ORGANIZATION AND GENERAL PRINCIPLES OF GASTROINTESTINAL PHYSIOLOGY

Color index

- Important
- Further explanation

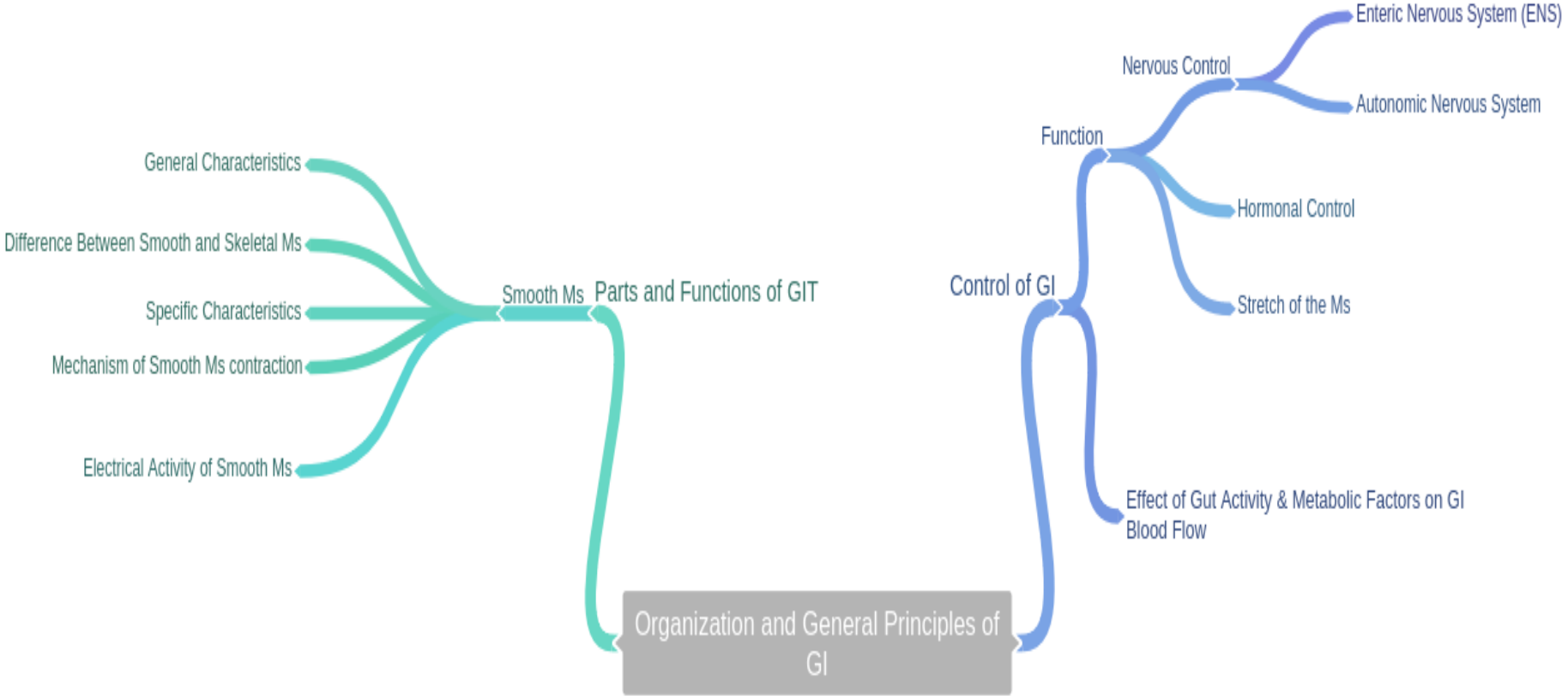
Contents

Smooth muscle function

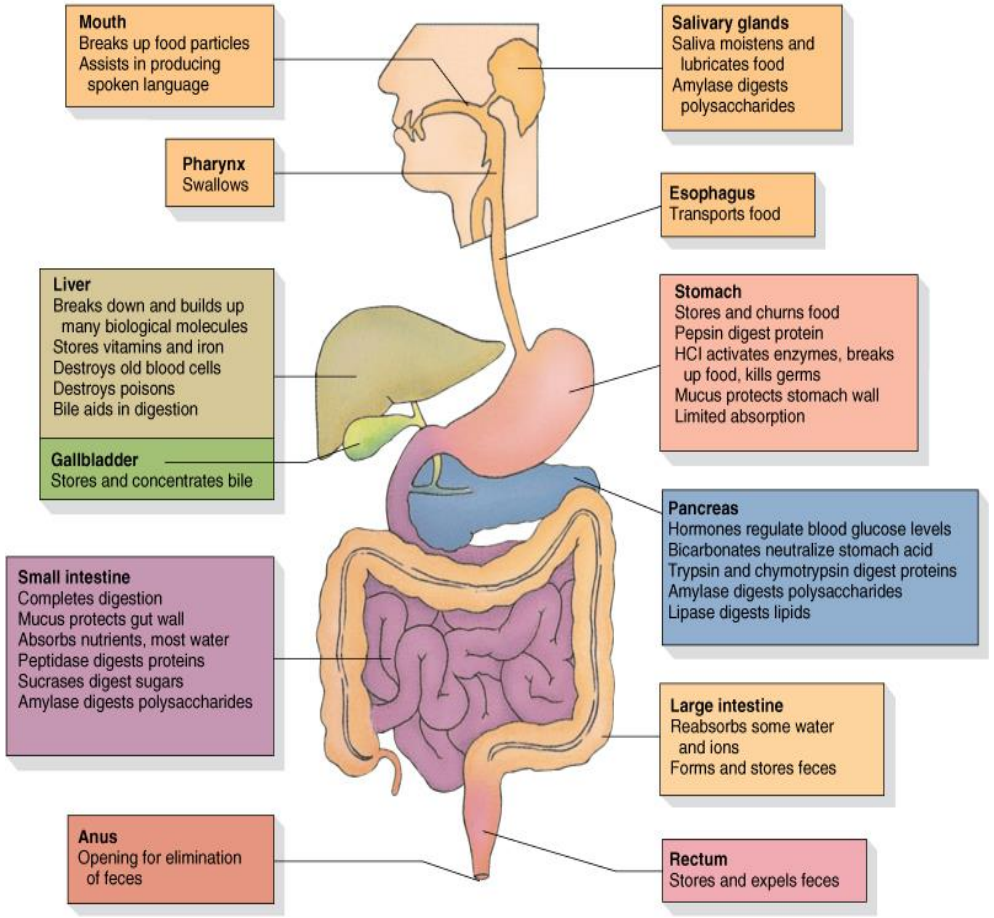
Control of GI Tract

Please check out this link before viewing the file to know if there are any additions/changes or corrections. The same link will be used for all of our work Physiology Edit

