

Introduction to Histology and Animal Physiology

Course Code: Z 102

1st year Science

Second semester

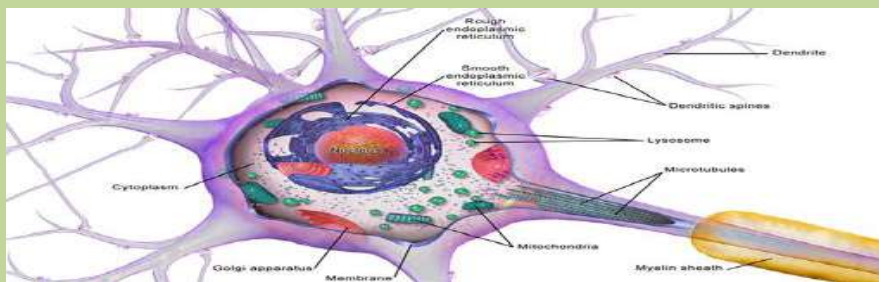
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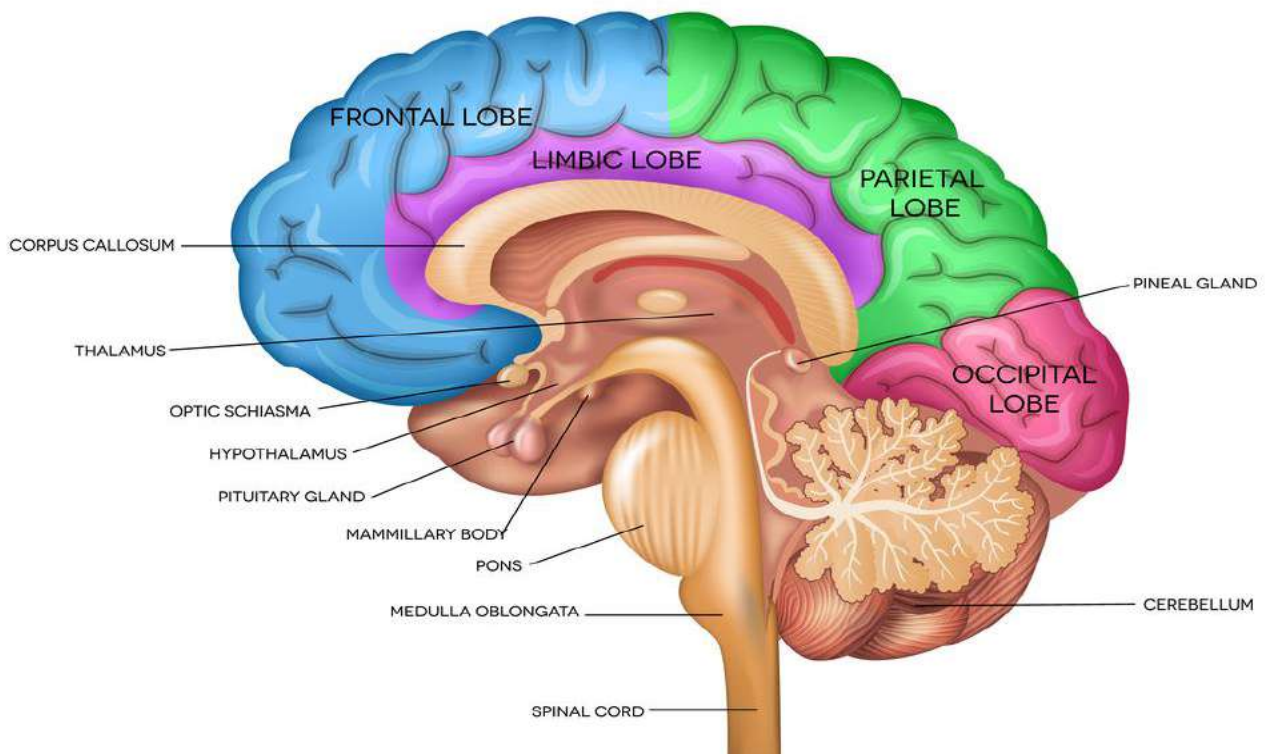
PRINCIPLES OF PHYSIOLOGY

FIRST YEAR BIOLOGY 102

2nd Semester .



ANATOMY OF THE BRAIN





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Introduction

What Is Physiology?

Word origin: Latin *physiologia*, from Ancient Greek *physis* (natural, origin) + *logia* (study of).

Physiology is the branch of biology relating to the function of organs and organ systems, and how they work within the body to respond to challenges. Although there are differences between animal, plant, and microbial cells, the basic physiological functions of cells can be divided into the processes of cell division, cell signaling, cell growth, and cell metabolism.

Physiology has long been studied together with anatomy and medicine. Ancient civilizations from Greece, Egypt, India, and China all have written records describing human physiology and treatments for various diseases. The history of physiology in Europe during the Renaissance from the 16th to the 18th century was greatly influenced by classical Greek works of natural philosophers such as Hippocrates, Aristotle, and Galen. The term physiology was first used by 16th-century French physician Jean Fernel.

Anatomy and physiology are two of the most basic terms and areas of study in the life sciences. Anatomy refers to the internal and external structures of the body and their physical relationships, whereas physiology refers to the study of the functions of those structures. Anatomy is visible, and ancient scientists studied it through dissections, surgeries, and observation. But how the body actually works is harder to explore. This means that physiology is a more modern science.

In the 17th century, microscopes helped shed new light on the cells that make up the human body, leading to a new understanding of physiology. More recently, tools like gene sequencing technologies and new types of body scans have given physiologists an expanded vision of the human body.

Human bodies are divided into two main regions, axial and appendicular. The axial part consists of the head, neck, thorax, abdomen, and pelvis whereas the appendicular part consists of the upper and lower extremities. The upper extremities include the shoulders, upper arms, forearms, wrists, and hands whereas the lower extremities include the hips, thighs, lower legs, ankles, and feet. The abdominal region can be further divided into nine regions or four quadrants.

Scientists who study physiology are called **physiologists**. Physiologists attempt to describe biological phenomena in physical and chemical terms. Physiologists come to

the field with extremely diverse backgrounds and apply their specialized skills and knowledge to understanding the function of living systems. Physiologists study living systems from the subcellular level (molecules and organelles) all the way to the level of the whole organism and how organisms adapt to vastly different environmental conditions such as hot, cold, dry, humid, or high altitude. In their attempt to elucidate the mechanisms operating in living systems, physiologists make use of an enormous array of experimental techniques. Techniques of cell and molecular biology, genetics, genomics, bioinformatics, chemistry, physics, and engineering, all find applications in the study of living systems by physiologists.

Physiology is the basis for all of the biomedical sciences, and forms the bridge between all of the other biomedical sciences. Physiology enables information gained by molecular biology, cell biology, genetics, pharmacology, biophysics, biomathematics, and biochemistry to be described in an integrated manner that can be applied to human medicine. Much of clinical medicine is based on a sound understanding of molecular, cellular, and organ-system physiology.

Physiology is the study of how the human body works. It describes the chemistry and physics behind basic body functions, from how molecules behave in cells to how systems of organs work together. It helps us understand what happens in a healthy body in everyday life and what goes wrong when someone gets sick.

Most of physiology depends on basic research studies carried out in a laboratory. An imaging scan like an X-ray or [ultrasound](#) can show your anatomy, but physiologists use other tests like [urine](#) and [blood](#) tests or electrocardiograms (ECGs) to reveal details about your body's physiology. Some physiologists study single proteins or cells, while others might do research on how cells interact to form tissues, organs, and systems within the body. Physiologists use physiology to learn more about many different organ systems, including:

- **Circulatory system** – including the heart, the blood vessels, properties of the blood, and how circulation works in sickness and health.
- **Digestive system** – charting the movement of solids from the mouth to the anus; this includes study of the spleen, liver, and pancreas, the conversion of food into fuel and its final exit from the body.
- **The excretory system: Renal/urinary system** including the kidneys, ureters, bladder, and urethra, this system removes water from the blood, produces urine, and carries away waste.
- **Endocrine system** – the study of endocrine hormones that carry signals throughout the organism, helping it to respond in concert. The principal

endocrine glands - the pituitary, thyroid, adrenals, pancreas, parathyroids, and gonads - are a major focus, but nearly all organs release endocrine hormones.

- **Immune system** - the body's natural defense system is comprised of white blood cells, the thymus, and lymph systems. A complex array of receptors and molecules combine to protect the host from attacks by pathogens. Molecules such as antibodies and cytokines feature heavily.
- **Integumentary system** - the skin, hair, nails, sweat glands, and sebaceous glands (secreting an oily or waxy substance).
- **Musculoskeletal system** - the skeleton and muscles, tendons, ligaments, and cartilage. Bone marrow - where red blood cells are made - and how bones store calcium and phosphate are included.
- **Nervous system** - the central nervous system (brain and spinal cord) and the peripheral nervous system. Study of the nervous system includes research into the senses, memory, emotion, movement, and thought.
- **Reproductive system** - consisting of the gonads and the sex organs. Study of this system also includes investigating the way a fetus is created and nurtured for 9 months.
- **Respiratory system** - consisting of the nose, nasopharynx, trachea, and lungs. This system brings in oxygen and expels carbon dioxide and water.

For each system, physiology sheds light on the chemistry and physics of the structures involved. For example, physiologists have studied the electrical activity of cells in the heart that control its beat. They're also exploring the process by which eyes detect light, from how the cells in the retina process light particles called photons to how the eyes send signals about images to the brain.

Physiology revolves around understanding how the human body maintains a steady state while adapting to outside conditions, a process called **homeostasis**. How do your organ systems keep your temperature relatively stable in different environments? How does your body keep your blood sugar and other chemical levels constant even when you eat different foods? These are the kinds of questions that physiologists aim to answer..

Manifestations of life

1- Metabolism: It is one of the most important characteristics of life. It is II process which takes place in the protoplasm. It includes the building up of complex substances, anabolism, and the breaking down of such substances into simpler compounds.

2- Irritability: It refers to the ability of an organism to respond to the different stimuli external stimuli such as heat, light, mechanical and/or electrical stimuli. As well as internal stimuli such as hunger and thirst.

3- Reproduction: It involves the formation of new individuals similar to the original ones. By this means, races of organisms are preserved and perpetuated.

4- The protoplasm: All functions of life are based on that wonderful complex substance which is found in all living beings and known as the protoplasm. The living protoplasm is translucent, often colourless and refracts light. It is a somewhat viscous semifluid which under different conditions undergoes changes in its viscosity and passes from the viscous semifluid condition (sol) to the more solid gelatinous one (gel) and vice versa.

No body known the exact chemical components of the living protoplasm. It is one of the secrets of God. The chemical analysis of dead protoplasm has shown that it contains the following compounds:

Organic Constituents:

- | | |
|--------------------------------|-----|
| 1- Carbohydrates | 1% |
| 2- Fats | 3% |
| 3- Proteins and nucleoproteins | 15% |

Inorganic Constituents:

- | | |
|-------------------|-----|
| 1- Inorganic salt | 1% |
| 2- Water | 80% |

Modes of nutrition

There are two modes of nutrition:

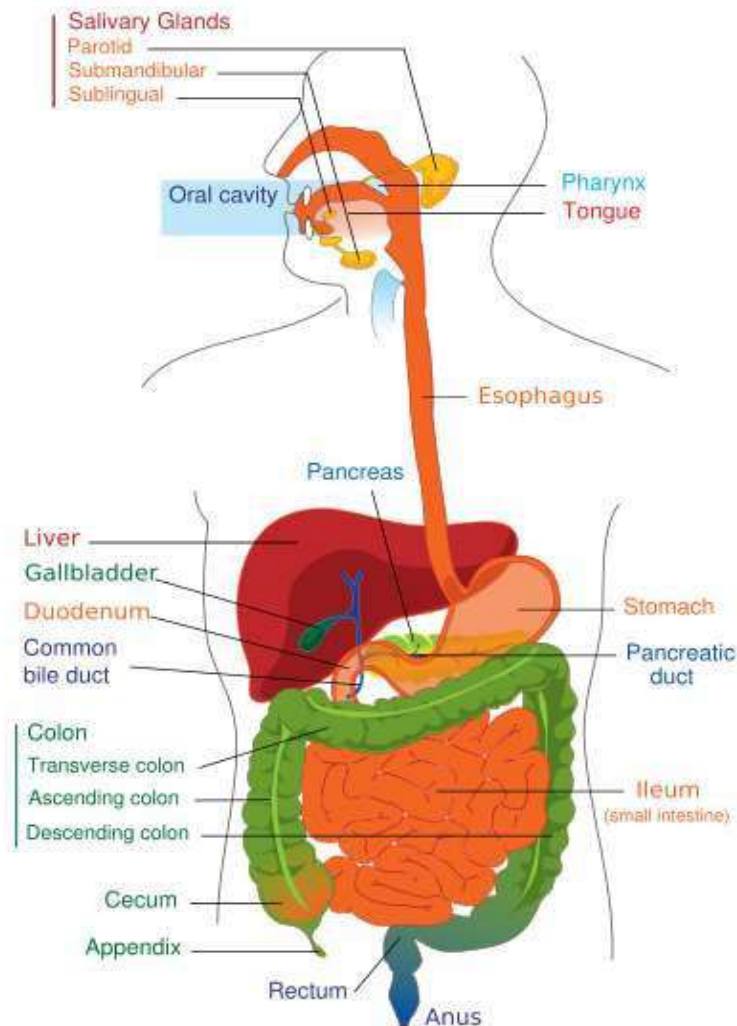
a- Autotrophic nutrition: Such as in plants that are able to manufacture their organic food material from inorganic sources taken from the surrounding media.

b- Heterotrophic nutrition: As in animals which depend on plants for their food which they get either directly by feeding on plants or indirectly by feeding on animals which have obtained their food by eating plants.

According to the kind of food, there are **three** types of animals:

- 1- **Herbivorous animals:** They feed entirely on plants.
- 2- **Carnivorous animals:** They feed on other animals.
- 3- **Omnivorous animals:** They feed on plant as well as animal matter.

Digestive System



Digestive System Anatomy

The digestive system is a group of organs working together to convert food into energy and basic nutrients to feed the entire body. Food passes through a long tube inside the body known as the alimentary canal or the gastrointestinal tract (GI) stomach, small intestines, and large intestines. In addition to the alimentary canal, there are several important accessory organs that help your body to digest food but do not have food pass through them. Accessory organs of the digestive system include the teeth, tongue, salivary glands, liver, gallbladder, and pancreas.

Mouth :Food begins its journey through the digestive system in the mouth, also known as the oral cavity. Inside the mouth are many accessory organs that aid in the digestion of food—the tongue, teeth, and salivary glands. Teeth chop food into small pieces, which are moistened by saliva before the tongue and other muscles push the food into the pharynx.

- *Teeth.* The teeth are 32 small, hard organs found along the anterior and lateral edges of the mouth. Each tooth is made of a bone-like substance called dentin and covered in a layer of enamel—the hardest substance in the body. Teeth are living organs and contain blood vessels and nerves under the dentin in a soft region known as the pulp. The teeth are designed for cutting and grinding food into smaller pieces.
- *Tongue.* The tongue is located on the inferior portion of the mouth just posterior and medial to the teeth. It is a small organ made up of several pairs of muscles covered in a thin, bumpy, skin-like layer. The outside of the tongue contains many rough papillae for gripping food as it is moved by the tongue's muscles. The taste buds on the surface of the tongue detect taste molecules in food and connect to nerves in the tongue to send taste information to the brain. The tongue also helps to push food toward the posterior part of the mouth for swallowing.
- *Salivary Glands.* Surrounding the mouth are 3 sets of salivary glands. The salivary glands are accessory organs that produce a watery secretion known as saliva. Saliva helps to moisten food and begins the digestion of carbohydrates. The body also uses saliva to lubricate food as it passes through the mouth, pharynx, and esophagus.

Pharynx: The pharynx, or throat, is a funnel-shaped tube connected to the posterior end of the mouth. The pharynx is responsible for the passing of masses of chewed food from the mouth to the esophagus. The pharynx also plays an important role in the respiratory system, as air from the nasal cavity passes through the pharynx on its way to the larynx and eventually the lungs. Because the pharynx serves two different functions, it contains a flap of tissue known as the epiglottis that acts as a switch to route food to the esophagus and air to the larynx.

Esophagus: The esophagus is a muscular tube connecting the pharynx to the stomach that is part of the **upper gastrointestinal tract**. It carries swallowed masses of chewed food along its length. At the inferior end of the esophagus is a muscular ring called the lower esophageal sphincter or cardiac sphincter. The function of this sphincter is to close off the end of the esophagus and trap food in the stomach.

Stomach: The stomach is a muscular sac that is located on the left side of the abdominal cavity, just inferior to the diaphragm. In an average person, the stomach is about the size of their two fists placed next to each other. This major organ acts as a storage tank for food so that the body has time to digest large meals properly. The stomach also contains hydrochloric acid and digestive enzymes that continue the digestion of food that began in the mouth.

Small intestine: The small intestine is a long, thin tube about 1 inch in diameter and about 10 feet long that is part of the **lower gastrointestinal tract**. It is located just inferior to the stomach and takes up most of the space in the abdominal cavity. The entire small intestine is coiled like a hose and the inside surface is full of many ridges and folds. These folds are used to maximize the digestion of food and absorption of nutrients. By the time food leaves the small intestine, around 90% of all nutrients have been extracted from the food that entered it.

Liver & gallbladder: The liver is a roughly triangular accessory organ of the digestive system located to the right of the stomach, just inferior to the diaphragm and superior to the small intestine. The liver weighs about 3 pounds and is the second largest organ in the body. The liver has many different functions in the body, but the main function of the liver in digestion is the production of bile and its secretion into the small intestine. The gallbladder is a small, pear-shaped organ located just posterior to the liver. The gallbladder is used to store and recycle excess bile from the small intestine so that it can be reused for the digestion of subsequent meals.

Pancreas: The pancreas is a large gland located just inferior and posterior to the stomach. It is about 6 inches long and shaped like short, lumpy snake with its “head” connected to the duodenum and its “tail” pointing to the left wall of the abdominal cavity. The pancreas

secretes digestive enzymes into the small intestine to complete the chemical digestion of foods.

Large intestine: The large intestine is a long, thick tube about 2.5 inches in diameter and about 5 feet long. It is located just inferior to the stomach and wraps around the superior and lateral border of the small intestine. The large intestine absorbs water and contains many symbiotic bacteria that aid in the breaking down of wastes to extract some small amounts of nutrients. Feces in the large intestine exit the body through the anal canal.

Nutrition, Digestion & Metabolism

Nutrition (Ingestion)

All substances taken into the body and used to build up protoplasm and to produce energy needed for performing the various life are considered foods..

Foods constituents may be classified according to their chemical composition (i.e. into carbohydrate, lipids, and proteins, mineral salts, water and vitamins), or they may be classified according to their functions. Where they include:

1- Body builders:

- Which help in the building up of the body i.e. form part of the composition of the body e.g. proteins, mineral salts and water.

2- Energy producers:

- Which on oxidation yield the energy necessary for the various body activities e.g. carbohydrates and fats which are good examples of energy producers (1 gm of carbohydrates or proteins yield 4.1 calories while that of fat is 9.3 cal.).

3- Regulators:

- Such as mineral salts and vitamin. They serve to regulate and coordinate the different functional activities of the body.
- A balanced diet is a mixture of food containing all substances essential for the development, growth and maintenance of the individual.

- **Balanced diet:**
- Balanced diet must have adequate amounts of protein, fat, carbohydrate, salts, vitamins and water. Special requirements must be taken into account in special cases, e.g. during pregnancy, lactation and illness.

Digestion

Digestion is the breakdown of complex food substance into simpler food substance which can be absorbed into the blood stream for body use.

Digestion is important because your body needs nutrients from the food you eat and the liquids you drink in order to stay healthy and function properly. Nutrients include **carbohydrates, proteins, fats, vitamins, minerals** and **water**. Your digestive system breaks down and absorbs nutrients from the food and liquids you consume to use for important things like energy, growth and repairing cells.

Metabolism

Metabolism is a term that is used to describe all chemical reactions involved in maintaining the living state of the cells and the organism. Metabolism can be conveniently divided into two categories:

- **Catabolism** - the breakdown of molecules to obtain energy
- **Anabolism** - the synthesis of all compounds needed by the cells

Metabolism is closely linked to nutrition and the availability of nutrients. Bioenergetics is a term that describes the biochemical or metabolic pathways by which the cell ultimately obtains energy. Energy formation is one of the vital components of metabolism.

IMPORTANT POINTS

- Nutrients, which the body uses for energy, growth, and cell repair are taken to the body by a process known as **Ingestion**.
- **Digestion** works by moving food through the gastrointestinal (GI) tract
- Digestion begins in the mouth with chewing and ends in the small intestine
- As food passes through the GI tract, it mixes with digestive juices, causing large molecules of food to break down into smaller molecules. The body then absorbs these smaller molecules through the walls of the small intestine into the blood stream **(Absorption)** , which delivers them to the rest of the body
- Waste products of digestion pass through the large intestine and out of the body as a solid matter called stool **(Excretion)**
- Digestive juices contain enzymes that break food down into different nutrients
- The small intestine absorbs most digested food molecules, as well as water and minerals, and passes them on to other parts of the body for storage or further chemical change **(Metabolism)**. Hormone and nerve regulators control the digestive process , finally:
 - Proteins break into **amino acids**
 - Fats break into **fatty acids and glycerol**
 - Carbohydrates break into **simple sugars**

I- Carbohydrates:

Carbohydrates are .widely distributed both In animal and in plant tissues. They are the cheapest source of calories. They provide about 50% of the calories in most diets.

Physiological Importance of carbohydrates:

- 1- They form about 50-60% of human diet
- 2- They form about 0.6% of human body weight.

- 3- stored In liver & muscles as glycogen.
- 4- Act as a source of energy (4.2 Kcal/g).
- 5- May be converted to fats or proteins.
- 6- They form a part of mucous membranes.
- 7- The pentose (ribose) sugar is a part of DNA & RNA.

Carbohydrates are classified into the following:

A- Monosaccharides: - Simple sugars composed of a single sugar unit.

- Are classified according to the number of carbon atom into: trioses (3C), tetroses (4C), pentoses (5C), hexoses (6C).
- E.g. of pentoses is ribose.
- E.g. of hexoses are glucose, galactose & fructose.

B- Disaccharides: -Compound sugars formed of 2 molecules of monosaccharides.

- E.g. maltose, lactose & sucrose.

C- Polysaccharides: -Consist of long chain of monosaccharide units.

- E.g. -starch, dextrans & cellulose (plant source), as well as glycogen (animal source).

Digestion of carbohydrates:

- **In mouth:** Salivary amylase starts the digestion of starch:



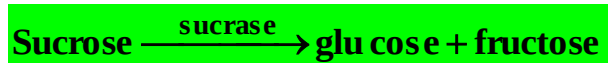
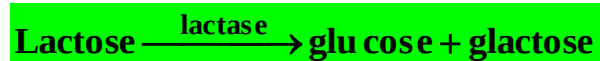
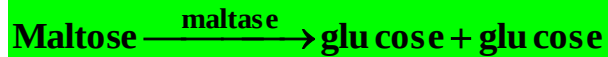
- **In stomach:** no digestion, but hydrolysis of carbohydrates by HCl.

- **In small intestine:**

a- By pancreatic juice



B- By intestinal juice:

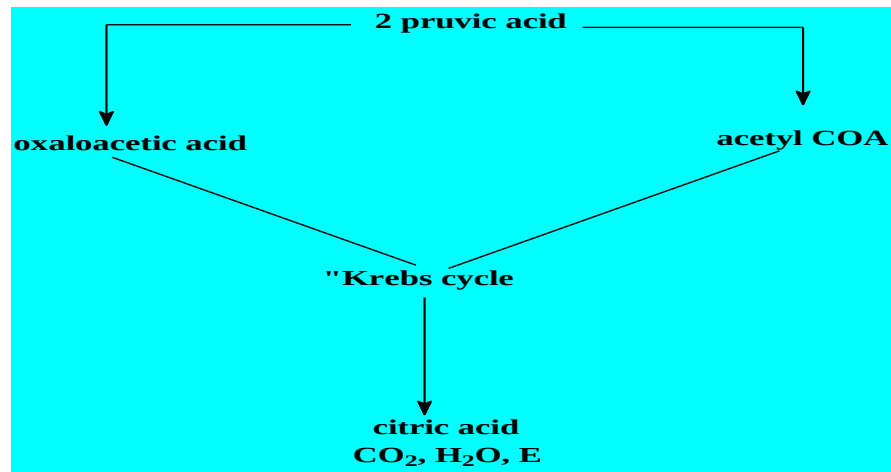


Absorption of sugars;

- Through blood route to portal vein by both simple diffusion & active transport.

Metabolism of carbohydrates (Fated absorbed carbohydrates)

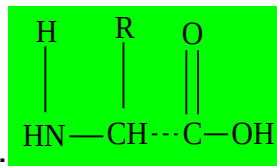
- 1- **Glycogenesis:** formation of glycogen from glucose in liver & muscle.
- 2- **Glycogenolysis:** breakdown of glycogen to glucose in liver & to pyruvic acid in muscles.
- 3- **Glycolysis:** conversion of glucose (6C) → 2 pyruvic acid (3C).
- 4- **Krebs cycle:** conversion of pyruvic acid → $\text{CO}_2 + \text{H}_2\text{O} + \text{E}$.
 - Krebs cycle starts by a reaction between oxaloacetic acid and acetyl CO-enzyme (acetyl CoA) and formation of citric acid, which undergoes many oxidation-reduction reactions to finally provide CO_2 , H_2O & E.
- 5- **Gluconeogenesis:** formation of glucose from non-carbohydrate sources.



II- Proteins:

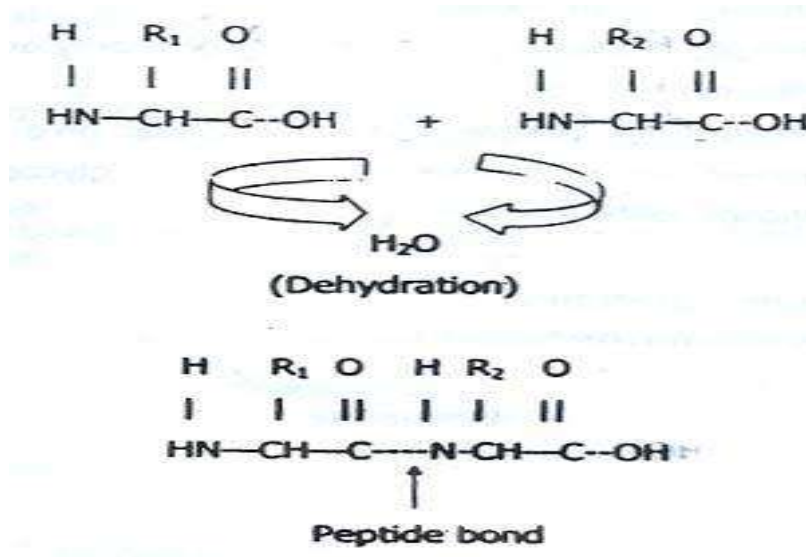
Proteins contain carbon, hydrogen, oxygen, nitrogen and in many instances, sulfur, phosphorous and copper.

Proteins are large polymers of amino acids



The box encloses the backbone of the amino acid (i.e. the constant part for all amino acids).

- Proteins are built up by binding of many amino acids.
- In the binding of amino acids a peptide bond, is formed between the carboxyl group of an amino acid; which loses an (OH) and the amino group of the next; which loses a (H) and a water molecule is formed. This process is called dehydration.



Physiological Importance of proteins:

- 1- Formation of supporting structures in the body as bone, cartilage, skin, nails, hair and muscles.
- 2- Enter in the formation of buffer system of the blood.
- 3- Form plasma proteins, which carry hormones, minerals & lipids (in the form of lipoproteins).
- 4- Enter in the formation of antibodies, haemoglobin, enzymes & protein hormones.
- 5- Provide the body with energy (4 Kcal/g).

