Anatomy, Structure, and Pathology of the Small Intestine (Small Bowel)

The small intestine (Latin: intestinum tenue) spans a range of about 3—5 m from the pylorus of the stomach to the Bauhin’s valve located at the passage to the colon. This section of the digestive tract represents the body’s most essential site of nutrient uptake and water resorption. Understanding the small intestine’s structure and processes is a crucial part of any physician’s education. The following article comprehensively sums up the most important facts about this central part of the gastrointestinal tract and its three sections—the duodenum, jejunum, and ileum.

Location and Surface Anatomy of the Small Intestine

The small intestine is part of the digestive tract that connects orally with the pylorus and leads aborally to the ostium ileale (Bauhin’s valve) in the colon. The small intestine is connected to the abdominal wall via mesentery, running through all types of vessels. The small intestine is located intraperitoneally and is divided anatomically into the:

- Duodenum, which is continuous with the gastric pylorus, where the common bile duct (ductus choledochus) and the pancreatic duct lead into the major duodenal papilla
- **Jejunum**, which is the middle section constituting about two-fifths of the small intestine
- **Ileum**, which is the terminal section ending in the right iliac fossa in the colon.
  The ileocecal junction consists of ostium ileale (Bauhin’s valve)

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### Structure of the Small Intestine

The small intestine is similar to the rest of the gastrointestinal tract in terms of its structural layout. However, it has essential anatomical features. Here are the individual layers listed from the outside to the inside.
The **serous membrane** (serosa) and **subserous membrane** (subserosa): The serosa corresponds to the visceral peritoneum. The subserosa correspond to loosely arranged connective tissue between the visceral peritoneum and the muscle layer. In parts of the duodenum, the small intestine is not completely surrounded by the peritoneum; it is located in a secondary retroperitoneal position. The connective tissue here is called the **tunica adventitia**.

The **muscular tunic** (muscle layer): The muscular tunic consists of an external and an internal circular muscular layer. The inner tunic is significantly more pronounced in the small intestine. The **myenteric plexus** (Auerbach’s plexus) lies between these layers. It is part of the enteric nervous system (ENS) and controls intestinal peristalsis. The muscular tunic is responsible for transporting food via peristaltic contractions.

The **submucosal tela** (submucosa): The submucosa consists of loose connective tissue and numerous elastic fibers. It contains blood vessels (especially small arteries and veins), lymphatic vessels, and nerve cells of the **submucosal plexus** (Meissner’s plexus) arranged in ganglia. The submucosal plexus is also part of the enteric nervous system (ENS). Its function is not entirely clear, but it appears to be involved in intestinal peristalsis and digestive secretions.

The **mucous membrane** (mucosa): The mucosa is the inner (luminal) layer of the small intestine and is further divided into three laminae. The lamina muscularis mucosae is a thin layer of muscle cells that facilitates the autonomous movement of the mucous membrane. Its adjacent inner layer is known as lamina propria mucosae, a layer of connective tissue that contains capillaries, nerve endings, and lymphatic vessels. The innermost layer coats the lumen of the small intestine and is known as lamina epithelialis mucosae. It consists of a single-layered cylindrical epithelium. The columnar epithelial cells, known as **enterocytes**, are studded with microvilli.

The mucosa is the most variable layer of the gastrointestinal tract and is adapted to the respective organs. The mucous membrane of the small intestine provides a large surface for optimal water and nutrient exchange.
The **plicae circulares** are folds in the mucous membrane visible to the naked eye. They extend about 1 cm deep into the lumen and include the submucosa. These folds carry 0.2 mm high **intestinal villi** protruding from the mucosa. They significantly increase the surface and thereby improve nutrient reabsorption. The smaller **crypts of Lieberkühn (intestinal glands)** between the villi run into the glandular ducts. These crypts are where cell division begins in the small intestinal epithelium. The epithelium is replaced every 24–72 hours.

**Note:** It is easy to distinguish the colon from the small intestine based on the villi; usually, they only appear in the small intestine.

**Duodenum**

The duodenum (about 30 cm long) is the first section of the small intestine that runs around the pancreatic head in a semi-circular C-shape connecting the pyloric orifice with the jejunum. The duodenum is divided into four parts:

- **Pars superior**, which is approx. 5 cm long and located intraperitoneally, has a large lumen initially, and is known as **ampulla duodeni, or duodenal cap**. It is located directly ventral from the pancreaticoduodenal artery. Thus, a duodenal ulcer perforating the duodenal wall in this section can cause severe bleeding.

