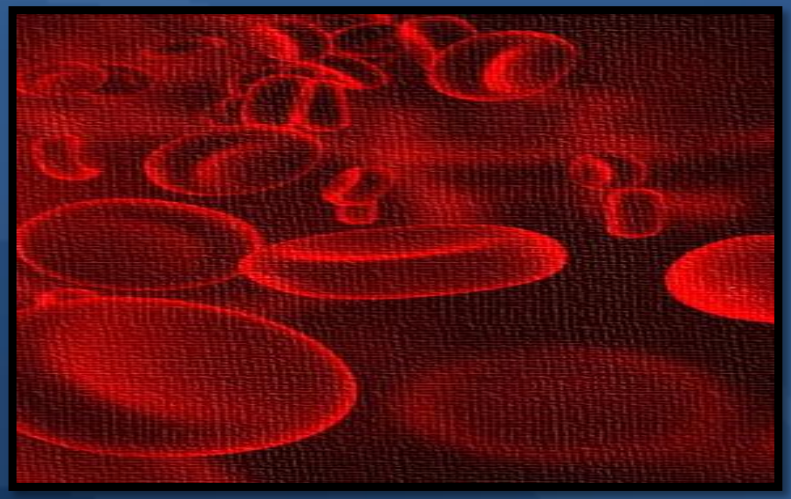
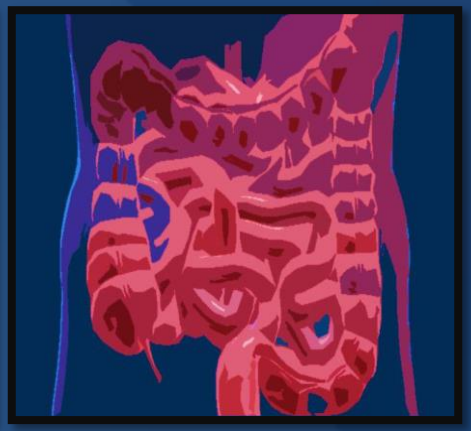
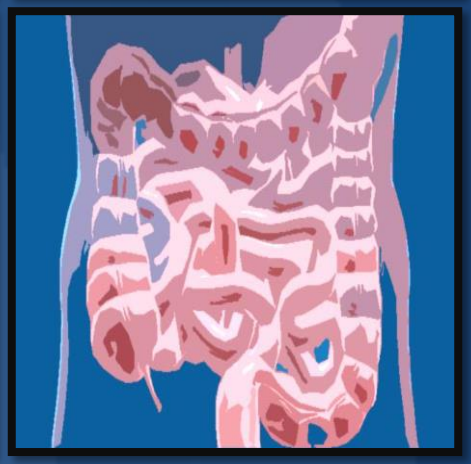
Physiology Team

# LECTURE 1

## General Principles of GIT Physiology





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GASTOINTESTINAL TRACT

# OBJECTIVES

It seems a long lecture but don't worry ! ☺
We have tried our best to make your life easier ..

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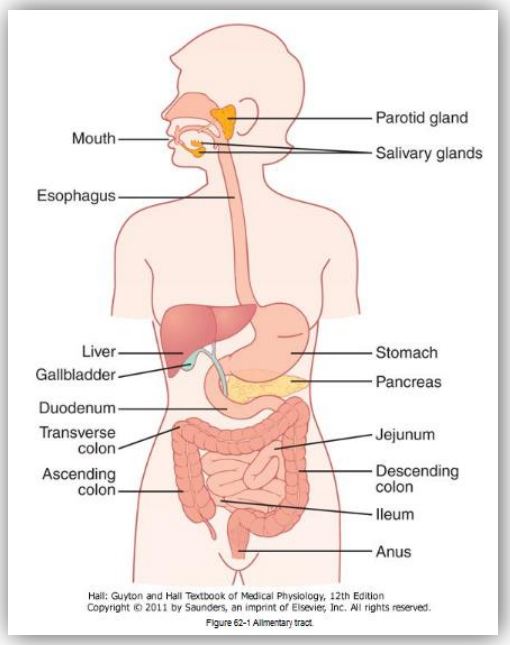
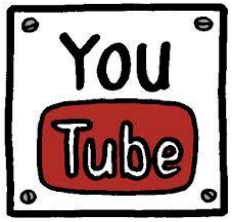
## At the end of this lecture, student should be able to describe:

- Physiologic Anatomy of the Gastrointestinal Wall.
- The General Characteristics of Smooth Muscle.
- The Specific Characteristics of Smooth Muscle.
- Neural & Hormonal Control of Gastrointestinal Function.
- Types of Neurotransmitters Secreted by Enteric Neurons.
- Functional Types of Movements in the GIT.
- Gastrointestinal Blood Flow-"Splanchnic Circulation".
- Effect of Gut Activity and Metabolic Factors on GI Blood Flow.



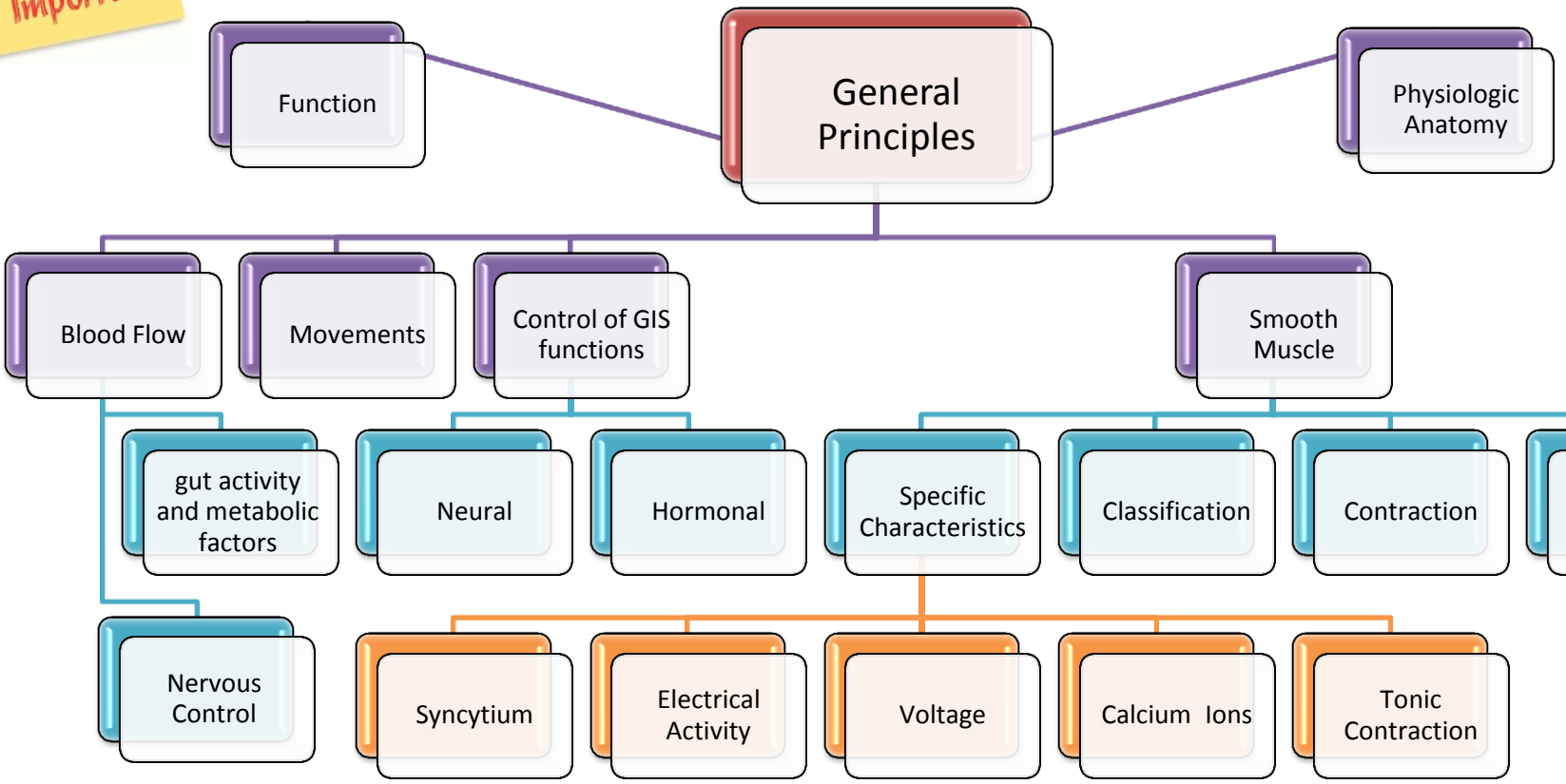




**These are some USEFUL VIDEOS that may give you an idea about what we are going to discuss ..** ( JUST CLICK ON THE TITLES BELOW )

