Gastrointestinal Physiology

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The Role of GIT

- Provides the body with water, electrolytes and nutrients
- Requires:

1. Movement of food
2. Break down the food to absorbable materials
3. Digestion of food by different juices
4. Absorption of digestive materials
5. Transferring the product via circulation

- Controlled by nervous system

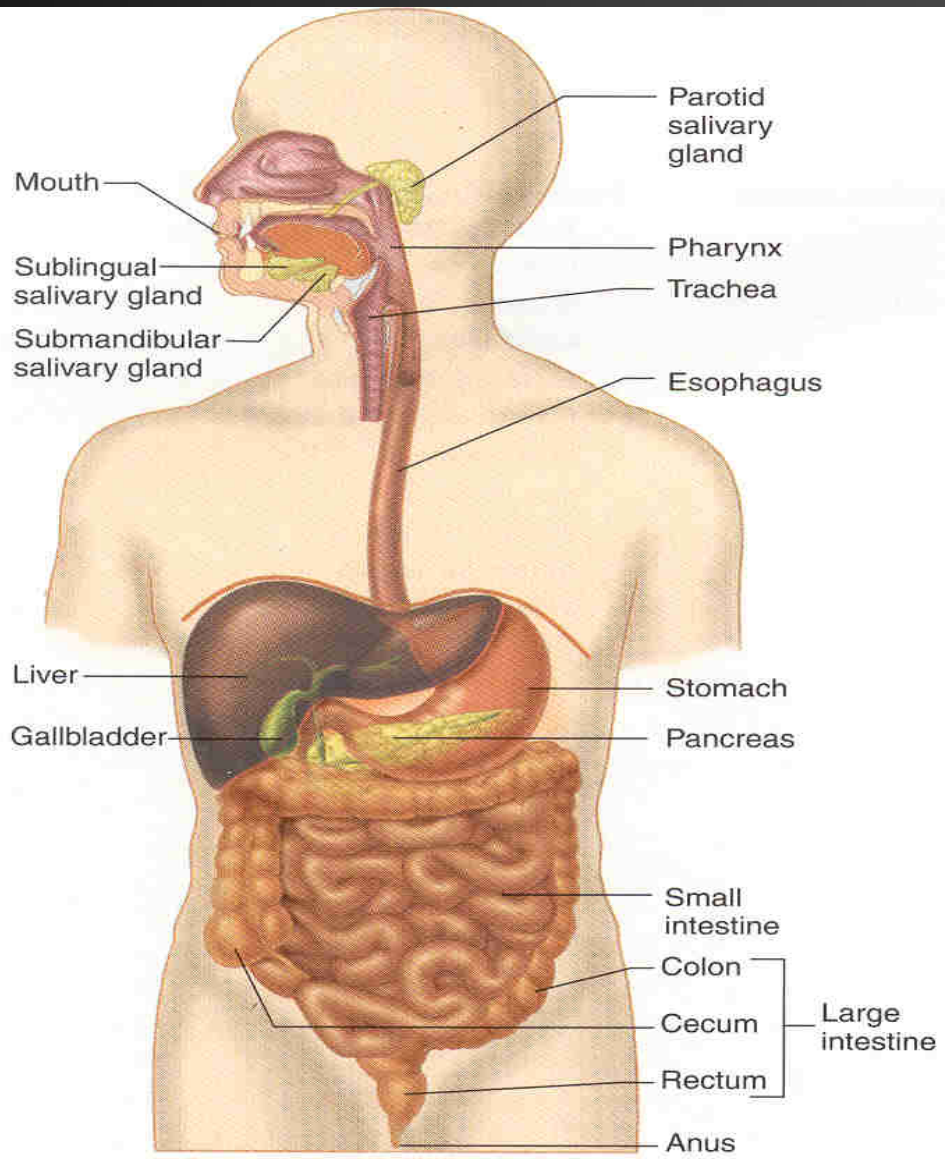


FIGURE 17–1

Anatomy of the gastrointestinal system. The liver overlies the gallbladder and a portion of the stomach, and the stomach overlies part of the pancreas.

SMOOTH MUSCLE OF G.I.

TWO SMOOTH MUSCLE CLASSIFICATIONS

- Unitary type
  - Contract spontaneously in the absence of neural or hormonal influence but in response to stretch (such as in stomach and intestine)
  - Cells are electrically coupled via gap junctions
- Multiunit type
  - Do not contract in response to stretch or without neural input (such as in esophagus & gall bladder)

The Musculature of the Digestive Tract

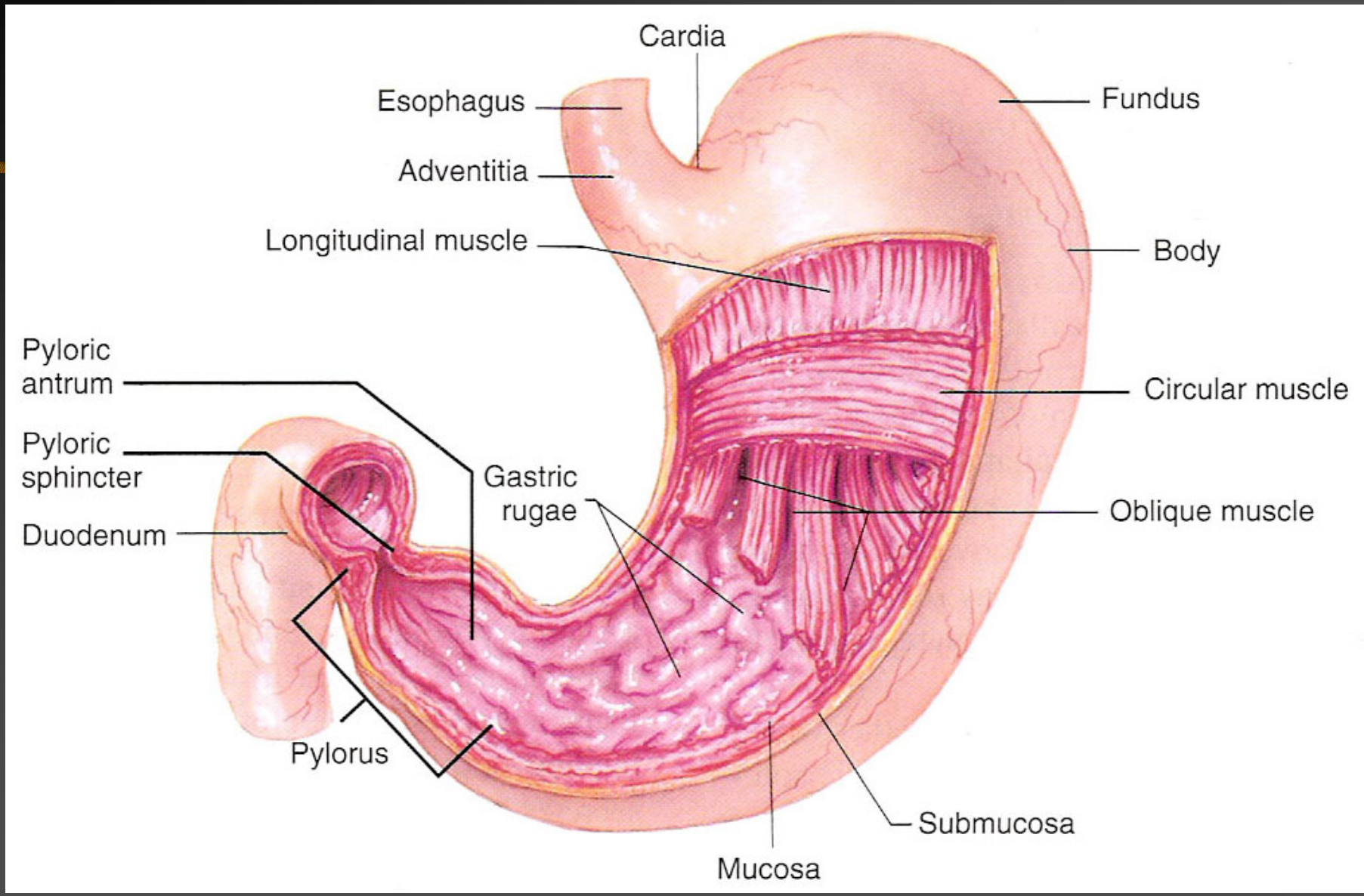
- Two main muscle layers:
  - Longitudinal muscle layer
  - Circular muscle layer
  - Oblique muscle layer (stomach only)

