ANIMAL PHYSIOLOGY

ANIMAL NUTRITION

- Nutrition is the sum of the processes by which an organism takes in, metabolises and utilises food substance.
- Nutrients are the organic or inorganic substances which help in our survival and in maintaining proper health. A nutrient supplies energy to the body, builds and repairs body tissues and regulates the body metabolism.

Nutritional Requirements

- Our bodies have certain nutritional needs and if they are not met it will cause catabolism of its own fats, carbohydrates and proteins.
- Vitamins (Vital Emines) and minerals are not used as energy, but are essential in enzyme reactions. Living tissue is kept alive by using the expenditure of ATP, found in the break down of food.
- A balanced diet is one that contains all essential nutrients in suitable proportion and amount to provide necessary energy and keep the body in a healthy state.
- Foods energy value is measured in kilocalories.

1 kilocalorie = 4.18 kJ

1 kilojoule = 1/4.18 X 1000 calories

Macronutrient

An energy-yeilding nutrient. Macronutrients are those nutrients that together provide the vast majority of metabolic energy to an organism. The three main macronutrients are carbohydrates, proteins, and fat.

Microminerals or trace elements, are dietary minerals needed by the human body in very small quantities (generally less than 100mg/day) as opposed to macrominerals which are required in larger quantities.

A. Carbohydrates

- They are made of organic compounds carbon, hydrogen, and oxygen.
- There are three sizes of carbohydrate and they are distinguished by a classification of two that is, *Simple carbohydrates* (mono saccharides and disaccharides) and *complex carbohydrates* (polysaccharides). Polysaccharides are the most abundant carbohydrate in the body along with glycogen.

a. Monosaccharides : Single carbohydrate unit, such as, Glucose, Fructose, and Galactose.

b. Disaccharides : Two single carbohydrates bound together. These are Sucrose (Glucose + Fructose), Maltose (Glucose + Glucose), and Lactose (Glucose + Galactose).

c. Polysaccharides : Have many units of monosaccharides joined together such as, Starch and Fiber.

B. Proteins ;

- **Protein** forms hormones, enzymes, antibodies; it is part of fluid and electrolyte regulation, the buffering effect for pH, and transporter of nutrients. A good example of a protein is the oxygen carrying haemoglobin found in red blood cells.
- **Proteins** are made of carbon, hydrogen, oxygen, and nitrogen, an inorganic molecule, the thing that clearly distinguishes them form the other macronutrients.
- The body requires amino acids to produce new body protein (protein retention) and to replace damaged proteins (maintenance) that are lost in the urine.
- Amino acids are the basic structural building units of proteins.
- They form short polymer chains called peptides or longer poly-peptides which in turn form structures called proteins.

C. Lipids :

- **Lipids** are madeup of organic molecules carbon, hydrogen, and oxygen. Fats consist of glycerol and fatty acids joined by an ester bond.
- Provide 9 Kcalories per gram; it is an energy-yielding nutrient
- **Functions** are stored energy (adipose tissue), organ protection, temperature regulator, provide insulation such as myelin that covers nerve cells, lipid membrane around cells, and emulsifiers to keep fats dispersed in body fluids.
- Lipids are structural components found in every cell of the human body. That is they form the lipid bilayer found in individual cells.

- Lipids provide us with energy, most of that energy is in the form of triacylglycerols.
- Both lipids and lipid derivatives serve as vitamins and hormones.
- Lipophilic bile acids aids in lipid solubility

A. **Triglycerides** composed of three fatty acids and one glycerol molecule.
B. **Saturated fatty acid** fatty acid with carbon chains fully saturated with hydrogen.
C. **Monounsaturated fatty acid** fatty acid that has a carbon chain with one unsaturated double bond.
D. **Polyunsaturated fatty acid** a fatty acid that has two or more double bonds on the carbon chain.

Vitamins :

- Vitamins are organic compounds that are essential for our body to function properly.
- Most vitamins are obtained from what you consume, because the body is unable to manufacture most of the essential vitamins that you need to survive.

- **Vitamin A (Retinol)**
  Functions: night vision, growth and repair of tissues, immune system functions
  Sources : eggs, dark green and yellow fruits and vegetables, dairy products, liver
  Deficiency : skin dryness, dry mucous membranes, night blindness

- **Vitamin C (Ascorbic acid)**
  Functions : wound healing, collagen maintenance, infection resistance, essential for healthy gums and blood vessels
  Sources : citrus fruits, tomatoes, melons, berries, green and red peppers, broccoli
  Deficiency : Scurvy - hemorrhages, loosening of teeth, bone damage.

- **Vitamin D (Calciferol)**
  Functions : bone and tooth formation
  Sources : egg yolk, fatty fish, milk synthesized in skin when exposed to sunlight
  Deficiency : Rickets - deformation of rib cage, skull, and bowlegs

- **Vitamin E (Tocoferol)**
  Functions: free radical scavenger, immune system function
  Sources: vegetable oil, wheat germ, nuts, dark green vegetables, whole grains, beans

- **Vitamin K (Menadione/Phylloquinone)**
  Functions : blood clotting, bone metabolism
  Sources : green leafy vegetables, beef, liver
  Deficiency: blood clotting disorders

- **Thiamin (B_1)**
  Functions : carbohydrate metabolism, appetite regulation, nervous system functions, growth
  Sources : wheat germ, pork, whole and enriched grains, dried beans, seafood
  Deficiency : Beriberi - muscular weakness, swelling of the heart, and leg cramps.

- **Riboflavin (B_2)**
  Functions : carbohydrate, fat and protein metabolism, mucous membranes.
  Sources : dairy products, green leafy vegetables, whole and enriched grains, beef, lamb, eggs.
  Deficiency : skin lesions and sensitivity to light, cheilosis disease

- **Niacin (B_3)**
  Functions : carbohydrate, fat and protein metabolism, maintenance of the GI system, blood circulation, nerve function, appetite regulation
  Sources : meat, fish, whole and enriched grains, beans, nuts, peas.
  Deficiency : Pellagra - sunburn-like eruption of the skin.

- **Pyridoxine (B_6)**
  Functions : carbohydrate and protein metabolism,formation of antibodies and red blood cells nerve function.
  Sources : fish, poultry, lean meat, whole grains, potatoes.
  Deficiency : skin disorders, kidney stones.

- **Folate/Folic Acid**
  Functions : red blood cell formation, protein metabolism, cell division and growth.
  Sources : green leafy vegetables, dried beans, poultry, fortified cereals, oranges, nuts.
- **Cyanocobalamine (B_{12})**
  Functions : carbohydrate, fat and protein metabolism, maintenance of the nervous system, blood cell formation.
  Sources : beef, fish, poultry, eggs, dairy products
  Deficiency : anaemia
- **Pantothenic Acid**
  Functions : energy production, vitamin utilization, nerve function
  Sources : plant and animal foods, whole grains, legumes
- **Biotin**
  Functions : carbohydrate, fat and protein metabolism, fatty acid production
  Sources : egg yolk, meat, dairy products, dark green vegetables
- **Choline**
  Functions : cardiovascular and brain function, cellular membrane composition and repair
  Sources : beef liver, egg yolks, peanuts, sunflower seeds

Minerals

- Minerals are atoms of certain chemical elements that are essential for body processes.
- Minerals are *inorganic*.
- They are either produced by our body, or we obtain them by eating certain foods that contain them.
- They are ions found in blood plasma and cell cytoplasm, such as sodium, potassium, and chloride.
- In addition, minerals represent much of the chemical composition of bones (calcium, phosphorus, oxygen).
- They also contribute to nerve and muscle activity (sodium, potassium, calcium). Minerals serve several many other functions as well.
- There are 21 minerals considered essential for our bodies. Nine of the essential minerals in the body account for less than .01% of your body weight. Because of the small amount of these minerals that our body needs, we call them *trace minerals*.

Important minerals

- **Calcium**
  Functions : essential for healthy bones and teeth, regulates muscle action, nerve function, blood clotting
  Sources : dairy products, calcium fortified orange juice, green leafy vegetables.
- **Chromium**
  Functions : essential for glucose metabolism, increases effectiveness of insulin, muscle function.
  Sources : cheese, whole grains, meat, peas, beans.
- **Copper**
  Functions : formation of red blood cells, pigment, essential for bone health.
  Sources : nuts, dried beans, oysters, cocoa.
- **Fluoride**
  Functions : hardens tooth enamel, decreases tooth cavities.
  Sources : fluoridated water, toothpaste.
- **Iodine**
  Functions : essential for thyroid gland function.
  Sources : seafood, iodized salt.
- **Iron**
  Functions : formation of hemoglobin.
  Sources : meat, fish, poultry, organ meats, beans, whole and enriched grains, green leafy vegetables.
- **Magnesium**
  Functions : enzyme activation, nerve and muscle function, bone growth.
  Sources : nuts, green vegetables, whole grains, beans.

- **Manganese**
  Functions : bone growth and development, sex hormone production, cell function.
  Sources : nuts, whole grains, vegetables, fruits, tea, coffee, bran.
- **Molybdenum**
  Functions : kidney and liver function, essential in the storage of iron, growth.
  Sources : meats, whole grain, peas, beans, green leafy vegetables.
- **Phosphorus**
  Functions : bone development, carbohydrate, fat and protein utilization.
  Sources : meat, poultry, fish, eggs, dairy products, beans, whole grains.
- **Selenium**
  Functions : fights cell damage.
  Sources : seafood, lean meat, grains, eggs, chicken, garlic.
- **Zinc**
  Functions : regulation of metabolism, aids in healing.
  Sources : meat, eggs, seafood, whole grains, dairy products.
- **Potassium**
  Functions : fluid balance, controls activity of the heart, nervous system function.
  Sources: vegetables and fruits, beans, bran, dairy products.
- **Sodium**
  Functions : fluid balance, transmission of nerve impulses.
  Sources : salt.

Water

- Water is an important constituent of our diet. 75% of an infant body and 60% of an adult body is nothing but water. Various functions of water are as follows.
- Essential for the transport and digestion of food material.
- Excretes wastes.
- Maintains the body temperature.
- As solvent in various reactions in the body.

Roughage

Roughage is the fibre present in some food items like fruits and vegetables. Though roughage is not a food, it forms an important part of our diet. Roughage consists mainly of cellulose.

Function

- It helps in bowel movement.
- It cleans our digestive tracts and protects from digestive ailments.
- It prevents constipation.
- It helps in retaining water in the body.
- It helps in maintaining optimum levels of blood sugar and cholesterol.

Experimental tests :

Benedict test

- Test to confirm reducing properties of sugars.
- Add a few drops of benedict solution into the sugar and boil. If it shows a brickred precipitate, a reducing sugar is present. Since Cu^{+2} is reduced to Cu^{+1}, it shows are brick red precipitate

Biuret test

- Test to confirm the contents of protein or the presence of protein.
- Add an equal amount of protein and biuret reagent. A purple-violet color would confirm the presence of proteins. This can be used as a qualitative test since the color is gets more intense as the protein content increases.

