Anatomy & Physiology of the Foregut

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GECHO Fellows Lecture

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Functions of the gastrointestinal system

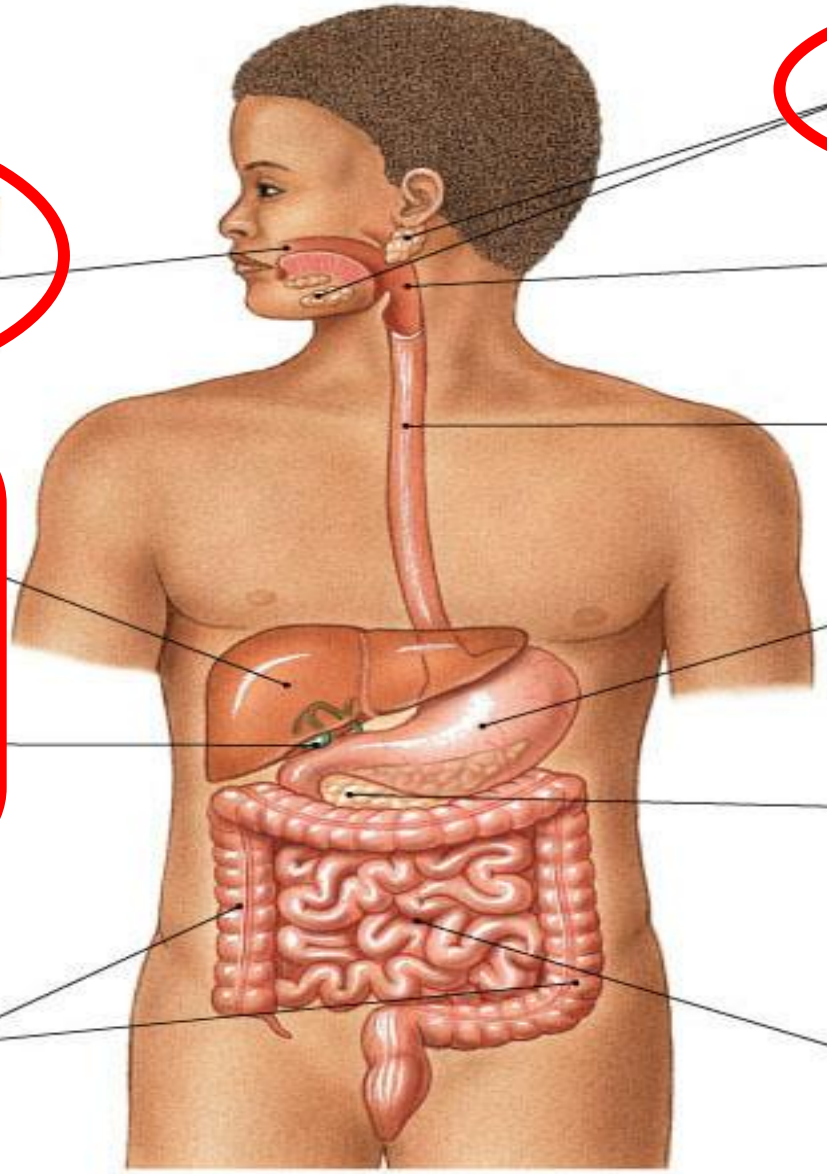
- The primary function of the alimentary tract is to provide nutrients to all the systems in the human body
- The GIT breaks down food to provide the body with a continual supply of water, electrolytes and nutrients by performing the following processes:
  I. Ingestion
  II. Mastication
  III. Propulsion
  IV. Secretion
  V. Digestion
  VI. Absorption
  VII. Elimination.

General principles

Components of the GI tract

- **GI tract:**
  a) **Accessory organs**
  b) Upper GI tract
  c) Lower GI tract
- **Accessory organs:**
  a) **Teeth**
  b) **Tongue**
  c) **Salivary glands**
  d) Liver
  e) Gall Bladder & Pancreas

The Components of the Digestive System



ORAL CAVITY, TEETH, TONGUE
Mechanical processing, moistening, mixing with salivary secretions

LIVER
Secretion of bile (important for lipid digestion), storage of nutrients, many other vital functions

GALLBLADDER
Storage and concentration of bile

LARGE INTESTINE
Dehydration and compaction of indigestible materials in preparation for elimination

SALIVARY GLANDS
Secretion of lubricating fluid containing enzymes that break down carbohydrates

PHARYNX
Pharyngeal muscles propel materials into the esophagus

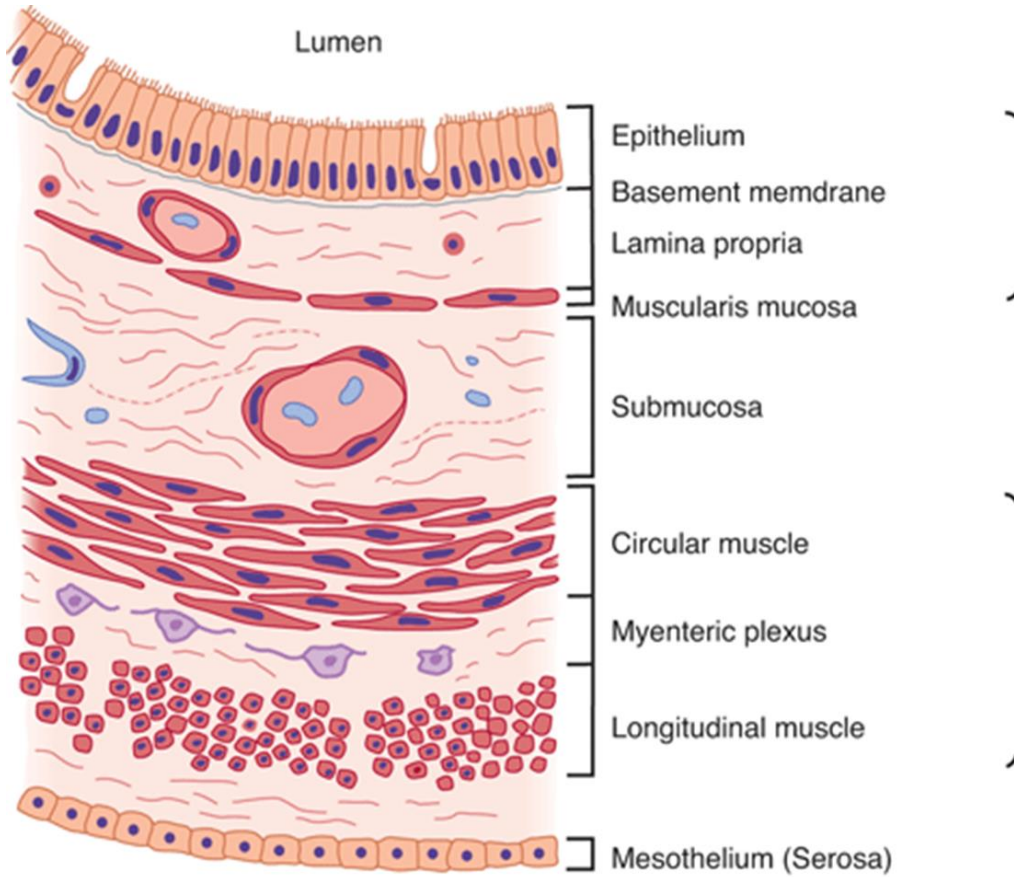
ESOPHAGUS
Transport of materials to the stomach

STOMACH
Chemical breakdown of materials via acid and enzymes; mechanical processing through muscular contractions

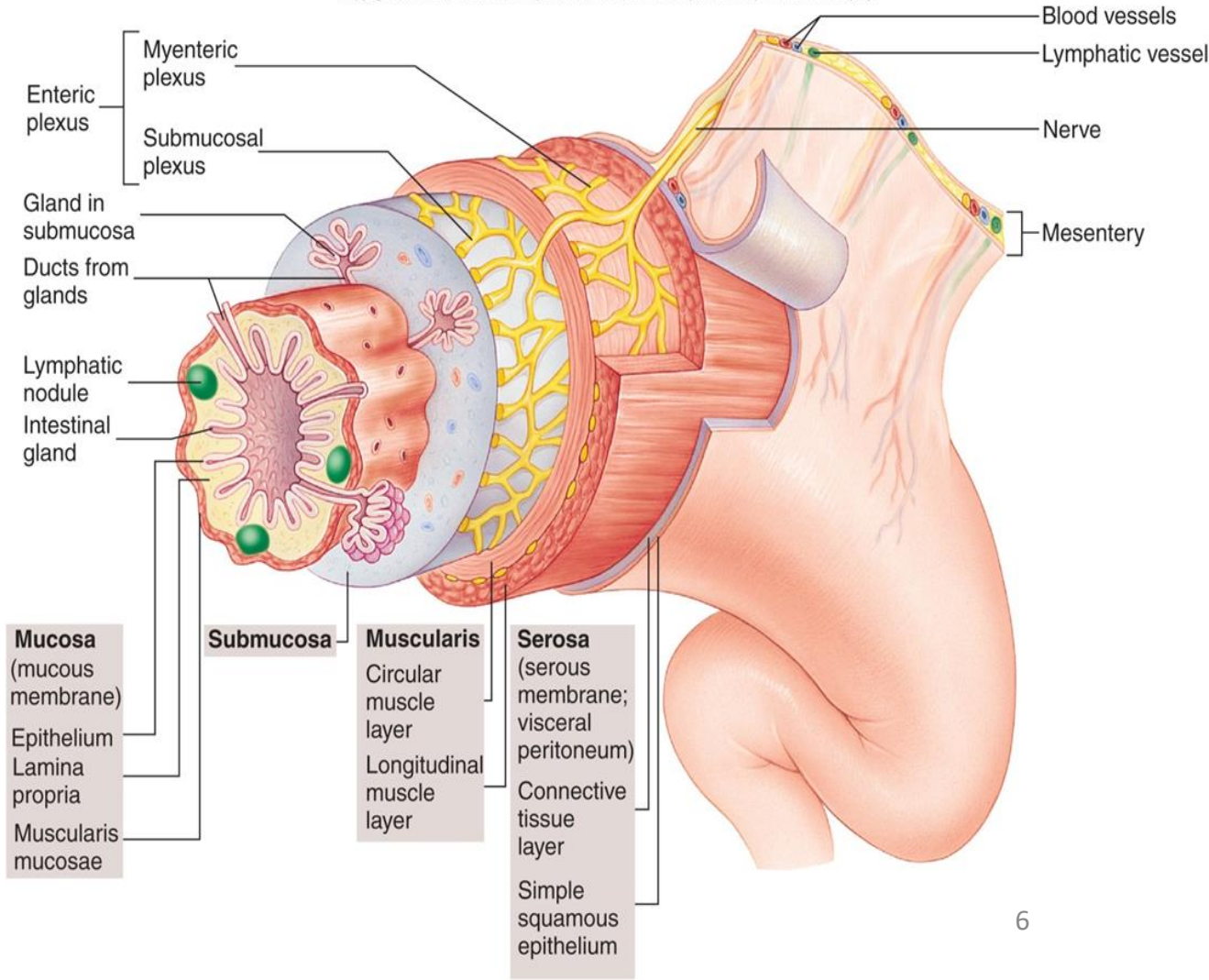
PANCREAS
Exocrine cells secrete buffers and digestive enzymes; endocrine cells secrete hormones

SMALL INTESTINE
Enzymatic digestion and absorption of water, organic substrates, vitamins, and ions

