!! JAY AMBE !!

12. DIGESTIVE SYSTEM

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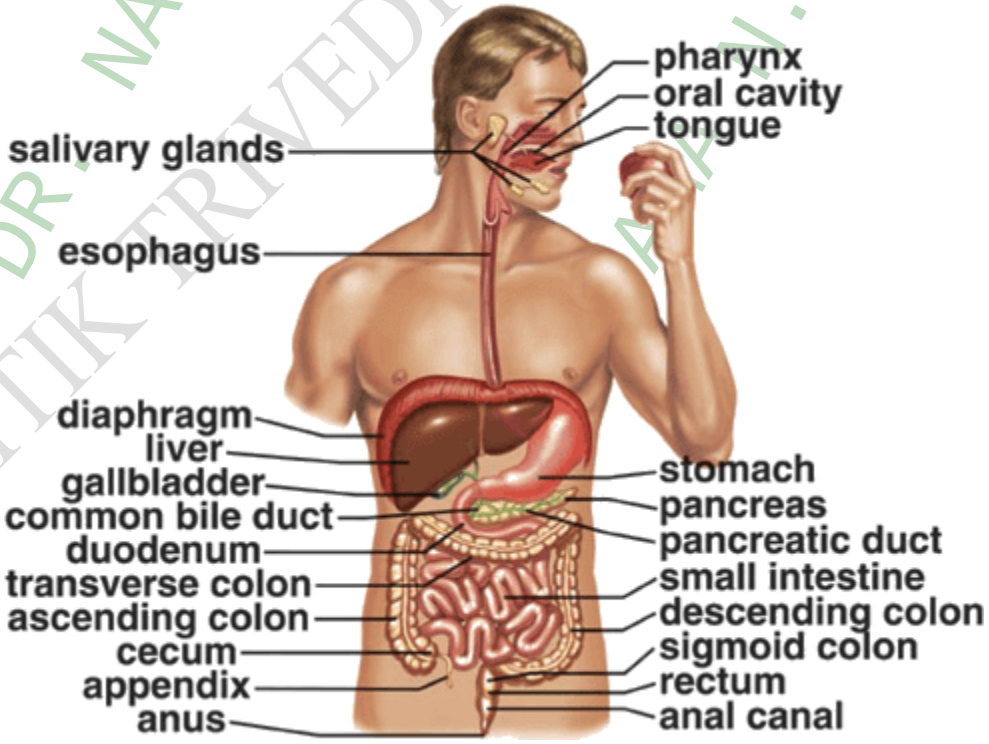
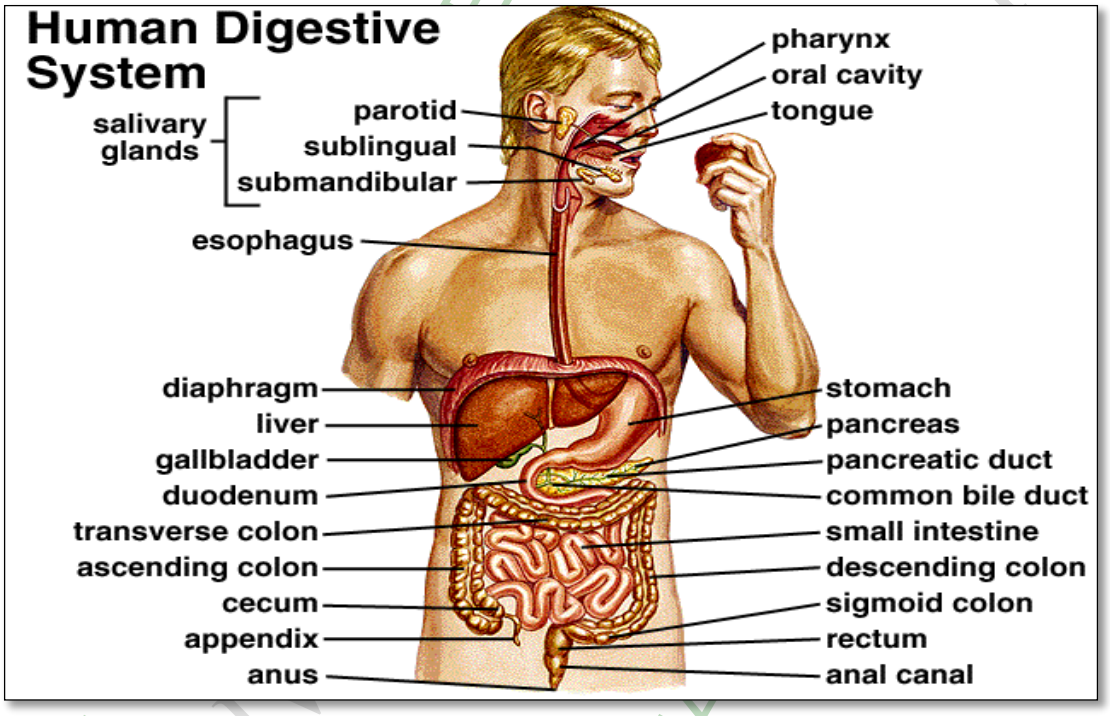


INTRODUCTION OF GIT

- The system by which ingested food is acted upon by physical and chemical means to provide the body with absorbable nutrients and to excrete waste products is called digestive system. **OR**

The organs involved in the breakdown of food—collectively called the digestive system.

- The medical specialty that deals with the structure, function, diagnosis, and treatment of diseases of the stomach and intestines is called gastroenterology.
- The medical specialty that deals with the diagnosis and treatment of disorders of the rectum and anus is called proctology.



The digestive system is divided into two groups of organs

The Gastrointestinal Tract (GIT)

- ✓ Mouth
- ✓ Oropharynx
- ✓ Esophagus
- ✓ Stomach
- ✓ Small Intestine
- ✓ Large Intestine
- ✓ Rectum
- ✓ Anus

The Accessory Digestive Organs

- ✓ Teeth
- ✓ Tongue
- ✓ Salivary Glands
- ✓ Liver
- ✓ Gallbladder
- ✓ Pancreas

The Gastrointestinal Tract (GIT)

- The gastrointestinal (GI) tract, or alimentary canal, is a continuous tube that extends from the mouth to the anus through the thoracic and abdominopelvic cavities.
- Organs of the gastrointestinal tract include the mouth, oropharynx, esophagus, stomach, small intestine and large intestine.
- The length of the GI tract is about 5–7 meters.

The Accessory Digestive Organs

- The accessory digestive organs include the teeth tongue, salivary glands, liver, gallbladder, and pancreas.
- The teeth help in the physical breakdown of food, and the tongue assists in chewing and swallowing.
- The other accessory digestive organs are not come in direct contact with food.
- They produce or store secretions that flows into the GI tract through ducts; the secretions aid in the chemical breakdown of food.

BASIC PROCESSES OF THE DIGESTIVE SYSTEM

There are total six basic processes carried out by digestive system

<table>
<tr><td>1</td><td>Ingestion</td><td colspan="2">✓ This is an eating process in which foods & liquids take into the mouth.</td></tr>
<tr><td>2</td><td>Secretion</td><td colspan="2">✓ In one day the secretary cells of the walls of the GI tract and accessory digestive organs secrete a total of about 7 liters of water, acid, buffers, and enzymes into the lumen of the tract.</td></tr>
<tr><td>3</td><td>Mixing & propulsion</td><td colspan="2">✓ Alternate contractions and relaxations of smooth muscle in the walls of the GI tract mix food & secretions & propel them toward the anus.
✓ This capability of the GI tract to mix and move material along its length is called motility or peristalsis movement.</td></tr>
<tr><td rowspan="2">4</td><td rowspan="2">Digestion</td><td colspan="2">There are two processes of break down ingested food into small molecules</td></tr>
<tr><td>Mechanical digestion
▪ teeth cut and grind food &
▪ then smooth muscles of the stomach and small intestine churn the food
▪ food molecules become dissolved & thoroughly mixed with digestive enzymes</td><td>Chemical digestion
▪ The large carbohydrate, lipid, protein, and nucleic acid molecules in food are split into smaller molecules by hydrolysis
▪ Digestive enzymes catalyzed the catabolic reactions</td></tr>
<tr><td>5</td><td>Absorption</td><td colspan="2">✓ The transfer of ingested and secreted fluids, ions, and the products of digestion into the epithelial cells lining the lumen of the GI tract is called absorption.
✓ The absorbed substances pass into blood or lymph and circulate to cells throughout the body.</td></tr>
<tr><td>6</td><td>Defecation</td><td colspan="2">✓ Wastes, indigestible substances, bacteria, cells sloughed from the lining of the GI tract, and digested materials that were not absorbed in their journey through the digestive tract leave the body through the anus in a process called defecation.
✓ The eliminated material is termed feces.</td></tr>
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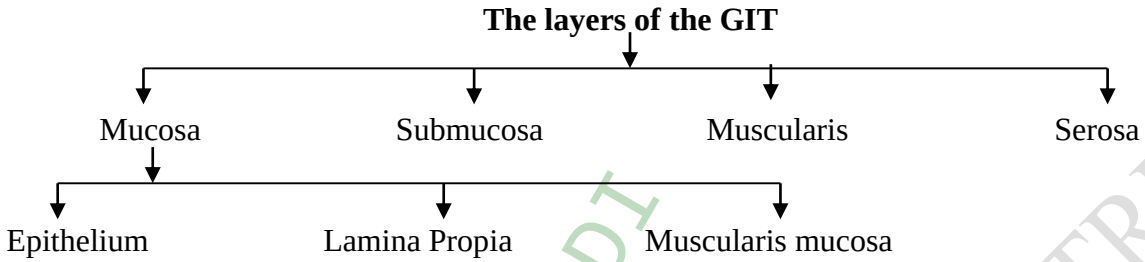
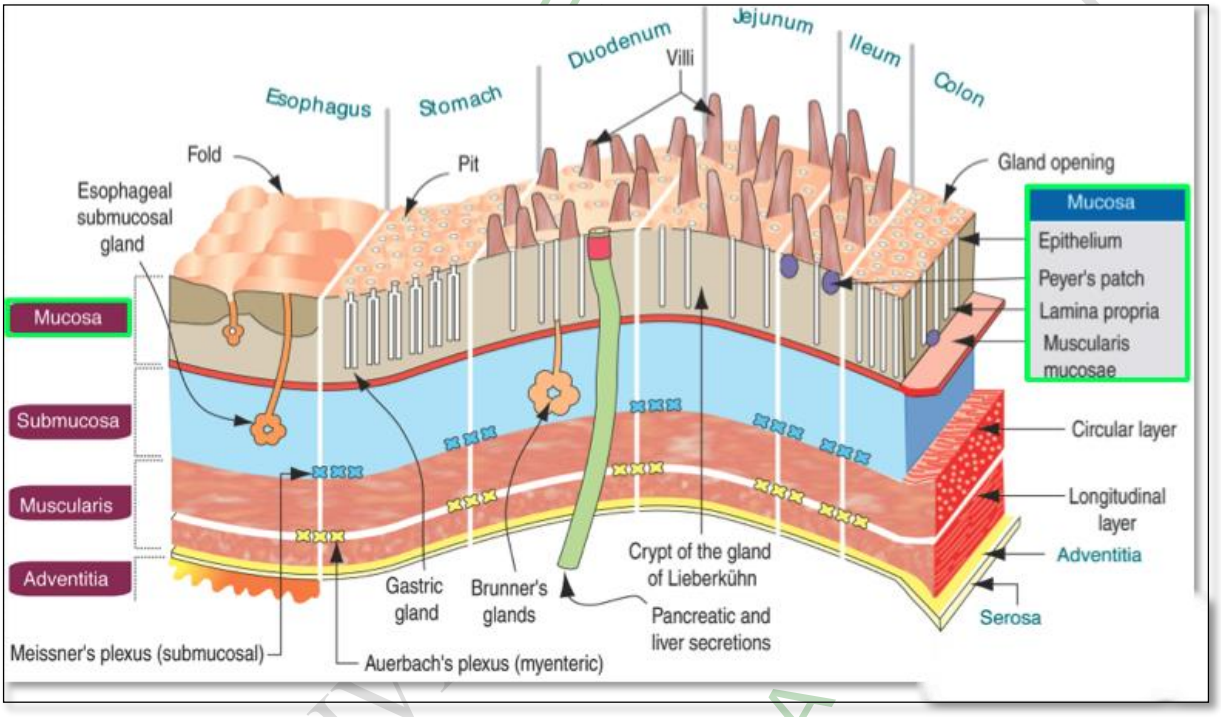
THE LAYERS OF THE GIT

- The wall of the GIT having same basic, four-layered arrangement of tissues.
- The four layers of the tract, from deep to superficial, are the





1. MUCOSA

- The mucosa is the innermost layer of the GI tract.
- The mucosa surrounds the lumen, or open space within the digestive tube.
- This layer comes in direct contact with digested food (chyme).
- It is absorptive & secretary layer of GIT.
- The epithelium of the mucosa is particularly specialized, depending on the portion of the digestive system.
- It is made up of three layers:

i. The epithelium

- ✓ A layer of epithelium in direct contact with the contents of the GI tract
- ✓ It is the innermost layer and it is responsible for most digestive, absorptive, and secretory processes.

ii. The lamina propria

- ✓ It is a layer of connective tissue that is unusually cellular compared to most connective tissue.

iii. The muscularis mucosae

- ✓ It is a thin layer of smooth muscle.

- In the esophagus, the epithelium is stratified, squamous, and non-keratinizing, for protective purposes.
- In the stomach. the epithelium is simple columnar, and is organized into gastric pits and glands to deal with secretion.
- In the small intestine, the epithelium (particularly the ileum) is specialized for absorption, with villi and microvilli increasing surface area.

2. SUBMUCOSA

- The submucosa consists of areolar connective tissue that binds the mucosa to the muscularis.
- The submucosa is relatively thick, highly vascular, and serves the mucosa.
- The absorbed elements that pass through the mucosa are picked up from the blood vessels of the submucosa.
- It also contains that receive absorbed food molecules.
- Also located in the submucosa is an extensive network of neurons known as the submucosal plexus.
- The submucosa may also contain glands, lymphatic vessels & lymphatic tissue.

3. MUSCULARIS

- The third layer of the alimentary canal is the muscularis also called the muscularis externa.
- The muscularis in the small intestine is made up of a double layer of smooth muscle:
  - Inner circular layer
  - Outer longitudinal layer.
- The contractions of these layers promote mechanical digestion, expose more of the food to digestive chemicals, and move the food along the GI tract.
- In the most proximal and distal regions of the GI tract, including the mouth, pharynx, anterior part of the esophagus, and external anal sphincter, the muscularis is made up of skeletal muscle.
  - Which gives you voluntary control over swallowing and defecation.
- In the rest of the GI tract, the muscularis consists of smooth muscle that is generally found in two sheets: an inner sheet of circular fibers and an outer sheet of longitudinal fibers.

- Involuntary contractions of the smooth muscle help break down food, mix it with digestive secretions, and propel/move it along the tract.

- The stomach is prepared for its churning function by the addition of a third layer, the oblique muscle.

4. SEROSA

- Those portions of the GI tract that are suspended in the abdominopelvic cavity have a superficial layer called the serosa.
- Instead of serosa, the mouth, pharynx, and esophagus have a dense sheath of collagen fibers called the adventitia.
- These tissues serve to hold the alimentary canal in place near the ventral surface of the vertebral column.

****NEURAL INNERVATION OF THE GI TRACT****

The gastrointestinal tract is regulated by

- An intrinsic set of nerves known as the enteric nervous system (ENS) and
- An extrinsic set of nerves that are part of the autonomic nervous system.

Intrinsic Set

- Intrinsic innervations of the alimentary canal is provided by the ENS, which runs from the esophagus to the anus, and contains approximately 100 million motor, sensory, and interneurons (unique to this system compared to all other parts of the PNS).
- These enteric neurons are grouped into two plexuses.
  - The myenteric plexus (plexus of Auerbach) lies in the muscularis layer of the alimentary canal and is responsible for motility, especially the rhythm and force of the contractions of the muscularis.
  - The submucosal plexus also called plexus of Meissner, lies in the submucosal layer and is responsible for regulating digestive secretions and reacting to the presence of food.

Extrinsic set

- Extrinsic innervations of the alimentary canal are provided by the ANS, which includes both sympathetic and parasympathetic nerves.
- In general, sympathetic activation restricts the activity of enteric neurons, thereby decreasing GI secretion and motility.
- In contrast, parasympathetic activation increases GI secretion and motility by stimulating neurons of the enteric nervous system.

PERITONIUM

The peritoneum supports the abdominal organs and give way for their blood and lymph vessels and nerves.

There are two layers of the peritoneum:

- The outer layer, called the parietal peritoneum, is attached to the abdominal wall;
- The inner layer, the visceral peritoneum, is wrapped around the internal organs that are located inside the intraperitoneal cavity.

The mesentery is the double layer of visceral peritoneum.

The potential space between these two layers, the peritoneal cavity, is filled with a small amount of slippery serous fluid.

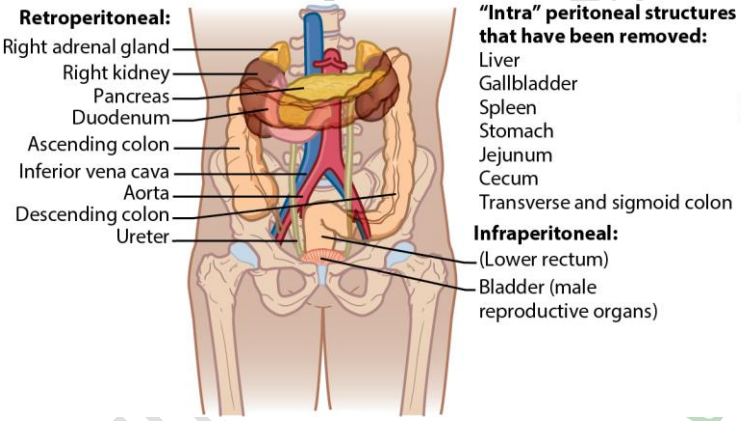
The structures in the abdomen are classified as intraperitoneal and retroperitoneal

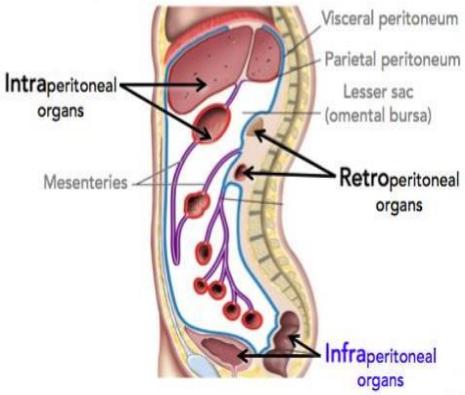
Intraperitoneal Organs

- Intraperitoneal organs are enveloped by visceral peritoneum, which covers the organ both anteriorly and posteriorly.
- Examples include the stomach, liver and spleen.

Retroperitoneal Organs

- Retroperitoneal organs are not associated with visceral peritoneum; they are only covered in parietal peritoneum, and that peritoneum only covers their anterior surface.





MOUTH

- The mouth, or oral cavity, is the first part of the digestive tract.
- It is adapted to receive food by ingestion, break it into small particles by mastication, and mix it with saliva.
- The lips, cheeks, and palate form the boundaries.
- The oral cavity contains the teeth and tongue and receives the secretions from the salivary glands.

❖ **Lips and Cheeks**

✓ The lips and cheeks help hold food in the mouth and keep it in place for chewing.