Sudan III test

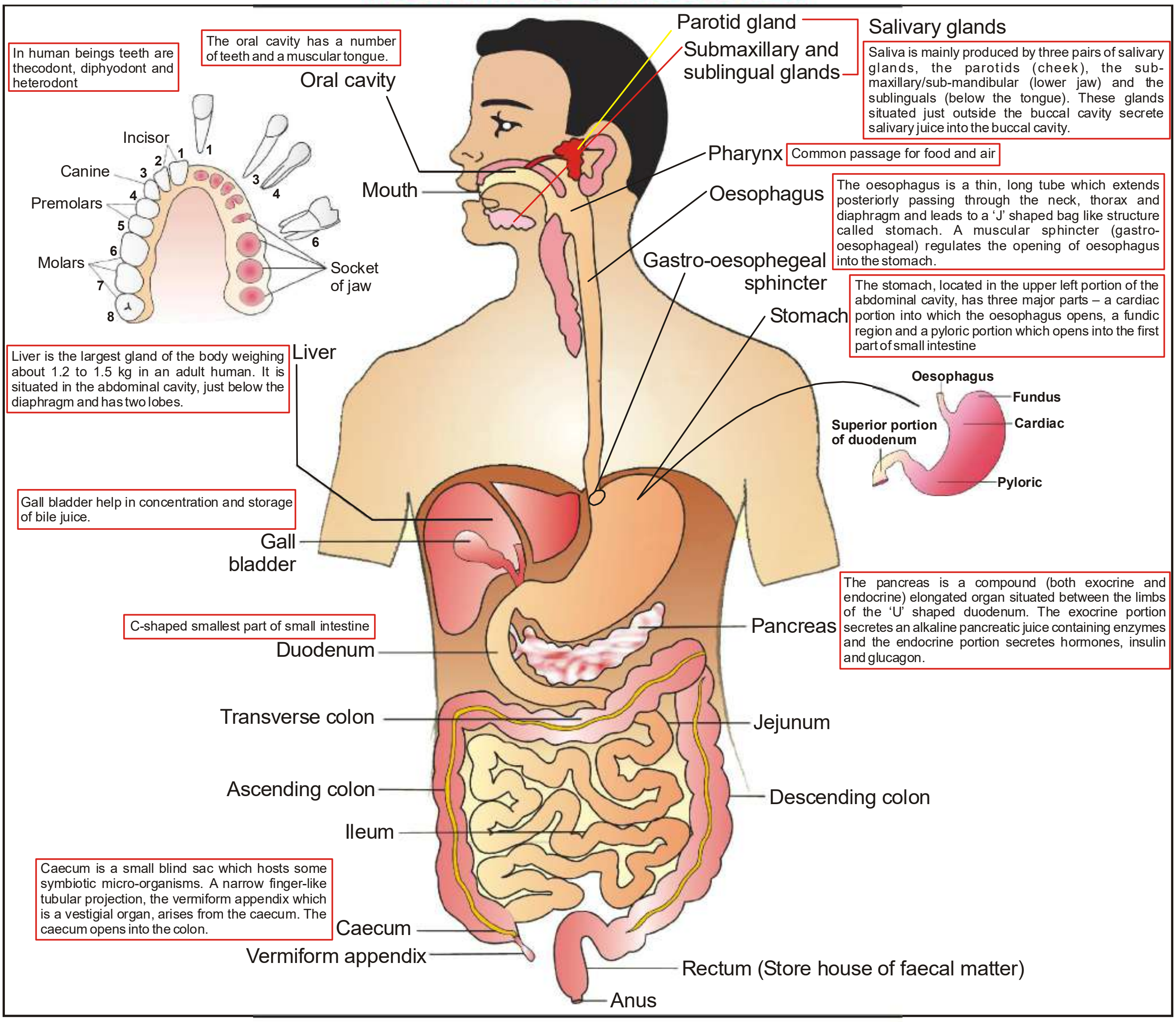
- To test the presence of fat.
- Add equal amount of Sudan III and fat contents together. A suspension of red liquid and white precipitate on the top would confirm that there is fat present.

GASTROINTESTINAL SYSTEM OR THE DIGESTIVE SYSTEM

- The Gastrointestinal System is responsible for the breakdown and absorption of various foods and liquids needed to sustain life.
- Many different organs have essential roles in the digestion of food, from the mechanical disrupting of the teeth to the creation of bile (an emulsifier) by the liver.
- Bile production of the liver plays a important role in digestion: from being stored and concentrated in the gallbladder during fasting stages to being discharged to the small intestine.
- During digestion two main processes occur at the same time.
- Mechanical digestion: larger pieces of food get broken down into smaller pieces while being prepared for chemical digestion. Mechanical digestion starts in the mouth and continues into the stomach.
- Chemical digestion: starts in the mouth and continues into the intestines. Several different enzymes break down macromolecules into smaller molecules that can be absorbed.
- The GI tract starts with the mouth and proceeds to the oesophagus, stomach, small intestine (duodenum, jejunum, ileum), and then to the large intestine (caecum, colon, rectum) and terminates at the anus.

DIGESTION AND ABSORPTION

HUMAN DIGESTIVE SYSTEM



Accessory Organs

1. **Salivary glands**

(a) Parotid gland (b) Submandibular gland (c) Sublingual gland

- The three glands (parotid, submandibular, and sublingual) produce varying amounts of salivary components.
- Salivary glands also produce an estimated 1-1.5 liters of saliva per day.
- The pH of this fluid is from 6.35 to 6.85,supporting the action of salivary amylase to begin the breakdown of polysaccharides to shorter chains. The action does not normally progress very far due to the short exposure to active enzyme.

2. **Tongue**

- Tongue is a muscular structure that has the organs of taste reception.
- The upper surface is rough due to the presence of multiple small elevated structures called papillae. There are four types of papillae-filiform (thread-shaped), fungiform (shaped like mushroom), circumvallate (circular) and foliate (leaf-shaped).
- Taste buds which are specialized cells responsible for appreciating different tastes are present on all the papillae except the filiform papillae.
- The under surface of the tongue is anchored to the floor of the mouth by a fold of mucous membrane called the frenulum.

3. **Teeth**

- An individual tooth consists of an exposed crown and a root, buried in the gum and jaw.
- The crown is usually at least partly covered by an outer layer of an especially hard substance related to bone called enamel.
- Beneath the enamel (and sometimes exposed to the surface if the enamel is missing or worn away) is an intermediate layer of material called dentine, which is also similar to bone but is not nearly as hard as enamel.
- It surrounds an inner pulp cavity filled with pulp (a living, vascular and well innervated tissue).
- Blood vessels and nerves reach the pulp cavity through a channel, the root canal, that penetrates the root. An additional layer of bony material, cementum, usually surrounds the root.

4. **Liver**

- Produces and excretes bile required for emulsifying fats. Some of the bile drains directly into the duodenum and some is stored in the gall bladder.
- Helps metabolize proteins, lipids, and carbohydrates.
- Gluconeogenesis (the formation of glucose from certain amino acids, lactate or glycerol)
- Glycogenolysis (the formation of glucose from glycogen)
- Glycogenesis (the formation of glycogen from glucose).
- Urea, chief end product of mammalian metabolism, is formed in liver from amino acids and compounds of ammonia.
- Breaks down insulin and other hormones.
- Produces coagulation factors.

Bile is produced in the liver and stored in the gallbladder, released in response to CCK. Bile salts (salts of cholic acid) act to emulsify fats, i.e. to split them so that they can mix with water and be acted on by lipase.

5. **Gall bladder**

Bile storage

6. **Pancreas**

- The pancreas is composed of pancreatic exocrine cells, whose ducts are arranged in clusters called acini (singular acinus).
- Exocrine functions: Digestive enzyme secretion.
- The cells are filled with secretory granules containing the precursor digestive enzymes (mainly trypsinogen, chymotrypsinogen, pancreatic lipase, and amylase) that are secreted into the lumen of the acinus. These granules are termed zymogen granules
- Stores zymogens (inactive enzymes) that will be activated by the brush border membrane in the small intestine when a person eats protein (amino acids).
- Trypsinogen - Trypsin: digests protein.
- Chymotrypsinogen - Chymotrypsin: digests proteins.

- Carboxypeptidases: digests proteins.
- Lipase : digests fats.
- Amylase: digests carbohydrates.
- Endocrine functions: Scattered among the acini are the endocrine cells of the pancreas, in groups called the islets of Langerhans. They are :
- Insulin-producing beta cells (50-80% of the islet cells)
- Glucagon-releasing alpha cells (15-20%)
- Somatostatin-producing delta cells (3-10%)
- Pancreatic polypeptide-containing PP cells (remaining %)
- Somatostatin: inhibits the function of insulin. Produced if the body is getting too much glucose.
- Glucagon: stimulates the stored glycogen in the liver to convert to glucose. Produced if the body does not have enough glucose.
- Insulin: synthesize in the beta cells of the Islets of Langerhans of the pancreas. Insulin is a hormone that regulates blood glucose.

7. Vermiform appendix.

ALIMENTARY CANAL

- The alimentary canal is the long tube of organs that runs from the mouth (where the food enters) to the anus (where indigestible waste leaves).
- The organs in the alimentary canal include the oesophagus, stomach and the intestines.
- The average adult digestive tract is about thirty feet (30') long.
- The bolus of food is swallowed in a process called **deglutition** which begins as voluntary and becomes involuntary.
- The pharynx, which is the body cavity that is common to both the digestive and respiratory systems behind the mouth, is about five inches (5") long. A small flap of skin called the epiglottis closes over the pharynx to prevent food from entering the trachea and thus choking.

Oesophagus

- The oesophagus is lined by a stratified squamous epithelium.
- It connects the pharynx, with the stomach, where the second stage of digestion is initiated (the first stage is in the mouth with teeth and tongue masticating food and mixing it with saliva).
- Peristalsis (involuntary wavelike longitudinal muscle contractions along the G.I. tract) moves the food from the oesophagus and pushes it down into the stomach.
- At the end of the oesophagus there is a sphincter muscle that allows food into the stomach then closes back up so the food cannot travel back up into the oesophagus.

Stomach

The stomach is composed of several regions and structures -

1) The gastroesophageal region(cardiac).
2) The fundus, the blind portion of the stomach above its junction with the oesophagus. This portion is thin walled compared to the rest of the stomach and has few secretory cells. As the bolus of food enters this area first some action of salivary amylase may continue briefly.
3) The body of the stomach. This is where extensive gastric pits are located which possess the secretory cells of the stomach. Parietal cells secrete hydrochloric acid; chief cells secrete pepsinogen; goblet cells secrete mucus; argentaffin cells secrete serotonin and histamine; and G cells secrete the hormone gastrin.
4) The pylorus. This narrowed region leads through the pyloric sphincter into the duodenum.

- 3-layered muscularis - an oblique layer in addition to the longitudinal and transverse layers. The three layers produce a churning and liquefying effect on the chyme in the stomach.
- Two smooth muscle valves, or sphincters, keep the contents of the stomach contained. They are the: 1) Cardiac or oesophageal sphincter, dividing the tract above, and 2) Pyloric sphincter, dividing the stomach from the small intestine.

- Enteroendocrine cells produce a number of hormone substances including gastrin, histamine, endorphins, serotonin and somatostatin. Cells lining the gastric pits are arranged in circular acini in the stomach called gastric glands.

Processes occurring in the stomach:

1) Storage - the stomach allows meal to be consumed and the materials released incrementally into the duodenum for digestion. It may take up to four hours for food from a complete meal to clear the stomach.
2) Chemical digestion - pepsin begins the process of protein digestion cleaving large polypeptides into shorter chains .
3) Mechanical digestion - the churning action of the muscularis causes liquefaction and mixing of the contents to produce acid chyme.
4) Some absorption - water, electrolytes, monosaccharides, and fat soluble molecules including alcohol are all absorbed in the stomach to some degree.

- Peptic ulcer is the name given to damage to lining cells due to stomach acid. The greatest proportion of peptic ulcers actually occur in the duodenum. A bacterium, Helicobacter pylori, has been associated with many ulcers.
- Increased histamine secretion may reflect the relationship of ulcers to stress.

Control of secretion and motility

- The movement and the flow of chemicals into the stomach are controlled by both the nervous system and by the various digestive system hormones.
- The hormone gastrin causes an increase in the secretion of HCL, pepsinogen and intrinsic factor from parietal cells in the stomach. It also causes increased motility in the stomach. Gastrin is released by G-cells into the stomach. It is inhibited by pH normally less than 4 (high acid), as well as the hormone somatostatin.
- Cholecystokinin (CCK) has most effect on the gall bladder, but it also decreases gastric emptying.
- Gastric inhibitory peptide (GIP) and enterogastron decrease both gastric motility and secretion of pepsin. Other than gastrin, these hormones act to turn off the stomach action.
- Secretin is also an enterogastrone. Its major function, however, is to stimulate the release of bicarbonate from the pancreas. It is released into the bloodstream in response to acid chyme entering the duodenum.

