

GASTROINTESTINAL PHYSIOLOGY

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General Principles of Gastrointestinal Function- Motility, Nervous Control, and Blood Circulation

◎ The alimentary tract provides the body with a continual supply of water, electrolytes, vitamins, and nutrients.

◎ *To achieve this requires*

peristaltic movement

◆ *Movement* of food through the alimentary tract.

◆ *Secretion* of digestive juices and digestion of the food.

ال large intestine فيها absorption of nutrients، لكن ممكن يصير فيها some absorption
(cecum, ascending colon) of eater in the right side of the colon وأول ال transverse

◆ *Absorption* of water, various electrolytes, vitamins, and digestive products.

◆ *Circulation* of blood through the gastrointestinal organs to carry away the absorbed substances.

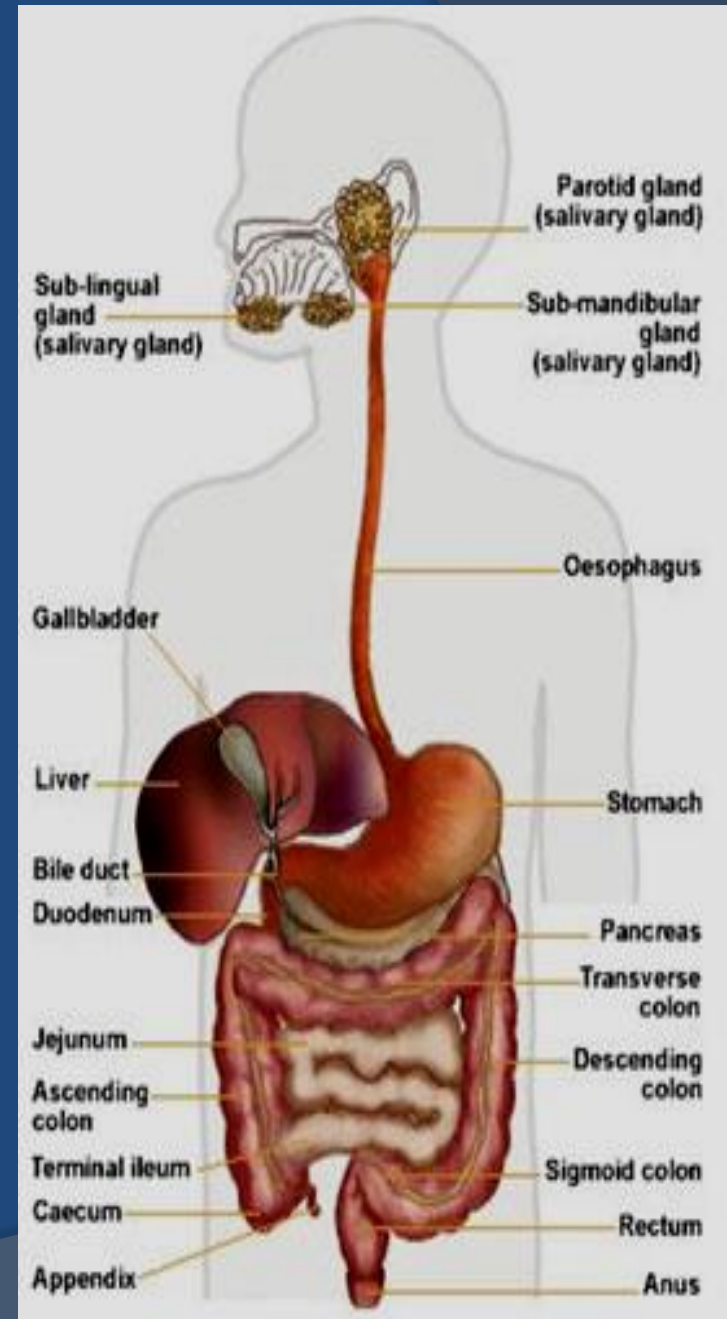
◆ *Control* of all these functions by local, nervous, and hormonal systems.

Central control by autonomic nervous system
Hormonal control like gastrin,.....

Digestive System

السبب هو فقدان ال muscle لل tone تبعها

- It is **5 meters** in living persons and **8 meters** outside the body.
- It is a muscular tube and its lumen is continuous with the mouth and the anus.
- The digestive tract is continuous with the external environment.



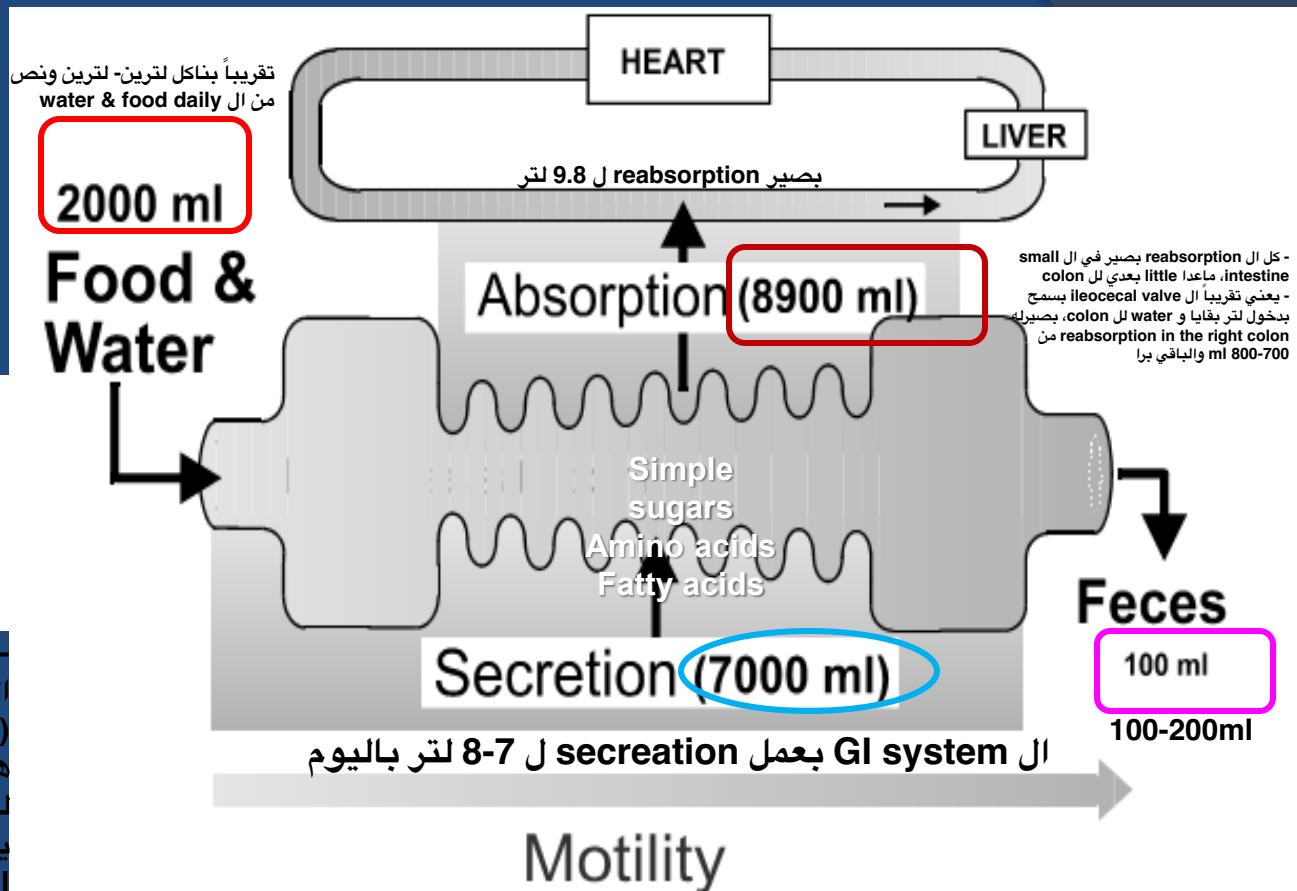
Components of digestive system

It consists of :

- 1 **Alimentary canal** (starts at the mouth and ends at the anus, consists of:
 - *Mouth , pharynx & esophagus.*
 - *Stomach.*
 - *Small intestine (duodenum, jejunum. Ileum).*
 - *Large intestine (cecum, appendix, colon & rectum).*
- 2 **Digestive glands** (Salivary glands, Liver, Gall Bladder, Exocrine Pancreas).

General functions of the Gut

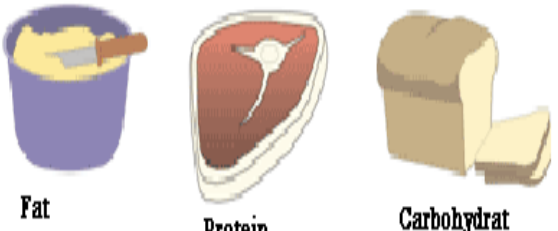
- ❖ **Food digestion.** What is the definition of digestion?
(Digestion is the breakdown of complex molecules into simple ones to facilitate their absorption).
- ❖ i.e. CHO $\Rightarrow$ Monosaccharide's, Proteins Amino Acids, Fat $\Rightarrow$ Fatty Acids). The process of digestion needs:-
 - Secretion of digestive juices.
 - Wall motility
- ❖ Food absorption
- ❖ Excretion of waste products



