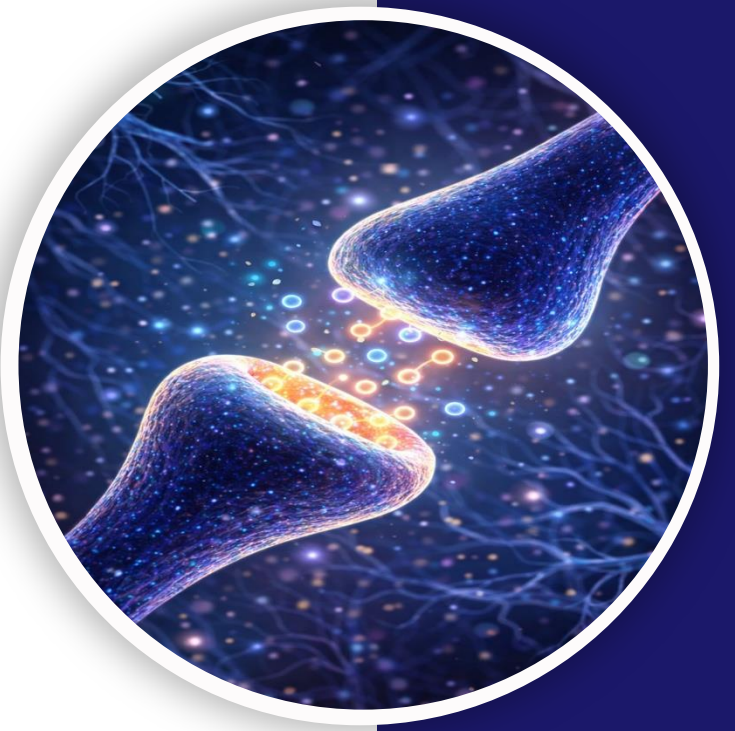
بسم الله الرحمـٰن الرحيم

(وَفَوْقَ كُلِّ ذِي عِلْمٍ عَلِيمٌ)

GIT Physiology | MID 1

Introduction GI physiology



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Leen Abukhalaf

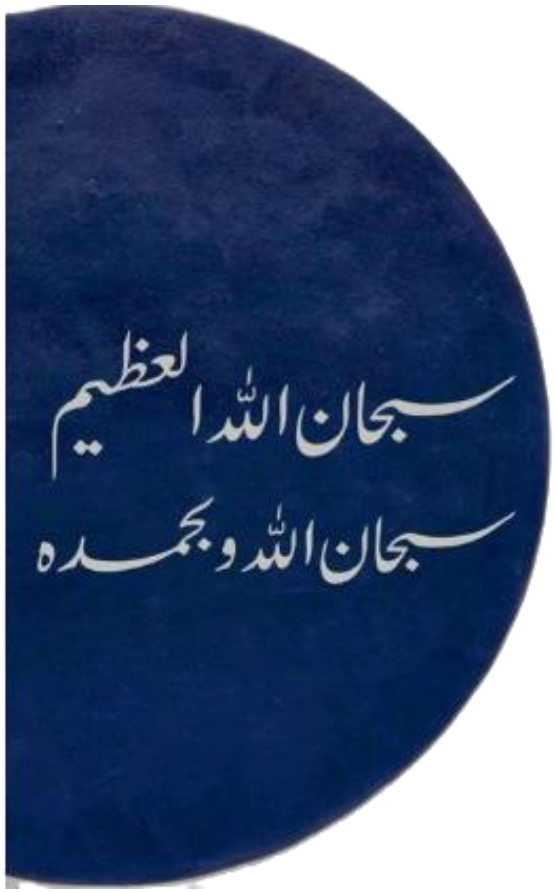
Reviewed by : NST members

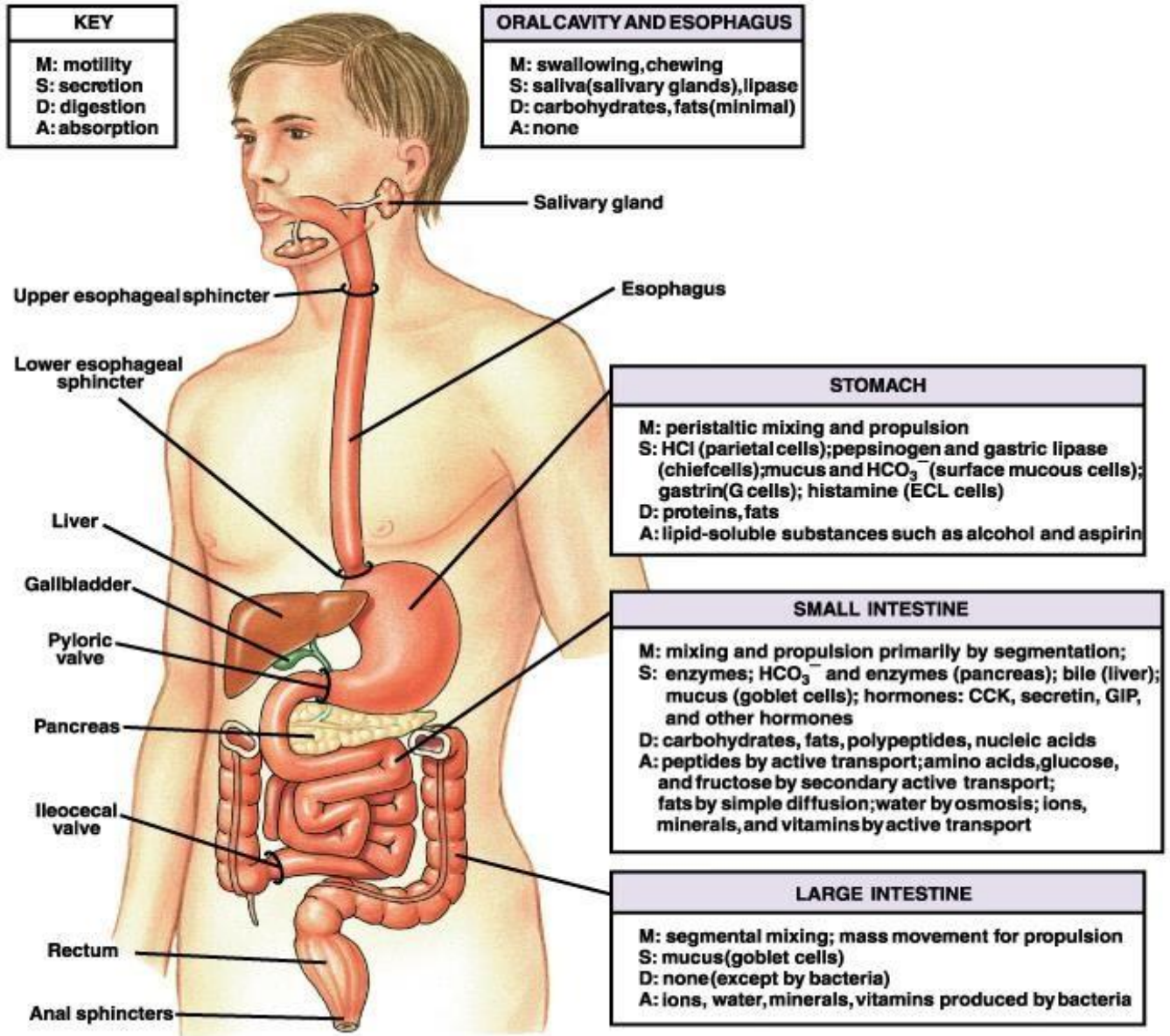
Gastrointestinal physiology

Textbook of Medical Physiology,

GUYTON and HALL,
Jordan Edition: 797-842, 887-897.13th ed: pp797-847, pp: 887-907, 12th Ed: pp753-803, pp: 843-863.
11th ed: pp771-818, pp865-888.

the Gastrointestinal (GI) tract is one of the largest and most complex internal system, it's composed of many organs starting from the oral cavity ending with annus, a lot of organs with various functions along the system





Physiological processes are taking place along the gastrointestinal (GI) tract. Four topics:

- **1. Motility.** Movement along GIT
- **2. Secretion**
- **3. Digestion.**
- **4. Absorption.**

discussed **together**, since they are closely correlated and function as a single integrated process

- In addition to these core topics, the **last topic** of the course addresses the **purpose and consequences of eating:** We eat food ,Food undergoes **digestion and absorption** ,Nutrients become available within the body, These nutrients are **used as fuel for energy.**

This leads to discussion of:

- **Body energy utilization**
- **Metabolism of nutrients**
- **Why we eat and how food supports body functions.**

Control of Food Intake

The final part focuses on the **control and regulation of feeding behavior**. This includes mechanisms that determine: when we feel hungry, when we feel full, how emotions (e.g., stress, sadness, anger) affect eating ,pathological conditions related to abnormal food intake regulation

Thus, the last topic discusses **the physiological and regulatory mechanisms controlling food intake and feeding behavior**.

Functional structures in the gastrointestinal tract

Like any physiological system, the **gastrointestinal (GI) tract has a functional structure** that allows it to perform its functions.

- **Smooth muscle cells**

Since one of the major functions of the GI tract is **movement**, the structure responsible for this function is **smooth muscle**.

Therefore, the GI tract contains **large amounts of smooth muscle cells**, which are mainly located in the **outer part of the gastrointestinal tube** and are responsible for motility.

- **Interstitial cells of Cajal**
- **Secretory cells**

These cells:

- ·Release digestive substances.
- ·Contribute to GI function.
- ·Are organized within the mucosa.

✓ The organization and functions of these **secretory structures** will be discussed later.

