Anatomy and Histology of the Small and Large Intestine

MACROSCOPIC FEATURES

Small Intestine

The small intestine is a specialized tubular structure within the abdominal cavity in continuity with the stomach proximally and the colon distally. The small bowel increases 20 times in length with aging, from 200 cm in the newborn to almost 6 m in the adult, and its length is approximated by three times the length of the infant, or height of the child or adult.\(^1\)

The duodenum, the most proximal portion of the small intestine, begins at the duodenal bulb, travels in the retroperitoneal space around the head of the pancreas, and ends on its return to the peritoneal cavity at the ligament of Treitz. The remainder of the small intestine is suspended within the peritoneal cavity by a thin, broad-based mesentery that is attached to the posterior abdominal wall and allows free movement of the small intestine within the abdominal cavity. The proximal 40% of the mobile small intestine is the jejunum, and the remaining 60% is the ileum. The jejunum occupies the left upper portion of the abdomen, and the ileum is positioned in the right abdomen and upper part of the pelvis. No distinct anatomic demarcation exists between jejunum and ileum.

Visual examination of the luminal surface of the small intestine reveals mucosal folds, the plicae circulares. More numerous in the proximal jejunum, the plicae circulares decrease in number in the distal small bowel and are absent in the terminal ileum. Aggregates of lymphoid follicles are scattered throughout the small intestine but are found in highest concentration within the ileum, where they are designated Peyer's patches. Peyer's patches normally are more prominent during infancy and childhood than they are in adulthood.

The small bowel is in continuity with the colon at the ileocecal valve, which comprises two semilunar lips that protrude into the cecum. The ileocecal valve provides a barrier to the retrograde flow of colonic contents into the small intestine. This barrier appears to be a function of the angulation between the ileum and cecum that is maintained by the superior and inferior ileocecal ligaments,\(^2\) and a true tonic, sphincter-type pressure does not appear to be present in this region.

Colon and Rectum

The colon is a tubular structure approximately 30 to 40 cm in length at birth in the full-term infant. In the adult, the colon measures 1.5 m, about one quarter of the length of the small bowel. The diameter of the colon is greatest in the cecum (7.5 cm) and narrowest in the sigmoid (2.5 cm). The colon is continuous with the small intestine proximally at the ileocecal valve and ends distally at the anal verge (Fig. 93-1). The external appearance of the colon differs from that of the small bowel, because the longitudinal muscle fibers of the colon coalesce into three discrete bands called teniae, located at 120-degree intervals about the colonic circumference: tenia liberis, tenia omentalis, and tenia mesocolica. The teniae start at the base of the appendix and extend continuously to the proximal rectum. Outpouchings of the colon, the haustra, are found between the teniae. Semilunar folds characterize the mucosa between the haustra. Sacs of peritoneum filled with adipose tissue, the appendices epiploicae, are found on the surface of the colon.
The first portion of the colon, the cecum, lies in the right iliac fossa and projects downward as a blind pouch below the entrance of the ileum. The cecum is a sacculated structure 6 to 8 cm in length and breadth. Because of its large diameter, it is the part of the colon most apt to rupture with distal obstruction, and cecal tumors can grow to be quite large without producing symptoms of obstruction. The mobility of the cecum normally is fixed by a small mesoceleum; an anomaly in fixation exists in 10% to 20% of people, predisposing them to cecal volvulus. The vermiform appendix is a blind outpouching of the cecum that begins inferior to the ileocecal valve. Appendiceal anatomy is discussed further in Chapter 113.
The ascending colon extends from the cecum for 12 to 20 cm along the right side of the peritoneal cavity to the hepatic flexure. The ascending colon is covered with peritoneum anteriorly and on both sides and thus constitutes a retroperitoneal organ.

At the hepatic flexure, the colon turns medially and anteriorly to emerge into the peritoneal cavity as the transverse colon. This longest portion of the colon (40 to 50 cm) is the most mobile segment of the colon and drapes itself across the anterior abdomen between the hepatic and splenic flexures. When a person assumes the upright position, the transverse colon may actually dip down into the pelvis. The transverse colon may become fixed in this festooned position by adhesions, most commonly resulting from hysterectomy and potentially leading to a technically difficult colonoscopy.