Small Intestine

- The three main sections of the small intestine is Duodenum, Jejunum, Ileum
- Duodenum is the shortest part of the small intestine,where the bile and pancreatic juices enter the intestine.
- The duodenum is the only portion with Brunner's glands in its submucosa which produce an alkaline mucus.
- The inner surface of the jejunum, its mucous membrane, is covered in projections called villi, which increase the surface area of tissue available to absorb nutrients from the gut contents.
- The ileum has Peyer's Patches, concentrated lymph tissue in the submucosa. Ileum function is to absorb vitamin B_{12} and bile salts.

Large Intestine

- The large intestine (colon) extends from the end of the ileum to the anus.
- It is about 5 feet long, being one-fifth of the whole extent of the intestinal canal.
- The large intestine is divided into the caecum, colon, rectum, and anal canal.
- There are trillions of bacteria, yeasts, and parasites living in our intestines, mostly in the colon.
- Helpful organisms synthesize vitamins, like B_{12}, biotin, and vitamin K. They breakdown toxins and stop proliferation of harmful organisms.
- There are many beneficial bacteria but some of the most common and important are Lactobacillus Acidophilus and various species of Bifidobacterium.

Anus

- The human anus is situated between the buttocks. It has two anal sphincters, one internal, the other external.
- These hold the anus closed until defecation occurs. One sphincter consists of smooth muscle and its action is involuntary; the other consists of striated muscle and its action is voluntary.

Enzyme	Produced In	Site of Release	pH Level
Carbohydrate Digestion :			
Salivary amylase	Salivary glands	Mouth	Near neutral [pH = 6.8]
Pancreatic amylase	Pancreas	Small intestine	Basic
Maltase	Small intestine	Small intestine	Basic
Sucrase	Small intestine	Small intestine	Basic
Lactase	Small intestine	Small intestine	Basic
Protein Digestion :			
Pepsin	Gastric glands	Stomach	Acidic
Trypsin	Pancreas	Small intestine	Basic
Chymotrypsin	Pancreas	Small intestine	Basic
Peptidases	Small intestine	Small intestine	Basic
Nucleic Acid Digestion :			
Nucleases	Pancreas	Small intestine	Basic
Nucleosidases	Pancreas	Small intestine	Basic
Fat Digestion :			
Lipase	Pancreas	Small intestine	Basic

Disorders of digestive system:

- **Hemorrhoids :** Hemorrhoids (also known as haemorrhoids, emerods, or piles) are varicosities or swelling and inflammation of veins in the rectum and anus.
- **Gastrointestinal Stromal Tumors** or GIST is an uncommon type of cancer in the GI tract (oesophagus, stomach, small intestine, and colon).
- **Hepatitis** is a viral condition that inflames a person's liver which can cause it to lose it's ability to function.
- **Cystic fibrosis** is a chronic, inherited illness where the production of abnormally thick mucous blocks the duct or passageways in the pancreas and prevents the digestive fluids from entering the intestines, making it difficult for the person with the disorder to digest protein and fats which cause important nutrients to pass through without being digested.

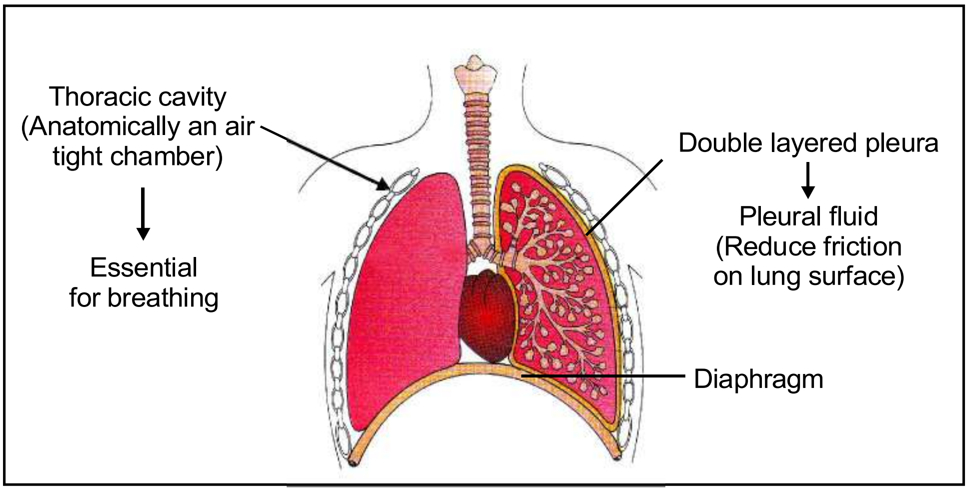
RESPIRATORY SYSTEM

- The respiratory tract is the path of air from the nose to the lungs.
- It is divided into two sections: Upper Respiratory Tract and the Lower Respiratory Tract.
- Included in the upper respiratory tract are the Nostrils, Nasal Cavities, Pharynx, Epiglottis, and the Larynx. The lower respiratory tract consists of the Trachea, Bronchi, Bronchioles, and the Lungs.

Parts of the Upper Respiratory Tract

- **Mouth, nose & nasal cavity :** The function of this part of the system is to warm, filter and moisten the incoming air
- **Pharynx :** The pharynx is also called the throat. As we saw in the digestive system, the epiglottis closes off the trachea when we swallow. Below the epiglottis is the larynx or voice box.
- **Larynx :** This contains 2 vocal cords, which vibrate when air passes by them. With our tongue and lips we convert these vibrations into speech. The area at the top of the trachea, which contains the larynx, is called the glottis

HUMAN RESPIRATORY SYSTEM



Parts of the Lower Respiratory Tract

Trachea :

- It ranges from 20-25mm in diameter and 10-16cm in length.
- The inner membrane of the trachea is covered by tiny hairs called cilia, which catch particles of dust which we can then remove it through coughing.
- The trachea is surrounded by 15-20 C-shaped rings of cartilage at the front and side which help protect the trachea and keep it open.
- They are not complete circles due to the position of the oesophagus immediately behind the trachea and the need for the trachea to partially collapse to allow the expansion of the oesophagus when swallowing large pieces of food.

Bronchi :

- The trachea divides into two tubes called bronchi, one entering the left and one entering the right lung.
- The left bronchi is narrower, longer and more horizontal than the right.
- Irregular rings of cartilage surround the bronchi, whose walls also consist of smooth muscle.
- Once inside the lung the bronchi split several ways, forming tertiary bronchi.

Bronchioles

- Tertiary bronchi continue to divide and become bronchioles, very narrow tubes, less than 1 millimeter in diameter.
- There is no cartilage within the bronchioles and they lead to alveolar sacs.

Alveoli

- Individual hollow cavities contained within alveolar sacs (or ducts).
- Alveoli have very thin walls which permit the exchange of gases - Oxygen and Carbon Dioxide.
- They are surrounded by a network of capillaries, into which the inspired gases pass. There are approximately 300 million alveoli within an average adult lung.

Diaphragm

- The diaphragm is a broad band of muscle which sits underneath the lungs, attaching to the lower ribs, sternum and lumbar spine and forming the base of the thoracic cavity.

LUNGS

- The lungs are spongy structure where the exchange of gases takes place.
- Each lung is surrounded by a pair of pleural membranes.
- Between the membranes is pleural fluid, which reduces friction while breathing.
- The lungs give up their oxygen to the capillaries through the alveoli.
- All pressures in the respiratory system are relative to atmospheric pressure (760mmHg at sea level).
- Air will move in or out of the lungs depending on the pressure in the alveoli.
- The body changes the pressure in the alveoli by changing the volume of the lungs. As volume increases pressure decreases and as volume decreases pressure increases.

The four processes of respiration

1. **BREATHING or ventilation-**Ventilation is the exchange of air between the external environment and the alveoli.
2. **EXTERNAL RESPIRATION,** which is the exchange of gases (oxygen and carbon dioxide) between inhaled air and the blood.
3. **INTERNAL RESPIRATION,** which is the exchange of gases between the blood and tissue fluids.
4. **CELLULAR RESPIRATION**

The Pathway

- Air enters the nostrils
- passes through the nasopharynx,
- the oral pharynx
- through the glottis
- into the trachea
- into the right and left bronchi, which branches and rebranches into
- bronchioles, each of which terminates in a cluster of alveoli

Inspiration(Inhalation)

- Active process
- Inspiration is initiated by contraction of the diaphragm and in some cases the intercostal muscles when they receive nervous impulses.
- During normal quiet breathing, the phrenic nerves stimulate the diaphragm to contract and move downward into the abdomen. This downward movement of the diaphragm enlarges the volume of the thoracic cavity.
- When necessary, the intercostal muscles also increase the thorax by contacting and drawing the ribs upward and outward.

Expiration (Exhalation)

- During quiet breathing, expiration is normally a passive process and does not require muscles to work.
- When the lungs are stretched and expanded, stretch receptors within the alveoli send inhibitory nerve impulses to the medulla oblongata, causing it to stop sending signals to the rib cage and diaphragm to relax and rise.
- Expiration happens as the diaphragm relaxes. When under physical or emotional stress, more frequent and deep breathing is needed, both inspiration and expiration will work as active processes. Additional muscles in the rib cage forcefully contract and push more air out of the lungs.

In order for the larynx to function and produce sound, we need air. That is why we can't talk when we're swallowing.

The length to which the vocal cords are stretched determines what pitch the sound will have. The strength of expiration from the lungs also contributes to the loudness of the sound.

Homeostasis

- Homeostasis is maintained by the respiratory system in two ways: gas exchange and regulation of blood pH.

External Respiration

- External respiration is the exchange of gas between the air in the alveoli and the blood within the pulmonary capillaries.
- A normal rate of respiration is 14-18 breaths per minute.
- In external respiration, gases diffuse in either direction across the walls of the alveoli. Oxygen diffuses from the air into the blood and carbon dioxide diffuses out of the blood into the air.
- Most of the carbon dioxide is carried to the lungs through plasma as bicarbonate ions (HCO_3^-).
- When blood enters the pulmonary capillaries, the bicarbonate ions and hydrogen ions are converted to carbonic acid (H_2CO_3) and then back into carbon dioxide (CO_2) and water. This chemical reaction also uses up hydrogen ions. The removal of these ions gives the blood a more neutral pH, allowing hemoglobin to bind up more oxygen.

Internal Respiration

- Internal respiration is the exchanging of gases at the cellular level.
- It is in the mitochondria of the cells where oxygen is actually consumed and carbon dioxide produced.
- Oxygen is produced as it combines with hydrogen ions to form water at the end of the electron transport chain.

Lung Capacity

- The normal volume moved in or out of the lungs during quiet breathing is called tidal volume. Its value is 500 mL.
- Breathing very deeply is **Inspiratory Reserve Volume** and can increase lung volume by 3000 mL.
- We can also increase expiration by contracting our thoracic and abdominal muscles. This is called Expiratory Reserve Volume and is about 1100 ml of air.
- **Vital capacity** is the total of tidal, inspiratory reserve and expiratory reserve volumes; it is called vital capacity because it is vital for life, and the more air you can move, the better off you are.Its value is 500 + 3000 + 1100 = 4600mL.
- Some air that we breathe never even reaches the lungs! Instead it fills our nasal cavities, trachea, bronchi, and bronchioles. These passages aren't used in gas exchange so they are considered to be **dead air space.** (150mL).
- Even when we exhale deeply some air is still in the lungs,(about 1200 ml) and is called **Residual Volume**. This air isn't useful for gas exchange.