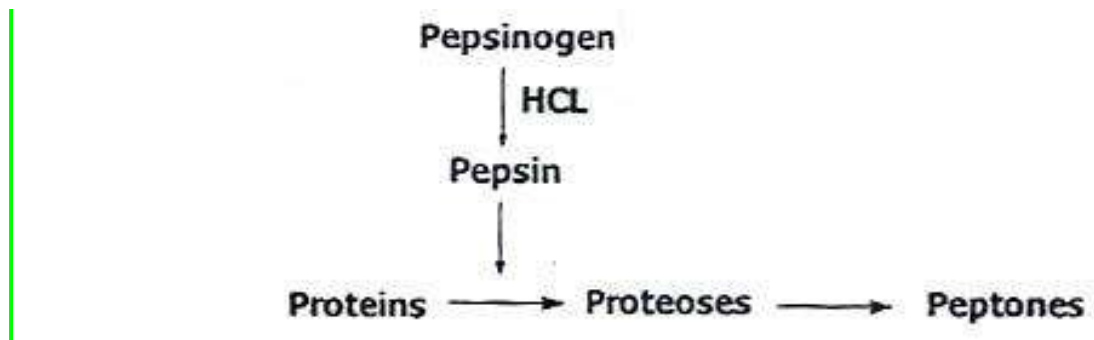
Classification of proteins:

A- Simple proteins: On hydrolysis give only amino acids. e.g. Albumin & globulins.

B- Compound proteins: On hydrolysis give amino acids & non-protein substances, e.g. glycoproteins and phosphoproteins.

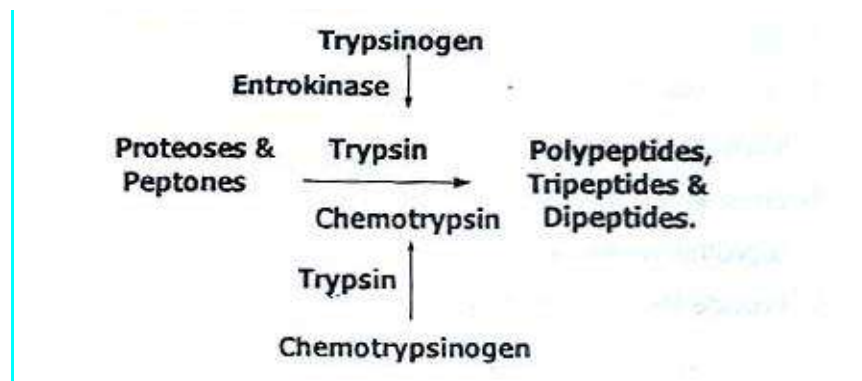
Digestion of proteins:

- **In stomach:** pepsin hydrolyses proteins into proteoses & peptones:

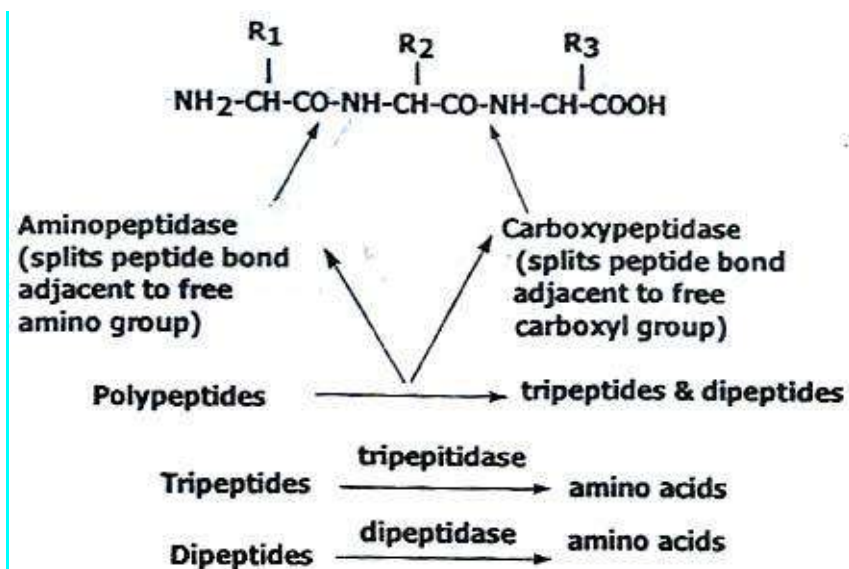


- In small intestine:

a. By pancreatic juice:



b. By intestinal juice:



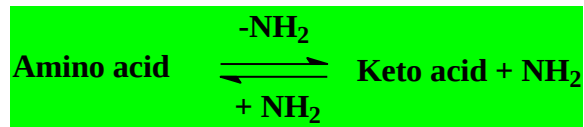
Absorption of proteins: amino acids are absorbed through .blood route by both simple diffusion & active transport.

Metabolism of proteins (Fate of amino acids after absorption):

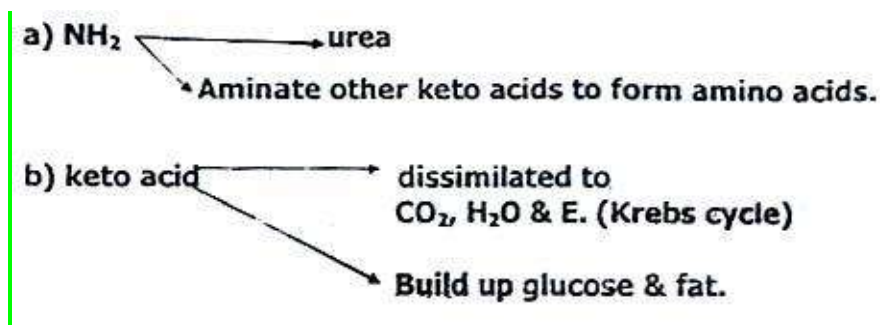
- 1- Used to form cells & tissues.
- 2- Form plasma proteins, enzymes & peptide hormones.
- 3- Undergo dissimilation.

Dissimilation of amino acids:

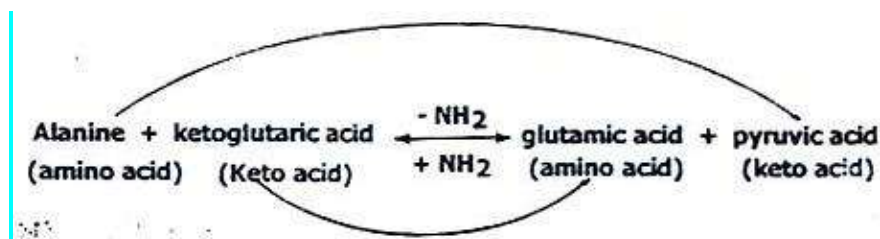
1- Deamination:



After deamination:



2- Transamination: Transfer of NH_2 group from amino acid to keto acid to build a new amino acid.



3- lipids:

Lipids (like carbohydrates) contain carbon, hydrogen and oxygen. The most important lipids in the body are triglycerides, phospholipids & cholesterol.

Physiological importance of lipids:

- 1- Act as a source of energy (9.3 Kcal/g).
- 2- Lipids are source of fat-soluble vitamins, essential fatty acids & steroid hormones.
- 3- Lipids in adipose tissue serve as energy store.
- 4- Lipids have a role in protection and fixation of internal organs as kidney.
- 5- Lipids in myelin sheath of nerve fibers serve as electrical insulator.
- 6- Lipids under skin serve as thermal insulator.
- 7- Lipids are essential components in the structure of cell membranes.

Classification of lipids:

1- Simple lipids: These are esters of fatty acids with various alcohols. For example:

- Neutral fats (triglyceride), these are esters formed by combination of glycerol with 3 molecules of fatty acids.



2- Compound lipids: These are esters of fatty acids containing groups in addition to an alcohol and a fatty acid. For example:

a- Phospholipids: Lipids containing In addition to fatty acids and alcohol, a phosphoric acid. Example: lecithin & cephaline.

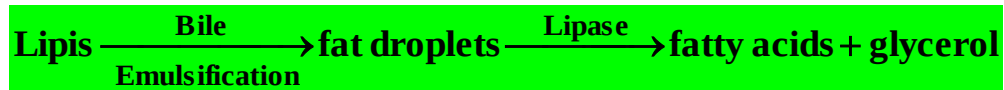
b- Glycolipids: These are lipids in combination with carbohydrate e.g. (cerebrosides & gangliosides) Which found in the brain tissues and in myelin sheath of the nerves.

3- Derived lipids: Substances derived from the above lipid groups by hydrolysis and still having the same general properties of lipids. For example: steroids such as, cholesterol.

Digestion of lipids:

- **In stomach:** By gastric lipase (weak enzyme).

- **In small intestine:** By pancreatic juice.



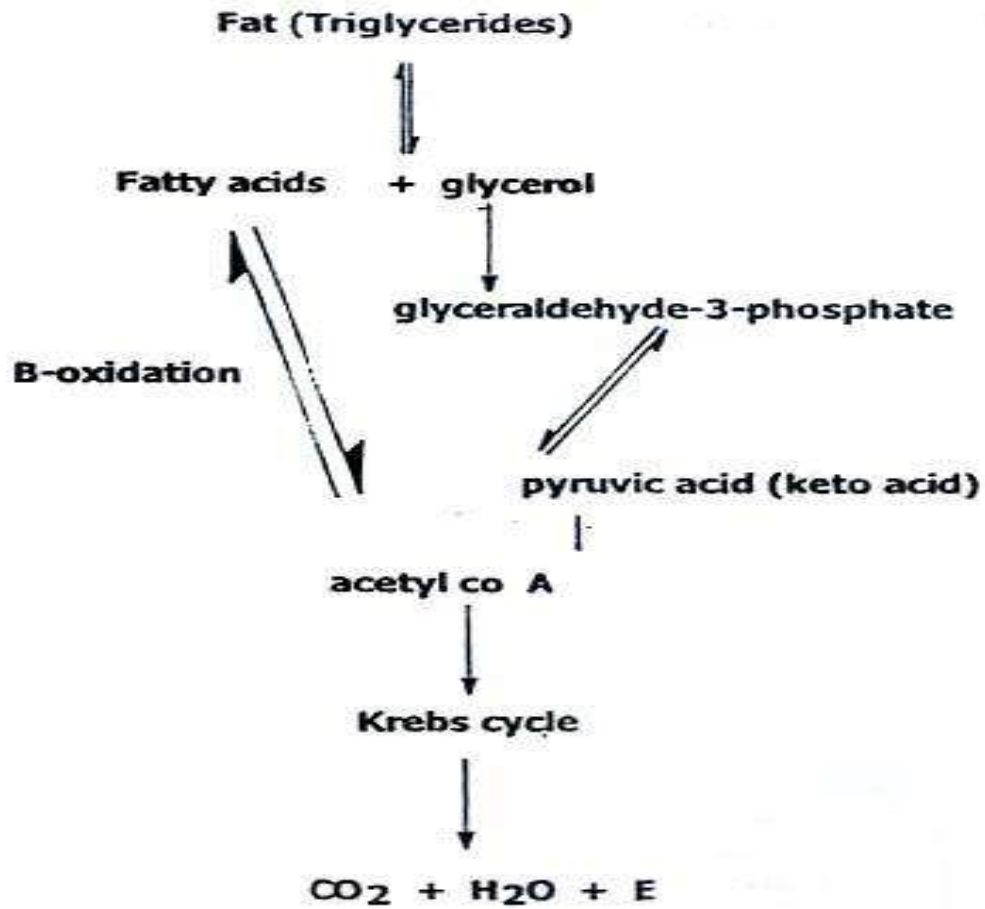
Absorption of fats:

- a) Short chain fatty acids (<10C) are absorbed through blood route.
- b) Long chain fatty acids (>10C) are absorbed through lymph route.

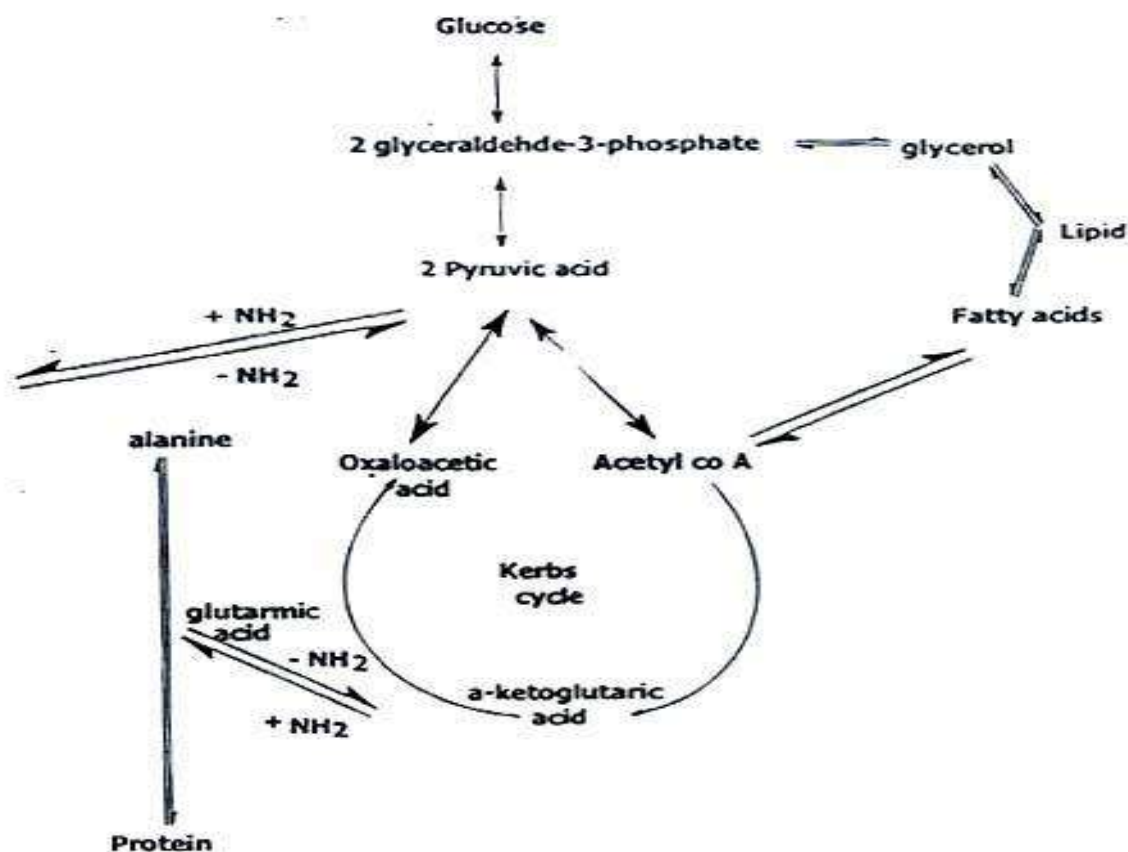
Metabolism of lipids (Fate of absorbed lipids):

- 1- Storage as neutral fats (triglycerides).
- 2- Building of cell membrane of all tissues & other lipid decreases compounds.
- 3- Oxidation,

Lipid oxidation:



The interrelationship between carbohydrates, proteins & lipids:



4- Minerals:

A number of minerals must be ingested daily for maintenance of health. They include:

Mineral	Function
Sodium	Essential for normal blood pressure.
Potassium	Normal function of nerve & muscle
Calcium	Bone & teeth formation. Muscle contraction & nerve impulse transmission. Blood clotting.
Phosphorous	Bone & teeth formation. Muscle contraction.
Iron	Haemoglobin formation.
Copper	Iron utilization & haemoglobin formation.
Manganese	Various enzyme activity.
Zinc	Insulin activity, sexual function, growth & tissue repair.
Iodine	Formation of thyroid hormones.

5- Vitamins:

- They are complex organic compounds, which must be present in the food in minute quantities to enable growth, health and maintenance of life.
- Vitamins are classified into fat-soluble and water-soluble categories.

The fat-soluble vitamins require a fat-based environment to function and the water-soluble vitamins require a water-based environment.

I- Fat soluble vitamins

Vitamin	Function	deficiency
Vitamin A	Regeneration of photopigments in retina	Night blindness
Vitamin D ₃ (1,25 (OH) ₂ vit. D ₃ (active form of vitamin D ₃))	Essential for deposition of Ca ²⁺ & phosphorous in bone & teeth.	Rickets in children & osteomalacia in adults (Bones become soft & deformed).
Vitamin E (Tocopherol)	Essential for normal function of reproductive system	Causes sterility. .
Vitamin K	Essential for normal blood clotting	Delayed blood clotting time.

II- Water soluble vitamins

Vitamin	Function	deficiency
Vitamin B complex (thiamin, nicotinic acid, biotin, folic acid, riboflavin, ..) & vitamin B ₁₂ .	Act as component of co-enzymes concerned with different metabolic reactions. Production of red blood cells.	Abnormal metabolic reactions. Abnormal production of RBCs.
Vitamin C (ascorbic acid)	Necessary for healthy blood vessels & wound healing.	Haemorrhage into tissues & delayed wound healing.

6-Water:

- 1- It is essential for life, where deprivation of water brings death much more rapidly than deprivation of food.
- 2- Daily water need of adult human is about 2.5 liters.
- 3- It forms about 60% of the body weight.
- 4- It forms about 90% of blood plasma.
- 5- It acts as thermo-regulator.
- 6- It is essential for transport of food & gases (O_2 , CO_2) to and from tissues.
- 7- All vital processes (digestion, respiration, excretion) occur in watery medium.

CIRCULATION

A-BLOOD

Blood is reddish fluid circulating continuously inside cardiovascular system. Loss of about 30% of blood leads to death. Blood is the body's fluid connective tissue, and it forms a vital part of the human circulatory system. Its main function is to circulate nutrients, hormones, minerals and other essential components to different parts of the body. Blood flows through aspecified set of pathways called blood vessels. The organ which is involved in pumping blood to different body parts is the heart. Blood cells, blood plasma, proteins, and other mineral components (such as sodium, potassium and calcium) constitute human blood.

Blood function :

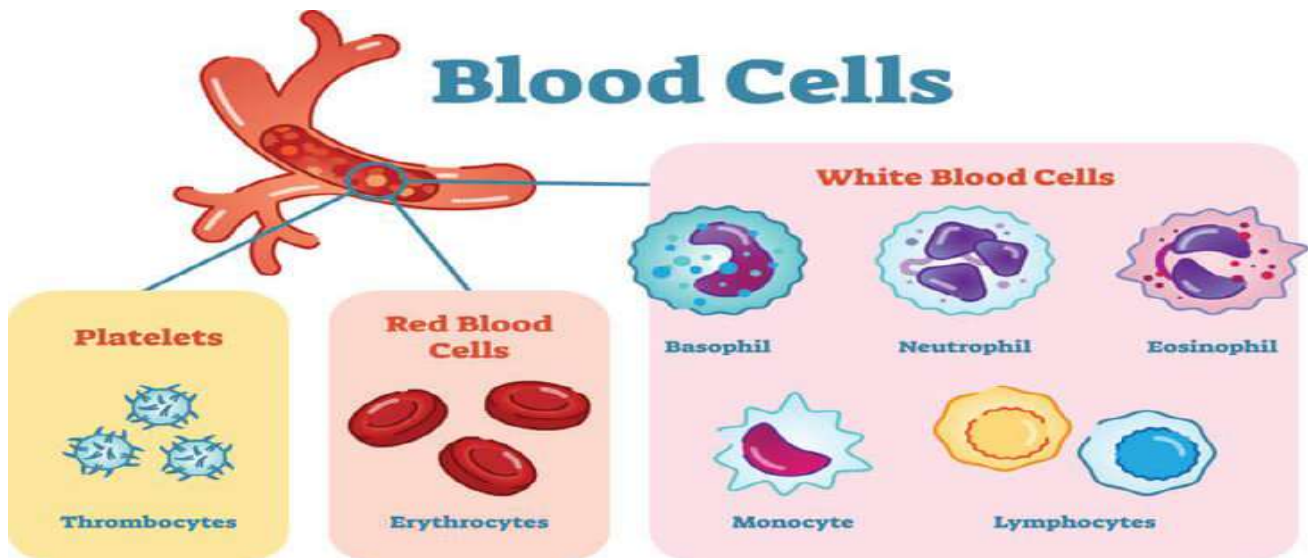
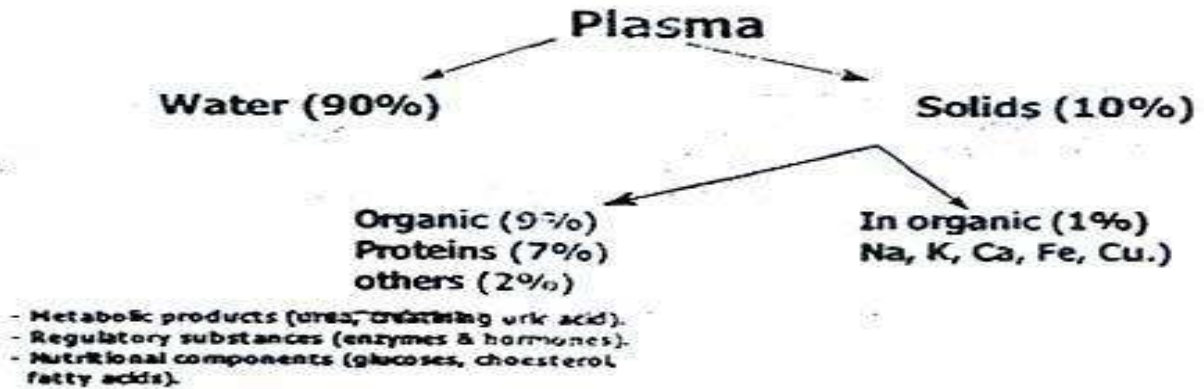
- 1- **Nutritional:** Transport of digested food from gut to tissues.
- 2- **Respiratory:** Transport of O₂ from lungs to tissues and CO₂ from tissues to lungs .
- 3- **Excretory:** Transport of waste products from tissues to kidney.
- 4- **Regulatory:** Regulates body temperature & body fluids (pH, viscosity & osmolarity).
- 5- **Protective:** Protects body against infection through antibodies (δ-globulin).
Protects against blood loss by formation of blood clot.

Composition of blood

Plasma (55%)	cells like structures & Cells (45%)
Clear yellowish fluid,	mm ³ RBCs 5×10^6 /

constituting the main part
of body extracellular fluid

WBCs $7 \times 10^3/\text{mm}^3$
 mm^3 Platelets $3 \times 10^5/$



Plasma proteins:

Plasma proteins consist of albumin (60%), globulins (20%), fibrinogen [(10%) & others (10%) coagulation & anti-coagulation proteins].

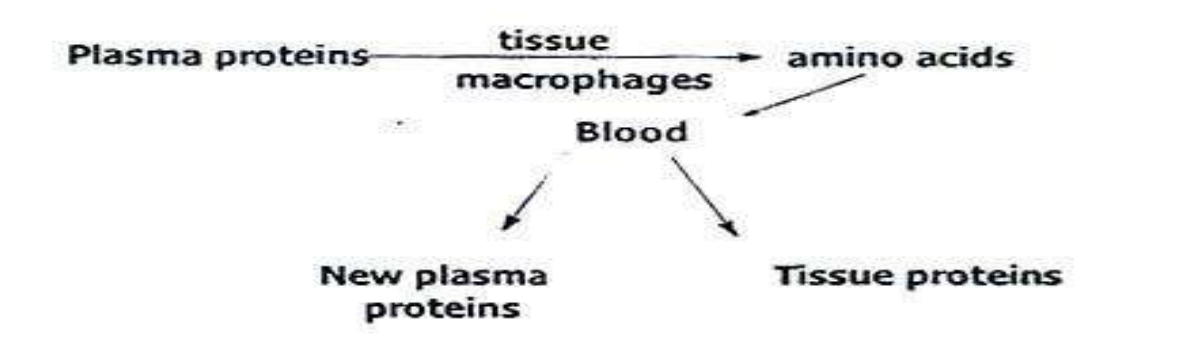
Function of plasma proteins:

- 1- Important for regulation of blood osmotic pressure.

- 2- Transport of minerals (Cu, Fe), lipids & hormones.
- 3- Provide tissues with amino acids.
- 4- Protection against viral, bacterial, and parasitic infection through (antibodies = δ -globulin).
- 5- Prevention of blood loss = (haemostasis) through clotting proteins (fibrinogen, prothrombin).
- 6- Prevention of thrombosis (clot formation).
- 7- Represent about 15% of the buffering power of blood (buffer: means substance that minimizes changes in blood pH).

Synthesis: Albumin, α , β -globulins & fibrinogen synthesized in liver, while δ -globulin synthesized inside lymphoid tissue (lymph nodes, spleen, thymus).

Catabolism: Tissue macrophages take up plasma proteins that are destroyed inside lysosomes → amino acid.



1- Red Blood Cells (RBCs) = Erythrocytes:

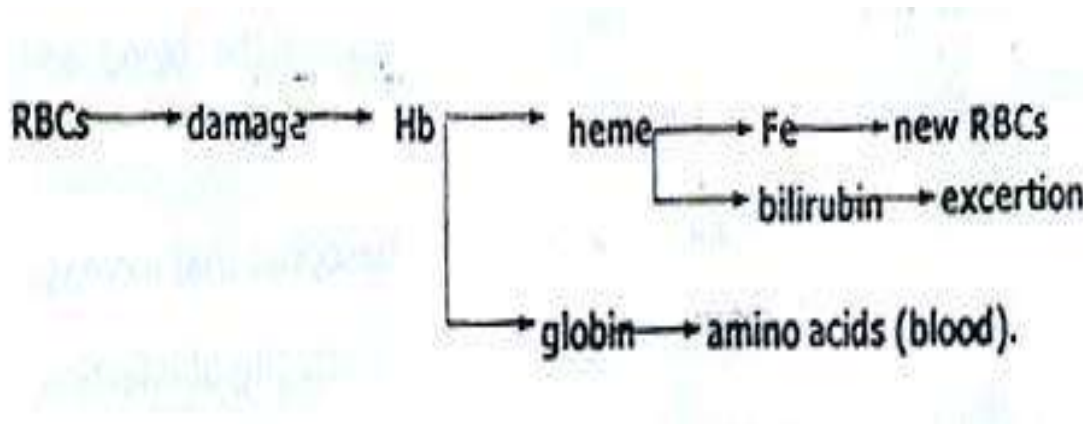
Structure: A plasma membrane, surrounding mass of cytoplasm containing haemoglobin. No nucleus, or organelles (so, can not divide).

Origin: Bone marrow.

Function: Transport of respiratory gases (CO_2 & O_2).

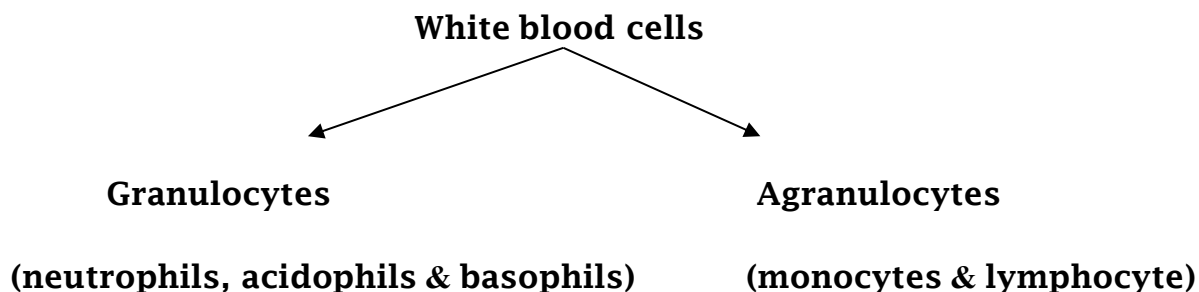
Life span: 120 days.

Fate of RBCs: Old RBCs become fragile, subjected to damage inside narrow blood vessel. Damage RBCs phagocytosed inside tissue macrophages giving haemoglobin (Hb).



2- White blood cells (WBC s)=leucocytes

- White blood cells are divided into granulocytes & agranulocytes.



Structure: Nucleated & larger than RBCs.

Function: a- Neutrophils, acidophils & monocytes move through blood vessels towards site of infection by chemotaxis (attraction to toxins) to phagocytose & damage viruses, bacteria & parasites.

b- Formation of antibodies (δ -globulin) by lymphocytes, that bind with antigens (foreign substances) in the blood and destroy them.

- c- Release of histamine (vasodilator) by basophils that increase movement of phagocytic leucocytes towards site of infection, thus increasing destruction of microorganisms.

Origin: Granulocytes, monocytes and some lymphocytes are formed bone marrow, but most lymphocytes are synthesized in the lymphoid tissue (from cells originally come from bone marrow).

Life span: 1-Granulocytes: about (4-5 days).

2- Monocytes: about 24 hours, after which they migrate to (liver, spleen or bone marrow) to form tissue macrophages, which remain for several months.

3- Lymphocytes: several months.

3- Blood Platelets = Thrombocytes

Structure: - Mass of cytoplasm surrounded by a plasma membrane.

Origin: Originated from large cells (megakaryocytes), inside bone marrow.

