PowerPoint Handout: GI Lab 3, Foregut

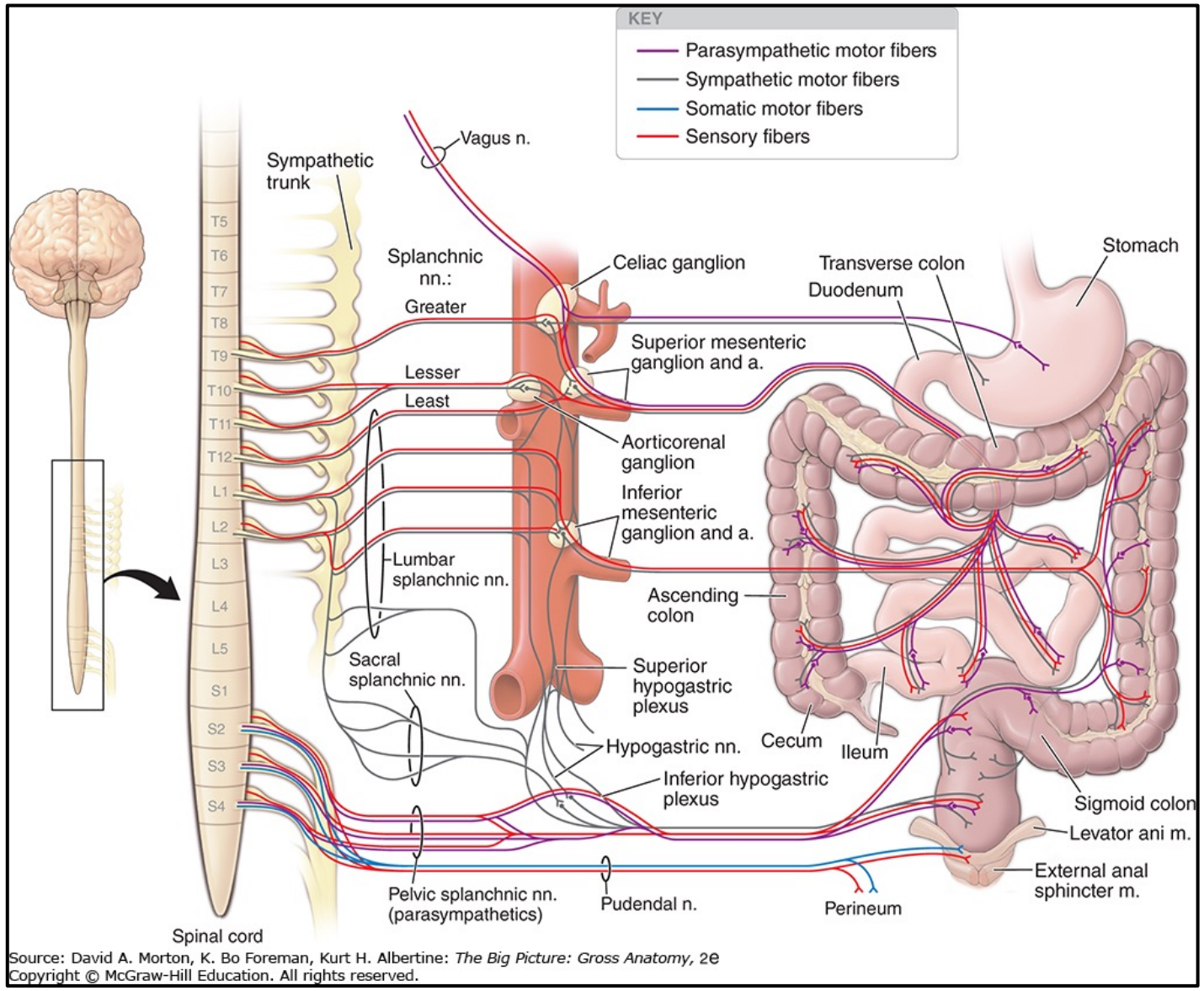
Sympathetic Innervation of Abdominal Viscera

The preganglionic sympathetic neurons that supply abdominal viscera reside in the lateral horn of the **T5-L2/L3 spinal cord** segments.

- The axons of these preganglionic neurons exit the sympathetic chain as thoracic (**greater, lesser** and **least**) and **lumbar splanchnic** nerves.
- With the exception of those preganglionic sympathetic neurons that will innervate the suprarenal (adrenal) medulla, all preganglionic sympathetic neurons involved in the innervation of abdominal viscera synapse on neurons located in the prevertebral (preaortic) sympathetic ganglia on the anterior surface of the abdominal aorta.

Postganglionic sympathetic fibers originating from the prevertebral ganglia follow the path of blood vessels to reach their target organs.

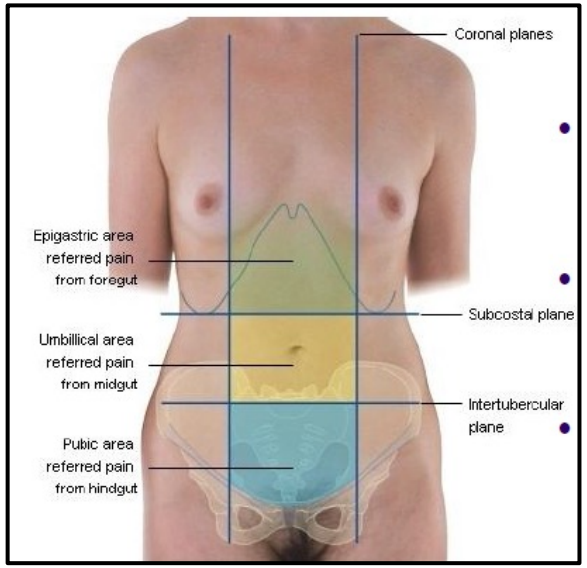
Visceral pain sensation from the foregut, midgut regions and the hindgut up to the middle of the sigmoid colon, as well as from the kidneys and abdominal ureters travel the path of sympathetic fibers. If an organ receives sympathetic motor fibers from T5, the visceral afferent fibers will enter the cord at T5. Note: The distal half of the sigmoid colon and remaining portion of the hindgut travel retrograde along with their parasympathetic supply, not the sympathetic fibers.

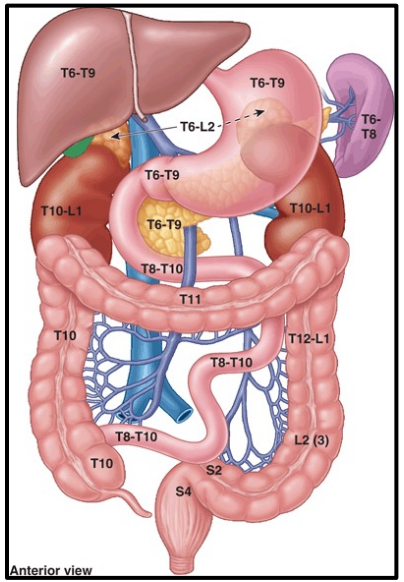


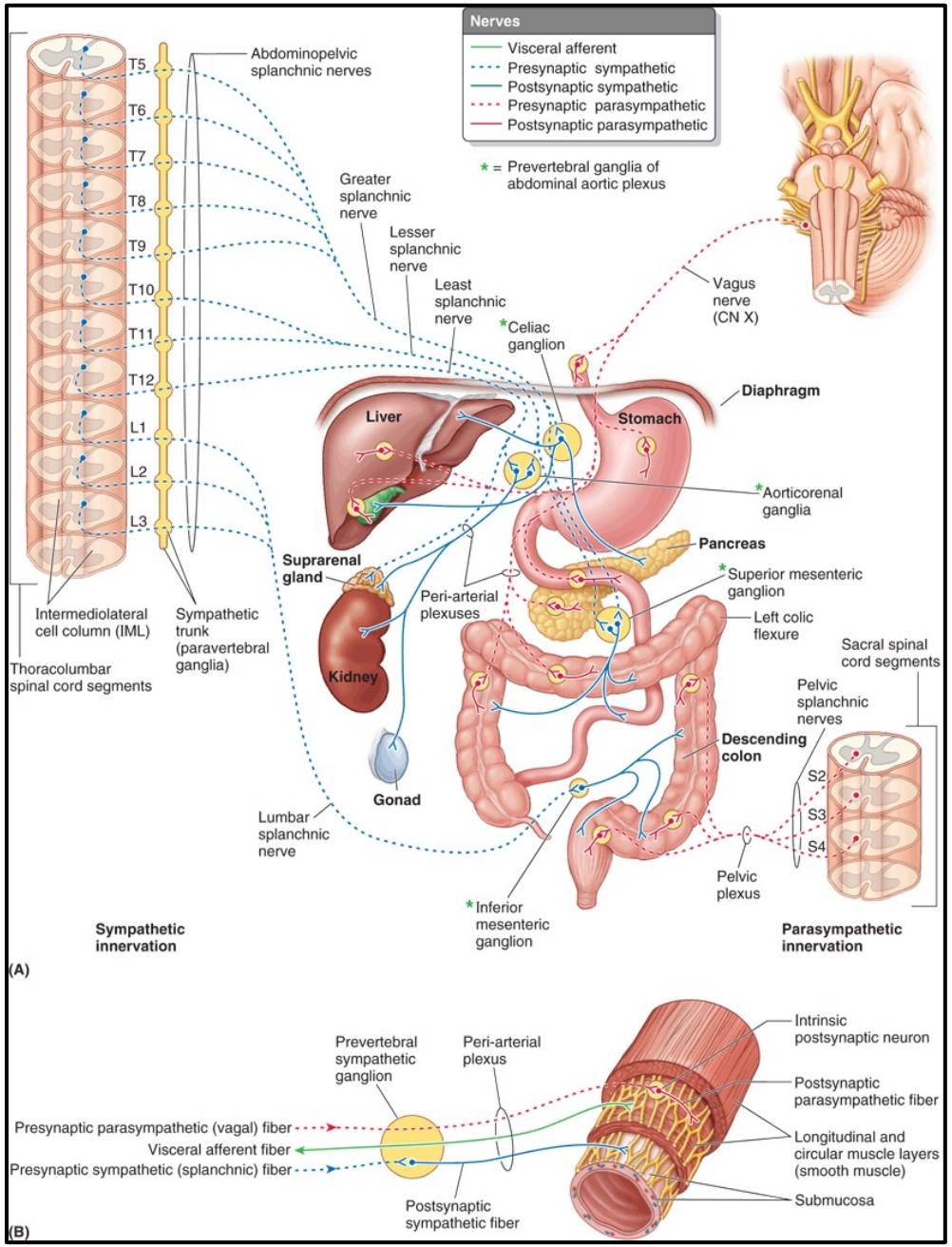
Sympathetic Innervation: Foregut, Midgut, & Hindgut

The abdominal viscera have distinct sympathetic innervations.

- Foregut:
  - Preganglionic cell bodies: **T5-T9/T10** lateral horns of spinal cord
  - Preganglionic axons: **Greater splanchnic nerves**
  - Postganglionic cell bodies: **Celiac** prevertebral ganglia
  - Postganglionic axons: Celiac perivascular plexus
  - Referred pain to **epigastric region**
- Midgut:
  - Preganglionic cell bodies: **T10-T12** lateral horns of spinal cord
  - Preganglionic axons: **Lesser (T10-T11) & least (T12) splanchnic nerves**
  - Postganglionic cell bodies: **Superior mesenteric** prevertebral ganglia (and aorticorenal)
  - Postganglionic axons: Superior mesenteric perivascular plexus
  - Referred pain to **umbilical region**
- Hindgut:
  - Preganglionic cell bodies: **L1-L2/L3** lateral horns of spinal cord
  - Preganglionic axons: **Lumbar splanchnic nerves**
  - Postganglionic cell bodies: **Inferior mesenteric** prevertebral ganglia and ganglia of hypogastric plexus
  - Postganglionic axons: Inferior mesenteric perivascular plexus
  - Referred pain to **hypogastric region: Referred pain region STOPS at proximal ½ of sigmoid colon**



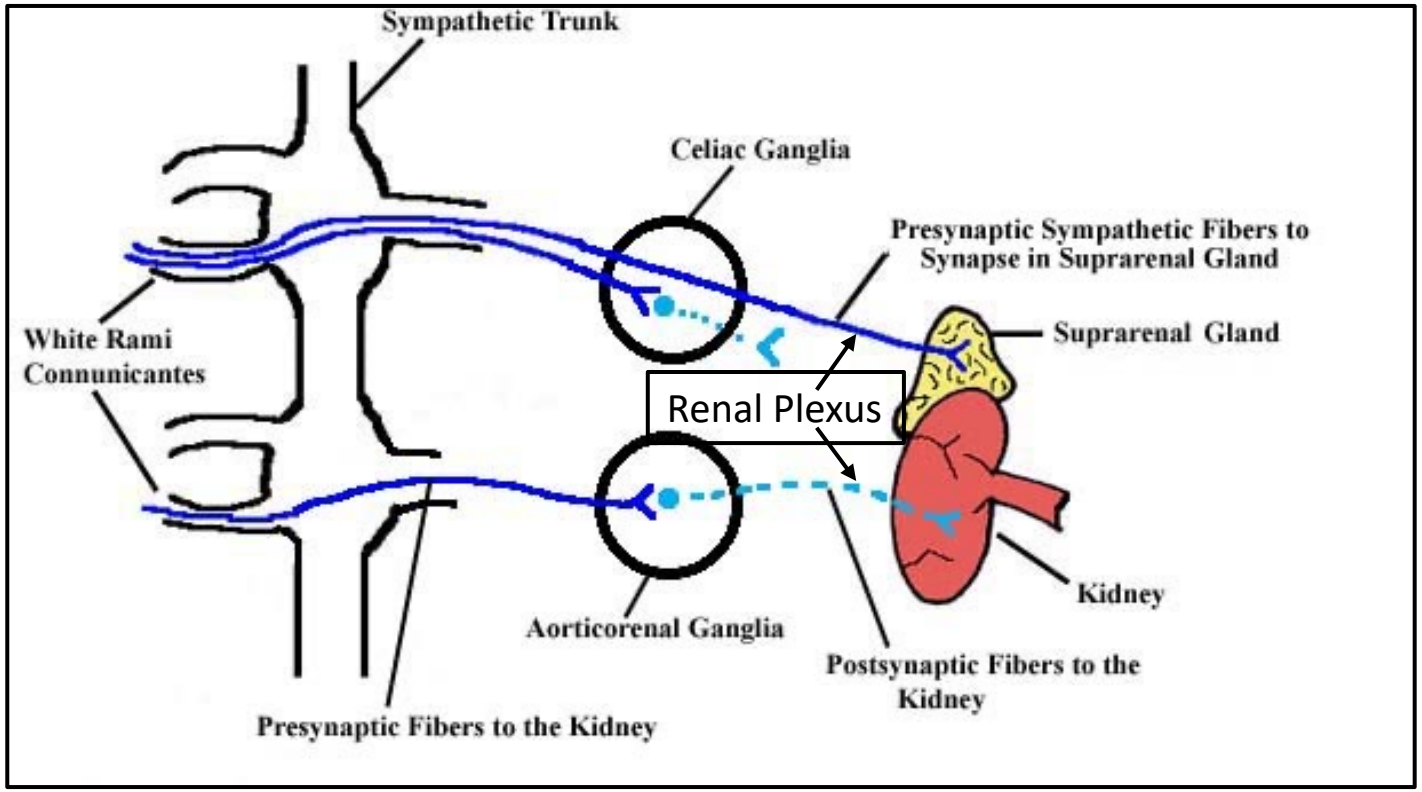




Sympathetic Innervation: Kidney, Ureters, and Adrenal

- Suprarenal (Adrenal) glands
  - Preganglionic cell bodies: **T5-T10** lateral horns of spinal cord
  - Preganglionic axons: **Greater and Lesser splanchnic nerves → Renal Plexus**
  - Postganglionic cell bodies: **Chromaffin cells**
  - Postganglionic axons: **None**

- Kidneys and abdominal portions of ureters:
  - Preganglionic cell bodies: **T10-T12** lateral horns of spinal cord
  - Preganglionic axons: **Lesser and Least splanchnic nerves**
  - Postganglionic cell bodies: **Aorticorenal prevertebral ganglia**
  - Postganglionic axons: Renal perivascular plexus

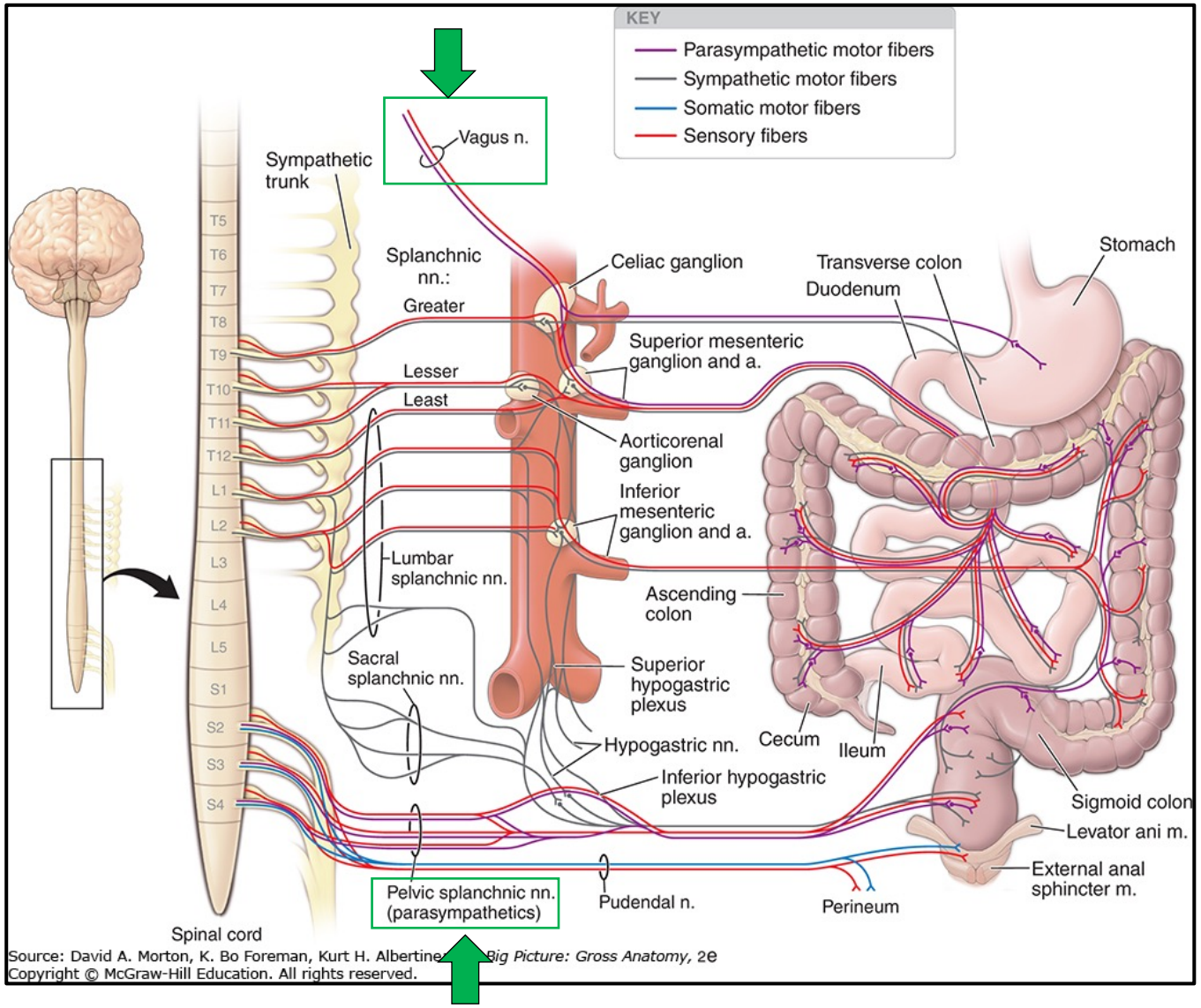


Parasympathetic Innervation of Abdominal Viscera

- Foregut
  - Preganglionic cell bodies: **Brainstem**
  - Preganglionic axons:
    - Esophagus: recurrent laryngeal and vagus → **esophageal plexus**
    - Foregut inferior to diaphragm: Vagal trunks → **celiac plexus**
  - Postganglionic cell bodies: **Wall of organ**
  - Postganglionic axons: **Wall of organ** (submucosal/myenteric plexus)