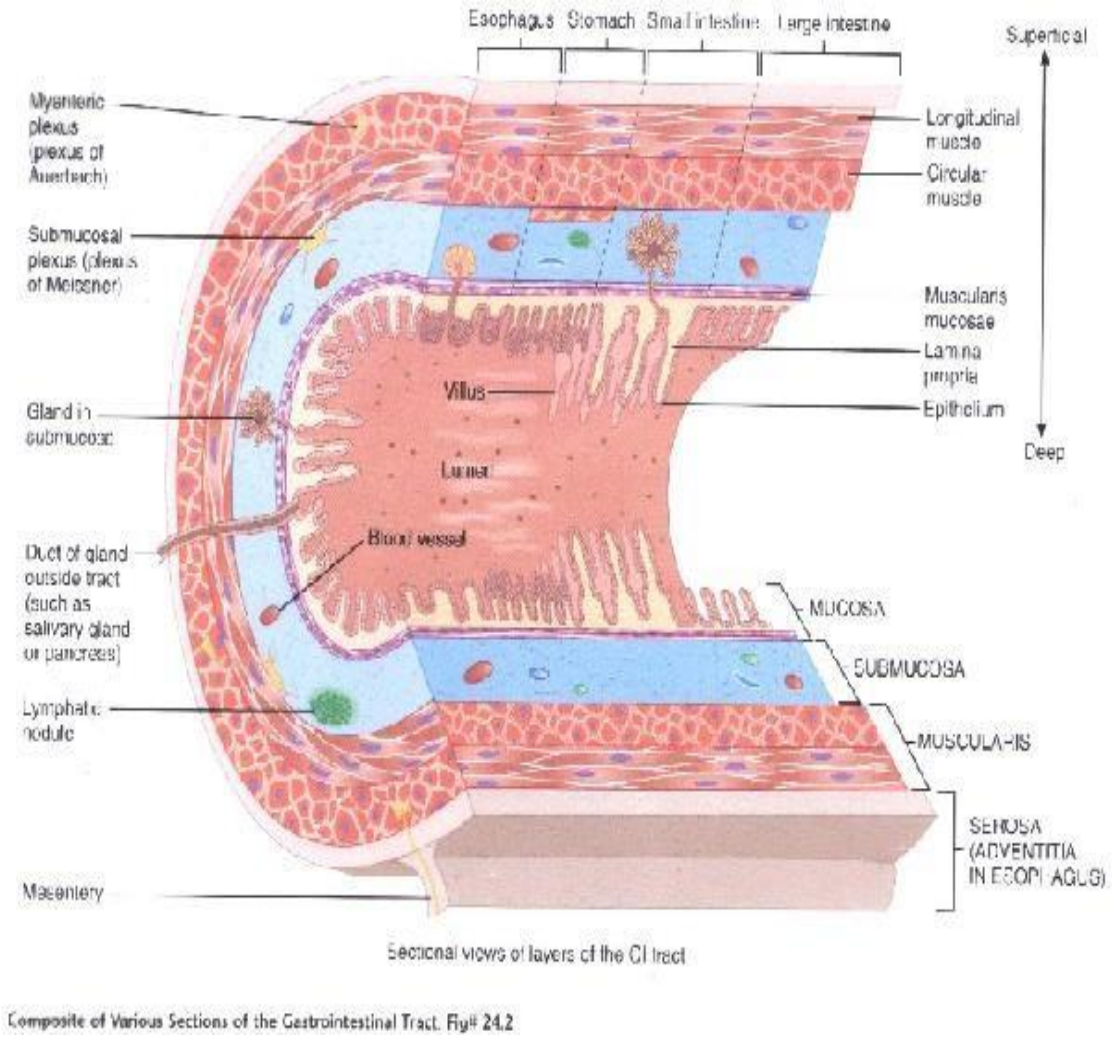
For physiological understanding, the GI tract can be imagined as a **tube structure composed of three main layers**. Although there are **variations between different organs**, these anatomical differences are usually discussed in **anatomy and histology classes**. In physiology, we focus on the general organization. The three main layers are:

1. **Outer layer – Muscle layer (smooth muscle)**
1. responsible for movement (motility).

2. **Middle layer – Submucosa**
1. connective tissue layer
2. contains vessels, nerves, and supporting structures.

3. **Inner layer – Mucosa**
1. lines the lumen
2. involved in secretion and absorption

Thus, the gastrointestinal tract is generally considered **three-layered tube**:
·outer muscular layer
·submucosa
·inner mucosa



Sectional views of layers of the GI tract

Composite of Various Sections of the Gastrointestinal Tract. Fig# 24.2

Although there are **variations between organs**, these are not discussed here; instead, we focus on the general structure. The GI tract contains **abundant smooth muscle in the outer layer**, which is responsible for movement along the tract.

Other related structures

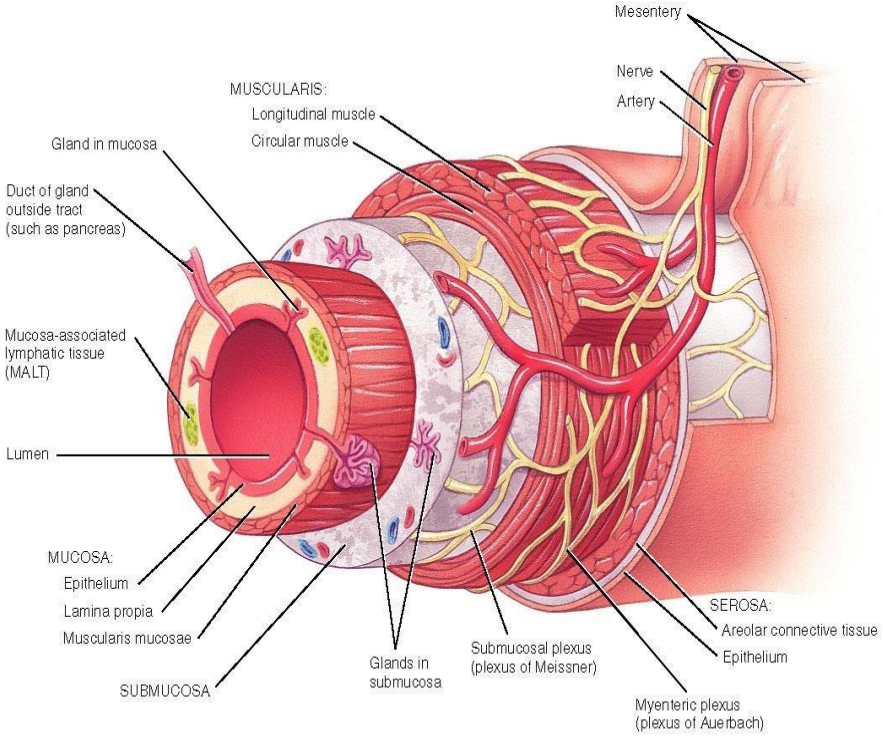
VERY POWERFUL

- **Control systems of GI functions.**
  - **Neural control:**
    - **Enteric nervous system**
    - **Autonomic nervous system**
  - **Hormonal control: GI endocrine**

We have a lot of hormones released along GIT involved in the control system

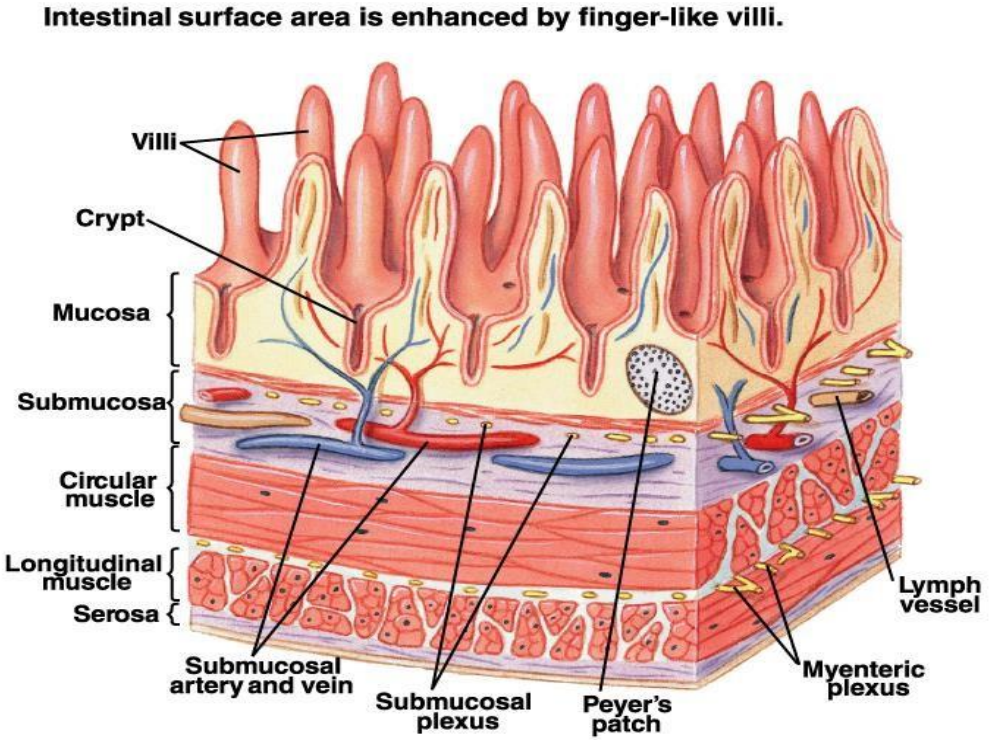
- **Blood flow to the GI.**

Very important for the process of secretion also for absorption.



24.02

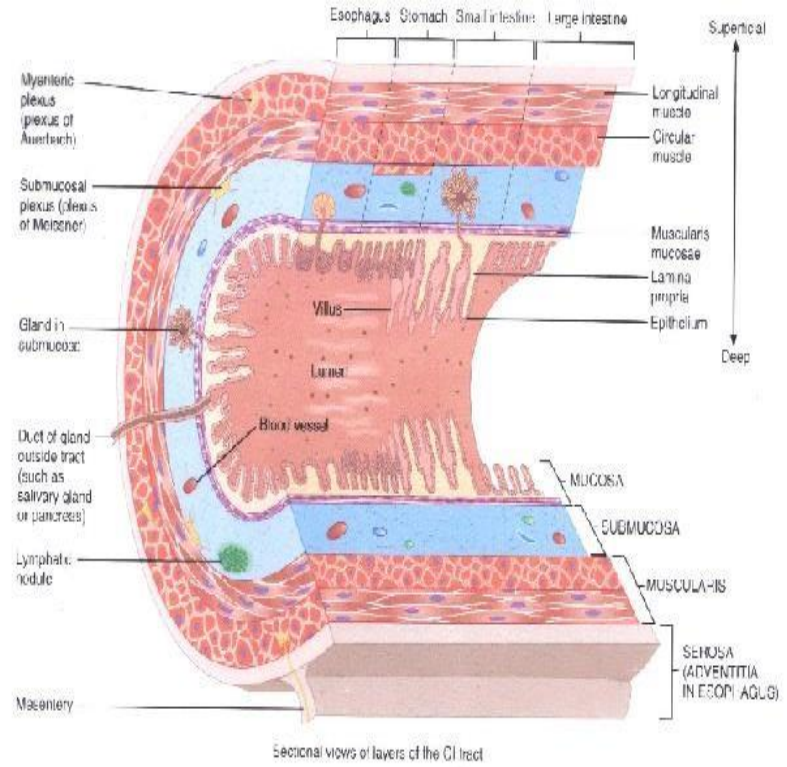
·The gastrointestinal tract shows prominent submucosa with rich vascular supply.



