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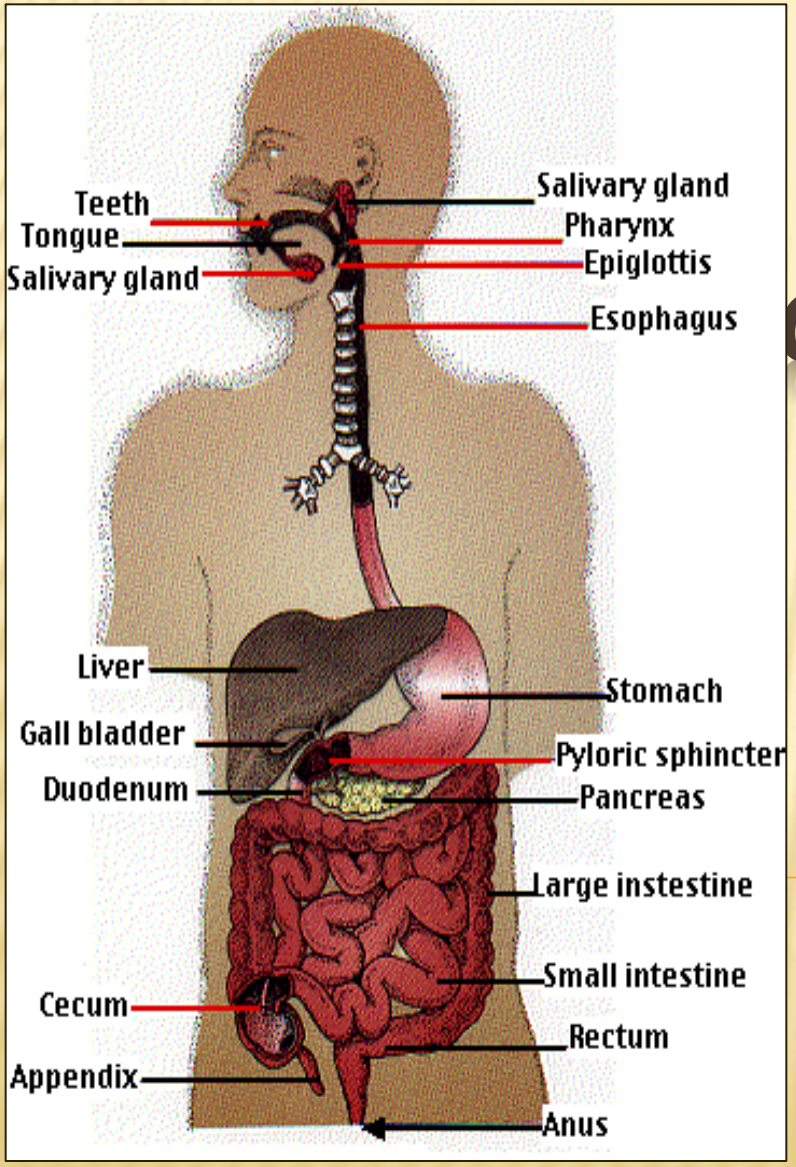

Lecture № 14

GENERAL PRINCIPLES OF GASTROINTESTINAL TRACT. PROPULSION AND MIXING OF FOOD IN THE ALIMENTARY TRACT

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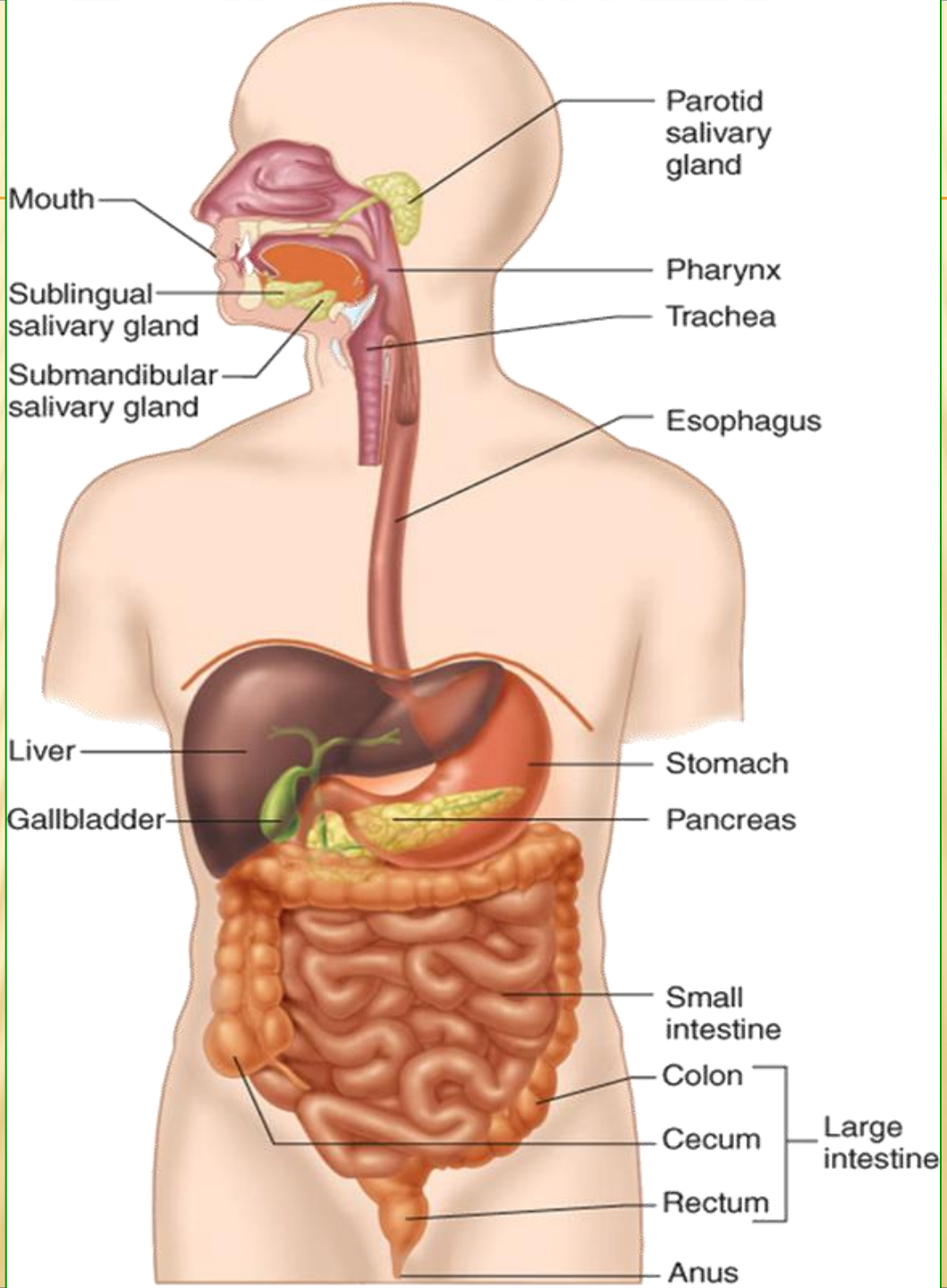

Parotid salivary gland
Mouth
Pharynx
Sublingual salivary gland
Trachea
Submandibular salivary gland
Esophagus
Liver
Stomach
Gallbladder
Pancreas
Small intestine
Colon
Cecum
Large intestine
Rectum
Anus

FUNCTIONS OF GASTROINTESTINAL SYSTEM

- The main function is to deliver the food staffs, water, salts and vitamins for energetic and plastic needs of organism.
- It occurs performing processes of:
  - motility
  - secretion
  - digestion
  - reabsorption

FUNCTIONS OF GASTROINTESTINAL SYSTEM

- **Excretory function:**
  - ✓ Excretion of non completely digestive and non reabsorbed products of the food, heavy metals(Fe, Cu), organic substances, drugs and ions.
- **Endocrine function**
  - ✓ Secretion of hormones, regulating its functions.
- **Blood depot**
  - ✓ Its vessels are the biggest blood reservoir that may mobilize when there is a need for this.

FUNCTIONS OF GASTROINTESTINAL SYSTEM

Defensive function:

- Specific immune mechanisms that perform defense against pathogenic microorganisms.

- Non specific defensive mechanisms:

* Secretion of mucus
* Secretion of substances with antibacterial action (lisosym, peroxidase, thiocyanats, HCl, deffensins)
* Normal bacterial flora in the mouth and in the collon
* Water-electrolyte secretion and peristalsis ensure mechanical cleaning of tract

Special characteristics of anatomical structure of GIT

- Gastrointestinal system is opened in both its sides.
- It consists of anatomically and functionally isolated hollow organs, separated by sphincters.
- It has the exocrine glands, situated out of the tract that secret into it (salivary glands, liver, pancreas).
- Into the walls of GIT is situated its own regulatory system (nervous and endocrine).
- It is connected with CNS by afferent and efferent pathways.

❖ The gastrointestinal tract is a tube that has the following wall structure:

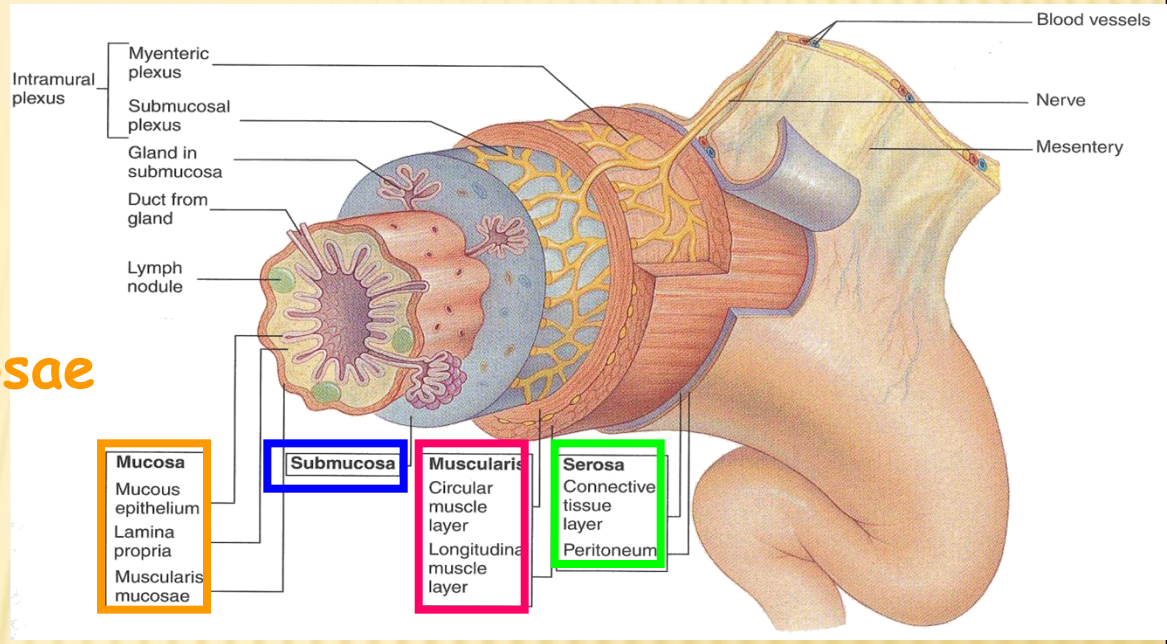
➢ 4 layers (tunica):

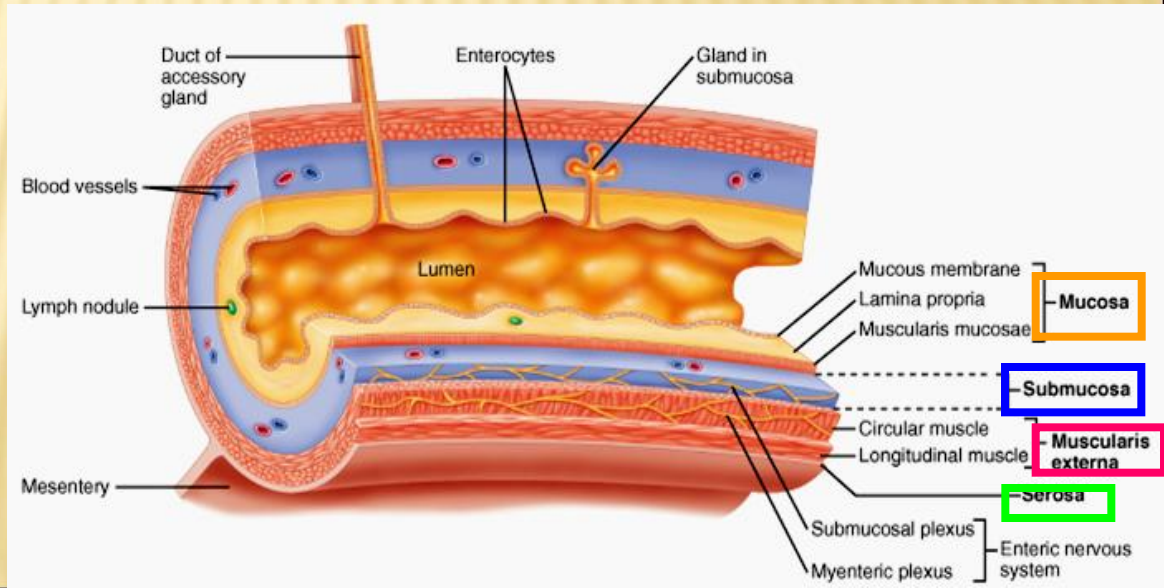
✓ Mucosa
- epithelium
- lamina propria
- muscularis mucosae

✓ Submucosa

✓ Muscularis

✓ Serosa (adventicia)