- Midgut
  - Preganglionic cell bodies: **Brainstem**
  - Preganglionic axons: **Vagal trunks and Superior mesenteric perivascular plexus**
  - Postganglionic cell bodies: **Wall of organ**
  - Postganglionic axons: **Wall of organ** (submucosal/myenteric plexus)

- Hindgut
  - Preganglionic**: Intermediolateral column (lateral horn) S2-4**
  - Preganglionic axons: **Pelvic splanchnic nerves**
  - Postganglionic cell bodies: **Wall of organ**
  - Referred pain: **Pain fibers from distal ½ of sigmoid colon to pectineal line travel with pelvic splanchnic nerves back to spinal cord**



Helpful Table to Bring Concepts Together

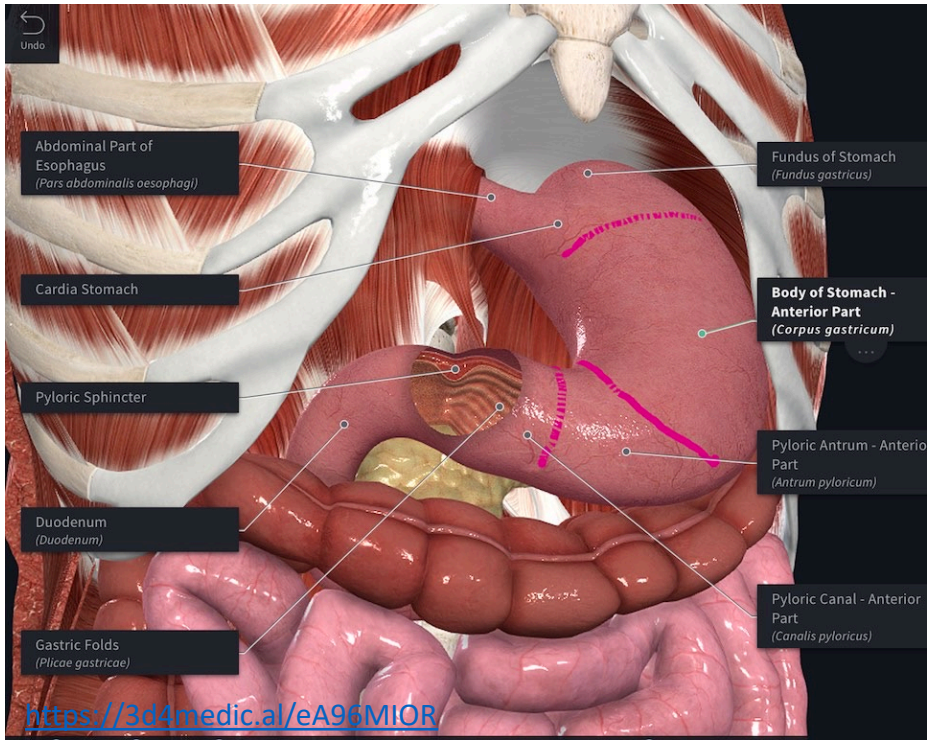
Table III-3-1. Adult Structures Derived from Each of the 3 Divisions of the Primitive Gut Tube

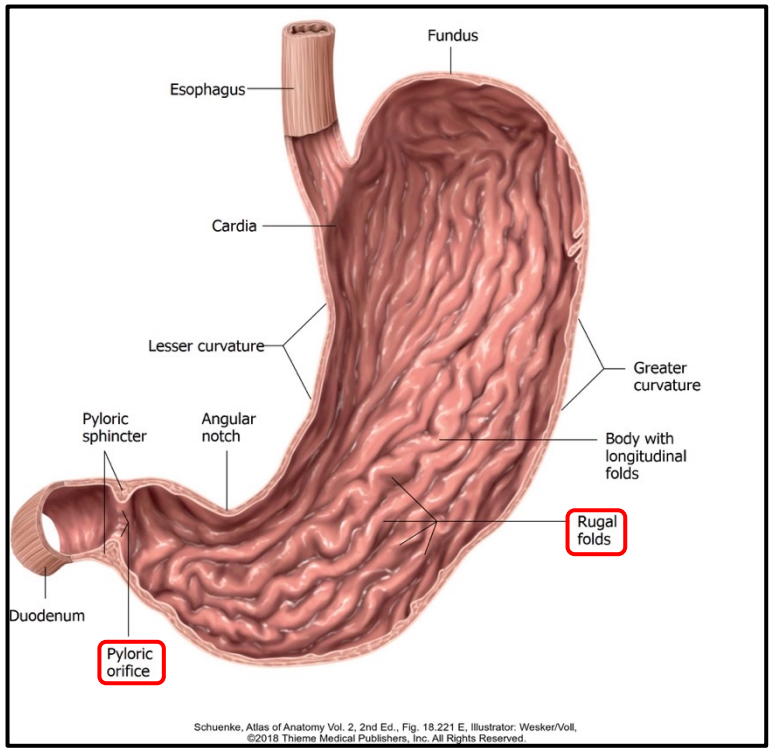
Foregut	Midgut	Hindgut
Artery: celiac	**Artery:** superior mesenteric	**Artery:** inferior mesenteric
Parasympathetic innervation: vagus nerves	**Parasympathetic innervation:** vagus nerves	**Parasympathetic innervation:** pelvic splanchnic nerves
Sympathetic innervation:	**Sympathetic innervation:**	**Sympathetic innervation:**
• Preganglionics: thoracic splanchnic nerves, T5–T9	• Preganglionics: thoracic splanchnic nerves, T9–T12	• Preganglionics: lumbar splanchnic nerves, L1–L2
• Postganglionic cell bodies: celiac ganglion	• Postganglionic cell bodies: superior mesenteric ganglion	• Postganglionic cell bodies: inferior mesenteric ganglion
Referred Pain: Epigastrium	**Referred Pain:** Umbilical	**Referred Pain:** Hypogastrium
Foregut Derivatives	**Midgut Derivatives**	**Hindgut Derivatives**
Esophagus Stomach Duodenum (first and second parts) Liver Pancreas Biliary apparatus Gallbladder	Duodenum (second, third, and fourth parts) Jejunum Ileum Cecum Appendix Ascending colon Transverse colon (proximal two-thirds)	Transverse colon (distal third—splenic flexure) Descending colon Sigmoid colon Rectum Anal canal (above pectinate line)

Stomach: Review

The **stomach** is a sac-like organ whose proximal end is located at the inferior end of the esophagus. The distal end of the stomach opens into the duodenum, which is the first section of the small intestine. Its size can vary from about 50 mL when empty to as much as 4L when full.

- The **lesser curvature** of the stomach is the concave superior curve off of which the lesser omentum projects.
- The **greater curvature** of the stomach is the inferior convex curve off of which the greater omentum projects.
- The stomach is divided into four major regions.
  - The **cardia** is a small region of the stomach that joins with the distal esophagus**.** A bolus of food enters the stomach through the cardiac region.
  - The **fundus** is the dome-shaped region of the stomach above the level of the cardial orifice.
  - The **body** is the largest, centrally located portion of the stomach.
  - The body narrows at its distal end to form the **pyloric region** of the stomach. It consists of a wider **pyloric antrum** that narrows to form the **pyloric canal**. The pylorus lies at the level of the L1 vertebra. As a result, this transverse level is referred to as the transpyloric plane.
- The **pyloric sphincter** is a ring of smooth muscle that surrounds the junction point where the stomach empties into the duodenum. It regulates the emptying of stomach contents into the small intestine.
- **Rugae** are longitudinal folds of the internal wall of the stomach that allow the stomach wall to stretch during a meal. They are formed by folding of both the mucosa and submucosa.



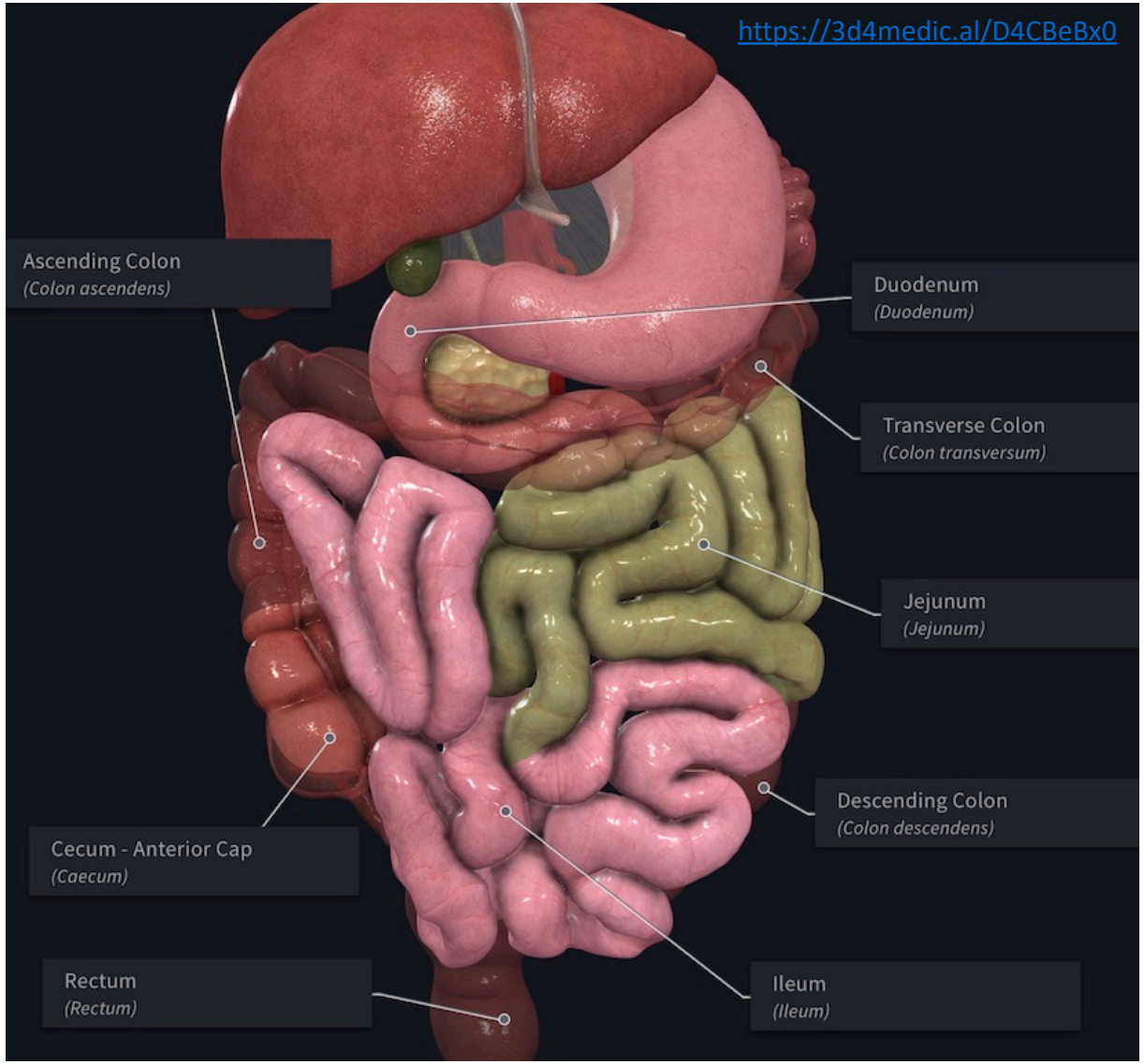


Small Intestine: Review

The small intestine is a 20 ft long (in a cadaver), highly coiled tube. The process of digestion is completed in the lumen of small intestine, which results in nutrients that can be transported across its wall by a process called nutrient absorption.

The small intestine consists of three regions.

- The **duodenum** (“twelve finger widths long”) is the first 10 inches of small intestine.
- The **jejunum** (“empty”) is the middle portion of the small intestine that is 8 feet in length.
- The **ileum** (“twisted”) is the distal 12 feet of the small intestine that joins with the large intestine at the cecum.

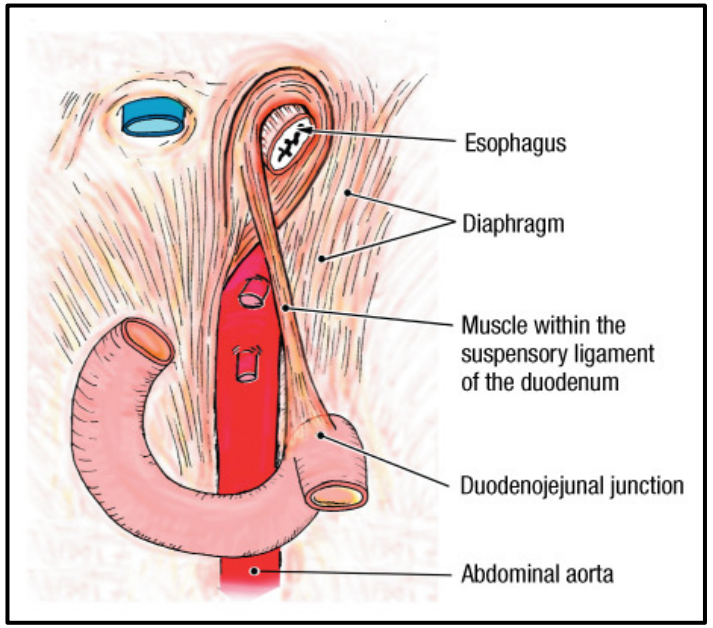


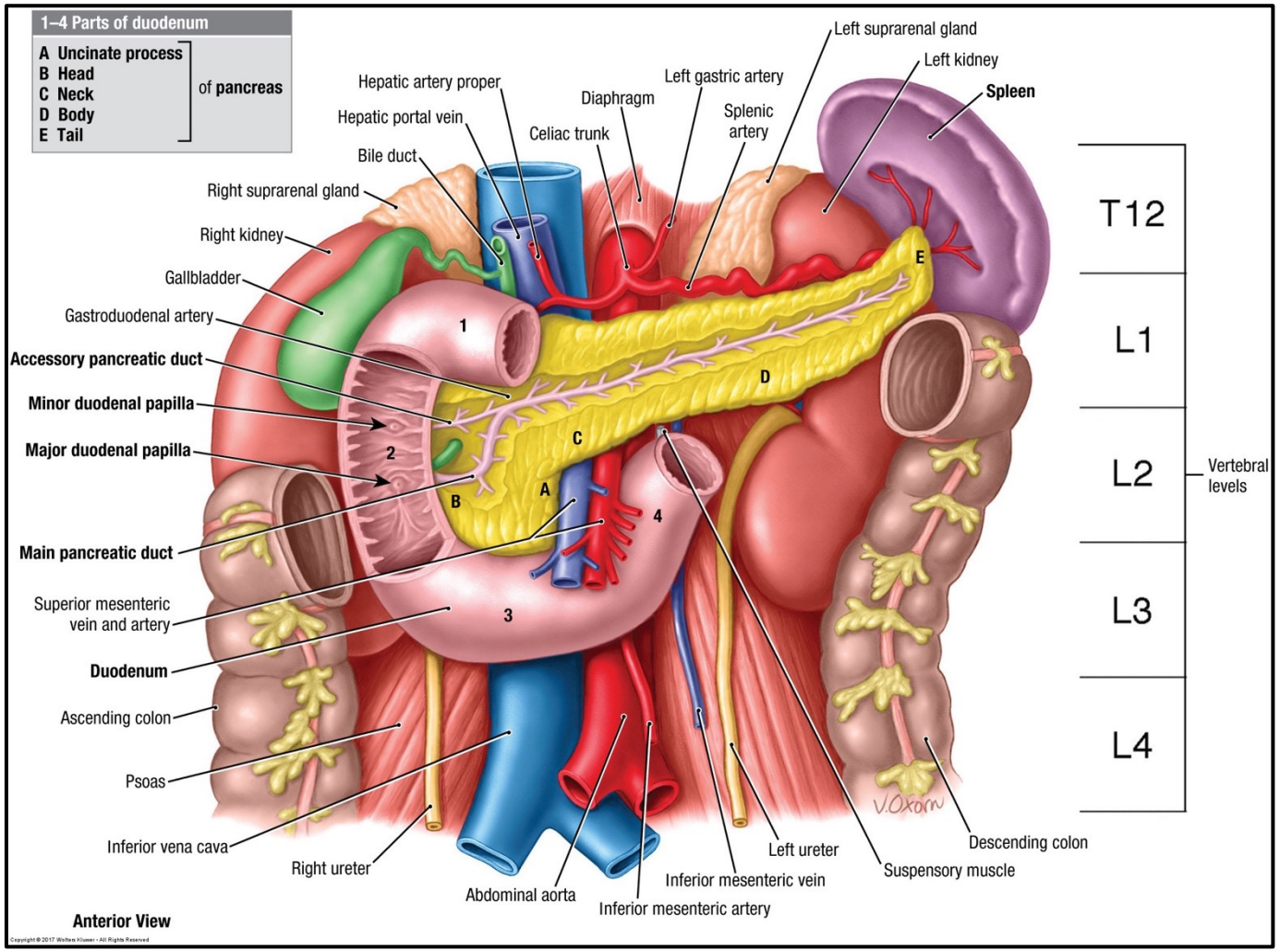
Duodenum

The duodenum is the first 10 inches of small intestine that connects the stomach to the jejunum. Its shape resembles the letter “C,” with its concave portion cradling the head of the pancreas. The major duodenal papilla marks the transition between the portion of the gastrointestinal tract derived from the embryonic foregut and the portion derived from embryonic midgut.

