Gastrointestinal System module-Physiology

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Gastrointestinal System module-Physiology

- No of lect: 8 L (6 before Mid-exam & 2 after) covering the following subjects:

1. General Principles of Gastrointestinal Function-Motility, Nervous Control, and Blood Circulation
2. Propulsion and Mixing of Food in the Alimentary Tract
3. Secretory Functions of the Alimentary Tract
4. Digestion in the Gastrointestinal Tract
5. Absorption in the Gastrointestinal Tract
6. Physiology of Gastrointestinal Disorders

- Textbook: Guyton and Hall Textbook of Medical Physiology

General Principles of Gastrointestinal Function — Motility, Nervous Control, and Blood Circulation

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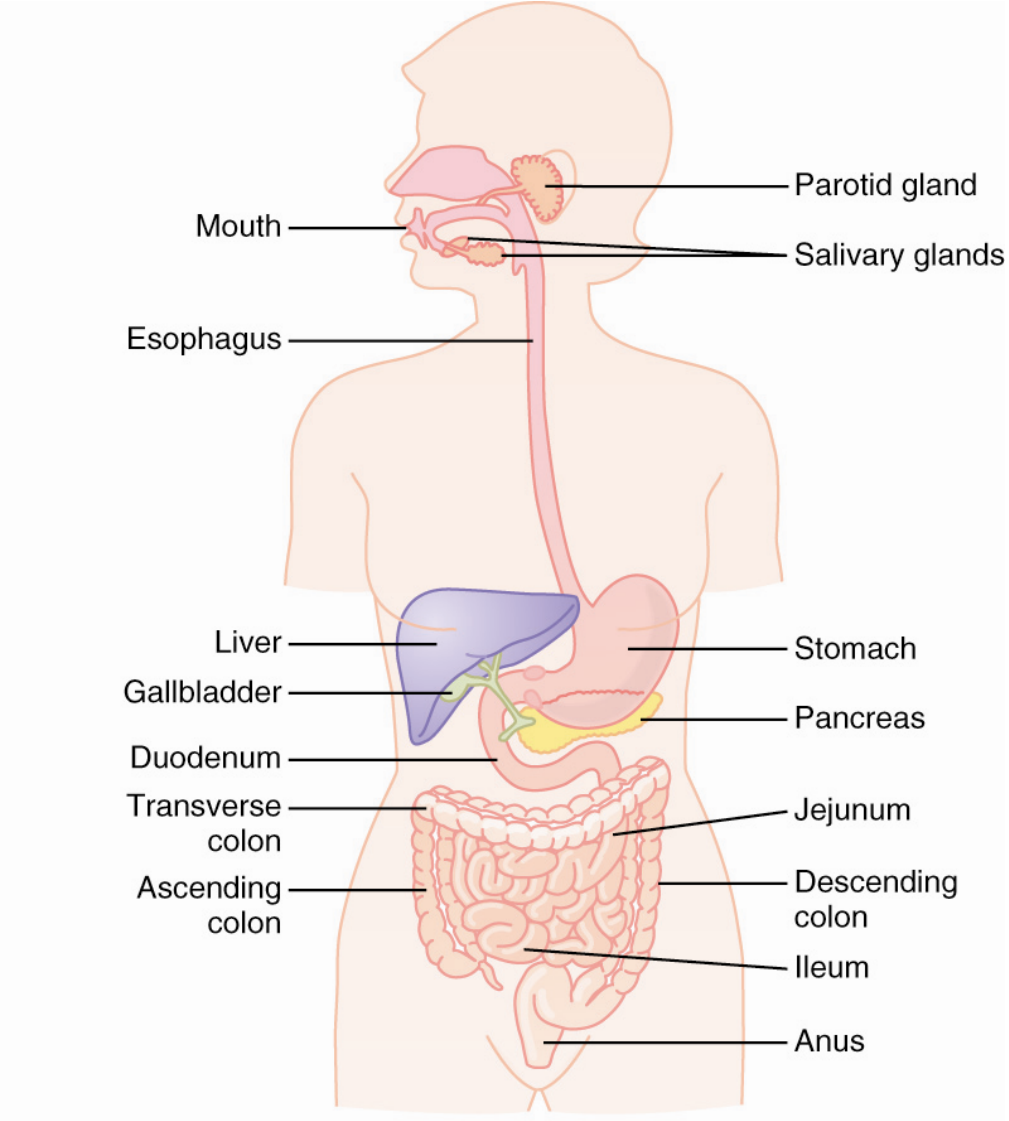
Segments of the GI Tract

1. Mouth
2. Pharynx
3. Esophagus : passage of food
4. Stomach : storage of food
5. Small Intestine :digestion and absorption
6. Large Intestine
7. Sphincters between segments
8. Liver
9. Gall Bladder
10. Pancreas



GIS-overview

- Provides body with water, electrolytes, vitamins, nutrients.