·In some organs, especially the small intestine, the mucosa is also highly vascularized.
·This mucosal vascularization includes dense capillarization.
·The high capillary network is important for rapid removal and transport of absorbed substances.

Functional structures in the gastrointestinal tract

Smooth muscle cells (SMCs)



Sectional views of layers of the GI tract

Composite of Various Sections of the Gastrointestinal Tract. Fig# 24.2

Smooth muscle cells are present along the gastrointestinal tract and are responsible for contraction. These cells are mainly located in the outer muscular layer of the GI tube. This muscular layer is composed of two sublayers: an outer **longitudinal layer**, where muscle fibers run along the axis of the tube, and an inner **circular layer**, where fibers run around the circumference of the tube.

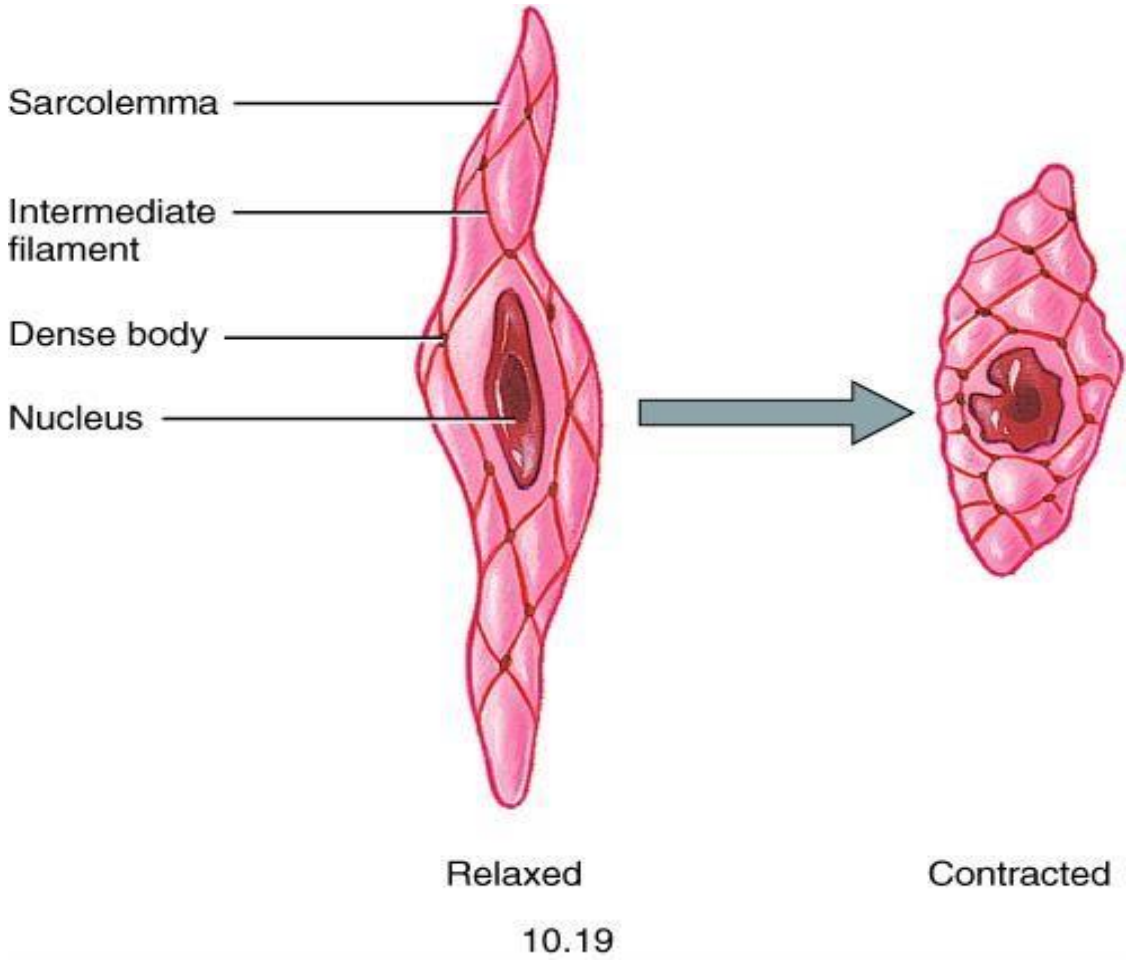
Contraction of the **longitudinal layer** causes shortening of a segment of the intestine, while relaxation leads to elongation. In contrast, contraction of the **circular layer** narrows the lumen (decreases the diameter), and relaxation widens it. These coordinated contractions are essential for propulsion and mixing of the intestinal contents.

In addition to these two main muscle layers, there is a very thin muscle layer called the **muscularis mucosae**, located between the mucosa and submucosa. This layer has an important functional role. In the small intestine, the mucosa forms folds that are not static. The muscularis mucosae produces local shortening and movement of these folds, changing the position of the mucosa relative to the luminal contents (chyme). This movement improves contact between the mucosa and chyme and enhances absorption.

So, the gastrointestinal tract contains three relevant smooth muscle components: the longitudinal layer, the circular layer, and the muscularis mucosae, each contributing to motility and absorption.

Smooth muscle contraction occurs through the interaction between contractile filaments. Dense bodies act as anchoring points that hold the thin filaments, while thick filaments lie in between them. During contraction, sliding occurs between the thick and thin filaments, which shortens the distance between the dense bodies, leading to shortening of the smooth muscle cell. Relaxation occurs when this sliding process is reduced and the distance between dense bodies increases.

After understanding the mechanism of contraction, the next step is to discuss how the activity of smooth muscle cells along the gastrointestinal tract is controlled.



Smooth muscle cells are controlled differently depending on their location, such as in blood vessels, uterus, or the gastrointestinal tract. In general, contraction of smooth muscle requires an increase in intracellular calcium. This calcium can originate either from intracellular stores or from the extracellular fluid.
The influx of extracellular calcium can be regulated, and in the gastrointestinal tract this regulation can occur electrically. Therefore, contraction of gastrointestinal smooth muscle is not controlled only by neurotransmitters or chemical signals, but also by electrical activity.

Thus, smooth muscle activity in the GIT is regulated by two main mechanisms: chemical control (such as neurotransmitters and hormones) and electrical control, which influences calcium entry and consequently contraction.

Smooth Muscle cells Characteristics

- **Electrical activity**

  - Slow waves (basic electrical rhythm)

Smooth Muscle cells Characteristics

1. Slow Waves (Basic Electrical Rhythm – BER)

·Slow waves are **rhythmic depolarization and repolarization** of GI smooth muscle membrane potential.

·They occur **continuously**: depolarization → repolarization → depolarization → ...

·They are **NOT true action potentials**.

·By themselves, **slow waves do NOT cause contraction** (no tension).

·They only **bring the membrane potential closer to threshold**.

·Some GI smooth muscle cells are **self-excitatory**, so slow waves occur spontaneously.

- Slow waves are probably caused by:
- rhythmic changes in **Na^+ pump activity.**
- changes in **ion channel conductance** .

If the slow wave **does not reach threshold → no contraction**.

2. Spike Potentials (True Action Potentials)

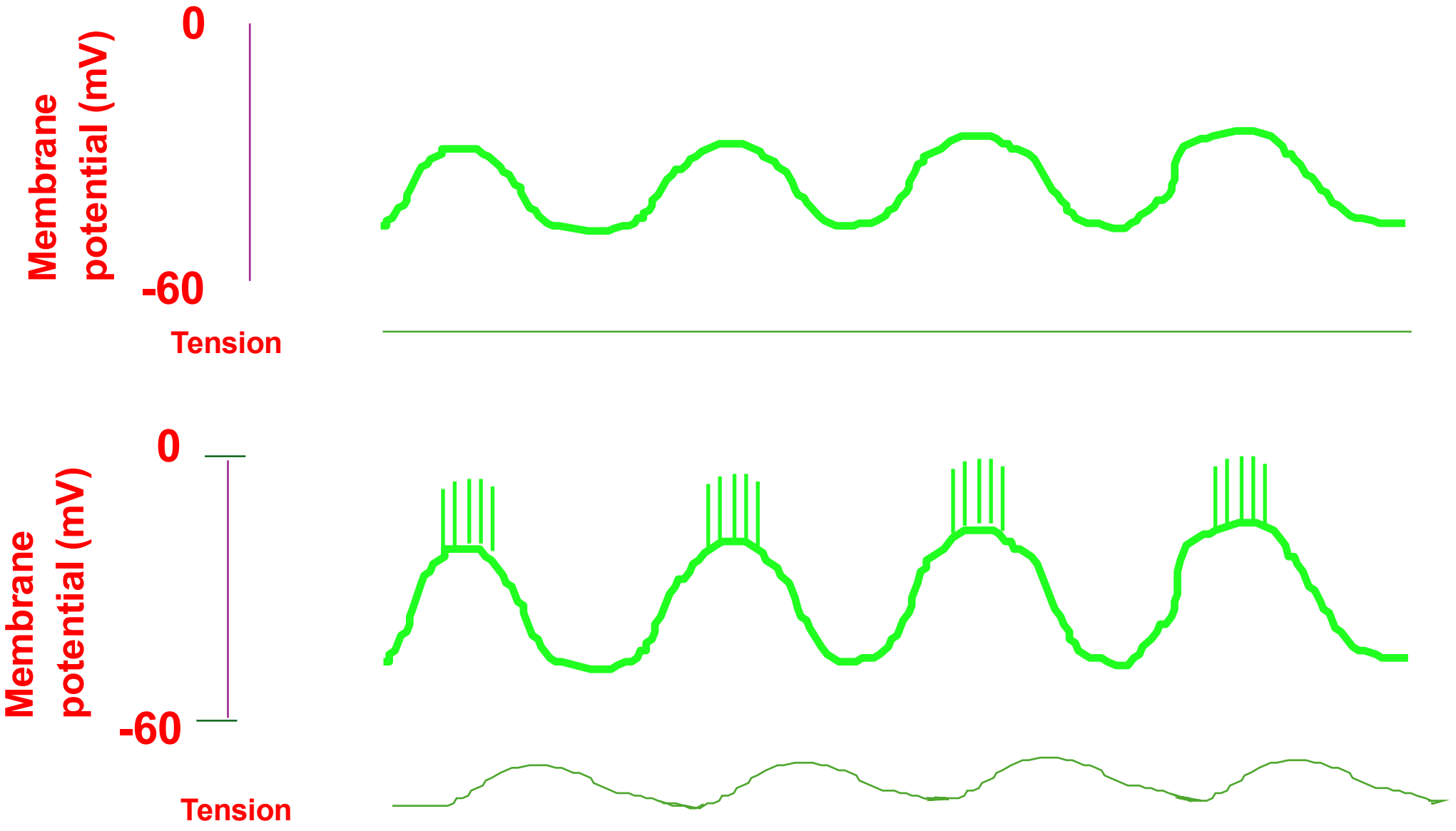
·Spike potentials are **true action potentials**.