1- HUMEN DIGESTIVE SYSTEM ANIMATION 2- DIGESTIVE SYSTEM

**The gastrointestinal system consists of the gastrointestinal tract (GIT) and associated organs that produce secretions**

Important



# Gastrointestinal Function

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**The alimentary tract provides the body with a continual supply of water, electrolytes, and nutrients. To achieve this function, it requires:**

| | | |
|---|---|---|
| **Motility** | • Movement of food through the alimentary tract | Movement of food in a forward direction – from mouth to direction of anus (except in certain situation) |
| **Secretion and digestion** | • Secretion of digestive juices and digestion of the food | Digestion of the food to formation of its end products. |
| **Absorption** | • Absorption of water, various electrolytes, and digestive products | Mainly to the blood circulation. |
| **Circulation** | • Circulation of blood through the gastrointestinal organs to carry away the absorbed substances | |

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

# Gastrointestinal Function

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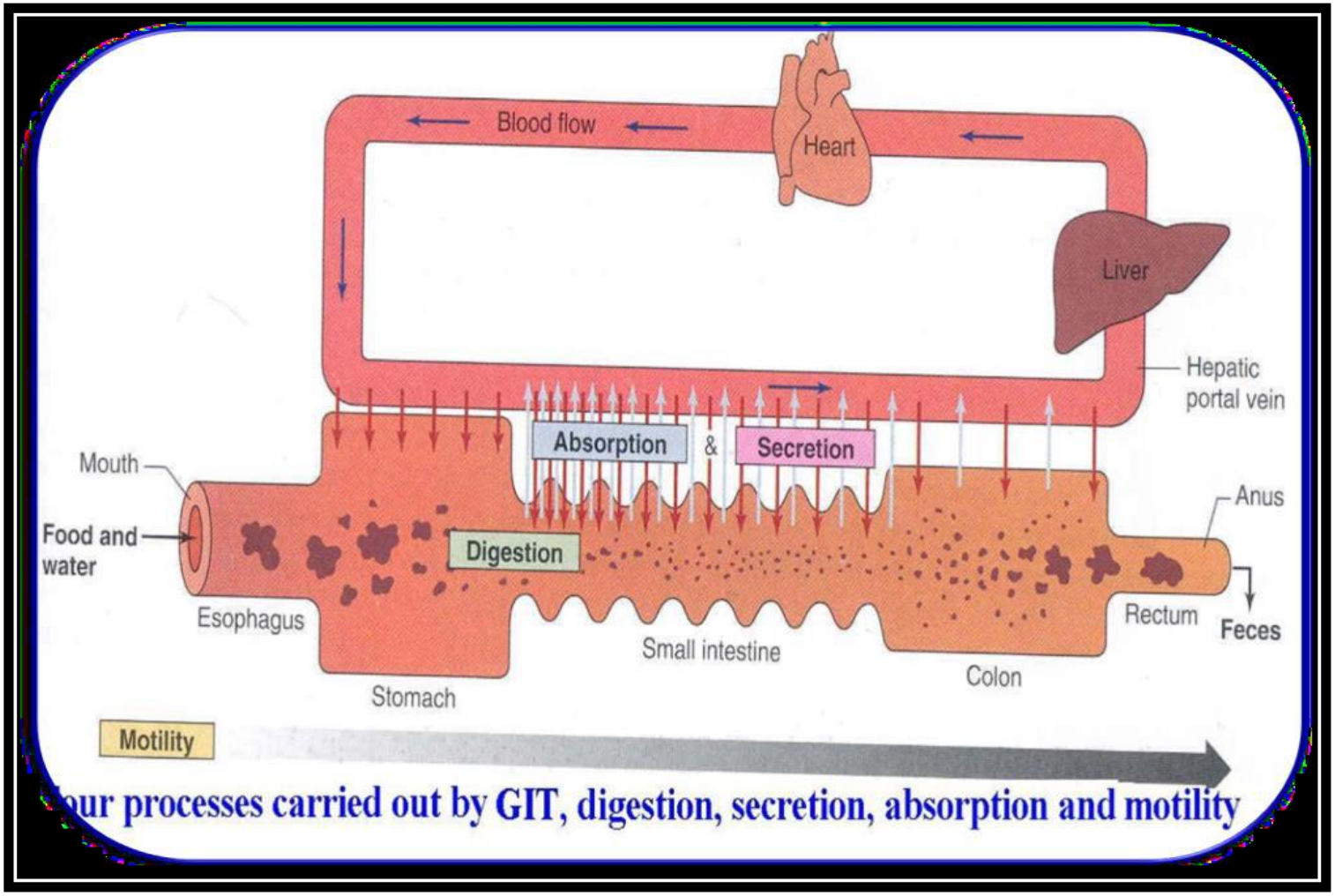


Slides | Important | Females' Notes | Explanation | Males' Notes

# Physiologic Anatomy of the Gastrointestinal Wall

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**The following layers structure the GI wall from outer surface inward:**

(1) The serosa
(2) longitudinal muscle layer
(3) Circular muscle layer
(4) The submucosa
(5) The mucosa.
(6) Sparse bundles of smooth muscle fibers, the mucosal muscle, lie in the deeper layers of the mucosa.

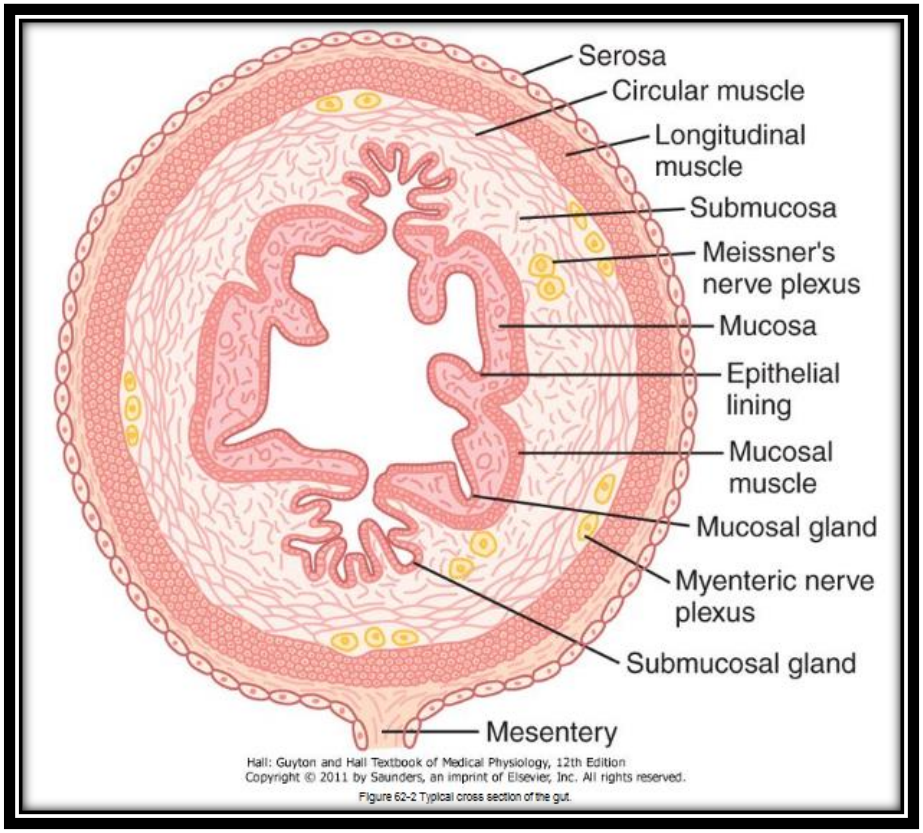


Figure 62-2 Typical cross section of the gut.

