Organization and General Principles of Gastrointestinal Physiology

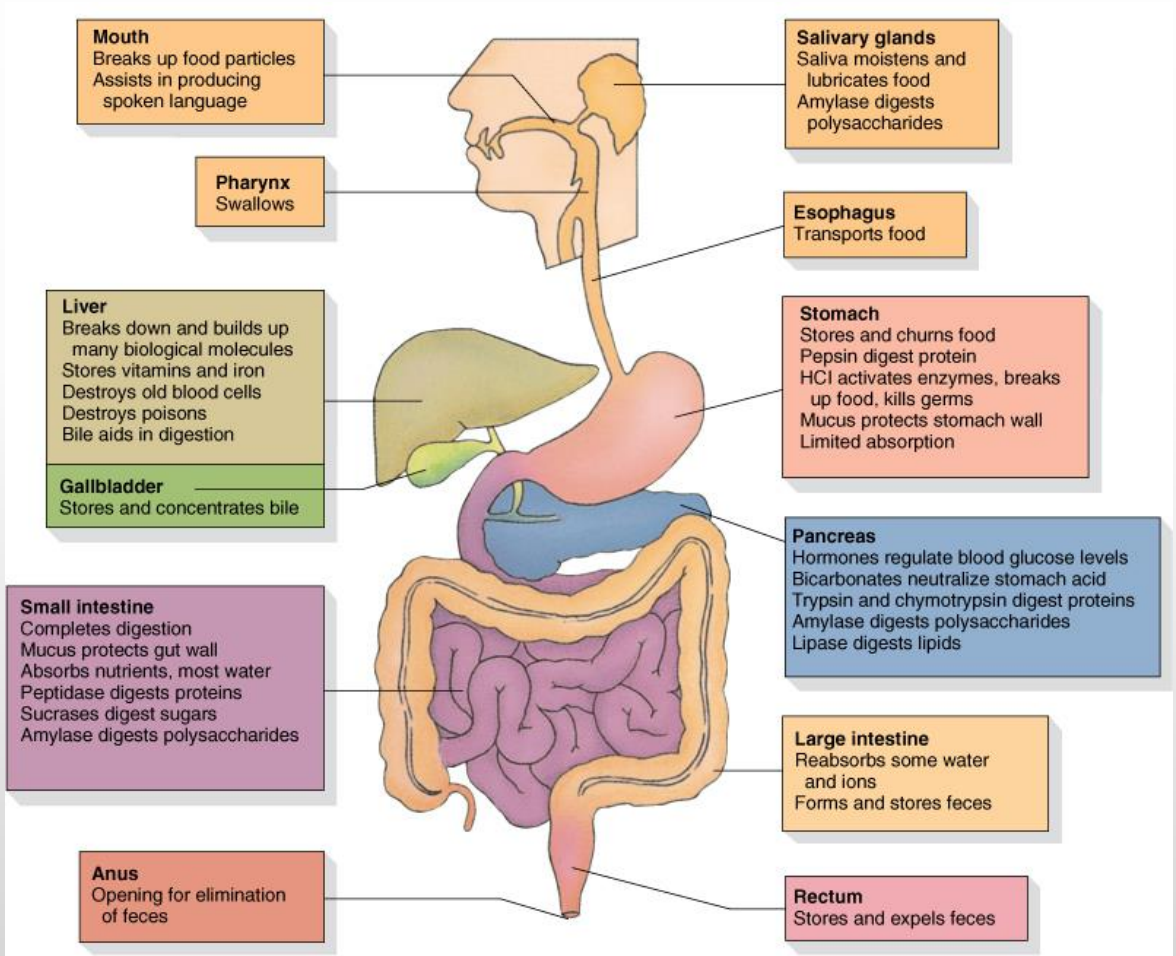
Dr. Hana Alzamil

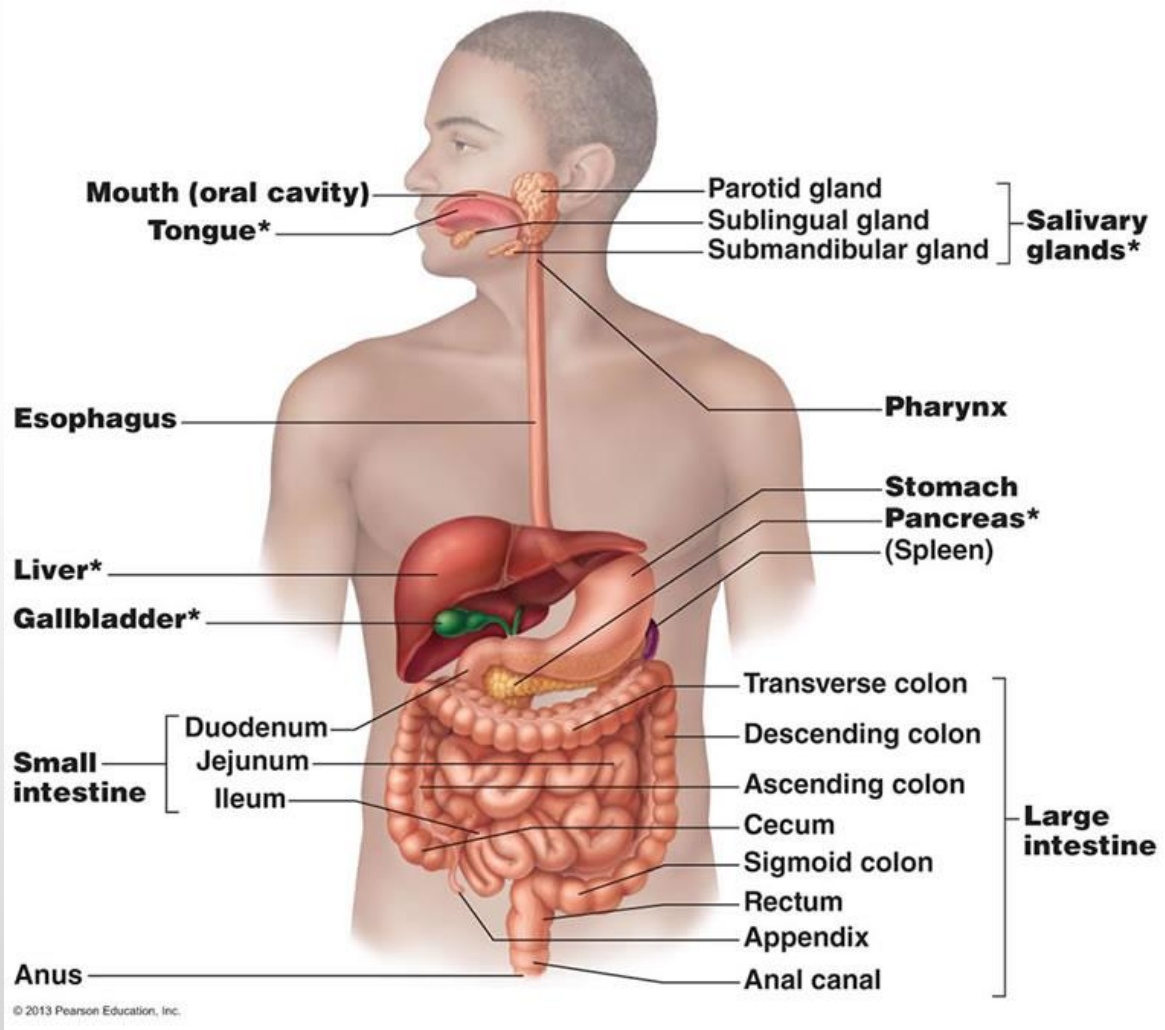
Objectives

- Physiologic anatomy of gastrointestinal wall
- The general characteristics of smooth muscle
- The specific characteristics of smooth muscle
- Control of gastrointestinal function (ENS)
- Functional types of movements in the gastrointestinal tract
- Gastrointestinal blood flow (Splanchnic circulation)
- Effects of gut activity and metabolic factors on GI blood flow

Group activity
Brain storming
What are the GIT parts?

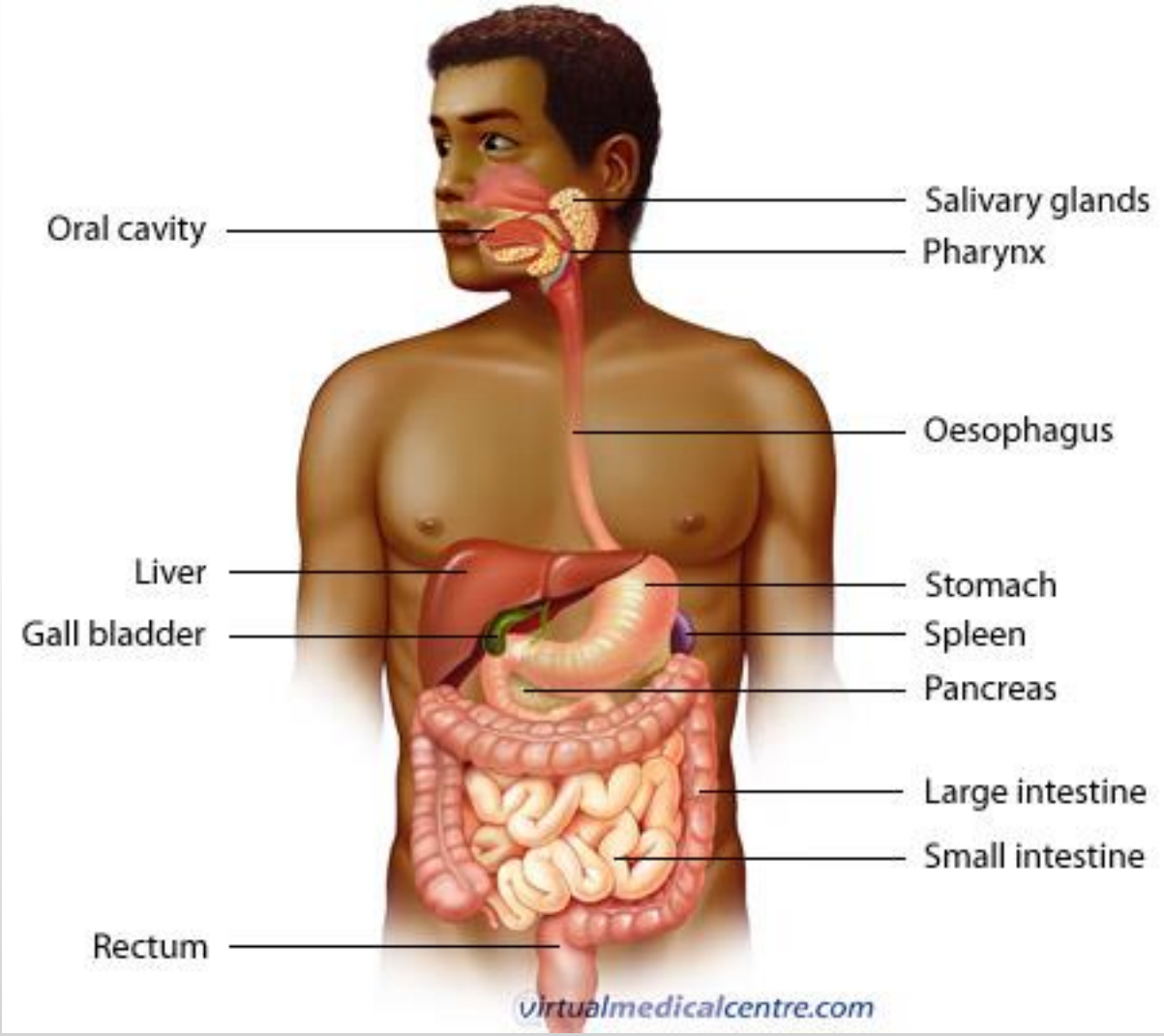
Gastrointestinal Tract





Parts and functions of gastrointestinal tract (GIT)

