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GENERAL PRINCIPLES OF GASTROINTESTINAL FUNCTION

MED 433 Teams

GIT

Objectives

- Physiologic Anatomy of the Gastrointestinal Wall
- The General Characteristics of Smooth Muscle and its Function
- 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 Gastrointestinal Tract
- Gastrointestinal Blood Flow-"Splanchnic Circulation"
- Effect of Gut Activity and Metabolic Factors on Gastrointestinal Blood Flow

Abbreviations

ENS = Enteric nervous system
VIP = vasoactive intestinal peptide
NO = Nitric Oxide

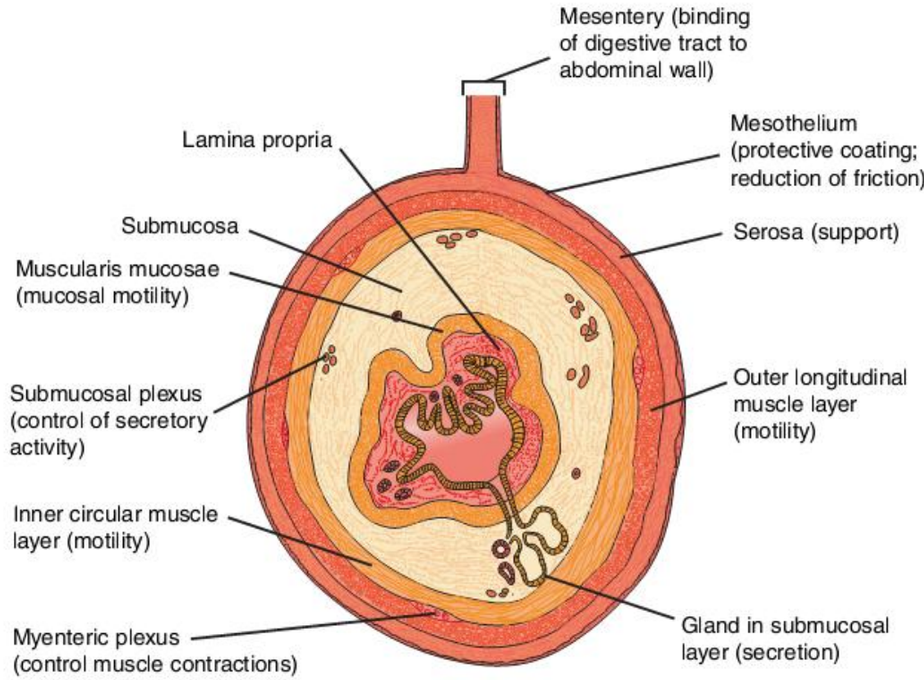
The alimentary tract

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

1. **movement of food through the alimentary tract.**
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.**
5. **control of all these functions by local, nervous, and hormonal systems.**

Physiologic Anatomy of the Gastrointestinal Wall

The following layers structure the GI wall from outer surface inward:
(1) the serosa (or adventitia).
(2) a longitudinal muscle layer.
(3) a circular muscle layer.
(4) the submucosa.
(5) the mucosa.
In addition, sparse bundles of smooth muscle fibers, **the mucosal muscle, lie in the deeper layers of the mucosa.**



Type of Contractions	
Phasic contractions (rhythmical)	**periodic contractions followed by relaxation.** such as: in gastric antrum, small intestine and esophagus .
Tonic Contraction	**maintained contraction without relaxation.** such as: in Orad region of the stomach, lower esoghageal, ileocecal and internal anal sphincters.

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.**

Tonic contraction is sometimes caused by:

1-continuous repetitive spike potentials.

2. hormones.

3. continuous entry of calcium ions into the interior of the cell brought about in ways not associated with changes in membrane potential **(Not via voltage-gated Ca channels).**

Type of smooth muscle based on type of stimulus	
Unitary type (such as in stomach and intestine)	**1- Contracts** in the absence of: **neural or hormonal influence** **2- Contracts** in response to: **response to stretch** **Cells are electrically coupled via gap junctions**
Multiunit type (such as in esophagus & gall bladder)	**1- Contract** in response to: **neural input** **2- Does not contract** in response to: **Stretch**

Type of smooth muscle based on direction and shape	
Longitudinal Smooth Muscles	• Contraction of this type will lead to: **1- shortens the segment of the intestine 2-expands the lumen.** • **They are innervated by ENS and mainly by excitatory motor neurons.** • The Ca **influx from out side is** important in the activity of this type of muscle.
Circular Smooth Muscles	• Contraction of this type will lead to: **1- reduces the diameter of the lumen 2- increases its length.** • **They are innervated by ENS, both excitatory and inhibitory motor neurons.** • **Intracellular release of Ca** is more important. • More gap junctions are available than in longitudinal muscle. • They are thicker and more powerful than longitudinal.