# General Characteristics of Smooth Muscle

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**Smooth muscles can be classified according to the following criteria:**

| # | Types | Information | Example |
|---|---|---|---|
| 1- Response | **Unitary** | ❑ Contracts spontaneously in response to stretch and in the absence of neural or hormonal influence (but they can modify the contraction)<br>❑ Cells are electrically coupled via gap junctions. | Stomach & Intestine |
| | **Multiunit** | ❑ Contracts spontaneously in response to neural input, but not in response to stretch. | Esophagus & Gall bladder |
| 2- Contraction | **Phasic (rhythmical)** | ❑ Periodic contractions followed by relaxation. | esophagus, gastric antrum & small intestine |
| | **Tonic** | ❑ Maintained contraction without relaxation.<br>❑ Not associated with slow waves. | orad region of the stomach, lower esophageal, ileocecal & internal anal sphincters |

# General Characteristics of Smooth Muscle

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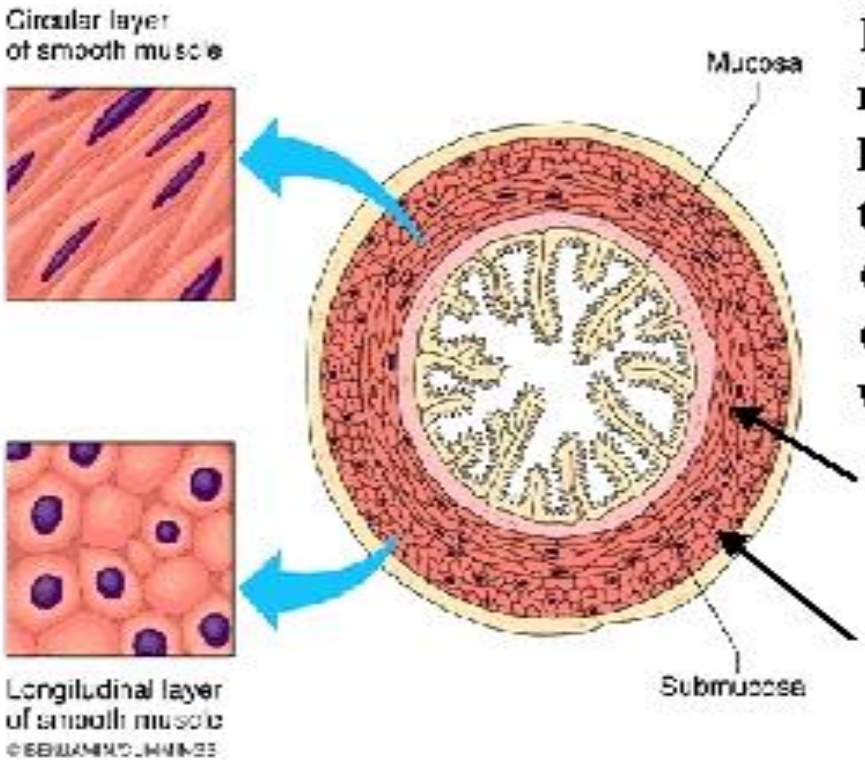
**Cont.**

| 3- Layers | | |
|---|---|---|
| **Types** | **Longitudinal** | **Circular** |
| **Contraction will** | **Shortens the segment** of the intestine and **expands the lumen**. | **Reduces** the **diameter of the lumen** and **increases its length**. |
| **innervated by** | Enteric Nervous System (ENS) | |
| **Motor Neurons** | Mainly by **excitatory** MN. | Both **excitatory** and **inhibitory** MN. |
| **Ca++** | Ca++ influx from **outside** is important in the activity of this type of muscle. | **Intracellular** release of Ca++ is more important. |
| **Thickness** | --- | Thicker and more powerful. |
| **Gap Junction** | Available | More available |
| **Function** | Absorption | Digestion |

# General Characteristics of Smooth Muscle

**Cont.**

## Smooth Muscle Arrangement in the Gut




In the intestine smooth muscle forms two distinct layers, one running along, the other running around the organ. Together these layers cause wave-like peristalsis which propels the contents.

The circular layer runs around the intestine and its contraction causes segmentation

The longitudinal layer runs along the intestine; it causes wave-like contractions.

# Specific Characteristics of Smooth Muscle

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## Mainly, They Are *5 Specific* Functions.

- **Syncytium**
  - Gap junctions
  - branching latticework
  - action potential travels in all directions
- **Electrical Activity**
  - Slow Waves (not APs)
  - Spikes Potentials (true APs)
- **Changes in Voltage of the RMP**
  - Depolarization
  - Hyperpolarization
- **Calcium Ions**
  - Slow Waves usually cause no muscle contraction
  - During Spike Potentials, most of the contraction
- **Tonic Contraction**
  - Continuous repetitive spike potentials
  - Hormones
  - Continuous entry of Ca++

Now, let's talk about each one of them in details ☺

# Specific Characteristics of Smooth Muscle

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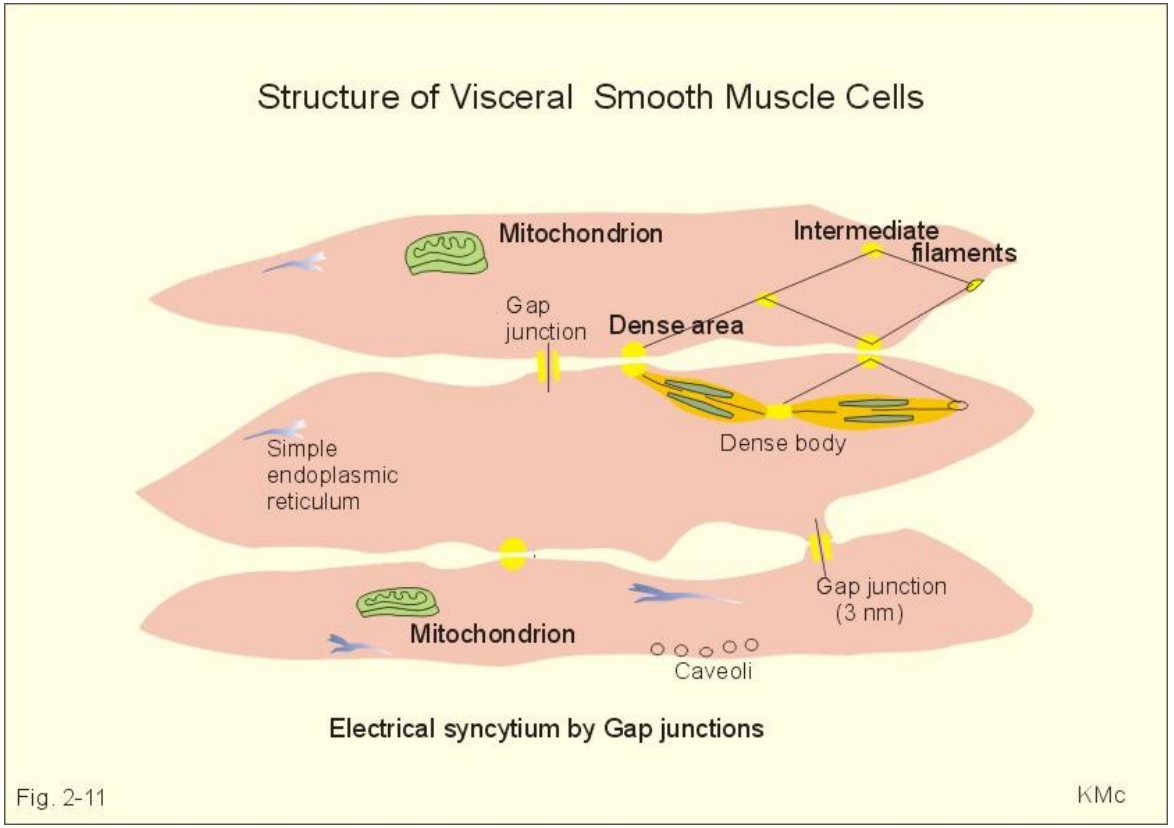
## 1 Gastrointestinal Smooth Muscle Functions as a Syncytium:

- The individual smooth muscle fibers are 200 to 500 µm in length and 2 to 10 µm in diameter, and they are arranged in bundles of as many as 1000 parallel fibers.
- Within each bundle, the muscle fibers are electrically connected with one another through large numbers of gap junctions (As in cardiac muscles).
- Each bundle of smooth muscle fibers is partly separated from the next by loose connective tissue but they fuse with one another at many points, so each muscle layer represents a branching latticework of smooth muscle bundles.
- 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.

## 1 Gastrointestinal Smooth Muscle Functions as a Syncytium:

To summarize the previous slide, we can say that:

- The muscle fibers of smooth muscles are electrically **connected** by **gab junction**.
- They are **separated** from each other by **loose C.T.**
- They **function** as one unit (**syncytium**).



## 2 Electrical Activity of Gastrointestinal Smooth Muscle:

- The smooth muscle of the gastrointestinal tract is excited by almost continual slow, intrinsic electrical activity along the membranes of the muscle fibers.
- This activity has two basic types of electrical waves:
  (a) **Slow waves**. (b) **Spikes.**

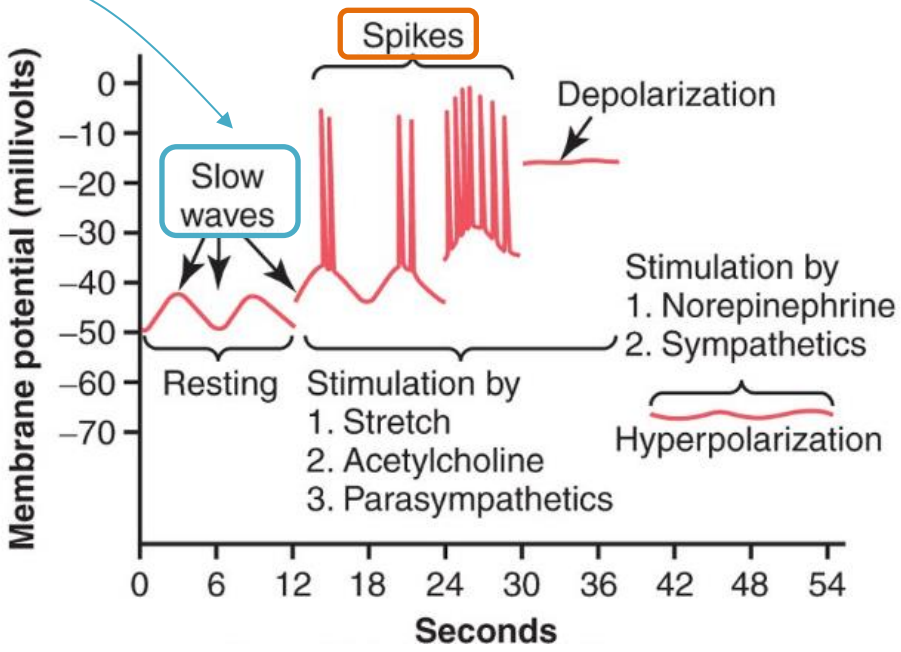
### A- The slow waves- basic electrical rhythm

- These waves are not action potentials. Instead, they are slow spontaneous change in RMP (cyclic waves of depolarization & repolarization).
- Their intensity varies between 5-15 mv. (this means the difference E.X. the difference between -70 & -65 )
- Their frequency ranges between **3/min**. in **stomach body** to **12/min** in **duodenum** and change to **8/min.** in **terminal ileum**.
- They do not directly cause contraction.
- Spikes of action potential are superimposed on the depolarization phase of slow waves followed by contraction

## 2 Electrical Activity of Gastrointestinal Smooth Muscle:

### A- The slow waves- basic electrical rhythm

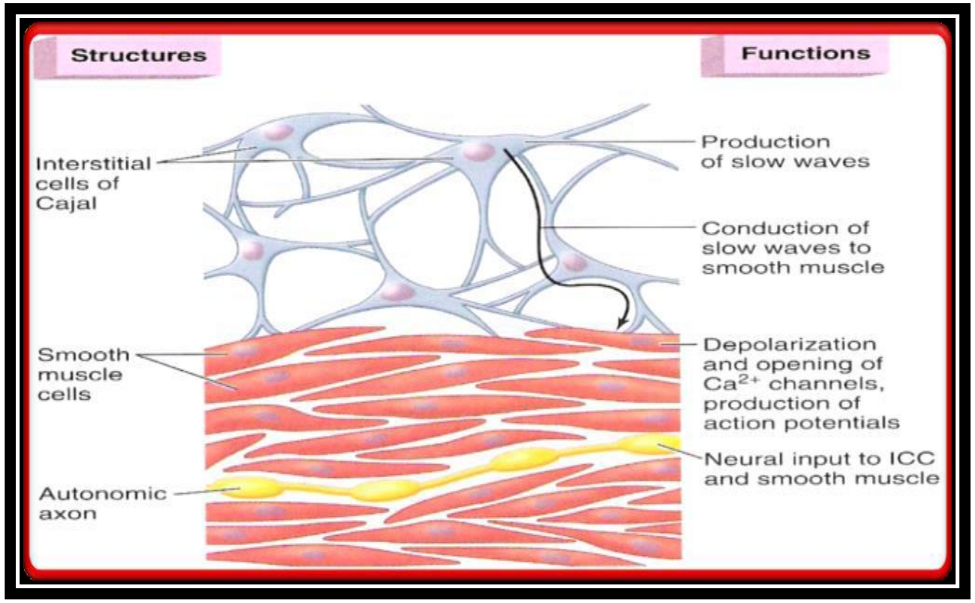
In this diagram, we can see clearly how the **spikes** superimpose on the depolarization phase of the **slow waves.**



## 2 Electrical Activity of Gastrointestinal Smooth Muscle:

### A- The slow waves- basic electrical rhythm

- They are generated by **interstitial cells of Cajal, ICC** (the GI pacemaker), located between the longitudinal & circular muscle layers. These interstitial cells form a network with each other and are interposed between the smooth muscle layers, with synaptic-like contacts to smooth muscle cells.
- **Parasympathetic** ↑ the amplitude and frequency of slow waves. SO, Increase contractions.
- **Sympathetic** ↓ their amplitude and frequency. So, Decrease contractions.



