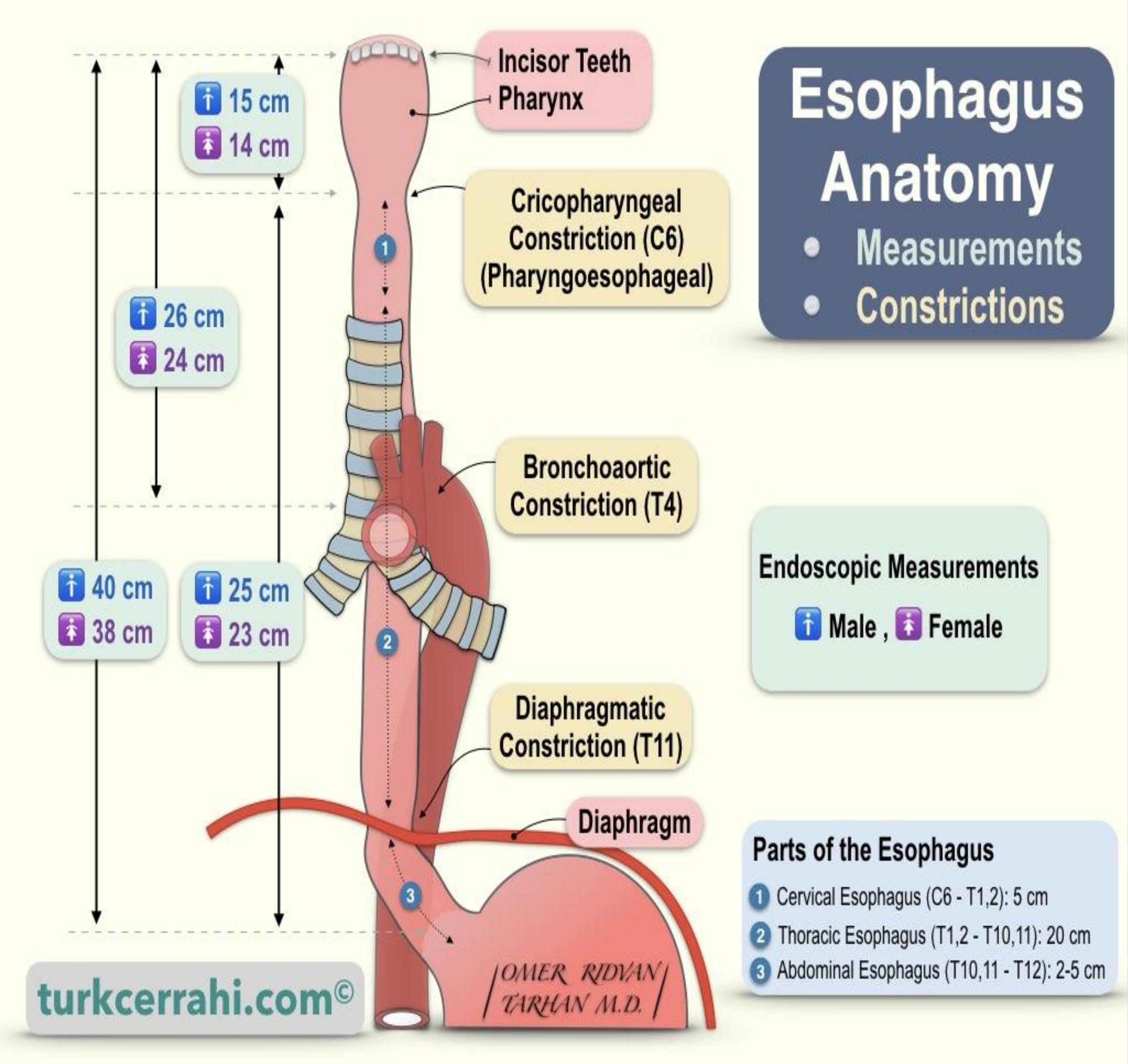
GI ANATOMY AND PHYSIOLOGY

Majdi Khrais, MD

Esophagus

- The esophagus is a 25 cm- long muscular tube (40 cm from the mouth) that begins at the pharynx (lower border of C6) and ends at the opening of the stomach (cardia)

- The muscle type varies along the esophagus:
  1. Upper 1/3: skeletal (striated) muscle
  2. Middle 1/3: mixed (skeletal + smooth)
  3. Lower 1/3: smooth muscle



There are 3 areas of Narrowing:

1. At the beginning of the esophagus (caused by the cricopharngeus muscle) (C6)
2. 2. Where the left main bronchus and aorta cross. (T4)
3. 3. At the hiatus of diaphragm (T11)

It has 2 sphincters:

1. Upper esophageal sphincter (UES):

anatomical sphincter, caused by actual thinking of the muscular wall, its main function is swallowing.

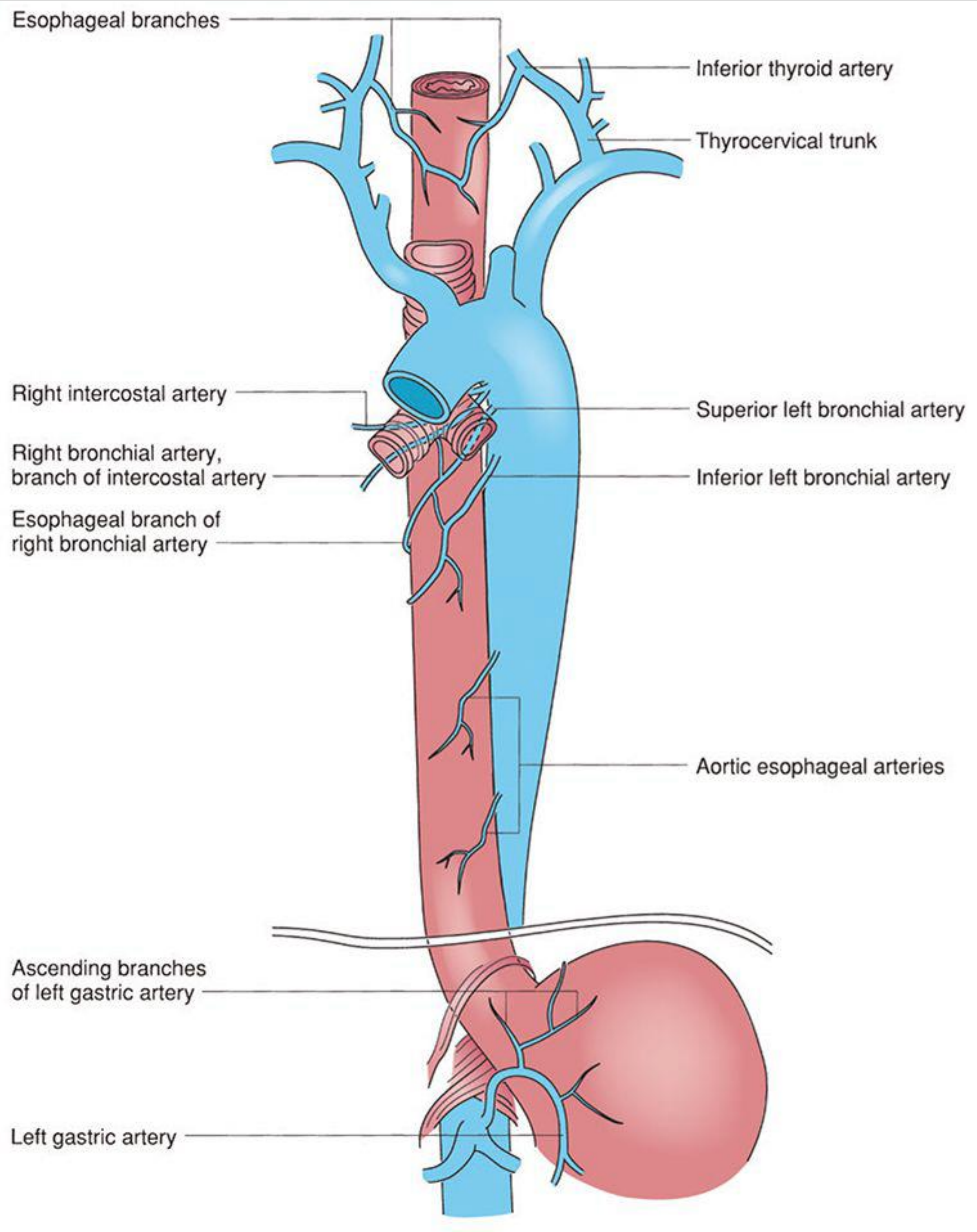
2. Lower esophageal sphincter (LES):

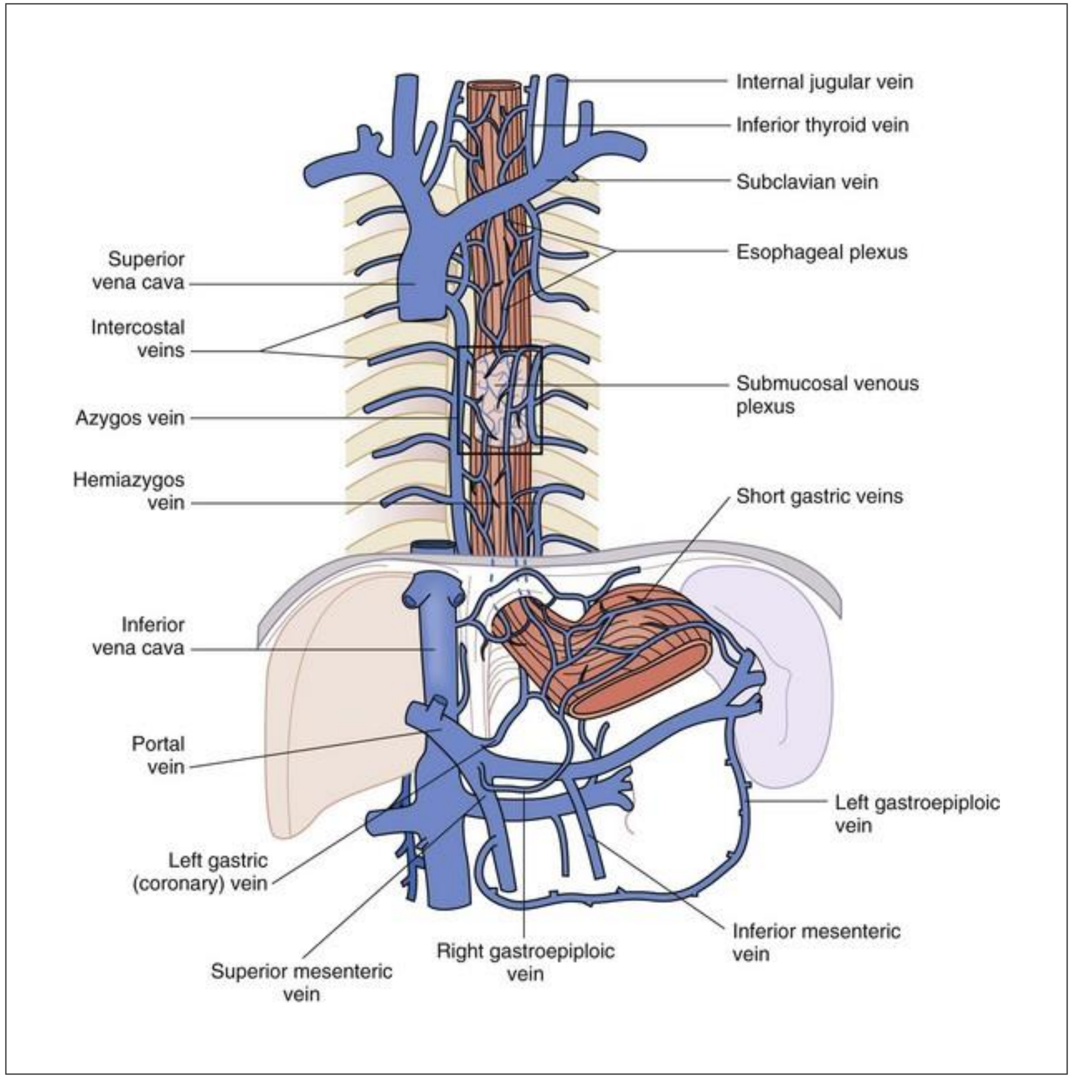
functional sphincter, so it’s an area of high pressure, its main function is prevention of reflux.