Mind map

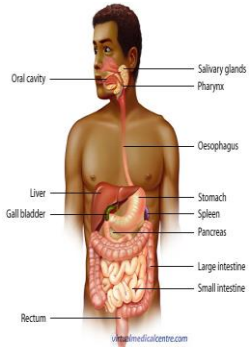

Organization and General Principles of GI
Smooth Ms
General Characteristics
Difference Between Smooth and Skeletal Ms
Specific Characteristics
Mechanism of Smooth Ms contraction
Electrical Activity of Smooth Ms
Parts and Functions of GIT
Control of GI
Function
Nervous Control
Enteric Nervous System (ENS)
Autonomic Nervous System
Hormonal Control
Stretch of the Ms
Effect of Gut Activity & Metabolic Factors on GI Blood Flow

PARTS AND FUNCTIONS OF GIT



PARTS AND FUNCTIONS OF GIT

GIT provides the body with continuous supply of water, electrolytes, vitamins and nutrients.



FUNCTIONS

- Movement of food through the alimentary tract
- Secretion of digestive juices and digestion of food
- Absorption of water, various electrolytes, vitamins and digestive products
- Circulation of blood through the GIT organs to carry away the absorbed substances
- Control of all these functions by local, nervous, and hormonal systems

CONCENTRIC LAYERS OF THE ALIMENTARY CANAL

Inner

Outer

Mucosa is the innermost, moist, epithelial membrane that lines the entire digestive tract. It has several functions such as:

1. Secretion of mucus, digestive enzymes, and hormones
2. Absorption of digestive products into blood
3. Protects against infectious disease

Consists of lining epithelium, lamina propria, and muscularis mucosa

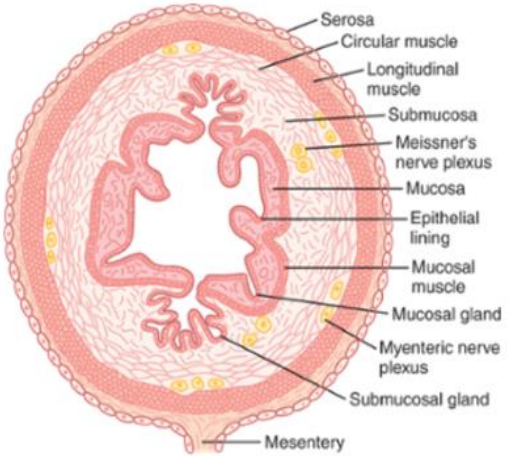
Sub mucosa is a moderately dense CT containing blood and lymphatic vessels, lymphoid follicles and nerve fibers.

Contains the **submucosal plexus (meissner's plexus)**

Muscularis externa typically consists of smooth muscle and is responsible for peristalsis and segmentation.

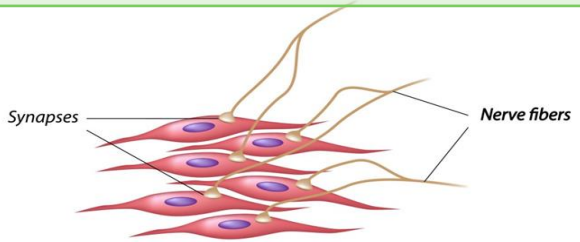
Contains the **myenteric plexus of Auerbach**

Serosa the protective outer layer of the intraperitoneal organs, is the visceral peritoneum

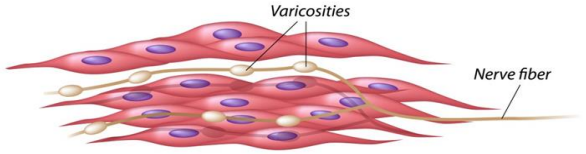


GENERAL CHARACTERISTICS OF SMOOTH MUSCLE

Multi-unit	Unitary (syncytial or visceral smooth muscle)
Each fiber can contracts independently (innervated by a single nerve ending)	Contract as a single unit
Controlled mainly by nerve signals	• Mass of 100-1000 smooth muscle fibers • Arranged in sheets or bundles • Cell membranes are adherent at multiple points • Many gap junctions that allow ion movements • When action potential is generated it travel in all directions
Examples: ciliary & iris muscles in the eye and piloerector muscles* of the hair	**Examples:** GIT, bile ducts, ureters, uterus, blood vessels



Multiunit Smooth Muscle



Single-unit Smooth Muscle

*Piloerector muscles: one of the small fan-shaped smooth muscles associated with the base of each hair that contract when the body surface is chilled and erect the hairs

DIFFERENCE BETWEEN SKELETAL AND SMOOTH MUSCLES

THE SPECIFIC CHARACTERISTICS OF SMOOTH MUSCLE

✓ **Slow cycling of the myosin cross-bridges**

- The rapidity of cycling of the myosin cross-bridges in smooth muscle is much slower than in skeletal muscle. Yet the fraction of time that the cross-briges remain attached to the actin filaments is believed to be greatly increased in smooth muscles.

✓ **Low energy requirement**

- Energy required to sustain the tension of contraction in smooth muscle is less than energy used in skeletal muscle

✓ **Slowness of onset of contraction and relaxation**

✓ **Greater maximum force of contraction**

✓ **Latch mechanism**

- Latch mechanism can maintain prolonged tonic contraction in smooth muscle for hours with little use of energy.

