Chapter 7 - Digestive system

The objectives of this chapter are:

1. Name the components of the digestive system.
2. Name the different sections of the small and large intestine.
3. Name the digestive glands and their location.
4. Describe the vascular supply of the digestive tract.
5. Describe the hepatic vascular system.
6. Describe the pancreatic vascular system.

1 - Elements of digestive system

The digestive system consists of a number of organs whose main function is the breakdown of food into small components and their absorption. It includes the digestive tube and accessory organs of digestion.

The digestive tube is about 10 meters long muscular canal that includes seven sections:

- mouth,
- pharynx,
- oesophagus,
- stomach,
- small intestine,
- large intestine.

The accessory organs of digestion are several glands that release their secretions into the lumen of the digestive tube:

- salivary glands,
- liver, gallbladder and extrahepatic bile ducts,
- pancreas.

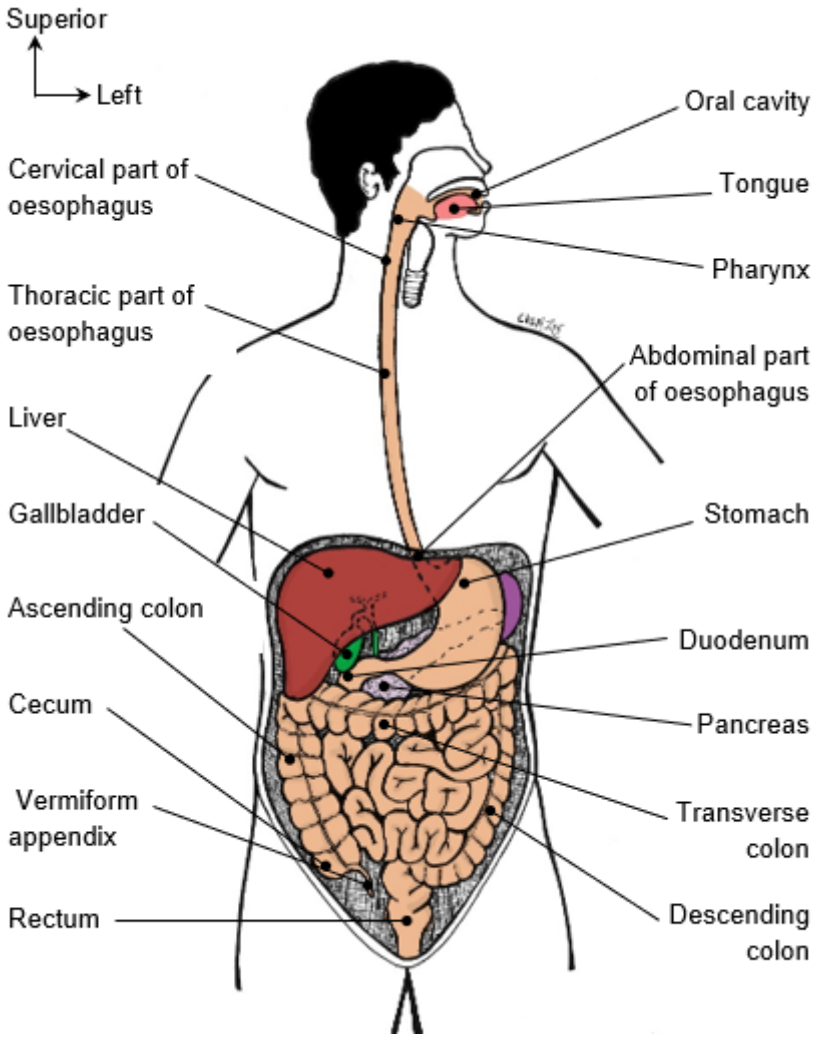

Figure 233: The digestive tract. Anterior view.

2 - Digestive tube

2.1 - Mouth

The mouth is the first part of the digestive tube. The opening between the lips leading to the oral cavity is called the oral opening.
The oral cavity is divided into two parts:

- oral vestibule is the area anterior to the teeth and behind the lips;
- oral cavity proper is the area behind the teeth.

The oral cavity contains the structures necessary for mastication: teeth, tongue and salivary glands.

Teeth

The teeth serve to cut and crush food, preparing it for swallowing and further digestion. They also participate in the production of sounds and word articulation.

Deciduous dentition consists of 20 teeth, called deciduous teeth or milk teeth. They begin erupting at the age of about six months and are usually fully erupted by the end of the second year of life.

Adult dentition consists of 32 permanent teeth, 16 in each jaw:

- incisors (4), which cut,
- canines (2), which crack,
- premolars (4), which grind,
- molars (6), which grind.

They start erupting at the age of six, subsequently replacing the deciduous teeth. The last tooth to erupt is the third molar, also named the wisdom tooth, usually erupting between 17 and 30 years of age.

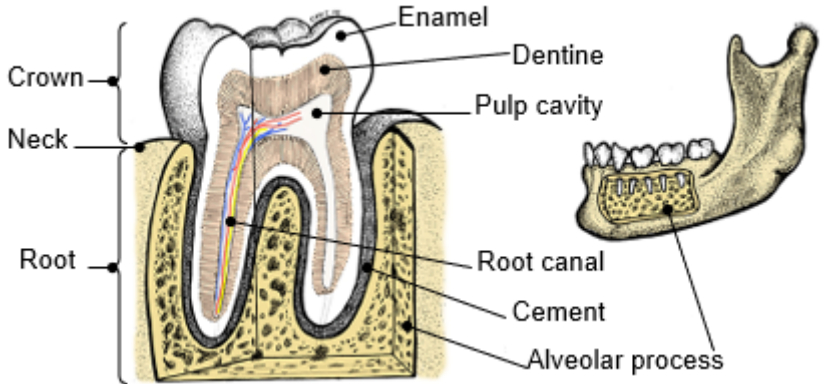

Figure 234: Frontal section of the tooth in its dental alveolus.

Currently, there is a universal tooth numbering system in use. The four half arches of teeth are numbered 1 to 4: arch 1 is the right upper arch, then clockwise follow the arches 2 (the left upper arch), 3 (the left lower arch) and 4 (the right lower arch).

The teeth in each arch are numbered from the midline: the first incisor is number 1 and so on until the third molar which is number 8. In deciduous teeth, the numbering follows the same principle.

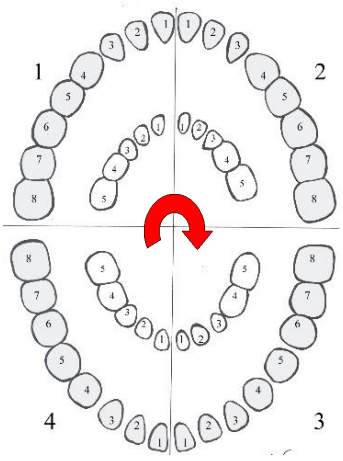

Figure 235: Numbering system for teeth.

Figure 236: Panoramic radiography captures all the teeth in a single image.

Tongue

The tongue is a muscular organ that facilitates the movement of food during mastication (chewing) and assists in swallowing. It is also used for tasting and articulating speech.

The tongue consists of striated muscle tissue and is covered with mucosa. It is divided into the right and left halves by a median fibrous septum.

The anterior part of the tongue is called the apex, the middle part is called the body, and the posterior part is called the root. The upper surface of the tongue is called the dorsum. A shallow groove that runs forward in a shape of V is called the terminal sulcus and separates the body from the root. It is lined by circumvallate papillae.

2.2 - Pharynx

The pharynx is a junction of the respiratory and the digestive system. It is located behind the nasal cavity, mouth and larynx and can be divided into nasopharynx, oropharynx, and laryngopharynx. The pharynx is shaped like a funnel, with its wider upper end attached to the occipital bone of the skull and its narrow lower end continuing into the oesophagus at the level of vertebra C6.

2.3 - Oesophagus

The oesophagus extends from the pharynx to the stomach. It is about 25 cm long and has a diameter of 2-3 cm. It lies in front of the spine and has three sections:

- the cervical part extends from the level of vertebra C6 to the level of vertebra T1 where it crosses the upper thoracic aperture,
- the thoracic part extends from the level of vertebra T1 to the level of vertebra T10 where it crosses the diaphragm,
- the abdominal part is short, it curves anteriorly to the left and continues into the stomach at the level of vertebra T11.

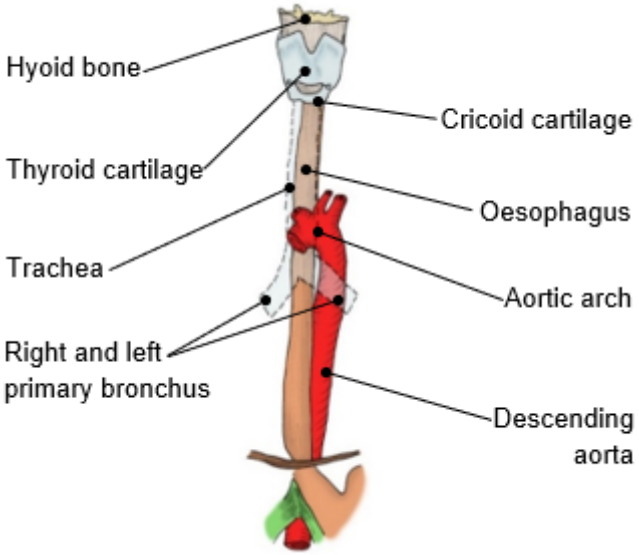

Figure 237: Topographic relations between the oesophagus, larynx, trachea and aorta. Anterior view.

The oesophagus crosses the diaphragm through a muscular opening called the oesophageal hiatus. A dehiscence of this orifice leads to a hiatal hernia.

