GASTROINTESTINAL PHYSIOLOGY

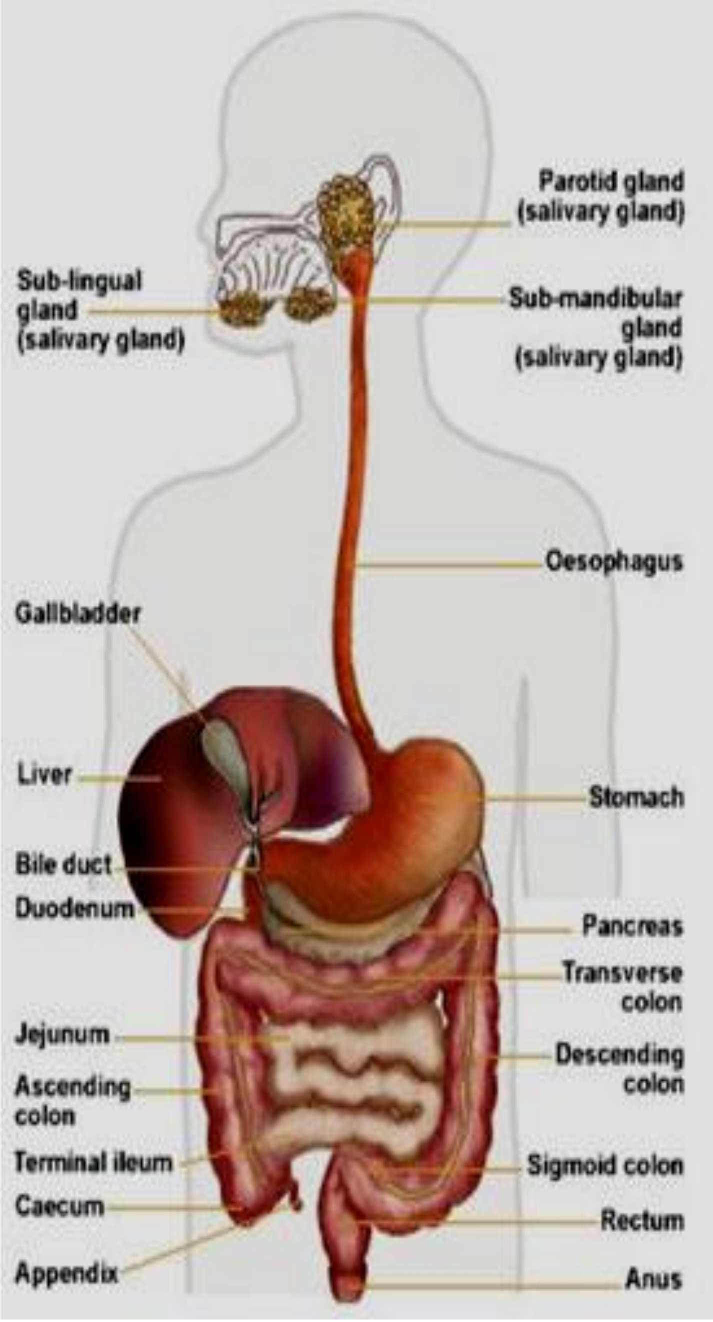
Elias Jan Arteen FRCSI

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

- **The alimentary tract provides the body with a continual supply of water, electrolytes, vitamins, and nutrients.**
- ***To achieve this requires***
  - ***Movement*** **of food through the alimentary tract.**
  - ***Secretion*** **of digestive juices and digestion of the food.**
  - ***Absorption*** **of water, various electrolytes, vitamins, and digestive products.**
  - ***Circulation*** **of blood through the gastrointestinal organs to carry away the absorbed substances.**
  - ***Control*** **of all these functions by local, nervous, and hormonal systems.**

Digestive System

- It is <u>*5 meters*</u> in living persons and <u>*8 meters*</u> outside the body.
- It is a muscular tube and its lumen is continuous with the mouth and the anus.
- The digestive tract is continuous with the external environment.



Components of digestive system

It consists of :

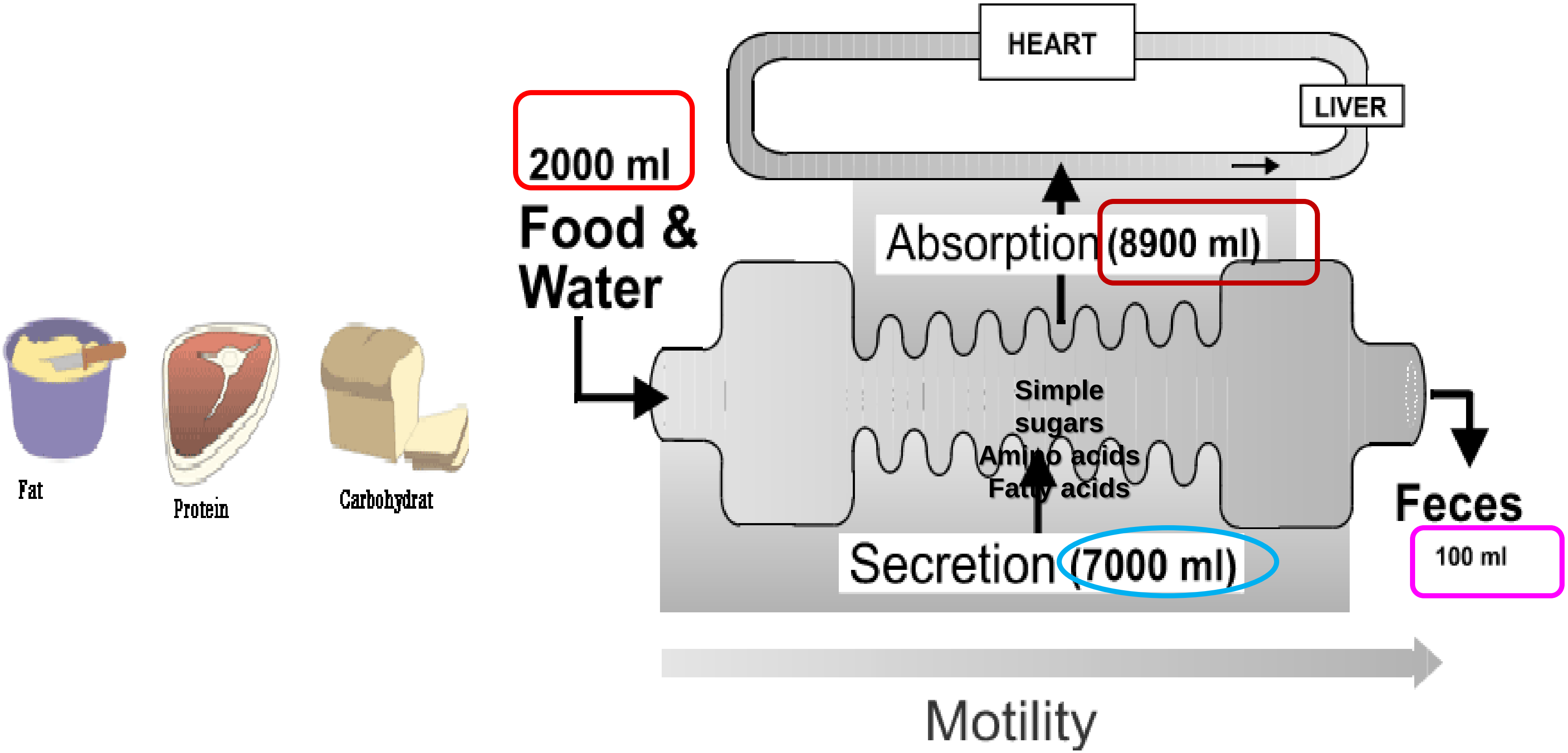
1 ***Alimentary canal*** (starts at the mouth and ends at the anus, consists of:

- *Mouth , pharynx & esophagus.*
- *Stomach.*
- *Small intestine (duodenum, jejunum. Ileum).*
- *Large intestine (cecum, appendix, colon & rectum).*

2 ***Digestive glands*** (Salivary glands, Liver, Gall Bladder, Exocrine Pancreas).

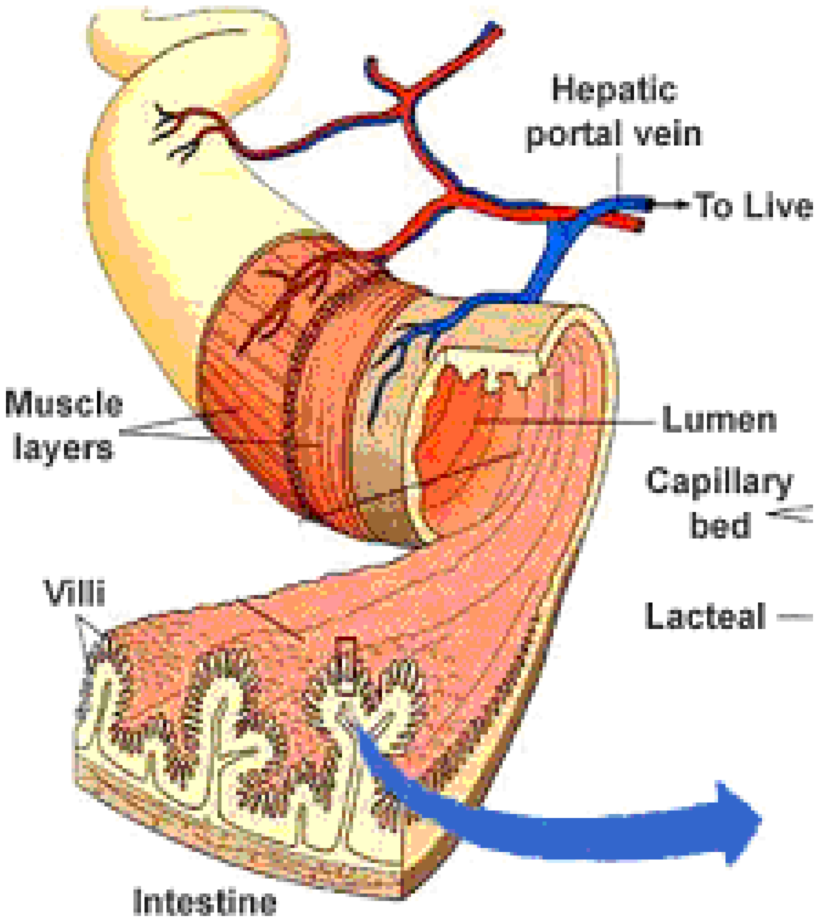
General functions of the Gut

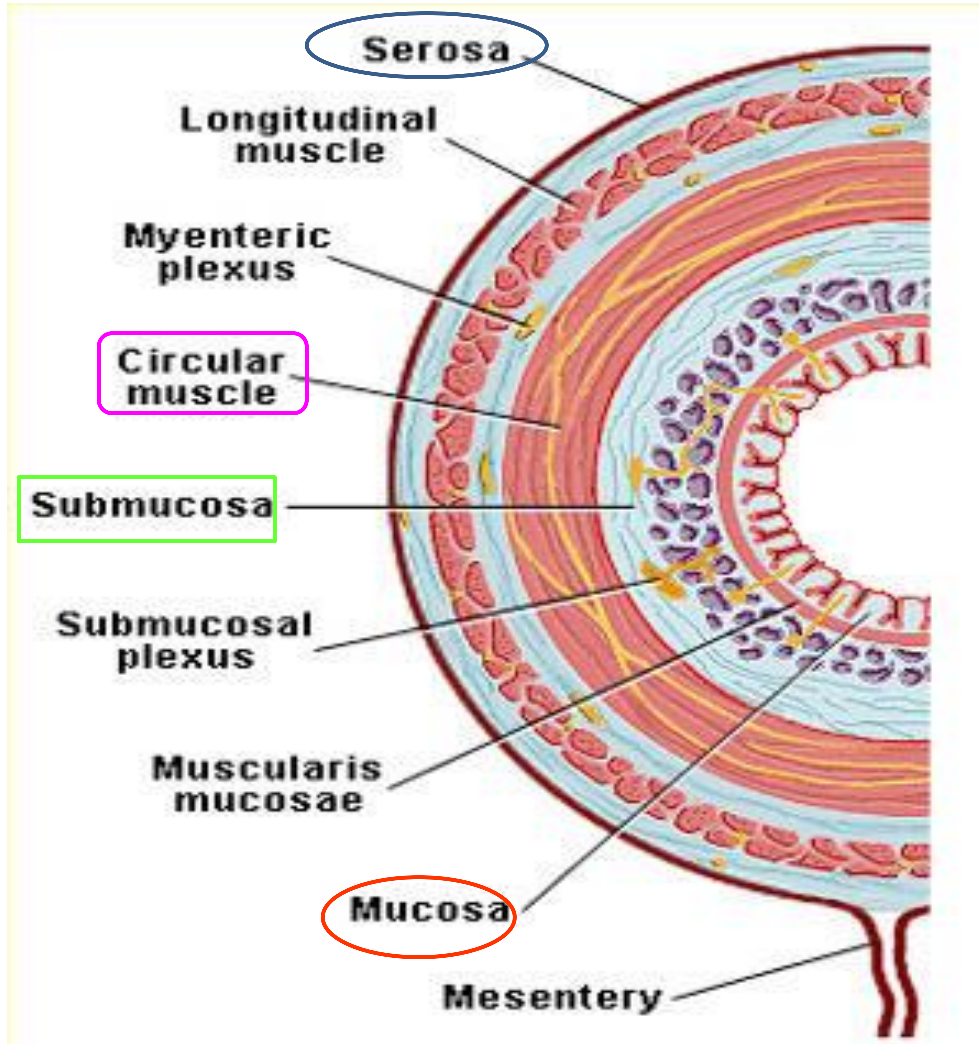
- *Food digestion.* **What is the definition of digestion?**
  (Digestion is the breakdown of complex molecules into simple ones to facilitate their absorption).
- **i.e. CHO⇨ Monosaccharide's, Proteins Amino Acids, Fat ⇨ Fatty Acids). The process of digestion needs:-**
  - **Secretion of digestive juices.**
  - **Wall motility**
- **Food absorption**
- **Excretion of waste products**

