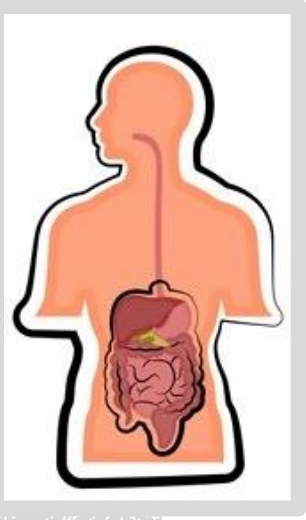

THE GASTROINTESTINAL SYSTEM

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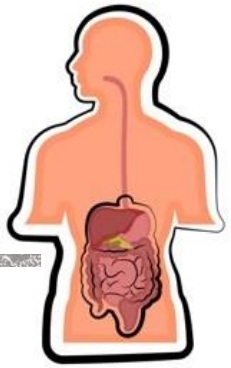
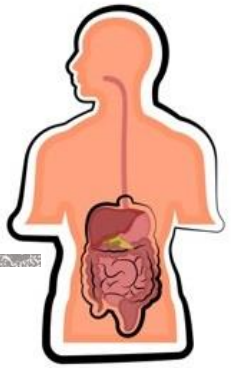
OBJECTIVES



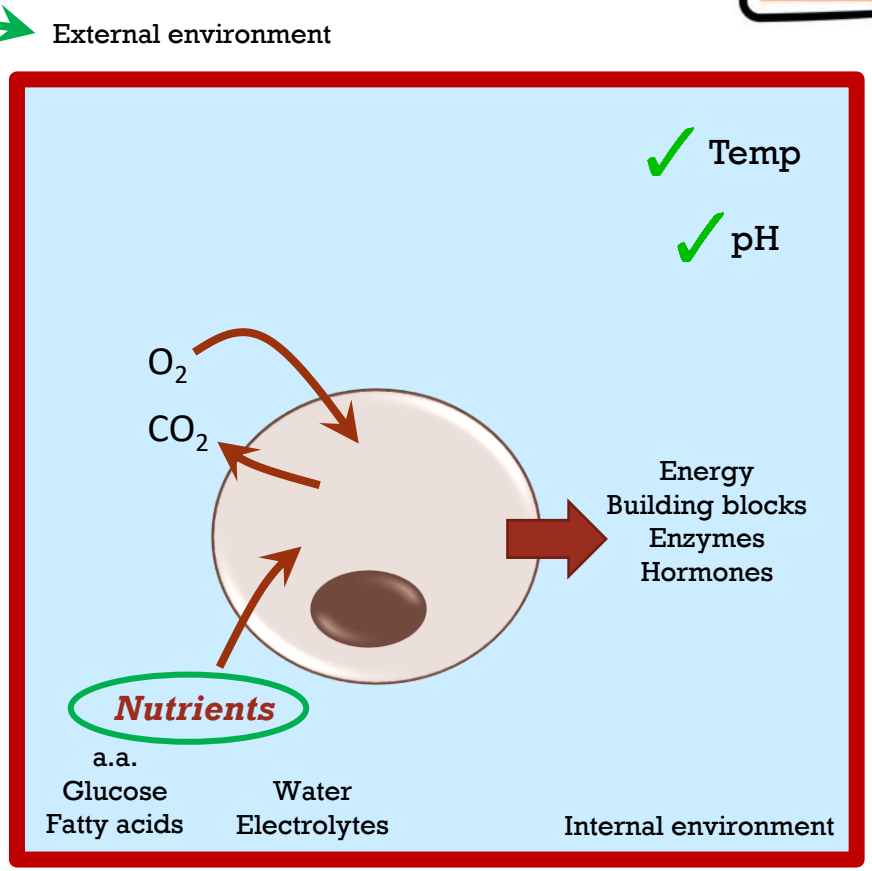
- Physiologic Anatomy of the Gastrointestinal Wall.
- The General Characteristics of Smooth Muscle.
- Smooth muscle cell classifications and types of contraction.
- Muscle layers in GI wall.
- Electrical Activity of Gastrointestinal Smooth Muscle.
- Slow Waves and spike potentials.
- Calcium Ions and 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.

INTRODUCTION



- Our bodies are made of cells.
- Cells works hard to keep our body well and healthy.
- For cells to do 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?***

Where do these nutrients come from?



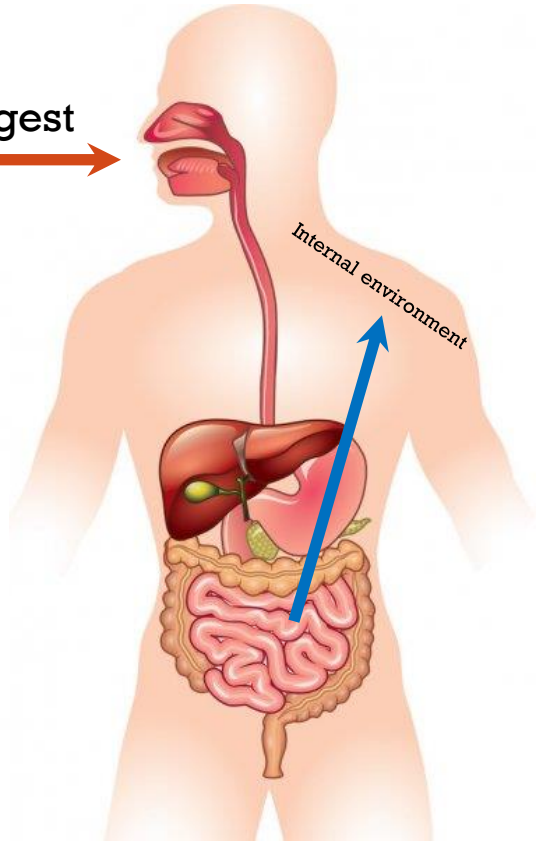
(Sherwood. Human Physiology: From cells to Systems, 7th ed.)

HOW DO THESE NUTRIENTS REACH OUR INTERNAL ENVIRONMENT?

- Through the GI system.
- The main function of the GI system is transfer nutrients from the external environment into the internal environment.
- ***Can our cells utilize nutrients immediately as they are in the food we consume?***
- ***Is it enough just to ingest food for us to make nutrients available for cells to use?***

External environment

ingest



Macromolecules in food

There are 4 basic GI processes that enable it to do this job

Micromolecules that cells can use

(Sherwood. Human Physiology: From cells to Systems, 7th ed.)

THE 4 BASIC GI PROCESSES

THE GI SYSTEM PERFORMS 4 BASIC DIGESTIVE PROCESSES

1. **Motility**

The muscular contractions that mixes and moves GI contents forward through the GI tract.

2. **Secretion**

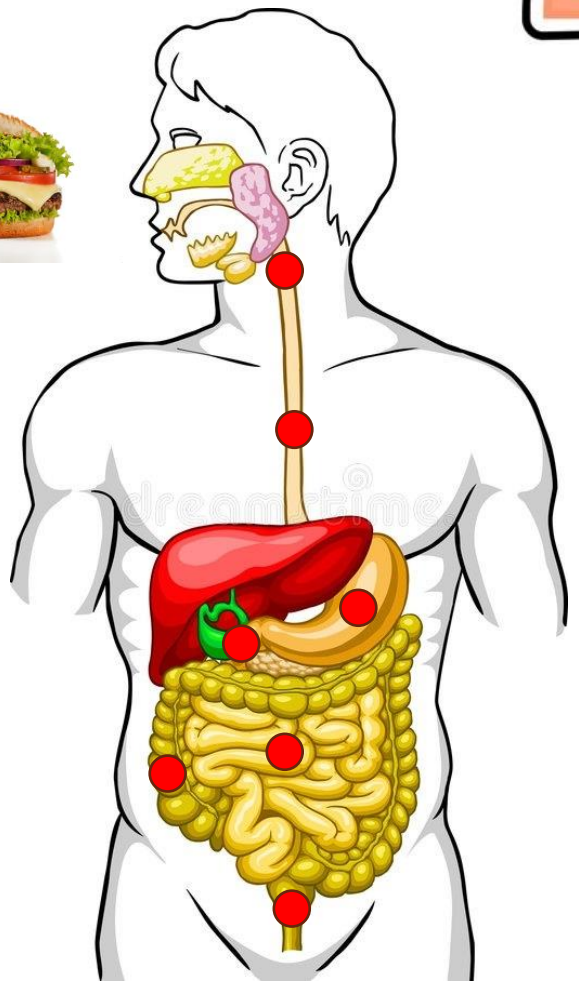
Along the way, digestive juices are secreted into the GI lumen by exocrine glands.

3. **Digestion**

As the contents move along the GI tract, complex foodstuff gets broken down into smaller absorbable molecules.

4. **Absorption**

These small units are transferred from GI lumen into blood or lymph.



(Sherwood. Human Physiology: From cells to Systems, 7th ed.)

AN OVERVIEW OF THE GI TRACT

The GI system

Digestive tract

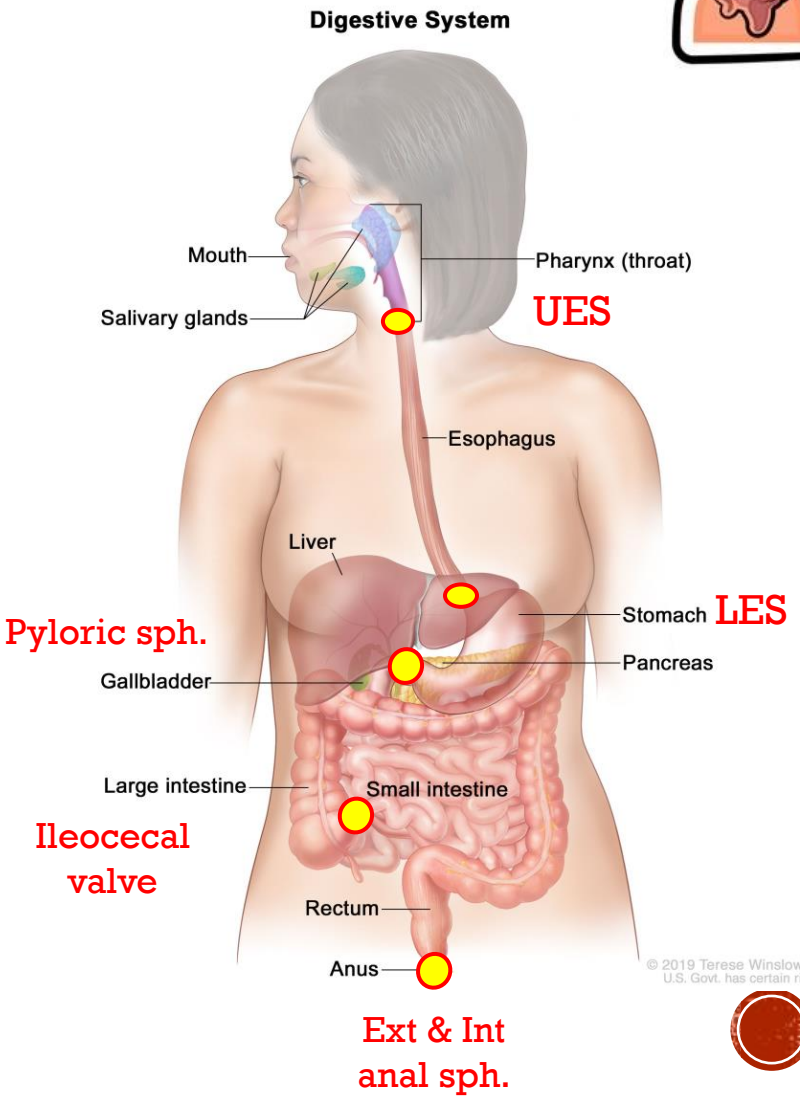
- A hollow tube extending from mouth to anus.
- Each region is modified to serve its function.
- Regions are separated by sphincters.

Accessory organs

Include:

- Salivary glands.
- Liver and gall bladder.
- Pancreas.

These add secretions to the digestive tract.



(Sherwood. Human Physiology: From cells to Systems, 7th ed.)

AN OVERVIEW OF THE GI TRACT

- The journey of the burger starts at the mouth and ends at the anus… ***what does it pass through along the way?***

The *mouth* & *oropharynx*
Chop and lubricate food
Initiate carb digestion
Propels food into esophagus

Esophagus
Conducts food to stomach

Stomach
Stores food
Initiate protein digestion

Salivary glands
Lubrication + enzymes for carb digestion

Pancreas
Digestive enzymes into duodenum
HCO_3^-

Liver & biliary system
Secretes bile for fat digestion

Large intestine
Reabsorbs fluid & electrolytes
Stores fecal matter

Small intestine
Continues digestion
Primary site of absorption

(Sherwood. Human Physiology: From cells to Systems, 7th ed.)

SECRETION

- The GI tract secretes digestive juices.

- These juices may come from the exocrine glans attached to the GI system or from specialized cells in the GI wall.

- ***Digestive secretions consist of:***

Water + electrolytes + specific organic constituents (enzymes, bile salts, mucus.. Etc).

- Secretion is an active process.

(Sherwood. Human Physiology: From cells to Systems, 7th ed.)

DIGESTION

Three different biochemical categories of foodstuff

Carbohydrates

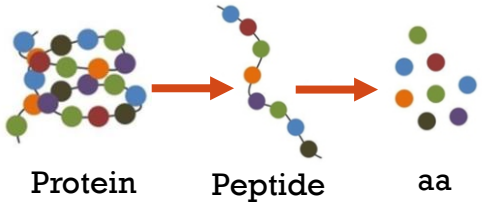
Carbs that we ingest are ***polysaccharides*** (starch, glycogen, mono- & disaccharides)

Carbs that can be reabsorbed are ***monosaccharides*** (glucose, fructose, galactose).

Digestion will break down polysacchs into monosacchs

Protein

Digestion will break down dietary proteins into small polypeptides and amino acids (a.a.)