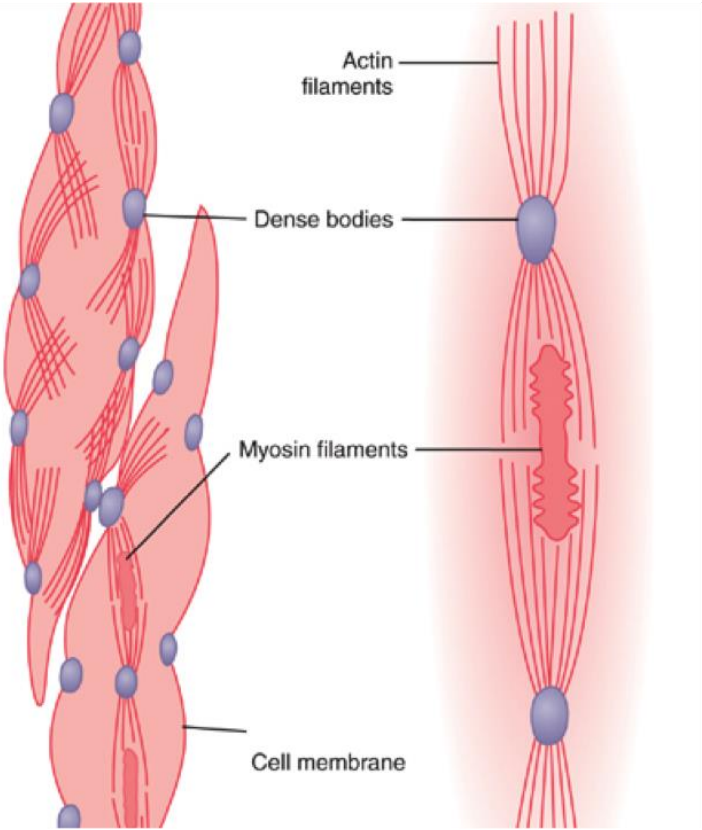
✓ **Stress-Relaxation**

✓ **Revers stress-relaxation**

- Stress-relaxation and reverse stress-relaxation is the ability of smooth muscles to return to nearly its original force of contraction seconds or minutes after it has been elongated or shortened.
- Eg. Sudden increase in fluid volume in the urinary bladder, thus stretching the smooth muscle, causes an immediate large increase in pressure in the bladder. However, during the next 15 seconds to a minute, the pressure returns almost exactly back to the original level ← **(stress-relaxation example).** Conversely, when the volume suddenly decreases, the pressure falls at first but then rises in another few seconds to the original level. This is called **reverse stress-relaxation.**

CHARACTERISTICS OF SMOOTH MUSCLE

- Smooth muscles don’t have the same striated arrangement as is found in skeletal muscle.
- There are large numbers of actin filaments attached to so-called dense bodies.
- Some of these bodies are attached to the cell membrane, other are dispersed inside the cell.
- Some of the **dense bodies** of adjacent cells are bonded together by intercellular proteins bridges. Through these bonds that the force of contraction is transmitted from one cell to the next.



Guyton

Additional reading

Gastrointestinal Smooth Muscle Functions as a Syncytium

In the *longitudinal muscle layer,* the bundles extend longitudinally down the intestinal tract; in the *circular muscle layer,* they extend around the gut.

Within each bundle, the muscle fibers are electrically connected with one another through large numbers of *gap junctions* that allow low-resistance movement of ions from one muscle cell to the next. Therefore, electrical signals that initiate muscle contractions can travel readily from one fiber to the next within each bundle but more rapidly along the length of the bundle than sideways.

Each bundle of smooth muscle fibers is partly separated from the next by loose connective tissue, but the muscle bundles fuse with one another at many points, so in reality each muscle layer represents a branching latticework of smooth muscle bundles. Therefore, each muscle layer functions as a *syncytium;* that is, when an action potential is elicited anywhere within the muscle mass, it generally travels in all directions in the muscle. The distance that it travels depends on the excitability of the muscle; sometimes it stops after only a few millimeters and at other times it travels many centimeters or even the entire length and breadth of the intestinal tract.

Also, a few connections exist between the longitudinal and circular muscle layers, so excitation of one of these layers often excites the other as well.

TYPES OF CONTRACTION

Phasic contractions (rhythmical)

- periodic contractions followed by relaxation; such as in gastric antrum, small intestine and esophagus

Tonic contractions

- maintained contraction without relaxation; such as in Orad region of the stomach, lower esoghageal, ileocecal and internal anal sphincter
- Caused by: 1- repetitive spike potentials, 2- hormones 3- continuous entry of Ca ions (not associated with changes in membrane potentials).
- Not associated with **slow waves** (often lasting several minutes or hours).

Based on male's lecture

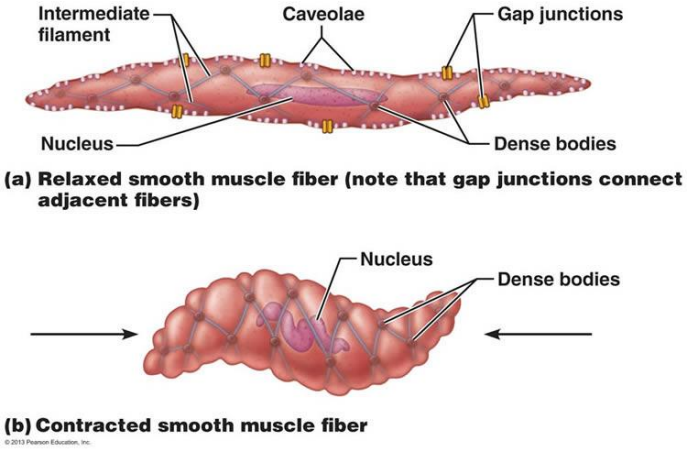
MAIN MUSCLE LAYERS IN SMOOTH MUSCLES

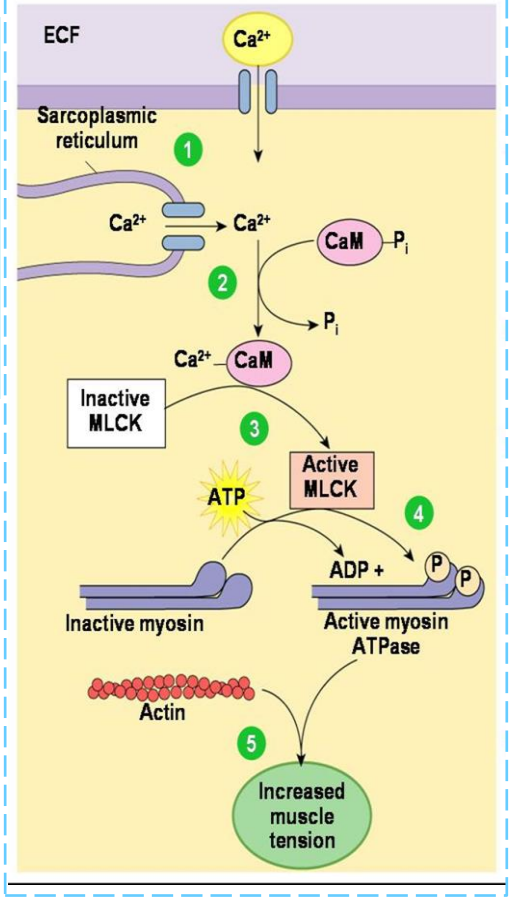
Muscle layer	Longitudinal Smooth muscle	Circular Smooth muscle
Effect of contraction	shortens the segment of the intestine and expands the lumen	reduces the diameter of the lumen and increases its length.
innervation	ENS, and mainly by **excitatory** motor neurons	ENS, both **excitatory** and **inhibitory** motor neurons
Calcium influx	The Ca influx from **out side** is important in the activity of this type of muscle.	**Intracellular** release of Ca is more important.