·They occur **at the peak (tip) of slow waves** when threshold is reached.

·They cause **rapid depolarization and repolarization** (short duration).

- They can be triggered by:
- hormones
- neurotransmitters
- stretch
- or when slow waves reach threshold, Spike potentials **open Ca^{2+} channels → Ca^{2+} enters → contraction occurs**.

·Slow waves **set the rhythm**
·Spike potentials **produce contraction**
·More spikes = **stronger contraction**
·No spikes = **no significant contraction**

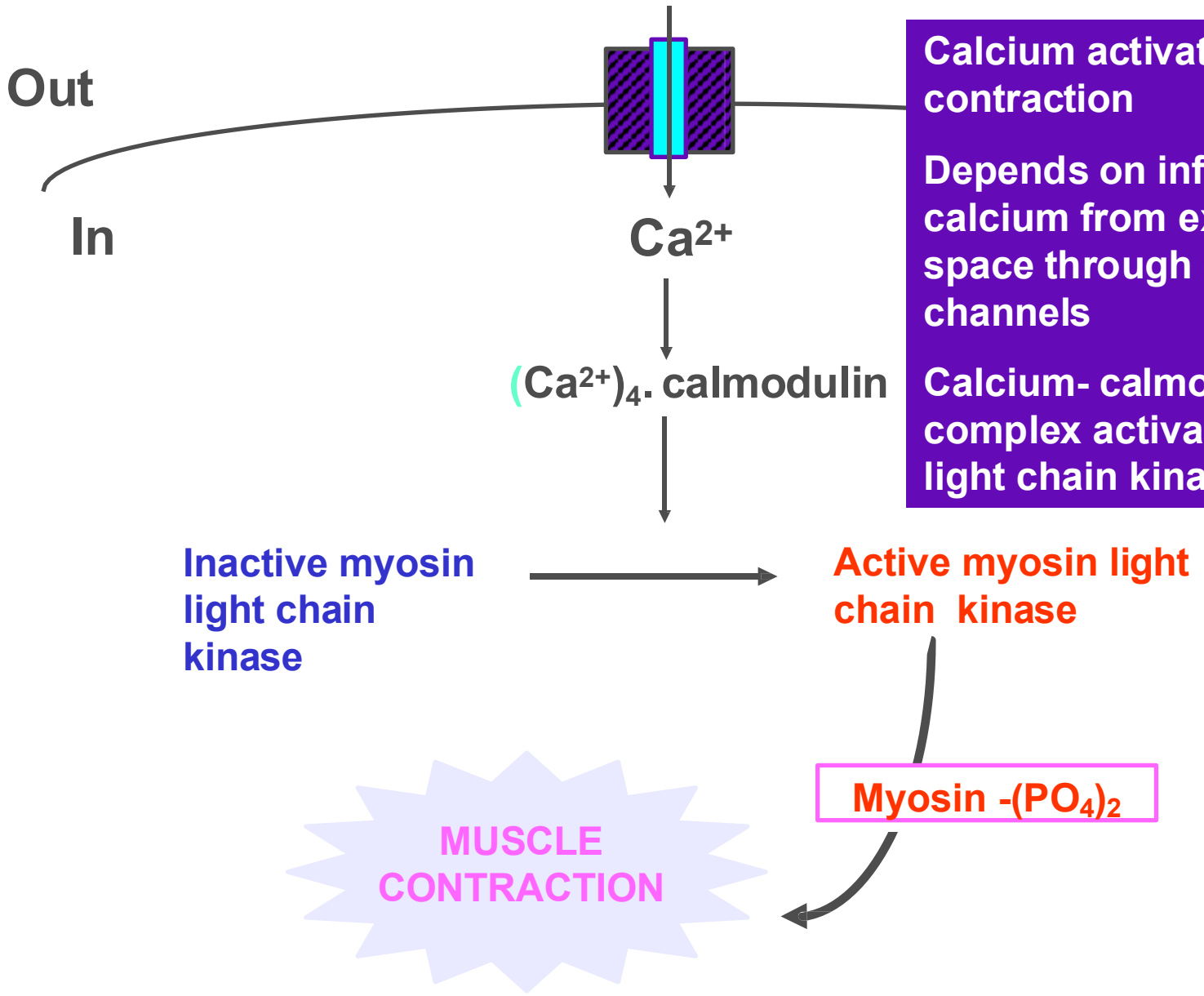

0
Membrane potential (mV)
-60
Tension
0
Membrane potential (mV)
-60
Tension

Contraction of GI smooth muscle

1) When spike potentials occur, **voltage-gated calcium channels in the smooth muscle cell membrane open.** This allows **calcium to enter the cell from the extracellular space.** The **increase in intracellular calcium initiates the contraction mechanism.**

2) Calcium binds to **calmodulin**, forming a calcium-calmodulin complex. This complex activates **myosin light-chain kinase (MLCK)**, which phosphorylates myosin. Phosphorylated myosin interacts with actin, leading to cross-bridge cycling and smooth muscle contraction.

3) Therefore, spike potentials trigger contraction by opening voltage-gated calcium channels, increasing intracellular calcium, activating calmodulin and MLCK, and finally producing smooth muscle contraction.



Calcium activates contraction

Depends on influx of calcium from extracellular space through calcium channels

Calcium- calmodulin complex activates myosin light chain kinase

Smooth Muscle cells Characteristics

- **Gap junctions:**
  - → **Communication between cells**
  - → **Functional syncytium**

Smooth muscle cells in the gastrointestinal tract are connected by **gap junctions**, which are very important for proper function. These gap junctions allow electrical signals to pass directly from one smooth muscle cell to another.
This connectivity ensures that groups of smooth muscle cells **contract and relax together**. If individual cells contracted independently, motility would be inefficient. Instead, the presence of gap junctions allows the smooth muscle cells to behave as a **functional syncytium**, meaning a group of cells acting as a single coordinated unit. This coordinated electrical activity improves the efficiency of gastrointestinal motility.

In addition to this **electrical control**, smooth muscle activity in the GIT is also regulated by **chemical control.**

Chemical control of SMCs

Gastrointestinal smooth muscle cells also have receptors such as **muscarinic receptors**. These receptors are linked to membrane phospholipids through intracellular signaling pathways. When activated, they stimulate phospholipase C, which leads to the breakdown of membrane phospholipids and the formation of **IP3 (inositol trisphosphate)**.
IP3 then triggers the release of calcium from intracellular stores, mainly the **sarcoplasmic reticulum**. The increase in intracellular calcium initiates contraction. Calcium binds to calmodulin, forming the calcium-calmodulin complex, which activates myosin light-chain kinase and leads to smooth muscle contraction.
This represents **chemical control** of gastrointestinal smooth muscle activity, where contraction occurs through release of calcium from intracellular stores. In general, **electrical control** regulates the basic rhythmic activity, while **chemical control** modulates the strength and type of contraction, particularly **tonic contractions**.

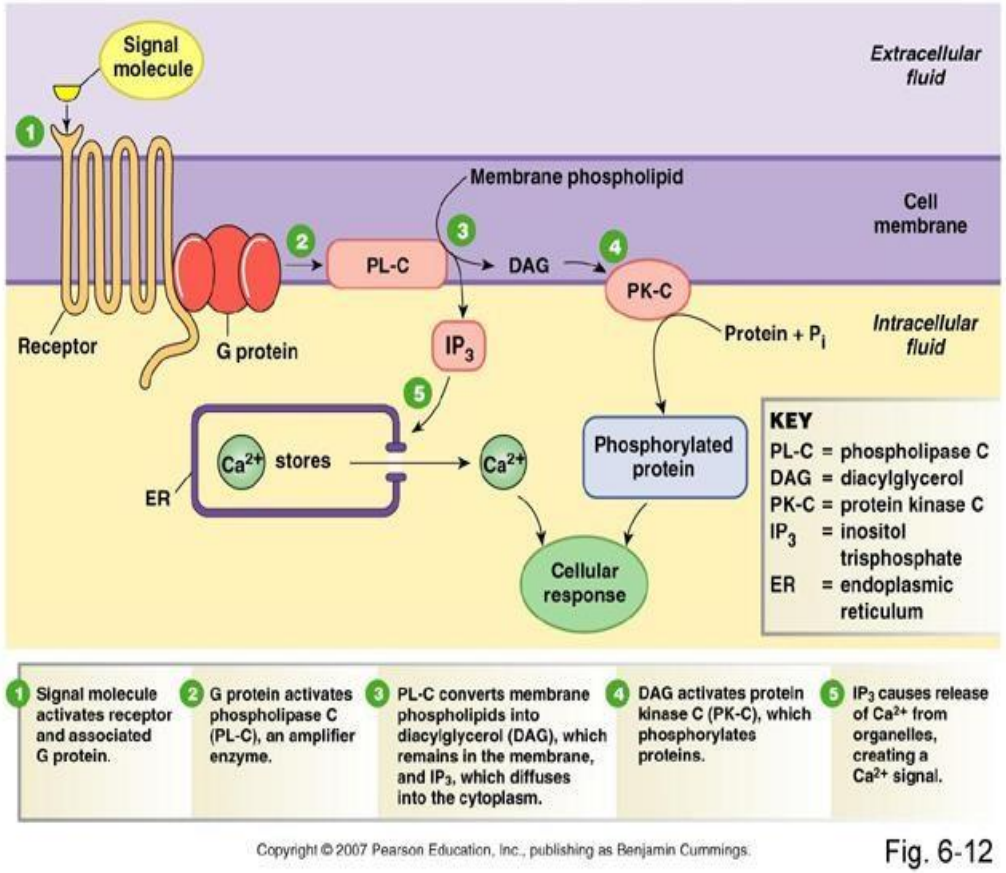
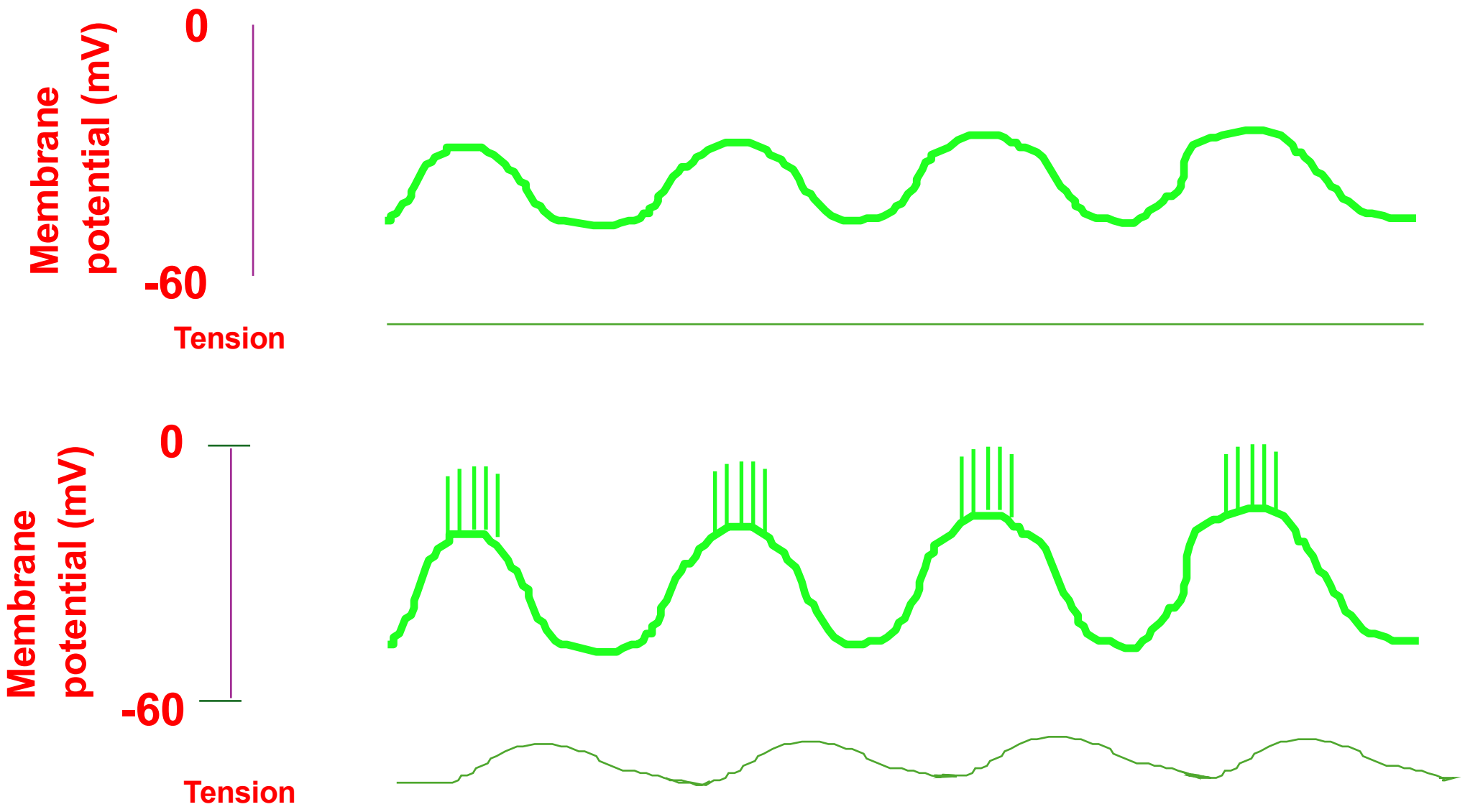