The vagus nerves form a plexus around the lower part of the oesophagus – the posterior and anterior vagal trunks which cross the oesophageal hiatus along with the oesophagus.

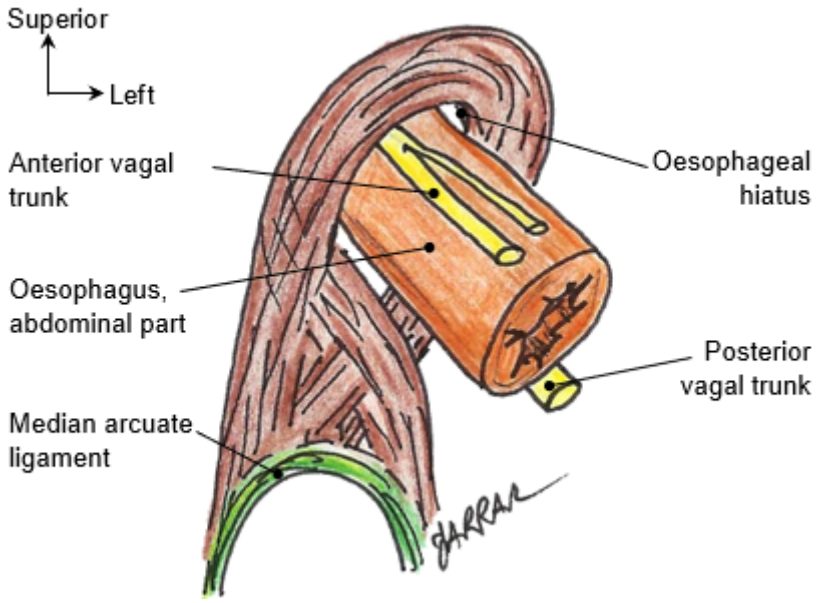

Figure 238: The oesophageal hiatus. Anterior view.

2.4 - Stomach

The stomach is the most dilated part of the digestive tube. It is roughly J-shaped and lies in the upper part of the abdominal cavity. It temporarily stores food. Its muscular contractions thoroughly mix the food with the gastric acid and the digestive enzymes, produced by the stomach glands.

The stomach has two openings (cardiac orifice and pyloric orifice), two curvatures (greater curvature and lesser curvature), and two walls (anterior wall and posterior wall).

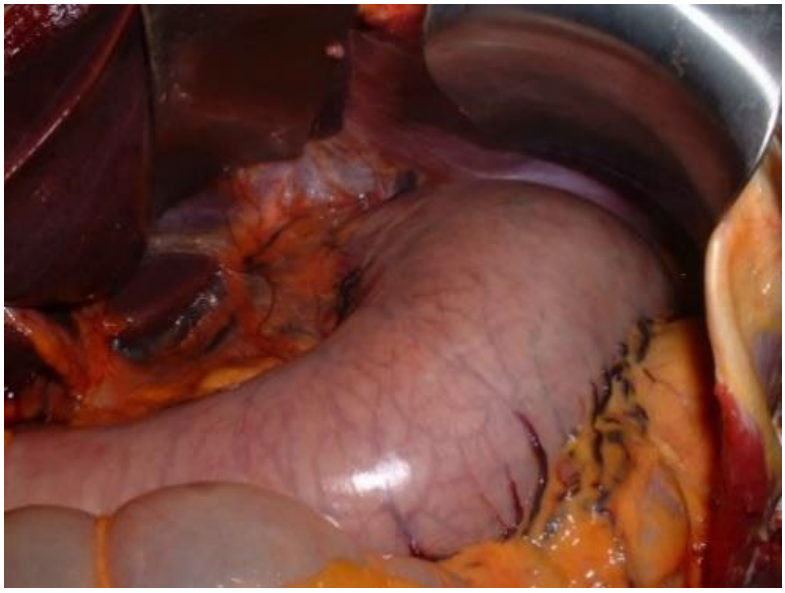

Figure 239: View of the stomach during the operation.

The stomach is divided into four parts:

- Cardia is the first part and connects the stomach to the oesophagus.
- Fundus of the stomach is the dome-shaped upper part of the stomach.
- Body of the stomach is the main, central part of the stomach.
- Pyloric part is the final part and connects the stomach to the duodenum. It is formed by pyloric antrum, pyloric canal, and pylorus. Pyloric sphincter surrounds the pyloric orifice at the junction of the stomach with the duodenum.

The stomach can distend if the duodenum is obstructed (stenosing duodenal ulcer, hypertrophic pyloric stenosis).

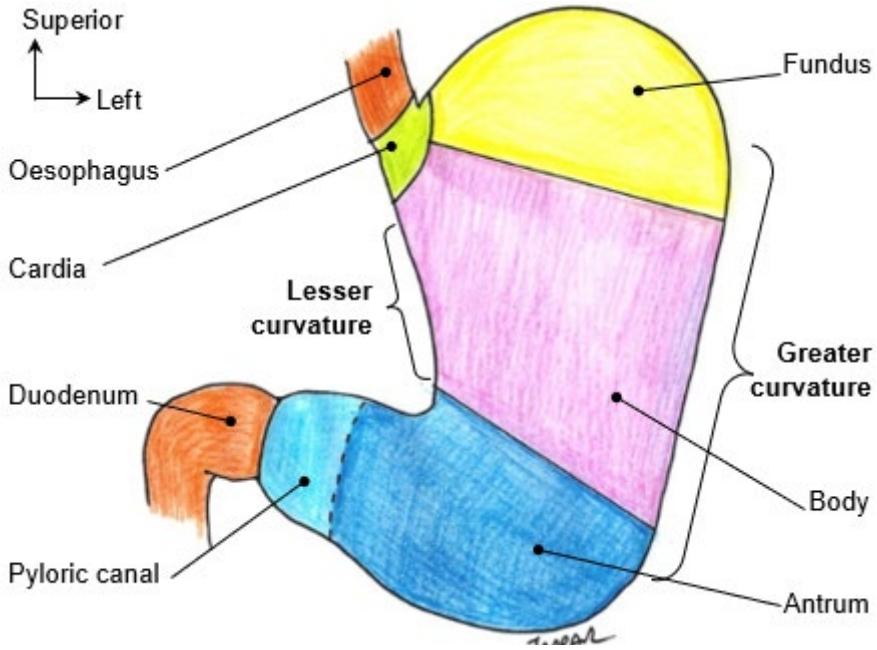

Figure 240: Parts of the stomach. Anterior view.

2.5 - Small intestine

The small intestine extends from the pylorus of the stomach to the ileocecal junction. It is divided into three parts:

- duodenum,
- jejunum,
- ileum.

Duodenum

The duodenum is the first section of the small intestine. It is about 30 cm long and 4-6 cm wide tube in the form of letter C which frames the pancreatic head. According to the position and course, 4 parts of duodenum are distinguished: the superior part, descending part, horizontal part, and ascending part. The pancreatic duct and common bile duct enter the descending part of the duodenum. The majority of

the duodenum (except for the beginning and final part) has a fixed position, behind the parietal peritoneum, anchored to the posterior abdominal wall.

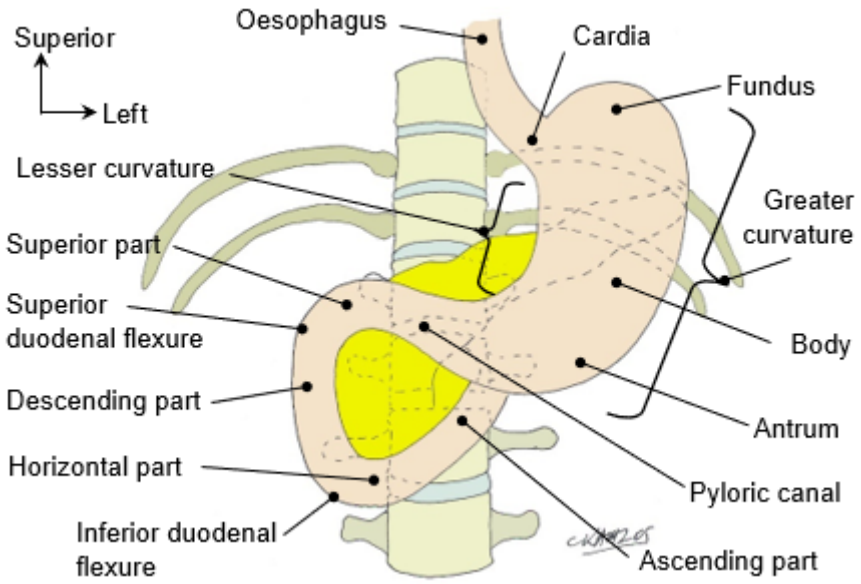

Figure 241: The stomach and the duodenum. Anterior view.

Jejunum and ileum

The jejunum and ileum are movable parts of the small intestine where the products of digestion are absorbed into the bloodstream.

- **Jejunum** begins at the duodenojejunal flexure. It is slightly shorter than ileum and lies mainly in the left upper quadrant of the abdomen. It has a wider lumen and a thicker wall than the ileum and is deep red in colour due to many vessels.
- **Ileum** is the longest part of the small intestine and lies mainly in the right lower quadrant of the abdomen. Small clusters of lymphatic tissue called Peyer's patches that can be found in

the wall of the small intestine are more numerous in the ileum, especially in its distal part.

