Anatomy and Physiology of the Upper Gut

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Introduction

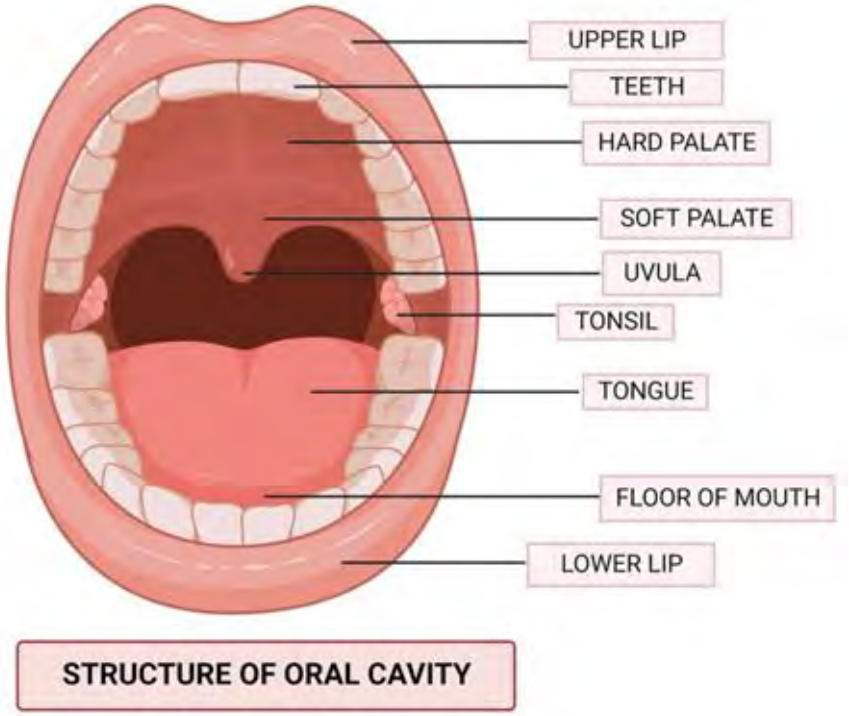
- The gastrointestinal tract is a hollow muscular tube that stretches from the mouth to the anus
- Its primary function is to serve as a portal whereby nutrients and water can be absorbed into the body
- In fulfilling this function, the meal is mixed with a variety of secretions that arise from both the gastrointestinal tract itself and accessory organs that drain into it, such as the pancreas, gallbladder, and salivary glands

- **Structural considerations**
- The parts of the gastrointestinal tract that are encountered by the meal or its residues include, in order, the mouth, oesophagus, stomach, duodenum, jejunum, ileum, cecum, colon, rectum, and anus

Oral Cavity and Pharynx: The Processor and the Gatekeeper

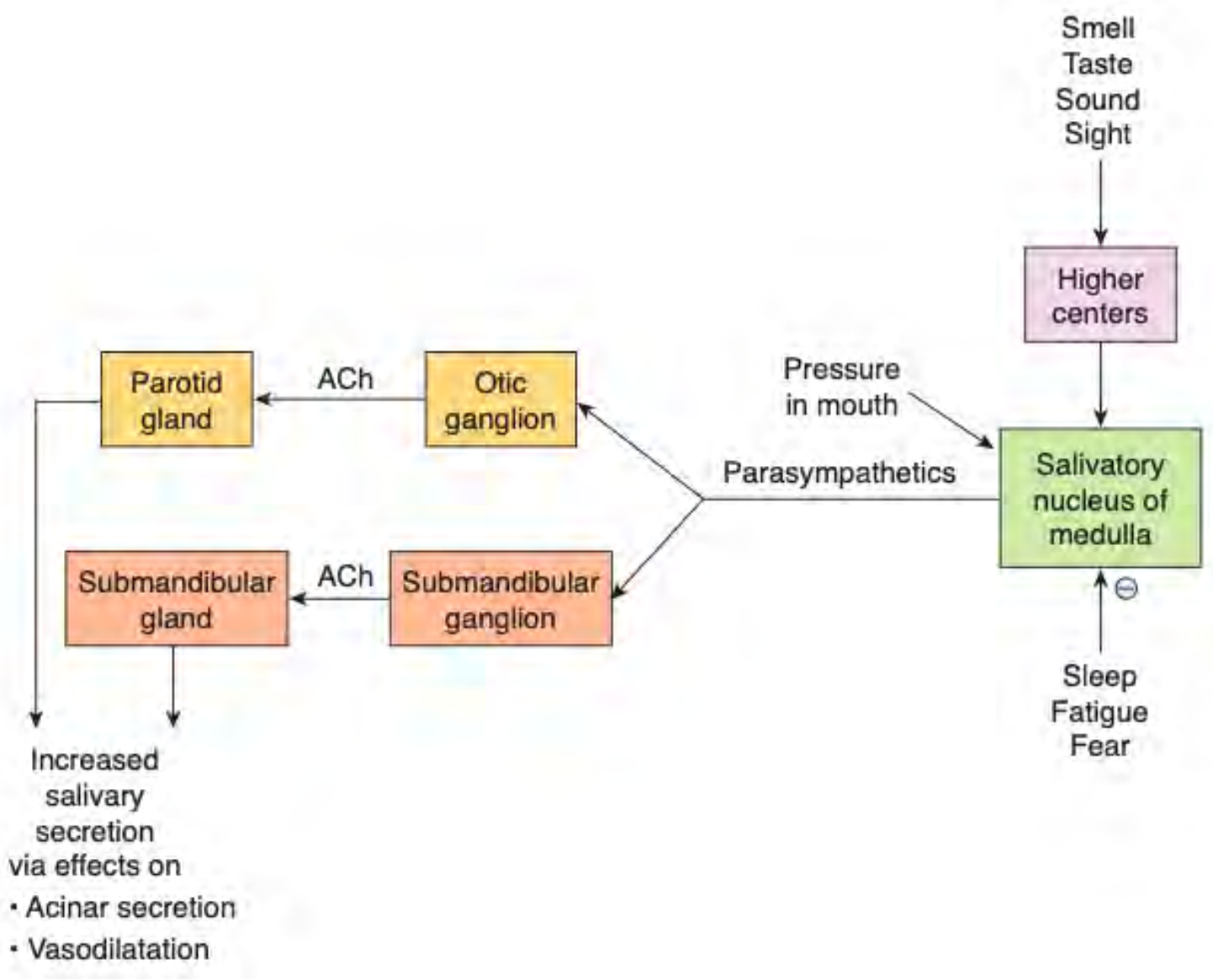
Oral cavity

- **Oral cavity**
- The oral cavity consists of the lips, teeth, tongue, hard and soft palates, and salivary glands
- Its primary functions are **mechanical breakdown** of food, **mixing** with saliva (which contains amylase and mucins), and formation of a cohesive bolus



Saliva

- **Salivary secretion:**
- First secretion encountered when food is ingested
- Produced by **three pairs of salivary glands**:
  - parotid,
  - submandibular,
  - sublingual glands
- Drains into the oral cavity
- 1- 1.5L produced per day
- Critical for digestion and oral protection



- **Composition of saliva**
- Contains water, electrolytes and organic molecules
- Amylase: initiates starch digestion
- Mucin: lubricates the food
- IgA and lysozyme: provides antibacterial defense
- Alkaline: important to neutralize any gastric secretions that reflux into oesophagus

- **Clinical importance**
- Buffers maintain oral pH at 7
- Neutralizes refluxed gastric acid
- Protects teeth and oral cavity

Pharynx

- The pharynx, derived from the foregut, is a muscular tube divided into nasopharynx, oropharynx, and hypopharynx
- It serves as a shared conduit for both the respiratory and digestive tracts
- During swallowing, the pharynx coordinates with the larynx to protect the airway and direct the bolus into the oesophagus
- This process is mediated by complex neuromuscular reflexes involving cranial nerves and brainstem swallowing centers, integrating both voluntary and involuntary control

Swallowing: Physiology

- Swallowing (deglutition) is a coordinated reflex process
- Initiated voluntarily but largely involuntary thereafter
- Transfers food safely from mouth to stomach
- Requires precise neuromuscular coordination

Swallowing: Physiology

- **Afferent pathway**
- Swallowing reflex triggered by sensory input
- Afferent impulses carried by:
  - Trigeminal nerve (CN V)
  - Glossopharyngeal nerve (CN IX)
  - Vagus nerve (CN X)

Swallowing: Physiology

- **Central integration**
- Swallowing center located in the brainstem
- Integration within nucleus tractus solitarius
- And nucleus ambiguus
- Coordinates timing and sequence of contractions

Swallowing: Physiology

- **Efferent pathways**
- Motor output to pharynx and tongue muscles
- Efferent fibers via:
  - Trigeminal nerve (CN V)
  - Facial nerve (CN VII)
  - Hypoglossal nerve (CN XII)

Swallowing: Physiology

- **Oral phase (voluntary)**
- Food collected on the tongue
- Bolus propelled posteriorly into the pharynx
- Under voluntary control
- Initiates the swallowing reflex

Swallowing: Physiology

- **Pharyngeal phase (involuntary)**
- Sequential contraction of pharyngeal muscles
- Bolus directed into the oesophagus
- Respiration temporarily inhibited
- Glottic closure prevents aspiration

Swallowing: Physiology

- **Oesophageal phase (peristalsis)**
- Peristaltic ring contraction follows the bolus
- Propels material down the oesophagus
- Average speed approximately 4 cm/s
- Mediated by coordinated muscle activity

Swallowing: Physiology

- **Role of gravity**
- Gravity assists bolus movement when upright
- Liquids and semisolids may descend ahead of peristalsis
- Peristalsis still required for complete clearance