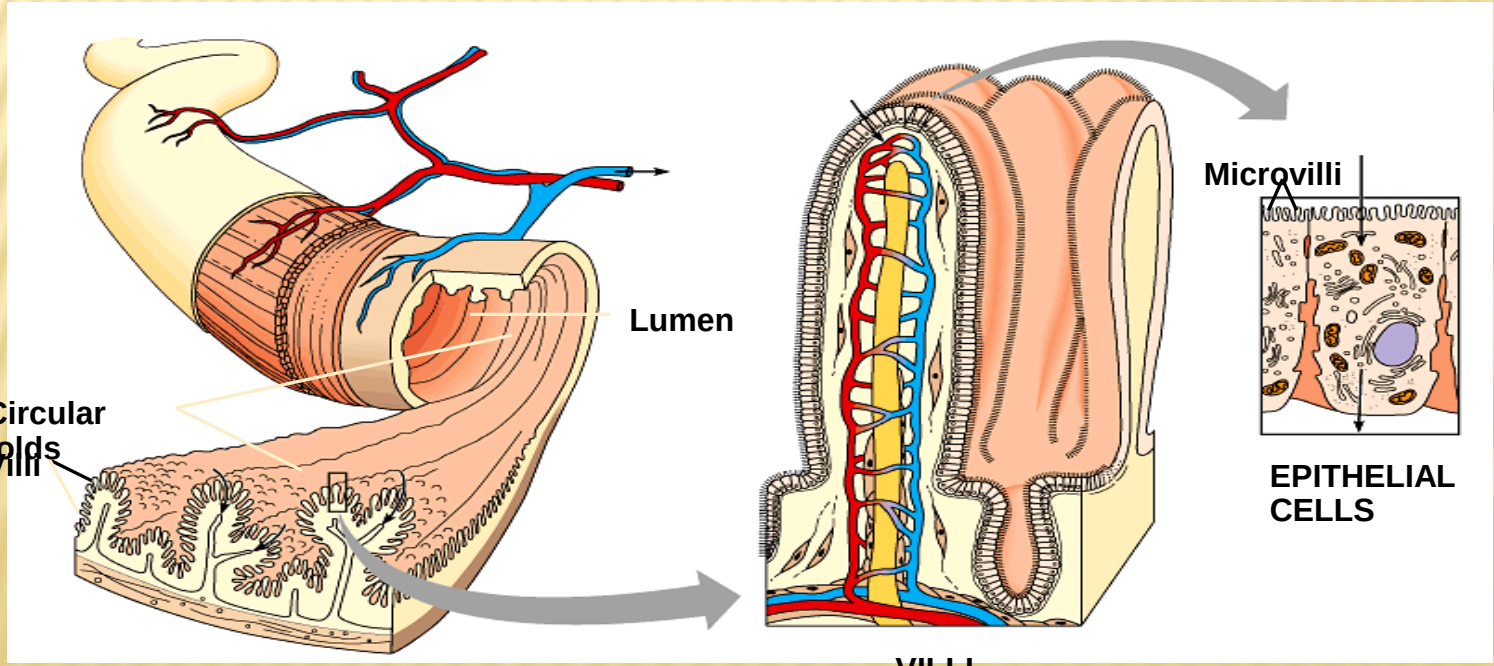


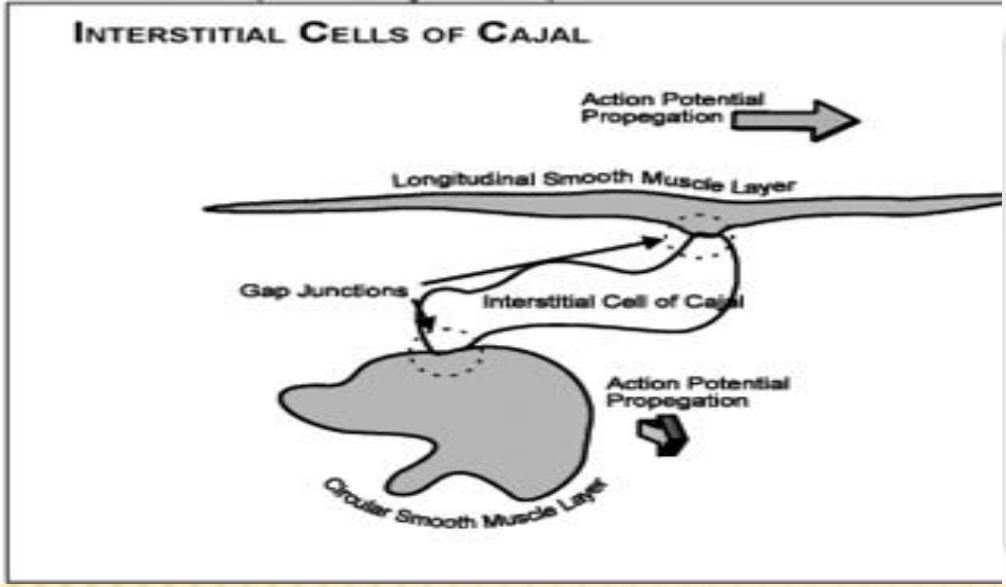


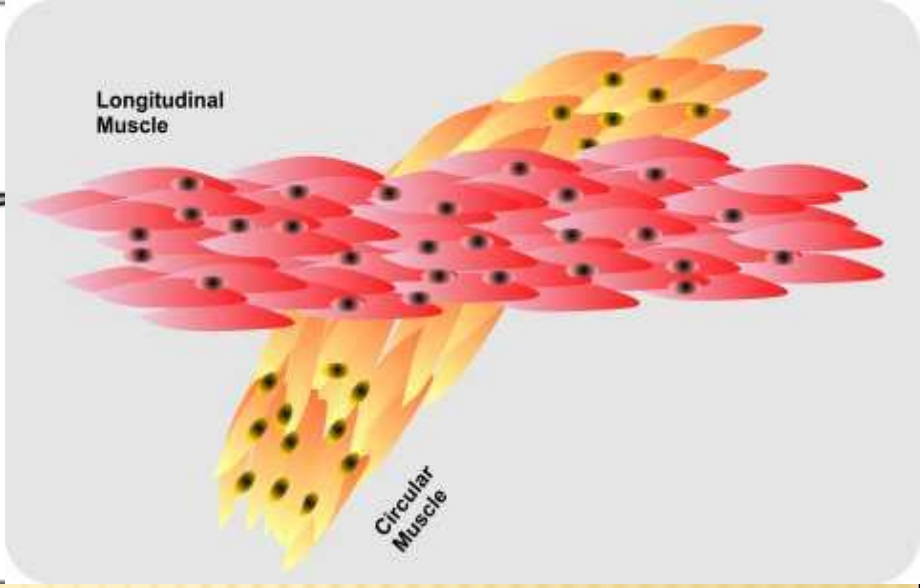
Mechanisms for increase of absorptive area of the mucosa

1. Absorptive surface of the intestinal mucosa is increased about **3 fold** by valvulae conniventes (**folds of Kerckring**)
2. These folds are covered by **villi**, which project 1mm from the surface of mucosa and enhances the absorptive area another **10 fold.**
3. Each intestinal epithelial cell is characterized by a brush border, consisting of 1000 **microvilli.** This increases the surface area exposed to the intestinal materials at least another **20 fold**.

Thus the combination of these factors increases the absorptive area 1000 fold.



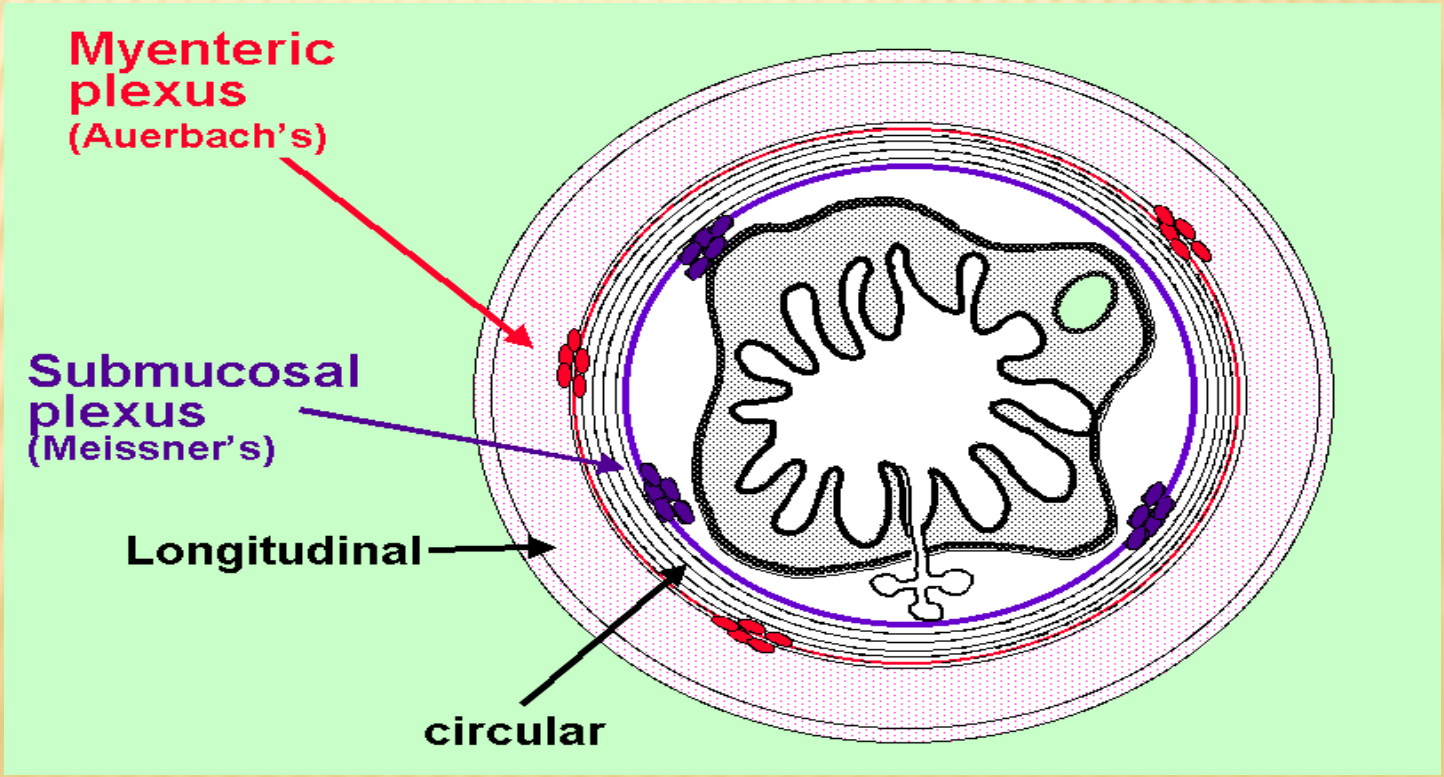




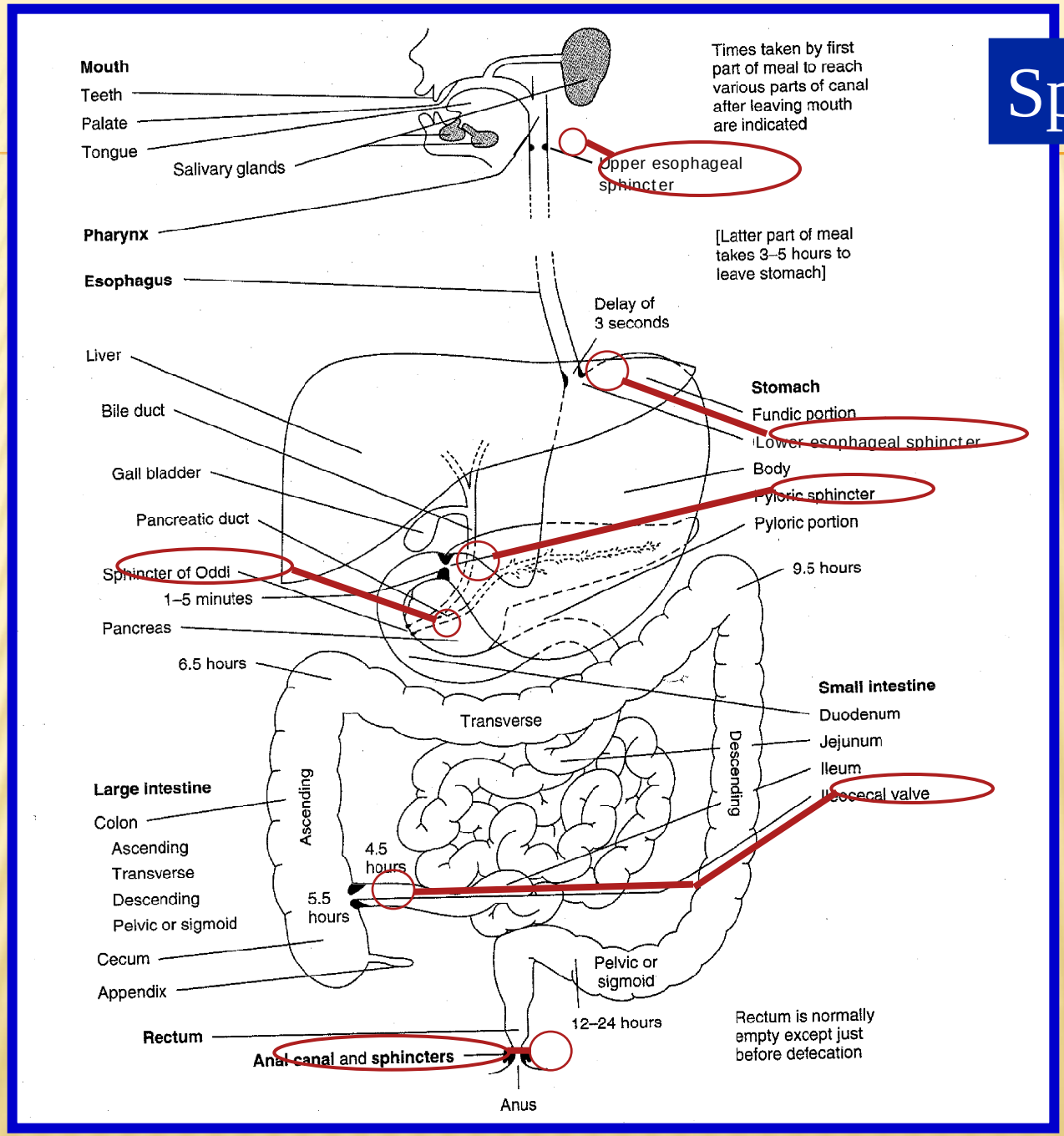
- Important property - automaticity: slow waves with frequency from 3 to 12 per minute, generated by intersticial cells of Cajal that excite smooth muscle cells of two layers.
- Propagation of excitation occurs through electrical synapses.
- Slow waves exist every time, but they perform contraction when their amplitude gains contractile threshold.

Smooth muscles and ENS

- Between circular and longitudinal layers are situated many neurons that form Myenteric (Auerbach's) plexus.