The descending colon, about 30 cm in length, travels posteriorly and then inferiorly in the retroperitoneal compartment to the pelvic brim. There, it emerges into the peritoneal cavity as the sigmoid colon. This is an S-shaped redundant segment of variable length, tortuosity, and mobility, which challenges the endoscopist and radiologist and causes it to be susceptible to volvulus. Because the sigmoid is the narrowest part of the colon, tumors and strictures of this region cause symptoms early in the course of disease.

The rectum, 10 cm in length in the adult, begins at the peritoneal reflexion and follows the curve of the sacrum ending at the anal canal.

Anal Canal

The anal canal, 5 cm in length in the adult, has discrete upper and lower demarcations. The anorectal ring is located proximally and is composed of the upper portion of the internal sphincter, the longitudinal muscle of the rectum, the deep portion of the external sphincter, and the puborectalis portion of the levator ani muscle; distally the anal verge represents the transition of anal skin to true skin. The mucosa of the distal 3 cm of the rectum and the anal canal contains 6 to 12 redundant longitudinal folds called the columns of Morgagni, which terminate in the anal papillae. These columns are joined together by mucosal folds called the anal valves, which are situated at the dentate line. The muscularis mucosae disappears in the anorectal canal, and the inner circular coat of muscularis propria thickens to form the internal anal sphincter. The sphincter ani externus muscle constitutes the external anal sphincter and surrounds the anal canal. The fibers of the external sphincter blend with those of the levator ani muscle and are attached posteriorly to the coccyx and anteriorly to the perineal body. The anatomy and function of these muscles are described in more detail in Chapter 122.

Intestinal Vasculature

The superior mesenteric artery delivers oxygenated blood to the distal duodenum, the entire jejunum and ileum, the ascending colon, and the proximal two thirds of the transverse colon. The remainder of the colon is supplied by branches of the inferior mesenteric artery. The anal canal is supplied by the paired middle and inferior rectal (hemorrhoidal) arteries. The rectal arteries are branches of the internal iliac (hypogastric) arteries. Veins follow the arterial distribution. The
superior and inferior mesenteric veins join the splenic vein to form the portal vein. (See Chapter 111 for additional discussion of the intestinal blood supply.)

Intestinal Lymphatic Drainage

The lymphatic drainage of both the small bowel and colon follows their respective blood supplies to lymph nodes in the celiac, superior preaortic, and inferior preaortic regions. Lymphatic drainage proceeds to the cisterna chyli and then via the thoracic duct into the left subclavian vein. The perianal region drains to the inguinal lymph nodes.

Intestinal Extrinsic Innervation

The autonomic nervous system—sympathetic, parasympathetic and enteric—innervates the gastrointestinal tract. The sympathetic and parasympathetic nerves constitute the extrinsic nerve supply and connect with the intrinsic nerve supply, which is composed of ganglion cells and nerve fibers within the intestinal wall. Innervation of the small intestine and colon is discussed in detail in Chapters 94 and 95, respectively.

MICROSCOPIC FEATURES

General Considerations

The small and large intestine share certain histologic characteristics. The wall of the small intestine and colon is composed of four layers: mucosa (or mucous membrane), submucosa, muscularis (or muscularis propria), and adventitia (or serosa) (Fig. 93-2).
**Mucosa**

The mucosa is the innermost layer formed by glandular epithelium, lamina propria, and muscularis mucosae (Fig. 93-3A and B). The glandular epithelium forms cylindrical structures, called crypts. The lamina propria, which supports the epithelium, is a layer of reticular connective tissue with elastin, reticulin, and collagen fibers, lymphocytes, plasma cells, and eosinophilic granulocytes, as well as lymphatics and capillaries. The muscularis mucosae consists of a thin layer of smooth muscle at the boundary of the mucosa and submucosa.
The glandular epithelium is composed of various cell types: stem cells, undifferentiated crypt cells, absorptive cells (also called columnar cells), goblet cells, Paneth cells, enteroendocrine cells, and M cells.