Life span: 10 days.

Function: Prevention of blood loss from damaged blood vessels (haemostasis).

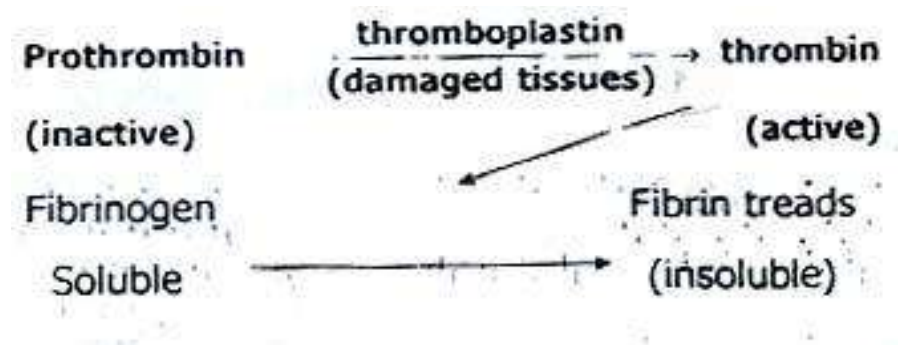
- **Haemostasis** means the stoppage of bleeding, when blood vessels are ruptured. It is done by:

a- Blood vessel spasm (contraction): When blood vessel is ruptured, platelets release substance called serotonin which cause the blood vessel to contract.

b- Platelet plug formation: The platelets adhere to the damaged blood vessels leading to formation of loose platelet plug that stop blood loss.

d- **Blood coagulation:** This plug is stabilized by deposition of fibrin threads which convert loose plug to strong blood clot.

Mechanism of blood coagulation:



This is a vital process which prevents the loss of blood as it escapes from the blood vessels when a wound or cut occurs. Essentially clotting is a mechanism by which the soluble blood protein fibrinogen is changed into the insoluble protein fibrin. Four stages are recognized in the process of blood clotting;

Stage 1: When the blood platelets break down in the region of the wound, thromboplastin is liberated from them (intrinsic thromboplastin). More thromboplastin (extrinsic thromboplastin) is produced by the wounded or cut tissue.

Stage 2: Thromboplastin acts, in presence of calcium ions (found in the blood), on the plasma protein called prothrombin (formed in the liver) changing it into the active enzyme thrombin.

Stage 3: Thrombin acts on the soluble plasma protein called fibrinogen, changing it into the insoluble protein fibrin. This is deposited in the form of fine threads at the wounded part, and together with some blood corpuscles they form the clot.

Stage 4: The blood clot then retracts under the effect of the enzyme retractozyme (found in the blood platelets). During this process, some serum (plasma without fibrinogen) oozes as a yellowish fluid out of the wound.

Anticoagulants :

There are several ways by which blood can be prevented from clotting, as by:

- 1- Collecting blood in containers coated with a thin layer of paraffin wax or paraffin oil to avoid injury of the blood platelets.
- 2- Cooling blood rapidly to 0°C.
- 3- Addition of oxalates, citrates or fluorides to rob the blood from the calcium ions necessary for clotting.
- 4- Heparin, which is a polysaccharide produced by the liver and other organs, acts as a powerful anticoagulant by preventing the change of prothrombin into thrombin. The presence of heparin in the blood prevents blood clotting inside the normal healthy blood vessels. Only when a wound occurs and sufficient blood platelets are broken that the effect of heparin is overcome and blood clots.

Blood diseases:

- 1- **Anemia:** A decrease in number of RBCs or haemoglobin content due to (severe blood loss or deficiency of iron).
- 2- **Leucopenia:** abnormal decrease in number of WBCs due to (severe viral infection or excess using of antibodies).
- 3- **Polycythemia:** abnormal increase in number of RBCs in blood circulation due to bone marrow tumours.
- 4- **Leukemia:** abnormal increase in number of WBCs due to bone marrow tumours.

Haemorrhage and blood transfusion:

Continuous haemorrhage may lead to death of the individual. If the amount of blood lost is less than 30%, the body can restore the lost blood during few weeks without any external aid. This is explained by the fact that the bone marrow becomes much activated in such cases, and produces much more blood cells than normal. At the same time, the tissues of the body supply that blood with the water necessary for

the production of the plasma, and the kidneys excrete much more concentrated urine to save some water for that blood too.

If the amount of blood lost from the body exceeds 30% of the total amount, blood transfusion must be carried out to the individual after his blood group has been identified.

Blood groups:

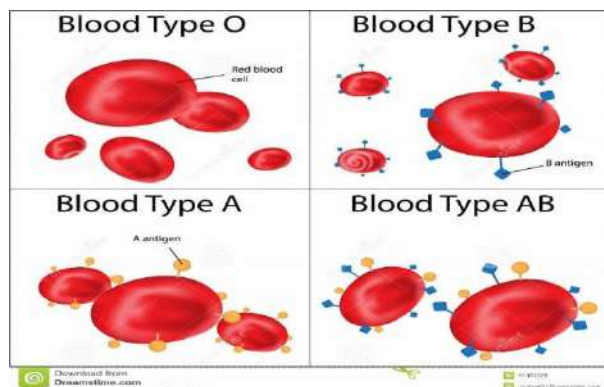
Before blood transfusion is carried out, the blood or the recipient must be first examined and its type identified, otherwise this process may have serious consequences. Certain substances are found in the blood, two of which are found in the red blood corpuscles and are known as the antigens, and two others exist in the plasma and are known as the antibodies. Antigens are denoted by the two capital letters A and B, and the antibodies are denoted by the small letters a and b. The blood of any human being belongs to one or another of the following four main blood groups. These are:

Group A: contains the antigen A, and the antibody b.

Group B: contains the antigen B, and the antibody a.

Group AB: contains the antigens A and B. but no antibodies.

Group O: does not contain antigens, but contains the antibodies a and b, as shown in the following table:



Blood group	Antigens in red cell	Antibodies in serum
A	A	b
B	B	a
AB	A and B	None
O	None	a and b

When blood containing the antigen A is mixed with or transferred to blood containing the antibody a, a process known as blood agglutination takes place. The blood corpuscles adhere together, then break down, and the kidneys are unable to get rid of them. Blood agglutination also takes place when blood containing the antigen B is mixed with or transferred to blood containing the antibody b.

On the other hand, no agglutination occurs when blood containing the antigen A is mixed with blood containing the antibody b, or with blood containing no antibodies such as that of group AB. Similarly, no agglutination happens when blood from group S is mixed with blood which is also of group B, or of group AB, where the former contains the antibody a, and the latter contains no antibodies. The following table summarises the results expected from mixing blood of one group with that of the other groups:

Donor	Recipient			
	A	B	AS	O
	Antibody (b)	(a)	(o)	(ab)
A	–	+	–	+
S	+	–	–	+
AB	+	+	–	+
O	–	–	–	–

+ agglutination.

- No agglutination

It is clear that blood from group O can be transferred safely to any individual with blood of the same group (O), or of any other group. Accordingly, group O is known as the universal donor. Also, a person belonging to group AB can receive blood from the same group (A B) or any other group. Thus, group AB is known as the universal recipient.

Worthy of notice is that although agglutination occurs when blood containing antigens A or B is transferred to blood containing the antibodies a or b respectively, the reverse

docs not usually produce agglutination. In other words, blood from a donor containing antibodies a or b does not produce agglutination when transferred to a recipient with blood containing antigens A or B respectively. This is because the amount of blood transferred is small compared to that found in the recipient's body, and since it becomes further diluted in the recipient's body, no effect is produced.

Rhesus (Rh) factor:

It was noticed that agglutination may take place during blood transfusion inspite of the fact that the blood groups of the discovered recipient have been identified and considered. This was discovered to be due to the presence of a certain antigen which was observed for the first time in monkeys of the genus Rhesus and has been referred to as Rhesus or Rh factor. Blood containing this antigen or factor is denoted by Rh⁺, whereas that lacking this factor is denoted by Rh⁻. When blood from an Rh⁺ person is transfused to an Rh⁻ one, this will induce the blood of the recipient to produce certain antibodies called anti-RH agglutinins. This is not dangerous when it happens for the first time because the antibodies produced are relatively few. But with a second transfusion of Rh⁺ blood to the same recipient, blood agglutination occurs as a result or the interaction between the RH agglutinogens and the anti-RH agglutinins.

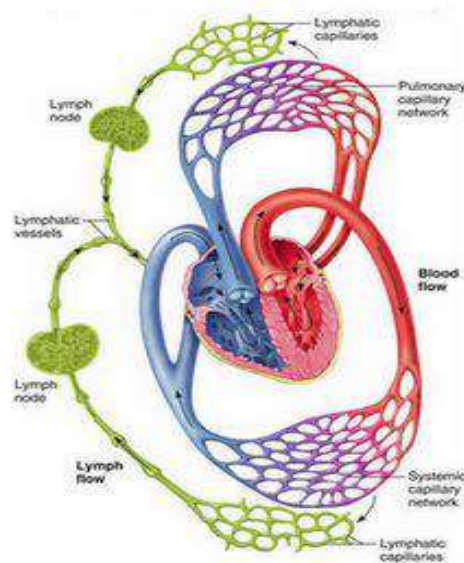
LYMPH:

The lymph (p. 101) is the medium across which continuous exchange of materials between the blood and the tissue cells is maintained. Lymph is produced mainly as a result of the diffusion and filtration of the plasma through the capillary walls. The lymph draining from the blood capillaries of different organs and tissues varies in composition, e.g. lymph draining from the liver contains more proteins than that from the limbs.

Circulation of lymph: Circulation of lymph in the body is maintained by:

- 1- The rhythmical contract ions of the walls of certain lymphatic vessels.

- 2- Some lower vertebrates. e.g. toads, have lymph hearts which act as pumps causing the movement of lymph.
- 3- The decrease in pressure within the chest and the increase in the volume of the thoracic cavity during inspiration lead to the dilation of the thoracic lymphatic ducts and the Bow of lymph into them.
- 4- Movement of the limbs during work or walk.
- 5- The presence of valves in the lymphatics makes the lymph flows in one direction.



B- HEART

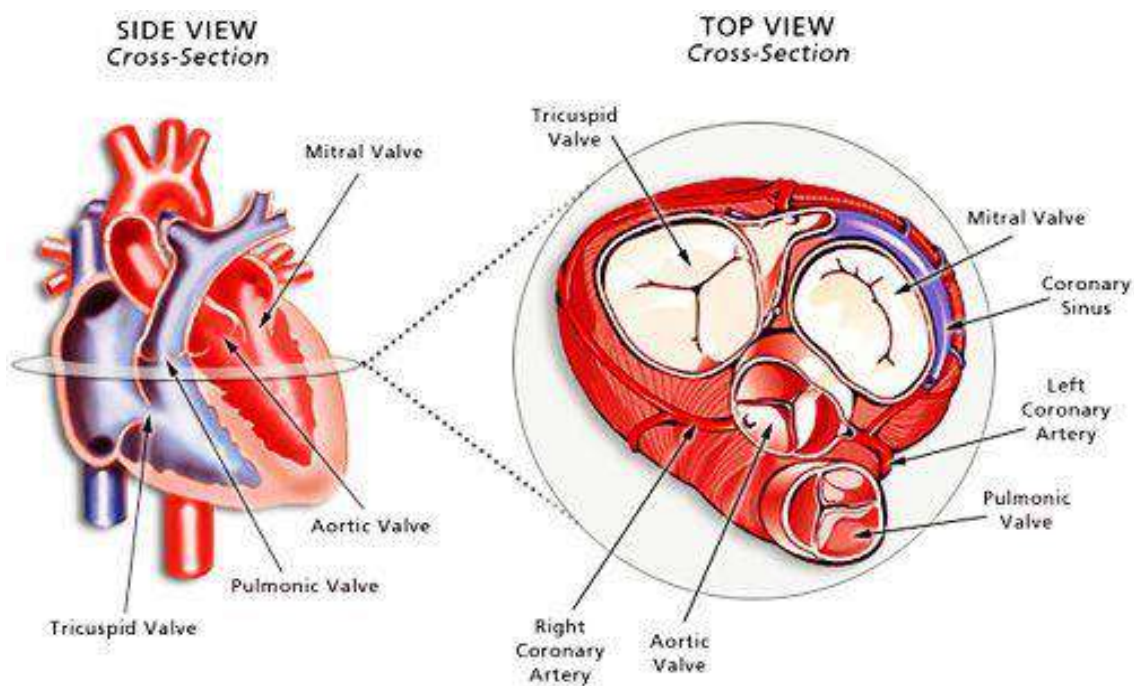
The heart is the central pumping organ in the circulatory system of the vertebrate body. It consists of a number of chambers with muscular walls. The heart is a muscular organ located in the chest cavity, right between the lungs and is enveloped by the pericardium. The human heart is separated into four chambers; namely, two upper chambers called atria (*singular: atrium*), and two lower chambers called ventricles.

Heart beat:

The work of the heart consists of rhythmic contractions and relaxations of the muscle fibres of the walls of the auricles and ventricles. The contraction of the heart is

known as systolic and its relaxation is known as diastole. Normally the systole and diastole occur alternatively in a regular pattern and constitute the cardiac cycle, i.e. the complete sequence of events during one complete heart beat.

During each cardiac cycle two chief sounds can be heard by the aid of a stethoscope in man. The first, called systolic sound, is due to the contraction of the ventricular muscles and the closure of the auriculo-ventricular valves. The second sound, called diastolic sound, is due to the closure of the semilunar valves during the ventricular diastole.



Two theories were put forward to explain the mechanism of heart contractions:

- 1- **The myogenic theory**, attributes these contractions to muscular activity only.
- 2- **The neurogenic theory**, regards these contractions as being due to nervous effect. i.e. an effect exerted by certain nerve ganglia scattered in the wall of the heart.

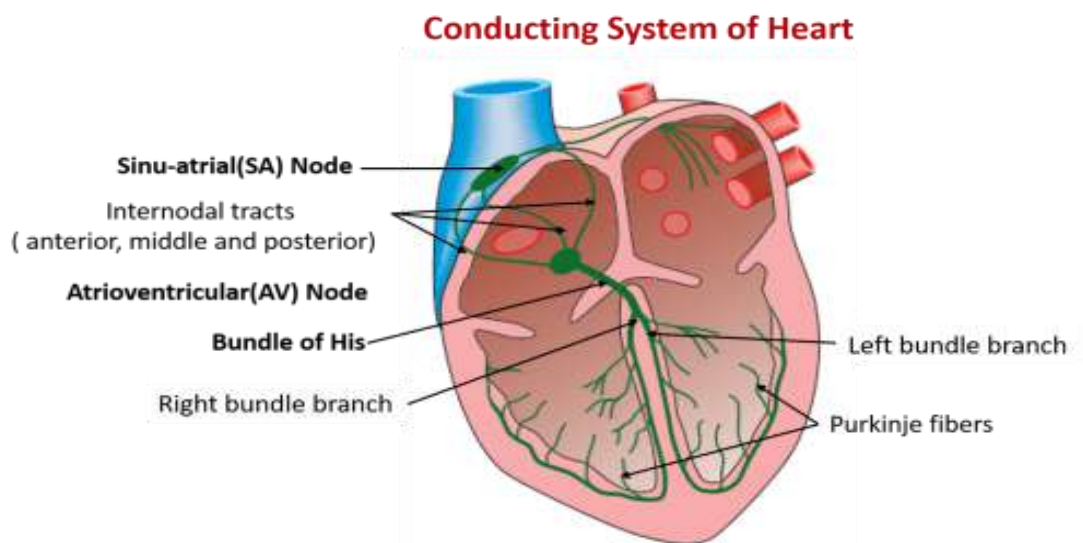
However, it is now believed that the heart beats in vertebrate animals are myogenic in nature, for the following reasons:

- a) When the nerve ganglia are removed from the heart, it still rhythmically contracts.

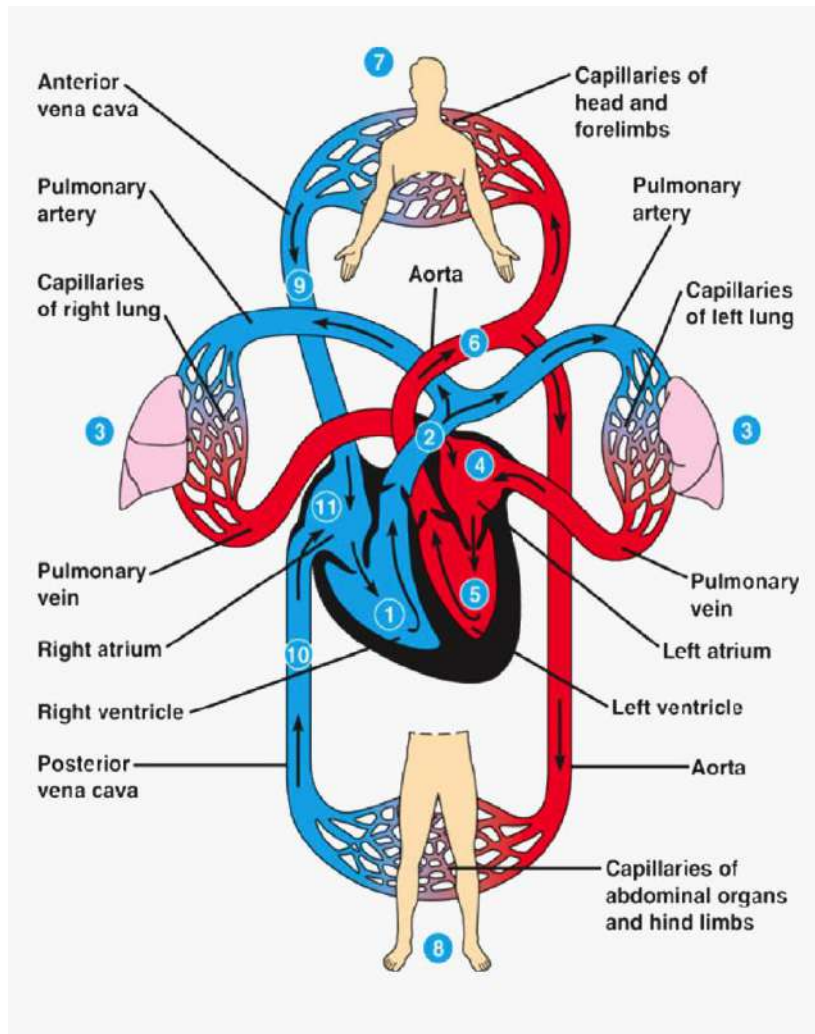
- b) The heart of a frog removed from its body continues to contract rhythmically for some time.
- c) Isolated cardiac muscles cultured outside the body show rhythmic contractions.
- d) The heart of birds begins to contract on the second day of incubation, before the appearance of the nerve cells.

However, the nerves connected to the heart play an important role in the regulation of heart beats, e.g, the vagus nerve inhibits heart beating. while the sympathetic nerve accelerates it, Some hormones, as adrenaline, also affect heart beating.

In the toad, the sinus venosus is the originator or pace-maker of the heart beat. In mammals, the rhythm originates in a special region of the right auricle known as the sinu-auricular node. When the pace-maker is stimulated, a wave of contraction spreads out to every part of the heart by a special conduction system called the Purkinje system. This system consists of bundles of modified heart muscle specialized for impulse conduction. During contraction, the heart muscles obey the "All or None Law", i.e. if the heart muscle contracts, it does so to its maximum. The refractory period, or period of non-contraction, is relatively long. This prevents overworking of the heart muscles.



Circulation in the blood vessels:

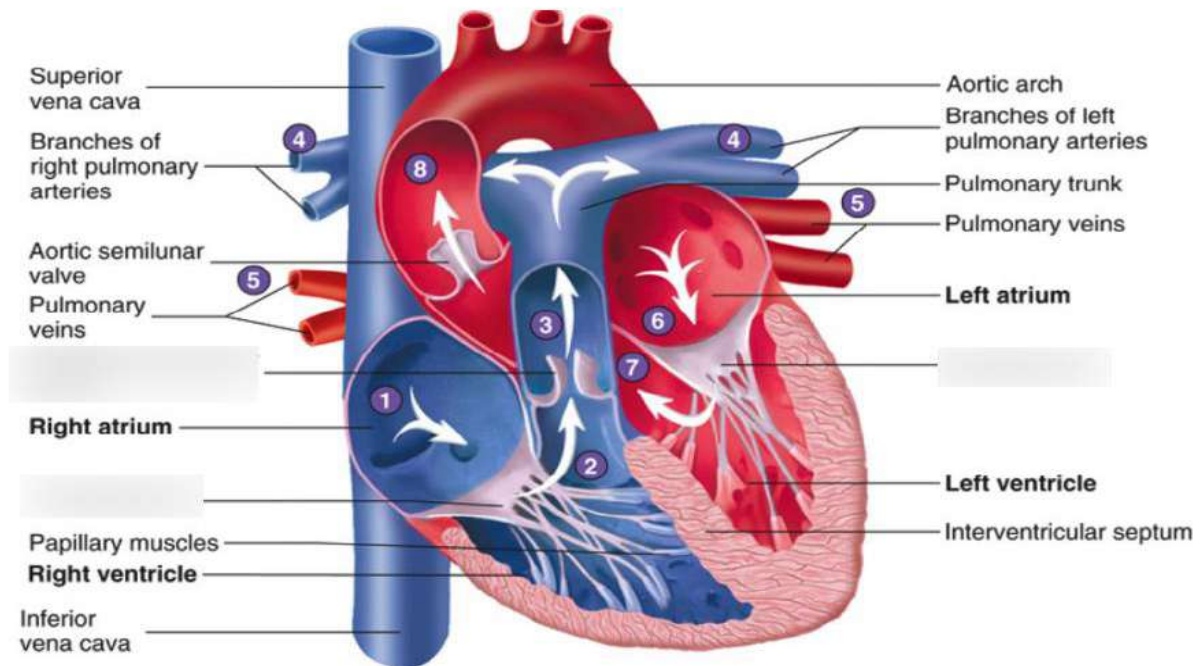


The movement of the blood through the blood vessels is due to the rhythmic beats of the heart. During contraction, the heart drives the blood under pressure into the arteries. The blood pressure is highest at the beginning of the circuit then drops gradually, reaching its lowest level at the end of the circuit, e.g, in man, the blood pressure in the aorta is 150 mmHg, in median arteries it is about 120 mmHg, in arterioles it is 40 mmHg, and in capillaries it is 20 mmHg. In veins it is still lower. This difference in blood pressure between the different parts of the vascular system is the direct cause of circulation, The blood moves

from the point of higher pressure to the point of lower pressure. The contraction of muscle fibres in the walls of arteries helps in propelling the blood into the arteries and capillaries.

Besides the work of the heart, two factors promote the return of venous blood to the heart: respiration and skeletal muscle contractions. In the process of breathing, the thoracic cavity widens and consequently the pressure inside it decreases than that in the abdominal cavity. Therefore, blood moves from the abdominal veins towards the thoracic ones. This movement is also aided by the contraction of muscles because these compress the veins and drive the blood they contain in the direction of the heart. The

venous blood is prevented from flowing back by valves which open only in the direction of the blood flow. The presence of the valves is particularly important in the veins of the lower limbs of man where blood has to flow upwards.



Immunity:

Immunity can be defined as the ability of a living organism to resist invasion by harmful microorganisms or other foreign material.

Blood plays an essential role in immunity. Certain types of leucocytes in the blood and in other tissues can ingest and destroy microorganisms and foreign material. Moreover, the blood plasma contains antibodies which are formed by certain body cells against any foreign proteins or other materials associated with proteins.

Any such protein materials that stimulate the tissues of the body to form antibodies are called antigens.

Some antibodies precipitate the foreign proteins and are thus called precipitins. Others cause microorganisms or red blood corpuscles to clump together and are called agglutinins, and some neutralize toxins and are thus termed antitoxins.

Immunity may be natural or acquired. An animal that resists invasion by certain microorganisms for the first time, i.e. without being previously in contact with it, is considered to have natural or innate immunity. But, immunity resulting from a previous exposure to microorganisms is called acquired immunity. Children recovering from infections with the measles virus and remaining capable of resisting a second infection with that particular virus are described as having acquired immunity to measles.

Acquired immunity may be natural or artificial. The above example of immunity developing after measles infection in children is natural acquired immunity, whereas immunity developing in a child after vaccination with diphtheria or typhoid vaccines is described as artificial acquired immunity.

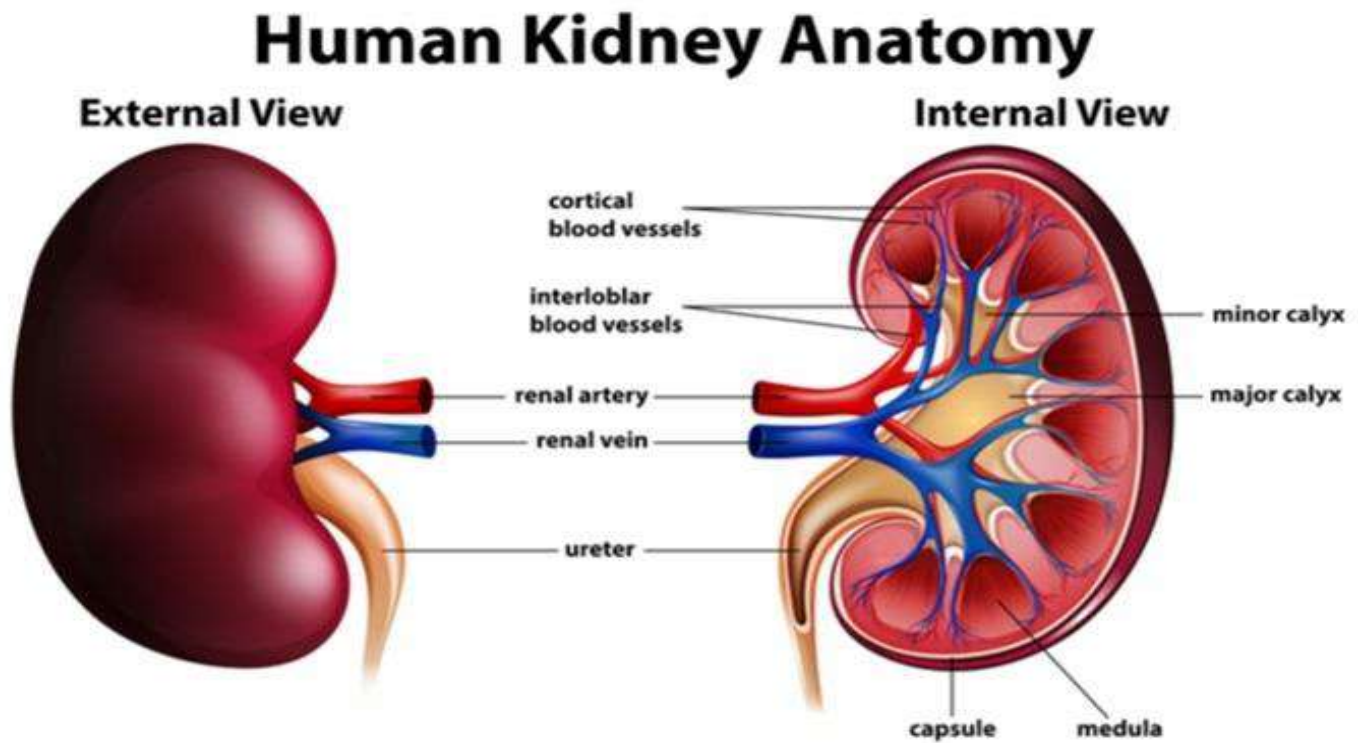
EXCRETION

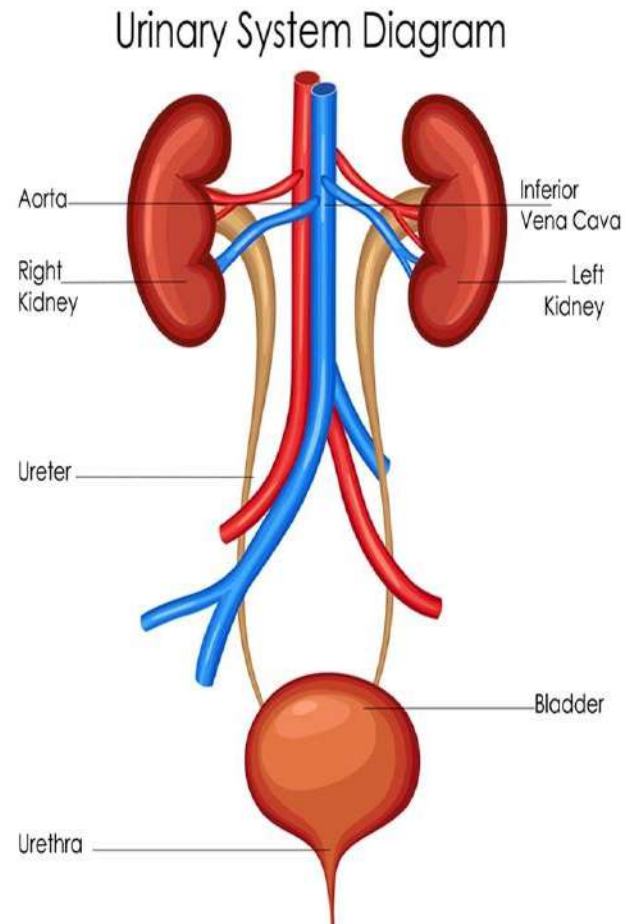
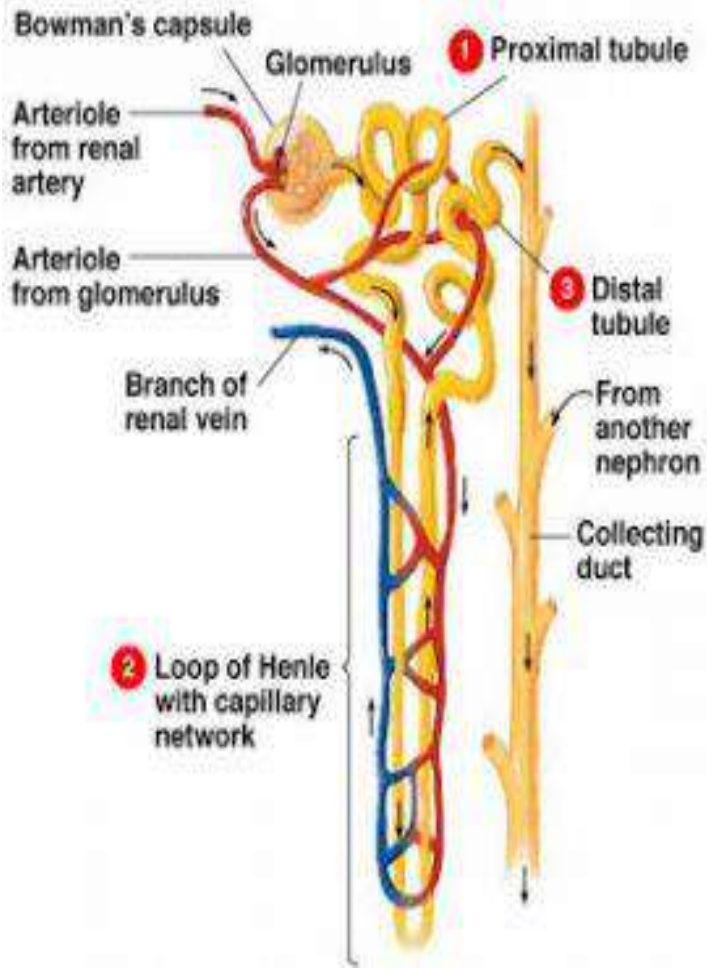
Excretion is the process by which waste products of metabolism are removed from the body. This term is not generally applied to the voiding of material which enters the body and passes out unchanged; thus the nitrogen which leaves the lungs and the undigested cellulose expelled in the faeces are not regarded as excretory products. Some wastes are disposed through the skin and the lungs; others are discharged from the liver in the bile, and some are expelled from the intestine with the faeces. However, the principal excretory organs in vertebrates are the kidneys (for their structure see below)

which eliminate water, nitrogenous substance and inorganic substances, all collectively known as urine.