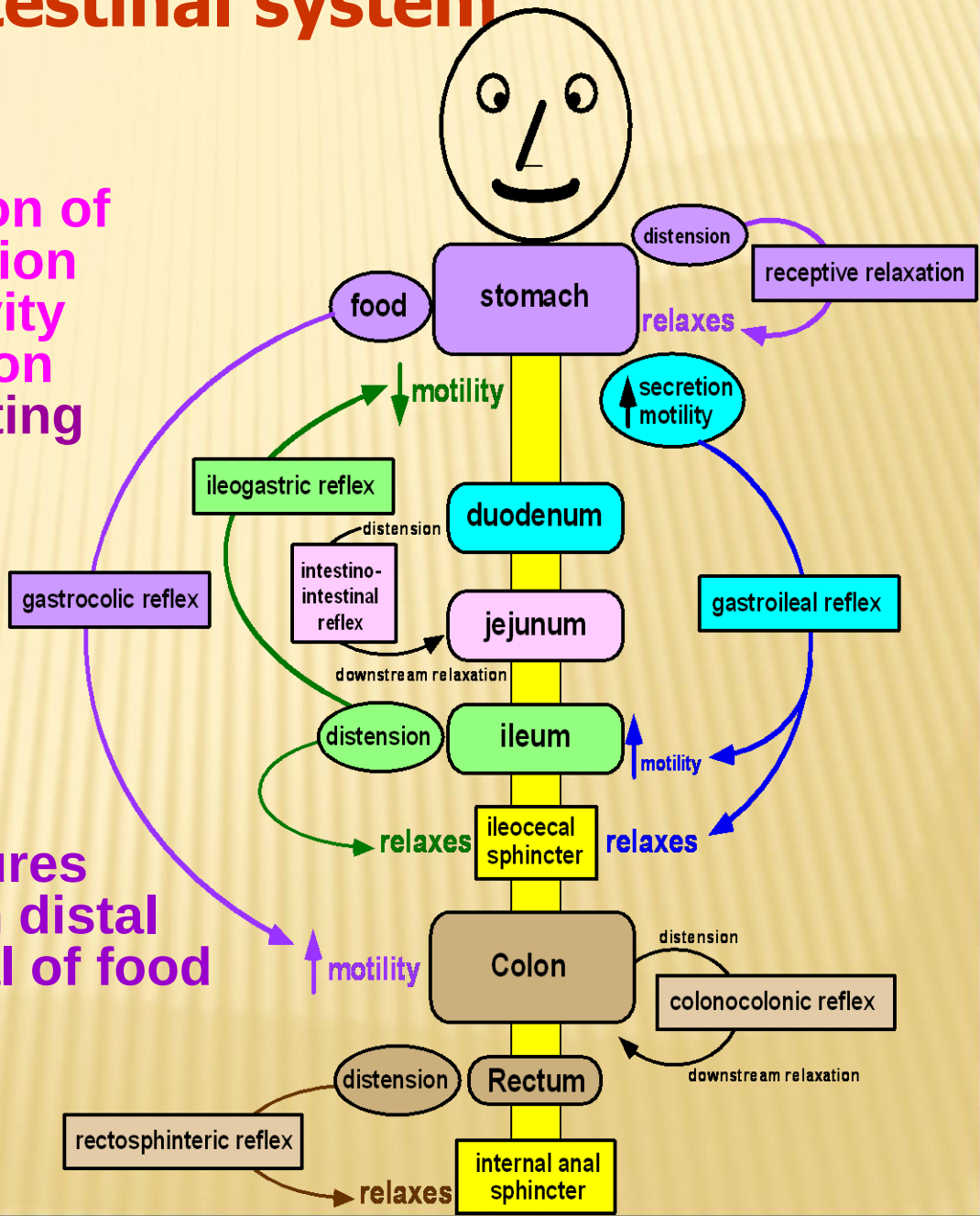


Sphincters


Mouth
Teeth
Palate
Tongue
Salivary glands
Pharynx
Esophagus
Liver
Bile duct
Gall bladder
Pancreatic duct
Sphincter of Oddi
1–5 minutes
Pancreas
6.5 hours
Large intestine
Colon
Ascending
Transverse
Descending
Pelvic or sigmoid
Cecum
Appendix
Rectum
Anal canal and sphincters
Anus
Times taken by first part of meal to reach various parts of canal after leaving mouth are indicated
Upper esophageal sphincter
[Latter part of meal takes 3–5 hours to leave stomach]
Delay of 3 seconds
Stomach
Fundic portion
Lower esophageal sphincter
Body
Pyloric sphincter
Pyloric portion
9.5 hours
Small intestine
Duodenum
Jejunum
Ileum
Ileocecal valve
Transverse
Ascending
Descending
4.5 hours
5.5 hours
Pelvic or sigmoid
12–24 hours
Rectum is normally empty except just before defecation

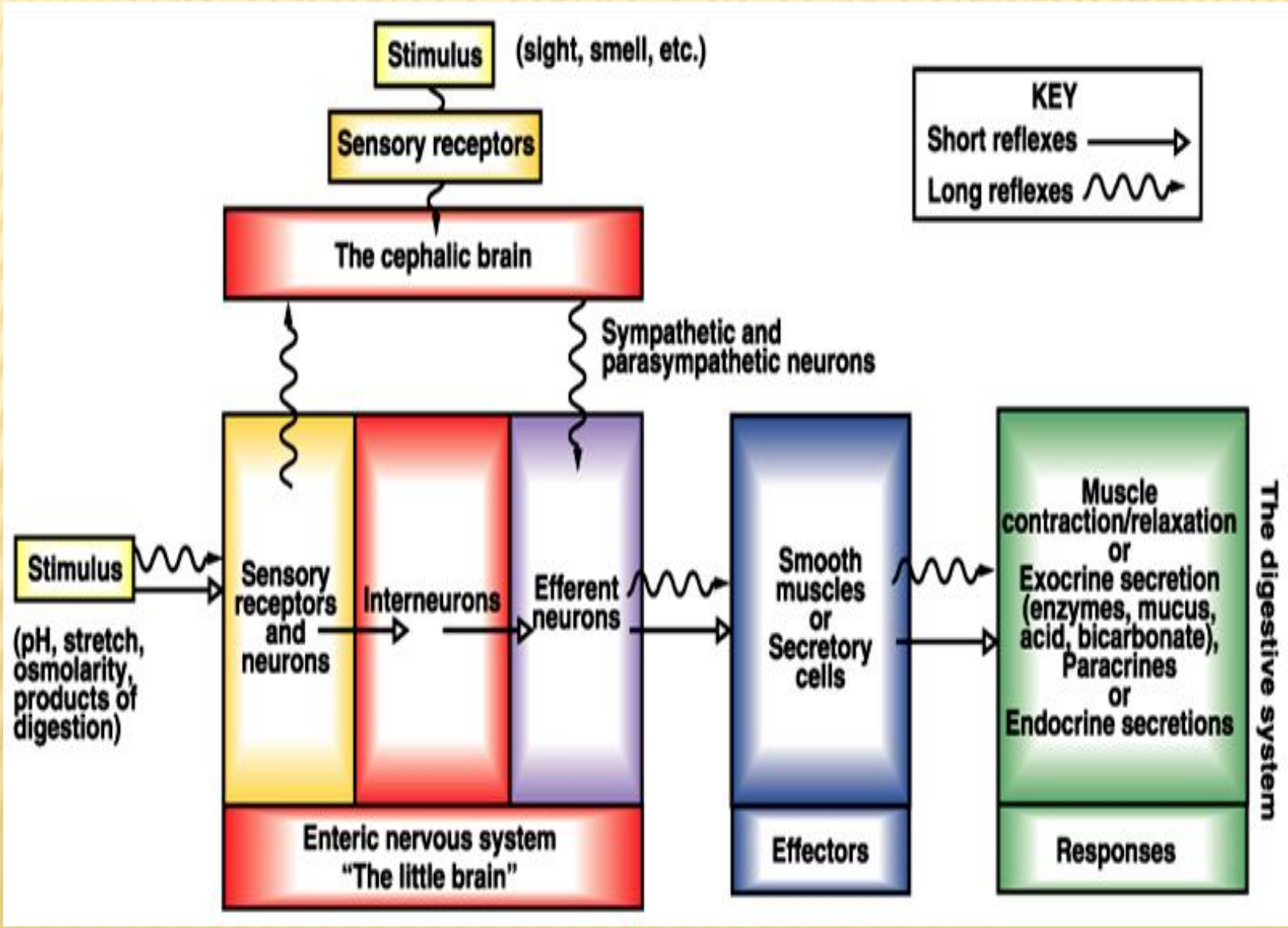
❖ Control of gastrointestinal system

✓The main principle: Digestion of one part of GIT causes inhibition of secretory and motility activity orally of this part and activation distally of this part - anticipating regulation.



✦Anticipating regulation ensures increased digestive activity in distal segment of tract before arrival of food to it.

THE COMMON SCHEME OF NERVOUS REGULATION OF GASTROINTESTINAL SYSTEM FUNCTIONS

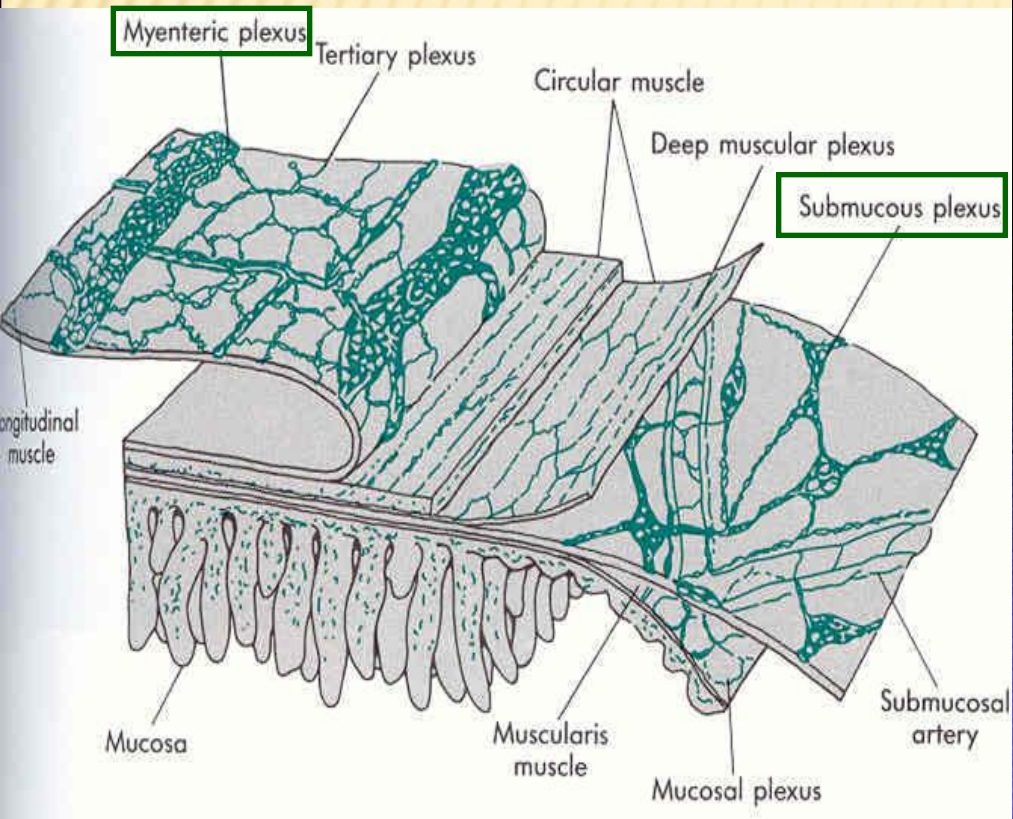


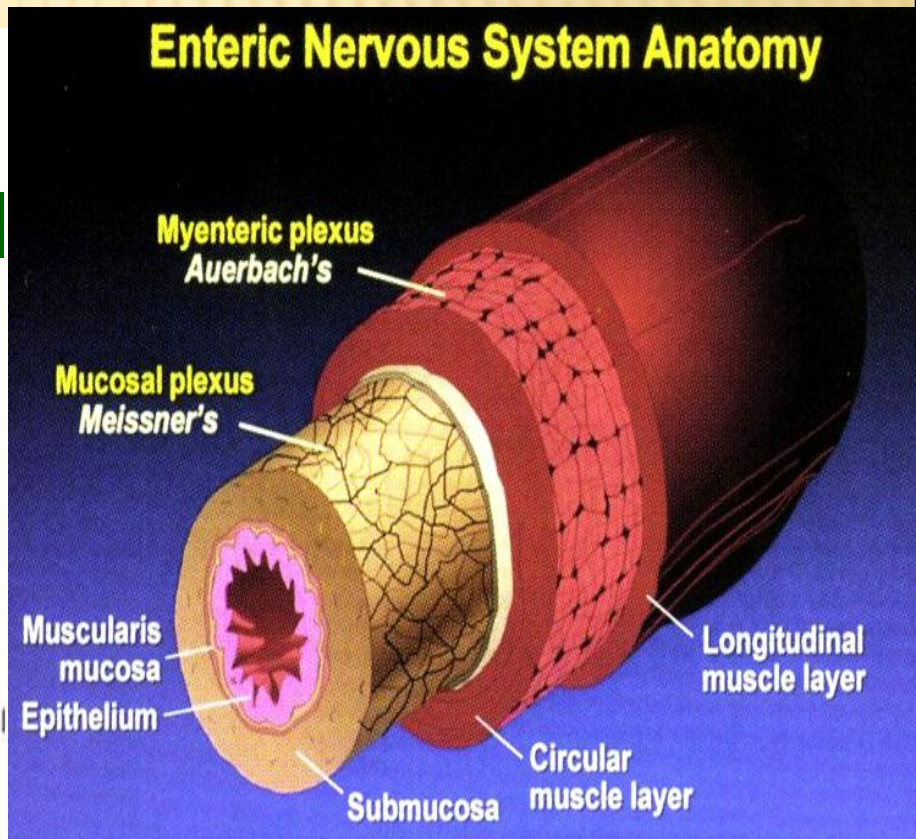
Enteric nervous system

- It consists of neurons and glial cells into the wall of GIT.

