

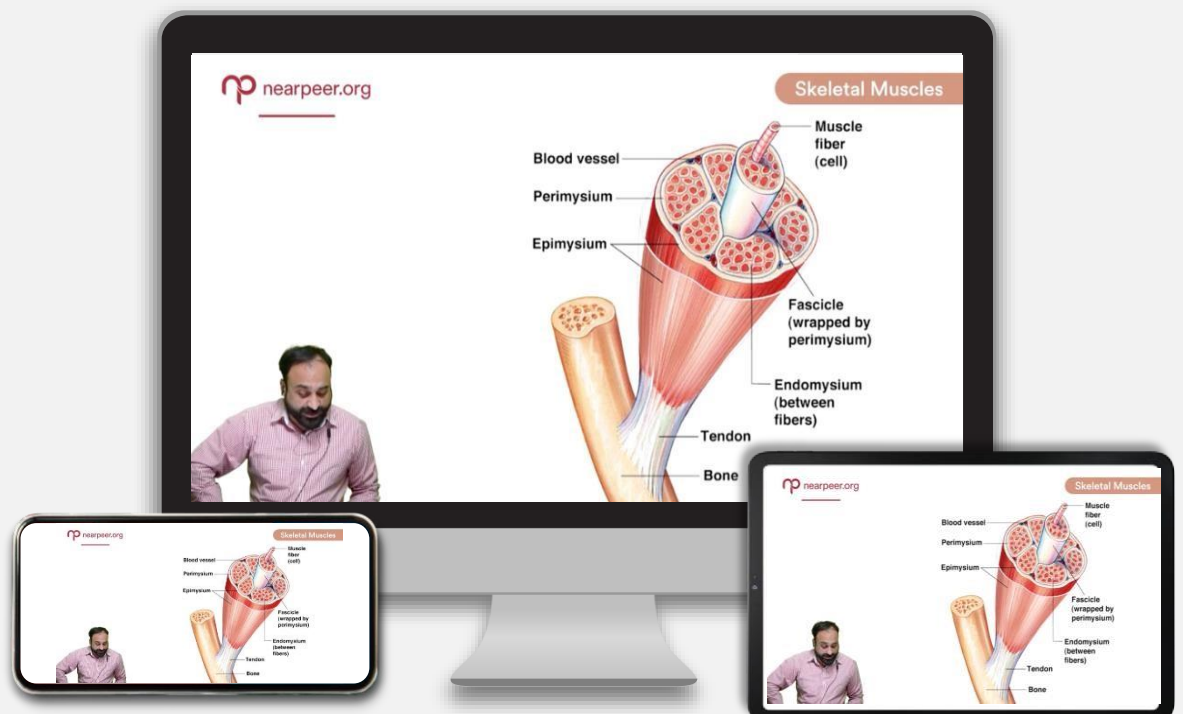
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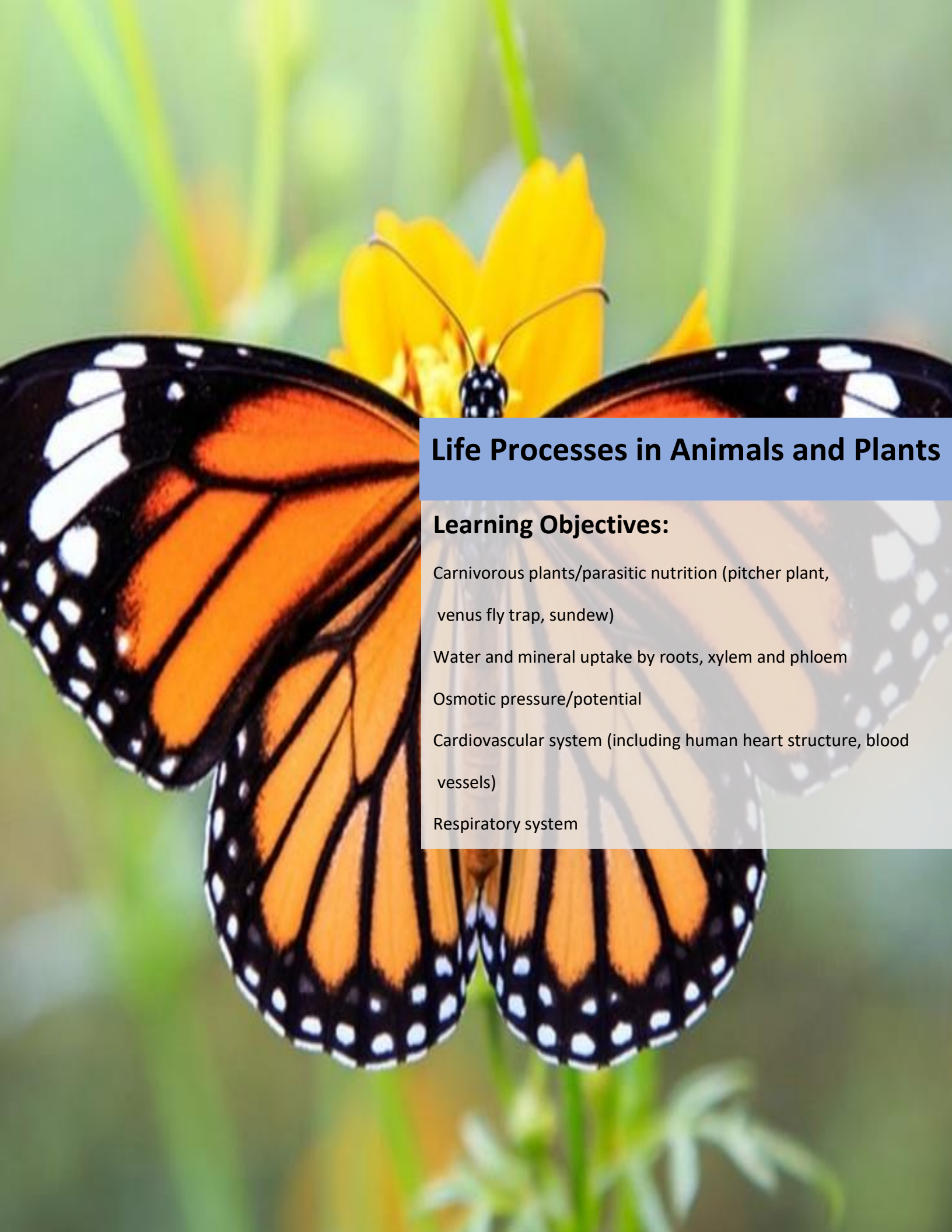
Biology

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Life Processes in Animals and Plants

Learning Objectives:

Carnivorous plants/parasitic nutrition (pitcher plant, venus fly trap, sundew)

Water and mineral uptake by roots, xylem and phloem

Osmotic pressure/potential

Cardiovascular system (including human heart structure, blood vessels)

Respiratory system

Human Digestive System:

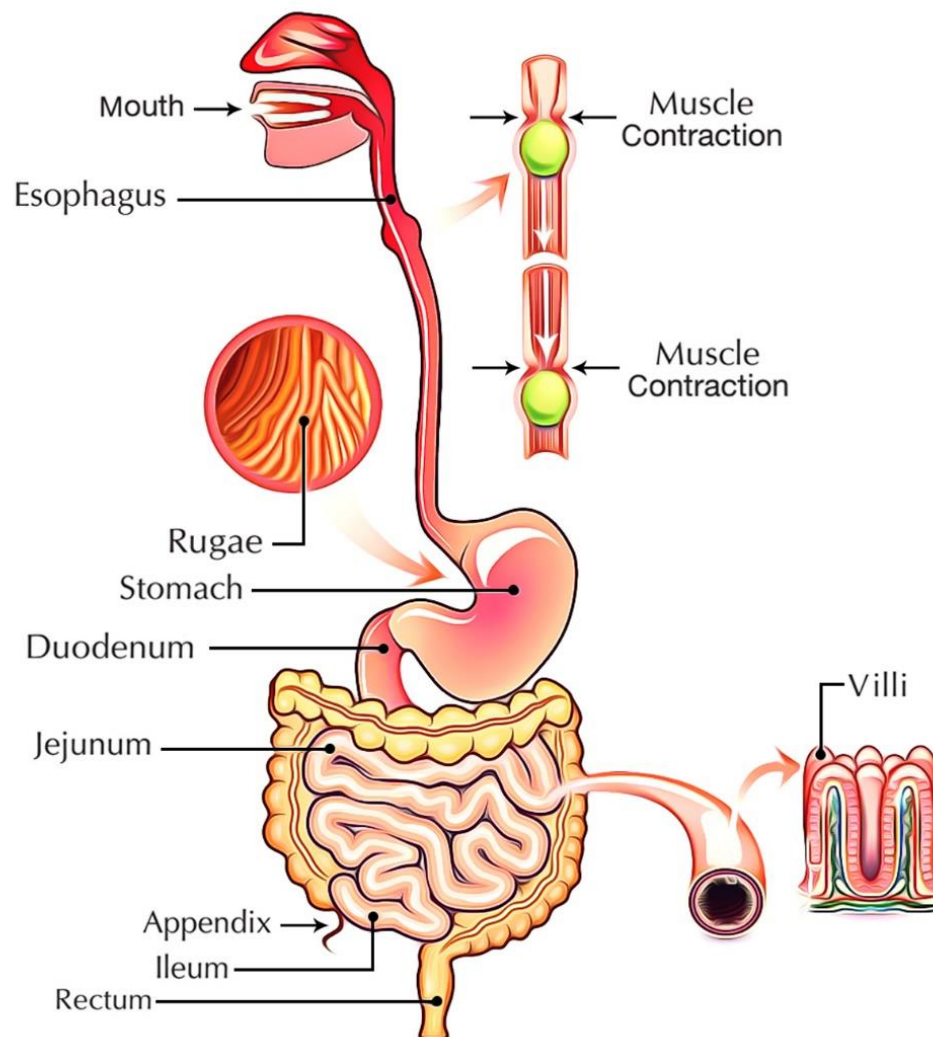


Fig. The digestive system of man

The digestive system of man consists of a long coiled tube that extends from the mouth to the main parts of the digestive system are the oral or buccal cavity, esophagus, stomach, small intestine (duodenum, jejunum and ileum), large intestine (ascending colon, transverse colon, descending colon, caecum and rectum). Associated glands are salivary glands, liver and pancreas. There are three sites of digestion in the digestive system of man oral cavity, stomach and small intestine.

Basic Features of the Gut Wall:

The gut is not the same all the way along the alimentary canal. Each region has specific features, which can be related to the function of different parts of the gut.

The gut wall is divided into three main layers:

- An outer muscle layer, protected by a thin coating of fibers.
- A middle layer, the sub-mucosa.
- An inner layer, the mucosa.

