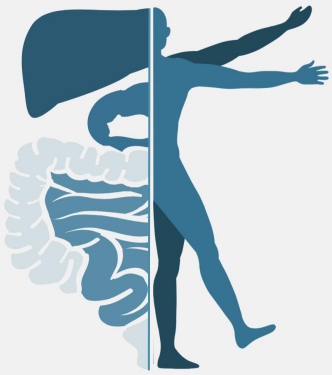
Physiology Team 439

MED439
KING SAUD UNIVERSITY

Revised & Approved
Bassam Alasmari
Rania Almutiri



General Principles of GIT Physiology

Special thanks to Shaden Alobaid

Objectives:

- Physiologic Anatomy of the Gastrointestinal Wall
- The General Characteristics of Smooth Muscle
- Smooth muscle cell classifications and types of
- contraction
- Muscle layers in GI wall
- Electrical Activity of Gastrointestinal Smooth Muscle
- Slow Waves and spike potentials
- Calcium Ions and Muscle Contraction
- Neural Control of Gastrointestinal Function-Enteric Nervous System
- Differences Between the Myenteric and Submucosal Plexuses
- Types of Neurotransmitters Secreted by Enteric Neurons
- Autonomic Control of the Gastrointestinal Tract
- Hormonal Control of Gastrointestinal Motility
- Functional Types of Movements in the GI Tract
- Gastrointestinal Blood Flow-"Splanchnic Circulation"
- Effect of Gut Activity and Metabolic Factors on Gastrointestinal Blood Flow.

Color index:

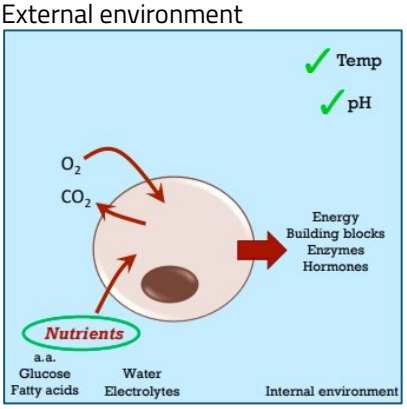
- Important.
- Girls slide only.
- Boys slide only.
- Dr's note.
- Extra information.

Editing File

Introduction

- Our bodies are made of cells. Cells live in an internal environment. This internal environment contains contents which define how the cell will live.
- Cells works hard to keep our body well and healthy
- For cells to their job they need to acquire some essential elements from the environment surrounding them " internal environment"
- What essential elements do cells need from the internal environment? O_2, Nutrients, pH, Temperature, waste products

External environment



How do nutrients reach our internal environment?

- Nutrients reach our internal env. through the GI system.
- The main function of the GI system is transfer nutrients from external environment into the internal environment.
- Can our cells utilize nutrients immediately as they are in the food we consume?
  No. The GI system will break down the macromolecule into a micromolecule then absorb it from the lumen of GI to blood so it can reach the cell. Ex: sugar -> monosaccharide, protein -> amino acid etc..

Protein, meat, carbs,nutrients fats, vitamins  **Ingest** → Macromolecules in food → There are 4 basic processes that enable it do its job → Micromolecules that cells can use

The 4 basic GI processes

1. **Motility:** movement of food
   The muscular contractions that mixes and moves GI contents forward through the GI tract.

2. **Secretion:**
   Along the way, digestive juices are secreted into the GI lumen by exocrine glands.
   Importance of secretion: contains enzymes that break down macromloecules

3. **Digestion:**
   As the contents move along the GI tract, complex foodstuff gets broken down into smaller absorbable molecules. It mixes bolus of food with other secretions and makes it more accessible for enzymes and secretion. It's a mechanical and a chemical process

4. **Absorption:**
   The small units are transferred from GI lumen into blood or lymph.

Gastrointestinal function*

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

To achieve this function, it requires:

1. Movement of food through the alimentary tract (motility) .
2. Secretion of digestive juices and digestion of the food
3. Absorption of water, various electrolytes, and digestive products.
4. Circulation of blood through the gastrointestinal organs to carry away the absorbed substances

The GI system

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

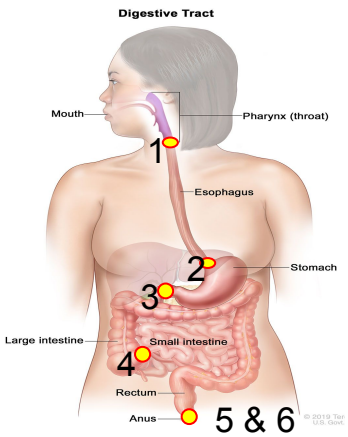
Accessory organs*

1. Salivary glands (into mouth)
2. Liver and gallbladder (They secrete in duodenum & aid in digestion)
3. Pancreas

These add secretions to the digestive tract.

Digestive Tract*

1. A hollow tube extending from mouth to anus
2. Each region is modified to serve its function.
3. Regions are separated by sphincters (They control movement from one region to the other)



1- Upper esophageal sphincter : Between the pharynx & esophagus

2- Lower esophageal sphincter: Between esophagus and stomach

3- Pyloric sphincter: Between stomach and duodenum

4- Ileocecal valve: Between small intestine and cecum

5- External and internal anal sphincter: Between GI system & External env.

Total = 6 sphincters

The journey of the burger starts at the mouth and ends at the anus

What does the burger pass through ?

2- Salivary glands

Lubrication & enzymes for carb digestion.

1- Mouth & Oropharynx

Chop and lubricate food, initiate carb digestion, propels food into the esophagus

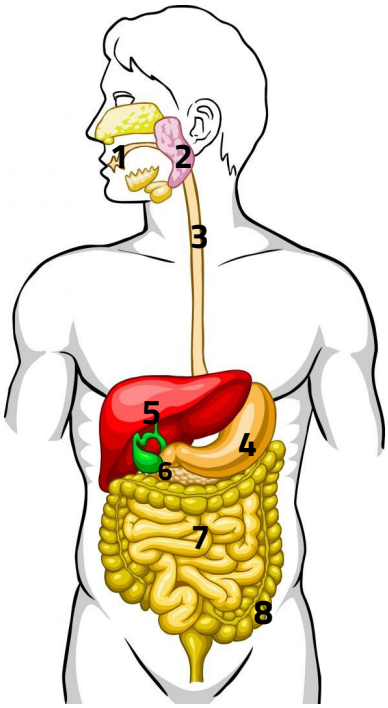
It has teeth, tongue powerful muscles like Masseter. Mechanical breakdown of food occurs and some of the chemical digestion starts (Carbs). Oropharynx will propel food into esophagus

5- Liver & Biliary system

Secretes bile for fat digestion.

6- Pancreas

Digestive enzymes into duodenum (HCO_3^-)



3- Esophagus

Conducts food to stomach.

The stomach is located in the abdomen, and the esophagus has to deliver food from the mouth through chest which contains (heart, lungs..). It's a path that allows food to reach the stomach.

8- Large intestine

Reabsorbs fluid & electrolytes and stores fecal matter. .

Large Intestine is responsible for reabsorbing electrolytes and fluid that have poured into the bolus whether its secreted or consumed. At the end it stores fecal material until it's appropriate to be excreted

4- Stomach

Stores food and initiates protein digestion.

Sometimes we eat a big meal in bouts which are large. Until the body breaks it down, it will be stored in the stomach since it's shape and capacity helps. The stomach continues the process of digestion and breaking down (chemically and mechanically)

7- Small Intestines

Continues Digestion. Primary site of absorption.

By the time the bolus of food leaves the stomach and reaches the intestine, it will be called chyme (more liquid). The intestine will continue digesting whatever had not been digested previously. It will start absorbing nutrients into the blood. There will be secretion of digestive enzymes coming from the pancreas as well as bile acids coming from biliary system and liver.

