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

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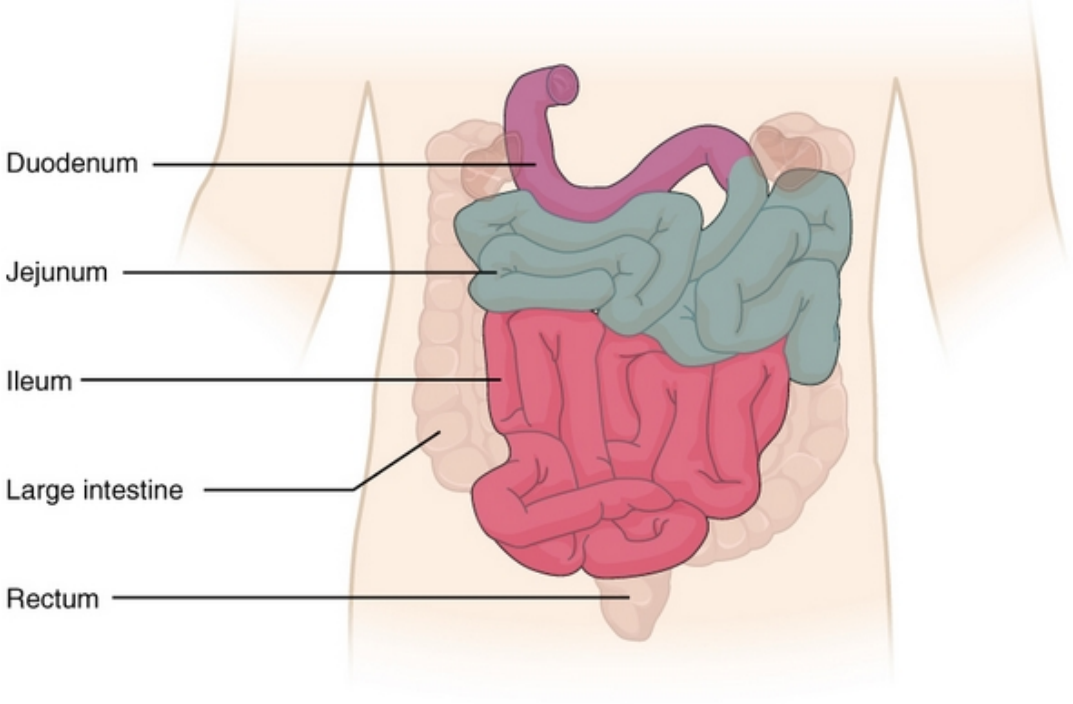
The small intestine (Latin: intestinum tenue) spans a range of about 3—5 m from the pylorus of the stomach to the Bauhin's valve located at the passage to the colon. This section of the digestive tract represents the body's most essential site of nutrient uptake and water resorption. Understanding the 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.



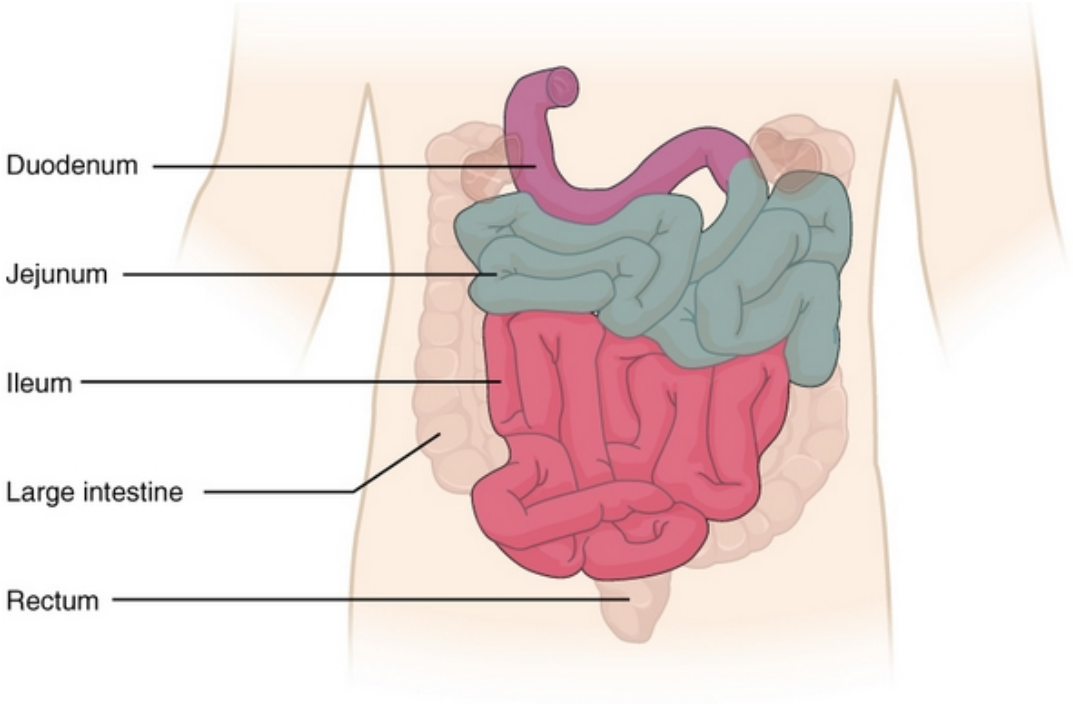
Location and Surface Anatomy of the Small Intestine

