

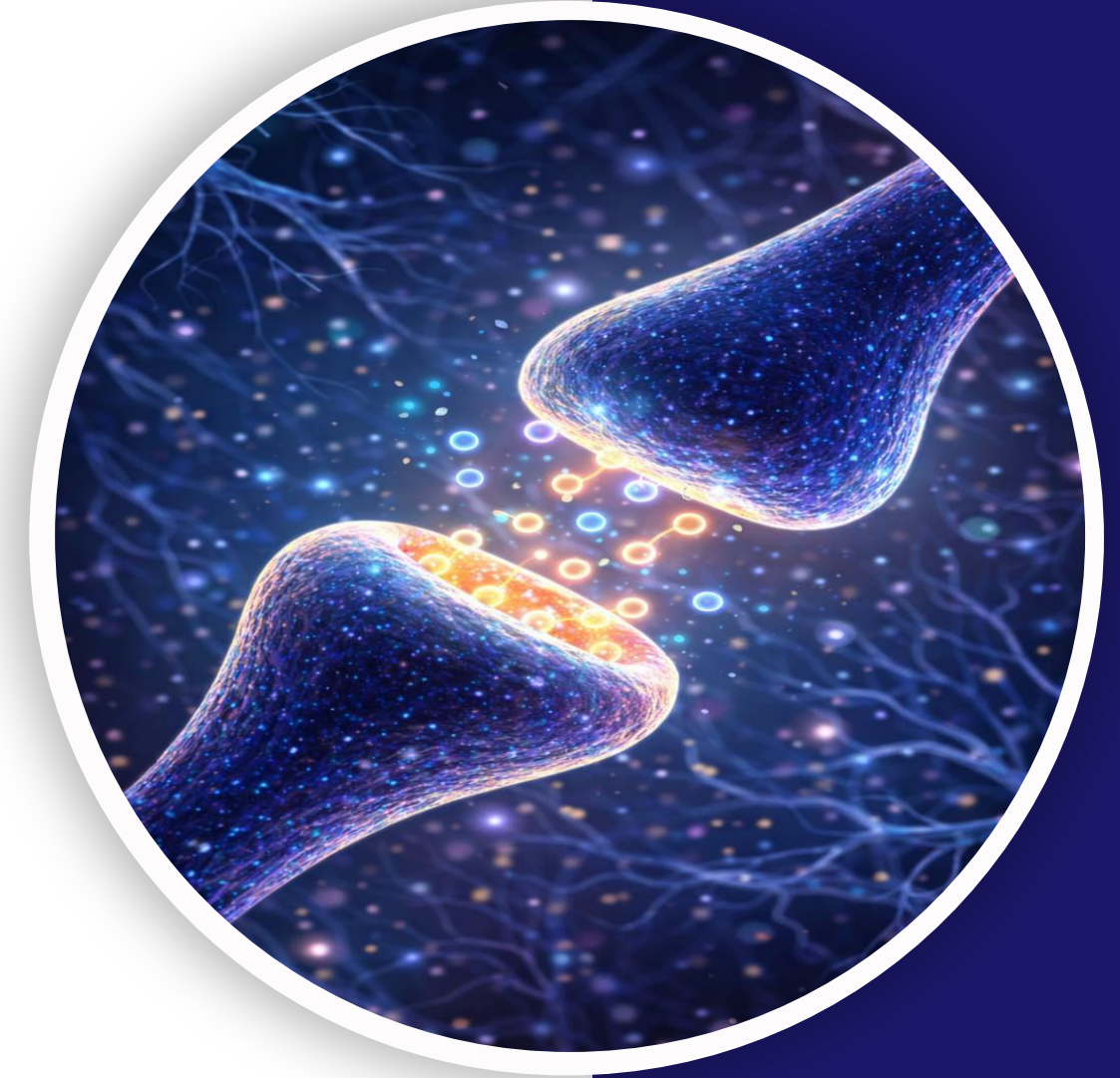
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جراحین

GI Physiology | MID 2

GI Motilities



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Gastrointestinal Motilities

Gastrointestinal Blood Circulation (Splanchnic Circulation)

- The blood vessels of the gastrointestinal system are part of a more extensive system called the **splanchnic circulation**, shown in Figure 63-6.
- It includes the blood flow through the gut plus blood flows through the **spleen, pancreas, and liver**.
- The design of this system is such that all the blood that courses through the gut, spleen, and pancreas then flows immediately into the liver by way of the portal vein.
- In the liver, the blood passes through millions of minute *liver sinusoids* and finally leaves the liver by way of hepatic veins that empty into the vena cava of the general circulation. This flow of blood through the liver, before it empties into the vena cava, allows the *reticuloendothelial* cells that line the liver sinusoids to remove bacteria and other particulate matter that might enter the blood from the gastrointestinal tract, thus preventing direct transport of potentially harmful agents into the remainder of the body.

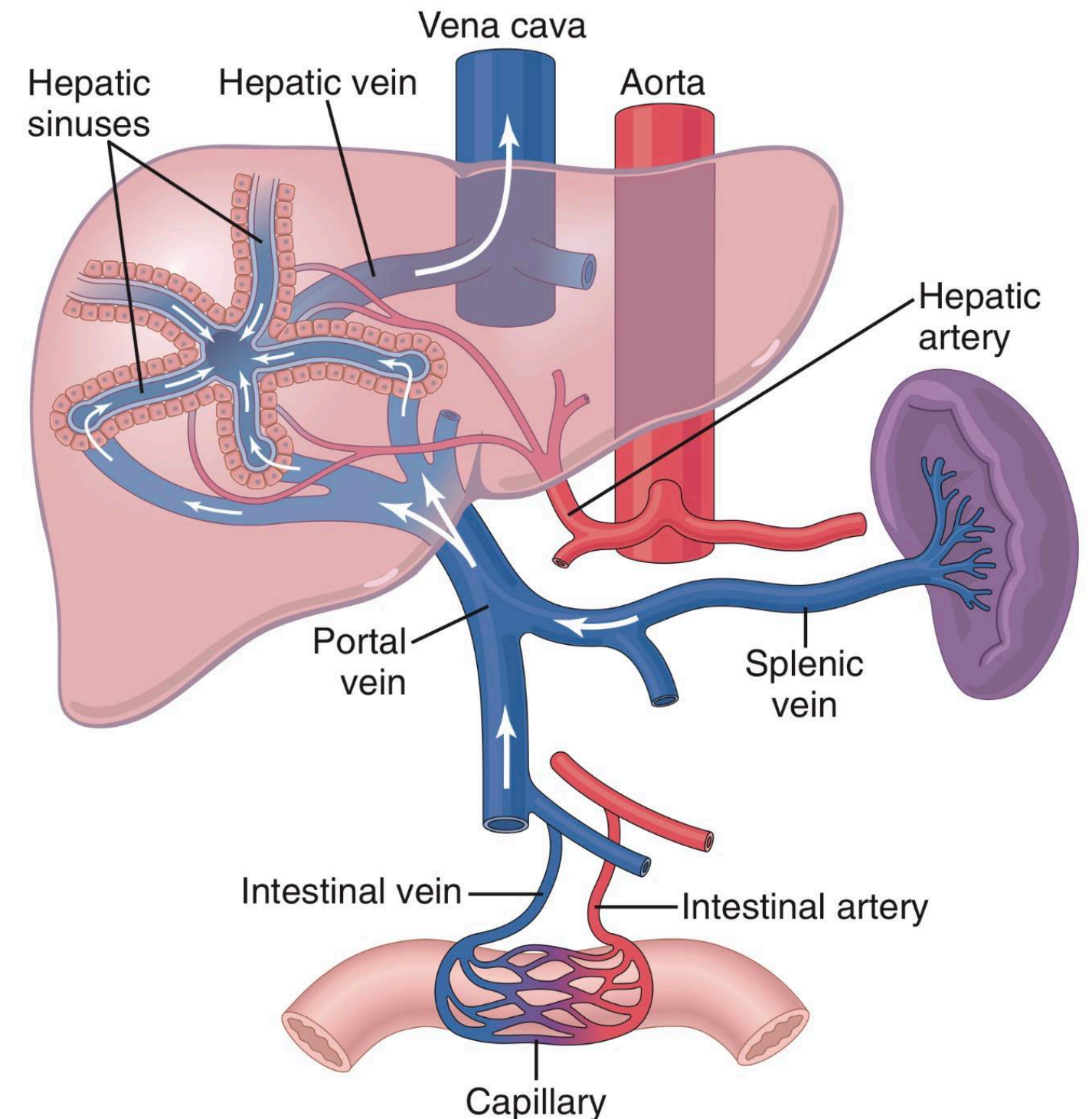


Figure 63-6. Splanchnic circulation.

Gastrointestinal Blood Circulation (Splanchnic Circulation)

- The non-fat, water-soluble nutrients absorbed from the gut (such as carbohydrates and proteins) are transported in the portal venous blood to the same liver sinusoids. Here, both the *reticuloendothelial cells* and the *principal parenchymal cells of the liver*, the hepatic cells, absorb and store temporarily from one half to three quarters of the nutrients.
- Almost all of the fats absorbed from the intestinal tract are not carried in the portal blood but instead are absorbed into the intestinal lymphatics and then conducted to the systemic circulating blood by way of the thoracic duct, bypassing the liver.

Absorption take place here at the capillaries.

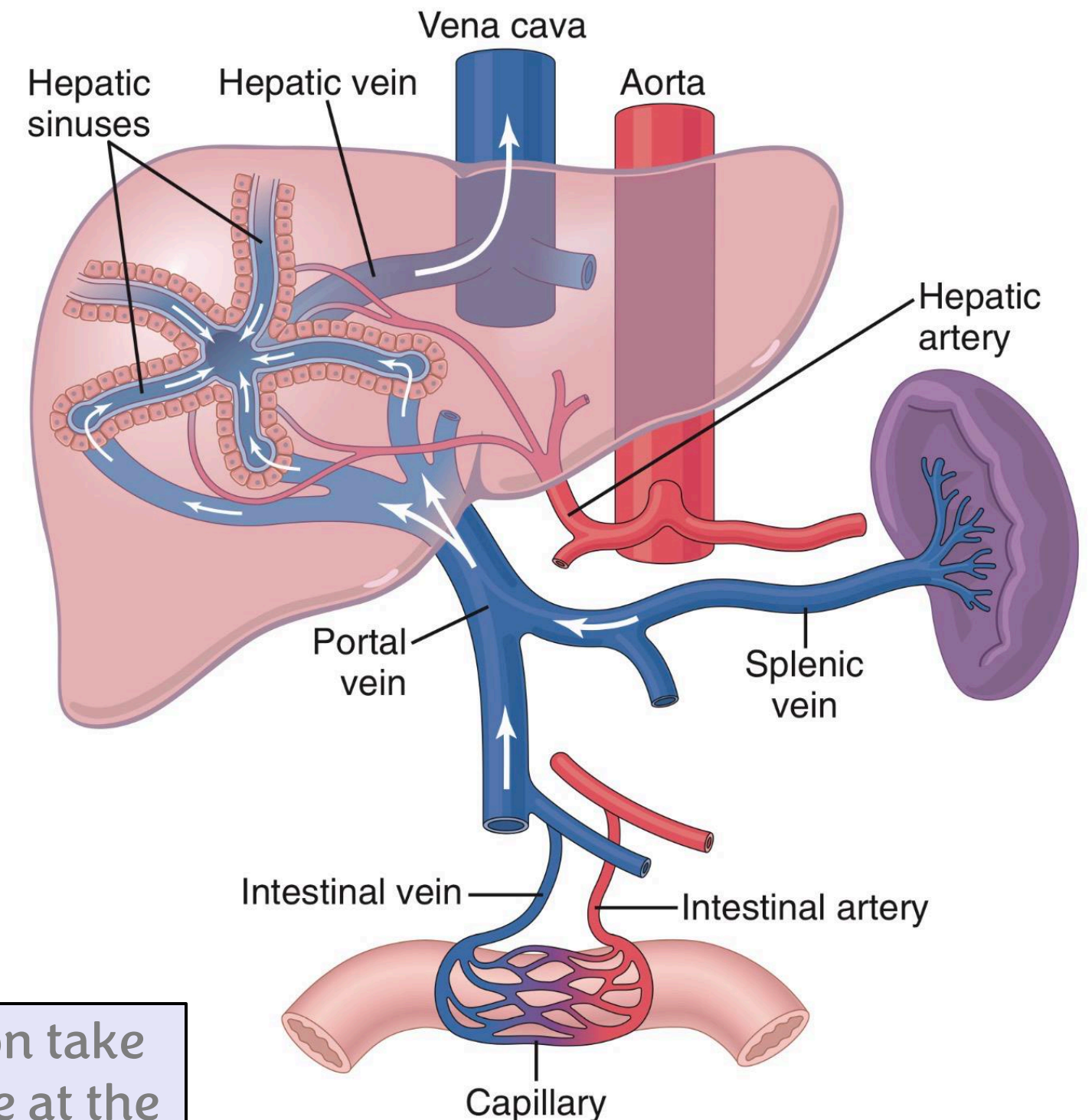


Figure 63-6. Splanchnic circulation.

Blood Flow of the GI

- Blood flow of the GI tract can be controlled by **vasodilators** which are **released by secretory cells, ex. ; cholecystokinin** which are released by I cells in the duodenum.
- We have **general control over the blood circulation** (common in all body organs) :
 - **Low oxygen levels → Vasodilation.**
 - **High oxygen levels → Vasoconstriction.**
- Also, ANS plays a major role in controlling blood flow in GIT :
 - **Sympathetic → Vasoconstriction (Direct effect).**
 - **Parasympathetic → Vasodilation (Indirect, Secondary effect by hormones released by secretory cells that parasympathetic innervation is acting on).**

Blood Flow of the GI

➤ Related to GI activities:

- Controlled by:

- **Hormones** (Secretin, CCK).
- **ENS** (VIP, SP, CGRP).

- **Vasodilators:**

Kinins (Kallidin, Bradykinin).
Decreased O₂ concentration.

- **ANS**

(Sympathetic and parasympathetic).

