GIT Physiology

Lec. 1 — Dr. Weaam J. Abbas

The primary function of alimentary tract or(GIT) is to break down food and to provides the body with a continual supply of water, electrolytes, and nutrients. Toachieve this requires to :-

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. **Blood Circulation** through the gastrointestinal organs to carry away the absorbed substances.
5. **Control of all these functions** by local, nervous, and hormonal systems.

Figure shows the entire alimentary tract. Each part is adapted to its specific functions: some to simple passage of food, such as the esophagus; others to temporary storage of food, such as the stomach; and others to digestion and absorption, such as the small intestine.

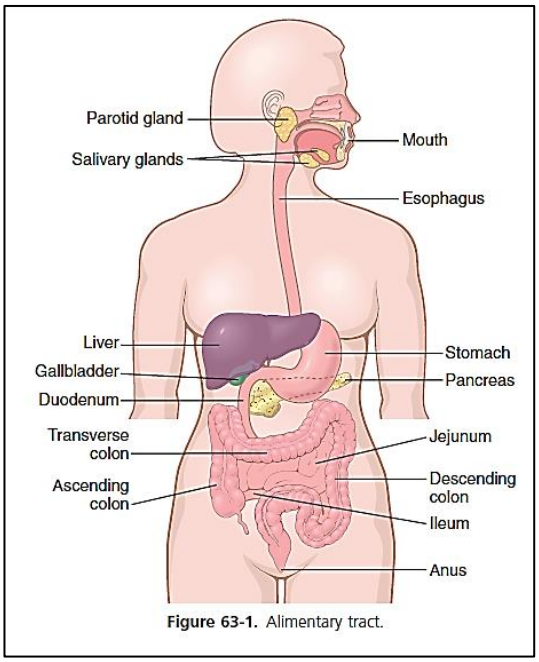

Figure 63-1. Alimentary tract.

General Principles of Gastrointestinal Motility

Physiologic Anatomy of the Gastrointestinal Wall

1. **Serosa** which continues onto the mesentery, which contains the nerves, lymphatics, and blood vesselssupplying the tract.
2. **Longitudinal muscle.**
3. **Myenteric (Auerbach's) plexus** which controls mainly the GIT movement.
4. **Circular muscle** which causes a decrease in the diameter of the lumen of the GI tract when itcontracts.
5. **Submucous (Meissner's) plexus** which is important in controlling secretion and blood flow and also subserves many sensory functions, receiving signals from chemoreceptors in the gut epithelium and from stretch receptors in the gut wall.
6. **Mucosa and submucosa** which consists of epithelium and subepithelial connective tissue and are specialized for secretion and absorption. In addition, sparse bundles of smooth muscle fibers, the mucosal muscle, lie in the deeper layers of themucosa. The motor functions of the gut are performed by the different layers of smooth muscle.

.1):

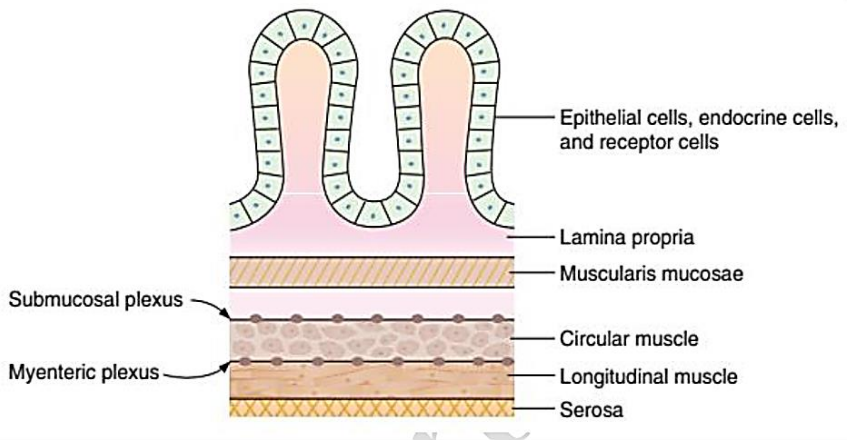

Figure 5.1: Histological cross section of the digestive tract.

