signaling is likely to be involved in cross talk with signals provided by other stimuli, such as growth factors, adding yet another level of complexity in the regulation of this critical homeostatic process.

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Gastrointestinal Tract Anatomy, Overview

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celiac disease Autoimmune disorder affecting the small intestine; caused by abnormal responses to certain grains, leads to small intestinal mucosal damage and nutrient malabsorption.

gastroesophageal reflux Retrograde movement of gastric contents into the esophagus, resulting in esophageal damage and inflammation (esophagitis).

pernicious anemia Form of anemia (red blood cell deficiency) caused by vitamin B_{12} deficiency; occurs secondary to an absence of gastric intrinsic factor, which is necessary for B_{12} absorption in the terminal ileum.

volvulus Twisting of intestinal loops, with subsequent obstruction of the vascular supply and/or lumen.

The gastrointestinal tract is a tubular conduit; it is responsible for processing food into an absorbable form, absorption of nutrients and electrolytes from the lumen, delivery of these nutrients to the body, and excretion of waste products. With the largest surface area of any organ in the body, the gastrointestinal tract is also exposed to a diverse assortment of foreign materials. Sampling of these materials and generation of appropriately directed immune responses, e.g., to pathogens but not to food products, are an essential part of gastrointestinal function.

ESOPHAGUS

The esophagus is a 20- to 25-cm-long tube (see Fig. 1) that transports food from the oral cavity to the stomach. It is composed of three primary segments; cervical, thoracic, and abdominal. Accordingly, the vascular supply is also segmental. The upper esophagus is supplied by the thyroid arteries, the midesophagus is supplied by branches of the aorta, and the lower esophagus is supplied primarily by the left gastric artery. Venous drainage is similar, with the upper third of the esophagus draining into the superior vena cava, the middle third draining into the azygous veins, and the lower