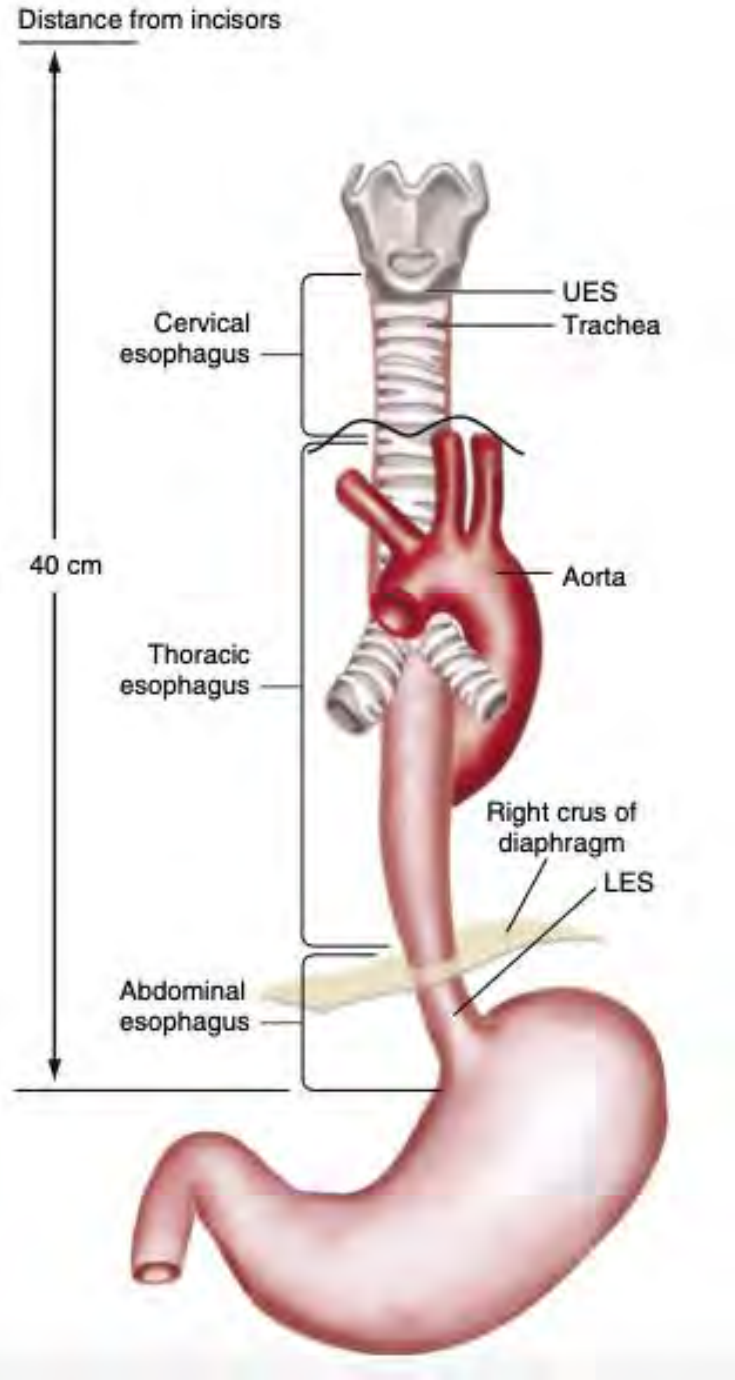
Swallowing: Physiology

- **Clinical significance**
- Disruption leads to dysphagia
- Risk of aspiration if airway protection fails
- Important in neuromuscular disorders
- Key mechanism in upper GI physiology

Oesophagus:
The Conduit for Food Transport

Oesophagus

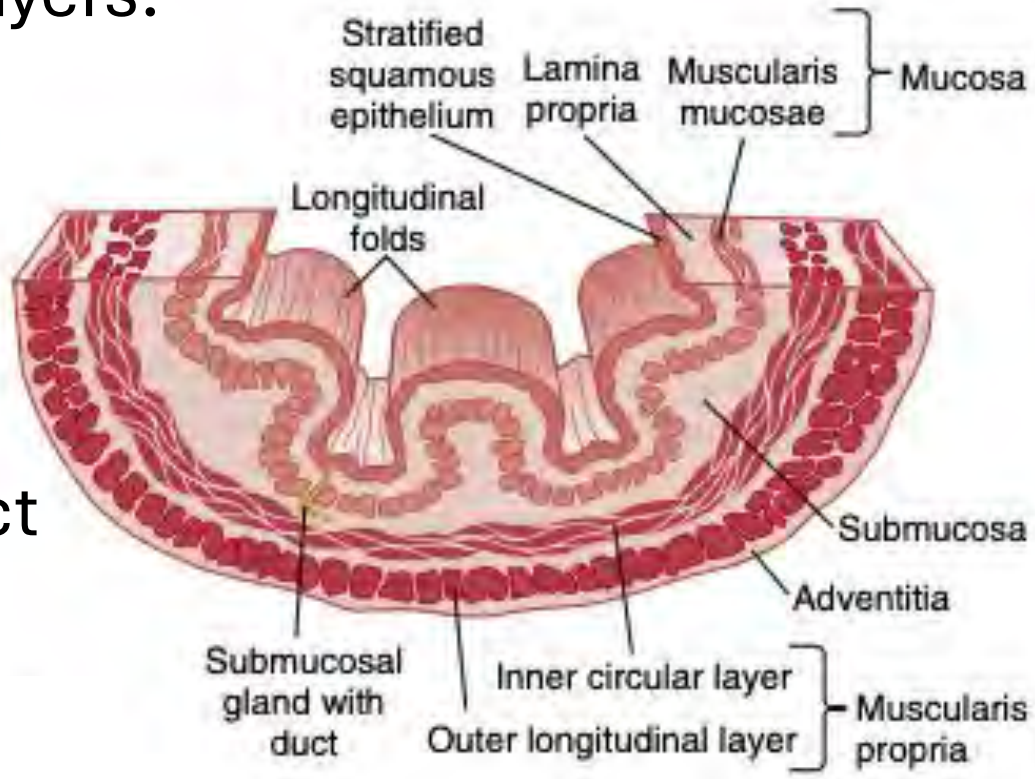
- The main function of the oesophagus is to **act as a conduit** for the transport of food from the oral cavity to the stomach
- 18 to 26 cm hollow muscular tube
- Inner lining of **stratified squamous epithelium**
- Typically collapsed between the swallows
- Can distend upto 2cm AP and 3 cm laterally to accommodate swallows



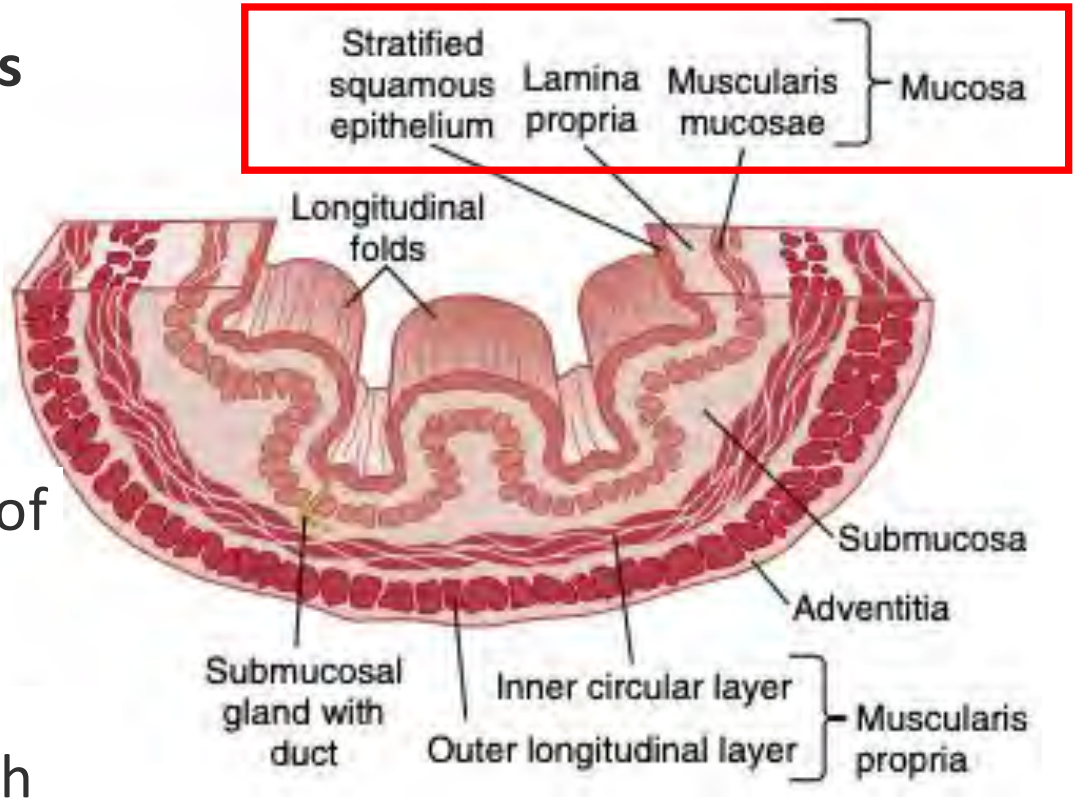
Oesophagus

- Oesophageal wall is composed of 4 layers:
  - Innermost **mucosa**
  - **Submucosa**
  - **Muscularis propria**
  - Outer most **adventitia**

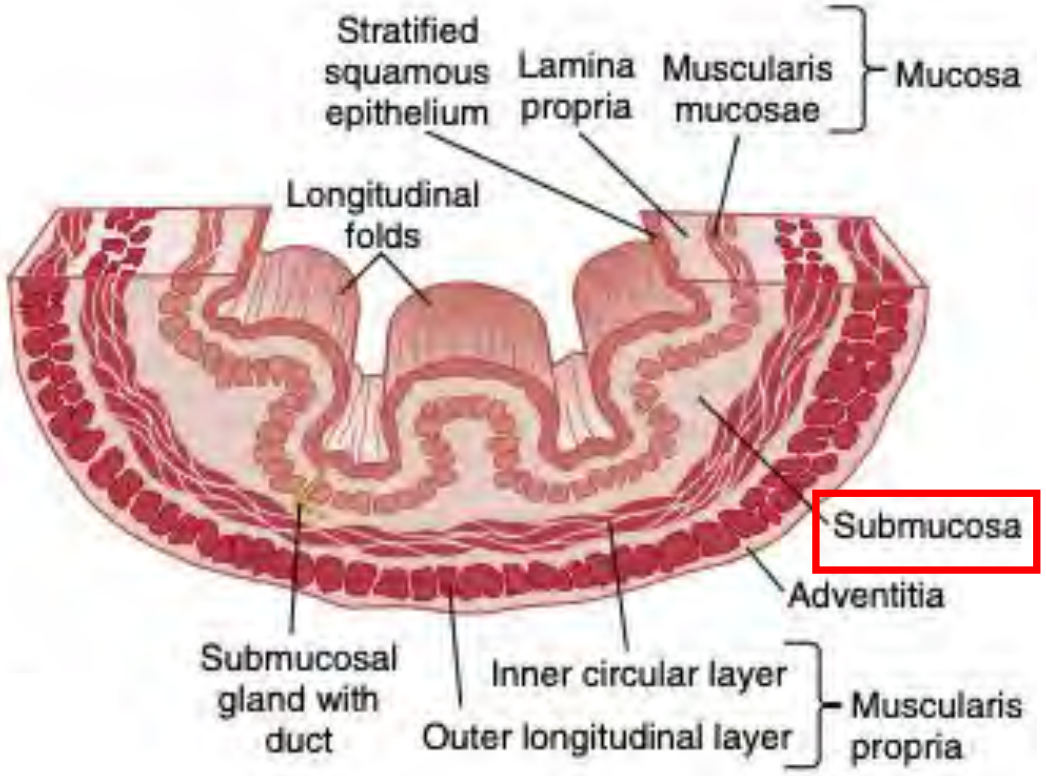
- No serosa unlike the rest of the GI tract