تقريباً بناكل لترين- لترين ونص
من ال water & food daily

بصير reabsorption ل 9.8 لتر

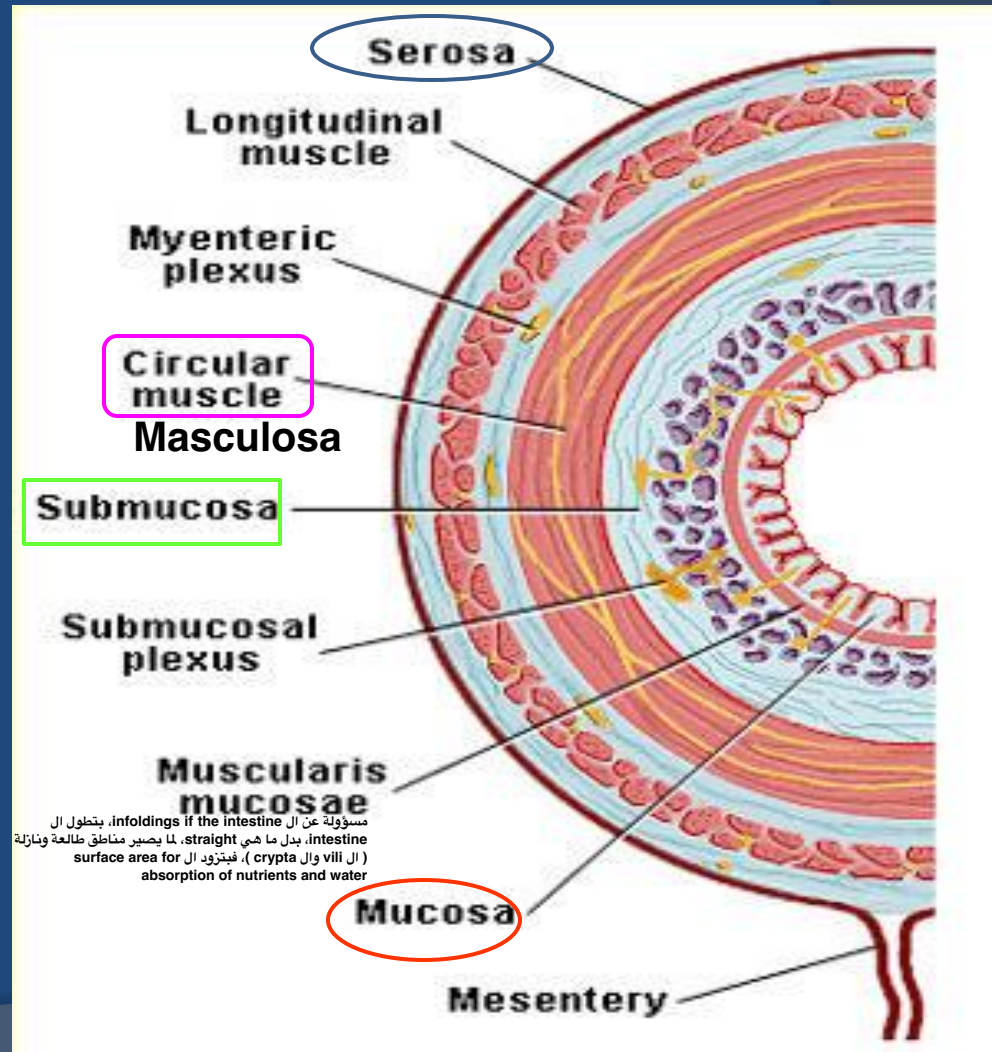
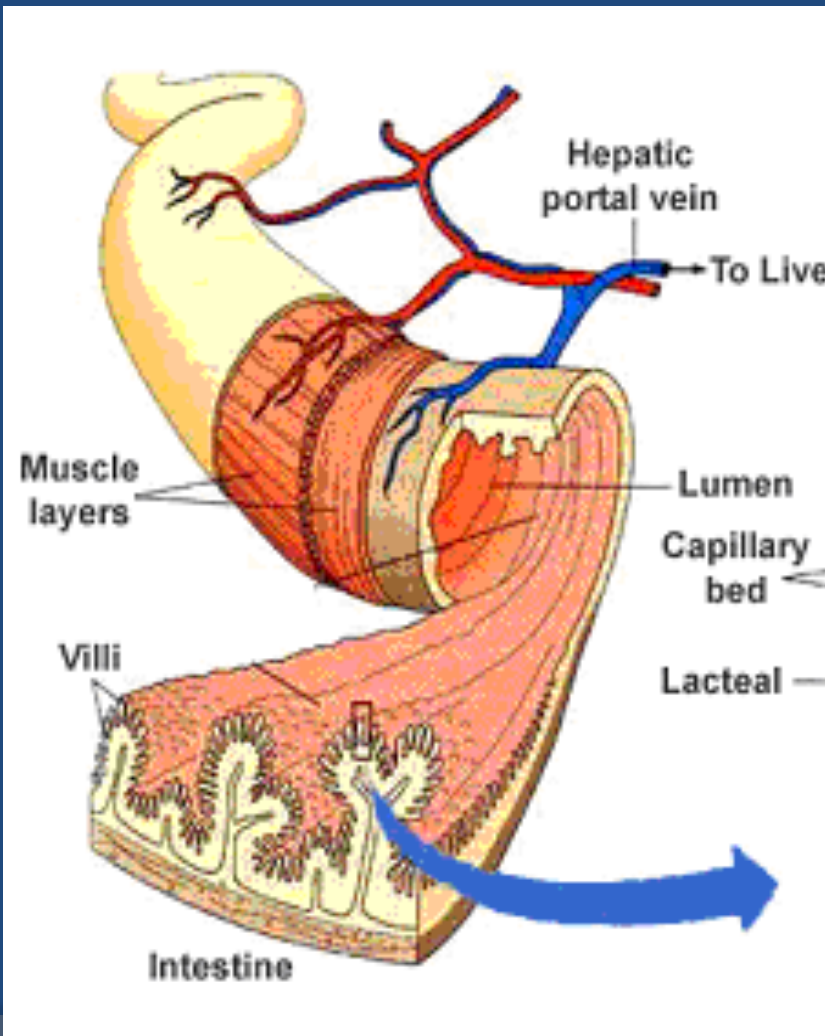
- كل ال reabsorption بصير في ال small intestine, ماعدا little بعدي لل colon يعني تقريباً ال ileocecal valve يسمج بدخول لتر بقايا و water لل colon, بصير ال reabsorption in the right colon من ال باقي برا 800-700 ml



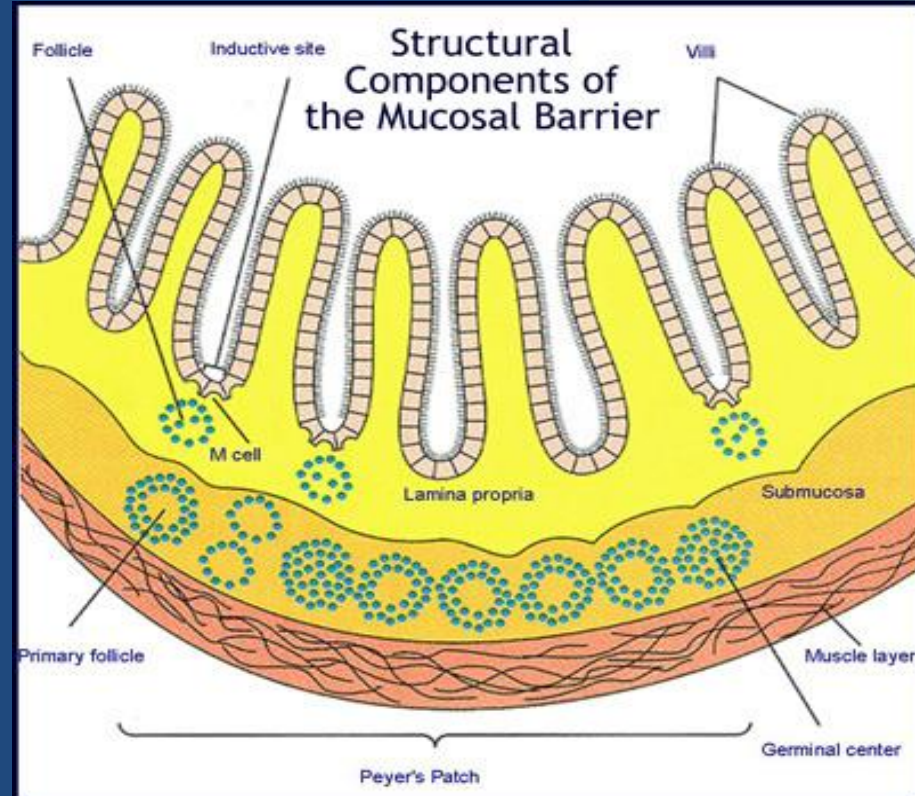
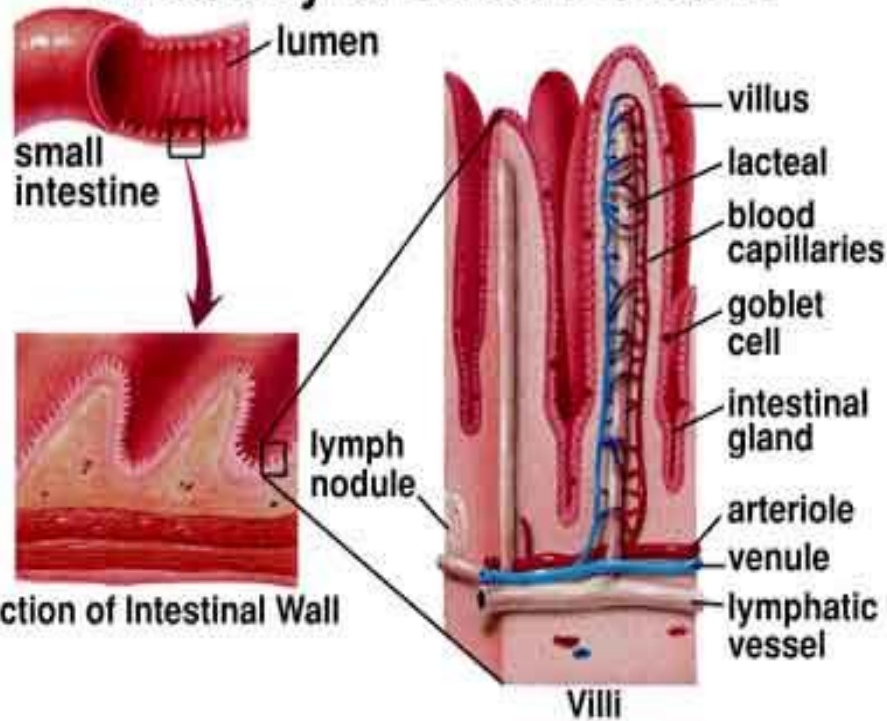
- طب عيان عنده cancer in the colon ال right side of the colon (right hemicolecotomy) شو بصير معه؟
هيصير اسهال طبعاً، لأنه مش هيصير امتصاص لتي كان بعدي في ال right colon، بدل ما كان يطلع 200ml في اليوم، هيصير يطلع 800-600 ml

Overview of gut functions

Structure of the Gut wall



Anatomy of Small Intestine



1. *The mucosa of the gut is highly folded. Why?*

● It is divided into:-

- Mucous membrane.
- Lamina propria (BV, nerves, lymphatic's & lymphoid tissue).
- Muscularis mucosa (modify the pattern of folding).