- the vagus nerve runs with the esophagus
- the esophagus is at risk of perforation due to absence of serosa
- All GIT has serosa except esophagus and rectum

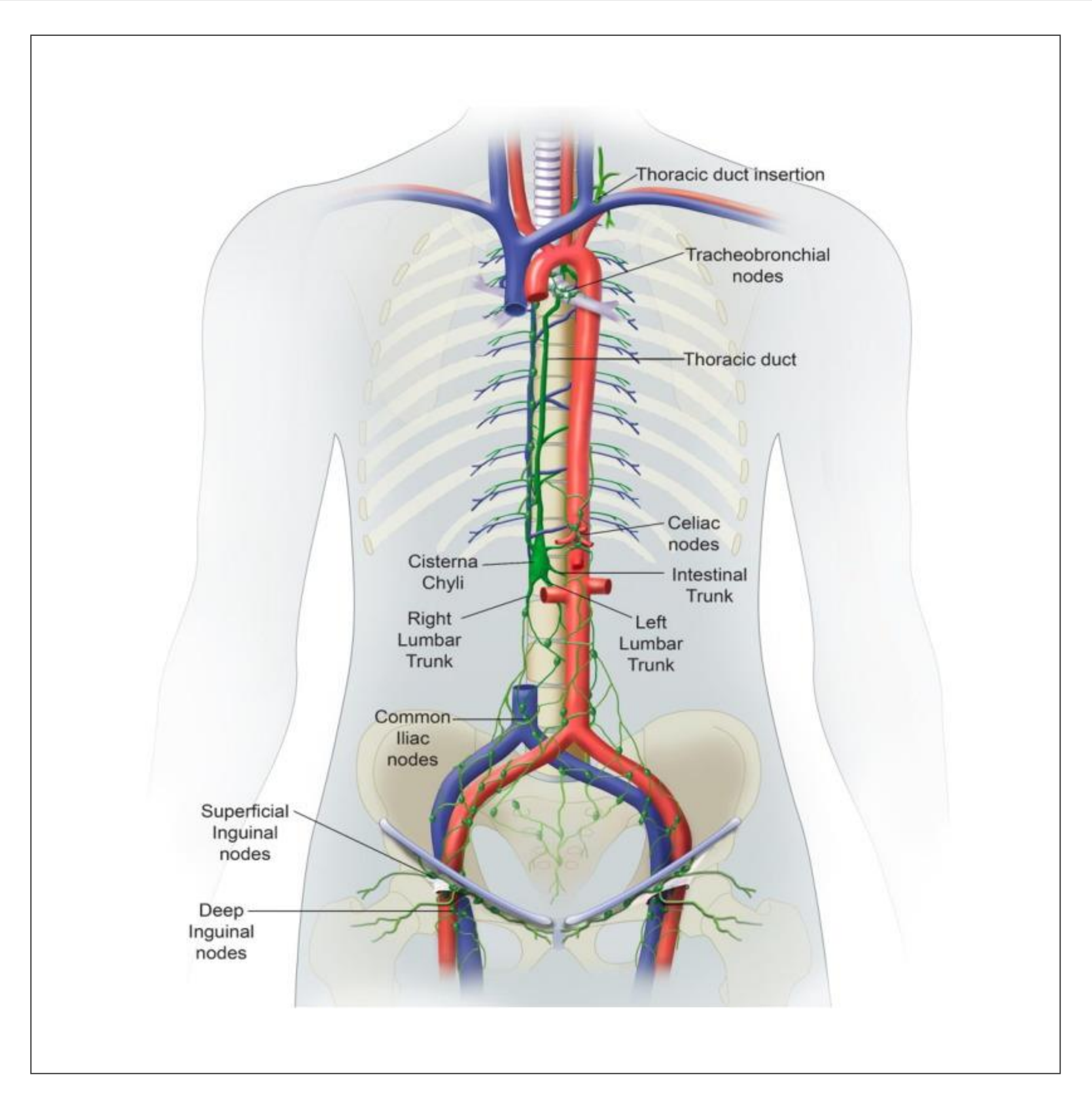
- **Histology:** lining epithelium of the esophagus is stratified squamous epithelium.

- **Thoracic esophagus** – vessels directly off the **aorta** are the major blood supply
- **Cervical esophagus** – supplied by **inferior thyroid artery**
- **Abdominal esophagus** – supplied by **left gastric** and inferior phrenic arteries

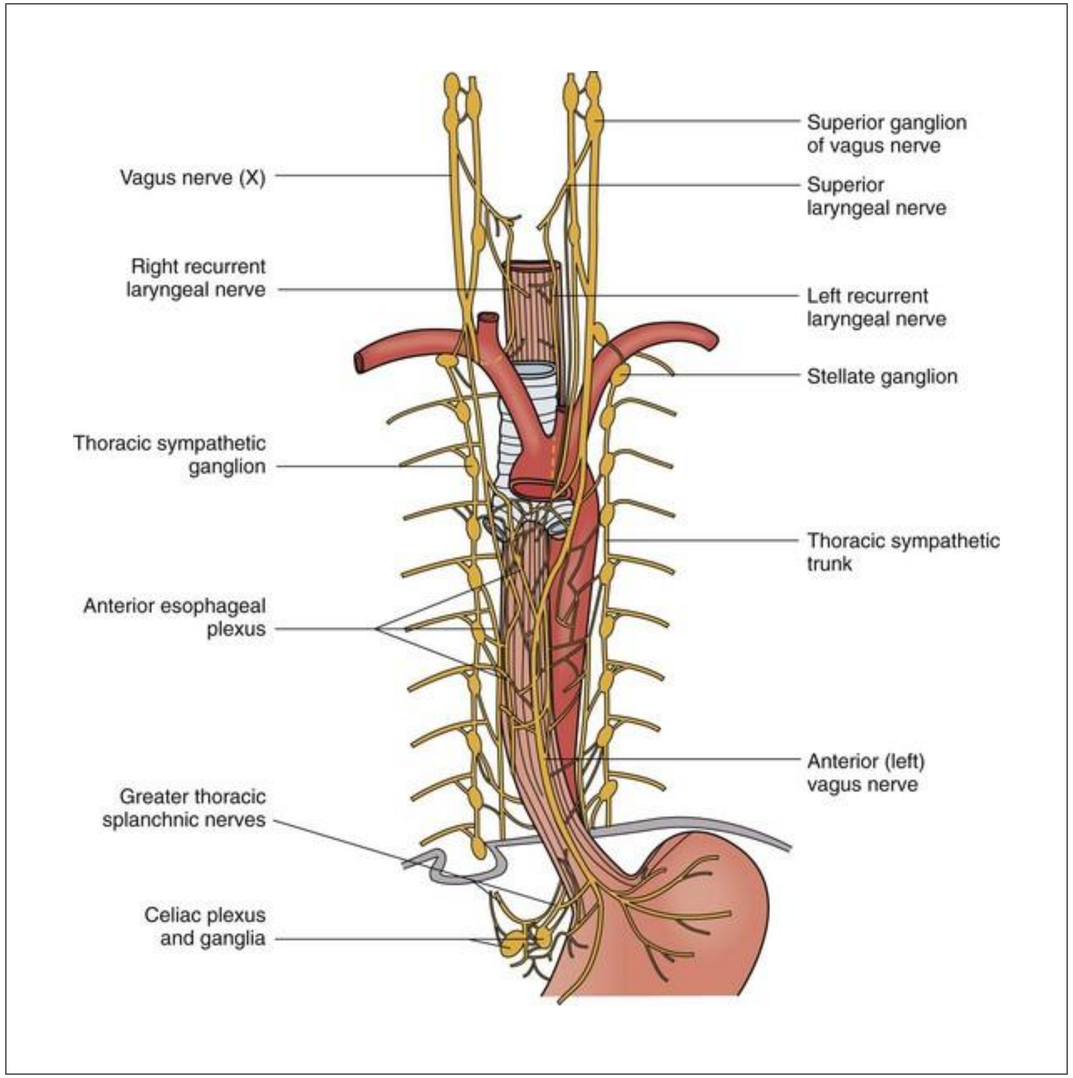




- **Venous drainage** – hemi-azygous and azygous veins in chest



- **Lymphatics** – upper ⅔ drains cephalad, lower ⅓ caudad
- **Thoracic duct** – travels from right to left at **T4–5** as it ascends mediastinum; inserts into left subclavian vein



- **Right vagus nerve** – travels on posterior portion of stomach as it exits chest; becomes **celiac plexus**; also has the criminal nerve of Grassi → can cause persistently high acid levels postoperatively if left undivided after vagotomy

- **Left vagus nerve** – travels on anterior portion of stomach; goes to **liver** and **biliary tree**

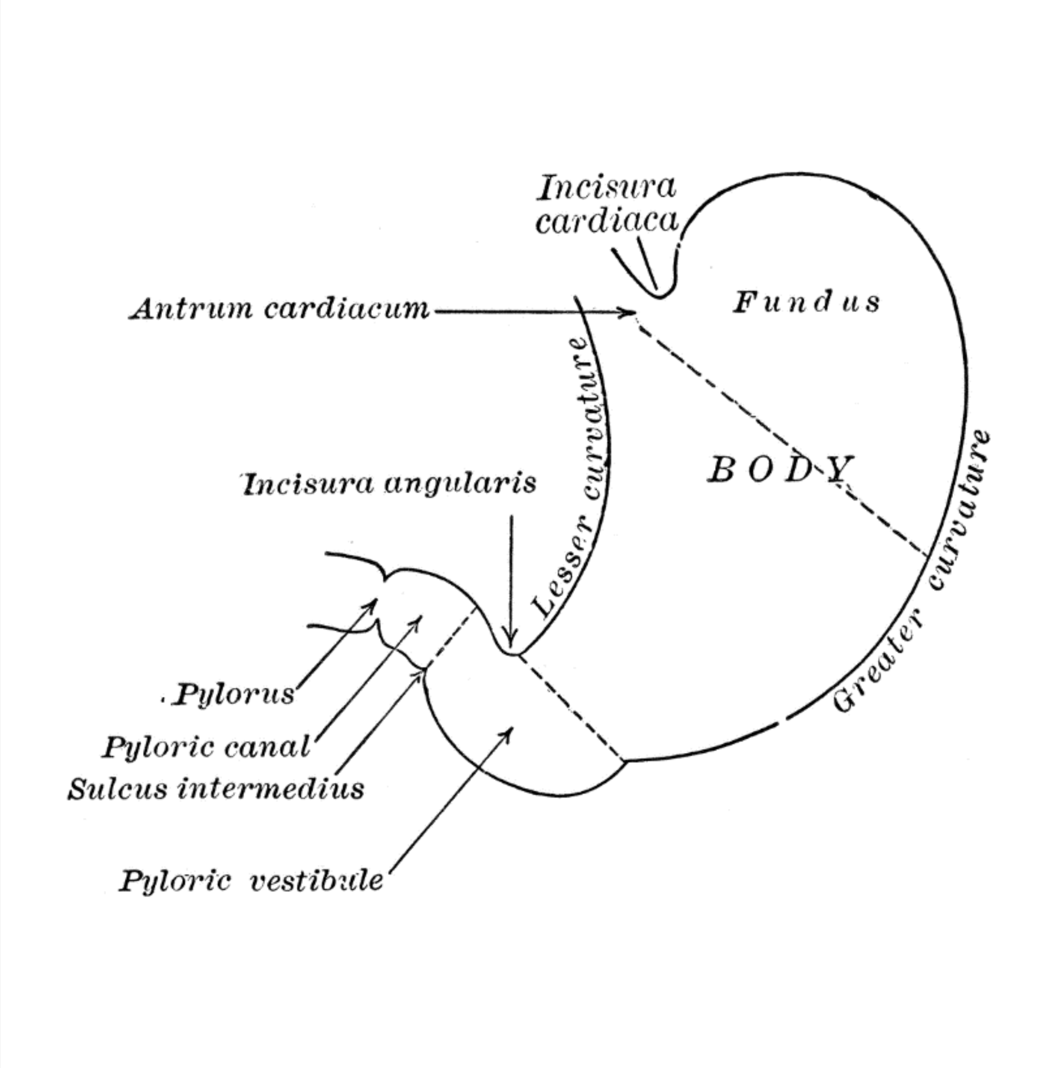
- Physiology: esophagus is a connection canal through which the food pass, it transfers food by peristalsis.

- Types of peristalsis:
  1. Primary: esophageal peristalsis accompanying swallowing.
  2. Secondary: initiated by the esophageal musculature without the pharyngeal phase to clean the esophagus of any substance left behind Primary peristalsis.