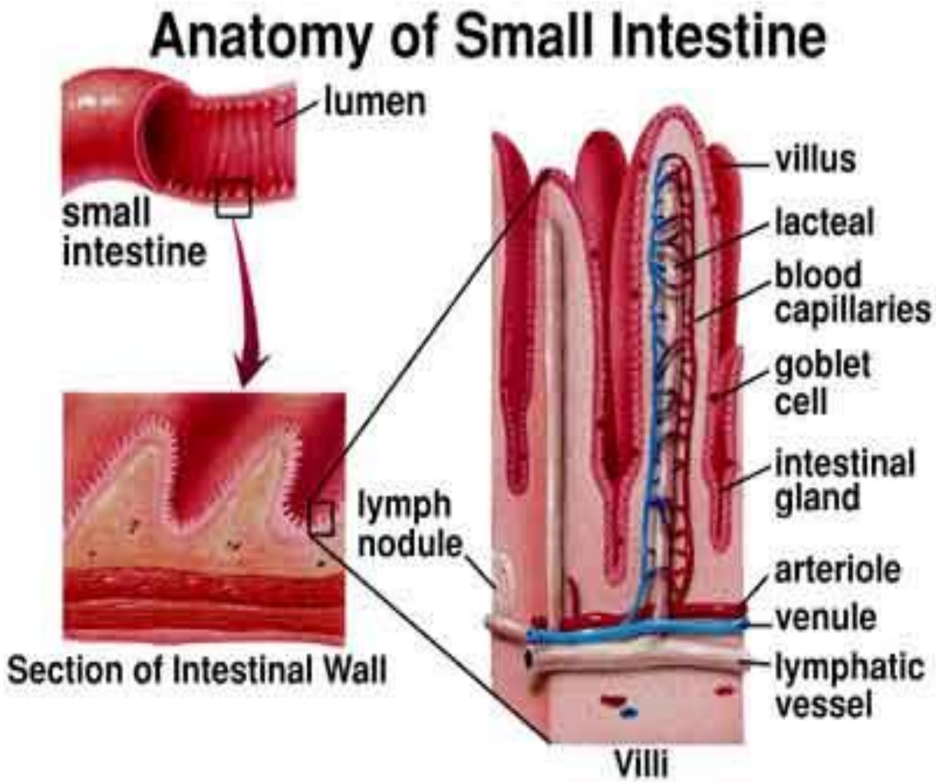


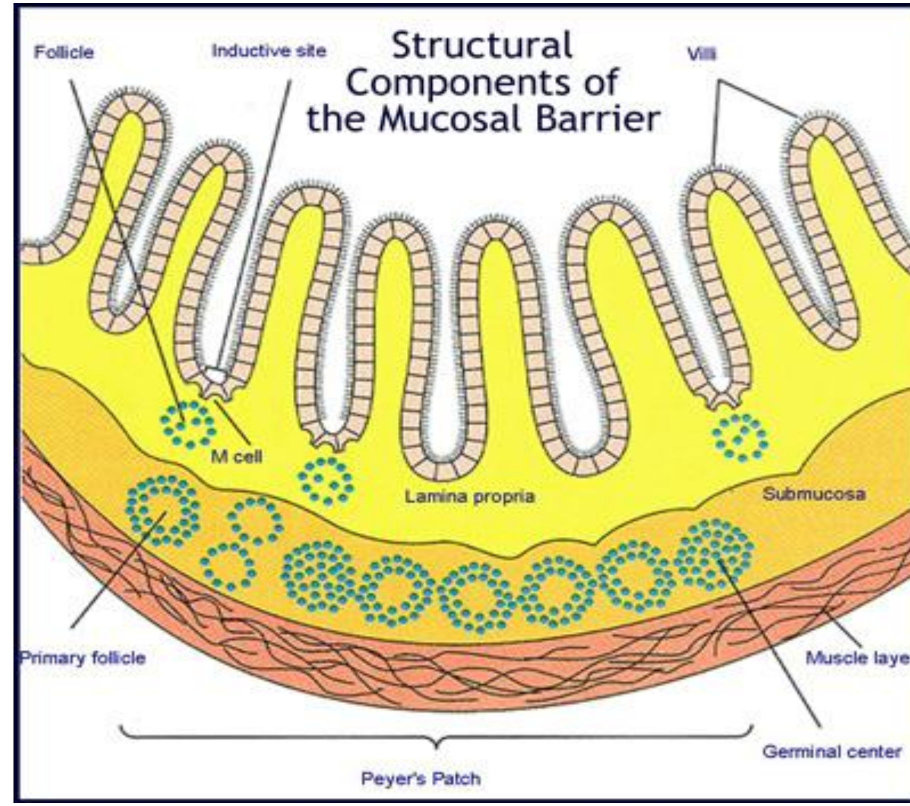
Overview of gut functions

Structure of the Gut wall







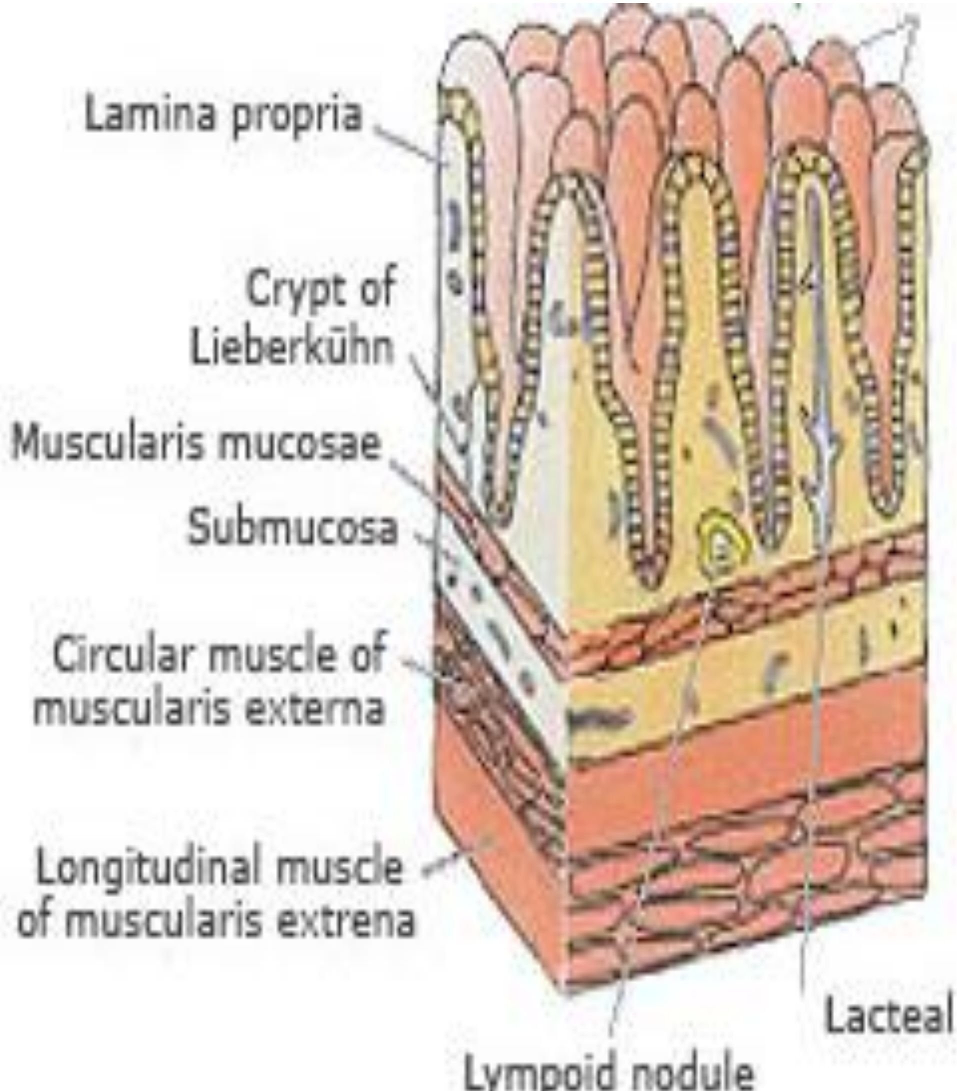


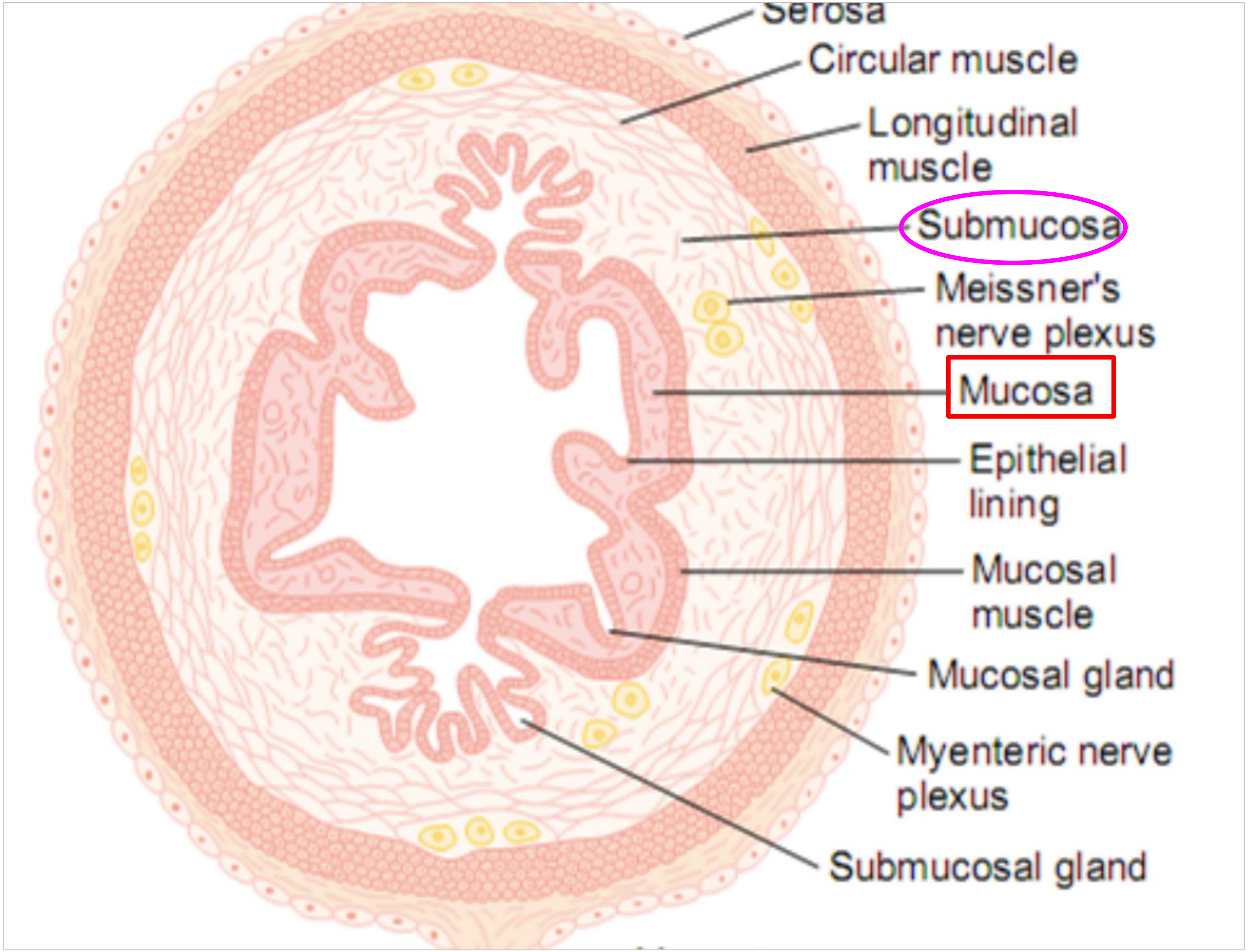
1. *The mucosa of the gut is highly folded. Why?*

