Physiology

Gastrointestinal tract (GIT)

Lecture 1 (Motor Function and secretory activity of stomach and small intestine)

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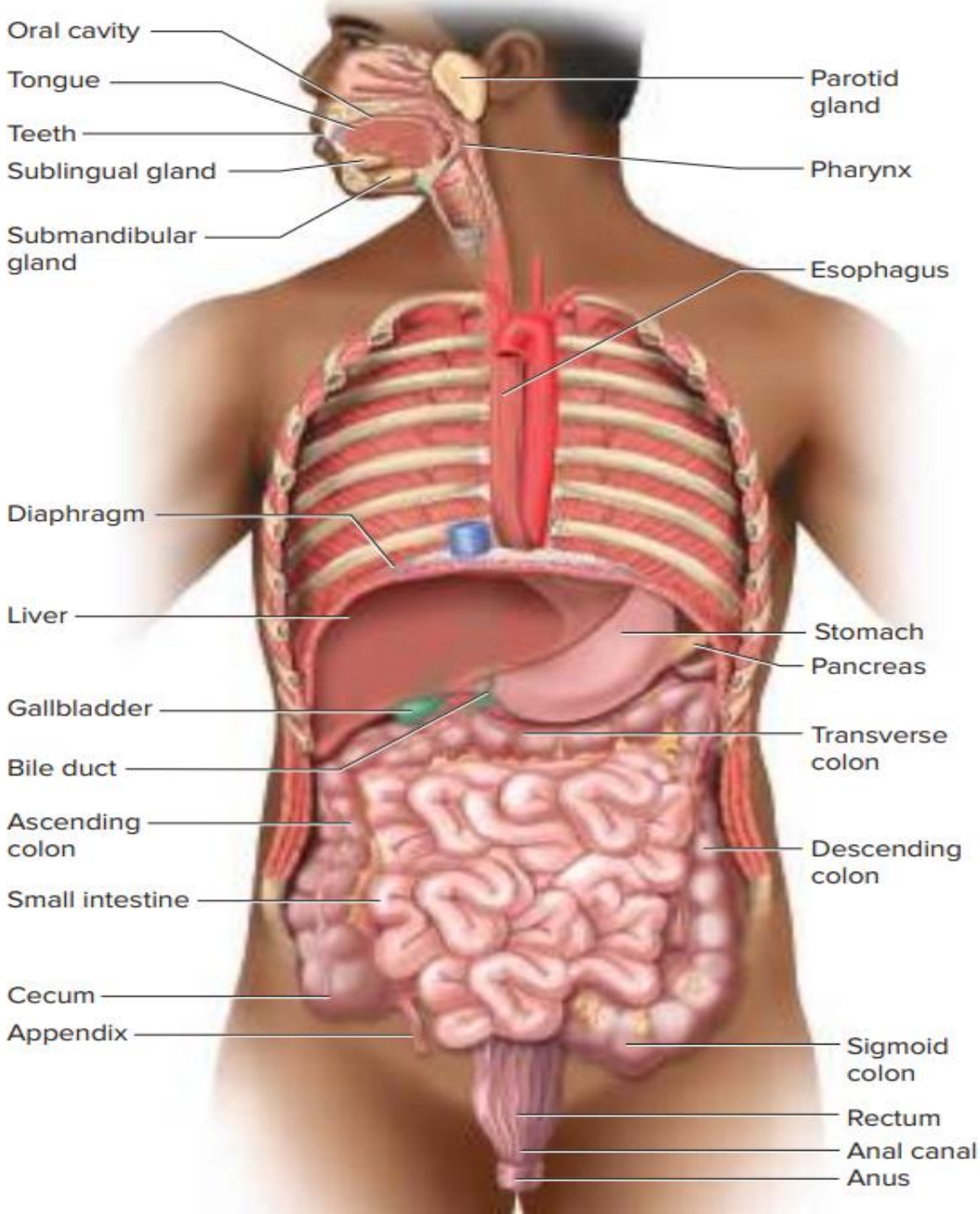
Objectives:

1.Describe the functions of the digestive system, and list it is structures and regions .

2.Describe the gastric secretion and its Control.

3.Describe the motor functions of the stomach and the control of that functions.

4. Describe the functions of the Small Intestine , and it is structures and regions


Oral cavity
Tongue
Teeth
Sublingual gland
Submandibular gland
Parotid gland
Pharynx
Esophagus
Diaphragm
Liver
Stomach
Pancreas
Gallbladder
Transverse colon
Bile duct
Ascending colon
Descending colon
Small intestine
Cecum
Appendix
Sigmoid colon
Rectum
Anal canal
Anus

• Digestive Function

The digestive system is the organ system that processes food, extracts nutrients from it, and eliminates the residue. It does this in five stages:

1. ingestion, the selective intake of food;

2. digestion, the mechanical and chemical breakdown of food into a form usable by the body;

3. absorption, the uptake of nutrient molecules into the epithelial cells of the digestive tract and then into the blood or lymph;

4. compaction, absorbing water and consolidating the indigestible residue into feces; and finally,

5. defecation, the elimination of feces

- **Digestive system includes**: the mouth, pharynx, esophagus, stomach, small intestine, and large intestine
- The teeth, tongue, salivary glands, liver, gallbladder, and pancreas are considered accessory organs of the digestive system.
- The digestive tract is a muscular tube extending from mouth to anus.

Anatomical feature

Most of the digestive tract with a wall composed of the following tissue layers in order from the inner to the outer surface:

- Mucosa (The inner lining of the digestive tract)

  Epithelium

  Lamina propria (a loose connective tissue layer)

  Muscularis mucosae(a thin layer of smooth muscle)

- Submucosa (thicker layer of loose connective tissue containing blood vessels and lymphatics, a nerve plexus, and in some places, glands that secrete lubricating mucus into the lumen.