- **Swallowing stages** – CNS initiates swallow:
  - **Primary peristalsis** – occurs with food bolus and swallow initiation
  - **Secondary peristalsis** – occurs with incomplete emptying and esophageal distention; propagating waves
  - **Tertiary peristalsis** – non-propagating, non-peristalsing (dysfunctional)
- UES and LES are normally contracted between meals

- Swallowing mechanism – soft palate occludes nasopharynx, larynx rises and airway opening is blocked by epiglottis, cricopharyngeus relaxes, pharyngeal contraction moves food into esophagus; **LES relaxes** soon after initiation of swallow (**vagus** mediated)

- Anti-reflux mechanism:
  - Lower esophageal sphincter (LES)
  - Crura of diaphragm
  - Cardiac angle (angle of His)
  - Peristaltic movement
  - Saliva



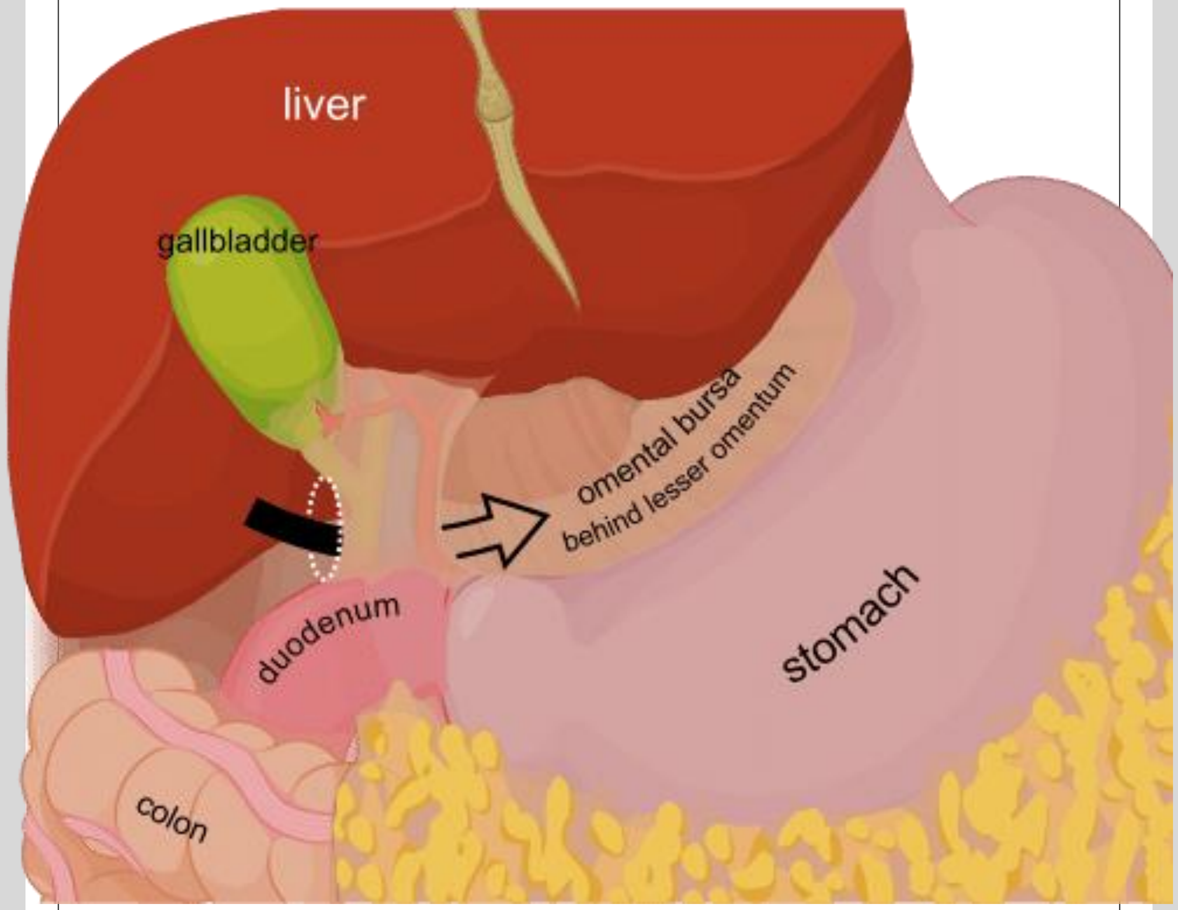
Stomach

The main anatomical parts of the stomach are:

the cardia, fundus, body, antrum, and pylorus.

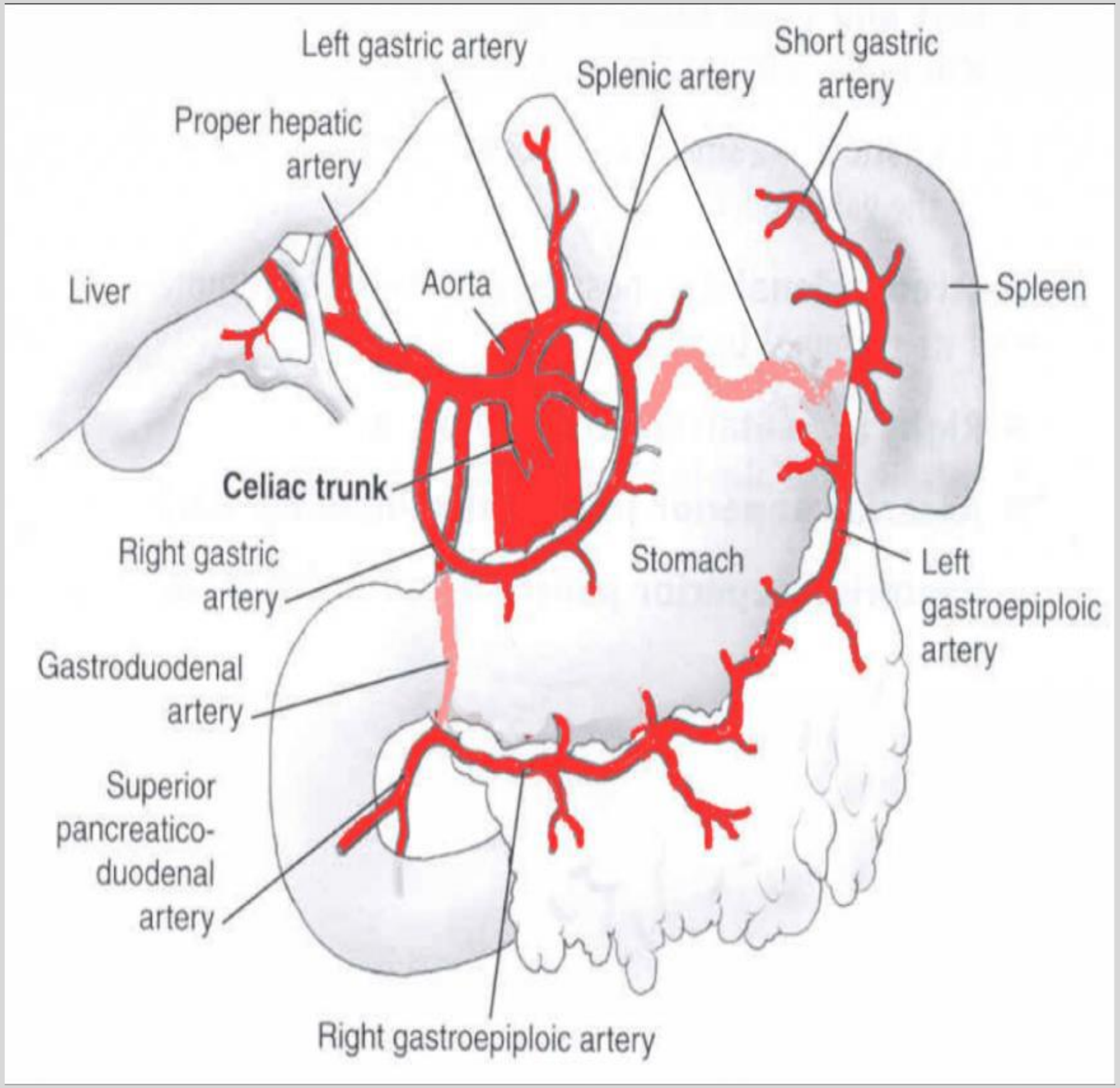
The left border of the stomach is called the greater curvature, and it's attached to the greater omentum

The right border of the stomach in called the lesser curvature and it's attached to the lesser omentum



- The stomach and lesser omentum separate the abdomen into two sacs
  - the greater sac (most of the abdominal cavity, anterior to the stomach)
  - the lesser sac (behind the stomach).

- The only connection between these sacs is the foramen of Winslow.



- Blood supply: All parts of the stomach are supplied by the branches of the celiac trunk.

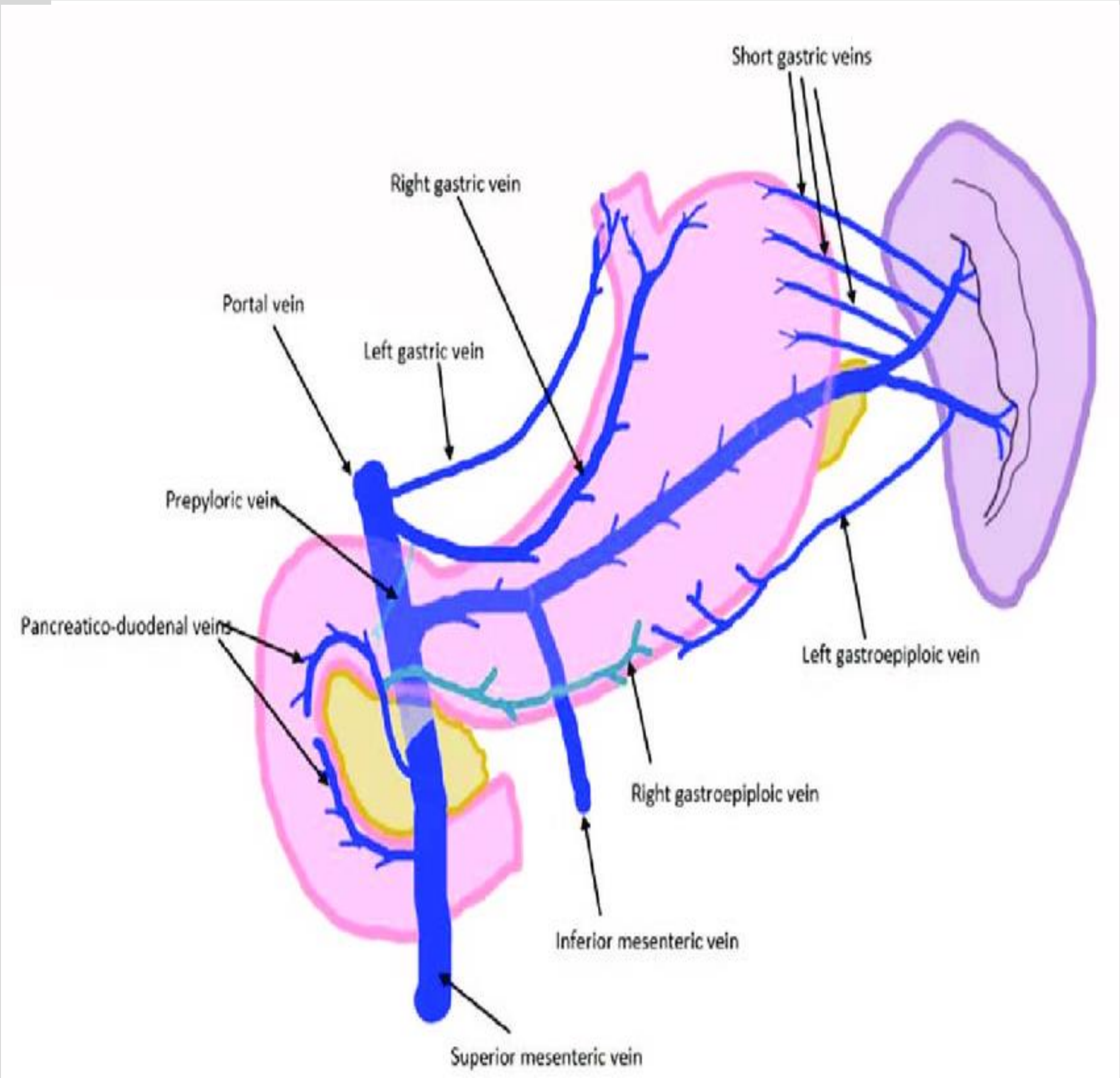
- The celiac trunk gives 3 major arteries;

- left gastric
- splenic
- common hepatic

- The left gastric artery supplies the lesser curvature (it gives also a branch to the esophagus)
- The splenic artery runs in a tortuous way behind the stomach, at the upper border of the pancreas, and before reaching the spleen, it gives one large artery, namely: the left gastroepiploic artery, to the greater curvature
- The spleen itself supplies the stomach from the terminal branches of the splenic artery with the short gastric arteries to the fundus of the stomach.

- The common hepatic artery gives two arteries before becoming the hepatic artery proper
- these arteries are the right gastric artery (to the lesser curvature) and the gastroduodenal artery,
- The gastroduodenal artery descends posteromedial to the second part of the duodenum and terminates as right gastroepiploic artery (to the greater curvature) and the superior pancreaticoduodenal arteries.