Urine formation:

Urine formation is accomplished by 3 processes, namely glomerular filtration, tubular reabsorption and tubular secretion.





Glomerular filtration: Ultrafiltration (nitration under blood pressure) takes place from the blood in the glomeruli out into the Bowman's capsules. Water and solutes are filtered off the glomeruli faster than the ordinary capillaries because of two structural features:

- The glomeruli have more pores than other capillaries.
- The efferent arteriole leaving the glomerulus is smaller in diameter than the afferent arteriole, thus offering higher resistance to the blood flowing out of the glomeruli than out of other capillaries. Consequently there is a higher blood pressure in the glomeruli.

Tubular absorption: During the passage of the blood filtrate, which is called primary urine, through the uriniferous tubule, a process of selective re-absorption occurs. Thus about 90-99% of water, all useful substances such as glucose, and various amounts of salts are returned to the blood against the concentration gradient by an active process which uses large quantities of energy. The loop of Henle, found in the kidneys of birds and mammals only, plays an important physiological role in this process.

Tubular secretion: During the passage of the primary urine along the kidney tubules, certain substances, such as ammonia and some drugs, are secreted by the cells of these tubules and added to the urine.

The components of the urine may be differentiated into two types:

a) Threshold substances, which, under normal conditions, are reabsorbed completely from the urine by the kidney tubules. These are useful substances which pass out with the excreted urine only when their concentration rises above a certain level in the blood (threshold value). Examples are glucose and amino acids.

b) Non-threshold substances, are useless substances or are waste products which are passed out even when present in low amounts in the blood. Such substances are not re-absorbed at all in the tubules. e.g. urea, creatinine and sulphates,

The amount of urine secreted is regulated chiefly by the antidiuretic hormone (ADH) of the pituitary gland and also by aldosterone of the adrenal cortex, through controlling the amount of water re-absorbed by the distal tubule cells.

The formed urine passes continuously through the ureter to the urinary bladder where it is stored temporarily. The involuntary muscles of the bladder's wall contract when it is full, driving the urine out, a process known as micturation.

Nitrogenous excretion:

The principal source of the excreted nitrogen is the protein of food. It results mainly from deamination of amino acids. This nitrogen may be excreted in the form of ammonia, urea or uric acid.

Animals are classified according to the type of nitrogenous excretory substance they produce into:

- a) **Ammonotelic animals**, in which ammonia is the main excretory product, e.g, most lower aquatic animals, freshwater fishes and marine teleosts, .
- b) **Ureotelic animals**, which excrete mainly urea in their urine, e.g, elasmobranchs, amphibians and mammals.
- c) **Uricotelic animals**, in which uric acid is the main excretory product. e.g, lizards, snakes and birds.

ARTIFICIAL KIDNEY :

The kidneys eliminate the body's metabolic wastes. However, the kidneys may fail Eventually due to some underlying illness or senility. In these cases, dialysis means the difference between life and death. "Dialysis is an artificial way to eliminate waste and excess fluid from the body. Dialysis maintains the body balance in the following ways:

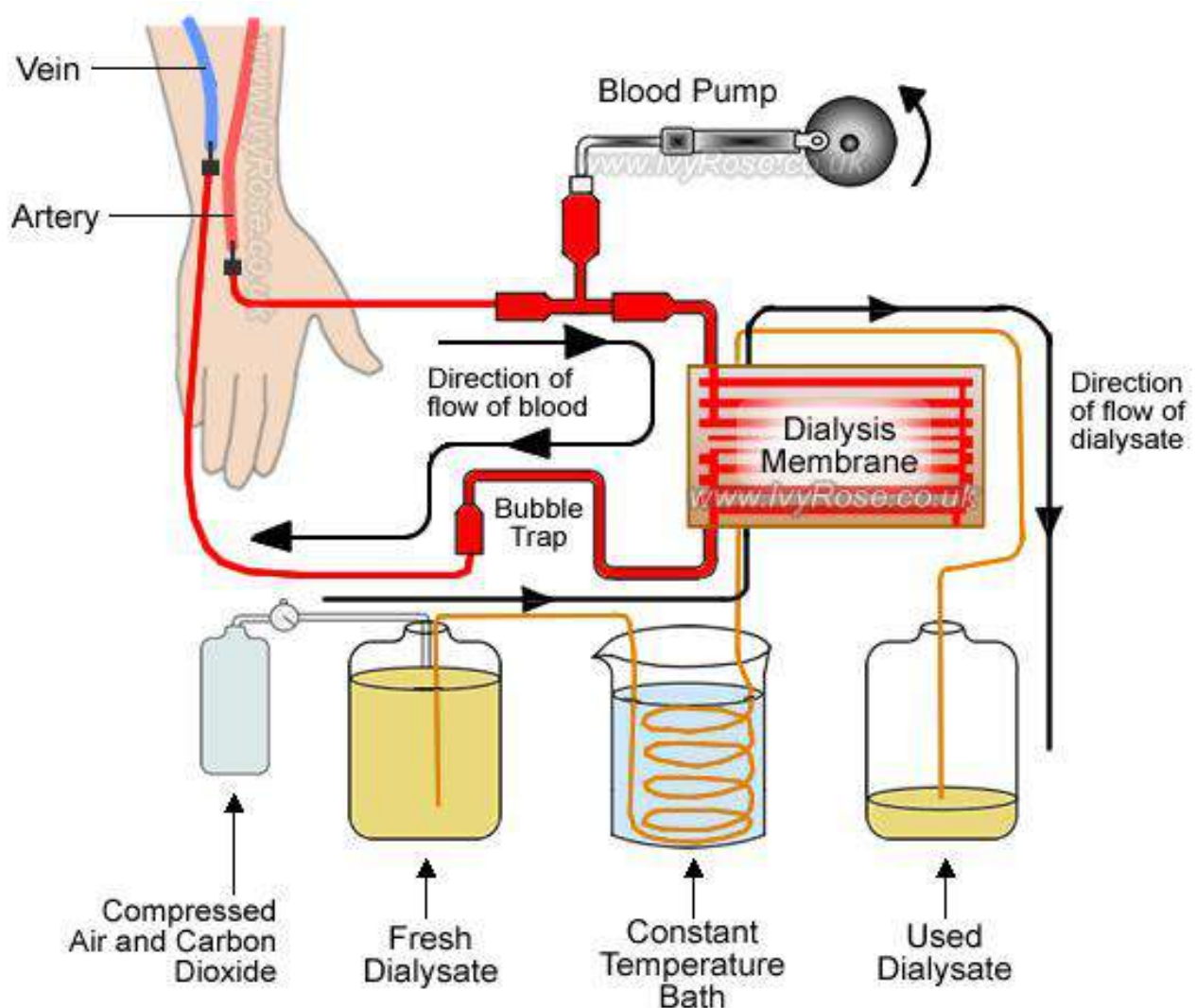
- It controls blood pressure.
- It removes excess water and metabolic wastes from the body.
- Prevents chemicals such as potassium, bicarbonate and sodium from reaching hazardous levels.

Dialysis is used for people with a critical kidney disorder. Death usually ensues when the number of nephrons falls below 5 to 20 % of normal .This treatment may Continue for months or years since most kidney failures are irreversible.

Dialysis functions on the ultrafiltration of fluid through a semipermeable membrane and concept of the dissipation of solutes. Diffusion is a characteristic of materials in water that has the tendency to flow against a concentration gradient.

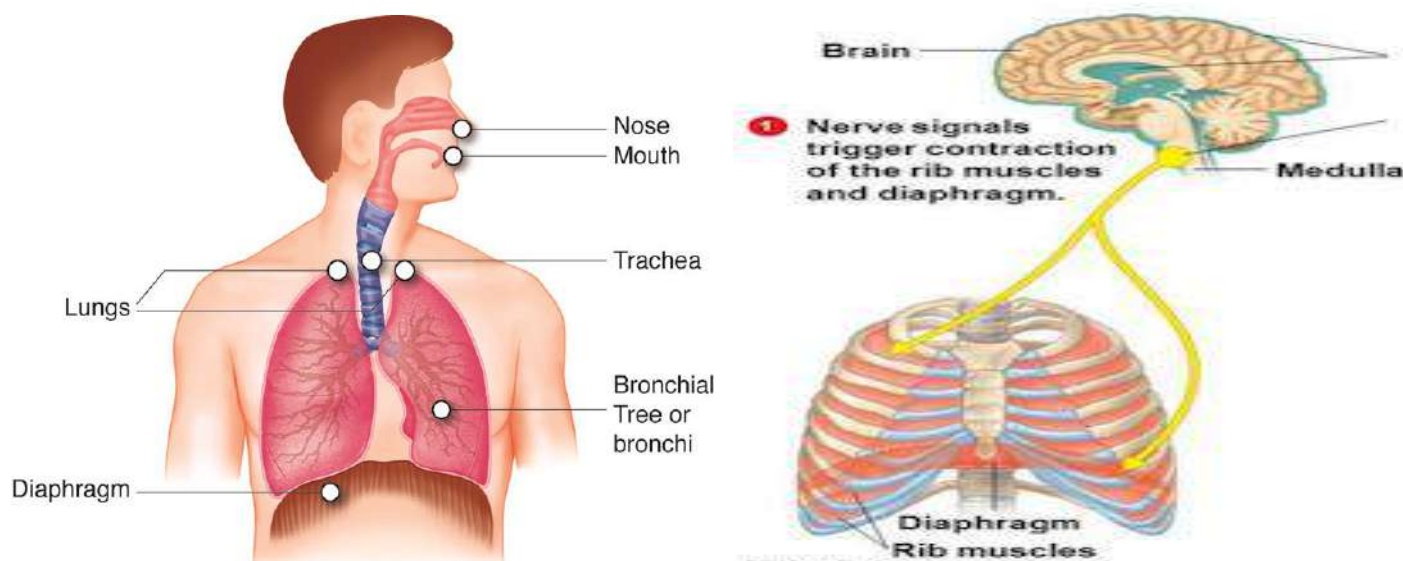
Blood runs on one flank of the semi-permeable film, and dialysate or distinct dialysis fluids flow on the opposite flank. A selectively permeable layer is a skinny membrane of material that comprises pores of different sizes or holes.

Minor solutes and fluids flow through the layer, but the membrane stops the path of Bigger substances (for instance, large proteins, red blood cells). This imitates the filtering procedure that happens in the kidneys when the blood moves into the kidneys and the bigger substances are divided from the minor ones in the glomerulus.



RESPIRATION

Oxygen is needed for the oxidation of food stuffs and the release of energy, and therefore must be provided to all parts of the body. Carbon dioxide, a waste product resulting from the oxidation of foods, must be eliminated from the organism. This important function of gaseous exchange between the body and the surrounding environment is carried out by the respiratory system.



In higher animals, the cells of different tissues are not in direct contact with atmospheric oxygen, therefore the process of respiration necessitates the presence of the following:

1. An oxygen supply from atmospheric air or oxygen dissolved in water.
2. A respiratory surface on which exchange of gases occurs.
3. A respiratory pigment, as haemoglobin. which is a compound protein formed of a protein part (globin) and a nonprotein (haem), At the respiratory surface, haemoglobin which is an unstable compound that is transported by the blood from the respiratory organs to the body tissues where it dissociates to release oxygen.

4. Transporting medium as blood and lymph, for the transportation of gases to and from the transportation of gases to and from the tissues combines with sodium and potassium in the blood plasma forming sodium and potassium bicarbonates, which are transported to the respiratory organs where CO_2 is discarded to the outside. Moreover a small amount of CO_2 combines with haemoglobin and is thus carried to the lungs where it is liberated.

The living organism requires energy for the performance of its vital functions. Energy is generally obtained by the oxidation of the food substances such as carbohydrates, fats etc. Oxidation is effected by the presence of oxygen, and as energy is needed to every living cell. it is also necessary that oxygen should be supplied to every cell. The source of this oxygen is the air which is essentially a mixture of nitrogen (79 parts), oxygen (21 parts) with traces of carbon dioxide and other substances. The body obtains oxygen and gets rid of impurities, principally carbon dioxide, and a great deal of water vapour, and excess of heat by means of the respiratory system. The interchange of gases, that is .the intake of oxygen and output of carbon dioxide at the body surface is usually known as respiration.

THE RESPIRATORY ORGANS:

The respiratory organs include a conduction system of airways, the respiratory area of the lungs where exchange of gases occurs, and a ventilating system that inflates and deflates the lungs, bringing air in and out of the airways and lungs.

The Airways:

Nose, mouth, pharynx, larynx and trachea, bronchi, and bronchioles- form the passages through which air enters the lungs. The walls of the airways are prevented from collapse during ventilation by cartilage and bone. The inner surface of the airways is lined by a mucous membrane consisting of ciliated epithelial cells, mucous cells, glands, and blood vessels, which contribute to the warming, humidifying, and filtering functions of the airways. The conduction system does not take part in gas exchange and is known as the anatomical dead space.

The Respiratory Area:

Consists of the respiratory bronchioles, which are the final divisions of the treelike subdivisions of the bronchioles, and the alveoli. The alveoli are thin walled, inflatable air sacs that bud off from the respiratory bronchioles. Complex capillary networks surround the alveoli, bring non-oxygenated blood from the pulmonary artery into close contact with the alveolar wall, permitting the rapid exchange of gases between the alveolar air and the capillary blood. The thin layer of epithelial cells that form the walls of the alveoli, together with the thin endothelium of the capillary wall, are the main components of the respiratory membrane. The respiratory membrane, through which gaseous exchange occurs, is one of the most delicate of living structures and separates the external environment (inhaled air) from the internal environment (blood).

The Ventilating System:

Consists of a lung thorax pump, which is operated by the respiratory muscles. The muscles actively expand the thorax during inspiration and release the thorax for passive recoil of the lungs in quiet expiration. During exercise, the thorax is actively compressed by the respiratory muscles. The respiratory muscles include the muscles of the thorax and diaphragm, assisted by neck and chest muscles. The elastic connective tissue of the lungs is an essential component for passive recoil of the lungs in expiration.

EXTERNAL RESPIRATION:

External respiration is the exchange of oxygen and carbon dioxide between the alveoli of the lungs and pulmonary blood capillaries through the following steps: (1) passage of air through the respiratory airways and lungs, (2) diffusion of the respiratory gases between the alveoli of the lungs and the pulmonary capillaries, (3) transport of oxygen and carbon dioxide through the blood, and (4) diffusion of the respiratory gases between the blood and the tissues, resulting in the conversion of non-oxygenated blood

(more carbon dioxide than oxygen) coming from the heart to oxygenated blood (more oxygen than carbon dioxide) returning to the heart.

INTERNAL RESPIRATION:

As soon as external respiration is completed, oxygenated blood leaves the lungs through the pulmonary veins and returns to the heart. From here it is pumped from the left ventricle into the aortic arch and through the systemic arteries to tissue cells. The exchange of oxygen and carbon dioxide between tissue blood capillaries and tissue cells is called internal respiration. It results in the conversion of oxygenated blood into non-oxygenated blood, which returns to the heart. From here it is pumped to the lungs for another cycle of external respiration.

CELLULAR RESPIRATION:

It occurs within the cells and involves the oxidation of food stuffs to liberate energy through a complicated series of chemical reactions that take place with the aid of some respiratory enzymes present in the cell protoplasm, such as the cytochromes and dehydrogenases.

RESPIRATORY QUOTIENT (R.O.):

It is the ratio between the volume of carbon dioxide expired and the volume of oxygen inspired in a given time. Since carbon dioxide is formed as a result of the oxidation processes of the different food materials, it has been Possible to find out the respiratory quotients of the three cases of food. It is 1.0 in case of carbohydrates, 0.79 for proteins, and 0.71 for fists.

NERVOUS CONTROL OF RESPIRATION:

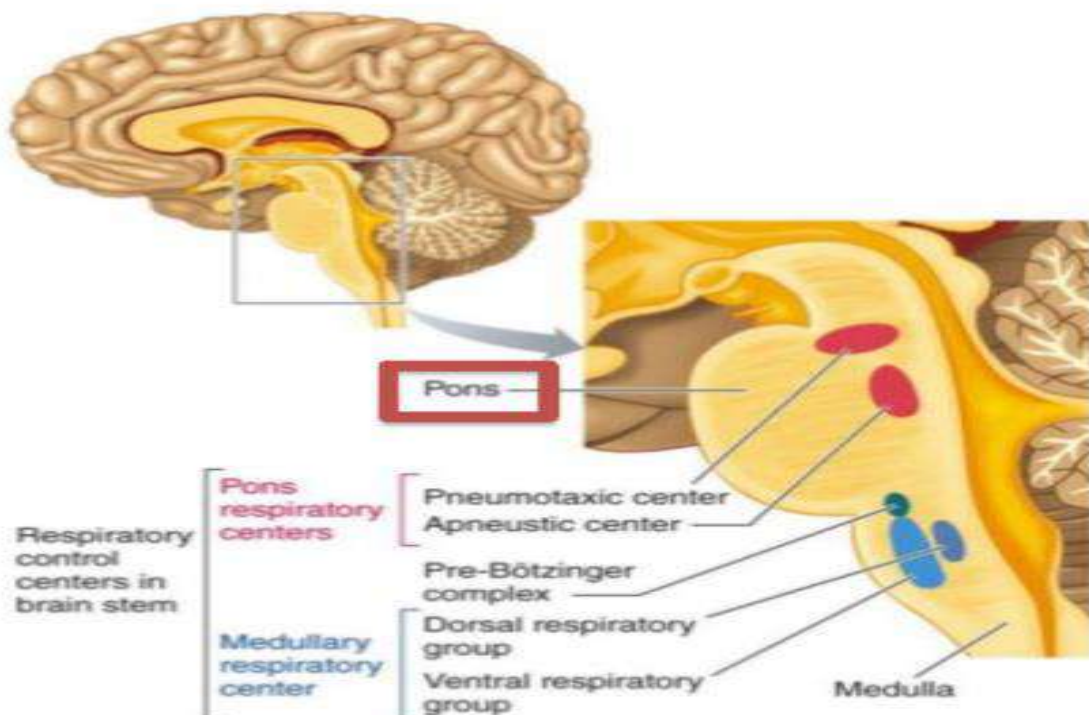
The size of the thorax is affected by the action of the respiratory muscles. These muscles contract and relax in turn as a result of nerve impulses transmitted to them from centers in the brain. The area from which nerve impulses are sent to the respiratory muscles is located in the reticular formation of the brain stem; it isreferred to as the respiratory center. The respiratory center consists of a widely dispersed group

of neurons and is functionally divided into three areas. These are (1) The medullary rhythmicity area in the medulla, (2) The apneustic area in the pons and (3) The pneumotaxic area, also in the pons. The function of the medullary rhythmicity area is to control the basic rhythm of respiration. In the normal resting state, inspiration usually lasts for about 2 seconds and expiration for about 3 seconds. This is the basic rhythmicity area where both inspiratory and expiratory neurons are arranged in circuits. Let us first consider the proposed role of the inspiratory neurons in respiration. When one of the neurons in the circuit becomes excited, it excites the next one, which, in turn, excites the next, and so on. In this way, the nerve impulses travel around the circuit from one neuron to the next. This continues for about 2 seconds, until the neurons become fatigued. However, as some nerve impulses travel around the circuit, other impulses travel from the circuit to the muscles of respiration (the diaphragm and intercostal muscles). These impulses reach the diaphragm by the phrenic nerves and the intercostal muscles by the intercostal nerves. When the impulses reach the respiratory muscles, the muscles contract and inspiration occurs.

In addition to sending impulses to the muscles of respiration, the inspiratory center also sends inhibitory impulses to the expiratory neurons. These impulses inhibit the circuit of expiratory neurons. As long as the inspiratory neurons maintain nerve impulses through their circuit, expiration is inhibited. But when the inspiratory neurons fatigue, the expiratory neurons are no longer inhibited. This causes the expiratory neurons to become excited, and nerve impulses travel around the circuit of expiratory neurons from one neuron to another. This continues for about 3 seconds until they fatigue. While the nerve impulses are maintained by circuit of expiratory neurons, some impulses are transmitted to the respiratory muscles and other inhibit the inspiratory neurons. The impulses to the respiratory muscles, via the phrenic and intercostal nerves, cause the muscles to relax, and expiration occurs. When the expiratory neurons fatigue, the inspiratory neurons are no longer inhibited, and they become excited once again. Thus; the basic rhythm of respiration is established by circuits of inspiratory and expiratory neurons that alternately act upon the muscles of respiration and mutually inhibit each other.

Although the medullary rhythmicity area control the basic rhythm of respiration, other parts of the nervous system can modify the rhythm. For example, in experiments where impulses from the apneustic and pneumotaxic areas are prevented from reaching the medullary rhythmicity area, respiration consist of short inspirations and prolonged expirations. Stimulation of the apneustic area alone sends impulses to the medullary rhythmicity area that result in forceful, prolonged inspirations and weak, short expirations. When the pneumotaxic area is stimulated, impulses to the medullary rhythmicity area result in the cessation of apneustic breathing. Stimulation of the pneumotaxic area can also alter the rate of respiration.

The respiratory center has connections with the cerebral cortex, which means we can voluntarily alter our pattern of breathing. We can even refuse to breath at all for a short time. Voluntary control is protective because it enables us to prevent water or irritating gases from entering the lungs, However, the ability to stop breathing is limited by the buildup of carbon dioxide in the blood, When the concentration of carbon dioxide increases to a certain level, the inspiratory center is stimulated, impulses are sent to inspiratory muscles, and breathing resumes whether or not the person wishes.



MUSCLE: MECHANISM OF CONTRACTION

Approximately 40 percent of the body is skeletal muscle and almost another 10 percent is smooth and cardiac muscle. Many of the same principles of contraction apply to all these different types of muscle.

Types of Muscle



Structure and actions of skeletal muscles:

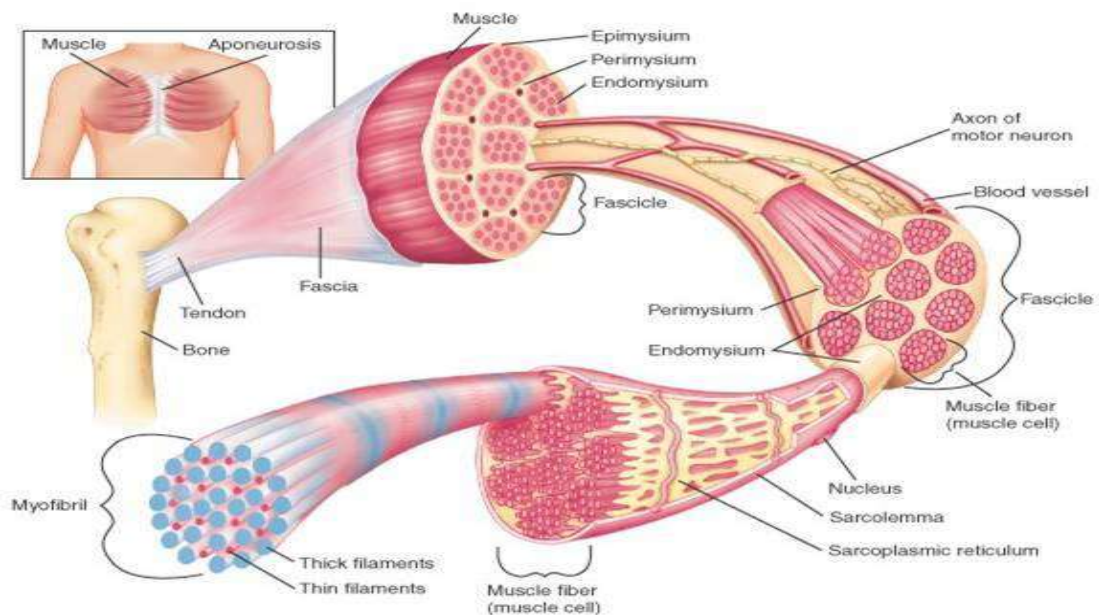
Skeletal muscles are composed of individual muscle fibers which contract when they are stimulated by a motor neuron. Each motor neuron branches to innervate a number of muscle fibers, and all of these fibers contract when their motor neuron is activated.

Activation of varying numbers of muscle fibers, results in gradations in the strength of contraction of the whole muscle. In this way, the muscle can shorten and cause its characteristic movement of the skeleton.

Skeletal muscles are usually attached to bone on each end by tough connective-tissue "tendons". When a muscle contracts it shortens, and this places tension on its tendons and attached bones. The muscle tension causes movement of the bones at a joint, where one of the attached bones generally moves more than the other. The more movable generally moves more than the other. The more movable bony attachment of the muscle, known as its "insertion", is pulled toward its less movable attachment "the origin". A variety of different skeletal movements are possible depending on the type of

joint possible depending on the type of joint involved and the attachments of the muscle.