Based on male's lecture

MECHANISM OF SMOOTH MUSCLE CONTRACTION

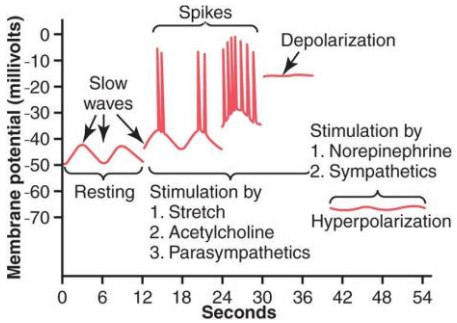
1. Intracellular Ca^{2+} concentrations increase when Ca^{2+} enters cell and is released from sarcoplasmic reticulum
2. Ca^{2+} binds to **calmodulin** (CaM)
3. Ca^{2+}-calmodulin activates **myosin light chain kinase** (MLCK)
4. MLCK phosphorylates light chains in myosin head and increases myosin ATPase activity
5. Active myosin crossbridges slide actin and create muscle tension





ELECTRICAL ACTIVITY OF GI SMOOTH MUSCLE

- There is continuous slow intrinsic electrical activity
- Most GI contractions occur rhythmically
- Rhythm is determined by the frequency of slow waves



Types of electrical waves:

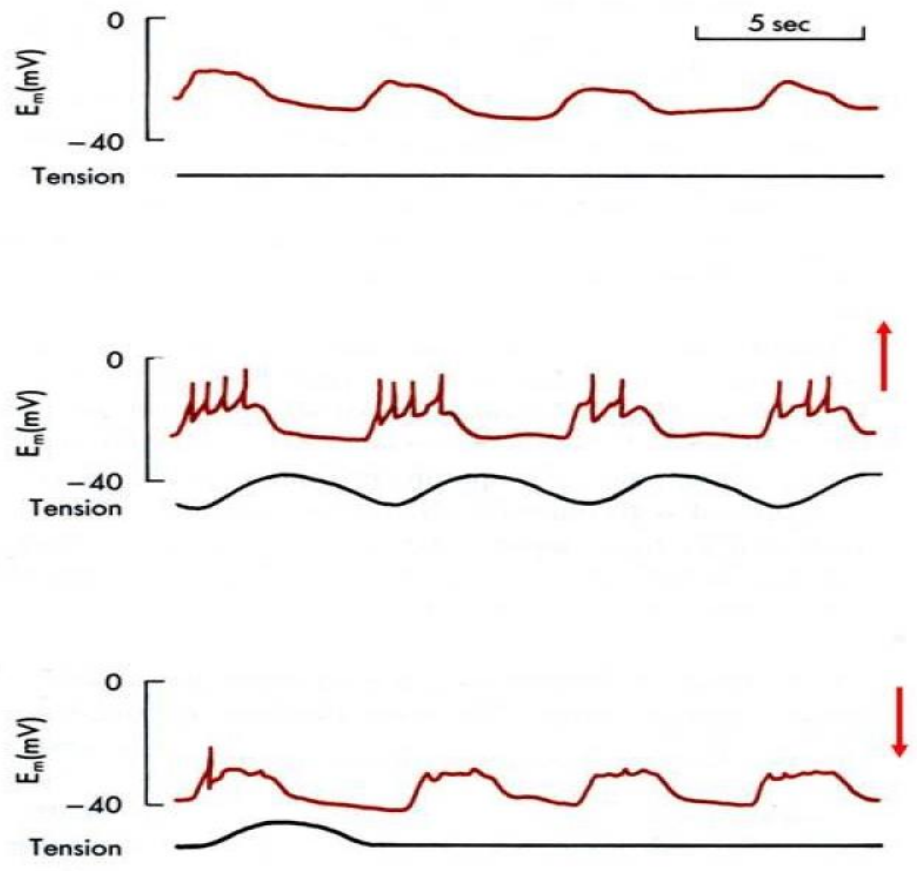
Slow waves

- Are changes in resting membrane potential
- **Are not** action potentials
- Their intensity **5-15 mv**
- Frequency: **3-12 /min**
- Stomach **3**, duodenum **12** and ileum **8-9/min**
- Caused by interaction between smooth muscle cells & interstitial cells of Cajal
- **Do not** by themselves cause muscle contractions
- **Do not** cause calcium ions to enter (only sodium ions)
- Mainly excite the appearance of intermittent spike potentials

Spike potential

- **Are true action potentials**
- Occurs when resting membrane potential become more positive than **-40** (normal range **-50mv** to **-60mv**) appear on the peaks
- The higher the slow wave potential the greater the frequency(1-10spikes/sec)
- Channels responsible for action potential are **calcium-sodium channels**
  - These channels are much slower to open and close
  - They allow large number of Calcium ions to enter + smaller number of sodium ions
- **They cause muscle contractions**

