures present throughout the stomach**
  - *Surface epithelium*
    - Simple columnar epithelium facing the lumen is modified so that all cells secrete mucus, forming a sheet gland that protects the stomach from its acidic environment.
    - Gastric pit. A channel formed by the invagination of the surface epithelium into the underlying lamina propria; connects the sheet gland with the gastric glands. The length of the gastric pit varies with each stomach region.
  - *Gastric glands*
    - Simple, branched tubular glands begin at a gastric pit and extend through the lamina propria to the muscularis mucosae.
    - The region of the gland that attaches to the gastric pit is called the neck region; the base region of the gland is located adjacent to the muscularis mucosae.
    - Secretory cells in these glands vary in each region of the stomach.
  - *Muscularis externa*. Subdivisions of this smooth muscle layer frequently interdigitate, making it difficult to distinguish one layer from another.
    - Internal oblique layer
    - Middle circular layer that is modified in the pyloric region to form the pyloric sphincter
    - Outer longitudinal layer is separated from the inner circular layer by Auerbach's plexus, nerve fibers from the autonomic nervous system that supply
  - *Serosa*



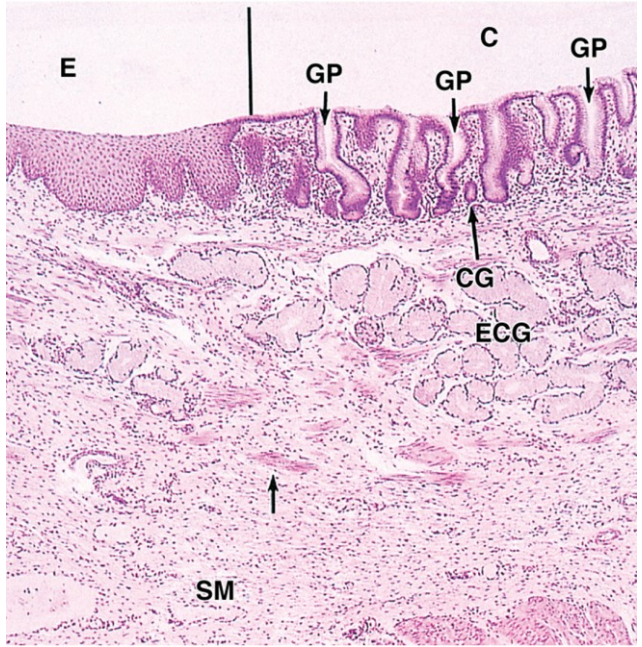
(a) SEM of the stomach lining cleared of its mucous layer reveals closely placed gastric pits (**P**) surrounded by polygonal apical ends of surface mucous cells. (X600)

(b) A section of the same lining shows that these surface mucous cells are part of a simple columnar epithelium continuous with the lining of the pits (**P**). Each pit extends into the lamina propria and then branches into several tubular glands. These glands coil and fill most of the mucosa. Around the various cells of the closely packed gastric glands are cells, capillaries, and small lymphatics of the connective tissue lamina propria. (X200; H&E)


Pit
Junction of gland and base of pit
Lamina propria
Glands
Muscularis mucosae
Cardia
Esophagus
Fundus
Cardia
Body
Pyloric sphincter
Pyloric canal
Pylorus
Duodenum
Pit
Neck
Gland
Lamina propria
Lymph nodule
Muscularis mucosae
Submucosa
Pylorus
Pit
Isthmus
Neck
Gland
Base
Body

STOMACH

- **Variations specific to the cardiac region** (narrow region adjacent to the esophagus)
  - Abrupt transition of epithelium from stratified squamous moist of the esophagus to a sheet gland lining the cardiac stomach
  - Length of gastric pits is about equal to the length of cardiac glands
  - Cardiac glands primarily secrete mucus, although other products are also produced. Glands are frequently coiled.
  - Cardiac glands of the stomach extend into the lower esophagus, forming the esophageal cardiac glands.



Esophagogastric junction

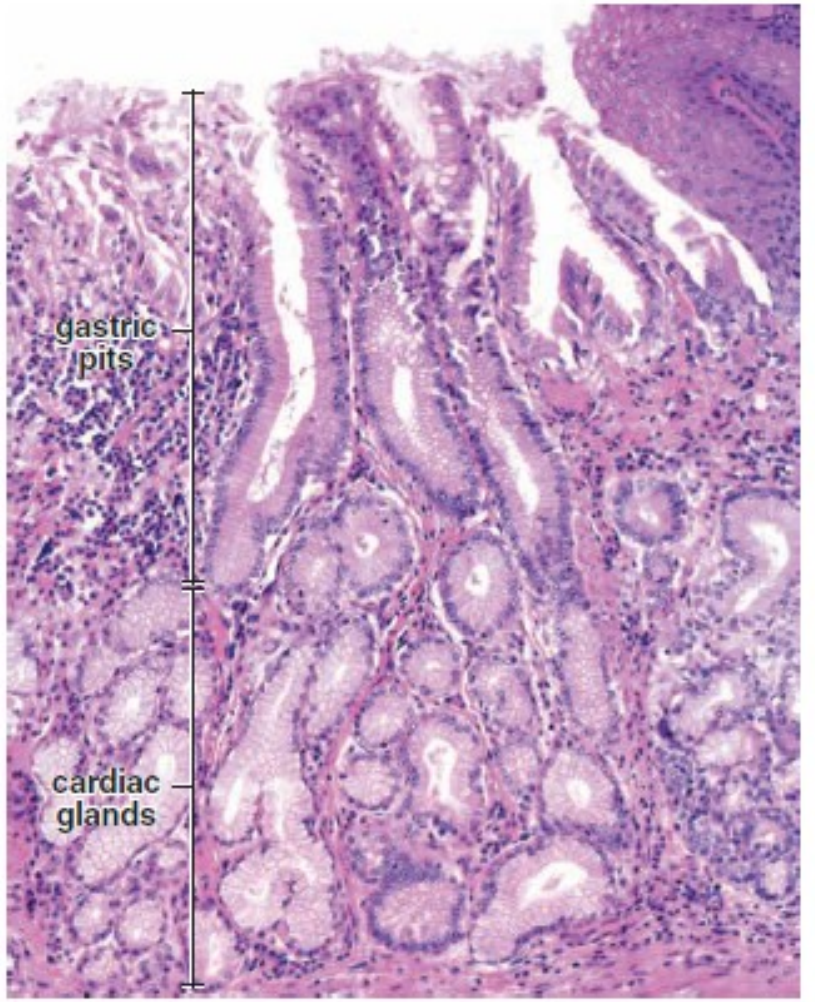


FIGURE 17.14 ▲ Photomicrograph of cardiac glands. This photomicrograph shows the esophagogastric junction. Note the presence of the stratified squamous epithelium of the esophagus in the *upper right corner* of the micrograph. The cardiac glands are tubular, somewhat tortuous, and occasionally branched. They are composed mainly of mucus-secreting cells similar in appearance to the cells of the esophageal glands. Mucous secretion reaches the lumen of the gastric pit via a short duct segment containing columnar cells. ×240.

STOMACH

- **Variations specific to the pyloric region**
    - Pits are longer in pylorus than in the cardiac region.
    - Pyloric glands, not as coiled as in the cardiac region; primarily secrete mucus.
    - Enteroendocrine cells are also present here.
    - Circular layer of muscularis externa is greatly thickened to form the pyloric sphincter.

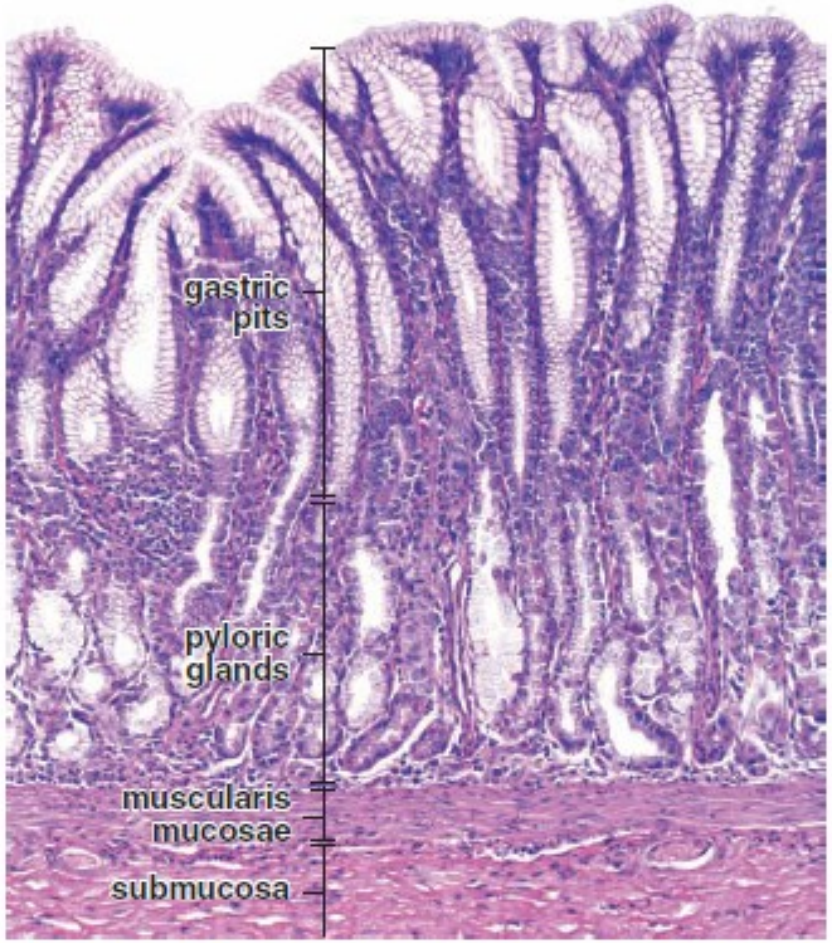


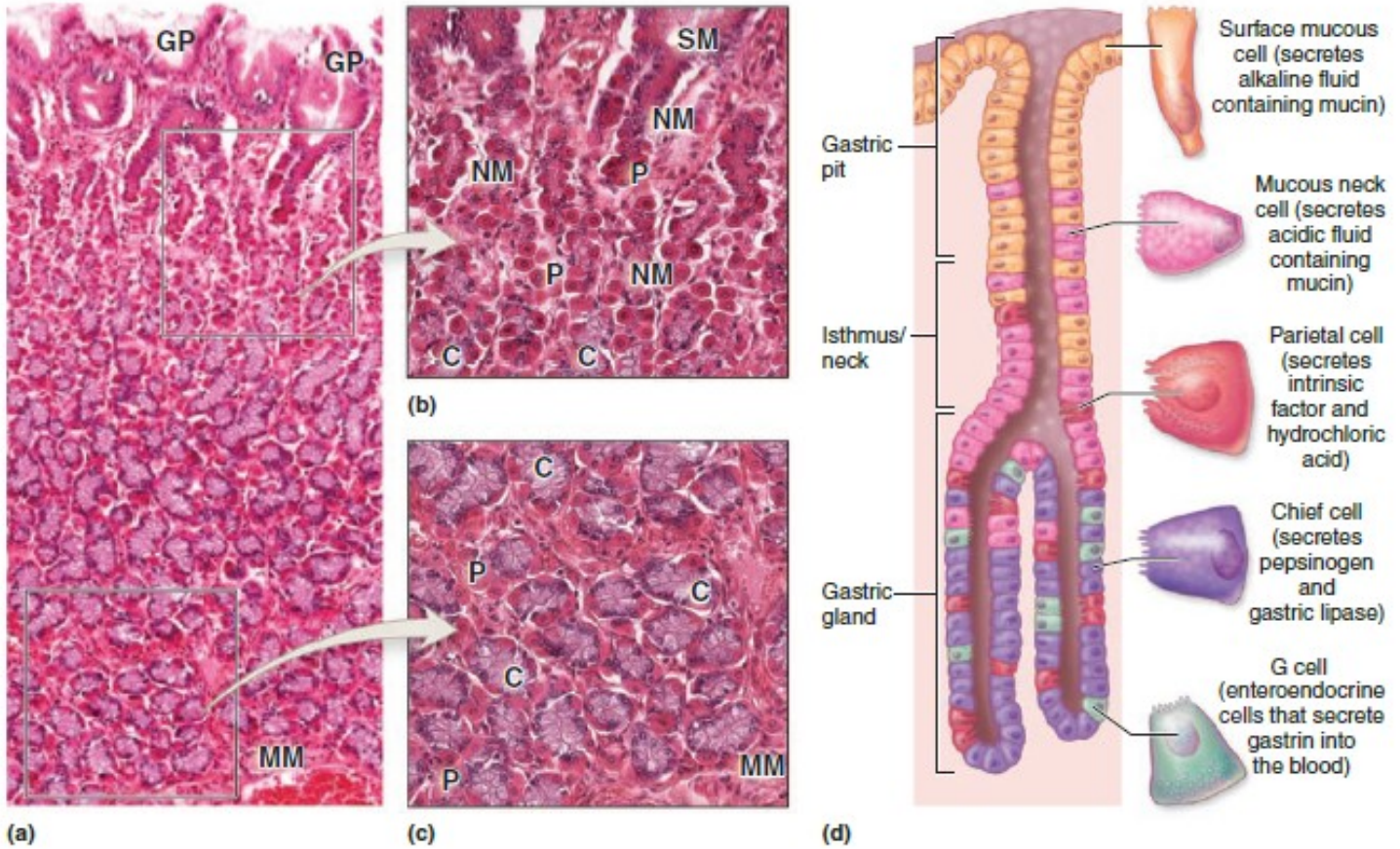
FIGURE 17.15 ▲ Photomicrograph of pyloric glands. This photomicrograph shows a section of the wall of the pylorus. The pyloric glands are relatively straight for most of their length but are slightly coiled near the muscularis mucosae. The lumen is relatively wide, and the secretory cells are similar in appearance to the surface mucous cells, suggesting a relatively viscous secretion. They are restricted to the mucosa and empty into the gastric pits. The boundary between the pits and glands is, however, hard to ascertain in routine H&E preparations. ×120.

DIGESTIVE SYSTEM

STOMACH

- **Variations specific to the fundic and body regions** (Glands in both regions are called fundic glands.)
  - Fundic glands are about twice as long as their gastric pits.
  - Cell types present in fundic glands:
    - *Stem cells* replenish both the surface epithelial cells and cells of the glands. Stem cells are located in the neck region.
    - *Mucous neck cells* are irregular in shape and stain basophilically. They secrete protective mucus and are located in the neck region.
    - *Parietal cells* are large, spherical, eosinophilic cells that secrete hydrogen and chloride ions and gastric intrinsic factor. They possess numerous mitochondria. An umbrella-shaped canaliculus indents the luminal surface, increasing surface area. Although present throughout the gland, parietal cells are more numerous in the upper regions.
    - *Chief or zymogen cells*, typical protein-producing cells, predominate in the bases; stain blue with hematoxylin(due to rough ER) and secrete pepsinogen (which is converted into pepsin by HCl).
    - *Enteroendocrine cells* (part of the diffuse neuroendocrine system, DNES) are located on the basement membrane and do not usually reach the lumen of the gland. This population of cells secretes a variety of hormones (e.g., gastrin) with endocrine and paracrine influences on digestive activity. Secretory granules cluster toward the basement membrane for their subsequent release into the lamina propria. Most common at the bases of the glands.

FIGURE 15–17 Gastric glands.



Throughout the **fundus** and **body** regions of the stomach, the gastric pits lead to gastric glands with various cell types.

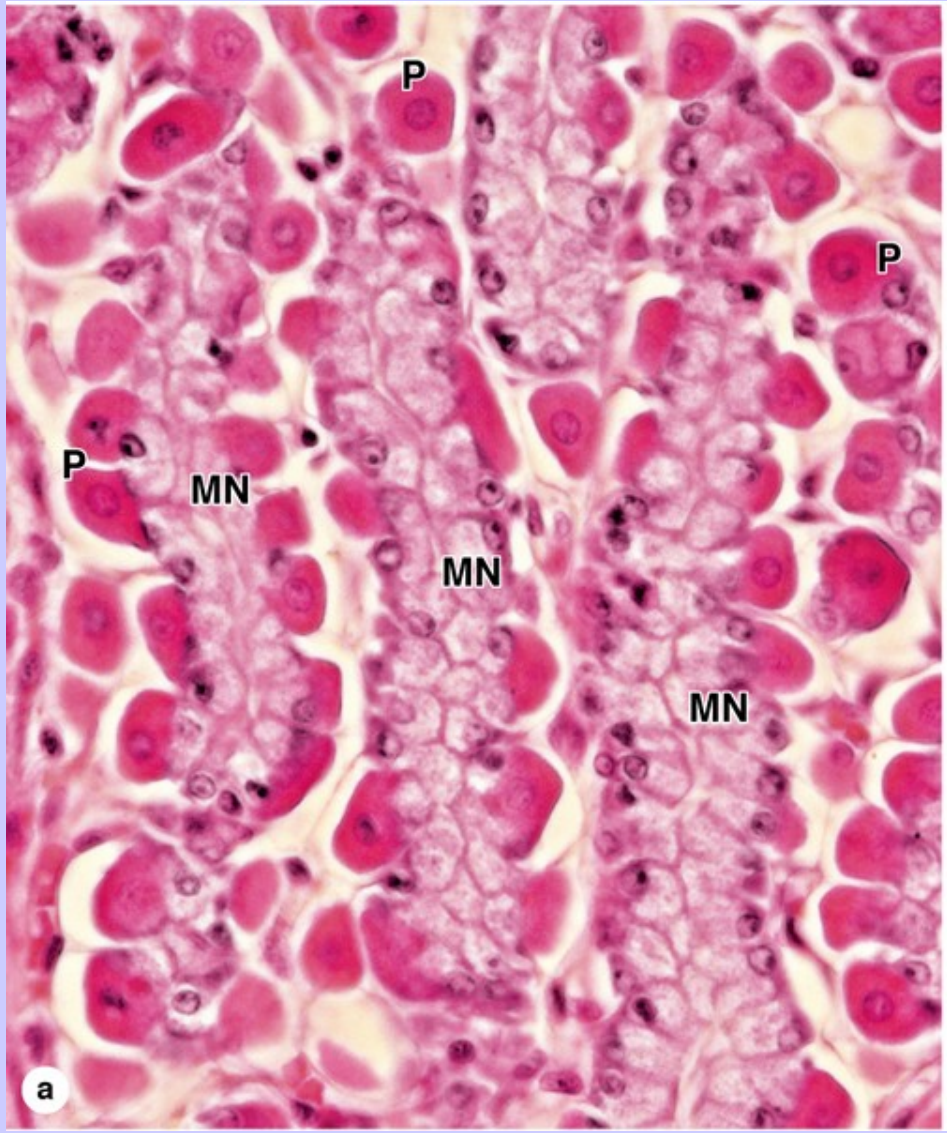
(a) The long, coiled gastric glands penetrate the complete thickness of the mucosa, from the gastric pits (**GP**) to the muscularis mucosae (**MM**).

(b) In the neck of a gastric gland, below the surface mucous cells (**SM**) lining the gastric pit, are small mucous neck cells (**MN**), scattered individually or clustered among parietal cells (**P**) and stem cells that give rise to all epithelial cells of the glands. The numerous parietal cells (**P**) are large distinctive cells often bulging from the tubules, with central nuclei surrounded by intensely eosinophilic cytoplasm with unusual ultrastructure. These cells produce HCl, and the numerous mitochondria required for this process cause the eosinophilia. Chief cells (**C**) begin to appear in the neck region. Around these tubular glands are various cells and microvasculature in connective tissue.

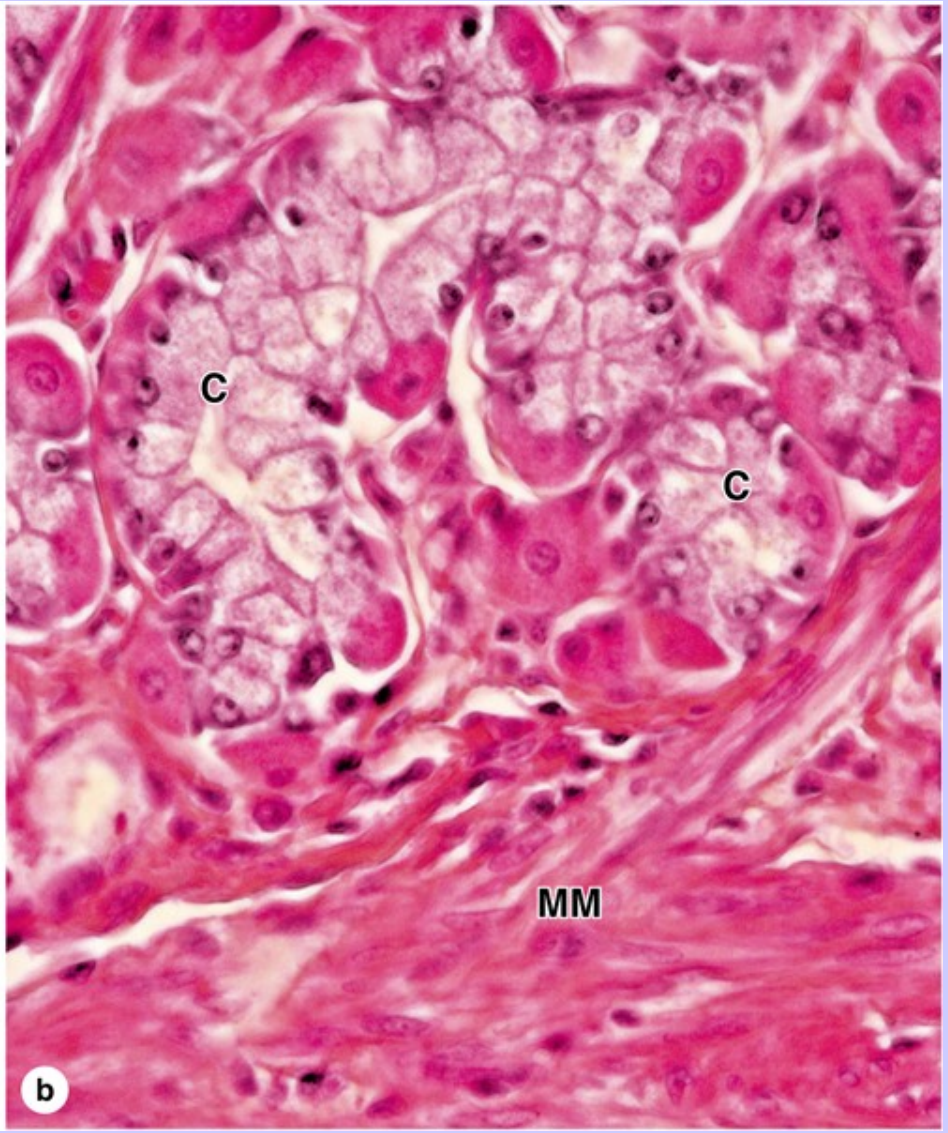
(c) Near the muscularis mucosae (**MM**), the bases of these glands contain fewer parietal cells (**P**) but many more zymogenic chief cells (**C**). Chief cells are found in clusters, with basal nuclei and basophilic cytoplasm. From their apical ends chief cells secrete pepsinogen, the zymogen precursor for the major protease pepsin. Zymogen granules are often removed or stain poorly in routine preparations. (Both X200; H&E)

(**d**) Diagram showing general morphology and functions of major gastric gland cells.

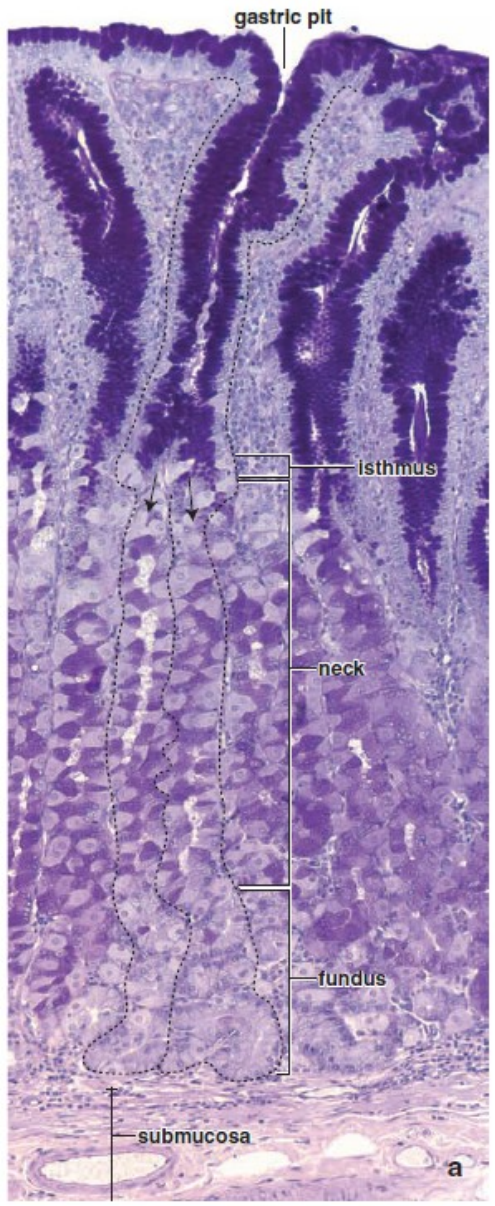
Gastric glands



Neck



Basal part of glands



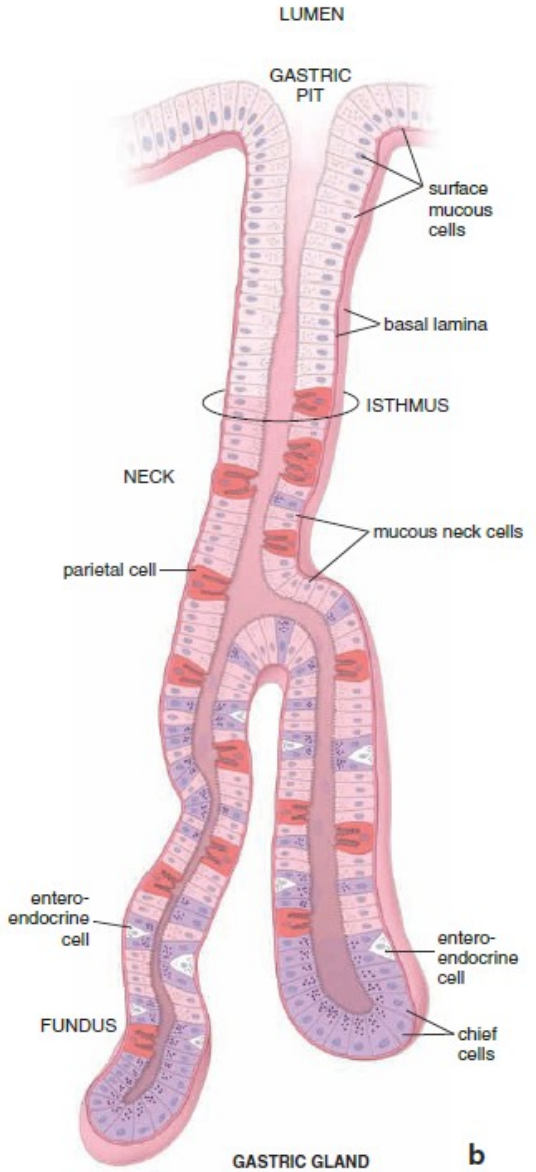
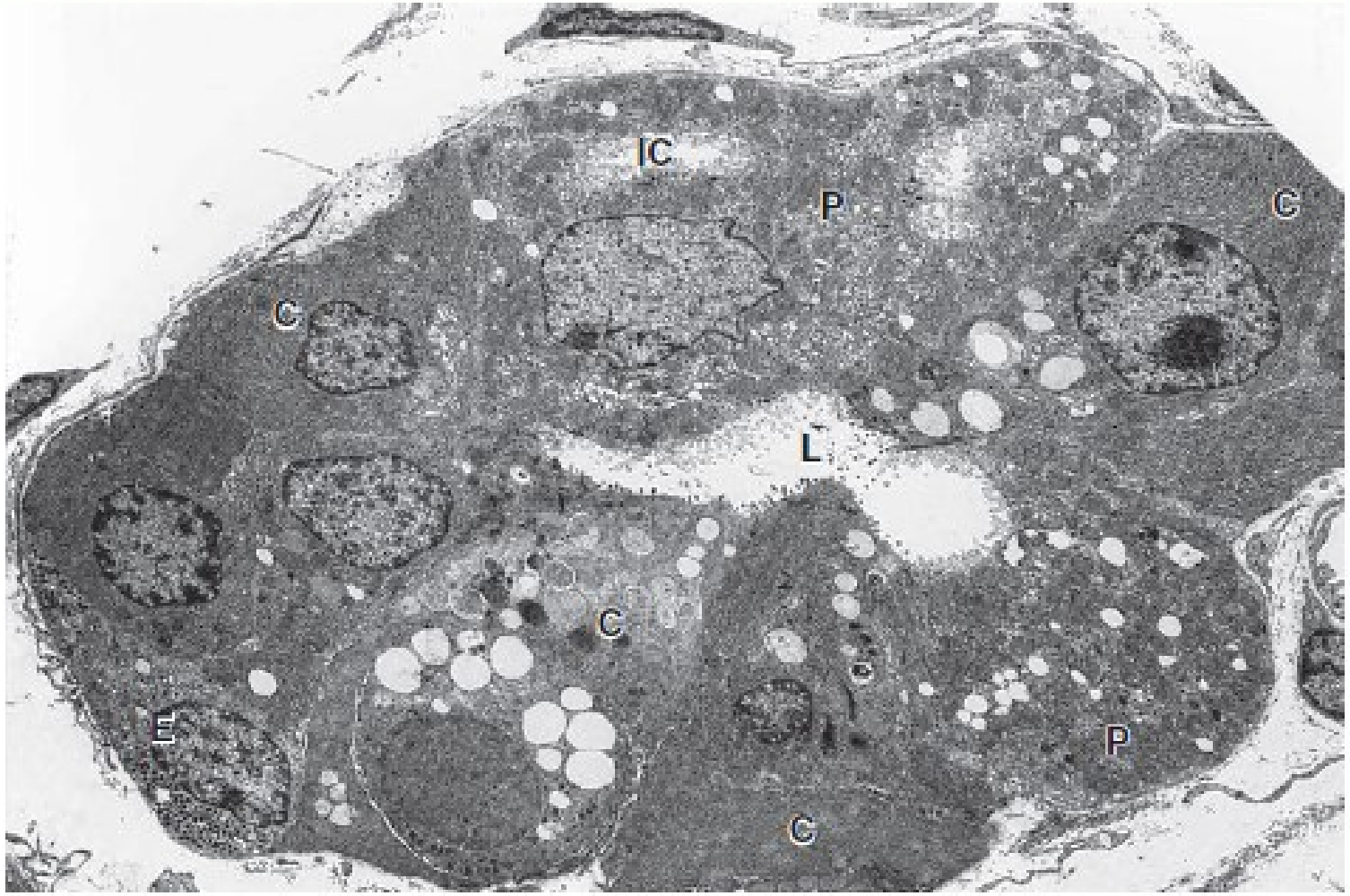


FIGURE 17.8 ▲ Gastric glands. a. This photomicrograph shows the fundic mucosa from an Alcian blue/PAS preparation to visualize mucus. Note that the surface epithelium invaginates to form the gastric pits. The surface mucous cells and the cells lining the gastric pits are readily identified in this preparation because the neutral mucus within these cells is stained intensely. One of the gastric pits and its associated fundic gland are depicted by the *dashed lines*. This gland represents a simple branched tubular gland (*arrows* indicate the branching pattern). It extends from the bottom of the gastric pit to the muscularis mucosae. Note the segments of the gland: the short isthmus, the site of cell divisions; the relatively long neck; and a shorter and wider fundus. The mucous secretion of mucous neck cells is different from that produced by the surface mucous cells as evidenced by the *lighter magenta* staining in this region of the gland. ×320. **b.** Schematic diagram of a gastric gland, illustrating the relationship of the gland to the gastric pit. Note that the isthmus region contains dividing cells and undifferentiated cells; the neck region contains mucous neck cells, parietal cells, and enteroendocrine cells, including amine precursor uptake and decarboxylation (APUD) cells. Parietal cells are large, pear-shaped acidophilic cells found throughout the gland. The fundus of the gland contains mainly chief cells, some parietal cells, and several types of enteroendocrine cells.

FIGURE 15–20 Ultrastructure of parietal, chief, and enteroendocrine cells.



TEM of a transversely sectioned gastric gland shows the ultrastructure of three major cell types. Parietal cells (**P**) contain abundant mitochondria and intracellular canaliculi (**IC**). Also shown are chief cells (**C**), which have extensive rough ER and apical secretory granules near the lumen (**L**). An enteroendocrine cell (**E**) shows dense basal secretory granules and is a closed-type enteroendocrine cell; that is, it has no contact with the gland's lumen and secretes product in an endocrine/paracrine manner. (X1200)

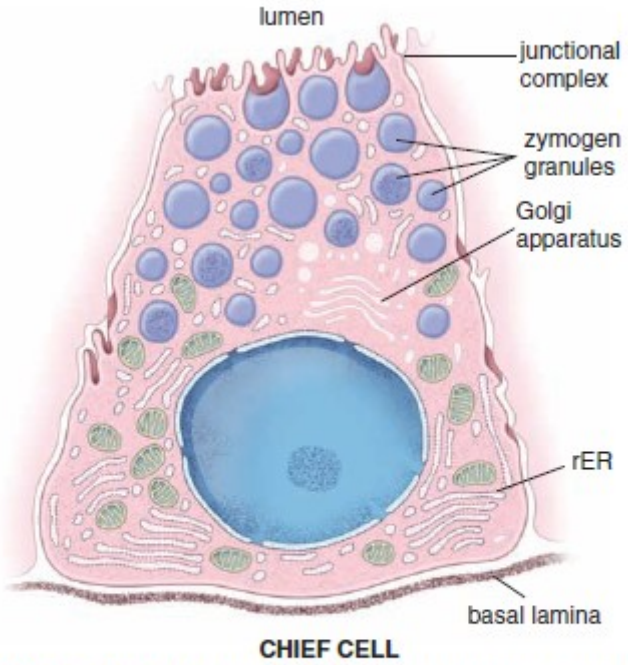


FIGURE 17.9 ▲ Diagram of a chief cell. The large amount of rER in the basal portion of the cell accounts for the intense basophilic staining seen in this region. Secretory vesicles (zymogen granules) containing pepsinogen and a weak lipase are not always adequately preserved, and thus, the staining in the apical region of the cell is somewhat variable. This cell produces and secretes the precursor enzyme of the gastric secretion.