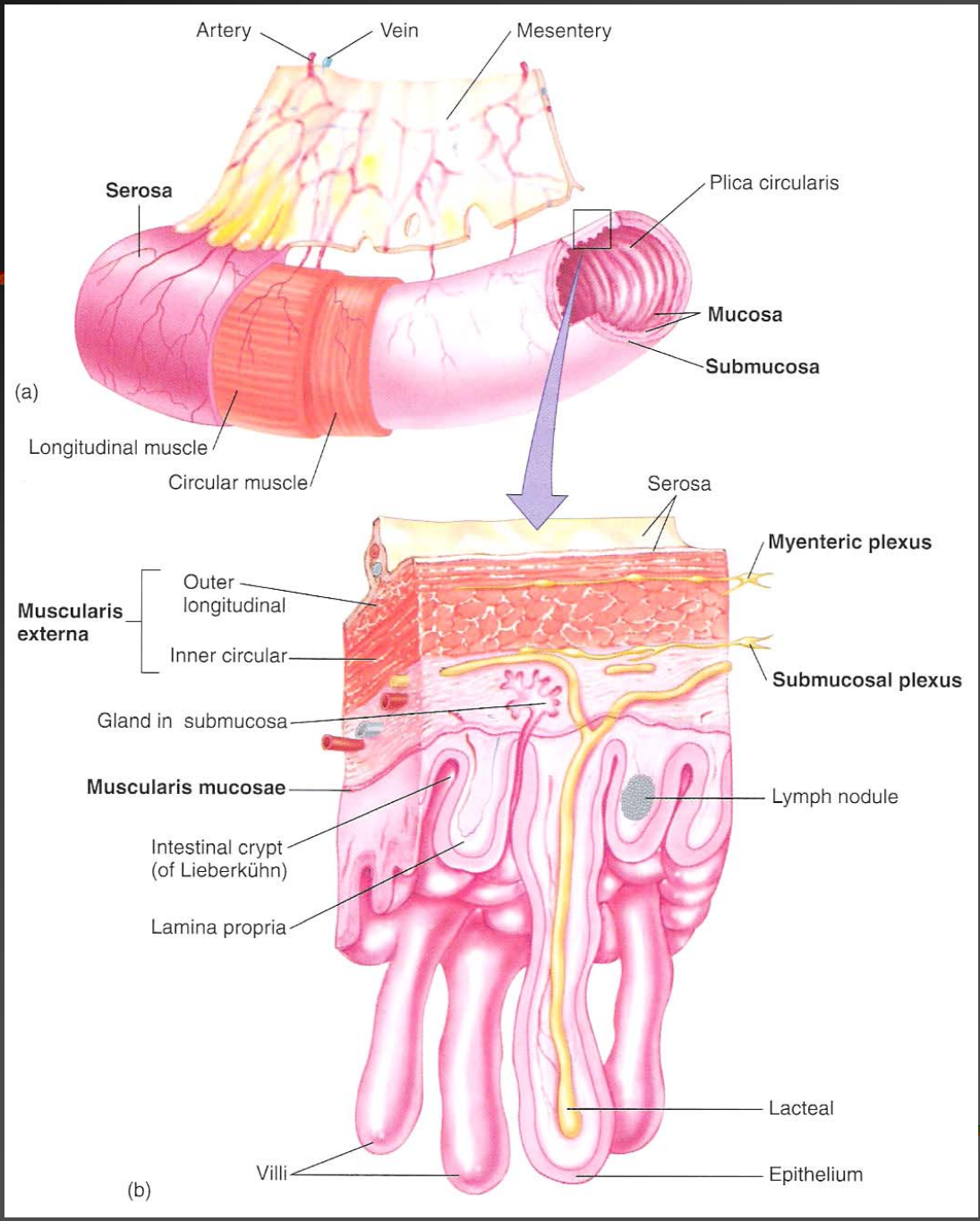
The Musculature of the Digestive Tract

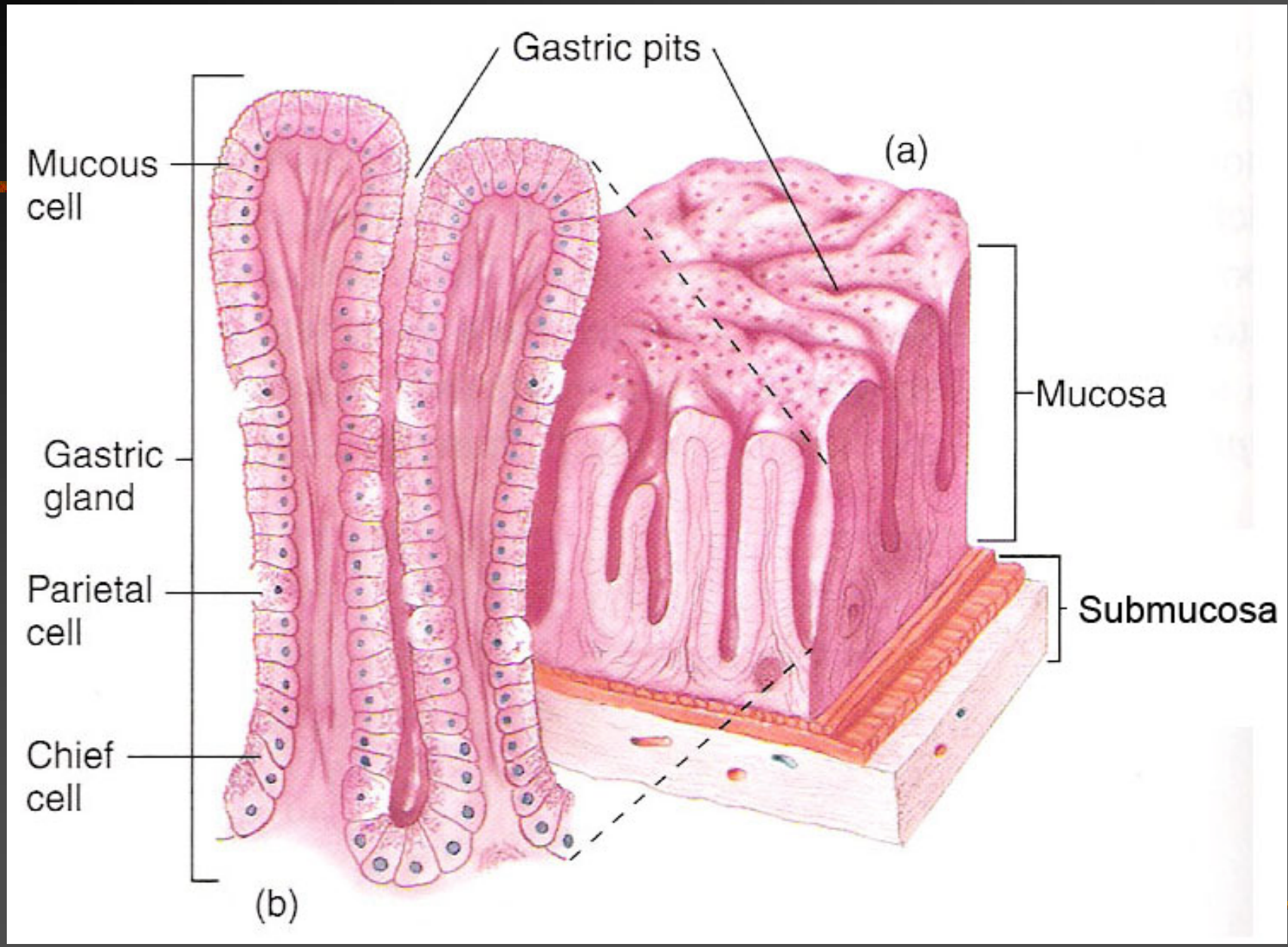
- Longitudinal Muscle:
  - Contraction shortens the segment of the intestine and expands the lumen
  - Innervated by ENS, mainly by excitatory motor neuron
  - Ca influx from out side is important