The Specific Characteristics of Smooth Muscle in the Gut

Gastrointestinal Smooth Muscle Functions as a Syncytium

- The individual smooth muscle fibers are 200 to 500 µm in length and 2 to 10 µm in diameter, and they are arranged in bundles of as many as 1000 parallel fibers.
- Within each bundle, the muscle fibers are electrically connected with one another through large numbers of gap junctions.
- Each bundle of smooth muscle fibers is partly separated from the next by loose connective tissue but they fuse with one another at many points, so each muscle layer represents a branching latticework of smooth muscle bundles.
- Therefore, each muscle layer functions as a syncytium; that is, when an action potential is elicited anywhere within the muscle mass, it generally travels in all directions in the muscle.

Electrical Activity of Gastrointestinal Smooth Muscle

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

This activity has two basic types of electrical waves:
(a) slow waves and (b) spikes

Factors that depolarize the membrane- that make it more excitable	(1) stretching of the muscle. (2) stimulation by acetylcholine (3) stimulation by parasympathetic nerves that secrete acetylcholine at their endings. (4) stimulation by several specific gastrointestinal hormones.
Factors that hyperpolarize the membrane and make it less excitable	(1) the effect of norepinephrine or epinephrine on the fiber membrane and (2) stimulation of the sympathetic nerves that secrete mainly norepinephrine at their endings.

Types of waves

Slow waves

1- not action potentials
2- caused by entering of Sodium only
3- intensity usually varies between 5 and 15 mV(1)*
4- may originate in the interstitial cells of Cajal (the GI pacemaker)(2)*

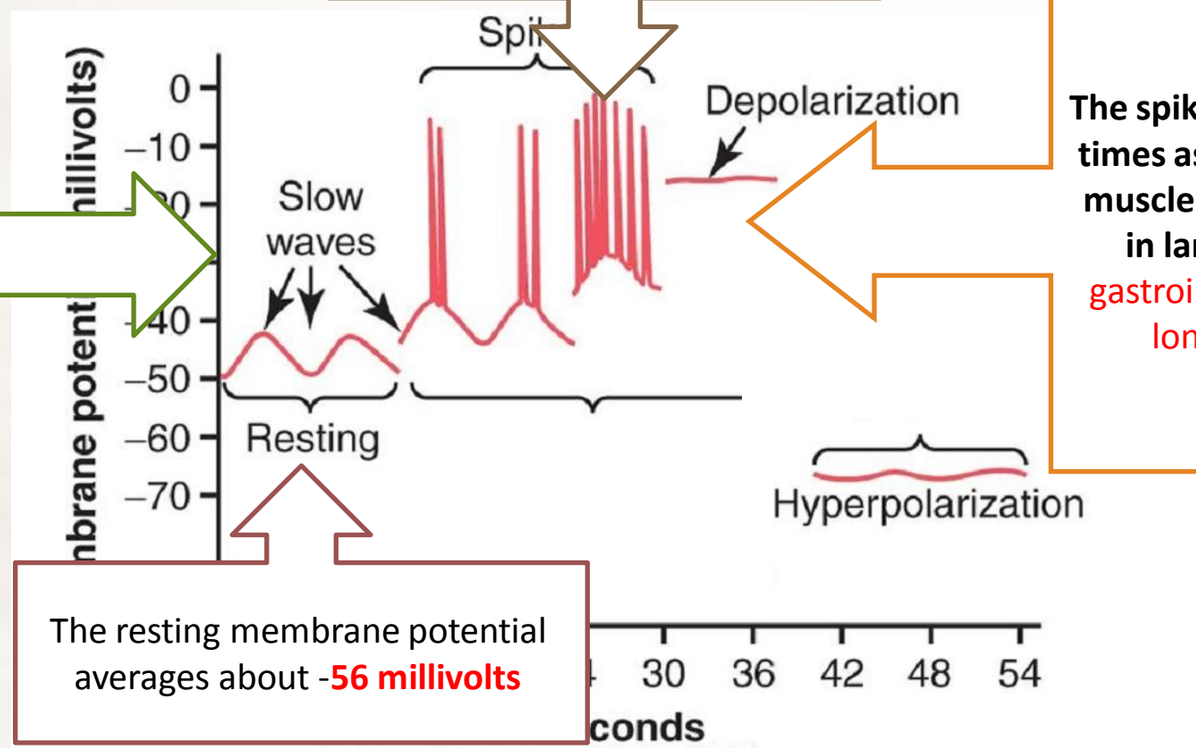
Spikes

1- True action potential
2- when the resting membrane potential of the gut smooth muscle becomes more positive (<-40 mV)
3- caused by calcium-sodium channels.