- GIT provides the body with continuous supply of water, electrolytes, vitamins and nutrients
- To achieve its function:
  - Movement of food
  - Secretion of digestive juice
  - Digestion
  - Absorption
  - Circulation of blood
  - Control of all these functions



- https://youtu.be/yzQAgfivX74

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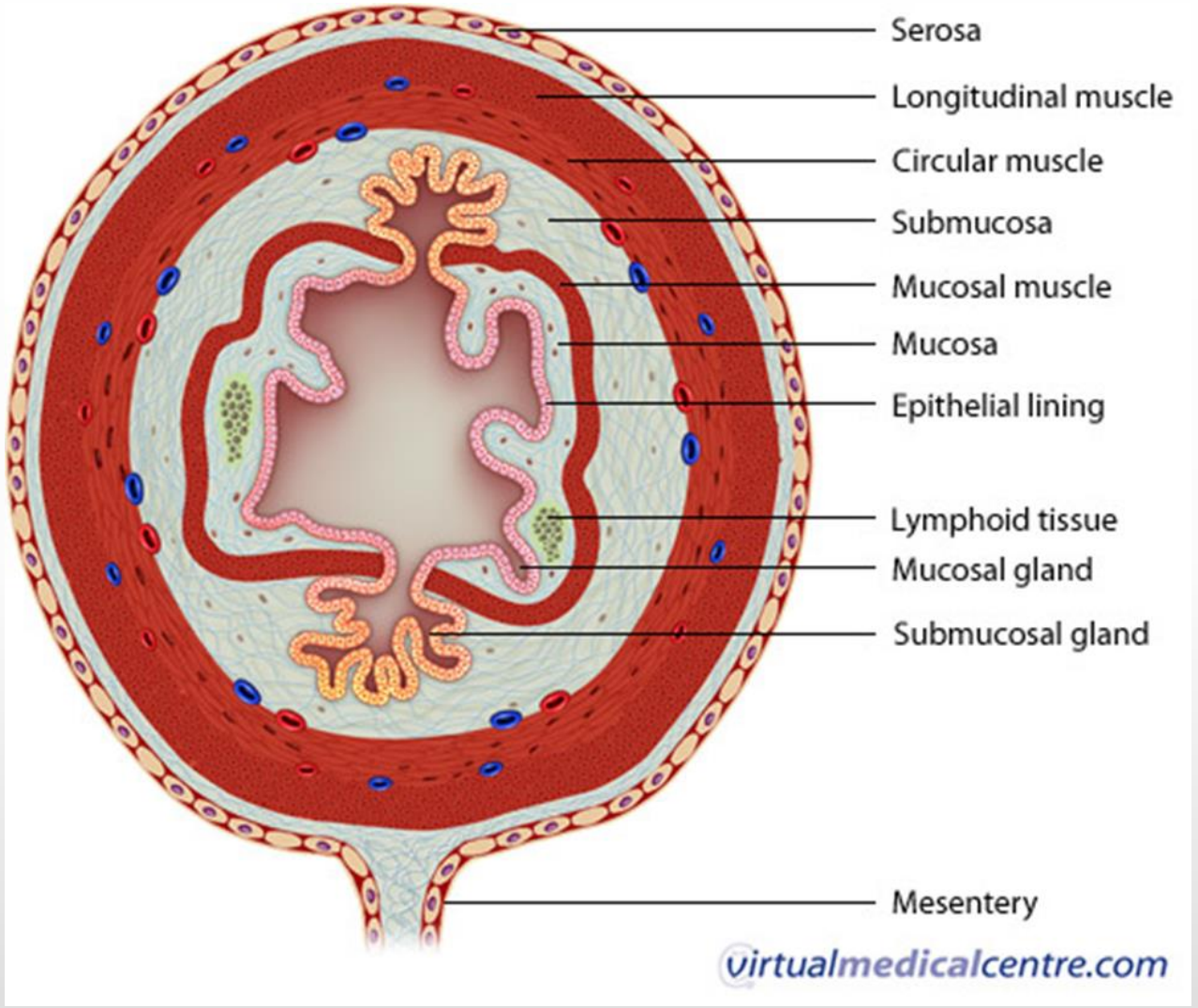
- **Mucosa** is the innermost, moist, epithelial membrane that lines the entire digestive tract.
  - (1) It secretes mucus, digestive enzymes, and hormones;
  - (2) absorbs digestive end products into the blood; and
  - (3) protects against infectious disease.
  - Consists of a lining epithelium, a lamina propria, and a Muscularis mucosa.
  - Epithelium - simple columnar epithelium and goblet cells
  - Lamina propria - areola C.T. with capillaries and lymphoid follicles
  - Muscularis mucosa - thin layer, produces local movements of t mucosa
- **Sub mucosa** is a moderately dense connective tissue layer containing blood and lymphatic vessels, lymphoid follicles, and nerve fibers.
- **Muscularis externa** typically consists of smooth muscle and is responsible for peristalsis and segmentation.
  - Contains the my enteric plexus of Auerbach, the other major intrinsic nerve plexus. Located between the two layers of smooth muscle, controls motility of the G.I. tract.
- **Serosa**, the protective outer layer of the intraperitoneal organs, is the visceral peritoneum



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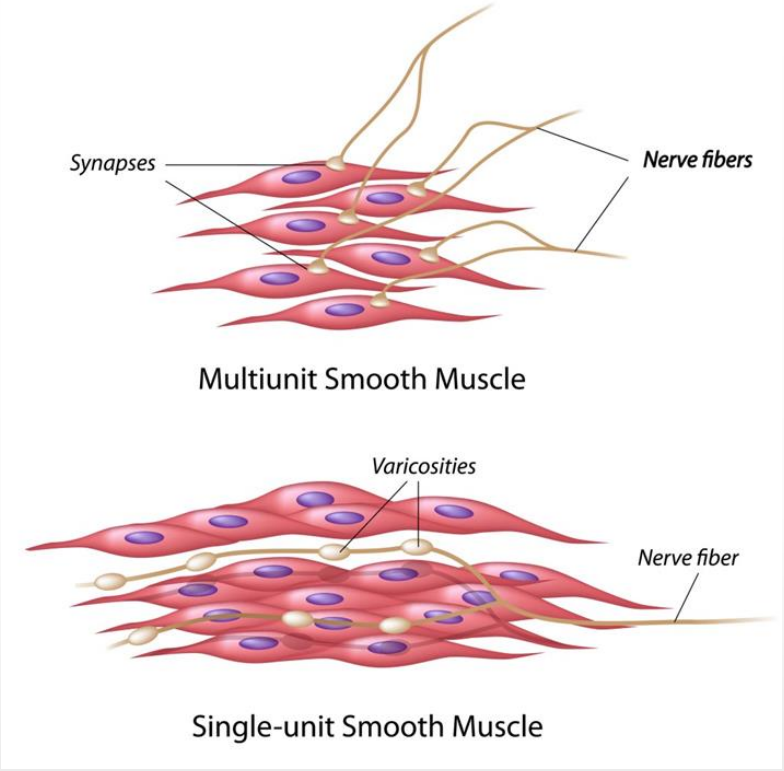
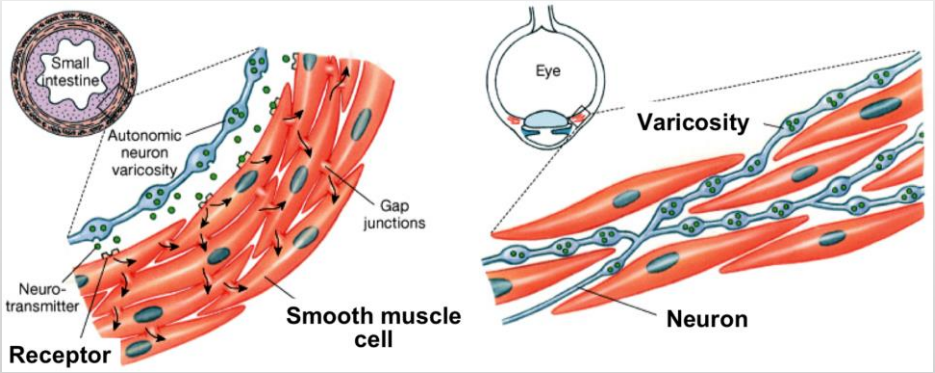
The general characteristics of smooth muscle

- Types of smooth muscle
  - Multi-unit.
  - Single-unit (unitary).
- Multi-unit
  - Each fiber can contract independently
  - Controlled mainly by nerve signals
  - Examples: ciliary & iris muscles in the eye and piloerector muscles of the hair
- Unitary (syncytial or visceral smooth muscle)
  - Mass of 100-1000 smooth muscle fibers
  - Contract as a single unit
  - Arranged in sheets or bundles
  - Cell membranes are adherent at multiple points
  - Many gap junctions that allow ion movements
  - When action potential is generated it travel in all directions
  - Examples: GIT, bile ducts, ureters, uterus, blood vessels.