Figure 93-3  Histologic and electron microscopic photographs of the small intestine.  
A, Components of the mucosa: ge, glandular epithelium; lp, lamina propria. Note the absorptive cells which appear as high columnar cells with eosinophilic cytoplasm (arrow).  
Hematoxylin-eosin stain, ×250.  
B, Goblet cells (arrow) are stained red. mm, muscularis mucosae. Periodic acid–Schiff stain, ×150.  
C, Microvilli (mv) are seen as delicate finger-like projections on electron microscopic examination. ×9000.  
(Courtesy of S. Teichberg, PhD.)
Stem cells are pluripotent cells located at the base of the crypt. Undifferentiated cells have fewer intracellular organelles and microvilli than do absorptive cells. The absorptive cells (Fig. 93-3A) are high columnar cells with oval, basal nuclei, eosinophilic cytoplasm, and a periodic acid–Schiff (PAS)–positive free surface, the brush border (see Fig. 93-3B). On electron microscopic examination, the brush border is seen to be composed of microvilli (see Fig. 93-3C), which are more numerous in the small intestinal than in the colonic epithelium. Small bowel enterocyte microvilli are estimated to increase the luminal surface area of the cell 14- to 40-fold. Goblet cells are oval or round, with flattened basal nuclei (Fig. 93-4A); their cytoplasm is basophilic, metachromatic (see Fig. 93-4B), and PAS positive (see Fig. 93-4C). Paneth cells are flask-shaped and have an eosinophilic granular cytoplasm and a broad base positioned against the basement membrane (Fig. 93-5). Paneth cells contain zinc, antimicrobial peptides, and growth factors and secrete lysoenzymes. The mucosa also contains specialized cells that because of their specific endocrine function are called enteroendocrine or neuroendocrine cells.
Figure 93-4  Photomicrographs of the small intestine demonstrating goblet cells. A, Clear, empty-looking cytoplasm and basal nuclei (arrow) are seen with use of the hematoxylin-eosin stain. ×250. B, Metachromatic staining of the cytoplasm results with use of the alcian blue stain. ×150. C, The cells demonstrate red staining with use of the periodic acid–Schiff stain. ×150

Figure 93-5  Photomicrograph of the small intestinal mucosa demonstrating the crypts of Lieberkühn (lc) and Paneth cells (arrow) which are characterized by granular eosinophilic cytoplasm. Hematoxylin-eosin stain, ×250

These neuroendocrine cells historically have been divided into argentaffin cells (granules able to reduce silver nitrate) and argyrophilic cells (granules that reduce silver nitrate only in the presence of a chemical reducer). Argentaffin cells stain positive with bichromate salts and also are called enterochromaffin cells. These cells are oval or triangular (also called “halo cells”) and have a basal position in relation to the remaining epithelial cells (Fig. 93-6A) and a pale cytoplasm filled with dark-stained granules. Variation in shapes and cell types has been detected with immunohistochemical staining.[8] The unifying APUD concept[9]—amino acid precursor, uptake, and decarboxylation—ascribes common characteristics to these neuroendocrine cells. APUD cells are a group of cells with a common embryonic neural crest origin and with similar cytochemical and
electron microscopic features; however, embryologic and morphologic data support an endodermal origin of these cells.¹⁹

Figure 93-6  Microscopic characteristics of neuroendocrine cells of the small intestine. A, Features include clear cytoplasm and a round nucleus (arrow). Hematoxylin-eosin stain, ×250. B, Neurosecretory granules are seen as electron-dense, round black bodies (arrow) on electron microscopic examination. ×20,000. C, Black granules can be seen with use of the Grimelius stain (arrow). ×150. D, Cells stained with synaptophysin have brown cytoplasm (arrow). ×250  (Courtesy of S. Teichberg, PhD.)