Stimulation of Breathing

- There are two pathways of motor neuron stimulation of the respiratory muscles. The first is the control of voluntary breathing by the cerebral cortex. The second is involuntary breathing controlled by the medulla oblongata.
- There are chemoreceptors in the aorta, the carotid arteries, and in the medulla oblongata of the brainstem that are sensitive to pH.
- As carbon dioxide levels increase there is a buildup of carbonic acid, which releases hydrogen ions and lowers pH. Thus, the chemoreceptors do not respond to changes in oxygen levels (which actually change much more slowly), but respond to changes in pH, which is an indirect measure of carbon dioxide levels.

- In other words, CO_2 is the driving force for breathing. The receptors in the aorta and the carotid arteries stimulate an immediate increase in breathing rate and the receptors in the medulla stimulate a sustained increase in breathing until blood pH returns to normal.

Problems Associated With the Respiratory Tract and Breathing

- **Carbon Monoxide Poisoning :** caused when carbon monoxide binds to haemoglobin in place of oxygen. Carbon monoxide binds much tighter, without releasing, causing the haemoglobin to become unavailable to oxygen. The result can be fatal in a very short amount of time.
- **"Strep throat"** is a primary bacterial infection and can lead to an upper respiratory infection that can be generalized or even systemic (affects the body as a whole).
- **Asthma** is an allergic respiratory disease of the bronchi and bronchioles.
- **Hyperventilation:** excessive rate and depth of breathing causing the blood pH to increase
- **Emphysema :** a chronic lung disease, in which the delicate walls of the alveoli break down, reducing the gas-exchange area of the lungs. Its often caused by exposure to toxic chemicals or long-term exposure to tobacco smoke
- **Pneumonia :** bacterial or viral infection in the lungs where the bronchi and the alveoli fill with a thick fluid

TRANSPORTATION IN PLANTS AND ANIMALS

MECHANISMS FOR MOVEMENT OF MOLECULES

- Molecules move in and out of a cell through the cell membrane, which forms the boundary of each cell.
- The cell membrane is selectively permeable to substances, which means that it permits entry and exit of certain molecules only.
- The movement of molecules takes place by diffusion, osmosis, and active transport.

Diffusion

- Movement of particles or molecules from a region of their higher concentration to a region of their lower concentration is termed diffusion.
- For example, during respiration, oxygen-laden air in lungs being at a higher concentration moves into blood capillaries having lower concentration of oxygen in them

Osmosis

- Osmosis is the movement of water molecules from a region having more water molecules (low solute cocentration) to a region having less water molecules (high solute concentration) when separated by a semipermeable membrane.
- No energy is spent during diffusion or osmosis.

Active transport

- In active transport, molecules have to move (against concentration gradient) i.e., from a region of their lower concentration to a region of their higher concentration. Energy is required in active transport

TRANSPORT OF MATERIALS IN PLANTS

Transport of water

- Tracheids and vessels, which are non-living cells of xylem, transport water picked up by root hairs from soil to the leaves.
- Root pressure: a pressure developed in the tracheary elements of xylem as a result of metabolic activities of the root.
- The upward movement of water and minerals termed 'ascent of sap' is against gravity and is due to transpiration pull.
- Transpirational theory or Cohension tension theory was given by Dixon and Jolly in 1894 to explain ascent of sap.

Transport of food material :

Transport of food material from leaves to other parts of the plant is called translocation. This food may be stored in fruits, stem or roots.

TRANSPORT OF MATERIALS IN ANIMALS

Human circulatory system

Human circulatory system consists of

1. Blood Vessels 2. Heart 3. Blood.

1. Blood vessels are of three kinds :

Arteries :

Structure : Thick, elastic

Contain layers of connective, and smooth muscle tissues

DO NOT CONTAIN VALVES

Function: Carry Blood AWAY from the heart.

The aorta is the largest of the arteries in the systemic circuit.

Arteries divide to form very small arteries called arterioles.

Veins :

Structure : Thin and slightly elastic.

Contain VALVES for one way flow of blood.

Function: return blood TO the heart

Veins divide to become venules.

Capillaries :

Structure: Microscopic blood vessels that connect arterioles and venules.

Thin walled and narrow

Blood cells pass through them in single file

Function: Allows material and gas exchange between the body cells and the blood.

2. THE HEART

Structure

- A four chambered muscular organ located in the chest cavity of human.
- Made of Cardiac muscle.
- It is Covered by a **Pericardium** that protects it.

Functions of Heart Structures

1. Inferior/Superior Vena Cava: Returns deoxygenated blood to the right atrium from the body.
2. Right Atrium: Thin walled chamber of the heart that receives deoxygenated blood from the body.
3. Right Ventricle: Muscular chamber that pumps blood TO the lungs.
4. Tricuspid valve: Controls the flow of blood entering the right ventricle from the right atrium.
5. Bicuspid Valve: A valve that controls the flow of blood from the left atrium to the left ventricle. Also called mitral valve
6. Semilunar Valves: Valves that control the flow of blood out of the heart. Present at opening of pulmonary artery & aorta.
7. Pulmonary Arteries: Arteries that carry blood TO the lungs.
8. Pulmonary Veins: Veins that bring blood to the heart from the lungs.
9. Left Atrium: Thin walled chamber that receives oxygenated blood from the lungs.
10. Left Ventricle: Thick walled chamber that pumps blood out of the heart and to the body.
11. Aorta: Large artery that carries blood away from the heart and to all parts of the body.
12. Septum: A wall of muscle that separates the left side of the heart from the right side. This prevents the mixing of oxygenated and deoxygenated blood.
13. Chordae Tendonae: Control the opening and closing of the Tricuspid and Bicuspid (Mitral) valves.

Blood Flow through the Heart

- Deoxygenated blood from the body enters the right Atrium via the Inferior and Superior Vena Cava.
- Here the blood is passed through the tricuspid valve to the right ventricle. The right ventricle contracts and forces blood up through the Semilunar valves and out through the left and right pulmonary arteries. This brings blood to the lungs to be oxygenated.
- Oxygenated blood from the lungs returns to the heart via the left and right pulmonary veins to the left atrium.
- The blood is passed to the left ventricle through the bicuspid valve. The left ventricle contracts and pushes blood through the Semilunar valves and out through the aorta to the body.

THE HEARTBEAT CYCLE

The human heartbeat occurs in two main stages.

These two stages are:

a. Diastole

- The stage where the heart is Relaxing
- During this stage the A-V valves (bicuspid, tricuspid) are open and the semilunar valves close. The ventricles are filled with blood.

b. Systole

- The stage where the heart is Contracting
- During this stage the ventricles contract. This causes the A-V valves to close and the semilunar valves to open. Blood is forced out through the semilunar valves to the lungs and body.

The "LubDub" sound of the Heartbeat

The "LubDub" sound of the heartbeat is caused by the closing of the heart's valves.

Lub Sound -- caused by the closing of the A-V valves (tricuspid, bicuspid).

Dub Sound -- caused by the closing of the semilunar valves.

Cardiac Cycle

- Cardiac cycle is the term used to describe the relaxation and contraction that occur, as a heart works to pump blood through the body.
- Heart rate is a term used to describe the frequency of the cardiac cycle.
- It is the number of contractions (heart beats) of the heart in one minute and expressed as "beats per minute" (bpm). When resting, the adult human heart beats at about 70 bpm (males) and 75 bpm (females).

Cardiac output -the amount of blood ejected by the heart per unit time.

Heart Conduction System

- The sinoatrial node (SAN), located within the wall of the right atrium (RA), normally generates electrical impulses that are carried by special conducting tissue to the atrioventricular node (AVN).
- Upon reaching the AVN, located between the atria and ventricles, the electrical impulse is relayed down conducting tissue (Bundle of HIS) that branches into pathways that supply the right and left ventricles.
- These paths are called the right bundle branch(RBBB) and left bundle branch (LBBB) respectively.
- The SAN is known as the "heart's pacemaker" because electrical impulses are normally generated here. At rest the SAN usually produces 60-70 signals a minute.
- If the SAN fail to produce impulses the AVN can take over. The resting rate of the AVN is slower, generating 40-60 beats a minute.
- The Bundle of HIS can generate 30-40 signals a minute. Ventricular muscle cells may generate 20-30 signals a minute.

CONTROL OF THE HEARTBEAT

- The heart is caused to beat regularly by a structure called the Sinoatrial Node (S - A node) or the PACEMAKER.
- An electrical impulse from the brain is received by the S-A node(pacemaker) in the right atrium.
- The SA node sends a signal to the A-V node (atrioventricular node) in the right atrium. This electrical impulse causes the heart (ventricles) to contract.
- The pacemaker controls the heartbeat for a human from the time they are born until they die or the pacemaker gives out.

CONTROL OF THE HEART RATE

The heart rate (speed) at which the heart beats is controlled by two nerves.

- Medulla Oblongata (Sometimes called the Cardioaccelerator nerve):Nerve in the brain that causes the heart to speed up when needed.
- Vagus nerve: Nerve in the brain that causes the heart to slow down when needed.

The medulla sends a message to the SA node to cause an impulse to be sent to the AV node causing the heart to contract more or less in an attempt to set the heart rate.

BLOOD PRESSURE

Blood Pressure : A measure of the pressure of blood exerts on the walls of blood vessels. Blood pressure is measured using a blood pressure cuff or Sphygmomanometer.

It measures the pressure in an artery while the heart is contracting (systolic pressure) and the pressure while the heart is resting (diastolic pressure).

Systolic Pressure

Systolic Pressure is the highest when the blood is being pumped out of the left ventricle into the aorta during ventricular systole. The average high during systole is 120 mm Hg.

Diastolic Pressure

Diastolic blood pressure lowers steadily lowers to a low of 80 mm Hg during ventricular diastole.

A simple fraction is calculated using the following formula:

$$\text{Blood Pressure} = \frac{\text{Systolic pressure}}{\text{Diastolic pressure}}$$

DIVISIONS OF CIRCULATION

There are two types of circulation that happen in the human organism.

1. Pulmonary Circulation
2. Systemic circulation

1. Pulmonary circulation

This is circulation of blood from the heart to the lungs and vice versa.This type of circulation adds oxygen and removes carbon dioxide from the blood.

2. Systemic circulation

This is circulation of blood between the heart and the body.This type of circulation brings blood to the cells and from the cells.

Systemic circulation has three subdivisions. They are:

(A) Coronary circulation is circulation that supplies blood and nutrients directly to the heart muscle.

(B) Hepatic - portal circulation is circulation that carries nutrients and blood from the digestive system to the liver to maintain glucose levels in the body.

(C) Renal Circulation is circulation that carries blood to and from the kidneys so that nitrogenous wastes may be removed from the blood and excreted by the kidneys.

3. BLOOD

Fluid found in the circulatory system of humans that carries nutrients and Oxygen to the cells and carries wastes (carbon dioxide) away from the cells. Helps to control and regulate body temperature as well.

Components of blood

There are two components to blood :

A. Plasma

B. Blood Cells

A. Plasma

- The liquid part of blood.
- Makes up 55% of the volume of blood.92% water and 7% proteins, 1 % dissolved solutes. Plasma has three proteins in it.

i) Albumins - Keeps water from leaving the blood.

ii) Fibrinogen - Used for blood clotting.

iii) Globulins - Transport proteins around the body. Some are antibodies.

Antibody : Proteins that binds to and helps destroy a foreign substance in the body.

B. Blood Cells

Three types:

Red Blood Cells (RBC's)

White Blood Cells (WBC's)

Platelets

(i) Red Blood Cells - called Erythrocytes

- Human blood contains about 5-5.5 million RBC's.
- DO NOT contain Nuclei (NONNUCLEATED)
- Formed by the bone marrow - stem cells.
- Life span - 120 day
- double concave shaped
- Contain a protein called haemoglobin.
- Worn out RBC's are removed by the liver and spleen.