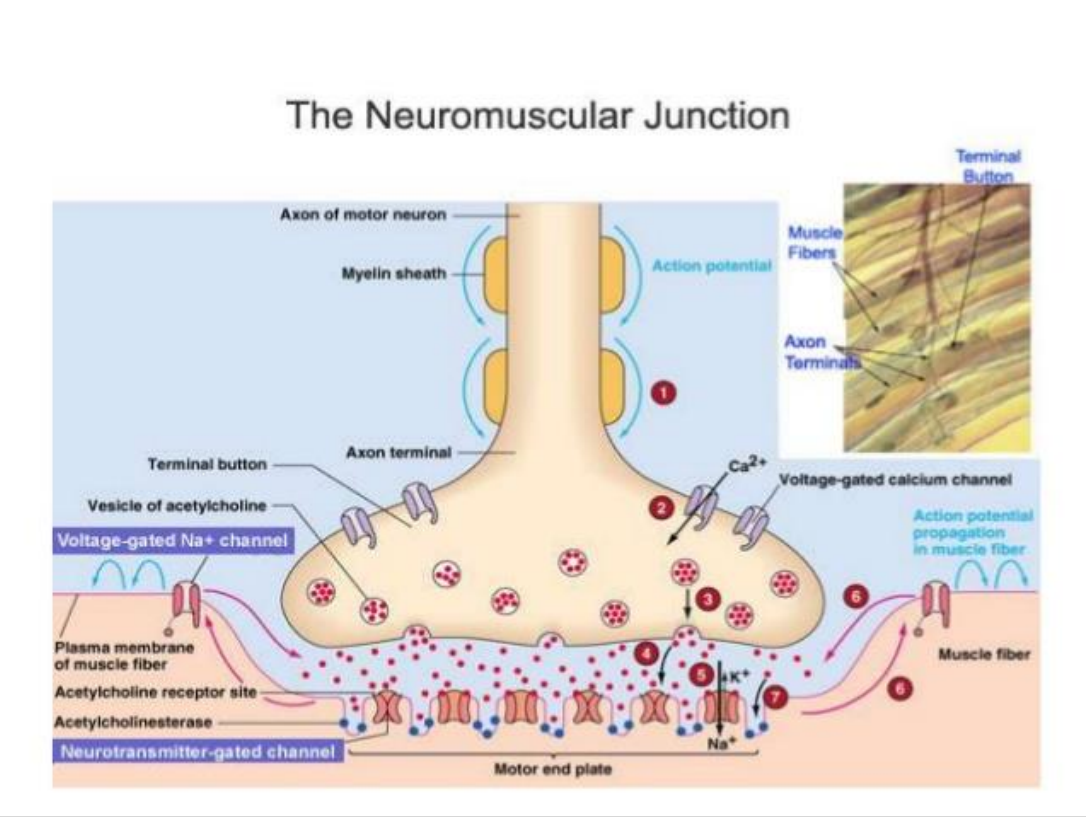




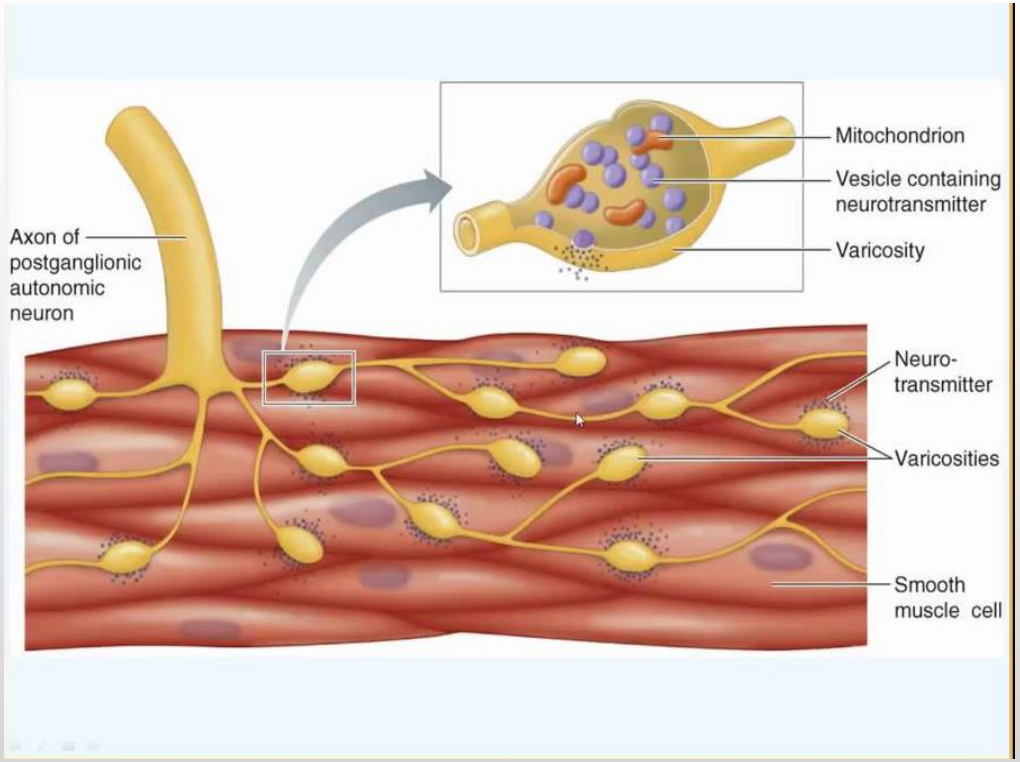
Difference between skeletal and smooth muscles

Nervous control

Neuromuscular junctions



Smooth muscle



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The specific characteristics of smooth muscle

- Smooth muscle does not have the same striated arrangement as is found in skeletal muscle.
- There are large numbers of actin filaments attached to so-called **dense bodies.**
- Some of these bodies are attached to the cell membrane.
- Others are dispersed inside the cell.
- Some of the dense bodies of adjacent cells are bonded together by intercellular protein bridges. through these bonds that the force of contraction is transmitted from one cell to the next.

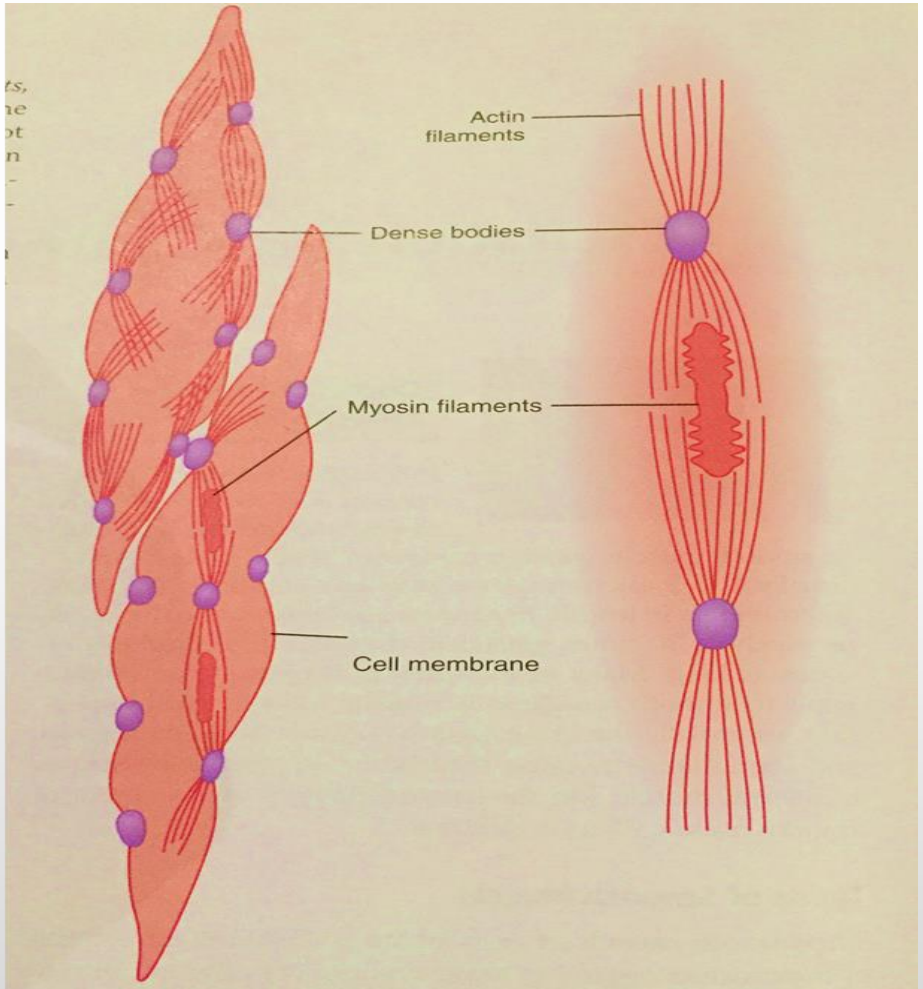
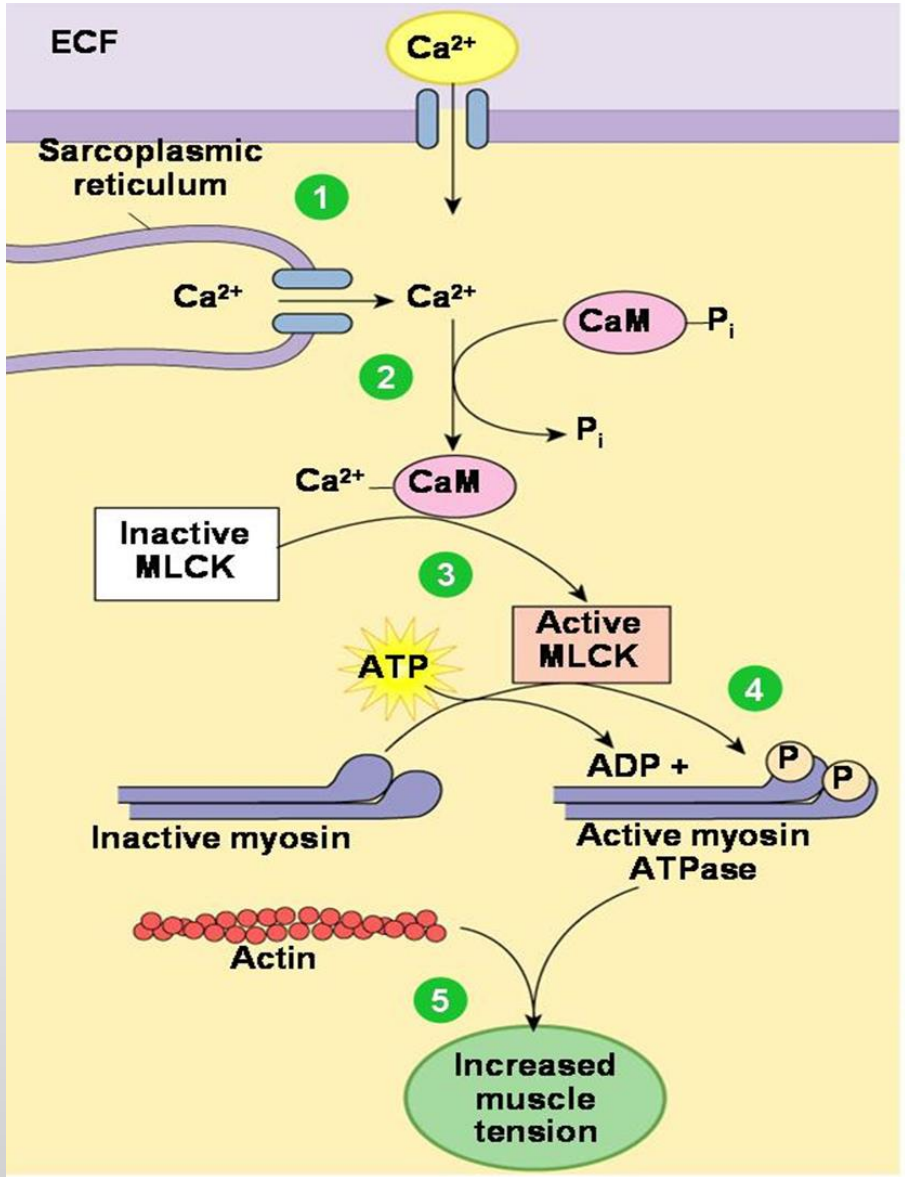


Figure 8-2 Physical structure of smooth muscle. The upper left-hand fiber shows actin filaments radiating from dense bodies. The lower left-hand fiber and the right-hand diagram demonstrate the relation of myosin filaments to actin filaments.

The specific characteristics of smooth muscle

- Slow cycling of the myosin cross-bridges
- Low energy requirement
- Slowness of onset of contraction and relaxation
- Greater max. force of contraction
- Latch mechanism
- Stress-Relaxation
- Revers stress-relaxation

Mechanism of smooth muscle contraction



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. Active myosin crossbridges slide along actin and create muscle tension.