Ultrastructurally, enteroendocrine cells contain membrane-bound granules with variably sized electrondense cores (see Fig. 93-6B), averaging 100 to 250 nm in diameter, and comprising large dense-core vesicles and smaller, synaptic-type microvesicles. Neurosecretory granules can be demonstrated with the Grimelius stain by light microscopy as dark granules (see Fig. 93-6C) or more specifically by immunofluorescence, with immunohistochemical stains such as neuron-specific enolase. Chromogranin enables visualization of the large-dense core vesicles, and
synaptophysin targets the small synaptic-like microvesicles (see Fig. 93-6D). VMAT1 and VMAT2 are two isoforms of the ATP-dependent vesicular monoamine transporters. These antigens, derived from both the large and small dense-core vesicles, are expressed differentially in small dense-core vesicles. Both are expressed in neuroendocrine cells, but VMAT1 is restricted to serotonin-producing enterochromaffin cells, and VMAT2 is expressed in histamine-producing cells, enterochromaffin-like cells, and pancreatic islet cells. Specific immunohistochemical stains allow for identification of individual protein products of the neuroendocrine cells.

Besides releasing hormones in the blood, neuroendocrine cells also regulate secretion, absorption, motility, mucosal cell proliferation, and possibly immunobarrier control. Electron microscopy and immunohistochemistry have led to the identification of a variety of cell types (Table 93-1).

Designation according to the nature of the stored peptide is preferable to characterization of neuroendocrine cells by letters. Serotonin-producing enterochromaffin cells, vasoactive intestinal polypeptide (VIP), and somatostatin D cells are distributed throughout the small and large intestine.

### Table 93-1 -- Enteroendocrine Cells of the Gastrointestinal Tract: Cell Types, Hormones Produced, Vesicle Markers, and Distribution

<table>
<thead>
<tr>
<th>Cell Type</th>
<th>Peptide</th>
<th>Amine</th>
<th>Hormones</th>
<th>Vesicle Markers</th>
<th>Stomach</th>
<th>Small</th>
<th>Large</th>
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<tr>
<td>P/D₁</td>
<td>Ghrelin</td>
<td>CgA, VMAT2</td>
<td>LDCV</td>
<td>e,f</td>
<td>f</td>
<td>f</td>
<td>f</td>
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<tr>
<td>EC</td>
<td>5HT</td>
<td>CgA, VMAT1</td>
<td>Syn</td>
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<td>+</td>
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<td>+</td>
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<tr>
<td>D</td>
<td>Som</td>
<td>CgA</td>
<td>Syn</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>f</td>
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<tr>
<td>L</td>
<td>GLI/PYY</td>
<td>SgII &gt; CgA</td>
<td>Syn</td>
<td>+</td>
<td>e</td>
<td>f</td>
<td>+</td>
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<td>A (alpha)</td>
<td>Glucagon</td>
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<td>Syn</td>
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<td>e</td>
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<td>e</td>
<td>f</td>
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<td>B (beta)</td>
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<tr>
<td>S</td>
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<td>5HT</td>
<td>CgA</td>
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<tr>
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<td>CgA</td>
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Intestine

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<th>Cell Type</th>
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<th>SLMV</th>
<th>Pancreas</th>
<th>Stomach</th>
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<tr>
<td>M</td>
<td>Motilin</td>
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<td></td>
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<td>+</td>
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<tr>
<td>N</td>
<td>Neurotensin</td>
<td>CgA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>f</td>
<td>+</td>
</tr>
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</table>


An, gastric antrum; Ap, appendix; B, gastric body; C, colon; CgA, chromogranin A; D, duodenum; e, presence of cells in fetus and newborn; EC, enterochromaffin cell, 5HT, 5-hydroxytryptamine (serotonin); ECL, enterochromaffin-like cell; f, presence of few cells; GIP, gastric inhibitory polypeptide; GLI, glucagon-like immunoreactants (glicentin, glucagon-37, glucagon-29, GLP-1, GLP-2); I, ileum; J, jejunum; LDCV, large dense-core vesicles; NESP55, neuroendocrine secretory protein 55; PP, pancreatic polypeptide; PYY, PP-like peptide with N-terminal tyrosine amide; R, rectum; SgII, secretogranin II (also known as chromogranin C); SLMV, synaptic-like microvesicles; Som, somatostatin; Syn, synaptophysin; VMAT1, VMAT2, vesicular monoamine transporter 1,2; +, presence of cells; >, heavier staining than.