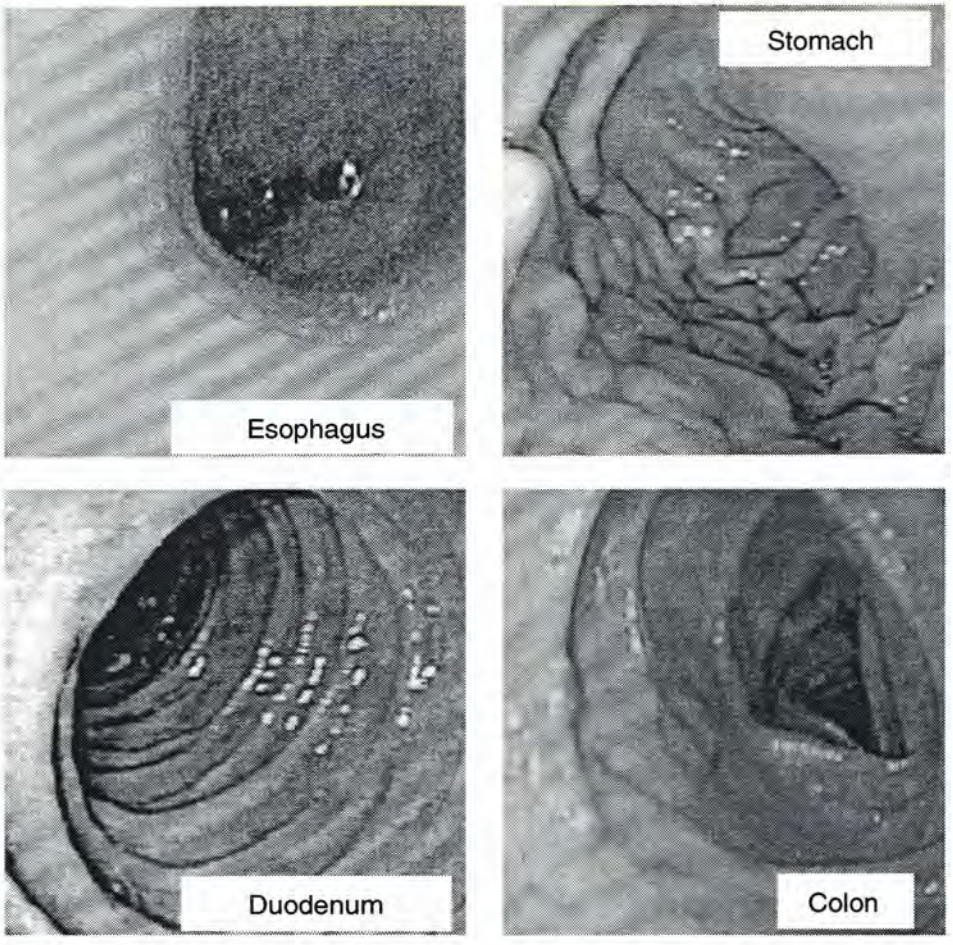

FIGURE 1 Endoscopic survey of the gastrointestinal tract. Endoscopic views of the esophagus, stomach, duodenum, and colon. The squamous mucosa of the esophagus is smooth and pink, without folds. In contrast, the gastric rugae are prominent. These stretch and flatten when the stomach is distended. In the duodenum, the plicae circularis are circumferential. The villi are appreciated as a velvety mucosal surface. The colonic mucosal folds are not circumferential and are tethered at sites corresponding to the teniae coli, resulting in a triangular profile.

third draining into the portal vein (via the gastric veins). With this rich vasculature, ischemia of the esophagus is uncommon. Unfortunately, this also makes the vascular network accessible to esophageal tumors and vulnerable to early local metastasis.

The esophagus begins in the pharynx, at the cricoid cartilage, and passes through the posterior mediastinum behind the aortic arch and left main stem bronchus. The esophagus then courses anterior to the aorta as it passes through the diaphragm, to the gastroesophageal junction. From the lumen outward, the esophageal wall is composed of the mucosa, submucosa, muscularis propria, and adventitia, respectively.

The principal esophageal function, transport of substances from the oral cavity to the stomach, is accomplished by coordinated contraction of the muscular layers. Like the entire gastrointestinal tract, the muscularis propria is composed of inner circular and outer longitudinal layers. Unlike the remainder of the gastrointestinal tract, the muscle layers include both skeletal (voluntary) and smooth (involuntary) muscle. Muscle in the upper third of the esophagus is composed primarily of skeletal muscle, while muscle in the middle third of the esophagus is a mixture of skeletal and smooth muscle, and that in the distal third is entirely smooth muscle. Thus, when food or liquid is ingested, a swallow is initiated voluntarily by coordinated relaxation and contraction of upper esophageal skeletal muscle. This continues involuntarily, as food is propelled via waves of contraction into the distal esophagus

and stomach. Auerbach's plexus lies between the circular and longitudinal muscles and generates the neural signals that control these contractions.

Entry into and exit from the esophagus is restricted by contractile muscle bundles termed the upper and lower esophageal sphincters, respectively. At rest, both sphincters are contracted, or closed; the upper esophageal sphincter closes to prevent air entry and the lower esophageal sphincter closes to prevent reflux of gastric contents. Relaxation of each sphincter must occur in coordination with a swallow to allow the appropriate passage of food and liquids. Failure of lower esophageal sphincter relaxation prevents passage of food from the esophagus into the stomach, resulting in the disease known as achalasia. In contrast, insufficient contraction of the lower esophageal sphincter results in gastroesophageal reflux and esophagitis. Commonly used substances, such as caffeine, alcohol, and nicotine, can prevent complete closure of the lower esophageal sphincter and cause or aggravate gastroesophageal reflux disease (GERD).

The esophageal lining is normally pink, moist, and covered by stratified squamous epithelium, much like the skin (Fig. 2). This ends abruptly at the Z-line, which marks the transition to the columnar epithelium of the stomach. The submucosa of the esophagus contains modified salivary glands that secrete mucus (for lubrication), growth factors (to augment epithelial cell growth and aid in repair), and, in the distal esophagus, bicarbonate (to neutralize acids).