Fig. 6-12

Control of smooth muscle cells activity

- **Electrical control:**
  - **Rhythm or phasic contractions**

- **Chemical control:**
  - **tonic contractions**


Membrane potential (mV)
0
-60
Tension
Membrane potential (mV)
0
-60
Tension

Explanation for the previous two slides

- Smooth muscle in the gastrointestinal tract is never completely relaxed; it always maintains a certain level of baseline tension. This constant partial contraction is called **tonic contraction** or **muscle tone**. Because of this tone, the intestine maintains a shorter functional length than its anatomical length.

- Tonic contraction results mainly from **chemical control** acting on smooth muscle receptors. Some receptors increase contraction, others promote relaxation, while the balance between them determines the **baseline level of tension** (tone). This tone can increase (higher tonic contraction) or decrease (lower tonic contraction) depending on physiological conditions.

- On top of this tonic contraction, there are **phasic contractions** produced by electrical activity (slow waves and spike potentials). These phasic contractions cause rhythmic increases and decreases in tension above the baseline tone.
- Therefore, **tonic contraction** represents the baseline level of smooth muscle tension, while **basic (phasic) contractions** are rhythmic contractions that occur above or below this baseline.

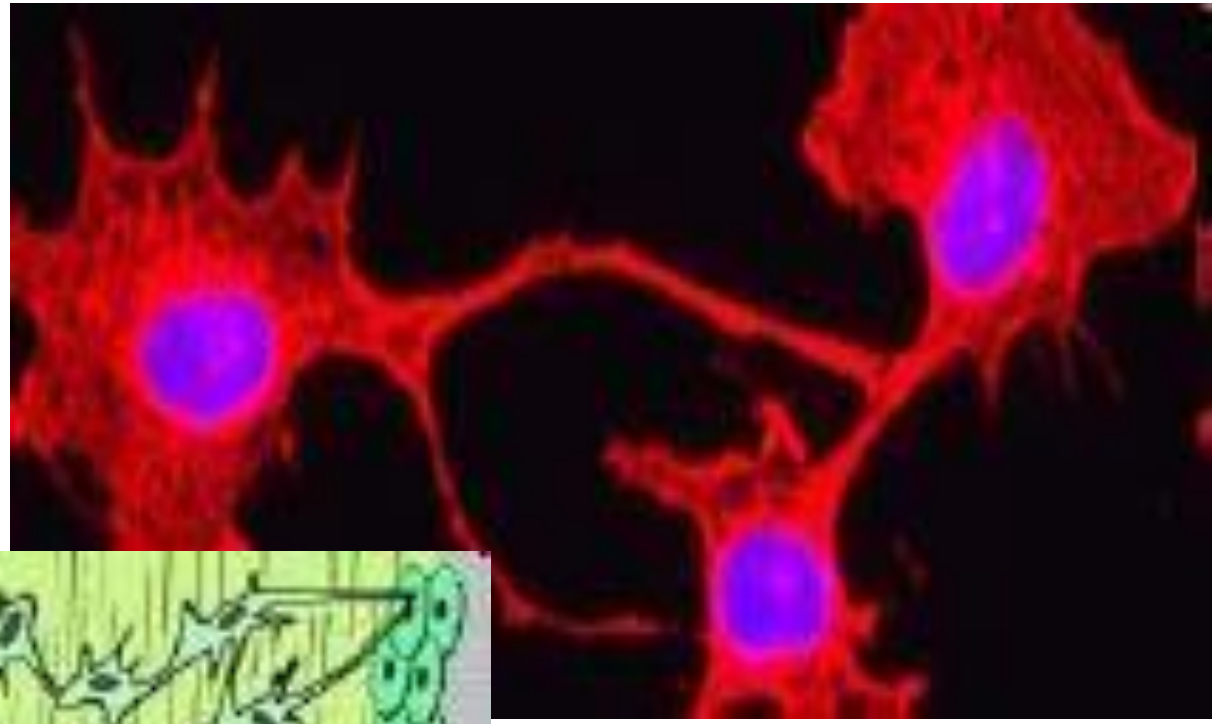
- The same smooth muscle cell maintains a **tonic contraction** that represents the baseline level of tension. On top of this tonic contraction, the muscle can also show rhythmic increases and decreases in tension. These rhythmic changes are the **basic (phasic) contractions**, which occur in an arrhythmic or cyclic manner and are mainly set by electrical control.

- Thus, tonic contraction establishes the baseline tension under **chemical control**, while the basic contractions are superimposed on this tone and are regulated by **electrical activity**.

- The final motor activity of the gastrointestinal smooth muscle results from the interaction between these two types of control.

Interstitial Cells of Cajal (ICCs)

Interstitial cells of Cajal are specialized cells present in the gastrointestinal tract. They are not neurons, but they have a neuron-like appearance with multiple processes or spike-like extensions.
These cells are connected to each other by **gap junctions**, and they are also connected to nearby **smooth muscle cells** through gap junctions. This arrangement allows electrical signals to spread between interstitial cells of Cajal and smooth muscle cells, helping coordinate gastrointestinal motility.



Characteristics of ICCs

- **Communications:**
  - ICCs-ICCs gap junctions
  - ICCs-smooth muscle cells gab junctions
  - inputs from ENS

- **Generation of action potentials:**
  → pacemaker cells of the GI tract

Characteristics of ICCs

- Interstitial cells of Cajal have a primary function: they generate **rhythmic electrical activity**. These cells possess a resting membrane potential, and periodically they produce spontaneous depolarizations in a rhythmic manner.

- Because interstitial cells of Cajal are connected to each other and to smooth muscle cells through **gap junctions**, this depolarization spreads to the adjacent smooth muscle cells. When the smooth muscle cells depolarize and reach the **threshold**, spike potentials are generated. These spikes open voltage-gated calcium channels, leading to calcium entry and smooth muscle contraction. This produces the **basic (phasic) contractions** of the gastrointestinal tract.

- Therefore, the sequence is:
  Interstitial cells of Cajal generate rhythmic depolarization → depolarization spreads to smooth muscle → threshold is reached → spike potentials develop → contraction occurs.

- For this reason, interstitial cells of Cajal are considered the **pacemaker cells of the gastrointestinal tract**, as they set the rhythm of motor activity. The spontaneous depolarization originates within these cells themselves, and although the exact mechanism is not fully defined, it is believed to involve intrinsic membrane ion channel activity rather than direct neural control.