Structure of skeletal muscles:



All skeletal muscle's are made of numerous fibers ranging between 10 and 80 microns in diameter. The fibrous connective tissue proteins within the tendons continue to an irregular arrangement around the muscle to form a sheath known as the epimysium (epi = above; my = muscle). Connective tissue from this outer sheath extends into the body of the muscle, subdividing it into columns, or fascicles (e.g., the "strings" in stringy meat). Each of these fascicles, is thus surrounded by its own connective tissue sheath, known as the "perimysium" (peri-around).

Dissection of a muscle fascicle under a microscope reveals that it, in turn, is composed of many, muscle fibers (or myofibers) surrounded by wisps of connective tissue called "endomysium". These fibers are actually the muscle cells. Since the connective tissue of the tendon, epimysium, perimysium, and endomysium is continuous, muscle fibers do not normally pull out of the tendons when they contract.

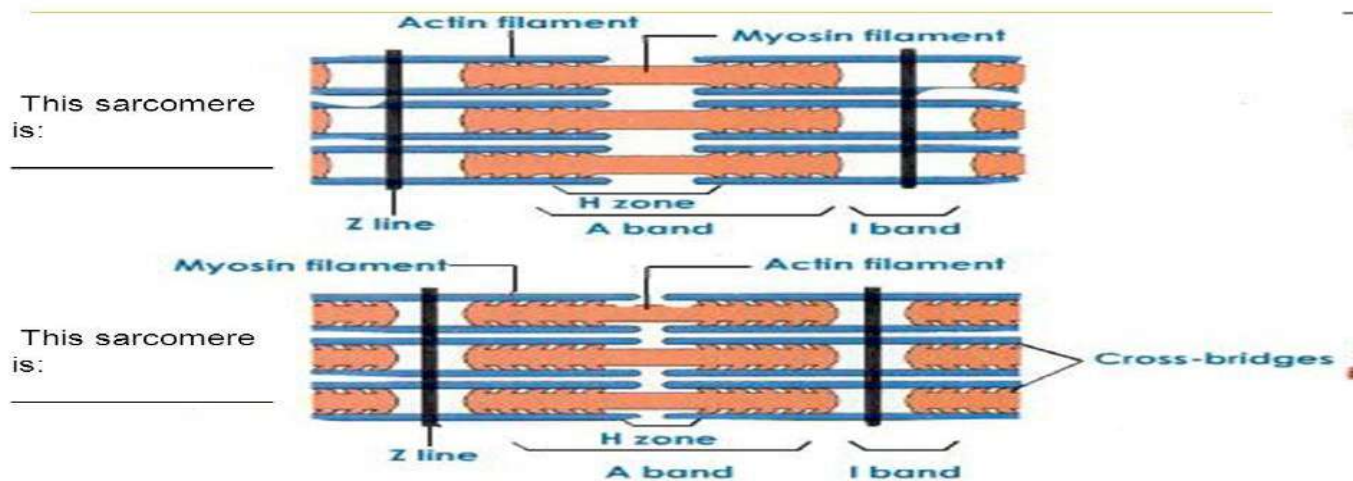
Despite their unusual fiber shape, muscle cells have the same organelles that are present in other cells: mitochondria, intracellular membranes, glycogen granules; and

others. Unlike most other cells in the body, skeletal muscle fibers are multinucleate - that is, they contain many nuclei. The most distinctive feature of the microscopic appearance of skeletal muscle fibers, however, is their striated appearance. The striations (stripes) are produced by alternating dark and light bands that appear to cross the width of the fiber.

Each muscle fibers contains several hundred to several thousand myofibrils. Each myofibril in turn has, lying side-by side, about 1500 myosin filaments and 3000 actin filaments, which are large. Polymerized protein molecules that are responsible for muscle contraction. These can be seen in longitudinal view in the electron micrograph.

The dark bands are called A bands and the light bands are called I bands. At high magnification in an electron microscope thin, dark lines can be seen in the middle of the I bands. These are called Z lines. The labels A, I and Z are usual for describing the functional architecture of muscle fibers, and-were derived during the history of muscle research. The letters A and I stand for "anisotropic" and "isotropic", respectively, which indicate the behavior of polarized light as it passes through these regions; the letter Z comes from the German word "Zwischenscheibe" which translates to "between disc".

Mechanisms or contractions:

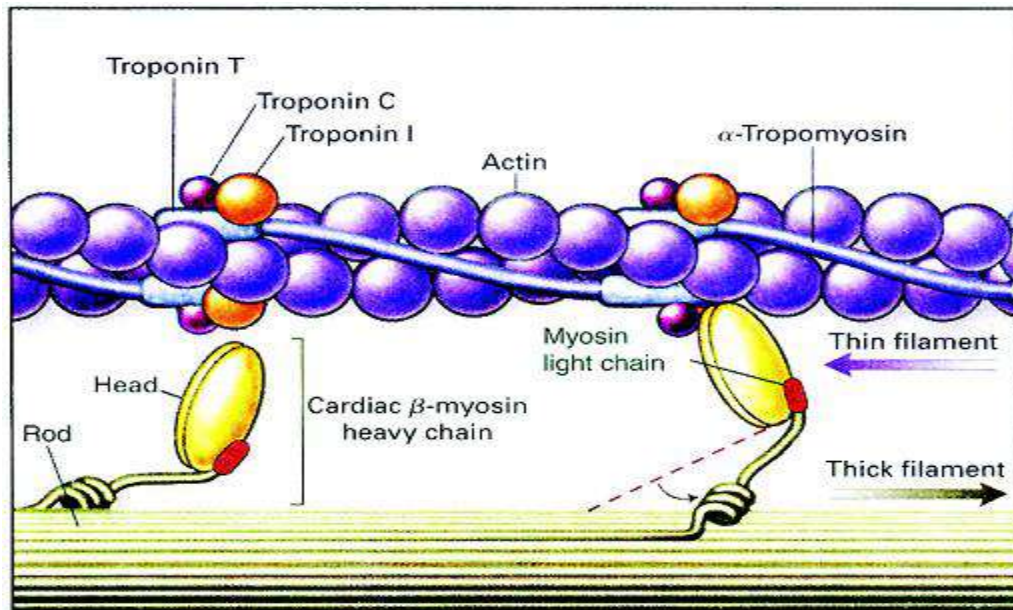


Which diagram shows a sarcomere (functional unit of muscle) that is contracted?
Which diagram shows a sarcomere that is relaxed? Label above.

Sliding filament theory of contraction:

When a muscle contracts isotonically, it decreases in length as a result of the shortening of its individual fibers. Shortening of the muscle fibers, in turn, is produced by shortening of their myofibrils, which occurs as a result of the shortening of the distance from Z line to Z line. As the sarcomeres shorten in length, however, the A bands do not shorten but instead move closer together. The I bands - which represent the distance between A bands of successive sarcomeres - decrease in length.

The thin actin filaments composing the I band, however, do not shorten. Close examination reveals that the thick and thin filaments remain the same length during muscle contraction. Shortening of the sarcomeres is produced, not by shortening of the filaments, but rather by the sliding of thin filaments over and between the thick filaments. In the process of contraction, the thin filament on either side of each A band slide deeper and deeper toward the center, producing increasing amounts of overlap with the thick filaments. The I bands (containing only thin filaments) and H bands (containing only thick filaments) thus get shorter during contraction.



Cross-bridges:

Sliding of the filaments is produced by the action of numerous cross-bridges that extended out from the myosin toward the actin. These cross- bridges are part of the myosin proteins that extend from the axis of the thick filaments to form "arms" that terminate in globular "heads". The orientation of cross-bridges on one side of the sarcomere is opposite to that on the other side, so that when they attach to actin on each side of the sarcomere they can pull the actin from each side toward the center.

Each globular head of a cross- bridge contains an ATP-bonding site closely associated -with an actiri-binding site. The globular heads function as myosin ATPase enzymes, splitting ATP into ADP and Pi. This reaction occurs before the cross-bridges combine with actin, and indeed is required for .activating the cross bridges so that they can attach to actin. The ADP and Pi remain bonded to the myosin heads until the cross-bridges attach to the actin.

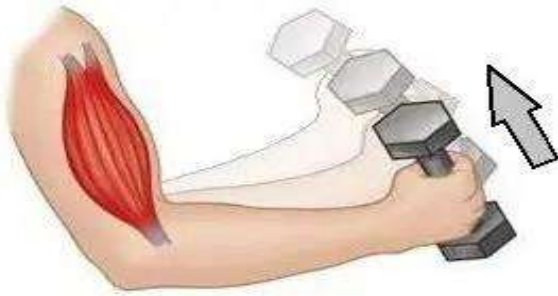
The myosin heads are able to bond to specific attachment sites in the actin subunits when the cross-bridges bond to actin they undergo a conformation change. This has two effects:

- 1) ADP and Pi are released and

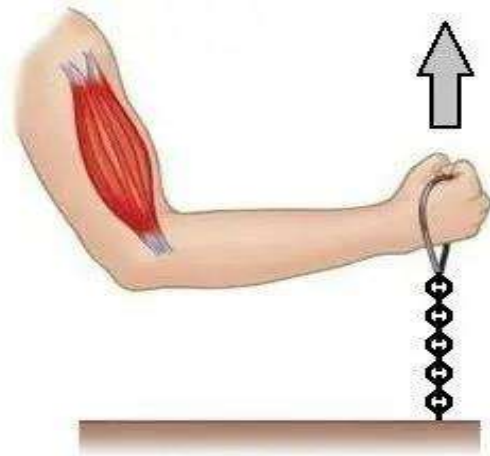
- 2) The cross-bridges change their orientations, resulting in a power stroke, which pulls the thin filaments toward the center of the A bands. At the end of the power stroke each cross-bridge bonds to a fresh ATP molecule. This binding of the cross-bridge to break its bond with actin and resume, its resting orientation. The myosin ATPase will then split ATP and become activated as in the previous cycle. Note that the splitting of ATP is required before a cross-bridge can attach to actin and undergo a power stroke and that the attachment of a new ATP is needed for the cross-bridge to release from actin at the end of a power stroke.

Isotonic and Isometric contractions: In order for muscle fibers to shorten when they contract, they must generate a force that is greater than the opposing forces that act to prevent movement of the muscle's insertion. Flexion of the forearm, for example, occurs against the force of gravity and the weight of the objects being lifted. The tension produced by the contraction of each muscle fiber separately is insufficient to overcome these opposing forces, but the combined contractions of many muscle fibers may be sufficient to overcome the opposing force and flex the forearm in this case the muscle and all its fibers shorten in length.

Contraction that results in muscle shortening is called isotonic contraction, so-called because the force of contraction remains relatively constant throughout the shortening process (iso = same; tonic = strength) if the opposing forces are too great or the number of motor units activated is too few to shorten the muscle, however, the contraction is called isometric (literally "same length").

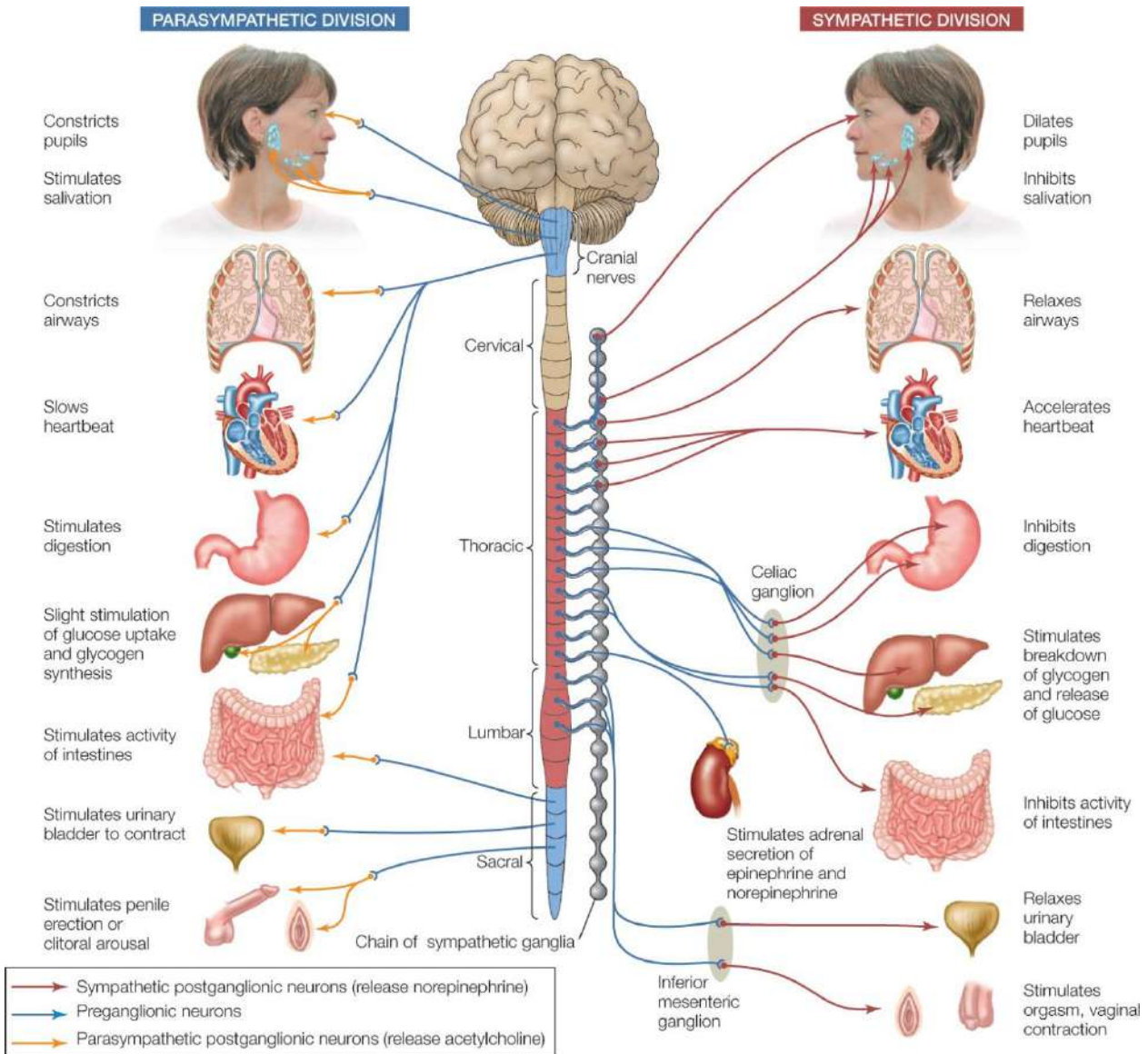


ISOTONIC



ISOMETRIC

NERVOUS COORDINATION



Nervous conduction and coordination is brought about by the nervous system, the basic functional and anatomical units of which are the neurons.

A neuron is composed of the cell body or cyton, dendrites and an axon which terminates in a number of terminal arborizations (page 106). The dendrites carry the nerve impulses to the cell body while the axon conducts the impulses from the cell body outwards. With respect to the direction of impulses, axons (or fibres) are classified into two groups: afferent axons (fibres) which carry the nerve impulses from the receptor organs (ear, eye, etc.) to the central nervous system, and efferent axons (fibres) which

carry impulses from the central nervous system to various organs or tissues inducing them to produce the appropriate reactions.

1-Transmission of nerve impulses:

A nerve impulse involves a sequence of electrochemical changes propagated along a nerve fibre. The conduction of impulses along neural pathways include: a) transmission along nerve fibres, and b transmission across synaptic areas.

a) Transmission along nerve fibres: Many theories were put forward to explain the way of transmission of impulses along nerve fibres; the most accepted theory is the membrane theory. This theory suggests that transmission occurs as a result of a wave of electrical depolarization that passes along the covering membrane of the nerve fibre.

In the resting, non stimulated nerve fibre, the surface membrane is electrically positive along its outer surface and negative along its inner side. The electric charges are carried by inorganic ions (Na, K, Cl) attached to the two sides of the membrane. In this form the membrane is said to be electrically polarized. This polarization of the membrane is due to its semi-permeability, i.e. at rest, it prevents the positive and negative ions from passing through it to neutralize each other.

When the nerve fibre is stimulated at any point, the semipermeability of its membrane is lost at that point. In other words, the membrane becomes depolarized at the point where the fibre is stimulated. It becomes permeable to the positive and negative ions which pass through it to neutralize each other.

Ions on an adjacent, not yet activated area, jump through this depolarized point to neutralize each other. Therefore, a new depolarized and permeable area is created next to the first one, and ions from a third adjacent point jump through it, and so on the ionic shift continues, along the length of the nerve fibre. This explains what is meant by the passage of the nerve impulse as a wave of depolarization in the membrane of the nerve fibre.

After the impulse has passed a certain spot, semipermeability and polarization of the membrane is restored at that spot.

All the nerve impulses are essentially the same, but they differ in the action they produce according to where the fibre terminates. If it ends in a muscle, the contraction or a muscle is produced; if it end, in a certain region of the cerebral cortex, the sensation of sight is experienced; or in other region of the cerebral cortex, the sensation of hearing is experienced. If it ends in contact with dendrites of another neuron at a synapse, an impulse is initialed in that neuron of the same chain.

2- Transmission across synapses :

Anatomically, a synapse is described as the site at which the terminal arborizations of a nerve cell axon (considered presynaptic in position) lies very close to the dendrites of a neighbouring neuron (considered postsynaptic in position). However, physiologically the synapse is defined as a functional connection between neurons accomplished through contact or near contact of their adjacent membranes. A synaptic knob or cleft is formed between the presynaptic membrane and the postsynaptic membrane, among which the transmission of nerve impulses takes place.

In a few examples of the invertebrates, transmission of nerve impulses across a synapse may be electrical. but in the majority of animals. especially among the vertebrates, transmission occurs by a diffusible chemical substance. This is confirmed by recent electron microscope studies of synapses, where the synaptic knobs or clefts were shown to contain numerous vesicles. These synaptic vesicles apparently contain the transmitter chemical which is secreted when the impulse reaches the synaptic knob. This chemical then diffuse to the dendrite terminals of the adjacent neuron where it initiates a new impulse. The impulse passes at the synapse in one direction only, from the axon of one neuron to the dendrites of the next neuron. i.e. the synapse acts as a one way valve. On the other hand, impulses are conducted in both directions in the neurons.

Two transmitter substances or local hormones known to play a role in synaptic transmission are:

a) Sympathin which is similar to adrenaline in chemical structure and biological effect. This is secreted by the axon terminals of the post-ganglionic fibres of the sympathetic or autonomic nervous system.

b) Acetylcholine is secreted by pre-ganglionic fibres of the sympathetic nervous system and all the parasympathetic and possibly also the nerve fibres of the central nervous system. The enzyme choline esterase is present at the synapse to split acetylcholine into acetyl and choline fractions to inhibit the action of acetylcholine.

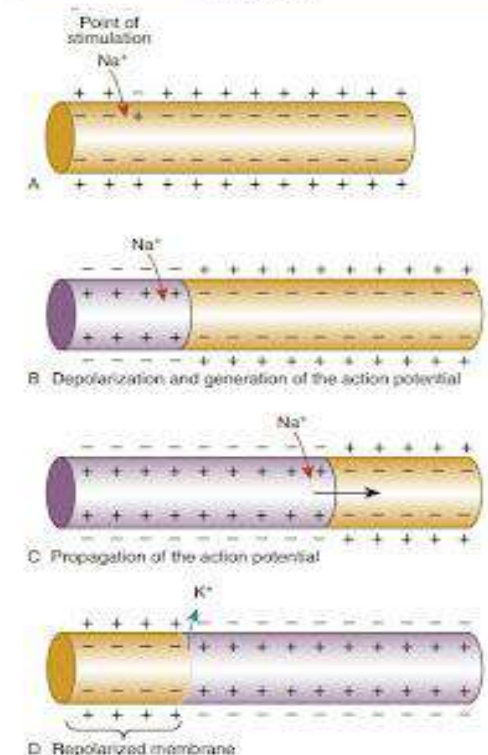
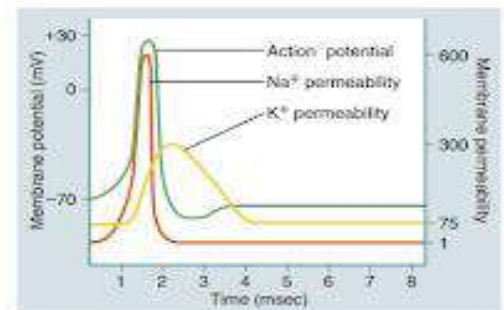
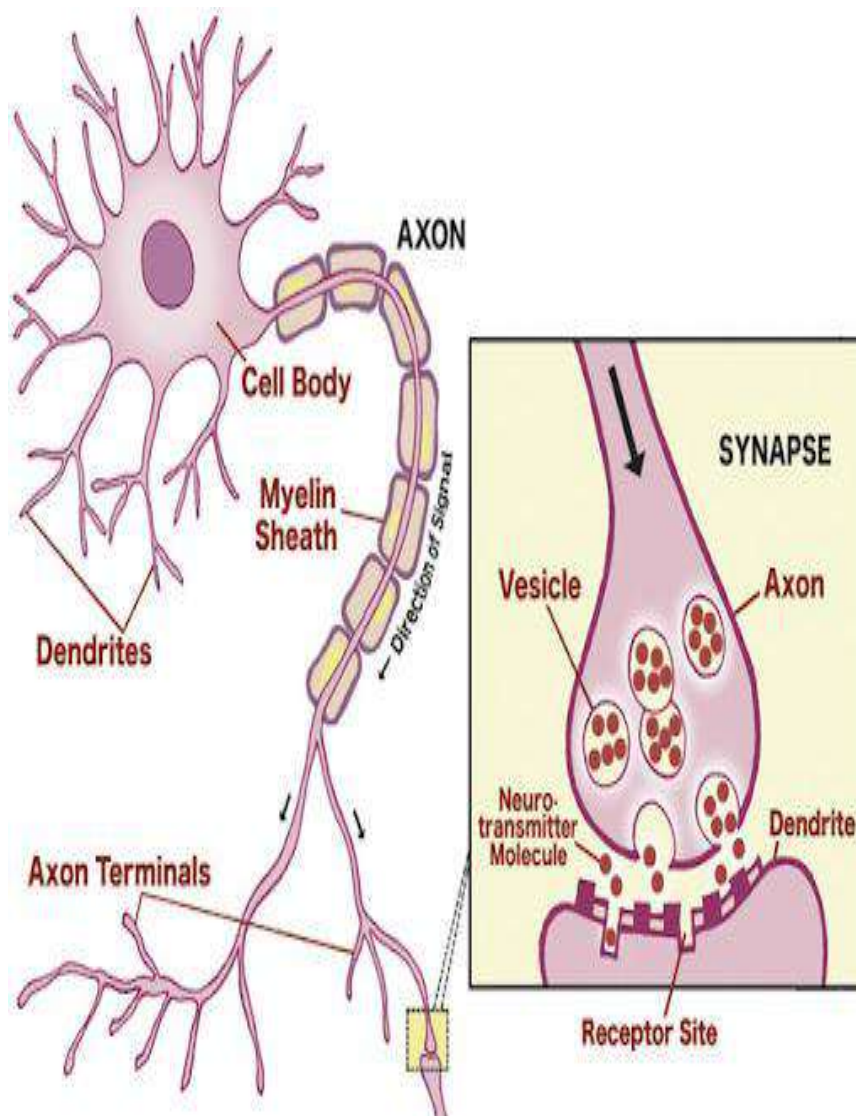


FIGURE 11-9 Nerve impulses.

Reflex arc:

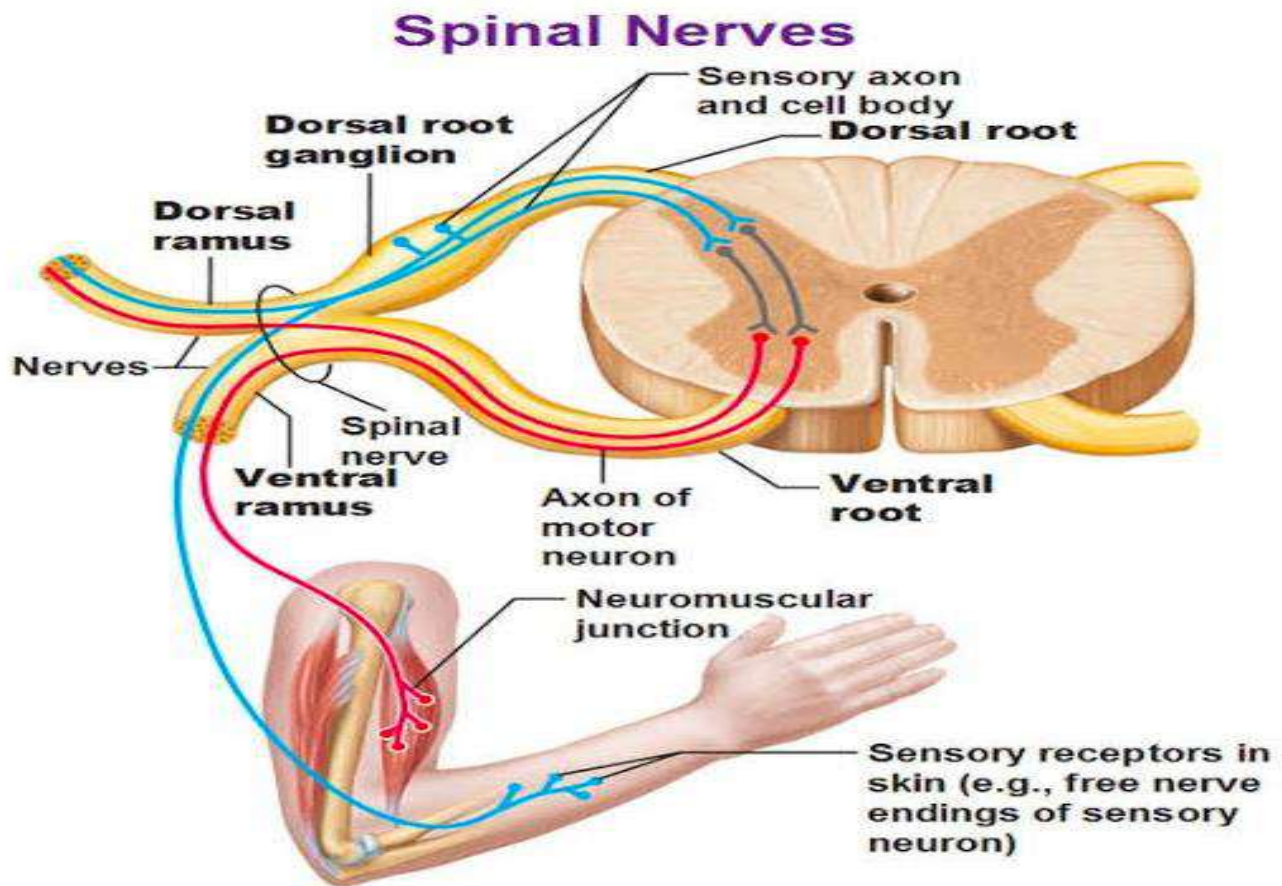
A reflex is a response to a stimulus that would cause an impulse to pass to the central nervous system, from which it is reflected back to the effective organ which produces that response.

The simplest example of nerve action which is not controlled by the will is the reflex arc, e.g. when a bright light shines suddenly in the eye, the eye pupil unconsciously contracts. Also a blow on the tendon of the quadriceps femoris (below the patella) causes the contraction of this muscle and the jerking of the leg upwards.

A reflex arc involves the following elements:

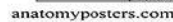
- 1- **A receptor**, usually a sensory cell, to receive the stimulus.
- 2- **Afferent or sensory fibre**, which runs along the sensory branch of the spinal nerve then along the main trunk of the nerve and it; dorsal root. It transmits the impulse from the receptor to the sensory cell found in the dorsal root ganglion. This fibre represents the dendrite of the sensory neuron.
- 3- **Sensory neuron**, which receives the stimulus and transmits it along its axon, that passes into the dorsal horns of the spinal cord and ends with fine branches, the terminal arborization.
- 4- **Adjustor neuron**, which is found in the grey matter between the dorsal and ventral horns of the spinal cord. It has short dendrites in the dorsal part of the spinal cord, and a small axon in the ventral region. It translates the sensory impulse into motor effects.
- 5- **Motor or effector neuron**, which is located in the ventral horn of the spinal cord, it bears small dendrites at the upper side and a long axon, known as the efferent or motor fibre, which passes along the ventral root, then through the spinal nerve and along the motor branch of that nerve to the effector organ.

6- An effector, which may be a muscle or gland.



A **reflex action** takes place in the following manner: The stimulus, received by the receptor, is passed along the afferent or sensory fibre which transmits, the sensory impulse to the sensory neuron. This carries the sensory impulse to the adjutor neuron which translates it into a motor impulse, that is transmitted along the motor fibre to the effector. The latter organ responds in an appropriate manner to the stimulus.