Pathways Controlling Digestive-System Activities

- We have effector cells, such as:
 - **Smooth muscles.**
 - **Exocrine & Endocrine Glands.**
- ✓ In order to control these cells, we have different controlling systems, which are :

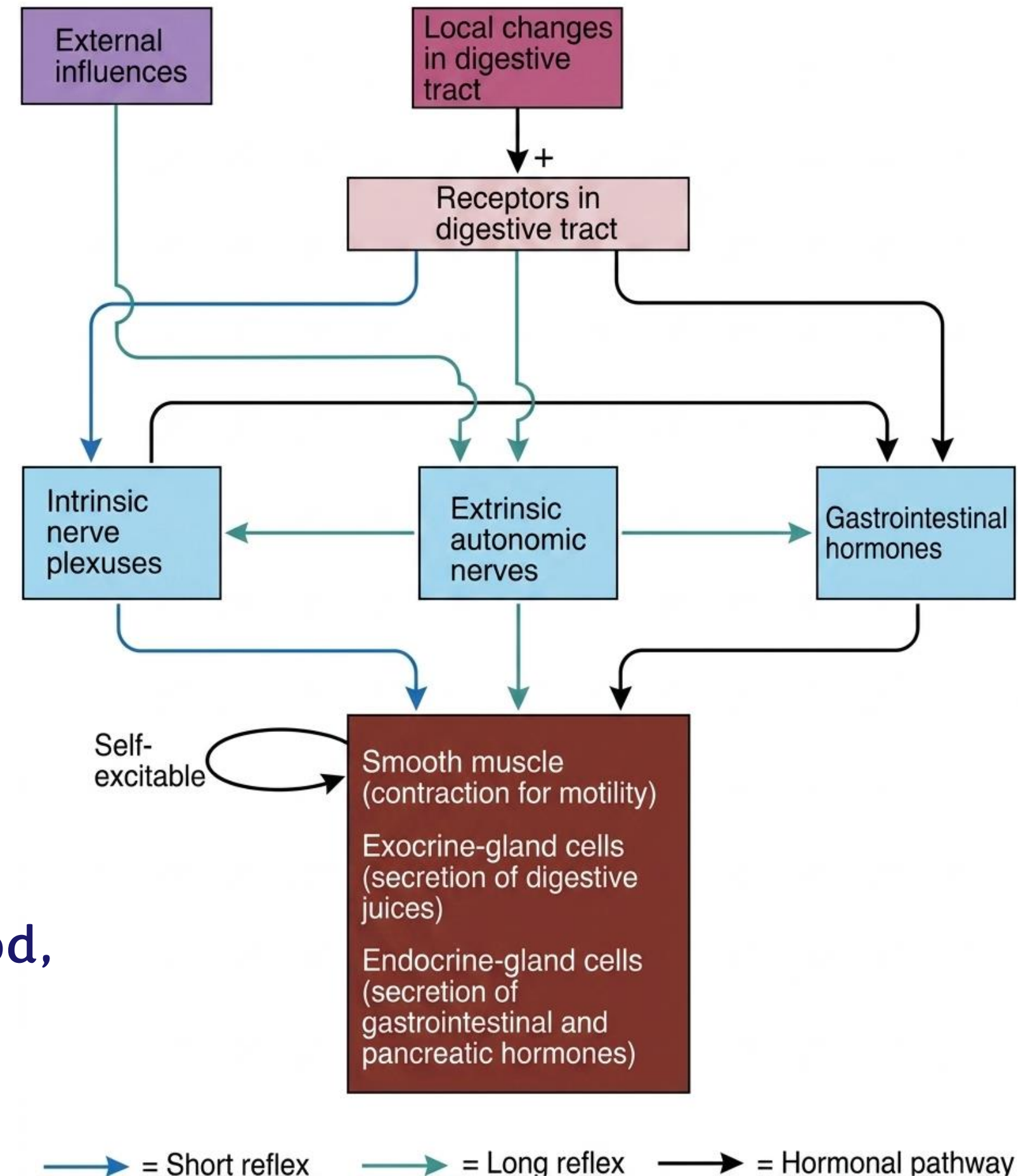
- **Extrinsic (Autonomic) Nervous Systems.**
- **Intrinsic (Enteric) Nervous System.**
- **Hormonal system by secretory cells.**

❑ How we can activate the control systems ?

- External influences, like : seeing food or smelling food, which is going to activate:

- **Extrinsic (Autonomic) nerves** → Effects on the effector cells that **ENS** is innervating.
- **Hormonal System.**

Summary of Pathways Controlling Digestive-System Activities



Pathways Controlling Digestive-System Activities

□ How we can activate the control systems ?

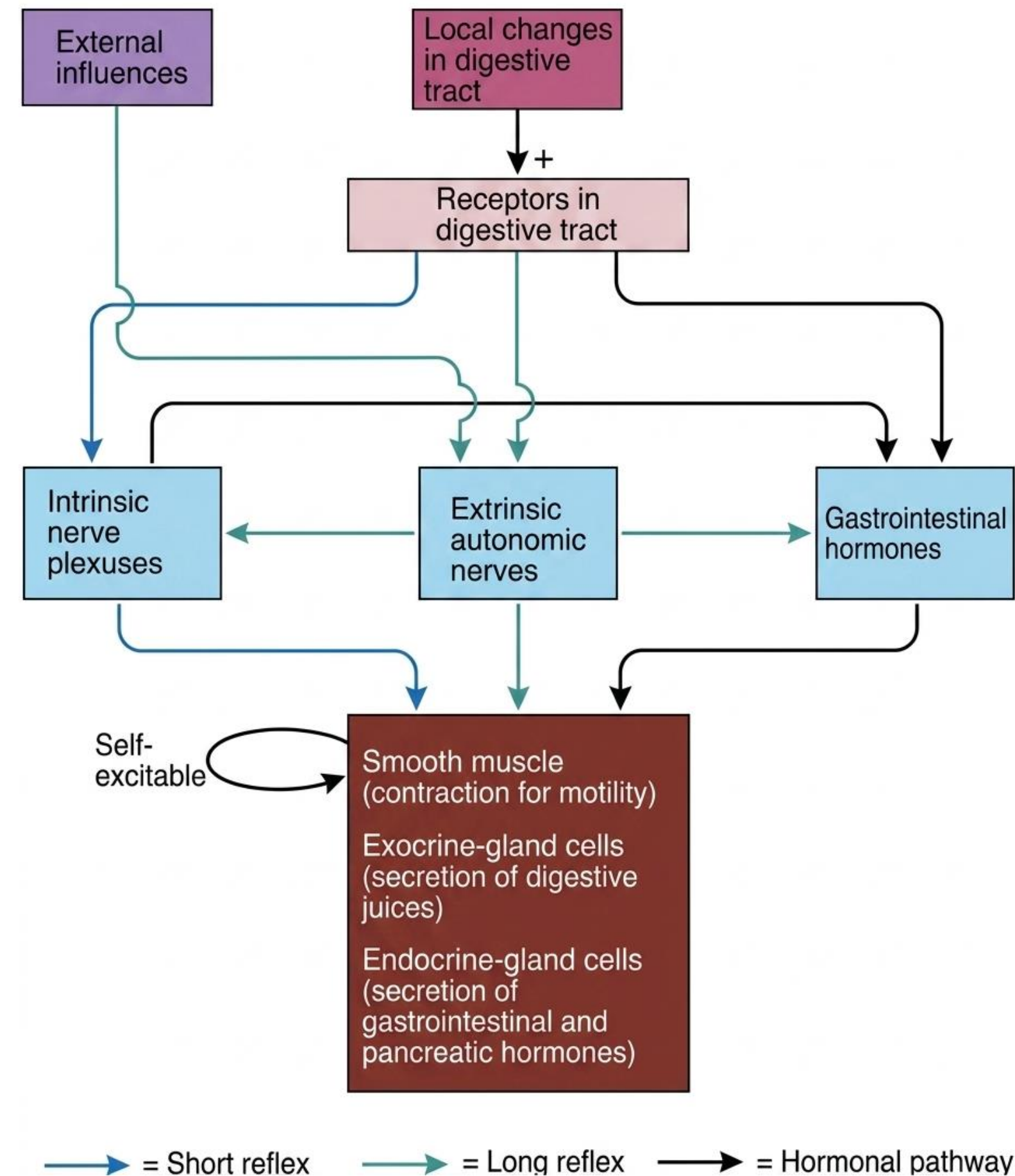
➤ **Local changes in the GI;** for example once you eat food, the chemical content of the food **activates the controlling systems:**

- **Intrinsic (Enteric) Nervous System, which can activate and control hormonal System.**

- **Hormonal System :** can be activated by **local changes in the GI** or by **External changes through Automatic NS.** Also, can be controlled by **Enteric NS.**

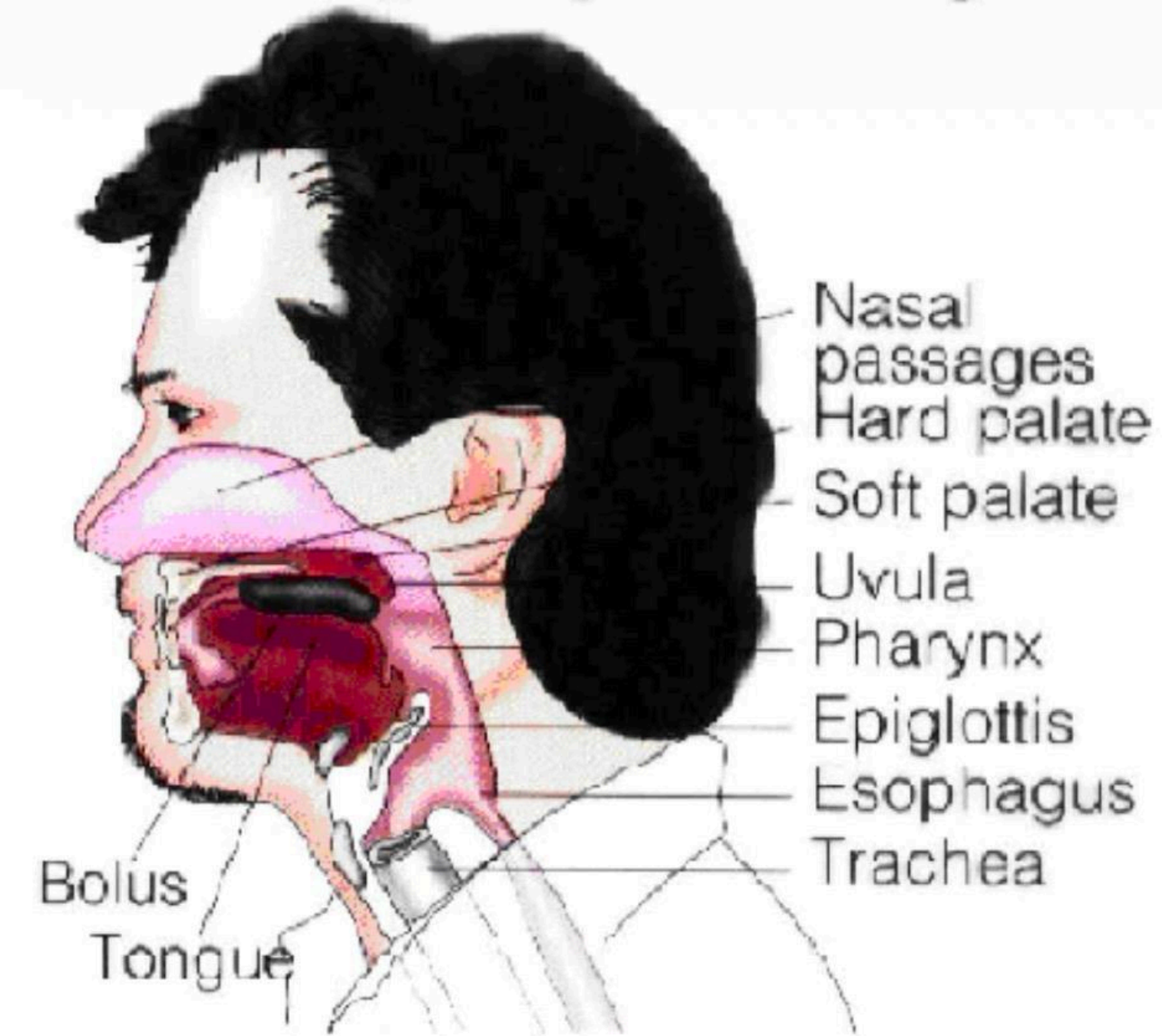
✓ *This is how we are having control over the GI effector cells.*

Summary of Pathways Controlling Digestive-System Activities



Chewing (mastication)

- First movement that the food experience once it enters the GI through oral cavity.
- **Voluntary**, but has more of reflex behavior.
 - Voluntary control allows us to initiate and regulate the chewing process consciously, while involuntary reflexes, help in the coordination and regulation of the muscles involved in chewing, such as the masseter and temporalis muscles, when we're not consciously focusing on it.
- **Purpose: Mixing** of food with saliva and grinding.



Glottis at entrance of larynx



Swallowing = Deglutition

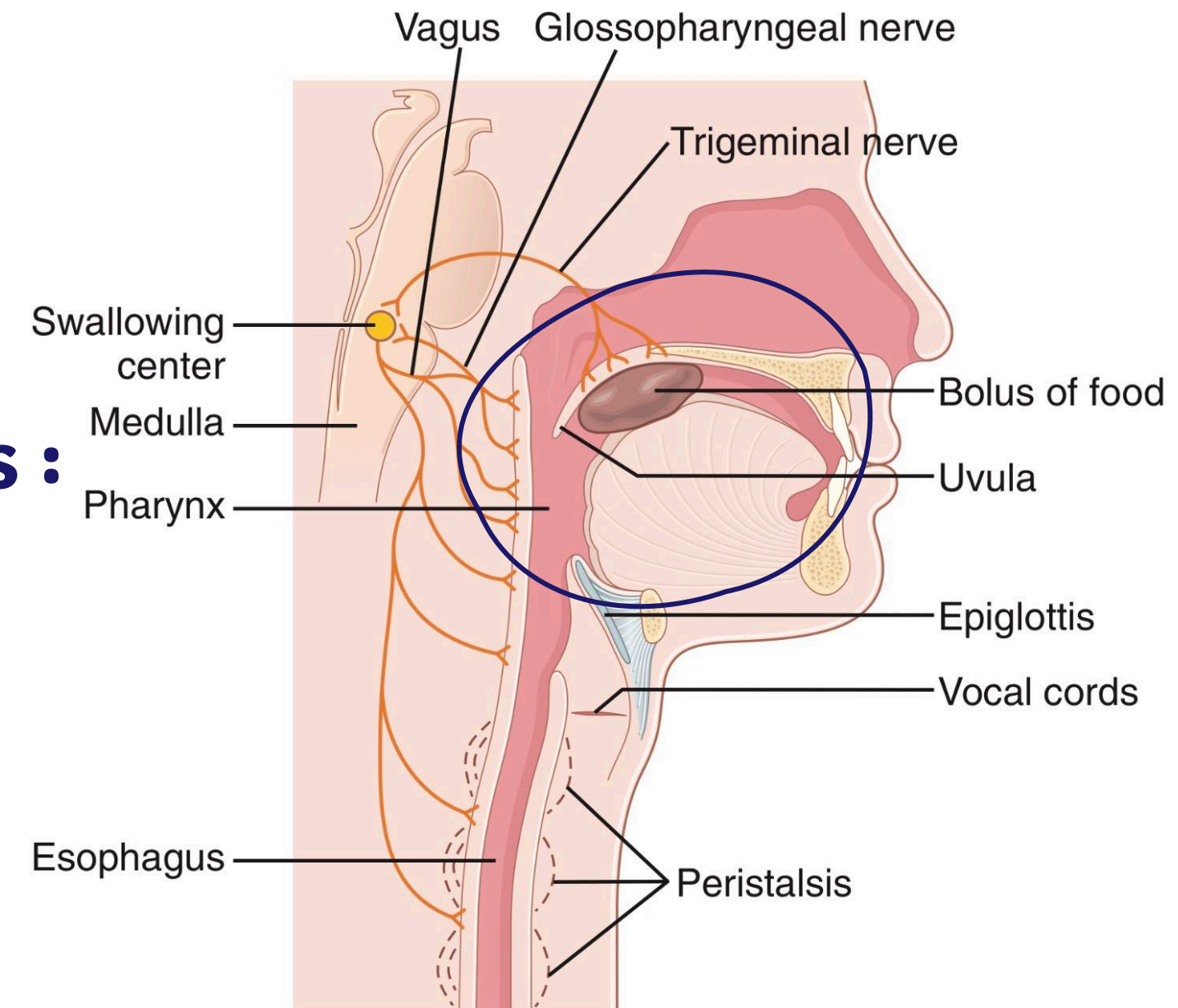
- initiated voluntarily
- Continuing as involuntary reflex.