- Functions through:

(1) Movement of food through GIS

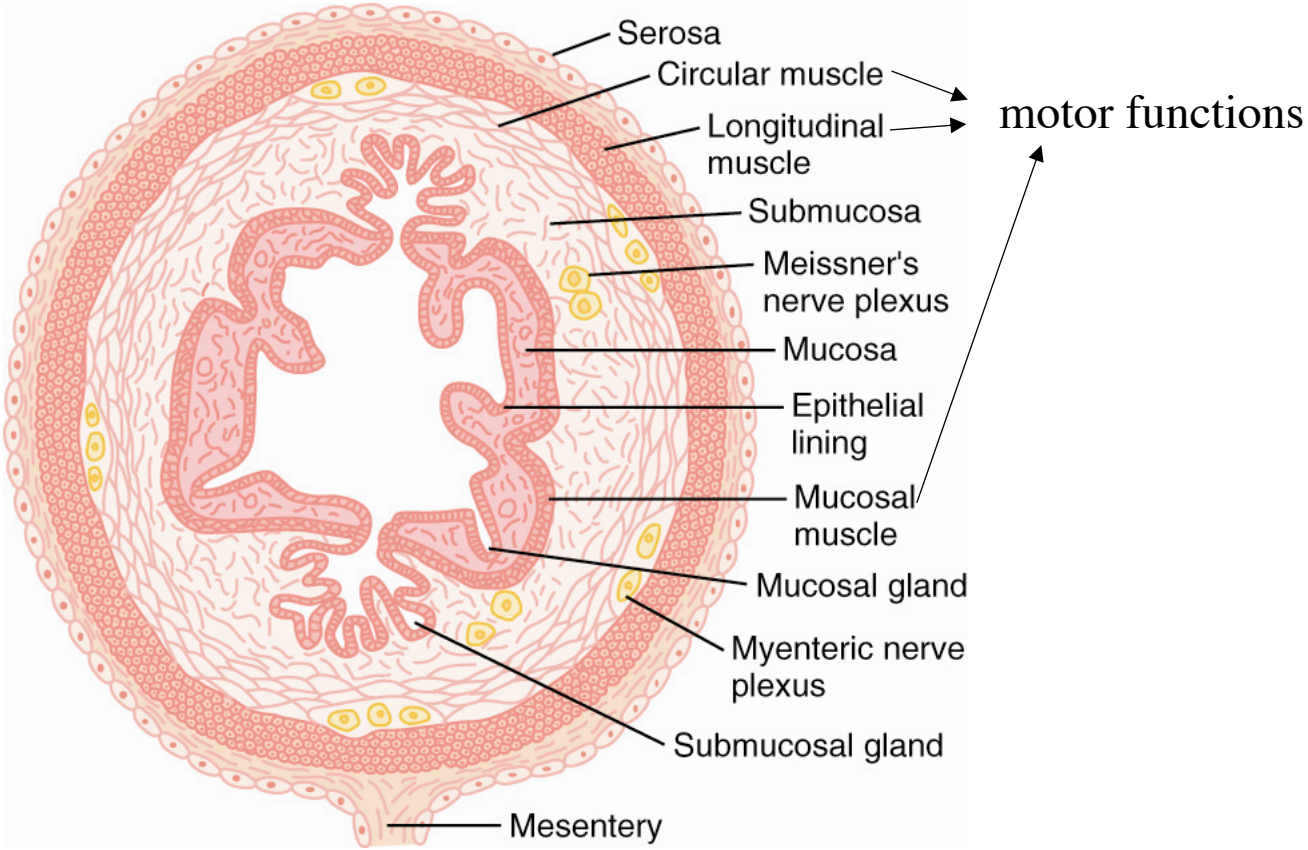
(2) Secretion of digestive juices

(3) Absorption of water, electrolytes, vitamins, & digestive products to circulation

- Control of GI functions by local, nervous, and hormonal systems.

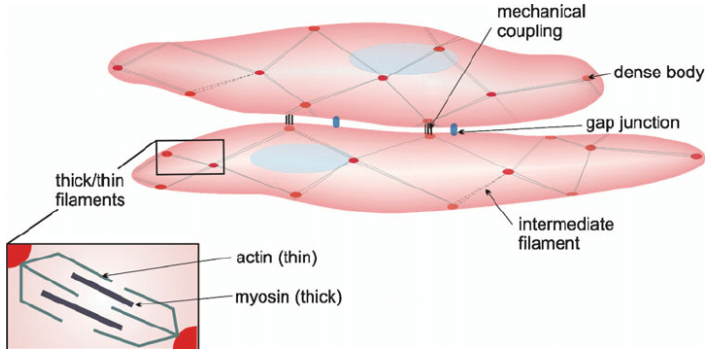
Physiological anatomy of GI wall

1. Serosa
2. LM
3. Myenteric (Auerbach's) nerve plexus
4. CM
5. Submucosa
6. Submucosal (Meissner's) nerve plexus
7. Muscularis mucosae
8. Mucosa
9. Epithelial lining



Typical cross section of the gut

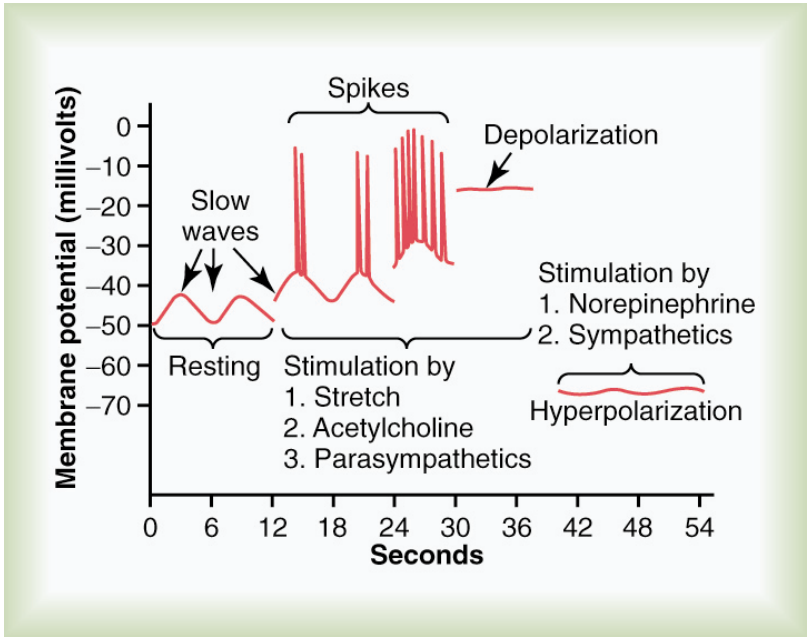
GI SM



- Arranged in bundles of fibers separated by loose CT
- Electrically connected with GJ (low-resistance movement of ions)
- Electrical signals initiating muscle contractions travel more rapidly along length of the bundle than sideways
- GI SM functions as a syncytium → AP elicited anywhere within muscle travels in all directions in muscle
- Due to connection between LM and CM layers, excitation of one of these layers often excites the other.