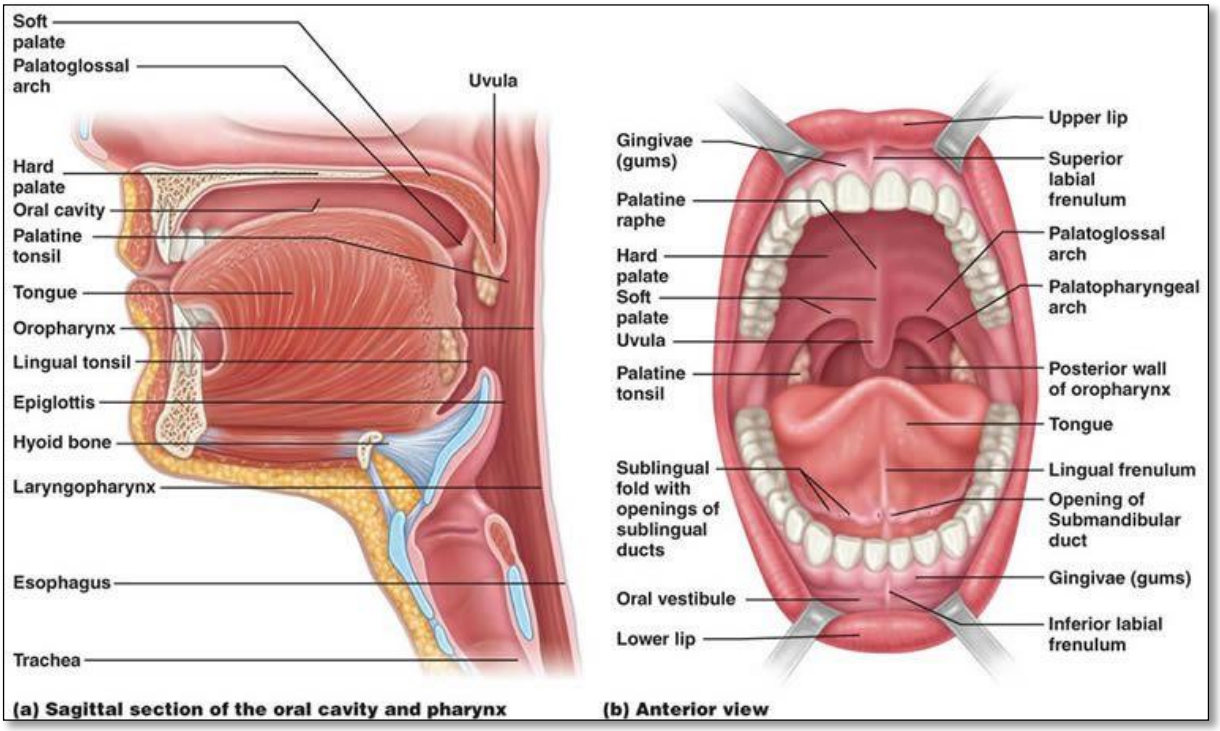
- ✓ They are also used in the formation of words for speech.
- ✓ The lips contain numerous sensory receptors that are useful for judging the temperature and texture of foods.

❖ **Palate**

- ✓ The palate is the roof of the oral cavity.
- ✓ It separates the oral cavity from the nasal cavity.
- ✓ The anterior portion, the hard palate, is supported by bone.
- ✓ The posterior portion, the soft palate, is skeletal muscle and connective tissue.
- ✓ Posteriorly, the soft palate ends in a projection called the uvula.
- ✓ During swallowing, the soft palate and uvula move upward to direct food away from the nasal cavity and into the oropharynx.

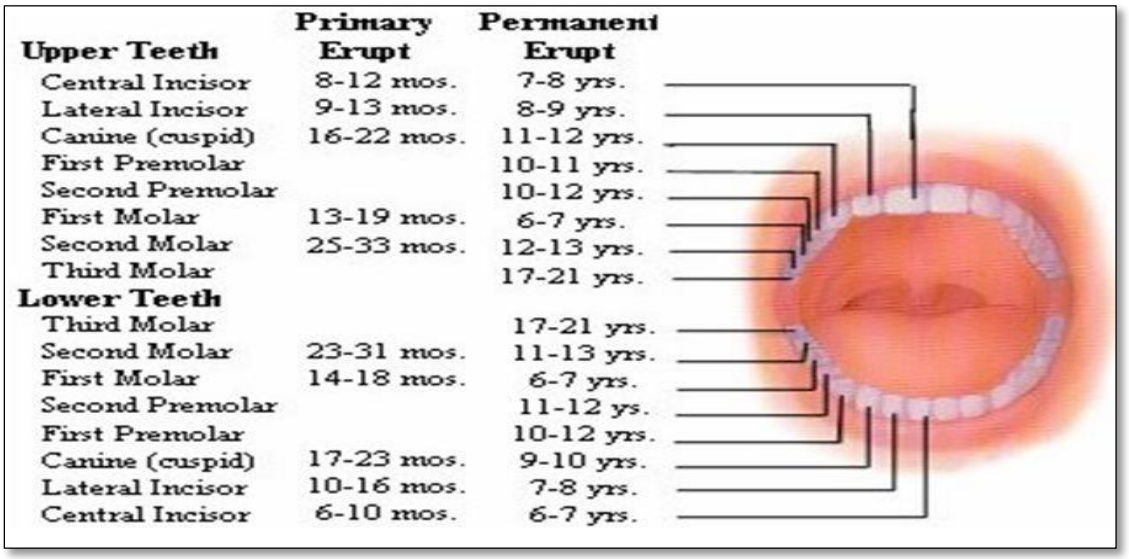
❖ **Tongue**

- ✓ The tongue manipulates food in the mouth and is used in speech.
- ✓ The surface is covered with papillae that provide friction and contain the taste buds.



❖ **Teeth**

- ✓ A complete set of deciduous (primary) teeth contains 20 teeth.
- ✓ There are 32 teeth in a complete permanent (secondary) set.
- ✓ The shape of each tooth type corresponds to the way it handles food.



	Primary Erupt	Permanent Erupt
Upper Teeth		
Central Incisor	8-12 mos.	7-8 yrs.
Lateral Incisor	9-13 mos.	8-9 yrs.
Canine (cuspid)	16-22 mos.	11-12 yrs.
First Premolar		10-11 yrs.
Second Premolar		10-12 yrs.
First Molar	13-19 mos.	6-7 yrs.
Second Molar	25-33 mos.	12-13 yrs.
Third Molar		17-21 yrs.
Lower Teeth		
Third Molar		17-21 yrs.
Second Molar	23-31 mos.	11-13 yrs.
First Molar	14-18 mos.	6-7 yrs.
Second Premolar		11-12 ys.
First Premolar		10-12 yrs.
Canine (cuspid)	17-23 mos.	9-10 yrs.
Lateral Incisor	10-16 mos.	7-8 yrs.
Central Incisor	6-10 mos.	6-7 yrs.

SALIVARY GLAND

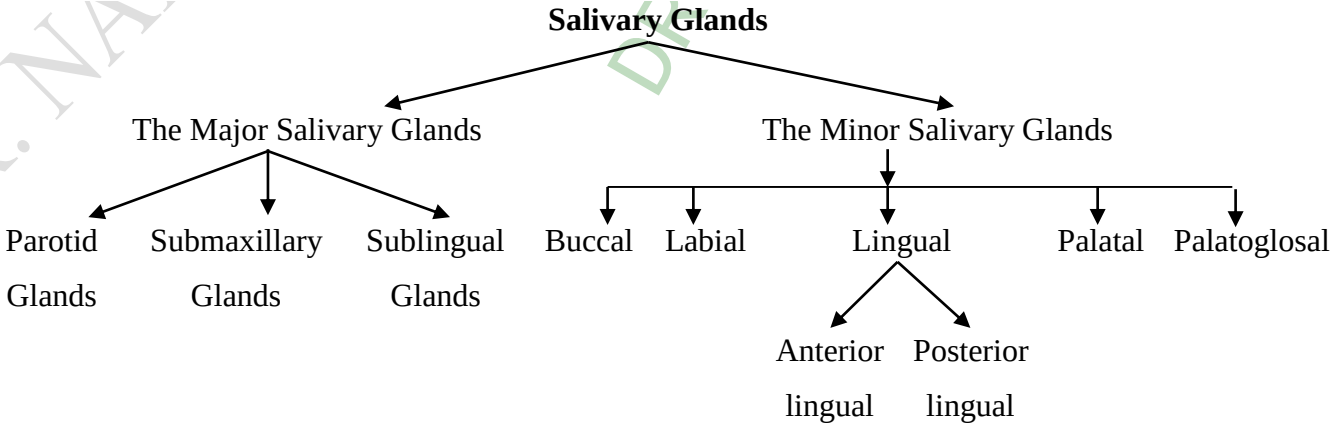
- Several glands associated with the oral cavity secrete saliva
- The basic secretory units of salivary glands are clusters of cells called an acini.
- These cells secrete a fluid that contains water, electrolytes, mucus and enzymes, all of which flow out of the acinus into collecting ducts
- The salivary glands make saliva & empty it into your mouth through ducts.

Classification of Salivary Glands Based On Secretion:

Two basic types of acinar epithelial cells exist in salivary glands:

1. **Serous gland**
   - Made up by serous cells, which secrete a watery fluid, essentially devoid of mucus. Ex.: paratid gland
2. **Mucous gland**
   - Made by mucous cells produce a very mucus-rich secretion.
     Ex.: Lingual, buccal etc.
3. **Mixed gland**
   - Made by both serous & mucous cell
     Ex.: Submandibular, sublingual and labial glands

Classification of Salivary Glands Based on Anatomy:



A. The Major Salivary Glands

1. The parotid glands

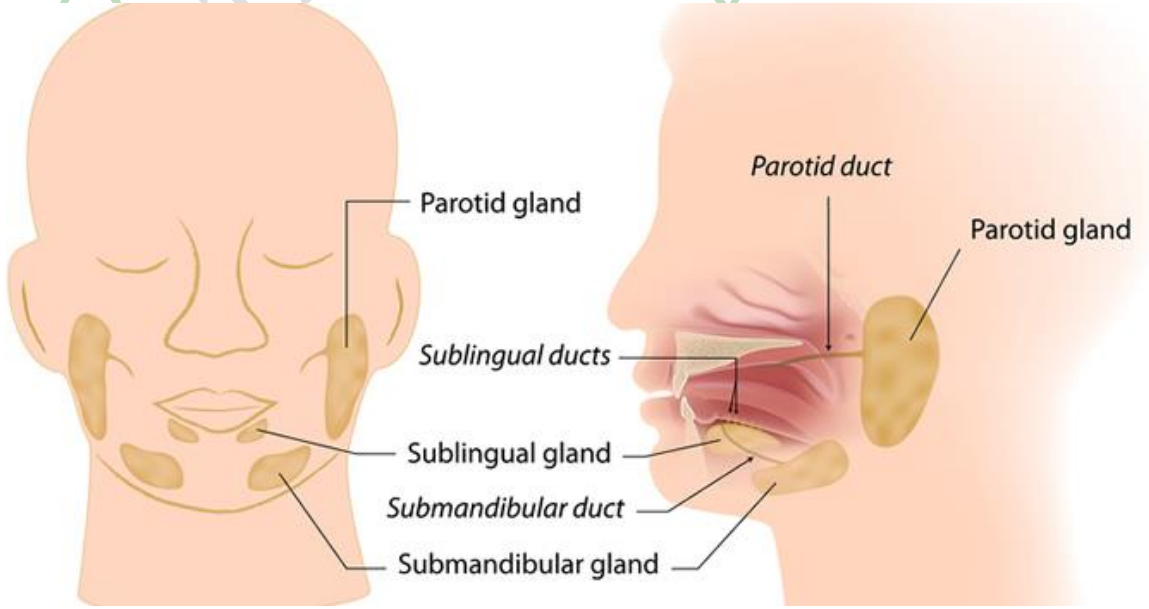
- Parotid glands are the largest salivary gland.
- Approximately 6 cm legnth and 3-4 cm width and weigh up to 30 grams.
- They are located within each of our cheeks and inferior and anterior to the ears, between the skin and the masseter muscle.
- In our oral cavity, they are responsible for the secretion of about 20% of saliva.
- Each secretes saliva into the oral cavity via a parotid duct
- This saliva is known as serous i.e. more liquid and fluid.
- It helps in the first phase of the digestion of food, facilitate mastication "chewing".
- These glands secrete a protein-rich fluid which is a suspension of alpha-amylase enzyme.

2. Submaxillary Glands

- These glands are located under the lower jaw, outside the oral cavity.
- This is the movable part of our jaw.
- It is the second-largest salivary gland and produces approx. 65-70% of saliva.
- It is a mixture of serous and mucous glands and released through submandibular ducts.
- Its saliva is more viscous as compared to the secretion of the parotid gland.

3. Sublingual Glands

- It is the smallest of the major salivary glands. They are located under the tongue.
- Approximately 5% of the saliva comes from these glands.
- The saliva that comes out is mostly mucus, having a viscous texture and flows into the mouth through sublingual ducts.



Salivary Glands

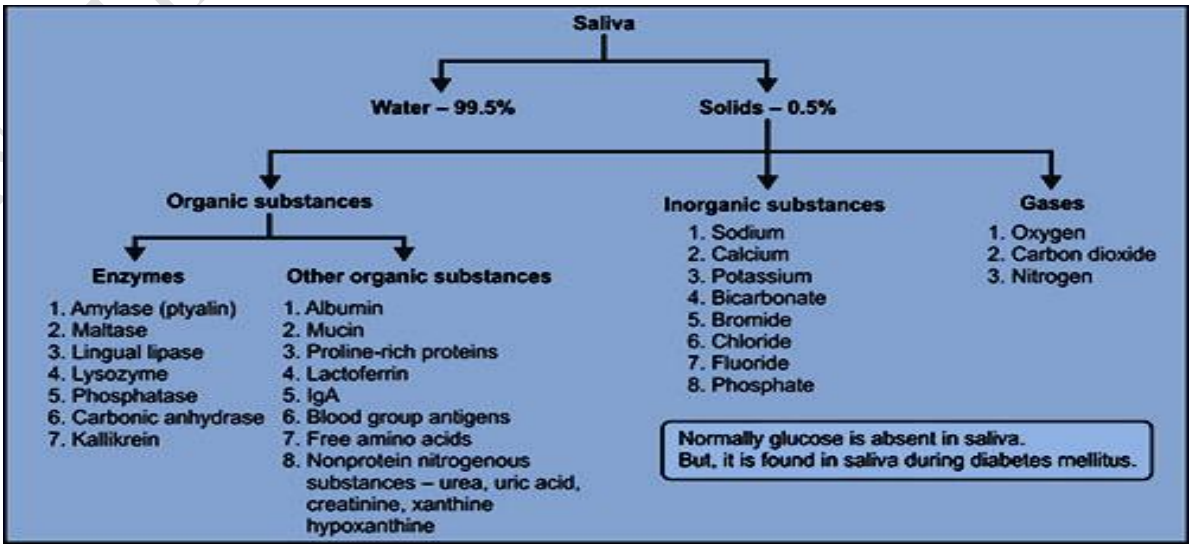
B. The Minor Salivary Glands

There are hundreds of minor salivary glands throughout the mouth. Most are found in the lining of the lips, the tongue, and the roof of the mouth, as well as inside the cheeks, nose, sinuses, and larynx.

1. **Buccal glands**
   - These are minor salivary glands located on the inner side of the cheeks.
2. **Labial glands**
   - These are minor salivary glands located on the inner side of the lip.
3. **Lingiual glands**
   - The anterior and posterior lingual glands are mainly mucous.
   - The anterior glands are embedded within muscle near the ventral surface of the tongue and open by means of four or five ducts near the lingual frenum and the posterior glands are located in the root of the tongue.
4. **Palatine glands**
   - These are minor salivary glands located on the tong on its lateral and posterior surfaces.
   - The palatal glands are mucous glands and occur in both the soft and hard palates.

Properties & Composition

- Saliva is mainly water. 1000 mL to 1500 mL of saliva is secreted per day and it is approximately about 1 mL/minute.
- In fact, it's 97-99.5% water which makes it hypoosmotic.
- Its osmolarity depends on the glands that are active and the amount and type of stimulus for salivation.
- Generally, saliva is a bit acidic, pH 6.75-7.00, but the PH can vary. Its solutes include electrolytes (mainly sodium, potassium, chloride, and bicarbonate); the digestive enzymes salivary amylase and lingual lipase; the proteins mucin, IgA, and lysozyme; metabolic wastes (uric acid, urea).
- When dissolved in water, the glycoprotein mucin forms thick mucus that lubricates the oral cavity and hydrates foodstuffs.



Salivation and Its Neuronal Regulation

- The secretion of saliva, called salivation and it is controlled by the autonomic nervous system.
- Parasympathetic stimulation promotes continuous secretion of a moderate amount of saliva. Sympathetic stimulation decrease salivation during stress, resulting in dryness of the mouth.

SYMPATHETIC INNERVATION

The sympathetic control of salivary production is by the **superior cervical ganglion.**

↓

Sympathetic stimulation results in the release of **noradrenaline**, which acts upon **alpha- and beta-adrenergic receptors.**

↓

This results in the following effects:

↓

- Decreased production of saliva by acinar cells
  - Increased protein secretion
- Decreased blood flow to the glands

↓

Decreases salivation

PARASYMPATHETIC INNERVATION

The parasympathetic outflow is coordinated via centres in the **medulla**, and innervation occurs via the facial and glossopharyngeal nerves.

↓

The information from the mouth, tongue, nose and other reflexes are integrated within the brain in the presence of food, parasympathetic stimulation occurs.

↓

Parasympathetic outflow results in the release of **acetylcholine** (ACh) onto M_3 muscarinic receptors.

↓

This results in the following effects:

↓

- Acinar cells increase secretion of saliva
  - Duct cells increase HCO_3^- secretion
- Co-transmitters result in increased blood flow to the salivary glands
  - to increase the rate of expulsion of saliva

↓

Increases salivation

Functions of Saliva

1. Chemical digestion: breaks down starch by the function of “salivary amylase”
2. Helps chewing and swallowing
3. Lubricating effect: moisturizes the inside of the mouth and creates smoother speech
4. Solvent effect: dissolves food and allows the tongue to taste food
5. Cleaning effect: washes away food debris and bacteria remaining in the mouth
6. Antibacterial effect: Lysozyme, peroxidase and lactoferrin fight against pathogenic microorganisms
7. pH buffering effect: Prevents sudden changes in pH
8. Supplies minerals, including calcium and phosphorus, to teeth

PHARYNX

- After swallowing of food, it enter into the pharynx
- Pharynx is a funnel-shaped tube that extends from the nasal cavity to the esophagus posteriorly and anteriorly to the larynx.
- The pharynx is composed of skeletal muscle and lined by mucous membrane,
- It is divided into three parts:

1. Nasopharynx 2. Oropharynx 3. Laryngopharynx.

- The functions of nasopharynx is only in respiration. The oropharynx & laryngopharynx involve in both digestive as well as respiratory functions.

ESOPHAGUS

- The esophagus start with throat and ends at stomach, it passes through the opening of diaphragm called esophageal hiatus.
- The esophagus is a collapsible muscular tube, about 25 cm long.
- There are two sphincters- an areas which open & close in the esophagus.

Sphincters of Esophagus

The upper esophageal sphincter (UES)	**The lower esophageal sphincter (LES)**
✓ It is under voluntary as well as involuntary control. ✓ Prevent food & liquids from entering the windpipe. ✓ It can be opened & closed consciously, as during swallowing & vomiting.	✓ It is under only involuntary control ✓ It prevents stomach acid entering into the esophagus.

Function

- The esophagus serves to pass food and liquids from the mouth down to the stomach.
- This is carried by periodic contractions (peristalsis).
- With vomiting, these contractions are reversed, allowing stomach contents to be returned to the mouth to spit out.