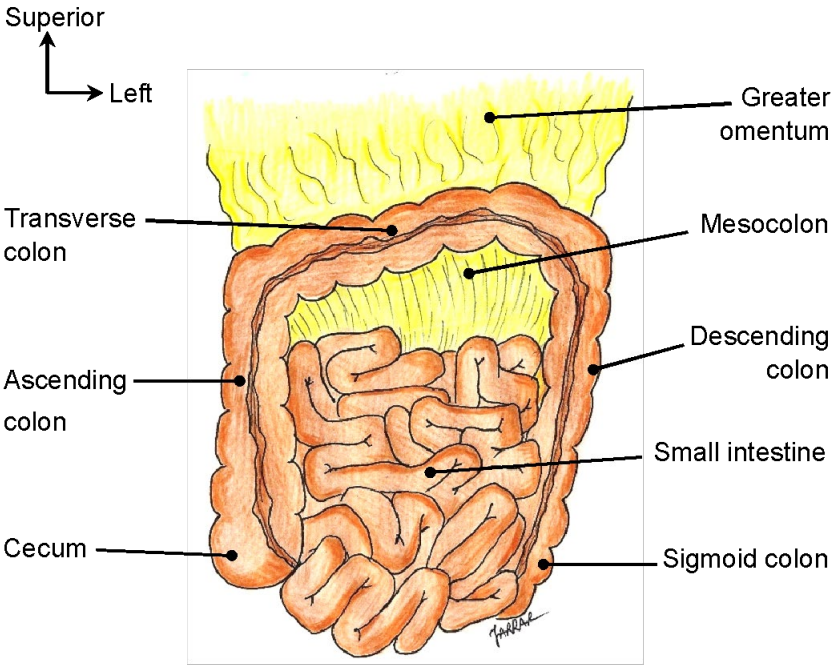

Figure 242: Arrangement of the jejunum and the ileum. Anterior view.

2.6 - Large intestine

The large intestine extends from the ileocecal junction to the anus. It is about 1.5 meters long and is divided into four parts:

- cecum with the attached appendix
- colon, which is further divided into ascending colon, transverse colon, descending colon, and sigmoid colon;
- rectum;
- anal canal.

In the large intestine, water and electrolytes are absorbed into the blood stream, leaving only the indigestible matter inside the lumen of digestive tube.

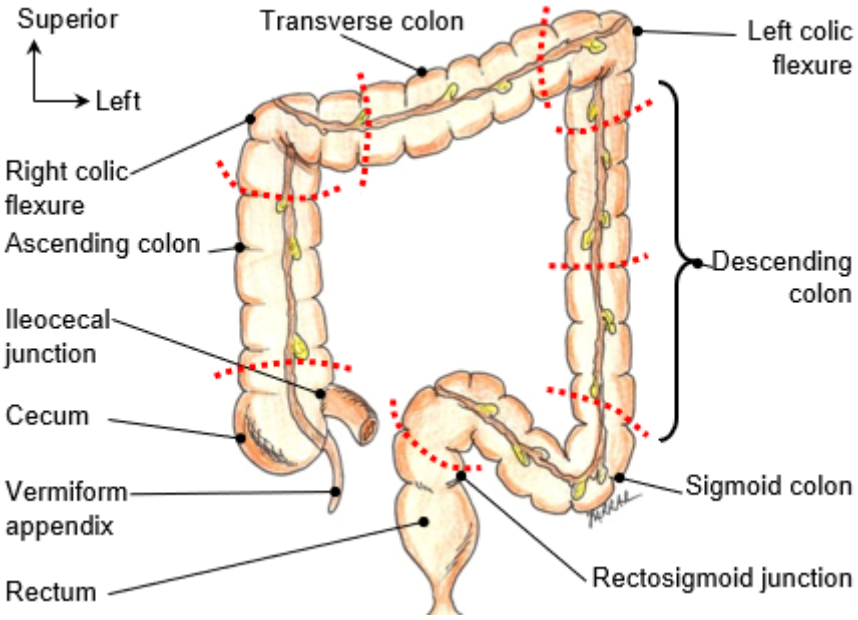

Figure 243: Arrangement and different segments of the large intestine. Anterior view

Cecum and **appendix** lie in the right iliac region. Cecum is joined to the end of the ileum via the ileocecal valve. It continues upwards as the **ascending colon** until it reaches the liver, where the colon makes the right colic flexure and then continues across the abdominal cavity to the left as the **transverse colon**. When it reaches the spleen, it makes the left colic flexure and continues downwards as the **descending colon**. The final part of the colon is the S-shaped **sigmoid colon**, which enters the pelvis and becomes **rectum** at the level of vertebra S3. The lower part of the rectum is dilated into the rectal ampulla, which serves as the reservoir for faeces storage. The large intestine then narrows into the **anal canal** which ends with the aperture at the terminal end of the digestive tube, called the anus.

The final segment of the digestive tube is equipped with two sphincters. The internal anal sphincter is part of the anal wall and consists of smooth muscle tissue. The external anal sphincter is one of the

perineal muscles and consists of striated muscle tissue, enabling the voluntary defecation.

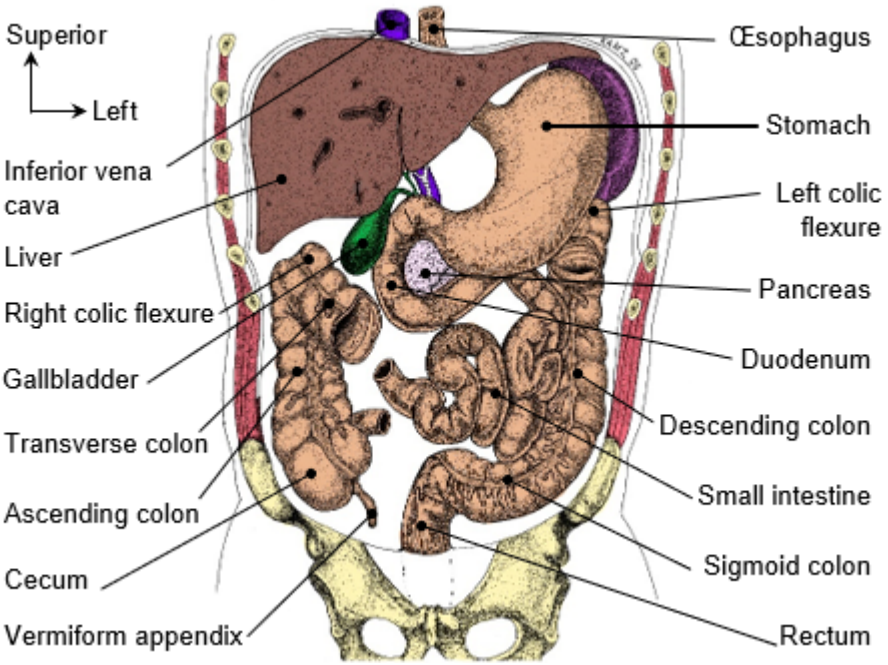

Figure 244: The digestive tract. Anterior view.

3 - Accessory organs of digestion

3.1 - Salivary glands

The salivary glands produce and secrete saliva into the oral cavity. Daily production of saliva is approximately 1.5 litres.

Minor salivary glands are located within the submucosa of the buccal, labial, and lingual mucosa, the soft and the hard palate, and the floor of the mouth.

The major salivary glands are 3 paired glands: the parotid, submandibular and sublingual gland.

The parotid gland is the largest salivary gland. It is located in front of the ear, wrapped around the ramus of mandible. It is separated into the superficial and deep lobes by the facial nerve which passes through the gland, dividing into the branches. The parotid duct runs horizontally over the surface of the masseter muscle, crosses the buccinator muscle and opens into the oral vestibule, forming the palpable papilla adjacent to the upper second molar.

The submandibular gland lies posterior-inferior to the body of the mandible, wrapping around the posterior border of the mylohyoid muscle which divides the gland into the superficial and deep part. The submandibular duct opens into the oral cavity under the tongue, forming a sublingual caruncle lateral to the lingual frenulum.

The sublingual gland is the smallest of the major salivary glands. It is located in the floor of the mouth, within its mucosa (within the sublingual fold) near the lingual frenulum. Numerous sublingual ducts (8 to 20) open into the oral cavity along the margin of the sublingual fold.

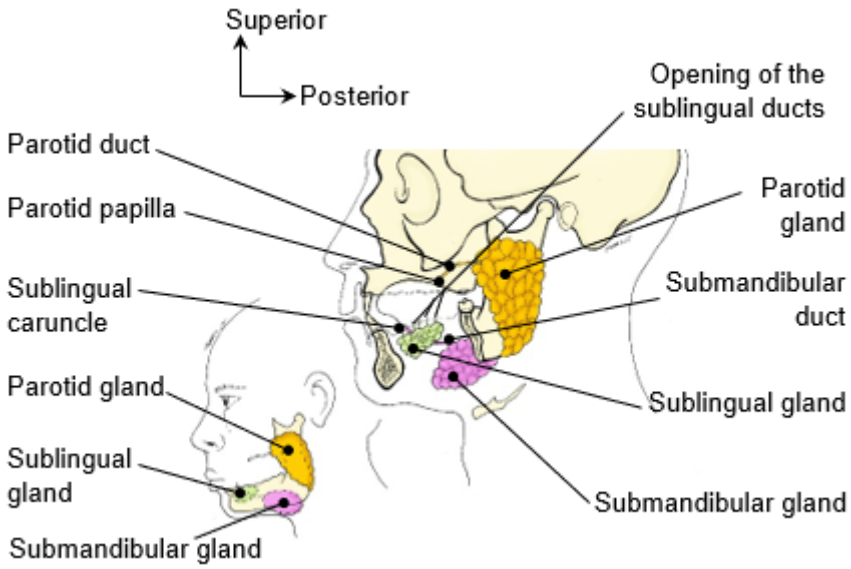

Figure 245: The salivary glands.

3.2 - Liver

The liver is the largest gland in the human body, weighing approximately 1.5-2 kilograms. It occupies the upper right quadrant of the abdominal cavity, lying just below the diaphragm and behind the right costal arch, extending to the left into the epigastric and also the left hypochondriac region.