- blood supply to the greater curvature is from the right and left gastroepiploic arteries, and the blood supply to the lesser curvature is from the right and left gastric arteries.



- Venous drainage of the stomach:

• Right and left gastric veins →Directly to the portal vein.

• Left gastroepiploic vein → splenic vein.

• Right gastroepiploic vein→ SMV.

Innervation

- Anterior gastric wall → left vagus nerve.
- Posterior gastric wall→ right vagus nerve.
- Gastroduodenal pain is sensed via sympathetic afferents from T5 to T10

◦ **Cardia glands** – mucus secreting

◦ **Fundus and body glands:**

• **Chief cells** – **pepsinogen** (1st enzyme in proteolysis)

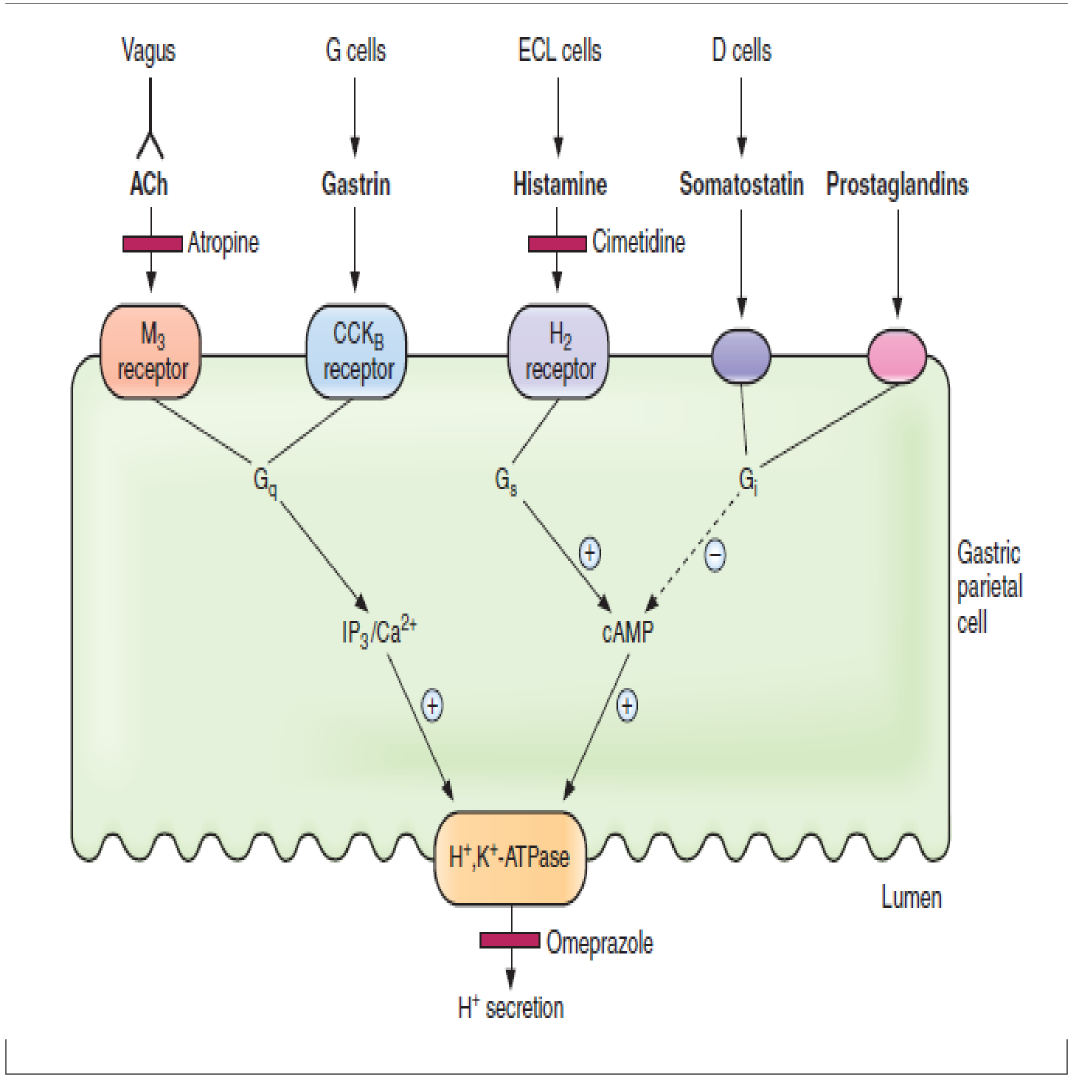
• **Parietal cells** – release **H+** and **intrinsic factor**

• **Acetylcholine** (vagus nerve), **gastrin** (from G cells in antrum), and **histamine** (from mast

cells) cause H+ release.

• **Acetylcholine** and **gastrin** activate ***phospholipase*** (PIP DAG + IP3 to **Ca**); Ca calmodulin activates **phosphorylase kinase**   H+ release

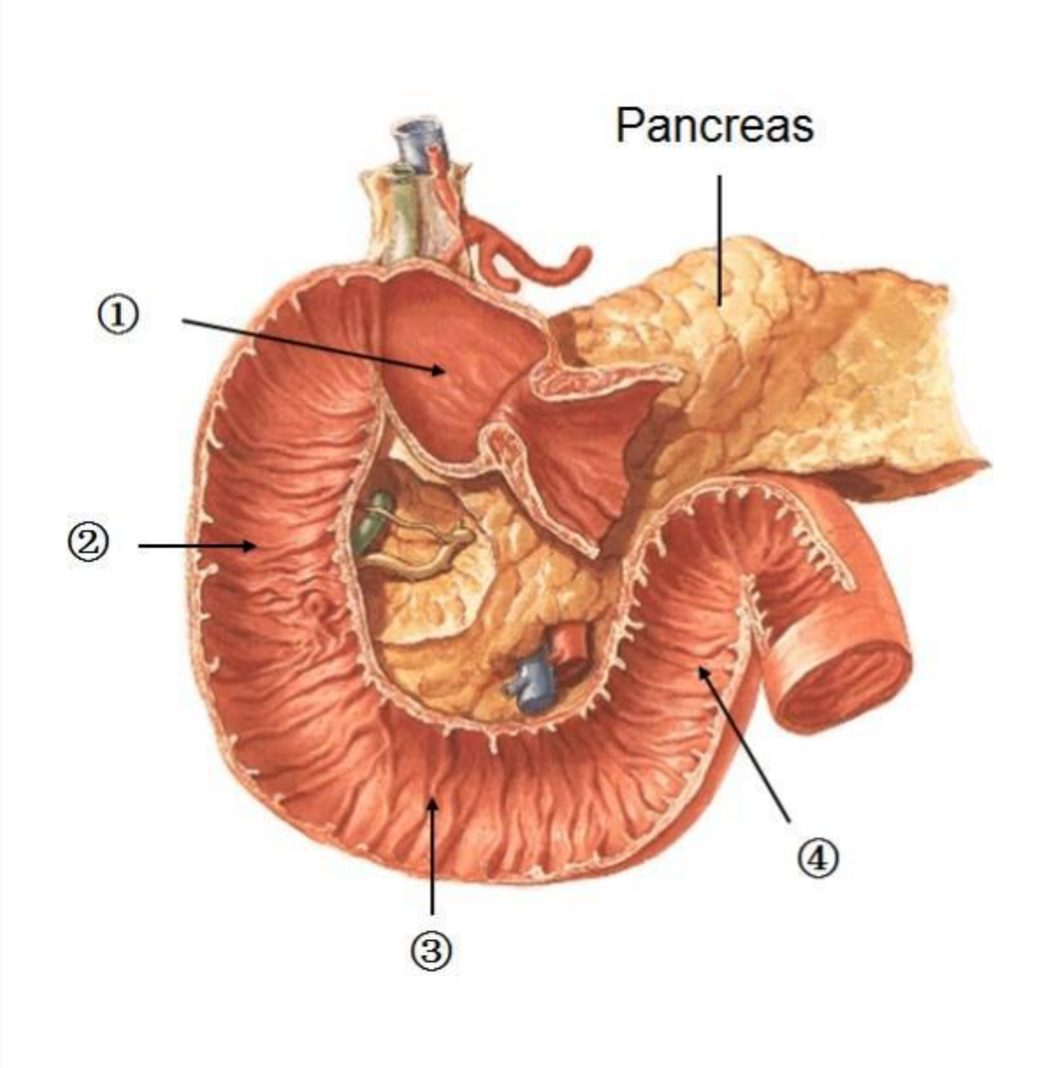
- **Histamine** activates ***adenylate cyclase*** □ **cAMP** □ activates **protein kinase A** □ □ H+ release
- **Phosphorylase kinase** and **protein kinase A** phosphorylate **H+/K+ ATPase** to □ H+ secretion and K+ absorption
- **Omeprazole** blocks H+/K+ ATPase in parietal cell membrane (**final pathway for H+** release).
- **Inhibitors of parietal cells** – somatostatin, prostaglandins (PGE1), secretin, CCK
- **Intrinsic factor** – binds B12 and the complex is reabsorbed in the terminal ileum



- Main factors that increase gastric acid secretion are gastrin, Acetylcholine and histamine.
- Somatostatin and prostaglandins decrease gastric acid secretion

- **Antrum and pylorus glands**
- **Mucus** and **HCO3–** secreting glands – protect stomach
- **G cells** release **gastrin** – reason why antrectomy is helpful for ulcer disease
- ***Inhibited*** by **H+ in duodenum**
- ***Stimulated*** by **amino acids**, **acetylcholine**
- **D cells** – secrete **somatostatin**; inhibit gastrin and acid release

- **Brunner's glands** – in duodenum; secrete **alkaline mucus**
- **Somatostatin**, **CCK**, and **secretin** – released with antral and duodenal acidification



Doudenum

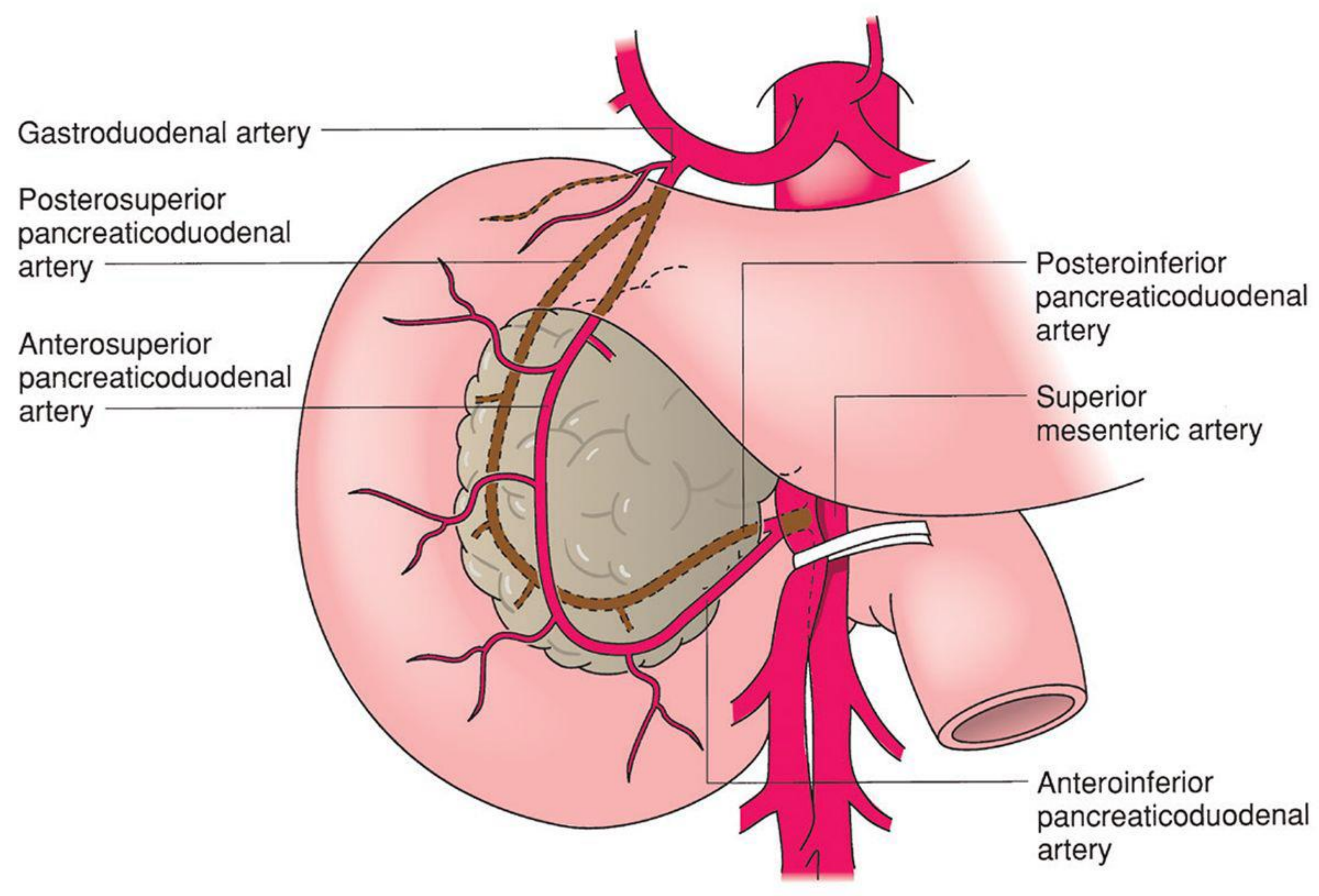
- Extends from pylorus to the duodenojejunal junction.
- It's Retroperitoneal except the 1st 2cm
- 1st part (Superior) → 5cm , Duodenal bulb "site of most ulcers"
- 2nd Part (Descending) → 10 cm, curves around the head of pancreas.
- 3rd Part (Transverse) → 10 cm, crosses anteriorly to the aorta & IVC & posteriorly to SMA & SMV
- 4th Part (Ascending) → 5 cm, ascends past left side of aorta then curves anteriorly to meet DJ Junction suspended by ligament of trietz.