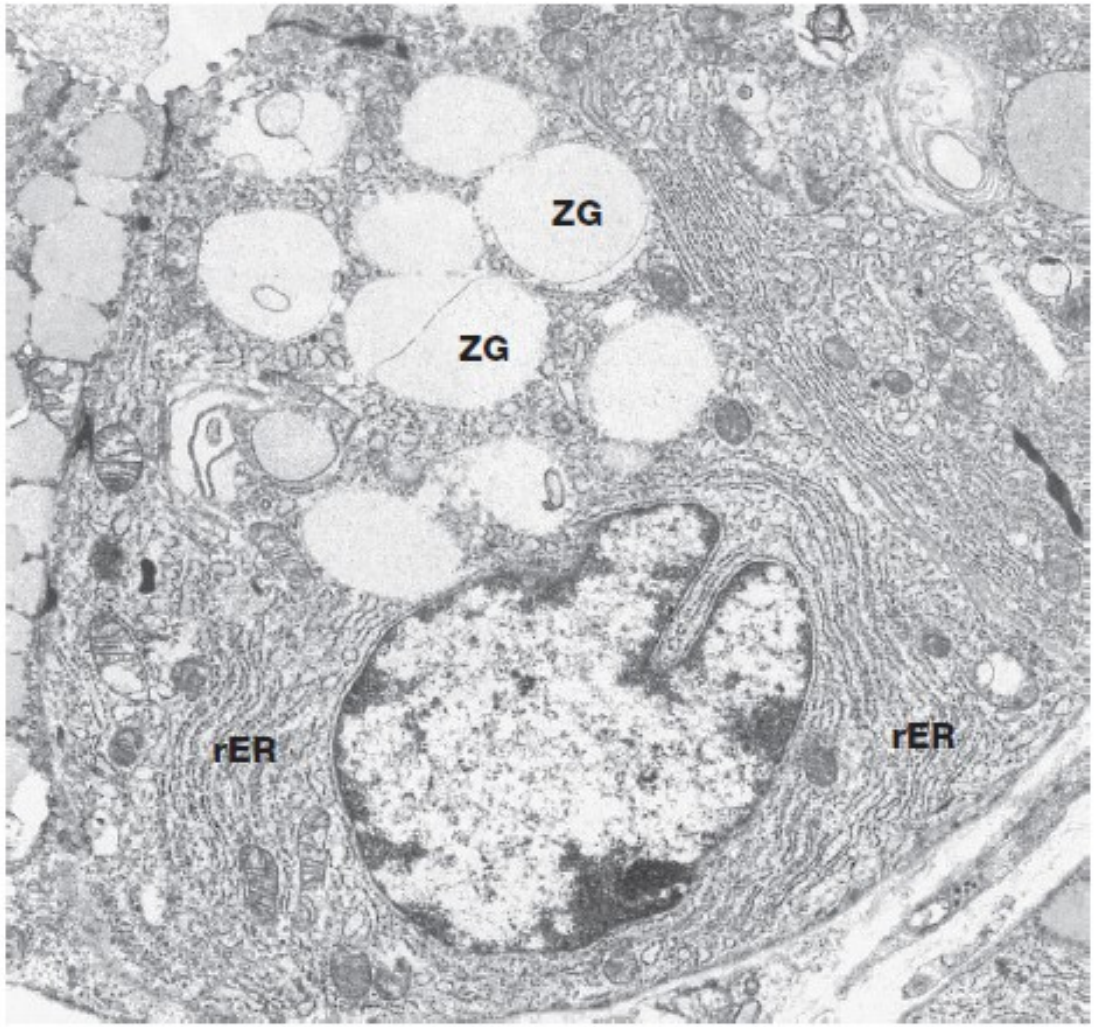


FIG. 14.13 Chief cell
EM ×7200

This electron micrograph illustrates a chief (zymogen) cell at the base of a gastric gland. The typical ultrastructural features of chief cells are those of protein-secreting cells in general. These features include an extensive rough endoplasmic reticulum **rER** and membrane-bound secretory vesicles (***zymogen granules***) **ZG** containing pepsinogen. These are crowded in the apical cytoplasm, thus restricting the nucleus to the base of the cell. The extensive rough endoplasmic reticulum accounts for the basophilia of chief cells in H&E sections.

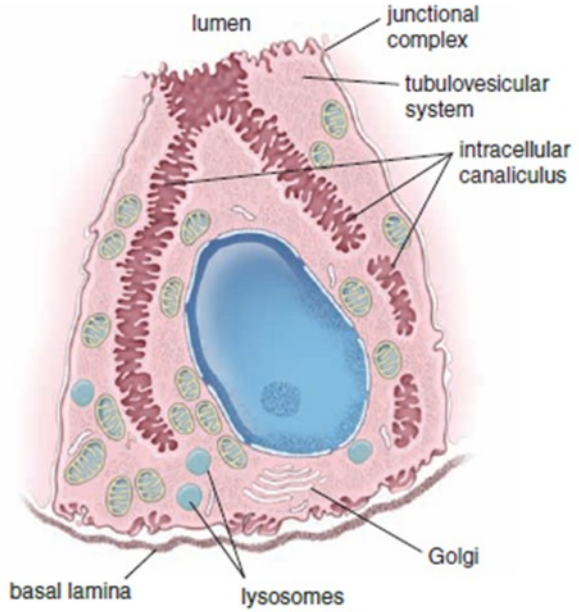


FIGURE 17.10 ▲ Diagram of a parietal cell. The cytoplasm of the parietal cell stains with eosin largely because of the extensive amount of membrane comprising the intracellular canaliculus, tubulovesicular system, mitochondria, and the relatively small number of ribosomes. This cell produces HCl and intrinsic factor.

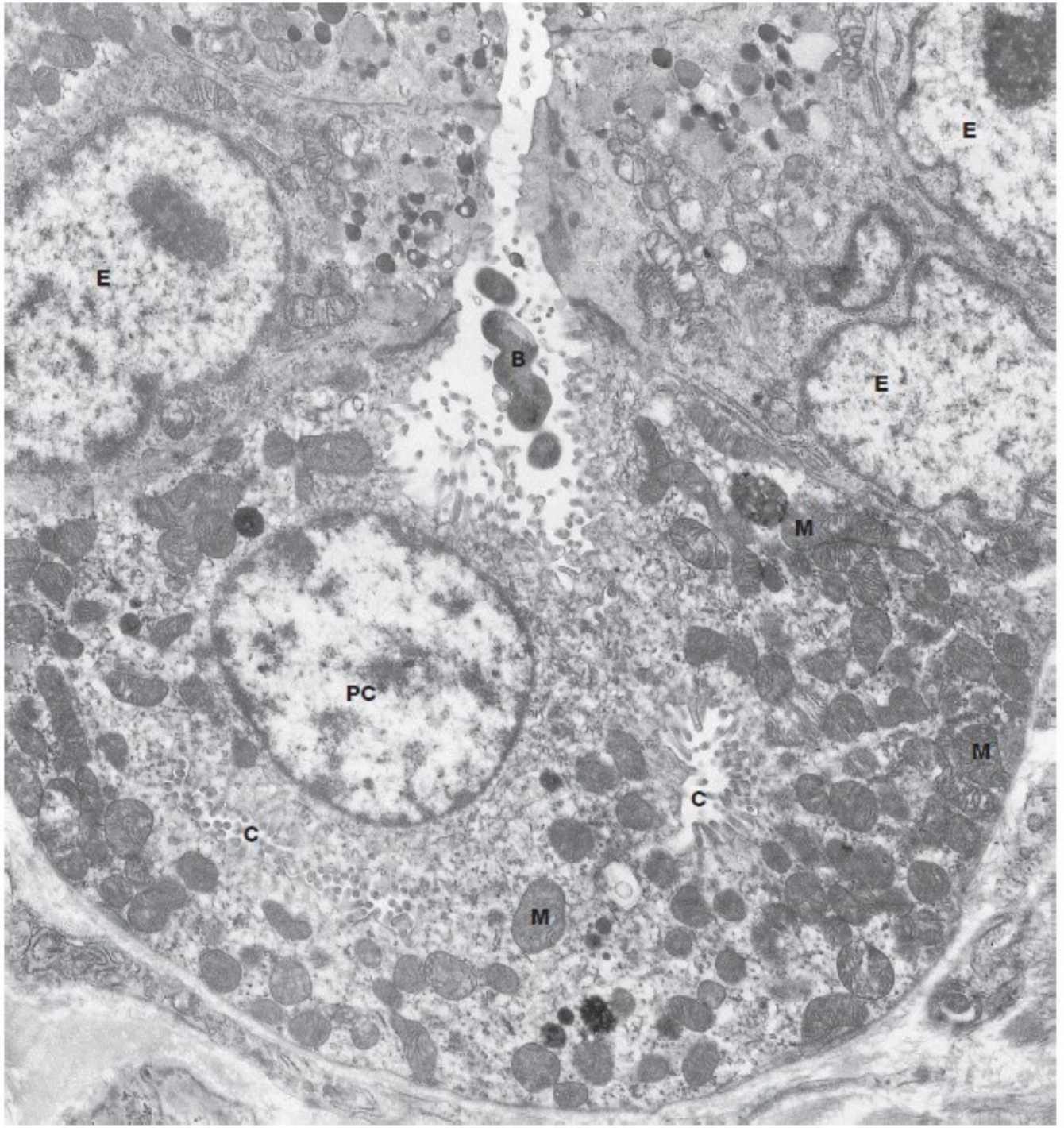
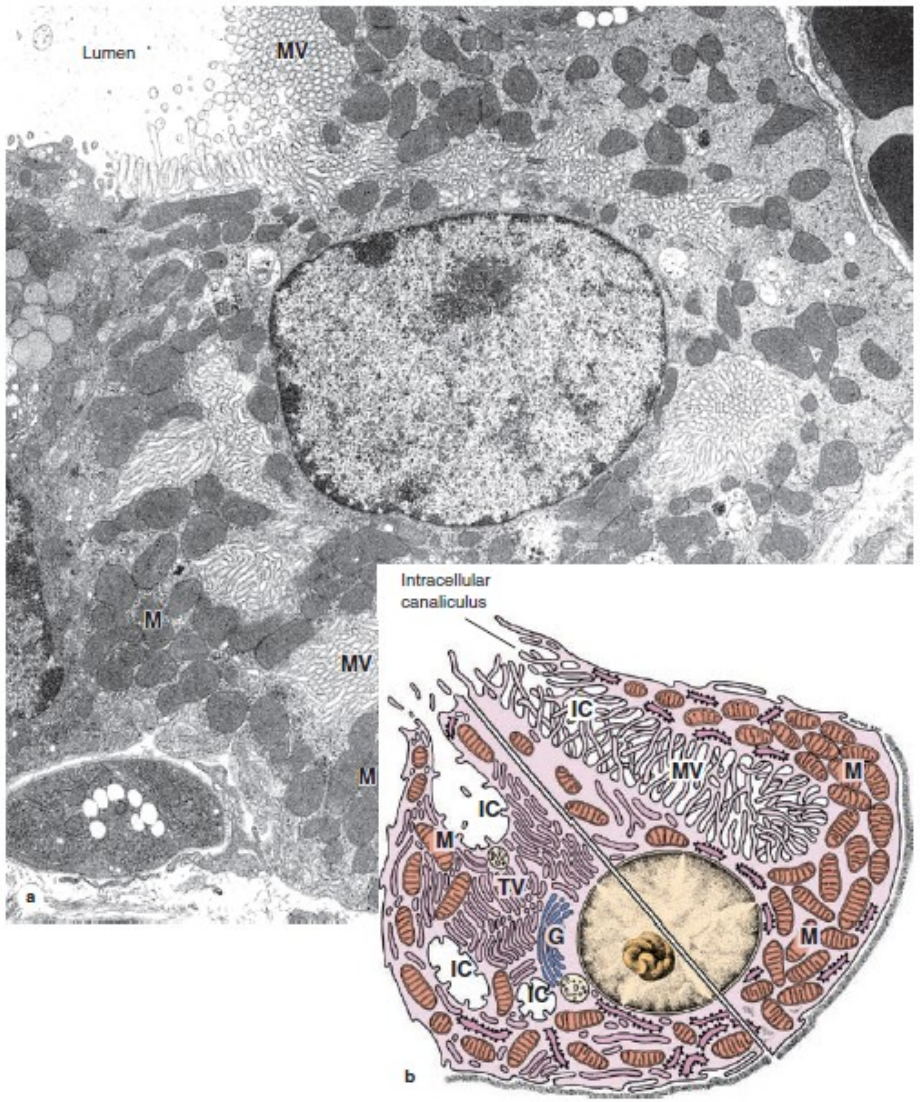


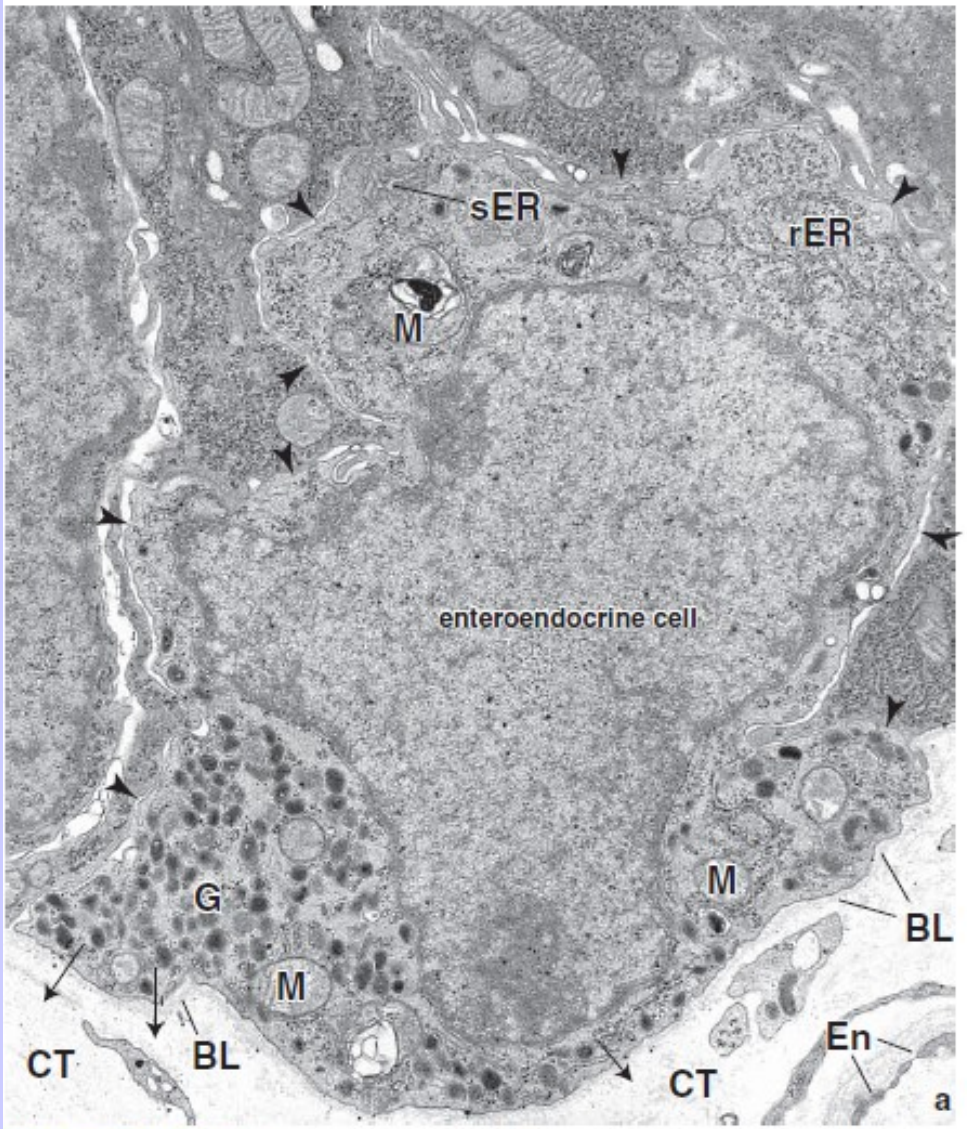
FIGURE **15–18** **Ultrastructure of parietal cells.**

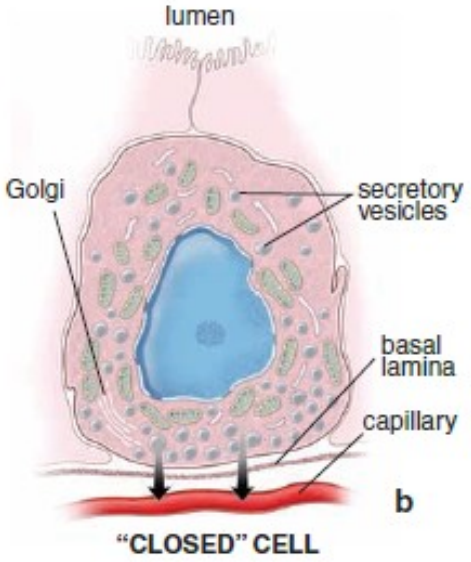


(a) A TEM of an active parietal cell shows abundant microvilli (**MV**) protruding into the intracellular canaliculi, near the lumen and deep in the cell. The cytoplasm contains numerous mitochondria (**M**). (X10,200)

(Figure 15–18a, used with permission from Dr Susumu Ito, Department of Cell Biology, Harvard Medical School, Boston, MA.)

(b) Composite diagram of a parietal cell shows the ultrastructural differences between a resting cell (left) and an active cell (right). In the resting cell a number of tubular vesicles (**TV**) are seen below the apical plasmalemma (left), but the cell has few microvilli and only short intracellular canaliculi (**IC**) among the mitochondria (**M**) and Golgi vesicles (**G**). When stimulated to produce HCl (right), the tubular vesicles fuse with the cell membrane to form large intracellular canaliculi (**IC**) and microvilli (**MV**), thus providing a generous increase in the surface of the cell membrane for diffusion and ion pumps. Prolonged activity may produce more mitochondria.





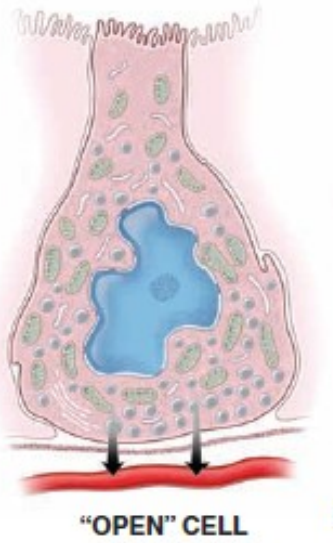
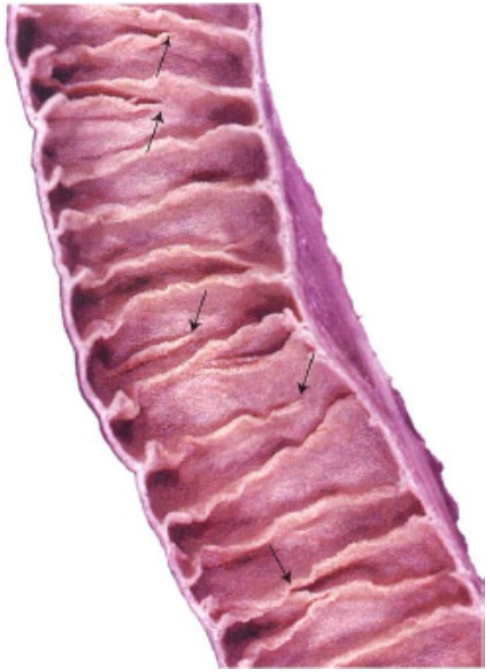


FIGURE 17.12 ▲ Electron micrograph and diagrams of enteroendocrine cells. a. This electron micrograph shows an example of the "closed" enteroendocrine cell. *Arrowheads* mark the boundary between the enteroendocrine cell and the adjacent epithelial cells. At its base, the enteroendocrine cell rests on the basal lamina (*BL*). This cell does not extend to the epithelial or luminal surface. Numerous secretory vesicles (*G*) in the base of the cell are secreted in the direction of the *arrows* across the basal lamina and into the connective tissue (*CT*). *En*, endothelium of capillary; *M*, mitochondria; *rER*, rough endoplasmic reticulum; *sER*, smooth endoplasmic reticulum. **b.** This diagram of an enteroendocrine "closed" cell is drawn to show that it does not reach the epithelial surface. The secretory vesicles are regularly lost during routine preparation. Because of the absence of other distinctive organelles, the nucleus appears to be surrounded by a small amount of clear cytoplasm in H&E–stained sections. **c.** The enteroendocrine "open" extend to the epithelial surface. Microvilli on the apical surface of these cells possess taste receptors and are able to detect sweet, bitter, and umami sensations. These cells serve as chemoreceptor cells, which monitor an environment on the surface of the epithelium. They are involved in a regulation of gastrointestinal hormone secretion.

DIGESTIVE SYSTEM

SMALL INTESTINE



- Complete digestion of food
- Absorb final products of digestion (amino acids, monosaccharides, fatty acids, etc.)
- Secrete protective mucus
- Secrete hormones

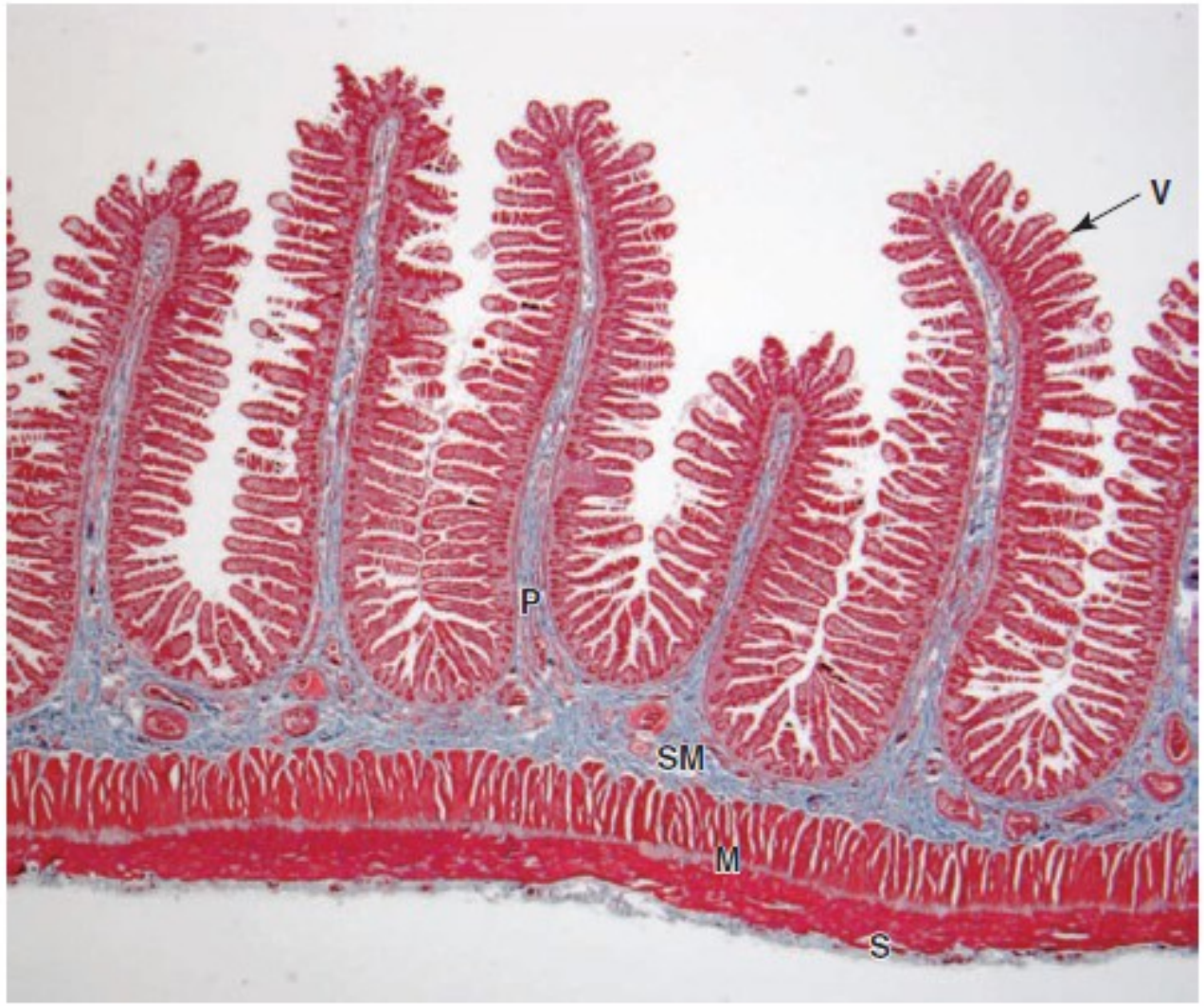
- Subdivided into duodenum (immediately distal to pylorus of stomach), jejunum (distal to duodenum), and ileum (most distal region)

- **Common features of the small intestine**

  Structures that increase the surface area of the small intestine:

  - *Plicae circulares*. Permanent circular folds formed by an up-welling of the submucosa and its overlying mucosa into the lumen. Villi protrude from the plicae.
  - *Villi.* Finger-like protrusions of the lamina propria and overlying epithelium into the lumen
    - Villi assume different shapes in each of the three intestinal subdivisions.
    - A lacteal (blind-ending lymphatic capillary) is located in the center of each villus to absorb digested fat.
    - Individual smooth muscle cells lie parallel to the long axis of each villus, "milking" the lacteal contents to the periphery.
  - *Microvilli.* Increase surface area of absorptive cells and, collectively, form a brush or striated border

FIGURE **15–23** **Circular folds (plicae circulares) of the jejunum.**

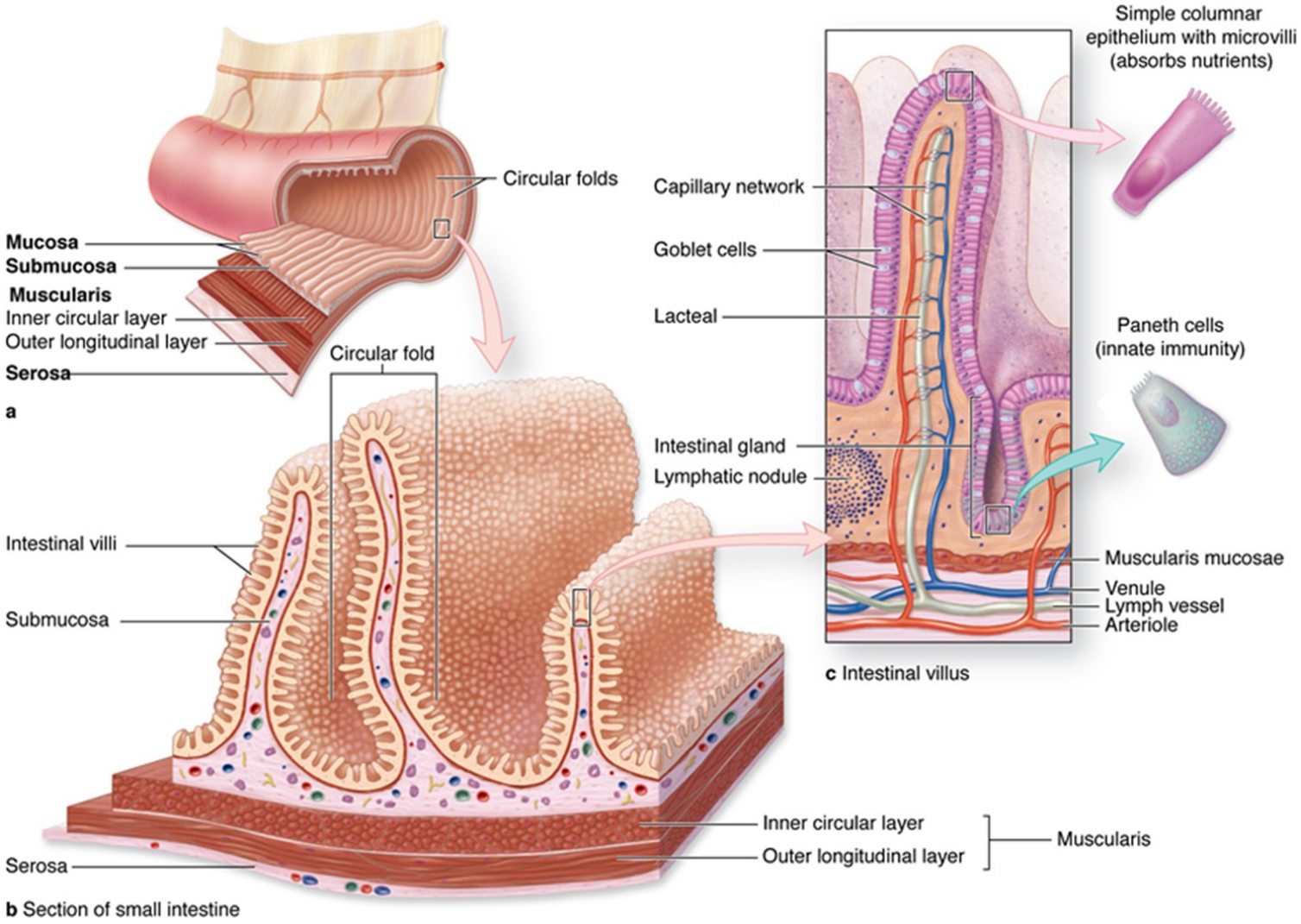


The mucosa and submucosa (**SM**) of the small intestine form distinct projecting folds called plicae (**P**), which encircle or spiral around the inner circumference and are best developed in the jejunum. On each fold the mucosa forms a dense covering of projecting structures called **villi** (**V**). In this longitudinal section the two layers of the muscularis (**M**) are clearly distinguished. The inner layer has smooth muscle encircling the submucosa; the outer layer runs lengthwise just inside the serosa (**S**), the gut's outer layer. This arrangement of smooth muscle provides for strong peristaltic movement of the gut's contents. (X12; Masson trichrome)

DIGESTIVE SYSTEM

SMALL INTESTINE

- **Common features of the small intestine**
  - *Intestinal glands (Crypts of Lieberkühn)* are invaginations of epithelium into the lamina propria
  - *Epithelium* covering the villi and lining the crypts is continuous (with different cell types in different part)
- **Small intestine: layers**
  - Mucosa
    - Epithelium
    - Lamina propria
    - Lamina muscularis mucosae
  - Submucosa
  - Muscularis externa
    - Inner circular layer
    - Outer longitudinal layer
  - Serosa



DIGESTIVE SYSTEM

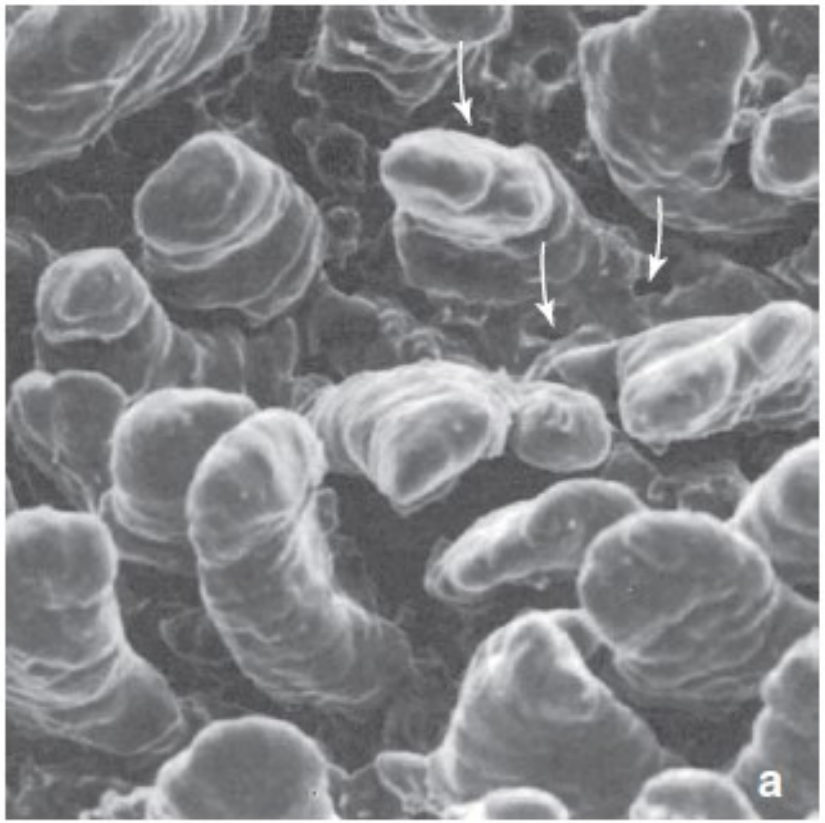
SMALL INTESTINE

- **Mucosal epithelium** is composed of:
  - *Absorptive cells (enterocytes)*, forming a simple columnar epithelium with microvilli – „brush border“, absorb digested food
  - *Goblet cells (unicellular glands)* are interspersed among absorptive cells and secrete mucus for protection. These cells increase in number from duodenum to rectum.

- **Intestinal glands (crypts of Lieberkühn)** are simple tubular glands that begin at the bases of the villi in the mucosa and extend through the lamina propria to the muscularis mucosae.
  Possess:
  - *Absorptive cells*
  - *Goblet cells*
  - *Paneth cells* possess large, eosinophilic granules whose contents, e.g, lysozyme, digest bacterial cell walls. Deep in crypts.
  - *Enteroendocrine cells* – secrete hormones (e.g., cholecystokinin) related to digestion

- **Muscularis externa** of inner circular and outer longitudinal layers with an intervening *Auerbach's nerve plexus*.

- **Serosa** covers small intestine.



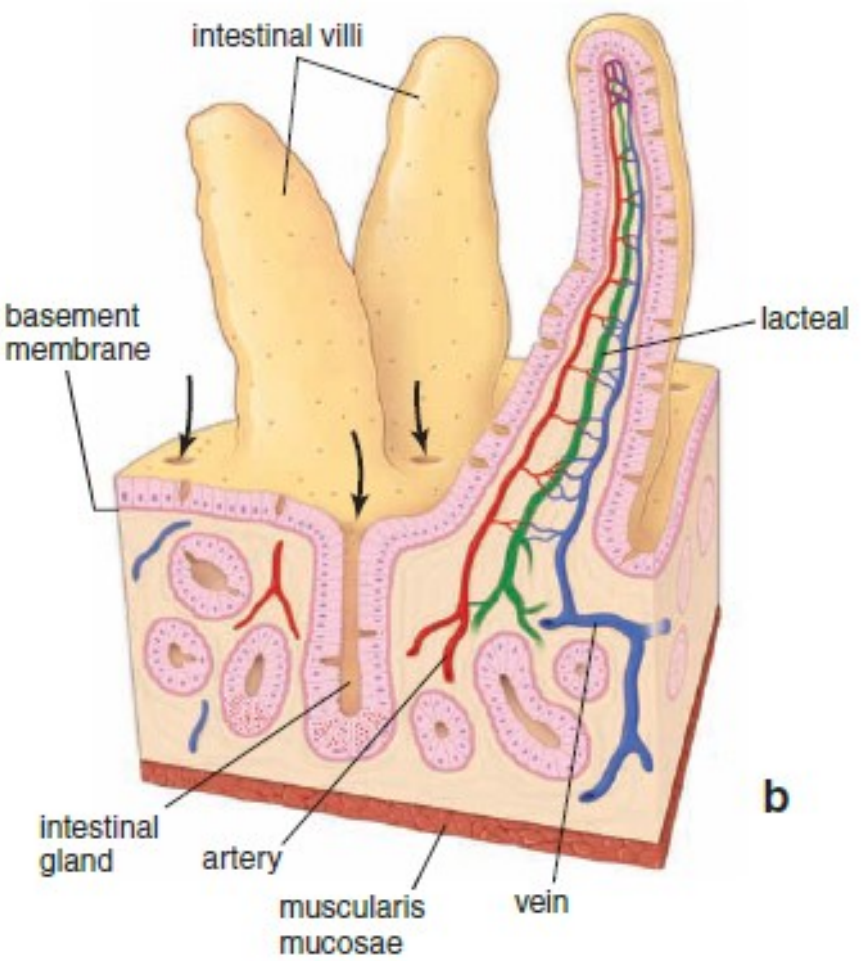


FIGURE 17.18 ▲ Intestinal villi in the small intestine. a. Scanning electron micrograph of the intestinal mucosa showing its villi. Note the openings (*arrows*) located between the bases of the villi that lead into the intestinal glands (crypts of Lieberkühn). ×800. **b.** This three-dimensional diagram of the intestinal villi shows the continuity of the epithelium covering the villi with the epithelium lining the intestinal glands. Note blood vessels and the blind-ending lymphatic capillary, called a lacteal, in the core of the villus. Between the bases of the villi, the openings of the intestinal glands can be seen (*arrows*). Also, the small openings on the surface of the villi indicate the location of discharged goblet cells.

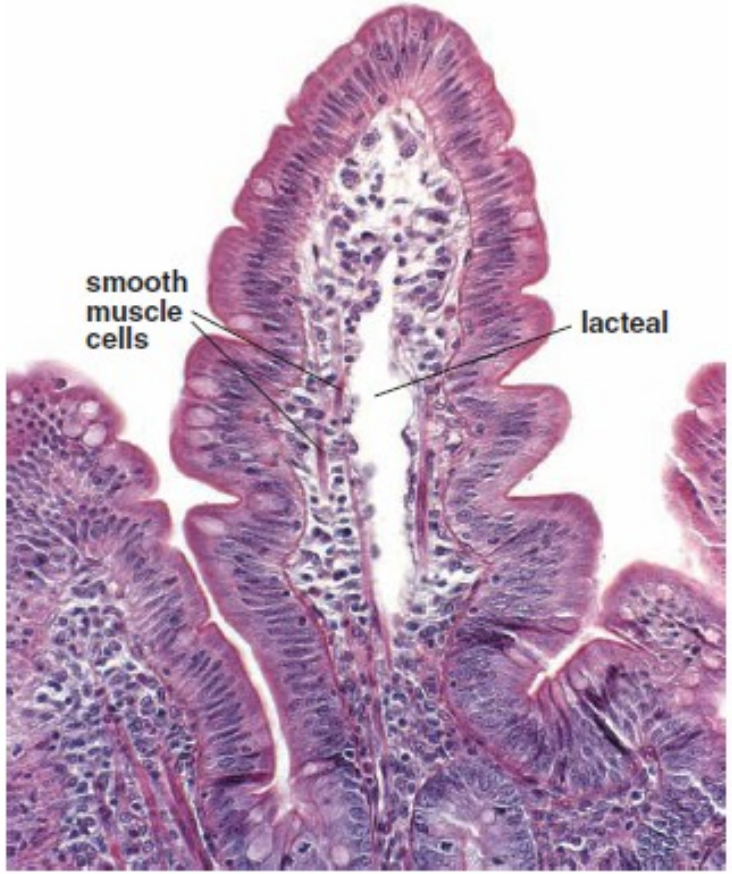


FIGURE 17.19 ▲ Photomicrograph of an intestinal villus. The surface of the villus consists of columnar epithelial cells, chiefly enterocytes with a striated border. Also evident are goblet cells that can be readily identified by the presence of the apical mucous cup. Located beneath the epithelium is the highly cellular loose connective tissue, the lamina propria. The lamina propria contains large numbers of round cells, mostly lymphocytes. In addition, smooth muscle cells can be identified. A lymphatic capillary called a lacteal occupies the center of the villus. When the lacteal is dilated, as it is in this specimen, it is easily identified. ×160.