- **It is divided into:-**
  - **Mucous membrane.**
  - **Lamina propria (BV, nerves, lymphatic's & lymphoid tissue).**
  - **Muscularis mucosa (modify the pattern of folding).**

- ***The submucosa consists of:-***
  - **Blood vessels**
  - ***Meissner's plexus***
  - **Lymphatic's**
  - **Lymphoid tissue**
- ***Muscularis externa consists of :-***
  - **Outer longitudinal layer**
  - **Inner circular layer**
  - ***Nerve plexus in between (Auerbach's’ s plexus)***
- ***Serosa***

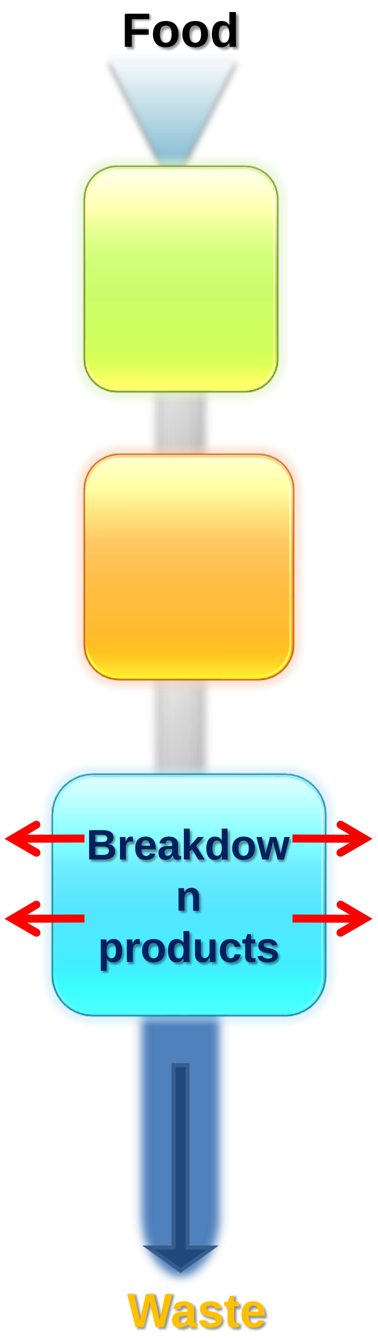
  It is the outer covering layer.




Serosa
Circular muscle
Longitudinal muscle
Submucosa
Meissner's nerve plexus
Mucosa
Epithelial lining
Mucosal muscle
Mucosal gland
Myenteric nerve plexus
Submucosal gland

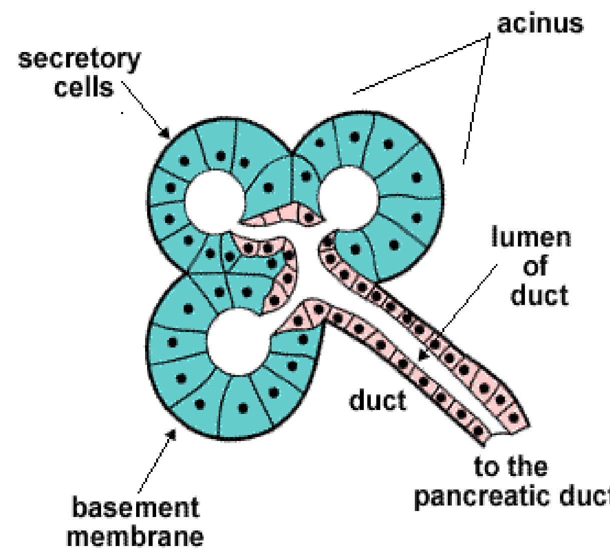
Gut layer	Function	Structure
Mucosa	1. Secretion of digestive juices and hormones. 2. Absorption of various nutrients. 3. Protection against infection.	1. Epithelial cells 2. Exocrine cells 3. Endocrine cells. 4. Muscle layer (muscularis mucosa) 5. Blood vessels , Lymph vessels & nerves
Sub mucosa	Contain the submucosal (Meissner's) nerve plexus which control GIT secretions.	1. Dense connective tissue. 2. Blood vessels, lymph vessels, and lymph nodes. 3. *Submucosal (Meissner's*) nerve plexus.
Musculosa	Gut motility	1. Outer longitudinal layer. 2. Inner circular layer 3. *Nerve plexus in between (Auerbach's' s plexus)*
Serosa	Secrete watery serous fluid. Lubricates and prevent friction	It continues with the mesentery. It contains nerves & blood vessels

Movement of materials from one container to another and mixing
Measure the concentration of hydrogen ion, the concentrations of protein, fat, and carbohydrate, and the tonicity of the digest
Addition of enzymes and fluid
Extraction of breakdown products



Gut Secretion

- There are Exocrine glands located along the wall of the gut.
- Each digestive juice consists of :-
  - Water & Electrolytes
  - Organic constituent .e.g. Enzymes & Mucus.



- The gland extract water & raw material from the plasma.
- The digestive secretion is then reabsorbed back to the blood after participation in the digestive process.
- Failure of reabsorption of digestive juices may lead to <u>*Circulatory Shock.*</u>

Digestion & Absorption

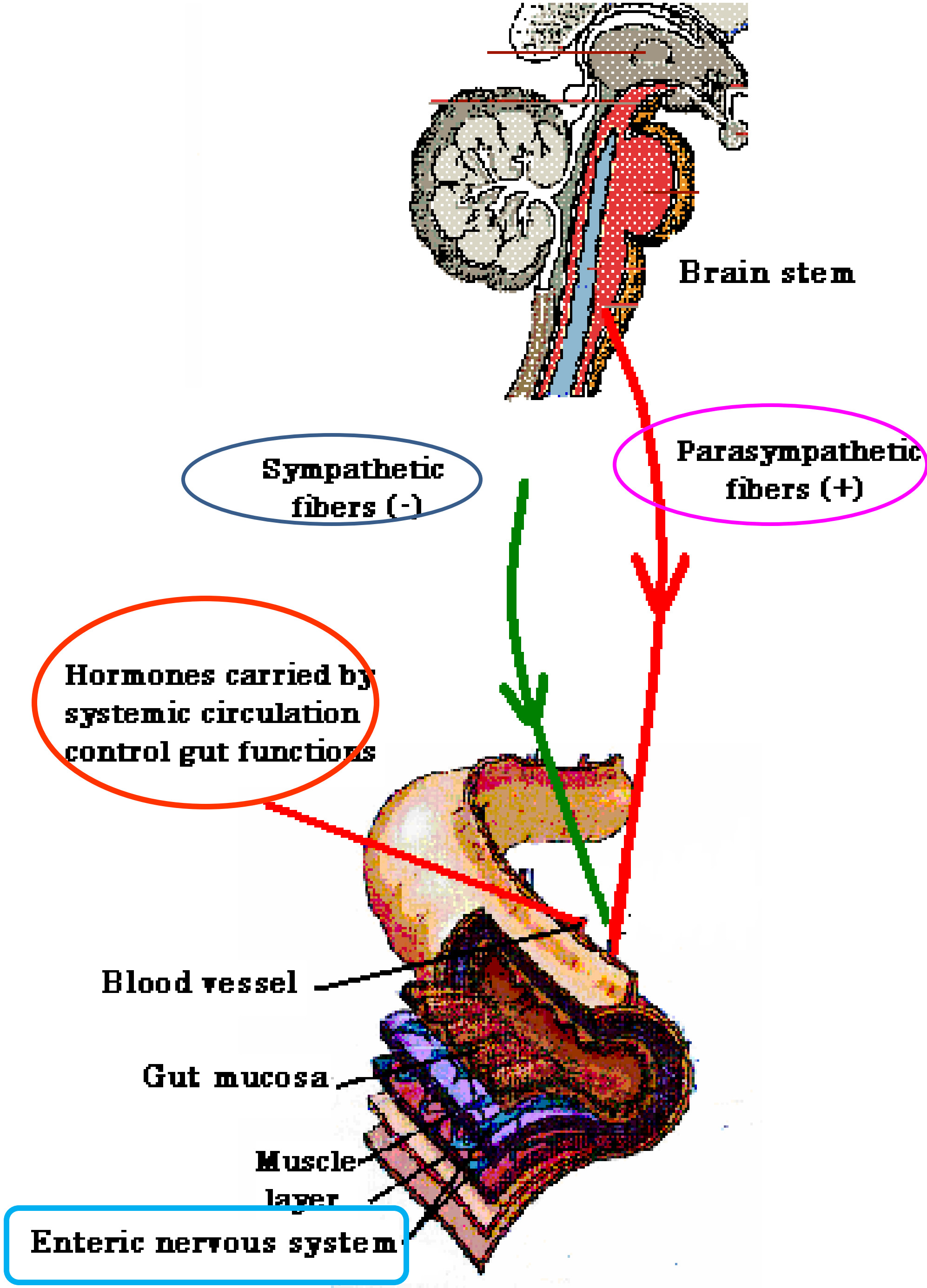
- ***Digestion*** is the breakdown of complex molecules into simple absorbable unites.

It is accomplished by enzymes that hydrolyze certain bonds in the food molecule.

- ***Absorption*** occurs in the small intestine.

Undigested & unabsorbed materials are excreted to the outside by the process of defecation .

Regulation of gut functions



Control Of gut functions

Gut functions are controlled by :-

- Autonomous Smooth Muscle Activity.
- Nervous Regulation.
- Hormonal Regulation.

Nerve supply of the gut

1-Enteric nervous system

(local nerve plexuses)

a- Meissner's plexus.

b- Auerbach's plexus.

2-Autonomic nerves:

a-Sympathetic.