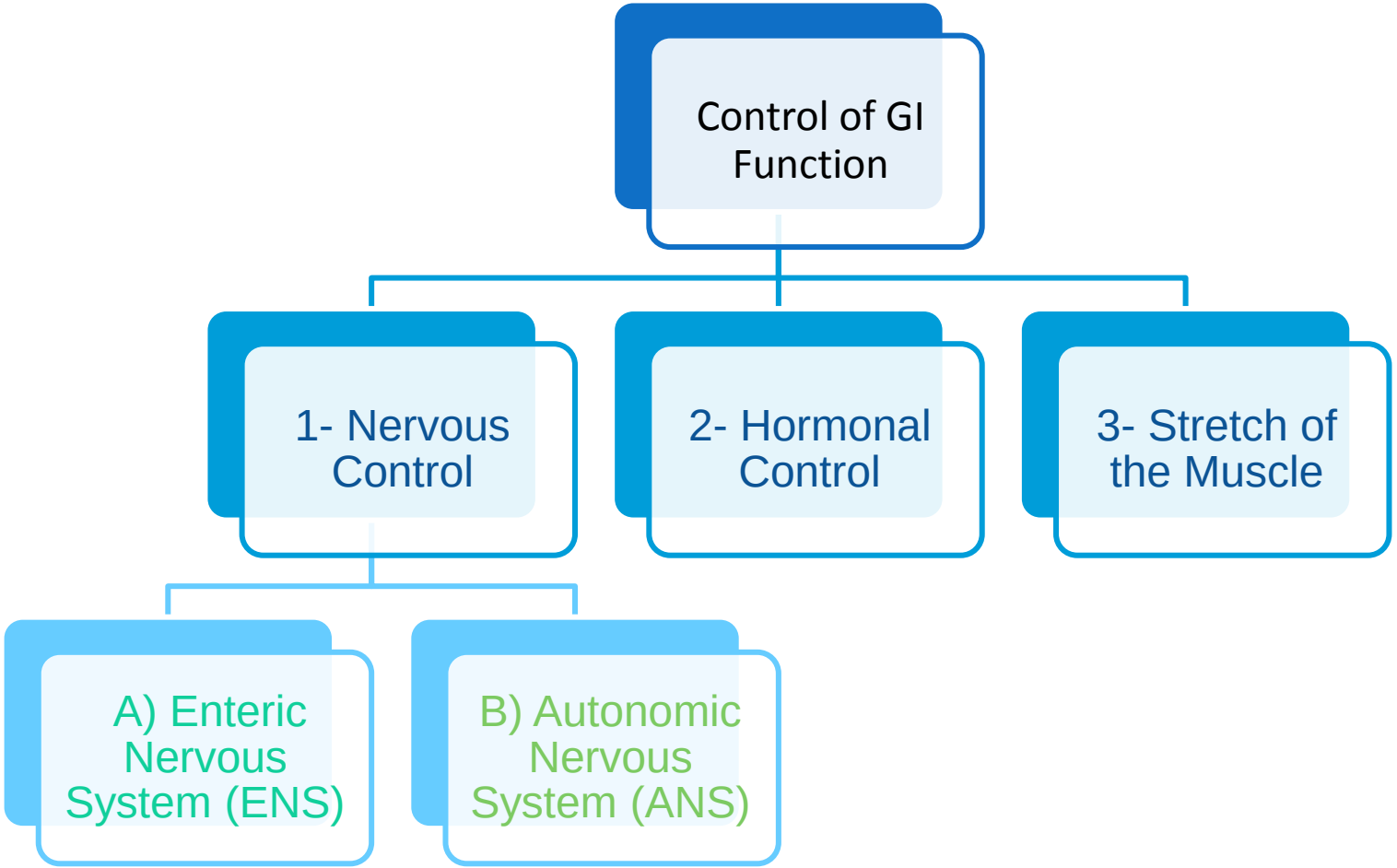
SMOOTH MUSCLE IS EXCITABLE TISSUE AND SHOWS ELECTRICAL ACTIVITY



Slow or myogenic waves (oscillating depolarization and repolarization; "basic electrical rhythm") fail to induce contraction because Em is below threshold.

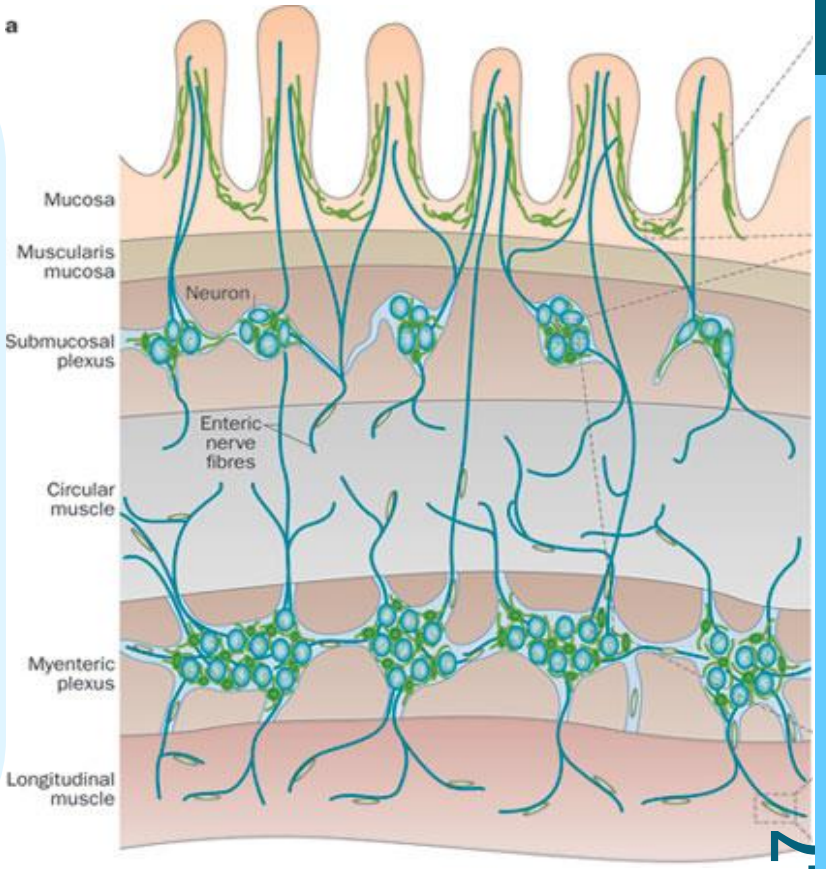
With **parasympathetic input**, the membrane at the plateau of the slow wave depolarizes all the way to threshold; action potentials occur "on top of" the slow wave, and these set off contractions. The contraction/ tension follows slightly after the electrical response.

If resting potential is shifted to more negative values (from **sympathetic input**) spikes and contractions will not occur.


Control of GI Function
1- Nervous Control
2- Hormonal Control
3- Stretch of the Muscle
A) Enteric Nervous System (ENS)
B) Autonomic Nervous System (ANS)

1- NERVOUS CONTROL: A) ENS (LITTLE BRAIN)

- Lies in the wall of the gut, beginning in the esophagus and extending all the way to the anus and contain 100 million neurons (same as SC).
- Connected to CNS by sympathetic & parasympathetic fibers.
- Can function autonomously (separately, independently)
- Controls gastrointestinal movements and secretion.
  - Myenteric or Auerbach's plexus.
  - Submucosal or Meissner's plexus.



1- NERVOUS CONTROL: A) ENS (LITTLE BRAIN)

	Myenteric or Auerbach's Plexus	Submucosal or Meissner's Plexus
Location	An outer plexus between the longitudinal and circular muscles.	An inner plexus, that lies in the submucosa.
Function	- Controls mainly the **GI movements**. - Increase tone, rate, intensity and velocity of rhythmic contraction.	- Control the function within inner wall of each minute segment. - Controls mainly **GI secretion** and **local blood flow**.
Structure	- A linear chain of interconnecting neurons. - Some neurons are inhibitory (eg. pyloric & ileocecal valves).	_____

TYPES OF NEUROTRANSMITTERS RELEASED BY ENS

Substance	Source	Action
Acetylcholine	Cholinergic neurons	-Contraction of smooth ms in wall. -Relaxation of sphincters. ↑ salivary, gastric and pancreatic secretions
Norepinephrine	Adrenergic neurons	-Relaxation of smooth ms in wall. -Contraction of sphincters. ↑ salivary secretion.
Vasoactive Intestinal Peptide (VIP)	Neurons of mucosa and smooth muscle	Relaxation of smooth muscle ↑ gastric and pancreatic secretions
Gastrin-Releasing Peptide (GRP) or Bombsin	Neurons of gastric mucosa	↑ gastrin secretion
Enkephalins (Opiates)	Neurons of the mucosa and smooth muscle	Contraction of smooth muscles. ↓ intestinal secretion
Neuropeptide Y	Neurons of the mucosa and smooth muscle	Relaxation of smooth muscles ↓ intestinal secretion
Substance P	Cosecreted with ACh	-Contraction of smooth muscles. ↑ salivary secretion