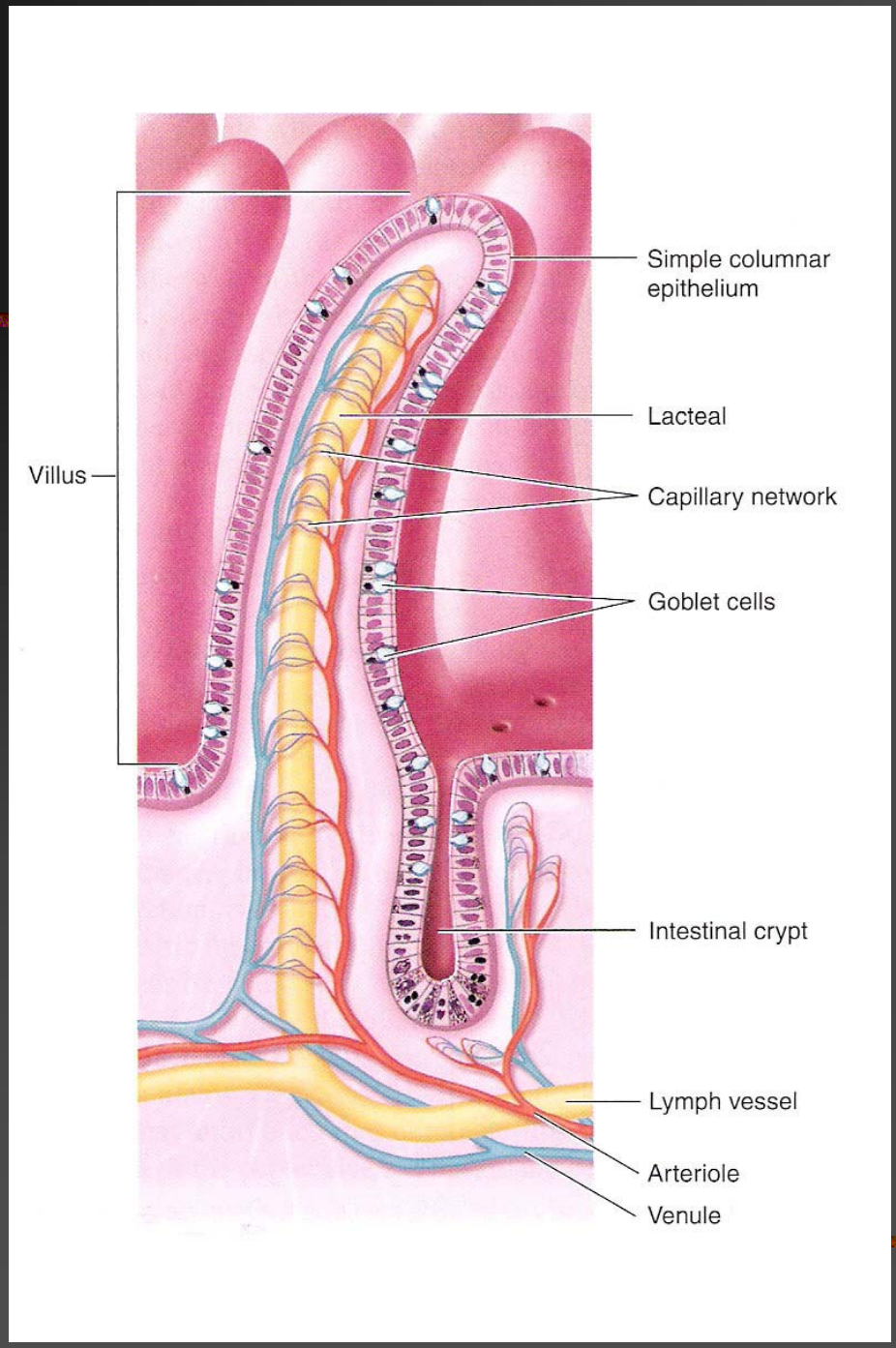
The Musculature of the Digestive Tract

- Circular muscle:
  - Thicker and more powerful than longitudinal
  - Contraction reduces the diameter of the lumen and increases its length
  - Innervated by ENS, both excitatory and inhibitory motor neurons
  - More gap junctions than in longitudinal muscle
  - Intracellular release of Ca is more important


Cardia
Esophagus
Fundus
Adventitia
Longitudinal muscle
Body
Pyloric antrum
Circular muscle
Pyloric sphincter
Gastric rugae
Oblique muscle
Duodenum
Pylorus
Submucosa
Mucosa


Artery
Vein
Mesentery
Serosa
Plica circularis
Mucosa
Submucosa
(a)
Longitudinal muscle
Circular muscle
Serosa
Myenteric plexus
Muscularis externa
Outer longitudinal
Inner circular
Submucosal plexus
Gland in submucosa
Muscularis mucosae
Lymph nodule
Intestinal crypt (of Lieberkühn)
Lamina propria
Lacteal
Villi
Epithelium
(b)


Gastric pits
Mucous cell
(a)
Mucosa
Gastric gland
Parietal cell
Submucosa
Chief cell
(b)


Simple columnar epithelium
Lacteal
Villus
Capillary network
Goblet cells
Intestinal crypt
Lymph vessel
Arteriole
Venule

Electromechanical & Pharmacomechanical Coupling Trigger Contractions in GI Muscles

- Depolarization opens the voltage-gated Ca channels (electromechanical coupling)
- Ligands open the ligand-gated Ca channels (pharmacomechanical coupling)

Gastrointestinal Peptides

- Hormones
  - endocrine cells
  - via portal circulation and liver
  - e.g., gastrin, CCK, secretin and GIP