The submucosa consists of:-

- Blood vessels
- Submucosal plexus
- Meissner's plexus مسؤول عن ال secretion
- Lymphatic's
- Lymphoid tissue

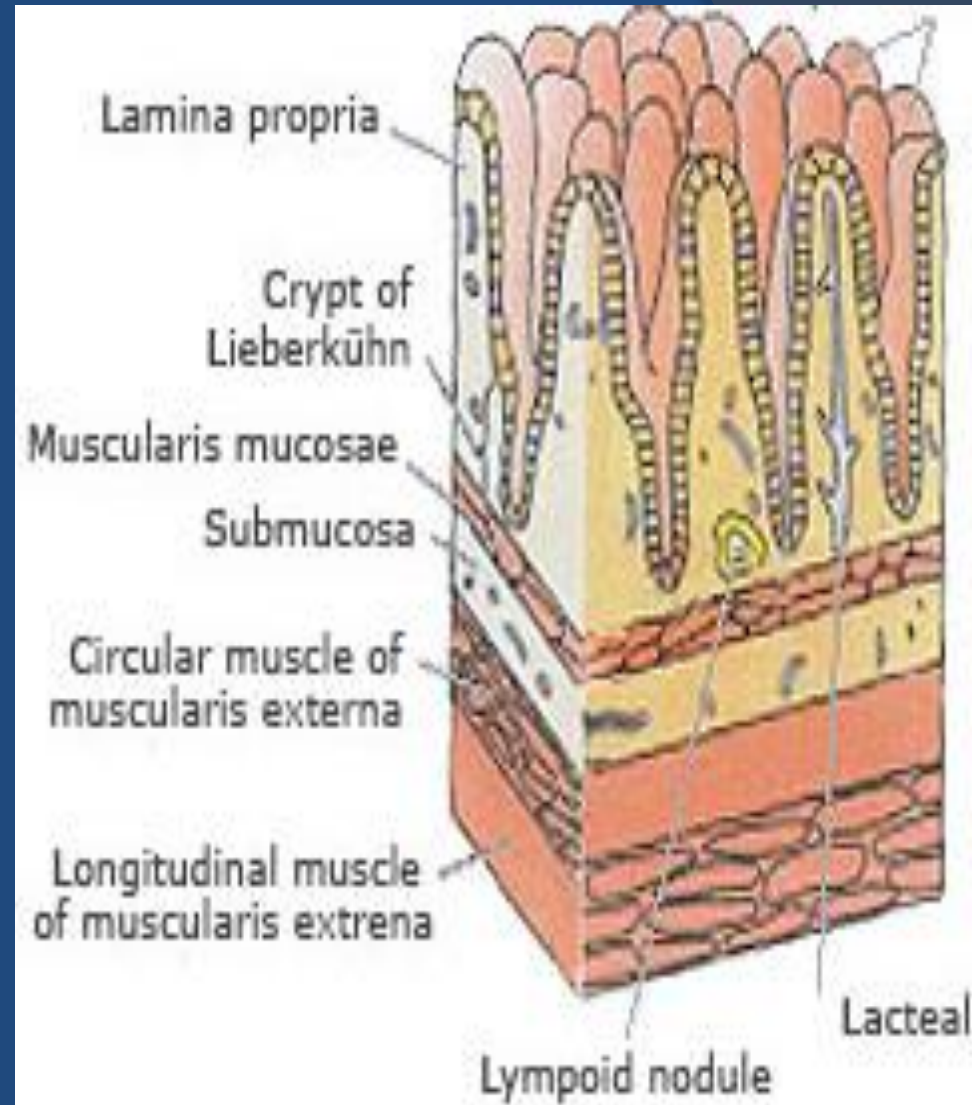
Muscularis externa consists of :-

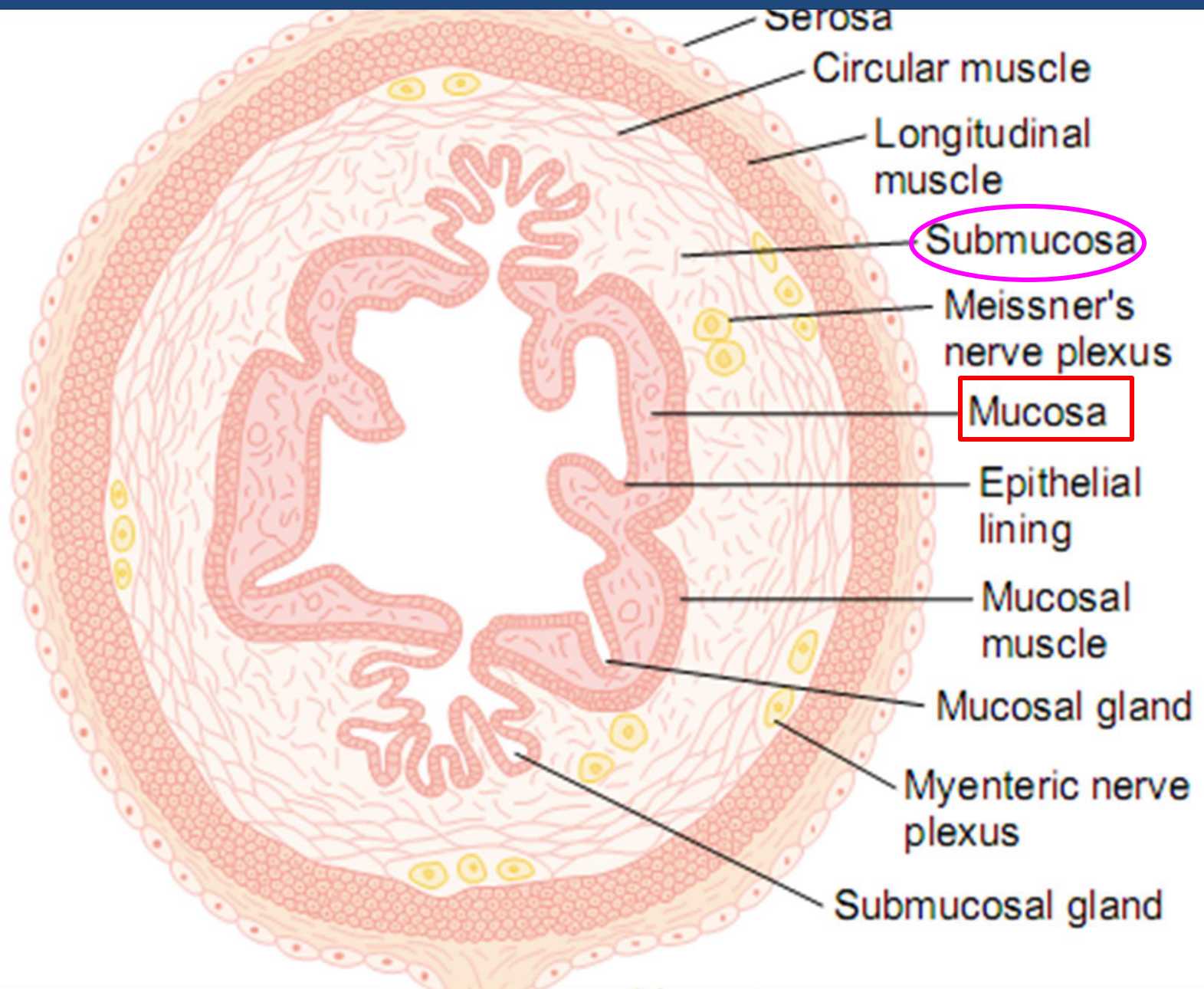
- Outer longitudinal layer
- Inner circular layer
- Nerve plexus in between (Auerbach's's plexus)

مسؤول عن ال GI motility

Serosa

It is the outer covering layer.





Gut layer

Function

Structure

<u>Mucosa</u>	1. Secretion of digestive juices and hormones. 2. Absorption of various nutrients. 3. Protection against infection.	1. Epithelial cells 2. Exocrine cells 3. Endocrine cells. 4. Muscle layer (muscularis mucosa) 5. Blood vessels , Lymph vessels & nerves
<u>Sub mucosa</u>	Contain the submucosal (Meissner's) nerve plexus which control GIT secretions.	1. Dense connective tissue. 2. Blood vessels, lymph vessels, and lymph nodes. 3. <u>Submucosal (Meissner's) nerve plexus.</u>
<u>Musculosa</u>	Gut motility	1. Outer longitudinal layer. 2. Inner circular layer 3. <u>Nerve plexus in between (Auerbach's' s plexus)</u>
<u>Serosa</u>	Secrete watery serous fluid. Lubricates and prevent friction	It continues with the mesentery. It contains nerves & blood vessels

Movement of materials from one container to another and mixing

Measure the concentration of hydrogen ion, the concentrations of protein, fat, and carbohydrate, and the tonicity of the digest

Addition of enzymes and fluid

Extraction of breakdown products



Gut Secretion

There are Exocrine glands located along the wall of the gut. في فال pharynx في ال esophagous و ال stomach وال small intestine و ال colon ..

- ال glands composed of two parts

- acinur
- duct

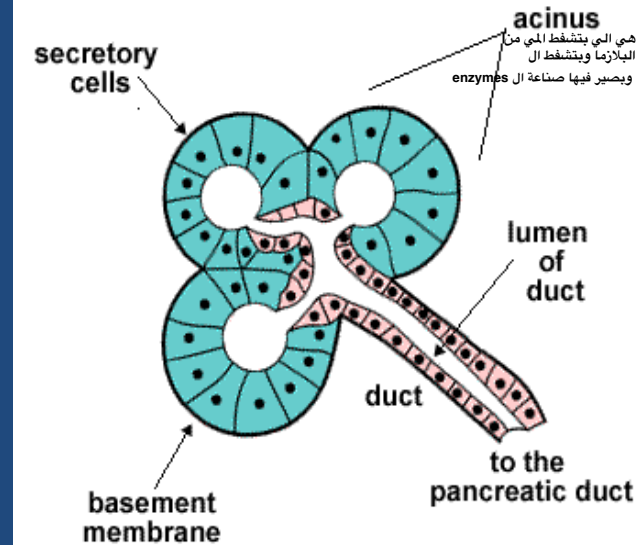
Each digestive juice consists of :-

- Water & Electrolytes
- Organic constituent .e.g. Enzymes & Mucus.

The gland extract water & raw material from the plasma.

The digestive secretion is then reabsorbed back to the blood after participation in the digestive process.

Failure of reabsorption of digestive juices may lead to **Circulatory Shock.**



ال duct بتعمل modification of secretion، يعني ممكن
تعمل reabsorption of sodium من ال initial fluid الى اجا
من ال acinus، نفرز بوتاسيوم، نغير ال acidity، نغير ال

Digestion & Absorption

- *Digestion* is the breakdown of complex molecules into simple absorbable unites.

It is accomplished by enzymes that hydrolyze certain bonds in the food molecule.