Structure of the Digestive Tract



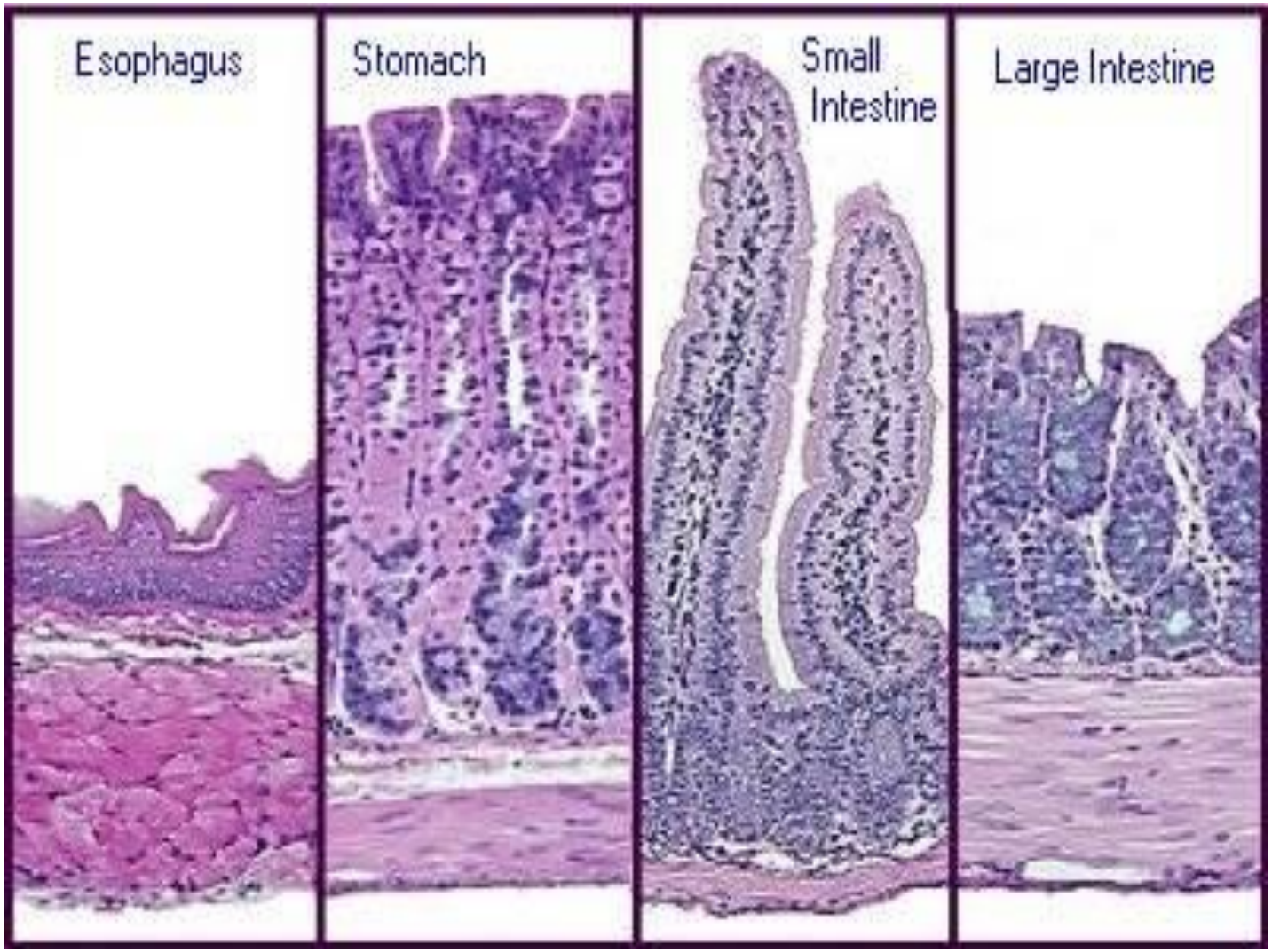
Source: Barrett KE, Barman SM, Boitano S, Brooks H: *Ganong's Review of Medical Physiology, 23rd Edition*: http://www.accessmedicine.com



Mucosa

- **Mucosa** – variable in structure + function along git→ perform diverse & specialized tasks
  - ❖**Epithelium** –innermost layer & includes cells dedicated to secretion, absorption or production of hormones
  - ❖**Lamina propria** –loose connective tissue through which course blood vessels and lymphatics that supply the epithelium. Also has immune cells + nerve fibres
  - ❖**Muscularis mucosae** -thin layer of smooth muscle beneath the lamina propria which permits the mucosa to move and fold.

Histological features of the GIT



Regulation of GIT Processes

- Git processes (secretion, digestion, absorption & motility) are integrated to ensure efficient assimilation of nutrients
- 3 main modalities operating in complimentary fashion regulate git fxn
  - ❖ Endocrine
  - ❖ Paracrine
  - ❖ Nervous system

Endocrine

- Meal events⟶ triggers hormone release
- Messengers travel through the bloodstream to influence activity of a distant segment or draining organ
- Gastrin (antrum and duodenum) →acid secretion, mucosal growth, antral motility
- CCK (small bowel)→ pancreatic enzyme and bile secretion, relaxation of Sphincter of Oddi, decreased gastric emptying
- Secretin-(duodenum)→pancreatic and bile bicarbonate secretion + ↓ acid secretion

Paracrine

- Mediators/messengers – regulate function on cells a short distance from site of secretion vs distant control of endocrine

- Somatostatin (D cells in stomach and SI) →reduce gastrin and gastric acid release

- Histamine (gastric mast cells) →potentiates parietal cells

Nervous System

- **Neural Control**⟶ enteric nervous system & parasympathetic + sympathetic nerves
- **Enteric Nervous System** - neurones with cell bodies within the wall of the GI tract (intrinsic to git)
- **Extrinsic nervous system**- cell bodies outside of the gut wall & allow a bidirectional communication between the brain and the gut ⟶brain-gut axis

Nervous regulation of the Digestive System

- **Local**: **Enteric nervous system:**
  I. Types of neurons: sensory, motor, interneuron.
  II. Coordinates peristalsis and regulates local reflexes.
  III. As stomach empties into small intestine, local reflex regulates rate of emptying
- **General**:
  - coordination with the CNS. May initiate reflexes because of sight, smell, or taste of food.
  - Parasympathetic primarily.
  - Sympathetic input inhibits muscle contraction, secretion, and decrease of blood flow to the digestive tract.

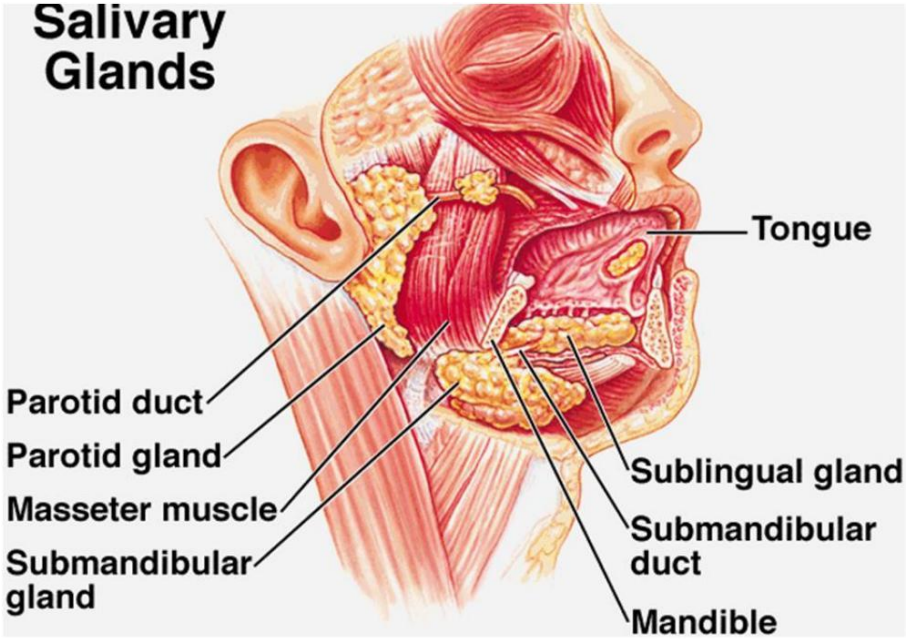
The Foregut

Anatomy and physiology of foregut

- The foregut is defined as the section of the gut from the mouth to the 1st part of the duodenum.
- Outline:
  a. **Oral cavity: Salivary glands**
  b. **Oesophagus**
  c. **Stomach**

Oral cavity: Salivary glands

- Salivary glands: accessory organs of digestion that produce saliva.
- 3 sets of glands: **Parotid** (20%), **submandibular** (65-70%) & **sublingual glands** (5%)
- Secretion (salivation) mediated by parasympathetic stimulation (ANS)
- 0.5-1.5 Liters produced /24 HRS
- **Composition**:
  - 97-99.5% water (hypo-osmotic)
  - pH 6.55-7.0 (variable)
  - Solutes: Na^+, K^+, Cl^-, $HCO3^-$
  - Digestive enzymes: Amylase, Lipase
  - Proteins: Mucin, IgA & Lysozyme, defensins
  - Metabolic wastes: Urea, Uric acid



Functions of saliva

- Initiate the digestion of starch and lipids
- Protects oral cavity (IgA and lysozymes): functions as cytokines (lymphocytes) in the mouth
- Provide lubrication for food to make bolus
- Facilitate the taste
- Helps in speaking, swallowing, chewing
- Buffer the gastric refluxate in the oesophagus.

- When **food is ingested**, **chemoreceptors** and **mechanoreceptors** in the mouth send signals to the **salivatroy nuclei** in the brain stem to the pons and medulla.
- As a result, **parasympathetic nervous system** activity **increases**.
- Impulses: **Sensorimotor fibers facial (VII)** and **glossopharyngeal (X)** nerves dramatically **increase** the output of watery saliva
- The chemoreceptors are activated the most by acidic foods and liquids (vinegar, pickles, amadumbe etc.).
- The mechanoreceptors are activated by almost any type of mechanical stimulus in the mouth (chewing).

Physiology of swallowing

- Swallowing consists of 3 phases (oral preparatory, pharyngeal, and oesophageal) usually **performed effortlessly up to 600/day.**
- Once swallowing has been initiated, it takes <1 sec for a bolus to reach the esophagus.
- Additional 10-15 seconds to complete the swallow; process involves more than 30 muscles.
- The swallowing centers within the brainstem are **interdependent** and **receive bilateral, though asymmetric**, projections from the motor and premotor cortex.

Oral preparatory phase

- The bolus is processed by mastication to an appropriate size, shape, and consistency to pass through the pharynx and esophagus.
- This phase is **largely voluntary**.
- The tongue is a critical part of this phase, both for controlling the food so that proper chewing can occur and for directing the bolus to its proper position for swallowing.
- After chewing, the bolus is moved to the back of the tongue.
- The anterior portion of the tongue lifts up to the hard palate and retracts posteriorly forcing the bolus into the upper pharynx.
- **Elevation of the posterior portion** of the tongue by **the mylohyoid muscles elevates the soft palate,** thereby sealing the **nasopharynx and preventing nasal regurgitation.**
- The oral preparatory phase is **under voluntary control** and involves use **of cranial nerves V (trigeminal), VII (facial), and XII (hypoglossal)**

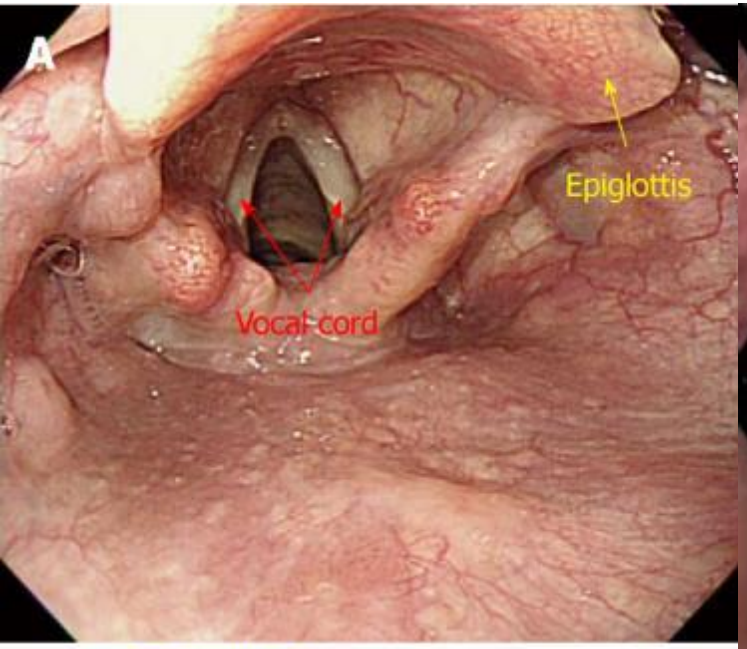
Pharyngeal phase

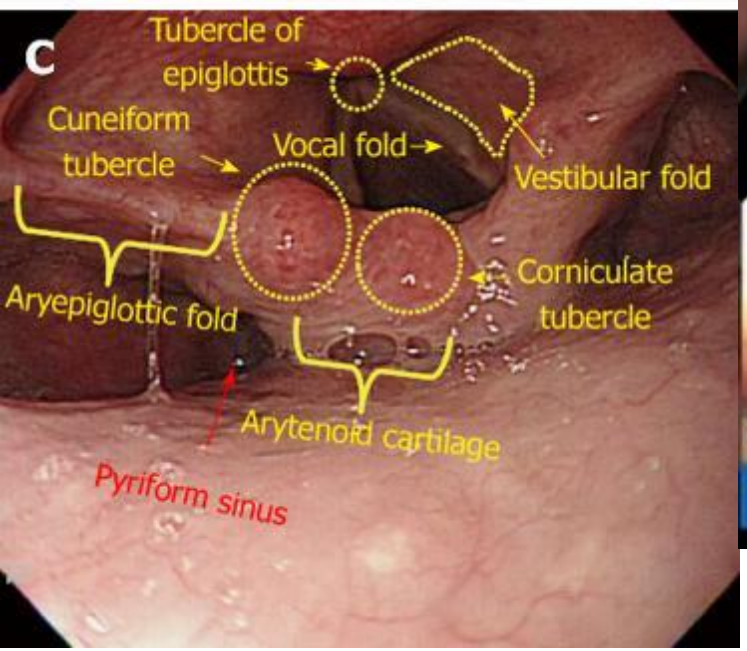
- The bolus is advanced through the pharynx and into the esophagus by **pharyngeal peristalsis.**
- This occurs by approximation of the soft palate to the posterior nasopharyngeal wall, which seals off the nasopharyngeal inlet and by contraction of the superior constrictor muscles.
- Simultaneously, the larynx and hyoid are pulled upward and forward allowing the bolus to pass over the larynx without aspiration and causing relaxation of the **cricopharyngeus muscle**, which makes up much of the upper esophageal sphincter.
- The pharyngeal phase, unlike the oral phase, is **controlled reflexively and is referred to as the swallow response.**
- It involves cranial nerves V (trigeminal), IX (glossopharyngeus), X (vagus), and XII (hypoglossal).
- During swallowing, **respiration is inhibited centrally.**