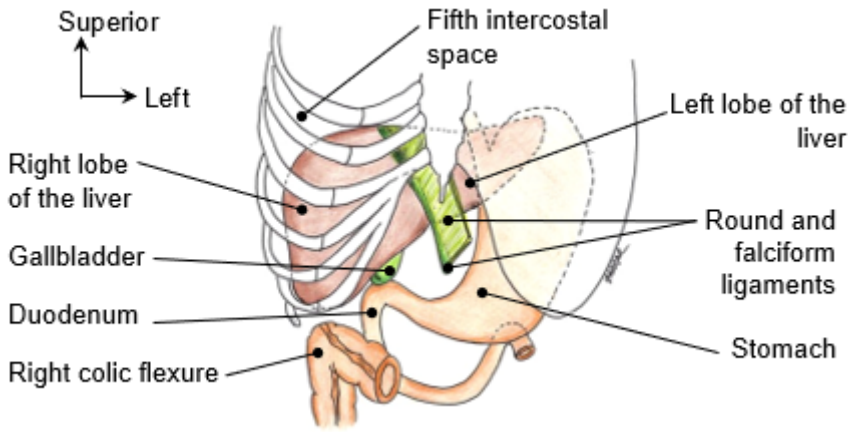

Figure 246: Location of the liver.

The liver contributes to the maintenance of homeostasis and has several essential functions, among which are:

- detoxification of the toxins in the food and of waste products of metabolism such as nitrogenous waste products from protein metabolism (ammonium, urea), etc.
- protein synthesis (coagulation factors);
- bile production;
- nutrient storage.

All the venous blood from the abdominal organs of the gastrointestinal system and from the spleen is collected by portal vein and carried into the liver where it is filtered prior to entering the inferior vena cava via the hepatic veins.

Surfaces and lobes of liver

The liver is a soft, dark reddish, wedge-shaped organ with two main surfaces – the diaphragmatic and visceral surface one.

Diaphragmatic surface is convex and adjacent to the inferior surface of the diaphragm.

Visceral surface is concave and faces posteriorly and inferiorly. It is in relation with several abdominal organs: gallbladder, abdominal part of the oesophagus, minor curvature of the stomach, superior part of the duodenum, right colic flexure, right kidney, and right suprarenal gland. On this surface lies the porta hepatis through which pass the portal vein, proper hepatic artery, common hepatic duct, lymphatic vessels, and nerves. The surface is divided into four lobes: the right lobe, quadrate lobe, caudate lobe, and left lobe.

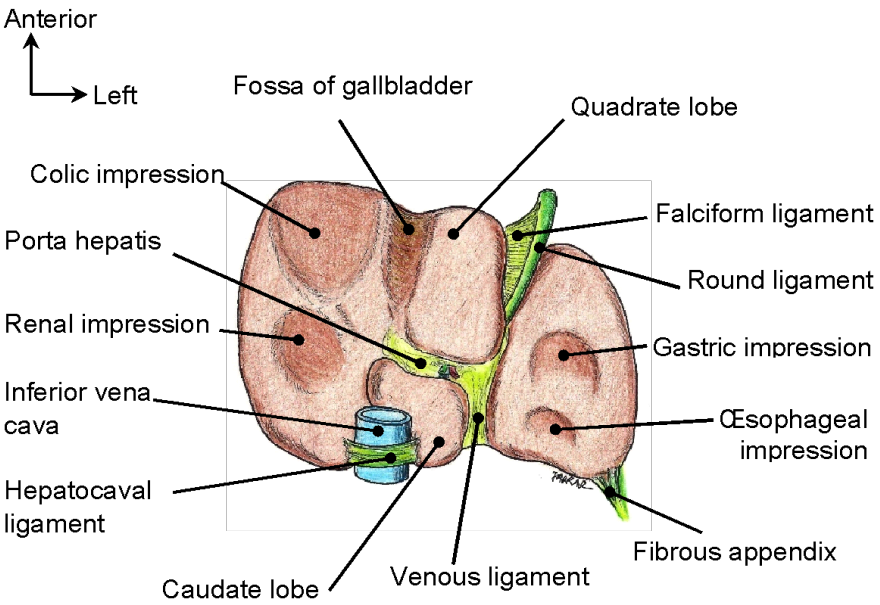

Figure 247: Visceral surface of the liver.

Segmentation of liver

Functionally, the liver can be divided into 8 independent functional segments based on the position of the veins. The 3 hepatic veins represent the 3 vertical planes, separating the liver in 4 sections. A horizontal plane called the portal plane lies at the level where the portal vein bifurcates into 2 horizontally running branches; the plane divides each liver section into superior and inferior segments.

Each segment has its own vascular inflow, outflow and biliary drainage. In the centre of the segment there is a branch of portal vein, hepatic artery, and bile duct. On the periphery of the segment there is a hepatic vein.

The liver segments are named by numbers from 1 to 8. Segment 1 (I) is the caudate lobe; the segments 2 (II) to 8 (VIII) then follow numbered in a clockwise fashion, starting superiorly in the left hepatic lobe. The liver segmentation is essential for surgical procedures.

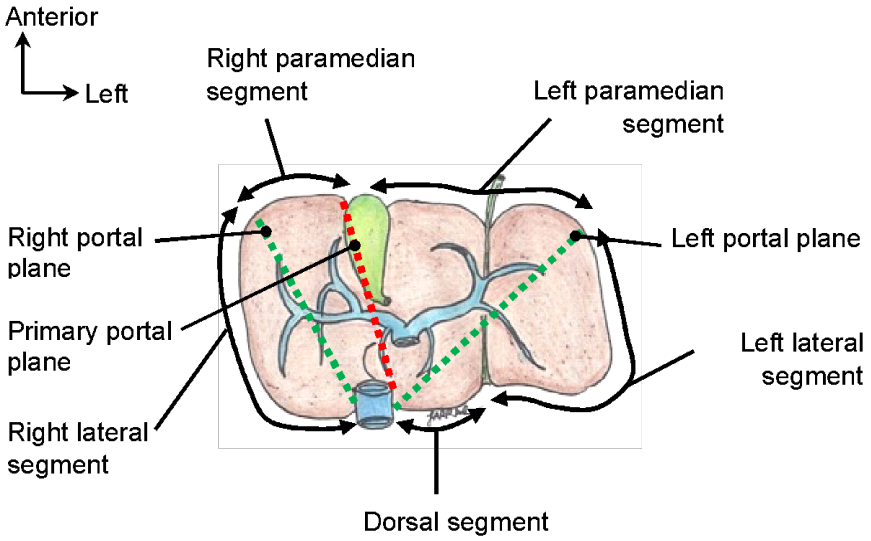

Figure 248: Planes and liver segments. Inferior view.

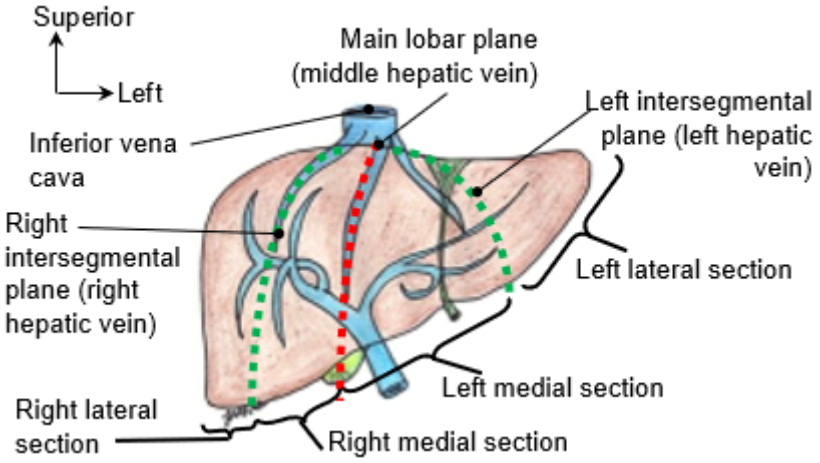

Figure 249: Sections of the liver and boundary planes between them. Anterior view.

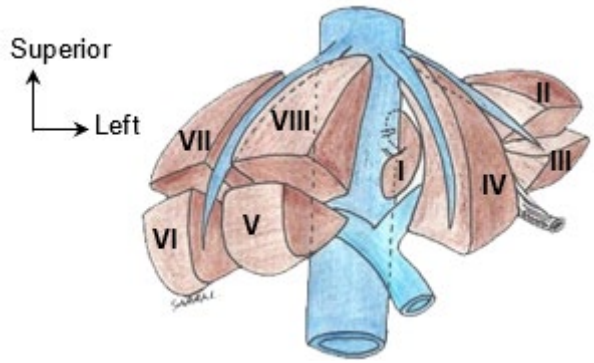

Figure 250: Segments of the liver. Anterior view.

3.3 - Extrahepatic bile ducts and gallbladder

The bile is synthesised by liver cells called the hepatocytes and secreted into thin tubes in between the hepatocytes called the bile canaliculi. Inside the liver, canaliculi empty into a series of progressively larger ducts. Finally, the left and right hepatic ducts arising from the left and right liver lobe join to form the common hepatic duct.

Common hepatic duct is about 4 cm long. It exits the liver through the porta hepatis and joins the cystic duct from the gallbladder to form the bile duct.

Bile duct is about 8 cm long. It runs within the free margin of the lesser omentum towards the superior part of the duodenum, then passes behind the superior part of the duodenum and behind the head of the pancreas, ending in the descending part of the duodenum. Just before crossing the wall of the duodenum it usually joins with the pancreatic duct to form the hepatopancreatic ampulla.

Gallbladder is about 10 cm long pear-shaped organ that lies on the visceral surface of the liver, in the gallbladder fossa. It receives bile produced in the liver via the common hepatic duct and cystic duct and stores it. During digestion, it releases the bile into the duodenum via the cystic duct and the bile duct.