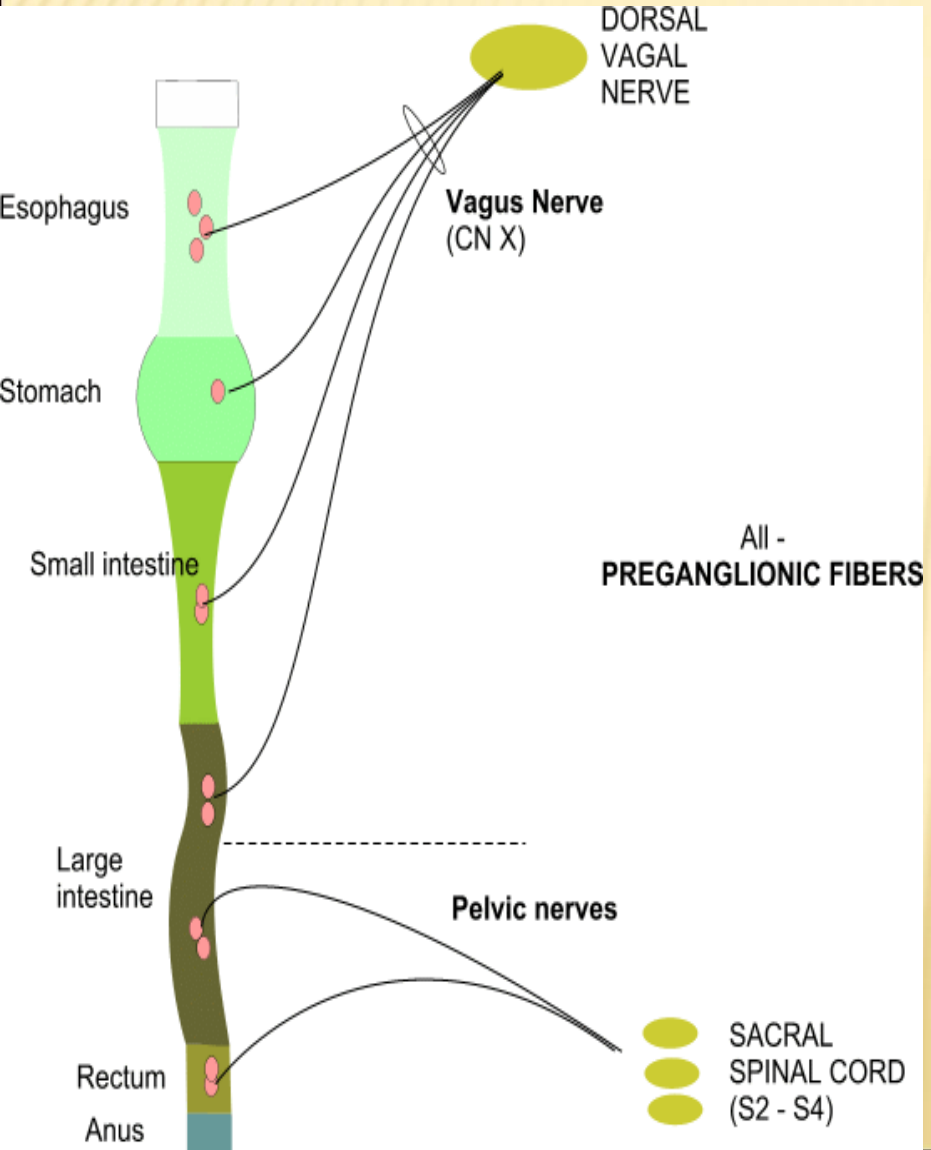
- The neurons are situated in:

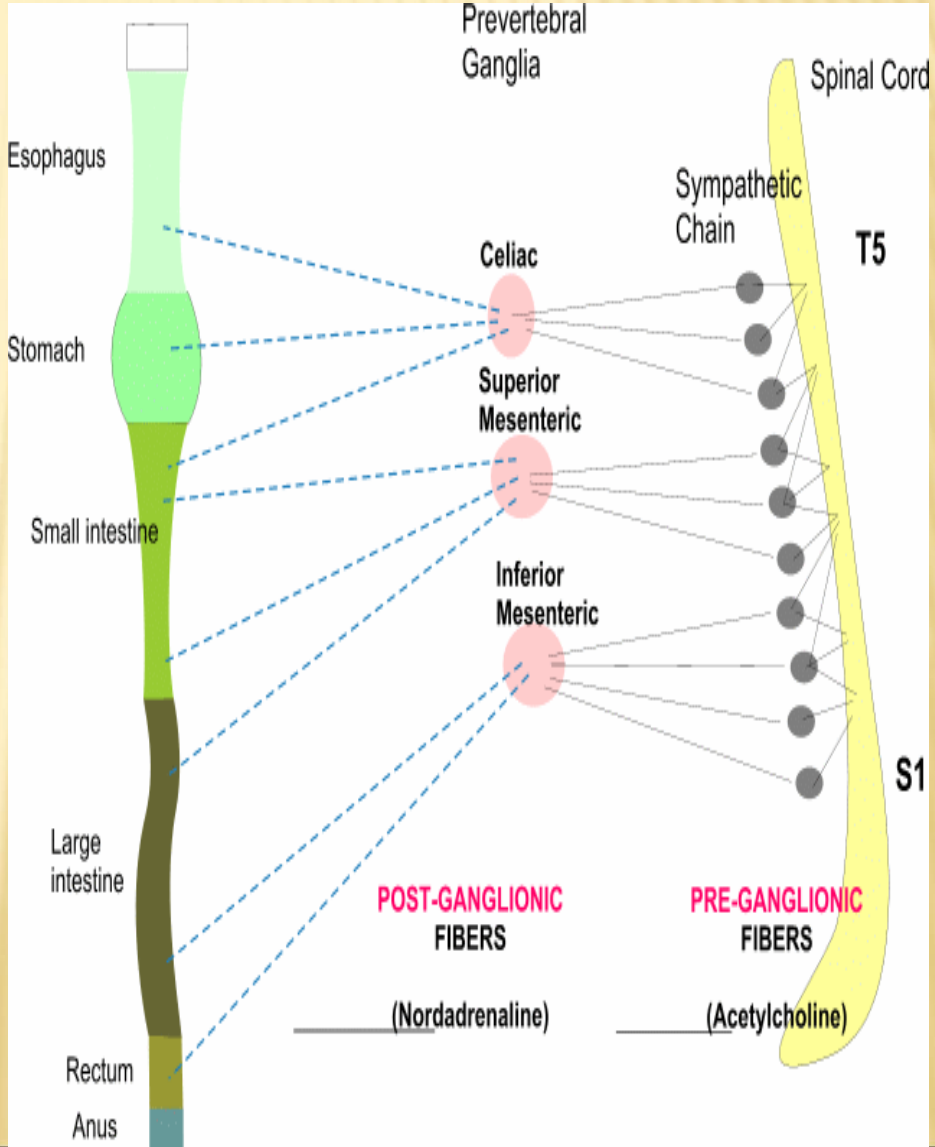
✓ plexus submucosus Meissneri
✓ plexus myentericus Auerbachi





PARASYMPATHETIC AND SYMPATHETIC INNERVATIONS OF GIT





HUMORAL MECHANISMS INCLUDE:

- Hormones of endocrine glands
- Hormones of endocrine cells, situated in the wall of GIT
  - *Gastrin*
  - *Holecystokinin (CCK)*
  - *Secretin*
  - *Gastroinhibitory peptide (GIP)*
- The substances with paracrin effect
  - *Somatostatin*
  - *Histamine*

THE MUSCLES OF GIT HAVE THE ROLE TO BREAK TO PIECES, MIX AND PROPELS THE INGESTED FOOD.

- Two types of movements occur in the gastrointestinal tract:

(1) *propulsive movements*, which cause food to move forward along the tract at an appropriate rate to accommodate digestion and absorption, and

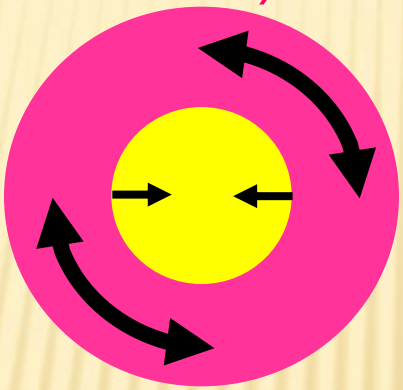
(2) *mixing movements*, which keep the intestinal contents thoroughly mixed all time.

- **The muscles presented in GIT are two types:**

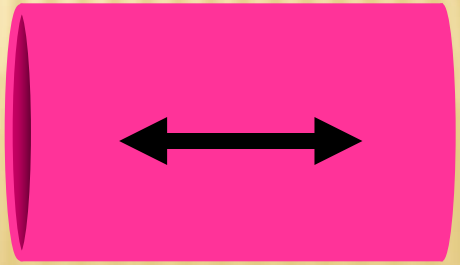
- Striated, that are situated at the beginning of the system (mouth cavity, pharynx, upper part of esophagus) and at the end (external sphincter of the anus);
- Smooth - that are presented at the other part of GIT, situated into 2 layers:

SMOOTH MUSCLES IN GIT

- *Internal circular muscle layer* (decreases the diameter of the lumen)



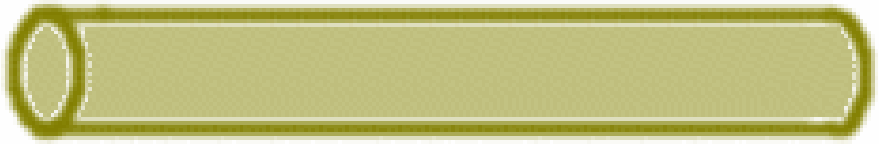
- *External longitudinal muscle layer* (decreases the length of the tube)



Functions of motion activity:

- Storage of ingested food and of intestinal content (stomach,colon)
- Mechanical breakdown of the food, that increases the surface area for enzymes action
- Mixing of the food with digestive juices for ensuring better contact with absorptive surface of the epithelium

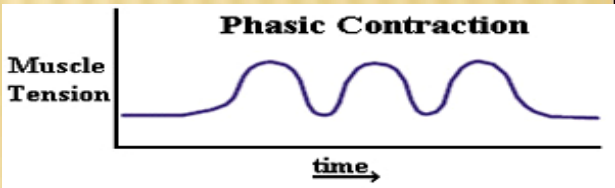
- Ensuring enough time for digestion of the food into the different part of GIT by the contraction of the sphincters
- Push the chyme forward

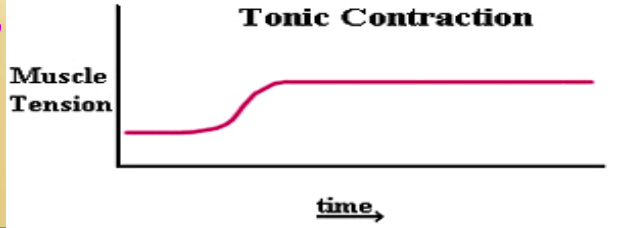


Smooth muscles perform 2 types of movements:

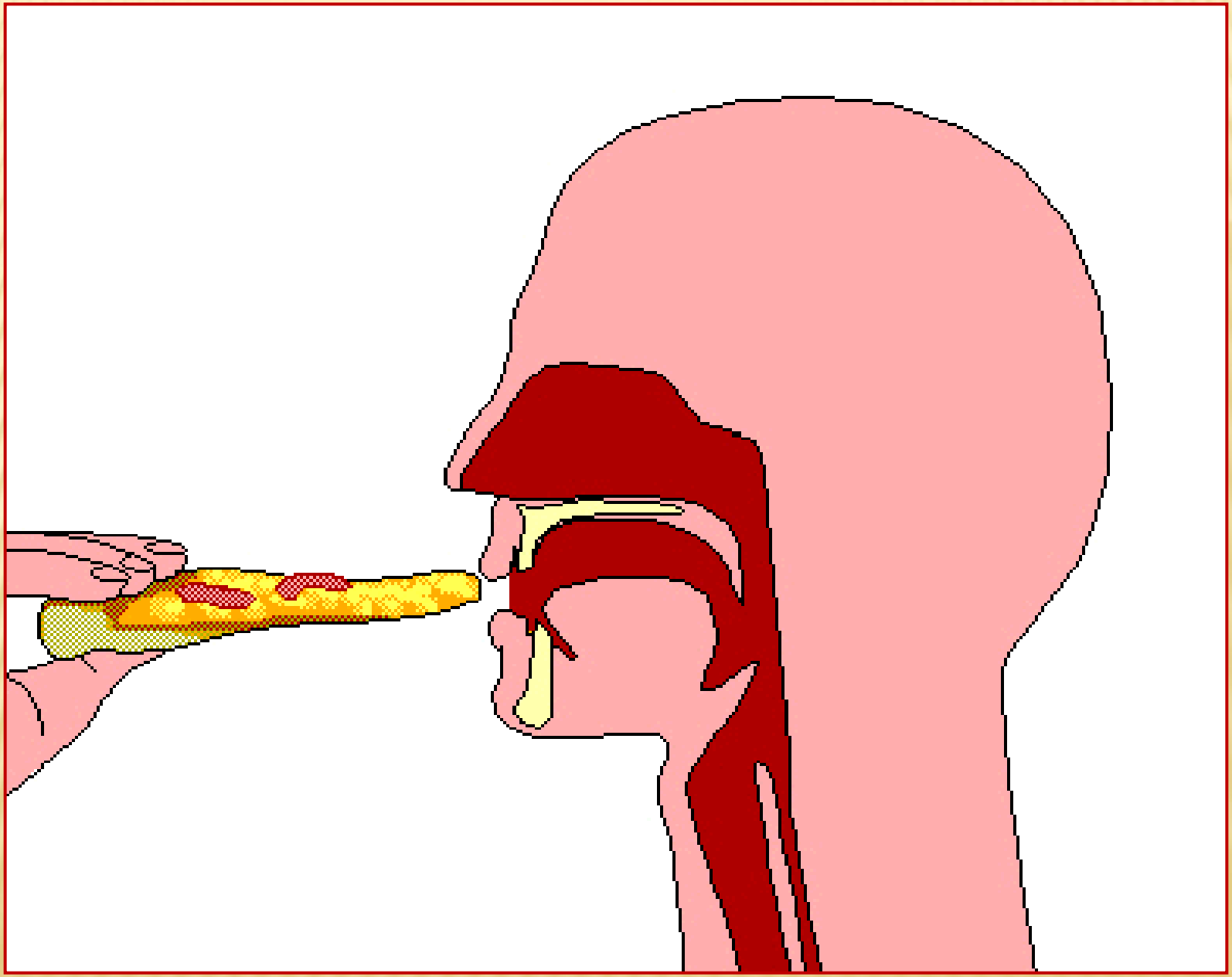
✓Phasic – fast contractions and relaxations, that last during seconds and play a role to mix and push the food

✓Tonic – slow contractions, for a long time (minutes), that maintain a size of the organs with reservoir function and detain the food into the different part of the tract (sphincters)





Mastication and Swallowing



Mastication (Chewing)

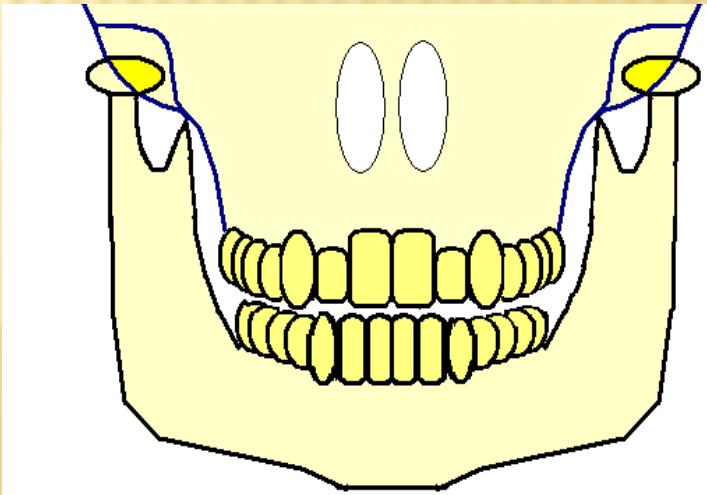
❖ Functions:

- ➢ break the food to pieces
- ➢ activation of salivary secretion
- ➢ mixing the food with saliva gives the possibility for enzymatic action of salivary amylase and lipase and for taste sensation
- ➢ formation of mouthful for swallowing
- ➢ triggers the cephalic phase of control of gastric, pancreatic and biliary secretion