Oral cavity in digestion

Introduction:

The oral cavity is bounded by palate, tongue, teeth and cheeks. There are several functions of oral cavity. Three functions are most important which are:

1. Selection of food
2. Grinding or mastication
3. Lubrication and digestion

1. Selection of Food: When the food enters the oral cavity it is tasted, smelled and felt. If the taste or smell is unpleasant or if hard objects like bone or dirt are present in the food, it is rejected. The senses of smell, taste and sight help the oral cavity in the selection of food. The tongue which is sensory and muscular organ plays the most important role in selection of food through its taste buds.

2. Grinding or Mastication: After selection, the food is ground by means of molar teeth into smaller pieces. This is useful because:

The esophagus allows small pieces to pass through and small pieces have much more surface for the enzymes to attack.

3. Lubrication and Digestion:

These two are the main functions of the oral cavity which occurs by saliva.

Saliva is secreted by three pairs of salivary glands:

Sublingual glands present below the tongue, Sub maxillary glands behind the jaws and Parotid glands in front of the ears.

Salivary glands produce saliva at the rate of about 1 to 1.5 liters per day. It is produced constantly, but more is released when we see, smell, taste or even just think about food. Saliva is mainly water (99.5 percent) with some dissolved substances (0.5 percent) including:

Water:

- Mineral salts such as Sodium bicarbonate phosphates and hydrogen carbonates.

- Salivary amylase or Ptyalin, a starch-digesting enzyme that breaks molecules of starch into maltose.
 - Mucin, a slimy glycoprotein lubricant.
 - Lysozyme, an enzyme that kills bacteria.
- Salivary amylase, the starch-splitting enzyme in saliva, begins the process of chemical breakdown.
- (i) **Water and Mucous:** Water and Mucous together make a slimy liquid which moisten and lubricate the food. As a result, it can be chewed efficiently and passed through the esophagus smoothly.
- (ii) **Sodium Bicarbonate and Some Other Salts:**
Sodium bicarbonate and some other salts are slightly antiseptic but their main function is to stabilize the pH of the food. Fresh Saliva is alkaline with a pH nearly 8 it quickly loses carbon dioxide and the pH is now 6.
- (iii) **Ptyalin:** Ptyalin is a carbohydrate digesting enzyme. It digests starch and glycogen to maltose.

Bolus Formation:

As a result of mastication, the softened, partly digested, slimy food is rolled into all oval lumps called bolus. It is pushed to the back of the mouth by the action of tongue and muscles of pharynx which ensure that the food does not enter the windpipe.

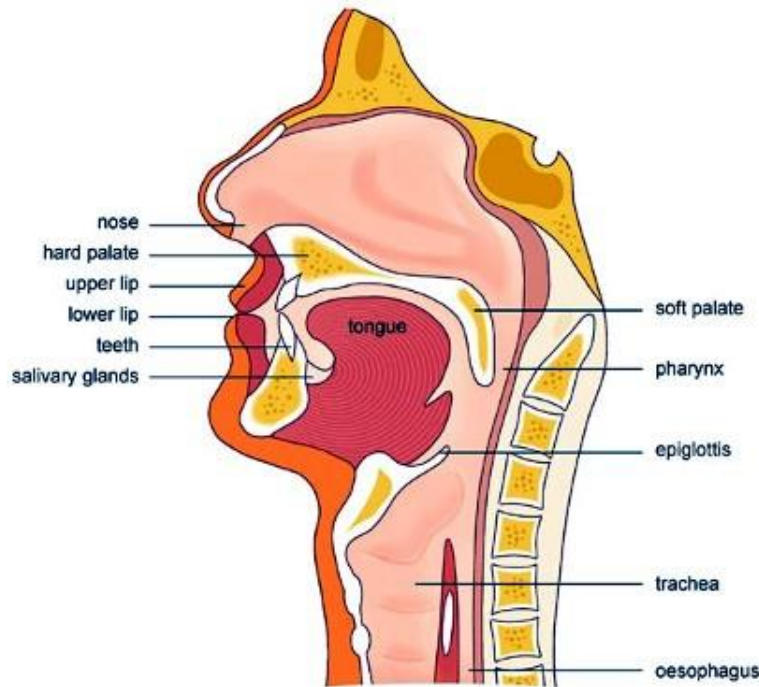
The mouth is lined by stratified epithelium (epithelial cells stacked on top of each other). This protects the deeper tissues of the mouth from friction damage and has a very high turnover.

We replace the lining of our mouth and the rest of the gut every 24 hours or so.

Swallowing:

Following steps are involved during swallowing:

- The tongue moves upwards and backwards against the roof of the mouth. As a result, the bolus is forced to the back of the mouth cavity.
- The backward movement of the tongue pushes the soft palate up and closes the internal nostrils.
- At the same time the tongue forces the epiglottis into horizontal position. As a result, the opening of the windpipe (the glottis) is closed. (Epiglottis is a flap of cartilage).
- The larynx moves upward under the back of the tongue.
- The glottis is partly closed by the contraction of a ring like muscle.
- The food does not enter the partly open glottis. This is because that the epiglottis diverts the
- food to one side of the opening and safely down the esophagus.



- viii. The beginning of the swallowing action is voluntary, but once the food reaches the back of the mouth, swallowing becomes automatic. The food is then forced down the esophagus by peristalsis.

Peristalsis

The intestine, along with many other tubular organs in the body (ureters, vas deferens and uterus) are made from smooth muscle whose main function is the slow rhythmic contraction known as peristalsis.

Introduction:

Peristaltic movements are characteristic movements of the digestive tract by which food is moved along the cavity of the canal.

Definition:

It is a wave of contraction and relaxation of the circular and longitudinal muscles, which squeezes the food down along the digestive canal.

Occurrence:

Peristalsis starts just behind the food from the buccal cavity along the esophagus to the stomach and then along the whole alimentary canal.

Anti-peristalsis:

The reversal of peristalsis is called anti-peristalsis. As a result of a peristalsis the food may pass from the intestine back into the stomach and even into the mouth leading to vomiting.

Hunger Pang:

Hunger contractions are peristaltic contractions which are increased by low blood glucose level and are sufficiently strong to create an uncomfortable sensation called a “hunger pang”. Hunger pangs usually begin 12 to 24 hours after the previous meal or in less time for some people.

Effect of Gravity on the Movement of Material:

Gravity helps the movement of material through the esophagus especially when liquid is swallowed. However, the peristaltic contractions that move material through the esophagus are sufficiently forceful. Therefore, a person can swallow even while doing a headstand.

Digestion in stomach:

Introduction:

Overall, the stomach:

- Mixes food with gastric juice by muscular action.
- Retains food, giving enzymes time to act.
- Digests proteins through the action of the enzyme pepsin.
- Curdles milk with the enzyme rennin.
- Absorbs some simple chemicals.

The stomach is located below the diaphragm on the left side of the abdominal cavity. It is an elastic muscular bag. The stomach stores food for some time, making discontinuous feeding possible. It also partly digests the food.

Cardiac Sphincter:

At the junction of esophagus and the stomach there is a special ring of muscles called cardiac sphincter. When the sphincter muscles contract, the entrance to the stomach closes, therefore, the contents of the stomach cannot move back into the esophagus. It opens when a wave of peristalsis coming down the esophagus reaches it.

Heart Burn or Pyrosis:

It is a painful burning sensation in the chest usually associated with the back flush of acidic chyme into the esophagus. This is due to:

- Overeating
- Eating fatty food
- Lying down immediately after a meal
- Consuming too much alcohol, caffeine or smoking

Stomach Wall:

The stomach wall is composed of three principal layers.

Outer Layer:

It is formed of connective tissue.

Middle Layer:

It is formed of smooth muscles. Outer layer is formed of longitudinal muscles while the inner layer is formed of circular muscles. All regions of the gut have two layers of muscle, apart from the stomach, which has three. The extra oblique layer runs at 45° to the other two, and helps churn the food.

The stomach has deep ridges called rugae that help with the mechanical breakdown of food.

Inner Layer (Mucosa):

It is composed of connective tissue. It has many tubular gastric glands. These glands are composed of three kinds of cells:

(i) Mucous Cells:

These cells secrete mucus which is a thick secretion. It covers inside of the stomach due to mucous the underlying wall are prevented from digestion.

(ii) Parietal or Oxyntic Cells:

These cells secrete hydrochloric acid (HCl). HCl is secreted in concentration form having pH 1.3; its functions are as follows:

It adjusts the pH of stomach contents from 2 – 3. At this pH the pepsin can act on proteins. It also softens the food and kills many microorganisms that enter the stomach along with the food, it converts pepsinogen to pepsin.

(iii) Zymogen Cells:

These cells secrete pepsinogen; Pepsinogen is inactive form of Pepsin. Pepsinogen is activated to pepsin by HCl or by already activated pepsin. Pepsin hydrolyzes protein to yield peptones and polypeptides. The secretion of all these cells is collectively called gastric juice.

Protein Digestion in the Stomach:

One of the main functions of the stomach is to begin the digest proteins. Pepsin a powerful endopeptidase enzyme digests proteins. The enzyme breaks peptide bonds in the middle of the protein chain, turning protein molecules into polypeptides. Protein digestion is completed when exopeptidase enzymes remove amino acids from the ends of the polypeptides.

The stomach avoids digesting its own tissue by secreting pepsin in an inactive form pepsinogen. This is converted to pepsin in the lumen of the stomach only after contact with hydrochloric acid. The hydrogen ions in the acid cause the pepsinogen to unfold and become pepsin the active form of the enzyme.

Milk Digestion:

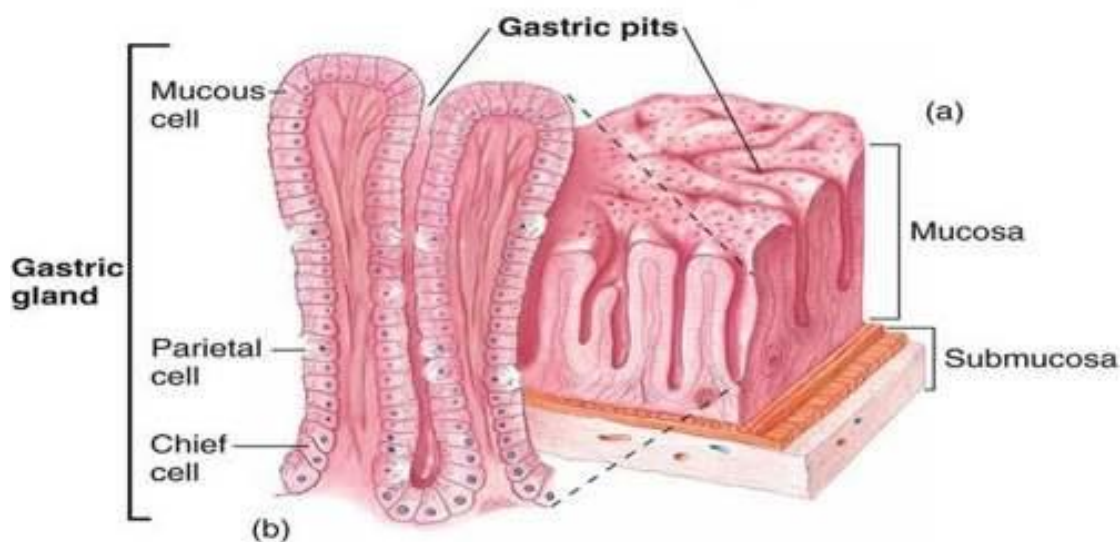
Caseinogen the proteins in milk are water soluble. They are available nutrients (milk is the sole source of food for young mammals) but if they remained in their soluble form they would leave the stomach before protein digestion had finished. To avoid this, the stomach produces rennins. This curdles milk converting soluble caseinogen into insoluble casein like pepsin remains is also secreted in an inactive form, Prorennin. Like pepsinogen prorennin is converted to its active form by contact with stomach acid.