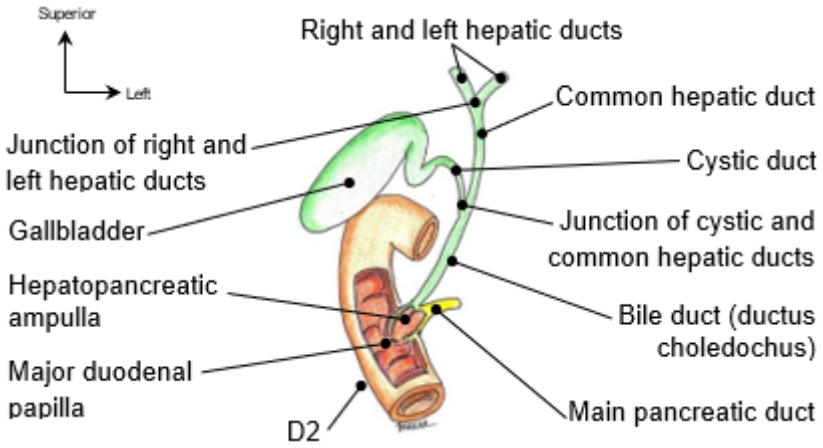

Figure 251: The extrahepatic bile ducts.

3.4 - Pancreas

The pancreas is a gland with two main functions: its exocrine function is secretion of pancreatic juice with enzymes necessary for food digestion, and its endocrine function is secretion of hormones insulin and glucagon necessary for blood sugar regulation.

It is an elongated organ which lies obliquely across the posterior abdominal wall behind the parietal peritoneum, at the level of vertebrae L1 and L2, in the epigastric and left hypochondriac region.

The pancreas is a soft and lobulated parenchymatous organ divided into the head, neck, body and tail. The head lies to the right side of the spine, in the curvature of the duodenum. The body lies behind the stomach. The tail extends towards the hilum of the spleen.

Two pancreatic ducts drain the pancreatic juice and carry it to the duodenum. The main pancreatic duct (duct of Wirsung) runs across the whole length of the pancreas. It joins with the bile duct to form the hepatopancreatic ampulla (ampulla of Vater) which opens into the descending part of the duodenum at the major duodenal papilla. A smooth muscle sphincter, called the sphincter of Oddi, regulates the secretion of pancreatic juice and bile into the duodenum and prevents reflux from the duodenum. Small gallstones can be trapped at the level of sphincter, blocking the emptying of the hepatopancreatic ampulla. The accessory pancreatic duct opens into the duodenum at the minor duodenal papilla which lies above the major one. Both ducts usually communicate.

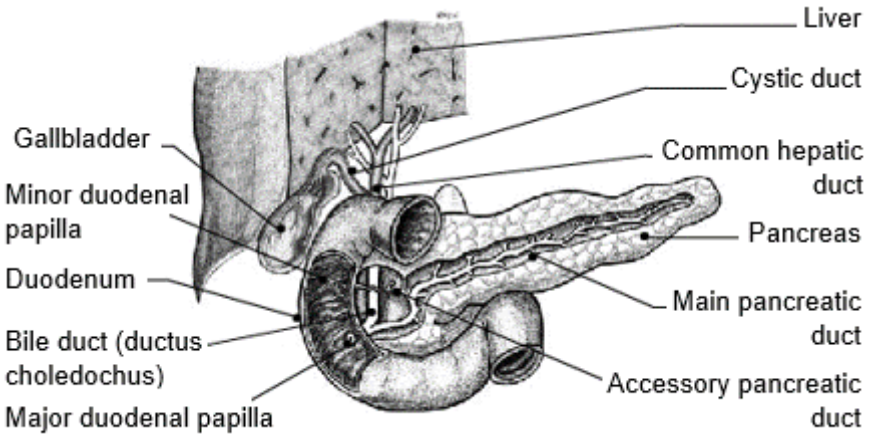

Figure 252 Pancreas and pancreatic ducts. Anterior view.

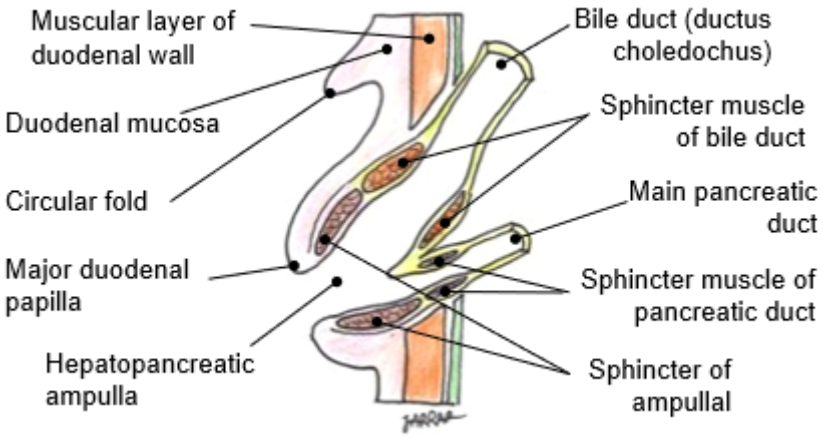

Figure 253: Section through the hepatopancreatic ampulla showing the sphincter of hepatopancreatic ampulla.

4 - Arterial supply

The abdominal part of gastrointestinal tract is supplied by three visceral branches of the abdominal aorta:

- **The coeliac trunk** arises from the abdominal aorta at the level of the vertebra T12. It is very short and has three terminal branches. The left gastric artery supplies the abdominal part of oesophagus and upper part of the stomach. The splenic artery supplies the spleen, pancreas, and stomach. The common hepatic artery supplies the liver, distal part of the stomach, proximal part of the duodenum, and pancreatic head.
- **The superior mesenteric artery** arises from the abdominal aorta at the level of vertebra L1. It supplies distal part of the duodenum, jejunum, ileum, cecum, appendix, ascending colon, right colic flexure, and the majority of the transverse colon.
- **The inferior mesenteric artery** arises from the abdominal aorta at the level of vertebra L3. It supplies the left third of the transverse colon, left colic flexure, descending colon, sigmoid colon, rectum, and the proximal part of the anal canal.

Figure 254: CT angiography showing the origin of the superior mesenteric artery from the abdominal aorta. Cross-section through the abdomen.

Arterial supply of the oesophagus

The cervical part of the oesophagus is supplied by the inferior thyroid artery. The thoracic part of the oesophagus is supplied by the oesophageal branches that arise from the thoracic aorta. The abdominal part of the oesophagus is supplied by the left gastric artery which arises from the coeliac trunk.

Arterial supply of the stomach

The rich blood supply to the stomach is provided by several arteries that arise from the coeliac trunk and anastomose with each other:

- The supply of the lesser curvature is formed by the left gastric artery which is a direct branch of the celiac trunk, and the right gastric artery, a branch of the common hepatic artery.
- The supply of the greater curvature is formed by the left gastroomental artery which is a branch of the splenic artery, and the right gastroomental artery which is an indirect branch of the common hepatic artery.
- Short gastric arteries from the splenic artery supply the posterior wall of the stomach.

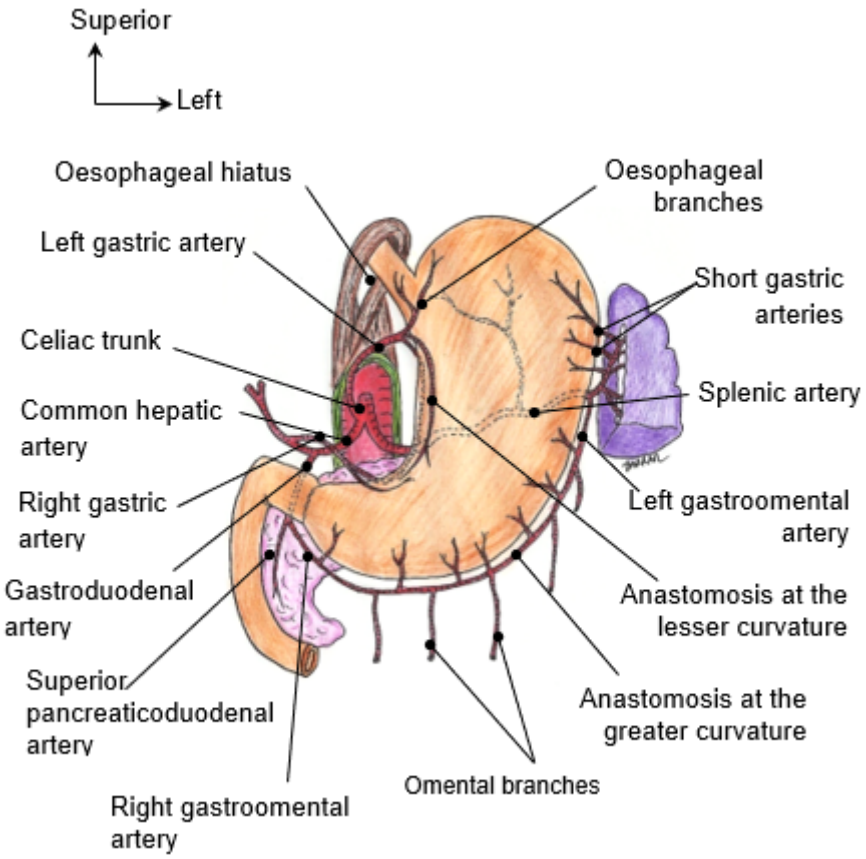

Figure 255: Blood supply of the stomach.

Arterial supply of the small intestine

The proximal part of the duodenum is supplied by branches of the common hepatic artery which arises from the coeliac trunk, while the distal part of the duodenum is supplied by a branch of the superior mesenteric artery.