Electrical Activity of GI SM

- SM is excited by continual slow, intrinsic electrical activity along membranes of muscle fibers.
- Normal RMP in SM of gut is - 50-60 mV (Avg −56 mV)
- Voltage of RMP of SM can change to different levels



- **Types of electrical waves**:
- **<u>Slow waves</u>**

-Rhythmical changes in MP, **not** AP

-Slow changes in RMP.

-5-15 mV intensity, 3-12/min freq.

-Cause: interactions among the SM cells & interstitial cells of Cajal (electrical pacemakers for SM cells) → cyclic changes in MP due to activity ion channels.

-Don't cause GI muscle contraction (except stomach) → stimulates spike potentials → muscle contraction.

Electrical Activity of GI SM

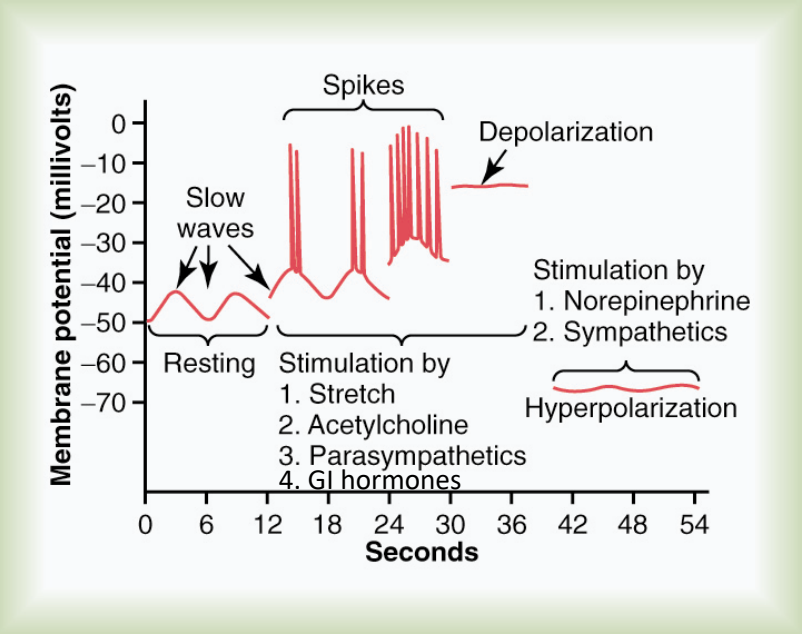
- **Types of electrical waves**:
- **<u>Spikes:</u>**
- When slow waves reach threshold (-40 mV) → spike P → depolarization→ Ca^{2+} entery→ contraction

-True AP.

-↑ slow wave P → ↑ spike potential frequency (range 1-10 spikes/s, duration 10-20 ms)

- AP in GI SM vs nerves:
- Nerve: Na through Na channels (rapid)
- GI SM Ca^{2+} (mainly)+ Na through Ca^{2+}-Na^{+} channels (slow) → longer duration AP in GI SM

- More negative RMP → hyperpolarization



Tonic Contraction

- Continuous (no relaxation).
- Usually observed in sphincters.
- Not associated with basic electrical rhythm of the slow waves.
- Caused by :

-Continuous repetitive spike potentials

-Hormones

-Continuous entry of Ca^{2+} into cell in ways not associated with changes in MP

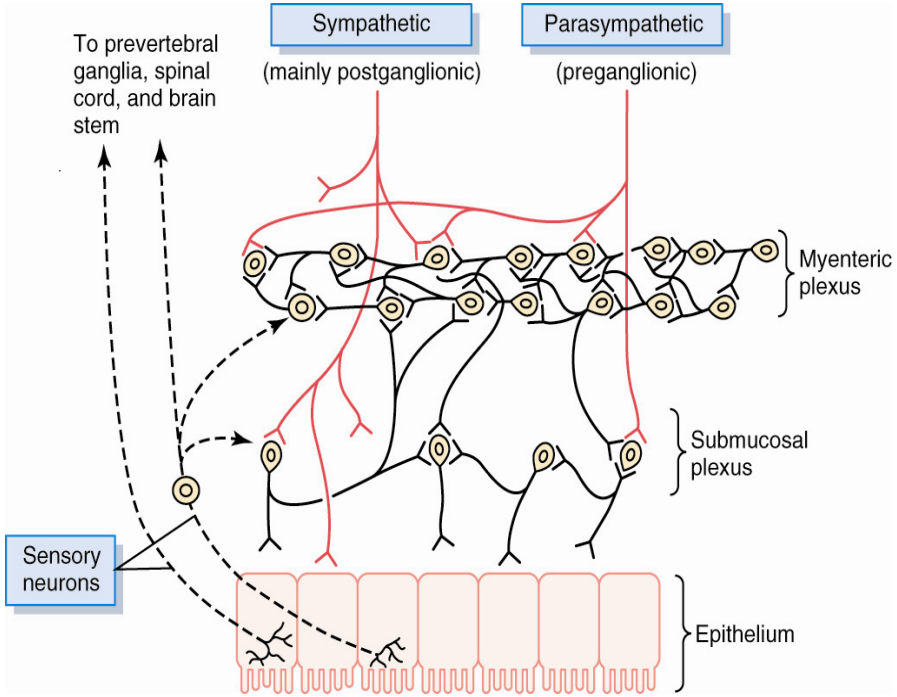
Neural Control of GI Tract

- Intrinsic Control - Enteric nervous system
  - Esophagus → anus
  - Can function independently of extrinsic nerves
  - Controls movements & secretion
  - Myenteric (Auerbach's) plexus
  - Submucosal (Meissner's) plexus