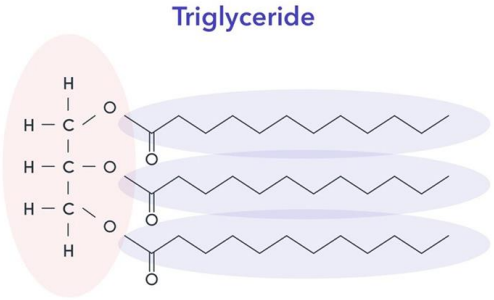


Fat

Dietary fats is usually triglycerides

↓

Monoglycerides



(Sherwood. Human Physiology: From cells to Systems, 7th ed; Boron & Boulpaep. Medical Physiology. Updated 2nd ed)

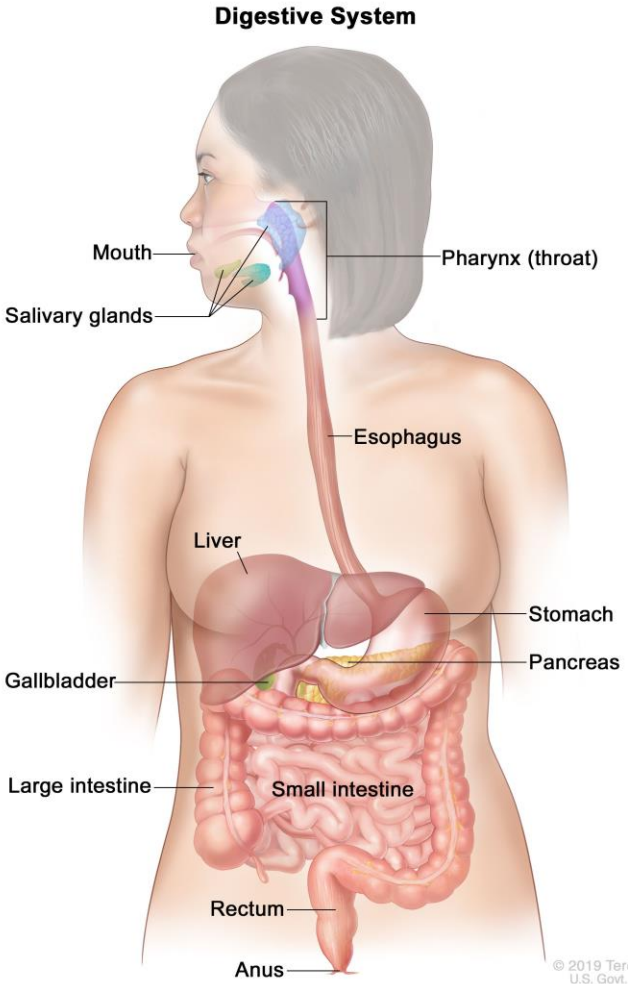
ABSORPTION

- The transfer of small absorbable units from GI lumen into blood and lymph.
- How and where?
- Splanchnic circulation!!

(Sherwood. Human Physiology: From cells to Systems, 7th ed.)

HOW ARE WE GOING TO STUDY THE GI SYSTEM?

- We will follow the burger as it moves through the GI tract.
- In each organ within the system, we will discuss the 4 basic process occurring in it.
- There are regional differences in these 4 processes that enable each organ to perform the function it is meant to do.
- Today.. We will discuss the general principles of motility.



(Sherwood. Human Physiology: From cells to Systems, 7th ed.)

GI MOTILITY

GI MOTILITY

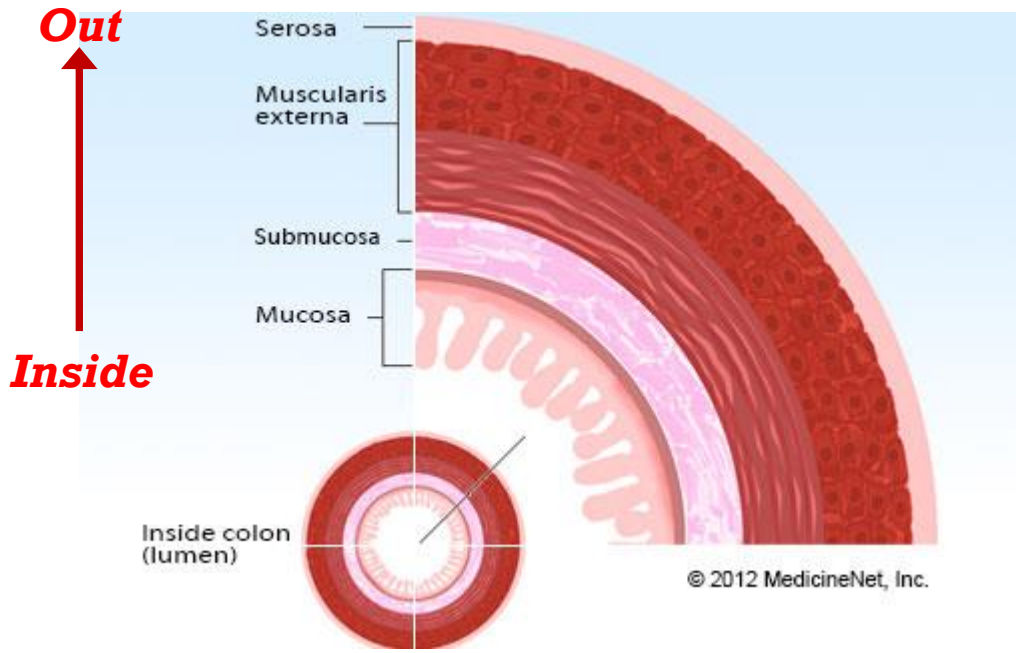
- Why is it important for the wall of the GI system to move?
  - ✓ Mixing
  - ✓ Propulsion
  - ✓ Exposure to absorptive surface.

- What structure in the GI wall is responsible for its ability to produce movement?
  - ✓ Smooth muscle cells.

- Let's have a look at the general organization (structure) of the GI wall!

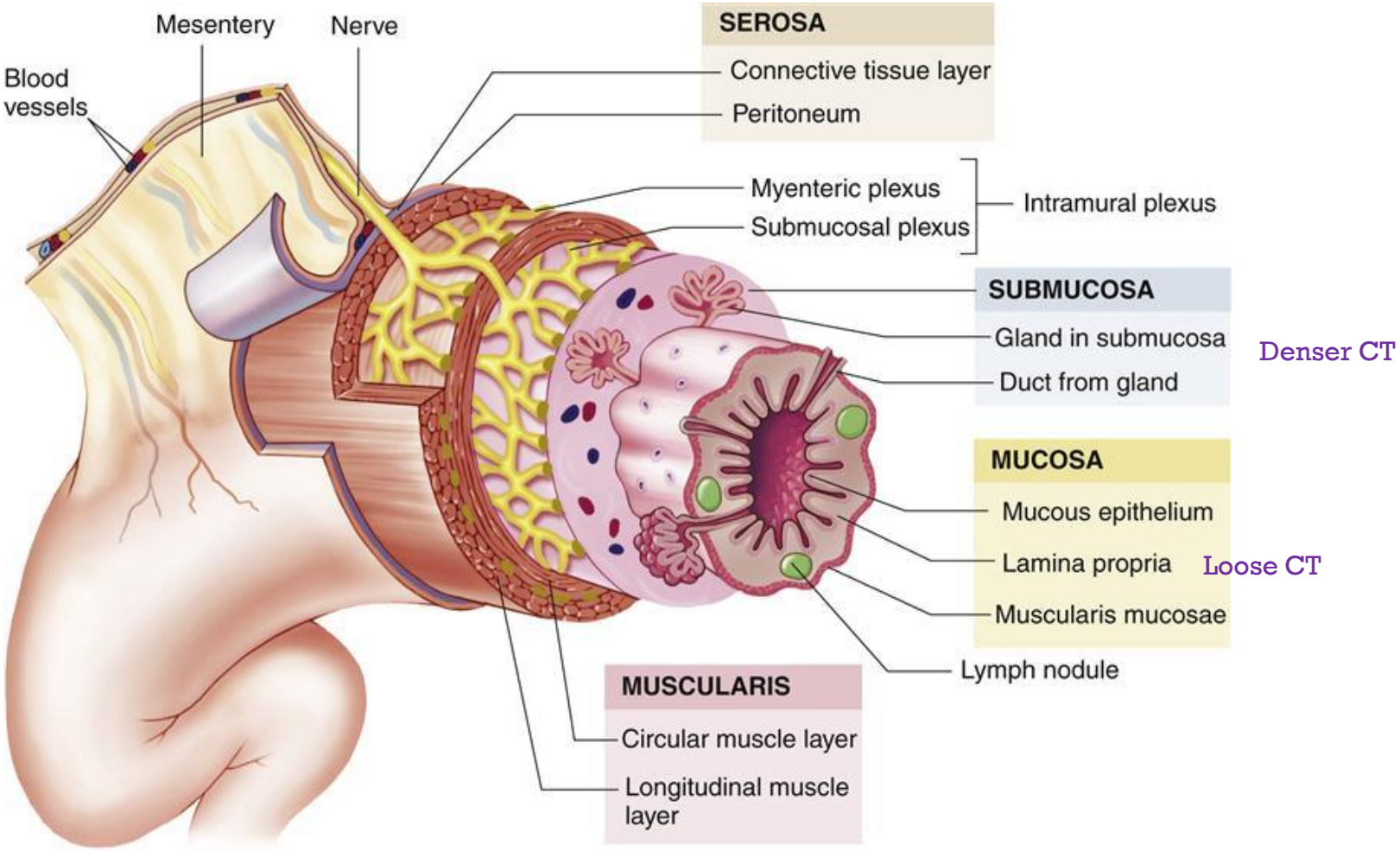
PHYSIOLOGIC ANATOMY OF THE GI WALL

- ***4 main layers:***
  1. Mucosa
  2. Submucosa
  3. Muscularis.
  4. Serosa.



Let us add more detail to each layer!

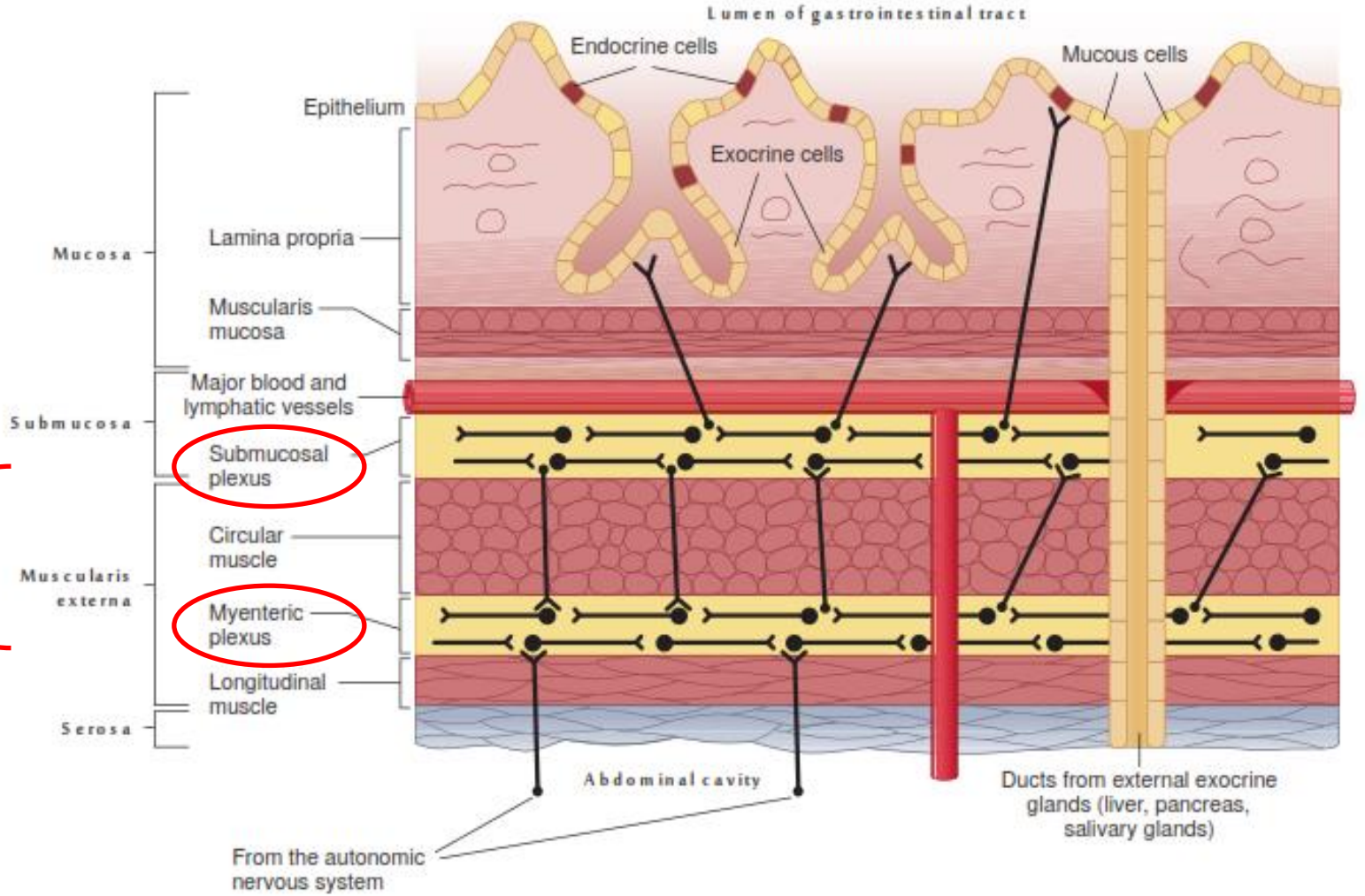
PHYSIOLOGIC ANATOMY OF THE GI WALL



PHYSIOLOGIC ANATOMY OF THE GI WALL

Movement is possible in the GI tract because of the presence of smooth muscle layers

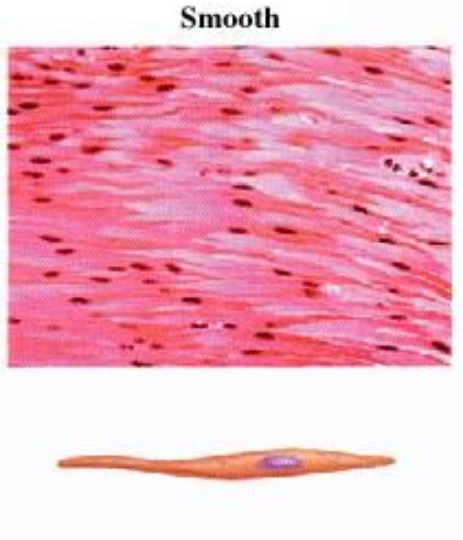
Submucosal + Myenteric plexus = ***Enteric nervous system***