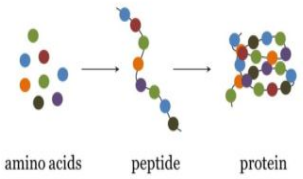
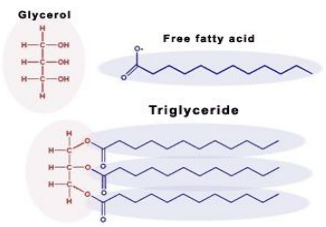
Secretion

Definition: it is an active process in which the GI tract secretes digestive juices (ex: acids, enzymes) which may come from the exocrine glands that are attached to the GI system, or from specialized cells in the GI wall.

Digestive secretions consist of:
Water + electrolytes + specific organic constitutes (enzymes, bile salts, mucus..ect) each region will have its own juice

Digestion

Three different biochemical categories of foodstuff

Carbohydrates Main energy source	Protein Imp. for everything	Fat Energy source
Carbs that we ingest are polysaccharides (starch, glycogen, mono-disaccharides) Carbs that can be reabsorbed are monosaccharides (glucose, fructose, galactose) Digestion will break down polysaccharides into monosaccharides.	Digestion will break down dietary proteins into small polypeptides and amino acids  	Dietary fats is usually triglycerides ↓ Monoglycerides 

Absorption

Definition: The transfer of small absorbable units form the GI lumen into blood and lymph.

- ❖ It occurs by the splanchnic circulation

Motility*

*Only in girls slides

- The importance of movement of the wall of the GI system is:
1. Mixing with digestive secretions
2. Propulsion
3. Exposure to absorptive surface

- The structure that is responsible for its ability to produce movement is: the smooth muscle cells located on GI wall

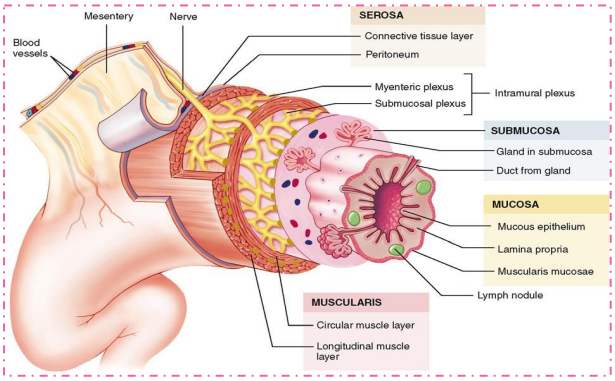
Anatomy of the GI wall

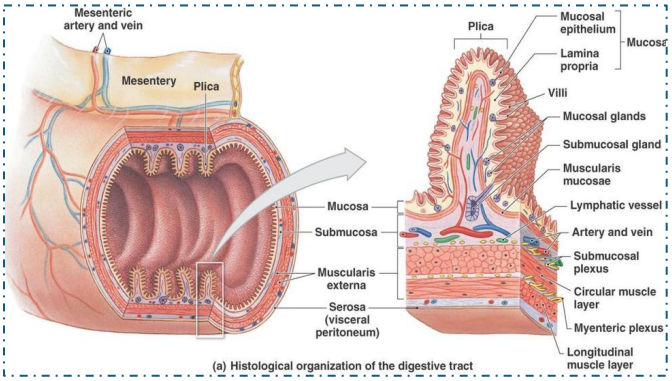
4 main layers/ 5 layers (from outer surface inward) muscularis layer can be considered as one layer or two

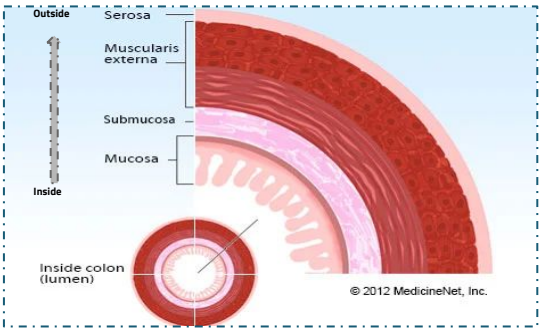
1. Serosa
2. Muscularis (longitudinal muscle layer) **Outer:** fibers of the longitudinal smooth muscle تمشي طوليا علي الجي اي تراكت When it contracts, it will shorten the segment of the GI.
3. Muscularis (Circular muscles layer) **Inner:** The circular smooth muscle surrounds the lumen. When it contracts, it will constrict the lumen and decrease its diameter.
4. Submucosa (Denser CT) larger blood vessels, nerves and lymphatics pass through
5. Mucosa (Loose CT) small capillaries, vessel and nerves pass through

In addition, sparse bundles of smooth muscle fibers, the mucosal muscle lies in the deeper layers of the mucosa.*

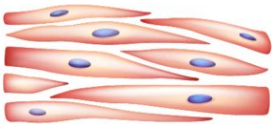
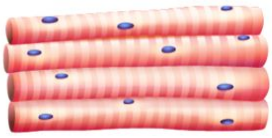
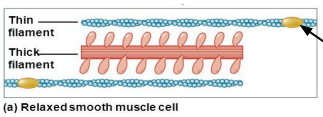
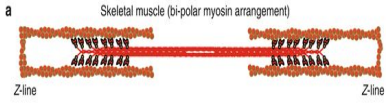
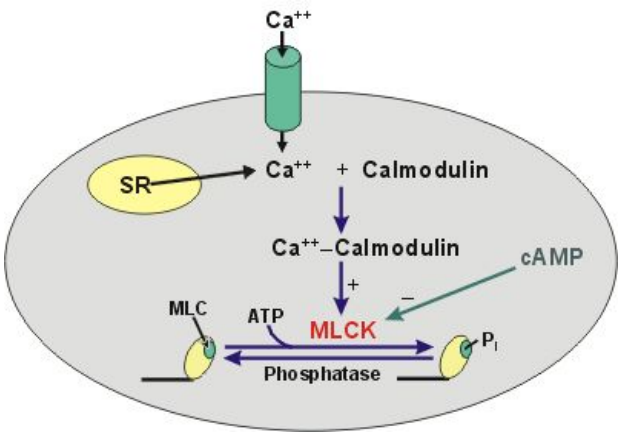
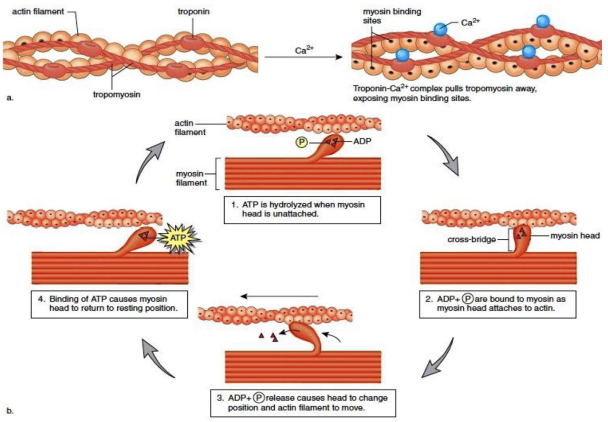
A cross section of the GIT will look the same from the esophagus to anus, because the structure and layers of the wall are the same. All contain 5 layers. However they are different in cells, glands, length etc..







Characteristics of smooth and skeletal muscle

Smooth muscles	Skeletal muscle
	
Spindle shaped, Non-striated	Cylindrical muscle fibers , Striated
Single nucleus	Multinucleated
Smaller and shorter	Long
Involuntary	Voluntary
Contractile units arranged diagonally	Contractile units arranged parallel to long axis of fiber
 Dense bodies	Z-lines
Cross bridges are present along the entire length of the thick filament.	Bare portion in the center of the thick filament.
Ca^{+2} induces a chemical change in myosin (thick filament)	Ca+2 induces a physical change in actin (thin filament)
Side- polar myosin arrangement. Cross bridge is covering the whole thick filament (myosin)	Bipolar myosin arrangement (no cross bridge in the middle)
Contraction: thin filaments surrounding the thick filament will move into opposite directions	Contraction: both thin filaments surrounding thick filament will move in the same direction
	
	

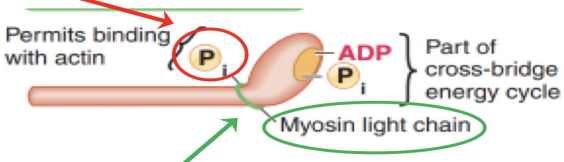
Contraction of smooth muscles

- Contraction is brought about by sliding of the thin filament over the thick filament.
- Myosin attaches to actin by its actin-binding site and then the power stroke causes sliding of the actin filament over myosin.
- The thin filament of smooth muscle **does not** have troponin.
- Tropomyosin **does not** block actin-binding site.