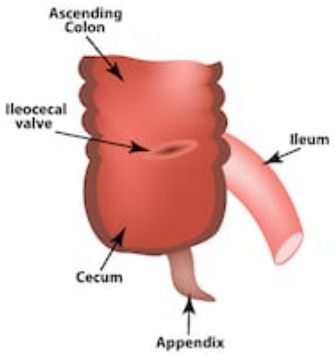
} Connected with each other

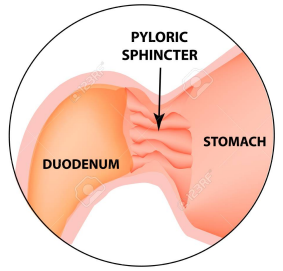
ENS - Myenteric Plexus

- Location -
  - Between longitudinal and circular SM layers



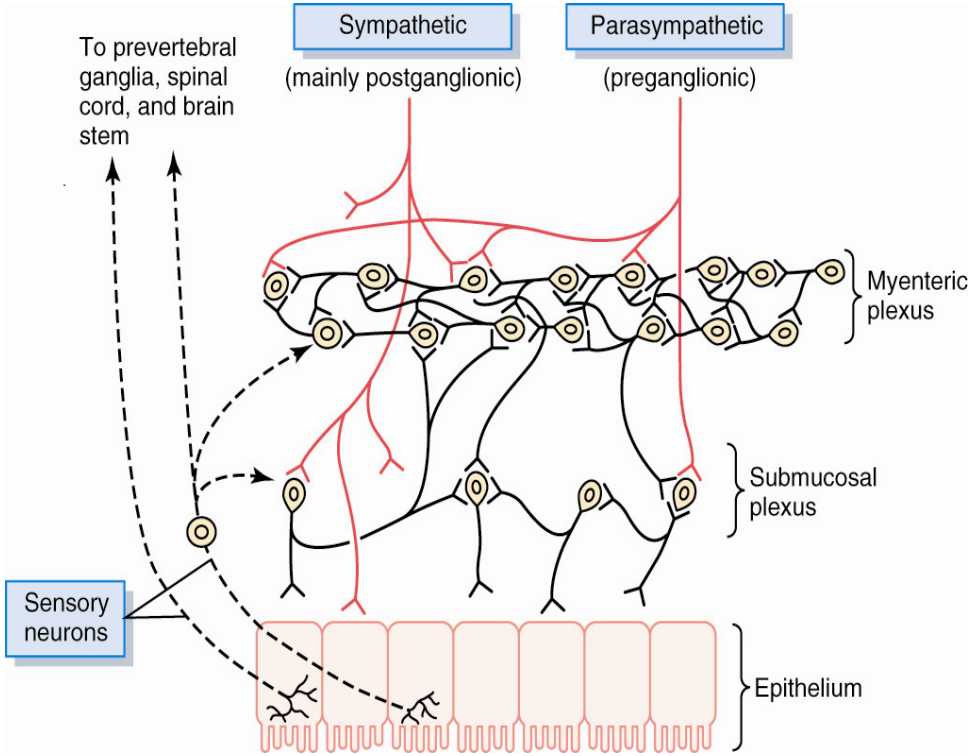
- Function - controls GI motility
  - Stimulatory influences -
    - ↑ tonic contraction (tone)
    - ↑ contraction frequency / intensity
    - ↑ velocity of conduction of excitatory waves (peristalsis)
  - Inhibitory- vasoactive intestinal polypeptide → inhibits sphincter muscles (pyloric & ileocecal valve)
    -





ENS – Submucosal

- Location - submucosa
- Function
  - Control secretion
  - Absorption (local blood flow)
  - Contraction of muscularis mucosa (infolding)



Neurotransmitters secreted by ENS

(1) Acetylcholine → excitatory
(2) Norepinephrine/epinephrine → inhibitory (via circulation)
(3) ATP
(4) Serotonin
(5) Dopamine
(6) Cholecystokinin
(7) Substance P
(8) Vasoactive Intestinal Polypeptide
(9) Somatostatin
(10) Leu-enkephalin
(11) Met-enkephalin
(12) Bombesin