Chyme formation:

The muscles of stomach wall thoroughly mix up the food with gastric juice and convert it to semi-solid mass called chyme. Gradually the stomach empties into the duodenum through the relaxed pyloric sphincter.

Control or Regulation of Gastric Juice Production:

The secretion of the gastric juice is regulated by smell, sight and quality of food. If more protein is present in the food it stimulates the production of gastrin hormone from the gastric endocrine gland. The gastrin is carried by blood to the gastric glands. The gastric glands are stimulated and produce more gastric juice. We can say that more proteins, more gastrin and more gastric juice for protein digestion.



Digestion in small intestine

Introduction:

Small intestine in man consists of duodenum, jejunum and ileum.

Duodenum:

Duodenum is about 20 – 25 cm long. It leads into jejunum and then ileum. When chyme passes from stomach into duodenum its acidity stimulates the release of secretions from pancreas, liver and duodenal cells.

Hepatic and pancreatic secretions are also stimulated by a hormone called secretin which is produced by the intestine mucosa on the entry of acidic food from stomach.

The acidity stimulates secretin production in duodenum and secretin is carried by blood to pancreas. The pancreas is stimulated to produce pancreatic juice; secretin also inhibits gastric secretion.

Pancreas:

Pancreas is a large gland whose exocrine tissue secretes a juice that flows through pancreatic duct into the duodenum. Pancreatic juice contains NaHCO_3 which partly neutralizes the chyme coming from the stomach. This is necessary because enzymes of the pancreas do not work well in the acidic medium. Pancreatic juice contains enzymes that digest carbohydrates, fats and proteins (principal components of food). These enzymes are as follows:

(i) **Amylase:**

It is the Carbohydrate digesting enzyme. It is also called amylase. It digests starch into maltose.

(ii) **Lipase:**

It is fat digesting enzyme. It hydrolyzes a small percentage of fats into fatty acids and glycerol.

(iii) **Trypsin:**

Trypsin breaks proteins into peptones and polypeptides. Like pepsin trypsin is also secreted as inactive trypsinogen. It is activated to trypsin by enterokinase, Enterokinase enzyme is secreted by the lining of the duodenum.

Liver:

The liver is reddish brown gastric gland present in the anterior part of the body cavity. The liver is the large structure of the body performing over 500 different chemical functions. It filters over a liter of blood each minute.

Liver secretes bile. It is temporarily stored in the gall bladder and released into the duodenum through the bile duct. The bile is green, watery fluid. It contains no enzymes but salts are present. Its green colour is due to the bile pigments which are formed from the breakdown of hemoglobin in the liver.

Liver cells produce around 0.8 to 1.0 liter of bile daily. Secretions from individual cells pass into tiny canals called bile canaliculi. These lead to the gall bladder, a small sac-like organ which stores the bile until it is needed. Bile is released into the duodenum when the muscle walls of the gall bladder contracts. Bile reaches the duodenum through the bile duct. Bile:

- Emulsifies fats (breaks large fat or oil droplets into an emulsion of microscopic droplets). This process massively increases the surface area available for fat digesting enzymes;
- Neutralizes the (acidic) chyme from the stomach and creates the ideal pH for intestinal enzymes;
- Stimulates peristalsis in the duodenum and ileum;
- Allows the excretion of cholesterol, fats and bile pigments.

The hormone secretin acts with nervous stimulation by the vagus nerve to increase the rate of bile secretion. The acidity of chyme in the duodenum and the hormone CCK-PZ stimulate the gall bladder to contract.

Malfunctioning of the Liver:

(i) Jaundice:

If bile pigments are prevented from leaving digestive tract, they may accumulate in blood. The result is a condition called as jaundice.

(ii) Gall Stones:

Cholesterol, secreted by the liver, may precipitate in the gall bladder. As a result, gallstones are produced this may block the release of bile.

Liver Damage:

The liver is easily ruptured because it is large, fixed in position and fragile. It may lacerate by a broken rib. Liver rupture or laceration may result in severe internal bleeding.

Liver Enlargement:

The liver may become enlarged as a result of heart malfunctioning or hepatic cancer. Similarly, liver may be damaged due to hepatitis or being alcoholic. Urea formation in the liver, liver converts toxic substance ammonia to less toxic compound urea. Urea is then excreted by kidneys. Ammonia is a waste product of amino acid metabolism.

Jejunum and Ileum:

Jejunum is the second part of the small intestine extending from the duodenum to the ileum. It is about 2.4 meter in length comprising about $\frac{2}{5}$ (two fifth) of the small intestine. The lower $\frac{3}{5}$ (three fifth) of the small intestine from jejunum is the ileum. The food which is not digested in the duodenum is completely digested in the jejunum and ileum.

Jejunum and ileum produces following enzymes. These enzymes are present in the intestinal juice.

ENZYMES	SUBSTRATE	PRODUCTS
Amino peptidase	Polypeptides	Di-peptides
Erypsin	Dipeptides	Amino acids
Lipase	Fats	Fatty acids and glycerol
Maltase	Maltose	Glucose
Lactase	Lactose	Glucose and galactose

Absorption of Food:

Nearly all absorption of the products of digestion takes place in the ileum. This is because that the internal surface of ileum has many finger-like outgrowths called villi.

Internal Surface of the Ileum:

The internal surface of the ileum has many folds. These folds show velvety appearance due to the presence of many fingerlike outgrowths called villi.

Structure of a Villus:

A villus is a fingerlike outgrowth.

It is richly supplied with blood capillaries.

It has also a vessel called lacteal of lymphatic system.

Each villus has a covering of epithelial cells.

Ultra Structure of a Villus:

Electron microscope reveal that these cells have countless, closely packed cylindrical processes called microvilli.

Total Area of Absorption:

The total area of absorption is very large due to enfolding, villi and microvilli. An average 70 kg man has approximately 100 square meters of absorbing surface in his small intestine.

Absorption of Digested Food:

Some digested contents are absorbed into the blood while the others into the lacteals.

Absorption into the Blood:

Simple sugars and amino acids are absorbed by diffusion or active transport into the blood capillaries through the microvilli. Some of the fatty acids and glycerol are also absorbed into blood.

Absorption into the Lacteals:

A large proportion of fatty acids and glycerol enter the epithelial cells of villi. Here they recombine into fats. These fats then enter the lacteals.

Formation and Use of Lipoproteins:

Proteins present in lymph vessels combine with fat molecules to form lipoprotein droplets. These pass into blood stream via thoracic lymphatic duct.

The lipoproteins are then hydrolyzed by blood plasma enzyme and enter body cells. Here they may be used in respiration or stored as fat in the liver or in the muscle present under the skin.

Intestinal Gas:

Many humans develop intestinal gas and diarrhea from consuming milk product because they lack the enzyme (lactase) for digesting lactose in milk.

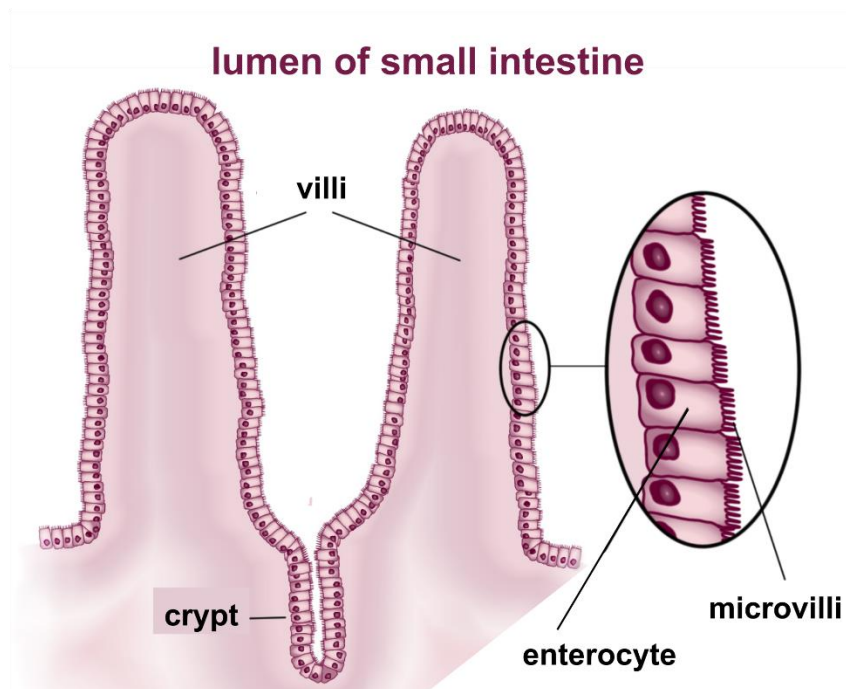
Formation of New Epithelial Cells of Villi:

The epithelial cells of villi constantly shed into the intestine. These cells are replaced by New cells moving p due to rapid cell division in crypts (underlying cells).

The intestinal contents are pushed along the alimentary canal by normal peristaltic activity.

Ileocolic Sphincter:

At the end of ileum, there is an ileocolic sphincter. It opens and closes time to time to allow a small amount of residue from the ileum to enter the large intestine.



**Fig. Part of wall of small intestine showing glands and villi
(b) Detail of villus structure.**

Large intestine

Introduction:

At the end of ileum there is an ileocolic sphincter. It opens and close time to time to allow a small amount of residue from the ileum to enter the large intestine.

The large intestine is compound of a caecum, colon and rectum.