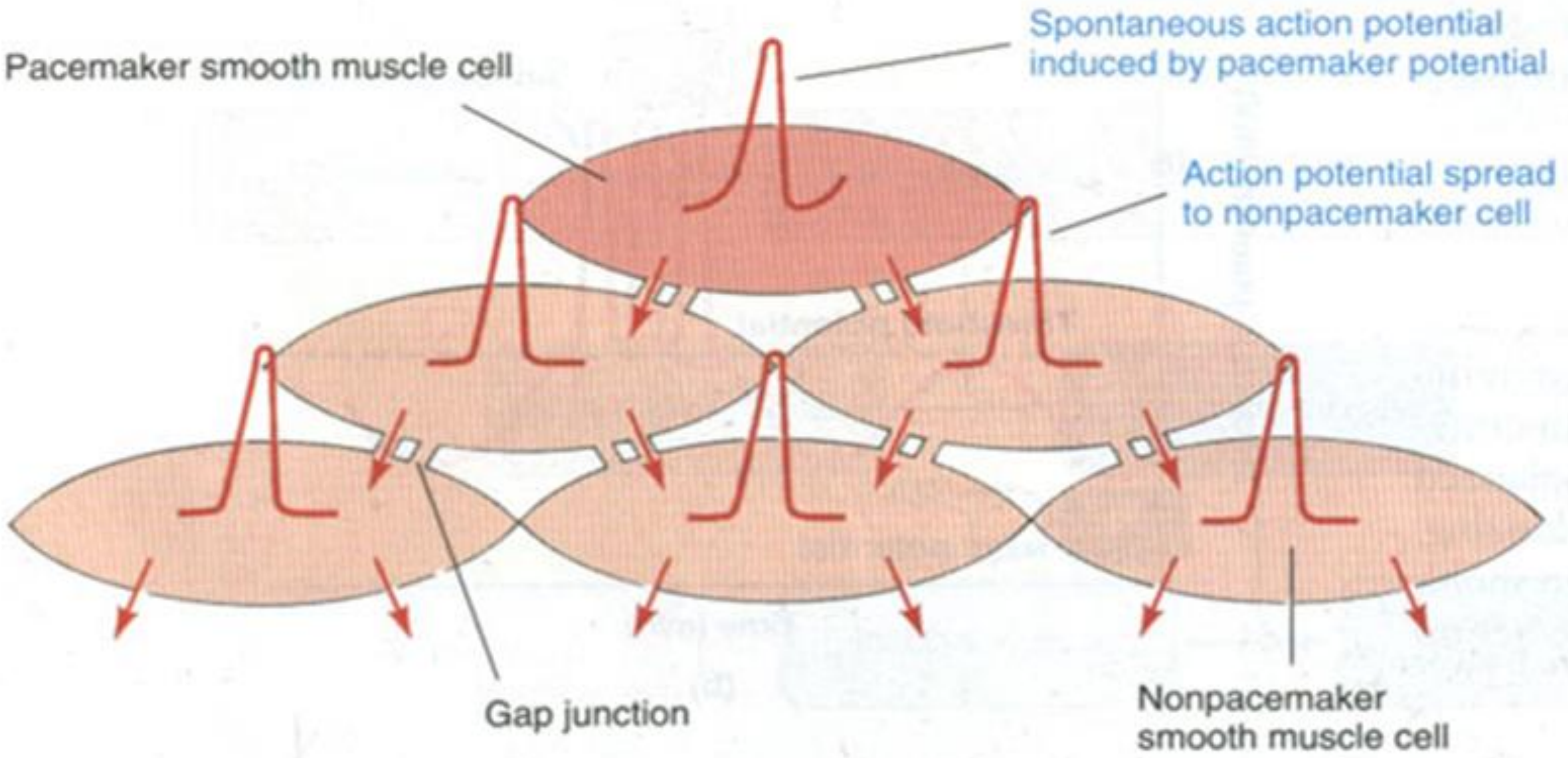
b-Parasympathetic *(vagal, sacral).*

Electrophysiology of GIT smooth muscles:

- **Gastrointestinal smooth muscle cells exhibit the following electric changes:-**
  - ***Changes in the level of smooth muscle resting potential*** *(it is changed by sympathetic & parasympathetic stimulation as well as hormones).*
  - ***Slow wave potential (BER).***
  - ***Spike potentials***

Functional syncytium of the GIT smooth muscles:-

- **Sheets of smooth muscles cells are connected by *Gap Junctions* which are points of low electric resistance.**
- **If AP was triggered in pace maker cells, it rapidly spreads to all smooth muscles.**

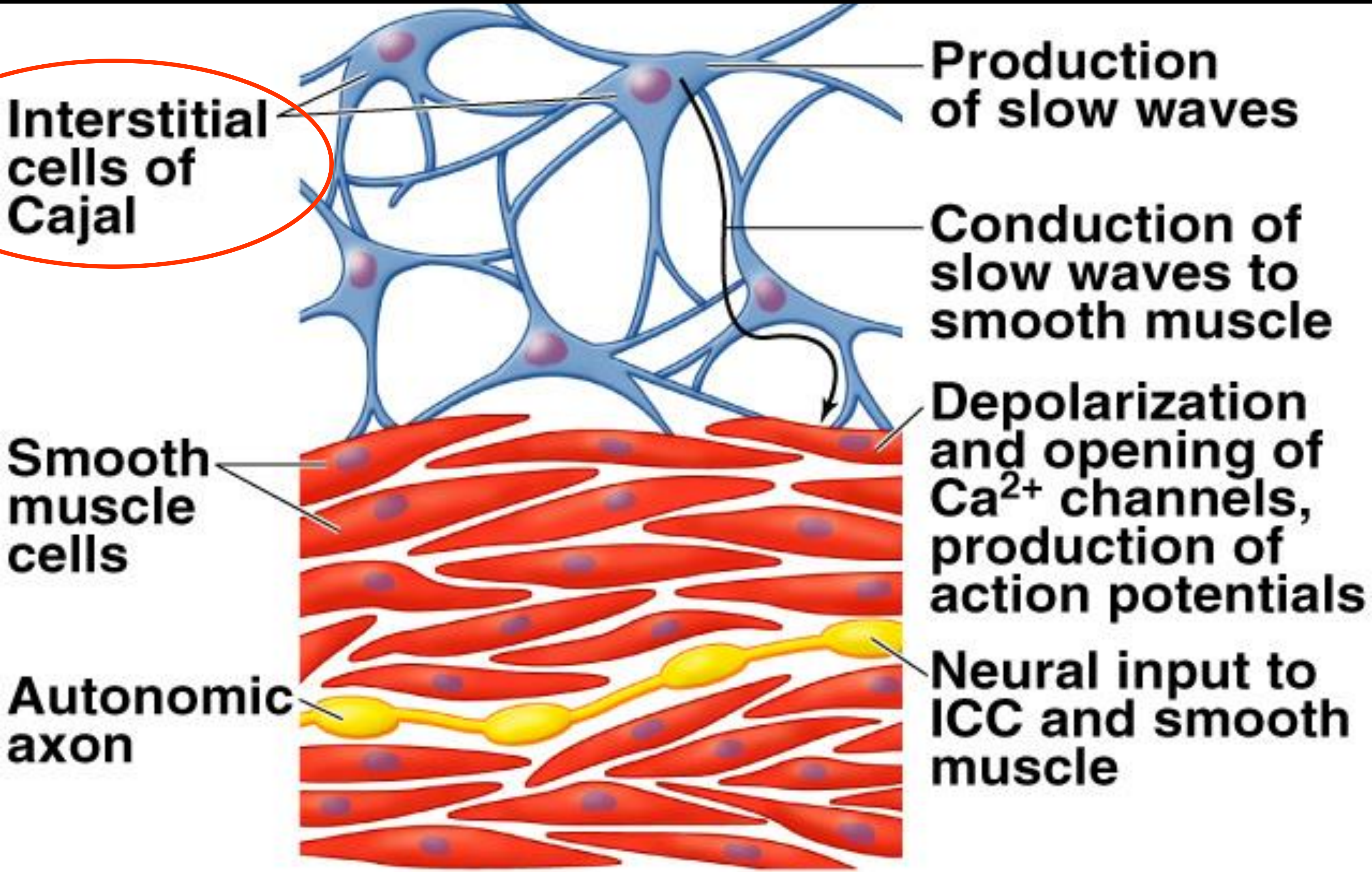


Functional syncytium of gut smooth muscles

Electrophysiology of GIT smooth muscles:

- There are ***pace maker cells*** in the GIT smooth muscles (between the longitudinal & circular smooth muscle layers) called ***(INTERSTITIAL CELLS OF CAJAL).***
- These cells are non contractile and have unstable RMP.
- They produce spontaneous depolarization and repolarization in the form of ***SLOW WAVES WHICH ARE CALLED BASIC ELECTRIC RHYTHM (BER).***

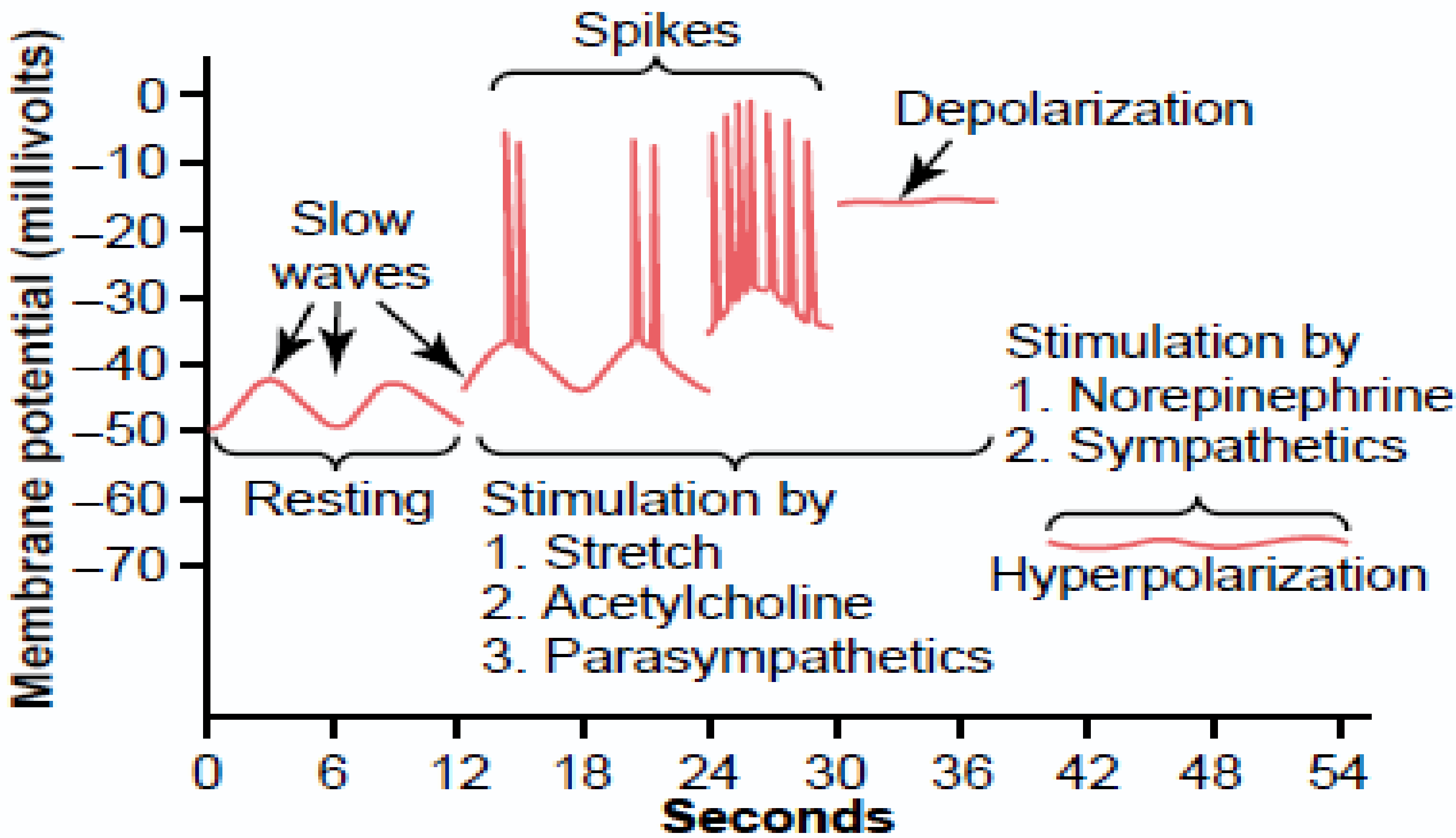
PACEMAKER OF THE GUT



- ***The frequency of slow waves depends on the section of the digestive tube***
  - **In the body of the stomach *3 / min***
  - **In the duodenum *12 /min***
  - **In the terminal ileum *8 or 9 /min.***
  - **In colon *3 /min***
- **Slow wave activity appears to be a property intrinsic to smooth muscle and not dependent on nervous stimuli or hormones.**
- **It is *Not an action potential & doesn’t induce muscle contraction.* (stomach).**

Changes in Voltage of the Resting Membrane Potential.

- **The resting membrane potential averages about *-56 mill volts*, but multiple factors can change this level.**
- **When the potential becomes *less negative,* which is called *Depolarization* of the membrane, the muscle fibers become *More Excitable.***
- **When the potential becomes More negative, which is called *Hyperpolarization,* the fibers become *Less Excitable.***



Spikes
Depolarization
Slow
waves
Membrane potential (millivolts)
0
–10
–20
–30
–40
–50
–60
–70
Resting
Stimulation by
1. Stretch
2. Acetylcholine
3. Parasympathetics
Stimulation by
1. Norepinephrine
2. Sympathetics
Hyperpolarization
0
6
12
18
24
30
36
42
48
54
Seconds

Factors that depolarize the membrane — that is, make it more excitable— are :

- *Stretching* of the muscle.
- Stimulation by *Acetylcholine*.
- Stimulation by *parasympathetic nerves* that secrete acetylcholine at their endings,
- Stimulation by several *specific gastrointestinal hormones*.