CHARACTERISTICS OF SMOOTH MUSCLE

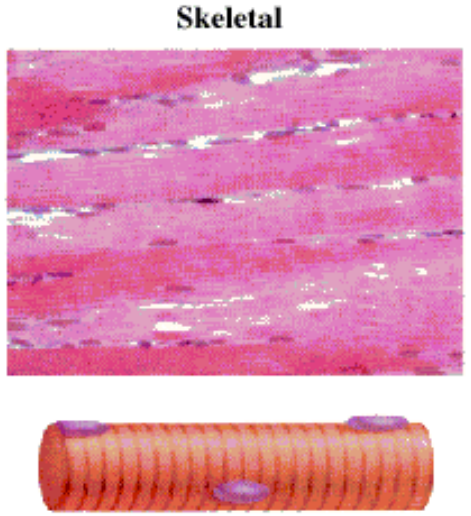
Let's study it by comparing smooth muscle with skeletal muscle

Smooth Muscle



Spindle-shaped
Single nucleus.
Smaller & shorter.
Non-striated.
Involuntary

Skeletal Muscle

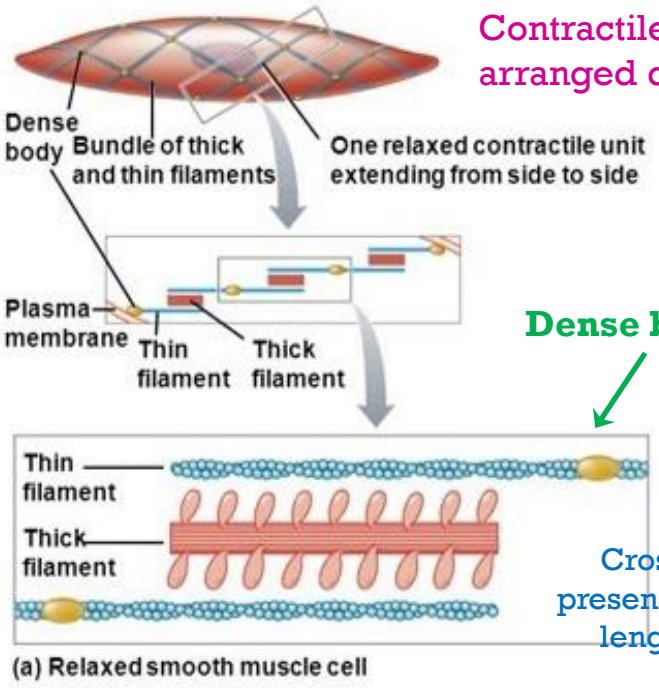


Cylindrical ms. Fiber
Multinucleated.
Long
Striated
Voluntary

CHARACTERISTICS OF SMOOTH MUSCLE

Let's study it by comparing smooth muscle with skeletal muscle

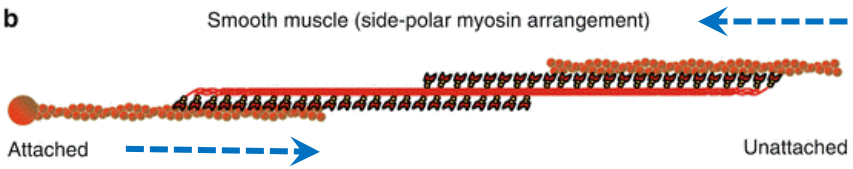
Smooth Muscle



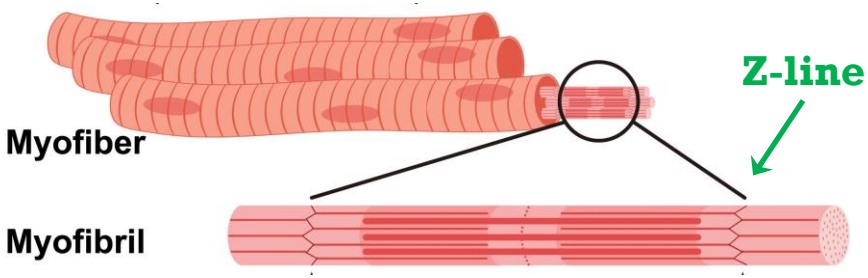
Contractile units arranged diagonally

Dense bodies

Cross bridges are present along the entire length of the thick filament

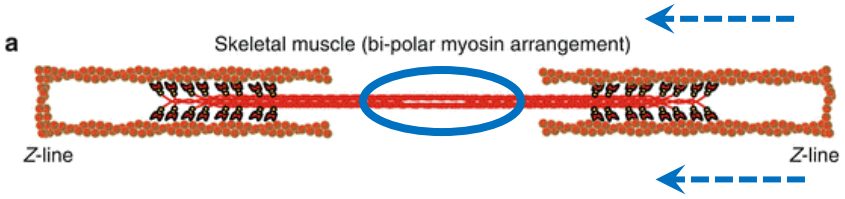


Skeletal Muscle



Contractile units arranged parallel to long axis of fiber

Bare portion in the center of the thick filament



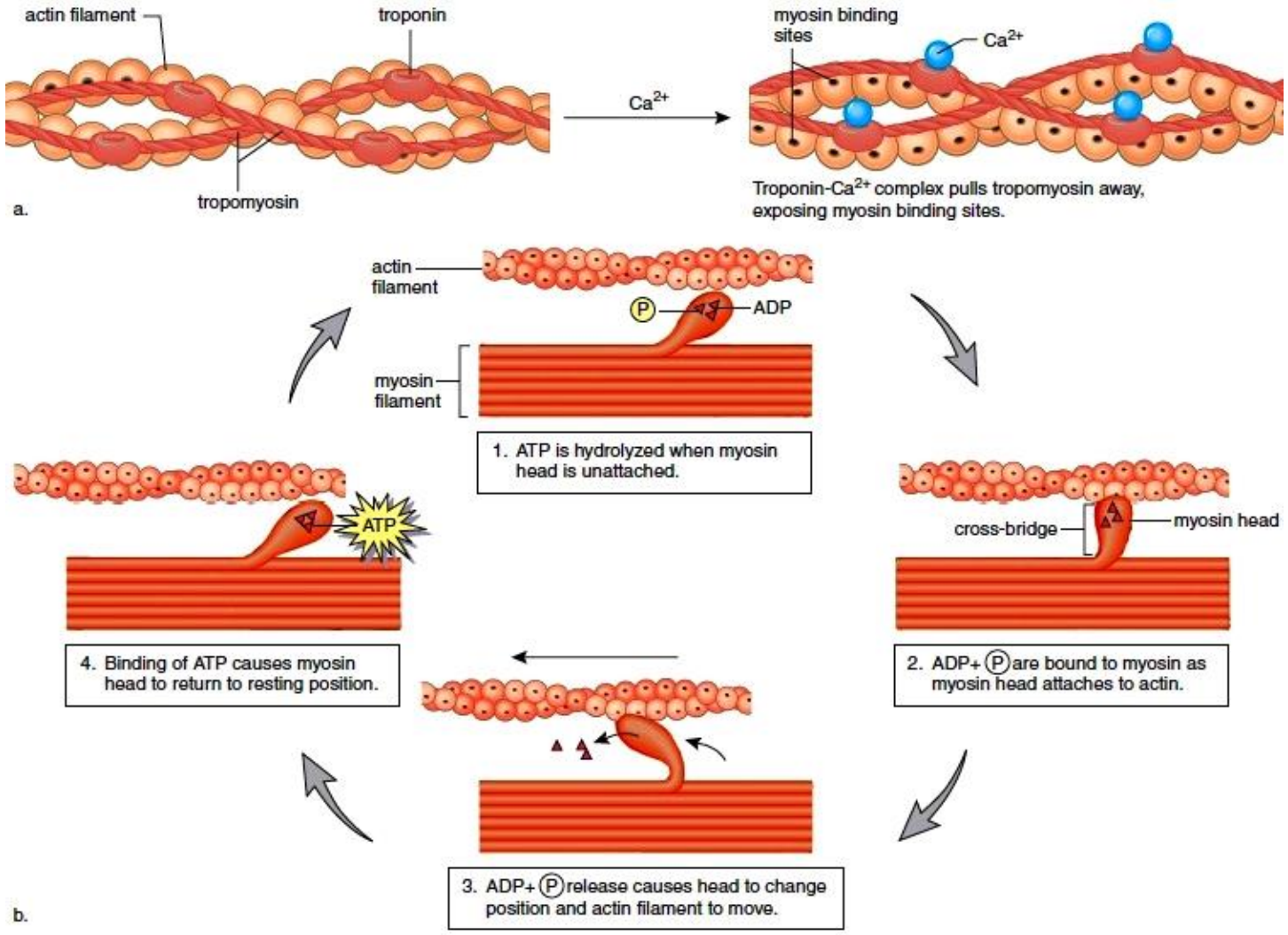
CONTRACTION OF SMOOTH MUSCLE

Let's study it by comparing smooth muscle with skeletal muscle

- 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 way this is achieved is different than what you have learned for skeletal muscle!

CONTRACTION OF SKELETAL MUSCLE

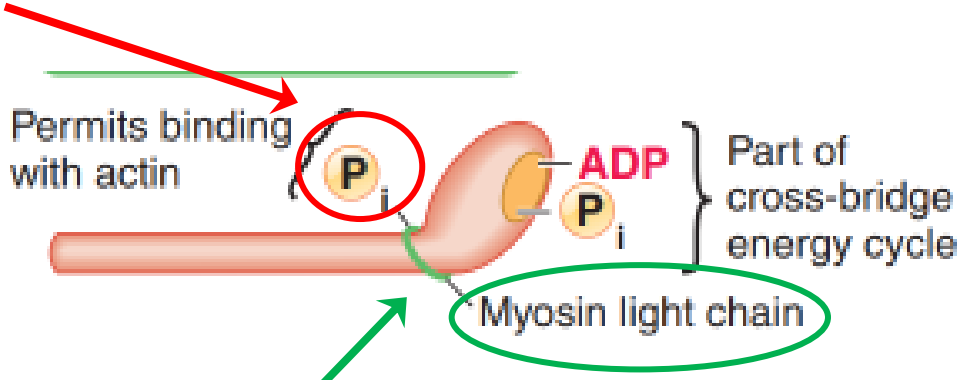


CONTRACTION OF SMOOTH MUSCLE

- The thin filament of smooth muscle does not have troponin.. Tropomyosin does not block actin-binding site.

Then what stops myosin from binding to actin at rest?!