What stops myosin from binding to actin at rest?

The myosin head can interact with actin only when the MLC is ***phosphorylated***

The **thick filaments** are composed of myosin, and the **thin filaments** are predominantly actin.



At the neck region of the myosin head → a lightweight protein is attached = Myosin light chain (MLC)

Myosin is prevented from binding to actin at rest by myosin light chain (MLC). When MLC is phosphorylated, myosin will form a cross bridge with actin and a contraction will occur

Ca+2

↓

Ca+2 binds to calmodulin

↓

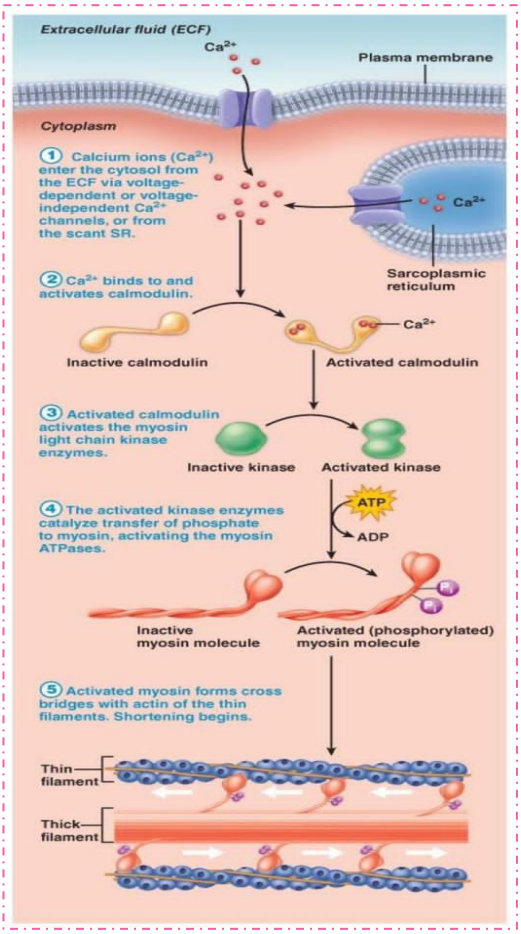
Ca-CaM complex activates MLCK

↓

Phosphorylates myosin head increasing the activity of ATPase

↓

Myosin head attaches to actin causing sliding of the filaments



Smooth muscle cells use cross-bridge cycling between actin and myosin to develop force, and calcium ions (Ca^{+2}) serve to initiate contraction. Thus, contractile activity in smooth muscle is determined primarily by the phosphorylation state of the light chain of myosin

Types of smooth muscle

Smooth muscles can be classified in many ways depending on the timing and means of increasing cytosolic Ca+2

Classification of Smooth muscles

- Phasic vs tonic
- Multiunit vs. Single unit
- Neurogenic vs Myogenic

A smooth muscle of one organ may be multiunit, phasic and neurogenic While another organ it might be single-unit, tonic and myogenic

A smooth muscle can be classified by the 3 classifications at the same time.

Phasic vs. Tonic

(depending on its contractile activity and how its cytosolic Ca^{+2} increases)*

Phasic

- Contracts in bursts "intermittently"
  a cycle of a contraction followed by a relaxation. A new stimulus arrives: contraction -> relaxation .. and the cycle goes on
- Contraction ⟶ Relaxation
- Contraction triggered by an action potential which increase [Ca^{+2}]
  When an AP reaches cell, it will open Ca+2 channels. Ca+2 will flow from ECF to ICF, and some will come from Sarcoplasmic reticulum -> trigger contraction process.
- **Examples:**
  GI tract
  Gastric antrum
  Small intestine
  Esophagus

Tonic

- Muscle is usually partially contracted at all times. Continuous partial contraction (Tone) they only relax when there's an inhibitory signal coming from NS
- **Examples:**
  1. Blood vessels are always at a certain tone (not always relaxed or always contracted). This plays a role in BP regulation
  2. Airways
  3. Orad region of stomach,
  4. Lower esophageal, ileocecal, internal anal sphincter
- **Causes of tonic contractions*:**
  (1) Repetitive spike potentials
  (2) Hormones
  (3) Continuous entry of Ca ions

Not associated with slow wave unlike phasic (often lasting several minutes or hours)

This type has a **low RMP** (close to +ve than -ve) at which some **voltage gated Ca^{+2}** channels are open ⟶ entry of Ca^{+2}⟶ partial contraction*

Types of smooth muscle cont.

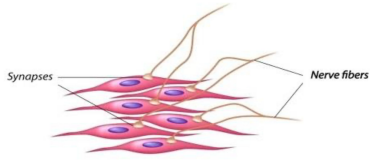
Single unit vs. Multi-unit

Based on how they get excited

Multiunit

- Composed of discrete, separate smooth muscle fibers.
- Each fiber operates **independently.**
- Each is innervated by a single-nerve ending.
- E.g. ciliary muscle and iris of the eye, piloerector muscle.
- Does not contract in response to stretch or **without** neural input (such as in esophagus & gallbladder)

activated by hormones and neurotransmitters.

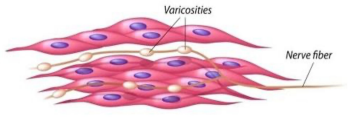


Multiunit Smooth Muscle

Single (Unitary)

- Composed of many smooth muscle fibers that become excited and contract as a single unit.
- Cells are connected by gap junction
- Function as a **syncytium.**
- E.g. Uterus, GI tract.
- Contracts spontaneously in the absence of neural or hormonal influence but in response to stretch (such as in stomach and intestine)

The smooth muscles are connected to each other by gap junctions. So when a stimulus arrives it doesn't have to arrive at each muscle, it's enough for it to arrive at one then the signal will spread to the rest of the muscle through gap junctions



Single-unit Smooth Muscle

Myogenic vs. Neurogenic*

Myogenic

- Self-excitable.
- Contraction is initiated intrinsically within the muscle without external nervous stimulus.

They are specialized cells that act as pacemakers and generate an AP regardless of external innervation

Neurogenic

- Contraction is initiated in response to nerve"signals" stimulation.

Male slides

Types of smooth muscle cont.*

	Longitudinal	Circular
Characteristics	❖ Thinner and weaker than circular ❖ Contraction shortens the segment of the intestine and expands the lumen ❖ The **Ca^{+2} influx from outside** is important in the activity of this type of muscle. because the intracellular Ca^{++} storage is insufficient ❖ Contraction shortens the distance that the food has to travel	❖ Thicker and more powerful than longitudinal ❖ Contraction reduces the diameter of the lumen and increases its length ❖ More gap junctions are available. ❖ **Intracellular release of Ca^{+2}** is more important. ❖ Contraction pushes food forward or backward
Contains	Excitatory motor neurons	Excitatory and inhibitory motor neurons
Innervated by	**Enteric Nervous System (ENS)**	

The Specific Characteristics of Smooth Muscle in the Gut

Gastrointestinal Smooth Muscle Functions as a Syncytium

Numbers are not important

Individual smooth muscle fibers

Length: 200 to 500 µm

Diameter : 2 to 10 µm

Arranged in bundles of ≤ 1000 parallel fibers.

Within each bundle, the muscle fibers are electrically connected with one another through large numbers of gap junctions.