- **1st part: superior**
- **2nd part: descending**
- **3rd part: horizontal**
- **4th part: ascending**

The duodenum ends at the duodenojejunal flexure which is anchored to the posterior abdominal wall by a fibromuscular band, called the suspensory ligament of the duodenum (ligament of Treitz). The suspensory ligament is an important surgical landmark that is helps to identify the transition point between the duodenum and the jejunum.



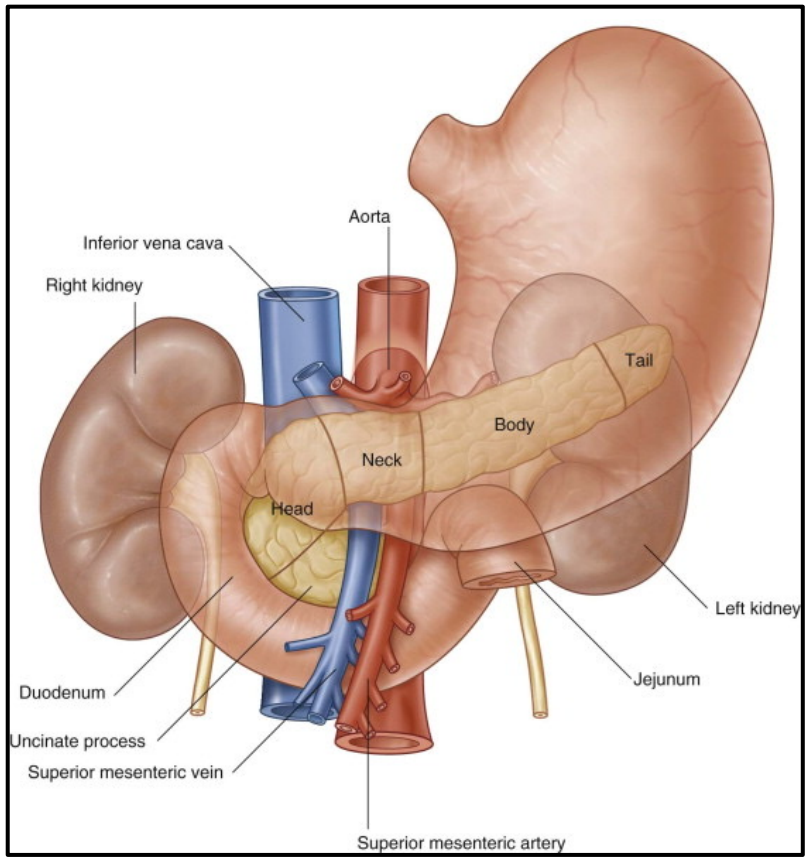


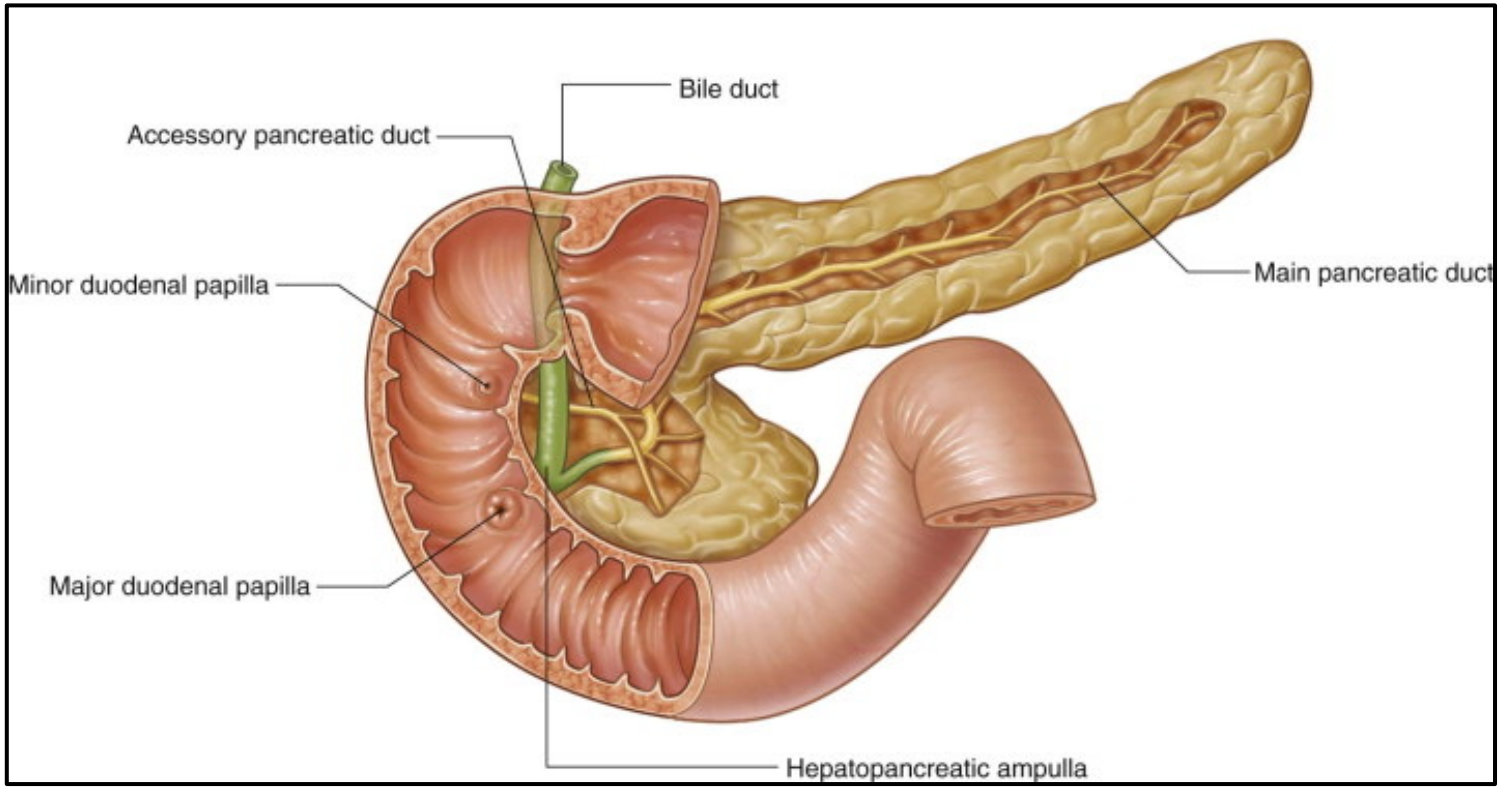
Pancreas

The pancreas consists of the following parts.

- The **head** of the pancreas is nestled into the C-shaped curve of the duodenum.
- The **uncinate process** of the pancreas is a continuation of the pancreas' head that projects in a slight posterior direction. The superior mesenteric artery and vein pass over the duodenum as well as the uncinate process of the pancreas to pass posterior to the neck of the pancreas.
- The **neck of the pancreas** is between the pancreas' head and **body**. The superior mesenteric artery and vein pass posterior to the neck.
- The major portion of the pancreas is called the **body of the pancreas** and projects toward the left side of the body away from the head.
- The narrow distal end is called the **tail of the pancreas** and is located near the hilum of the spleen.

The major drainage of pancreatic juice out of the pancreas is through the pancreatic duct that runs the length of the interior of the pancreas.
The bile duct from the gall bladder and the pancreatic duct join just before entering the duodenum to form the hepatopancreatic ampulla (of Vater).



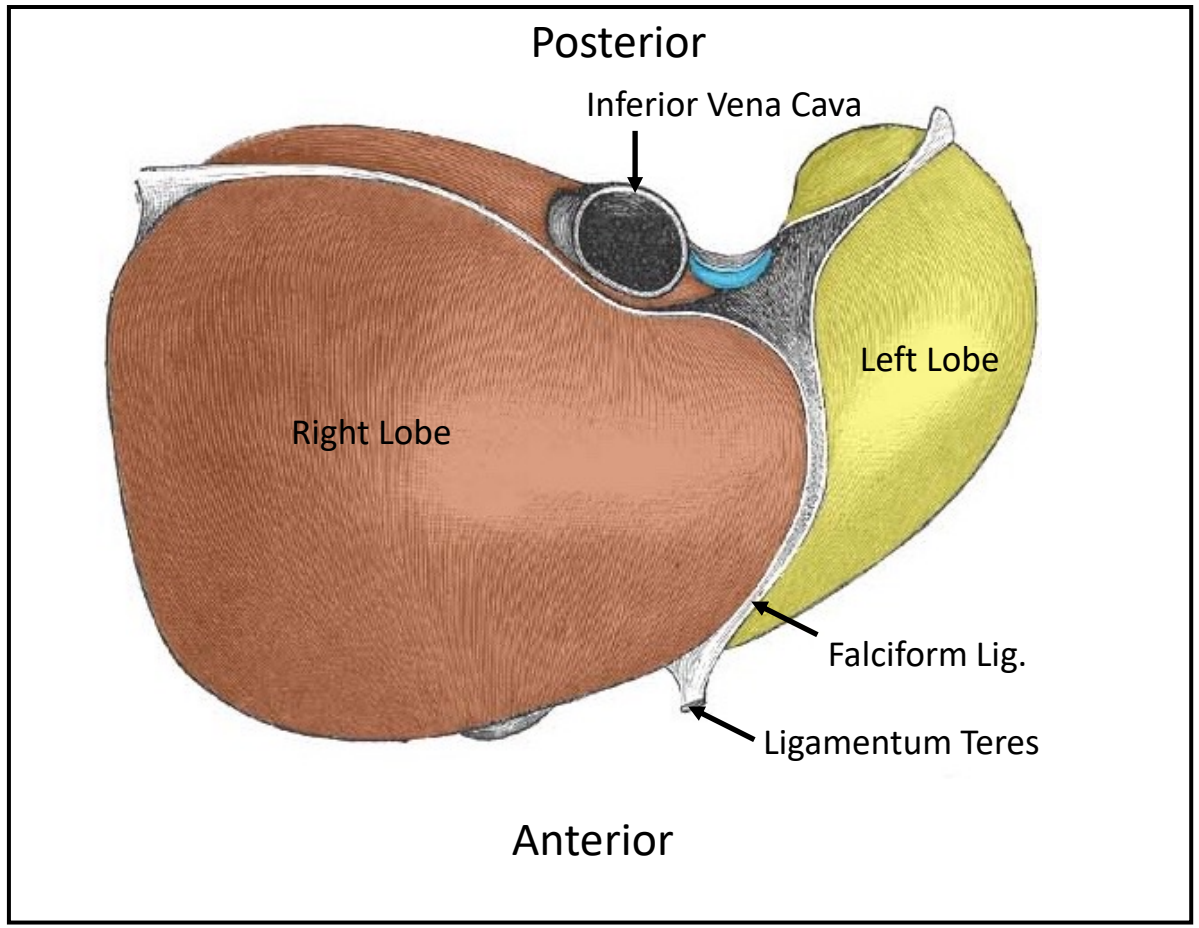


Liver Anatomical Lobes

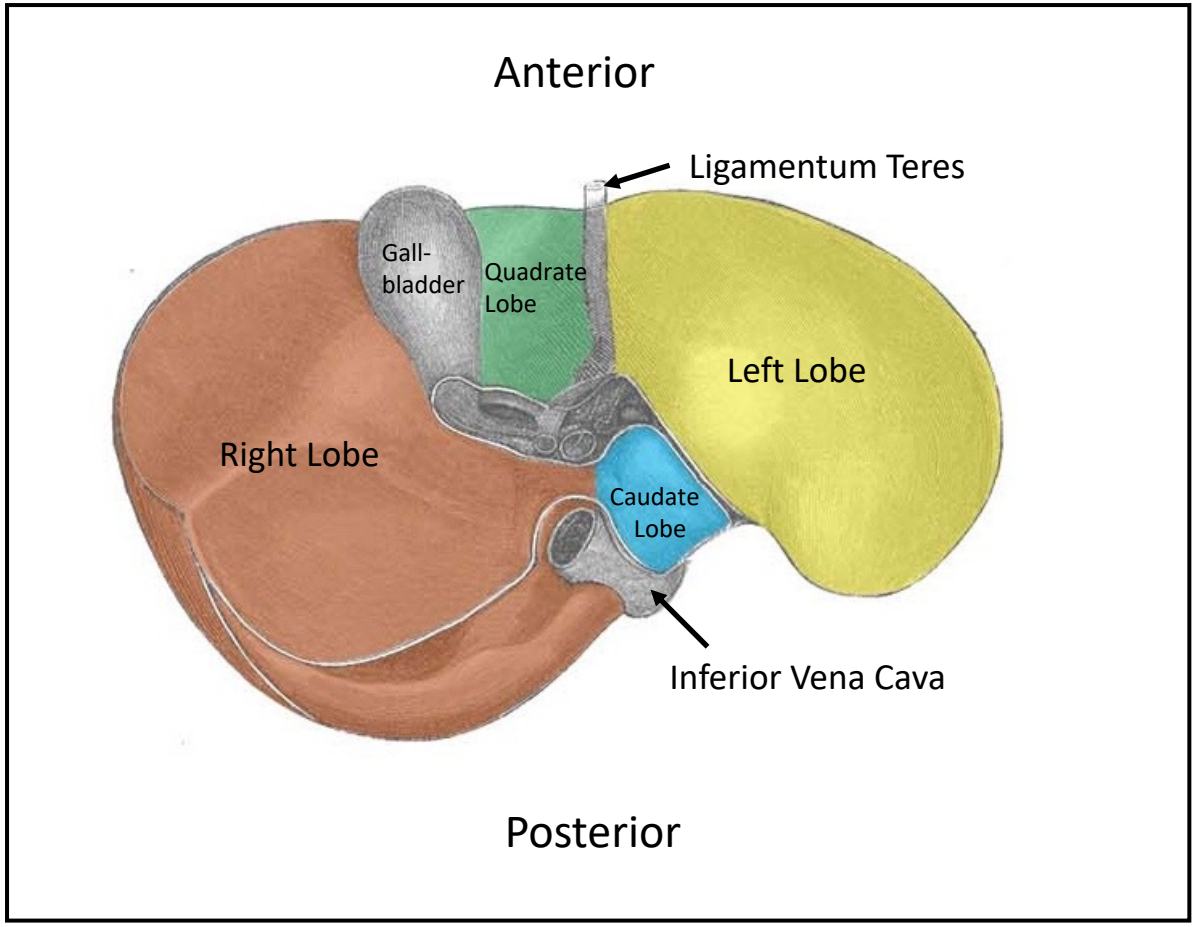
The **liver** is the largest and one of the most important metabolic organs of the body. However, its only digestive function is to produce complex fluid called bile that aids in fat digestion.

- Anatomically the **liver** is divided into four lobes.
  - The **right and left lobes** can be seen in an anterior view and are separated by the falciform ligament.
  - The **quadrate and caudate lobes** can be visualized in an inferior view.
    - The **quadrate lobe** is surrounded by the gallbladder on the right, the porta hepatis posteriorly, and the round ligament on the left.
    - The **caudate lo**be is posterior to the porta hepatis and is bordered on the right by the inferior vena cava.

Superior View of Liver



Inferior View of Liver



Portal Circulation

Venous drainage from the spleen, pancreas, gallbladder, and abdominal part of the gastrointestinal tract (except for the inferior part of the rectum), is through the hepatic portal system of veins. This blood is described as being nutrient-rich blood as compared to arterial blood, which is described as oxygen-rich blood.

- The **hepatic portal vein** is the final common pathway for nutrient-rich blood on its path to enter the liver. Within the liver, nutrient-rich blood mixes with oxygen-rich blood. This mixing occurs within the liver's capillary network called hepatic sinusoids.
- After exiting hepatic sinusoids, this blood passes through progressively larger veins to enter the **hepatic veins**. The hepatic veins ultimately drain this mixed blood into the vena cava to join the venous circulation destined to be transported back to the heart. This junction between hepatic veins and the inferior vena cava is located just inferior to the diaphragm. The hepatic veins are difficult to see in anatomical dissection because they are short, covered by the diaphragm, and surrounded by liver tissue.