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



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

CONTRACTION OF SMOOTH MUSCLE

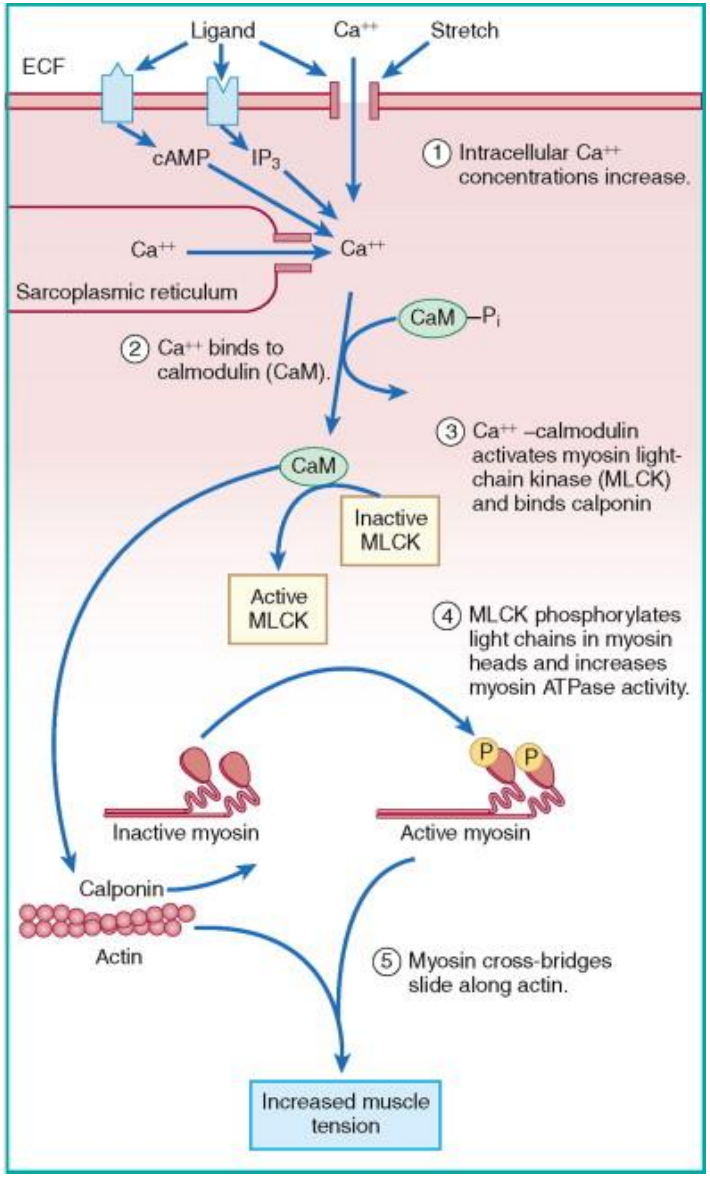
$\uparrow [Ca^{+2}]_i$

Ca^{+2} binds to calmodulin

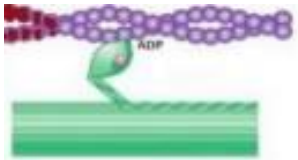
Ca-CaM complex activates MLCK

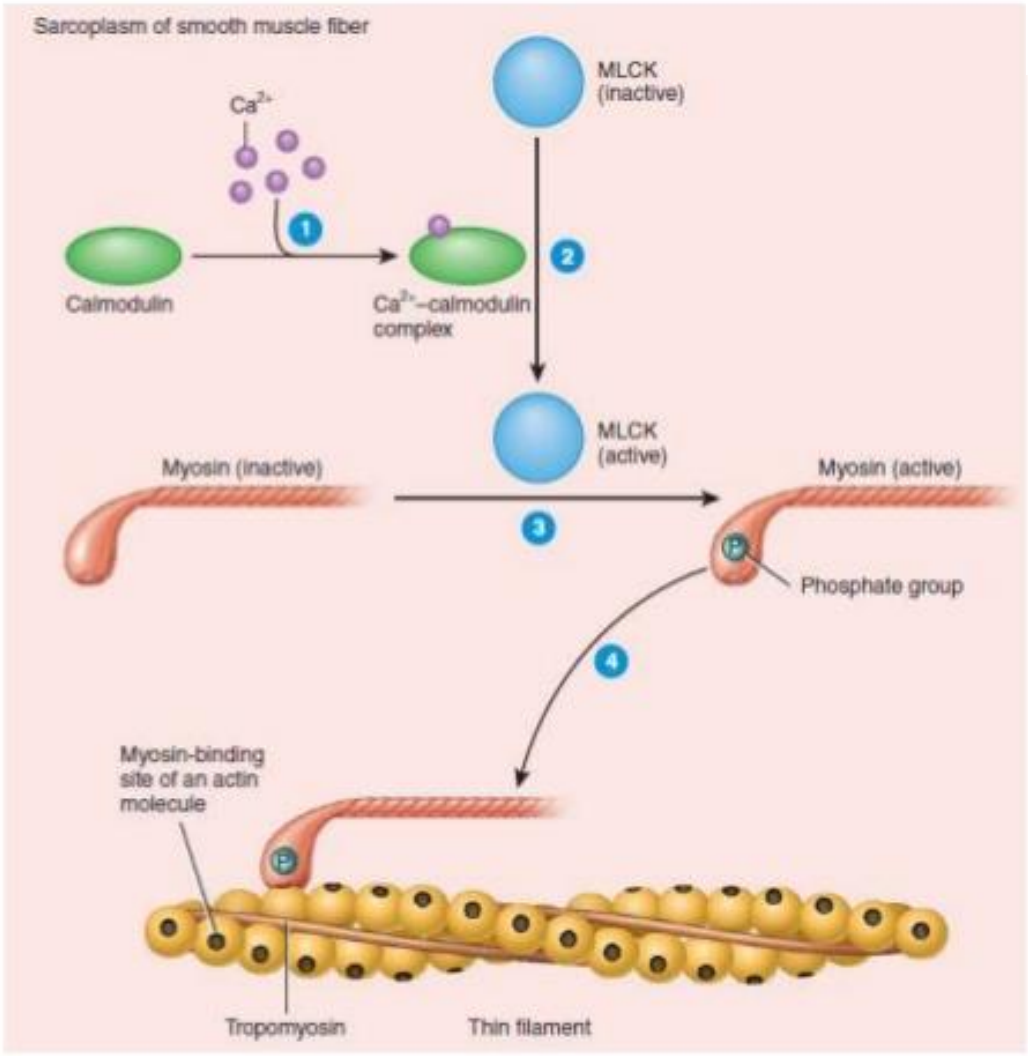
Phosphorylates Myosin head increasing the activity of ATPase

Myosin head attaches to actin causing sliding of the filaments

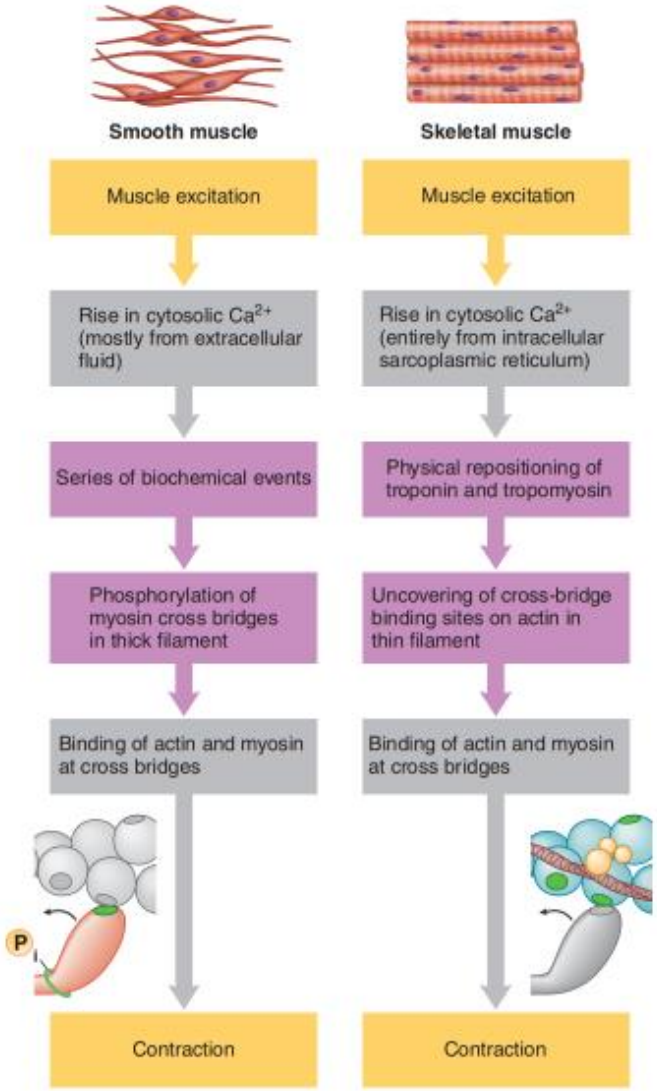


CONTRACTION OF SMOOTH MUSCLE





SKELETAL VS SMOOTH MUSCLE CONTRACTION



Ca^{+2} Induces a ***chemical*** change in ***myosin*** (thick filament)

Ca^{+2} Induces a ***physical*** change in ***actin*** (thin filament)

What brings about a rise in Ca^{+2} smooth muscle?

TYPES OF SMOOTH MUSCLE

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

- ***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.

PHASIC VS TONIC SMOOTH MUSCLE

Depending on its contractile activity and how its cytosolic Ca^{+2} increases

Phasic Smooth Muscle

- Contracts in ***bursts*** "***intermittently***"
- ***Contraction → relaxation***
- Contraction triggered by an action potential which increase [Ca^{+2}].
- ***Example:***
  - GI tract

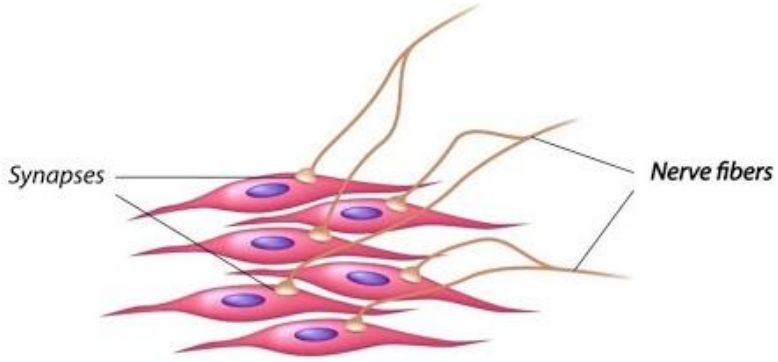
Tonic Smooth Muscle

- Muscle is usually ***partially contracted at all times***.
- ***Continuous partial contraction = tone.***
- This type has a low RMP at which some voltage-gated Ca^{+2} channels are open → entry of Ca^{+2} → partial contraction.
- ***Example:***
  - Blood vessels, airways

MULTIUNIT VS SINGLE-UNIT SMOOTH MUSCLE

Based on how they get excited, smooth muscle can be classified into:

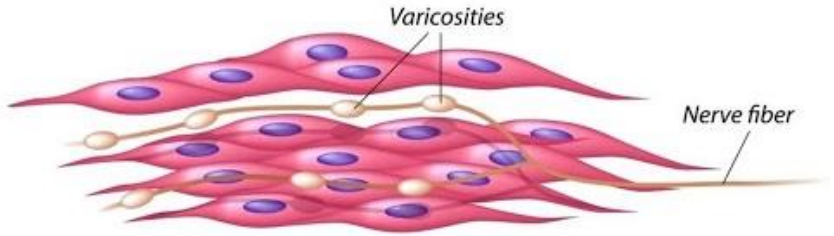
Multiunit Smooth Muscle



Multiunit Smooth Muscle

- 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.

Single-unit Smooth Muscle



Single-unit Smooth Muscle

- Composed of many smooth muscle fibers that become excited and contract as a single unit.
- Cells are connected by gap junctions.
- Function as a syncytium.
- E.g. Uterus, GI tract.

NEUROGENIC VS MYOGENIC SMOOTH MUSCLE

Neurogenic Smooth Muscle

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

Myogenic Smooth Muscle

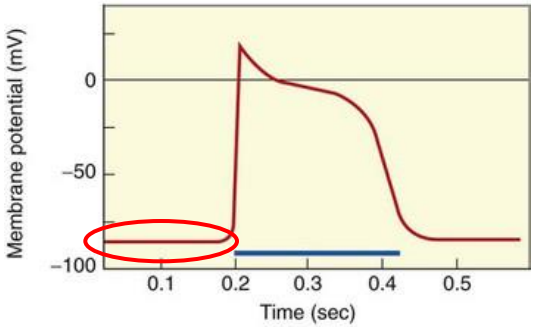
- Self-excitable.
- Contraction is initiated intrinsically within the muscle without external nervous stimulus.

HOW??

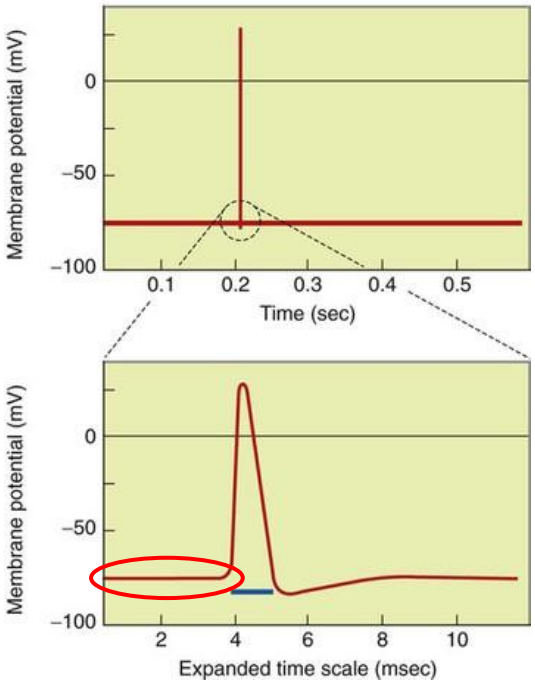
SMOOTH MUSCLE ELECTRICAL ACTIVITY

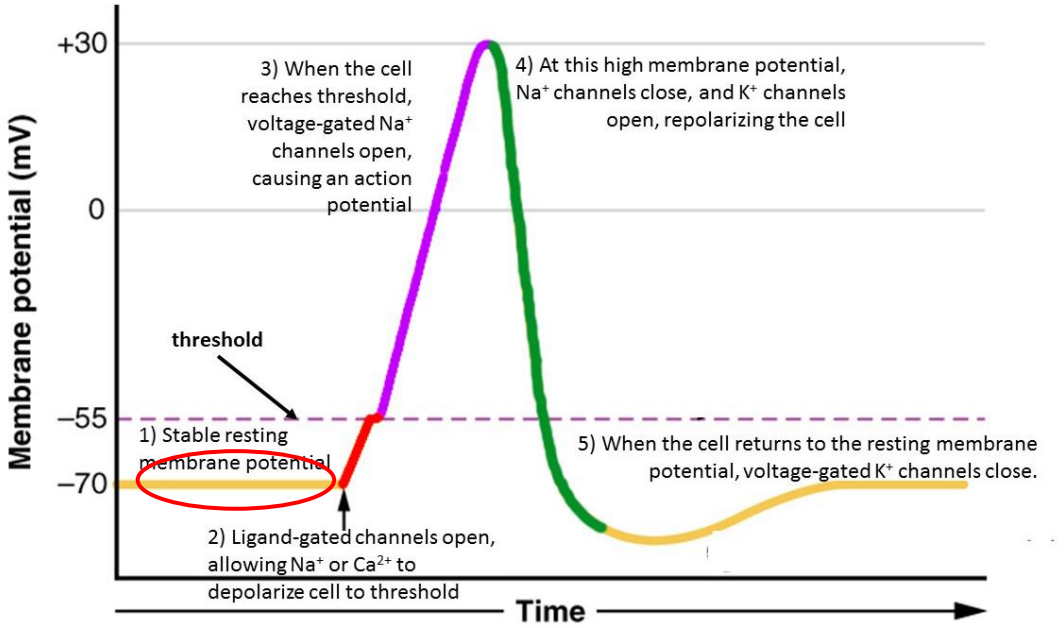
ELECTRICAL ACTIVITY OF NERVE & SKELETAL MUSCLE