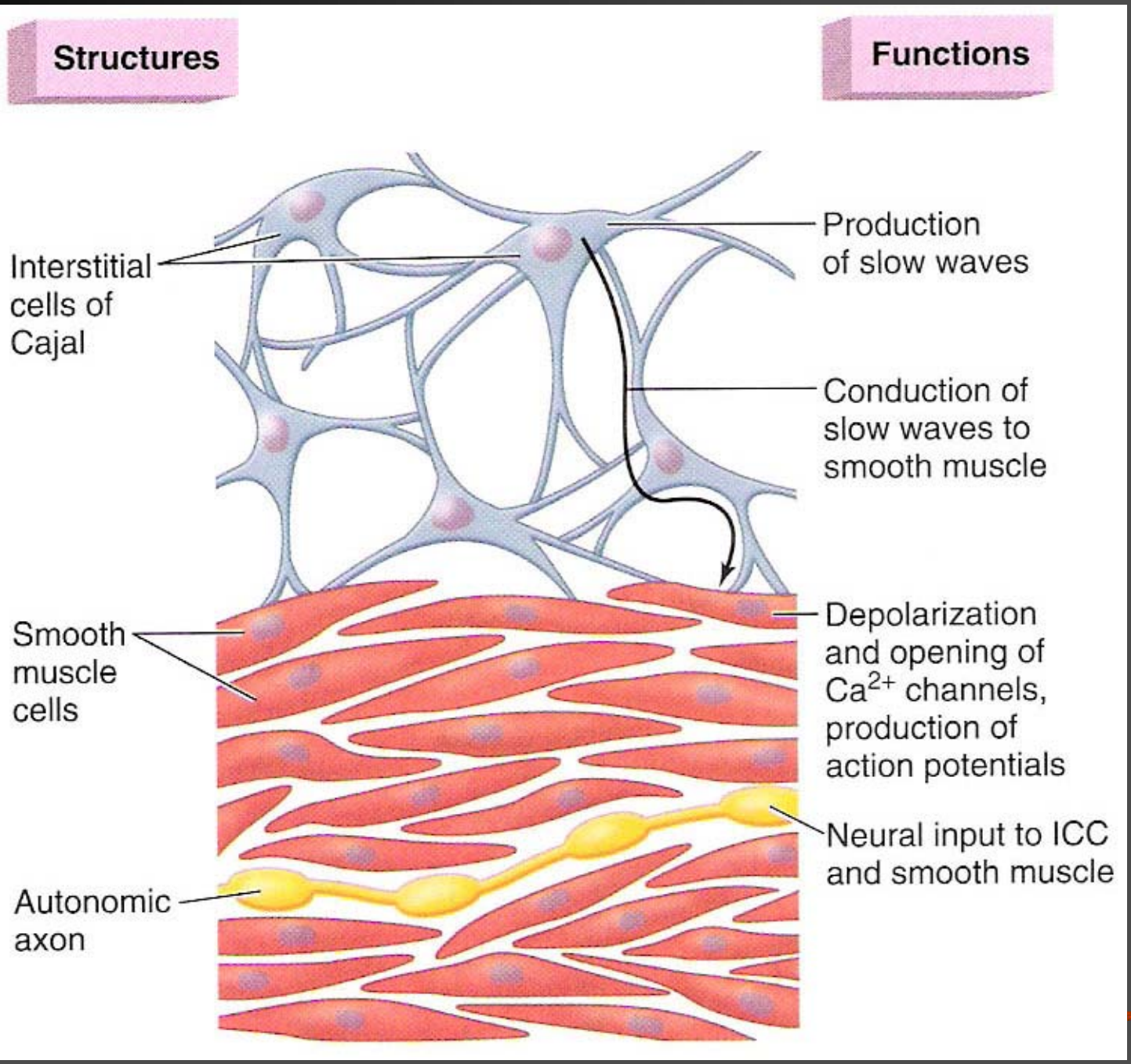
- Paracrines
  - endocrine cells
  - thru diffusion at the same tissue
  - e.g., somatostatin (mucosa), to inhibits gastric H secretion

- Neurocrines
  - neuronal cells in GI tract
  - e.g., VIP, GRP and Enkephalins

Slow Waves & Action potentials are Forms of Electrical Activity in GI Muscles

Slow waves

- Unknown cause
- Responsible for triggering AP in G.I.
- Interstitial cells of Cajal, ICCs (pacemaker)
  - Myenteric border
  - Submucosa border
- Occur at different frequency
  - stomach (3/min)
  - small intestine (duodenum, 12-18/min)
  - ileum & colon (6-10/min)
- May or may not accompanied by AP


Structures
Functions
Interstitial cells of Cajal
Production of slow waves
Conduction of slow waves to smooth muscle
Smooth muscle cells
Depolarization and opening of Ca^{2+} channels, production of action potentials
Neural input to ICC and smooth muscle
Autonomic axon

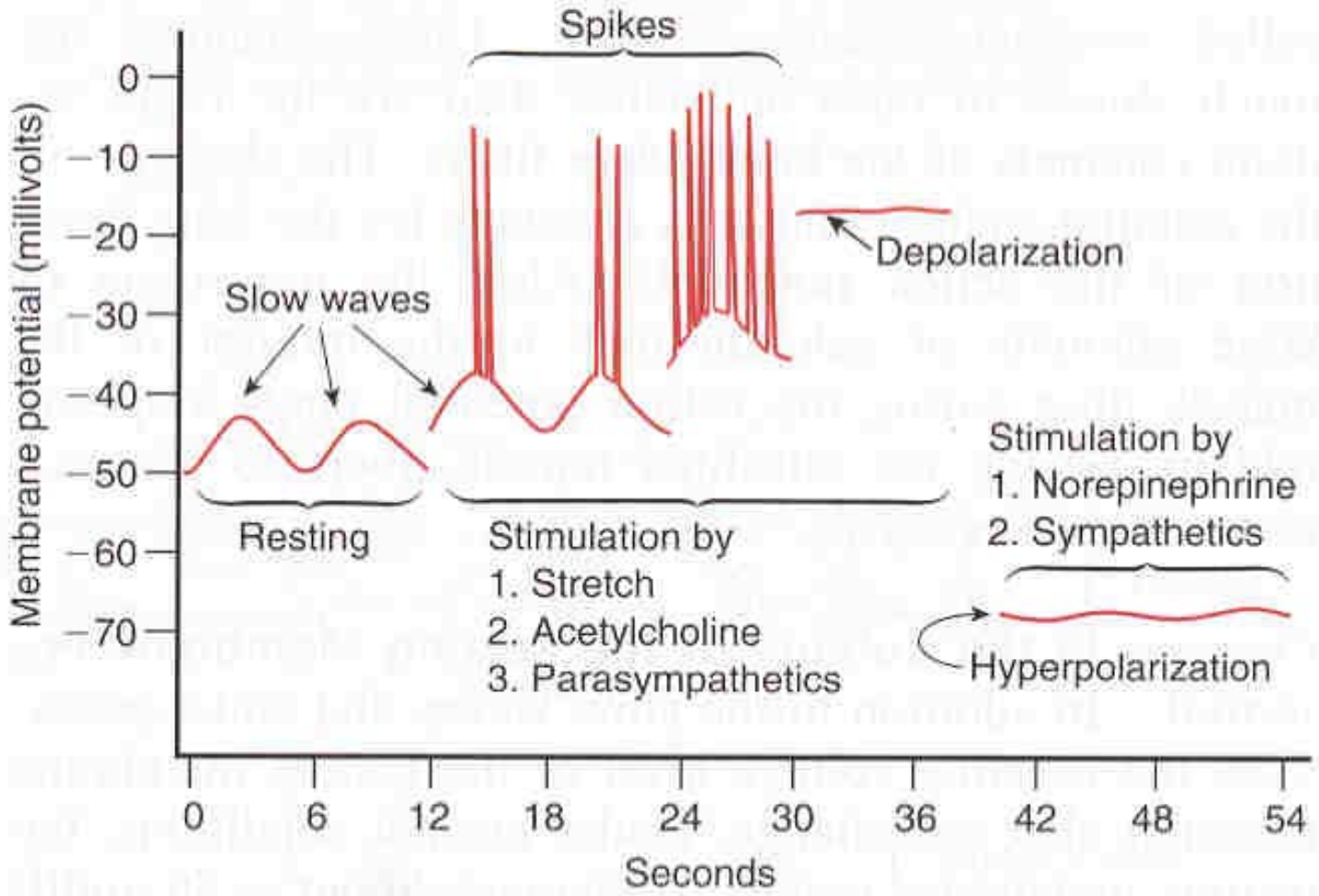


FIGURE 62–3

Membrane potentials in intestinal smooth muscle. Note the slow waves, the spike potentials, total depolarization, and hyperpolarization, all of which occur under different physiologic conditions of the intestine.