The small intestine as part of the digestive tract connects orally to the **pylorus** and leads aborally at the ostium ileale (**Bauhin's valve**) into the colon. The small intestine lies highly convoluted in the abdomen. It is connected to the abdominal wall via the **mesentery through** which run all types of vessels. In its course, the small intestine mainly runs intraperitoneally. It is anatomically divided into the following sections:

- The **duodenum**: This short section is continuous with the pylorus of the

stomach. It is where the common bile duct (Ductus choledochus) and the pancreatic duct (pancreatic duct) lead to the major duodenal papilla.

- The **jejunum**: The middle section constitutes about two-fifths of the small intestine's length.
- The **ileum**: The terminal section ends in the right iliac fossa in the colon. The ileocecal junction consists of the ostium ileale (Bauhin's valve).



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Wall Structure of the Small Intestine

The small intestine's structure is similar to the rest of the gastrointestinal tract's structural layout. However, it presents some important anatomical characteristics that to be seen in relation to its function. Here are the individual layers listed from the outside to the inside:

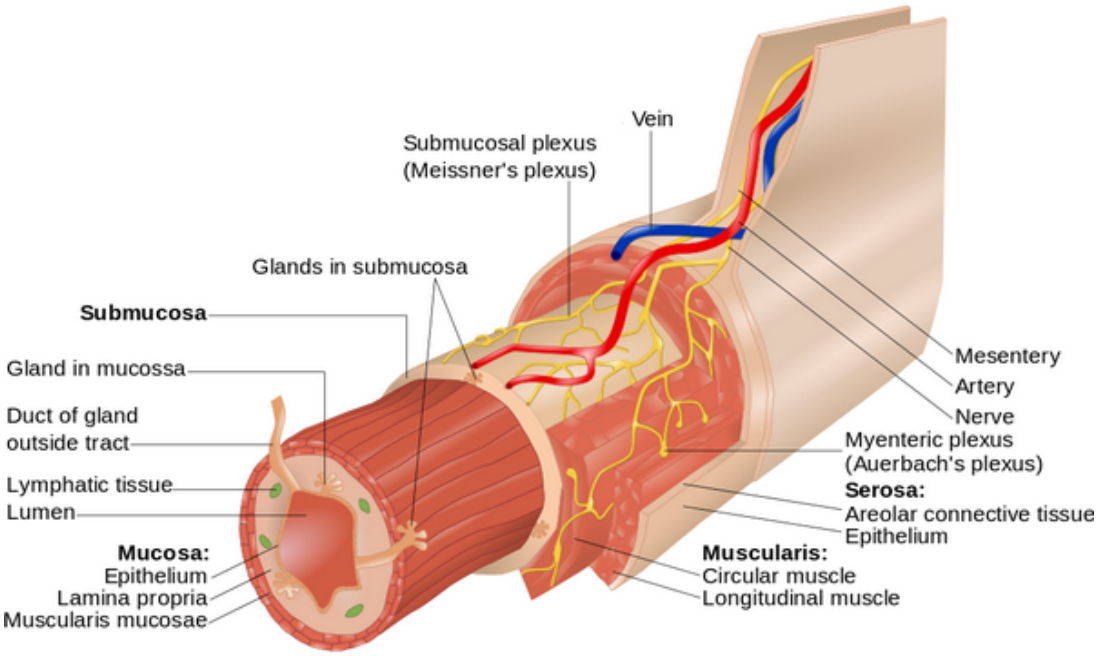


Image: “Layers of the Alimentary Canal” by Goran tek-en. License: CC BY-Sa 3.0

The **serous membrane** (serosa) and **subserous membrane** (subserosa): the serosa corresponds to the visceral peritoneum and the subserosa to loosely arranged connective tissue between this visceral peritoneum and the muscle layer. In those parts of the duodenum where the small intestine is not completely surrounded by peritoneum, therefore laying in a secondary retroperitoneal position, the connective tissue is called **Tunica adventitia**.