- **Important factors that make the membrane potential more negative—that is, *Hyperpolarize the membrane* and make the muscle fibers less excitable—are:**
- **The effect of *norepinephrine* or *epinephrine* on the fiber membrane .**
- **Stimulation of the sympathetic nerves that secrete mainly norepinephrine at their endings.**

Slow wave & spike potentials

	Slow wave potential	Spike potentials
Definition	Oscillatory changes in membrane potential.	Train of action potentials that occur on top of slow waves when membrane potential reaches threshold.
Nature	Muscle property	The muscle must be primed by neurotransmitters released in the vicinity due to stimulation.
Frequency	Inherent to each region.	Depend on mechanical, nervous & hormonal factors
Mechanism	Not well understood	Opening of ion channels
Significance	Determines the rate of muscle contraction	Induce muscle contraction. Number of spike potentils determines the intensity of muscle contraction

Functional Types of Movements in the Gastrointestinal Tract

- ***All GIT muscle is Smooth Muscle*** **except:**
- ***Upper 1/3 of esophagus (skeletal muscle).***
- ***Middle 1/3 of esophagus (skeletal and smooth).***
- ***External anal sphincter (skeletal muscle).***
- ***Movement of materials through the digestive tract is accomplished by smooth muscle contraction***

(Involuntary Control), except at the Oral & the Anal ends of the tract which contain skeletal muscles.

TYPES OF BOWEL MOVEMENTS

(1) *Propulsive movements:*, which cause food to move forward along the tract at an appropriate rate to accommodate digestion and absorption.

(2) *Mixing movements* :which keep the intestinal contents thoroughly mixed at all times.

Propulsive Movements—Peristalsis

- **A contractile ring appears around the gut and then moves forward.**
- **Peristalsis is an inherent property of many syncytial smooth muscle tubes, stimulation at any point in the gut can cause a contractile ring to appear in the circular muscle, and this ring then spreads along the gut tube.**
- **(Bile ducts, Glandular ducts, Ureters).**

- **The usual stimulus for intestinal peristalsis is *<u>Distention of the gut</u>*.**

That is, if a large amount of food collects at any point in the gut, the stretching of the gut wall stimulates the enteric nervous system to contract the gut wall 2 to 3 centimeters behind this point, and a contractile ring appears that initiates a peristaltic movement.

- **<u>Chemical</u> or <u>physical</u> irritation of the epithelial lining in the gut.**
- **<u>Parasympathetic nervous</u> signals.**

Function of the Myenteric Plexus in Peristalsis

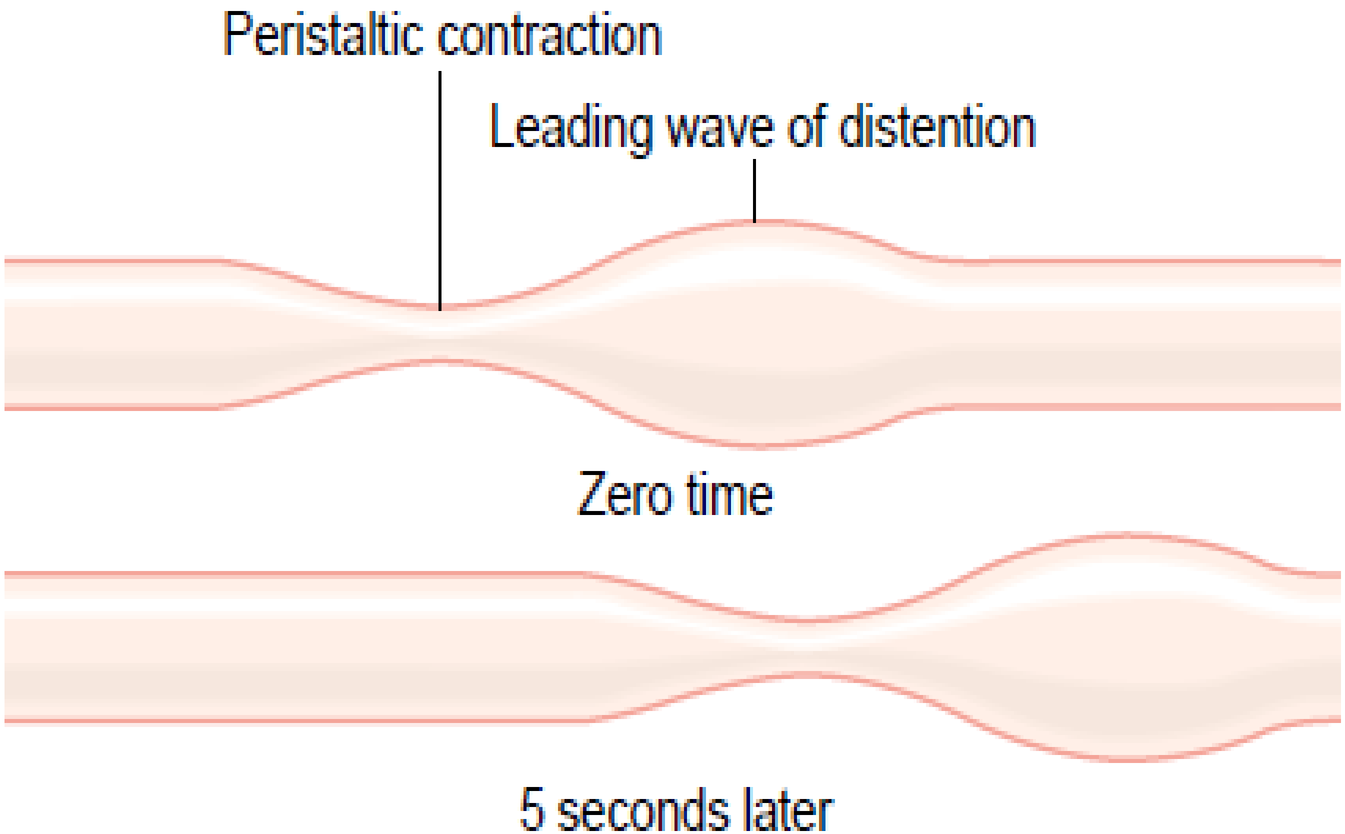
- **Peristalsis occurs only weakly or not at all in any portion of the GIT that has congenital *Absence of the Myenteric plexus*.**
- **Also, it is greatly depressed or completely blocked in the entire gut when a person is treated with Atropine to paralyze the cholinergic nerve endings of the Myenteric plexus.**
- **Therefore, *effective* peristalsis requires an active *Myenteric Plexus*.**

Directional Movement of Peristaltic Waves Toward the Anus.

- **The exact cause of this directional transmission of peristalsis has never been ascertained, although it probably results mainly from the fact that the myenteric plexus itself is *"Polarized"* in the anal direction.**

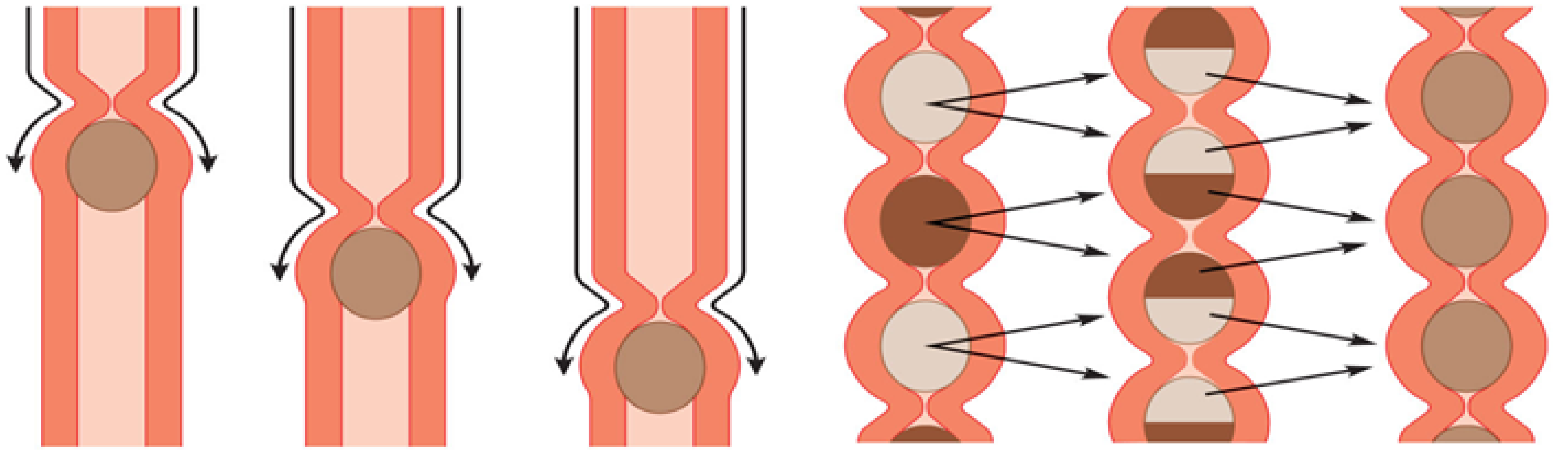
Peristaltic Reflex and the "Law of the Gut"

- **When a segment of the GIT is excited by distention and initiates peristalsis, the contractile ring causing the peristalsis normally begins on the *oral side of the distended segment* and moves toward the distended segment, pushing the intestinal contents in the anal direction for *5 to 10 cm* before dying out.**
- **At the same time, the gut relaxes several centimeters downstream toward the anus, which is called *"receptive relaxation,"* thus allowing the food to be propelled more easily toward the anus than toward the mouth.**
- **Therefore, this complex is called the *Myenteric reflex* or the *peristaltic reflex.***
- **The peristaltic reflex plus the anal direction of movement of the peristalsis is called the *"law of the Gut"***


Peristaltic contraction
Leading wave of distention
Zero time
5 seconds later

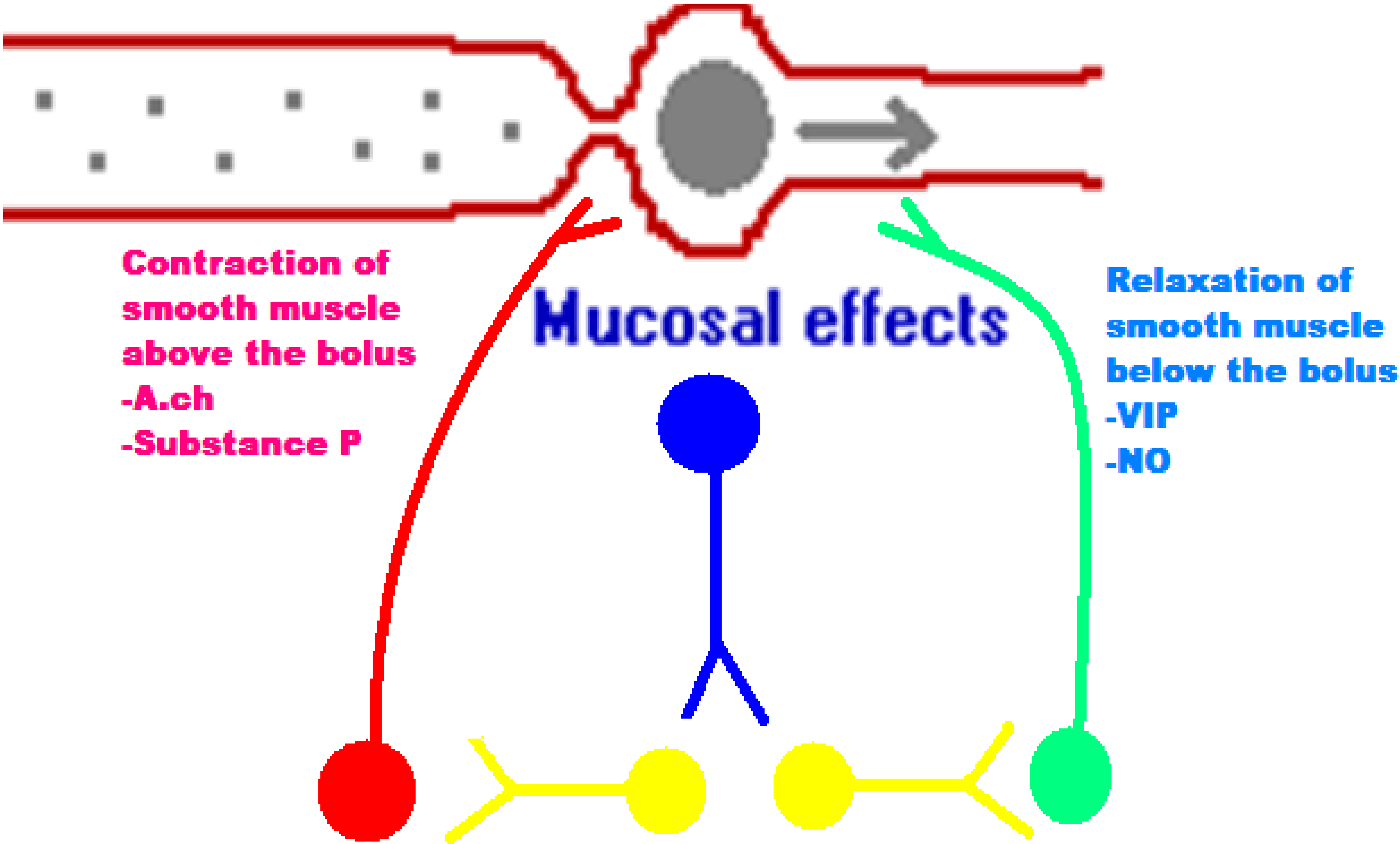
Mixing Movements

- **In some areas, the peristaltic contractions themselves cause most of the mixing.**
- **This is especially true when *Forward Progression* of the intestinal contents is *Blocked by a sphincter*, so that a peristaltic wave can then only churn the intestinal contents, rather than propelling them forward.**
- **At other times, *local intermittent constrictive contractions* occur every few centimeters in the gut wall.**
- **These constrictions usually last only 5 to 30 seconds, then new constrictions occur at other points in the gut, thus *"Chopping" and "Shearing"* the contents first here and then there.**