Duodenum

- Blood Supply:
- Proximal part (up to ampulla of vater) → Gastro duodenal artery (branch of proper hepatic artery)
- it bifurcates into ant. & Post. Superior pancreatic duodenal artery –

- Distal Part (beyond the ampulla of vater) → inf. Pancreatic duodenal artery (branch of SMA)
- also bifurcates into Ant & Post art.

- Venous Drainage: - Ant & Post pancreatic duodenal vein, drain into → SMV (which joins splenic v. to form portal vein.) - Prepyloric vein of mayo → it's a landmark for pylorus.


Gastroduodenal artery
Posterosuperior pancreaticoduodenal artery
Anterosuperior pancreaticoduodenal artery
Posteroinferior pancreaticoduodenal artery
Superior mesenteric artery
Anteroinferior pancreaticoduodenal artery

Jejunum and Ileum

- No anatomic boundaries b/w them ➢
- Jejunum is the proximal (40% of small intestines)→"distal to ligament of trietz"
- Ileum is the distal (60% of small intestine)
- Mesentery tethers the jejunum & ileum to post. Abd. Wall

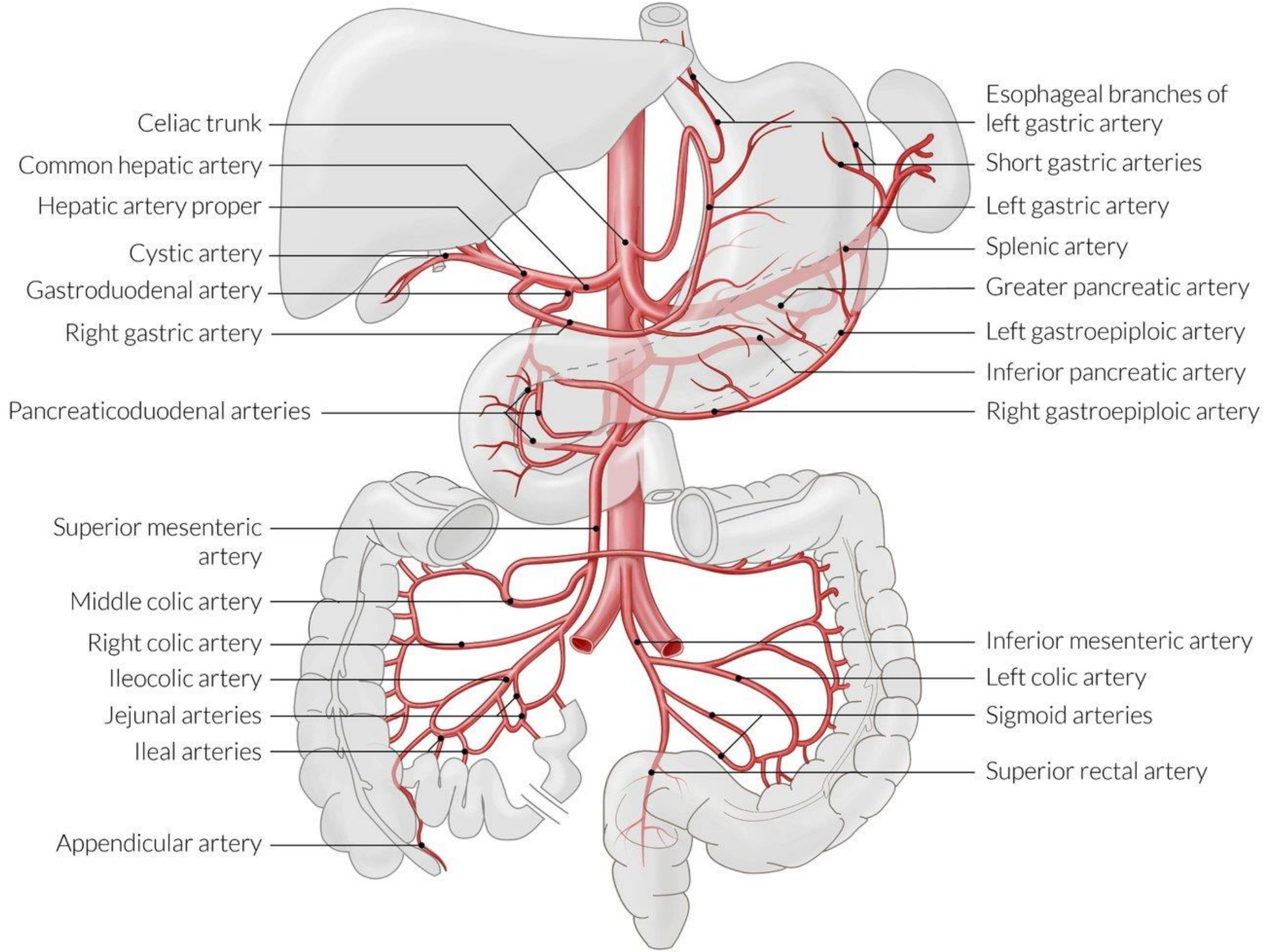
- Jejunum → Long vasa recta + Large plica circularis + Thicker wall
- Ileum → Short vasa recta + Smaller plica circularis + Thinner wall

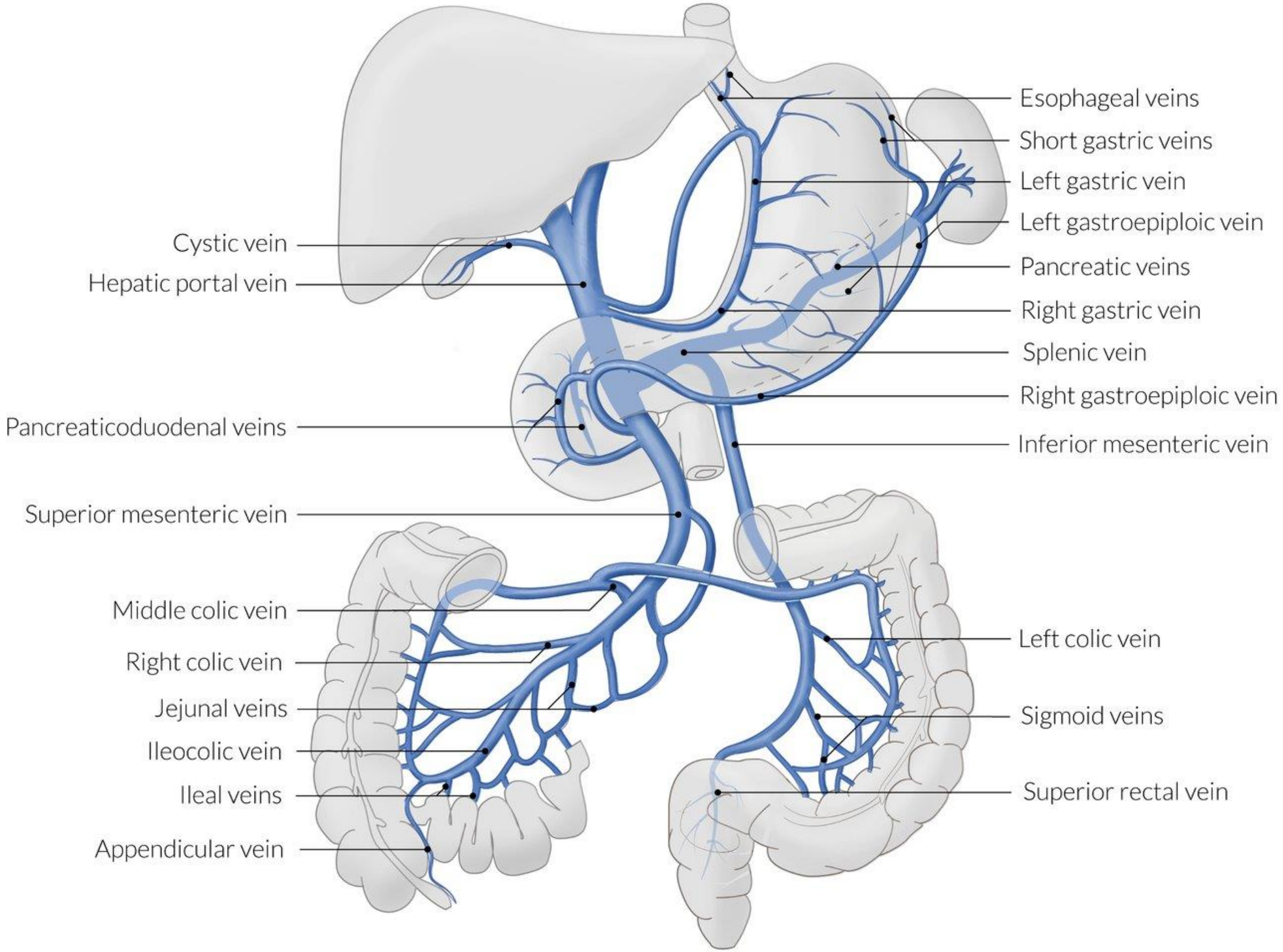
- Plica circularis: the circular folds of mucosa in small intestines lumen AKA (valvulae conniventes) plica = folds

- Terminal ileum absorbs → B12, fatty acids and bile salts.

- Blood supply: branches of SMA (which runs in the mesentery) arteries loop to form arcades that give rise to straight arteries → vasa recta

- Venous Drainage → SMV


Celiac trunk
Common hepatic artery
Hepatic artery proper
Cystic artery
Gastroduodenal artery
Right gastric artery
Pancreaticoduodenal arteries
Superior mesenteric artery
Middle colic artery
Right colic artery
Ileocolic artery
Jejunal arteries
Ileal arteries
Appendicular artery
Esophageal branches of left gastric artery
Short gastric arteries
Left gastric artery
Splenic artery
Greater pancreatic artery
Left gastroepiploic artery
Inferior pancreatic artery
Right gastroepiploic artery
Inferior mesenteric artery
Left colic artery
Sigmoid arteries
Superior rectal artery


Esophageal veins
Short gastric veins
Left gastric vein
Left gastroepiploic vein
Pancreatic veins
Right gastric vein
Splenic vein
Right gastroepiploic vein
Inferior mesenteric vein
Cystic vein
Hepatic portal vein
Pancreaticoduodenal veins
Superior mesenteric vein
Middle colic vein
Right colic vein
Jejunal veins
Ileocolic vein
Ileal veins
Appendicular vein
Left colic vein
Sigmoid veins
Superior rectal vein

- Lymphatics: - Bowel wall → mesenteric nodes → lymphatic vessels → Cisterna chili → thoracic duct → Lt subclavian vein