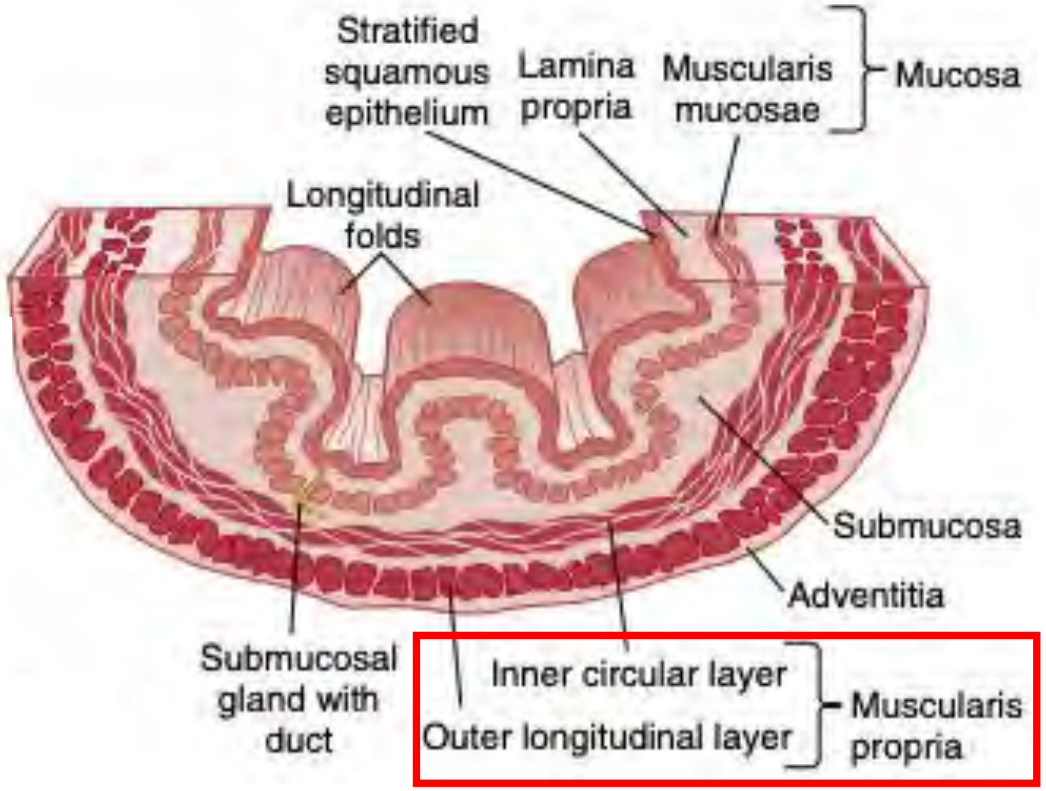
- **Mucosa**
- The inner lining consists of **stratified squamous epithelium** (non-keratinized)
- Epithelium is multilayered:
  - stratum corneum (acting as a permeability barrier)
  - stratum spinosum (metabolically active cells), and
  - stratum germinativum (basal cells capable of replication).
- Beneath the epithelium is the **lamina propria** (connective tissue) and
- the **muscularis mucosae** (a thin layer of smooth muscle)



- **Submucosa:**
- This layer contains **a dense network of connective tissue**, blood vessels, lymphatic channels, the **Meissner plexus** of neurons, and oesophageal glands.
- The **oesophageal glands** produce and secrete mucus, bicarbonate, and epidermal growth factor crucial for epithelial defense and repair



- **Musculature (Muscularis Propria):**
- This layer is responsible for the **organ's motor function**.
- The **upper 5% to 33**% is comprised exclusively of **skeletal muscle**, while the **distal 50%** is composed of **smooth muscle**, with a mix in between.
- The muscular layers consist of an inner circular layer and an outer longitudinal layer



Sphincters

- The oesophagus features two specialized muscle areas that regulate passage and prevent reflux:
- **Upper Oesophageal Sphincter (UES):**
  - Located proximally where the inferior pharyngeal constrictor meets the cricopharyngeus.
  - It is composed of skeletal muscle and is contracted at rest, creating a high-pressure zone to prevent inspired air from entering the oesophagus
- **Lower Oesophageal Sphincter (LES):**
  - A 2- to 4-cm segment of thickened circular smooth muscle located at the diaphragmatic hiatus.
  - The LES is contracted at rest, preventing gastric contents from entering the oesophagus, and relaxes during peristalsis to permit the swallowed bolus to pass into the stomach
  - Diaphragmatic contractions assist the LES in maintaining high pressure

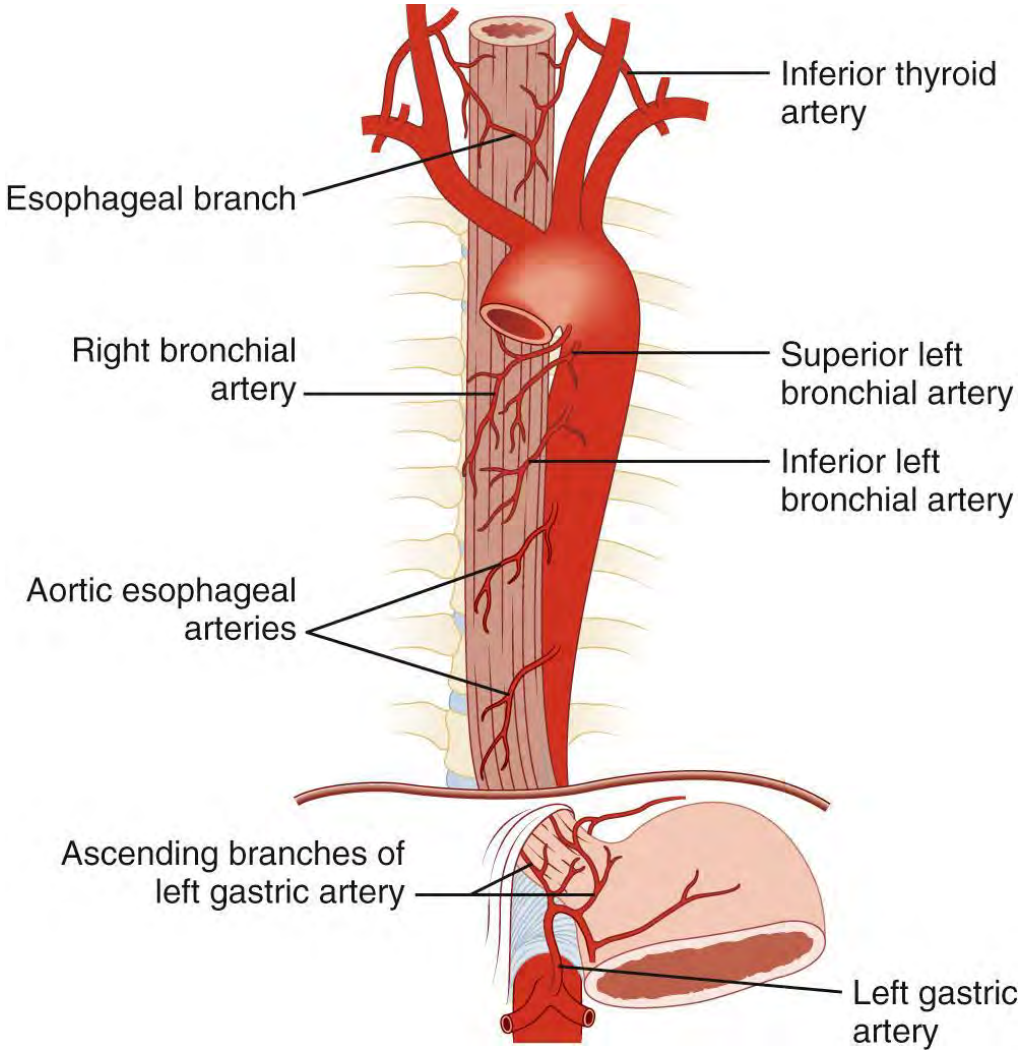
Innervation

- Peristalsis is regulated by parasympathetic nerves through the **vagus nerve**
- Vagal cell bodies originating in the medulla control muscle types: the **nucleus ambiguus controls skeletal muscle**, and the **dorsal motor nucleus controls smooth muscle.**
- Vagal preganglionic efferent nerves heading to smooth muscle terminate on neurons within the **Auerbach (myenteric) plexus**
- **Pain Sensation:**
- Pain is typically triggered by chemoreceptors in the mucosa or submucosa or mechanoreceptors in the musculature.
- These impulses are transmitted to the central nervous system via sympathetic and vagal afferent pathways