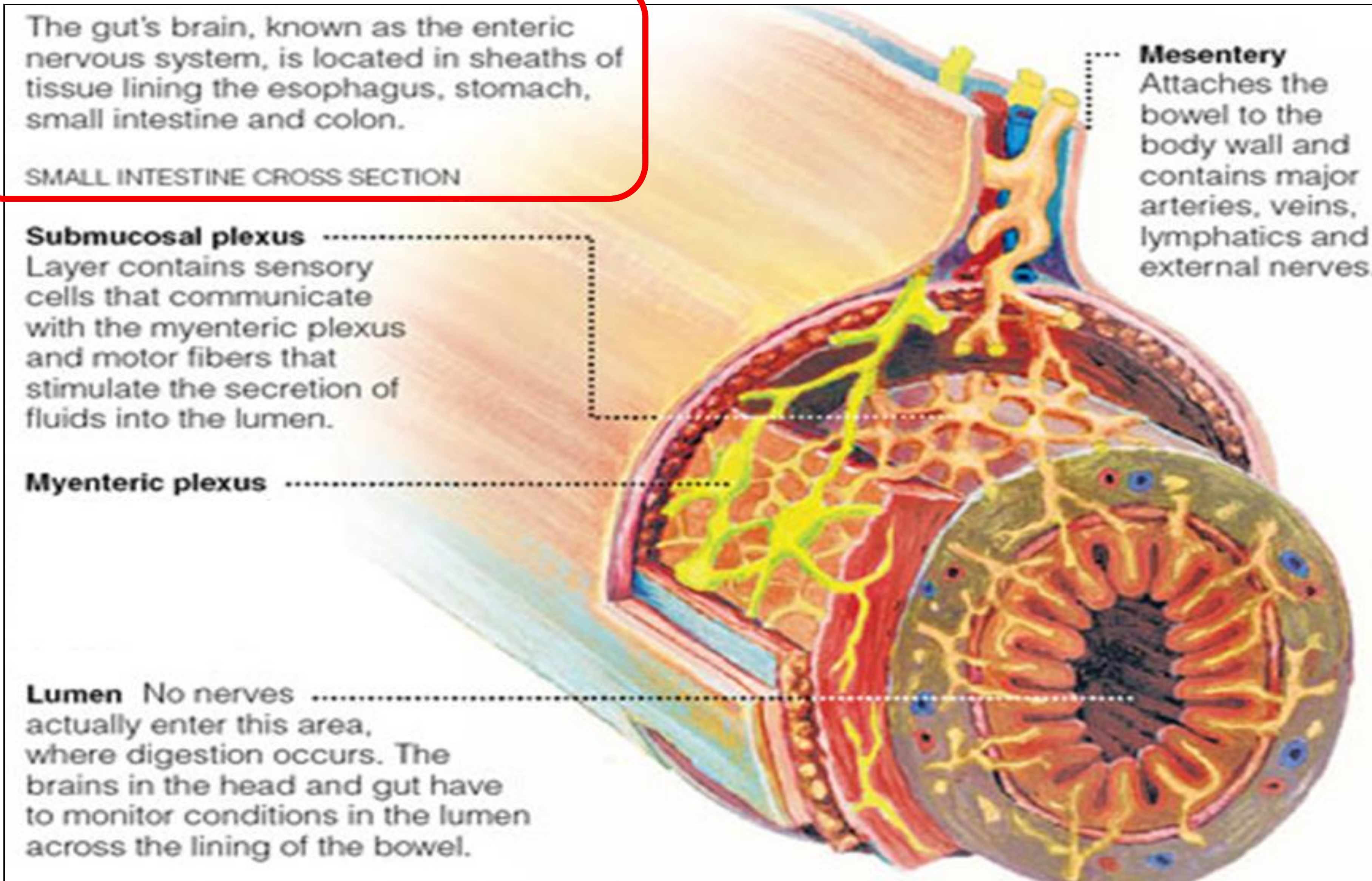


Peristalsis: Adjacent segments of alimentary tract organs alternately contract and relax, which moves food along the tract distally.

Segmentation: Nonadjacent segments of alimentary tract organs alternately contract and relax, moving the food forward then backward. Food mixing and slow food propulsion occurs


Contraction of smooth muscle above the bolus
-A.ch
-Substance P
Mucosal effects
Relaxation of smooth muscle below the bolus
-VIP
-NO

Minibrain of the gut



Neural Control of GIT Function
Enteric Nervous System

- **GIT has a nervous system of its own called the Enteric Nervous System.**
- **It lies entirely in the wall of the gut, beginning in the esophagus and extending all the way to the anus.**
- **The number of neurons in this ENS is about 100 Million.**
- **This highly developed ENS is especially important in controlling *Gastrointestinal movements and secretion.***

Enteric nervous system

- **It is a displaced part of the CNS that is concerned with the regulation of the gastrointestinal functions.**
- ***It doesn't depend on CNS in its function.***

It consists of two plexuses;

- ***Meissner's plexus (submucosa):.***

It controls exocrine and endocrine secretions.

- **Control local *intestinal secretion,* local *absorption,* and local *contraction of the submucosal muscle* that causes various degrees of infolding of the gastrointestinal mucosa.**

- ***Myenteric plexus*** **(Auerbach's plexus)between the 2 muscle layer).**
  - ***It Controls the GIT motility.***

- **Output neurons are either excitatory or inhibitory. What are their neurotransmitters?**
- **The neurons of the ENS secrete Ach, GABA, seretonin, and nitrous oxide (which is the major mediator for smooth muscle relaxation in GIT).**
- **Autonomic nerves terminate on it but it can functions independent of them.**
- **The parasympathetic nerve supply is generally *Stimulatory* to ENS while the sympathetic is generally *Inhibitory.***

Types of Neurotransmitters Secreted by Enteric Neurons

1) ***acetylcholine*** **and**
2) ***norepinephrine.***
3) ***adenosine triphosphate,***
4) ***serotonin,***
5) ***dopamine,***
6) ***cholecystokinin,***
7) ***substance P,***
8) ***vasoactive intestinal polypeptide,***
9) ***somatostatin,***
10) ***leu-enkephalin,***
11) ***met-enkephalin,*** **and**
12) ***bombesin*****.**

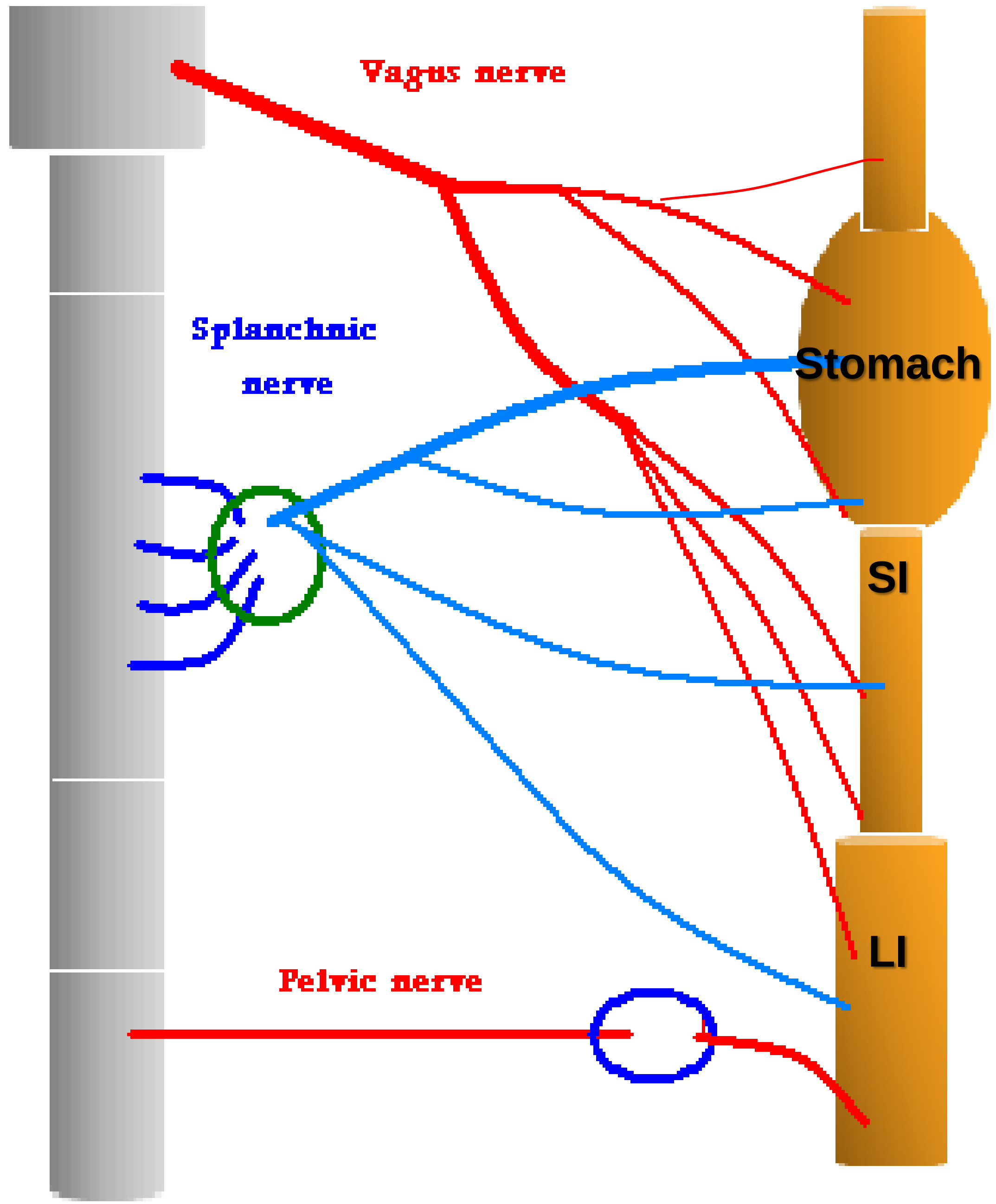
- **The *Myenteric plexus* is mainly *Excitatory* but some of its neurons are *Inhibitory, that secrete* an inhibitory transmitter, possibly *VIP* .**

- **The resulting inhibitory signals are useful for inhibiting some of the intestinal sphincter muscles that impede movement of food along successive segments of the gastrointestinal tract, such as the *pyloric sphincter* and the *sphincter of the ileocecal valve.***

Autonomic Innervation

	Sympathetic	Parasympathetic
1-Origin	Thoracolumbar (T5-L2).	Cranial (mainly vagus) to esophagus till upper LI. Sacral (S2-4) pelvic nerve to lower LI, rectum, anal canal.
2-Fiber	Postganglionic	Preganglionic
3-Chemical transmitter	Norepinephrine	Acetylcholine
4-Effect	a-Relaxation of wall b-contraction of sphincters c-mainly :↓ secretions	a-Contraction of wall b-Relaxation of sphincters c-mainly :↑ secretions
5-Termination	Myenteric and Meissner's plexus others bypass:- to Blood vessels. And smooth muscles.	Myenteric and Meissner's plexus.