(1) about 3 in the body of the stomach, as much as 12 in the duodenum, and about 8 or 9 in the terminal ileum
(2) are abundant in the myenteric plexues.

The higher the slow wave potential rises, the greater the frequency of the spike potentials, usually ranging between 1 and 10 spikes per second.

Slow waves: oscillating depolarization and repolarization in the resting membrane potential



The resting membrane potential averages about -**56 millivolts**

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

Neural Control of Gastrointestinal Function- Enteric Nervous System

Enteric Nervous System is **the nervous system of GI tract.**

- It lies entirely in the wall of the gut
- beginning in the esophagus and extending all the way to the anus.
- It has as many neurons as spinal cord (about 100 million).

The enteric nervous system is composed mainly of two plexuses:

(1) an outer plexus lying between the longitudinal and circular muscle layers, called the *myenteric or Auerbach's plexus*

controls mainly the gastrointestinal movements by:

A. increased tonic contraction.
B. increased intensity of the rhythmical contractions.
C. increased rate of the rhythm of contraction.
D. increased velocity of conduction of excitatory waves along the gut wall.

(2) an inner plexus, called the *submucosal plexus* or *Meissner's plexus*, that lies in the submucosa;

controls mainly gastrointestinal secretion and local blood flow by:

A. local intestinal secretion.
B. local absorption.
C. local contraction of the submucosal muscle.

Types of Neurotransmitters Secreted by Enteric Neurons

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

I. 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. **VIP.**
3. **Histamine (neurogenic secretory diarrhea).**

II. Inhibitory Motor Neurons Suppress Muscle Contraction:

1. **ATP.**
2. **NO.**
3. **VIP.**

Autonomic Control of the Gastrointestinal Tract

Parasympathetic Innervation

(Cranial and sacral divisions)

- **The cranial parasympathetic nerve fibers are almost entirely in the vagus nerves.**

1. **Vagus nerve supply: The esophagus, stomach, pancreas and the intestines down through the first half of the large intestine**
2. **Sacral part supply: The distal half of the large intestine and the anus (to execute the defecation reflexes).**

Sympathetic Innervation

- **The sympathetic fibers originate from T-5 and L-2.**
- **The sympathetic nerve endings secrete mainly norepinephrine.**

A. **Stimulation of the sympathetic nervous system inhibits activity of the GI.**
B. **Strong stimulation of the sympathetic system can inhibit motor movements of and block movement of food.**

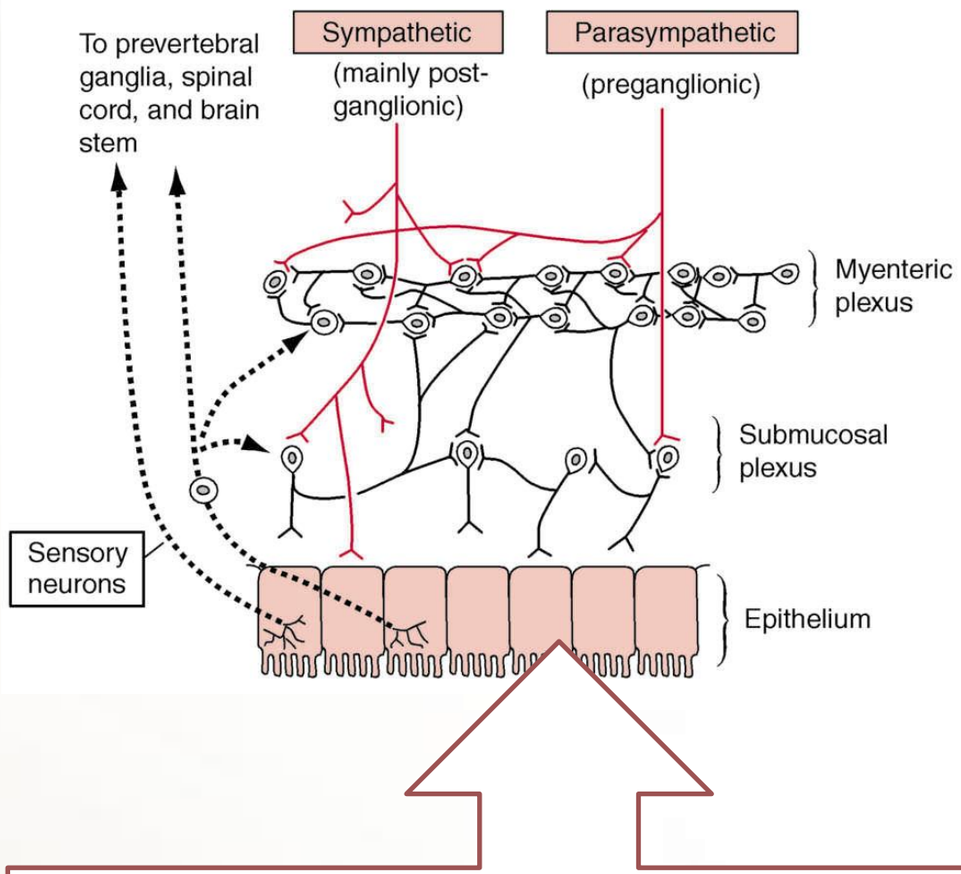
Afferent Sensory Nerve Fibers from the Gut