□ It is divided into voluntary & involuntary parts :

- **Voluntary stage:**

in which tongue is pressing food by **upward and backward movement against soft palate, which results in squeezing food bolus into pharynx, as shown in the figure.**

- **From here on, swallowing becomes entirely—or almost entirely—automatic and ordinarily cannot be stopped.**



Tongue is pushing up the food backwards & upwards against.

Swallowing

Involuntary stages

Reflexes initiated by introducing food into pharynx.

□ It is divided into :

- **Pharyngeal phase: Next Slide...**
- **Esophageal phase:**
 - **Primary peristaltic contractions**
 - **Secondary peristaltic contractions**

Swallowing

□ It is divided into voluntary & involuntary parts :

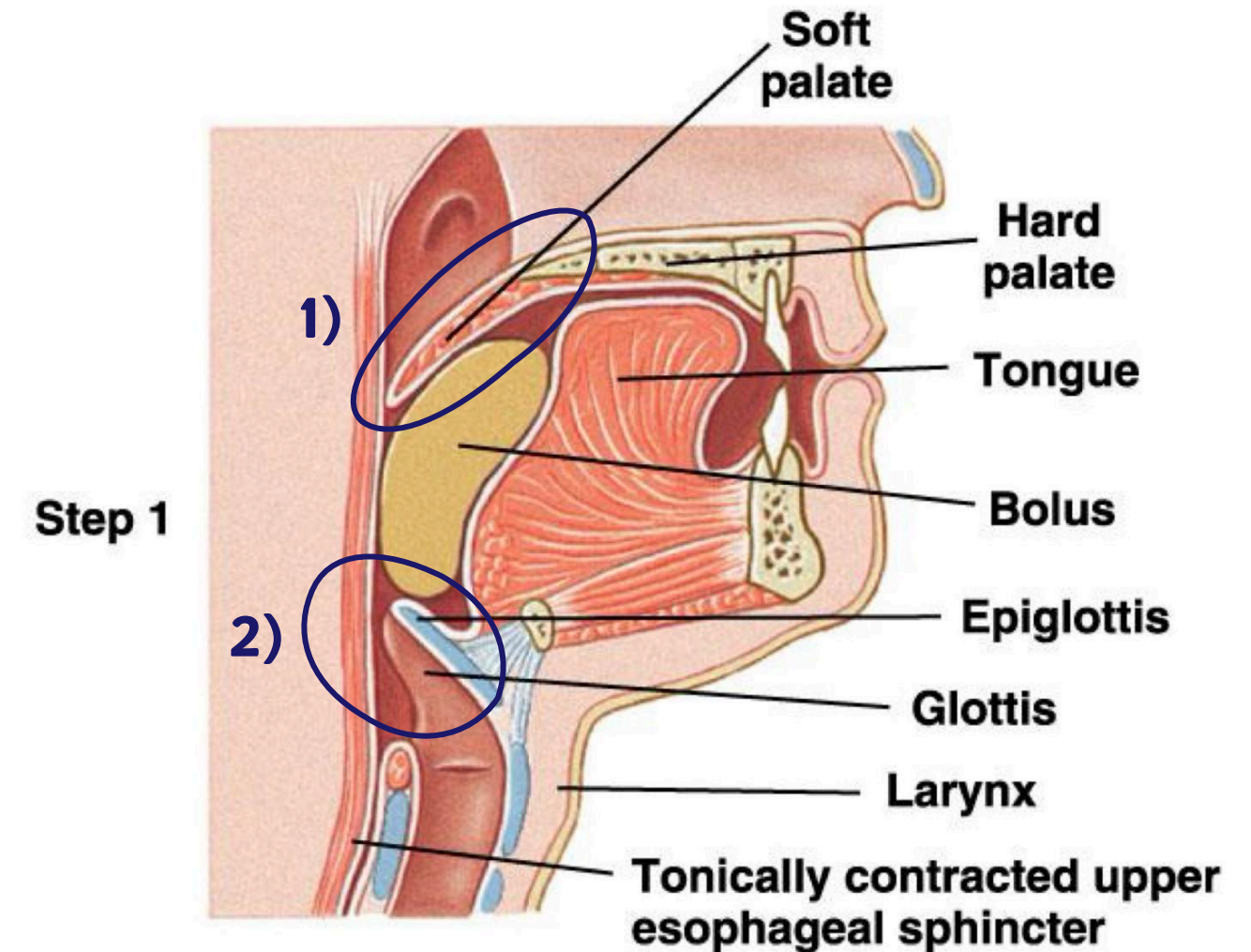
❖ Involuntary stages (Pharyngeal Phase):

- reflexes initiated by introducing food into pharynx will result in **contraction of pharynx** and then **esophageal peristalsis** that induce movement of bolus along esophagus. In these reflexes, swallowing receptors at the pharyngeal mucosa and swallowing centers in the brain are

- **involved.** Don't forget that the pharynx has many openings :

- 1) **Nasal Cavity (choanae)** → will be closed with **soft palate**.
- 2) **Larynx (Inlet of larynx, leads to trachea)** → will be closed with **epiglottis** (secondary, mainly by vocal cords approximation).
- 3) **Opening with the esophagus** → bolus pass through it.

- ✓ The closure of other openings force the bolus to move through esophagus, and prevent them from passing towards the respiratory system.

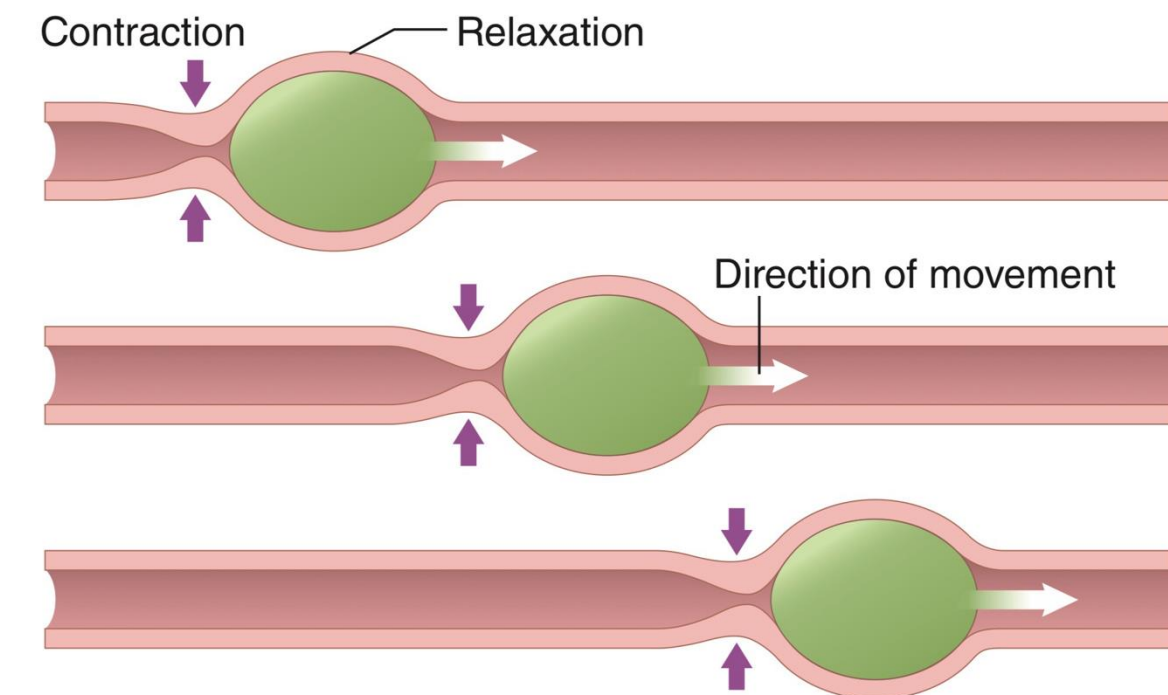
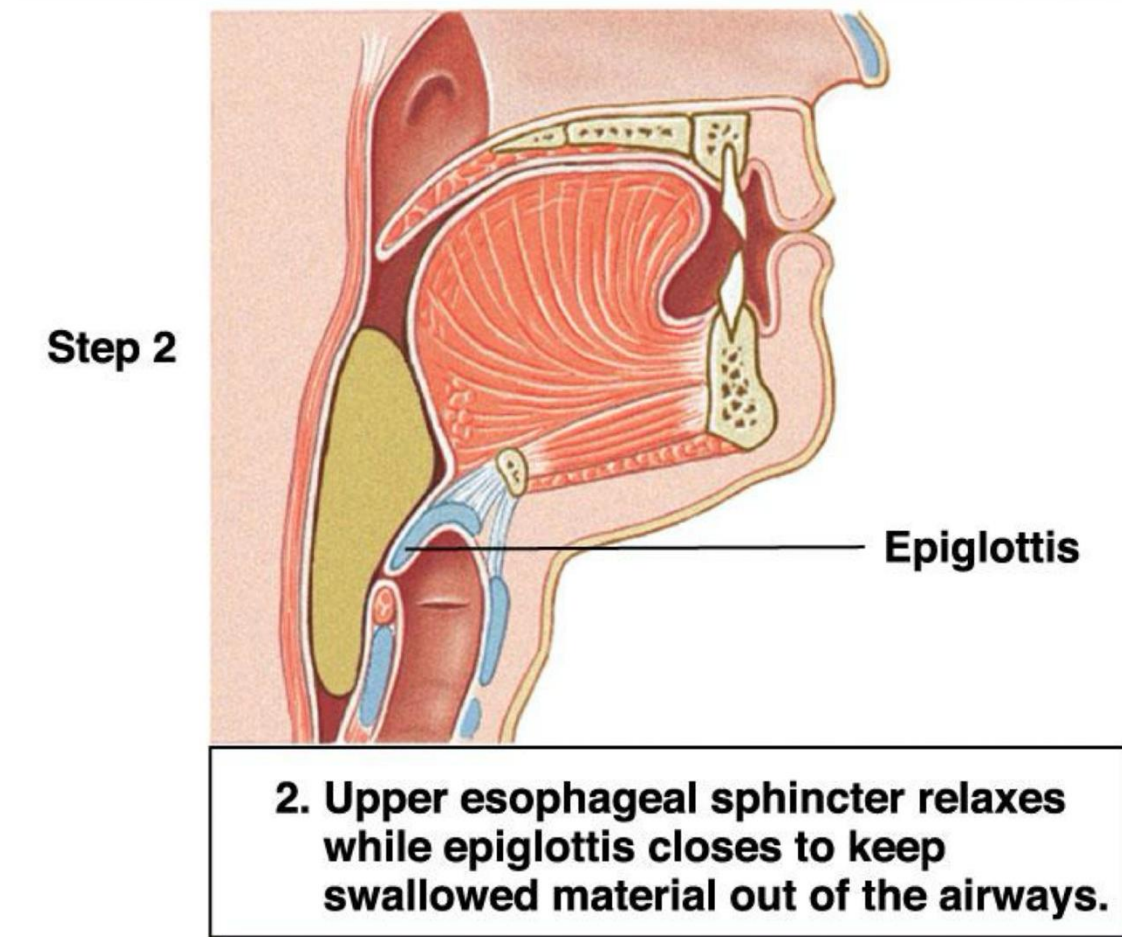


1. Tongue pushes bolus against soft palate and back of mouth, triggering swallowing reflex.

Swallowing

❖ Involuntary stages (Pharyngeal Phase):

- We have relaxation of the esophageal sphincter and contraction of the pharynx; complex pattern of muscle activity that results in enforcing the bolus to move into the esophagus.
- Also, at the level of the esophagus, we are having motor movement called *peristaltic movement*.
- Two types of movements occur in the gastrointestinal tract:
 - 1) **Propulsive (peristaltic) movements**, which cause food to move forward along the tract at an appropriate rate to accommodate digestion and absorption.
 - 2) Mixing movements, which keep the intestinal contents thoroughly mixed at all times.
- ***Peristaltic movement:*** A contractile ring appears around the gut and then moves forward;
- Peristalsis involves contraction behind the bolus and relaxation in front of it.
- This mechanism is analogous to putting one's fingers around a thin distended tube, then constricting the fingers and sliding them forward along the tube. Any material in front of the contractile ring is moved forward.