MASTICATION

- Mastication is a sensory-motor activity aimed at the preparation of food for swallowing.
- It is a complex process involving activities of the facial, the elevator and suprahyoidal muscles, and the tongue.
- These activities result in patterns of rhythmic mandibular movements, food manipulation and the crushing of food between the teeth.
- Saliva facilitates mastication, moistens the food particles, makes a bolus, and assists swallowing.
- The movement of the jaw, and thus the neuromuscular control of chewing, plays an important role in the reducing partical size of the food.
- Characteristics of the food, e.g. water and fat percentage and hardness, are influences the masticatory process.
- Food hardness is sensed during mastication and affects masticatory force, jaw muscle activity, and mandibular jaw movements.

DEGLUTITION / SWALLOWING

↓

The movement of food from the mouth into the stomach is called swallowing or deglutition

↓

Deglutition is facilitated by the secretion of saliva and mucus

↓

Swallowing occurs in three stages

1st stage	**2nd stage**	**3rd stage**
↓	↓	↓
the voluntary stage, the bolus is passed into the **oropharynx**	the involuntary stage, the bolus through the pharynx into the **esophagus**	the involuntary stage, the bolus through the esophagus into the **stomach**

STOMACH

- The stomach is a J-shaped organ of the GI tract directly inferior to the diaphragm
- The stomach connects the esophagus to the duodenum, the 1st part of the small intestine.
- Anatomically the stomach has four parts

PARTS OF STOMACH

1. Cardia — The opening of the stomach.

2. Fundus — The rounded portion superior to and to the left of the cardia

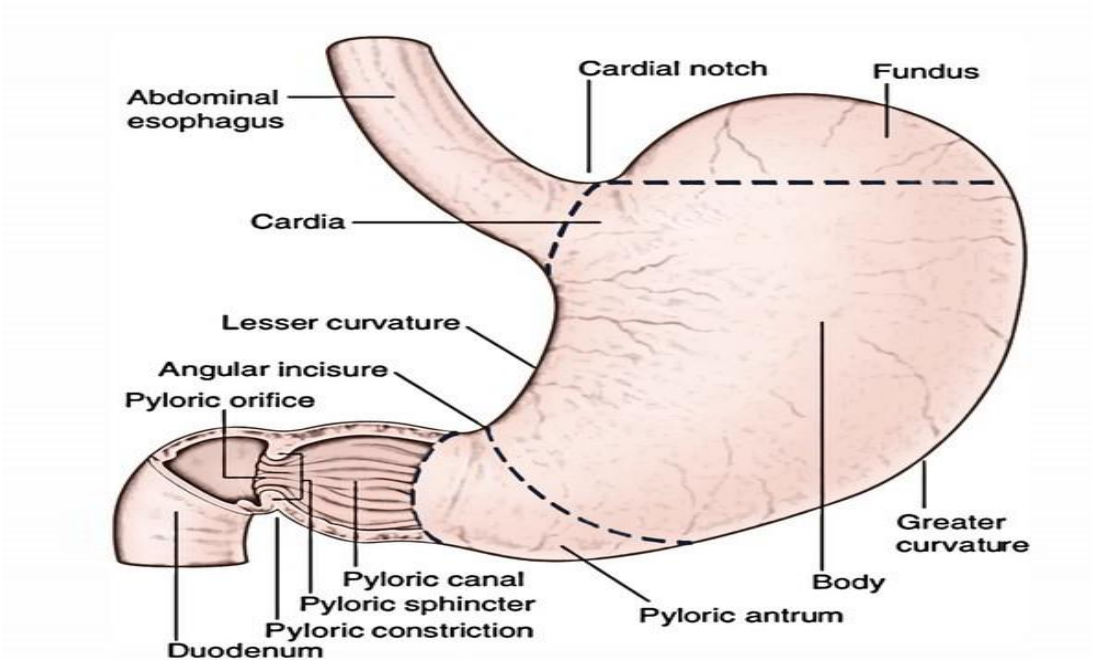
3. Body — The large central portion of the stomach- inferior to the fundus

4. Pylorus — The region of the stomach that connects stomach to the duodenum

- **Pyloric antrum** — connects to the body of the stomach to duodenum
- **Pyloric Canal** — which leads into the duodenum

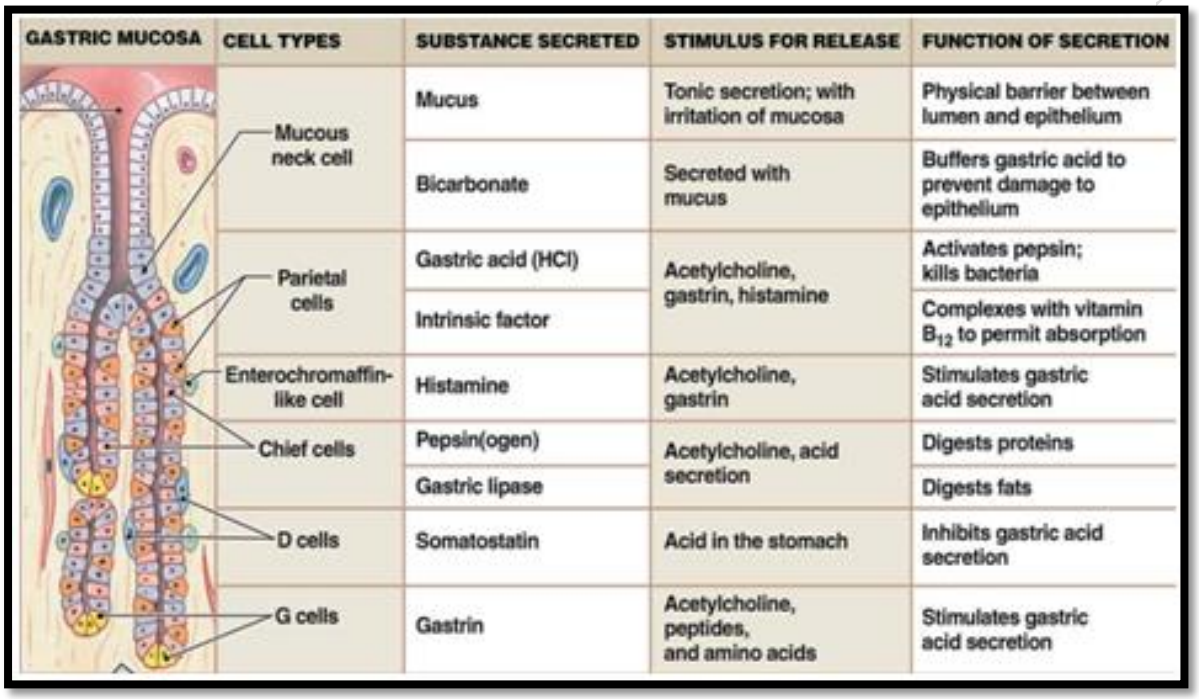
When the stomach is empty, the mucosa lies in large folds, called rugae.

- The pylorus communicates with the duodenum by smooth muscle sphincter called the pyloric sphincter.
- The concave medial border of the stomach is called the lesser curvature, & the convex lateral border is called the greater curvature.



Histology of stomach

- The wall of the stomach is made of the same four layers like remiang GIT, but some adaptations make it for the unique functions.
- In addition to the typical circular and longitudinal smooth muscle layers, the muscularis has an inner oblique smooth muscle layer.
- The surface of the mucosa is a layer of simple columnar epithelial cells called surface mucous cells.
- The mucosa contains a lamina propria (areolar connective tissue) and a muscularis mucosae (smooth muscle).



CELL TYPES	SUBSTANCE SECRETED	STIMULUS FOR RELEASE	FUNCTION OF SECRETION
Mucous neck cell	Mucus	Tonic secretion; with irritation of mucosa	Physical barrier between lumen and epithelium
	Bicarbonate	Secreted with mucus	Buffers gastric acid to prevent damage to epithelium
Parietal cells	Gastric acid (HCl)	Acetylcholine, gastrin, histamine	Activates pepsin; kills bacteria
	Intrinsic factor		Complexes with vitamin B_{12} to permit absorption
Enterochromaffin-like cell	Histamine	Acetylcholine, gastrin	Stimulates gastric acid secretion
Chief cells	Pepsin(ogen)	Acetylcholine, acid secretion	Digests proteins
	Gastric lipase		Digests fats
D cells	Somatostatin	Acid in the stomach	Inhibits gastric acid secretion
G cells	Gastrin	Acetylcholine, peptides, and amino acids	Stimulates gastric acid secretion

Gastric glands

❖ Flow pathway of gastric juice

Epithelial cells extend down into the lamina propria, where they form columns of secretory cells called **Gastric glands**

↓

Several gastric glands open and secrets there secretions into the bottom of narrow channels called **Gastric pits.**

↓

Then Secretions flow into the lumen of the stomach.

❖ The gastric glands contain three types of exocrine gland cells that secrete their products into the stomach lumen:

Exocrine Gland Cells/ Secretary Cells

Mucous Neck Cell	Chief Cells	Parietal Cells
↓	↓	↓
Secrete thin, acidic mucus	secrete pepsinogen and gastric lipase	produce intrinsic factor & HCL

- The secretions of gastric cells form gastric juice, which total 2000–3000 mL per day.
- The gastric glands also include a type of enteroendocrine cell, the G cell, which is located mainly in the pyloric antrum and secretes the hormone **gastrin** into the bloodstream.

GASTRIC JUICE

- Gastric juice is the secretion of gastric glands.
- Total amount secreted: 1, 200-1500 ml per day.
- Night secretion alone is 400 ml/day.
- pH: 0.9-1.5
- Composition of gastric juice

GASTRIC JUICE COMPOSITION

- **Water 99.5%**
- **Solid 0.5%**
  - Organic substances
    - Enzymes
      1. Pepsin
      2. Rennin
      3. Gastric
      4. Lipase
      5. Gelatinase
      6. Urease
    - Other organic
      1. Mucus
      2. Intrinsic factors
  - Inorganic Substances
    1. Hydrochloric Acid
    2. Calcium
    3. Sodium
    4. Potassium
    5. Bicarbonate
    6. Chloride
    7. Phosphate
    8. Sulphate

ACID PRODUCTION IN STOMACH

HCl is produced by the **parietal cells** of the stomach.

↓

Inside the parietal cell water (H_2O) and carbon dioxide (CO_2) combine to produce carbonic acid (H_2CO_3)

↓

Carbonic anhydrase converts carbonic acid into its component ions a hydrogen ion (H^+) and a bicarbonate ion (HCO_3^-) in the parietal cell.

↓

Then H^+ ion is transported into the stomach lumen & K^+ ions in the parietal cell via the H^+–K^+ ATPase by using ATP for energy

↓

The bicarbonate ion is transported out of the cell into the blood in exchange for a chloride ion (Cl^-) called **Protein pump**

↓

This chloride ion is then transported into the stomach lumen via a chloride channel.

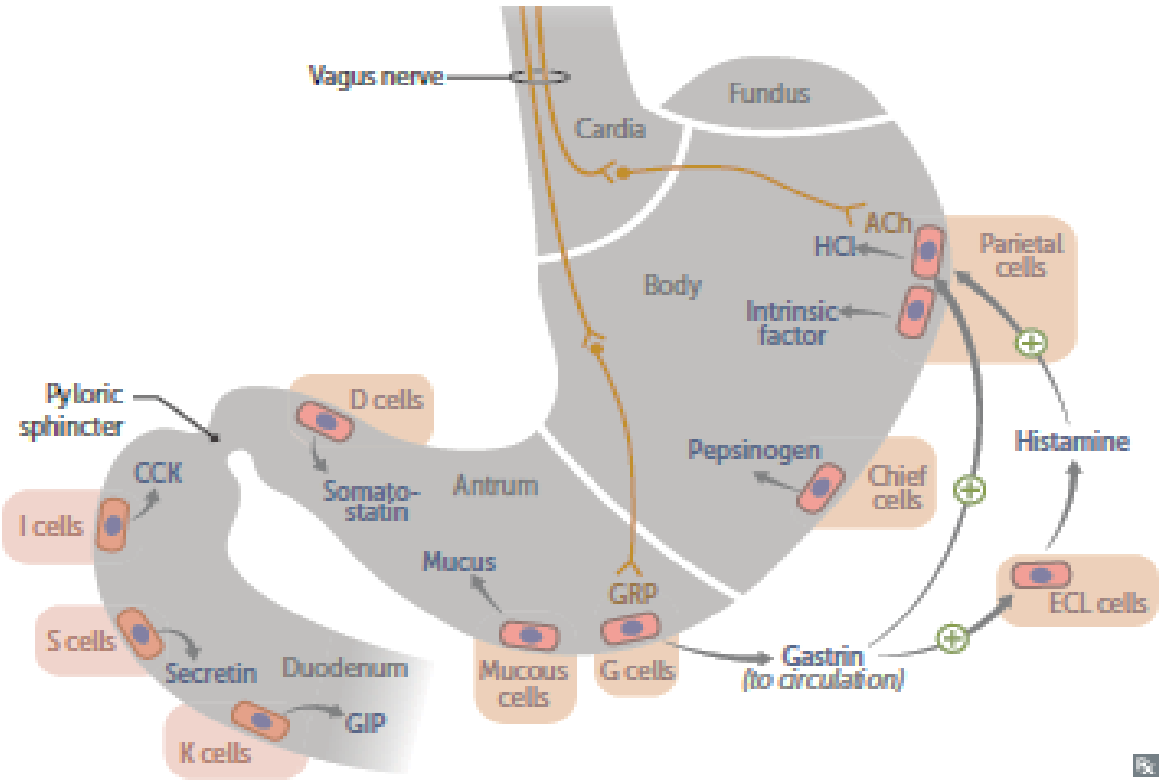
↓

This results in both hydrogen and chloride ions being present within the stomach lumen.

↓

Their opposing charges leads to them associating with each other to form Hydrochloric acid (HCl).

Regulation of acid production through parasympathetic nervous system



Increase acid production

- HCl secretion by parietal cells can be stimulated by several sources:
  - **Acetylcholine (ach)** which is released from the vagus nerve of parasympathetic neurons
- Gastrin secreted by G cells
  - G cells are activated by the vagus nerve
- Histamine, released by mast cells in the nearby lamina propria.
  - Histamine release in response to the presence of gastrin and ACh.
- Acetylcholine and gastrin stimulate parietal cells to secrete more HCl in the presence of histamine.
- Receptors for all three substances are present in the plasma membrane of parietal cells.
- This leads to increased fusion of vesicles in parietal cell however it is via the secondary messenger cAMP
- Stimulation of the vesicles fuse with the cell membrane which leads to the increased insertion of H^+– K^+ ATPase into the membrane, hence allowing for the increased movement of hydrogen ions into the stomach thus increasing acid production.

Decreasing acid production

- The increase of acid in the empty stomach between meals, increase in acid leads to a lower pH within the stomach, which inhibits the secretion of gastrin, via the production of somatostatin from D cells.
- Once food has been broken down into chyme, it passes into the duodenum, triggering the enterogastric reflex.
- Inhibitory signals are sent to the stomach via the enteric nervous system, as well as signals to medulla – reducing vagal stimulation of the stomach.

Pepsin role in protein digestion

- The pepsin is only proteolytic enzyme which digest protein in the stomach.
- Pepsin is secreted by chief Cells.
- Pepsin severs certain peptide bonds between amino acids, breaking down a protein chain of many amino acids into smaller peptide fragments.
- Pepsin is most effective in the very acidic environment of the stomach (pH 2); it becomes inactive at a higher pH.
- Testing, smelling, seeing or just thinking about food can cause gastric glands in the stomach to secrete gastric juice.
- The hydrochloric acid in the gastric juice converts pepsinogen into pepsin by cleaving off a stretch of amino acids called a peptide.
- This reaction requires very acidic pH, ranging between 1 to 3.
- The acidic environment is needed for the generation and activity of pepsin.
- The hydrochloric acid in the stomach generally provides a pH of about 1.5 to 3.5.
- The acid in the stomach causes food proteins to unfold in a process called denaturation.
- Due denaturation, pepsin break the proteins into smaller fragments, called peptides or polypeptides.
- The small intestine will continue to break down proteins by chopping the peptides into amino acids, which can readily be absorbed into the blood stream.
- Pepsin digests proteins for several hours before the partially digested food mix is slowly transferred to the small intestine.

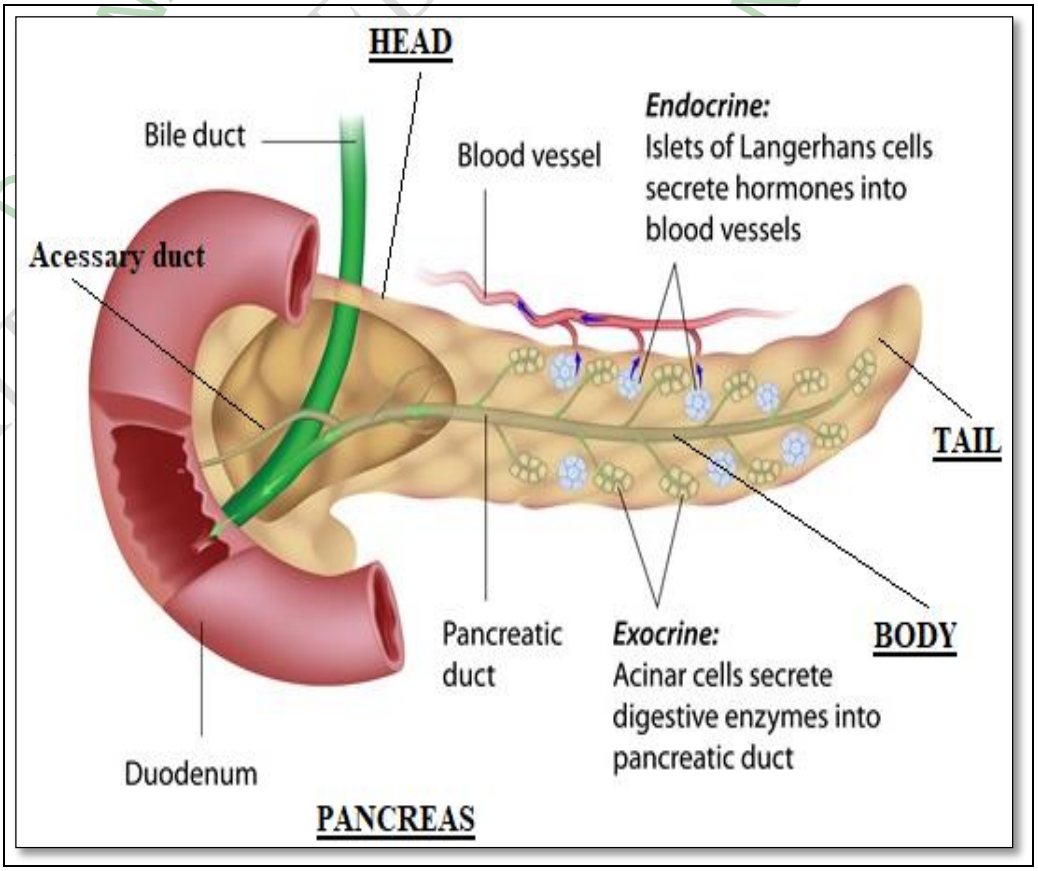
Functions of the Stomach

1. Mixes saliva, food, and gastric juice to form chyme.
2. Serves as a reservoir for food before release into small intestine.
3. Secretes gastric juice, which contains
    - ✓ Hcl -kills bacteria and denatures protein
    - ✓ Pepsin-begins the digestion of proteins,
    - ✓ Intrinsic factor-aids absorption of vitamin B
    - ✓ Gastric lipase-aids digestion of triglycerides
4. Secretes gastrin into blood.