- Muscularis externa

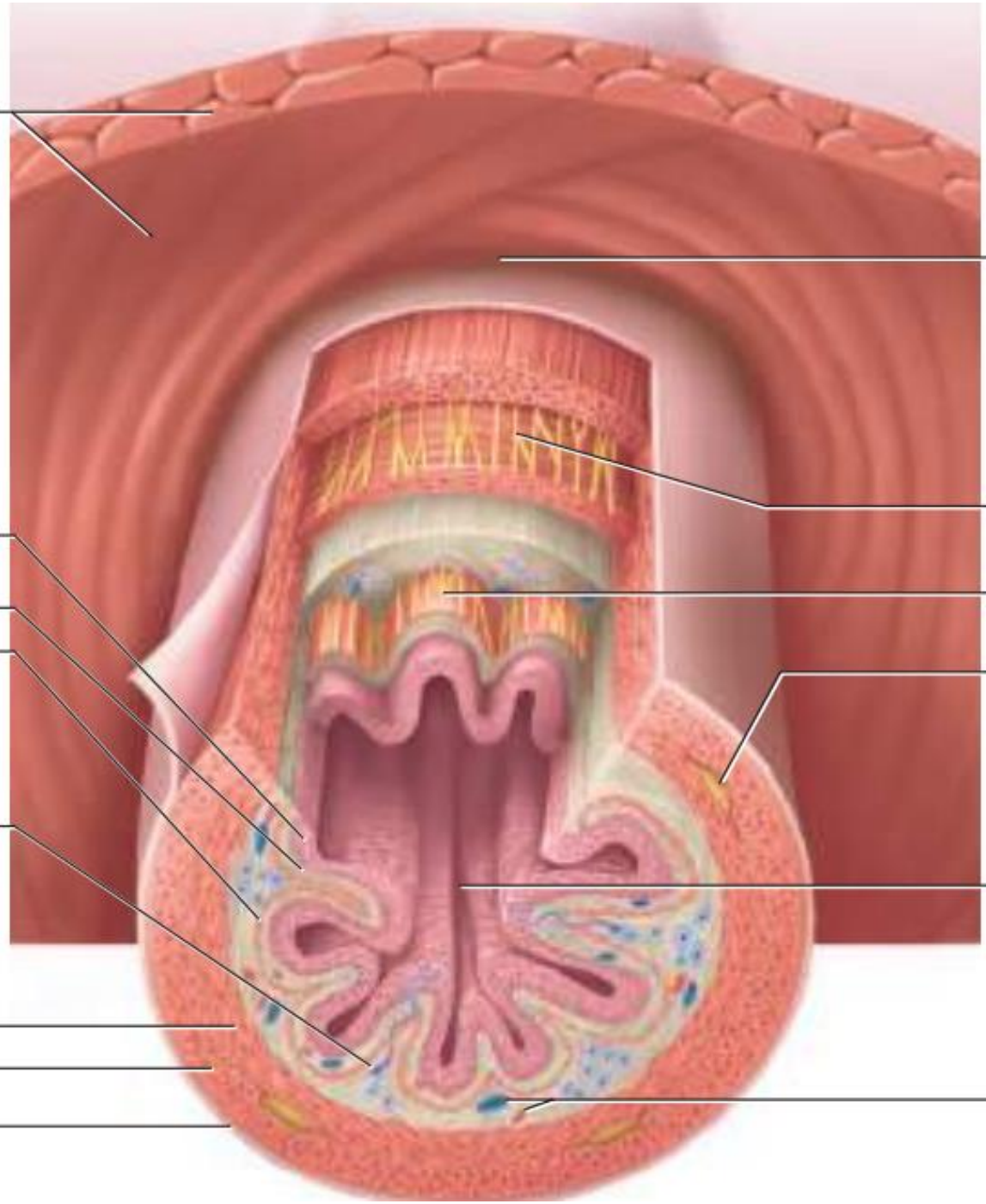
  Inner circular layer

  Outer longitudinal layer

- Serosa

  Areolar tissue

  Mesothelium


Diaphragm
Esophageal hiatus
Enteric nervous system:
Myenteric plexus
Mucosa:
Stratified squamous epithelium
Lamina propria
Muscularis mucosae
Submucosal plexus
Parasympathetic ganglion of myenteric plexus
Submucosa:
Esophageal gland
Lumen
Muscularis externa:
Inner circular layer
Outer longitudinal layer
Blood vessels
Serosa

STOMACH
ANATOMY OF STOMACH

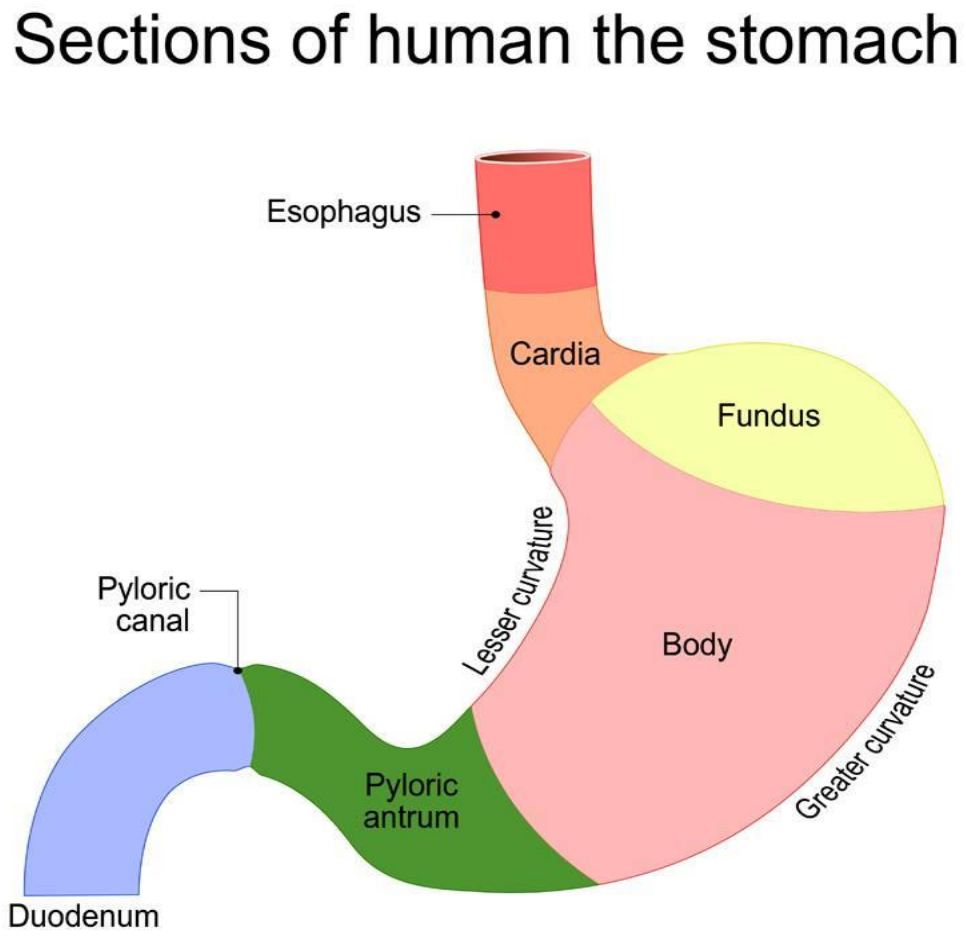
• Stomach is the most dilated part of the gastrointestinal tract

• It lies upper left quadrant of abdominal cavity,

Capacity- 1.5 to 2 Ltr.