Nerve Supply Of The Gut



Importance of the autonomic innervation to the gut

- Coordinate the activity between different regions of the gut.

e.g. Chewing ⇨ Salivation , ⇨↑ Gastric secretion , ⇨ ↑ Bile , ⇨ ↑ Pancreatic secretion.

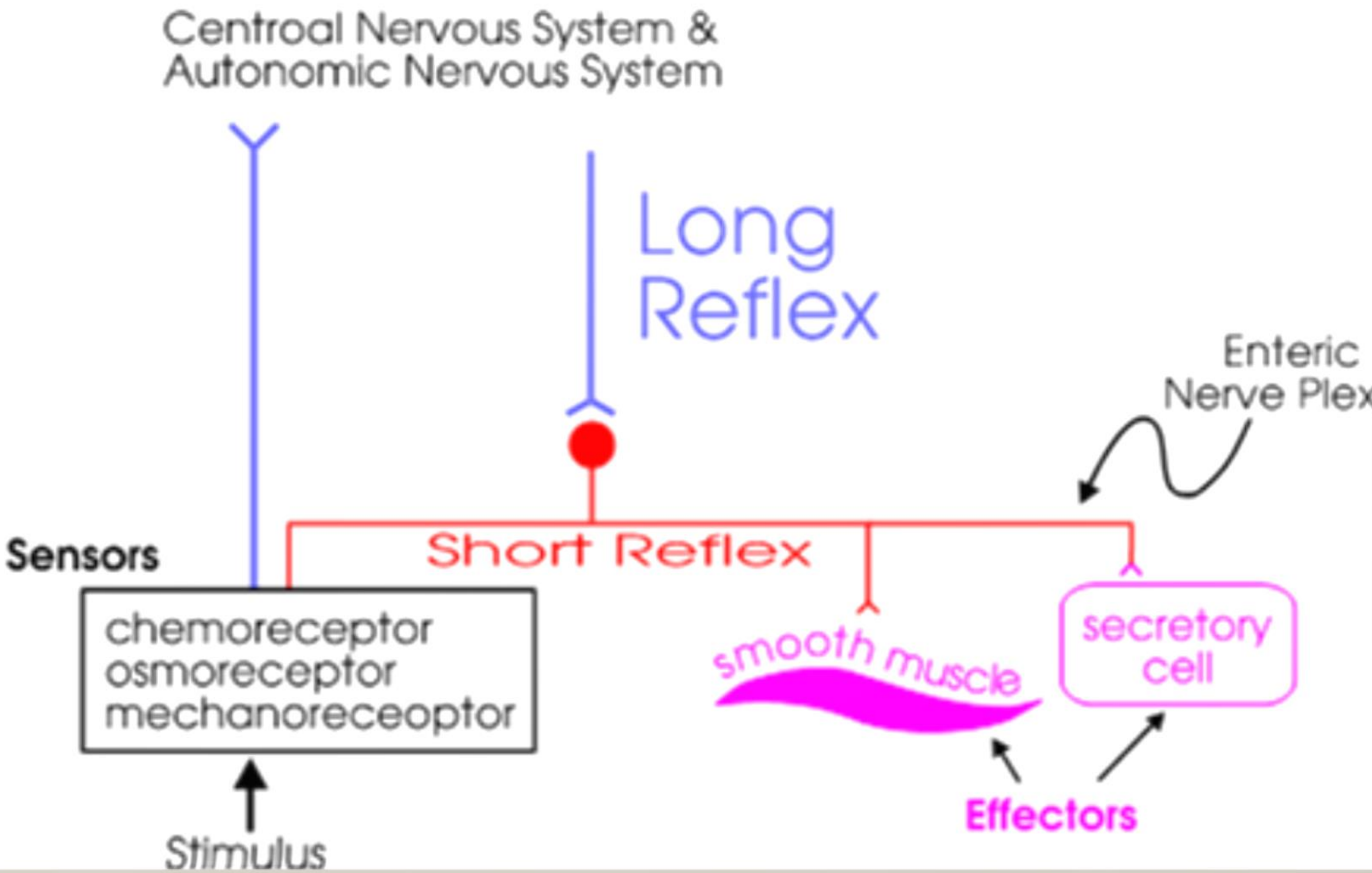
- Make digestive system respond to the external stimuli.

e.g. Smell or sight of food ⇨ stimulation of salivary, gastric, pancreatic & liver secretion

Gastrointestinal Reflexes

- ***Reflexes that are*** ***Integrated Entirely within the gut wall*** ***ENS*** **These include reflexes that control much gastrointestinal** ***Secretion, Peristalsis, Mixing contractions, Local inhibitory effects.***
- ***Reflexes from the gut to the prevertebral sympathetic ganglia and then back to the GIT.*** **Signals from the stomach to cause evacuation of the colon** ***(Gastrocolic reflex).***
- **Signals from the colon and small intestine to** ***Inhibit*** ***stomach motility and secretion*** ***(Enterogastric reflexes).***
- **Reflexes from the colon to inhibit** ***emptying of ileal contents into the colon*** **(colonoileal reflex).**

Reflexes


Centroal Nervous System &
Autonomic Nervous System
Long
Reflex
Enteric
Nerve Plex
Short Reflex
Sensors
chemoreceptor
osmoreceptor
mechanoreceoptor
smooth muscle
secretory
cell
Effectors
Stimulus

Continue

- ***Reflexes from the gut to the spinal cord or brain stem and then back to the gastrointestinal tract.*** **These include *especially***
- ***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.**
- ***Pain reflexes*** **that cause general inhibition of the entire GIT**
- ***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 (the defecation reflexes).**

Hormonal Control of Gastrointestinal Motility

- ***Polypeptide hormones*** **secreted from** ***Entero-Endocrine*** **cells in the mucosa called** ***APUD*** **cells ⇨ portal vein ⇨ liver ⇨ Systemic circulation ⇨GIT tract ⇨ gut motility &secretion.**
- **They are secreted in response to stimulation by:**
  - ***a- External autonomic nerves.***
  - ***b- Enteric nervous system.***
  - ***c- Changes in luminal contents of GIT.***
- **They are secreted in blood and circulate in it, and reach GIT to produce their effects on GIT motility and secretion (↑ or ↓).**
- **They all have** ***Trophic*** **effects:**
  - **Gastrin H. → growth of gastric mucosa.**
  - **CCK H. → growth of pancreas.**

Classification of Gut Hormones

Gastrin Family	Secretin Family	Other GIT Peptides
Gastrin Cholecystokinin (CCK)	Secretin Glucagon GIP VIP Glicentin	Motilin Somatostatin Substance P Serotonin ,guanilin, substance-P, neurotensin, GRP

- ***Gastrin*** **is secreted by the *"G"* cells of the *antrum of the stomach* in response to stimuli associated with ingestion of a meal .**

- ***Distention of the stomach .***
- ***Products of protein digestion.***
- ***Gastrin releasing peptide,*** **which is released by the nerves of the gastric mucosa during *vagal stimulation*. The primary actions of gastrin are**

(1) Stimulation of gastric acid secretion .

(2) Stimulation of growth of the gastric mucosa.

Gastrin

- A polypeptide hormone, secreted from ***G cells*** in Antral glands of the stomach.
- It is present in different forms, the commonest of which are G_{14}, G_{17} *(principal form for gastric secretion)*& G_{34}.

Control of gastrin secretion:

	Stimulators	Inhibitors
Luminal factors •Mechanical •Chemical	 Gastric distention Amino acids, peptides , low Hcl	 Excess H^+, somatostatin
Nervous factors	Vagal stimulation (the neurotransmitter is GRP)	Sympathetic stimulation
Blood –borne	Calcium, epinephrine	Secretin, GIP, VIP , glucagon & calcitonin

Functions of Gastrin:-

- Increase gastric Hcl & pepsinogen secretion.
- Increase gastric motility.
- Increase motility of the ileum (gastroileal reflex).
- Relaxes ileocecal sphincter.
- Cause mass contractions of the colon which move feces to anus & initiate defecation.
- Trophic to the stomach & intestine.

Cholecystokinin (CCK) **is secreted by *"I"* cells in the *mucosa of the* Duodenum and Jejunum mainly in response to digestive products of *fat, fatty acids, and monoglycerides* in the intestinal contents.**
This hormone strongly contracts the gallbladder, expelling bile into the small intestine.
CCK *Inhibits stomach contraction* moderately.
CCK *Inhibits appetite* to prevent overeating during meals by stimulating sensory afferent nerve fibers in the duodenum, these fibers, in turn, send signals by way of the vagus nerve to inhibit feeding centers in the brain .

Cholecystokinin

It is secreted from:-

- ***I*** **cells in the upper small intestine.**
- **Nerves in the distal ileum.**

It is secreted in response to products of fat & protein digestion.

Function:-

- **Inhibit gastric motility, emptying & secretion.**
- **Stimulate pancreatic *Acinar cell* to secrete juice *Rich in enzymes.***
- **Trophic to exocrine pancreas**
- **Augment action of secretin.**
- **Stimulate GB contraction act as (*Cholagogue*).**
- **Involved in regulation of food intake.**

Secretin **was the first GIT hormone discovered and is secreted by the *"S"* cells in the *Mucosa of the Duodenum* in response to acidic gastric juice emptying into the duodenum from the pylorus of the stomach.**

- **Secretin has a mild effect on motility of the GIT**
- **Promote pancreatic secretion of bicarbonate, which in turn helps to neutralize the acid in the small intestine.**

Secretin

It is a polypeptide hormone secreted from specialized cells called ***S cells*** in the glands of the duodenum& jejunum.

It is secreted in response to:-

- Acidic chyme in the duodenum.
- Products of protein digestion.

- **Function:-**
  - Stimulate secretion of pancreatic juice rich in ***Hco_3*** from pancreatic ***Duct cells.***
  - Stimulate secretion of Hco_3 from duct cells of the biliary tract which increase bile flow.
  - Augment the action of CCK on pancreatic cells.
  - Inhibit gastric acid secretion & emptying.
  - Has trophic effect on exocrine pancreas.

Gastric inhibitory peptide (GIP) **is secreted by the *mucosa of the upper small intestine(K cells),* is the only GI hormone that is released in response to fat, protein, and carbohydrate.**

- **Inhibit gastric motility & secretion.**
- **Stimulation of insulin release: GIP, at blood levels even lower than those needed to inhibit gastric motility, also stimulates insulin secretion and for this reason is also known as *glucose-dependent insulinotropic peptide.***

Thus, oral glucose is more effective than intravenous glucose in causing insulin release and, therefore, glucose utilization.

Motilin **is secreted by the stomach and *upper duodenum* during fasting, and the only known function of this hormone is to *increase gastrointestinal motility*. Motilin is released cyclically and stimulates waves of gastrointestinal motility called *interdigestive myoelectric complexes* that move through the stomach and small intestine every 90 minutes in a fasted person. Motilin secretion is inhibited after ingestion by mechanisms that are not fully understood.**

Paracrines

- **Are released from endocrine cells in the GI mucosa.**
- **Diffuse over short distances to act on target cells located in the GI tract.**
- **The GI paracrines are *Somatostatin and Histamine***

1. Somatostatin

- Is secreted by cells throughout the GI tract in response to H+ in the lumen. Its secretion is inhibited by vagal stimulation.
- Inhibits the release of all GI hormones.
- Inhibits gastric H+ secretion.

2. Histamine

- is secreted by ***mast cells*** of the gastric mucosa.
- ■ increases gastric H+ secretion directly and by potentiating the effects of gastrin and vagal stimulation.