PANCREAS

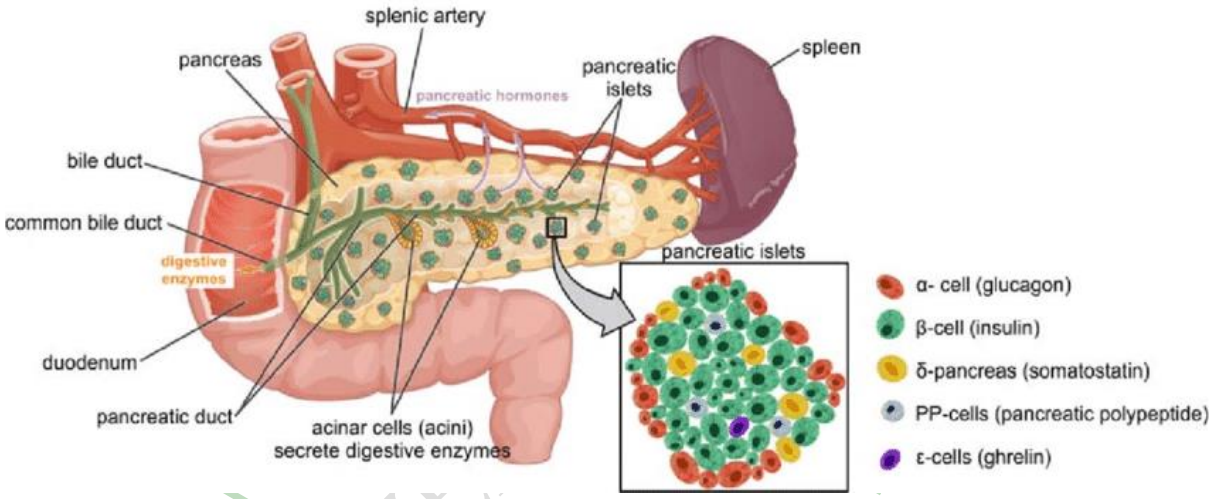
Anatomy of pancreas

- The pancreas is a retroperitoneal gland
- It is about 12–15 cm (5–6 in.) long and 2.5 cm (1 in.) thick,
- Located posterior to the greater curvature of the stomach.
- The pancreas consists of
  - Head
  - Body
  - Tail
- The head is the expanded portion of the organ near the curve of the duodenum; superior to and to the left of the head are the central body and the tapering tail.
- It connected to the duodenum by two ducts.
  - Accessory duct
  - Pancreatic duct
- The pancreatic duct is the larger duct.
- The pancreatic duct joins to the common bile duct from the liver and gallbladder and enters the duodenum as a dilated common duct called the hepatopancreatic ampulla.
- The passage of pancreatic juice and bile through the hepatopancreatic ampulla into the small intestine is regulated by the sphincter of the hepatopancreatic ampulla.
- The other major duct of the pancreas, the accessory duct (duct of Santorini), empties into the duodenum about 2.5 cm (1 in.) superior to the hepatopancreatic ampulla.



Histology of the Pancreas

- **Exocrine portion**
  - The pancreas is made up of small clusters of glandular epithelial cells.
  - About 99% of the clusters, called acini, constitute the exocrine portion of the pancreas.
  - The cells within acini secrete a mixture of fluid and digestive enzymes called pancreatic juice.
- **Endocrine portion**
  - The remaining 1% of the clusters, called pancreatic islets (islets of Langerhans), forms the endocrine portion of the pancreas.
  - These cells secrete the hormones glucagon, insulin, somatostatin, and pancreatic polypeptide.

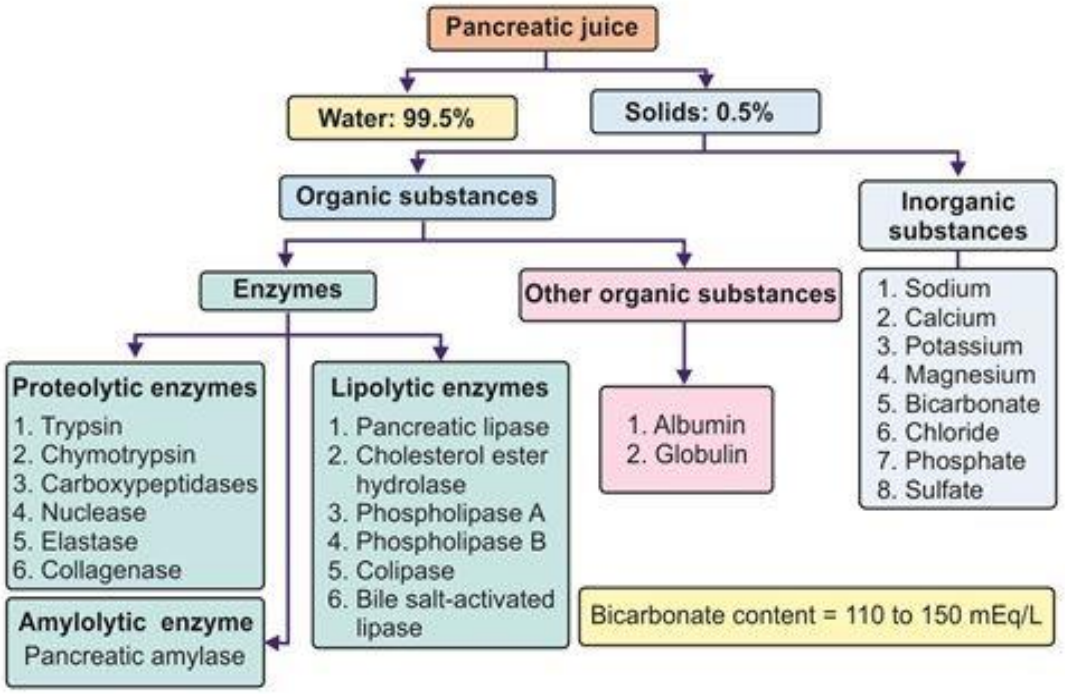


PANCRATIC JUICE

Properties

- The pancreas produces 1200–1500 mL of pancreatic juice per day.
- It is a clear, colorless, odorless liquid consisting mostly of water, some salts, sodium bicarbonate, and several enzymes.
- Pancreatic juice is highly alkaline fluid of low viscosity,.
- pH = 7.1- 8.2

Composition



Functions of pancreas/ pancreatic juice

1. **Buffering**
   - ✓ The sodium bicarbonate gives pancreatic juice a slightly alkaline pH (7.1–8.2) that buffers acidic gastric juice in chime.
   - ✓ Maintain the proper pH for the action of digestive enzymes in the small intestine.
2. **Starch digestion**
   - ✓ The enzymes in pancreatic juice include a starch digesting enzyme called pancreatic amylase.
3. **Protein digestion**
   - ✓ **Trypsin**
     - Trypsinogen is the inactive form of trypsin.
     - It is activated by enteropeptidase secreted by intestinal mucosa.
     - It activates trypsinogen to trypsin.
     - Once trypsin is formed, trypsin by itself activates trypsinogen. This type of a reaction is known as an autocatalytic reaction.
   - ✓ **Chymotrypsinogen:**
     - Chymotrypsinogen is activated to chymotrypsin-an endopeptidase by trypsin.
     - Chymotrypsin breaks peptide bonds adjacent to aromatic amino acids.
     - The pH required for this action is about 7-8.
     - This enzyme helps to digest large proteins into smaller peptides.
   - ✓ **Procarboxypeptidase A and B:**

- Both are activated by trypsin into carboxypeptidase A and B, respectively.
- They are exopeptidases because they cleave or break peptide bonds at the carboxy terminal of the protein.

✓ **Elastase:**

- Activated to elastase by trypsin.
- An elastase acts on the protein elastin attacking peptide bonds adjacent to aliphatic amino acids.

✓ **Collagenase:**

- Activated into collagenase by trypsin and digests collagen.

✓ **Nucleases:**

- Convert the RNA & DNA into mononucleotides.

4. Lipid Digestion

✓ **Pancreatic lipase**

- It is the most important fat splitting enzyme in the GIT.
- It acts on emulsified fats, emulsification carried by bile salts in the presence of lecithin and monoglycerides.
- Bile salts activate pancreatic lipase.
- The triglycerides are broken down by lipase into glycerol and fatty acids

✓ **Prophospholipase:**

- This is activated by trypsin to phospholipase.
- Phospholipase converts lecithin into lysolecithin by splitting of fatty acid and then absorbed it.

✓ **Cholesterol esterase:**

- This enzyme hydrolyses cholesterol ester to yield free cholesterol which is absorbed along with fatty acids.

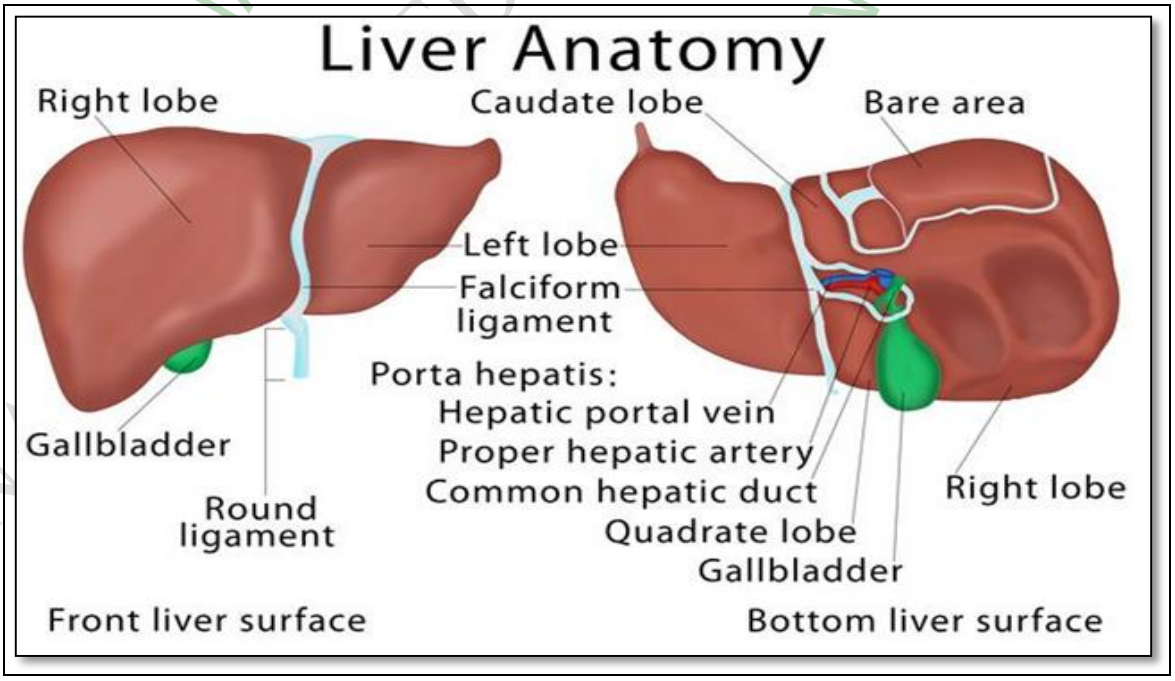
LIVER

- The liver is a peritoneal organ positioned in the right upper quadrant of the abdomen. It is the largest visceral structure in the abdominal cavity.
- The largest gland in the human body.
- The liver is the heaviest gland of the body, weighing about 1.4 kg in an average adult.
- It is an accessory digestion gland, performs a wide range of functions; including synthesis of bile, glycogen storage and clotting factor production.

Anatomy of liver

- **Liver Surfaces**

Liver Surfaces	
Diaphragmatic surface	**Visceral surface**
the anterosuperior surface of the liver	the posteroinferior surface of the liver.
The posterior aspect of the diaphragmatic surface is not covered by visceral peritoneum,	Except the fossa of the gallbladder & porta hepatis, it is covered with visceral peritoneum.
In direct contact with the diaphragm, area known as the 'bare area' of the liver.	It lies in contact with the right kidney, right adrenal gland, right colic flexure, transverse colon



Ligaments of the Liver

There are various ligaments that attach the liver to the surrounding structures. These are formed by a double layer of peritoneum.

Falciform ligament	✓ It is attaches the anterior surface of the liver & anterior to abdominal wall. ✓ Falciform ligament divide liver into 2 lobes ➢ the small left and ➢ large right lobs ➢ The right lobe divides into the caudate and quadrate lobes by a deep, transverse fissure called as the porta hepatis**.** ➢ It transmits all the vessels, nerves and ducts entering or leaving the liver with the exception of the hepatic veins.
Coronary ligament	✓ It attaches the superior surface of the liver to the inferior surface of the diaphragm and boundaries of the bare area of the liver ✓ The anterior and posterior folds unite to form the triangular ligaments on the right and left lobes of the liver.
Triangular ligaments	✓ The left triangular ligament is formed by the union of the anterior and posterior layers of the coronary ligament at the apex of the liver. ✓ The right triangular ligament is formed in a similar fashion adjacent to the bare area and attaches the right lobe of the liver to the diaphragm.
Lesser omentum	✓ It the liver to the lesser curvature of the stomach and first part of the duodenum. ✓ It consists of the hepatoduodenal ligament & the hepatogastric ligament,

HISTOLOGY OF LIVER

1. **Hepatocytes**

- Hepatocytes are the major functional cells of the liver and perform a variety of the functions like metabolic, secretory, and endocrine.
- These are specialized epithelial cells with 5 to 12 sides that make up about 80% of the volume of the liver.
- Hepatocytes form complex three-dimensional arrangements called hepatic laminae.
- Grooves in the cell membranes between neighboring hepatocytes provide spaces for canaliculi into which the hepatocytes secrete bile.
- Bile, a yellow, brownish, or olive-green liquid secreted by hepatocytes, serves as both an excretory product and a digestive secretion.

2. **Bile canaliculi**

- These are small ducts between hepatocytes that collect bile produced by the hepatocytes.

From bile canaliculi, bile passes into

↓

Bile ductules

↓

Then into the bile ducts.

↓

The bile ducts merge and eventually form the

Larger right and Left hepatic ducts,

↓

Which unite and exit the liver as the common hepatic duct.

↓

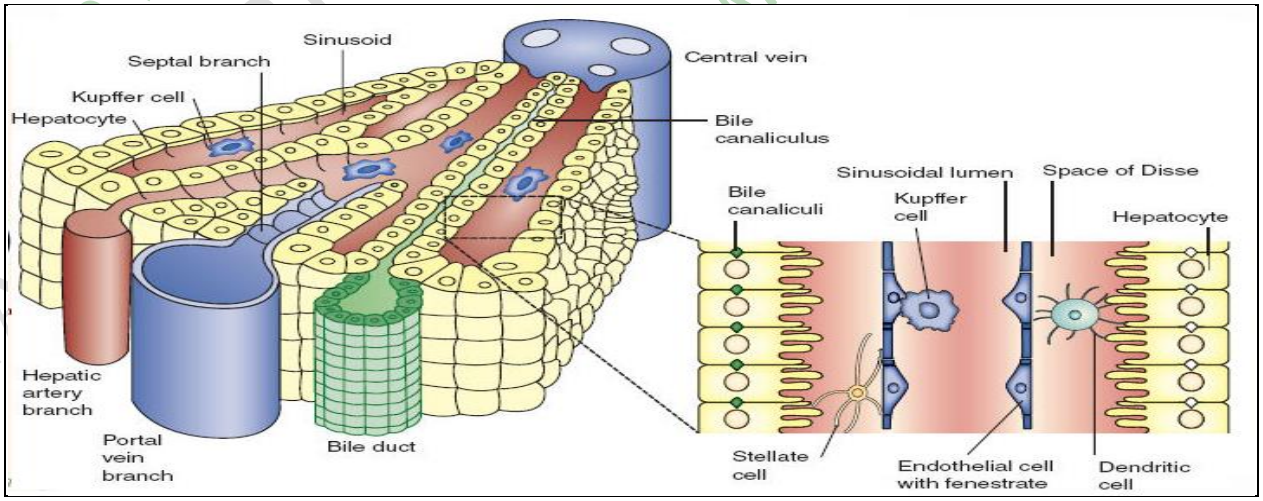
The common hepatic duct joins the cystic duct from the gallbladder to form the common bile duct

↓

Bile enters the small intestine to participate in digestion.

3. Hepatic sinusoids

- Hepatic sinusoids are highly permeable blood capillaries between rows of hepatocytes that receive
  - Oxygenated blood from branches of the hepatic artery
  - Nutrient-rich deoxygenated blood from branches of the hepatic portal vein.
- Hepatic sinusoids deliver blood into a central vein then the blood flows into the hepatic veins, which drain into the inferior vena cava.
- The hepatic sinusoids contains Kupffer cells- a phagocytic cell.
- Together, a bile duct, branch of the hepatic artery, and branch of the hepatic vein are referred to as a portal triad.



FUNCTIONS OF LIVER

1. **Metabolism**

   Liver contains many metabolic enzyme which metabolized carbohydrates, protein & lipids.

2. **Detoxification**

   The liver is detoxifies many toxins. Those toxins can be naturally present in the waste generated by our body, like ammonia, or in the ones we eat or drink, like medicine or alcohol.

3. **Excretion**

   Excretion of bilirubin, cholesterol, hormones, toxins and drugs

4. **Synthesis**

   Synthesis of plasma proteins, such as albumin, glucose, glycogen, ATP, liporpteins, cholesterol and clotting factors.

5. **Storage**

   Storage of glycogen, vitamins (A B_{12}, D, E & K) and minerals (iron & copper)

6. **Protection**

   Cells of the liver phagocytize aged red blood cells, white blood cells, and some bacteria.

7. **Activation of vitamin D**

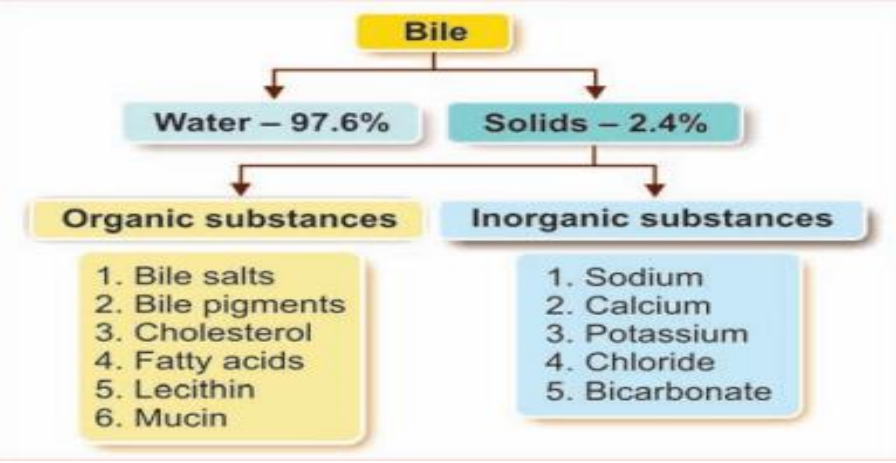
   The skin, liver, and kidneys participate in synthesizing the active form of vitamin D.