## 2 Electrical Activity of Gastrointestinal Smooth Muscle:

**B- The Spike Potentials.**

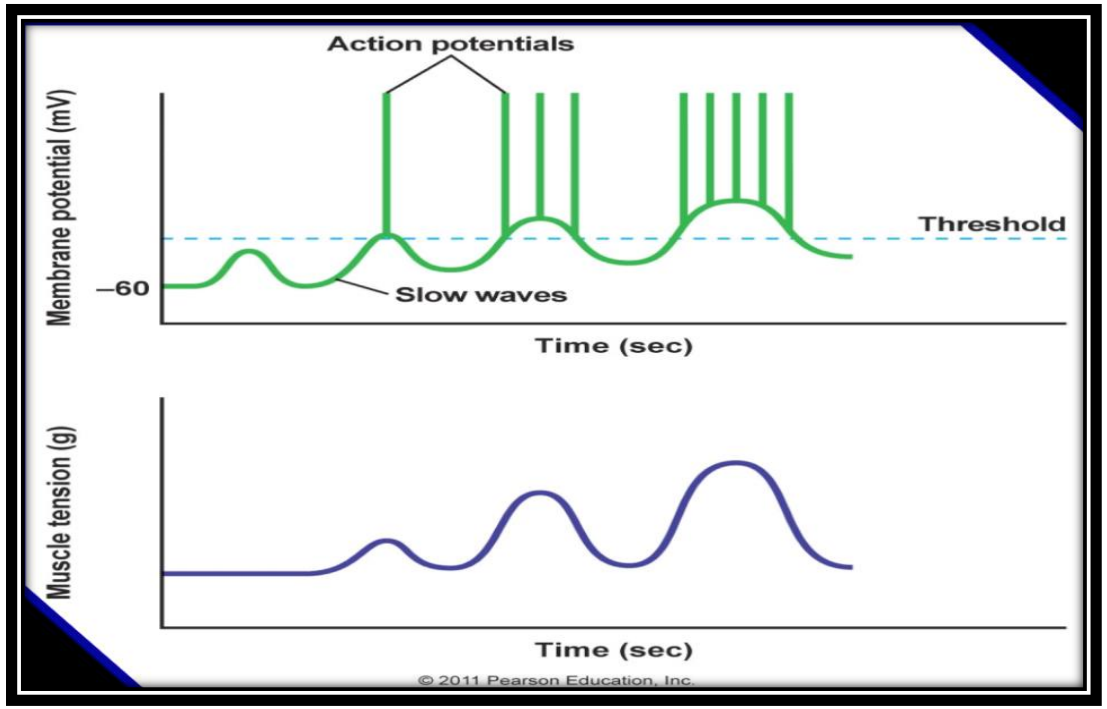
- They are true action potentials that occur when RMP rises above -40 mv [RMP= -50- (-60) mv].
- They are more prolonged than those of skeletal muscles.
- The rising phase of AP is caused by Ca++ and Na+ inflow through the channels that allow especially large numbers of Ca++ to enter along with smaller numbers of Na+ (Ca++-Na+ channels). They open slowly. Ca++ that enters cells helps to initiate contraction.
- (N.B: slow waves do not cause Ca++ entry).
- They usually do not propagate more than a few mm. (do not propagate for long distance) Instead slow waves are propagated & spike potentials occur at the peak of slow waves.
- The higher the slow wave potential rises, the greater the frequency of the spike potentials, usually ranging between 1 and 10 spikes per second.

## 2 Electrical Activity of Gastrointestinal Smooth Muscle:

**B- The Spike Potentials.**

When slow waves become closer to -40 (rising level), the spike potentials will superimpose the slow waves

**The spike potentials last 10 to 40 times as long in gastrointestinal muscle as the action potentials in large nerve fibers, each gastrointestinal spike lasting as long as 10 to 20 msec.**



## 3 Changes in Voltage of the Resting Membrane Potential:

- **The resting membrane potential averages about -56 mv [-50- (-60) mv] but multiple factors can change this level:-**

❖ When the potential becomes less negative (towards positive), 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**

(1) Stretching of the muscle
(2) Stimulation by acetylcholine
(3) Stimulation by parasympathetic nerves that secrete acetylcholine at their endings
(4) Stimulation by several specific gastrointestinal hormones

(1) Norepinephrine or epinephrine
(2) Stimulation of the sympathetic nerves that secrete mainly norepinephrine at their endings.

## 4 Calcium Ions and Muscle Contraction:

- Smooth muscle contraction occurs in response to entry of Ca++ into the muscle fiber.
- The slow waves **do not** cause Ca++ to enter the smooth muscle fiber (only Na+). Therefore, the slow waves by themselves usually cause no muscle contraction.
- Instead, it is during the spike potentials, generated at the peaks of the slow waves, that significant quantities of Ca++ do enter the fibers and cause most of the contraction.

## 5 Tonic contraction of some gastrointestinal smooth muscle:

- Some smooth muscle of the GI exhibits tonic contraction as well as or instead of rhythmical contractions. It is continuous, **not associated with the basic electrical rhythm of the slow waves** but often lasting several minutes or even hours.
- Tonic contraction is sometimes caused by:

1. **Continuous repetitive spike potentials.**
2. **Hormones.**
3. **Continuous entry of Ca++ into the interior of the cell brought about in ways not associated with changes in membrane potential.**

Where dose it occur ! >> in lower esophageal sphincter

# Control of GIS functions

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## Alimentary tract is controlled by two Mechanisms or Ways:

| Mechanism | Information |
|---|---|
| **Neural Control** | ❑ Autonomic (extrinsic) nervous system.<br>A- Sympathetic.<br>B- Parasympathetic. **(1)**<br>❑ The enteric nervous system (Next slides) |
| **Hormonal Control** | ❑ **As an endocrine organ.**<br>❑ Endocrine cells are located the pancreas, in the mucosa and submucosa of the stomach and intestine.<br>❑ They produce hormones that act on the secretory cells located in the wall of GIT, in the pancreas or in the liver to alter the rate or composition of their secretion.<br>❑ Other hormones act on smooth muscle cells or on sphincters.<br>❑ All the GI hormones are peptide such as **gastrin, secretin** and **cholecystokinin.** |

*(1)*

***A- sympathetic** generally inhibitory to the wall, but it contracts the sphincter.*
*Blood Flow: vasoconstrictor. so, will decrease the splanchnic blood flow.*

***B- parasympathetic** mainly through vagus nerve, generally stimulatory to the wall, but inhibits the contraction of the sphincter.*

# Sympathetic and Parasympathetic

Males' Slide

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| Sympathetic | Parasympathetic |
|---|---|
| ❑ The sympathetic fibers to the gastrointestinal tract originate in the spinal cord between segments T-5 and L-2.<br>❑ The sympathetics innervate essentially all of the GI tract, rather than being more extensive nearest the oral cavity and anus as is true of the parasympathetics.<br>❑ The sympathetic nerve endings secrete mainly *norepinephrine*.<br>❑ Stimulation of the sympathetic nervous system *inhibits* activity of the GI. Strong stimulation of the sympathetic system can inhibit motor movements of the gut so greatly that this literally can block movement of food through the gastrointestinal tract. | ❑ The parasympathetic supply to the gut is divided into *cranial* and *sacral divisions*.<br>❑ The *cranial parasympathetic* nerve fibers are almost entirely in the *vagus nerves*.<br>❑ The esophagus, stomach, pancreas and the intestines down through the first half of the large intestine are innervated by *vagus nerves*.<br>❑ The distal half of the large intestine and the anus are innervated by the *sacral parasympathetic* which pass through the *pelvic nerves* (to execute the defecation reflexes).<br>❑ The *postganglionic neurons* of the gastrointestinal parasympathetic system are located mainly in the myenteric and submucosal plexuses. Stimulation of these parasympathetic nerves causes general increase in activity of the entire enteric nervous system. |

