University of Baghdad
College of Veterinary Medicine
Department of Physiology and Pharmacology

Lecture - 1

Cell Physiology

For Class- Two

By

Professor

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2017

Physiology:

- from Ancient Greek ***(physis),*** meaning 'nature, origin', and - ***-logia,*** meaning 'study .
- Is the branch of science that deals to study the normal mechanisms, functions and activities of living organism including all physical and chemical processes which works within a living system.
- it is divided into, among others, animal physiology (including that of humans), plant physiology, microbial physiology and viral physiology etc…

History :

- The study of human physiology as a medical field dates back to at least 420 BC to the time of **Hippocrates**, also known as the "**Father of Medicine**.
- **Claudius Galenus** (c. ~130–200 AD), was the first to use experiments to investigate the functions of the body.
- **Jean Fernel** (1497–1558), a French physician, introduced the term (**physiology**).
- **The Physiological Society** was founded in London in 1876 as a dining club.
- **The American Physiological Society (APS)** was founded in 1887. This Society is, devoted for scientific research, and publishing of information in the physiological sciences.
- **In the 19th century** , particularly with the 1833, Cell theory of **Matthias Schleiden and Theodor Schwann** were grown.
- **Claued Bernard's (1813-1878)** , was given the name of **"Father of Physiology ".** All discoveries **by Claued Bernard's** led to concept of internal environment and later called **"homeostasis"** by **Walter Cannon in 1929.**
- In Nineteenth century physiological scientists ,based on **Haeckel's ideas**, set the basis of the science called "**General Physiology**" and later renamed in the Twentieth Century as "**Cell Biology".**
- In **1920**, **August Krogh** won the **Nobel Prize** for discovering mechanism of blood flow in capillaries.
- In **1954**, **Andrew Huxley and Hugh Huxley**, discovered the sliding filaments in skeletal muscle, known today as the **"Sliding Filament Theory"**.

The Cell :

The cell is the basic unit of all living organisms that performs the followings:

1. provide structure for the body,
2. take nutrients from food and convert those nutrients into energy.
3. contain the hereditary material and can make copies of themselves.

Each organ is an aggregate of many different cells held together by intercellular supporting structure. Cells of different living organisms are share with common features, however, they are different in their structure and functions. For example: Red blood cells transport oxygen and CO_2 ; Pancreatic β-cells synthesized and secreting insulin and Leydigs cells synthesized testosterone hormone.

Chemical Composition of the Cell:

The chemical composition of the cell is illustrated in the following table :

Substance	Percentage %
Water	**70-80**
Protein	**10-20**
Fat	**2-3**
Carbohydrate	**1**
Salts	**1**
Other organic materials (electrolytes)	**0.4**

Functional Morphology of the Cell : There are two primary types of the cell :

1- **Eukaryotic** cells including : animal cells and plant cells.

2- **Prokaryotic** cells : e.g. Bacteria.

Parts of the cell including :

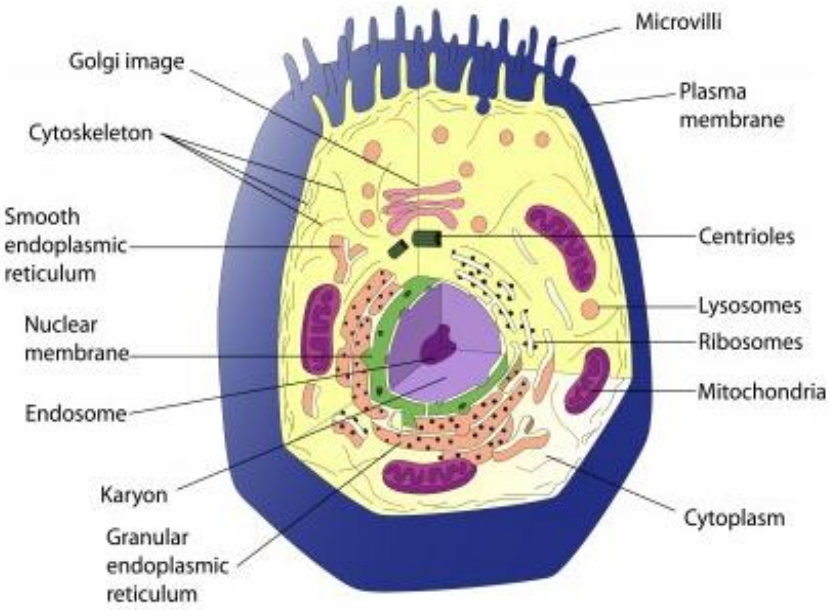
I. A. Cell membrane , it bound the nucleus and other organelles of the cell .