Each muscle layer functions as a **syncytium.**

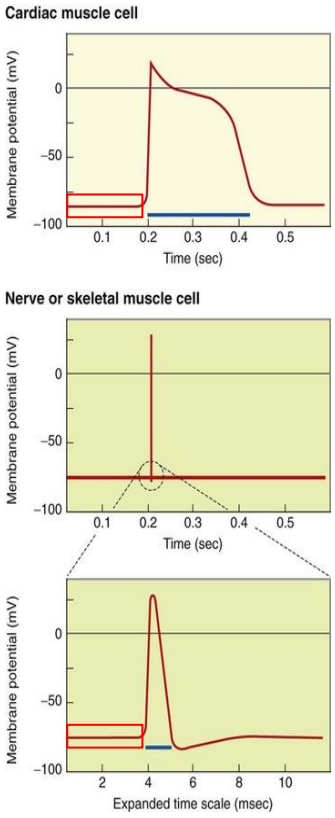
Electrical Activity of Gastrointestinal Smooth Muscle

The smooth muscle of the gastrointestinal tract is excited by almost continual slow, intrinsic electrical activity along the membranes of the muscle fibers.

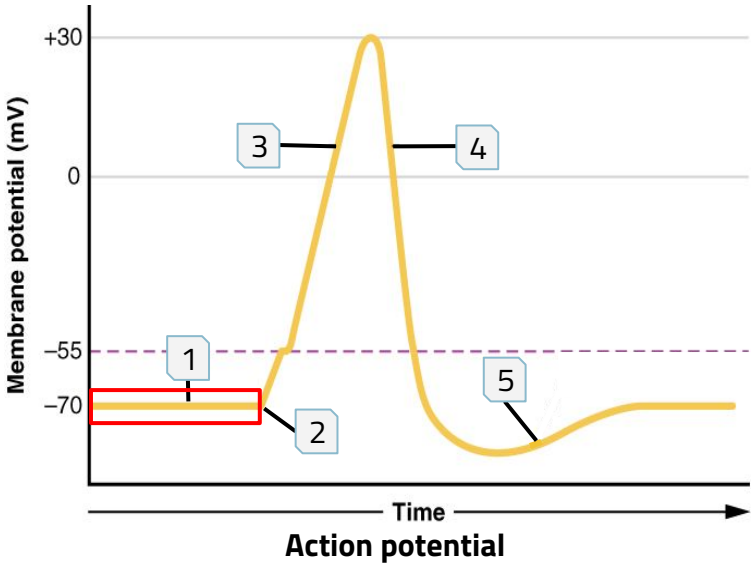
The activity is divided into two types of electrical waves :

- Slow Waves
- Spikes (Action potentials)

Electrical activity of Nerve & Skeletal Muscle



A resting membrane potential RMP is linear and constant = no activity. It changes (upstroke) when there's a stimulus that will push the membrane potential to the threshold. When it reaches a threshold, an AP will be generated. Depolarization: caused by Na+ entry. Repolarization: caused by K+ efflux.



- RMP is around = -70mV and is stable
- If a stimulus arrives and pushes it towards threshold and AP develops

Graph explanation

1. Stable resting membrane potential
2. Ligand-Gated channels open, allowing Na^+ or Ca^{2+} to depolarize cell to threshold
3. When the cell reaches the threshold, voltage-gated Na^+ channels open, causing an action potential
4. At this high membrane potential, Na^+ channels close, and K^+ channels open, repolarizing the cell
5. When the cell returns to the resting membrane potential, voltage-gated K^+ channels close

Smooth Muscle Electrical Activity

Slow waves

Most GI contractions occur rhythmically, determined mainly by "slow waves". These waves are **not action potentials.** They are oscillating depolarization and repolarization in the resting membrane potential with unknown cause.

RMP is NOT stable. It is characterized by **spontaneous alternating hyperpolarizing and depolarizing swings** in potential (slow wave potential) *

The Intestinsity of slow wave varies between 5-15mV.

The frequency of slow wave varies from one organ to the other in GIT tract:

- Stomach 3/min which is why gastric emptying is considered slow when compared to the rest of GIT
- Duodenum 12/min
- Ilium 8-9/min

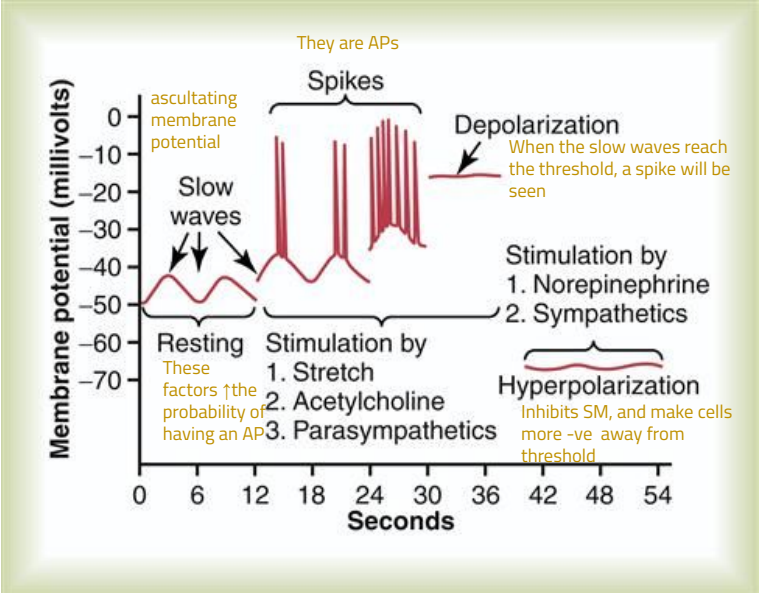
When the slow wave potential reaches threshold -> true action potential is generated on the peak of slow wave = spike potential. one slow wave can produce 10 action potentials. Every action potential will have a depolarization followed by repolarization.

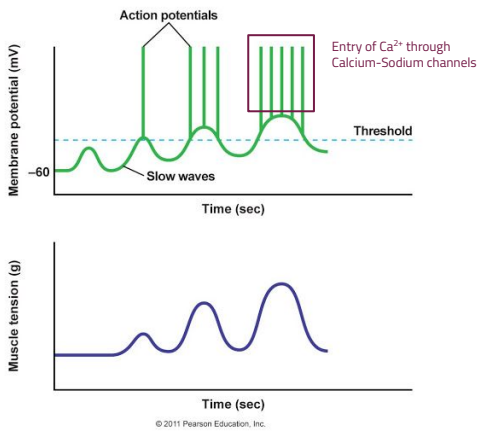
Slow waves are not AP. They can not generate contractions. Slow waves can generate an AP that will generate a contraction.

Origin of slow waves:

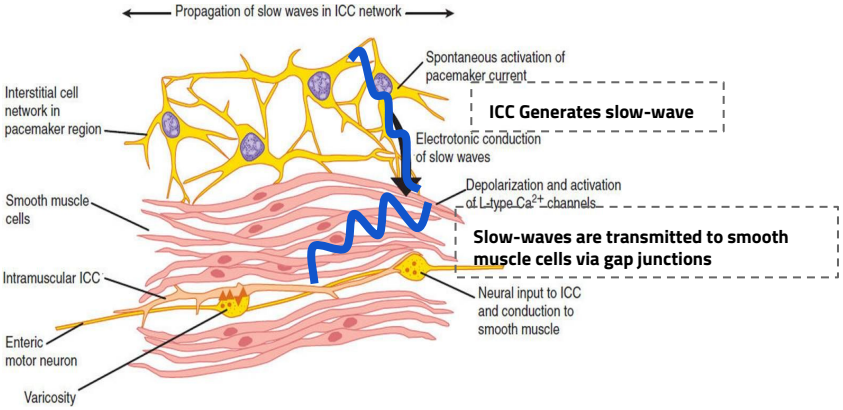
- They may originate in the **interstitial cells of Cajal** (ICC neuronal cells, the GI pacemaker), which are abundant in the myenteric plexuses. (but not exclusive)
- These ICCs form a network with each other and are interposed between the smooth muscle layers, with synaptic-like contacts to smooth muscle cells.