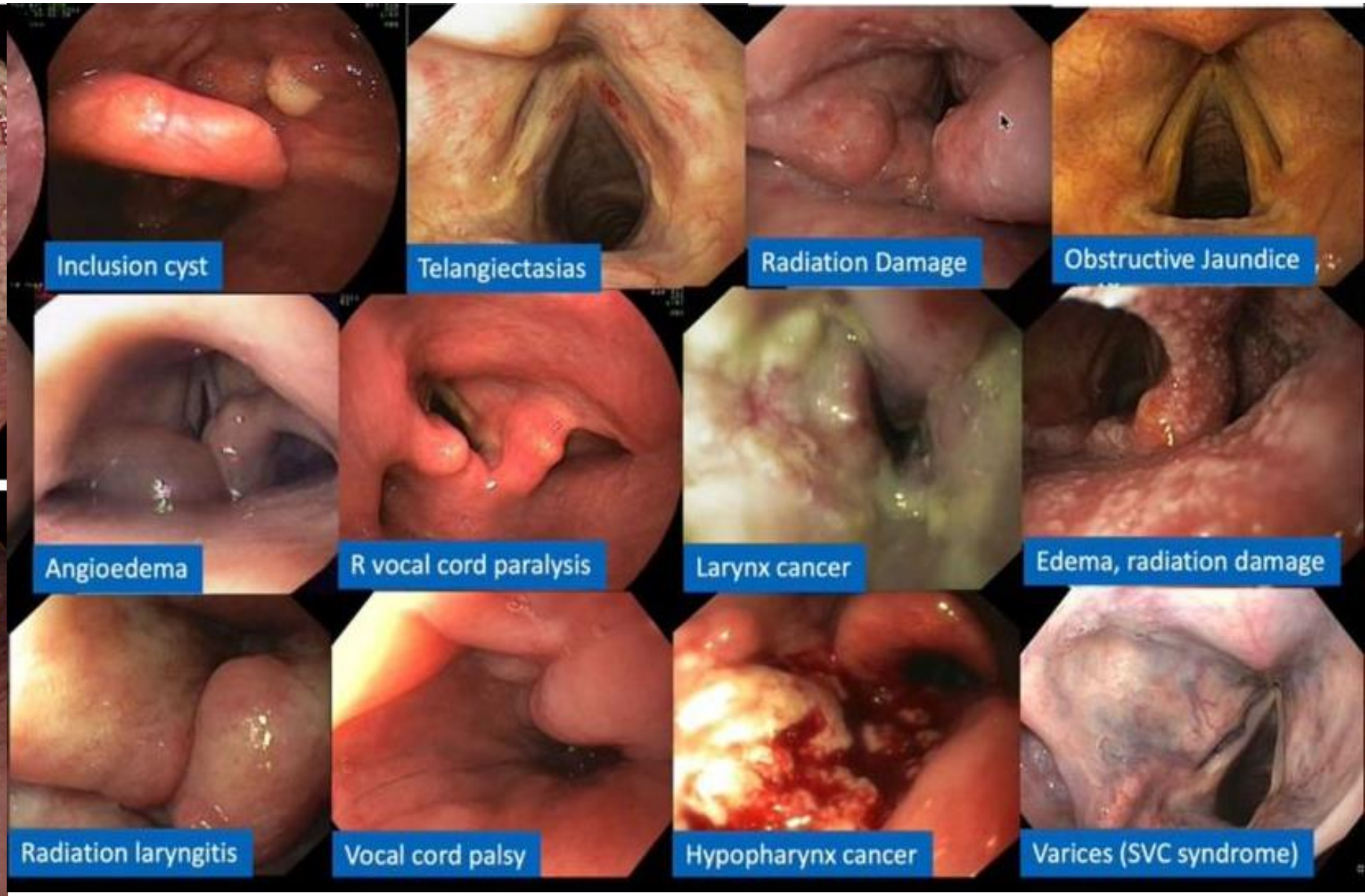
Esophageal phase

- Peristaltic contractions in the body of the esophagus combined with simultaneous relaxation of the lower esophageal sphincter propel the bolus into the stomach.

Anatomy of intubation– gastroscopy & spectrum of abnormalities







Oesophagus

- 18- to 26-cm long hollow muscular tube, with an inner lining of stratified squamous epithelium.
- Collapsed between swallows: Lumen distends up to 2 cm AP and 3 cm laterally to accommodate a swallowed bolus.
- Structurally composed of 4 layers:
  - ✓innermost mucosa
  - ✓sub-mucosa
  - ✓muscularis propria
  - ✓outermost adventitia; **has no serosa**.
- The muscularis propria is responsible for the organ's motor function.
- Musculature:
  - ✓**Upper** 5-33% **exclusively skeletal muscle**
  - ✓Distal 50% is composed of smooth muscle.
  - ✓In between is a mixture of both types.

- **UES**
  - inferior pharyngeal constrictor merges with the cricopharyngeus-Skeletal muscle.
  - contracted at rest and creating a high-pressure zone that prevents inspired air from entering the esophagus.
  - Below the UES, the esophageal wall is composed of inner circular and outer longitudinal layers of muscle.
- **Esophageal body:**
  - lies within the posterior mediastinum behind the trachea and left mainstem bronchus
  - swings leftward to pass behind the heart and in front of the aorta.
  - At the T10 vertebral level the esophageal body leaves the thorax through a hiatus located within the right crus of the diaphragm
- **LES:**
  - 2-4cm length of asymmetrically thickened circular smooth muscle where the esophageal body ends within the diaphragmatic hiatus.
  - Phrenoesophageal ligament responsible for fixation
  - Enables diaphragmatic contractions to assist the LES in maintenance of a high-pressure zone during exercise

Oesophageal Mucosa

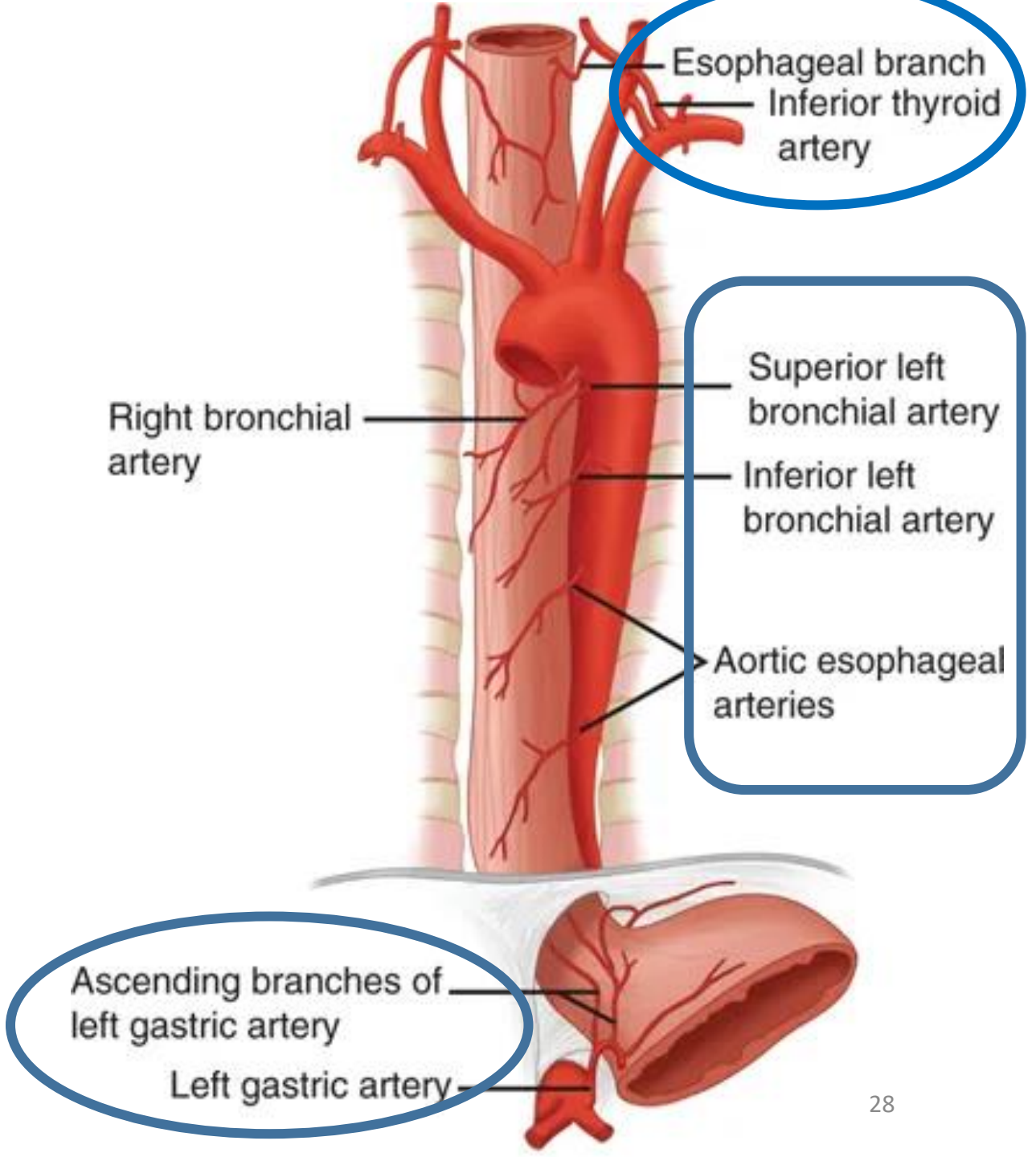
- Endoscopic Evaluation: smooth and pink .
- OGJ: an irregular white Z-line demarcating the interface between the lighter esophageal and the redder gastric mucosa.
- Histologically: nonkeratinized, stratified squamous epithelium
- Consists of 3 functionally distinct layers:
  - **Stratum corneum**: acts as a permeability barrier between luminal content
  - **Stratum spinosum:** contains metabolically active cells with a spiny shape.
  - **Stratum germinativum:** contain cuboidal cells; 10-15% of the epithelium's thickness and are uniquely capable of replication.
- Basal cell hyperplasia, defined as basal cells >15% of epithelial thickness, reflects an increased rate of tissue repair, as is often seen **in GERD**
- Small number of other cell types (argyrophilic neuroendocrine cells, melanocytes, lymphocytes, Langerhans cells (macrophages), and eosinophils).
- Neutrophils are **not present in healthy epithelium.**