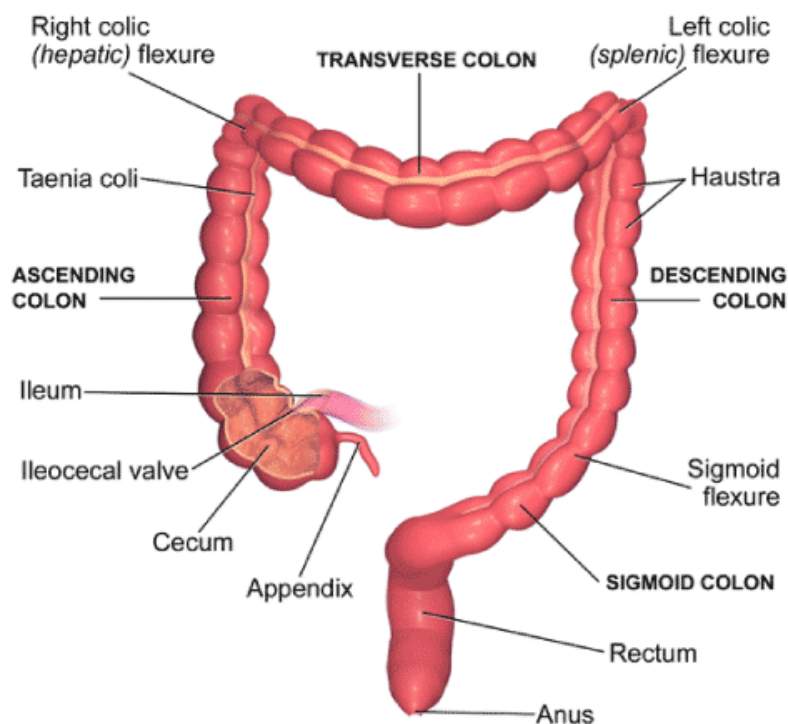
(i) Caecum:

It is a blind sac that projects from the large intestine between ileum and colon.

Appendix: from the blind end of the caecum there arises a finger like process called appendix. Sometimes the appendix is inflamed due to entrapping and then purification (decomposition of fluid causing appendicitis in severe cases it is removed surgically).

(ii) Colon:

It has three parts which are ascending transverse and descending colon



Functions of colon

Following are the functions of colon:

1. Absorption of Water and Salts:

The material that passes from the small intestine to the large intestine contains a large amount of water, dissolved salts and undigested material. Water and salts are absorbed into blood, while undigested material is rejected as feces. If the absorption of water and salts does take place due to infection, drug action, physical irritation or emotional disturbance, a condition known as diarrhea occurs. If this condition is not controlled then dehydration develops that may prove to be fatal.

Another extreme condition is constipation which is caused by the excessive absorption of water by the colon.

2. Role of Bacteria:

Large intestine also has many useful bacteria that synthesize some vitamins especially vitamin K. which are absorbed in blood.

3. Rectum:

Rectum is the last part of large intestine. Here feces are temporarily stored and rejected through anus at intervals.

4. Anus:

Anus is surrounded by two sphincters. The internal is of smooth and external of striped muscles.

5. Defecation Reflex:

Under normal conditions, when the rectum is filled up with feces, it gives rise to defecation reflex. This reflex can be consciously inhibited in individuals but not in infants. Gradually the child learns to bring this reflex under control.

6. **Feces:**

The feces contain a large number of bacteria, plant fibers, sloughed off mucosal cells, mucous, cholesterol, bile pigments and water.

ORGAN	FUNCTION	SECRETION
Oral cavity		
Teeth	Mastication (cutting and grinding of food); communication.	None
Lips and Cheeks	Manipulation of food; hold food in position between the teeth; communication.	Saliva from buccal glands (mucus only)
Tongue	Manipulation of food; holds food in position between the teeth; cleansing teeth; taste.	Some mucus; small amount of serous fluid
Salivary Glands		
Parotid gland	Secretion of saliva through ducts to superior and posterior portions of oral cavity	Saliva with amylase.
Submandibular glands	Secretion of saliva in floor of oral cavity	Saliva, with amylase: mucus.
Sublingual glands	Secretion of saliva in floor of oral cavity	Saliva mucus only
Pharynx	Swallowing Movement of food by peristalsis from pharynx to stomach.	Some mucus

Esophagus	Mechanical mixing of food; enzymatic digestion; storage; absorption.	Mucus
Stomach	Protection of stomach wall by mucus production.	
Mucous cells	Decrease in stomach pH	Mucus
Parietal cells	Protein digestion	
Zymogen cells	Regulation of secretion and motility	Hydrochloric acid
Endocrine cells		Pepsinogen
		Gastrin
Accessory Glands		
Liver	Secretion of bile into duodenum	Bile
Gall Bladder	Bile storage; absorbs water and electrolytes to concentrate bile.	No secretion of its own, stores and concentration bile.
Pancreas	Secretion of several digestive enzymes and bicarbonate ions into duodenum.	Trypsin, chymotrypsin, pancreas, amylase, pancreatic lipase, bicarbonate ions
Small Intestine		
Duodenal glands	Protection	Mucus
Goblet cells	Protection	Mucus
Absorptive cells	Secretion of digestive enzymes and absorption of digested materials.	Enterokinase, amylase, peptidases, sucrose, maltase, lactase, lipase gastrin, secretin
Endocrine cells	Regulation of secretion and motility.	
Large Intestine		
Goblet cells	Absorption, storage and food movement.	Mucus
	Protection	



Gaseous Exchange

Respiration occurs at two levels:

1. Organismic Level
2. Cellular Level

1. Organismic Respiration:

It is also known as breathing or ventilation. Breathing is the process in which fresh air containing more oxygen is pumped into the lungs and the air with more CO₂ is pumped out of the lungs.

2. Cellular Respiration:

Cellular respiration is the process by which cell utilizes oxygen produces carbon dioxide extracts and conserve the energy from food molecules in biologically useful form such as ATP.

The cellular respiration is directly involved in the production of energy. All living activities are performed by this energy.

Respiration in Man:

In man respiratory system includes lungs and air passages which carry fresh air to the respiratory sites.

Air passage ways:

Air passage ways consist of nostrils, nasal cavities, pharynx, larynx, trachea, bronchi, bronchioles and alveolar ducts which lead into the alveolar sac.

1. Nasal Cavities:

Nasal cavities are lined by mucous membrane of the ciliated epithelium. Each nasal cavity is subdivided into three passage ways by the projection of bones from the walls of the internal nose.

Functions of the Nasal Cavities:

(i) Filtration:

When the air enters the nasal cavity through nostril, the larger dust particles are trapped by the hair and mucus in the nostrils.

(ii) Moistening:

When the air passes through the nasal cavity, it becomes moist.

(iii) Temperature Regulation:

While passing through the nasal cavities, the temperature is regulated and becomes closer to the body temperature. In the above functions, mucous membrane is actively involved.

2. Pharynx:

The nasal cavity leads into the throat or pharynx by two internal openings. Pharynx is a muscular passage lined with mucous membrane.

3. Larynx:

The air enters from the pharynx into the larynx. The larynx or voice box is a complex cartilaginous structure surrounding the upper end of the trachea. The opening of larynx is called glottis. It is also lined by mucous membrane.

(i) Epiglottis:

It is a lid which automatically covers the opening of the larynx during swallowing. Therefore, food or liquids cannot enter into the larynx. The properties of epiglottis are as follows:

- Epiglottis is a cartilaginous structure
- It is muscularly controlled
- It has a hinge like action

(ii) Vocal Cords:

In the glottis, the mucous membrane is stretched across into two thin edged fibrous bands called vocal cords. These help in voice production, when vibrated by air.

4. Trachea and Bronchi:

The trachea or wind pipe is a tubular structure. It is ventral to the oesophagus and extends to the chest cavity or thorax where it is divided into right and left branches. In the wall of trachea there are a series of C shaped cartilage rings. These prevent the trachea from collapsing and keep the passage of air open. Bronchi have the same cartilage rings as the trachea. However, the rings are progressively replaced by irregularly placed cartilage plates.

5. Bronchioles:

Each bronchus on entering the lung divides and subdivides progressively into smaller and smaller bronchi. When the smaller bronchi attain a diameter of one mm or less, then they are called bronchioles. The bronchioles totally lack cartilages. Bronchioles are made up of mainly circular smooth muscles.

6. Air Sacs:

The bronchioles continue to divide and subdivide deep into the lungs and finally open into a large number of air-sacs. Air-sac is the functional unit of the lungs. Each air-sac consists of several microscopic single layered structures called alveoli. Overlying the alveoli, there is a rich network of blood capillaries. It is an excellent site for the exchange of gases.

7. Lungs:

The lungs are closed sacs that are connected to the outside by the way of the trachea end the nostrils or mouth.

Note: The human gas exchanging organ, the lung, is located in the thorax, where it's delicate tissues are protected by the bony and muscular thoracic cage.

Note: The trachea is a tube about 10 to 12 centimeters long and two centimeters wide.

Note: The larynx is an organ of dual function: as an air canal to the lungs and as the organ of phonation.

Note: On average, an adult human lung has about 300,000,000 alveoli. They are polyhedral structures, with a diameter of about 250 to 300 micrometers.



Lungs are spongy because of the presence of millions of alveoli. Lungs are placed in the chest cavity. Chest cavity is bounded by ribs and muscles on the sides. The floor of the chest is called diaphragm. Diaphragm is a sheet of skeletal muscles. Lungs are covered with double layered thin membranous sacs called pleura.



Breathing and its mechanism

Breathing is a process in which fresh air containing more oxygen is pumped into the lungs and air with more carbon dioxide is pumped out of the lungs. In other words breathing is a mechanical process consisting of two phases, Inspiration and expiration. During inspiration, fresh air moves in while during expiration the consumed air moves out of the lungs.

Breathing rate:

During rest, breathing occurs rhythmically at the frequency of 15 to 20 times per minute in humans. This is sufficient to remove CO₂ from the blood.

1. Inspiration:

During inspiration the space inside the chest cavity is increased by two ways the muscles of ribs contract and elevate the ribs upwards and forwards. The muscles of the diaphragm also contract and diaphragm becomes less dome-like.

This downward movement of diaphragm and outward and upward movement of the ribs, causes increase in the chest cavity and reduces internal pressure.

When the pressure from the lungs is removed, they expand. With the expansion of the lungs vacuum is created inside the lungs. The air rushes into the lungs from the outside due to the higher atmospheric pressure. This is called inspiration.

2. Expiration:

During expiration the muscles of the ribs are relaxed and the ribs move downward and inward. In this way from the side of chest cavity the space becomes less. At the same time the muscles of diaphragm also relax, becoming more dome-like chest cavity is also reduced from the floor as well. The chest cavity is reduced and a pre-exerted on the lungs. The air inside the lungs moves out. This is called expiration.

Respiratory Distress Syndrome:

It is common in premature infants especially in infants with a gestation age of less than 7 months. This occurs because enough surfactant is not produced to reduce the tendency of the lungs to collapse.

Surfactant is a mixture of lipoprotein molecules produced by the secretory cells of the alveolar epithelium. This mixture forms a layer over the surface of the fluid within the alveoli to reduce the surface tension.