ENDOCRINE SYSTEM



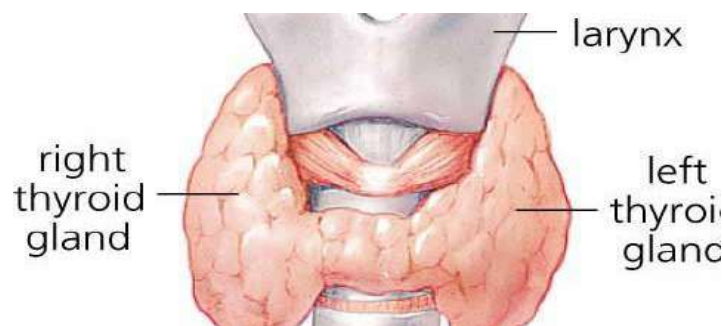
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(hyperactivity) or decrease (hypoactivity) in the normal activity of the endocrine glands lead to various disturbances in the metabolism of the organism.

Chemical nature and properties of hormones:

- 1- Hormones are organic substances of varying structural complexity. They are either steroids or amino-acid derivatives, including proteins, peptides and modified amino-acids.
- 2- Hormones have a marked influence on several life processes, ,such as growth .development reproduction energy utilization cell permeability, .. etc
- 3- Hormones may either slimulll or inhibit a function, but they generally do not initiate a process, e.g. oxidative processes still go on in absence of the thyroid hormones, but not at the normal rates.
- 4- Hormones are effective in remarkably small quantities e.g. the injection of a few micrograms of adrenaline into a dog causes a pronounced increase I the rate of heart beat.
- 5- Hormones, with a few exceptions. are not species specific. Extractsor sheep's thyroid, for example, can accelerate the development and metamorphosis or tadpoles.
- 6- Some hormones seem to be highly specific as regards their action in their target tissue, e.g. the follicle-stimulating hormone. Others, such as the adrenal conical hormones, affect a wide variety or cells and tissues.

THYROID GLAND



The thyroid gland in mammals is situated in front of trachea, just below the level of the thyroid cartilage of the larynx. The gland consists of two lobes joined together by an isthmus. In toads, this gland is found as a dif-fused mass on the pulmoeutaneous arch.

Histologically, the thyroid gland consists of a great number of glandular follicles or acini, each lined by a single layer of cubical epithelium. The lumen of these follicles is filled with a semi-fluid colloid called thyroglobulin which is rich in iodine (65% iodine). From this colloid, the hormones of the thyroid, thyroxine and tri-iodothyronine, have been isolated. These hormones influence the body metabolism, development and growth of the organism, excitability of the nervous system. etc.

Hypothyroidism: Deficiency of the thyroid hormones occurring during infancy produces a conditions known as cretinism. This is characterized by diminished metabolism. retarded growth (dwarfism), deformity in various parts of the body, extremely low mentality and arrested sexual development.

Hypoactivity of the gland in adults results in a condition called myxoedema (mucus swelling), which is characterized by the deposition of mucous tissues under the skin, decreased metabolic rate, sleepiness and lack of spirit although the general intelligence is retained, increased body fat and hypercholesterolemia, greater susceptibility to cold. and disturbances in the sexual functions (cessation of menstruation in females).

Deficiency of iodine in the diet may lead to reduced production of the hormone and enlargement of the thyroid gland tissue, a disease known as simple or endemic goitre.

Hyperthyroidism: Excessive production of the thyroid hormone causes the disease known as exophthalmos goitre which is characterized by enlargement of the thyroid gland, bulging of the eye-balls (exophthalmos), increased metabolism, general muscular weakness and rapid fatigue, increased production of heat, nervous excitability, dissipation of fat stores, etc.

Effect of thyroxine on animals:

When thyroxine is administered to lizards and birds, it causes premature moulting. In tadpoles, thyroxine accelerates the metamorphosis before attaining their full size, while the thyroidectomized tadpoles do not metamorphose to frogs.

PARATHYROID GLANDS

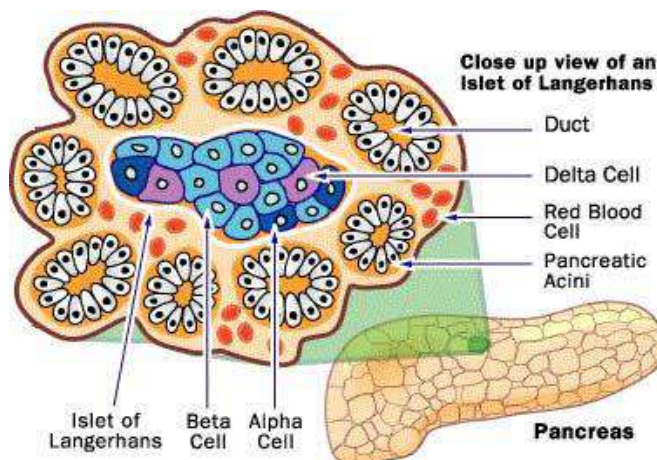
In mammals, the parathyroid glands are 4 small oval bodies lying adjacent to the posterior edge of the thyroid glands. In man, they are sometimes embedded in the thyroid tissue.

Histologically, the parathyroids are formed of cuboidal epithelial cells arranged in closely packed masses, separated by irregular bands of connective tissue richly supplied with blood vessels. Two types of cells are identified: **(a) Chief cells:** these are small with large nuclei and pale non-granular cytoplasm. They are considered to be the active secretory cells which produce the hormone parathormone, **(b) Oxyphil cells:** these are large cells containing eosinophil granules and are of unknown function.

Hypoparathyroidism: Parathormone deficiency is characterized by a drop in the calcium content of blood (hypocalcemia) and a rise in the blood phosphorus. The drop in calcium causes increased irritability in the peripheral motor fibres giving rise to tremors followed by tetanic spasms or muscle contractions (tetany). Death may result from spasms of the muscles of the respiratory system.

Hyperparathyroidism: This condition is due to malignant tumours in one or more of the glands. It is accompanied by an increase in the calcium content of the blood plasma together with a decrease in the inorganic phosphorus, while these 2 substances are excreted in large amounts in the urine. This is followed by diseases in the skeletal system due to withdrawal of calcium from the bones which may become deformed and cavitied, a condition known as osteitis fibrosa.

PANCREAS



The mammalian pancreas consists mostly of an exocrine portion, which secretes the digestive pancreatic juice and an endocrine portion which secretes certain hormones. The endocrine portion is formed of groups or clusters of cell found between the enzyme-secreting acini, and are called islets of Langerhan, The islets of Langerhans contain three types of cells: alpha, beta and gamma-cells.

Alpha-cells constitute about 25% of the islets, they are large cells with granular cytoplasm and are supposed to secrete the hormone glucagon.

Beta-cells are the most numerous (about 75%) and occupy mainly the periphery of the islets. They are smaller than the others and contain acidophilic granules and are supposed to secrete the hormone insulin.

Gamma-cells are non-granular. They are of unknown function.

Insulin:

This is a polypeptide consisting of 2 chains of amino acids, linked together by disulphide bridges. The insulin molecule does not contain zinc, but when it combines with zinc its effect becomes intensified.

Insulin influences carbohydrate metabolism, i.e, it helps to oxidize carbohydrates in the tissues and promotes glycogenesis (synthesis of glycogen) in the liver and muscles.

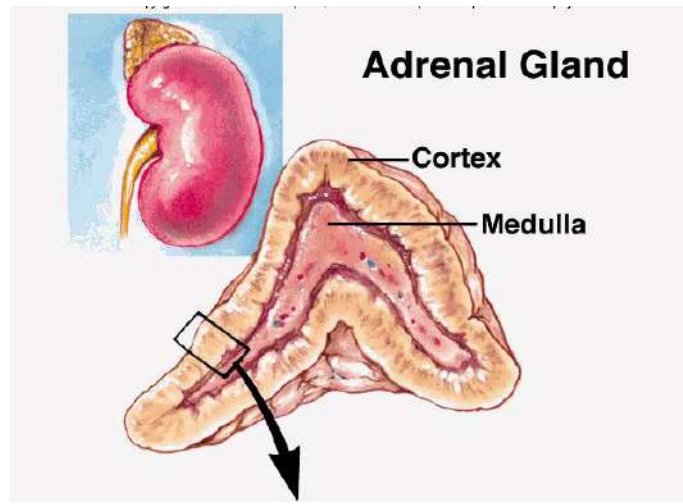
Hypofunction of the pancreatic islets, resulting in a decreased secretion of insulin, causes the disease known as diabetes mellitus. In this disease, the tissues cannot assimilate glucose normally and the liver fails to store glycogen. As result, the blood glucose increases (hyperglycaemia) above the normal level which is 80-120 mg %. When the blood glucose increases than the renal threshold (180 mg%), glucose appears in the urine (glycosuria). Insulin deficiency also affects oxidation of fats. In severe cases, fats are only oxidised to intermediate substances known as ketone bodies (acetone, acetic acid and β -hydroxybutyric acid). Some of the proteins are also transformed into intermediate acid products. These products of incomplete fat and protein metabolism are harmful and may poison the individual causing cardiac weakness and loss of consciousness, a condition known as diabetic coma.

Some conditions are characterized by increased insulin secretion, on the other hand, (as occurring in tumours of the pancreas) is accompanied by a decrease in blood sugar (hypoglycaemia), which may show dangerous symptoms such as convulsions, drop in temperature and loss of consciousness, a condition known as hypoglycaemic shock.

Glucagon:

This hormone is secreted by the alpha-cells of the islets of Langerhans. It is a polypeptide of relatively low molecular weight. Its effect is antagonistic to that of insulin. Glucagon promotes the intracellular conversion of inactive phosphorylase enzyme to an active form. This enzyme is concerned with the breakdown of glycogen into glucose, thus bringing about a sharp increase in the blood sugar level.

ADRENAL (SUPRARENAL) GLANDS



These are two small bodies found near the kidneys in mammals and on the ventral side of the kidney in toads. Each gland is composed of 2 parts, the cone: and medulla, which are histologically and physiologically two different endocrine glands.

A. Adrenal cortex :

This consists of 3 zones, an external glomerular zone (zona glomerulosa), a middle fascicular zone (zona fasciculata), and an internal reticular zone (zona reticularis), More than 40 corticosteroid compounds have been derived from the adrenal cortex, but only few are physiologically active. The cortical hormones may be classified into three groups:

- 1- Mineralocorticoids: e.g. aldosterone and deoxycorticosterone. These are secreted by the glomerular zone and regulate metabolism of mineral salts.
- 2- Glucocorticoid: e.g. cortisone. These hormones are secreted by the fascicular zone and influence the metabolism of carbohydrates, proteins and fats.
- 3- Sex hormones: e.g. androgens and oestrogens. These hormones are secreted by the reticular zone. In old age, the internal secretions of the sex glands (gonads) cease and the adrenal cortex becomes the only source of sex hormones.

Hypoactivity:

Adrenocortical insufficiency results in Addison's disease. This disease is characterized by disturbance in metabolism, loss of weight, loss of appetite, drop in blood pressure, decrease in blood glucose, acidosis of the blood, and a darkening of the skin due to deposition of melanin in the basal layers of the epidermis. The removal or destruction of the adrenal cortex is fatal within few days.

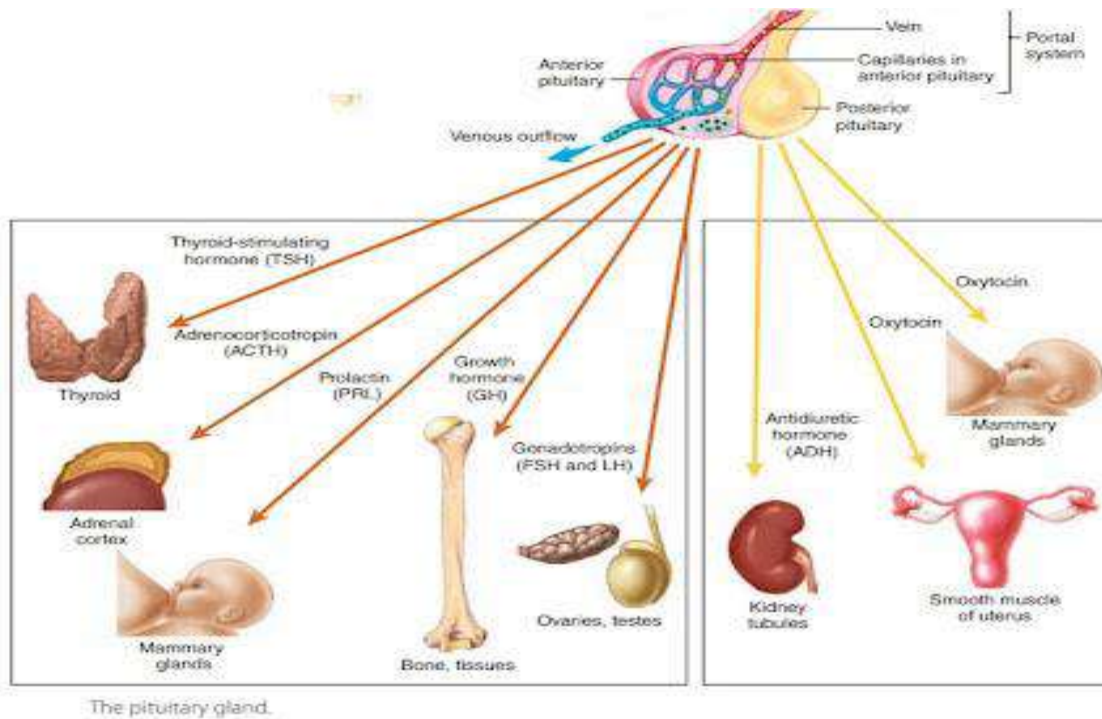
Hyperactivity:

This condition is accompanied by changes in sexual development. In young children, premature puberty appears, e.g. a male child of 4 years, old may show the sexual features of an adult. In young girls, the breast hypertrophies. In adult women, the voice deepens, menstruation ceases, the breasts atrophy and the hair may grow upon the face, chest and limbs.

B. Adrenal medulla:

This is composed of closely packed group, of polyhedral granular cells. The medulla secretes a mixture of adrenaline (epinephrine) and noradrenaline. Adrenaline influences many functions, including intracellular metabolism. It promotes the breakdown of glycogen and reduces its reserves in the liver and muscles, with subsequent increase in blood sugar. It also intensifies and accelerates cardiac contraction and constricts the arterioles causing rise in arterial blood pressure. On the other hand, adrenaline inhibits the contraction of the smooth muscle of the stomach, intestine and urinary bladder. Moreover, adrenaline postpones muscles fatigue, thus increasing the working capacity of the organism under certain circumstances. It is therefore said that adrenaline is released to prepare the organism to fight, flight and fright.

PITUITARY GLAND



This gland is considered the master gland of the endocrine system because it produces special hormones which affect the activities of other endocrine glands.

It is located in the cranial cavity below the brain. It originates partly from the brain and partly from the buccal epithelium in the roof of the buccal cavity. The gland consists of 3 lobes: the anterior lobe, the intermediate lobe and the posterior lobe.

Hormones of the adenohypophysis:

1- Growth hormone: This hormone affects a number of metabolic processes. It increases protein synthesis and controls growth. Manifestations of its deficiency differ according to age. If it occurs in early childhood, it causes dwarfism. The intelligence is not noticeably affected, and the genital organs remain infantile. Men suffering from the deficiency of this hormone are impotent, i.e., are unable to perform the sexual act; while women are sterile.

On the other hand, excessive production of the growth hormone in early childhood results in gigantism. But if this occurs in adults, the distal parts of the long bones (hands, feet, fingers and toes) and the bones of the face (cheek bones and the lower jaw) exhibit renewed growth, a condition called acromegaly.

2- Thyrotrophin: This hormone stimulates the growth of the thyroid gland and intensifies its activity. It initiates metamorphosis in tadpoles and other larvae.

3- Adrenocorticotrophin (ACTH): This hormone controls the activity of the adrenal cortex.

4- Gonadotrophic hormones: These are 3 hormones: the follicle-stimulating hormone (F.S.H.), luteinizing hormone (L.H.) or interstitial cell-stimulating hormone (I.C.S.H.), and prolactin. In females, the F.S.H. promotes the development of follicles in the ovaries and their conversion to Graafian follicles. While in males it promotes the development of seminiferous tubules in the testes and accelerates spermatogenesis and the development of the prostate gland. L.H. stimulates the production of the corpus luteum, while in the male it is responsible for the development and secretion of the interstitial gland cells of the testes. Both these hormones are necessary for normal sexual development. Prolactin stimulates the secretion of milk in the mammary gland and the production of progesterone in the corpus luteum.

Hormones of the neurohypophysis:

Two hormones are secreted by the posterior lobe; the first is the **antidiuretic** hormone (ADH) or vasopressin, which markedly inhibits urine formation and increases blood pressure by inducing the contraction of the smooth muscles of the blood vessels. The second hormone is **oxytocin** which causes the contraction of the uterine muscles, particularly at the end of pregnancy, and its presence is indispensable for normal childbirth.

GONADS

In addition to producing gametes, gonads secrete hormones whose function is to develop the sexual organs and the secondary sex characters. Moreover, they participate in the regulation of metabolism. The male sex hormones are called androgens, whereas those of the female are called oestrogens.

Male sex hormones (androgens):

The interstitial cells of the testis (Leydig's cells) secrete 2 hormones, namely **testosterone** and **androsterone**. When these hormones are injected into castrated animals, they stimulate the growth of the prostate and the seminal vesicles, but they have no effect upon the seminiferous tubules. In man, these hormones are secreted continuously throughout the sexual life.

Female sex hormones (oestrogens):

The ovaries produce 3 hormones; oestradiol, progesterone and relaxin:

- 1- Oestradiol:** is normally secreted by the Graafian follicles, but during pregnancy by the placenta. It influences the sexual features. such as enlarging mammary glands. and regulating menstruation.
- 2- Progesterone:** is secreted by the corpus luteum. It influences the normal course of pregnancy, i.e. it controls the periodic changes in the mucous membrane of the uterus to be ready for the implantation of the fertilized egg. It also delays the maturation of Graafian follicles and is responsible for the changes occurring in the mammary glands during pregnancy. If the corpus luteum (which produces progesterone) is destroyed or removed,. pregnancy will not take place.
- 3- Relaxin:** is also secreted by the corpus luteum. It causes relaxation of the pubic symphysis at the end of pregnancy to facilitate delivery of the young.

PINEAL BODY

This gland is a rounded body situated at the end of the pineal stalk arising on the roof of the diencephalon. It secretes a hormone called **melatonin** which is so called because it affects the melanophores, causing paleness of the skin. This hormone probably also delay sexual maturation in animals, reduces the size of the ovaries, and Inhibits the oestrous cycle in adult females. The removal of the gland results in the enlargement of the gonads, adrenals and the pituitary glands.

HORMONES OF THE MUCOUS MEMBRANES OF THE ALIMENTARY CANAL

The mucous membrane of the alimentary canal contains digestive glands which secrete the digestive juices. In addition, the mucous membrane secretes certain hormones of which are;

- 1- Gastrin:** stimulates gastric glands of the stomach to secrete the gastric juice.
- 2- Secretin:** secreted by the mucous membrane of the duodenum and stimulates the secretion of pancreatic juices.
- 3- Cholecystokinin:** secreted also the mucous membrane and- induces the gall bladder to pour its bile.

REPRODUCTIVE SYSTEM

Reproductive system of an organism, also known as the **genital system**, is the biological system made up of all the anatomical organs involved in sexual reproduction. Many non-living substances such as fluids, hormones, and pheromones are also important accessories to the reproductive system. Unlike most organ systems, the sexes of differentiated species often have significant differences. These differences allow for a combination of genetic material between two individuals, which allows for the possibility of greater genetic fitness of the offspring.

Male

The male reproductive system is a series of organs located outside of the body and around the pelvic region of a male that contribute towards the reproduction process. The primary direct function of the male reproductive system is to provide the male sperm for fertilization of the ovum.

The major reproductive organs of the male can be grouped into three categories. The **first category** is sperm production and storage. Production takes place in the testes which are housed in the temperature regulating scrotum, immature sperm then travel to the epididymis for development and storage. **The second category** is the ejaculatory fluid-producing glands which include the seminal vesicles, prostate, and the vas deferens. **The final category** are those used for copulation, and deposition of the spermatozoa (sperm) within the male, these include the penis, urethra, vas deferens, and Cowper's gland.

Major secondary sex characteristics include larger, more muscular stature, deepened voice, facial and body hair, broad shoulders, and development of an Adam's apple. An important sexual hormone of males is androgen, and particularly testosterone.

The testes release a hormone that controls the development of sperm. This hormone is also responsible for the development of physical characteristics in men such as facial hair and a deep voice.

Female

The human female reproductive system is a series of organs primarily located inside of the body and around the pelvic region of a female that contribute towards the reproductive process. The human female reproductive system contains three main parts: the vulva, which leads to the vagina, the vaginal opening, to the uterus; the uterus, which holds the developing fetus; and the ovaries, which produce the female's ova. The breasts are involved during the parenting stage of reproduction, but in most classifications they are not considered to be part of the female reproductive system.

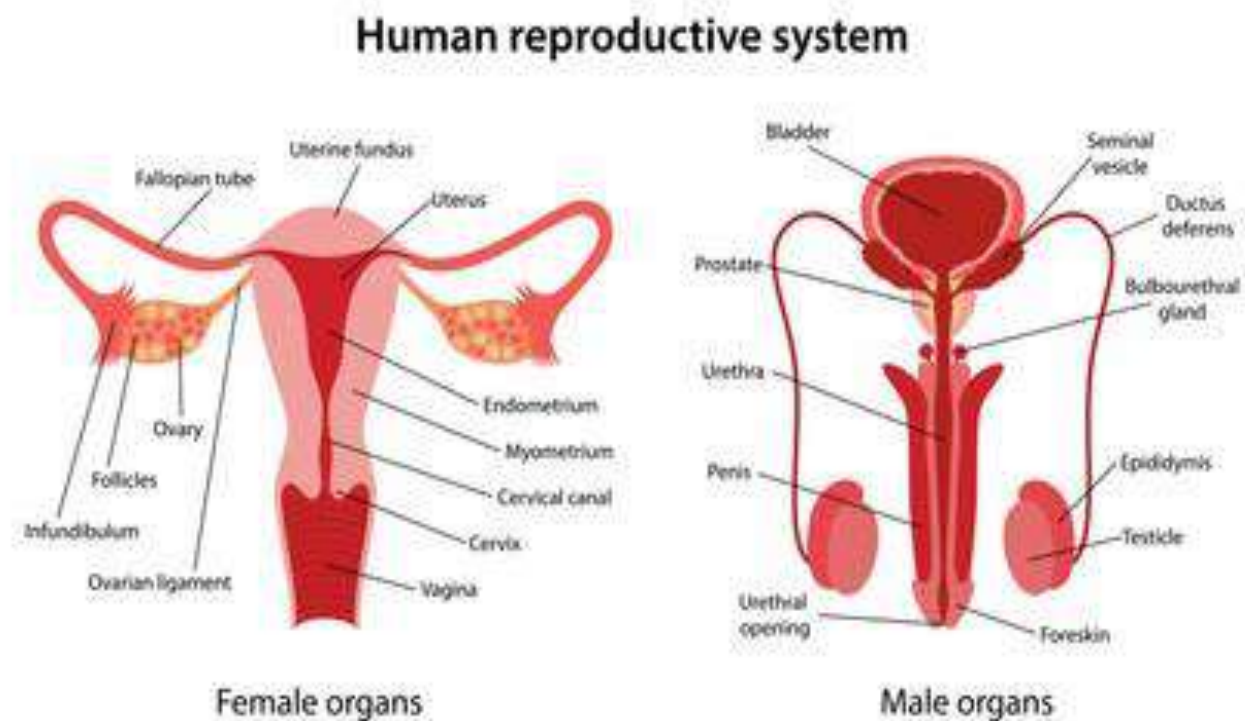
The vagina meets the outside at the vulva, which also includes the labia, clitoris and urethra; during intercourse this area is lubricated by mucus secreted by the Bartholin's glands. The vagina is attached to the uterus through the cervix, while the uterus is attached to the ovaries via the fallopian tubes. Each ovary contains hundreds of ova (singular ovum).

Approximately every 28 days, the pituitary gland releases a hormone that stimulates some of the ova to develop and grow. One ovum is released and it passes through the fallopian tube into the uterus. Hormones produced by the ovaries prepare the uterus to receive the ovum. The ovum will move through her fallopian tubes and awaits the sperm for fertilization to occur. When this does not occur i.e. no sperm for fertilization, the lining of the uterus, called the endometrium, and unfertilized ova are shed each cycle through the process of menstruation. If the ovum is fertilized by sperm, it will attach to the endometrium and embryonic development will begin.

Reproduction is the process by which living organisms maintain their kind. In the vertebrates in general, the gonads arise as paired pouches from the coelomic epithelium and project in the coelomic body cavity. The testes either remain permanently inside the body cavity, as in case of rats, or lie outside that cavity, in a special sac known as the scrotum, as in man. In some animals, as in many rodents, the testes remain in the body cavity most of the year and move out into the scrotum only during the breeding season.

In early embryos, each gonad appears formed of an outer cortical layer and an inner medulla. The former corresponds to a female gland and the latter to a male gland. The gonads of the two sexes are thus identical at the beginning and have equal potentialities for both sexes.

The sex chromosomes, which are already inherited in the genotype of the individual, then induce the secretion of certain hormones which initiate the development of either the male or the female sexuality, i.e. direct the development of the originally undifferentiated gonads to one sex and inhibit the development of the other sex.



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Sexual cycles:

Most animals produce gametes during certain breeding seasons, the duration of which varies considerably. It may be one day or one night, as in some marine annelids, or may extend for one season, as in most fishes, birds and some mammals (in spring) as well as in the deer and sheep (in autumn). Some animals, however, may have 2 or more breeding seasons per year, as the dog (in spring and in autumn). For others, such as the monkeys, apes, man and domesticated cattle, the breeding season extends throughout the whole year.

Males usually produce sperms continuously throughout the breeding season or seasons and often also, but to a lesser extent, in between those seasons. But females do not produce eggs continuously. Therefore, the sexual rhythm is often more marked in the females. Most females produce a single batch of eggs during the breeding season. This is true also for many mammals, in which the period of egg production and maturation is called the oestrous cycle. It is the period of maximum breeding activity,

when the female is most attractive to the male and most receptive to it. The oestrous cycle in mammals ensures optimum conditions for implantation of the fertilized ovum in the uterus.

Some animals are monoestrous, such as the silver fish, having a single cycle per year extending for about 5 days during late winter. If the produced eggs are not fertilized during these days, the animal remains infertile till the following breeding season.

Other animals, such as the horse and sheep, are seasonal polyoestrous. i.e, they undergo several oestrous cycles during the breeding season, thus producing successive batches of eggs during that season. However, as soon as one batch is fertilized, the production of the succeeding batches is stopped throughout the rest of the breeding season.

Gestation or pregnancy is defined as the period of growth of the embryo in the uterus of the mother. It differs in the different animals: being longer in larger animals. e.g, in the elephant it is 21-22 months, horse: 11 months, sheep: 5 months, dog: 63 days, cat: 56 days and rabbit: 32 days.

Parturition is the process of birth and is mainly brought about by the rhythmic contractions of the smooth muscles of the uterus.

Oestrous cycle:

With the onset of puberty, ovulation occurs periodically in human beings. In women the sex cycle lasts from 25-28 days and is divided into 4 periods:

1- Pro-oestrous or pre-ovulation period: In this period the woman is prepared for pregnancy. The uterus becomes enlarged filled with blood and its mucous membrane thickens. These changes are caused by increased secretion of the follicle stimulating hormone (F.S.H.).