Neural control of GIT

The enteric nervous system (ENS):

The GIT has an intrinsic nervous system of its own called the enteric nervous system which controls most GI functions, especially GIT movements and secretion. The enteric nervous system is composed of two layers of neurons and connecting fibers, the outer layer is called the **myenteric (Auerbach's) plexus**, the inner layer is called the **submucous (Meissner's) plexus.**

The degree of activity of this enteric nervous system can strongly be altered by extrinsic (autonomic) nervous system, i.e. parasympathetic and sympathetic nervous systems. Both systems send signals to GIT from the brain and spinal cord to modulate the activity of the enteric nervous system.

The parasympathetic nerve fibers: the "rest and digest". Stimulation of the parasympathetic nerves fibers release acetylcholine and causes in general:

- **An increase in the activity of most GIT functions**.
- **Relaxation of sphincters** (except the lower esophageal sphincter, which they stimulate).

Autonomic control of the gastrointestinal tract.

Parasympathetic stimulation increases activity of the enteric nervous system

The parasympathetic supply to the gut is divided into:

Cranial division: Is mediated almost entirely through the **vagus (X cranial nerve).** Vagus nerves innervate esophagus, stomach, pancreas, gallbladder and first half of the large intestine, and little innervations to the small intestine .Except for a few parasympathetic fibers to the mouth and pharyngeal regions of the alimentary tract

Sacral divisions: The sacral divisions originate in S2, 3, 4 sacral segments of the spinal cord, and pass through the pelvic nerves to the distal half of the large intestine. These fibers function especially in the defecation reflex.

Sympathetic stimulation usually inhibits gastrointestinal tract activity

The sympathetic nerve fibers: The sympathetic nerve endings secrete norepinephrine. In general, stimulation of the sympathetic nervous system:

Inhibits activity in the GIT

Contraction of sphincters, causing effects essentially opposite to those of the parasympathetic system. The sympathetic nerve fibers to the GIT originate in the spinal cord between the segments T- 8 and L -2. The preganglionic fibers after leaving the cord pass through the sympathetic chains to outlying ganglia, such as the celiac, hypogastric, and mesenteric ganglia. Here, the postganglionic neuron bodies are located, and postganglionic fibers spread from them along with the blood vessels to all parts of the gut, terminating principally on neurons of the enteric nervous system.

Reflexes of GIT are either occur entirely within the enteric nervous system (short reflex arc), or the reflex arc is originated from the gut and to the CNS (spinal cord or brain stem) and then back to the gut (long reflex arc) Signals transmitted through these reflexes can cause reflex excitation or inhibition of intestinal movements or secretion.

In addition to its anatomic complexity, the ENS utilizes many different neurotransmitters, including acetylcholine, adenosine triphosphate (ATP), nitric oxide, and numerous peptides.

Electrical Activity of Gastrointestinal Smooth Muscle

The smooth muscle of the gastrointestinal tract is excited by almost continual slow, intrinsic electrical activity along the membranes of the muscle fibers. This activity has two basic types of electrical waves:

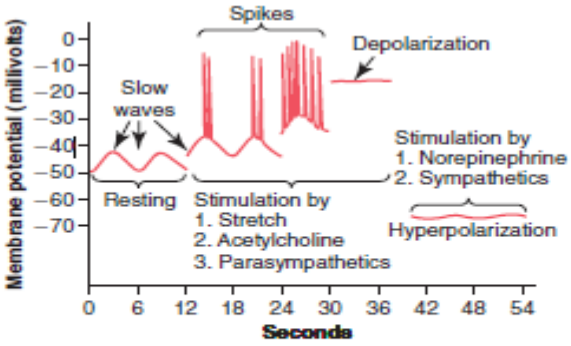

Figure 63-3. Membrane potentials in intestinal smooth muscle. Note the slow waves, the spike potentials, total depolarization, and hyperpolarization, all of which occur under different physiological conditions of the intestine.

(1) slow waves and

(2) spikes,

The slow waves usually do not by themselves cause muscle contraction in most parts of the GIT, except perhaps in the stomach.