Cardiac muscle cell



Nerve or skeletal muscle cell

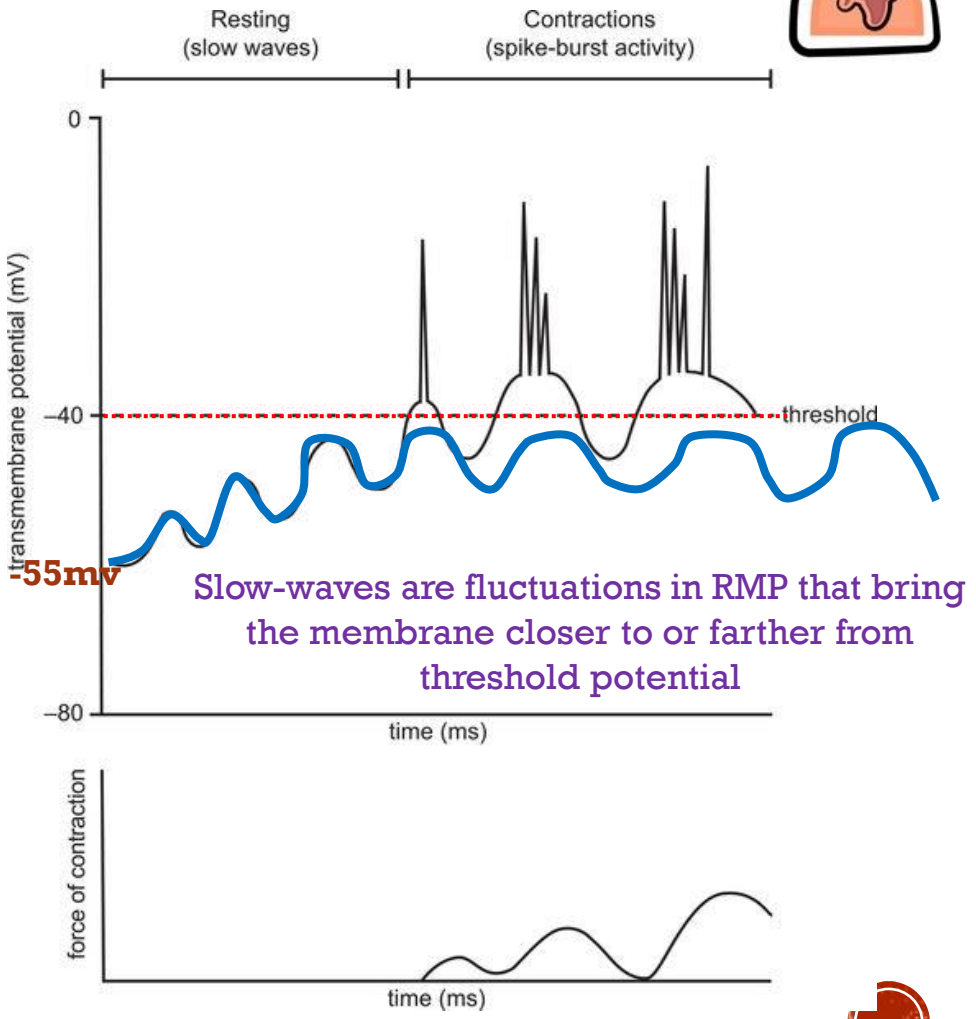




- RMP is around = -70mV and is stable
- If a stimulus arrives and pushes it towards threshold and AP develops

ELECTRICAL ACTIVITY OF SMOOTH MUSCLE

- **Normal RMP** in smooth muscle = -50 to -60 mV.
- **Threshold** = -40mV.
- RMP is ***NOT*** stable.. It is characterized by ***spontaneous, gradually alternating hyperpolarizing and depolarizing swings*** in in potential.
- ***Does it remind you of another type of electrical activity?***

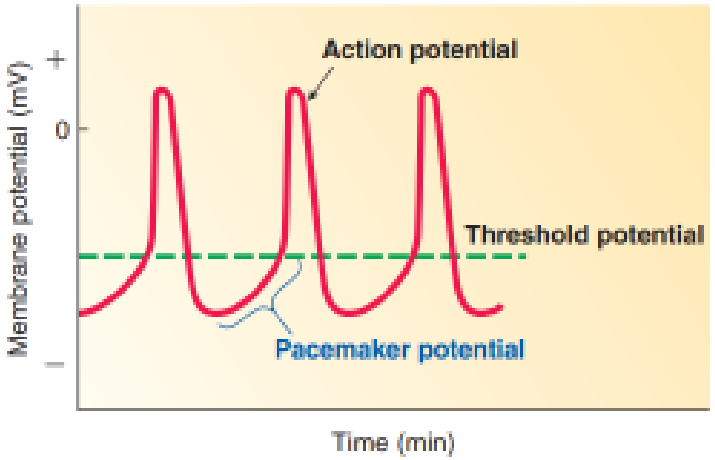


Slow-waves are fluctuations in RMP that bring the membrane closer to or farther from threshold potential

ELECTRICAL ACTIVITY OF SMOOTH MUSCLE

Pacemaker potential of the SA node

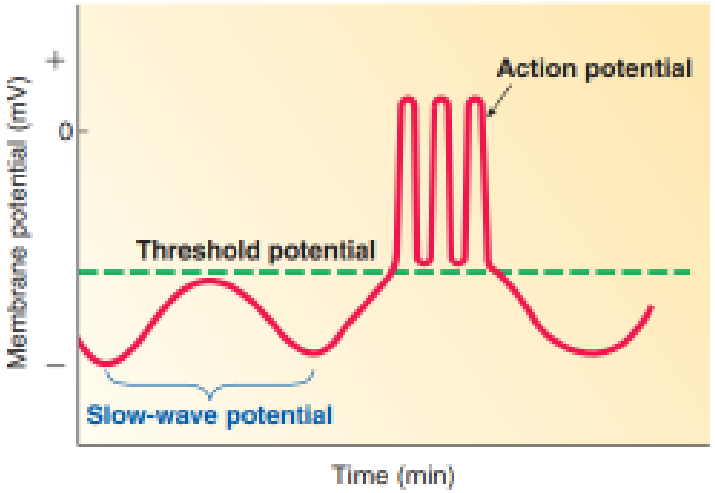
- Did cardiac muscle fibers generate this activity?
- what generates the Pacemaker potential in the heart?



(a) Pacemaker potential

Slow wave potential of the smooth muscle

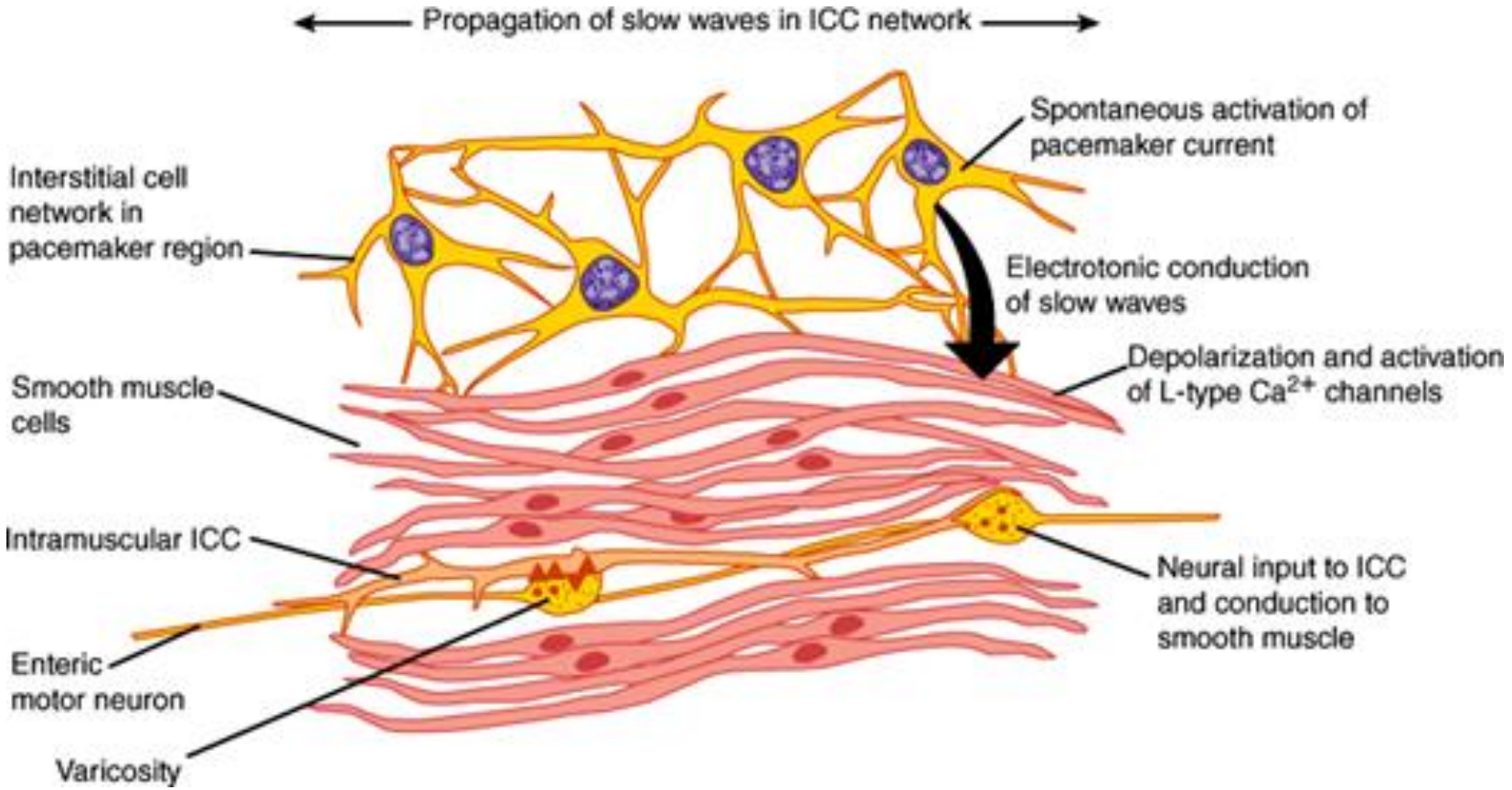
- Do smooth muscle cells generate this activity?
- What generates the slow-wave potential in GI smooth muscle?



(b) Slow-wave potential

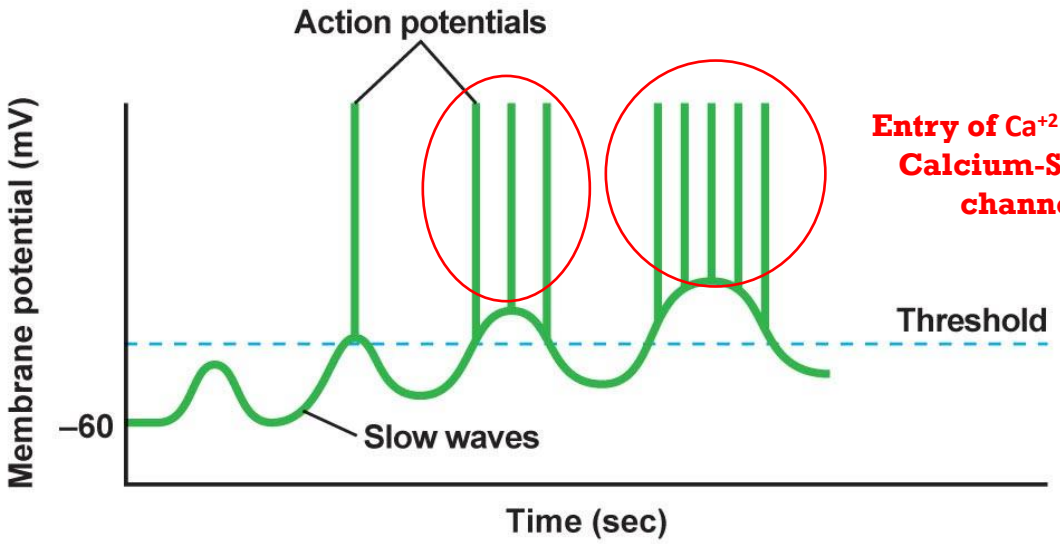
PACEMAKERS OF THE GUT

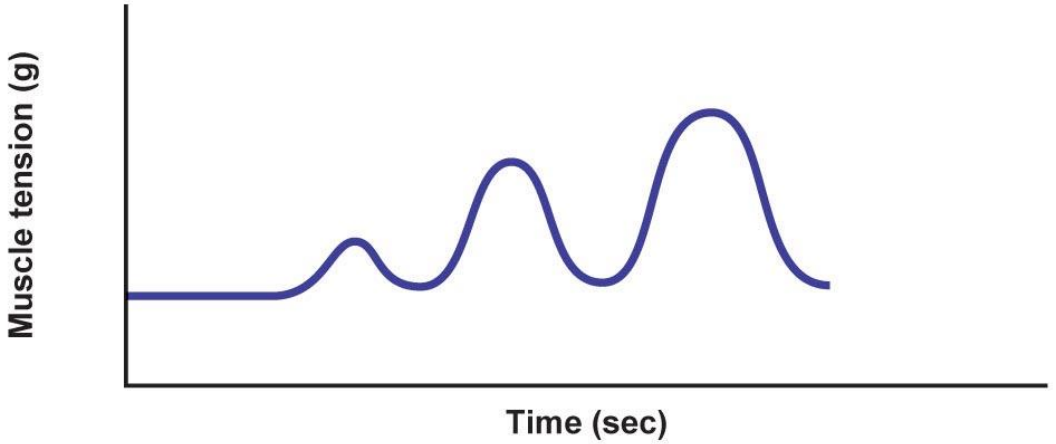
- ***Interstitial cells of Cajal (ICC)***= are a specialized, non-contractile cell that can undergo cyclical changes in membrane potential.
- The pacemakers of the gut.



SLOW-WAVE VS SPIKE POTENTIAL

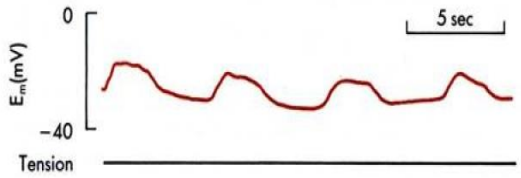
- The ***frequency of slow-wave*** potentials differs from one organ to the other;
  - ✓ Stomach = 3/min
  - ✓ Duodenum = 12/min
  - ✓ Ilium = 8-9/min
- When the slow-wave potential reaches threshold → a true action potential is generated on the peak of the slow-wave = ***spike potential***.