It has 4 parts-

• Cardia
• Fundus
• Body
• Pyloric antrum



Main functions of the stomach are:

1. Storage of food until digested. When food enters the stomach a vagel reflex greatly reduces the tone in the muscular wall of the body of the stomach, so that the wall can bulge progressively outward accommodating greater and greater quantities of food up to a limit of about (1 liter), this process is called **receptive relaxation**.

2. Mixing of food with gastric secretion until it forms a semi fluid mixture called **chyme**. When the stomach is filled, weak peristaltic constrictor waves called **mixing waves**, move toward the antrum along the stomach wall approximately once every 20 seconds. As the constrictor waves progress from the body of the stomach into the antrum, they become more intense, providing powerful peristaltic constrictor rings that force the antral contents under high pressure toward the pylorus.

3. Slow emptying of chyme to the duodenum at a rate suitable for proper digestion and absorption by the small intestine.

- Normal diet takes 3 hours to be emptied to the duodenum. Fasting for 12 hours → increases antral peristalsis → hunger contraction accompanied with pain.

Gastric secretions:

Are aid in the breakdown of food into small particles and continue the process of digestion had begun by the salivary enzymes. The stomach mucosa contains two types of gastric glands:

1. **Oxyntic glands** which are located in the fundus and the body of the stomach, they contain three types of cells:

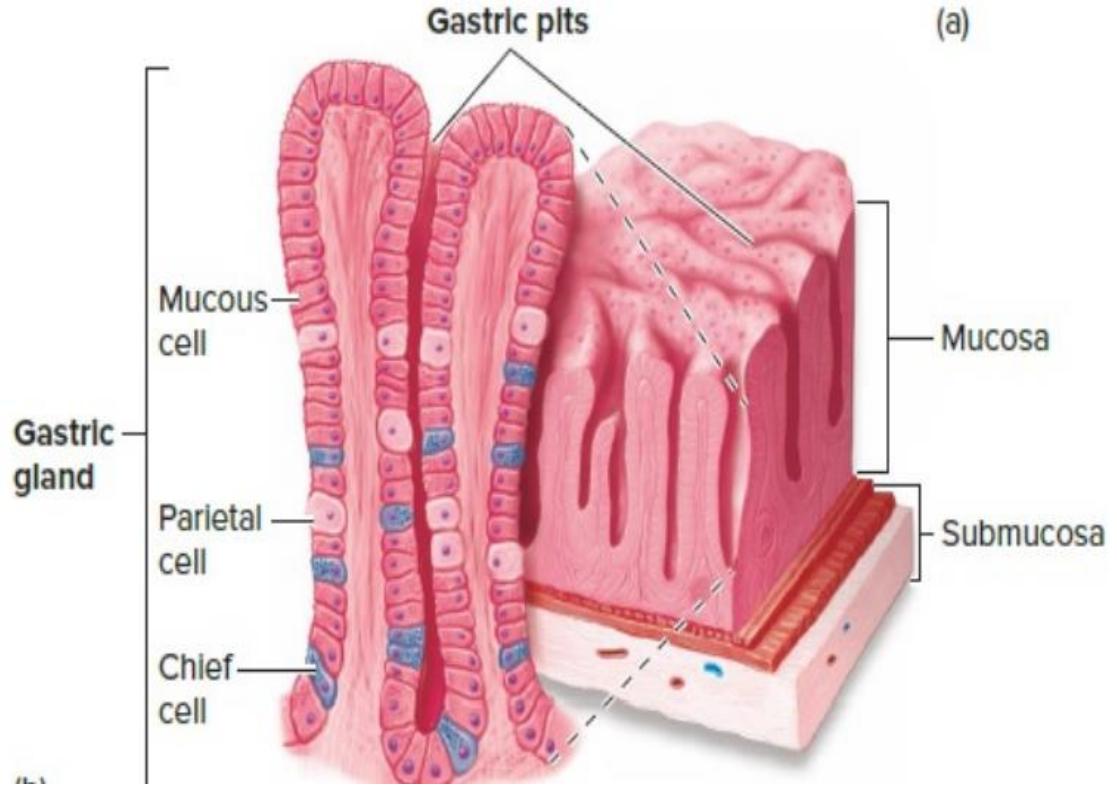
a. *Mucus secreting cells* that line the surface of the stomach.

b. *Oxyntic (parietal) cells* which secrete intrinsic factor and HCL.

c. *Peptic (chief) cells* which secrete pepsinogen.

2. **Pyloric glands** which are located in the antral and pyloric regions of the stomach, contain G cells (responsible for the release of the gastrin hormone) and some mucous cells.

Pepsin and gelatinase enzyme: They are released by exocytosis (need Ca++ and energy) by chief cells in mucosa of stomach. The cells release their secretion directly to the lumen of stomach.



Mucous secretion of stomach:

•The surface of the stomach mucosa between glands has a continuous layer of mucus cells that secrete large quantities of a viscid and alkaline mucus that coats the mucosa with a mucus gel layer often more than 1mm thick. Thus providing a major shell of protection for the stomach wall from auto digestion by acid as well as contributing to lubrication of food transport. The irritation of the mucosa directly stimulate the mucus cells to secrete this thick, viscid mucus.

- Patient with peptic ulcer will have a defect in mucous secretion, when damage to the mucosa as it occurs due to highly concentrated HCL, 10% ethanol, drugs (e.g. aspirin) and smoking , allows pepsin and HCL to penetrate the mucosal barrier and destroy mucosal cells, this liberates histamine, which increases acid secretion and produces increased capillary permeability and vasodilatation and lead to edema. Direct exposure of mucosal capillaries to the digestive process and lead to bleeding.
- The mucous layer covering is only found in stomach
- Patient with lower esophageal sphincter incompetence → regurgitation of gastric juice → reflex esophagitis (heart burn).