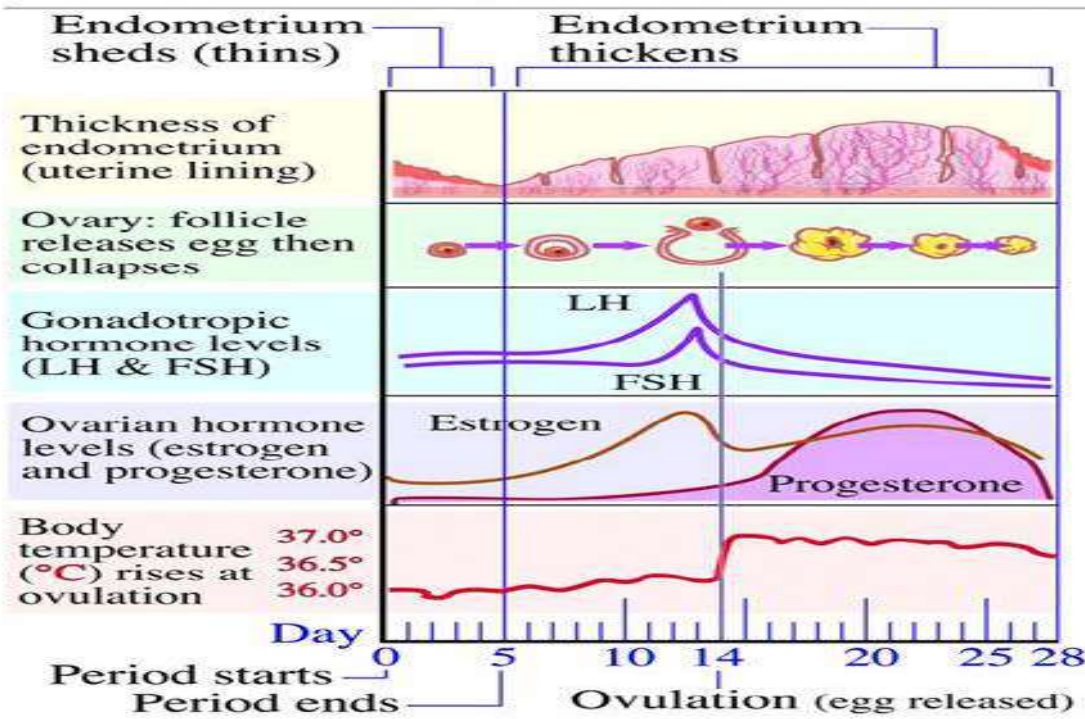
2- Oestroos or ovulation period: The Graafian follicle ruptures and the discharged ovum moves along the Fallopian tube into the uterus. Fertilization with the sperms

may occur during its passage in the tube and in this case the cycle is interrupted and pregnancy sets in. If the ovum is not fertilized, the third period begins.

3- Post-oestrous or post-ovulation period: The unfertilized ovum, having reached the uterus, remains there for several days before it disintegrates. Under the influence of the hormone progesterone, the secretion of gonadotrophic hormones decreases. The decrease in the luteinizing hormone (L.H.) leads to the atrophy of the corpus luteum and to tonic contractions of the uterus with the result of discharge of its mucous lining together with some blood. This is called menstruation; it lasts for about 5 days. Menstruation occurs only in human beings and higher primates not in other animals.

4- Di-oestrous or period of rest: During this period (10 days), a new Graafian follicle is in the process of development. It reaches maturity about 14 to 15 days after the beginning of the last menstrual period.

The reproductive period of human females ends in middle age, a time known as menopause.



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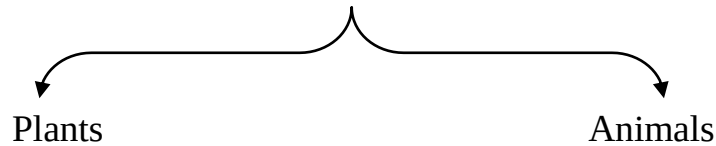


Histology

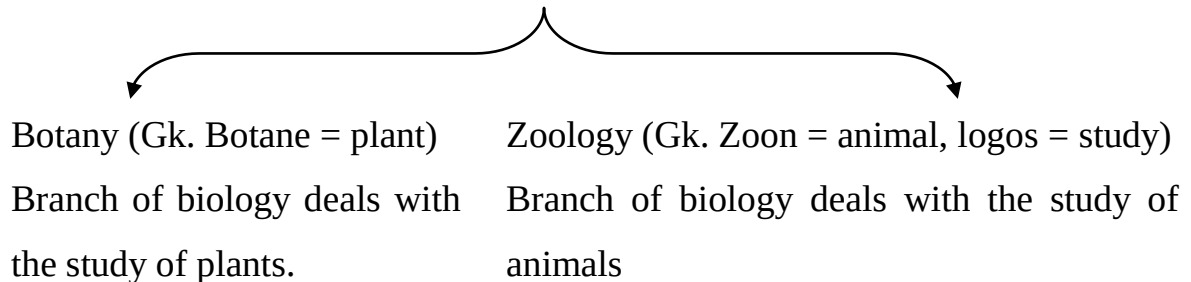
Biology (Gk. Bios = life, logos = study)

Thus Biology, Science deals with the study of living objects.

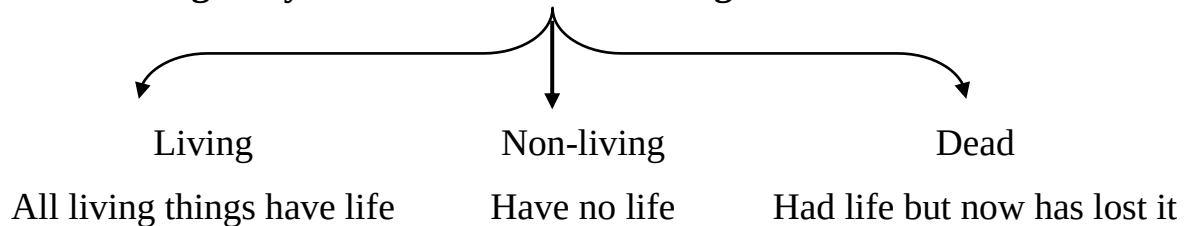
The living objects are of two types



Thus Biology has two branches



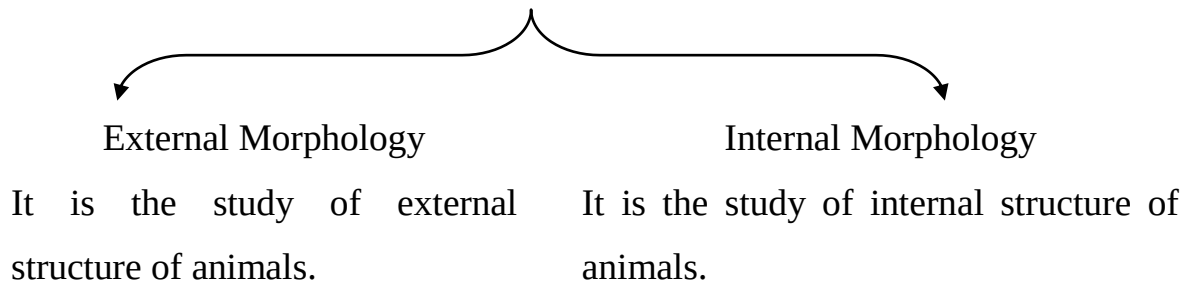
All the things may be divided into three categories



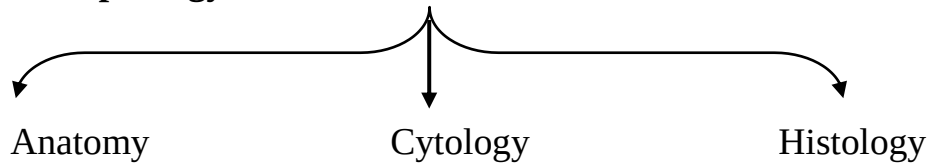
Main branches of Zoology:

- 1- Taxonomy (Systematic Zoology):** It deals with the nomenclature and classification of animals.
- 2- Physiology:** It is the study of various function of the different parts of the body.
- 3- Embryology:** It is the study of the different developmental stages of animals from fertilized egg (zygote) to the adult.
- 4- Genetics:** It is the study of heredity, which means the transmission of characters from the parents to the offsprings.

5- Morphology: It is the study of form and structure of the animals. It has two branches:



Internal Morphology has three sub-branches



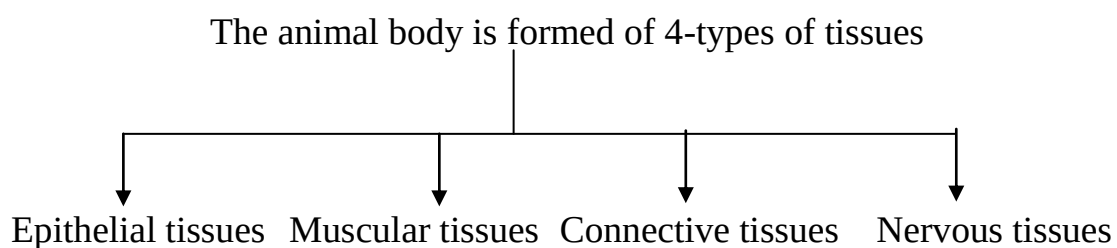
(a) Anatomy is the study of the structure of internal organs of animals as seen by naked eye after dissection.

(b) Cytology is the microscopic study of the cells.

(c) Histology is the microscopic study of the tissues of the different organs.

Each living organism starts its life as a single cell which is the fertilized egg (zygote). This cell undergoes successive mitotic divisions giving rise to a large number of cells which become arranged into 3-layers called the primary germ layers; an outer ectoderm, a middle mesoderm and an inner endoderm. The cells in each layer are differentiated to form specialized groups of cells. The cells of each group constitute what is known as a tissue. Thus the tissue is defined as a specialized group of cells similar in structure, perform the same function, and are bound together by a certain substance called the intercellular substance or matrix, produced by the cells themselves.

The tissues do not exist in the body as isolated units, they are associated together to form the organs of the body, and a number of organs form an organ system. The different systems form the animal body.



Epithelial Tissues

They are characterized by:

- 1- Arise from all 3-germ layers.
- 2- It is called an epithelium, when it is found covering the outer surface of the body.
- 3- It is called an endothelium, when it is found lining certain hollow organs.

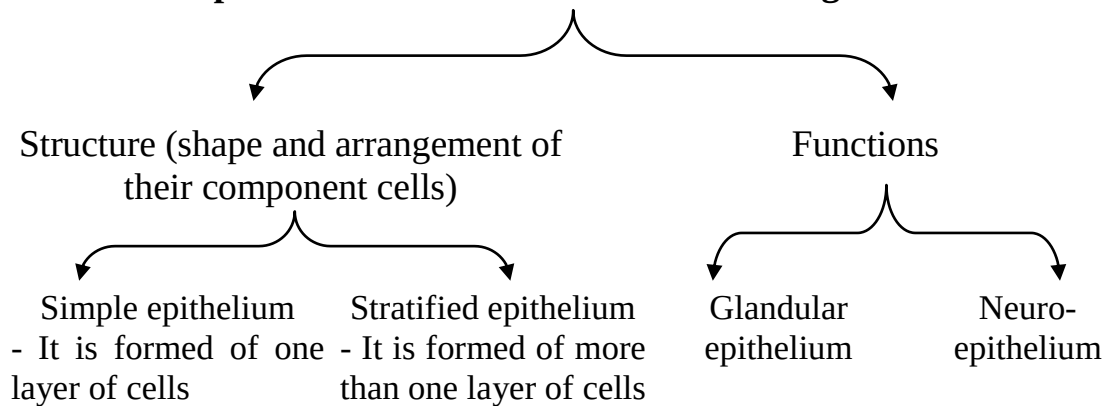
- 4- It is called mesothelium, when it is found lining the internal body cavity.
- 5- Its component cells rest on a basement membrane.
- 6- The matrix which binds their cells together is scanty.
- 7- The blood vessels and lymphatics are not seen between epithelial cells.
- 8- Nutrients reach the cells by diffusion from the basement membrane.
- 9- The nerve fibers can pass within epithelial cells.
- 10- Most of epithelial cells have the ability of regeneration.
- 11- Some epithelial cells are modified to be secretory and form glandular epithelium.
- 12- Some epithelial cells are modified to receive the nervous stimuli and form neuroepithelium.
- 13- Some epithelial cells modified to produce germ cells (sperms and eggs) and form germinal epithelium.

Function of epithelial tissues:

- 1- Protect the body against mechanical, thermal, chemical and bacterial agents through the epidermis of the skin.
- 2- Perform absorbed function through the gastro-intestinal epithelium.
- 3- Perform excretory function through the epithelium of renal tubules.
- 4- Perform secretory function by glandular epithelium.
- 5- Perform sensory function by neuro-epithelium.
- 6- Produce germ cells by germinal epithelium.

Classification of Epithelial Tissues

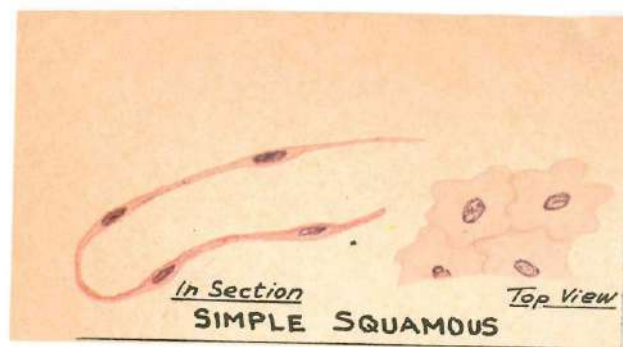
Epithelial tissues are classified according to their



Simple Epithelial Tissues include

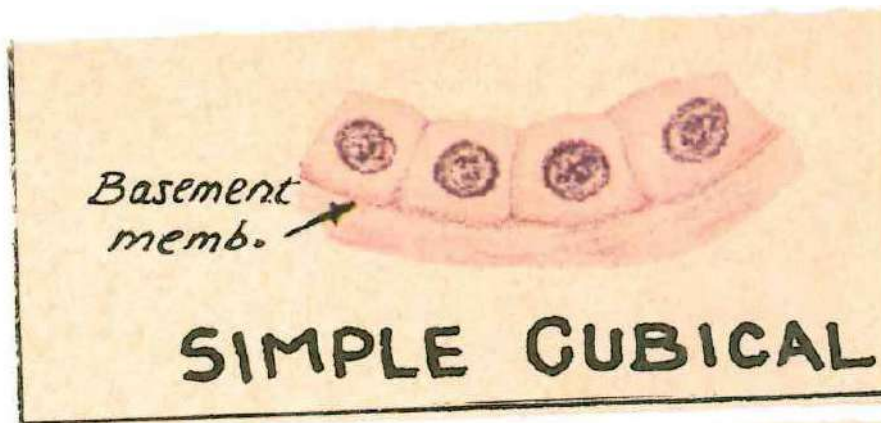
1- Simple squamous epithelium:

It is formed of one layer of flat cell with flattened nuclei as the lining epithelium of Bowman's capsules of the kidney and the lining epithelium of the blood vessels. It does not lying on a basement membrane.



2- Simple cuboidal epithelium:

It is formed of one layer of cubical cells with central rounded nuclei, lying on a basement membrane. It is found in the thyroid follicles of the thyroid gland and in the kidney tubules.

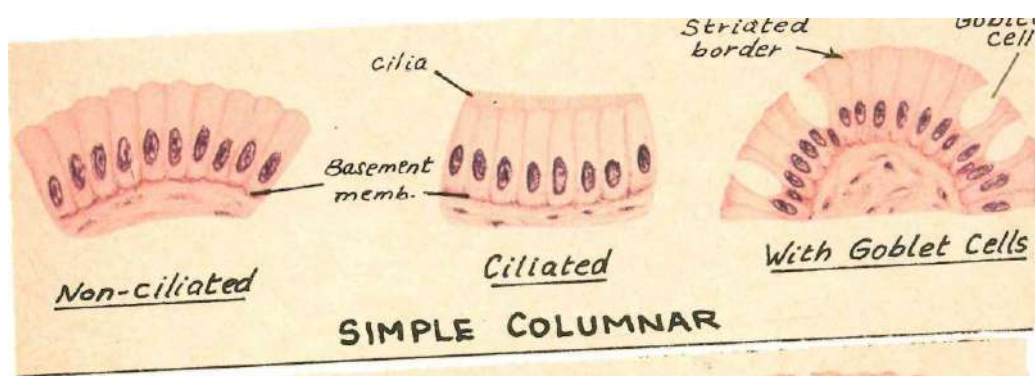


3- Simple columnar epithelium:

It is formed of one layer of tall cells with basal oval nuclei, lying on a basement membrane. It lines the stomach perform secretory function. It is also lines the small intestine and perform absorptive function.

4- Ciliated simple columnar epithelium:

It is formed of one layer of columnar cells carrying cilia on their free borders. It is found in the bronchioles of the lung.

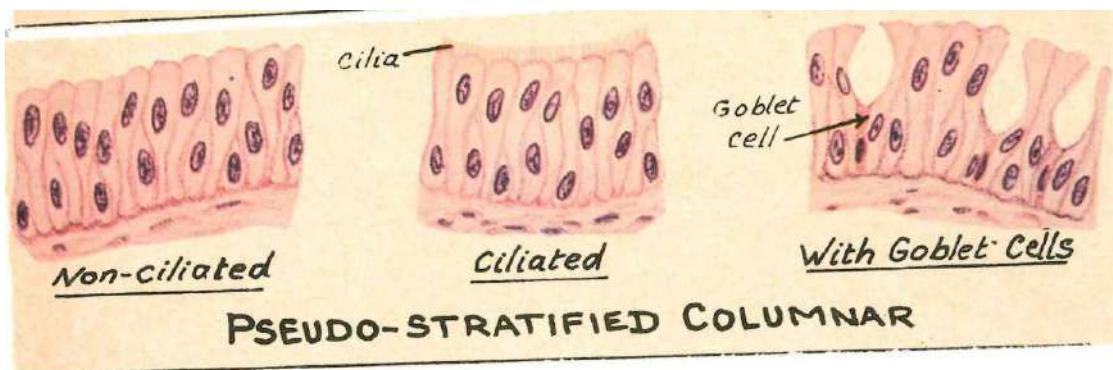


5- Pseudostratified epithelium:

It is formed of 2-kinds of cells. The first kind is tall cell with an inner narrow ends lying on the basement membrane and broad outer ends reach the outer surface of the epithelium. The second kind is short conical cells wedged inbetween the tall cells. Their outer ends do not reach the outer surface of the epithelium. Two rows of nuclei can be seen, giving false appearance of being formed of two layers of cells. This type is found lines the ducts of parotid gland.

6- Ciliated pseudostratified epithelium:

It is pseudostratified epithelium, except that the tall cells carry cilia on their free surface. This type is found in the trachea.



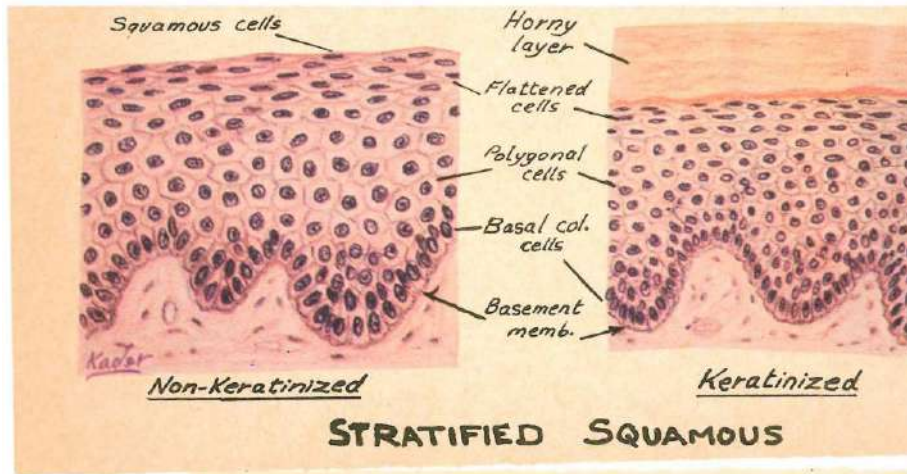
Stratified Epithelial Tissues include

1- Stratified squamous epithelium:

It is of two types:

Non-keratinized type	Keratinized type
- It does not contain keratin it is found lining the mouth, oesophagus and tongue. - The lower most layer of this type is formed of short columnar or	- It contains keratin it is found in the epidermis of the skin. - The lower most layer of this type is formed of short columnar or cubical cells.

- cubical cells.
- The intermediate layers are of polygonal cells.
- The outer most layer is squamous layer.
- The intermediate layers are of polygonal cells.
- The outermost layer change gradually to a non living horny layer (keratin,



2- Stratified cuboidal epithelium:

- The lowermost layer of this type is formed of cubical cells.
- The intermediate layers are of polygonal cells.
- The outermost layer is formed of cubical cells.

This type is found lining the ducts of sweat glands and the seminiferous tubules of the testis.

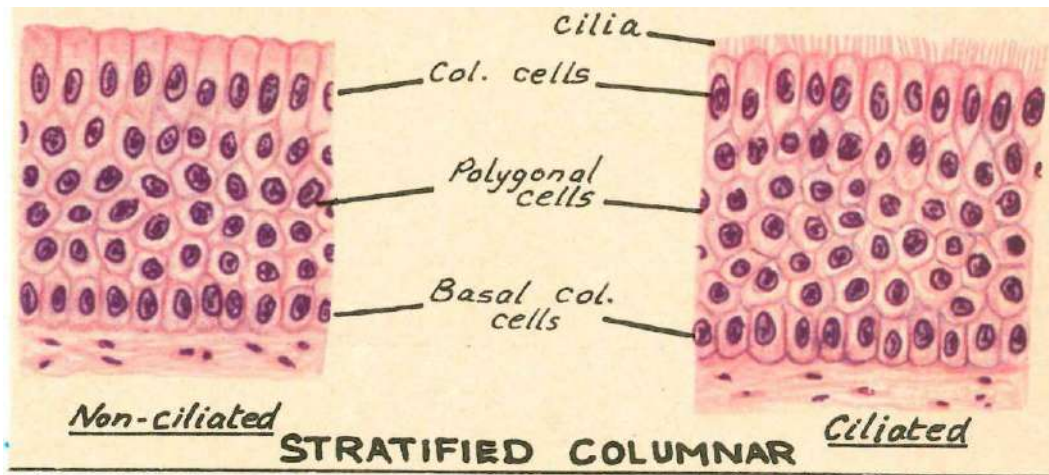
3- Stratified columnar epithelium:

- The lowermost layer of this epithelium is formed of columnar cells.
- The intermediate layer are of polygonal cells.
- The outermost layer is formed of columnar cells.
- It is found lining the large duct of a livery gland.

4- Ciliated stratified columnar epithelium:

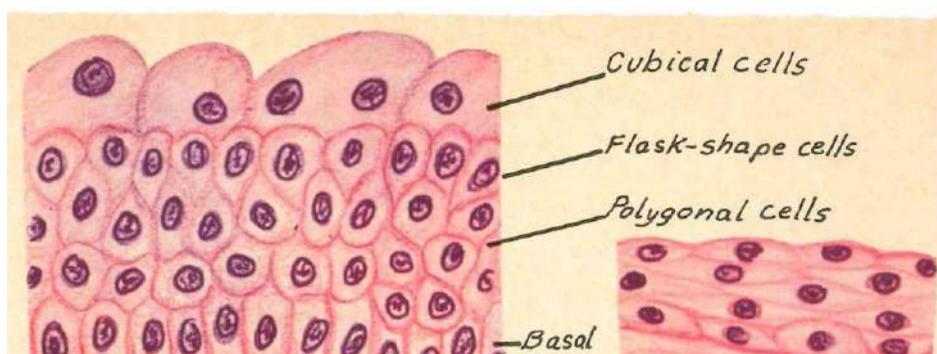
- It is stratified columnar epithelium, except the outermost layer carry cilia.

- It is found lining the larynx.



5- Transitional epithelium:

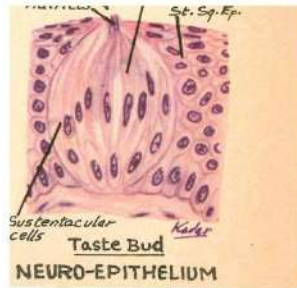
- The lowermost layer is formed of columnar cells rest on thin basement membrane.
- The intermediate layers are of polygonal cells separated from each other by wide intercellular spaces. The cells of this layer glide on each other, because this epithelium is rich with mucoid matrix.
- The outermost layer is formed of cubical cells with a broad convex free border and a concave inner surface.
- This type is found lines the urinary bladder.



Modified Epithelium

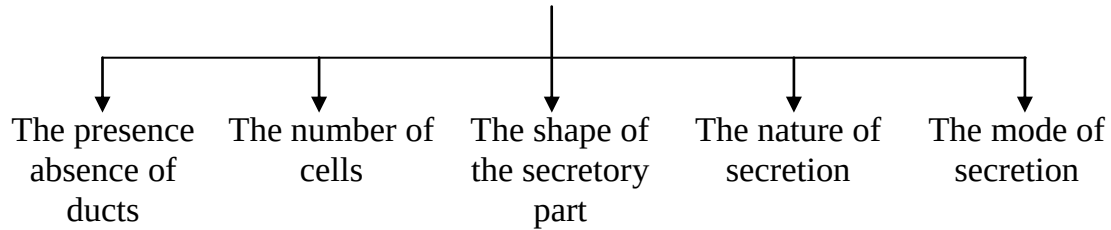
It is of 3-types

Germinal epithelium	Neuro-epithelium	Glandular epithelium
- It produces gametes in ovary and testis.	- The epithelial cells are modified to receive the nervous stimuli, perform sensory function. It is found in taste buds. The centrally placed neuro-epithelial cells in the taste bud are called gustatory cells, while the peripheral cells are called supporting cells. Hairlets project to the gustatory pore.	- The epithelial cells of this type are modified to produce secretion. They form gland.