- **Pars descendens** in the duodenum is the **secondary retroperitoneal**. The orifice of the shared excretory duct of the ductus choledochus (bile duct) and the ductus pancreaticus (pancreatic duct) is located at the **major duodenal papilla** (papilla of Vater). The **minor duodenal papilla** (papilla of Santorini) is considered an anatomical variation and is an additional orifice of the pancreatic duct.
- **Pars horizontalis** runs horizontally and is occasionally called Pars inferior.
- **Pars ascendens** is where the duodenum leads into the intraperitoneal jejunum. This junction, known as the duodenojejunal flexure, forms the end of the upper gastrointestinal tract.

**Jejunum and Ileum**

The lower gastrointestinal tract begins with the 3-5 m long intestinal sections jejunum and ileum. The small intestine lies intraperitoneally in these two sections. The jejunum and ileum are suspended from the abdominal wall by the mesentery, ensuring the vascular supply; they have specific mobility inside the abdominal cavity. They are bound by the colon on three sides.

The mucous membrane of the small intestine changes during its course. In the aboral direction, the plicae circulares start to level out until the ileum, where they are no longer detectable. Similarly, the villi on the plicae become shorter, whereas the crypts run deeper towards the end of the ileum. The Peyer’s patches (or aggregated lymphoid nodules) in the lamina propria are unique to the ileum. These lymphoid follicles are detectable microscopically as protrusions in the ileum without deep folds.
The differences in mucosal structure between jejunum and ileum are frequently asked in examinations.

**Characteristics of jejunum and ileum**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Colour</th>
<th>Diameter</th>
<th>Wall thickness</th>
<th>Blood supply</th>
<th>Fat in mesentery</th>
<th>Circular folds</th>
<th>Lymphoid nodules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jejunum</td>
<td>Red</td>
<td>4 cm</td>
<td>Thicker</td>
<td>More</td>
<td>Less</td>
<td>Many</td>
<td>Few</td>
</tr>
<tr>
<td>Proximal ileum</td>
<td>↓</td>
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<tr>
<td>Distal ileum</td>
<td>Pink</td>
<td>2 cm</td>
<td>Thinner</td>
<td>Less</td>
<td>More</td>
<td>Few</td>
<td>Many</td>
</tr>
</tbody>
</table>

**Vasculature and Nerve Supply of the Small Intestine**

The arterial supply to the small intestine varies.

- The duodenum is vascularized by the **coeliac trunk** and the **superior mesenteric** artery. The **anterior** and posterior branches of the **superior pancreaticoduodenal artery**, arising in the gastroduodenal artery (a branch of the hepatic artery of the celiac trunk), supply the **upper** sections of the duodenum. The retroduodenal artery, emerging from the gastroduodenal artery, supplies the dorsal segments of the duodenum. The **inferior pancreaticoduodenal artery**, with its anterior and posterior branches emerging from the superior mesenteric artery, supply the **lower** sections of the duodenum.

- The jejunum is supplied by the jejunal arteries arising from the **superior mesenteric** artery, running inside the mesentery and vertically along the arteriae rectae into the intestinal wall.
The ileum is supplied by the iliac arteries emerging from the superior mesenteric artery. They run inside the mesentery similar to the arteries of the jejunum.

The venous drainage occurs parallel to the arteries. The superior mesenteric vein fuses with the splenic vein and forms the vena portae (portal vein). Thus, blood from the small intestine travels to the liver.

In the small intestine, lymph is first drained into numerous lymph nodes located in the mesentery via the nodi lymphoidei mesenterici superiores (superior mesenteric lymph nodes) into the intestinal trunk and the cisterna chyli, where the thoracic duct originates. The thoracic duct is the largest lymphatic vessel in the human body.

The motility and secretion of the small intestine are regulated by the enteric nervous system but can occur autonomously. Nevertheless, the vegetative nervous system influences the ENS via the sympathetic and parasympathetic nervous systems.

The sympathetic nervous system innervates the small intestine with the major splanchnic nerve, which, after synapsis in the celiac ganglion, runs into the duodenum and after synapsis in the superior mesenteric ganglion, to the jejunum and ileum. The sympathetic nervous system inhibits the glandular secretion and the movement of the digestive tract muscles.