Changes in Voltage of the Resting Membrane Potential.

In addition to the slow waves and spike potentials, the baseline voltage level of the smooth muscle resting membrane potential can also change.

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

(1) stretching of the muscle,
(2) stimulation by acetylcholine released from the endings of parasympathetic nerves,
(3) stimulation by several specific gastrointestinal hormones.

Important factors that make the membrane potential more negative-that is, that hyperpolarize the membrane and make the muscle fibers less excitable-are

(1) The effect of norepinephrine or epinephrine on the fiber membrane.
(2) stimulation of the sympathetic nerves that secrete mainly norepinephrine at their endings.

Smooth muscle contraction occurs in response to entry of **calcium** ions into the muscle fiber.

Neural Control of Gastrointestinal Function— Enteric Nervous System

The gastrointestinal tract has a nervous system all 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 enteric system is about 100 million, almost exactly equal to the number in the entire spinal cord. This highly developed enteric nervous system is especially important in controlling gastrointestinal movements and secretion. The enteric nervous system is composed mainly of two plexuses, shown in figure below:

(1) myenteric plexus or Auerbach's plexus: *An outer plexus lying between the longitudinal and circular muscle layers.* (controls mainly the gastrointestinal movement)

(2) ***submucosal plexus or Meissner's plexus****: An inner plexus, called the, that lies in the submucosa (controls mainly gastrointestinal secretion and local blood flow.).*

The nervous connections within and between these two plexuses (figure below). Extrinsic sympathetic and parasympathetic fibers connect to both plexus and can greatly enhance or inhibit GIT function.

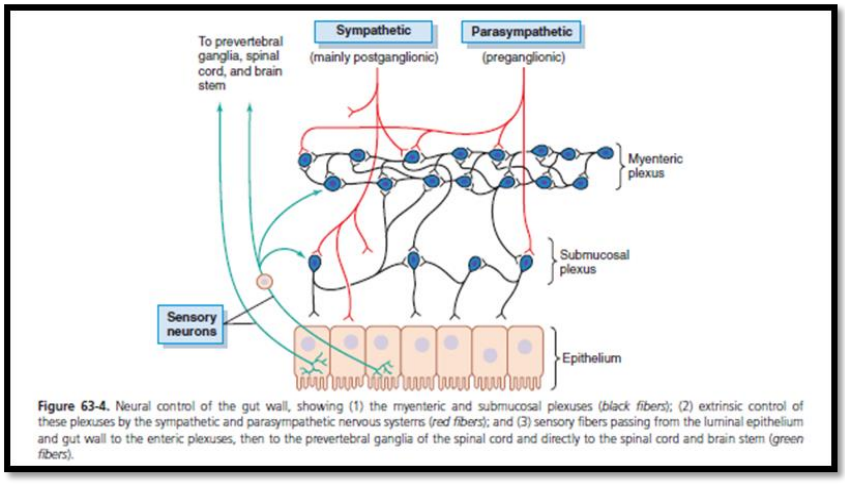

Figure 63-4. Neural control of the gut wall, showing (1) the myenteric and submucosal plexuses (*black fibers*); (2) extrinsic control of these plexuses by the sympathetic and parasympathetic nervous systems (*red fibers*); and (3) sensory fibers passing from the luminal epithelium and gut wall to the enteric plexuses, then to the prevertebral ganglia of the spinal cord and directly to the spinal cord and brain stem (*green fibers*).

Although the enteric nervous system can function on its own, independently of these extrinsic nerves, sensory nerve endings that originate in the gastrointestinal epithelium or gut wall and send afferent fibers to both plexuses of the enteric system, as well as:

1. To the prevertebral ganglia of the sympathetic nervous system.
2. To the spinal cord.In
3. the vagus nerves all the way to the brain stem.

These sensory nerves can elicit local reflexes within the gut wall itself and still other reflexes that are relayed to the gut from either the prevertebral ganglia or the basal regions of the brain.