Haemoglobin:

A protein found in the blood that is made up of IRON. It carries oxygen to the cells and removes CO_2.Composed of an Alpha and Beta Chain with 2 Haeme (Iron) groups on each chain. The Haeme groups bind to and attach Oxygen and CO_2.

Function of RBC's: Transport oxygen to cells from the lungs.

Transport carbon dioxide from the cells to the lungs.

(ii) White Blood Cells - called Leukocytes

- In the circulating blood 4,000 to 11,000 mm^3 WBCs are present
- Larger than RBC's
- have a nucleus
- less numerous than RBC's
- Can move on their own

There are five types of white blood cell

- neutrophils 40 - 75 %

- eosinophils 5 %
- basophils 0.5 %
- lymphocytes 20 - 50 %
- monocytes 1 - 5 %

Neutrophils, eosinophils and basophils are collectively known as granulocytes due to prominent granules in their cytoplasm.

I. Garnular WBC's

Neutrophils

- Neutrophils, which make up 65% of the body's white blood cells are the most numerous.
- Because they are phagocytic they are mainly found at the sites of wounds where they begin to form what eventually becomes a scab by glueing themselves to the walls of blood vessels and engulf any bacteria that try to get into the body through the site of the wound.

Eosinophils

- Eosinophils make up anywhere from 2-4% of the body's white blood cells and are mainly responsible for attacking parasites that enter the blood stream.

Basophils

- Response to specific allergens is rapid and results in expulsion of the cells granular contents which contain histamines and other vasodilating agents.

II. Non-Granular White Blood Cells

Lymphocytes

- Lymphocytes make up 20-25% of the body's white blood cells and are responsible for helping the body to develop immunity towards infections.
- Lymphocytes also produces antibodies, but unlike the Basophils these antibodies are designed specifically to target the excretions of harmful bacteria.
- They will also help the Neutrophils do their job by clustering the bacterium together so that they can be engulfed by the phagocytes easily.

Monocytes

- Monocytes make up 3-8% of the body's white blood cells and are much like stronger, larger versions of the neutrophils for they take on the bacteria that the Neutrophils are unable to handle.
- Monocytes are also phagocytic.

III. Platelets

- Small pieces of cells found in the blood.
- NO Nuclei
- Live about 7 days.

FUNCTION OF PLATELETS : Blood Clotting Process.

THE BLOOD CLOTTING PROCESS

Blood Clotting is actually a complicated chemical process. This is how it works.

When a blood vessel is ruptured the following happens:

Step 1:

Platelets rush to the area. They release an enzyme called Thromboplastin.

Step 2:

Thromboplastin causes prothrombin (a protein) to be converted in thrombin (enzyme).

$$\text{Prothrombin} \xrightarrow{\text{thromboplastin}} \text{Thrombin}$$

Step 3 :

Thrombin causes fibrinogen (found in blood plasma) to be changed into fibrin.

$$\text{Fibrinogen} \xrightarrow{\text{thrombin}} \text{Fibrin}$$

Step 4 :

Fibrin forms a net of fibres over the cut and traps red blood cells and platelets and forms a blood clot.

Circulatory System Disorders

1. **Hypertension -** High Blood Pressure

   Causes: diet, stress, inactivity

   Effects on body : Leads to heart disease and possible failure

2. **Arteriosclerosis -** Hardening of the Arteries

   Causes: Diet - High in Cholesterol (LDL) and Fats.

   Effect on body: Causes arteries to become inelastic which can reduce the amount of blood flow in them. This can lead to a heart attack and/or stroke.

3. **Atherosclerosis -** Narrowing of Arteries

   Causes: Fatty deposits within the artery walls from poor diet/fat intake etc.

   Effect on body: Narrowing of arteries reduces blood flow to heart and brain which may lead to heart attack and/or stroke.

4. **Stroke :-** Loss of blood flow to brain tissue causing cell death.

   Causes: Any one of the above and others

   Effect on Body: loss of brain function and/or motor control (paralysis), death.

5. **Coronary Blockage -** A blockage in the coronary arteries of the heart.

   Causes: Diet, lack of exercise

   Effect on Body: Heart attack, death.

THE LYMPHATIC SYSTEM

This is the part of the circulatory system that returns excess fluids to the blood from the body.

Parts of the Lymphatic System

1. Lymph
2. Lymph Nodes
3. Intercellular Fluid
4. Spleen

1. Lymph : The white vascular tissue

This is the fluid that is found within the lymphatic system.

It contains water, proteins and intercellular fluid.

2. Lymph Nodes

These are small glands at various locations in the body that filter foreign matter from the lymph. Foreign matter usually means bacteria, cancer cells and other disease causing organisms.

The Lymph nodes also contain White Blood Cells that fight off infection.If you have swollen lymph nodes then this is an indication that you may have an infection.

3. Intercellular Fluid

This is the fluid that is usually squeezed out of a capillary during normal cell activities.

It helps move materials between the cells and the capillaries.

It usually contains salt, water, proteins and nutrients.

4. Spleen

An organ near the stomach that contains lymph tissue.

Function: Filter out bacteria and worn out RBC's from the blood.

EXCRETORY SYSTEM

Excretion - Excretion is the removal of the metabolic wastes of an organism. Wastes that are removed include carbon dioxide, water, salt, urea and uric acid. All excreted wastes travel some time in the blood.

Function of the Excretory System

- The excretory system functions in getting rid off the body of nitrogenous (nitrogen-containing, discussed below) and other wastes.
- It also regulates the amount of water and ions present in the body fluids.

Organs of Excretion in various types of animals

- **Contractile Vacuoles** paramoecium
- **Flame Cells, Protonephridia**

  Planarians have two protonephridia composed of branched tubules that empty wastes through excretory pores on their surface.

  The protonephridia contain numerous bulblike flame cells with clustered, beating cilia that propel fluid into the tubules.

  These structures function in waste excretion and osmotic regulation.
- **Metanephridia**

  Earthworms have two metanephridia in almost all of the body segments.

  Each metanephridium consists of a tubule with ciliated opening (nephrostome) on one end and an excretory pore (nephridiopore) that opens to the outside of the body at the other end.

  Fluid is moved in by cilia. Some substances and water are reabsorbed in a network of capillaries that surround the tubule.

  This system produces large amount of urine (60% of body wt./day).
- **Malpighian Tubules**

  The excretory organs of insects are malpighian tubules.

  They collect water and uric acid from surrounding hemolymph (blood) and empty it into the gut.

  Water and useful materials are reabsorbed by the intestine but wastes remain in the intestine.
- **Kidneys**

  The kidneys of vertebrates (discussed below) function in the removal of nitrogenous and other wastes and in osmotic regulation of the body fluids.
- **Organs of the Excretory System in Humans**

1. Lungs - removal of excess carbon dioxide
2. Liver - produces urea and uric acid as a by-product of the breakdown of proteins by ornithine cycle.
3. Skin - removal of excess water, salt, urea and uric acid
4. Urinary System - kidneys filter the blood to form urine, which is excess water, salt, urea and uric acid

Nitrogenous wastes

- When amino acids are oxidized or converted to other kinds of molecules, the amino (NH_2) group must be removed.
- The nitrogen-containing compounds produced as a result of protein breakdown are toxic and must be removed by the excretory system.
- Nitrogenous wastes of animals are excreted in form of ammonia, urea, or uric acid.

Ammonia

- Ammonia is highly soluble in water but very toxic.
- Aquatic animals such as bony fishes, aquatic invertebrates, and amphibians excrete ammonia because it is easily eliminated in the water.
- **Urea**
- Terrestrial amphibians and mammals excrete nitrogenous wastes in the form of urea because it is less toxic than ammonia and can be moderately concentrated to conserve water.

Uric Acid

- Insects, reptiles, birds, and some dogs (Dalmatians) excrete uric acid.
- Reptiles and birds eliminate uric acid with their feces. The white material seen in bird droppings is uric acid. It is not very toxic and is not very soluble in water.

THE URINARY SYSTEM

Structures of the excretory system

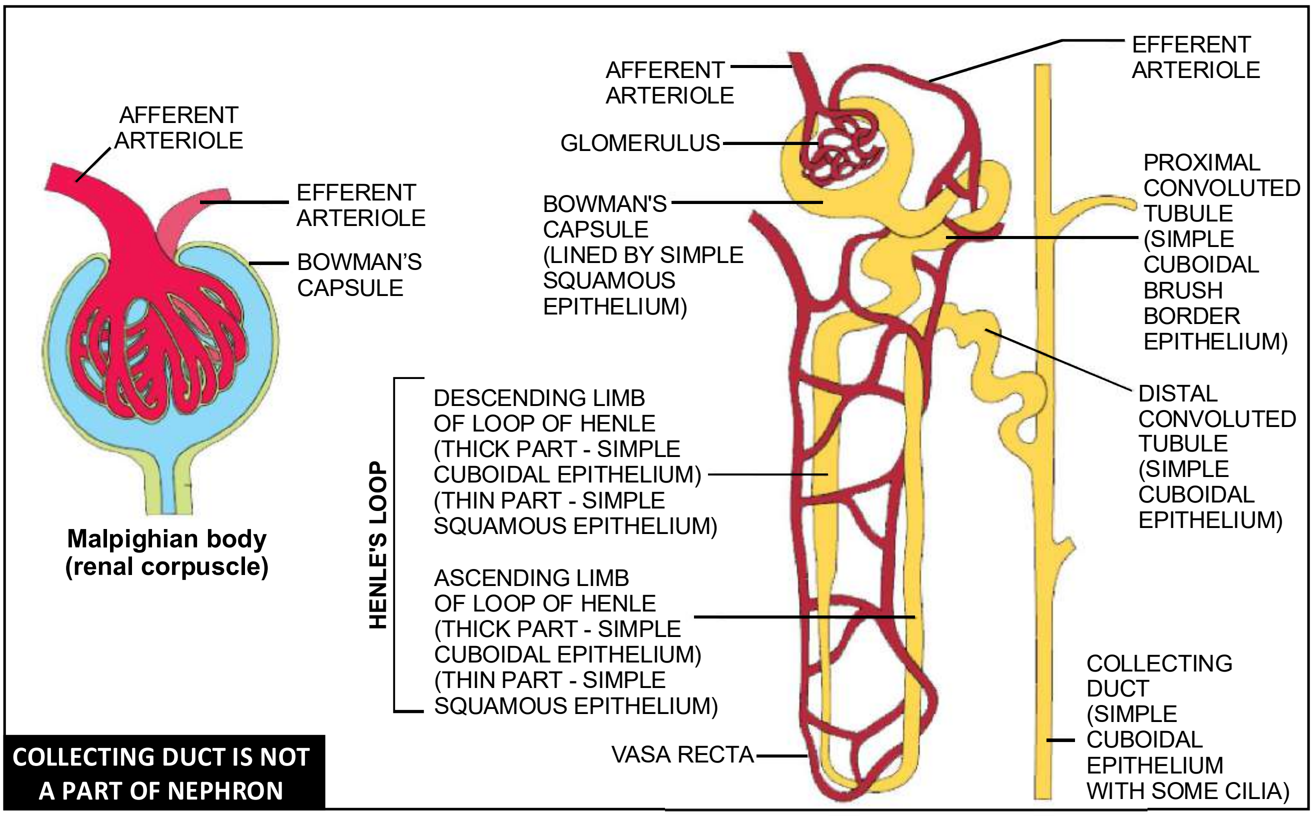
- Kidneys -bean shaped, mesodermal in origin, 2 kidneys composed of millions of nephrons constantly filter about 170 to 200 litres of blood to produce about 1.5 to 2 litres of urine daily.
- Left kidney is situated at a higher level than right one in a man because of the presence of liver at right side.
- Ureters - 2 ureters carry urine from the kidneys to the urinary bladder.
- Urinary Bladder - Inner wall is composed of transitional epithelium. The urinary bladder temporarily stores urine until it is released from the body.
- Urethra - The urethra is the tube that carries urine from the urinary bladder to the outside of the body. The outer end of the urethra is controlled by a circular muscle called a sphincter.