I. B. Organelles including : nucleus, cytoplasm, Golgi complex, mitochondria, endoplasmic reticulum, ribosomes, lysosomes and peroxisomes as in the following figure.

I.A.- Cell Membrane (also called plasma membrane) :

The common features of the cell membrane are :

- Its envelops the cell to form a clear boundary(support the cell).
- thin elastic structure with thickness about 7.5nm (75Aº).
- used for transport of materials.
- it protect the cellular structures from the toxic materials or substance that may alter the structure or function of the cell.



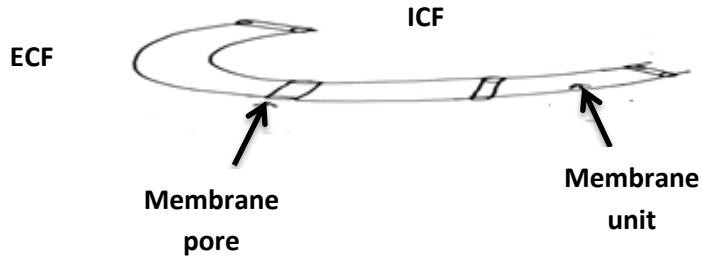
Organization of Generalized Cell

All these processes are accomplished by its special property called "**Semipermeable**" also called "**Selectively permeable**" membrane. Therefore, it select some molecules of certain substances to move across it.

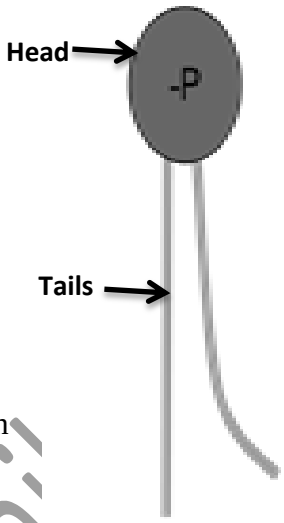
The membrane units are occasionally separated by small gaps which is called **"Membrane Pores**" with a diameter about 7-10 Aº. So, the molecules of size less than 7-10 Aº can pass through these pores easily or freely.

Structure of cell membrane:

The basic structure of the cell membrane is a double thin layers, it is primarily composed of a mix of lipids and proteins . The lipid is a lipid bilayer (i.e. a double layer of lipids) interspersed in these layers of lipids are globular protein molecules.



The major composition of lipid (<u>in eukaryotes</u>) are :



(A) Phospholipids and **(B)** cholesterol. While, <u>in plant cell</u> contain phospholipids and some steroids. Besides, the major lipid <u>in prokaryotes</u> (like bacteria) only phospholipids.

1- Phospholipid: the phospholipids molecules are the major components of plasma membrane, that is composed of a head and two tails.

a- The head contain phosphate portion and it is relatively soluble in water (hydrophilic).

b- The tails contain lipid portion and it is relatively water insoluble (hydrophobic).

Thus, the phosphate portions constitute the two surface of the cell membrane, the inside of the cell membrane which contact with intracellular water and on the outside surface contact with extracellular water.

2-Cholesterol: cholesterol molecules are selectively scattered between membrane phospholipids. This helps to keep the fluidity of the cell membrane from becoming stiff. (note: cholesterol is not found in the membranes of plant cells).

Thus, the passage of substances across the cell membrane, depending on the nature of the cell membrane as the follows,

A- Fat soluble materials can penetrate or diffuse the membrane easily, such as alcohol, oxygen, carbon dioxide (CO_2) and steroid hormones (e.g. estrogens, progesterone and testosterone).

B- Fat non-soluble materials cannot penetrate or diffuse the membrane easily, e.g. glucose, urea, ions, protein, peptide hormones (e.g. insulin, ADH, FSH,LH, T3,T4 etc…..).