HCL secretion by stomach:

Functions of HCL:

1. Important for activation of pepsinogen to pepsin.

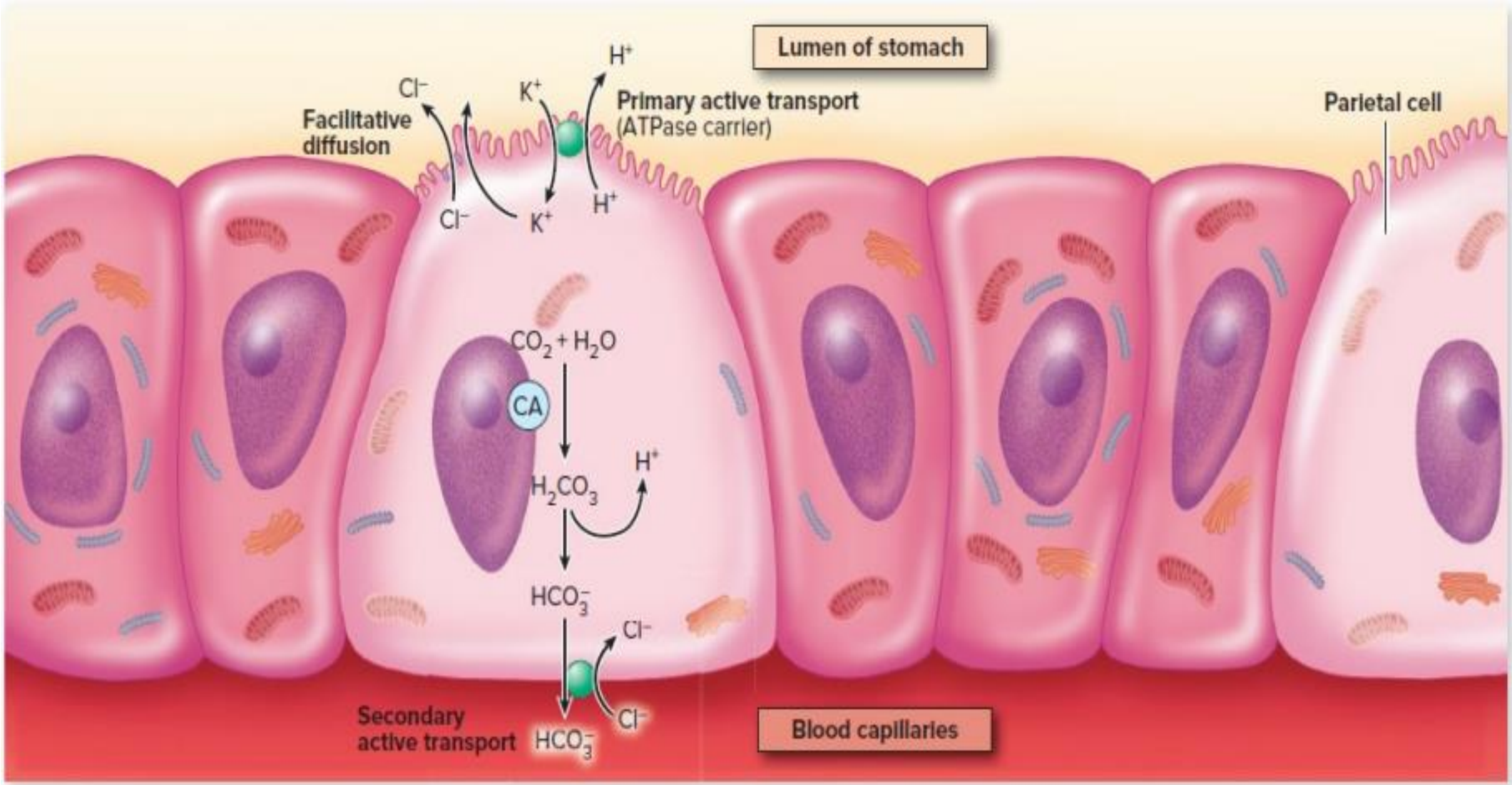
2. Aid in protein digestion (due to formation of pepsin).

3. Kills bacteria, viruses, and many toxins.

4. Converts the dietary ferric Fe^{+3} to ferrous Fe^{+2} , which is better absorbed. Without HCL the person→ decrease iron absorption suffer → iron deficiency anemia.

Mechanism of HCL secretion:

- **Secretion of gastric acid by parietal cells :**The apical membrane (facing the lumen) secretes H + in exchange for K + using a primary active transport carrier that is powered by the hydrolysis of ATP.
- The basolateral membrane (facing the blood) secretes bicarbonate (HCO_3^-) in exchange for Cl^-. The Cl^- moves into the cell against its electrochemical gradient, powered by the downhill movement of HCO_3^- out of the cell.
- This HCO_3^- is produced by the dissociation of carbonic acid (H_2CO_3), which is formed from CO_2 and H_2O by the action of the enzyme carbonic anhydrase (abbreviated CA).
- The Cl^- then leaves the apical portion of the membrane by diffusion through a membrane channel. The parietal cells thus secrete HCl into the 1. 2. 3. stomach lumen as they secrete HCO_3^- into the blood.


Lumen of stomach
Cl⁻
K⁺
H⁺
Facilitative diffusion
Primary active transport (ATPase carrier)
Parietal cell
Cl⁻
K⁺
H⁺
$CO_2 + H_2O$
CA
H_2CO_3
H⁺
HCO_3^-
Cl⁻
Secondary active transport
HCO_3^-
Cl⁻
Blood capillaries

Transmitters involved in HCL secretion:

1.Histamine

2.Acetyl choline

3. Gastrin hormone

Control of gastric secretion:

a. ***Cephalic phase*** this is responsible for about 1/3 of gastric juice secreted /day, this phase is initiated by:

1. Food in the mouth.

2. Smell, sight and thought of food.

3. Anger and hostility.

•Neurogenic signals originate in cerebral cortex or appetite centre →vagus n →stomach → HCL secretion.