Regions of the Kidney

- cortex (outer)
- medulla (inner)
- renal pelvis (innermost chamber)- collects the urine

STRUCTURE & HISTOLOGY OF NEPHRON

(Nephron is the basic unit of kidney)



Nephrons : Structural and Functional unit of Kidney (uriniferous tubule)

- microscopic; about 1 million/kidney
- some are primarily in the cortex, others dip down into the medulla
- Nephrons filter 125 ml of body fluid per minute; filtering the entire body fluid component 16 times each day.
- In a 24 hour period nephrons produce 180 liters of filtrate, of which 178.5 liters are reabsorbed. The remaining 1.5 liters forms urine.

Parts

- Glomerulus - a capillary tuft from which fluid leaves the circulatory system (filtration)

  It mechanically filters blood having effectives filteration.
- Bowman's capsule- a funnel-like structure lined by squamous epithelium (podocytes) that collects filtrate from the glomerulus. It also mechanically filters blood
- Proximal Convoluted Tubule : It is brush bordered, reabsorbs 75% of the water, salts, glucose, and amino acids
- Loop of Henle : It is U-shaped tube. It is surrounded by tubular capillaries known as vasarecta. Helps in countercurrent exchange, which maintains the concentration gradient
- Distal Convoluted Tubule: Tubular secretion of H ions, potassium, and certain drugs.

Blood Supply

The path of blood flow through a kidney is listed below.

- Blood enters the kidney through a branch of the aorta called the **renal artery**.
- Branches of the renal artery within the kidney produce **afferent arterioles**.
- Each afferent arteriole leads to a network of capillaries called a **glomerulus**. Fluid leaks out of the capillaries of the glomerulus but large molecules and cells do not filter through the pores. This process is called filtration.
- Blood leaves the capillaries of the glomerulus via an **efferent arteriole** which is less diameter than afferent arferiole and enters capillaries in the medulla called **peritubular capillaries**, which collect much of the water that was lost through the glomerulus.
- **Venules** from the peritubular capillaries lead to the **renal vein**, which exits the kidney and returns blood to the **inferior vena cava**.

Urine

- The first nitrogenous waste to be formed from the breakdown of protein is ammonia, a highly toxic chemical that is quickly converted by the liver to urea and uric acid. These are less toxic than ammonia and are transported in the blood to the kidneys for excretion in urine. Urine consists of excess water, excess salt, urea and uric acid.

Urine Production

1. **Filtration in the glomerulus and nephron capsule.**

- Filterable Blood components now take on plasma like form called glomerular filtrate.
- A few of the filterable blood components are water, nitrogenous waste, nutrients and salts (ions).
- Non filterable blood components include formed elements such as blood cells and platelets along with plasma proteins.

2. Reabsorption in the proximal tubule.

- Excess water and salts like sodium and chloride also get reabsorbed into the blood from the renal tubule.
- ADH plays a role in increasing water reabsorption in the kidneys, thus helping to dilute body fluids.
- The kidneys also have a regulated mechanism for reabsorbing sodium in the distal nephron which is controlled by aldosterone, a steroid hormone produced by the adrenal cortex.
- Aldosterone promotes the excretion of potassium ions and the reabsorption of sodium ions.

3. Tubular secretion in the Loop of Henle.

- Maintenance of the correct amount of water and mineral ions in the blood is termed osmoregulation.
- Osmoregulation is the primary function of the kidney.
- Drugs and Toxin removed mainly by this process.

Homeostasis means maintaining a steady state inside the body. It requires the regulation of all substances inside the body in the correct amount and proportion. Kidneys and liver play an important role in maintenance of homeostasis.

Diseases of urinary system

- **Nephritis** is an inflammation of the glomeruli, due to a number of possible causes, including things like strep throat. Symptoms include bloody urine, scant urine output, and edema (swelling/puffliness).
- **Nephrosis** also affects the glomeruli, and is characterized by excretion of abnormally large amounts of protein (often causing "foamy" urine) and generalized edema (water retension/swelling) throughout the whole body, especially noted as "puffy" eyelids.
- Infections of urinary tract.Most urinary tract infections **(UTIs)** are caused by Gram negative bacteria such as E. coli.
- In some cases, excess wastes crystallize as **kidney stones**. They grow and can become a painful irritant that may require surgery or ultrasound treatments.
- A condition of failure of kidney to form urine - Anuria.

Some Facts about Excretory System

- The excretory system of an adult human being normally passes about 1-1.8 L of urine in 24 hours.
- The urine(waste product) consists of 95% water, 2.5 % urea and 2.5% other waste products.
- The way in which waste chemicals are removed from the body of the animal depends on the availability of water.
- Sometimes a person's kidneys may stop working due to infection or injury. As a result of kidney failure, waste products start accumulating in the blood. Such persons cannot survive unless their blood is filtered periodically through an **artificial kidney**. This process is called **dialysis**.

CONTROL AND COORDINATION

COORDINATION THROUGH HORMONES

The Endocrine System

- Hormones are secretions from specific cells or glands in the body that are carried by the blood.
- Their effect is produced in one or more specific parts only.
- Most hormones are secreted by special glands called the endocrine glands meaning 'secrete internally'.
- These are also called ductless glands because their secretions are poured directly into the blood and not through ducts.
- Certain hormones are produced by other glands or body parts also, for example, the stomach and the duodenum.

Nature and Function of Hormones

- Hormones are secreted from their source directly into the blood.
- Blood carries the hormone to the target cells which respond to it.
- Hormones regulate the physiological processes.
- They are produced in very small quantities and are biologically very active.
- For example, adrenaline is active even at a concentration of 1 in 300 million parts.
- Their excess and deficiency, both, cause serious disorders.
- Chemically, the hormones may be water-soluble proteins (peptides), glycoproteins and amines or lipid-soluble steroids.
- The extra hormones are not stored in the body and are excreted out.

Hormone Secretors — the Endocrine Glands

- In humans there are more than a dozen tissues and organs that produce hormones.
- These can be listed under two categories
- **Exclusively endocrine** : the pituitary, the thyroid, the parathyroid, thymus and the adrenals.
- **Partially endocrine** : The pancreas, gastric and duodenal epithelium, the gonads (testis in males and ovary in females) and placenta in females.

1. Pituitary — the master gland

- The pituitary gland (also called hypophysis) (Fig. 16.10) is a small projection (about the size of a pea) which hangs from the base of the mid-brain.
- It is connected to the hypothalamus of the brain by the pituitary stalk. The hypothalamus, although a part of the brain, also secretes some hormones one of which is **somatostatin** which inhibits the secretion of growth hormone from the anterior pituitary.
- The pituitary controls most other endocrine glands. It has two distinct parts: the **anterior pituitary** and the **posterior pituitary**.

Pituitary hormones, their action and abnormalities due to its
Oversecretion or undersecretion

Sourer	Hormones	Action and abnormalities pralad
Anterior lobe of pituitary	Growth hormone (GH), also known as somatotrophic hormone (STH)	Promotes growth of whole body, particularly of the skeleton. Undersecretion In childhood lead to Dwarfism: oversecretion in childhood causes gigantism and in adult, acromegaly.
	Trophic hormones (stimulate other endocrine glands) Gonadotropic hormones	1. Thyroid stimulating hormone (TSH) stimulates thyroid. 2. Adrenocortico trohic hormone (ACTH) stimulates adrenal cortex. 3. Follicle stimulating hormone (FSH) stimulates egg formation In females and sperm formation in males. 4. Luteinizing hormone
Posterior lobe of pituitary	Antidiuretic hormone (ADH) or vasopressin	Increase absorption of water from the kidney tubules (osmoregulation). Deficiency causes diabetes insipidus.
	Oxytocin	Stimulates contractions of the uterus during childbirth.

2. **Thyroid**

- Thyroid is a bilobed structure situated in the front region of the neck. It secretes two hormones **thyroxine** and **calcitonin.**
- **Thyroxine** regulates basal metabolism i.e. the rate of cellular oxidation resulting in heat production.
- Controls growth and development, ossification of the bones, body temperature, mental development, etc.

Undersecretion of thyroxine (hypothyroidism) produces three conditions

- Simple **goitre.** Enlargement of thyroid visible as a swelling in the neck. It is caused due to iodine deficiency in food as iodine is needed for production of thyroid hormones.
- **Cretinism.** Poor body growth (dwarfism) and mental retardation
- **Myxoedema.** Swelling of the face and hands. General sluggishness.

Oversecretion of thyroxine (hyperthyroidism) produces exophthalmic goitre. This condition causes marked increase in the metabolic rate, rapid heart beat, shortness of breath and the eyes protrude out together with goitre in the neck.

- **Calcitonin.** It regulates the calcium and phosphate levels in the blood.
- If the calcium level in blood is high more calcitonin is secreted and the calcium ions are moved from the blood to the bones making them harder.
- The reverse happens when the calcium level in the blood is low making the bones soft.

3. **Parathyroids**

- These are two small pairs of glands wholly or partially embedded in the thyroid gland.
- Their secretion **parathormone** raises blood calcium level by stimulating release of calcium from bones.

4. **Thymus**

- It is located at the base of neck. It produces some hormones involved in maturation of T lymphocytes.
- It begins to atrophy after puberty.

5. **Adrenals**

- The adrenals (ad: adjacent, renal; kidney) are a pair of glands situated like caps one above each kidney. Each adrenal consists of two parts: a central **medulla** and a peripheral **cortex**.

The **adrenal medulla** secretes adrenaline which,

- increases heart beat accompanied by an increase in the blood pressure.
- increases blood supply to the muscles while decreasing blood supply to the visceral organs.
- releases more glucose into the blood from the liver.

The **adrenal cortex** secretes two categories of hormones: **glucocorticoids** and **mineralocorticoids**.

(a) Glucocorticoids e.g. **cortisone**

- In response to stress it raises blood glucose through action of the liver including deamination of amino acids. During starvation and prolonged fasting the required glucose is partly provided through this hormone.
- It adapts the body to stresses such as extreme heat or cold, burns, infections, etc.
- Some of the cortical hormones behave like sex hormones.

Overgrowth of adrenal cortex in young children causes premature sexual maturity.

Overgrowth of adrenal cortex in mature females results in the development of male characters such as beard and deep voice.

Overgrowth of adrenal cortex in mature males results in the development of some feminine characters such as enlargement of breasts.

(b) Mineralocorticoids e.g. **aldosterone**

- This hormone is concerned with water retention. It increases reabsorption of sodium and chloride ions in kidneys.

6. Pancreas

- Pancreas is an endocrine as well as an exocrine gland. It has special groups of cells called **Islets of Langerhans**, which consists of three kinds of cells – *alpha cells* producing glucagon, *beta cells* producing insulin and *gamma* cells producing somatostatin.

(i) Glucagon. It stimulates breakdown of glycogen to glucose in the liver, leading to rise in the blood sugar level.

(ii) Insulin. It performs two principal tasks;

- Promotes glucose utilization by the body cells.
- Stimulates deposition of extra glucose in the blood as glycogen in the liver.

Non-secretion or under secretion of insulin causes **diabetes mellitus**

(**hyperglycemia**, meaning 'more than normal sugar in blood'.

A diabetic person,

has higher glucose in blood;

excretes a great deal of urine loaded with sugar;

feels thirsty because of loss of water through too much urination;

loses weight and becomes weak. In some cases, the patient even loses the eyesight.

Oversecretion of insulin causes **hypoglycemia** or low blood sugar. The brain may enter a state of coma if the level of sugar in blood becomes too low.

(iii) Somatostatin also called Growth Hormone-Inhibiting Hormone (GHIH) inhibits secretion of insulin as well as glucagon.