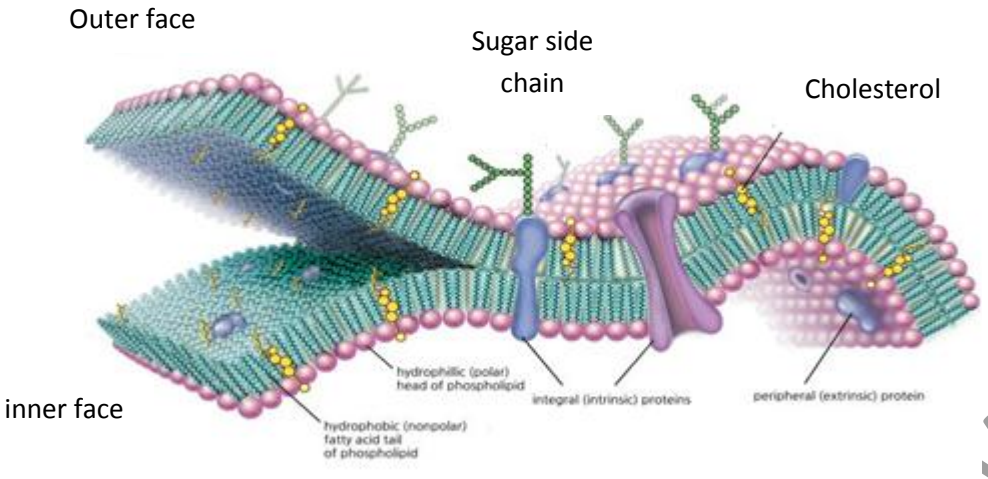


Figure: Molecular structure of the cell membrane illustrate phospholipids, cholesterol, and intrinsic and extrinsic proteins **(Encyclopaedia Britannica/UIG/Getty).**

The cell membrane proteins:

Cell membrane proteins are globular mass floating in the lipid bilayer, most of which is glycoproteins.

There are two main types of proteins including:

1- Peripheral membrane proteins (extrinsic): are proteins that attached to the exterior surface of membrane and don't penetrate the membrane.

2- Integral membrane proteins (intrinsic): are proteins that penetrate into the membrane, which have a number of different functions and act as:

a- Structural proteins: help to give the cell support and shape**.**

b- Receptor proteins : these are specific bind sites in the cell membrane help the cells to communicate with their external environment through binding to neurotransmitters or hormones, such as peptide hormones, that is do not cross the cell membrane, so interaction or binding of these receptors to a specific a chemical substance (ligand) causes conformational changes in the receptor protein and induces receptor- substance complex.

c- Carrier proteins (Transport proteins): proteins that act for transport of highly selective types of molecules or ions that are across the membrane (e.g. Facilitated diffusion).

d- Enzymatic proteins: proteins that catalyzed chemical reaction.

e- Channels proteins: proteins that act as ion channels **,** that is transport of ions through the cell membrane, e.g. Na+ ion channels ; K+ ion channels and Ca++ ion channels.

f- Pumps proteins: proteins act as pumps for active transport across the cell membrane, e.g. Na+ - K+ ATPase.

g-Proteins: proteins used for antigenicity and cell recognition. e.g. antigen on RBCs membrane used for blood grouping.

Glycoproteins and glycolipids, the attachment of membrane carbohydrates(CHO) chain to proteins called "**glycoproteins**" , whereas, attachment carbohydrates(CHO) chain to lipids called " **glycolipids**" . The "glyco" portion of these molecules emerged (or protrude) to the outside of the cell membrane and help in cell to cell communications.

Movement of materials across the cell membrane:

A- Small size molecules transport:

The internal composition of the cell is maintained under normal conditions because the plasma membrane is selectively permeable, that is forms a barrier that blocks the ***"free exchange*** " of molecules between the cytoplasm and the external environment of the cell .

Thus , small size molecules transport by one of the following processes:

I- Diffusion. or by **II- Active transport** .

I- **Diffusion** including : **a-** simple diffusion. and **b-** Facilitated diffusion.

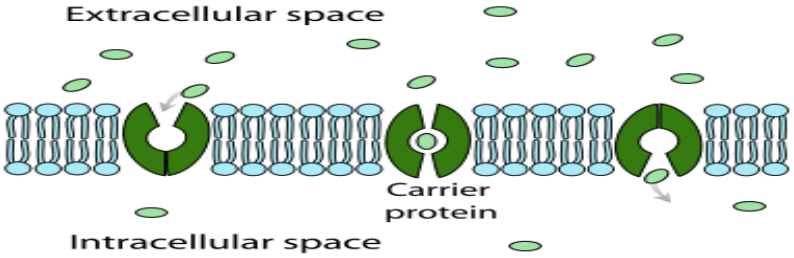
a- Simple diffusion: means transport of molecules through the cell membrane (biological membrane) in direction from an area of high concentration to an area of low concentration until a state of equilibrium is established, without need energy (Downhill movement).

Factors affecting the simple diffusion :

1- Concentration gradient across the cell membrane:
2- Charge of molecules: membrane pores have –ve charge.
3- Size of molecules: the diameter of membrane about 7-10 Aº.
4- Solubility of molecules.
5- Thickness of molecules.
6- Cross-sectional area of barrier.
7- Temperature of medium.

b- Facilitated diffusion: also called **carrier –mediated diffusion**, that means the molecules enter or leave the cell by binding with a specific protein called "**carrier protein**". In this type the movement of molecules from an area of high concentration to an area of low concentration, without need energy. (Downhill movement).