Factors Causing Gaseous Exchange:

Following factors bring about gaseous exchange (Intake of oxygen and release of carbon dioxide) between blood and the alveolar air.

- (i) Diffusion of oxygen in and carbon dioxide out occurs because of difference in partial pressure of these gases.
- (ii) The alveoli are surrounded by a network of capillaries. The blood is distributed in thin layers and therefore exposed to large alveolar surface.
- (iii) Blood in the lungs is separated from the alveolar air by extremely thin membranes of the capillaries and alveoli.

Transport of Oxygen:



In human beings the respiratory pigment is haemoglobin. It is contained in the red blood corpuscles (R.B.C.). Haemoglobin combines with oxygen to form bright red oxyhaemoglobin. At low oxygen concentration and less pressure, the reaction becomes reversible. Now oxyhaemoglobin (which is unstable) splits back to its normal purple-red coloured haemoglobin after giving out most of its oxygen. This reaction occurs with the help of an enzyme carbonicanhydrase present in R.B.C.

In this way haemoglobin acts as an efficient oxygen carrier.

A small proportion of oxygen also dissolved in blood plasma.

Carbonic anhydrase



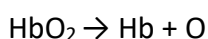
Maximum Absorption Capacity:

Haemoglobin can absorb maximum oxygen at the sea level. The maximum amount of oxygen which normal human blood absorbs and carries at the sea-level is about 20 ml/100 ml of blood. This is the maximum capacity of haemoglobin for oxygen when it is fully oxygenated.

Under normal conditions blood of alveoli of the lungs, is not completely oxygenated. When an oxygen tension is 100 mm mercury then haemoglobin is 98 percent oxygenated. Therefore, 100 ml of blood contains 19.6 ml of oxygen. This means that haemoglobin can be almost completely oxygenated by an oxygen pressure of 100 mm mercury which is present in the lungs. Any higher oxygen pressure would have the same result.

What happens when O₂ pressure is below 60 mm of Hg?

In many cells and tissues, the oxygen pressure is below 60 mm of mercury. Now the reaction becomes reversible.



This results in the liberation of large quantities of oxygen from haemoglobin. In this way in the tissue where oxygen pressure is low oxyhaemoglobin dissociates rapidly.

Factors affecting the capacity of haemoglobin to combine with oxygen:

Three important factors affect the capacity of haemoglobin to combine with oxygen:

1. Carbon Dioxide:

When CO₂ pressure increases, the O₂ pressure decreases. As a result the capacity of haemoglobin to hold oxygen becomes less. In this way increased CO₂ pressure favours the greater liberation of oxygen from the blood to the tissue.

2. Temperature:

Rise in temperature also decreases the oxygen-carrying capacity of blood. For example when muscular activity is increased, O₂ is released from the blood and is supplied to the muscles.

3. pH:

When the pH of the blood declines, the amount of oxygen bound to haemoglobin also declines. This occurs because decreased pH results from an increase in hydrogenions. The hydrogen ions combine with the protein part of the haemoglobin. As a result, the ability



of haemoglobin to bind oxygen is decreased. An increase in blood pH results in an increased ability of haemoglobin to bind oxygen.

Transport of carbon dioxide:

Carbon dioxide is more soluble than oxygen and dissolves freely in the tissue fluid surrounding the cells.

From the tissue fluid, dissolved carbon dioxide passes to the plasma within the blood capillaries.

Carbon dioxide is transported in the blood in several different states.

1. As Carboxyhaemoglobin:

Some of the CO₂ (about 20%) is carried as carboxyhaemoglobin. Carboxyhaemoglobin is formed when carbon dioxide combines with amino group of hemoglobin.

2. In Combination with Plasma Proteins:

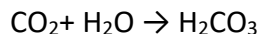
The plasma proteins also carry about 5% carbon dioxide from the body fluids to the capillaries of lungs.

3. In Combination with Potassium:

Small amount of carbon dioxide is also carried by corpuscles combined with potassium.

4. As Bicarbonate:

About 70% carbon dioxide is carried as bicarbonate ion combined with sodium in the plasma. As carbon dioxide from tissue fluid enters in the capillaries, it combines to form carbonic acid.



The carbonic acid splits quickly and ionizes to produce hydrogen ions and bicarbonate ions.

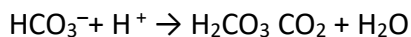


When blood leaves the capillaries most of the carbon dioxide is in the form of bicarbonate ions.

All these reactions are reversible.

In the lungs bicarbonate ions combine with hydrogen ions to form carbonic acid which splits into water and carbon dioxide.

The carbon dioxide diffuses out from the capillaries of the lungs into the space of alveolar sac.



Carbon Dioxide Concentration in Arterial and Venous Blood:

The arterial blood contains about 50 ml of carbon dioxide per 100 ml of blood. The venous blood has 54 ml of carbon dioxide per 100 ml of blood. Each 100 ml of blood takes up 4 ml of CO₂ as it passes through the tissues and gives off 4 ml of CO₂ per 100 ml of blood as it passes through the lungs.

CO₂ as a Ventilation (Breathing) Regulator:

Carbon dioxide is much more important than oxygen as a regulator of normal alveolar Breathing. However under certain conditions a reduced PO₂ (partial pressure of O₂) in the arterial blood plays an important stimulatory role especially during conditions of shock.



Important points to remember:

Respiratory distress syndrome occurs because enough surfactant is not produced to reduce the tendency of the lungs to collapse. It is common in premature infants especially in infants with a gestation age of less than 7 months.

2. Alveolar Breathing is regulated by CO_2 and O_2 .
3. Normally, at rest we inhale and exhale 15 – 20 times per minutes. During exercise the breathing rate may rise to 30 times per minute.

TABLE: Changes in the composition of the breathed air

GASES	INHALED EXHALED %	SECRETION
Oxygen	21	16
Carbon dioxide	0.04	4
Water vapors	Variable	Saturated
Nitrogen	79	79

4. Lung cancer is one of the most serious diseases of respiratory system. 90% of lung cancer is caused by smoking.
5. More than ten compounds of tar of tobacco smoke are involved to cause cancer.
6. Cancer or carcinoma is basically malignant tumor of potentially unlimited growth. It expands locally by invasion and systemically by metastasis.
7. Tuberculosis is the general name of a group of diseases caused by *Mycobacterium tuberculosis*.
8. Asthma is an allergic reaction to pollen, spores, cold, humidity, pollution etc. This allergic reaction causes sudden contraction of small bronchioles.
9. Emphysema is a breakdown of alveoli due to “smoker’s cough”.
10. Haemoglobin is the most important protein present in many animals including man.
11. Haemoglobin in man increases the oxygen carrying capacity of the blood to about 75 times.
12. Myoglobin is haemoglobin like iron containing protein pigment present in the muscle fibers.
13. Myoglobin is also known as muscle haemoglobin. It is an intermediate compound for the transfer of oxygen from haemoglobin to aerobic metabolic processes of the muscle cells. Myoglobin can also store some oxygen.
14. Myoglobin consists of one polypeptide chain associated with an iron containing ring structure which can bind with the molecule of oxygen. The affinity of myoglobin to combine with oxygen is much higher as compared to haemoglobin.
15. Aquatic mammals especially the Cetaceans can stay in the depth of the ocean for about two hours without coming up for air. Diving mammals have almost twice the volume of the blood in relation to their body weight as compared to the non-divers. Most of the diving mammals have high concentration of myoglobin in their muscles. Myoglobin binds extra oxygen.
16. When a mammal dives to its limit, the diving reflex is activated. Now the breathing stops, rate of heart beat slows down to $1/10^{\text{th}}$ of the normal, most of the blood goes to the brain and heart which can least withstand anoxia, Muscles shift from aerobic to an aerobic respiration.
17. In an adult human being when the lungs are fully inflated, the total inside capacity of the lungs is about 5 liters.
18. Normally when we are at rest or asleep, the exchange is only about half a liter. The volume of air taken inside the lungs and expelled during exercise is about 3.5 liters. It means, there is a residual volume of 1.5 liters even during exercise which cannot be expelled.



ADDITIONAL / RELATED READINGS

1. Respiration is the most important metabolic activity of all living organisms.
2. Respiration occurs at two levels:
 - (i) Organismic level
 - (ii) Cellular level.
3. Organismic respiration is also known as breathing or ventilation.
4. Cellular respiration is the process by which cell utilizes oxygen, produces carbon dioxide, extracts and conserve the energy from food molecules in biologically useful form such as ATP.
5. Respiratory gases are exchanged between body fluid and outside medium. The outside medium may be water or air.
6. Exchange of gases occurs only by diffusion.
7. Air is better respiratory medium than water. In the equal volumes of air and water, oxygen is higher in the air. A liter of air has about 200 ml oxygen while one-liter water cannot contain even 10 ml oxygen.
8. Oxygen diffuses about 8000 times more quickly in air than in water. Water is 8000 times denser than air.
9. Water is 50 times more viscous than the air.
10. The transport system of plants (xylem and phloem) is not involved in the transport of gases. This is because that in plants there is no special organ or system for gaseous exchange.
11. Land plants get their oxygen from air through stomata. Therefore, stomata are the main source of exchange of gases in plants. Stomata are largely present in the leaves and in young stem.
12. There are about 12000 stomata per square centimeter of leaf surface in Tobacco plant.
13. The stomata lead to the intercellular spaces between mesophyll cells.
14. The air spaces in the leaf are similar to honey comb. The air spaces cover up to 40% of the total volume of the leaf.
15. In the older stems, cork tissue is present which is formed of dead cells. The cork tissue has special pores called lenticels which are involved in gaseous exchange.
16. The roots of the land plants get their oxygen from the air present in the spaces between the soil particles.
17. Respiratory activity which occurs in plants during daytime is called photorespiration.
OR
The pathway in which RuBP is converted into serine is called photorespiration.
18. Photorespiration starts in hot dry weather when temperature above 40° C. Now ABA is released and stomata close. But light reaction will continue. As a result the level of oxygen inside the leaf rises while the level of carbon dioxide falls due to its consumption. Now photorespiration starts.
19. The process of photorespiration uses ATP and NADPH produced in the light reactions just like Calvin-Benson cycle. However photorespiration is reverse of the Calvin cycle. In this



process carbon dioxide is released and oxygen is absorbed. This oxygen is produced in the light reactions.

20. Three main reactions in the photorespiration:

- (i) $\text{RuBP} + \text{O}_2 \rightarrow \text{Glycolate}$ (in the Chloroplast)
- (ii) $\text{Glycolate} \rightarrow \text{Glycine}$ (in the Peroxisomes)
- (iii) $2 \text{ glycine} \rightarrow \text{Serine} + \text{CO}_2$ (in the Mitochondria)

21. The rubisco is carboxylase as well as oxygenase. When the rubisco acts as carboxylase it adds carbon dioxide to RuBP, which is an accepter molecule. On the other hand when rubisco is oxygenase it adds oxygen to RuBP. Both these reactions compete with each other.