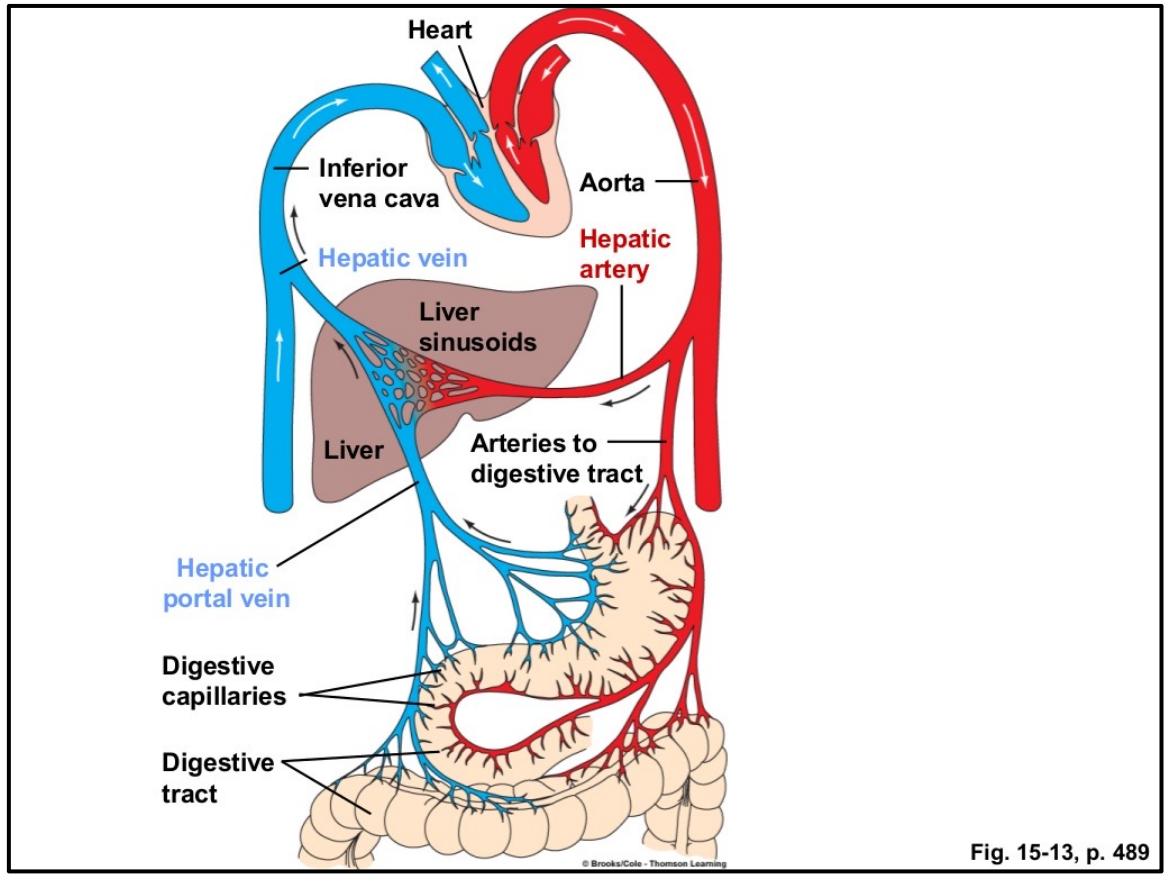
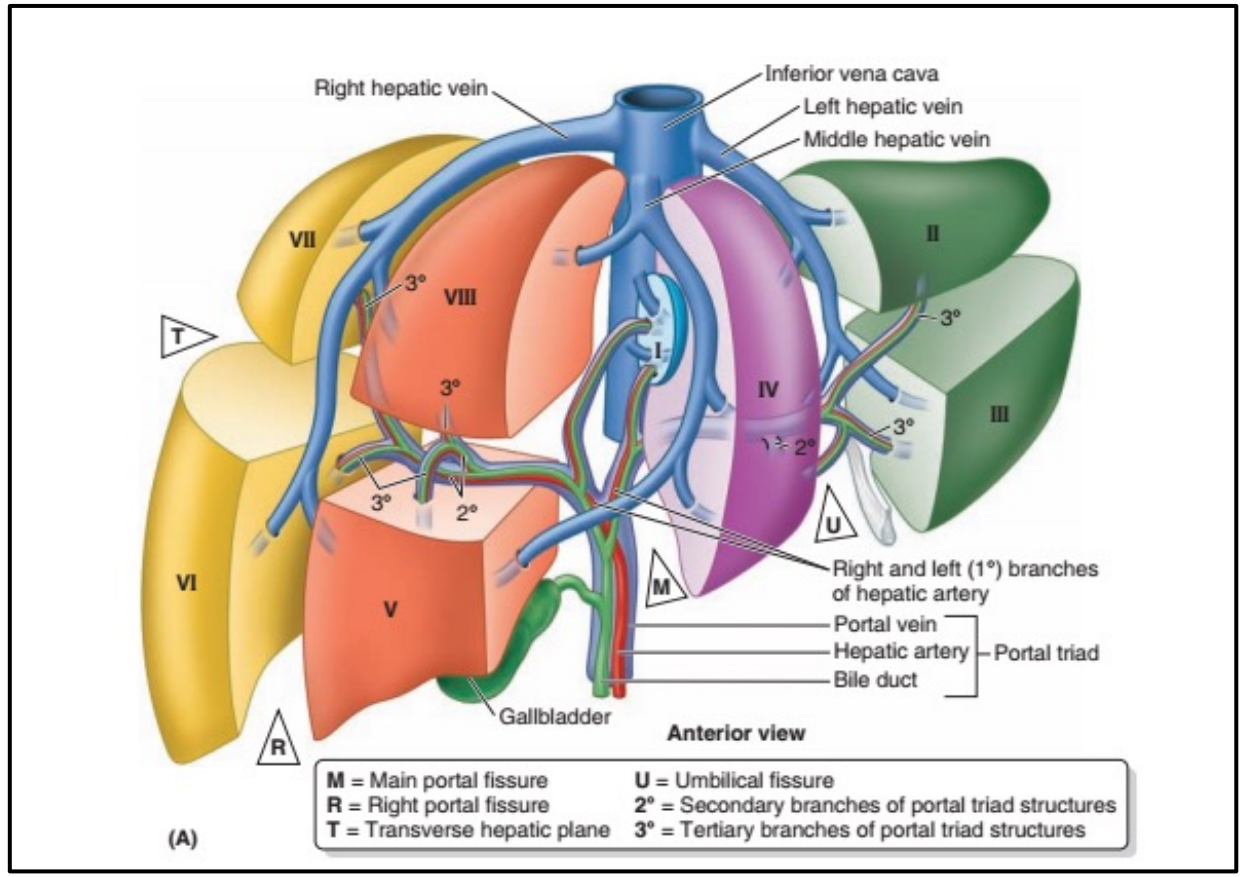


Fig. 15-13, p. 489

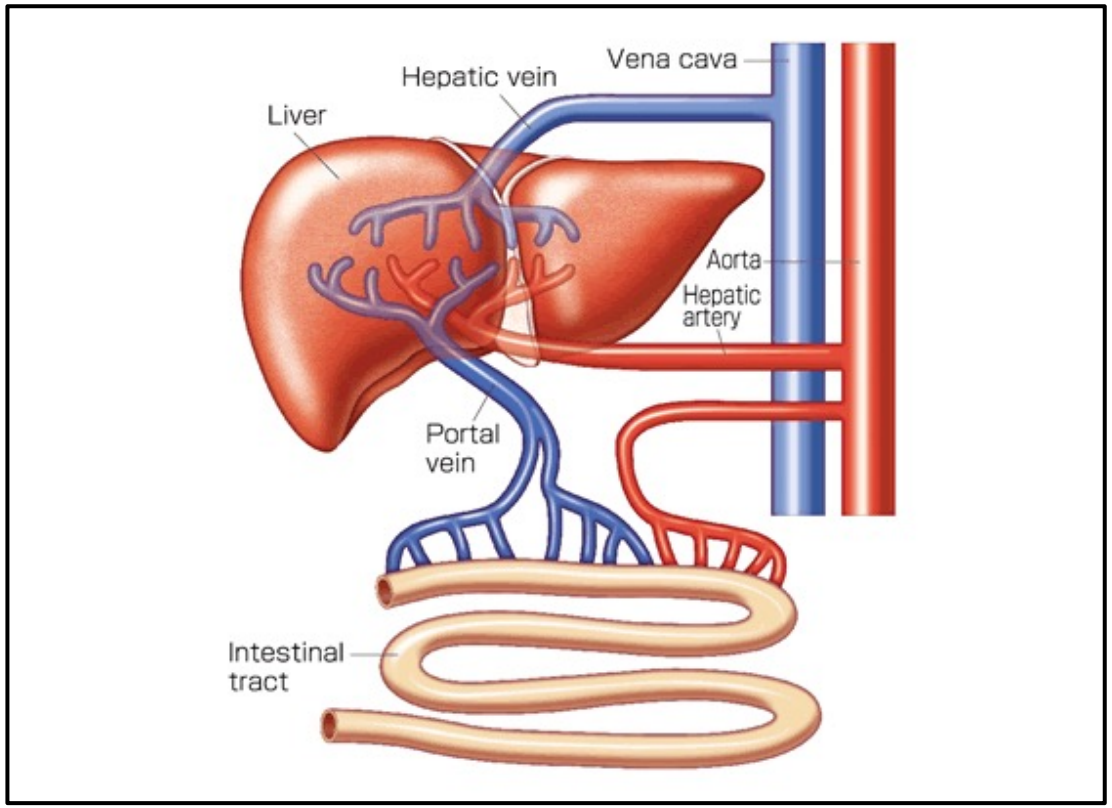


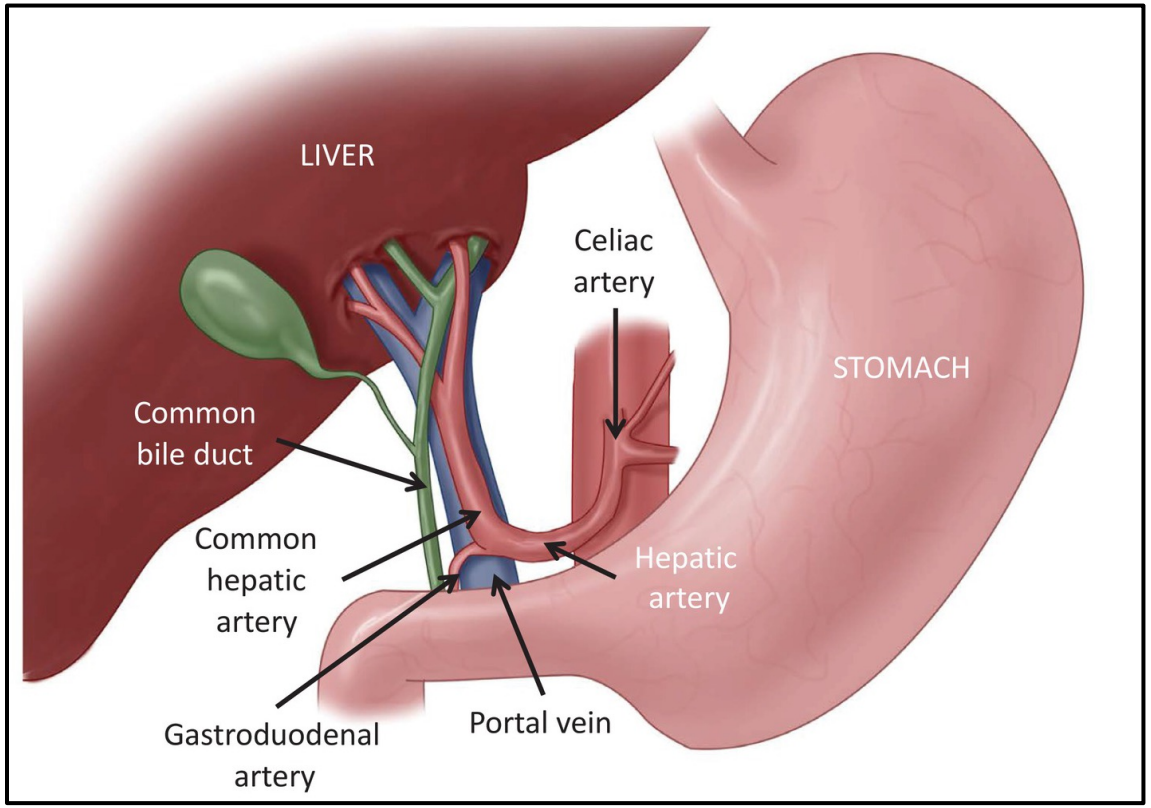
Liver Blood Supply

The liver is the only organ in the body that receives its oxygen supply and nutrient supply through two different types of blood vessels. All other organs are supplied by a single type of vessel, an artery, and a vein that drains the organ of waste products.

Three major structures enter and exit the liver on its inferior side at a location called the **porta hepatis**, or "gateway to the liver." The porta hepatis is the liver fissure in which the contents of the portal triad enter and exit the liver. The portal triad consists of the following structures.

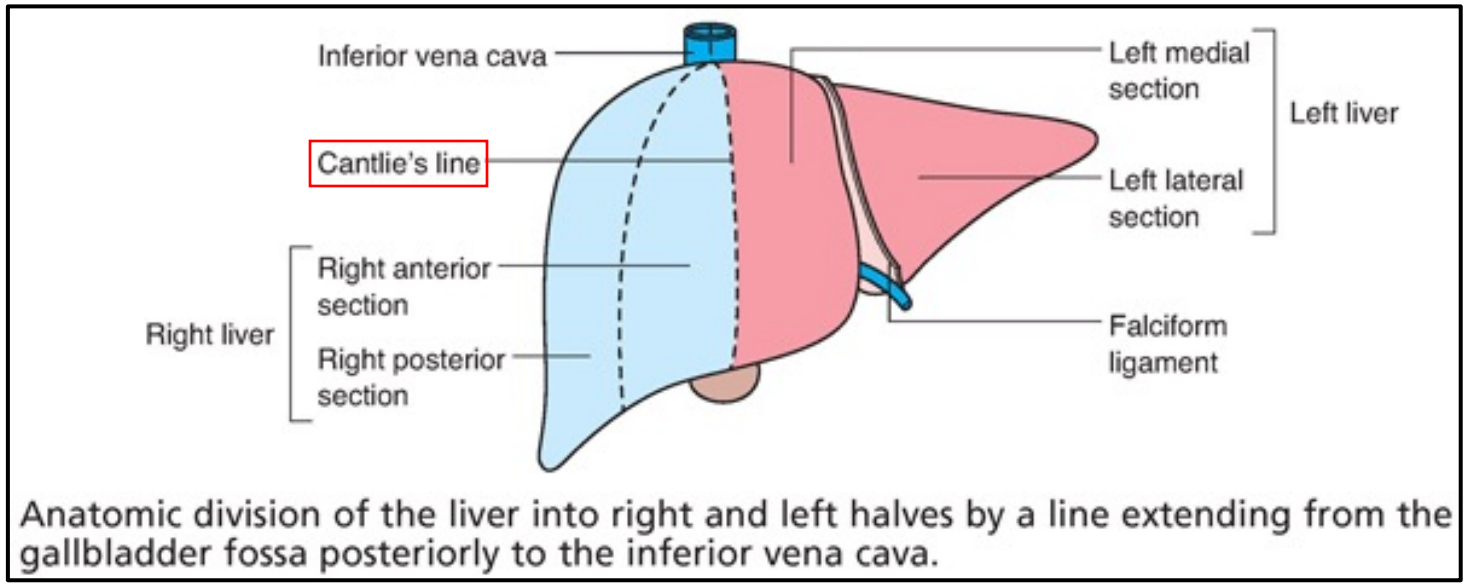
- The **hepatic artery** is a small, round blood vessel that transports oxygen-rich blood to the liver. It is typically colored red in anatomical drawings.
- The **hepatic portal vein,** which transports nutrient-rich blood to the liver from the GI tract, is larger in diameter than the hepatic artery and thinner-walled. Because it is thinner-walled, it appears more collapsed in the cadaver. It is typically colored blue in anatomical drawings.
- The **common hepatic duct** is a small-diameter, greenish colored duct that transports bile to the common bile duct. It is typically colored green in anatomical drawings.





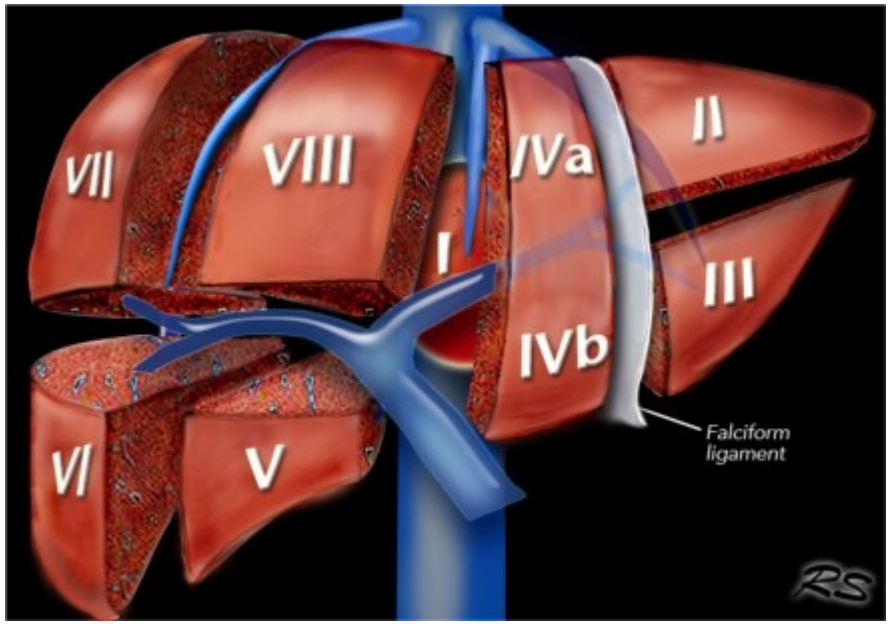
Liver Segments

CLINICAL ANATOMY: Although divided anatomically into four lobes, from a functional perspective the liver consists of right and left "portal lobes" each of which receives its own hepatic artery and hepatic portal vein and is drained by its own hepatic duct. The portal lobes are further divided into arterially-independent (and, therefore, surgically resectable) segments. The division between right and left portal lobes is an imaginary sagittal line drawn from the inferior vena cava to the gallbladder (Cantlie's line).



Anatomic division of the liver into right and left halves by a line extending from the gallbladder fossa posteriorly to the inferior vena cava.