# Control of GIS functions

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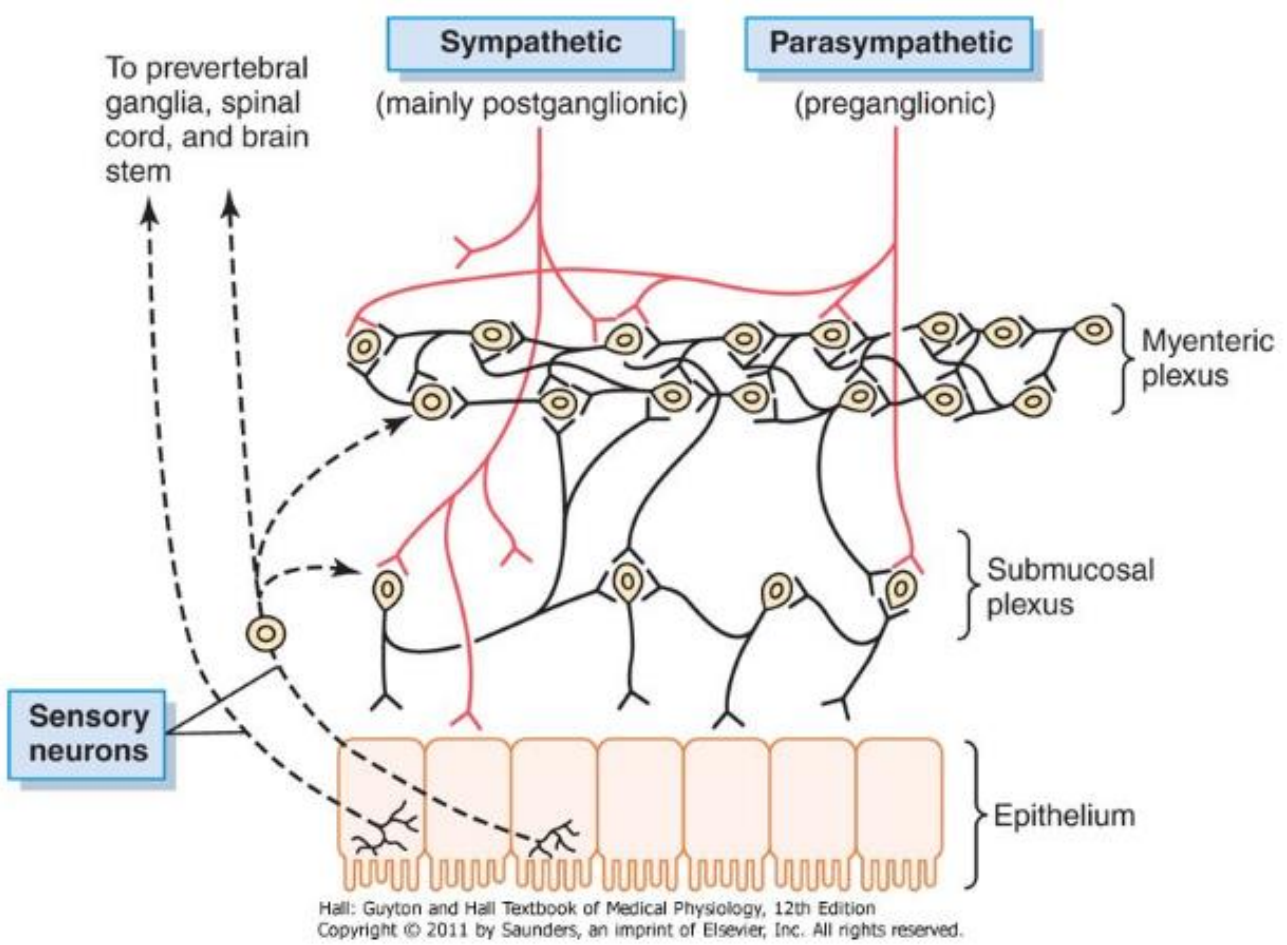
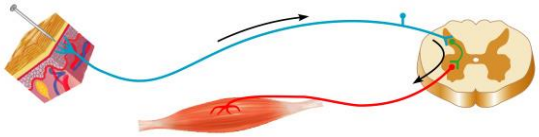


## Enteric Nervous System:



- Enteric Nervous System is the nervous system of GI tract.
- It lies entirely in the wall of the gut, beginning in the esophagus and extending all the way to the anus.
- It has as many neurons as spinal cord (about 100 million).
- It is composed mainly of two plexuses:

  **(1) The myenteric (Auerbach's)plexus** lies between the longitudinal and circular muscle layers) controls mainly the gastrointestinal movements ( motility )

  **(2) The submucosal (Meissner's) plexus** lies in the submucosa, controls mainly gastrointestinal secretion and local blood flow ( digestion )
- The enteric nervous system can function on its own, independently of the parasympathetic and sympathetic systems, however, these extrinsic nerves can greatly enhance or inhibit gastrointestinal functions.

The sensory nerve endings send afferent fibers to both plexuses of the enteric system and then to: (1) the prevertebral ganglia of the sympathetic nervous system (2) the spinal cord (3) the vagus nerves all the way to the brain stem. These sensory nerves can elicit local reflexes within the gut wall.

## Differences Between the Myenteric and Submucosal Plexuses:

| The myenteric plexus | The submucosal plexus |
|---|---|
| ❑ When it is stimulated, its principal effects are:<br>(1) Increased tonic contraction<br>(2) Increased intensity of the rhythmical contractions<br>(3) Increased rate of the rhythm of contraction<br>(4) Increased velocity of conduction of excitatory waves along gut wall | ❑ Controls local intestinal secretion, local absorption, and local contraction of the submucosal muscle that causes various degrees of infolding of the gastrointestinal mucosa.<br>❑ (related to secretion & blood flow) |
| ❑ Has **excitatory** and **inhibitory** motor neurons (fiber endings secrete an inhibitory transmitter, e.g., vasoactive intestinal polypeptide; VIP) | |

## Types of Neurotransmitters Secreted by Enteric Neurons:

The specific functions of many of GI neurotransmitters are not well known, but some research workers have discovered the effects of some of these substances as following:

| Excitatory Motor Neurons | Inhibitory Motor Neurons |
|---|---|
| ❑ **Evoke Muscle Contraction & Intestinal Secretion.** | ❑ **Suppress Muscle Contraction.** |
| **A. Neurotransmitters of motor neurons:**<br>i. Substance P<br>ii. Ach | Neurotransmitters:<br>i. ATP<br>ii. NO<br>iii. VIP |
| **B. Neurotransmitters of secretomotor neurons** (releasing of water, electrolytes and mucus from crypts of Lieberkuhn):<br>i. Ach<br>ii. VIP<br>iii. Histamine | |

# Afferent Sensory Nerve Fibers

Males' Slide

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- Many afferent sensory nerve fibers innervate the gut. Some of them have their cell bodies in the enteric nervous system and some in the dorsal root ganglia of the spinal cord.
- These sensory nerves can be stimulated by:
  - (1) Irritation of the gut mucosa
  - (2) Excessive distention of the gut
  - (3) Presence of specific chemical substances in the gut.
- Signals transmitted through the fibers can then cause *excitation* or *inhibition* of intestinal movements or intestinal secretion.
- Other sensory signals from the gut go all the way to multiple areas of the spinal cord and even the brain stem. For example, 80% of the nerve fibers in the vagus nerves are afferent rather than efferent. These afferent fibers transmit sensory signals from the gastrointestinal tract into the brain medulla, which in turn initiates vagal reflex signals (vagovagal reflexes).

# Gastrointestinal Reflexes

Males' Slide

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The anatomical arrangement of the enteric nervous system and its connections with the sympathetic and parasympathetic systems support three types of gastrointestinal reflexes that are essential to gastrointestinal control. They are the following:

1. *Reflexes that are integrated entirely within the gut wall enteric nervous system.*
2. *Reflexes from the gut to the prevertebral sympathetic ganglia and then back to the gastrointestinal tract.*

   These reflexes transmit signals long distances to other areas of the gastrointestinal tract, such as signals from the stomach to the colon (the *gastrocolic reflex*), signals from the colon and small intestine to inhibit stomach motility and stomach secretion (the *enterogastric reflexes*), and reflexes from the colon to inhibit emptying of ileal contents into the colon (the *colonoileal reflex*).

