

DIGESTIVE SYSTEM

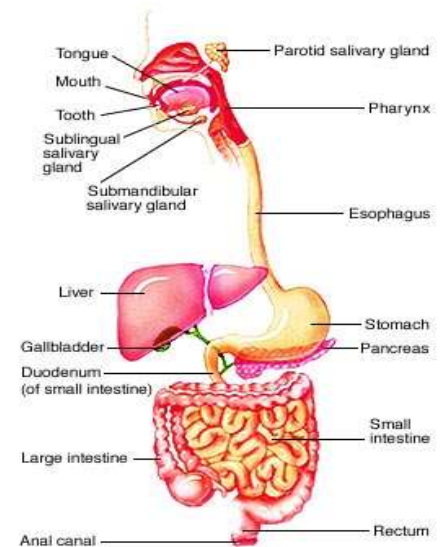
Digestive system : system in the body responsible for break down large nutrient particles & molecules into smaller molecules that can be absorbed into blood or lymph to be transported to cells.

Three main functions

- Ingestion-receiving food**
- Digestion-breakdown of food particles into particles small enough to pass through cell membranes**
- Transfer of food into circulation**

Digestion: mechanical & chemical breakdown of food into smaller components that can be absorbed.

- Mechanical digestion breaks down food into smaller particles.
- Chemical digestion consists of hydrolysis reactions that break down dietary macromolecules (Large molecule) into their subunits of organic molecules, which allows for absorption of nutrients.
- Hydrolysis:chemical process of decomposition involves splitting of a bond & addition of water.



END PRODUCTS OF DIGESTION

1. CHO (starch & disaccharide) digested to → monosaccharide (glucose, fructose & galactose).
2. Fats are digested to fatty acids (f.a) & glycerol.
3. Proteins are digested to amino acids.
4. Other end products are vitamins, minerals, & water.

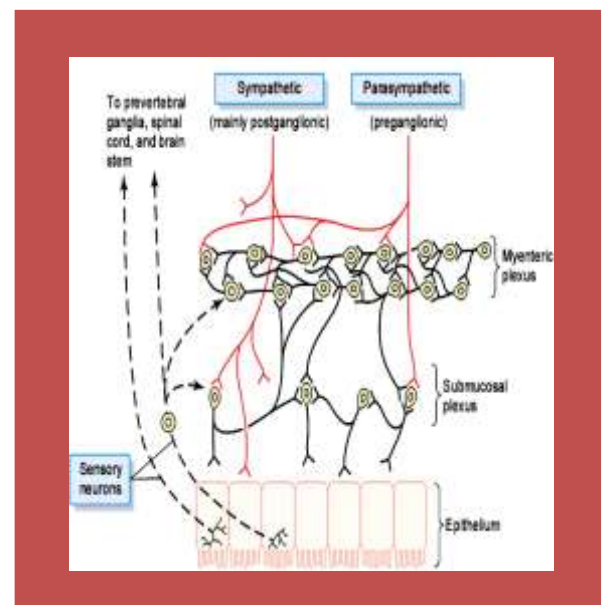
DIVISIONS OF THE DIGESTIVE SYSTEM

- Digestive tract (alimentary canal): Tubular portion of GIT extends from mouth to anus), includes:
 - ❖ Mouth , Pharynx, Esophagus, Stomach , Small intestine , Large intestine, & anal canal
 - Digestion occur in oral cavity, stomach, & small intestine;
 - Most absorption of takes place in small intestine.
 - Undigestible material is eliminated by large intestine.
- Accessory organs, Teeth, tongue, salivary gland , Liver , Gallbladder, Pancreas.
- Digestion does not take place within them, but each contributes to digestive process through their release secretions into the canal.

Elementary tract & nervous system:

- **Enteric nervous system (ENS)** is 2 plexuses:

- Myenteric or Auerbach's plexus;** between



longitudinal & circular muscle layers. It controls GIT movement.

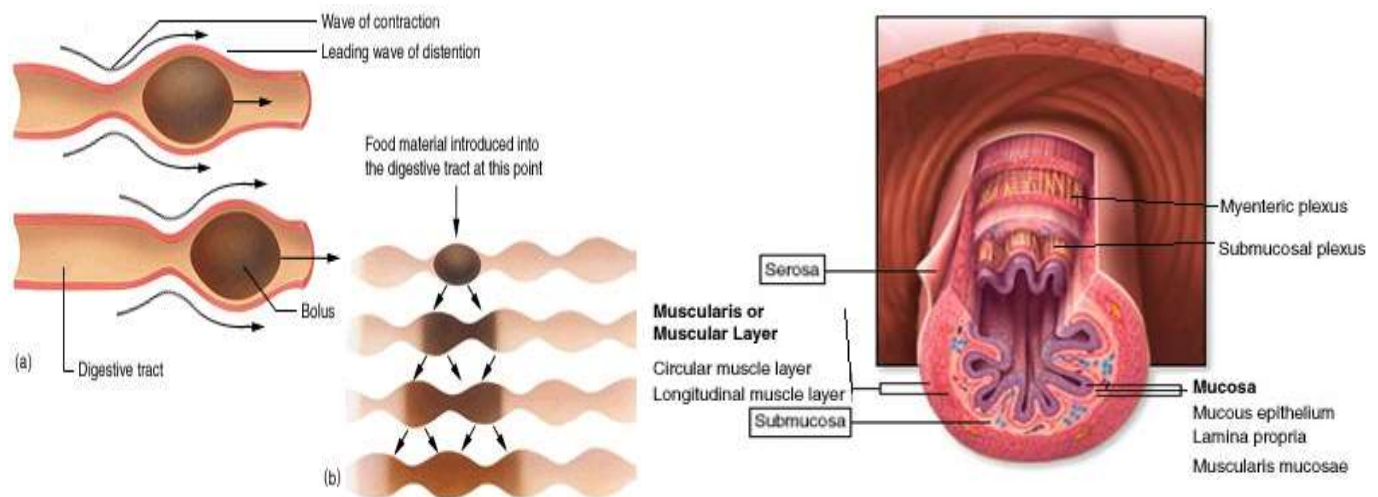
- II. **Submucosal or Meissner's plexus;** in submucosa. It controls mainly GIT secretion & local blood flow.
- Symp. & parasymp. fiber connect to myenteric & submuc. plexus. Although ENS can function independently, stimulation by parasymp. & symp. Systems can enhance or inhibit GIT functions..
 - **Sensory nerve endings** that originate in GIT epithelium or gut wall, send afferent fibers to
 - (1) Both plexuses of ENS,
 - (2) Prevertebral ganglia of symp. nervous system.
 - (3) Spinal cord.
 - (4) vagus nerves all the way to brain stem.

Movements in Digestive Tract

(a) Peristalsis. A wave of relaxation followed by a wave of strong contraction of circular muscles, which propels the bolus of food through the digestive tract.

- Stimulated by distention, chemical or physical irritation of gut wall. Movement of peristalsis occurs in direction of anus. Peristaltic reflex + anal direction of movement called "law of the gut."
- It is an inherent property of many syncytial smooth muscle tubes; stimulation at any point in gut can cause a contractile ring to appear in circular muscle, & spreads along gut.
- It depends on Myenteric plexus.
- It also occurs in bile ducts, glandular ducts, ureters, & other smooth muscle tubes.

(b) Segmental contractions. Each part of GIT involved in segmental contractions alternates between contraction & relaxation. Material direction in a given part of intestine moves with each contraction.



STRUCTURAL LAYERS OF THE ALIMENTARY TUBE (HISTOLOGY)

Alimentary tube has 4 layers :mucosa, submucosa, external muscle layer, & serosa.