Slow Waves & Action potentials are Forms of Electrical Activity in GI Muscles

- Factors that depolarize the membrane:
  - Stretching of the muscle
  - Ach
  - Parasympathetic stimulation
  - Hormonal stimulation

- Factors that hyperpolarize the membrane:
  - Norepinephrine
  - Sympathetic stimulation

CONTROL OF DIGESTIVE FUNCTIONS BY NERVOUS SYSTEM

- Autonomic nervous system (ANS) is divided into
  - Parasympathetic
  - Sympathetic
  - ENS

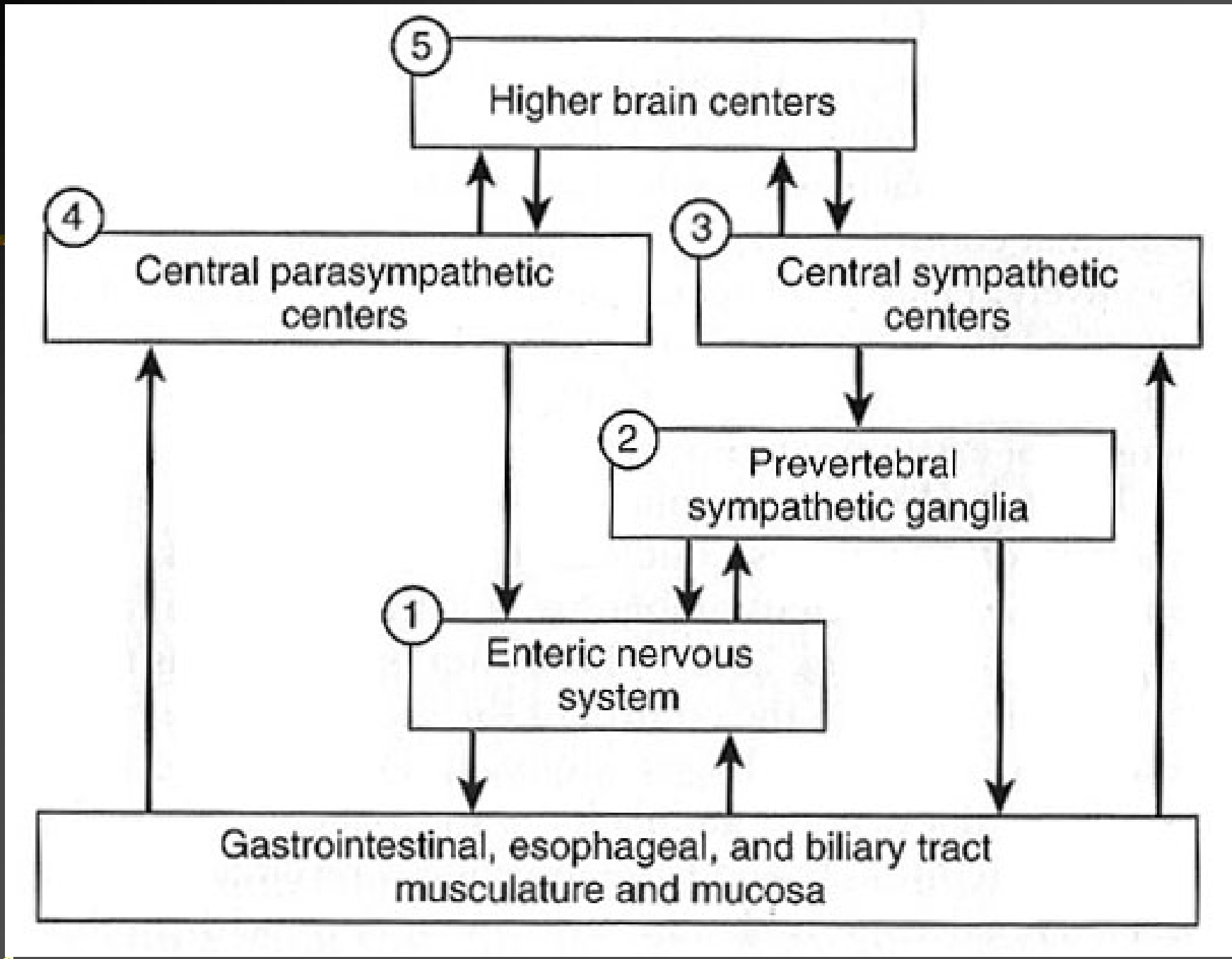
CONTROL OF DIGESTIVE FUNCTIONS BY NERVOUS SYSTEM

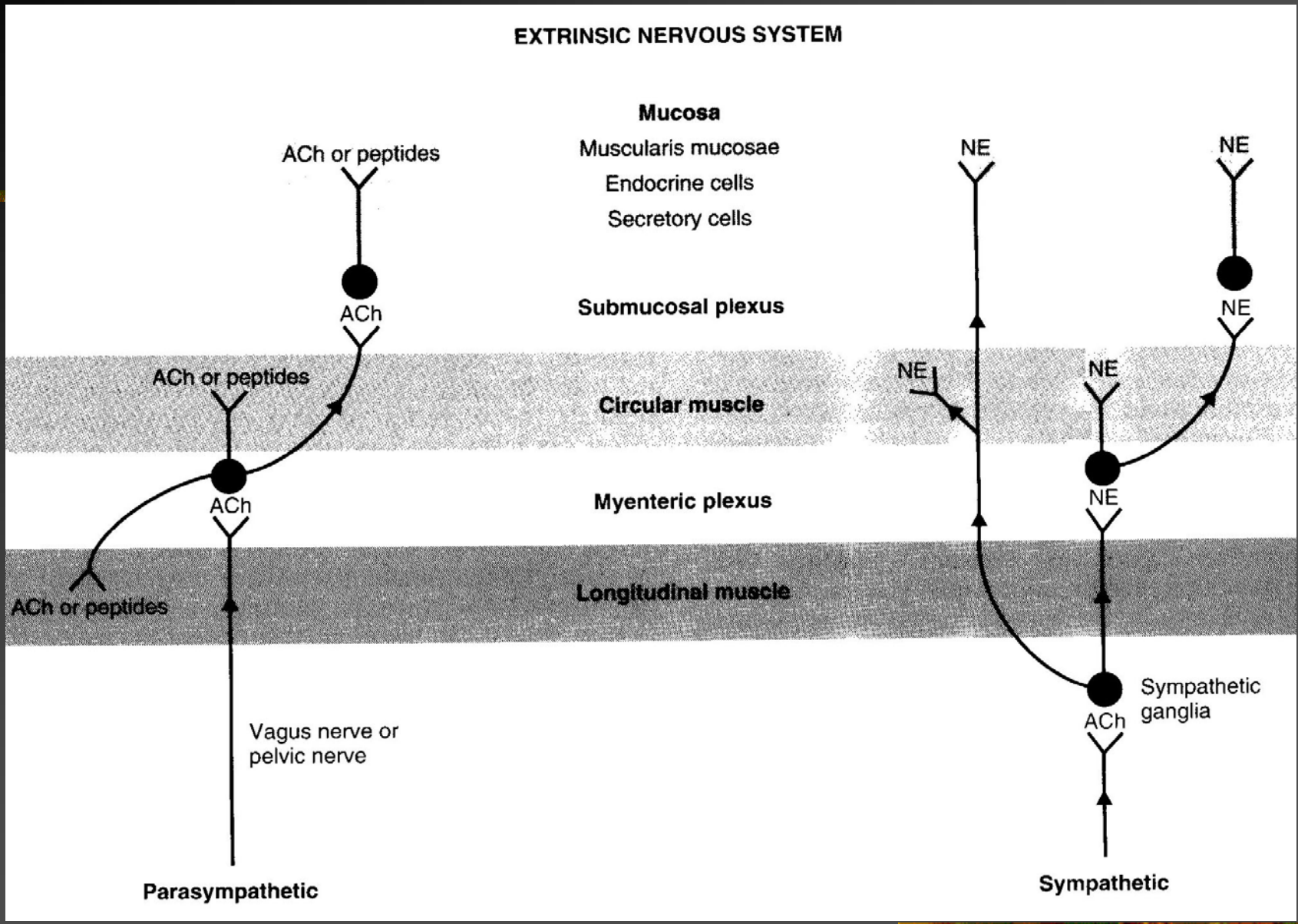
- Parasympathetic Nerves:

- Located in brain stem & sacral region
- Projection to the G.I. are preganglionic efferents
- Vagus & pelvic nerves
- Vagus nerves synapse with neurons of ENS in esophagus, stomach, small intestine, colon, gall bladder & pancreas
- Pelvic nerves synapse with ENS in large intestine
- Neurotransmitter is Ach

CONTROL OF DIGESTIVE FUNCTIONS BY NERVOUS SYSTEM

- Sympathetic nerves:
  - Located in thoracic & lumbar regions
  - Neurotransmitter is NE
  - NE increases sphincter tension
  - Inactivate the motility


5
Higher brain centers
4
Central parasympathetic centers
3
Central sympathetic centers
2
Prevertebral sympathetic ganglia
1
Enteric nervous system
Gastrointestinal, esophageal, and biliary tract musculature and mucosa


EXTRINSIC NERVOUS SYSTEM
Mucosa
Muscularis mucosae
Endocrine cells
Secretory cells
Submucosal plexus
Circular muscle
Myenteric plexus
Longitudinal muscle
ACh or peptides
ACh
ACh or peptides
ACh
ACh or peptides
Vagus nerve or
pelvic nerve
Parasympathetic
NE
NE
NE
NE
NE
NE
NE
Sympathetic
ganglia
ACh
Sympathetic

CONTROL OF DIGESTIVE FUNCTIONS BY NERVOUS SYSTEM

- Enteric Nervous System (minibrain)
  - Has as many neurons as spinal cord
  - Located close to the effector systems such as:
    - Musculature
    - Glands
    - Blood vessels (from esophagus to the anus)
  - Consists of ganglia & fibers projecting to the effector systems

CONTROL OF DIGESTIVE FUNCTIONS BY NERVOUS SYSTEM

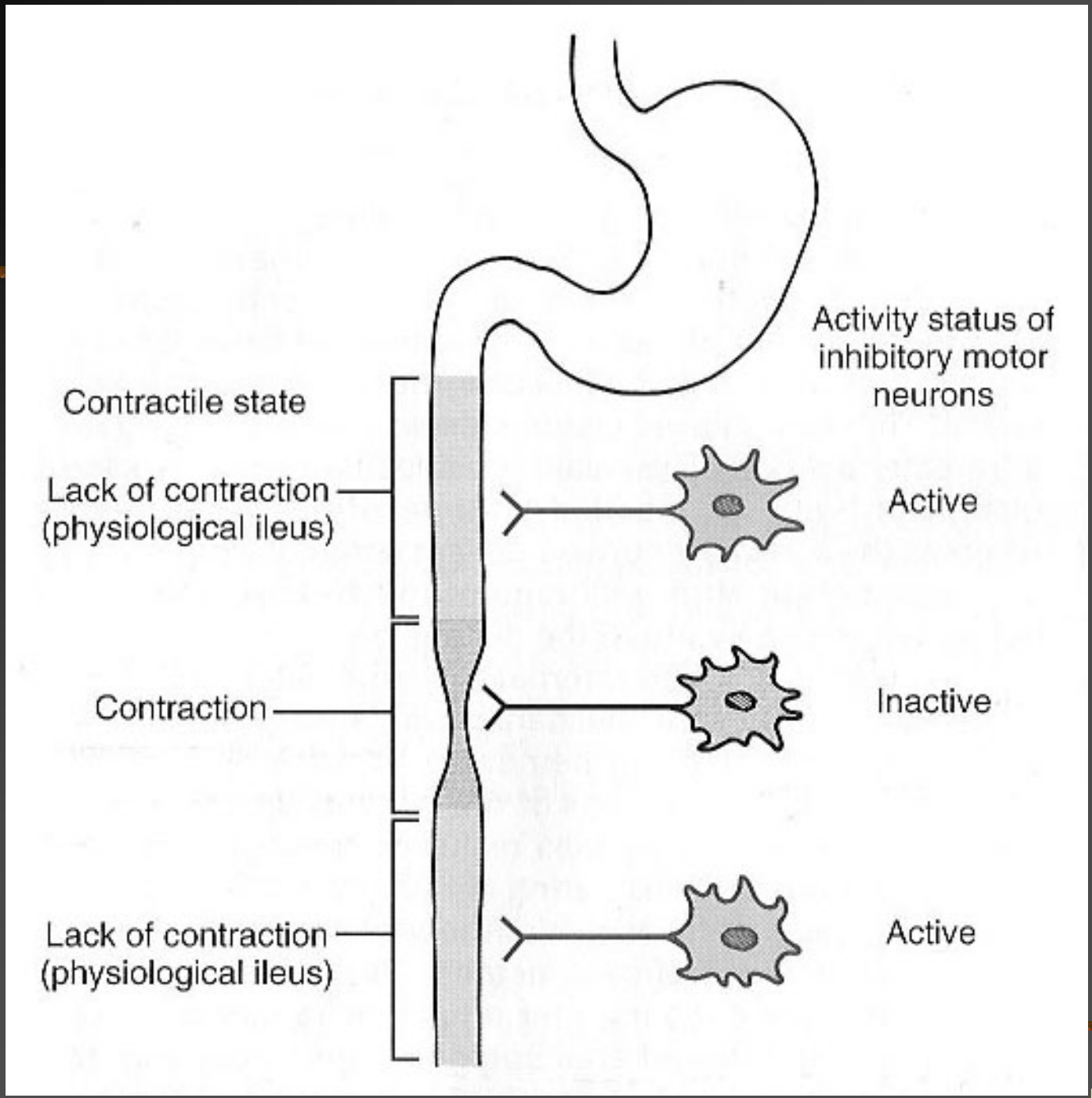
Enteric Nervous System (minibrain)