Based on male's lecture

1- NERVOUS CONTROL: B) AUTONOMIC NS

1- : B) ANS		Origin	Innervations	Stimulation	Postganglionic
Sympathetic		- Between segment T5 and L2 of SC. - Enter sympathetic chain then pass to ganglia: - Celiac ganglia - Superior mesenteric ganglia - Inferior mesenteric ganglia	_____	Inhibit intestinal tract smooth ms (except mucosal ms).	- Spread to all parts of the gut. - Secrets mainly (NE)
Para-symp.	Cranial	Almost entirely in the vagus nerve (except mouth and pharynx).	Innervate esophagus, stomach, pancreas, small intestine and first half of large intestine.	_____	_____
	Sacral	in 2^{nd}, 3^{rd} and 4^{th} sacral segments of SC.	Innervate distal half of large intestine, and anus through pelvic nerves.	causes general increase in activity of the ENS.	- Postganglionic neurons are located in myenteric and submucosal plexuses. - More extensive near the oral cavity and anus.

1- NEURAL CONTROL: SENSORY NERVES

- Sensory nerve fiber cell bodies are either in:
  - ENS. (locally)
  - Dorsal root ganglia. (Spinal Cord)
- Sensory nerves can be stimulated by:
  - Irritation of the gut mucosa.
  - Excessive distention of the gut.
  - Presence of specific chemicals.
- Signals transmitted through the fibers can cause :
  - Excitation.
  - Inhibition.
- 80% of fibers in vagus nerves are afferent.
- Sensory signals transmitted by sensory nerve fibers initiate GI reflexes.

1- NEURAL CONTROL: GI REFLEXES:

Reflexes integrated within gut wall:
Reflexes that controls secretion, peristalsis, mixing contractions and local inhibition.

Reflexes from the gut to sympathetic ganglia back to the gut:

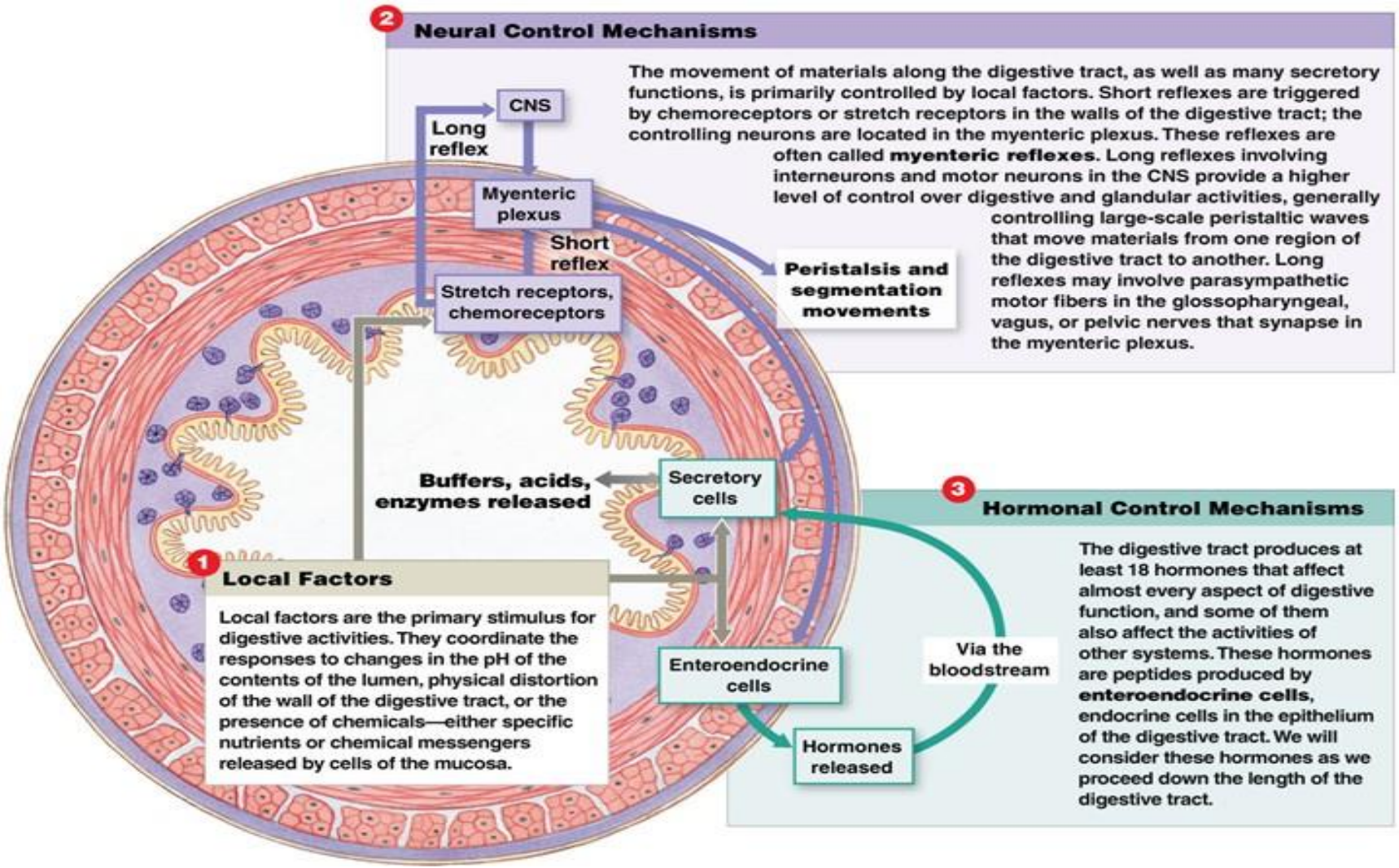
- Gastrocolic reflex: stimulate evacuation of the colon.
- Enterogastric reflex: inhibit stomach motility and secretion.
- Colonoileal reflex: inhibit empting of ileal contents.

Reflexes from the gut to the spinal cord or brain stem then back to GIT:

- From stomach and duodenum to the brain stem and back to stomach to control gastric motor and secretory activity.
- Pain reflexes that cause general inhibition of GIT
- Defecation reflexes from colon and rectum to spinal cord and back to cause powerful colonic, rectal and abdominal contractions.