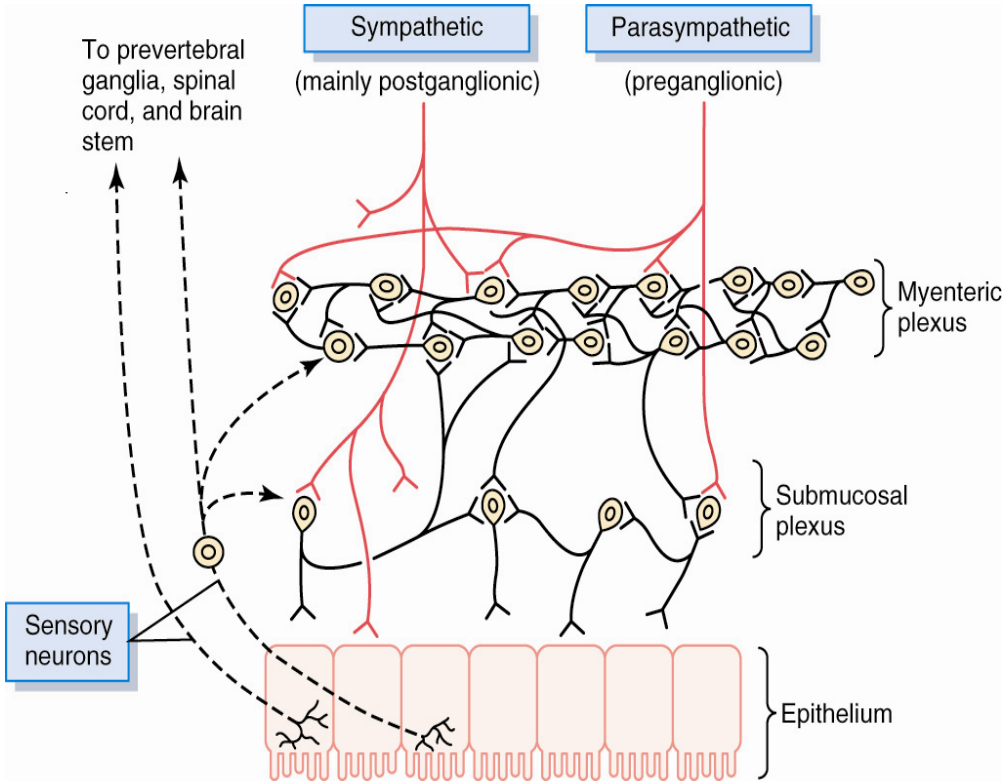
Afferent Sensory Nerve Fibers From the Gut

- Cell bodies in ENS/DRG
- Sensory signals to DRG, SC & BS

  -Vagus nerve 80% afferent →brain medulla →vagal reflex

- Stimulation of afferent neurons
  - Distention of gut
  - Irritation of gut mucosa
  - Chemical stimuli

- Stimulation - can excite or inhibit
  - Intestinal movements or secretions

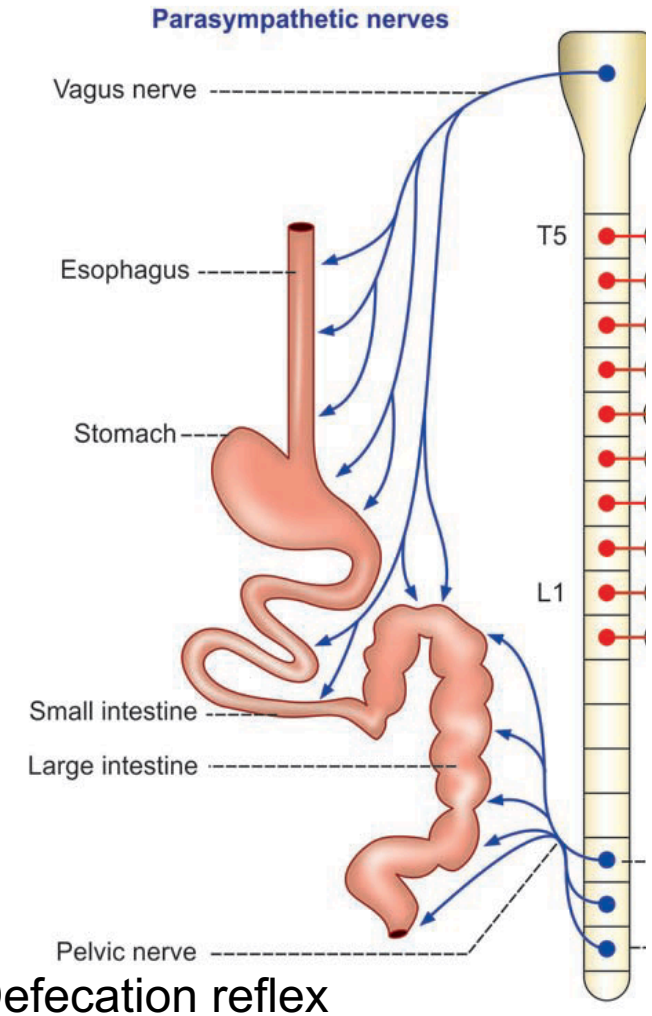


Neural Control of GI Tract

- Extrinsic Control - Autonomic nervous system
  - Parasympathetic - mainly stimulates (Ach)
  - Sympathetic - mainly inhibits (NE)

Parasympathetic Innervation

- Cranial Division - (mostly Vagus N.) - first half of gut
- Sacral Division (S2-4) - (Pelvic N.) - second half of gut
- Neurons
  - preganglionic - long
  - postganglionic - short, entirely in ENS
    Synapse with ENS neurons (mainly)
- Stimulation - Excites ENS (in general)
- Parasympathetic nerves also contain afferent sensory fibers (80%)