The **muscular tunic** (muscle layer): the muscular tunic consists of the external longitudinal muscular tunic (longitudinal layer) and the internal circular muscular tunic (circular layer). The inner tunic is significantly more pronounced in the small intestine. The **myenteric plexus** (Auerbach’s plexus) lies between these layers. This plexus belongs to the enteric nervous system (ENS) and controls intestinal peristalsis. The muscular tunic is responsible for the transport of 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 **plexus submucosus** (Meissner’s plexus) arranged in ganglia. The plexus submucosa is also part of the enteric nervous system (ENS) and is responsible for intestinal peristalsis as well as for secretory regulation.

The **mucous membrane** (mucosa): the mucosa is the inner (luminal) layer of the small intestine’s wall and is further divided into 3 laminae. The lamina muscularis mucosae is a thin layer of muscle cells that allows the autonomous movement of the mucous membrane. Its inner adjacent layer is called 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 called lamina epithelialis mucosae. It consists of a single-layered cylindrical epithelium. The columnar epithelial cells called **enterocytes** are studded with microvilli.

Hint: The small intestine’s wall is known for its super-fast cell division. The epithelium is replaced every 24-72 hours.
The mucosa is the most variable layer of the gastrointestinal tract and is very well

adaptable to the respective organs. The mucous membrane of the small intestine has to provide a very large surface to achieve optimal water and nutrient exchange.

The **plicae circulares (Kerckring-folds)** are folds of the mucous membrane visible to the naked eye. They extend about 1 cm deep into the lumen and include the submucosa. Then there are the 0.2 mm high **intestinal villi** on these folds protruding from the mucosa. They significantly increase the surface and in that way improve the resorption of nutrients. There are smaller crypts **(Lieberkühn-crypts)** between the villi. These crypts run into the glandular ducts and are the site where cell division of the small intestine's epithelium is initiated.

Note: It is easy to distinguish the colon from the small intestine based on the villi which typically are only found in the small intestine.