These sensory nerves can be stimulated by:

(1) irritation of the gut mucosa
(2) excessive distention of the gut
(3) presence of specific chemical substances in the gut.

Signals transmitted through the fibers can then cause excitation or inhibition of intestinal movements or intestinal secretion.

The postganglionic neurons of the gastrointestinal parasympathetic system are located mainly in **the myenteric and submucosal plexuses**. Stimulation of these parasympathetic nerves causes **general increase in activity of the entire enteric nervous system**.



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 (80%)** all the way to the brain stem. These sensory nerves can elicit local **Vagovagal reflexes within the gut wall**

Gastrointestinal Reflexes

Reflexes that are integrated entirely within the gut wall enteric nervous system. (local reflexes)	Reflexes from the gut to the prevertebral sympathetic ganglia and then back to the gastrointestinal tract.	Reflexes from the gut to the spinal cord or brain stem and then back to the gastrointestinal tract (Vagovagal reflexes)
_____	These reflexes transmit signals long distances to other areas of the gastrointestinal tract 1- The gastrocolic reflex: signals from the stomach to the colon 2- The enterogastric reflexes: signals from the colon and small intestine to inhibit stomach motility and stomach secretion 3- The colonoileal reflex: reflexes from the colon to inhibit emptying of ileal contents into the colon	(1) reflexes from the stomach and duodenum to the brain stem and back to the stomach—by way of the vagus nerves—to control gastric motor and secretory activity. (2) pain reflexes that cause general inhibition of the entire gastrointestinal tract (3) defecation reflexes that travel from the colon and rectum to the spinal cord and back again to produce the powerful colonic, rectal, and abdominal contractions required for defecation.

Functional Types of Movements in the Gastrointestinal Tract

- **Two types of movements occur in the GI tract:**

***(1) Propulsive Movements* – Peristalsis:**

- **Stimulus:**

1- distention "More common"
2- chemical
3- physical irritation of the epithelial lining in the gut.

- **Myenteric plexus is important (if absence there is no peristalsis)**
- **Atropine (cholinergic blocker) depresses propulsion**

❖ **Receiving segment---contraction (longitudinal M.)**
---relaxation (circular M.)
❖ **Propulsive segment ---contraction (circular M.)**
----relaxation (longitudinal M.)

(2) Mixing movements (segmentation)

- Blend different juices with the chyme

- Bring products of digestion in contact with absorptive surfaces

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

Gastrointestinal Blood Flow- "Splanchnic Circulation"

- Splanchnic circulation includes: the blood flow through the gut itself + blood flows through the spleen, pancreas, and liver.
- The design of this system is such that all the blood that courses through the gut:

1- spleen, and pancreas then flows immediately into the liver by way of the *portal vein*.

2- In the liver, the blood passes through millions of minute *liver sinusoids* and finally leaves the liver by way of *hepatic veins*

3-empty into the vena cava of the general circulation.

Effect of Gut Activity and Metabolic Factors on Gastrointestinal Blood Flow

- Possible Causes of the Increased Blood Flow During Gastrointestinal Activity are:

1- Most of the peptide hormones, including cholecystokinin, vasoactive intestinal peptide, gastrin, and secretin.

2- Some of the GI glands release into the gut wall two kinins, kallidin and bradykinin

3- Decreased oxygen concentration in the gut wall can increase intestinal blood flow at least 50 to 100 per cent.

Nervous Control of Gastrointestinal Blood Flow

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

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GOOD LUCK