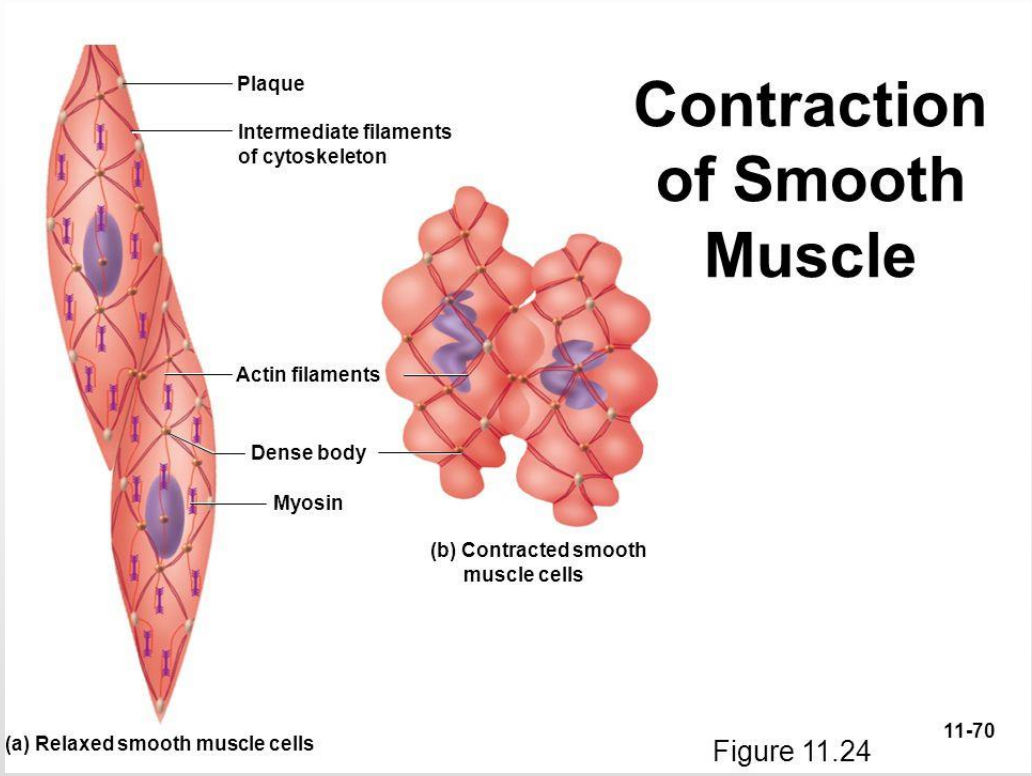
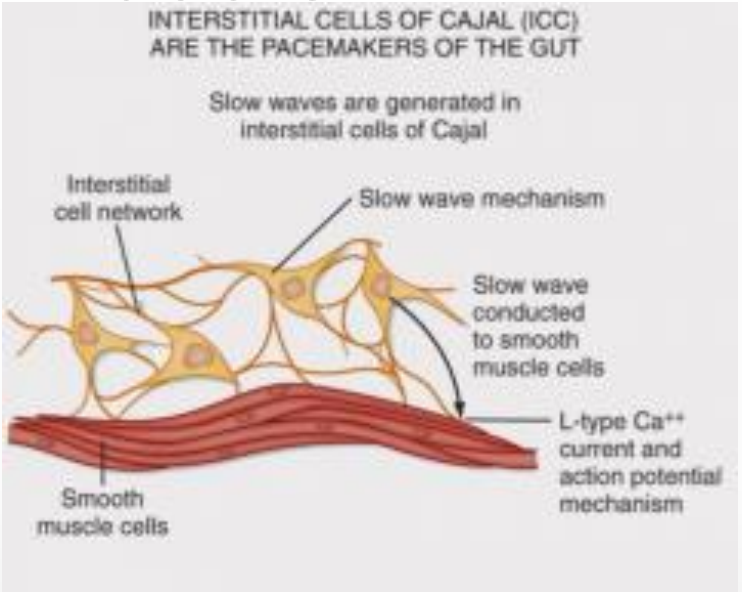


Figure 11.24

Electrical activity of GI smooth muscle

- There is continuous slow intrinsic electrical activity
- Two basic types of electrical waves:
  - Slow waves
  - Spikes
- Most GI contractions occur rhythmically
- Rhythm is determined by the frequency of slow waves

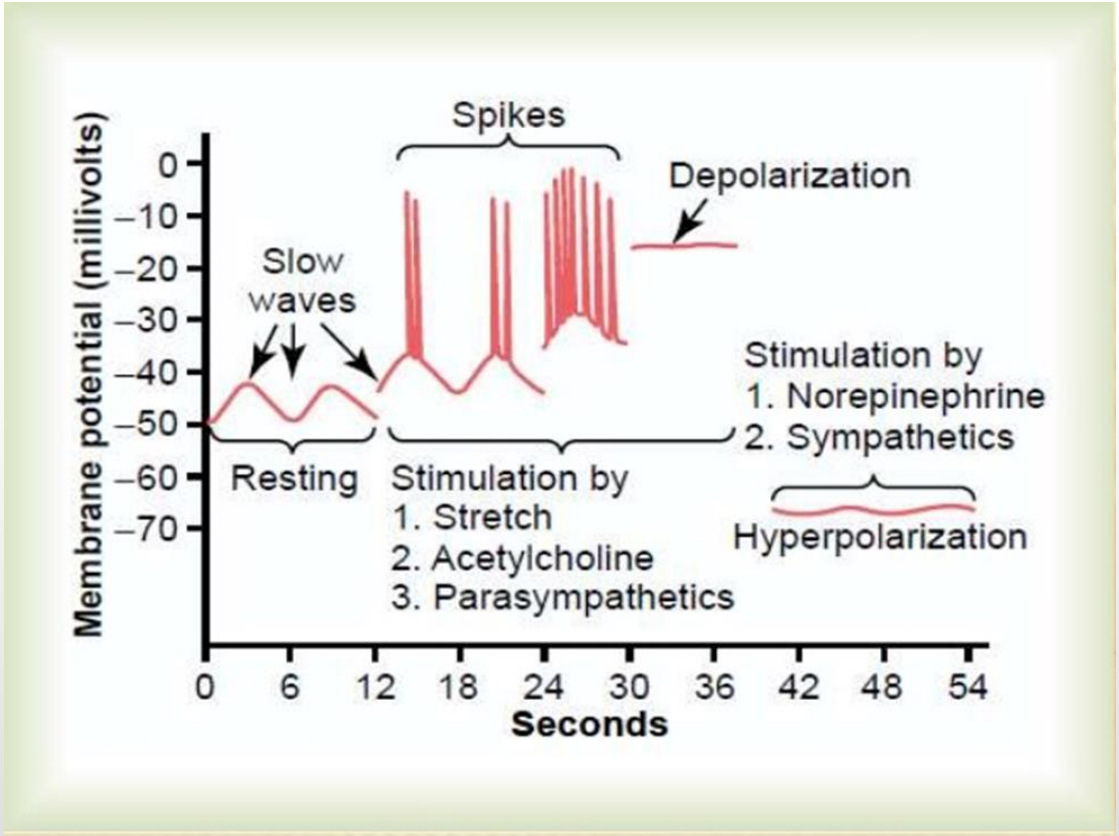
Electrical activity of GI smooth muscle

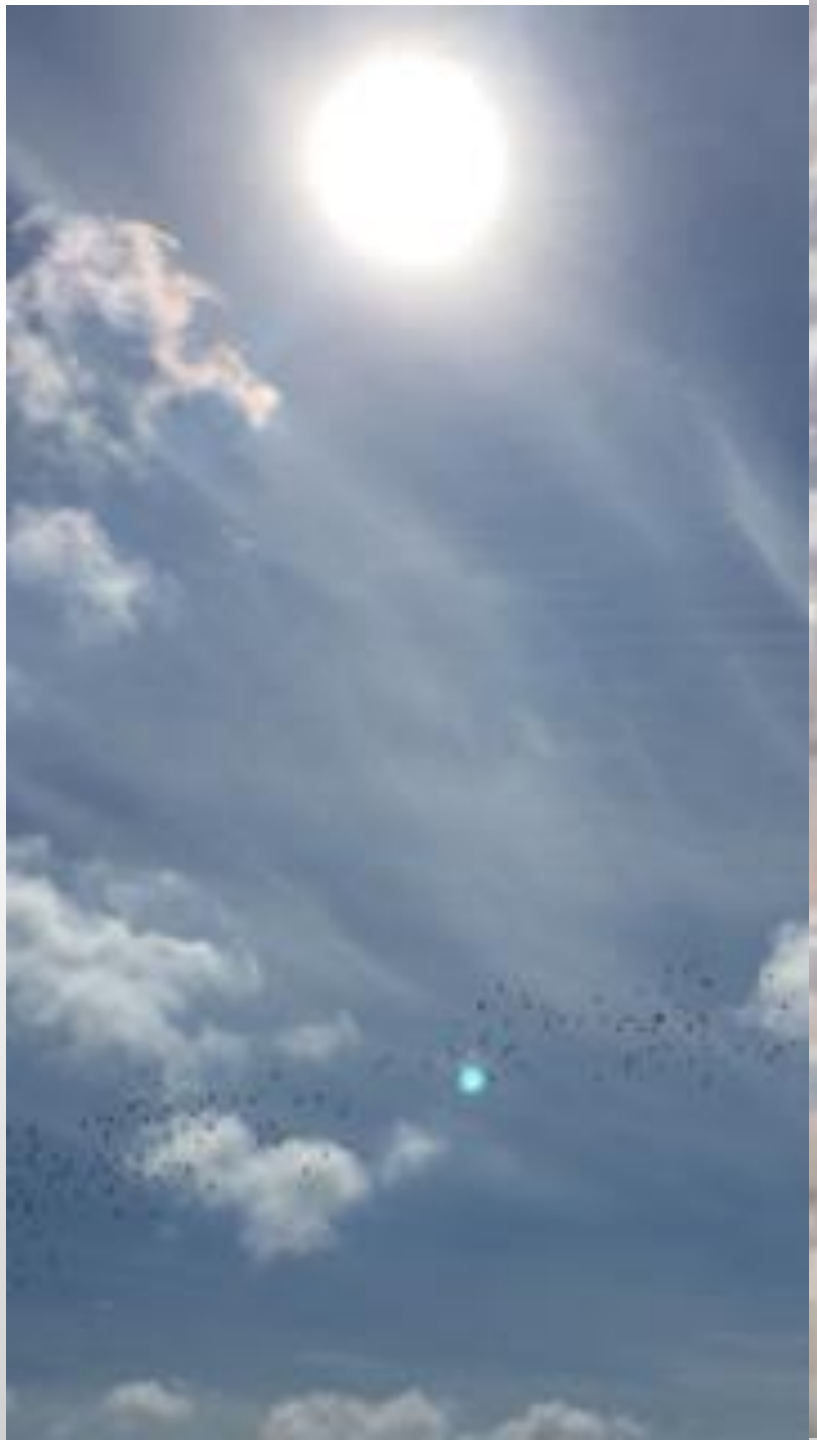


- Slow waves:
  - Are changes in resting membrane potential
  - **Are not** action potentials
  - Their intensity 5-15 mv
  - Frequency: 3-12 /min
    - Stomach 3, duodenum 12 and ileum 8-9/min
  - Caused by interaction between smooth muscle cells & interstitial cells of Cajal
  - **Do not** by themselves cause muscle contractions
  - **Do not** cause calcium ions to enter (only sodium ions)
  - Mainly excite the appearance of intermittent spike potentials

Electrical activity of GI smooth muscle

- Spike potential:
  - Are **true** action potentials
  - Occurs when resting membrane potential become more positive than -40 (normal range -50mv to -60mv) appear on the peaks
  - The higher the slow wave potential the greater the frequency(1-10spikes/sec)
  - Channels responsible for action potential are calcium-sodium channels
    - These channels are much slower to open and close
    - They allow large number of Calcium ions to enter + smaller number of sodium ions
  - They cause muscle contractions





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Control of gastrointestinal function

- Nervous control
  - Enteric nervous system (ENS)
  - Autonomic nervous system
- Hormonal control
- Stretch of the muscle

Pair and share activity:

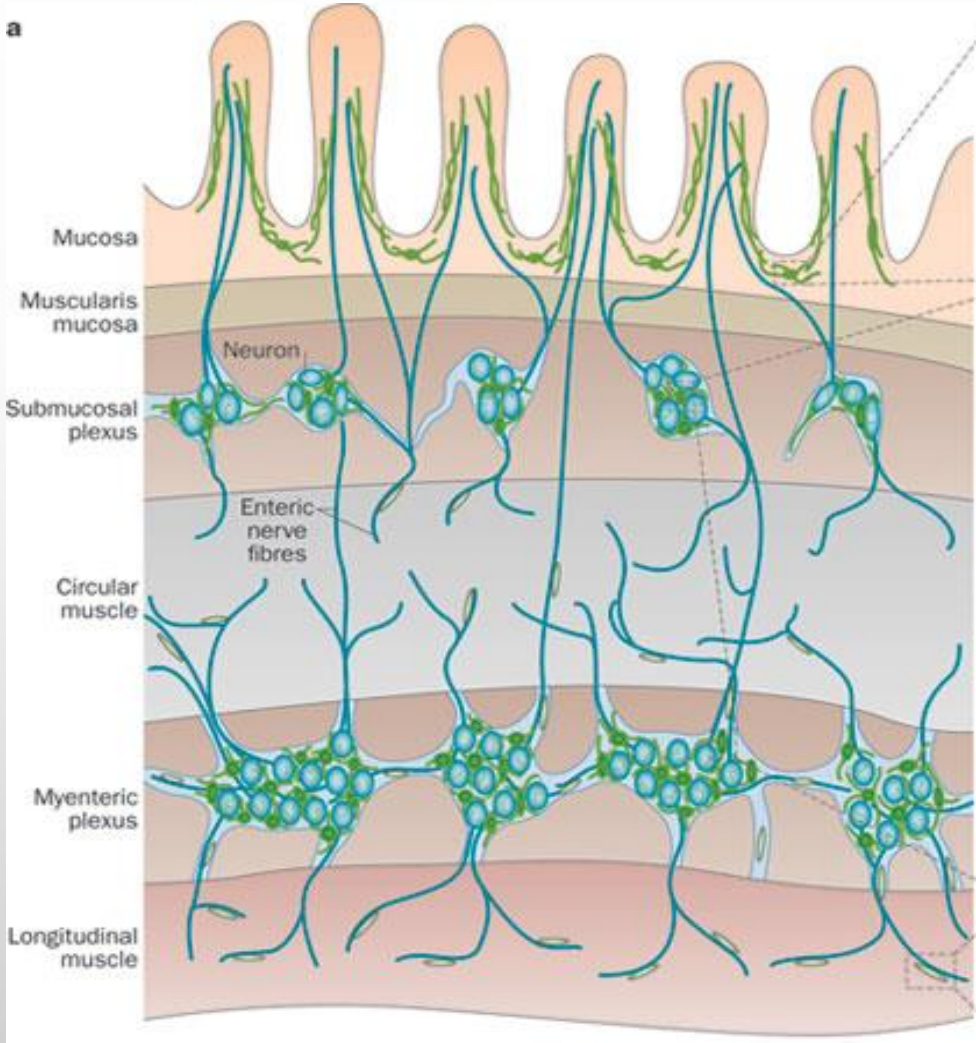
- How many brains we have?