**M cells** are specialized epithelial cells overlying lymphoid follicles in the small intestine and colon. M cells selectively bind, process, and deliver pathogens directly to lymphocytes, macrophages, or other components of the mucosal lymphoid system.14

**Interstitial cells of Cajal** are present in both the small intestine and the colon and are mesenchymal cells, located in the myenteric plexus, the muscularis propria and the submucosa.15 The distribution of the interstitial cells of Cajal is similar in children and in adults (Fig. 93-7) although a difference in their distribution is seen in fetuses of different gestational ages. 15 Recognized as the pacemaker cells of the intestine, they regulate intestinal motility. The interstitial cells of Cajal are spindle-shaped or stellate, with long ramified processes, and have large, oval, light-staining nuclei with sparse perinuclear cytoplasm.15 The interstitial cells of Cajal express the receptor for tyrosine kinase (c-kit) or CD117. Immunohistochemical stains that utilize antibodies against c-kit allow the interstitial cells of Cajal to be labeled. The distribution and onset of appearance of these cells in the gastrointestinal tract have been described.16
Figure 93-7  Photomicrograph showing the interstitial cells of Cajal in the small intestine. Brown-staining, elongated cells are evident around the myenteric plexus (arrow). CD117 immunostain, ×250

Submucosa

The submucosa, between the muscularis mucosae and the muscularis propria, is a fibrous connective tissue layer that contains fibroblasts, mast cells, blood and lymphatic vessels, and a nerve fiber plexus—Meissner's plexus—composed of nonmyelinated, postganglionic sympathetic fibers, and parasympathetic ganglion cells.

Muscularis or Muscularis Propria

The muscularis propria, mainly responsible for contractility, consists of two layers of smooth muscle: an inner circular coat and an outer longitudinal coat arranged in a helicoidal pattern. A prominent nerve fiber plexus called the myenteric plexus, or Auerbach's plexus, is found between these two muscle layers (Fig. 93-8). Parasympathetic and postganglionic sympathetic fibers terminate in parasympathetic ganglion cells, and postganglionic parasympathetic fibers terminate in smooth muscle.
Figure 93-8  Photomicrograph of the muscularis propria of the small intestine. The myenteric plexus (mp) is seen as a pale area between the inner and outer layers (il, ol) of the muscularis propria with ganglion cells (arrow). Hematoxylin-eosin stain, ×250

Adventitia or Serosa

The adventitia is the outermost layer of connective tissue. When covered by a single layer of mesothelial cells, it is called the serosa.

Small Intestine

The mucosa of the small intestine is characterized by mucosal folds (plicae circulares, or valves of Kerckring) and villi. The mucosal folds are composed of mucosa and submucosa. Villi are mucosal folds that decrease in size from the proximal to distal small intestine and are of different shapes in the various segments of the small intestine: they may be broad, short, or leaf-like in the duodenum, tongue-like in the jejunum, and finger-like more distally (Fig. 93-9A). The villous pattern also may vary in different ethnic groups. Thus, for example, biopsy specimens from Africans, Indians, South Vietnamese, and Haitians have shorter and thicker villi, an increased number of leaf-shaped villi, and more mononuclear cells in comparison with specimens from North Americans.
Figure 93-9  Photomicrograph of the duodenal mucosa. A, Villi are seen as finger-like projections. Hematoxylin-eosin stain, ×250. B, Brunner glands (bg) are found below the mucosa. Hematoxylin-eosin stain, ×150

Various methods have been suggested to determine normal villus height. The height of the normal villus is 0.5 to 1.5 mm; villus height should be more than one half of the total thickness of the mucosa,[17] and three to five times the length of the crypts.