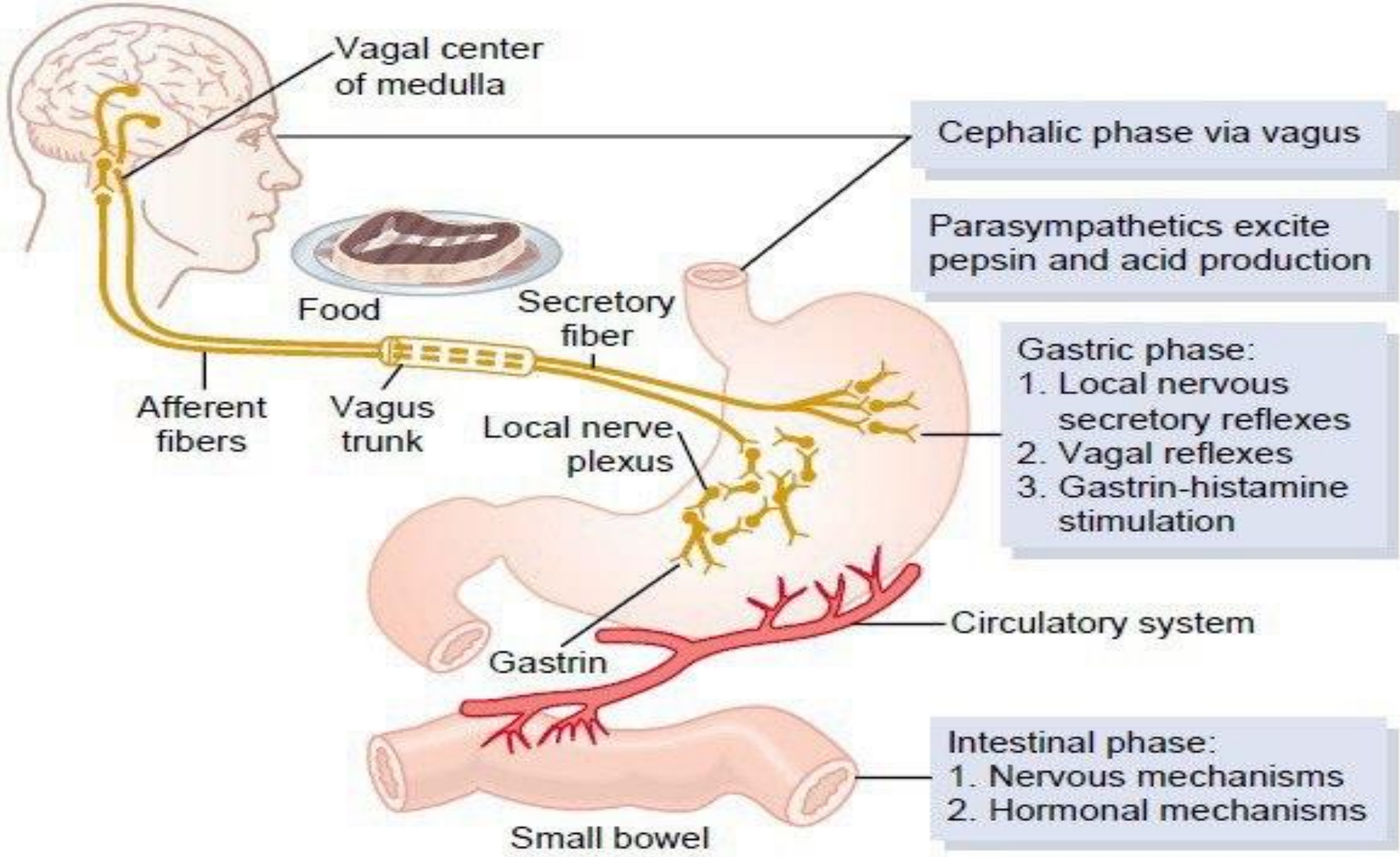
b. Gastric phase this is responsible for 2/3 of gastric juice /day occurs when there is food in stomach this cause :

a. Nerve effect:

•*ENS:* mechanoreceptors and chemoreceptors stimulation → stimulation of enteric nervous system (ENS) → release of acetylcholine which will act on parietal cells to release HCL and on G cells causing release of gastrin.

•*Vagus:* nervous effect stimulate vagus nerve to lead the secretion of acetylcholine .

•*Acetylcholine* act on parietal cell and G cells directly.



Phases of gastric secretion and their regulation.

b. Humoral effect:

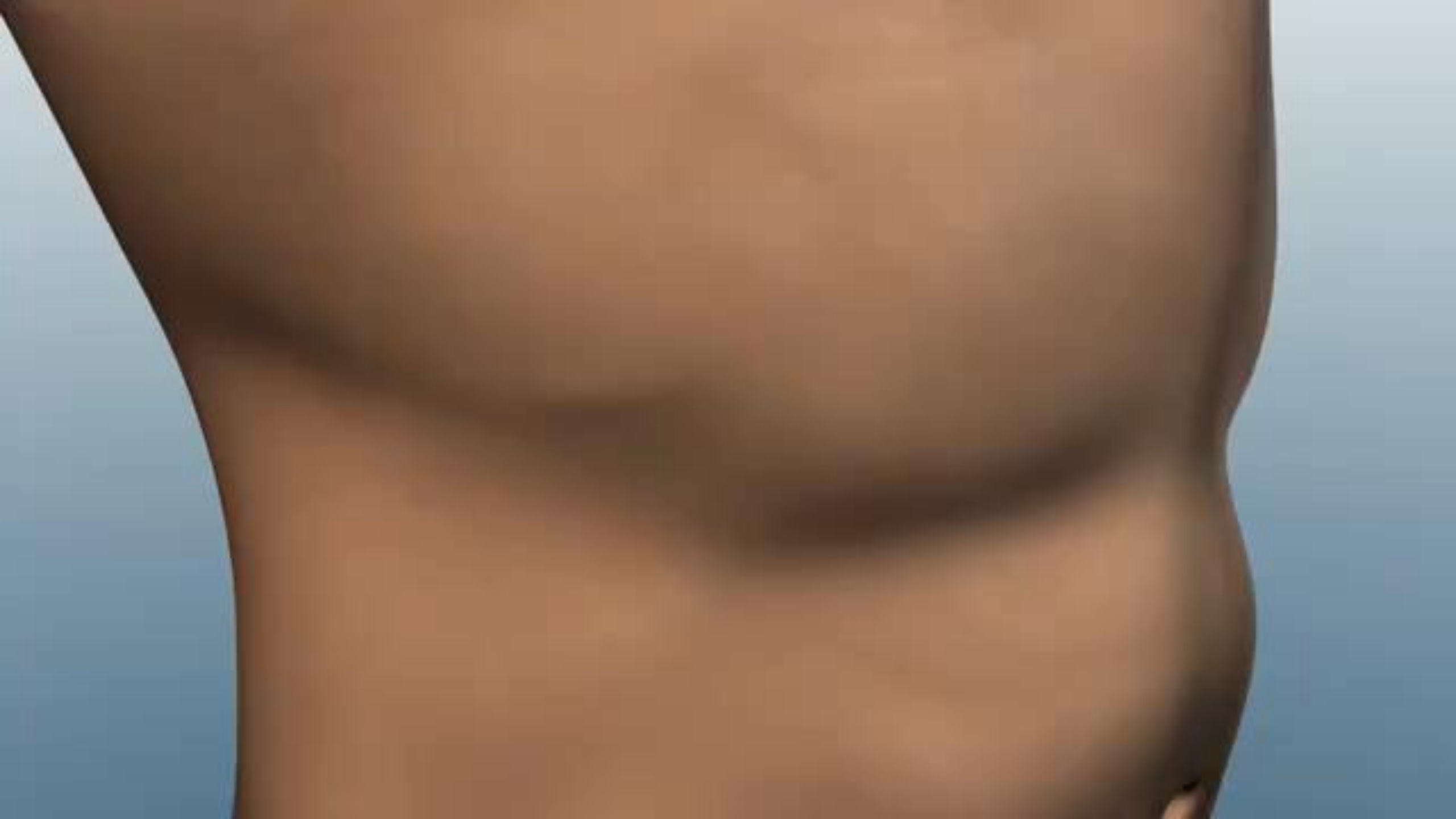
•Gastrin: from G cells act on parietal cells causing secretion of HCL.