Jejunum and ileum are supplied by jejunal and ileal arteries which are all branches of the superior mesenteric artery. They all arise from the left side of the superior mesenteric artery and are interconnected with rich anastomoses in the form of arcades.

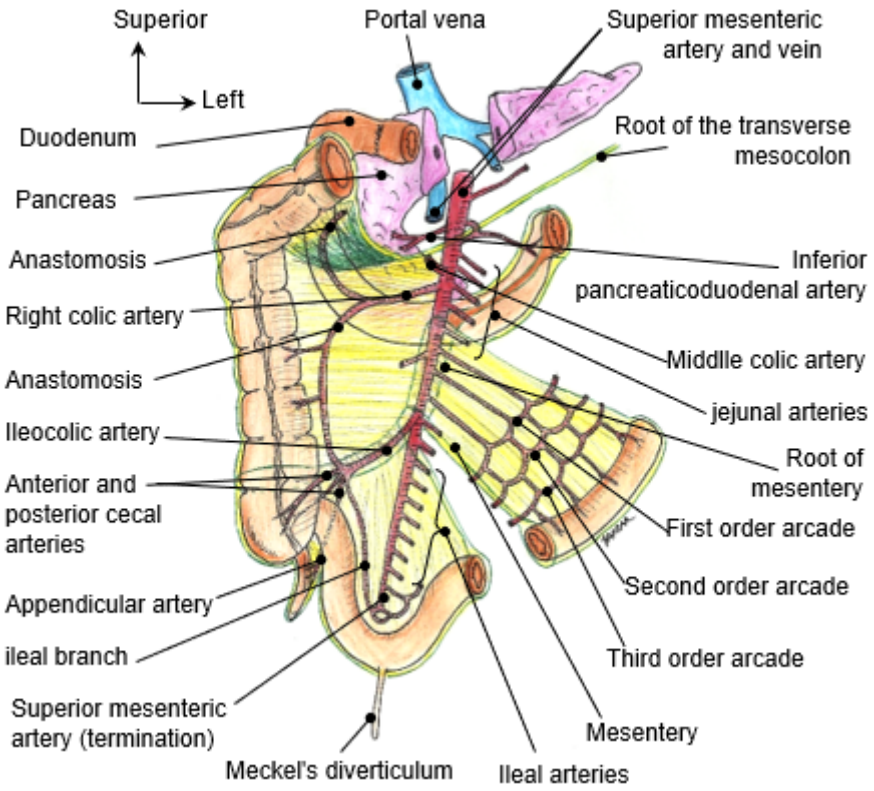

Figure 256: The superior mesenteric artery and its branches. Anterior view.

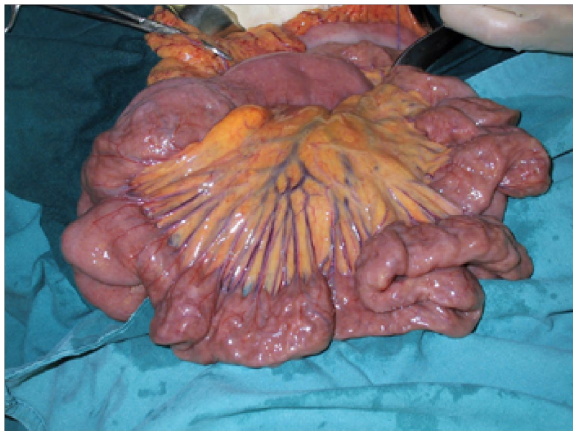

Figure 257: The vascular arcades of the jejunum and ileum. Operative view.

Arterial supply of the large intestine

The cecum with the appendix, ascending colon, right colic flexure and the right 2/3 of the transverse colon are supplied by the branches that arise from the superior mesenteric artery on the right side: the ileocolic artery, right colic artery and middle colic artery.

The left third of the transverse colon, left colic flexure, descending colon, sigmoid colon, rectum, and the proximal part of the anal canal are supplied by branches of the inferior mesenteric artery: the left colic artery, sigmoid arteries, and superior rectal artery. The sigmoid arteries form the arcades.

Each artery has its own territory, which allows identification of vascular or surgical division. The arteries supplying the large intestine are interconnected by a vascular arcade called the marginal artery. The marginal artery provides an important anastomosis between the superior and inferior mesenteric arteries. In some individuals, there is an additional anastomosis called the arc of Riolan. When present, it usually connects the middle colic artery with a branch of the left colic artery.

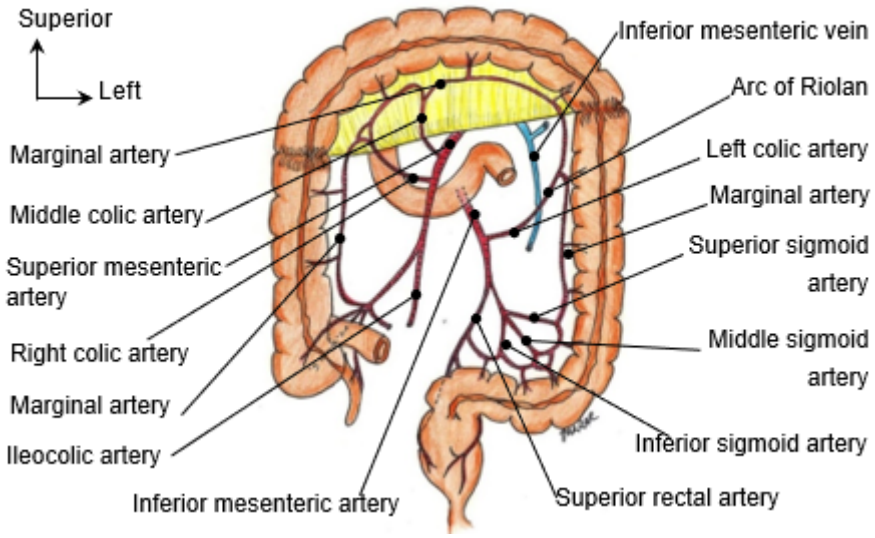

Figure 258: Arterial supply of the large intestine. Anterior view.

Arterial supply of the liver and pancreas

The liver is supplied by the proper hepatic artery, which is the branch of common hepatic artery. The proper hepatic artery also supplies the gallbladder.

The head of the pancreas is supplied by the same branches of common hepatic artery and superior mesenteric artery that also supply the duodenum. The body and tail of pancreas are supplied by branches of splenic artery.

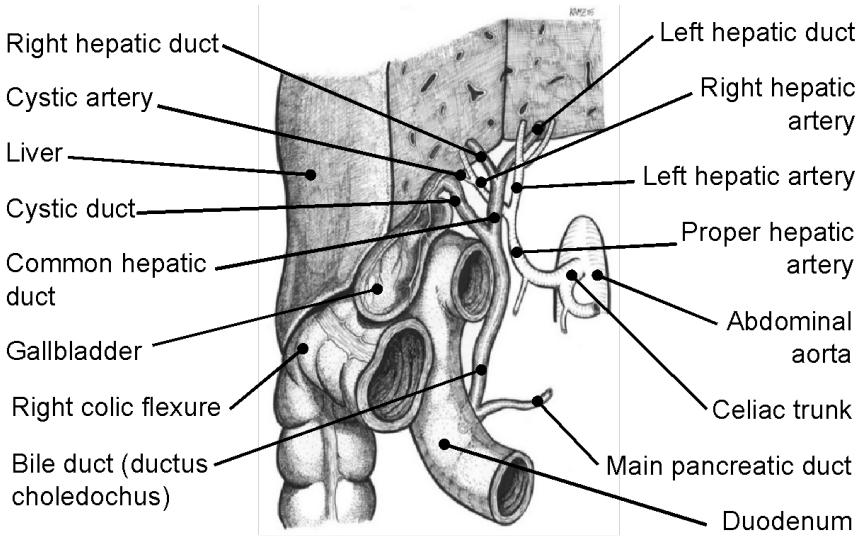

Figure 259: The bile ducts and their blood supply. Anterior view.

5 - Hepatic portal vein

The venous blood of the abdominal part of the oesophagus, stomach, intestine, pancreas, and spleen is collected by the hepatic portal vein.

The portal vein is formed by fusion of the splenic vein and superior mesenteric vein behind the head of the pancreas. The inferior mesenteric vein usually drains into the splenic vein.

The portal vein then runs towards the visceral site of the liver in the free margin of the omentum minus, accompanied by the bile duct and the proper hepatic artery.

It enters the liver through the porta hepatis and divides into the left and right branch. The blood that is delivered to the liver by the portal vein is filtered by the hepatocytes and returned to the systemic blood flow through short hepatic veins that drain into the inferior vena cava.