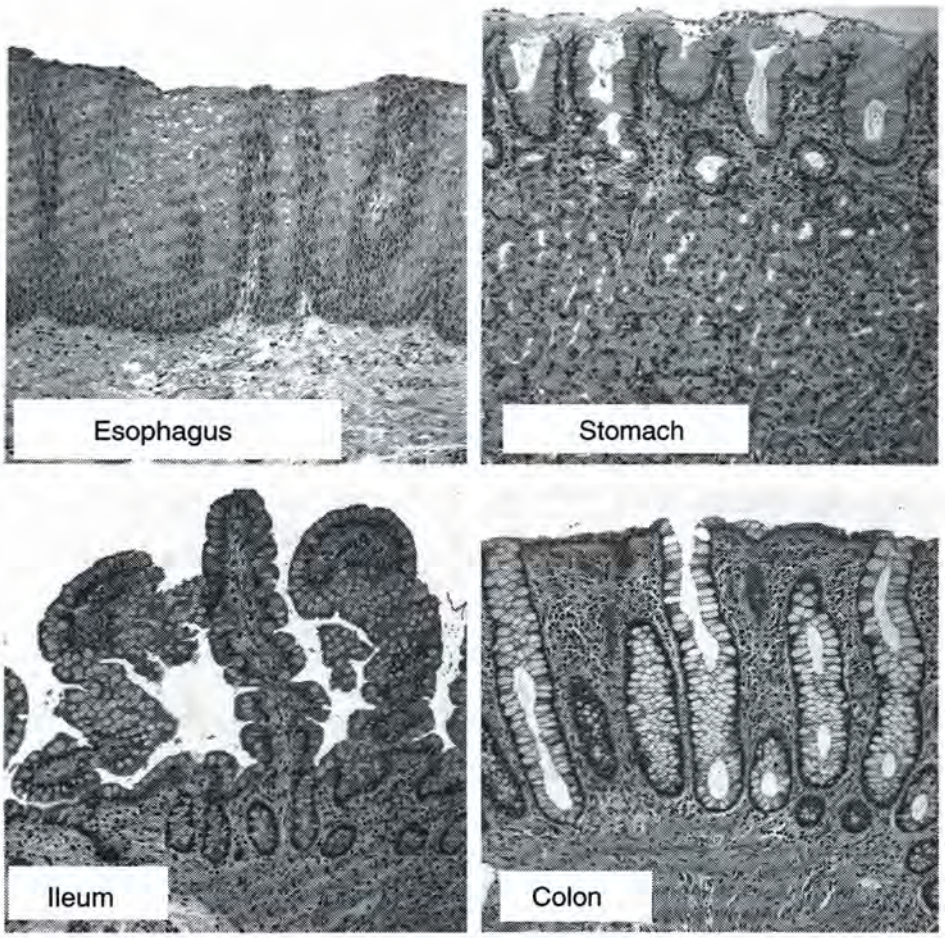

FIGURE 2 Histology of the esophagus, stomach, ileum, and colon. The esophagus is lined by a multilayered squamous epithelium, with the basal proliferative zone represented by the darker region at the bottom of the epithelium. The gastric body is lined superficially by mucus cells. Specialized parietal and chief cells are seen in deeper layers of the mucosa, in the glandular compartment. The ileum of the small intestine is distinguished by the presence of villi. These are absent in the colonic mucosa, which is dominated by crypts that are normally arranged in a uniform array.

STOMACH

The stomach is a distensible saccular portion of the gastrointestinal tract between the esophagus and the small intestine. Food enters the stomach through the gastroesophageal junction. While in the stomach, food is mixed with gastric acid and digestive enzymes to form chyme. Thus, the stomach serves, in part, as a reservoir, holding ingested food and chyme and delivering the latter to the small intestine at a controlled rate. As chyme exits the stomach, the narrow pyloric channel acts as a sieve, preventing large food particles from entering the duodenum until they are adequately processed.