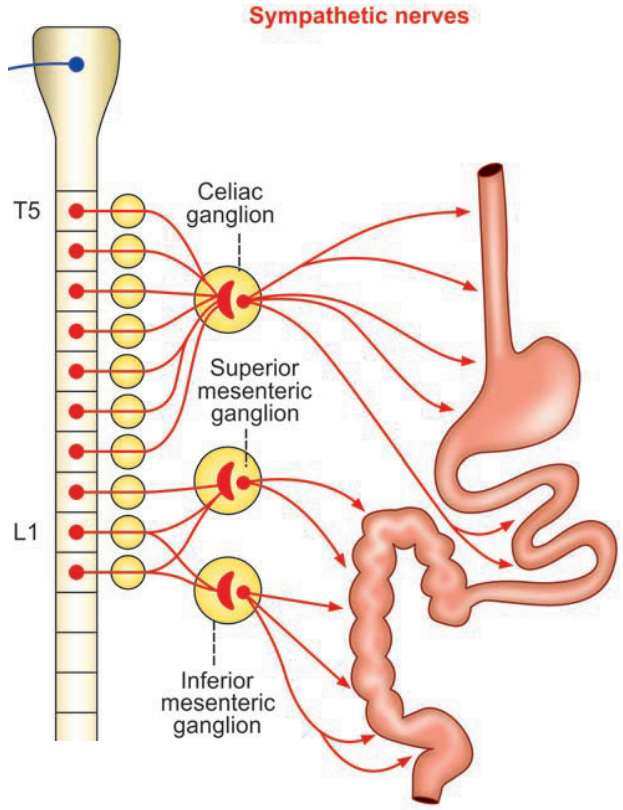
Defecation reflex

Sympathetic Innervation

- Preganglionic Neurons (long) - Originate at T5-L2 (cell bodies). Synapse in prevertebral ganglia
- Postganglionic Neurons (long)
  - Originate in ganglia (cell bodies)
  - Innervate entire gut. Terminate in ENS (mostly)
  - Nerve endings mainly secrete norepinephrine
- Inhibitory

(a) Decreasing activity of ENS (mostly)
(b) Inhibit SM (except mucosal SM)-Slight activity

- Sympathetic nerves also contain afferent sensory fibers (50%)



Neurotransmitters (Neurocrines)

- Preganglionic efferent neurons - acetylcholine

- Postganglionic efferent neurons
  - PNS - acetylcholine
  - SNS - norepinephrine

GI Reflexes

- Local (within ENS)
  - Afferent fibers from gut terminate in ENS
  - Control secretion, peristalsis, mixing movements & local inhibitory effects

- Long loop
  - Gut → Aff. N. → prevertebral symp. ganglia → Eff. N. → gut
  - Reflexes:
  - Gastrocolic (from stomach → colon evacuation)
  - Enterogastric (from colon & SI → inhibit stomach motility & secretion)
  - Colonoileal (from colon → inhibit emptying of ileal contents into colon)

Gastrointestinal Reflexes (cont'd)

- Vagovagal Reflexes
  - Stomach / duodenum → Aff. N. → BS→ Eff. N. → stomach / duodenum
  - Controls gastric motor and secretory activity

- Defecation Reflexes
  - Colon / rectum → Aff. N. → SC → Eff. N. → colon / rectum

- Pain Reflexes - overall inhibition of GI tract

Hormonal control of GI motility

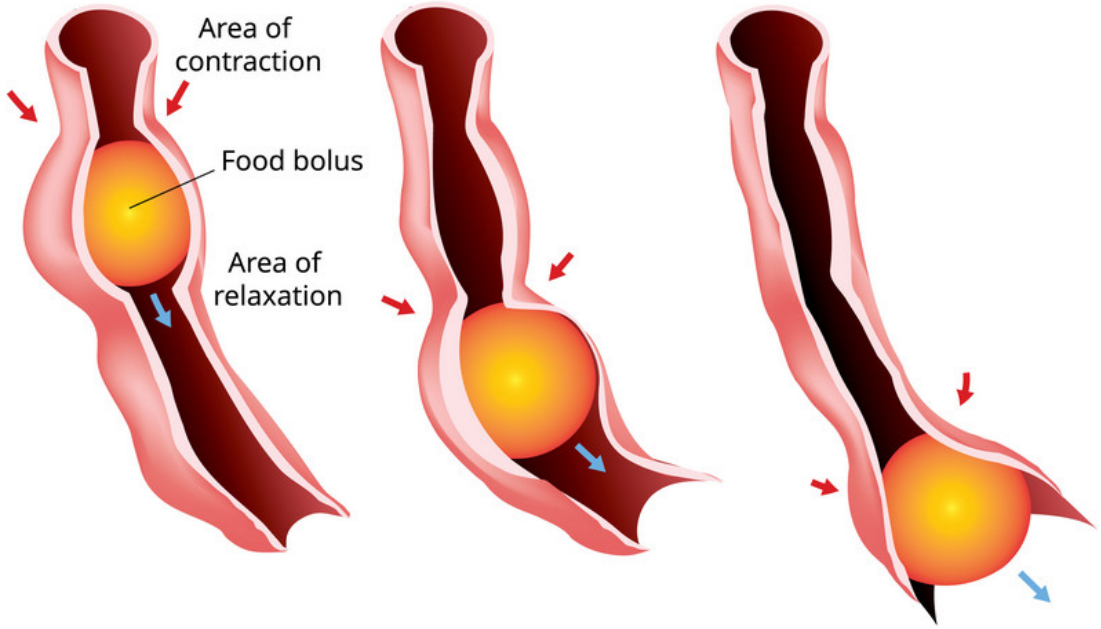
Hormone	Stimuli for Secretion	Site of Secretion	Actions
Gastrin	Protein Distention Nerve Vagal/ gastrin-releasing peptide *(Acid inhibits release)*	G cells of the antrum, duodenum, and jejunum	Stimulates Gastric acid secretion Mucosal growth
Cholecystokinin	Protein Fat Acid	I cells of the duodenum, jejunum, and ileum	Stimulates Pancreatic enzyme secretion Pancreatic bicarbonate secretion Gallbladder contraction Growth of exocrine pancreas Inhibits Gastric emptying Appetite-vagus
Secretin	Acid Fat	S cells of the duodenum, jejunum, and ileum	Stimulates Pepsin secretion Pancreatic bicarbonate secretion Biliary bicarbonate secretion Growth of exocrine pancreas Inhibits Gastric acid secretion
Gastric inhibitory peptide Glucose-dependent insulinotropic peptide	Protein Fat Carbohydrate	K cells of the duodenum and jejunum	Stimulates Insulin release Inhibits Gastric acid secretion Gastric emptying
Motilin	Fat Acid Nerve inhibited by food ingestion	M cells of the duodenum and jejunum during fasting	Stimulates interdigestive myoelectric complexes Gastric motility Intestinal motility