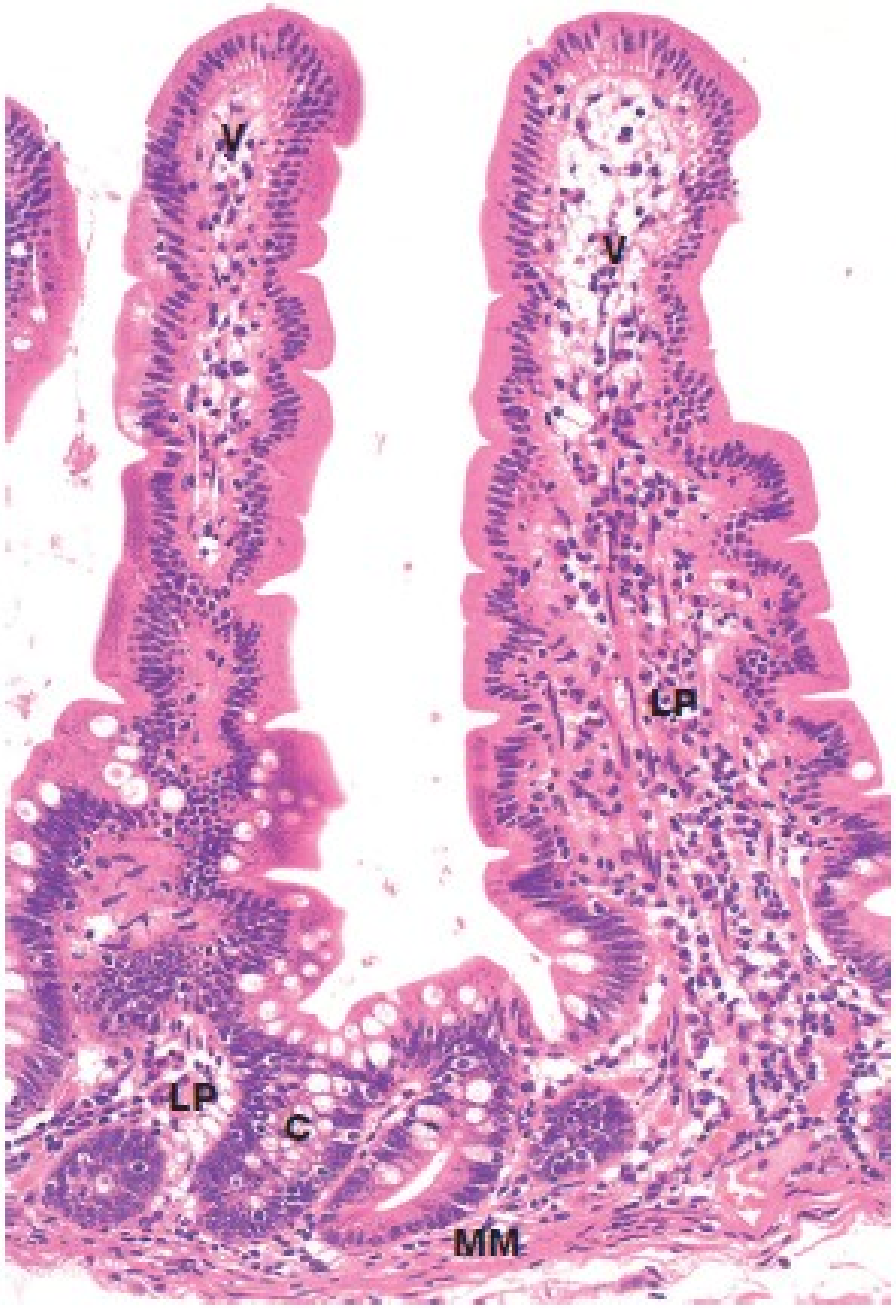
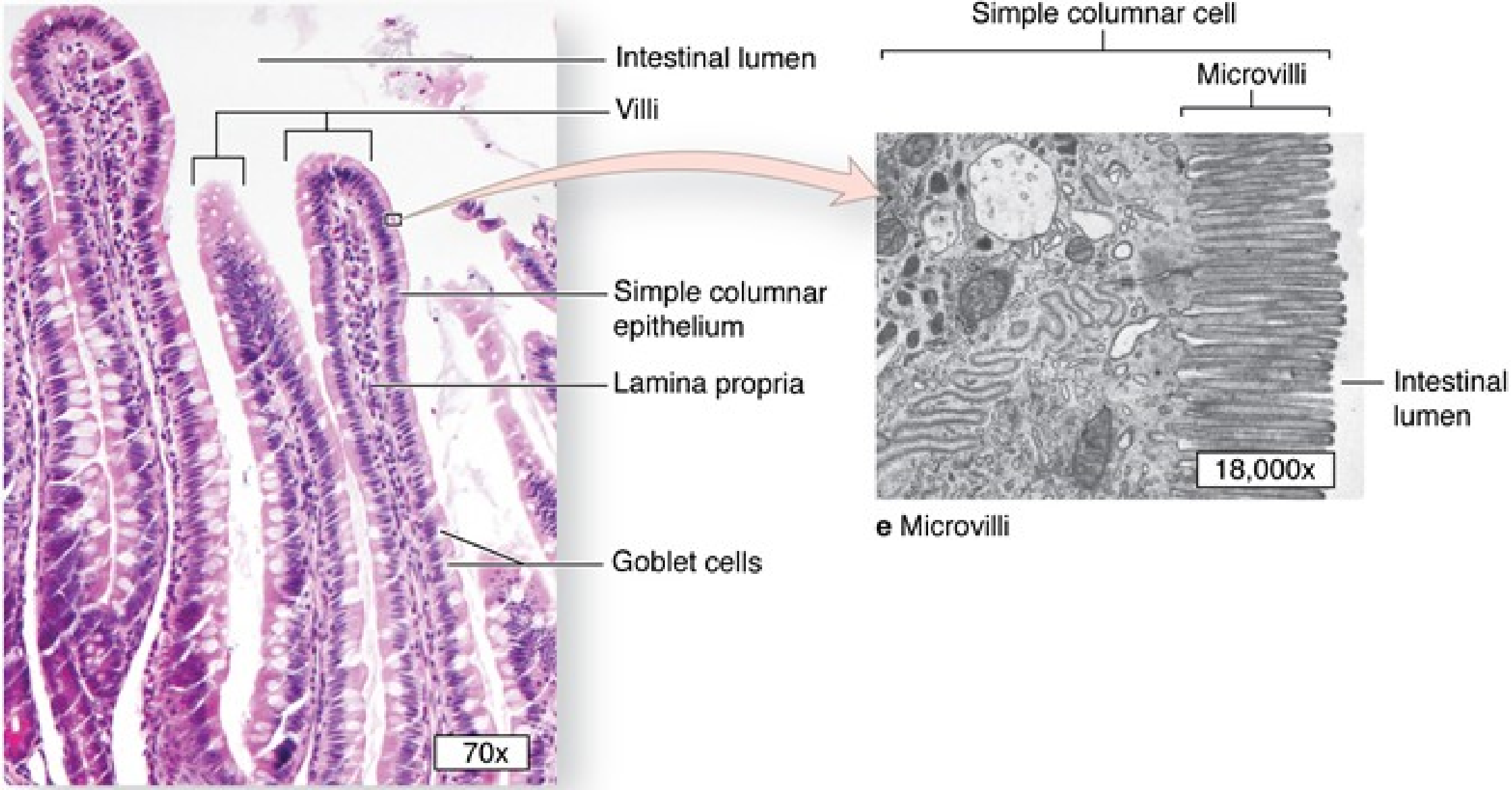


FIG. 14.19 Intestinal villi and crypts
H&E (MP)

The intestinal *villi* **V** are lined by a simple columnar epithelium which is continuous with that of the *crypts* **C**. As in other parts of the gastrointestinal tract, the epithelium includes a variety of cell types, each with its own specific function. Cell types in the small intestine epithelium include:

- **Enterocytes**, the most numerous cell type, are tall columnar cells with surface microvilli that are seen as a ***brush border*** in light micrographs. These cells are the main absorptive cells.
- **Goblet cells** are scattered among the enterocytes and produce mucin for lubrication of the intestinal contents and protection of the epithelium.
- **Paneth cells** are found at the base of the crypts and are distinguished by their prominent eosinophilic apical granules. These cells have a defensive function.
- **Neuroendocrine cells** produce locally acting hormones that regulate gastrointestinal motility and secretion.
- **Stem cells**, found at the base of the crypts, divide continuously to replenish all of the above four cell types.
- **Intraepithelial lymphocytes**, which are mostly T cells, provide defence against invasive organisms.

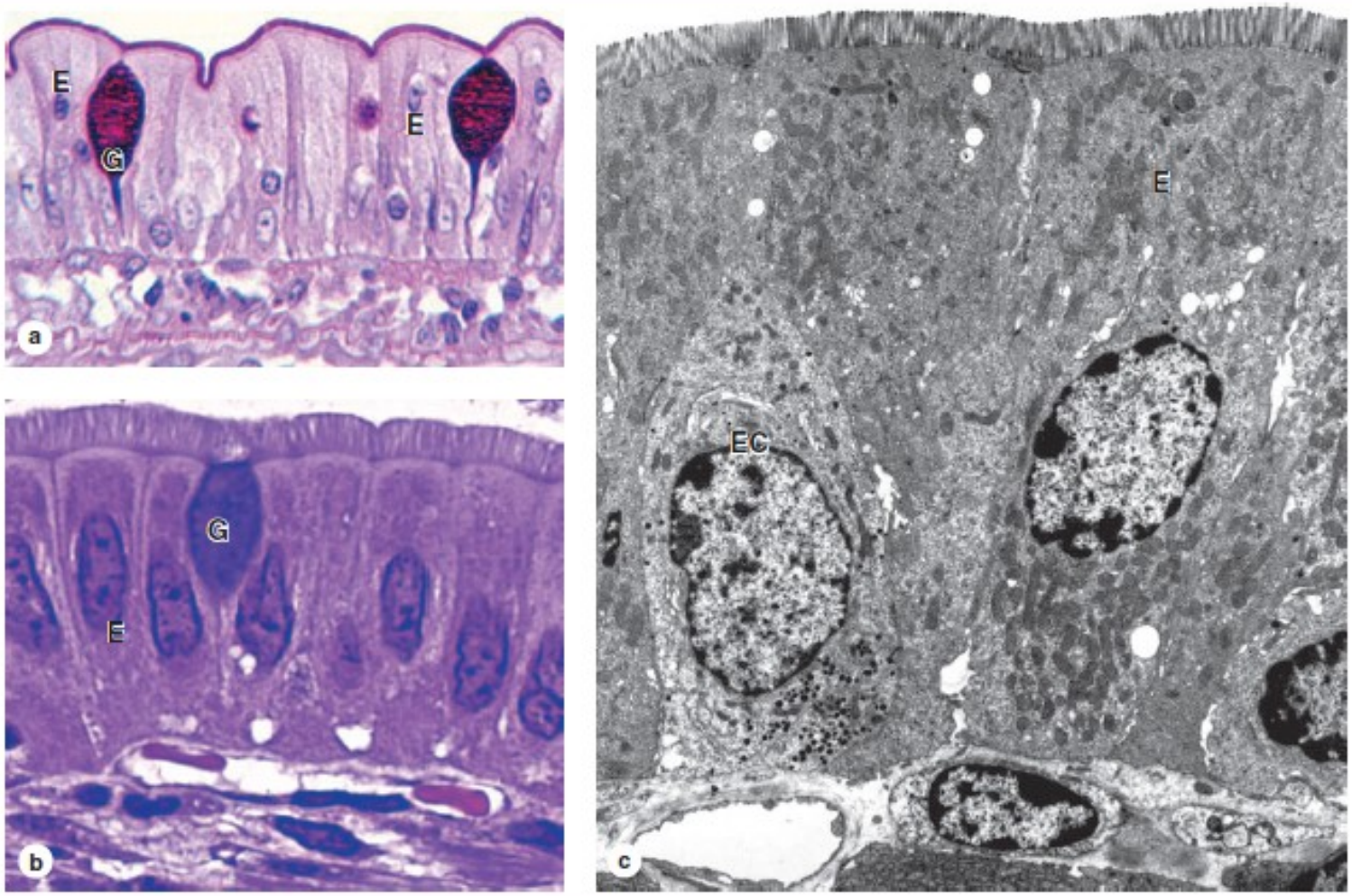
The lamina propria **LP** extends between the crypts and into the core of each villus and contains a rich vascular and lymphatic network into which digestive products are absorbed. The muscularis mucosae **MM** lies immediately beneath the base of the crypts.



d Intestinal villi

e Microvilli

FIGURE 15–24 Cells covering the villi.



(a) The columnar epithelium that covers intestinal villi consists mainly of the tall absorptive enterocytes (**E**). The apical ends of these cells are joined and covered by a **brush border** of microvilli. Covered by a coating of glycoproteins, the brush border, along with the mucus-secreting goblet cells (**G**), stains with carbohydrate staining methods. Other cells of the epithelium are scattered enteroendocrine cells, which are difficult to identify in routine preparations, and various immune cells such as intraepithelial lymphocytes. The small spherical nuclei of lymphocytes can be seen between the enterocytes. (X250; PAS-hematoxylin)

(b) At higher magnification individual **microvilli** of enterocytes are better seen and the striated appearance of the border is apparent. (X500)

(c) TEM shows microvilli and densely packed mitochondria of enterocytes (**E**), and enteroendocrine cells (**EC**) with basal secretory granules can be distinguished along the basal lamina. (X2500)

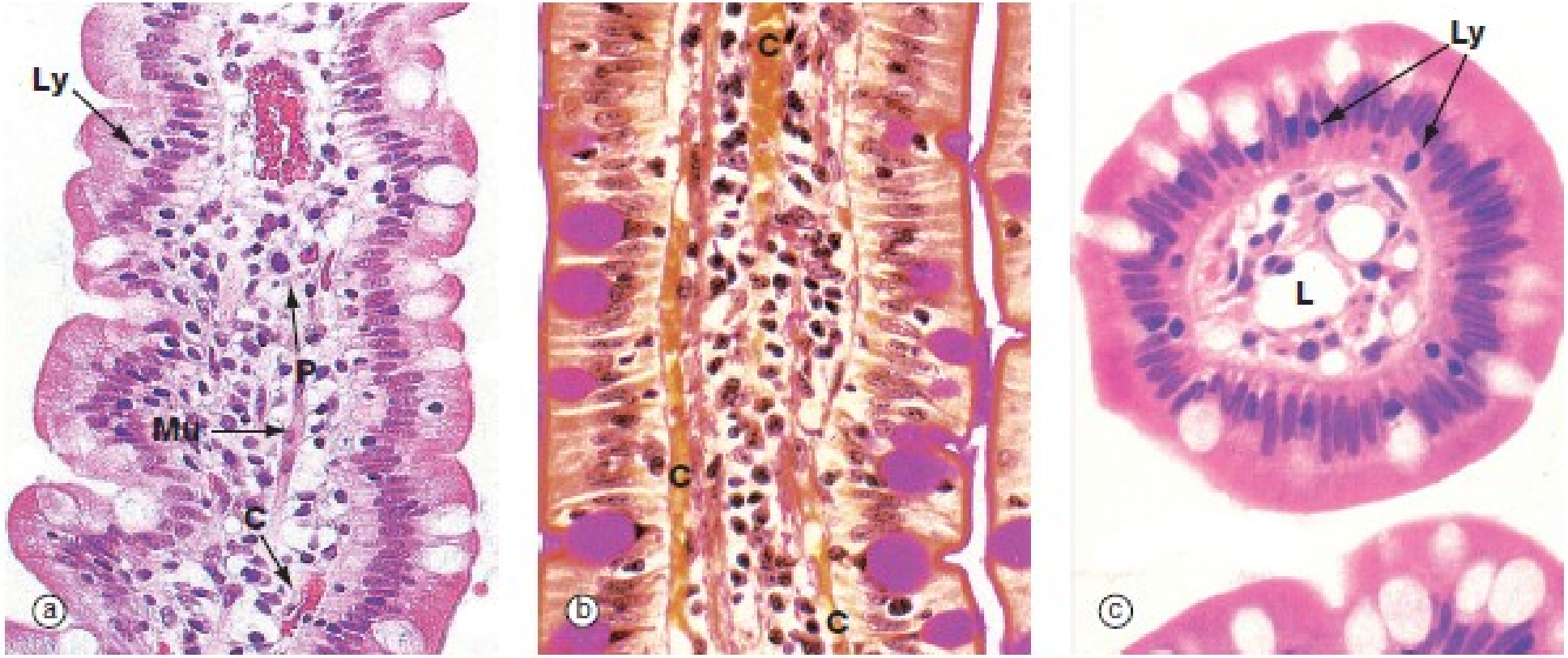


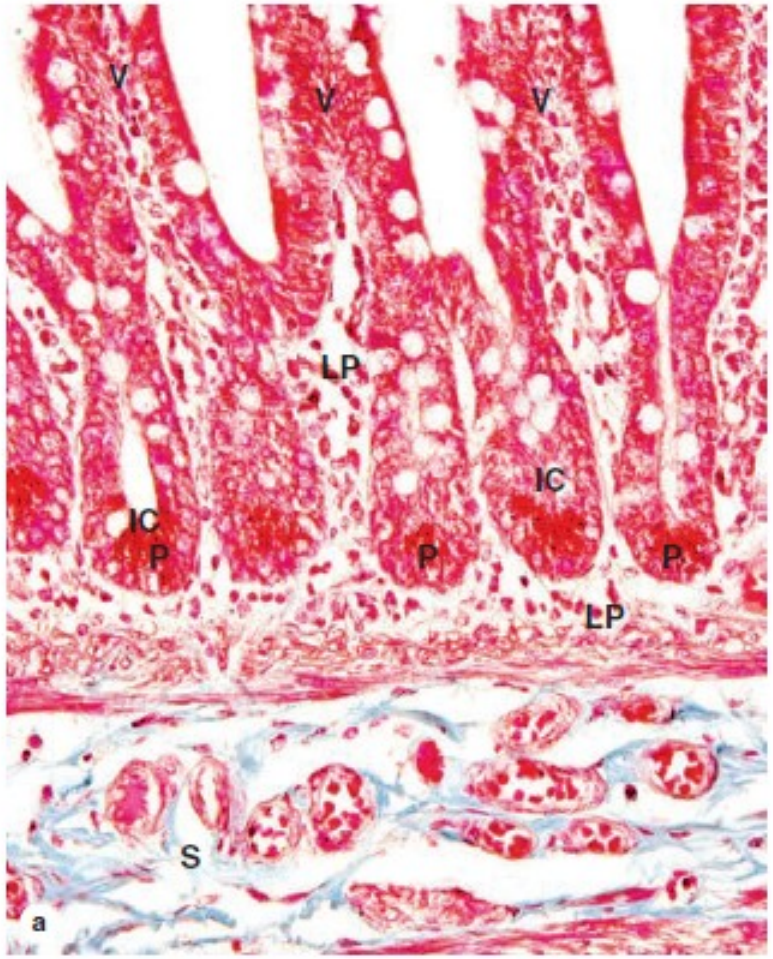
FIG. 14.22 Intestinal villi
(a) H&E, LS (MP) (b) PAS/iron-haematoxylin/orange G, LS (HP) (c) H&E, TS (HP)

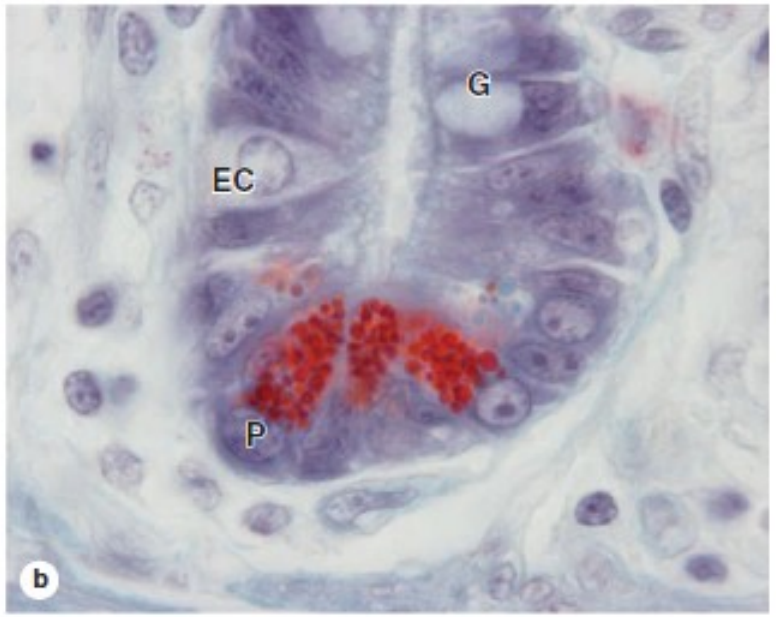
These micrographs illustrate the tall columnar *enterocytes* that cover the intestinal villi, as well as the *goblet cells* scattered among them. The luminal surface of the enterocytes seen in micrograph (b) is strongly PAS-positive due to a particularly thick glycocalyx and a surface layer of goblet cell–derived mucus. Both features protect against autodigestion. The glycocalyx is also the site for adsorption of pancreatic digestive enzymes.

T lymphocytes **Ly** are scattered among the enterocytes. Plasma cells **P** in the villous core secrete IgA into the intestinal lumen by transcytosis across epithelial cells.

The cores of the villi are extensions of the lamina propria and consist of loose supporting tissue. Capillaries **C** lie immediately beneath the basement membrane and transport most digestive products to the hepatic portal vein. Tiny lymphatic vessels drain into a single larger vessel called a *lacteal* **L** at the centre of the villus. The lacteals transport absorbed lipid into the circulatory system via the thoracic duct. Smooth muscle fibres **Mu** are seen in the long axis of the villous core in micrograph (a) and represent extensions of the muscularis mucosae.

FIGURE **15–26** **Intestinal crypts or glands, with Paneth cells.**





(a) Between villi (**V**) throughout the small intestine, the covering epithelium invaginates into the lamina propria (**LP**) to form short tubular glands called intestinal glands or intestinal crypts (**IC**). The lining near the openings of the crypts contains a population of stem cells for the entire epithelial lining of the small intestine. Daughter cells slowly move with the growing epithelium out of the crypts, differentiating as **goblet cells, enterocytes**, and **enteroendocrine cells**. These cells continue to move up each villus and within a week are shed at the tip, with billions shed throughout the small intestine each day. At the base of the crypts are many Paneth cells (**P**) with an innate immune function. The submucosa (**S**) has many lymphatics draining lacteals. (X200; H&E)

(b) Higher magnification at the base of an intestinal gland shows the typical eosinophilic granules of Paneth cells (**P**), along with an open-type enteroendocrine cell (**EC**) and a differentiating goblet cell (**G**). (X400; H&E)

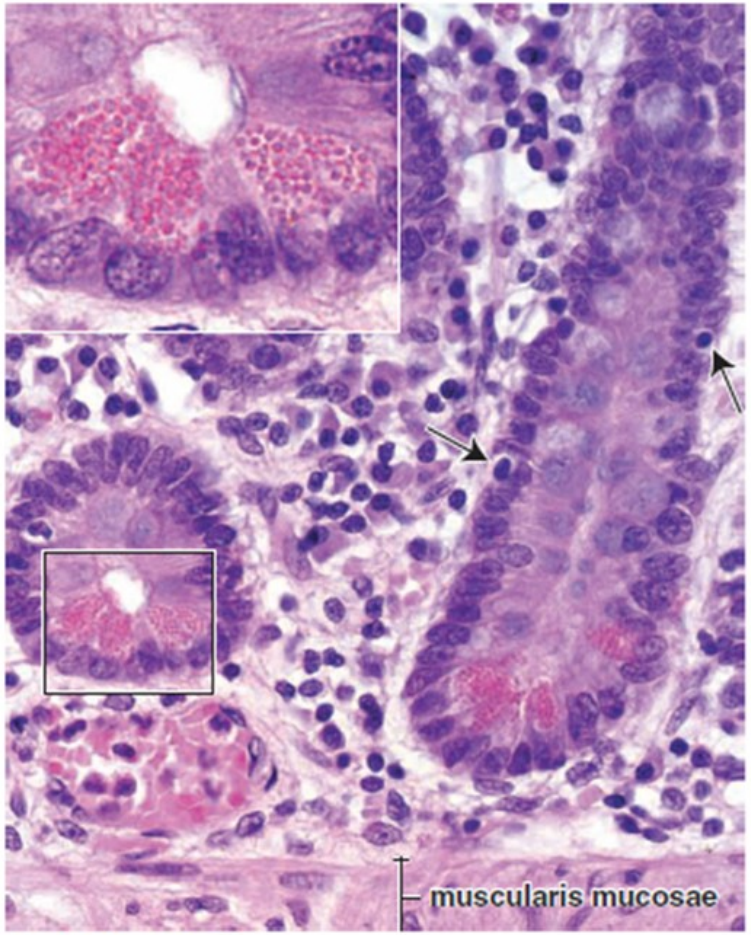


FIGURE 17.23 ▲ Photomicrograph of intestinal glands showing Paneth cells. This photomicrograph shows the base of intestinal (jejunal) glands in an H&E preparation. The gland on the *right* is sectioned longitudinally; the circular cross-sectional profile of another gland is seen on the *left*. Paneth cells are typically located in the base of the intestinal glands and are readily seen in the light microscope because of the intensive eosin staining of their vesicles. The lamina propria contains an abundance of plasma cells, lymphocytes, and other connective tissue cells. Note several lymphocytes in the epithelium of the gland (*arrows*). ×240. **Inset.** This high magnification of the area indicated by the *rectangle* shows the characteristic basophilic cytoplasm in the basal portion of the cell and large accumulations of intensely staining, eosinophilic, refractile secretory vesicles in the apical portion of the cell. An arginine-rich protein found in the vesicles is probably responsible for the intense eosinophilic reaction. ×680.

SMALL INTESTINE

- **Variations specific to the intestinal subdivisions**

- *Brunner's glands* in the submucosa are present only in the duodenum. These compound tubular glands open into the bases of the intestinal glands and secrete an alkaline mucus to neutralize the acidity of the stomach contents.

- *Peyer's patches* are clusters of 10-200 lymphoid nodules located primarily in the lamina propria of the ileum. Each cluster is positioned on the side of the intestine away from the mesentery and forms a bulge that may protrude into the lumen as well as into the submucosa.

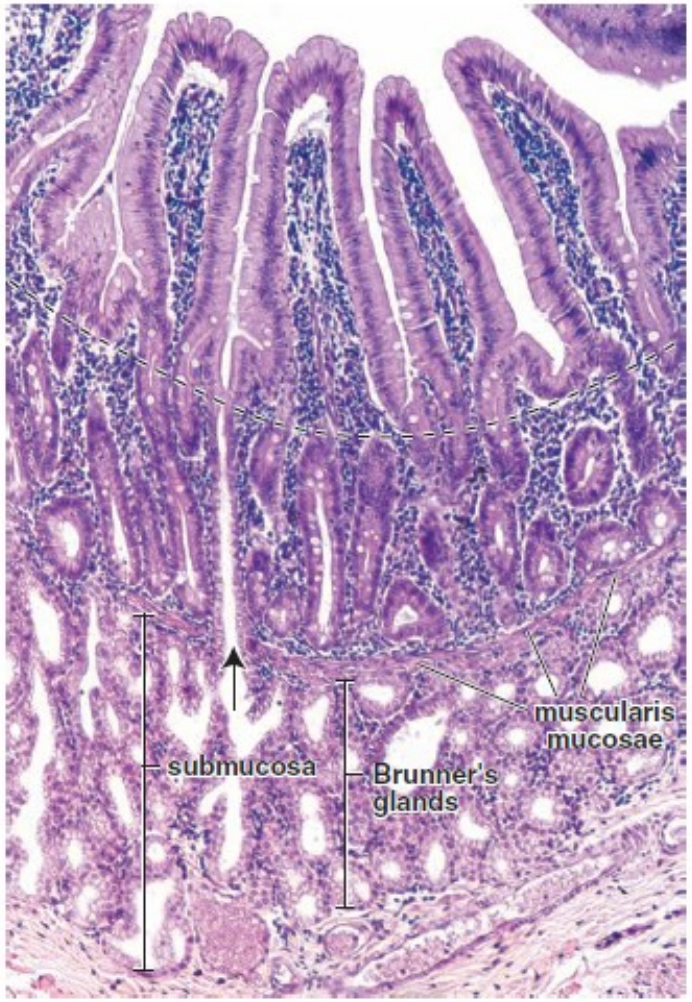


FIGURE 17.25 ▲ Photomicrograph of Brunner's glands in the duodenum. This photomicrograph shows part of the duodenal wall in an H&E preparation. A distinctive feature of the duodenum is the presence of Brunner's glands. The *dashed line* marks the boundary between the villi and the typical intestinal glands (crypts of Lieberkühn). The latter extend to the muscularis mucosae. Under the mucosa is the submucosa, which contains Brunner's glands. These are branched tubular glands whose secretory component consists of columnar cells. The duct of the Brunner's gland opens into the lumen of the intestinal gland (*arrow*). ×120.

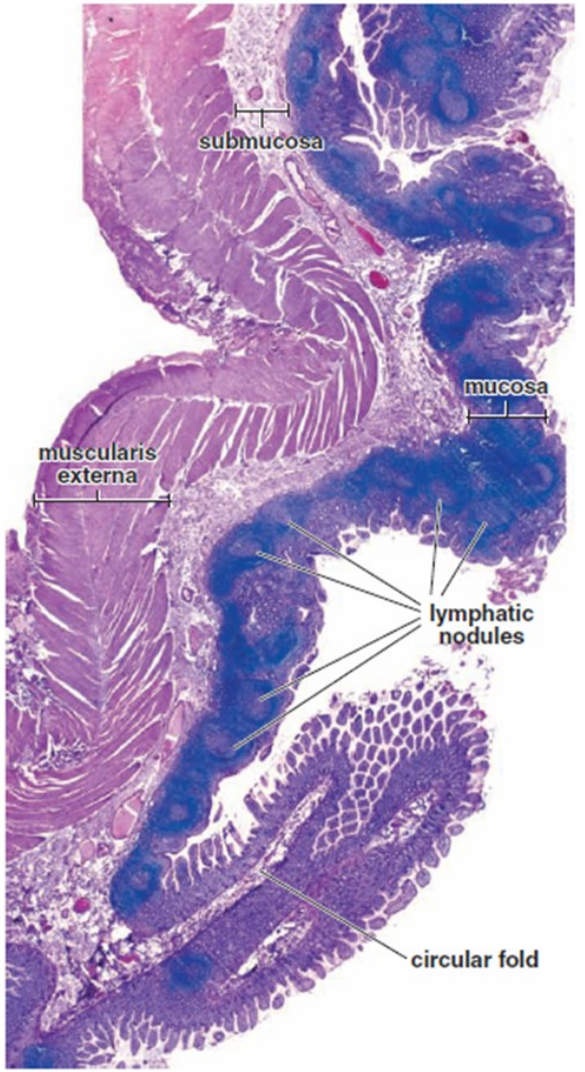
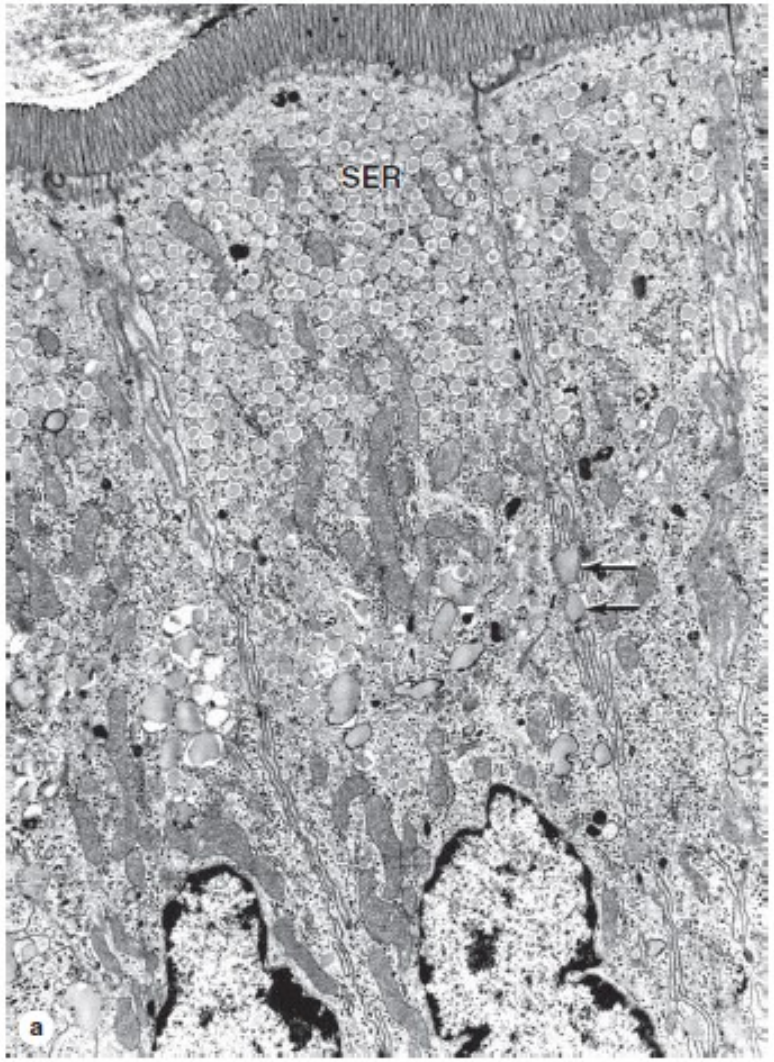
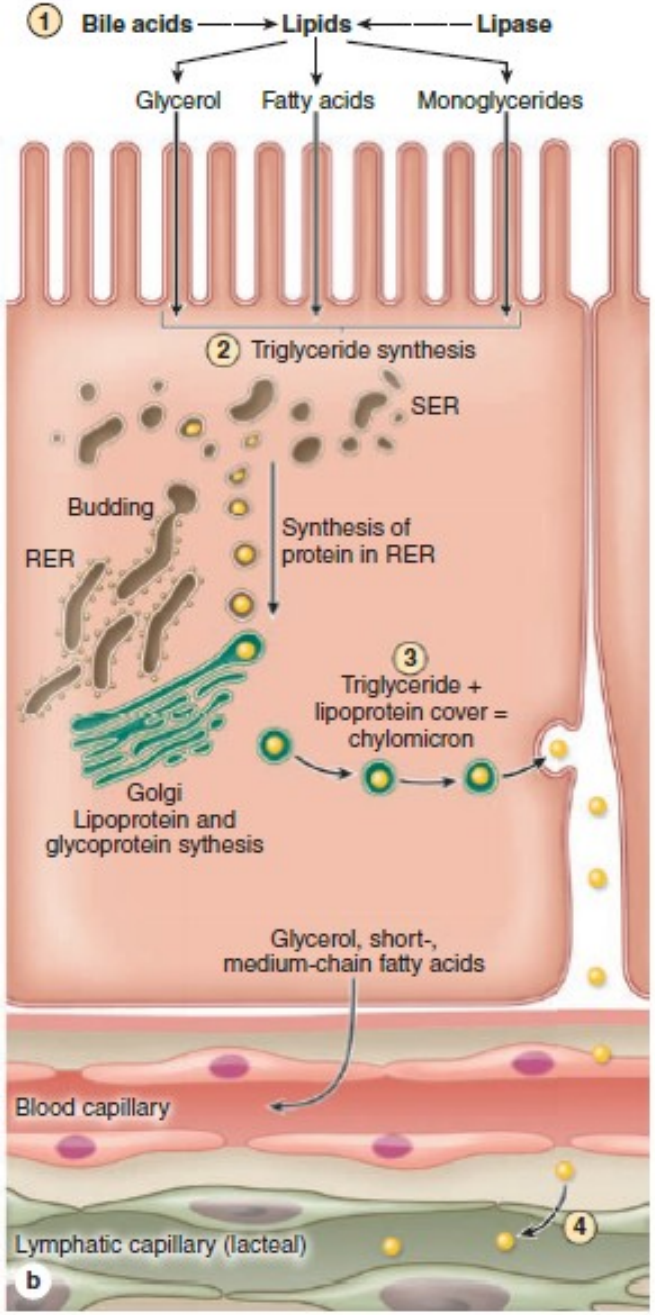


FIGURE 17.20 ▲ Photomicrograph of Peyer's patches. This photomicrograph shows a longitudinal section through the wall of a human ileum. Note the extensive lymphatic nodules located in the mucosa and the section of a circular fold projecting into the lumen of the ileum. Lymphatic nodules within the Peyer's patch are primarily located within the lamina propria, although many extend into the submucosa. They are covered by the intestinal epithelium, which contains enterocytes, occasional goblet cells, and specialized antigen-transporting M cells. ×40.