22. The photorespiration reduces the photosynthetic process. In most plants, by photorespiration, the carbohydrate production is reduced up to 25%.

23. The distance across which diffusion of gases has to take place should be little. In most animals the epithelium which separates air and blood is only two cells thick. Therefore, the distance for diffusion is very short.

24. Blood in the lungs is separated from the alveolar air by extremely thin membranes of the capillaries and alveoli.

25. Organismic respiration/breathing/Ventilation maintains a steep diffusion gradient.

26. Hydra has no specialized organs for respiration. Exchange of gases (intake of O_2 and removal of CO_2) occurs through the entire surface of the body by diffusion.

27. Earthworm has no specialized organs for respiration. The exchange of gases occurs mainly through the skin.

28. The respiratory system of the cockroach consists of branching systems of air tubules called tracheae lined by chitin.

29. In the cockroach the main tracheal trunk communicates with exterior by 10 pairs of apertures called spiracles. These are present on the lateral sides of the body. Two pairs are in the thorax while eight pairs in the first eight abdominal segments.

30. In the cockroach Air is pumped in and out of the tracheae by the expansion and contraction of the abdominal muscles (Dorsoventral muscles). When abdomen expands the first four pairs of spiracles open, the air rushes in through these spiracles into the tracheoles. When the abdomen contracts, the anterior four pairs of spiracles close and posterior six pairs of spiracles open. The air is forced out of the body through these spiracles.

31. Fish respire through the gills Gills are paired structures present on the either side of the body almost at the junction of head and trunk. There are four to five pairs of gills which may be visible on the surface of the pharynx (in the cartilaginous fishes) or placed in the branchial cavities (in bony fishes).

32. In frog, the gaseous exchange occurs through the lungs, by skin and the buccal chamber. The gaseous exchange through the skin is known as cutaneous respiration. Gaseous exchange through the lungs is called pulmonary respiration.

33. Respiratory system in birds is the most efficient and complicated. The birds are very active animals with high metabolic rate. Therefore, they need large amount of oxygen.



34. In birds there is one-way flow of the air through the lungs and the air is renewed after inspiration.
35. The lungs of birds have parabronchi instead of alveoli. These are tiny thin walled ducts. These parabronchi are opened at both ends and the air is constantly ventilated. The walls of the parabronchi are chief sites of gaseous exchange. The direction of the blood flow in the lungs is opposes to the air flow through the parabronchi. This counter current exchange increases the amount of oxygen which enters the blood.
36. In birds the lungs have also developed several extensions known as air sacs. These reach into all parts of the body and even penetrate some of the bones. In most birds the air sacs are nine in number. The air sacs send air into the parabronchi. Photo respiration is a process which is reverse of:



Transportation:

Blood Circulatory System:

The circulatory system of man has the following basic components.

- (i) Circulating fluid – the blood
- (ii) The pumping organ – the heart
- (iii) The blood vessels – arteries, capillaries and veins

The Circulatory Fluid the Blood:

- The blood is the medium in which dissolved nutrients, gases, hormones, and wastes are transported through the body.
- It is made up of two main components:
 - (i) plasma and
 - (ii) cells or cell like bodies (white blood cells, red blood cells, platelets)
- The weight of the blood in our body is about $1/12^{\text{th}}$ of our body

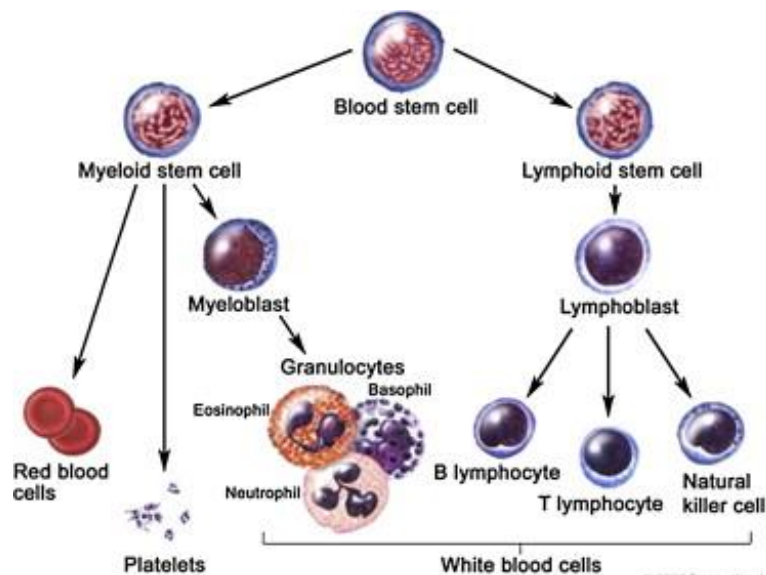
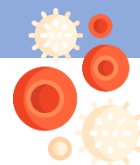


Fig. Red blood cells (erythrocytes) and white blood cells (Leucocytes) both develop from stem cells in bone marrow.

Plasma:

- In a normal person plasma is 55 by volume of the blood, and cells or cell-like bodies about 45 % by volume of the blood.



- Plasma is primarily water in which proteins, salts, nutrients and wastes are dissolved/ Water constitutes about 90 of plasma, 10 are solutes which are as follows:
- The inorganic ions and salts make up 0,9 per cent of the plasma, of humans, by weight. More than two thirds of this amount is sodium chloride the 'ordinary table salt.
- The normal pH of human blood is 7.4 and it is maintained between narrow limits because the change in pH would affect the chemical reactions of the body.
- The plasma proteins constitute 7-9 percent by weight of the plasma. Most of these proteins are synthesized in the liver. Some of the globulins, called immune globulins or antibodies are produced in response to antigens by lymphocytes cells and then are passed to plasma and lymph immunoglobulins play important role in body's defenses against disease.
- The proteins like Prothrombin acts as a catalyst in blood clotting process. Fibrinogen takes part in the blood clotting process.
- Organic nutrients in the blood include glucose, fats, phospholipids amino acids and lactic acids. Some of them enter the blood from the intestine (absorption).
- Lactic acid is produced in muscles as a result of glycolysis and is transported by blood to liver. Cholesterol is metabolized to some extent but also sense as precursor of steroid hormones.
- Plasma also contains nitrogenous waste products formed as a result of cellular metabolism. These products are carried from the liver where they are produced to the organs from where they are removed i.e. kidneys. Urea and small amounts of uric acid are present in plasma.
- All the hormones in the body are carried by blood - so they are present in the plasma.
- The gases such as CO₂ and O₂ are present in the plasma of the blood.

Blood cells and cell like bodies:

These include Red blood cells (Erythrocytes), white blood cells (Leucocytes) and platelets (Thrombocytes).

- a) **Red Blood Cells (Erythrocytes):** These are most numerous of the cells in the blood. A cubic millimeter of blood contains 5-5 ½ million of them in males and 4-4 ½ million in females.
- These cells when formed have nucleus but is lost before they enter the circulatory fluid or blood.
 - 95 % of the cytoplasm of red blood cells is the red pigment, called hemoglobin. The remaining 5 % consists of enzymes, salts and other proteins.
 - The red cells once mature do not divide.
 - These cells are biconcave and have an elastic cell membrane.



- Red blood cells are formed principally in the red bone marrow of short bones, such as the sternum, ribs and vertebrae. In the embryonic life, they are formed in the liver and spleen.
- The average life span of red blood cell is about four months after which it breaks down and disintegrated in the liver and spleen - partly by phagocytes by phagocytosis.
- About 2 – 10 million red blood cells are formed and destroyed every second in a normal person.
- Their main function is to transport O_2 and CO_2 .
- Having Hb inside red blood cells rather than In solution In the plasma gives several advantages:
- A much greater volume of Hb can be carried in cells than could be' dissolved in plasma.
- Hb can be kept in a favourable chemical environment to allow taster loading and unloading of respiratory gases.
- Hb molecules of particular age are kept together and can be easily replaced when old.
- Hb in cells does not affect the osmotic properties of the blood (free Hb would).
- Hb in cells cannot be lost by excretion.

(b) White Blood Cells (Leucocytes):

- These blood cells are colourless, as they do not contain pigments.
- One cubic millimeter of blood contains 7000 to 8000 of them. They are much larger than the red blood cells.
- There are at least five different types which can be distinguished on the basis of the shape of the nucleus and density of granules in the cytoplasm. They can be grouped into two main types, granulocytes and agranulocytes.
- Granulocytes include neutrophils, eosinophils and basophils. They are formed in the red bone marrow.
- Agranulocytes are formed in the lymphoid tissue such as those of the lymph nodes, spleen, tonsils, adenoids and the thymus. Agranulocytes include monocytes and lymphocytes (B and T),
- Monocytes stay from 10 – 20 hours in the blood, then enter tissues and become tissue macrophages, performing phagocytic function.
- Lymphocytes have life spans of months or even years but this depends on the body's need for these cells.

Functions of WBCs:

- Leucocytes protect the body against foreign invaders, and use circulatory system to travel to the site of invasion.
- Monocytes and neutrophils travel through capillaries and reach the site of wound where bacteria have gained entry.



- Macrophages and neutrophils feed on bacterial invaders or other forcing cells including cancer cells. They typically die in the process and their dead bodies accumulate and contribute to the white substance called pus, seen at infection sites.
- Basophils produce heparin - a substance that inhibit blood clotting these also produce chemicals, such as histamine that participate In allergic reaction and in responses to tissue damage and microbial invasion.

Lymphocytes help provide immunity against the disease.

(c) Platelets (Thrombocytes):

- These are not cells, but are fragments of large cells called megakaryocytes. There is no nucleus in them. There is no pigment in them.
- Platelets help in conversion of fibrinogen, a solid plasma protein, into insoluble form fibrin. The fibrin threads enmesh red blood cells and other platelets in the area of damaged tissue, ultimately forming blood clot. The clot serves as a temporary seal to prevent bleeding until the damaged tissue can be repaired.