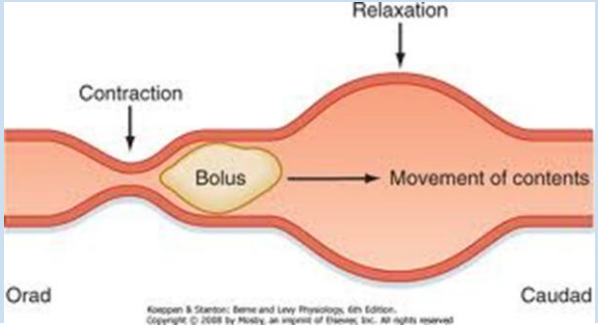
2- HORMONAL CONTROL:

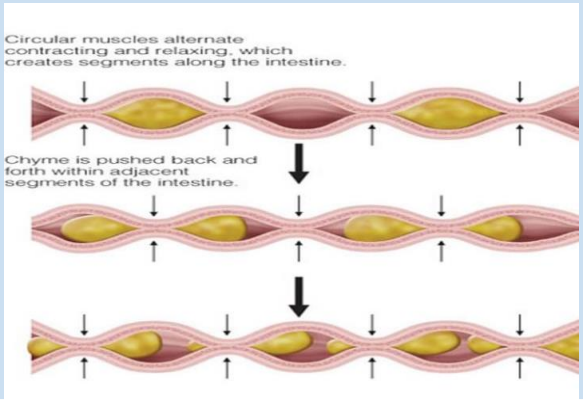
Hormone	Stimuli of Secretion	Site of Secretion	Action	
			Stimulates	Inhibits
Gastrin	Protein - Distention - Nerve - (Acid inhibits release)	G cells of antrum, duodenum and jejunum	gastric acid secretion - mucosal growth.	___
Cholecystokinin (CCK)	Protein - Fat - Acid	I cells of duodenum, jejunum and ileum	• pancreatic enzyme • pancreatic bicarbonate secretions • gall bladder contraction • growth of exocrine pancreas	gastric emptying.
Secretin	Acid - Fat	S cells of duodenum, jejunum and ileum	pepsin, pancreatic bicarbonate, Biliary bicarbonate secretions, growth of exocrine pancreas	gastric acid secretion.
Gastric Inhibitory Peptide (GIP)	Protein - Fat - Carbohydrate	K cells of duodenum and jejunum	insulin release	gastric acid secretion.
Motilin	Fat - Acid - Nerve	M cells of duodenum and jejunum	gastric, intestinal motility.	___


2 Neural Control Mechanisms
The movement of materials along the digestive tract, as well as many secretory functions, is primarily controlled by local factors. Short reflexes are triggered by chemoreceptors or stretch receptors in the walls of the digestive tract; the controlling neurons are located in the myenteric plexus. These reflexes are often called myenteric reflexes. Long reflexes involving interneurons and motor neurons in the CNS provide a higher level of control over digestive and glandular activities, generally controlling large-scale peristaltic waves that move materials from one region of the digestive tract to another. Long reflexes may involve parasympathetic motor fibers in the glossopharyngeal, vagus, or pelvic nerves that synapse in the myenteric plexus.
CNS
Long reflex
Myenteric plexus
Short reflex
Stretch receptors, chemoreceptors
Peristalsis and segmentation movements
Buffers, acids, enzymes released
Secretory cells
1 Local Factors
Local factors are the primary stimulus for digestive activities. They coordinate the responses to changes in the pH of the contents of the lumen, physical distortion of the wall of the digestive tract, or the presence of chemicals—either specific nutrients or chemical messengers released by cells of the mucosa.
3 Hormonal Control Mechanisms
The digestive tract produces at least 18 hormones that affect almost every aspect of digestive function, and some of them also affect the activities of other systems. These hormones are peptides produced by enteroendocrine cells, endocrine cells in the epithelium of the digestive tract. We will consider these hormones as we proceed down the length of the digestive tract.
Enteroendocrine cells
Via the bloodstream
Hormones released

FUNCTIONAL TYPES OF MOVEMENTS IN THE GIT

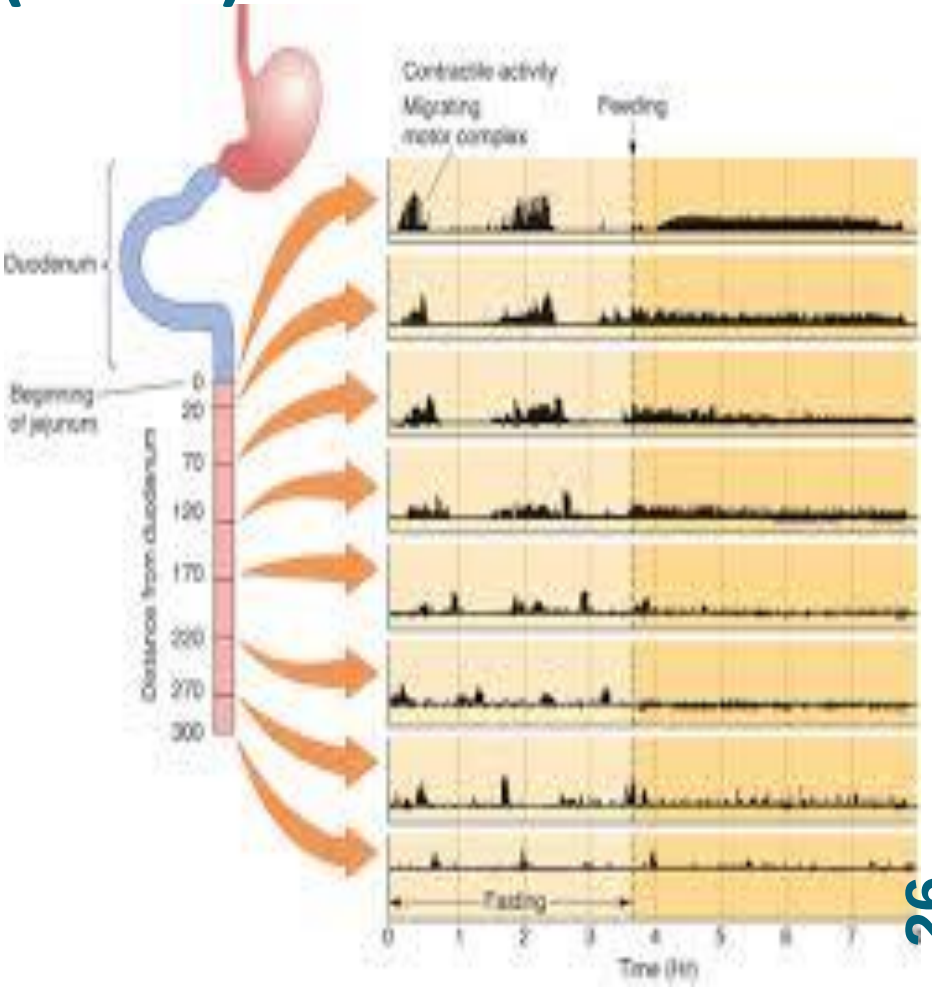
Propulsive	Mixing & segmentation
- Peristalsis which is inherent property of syncytial smooth muscle tube. - Stimulus is distention of the gut. - Stimulation of ENS. - Contractile ring 2-3 Cm behind stimulus. - Contractile ring moves forward. - Can not occur in absence of Myenteric plexus ➢ Peristaltic (myenteric) reflex and the low of gut	- Provides mixing of intestinal contents (know as chyme) with digestive juices. - Segment of bowel contracts at both ends. - A second contraction occurs in the center of the segment. - Chyme is forced forward and backward. - Can occur independent of central input.