Functional types of movements in GIT

Propulsive Movements - Peristalsis

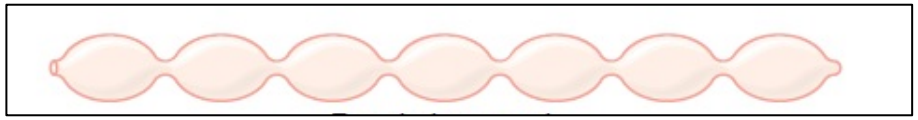
- Stimuli that initiate peristalsis -
  - Distention - orad contraction with downstream receptive relaxation = "Law of the Gut"
  - Irritation of gut epithelium
  - Parasympathetic nervous system

- Function -
  - Myenteric plexus required
  - Congenital absence of plexus - no peristalsis
  - Atropine (blocks Ach receptors) - ↓ peristalsis



Mixing movements

- Local intermittent constrictive contractions (segmentation) → chops the GI contents + mixing it without moving it



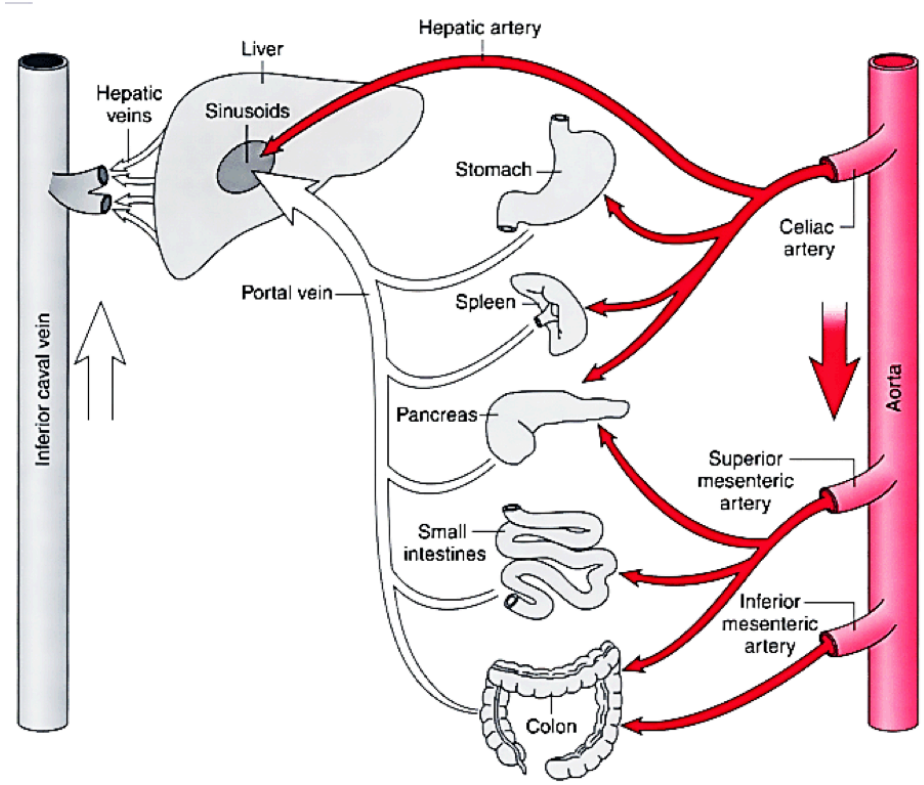
- Peristaltic contractions + sphincter → mixing.

Muscularis Mucosae

- Function-folding of intestinal mucosa+ contraction of intestinal villi
- Mucosal folds →↑surface area exposed to chyme→ ↑absorption
- Mucosal & villous contractions are initiated mainly by local nervous reflexes in the submucosal nerve plexus in response to chyme in SI.