Oesophageal Submucosa

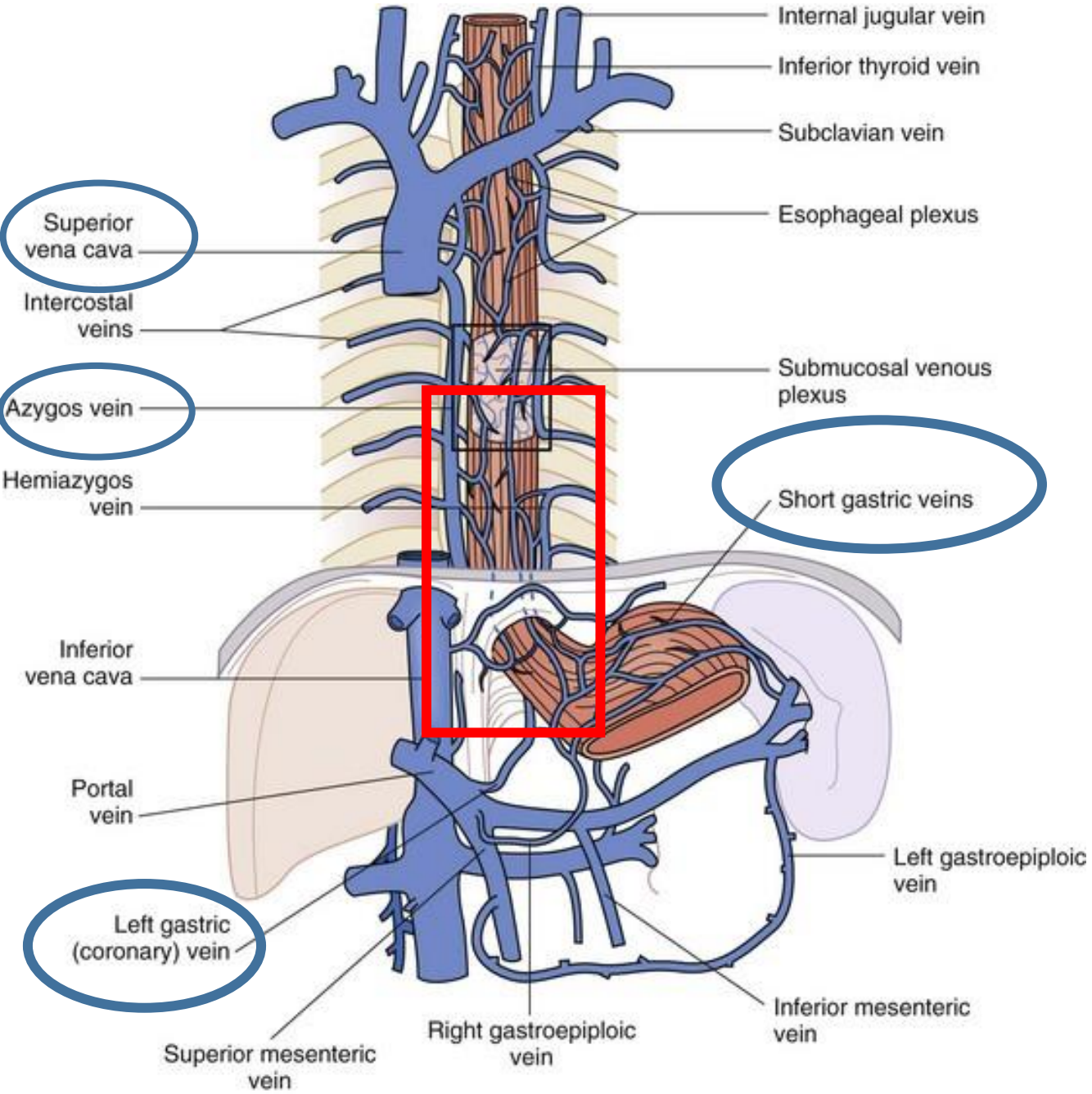
- The submucosa comprises a dense network of connective tissue, within which are blood vessels, lymphatic channels, neurons of Meissner plexus, and esophageal glands.
- These glands, which vary as to number and distribution along the esophagus, consist of cuboidal cells organized as acini.
- They produce and secrete a lubricant, mucus, and factors such as bicarbonate and epidermal growth factor that are important for epithelial defense and repair.
- The secretions from these glands pass into tortuous collecting ducts that deliver them to the esophageal lumen.

Circulation: Arterial

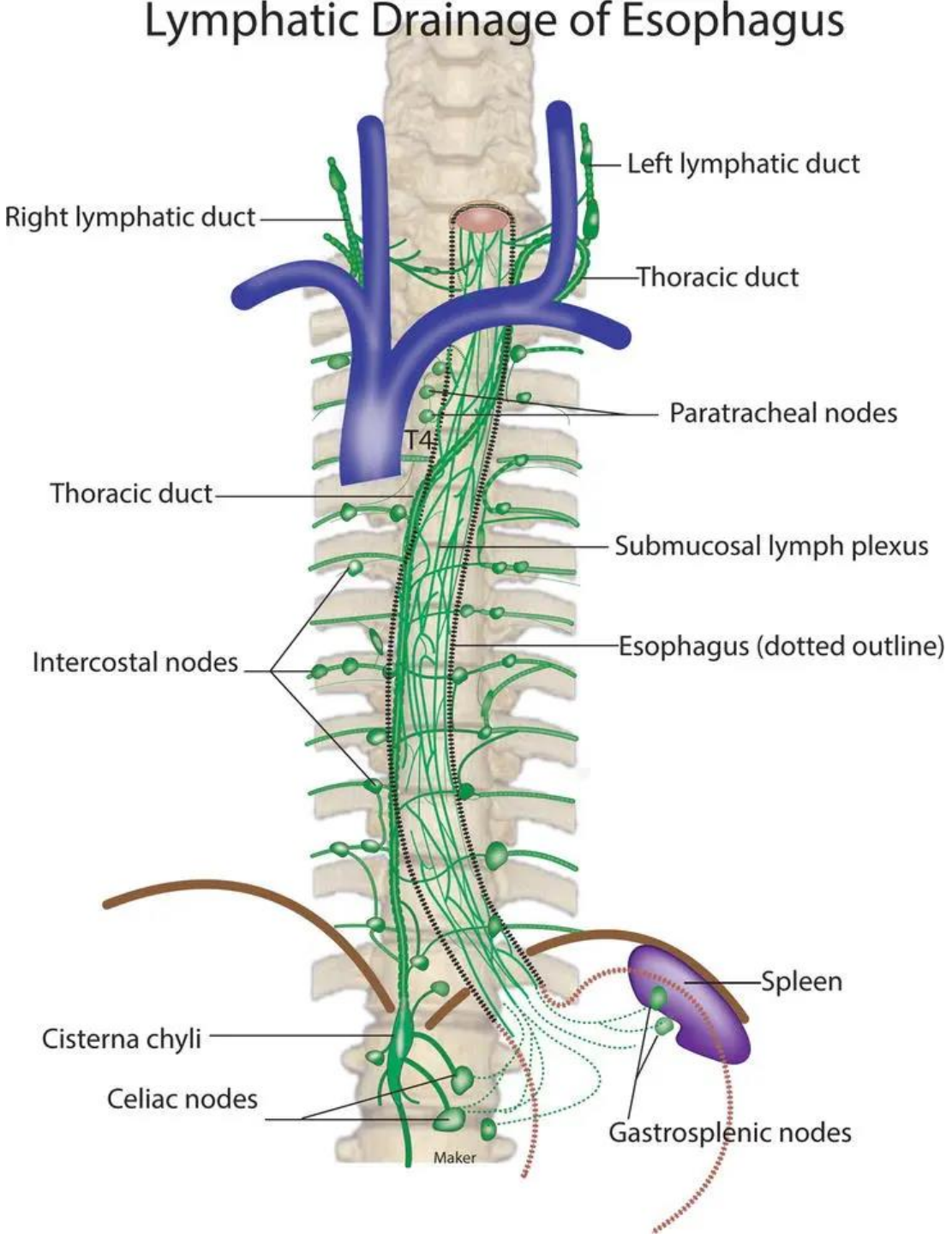
- The arterial and venous blood supply to the oesophagus is **segmental**.
- The **upper esophagus** : branches of the superior and inferior thyroid arteries,
- The **mid esophagus** by branches of the bronchial and right intercostal arteries and descending aorta,
- The **distal esophagus** by branches of the left gastric, left inferior phrenic, and splenic arteries.
- These vessels anastomose to create a dense network within the **submucosa** that probably accounts for the rarity of esophageal infarction.



Venous Circulation



- The venous drainage of the upper oesophagus is through the **superior vena cava,**
- The midesophagus through the **azygos veins**,
- The distal esophagus through the portal vein by means of **the left and short gastric veins.**
- The **submucosal venous anastomotic network** of the **distal esophagus** is important because it is where **oesophageal varices** emerge in patients with **portal hypertension.**

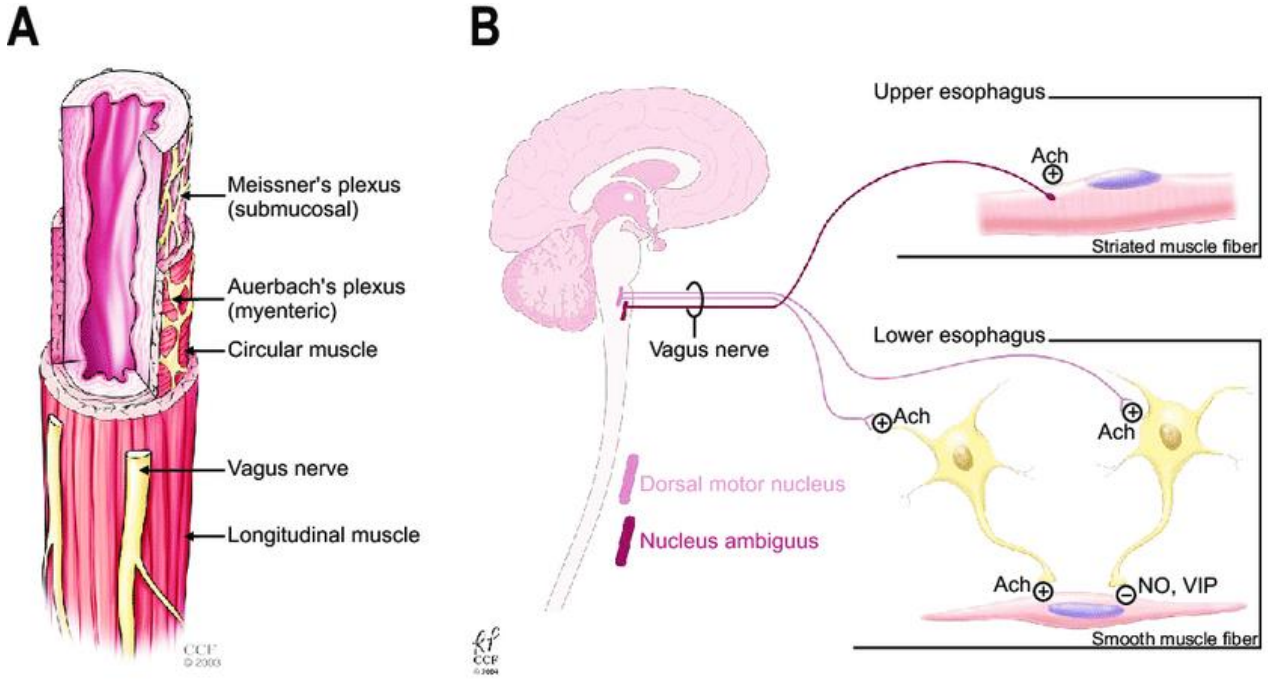


- The lymphatic system of the esophagus is also **segmental**;
- The upper esophagus drains to the **deep cervical nodes**,
- The midesophagus to the **mediastinal nodes**, and
- The distal esophagus to the **celiac and gastric nodes.**
- However, these lymphatic systems are also interconnected by numerous channels, **accounting for the spread of most esophageal cancers beyond the region at the time of their discovery**

Innervation

- Both parasympathetic and sympathetic supply
- **Parasympathetic**:
  - Regulate peristalsis through the **vagus** nerve
  - Cell bodies of the vagus nerve originate in the medulla.
  - CB located in nucleus ambigus control skeletal muscle
  - CB located in dorsal motor nucleus control smooth muscle.
- Medullary vagal postganglionic efferent nerves terminate directly on the motor endplate of skeletal muscle in the upper oesophagus
- Vagal preganglionic efferent nerves:
  - Smooth muscle in the distal oesophagus terminate on neurons within Auerbach (myenteric) plexus, located between the circular and longitudinal muscle layers.
  - Meissner plexus, located within the submucosa, is the site of afferent impulses within the oesophageal wall.
- These are transmitted to the CNS through vagal parasympathetic and thoracic sympathetic nerves.
- Sensory signals transmitted via vagal afferent pathways travel to the nucleus tractus solitaries within the CNS from there nerves pass to the nucleus ambiguus and dorsal motor nucleus of the vagus nerve, where their signals may influence motor function.