The stomach is located in the left upper quadrant of the abdomen. In general, the stomach is J-shaped, but there is considerable variation based on the volume of the gastric contents. Sites within the stomach are commonly described based on two curvatures; the lesser curvature of the stomach forms the right upper border and the greater curvature forms the left lower border. The stomach receives arterial circulation from branches of the celiac artery.

The mucosal surface of the stomach forms prominent folds, or rugae, in an empty state (see Fig. 1). The gastric wall consists of four layers: mucosa, submucosa, muscularis propria, and serosa. The mucosa contains the secretory glands. The submucosa is mainly connective tissue containing lymphocytes, plasma cells, and neurovascular elements. The muscularis propria contains three layers: longitudinal fibers, circular fibers, and oblique fibers. The circular fibers course around the body of the stomach and thicken at the exit from the stomach, forming the pyloric sphincter.

The stomach can be divided into cardia, fundus, body, antrum, and pylorus. The cardia is a small section of the stomach located next to the gastroesophageal (GE) junction, just left of the midline. The Z-line marks the abrupt mucosal transition from the esophagus to the cardia. The fundus is a dome-shaped region projecting upward and to the left of the GE junction. The body is the largest section, beginning below the fundus and extending to the incisura angulus, a notch in the lesser curvature. The glands of the body and fundus are composed of parietal, chief, mucus, and endocrine cells (Fig. 2). Parietal cells secrete acid as well as intrinsic factor, which is necessary for the absorption of vitamin B_{12} in the terminal ileum. Lack of intrinsic factor causes an inability to absorb vitamin B_{12} in the ileum, resulting in pernicious anemia. The antrum extends from the incisura angulus and its border with the body to the pylorus. The pylorus contains the pyloric sphincter, a thick ring of muscle that regulates release of gastric contents into the duodenum. Hypertrophy of this muscle results in the inability of food to pass, resulting in projectile vomiting, and is most commonly seen in infants. The antrum, similar to the cardia, contains mainly mucus-secreting cells, but also includes endocrine and gastrin-secreting cells. The vagus nerve is one source that stimulates this secretion.

SMALL INTESTINE

The small intestine receives the contents of the stomach and is the primary site of nutrient absorption. It consists of three parts, duodenum, jejunum, and ileum, for a total length of about 6 m in the adult. The celiac trunk provides the arterial supply to the proximal duodenum and the superior mesenteric artery supplies the distal duodenum, jejunum, and ileum.

From the lumen outward, the small intestinal wall consists of four layers: mucosa, submucosa, muscularis propria, and serosa. Like the other sections of the gastrointestinal tract, the muscularis propria contains outer longitudinal and inner circular muscle layers, with the ganglion cells of Auerbach's plexus between the layers. The submucosa contains lymphatics, connective tissue, and Meissner's plexus. The submucosa also contains Brunner's glands in the duodenum and Peyer's patches in the ileum.

The duodenum is 25–30 cm in length and makes a C-shape to curve around the head of the pancreas. At the proximal end of the duodenum is the duodenal bulb, which has a smooth, featureless mucosal surface. The duodenum can be distinguished histologically by the presence of Brunner's glands, which secrete mucus. Distal to the duodenal bulb, the small intestinal mucosa is thrown into circular folds, termed plicae circulares, which decrease in number distally (Fig. 1). The ampulla of Vater, which drains secretions from the pancreatic and biliary ducts, is located in the second portion of the duodenum. Ampullary obstruction, as occurs with impacted gallstones or tumors, can result in pancreatitis.