Duodenum

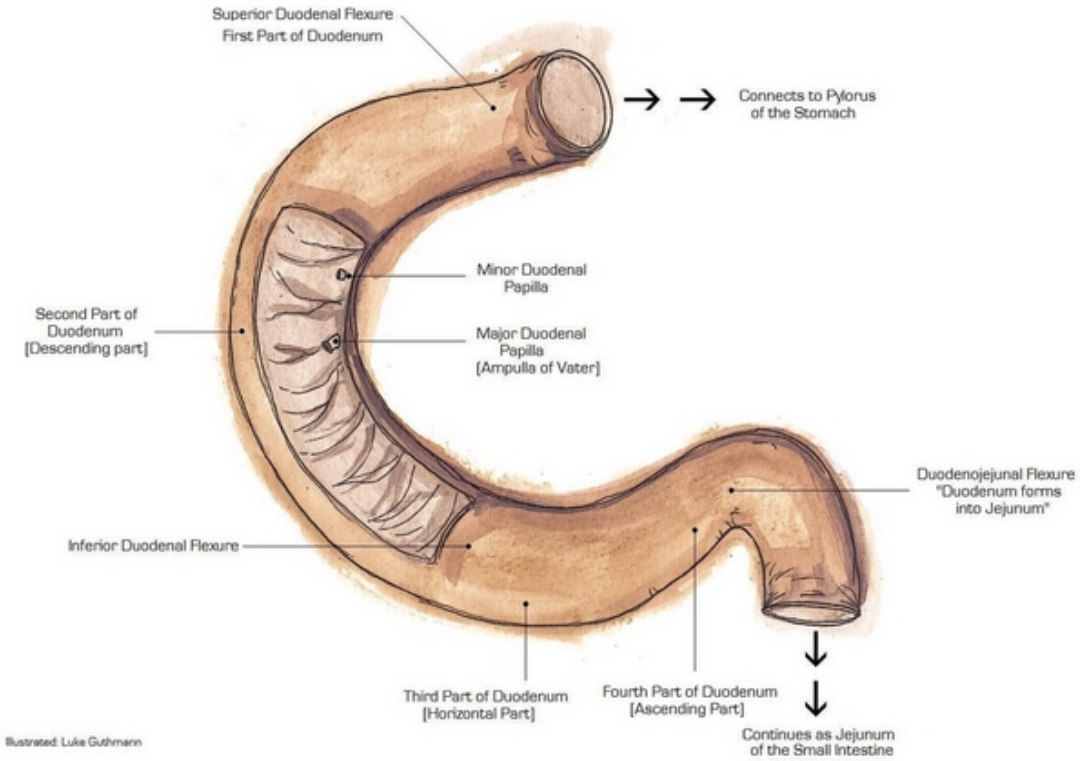


Image: "Anatomical illustration using traditional media to display the duodenum." by Luke Guthmann. License: CC BY-Sa 3.0

The duodenum (about 10 inches (30cm) long), is the first section of the small intestine. It runs around the head of the pancreas in a semi-circular C-shape, connecting the pyloric orifice with the jejunum. The duodenum can be divided into four parts:

- **Pars superior:** the Pars superior is about 5cm long. Its initially large lumen is called **ampulla duodeni, or duodenal cap,** and is located directly ventral from the pancreaticoduodenal artery. Thus, a duodenal ulcer perforating the duodenal wall in this section can cause severe bleedings. The Pars superior lies **intraperitoneally**.
- **Pars descendens:** from here, the duodenum is **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**

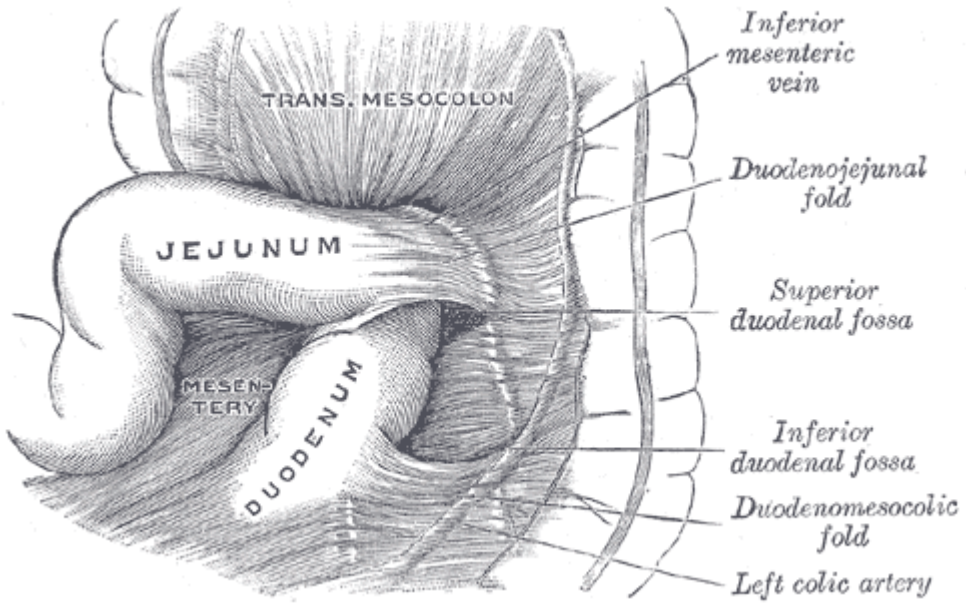
duodenal papilla (papilla of Vater). The **minor duodenal papilla** (papilla of Santorini) is considered an anatomical variation; it is an additional orifice of the pancreatic duct.

- **Pars horizontalis:** this short section runs horizontally and is occasionally called Pars inferior.
- **Pars ascendens:** this is where the duodenum leads into the intraperitoneal jejunum. This junction named duodenojejunal flexure forms the end of the upper gastrointestinal tract.