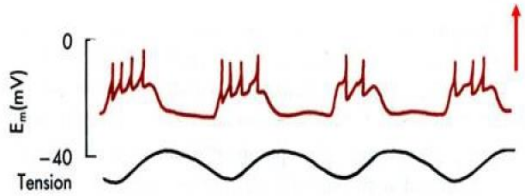


FACTORS AFFECTING RMP IN SMOOTH MUSCLES

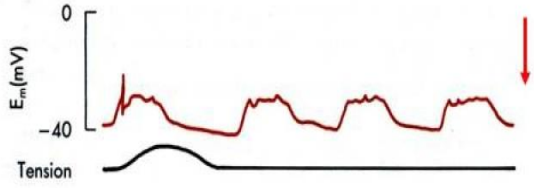
Smooth muscle is excitable tissue, and shows electrical activity



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



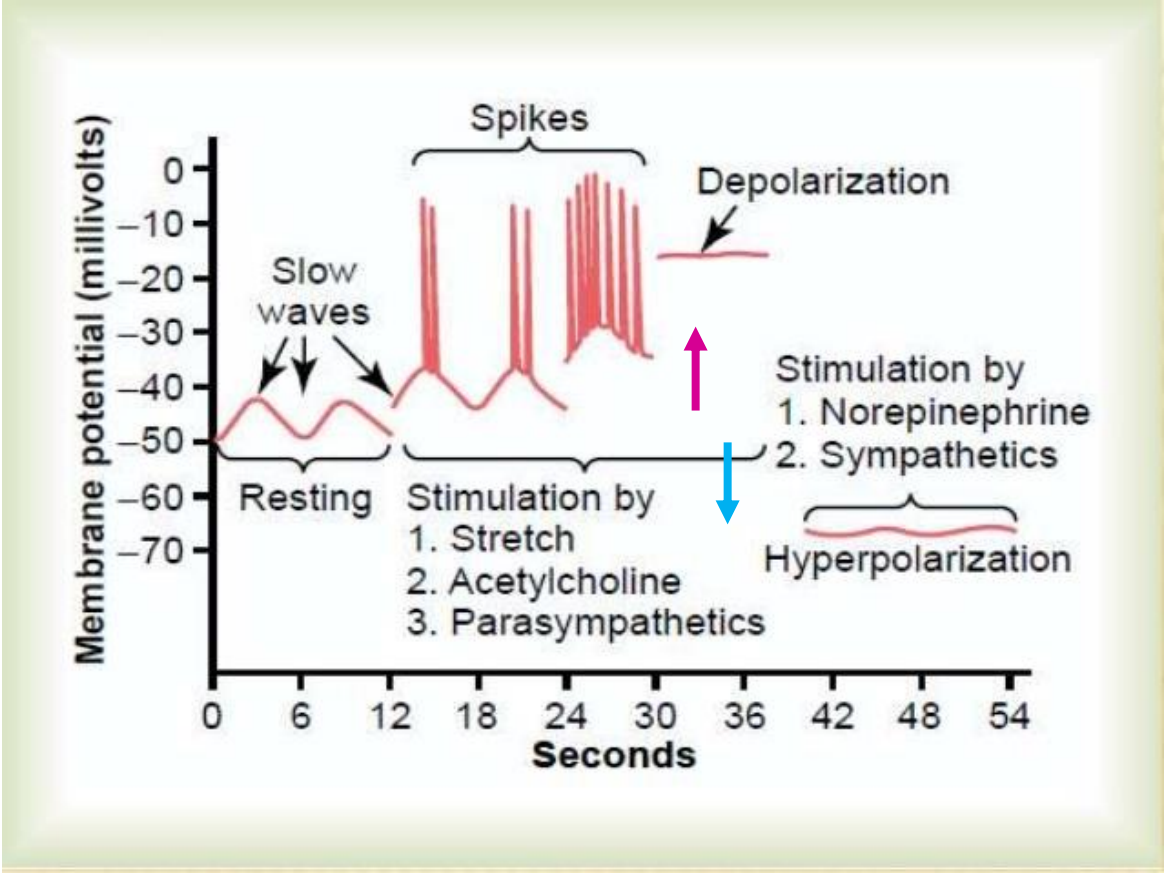
With ***parasympathetic*** **input**, the membrane at the plateau of the slow wave depolarizes all the way to threshold; action potentials occur "on top of" the slow wave, and these set off contractions. The contraction / tension follows slightly after the electrical response.



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

FACTORS AFFECTING RMP IN SMOOTH MUSCLES

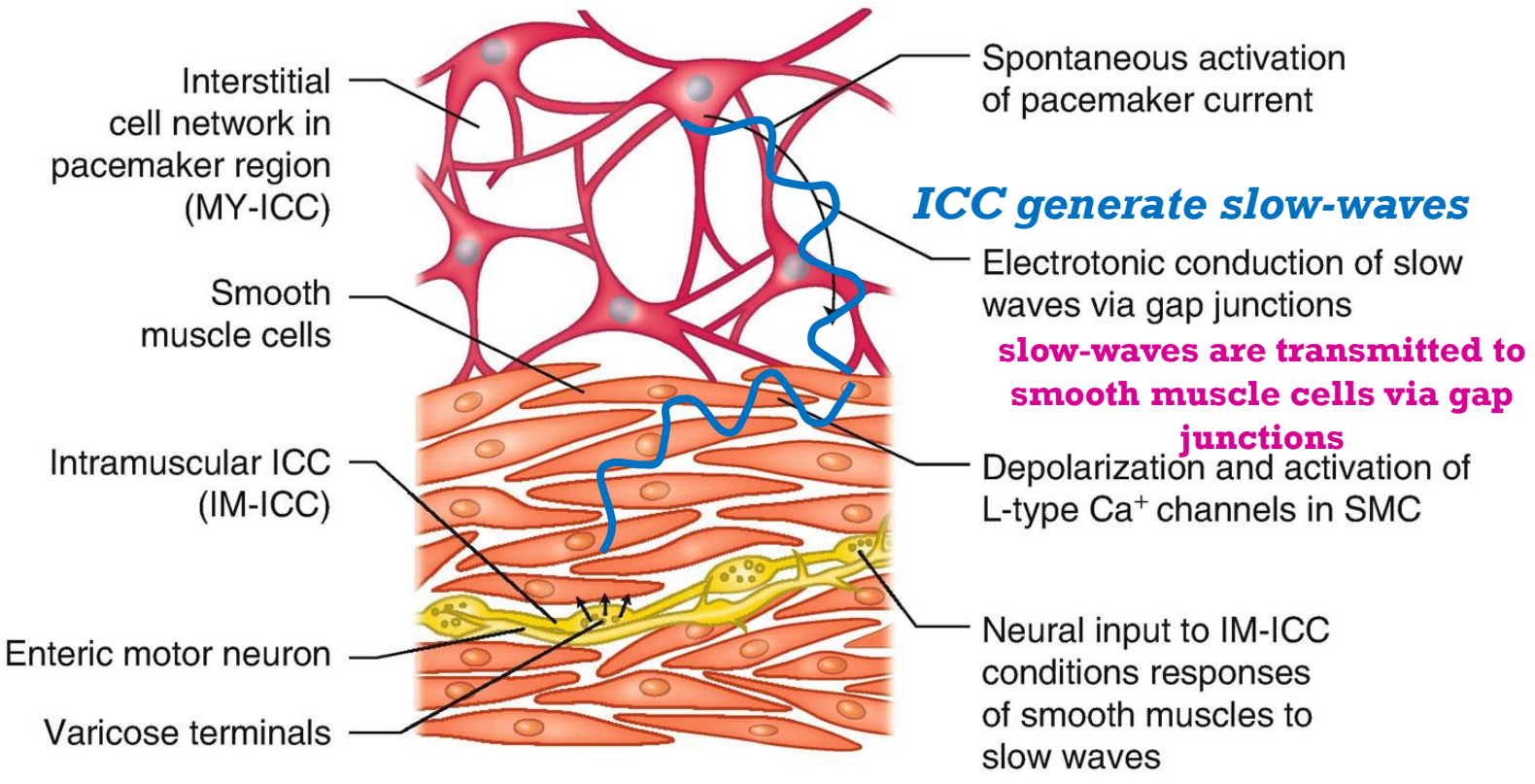
- The level of RMP in smooth muscle can be modified by several factors.
- If it becomes ***less negative*** = ***depolarized*** → muscle is ***more excitable***.
- If it becomes ***more negative*** = ***hyperpolarized*** → muscle becomes ***less excitable***.



WHAT HAVE WE DISCUSSED SO FAR?

- The importance of the GI system and its role in homeostasis.
- The four basic function that the GI system do to achieve its role.
- Then we zoomed in on motility of the GI.
- Motility is possible because of the presence of smooth muscle cells in the walls of the GI tract → structure of the GI wall.
- Smooth muscle characteristics; phenotype, how do they contract and types.
- Then, we moved to smooth muscle of the GI tract → electrical activity

TO SUMMARIZE



IM-ICC and MY-ICCs are electrically coupled to smooth muscle cells via gap junctions

CONTROL OF THE GI SYSTEM

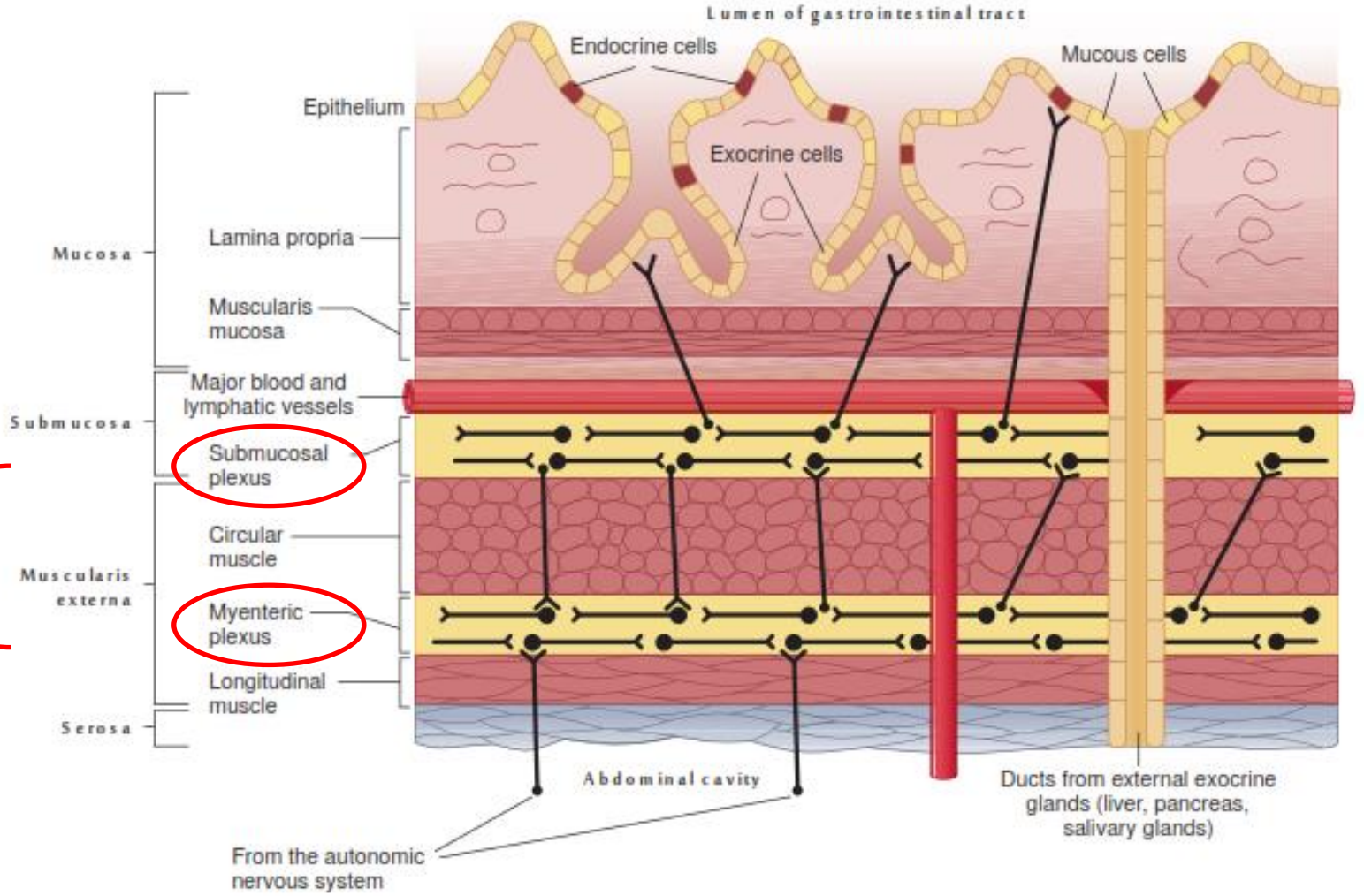
CONTROL OF THE GI SYSTEM

Control of the GI system

- Neural
  - Local — Embedded in the wall of the GI tract
    Enteric nervous system
  - External — Autonomic innervation
- Hormonal

THE ENTERIC NERVOUS SYSTEM

Submucosal + Myenteric plexus = ***Enteric nervous system***



THE ENTERIC NERVOUS SYSTEM

The ENS is made of two nervous plexuses

Myenteric nervous plexus

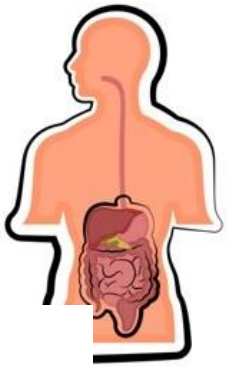
- The outer one.
- Between circular and longitudinal muscle layers.
- Auerbach's plexus
- Controls mainly GI movement.