A carrier protein have a pore large enough to transport of a specific molecules. The substance to be transport enters the pore and binding to carrier protein to form carrier – substance complex, within a fraction of a second, a conformational change occurs in the carrier protein then reaches the opposite side of the membrane and released the substance from carrier protein as illustrated in the following figure :



II- Active transport: it means the ions or molecules enter or leave the cell across the membrane via carrier specific proteins against the concentration gradient from an area of low to an area of high concentration (Uphill movement). This form of transportation requires the use of energy in the form of ATP (adenine triphosphate).

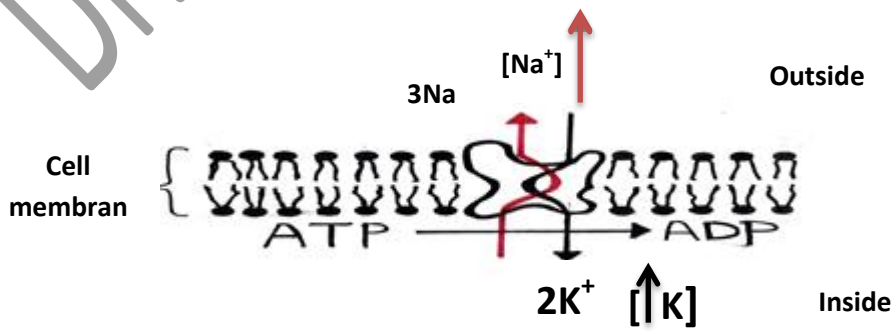
According to the source of energy ,there are **two types** of active transport :

A- Primary active transport : the energy in this type is derived from breakdown of ATP (i.e. hydrolysis of ATP).

e.g. of primary active transport that include :

1- Sodium-potassium pump (Na^+-K^+ ATPase) as in the following figure :

The function of ***Na^+-K^+ ATPase*** is to extruding the *three* sodium ions outside the cell membrane and at the same time the *two* potassium ions pumps to the inside .



Sodium -potassium pump
(Na^+- K ATPase)

2- Plasma membrane Ca^{+2} ATPase.
3- Sarcoplasmic reticulum Ca^{+2} ATPase, that transfers calcium after muscle contraction.
4- H^+/K^+ ATPase (or gastric hydrogen potassium ATPase): it is pump primarily responsible for the acidification of the stomach contents and the activation of the digestive enzyme pepsin.

B- Secondary active transport: also known as ***coupled transport or co-transport.***
In this type, when sodium ions are transported out of the cell by primary active transport causes develops of high concentration of sodium ions out of the cell and low concentration of sodium ions inside. Therefore, the high gradient of Na^+ ions outside the cell creates an energy by primary active transport, such energy can pull other substance along with sodium through the cell membrane.
e.g. ***co-transport of glucose along with sodium ions.***
co-transport of amino acids along with sodium ions.

Filtration:
The movement of fluid (virtually free of large molecules such as proteins), across the membrane under the deference of hydrostatic pressure between two sides.

Isosmotic solution (or isotonic) :
a solution having the same total osmotic pressure or osmolarity as another fluid (as plasma). If the cells (RBCs) are placed in a solution (extracellular fluid) having an osmolarity as the plasma, the cell will not be shrink or swell because the water cannot enter or leave the cell. Isotonic solutions including :
0.9% Nacl solution. OR :5%glucose solution.
Adding of isotonic solution to the extracellular fluid (ECF) compartment, no change in osmolarity of ECF occur, but only increase in the volume of ECF.

Hypotonic solution:
A solution having an osmotic pressure or osmolarity lower than that of plasma. If the cells (RBCs) are placed in a solution (extracellular fluid) having an osmolarity lower than plasma, the cell will be swelled because the water can be diffuse into the cell. (The concentration of hypotonic solution is less than 0.9% Nacl) .
Added of hypotonic solution to the extracellular fluid (ECF) compartment, causing an decrease in osmolarity of ECF occur with increase in the volume of ICF.