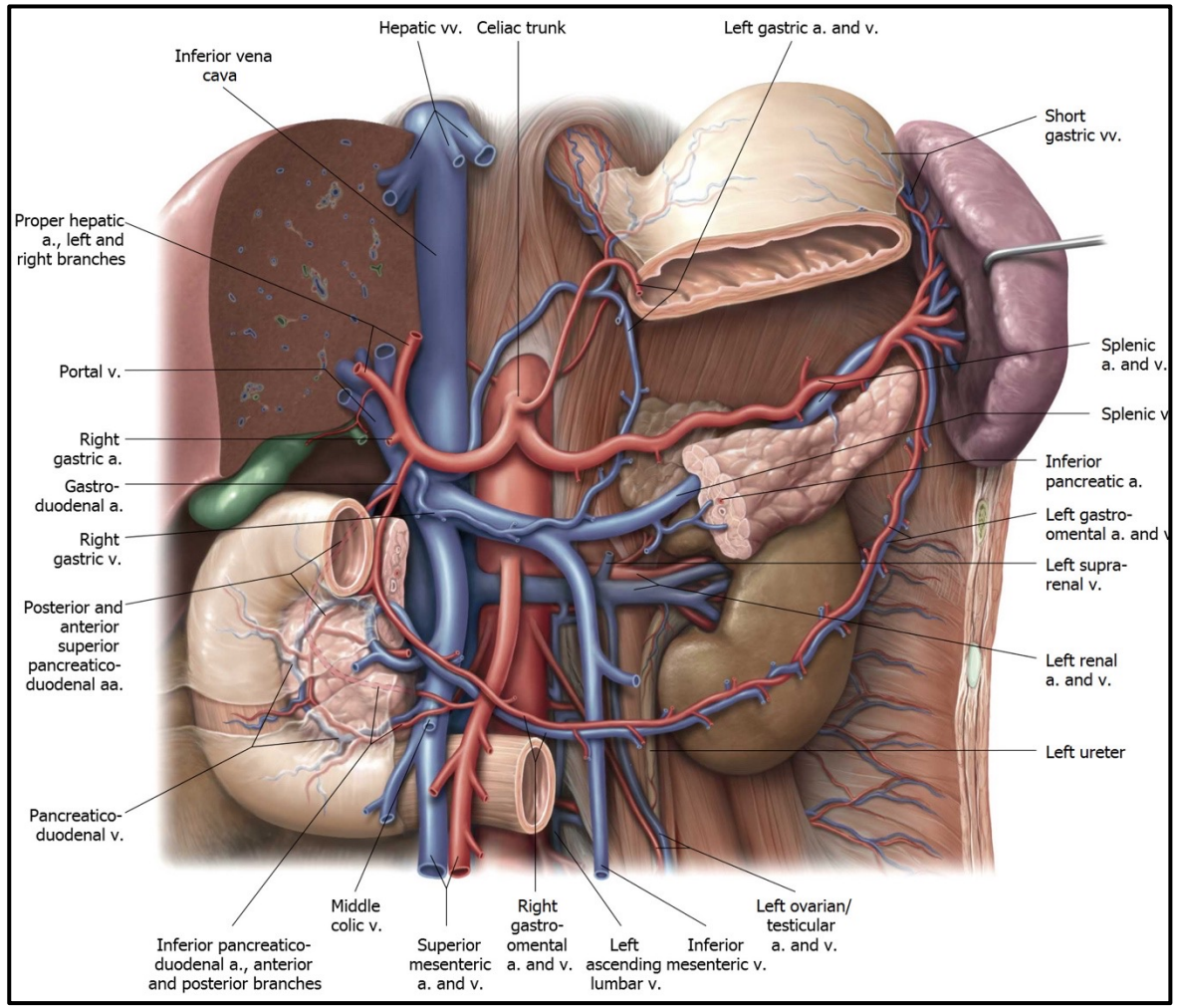
Surgically Resectable Liver Segments

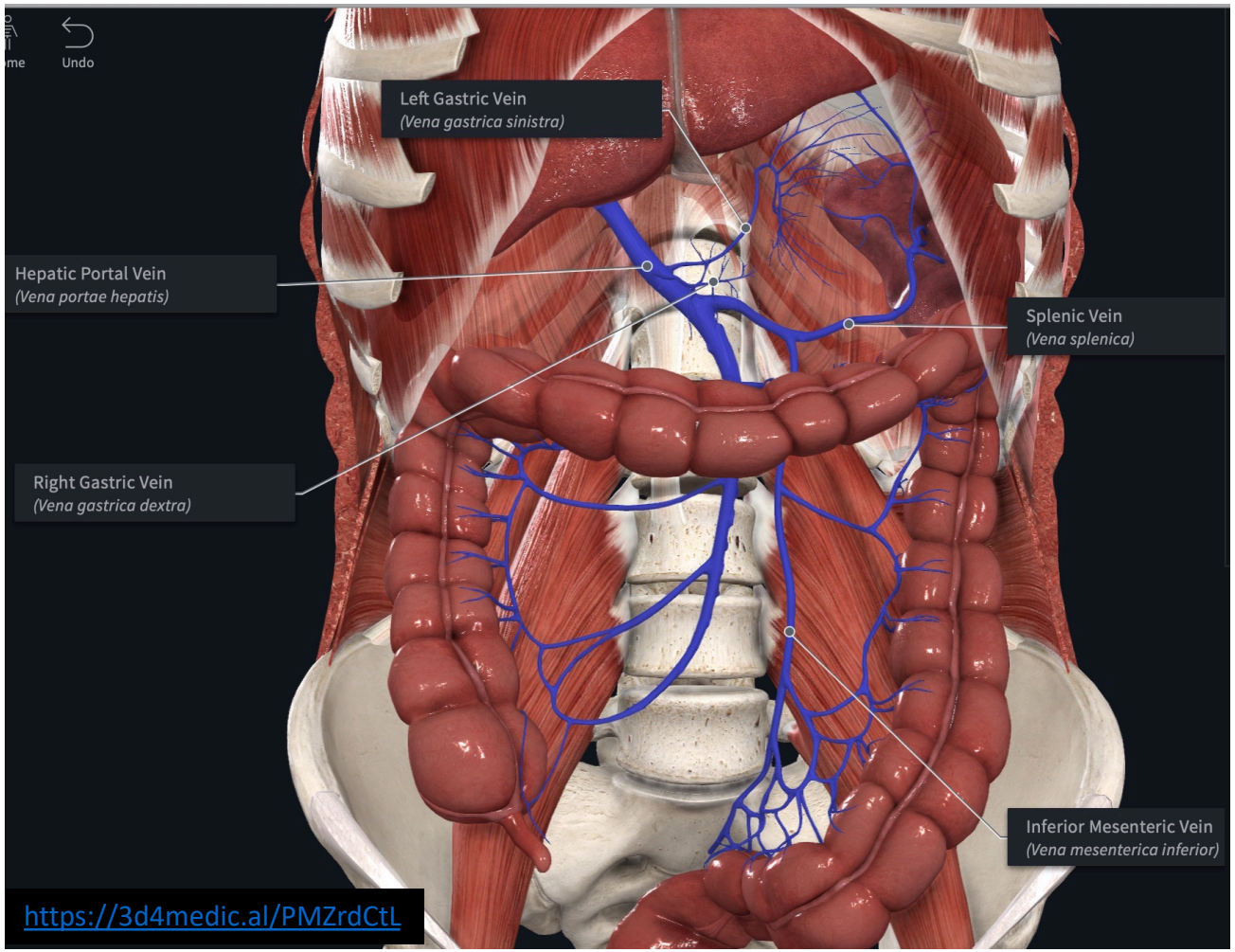


Tributaries of the Hepatic Portal Vein

All of the following veins drain into the hepatic portal vein.

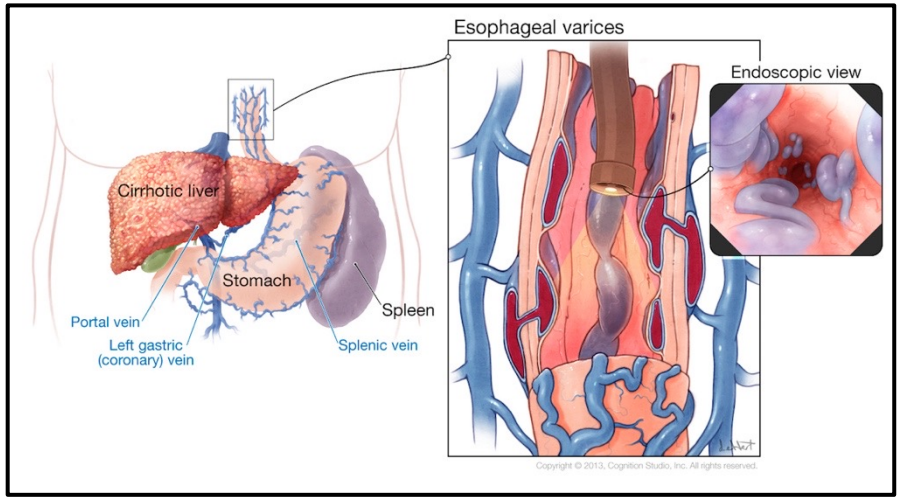
VEIN	DRAINS INTO	ORGANS DRAINED
Splenic v	Joins superior mesenteric vein to form hepatic portal v.	Last 1/3 of transverse colon and descending colon
Superior mesenteric v..	Joins splenic vein to form hepatic portal v.	Midgut and part of foregut (greater curvature of stomach via greater omental veins)
Inferior mesenteric v.	Splenic vein (sometimes SMA)	Hindgut including proximal third of rectum
Gastric veins (left and right)	Hepatic portal v.	Lesser curvature of stomach

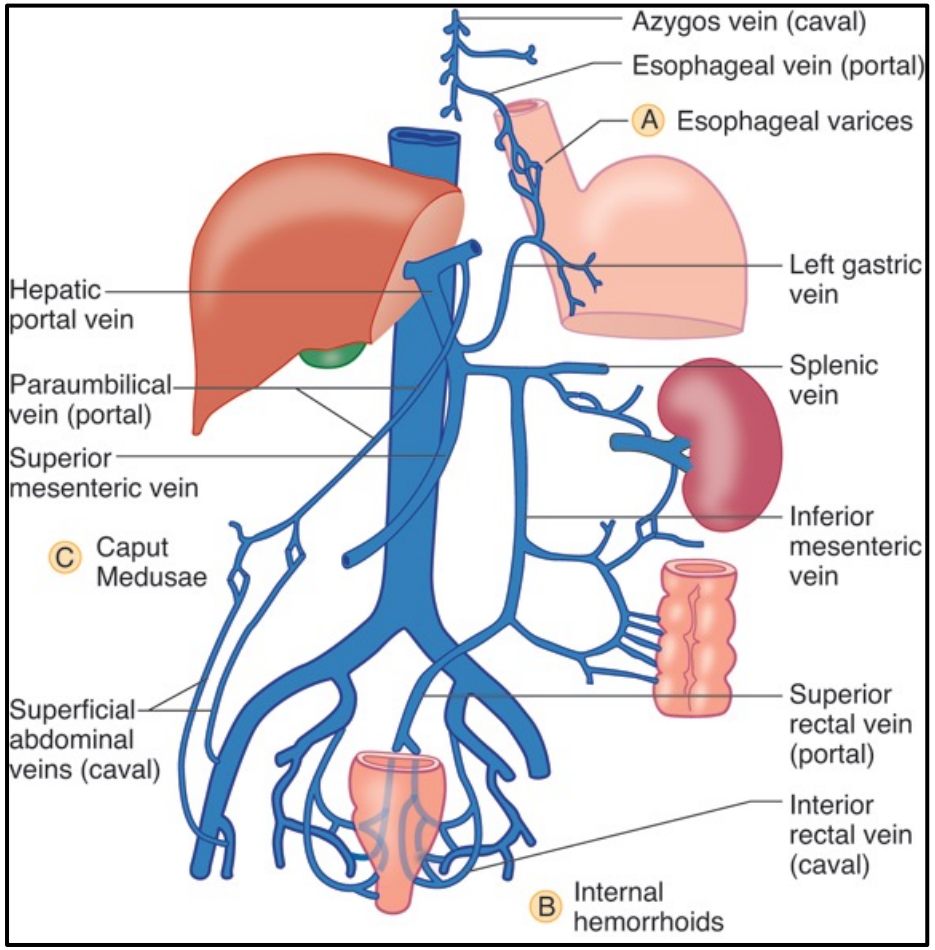




Portacaval Anastomoses

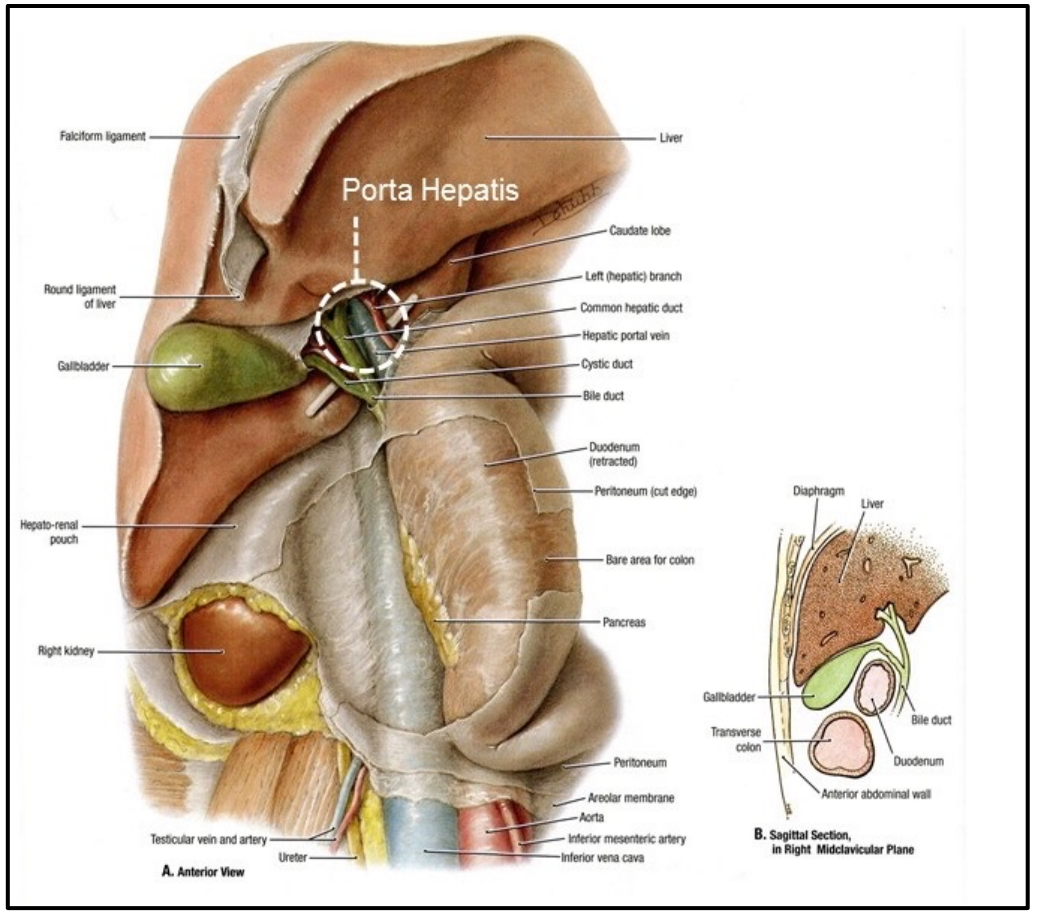
- **Hepatic portal venous system** refers to the ”nutrient-rich” venous blood that is transported from the foregut, midgut, and hindgut to the liver.
- **Caval (venous) system** refers to veins from the lower limbs, pelvis, and posterior abdominal wall that transport venous blood directly to the inferior vena cava.
- A **portacaval anastomosis** is a junction between areas drained by BOTH the portal and caval systems. The clinically important portal-caval anastomoses include the following junctions. In severe cases of portal hypertension, these regions become engorged with blood.
  - Anterior abdominal wall (Figure = Letter C): Results in caput medusae
    - Superficial epigastric veins (skin around umbilicus) → paraumbilical veins → hepatic portal
    - Superficial epigastric veins (skin around umbilicus) → epigastric veins → venous circulation
  - Distal esophagus (Figure = Letter A): Results in esophageal varices
    - Esophagus → Azygos vein → superior vena cava
    - Esophagus → left gastric v.→ hepatic portal v.
  - Rectum (Figure = Letter B): Results in internal hemorrhoids
    - Superior rectal v. → Portal circulation
    - Middle and inferior rectal v. → inferior vena cava

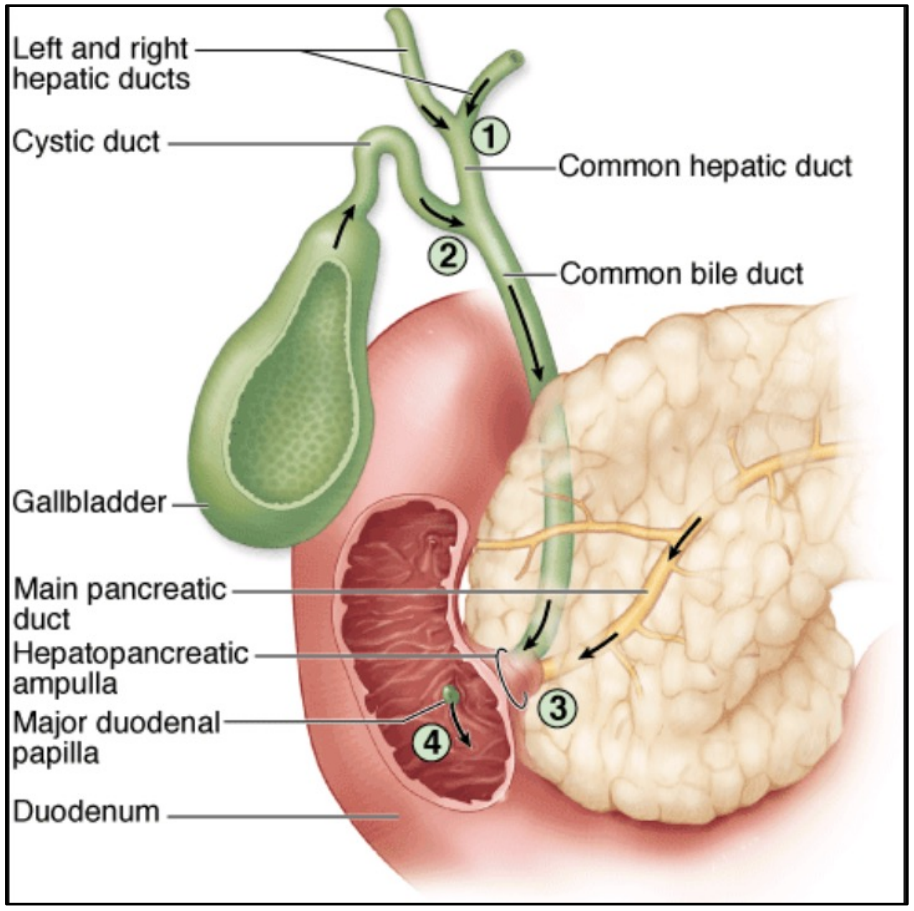




Biliary Tract

- Bile is transported out of the liver through the right and left **hepatic ducts** that unite to form the **common hepatic duct**. The common hepatic duct exits the liver at the **porta hepatis**.
- The cystic duct, which transports bile to and from the gallbladder, joins the common hepatic duct to form **the common bile duct**.
- The **gallbladder** is a four inch long storage sac for bile that is found on the inferior side of the liver. Bile enters and exits the gallbladder through the **cystic duct**.
- The common bile duct joins with the pancreatic duct just before penetrating the wall of the duodenum to form the **hepatopancreatic ampulla (of Vater).**
- The **hepatopancreatic sphincter (of Oddi)** is a ring of smooth muscle located in the wall of the ampulla where the ampulla empties into the duodenum. It controls the flow of bile and pancreatic secretions into the duodenum and prevents duodenal contents from entering into the ampulla.

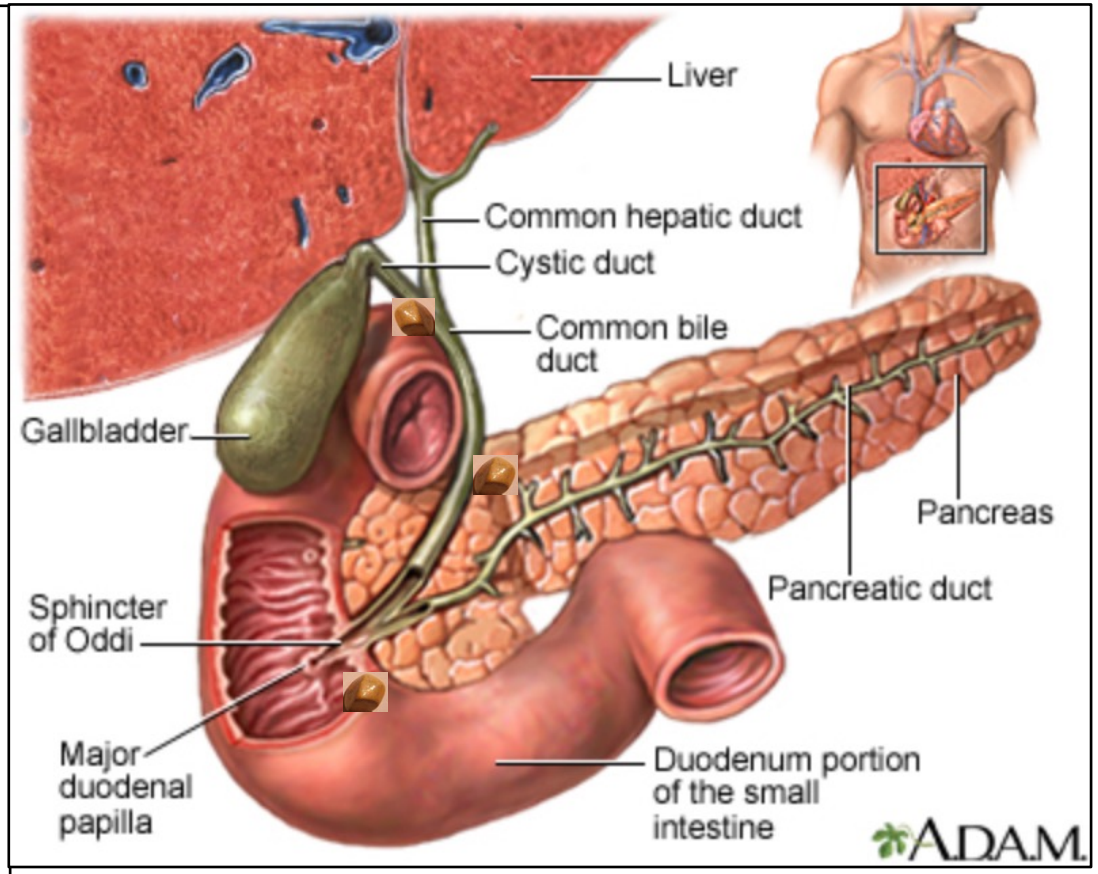




Gallstones

CLINICAL ANATOMY: Cholelithiasis (gallstones in the gallbladder) is a fairly common condition affecting 10-15% of the population. Most of the time, cholelithiasis is an asymptomatic and the presence of gallstones is discovered incidentally. There are three locations where gallstones are more likely to cause an obstruction along the biliary tree.