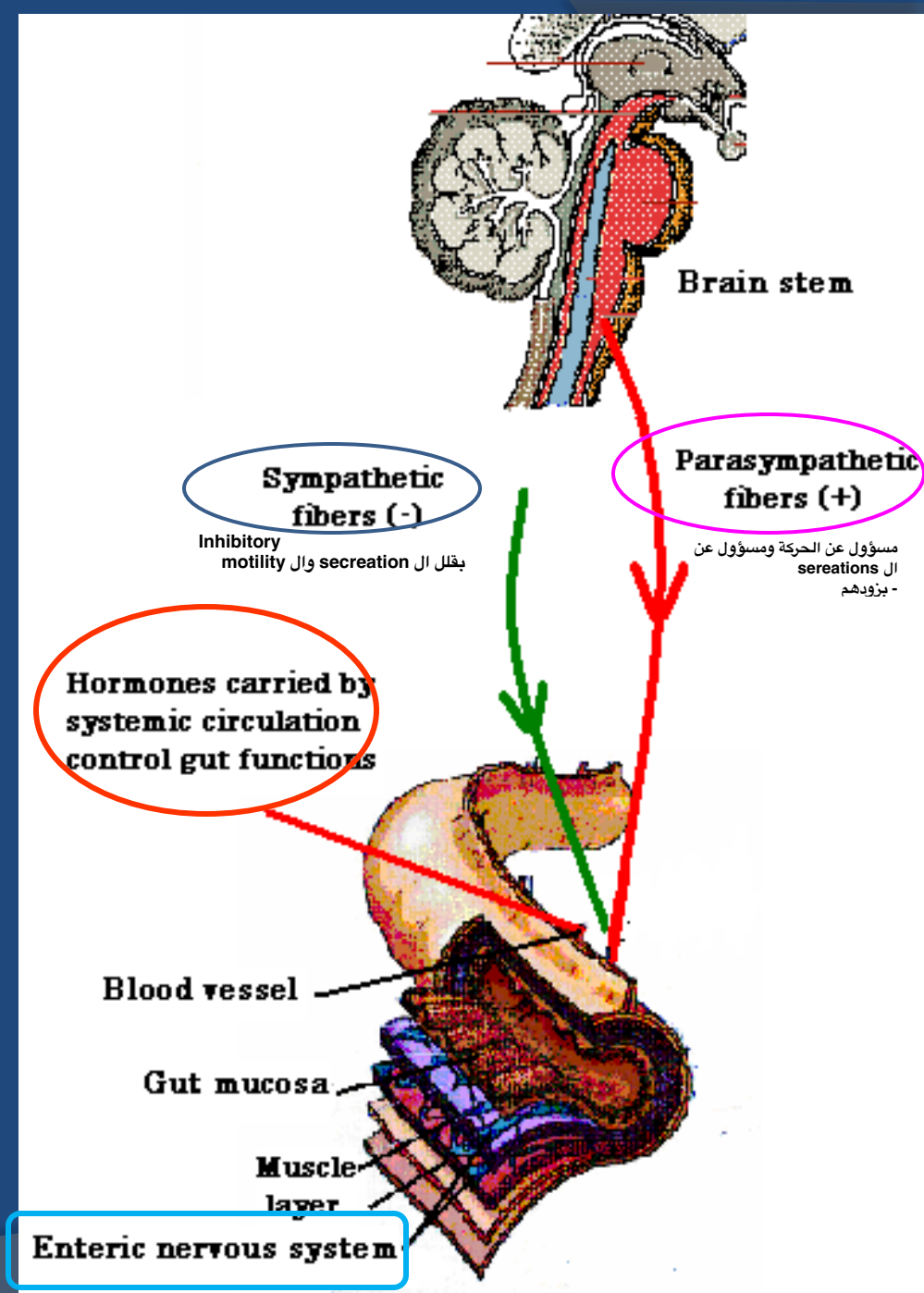
- *Absorption* occurs in the small intestine.

Undigested & unabsorbed materials are excreted to the outside by the process of defecation .

- Central regulation by Autonomic nervous system: sympathetic and parasympathetic nervous system
- hormonal regulation: like gastrin in the stomach (enhance gastrin secretion)
- enteric nervous system (Auerbach's's plexus & Meissner's plexus)

Regulation of gut functions

- ال parasympathetic في ال stomach هو ال vagus وهو 10 cranial nerve number، طب شو بعمل؟
- بعمل stimulation لل HCL secretion و ال stomach motility وعشان العصارة من ال pyloric تروح لل intestine لازم يصير ارتخاء في ال sphincter
- ال sympathetic عكس الكلام هاد



Control Of gut functions

Gut functions are controlled by :-

- Autonomous Smooth Muscle Activity.
- Nervous Regulation.
- Hormonal Regulation.

Nerve supply of the gut

1-Enteric nervous system

(local nerve plexuses)

- a- Meissner's plexus.
- b- Auerbach's plexus.

2-Autonomic nerves:

- a-Sympathetic.
- b-Parasympathetic (vagal, sacral).

Electrophysiology of GIT smooth muscles:

■ Gastrointestinal smooth muscle cells exhibit the following electric changes:-

-56 mv

■ *Changes in the level of smooth muscle resting potential (it is changed by sympathetic & parasympathetic stimulation as well as hormones).*

السkeletal muscle ال موجود في ال
في ال nerve cells وفي ال
smooth muscles of the GI

الresing ال هي عبارة عن تغير في ال
membrane potential

■ *Slow wave potential (BER).* Basic Electrical Rythim

■ *Spike potentials* contraction لما يصير

Functional syncytium of the GIT smooth muscles:-

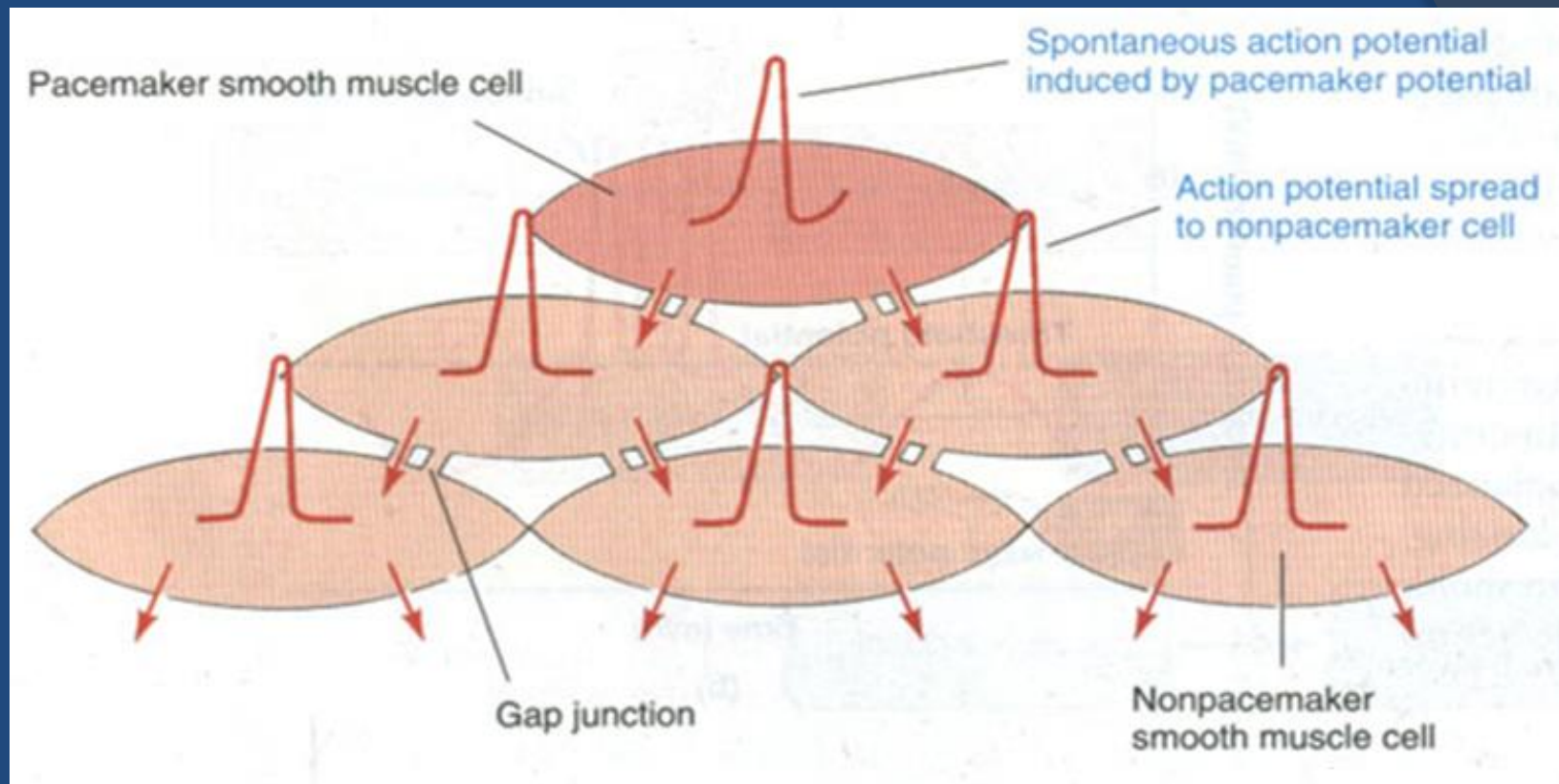
■ Sheets of smooth muscles cells are connected by Gap Junctions which are points of low electric resistance.

■ If AP was triggered in pace maker cells, it rapidly spreads to all smooth muscles.

syncytium is:

A large multinucleated cell that forms either by:

- The fusion of multiple individual cells, or
- Repeated nuclear division without cell (cytoplasmic) division



Functional syncytium of gut smooth muscles

يعني لما تشتغل وحدة pacemaker cell (بكون الها unstable resting membrane potential، يعني على طول بتغير) ويصير فيه تغير، عن طريق ال gap junction بتشغل كل ال smooth muscles الي حوالها

Electrophysiology of GIT smooth muscles:

- There are pace maker cells in the GIT smooth muscles (between the longitudinal & circular smooth muscle layers) called (INTERSTITIAL CELLS OF CAJAL).
هي التي بتبدأ ال impulse عشان ال smooth muscles تنقبض
- These cells are non contractile and have unstable RMP.
- They produce spontaneous depolarization and repolarization in the form of SLOW WAVES WHICH ARE CALLED BASIC ELECTRIC RHYTHM (BER).