•Histamine: acts on parietal cells causing increase release of HCL.

c. Intestinal phase:

Can be present but not always. It depends on nature of chyme entering the small intestine. Some types of chyme can stimulate duodenal mucosa to release enteric gastrin which act on parietal cells to increase HCL especially when diet needs more digestion so the intestine will share in this part.

The effect of intestine on gastric secretion is mostly inhibitory this is when the chyme contains acid or fat or both in the duodenum.



1.Small Intestine

Layers of Small intestine (4)

1)Mucosa Absorb nutrients from chyme.

2)Submucosa Provides blood vessels ,lymphatic vessels and nerves to support mucosa on the surface.

3)Muscularis layer Contracts and moves the small intestine.

4)Serosa Continuous throughout and surrounds the intestine.

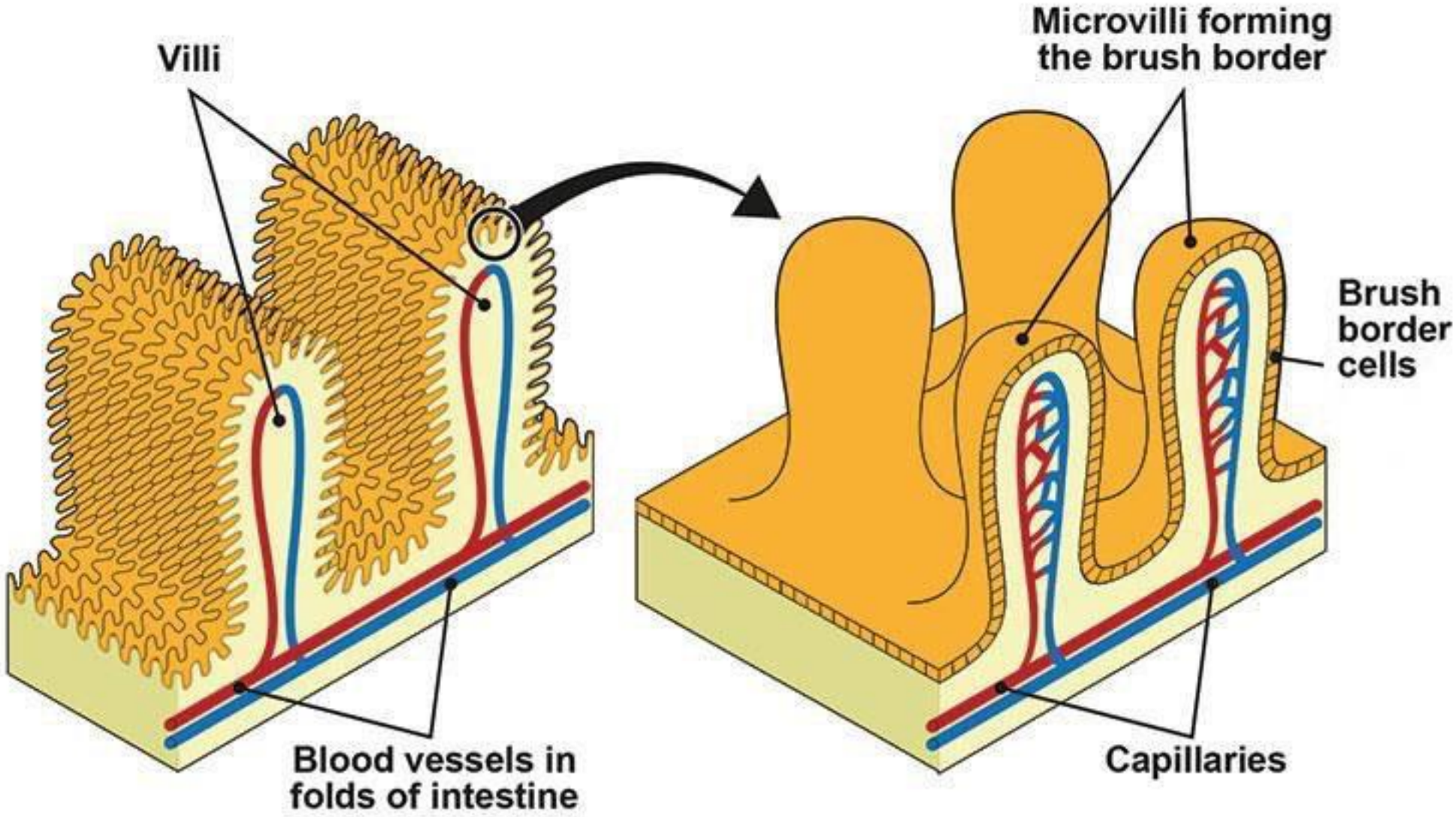
major regions of Small intestine:

1:Duodenum: (10 inches) Shortest region of small intestine Chyme and bile mix completing digestion.

2:Jejunum: (3 feet) Middle section Serves as primary site of nutrient absorption.

3:Ileum: (6 feet) Final section of small intestine Empties into large intestine Completes nutrient absorption.