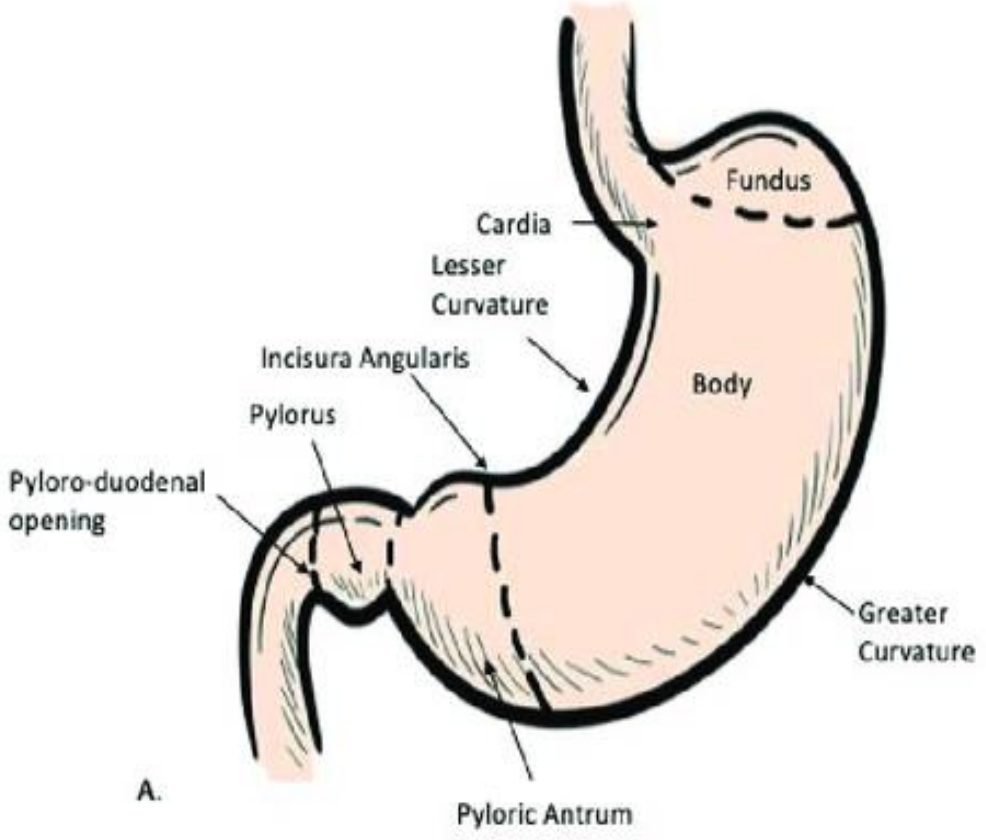
- **Pain sensation** arising from the oesophagus is typically triggered by stimulation of chemoreceptors in the mucosa or submucosa and/or mechanoreceptors in the musculature.
- Central perception then occurs when these impulses are **transmitted to the brain by sympathetic and vagal afferents**.
- Sympathetic afferents travel through the dorsal root ganglia to the dorsal horn of the spinal cord, and vagal afferents travel through the nodose ganglia to the nucleus tractus solitarius in the medulla.
- Oesophageal neuroanatomic pathways **overlap with those of the heart and respiratory system**: may be difficult to discern the organ of origin for **some chest pain syndromes**

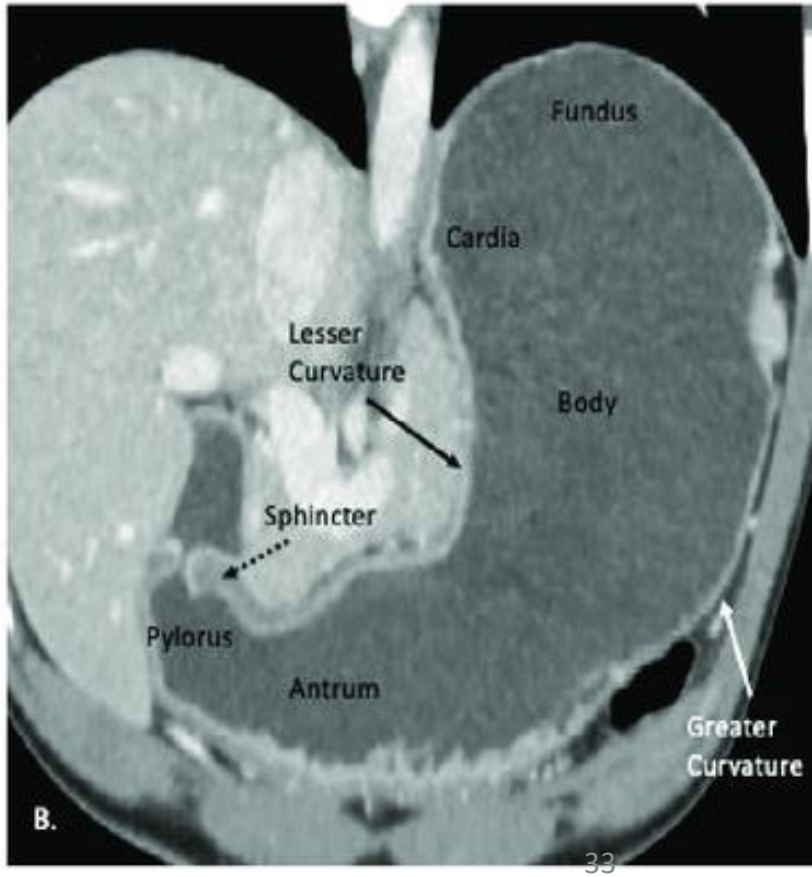


Stomach: Anatomy

- J-shaped dilation of the alimentary canal.
- Volume: 1.5 to 2 L in adulthood.
- 4 regions : anatomic or histologic landmark

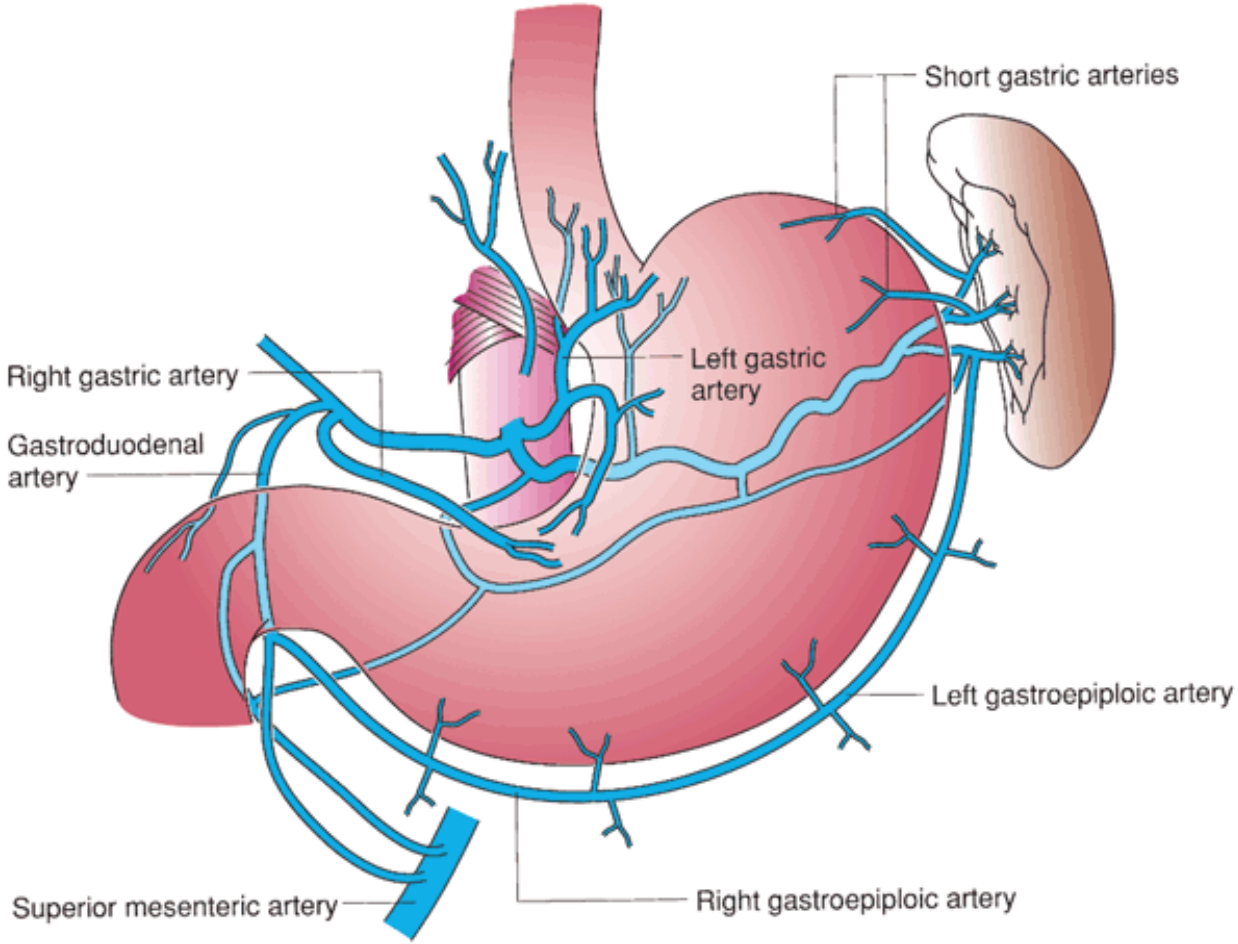
- **Corpus:** which is the largest portion of the stomach, is located immediately below and continuous with the fundus.
- **Incisura angularis:** a fixed, sharp indentation 2/3 the distance down the lesser curvature - caudal aspect of the gastric body
- **Antrum** extends from its indistinct border with the body to the junction of the pylorus with the duodenum.
- **Pylorus:** is a tubular structure & contains the palpable circular muscle(pyloric sphincter). Mobile owing to its enclosure between the peritoneum of the greater and lesser omentum but is generally located 2 cm to the right of midline at L1.





Gastric: arterial Supply

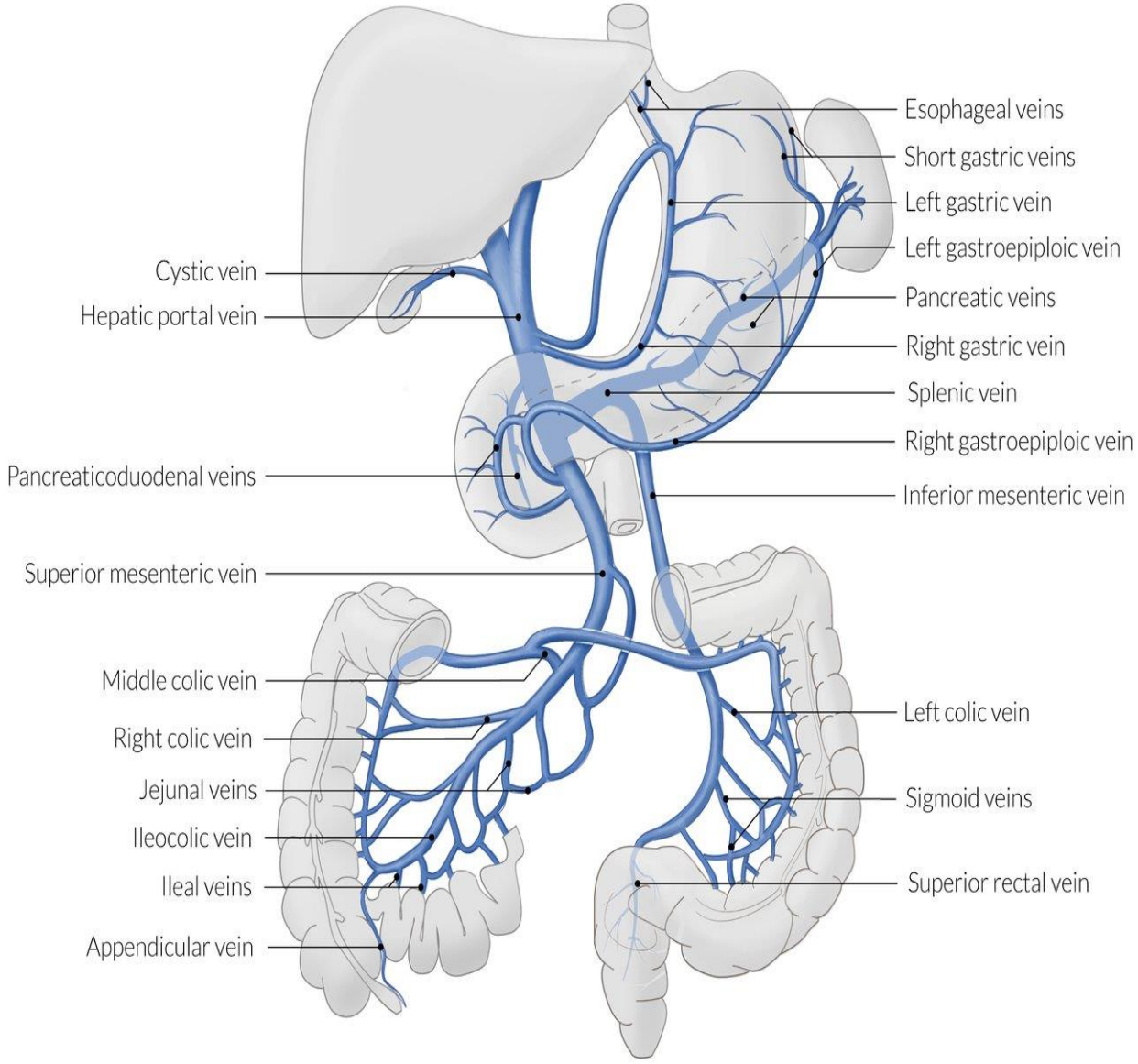
- Branches of Celiac artery: Common hepatic, Left gastric, and Splenic arteries:
- Formation of 2 arterial arcades situated along the lesser curvature and the lower 2/3 of the greater curvature.
- Lesser curvature: From above Left gastric artery & from below by the right gastric artery, (branch of the common hepatic artery) or gastroduodenal artery (which is a branch of the common hepatic artery).
- Greater curvature below the fundus is supplied from above by the left gastroepiploic artery (a branch of the splenic artery) and from below by the right gastroepiploic artery (a branch of the gastroduodenal artery).
- The right and left gastroepiploic arteries usually terminate by anastomosing, therefore completing the greater curvature arterial arcade; occasionally they end without anastomosis.
- The arterial supply to the gastric fundus and left upper aspect of the greater curvature is via the short gastric arteries, which arise from the splenic artery



Arterial blood supply of the stomach.