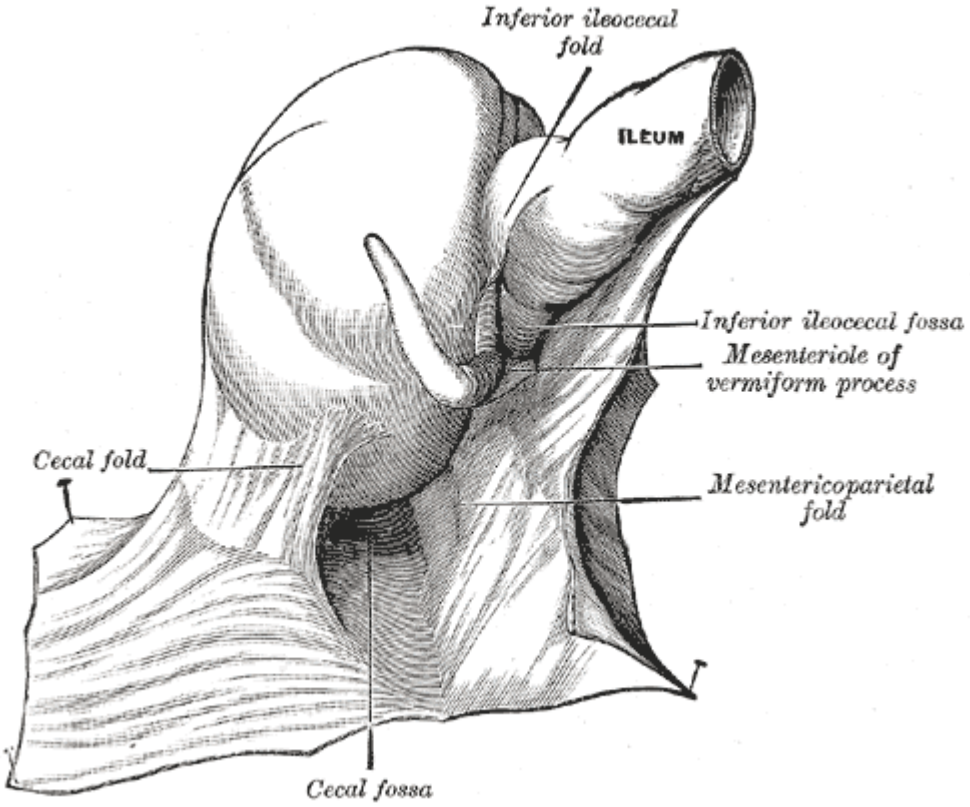
Attention: The shift between intra- and secondary retroperitoneal position of the duodenum is a popular exam question.

Jejunum and Ileum

The lower gastrointestinal tract begins with the altogether 3-5m long intestinal sections jejunum and ileum. The small intestine lies intraperitoneally in these two sections. Jejunum and ileum are suspended from the abdominal wall by the mesentery which also ensures the vascular supply, and this way, they have certain mobility inside the abdominal cavity. They are framed by the colon on three sides.



The mucous membrane of the small intestine changes along its way. In aboral direction, the plicae circulares start to **level out** until reaching the ileum where they are not detectable anymore. In like manner, the villi on the plicae become shorter whereas the crypts become deeper towards the end of the ileum. The Peyer’s plaques in the lamina propria are a peculiarity of the ileum. These lymph follicles are detectable microscopically as protrusions in the ileum which does not display deep folds anymore.



Hint: The differences between jejunum and ileum in regard to the mucosa relief are frequently asked in exams.

Characteristics of jejunum and ileum

Feature	Colour	Diameter	Wall thickness	Blood supply	Fat in mesentery	Circular folds	Lymphoid nodules
Jejunum	Red	4 cm	Thicker	More	Less	Many	Few
Proximal ileum	↓	↓	↓	↓	↓	↓	↓
Distal ileum	Pink	2 cm	Thinner	Less	More	Few	Many

Vasculature and Nerve Supply of the Small Intestine

The arterial supply of the small intestine's sections is distributed as follows:

- Duodenum: The duodenum is supplied with blood by the **coeliac trunk** and the **superior mesenteric** artery. The **anterior** and posterior branches of the **superior pancreaticoduodenal artery,** coming from the gastroduodenal artery (a branch from the hepatic artery of the coeliac trunk), supply the **upper** sections of the duodenum. The retroduodenal artery coming from the gastroduodenal artery supplies the dorsally located parts of the duodenum. The **inferior pancreaticoduodenal artery** with its anterior and posterior branches coming from the superior mesenteric artery supply the **lower** sections of the duodenum.
- Jejunum: The supply of the jejunum is provided by the jejunal arteries which come from the **superior mesenteric** artery. They proceed inside the mesentery and run vertically through arteriae rectae into the intestinal wall.