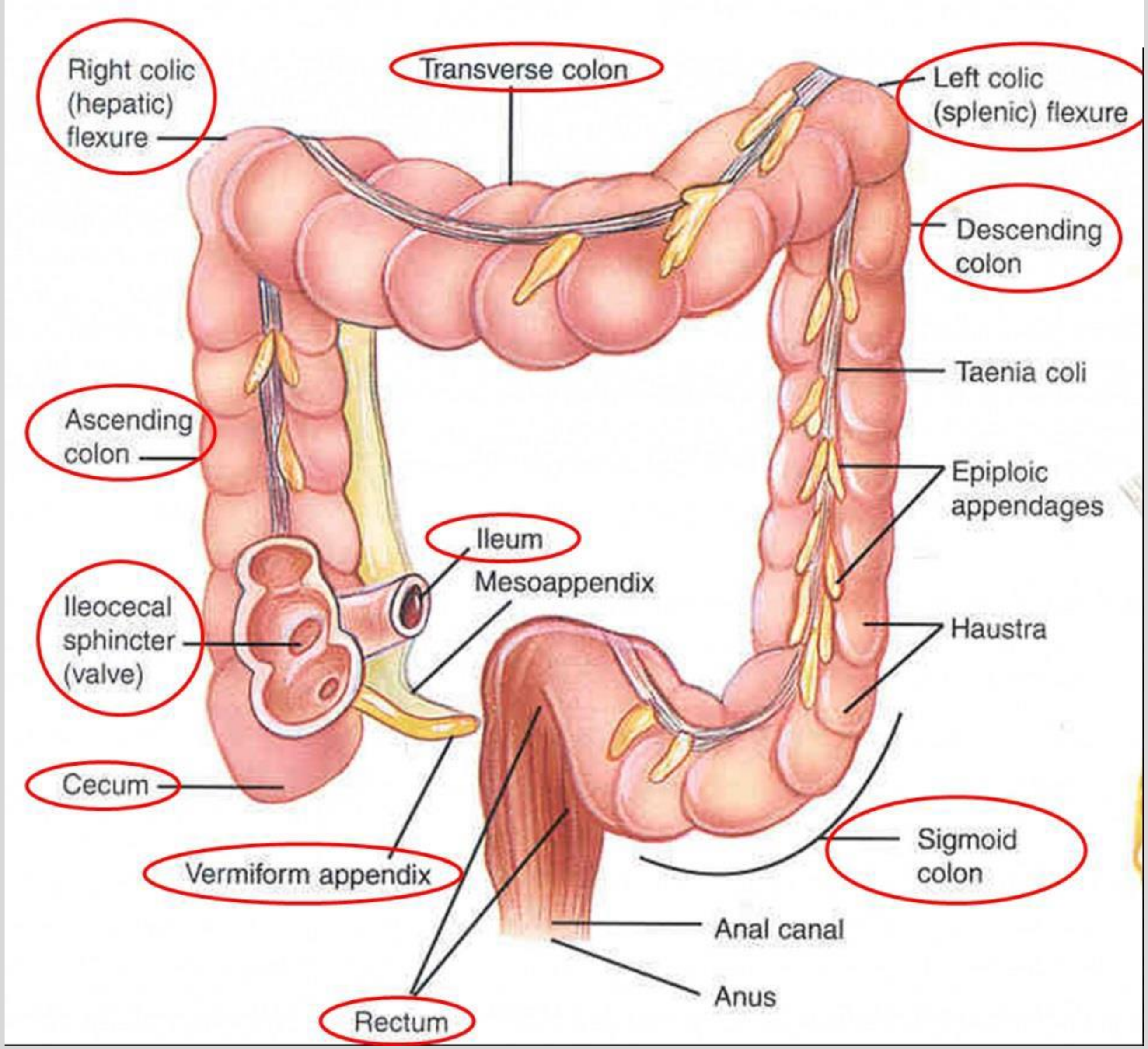
- Physiology: 90% of digestion & Absorption Digestion in duodenum → food is mixed with (bile from liver, pancreatic juice + intestinal juice "Succus entericus")

Colon

- The colon is approximately 1.5 m long.
- The colon begins at the ileocaecal valve and extends to the rectum.
- It includes: Cecum [7 cm], right (ascending) colon [20 cm], transverse colon[45 cm], left (descending) colon [30 cm] and sigmoid colon [40

- Between the ileum and the cecum there’s an ileocecal valve which prevent the reflux of bowel content from the cecum back to the ileum.
- The cecum is the widest, the colon progressively narrows distally

- The colon has taenia coli, haustra and appendices epiploicae (fat appendages that hang off antimesenteric side of the colon).


Right colic
(hepatic)
flexure
Transverse colon
Left colic
(splenic) flexure
Descending
colon
Taenia coli
Ascending
colon
Epiploic
appendages
Ileum
Mesoappendix
Ileocecal
sphincter
(valve)
Haustra
Cecum
Sigmoid
colon
Vermiform appendix
Anal canal
Anus
Rectum

- Taenia coli are three distinct bands of longitudinal muscle which converge at the appendix and spread out to form the longitudinal muscle layer at the proximal rectum.

- Haustra are sac-like segments which appear after contractions of the colon.

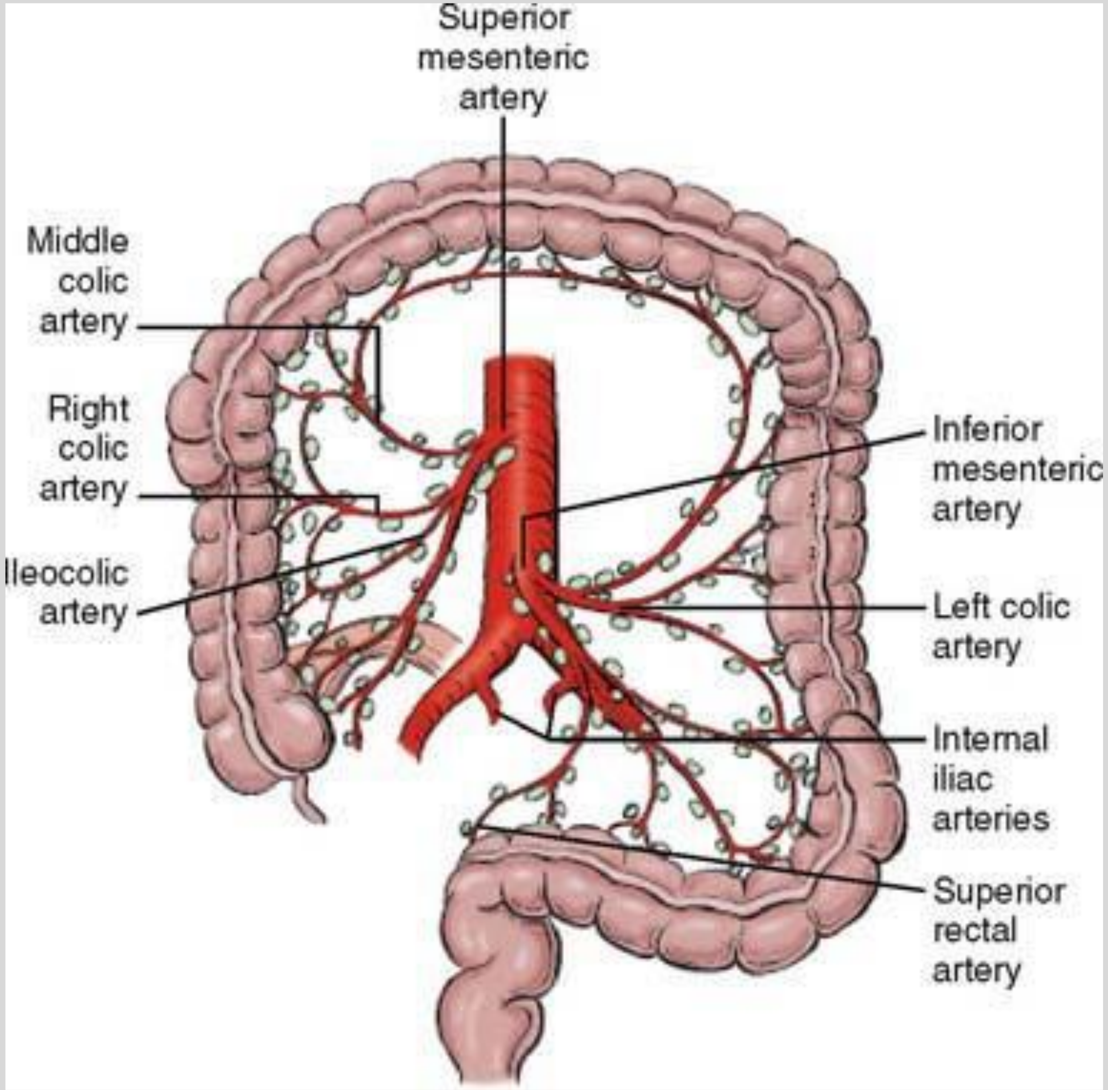
- Retroperitoneal structures: Ascending colon and descending colon.

- Intraperitoneal structures: Cecum, Transverse colon and sigmoid colon.

- Note: the only parts of the GI tract which are not covered by serosa are: the esophagus, middle rectum and distal rectum.

- Superior mesenteric artery gives three branches:
- 1. Ileocolic artery → Supplies the cecum.
- 2. Right colic artery → Supplies the ascending colon.
- 3. Middle colic artery → Supplies the proximal 2/3 of the transverse colon

- Inferior mesenteric artery gives three branches:
- 1. Left colic artery → Supplies the distal 1/3 of the transverse colon.
- 2. Sigmoidal artery → Supplies the sigmoid.
- 3. Superior rectal artery →Supplies the superior third of the rectum.



- **Marginal artery** – runs along colon margin, connecting SMA to IMA (provides collateral flow)
- **Arc of Riolan** (meandering mesenteric artery) – short direct collateral connection between SMA and IMA

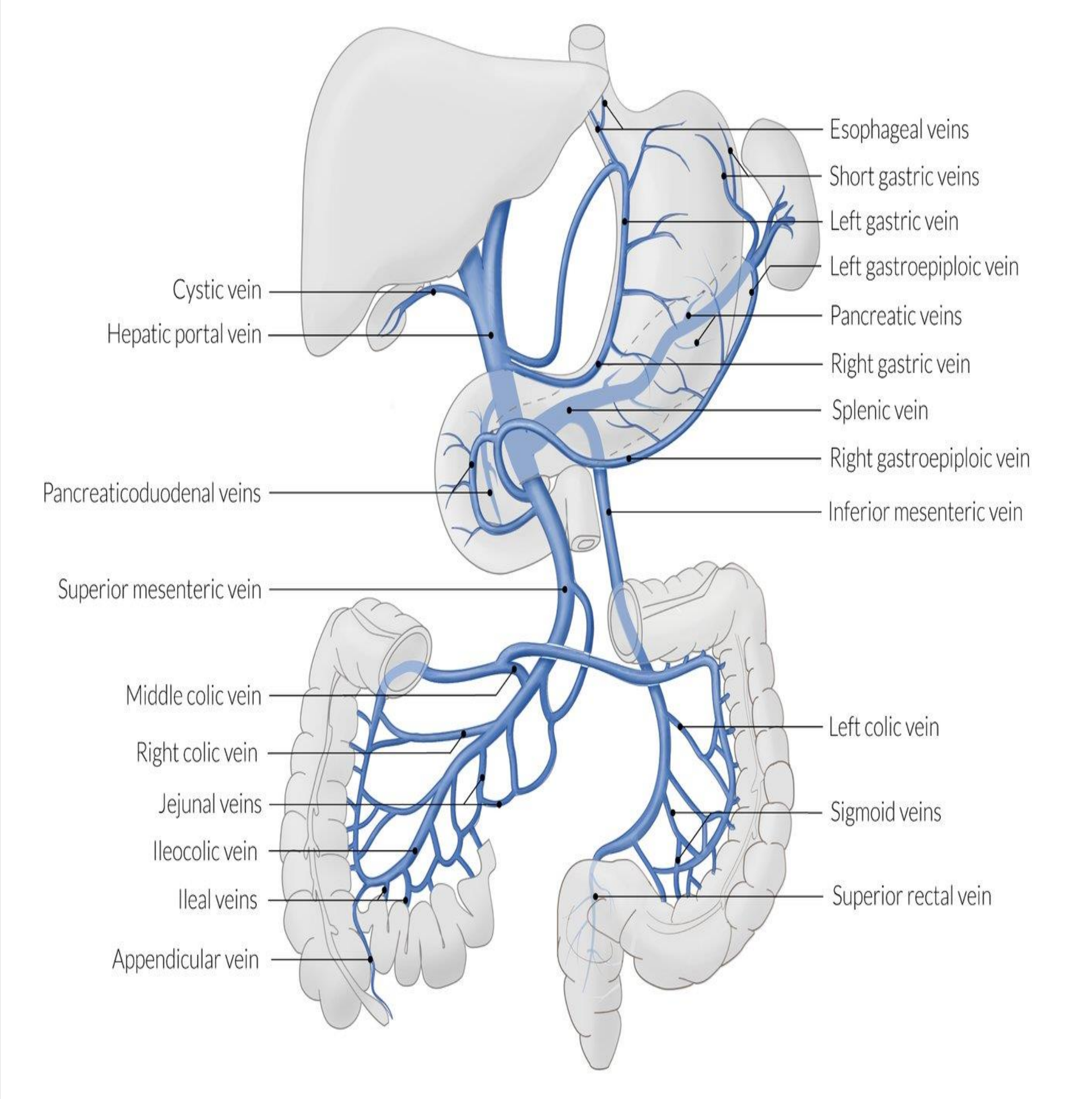
- **Watershed areas:**

  Splenic flexure (Griffith's point) – SMA and IMA junction

  Rectum (Sudeck's point) – superior rectal and middle rectal junction

  Hypotension or low-flow state causes ischemia in these areas.