MUCOSA (lining); made of :

- ❖ Epithelial tissue that produces the digestive secretions; Epithelium secretes;
 - Mucus, which lubricates passage of food,
 - Digestive enzymes of stomach & small intestine.
- ❖ Lymph nodules contain macrophages to phagocytize pathogens that penetrate mucosa.
- ❖ Thin layers of smooth muscle create folds in mucosa, & ripples, so that all of epithelial cells are in touch with contents of the organ (important for absorption).

SUBMUCOSA

- ❖ It is areolar connective tissue with blood vessels & lymphatic vessels.
- ❖ It contains Meissner's plexus (part of ENS) that innervates mucosa to regulate secretions.

MUSCULAR LAYER

- ❖ Contains two layers of smooth muscle: Inner, circular layer & outer, longitudinal layer.
 - Stomach has 3 layers of smooth muscle, rather than 2.
 - Contractions of this layer help break up food & mixes it with digestive juices.
- ❖ *Function*; mechanical digestion & peristalsis;
- ❖ Innervated by **Auerbach's plexus**. In this layer, some of neurons are autonomic;
 - ☒ Sympath. impulses → ↓ contractions & peristalsis,
 - ☒ Parasymp. impulses (via vagus n) → ↑ contractions & peristalsis.

SEROSA (Adventitia) : It is the outermost connective tissue layer of the GIT.

ORAL CAVITY .(have the structures : teeth, tongue, salivary glands)

- ❖ Teeth and tongue break up food and mix it with saliva

Tooth : important for mastication . Mastication is vital for:

- 1- Destruction of cellulose covering fruits & raw vegetables. Cooking & steam also breaks cellulose.
- 2- Aid in digestion because digestive enzymes acts only on surface of food particles. Chewing → cutting large particles into smaller particles.
- 3- Bolus formed which is reduced into paste form, prevents excoriation of mucus membrane & facilitates movement of food through GIT.

Tongue

- It is skeletal muscle innervated by 12th cranial nerve.
- Papillae on upper surface contain taste buds (facial & glossopharyngeal nerves).
- **Functions**: taste, keeps food between teeth when chewing, elevates to push food backward for swallowing, & help in speech.

Salivary glands; parotid, submandibular, & sublingual ; ducts take saliva to oral cavity. In addition, there are small salivary glands scattered in the lining of oral cavity.

- **There are 3 types of secretory cells in the salivary glands:**
- Serous (secret serous (thin, watery), & provides ptyalin.
- Mucus secret mucus (viscid, thick)
- Seromucinous.

Saliva;

- It is made from blood plasma (contains many chemicals that are found in plasma).
- Daily secretion 1-1.5 L/day. Mainly secreted at meal time.
- Saliva contains: 99.5% water , 0.5% solids (organic & inorganic)

Organic constituents of saliva : (glucose is absent)

- 1- Protein mucin.
- 2- Ptyalin or alpha amylase for digestion of starch.
- 3- Lingual lipase: plays an important role in hydrolysis of triglycerides.
- 4- Urea, uric acid, & creatinine.
- 5- Kallikrein: enzyme act on plasma protein to produce kinin (powerful vasodilator peptide).
- 6- Specific blood group Ag (ABO system): blood groups substances agglutinogens present in 80% of people called secretors. It can determine an individual blood group from a recent used drinking glass or cigarettes (medico- legal significance).
- 7- Somatostatin, glucagons , rennin, & several growth factors.
- 8- Lysozyme: destroy bacteria by lysis.
- 9- Lactoferrin: bind to iron & deprive organisms of nutrients iron (bacteriostatic)
- 10- Praline-rich protein: protect teeth enamel & bind toxic tannins.
- 11- IGA: can destroy bacteria including that causes dental caries.

Inorganic constituents of saliva:

- Anions : Cl⁻, phosphate, bicarbonate, fluoride.
- Cations: Ca⁺², Na⁺, K⁺.
- + Fluoride important to prevent dental caries. Ca Salt is a source of tartar deposits on teeth.
- + [Na⁺] & [Cl⁻] in saliva < in plasma, while [K⁺] in saliva > in plasma.
- + Low Na⁺ & absence of glucose in saliva help to taste sweet & salty substance.
- + Ductal epithelium impermeable to water. Absorption of Na⁺ & Cl⁻ faster than secretion of K⁺ thus saliva becomes hypotonic.
- + PH of saliva (6-7.4). At more acidic PH Ca will be lost from teeth to saliva.
- **Innervations** of salivary glands: parasympathetic stimulation causes:
 - 1- Increase salivation.
 - 2- Vasodilation (increase kallikrein)
- Sympathetic stimulation causes: Vasoconstriction.
- **Reflexes of salivary secretion:**
 - 1- Unconditioned reflex: due to stimulation of nerves within mouth. Material placed in mouth → secretion which varies according to physical & chemical substances. Acid → profuse secretion. Manipulation of dentists → secretion.
 - 2- Conditioned reflex stimulus received by special senses other than taste e.g sight, smell & hearing. It requires previous training e.g Pavlov experiment on the dog.
 - 3- Abnormal situation: due to reflex originated in esophagus, stomach, & small intestine by vagal afferent stimulation. E.g eating irritating or nauseating food → ↑ salivation.
- **Functions of Saliva:** it facilitates swallowing, keeps the mouth moist, serves as a solvent for molecules that stimulate taste buds, aids speech by facilitating movements of lips & tongue, & keeps the mouth & teeth clean.

PHARYNX

- ❖ It is food passageway from oral cavity to esophagus. No digestion takes place.
- ❖ Function; swallowing reflex. Contraction of pharyngeal muscles is part of swallowing reflex.
- ❖ Regulation; by the medulla.
- ❖ Talking or laughing while eating, may interfere with swallowing reflex & cause food to go into larynx. When that happens, cough reflex is usually effective in clearing airway.

ESOPHAGUS

- ❖ It is food passageway from pharynx to stomach, No digestion takes place.
- ❖ Peristalsis propels food toward stomach (one direction) even if body is horizontal or upside down.
- ❖ Lower esophageal sphincter at junction with stomach prevents backup of stomach content.

STOMACH

- ❖ It is a sac (not a tube), that extends from esophagus to small intestine.
- ❖ It is a reservoir for food (because it is a sac), so that digestion proceeds gradually.
- ❖ Both mechanical & chemical digestion takes place in it.
- ❖ **Rugae**; folded mucosa of stomach, that permit expansion of lining without tearing it.
- ❖ **Gastric pits**: are glands of stomach, that consist of several types of cells; (their collective secretions called gastric juice);
- ☒ **Mucous cells** secrete mucus, which coats stomach lining & helps prevent erosion by gastric juice
- ☒ **Chief cells** secrete **pepsinogen**, which is an inactive form of enzyme **pepsin**.
- ☒ **Enteroendocrine cells (G cells)** secrete **gastrin** H.
- ☒ **Parietal cells** ;
 - i. Secrete intrinsic factor, which is necessary for absorption of vitamin B12.
 - ii. Produce hydrochloric acid (HCl); through mechanism;
 - H⁺ ions secreted by **Proton pumps** enzymes into stomach cavity.
 - Cl⁻ ions from parietal cells.
 - H⁺ + Cl⁻ → HCl (HCl function)

1. $\text{Pepsinogen} \xrightarrow{\text{HCL}} \text{Pepsin}$, (by removing some of amino acids from pepsinogen)
 - Pepsin begins digestion of proteins \rightarrow polypeptides.
 2. Gives gastric juice its pH of 1 - 2. This very acidic pH is necessary for;
 - a- Pepsin to function
 - b- Kills most microorganisms that enter stomach.
- Time to empty stomach 2-6 Hours.