Nerve fibers of the truncus vagalis posterior (N. vagus) innervate the small intestine as part of the parasympathetic nervous system. The nerve fibers synapse in the intestinal wall. The parasympathetic nervous system triggers intestinal secretion and motility.
Small Intestine Function

The small intestine is the key organ involved in nutrient decomposition and the seat of several enzymatic processes catalyzing the breakdown of chymus, a liquid mass of partly digested food. It is also the site of reabsorption of valuable nutrients. The small intestine’s slow peristaltic movements facilitate close contact between food and the mucous membrane before the food is further transported into the large intestine (colon).

Two liters of pancreatic secretions reach the duodenum daily, via the papilla duodeni major in the pars descendens of the duodenum, combining with the chymus. Due to stomach acid, the chymus has an acidic pH of 2 when entering the duodenum, where it is alkalized by the bicarbonates in the pancreatic secretions.

Neutral pH is essential for digestive enzymes, which are secreted by the pancreas in an inactive form and are physiologically changed into their active form near the mucous membrane of the small intestine. Activated pancreatic enzymes, such as amylase, trypsin, and lipase, decompose food into usable nutrients, such as monosaccharides and amino acids, which are then absorbed by the small intestinal epithelium.

Additionally, the bile fluid is secreted under hormonal regulation via the ductus choledochus into the lumen of the duodenum, where it blends with the chymus. Here, the bile acids digest the fats. Together with the fat-soluble components in the food, they form the so-called micelles, which are reabsorbed by the mucous membrane.

The triglycerides are then transported in chylomicrons via lymphatic vessels. A large amount of bile fluid is reabsorbed by the mucous membrane in the terminal ileum and transported back into the liver via the portal vein. This circulation, which minimizes the demand for fresh synthesis, is called enterohepatic circulation.

The small intestine is crucial for water reabsorption in the human body. Research suggests that up to 80% of water gets reabsorbed in the small intestine, predominantly in the jejunum. However, the epithelium also secretes water to balance hypertonic chymus. Therefore, diarrheal diseases represent a great danger in the form of exsiccosis (dehydration).

Furthermore, the small intestine, especially the ileum, plays an integral part in immune defense. Lymphatic tissue, particularly the Peyer’s patches, encounter antigens in the intestinal lumen, which triggers a targeted immune response to facilitate the screening of beneficial and foreign intestinal bacteria. The whole of the lymphatic tissue is designated as the gut-associated lymphatic tissue (GALT).

Important Diseases of the Small Intestine

Duodenal ulcer

Research suggests that 1% of the western population is affected by duodenal ulcers (ulcus duodeni), which are more frequent than stomach ulcers. It is defined as an erosion of the duodenal wall that breaks through the lamina muscularis mucosae. Ulcers are often caused by chronic infection with Helicobacter pylori or frequent intake of non-steroidal anti-inflammatory drugs such as ibuprofen. They cause severe pain, which is typically relieved by food intake. Complications may lead to bleeding and perforations.
Malassimilation syndrome (food intolerance)

Food intolerance (malassimilation) is another common disease of the small intestine. A distinction is made between malfunction in food decomposition (maldigestion) and malfunction in resorption (malabsorption). Celiac disease is a very severe malabsorption syndrome and is defined as chronic gluten intolerance. It is characterized by severe inflammation and villous atrophy of the small intestine and can be relieved with a strict gluten-free diet.

Another severe case of malabsorption is lactose malabsorption (lactose intolerance). Nearly 75% of the world’s adult population suffers from lactose intolerance due to a lack of the enzyme lactase. Patients suffer from meteorism and diarrhea when consuming lactose since milk sugar passes the small intestine undigested; it is then fermented by gut bacteria in the large intestine.

Crohn’s Disease

Crohn’s disease is a chronic inflammatory bowel disease (CIBD) of the small intestine. It is characterized by chronic, recurrent inflammation of the intestinal wall. It usually affects separate segments of the ileum and the colon (“skip lesions”) and manifests as a cobblestone-like appearance of the mucosa.

Patients between the ages of 15 and 35 years manifest:

- Weight loss
- Fever
- Abdominal pain
- Arthritis
- Skin changes
- Diarrhea
- Growth failure
- Perianal disease or mouth ulcers

Affected patients also carry a high risk of complications, such as strictures and fistulae, warranting surgical resection.
References


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