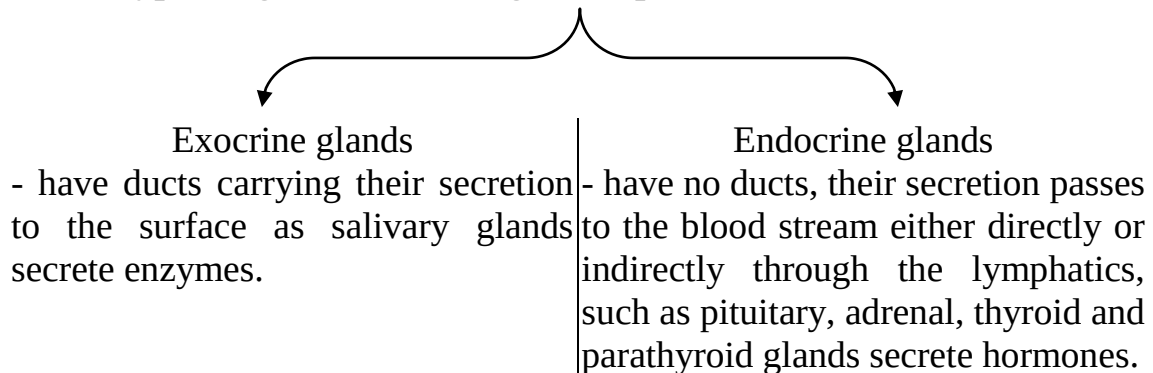


Classification of glands

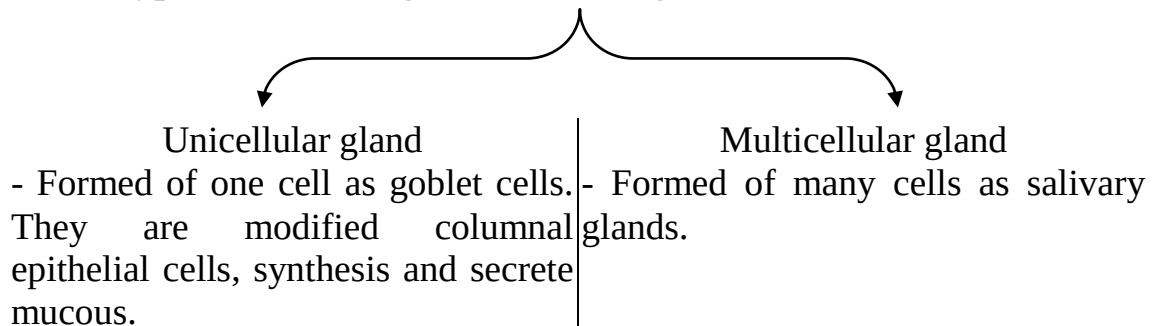
They are classified according to



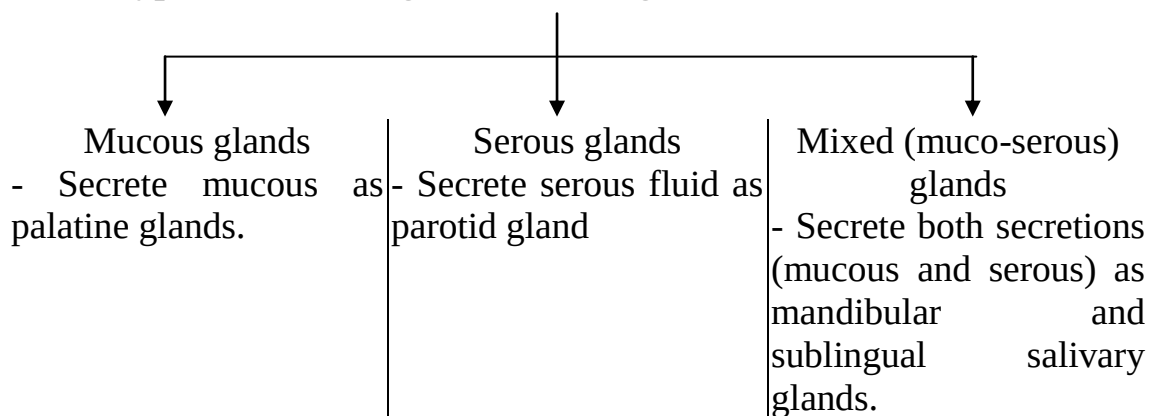
1- The types of glands according to the presence or absence of ducts:

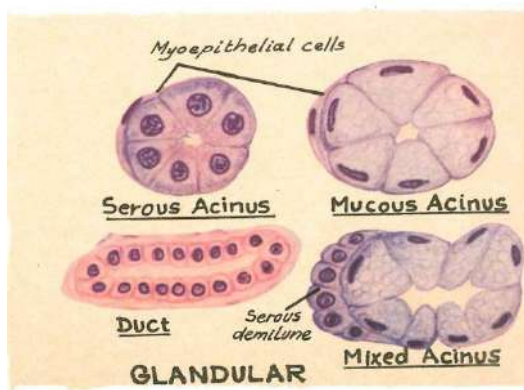


2- The types of exocrine glands according to the number of cells:

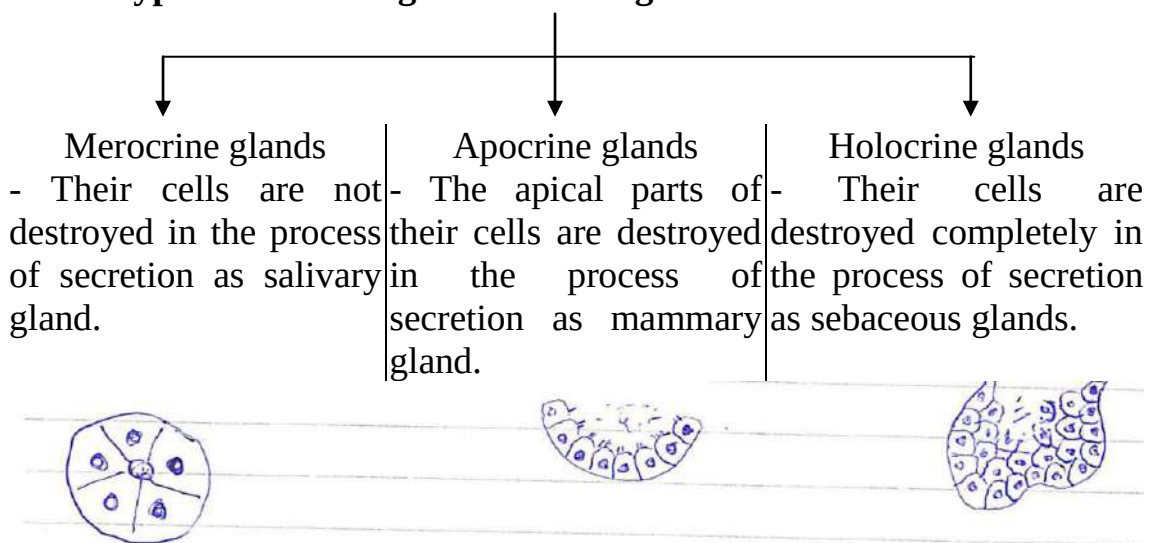


3- The types of exocrine gland according to the nature of secretion:

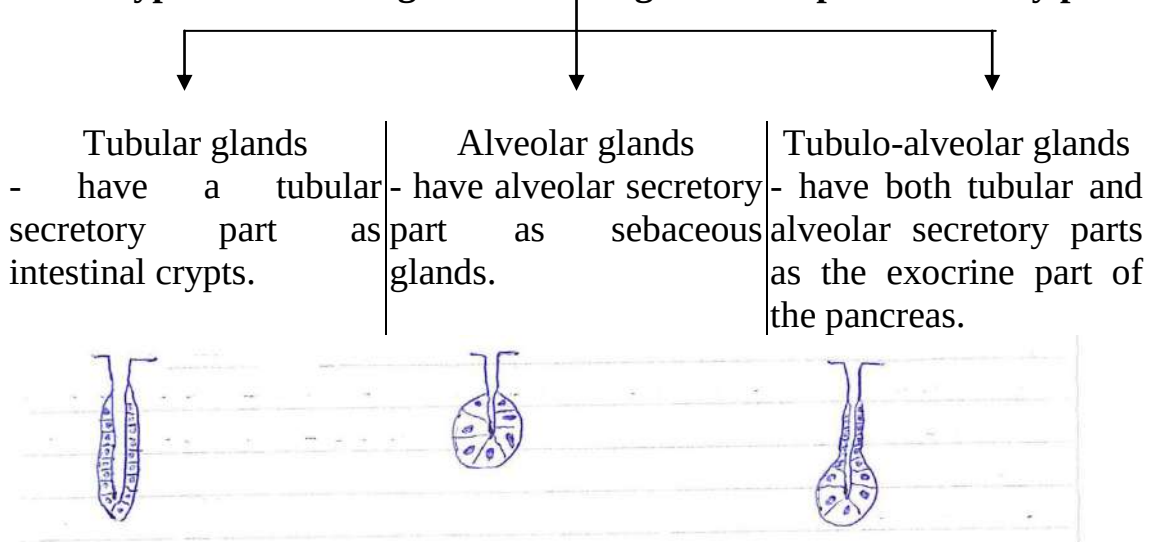




4- The types of exocrine gland according to the mode of secretion:



5- The types of exocrine gland according to the shape of secretory part:



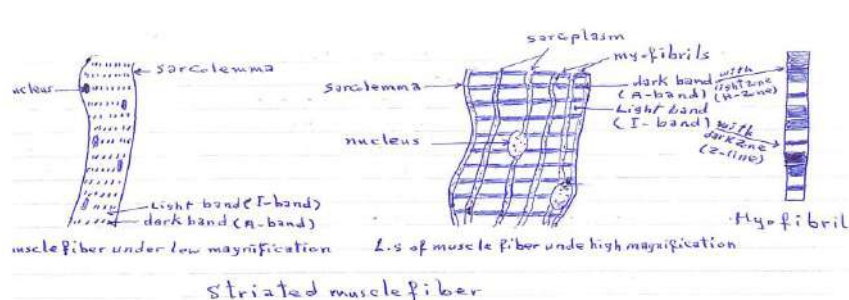
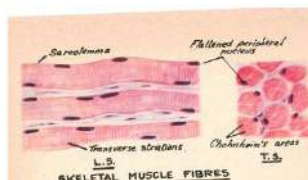
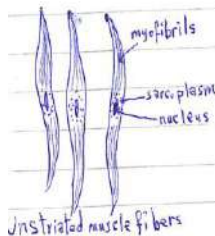
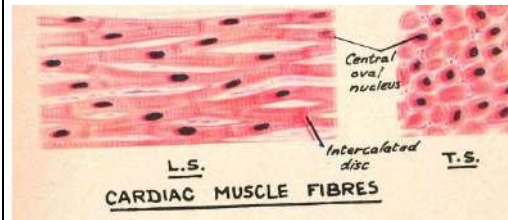
Muscular Tissues

They are characterized by:

- 1- Arise from mesoderm.
- 2- Form the muscles of the body.
- 3- They are formed of an elongated cells, hence their name muscle fibers which are capable of contraction and relaxation.
- 4- The muscle fibers differ from other body cells in the fact that most of their cytoplasm is modified into contractile threads, called myofibrils. The remaining cytoplasm is called sarcoplasm.
- 5- The plasma membrane of muscle fibre is called sarcolemma.

The muscles of the body are of 3-types:

Unstriated (smooth) muscles	Striated (skeletal) muscles	Cardiac muscles
- Involuntary muscles because their movement is not controlled by the will of the individual. - Show no striations. - Their contraction produces peristaltic movement to drive the food along the digestive tract. - They are elongated and pointed at both ends, contain number of myofibrils, small amount of sarcoplasm and central oval nucleus.	- Voluntary muscles because their movement are controlled by the will of the individual. - Show transverse striations. - Responsible for the movement of the limbs, head and jaws. - They are cylindrical, bounded by sarcolemma, contain large number of nuclei without partitionations, such structure is called syncytium. They contain numerous myofibrils, each being formed of pale (I-bands) and dark (A-bands) along their length.	- Involuntary muscles because their movement is not controlled by the will of the individual. - Show fainter striations. - characterized by their rhythmic contractions producing heart beats. - The muscle fibers are branched and connect together forming a network structure, bounded by sarcolemma and they are striated, but their striations are not clear.



Basic

Histology

For Students of 1st.Year

2022-2023

Preface

***Histology** is the study of tissues of the body and how these tissues are arranged to constitute organs. This subject involves all aspects of tissue biology, with the focus on how cell' structure and arrangement optimize functions specific to each organ.*

*The **purpose** of this booklet is to help students to review the massive amount of material that comprises Histology. This educational resource has met the needs of learners for a well-organized and concise presentation of **Histology** that integrates the material with that of **Biochemistry, Immunology, Endocrinology, Pathology and Physiology**. The text is prepared specifically for students of Science as well as for advanced undergraduate courses in tissue biology.*

The author

Tissues of the body

There are four types of tissue in the body:

1-Epithelial tissue

2-Connective tissue

3-Muscular tissue

4- Nervous tissue

2. Connective Tissues

Characters

1. Origin: from mesoderm.
2. Matrix: extensive.
3. No basement membrane.
4. Contain blood vessels.
5. Consist of cells, fibers and extracellular material (ground substance).
6. Cell types are classified as “fixed” or “wandering”.
7. Fibers may include collagen, reticular, or elastic fibers and further classified according to size , morphology and chemical composition.
8. **Functions** in support, as a medium for exchange between blood and tissues, for storage, and for protection and repair.

Connective tissue fibers

Three types:

i-Collagenous fibers

ii-Elastic fibers

iii-Reticular fibers

i. Collagenous fibres

-Strong and resist stretch -By boiling→ gelatin

- Destroyed by acids and alkalies.-Digested by pepsin & trypsin.
- Wavy branching bundles formed of non- branching fibers.
- Although fresh collagen fibers are colorless, when they are present in great numbers the tissues (eg, tendons, aponeuroses) they appear white
- Collagen fibers are acidophilic: they stain pink with eosin, blue with Mallory's trichrome stain, and red with Van Gieson stain.

ii. Elastic fibers

Structure: formed of 2 types of protein:

Amorphous protein called elastin in the center surrounded by microfibrillar protein.

- Single, thin, branched.
- Yellow in fresh state.
- Stained by: HX & E (pink), Orcein(brown) and Van Geison(yellow).
- Stretch and recoil (elastic)
- Resist boiling.
- Resist chemicals.
- Digested by pancreatic elastase.

Functions: give elasticity to the tissue.

iii. Reticular fibres

Structure: formed mainly of type 3 collagen where tropocollagen molecules make thin fibers bound together by glycoprotein. They contain 6-12% hexoses compared to 1% in collagen type 1.Synthesized by fibroblast, reticular cells and smooth muscle cells.

-Fibrillary network stained by silver and PAS due to high carbohydrate content:black with silver (argyrophilic) and purple with PAS.

Functions: supporting network that allow motile cells to move about in loosely arranged tissue as bone marrow, spleen and lymph node.

Connective tissue cells

1. Undifferentiated mesenchymal cell

- Less differentiated cells and could be transformed to any other type of cells. It is usually found near blood capillaries.

2. Macrophages

-large spherical cells called histiocytes, and possess a slightly basophilic cytoplasm. Active macrophages develop filopodia, phagocytic vacuoles, secondary lysosomes, and residual bodies. Coalesced macrophages surrounding a foreign body form foreign-body giant cells (multinucleated masses).

- Originate in the bone marrow, circulate in the blood stream as monocytes, and migrate into the connective tissue, where they perform their main function.

The main phagocytic cell in c.t. responsible for removing the foreign matter and help in the immune response.

3. Fibroblasts

-The predominant cell of C.T. that manufactures the precursors of the extracellular environment (matrix and fibers).

- Fusiform, with long tapering ends when they are synthesizing; less-active fibroblasts may be flattened and possess several processes.
- Nucleus is usually oval and often has two nucleoli.

4. Pigment cells

Branched cells with central, rounded nuclei. Found in retina and skin of man. Their cytoplasm contains a large number of melanin granules (melanosomes).

5. Plasma Cells

Ovoid, contain an eccentric nucleus, and possess clumped heterochromatin that appear in a spoke-wheel fashion. Arise from active B-lymphocytes. **Function:** antibodies-secreting cells.

6. Fat Cells

Function: are responsible for the synthesis and storage of fat.

Types: unilocular and multilocular.

a. Unilocular Cells

Cytoplasm is squeezed to a thin peripheral rim around the cell, with flattened nucleus to accommodate fats. They form adipose tissue when present in large numbers.

b. Multilocular Cells

Contain many small fat droplets and groups of these cells form brown adipose tissue.

7. Mast Cells

Large oval cells with small, ovoid, central and pale-stained nuclei.

- Cytoplasm is filled with coarse deeply-stained metachromatic granule by toluidine blue (purple). Found near small blood vessels.

Contain heparin, histamine, the slow-reacting substance of anaphylaxis, and eosinophil chemotactic factor.

8. Lymphocytes

- Cells that have migrated from the bloodstream into the connective tissue.

T-lymphocytes responsible for initiation of cell-mediated immune response; B-lymphocytes , when activated, differentiate to form plasma

cells, which provide humoral immunity ; and null cells, which have no surface determinant.

Sites: throughout the body in the sub-epithelial connective tissue. Accumulations of lymphocytes are found in respiratory system, gastrointestinal tract, and especially in areas of chronic inflammation.

9. Eosinophils

- White blood cells that have migrated from the blood into the connective tissue. They phagocytose Ab-Ag complexes and assist in destroying parasites.

Types of connective tissues

Three types according to the nature of their matrix;

I- Connective Tissues proper: Having jelly-like matrix (6 types).

II- Skeletal connective tissues: With semisolid or solid matrix (cartilage, bone).

III- Vascular connective tissues: Having fluid matrix (blood, lymph).

I- Connective tissues proper

Having jelly-like matrix; 6 types

1- Areolar (loose) connective tissue

-Contains all types of C.T. cells and fibers. – Matrix: extensive with cavities. Sites: Under epithelia, subserous, submucosa, around blood vessels, fills spaces between other tissues. Function: connect and support other tissues like epithelium, blood elements and nerves.

2. Fibrous connective tissue

- Contains fibroblasts and collagenous fibers. – Matrix: scar tissue
- Types, sites: **a. Regular**; having regular collagen bundles (in tendons, cornea) and resist stretch in one direction. **b. Irregular**; with irregular collagen bundles (in perichondrium, periosteum, sclera).

3. Elastic connective tissue

- Contains fibroblasts and elastic fibers. – Matrix: little
- Found: in arteries and large vessels, bronchi and bronchioles, ligamentum nuchae and ligamentum flavum. Provides flexible support.

4. Mucous connective tissue

- Contains large stellate-shaped fibroblasts with some collagen fibers.
- A type of loose connective tissue found in the embryo (deep to the skin and in the umbilical cord), vitreous humour of the eye and pulp of growing teeth. Protects adjacent structures from pressure.

5. Adipose connective tissue

- Contains a large number of fat cells forming lobules separated by connective tissue septa of collagenous and elastic fibers. It may be white (unilocular in mesentery, under skin, around kidney and BV) or brown (multilocular in foetus and new born, heat insulator) and brown (generating heat).

6. Reticular connective tissue

- Contains reticular cells (specialized fibroblasts joined by desmosomes) and bundles of thin, small reticular fibers stain black with silver.

–Sites: around liver sinusoids, in bone marrow and forms stroma of lymphatic organ. – Function: supportive in its sites.

II- Skeletal connective tissues: With semisolid or solid matrix (cartilage, bone).

- Specialized types of connective tissues (skeletal C.T.).
- Matrix of cartilage is semisolid.
- Matrix of bone is solid (calcified) and forms skeleton of vertebrates.
- Both bone and cartilage function in support, but bones also serve as stores for calcium and phosphate, protect vital organs, and contain bone marrow, which functions in hemopoiesis (blood formation).

1. Cartilage

Matrix:

- Composed of amorphous ground substance and Type II collagen fibrils.
- Stains deeply basophilic. It is also metachromatic and stains more intensely with periodic acid-Schiff reaction (PAS) than other areas of the matrix.

Perichondrium:

- Is a connective tissue region surrounding cartilage, except at articular surfaces.
- Composed of an outer fibrous layer containing type I collagen, fibroblasts, and blood vessels and an inner cellular (chondrogenic) layer composed of chondrogenic cells.
- It functions in protection, blood supply and regeneration of the cartilage.

Chondrogenic cells:

- In the inner layer of the perichondrium differentiate into chondroblasts, the cells that produce cartilage.

Chondrocytes:

- Are matured chondroblasts located in the lacune of cartilage and are surrounded by matrix.
- Located superficially, chondrocytes are ovoid.
- Located deeper, they are more spherical.

Histophysiology:

- Chondrocytes manufacture the matrix through which nutrients and waste materials pass to and from the cells via diffusion.
- Hormones influence the growth of the cartilage:
 - thyroxine, testosterone, and growth hormone increase the growth rate.
 - Cortisone, hydrocortisone, and estradiol decrease it.

2.Bone

- composed of a calcified matrix containing osteogenic cells, osteoblasts, osteocytes, and osteoclasts.
- Osteogenic cells differentiate into osteoblasts, which secrete the organic matrix that entraps these cells.
- Osteocytes (are entrapped) lie in cavities called lacunae.
- Osteoclasts are multinucleated giant cells originated from monocytes and responsible for resorbing and remodeling bone.

Matrix:

- Organic portion: is composed of about 95% Type I collagen (protein) and amorphous ground substance.
- Contains chondroitin 4-sulfate, chondroitin 6-sulfate, and keratan sulfate in addition to osteomucoid (a protein differing from collagen in that it

does not contain hydroxyproline, has only a small amount of proline and glycine, but an abundance of tyrosine and leucine).

-Inorganic portion: represents about 50% of the dry weight of the matrix and is composed of calcium, phosphorus, bicarbonate, citrate, magnesium, potassium and sodium.

-Hydroxyapatite crystals $\text{Ca}_{10}(\text{PO}_4)_6(\text{OH}_2)$ formed of calcium and phosphorus.

Vascular supply:

-Blood vessels entering the periosteum and endosteum penetrate the bone matrix via Volkmann's canals, which run perpendicularly to the Haversian canals.

III- Vascular Connective Tissue

This is a type of connective tissue which contain a fluid matrix and comprises: a-Blood b-Lymph .

Blood:

Blood is a unique form of connective tissue composed of forming element (RBCs , WBCs and Platelets) suspended in a liquid plasma .

Main differences between RBCs and WBCs

RBCs	WBCs
-Number : 4.5 to 5.5/ m^3 blood.	-Number: 5000 to 11000/ m^3 blood
- they are of one type.	-they are of 5 types.
- they are corpuscles =not true cells	-they are true cells .
.	They contain nuclei and cell
- they have no nuclei and no cell	organoid.

organoids - they have no movement. - biconcave corpuscles. - Appear in rouleaux . - diameter : 7.5μ. -easily hemolysed. - contain Hb. - carry O₂ and CO₂ inside the blood vessels. They develop in red bone marrow. -life span: about 4 months.	-they have amoeboid movement -spherical cells -No rouleaux appearance. -diameter : 8-18μ -they resist hemolysis partially. -having no Hb -phagocytic cells but outside the blood vessels. -develop in red bone marrow and in lymphatic tissue -life span: from few days to years
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Thrombocytes (Blood platelets):

They are not true cells, but they are non-nucleated discs. They are originated from red bone marrow from a mother cell called megakaryocyte. The platelets having a cytoplasm rich in azurophilic granules. They secrete thromboplastin which helps in blood clotting.

They also secrete a vasoconstrictor called serotonin .their number is about 250,000 to 500,000 per m³ of blood. This number is decreased in case of diseases such as purpura.

Plasma:

It is the fluid matrix of blood and composed of 90% water and the remaining 10% comprises inorganic and organic constituents.

4. Nervous Tissues

Characteristics:

- 1- Ectodermal in origin.
- 2- Their cells are adapted to receive and transmit stimuli.
- 3- Their mature cells do not divide again.
- 4- Distributed throughout the body as integrated and communicated network.
- 5- Constitute what is called as **nervous system** (NS).
- 6- Structurally, nervous tissues consist of two cell types: **nerve cells** (**neurons**) and **glial cells** (several types).

Neurons

- The functional and specialized cells of the NS.
- Have the ability to conduct impulses to higher centers in the brain for processing, and from these centers a response is initiated.
- **A neuron structure** is formed of: cell body and processes.
- The cell body (perikaryon) comprises a nucleus and cytoplasm. The cytoplasm contains Nissl granules, Golgi bodies, mitochondria, neurofibrils, lysosomes, centrosome during embryonic period only but the mature neurons lacks it and other inclusions such as pigments (lipofuscin and melanin, glycogen, fat droplets and iron.
- The processes are of two types; several short ones carry impulses to the body called dendrites and a long one named axon that carries impulses from the body to other neuron or muscle

Axons

- vary in diameter and length (some are as long as 100 cm).
- Originate from the axon hillock, a specialized region of soma devoid of rough endoplasmic reticulum and ribosomes.
- Collaterals arise at right angles from the trunk of an axon .

- Axoplasm is surrounded by axolemma (plasma membrane) and possessed only a few organelles, since it has low synthetic activity.

Synapse

-site where information is transferred between a neuron and another cell.

Various types of synapses exist;

- 1. axodendritic synapse** : site of contact between an axon and a dendrite.
- 2. axosomatic synapse** : site of contact between an axon and a nerve cell body.
- 3. axoaxonic synapse** : site of contact between axons.
- 4. dendodendritic synapse** : site of contact between dendrites.

-Types of neurons: according to the number of cell processes.

- Pseudo-unipolar; having one process as in spinal and cranial ganglia.
- Bipolar; having two processes one is dendrite and the other is axon, e.g retina.
- Multipolar; with several dendrites and one axon, e.g autonomic ganglia and cerebral cortex.

Glial cells

-Having short processes, support and protect neurons and participate in neural nutrition, neural activity and defense processes of the central nervous system.

Nerve fibers

Axons

- Myelinated axons are those enveloped by myelin sheath produced by Schwann's cells (in the PNS) or by oligodendrocytes (in the CNS).
- Unmyelinated axons are those which not enveloped by myelin.

-an axon diameter increases , myelin sheath thickness also usually increase.

-unmyelinated axons are not enveloped by myelin and are usually small.

Myelin

-A lipoprotein organized into a sheath that is formed by several layers of plasma membrane of oligodendrocytes or Schwann cells wrapping around the axon.

-Myelin is removed by histological processing, but methods using osmium tetroxide preserve it.

-Electron micrographs display major dense lines and intraperiod lines: major dense lines represent fusions between the cytoplasmic surfaces of Schwann cells (or oligodendroglia) plasmalemma; intraperiod lines represent close contact between extracellular surfaces of Schwann cell (or oligodendroglia) plasma membranes.

- Myelin sheath does not uniformly cover the axon but covers it in a fashion resembling a string of beads, where the beads represent the myelin.

Node of Ranvier

- Represents region of discontinuities between adjacent Schwann cells (or oligodendroglia) .The axolemma at the node displays a unique electron density that is characteristic of this area.

Internode

- Represents the distance between two nodes . It varies in dimension, depending on the size of Schwann cell (or oligodendroglia),from 0.08 to 1 mm.

- Displays oblique discontinuities called clefts or incisures of Schmidt-lanterman.

Unmyelinated fibers

- Axons that do not possess myelin sheaths but are ensheathed by oligodendroglia (in the CNS) or Schwann cells (in the PNS).

Nerves

-These are bundles of nerve fibers ensheathed by connective tissue.

- Nerve structure:

a. Epineurium

-The outer layer of dense connective tissue surrounding bundles of nerve fibers and extending into the spaces between them .

b. Perineurium

-The connective tissue investment around individual nerve fascicles.

-Consists of layers of epithelial cells that are joined by tight junctions.

-Functions as a barrier to most macromolecules.

c. Endoneurium

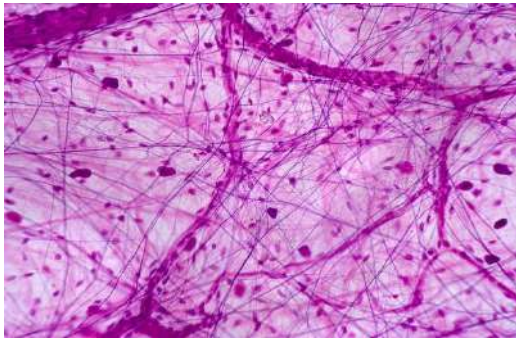
A thin layer of connective tissue investing individual nerve fiber.

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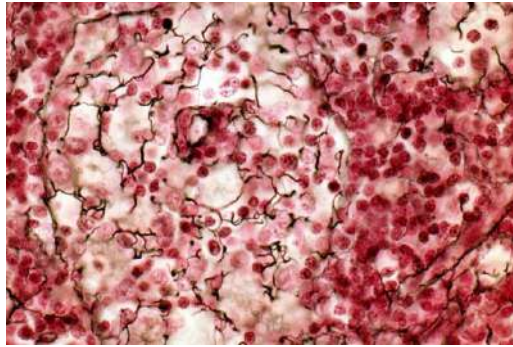
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Representative practical slides (Illustrations):

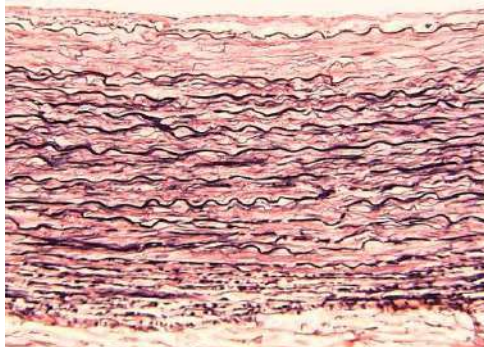
1. Areolar C.T.
2. Reticular C.T.



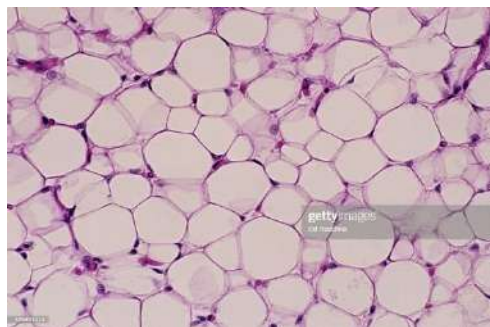
3. Elastic C.T.



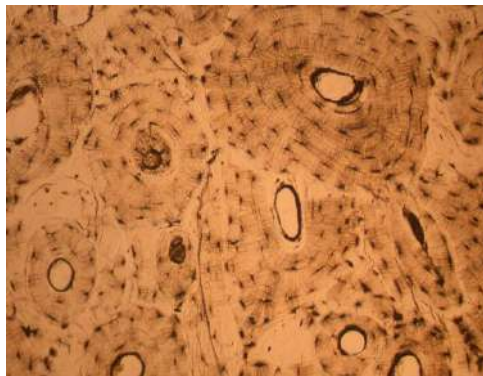
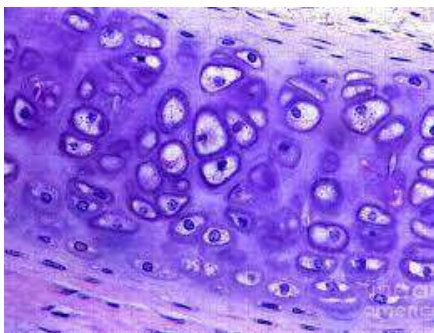
4. Adipose C.T.



5. Hyaline cartilage



6. Compact bone



7. Blood film



8. Adult neuron