- The interior walls of the small intestine are tightly wrinkled into projections called ***circular folds*** that greatly increase their surface area.
- Microscopic examination of the mucosa reveals that the mucosal cells are organized into finger-like projections known as ***villi***, which further increase the surface area. Many villi are present on the surface of intestine.
- The cells on the surface of the mucosa also contain finger-like projections of their cell membranes known as ***microvilli***, which further increase the surface area of the small intestine.
- Epithelial cells have a ‘brush like’ border
- Purpose: All of these wrinkles and projections help to greatly increase the amount of contact between the cells of the mucosa and chyme to maximize the absorption of vital nutrients.
- Each square inch of mucosa contains around 20,000 villi.


Villi
Microvilli forming the brush border
Brush border cells
Blood vessels in folds of intestine
Capillaries

Digestion in GIT:

•***Digestion of carbohydrates*:** Because the food remains only for a short time in the mouth, only 3-5% of all starches that have been eaten will have become digested, enzyme ά-amylase hydrolyzes starches into disaccharide, maltose and other small polymers of glucose. The action of the enzyme can continue for up to an hour after the food has entered the stomach, then the action is blocked by the acid of the gastric secretions, about 30-40% of the starches will hydrolyzed mainly to maltose.

Pancreatic secretion in the small intestine contains a large quantities of amylase that continue splitting starches into maltose and other small polymers of glucose. The brush border epithelial cells lining the small intestine contain enzymes lactase, sucrose and maltase, which are capable of splitting the disaccharides lactose, sucrose and maltose into their constituent monosaccharides.

•***Digestion of fat:*** The first step in fat digestion is to break the fat globules into small size so that the water soluble digestive enzymes can act on the globule surfaces, this process is called **emulsification** of the fat and it is achieved under the influence of bile salts. Digestion of fats by pancreatic enzymes (lipases, cholesterol esterase and phospholipase A2), however, the epithelial cells of the small intestine also contain a minute quantity of lipase known as **enteric lipase**.

•***Digestion of proteins:*** Pepsin is capable of digesting essentially all different types of proteins in the diet, pepsin digestion represents 10-30% of total protein digestion. Most protein digestion occurs principally in the small intestine under the influence of the proteolytic enzymes of the pancreatic secretions. Trypsin and chymotrypsin can split protein molecules into small polypeptides. The brush border of the small intestine contains several different enzymes aids in the digestion of proteins.

Absorption in GIT:

Absorption in stomach:

•Although gastric enzymes begin breaking down proteins, the stomach wall is not well adapted to absorb digestive products. However, the stomach absorb small quantities of water, glucose, certain salts, alcohol, and some lipid soluble drugs.

•Most nutrients are absorbed in the small intestine. Alcohol, which is not a nutrient, is absorbed in the stomach. This is why?? The intoxication effects of alcohol are felt soon after consuming alcoholic beverages.

Absorption in the small intestine: The villi and microvilli greatly increase the surface area of the intestinal mucosa.

Control of GIT functions:

1. Nervous control (control motility and secretion):

a. Intrinsic control (local) specific for GIT, it is called enteric nervous system (ENS) which has neurons, nerve fibers, receptors and chemical transmitters.

•The enteric nervous system is composed of two layers of neurons and connecting fibers, the outer layer called the **myenteric (Auerbach,s) plexus** which controls mainly the GIT movement. The inner layer called the **submucous(Meissner's) plexus**, which is important in controlling secretion and blood flow and also subserves many sensory functions, receiving signals from the gut epithelium and from stretch receptors in the gut wall. All these plexuses are connected to each other in some way, and the plexus in the upper GIT are continuous with neurons plexus in lower GIT.

- The Meissner's plexus are usually attach to receptors in mucosa, these receptors are of 2 types (chemoreceptors :stimulated by chemical nature of food, and mechanoreceptors :stimulated by mechanical stimuli e.g. stretch and pressure)

- Chemical transmitters of GIT: The usual chemical transmitter is acetylcholine but in some neurons there are other transmitters (peptide in nature)→Glucagons, substance P (pain), and VIP (vasoactive intestinal polypeptide).

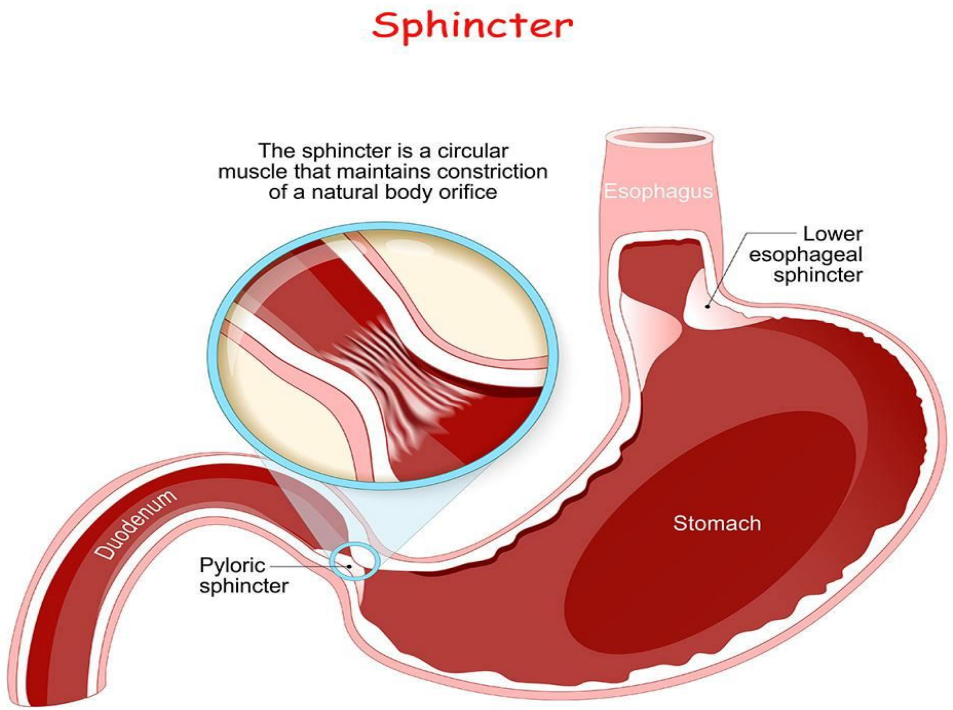
- If we remove all neurons from GIT except enteric nervous system, all parts of GIT with work normally.

b. Extrinsic control related to autonomic nervous system:

1. Parasympathetic : supply to the gut is divided into cranial and sacral divisions. The cranial division is mediated almost entirely through the vagus. Vagus nerves innervate esophagus, stomach, little innervations to small intestine, pancreas, and first half of the large intestine. The sacral fibers originate in S2, S3 S4 sacral segments of the spinal cord, and supply the distal part of the large intestine.