PACEMAKER OF THE GUT

المسؤولة عن ال
gastrointestinal
stromal tumor of the GIT

Interstitial
cells of
Cajal

Smooth
muscle
cells

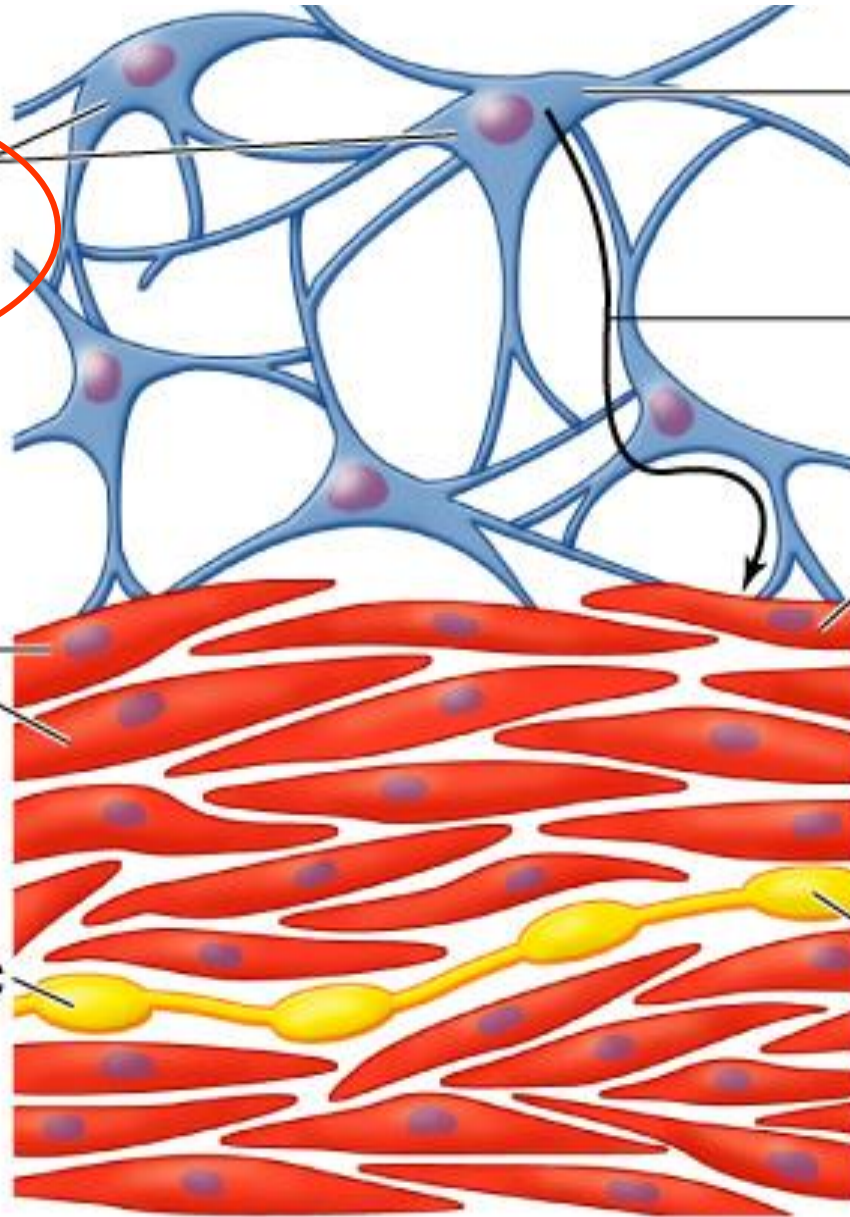
Autonomic
axon

Production
of slow waves

Conduction
of
slow waves to
smooth muscle

Depolarization
and opening of
 Ca^{2+} channels,
production of
action potentials

Neural input to
ICC and smooth
muscle

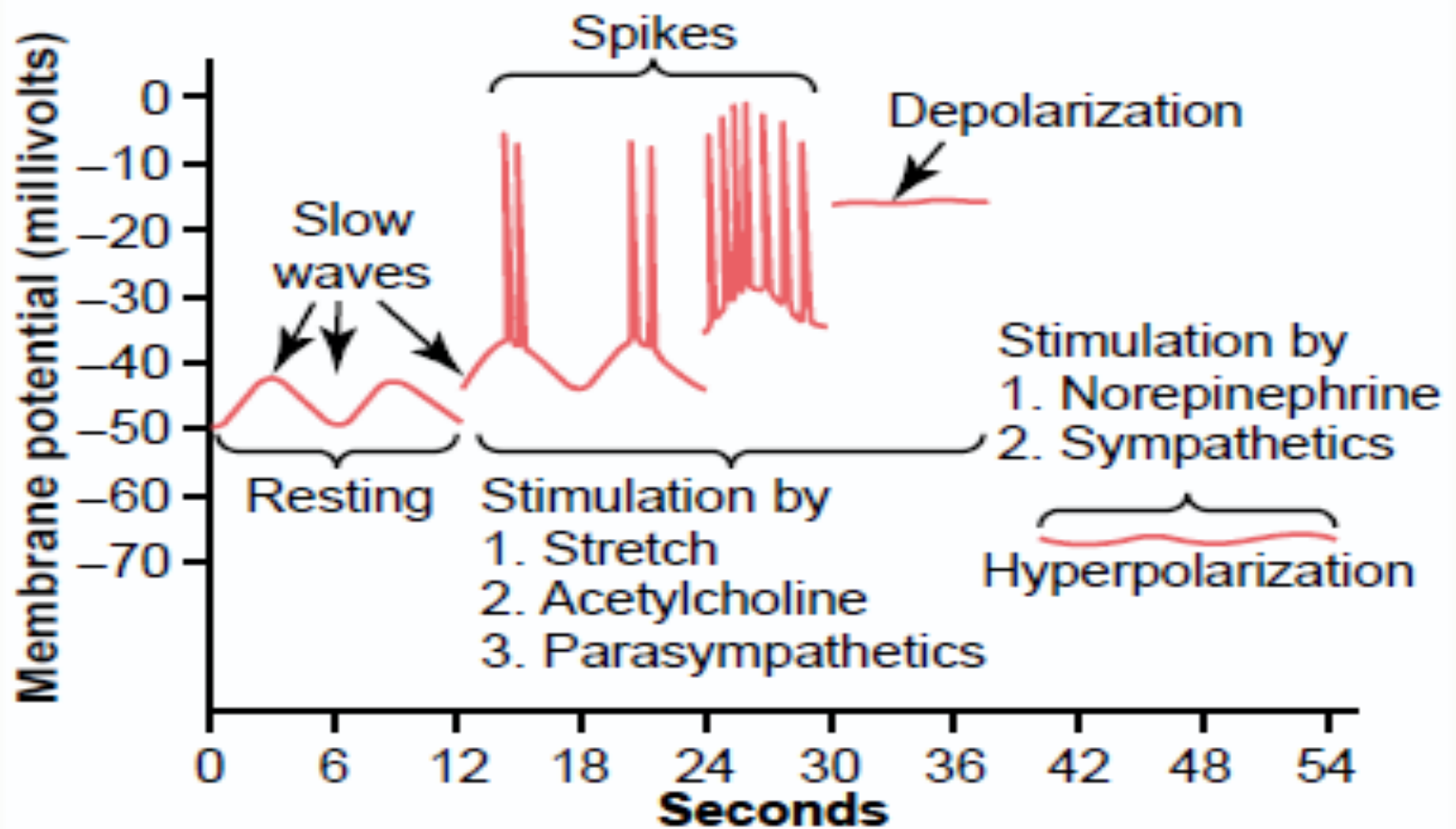


- *The frequency of slow waves depends on the section of the digestive tube*
- In the body of the stomach *3 / min*
- In the duodenum *12 / min*
- In the terminal ileum *8 or 9 / min.*
- In colon *3 / min*
- Slow wave activity appears to be a property intrinsic to smooth muscle and not dependent on nervous stimuli or hormones.
- It is *Not an action potential & doesn't induce muscle contraction.* (stomach).

- Action potentials difference between GIT smooth muscle and those of nerve fibers:
 - ◆ The spike potentials last 10 to 40 times as long in gastrointestinal muscle.
 - ◆ In nerve fibers, the action potentials are caused almost entirely by rapid entry of sodium ions through sodium channels.
 - ◆ In gastrointestinal smooth muscle fibers, the channels responsible for the action potentials Are calcium-sodium channels. (much slower to open and close).

Changes in Voltage of the Resting Membrane Potential.

- The resting membrane potential averages about -56 mill volts, but multiple factors can change this level.
- When the potential becomes less negative, which is called Depolarization of the membrane, the muscle fibers become More Excitable.
- When the potential becomes **More negative**, which is called Hyperpolarization, the fibers become Less Excitable.



Factors that depolarize the membrane—that is, make it more excitable—are :

- ◆ ***Stretching* of the muscle.** أهم وحدة
- ◆ **Stimulation by *Acetylcholine*.** neurotransmitter pf ال the parasympathetic
- ◆ **Stimulation by *parasympathetic nerves* that secrete acetylcholine at their endings,**
- ◆ **Stimulation by several *specific gastrointestinal hormones*.**

- Important factors that make the membrane potential more negative—that is, Hyperpolarize the membrane and make the muscle fibers less excitable—are:
- The effect of *norepinephrine* or *epinephrine* on the fiber membrane .
- Stimulation of the sympathetic nerves that secrete mainly norepinephrine at their endings.

هي not followed with spike بس لو
صار spike هيصير contraction

Slow wave & spike potentials

	Slow wave potential	Spike potentials
Definition	Oscillatory changes in membrane potential.	Train of action potentials that occur on top of slow waves when membrane potential reaches threshold.
Nature	Muscle property	The muscle must be primed by neurotransmitters released in the vicinity due to stimulation.
Frequency	Inherent to each region.	Depend on mechanical, nervous & hormonal factors
Mechanism	Not well understood	Opening of ion channels
Significance	Determines the rate of muscle contraction	Induce muscle contraction. Number of spike <u>potentials</u> determines the intensity of muscle contraction

Functional Types of Movements in the Gastrointestinal Tract

معناها هتكون autonomic nervous system

● **All GIT muscle is Smooth Muscle** except:

- ال smooth muscles بكون لونها أبيض

- Upper 1/3 of esophagus (skeletal muscle).
- Middle 1/3 of esophagus (skeletal and smooth).
- External anal sphincter (skeletal muscle).
- Movement of materials through the digestive tract is accomplished by smooth muscle contraction (Involuntary Control), except at the Oral & the Anal ends of the tract which contain skeletal muscles.

عشان يكون في control

TYPES OF BOWEL MOVEMENTS

= Peristalsis movement

(1) **Propulsive 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 mixing food مع ال tract من ال بتنفرز الي العصارة التي
movment

Propulsive Movements—Peristalsis

- ◆ A contractile ring appears around the gut and then moves forward.
- ◆ Peristalsis is an inherent property of many syncytial smooth muscle tubes, stimulation at any point in the gut can cause a contractile ring to appear in the circular muscle, and this ring then spreads along the gut tube.
- ◆ (Bile ducts, Glandular ducts, Ureters).

- **The usual stimulus for intestinal peristalsis is Distention of the gut.** هاد ال normal physiology

That is, if a large amount of food collects at any point in the gut, the stretching of the gut wall stimulates the enteric nervous system to contract the gut wall 2 to 3 centimeters behind this point, and a contractile ring appears that initiates a peristaltic movement.

- **Chemical or physical irritation of the epithelial lining in the gut.**
Chemical: يعني لو مثلاً شربت حاجة بتعمل diarrhea يعني هتزوّد ال peristalsis
Physical: حاجة inside، مثلاً بكتيريا، gastroenteritis، Cholera وهادي برضو بتزوّد ال peristalsis
- **Parasympathetic nervous signals.**

Function of the Myenteric Plexus in Peristalsis

- Peristalsis occurs only weakly or not at all in any portion of the GIT that has congenital *Absence of the Myenteric plexus.*
- Also, it is greatly depressed or completely blocked in the entire gut when a person is treated with Atropine to paralyze the cholinergic nerve endings of the Myenteric plexus.
- Therefore, *effective* peristalsis requires an active *Myenteric Plexus.*

- ال minibrain of the gut هما ال Auerbach's's plexus & Meissners plexus.
- لو فش Auerbach's plexus يبقى فش حركة، زي الي بصير في ال achalasia of the esophagous والي تعريفها
aperistalsis of the body of the esophagous and faliure of relaxation of the lower esophageal sphincter