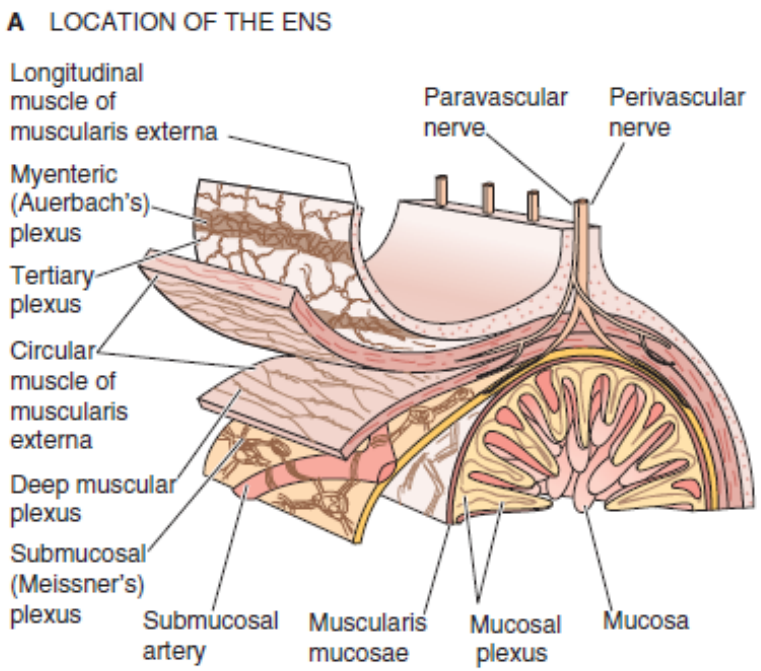
Submucosal nervous plexus

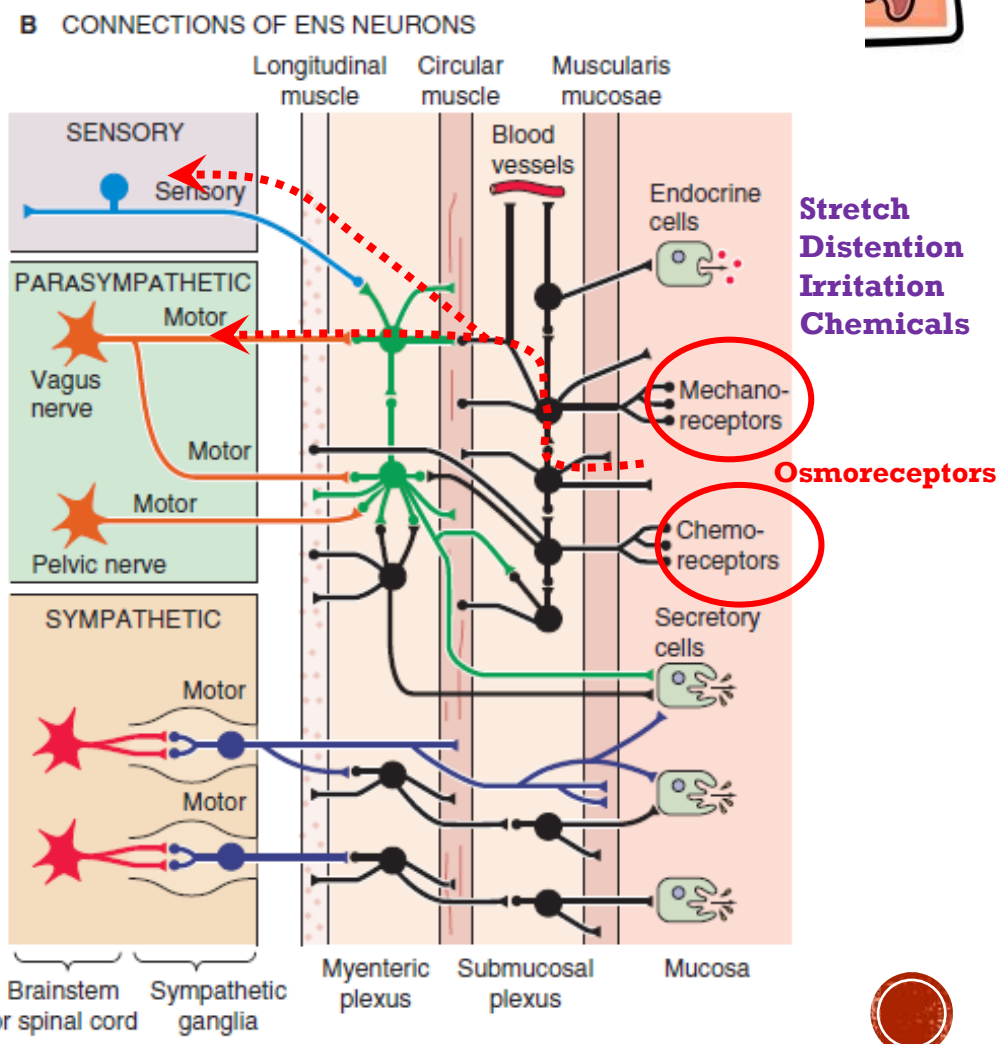
- The inner one.
- Lies in the submucosa beneath the circular muscle layer.
- Meissner's plexus
- Controls mainly GI secretion & local blood flow.

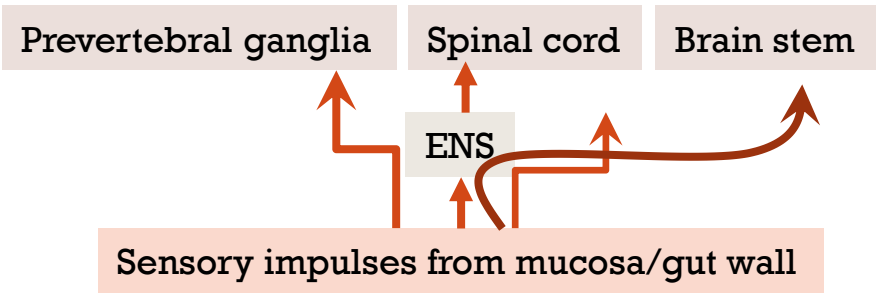
The two plexus are interconnected

CONNECTIONS OF THE ENS
"SENSORY"





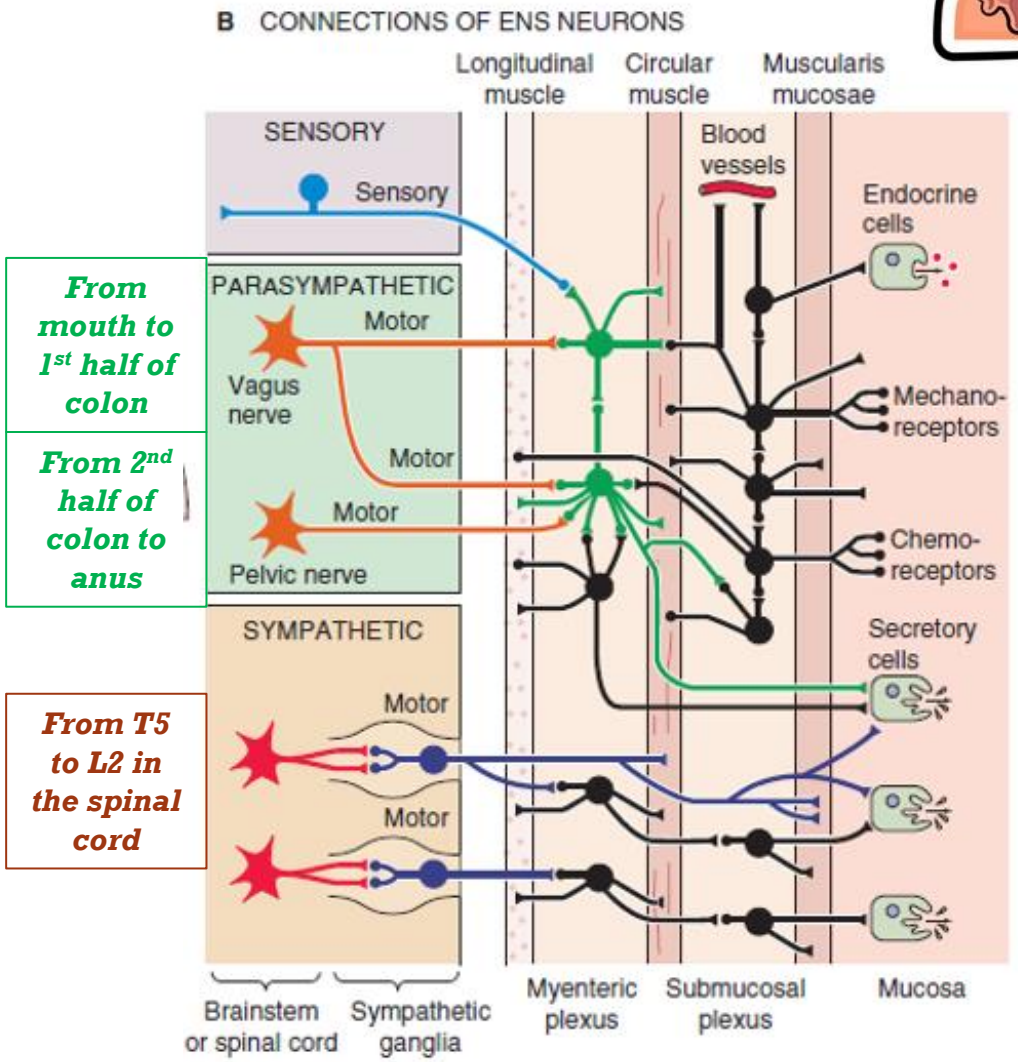




CONNECTIONS OF THE ENS
"AUTONOMIC"

Parasympathetic
- Postganglionic neurons are in the myenteric and submucosal plexuses.
- Stimulation generally ***increases*** activity of GI.

Sympathetic
- Stimulation generally ***inhibits*** activity of GI.



GI REFLEXES

Given the anatomical arrangement of the ENS and its connections, it will support three types of reflexes

GI reflexes

Short reflex

Reflexes within the GI wall (ENS)

Local short reflexes

GI movement (peristalsis/mixing)
Secretions
Local inhibitory effects

Long reflexes

Reflexes through prevertebral sympathetic ganglia

Long reflexes that travel a distance in the GI tract

A way for organs to communicate with each other

Gastrocolic reflex
Enterogastric reflex
Colonoileal reflex

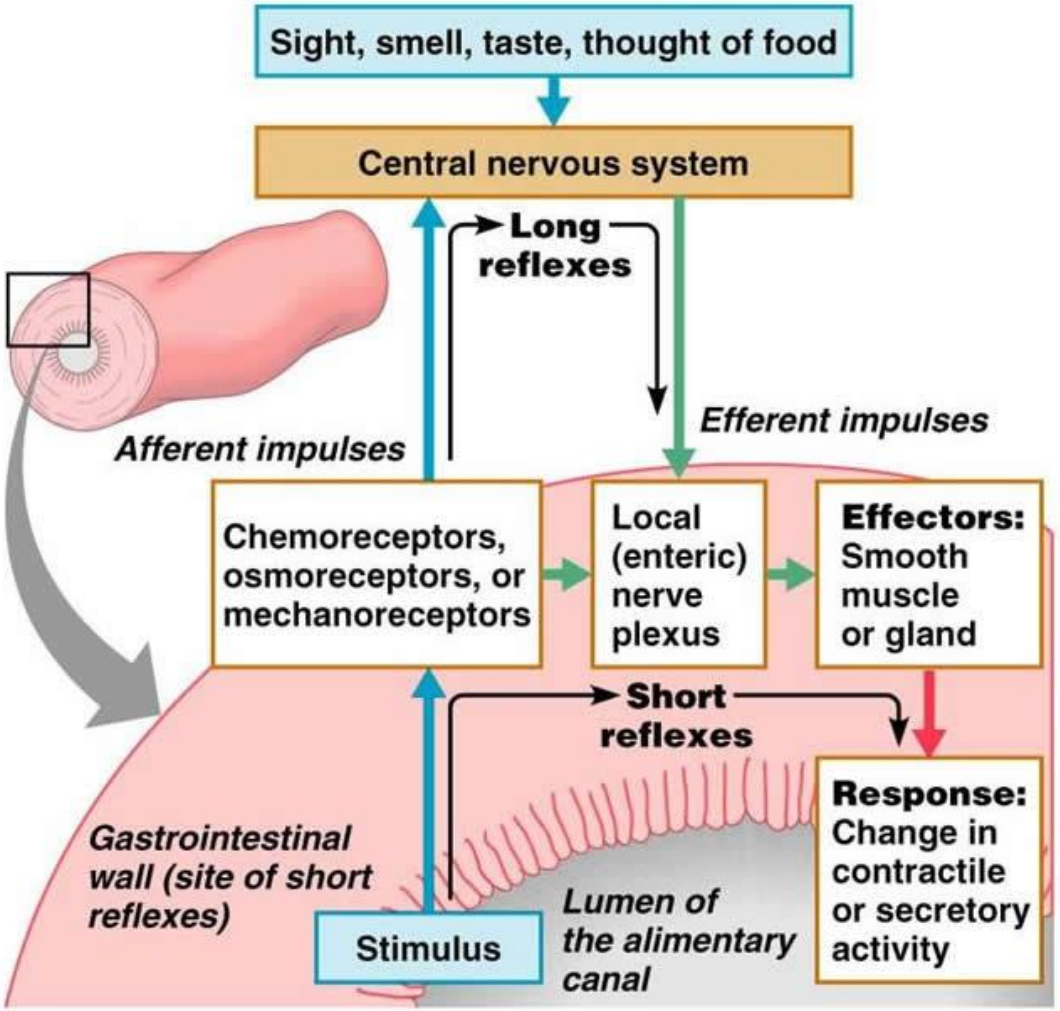
Reflexes through spinal cord and brain stem

Long reflexes that travel a distance in the GI tract

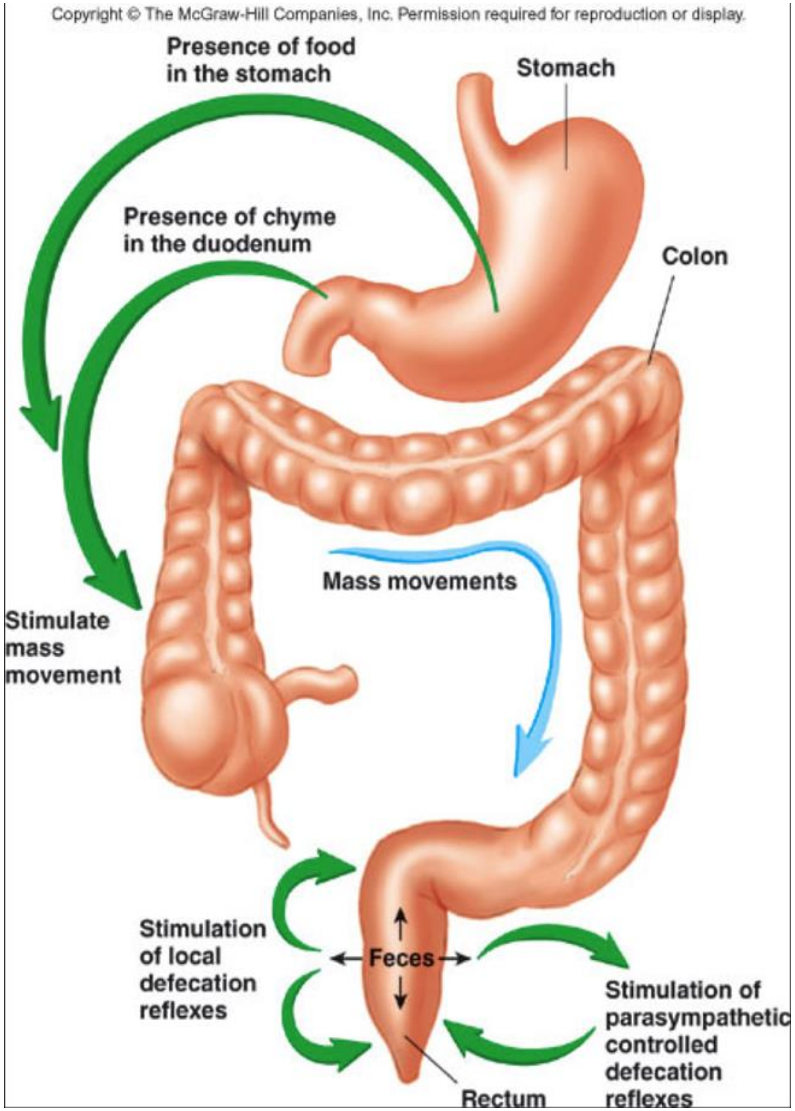
A way for organs to communicate with each other