Two types of glands are present in the small intestine: Brunner's glands and crypts of Lieberkühn (intestinal crypts). The first are submucosal glands (see Fig. 93-9B ) found primarily in the first portion of the duodenum and in decreased numbers in the distal duodenum. In children, these
glands also may be present in the proximal jejunum. Brunner's glands open into the intestinal crypts and morphologically resemble pyloric glands. Crypts of Lieberkühn are tubular glands that extend to the muscularis mucosae (see Fig. 93-5).

Absorptive, goblet, Paneth, and enteroendocrine cells are observed in the crypts of Lieberkühn. Paneth and columnar cells predominate in the base of the crypt. Above the base are absorptive cells and oligomucin cells; the latter originate from undifferentiated cells and differentiate into goblet cells. Goblet cells predominate in the upper half of the crypt. Enteroendocrine cells are admixed with goblet cells. A certain number of CD3⁺ intraepithelial T lymphocytes (30 per 100 epithelial cells) normally are present in the villi. Smooth muscle is found in the lamina propria of the small intestinal villus, extending from the muscularis mucosae vertically. Plasma cells containing primarily IgA, and mast cells also are present. Lymphoid tissue is prominent in the lamina propria as solitary nodules and as confluent masses—Peyer's patches—and also is seen in the submucosa. Peyer's patches are distributed along the antimesenteric border and are most numerous in the terminal ileum; their numbers decrease with age.

Most types of enteroendocrine cells are present in the duodenum. Cells that produce ghrelin, gastrin, cholecystokinin, motilin, neurotensin, gastric inhibitory polypeptide, and secretin are restricted to the small intestine.

The proportions of these cells differ in the villi and crypts, as well as in different segments of the intestine. Ninety percent of the villus epithelial cells are absorptive cells intermingled with goblet and enteroendocrine cells. The proportion of goblet to absorptive cells increases aborad toward the ileum. The interstitial cells of Cajal are more abundant in the myenteric plexus of the small bowel than in the colon.

Large Intestine

The mucosa of the large intestine is characterized by the presence of crypts of Lieberkühn, associated predominantly with goblet cells intermixed with a few absorptive and enteroendocrine cells (see Fig. 93-4). GLI (glucagon-like immunoreactant)/pancreatic polypeptide–like peptide (PYY) with N-terminal tyrosine amide–producing L cells predominate in the large intestine. Enterochromaffin, enterochromaffin-like, and pancreatic polypeptide–producing cells also are found. Paneth cells are scarce and normally are noted only in the proximal colon. The lamina propria of the large intestine contains solitary lymphoid follicles extending into the submucosa. These follicles are more developed in the rectum and decrease in number with age. Confluent lymphoid tissue is present in the appendix. Macrophages (muciphages) predominate in the subepithelial portion of the lamina propria. These cells are weakly PAS positive and are associated with stainable lipids.

Anal Canal

Microscopically, the anal canal is divided into three zones: proximal, intermediate or pectin, and distal or anal skin. The proximal zone is lined by stratified cuboidal epithelium, and the transition with the rectal mucosa, lined by high columnar mucus-producing cells, is called the anorectal histologic junction (Fig. 93-10A). The intermediate or pectin zone is lined by stratified squamous
epithelium but without adnexae (e.g., hair, sebaceous glands). Its proximal margin, in contact with the proximal zone, is called the \textit{dentate line}; its distal margin, in contact with the anal skin, constitutes the \textit{pectinate line}, also referred to as the \textit{mucocutaneous junction} (see Fig. 93-10B). The anal skin is lined by squamous stratified epithelium and contains hair and sebaceous glands.