BILE

PROPERTIES OF BILE

- Each day, hepatocytes secrete 800–1000 mL of bile,
- A yellow, brownish, or olive-green liquid. It has a pH of 7.6–8.6

COMPOSITION OF BILE

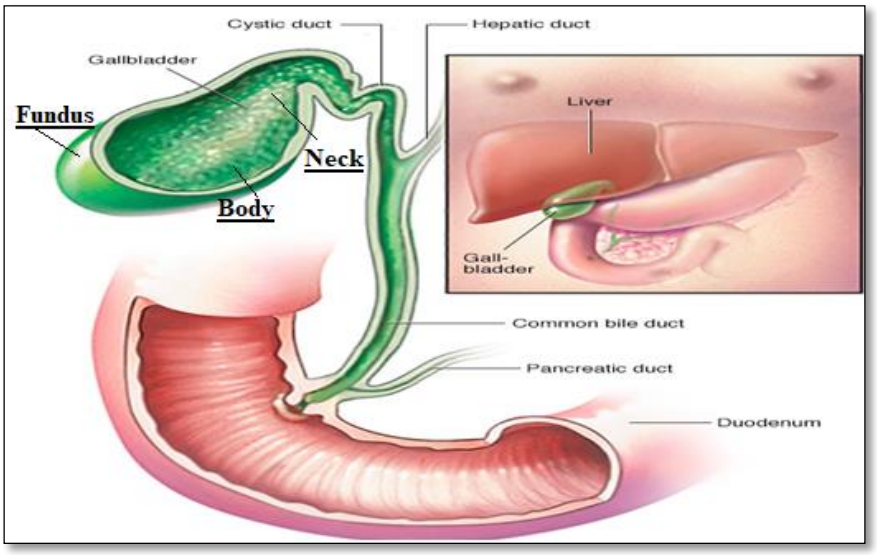


FUNCTIONS OF BILE

- **Bile salts**
  - Which are sodium salts and potassium salts of bile, play a role in emulsification, the breakdown of large lipid globules into a suspension of small lipid globules.
  - The small lipid globules present a very large surface area that allows pancreatic lipase to more rapidly accomplish digestion of triglycerides.
  - Bile salts reduce the surface tension, help in the absorption of lipids after their digestion.
  - Bile salts help in the absorption of lipid-soluble vitamins A, D, E and K.
- **Mucin**
  - Mucin of bile acts as a buffer and a lubricant.
- **Lecithin and cholesterol:**
  - First, they are treated as food and are reabsorbed.
  - Secondly, they act as adjuvants to bile salts in the process of emulsification of fats.
- **Maintain pH**
  - Bile is an important source of alkali for neutralising the HCl entering the intestine from stomach**.**
- **Laxative Action:**
  - Bile salts stimulate peristalsis. When introduced directly into the colon it stimulates peristalsis of these parts.

GALL BLADDER

- **STRUCTURE**
  - It has a pear shape and its tip opens towards the cystic duct.
  - In adults, the gallbladder is approximately 7 to 10 cm long and 4 cm in diameter.
  - It has a capacity of approximately 50 milliliters.
  - The parts of the gallbladder include the broad fundus, body and neck.
- **FUNCTIONS**
  - Storage of bile made by liver, in gallbladder it is called gall.
  - Concentrate bile by absorbing water from bile
  - Regulate pressure in bilary system.
  - Maintain pH of bile
  - Secretes mucus.



SMALL INTESTINE

- The small intestine is the longest part of the digestive system.
- The small intestine begins at the pyloric sphincter of the stomach & opens into the large intestine.
- It averages 2.5 cm in diameter; its length is about 3 m and about 6.5 m.

ANATOMY OF SMALL INTESTINE

It consists of three parts:

i. Duodenum:

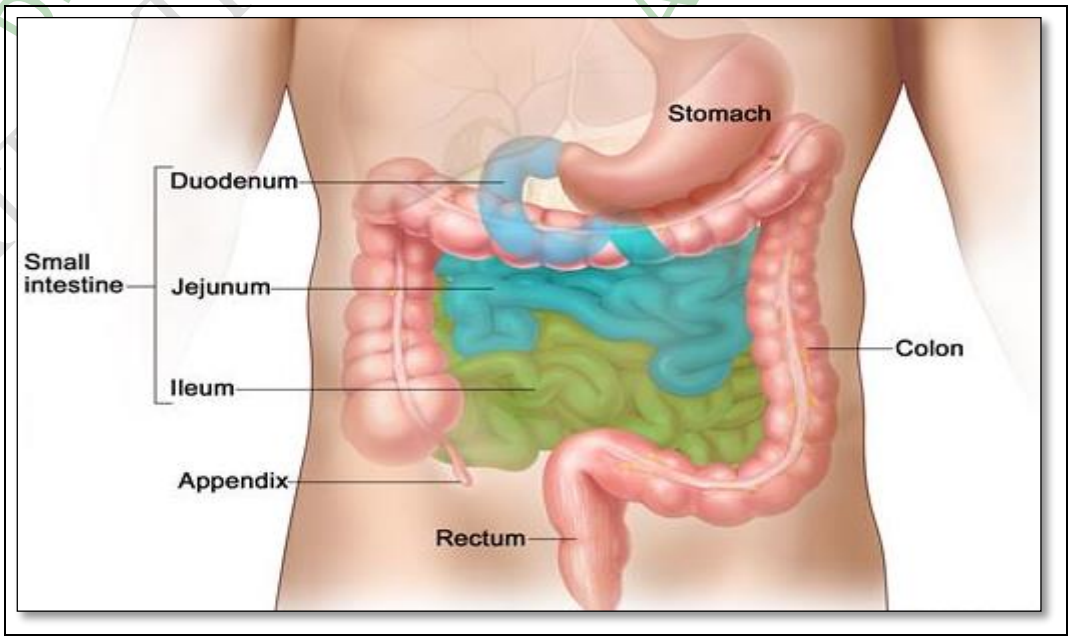
- The duodenum is the shortest region, in retroperitoneal. It starts at the pyloric sphincter of the stomach and extends about 25 cm. It merges with the jejunum.

ii. Jejunum:

- The jejunum is about 1m long & ends to the ileum. Jejunum means "empty,"

iii. Ileum:

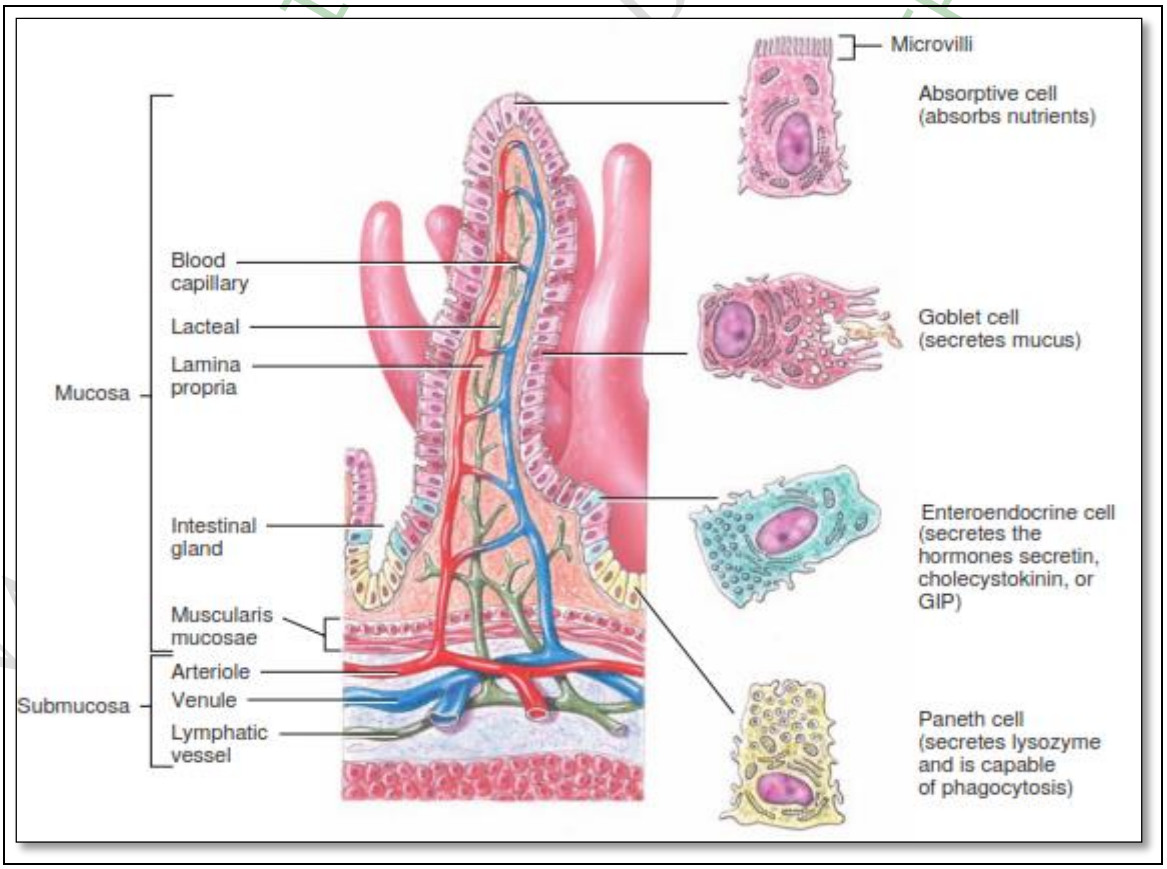
- Last & longest region of the small intestine, ileum means twisted, it is about 2 m and joins the large intestine at a smooth muscle sphincter called the ileocecal sphincter.



HISTOLOGY OF SMALL INTESTINE

- The wall of the small intestine is composed of the same four layers that make up most of the GI tract: mucosa, submucosa, muscularis, and serosa.
- The mucosa is composed of a layer of epithelium, lamina propria, and muscular mucosa
- Its length alone provides a large surface area for digestion and absorption. The area is further increased by circular folds, villi, and microvilli.

LAYER OF GIT		NAME OF CELLS	THEIR FUNCTION
Mucosa	Epithelial Layer	Absorptive cells	Digest and absorb nutrients in small intestinal chime
		goblet cells	secrete mucus
		Paneth cells	Secrete lysozyme, a bactericidal enzyme, and are capable of phagocytosis. Paneth cells may have a role in regulating the microbial population in the small intestine.
		Enteroendo-crine cells S cells, CCK cells K cells	secrete the hormones
			Secretin
			Cholecystokinin
			glucose-dependent insulinotropic peptide or GIP
	Lamina Propria	Solitary Lymphatic Nodules	Protection
		Peyer's Patches	
Sub Mucosa		Brunner's Glands	Secrete analkaline mucus that helps neutralize gastric acid in the chyme.



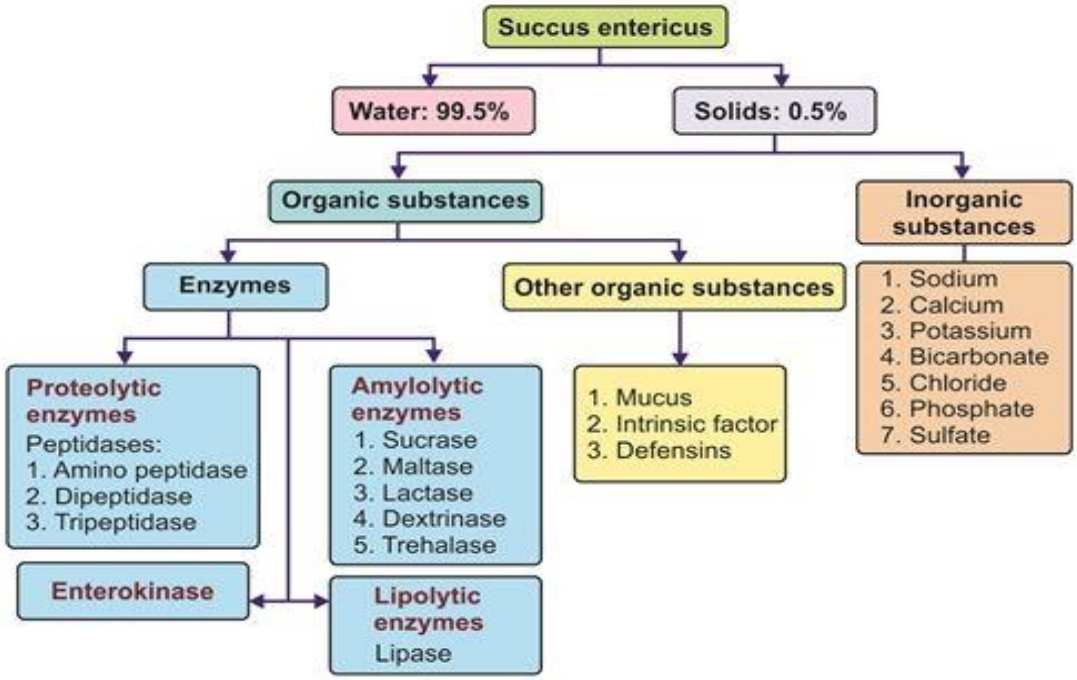
INTESTINAL JUICE AND BRUSH-BORDER ENZYMES

- About 1–2 L of intestinal juice, a clear yellow fluid, are secreted each day.
- Intestinal juice contains water and mucus and is slightly alkaline pH 7.6
- Together, pancreatic and intestinal juices provide a liquid medium that absorb of substances from chyme in the small intestine.
- The absorptive cells of the small intestine synthesize several digestive enzymes, called **brush-border enzymes**, and insert them in the plasma membrane of the microvilli.

BRUSH-BORDER ENZYMES

Carbohydrate-Digesting Enzymes	Protein-Digesting Enzymes	Nucleotide-Digesting Enzymes
Dextrinase	Aminopeptidase	Nucleosidases
Maltase	Dipeptidase	Phosphatases
Sucrase		
Lactase		

COMPOSITION OF INTESTINAL FLUID/ SUCCUS ENTERICUS



FUNCTION OF SMALL INTESTINE

- Duodenum

The duodenum is act like the mixing pot.

↓

It receives chyme from the stomach, which is a mixture of food products and acid.

↓

Pancreatic enzymes enter here to break down the products from the stomach, bicarbonate to neutralize the acid from the stomach before reaching the jejunum.

↓

Liver introduces bile which allows for the breakdown & absorption of fat from food.

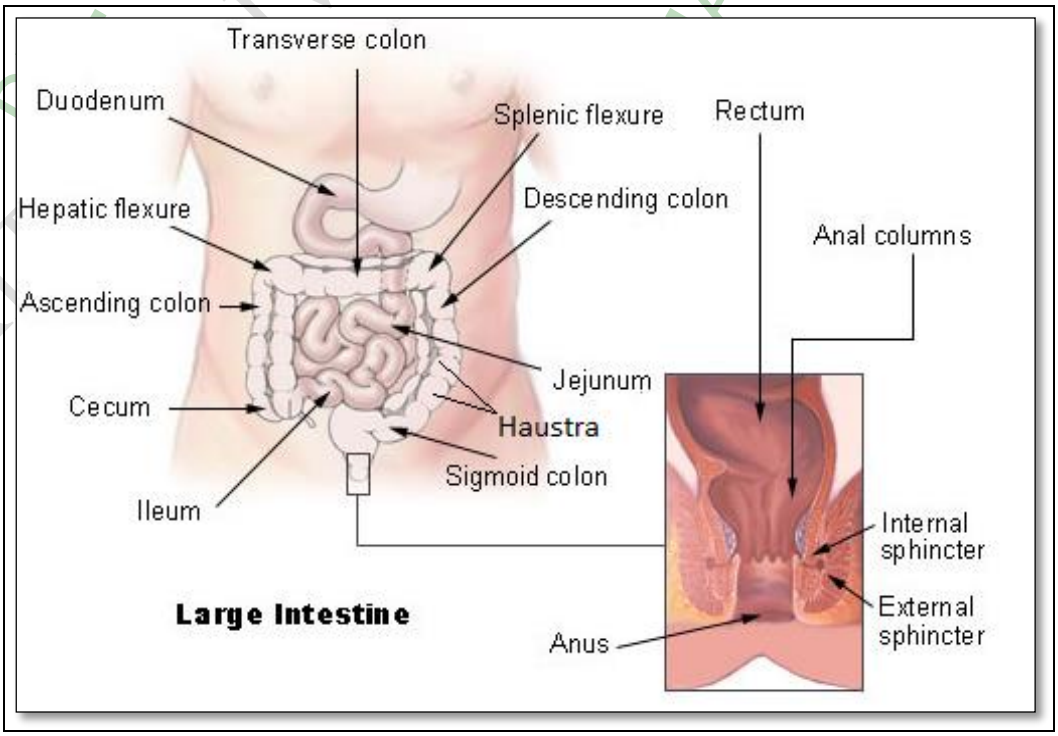
- The jejunum primary function is absorption, where sugars, amino acids, and fatty acids are absorbed.
- The ileum absorbs nutrients that did not get absorbed by the jejunum, with important nutrients being vitamin B12 and bile acids for reuse.

LARGE INTESTINE

- The **large intestine**, also known as the colon, is part of the digestive tract.
- The large intestine, which is the terminal part of gastrointestinal (GI) tract, is so called because its diameter of lumen is larger, not because its length.

ANATOMY OF THE LARGE INTESTINE

- The large intestine, which is about 1.5 m long and 6.5 cm in diameter, extends from the ileum to the anus.
- Structurally, the four major regions of the large intestine are
  I. cecum
  II. colon
  III. rectum
  IV. anal canal



Cecum	✓ Continue from ileum to colon ✓ Ileocecal sphincter is present in between small and large intestine. ✓ Hanging inferior to the ileocecal valve is the cecum, a small pouch of 6 cm. ✓ Appendix is a twisted, coiled tube, measuring about 8 cm (3 in.) in length join to the cecum.
Colon	✓ The colon (large intestine) is the distal part of the gastrointestinal tract, extending from the cecum to the anal canal. ✓ Colon is divided into ascending, transverse, descending, and sigmoid portions
	Ascending Colon ✓ The colon begins as the ascending colon, a retroperitoneal structure which ascends superiorly from the cecum. ✓ When it meets the right lobe of the liver, it turns 90 degrees to move horizontally. This turn is known as the right colic flexure or hepatic flexure, and marks the start of the transverse colon. **Transverse colon** ✓ The **transverse colon** extends from the right colic flexure to the spleen, where it turns another 90 degrees to point inferiorly. ✓ This turn is known as the left colic flexure or splenic flexure. **Descending Colon** ✓ After the left colic flexure, the colon moves inferiorly towards the pelvis – and is called the descending colon. ✓ When the colon begins to turn medially, it becomes the sigmoid colon. **Sigmoid Colon** ✓ The 40cm long sigmoid colon is located in the left lower quadrant of the abdomen, extending from the left iliac fossa to the level of the S3 vertebra. ✓ This journey gives the sigmoid colon its characteristic “S” shape.

RECTUM

- The roles of the rectum include temporary storage of fecal matter and defecation.
- The Rectum last 20 cm (8 in.) of the GI tract, lies anterior to the sacrum and coccyx.
- The terminal 2–3 cm of the rectum is called the anal canal. The mucous membrane of the anal canal is arranged in longitudinal folds called anal columns

ANAL CANAL

- The anal canal forms the terminal part of the gastrointestinal tract.
- It extends from the anorectal junction to the anus.

- The opening of the anal canal to the exterior, called the anus, is guarded by an internal anal sphincter of smooth muscle (involuntary) and an external anal sphincter of skeletal muscle (voluntary).
- Normally these sphincters keep the anus closed except during the elimination of feces.