1. Obstruction at the opening of or within the **cystic duct** can cause:
   - Cholelithiasis – (usually) asymptomatic presence of gallstones in the gallbladder. Can cause biliary colic as stones intermittently occlude cystic duct: Severe, intermittent RUQ/Epigastric pain. Pain usually lasts up to a few hours. Post-fatty meal. No fevers/chills.
   - Cholecystitis – Severe, constant RUQ/Epigastric pain. Positive fevers, chills, nausea, vomiting. May radiate to right shoulder. Positive murphy's sign (sensitive, not specific)
2. Obstruction in the **common bile duct** can cause:
   - Choledocholithiasis – Presence of gallstones in the CBD. RUQ pain, jaundice, clay-colored stools. Elevated liver enzymes. Usually negative murphy's sign.
   - Acute (Ascending) Cholangitis is inflammation of the bile duct typically due to bacteria ascending into the duct from the duodenum.
3. Obstruction at the **Hepatopancreatic ampulla (of Vater)** can cause:
   - Gallstone Pancreatitis – Severe epigastric pain, nausea, vomiting, elevated lipase/amylase. Can also have cholangitis.



CLINICAL ANATOMY: A pancreatic tumor in the head of the pancreas can block the common bile duct leading to jaundice. For this reason, jaundice can be an early sign of a tumor located in the pancreatic head .

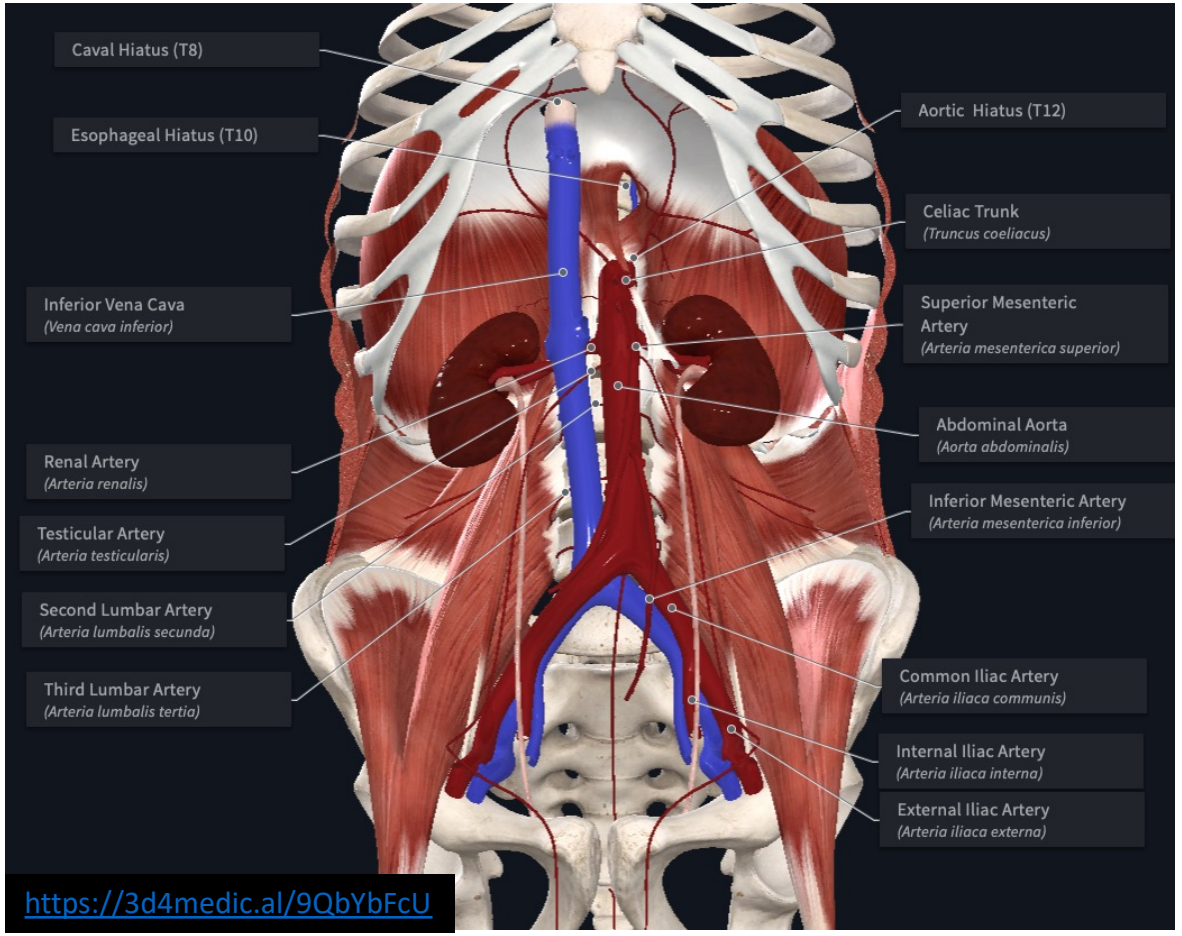
CLINICAL ANATOMY: Obstruction anywhere in the biliary tree that impedes the flow of bile FROM THE LIVER will cause overflow of bile into the bloodstream and thus an **obstructive jaundice**.

Abdominal Aorta

Path of the abdominal (descending) aorta (and its branches) through the abdominopelvic cavity.

- The **aorta** enters the abdomen by passing through the *aortic hiatus* of the thoracic diaphragm (at the level of the T12 vertebra).
- As the aorta descends through the abdomen it provides blood supply to the abdominal foregut, midgut and hindgut structures via the celiac trunk, superior mesenteric artery, and inferior mesenteric artery.
- At the level of the L4 vertebra the abdominal aorta bifurcates into **right** and **left common iliac arteries**, which diverge and descend towards the pelvis.
- At the level of the sacroiliac joint, the common iliac arteries divide into **external** and **internal iliac arteries**.
  - The external iliac artery passes through the subinguinal space and enters the thigh as the **femoral artery**.
  - The internal iliac artery is the principal supply to the pelvic viscera and walls, the perineum and the gluteal region.
- Major branches of the abdominal aorta and what each branch supplies is listed below in the table.

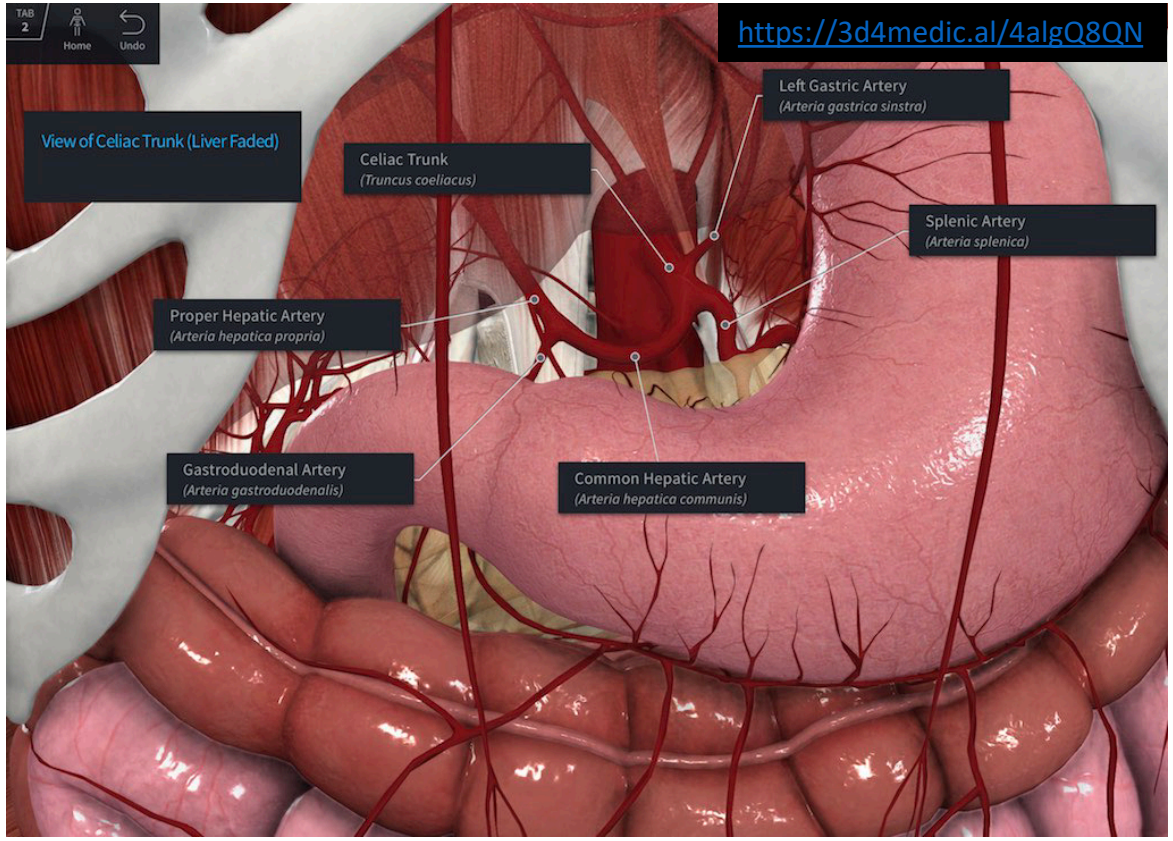
ORIGIN	ARTERY	MAJOR STRUCTURES SUPPLIED
Abdominal aorta	Intercostals/lumbar	abdominal wall
Abdominal aorta	Gonadal	testis and ovary
Abdominal aorta	Renal	kidney
Abdominal aorta	Celiac	foregut organs
Abdominal aorta	Superior mesenteric	midgut organs
Abdominal aorta	Inferior mesenteric	hindgut organs

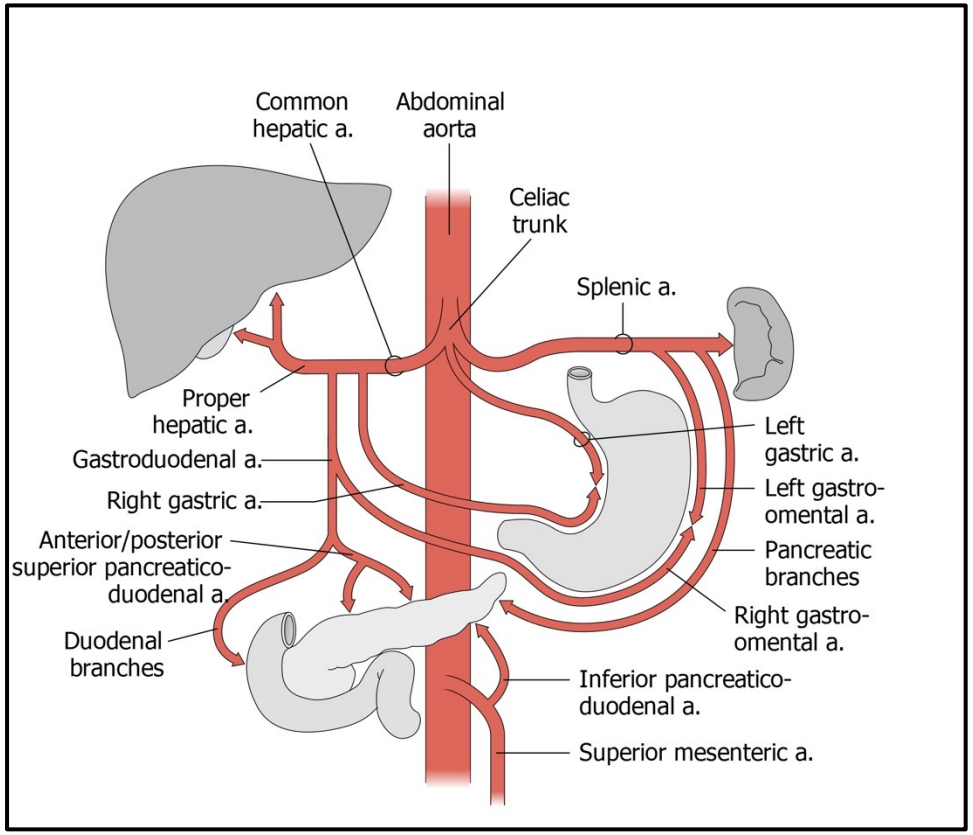


Celiac Trunk

The **celiac trunk** is the first major branch of the abdominal aorta and is the artery supplying the foregut. It branches from the aorta on the aorta's anterior side just distal to the aortic hiatus in the diaphragm through which the aorta passes. It branches from the aorta at approximately the T12 vertebral level and is around 1 cm in length. It forms 3 terminal arterial branches.

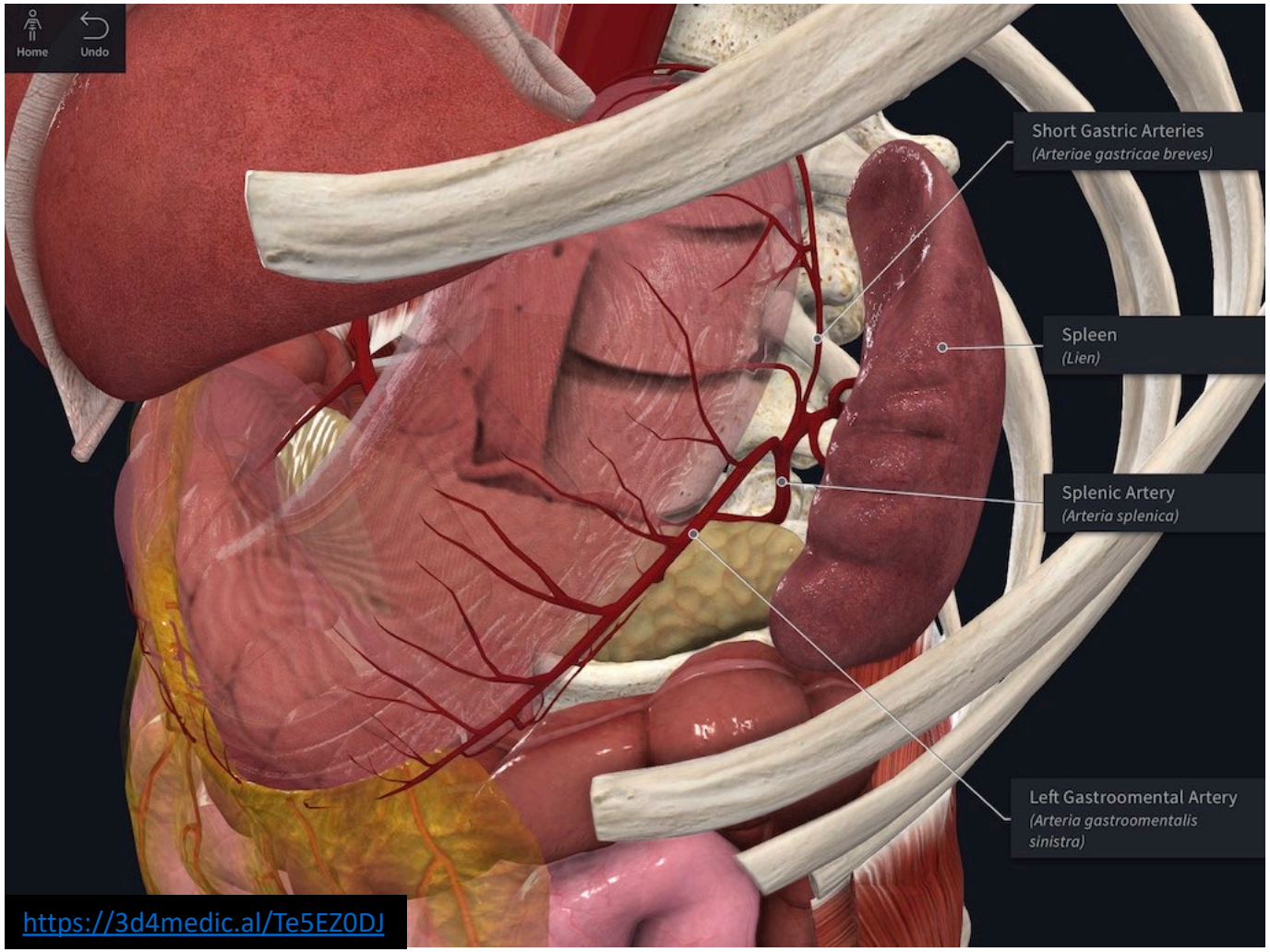
ARTERY	ORIGIN	ORGANS SUPPLIED	ANASTOMOSIS
Left gastric a	Celiac Trunk	• Distal (mostly abdominal) part of esophagus • Lesser curvature of stomach	Right Gastric
Splenic a		• Body of pancreas, • Spleen • Stomach (greater curvature and fundus)	-----
Common hepatic a		• Liver, gallbladder and biliary ducts, stomach, duodenum, and pancreas,	-----