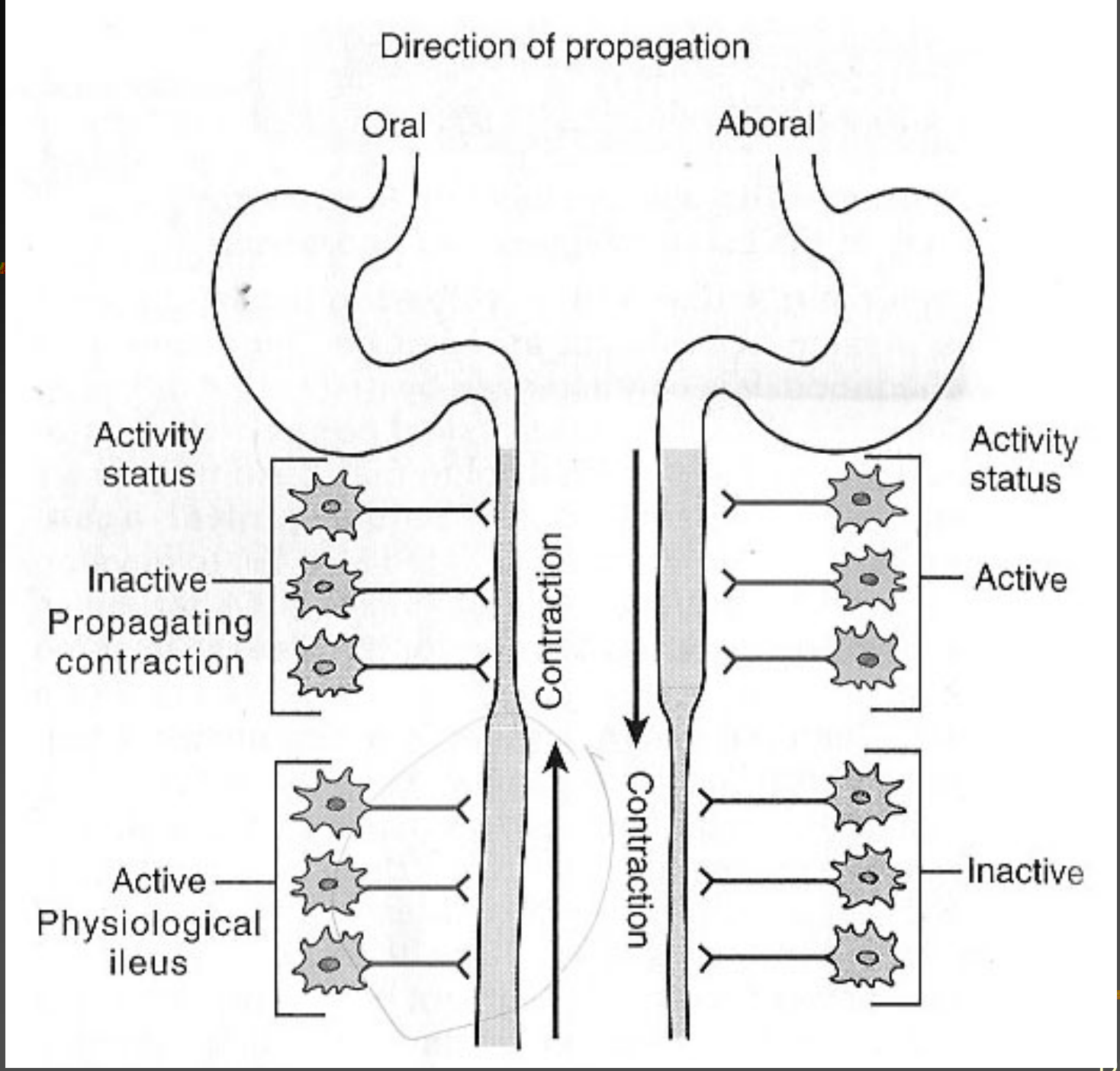
- Composes of two plexuses:

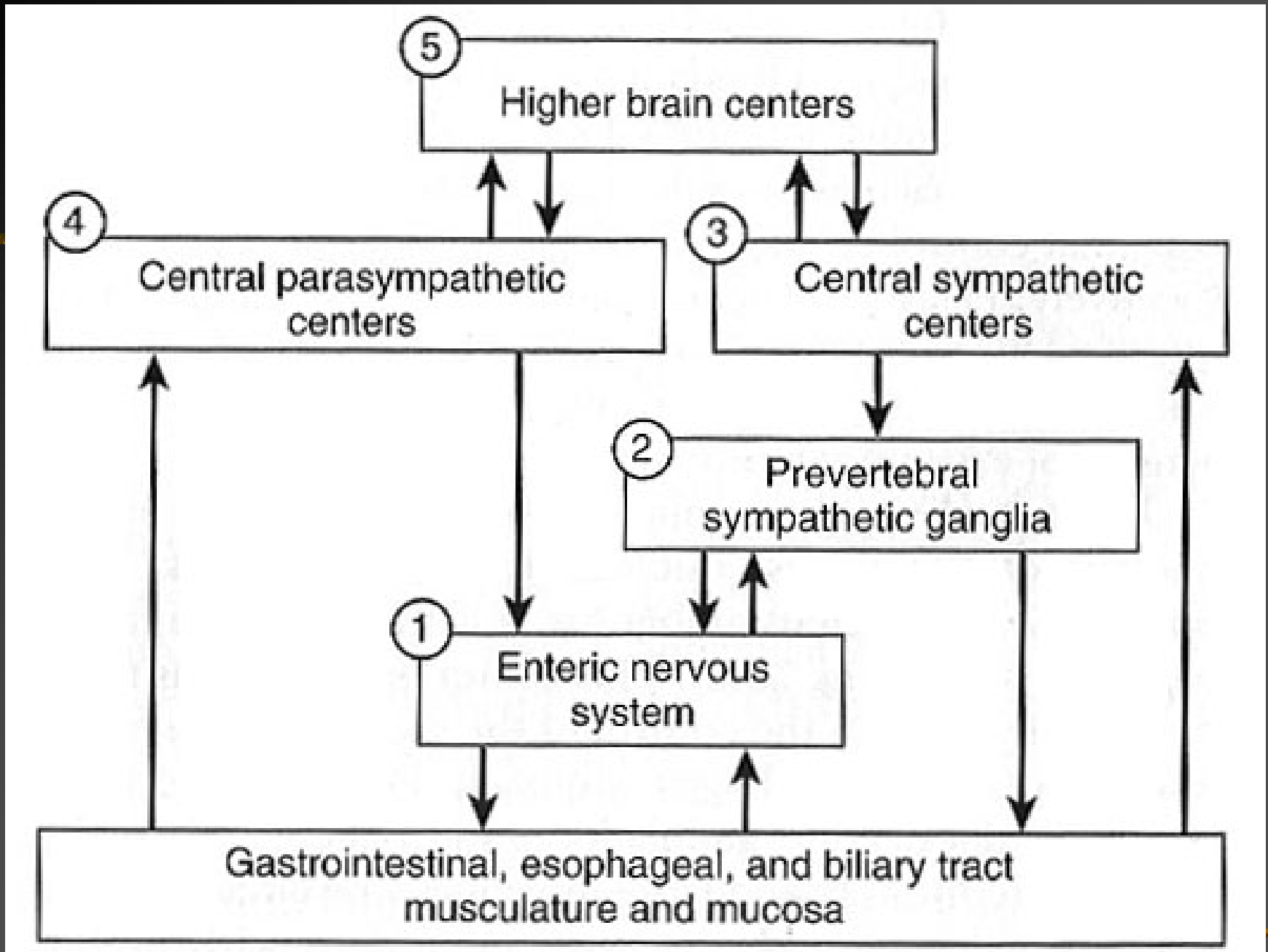
1- myenteric plexus: excitatory or inhibitory (outer plexus)

- increases intensity of rhythm of contraction
- increases tone
- increases rhythm rate
- increases velocity of conduction of excitatory waves

2- Submucous plexus (inner plexus)


Activity status of inhibitory motor neurons
Contractile state
Lack of contraction (physiological ileus)
Active
Contraction
Inactive
Lack of contraction (physiological ileus)
Active