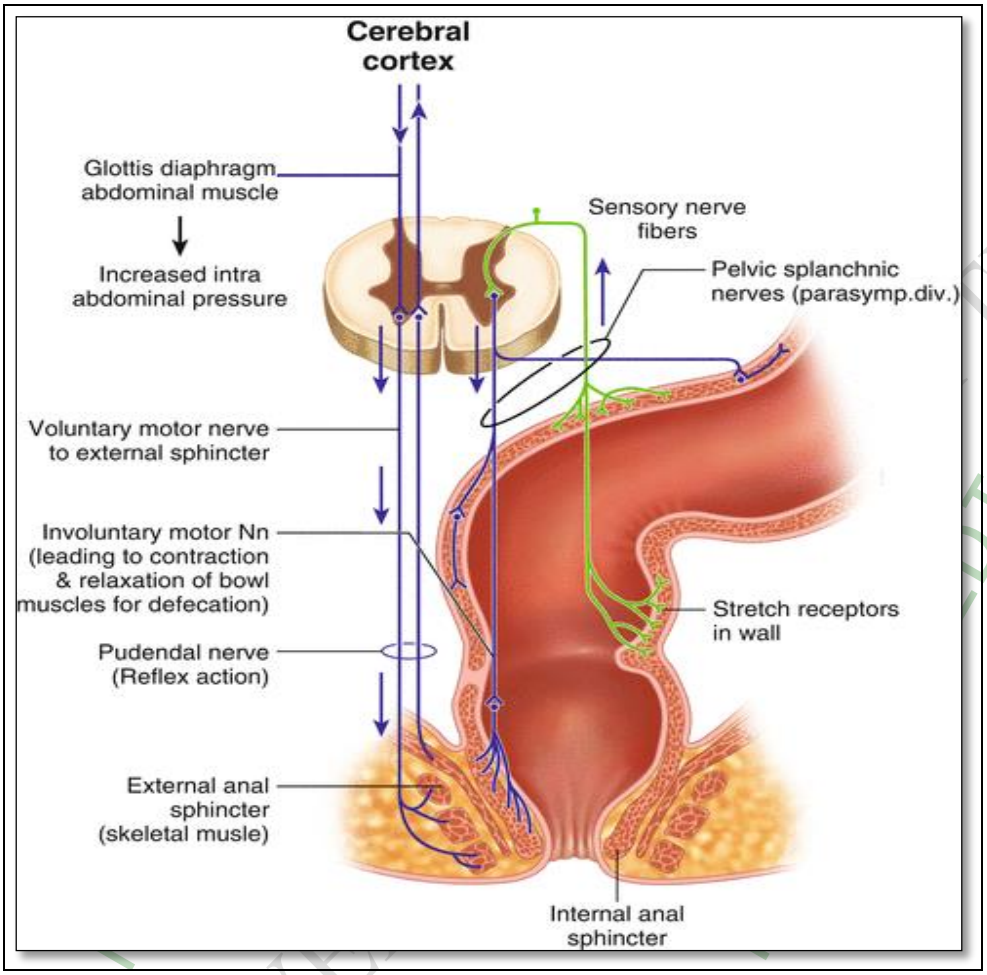
FUNCTIONS OF THE LARGE INTESTINE

- Reabsorption of water and mineral ions such as sodium and chloride
- Bacteria in the large intestine convert proteins to amino acids, break down amino acids, and produce some B vitamins and vitamin K.
- Formation and temporary storage of faeces.
- Defecating (emptying the rectum).

DEFECATION

- The process of defecation is normally a combination of both voluntary and involuntary processes that create enough force to remove waste material from the digestive system.
- The rectal ampulla acts as a temporary storage for the fecal material.
- As additional fecal material enters the rectum, the rectal walls expand.
- A sufficient increase in fecal material in the rectum causes the stretch receptors from the nervous system, located in the rectal walls, to trigger the contraction of rectal muscles, the relaxation of the internal anal sphincter, and an initial contraction of the skeletal muscle of the external sphincter.
- The relaxation of the internal anal sphincter causes a signal to be sent to the brain indicating an urge to defecate.
- If this urge is not acted upon, the material in the rectum is often returned to the colon by reverse peristalsis where more water is absorbed, thus temporarily reducing pressure and stretching within the rectum.
- The additional fecal material is stored in the colon until the next mass peristaltic movement of the transverse and descending colon.
- If defecation is delayed for a prolonged period, the fecal matter may harden and autolyze, resulting in constipation.
- Once the voluntary signal to defecate is sent back from the brain, the final phase begins. The abdominal muscles contract (straining), causing the intra-abdominal pressure to increase.
- The external anal sphincter relaxes.
- The rectum now contracts and shortens in peristaltic waves, thus forcing fecal material out of the rectum and down through the anal canal.

- The internal and external anal sphincters, along with the puborectalis muscle, allow the feces to be passed by pulling the anus up and over the exiting feces in shortening and contracting actions.



MOVEMENT OF GIT

THE GASTROINTESTINAL MOTILITY

- Motility is defined as **involuntary mobility of human tubular organs**.
- For the effective digestion & absorption of food, it is necessary to mix as well as to propel the chyme to next part of GIT.
- For this purpose , there are two types of movements in the GIT:
    1. Propulsion movements
    2. Mixing movements

❖ **Propulsion movements**

Propulsion movements, provide movement of chyme in the digestive tract to that of the rate of absorption and digestion.

Peristalsis

✓ Basic propulsion movement is called **peristalsis**.

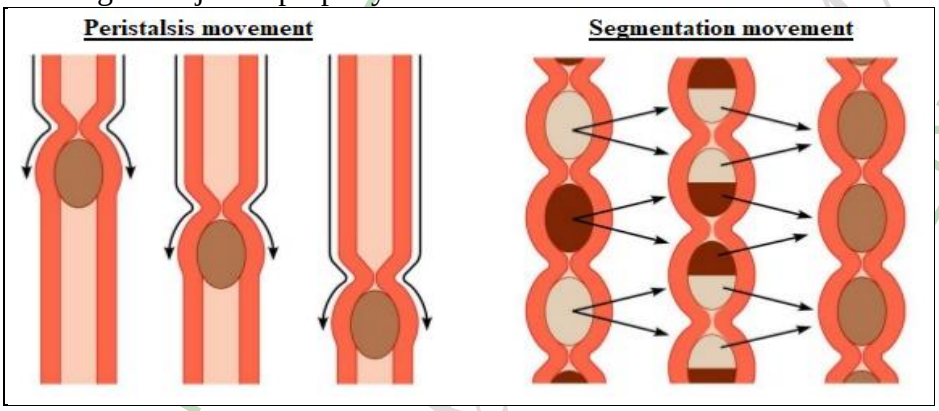
- ✓ Peristalsis is carried out by circular muscle of muscularis layer. Circular muscles form a contractile ring, which pushes chyme ahead.
- ✓ Alternate contraction and relaxation of GIT pushes chyme in the next part of GIT, this is called peristalsis, the peristaltic movements are therefore unidirectional.

❖ **Mixing movements**

- ✓ Mixing movement ensures constant mixing of chyme, so that the entire volume of the nutritionally important components is exposed to enzymes and came into a contact with the lining of the intestine to be absorbed.
- ✓ These movements have different forms and varies throughout the digestive tract.

Segmentation

- ✓ Segmentation is the processes in which chyme move back and forth to mix chyme and digestive juices properly.



THE MOVEMENT/ MOTILITY OF THE STOMACH

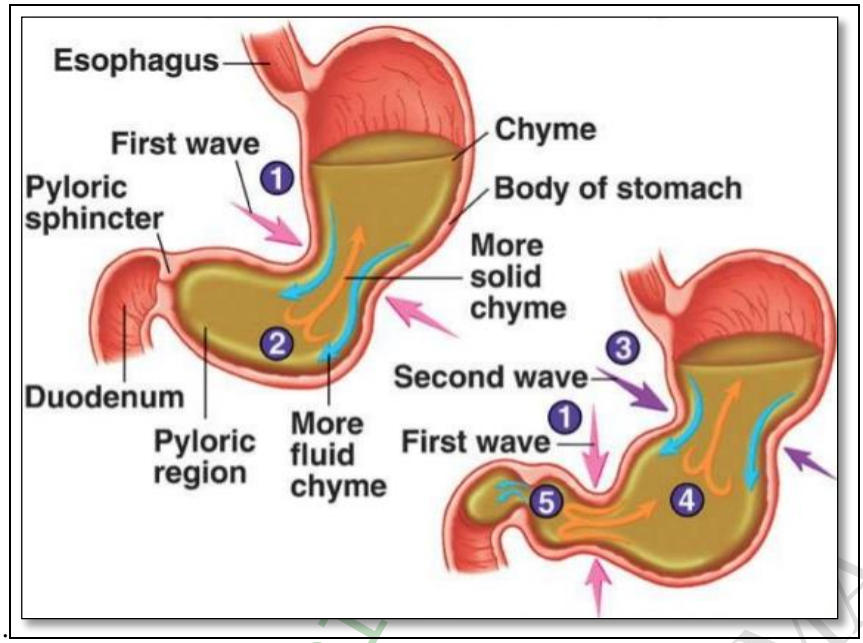
1) Mixing of food
2) Emptying into the duodenum

MIXING OF FOOD

- Few minutes after food enters the stomach, gentle, peristaltic movements called mixing waves starts in the stomach in every 15 to 25 seconds.
- These waves macerate food, mix it with secretions of the gastric glands, and convert it to a soupy liquid called chyme

GASTRIC EMPTYING

- As food reaches the pylorus, each mixing wave periodically forces about 3 mL of chyme into the duodenum through the pyloric sphincter, a phenomenon known as gastric emptying.
- Most of the chyme is forced back into the body of the stomach, where mixing continues.
- The next wave pushes the chyme forward again and forces a little more into the duodenum.
- These forward and backward movements of the gastric contents are responsible for most mixing in the stomach



MOTILITY OF THE SMALL INTESTINE

1) Segmentation contractions

2) Propulsion contractions

Segmentation contractions

- Segmentation is a manifestation of electrical slow-waves, which represent action potentials generated by the automaticity of smooth muscle.
- The maximum frequency of these slow waves is 12/min.
- Therefore, segmentation can also occur up to 12 times per minute in duodenum.
- The normal frequency of segmentation movement at ileum is about 8 per minute.

Propulsion contractions

- The contractile ring in the small intestine has a velocity of about 0.5-2 cm/min.
- Faster in the proximal segments, in distal segments it slows down. One contractile ring travels a maximal distance of 10 cm, then it goes out and chymus wait for the new one.
- Therefore, the overall speed of passage of chyme is 1 cm/min.

Ileocecal valve

- Function of this valve is to prevent reflux of chyme from colon into the small intestine.

MOTILITY OF THE COLON

Haustration churning

- It is a modified segmentation movement.
- One movement characteristic of the large intestine is haustral churning. In this process, the haustra remain relaxed and become distended while they fill up.

- When the distension reaches certain point, the walls contract and squeeze the contents into the next haustrum.

Peristalsis

- Peristalsis occurs at a slower rate (3–12 contractions per minute) than in more proximal portions of the tract.
- The final type of movement is a mass peristalsis, strong peristaltic wave that begins at about the middle of the transverse colon and quickly drives the contents of the colon into the rectum.
- Because food in the stomach initiates this gastrcolic reflex in the colon, mass peristalsis usually takes place three or four times a day, during or immediately after a meal.

DIGESTION AND ABSORPTION OF NUTRIENTS

DIGESTION AND ABSORPTION OF CARBOHYDRATES

Mouth

- The digestion of carbohydrates is start in the mouth.
- The salivary enzyme amylase starts the breakdown of

Starches-a polysaccharides **Salivary amylase** **maltose-a disaccharide.**

Esophagus

- The bolus of food travels through the esophagus to the stomach, their no significant digestion of carbohydrates takes place because esophagus not produces digestive enzymes.

Stomach

- The acidic environment in the stomach stops the action of the amylase enzyme.

Small intestine

- The next step of carbohydrate digestion takes place in the duodenum.
- The chyme from the stomach enters the duodenum and mixes with the digestive secretion from the pancreas, liver, and gallbladder.
- Pancreatic juices also contain amylase, which continues the breakdown of starch and glycogen into maltose, a disaccharide.

Starches & glycogen **Pancreatic amylase** **maltose-a disaccharide**

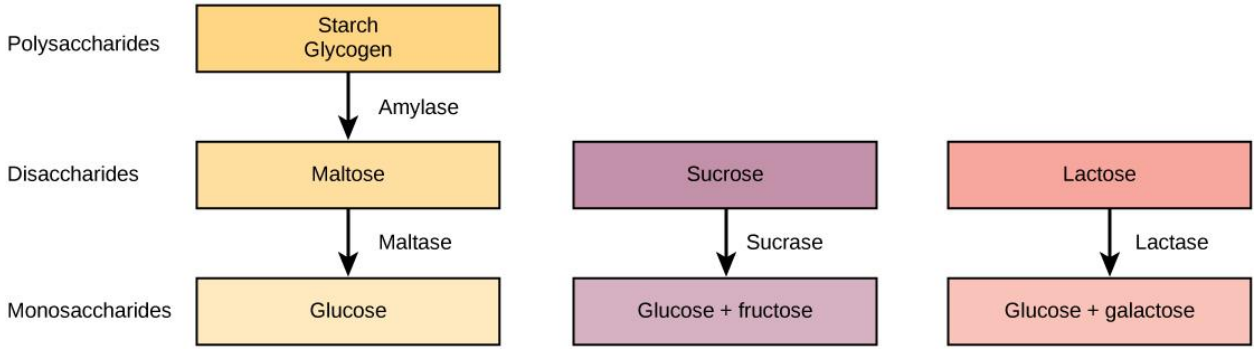
- The disaccharides are broken down into monosaccharides by enzymes called **maltases**,
- Sucrases and **lactases**, which are also present in the brush border of the small intestinal wall.

Maltose- a disaccharide —Maltase→ **glucose a monosaccharide**

Sucrose- a disaccharide —Sucrase→ **glucose + Fructose**

Lactose- a disaccharide —Lactase→ **glucose + galactose**

- Digestion of carbohydrates ends with the production of monosaccharides, which the digestive system is able to absorb.



ABSORPTION

- All carbohydrates are absorbed in the form monosaccharides.
- The capacity of the small intestine to absorb monosaccharides is 120 grams per hour.
- All dietary carbohydrates are absorbed, only indigestible cellulose and fibers excreted in the feces.
- Monosaccharides are transported via facilitated diffusion or active transport.
- Fructose is transported via facilitated diffusion
- Glucose and galactose are transported into absorptive cells of the villi via secondary active transport, that is coupled to the active transport of Na.
- The transporter has binding sites for one glucose molecule and two sodium ions; unless all three sites are filled, no substance is transported.
- Galactose competes with glucose to ride the same transporter.

Enzyme	Produced By	Site of Action	Substrate Acting On	End Products
Salivary amylase	Salivary glands	Mouth	Polysaccharides (Starch)	Disaccharides (maltose), oligosaccharides
Pancreatic amylase	Pancreas	Small intestine	Polysaccharides (starch)	Disaccharides (maltose), monosaccharides
Oligosaccharidases	Lining of the intestine; brush border membrane	Small intestine	Disaccharides	Monosaccharides (e.g., glucose, fructose, galactose)

DIGESTION AND ABSORPTION OF PROTEIN

Stomach

- A large part of protein digestion takes place in the stomach.
- The enzyme pepsin plays an important role in the digestion of proteins by breaking down the intact protein to peptides, which are short chains of four to nine amino acids.

Duodenum

- Pancreatic enzymes trypsin, elastase, carboxypeptidase and chymotrypsin are produced released into the duodenum where they act on the chyme.
- Trypsin, chymotrypsin, and elastase all cleave the peptide bond between a specific amino acid
- But carboxypeptidase splits off the amino acid at the carboxyl end of a peptide.
- Protein digestion is completed by two peptidases in the brush border: aminopeptidase and dipeptidase.
- Aminopeptidase cleaves off the amino acid at the amino end of a peptide.
- Dipeptidase splits dipeptides (two amino acids joined by a peptide bond) into single amino acids.
- The amino acids are absorbed into the bloodstream through the small intestines.

ABSORPTION

- Most proteins are absorbed in the duodenum and jejunum.
- Amino acids are absorb via active transport processes.
- Different transporters carry different types of amino acids.
- Some amino acids enter absorptive cells of the villi via Na^+ dependent secondary active transport processes.
- Other amino acids are actively transported by themselves.
- At least one transpoter brings in dipeptides and tripeptides together with H^+; the peptides then are hydrolyzed to single amino acids inside the absorptive cells.

DIGESTION AND ABSORPTION OF FATS

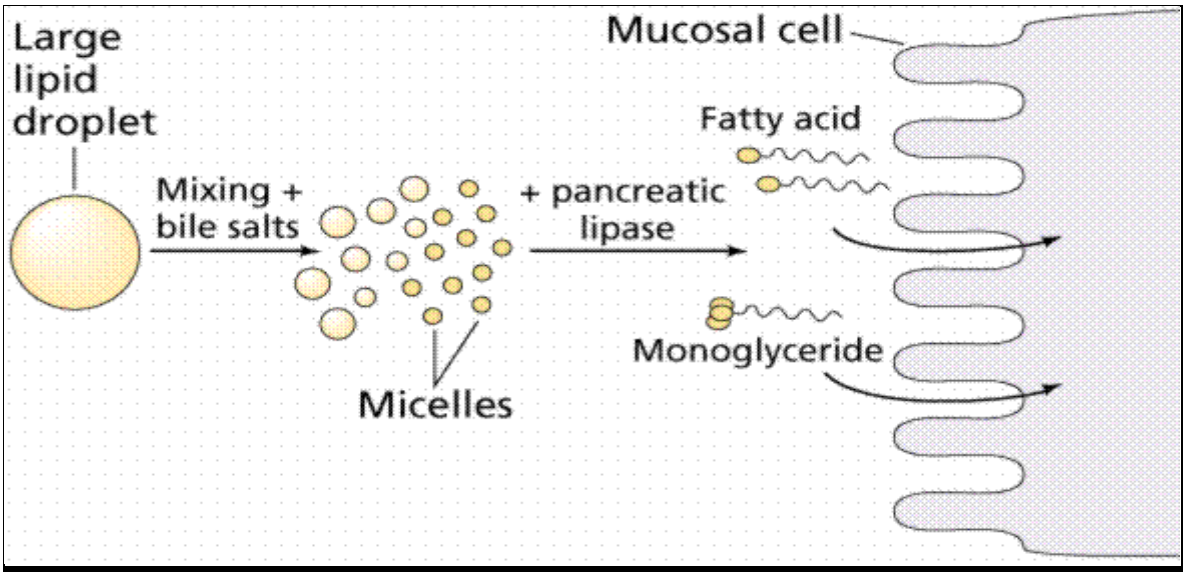
Stomach

- Lipid digestion begins in the stomach with the aid of lingual lipase and gastric lipase.

Small intestine

- The large amount of lipid digestion occurs in the small intestine due to pancreatic lipase.
- When chyme enters the duodenum, the hormonal responses trigger the release of bile, which is produced in the liver and stored in the gallbladder.
- Bile involves in the digestion of lipids,
- Emulsification is a process in which large lipid globules are broken down into several small lipid globules.

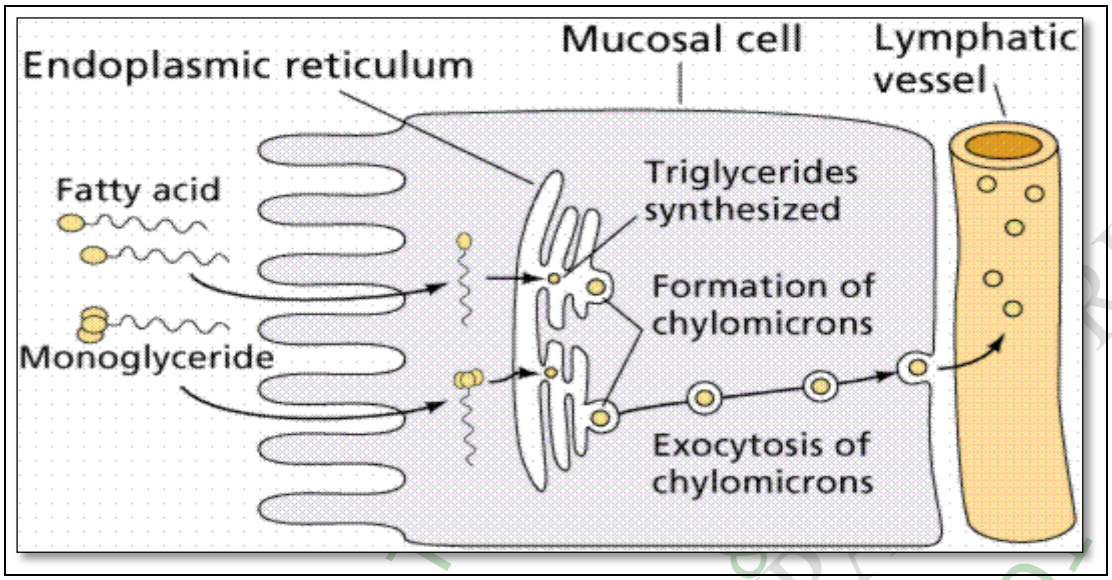
- These small globules are more widely distributed in the chyme rather than forming large aggregates.
- Lipids are hydrophobic substances: in the presence of water, they will aggregate to form globules to minimize exposure to water.
- Bile contains bile salts, which are amphipathic, meaning they contain hydrophobic and hydrophilic parts.
- Thus, the bile salts hydrophilic side can interface with water on one side and the hydrophobic side interfaces with lipids on the other.
- By this way bile salts emulsify large lipid globules into small lipid globules.
- Pancreatic juices contain enzymes called lipases.
- The pancreatic lipases break down the lipids into fatty acids and glycerides.