- Interstitial Cells of Cajal (ICCs)
- Act as pacemakers of the GI tract
- Control the rhythm of motor activity via action potentials
- Cause depolarization of smooth muscle cells → spike potentials → contraction

- Mechanism of generating action potentials
- Not fully understood
- Thought to be due to intrinsic metabolic changes
- Function independently of neural control

- Neural relation:
- ENS nerve endings found near ICCs
- No definitive proof of direct control

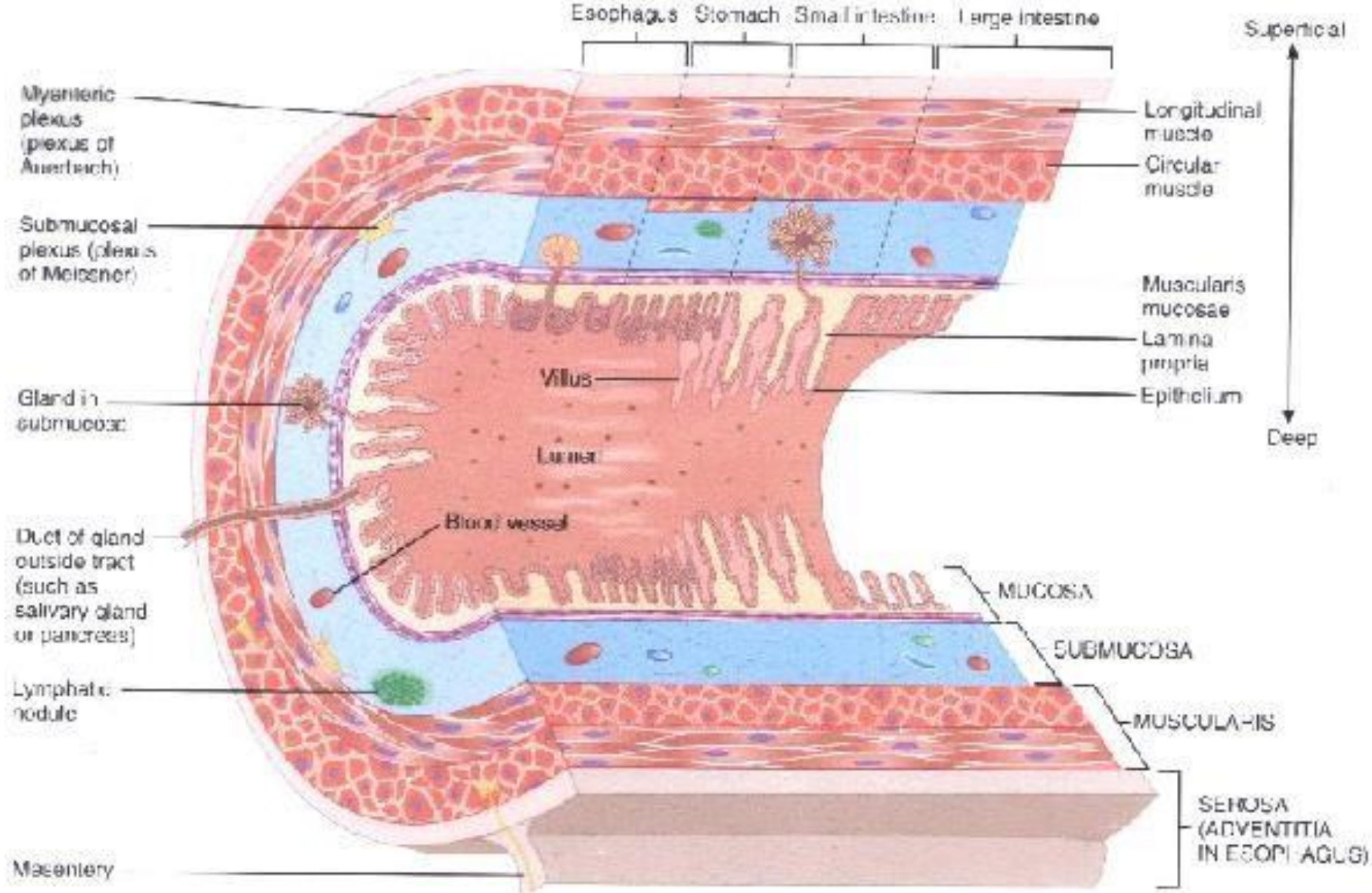
Secretory Cells

- Mucous secretion and serous secretion
  - Solitary cells :Scattered individually throughout the mucosa
- Pits Groups of simple secretory cells
  - Located in the mucosa
  - Function like simple glands
  - Compound glands
  - Located in the submucosa
  - More complex than pits
  - Difference from pits = location + structure
- Secretory organs
- Located outside the GI tract
- Examples: salivary glands, pancreas

Mucous secretion:
Rich in mucin (glycoprotein)

Serous secretion:
Contains water
and electrolytes

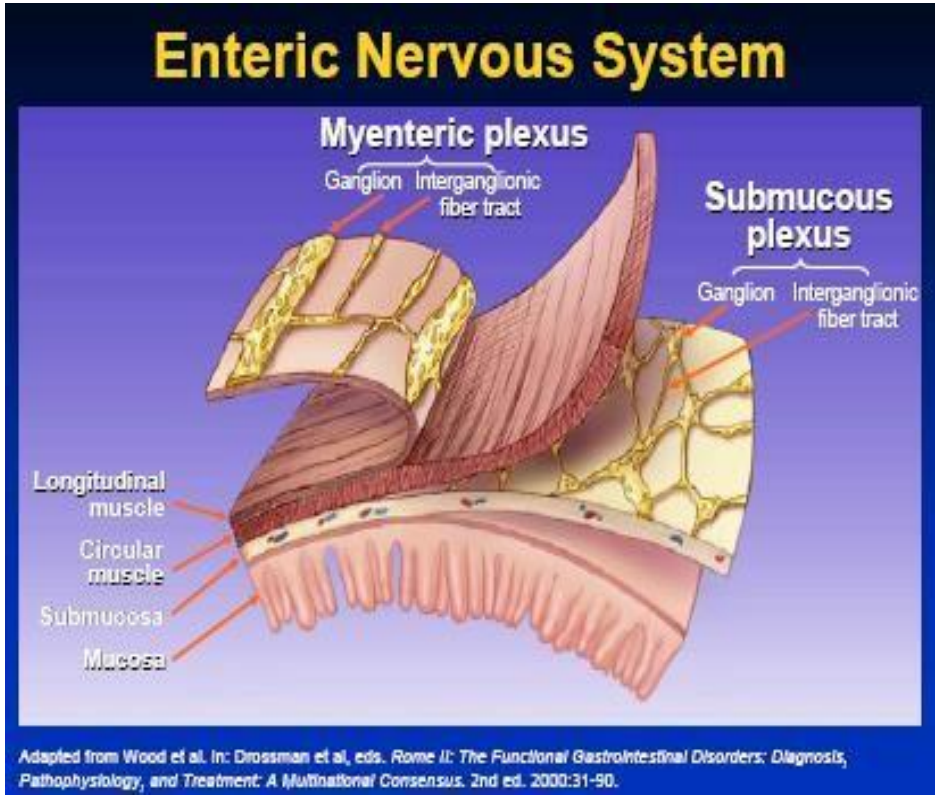
Secretions flow through duct systems → into the GI lumen.



Sectional views of layers of the GI tract

Composite of Various Sections of the Gastrointestinal Tract. Fig# 24.2

- Enteric Nervous System (ENS)
- Two neural network structures along the GI tract:



- 1. Myenteric Plexus
- Located between longitudinal and circular muscle layers
- Controls motility (muscle movement

- 2. Submucosal Plexus
- Located in the submucosa
- Controls secretion and blood flow
- There is communication (intertalk) between the two plexuses

Characteristics of ENS

- Enteric Neurons:

- –Excitatory : for the muscles they can cause contraction force
- And for the secretory cells they can cause increased secretions
- –Inhibitory : for the muscles they can cause relaxation force
- And for the secretory cells they can cause decreased secretions

- ✓ ENS contains a large number of neurons.
  - Equal to or greater than the spinal cord
  - More than 15 types of neurons identified
  - Referred to as the “brain of the GI tract”

- Neurotransmitters
  Ach, SP (Substance P), VIP (Vasoactive intestinal peptide), CGRP (Calcitonin gene related peptide), GRP (Gastrin releasing peptide)…etc

  - Vasoactive Intestinal Peptide (VIP)
    - Causes smooth muscle relaxation
    - Causes vasodilation
    - Increases blood flow

Autonomic Nervous System (ANS)

- ENS is fully functional independently, and ANS modulates ENS activity
- ANS effects:
  - Mostly indirect via ENS
  - Sometimes direct (e.g., vasoconstriction / vasodilation)

Autonomic Nervous System (ANS)

- **Sympathetic** Origin: spinal cord

Effects:

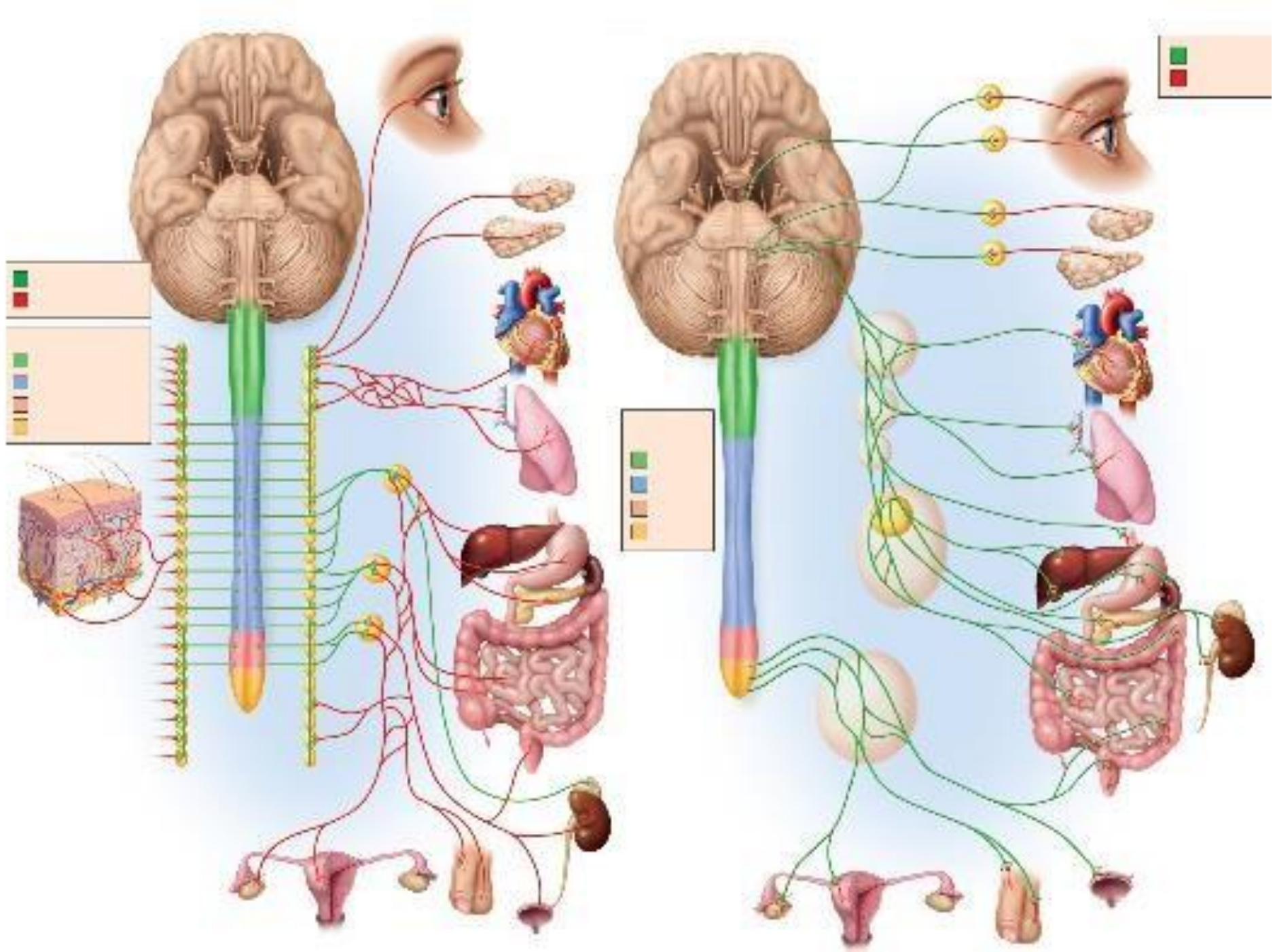
↓ secretion, ↓ motility

Causes vasoconstriction

- **Parasympathetic** Origin: craniosacral

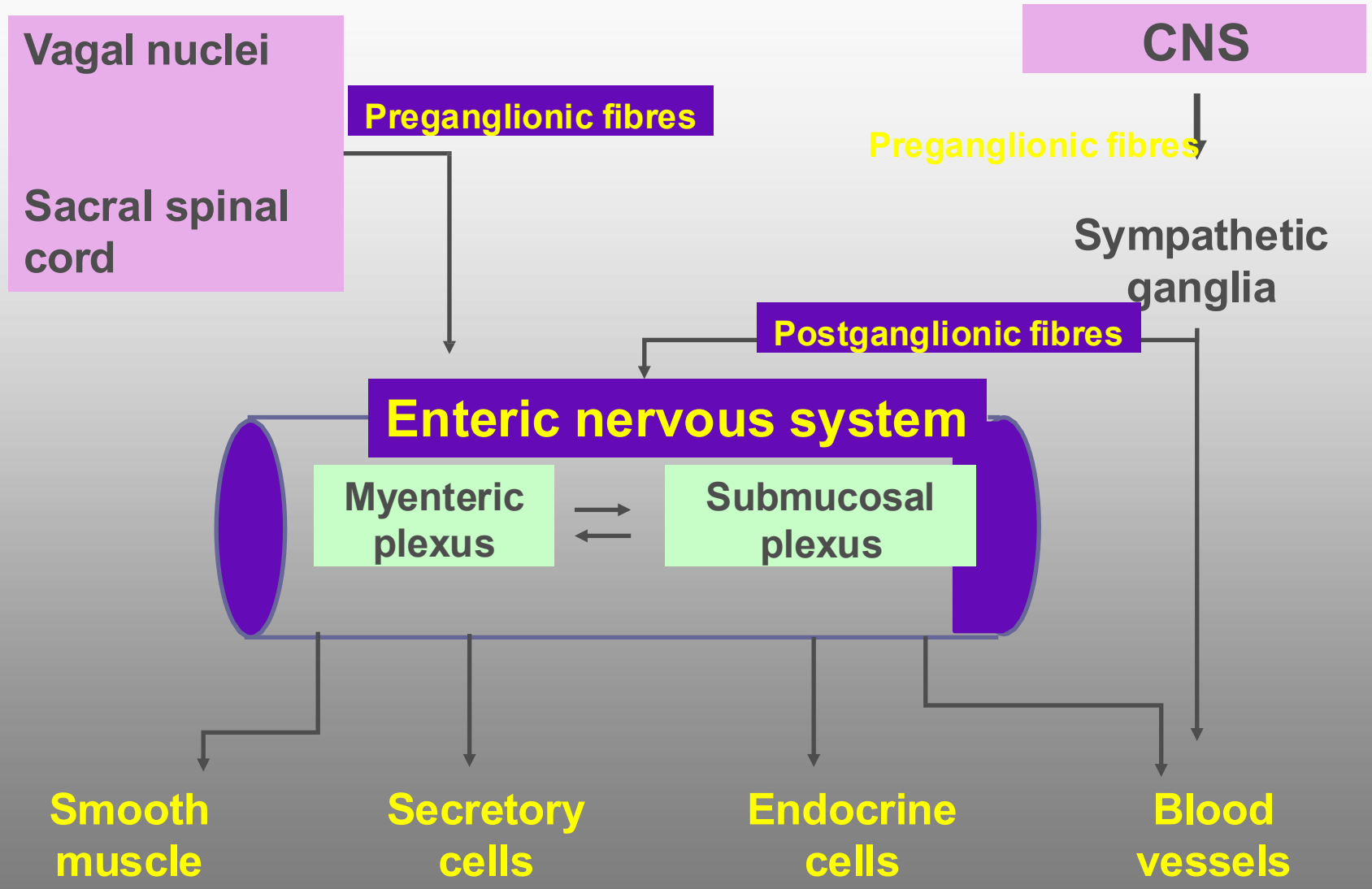
  Dominant control in GI

  Effects:
  ↑ secretion, ↑ motility



Parasympathetic N.S

Sympathetic N.S.



Enteric Endocrine System

- In addition to neural control, GI has hormonal control
- Hormone definition: A ligand released into the bloodstream and acts on distant target cells
- Endocrine cells: Dispersed throughout the GI mucosa and not organized into a single gland

Endocrine View of GI Tract

- GI tract can be considered a functional endocrine organ
- Due to presence of multiple hormone-secreting cells

Enteric Endocrine System

- **Gastrin**
- **Chlecystokinin (CCK)**
- **Secretin**
- **GIP (Gastric Inhibitory peptide) or (Glucose dependent Insulinotropic Polypeptide)**

Enteric Endocrine System

Glucagon-like peptide-1(GLP-1),

Motilin,

Ghrelin,

Amylin,

Enterostatin,

Neuropeptide Y (NPY),

polypeptide YY,

Pancreatic polypeptide which is closely related to polypeptide YY and NPY

Somatostatin,,

Neurotensin,

Thyrotropin releasing hormone (TRH),

Adrenocorticotropic hormone ACTH.

GI Hormones

- Gastric Inhibitory Peptide (GIP)
  - ➢ Released when food enters GI tract
  - ➢ Stimulates insulin secretion before blood glucose rises

- Glucagon-like peptide (GLP)
  - ➢ Also involved in insulin secretion

- TRH (Thyrotropin-Releasing Hormone)
  - ➢ From hypothalamus → acts on pituitary → thyroid axis

- ACTH (Adrenocorticotropic Hormone)
  - ➢ From pituitary → acts on adrenal (suprarenal) gland

- secretion of Insulin:

Once you have eaten you are not waiting until getting increase in glucose in your body. Instead, when there is a meal coming we secretions of GIP to stimulate the beta-cells of the pancreas to start releasing Insulin→ Initiation is by endocrine cells located among the GIT.

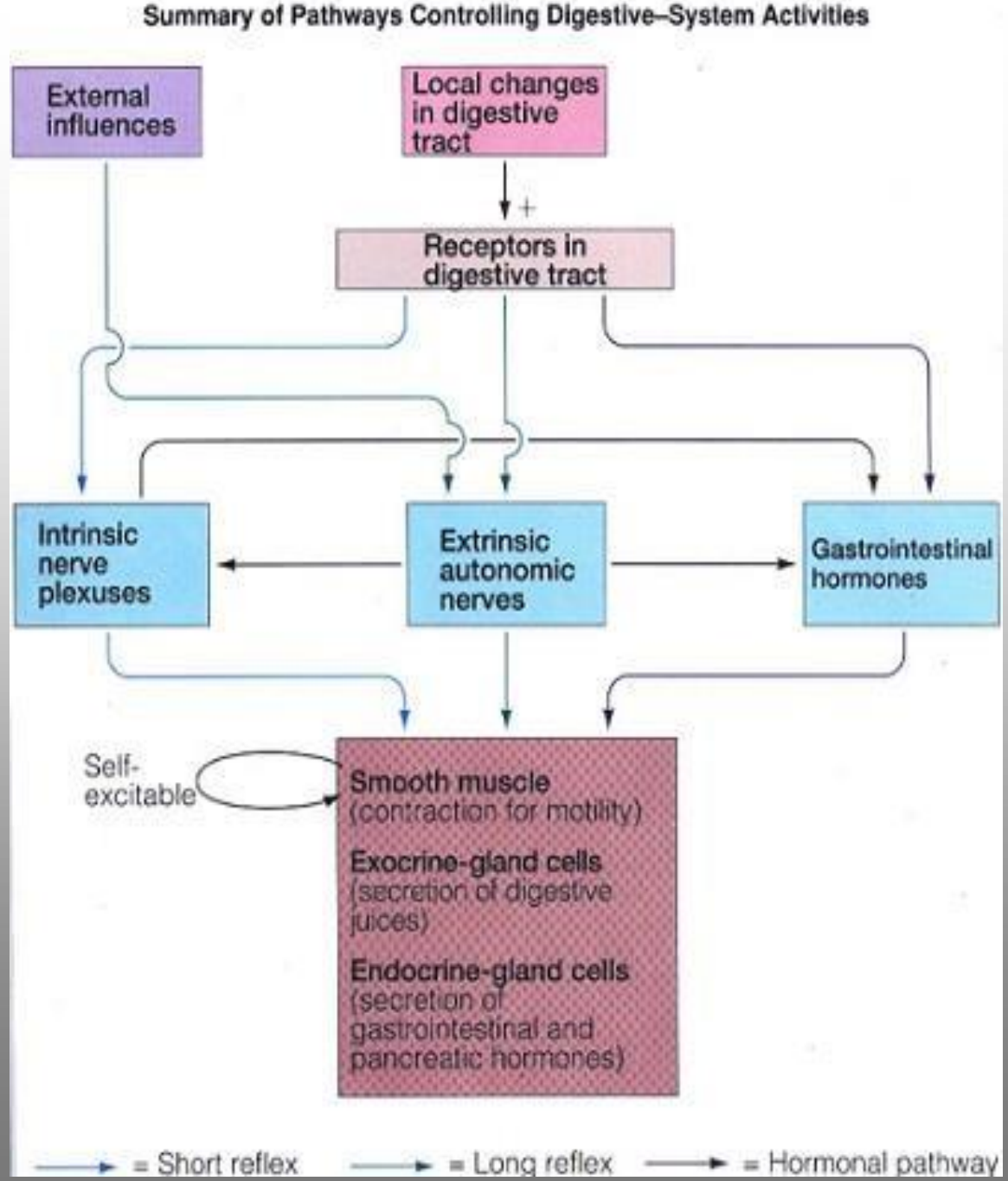
Functions of Hormones

- **Control of motility**
  - Not the main controller, but they have effect
- **Control of secretion**
  - Gastrin / secretin / cholecystokinin
- **Control of blood flow**
  - Vasoconstriction/ vasodilation
- **Regulation of food intake**
  - Ghrelin/ amylin
- **Regulation of metabolic activities in the body**
  - This is exemplified by thyroid hormones, which play a major role in controlling the basal metabolic rate (BMR)