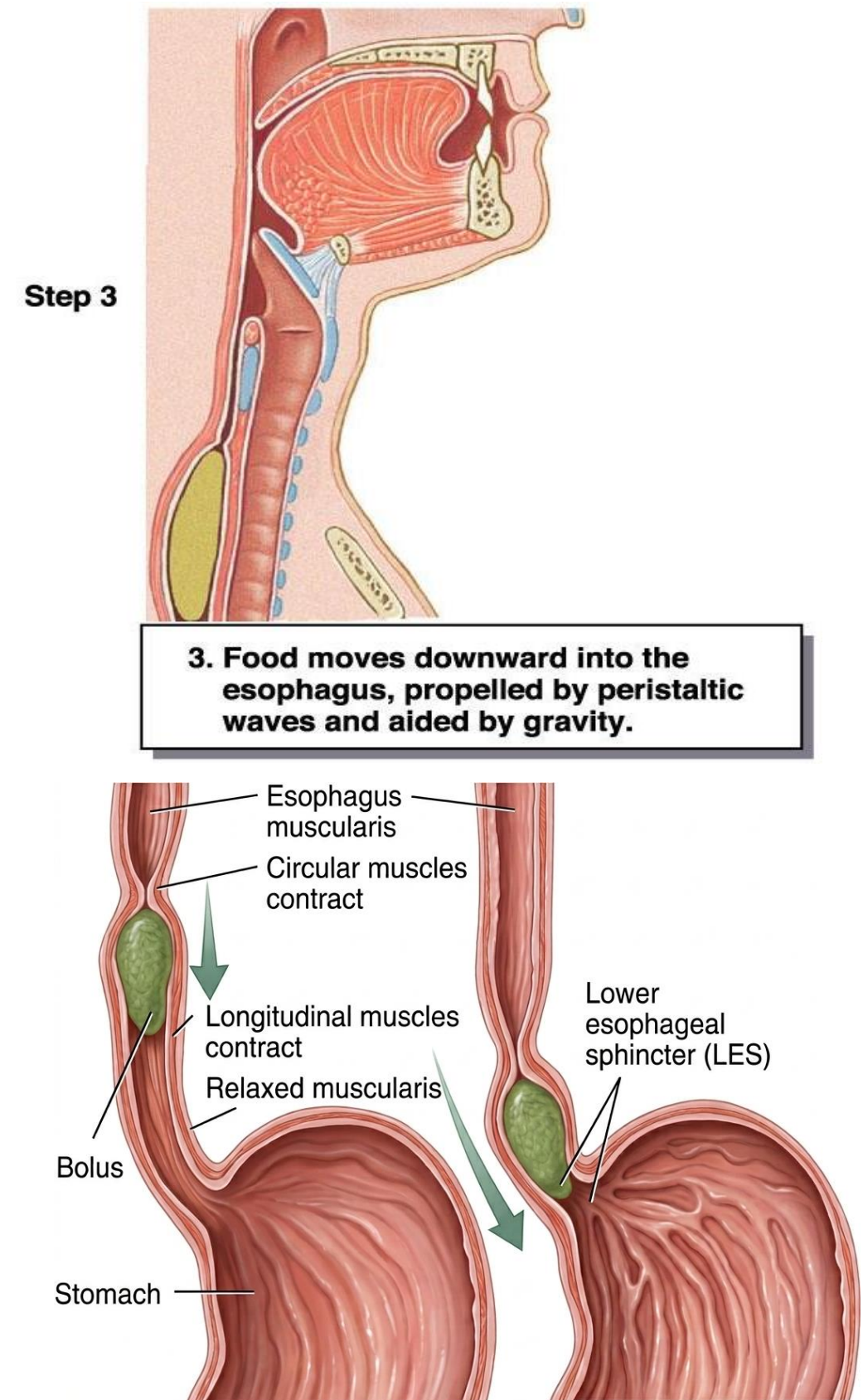


Swallowing

❖ Involuntary stages (Esophageal Phase):

- The **peristaltic movement** propels the **bolus downward** until it reaches the **lower end of the esophagus** that contains a sphincter called ***Lower Esophageal Sphincter***.
- We have 2 types of propulsive (peristaltic) movement :
 - 1) **Primary (Esophageal) Peristaltic movement :**
 - The movement of bolus of food along the esophagus from the pharynx down until the stomach.
 - 2) **Secondary Peristaltic movement:**
 - If the primary peristaltic wave fails to move all the food that has entered the esophagus into the stomach, ***secondary peristaltic waves*** result from distention of the esophagus itself by the retained food; **these waves continue until all the food has emptied into the stomach.**

- ✓ Are we swallowing mainly by the force of gravity ? No, it is by the peristaltic movement of smooth muscles (contraction of skeletal muscles at the start) ; You can Swollen food while you are standing in your hand ;)



Anterior view of frontal sections peristalsis in esophagus

Difference between primary & secondary

Difference	Primary Peristalsis	Secondary Peristalsis
Definition	Direct continuation of the peristaltic wave that begins in the pharynx during the pharyngeal stage of swallowing.	A backup wave of contractions that occurs if the primary wave is insufficient.
Trigger	the act of swallowing food (introducing food into the pharynx).	Initiated by the distention (stretching) of the esophagus caused by retained food that the primary wave failed to move.
Function	Conducts the main food bolus rapidly from the pharynx down through the esophagus to the stomach.	Clears out any remaining food in the esophagus, continuing to fire until the esophagus is completely empty.
Neuronal control		It is driven by two pathways: <ul style="list-style-type: none"> · Intrinsic reflexes: Local circuits within the esophageal myenteric nervous system. · Extrinsic reflexes: Signals transmitted upward through vagal afferent fibers to the medulla, and back down to the esophagus through glossopharyngeal and vagal efferent nerve fibers.
Duration	The wave passes along the entire esophagus in about 8 to 10 seconds (though gravity can speed this up to 5 to 8 seconds if the person is upright).	Repeats continuously until all retained food is cleared.

Explanation of GI Disorder That was mentioned by the doctor

- Some people are having difficulties in swallowing, which is called *dysphagia*.
- **There are many factors that cause dysphagia, one of the most important is having decrease representation (Function) of enteric nervous system at one of GI-Swallowing involved parts levels.**
- *Achalasia* is a condition in which the lower esophageal sphincter fails to relax during swallowing.
- As a result, food swallowed into the esophagus fails to pass from the esophagus into the stomach.
- There are many cases that are believed to cause dysphagia, one of the causes mostly proved by pathological studies is the damage in the neural network of the myenteric plexus in the lower two thirds of the esophagus.
- As a result, the musculature of the lower esophagus remains spastically contracted and the myenteric plexus has lost its ability to transmit a signal to cause “receptive relaxation” of the gastroesophageal sphincter as food approaches this sphincter during swallowing.
- When *achalasia* becomes severe, the esophagus often cannot empty the swallowed food into the stomach for many hours, instead of the few seconds that is the normal time. Over months and years, the esophagus becomes tremendously enlarged until it often can hold as much as 1 liter of food, which often becomes putridly infected during the long periods of esophageal stasis. The infection may also cause ulceration of the esophageal mucosa, sometimes leading to severe substernal pain or even rupture and death. Considerable benefit can be achieved by stretching the lower end of the esophagus by means of a balloon inflated on the end of a swallowed esophageal tube. Antispasmodic drugs (i.e., drugs that relax smooth muscle) can also be helpful.

Gastric Motilities

- **Receptive relaxation**
 - **Gastric Peristaltic movements**
 - **Retropulsion.**
 - **Gastric emptying.**
 - **Hunger contractions**

Gastric Motilities

□ The motor functions of the stomach are threefold :

- 1) storage of large quantities of food until the food can be processed in the stomach, duodenum, and lower intestinal tract.
- 2) mixing of this food with gastric secretions until it forms a semifluid mixture called chyme.
- 3) slow emptying of the chyme from the stomach into the small intestine at a rate suitable for proper digestion and absorption by the small intestine.

- The Stomach is divided anatomically into:

- 1) the body.
- 2) the antrum.

- Physiologically, it is more appropriately divided into :

- 1) The “orad” portion, comprising about the first two thirds of the body.
- 2) The “caudad” portion, comprising the remainder of the body plus the antrum.

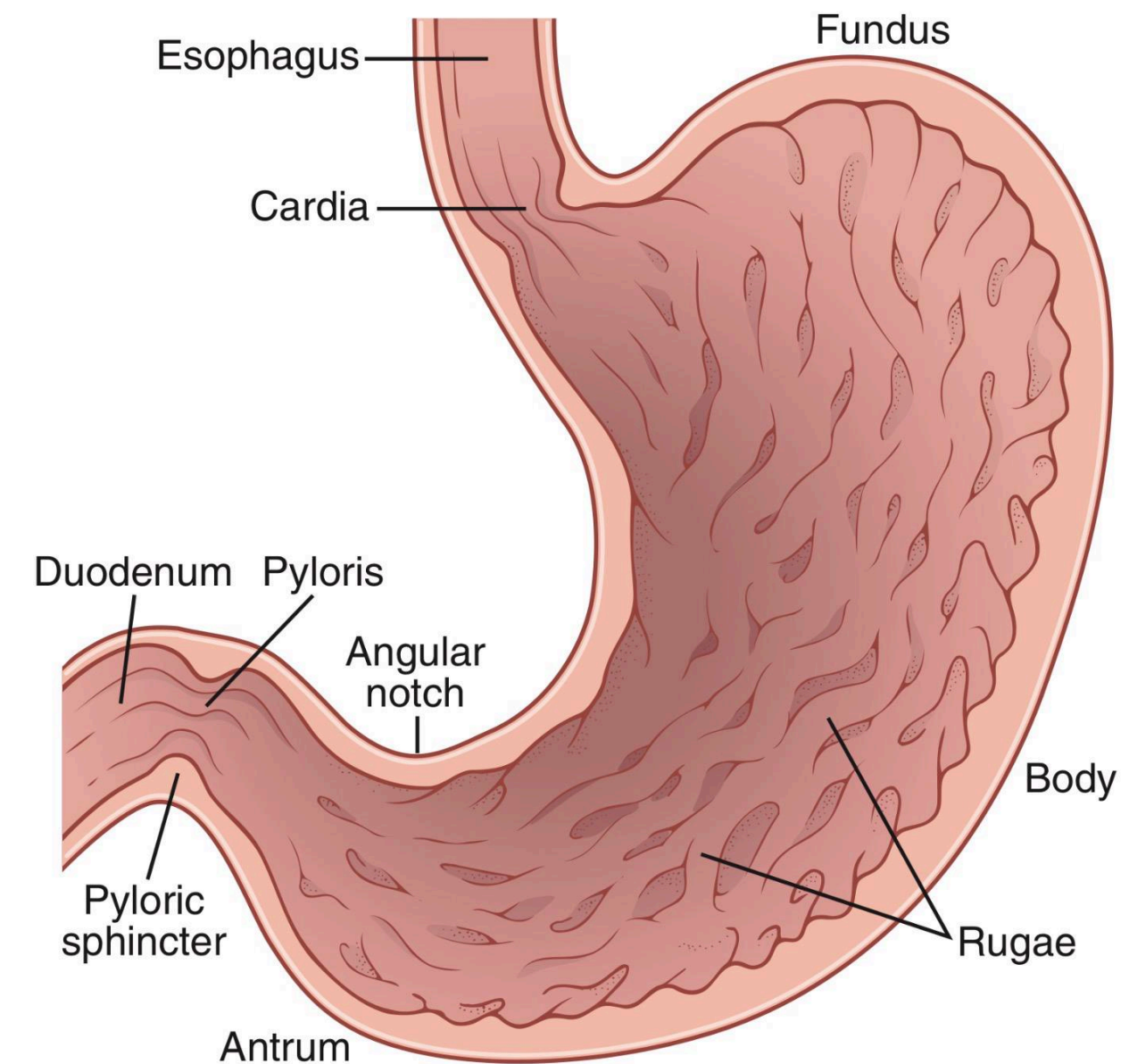


Figure 64-2. Physiological anatomy of the stomach.

Gastric Motilities

□ STORAGE FUNCTION OF THE STOMACH

- As food enters the stomach, it forms **concentric circles of the food in the orad portion of the stomach (upper 1/3 of the body)**, with the newest food lying closest to the esophageal opening and the oldest food lying nearest the outer wall of the stomach.
- Normally, when food stretches the stomach, a “vagovagal reflex” from the stomach to the brain stem and then back to the stomach **reduces the tone in the muscular wall of the body of the stomach so that the wall bulges progressively outward (Relaxation)**, accommodating greater and greater quantities of food up to a **limit in the completely relaxed stomach of 0.8 to 1.5 liters**.
- As long as food is in the stomach, weak peristaltic constrictor waves, called **mixing waves**, begin in the mid to upper portions of the stomach wall and move toward the antrum about **once every 15 to 20 seconds**.
- As the constrictor waves progress from the body of the stomach into the antrum, they become more intense, some becoming **extremely intense and providing powerful peristaltic action potential-driven constrictor rings that force the antral contents under higher and higher pressure toward the pylorus**.

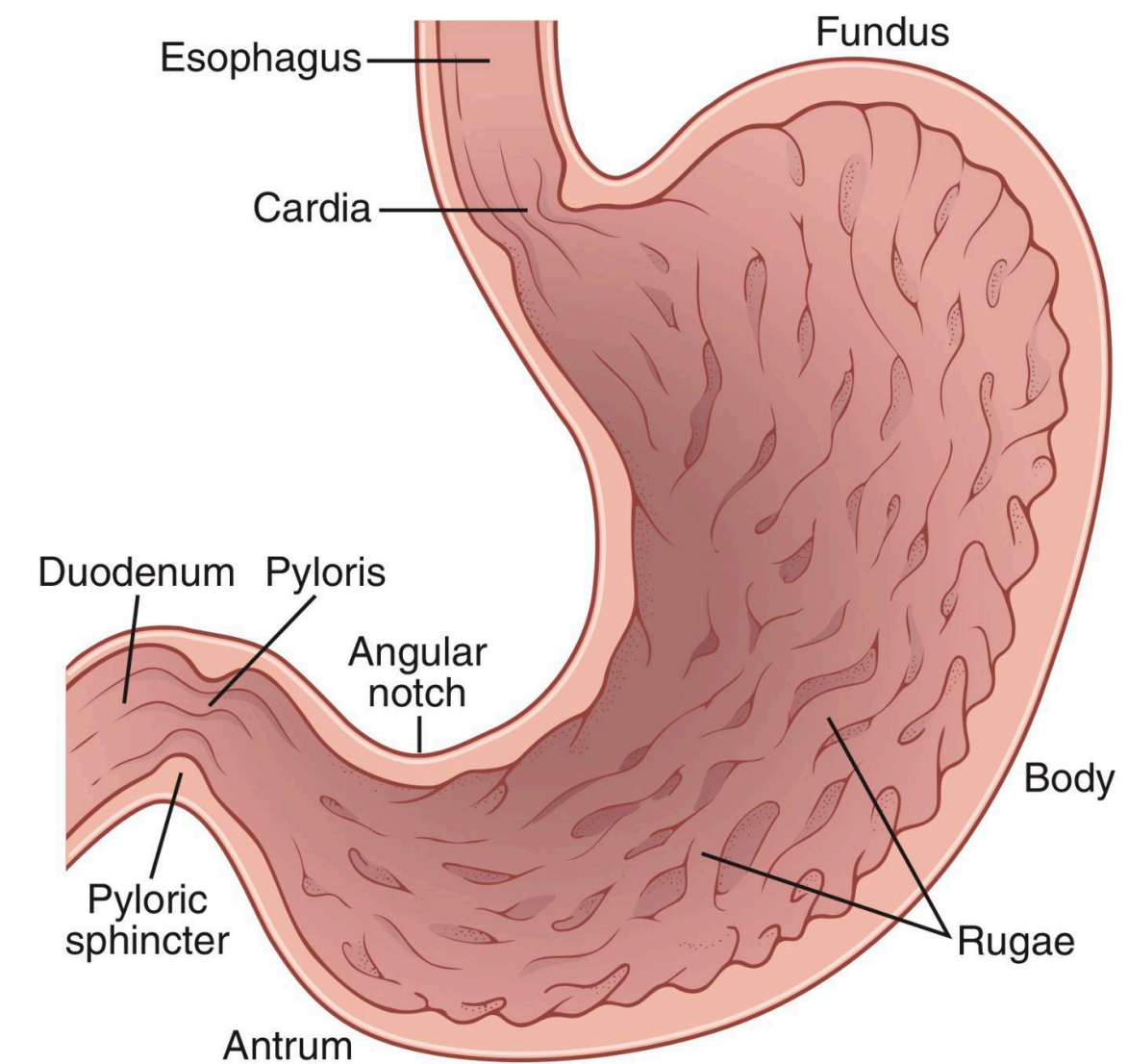


Figure 64-2. Physiological anatomy of the stomach.