❖ **Regulation of gastric juice :**

- ☒ **Nervous Regulation;** Sight or smell of food; parasymp. impulses along 10th cranial n.
 ☒ **Chemical Regulation;** Gastrin — when food is present in the stomach. Gastrin action :

- Stimulates increased secretion of gastric juices.
- Stimulates intestinal motility.

❖ **Chyme:** Semifluid mass of partially digested food that passes from stomach to small intestine

❖ **Pyloric sphincter;**

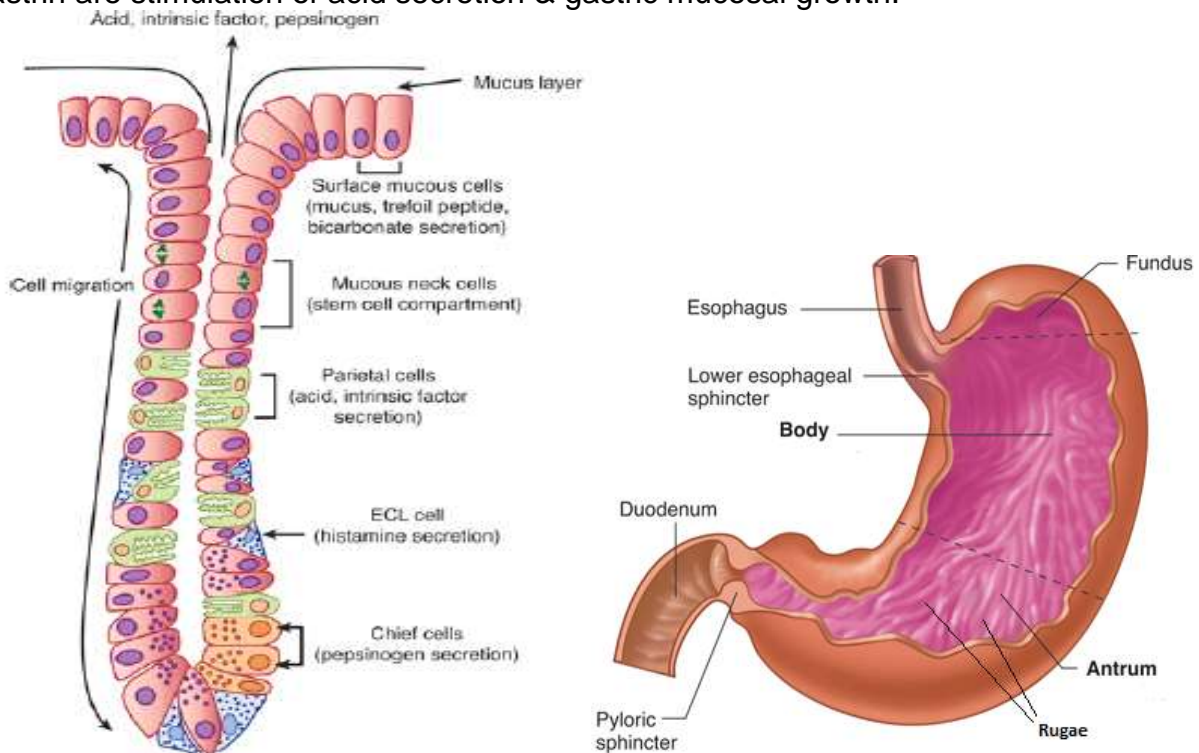
- It relaxes at intervals to permit small amounts of chyme to pass into duodenum.
- Then contracts again to prevent backup of intestinal contents into stomach.

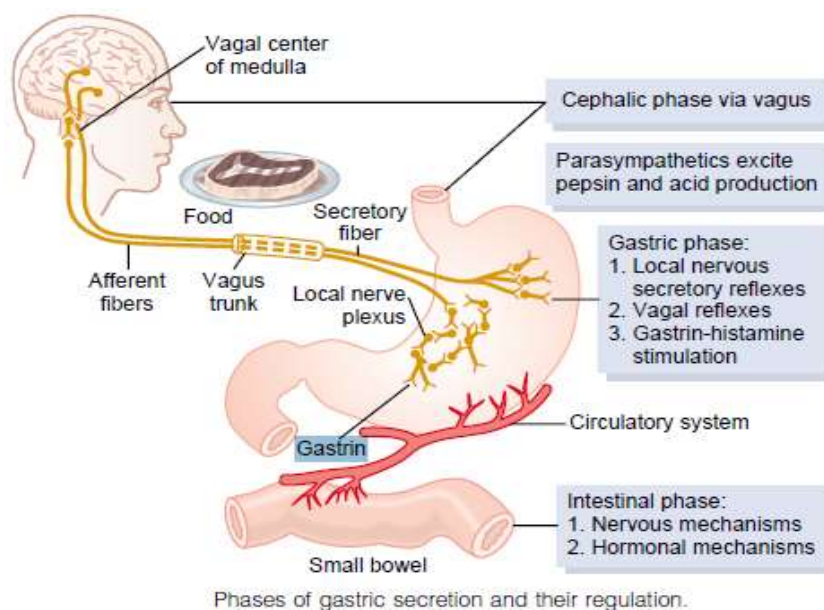
❖ Normally, gastric juices are secreted in: the presence of food, Stress , & Smoking.

❖ In absence of food, acidic juices erode lining of stomach, leaving an open sore (ulcer) that may bleed. [Helicobacter pylori](#) (A bacterial species that produces urease & causes gastritis & is involved in peptic ulcer of stomach & duodenum), may be a major factor in ulcer formation.

❖ **Gastrin H** is produced by G cells of gastric mucosa and released into the blood in response to stomach wall stretching (gastric distention) & when food enters stomach (mainly protein).

❖ Its secretion is inhibited when pH of gastric/duodenal lumen falls below 3.5. The main effects of gastrin are stimulation of acid secretion & gastric mucosal growth.



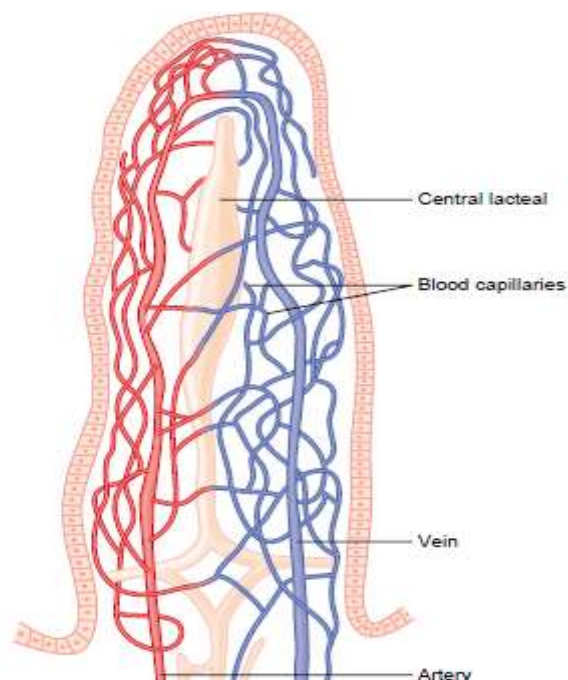
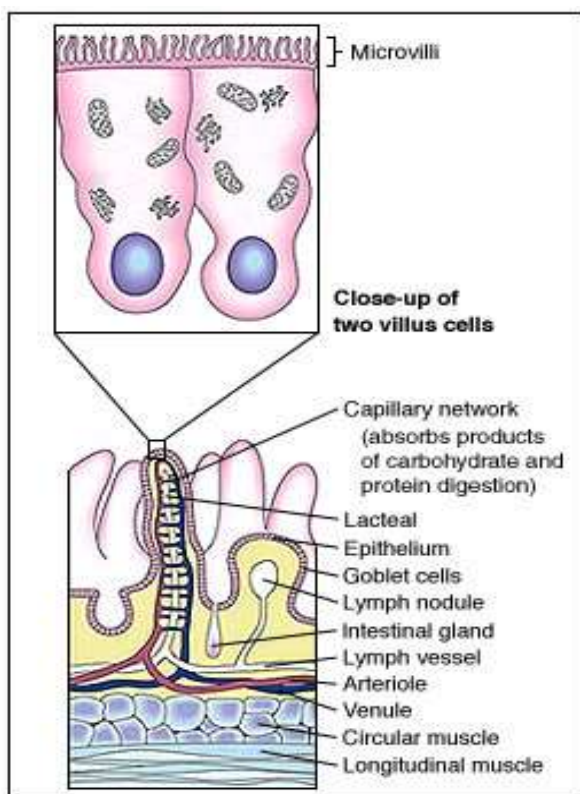