Much of the chewing process is caused by a ***chewing reflex***, which may be explained as follows:

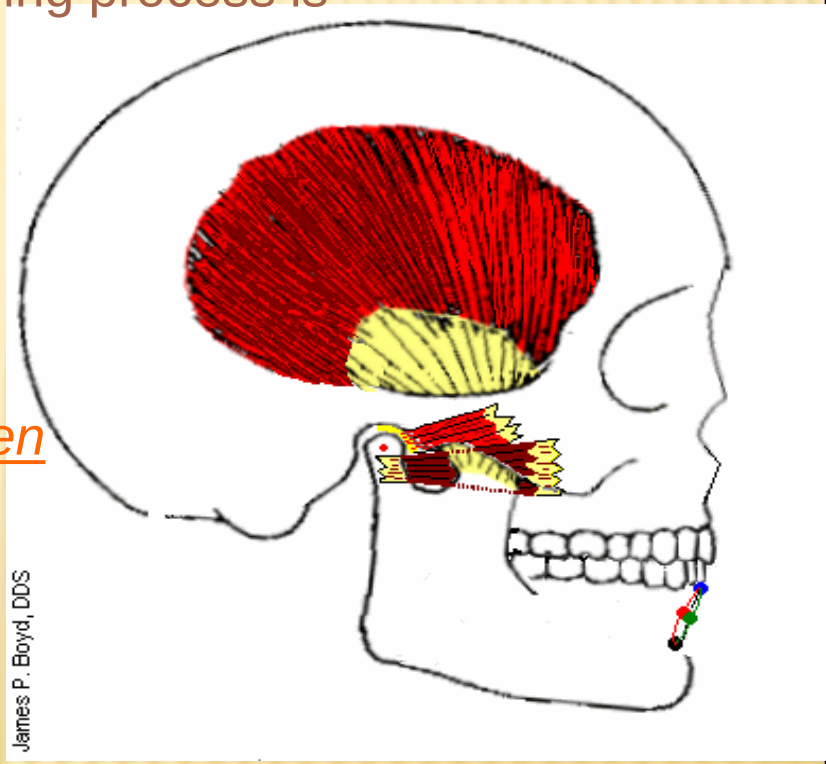
- ✓The presence of a bolus of food in the mouth at first initiates reflex inhibition of the muscles of mastication, which allows the lower jaw to drop.
- ✓The drop in turn initiates a stretch reflex of the jaw muscles that leads to *rebound* contraction.
- ✓This automatically raises the jaw to cause closure of the teeth, and this is repeated again and again.

✓The main role of the tongue during mastication is to separate prepared for swallowing food from the other ingested food.



Control of mastication

Most of the muscles of chewing are innervated by the motor branch of the fifth cranial nerve, and the chewing process is controlled by nuclei in the brain stem.
The nervouse center of this reflex has automaticity.
Stimulation of specific reticular areas in the brain stem taste centers will cause rhythmical chewing movements. Also, *stimulation of areas in the hypothalamus,amygdala, and even the cerebral cortex near the sensory areas for taste and smell* can often cause chewing.



The motor area of brain cortex triggers the mastication.*This reflex is influenced by the information from the mechanoreceptors of peridontium and proprioreceptors of the chewing muscles and also by the information from termoreceptors and taste receptors in the mouth and sensory receptors on the jaws areas of the face skin.*
This information plays a role for modulation of chewing movements, depending on the quality of ingested food.

Swallowing (Deglutition)

- **Swallowing has 3 phases:**

1. Voluntary Stage of Swallowing. When the food is ready for swallowing, it is "voluntarily" squeezed or rolled posteriorly into the pharynx by pressure of the tongue upward and backward against the palate,

2. Pharyngeal Stage of Swallowing. As the bolus of food enters the posterior mouth and pharynx, it stimulates *epithelial swallowing receptor areas* all around the opening of the pharynx, and impulses from these pass to the brain stem to initiate a series of **automatic pharyngeal muscle contractions as follows:**

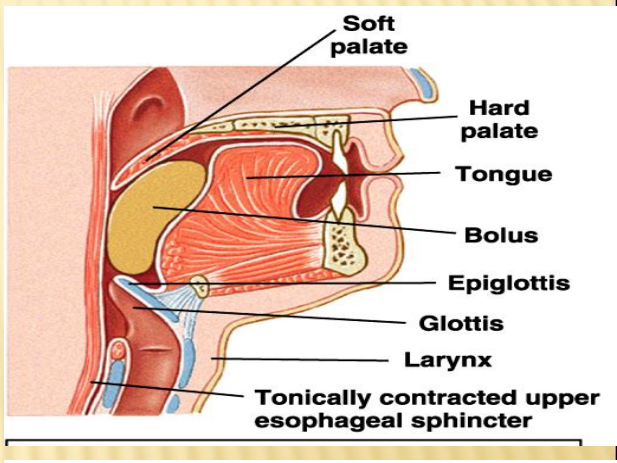
***The soft palate is pulled upward to close the posterior nares.**

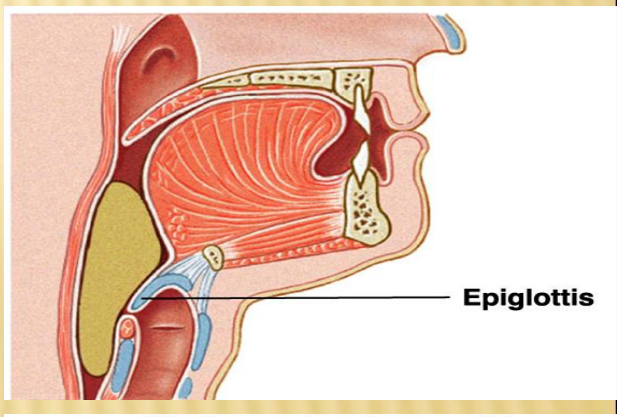
***The trachea is closed.**

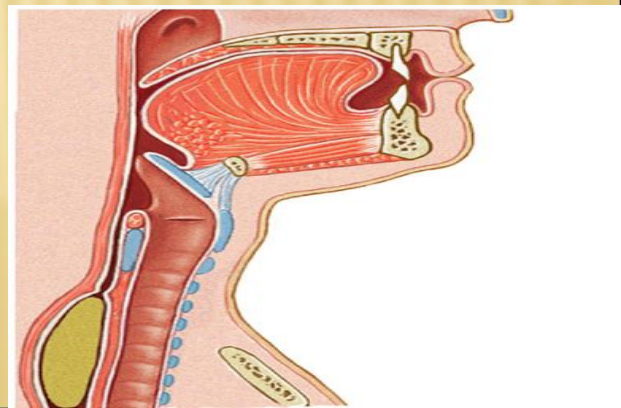
***The swallowing center specifically inhibits the respiratory center of the medulla during this time.**

***The esophagus is opened.**

3. Esophageal Stage of Swallowing. The esophagus functions primarily to conduct food rapidly from the pharynx to the stomach, and its movements are organized specifically for this function.



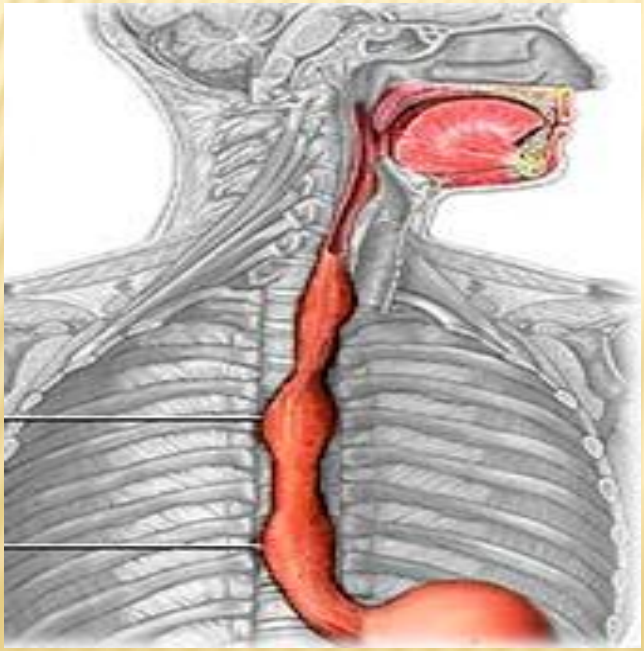




MOTILITY OF ESOPHAGUS

- 1. Closure of Upper Esophageal Sphincter occurs.
- 2. The primary peristaltic wave of esophagus begins.
- 3. Oppening of the Lower Esophageal Sphincter (Gastroesophageal Sphincter) performs.

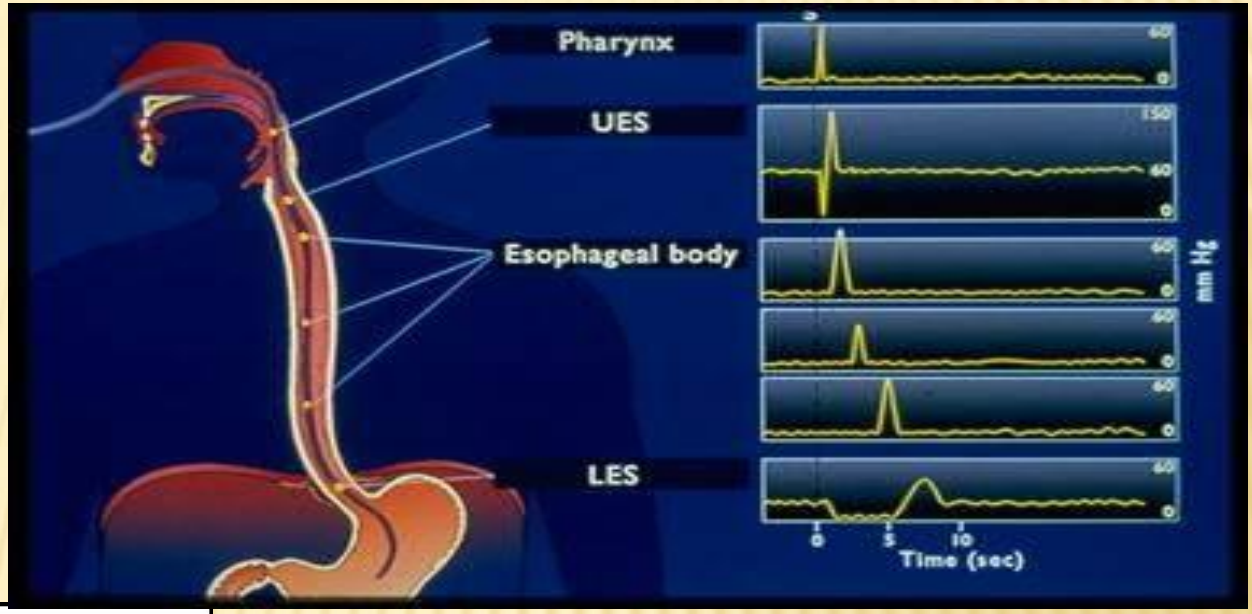
- Secondary peristaltic wave is formed, when the whole bolus is not moved.

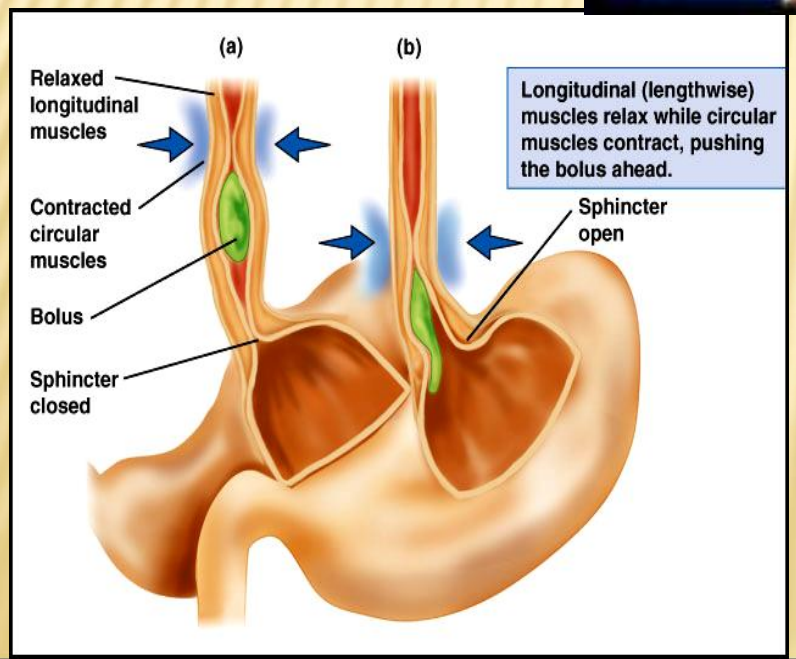


The primary peristaltic wave triggers from CNS, whale the second is function of *enteric nervous system*.

Motility of esophagus

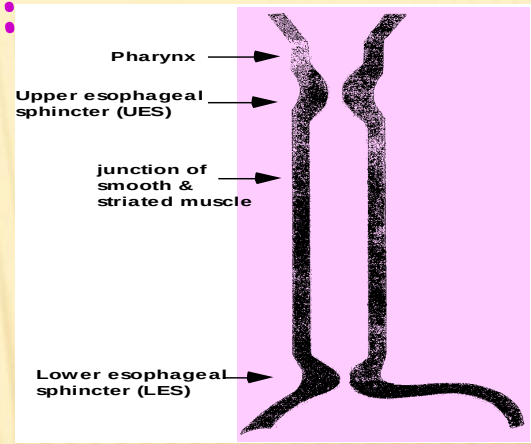
The time for passing of bolus through the esophagus is 10s.





Peristaltic wave is contraction of circular muscle layer and relaxation of longitudinal layer orally from the bolus; contraction of the longitudinal and relaxation of circular muscle layers distally from the bolus.