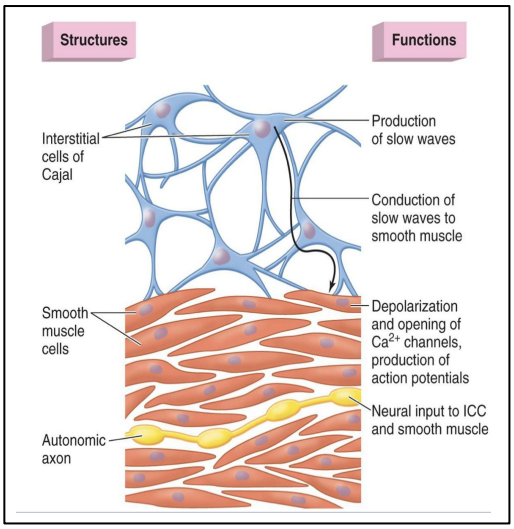
When we disconnect the GI system from CNS, the GI can work normally since it has its own pacemaker. The enteric nervous system is a large division of PNS which controls the GI behavior independently of CNS input.





Pacemakers of the GUT





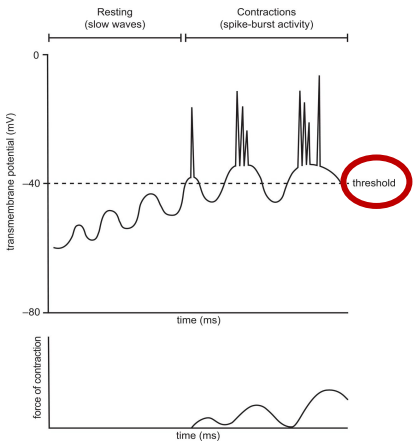
- **Interstitial cells of Cajal (ICC)** are a specialized, non-contractile cell that can undergo cyclical changes in membrane potential.
- The pacemakers of the gut.

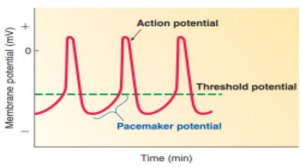
If we assume we have one ICC. Once we reach the threshold, a slow wave will generate an AP. The AP can propagate and activate all cells (neural cells and smooth cells). So, a whole segment can be activated by **one ICC**.

IMPORTANT: The ion that is responsible for the slow wave is Na+ influx **not** Ca^{+2}

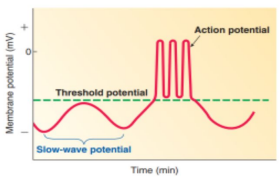
Spike Potentials

- Spike potential are **real action potentials.**
- They occur automatically when the resting membrane potential of the gut smooth muscle is more positive (<-40mV).
  Threshold: (<-40mV)
  Normal RMP in smooth muscles: between -50 and -60 mV
- **The higher the slow wave potential rises, the greater the frequency of the spike potential ranging between 1 and 10 pikes per second.**
- They last **10 to 40 times** as long in gastrointestinal muscle as the action potentials in large nerve fibers, each garoeintenal spike lasting as long as **10 to 20 msec**.





Pacemaker potential



Slow-Wave potential

The AP of the smooth muscle is similar to the AP pacemaker of cardiac muscle "SA node". The difference it that the SA node is unstable but it's regular. It always reaches the threshold, unlike muscle contraction. Significance: we don't need the GIT to work while we're asleep, unlike the cardiac muscle. we need our heart to pump through out our whole life.

Smooth Muscle Electrical Activity*

In GI smooth muscle fibers, the channels responsible for the action potentials are somewhat different; they allow especially large numbers of calcium ions to enter along with smaller numbers of sodium ions and therefore are called calcium-sodium channels. These channels are **much slower** to open and close than the rapid Na channels of large nerve fibers.

Ca++ ions & Muscle Contraction*

- Smooth muscle contraction occurs in response to entry of calcium ions into the muscle fiber. The slow waves do not cause calcium ions to enter the smooth muscle fiber (only sodium ions).

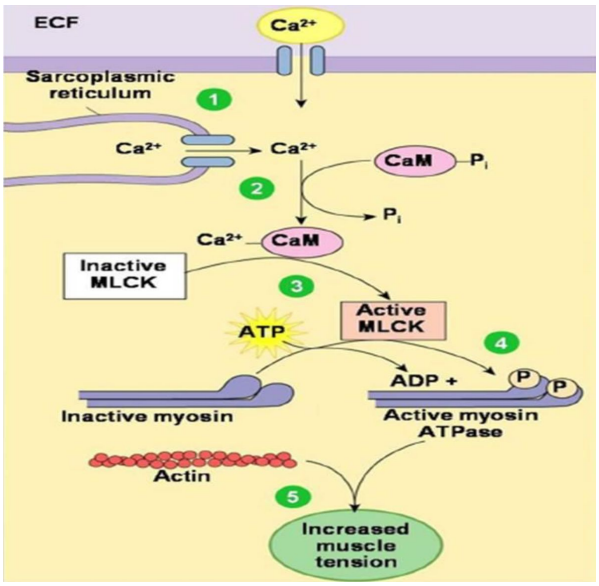
- Therefore, the slow waves by themselves usually cause no muscle contraction (except in the stomach). Instead, it is during the spike potentials, generated at the peaks of the slow waves, that significant quantities of calcium ions do enter the fibers and cause most of the contraction.

Tonic Contraction of Some Gastrointestinal Smooth Muscle*

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

They don't depend on slow wave because a slow wave may and may not generate an AP. They are controlled by: repetitive spike potentials, hormones and continuous entery of Ca++ ions.

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 heads and increases myosin ATPase activity.
5. Activate myosin crossbridges slide along actin and create muscle tension.



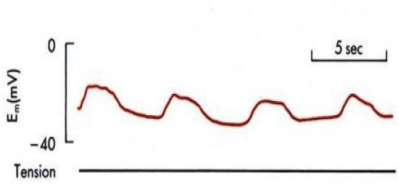
Smooth Muscle Electrical activity (M)

1- The effect of norepinephrine or epinephrine on the fiber membrane

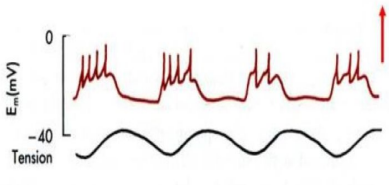
Factors that hyperpolarize the membrane potential

2- Stimulation of the sympathetic nerves that secrete mainly norepinephrine at their endings. Sympathetic stimulation decrease number of spike potentials

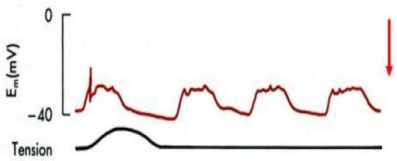
Slow or myogenic wave (oscillating depolarization and repolarization; "basic electrical rhythm") fail to induce contraction because E_m is below threshold



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

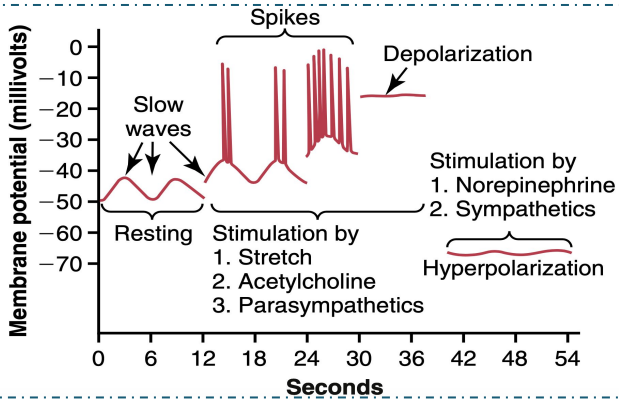


If resting potential is shifted to more negative values (from sympathetic input) spikes and contractions will not occur



Factors that depolarize the membrane potential

1. Stretching of the muscle
2. stimulation by acetylcholine released from the endings of parasympathetic nerves
   it is considered as an excitatory NS for the GI
3. Stimulation by several specific gastrointestinal hormones



- **The level of RMP in smooth muscle can be modified by several factors, it averages about -56mV.** which is less negative than other cells making it easily excitable **(M)**
- **If it becomes less negative = depolarized → muscle is more excitable.**
- **If it becomes more negative= hyperpolarized → muscle becomes less excitable.**