Differences Between the Myenteric and Submucosal Plexuses

Table 5A: Differences Between the Myenteric and Submucosal Plexuses	
Myenteric Plexus(motility)	***Submucosal Plexus(secretion)***
*It is concerned mainly with controlling **muscle activity** along the length of the gut with specific effects:* *(i) Increased "tone" of the gut wall* *(ii) Increased intensity of the rhythmical contractions* *(iii) Slightly increased rate of the rhythm of contraction* *(iv) Increased velocity of conduction of excitatory waves along the gut wall, causing more rapid movement of the gut peristaltic waves*	*It is mainly concerned with controlling function within the inner wall of each minute segment of the intestine such as:* *(i) local intestinal secretion* *(ii) local absorption* *(iii) local contraction of the submucosal muscle*
*Composed of **excitatory** as well as **inhibitory** neurons Inhibitory neurons are useful for inhibiting some of the intestinal sphincter muscles such as the pyloric sphincter, which controls emptying of the stomach into the duodenum, and the sphincter of the ileocecal valve, which controls emptying from the small intestine into the cecum.*	*Composed mainly of **excitatory** neurons*

Types of Neurotransmitters Secreted by Enteric Neurons

In an attempt to understand better the multiple functions of the gastrointestinal enteric nervous system, research workers the world over have identified a dozen or more different neurotransmitter substances that are released by the nerve endings of different types of enteric neurons. Two of them with which we are already familiar are (1) acetylcholine and (2) norepinephrine. Others are (3) adenosine triphosphate, (4) serotonin, (5) dopamine, (6) cholecystokinin, (7) substance P, (8) vasoactive intestinal polypeptide, (9) somatostatin, (10) leu-enkephalin, (11) met-enkephalin, (12) bombesin. The specific functions of many of these are not known well enough to justify discussion here, other than to point out the following.

Acetylcholine most often excites gastrointestinal activity. Norepinephrine almost always inhibits gastrointestinal activity.

Afferent sensory nerve fibers from the gut.

Many afferent sensory nerve fibers innervate the gut. Some of them have their cell bodies in the enteric nervous system itself and some in the dorsal root ganglia of the spinal cord. 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, under other conditions,* ***inhibition*** *of intestinal movements or intestinal secretion. In addition, other sensory signals from the gut go all the way to multiple areas of the spinal cord and even the brain stem. For example, 80 percent of the nerve fibers in the vagus nerves are afferent(toward the CNS) rather than efferent(tout the CNS). These afferent fibers transmit sensory signals from the gastrointestinal tract into the brain medulla, which in turn initiates* ***vagal*** *reflex signals that return to the gastrointestinal tract to control many of its functions.*

Gastrointestinal reflexes.

The anatomical arrangement of the enteric nervous system and its connections with the sympathetic and parasympathetic systems support three types of gastrointestinal reflexes that are essential to gastrointestinal control. They are the following:

1. *Reflexes that are integrated entirely within the gut wall enteric nervous system. These include reflexes that control much gastrointestinal secretion, peristalsis, mixing contractions, local inhibitory effects, and so forth.*

2. *Reflexes from the gut to the prevertebral sympathetic ganglia and then back to the gastrointestinal tract. These reflexes transmit signals long distances to other areas of the gastrointestinal tract, such as signals from the stomach to cause evacuation of the colon (the gastrocolic reflex), signals from the colon and small intestine to inhibit stomach motility and stomach secretion (the enterogastric reflexes), and reflexes from the colon to inhibit emptying of ileal contents into the colon (the colonoileal reflex).*

3. *Reflexes from the gut to the spinal cord or brain stem and then back to the gastrointestinal tract.* These include especially

(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 (the defecation reflexes).