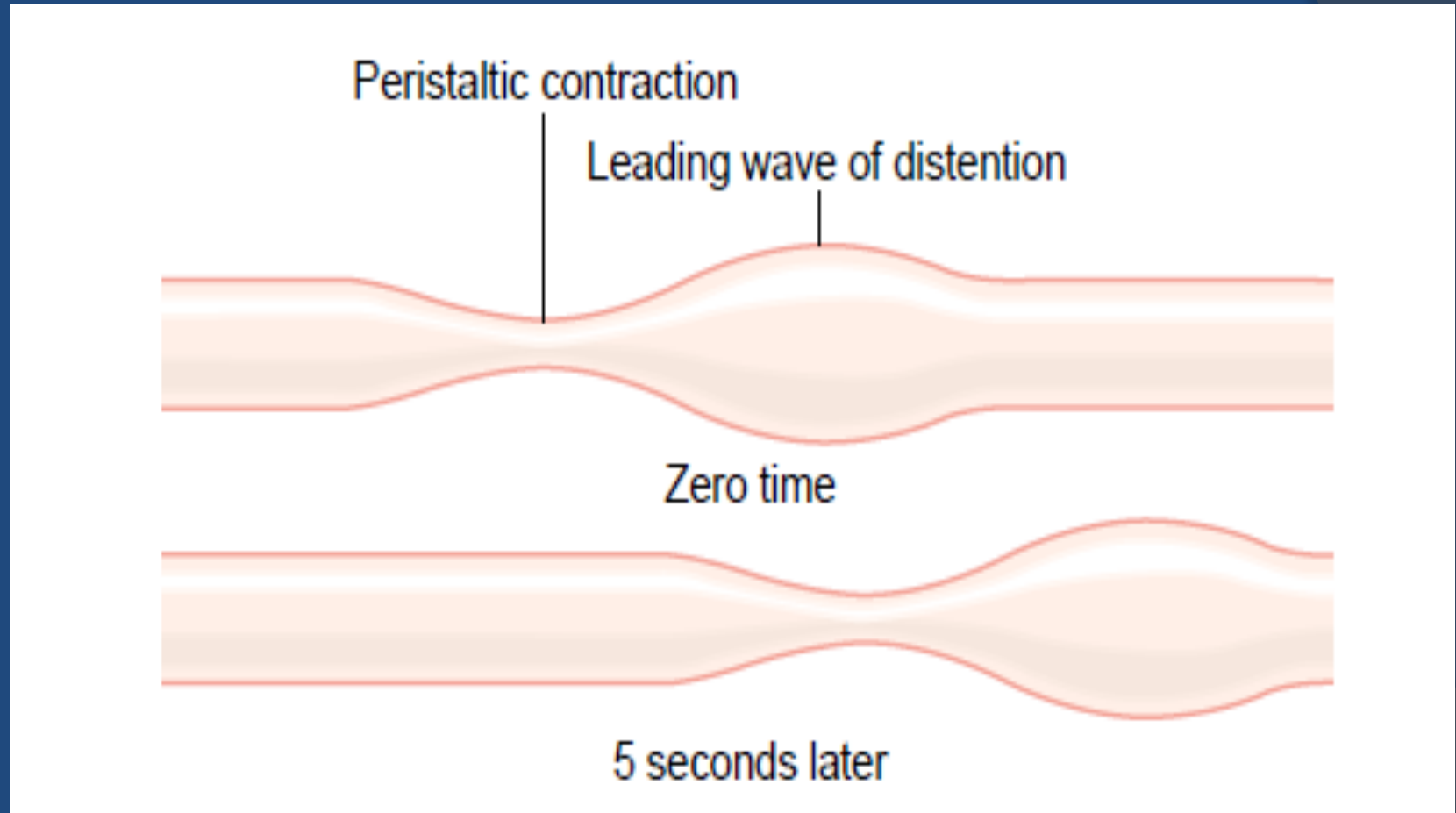
Directional Movement of Peristaltic Waves Toward the Anus.

- The exact cause of this directional transmission of peristalsis has never been ascertained, although it probably results mainly from the fact that the myenteric plexus itself is *“Polarized”* in the anal direction.

Peristaltic Reflex and the "Law of the Gut"

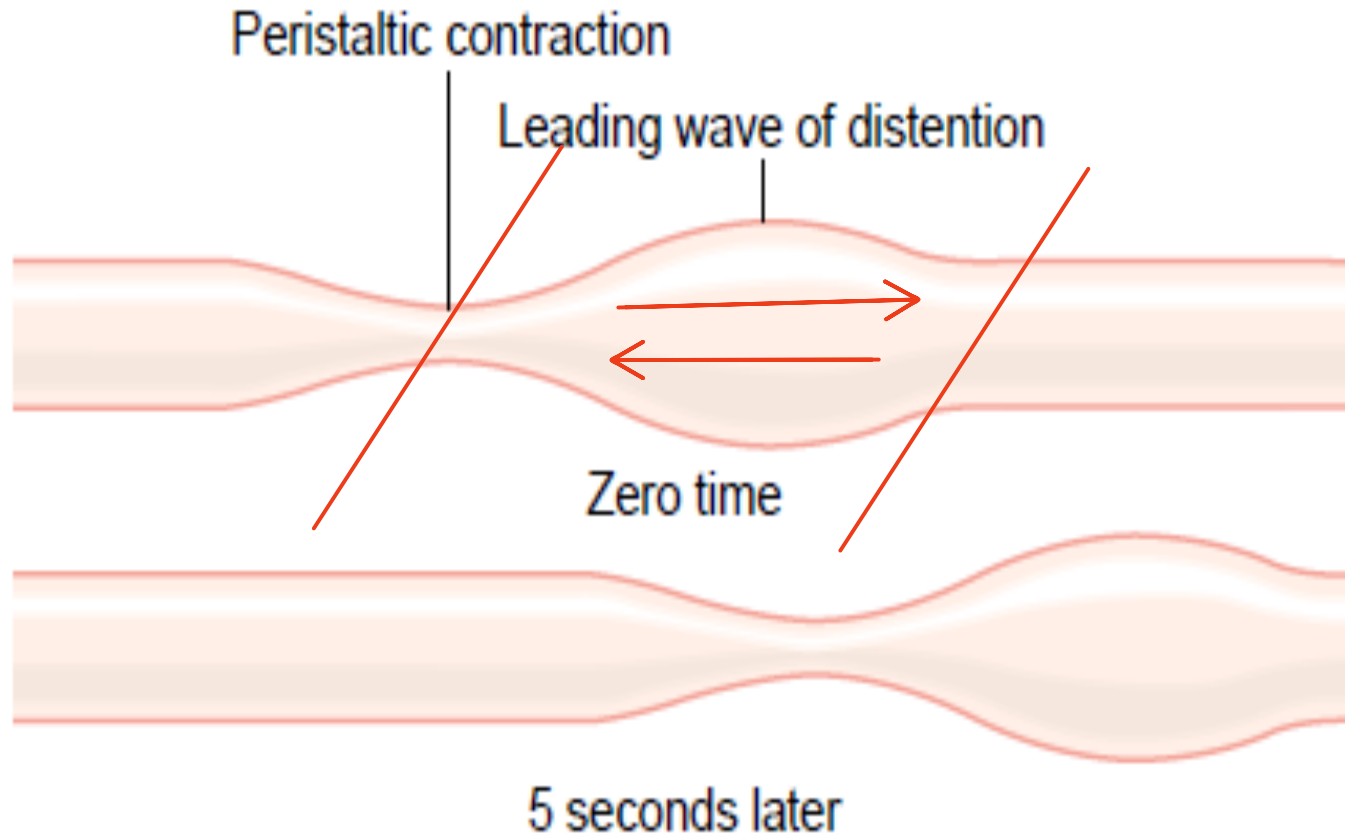
- When a segment of the GIT is excited by distention and initiates peristalsis, the contractile ring causing the peristalsis normally begins on the oral side of the distended segment and moves toward the distended segment, pushing the intestinal contents in the anal direction for 5 to 10 cm before dying out.
- At the same time, the gut relaxes several centimeters downstream toward the anus, which is called "receptive relaxation," thus allowing the food to be propelled more easily toward the anus than toward the mouth.
- Therefore, this complex is called the *Myenteric reflex* or the *peristaltic reflex*.
- The peristaltic reflex plus the anal direction of movement of the peristalsis is called the "law of the Gut"

المنطقة التي فيها الأكل صار فيها stretch وهو ال main stimulus، فقبل المنطقة هادي ب 2-3 cm بصير ال peristaltic contraction فبعملها Porsche حوالي 5-10 cm



- ال distention بيعمل stimulation لل depolarization و action potential الي يبدأ proximal 2-3cm
 - طيب عشان ال food يمشي لازم يصير في ال distal part حاجة بنسميها receptive relaxation

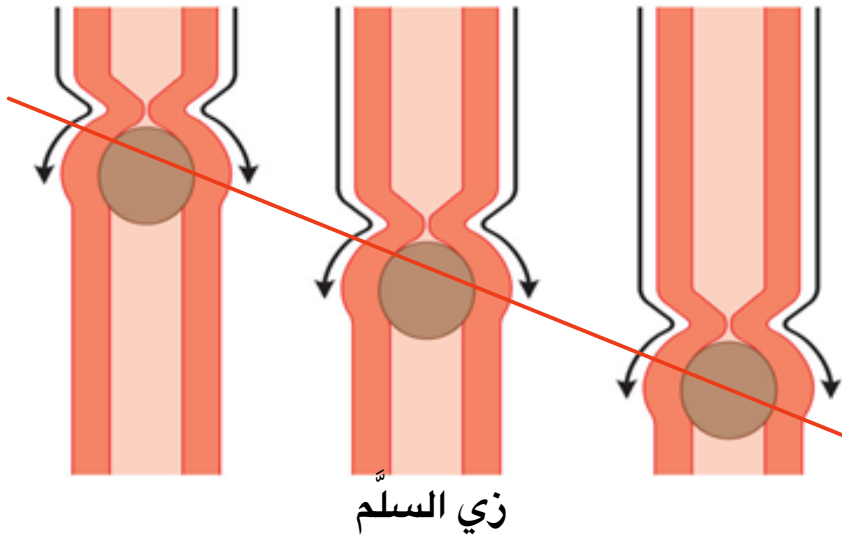
- في ال Mixing movment شو بصير؟؟
بصير contraction هان وهان (قبل وبعد ال streched part) فبصير يدخل



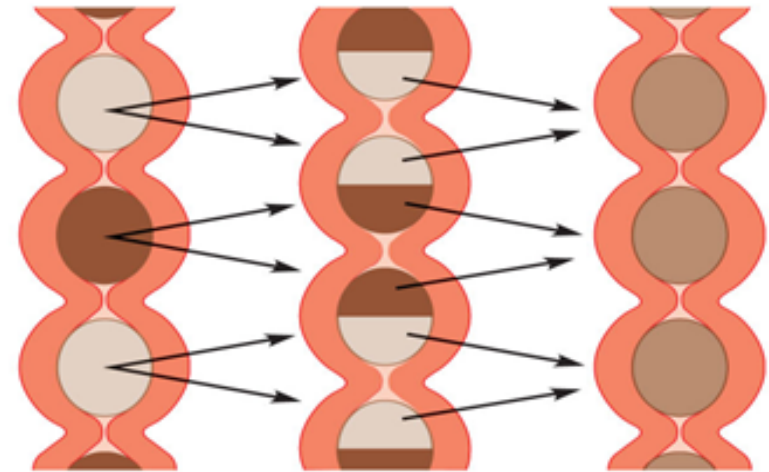
Mixing Movements

- ❖ In some areas, the peristaltic contractions themselves cause most of the mixing.
- ❖ This is especially true when Forward Progression of the intestinal contents is Blocked by a sphincter, so that a peristaltic wave can then only churn the intestinal contents, rather than propelling them forward.
- ❖ At other times, **local intermittent constrictive contractions** occur every few centimeters in the gut wall.
- ❖ These constrictions usually last only **5 to 30 seconds**, then new constrictions occur at other points in the gut, thus “Chopping” and “Shearing” the contents first here and then there.