  Colon more sensitive to ischemia than small bowel secondary to decrease collaterals



- The venous drainage of the colon is through the SMV (drains the cecum, ascending and descending colon) and IMV (drains the descending, sigmoid and proximal rectum).

- Histology:
- Mucosa → Submucosa → innercircular muscular layer →outer longitudinal muscular layer (forming taenia coli)

- The mucosal layer consists of epithelium, lamina propria and muscularis mucosa.
- The submucosal layer contains the Meissener plexus (submucosal plexus) which is part of the enteric nervous system (ENS) and it controls colon secretions.
- Between the circular and longitudinal muscular layers there’s the Myenteric plexus (Auerbach plexus) which is part of the enteric nervous system (ENS) and it controls colon motility.

- Innervation: Derived mainly from the autonomic nervous system (ANS):

1. Sympathatic → inhibits peristalsis and secretion.
2. Parasympathatic → stimulates peristalsis and secretion.

- The colon is sterile at birth.
- Normal flora is established shortly after birth.
- Normal flora includes:
  - 99% Anaerobic (Predominantly Bacteroides fragilis).
  - 1% Aerobic (Predominantly E.coli).

- Physiology: The main physiological functions of the colon are:

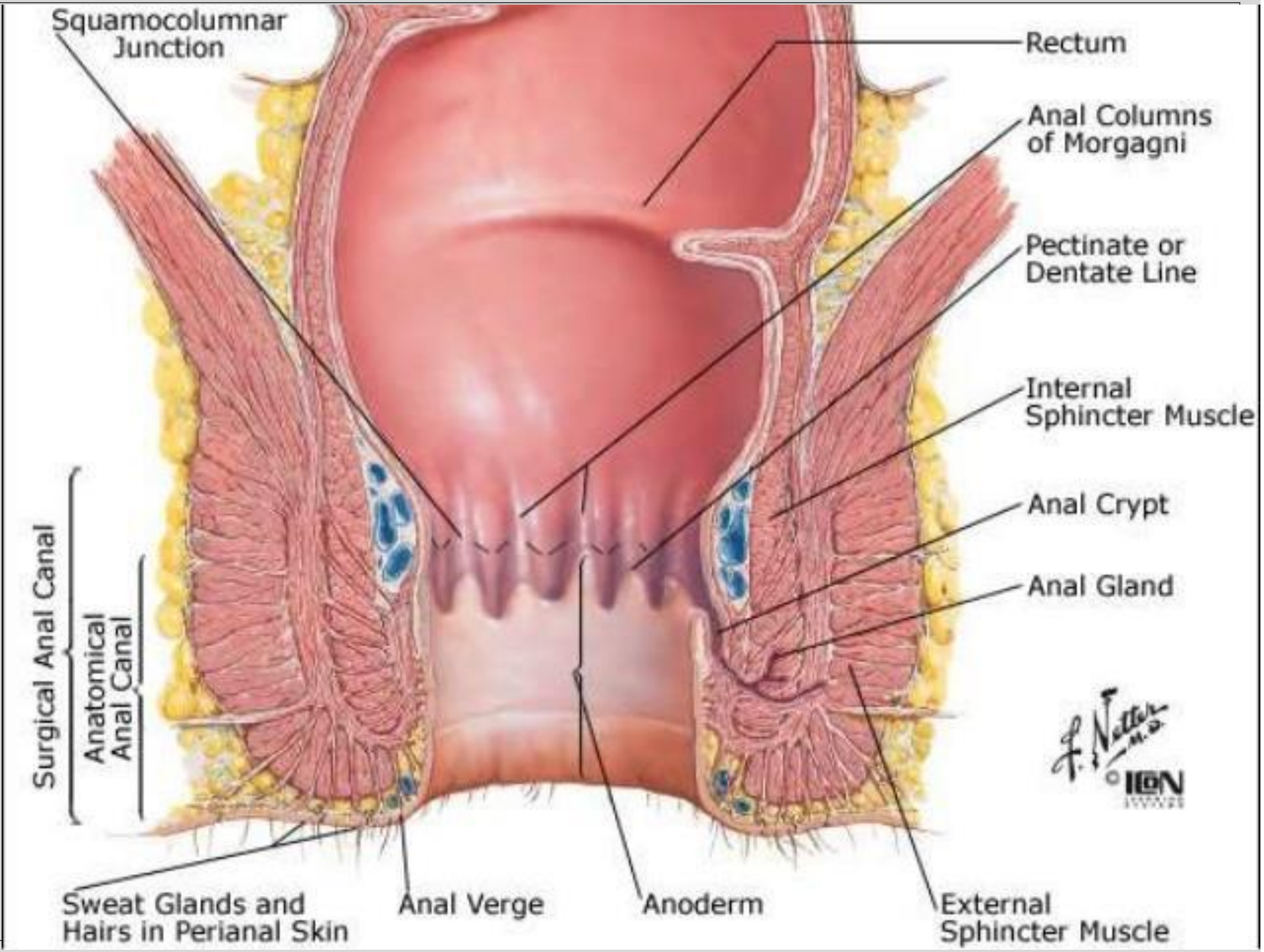
- Absorptions and Secretions:
  - The principal function of the colon is absorption of water.
  - Sodium and chloride absorption also take place in the colon.
  - Active excretion of Potassium takes place.

- Motility: Colonic motility is variable.,Two types of contractions take place:
  - 1. Segmentation → Mixing contractions which are responsible for the appearance of haustra.
  - 2. Contractions resulting in mass movement → 1-3 times/day.

- Storage of feces.

Anal and Rectum

- The rectum and the proximal anus are hindgut organs, so they are derived from Endoderm. Distal anus is derived from ectoderm.



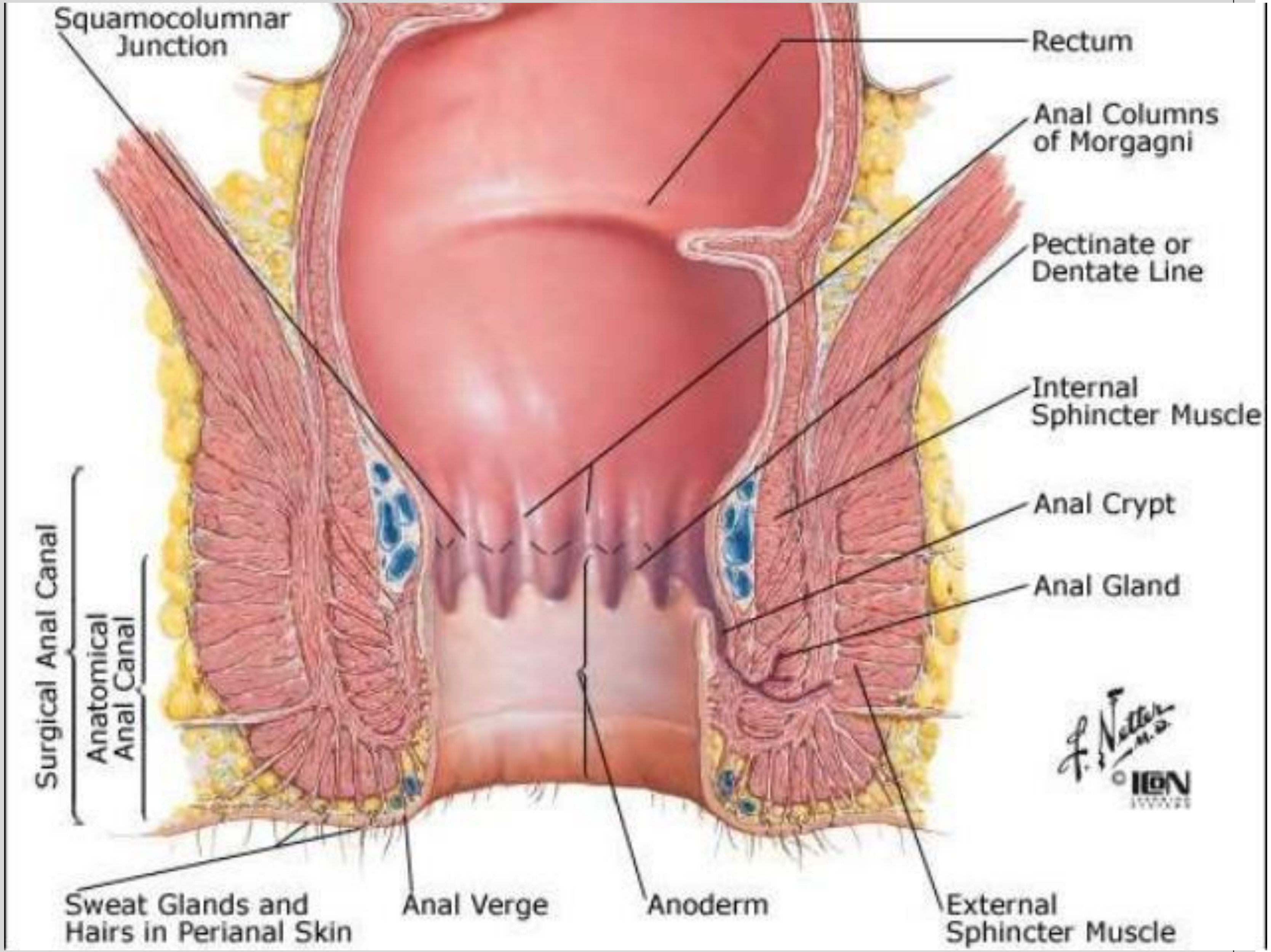
Rectum

- 12-15 cm. Divided into upper, middle and lower thirds.
- Upper third is covered by peritoneum anteriorly and laterally.
- Middle third is covered by peritoneum anteriorly.
- Lower third is extraperitoneal.
- Fascia in front of the lower third is called Denovillier’s fascia.

- Waldey’s fascia (rectosacral fascia): Condensations of presacral fascia in the lower part of the sacrum (s4).
- Lateral ligaments: From the rectum to the sides of the pelvis. Contain middle rectal vessels.

Anus

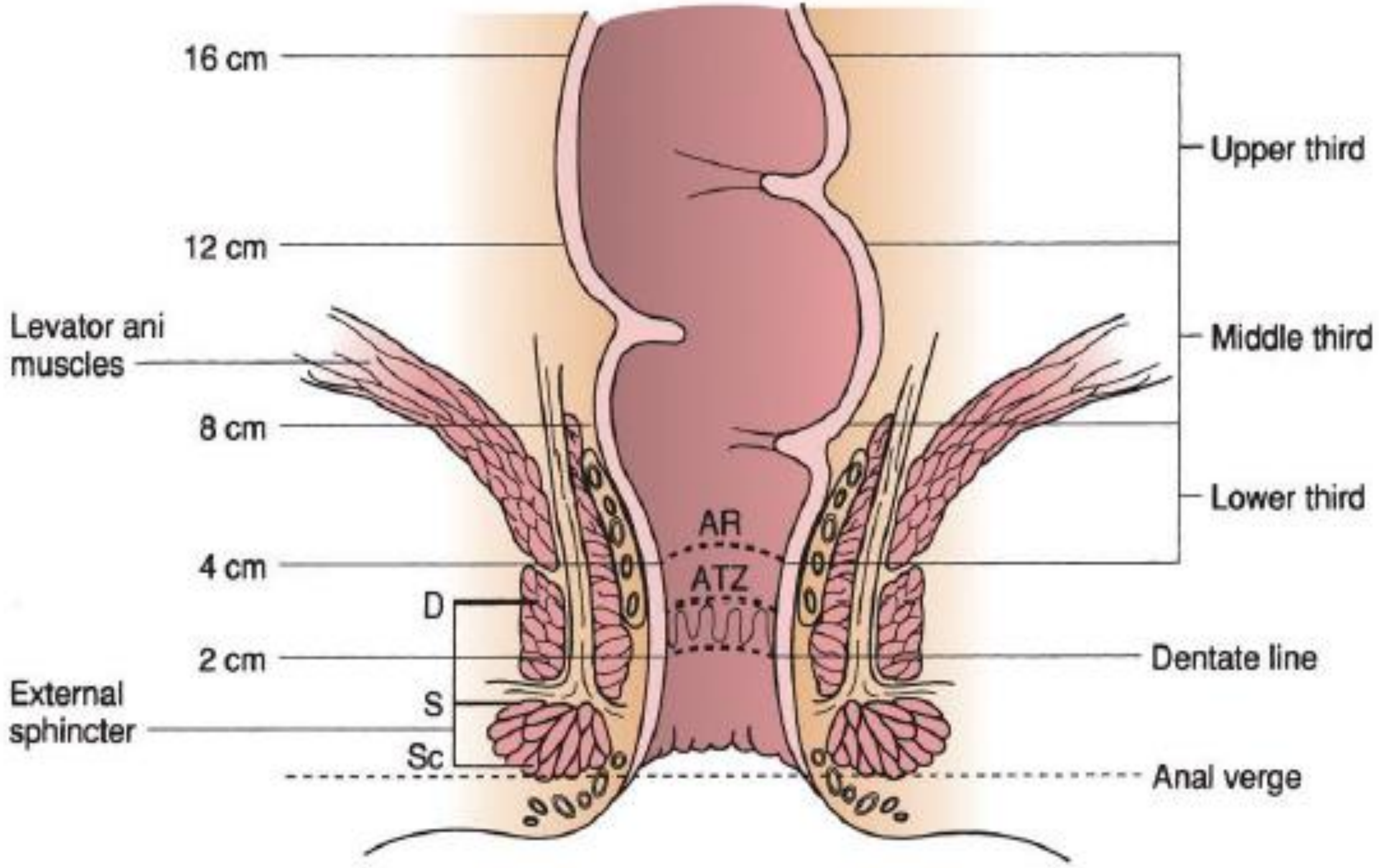
- Anatomical anal canal: From anal verge to the dentate line (3 cm)
- Surgical anal canal: From anal verge to the anorectal ring (5 cm).