Cell type	Illustration	Description*	Cells/mm ³ (μl) of blood	development (D) and life span (LS)	Function
Erythrocytes (red blood cells, RBCs)		Biconcave, anucleate disc; salmon-colored; diameter 7–8 μm	4–6 million	D: about 15 days LS: 100–120 days	Transport oxygen and carbon dioxide
Leukocytes (white blood cells, WBCs)		Spherical, nucleated cells	4800–10,800		
<i>Granulocytes</i> Neutrophil		Nucleus multilobed; inconspicuous cytoplasmic granules; diameter 10–12 μm	3000–7000	D: about 14 days LS: 6 hours to a few days	Phagocytize bacteria
Eosinophil		Nucleus bilobed; red cytoplasmic granules; diameter 10–14 μm	100–400	D: about 14 days LS: about 5 days	Kill parasitic worms; complex role in allergy and asthma
Basophil		Nucleus lobed; large blue-purple cytoplasmic granules; diameter 10–14 μm	20–50	D: 1–7 days LS: a few hours to a few days	Release histamine and other mediators of inflammation; contain heparin, an anticoagulant
<i>Agranulocytes</i> Lymphocyte		Nucleus spherical or indented; pale blue cytoplasm; diameter 5–17 μm	1500–3000	D: days to weeks LS: hours to years	Mount immune response by direct cell attack or via antibodies
Monocyte		Nucleus U- or kidney-shaped; gray-blue cytoplasm; diameter 14–24 μm	100–700	D: 2–3 days LS: months	Phagocytosis; develop into macrophages in tissues
<i>Platelets</i>		Discoid cytoplasmic fragments containing granules; stain deep purple; diameter 2–4 μm	150,000–400,000	D: 4–5 days LS: 5–10 days	Seal small tears in blood vessels; instrumental in blood clotting



Functions of Blood:

- The plasma proteins maintain colloid osmotic pressure of the blood (75 % by albumins 25 % by globulins and almost none by fibrinogen).
- Blood helps to transport of materials, in the body including nutrients, water, salts and waster products. All hormones are transported by blood from the endocrine tissues to the larger cells.
- O₂ and CO₂ are transported by blood.
- Blood helps in body defenses against disease neutrophils and monocytes engulf and destroy invading microorganisms e.g. bacteria. Blood provides immunity by the lymphocytes.
- Blood produces interferon and antitoxins which are proteins and protects our body from nucleic acids of invading organism; and toxins of the invaders.
- Blood acts as a buffer to maintain the acid base balance i.e, concentration of H⁺ and OH⁻ ions of the body.
- Helps in maintaining the body temperature, concentration of water and silts, this helps in homeostasis.
- Blood helps in the exchange of materials between blood and body tissue tissues through blood capillaries.
- Blood helps the body in maintaining the internal environment, by producing, heparin, histamines and also maintaining the amounts of chemicals in the body to a constant or nearly constant level.
- Blood undergoes a clotting process under certain circumstances due to specific proteins.



Disorders of blood

1. Leucaemia (Blood Cancer):

It is the result of uncontrolled production of white blood cells (Leucocytes). This is caused by a cancerous mutation of a myelogenous or lymphogenous cell. The Leucaemia is usually characterized by greatly increased numbers of abnormal white blood cells in the circulating blood.

Myelogenous cells (bone marrow cells) are in the bone marrow and may spread throughout the body so that white blood cells are produced in many other organs. These white blood cells are not completely differentiated and so are defective.

Leucaemia may be of different kinds depending on the type of white blood cells, which are undifferentiated and being produced at a faster, than normal rate. There may be neutrophilic leucaemia, eosinophilic leucaemia and basophilic leucaemia, monocytic or lymphocytic leucaemia.

It is a very serious disorder and the patient needs to change the blood regularly with the normal blood, got from donors. It can be cured by bone marrow transplant, which is in most cases effective but very expensive treatment.

2. Thalassemia (G. Thalassa = Thesea; haema = blood):

It is also called Cooley's anaemia on the name of Thomas B. Cooley American pediatrician. It is a genetically transmitted haemoglobin abnormality. Haemoglobin molecules in most cases, does not have β -chains in it instead F chain is present.

(F is foetal haemoglobin)

It is characterized by the presence of microcytes by splenomegaly (enlargement of spleen) and by changes in the bones and skin.

This disease is more common in children especially of Mediterranean parents. The blood of these patients is to be replaced regularly, with normal blood.

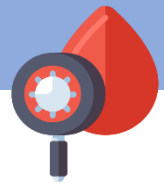
It can be cured by bone marrow transplant - which is very expensive and does not give 100 % cure rate.

3. Oedema:

It means the presence of excess fluid in the tissues of the body. The excess fluid may be in the cells or outside the cells. The intracellular oedema is caused by osmosis of water into the cells and cause, depression of metabolic systems (due to lack of nutrition and O_2 in the tissues) especially and the Na-pump.

The extracellular oedema may result by:

- (i) Abnormal leakage of fluid from the blood capillaries or failure of the lymphatic system to return fluid from the interstitial fluid.
- (ii) Oedema is caused by renal retention of salts and water.



Oedema disturbs the exchange and concentration of minerals and ions in the blood and body cells, it also affects blood pressure, increases heart load etc.

The heart (pumping organ)

Structure and action:

1. Location:

The heart of humans is located in the chest cavity.

2. Pericardium:

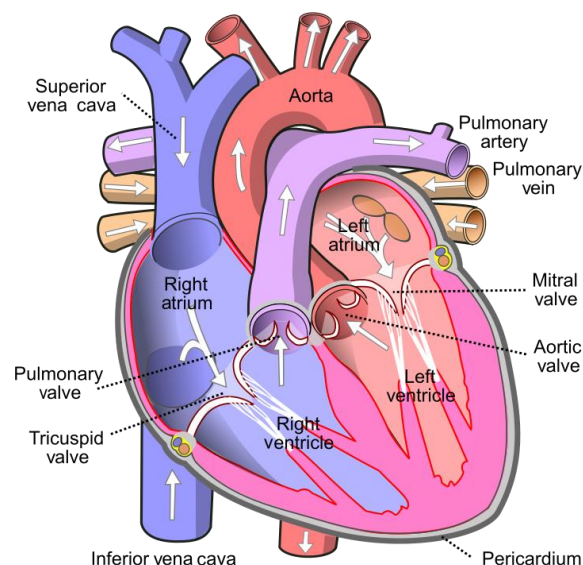
The heart is enclosed in a double membranous sac - the pericardial cavity which contains the pericardial fluid. Pericardium protects the heart, prevents it from overextension.

3. Wall of Heart:

The wall of the heart is composed of three layers.

- (i) Epicardium
- (ii) Myocardium
- (iii) Endocardium

- Myocardium of the heart is made up of cardiac muscles.
- These muscles contain myofibrils, and myofilaments of myosin and actin.
- Their arrangement is similar to those in skeletal muscle fibres and their mechanism of contraction is also the same, except they are branched cells, in which the successive cells are separated by junctions called intercalated discs.
- The heart contracts automatically within rhythmicity, due to the autonomic nervous system of the body.





Chambers of Heart:

There are four chambers of the heart, two upper thin walled atria and two lower thick walled ventricles. Atria receive the blood and pass on to the ventricle which distribute the blood.

Double Pump:

Human heart functions as a double pump, and is responsible for pulmonary and systemic circulation. Complete separation of deoxygenated blood (Right side) and oxygenated blood (left side) in the heart is maintained.

Function:

- (i) The right atrium receives deoxygenated blood via vena cava (inferior and superior) from the body.
- (ii) The blood is passed on to right ventricle through tricuspid valve (because it has 3 naps). These naps are attached with fibrous cords called chordaetendinae, to the papillary muscles which are extensions of wall of the right ventricle.
- (iii) When right ventricle contracts, the blood is passed to pulmonary trunk which carry blood via left and right pulmonary arteries, to the lungs.
- (iv) At the base of the pulmonary trunk, semi lunar valves are present.
- (v) After oxygenation in the lungs the blood is brought by pulmonary veins to the left atrium which passes this blood via bicuspid valve (because it has two flaps) to the left ventricle. The flaps of bicuspid valve are similarly attached through chordae tendinae, with papillary muscles of wall of left ventricle.
- (vi) When the left ventricle contracts. it pushes the blood through aorta to all parts of the body (except lungs).
- (vii) At the base of aorta semi lunar valves are also present. The valves of the heart control the direction of flow of blood.
- (viii) The wall of left ventricle is thicker (about 3 time) than that of the right ventricle.
- (ix) At the base of aorta, first pair of arteries, the coronary arteries, arise and supply blood to the heart.
- (x) The aorta forms an arch, and before descending down gives three branches supplying blood to head, arms shoulders.
- (xi) Aorts descends down in the chest cavity. It gives many small branches to the chest wall and then passes down to the abdominal region. Here it gives branches which supply blood to different parts of alimentary canal, kidneys and the lower abdomen.
- (xii) Aorta bifurcates into iliac arteries, each of which divides into two femoral and sciatic arteries supplying blood to legs.
- (xiii) The blood from the upper part of the body is collected by different veins, which join to form superior vena cava; which pass the blood to right atrium.

- (xiv) Two iliac veins are formed by veins which collect blood from legs, and unite to form inferior vena cava. It receives renal vein from each kidney; and hepatic vein from liver, before it enters right atrium. The liver receives hepatic portal vein which is formed by many veins collecting deoxygenated blood with absorbed food from different parts of alimentary canal.



Important points to remember

1. Myocardium of the heart is made up of special type of muscles the cardiac muscles.
2. Human heart functions as a double pump, and is responsible for pulmonary and systemic circulation.
3. In human heart: The right atrium receives deoxygenated blood via vena cava (inferior and superior) from the body.
4. Heartbeat involves three distinct stages:
 - (i) Diastole
 - (ii) Atrial systole
 - (iii) Ventricular systole.

One complete heart beat consists of one systole and one diastole, and lasts for about 0.8 seconds.
5. The heart beat cycle starts when the sino-atrial node (Pace maker) at the upper end of right atrium sends out electrical impulses to the atrial muscles and causing both atria to contract.
6. The recording of heart beat is known as electrocardiogram which is taken by electrocardiograph (E.C.G) machine.
7. Pacemaker is responsible for initiating the impulse which triggers the heart beat rate.
8. If there is some block in the flow of the electrical impulses, or if the impulses initiated by S.A, node are weak; it may lead to death of the individual. So an artificial pacemaker which is battery operated producing electrical stimulus is used.
9. Failure of interatrial foramen (an opening in the inter-atrial septum) to close or of ductus arteriosus to fully constrict results in cyanosis (blueness of skin) of new born.
10. The contraction. of the circular (smooth) muscles of arteries and arterioles is under the control of nervous and endocrine systems
(**Examples:** Vasoconstriction and Vasodilation),
11. Capillaries are only one cell thick, Exchange only at capillary level.
12. The diameter of capillary can be altered by nervous stimulation; which tends to close them and by chemicals such as histamine which dilates them.
13. The pre capillary sphincters also regulate the amount of blood flowing capillaries, Thus the amount of blood flowing in a certain tissue is controlled.
14. Capillaries join to form venules, which join to form veins.
15. The pressure within capillaries causes a continuous leakage of fluid from the blood plasma into the spaces that surround the capillaries and tissues, This fluid is interstitial fluid, It has water in which are dissolved nutrients, Hormones, gases, wastes and small proteins from the blood.
16. Large proteins. red blood cells and platelets cannot go to the intercellular spaces of, capillary



17. Atheroma + arteriosclerosis = Atherosclerosis
18. Atherosclerosis causes narrowing and hardening of arteries.
19. Blood pressure is the measure of force with which, blood pushes up against blood vessel walls.
20. The pressure reaching its high point during systole (systolic pressure which in normal individuals is 120 mm Hg) and its low point during diastole (diastolic pressure which in normal individuals ranges between 75-85 mm Hg).
21. The walls of arteries are elastic and the flow of blood stretches them, and it is felt as pulse.
22. Hypertension is a condition of high blood pressure.
23. Thrombus is a solid mass or plug of blood constituents (clot) in a blood vessel.
24. Thrombosis is the formation of thrombus.
25. Blockage of blood vessel in the heart by an embolus (or by locally formed thrombus) causes necrosis or damage to portion of the heart muscles. a condition known as a heart attack or technically myocardial infarction.
26. If the normal flow of blood is blocked by an embolus (or a locally formed thrombus), in a blood vessel in the brain, and causes necrosis, or death, of the surrounding neural tissue (owing to lack of O₂) the condition is called a stroke or cerebral infarction.
27. Haemorrhage is the discharge of blood from blood vessels.