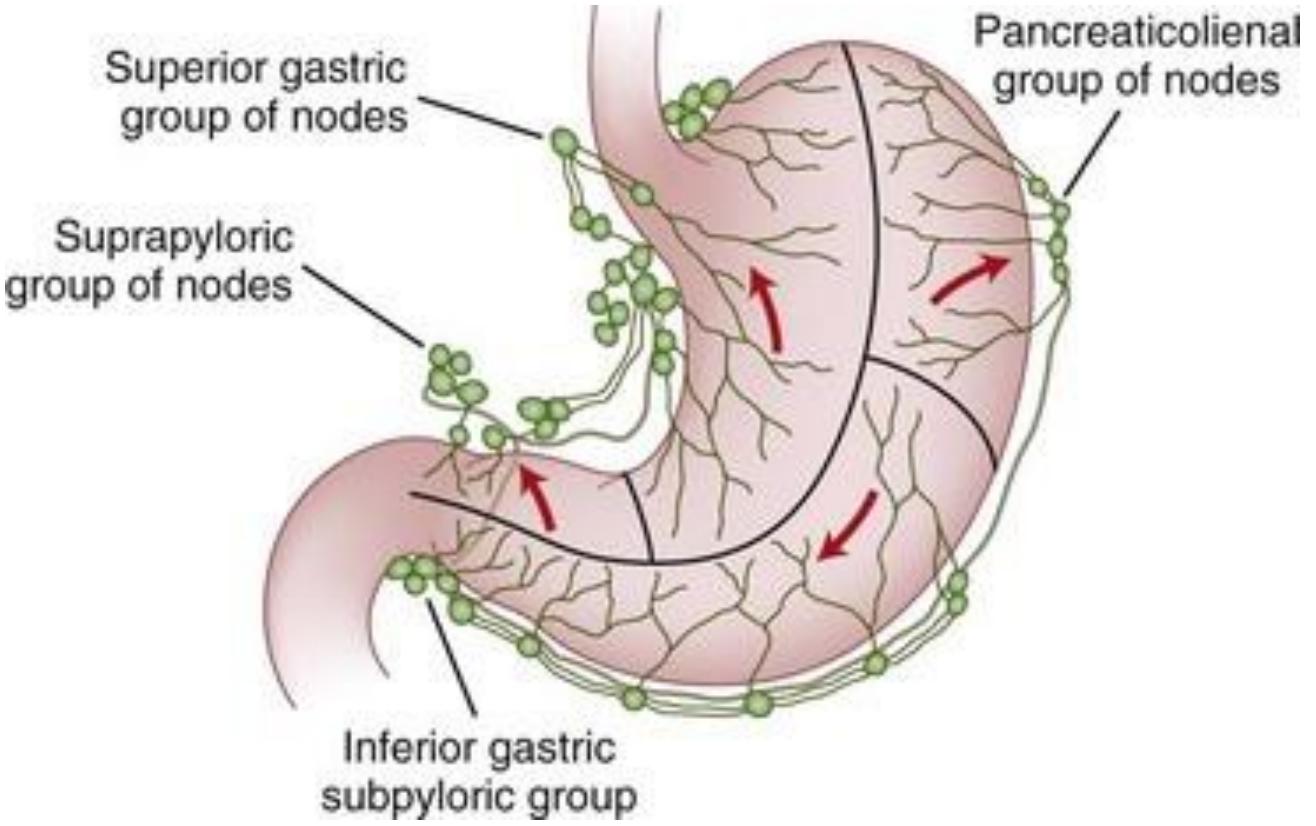
Gastric: Venous drainage

- The venous drainage generally accompanies the arterial supply, emptying into the **portal vein** or 1 of its tributaries, **the splenic or superior mesenteric veins.**
- The left and right gastric veins drain the lesser curvature of the stomach.
- The left gastric vein is also known as the coronary vein.
- The right and left gastroepiploic veins drain the inferior aspect and a portion of the greater curvature of the stomach.
- The right gastroepiploic vein and several more distal veins become the gastrocolic veins, eventually terminating in the superior mesenteric vein.
- There is no gastroduodenal vein.
- The left gastroepiploic vein becomes the splenic vein and later receives the short gastric veins, therefore draining the fundus and upper great curvature of the stomach



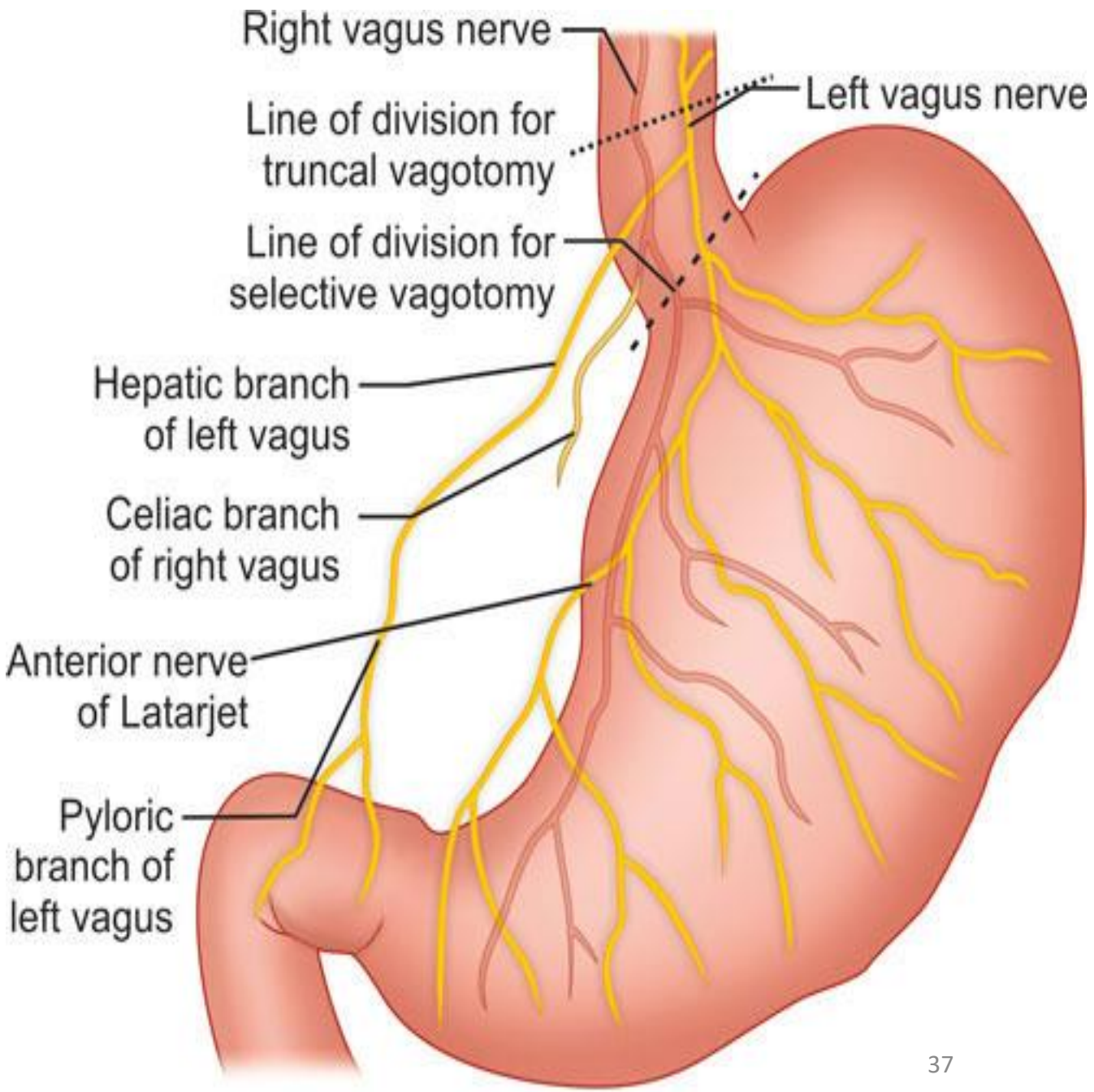
Gastric: Lymphatics

- Celiac nodes : majority of lymphatic drainage
- Lymphatic channels anastomose freely in the gastric wall, with lymphatic flow directed through 1-way valves into 1 of 4 groups of nodes.
- The inferior gastric region drains into subpyloric and omental nodes, then the hepatic nodes, terminating in the celiac nodes.
- The splenic or superior aspect of the greater curvature lymph initially drains into pancreaticosplenic nodes and then into celiac nodes.
- The superior gastric or lesser curvature region lymph drains into the left and right gastric nodes adjacent to their respective vessels and terminates in the celiac nodes.
- The hepatic or pyloric portion of the lesser curvature lymph drains into the suprapyloric nodes, then into the hepatic nodes, and finally into the celiac nodes.



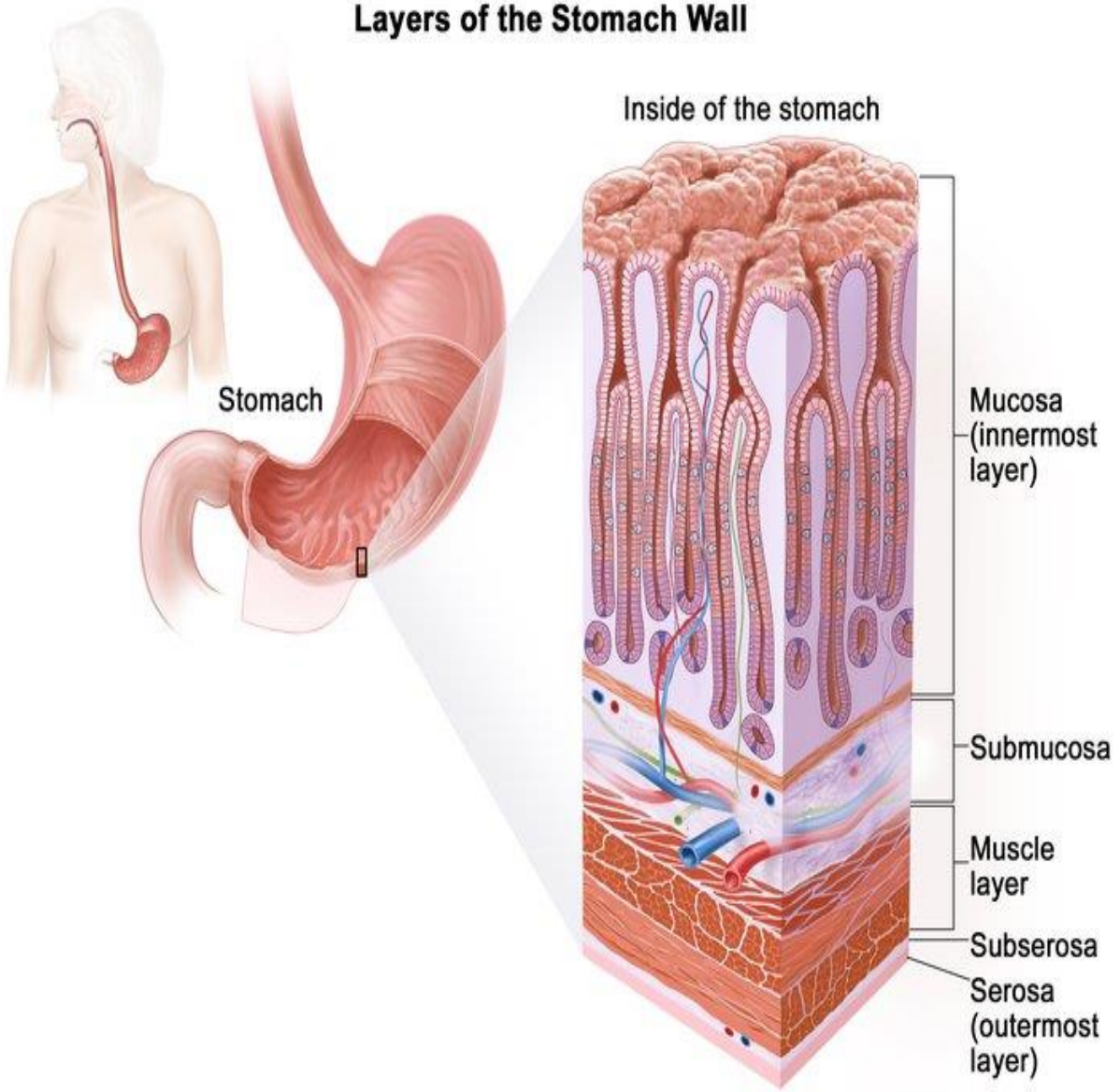
Gastric Innervation

- **ANS** : sympathetic & parasympathetic NS
- **Sympathetic**: preganglionic fibers arising predominantly from T6-T8 SN, which synapse in the bilateral celiac ganglia with neurons whose postganglionic fibers course through the celiac plexus along the vascular supply of the stomach.
- Afferent pain-transmitting fibers from the stomach and motor fibers to the pyloric sphincter.
- **Parasympathetic** innervation is via the right and left vagus nerves, which form the distal oesophageal plexus, and gives rise to the posterior and anterior vagal trunks near the gastric cardia.
- The trunks contain preganglionic parasympathetic fibers, as well as afferent fibers from the viscera.
- Both trunks give rise to celiac and hepatic branches before continuing on within the lesser omentum slightly to the right of the lesser curvature as the anterior nerve of Latarjet and the posterior nerve of Latarjet.
- These nerves give rise to multiple gastric branches to the stomach wall, where the preganglionic fibers synapse with the ganglion cells in the submucosal (Meissner's) and myenteric (Auerbach's) plexuses.
- From these plexuses, postganglionic fibers are distributed to cells and glands and to smooth muscle.