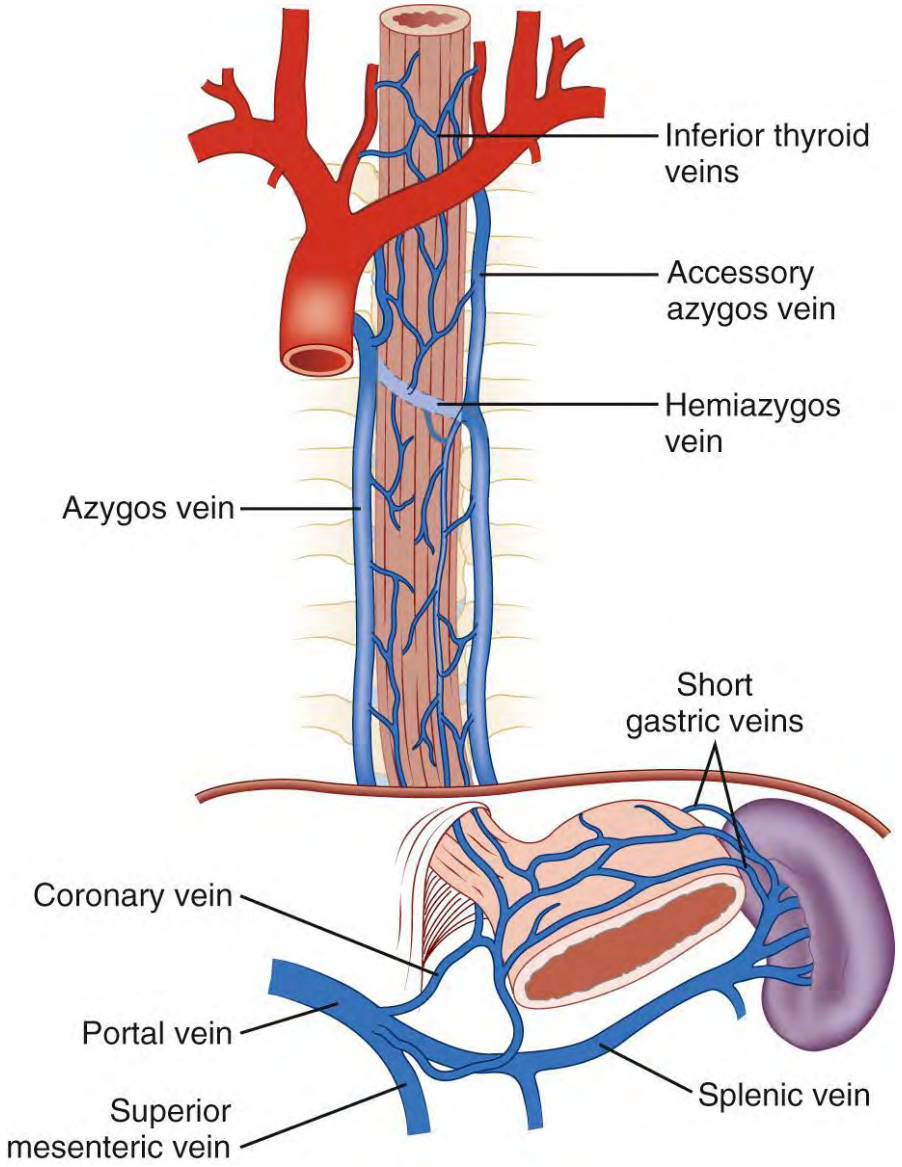
Circulation

- The circulation of the oesophagus is characterized by a **segmental arrangement** of its arterial supply, venous drainage, and lymphatic systems

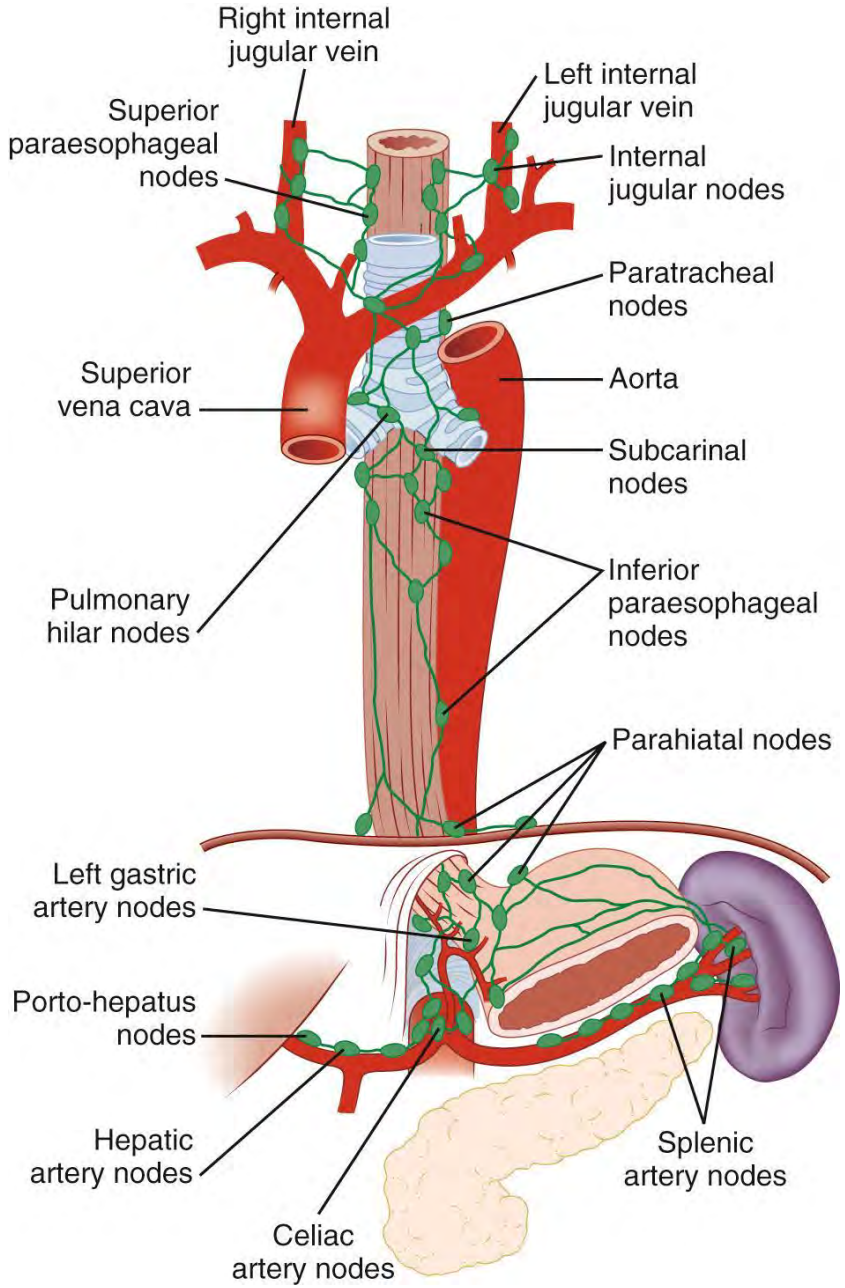
- **Arterial Supply**
- The arterial blood is delivered to the oesophageal wall through three primary segments:
- **Upper oesophagus:** from branches of the **superior** and **inferior thyroid arteries.**
- **Mid oesophagus**: by branches of the **bronchial arteries**, **right intercostal arteries**, and the **descending aorta**.
- **Distal oesophagus**: by branches of the **left gastric**, **left inferior phrenic**, and **splenic arteries**



- **Venous Drainage**
- The venous system of the oesophagus is medically significant because it connects the systemic and portal circulations:
- **Upper oesophagus**: Drains into the **superior vena cava.**
- **Mid oesophagus**: Drains through the **azygos veins.**
- **Distal oesophagus**: Drains into the **portal vein** by way of the **left** and **short gastric veins**
- The **submucosal venous anastomotic network** in the distal oesophagus is particularly critical; it is the site where **oesophageal varices** emerge in patients suffering from portal hypertension



- **Lymphatic drainage**
- The lymphatic system follows a similar segmental pattern, though its channels are highly interconnected, which often facilitates the spread of oesophageal cancer beyond the initial site.
- **Upper oesophagus**: Drains to the **deep cervical nodes.**
- **Mid oesophagus**: Drains to the **mediastinal nodes.**
- **Distal oesophagus**: Drains to the **celiac** and **gastric nodes**



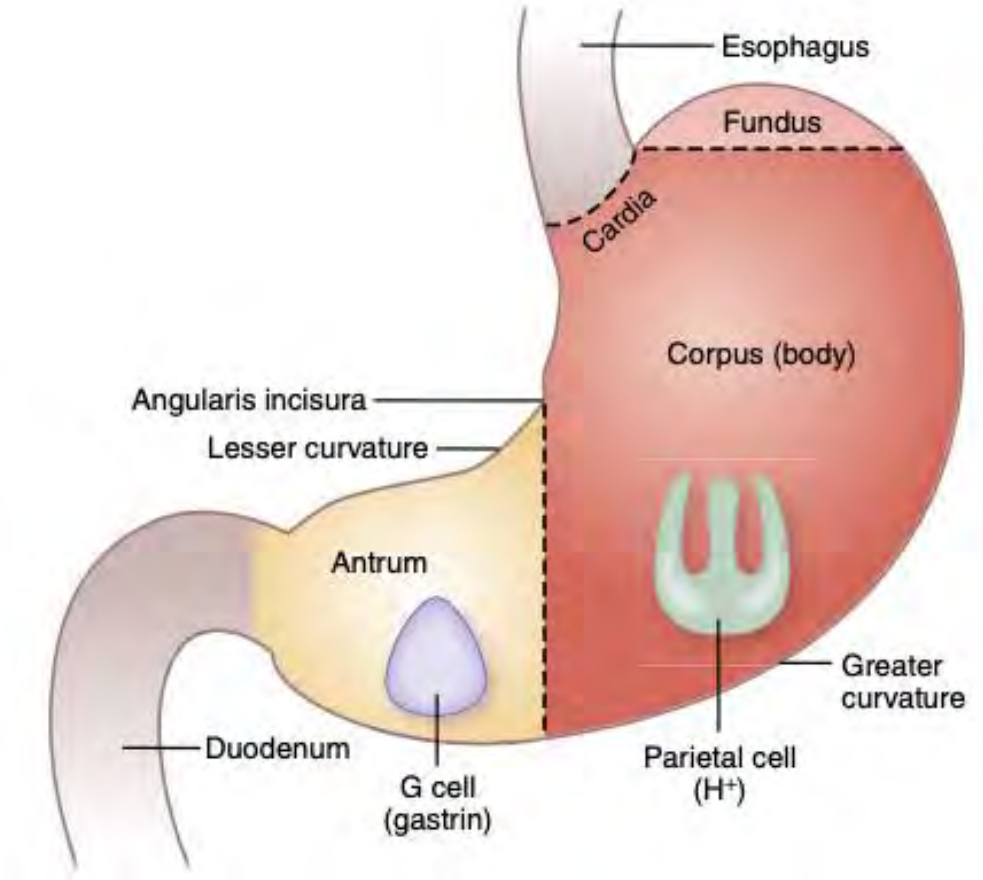
The Stomach: A J-shaped Reservoir in Motion