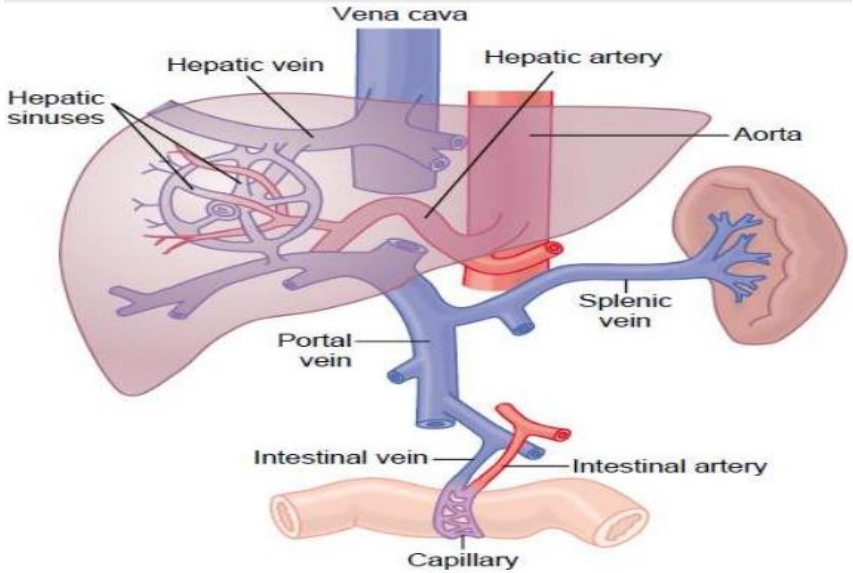
Migrating motor complex (MMC):

- Cycles of motor activity migrate from the stomach to the distal ileum. Have 3 phases:
Phase1: quiescence.
Phase2: irregular electrical & mechanical activity.
Phase3: burst of regular activity.
- Occurs during fasting.
- Initiated by motilin.
- Migrate at a rate of 5cm/min.
- Occurs at intervals of ~ 90 min.(1hr and half)
- Accompanied by increase gastric, bile and pancreatic secretion.
- Serve to clear the stomach and small intestine of luminal contents.



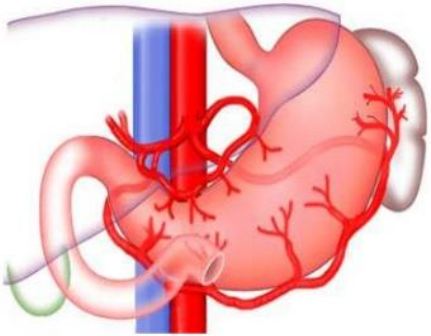
GI BLOOD FLOW (SPLANCHNIC CIRCULATION)

- It's different from other circulations because the blood coming to the stomach, spleen, pancreas and intestine will go through the venous collection and collects into the portal vein which go through the liver that means that anything passes the GIT will go to the liver which act as a sorting area that kills and get rid of toxins and poisons materials from going to the systemic circulation and will also store nutrient. (check the anatomy part of this circulation)



Celiac Trunk

- It arises from the abdominal aorta immediately below the aortic hiatus of the diaphragm anterior to the upper part of vertebra LI.
- It divides into the:
  - ***left gastric artery,***
  - ***splenic artery,***
  - ***common hepatic artery***.



EFFECTS OF GUT ACTIVITY & METABOLIC FACTORS ON GI BLOOD FLOW

- Blood flow in GIT is directly related to local activity.

- Blood flow in villi during active absorption increased up to 8 folds.

- After a meal blood flow increases greatly then return to resting level over 2-4 hrs
(so we shouldn't exercise right after eating because the blood supply will shift to the ms)

- Causes of increase blood flow:

  - Vasodilators such as peptide hormons.
  - Kinins secreted by GI glands (kallidin & bradykinin).
  - Decreased oxygen concentration increase blood flow 50-100%.
  - Four folds increase in adenosine (vasodilator) secretion due to decrease oxygen.

MCQs

Answer key: 1-B. 2-D. 3-A. 4-C. 5-B. 6-A. 7-C.

1- The ENS lies in:
A. Mouth.
B. from Esophagus all the way to the Anus.
C. Pharynx.
D. Mouth and Pharynx.

2- Meissner's Plexus:
A. An outer plexus between the longitudinal and circular ms.
B. A linear chain of interconnecting neurons.
C. Controls mainly the GI movements.
D. Controls mainly GI secretion and local blood flow.

3- MCC is initiated by:
A. Motilin.
B. Norepinephrine.
C. Dopamine.
D. Serotonin.

4- Blood flow in villi during active absorption increased up to:
A. 15 Folds.
B. 2 Folds.
C. 8 Folds.
D. 1 Fold.

5- Electrical activity of GI smooth muscle that produces an action potential
A. Slow wave
B. Spike potential
C. Both of them
D. None of the above

6- A type of smooth muscle that can contract independently and controlled mainly by nerve signals?
A. Multi unit
B. Syncyial
C. Visceral smooth muscle
D. Skeletal muscle

7- Which of the following secretes hormones and digestive enzymes?
A. Submucosa
B. Serosa
C. Mucosa
D. Muscularis externa

SAQs

Q1: Give examples of syncytial smooth muscles

GIT, bile ducts, ureters, uterus and blood vessels.

Q2: List the differences between smooth and skeletal muscles:

Skeletal muscles contract and relax rapidly, while smooth muscles contraction is slow, prolonged, and requires less energy.

Q3: Where is the inhibition of empting of ileal contents reflex integrated and what is it called?

Sympathetic ganglia, Colonoileal reflex

Q4: Which hormone stimulates insulin release?

Gastric inhibitory peptide

Thanks for checking our work

Good Luck

Done by:

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