- Ileum: The ileum is arterially supplied by the ileac arteries which come from the **superior mesenteric.** They run inside the mesentery; just like the arteries of the jejunum.

The venous drainage takes place parallel to the arteries. The mesenteric superior vein fuses with the splenic vein and they both form the **vena portae** (portal vein). Thus, the blood from the small intestine, just like that of all unpaired abdominal organs, is transported to the liver.

The important lymph drainage of the small intestine first leads into numerous lymph nodes located in the mesentery. From here, it goes via the **nodi lymphoidei mesenterici superiores** into the intestinal trunk and after that into the **cisterna chyli**. This is where the **thoracic duct** begins which is the biggest lymphatic vessel of the human body.

The motility and secretion of the small intestine are regulated by the enteric nervous system and basically, work autonomously. Nevertheless, the vegetative nervous system exerts influence on the ENS via the sympathetic and parasympathetic nervous system.

The sympathetic nervous system innervates the small intestine with the **major splanchnic nerve** which, after synapsis in the ganglion coeliac, runs to the duodenum and, after synapsis in the superior mesenteric ganglion, to the jejunum and ileum. The sympathetic nervous system exerts an inhibiting effect on 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. Those nerve fibers synapse in the intestinal wall. The parasympathetic nervous system stimulates intestinal secretion and motility.

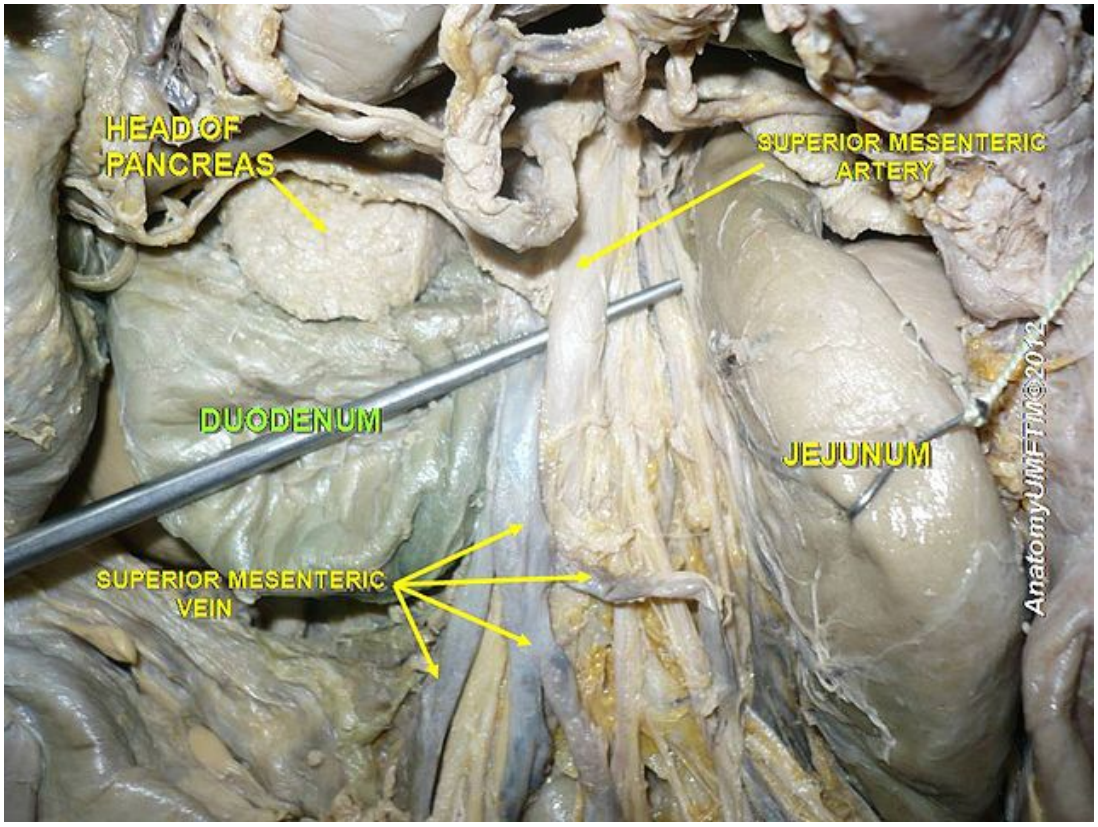


Image "Anatomical dissections" by Anatomist90. License: (CC BY-SA 3.0)