Stomach

- The stomach is a J-shaped dilation continuous with the oesophagus proximally and the duodenum distally.
- Its primary role is as a **reservoir** to store large quantities of ingested food, initiate the digestive process, and release contents in a controlled manner.
- An adult stomach volume can range from 1.5 to 2 L

Anatomy of the stomach

- The stomach rotates 90 degrees during gestation, resulting in the greater curvature lying to the left and the lesser curvature to the right.
- The stomach is **divided into**
- **Cardia:** A small area adjacent to the esophagogastric junction.
- **Fundus**: The most superior, dome-shaped portion.
- **Body (Corpus):** The largest portion, continuous with the fundus.
- **Antrum**: Extends from the body to the pylorus, demarcated roughly by the incisura angularis along the lesser curvature.
- **Pylorus (Pyloric Channel**): A tubular structure joining the duodenum to the stomach, containing the circular muscle known as the **pyloric sphincter**



Tissue layers of the stomach

- The gastric wall is composed of **four layers**:
- **mucosa,**
- **submucosa,**
- **muscularis propria**,
- **serosa**

- **Mucosa (Innermost Layer):**
- Lined with **simple columnar epithelial cells**, the mucosa appears as a smooth, velvety, blood-filled lining.
- It is organized into **vertical tubular units** containing **gastric pits** and **specialized glands** (oxyntic in the body/fundus and pyloric in the antrum) responsible for secreting acid, enzymes, and hormones.
- The surface forms thick, longitudinal folds called **rugae** that flatten when the stomach is distended

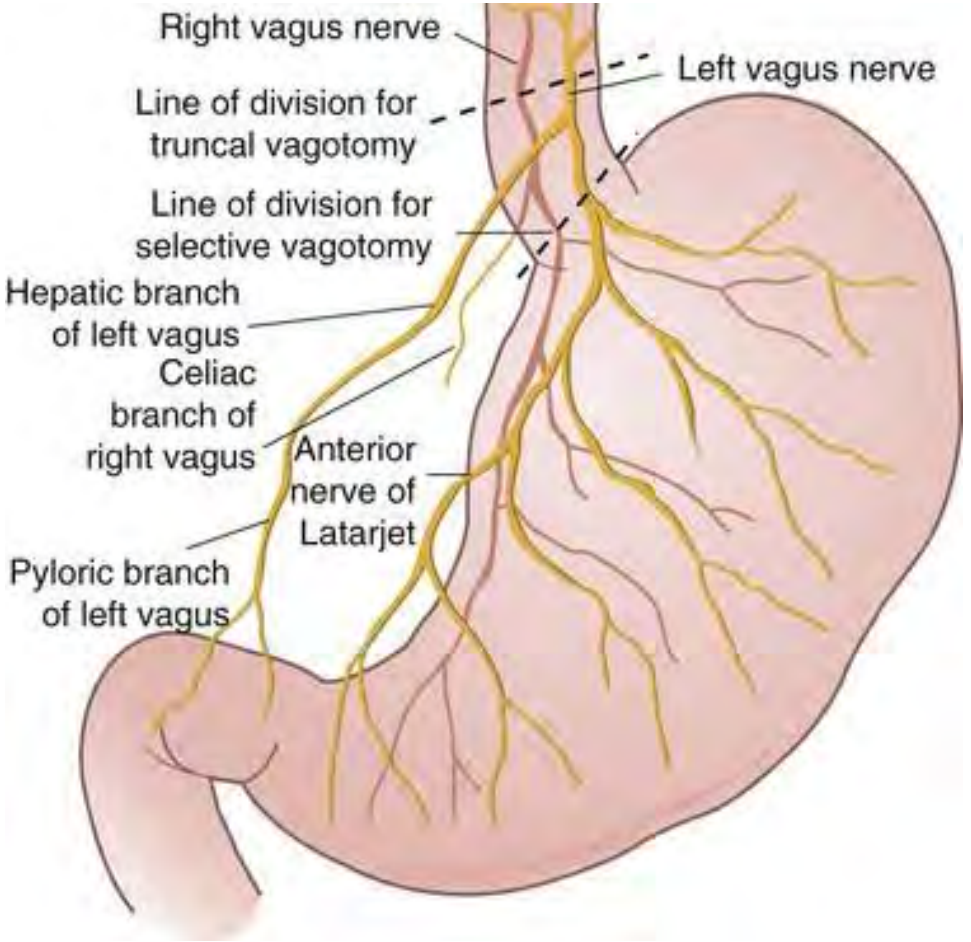
- **Submucosa:**
- Consists of a dense connective tissue skeleton of **collagen and elastin fibers** deep to the mucosa.
- This layer serves as the primary neurovascular housing, containing arterioles, venules, lymphatic channels, and the **submucosal (Meissner's) plexus**

- **Muscularis Propria:**
- Features a unique **three-layer configuration**:
  - an **inner oblique layer** (covering the fundus and walls),
  - a **middle circular layer** (which thickens distally to form the pyloric sphincter), and
  - an **outer longitudinal layer** (coursing along the curvatures).
- The **myenteric (Auerbach's) plexus** is located between these muscle layers to coordinate mechanical grinding and motility

- **Serosa (Outermost Layer):**
- A transparent, protective membrane that is a continuation of the **visceral peritoneum**
- The stomach is almost entirely invested by serosa, distinguishing it from the oesophagus, which lacks this layer

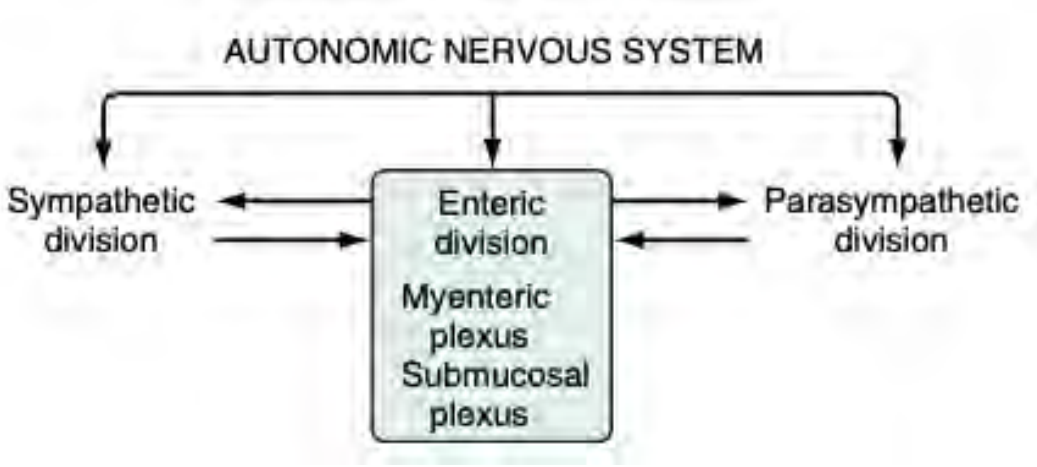
Gastric innervation

- **Innervation**
- Gastric innervation comes from the **sympathetic** (T6–T8 spinal nerves, synapsing in celiac ganglia) and **parasympathetic** systems
- The **vagus nerves** (right and left trunks) provide the parasympathetic input, synapsing with neurons in the **submucosal (Meissner's) and myenteric (Auerbach's) plexuses** in the stomach wall



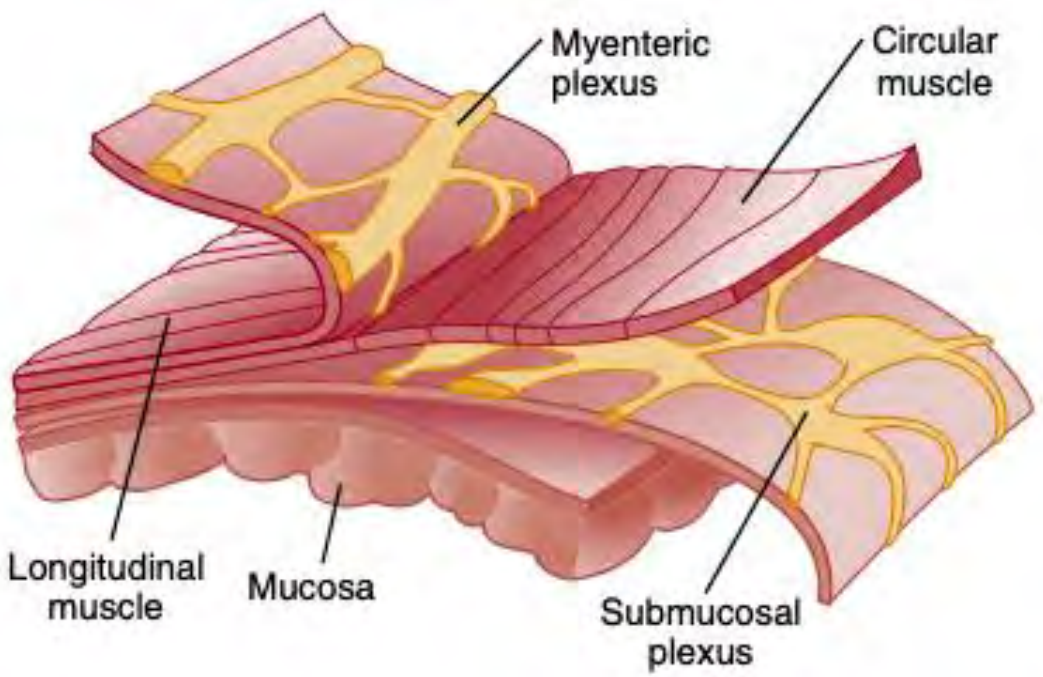
Enteric Nervous System (ENS)