- Anal verge: The opening of the anus on the surface of the body. Or it is the transitional zone between the moist, hairless, modified skin of the anal canal and the perianal skin.

- Dentate line (Pectinate line): A mucocutaneous line that separates proximal, pleated mucosa from distal, smooth anoderm (1–1.5 cm above anal verge Formed by series of cusps. The spaces within the cusps are called crypts, into which the ducts of mucus secreting anal glands open.

- Anal mucosa proximal to dentate line lined by columnar epithelium; mucosa distal to dentate line is a specialized form of skin (squamous) that is devoid from skin appendages. It is called the anoderm.



Anorectal anatomy with important landmarks. Approximate measurements are relative to the anal verge. AR, anorectal ring; ATZ, anal transition zone; D, deep; S, superficial; Sc, subcutaneous.

◦ The transitional area (a.k.a. Cloacogenic area) is the actual mucocutaneous junction (not the dentate line). It is 1 cm above the dentate line. This area is lined by columnar, squamous or any type of epithelium.

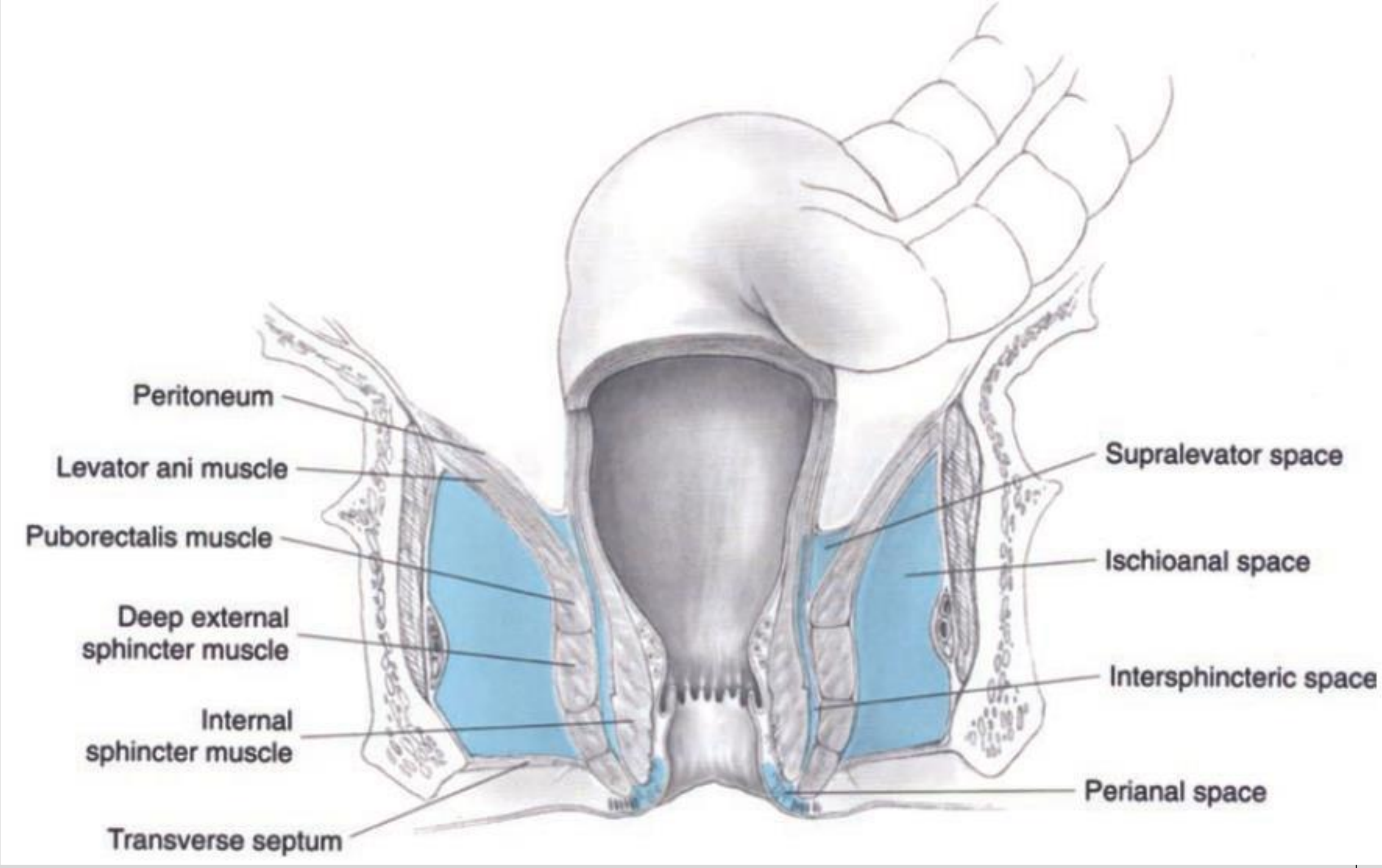
◦ Columns of Morgangi: 12–14 columns o pleated mucosa superior to the dentate line separated by crypts.

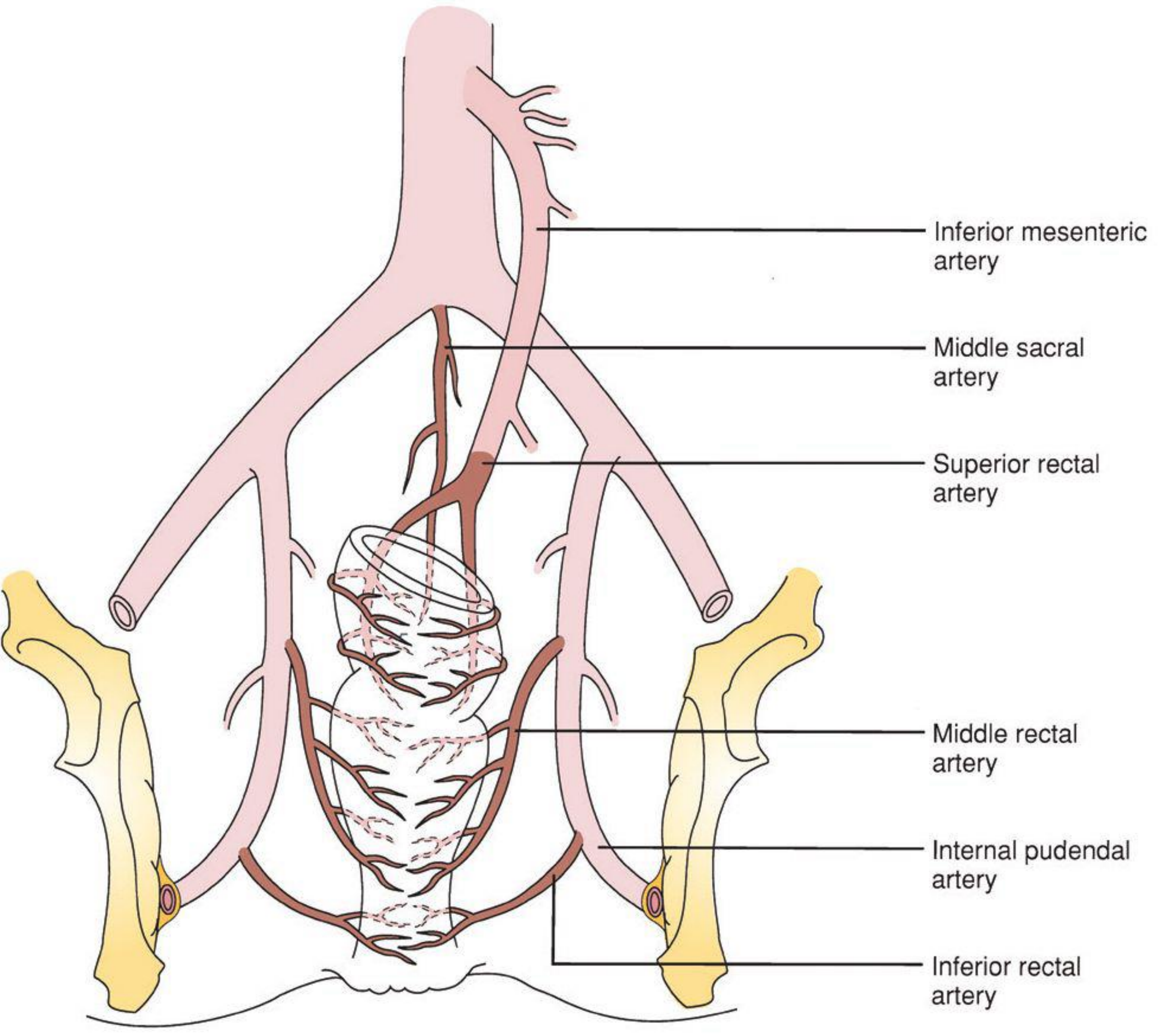
◦ Anal glands: ➢ 8 – 12 in number. ➢ Lay in the intersphincteric plate. ➢ Their ducts open in the crypts. ➢ Most of them are located in the anterior part of the anus.

- Anal sphincters: Internal and External.
- The internal sphincter: specialized rectal smooth muscle (from inner circular layer); involuntary, contracted at rest, responsible or 80% of resting pressure.
- The external sphincter: Striated muscle. A continuation of puborectalis muscle; responsible or 20% of resting pressure and 100% of voluntary pressure.

◦ Perianal spaces:

◦ Perianal space proper.
◦ Ischiorectal fossa.
◦ Intersphincteric space.
◦ Supralevator space.





Blood supply:

- Arterial:
- Rectum: Porto-systematic:

1- Superior rectal arteries from IMA – Portal.

2- Middle and Inferior rectal arteries from Internal Iliac – Systematic.

- Anus: Systematic: Internal pudendal artery (from internal iliac).

- Hemorrhoidal plexuses: Three complexes within the anus (Internal; contains highly oxygenated blood) that drain into the superior rectal veins and one external complex that drains into the pudendal veins.

- Lymphatic drainage:
- Perirectal lymphatics → Mesenteric (mostly) and internal iliac nodes.
- Anal lymphatics → Superficial inguinal nodes.
- Note: Anal canal above dentate line drains to inferior mesenteric nodes or to internal iliac nodes. Lower anal canal drains to inguinal nodes.

- Nerve supply:

- Sphincters:

1- Internal: Sympathetic (L1-L3) and parasympathetic (s2-s4) [Hypogastric plexus a.k.a. presacral plexus]

2- External: Internal pudendal nerve (S2-S4).

- Anus: Internal pudendal nerve (S2-S4) [sensory and motor].
- Below dentate → Sensitive to pain.
- Above dentate → Insensitive to pain

- Internal sphincter is a smooth muscle; involuntary and has tonic activity. It does not fatigue.
- External sphincter is a skeletal muscle; voluntary and has somatic supply. Fatigues easily.

Physiology:

Defecation:

Rectal distension

↓

Inhibition of internal sphincter and Activation of defecation center

↙ ↘

Cortical facilitation (when it is appropriate to defecate)

↓

Contraction of levator ani and abdominal muscles

↓

Defecation

Cortical inhibition (when it is inappropriate to defecate)

↓

Contraction of external sphincter and puborectalis

↓

Receptive relaxation of rectum

Receptive relaxation: It allows volume expansion without increment in the pressure (so when urge comes and no defecation occurs → dilation of rectum → urge will disappear).