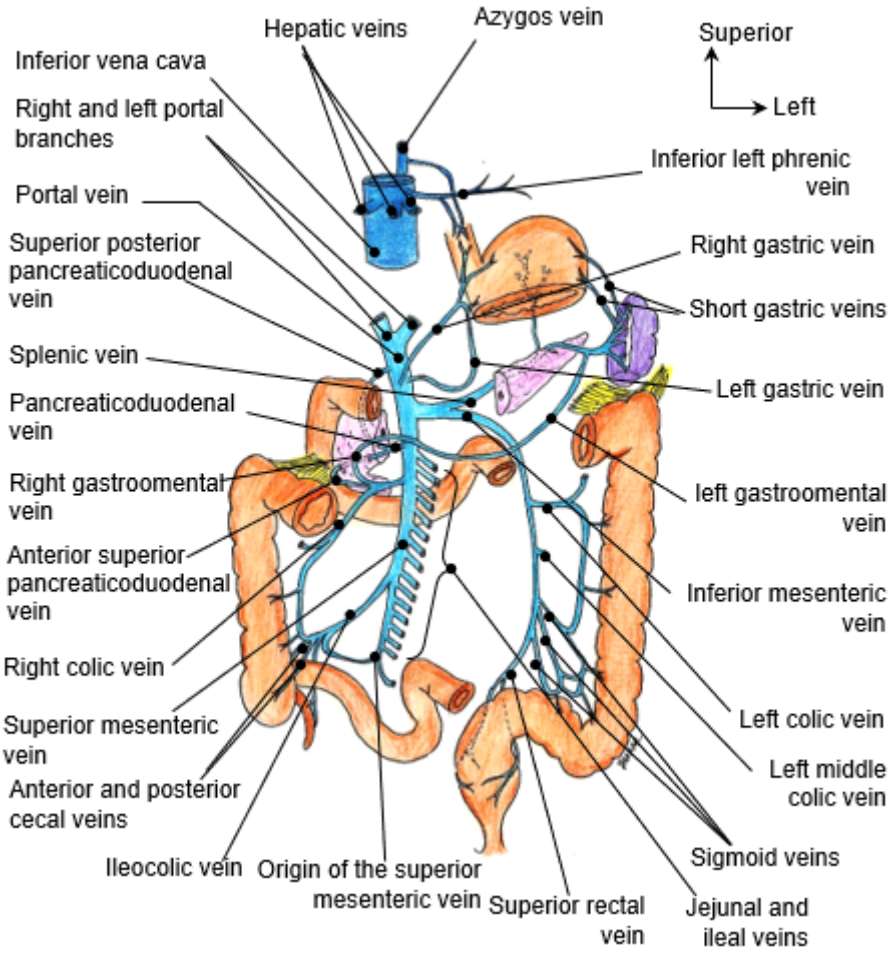

Figure 260: Tributaries of portal vein. Anterior view.

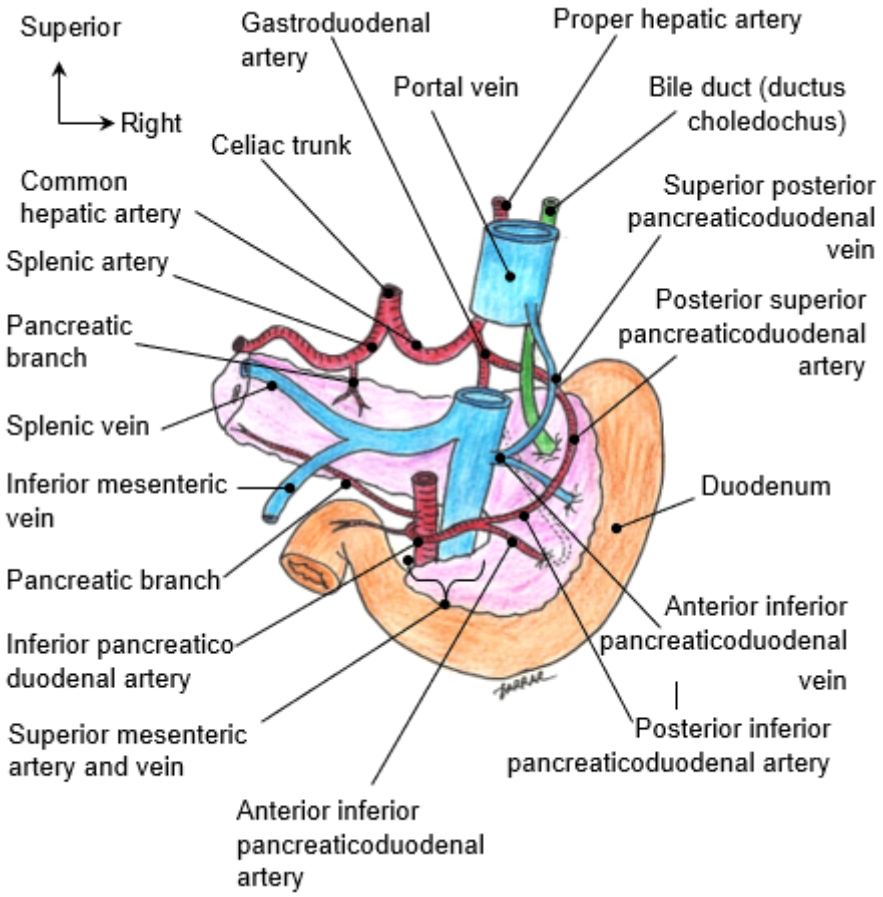

Figure 261: Formation of the portal vein behind the pancreas. Posterior view.

The lymphatic vessels of the digestive tract

The lymphatic vessels of the colon follow the arteriovenous pedicles and are divided into five groups. They open into the lymphatic vessels of the intestine, which are involved in the formation of the thoracic duct.

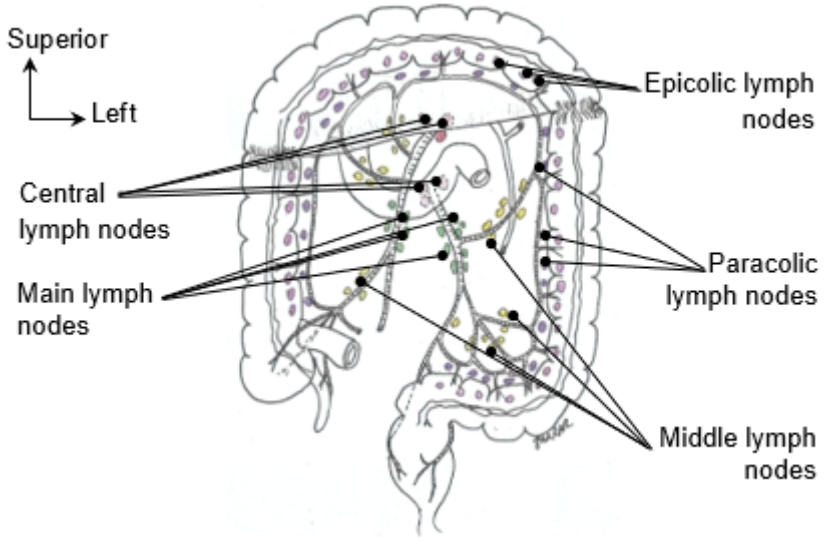

Figure 262: Lymphatic drainage of the colon. Frontal view.

6 - Peritoneum

The peritoneum is a serous membrane that covers the walls of the abdominopelvic cavity and completely or partially envelops some of the organs of the abdominopelvic cavity:

- The parietal peritoneum is the outer layer that adheres to the abdominal and pelvic walls;
- The visceral peritoneum wraps around the intraperitoneal internal organs;
- The parietal peritoneum is continuous with the visceral peritoneum and reflects from the abdominal wall to the internal organs forming the duplicatures;
- between the parietal and visceral peritoneum is a potential space called the peritoneal cavity; the cavity is filled with a small amount of serous peritoneal fluid secreted by the peritoneum; the fluid minimises the friction during the movements of the abdominal organs.

6.1 - Peritoneal structures

Peritoneal ligaments

The peritoneal ligaments are double-layered folds of peritoneum that connect an abdominal organ to the abdominal wall or to other abdominal organs. The liver, for example, is connected to the diaphragm by the falciform ligament, the coronary ligament, and the right and left triangular ligaments, to the stomach by the hepatogastric ligament, and to the superior part of duodenum by the hepatoduodenal ligament.

Mesentery

The mesentery is a peritoneal duplicature that suspends an organ from the posterior abdominal wall. Between the two layers of the peritoneum that form the mesentery lies the neurovascular bundle that supplies the organ.

The mesentery of the jejunum and ileum is simply called the **mesentery**. The mesentery of the colon is called the **mesocolon**: more specifically, the transverse mesocolon and sigmoid mesocolon. The mesentery of the vermiform appendix is called the mesoappendix.

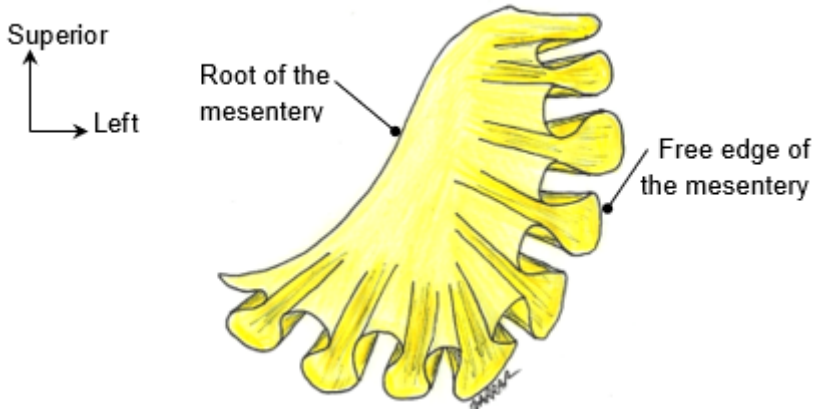

Figure 263: The mesentery of the jejunum and ileum. Anterior view.

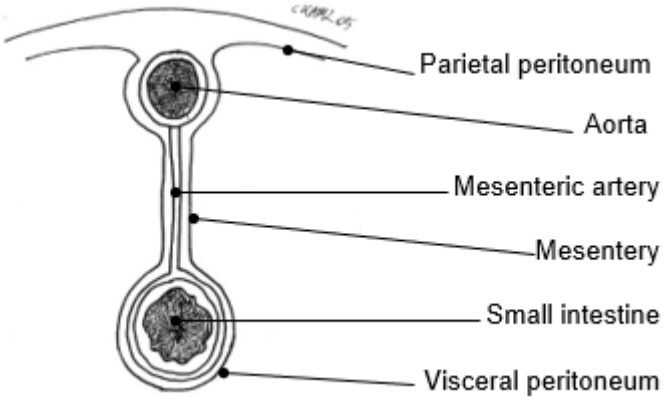

Figure 264: A scheme of the intraperitoneal organ and the mesentery. Posterior part of the cross-section through the abdominal cavity.