Nervous control
Enteric Nervous System (little brain)

- Lies in the wall of the gut, beginning in the esophagus and extending all the way to the anus and contain 100 million neurons
- Connected to CNS by sympathetic &

  parasympathetic fibers
- Can function autonomously
- Controls gastrointestinal movements and secretion.
  - Myenteric or Auerbach's plexus
  - Submucosal or Meissner's plexus



Nervous control
Enteric Nervous System (little brain)
Differences between myenteric & messiner's plexuses

Myenteric or Auerbach's plexus	Submucosal or Meissner's plexus
• An outer plexus between the longitudinal and circular muscle • A linear chain of interconnecting neurons • Controls mainly the GI movements • Increase tone, rate, intensity and velocity of rhythmic contraction • Some neurons are inhibitory (eg. pyloric &ileocecal valves)	• An inner plexus, that lies in the submucosa. • Control the function within inner wall of each minute segment • Controls mainly GI secretion and local blood flow

Nervous control
Enteric Nervous System (little brain)

- Types of neurotransmitters secreted by enteric neurons:
  - **Acetylcholine**
  - **Norepinephrine**
  - Substance P
  - Vasoactive intestinal peptide (VIP)
  - Somatostatin
  - Serotonin
  - Dopamine
  - Cholecystokinin (CCK)
  - Gama aminobutyrate (GABA).
  - The gases nitric oxide (NO) & carbon monoxide (CO)

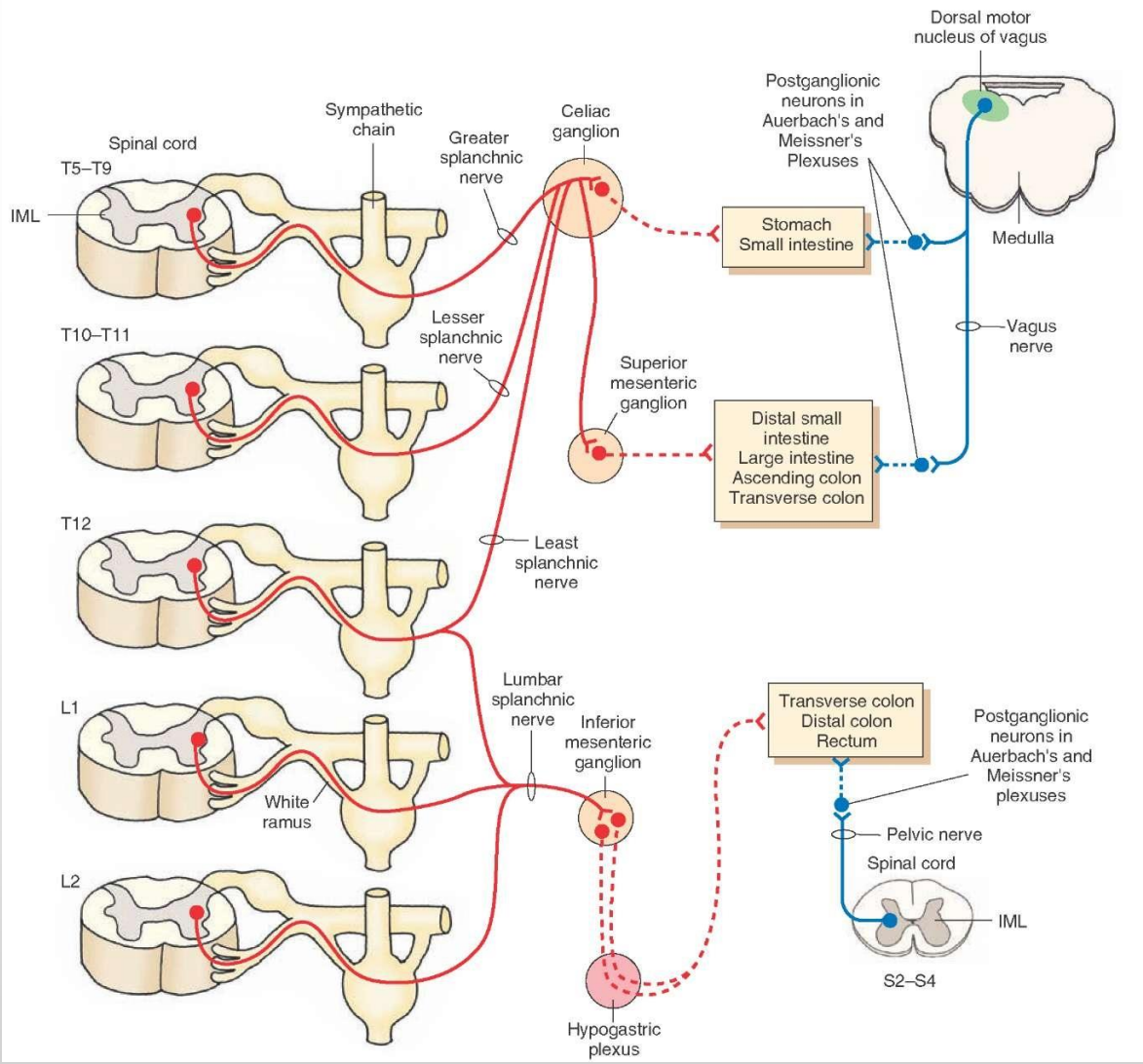
Nervous control (Autonomic Nervous System)

- Parasympathetic
  - Cranial
    - Almost entirely in the vagus nerve (except mouth and pharynx)
    - Innervate esophagus, stomach, pancreas, small intestine and first half of large intestine
  - Sacral
    - Originate in 2^{nd}, 3^{rd} and 4^{th} sacral segments of spinal cord
    - Innervate distal half of large intestine, and anus through pelvic nerves
  - Postganglionic neurons are located in myenteric and submucosal plexuses
  - More extensive near the oral cavity and anus
  - Stimulation causes general increase in activity of the entire enteric nervous system

Neural control (Autonomic Nervous System)

- Sympathetic
  - Originate in the spinal cord between segment T5 and L2 of spinal cord
  - Enter sympathetic chain then pass to ganglia:
    - Celiac ganglia
    - Superior mesenteric ganglia
    - Inferior mesenteric ganglia
  - Postganglionic fibers spread to all parts of the gut
  - Stimulation inhibit intestinal tract smooth muscle (except mucosal muscle)
  - Secretes mainly norepinephrine