FIGURE **15–25** **Lipid absorption and processing by enterocytes.**



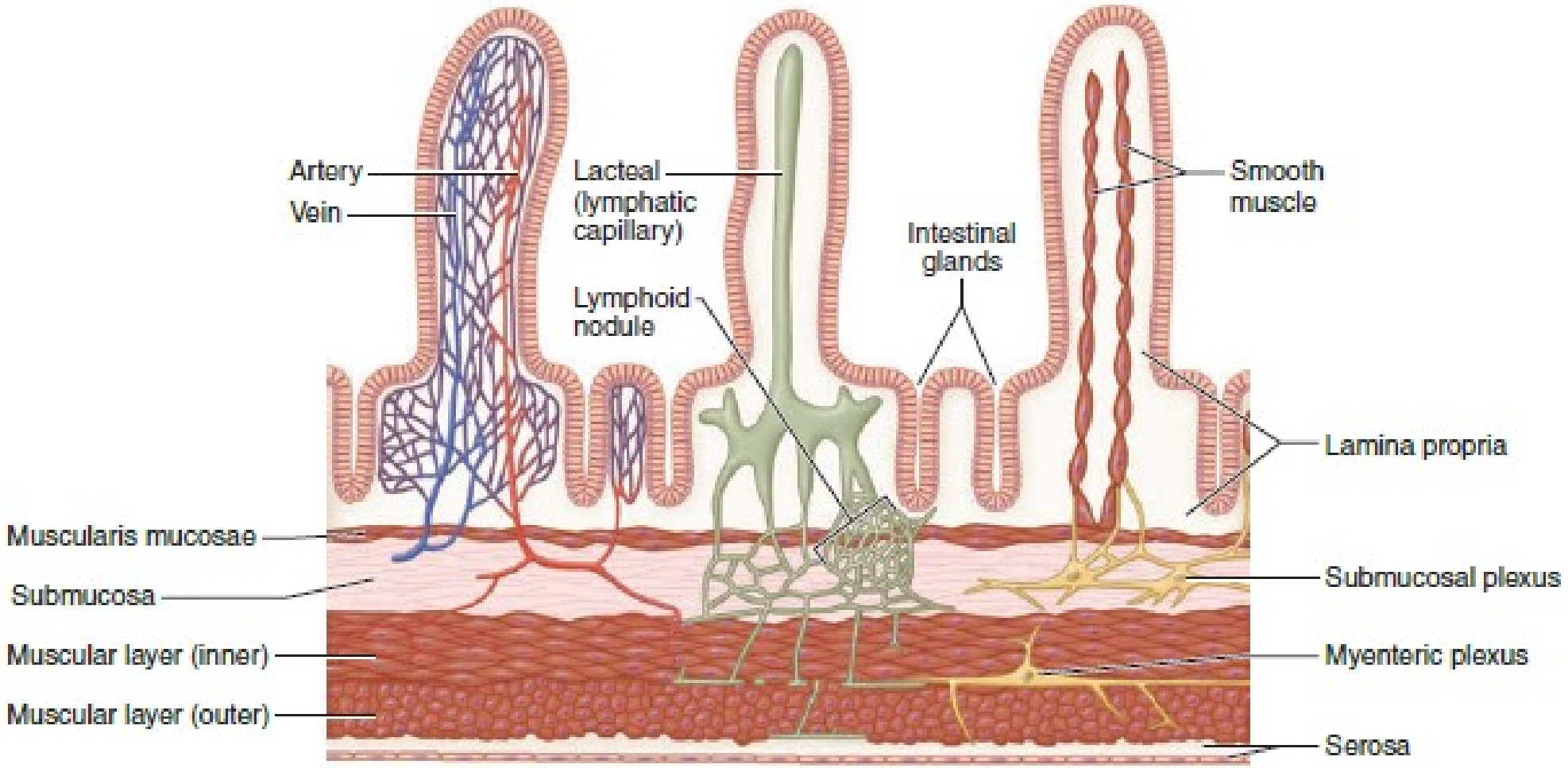


(a) TEM shows that enterocytes involved in lipid absorption accumulate many small lipid droplets in vesicles of the smooth ER (**SER**). These vesicles fuse near the nucleus, forming larger globules that are moved laterally and cross the cell membrane to the extracellular space (**arrows**) for eventual uptake by lymphatic capillaries (lacteals) in the lamina propria. (X3000)

(Figure 15–25a, used with permission from Dr Robert R. Cardell, Jr, Department of Cancer and Cell Biology, University of Cincinnati College of Medicine, Cincinnati, OH.)

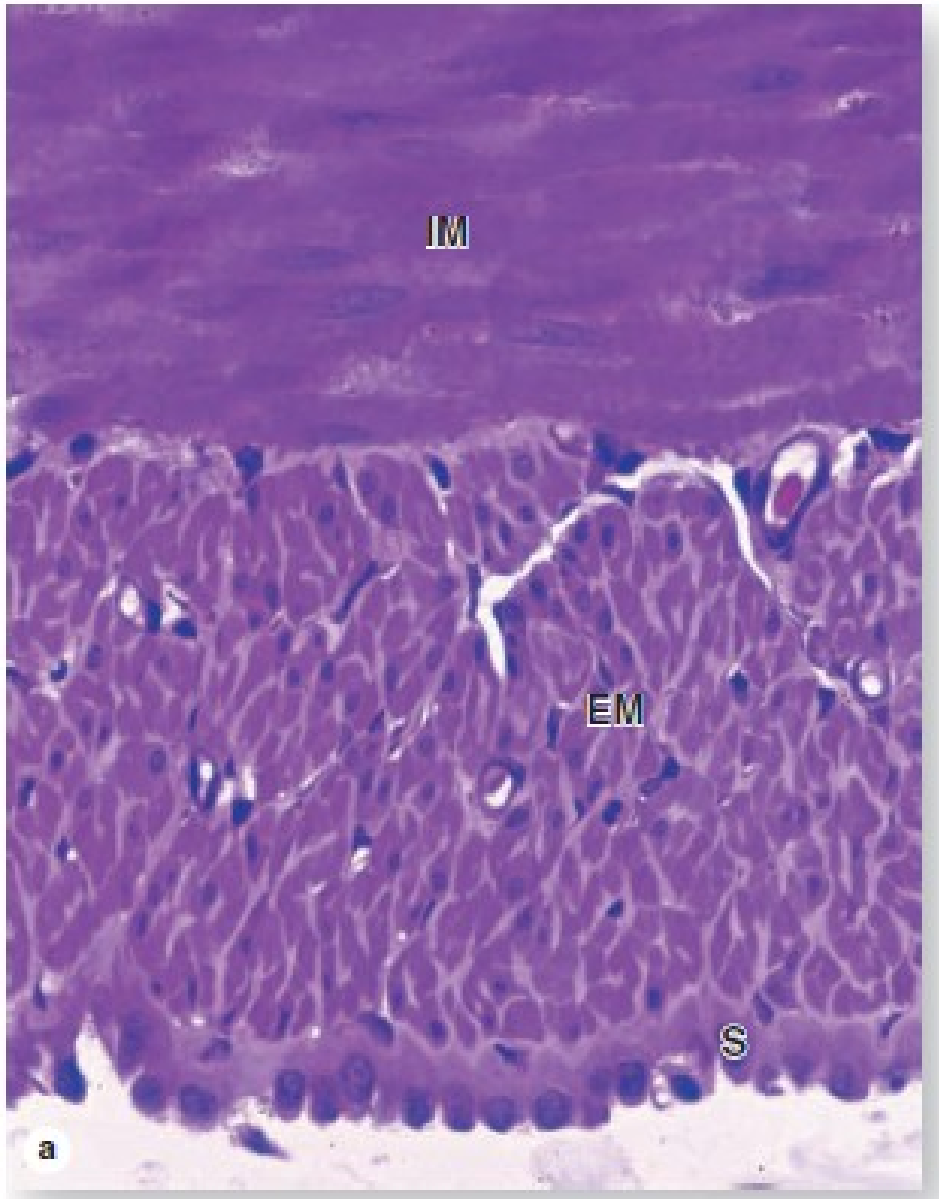
(b) Diagram showing lipid processing by enterocytes. Ingested fats are emulsified by **bile acids** to form a suspension of lipid droplets from which lipids are digested by **lipases** to produce glycerol, fatty acids, and monoglycerides **(1)**. The products of hydrolysis diffuse passively across the microvilli membranes and are collected in the cisternae of the smooth ER, where they are resynthesized as **triglycerides (2)**. Processed through the RER and Golgi, these triglycerides are surrounded by a thin layer of proteins and packaged in vesicles containing **chylomicrons** (0.2-1 µm in diameter) of lipid complexed with protein **(3)**. Chylomicrons are transferred to the lateral cell membrane, secreted by exocytosis, and flow into the extracellular space in the direction of the lamina propria, where most enter the lymph in **lacteals (4)**.

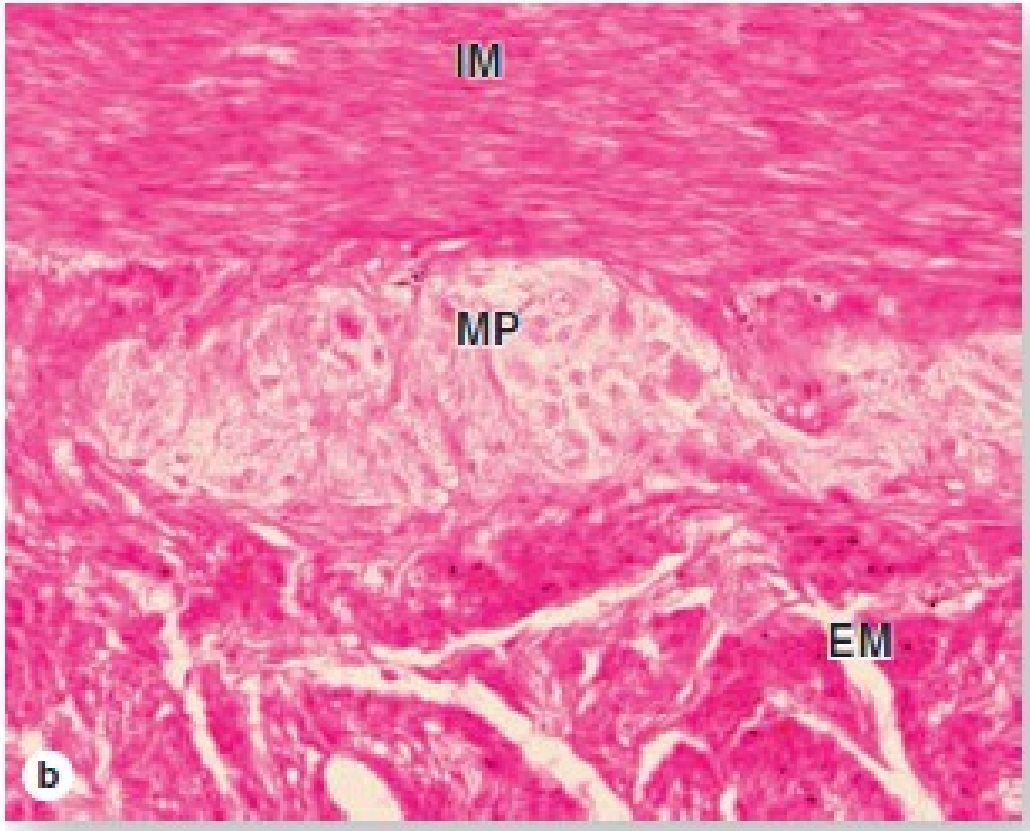
FIGURE 15–28 Microvasculature, lymphatics, and muscle in villi.



The villi of the small intestine contain blood microvasculature (left), lymphatic capillaries called lacteals (center), and both innervation and smooth muscle fibers (right).

FIGURE 15–30 Small intestine muscularis and myenteric plexus.





(a) Transverse sections of the small intestinal wall show the orientation of the internal (**IM**) and external (**EM**) smooth muscle layers. The inner layer is predominantly circular, while the outer layer is longitudinal. The serosa (**S**) is a thin connective tissue covered here by a mesothelium of cuboidal or squamous cells. (X200; PT)

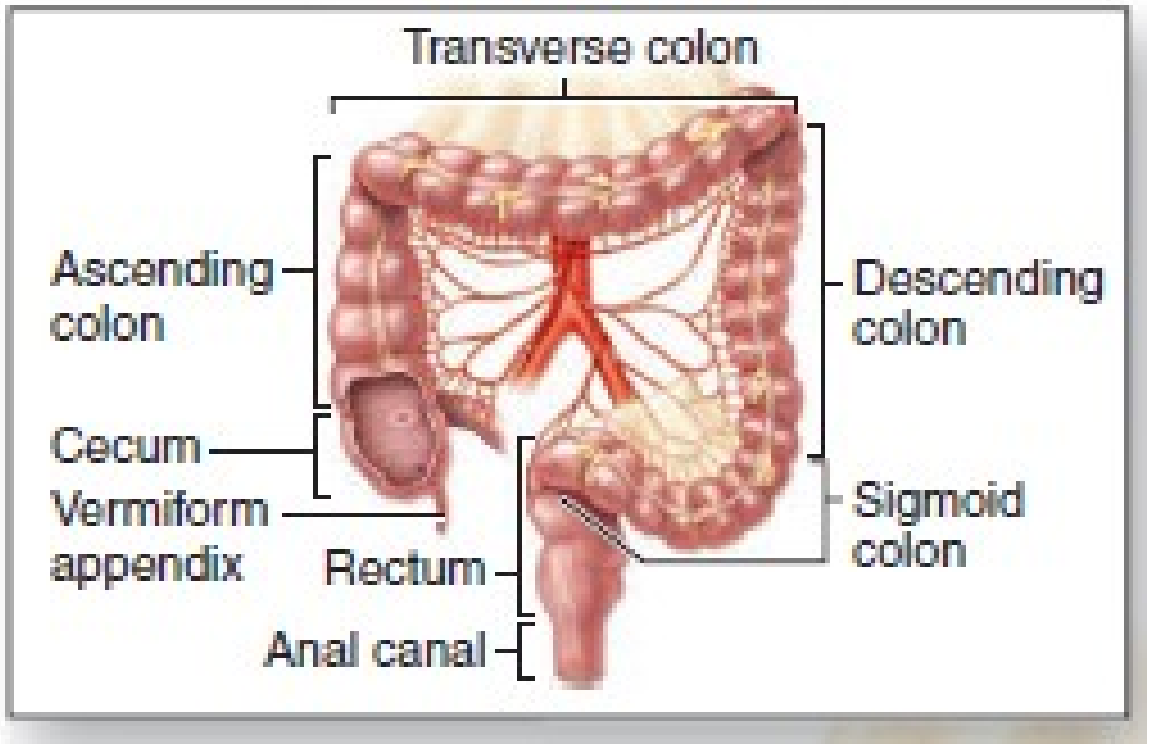
(b) Between the internal and external layers of muscularis (**IM** and **EM**) are ganglia of pale-staining neurons and other cells of the myenteric plexus (**MP**). (X100; H&E)

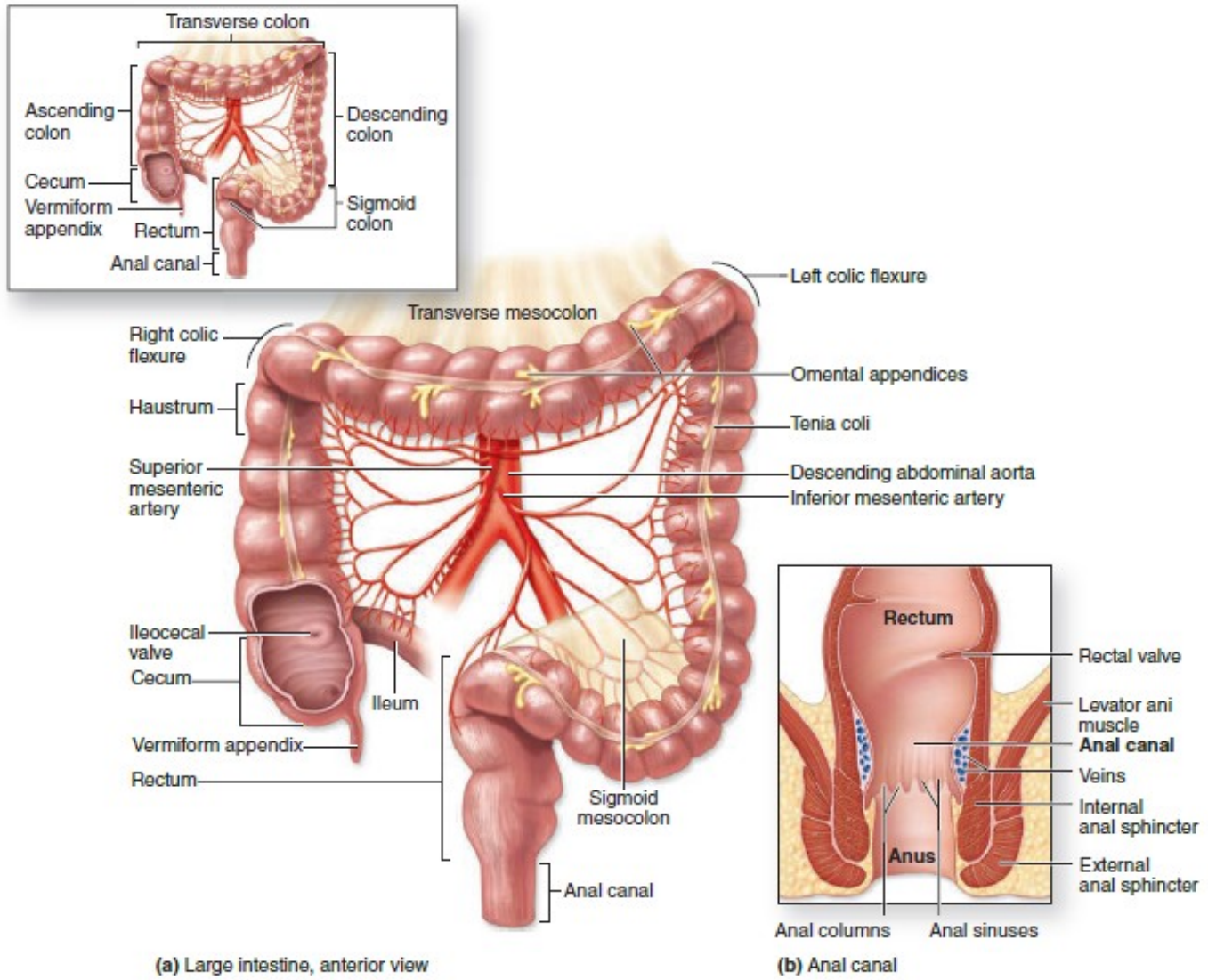
	Duodenum	Jejunum	Ileum
Villi	yes	yes	yes
Microvilli on absorptive cells	yes	yes	yes
Goblet cells	some	more	most
Paneth cells	yes	yes	yes
Brunner’s glands	yes	no	no
Peyer’s patches	no	no	yes

LARGE INTESTINE (COLON)

- **Function:**
  - Absorption of water
  - Secretion of mucus to lubricate dehydrated feces

- **Regions:**
  - *Ascending colon*. Rises on the right side of the abdominal cavity.
  - *Transverse colon*. Horizontal region that passes across the abdomen from right to left below the stomach.
  - *Descending colon*. Descends on the left side of the abdominal cavity.
  - *Sigmoid colon.* "S"-shaped
  - *Rectum* is a 12-cm-long tube continuing from the sigmoid colon. The mucosa of the rectum is similar to that of the majority of the large intestine. The rectum narrows abruptly to become the *anal canal*.





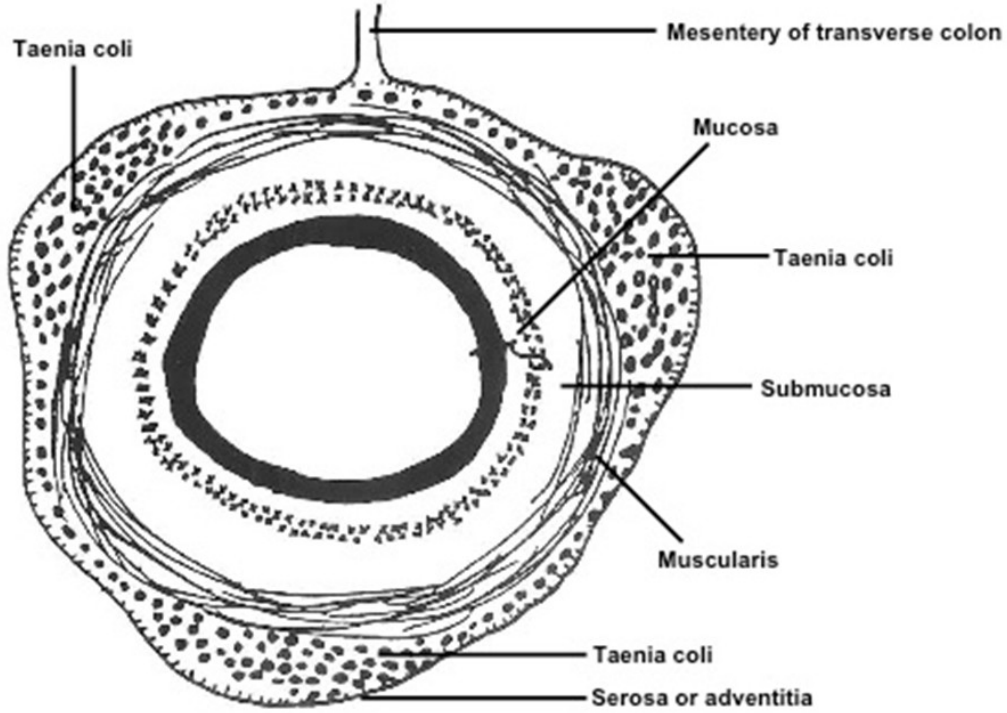
As shown at the top, the large intestine consists of the cecum; the ascending, transverse, descending, and sigmoid regions of the colon; and the rectum.

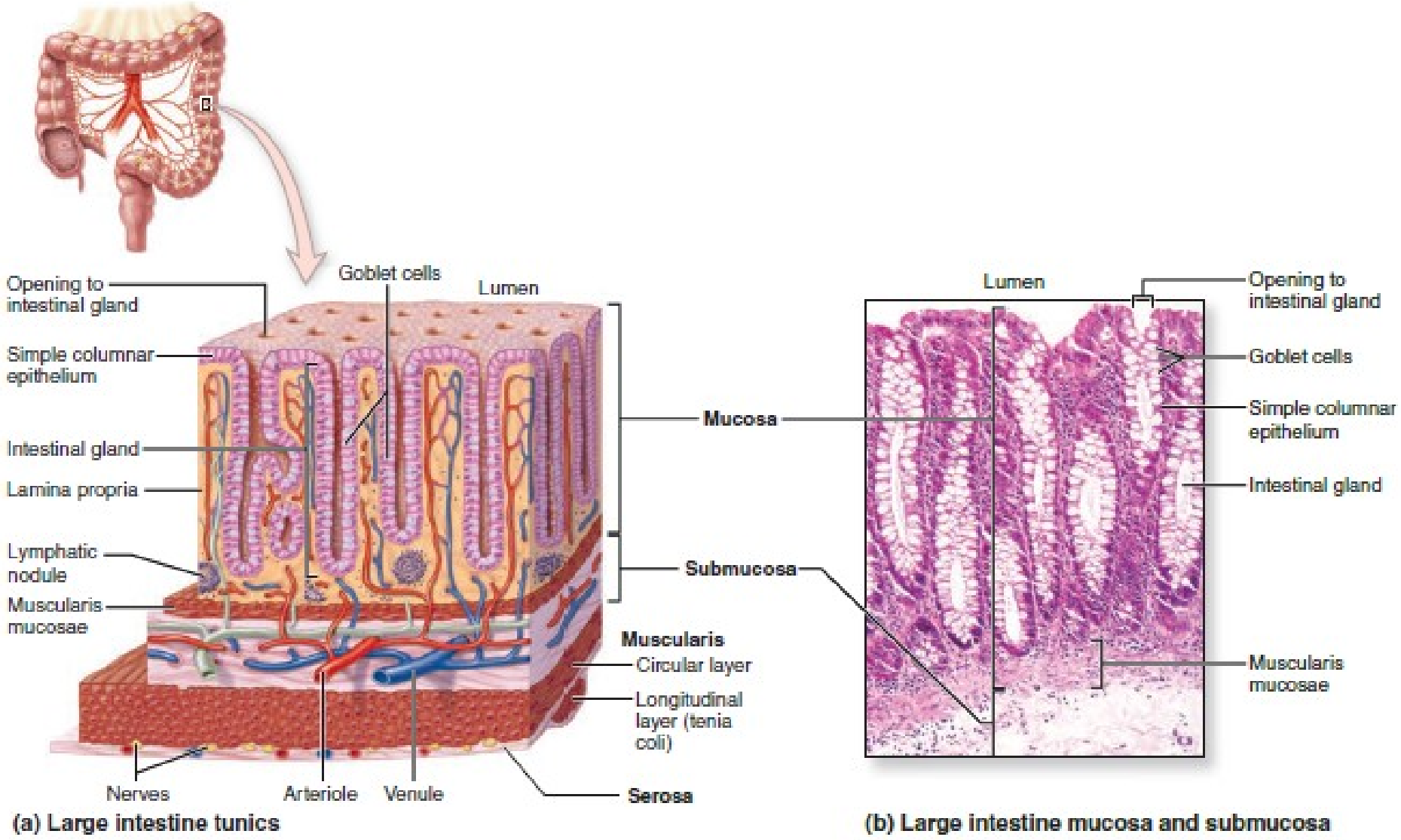
(a) Anterior view of the large intestine with the proximal end exposed shows the **ileocecal valve** at its attachment to the ileum, along with the sac called the **cecum** and its extension, the **appendix**. The mucosa has only shallow plicae and no villi. The muscularis has two layers, but the outer longitudinal layer consists only of three distinct bundles of muscle fibers called **teniae coli** that produce the haustra in the colon wall. The serosa of the colon is continuous with that of the supporting mesenteries and displays a series of suspended masses of adipose tissue called **omental appendages**.

(b) At the distal end of the rectum, the anal canal, the mucosa, and submucosa are highly vascularized, with venous sinuses, and are folded as a series of longitudinal folds called **anal columns** (of Morgagni) with intervening **anal sinuses**. Fecal material accumulates in the rectum is eliminated by muscular contraction, including action of an **internal anal sphincter** continuous with the circular layer of the muscularis and an **external sphincter** of striated (voluntary) muscle.

LARGE INTESTINE (COLON)

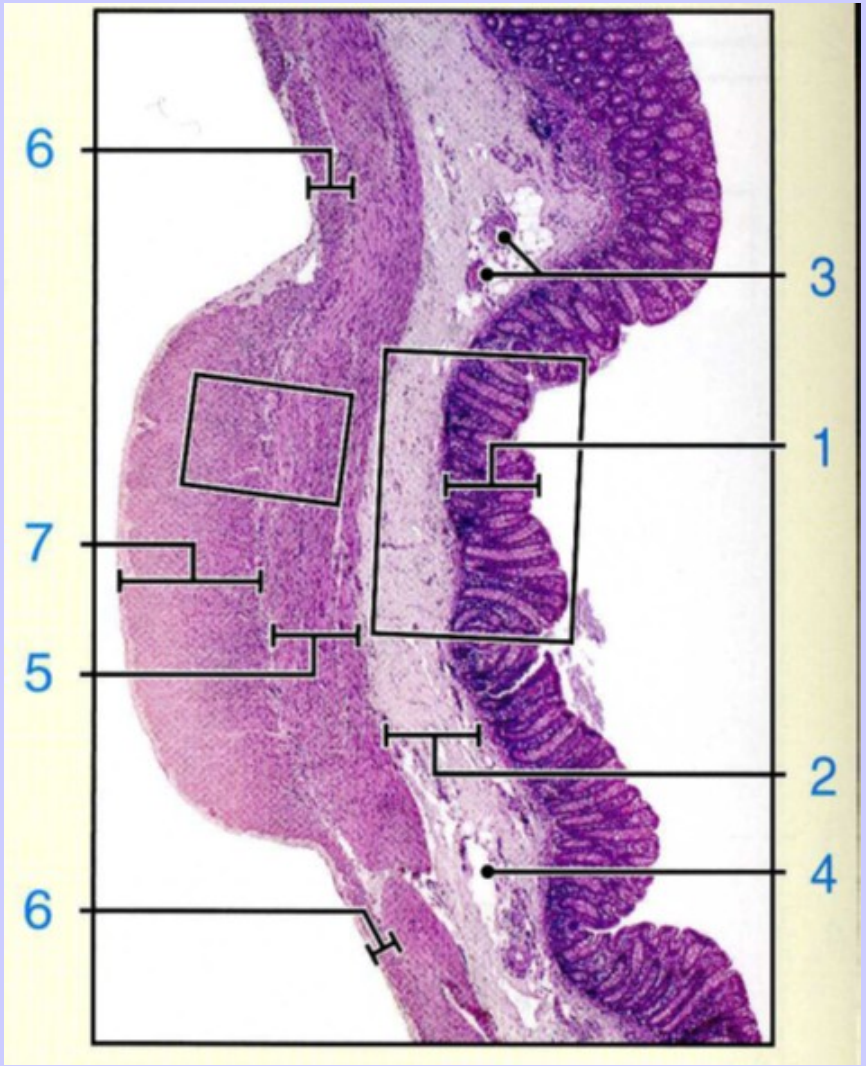
- **Layers and structures forming the wall of the large intestine:**
  - *Mucosal epithelium:*
    - Absorptive cells form a simple columnar epithelium with microvilli.
    - Goblet cells increase in number toward the rectum and provide lubrication.
    - A reduced number of enteroendocrine cells is present.
      - Intestinal glands (crypts of Lieberkühn) are very straight in the large intestine.
      - No villi or plicae circulares are present in the large intestine.
  - *Muscularis externa*
    - Inner circular layer is complete around the circumference of the tube
    - Outer longitudinal layer is segregated into three longitudinal bands, the **taeniae coli**, that are placed equidistantly around the tube. The contraction of the taenia produces permanent sacculations in the large intestine, termed haustrae.
  - Either an *adventitia* or a *serosa* is present, depending on the particular portion of the large intestine.





(a) Diagram shows the wall of the large intestine composed of the four typical layers. The **submucosa** is well vascularized. The **muscularis** has a typical inner circular layer, but the outer longitudinal muscle is only present in three equally spaced bands, the **teniae coli**.