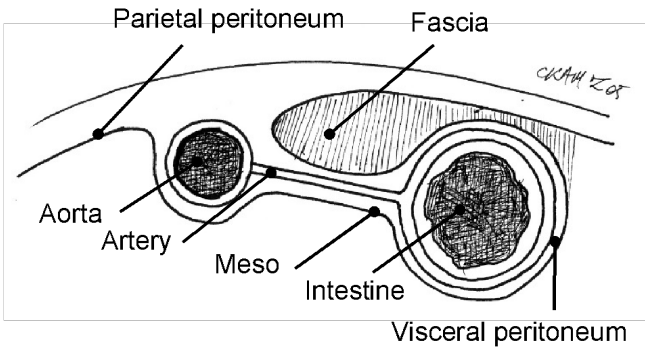

Figure 265: A scheme of the retroperitoneal organ. Posterior part of the cross-section through the abdominal cavity.

Omentum

The omentum is a double-layered fold of peritoneum that extends from the stomach to adjacent organs:

- **Lesser omentum** extends from the lesser curvature of the stomach and proximal duodenum to the liver. It is formed by the hepatogastric and hepatoduodenal ligament. The latter forms the free margin of the lesser omentum and envelops the structures running towards the porta hepatis: the portal vein, proper hepatic artery, bile duct, lymphatic vessels, and nerves.

- **Greater omentum** extends from the greater curvature of the stomach. The proximal part of the greater omentum is attached to the transverse colon, forming the gastrocolic ligament. The distal part hangs freely from the transverse colon like a curtain, covering the anterior surface of the jejunum and ileum.

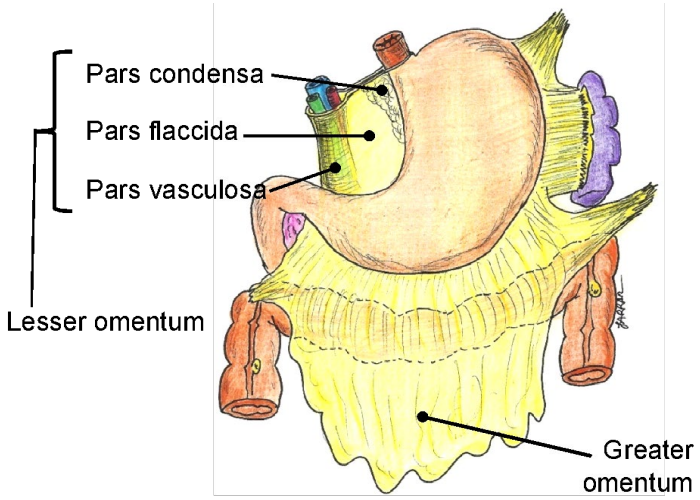

Figure 266: Anterior view of the two omenta.

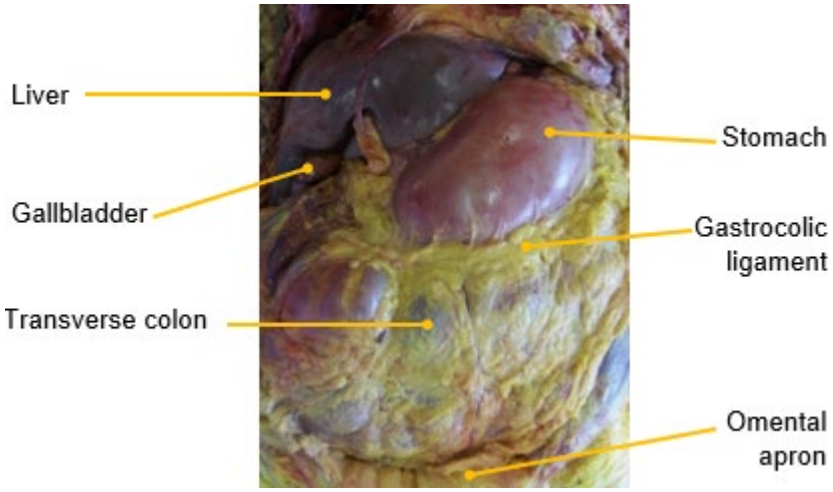

Figure 267: Parts of greater omentum. Anterior view.

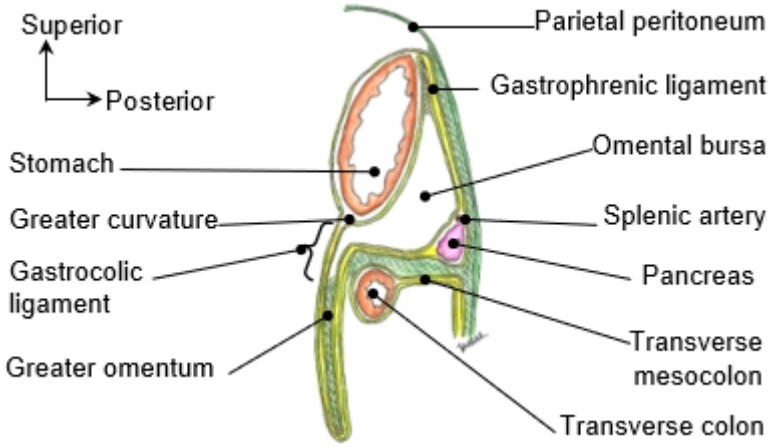

Figure 268: Scheme of the omental bursa. Sagittal section through the abdomen, view from the left.

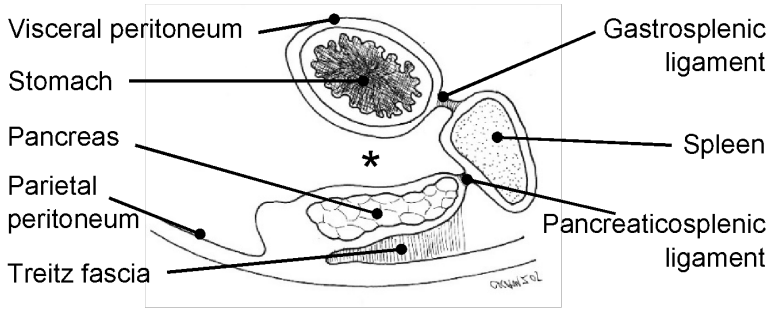

Figure 269: Scheme of the omental bursa (*). Cross-section through the abdomen.

6.2 - Peritoneal compartments

Peritoneal structures divide the peritoneal cavity into the compartments:

- transverse mesocolon divides the abdominal cavity into the supramesocolic and inframesocolic compartments; mesenterium of small intestine further divides the inframesocolic compartment into the left and right inframesocolic compartment.

- secluded part of the cavity behind the liver, stomach and lesser omentum is called the omental bursa or lesser sac; the omental bursa communicates with the main part of the abdominal cavity (also referred to as the greater sac) through the omental foramen which lies behind the hepatoduodenal ligament.

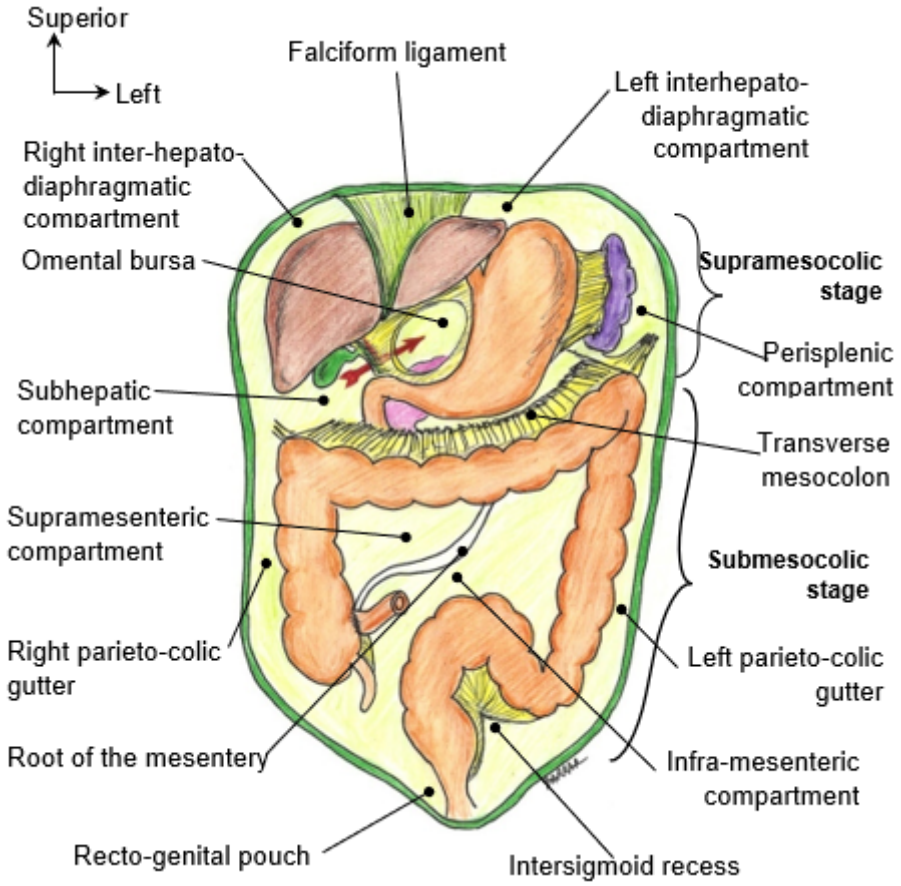

Figure 270: The compartments of the peritoneal cavity. Anterior view.