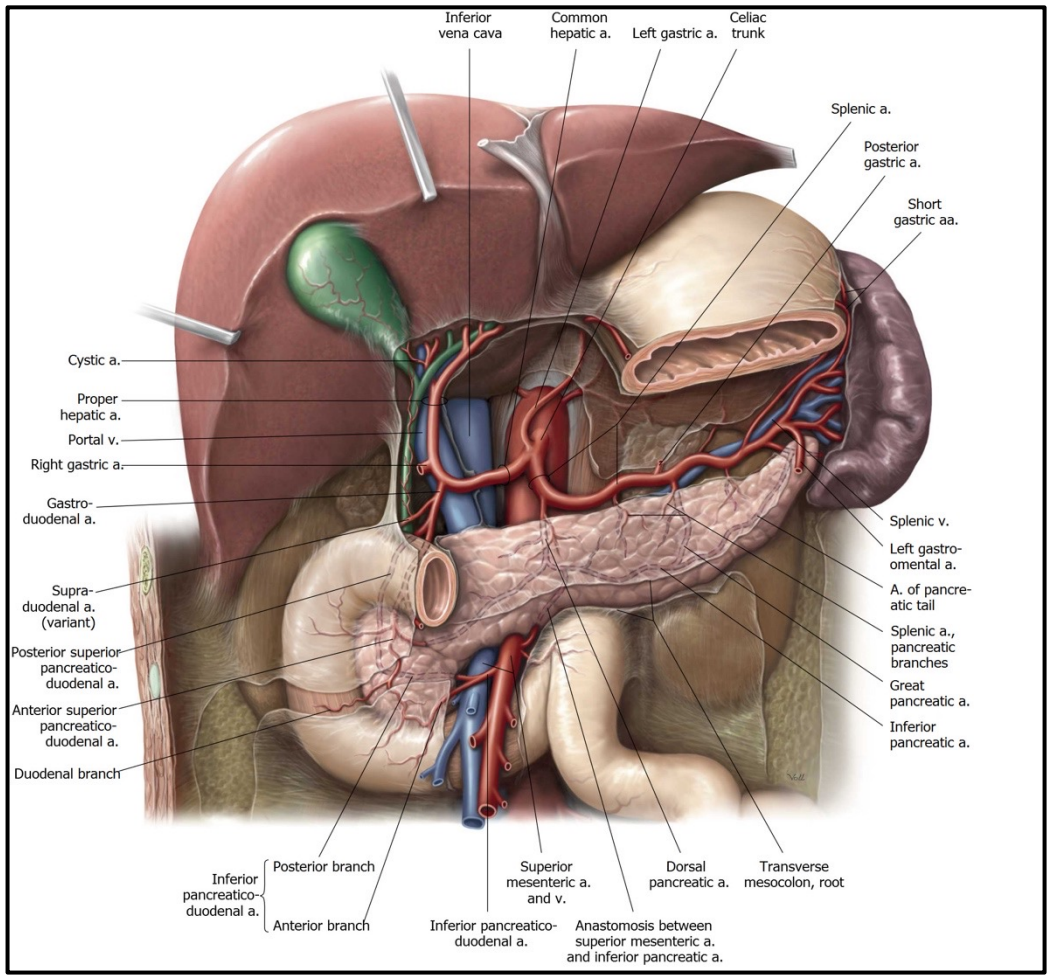




Branches of Splenic Artery

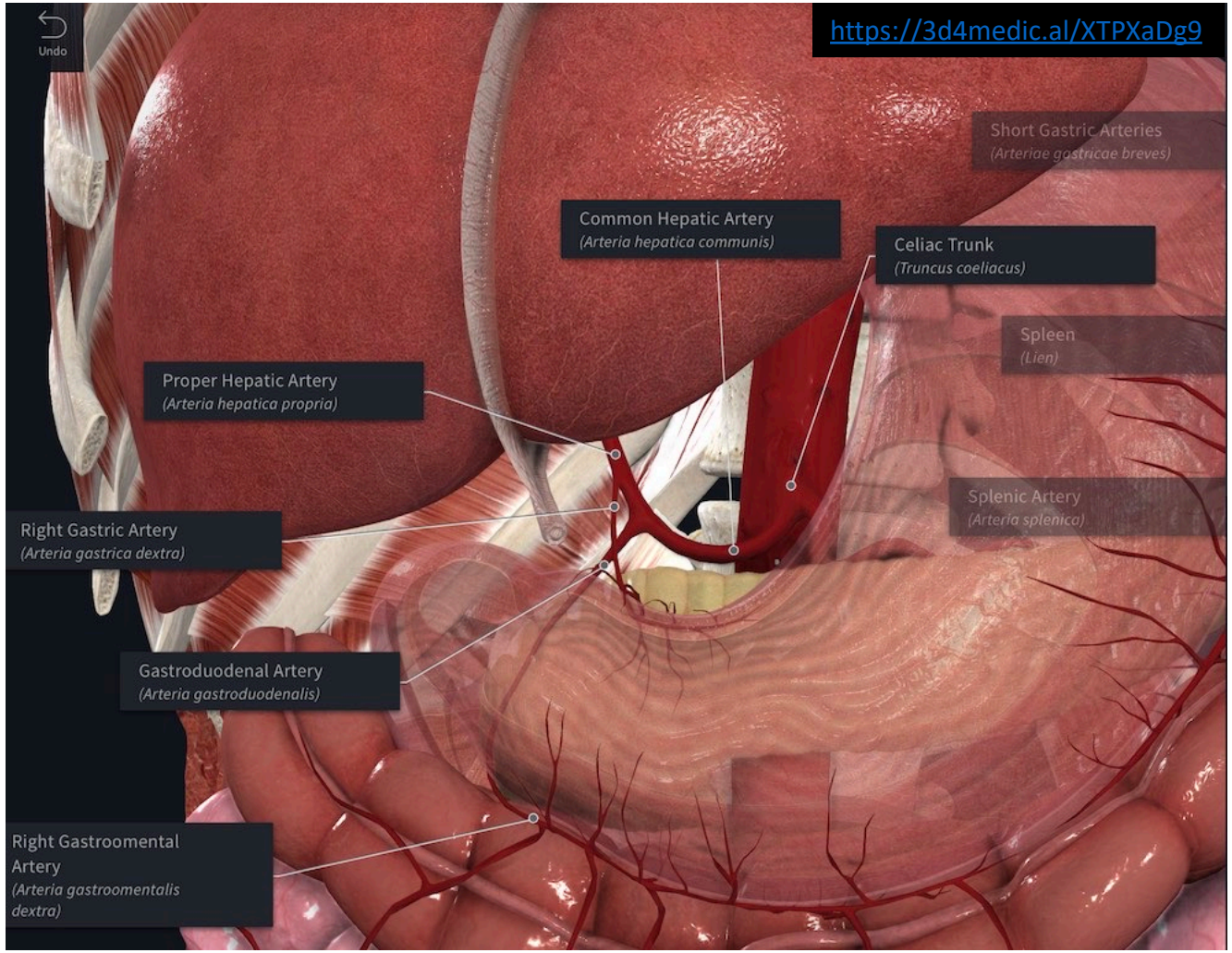
ARTERY	ORIGIN	ORGANS SUPPLIED	ANASTOMOSIS
Pancreatic branches	Splenic	Body of Pancreas	-----
Left gastro-omental	Splenic (at hilum of spleen)	• Left portion of greater curvature of stomach • Greater omentum	Right gastro-omental
Short gastric (4-5 branches)	Splenic	Fundus of stomach	-----

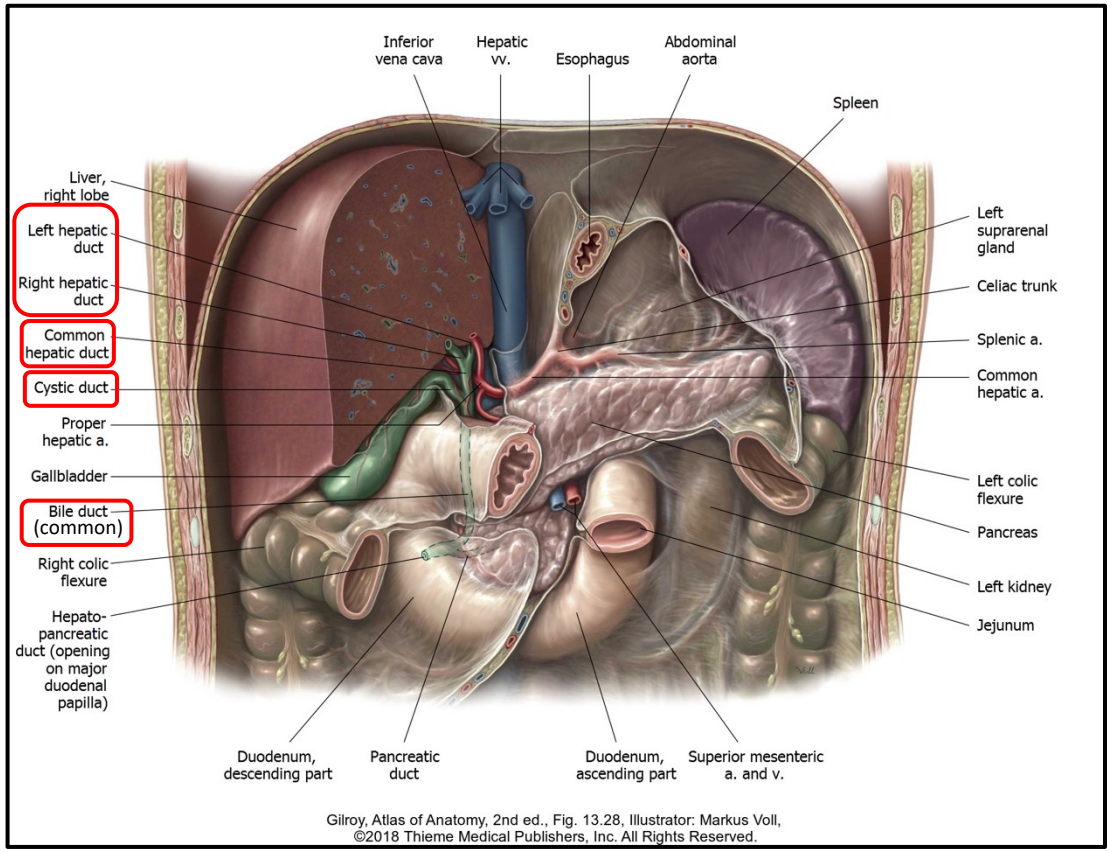




Branches of Common Hepatic Artery

ARTERY	ORIGIN	ORGANS SUPPLIED
Proper hepatic a	Common Hepatic a	Liver, gallbladder and biliary ducts
Right gastric	Common Hepatic a	Right portion of lesser curvature of stomach
Gastroduodenal	Common Hepatic a	Stomach, pancreas, first part of duodenum, and distal part of bile duct

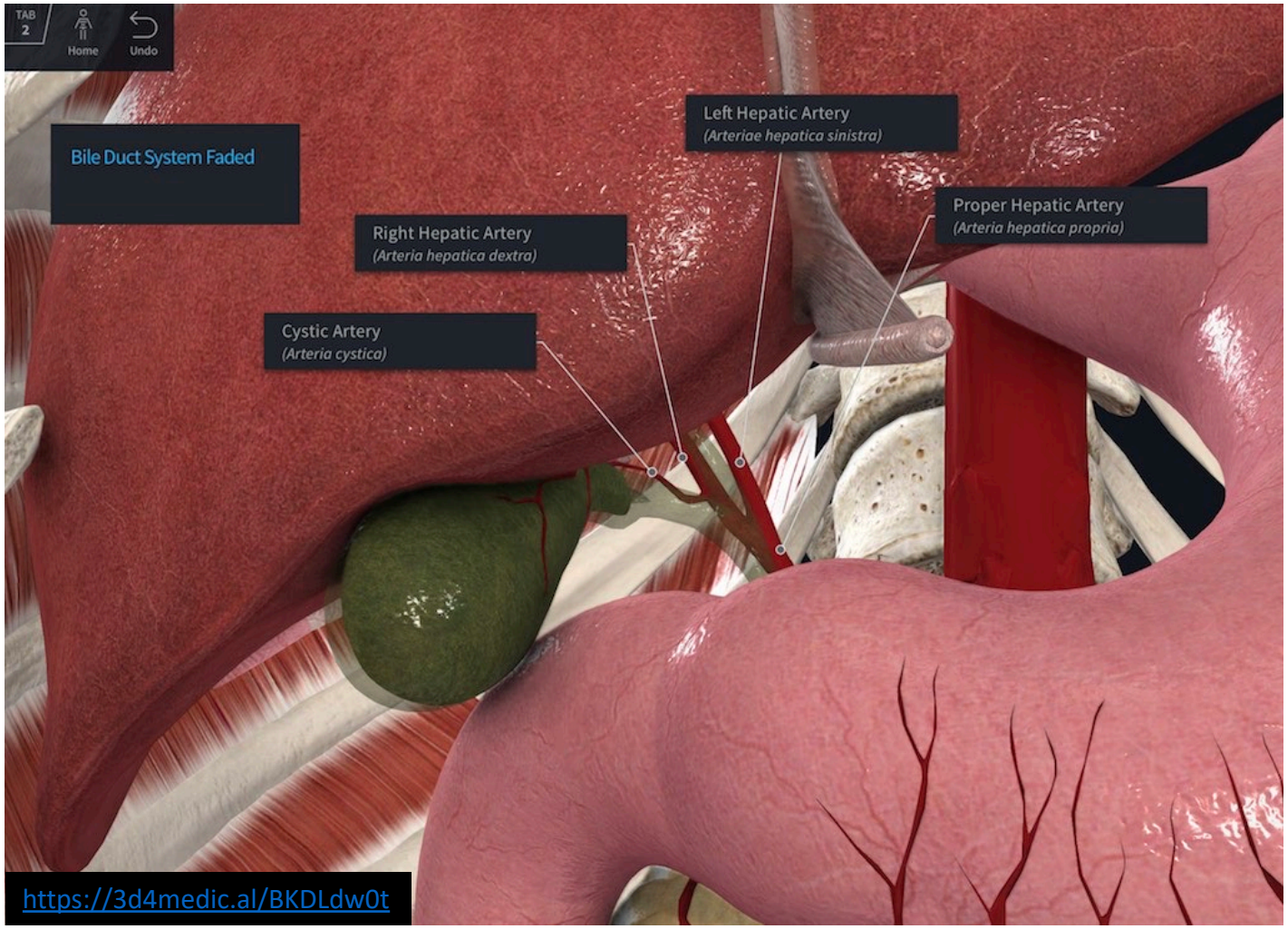


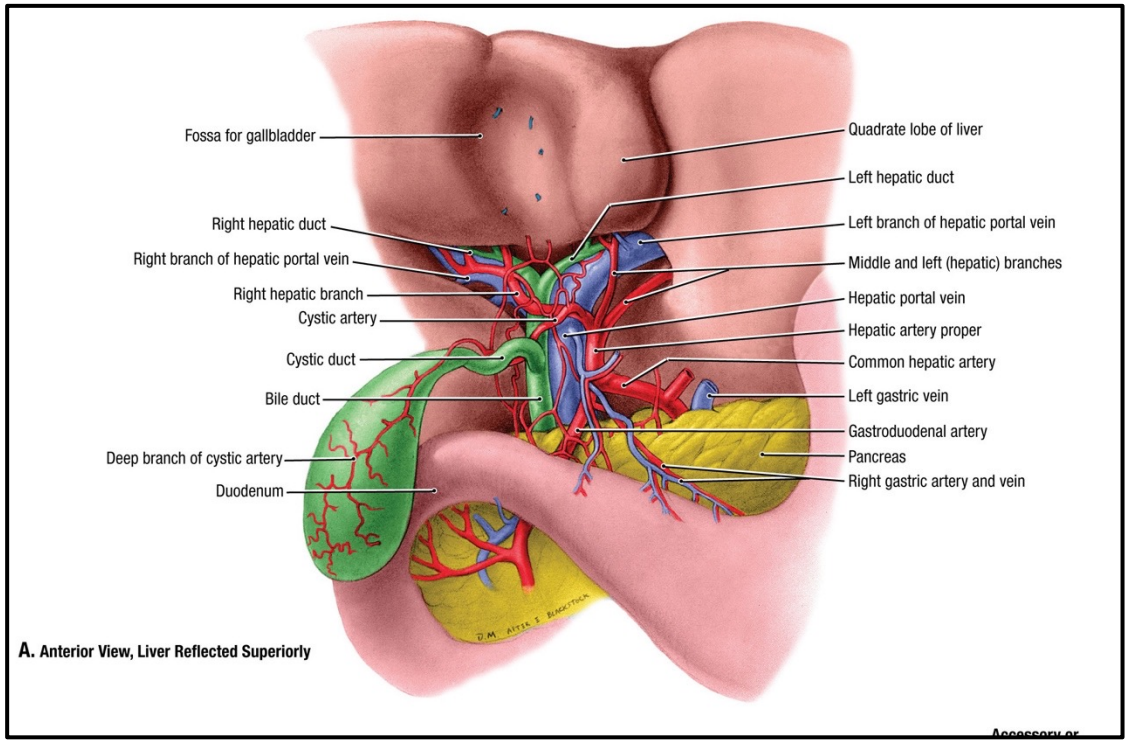


Gilroy, Atlas of Anatomy, 2nd ed., Fig. 13.28, Illustrator: Markus Voll,

Branches of Proper Hepatic Artery

ARTERY	ORIGIN	ORGANS SUPPLIED
Right hepatic a.	Proper hepatic a.	Right side of liver
Left hepatic a.	Proper hepatic a.	Left side of liver
Cystic a.	Right hepatic artery	Gallbladder and cystic duct



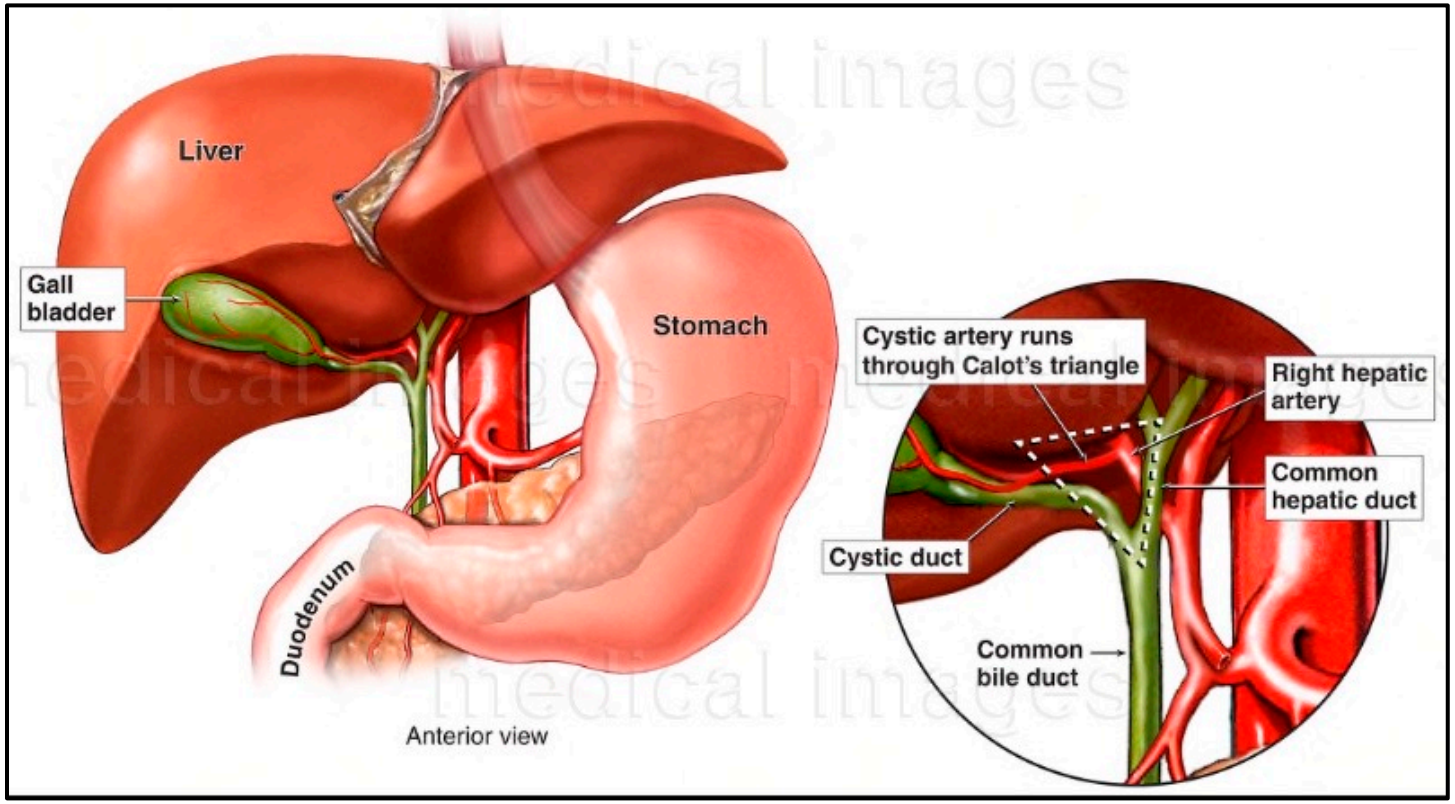


Cystohepatic Triangle (of Calot)

Calot's triangle (cystohepatic triangle) is a small anatomical space located at the **porta hepatis** of the liver. **Calot's triangle** is orientated so that its apex is directed at the liver.