- **The ENS** is the third division of the autonomic nervous system and is often referred to as the "**little brain**"
- Composed of intrinsic neurons with cell bodies located within the walls of the GI tract
- Can function autonomously of central input while still receiving and sending signals to the central nervous system (CNS) via sympathetic and parasympathetic pathways



Enteric Nervous System (ENS)

- **Structural Organization: The Plexuses**
- Organized into two primary neuronal networks found throughout the upper gastrointestinal tract:
- **Myenteric (Auerbach's) Plexus**: Situated between the inner circular and outer longitudinal muscle layers, this plexus is primarily responsible for regulating **motility**
- **Submucosal (Meissner's) Plexus**: Located within the submucosa, this network primarily regulates **secretory functions** and serves as a site for afferent sensory impulses

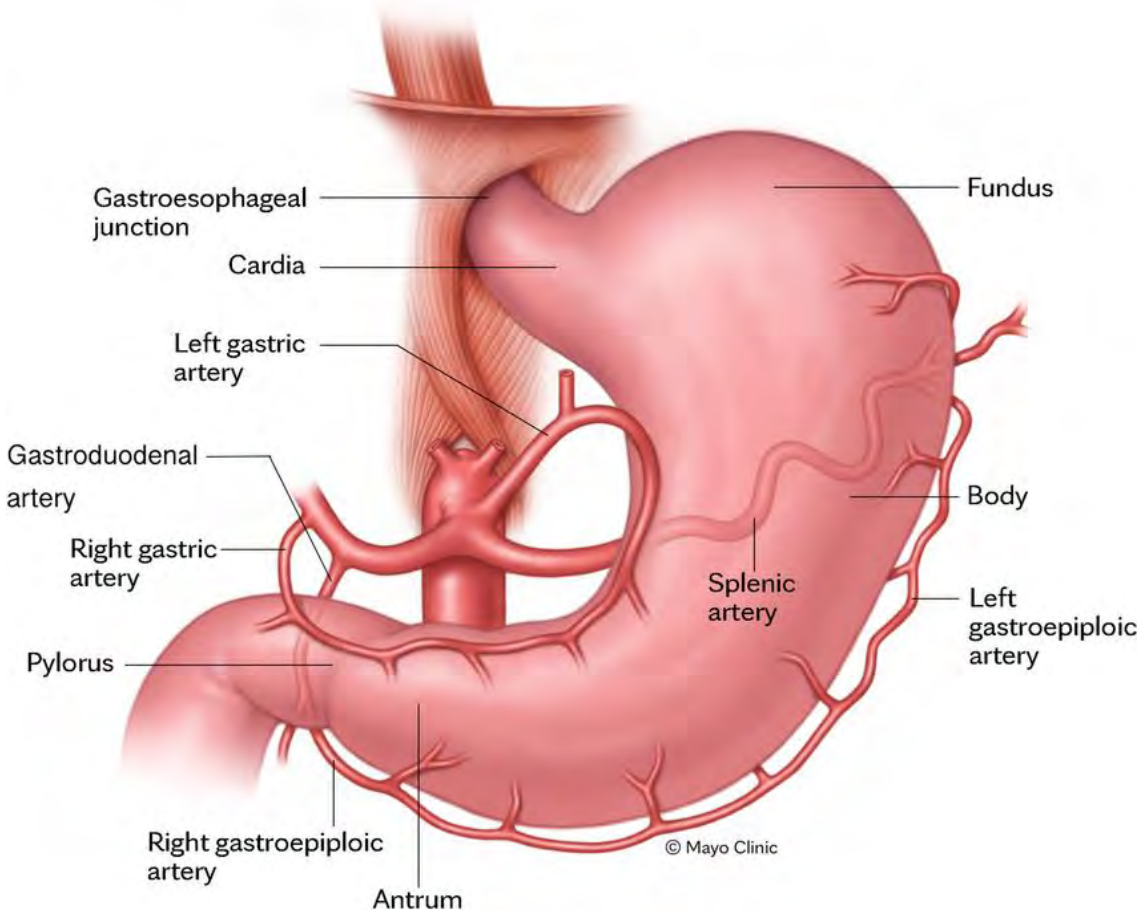


Gastric blood supply

- The gastric blood supply is characterized by a rich network of vessels derived from the **celiac artery** and its primary branches:
  - **left gastric**,
  - **common hepatic**, and
  - **splenic arteries**.
- This supply is organized into two major arterial arcades that run along the curvatures of the stomach

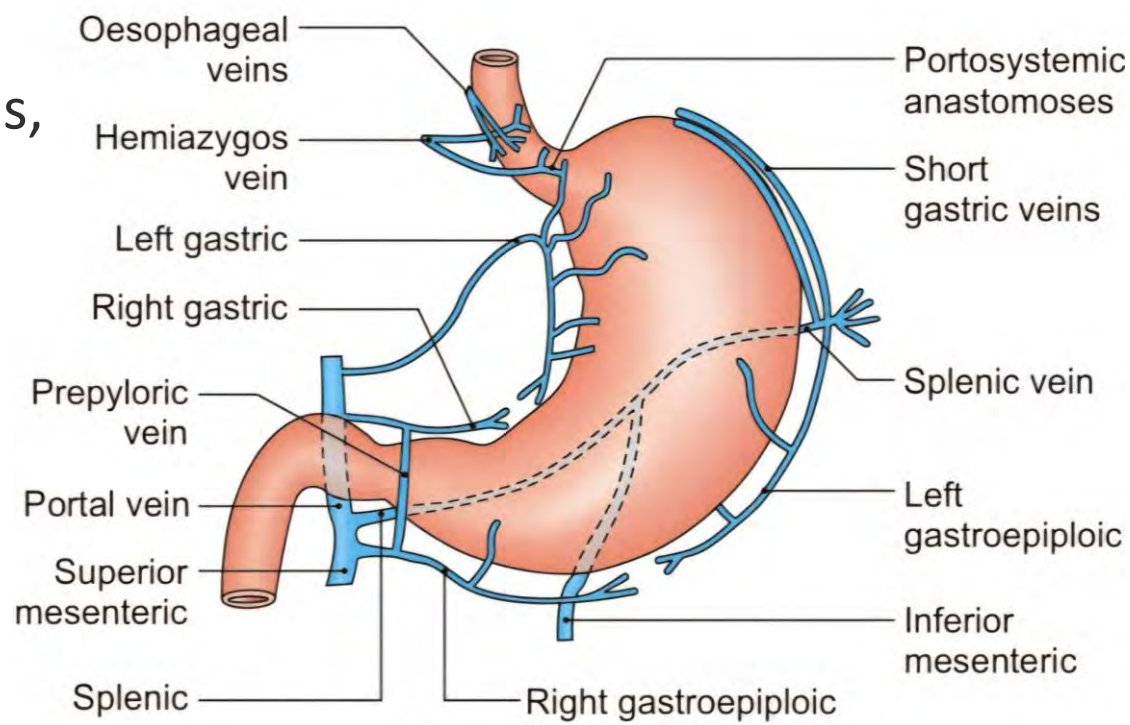
Arterial supply

- **Lesser Curvature:** This region is supplied by an arcade formed by the **left gastric artery** (entering from above) and the **right gastric artery** (entering from below).
- The right gastric artery is typically a branch of the common hepatic or gastroduodenal artery
- **Greater Curvature:** The lower two-thirds of this curvature are supplied by the **left gastroepiploic artery** (a branch of the splenic artery) and the **right gastroepiploic artery** (a branch of the gastroduodenal artery).
- These two vessels usually **anastomose** to complete the arcade
- **Fundus:** The fundus and the left upper aspect of the greater curvature receive blood via the **short gastric arteries**, which arise directly from the splenic artery



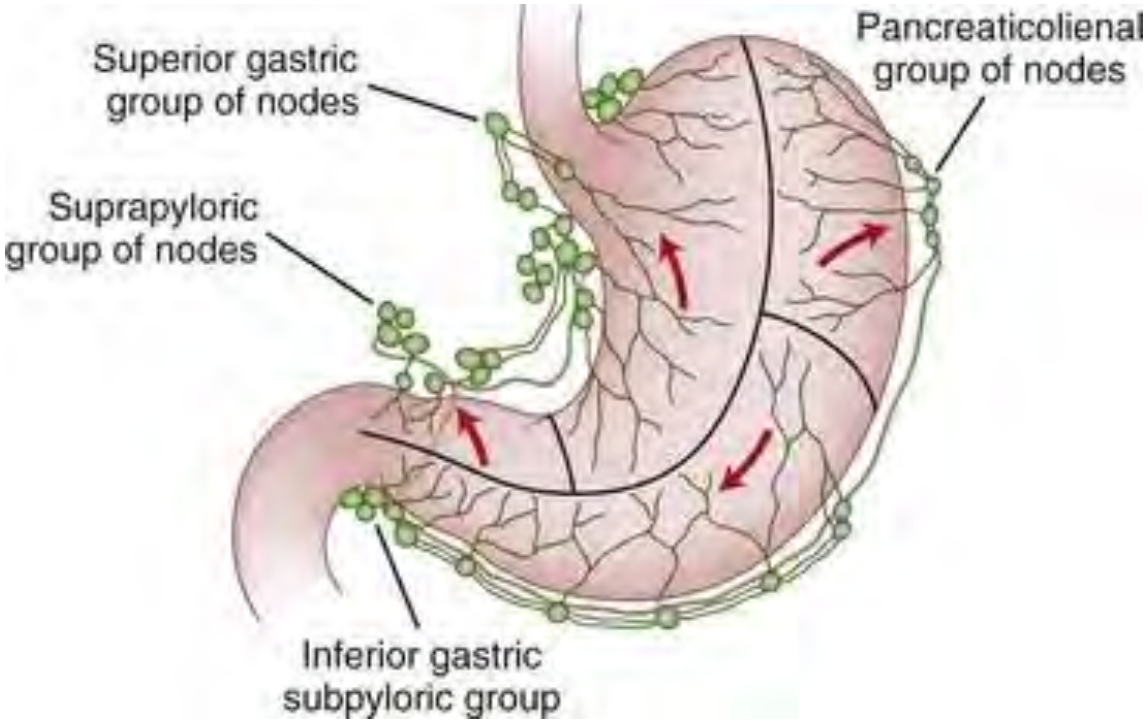
Venous drainage

- The venous system generally mirrors the arterial arrangement, with blood eventually emptying into the **portal vein** or its tributaries, the **splenic** and **superior mesenteric veins**
- **Lesser Curvature:** Drained by the **left gastric (coronary) vein** and the **right gastric vein**
- **Greater Curvature:** Drained by the **right and left gastroepiploic veins**. The right gastroepiploic vein, along with more distal vessels, forms the **gastrocolic veins**, which terminate in the superior mesenteric vein
- **Fundus:** The fundus and upper greater curvature are drained by the **short gastric veins**, which empty into the splenic vein