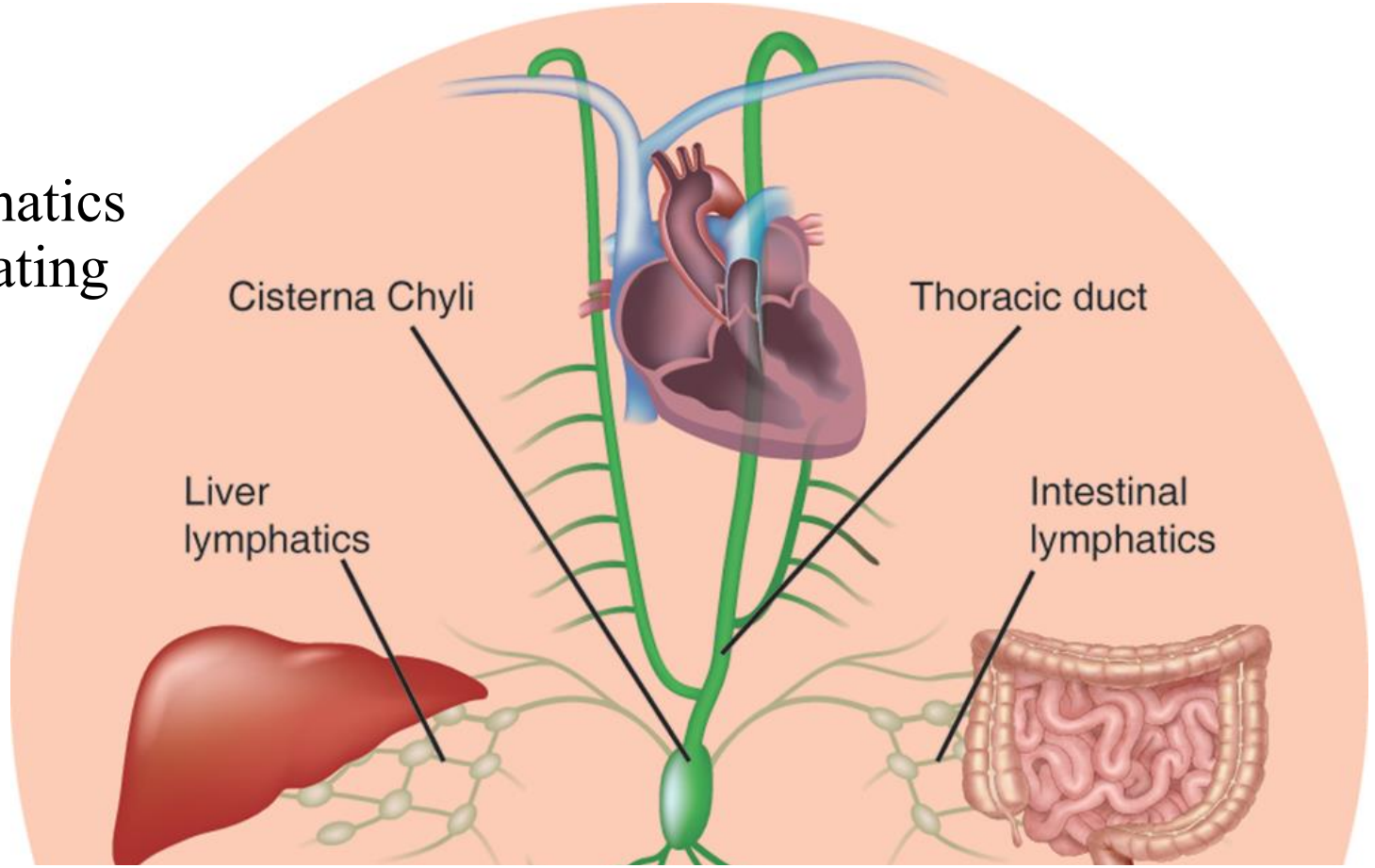
GI blood flow-Splanchnic Circulation

- Components - GI tract, spleen, pancreas, and liver



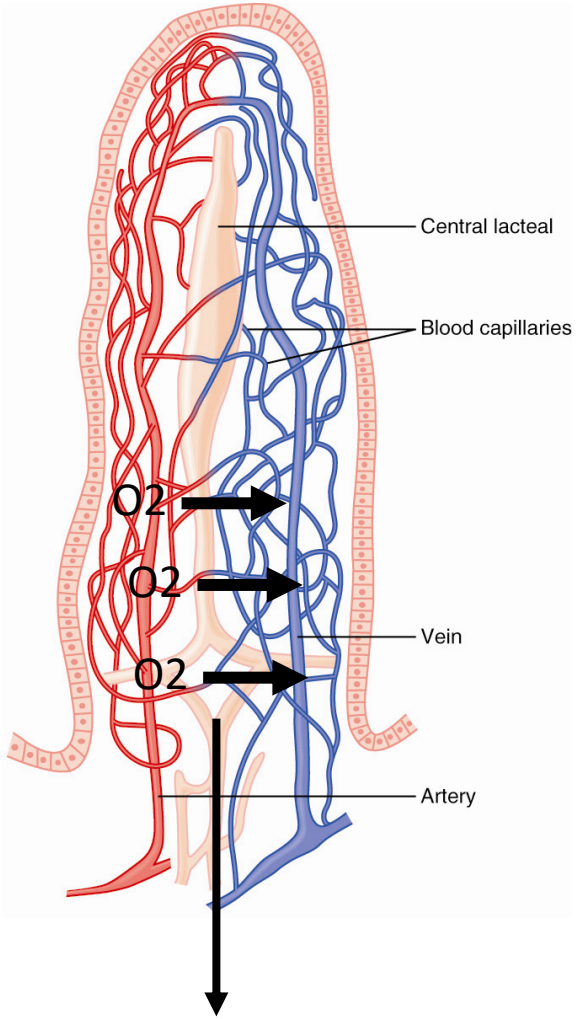
- Feed Arteries (25-30% CO)
  - Celiac artery - stomach, spleen
  - Sup. Mesen. A. - S.I., pancreas, prox. colon
  - Inf. Mesen. A. - majority of colon
- Venous drainage
  - Portal vein → liver sinusoids → hepatic vein
  - Reticuloendothelial cells remove bacteria
  - 1/2 to 1/3 water-soluble nutrients (Carb. & proteins) removed and stored in liver

-Fats absorbed into intestinal lymphatics → thoracic duct → systemic circulating (bypassing the liver).



Blood flow through intestinal villus

- Countercurrent Blood Flow in the Villi
  - 80% oxygen is shunted from artery to vein
    - Not harmful
    - In disease conditions e.g Circulatory Shock → Splanchnic blood flow ↓ → Villus tip or entire villus suffers ischemic death → ↓ Absorptive capabilities
    - Lymph flows freely from the central lacteals of villi into lymphatic system



Control of Gut Blood Flow

- Blood flow proportional to local activity
  - Meal → ↑ blood flow
  - ↑ motor activity → ↑blood flow

- Causes of activity-induced blood flow
  - Vasodilator hormones - CCK, VIP, gastrin, secretin.
  - Vasodilator kinins-kallidin, bradykinin
  - Low oxygen (high adenosine)

- Nervous control of blood flow
  - PNS - ↑ gut activity → ↑ blood flow
  - SNS, exercise, shock - Directly ↓ blood flow- overcome> Autoregulatory escape (local metabolic vasodilator mechanisms)
  - SNS – vasoconstriction of intestinal and mesenteric veins to sustain (200-400 ml) the general circulation


The End