Gastric Motilities

□ Mixing of the food in the stomach:

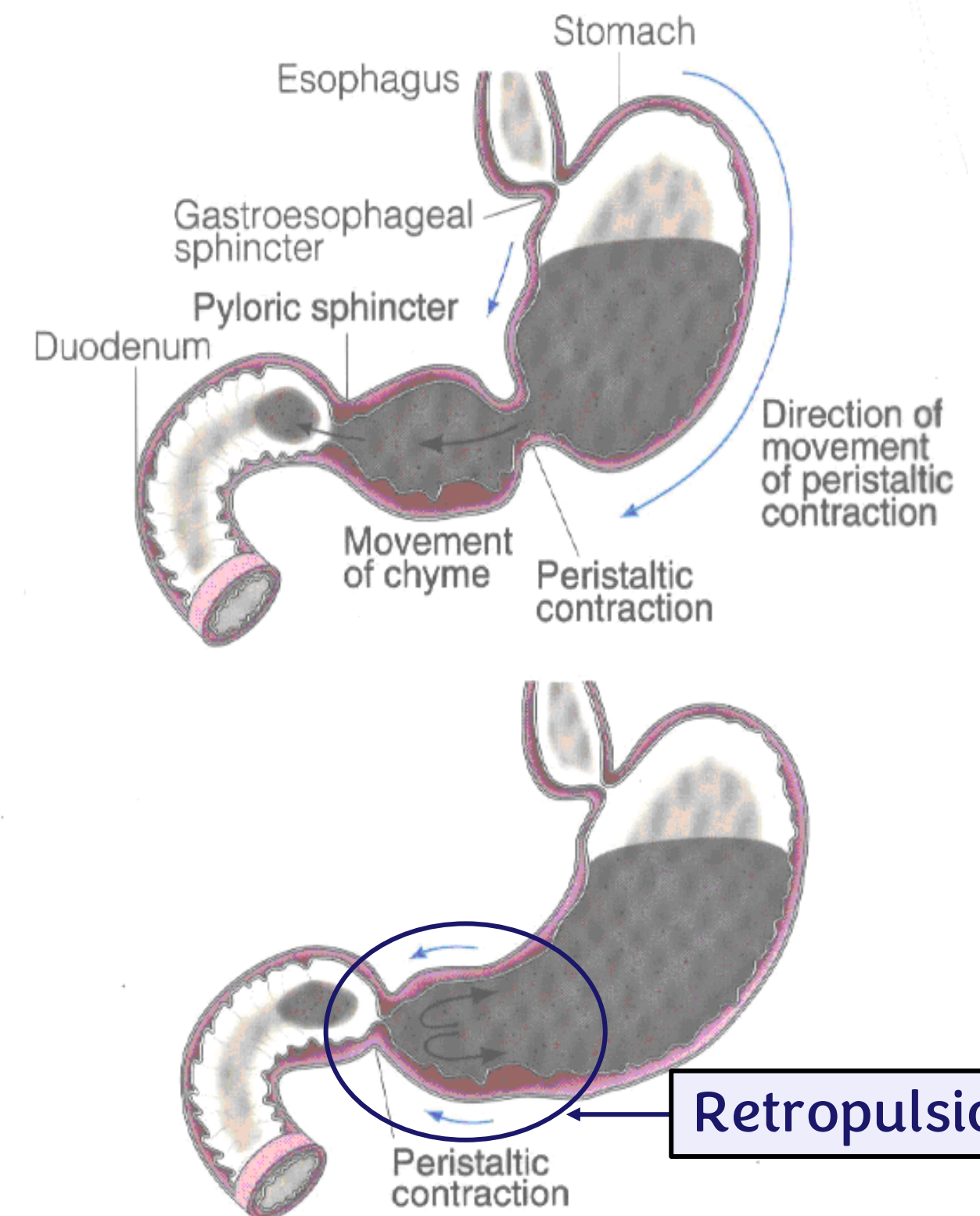
- **Constrictor rings** also play an important role in mixing the stomach contents in the following way:

Each time a **peristaltic wave** passes down the antral wall **toward the pylorus**, it digs deeply into the food contents in the antrum. Yet, the opening of the pylorus is **still small enough that only a few milliliters or less of antral contents are expelled into the duodenum with each peristaltic wave**. Also, as each peristaltic wave approaches the pylorus, the pyloric muscle often contracts, which further impedes emptying through the pylorus.

Therefore, most of the antral contents are squeezed upstream through the peristaltic ring toward the body of the stomach, not through the pylorus.

Thus, the moving peristaltic constrictive ring, combined with this upstream squeezing action, called **“retropulsion,”** is an exceedingly important mixing mechanism in the stomach.

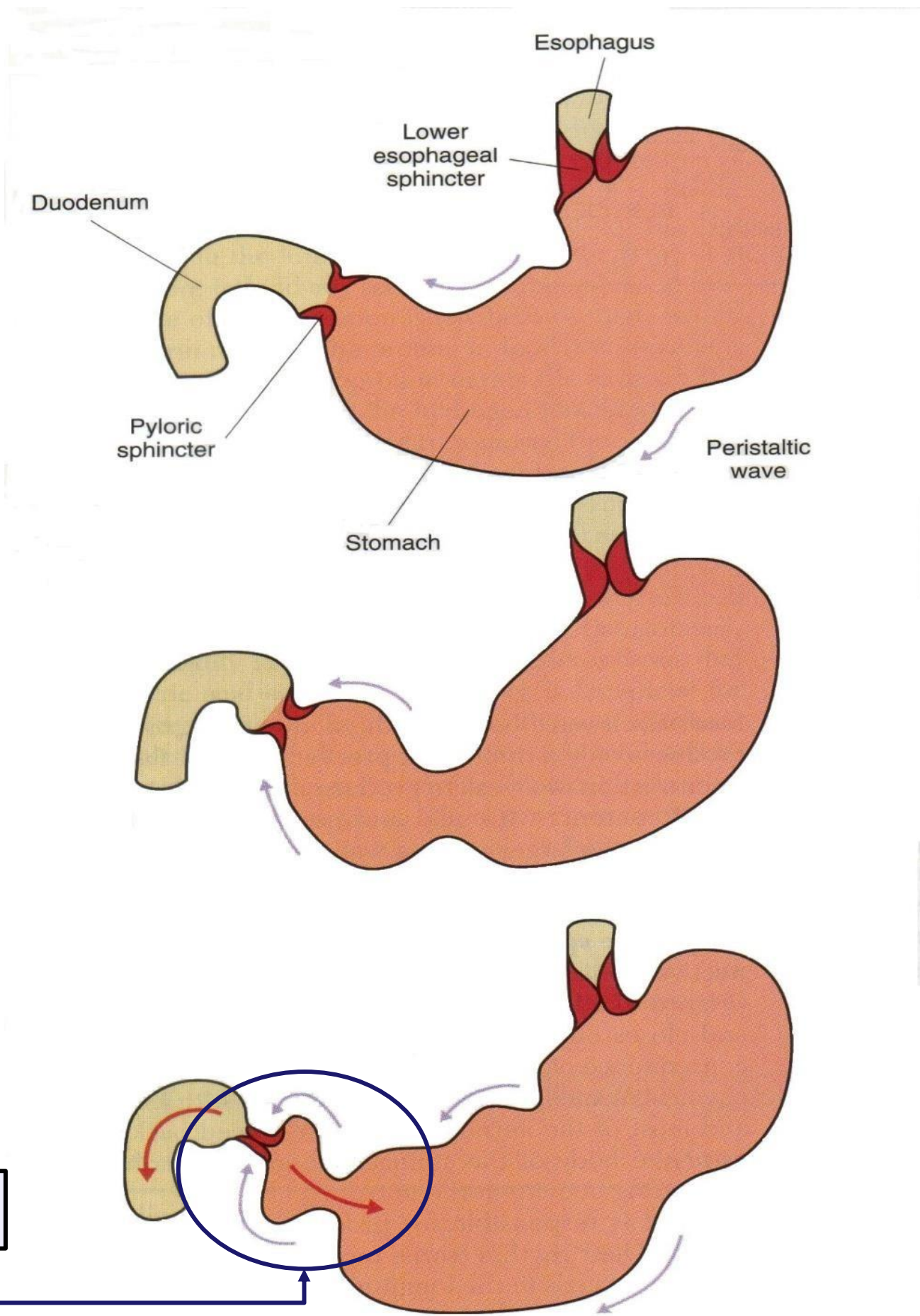
Gastric Emptying and Mixing as a Result of Antral Peristaltic Contractions



**Gastric Peristaltic contraction
At the upper & mid part of the
body of the stomach.**

**Gastric Peristaltic contraction
That propel the food toward
the antrum of the stomach.**

Retropulsion



To Sum up (Gastric Motilities)

Gastric Motility (Stomach Movements)

After food enters the stomach, two main types of motor activity occur:

1. Receptive Relaxation (Filling Phase)

- When you eat, the stomach does **not contract immediately**. Instead, it undergoes: **Relaxation of the stomach wall (fundus & body)**.
- This allows the stomach to **expand (dilate)** and accommodate large amounts of food.
- This process is called **receptive relaxation**.
- It occurs **without increasing intragastric pressure** → therefore **no pain**.

2. Tonic Contraction

- The stomach wall maintains a **baseline level of contraction (tone)**.
- This helps keep the food mass organized and ready for further processing.

3. Gastric Peristalsis (Mixing Waves)

- Begins as **weak constricting rings** in the **upper part (body)** of the stomach.
- These waves **travel toward the pyloric sphincter**.
- As they move downward, they become **stronger**.

• What happens at the pyloric sphincter?

- The pyloric sphincter **does NOT fully open**.
- It allows only **small amounts of liquid/semi-liquid content** to pass into the duodenum.
- Most of the gastric content is **pushed back into the stomach**.

Gastric Motilities

- Receptive relaxation

- Gastric Peristaltic movements

→ Retropulsion. (Already explained).

→ Gastric emptying. (Next Slide).

- Hunger contractions

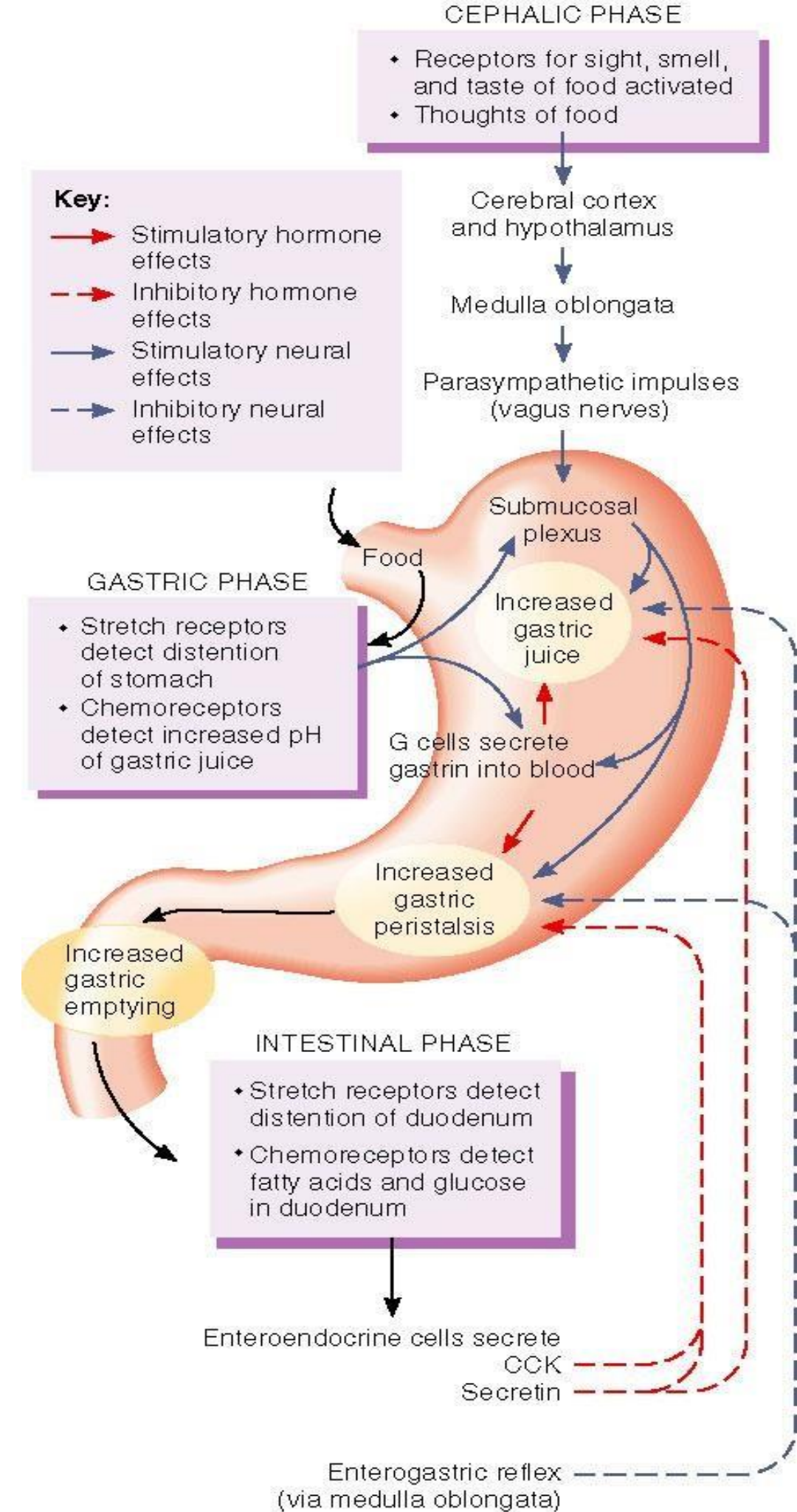
- Besides the peristaltic contractions that occur when food is present in the stomach, another type of intense contractions, called *hunger contractions*, often occurs when the stomach has been empty for several hours or more. These contractions are rhythmical peristaltic contractions in the body of the stomach. When the successive contractions become extremely strong, they often fuse to cause a continuing tetanic contraction that sometimes lasts for 2 to 3 minutes.
- Hunger contractions are most intense in :
 - 1) Young.
 - 2) healthy people who have high degrees of gastrointestinal tonus.
 - 3) greatly increased by the person's having lower than normal levels of blood sugar.

The exact mechanism of hunger contractions in the stomach is not completely clear, and there is no clear explanation of the role of decreased blood glucose level in initiating these contractions; therefore, this point is not usually emphasized.