Lymphatic drainage

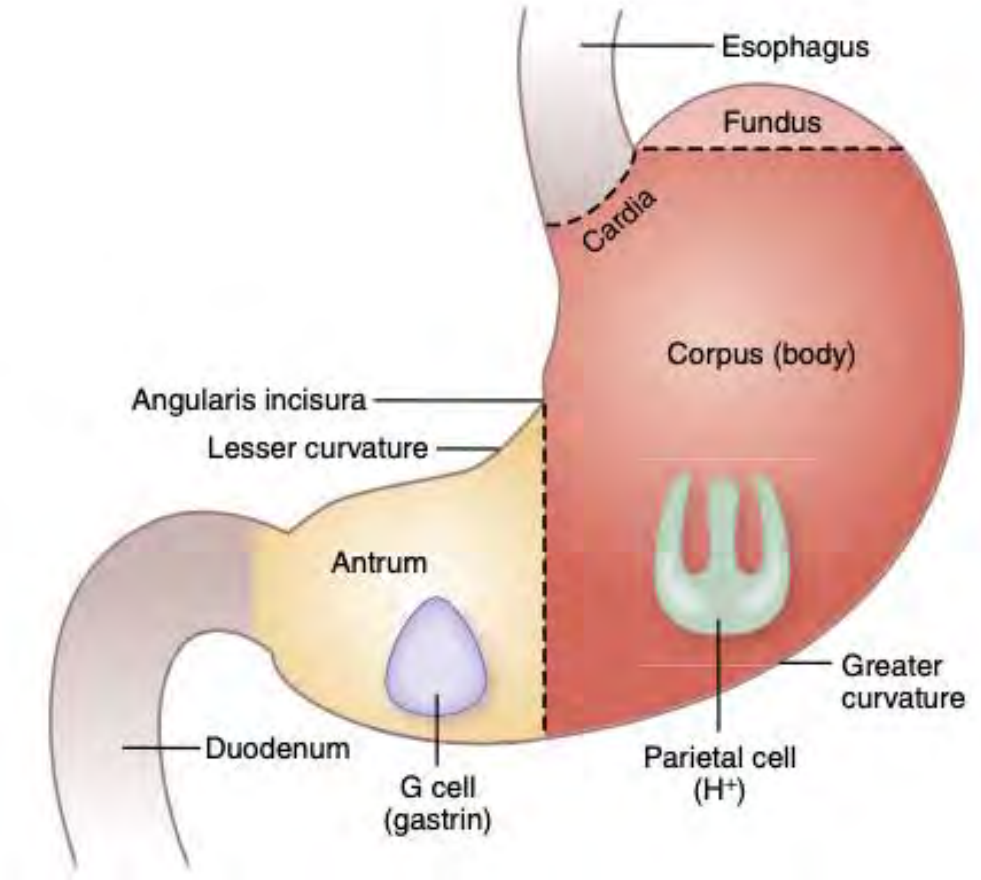
- The drainage is divided into four primary groups based on the anatomic region of the stomach and the associated blood vessels:
- **Superior Gastric (Lesser Curvature):** Lymph from this region drains into the **left and right gastric nodes**, which are situated adjacent to their respective vessels, before terminating in the celiac nodes.
- **Inferior Gastric Region:** Lymph flows first into the **subpyloric and omental nodes**, then into the **hepatic nodes**, and finally to the celiac nodes.
- **Splenic/Superior Greater Curvature:** Initial drainage from the fundus and the upper portion of the greater curvature goes to the **pancreaticosplenic nodes**, which then feed into the celiac nodes.
- **Hepatic/Pyloric Portion (Lesser Curvature):** Lymph from this area drains into the **suprapyloric nodes**, then moves through the hepatic nodes toward the celiac nodes



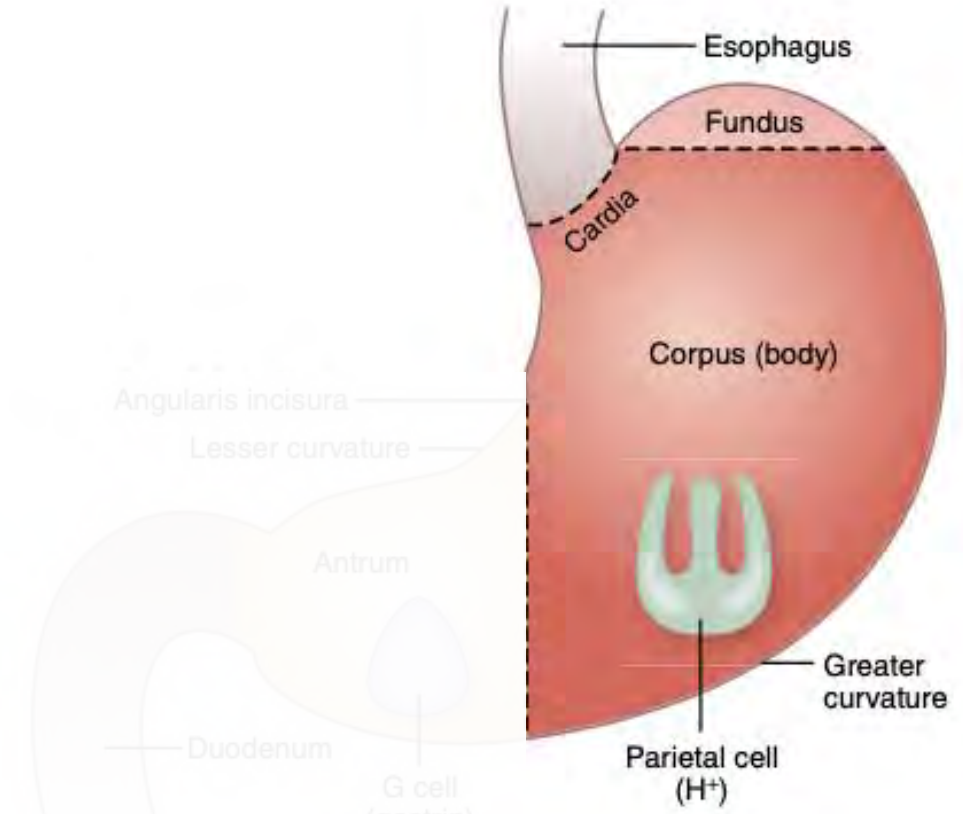
- **Microscopic and Clinical Context**
- At the tissue level, a **mucosal capillary plexus** resides in the lamina propria, communicating with venules in the muscularis mucosa that eventually reach the submucosal veins
- Additionally, the distal oesophagus and the gastric cardia share a vascular connection; the distal oesophagus receives arterial branches from the **left gastric artery** and drains venously into the portal system via the **left and short gastric veins**.
- This connection is clinically vital, as the submucosal venous network in this region is where **oesophageal varices** develop in the presence of portal hypertension.

Physiology and secretory cells

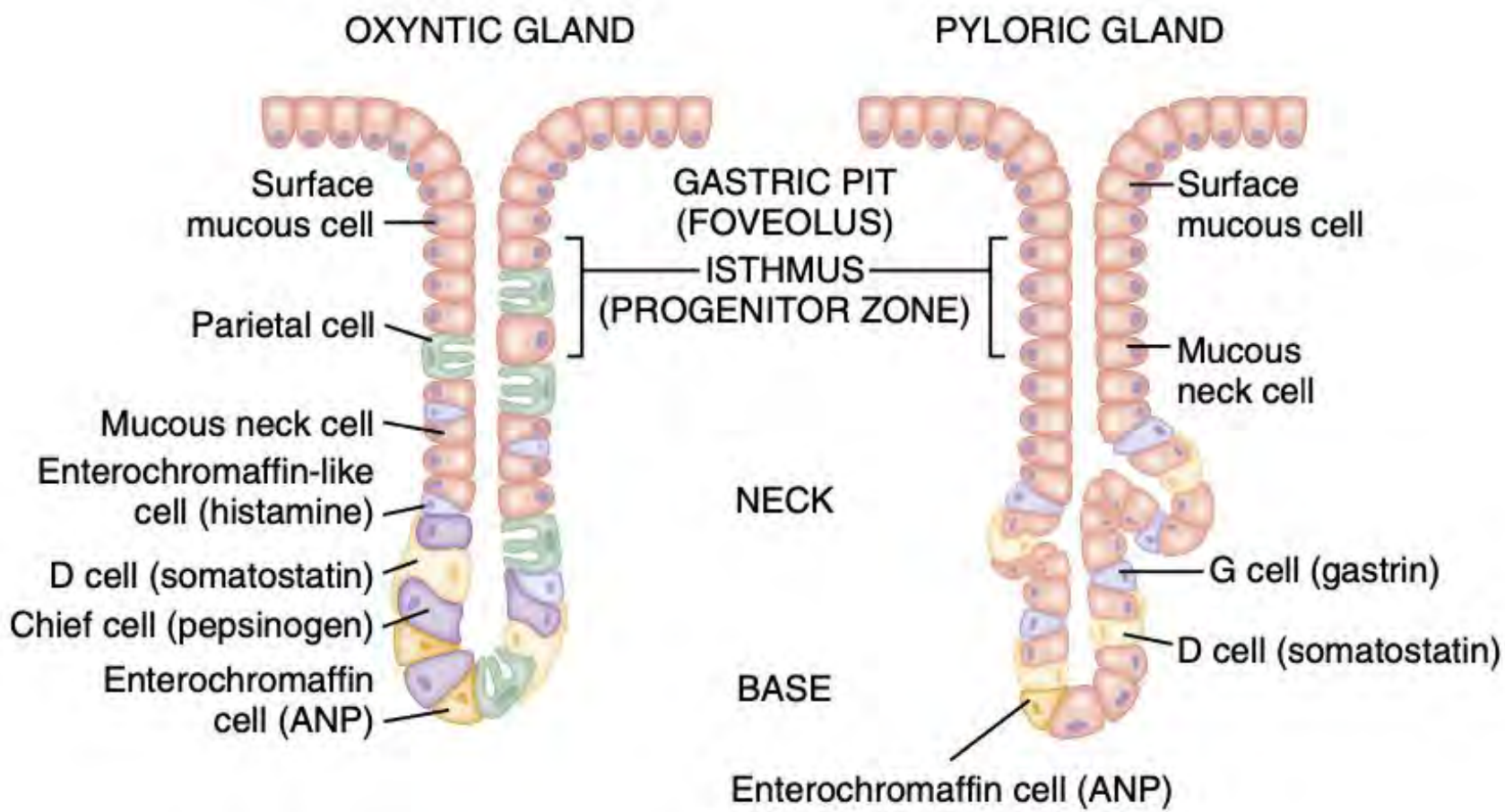
- Gastric secretion is a highly regulated process including secretions of HCL, pepsinogens
- The gastric mucosa contains surface mucous cells, which secrete mucus and bicarbonate for **luminal cytoprotection** against acid and pepsin.
- The stomach is histologically divided by its gastric glands
- **Oxyntic Glands (Fundus and Body)**
- **Pyloric Glands (Antrum and Pylorus)**