Control of the GIT system

1 Neural

2 Hormonal

External

Sympathetic Innervation
(Thoracolumbar Outflow)

External

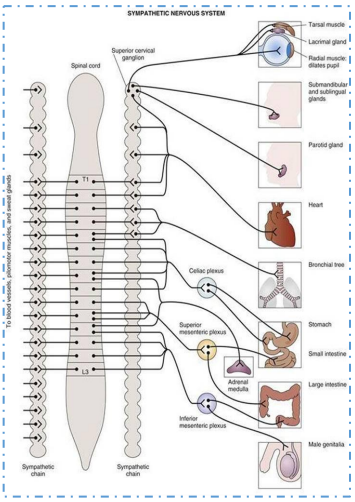
Parasympathetic Innervation
(Craniosacral Outflow)

Local
Brain of gut

Enteric Nervous System

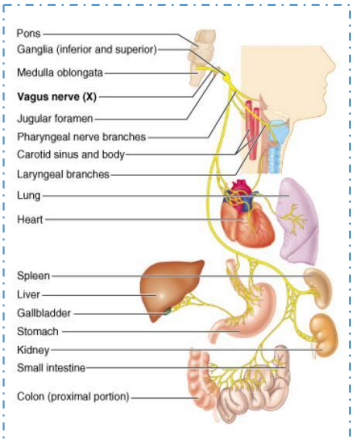
Sympathetic*

- The sympathetic fibers originate in the spinal cord between segments T- 5 and L2.
- The sympathetics innervate essentially all of the GI tract.
- The sympathetic nerve endings secrete mainly norepinephrine.
- Stimulation of the sympathetic nervous system inhibits activity of the GI system.
- 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 GI tract.



Parasympathetic*

- The vagus nerves (cranial division) innervate the esophagus, stomach, pancreas and intestines down to the first half of the large intestine.
- The pelvic nerves (sacral division) innervate the distal half of the large intestine and the anus (to execute the defecation reflexes).
- The postganglionic neurons of the gastrointestinal parasympathetic system are located mainly in the myenteric and submucosal plexuses.
- Stimulation of parasympathetic nerves causes general increase in activity of the entire enteric nervous system.



Enteric Nervous System

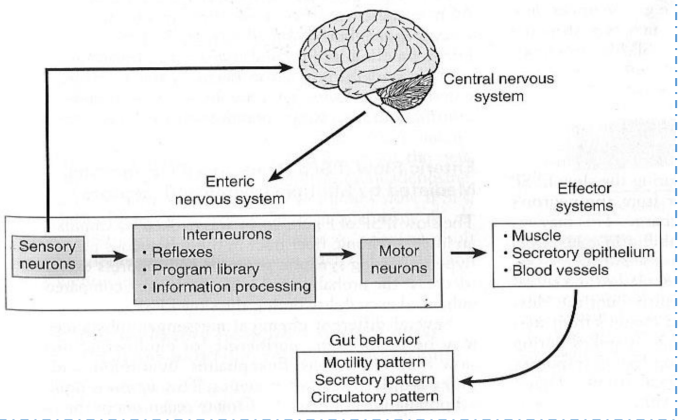
- Enteric Nervous System (ENS) is the nervous system of GI tract.
- It lies entirely in the wall of the gut, beginning in the esophagus and extending all the way to the anus.
- It has as many neurons as the spinal cord (about 100 million).

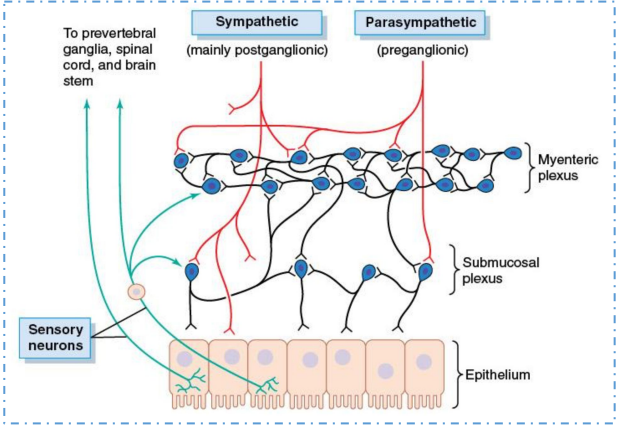
Neural Control of Gastrointestinal Function-Enteric Nervous System

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 brainstem.

These sensory nerves can elicit local reflexes within the gut wall





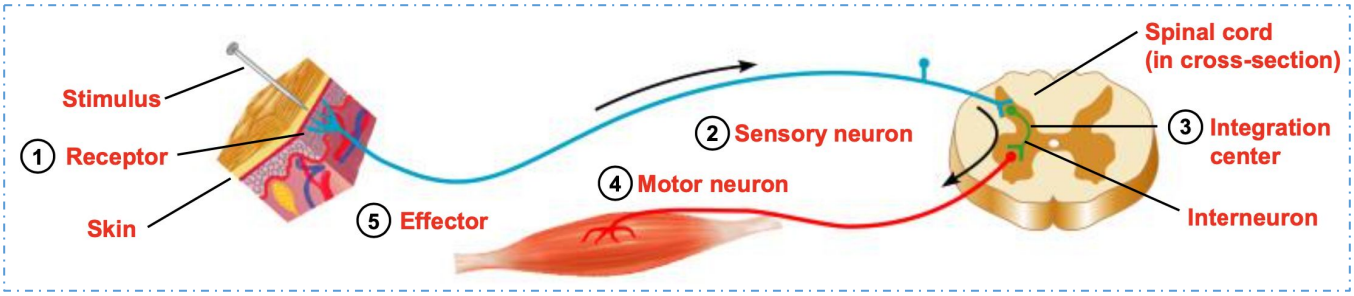
Components of the enteric nervous system It is composed mainly of two plexuses (interconnected) **VERY IMPORTANT**

The Myenteric Plexuses

- An outer plexus lying between the longitudinal and circular muscle layers.
- Consists mainly of a linear chain of many interconnecting neurons.
- When stimulated, its principal effect is to:
  (1) Increase tonic contraction
  (2) Increase intensity and rate of the rhythmical contractions.
  (3) Increase velocity of conduction of excitatory waves along the gut wall.
- **Control mainly the gastrointestinal movements (motility)**
- **Auerbach's plexus**
- The myenteric plexus has excitatory and inhibitory motor neurons.

The Submucosal (Meissner's) Plexuses

- An inner plexus that lies in the submucosa
- It lies in the submucosa beneath the circular muscle layer
- **Meissner's plexus**
- **Controls mainly GI secretion and local blood flow**
- Controls :
  (1) Local intestinal secretion,
  (2) Local absorption
  (3) Local contraction of the submucosal muscle that causes various degrees of enfolding of the gastrointestinal mucosa.



Neurotransmitters Secreted by Enteric Neurons

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

1. Excitatory Motor Neurons, Evoke Muscle Contraction & Intestinal Secretion

(A) Neurotransmitters of motor neurons:
1. Substance P
2. Ach

(B) Neurotransmitters of secretomotor neurons (releasing of water, electrolytes and mucus from crypts of Lieberkuhn)
1. Ach
2. Vasoactive intestinal peptides (VIP)[1]
3. Histamine

2. Inhibitory Motor Neurons Suppress Muscles contraction

(A) Adenosine tri-peptide (ATP)

(B) Nitric oxide (NO)

(C) VIP

Notice that VIP has dual action
A. Released near glands → Gland activation
B. Released near muscle → Muscle inhibition

Afferent Sensory Nerve Fibers from the Gut

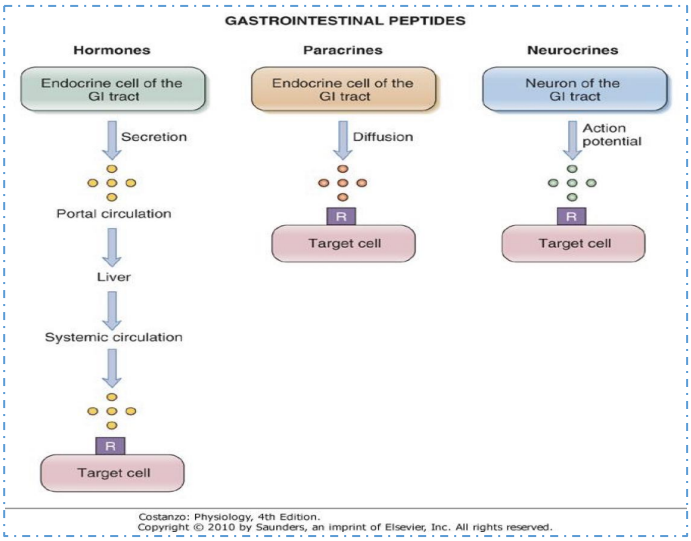
▪ Many afferent sensory nerve fibers innervate the gut. Some of them have their cell bodies in the enteric nervous system and some in the dorsal root ganglia of the spinal cord.