Gastric Emptying

- Stomach emptying is promoted by intense peristaltic contractions in the stomach antrum. At the same time, emptying is opposed by varying degrees of resistance to passage of chyme at the pylorus.
- Most of the time, the rhythmic stomach contractions are weak and function.
- Mainly to cause mixing of food and gastric secretions. However, for about 20% of the time while food is in the stomach, the contractions become intense, beginning in Mid stomach and spreading through the caudad stomach.
- These contractions are strong peristaltic, very tight ringlike constrictions that can cause stomach emptying. As the stomach becomes progressively more and more empty, these constrictions begin farther and farther up the body of the stomach, gradually pinching off the food in the body of the stomach and adding this food to the chyme in the antrum. These intense peristaltic contractions often create 50 to 70 centimeters of water pressure, which is about six times as powerful as the usual mixing type of peristaltic waves.
- When pyloric tone is normal, each strong peristaltic wave forces up to several milliliters of chyme into the duodenum. Thus, the peristaltic waves, in addition to causing mixing in the stomach, also provide a pumping action called the “pyloric pump.”

Control of Gastric Motility



Motility in the small Intestine

- Site of most **digestion and absorption: duodenum and jejunum.**
- **Types of movement :**
 - **Segmentation** (mixing) - digestive state.
 - **Peristalsis** (propulsive)-inter-digestive.
 - **Migrating** motor complex.
 - **Peristaltic rush** (power propulsion).

Motility in the small Intestine

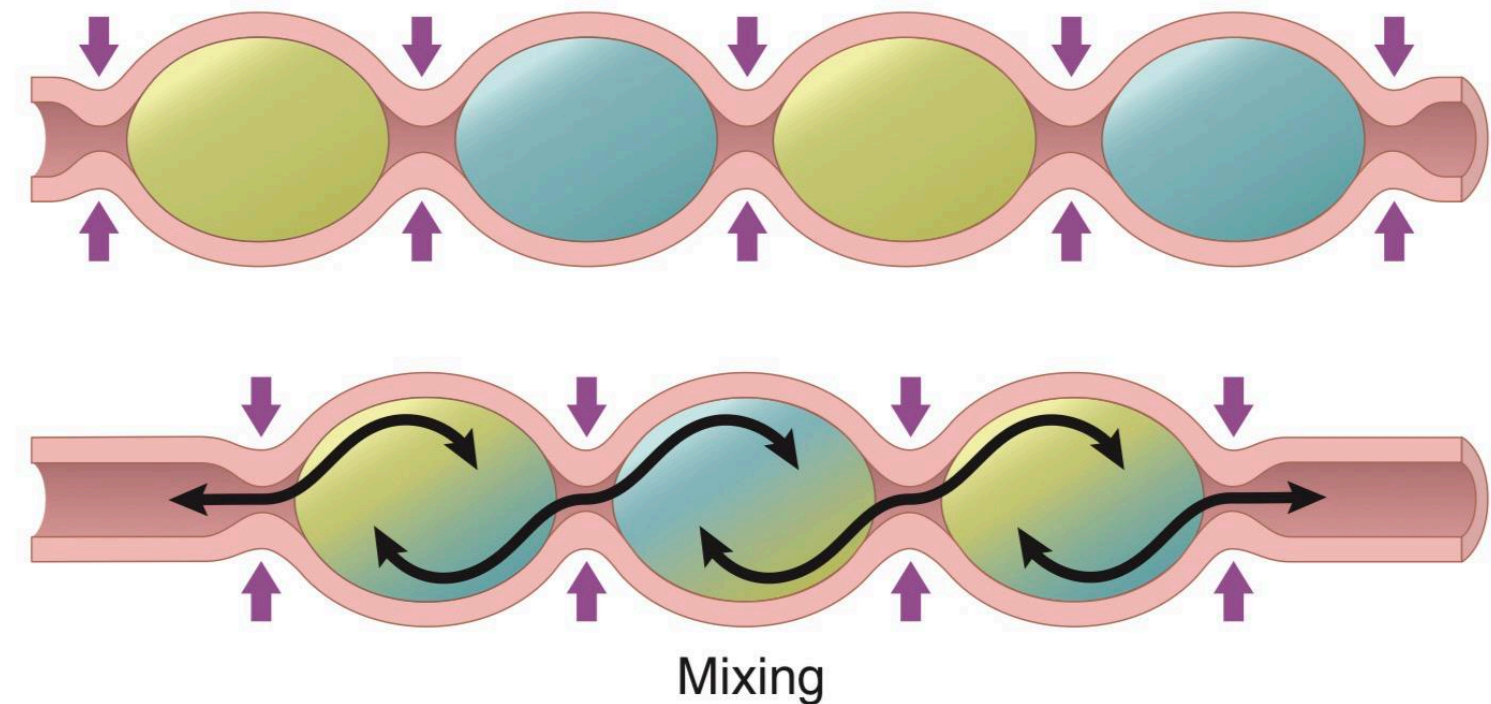
The small intestine shows three main types of movements:

1. Segmentation contractions
2. Peristaltic contractions
3. Migrating motor complex contractions

1) Segmentation Contractions:

These are produced mainly by the **circular smooth muscle layer**.

- A group of circular smooth muscle cells undergoes **rhythmic contraction and relaxation**: one segment contracts → then relaxes
- the adjacent segment contracts → then relaxes
- This gives the intestine a **segmented appearance**, hence the name **segmentation contractions**.
- The rhythm is controlled by the **electrical activity (slow waves)** of the intestine.
- The frequency differs along the intestine:
 - **upper small intestine: about 12 contractions/minute**
 - **lower small intestine: about 8 contractions/minute**
- The **main effect is mixing** the chyme with intestinal and pancreatic secretions to facilitate enzymatic digestion.
- Although mixing is the main role, a **slight propulsive effect** may also occur.



Motility in the small Intestine

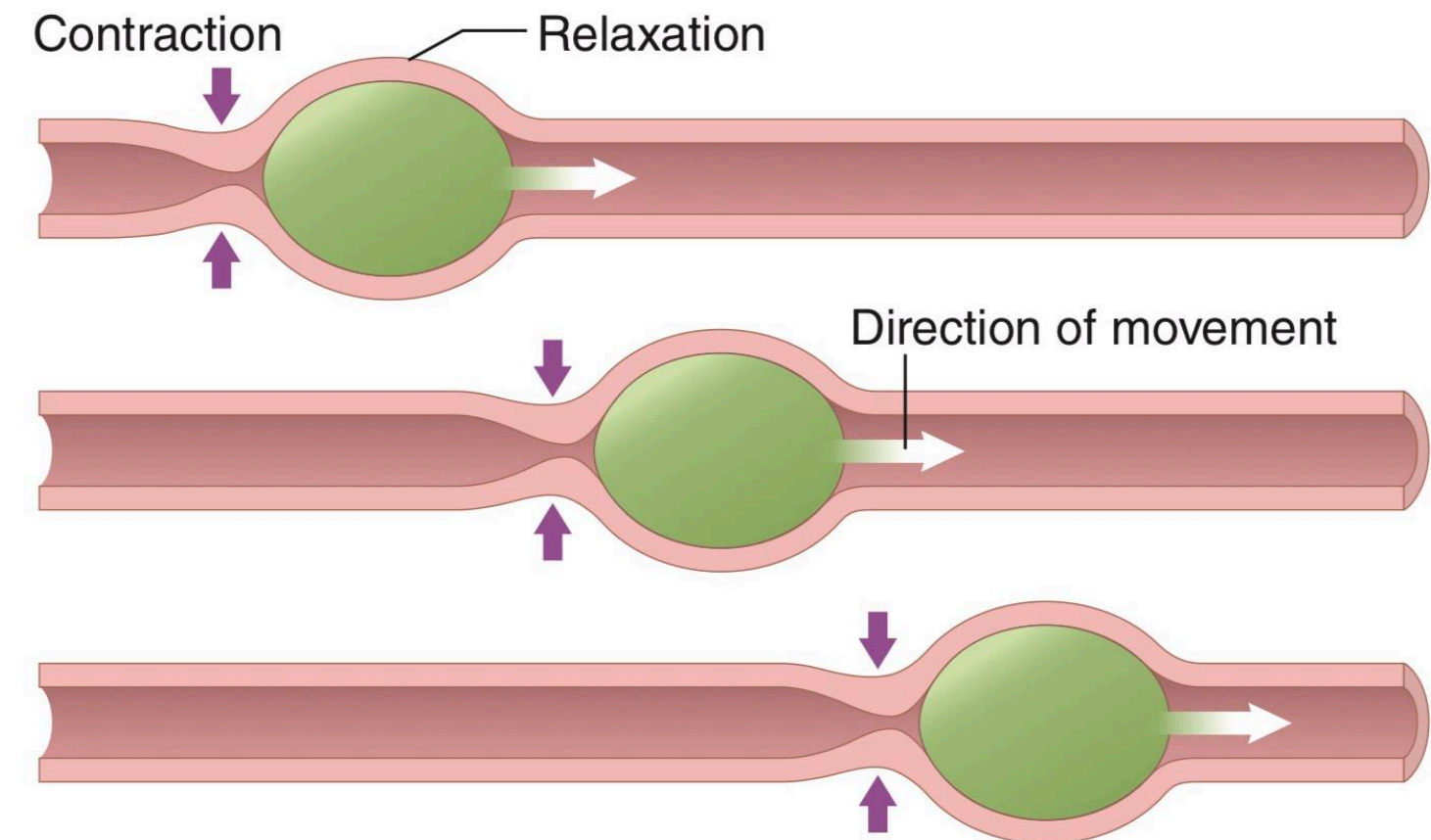
The small intestine shows three main types of movements:

1. Segmentation contractions
2. Peristaltic contractions
3. Migrating motor complex contractions

2) Peristaltic Contractions

Peristalsis involves:

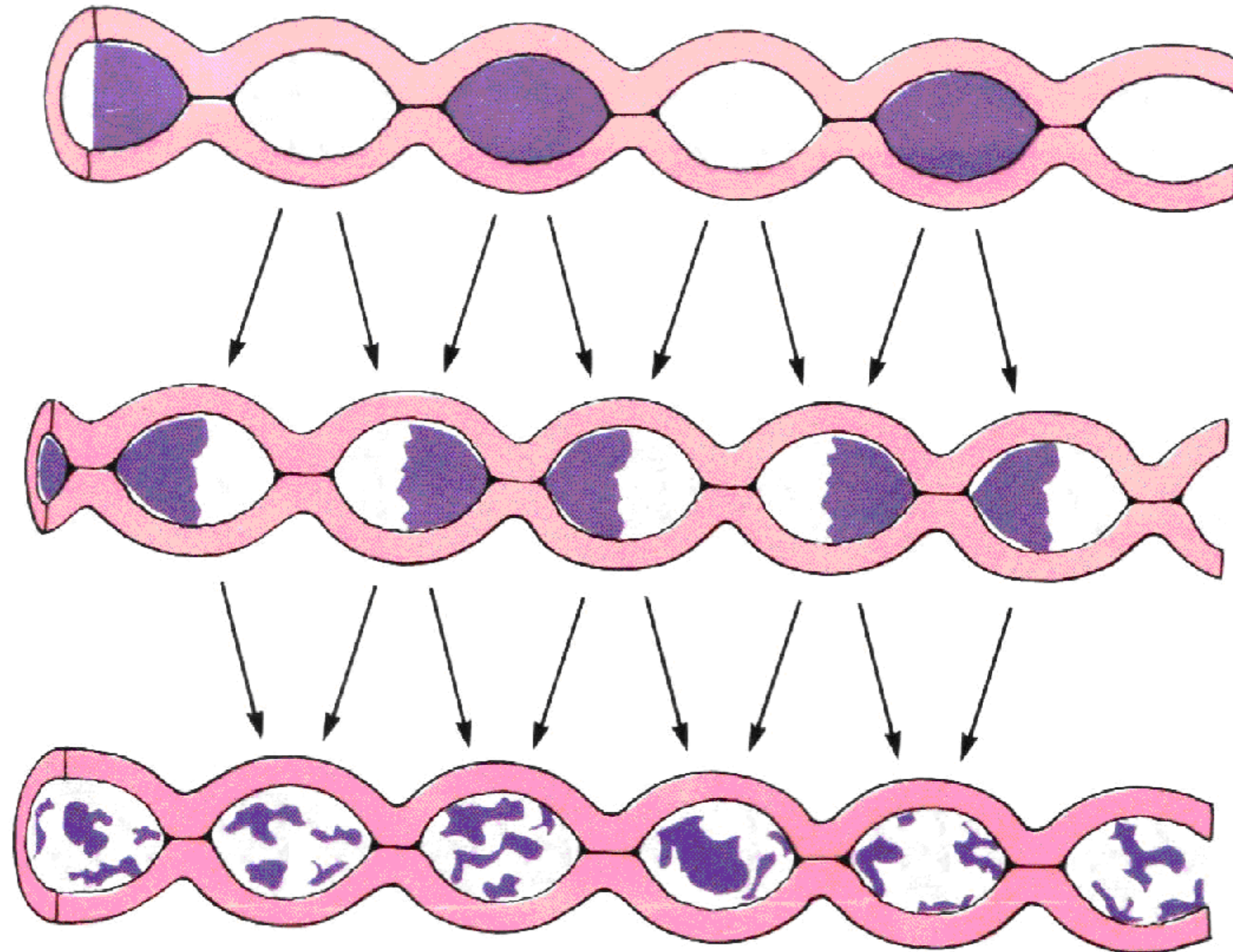
- **contraction above the chyme.**
- **relaxation below the chyme.**
- This pattern moves the intestinal content **forward**.
- The mechanism depends on the **enteric nervous system**: **excitatory neurons project upward** → causing contraction above.
- **inhibitory neurons project downward** → causing relaxation below.
- As a result, the chyme moves at approximately **1 cm per minute**.
- The **main effect is propulsion**, although some mixing also occurs.