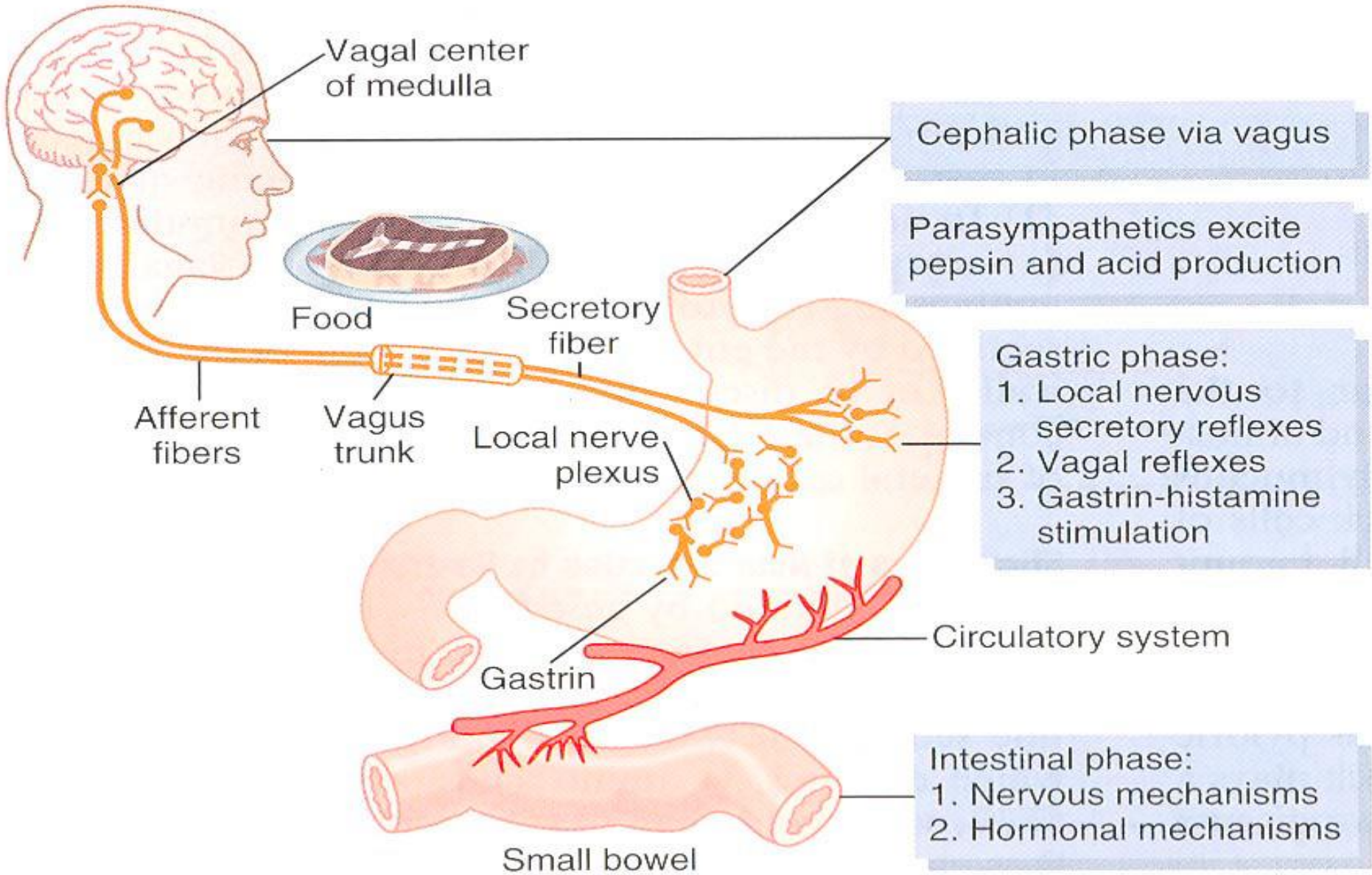
Gastric: Tissue layers

- **Mucosa:**
  - smooth, velvety, blood-filled lining.
  - cardia, antrum, and pylorus > paler than that of the fundus and body.
  - fundic and body mucosa that most of the functional secretory elements of the stomach are located
- **Submucosa:**
  - dense connective tissue skeleton of collagen and elastin fibers.
  - Lymphocytes, plasma cells, arterioles, venules, lymphatics, and the submucosal plexus.
- **Muscularis propria (3 muscle layers):**
  - inner oblique, middle circular, and outer longitudinal.
  - The inner oblique muscle fibers course over the gastric fundus, covering the anterior and posterior aspects
  - Circular fibers encircle the body of the stomach, thickening distally to become the pyloric sphincter
  - Longitudinal muscle fibers course primarily along the greater and lesser curvatures of the stomach.
- **Serosa:** Transparent, a continuation of the visceral peritoneum



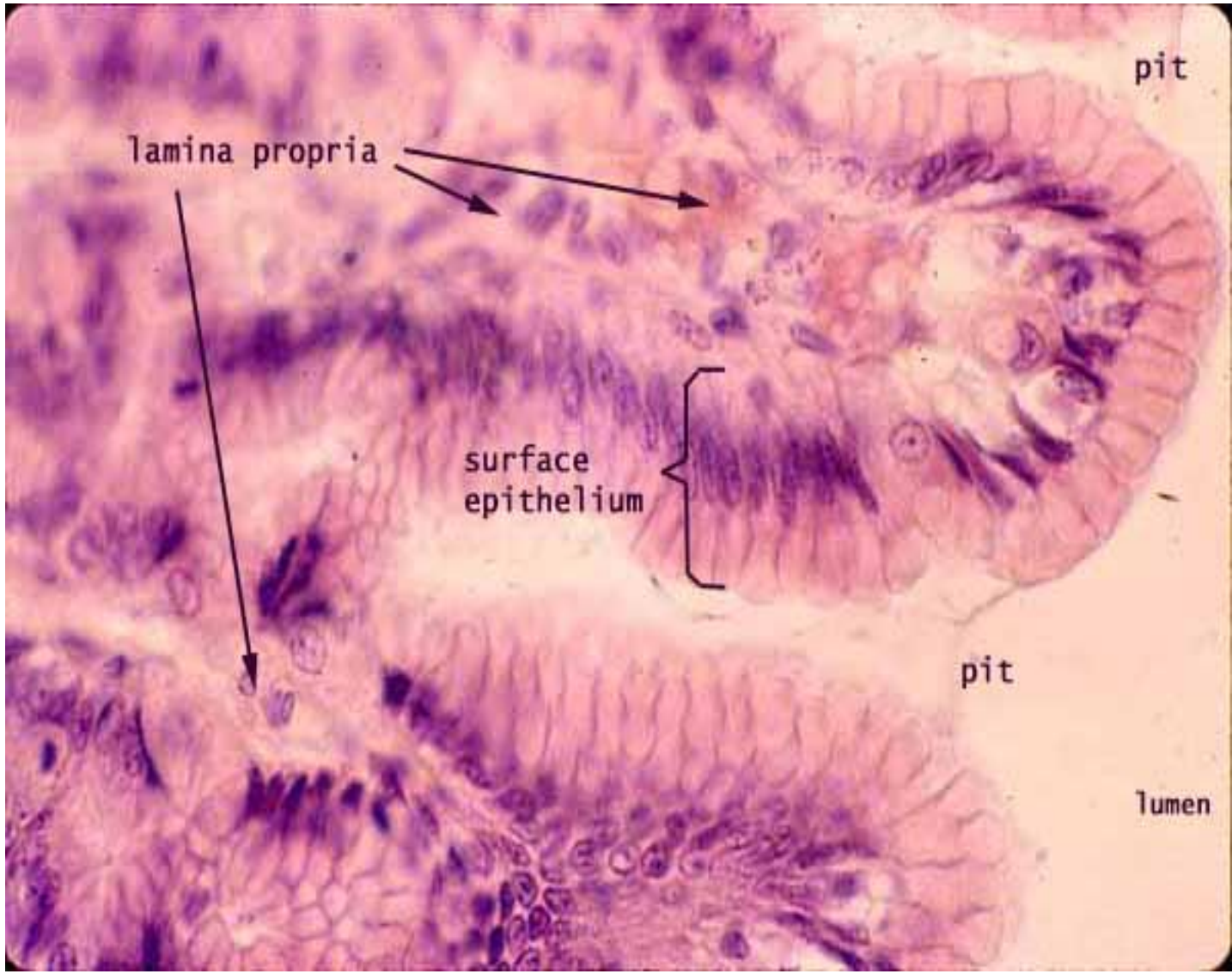
Gastric Acid Secretion

- Redundant, overlapping pathways⟶ 3 phases: cephalic, gastric, and intestinal
- **Cephalic** -vagal/cholinergic ⟶activated by the thought, taste, smell and site of food, and swallowing
- **Gastric**-chemical effects of food and gastric distension ⟶gastrin/histamine stimulation
- **Intestinal**-food stimulate hormone release