Function of the Small Intestine

The small intestine is the central organ for **nutrient decomposition** since a lot of important enzymatic processes of the breakdown of the chymus, a liquid mass of partly digested food, as well as the resorption of utilizable nutrients, take place here. Slow peristaltic movements of the small intestine allow a long contact between food and mucous membrane before the food is further transported into the large intestine (colon).

Two liters of **pancreatic secretions** reach the duodenum per day via the papilla duodeni major in the pars descendens of the duodenum, mixing here with the chymus. Due to stomach acid, the chymus has an acidic pH of 2 when entering the duodenum. Here, it becomes alkalized through the bicarbonate contained in the secretion of the pancreas.

The neutral pH is essential for the activity of digestive enzymes. Those digestive enzymes are secreted by the pancreas in an inactivated form which physiologically only change into their active form when encountering the small intestine's mucous membrane. Activated pancreatic enzymes such as amylase, trypsin, and lipase decompose the food into utilizable nutrients like monosaccharides and amino acids which can then be absorbed by the small intestine's 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 are then able to perform the important task of fat digestion. Together with the fat-soluble components of the food, they form the so-called micelles, which can be resorbed by the small intestine's mucous membrane.

After that, the triglycerides are carried away in chylomicrons via lymphatic vessels. A large part of bile fluids is resorbed by the mucous membrane in the terminal ileum and travels 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 resorption** in the human body. Research suggests that up to 80% of water gets resorbed in the small intestine, predominantly in the jejunum. On the other hand, the epithelium of the small intestine also secretes water in order to balance hypertonic chymus. This is why diarrheal diseases represent a great danger in form of exsiccosis (dehydration).

Furthermore, the small intestine, especially the ileum, plays an important part in the **immune defense**. Lymphatic tissue, particularly the Peyer's-plaques of the ileum, manages to take up antigens from the intestinal lumen, to trigger targeted immune reactions and to screen for utilizable and foreign intestinal bacteria. The entirety of the lymphatic tissue is named gut-associated lymphatic tissue (**GALT**).

Important Diseases of the Small Intestine

Duodenal Ulcer

Research suggests that 1 % of the western population is affected by a **duodenal ulcer** (ulcus duodeni). This ulcer is more frequent than the stomach ulcer and is defined as an erosion of the duodenal wall that breaks through the lamina muscularis mucosae. Ulcers are often caused by chronic infection with H.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 bleedings and perforations.

Malassimilation Syndrome (Food Intolerance)

Food intolerance (malassimilation) belongs to the frequent diseases of the small intestine as well. A distinction is made between a malfunction in food decomposition (maldigestion) and a malfunction in resorption (malabsorption). One very severe malabsorption syndrome would be the **coeliac disease** which is defined as a chronic gluten intolerance of the small intestine's mucous membrane. The symptoms are accompanied by severe inflammation and villi atrophy of the small intestine. However, it normalizes when adhering to a strict gluten-free diet.

Another severe case of malabsorption is the lactose malabsorption (lactose intolerance). It is assumed that up to 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 the milk sugar passes the small intestine undigested and is then fermented by gut bacteria in the large intestine.

Crohn's Disease

The chronic inflammatory bowel disease (CIBD) which also infests the small intestine is Crohn's disease. This chronic inflammation of the intestinal wall occurs in recurrent attacks. It usually affects separate (segmental) sections of the ileum and the colon ("skip lesions") and manifests itself through a cobblestone-like appearance of the mucosa.

Patients between the ages of 15 to 35 suffer:

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

In addition, affected patients have a high risk for complications like strictures and fistulae which call for operative partial resections.