3. *Reflexes from the gut to the spinal cord or brain stem and then back to the gastrointestinal tract.*

   These include: (1) reflexes from the stomach and duodenum to the brain stem and back to the stomach—by way of the vagus nerves—to control gastric motor and secretory activity.
   (2) pain reflexes that cause general inhibition of the entire gastrointestinal tract.
   (3) defecation reflexes that travel from the colon and rectum to the spinal cord and back again to produce the powerful colonic, rectal, and abdominal contractions required for defecation (the defecation reflexes).

# Functional Types of Movements in GIT

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## Two types of movements occur in the gastrointestinal tract:

| Propulsive movements (peristalsis) | Mixing movements (segmentation) |
|---|---|
| ❑ Organizes propulsion of material over variable distances within the GI lumen (proximal to it - towards mouth -is contracted)<br>❑ A contraction ring appears around gut, then moves forward.<br>❑ Usual stimulus is distention. Other stimuli include chemical or physical irritation of the epithelial lining in the gut.<br>❑ Myenteric plexus is important<br>❑ Atropine (cholinergic blocker) depresses propulsion.<br>❑ **Receiving segment:** contraction (longitudinal M.) and relaxation (circular M.)<br>❑ **Propulsive segment:** contraction (circular M.) and relaxation (longitudinal M.) | ❑ Blend different juices with the chyme.<br>❑ Bring products of digestion in contact with absorptive surfaces.<br>❑ There are constriction rings appear at the same time (constriction of circular muscles at many points) |

**Peristaltic Reflex and the "Law of the Gut."**
When a segment of the intestinal tract is excited by distention and thereby initiates peristalsis, the contractile ring causing the peristalsis normally begins on the orad side of the distended segment and moves toward the distended segment, pushing the intestinal contents in the anal direction for 5 to 10 centimeters before dying out.

# Functional Types of Movements in GIT

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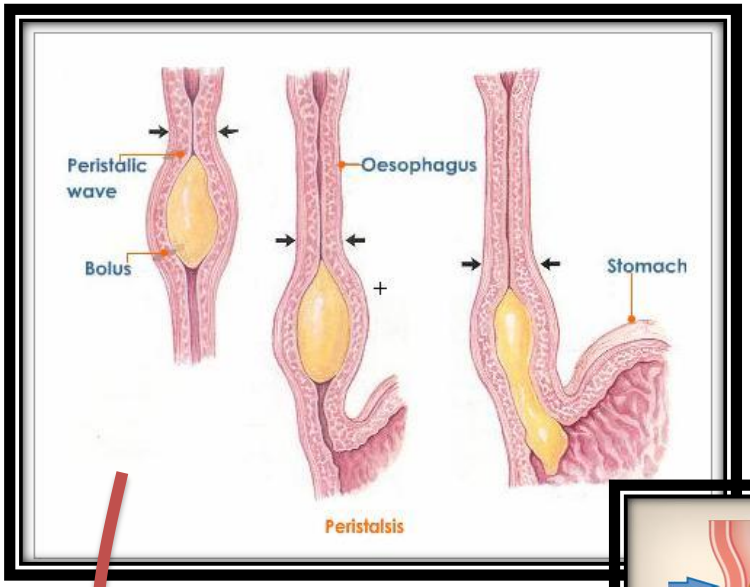
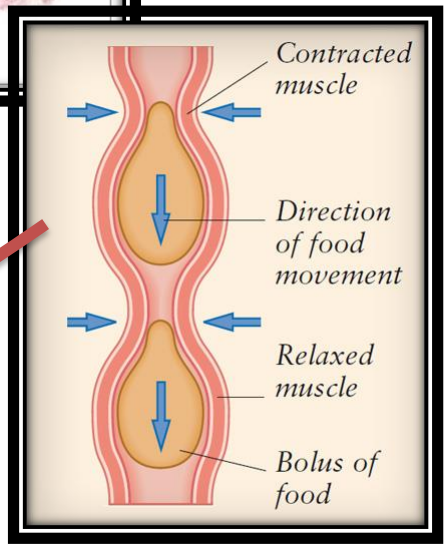
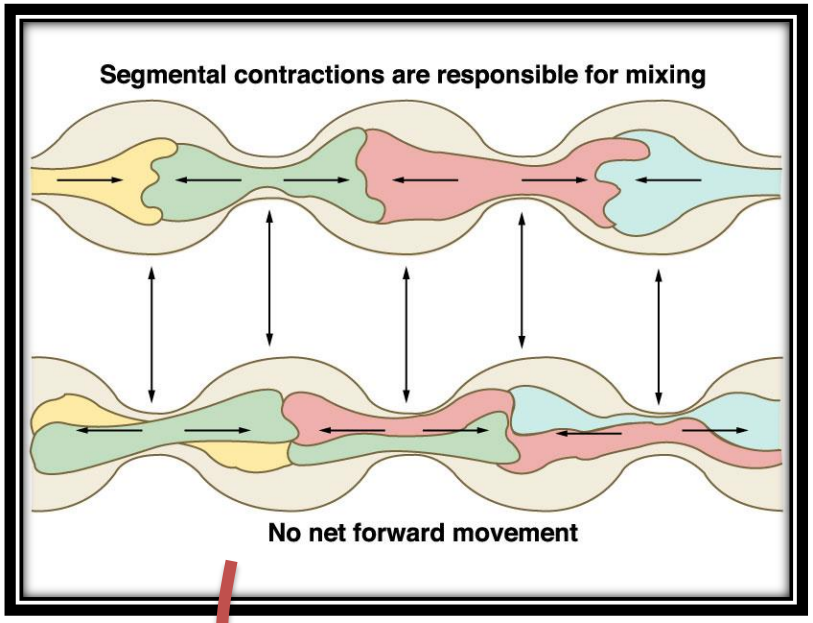