SMALL INTESTINE

- ❖ It is 6 m long , extends from stomach to cecum of large intestine.
- ❖ In a living person, small intestine is always contracted & is, therefore, shorter.
- ❖ Within it; digestion is completed, & absorption of the end products occurs into blood & lymph.
- ❖ **Plica circulares**, or circular folds, are macroscopic folds of mucosa & submucosa. Mucosa is further folded into projections called **villi**. Each cell (except mucus-secreting goblet cells) of villi also has **microvilli** on its free surface.
- ❖ Microvilli are microscopic folds of cell membrane, & are collectively called brush border. All of these folds greatly ↑ surface area of intestinal lining.
- ❖ Within each villus is a **capillary network** & a **lacteal**, which is a dead-end lymph capillary. Absorption of nutrients takes place from lumen of intestine into vessels within villi.
- ❖ Enteroendocrine cells secrete Hs of small intestine.
- ❖ Lymph nodules called Peyer's patches are abundant in ileum to destroy absorbed pathogens.
- ❖ Stimulatory impulses from CNS to ENS are carried by vagus nerves.
 - However, waves of peristalsis, ,can take place without stimulation by CNS;
 - ENS can function independently & promote normal peristalsis.

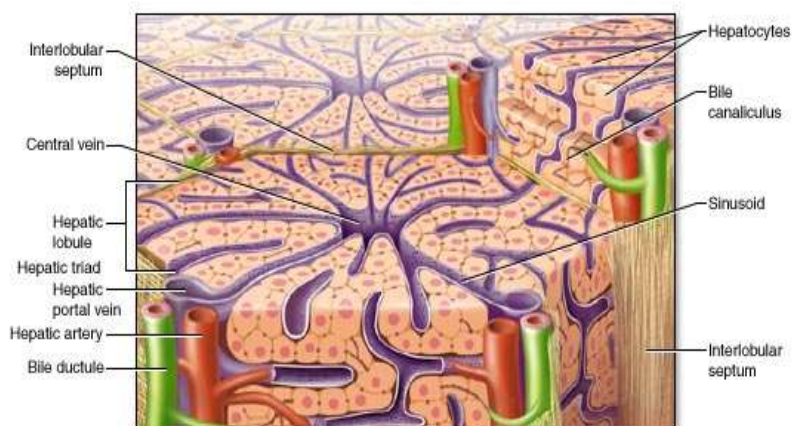
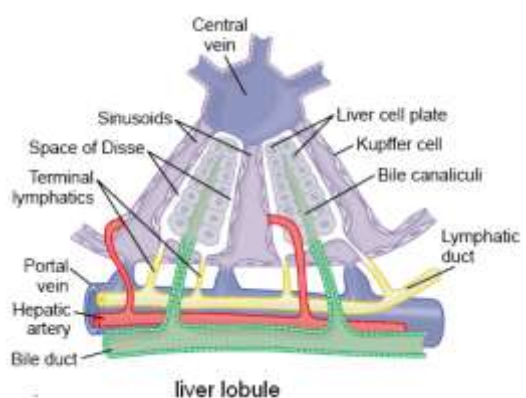
Hormone**	Source	Stimulus	Stomach Motility and Secretion	Pancreas	Gallbladder
Secretin	S cells lining duodenum	Acid entering duodenum	Inhibits	Stimulates fluid secretion (HCO_3^-)	
CCK	Cells lining duodenum	Fat and amino acids entering duodenum	Inhibits emptying	Stimulates enzyme secretion	1. Contraction 2. Relaxation sphincter (Oddi)

- Both of these 2 Hs are released then absorbed by blood to do their effect.
- ❖ **Motilin** released by neurons in the small intestine (*duodenum*) during fasting (& interdigestive phase), & the only function of this H is to *increase GIT motility*. Motilin secretion is inhibited after ingestion by mechanisms that are not fully understood.
- ❖ There are three sources of digestive secretions that function within small intestine: Liver, pancreas, & the small intestine itself.



LIVER

- It is the largest organ in the body, contributing 2% of total body weight.
- Its basic functional unit is *liver lobule*.
- Liver lobule is;
 - Constructed around a *central vein* that empties into hepatic veins→ vena cava.
 - Composed of many liver cellular plates that radiate from central vein. Each hepatic plate is two cells thick, & between adjacent cells lie small *bile canaliculi* that empty into *bile ducts* in fibrous septa separating adjacent liver lobules.
 - In septa are small *portal venules* that receive their blood from portal vein.
 - From these venules blood flows into *hepatic sinusoids* (lie between hepatic plates) & then into central vein. Thus, hepatic cells are exposed continuously to portal venous blood.
- ☒ **Sinusoids**; are large & very permeable vessels (capillaries) between rows of liver cells, that receive blood from both hepatic artery & portal vein (it is with this mixture of blood that liver cells carry out their functions).
 - Hepatic artery brings oxygenated blood,
 - Portal vein brings blood from digestive organs & spleen.
- ❖ In addition to hepatic cells, sinusoids are lined by two other types of cell:
 - 1- Large *Kupffer cells* which are resident macrophages (fixed macrophages).
 - 2- *Endothelial cells* which has extremely large pore.
- ☒ Between endothelial cells & hepatic cells, are narrow tissue spaces called *spaces of Disse* (*perisinusoidal spaces*), which are connected with lymphatic vessels in interlobular septa. Therefore, excess fluid in spaces is removed through lymphatic.
- ☒ Liver **parenchyma** (Parenchyma: are tissue that performs the main physiological functions of an organ, especially a gland as opposed to tissues that mainly provide structural support) consists primarily of **hepatocytes** (parenchymal liver cell) arranged in cylinders called hepatic lobules.



Hepatic circulation

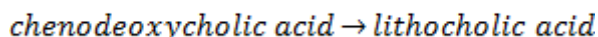
- If hepatic pressure ↑ in disease (liver cirrhosis) → fluid accumulate in peritoneal cavity as ascites.
- Intrahepatic portal vein has smooth muscle in their walls, innervated by noradrenergic vasoconstrictor nerve fibers. No known vasodilator fibers reach liver.
- When ↑ systemic venous pressure, portal vein are dilated & ↑ amount of blood in liver.
- When ↓ BP → diffuse noradrenergic discharge → ↑ portal pressure, & blood flow through liver is brisk, bypassing most of the liver.