7. Gonads (testis and ovary)

- **Testes in males** possess two kinds of cells : the sperm-producing germinal cells and the hormone-producing interstitial cells. The hormones produced are called **androgens** and the commonest one among them is **testosterone**.
- The **testosterone** stimulates the development of the male characters during which the body at **puberty** starts developing facial hair**,** and their voice cracks and deepens.
- **Ovaries in females** produce two kinds of hormones—**estrogen** and **progesterone**.
- **Estrogen** is secreted from the follicles of the ovary and stimulates the development of breasts and fat deposition on the hip in a mature woman. Estrogen prepares the wall of the uterus for receiving the fertilized egg.
- **Progesterone** is secreted by the corpus luteum (follicle left after the release of ovum). It brings about the final changes in the uterus for the retention and growth of the foetus during pregnancy.

8. Placenta

- Placenta of a pregnant woman produces certain hormones. One such hormone is **human chorionic gonadotropin** (HCG), which maintains the activity of corpus luteum in secreting progesterone continuously.

9. Hormones from stomach and intestine

- **Gastrin** is the hormone secreted by the mucus membrane of the pyloric end of the stomach. It stimulates the gastric glands to secrete gastric juice.
- **Secretin** is the hormone secreted by the inner lining of the duodenum. It stimulates the production of pancreatic juice while the hormone **cholecystokinin** stimulates release of bile from gall bladder.

THE FEEDBACK MECHANISM (CONTROL OF HORMONAL SECRETION)

- The amount of hormone released by an endocrine gland is determined by the body's need for the particular hormone at any given time.
- The product of the target tissue exerts an effect on the respective endocrine gland. This effect may be positive ('*secrete more*') or negative ('*secrete no more*' or '*slow down*').

- This can be explained by taking the example of thyroid gland.

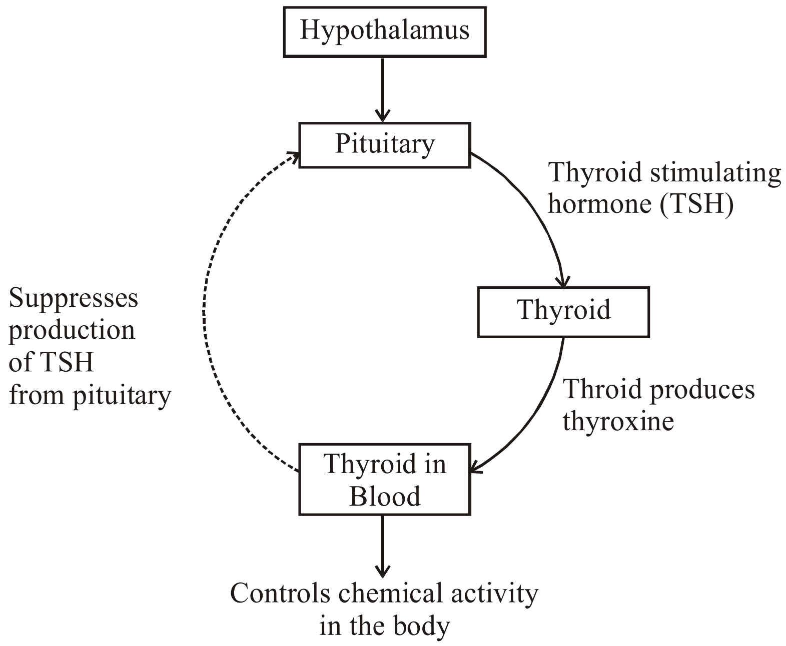


Figure : Feed back mechansim in hormone action
(Solid line = stimulation : broken line = suppression/inhibition)

NERVOUS SYSTEM :

- The organ system in an animal that serves to coordinate and control the functioning of all other organ systems in the body is known as nervous system.
- Nervous system works with the endocrine system to communicate, integrate and coordinate the functions of various organs and systems in our body and helps the body to respond to the external stimuli.

Neuron

- Each neuron has a central area called the cell body or cyton.
- The **cell body** has a large central nucleus and cytoplasm.
- Several short, thread like branches called **dendrites** arise from the cell body. One branch arising out of the cell body is very long in comparison to others. This branch is called **axon or nerve fibre**.
- Axon may or may not be covered by a fatty sheath called **myelin sheath.** This covering is missing at intervals. These gaps on the sheath are known as **nodes of Ranvier**.

Types of neurons

(i) **Sensory neurons**, which transmit impulse from receptor (sense organ) to coordinator (brain or spinal cord).
(ii) **Motor neurons**, which transmit impulse from modulator to effectors (muscle or glands).
(iii) **Connecting neurons**, which connect sensory and motor neurons, found in the grey matter.

Nerves

Nerves are thread like structures, which emerge from brain and spinal cord and branch out to almost all parts of the body. The nerves are composed of axons or nerve fibres bundled together like the strands of an electric cable.

Kinds of nerves

There are three kinds of nerves. These are :

(i) Sensory nerves: These nerves contain sensory fibres. Sensory nerves bring impulse from sense organs to the brain or the spinal cord.
(ii) Motor nerves: These nerves contain motor fibres. Motor nerves carry impulse from brain or spinal cord to the effector organ like muscle or glands.
(iii) Mixed nerves: These nerves contain both sensory and motor nerve fibres and perform a mixed function.

Some basic terms

Stimulus : an agent or a sudden change of the external or the internal environment that results in a change in the activities of the organism.

Impulse : a wave of electrical disturbance that travels accross the nerve cell and its fibre.

Response : a change in the activity of the organism caused due to stimulus.

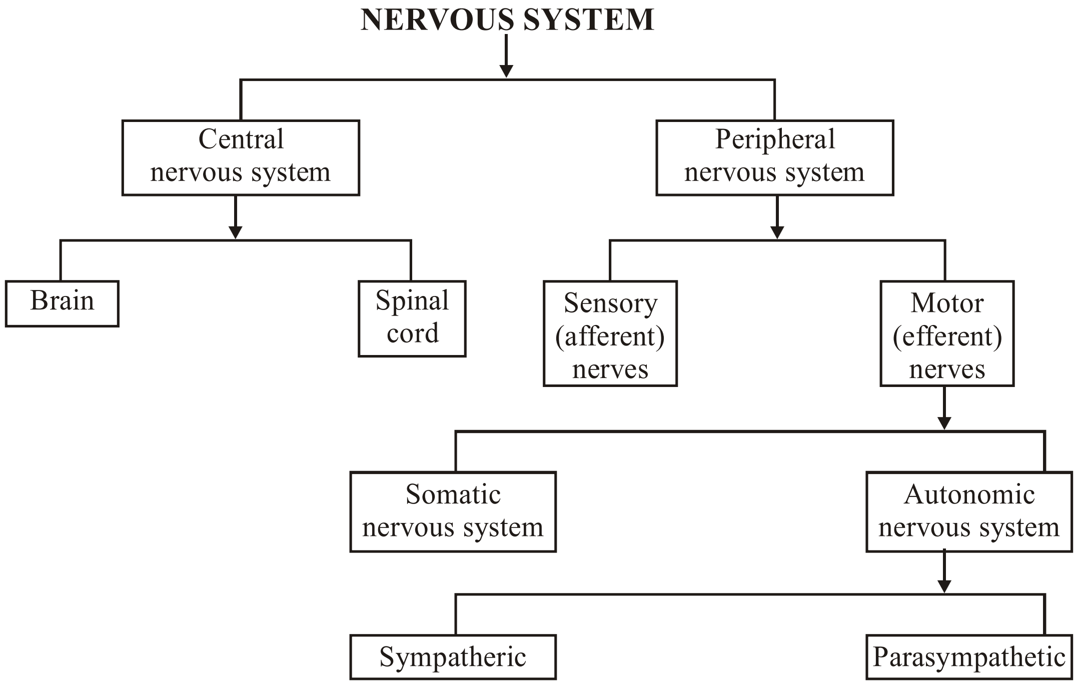
Receptors : The nerve cells which on receiving the stimulus, set up wave of impulses towards the central nervous system (brain and spinal cord).

Effectors : muscles or glands, which on receiving the impulse from the brain or spinal cord contract or secrete substances.

TWO MAJOR DIVISIONS OF THE NERVOUS SYSTEM :

(a) **Central Nervous System (CNS**), consisting of brain and spinal cord. It is the site of information processing (receiving information and responding to it). It is regarded as the 'thinker' or 'information processor' in the body.

(b) **Peripheral Nervous System (PNS)**, consisting of all the nerves entering and leaving the brain and the spinal cord.The peripheral nervous system is regarded as 'actor' or 'performer' in the body.



THE BRAIN

- The brain is a very delicate organ lodged inside the cranium of the skull.
- It is protected by three coverings, the meninges (meninx: membrane): an outer tough duramater (dura: tough; mater: mother), a thin delicate web-like middle arachnoid (arachne: spider), and the innermost highly vascular piamater (pia: tender) richly supplied with blood vessels.
- The space between the membranes is filled with a fluid called cerebrospinal fluid. There are cavities inside the brain, which are also filled with the same fluid.

The brain consists of three main regions :

(i) forebrain consisting of cerebrum and diencephalon,

(ii) midbrain a small tubular part between the fore and the hindbrain,

(iii) hindbrain consists of cerebellum, pons, and medulla oblongata.

The individual parts of the brain are described below :

(a) **Cerebrum**

- This is the largest part of the brain, divided into two (the right and the left) parts called cerebral hemispheres.
- Their outer surface is highly convoluted with ridges and grooves.
- Each hemisphere is hollow internally and the walls have two (an inner and an outer) regions.
- The outer region (cerebral cortex) contains cell bodies of the nerve cells and being grayish in colour it is called gray matter.

- The inner region is composed of whitish axon fibres and is called the white matter.
- Corpus callosum is a sheet of cris-cross nerve fibres connecting the two cerebral hemispheres.
- Left side of the cerebrum controls the right side of the body and vice-versa.

The cerebral cortex has three main functions:

(i) It controls and initiates voluntary muscle contractions.

(ii) It receives and processes information form the sense organs, like eyes, ear, nose etc.

(iii) It carries out mental activities of thinking, reasoning, planning, memorizing etc.

(b) **Diencephalon**. This is the part of the forebrain lying below the cerebrum. It consists of the following two parts:

1. **Thalamus :** This is an egg shaped mass of gray matter, located in the centre below the cerebrum. It is the relay centre for sensory impulses (e.g. pain and pleasure) going to the cerebrum.

2. **Hypothalamus :** This is a region of the brain located below thalamus. It controls motivated behavior such as eating, drinking and sex. It controls the secretions of pituitary gland hanging below it. It also serves as the regulation centre of body temperature and body fluids.

(c) **Cerebellum.**

The cerebellum is a smaller region of the brain located at the base and under the cerebrum. It has numerous furrows instead of convolutions. It also has a cortex of gray matter. Its two main functions are.

I. to maintain the (equilibrium)balance of the body, and

II. controls posture of the body.

III. to coordinate muscular activities.

(d) **Medulla oblongata :** This is the last part of the brain, which is connected to the spinal cord. Its functions are as follows:

(i) It is the cente for breathing, coughing, swallowing, etc.

(ii) It controls vital reflex centres such as cardiac centre, respiratory centre and centres for swallowing, sneezing, coughing and vomiting

In all, 12 pairs of nerves (cranial nerves) come out of the brain, some of these are sensory, some motor and some are of mixed type.

IMPORTANT :

Our brain sends out certain waves, which are different in nature at different times depending on our body activity. An instrument called **electroencephalograph** can record this activity of our brain. For doing this, electrodes are taped on different parts of the scalp and the activity is recorded in the form of an **electrocephalogram** (EEG).

THE SPINAL CORD :

- The spinal cord extends form the medulla of the brain downward almost the whole length of the backbone.
- It is also wrapped in the same three meninges as the brain and the space between them contains the same cerebrospinal fluid.
- The arrangement of the white and gray mater is reversed in it i.e. white matter is outside and the gray matter inside.
- It also shows the manner in which the spinal nerves originate from it.