(b) The **mucosa** is occupied mostly by tubular **intestinal glands** extending as deep as the muscularis mucosae and by lamina propria rich in MALT. (X80; H&E)



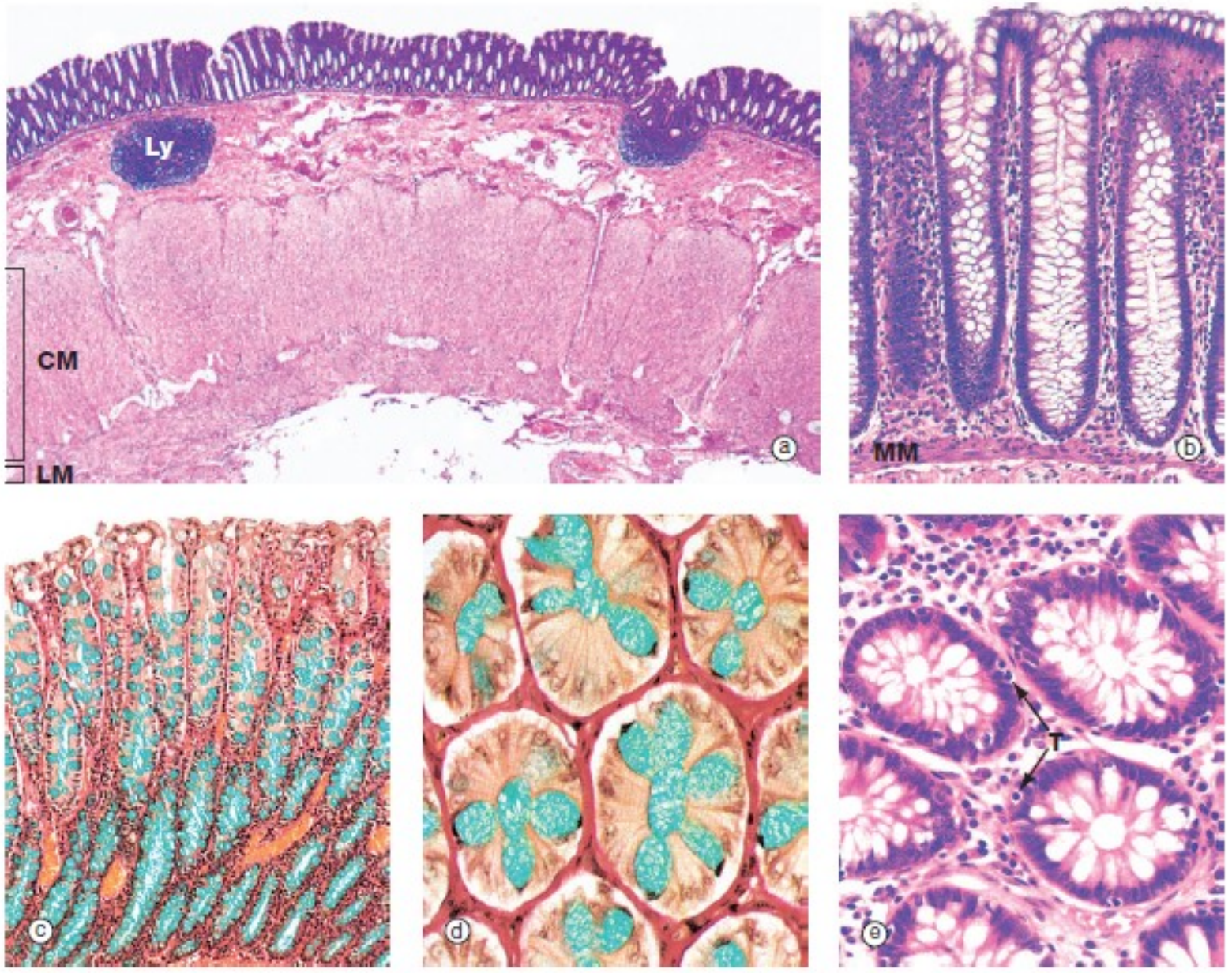
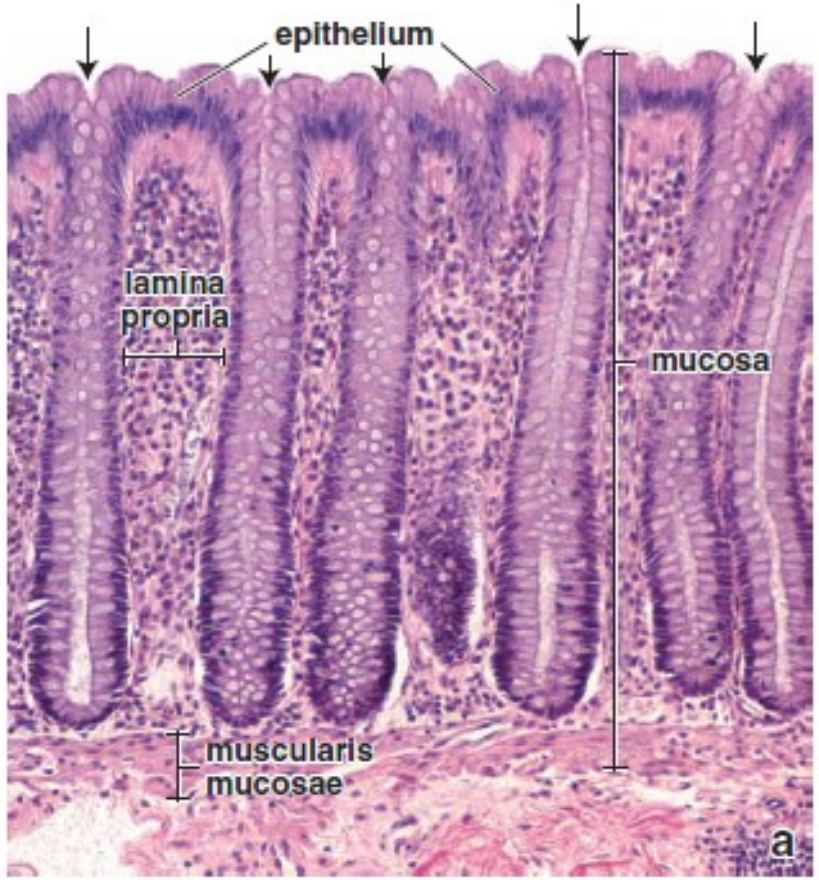


FIG. 14.29 Colon
(a) H&E (LP) (b) H&E (MP) (c) Alcian blue/van Gieson (MP) (d) Alcian blue/van Gieson (HP) (e) H&E (HP)



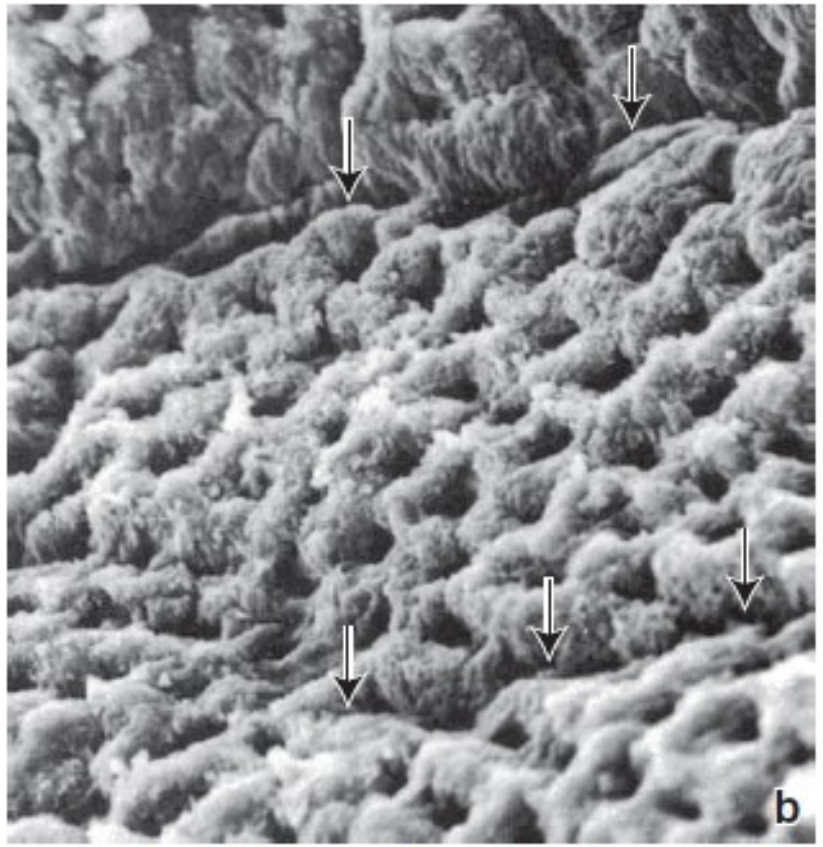
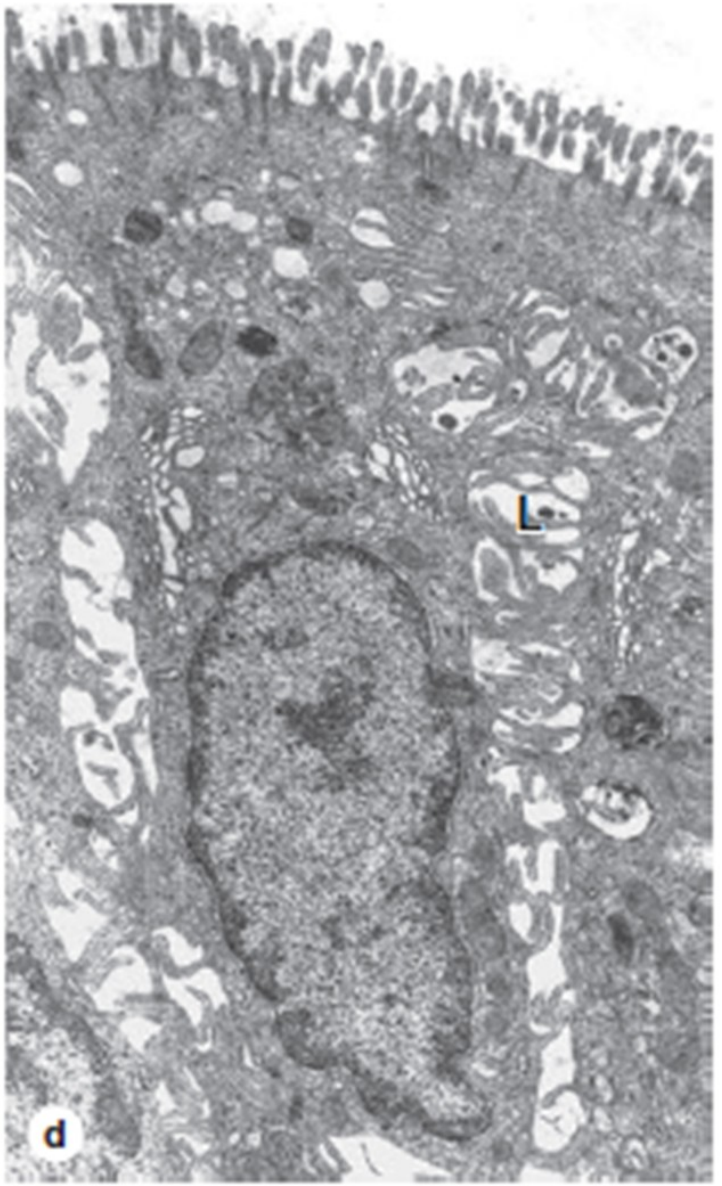


FIGURE 17.28 ▲ Mucosa of the large intestine. a. This photomicrograph of an H&E preparation shows the mucosa and part of the submucosa. The surface epithelium is continuous with the straight, unbranched, tubular intestinal glands (crypts of Lieberkühn). The openings of the glands at the intestinal surface are identified (*arrows*). The epithelial cells consist principally of absorptive and goblet cells. As the absorptive cells are followed into the glands, they become fewer in number, whereas the goblet cells increase in number. The highly cellular lamina propria contains numerous lymphocytes and other cells of the immune system. **b.** Scanning electron micrograph of the human mucosal surface of the large intestine. The surface is divided into territories by clefts (*arrows*). Each territory contains 25 to 100 gland openings. ×140. (Reprinted with permission from Fenoglio CM, Richart RM, Kaye GI. Comparative electron-microscopic features of normal, hyperplastic, and adenomatous human colonic epithelium. II. Variations in surface architecture found by scanning electron microscopy. Gastroenterology 1975;69:100–109.)



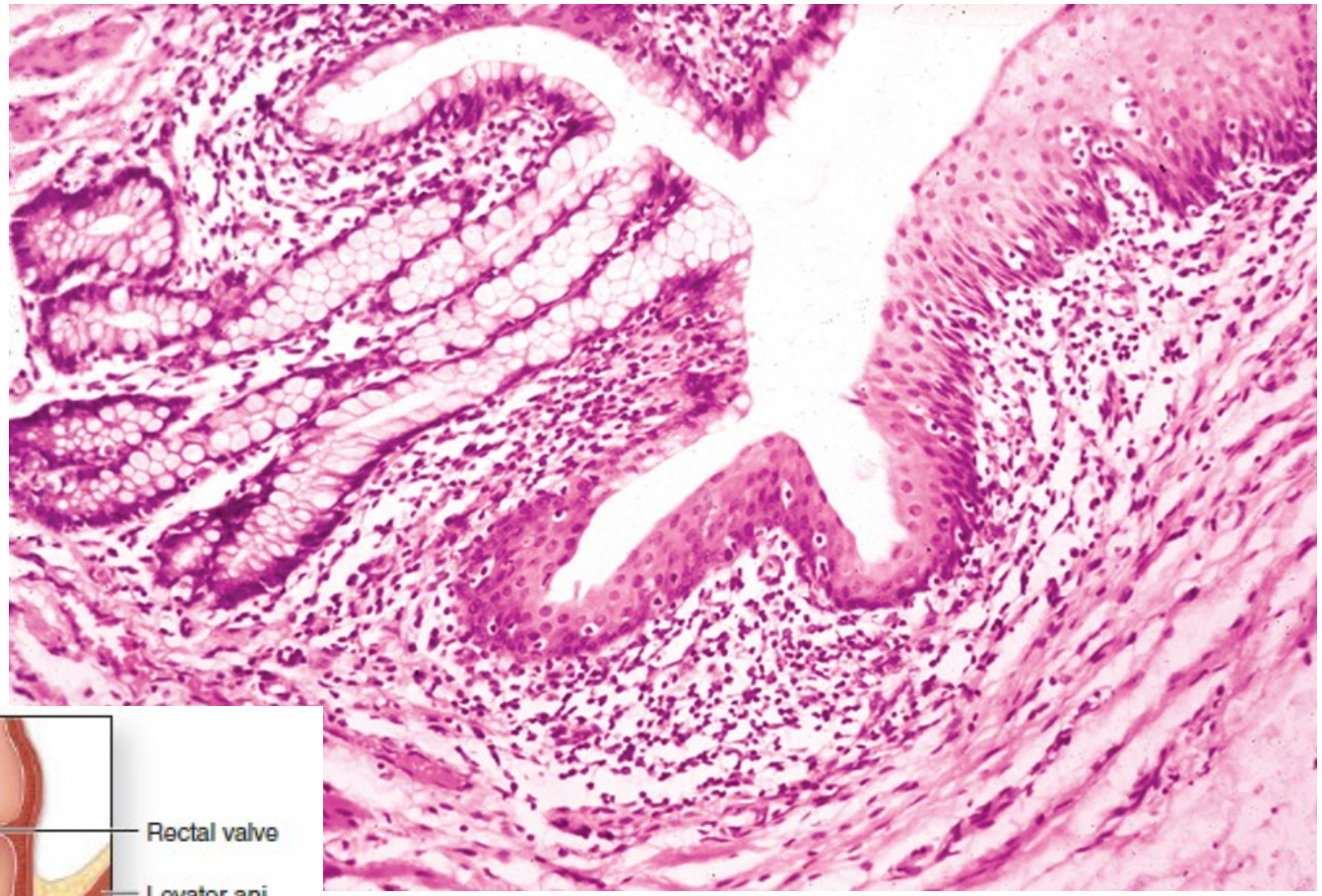
(d) TEM of the absorptive cells, or **colonocytes**, reveals short **microvilli** at their apical ends and dilated **intercellular spaces** with interdigitating leaflets of cell membrane (**L**), a sign of active water transport. The absorption of water is passive, following the active transport of sodium from the basolateral surfaces of the epithelial cells. (X2500)

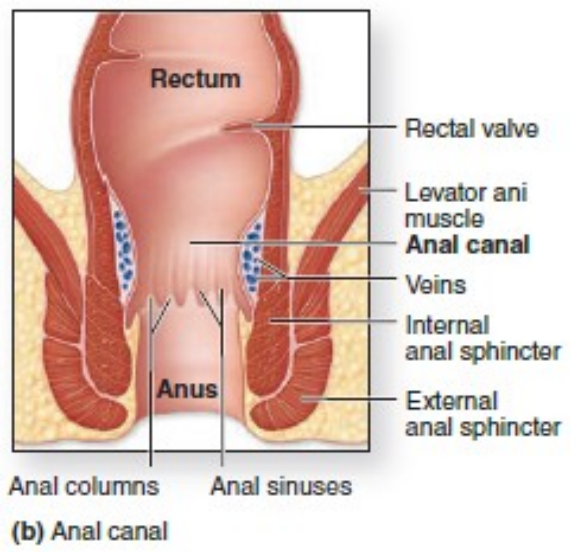
DIGESTIVE SYSTEM

LARGE INTESTINE (COLON)

- **Anal canal**. The terminal portion of the intestinal tract is about 4 cm long.
  - The intestinal glands disappear and the epithelium undergoes an abrupt transition *from simple columnar to stratified squamous* with sebaceous and apocrine sweat glands.
  - The inner circular portion of the muscularis externa expands to form the internal anal sphincter. The external anal sphincter is composed of skeletal muscle.

- **The anus** is located at the level of the external anal sphincter and is covered by *stratified squamous keratinized epithelium* (skin).





(b) Anal canal

The simple columnar epithelium with tubular **intestinal glands** in the rectum (left side of photo) changes abruptly to stratified squamous epithelium in the **anal canal** (right side of photo), as seen in this longitudinal section. The connective tissue of the lamina propria is seen to contain many free lymphocytes. (X40; H&E)

DIGESTIVE SYSTEM

APPENDIX

- Attached to cecum
- No taenia coli
- Lots of lymphatic tissue (diffuse and in nodules) present in lamina propria and submucosa

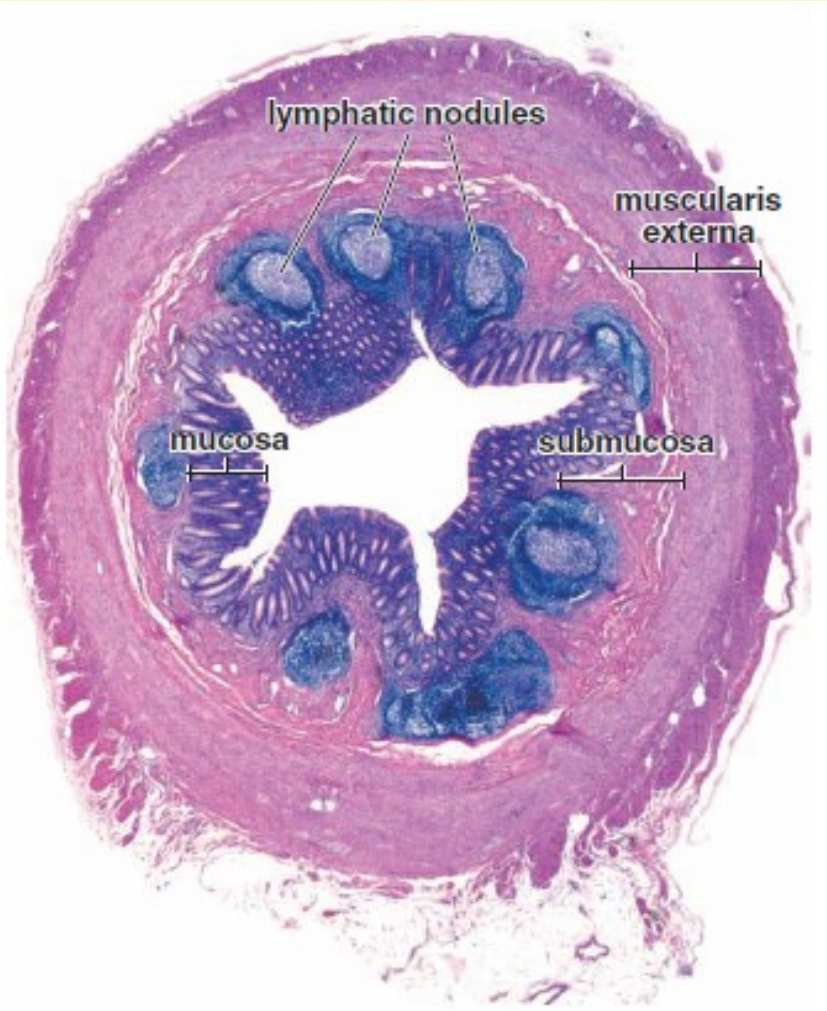


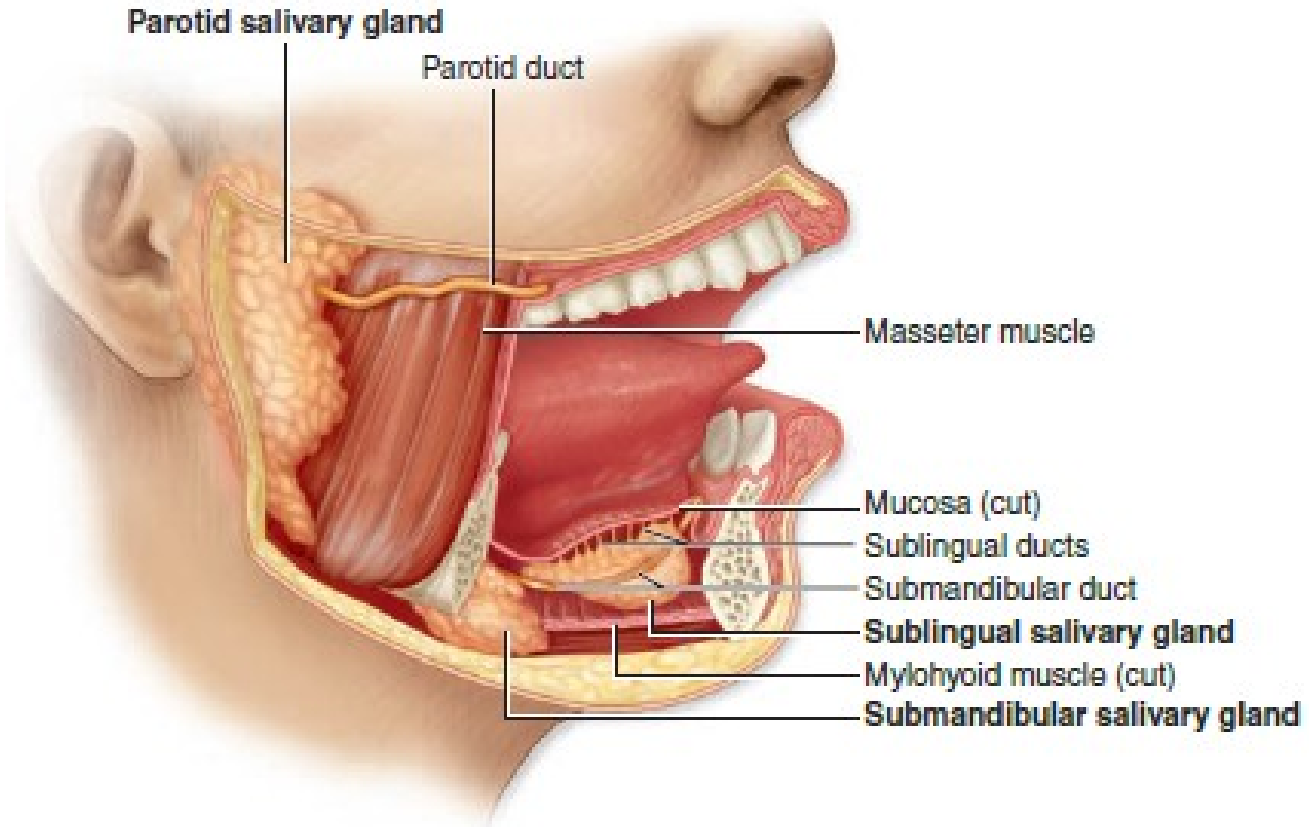
FIGURE 17.30 ▲ Photomicrograph of a cross-section through the vermiform appendix. The vermiform appendix displays the same four layers as those of the large intestine except that its diameter is smaller. Typically, lymphatic nodules are seen within the entire mucosa and usually extend into the submucosa. Note the distinct germinal centers within the lymphatic nodules. The muscularis externa is composed of a relatively thick circular layer and a much thinner outer longitudinal layer. The appendix is covered by a serosa that is continuous with the mesentery of the appendix (*lower right*). ×10.

TABLE 15–2 Summary of distinguishing digestive tract features, by region and layers.

Region and Subdivisions	Mucosa (Epithelium, Lamina Propria, Muscularis Mucosae)	Submucosa (With Submucosal Plexuses)	Muscularis (Inner Circular and Outer Longitudinal Layers, With Myenteric Plexuses Between Them)	Adventitia/Serosa
Esophagus (upper, middle, lower)	Nonkeratinized stratified squamous epithelium; cardiac glands at lower end	Small esophageal glands (mainly mucous)	Both layers striated muscle in upper region; both layers smooth muscle in lower region; smooth and striated muscle fascicles mingled in middle region	Adventitia, except at lower end with serosa
Stomach (cardia, fundus, body, pylorus)	Surface mucous cells and gastric pits leading to gastric glands with parietal and chief cells, (in the fundus and body) or to mucous cardiac glands and pyloric glands	No distinguishing features	Three indistinct layers of smooth muscle (inner oblique, middle circular, and outer longitudinal)	Serosa
Small intestine (duodenum, jejunum, ileum)	Plicae circulares; villi, with enterocytes and goblet cells, and crypts/glands with Paneth cells and stem cells; Peyer patches in ileum	Duodenal (Brunner) glands (entirely mucous); possible extensions of Peyer patches in ileum	No distinguishing features	Mainly serosa
Large intestine (cecum, colon, rectum)	Intestinal glands with goblet cells and absorptive cells	No distinguishing features	Outer longitudinal layer separated into three bands, the teniae coli	Mainly serosa, with adventitia at rectum
Anal canal	Stratified squamous epithelium; longitudinal anal columns	Venous sinuses	Inner circular layer thickened as internal sphincter	Adventitia

MAJOR SALIVARY GLANDS

- All major salivary glands are compound, exocrine glands, and all open into the oral cavity.
- *Glandula parotis, glandula submandibularis, glandula sublingualis*
- **Functions:**
  - Produce saliva to wet, lubricate, and buffer the oral cavity and its contents
  - Produce amylase for the initial digestion of carbohydrates
  - Produce lysozyme to control bacteria in the oral cavity



There are three bilateral pairs of major salivary glands, the **parotid**, **submandibular**, and **sublingual glands**, which together produce about 90% of saliva. Their locations, relative sizes, and excretory ducts are shown here. These glands plus microscopic minor salivary glands located throughout the oral mucosa produce 0.75-1.50 L of saliva daily.

DIGESTIVE SYSTEM

MAJOR SALIVARY GLANDS

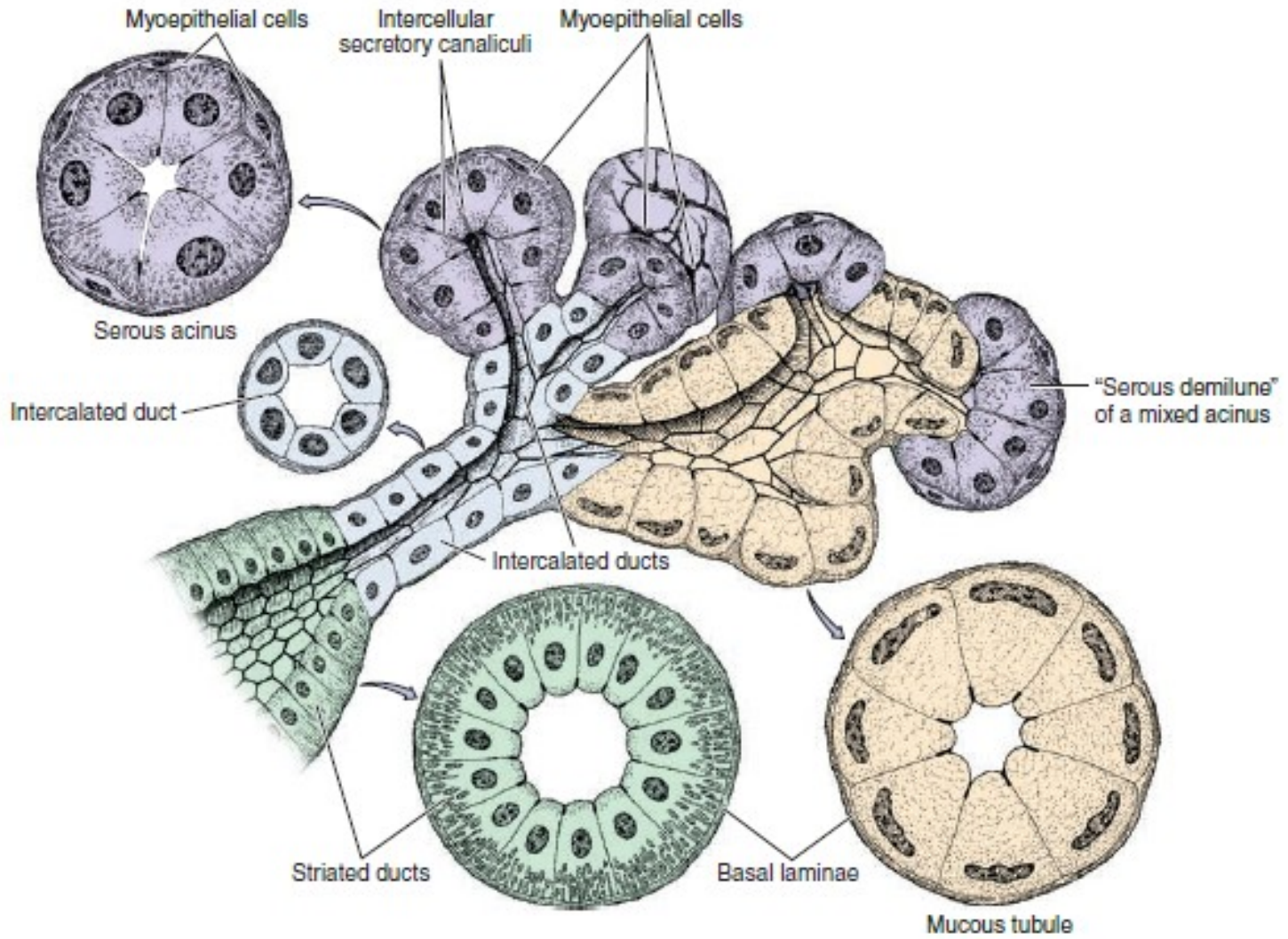
Major cell types

- **Serous cells**
  - Synthesize, store, and release a thin, protein-rich secretion containing digestive enzymes, primarily amylase
  - Are pyramidal in shape and possess all organelles necessary for protein production and secretion (e.g., basal rough endoplasmic reticulum, Golgi, and apical secretory granules)
  - Are arranged into either:
    - Acini (singular, acinus) or alveoli (singular, alveolus). Flask-shaped sacs with tiny lumens
    - Serous demilunes. Half moon–shaped caps positioned over the ends of mucous tubules

- **Mucous cells**
  - Synthesize, store, and release mucus, a viscous, thick, glycoprotein secretion that protects and lubricates epithelia
  - Have flattened nuclei that are located at the bases of the cells along with the rough endoplasmic reticulum. Abundant mucigen droplets are located in the apex of each cell, giving it a frothy, vacuolated appearance.
  - Are organized in test tube–shaped tubules with relatively wide lumens

- **Myoepithelial cells** are stellate-shaped epithelial cells with contractile functions that lie between the secretory or duct cells and the basement membrane. These cells contract to aid in movement of the secretory product.

FIGURE 16–2 Epithelial components of a submandibular gland lobule.



The secretory portions are composed of pyramidal serous (violet) and mucous (tan) cells. **Serous acini** consist of typical protein-secreting cells with rounded nuclei, basal accumulation of RER, and apical ends filled with secretory granules. The cells of **mucous tubules** have flattened, basal nuclei with condensed chromatin. In the submandibular gland mixed tubuloacinar secretory units also occur, combining short mucous tubules with distal clusters of serous cells called "**serous demilune**." The short **intercalated ducts** are lined with low cuboidal epithelium. The **striated ducts** consist of columnar cells with characteristics of ion-transporting cells: basal membrane invaginations with mitochondrial accumulations. **Myoepithelial cells** are shown around the serous acini.

DIGESTIVE SYSTEM

MAJOR SALIVARY GLANDS

Duct system conducts secretions to oral cavity.

Ducts are more numerous with serous acini than with mucous tubules because the tubules can act as their own ducts.

- *Intralobular ducts*
  - *Intercalated ducts* exit from secretory acini and are smaller in diameter than the acini they drain. These ducts are lined by simple cuboidal epithelia.
  - *Striated ducts* continue from intercalated ducts and are larger in diameter than the secretory units they drain. They are lined by simple columnar epithelia. Numerous mitochondria and infoldings of the plasma membrane in the basal region of the cells give the duct a striated periphery. Striated ducts alter the content and concentration of the saliva.
- *Interlobular ducts* form by the anastomosis of striated ducts and are located in the connective septa between lobules. Interlobular ducts are lined with simple columnar to stratified columnar epithelia.
- *The main excretory duct*(s) is formed by the union of interlobular ducts. An excretory duct (s) is lined by a stratified epithelium that becomes stratified squamous moist just prior to its junction with the epithelium of the oral cavity.

DIGESTIVE SYSTEM

MAJOR SALIVARY GLANDS

Major salivary glands

Parotid glands

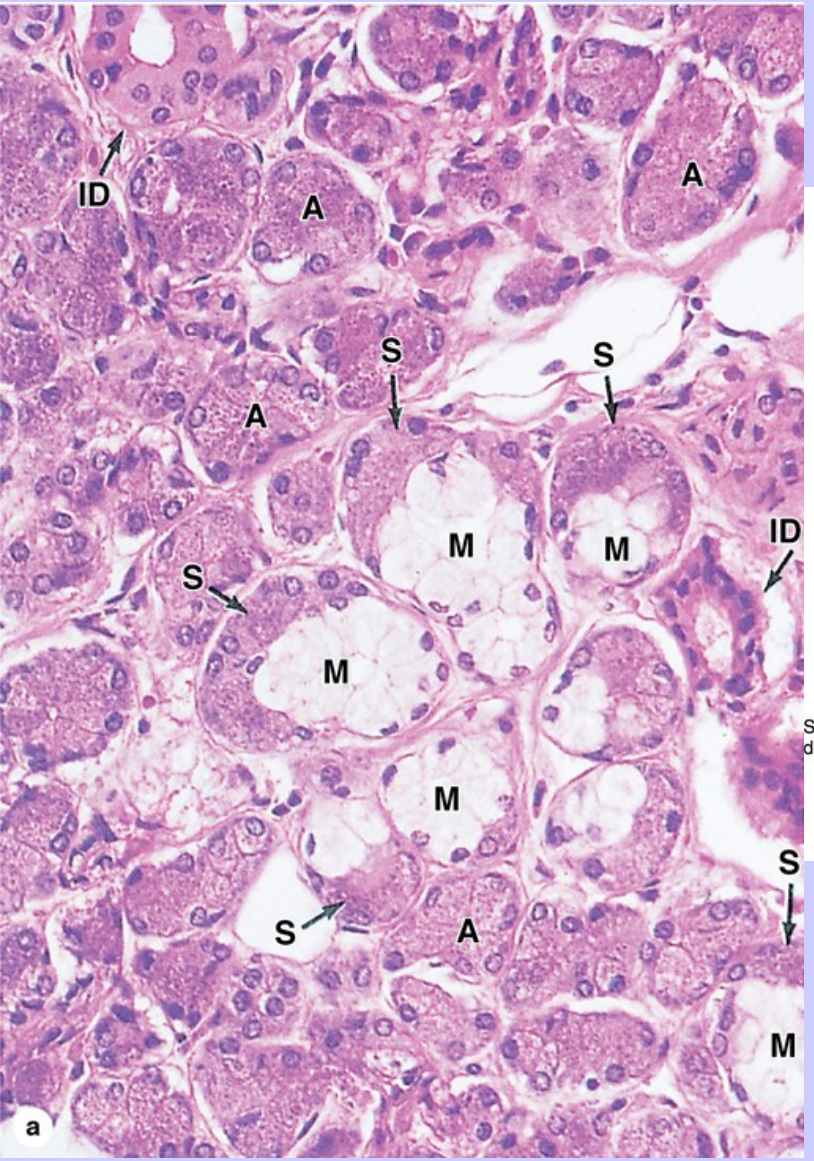
- Compound acinar glands producing only serous products; their secretions account for 25% of the saliva
- Possess the most highly developed duct system of the major salivary glands

Submandibular glands

- Compound tubulo-acinar glands producing both serous and mucous products, although serous acini predominate. Their secretions account for 70% of the saliva.
- Serous cells are present as both acini and serous demilunes.

Sublingual glands

- Secrete approximately 5% of the saliva.
- These are compound tubulo-acinar glands, producing both mucous and serous products, although mucous tubules predominate.



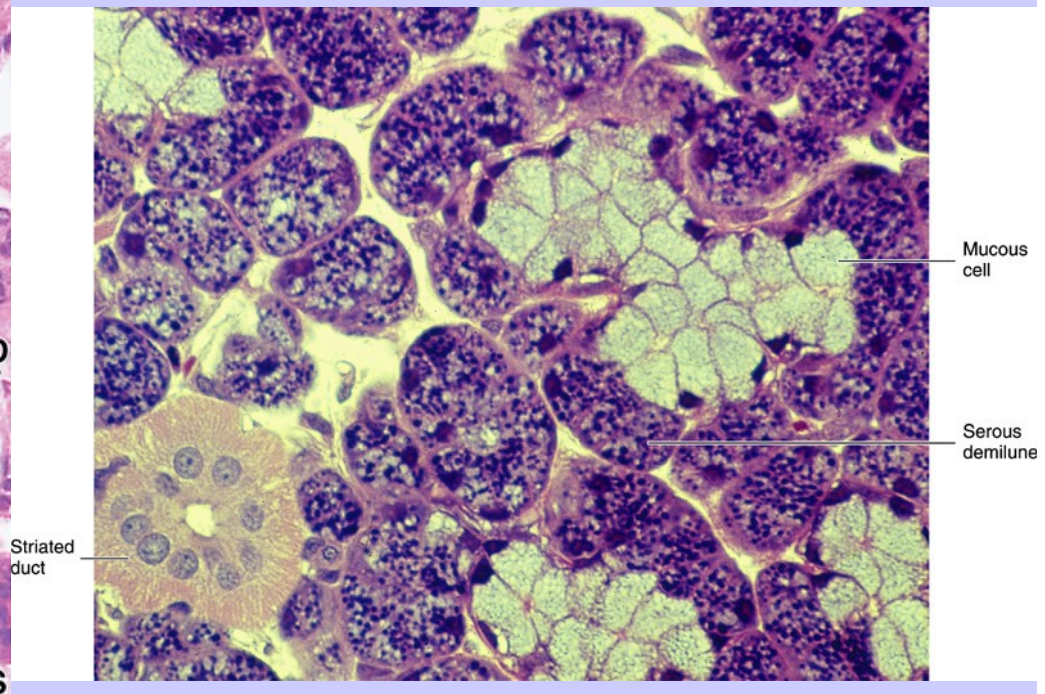
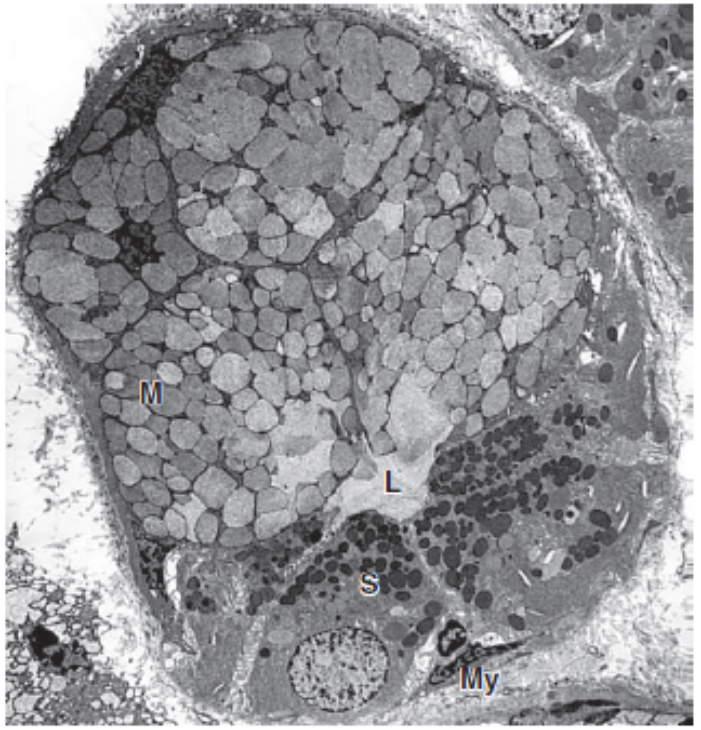


FIGURE 16–4 Ultrastructure of serous and mucous cells.