The ligament of Treitz fixes the junction of the duodenum to the jejunum and marks the division of the upper and lower gastrointestinal tracts. Lymphoid follicles, present throughout the small intestinal mucosa, are most prominent in the ileum, where they form aggregates known as Peyer's patches. Intestinal infection may result in significant hyperplasia of these lymphoid nodules. The small intestine ends at the terminal ileum, where the ileocecal valve, made of two mucosal folds, forms the entrance into the colon.

The epithelium of the small intestine, consisting of crypts and villi (Fig. 2), is specialized to maximize

absorption. Villi are fingerlike projections into the lumen, where absorption occurs. They are covered by absorptive enterocytes (intestinal cells) and amplify their surface area further with a microvillus brush border. Blunting of villi, as occurs in celiac disease, results in significant malabsorption. Similarly, small intestinal infections can cause malabsorption and diarrhea. The brush border contains digestive enzymes and the transporters and ion channels necessary for efficient nutrient absorption. The crypts contain Paneth and endocrine cells as well as stem cells that differentiate as they migrate toward the villus. The majority of nutrient absorption takes place in the duodenum and jejunum. However, as noted previously, the ileum is essential for absorption of vitamin B_{12} and bile salts.

COLON

The colon begins at the ileocecal valve and continues through the rectum. It is approximately 1–1.5 m in length and is divided into cecum, ascending colon, transverse colon, descending colon, sigmoid colon, and rectum. Although the small intestine is mobile, the colon is relatively fixed. Significant landmarks include the hepatic flexure (adjacent to the liver), where the ascending colon joins the transverse colon, and the splenic flexure (adjacent to the spleen), where the transverse colon joins the descending colon. The main functions of the colon are absorption of water and electrolytes and storage of waste products before excretion.

The layers of the colonic wall are similar to those of the small intestine. Unlike the small intestine, however, the longitudinal muscle is organized into three separate bands, the teniae coli. These run from the appendix to the rectum. The outpouchings between the teniae are called haustra (Fig. 1). The superior mesenteric artery supplies the colon from the cecum to the proximal transverse colon. The inferior mesenteric artery supplies the remainder of the colon, excluding the rectum, which is supplied by rectal, or hemorrhoidal, vessels.

The cecum is the first section of the colon and is dilated relative to the remainder of the colon. It contains the appendix, a small, blind pouch enriched in mucosal lymphoid tissue. Inflammation of this tissue, resulting from retained material, results in appendicitis, a surgical emergency. The cecum is relatively mobile and therefore is more susceptible to volvulus, or twisting upon itself. Because it is dilated, a mass lesion or tumor in the cecum may go undetected for a long period of time.

The ascending colon extends from the cecum upward toward the liver, along the right side of the abdomen. At the hepatic flexure, it joins the transverse colon, which can be mobile as it drapes across the abdominal cavity toward the splenic flexure. Here the transverse colon joins the descending colon that courses along the left abdominal cavity to join the sigmoid colon in the lower abdomen. The sigmoid colon is S-shaped. It is the narrowest region of the colon, thus mass lesions in this area are generally symptomatic early.

The epithelium of the colon, unlike that of the small intestine, lacks villi. The mucosa consists of crypts containing goblet cells and absorptive enterocytes. Because the small intestine, rather than the colon, is responsible for the bulk of fluid absorption, the diarrhea associated with colonic disease is not as dramatic as that seen with small intestinal disease.

During development, ganglion cells of both Auerbach's and Meissner's plexi migrate in a proximal to distal direction. Failure of this migration results in Hirschprung's disease. The distal, aganglionic, segment of colon lacks inhibitory input and is tonically contracted, without normal peristaltic contractions. This results in obstruction and requires surgical removal of the aganglionic segment.

See Also the Following Articles

Biliary Tract, Anatomy • Colon, Anatomy • Duodenum, Anatomy • Esophagus, Anatomy • Liver, Anatomy • Pancreas, Anatomy • Peritoneum, Anatomy and Development • Rectum, Anatomy • Salivary Glands, Anatomy • Small Intestine, Anatomy • Stomach Anatomy

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