Functions of spinal cord :

(i) Carry out reflexes below the neck,

(ii) Conducts sensory impulses from the skin and muscles to the brain,

(iii) Conducts motor responses from the brain to the trunk and limbs.

PERIPHERAL NERVOUS SYSTEM :

The peripheral nervous system consists of all nerves arising from the brain and the spinal cord. Overall, it consists of two kinds of pathways: the afferent (receiving) sensory pathways and efferent (carrying aways) motor pathways.

A. The afferent (receiving/sensory) pathways are included in two kinds of nerves.

- Purely sensory nerves, for example the cranial nerves received from the eyes, ears, nose, etc.
- Mixed cranial nerves like the fifth (facial nerve) which contains sensory fibres bringing sensations from the face but it also contains motor fibres which carry impulses away to the jaw muscles.

B. The efferent (sending) pathway may be subdivided into somatic and autonomic nervous systems.

- The somatic nervous system controls the voluntary muscles. It includes most cranial nerves as well as the motor nerve fibres of the spinal nerves. Both these convey message from the CNS to the voluntary muscles.
- Autonomic nervous system (ANS). This innervates the involuntary muscles and the glands. It consists of a pair of chains of ganglia and nerves on either sides of the backbone.
  This system is essentially a motor system, which regulates the involuntary actions of the internal organs. It consists of two parts :
  (a) Sympathetic nervous system and (b) parasympathetic nervous system.
- Sympathetic nervous system prepares the body for facing emergency situations and the parasympathetic nervous system re-establishes the normal conditions once the emergency is over.
- The autonomic nervous system is strongly influenced by emotions such as grief, anger, fear, sexual stimulation, etc.

REFLEX ACTION AND REFLEX ARC :

Reflex actions are controlled by spinal cord. A reflex action may be defined as a spontaneous, autonomic and mechanical response to a stimulus controlled by the spinal cord without the involvement of brain.

For example, we blink our eyes in response to high beam of light that falls on our eyes. Similarly we withdraw our hand immediately if we prick our finger or touch a hot object.

Components of a reflex arc

A reflex arc has the following components:

(i) a receptor or sensory neuron which perceives the stimulus,
(ii) a sensory nerve which carries the message from sensory neuron to spinal cord,
(iii) a relay or intermediate neuron of spinal cord which transmits the impulse from sensory to motor neuron, and
(iv) motor nerve which carries the message from spinal cord to effector organ, muscle or gland.

Two types of reflexes – **simple and conditioned**

The first one is inborn or natural, which did not require previous learning. Such reflexes are called **simple reflexes**.
Examples:

- Quick closing of eyelids on noticing an object suddenly approaching the eye.
- Coughing when the food swallowed enters the windpipe instead of the food pipe.
- Narrowing of the eye pupil in strong light.
- If the foot of sleeping person is tickled, it is jerked away.

The other example is the outcome of repeated experience. Here the brain actually remembers the taste of food and works in an unconscious manner- such reflexes are called **conditioned reflexes**.

Examples :

- **Applying brakes** in your vehicle (car or bicycle) on noticing someone suddenly coming in front of it.
- **Tying shoe laces** while talking to someone, not knowing whether you are first putting the left lace over the right or the vice versa.
- **A dog runs away** if it notices you kneeling down as if you are picking up a stone for striking.
- **Standing up on** seeing the teacher entering the classroom.

CONDUCTION OF NERVE IMPULSE ALONG THE NEURON AND OVER THE SYNAPSE :

- Nerve impulse upon generation passes along a neuron in only one direction.
- The neuron is connected to a sensory receptor that receives the message or stimulus and converts it into **electrochemical waves.** These electrochemical waves are carried by the neuron.
- The stimulus from the receptor organ is received by the dendrites, conducted to cell body (cyton) of the neuron and finally to the effector organ.

Electrical signalling

- In normal resting condition the outside of the nerve fibre carries positive (+) charge. In this condition nerve fibre is said to be polarized.
- The polarization is due to the presence of more Na^+ ions outside the cell membrane. Such state is maintained due to the sodium ions being continuously pumped out by means of the sodium potassium pump and operated by active transport using ATP for energy.

- Sodium potassium pump is a carrier protein on the plasma membrane which transports sodium and potassium ions across the membrane. Normally ions move from the region of their high concentration to the region of their low concentration.
- The changes when a stimulus arrives at the nerve fibre are as follows:
- The axon membrane at that spot becomes more permeable to Na+ ions, which move inward and bring about depolarization on that spot.
- This point of depolarization itself becomes the stimulus for the adjoining area of the membrane, which in turn becomes depolarized.
- Meanwhile the previous area becomes repolarized due to active movement of the sodium ions to the outside of the membrane by means of what is called 'sodium pump'.
- And now the fibre is ready for the next wave of depolarization.
- Thus a nerve impulse is a self- propagating wave of depolarization and repolarization

Synapse

- The axon of one neuron is close to the dendrites of cell body of the next neuron.
- This junction of two neurons is called synapse. There is a space at the synapse between the end of axon of first neuron and cell body or dendrite of the next neuron. This is called synaptic cleft.

Neurotransmitter

- When the impulse reaches the end of axon of first neuron, a **neurotransmitter** (a chemical substance) is released in the synaptic cleft of the synapse, which helps in passage of nerve impulse from one neuron to the next neuron.
- The transmission of impuse over a synapse is a chemical process.

What does a synapse do?

- It allows the information to pass from one neuron to another.
- It ensures the passage of nerve impulse in one direction only.
- It helps in information processing by combining the effects of all impulses received.
- It filters out low-level stimuli.

ANIMAL REPRODUCTION

- **Asexual reproduction** involves the formation of individuals whose genes come from a single parent.
  - There is no fusion of sperm and egg.
- Many invertebrates can reproduce asexually by **fission,** in which a parent separates into two or more approximately equal-sized individuals.
  - **Budding** is also common among invertebrates. This is a form of asexual reproduction in which new individuals split off from existing ones.
  - In **fragmentation,** the body breaks into several pieces, some or all of which develop into complete adults.
    - Reproducing in this way requires **regeneration** of lost body parts.
    - Many animals can also replace new appendages by regeneration.
- Asexual reproduction has a number of advantages.
  - It allows isolated animals to reproduce without needing to find a mate.
  - It can create numerous offspring in a short period of time.
  - In stable environments, it allows for the perpetuation of successful genotypes.
- Most animals exhibit cycles in reproductive activity, usually related to changing seasons.
  - This allows animals to conserve resources and reproduce when more energy is available and when environmental conditions favor the survival of offspring.
- Reproductive cycles are controlled by a combination of environmental and hormonal cues.
  - Environmental cues may include seasonal temperature, rainfall, day length, and lunar cycles.
- Animals may reproduce exclusively asexually or sexually or they may alternate between the two modes, depending on environmental conditions.
  - *Daphnia* reproduce by parthenogenesis under favorable conditions and sexually during times of environmental stress.
- **Parthenogenesis** is the process by which an unfertilized egg develops without being fertilized.
  - Parthenogenesis plays a role in the social organization of some bees, wasps, and ants.
    - Male honeybees (drones) are haploid, and female honeybees (queens and workers) are diploid.
- **Sexual reproduction** is the formation of offspring by the fusion of haploid **gametes** to form a diploid **zygote.**
- Sexual reproduction presents a problem for sessile or burrowing animals or parasites that may have difficulty encountering a member of the opposite sex.
  - One solution is **hermaphroditism,** in which one individual functions as both a male and a female.
    - Some hermaphrodites can self-fertilize, but most mate with another member of the same species.
      - In such matings, each individual receives and donates sperm.
      - This results in twice as many offspring as would be produced if only one set of eggs were fertilized.
- The mechanisms of **fertilization**, the union of sperm and egg, play an important part in sexual reproduction.
- A moist habitat is almost always required for external fertilization, both to prevent gametes from drying out and to allow the sperm to swim to the eggs.
- Internal fertilization is an adaptation to terrestrial life that enables sperm to reach an egg in a dry environment.
- Mating animals may use **pheromones,** chemical signals released by one organism that influence the behavior or physiology of other individuals of the same species.
  - Pheromones are small, volatile, or water-soluble molecules that disperse into the environment.
  - Like hormones, pheromones are active in minute amounts.
  - Many pheromones act as male attractants.
  - The survival rate is higher for internal fertilization.
- Marsupial mammals retain their embryos for only a short period in the uterus.
  - The embryos crawl out and complete fetal development attached to a mammary gland in the mother's pouch.
- The basic plan of all vertebrate reproductive systems is very similar.
- The reproductive anatomy of the human female includes external and internal reproductive structures.

- The **ovaries,** the female gonads, lie in the abdominal cavity, attached to the uterus by a mesentery.
    - A woman is born with about 400,000 follicles.
    - Follicles produce the primary female sex hormones, estrogens.
- Usually one follicle matures and releases its egg during each menstrual cycle in the process of **ovulation.**
    - After ovulation, the remaining follicular tissue develops into the **corpus luteum.**
    - The corpus luteum secretes additional estrogens and progesterone, hormones that help maintain the uterine lining during pregnancy.
- At ovulation, the egg is released into the abdominal cavity near the opening of the **oviduct.**
- The male's external reproductive organs consist of the scrotum and penis.
- The internal reproductive organs consist of gonads that produce sperm and hormones, accessory glands that secrete products essential to sperm movement, and ducts to carry the sperm and glandular secretions.
    - The male gonads, or **testes,** consist of highly coiled tubes surrounded by layers of connective tissue.
    - The tubes are **seminiferous tubules,** where sperm are produced.
    - **Leydig cells** scattered between the seminiferous tubules produce testosterone and other androgens.
    - The **scrotum,** a fold in the body wall, holds the testes outside the body cavity at a temperature about 2°C below that of the abdomen.
        - This keeps testicular temperature cooler than that in the body cavity.
    - The testes develop in the body cavity and descend into the scrotum just before birth.
- From the seminiferous tubules of the testes, the sperm pass through the coiled tubules of the **epididymis.**
    - As they pass through this duct, sperm become motile and gain the ability to fertilize an egg.
- **Ejaculation** propels sperm from the epididymis to the vas deferens.
- Accessory sex glands add secretions to **semen.**
    - A pair of **seminal vesicles** contributes about 60% of total semen volume.
        - Seminal fluid is thick, yellowish, and alkaline.
        - It contains mucus, fructose, a coagulating enzyme, ascorbic acid, and prostaglandins.
- A male usually ejaculates about 2–5 mL of semen, with each milliliter containing about 50–130 million sperm.
- During menstruation, new ovarian follicles begin to grow.
    - Estrogen is also responsible for female secondary sex characteristics, including deposition of fat in the breasts and hips, increased water retention, and stimulation of breast development.
    - It also influences sexual behavior.
- **Menopause,** the cessation of ovarian and menstrual cycles, usually occurs between ages 46 and 54.
    - During these years, the ovaries lose their responsiveness to FSH and LH, and menopause results from a decline in estrogen production by the ovary.

The principle sex hormones in the male are the androgens.

- The male sex hormones, androgens, are steroid hormones produced mainly by the Leydig cells of the testes, interstitial cells near the seminiferous tubules.
- Testosterone, the most important male androgen, and other androgens are responsible for the primary and secondary male sex characteristics.
    - Primary sex characteristics are associated with the development of the vas deferens and other ducts, development of the external reproductive structures, and sperm production.
    - Secondary sex characteristics are features not directly related to the reproductive system, including deepening of the voice, distribution of facial and pubic hair, and muscle growth.
- **Lactation** is unique to mammals.
    - After birth, decreasing levels of progesterone free the anterior pituitary from negative feedback and allow prolactin secretion.
    - Prolactin stimulates milk production 2–3 days after birth.
    - The release of milk from the mammary glands is controlled by oxytocin.