Hormonal control of gastrointestinal motility

Hormone	Stimuli for Secretion	Site of Secretion	Actions
Gastrin	**Protein Distention Nerve *(Acid inhibits release)***	**G cells of the antrum,duodenum, and jejunum**	**Stimulates Gastric acid secretion Mucosal growth**
Cholecystokinin (CCK)	Protein Fat Acid	I cells of the duodenum, jejunum, and ileum	**Stimulates:** Pancreatic(enzyme ,bicarbonate secretions) Gallbladder contraction Growth of exocrine pancreas **Inhibits** Gastric emptying
Secretin Acid	Fat Acid	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	Protein Fat Carbohydrate	K cells of the Duodenum and jejunum	**Stimulates** Insulin release **Inhibits** **Gastric acid secretion**
Motilin	Fat Acid Nerve	M cells of the Duodenum and jejunum	**Stimulates** Gastric motility Intestinal motility

Functional types of movements in the gastrointestinal tract

Two types of movements occur in the gastrointestinal tract:

(1) ***Propulsive movements*** (peristalsis) *which cause food to move forward along the tract at an appropriate rateto accommodate digestion and absorption,*
(2) ***Mixing movements,*** *which keep the intestinal contents thoroughly mixed at all times.*

1. Propulsive movements—Peristalsis

The basic propulsive movement of the gastrointestinal tract is peristalsis, A contractile ring appears around the gut and then moves forward; this is analogous to putting one's fingers around a thin distended tube, then constricting the fingers and sliding them forward along the tube. Any material in front of the contractile ring is moved 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. (Peristalsis also occurs in the bile ducts, glandular ducts, ureters, and many other smooth muscle tubes of the body.
The usual stimulus for intestinal peristalsis is distention of the gut. 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. Other stimuli that can initiate peristalsis include chemical or physical irritation of the epithelial lining in the gut. Also, strong parasympathetic nervous signals tothe gut will elicit strong peristalsis.*

- Function of the myenteric plexus in peristalsis.

*Peristalsis occurs only **weakly** or **not** at all in any portion of the gastrointestinal tract 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, effectual peristalsis requires an active myenteric plexus.*

- Directional movement of peristaltic waves toward the anus.

*Peristalsis, theoretically, can occur in either direction from a stimulated point, but it normally dies out rapidly in the orad direction while continuing for a considerable distance **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, which can be explained as follows.*

- 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. At the same time, the gut sometimes relaxes several centimeters downstream toward the anus, which is called ―receptive relaxation,‖ thus allowing the food to be propelled more easily anally than orad. This complex pattern does not occur in the absence of the myenteric plexus. Therefore, the 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.(eg for congenital myenteric plexus absence caused functional colon obstruction)

2. Mixing movements

*Mixing movements differ in different parts of the alimentary tract. 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 lastonly 5 to 30 seconds; then new constrictions occur at other points in the gut, thus **―chopping and―shearing(segmentation contraction)** the contents first here and then there. These peristaltic and constrictive movements are modified in different parts of the gastrointestinal tract for proper propulsion and mixing.*

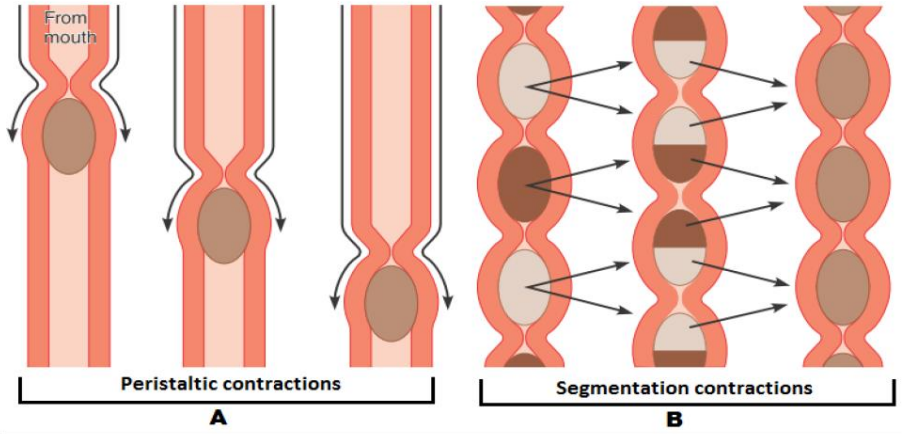

Figure 5.3: Types of GIT smooth muscle contractions.