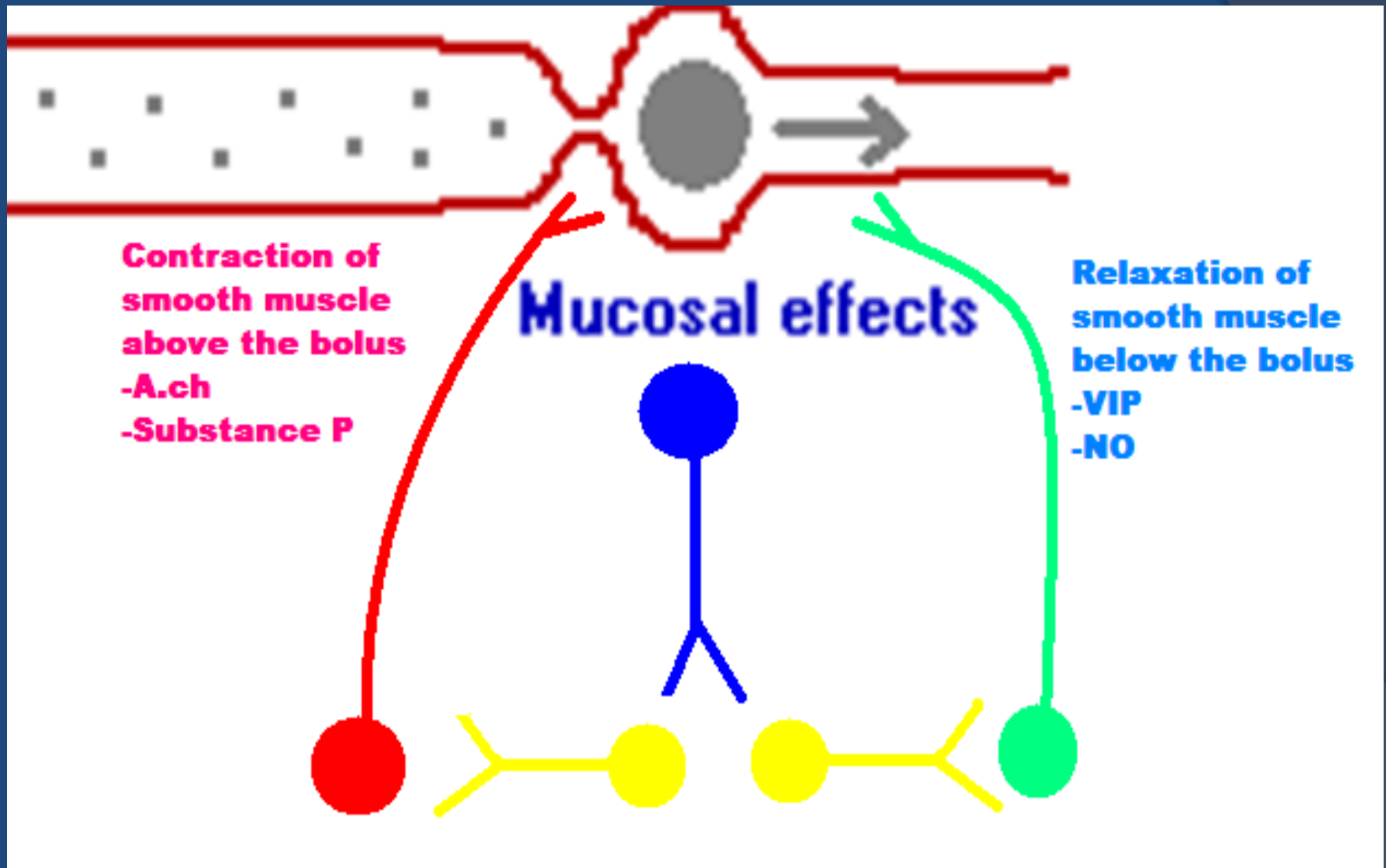
زي شكلك وانت بتخض بالقهوة مع السكر عشان تعملها رغوة زي اليوتيوب



Peristalsis: **Adjacent** segments of alimentary tract organs alternately contract and relax, which **moves** food along the tract distally.



Segmentation: **Nonadjacent** segments of alimentary tract organs alternately contract and relax, **moving the food forward then backward.** Food mixing and **No propagation** and slow food propulsion occurs



Minibrain of the gut

The gut's brain, known as the enteric nervous system, is located in sheaths of tissue lining the esophagus, stomach, small intestine and colon.

SMALL INTESTINE CROSS SECTION

Submucosal plexus

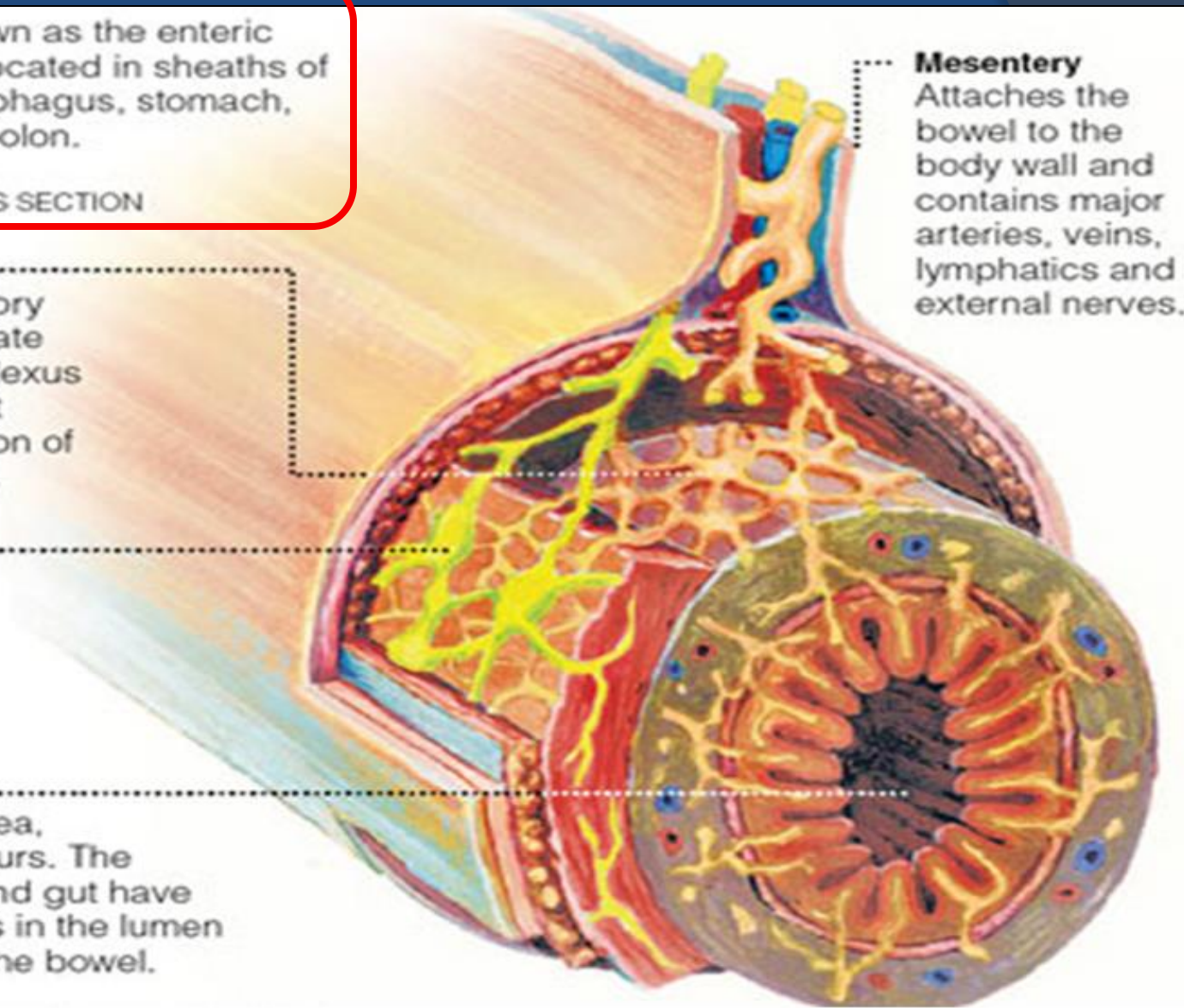
Layer contains sensory cells that communicate with the myenteric plexus and motor fibers that stimulate the secretion of fluids into the lumen.

Myenteric plexus

Lumen No nerves actually enter this area, where digestion occurs. The brains in the head and gut have to monitor conditions in the lumen across the lining of the bowel.

Mesentery

Attaches the bowel to the body wall and contains major arteries, veins, lymphatics and external nerves.



Neural Control of GIT Function

Enteric Nervous System

- GIT has a nervous system of its own called the Enteric Nervous System.
- It lies entirely in the wall of the gut, beginning in the esophagus and extending all the way to the anus.
- The number of neurons in this ENS is about 100 Million.
- This highly developed ENS is especially important in controlling Gastrointestinal movements and secretion.

Enteric nervous system

- It is a displaced part of the CNS that is concerned with the regulation of the gastrointestinal functions.
- *It doesn't depend on CNS in its function.*

It consists of two plexuses;

- *Meissner's plexus (submucosa):.*
It controls exocrine and endocrine secretions.
- Control local *intestinal secretion*, local *absorption*, and local *contraction of the submucosal muscle* that causes various degrees of infolding of the gastrointestinal mucosa.
- *Myenteric plexus* (Auerbach's plexus) between the 2 muscle layer).
 - *It Controls the GIT motility.*

- Output neurons are either excitatory or inhibitory. **What are their neurotransmitters?**
- The neurons of the ENS secrete Ach, GABA, serotonin, and nitrous oxide (which is the major mediator for smooth muscle relaxation in GIT).
- Autonomic nerves terminate on it but it can function independent of them.
- The **parasympathetic nerve supply is generally Stimulatory to ENS while the sympathetic is generally Inhibitory.**

Types of Neurotransmitters Secreted by Enteric Neurons

- 1) *acetylcholine* and *stimulatory secretions* في الغالب بتكون بتزود الحركة وال
- 2) *norepinephrine*.
- 3) *adenosine triphosphate*,
- 4) *serotonin*,
- 5) *dopamine*,
- 6) *cholecystokinin*,
- 7) *substance P*,
- 8) *vasoactive intestinal polypeptide*,
- 9) *somatostatin*,
- 10) *leu-enkephalin*,
- 11) *met-enkephalin*, and
- 12) *bombesin*.