Blood Flow of the GI

- Related to GI activities:
  - -Controlled by:
    - Hormones (Secretin, CCK)
    - ENS (VIP, SP, CGRP)
    - Vasodilators:
      - Kinins (Kallidin, Bradykinin)
    - Decreased O2 concentration

    - ANS
      - (Sympathetic and parasympathetic)


Summary of Pathways Controlling Digestive–System Activities
External influences
Local changes in digestive tract
+
Receptors in digestive tract
Intrinsic nerve plexuses
Extrinsic autonomic nerves
Gastrointestinal hormones
Self-excitable
Smooth muscle (contraction for motility)
Exocrine-gland cells (secretion of digestive juices)
Endocrine-gland cells (secretion of gastrointestinal and pancreatic hormones)
= Short reflex
= Long reflex
= Hormonal pathway

DR.'S HANDOUT

Medical students, Academic year 2023/2024.
****

Gastrointestinal physiology

Textbook of Medical Physiology, by GUYTON and HALL, **Jordan Edition: 797-842, 887-897.** 13th ed: pp: 797-847, 887-907, 12th Ed: pp: 753-803, 843-863.

Objectives: After studying, the student should be able to:

1. Relate anatomical structures of GI tract to their functions.
2. Relate electrical activity and smooth muscle cells responses to their functions in the GI tract.
3. describe motor activities along GI tract, and organ variations of these activities.
4. Describe secretions along GI tract, their function and mechanisms involved in regulation.
5. Describe digestion and absorptive mechanisms and their regulation.
6. Describe dietary balance, regulation of food intake and feeding abnormalities (obesity and starvations) that may accompany dietary balance disorders.
7. Describe energetics in human body and measurements of Basal Metabolic Rates (BMR).

Introduction

Four physiological processes are taking place along the gastrointestinal (GI) tract. These include:

1. Motility.
2. Secretion.
3. Digestion.
4. Absorption.

Related to these processes:

Control systems of GI functions.

- Neural control - Hormonal control

- Blood flow to the GI.

Functional structures in the gastrointestinal tract:

Smooth muscle cells:

2 main layers are generally forming Gastro-intestinal tract with some variations according to organ. These layers are clearly seen in small intestine:

-Longitudinal layer: outer layer of smooth muscle cells
arranged longitudinally along the digestive tract.

-Circular layer: extend circumferentially around the gut.
Located beneath longitudinal layer.

Each layer is forming a bundle like structure. Cells in each bundle are connected together by gap junctions with permit these cells to function as syncytium. Therefore, by this organization, a group of cells is functioning together to an effective contraction along gastro-intestinal tract.

In addition to these two main layers, a third thin layer of smooth muscle cells is also described at the junction between the mucosa and submucosa which is known as ***Muscularis mucosa***. This layer is involved in the secretion from tubular glands and movements of mucosal folds.

Characteristics of smooth muscle cells:

* Electrical activity of smooth muscle:

Smooth muscle cells are characterized by the presence of slow waves (undulating changes in membrane potential known as **basic electrical rhythm (BER)**) and **spike potentials**. The spike potentials are the true action potentials that appear at the peak of slow waves.

*Ca++ in smooth muscle cells contractions: The role of calcium in smooth muscle contraction is known. The source of Ca++ for contraction is either from extracellular fluid or sarcoplasmic reticulum.

The entry of Ca++ from the interstitial fluid appears by activation of Ca++ channels. This activation is generated by **spike potentials** that occur at the peak of slow waves which represents the true action potentials at smooth muscle cells.

The release of Ca++ from sarcoplasmic reticulum
occurs by formation of IP3 that results during signal transduction mechanisms by activation of phospholipase C in response to binding of ligand (hormone or neurotransmitter) to its receptor.

Ca++ acts via calmodulin to activate myosin filaments which results in developing of attractive forces between actin and myosin.

* Chemical control of smooth muscle cells activity:

Smooth muscle cells respond to a wide range of stimuli caused by neurotransmitter or hormones. This activity appears by activation of receptors on smooth muscle cells. These transmitters may induce relaxation or contraction of smooth muscle cells according to the type of transmitter, type of receptor and the transduction mechanism involved in receptor activation.

Finally, integration of responses by smooth muscle cells by binding of ligands to their receptor will result in exhibition of tonic contraction. Variations in the **tonic** contractions by increase or decrease in intensity is seen along gastro-intestinal smooth muscle. In addition to these, also rhythmic contractions have also been described along gastro-intestinal tract (known also as **phasic** or **rhythmic** contractions). In the later type, a group of smooth muscle cells are exhibiting a rhythmical contractions and relaxations as we will see in small intestinal motilities. These contractile activities are controlled mainly by the electrical rhythm that smooth muscle cells of the GI tract are displaying.

Summary of control for GI smooth muscle cells activity:

Smooth muscle cells activity is controlled by

Electrical activity of smooth muscle cells: (slow waves and spike potentials).

Neurochemical control: represented by the response of smooth muscle cells of the GI to a large number of transmitters that are released by many types of neurons in the ENS.

To have an effective activity by smooth muscle cells of the GI tract, cells are functioning in syncytium (the activity is very well synchronized by organized contraction and relaxation at the segmental level which promote an efficient motility of the GI tract). The synchronization in part is provided by the ENS. In addition to these, the cells of Cajal play also an important role in the synchronization of this activity.

Interstitial Cells of Cajal (ICCs):

Interstitial cells are widely spread all over the gastrointestinal tract. These cells have certain characteristics. They have large number of processes. Also, these cells communicate through these processes by gap junction with other ICCs as well as smooth muscle. In addition, these cells eliciting by themselves electrical activity as action potentials. All these have supported the theory of considering these cells as pacemaker cells of the gastro-intestinal tract.

Characteristics of ICCs:

*** ICCs communications:**

The ICCs-ICCs and ICCs-smooth muscle cells communication (by a gap junction) provide the basis for the synchronization of the electrical activity of smooth muscle cells as a group and consequently the harmony of contractile responses of smooth muscle cells. This will result in the functional syncytium of gastro-intestinal smooth muscle cells.

***ICCs generate slow wave:**

ICCs are excitable cells and elicit an electrical activity. These electrical activities have a sudden and periodical appearance of an upstroke from a constant resting potential of about –70mV. The initiation of these activities is believed to be metabolic dependent.

The appearance of the upstroke is believed to cause the slow waves in smooth muscle cells that are in junction with ICCs or to regulate the rhythm of slow waves in smooth muscle cells.

***ICCs also receive inputs from the ENS:**

In addition to their communication with smooth muscle cells, ICCs also receive inputs from the ENS. These inputs may give these cells an important role in mediating the activity to smooth muscle cells which promote a regulatory role of smooth muscle cells activity.

Secretory cells:

These are represented as solitary cells that line the digestive tube or grouped in functional structures (known as glands). These cells are specialized in synthesis and secretion of organic substances that function as enzymes, hormones, factors or mucus. Some of these structures are secreting only water and electrolytes (this type is known as serous secretions). More details about secretory cells, their functions and regulation will be given with gastro-intestinal secretion.

Enteric nervous system: (ENS)

Beginning from the esophagus and extending along the entire GI tract, there is a neural network known as **Enteric Nervous System**. Neurons in this system are grouped into two main plexuses. One is located between longitudinal and circular smooth muscle layers known as *myenteric plexus* or *Auerbach's plexus*. The second plexus lies in submucosa and known as *submucosal* or *Meissner's plexus*. Neurons within each plexus are connected by nerve fibers that are projecting orally, caudally and circumferentially. Some neural fibers connect neurons from the two plexuses together.

Neurons from myenteric plexus usually control the activity smooth muscle cells from longitudinal and circular layer, and consequently, gastrointestinal movements. Submucosal plexus usually controls gastrointestinal secretion and local blood flow. Some neurons are considered sensory neurons that transmit signals from gastrointestinal epithelium to both enteric plexuses, prevertebral ganglia of sympathetic, spinal cord, and to brain stems through vagus nerve. These fibers are stimulated by excessive distension of the gut, irritation of the mucosa, or by specific chemical substances in the lumen.

Enteric neurons that control gastrointestinal functions contain transmitters that could have inhibitory or excitatory effects on motility, secretion, or vascular blood flow. Many types of transmitters have been identified in ENS, such as, Ach, SP (substance P), VIP (vasoactive intestinal peptide), CGRP (Calcitonin Gene Related Peptide), GRP (Gastrin Releasing Peptide), and many others.

Autonomic nervous system..

Parasympathetic nervous system:

According to the location of neural cell bodies, it is divided into:

-Cranial division:

Provide innervations through vagus nerve to esophagus, stomach, pancreas, small intestine and first half of large intestine.

-Sacral division:

Provide innervation through pelvic nerves to the distal half of the colon, sigmoidal, rectum and anal region. Fibers in this division have importance in executing defecation reflex.

Generally, stimulation of parasympathetic system causes an increase in the activity of enteric nervous system and consequently, enhances the activity of the gastrointestinal functions. These include motility, secretion and blood flow.

Sympathetic nervous system:

Sympathetic fibers that innervate gastro-intestinal tract originate in the spinal cord (segments T5-L2). These fibers pass through paravertebral ganglia and synapse with the second neuron in celiac, superior mesenteric or inferior mesenteric ganglia.

Generally, stimulation of sympathetic system causes a decrease in the activity of enteric nervous system and GI smooth muscle cells.

Made with tears… click the sweater, face your fears

رسالة من الفريق العلمي:

﴿قُلْ يَا عِبَادِيَ الَّذِينَ أَسْرَفُوا عَلَىٰ أَنفُسِهِمْ
لَا تَقْنَطُوا مِن رَّحْمَةِ اللَّهِ ۚ إِنَّ اللَّهَ يَغْفِرُ
الذُّنُوبَ جَمِيعًا ۚ إِنَّهُ هُوَ الْغَفُورُ الرَّحِيمُ﴾

الزمر:٥٦

For any feedback, scan the code or click on it.

Corrections from previous versions:

Versions	Slide # and Place of Error	Before Correction	After Correction
V0 → V1	Slide 4;	-	-
V1 → V2			