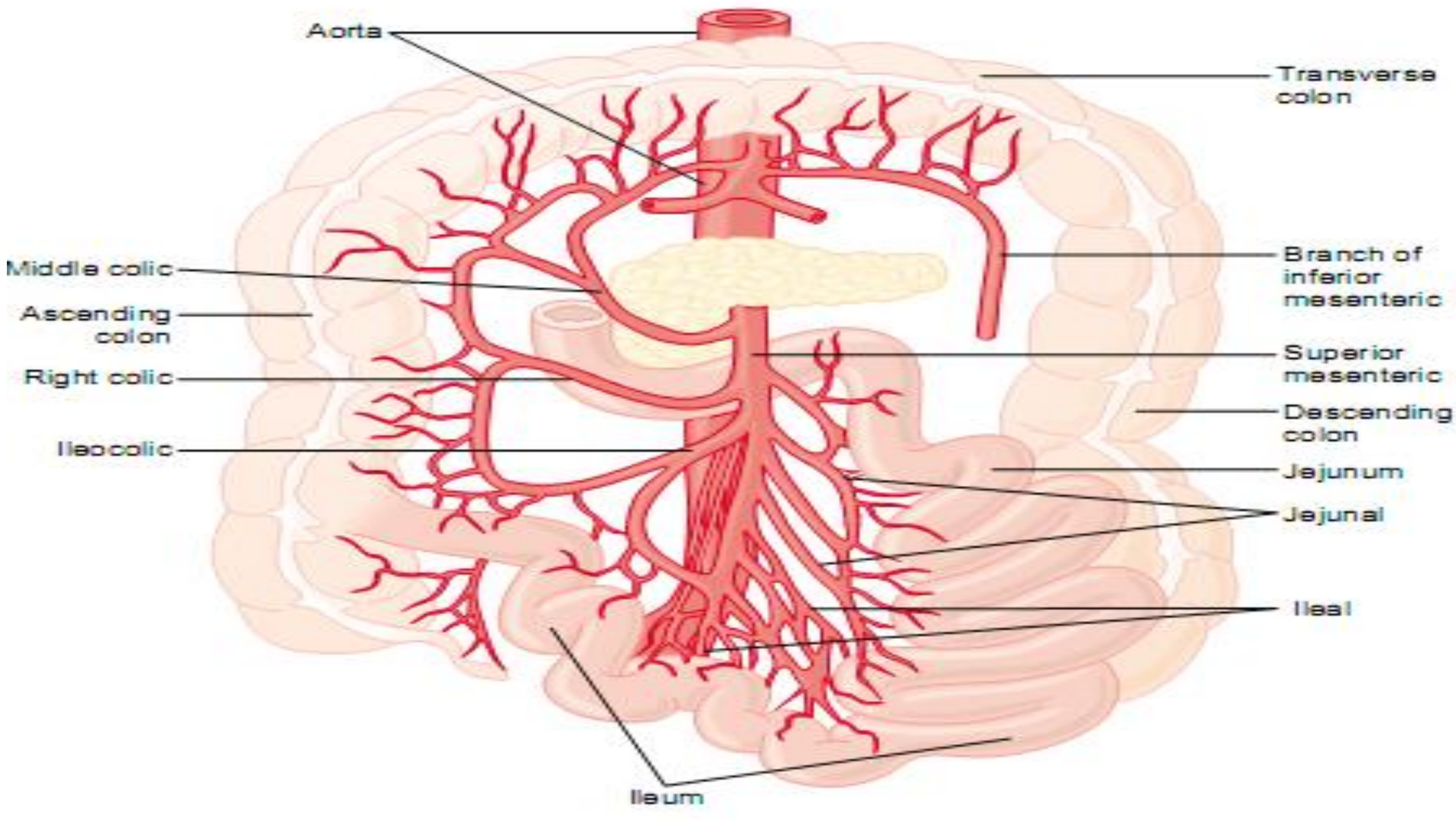
1. VIP

- Contains 28 amino acids.
- Is released from neurons in the mucosa and smooth muscle of the GI tract.
- Produces relaxation of GI smooth muscle, including the lower esophageal sphincter.
- Stimulates pancreatic HCO3 secretion and inhibits gastric H+ secretion. In these actions, it resembles secretin.
- Is secreted by pancreatic islet cell tumors and is presumed to mediate pancreatic cholera.

2. Gastrin-releasing peptide GRP (bombesin)

Is released from vagus nerves that innervate the G cells. Stimulates gastrin release from G cells.

Gastrointestinal Blood Flow "Splanchnic Circulation"



- **On entering the wall of the gut, the arteries branch and send smaller arteries *circling* in both directions around the gut, with the tips of these arteries meeting on the side of the gut wall opposite the mesenteric attachment.**
- **From the circling arteries, still much smaller arteries *penetrate* into the intestinal wall and spread**
- **Along the muscle bundles.**
- **Into the intestinal villi.**
- **Into submucosal vessels beneath the epithelium to serve the secretory and absorptive functions of the gut.**

The Non-fat, Water-soluble nutrients **absorbed from the gut (such as carbohydrates and proteins)**

- **Here, both the reticuloendothelial cells and the principal parenchymal cells of the liver, the *hepatic cells*, absorb and store temporarily from one half to three quarters of the nutrients.**
- ***Almost all of the Fats* (except small quantities of short- and medium-chain fatty acids) absorbed from the intestinal tract *are not carried in the portal blood* but instead are absorbed into the intestinal lymphatic's and then conducted to the systemic circulating blood by way of the Thoracic Duct, by passing the liver.**

Effect of Gut Activity and Metabolic Factors on Gastro-intestinal Blood Flow

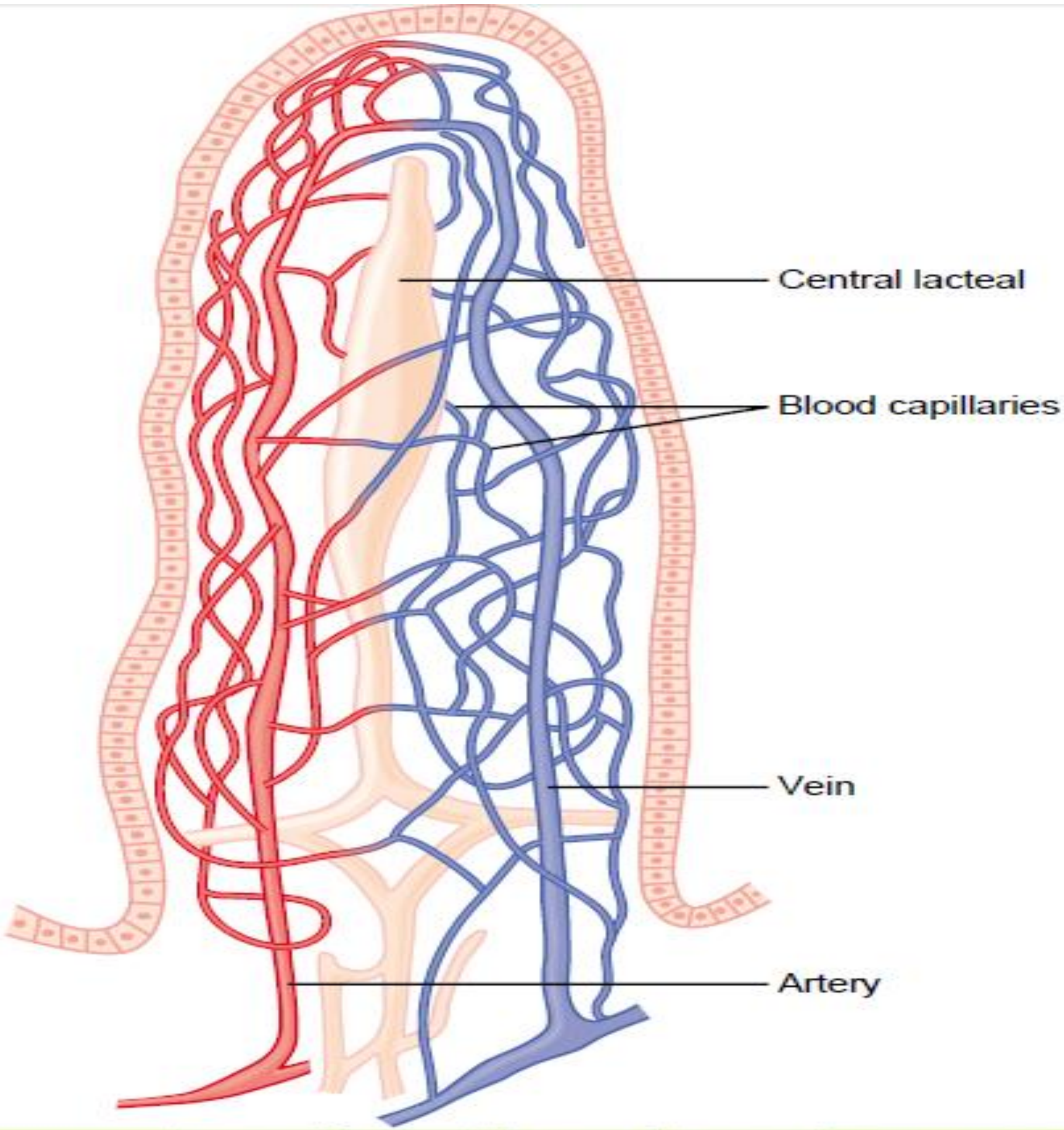
- **Under normal conditions, the blood flow in each area of the GIT, is directly related to the *level of local activity.***
- **During active absorption of nutrients, blood flow in the *Villi and adjacent regions of the submucosa* is increased as much as Eight Fold.**
- **Blood flow in the *Muscle layers* of the intestinal wall increases with increased motor activity in the gut.**
- **After a meal, the motor activity, secretory activity, and absorptive activity all increase; likewise, the blood flow increases greatly but then decreases back to the resting level over another *2 to 4 hours*.**

Possible Causes of the Increased Blood Flow During Gastrointestinal Activity.

- ***Several hormones*** **are released from the mucosa of the intestinal tract during the digestive process. including *cholecystokinin, vasoactive intestinal peptide, gastrin, and secretin*.**
- **Some of the gastrointestinal glands also release into the gut wall two *kinins, kallidin and bradykinin*, at the same time that they secrete their secretions into the lumen. These kinins are *Powerful Vasodilators* that are believed to cause much of the increased mucosal vasodilation that occurs along with secretion.**
- **Decreased Oxygen Concentration in the gut wall can increase intestinal blood flow at least 50 to 100 per cent; The decrease in oxygen can also lead to as much as a fourfold increase of *adenosine*, a well known vasodilator that could be responsible for much of the increased flow.**

"Countercurrent" Blood Flow in the Villi.

- **The arterial flow into the villus and the venous flow out of the villus are in directions opposite to each other, and that the vessels lie in close apposition to each other.**
- **Because of this vascular arrangement, much of the blood oxygen diffuses out of the arterioles directly into the adjacent venules without ever being carried in the blood to the tips of the villi.**
- **As much as *80 %* of the oxygen may take this short-circuit route and therefore not be available for local metabolic functions of the villi.**


Central lacteal
Blood capillaries
Vein
Artery

- **In *Circulatory Shock,* the oxygen deficit in the tips of the villi can become so bad that the villus tip or even the whole villus suffers *Ischemic Death* and can disintegrate.**

- **Therefore, for this reason and others, in many gastrointestinal diseases the villi become seriously *Blunted,* leading to greatly diminished intestinal absorptive capacity.**

Nervous Control of Gastrointestinal Blood Flow

- ***Parasympathetic Stimulation*** **of the nerves going to the** ***stomach*** **and** ***lower colon*** **increases local blood flow at the same time that it increases glandular secretion.**
- **This increased flow probably results** ***secondary from the increased glandular activity and not as a direct effect of the nervous stimulation.***
- **Sympathetic stimulation, by contrast, has a** ***Direct effect*** **on essentially all the GIT to cause intense vasoconstriction of the arterioles with greatly decreased blood flow.**

Autoregulatory escape

- **After a few minutes of vasoconstriction, the flow often returns almost to normal.**

- **That is, the local metabolic vasodilator mechanisms that are elicited by ischemia become prepotent over the sympathetic vasoconstriction and, therefore, redilate the arterioles, thus causing return of necessary nutrient blood flow to the GI glands and muscle.**

Importance of Nervous Depression of GIT Blood Flow When Other Parts of the Body Need Extra Blood Flow.

A major value of Sympathetic Vasoconstriction in the gut is that:

- **1-It allows shut-off of GIT and other splanchnic blood flow for short periods of time *During Heavy Exercise*, when increased flow is needed by the skeletal muscle and heart.**
- **2-Also, in *Circulatory Shock*, when all the body's vital tissues are in danger of cellular death for lack of blood flow—especially the *Brain and the Heart*—sympathetic stimulation can decrease splanchnic blood flow to very little for many hours.**

- **Sympathetic stimulation also causes *Strong vasoconstriction of the large-volume intestinal and mesenteric veins.* This decreases the volume of these veins, thereby displacing large amounts of blood into other parts of the circulation.**

- **In hemorrhagic shock or other states of low blood volume, this mechanism can provide as much as 200 to 400 milliliters of extra blood to sustain the general circulation.**