Functions of lower esophageal sphincter:

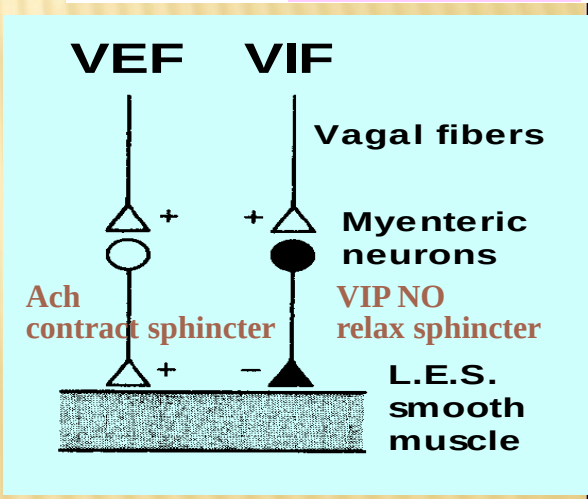


- coordination of movements of the bolus
- prevention against reflux of stomach content into esophagus

- **Innervations of lower esophageal shincter :**

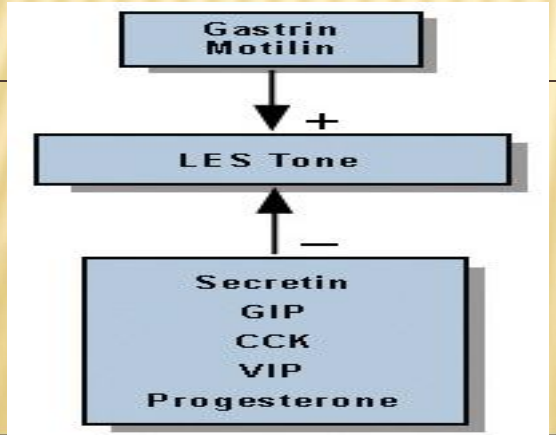
  The nervous fibers of ANS end to excitatory neurons (ACh), and inhibitory neurons (VIP и NO) of ENS

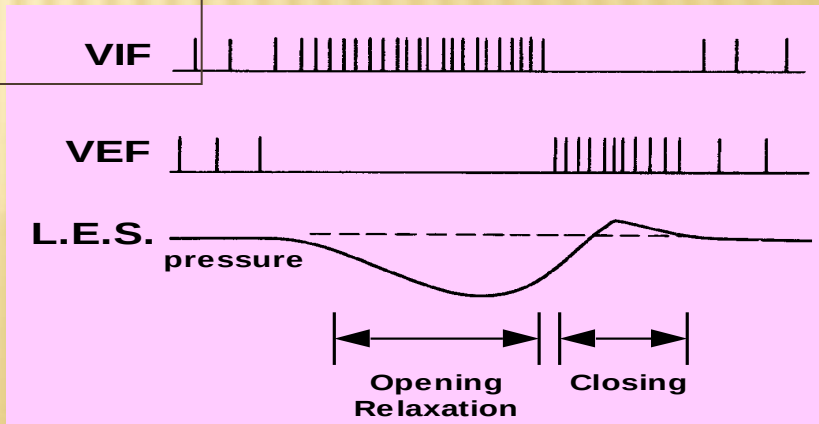
✓**pharasimpaticus (n.vagus has excitatory and inhibitory effects; simpathicus has only excitatory actions**



Stretching of esophagus causes excitation of inhibitory neurons that performed relaxation of sphincter, and after (5-20 s) activation of excitatory neurons occurs that closes the sphincter.

✦**hormonal control of LES:**





Control of swallowing

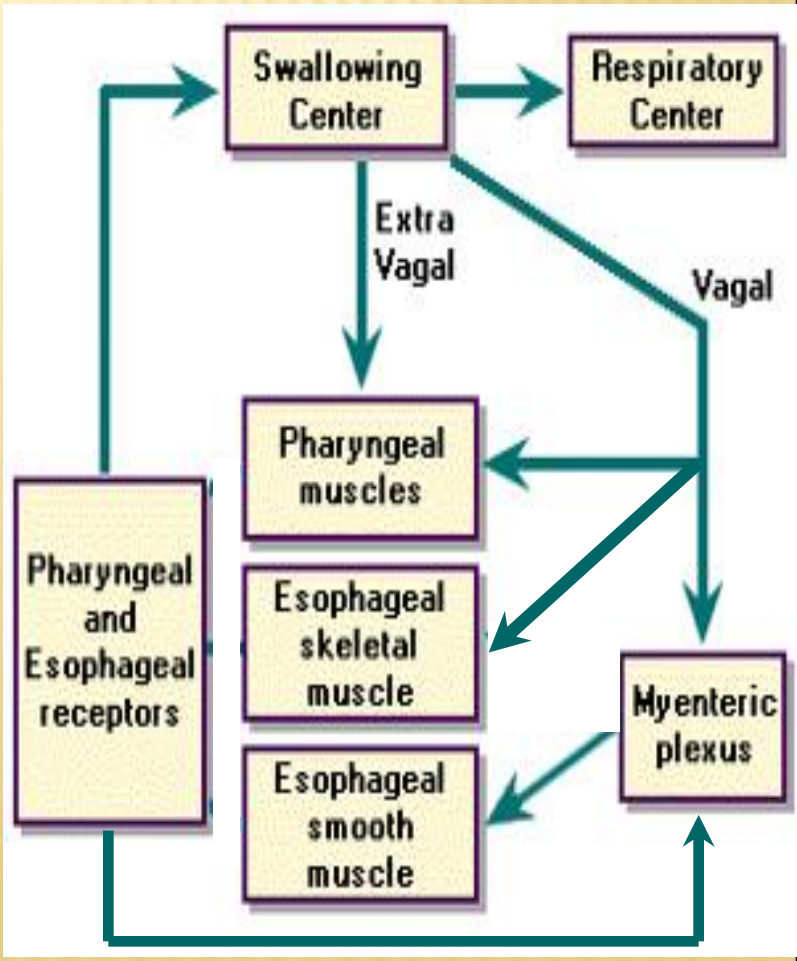
❖ The center of swallowing is situated at medulla oblongata and the lower part of pons.

➢ The swallowing may trigger voluntary (by the cortex) or involuntary by the signals from pharyngeal receptors.

❑ The center of swallowing sends impulses to motor nuclei of cranial nerves (V, VII, IX, X, XII) and initiates contractions of the muscles, that take part in swallowing.

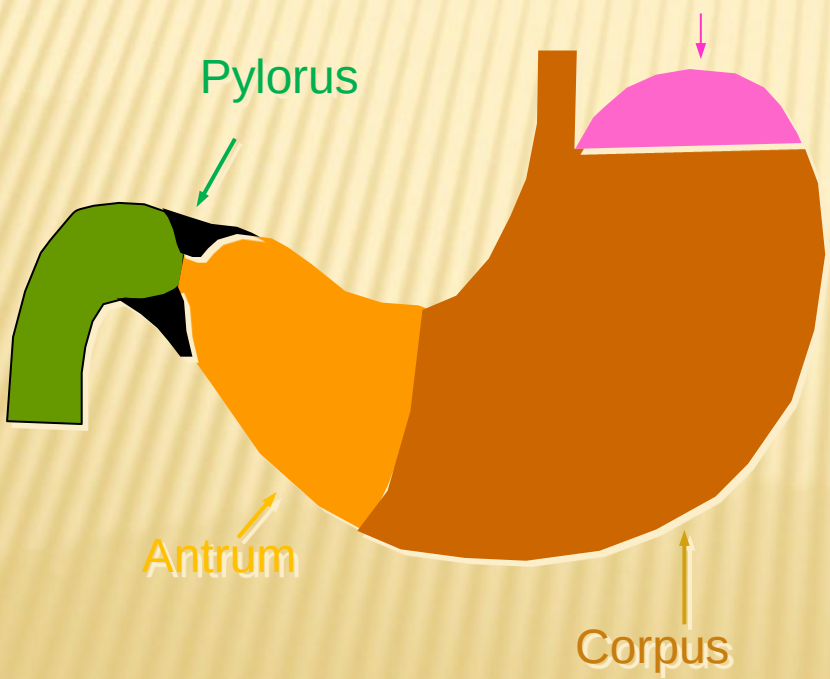
☞ The swallowing center inhibits respiratory center during process of deglutition.

✦Under physiological conditions the program of the swallowing center is modified by the information from peripheral receptors (from the swallowing muscles) thus the force and the time of contractions may be adapt to the size of the bolus.

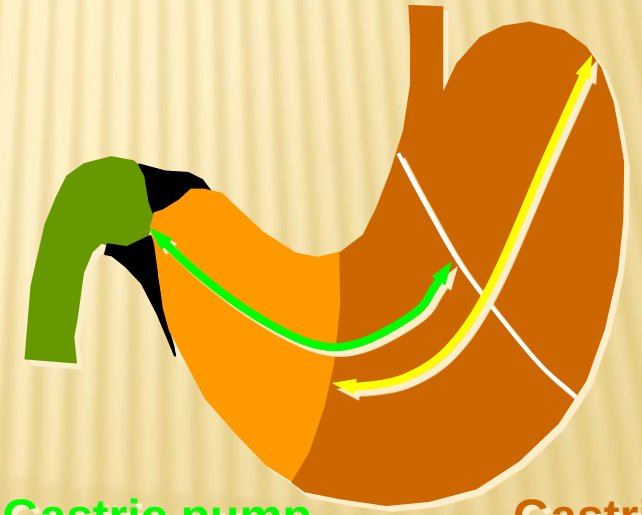


MOTOR FUNCTIONS OF THE STOMACH

Anatomical parts of the stomach



Functional parts of the stomach



Gastric pump
Phasic contractions

Gastric reservoir
Tonic contractions

MOTOR FUNCTIONS OF THE STOMACH

1. Storage of food

Function of fundus and upper 2/3 of the corpus of the stomach is realized by the change of muscle tone (tonic contractions).

2. Mixing of food with gastric secretions – formation of semifluid mixture called chyme

3. Emptying of food into the small intestine

✓ The last two functions are performed by the distal part of the stomach, called stomach pump (lower 1/3 of the corpus, antrum and pylorus) through phasic peristaltic contractions.

1. STORAGE OF FOOD:

- **RECEPTIVE RELAXATION** - INCREASE OF THE VOLUME OF THE STOMACH WITHOUT INCREASE OF THE TONE
- **ACCOMMODATION** OF THE VOLUME OF THE STOMACH TO THE ENTERED FOOD
- **DEPOSIT OF FOOD** IN THE ORDER OF ENTERING INTO STOMACH

- As food enters the stomach, it forms concentric circles of the food in the orad portion of the stomach, 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, accommodating greater and greater quantities of food up to a limit in the completely relaxed stomach of 0.8 to 1.5 liters.The pressure in the stomach remains low until this limit is approached.

2. MIXING OF FOOD WITH GASTRIC SECRETIONS

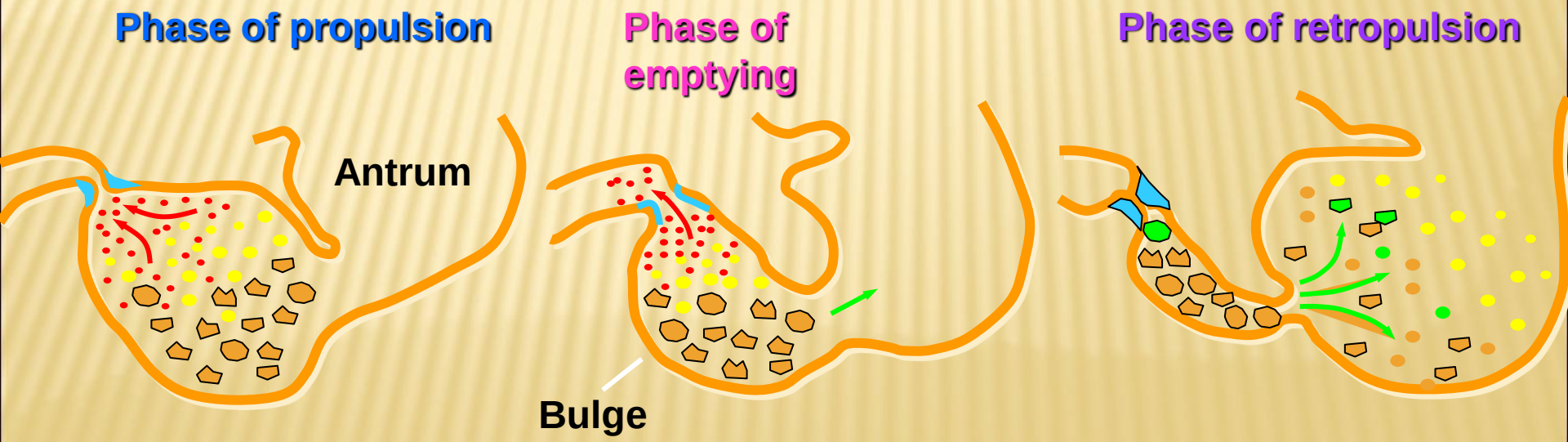
- As long as food is in the stomach, weak peristaltic *constrictor waves*, called *mixing waves*, begin in the mid- to upper portions of the stomach wall and move toward the antrum about once every 15 to 20 seconds.These waves are initiated by the gut wall *basic electrical rhythm.*
- "Slow waves" that occur spontaneously in the stomach wall with frequency 3-5 / min depolarize smooth muscle cells causing generation of AP and contraction.
- 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.
- Also, as each *peristaltic wave* approaches the pylorus, the pyloric muscle itself 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.

3. Emptying of food into the small intestine

- Phase of propulsion – contraction of proximal part of antrum propels chyme to its distal part that relaxes (fast movement of small fragments)

- Stomach Emptying – contraction of the midle part of antrum that propels fluid (av.7 ml) with small particles (1-2 mm) throuth the oppened pilorus into relaxed duodenum. The larger particles come back to proximal antrum.

- Phase of retropulsion – powerful contraction of distal part of antrum and closure of pilorus. This causes return of large particles back to antrum and breack up small.



CONTROL OF STOMACH EMPTYING

IT DEPENDS ON:

1. THE VOLUME OF INGESTED FOOD

2. THE CONTENT OF INGESTED FOOD

- The rate at which the stomach empties is regulated by signals from both the stomach and the duodenum.

Gastric Factors That Promote Emptying:

- **Increased food volume** in the stomach promotes increased emptying from the stomach.
- Effect of the **Hormone *Gastrin*** on Stomach Emptying - enhance the activity of the pyloric pump.

CONTROL OF STOMACH EMPTYING

Powerful Duodenal Factors That Inhibit Stomach Emptying:

The types of factors that are continually monitored in the duodenum and that can initiate enterogastric inhibitory reflexes include the following:

1. The degree of distention of the duodenum
2. The presence of any degree of irritation of the duodenal mucosa
3. The degree of acidity of the duodenal chyme
4. The degree of osmolality of the chyme
5. The presence of certain breakdown products in the chyme, especially breakdown products of proteins and perhaps to a lesser extent of fats

CONTROL OF STOMACH EMPTYING

Enterogastric inhibitory nervous feedback reflexes

1. antral reflex
2. enterogastral reflex

The effects of autonomic nervous system

* Parasympathicus increases peristalsis, relaxes pyloric sphincter and accelerates stomach emptying.
* Sympathicus has the opposite effect.