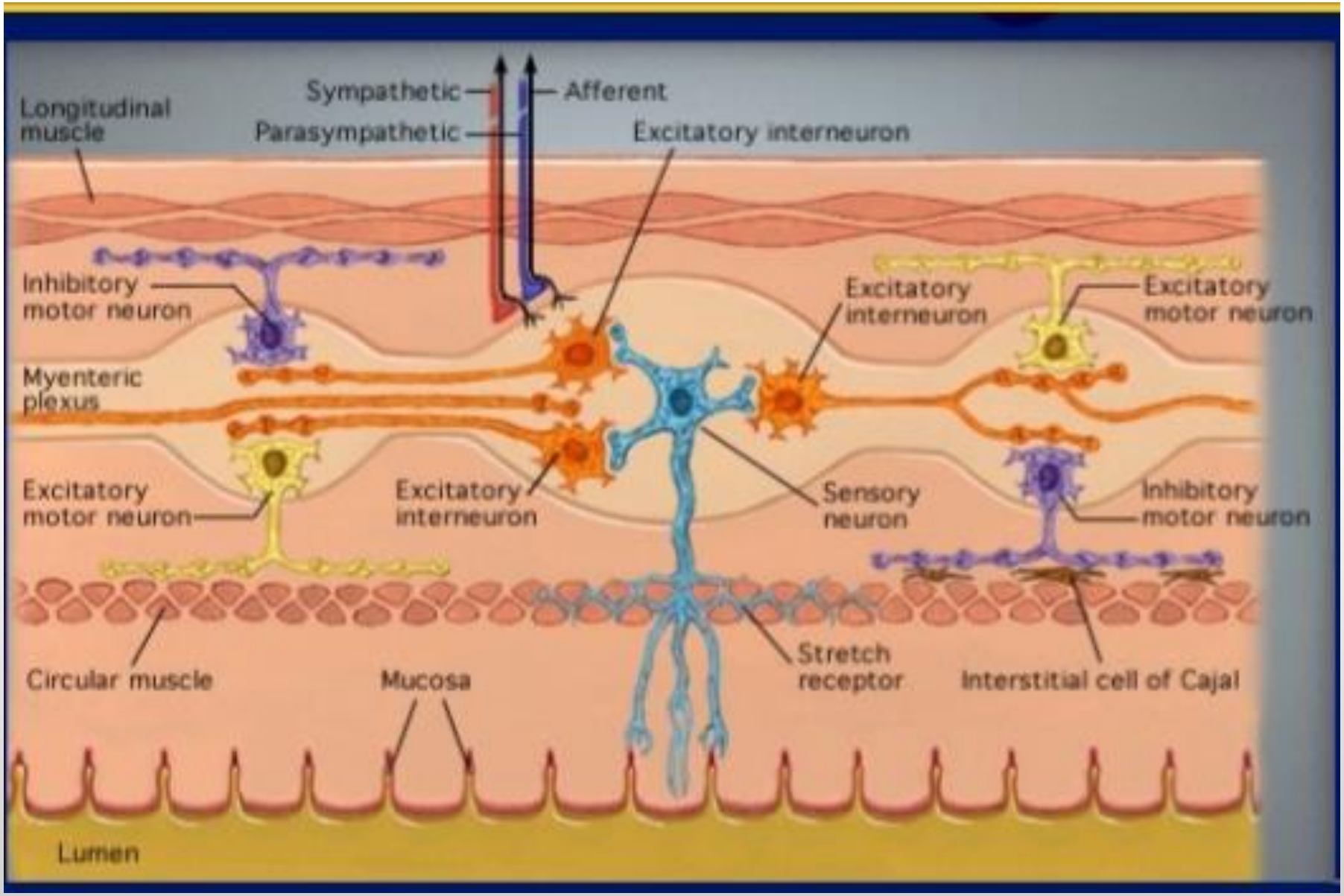
Neural control
Autonomic Nervous System



Neural control
Sensory nerves

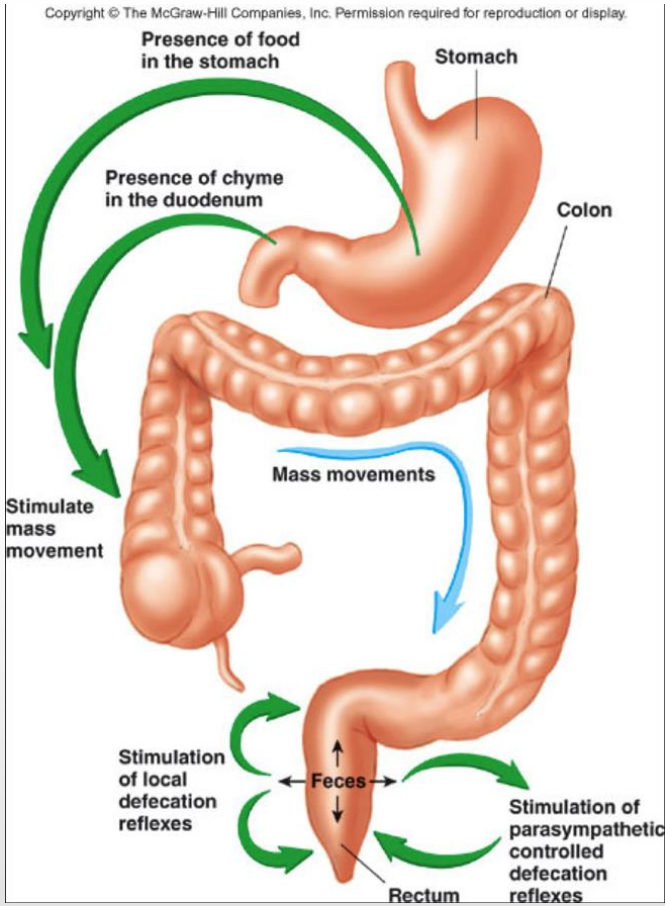
- Sensory nerve fiber cell bodies are either in
  - The enteric nervous system
  - Dorsal root ganglia
- Sensory nerves can be stimulated by:
  - Irritation of the gut mucosa
  - Excessive distention of the gut
  - Presence of specific chemicals
- Signals transmitted through the fibers can cause :
  - Excitation
  - Inhibition
- 80% of fibers in vagus nerves are afferent
- Sensory signals transmitted by sensory nerve fibers initiate GI reflexes

Neural control (Integrated control)

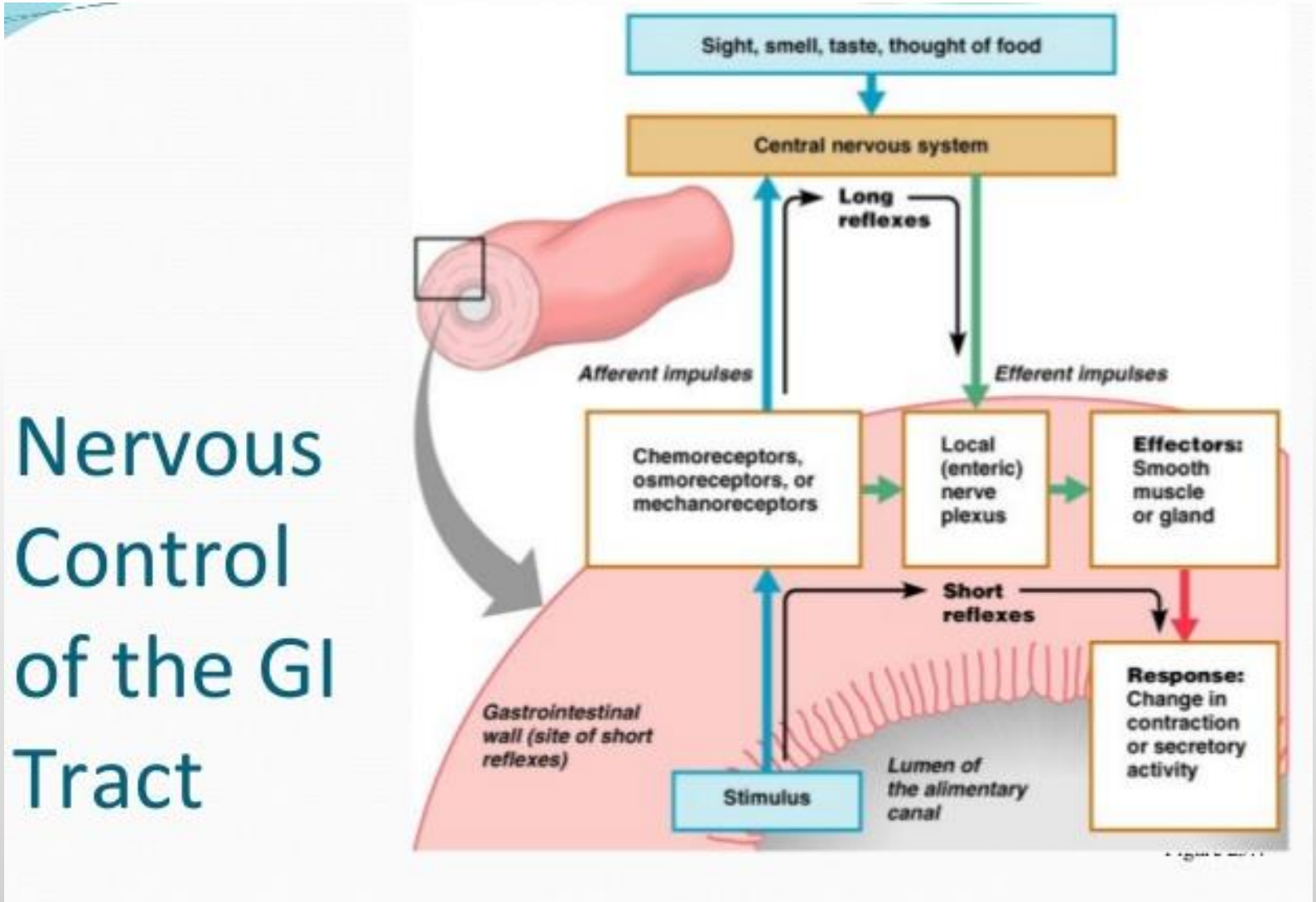


Neural control
Gastrointestinal reflexes:

- Reflexes integrated within gut wall
  - Reflexes that controls secretion, peristalsis, mixing contractions and local inhibition
- Reflexes from the gut to sympathetic ganglia back to the gut
  - Gastrocolic reflex: stimulate evacuation of the colon
  - Enterogastric reflex: inhibit stomach motility and secretion
  - Colonoileal reflex: inhibit empting of ileal contents
- Reflexes from the gut to the spinal cord or brain stem then back to GIT
  - From stomach and duodenum to the brain stem and back to stomach to control gastric motor and secretory activity
  - Pain reflexes that cause general inhibition of GIT
  - Defecation reflexes from colon and rectum to spinal cord and back to cause powerful colonic, rectal and abdominal contractions.