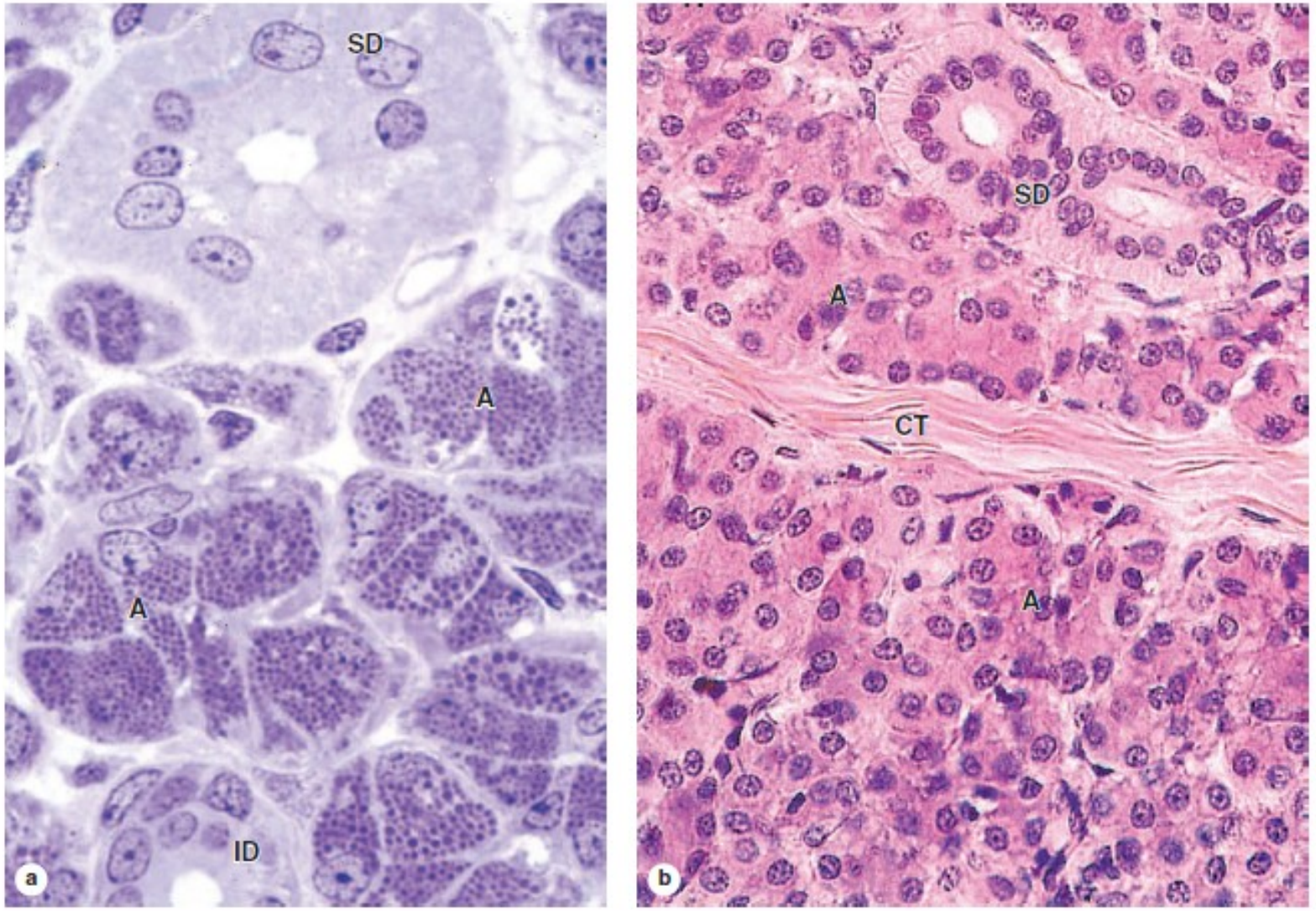


A micrograph of a mixed acinus from a submandibular gland shows both serous and mucous cells surrounding the small lumen (**L**). Mucous cells (**M**) have large, hydrophilic granules like those of goblet cells, while serous cells (**S**) have small, dense granules. Small myoepithelial cells (**My**) extend contractile processes around each acinus. (X2500)

(Used with permission from Dr John D. Harrison, King's College London Dental Institute, London, UK.)

Glandula submandibularis

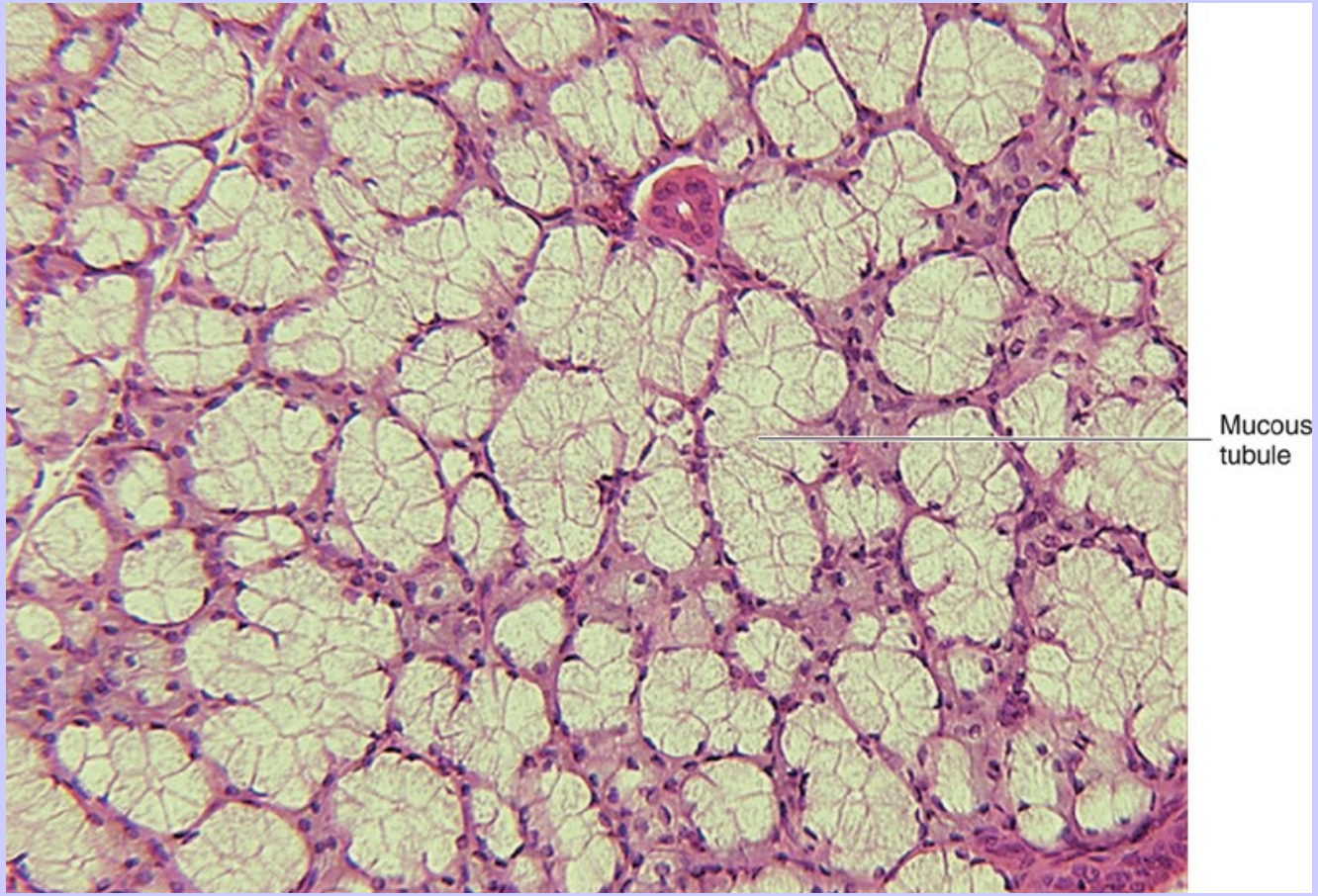
FIGURE **16–3** **Parotid gland.**

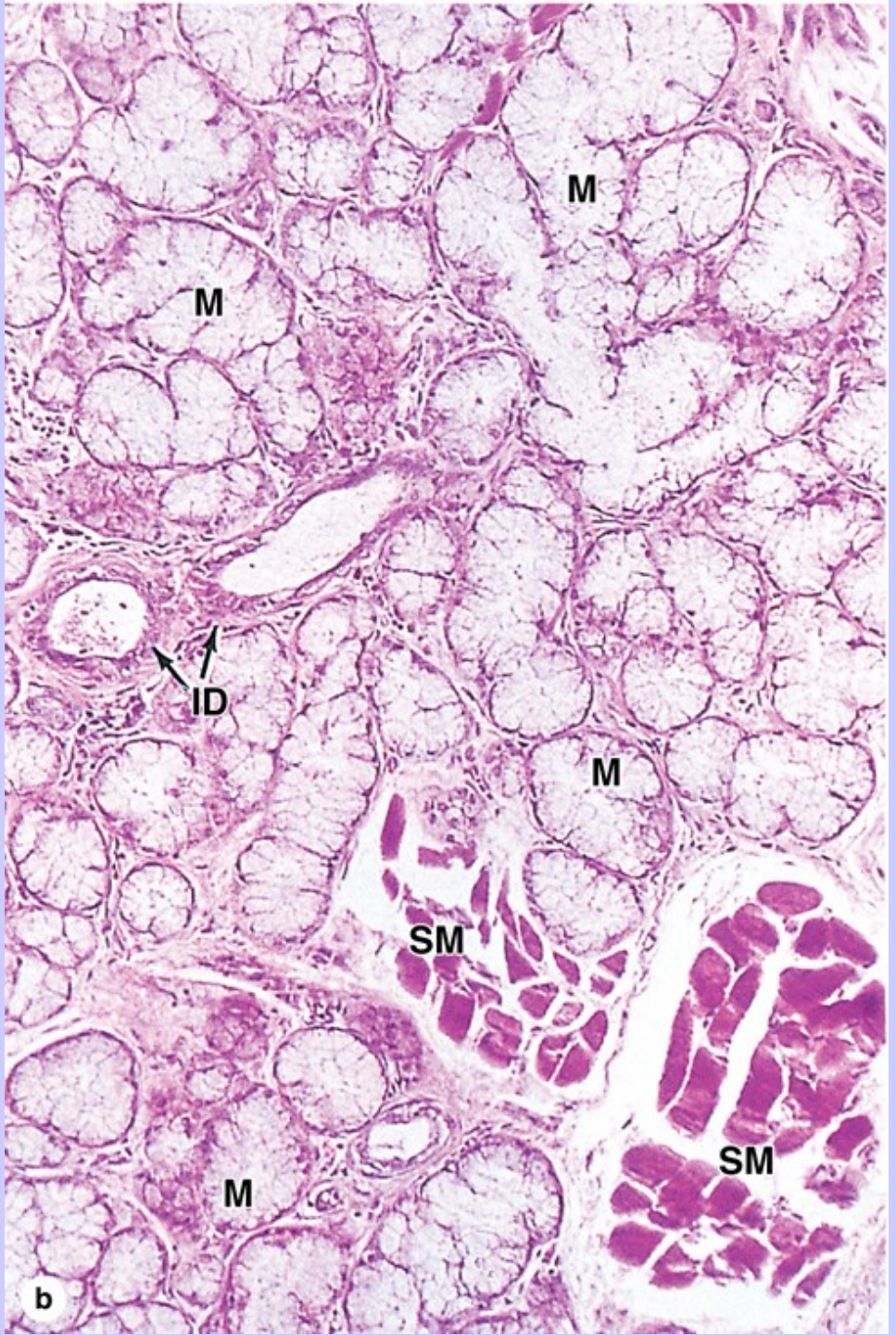


The large parotid gland consists entirely of serous acini with cells producing amylase and other proteins for storage in secretory granules.

(a) Micrograph of a parotid gland shows densely packed serous acini (**A**) with ducts. Secretory granules of serous cells are clearly shown in this plastic section, as well as an intercalated duct (**ID**) and striated duct (**SD**), both cut transversely. (X400; PT)

(b) Striations of a duct (**SD**) are better seen here, along with a septum (**CT**) and numerous serous acini (**A**). The connective tissue often includes adipocytes. (X200; H&E)





Glandula sublingualis

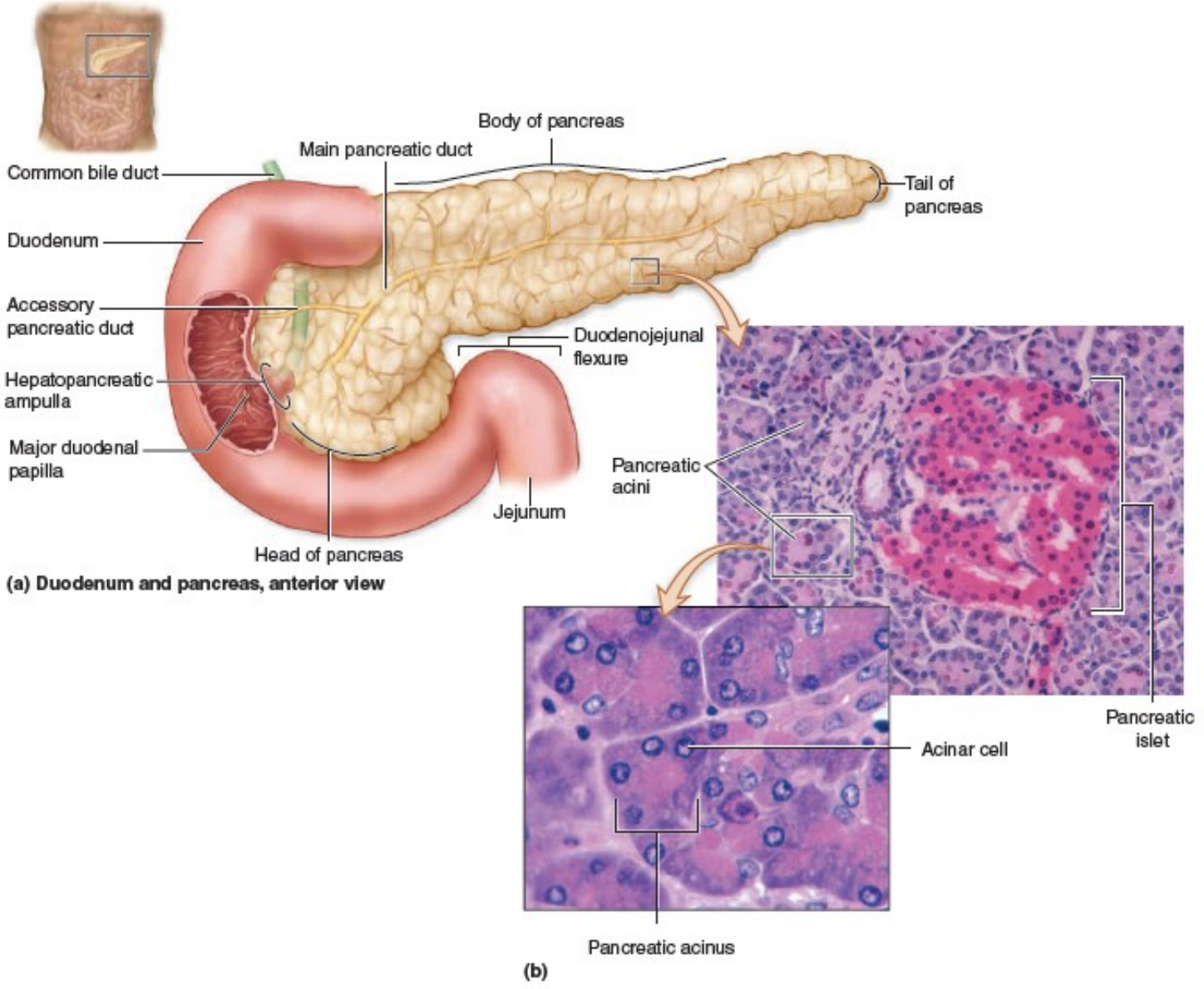
DIGESTIVE SYSTEM

PANCREAS

- Located in the abdomen in the curve of the duodenum and divided into a head, body, and tail

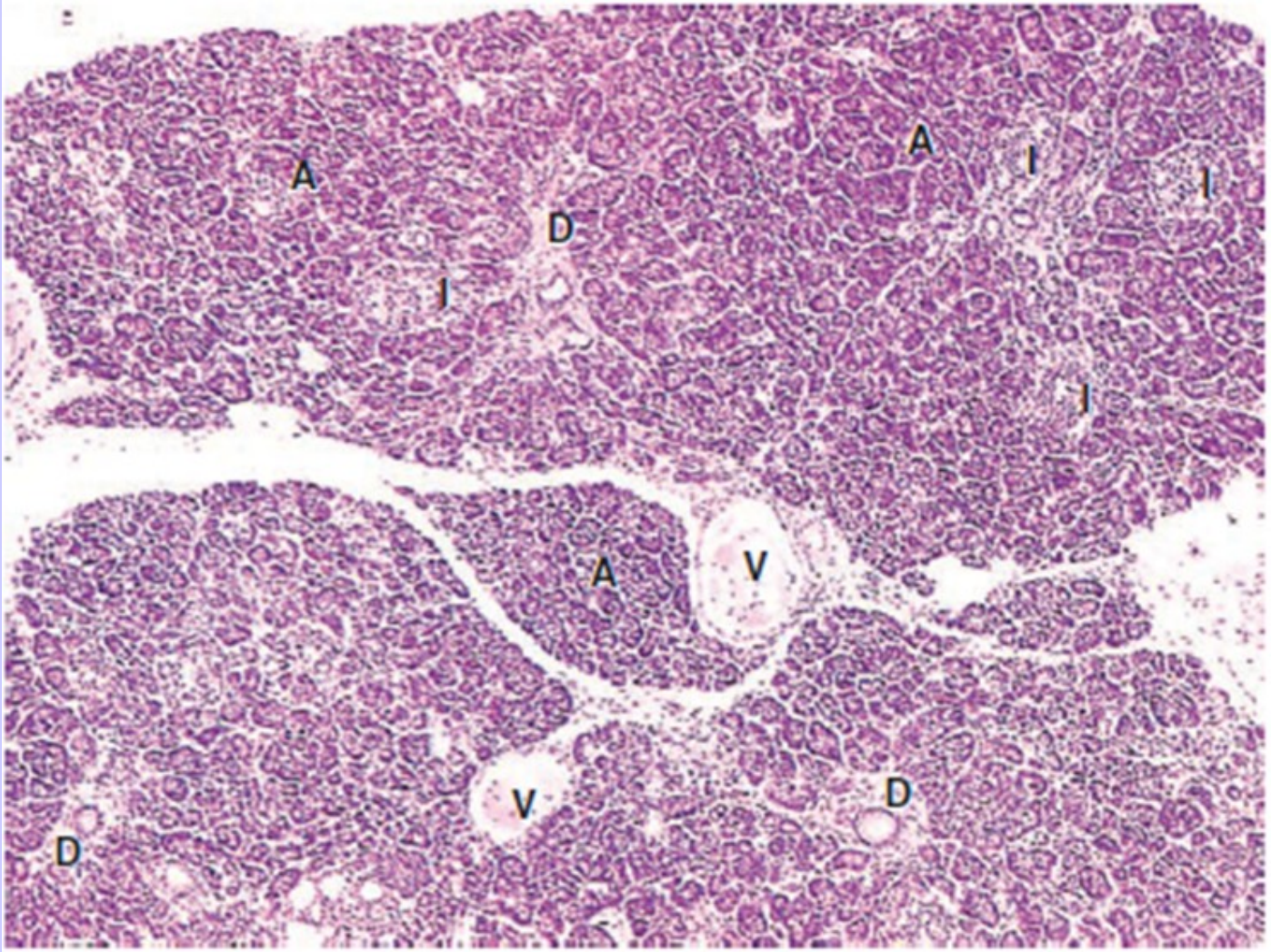
- Is both an exocrine and an endocrine gland
  - The exocrine portion produces an alkaline secretion containing digestive enzymes that empties into the duodenum.

  - The endocrine portion secretes insulin, glucagon, and somatostatin that regulate blood glucose levels.



(a) The main regions of the pancreas are shown in relation to the two pancreatic ducts and the duodenum.

(b) Micrographs show a pancreatic islet and several pancreatic acini. (X75 and X200; H&E)



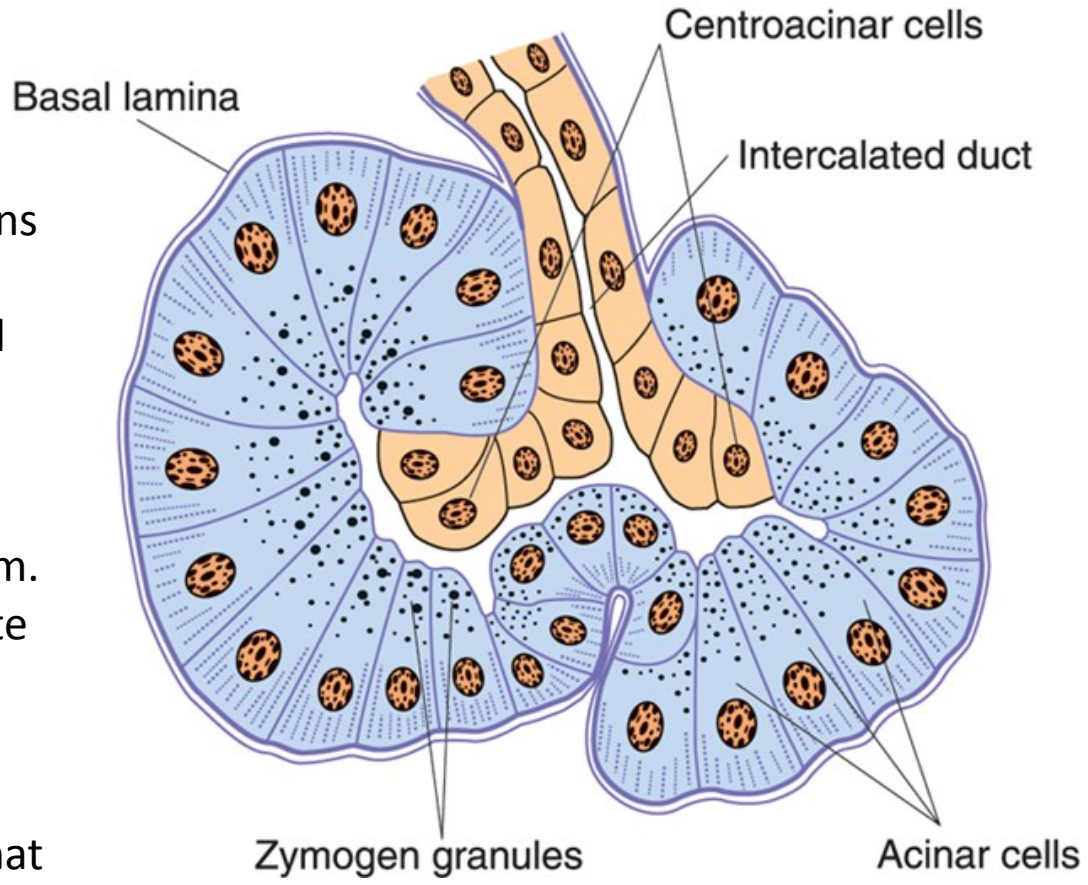
Low-power view of pancreas includes several islets (**I**) surrounded by many serous acini (**A**). The larger intralobular ducts (**D**) are lined by simple columnar epithelium. The ducts and blood vessels (**V**) are located in connective tissue, which also provides a thin capsule to the entire gland and thin septa separating the lobules of secretory acini. (X20; H&E)

DIGESTIVE SYSTEM

PANCREAS

Exocrine pancreas

- *Compound acinar gland*; the acinar cells secrete numerous digestive enzymes that break down proteins (trypsin), carbohydrates (carbohydrates), lipids (lipase), and nucleoproteins (nucleases).
- Cells show polarity with basal rough endoplasmic reticulum and apical secretory granules.
- *Duct system*
    - Ducts begin as *centroacinar cells* located within the acini.
    - *Intercalated ducts* are lined with simple cuboidal epithelium. Centroacinar cells and cells of the intercalated ducts secrete bicarbonates to neutralize the acidity of the stomach contents (chyme) entering the duodenum.
    - Striated ducts are not present.
    - Interlobular ducts lead into one or more excretory ducts that empty into the duodenum.
- Resembles the parotid gland except the pancreas has centroacinar cells and fewer ducts.
- Secretion is regulated by cholecystokinin and secretin from enteroendocrine cells in the small intestine



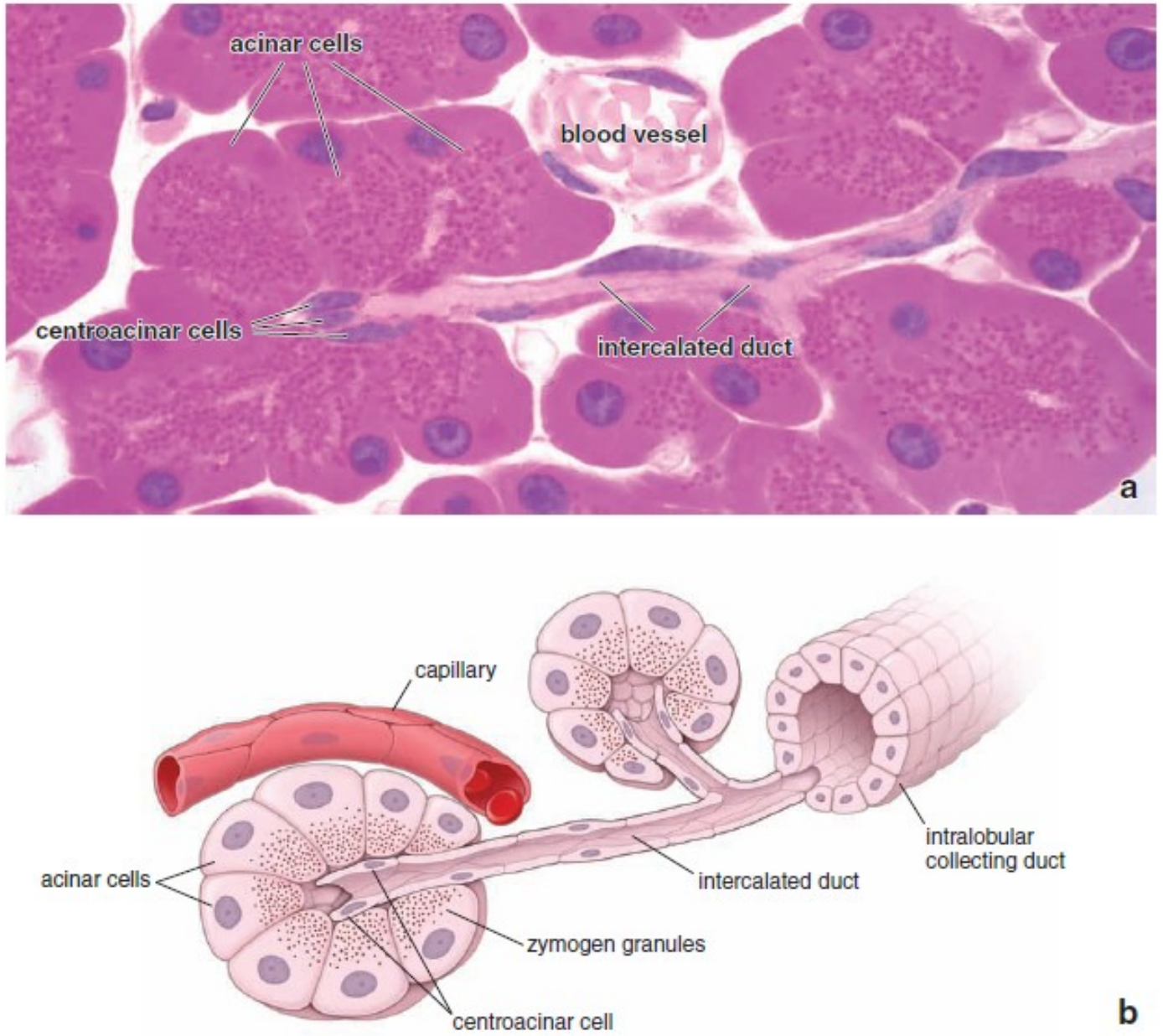
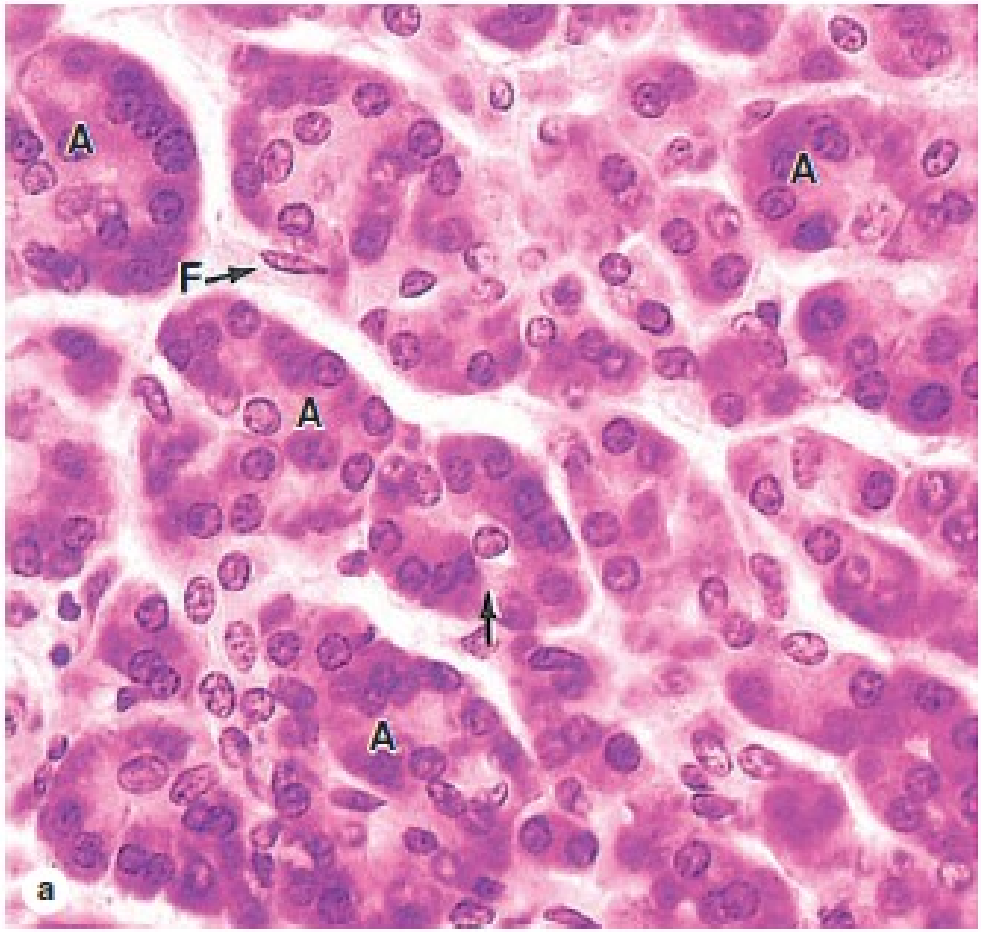
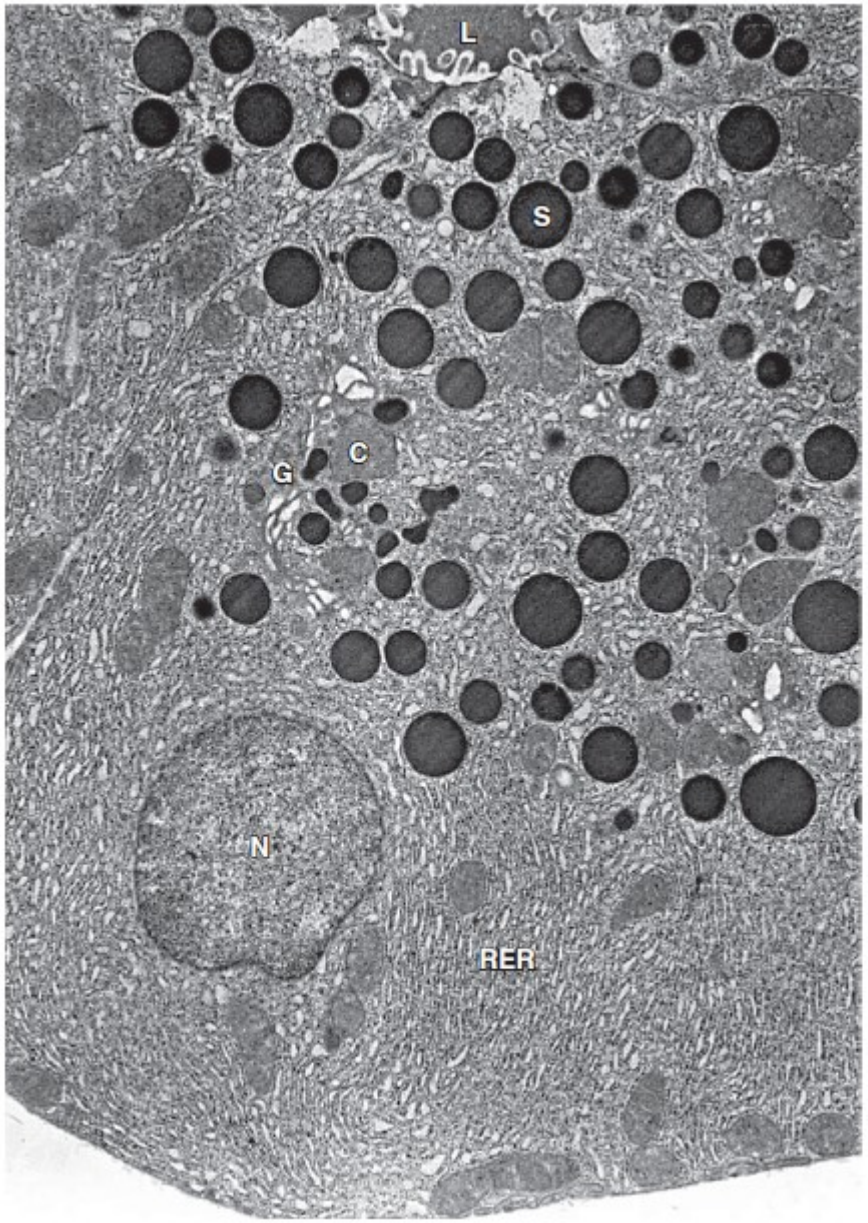


FIGURE 18.19 ▲ Pancreatic acinus and its duct system. a. In this photomicrograph of a thin, H&E–stained plastic section, an intercalated duct can be seen beginning within a pancreatic acinus. The cells forming the duct within the acinus are the centroacinar cells. The eosinophilic zymogen granules are clearly seen in the apical cytoplasm of the parenchymal cells. ×860. **b.** In this schematic diagram, observe the beginning of the intercalated duct. Note the location and shapes of the centroacinar cells within the acinus. They represent the initial lining of the intercalated duct, which drains into an intralobular collecting duct.