Lymphatic system:

- In humans in addition to blood vascular system there is another system which is responsible for the transport and returning of materials from the tissues of the body to the blood this system is called lymphatic system.
- It consists of lymph capillaries, lymph vessels, lymphoid masses lymph nodes and lymph (the fluid) which flows in the system.
- The Lymph capillaries end blindly in the body tissues where pressure from the accumulation of interstitial fluid or extracellular fluid forces the fluid into the lymph capillaries, when this fluid enters the lymph capillaries it is called lymph. The lymph vessels empty in veins; so lymph is a fluid in transit between interstitial fluid and the blood.
- The intercellular spaces in the walls of lymph vessels are larger than those of the capillaries of blood vascular system. So larger molecules, from the interstitial fluid can also enter the lymph capillaries.
- Lymph capillaries join to form larger and larger lymph vessels and ultimately form thoracic lymph duct, which opens into subclavian vein. The flow of lymph is always towards the thoracic duct.
- In the intestine the branches of lymph capillaries within villi are called lacteals.
- The flow of lymph is maintained by:
 - (i) Activity of skeleton muscles
 - (ii) Movement of viscera
 - (iii) Breathing movements
 - (iv) The valves which prevent back flow of lymph
- Along the pathway, the lymph vessels, have, at certain points, masses of connective tissue where lymphocytes are present, these are lymph nodes.
- Several afferent lymph vessels enter a lymph node which is drained by a single efferent lymph vessel. Lymph nodes are present in the neck region axilla and groin of humans.
- In addition several lymphoid masses are present in the walls of digestive tract in the mucosa and sub-mucosa. The larger masses, spleen and thymus, tonsils and adenoids are all lymphoid masses. These produce lymphocytes.

Functions:

These are several functions performed by lymphatic system.

- In an average person, about three liters more fluid leaves the blood capillaries than is reabsorbed by them each day. It returns this excess fluid and its dissolved proteins and other substances to the blood.
- The lacteals of villi absorb large fat globules, which are released by interstitial cells after the products of digestion of fats are absorbed. After a fatty meal these fat globules may make up 1 of the lymph.
- The lymphatic system helps to defend the body against foreign invaders; Lymph nodes have lymphocytes and macrophages that destroy the bacteria and viruses. The painful swelling of lymph nodes in certain diseases (mumps is an extreme example) is largely a result of the accumulation of dead lymphocytes and macrophages.
- Just as the lymph nodes filter lymph, the spleen filters blood, exposing it to macrophages and lymphocytes that destroy foreign particles and aged red blood cells.

Note: Lymphatic system is actually a subsystem of the circulatory system in the vertebrate body that consists of a complex network of vessels, tissues, and organs.

Summary

The lymphatic system is part of the immune system. It is also part of the circulatory system; it returns to the heart the small amount of tissue fluid that cannot be returned by the veins. Lymphatic summery flow begins in the capillary beds, where small amounts of tissue fluid drain into tin y lymphatic capillaries. The walls of these vessels are more permeable than blood capillaries) lipids and large molecules such as proteins, and so lymph contains a high proportion of the» ~ substances. Many cells secrete substances that are too large to enter the blood directly, and so can only pass into the general circulation via the lymphatic's. The lymph capillaries drain into larger lymph vessels that look like thin, transparent veins. These vessels have valves to prevent backflow. Lymph contains no red blood cells, and so is pale and clear.

Immunity

- In animals in addition to physical barriers (skin + mucous membranes) and phagocytes, there is a third mechanism, to defend their bodies against the foreign invaders; this is the immune system.
- Immunity is the capacity to recognize the material entered in the body and to mobilize cells and cell products for removal of this foreign material with greater speed and effectiveness.
- The components of immune system include the lymphocytes (B and T) and the antibodies which are special type of proteins.
- These antibodies are immunoglobulin's which are synthesized by vertebrates, in response to antigens.
- Antigen or immunogenic is a foreign substance often a protein which stimulates the formation of antibodies.
- Antibodies are specific i.e. cause the destruction of the antigen, which stimulated their production.
- Antibodies are manufactured in B-lymphocytes then secreted into the lymph and blood where they circulate freely.
- Lymphocyte T and B have been named due to their relationship with Thymus gland, and Bursa of Fabricius respectively.
- B-cells recognize antigen then combat micro-organisms and or effect the rejection of foreign tissues (in case of tissue transplant). This is called cell-mediated response.
- B-cells recognize antigen and form plasma cell clone. These plasma cells synthesize and liberate antibodies into the blood plasma and tissue fluid. Here antibodies attach to the surfaces of bacteria and speed up their phagocytosis, or combine with and neutralize toxins produced by micro-organisms by producing antitoxins. This is called humoral immune response.

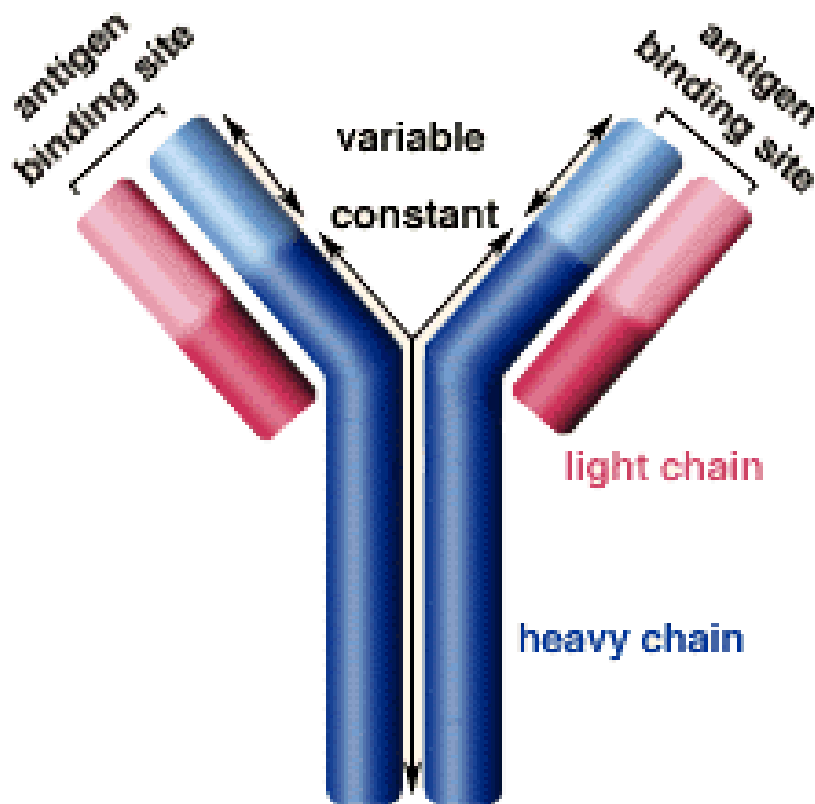


Fig. (a) An antibody molecule consists of four polypeptide chains, two identical light chains and two identical heavy chain - linked by disulfide (- S - S -) bridges. Variable amino acid Sequences (V) in the light chains and upper regions of the heavy chains determine which antigen will bind to that particular antibody constant amino acid sequences (C) are the same for all the antibodies in one class (b) large antigen-antibody complexes will form if there are multiple copies of the antigenic molecule on the foreign cell's surface.

Types of immunity:

There are following two types of immunity.

Active Immunity:

- The use of vaccines, which stimulate the production of antibodies in the body, and making a person immune against the disease or infection, is called active immunity. But this active immunity has been achieved by artificially introducing antigens in the body, so it is called artificially induced active immunity. Most of the vaccines consist of non-virulent, mutant strains of the poliovirus.

- When a person is exposed to an infection (antigen) - becomes ill, and in most cases survives then this immunity, developed against that disease is called naturally induced immunity or autoimmune response.
- When we get vaccination, against a specific disease (antigen), we become immune to that infection or disease. If we get vaccination against, Polio, Smallpox, measles, mumps etc. once in our life time, we are protected or become immune to that infection in our future life.

Passive Immunity:

- If antibodies are injected in the form of antisera (Antiserum is a serum containing antibodies), to make a person immune against a disease. This called passive immunity.
- Passive immunity response is immediate, but not long lasting.
- The method of passive immunization is used to combat active infections of, tetanus, infectious hepatitis, rabies, snake bite venom etc.
- Antiserum is a serum containing antibodies.
- In the case of snake bite venom passive immunity is produced by the antitoxins - so the serum is called antivenin serum. The patient is the complications (or possibly death) caused by the infection or venom, spared.
- In the body antigen - antibody complexes are formed which are taken up by phagocytes and destroyed.

In AIDS the affected suffer deficiency in the immune system of the body. This is because that the Viruses live in the Helper T-lymphocytes.

Immunization:

- Immunization is the process of making a person immune to a disease by inoculating them against it.
- Inoculation is the introduction of an antigen into the body--usually through an injection--to stimulate the production of antibodies.
- The medical practice of immunization began at the end of the eighteenth century, when English physician Edward Jenner (1749-1823) successfully vaccinated 23 people against small pox. Jenner called his method "vaccination," using the Latin words vacca, meaning "cow" and vaccinia, meaning "cowpox" Because the two diseases are caused by similar viruses that have the same antigens, antibodies that work against cowpox will also fight smallpox.
- In 1885 a rabies vaccine developed by French scientist Louis Pasteur (1822-1895) from the spinal fluid of infected rabbits proved to be successful, since that time, vaccines have been developed for many diseases including diphtheria, polio, pertussis (whooping cough), measles, mumps, rubella (German measles), hepatitis and influenza.

- Vaccines are made from either weakened live or killed microorganisms. When introduced into the body they stimulate the production of antibodies providing active immunity against bacterial and viral diseases.