Humoral control – Gastrin, Cholecystokinin, GIP, Secretin

"HUNGER CONTRACTIONS"

occur *when the stomach has been empty* for several hours or more

cyclic activity between having of meal

duration 90-120 min

3 phases:

* the first 2 phases – slow waves
* the third phase - 10-15 min peristalsis, cleared undigested particles to duodenum and secretion of stomach juice

are controlled by ENS

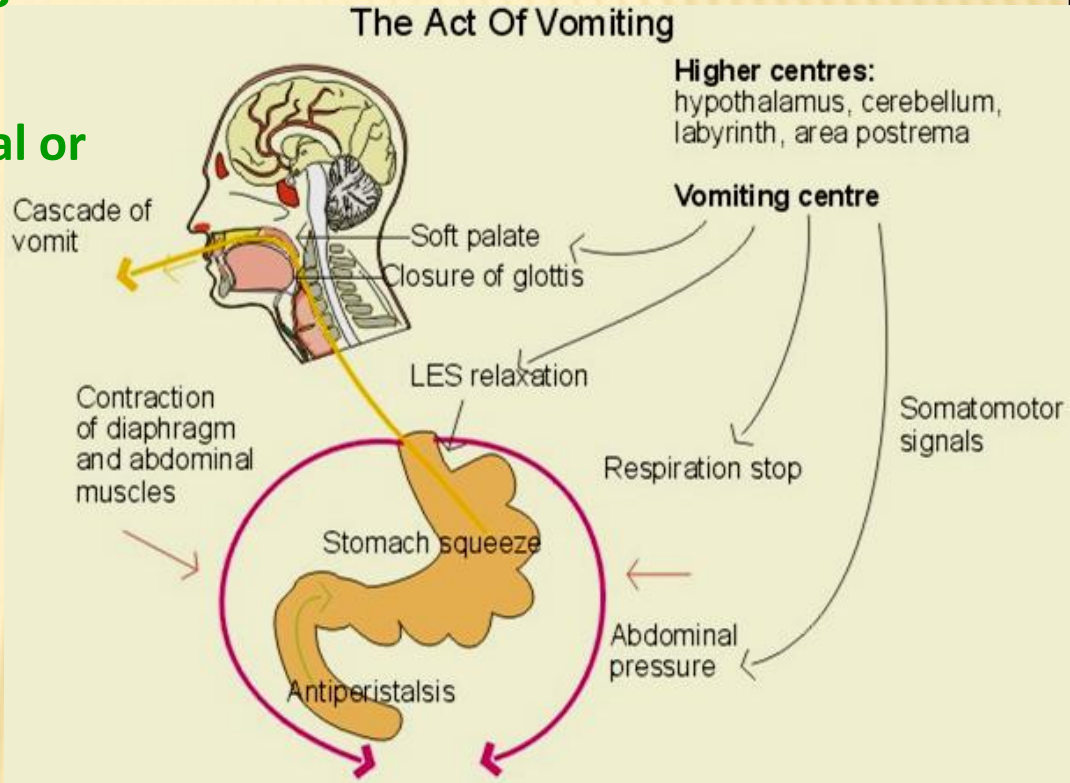
The act of vomiting

❖ The vomiting is a defensive reaction (reflex) of the organism to expel from the mouth stomach and some times intestinal content.

➢ NC is situated at medulla oblongata

➢NC receives information from:

- Receptors of GIT irritated by chemical or physical factors
- chemoreceptors of area postrema
- Hypotalamus; Cortex
- Cerebellum; Labyrint
- Meningeal receptors
- Nociceptors
- Taste receptors for sour sensation
- Peritoneal receptors



❑ The center of vomiting sends the impulses for:

✦coordinative contractions of abdominal muscles, diaphragm, stomach, esophagus and larynx

✦relaxation of upper and lower esophageal sphincters

✦stop of breathing

MOVEMENTS OF THE SMALL INTESTINE

Functions:

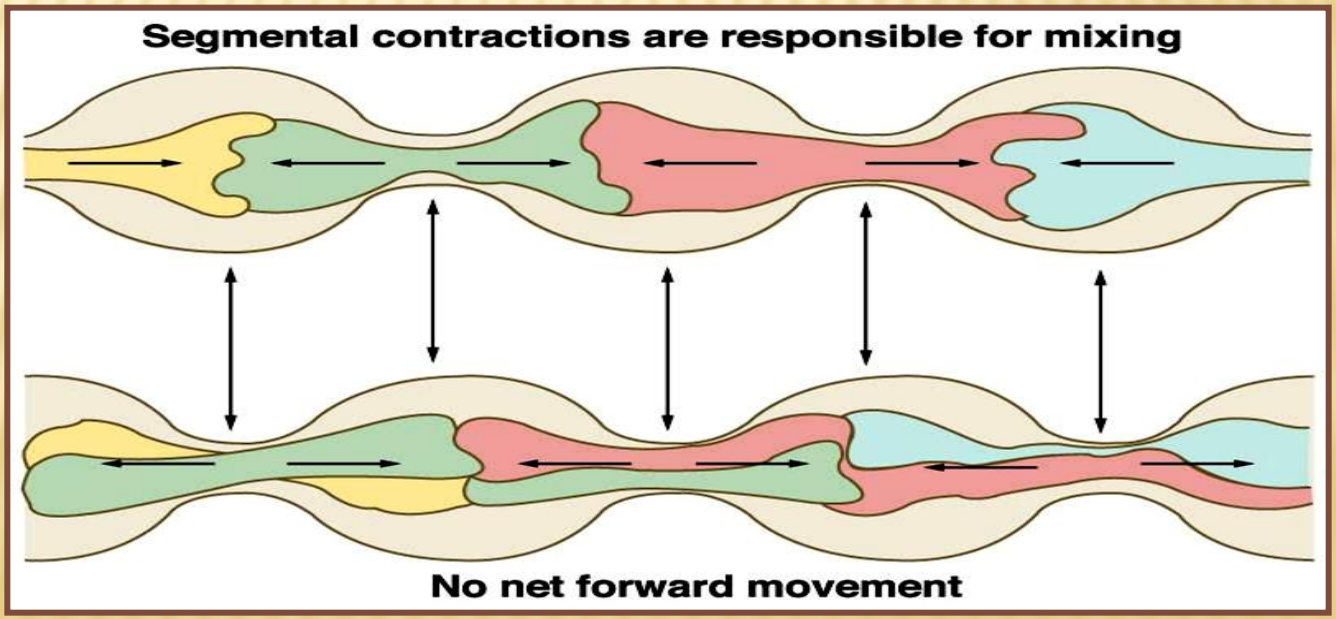
- **To intermix the intestinal content with bile, pancreatic and intestinal juices**
- **To ensure well contact of nutrients with intestinal mucosa for digestion and absorption at brush border**
- **To push forward the chyme into the colon**

The movements of the small intestine, like those elsewhere in the gastrointestinal tract, can be divided into

- *mixing contractions* and
- *propulsive contractions*.

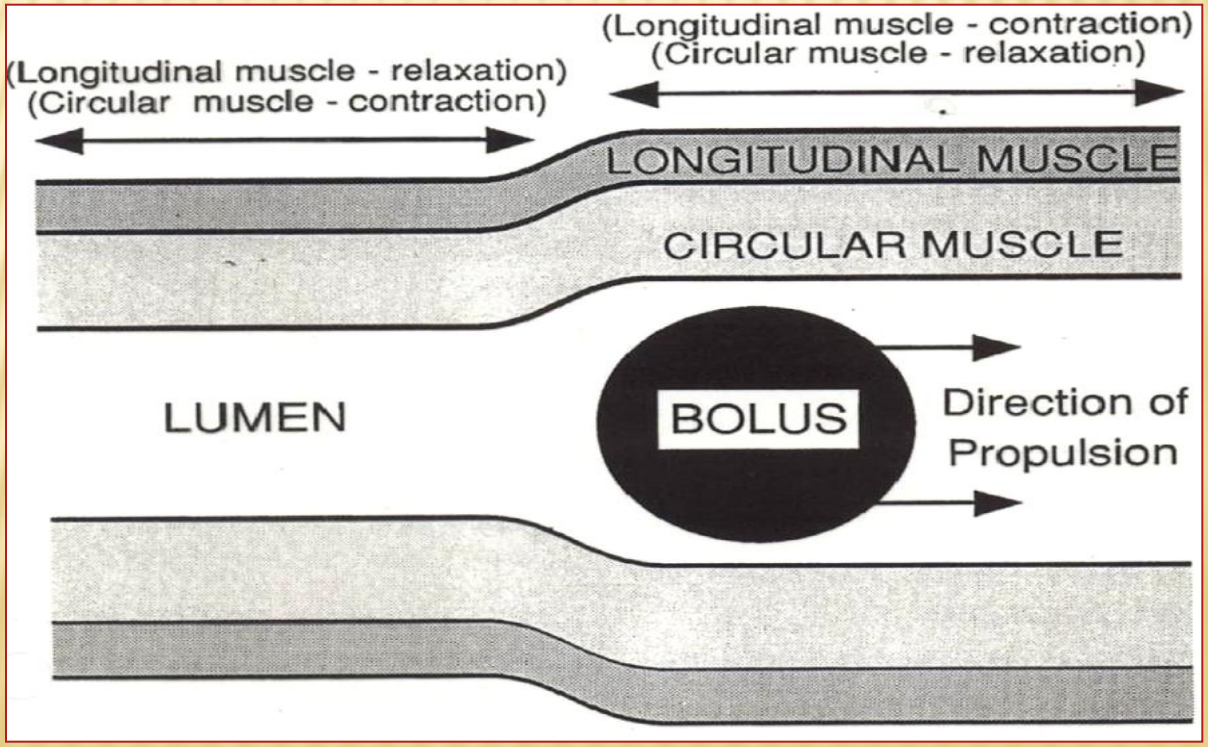
MIXING CONTRACTIONS (SEGMENTATION CONTRACTIONS)

- They divide the chyme into portions.
- The part of the small intestine contracts and pushes the chyme in two directions: oral and distal. After that the same segment relaxes and the chyme comes back.
- Their function is mainly to mix nutrients with digestive juices – forward/backward.
- They are performed by the circular muscles layer.
- The maximum frequency of the segmentation contractions in the small intestine normally is not over 12 per minute in the duodenum and proximal jejunum.In the terminal ileum, the maximum frequency is usually 8 to 9 contractions per minute.



PROPULSIVE (PERISTALTIC) MOVEMENTS

- Spreading ring contractions for propulsion of the chyme forward to colon
- The part behind the bolus contracts, whale this in front of it relaxes
- Peristaltic waves to short distance: 3-10 cm
- 3 to 5 hours are required for passage of chyme from the pylorus to the ileocecal valve.



CONTROL OF SMALL INTESTINE CONTRACTIONS

- Control by ENS (*gastroenteric reflex)*

  Local stretching of the smooth muscle layers

  The chemical content of the chyme: break down products of lipids, carbohydrates and proteins
- Control by ANS

  Parasympathicus - accelerates motility

  Sympathicus - inhibits motility
- *Control by the hormones*

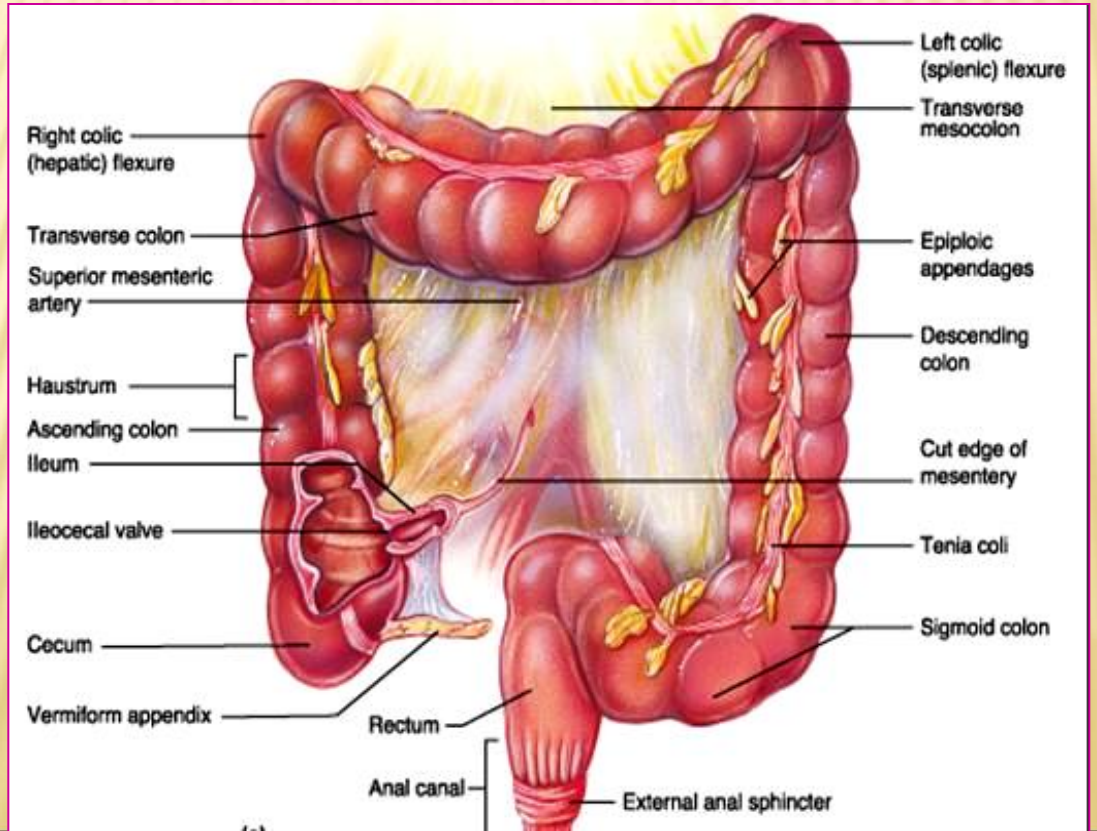
  gastrin, CCK, motilin, insulin – accelerate motility

  NA, A , secretin, glucagon – inhibit motility

❑ Colon is divided into 2 functional parts (the border between them is the middle part of transverse colon):

✓ right colon (cecum and ascending colon)-functions: absorption of water and electrolytes; bacterial fermentation

✓ left colon (descending colon, sigmoid colon and rectum) - functions: storage and expelling the faeces



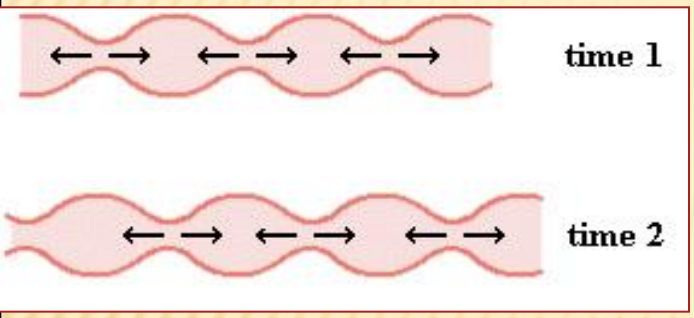
MOVEMENTS OF THE COLON

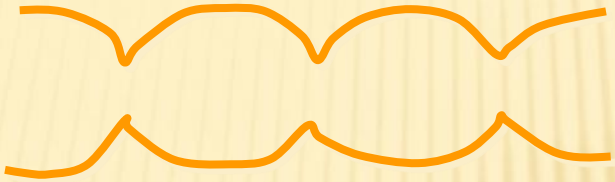
❖Functions:

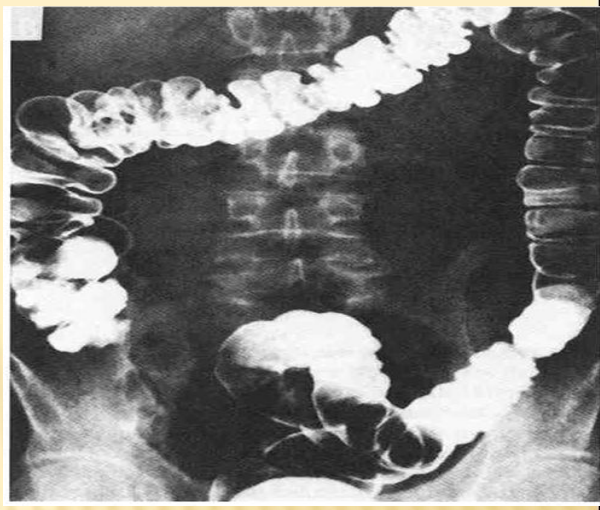
- To provide enough time for sufficient absorption of water and electrolytes
- To provide bacterial fermentation of undigested substances (cellulose) and absorption of their break down products
- To provide storage and formation of feces that periodically are moved and excreted

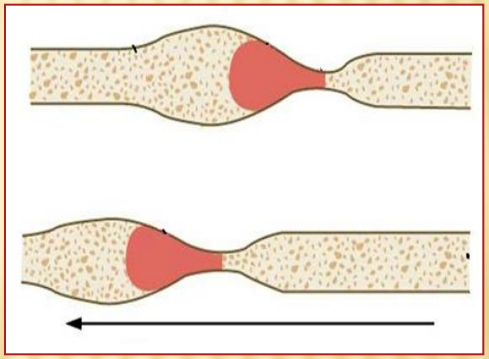
Movements of the Colon

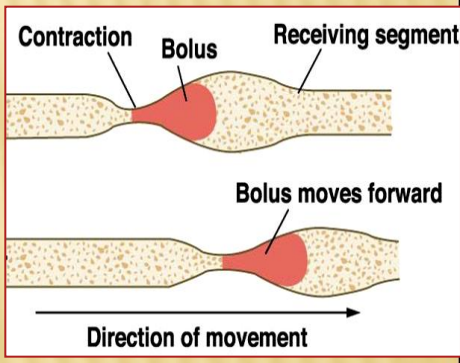
Mixing Movements - “Haustrations”



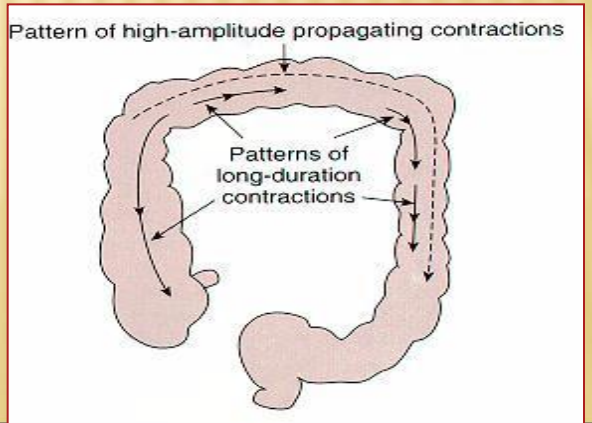






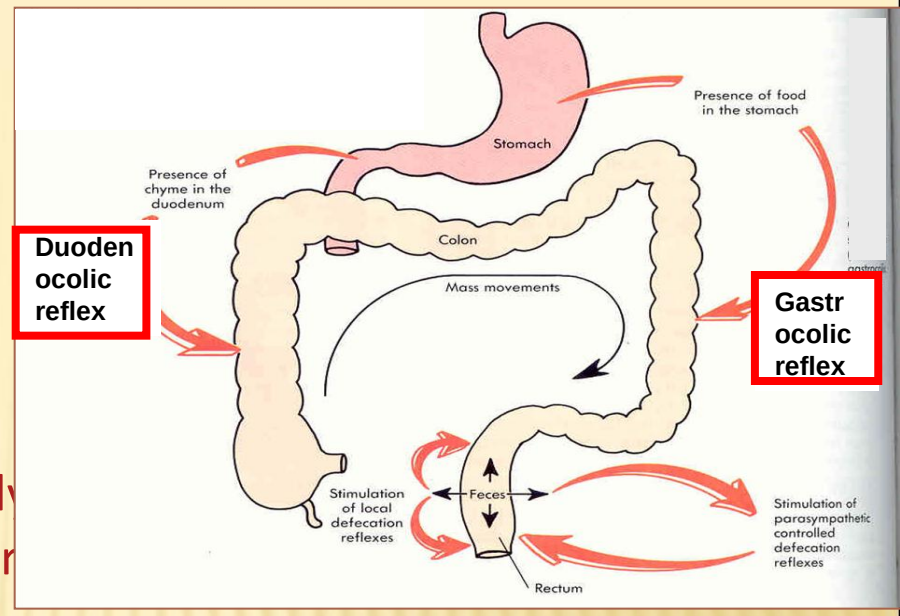


► **Propulsive Movements - “Mass Movements”**



Mass movements

Appearance of mass movements after meals is facilitated by ***gastrocolic*** and ***duodenocolic reflexes***. These reflexes result from distention of the stomach and duodenum.

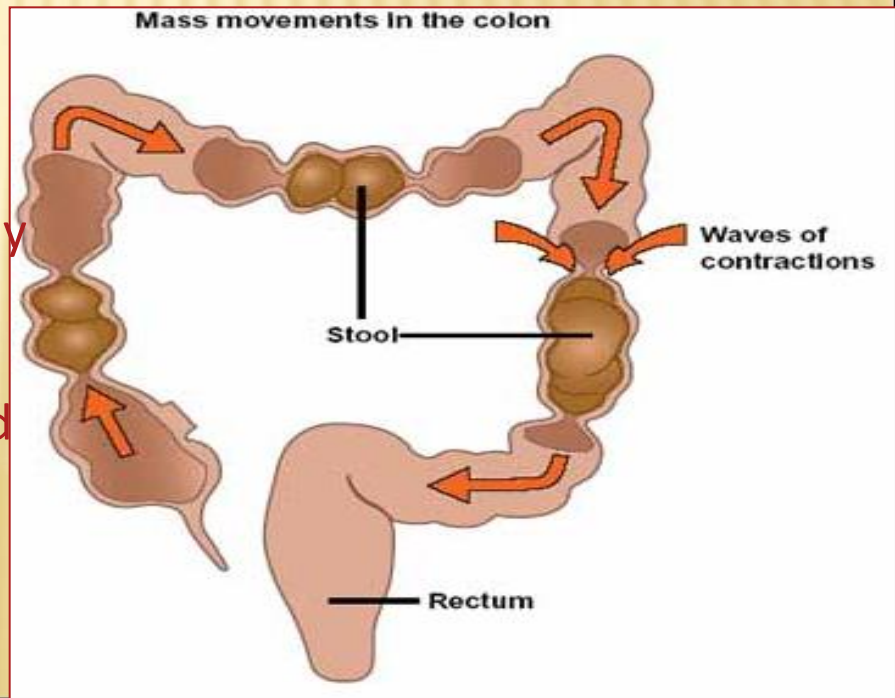


These movements usually occur only one to three times each day, in many people especially for about 15 minutes during the first hour after eating breakfast.

♦ A mass movement is a modified type of peristalsis characterized by the following sequence of events:

a *constrictive ring* occurs in response to ▪ a distended or irritated point in the colon, usually in the transverse colon

the 20 or more centimeters of colon *distal to the constrictive ring* lose their haustrations and instead contract as a unit, propelling the fecal material in this segment further down the colon.



CONTROL OF MOVEMENTS OF THE COLON

ANS

- **Parasympathicus** (n.vagus and nn. pelvici) increases motility
- Excitatory mediators: acetilcholin, substance P, serotonin

- **Sympathicus inhibits motility**
- mediators: ***noradrenalin and somatostatin***

Defecation

❖ Most of the time, the rectum is empty of feces.

When a mass movement forces feces into the rectum and it is distented, the desire for defecation occurs immediately, including reflex contraction of the rectum and relaxation of the anal sphincters.

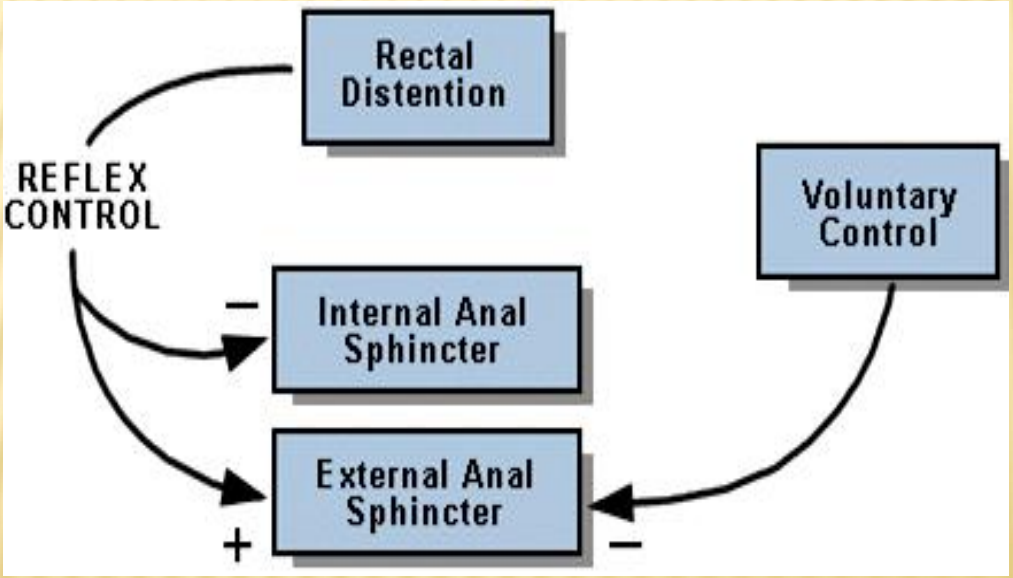
* **defecation reflex has reflex and voluntary control**

* NC is situated at S_2-S_4 segments of spinal cord.

* Information from this center to the brain cortex is sent and desire for defecation occurs.

✓ **relaxation of internal anal sphincter (smooth muscle)**

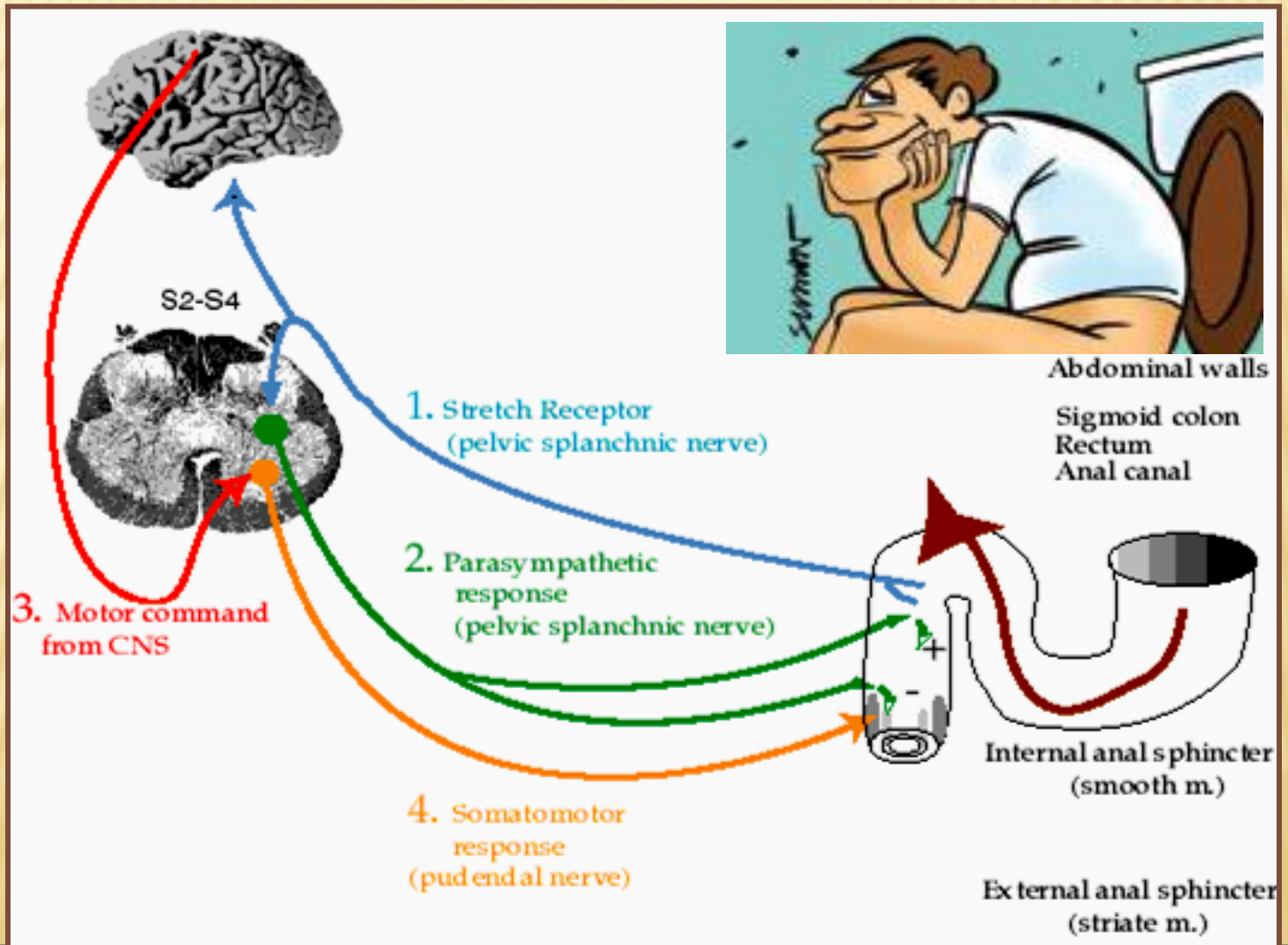
✓ **peristaltic wave in left colon and rectum**



Reflex contraction of external anal sphincter (striated muscles) or relaxation is controlled voluntary.

Defecation

Defecation signals entering the spinal cord initiate other effects, such as taking a deep breath, closure of the glottis, and contraction of the abdominal wall muscles to force the fecal contents of the colon downward and at the same time cause the pelvic floor to relax downward and pull outward on the anal ring to evaginate the feces.



Благодаря за вниманието!