BILIARY SECRETION

- ❖ Bile is produced in liver cells & stored in gall bladder until release during a meal into duodenum.
- ❖ Gall bladder is a sac that stores bile until it is needed. It also concentrates bile by absorbing water.
- ❖ About 500 mL is secreted per day. Some of bile components (bile salts) are reabsorbed in intestine & then excreted again by liver (**Enterohepatic circulation**).
- ❖ Bile is formed of 3 elements: [bile salts](#), [bilirubin](#) & [cholesterol](#).
 - Bilirubin is a waste product of Hb breakdown.
 - Cholesterol is secreted with the feces.
 - Bile salt component are formed in hepatocytes from (bile acids + a.a).
 - Other compounds such as waste products of drug degradation also present in bile.

Bile acids

- Synthesized from cholesterol & conjugated to glycine or taurine, a derivative of cysteine.
- The 4 bile acid (cholic acid, chenodeoxycholic acid, deoxycholic acid, & lithocholic acid).
- Two primary bile acids formed in liver are cholic acid & chenodeoxycholic acid.
- In colon, bacteria converts *cholic acid* → *deoxycholic acid*

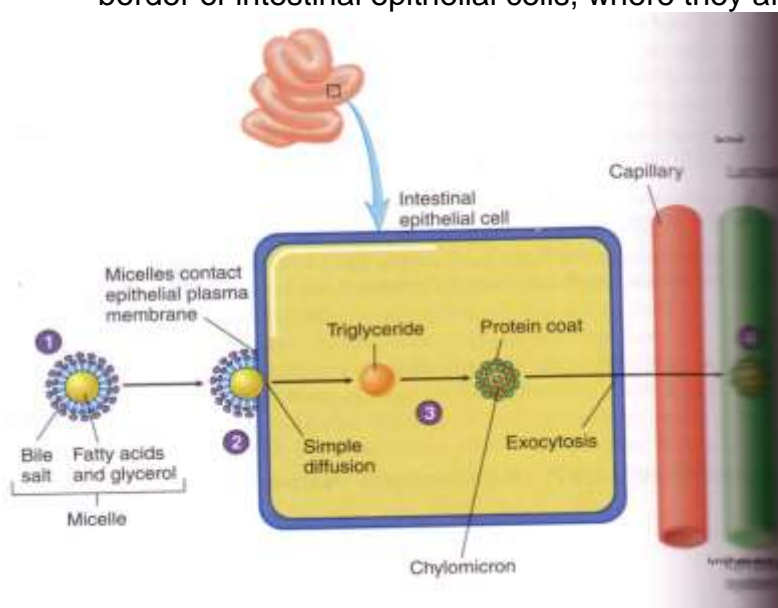


- Small quantities of ursodeoxycholic acid are formed from chenodeoxycholic acid.
- Because they are formed by bacterial action, deoxycholic, lithocholic, & ursodeoxycholic acids are called secondary bile acids.

Bile salts actions

- An active non-enzymatic substance that facilitates fat absorption by helping it to form an emulsion with water.
- *Emulsification* means large fat globules broken into smaller globules. It is mechanical digestion; fat is still fat but now has more surface area, so that pancreatic lipase works effectively.
- They are **amphipathic**, that is, they have both hydrophilic & hydrophobic domain.
- Therefore, bile salts tend to form cylindrical disks called **micelles**.
 - All bile salts added to a solution form micelles.
 - Lipids collect in micelles, with cholesterol in hydrophobic center & amphipathic phospholipids & monoglyceride lined up.

- Micelles play an important role in keeping lipids in solution & transporting them to brush border of intestinal epithelial cells, where they are absorbed.



1. Bile salts surround fatty acids and glycerol to form micelles.
2. Micelles attach to the plasma membranes of intestinal epithelial cells, and the fatty acids and glycerol pass by simple diffusion into the intestinal epithelial cells.
3. Within the intestinal epithelial cell, the fatty acids and glycerol are converted to triglyceride; proteins coat the triglyceride to form chylomicrons, which move out of the intestinal epithelial cells by exocytosis.
4. The chylomicrons enter the lacteals of the intestinal villi and are carried through the lymphatic system to the general circulation.

- 90-95% of bile salts are absorbed in their conjugated forms from terminal ileum by Na^+ -bile salt co transport system. Once they are deconjugated, they can be absorbed by nonionic diffusion.
- The remaining 5-10% enter colon & converted to salts;
 - Lithocholate; relatively insoluble & is mostly excreted in stools; only 1% is absorbed.
 - Deoxycholate → absorbed.

OTHER FUNCTIONS OF THE LIVER

1. CHO metabolism—

- ❖ Liver regulates blood glucose level.

- During hyper glycemia → Excess glucose is converted to glycogen (glycogenesis).
- During hypoglycemia, glycogen is converted back to glucose (glycogenolysis).

- ❖ It Changes other monosaccharides to glucose, because cells cannot use fructose & galactose as energy sources, while glucose is easily used by cells.

2. A. A metabolism— liver regulates a.a level in blood based on tissue needs for protein synthesis.

- 20 different a.a needed for protein production.

- ❖ **Transamination**; is a chemical process of which liver synthesizes 12 (of 20), called **Nonessential a.a.** (a.a do not have to be supplied in food because liver *can* make them).

- The other 8 a.a, which liver cannot synthesize, called **Essential a.as.** (a.a must be supplied by food, because liver cannot manufacture them).

- ❖ **Deamination**, occurs in liver, a.a = (NH_2 & carbon chain)

- NH_2 groups that are detached from a.as are combined to form urea.
- Carbon chain (after removal of NH_2), is converted to a simple CHO or to fat.

3. Lipid metabolism—

- ❖ Liver forms lipoproteins, for fat transport in blood to other tissues.
- ❖ Liver synthesizes cholesterol & excretes excess cholesterol into bile → feces.
- F.a are a potential source of energy, but in order to be used in cell respiration they must be broken down to smaller molecules.
- ❖ **Beta-oxidation**, f.a (long carbon chain) split into Acetyl groups, which are simple CHO, either;
 - Used by liver cells to produce ATP or
 - Combined to form ketones that are transported in blood to other cells & used to produce ATP.

4. Synthesis of plasma proteins—

- **Albumin**, the most abundant plasma protein.

- **Clotting factors**, include prothrombin, fibrinogen, & Factor 8.
 - **α & β globulins**; proteins that serve as carriers for other molecules, e.g fats, in blood.
5. **Formation of bilirubin**—
- ❖ Liver contains fixed macrophages that do phagocytosis of old RBCs.
 - ❖ Liver removes bilirubin (from blood) formed in spleen & red bone marrow.
6. **Phagocytosis by Kupffer cells**—
- ❖ They destroy old RBCs & Phagocytize pathogens that circulate through liver.
 - ❖ Many of bacteria that get to liver come from colon, which are either;
 - Part of normal flora of colon which are very harmful elsewhere in body.
 - Bacteria that enter blood with water absorbed by colon are carried to liver by portal circulation.
7. **Storage**—
- ❖ Fat-soluble vitamins A, D, E, & K, & water-soluble vitamin B12. Up to a 6-12 month supply of vit. A & D may be stored, (beef or chicken liver is an excellent dietary source of these vit.).
 - ❖ Minerals- iron & copper;
8. **Detoxification**—Liver is capable of synthesizing enzymes that will detoxify harmful substances (change them to less harmful substances).
- Alcohol is changed to acetate (an acetyl group) that can be used in cell respiration.
 - Medications are potentially toxic, but liver produces enzymes that break them down.
 - Overdose of a drug means that there is too much of it for liver to detoxify in a given time, & the drug will remain in body with possibly harmful effects.
 - This is why alcohol should never be consumed when taking medication. Such a combination cause liver's detoxification to be ineffective → both of them will remain toxic for a longer time.
 - Ammonia is a toxic substance produced by bacteria in colon. Liver converts it to urea (less toxic), before ammonia circulate & damage other organs especially brain.