مش ضروري تعرفهم كلهم

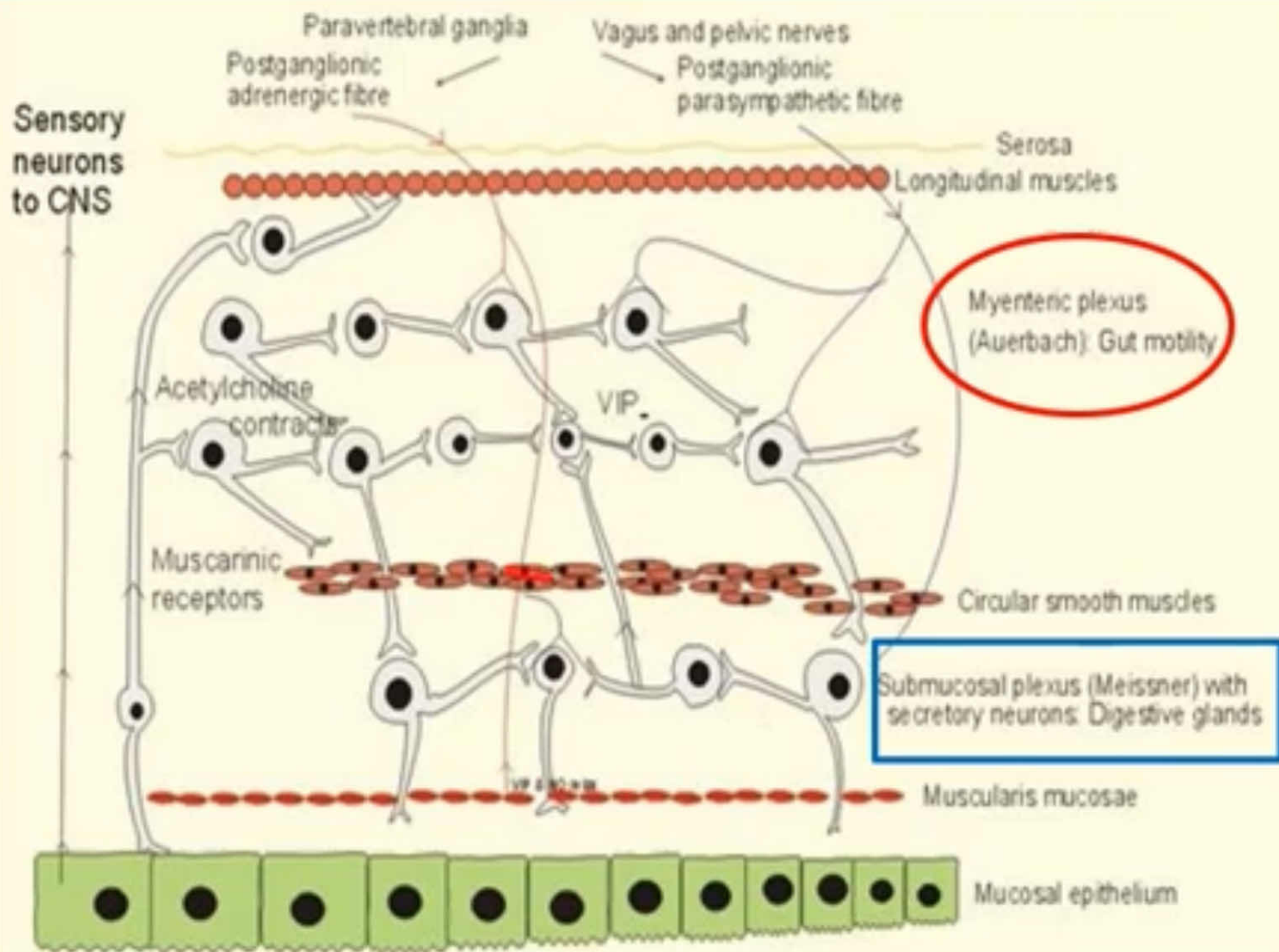
- The *Myenteric plexus* is mainly Excitatory but some of its neurons are Inhibitory, that secrete an inhibitory transmitter, possibly *VIP*.

- قصده في inhibitory في حالة ال sphincter لا بصيرله relaxation

- The resulting inhibitory signals are useful for inhibiting some of the intestinal sphincter muscles that impede movement of food along successive segments of the gastrointestinal tract, such as the *pyloric sphincter* and the *sphincter of the ileocecal valve*.

When Myenteric plexus is stimulated, its principal effects are:

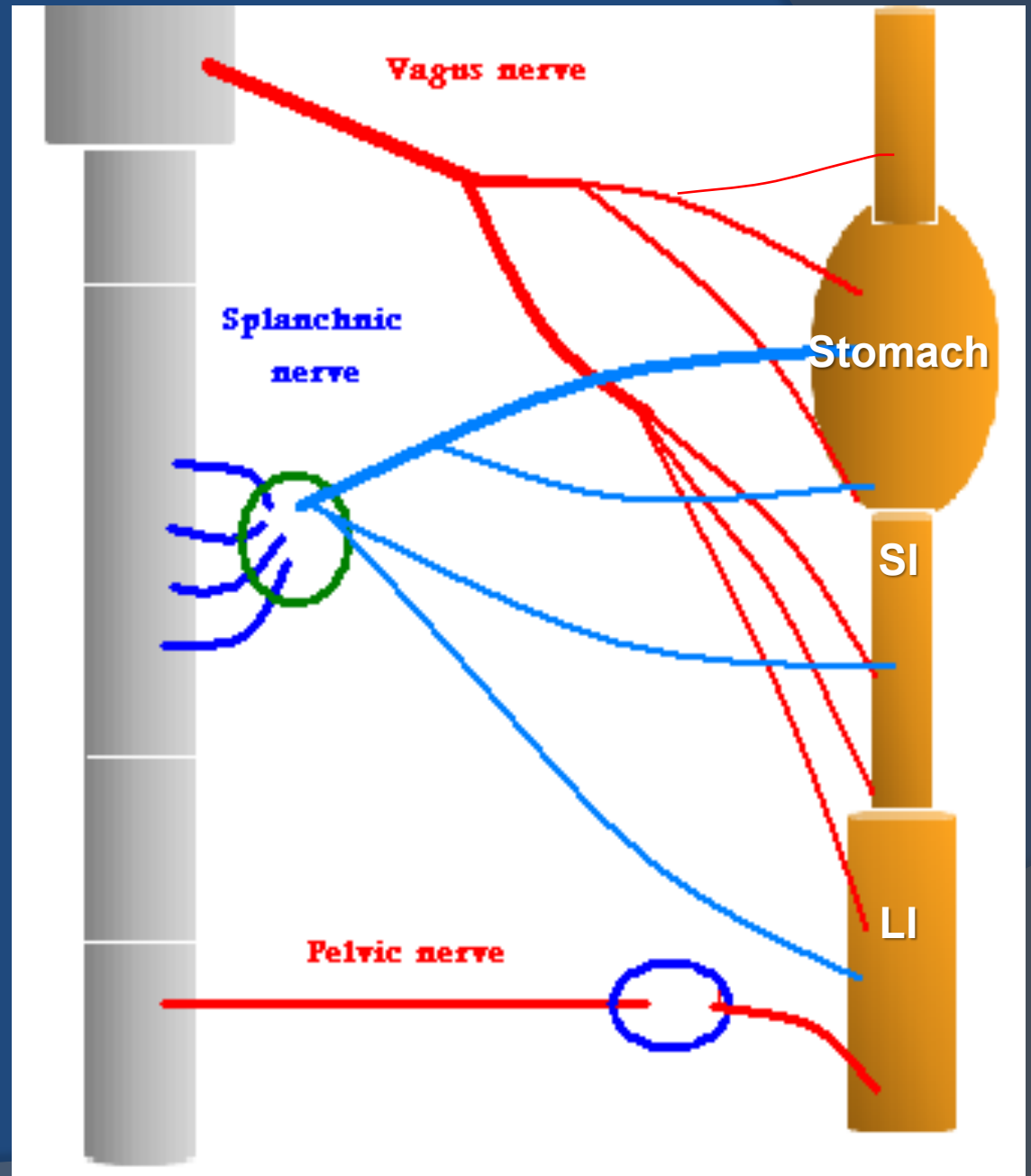
- ❖ (1) Increased tonic contraction, "Tone," of the gut wall.
- ❖ (2) Increased Intensity of the rhythmical contractions.
- ❖ (3) Increased Rate of the rhythm of contraction.
- ❖ (4) Increased Velocity of conduction of excitatory waves along the gut wall, causing more rapid movement of the gut peristaltic waves.



Autonomic Innervation

	Sympathetic	Parasympathetic
1-Origin	<u>Thoracolumbar</u> (T5-L2).	<u>Cranial</u> (mainly vagus) to esophagus till upper LI. ال vagus يمشي من ال mouth لغاية ال prodimal 2/3 of the transverse colon <u>Sacral</u> (S2-4) pelvic nerve to lower LI, rectum, anal canal.
2-Fiber	Postganglionic	Preganglionic
3-Chemical transmitter	Norepinephrine	Acetylcholine
4-Effect	a-Relaxation of wall b-contraction of sphincters c-mainly :↓ secretions	a-Contraction of wall b-Relaxation of sphincters c-mainly :↑ secretions
5-Termination	Myenteric and Meissner's plexus others bypass:- to Blood vessels. And smooth muscles.	Myenteric and Meissner's plexus.

Nerve Supply Of The Gut



Importance of the autonomic innervation to the gut

ومسؤول عن ال condition (زي لما تمضغ، وانت يتمضغ بزید ال
bile secretion و ال HCL) وال uncondition refluxes (واحد
شم ريحة لحمية مشوية، بصير عنده salivation بصير عنده
(increase in bile and HCL secretion

- Coordinate the activity between different regions of the gut.

e.g. Chewing ⇒ Salivation , ⇒↑ Gastric secretion , ⇒ ↑ Bile , ⇒ ↑ Pancreatic secretion.

- Make digestive system respond to the external stimuli.

e.g. Smell or sight of food ⇒ stimulation of salivary, gastric, pancreatic & liver secretion

Gastrointestinal Reflexes

- Reflexes that are Integrated Entirely within the gut wall ENS These include reflexes that control much gastrointestinal Secretion, Peristalsis, Mixing contractions, Local inhibitory effects.
- Reflexes from the gut to the prevertebral sympathetic ganglia and then back to the GIT. Signals from the stomach to cause evacuation of the colon (Gastrocolic reflex).
- Signals from the colon and small intestine to Inhibit stomach motility and secretion (Enterogastric reflexes).
- Reflexes from the colon to inhibit emptying of ileal contents into the colon (colonoileal reflex).

- بتنظيم لقسمين:

1- local reflexes:

هادي ما بتصل لل higher center وبترجع، هادي بتصير في ال Minibrain of the gut

2-

هادي بتروح لل higher center وبترجع، زي ال gastrocolic reflux، وهادي من أهم ال refluxes الي بتصير، وهاد بصير كل يوم الصبح بعد الفطور، لما تاكل الصبح بصير حركة سريعة في ال colon فبتصير بدك تروح ع الحمام، يعني هي stimulatory reflux، بصير في الصبح و أحيانا في الليل

- في inhibitory reflexes زي ال Enterogastric reflexes، يعني inhibition of the stomach بعمل distention of the small intestine