ABSOPTION

- Fatty acids and glycerides molecules can pass through the plasma membrane of the cell and enter the epithelial cells of the intestinal lining.
- The bile salts surround long-chain fatty acids and monoglycerides forming tiny spheres called **micelles**.
- The micelles move into the brush border of the small intestine absorptive cells where the long-chain fatty acids and monoglycerides diffuse out of the micelles into the absorptive cells leaving the micelles behind in the chyme.
- The long-chain fatty acids and monoglycerides recombine in the absorptive cells to form triglycerides, which aggregate into globules and become coated with proteins.
- These large spheres are called **chylomicrons**.
- Chylomicrons contain triglycerides, cholesterol, and other lipids and have proteins on their surface.
- The surface is also composed of the hydrophilic phosphate “heads” of phospholipids.

- Chylomicrons leave the absorptive cells via exocytosis.
- Chylomicrons enter the lymphatic vessels, and then enter the blood.

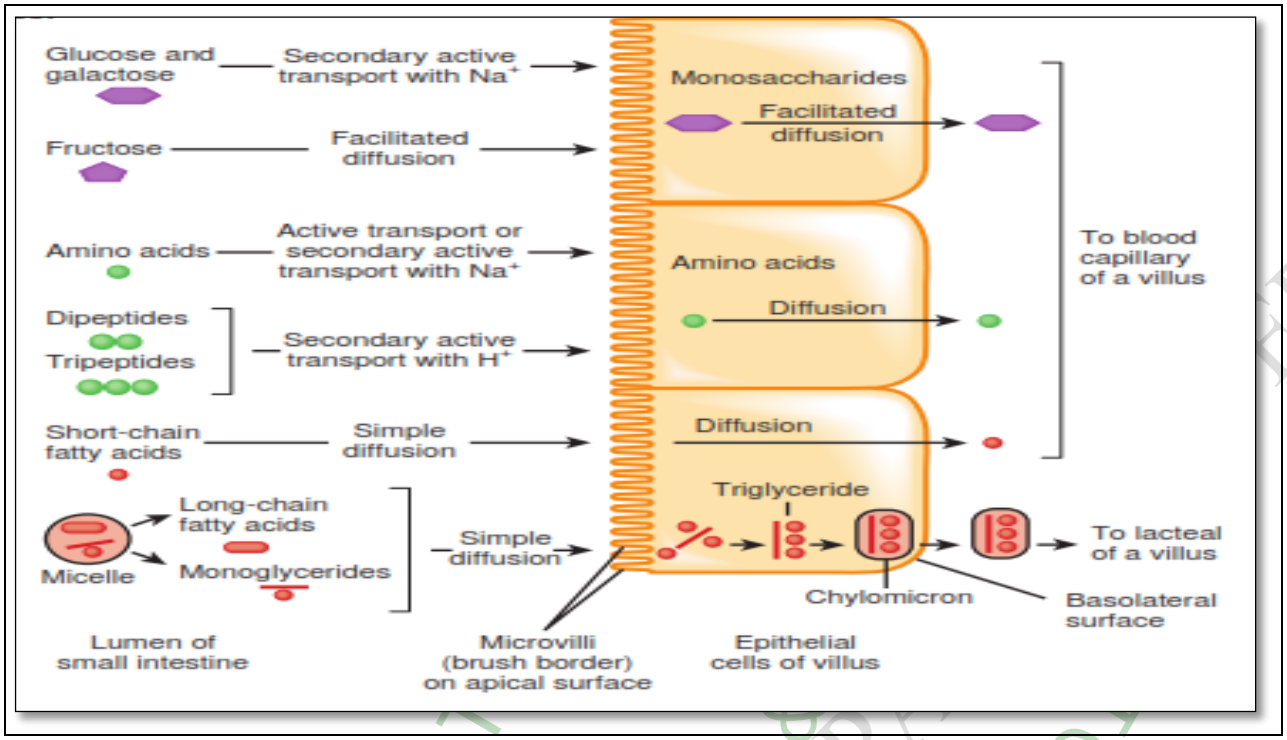


DIGESTION AND ABSORPTION OF VITAMINS

- Vitamins can be either water-soluble or lipid-soluble.
- Fat soluble vitamins are absorbed in the same manner as lipids.
- It is important to consume some amount of dietary lipid to aid the absorption of lipid-soluble vitamins.
- Water-soluble vitamins can be directly absorbed into the bloodstream from the intestine.

DIGESTION AND ABSORPTION OF NUCLEIC ACIDS

- Pancreatic juice contains two nucleases: ribonuclease, which digests RNA, and deoxyribonuclease, which digests DNA.
- The nucleotides that result from the action of the two nucleases are further digested by brush-border enzymes called nucleosidases and phosphatases into pentoses, phosphates, and nitrogenous bases.
- These products are absorbed via active transport.



PHASES OF DIGESTION

Digestive activities occur in three phases:

1. The Cephalic Phase
2. The Gastric Phase
3. The Intestinal Phase

CEPHALIC PHASE

- During the cephalic phase of digestion, the smell, sight, thought, or initial taste of food activates neural centers in the cerebral cortex, hypothalamus, and brain stem.
- The brain stem then activates the facial (VII), glossopharyngeal (IX), and vagus (X) nerves.
- The facial and glossopharyngeal nerves stimulate the salivary glands to secrete saliva.
- The vagus nerves stimulate the gastric glands to secrete gastric juice.
- The purpose of the cephalic phase of digestion is to prepare the mouth and stomach for food that is about to be eaten.

GASTRIC PHASE

- Once food reaches the stomach, the gastric phase of digestion begins. Neural and hormonal mechanisms regulate the gastric phase of digestion to promote gastric secretion and gastric motility.

Neural mechanisms

- Food in the stomach stimulates stretch receptors in its walls & Chemoreceptors in the stomach monitor the pH of the stomach chyme.

↓

Expanded of wall of stomach or pH increases activates,
the stretch receptors and chemoreceptors

↓

Both receptors send nerve impulses to the submucosal plexus,
where they activate parasympathetic and enteric neurons.

↓

Result is increase peristalsis and continue to stimulate
the flow of gastric juice from gastric glands.

↓

The peristaltic waves mix the food with gastric juice
when the waves become strong enough, a small quantity of chyme undergoes gastric emptying into the duodenum.

Hormonal mechanisms

- Gastric secretion is stimulated chiefly by three chemicals:
    1. Acetylcholine (ACh)
       This is secreted by the parasympathetic nerve fibers of both the short and long reflex pathways.
    2. Histamine
       This is a paracrine secretion from the enteroendocrine cells in the gastric glands.
    3. Gastrin
       This is a hormone produced by enteroendocrine G cells in the pyloric glands.
- All three of these stimulate parietal cells to secrete hydrochloric acid and intrinsic factor.
- The chief cells secrete pepsinogen in response to gastrin and especially ACh, and ACh also stimulates mucus secretion.

INTESTINAL PHASE

- The intestinal phase of digestion begins once food enters the small intestine.
- The intestinal phase have inhibitory effects that decrease gastric activity & slow the exit of chyme from the stomach. This prevents the duodenum from being overloaded with more chyme than it can handle.
- These activities of the intestinal phase of digestion are regulated by neural and hormonal mechanisms.

Neural mechanisms

✓ Distension of the duodenum by the presence of chyme causes the enterogastric reflex.

Stretch receptors in the duodenal wall send nerve impulses to the medulla oblongata,

↓

where they inhibit parasympathetic stimulation and

stimulate the sympathetic nerves to the stomach.

↓

As a result,

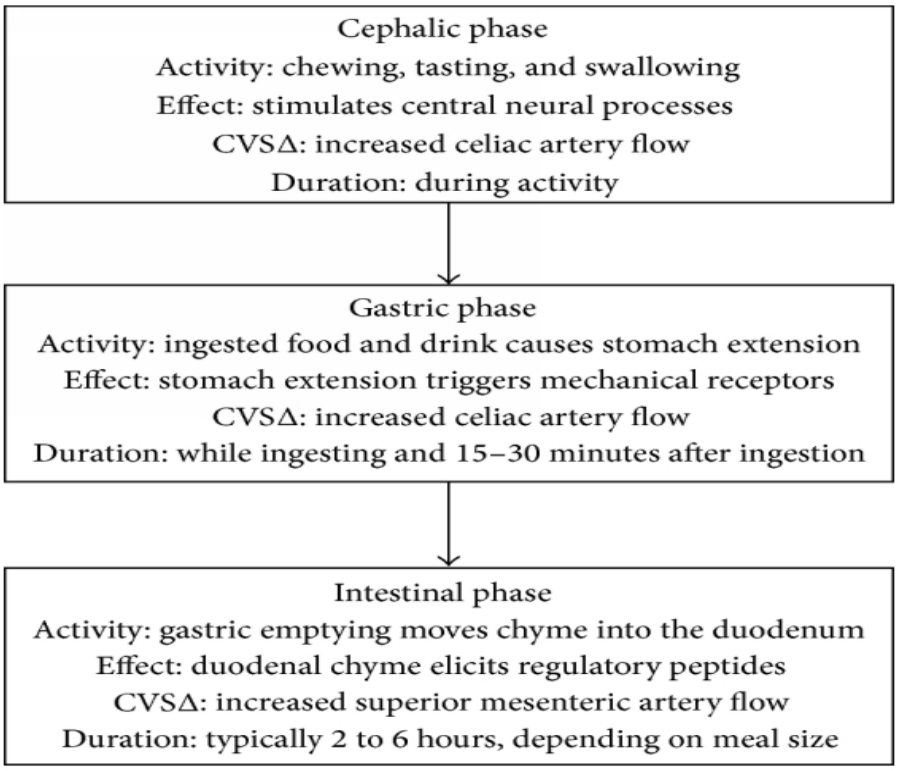
gastric motility is inhibited and

there is an increase in the contraction of the pyloric sphincter

which decreases gastric emptying.

Hormonal regulation

- The intestinal phase of digestion is mediated by two major hormones secreted by the small intestine:
  - cholecystokinin & secretin
- **Cholecystokinin** (CCK) is secreted by the CCK cells of the small intestinal secretary cells in response to chyme.
- CCK stimulates secretion of pancreatic juice that is rich in digestive enzymes.
- It also causes contraction of the wall of the gallbladder, which squeezes stored bile out of the gallbladder into the cystic duct and through the common bile duct by relaxation of the sphincter of the hepatopancreatic ampulla
- CCK also slows gastric emptying by contraction of the pyloric sphincter
- **Secretin**-Acidic chyme entering the duodenum stimulates the release of secretin from the S cells of the small intestinal cells.
- In turn, secretin stimulates the flow of pancreatic juice that is rich in bicarbonate (HCO) ions to buffer the acidic chyme that enters the duodenum from the small intestine.
- Besides this major effect, secretin inhibits secretion of gastric juice, promotes normal growth and maintenance of the pancreas, and enhances the effects of CCK.



DISEASES/DISORDERS

1. Peritonitis

- A common cause of **peritonitis,** an acute inflammation of the peritoneum, is contamination of the peritoneum by infectious microbes, which can result from accidental or surgical wounds in the abdominal wall, or from perforation or rupture of abdominal organs.

2. Mumps

- The salivary glands may be the target of a nasopharyngeal infection, the mumps virus *(paramyxovirus)* typically attacks the parotid glands.
- **Mumps** is an inflammation and enlargement of the parotid glands accompanied by moderate fever, malaise (general discomfort), and extreme pain in the throat, especially when swallowing sour foods or acidic juices.

3. Gastroesophageal reflux disease

- If the lower esophageal sphincter fails to close adequately after food has entered the stomach, the stomach contents can reflux into the inferior portion of the esophagus. This condition is known as **Gastroesophageal reflux disease (gerd).**
- Hydrochloric acid (hcl) from the stomach contents can irritate the esophageal wall, resulting in a Burning sensation that is called **heartburn** because it is experienced in a region very near the heart

4. Pyloric stenosis

- It is a narrowing of the pyloric sphincter that must be corrected surgically. The hallmark symptom is vomiting the spraying of liquid vomitus some distance from the infant.

5. Jaundice

- **Jaundice**is a yellowish coloration of the sclera, skin, and mucous membranes due to a buildup of a yellow compound called bilirubin.
- After bilirubin is formed from the breakdown of the heme pigment in aged red blood cells, it is transported to the liver, where it is processed and eventually excreted into bile.
- The three main categories of jaundice are (1) *prehepatic jaundice,* due to excess production of bilirubin; (2) *hepatic jaundice,* due to congenital liver disease, cirrhosis of the liver, or hepatitis; and (3) *extrahepatic jaundice,* due to blockage of bile drainage by gallstones or cancer of the bowel or the pancreas.

6. Liver cirrhosis

- Cirrhosis of liver refers to inflammation and damage of parenchyma of liver.
- It results in degeneration of hepatic cells and dysfunction of liver.

7. Gallstones

- If bile contains either insufficient bile salts or lecithin or excessive cholesterol, the cholesterol may crystallize to form **gallstones.**
- As they grow in size and number, gallstones may cause obstruction to the flow of bile from the gallbladder into the duodenum.

8. Pancreatitis

- Inflammation of the pancreas, as may occur in association with alcohol abuse or chronic gallstones, is called **pancreatitis.**

9. **Diarrhea**:

- Symptoms of diarrhea include frequent, loose, watery stools (feces) which are usually accompanied by an urgent need to go to the toilet.
- Abdominal pain or cramping may also occur, and sometimes nausea or vomiting.
- Viruses or bacterial infection also leads diarrhea.

10. **Vomiting**:

- Vomiting is the contents of the stomach are forcefully expelled through the mouth, usually involuntarily.
- Nausea is the term used to describe feeling sick or like you are just about to vomit.
- Infection from bacteria, viruses or ther micro-organisms causes of vomiting.

11. **Crohn's Disease**:

- Crohn's disease is a chronic bowel disease that causes patches of inflammation in the GI tract anywhere between the mouth and the anus, although the area where the small intestine joins the large intestine is most commonly affected.
- Symptoms may include diarrhea that persists for several weeks, abdominal pain and weight loss.

12. **Ulcerative colitis**:

- Ulcerative colitis affects only the innermost lining of the colon. Although the colon is the only part of the bowel affected, the whole of the colon is inflamed. Symptoms are similar to Crohn's disease and include diarrhea, rectal bleeding or bloody stools, abdominal pain, tiredness, and loss of appetite.

13. **Malabsorption syndromes**:

- Malabsorption syndromes refers to a number of different conditions in which the small intestine is unable to absorb nutrients, such as proteins, carbohydrates, fats, vitamins or minerals.

14. **Peptic Ulcer Disease (PUD):**

- Peptic ulcer disease is an used to describe both gastric and duodenal ulcers, which are small holes that can occur in the lining of your stomach (gastric ulcer) or upper part of your small intestine (duodenal ulcers).
- The most common cause is an infection with a bacteria called *Helicobacter pylori.*
- Overuse of anti-inflammatory drugs such as aspirin, ibuprofen, or diclofenac, excessive acid production in the stomach, and smoking are also common causes.
- Symptoms typically include abdominal pain and heartburn.

15. Hemorrhoids

- Hemorrhoids are swollen blood vessels that line the anal opening.
- They are caused by chronic excess pressure from straining during a bowel movement, persistent diarrhea, or pregnancy.

16. Anal fissures

- Anal fissures are splits or cracks in the lining of the anal opening.
- The most common cause of an anal fissure is the passage of very hard or watery stools.
- An anal fissure is one of the most painful problems because the exposed muscles become irritated from exposure to stool or air, and leads to intense burning pain, bleeding, or spasm after bowel movements.

17. Appendicitis

- Appendicitis is an inflammation of the appendix, a finger-shaped pouch that projects from your colon on the lower right side of your abdomen.

- **Appendicitis** causes pain in your lower right abdomen.

18. Hernia

- A hernia is the abnormal exit of tissue or an organ, such as the bowel, through the wall of the cavity in which it normally resides.
- Hernias come in a number of types. Most commonly they involve the abdomen, specifically the groin.
- Groin hernias are most commonly of the inguinal type but may also be femoral.

ENERGETICS

ADENOSINE TRIPHOSPHATE (ATP)

- Adenosine triphosphate (ATP) is a unique and the most important high-energy molecule in the living cells.
- It consists of an adenine, a ribose and a triphosphate moiety.
- ATP is a high-energy compound due to the presence of two phosphoanhydride bonds in the triphosphate unit.
- The hydrolysis of ATP is a classical example of exergonic reaction

$$ATP + H_2O \longrightarrow ADP + Pi \ (G° = -7.3 \text{ Cal/mol})$$

FORMATION OF ATP

- ATP can be synthesized in two ways
  1. **Oxidative phosphorylation :**
     This is the major source of ATP in aerobic organisms. It is linked with the mitochondrial electron transport chain.
  2. **Substrate level phosphorylation :**
     ATP may be directly synthesized during substrate oxidation in the metabolism. In glycolysis & citric acid cycle transfer high-energy phosphate to use produce ATP.

ELECTRON TRANSPORT CHAIN

The electron transport chain (ETC) or respiratory chain carried out in mitochondria.

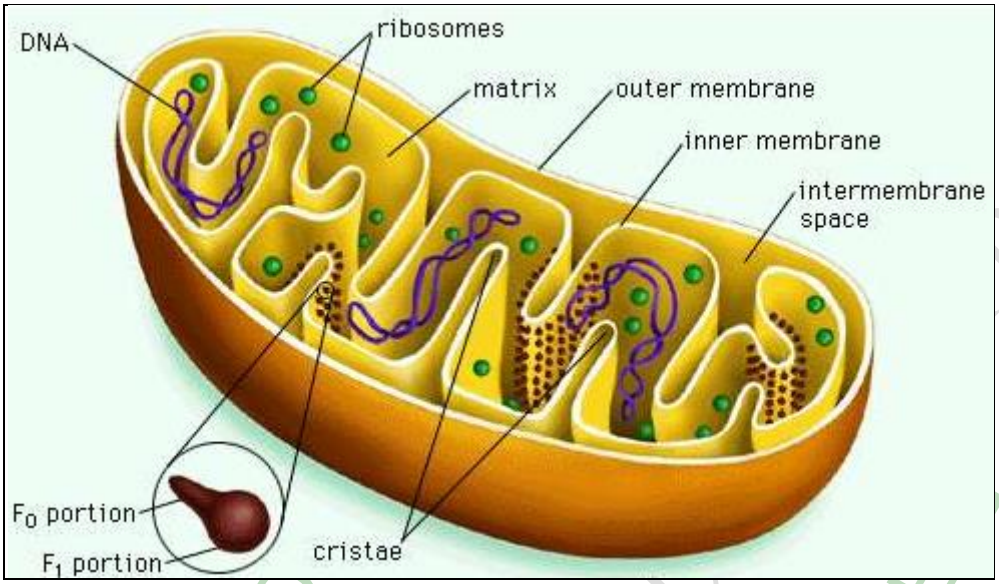
Mitochondria

- The power houses of cell
- The mitochondria are the centres for metabolic oxidative reactions to generate reduced coenzymes (NADH and FADH2) which, in turn, are utilized in ETC to liberate energy in the form of ATP.