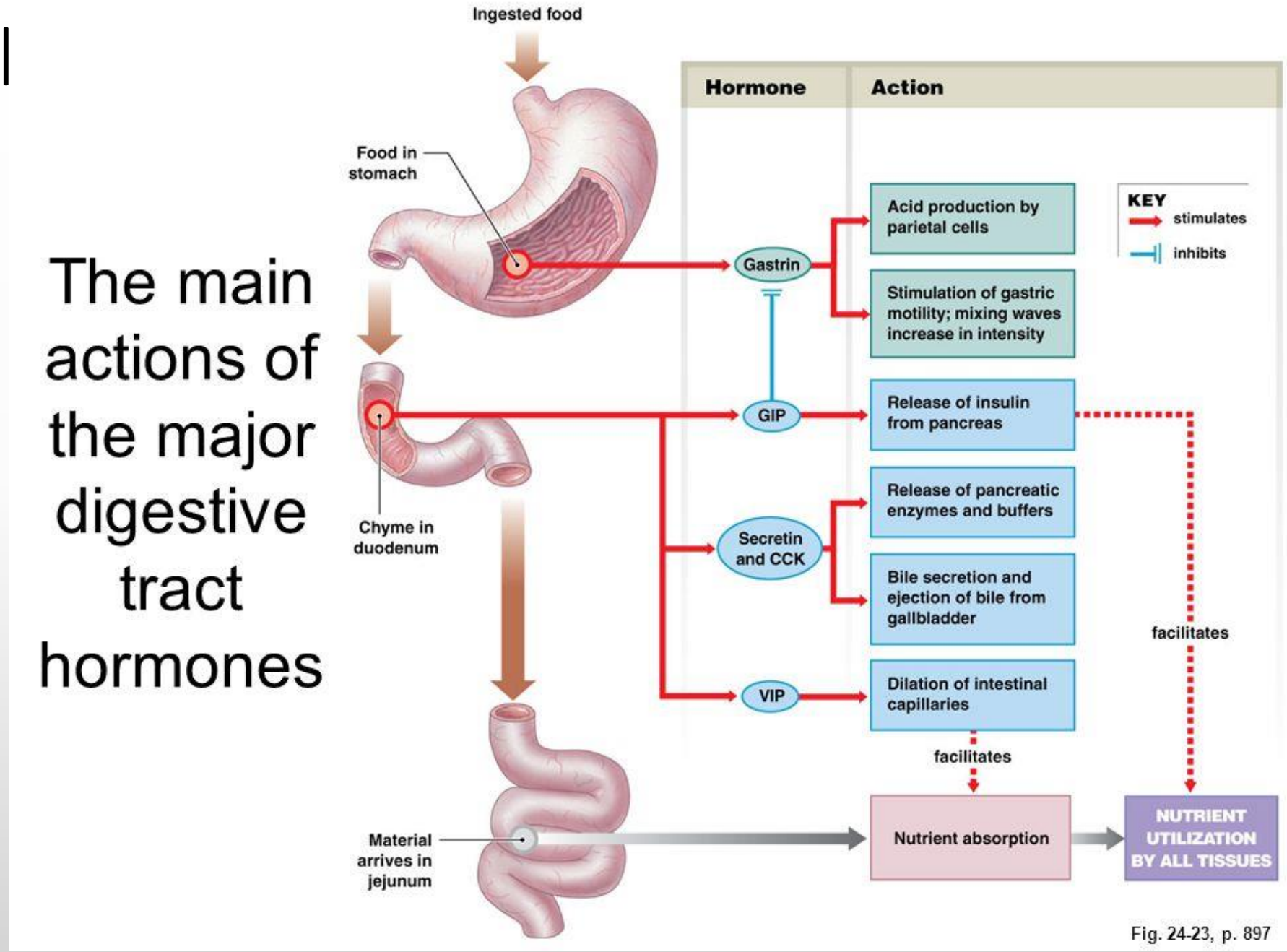


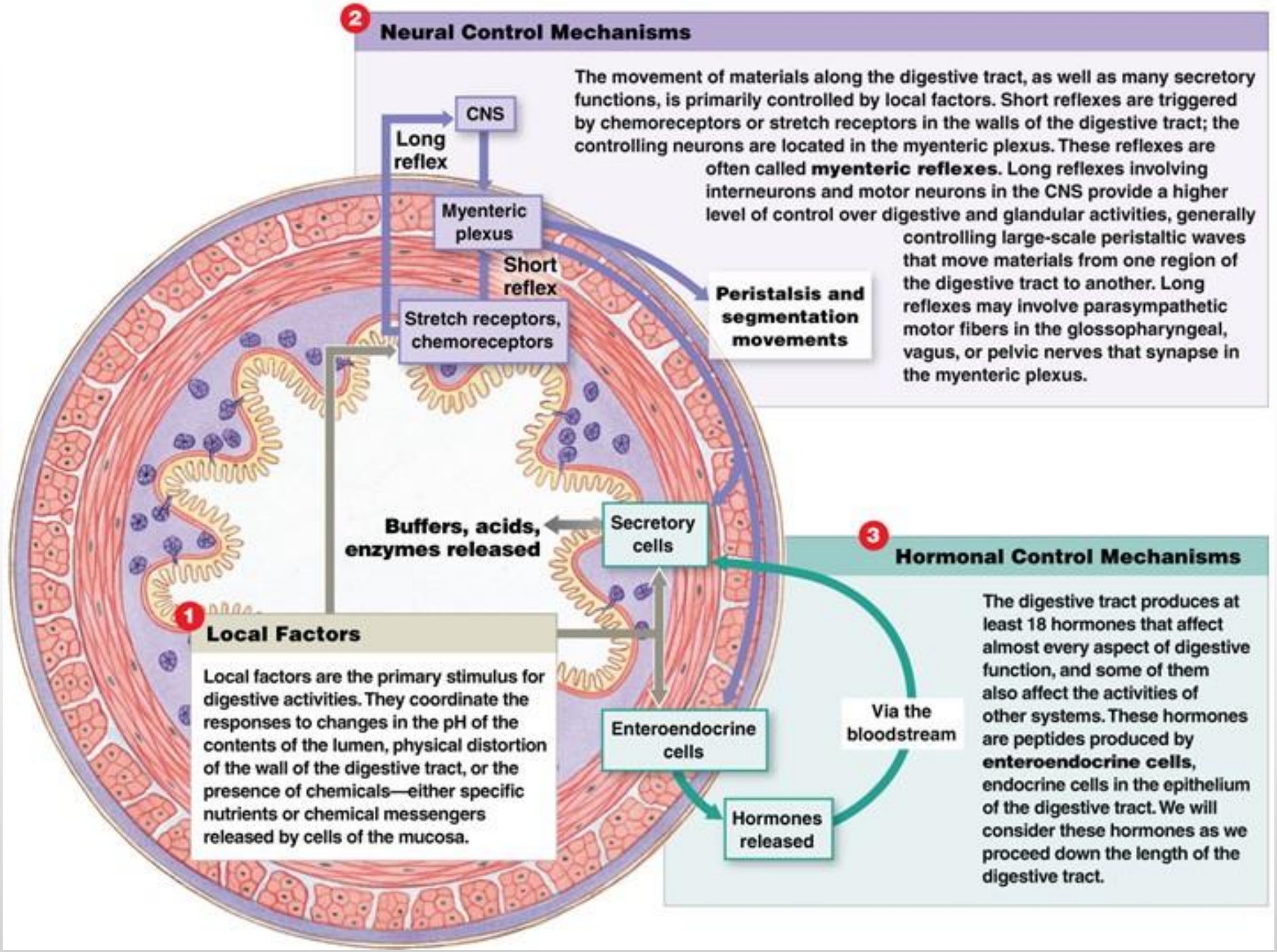
Neural Control of gastrointestinal function



Hormonal control

The main actions of the major digestive tract hormones




2
Neural Control Mechanisms
The movement of materials along the digestive tract, as well as many secretory functions, is primarily controlled by local factors. Short reflexes are triggered by chemoreceptors or stretch receptors in the walls of the digestive tract; the controlling neurons are located in the myenteric plexus. These reflexes are often called myenteric reflexes. Long reflexes involving interneurons and motor neurons in the CNS provide a higher level of control over digestive and glandular activities, generally controlling large-scale peristaltic waves that move materials from one region of the digestive tract to another. Long reflexes may involve parasympathetic motor fibers in the glossopharyngeal, vagus, or pelvic nerves that synapse in the myenteric plexus.
CNS
Long reflex
Myenteric plexus
Short reflex
Stretch receptors, chemoreceptors
Peristalsis and segmentation movements
Buffers, acids, enzymes released
Secretory cells
1
Local Factors
Local factors are the primary stimulus for digestive activities. They coordinate the responses to changes in the pH of the contents of the lumen, physical distortion of the wall of the digestive tract, or the presence of chemicals—either specific nutrients or chemical messengers released by cells of the mucosa.
3
Hormonal Control Mechanisms
The digestive tract produces at least 18 hormones that affect almost every aspect of digestive function, and some of them also affect the activities of other systems. These hormones are peptides produced by enteroendocrine cells, endocrine cells in the epithelium of the digestive tract. We will consider these hormones as we proceed down the length of the digestive tract.
Enteroendocrine cells
Hormones released
Via the bloodstream

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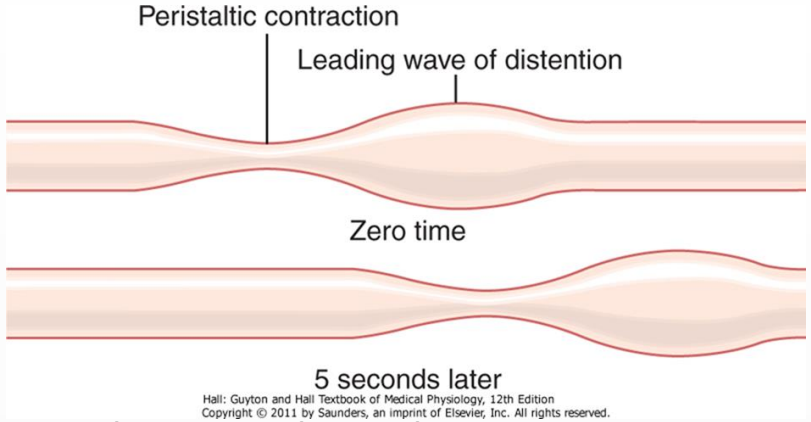
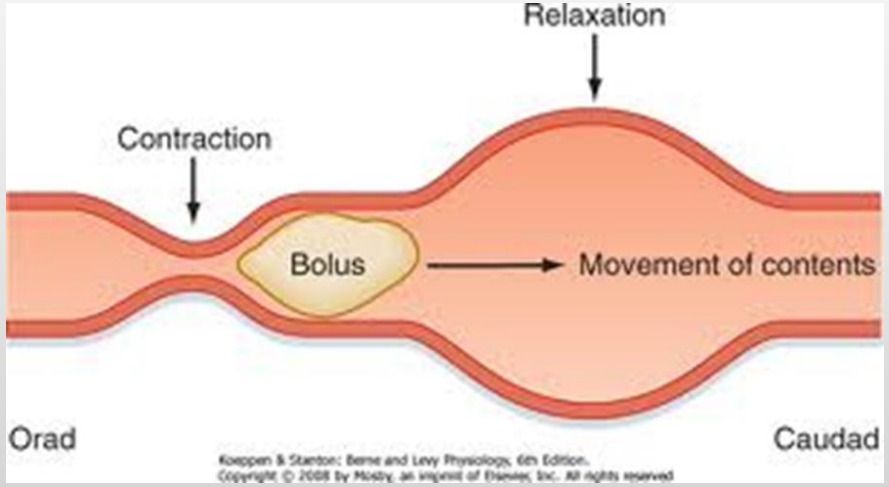
Functional types of movements in the GIT

- Two types of movements:
  - Propulsive movements
  - Mixing movements

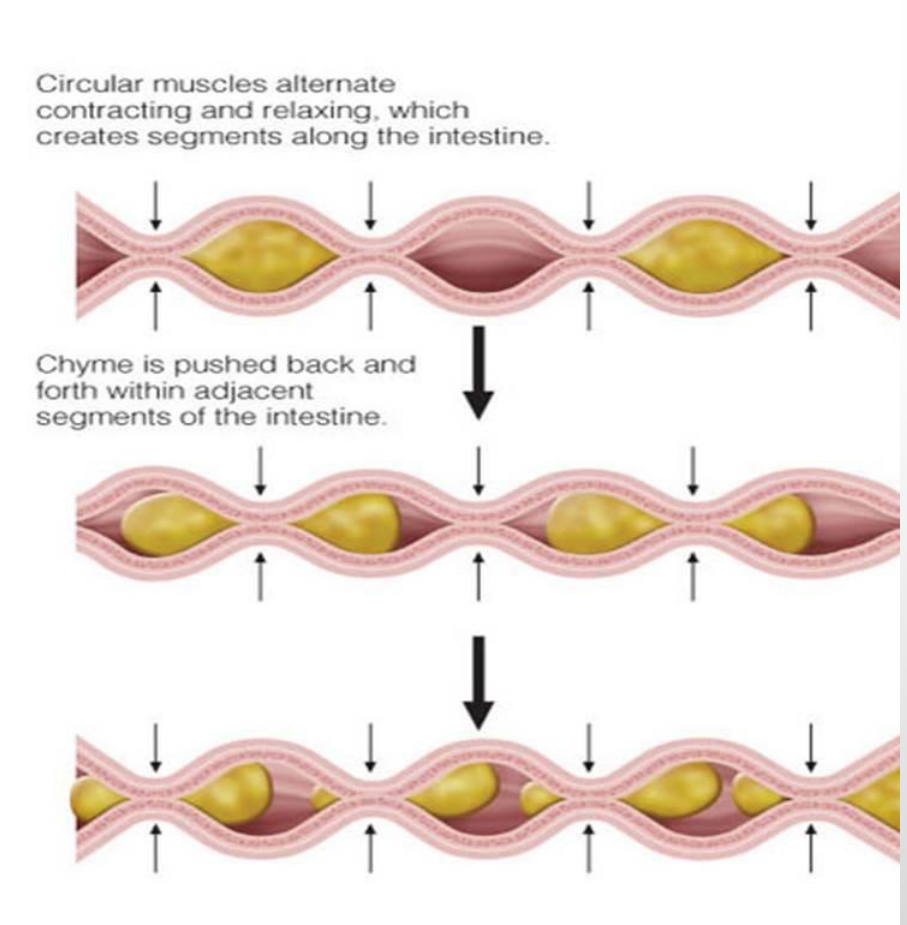


- Propulsive movements:
  - Peristalsis which is inherent property of syncytial smooth muscle tube
  - Stimulus is distention of the gut
  - Stimulation of enteric nervous system
  - Contractile ring 2-3 Cm behind stimulus
  - Contractile ring moves forward
  - Can not occur in absence of Myenteric plexus
- Peristaltic (myenteric) reflex and the low of gut



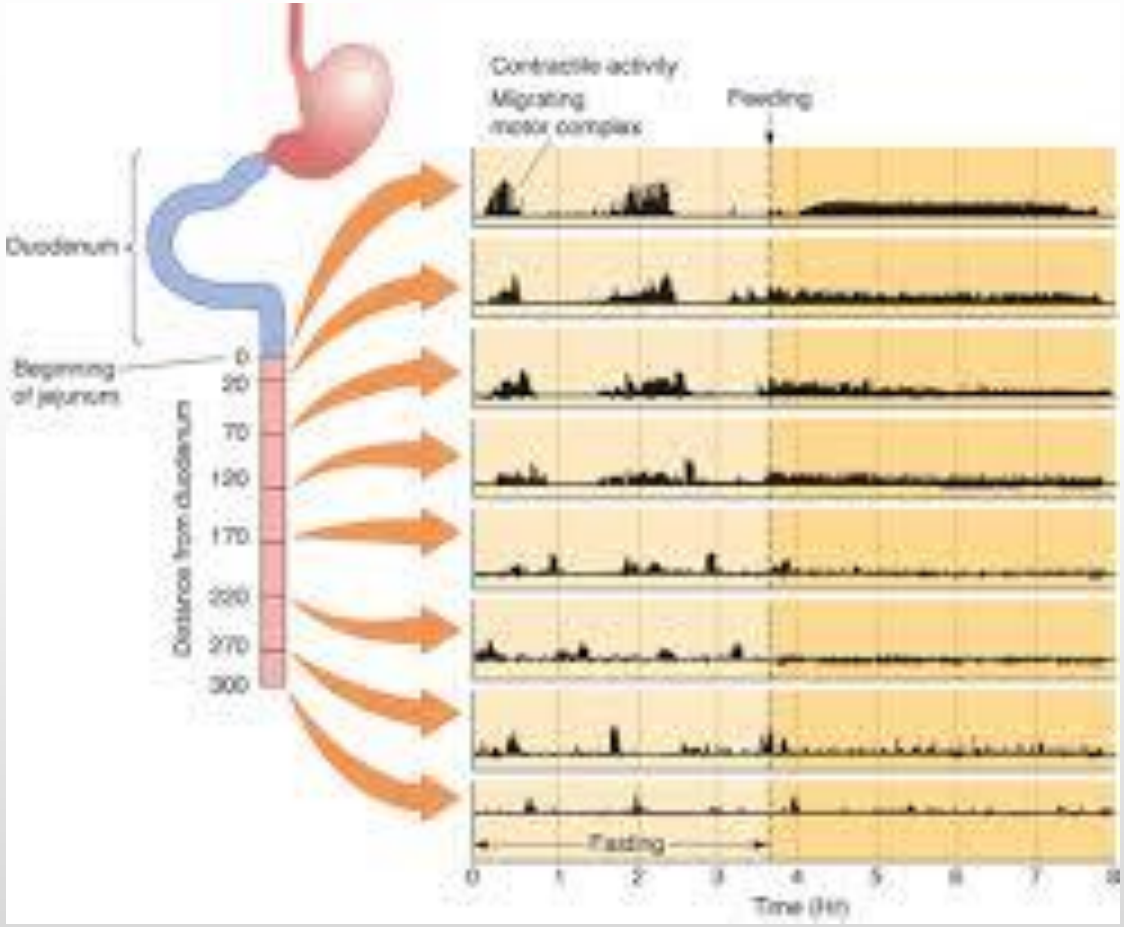
Functional types of movements in the GIT