- Stimulation of the fibers (parasympathetic) release acetylcholine and cause a general increase in the activity of the entire enteric nervous system which in turn enhances the activity of most GIT functions, and causing sphincters to relax, so they are stimulatory to GIT.

2. Sympathetic : The fibers originate in the spinal cord between the segmentsT8 and L2. Stimulation of the sympathetic nervous system inhibits activity in the GIT, causing sphincters to contract, they inhibit the secretion of acetylcholine, inhibit the motility and secretion, so they are inhibitory the GIT.



Humoral control (hormonal control):

This is done through gastro intestinal hormones secreted from GIT mucosa including:

1.Gastrin hormone: It is polypeptide, released from antrum of the stomach by cells called G-cells. The main stimulus for its release is the presence of food in the stomach. Food in the stomach → stretch the stomach → stimulate mechanoreceptor and chemical materials in the food →stimulate chemoreceptors → gastrin secretion

Action of gastrin:

1. Increases gastric motility and secretion.
2. Closing the lower esophageal sphincter (between esophagus and stomach).
3. Increases small intestinal motility →gastro-enteric reflex.
4. Increases large intestinal motility →gastro-colic reflex.
5. Relaxes pyloric sphincter.

2.Cholecystokinin-pancreazymin (CCK-PZ):

.Released by mucosa of upper part of small intestine, mainly the duodenum.

.Main stimulus for its release is the presence of fat in the duodenum.

Actions:

1. Decreases the secretion and motility of stomach, so delays digestion of food (delays the feeling of hunger).
2. Contract the gall bladder and causes release of bile.
3. Stimulates the pancreatic exocrine secretion (secretion of digestive enzymes).

3.Secretin:

- Released from mucosa of upper small intestine, mainly the duodenum.
- Stimulus for secretion: acid in duodenum.

Actions:

1. ↓ Gastric secretion and emptying.
2. ↑ Pancreatic exocrine secretion (HCO_3^-).

4.Gastric inhibitory peptide (GIP) :

- Released from duodenum.
- Stimulus for secretion: acid and fat in duodenum.
- Actions: Inhibits gastric secretion and emptying .

The movement of GIT (GIT motility): There are 2 types of movements in GIT:

1. Mixing movement: local mix the food with secretion in GIT, done by visceral smooth muscle of the organ.
2. Propulsive movement: push the food from one part of GIT to the other. It is also called peristalsis.

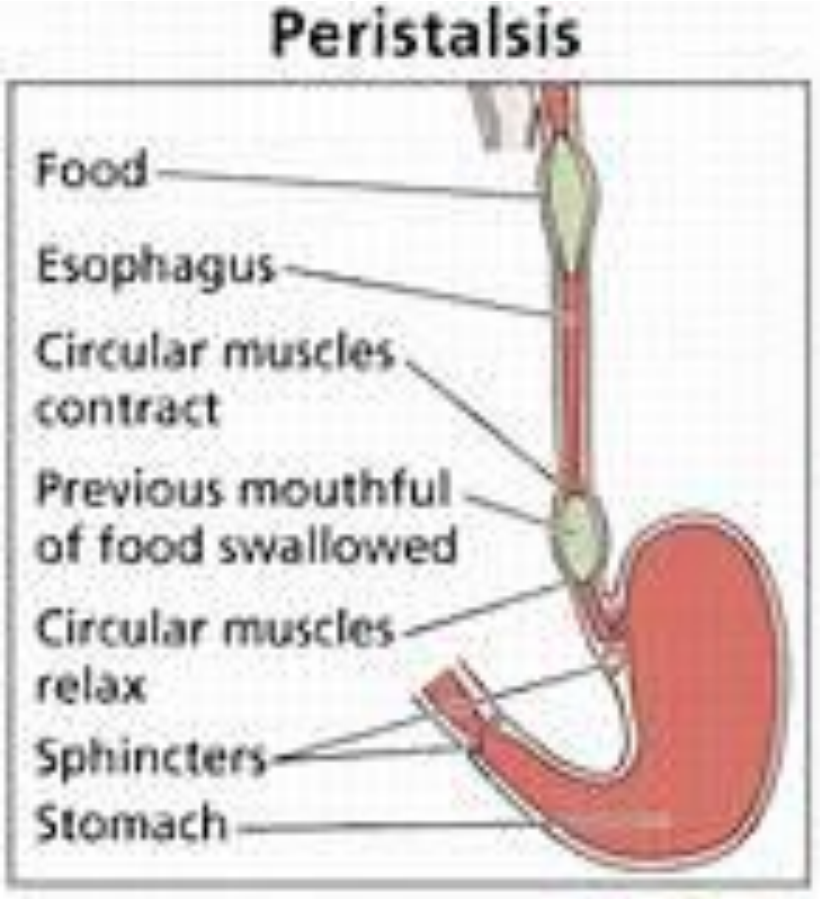
It is due to contraction of the smooth muscle and it's not unique for GIT it is also occurs in other organs like ureters.

•Peristalsis has one direction of movement called oral to caudal direction (oral to rectal) while in abnormal conditions e.g. vomiting, the direction will be reversed (opposite).

•The stimulus for peristalsis is distention of lumen of GIT by food (or other material even a foreign body). This distention is going to stimulate the mechanoreceptor which will send impulse to Myenteric nerve plexus which will initiates peristalsis.

The area behind the distention will contract due to release of acetylcholine and substance P while the area after (in front of) the distention will relax due to the release of vaso-active intestinal polypeptide (VIP). This is called the law of gut.

The area in front of distention is going to do receptor relaxation so food will move from oral to caudal end, and food will move to the relaxed area.



•Peristalsis in intestine need intact and integrated regularly distributed Myenteric nerve plexus. If any part of GIT is removed then re-sutured in opposite side → no peristalsis.

•Peristalsis is due to local Myenteric nerve plexus and it is controlled by extrinsic nerve system (sympathetic → inhibitory, parasympathetic → stimulatory).

•In vomiting the peristalsis is reversed and this is done by extrinsic nervous system.


Thank You!