\textbf{Figure 93-10} Photomicrograph of the anal canal. \textit{A}, Anorectal histologic junction: Transition from rectal glandular mucosa (rg) to proximal anal mucosa lined by stratified squamous epithelium (ep) is evident. Hematoxylin-eosin stain, \( \times 150 \). \textit{B}, The pectinate line is characterized by anal mucosa with stratified squamous epithelium (ep) and anal skin containing adnexae (arrow). Hematoxylin-eosin stain, \( \times 150 \)
Large arterial branches enter the muscularis propria and pass to the submucosa, where they branch to form large plexuses. In the small intestine, two types of branches arise from the submucosal plexuses: some arteries branch on the inner surface of the muscularis mucosae and break into a capillary meshwork that surrounds the crypts of Lieberkühn. Other arteries are destined for villi, each receiving one or two arteries, and set up the anatomic arrangement that allows a countercurrent mechanism during absorption. These vessels enter at the base of the villus and form a dense capillary network immediately underneath the epithelium of the entire villus structure. One or several veins originate at the tip of each villus from the superficial capillary plexus, anastomose with the glandular venous plexus, and then enter the submucosa joining the submucosal venous plexus. In the colon, branches from the submucosal plexus extend to the surface, giving rise to capillaries supplying the submucosa, and there branch to form a capillary meshwork around the crypts of Lieberkühn. From the periglandular capillary meshwork, veins form a venous plexus between the base of the crypts and the muscularis mucosae. From this plexus, branches extend into the submucosa and form a venous plexus, from which large veins follow the distribution of the arteries and pass through the muscularis propria into the serosa.

Lymph Vessels of the Intestine

The lymphatics of the small intestine are called lacteals and become filled with milky-white lymph called chyle after eating. Each villus contains one central lacteal, except in the duodenum where two or more lacteals per villus may be present. The wall of the lacteal consists of endothelial cells, reticulum fibers, and smooth muscle cells. The central lacteals anastomose at the base of the villus with the lymphatic capillaries between the crypts of Lieberkühn. They also form a plexus on the inner surface of the muscularis mucosae. Branches of this plexus extend through the muscularis mucosae to form a submucosal plexus. Branches from the submucosal plexus penetrate the muscularis propria, where they receive branches from plexuses between the inner and outer layers. Lymphatic vessels are absent in the colonic mucosa, but the distribution of lymphatics in the remaining colonic layers is similar to that in the small intestine.

Nerves of the Intestine

The intrinsic nervous system (enteric nervous system) consists of subserosal, muscular, and submucosal plexuses. The subserosal plexus contains a network of thin nerve fibers, without ganglia, that connects the extrinsic nerves with the intrinsic plexus. The myenteric plexus, or Auerbach's plexus, is situated between the outer and inner layers of the muscularis propria (see Fig. 93-8); it consists of ganglia and bundles of unmyelinated axons that connect with the ganglia forming a meshwork. These axons originate from processes of the ganglion cells and extrinsic vagus and sympathetic ganglia. The deep muscular plexus is situated on the mucosal aspect of the circular muscular layer of the muscularis propria. It does not contain ganglia; it innervates the muscularis propria and connects with the myenteric plexus. The submucosal plexus, or Meissner's plexus, consists of ganglia and nerve bundles. The nerve fibers of this plexus innervate the muscularis mucosae and smooth muscle in the core of the villi. Fibers from this plexus also form a mucosal plexus that is situated in the lamina propria and provides branches to the intestinal crypts and villi. The ganglion cells of the submucosal plexus are distributed in two layers: One is adjacent to the circular muscular layer of the muscularis propria; the other is contiguous to the muscularis
mucosae. Ganglion cells are large cells, isolated or grouped in small clusters called ganglia (Fig. 93-11). Ganglion cells have an abundant basophilic cytoplasm, a large vesicular round nucleus, and a prominent nucleolus. Ganglion cells are scarce in the physiologic hypoganglionic segment 1 cm above the anal verge.

**Figure 93-11** Photomicrograph showing a submucosal plexus of the colon. The ganglia (g) are identified by their oval structure and thin nerve trunks (arrow). Hematoxylin-eosin stain, ×150