Gastrointestinal blood flow—"splanchnic circulation"

The blood vessels of the gastrointestinal system are part of a more extensive system called the ***splanchnic circulation****, shown in Figure below It includes the blood flow through the gut itself plus blood flows through the spleen, pancreas, and liver. The design of this system is such that all the blood that courses through the gut, spleen, and pancreas then flows immediately into the liver by way of the portal vein. In the liver, the blood passes through millions of minute liver sinusoids and finally leaves the liver by way of* ***hepatic veins*** *that empty into the* ***vena cava*** *of the general circulation.*

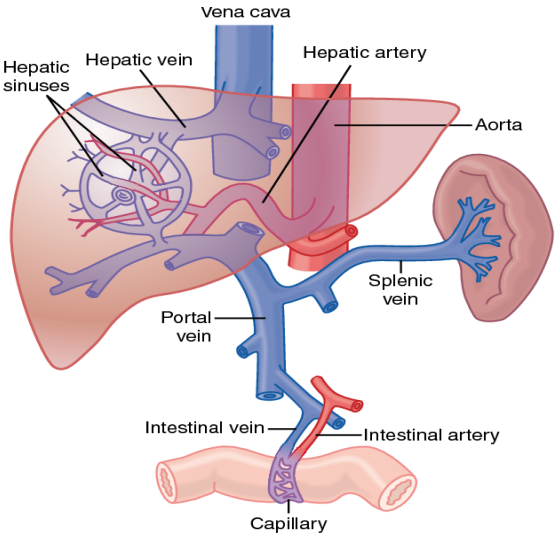

Figure 62-6 Splanchnic circulation.

This flow of blood through the liver, before it empties into the vena cava, allows the reticuloendothelial cells that line the liver sinusoids to remove bacteria and other particulate matter that might enter the blood from the gastrointestinal tract, thus preventing direct transport of potentially harmful agents into the remainder of the body. The nonfat, water-soluble nutrients absorbed from the gut (such as carbohydrates and proteins) are transported in the portal venous blood to the same liver sinusoids. Here, both the reticuloendothelial cells and the principal parenchymal cells of the liver, the hepatic cells, absorb and store temporarily from ***1/2 to 3/4*** *of the nutrients. Also, much chemical intermediary processing of these nutrients occurs in the liver cells. Almost all of the fats absorbed from the intestinal tract are not carried in the portal blood but instead are absorbed into the intestinal lymphatics and then conducted to the systemic circulating blood by way of the thoracic duct, bypassing the liver.*

Anatomy of the gastrointestinal blood supply.

Figure below shows the general plan of the arterial blood supply to the gut, including the ***superior mesenteric and inferior mesenteric arteries*** *supplying the walls of the small and large intestines by way of an arching arterial system. Not shown in the figure is the celiac artery, which provides a similar blood supply to the stomach. 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 to*

:

1. Along the muscle bundles
2. Into the intestinal villi
3. Into submucosal vessels beneath the epithelium to serve the secretory and absorptive functions ofthe gut. Figure below shows the special organization of the blood flow through an intestinal villus, including a small **arteriole and venule** that interconnect with a system of multiple looping capillaries. **The walls of the arterioles are highly muscular and are highly active in controlling villus blood flow**

.

Effect of gut activity and metabolic factors on gastrointestinal blood flow

Under normal conditions, the blood flow in each area of the gastrointestinal tract, as well as in each layer of the gut wall, is directly related to the level of local activity. For instance, during active absorption of nutrients, blood flow in the villi and adjacent regions of the submucosa is increased as much as ***eightfold****. Likewise, blood flow in the muscle layers of the intestinal wall increases with increased motor activity in the gut. For instance, 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.

Although the precise cause or causes of the increased blood flow during increased gastrointestinal activity are still unclear, some facts are known.