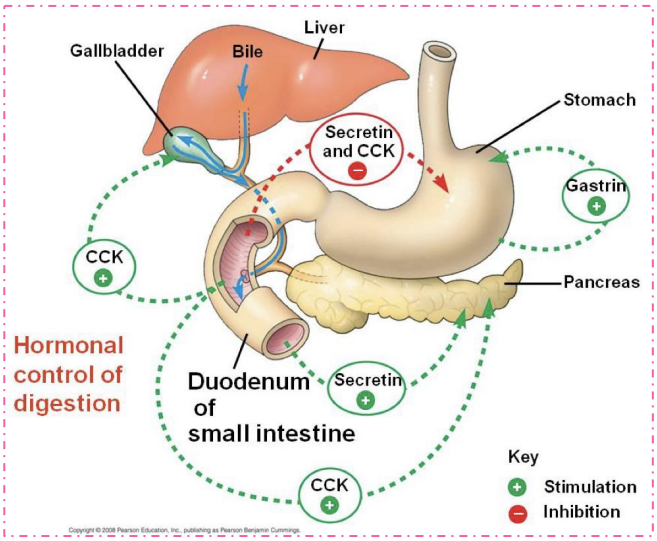
- These sensory nerves can be stimulated by (1) irritation of the gut mucosa, (2) excessive distention of the gut, or (3) presence of specific chemical substances in the gut.
- Signals transmitted through the fibers can then cause excitation or inhibition of intestinal movements or secretion.

▪ 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 GI tract into the brain medulla, which in turn initiates vagal reflex signals (vagovagal reflexes).

Hormonal Control

Click here to check a link that was mentioned in Dr. Maha's slides



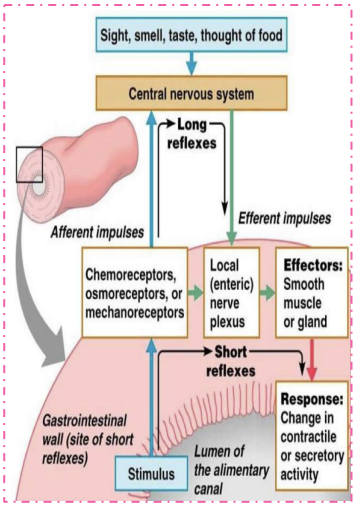


*Only in boys slides

Hormone	Site of secretion	Stimuli for secretion	Actions
Gastrin(M)	**G** cells of the antrum, duodenum and jejunum	-Protein -Distention of the stomach -Vagal stimulation -(GRP) -(Acid inhibits release)	**Stimulates:** Gastric H^+ secretion and growth of gastric mucosa
Cholecystokinin (CKK)	**I** cells of the duodenum, jejunum and ileum	-Protein -Fatty acids -Acids	**Stimulates:** -Pancreatic enzyme secretion -Pancreatic HCO^-_3 secretion -Gallbladder contraction -Growth of the exocrine pancreas -Relaxation of the sphincter of Oddi **Inhibits:** Gastric emptying
Secretin	**S** cells of the duodenum, jejunum and ileum	Acids and fat in the duodenum	**Stimulates:** -Pepsin secretion -Pancreatic HCO^-_3 secretion -Biliary HCO^-_3 -Growth of the exocrine pancreas **Inhibits:** Gastric H^+ secretion
Glucose-Dependent Insulinotropic Peptide (GIP)	**K** cells of the duodenum and jejunum	-Protein -Fatty acids -Oral glucose	**Stimulates:** -Insulin secretion from pancreatic **β** cells **Inhibits:** Gastric H+ secretion
Motilin	**M** cells of the duodenum and jej	-Fat -Acid -Nerve	**Stimulates:** -Gastric motility -Intestinal motility

GI reflexes

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



Locals short reflexes

1.Reflexes that are integrated entirely within the gut wall enteric nervous system (Reflexes within the GI wall (ENS))

- GI movement (Peristalsis/mixing)
- Secretions
- Local inhibitory effects

Long reflexes that travel a distance in the GI tract. A way for organs to communicate with each other

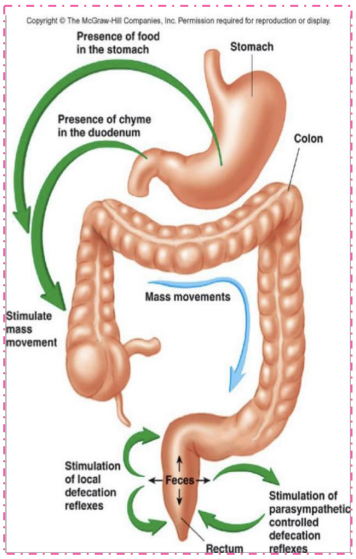
2.Reflexes from the gut to the prevertebral sympathetic ganglia and then back to the GI tract (Reflexes through prevertebral sympathetic ganglia)

These reflexes transmit signals long distances to other areas of the GI tract, such as:

A) Gastrocolic reflex: signals from the stomach to the colon. (stretch of stomach increases colon motility)

B) Enterogastric reflexes: signals from the colon and small intestine to inhibit stomach motility and stomach secretion

C) Colonoileal reflex: reflexes from the colon to inhibit emptying of ileal contents into the colon



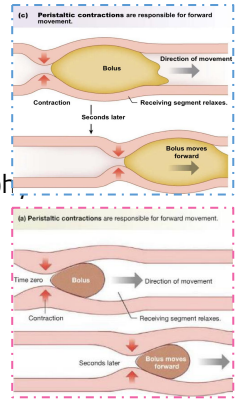
3.Reflexes from the gut to the spinal cord or brain stem and then back to the GI tract (Reflexes through spinal cord and brainstem), such as:

Reflexes are affected when there's an injury in SC or brainstem

- 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
- Pain reflexes that cause general inhibition of the entire GI tract
- **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) activated by stretch of sacral region

GI Movement

Propulsive "Peristalsis"

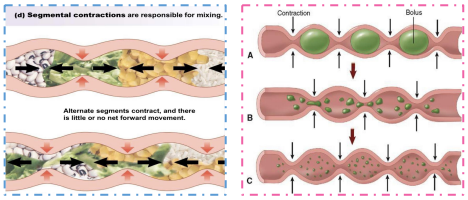


- Moves food forward along the tract.
- Usual stimulus is distention.
- Distension→stimulates the proximal portion to contract and the distal portion to relax
- Organizes propulsion of material over variable distances within the GI lumen.
- Other stimuli that can initiate peristalsis include chemical or ph the epithelial lining in the gut.
- Myenteric plexus is important.
- Atropine (cholinergic blocker) depresses propulsion.
- Propulsive segment: 1.contraction (circular M.) 2.relaxation (longitudinal M.)
- Receiving segment: 1.contraction (longitudinal M.) 2.relaxation (circular M.)

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 Orade side of the distended segment, pushing the intestinal contents in the anal direction (Caudad direction) for 5 to 10 cm before dying out.