The borders of the triangle are listed below.
•Medial**: common hepatic duct**
•Inferior: **cystic duct**
•Superior**:** inf**erior surface of the liver**

The contents of the Calot's triangle are listed below.
•**Right hepatic artery**
•**Cystic artery:** The cystic artery typically arises from the right hepatic artery and traverses the triangle to supply the gallbladder.

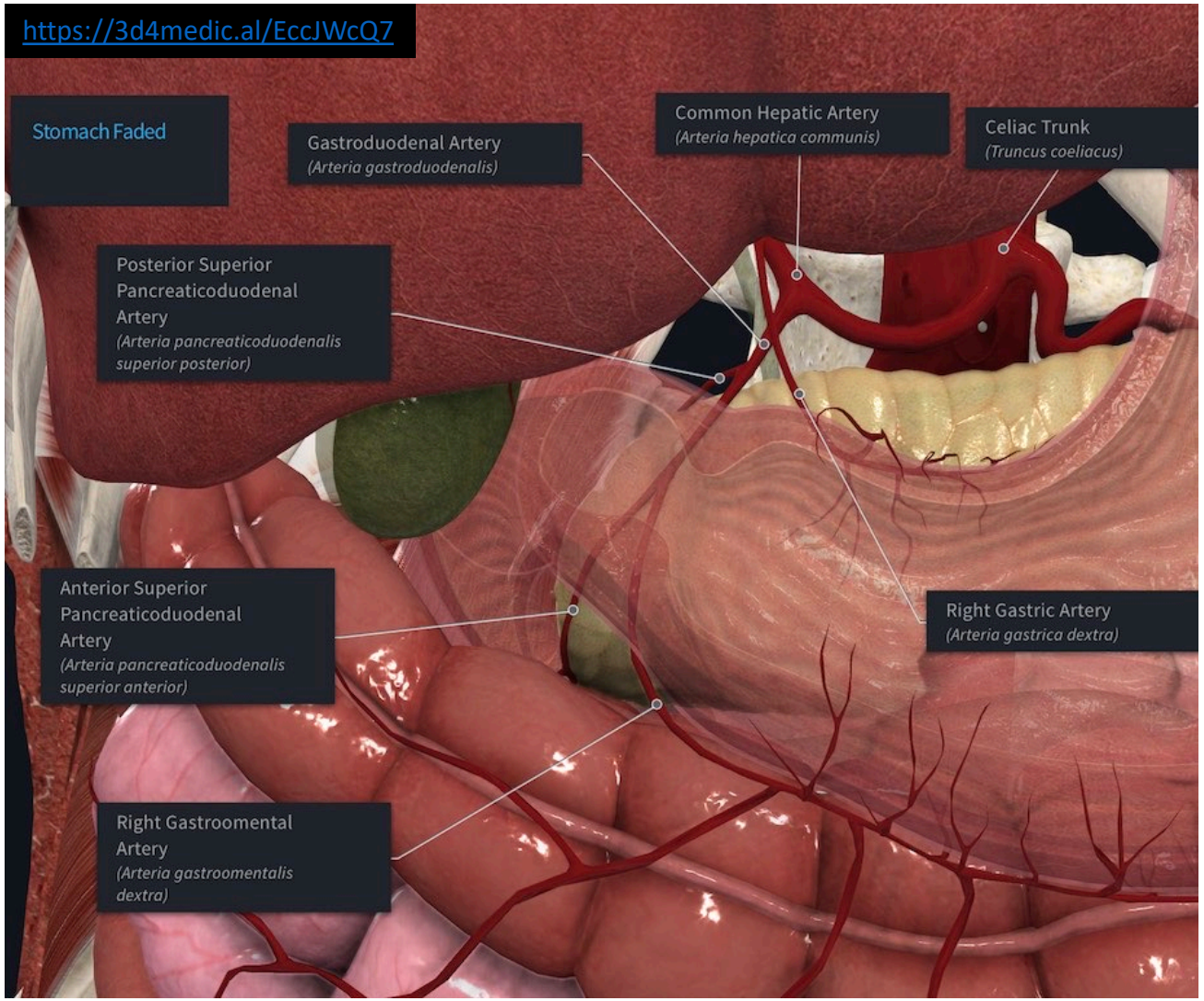


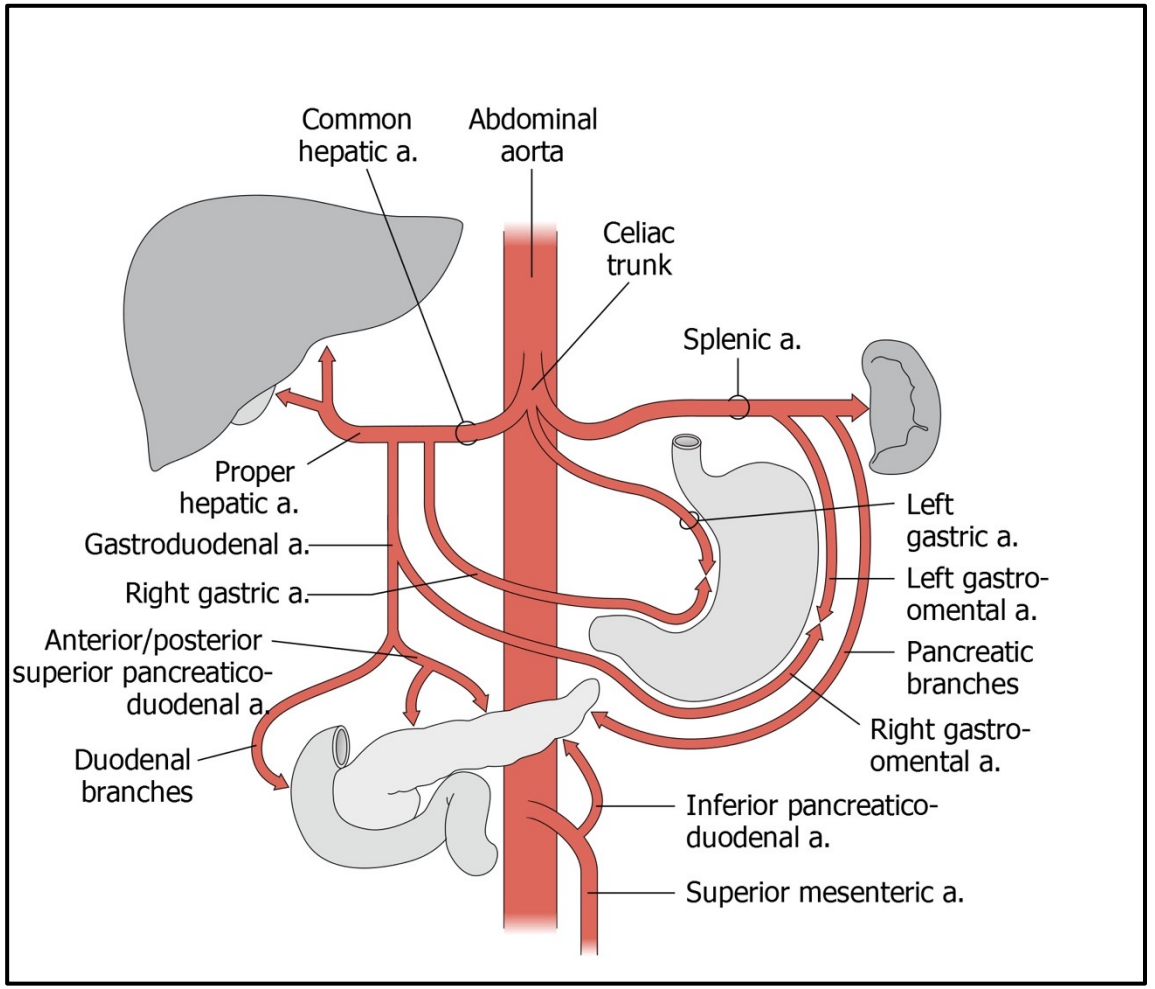
CLINICAL ANATOMY: The triangle of Calot is of clinical importance during **laparoscopic cholecystectomy** (removal of the gall bladder).
In this procedure, the borders of the triangle and its contents are identified and carefully dissected. This allows the surgeon to take into account any **anatomical variation** and permits safe ligation and division of the cystic duct and cystic artery.

- Of particular importance is the **right hepatic artery,** which must be identified by the surgeon prior to ligation of the cystic artery.
- If Calot's triangle cannot be delineated (such as in cases of severe inflammation), the surgeon may elect to perform a **subtotal cholecystectomy**, or convert to open surgery.

Branches of Gastroduodenal Artery

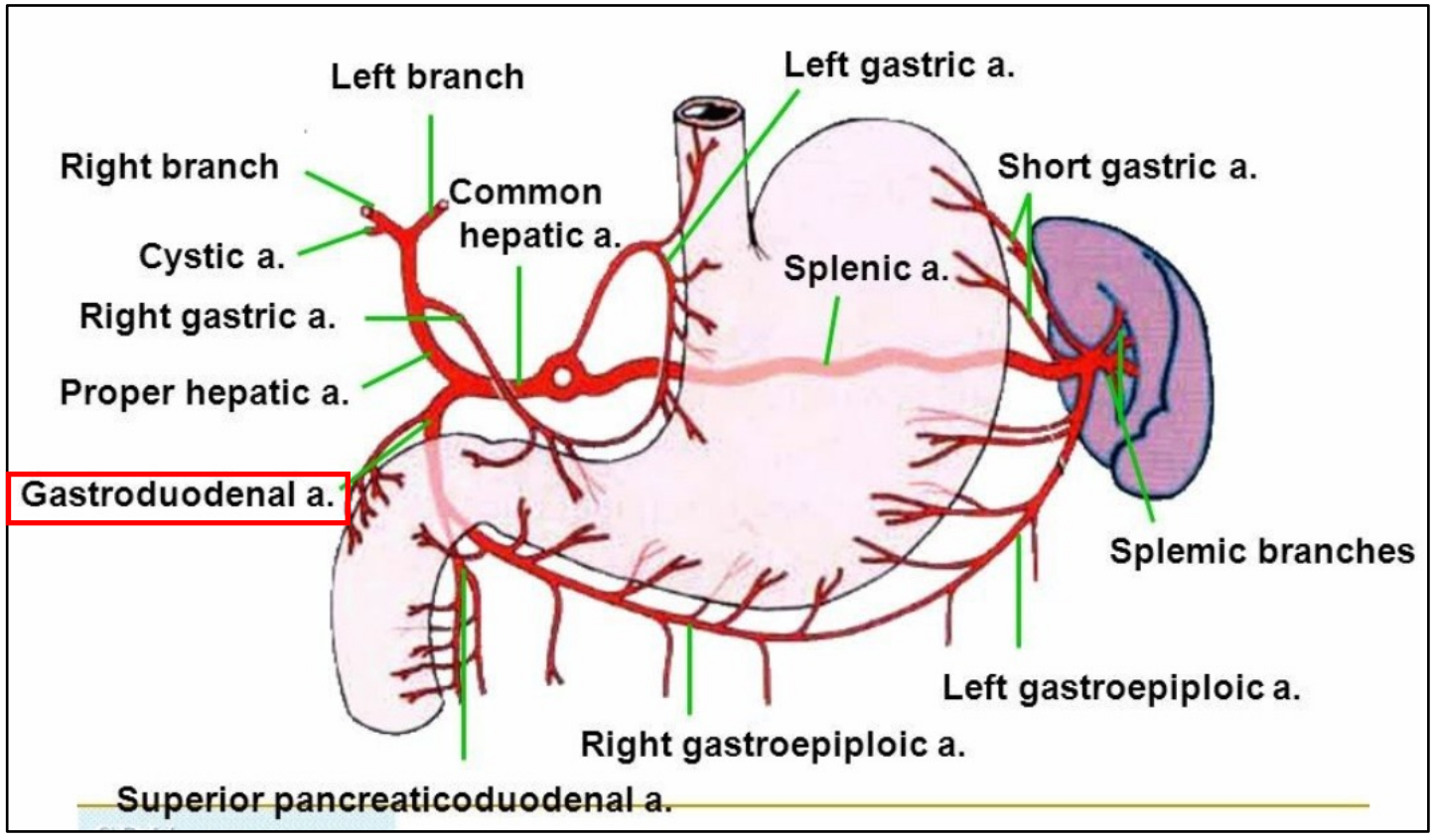
ARTERY	ORIGIN	ORGANS SUPPLIED	ANASTOMOSIS
Right gastro-omental (gastroepiploic)	Gastroduodenal artery	• Right portion of greater curvature of stomach • Greater omentum	Left gastro-omental (gastroepiploic)
Superior pancreaticoduodenal	Gastroduodenal artery	Proximal portion of duodenum and superior part of head of pancreas (Splits into anterior and posterior branches.)	(Anterior and posterior branches) Inferior pancreatoduodenal from SMA



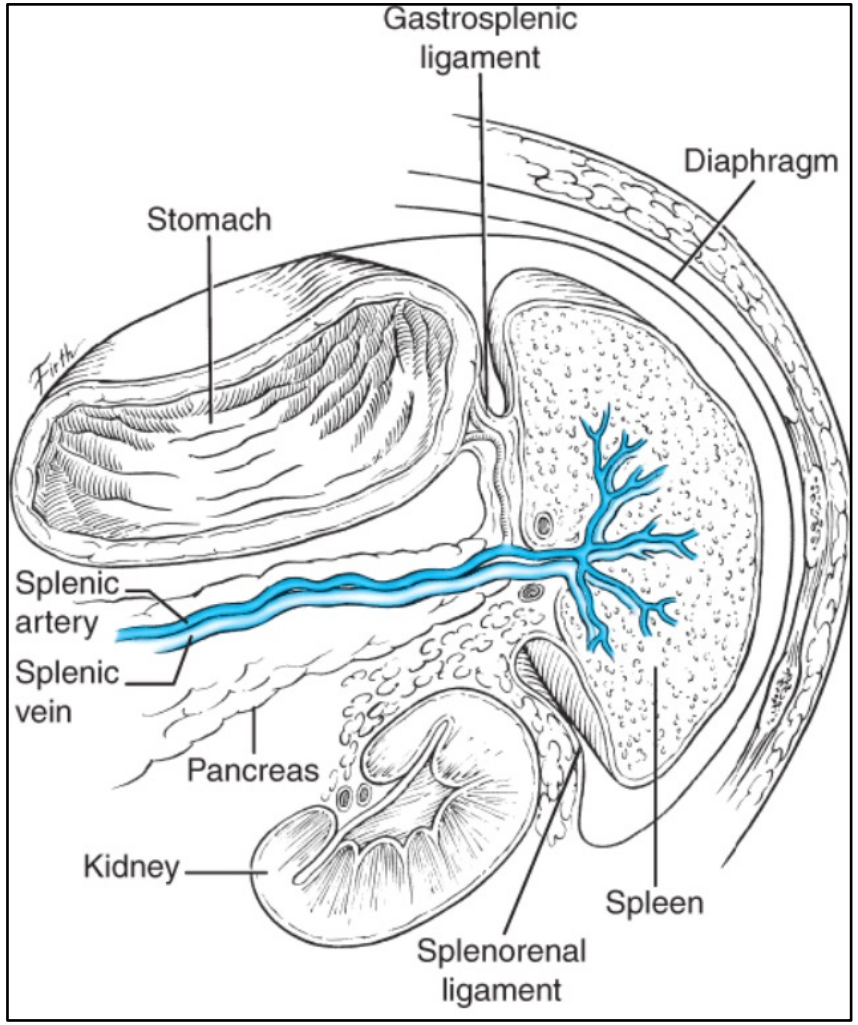


Duodenal Ulcer and Splenectomy

CLINICAL ANATOMY: A duodenal ulcer is a defect that extends through the muscularis mucosa and into the deeper layers of the wall of the duodenum. Perforation of a duodenal ulcer can have a varying presentation depending on the location of perforation. Posterior duodenal wall ulcers are at risk of eroding into the gastroduodenal artery (GDA) and adjacent structures (liver, gallbladder, pancreas). Erosion through the GDA can cause major hemorrhage. Perforation of an anterior duodenal wall ulcer usually leads to frank peritonitis as gastric contents spill into the abdomen.



CLINICAL ANATOMY: During a splenectomy, structures within the splenorenal ligament are at risk of injury due to close proximity. Structures contained within the splenorenal ligament include the terminal branches of the splenic artery, tributaries of the splenic vein, and the tail of the pancreas.



Inferior Vena Cava

The **path of the inferior vena cava** is outlined below.

- It is formed at the L5 vertebral body from the union of the **common iliac veins**, which drain blood from the lower extremities and pelvis.
- It then courses through the abdominal cavity receiving blood from the following major veins.
  - Common iliac veinsL5 vertebral body level:
  - Lumbar veins: L1-L5 vertebral body levels
  - Gonadal veins: L2 vertebral body level
  - Renal (and suprarenal veins): L1 vertebral body level
  - hepatic veins (and inferior phrenic veins): T8 vertebral body level
- It enters the thoracic cavity at the caval hiatus (T8 vertebral body level).
- In the thorax, it ends by emptying into the right atrium of the heart.