Pain reflexes
Defecation reflex

GI REFLEXES


Sight, smell, taste, thought of food
Central nervous system
Long reflexes
Efferent impulses
Afferent impulses
Chemoreceptors, osmoreceptors, or mechanoreceptors
Local (enteric) nerve plexus
Effectors: Smooth muscle or gland
Short reflexes
Response: Change in contractile or secretory activity
Gastrointestinal wall (site of short reflexes)
Stimulus
Lumen of the alimentary canal

GI REFLEXES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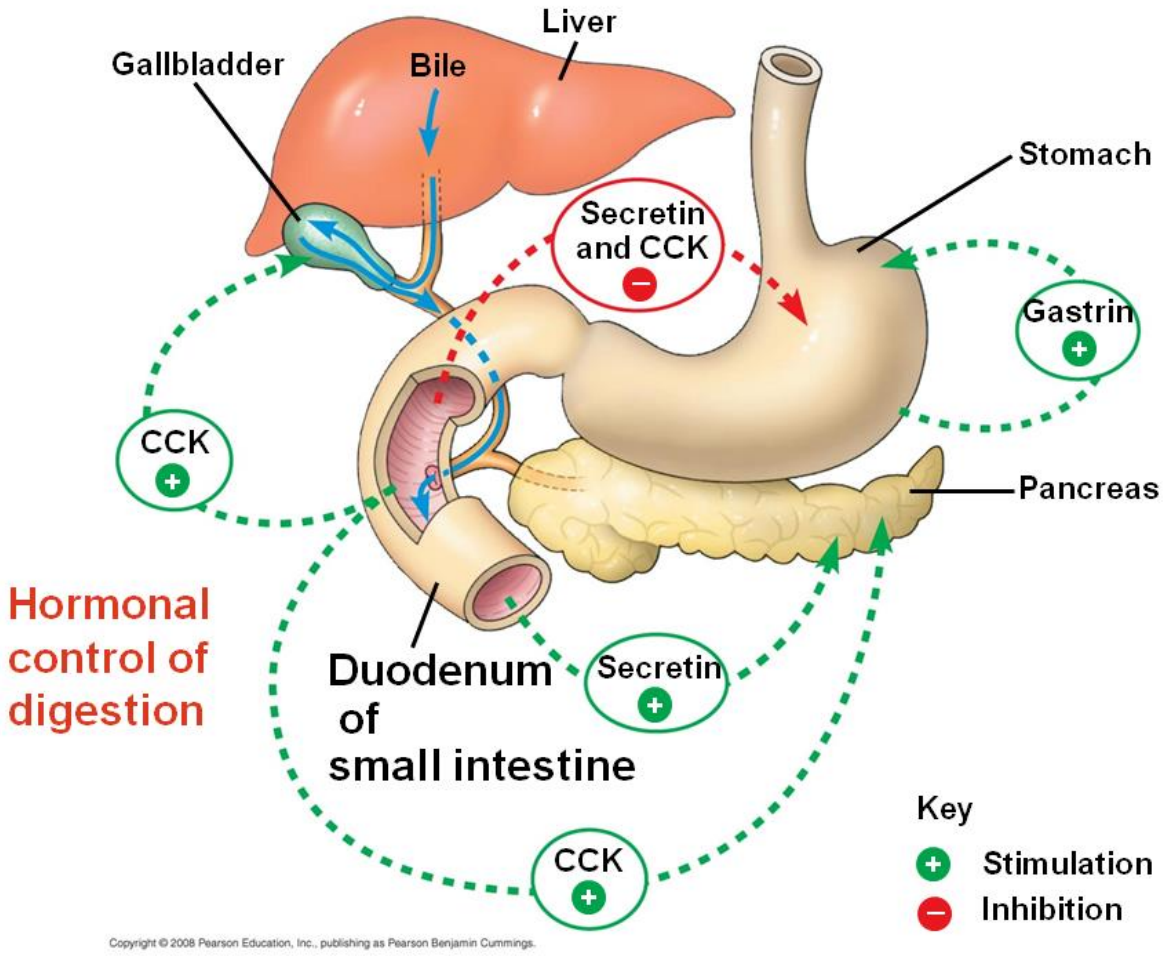
Presence of food in the stomach
Stomach
Presence of chyme in the duodenum
Colon
Mass movements
Stimulate mass movement
Stimulation of local defecation reflexes
Feces
Stimulation of parasympathetic controlled defecation reflexes
Rectum

HORMONAL REGULATION OF THE GI SYSTEM

https://www.sciencelearn.org.nz/resources/1836-hormonal-control-of-digestion



TYPES OF GI MOVEMENT

GI MOVEMENT

Two types of movement in the GIT

Propulsive "Peristalsis"

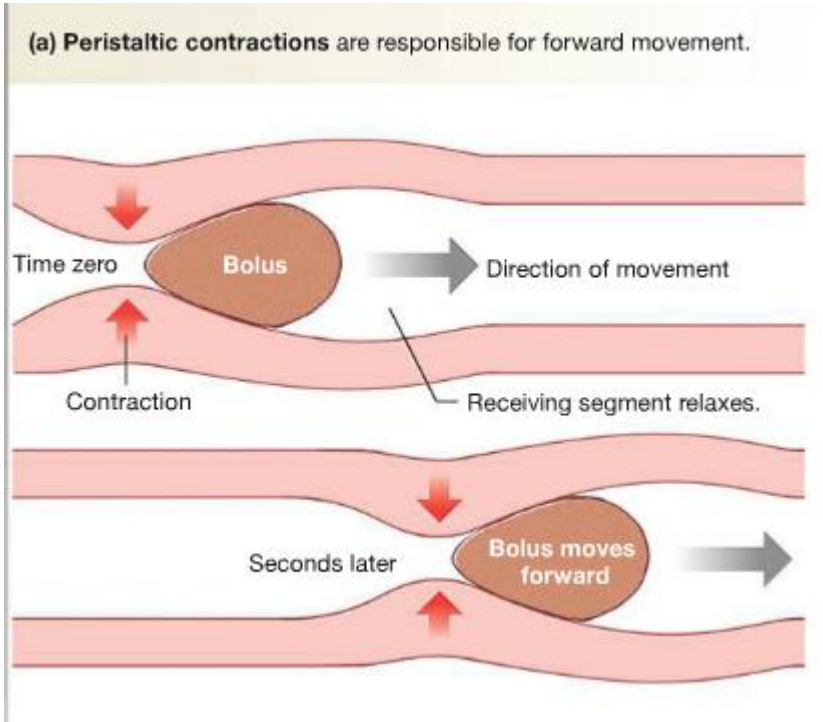
Moves food forward along the tract.
Usual stimulus is distention.
Distention → stimulates the proximal portion to contract and the distal portion to relax.

Mixing "Segmentation"

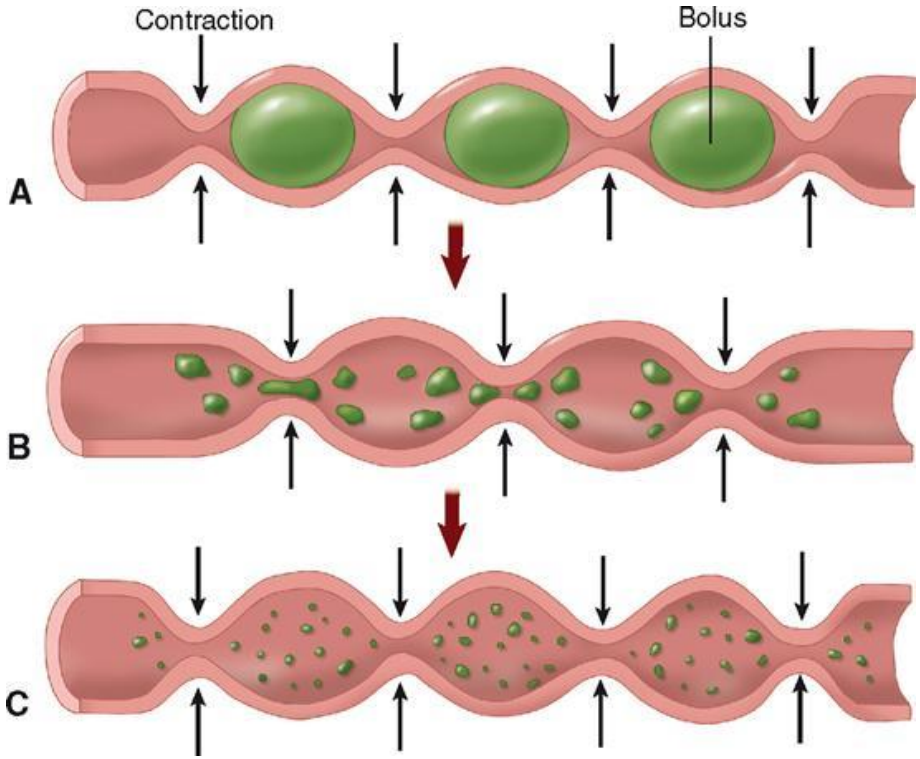
Provides mixing of intestinal contents with digestive juices.
Segment of bowel contracts at both ends
A second contraction occurs in the center of the segment

GI MOVEMENT

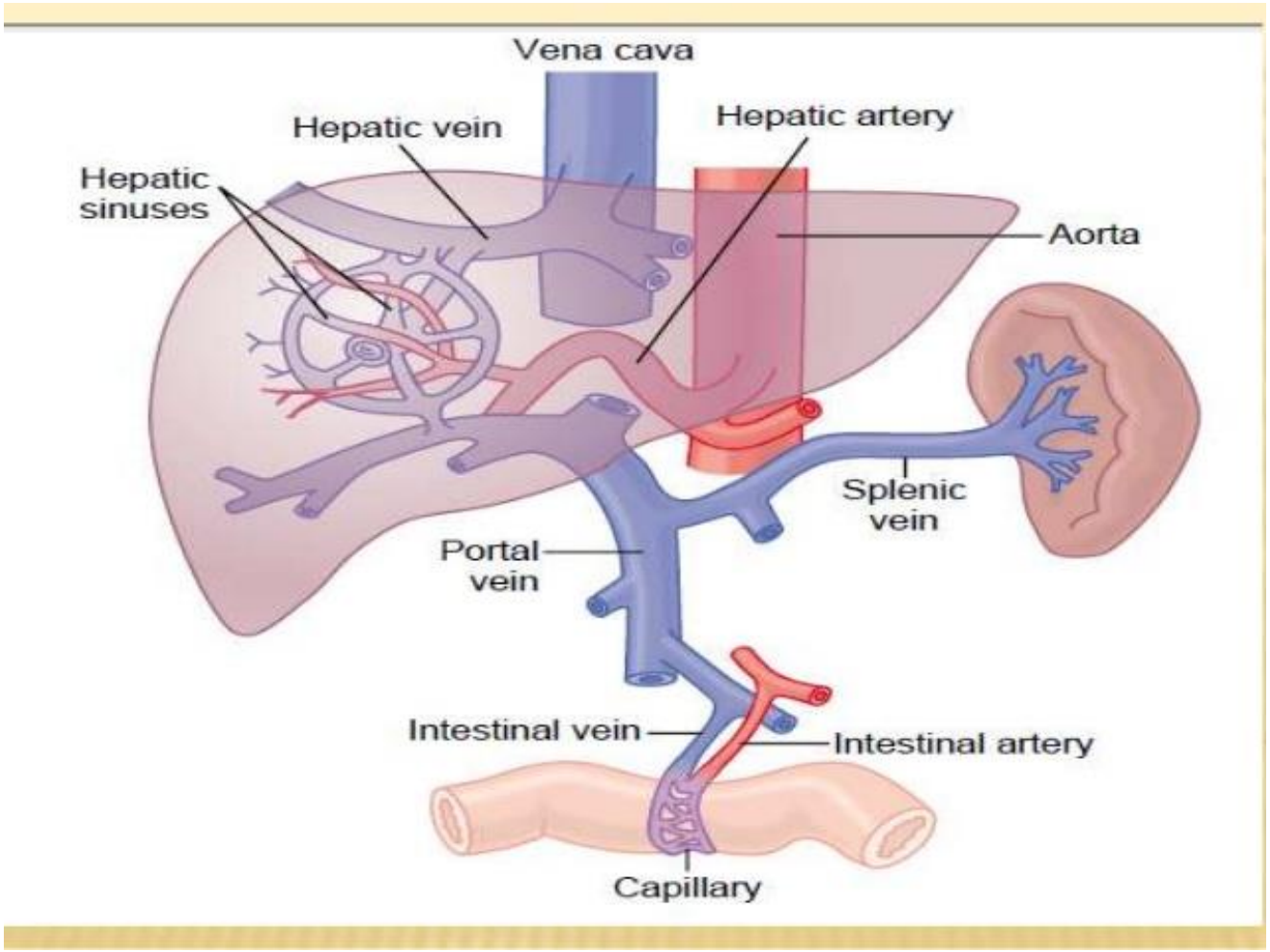
Peristalsis



Segmentation



SPLANCHNIC CIRCULATION



Read it on your own-if you have any questions do not hesitate to ask

Thank you

REFERENCES

- Images;
  - Vector stock.
- Sherwood
- Guyton & Hall

CONTRACTION OF SMOOTH MUSCLE