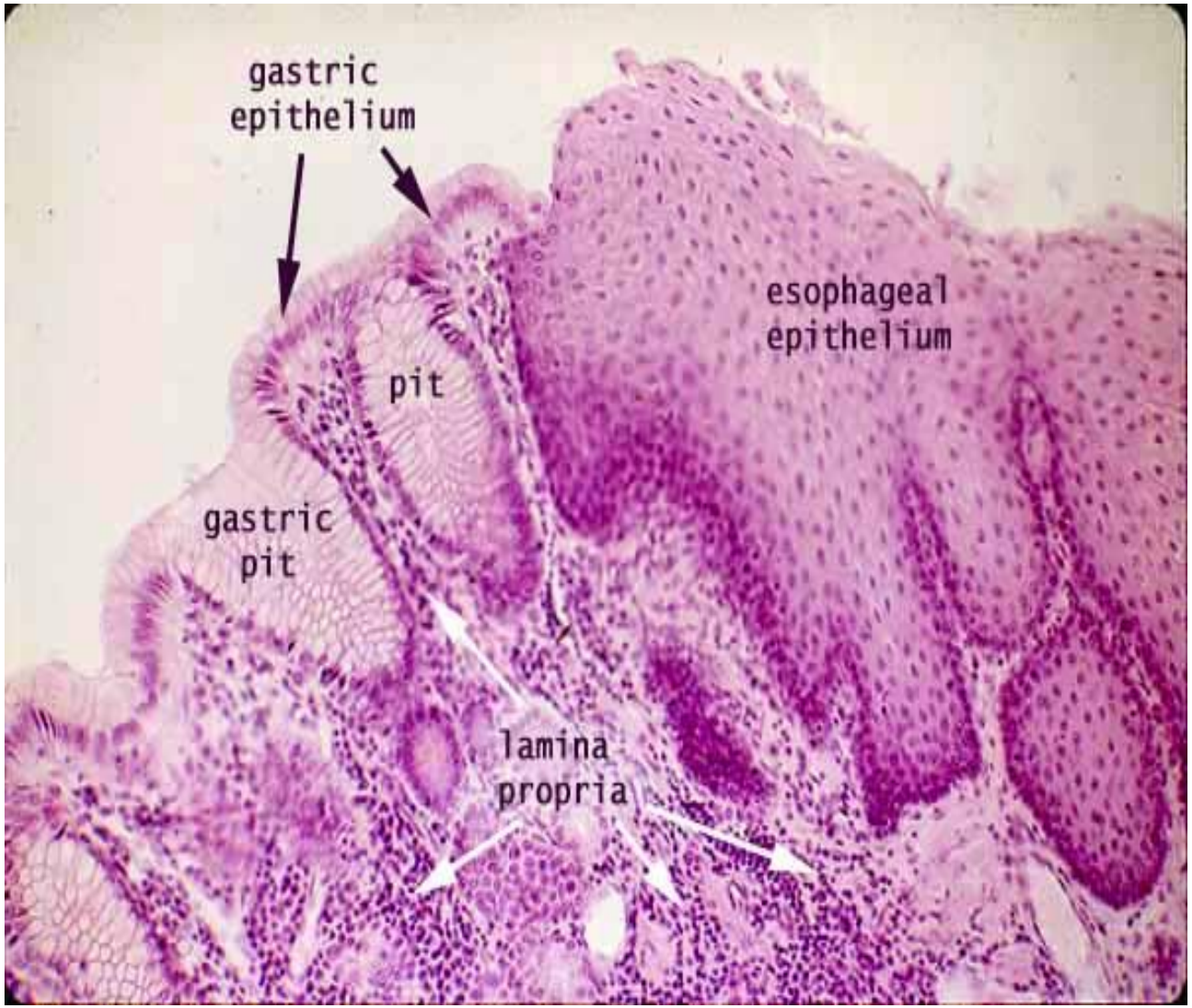

Vagal center of medulla
Cephalic phase via vagus
Parasympathetics excite pepsin and acid production
Food
Secretory fiber
Afferent fibers
Vagus trunk
Local nerve plexus
Gastric phase:
1. Local nervous secretory reflexes
2. Vagal reflexes
3. Gastrin-histamine stimulation
Circulatory system
Gastrin
Intestinal phase:
1. Nervous mechanisms
2. Hormonal mechanisms
Small bowel

Histology

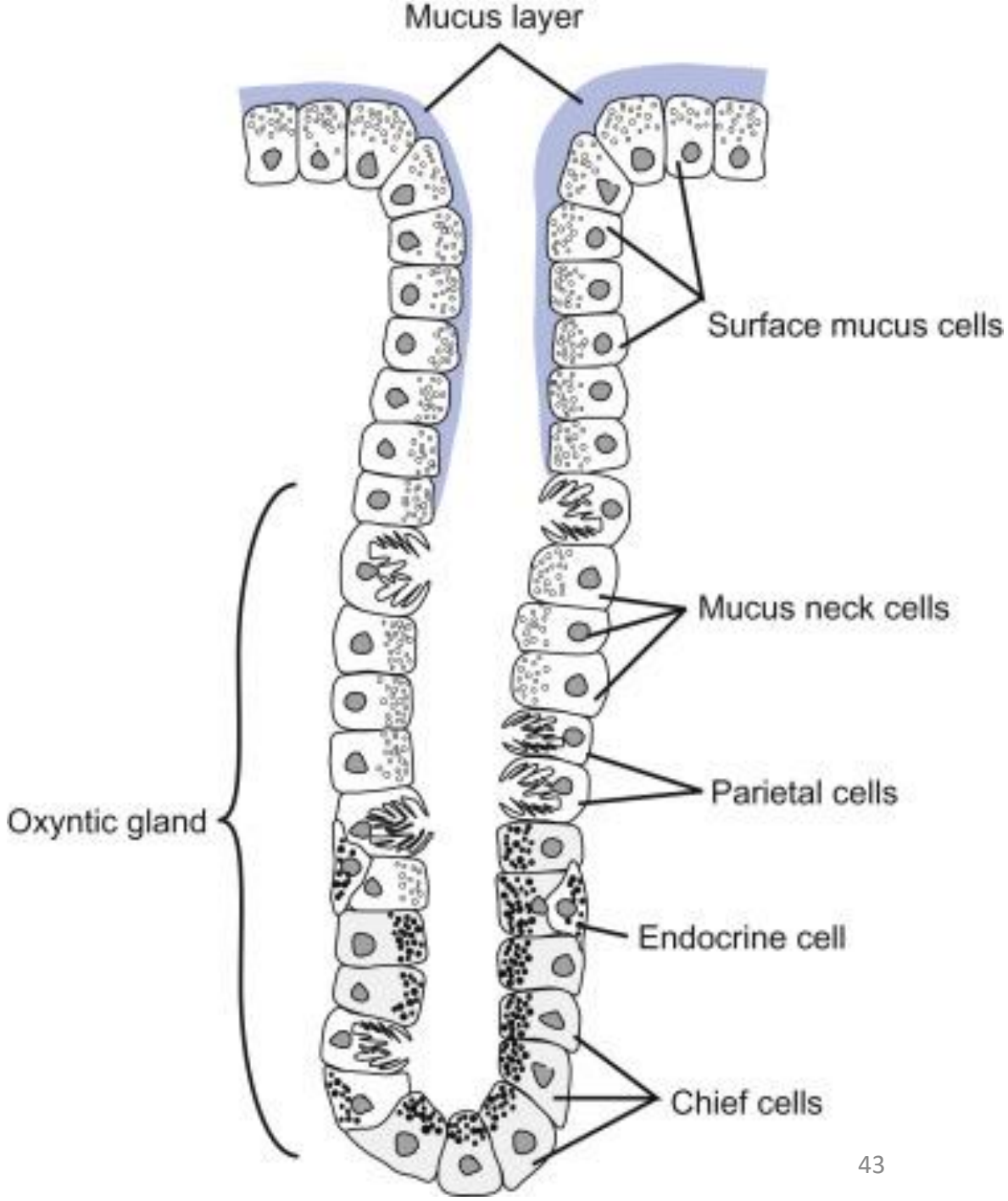
- Mucosal surface: simple columnar epithelial cells; 20-40 µm in height.
- Contain basally located nuclei, prominent Golgi stacks, and dense cytoplasm with especially apically located, dense, mucin-containing membrane-bound granules.
- The cells secrete mucus in granules that are released via exocytosis, apical expulsion, and cell exfoliation.
- 1^0 role of mucus (& bicarbonate): luminal cytoprotection.
- Cellular renewal time for surface mucous cell is ~ 3 days.



- Gastric pits (foveolae): formed by invagination of surface epithelial lining
  - These provide the gastric glands access to the gastric lumen, with a ratio of 1 pit to 4-5 gastric glands.
  - The gastric glands of different anatomic regions of the stomach are lined with different types of specialized epithelial cells
- Cardia:
  - small transition zone from oesophageal squamous epithelium to gastric columnar epithelium.
  - Glands have a branched & tortuous configuration and are populated by mucous, endocrine, and undifferentiated cells.
- Gradual transition from cardiac glands to the 2nd region:
  - Acid-secreting segment of the stomach.
  - Encompasses the gastric fundus & body and contains the parietal (oxyntic or fundic) glands.
  - Parietal, chief (also known as peptic), endocrine, mucous neck & undifferentiated cells compose the oxyntic glands.
- Final region:
  - Antrum and pylorus, contains the pyloric glands, composed of endocrine cells, including gastrin producing G cells and mucous cells.



- **Oxyntic glands**:
  - Most numerous & distinctive of gastric glands
  - Responsible for secretion of acid, intrinsic factor, and most gastric enzymes.
  - These fairly straight and simple tubular glands are closely associated in the areas of gastric fundus and body.
- Gland is subdivided into 3 areas:
  - Isthmus (where surface mucous cells predominate)
  - Neck (where parietal and mucous neck cells predominate)
  - Base (where chief cells predominate, along with some parietal & mucous neck cells).
- **Endocrine cells**:
  - somatostatin-containing D cells
  - Histamine-secreting enterochromaffin-like (ECL) cells (among others) are scattered throughout the oxyntic epithelium

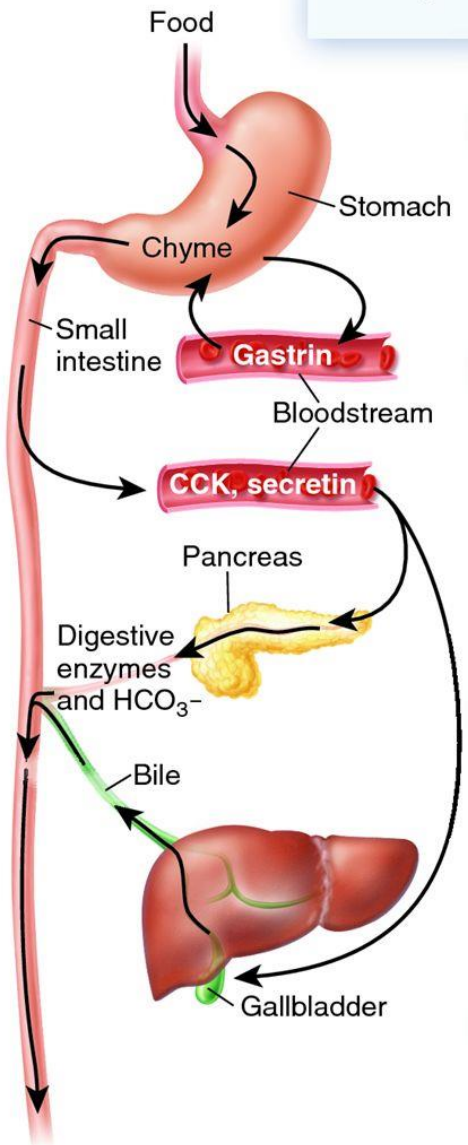


- **Parietal cell:**
  - Principle cell of the oxyntic gland
  - Responsible for the oxyntic mucosal secretion of **3×10^4 H^+ per second**, at a **final (HCl^+) conc of ~150 mmol/L**.
  - Parietal cells bulge into the lumina of the oxyntic glands and, as the 1^0hydrogen secretors, have ultrastructural characteristics different from other gastric cells:
  - Large mitochondria, microvilli lacking in glycocalyx & a cytoplasmic canaliculi system in contact with the lumen
- **Nonsecreting:**
  - a cytoplasmic tubulovesicular system predominates and short microvilli line the apical canaliculus.
- **Secreting state:**
  - Tubulovesicular system disappears, leaving an extensive system of intracellular canaliculi containing long microvilli.
  - Mitochondria occupy approximately 30% to 40% of the secreting parietal cell volume, providing energy required for acid secretion across apical microvilli

- Proton pump— H+,K+-ATPase—resides in the apical microvillus membrane, as does carbonic anhydrase.
- The apical H+,K+-ATPase functions as the proton translocator in gastric acid secretion.
- Acid secretion begins within 5-10 minutes of stimulation.
- Additionally, parietal cells are the site of IF secretion via membrane-associated vesicle transport.

- **Mucous neck cells**:
  - Closely associated with parietal cells
  - Appear singly close to parietal cells or in groups of 2 or 3 in the oxyntic gland neck or isthmus.
- Mucous neck cells differ from their surface counterparts in their synthesis of acidic, sulfated mucus rather than the neutral mucus.
- Mucous neck cells have basal nuclei and larger mucous granules around the nucleus, rather than apically located granules.
- Function of the 2 cell types appears different:
  - Surface mucous cells are **cytoprotective**.
  - Mucous neck cell functions as a **stem cell** precursor for surface mucous, parietal, chief, and endocrine cells.

- **Chief cells (zymogen cells):**
  - predominate in deeper layers of the oxyntic glands.
  - These pyramid-shaped cells play a role in synthesis and secretion of pepsinogens I and II.
  - The cytoplasm of chief cells has prominent basophilic staining owing to abundant ribosomes;
  - These ribosomes are either free in the cytoplasm or in association with an extensive endoplasmic reticulum system.
  - Zymogen granules lie in the apical cytoplasm; their contents are released into the gastric lumen following fusion of the limiting membrane of the granule with the luminal membrane.
  - Once in the lumen, pepsinogens are converted to pepsin
- **D cells:**
  - secretes somatostatin
  - Enterochromaffin(EC) cells:
  - most contain serotonin.
  - ECL cells are the only enteroendocrine cells containing histamine.



1. The stomach secretes gastrin into the blood in response to a meal.
2. Gastrin returns to the stomach and stimulates muscle contraction and acid production.
3. The partially digested food, which is called chyme, moves into the small intestine and stimulates the secretion of CCK and secretin into the blood.
4. CCK and secretin stimulate the secretion of digestive enzymes and bicarbonate ions from the pancreas into the small intestine.
5. CCK also stimulates contraction of the gallbladder, which then releases bile into the small intestine.

END