(a) Micrograph of exocrine pancreas shows the serous, enzyme-producing cells arranged in small acini (**A**) with very small lumens. Acini are surrounded by only small amounts of connective tissue with fibroblasts (**F**). Each acinus is drained by an intercalated duct with its initial cells, the centroacinar cells (**arrow**), inserted into the acinar lumen. (X200; H&E)

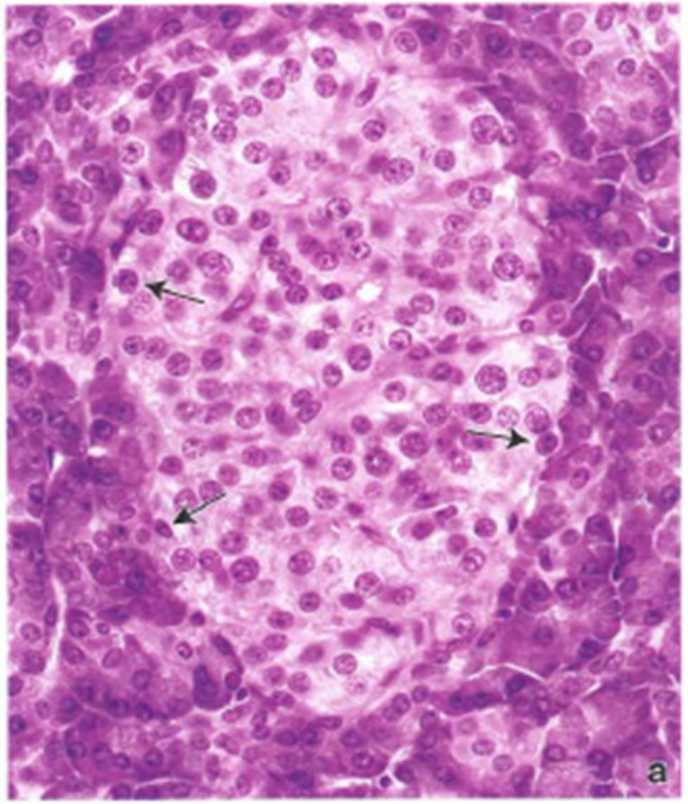


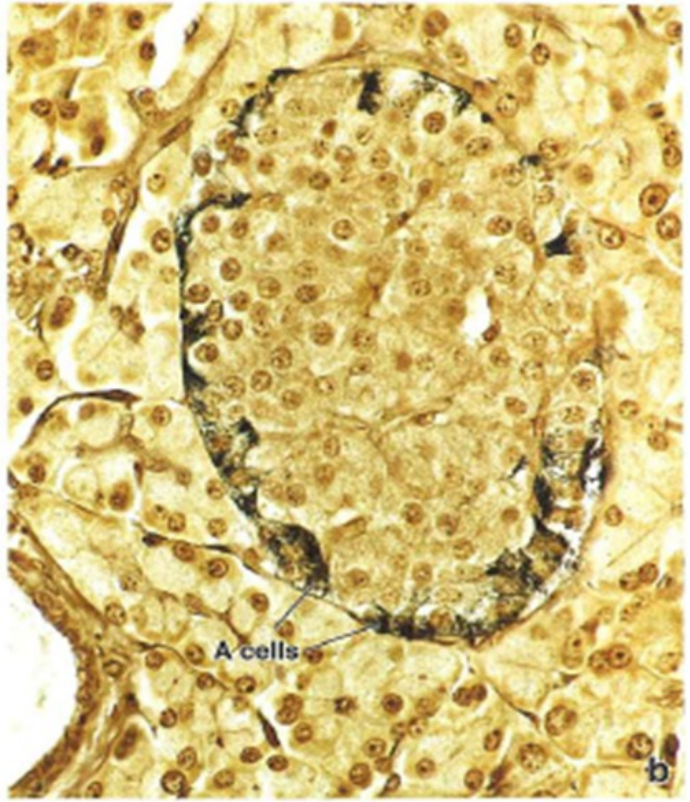
TEM of a pancreatic acinar cell shows its pyramidal shape and the round, basal nucleus (**N**) surrounded by cytoplasm packed with cisternae of rough ER (**RER**). The Golgi apparatus (**G**) is situated at the apical side of the nucleus and is associated with condensing vacuoles (**C**) and numerous secretory granules (**S**) with zymogen. The small lumen (**L**) of the acinus contains proteins recently released from the cell by exocytosis. Exocytosis of digestive enzymes from secretory granules is promoted by CCK, released by enteroendocrine cells of the duodenum when food enters that region from the stomach. (X8000)

PANCREAS

Endocrine pancreas (islets of Langerhans)

- Small clusters of cells, richly supplied by fenestrated capillaries, are scattered throughout the exocrine pancreas; these clusters show no orderly arrangement of secretory cells within the cluster.
- Predominate cell types and secretions
  - A cell (alpha cell). Secretes glucagon, which elevates glucose levels in the blood
  - B cell (beta cell). Secretes insulin, which lowers blood glucose levels; predominant cell type
  - D cell (delta cell). Secretes somatostatin, which modulates release of the other two major hormones
- Individual cell types cannot be distinguished with routine hematoxylin and eosin staining.





DIGESTIVE SYSTEM

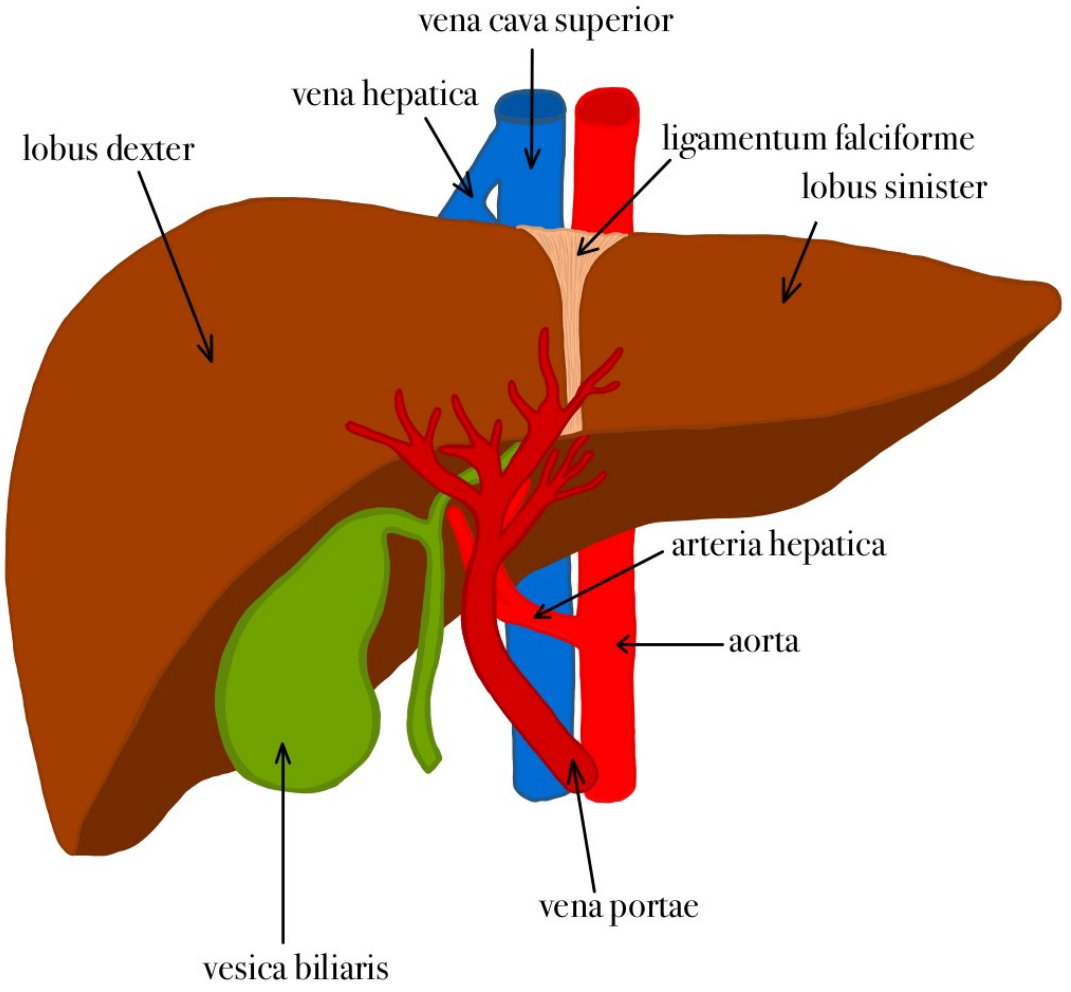
LIVER

- Located in right, upper quadrant of abdominal cavity under the diaphragm; the biggest organ, weight about 1,5 kg; large right (lobus dexter) and smaller left (lobus sinister) lobe, lobus quadratus, lobus caudatus

- Both an **exocrine and an endocrine gland**
  - Exocrine secretion (bile) is stored in the gall bladder and released into the duodenum. This secretory product contains bile acids that aid in the emulsification of lipids, bilirubin (the breakdown product of hemoglobin), phospholipids, and cholesterol.

  - Endocrine function is the synthesis of plasma proteins, including albumin, clotting factors, and lipoproteins that are released into the liver sinusoids.

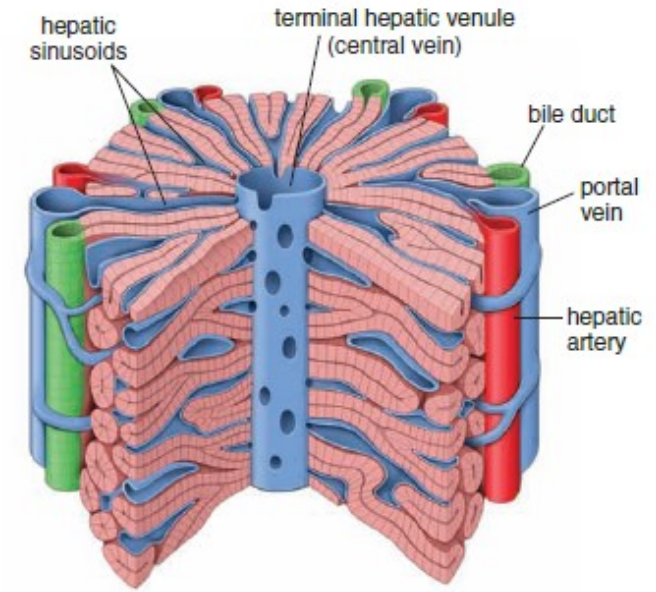
- Additional functions include the metabolization of digested food, storage of glucose as glycogen, and detoxification of hormones and drugs.

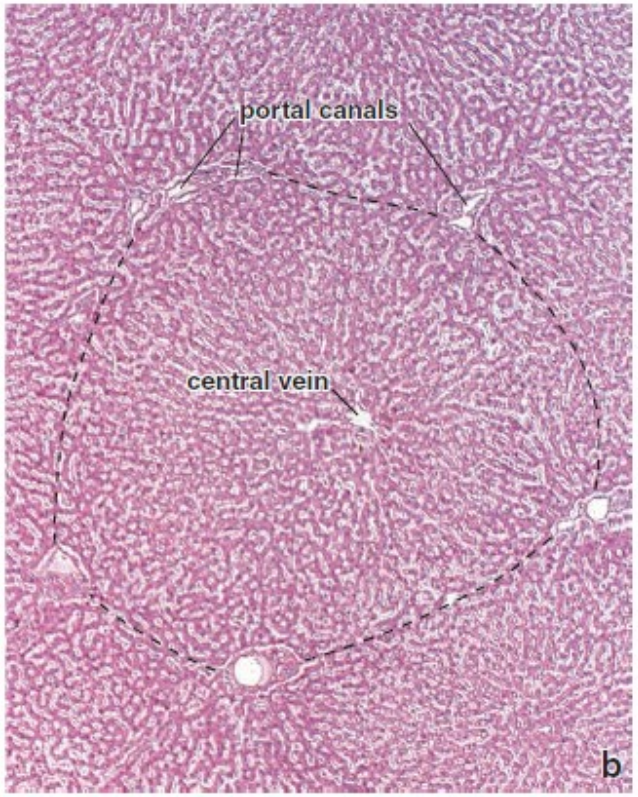


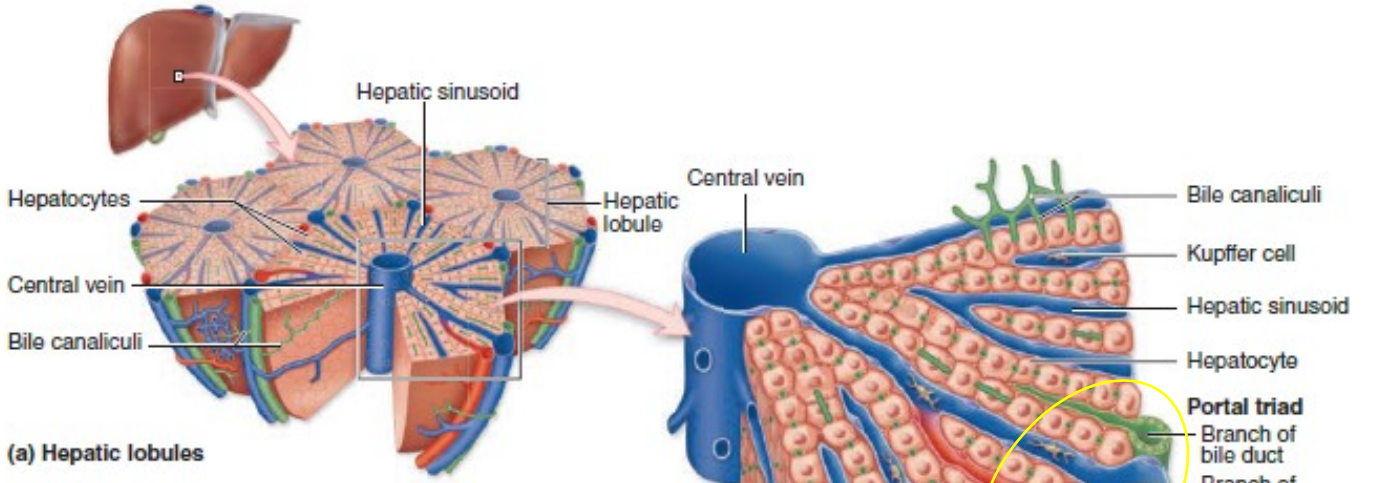
LIVER

ARCHITECTURE OF THE CLASSIC LIVER LOBULE

- The **classic liver lobule** resembles a column of wheels. Polyhedral shape. Structural and functional unit of the liver.
- Spokes of the wheels are cords or plates of **hepatocytes** radiating out from a central axis.
- Spaces between the spokes are occupied by liver **sinusoids** (discontinuous sinusoidal capillaries).
- Central axis of the lobule is a **central vein** into which sinusoids drain (i.e., blood is flowing from the periphery of the lobule to the center). The central vein runs parallel to the long axis of the lobule.
- The perimeter of the lobule is denoted by the position of three to six hepatic portal triads situated at intervals around the lobule.
    - Portal triad run parallel to the long axis of the lobule.
    - **Portal triad** contain branches of the
        - *Hepatic portal vein*. Lined with simple squamous epithelium; has the largest diameter of the three structures
        - *Hepatic artery*. Lined with simple squamous epithelium and two-three layers of smooth muscle
        - *Bile duct*. Lined with simple cuboidal epithelium; multiple branches may be present

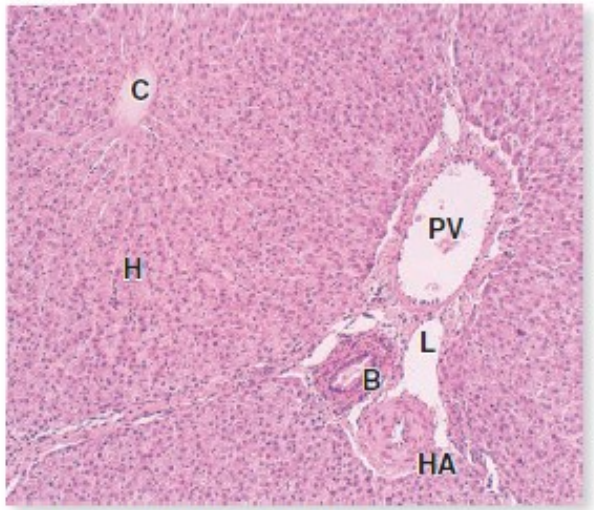






(a) Hepatic lobules

(b) Hepatocytes and sinusoids



(c) Portal triad and hepatic lobule

The liver, a large organ in the upper right quadrant of the abdomen, immediately below the diaphragm, is composed of thousands of polygonal structures called **hepatic lobules**, which are the basic functional units of the organ.

(a) Diagram showing a small **central vein** in the center of a hepatic lobule and several sets of blood vessels at its periphery. The peripheral vessels are grouped in connective tissue of the **portal tracts** and include a branch of the portal vein, a branch of the hepatic artery, and a branch of the bile duct (the **portal triad**).

(b) Both blood vessels in this triad branch as **sinusoids**, which run between plates of **hepatocytes** and drain into the central vein.

(c) Micrograph of a lobule shows the central vein (**C**), plates of hepatocytes (**H**), and in an adjacent portal area a small lymphatic (**L**) and components of the portal triad: a portal venule (**PV**), hepatic arteriole (**HA**), and bile ductule (**B**). (X220; H&E)

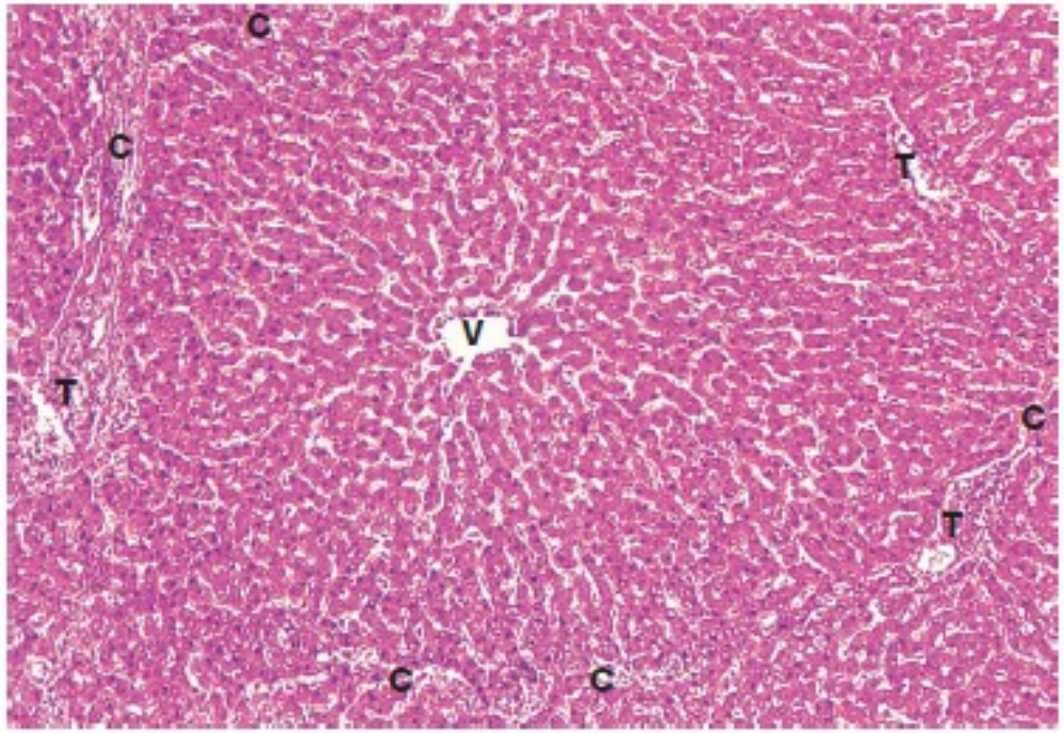
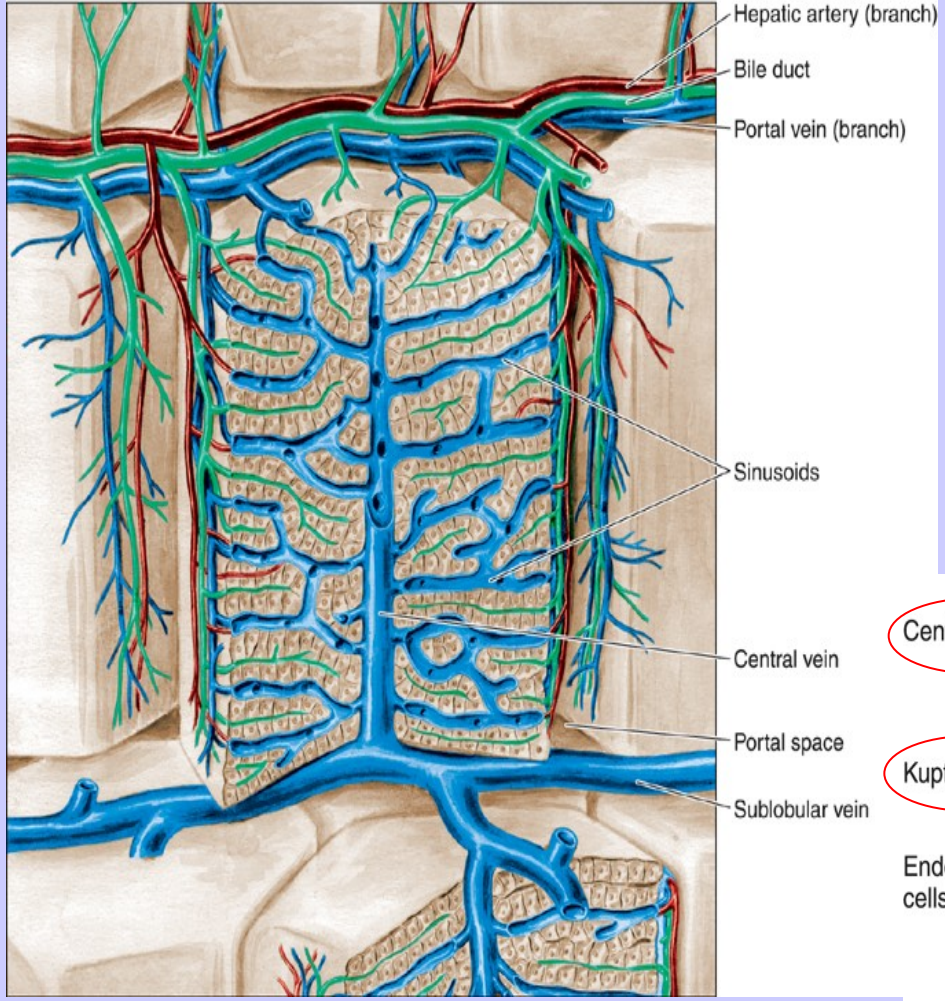


FIG. 15.8 Liver lobule
H&E (MP)

This micrograph illustrates a single human liver lobule and includes parts of a number of hepatic acini, each centred on a portal tract. The irregular hexagonal boundary of the lobule is defined by portal tracts **T** and sparse collagenous tissue **C**. Sinusoids originate at the lobule margin and course between plates of hepatocytes to converge upon the terminal hepatic (centrilobular) venule **V**. The plates of hepatocytes are usually only one cell thick and so each hepatocyte is exposed to blood on at least two sides. The plates of hepatocytes branch and anastomose to form a three-dimensional structure like a sponge.


Hepatic artery (branch)
Bile duct
Portal vein (branch)
Sinusoids
Central vein
Portal space
Sublobular vein

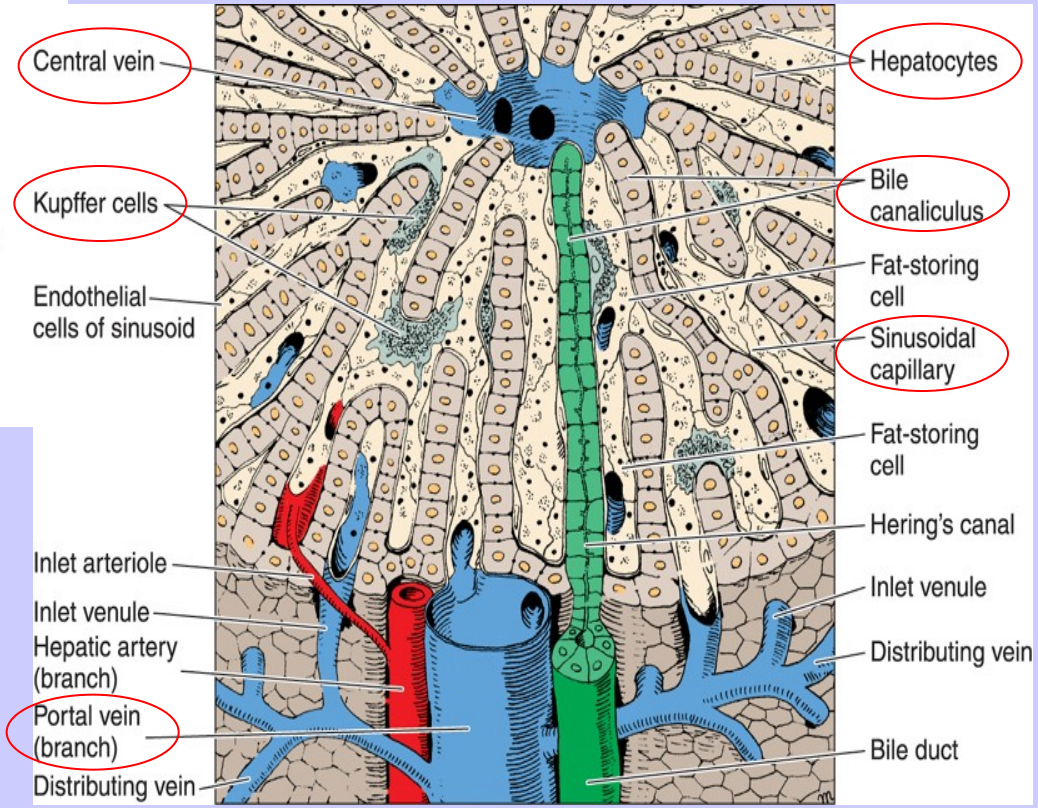
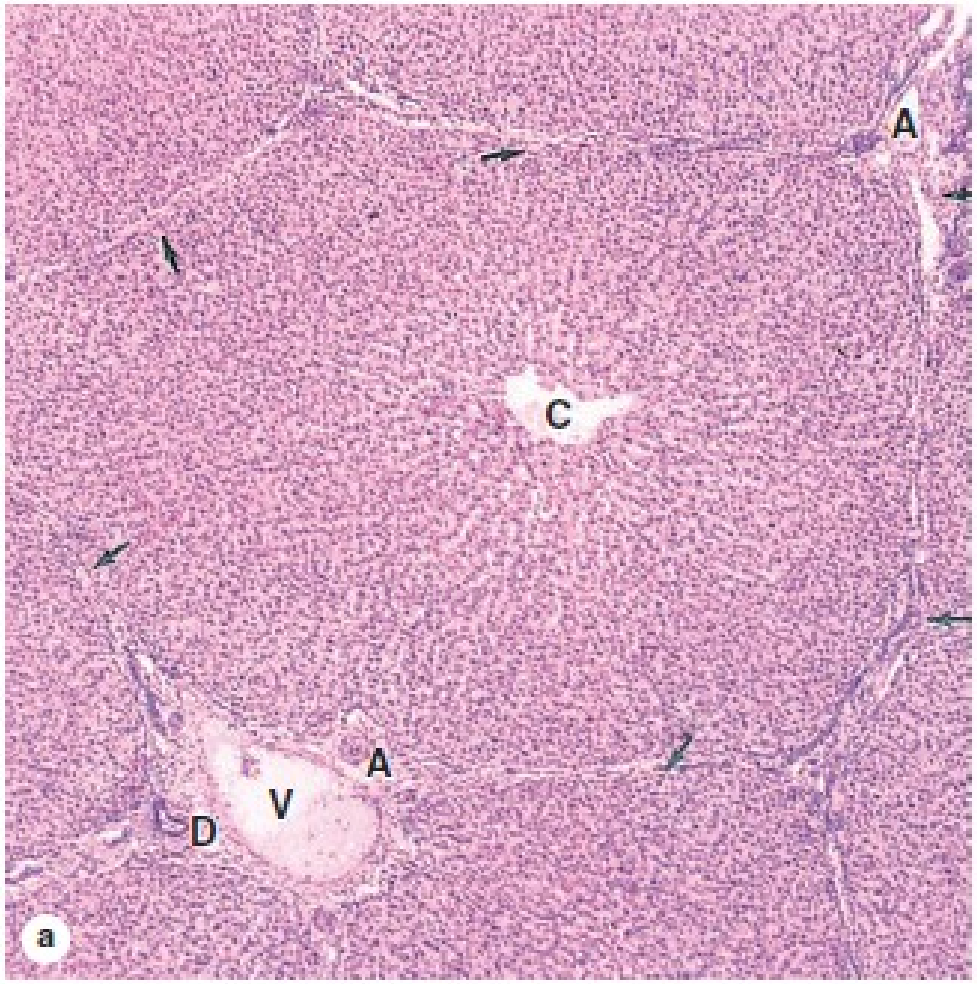
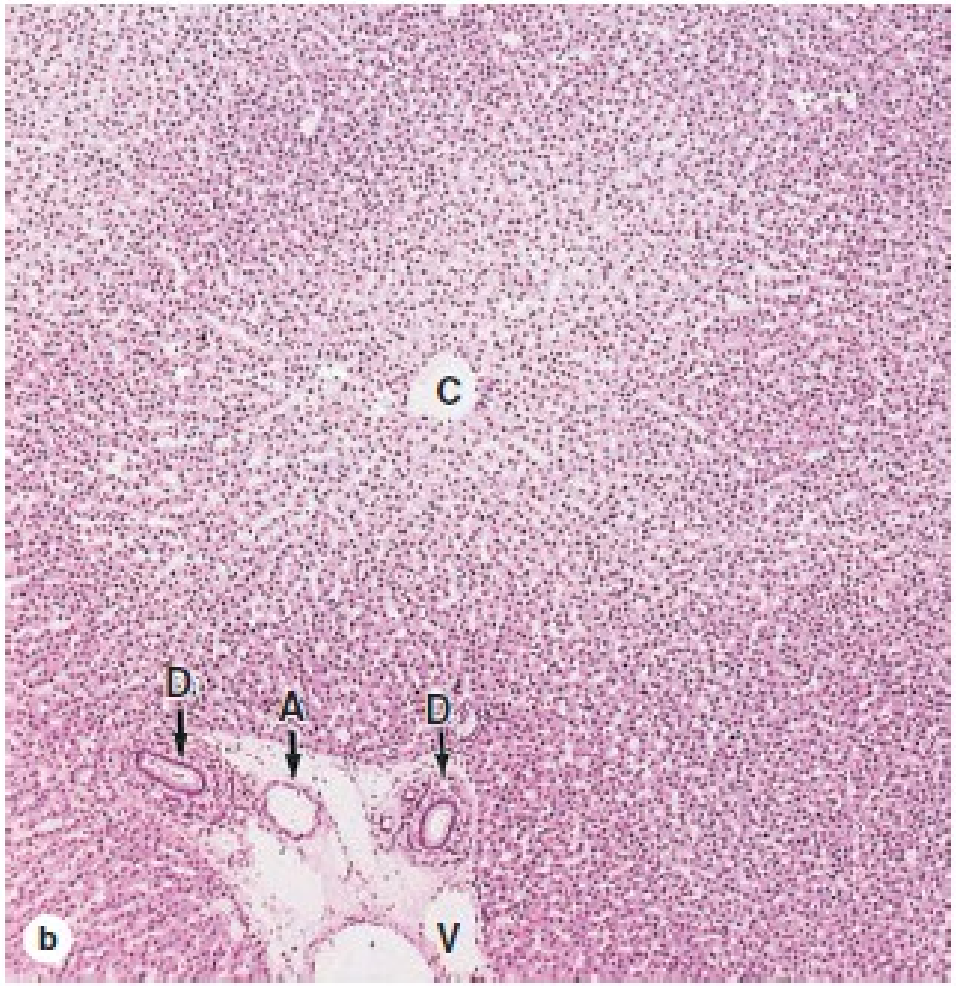
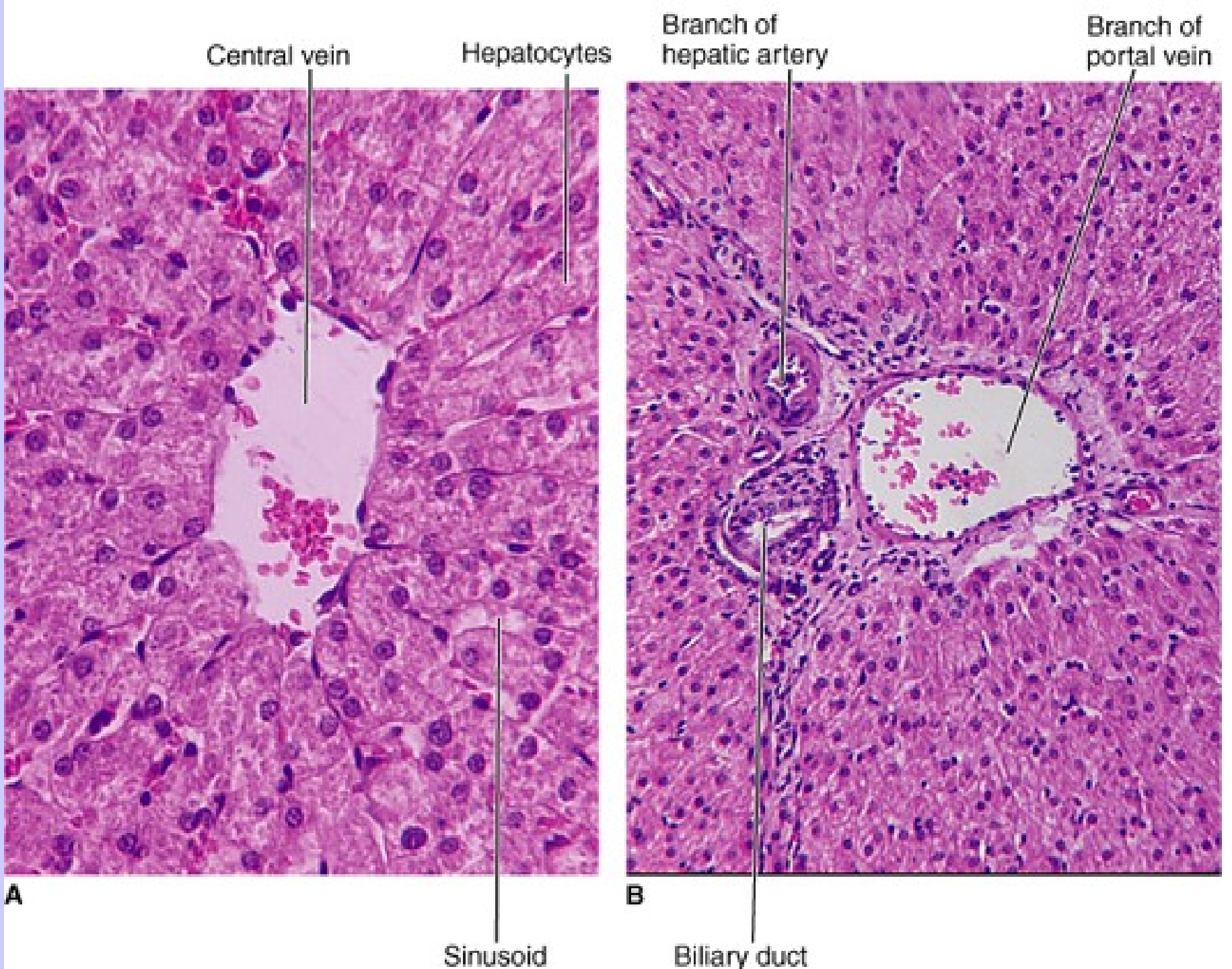

Central vein
Hepatocytes
Kupffer cells
Bile canaliculus
Fat-storing cell
Endothelial cells of sinusoid
Sinusoidal capillary
Fat-storing cell
Hering's canal
Inlet arteriole
Inlet venule
Inlet venule
Hepatic artery (branch)
Distributing vein
Portal vein (branch)
Bile duct
Distributing vein

FIGURE 16–12 Hepatic lobule.