PANCREAS(exocrine function).

Pancreatic Secretion

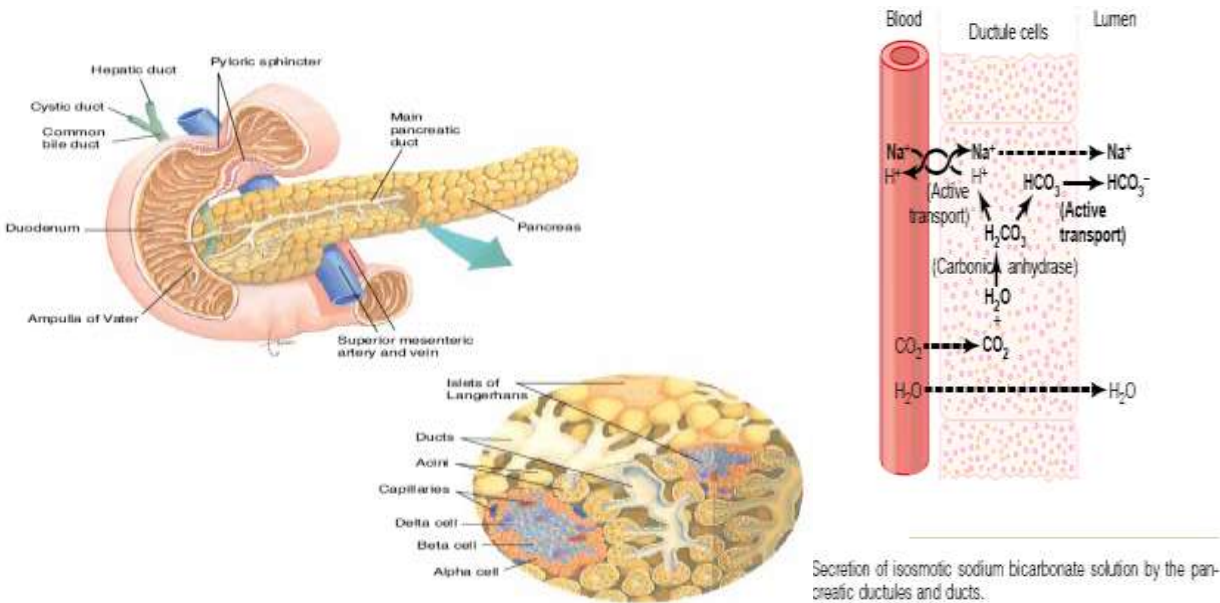
- ❖ Pancreatic digestive enzymes are secreted by *pancreatic acini*.
- ❖ Large volumes of Na bicarbonate solution secreted by small ductules & larger ducts from acini.
- ❖ Pancreatic juice consists of pancreatic digestive enzymes, sodium bicarbonate, & water.
- ❖ Pancr. juice is secreted in response to presence of chyme in upper part of small intestine.

Pancreatic Digestive Enzymes

It contains multiple enzymes for digesting all of all types of food: proteins, CHO, & fats.

- ❖ Pancreatic enzyme for **CHO** digestion is *pancreatic amylase*.
- ☒ *pancreatic amylase* hydrolyzes starches, glycogen, & other CHO (except cellulose) to form disaccharides & a few trisaccharides.
- ❖ Pancreatic enzymes for **fat** digestion are :
 - ☒ *Pancreatic lipase*, which hydrolyze neutral fat → f.a & monoglycerides;
 - ☒ *Cholesterol esterase*, which hydrolyze cholesterol esters;
 - ☒ *Phospholipase*, which splits f.a from phospholipids.
- ❖ Pancreatic enzyme for **proteins** digestion are *trypsin, chymotrypsin, & carboxypolypeptidase*.
- ☒ The most abundant of these, is trypsin.
- ☒ Trypsin & chymotrypsin split proteins into peptides of various sizes but donot cause release of individual a.a. However,
- ☒ Carboxypolypeptidase split some peptides into individual a.as, thus completing digestion of some proteins to a.a state.
- Proteolytic digestive enzymes are in the inactive forms (*trypsinogen, chymotrypsinogen, & procarboxypolypeptidase*). They become activated after they are secreted into intestinal tract.
 - *trypsinogen* $\xrightarrow{\text{activated by enterokinase}}$ *trypsin*
 - *Enterokinase*: enzyme secreted by intestinal mucosa when chyme comes in contact with mucosa.
 - Also, trypsinogen auto catalytically activated by trypsin formed from trypsinogen secreted previously.

- *Chymotrypsinogen* $\xrightarrow{\text{activated by trypsin}}$ *chymotrypsin* .
- *procarboxypolypeptidase* $\xrightarrow{\text{activated by trypsin}}$ *carboxypolypeptidase*.



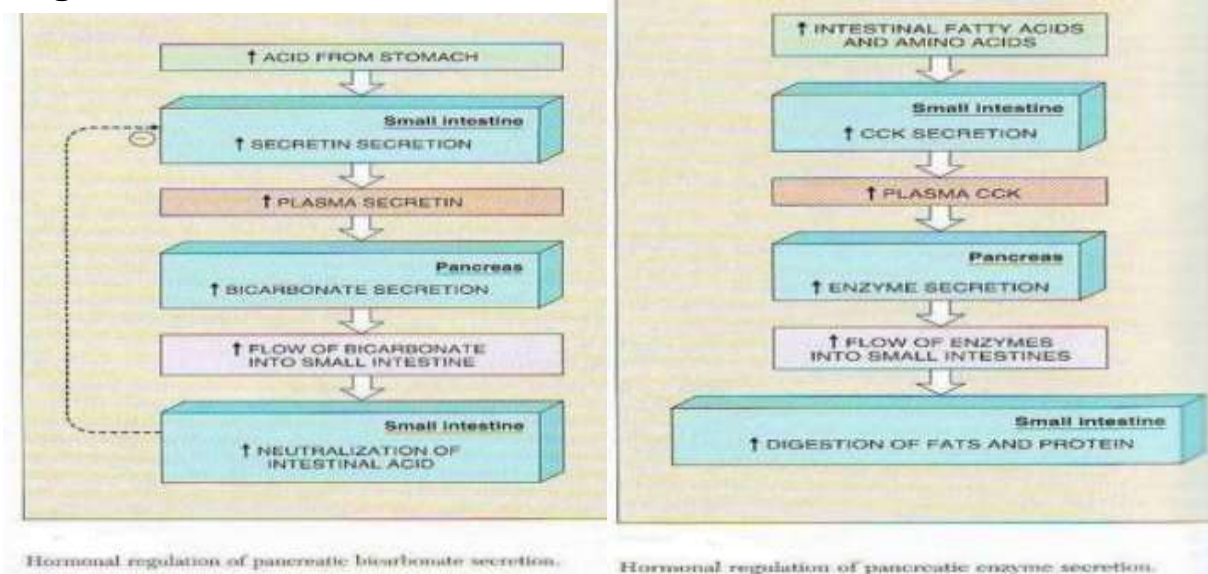
Secretion of Trypsin Inhibitor Prevents Digestion of Pancreas Itself.

Proteolytic enzymes of pancreatic juice not become activated until after their secretion into intestine: The same cells that secrete proteolytic enzymes into acini, secrete simultaneously *trypsin inhibitor*, which prevents activation of trypsin both inside secretory cells &, in acini & ducts of pancreas. And because trypsin activates other proteolytic enzyme, trypsin inhibitor prevents activation of the others. When pancreas severely damaged or when a duct blocked, large quantities of pancreatic secretion become pooled into damaged areas→ effect of trypsin inhibitor is overwhelmed, in which pancreatic secretions rapidly become activated & digest entire pancreas within a few hrs (*acute pancreatitis*).