- Segmentation & Mixing movements:
  - Provides mixing of intestinal contents (know as chyme) with digestive juices.
  - Segment of bowel contracts at both ends
  - A second contraction occurs in the center of the segment
  - Chyme is forced forward and backward
  - Can occur independent of central input



Functional types of movements in the GIT

- Migrating motor complex (MMC):
  - Cycles of motor activity migrate from the stomach to the distal ileum
  - Have 3 phases
    - Phase1 quiescence
    - Phase2 irregular electrical & mechanical activity
    - Phase3 burst of regular activity
  - Occurs during fasting.
  - Initiated by motilin
  - Migrate at a rate of 5cm/min
  - Occurs at intervals of ~ 90 min
  - Accompanied by increase gastric, bile and pancreatic secretion
  - Serve to clear the stomach and small intestine of luminal contents



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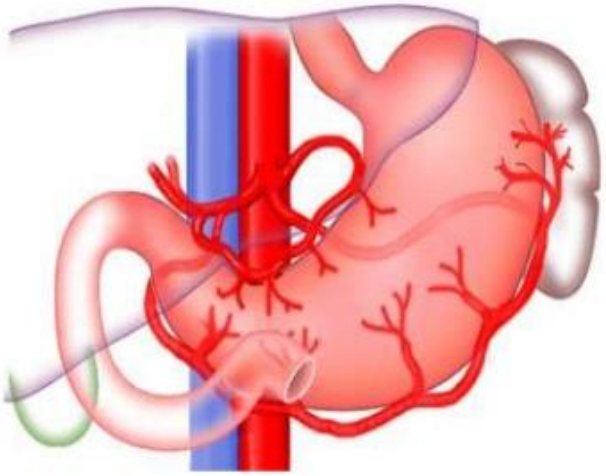
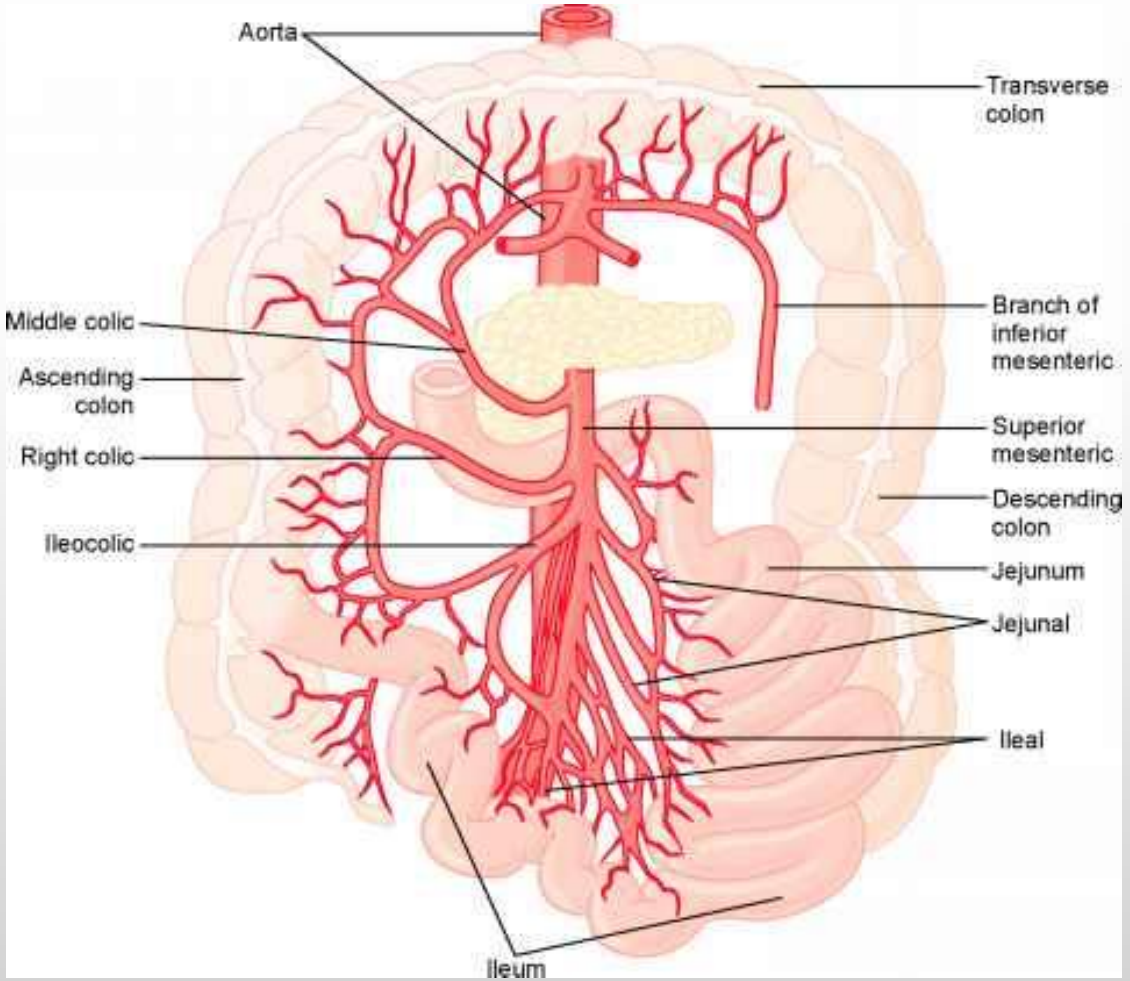
Gastrointestinal blood flow (Splanchnic circulation)

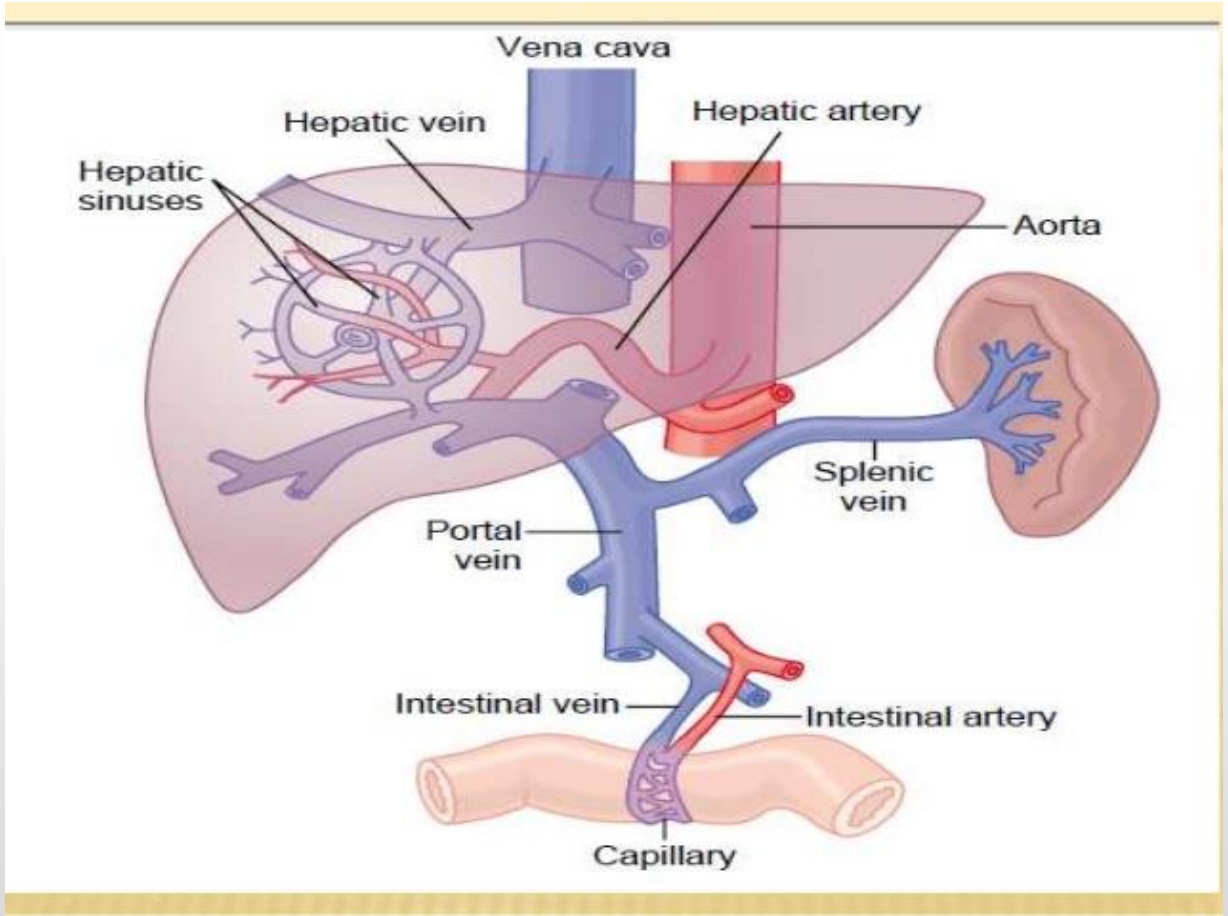
Celiac Trunk

- It arises from the abdominal aorta immediately below the aortic hiatus of the diaphragm anterior to the upper part of vertebra LI.
- It divides into the:
  - ***left gastric artery,***
  - ***splenic artery,***
  - ***common hepatic artery***.





Gastrointestinal blood flow (Splanchnic circulation)



Effects of gut activity & metabolic factors on GI blood flow

- Blood flow in GIT is directly related to local activity
- Blood flow in villi during active absorption increased up to 8 folds
- After a meal blood flow increases greatly then return to resting level over 2-4 hrs
- Causes of increase blood flow:
  - Vasodilators such as peptide hormons
  - Kinins secreted by GI glands (kallidin & bradykinin)
  - Decreased oxygen concentration increase blood flow 50-100%
  - Four folds increase in adenosine (vasodilator) secretion due to decrease oxygen

Summary

- Functional anatomy (mucosa, submucosa,Muscularis externa and serosa)
- General characteristics of SM (multi unit and unitary)
- Specific characteristics of SM (structure and contractions)
- Control of SM contraction (nervous, hormonal and stretch)
- Functional types of movements

- Effect of activity on blood supply.


THANKYOU