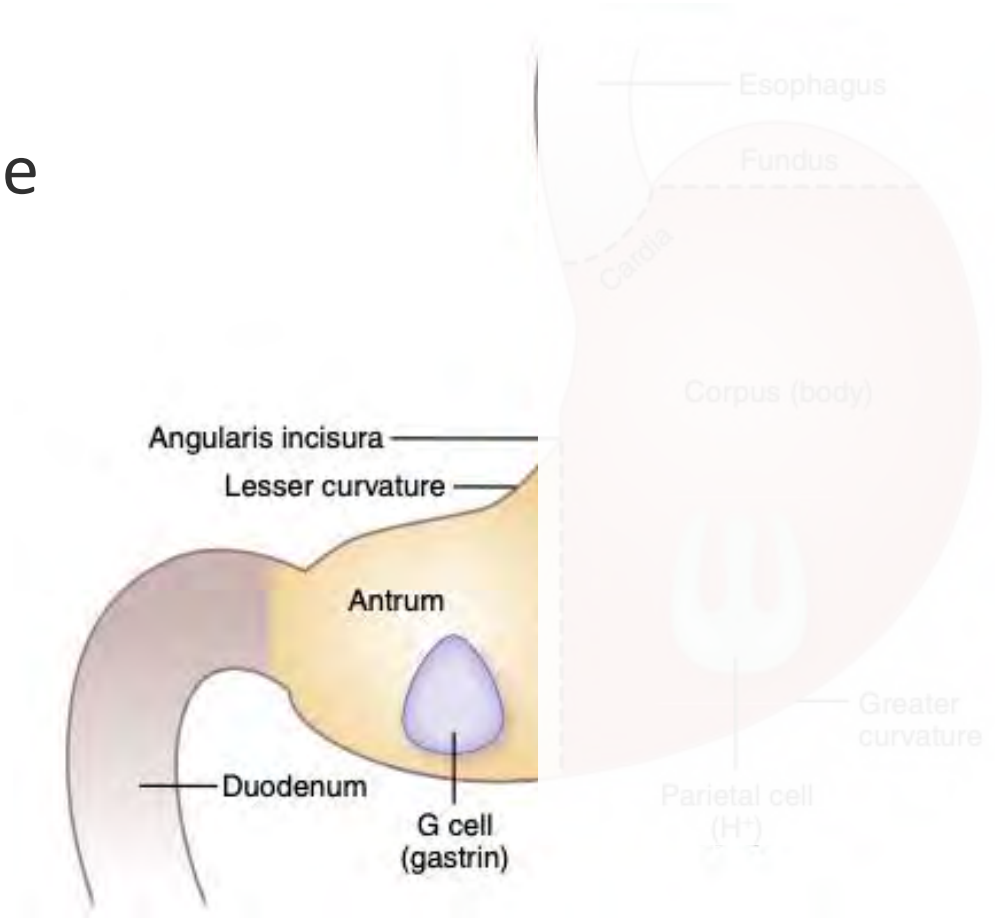
- **Oxyntic Glands (Fundus and Body):**
- These are the most numerous and are responsible for the secretion of **acid**, **intrinsic factor**, and most gastric enzymes
- **Parietal Cells (PC):** Primarily located in the neck and base of the glands, these are the principal hydrogen secretors, producing **hydrochloric acid** (HCl) via the H+,K+-ATPase ("**proton pump**"). They also secrete **intrinsic factor**
- **Chief Cells (Zymogen Cells):** Predominate in the deeper layers (base) and play a role in synthesizing and secreting **pepsinogens I and II** (which are converted to pepsin in the lumen) and gastric lipase



Gastric gland anatomy



- **Pyloric Glands (Antrum and Pylorus):**
- Composed of mucous cells and endocrine cells
- **G Cells: Gastrin**-secreting cells found in the mid- to deep sections of antral glands. Gastrin release is stimulated by **gastric distention** and **vagal stimulation**
- **D Cells:** Produce **somatostatin**, a potent inhibitor of gastrin secretion, acting via paracrine or endocrine effects



Hydrochloric Acid (HCl) Secretion

- HCl facilitates **protein digestion** by converting pepsinogen to its active form, pepsin, and aids in the absorption of iron, calcium, and vitamin B12
- **Mechanism:** Parietal cells use the **H+,K+-ATPase (proton pump)** to actively transport hydrogen ions into the lumen in exchange for potassium ions.
- This process is energy-intensive, supported by an extensive mitochondrial network within the cell

- **Regulatory Stimulants:**
- The three principal stimulants are **acetylcholine** (ACh) (neurocrine), **gastrin** (hormonal), and **histamine** (paracrine)
- **Gastrin** stimulates the parietal cell both directly and indirectly by triggering the release of histamine from ECL cells

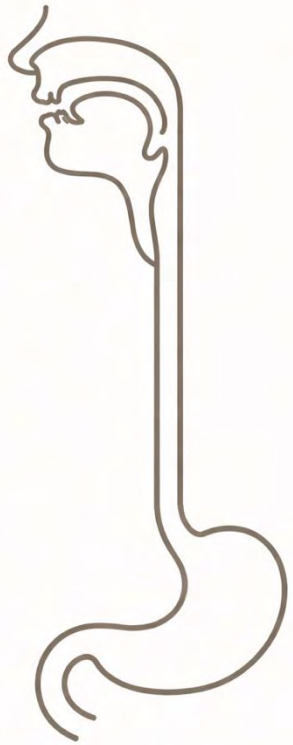
- **Inhibition:**
- **Somatostatin,** released from D cells, is the primary inhibitor of acid secretion, acting directly on parietal cells and indirectly by suppressing the release of gastrin and histamine

- **Integrated Response to a Meal**
- Gastric secretion occurs in three phases based on the location of the stimuli:
- **Cephalic Phase**: Anticipation, sight, smell, and taste of food trigger the vagus nerve to stimulate gastric enteric neurons, contributing up to 50% of postprandial acid response
- **Gastric Phase:** Mechanical distention of the stomach and the chemical presence of protein breakdown products further activate cholinergic neurons and GRP neurons, maximizing gastrin and acid release
- **Intestinal Phase:** As the meal enters the small intestine, "enterogastrones" like CCK are released to stimulate somatostatin, which restrains further acid and gastrin secretion

Enzymes and Specialized Factors

- **Pepsinogens:** These inactive proenzymes are secreted mainly by chief cells. Upon contact with HCl, they are converted into **pepsins**, which are active proteolytic enzymes that function optimally at a low pH (1.8 to 3.5).
- **Gastric Lipase**: Also secreted by chief cells, this enzyme initiates the digestion of dietary fats, hydrolyzing up to 10% to 25% of triglycerides.
- **Intrinsic Factor (IF):** This glycoprotein is essential for the absorption of **cobalamin (vitamin B12**) in the ileum. While parietal cell stimulants also increase IF, its secretion is not specifically coupled to acid production

Summary:
Upper GI Anatomy and Physiology



Summary

- **The oral cavity and the pharynx: The Processor and the Gatekeeper**
- **Oral Cavity:** Entry point of the GIT
- Mechanical breakdown and mixing of saliva
- Voluntary control of oral phase of swallowing
- **Pharynx:** shared muscular conduit for respiratory and GIT
- Initiates involuntary swallowing reflex
- Coordinated neuromuscular activity (CN V, VII, IX, X and XII)

Summary

- **Oesophagus: The Structural Conduit**
- **Anatomy:** An 18–26 cm hollow muscular tube
- **Layers:** Consists of mucosa, submucosa, muscularis propria, and adventitia; notably, it is the only part of the GI tract with **no serosa**
- **Histology:** Lined with **stratified squamous epithelium**
- **Sphincters:** The **UES** (skeletal muscle) and **LES** (smooth muscle) are both contracted at rest to prevent air entry and gastric reflux

Summary

- **Stomach: The Chemical Reservoir**
- **Anatomy:** J-shaped organ divided into the cardia, fundus, body (corpus), and antrum
- **Functional Areas**: The **Oxyntic area** (80%—fundus/body) secretes acid and enzymes; the **Pyloric area** (20%—antrum) regulates hormones
- **Musculature:** Unique three-layer muscularis propria (inner oblique, middle circular, outer longitudinal) for mechanical grinding.
- **Cellular Profile:**
  - **Parietal Cells**: Secrete **HCl** and **Intrinsic Factor** .
  - **Chief Cells**: Produce **pepsinogen** and **gastric lipase**.
  - **Endocrine Cells**: **G cells** (gastrin stimulant) and **D cells** (somatostatin inhibitor)

Summary

- **Secretory Regulation**
- **The Pump:** Acid is secreted via the **H+,K+-ATPase (proton pump)** on the parietal cell membrane.
- **Stimulants:** Regulated by **Acetylcholine** (neurocrine), **Gastrin** (hormonal), and **Histamine** (paracrine)
- **Inhibition**: **Somatostatin** acts as the "master off-switch," exerting a **tonic paracrine restraint on acid**, gastrin, and histamine release

References

- Sleisenger & Fordtran's Gastrointestinal and Liver Disease
- Ganong's Review of Medical Physiology

THANK YOU