Secretion of Bicarbonate Ions

Bicarbonate ions & water are secreted mainly by epithelial cells of ductules & ducts. This provides a large quantity of alkali in pancreatic juice that neutralizes HCl emptied into duodenum from stomach.

Regulation of Pancreatic Secretion



Vomiting

- ❖ It is expulsion of stomach & intestinal contents through esophagus & mouth.
- ❖ Stimuli include irritation of stomach, motion sickness, food poisoning or disease.

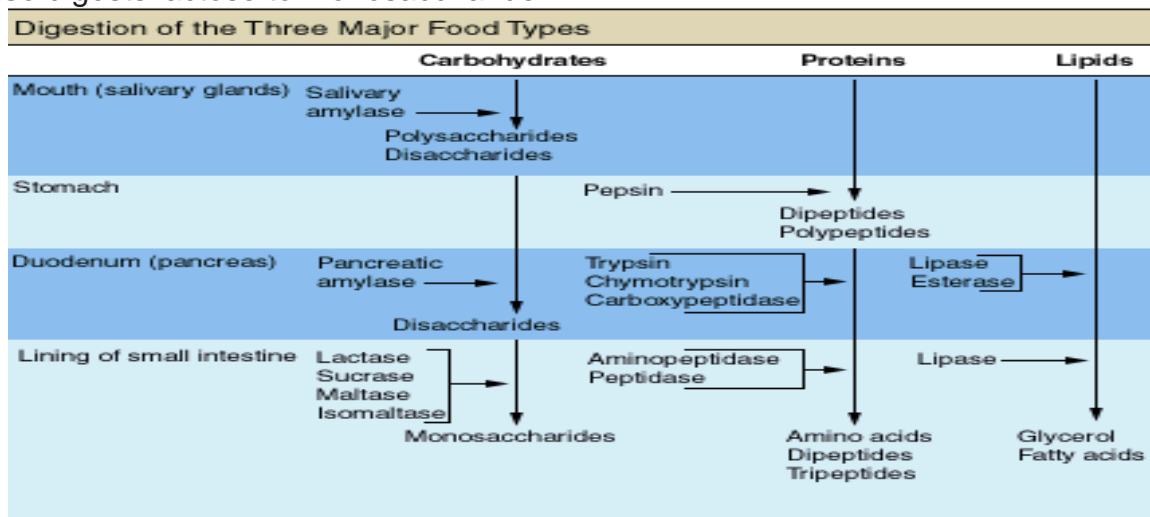
- ❖ Vomiting center is in the medulla, which coordinates simultaneous contraction of diaphragm & abdominal muscles. This squeezes stomach & upper intestine, expelling their contents. As part of reflex, the lower esophageal sphincter relaxes, & glottis closes.

COMPLETION OF DIGESTION & ABSORPTION in SMALL INTESTINE

Secretion of epithelium of intestinal glands (or crypts of Lieberkühn) is stimulated by presence of food in duodenum.

☒ Intestinal enzymes are peptidases & sucrase, maltase, & lactase.

- **Peptidases** complete protein digestion of by breaking down short polypeptide chains to a.a.
- **Sucrase & Maltase** digest disaccharides sucrose to monosaccharide.
- **Lactase** digests lactose to monosaccharide.



ABSORPTION

☒ Stomach does absorb water & alcohol.

☒ Most absorption of the end products of digestion takes place in small intestine.

- Water-soluble nutrients are absorbed into blood in capillary networks.
- Water is absorbed by osmosis following absorption of minerals, especially sodium.
- Monosaccharide, a.a, +ve ions, & water-soluble vit. (vit. C & B) absorbed by active transport.
- -ve ions maybe absorbed by either passive or active transport mechanisms.

Certain nutrients have additional special requirements for their absorption: For example,

- Vitamin B12 requires intrinsic factor ,
- Efficient absorption of calcium ions requires parathyroid hormone & vitamin D.
- Fat-soluble nutrients are absorbed into lymph in lacteals of villi.
- Bile salts are necessary for efficient absorption off.a& fat-soluble vitamins (A, D, E, & K).
- Once absorbed, f.a recombined with glycerol to form triglycerides. These triglycerides then form globules tha tinclude cholesterol & protein; these lipid–protein complexes called **chylomicrons**. In form of chylomicrons, most absorbed fat is transported by lymph & enters blood.
- Blood from capillary networks in villi does not return directly to heart but first travels through portal vein to liver. This pathway enables liver to regulate blood levels of glucose & a. a, store certain vitamins, & remove potential poisons from blood.

Lactose intolerance is inability to digest lactose because of deficiency of enzyme lactase. When lactose, or milk sugar, is not digested, it undergoes fermentation in intestine.

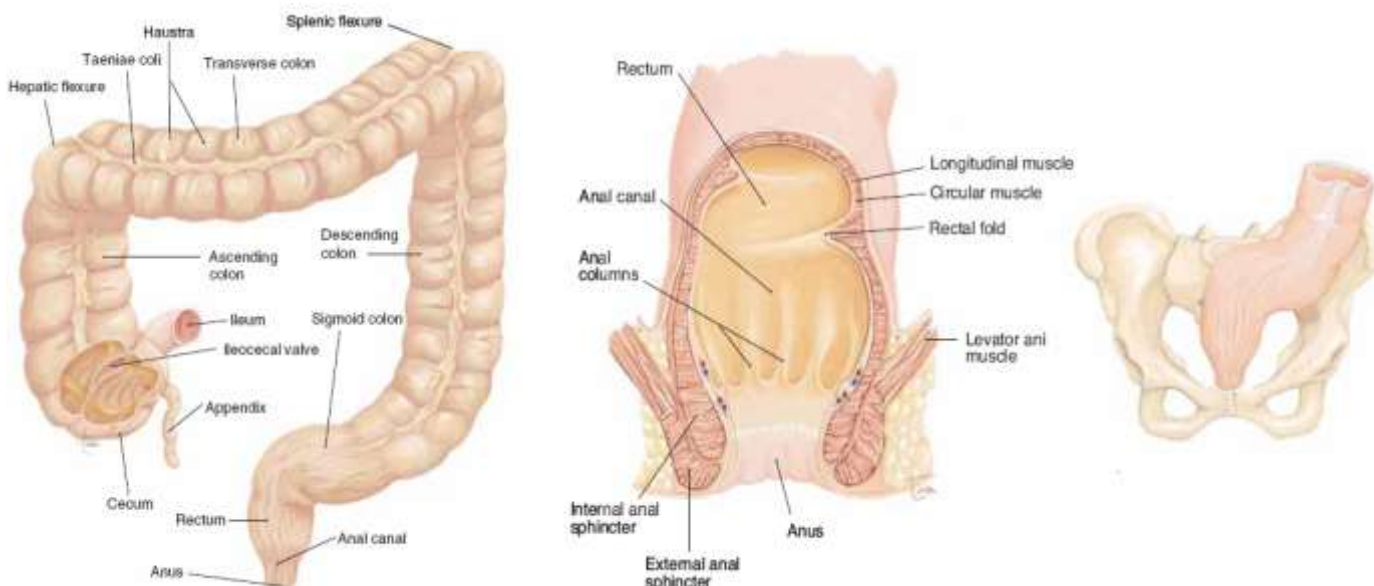
LARGE INTESTINE

❖ It extends from small intestine to anus (1.5 m length), & consist of; cecum, ascending colon, transverse colon, descending colon, sigmoid colon, rectum, & anal canal.