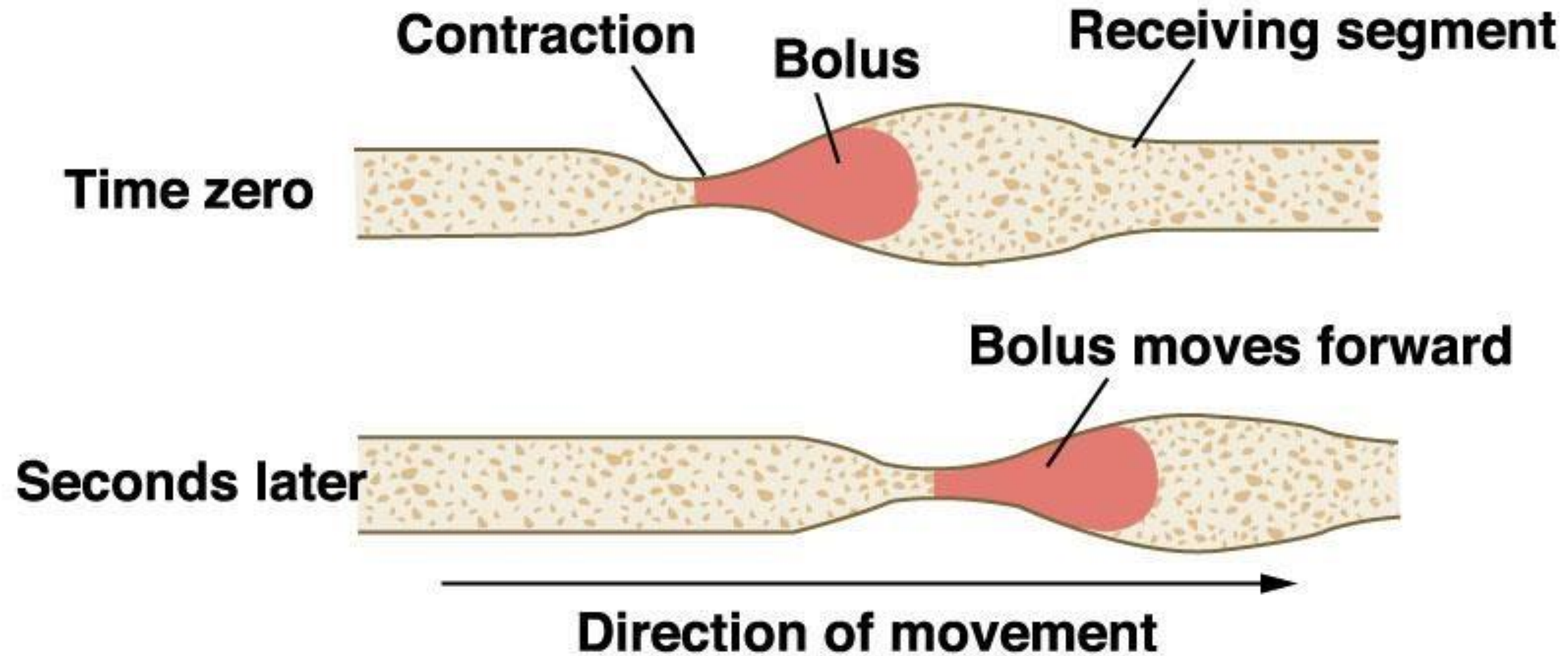
☐ Summary :

- **Segmentation** → mainly mixing.
- **Peristalsis** → mainly propulsion.

Segmentation



**Peristaltic contractions are responsible
for forward movement**



Migrating motor complex

- cycle of **quiescence** and **intense motor activity** that begins in antrum and continues along the small intestine.
- **Function:** Sweeps the stomach and intestine between meals.

Other Movements

❖ **Peristaltic rush:**

✓ Remove harmful agents.

➤ **Movements caused by the activity of muscularis mucosa:**

1) Spreading chyme.

2) over the mucosa.

Control of Intestinal Movement

- **Electrical activity of muscle.**
 - Neural control: ENS, ANS.
 - Hormonal control :
 - **Gastrin, CCK, Serotonin enhance intestinal motility.**
 - **Secretin and Glucagon inhibit intestinal motility.**
- The movements of the stomach and sphincters are mainly controlled by the **nervous system**, especially the **enteric nervous system** and the **autonomic nervous system**. In addition, when intestinal contents enter the duodenum, **inhibitory reflexes** may be initiated by the nervous system, called **enterogastric reflexes**, which inhibit gastric motility and gastric emptying when the stomach content is excessive.
- Besides neural control, **hormones also affect gastric motility**. For example, **gastrin stimulates gastric motor activity**, whereas **cholecystokinin (CCK)** and **GIP** have **inhibitory effects**.
- Abnormalities in gastric motility may lead to problems such as **gastroparesis** or **increased gastric tract activity**.

Motility of the colon

- **Segmentation contraction:** characterize the digestive or fed state and have mixing effect.
- **Peristaltic contractions:** mainly Propulsive effect.
- **Migrating motor complex** characterizes the inter-digestive state, ended with ingestion of food.
- **The migrating motor complex (MMC)** is a pattern of strong contractions that occurs when the **stomach and small intestine are empty**. It appears as a **wave of contractions starting from the stomach and traveling along the entire small intestine up to the ileocecal valve**. The main purpose of this activity is to **clean the gastrointestinal tract**, removing any remaining contents from the stomach and small intestine. It occurs periodically during the fasting state and acts as a “housekeeping” mechanism.
- **Peristaltic rush** is a response to harmful agents.

سؤال كويز لاب الفسيو

 The propulsive effect at the cecum results by .1

Segmentation contractions

Peristaltic contractions

Haustral contractions

Activity of muscularis mucosa

Motility of the colon

Haustration contractions:

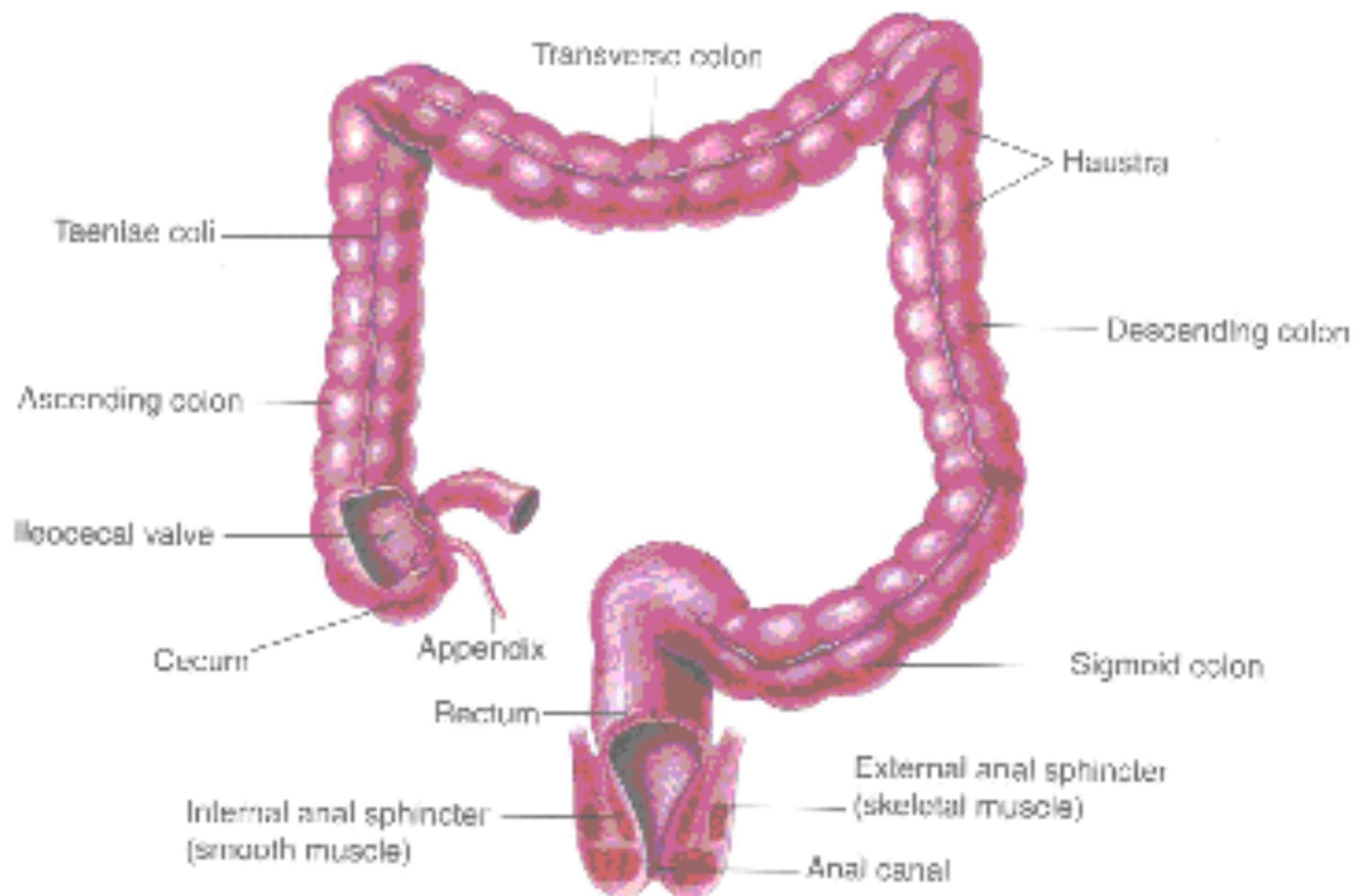
- effect: **propulsive.**

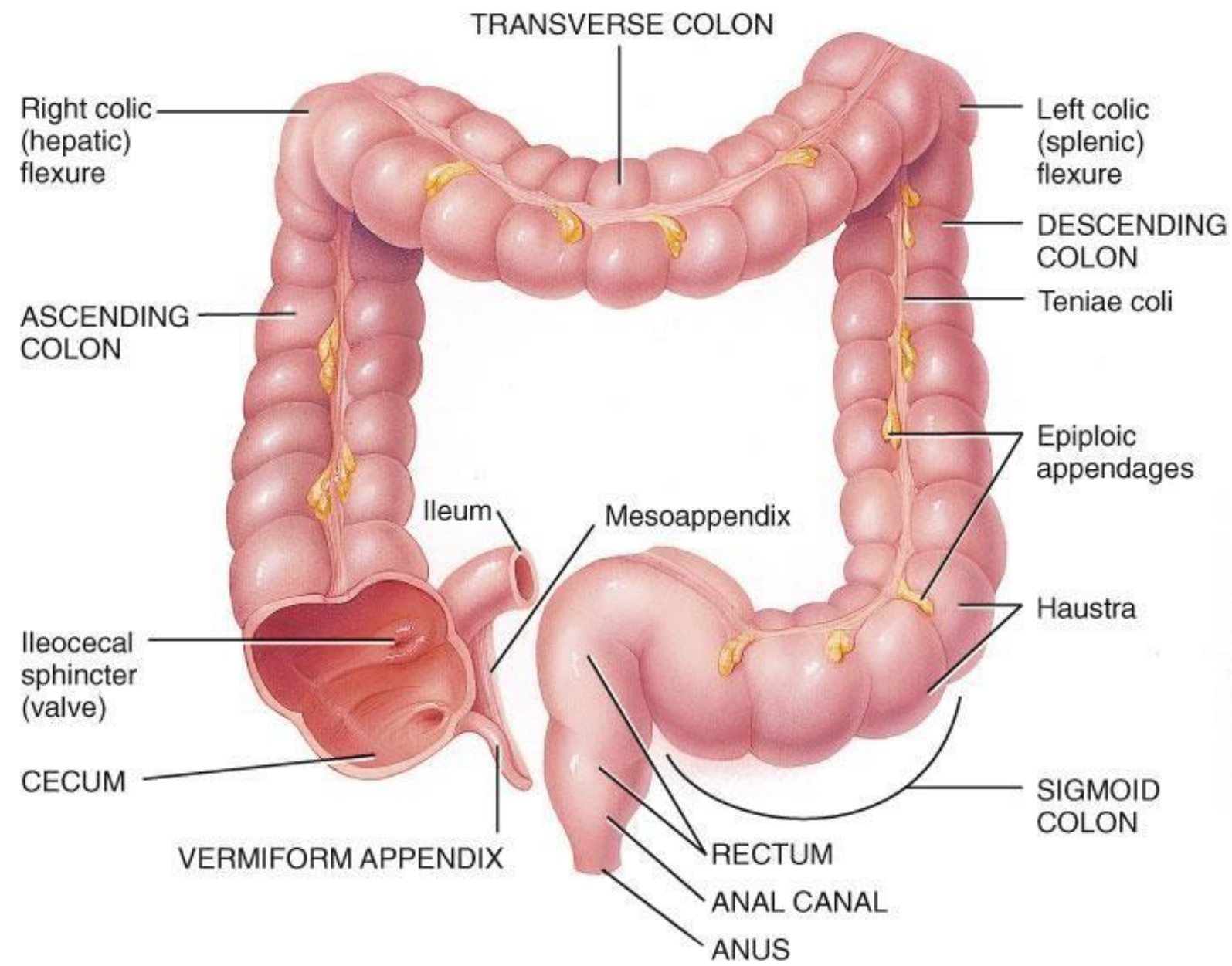
➤ **Mass contractions:**

➤ Facilitated by: gastrocolic and duodenocolic reflexes

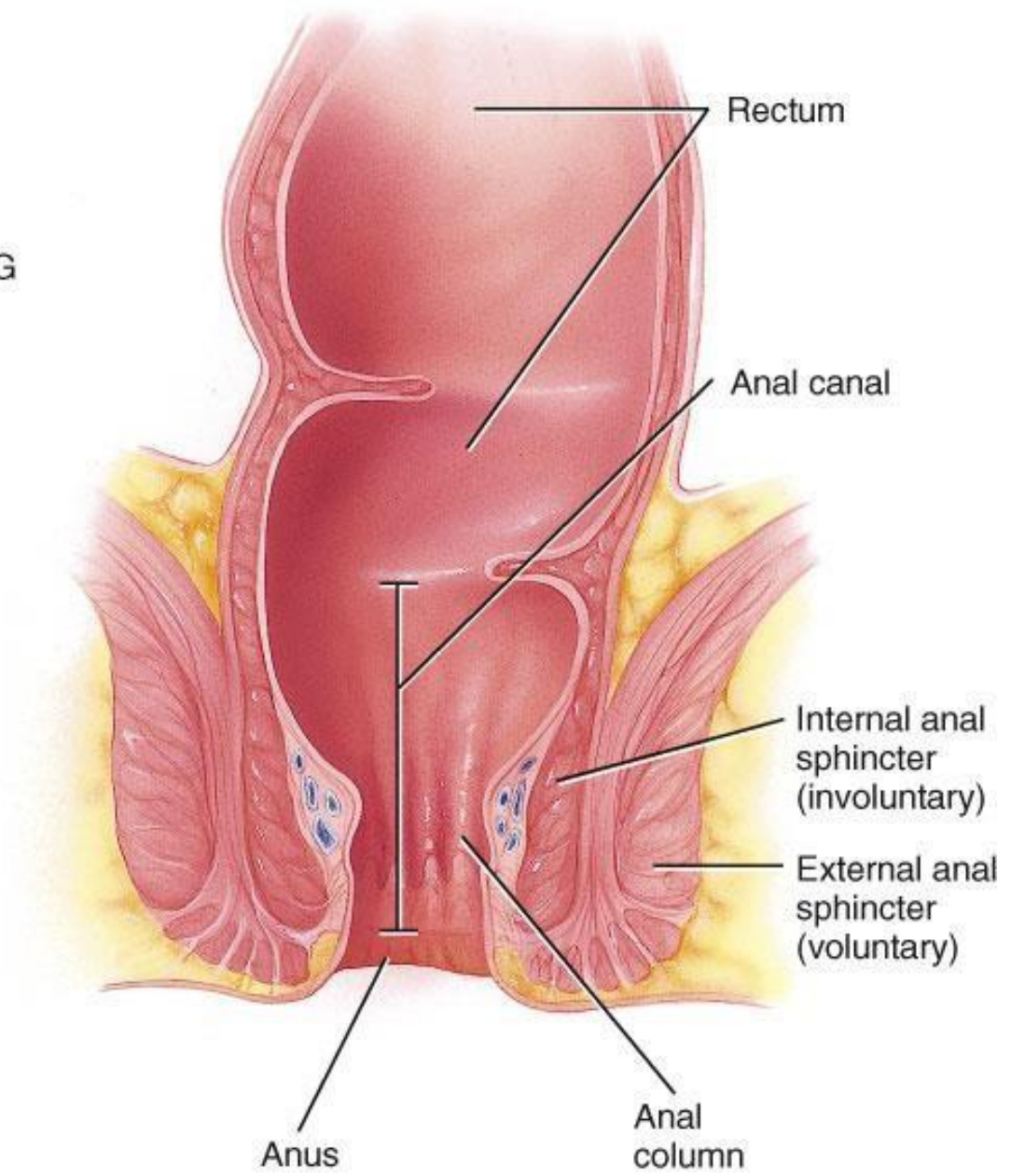
- effect: propulsive

Anatomy of Large Intestine





(a) Anterior view of large intestine showing major regions



(b) Frontal section of anal canal

Defecation

- Intrinsic reflexes.
- Extrinsic reflexes.