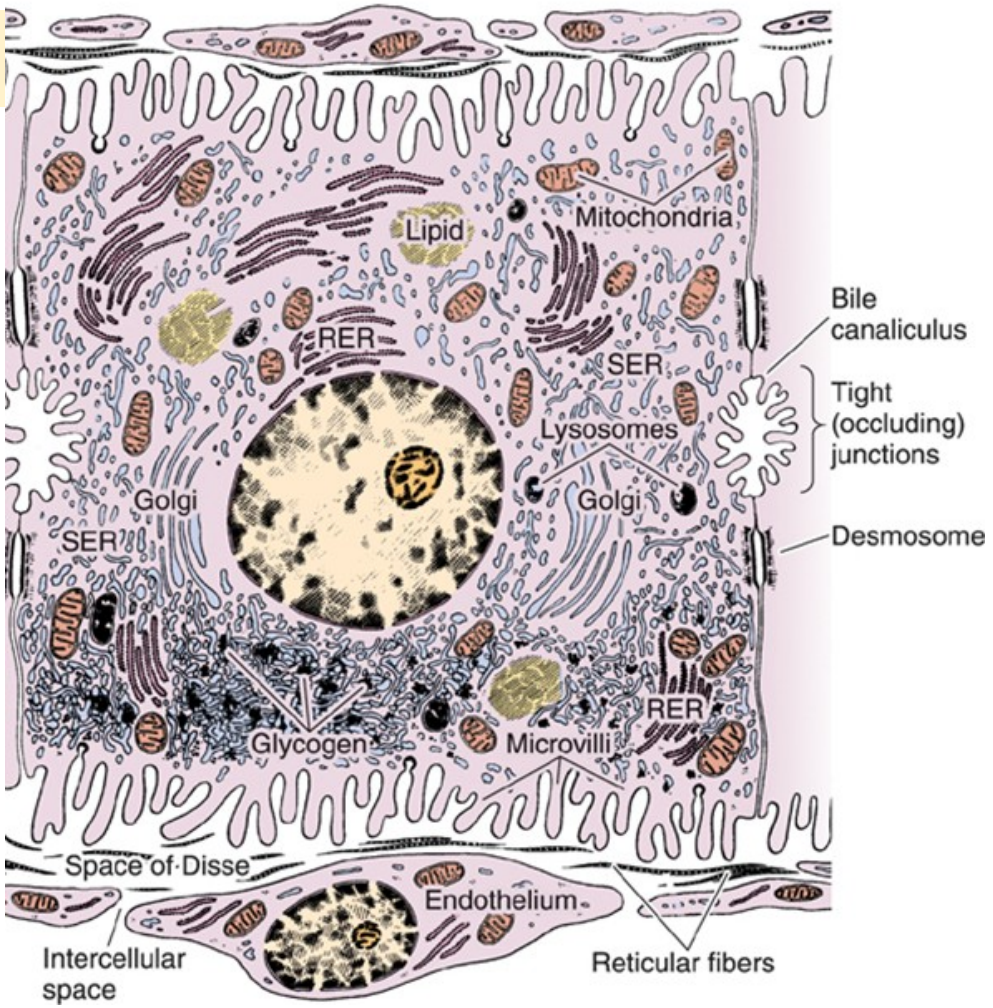
Cut transversely, hepatic lobules are polygonal units showing plates of epithelial cells called **hepatocytes** radiating from a central venule (**C**). **(a)** Hepatic lobules of some mammals, such as the pig, are delimited on all sides by connective tissue. **(b)** In humans these lobules have much less connective tissue and their boundaries are more difficult to distinguish. In both cases peripheral connective tissue of portal areas contains the portal triad: small bile ductules (**D**), venule (**V**) branches of the portal vein, and arteriole (**A**) branches of the hepatic artery. (Both X150; H&E)


Central vein
Hepatocytes
Sinusoid
A
Branch of hepatic artery
Branch of portal vein
Biliary duct
B

LIVER

FUNCTIONAL MICROANATOMY

- **Hepatocytes (liver cells)**
- Arranged as walls one to two cells thick that radiate out from the central vein like the spokes of a wheel
- Histology
  - Cells are polyhedral in shape.
  - Cells possess one or two nuclei.
  - Cells contain abundant smooth and rough endoplasmic reticulum, Golgi apparatus, mitochondria, and lysosomes. They also contain large accumulations of electron-dense glycogen granules that stain strongly with PAS. Numerous peroxisomes, along with smooth endoplasmic reticulum, carry out detoxification.
  - At intervals between adjacent cells, the plasma membranes bulge inward to form a bile canaliculus, the beginning of the bile transport system.
  - Microvilli project into the space of Disse, increasing surface area of the cells.



A diagram of hepatocyte cytoplasmic organization, with major functions localized. (**1**) RER is primarily engaged in synthesis of **plasma proteins** for release into the perisinusoidal space. (**2**) Potentially toxic compounds, bilirubin (bound to albumin) and bile acids are taken up from the perisinusoidal space, processed by enzymes in the tubulovesicular system of the SER, and secreted into the **bile canaliculi**. (**3**) Glucose is taken up from the perisinusoidal space and stored in **glycogen granules**, with the process reversed when glucose is needed.

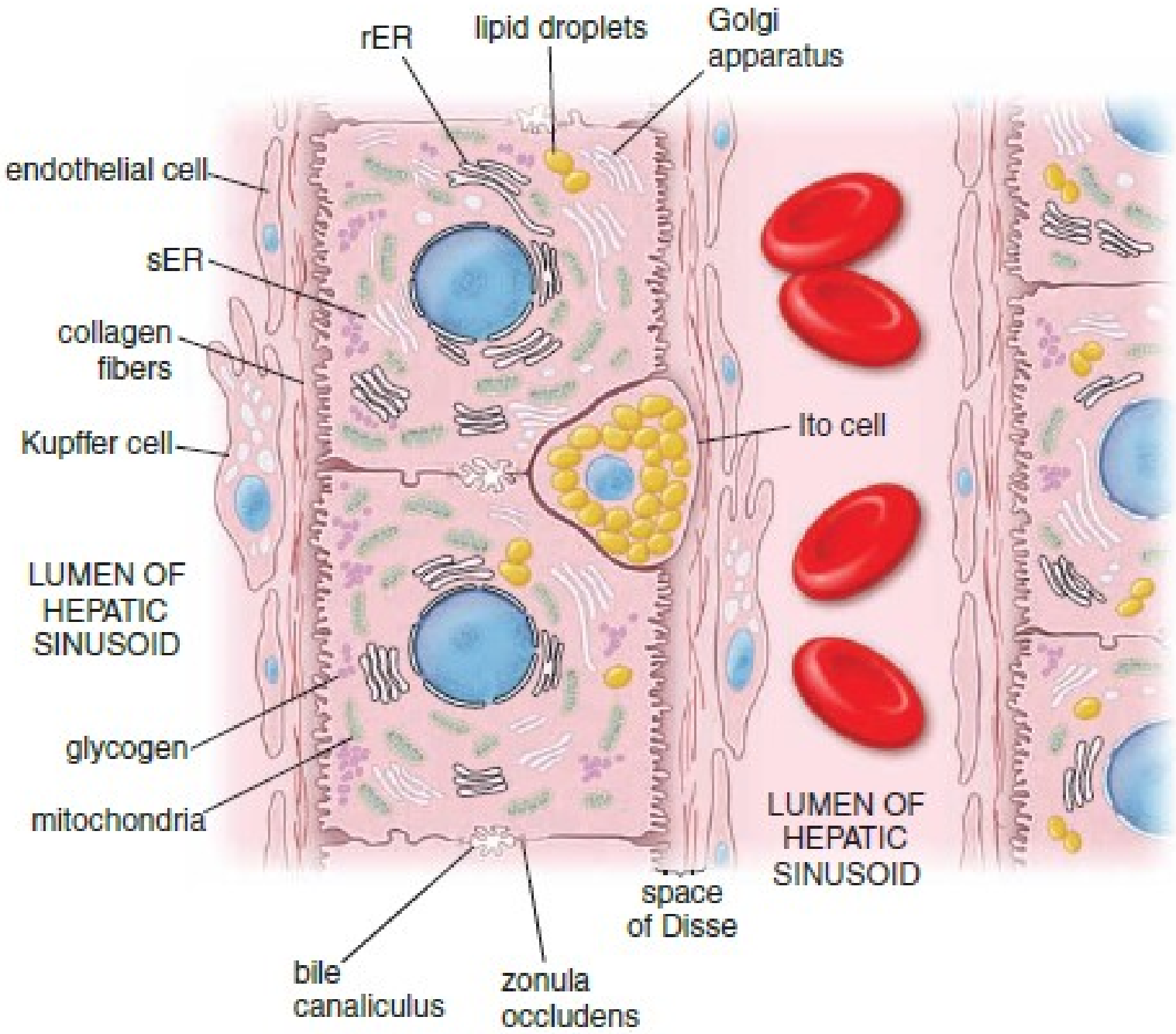


FIGURE 18.10 ▲ Schematic diagram of a plate of hepatocytes interposed between hepatic sinusoids. This diagram shows a one-cell-thick plate of hepatocytes interposed between two sinusoids. If it is assumed that the cell is cuboidal, two sides of each cell (shown) would face hepatic sinusoids, two sides of each cell (shown) would face bile canaliculi, and the additional two sides (not shown) would face bile canaliculi. Note the location and features of a hepatic stellate cell (Ito cell) filled with cytoplasmic vacuoles containing vitamin A. The sparse collagen fibers found in the perisinusoidal space (of Disse) are produced by the hepatic stellate cells (Ito cells). In certain pathologic conditions, these cells lose their storage vacuoles and differentiate into myofibroblasts that produce collagen fibers, leading to liver fibrosis. Observe that the stellate sinusoidal macrophage (Kupffer cell) forms an integral part of the sinusoidal lining.

LIVER

FUNCTIONAL MICROANATOMY

- **Sinusoids**
  - A variation of discontinuous capillaries, in that gaps exist between endothelial cells and the fenestrations lack diaphragms
  - The basal lamina is lacking beneath the fenestrations.
  - Fenestrations open into a subsinusoidal space, the space of Disse, separating the sinusoids from the hepatocytes beneath the space.
  - Kupffer cells, liver macrophages, span the sinusoids, filtering debris from the blood.

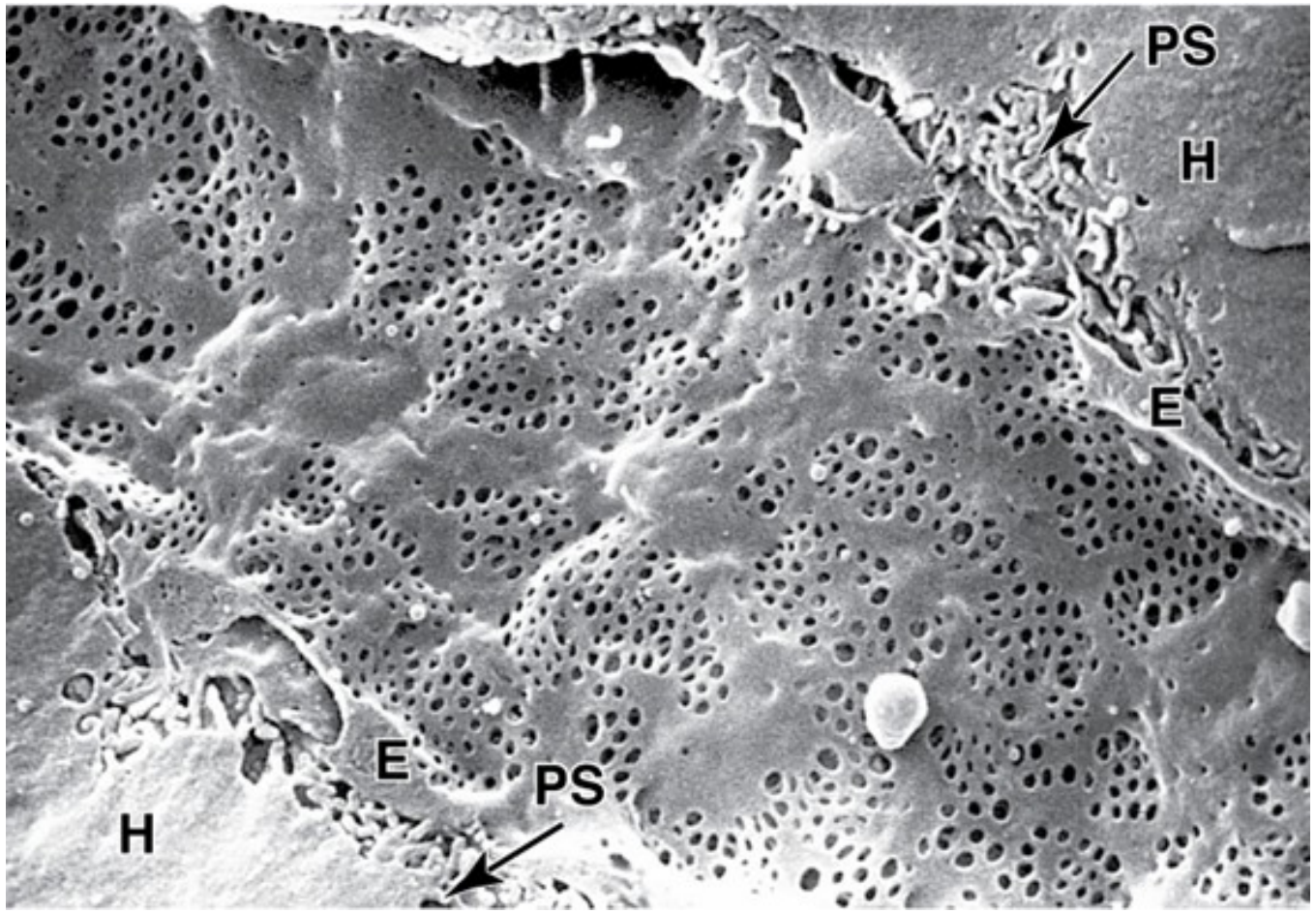
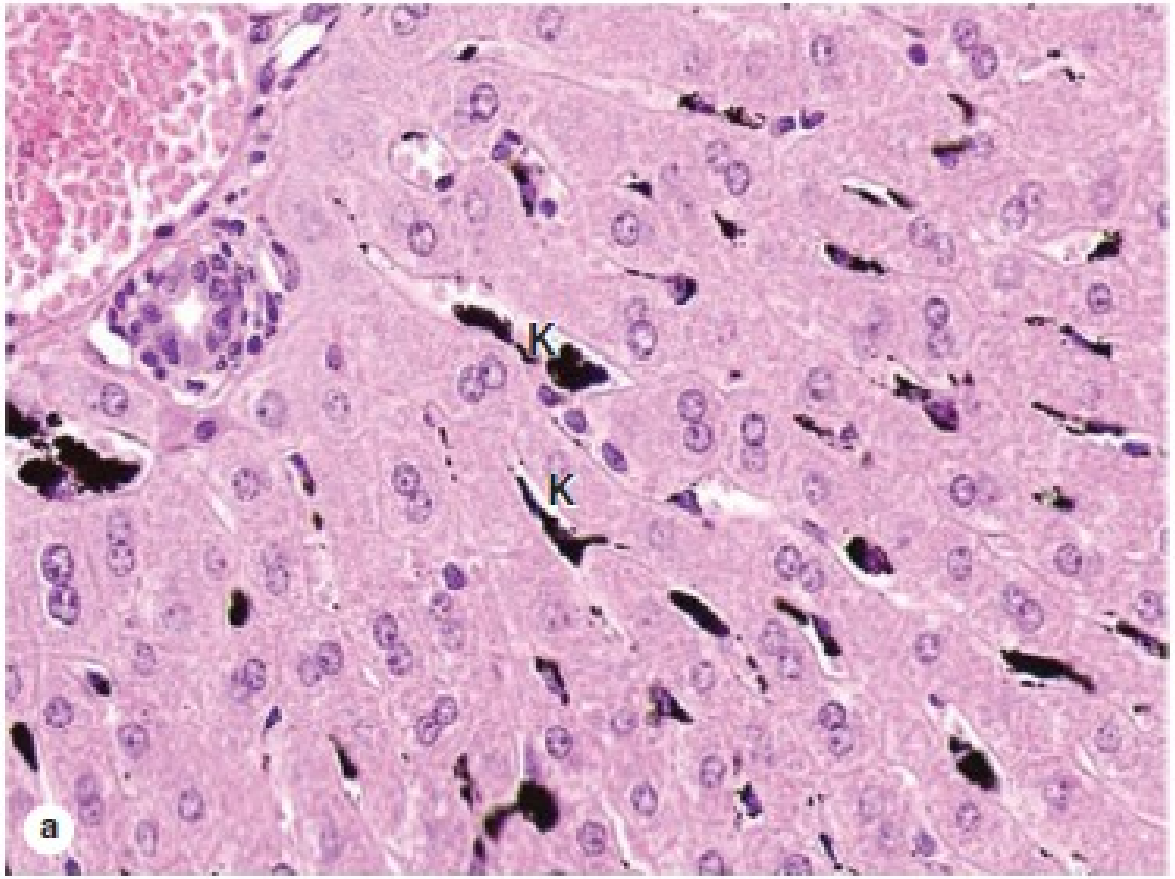
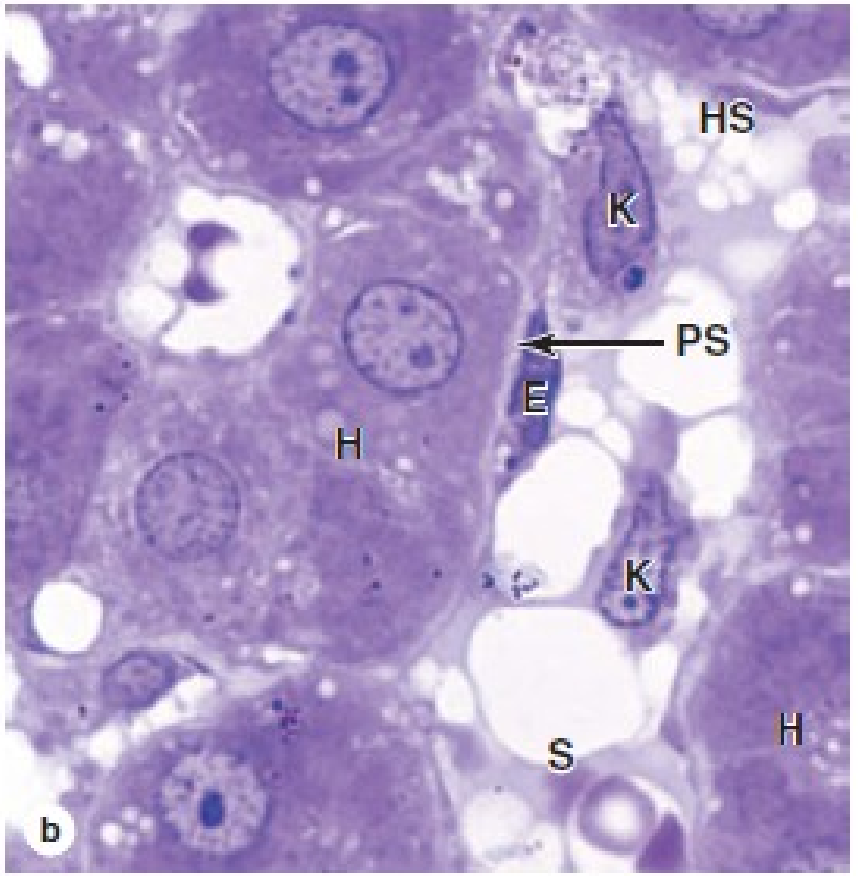


FIGURE 16–15 Hepatic sinusoids.





In the endothelial lining of the hepatic sinusoids are numerous specialized stellate macrophages or **Kupffer cells**, which detect and phagocytose effete erythrocytes.

(a) Kupffer cells (**K**) are seen as black cells in a liver lobule from a rat injected with particulate India ink. (X200; H&E)

(b) In a plastic section, Kupffer cells (**K**) are seen in the sinusoid (**S**) between two groups of hepatocytes (**H**). They are larger than the flattened endothelial cells (**E**). Between the endothelium and the hepatocytes is a very thin space called the perisinusoidal space (**PS**) of Disse, in which are located small hepatic stellate cells (**HS**), or Ito cells, which maintain the very sparse ECM of this compartment and also store vitamin A in small lipid droplets. These cells are numerous but are difficult to demonstrate in routine histologic preparations. (X750; PT)

DIGESTIVE SYSTEM

LIVER

BLOOD SUPPLY AND DRAINAGE OF THE LIVER

- Blood supply is from two sources:
  - **Hepatic portal vein**
    - Supplies about 75 % of the blood
    - Carries blood drained directly from the gastrointestinal tract, which, therefore, is deoxygenated and high in absorbed nutrients.
  - **Hepatic artery**. 35 % of the blood. Supplies oxygenated blood

- **Branches** from both vascular sources continue into smaller branches located in the **portal triad**. Portal triad branches supply the **hepatic sinusoids** that drain into a **central vein**. Multiple central veins anastomose to eventually form the **three hepatic veins** that empty into the **inferior vena cava**.

IN hepatic artery, portal vein
OUT hepatic vein, bile ducts

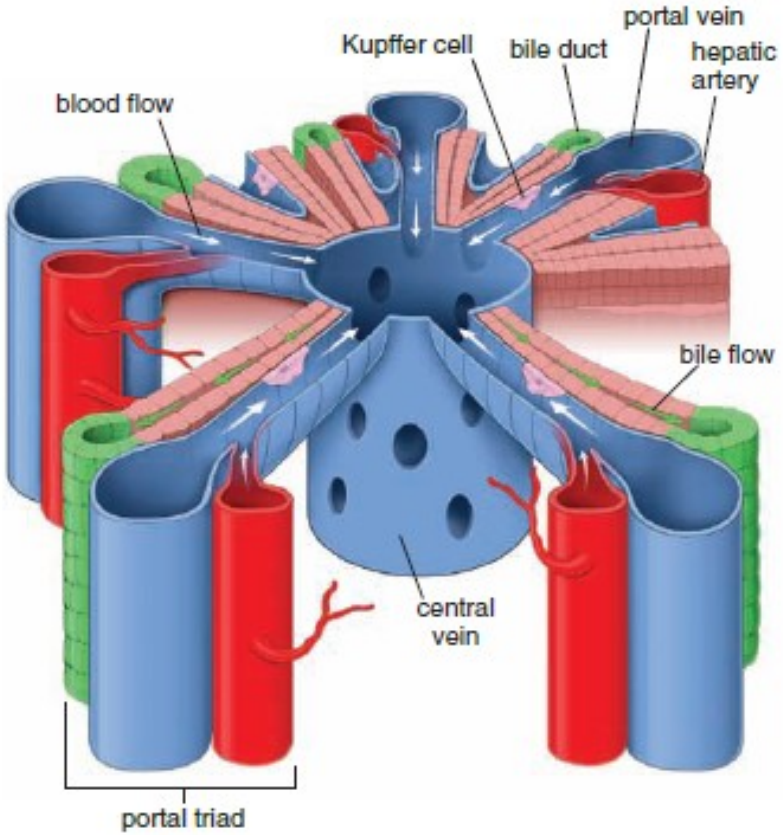


FIGURE 18.6 ▲ Diagram of the flow of blood and bile in the liver. This schematic diagram of a part of a classic lobule shows the components of the portal triads, hepatic sinuses, terminal hepatic venule (central vein), and associated plates of hepatocytes. *Arrows* indicate the direction of the blood flow in the sinusoids. Note that the direction of bile flow (*green arrows*) is opposite that of the blood flow.

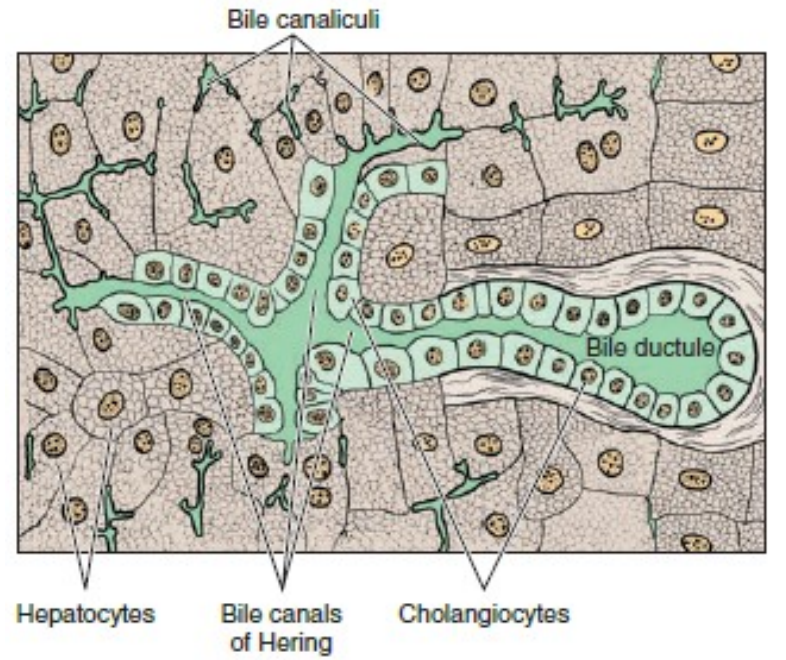
DIGESTIVE SYSTEM

LIVER

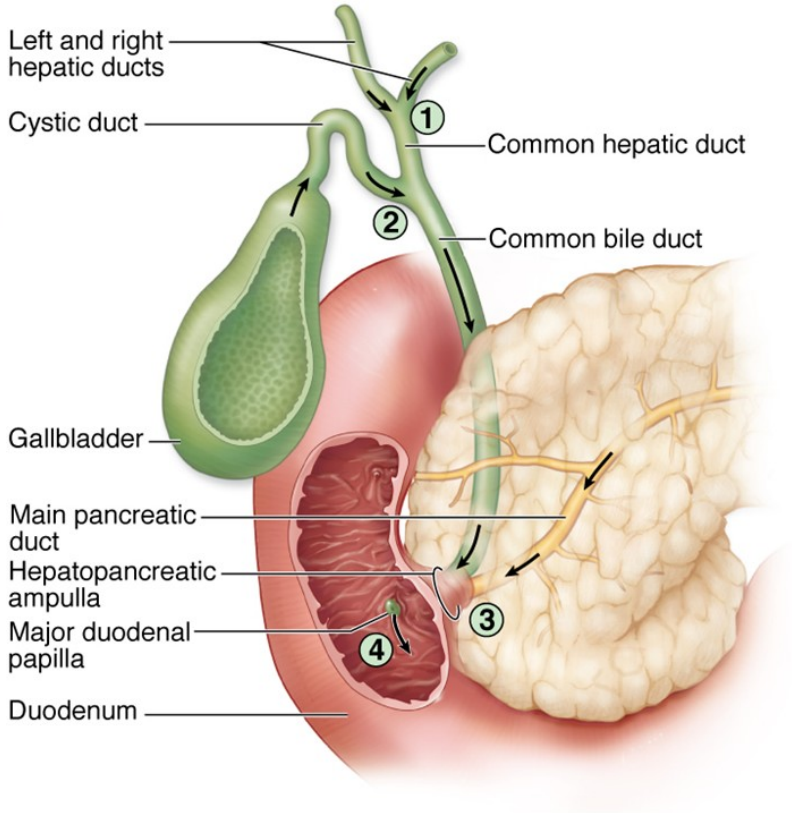
FLOW OF BILE FROM LIVER

- Bile is produced by hepatocytes in the liver and released into *bile canaliculi* located between two adjacent hepatocytes.
- Bile canaliculi form a meshwork configuration that continues into *bile ducts* lying in portal canals. These bile ducts anastomose to form *the left and right hepatic duct*.
- The hepatic ducts exit from the liver and fuse to form the *common bile duct*.

  The bile it contains can either:
  - Travel directly to the duodenum
  - Be transported via the cystic duct to the gall bladder where it is stored until needed



Near the periphery of each hepatic lobule, many bile canaliculi join with the much larger bile canals of Hering, which are lined by cuboidal epithelial cells called **cholangiocytes**. These canals soon join the bile ductules in the portal areas and drain into the biliary tree.



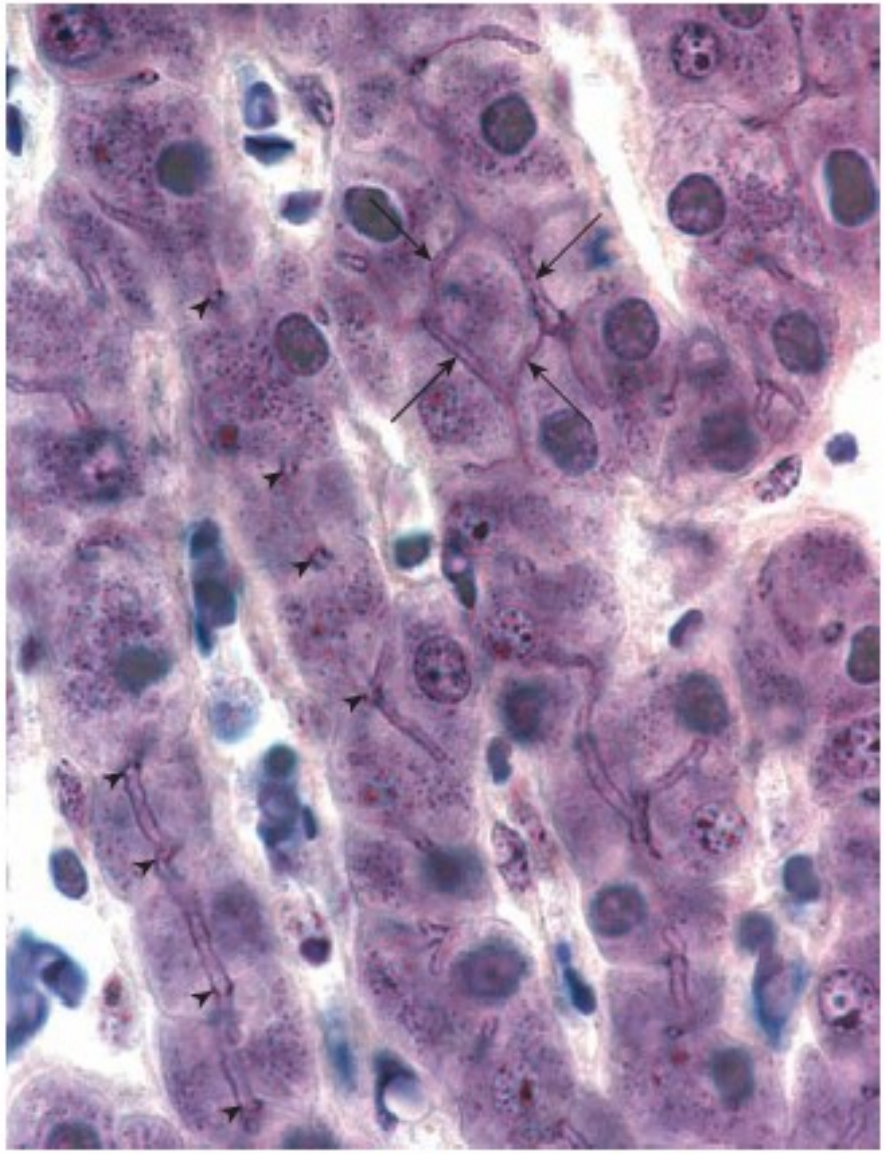
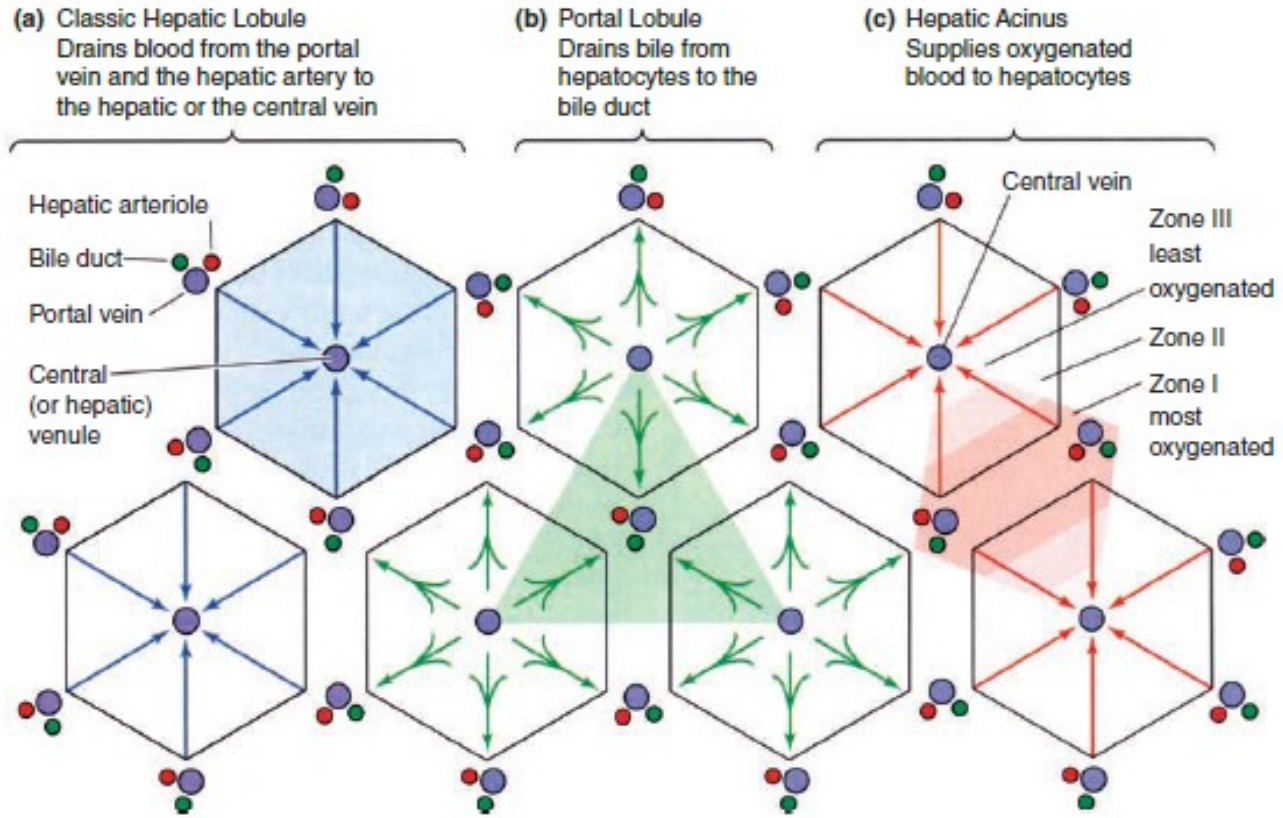


FIGURE 18.13 ▲ Photomicrograph of bile canaliculi. This high-magnification photomicrograph shows several one-cell-thick plates of hepatocytes separated by hepatic sinusoids. The plane of section in certain areas is parallel to the bile canaliculi. In this plane, the canaliculi reveal their arrangement on four sides of the hepatocytes (*arrows*). *Arrowheads* indicate those bile canaliculi that appear only in cross-sectional profile. ×1,240.

FIGURE 16–18 Concepts of structure-function relationships in liver.



Studies of liver microanatomy, physiology, and pathology have given rise to three related ways to view the liver's organization, which emphasize different aspects of hepatocyte activity.

(a) The **classic lobule** concept offers a basic understanding of the structure-function relationship in liver organization and emphasizes the endocrine function of hepatocytes as blood flows past them toward the central vein.

(b) The **portal lobule** emphasizes the hepatocytes' exocrine function and the flow of bile from regions of three classic lobules toward the bile duct in the portal triad at the center here. The area drained by each bile duct is roughly triangular.

(c) The **hepatic acinus** concept emphasizes the different oxygen and nutrient contents of blood at different distances along the sinusoids, with blood from each portal area supplying cells in two or more classic lobules. Major activity of each hepatocyte is determined by its location along the oxygen/nutrient gradient: periportal cells of zone I get the most oxygen and nutrients and show metabolic activity generally different from the pericentral hepatocytes of zone III, exposed to the lowest oxygen and nutrient concentrations. Many pathologic changes in the liver are best understood from the point of view of liver acini.

(Used with permission from Boron WF, Boulpaep EL. Medical Physiology: A Cellular and Molecular Approach. Philadelphia, PA: Saunders Elsevier, 2005.)

DIGESTIVE SYSTEM

GALL BLADDER

- Stores and concentrates bile produced in the liver by reabsorbing water
- Connects, via the cystic duct, with the hepatic duct from the liver to form the common bile duct that empties into the duodenum

- **Mucosa**
  Composed of:
    - Simple columnar epithelium with short microvilli. Accumulations of mitochondria and glycoprotein-filled secretory vesicles, particularly in the apices of the cells, are prominent.
    - Lamina propria
    - Muscularis mucosae is not present.

  Is thrown into complex, irregular folds that are particularly evident when the gall bladder is empty.
- **Submucosa**
- **Smooth muscle** is arranged in an irregular network surrounding the gall bladder.
- A **serosa** covers most of the gall bladder; an **adventitia** surrounds the portion that is attached to the liver.