Mixing "Segmentation"



- Provides mixing of intestinal contents with digestive juices.
- Segment of bowel contracts at both ends.
- A second contraction occurs in the center of the segment
- Blend different juices with the chime.
- Bring products of digestion in contact with absorptive surfaces
- Contraction happens at the middle of chyme

GI Reflexes

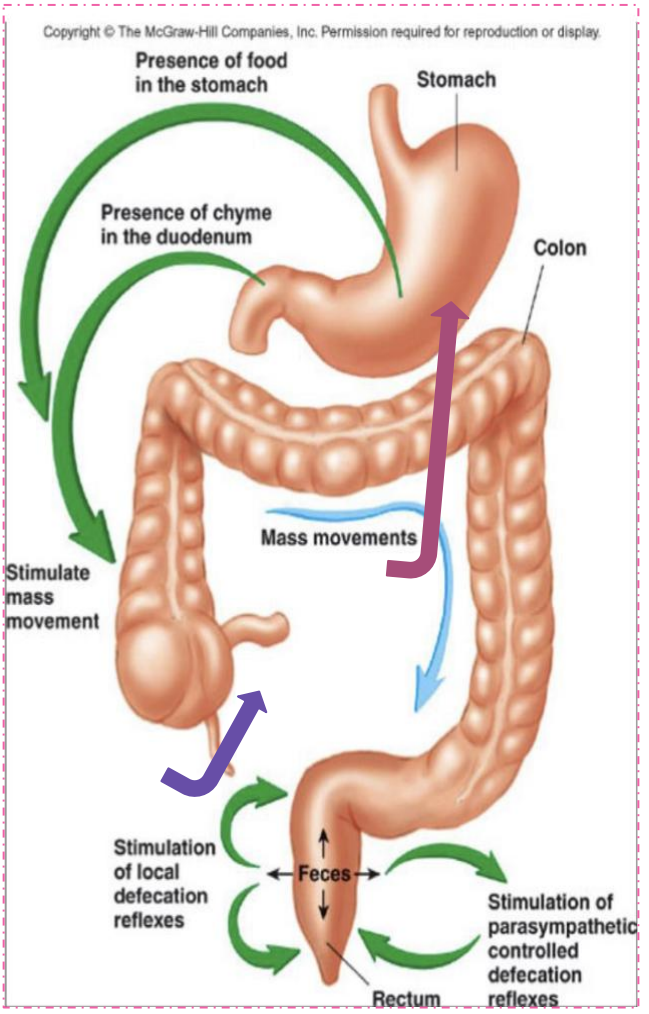
Gastrocolic reflex(M)

Signals from stomach causes evacuation of food.signals from stomach to colon and large intestine to get rid of the the storaged feces because there's a new day and a new food will arrive

Will be discussed in colon physiology lecture later

Colonileal reflex

Signals from colon inhibit emptying of ileal contents



Enterogastric reflex

Signals from intestine inhibit emptying of stomach

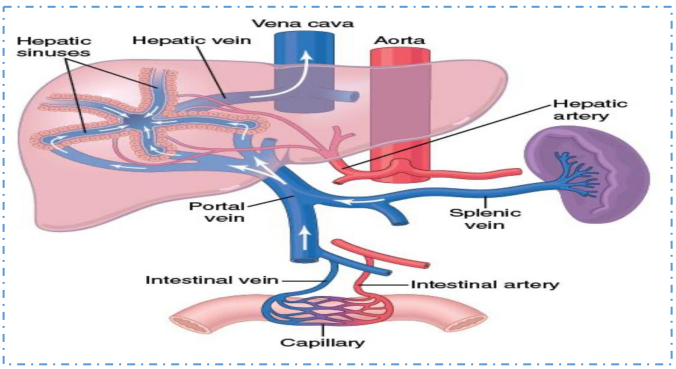
stimulates mass movements after a meal. Will be discussed in detail in stomach secretion lecture

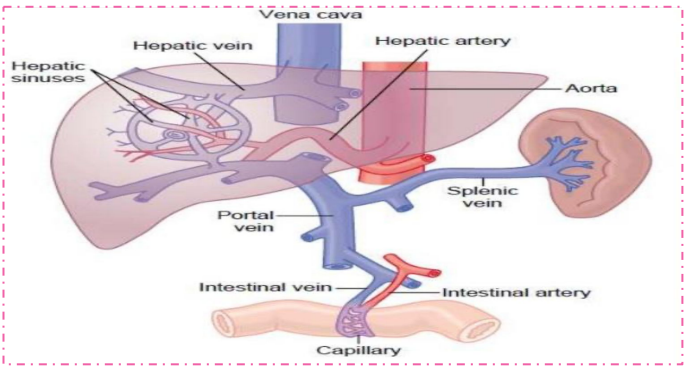
Gastrointestinal Blood Flow- "Splanchnic Circulation"

*Only in boys slides

Female Dr's: read about it

Splanchnic circulation includes the blood flow through the gut, 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.





Effect of Gut Activity and Metabolic Factors on Gastrointestinal Blood Flow

*Only in boys slides

❖ Possible Causes of the Increased Blood Flow During Gastrointestinal Activity:

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

Nervous Control of Gastrointestinal Blood Flow

*Only in boys slides

❖ Stimulation of 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 gastrointestinal tract to cause intense vasoconstriction of the arterioles with greatly decreased blood flow. But the local metabolic vasodilator mechanisms override the sympathetic vasoconstriction effects, returning the normal blood flow to GI muscle and glands.

MCQ & SAQ:

Q1: which one of the following is not considered as one of the accessory organs?

A. Gallbladder
B.liver
C. Spleen
D. Pancreas

Q2: Which one of the following is not true about smooth muscles?

A.multinucleated
B. Spindle shape
C. Not-Straited
D. Short

Q3: What is the frequency of slow-wave potential in the ileum

A. 3
B. 6
C. 9
D.12

Q4: Which of the following is an example of tonic contraction

A. GI tract
B. Gastric antrum
C. Small intestine
D. Blood vessels

Q5: Myenteric plexus of the wall of the stomach is present

A. In the serosa
B. Between the middle circular muscle layer and the mucosa
C. Between the outer longitudinal muscle layer and circular muscle layer
D. In the muscularis mucosa

Q6: Which one of the following increase blood flow during GI activity?

A. CCK
B. Bradykinin
C. Decrease oxygen concentration
D. All of the above

answer key:
1: C
2: A
3: C
4: D
5: C
6: D

1- What are the causes of tonic contraction?

2- Mention the factors that depolarize the membrane potential

3-List two hormones that decrease gastric acid secretion

4- What are the 4 GI processes? Define each one.

A1: 1. Repetitive spike potential 2. Hormones 3. Continuous entry of Ca ion

A2: 1- Stretching of the muscle, 2- stimulation by acetylcholine released from the endings of parasympathetic nerves 3- Stimulation by several specific gastrointestinal hormones

A3: 1. GIP 2. Secretin

A4: slide 3

Leaders:

- Abdulaziz Alsuhaim.
- Yara Alasmari.

Co-leader:

- Mayasem Alhazmi.

Organizers:

- Rawan baqader
- Haya Alanazi
- **Shaden Alobaid**
- Mayasem Alhazmi.
- Basel Fakeeha
- Leen Almadhyani

Note takers:

- **Shaden Alobaid**
- Raghad Albarrak
- Homoud Algadheb.

Revisers:

- Abeer Awwad.

MEMBERS:

- Abdulaziz Alamri
- Basel Fakeeha
- **Ahmad Alkhayatt**
- Aljoud Algazlan
- Almaha Alshathri
- Abdulrahman Barashid
- Nada Bin Obeid
- Tarfa Alkaltham
- **Yara alzahrani**
- Sarah AlQuwayz
- Abdulrhman Alsuhaibany
- Abeer Awwad
- Mohammed alkathiri
- ziyad alhosan
- Rand Alrefaie
- Omar Alhalabi
- Joud Alarifi
- Ibrahim Alnamlah
- Hamad Almousa
- Abdullah Alburikan
- Leen Almadhyani
- Abdullah Alanzan
- Bader Alrayes
- Faisal jazzar
- Khalid Almutlaq
- Yara Alomar
- Reem Alqahtani
- Aljoharah Albnyan
- Saud Alhasani
- **Muneerah Alsadhan**

Physiology439@gmail.com