DR.'S HANDOUT

Gastro-intestinal Motilities

- Mixing and movements of food along the GI tract:
 - Mastication (chewing):
 - Chewing results in grinding action on food to get smaller particles. This occurs by activation of chewing reflex (centers in hypothalamus and cerebral cortex are stimulated by smell and taste to cause chewing of food in the mouth). The initiation of chewing reflex appears by muscle stretching caused by drop of the lower jaw (due to the presence of food bolus in the mouth). This will result in a rebound of the lower jaw by activation of stretch reflex.
 - In mouth, in addition to grinding by chewing, mixing is also promoted by
 - the movements of the tongue.
 - Deglutition (Swallowing):
 - Two stages of deglutition:
 - Voluntary stage: in which tongue is pressing food by upward and backward movement against soft palate, which results in squeezing food bolus into pharynx.
 - Involuntary stages: reflexes initiated by introducing food into pharynx will result in contraction of pharynx and then esophageal peristalsis that induce movement of bolus along esophagus.

Gastro-intestinal Motilities

- In these reflexes, swallowing receptors at the pharyngeal mucosa and swallowing centers in the brain are involved.
- The involuntary stage is subdivided into:
 - - Pharyngeal stage: duration is about 2 sec. In this stage respiration is interrupted, soft palate is pulled upward to close posterior nares and larynx is pulled upward and anteriorly which results in closure of epiglottis. In addition to these complex events, the upper esophageal sphincter (pharyngo-esophageal sphincter) is relaxed and esophageal opening is enlarged. This will end in enforcing bolus to move into esophagus.

-Esophageal stage: conduct the bolus along esophagus to the stomach.

Two types of contraction are taking place by esophageal muscle:

- Primary peristaltic contractions: continuation of the contractions initiated in the pharynx which conduct bolus through the esophagus. The wave of contractions passes along esophagus in about 8-10 second.
- Secondary peristalsis:
Represented by intrinsic (within myenteric plexus) and extrinsic (through afferent and efferent vagus fibers) reflexes promoted by the distension of the esophagus by the retained food in esophagus or when the primary reflex fails to move bolus of food along esophagus.

Note: Pharynx and Upper third of the esophagus is striated muscle and controlled by glossopharyngeal nerve. The lower third is smooth muscle and controlled by the vagus nerve as extrinsic control.

Peristaltic wave of the esophagus ends with relaxation of **gastroesophageal sphincter** (lower esophageal sphincter) and receptive relaxation of the stomach. The relaxation is caused by the activation of the inhibitory neurons from the lower part of the esophagus. These neurons induce inhibition of the tonic contraction of the sphincter and the relaxation of the stomach.

Failure of the sphincter to relax may result in a pathological condition known as *achalasia*. In which the ability of myenteric plexus to cause relaxation of the sphincter has failed.

Gastro-esophageal sphincter is equipped also by valve like closure at the distal opening of the esophagus to prevent reflux of food from the stomach. The failure of this system may result in esophageal reflux (Return of gastric content toward esophagus).

The motor activities of the stomach:

- The most important function of the stomach is *storage of food*. This organ can dilate from the capacity of 50ml up to 1000ml. This dilation begins with receptive relaxation and the

intervention of vago-vagal reflex that decreases the muscular tone of the stomach upon the presence of food in the stomach.

- Stomach secretes large amount of secretions (2000ml/day). This secretion when mixed with the ingested food in the stomach is forming chyme. These secretions are mixed with food due to the motor activities of the stomach which is known as ***peristaltic constrictive waves or mixing waves***. These activities appear in the mid portion of the stomach at frequency of 3/min and move toward the antrum. The frequency is determined by the frequency of basic electrical rhythm (BER) of gastric smooth muscle. These contractions are very intense as they approach the antrum and they are forming *constrictive rings*. At the antrum, when the peristaltic constrictive wave reaches the pylorus, it causes constriction of the pyloric sphincter which impedes emptying of chyme into the duodenum. The result of these contractions not only mixes food, they also grind food and toss the content of the antrum back toward the body and forth. The process of tossing back the antral content is known as *retropulsion*. Very small amount of chyme with fluid consistency can pass into the duodenum because of the small opening of the pylorus and the constriction of pyloric sphincter. For about 20% of time these peristaltic contractions become very intense and cause an increase in the pressure in the antrum. This action forces several ml of chyme to pass into the duodenum. The process that results in passage of chyme into duodenum is known as **gastric emptying**. The whole activity that results in gastric emptying is known as *pyloric pump*.

Note: Gastric movements result in grinding food particles and mixing them with secretion.

Pylorus as functional structure:

Pylorus is a small opening between stomach and duodenum guarded by smooth muscle cells that form the pyloric sphincter. The muscle cells of this sphincter are in tonic contractions. This structure gives access only to fluids to pass into duodenum and prevents the passage of food particles until they are grind and mixed well with secretions by forming chyme with fluid consistency.

Hunger contractions: This type of intense contractions in the stomach appears when the stomach is empty and lasts for several hours. These contractions are

rhythmical peristaltic contractions with duration of 2-3 minutes for each. It seems that these contractions are in relation with glucose concentration in the blood (They are increased by decreasing glucose level in blood).

Neural and hormonal control of gastric emptying:

Stimulation of gastric emptying:

- Filling of the stomach: initiates myenteric reflexes that causes an increase in the activity of pyloric pump and inhibits the tone of pyloric sphincter.
- Gastrin: secreted by the antral mucosa. This hormone has mild stimulatory effect on the peristaltic activities of the stomach, which result in enhanced pyloric pump.

Inhibition of gastric emptying:

- Entero-gastric reflex: The passage of chyme to the duodenum causes decrease pH (in duodenum). This initiates intrinsic and extrinsic reflexes to decrease gastric emptying.

3 levels of inhibition induced by entero-gastric reflexes:

- Through ENS.
- Through prevertebral ganglia.
- Through signals via the vagus nerve to inhibit the excitatory signals of vagus nerve to the stomach (vago-vagal reflexes).

The effects of these reflexes decrease the antral propulsive contractions and increase the tone of the pyloric sphincter.

- Hormonal feedback from the duodenum:

- CCK cholecystinin: (secreted by jejunum) the release is stimulated by fat in chyme.
- GIP: Gastric Inhibitory Peptide: released from upper small intestinal specialized cells and stimulated by fat and carbohydrates in chyme.
- Secretin: stimulated by acid in duodenum.

Intestinal movements:

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1. Propulsive Movement: ensures the movement of chyme analward at an appropriate rate.

2. Mixing Movements: which result in mixing food with GI secretion.

Propulsive movements

Movements of food along the GI tube are caused by peristaltic contractions that appear at the GI tract. These contractions are described as a contractile ring of the circular muscle layer up to the distension and relaxation down to the distension of segment, which move forward along the GI tract. Other component of the contraction is rhythmic shortening of longitudinal layer. The peristalsis can be initiated usually by local reflexes caused by distention of the gut which induce contractile ring 2-3 cm above the distended part and relaxation of the part of the GI tube down to the distention which is called *receptive relaxation*.

These changes that appear in the motor activity of the smooth muscle cells of the GI describe complex patterns of activities that are known as *peristaltic reflex*. After the initiation of this reflex by the formation of the contractile ring and the distention of the segment down to stimulated part of the intestine, and shortening and elongation of longitudinal layer results in chyme movements downward along the GI (in analward direction). These changes with the peristaltic wave and including the analward movement of peristalsis are known as the "*law of the gut*".

Although, the main effect of this type of contraction is to propel chyme in caudal direction, they also have some effects on mixing food and spreading chyme along the intestine which help in the absorption of food.

Rhythmic contractions of longitudinal layer are controlled by electrical activities of smooth muscle cells.

Neural control:

*The role of the ENS:

The complex structures of the enteric nervous system provide a neural network connection that controls many of the GI functions including the movements and the rate of chyme movements. The oral (up direction) extension of the excitatory neurons and the caudad (down direction) extension of the inhibitory neurons provide a great networking

which play a big role in peristaltic reflex. The congenital absence or the decreased activity of the enteric nervous system may depress or weaken the peristaltic reflexes and decrease the effectiveness of peristalsis to move the chyme in analward direction.

As a result an effective peristaltic activity to cause a propulsive movement of chyme requires an intact and active ENS.

The peristaltic contractions can also be initiated by mucosal stimulation (as in peristaltic rush: rapid and powerful peristaltic contractions).

Other factors can also interfere with the peristaltic activities:

*Parasympathetic nervous system: this system can modulate the peristaltic activities by changing the activity of neural network or by changing the activity of smooth muscle cells.

Hormonal control:

Many hormones have shown to affect the gastrointestinal motility After meals many hormones are secreted during phases of food processing. For some of these hormones, the effect on intestinal motility is known. As example:

- Gastrin, CCK, serotonin enhance intestinal motility.
- Secretin and glucagon inhibit intestinal motility.

Mixing movements:

The mixing of food with secretions in the GI tract is provided by the activity of circular smooth muscle cells. The contractions that appear along the intestine which are inter-spaced by the relaxation of adjacent smooth muscle cells up and down to the contracted segment cause spaced segmentations of the intestine which are known as *segmentation contractions*.

The rate of contractile activity is determined by the rate of slow waves (the electrical activity of smooth muscle cells or BER) in that segment of the intestine. The maximum frequency of contractions is about 12/minute in the upper part of intestine (duodenum and jejunum) and 8/minute in the terminal ileum (the same as the rate of slow waves or Basic Electrical Rhythm (BER)).

Although these types of contraction have mainly mixing effect on chyme, they also have some propulsive effects which cause movement in analward direction.

Other types of contractions in intestine:

Peristaltic rush: Powerful and rapid peristalses that occur along small intestine caused by mucosal irritation and/or intestinal distension.

Migrating Motor Complex (MMC):

MMC is other type of motor activity that begins in the stomach in the inter-digestive periods. The activity begins in the distal part of the stomach and continues along the entire small intestine. The contractions that forming MMC appear in 3 phases:

In the first phase: slow waves (as electrical activity) without contraction are present.

In the second phase: not all slow waves are followed by contractions (one slow wave is followed by contraction and 1-5 slow waves are not followed).

In the third phase lasts for 5-15 minutes all slow waves are followed by contractions.

The function of these contractions is to sweep the intestinal content in the time between meals.

These movements are controlled by hormonal (Motilin is believed to be involved) and neural mechanisms.

Movements caused by the activity of muscularis mucosa:

The activity of muscularis mucosa is responsible for the shortening and elongating mucosal folds. This activity helps more in the absorptive process by intestinal mucosa.

The contractions caused by muscularis mucosa are also affected by the activity of enteric nervous system.

Movements of the colon:

Haustration contractions: the appearance is similar with segmentation contractions of the small intestine. The activity is represented as rhythmic contraction and relaxation of circular layer of colonic smooth muscle cells at a length of about 2.5cm. Each contraction lasts for 30-60 sec. In addition to the activity of circular layer, longitudinal muscle strips (known as *teniae coli*) are also involved to cause haustral appearance in the colon.

The role of these contractions is helping in absorption of water and electrolytes by spreading the colonic content over the mucosa. In addition, these contractions have also propulsive effect. Although, they

Have slow effect on the content of cecum and ascending colon, they are the main responsible in moving fecal materials into the transverse colon.

Propulsive movements (mass contractions): are series of contractions that appear 1-3 times/day and last each time about 10-30 minutes. These contractions appear mainly in the first hour after breakfast. They are the main responsible in moving fecal materials from the beginning of transverse colon to the sigmoid.

Mass contractions are described as constrictive rings that usually begin at the transverse colon followed by the contraction of about 20cm or more of the colon distal to the constrictive ring. Each contraction lasts for 30 sec, then, followed by 2-3 minutes relaxation and then another contraction wave begins.

Mass contractions are facilitated by gastrocolic and duodenocolic reflexes. These reflexes are conducted through the autonomic nervous system.

These contractions can also be initiated by the irritation of the colon. As example, in ulcerative colitis that results in mucosal irritation, causes an increase in mass movements of the colon.

The effect of these contractions: feces will be forced to move into the rectum which may result in the initiation of defecation reflex.

Defecation:

Two types of reflexes are preceding defecation act. These include:

Intrinsic reflexes: in which, distention of the rectum initiates signals through **myenteric plexus** (ENS) to cause more contractions in descendent colon, sigmoid and rectum. This will force feces to move toward the anus. This reflex is weak and will not cause defecation.

Extrinsic reflexes (parasympathetic defecation reflex): distension of rectum and sigmoid will result in:

Increased parasympathetic signals which fortify contractions that appear in the descendent colon, sigmoid and rectum.

Signals to the internal sphincter to cause relaxation.

Note: all these reflexes are involuntary.

After all these reflexes, the defecation in normal people occurs only as a **voluntary act** by relaxing external sphincter (which is under voluntary control) and increasing abdominal pressure by closure of glottis and contractions of the abdominal wall which cause the pelvic floor to be pulled downward on the anal ring and relax to evacuate feces.

Additional Resources:

رسالة من الفريق العلمي:

Reference Used:

1. Guyton & Hall Medical Physiology 14th Edition.
2. ChatGPT.
3. Gemini.
4. Dr.Mohammad Khatatbh's Lectures.
5. Dr.Mohammad Khatatbh's HandOuts.



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Corrections from previous versions:

Versions	Slide # and Place of Error	Before Correction	After Correction
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