First, *several* ***vasodilator substances*** *are released from the mucosa of the intestinal tract during the digestive process. Most of these are peptide hormones, including cholecystokinin, vasoactive intestinal peptide, gastrin, and secretin. The same hormones control specific motor and secretory activities of the gut.*

Second, *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.*

Third, *decreased oxygen concentration in the gut wall can increase intestinal blood flow at least 50 to 100 per cent; therefore, the increased mucosal and gut wall metabolic rate during gut activity probably lowers the oxygen concentration enough to cause much of the vasodilation. The decrease in oxygen can also lead to as much as a fourfold increase of adenosine, a wellknown vasodilator that could be responsible for much of the increased flow. Thus, the increased blood flow during increased gastrointestinal activity is probably a combination of many of the aforementioned factors plus still others yet undiscovered.*

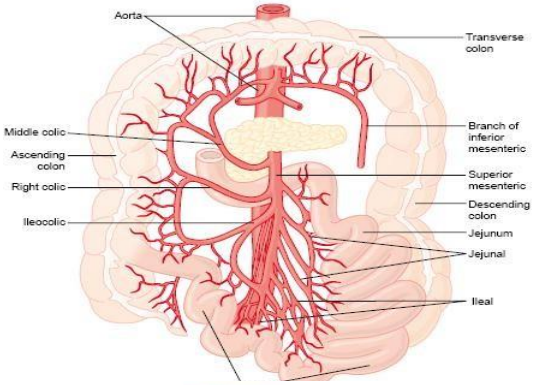

Figure 62–7

Arterial blood supply to the intestines through the mesenteric web.

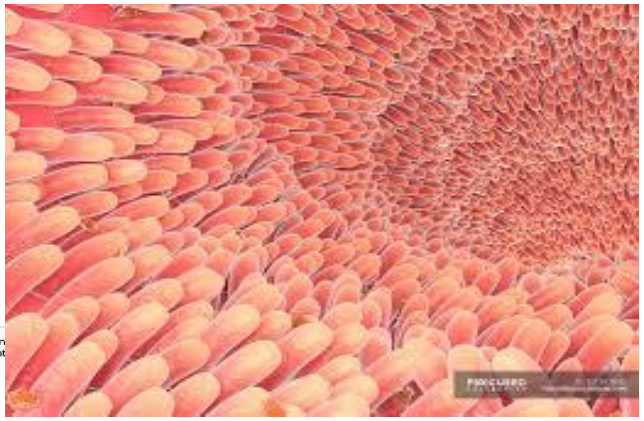

Figure 1 :Villi of small intestine

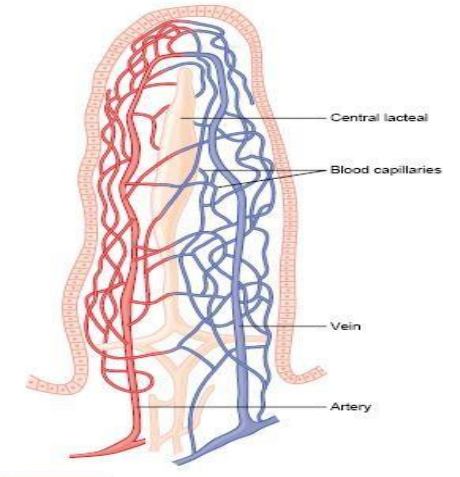

Figure 62–8

Microvasculature of the villus, showing a countercurrent arrangement of blood flow in the arterioles and venules.

"Countercurrent" blood flow in the villi.

Note in figure above that 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 per cent of the oxygen may take this short-circuit route and therefore not be available for local metabolic functions of the villi. Under normal conditions, this shunting of oxygen from the arterioles to the venules is not harmful to the villi, but in disease conditions in which blood flow to the gut becomes greatly curtailed, such as in circulatory shock, the oxygen deficit in the tips of the villi can become so great 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

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. This increased flow probably results secondarily 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 gastrointestinal tract to cause intense vasoconstriction of the arterioles with greatly decreased blood flow. After a few minutes of this vasoconstriction, the flow often returns almost to normal by means of a mechanism called —autoregulatory escape. 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 gastrointestinal glands and muscle.

Importance of nervous depression of gastrointestinal blood flow when other parts of the body need extra blood flow.

A major value of sympathetic vasoconstriction in the gut is that it allows ***shut-off*** *of gastrointestinal and other splanchnic blood flow for short periods of time during heavy* ***exercise****, when increased flow is needed by the skeletal muscle and heart. 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.*