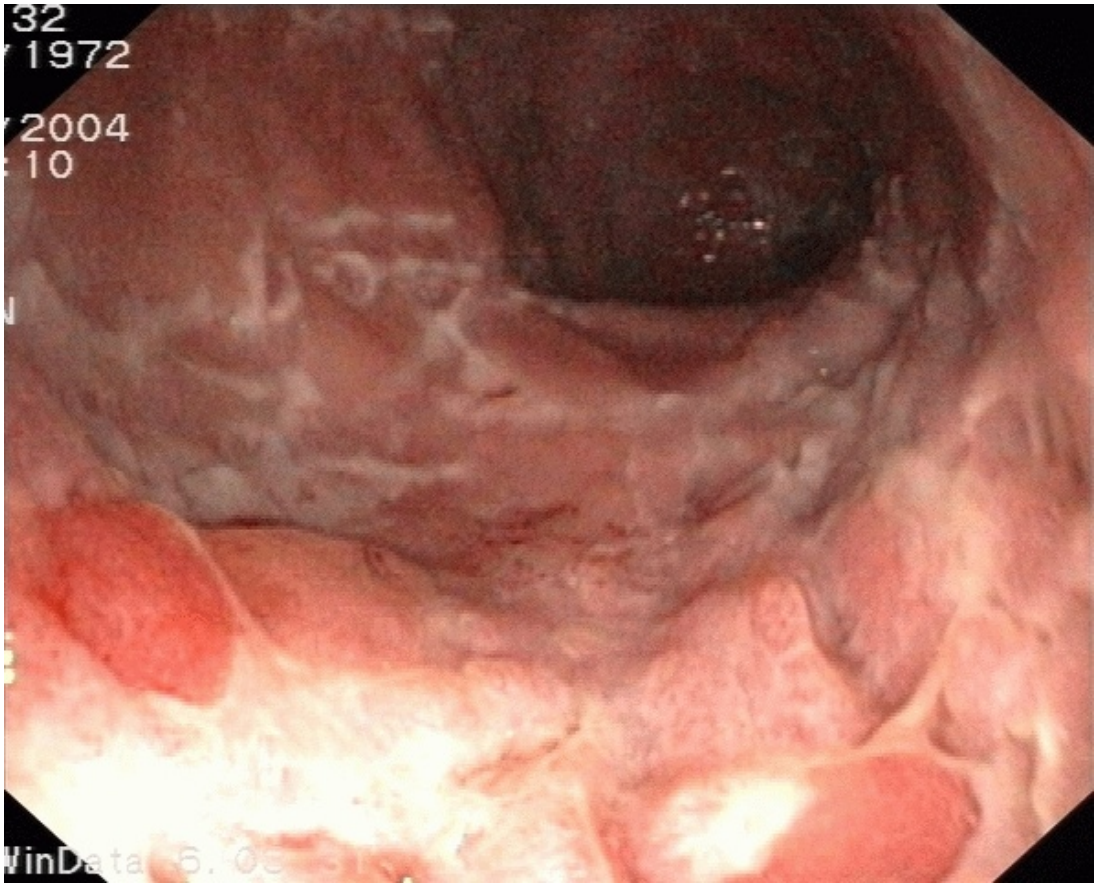


Image “Endoskopiebild Iliitis terminalis” by Joachim Guntau. License: (CC BY-SA 2.0 DE)

Review Questions

The solutions can be found below the references.

1. Which statement concerning the duodenum is correct?

A. The ductus choledochus runs into the pars ascendens of the duodenum.
B. The duodenum is with a length of about 10 inches (30cm) the shortest section of the small intestine.
C. The Kerckring folds are only visible through an electron microscope.
D. Pancreatic enzymes take effect in the duodenal cap (ampulla duodeni).
E. Numerous Peyer’s plaques can be found in the duodenum.

2. What is the function of GALT (gut-associated lymphatic tissue)?

B. Water resorption
C. Neutralization of acidic chymus
D. Activation of trypsin
E. Fighting off pathogenic bacteria
F. Synthesis of bile acid

3. Which statement concerning the duodenum is not correct?

C. Veins of the small intestine conduct venous blood to the portal vein.
D. The jejunum and the ileum lie intraperitoneally.
E. The inner layer of the small intestine is called mucosa.
F. The ileum is arterially supplied by the coeliac trunk.

G. The junction between ileum and colon is the Bauhin’s valve.

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Correct answers: 1B, 2D, 3D

Notes