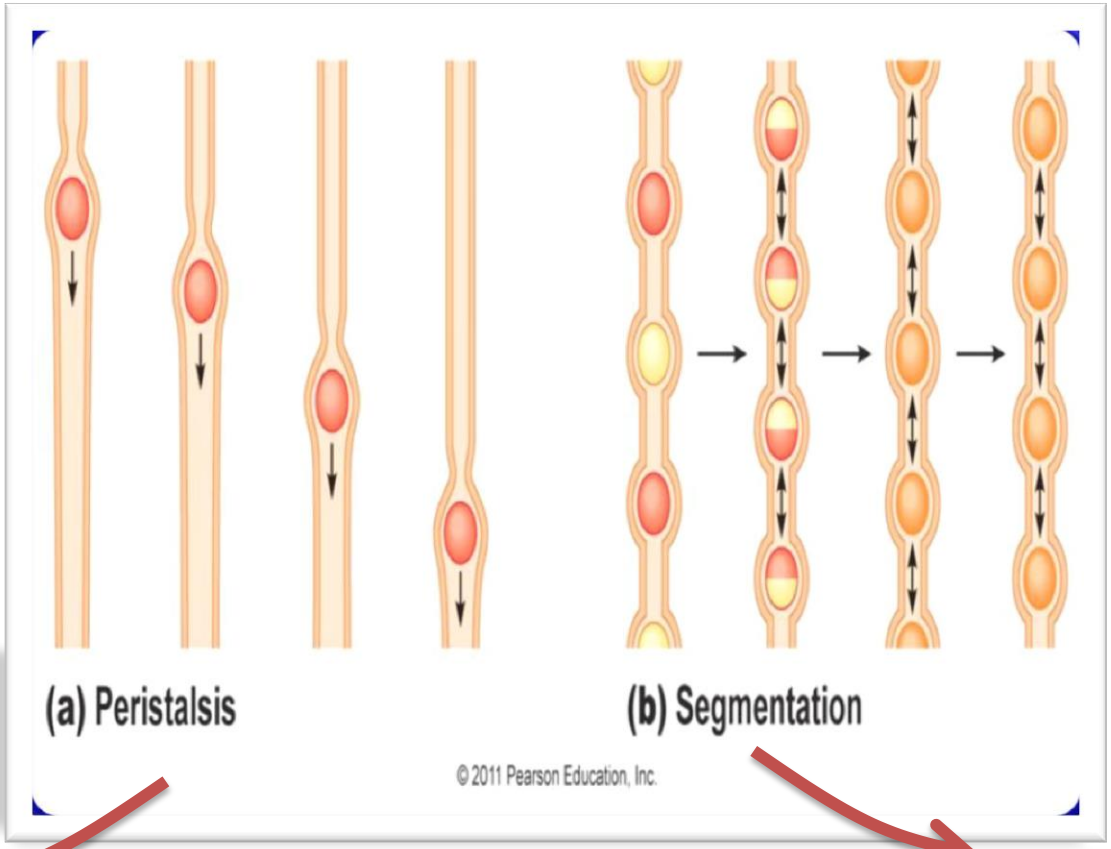




**Propulsive movements (peristalsis)**

**Mixing movements (segmentation)**

# Functional Types of Movements in GIT






**Propulsive movements (peristalsis)**

**Mixing movements (segmentation)**

# GI Blood Flow "Splanchnic Circulation"

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- Splanchnic circulation includes the blood flow through the gut itself 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.

**Factors that affect GI Blood Flow :** (2 factors)

**1- Effect of gut activity and metabolic factors.**

**Possible Causes of the Increased Blood Flow During Gastrointestinal Activity**

1. Most of the peptide hormones, including cholecystokinin, vasoactive intestinal peptide, gastrin, and secretin.
2. Some of the GI glands release into the gut wall two kinins: kallidin and bradykinin
3. Decreased oxygen concentration in the gut wall can increase intestinal blood flow at least 50 to 100 per cent.

**Factors that affect GI Blood Flow :**

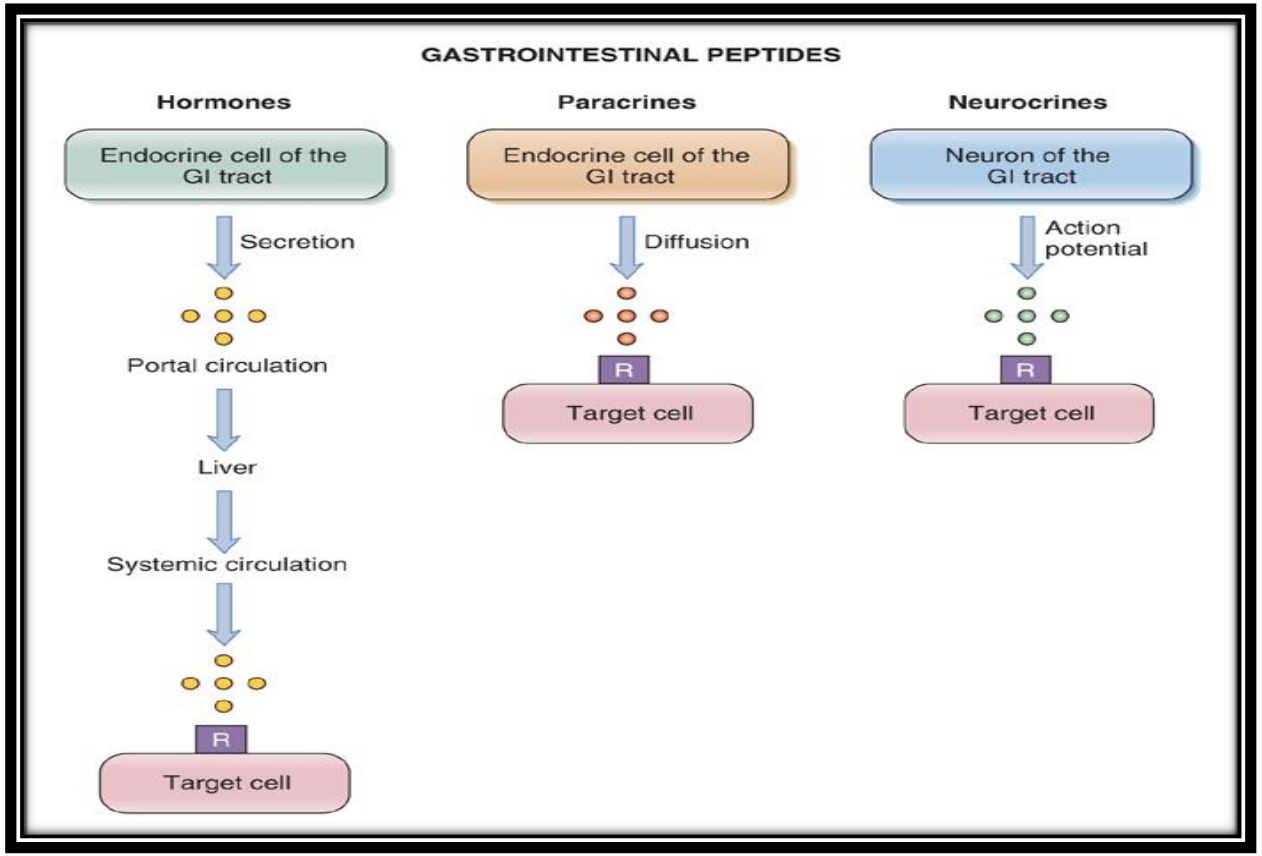
2- Nervous Control.

- Stimulation of the parasympathetic nerves going to the stomach and lower colon increases local blood flow at the same time that it increases glandular secretion.
- Sympathetic stimulation, by contrast, has a direct effect on essentially all the GIT to cause intense vasoconstriction of the arterioles with greatly decreased blood flow. But the local metabolic vasodilator mechanisms override the sympathetic vasoconstiction effects, returning the normal blood flow to GI muscle and glands.

# SUMMARY

Physiology Team

You can check Dr.Hayam's slides (Page 19-20) .. But at this level, That Two Tables are FYK .. By the end of GIT Block inshallah you will be able to make your own table according to what you obtain from this block.



# QUESTIONS

Physiology Team

**1. Decreased intestinal motility my be due to damage of which one of the following :** B

A- Ileocecal sphincter
B- Myenteric plexus
C- Sub mucosal plexus
D- Sympathetic adrenergic fibers

**2. Which one of the following is increased due to stimulation of the submucosal plexus :** B

A- Intensity of rhythmic contraction
B- Intestinal secretion
C- Tonic contraction
D- Velocity of conduction of excitatory waves

**3- Which of the following is not true as regard peristalsis?** B

A- Peristalsis is a reflex response
B- It occurs in all parts of the GIT except the esophagus
C- Its occurrence is independent of the extrinsic innervation
D- It is initiated when the gut wall is stretched by the contents of the lumen

**4- Contraction of longitudinal muscle:** A

A- Shortness the segment
B- Increases the length of that segment
C- Decreases the diameter of the lumen
D- Does not affect the length of that segment

**5- Slow Waves are ( pacemaker for GIT ):** C

A- Generated from G cells
B- Generated from parietal cells
C- Generated from cajal cells
D- Generated from S cells

# THE END

Physiology Team

**If there are any Problems or Suggestions,**
**Feel free to contact us:**


**Physiology Team Leaders**

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THANK YOU

IF YOU WANT TO SHARE ANY INFORMATION REGARDING PHYSIOLOGY OR ANY OTHER SUBJECT .. YOU CAN MENTION THIS ACCOUNT @MED432