❖ functions:

- a- Absorption of water, minerals, vitamins;
 - 80% of water that enters colon is absorbed

- +ve & -ve ions are also absorbed.
- **Normal flora**, are trillions of bacteria that live in colon;
 - ☒ Produce vitamins which are absorbed by colon.
 - ☒ Inhibit the growth of pathogens.
 - Vitamin K is produced & absorbed in amounts usually sufficient to meet a person's daily need. Other vit. produced in smaller amounts include riboflavin, thiamin, biotin, & folic acid.
 - Everything absorbed by colon circulates first to liver by portal circulation.
- b- Elimination of undigestible material.
 - ❖ The only secretion of colonic mucosa is mucus, which lubricates passage of fecal material.
 - ❖ No digestion takes place in the colon.
 - ❖ Longitudinal smooth muscle layer of colon is in three bands called **taeniae coli**. The rest of colon is "gathered" to fit these bands. This gives colon a puckered appearance; or pockets called **haustra**, which provide for more surface area within colon.
 - ❖ Feces consist of cellulose & other undigestible material, dead & living bacteria, & water. Elimination of feces is accomplished by **defecation reflex**,
 - Defecation Reflex: a spinal cord reflex that may be controlled voluntarily.
 - Rectum is empty until peristalsis of colon pushes feces into it. These waves of peristalsis tend to occur after eating, especially when food enters duodenum. Rectal wall is stretched by feces entry, & this is the stimulus for defecation reflex.
 - Stretch receptors in smooth muscle layer of rectum generate sensory impulses that travel to sacral spinal cord. The returning motor impulses cause smooth muscle of rectum to contract.
 - Surrounding anus is **internal anal sphincter** (smooth muscle), which relaxes, permitting defecation to take place.
 - **External anal sphincter** (skeletal muscle) surrounds internal anal sphincter. If defecation must be delayed, external sphincter voluntarily contracted to close anus. The awareness of the need to defecate passes as stretch receptors of rectum adapt. These receptors will be stimulated again when the next wave of peristalsis reaches rectum.



Botulism is most often acquired from food. When spores of botulism bacteria are in an anaerobic environment such as a can food, they germinate into active bacteria that produce a neurotoxin. If people ingest food containing this toxin, they will develop paralysis.

For infants <1 year of age, ingestion of just bacterial spores may be harmful.

- ❖ Infant's stomach does not produce much HCl, so ingested spores may not be destroyed.
- ❖ Infant's normal colon flora is not yet established. Without normal population of colon bacteria to provide competition, spores of botulism may germinate & produce their toxin.

Fiber: the organic materials in cell walls of plants, mainly cellulose & pectins.

Many studies showed that populations who consume high-fiber diets tend to have a lower frequency of certain diseases (colon cancer, coronary artery disease, diabetes, & hypertension). Such diseases are more common among populations whose diets are low in vegetables, fruits, & whole grains, & high in meat, dairy products, & processed foods. Claims that high-fiber diets directly lower blood levels of cholesterol & fats. A possible explanation; a person whose diet consists largely of high-fiber foods simply eats less foods of high cholesterol & fats, & this is the reason for that person's lower blood levels of fats & cholesterol. Besides benefits of fiber, unprocessed plant foods provide important amounts of vitamins & minerals.

Gastrointestinal Reflexes:

There are three types of GIT reflexes that are essential to GIT control. They are the following:

(1) Reflexes that are integrated entirely within gut wall ENS. These include reflexes that control much GIT secretion, peristalsis, mixing contractions, local inhibitory effects.

(2) Reflexes from gut to prevertebral symp. ganglia & then back to GIT, such as

- a- gastrocolic reflex; signals from stomach to cause evacuation of colon,
- b- enterogastric reflexes; signals from colon & small intestine to inhibit stomach motility & stomach secretion,
- c- colonoileal reflex; from colon to inhibit emptying of ileal contents into colon.

(3) Reflexes from the gut to spinal cord or brain stem & then back to GIT. These include;

- a- reflexes from stomach & duodenum to brain stem & back to stomach-by vagus nerves-to control gastric motor & secretory activity;
- b- pain reflexes that cause general inhibition of the entire GIT;
- c- Defecation reflexes that travel from colon & rectum to spinal cord & back again to produce powerful colonic, rectal, & abdominal contractions required for defecation.

Gastrointestinal Blood Flow-"Splanchnic Circulation":

- Blood vessels of GIT are part of a more extensive system called splanchnic circulation.
- This system design is such that all blood that courses through gut, spleen, & pancreas then flows immediately into liver by way of portal vein.
- In liver, blood passes through millions of liver sinusoids, allows reticuloendothelial cells that line liver sinusoids to remove bacteria & other particulate matter that might enter blood from GIT, thus preventing direct transport of potentially harmful agents into remainder of body. Finally leaves liver by hepatic veins that empty into vena cava of general circulation.
- Nonfat, water-soluble nutrients absorbed from gut (such as CHO & proteins) are transported in portal venous blood to the same liver sinusoids. Here, reticuloendothelial cells & principal parenchymal cells of liver, hepatic cells, absorb & store temporarily from one 1/2 to 3/4 of the nutrients. Also, much chemical intermediary processing of these nutrients occurs in liver.
- Almost all of fats absorbed from intestinal tract are absorbed into intestinal lymphatics (not carried in portal blood) & then conducted to systemic circulating blood by thoracic duct, bypassing liver.

Under normal conditions, blood flow in each area of GIT, as well as in each layer of gut wall, is directly related to level of local activity. During active absorption of nutrients, blood flow in villi & adjacent regions of submucosa is \uparrow 8 folds. Likewise, blood flow in muscle layers of intestinal wall is \uparrow with \uparrow motor activity in gut. After a meal, motor activity, secretory activity, & absorptive activity all \uparrow ; likewise, blood flow \uparrow greatly but then \downarrow back to the resting level over another 2 - 4 hours.

"Countercurrent" Blood Flow in the Villi:

Arterial flow into villus & venous flow out of villus are in directions opposite to each other, & that vessels lie in close apposition to each other. Because of this vascular arrangement, much of blood O₂ diffuses out of arterioles directly into adjacent venules without ever being carried in blood to tips of villi. As much as 80 % of O₂ may take this short-circuits route & therefore not be available for local metabolic functions of villi.

Under normal conditions, this shunting of O₂ from arterioles to venules is not harmful to villi, but in disease conditions in which blood flow to gut becomes greatly curtailed, O₂ deficit in tips of villi can become so great that villus tip become blunted \rightarrow greatly diminished intestinal absorptive capacity.

Importance of Nervous Depression of GIT Blood Flow When Other Parts of Body Need Extra Blood Flow: A major value of sympathetic vasoconstriction in gut is that it allows shut-off of GIT & other splanchnic blood flow for short periods of time during heavy exercise, when \uparrow flow is needed by skeletal muscle & heart. Also, in circulatory shock, when all body's vital tissue are in danger of cellular death for lack of blood flow-especially brain & heart, Symp. stimulation can \downarrow splanchnic blood flow to very little for many hrs.

Hunger Contractions:

Intenserhythmical peristaltic contractions in the body of stomach, often occurs when stomach has been empty for several hrs or more. When successive contractions become extremely strong, they fuse to cause a continuing tetanic contraction that sometimes lasts for 2- 3 min.

Hunger contractions are most intense in;

- Young, healthy people who have high degrees of GIT tonus;
- Person's having lower than normal levels of blood sugar.
- When hunger contractions occur in stomach, person sometimes experiences mild pain in pit of stomach, called **hunger pangs**, which do not begin until 12 -24 hrs after last ingestion of food;
- In starvation, they reach greatest intensity in 3- 4 days & gradually weaken in succeeding days.