- So the mitochondria is called a power house of the cell.

Mitochondrial organization

- The mitochondrion consists of five distinct parts. These are the outer membrane, the inner membrane, the intermembrane space, the cristae and the matrix



Inner mitochondrial membrane:

- The electron transport chain and ATP synthesizing system are located on the inner mitochondrial membran.
- It is impermeable to ions (H+, K+, Na+) and small molecules (ADP, ATP).
- This membrane is highly folded to form cristae.
- The surface area of inner mitochondrial membrane is greatly increased due to cristae.
- The inner surface of the inner mitochondrial membrane possesses specialized particles, the phosphorylating subunits which are the centres for ATP production.

Mitochondrial matrix:

- The interior ground substance forms the matrix of mitochondria.
- It is rich in the enzymes responsible for the citric acid cycle, E-oxidation of fatty acids and oxidation of amino acids.

Structural organization of ETC/respiratory chain:

- The inner mitochondrial membrane can be disrupted into five distinct respiratory or enzyme complexes, denoted as complex I, II, III, IV and V.
- The complexes I-IV are carriers of electrons while complex V is responsible for ATP synthesis.
- Besides these enzyme complexes, there are certain mobile electron carriers in the respiratory chain. These include NADH, coenzyme Q, cytochrome C and oxygen.

- The enzyme complexes (I-IV) and the mobile carriers are collectively involved in the transport of electrons.

COMPLEX I

- To start ETC, two electrons are carried to the first complex on chain NADH.
- Complex I is composed of flavin mononucleotide (FMN) and an enzyme containing iron-sulfur (Fe-S).
- FMN, which is prosthetic groups or co-factors in the ETC. A prosthetic group is a non-protein molecule required for the activity of a protein.
- The enzyme in complex I is NADH dehydrogenase, a very large protein containing 45 amino acid chains. Complex I can pump four hydrogen ions from the matrix into the intermembrane space'

UBIQUINONE (Q) AND COMPLEX II

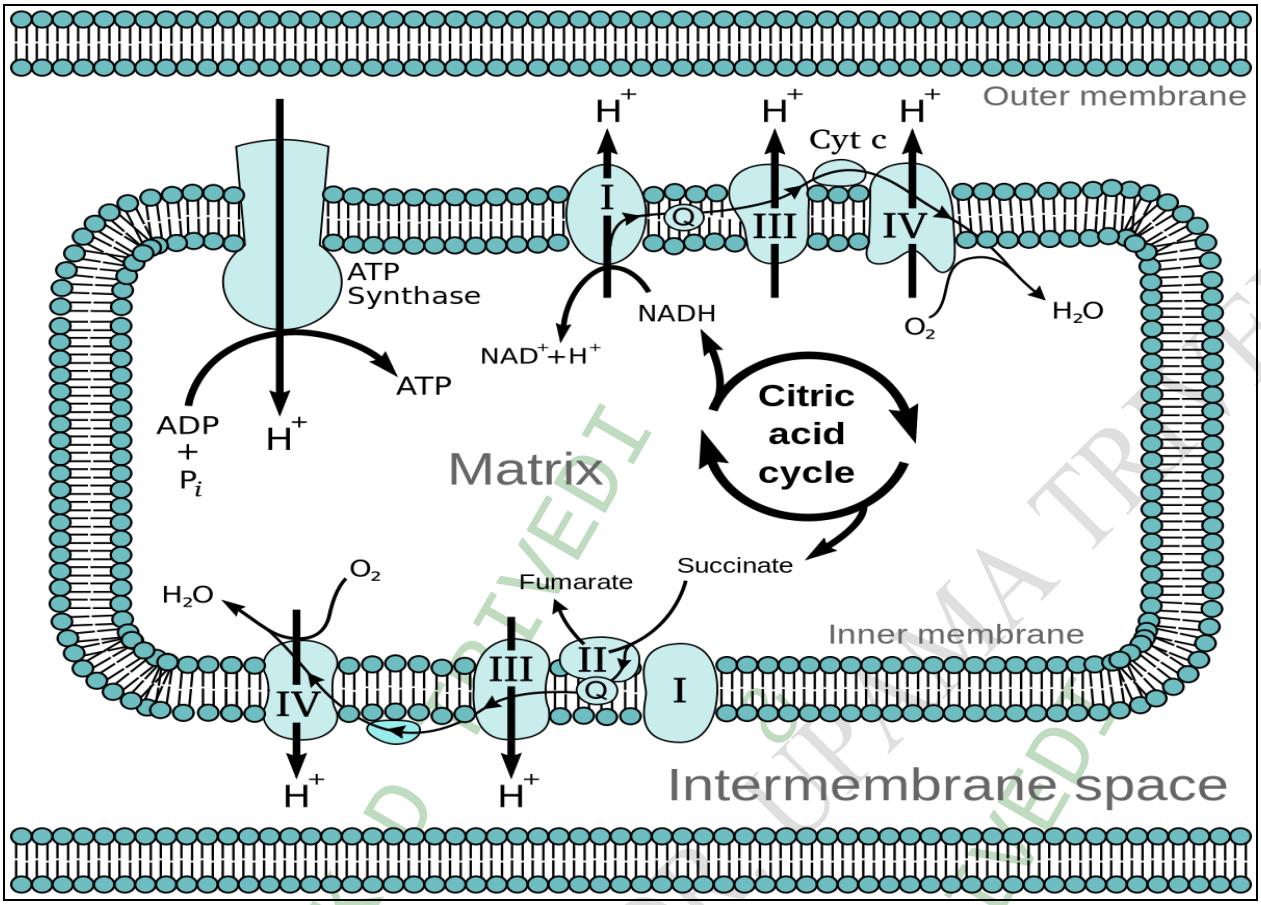
- Complex II directly receives $FADH_2$, which does not pass through complex I.
- The compound connecting the first and second complexes to the third is ubiquinone (Q).
- The Q molecule is reduced to QH_2, & delivers its electrons to the next complex in the ETC.
- Q receives the electrons from NADH from complex I and from the $FADH_2$ from complex II, including succinate dehydrogenase.

COMPLEX III

- The third complex is composed of cytochrome B, another Fe-S protein, rieske center (2Fe-2S center), and cytochrome C proteins; this complex is also called cytochrome oxidoreductase.
- Cytochrome proteins have a prosthetic heme group. The heme molecule carries electrons.
- Complex III pumps protons through the membrane and passes its electrons to cytochrome c for transport to the fourth complex of proteins and enzymes.

COMPLEX IV

- The fourth complex is composed of cytochrome proteins C, A, and A_3.
- This complex contains two heme groups (one in each of the cytochromes A and A_3) and three copper ions (a pair of Cu_a and one Cu_b in cytochrome A_3).
- The cytochromes hold an oxygen molecule very tightly between the iron and copper ions until the oxygen is completely reduced. The reduced oxygen then picks up two hydrogen ions from the surrounding medium to produce water (H_2O).
- The removal of the hydrogen ions from the system also contributes to the ion gradient used in the process of chemiosmosis.



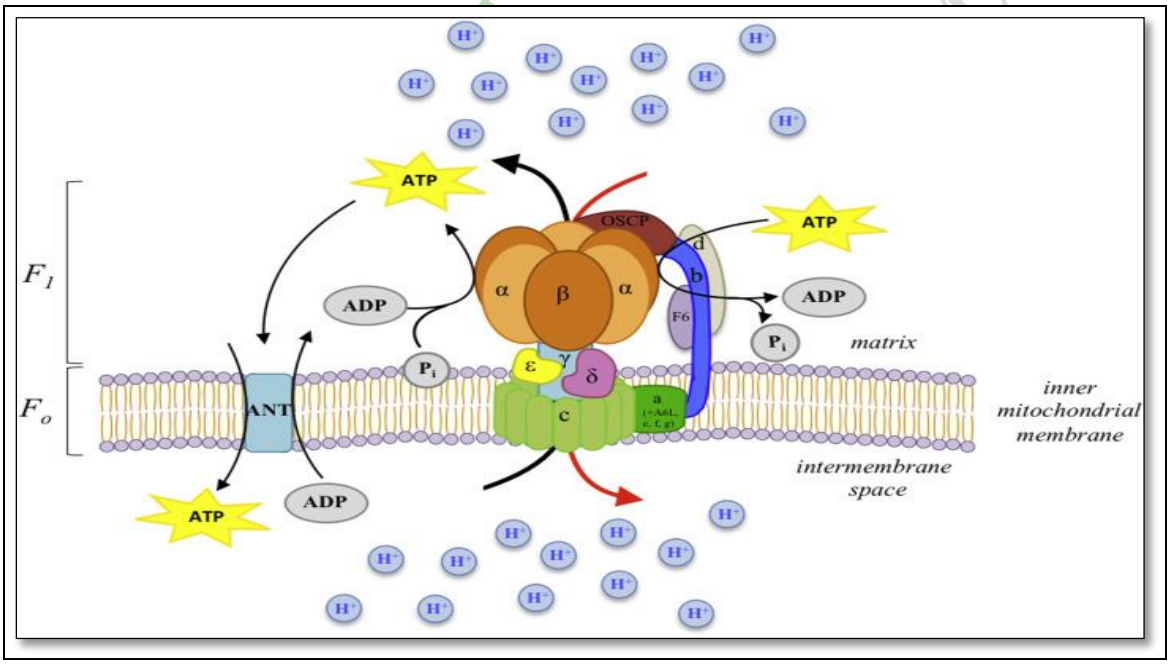
OXIDATIVE PHOSPHORYLATION

- The transport of electrons through the ETC is linked with the release of free energy.
- The process of synthesizing ATP from ADP and Pi coupled with the electron transport chain is known as oxidative phosphorylation.
- The complex V of the inner mitochondrial membrane is the site of oxidative phosphorylation.

Enzyme system for ATP synthesis :

- ATP synthase, present in the complex V, utilizes the proton gradient for the synthesis of ATP.
- ATP synthase is a complex enzyme and consists of two functional subunits, namely F1 and F0.
- Its structure is comparable with 'lollipops'.
- The F0 subcomplex is composed of channel protein 'C' subunits to which F1-ATPsynthase is attached
- F-ATPsynthase consists of a central γ subunit surrounded by alternating α and β subunits.
- In response to the proton flux, the subunit physically rotates.
- This induces conformational changes in the β subunits that finally lead to the release of ATP.

- According to the binding change mechanism, the three subunits of F-ATP synthase adopt different conformations.
- One subunit has 1st **open** (**O**) conformation, the second has **loose** (**L**) conformation while the third one has **tight** (**T**)**conformation**).
- The rotation of γ subunit, which in turn induces conformation changes in β subunits.
- The substrates ADP and Pi bind to β subunit in L-conformation.
- The L site changes to T conformation, and this leads to the synthesis of ATP.
- The O site changes to L conformation which binds to ADP and Pi.
- The T site changes to O conformation, and releases ATP. This cycle of conformation changes of subunits is repeated.
- And three ATP are generated for each revolution.



THE ROLE OF ATP

- Adenosine triphosphate (ATP) is a small molecule that acts as a coenzyme within a cell.
- The main role of ATP is to provide energy. Below are the ways it provides energy which

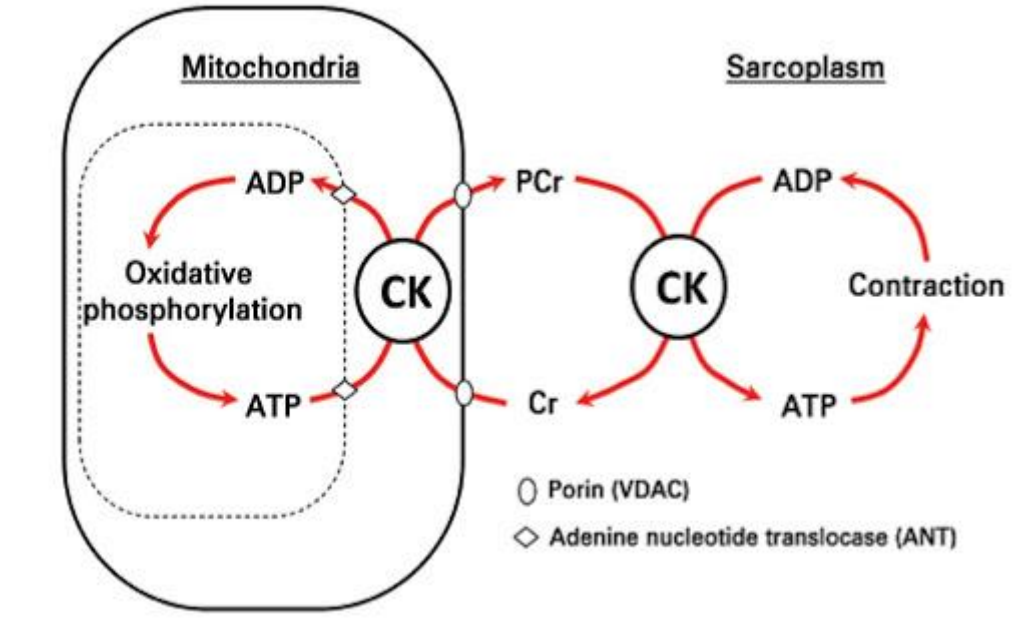
1. A source of energy.
    - An ATP molecule releases approximately 30kj (mol^-1) of energy
    - Energy from an ATP molecule is released in small quantities to prevent damage to the cell
    - Energy released is used for metabolism in the cell.
2. Muscle contraction
    - ATP is critical for the contraction of muscles; it binds to myosin to provide energy and facilitate its binding to actin to form a cross-bridge.

- ADP and phosphate are then released and a new ATP molecule binds to myosin.

3. Structural Maintenance
    - ATP plays a very important role in preserving the structure of the cell by helping the assembly of the cytoskeletal elements.
4. Cell Signaling
    - ATP has key functions both in intracellular and extracellular signaling.
5. Active Transport
    - ATP plays a critical role in the transport of macromolecules such as proteins and lipids into and out of the cell.
6. Synthesis of DNA and RNA
    - During DNA synthesis, ribonucleotide reductase (RNR) reduces the sugar residue from ribonucleoside diphosphates to form deoxyribonucleoside diphosphates such as dADP.

CREATININE PHOSPHATE

- The muscles of the body function through the use of ATP, or adenosine triphosphate, to power contractions.
- When one molecule of ATP is used in the contraction process, it is hydrolyzed to ADP, adenosine diphosphate, and an inorganic phosphate.
- The muscles' limited ATP supply is used very quickly in muscle activity, so the need to regenerate ATP is essential.
- One of the ways that this ATP supply is regenerated is through the molecule creatine phosphate (or phosphocreatine).
- Formula: **Creatine~PO_3-**
- The high energy phosphate bond in phosphocreatine has more energy than the bond in ATP, 10,300calories per mole in comparison with ATP- 7300.
- In the process of regeneration of ATP, creatine phosphate transfers a high-energy phosphate to ADP.
- The products of this reaction are ATP and creatine.
- Creatine phosphate can be obtained from two sources: ingestion of meat and internal production by the liver and kidneys.
- Creatine and creatinine (fromed from the metabolism of creatine) waste is removed from the body through the kidneys and urinary system.



ADP: adenosine diphosphate; CK: creatinine kinase; PCr: phosphocreatine; ATP: adenosine triphosphate; Cr: free creatinine

BASAL METABOLIC RATE

- Basal metabolism or basal metabolic rate (BMR) is defined as the minimum amount of energy required by the body to maintain life at complete physical and mental rest in the postabsorptive state (i.e. 12 hours after the last meal).
- It may also called resting metabolic rate (RMR).

MEASUREMENT OF BMR

Preparation of the subject:

- For the measurement of BMR the subject should be awake, at complete physical and mental rest, in a post-absorptive state and in a comfortable surrounding (at 25°C).

Measurement :

- The BMR is determined either by the apparatus of Benedict and Roth (closed circuit device) or by the Douglas bag method (open circuit device).
- The Benedict-Roth method, the volume of O_2 consumed (recorded on a graph paper) by the subject for a period of 2-6 minutes under basal conditions is determined.
- Let this be A liters for 6 minutes. The standard calorific value for one liter O_2 consumed is 4.825 Cal.
    - Heat produced in 6 min = 4.825 × A
    - Heat produced in one hour = 4.825A × 10

Units of BMR :

- BMR is expressed as Calories per square meter of body surface area per hour i.e. Cal/sq.m/hr.
- For the calculation of body surface area, the simple formula devised by Du Bois is used.

$$A = H^{0.725} \times W^{71.84} \times 0.425$$

where A = Surface area in cm^2

H = Height in cm

W = Weight in kg.

- To convert the surface area into square meters(m^2), divide the above value (cm^2) by 10,000.

Normal values of BMR :

- For an adult man 35–38 Cal/sq. m/hr
- For an adult woman 32-35Cal/sq.m/hr.
- A BMR value between –15% and+20% is considered as normal.

Some authors continue to represent BMR as Cal/day.

- For an adult man BMR is around 1,600 Cal/day
- For an adult woman around 1,400 Cal/day.
- This is particularly important for easily calculating energy requirements per day.

FACTORS AFFECTING BMR

1. **Surface area :** The BMR is directly proportional to the surface area. Surface area is related to weight and height.
2. **Sex :** Men have marginally higher (about 5%) BMR than women. This is due to the higher proportion of lean muscle mass in men.
3. **Age :** In infants and growing children, with lean muscle mass, the BMR is higher. In adults, BMR decreases at the rate of about 2% per decade of life.
4. **Physical activity:** BMR is increased in persons (notably athletes) with regular exercise. This is mostly due to increase in body surface area.
5. **Hormones :** Thyroid hormones (T) have a stimulatory effect on the metabolism of the body and, therefore, BMR. Thus, BMR is raised in hyperthyroidism and reduced in hypothyroidism. In fact, the measurement of BMR was earlier used to assess thyroid function.

QUESTIONS

1. Draw a neat diagram of GI tract. Explain how fats are digested and absorbed.
2. Explain how digestion of carbohydrates, proteins and fats takes place.
3. List out the various enzymes present in the secretions of GIT.
4. Discuss the digestion of carbohydrates
5. Describe the gross anatomy of stomach. Explain its physiological functions.
6. Explain various phases of acid secretion in stomach.
7. Explain how digestion takes place in stomach.
8. Write composition and functions of gastric juice.
9. Draw a neat labeled diagram of stomach Mention the functions of stomach.
10. Write the anatomy of pancreas. Mention the functions of pancreatic enzymes.
11. Discuss the endocrine and exocrine secretions of pancreas.
12. Describe the anatomy, histology and functions of small intestine.
13. Discuss the food absorption in small intestine.
14. Explain peristaltic movement of small intestine.
15. Describe the anatomy of liver and mention its functions.
16. What is liver cirrhosis?
17. Name salivary glands and discuss the composition and functions of saliva..
18. Write the composition of bile. Give functions of bile.
19. Note on BMR and give use of creatinine phosphate.
20. Explain formation and role of ATP.

Define following terms:-

a. Peptic Ulcer Disease
b. Inflammatory Bowel Disease
c. Hernia
d. Diarrhea
e. Liver Cirrhosis
f. Hepatitis
g. Gastroenteritis
h. Heart Burn