Direction of propagation
Oral
Aboral
Activity status
Inactive
Propagating contraction
Active
Physiological ileus
Contraction
Contraction
Activity status
Active
Inactive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2
Prevertebral sympathetic ganglia
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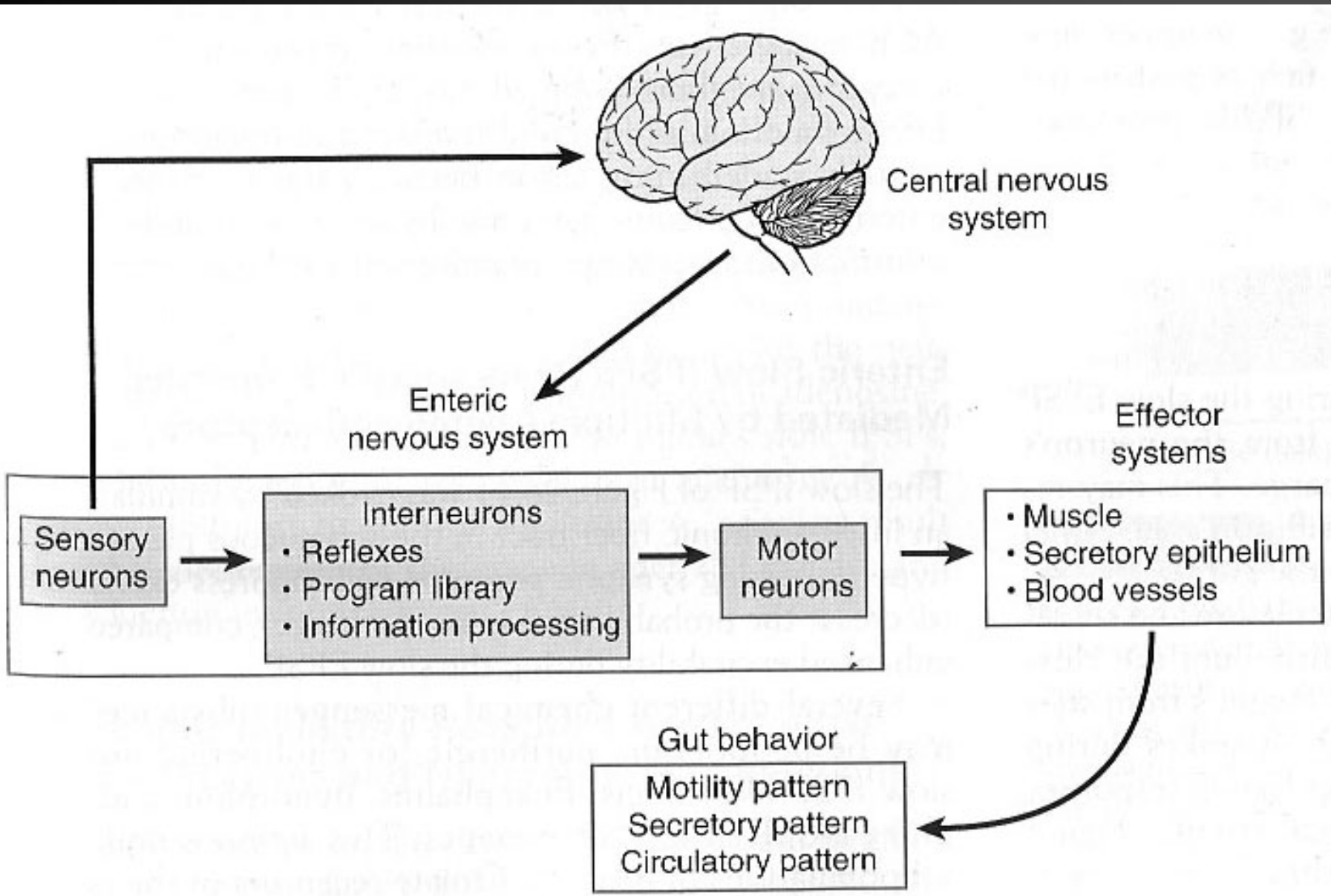
Enteric nervous system
Gastrointestinal, esophageal, and biliary tract musculature and mucosa


Central nervous system
Enteric nervous system
Effector systems
Sensory neurons
Interneurons
• Reflexes
• Program library
• Information processing
Motor neurons
• Muscle
• Secretory epithelium
• Blood vessels
Gut behavior
Motility pattern
Secretory pattern
Circulatory pattern

Excitatory Motor Neurons Evoke Muscle Contraction & Intestinal Secretion

- Neurotransmitters of motor neurons:

1. Substance P
2. Ach

- Neurotransmitters of secretomotor neurons (releasing of water, electrolytes and mucus from crypts of Lieberkuhn):

1. Ach
2. VIP
3. Histamine (neurogenic secretory diarrhea)

Inhibitory Motor Neurons Suppress Muscle Contraction

- Neurotransmitters:

1. ATP
2. NO
3. VIP

N.B. Longitudinal muscles do not have inhibitory motor innervation

SMOOTH MUSCLE OF G.I.

- Phasic contractions

  - periodic contractions followed by relaxation; such as in gastric antrum, small intestine and esophagus

- Tonic contractions

  - maintained contraction without relaxation; such as in orad region of the stomach, lower esoghageal, ileocecal and internal anal sphincter

  - not associated with slow waves

SMOOTH MUSCLE OF G.I.

- Tonic contractions (continued):

  - Caused by:

- Continuous repetitive spike potential
- Hormonal effects
- Continuous entery of Ca

TABLE 8–2. Summary of Gastrointestinal Hormones

Hormone	Hormone Family	Site of Secretion	Stimuli for Secretion	Actions
Gastrin	Gastrin-CCK	G cells of the stomach	Small peptides and amino acids Distention of the stomach Vagal stimulation (GRP)	↑ Gastric H^+ secretion Stimulates growth of gastric mucosa
Cholecystokinin (CCK)	Gastrin-CCK	I cells of the duodenum and jejunum	Small peptides and amino acids Fatty acids	↑ Pancreatic enzyme secretion ↑ Pancreatic HCO_3^- secretion Stimulates contraction of the gallbladder and relaxation of the sphincter of Oddi Stimulates growth of the exocrine pancreas and gallbladder Inhibits gastric emptying
Secretin	Secretin-glucagon	S cells of the duodenum	H^+ in the duodenum Fatty acids in the duodenum	↑ Pancreatic HCO_3^- secretion ↑ Biliary HCO_3^- secretion ↓ Gastric H^+ secretion Inhibits trophic effect of gastrin on gastric mucosa
Gastric inhibitory peptide (GIP)	Secretin-glucagon	Duodenum and jejunum	Fatty acids Amino acids Oral glucose	↑ Insulin secretion from pancreatic β cells ↓ Gastric H^+ secretion

TABLE 8–1. Neurotransmitters and Neuromodulators in the Enteric Nervous System

Substance	Source	Actions
Acetylcholine (ACh)	Cholinergic neurons	Contraction of smooth muscle in wall Relaxation of sphincters ↑ Salivary secretion ↑ Gastric secretion ↑ Pancreatic secretion
Norepinephrine (NE)	Adrenergic neurons	Relaxation of smooth muscle in wall Contraction of sphincters ↑ Salivary secretion
Vasoactive intestinal peptide (VIP)	Neurons of mucosa and smooth muscle	Relaxation of smooth muscle ↑ Intestinal secretion ↑ Pancreatic secretion
Gastrin-releasing peptide (GRP) or bombesin	Neurons of gastric mucosa	↑ Gastrin secretion
Enkephalins (opiates)	Neurons of mucosa and smooth muscle	Contraction of smooth muscle ↓ Intestinal secretion
Neuropeptide Y	Neurons of mucosa and smooth muscle	Relaxation of smooth muscle ↓ Intestinal secretion
Substance P	Cosecreted with ACh	Contraction of smooth muscle ↑ Salivary secretion