Hypertonic solution:
A solution having an osmotic pressure or osmolarity more than that of plasma. If the cells (RBCs) are placed in a solution (extracellular fluid) having an osmolarity more than plasma, the cell will be shrink because the water can be flow out of the cell into the extracellular fluid. (The concentration of hypertonic solution more than 0.9% Nacl). Adding of hypertonic solution

to the extracellular fluid (ECF) compartment , causing an increase in volume of ECF with a decrease in ICF volume and increase in osmolarity of ICF

B- Transport of Large Size Molecules Transport:

Large macromolecules (e.g., proteins, viruses, lipoprotein particles) require more complex mechanisms to transport into and out of cells membranes, selectively via the following :

a- Endocytosis: (cell eating)

Is a processes by which the cell engulfed different types of particles include, bacteria, cell debris and dead tissue. The main mechanism is that regions of the plasma membrane fold into the cell to forms small pockets on the inside of the cell. Fusion of particles with in the membrane, then the pockets pinch off into membrane to form a vesicles inside the cell. This transportation process requires Ca^{+2} and energy.

e.g. polymorphonuclear leukocytes.

b- Pinocytosis or fluid endocytosis (cell drinking):

In this type the mechanisms are the of endocytosis, except that the engulfed materials are a small volume of extracellular fluid (a solution).

c- Exocytosis (secretion or cell vomiting)

In this type the mechanisms are reverse to endocytosis. Move OF things from the inside of the cell to the outside, membrane-bound vesicles in the cytoplasm will fuse with the plasma membrane and release their contents outside the cell. This transportation process requires Ca^{+2} and energy. This process provides a route by which membrane impermeable molecules, such as protein hormones and neurotransmitters (NTs) that are synthesized by cells can be released outside the cell into the ECF.

I.B. Organelles:

- **Cytoplasm** - is a gel-like matrix filling the space between the nucleus and the cell membrane. It contains and supports the cell organelles.
- **Endoplasmic Reticulum** – is complex series of interconnected network of flattened, membrane-enclosed sacs or tube-like structures. The endoplasmic reticulum occurs in most types of eukaryotic cells, but is ***absent*** from red blood cells(RBCs) and spermatozoa. There are two types of endoplasmic reticulum:

- **Rough endoplasmic reticulum**: (granular) contains ribosomes that are the sites of protein synthesis .e.g. specially present in hepatocytes, pancreatic cells and GIT mucosa etc..

- **Smooth endoplasmic reticulum**: (a granular) lacks ribosomes and the main functions are (1) lipid biosynthesis (steriodogenesis) that mean the production of steroid hormones such as testosterone, estrogens and testosterone. (2) detoxification. The smooth ER is especially abundant in mammalian liver and gonad cells.

- **Sarcoplasmic reticulum :**

  i- is smooth ER found abundant in myocytes (skeletal and cardiac muscles).

  ii-The sarcoplasmic reticulum plays a major role in excitation-contraction coupling skeletal and cardiac muscles.

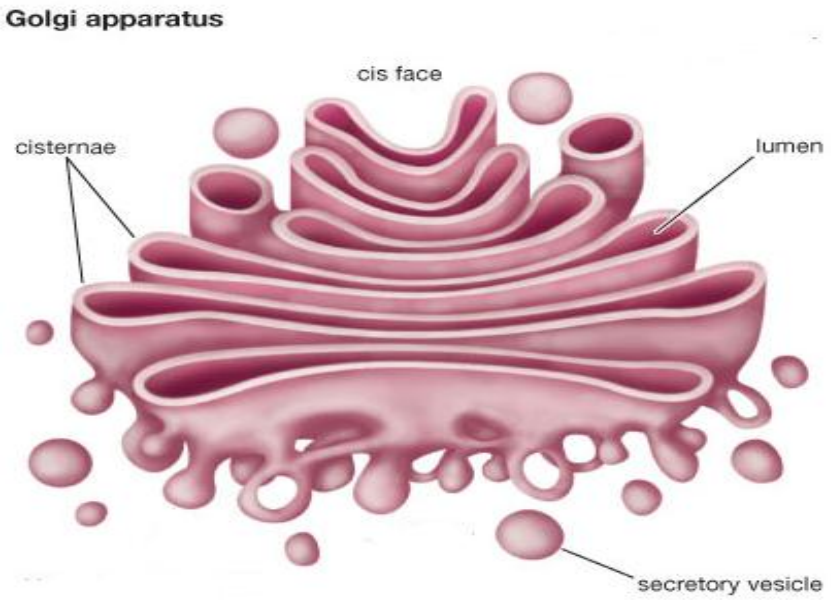
  iii- it stores calcium ions and pumps them out into the sarcoplasm when the muscle (skeletal and cardiac muscles) fiber is contracted, whereas during relaxation it reuptakes Ca^{+2} ions into sarcoplasmic reticulum by active transport.

- **Golgi apparatus**- also called **Golgi complex**,

Golgi apparatus is made up of a series of approximately four to eight cisternae flattened pouches called **cisternae**.

The Golgi apparatus is responsible:

- for storing, transporting and packaging of proteins and lipids into vesicles for delivery to the end pion.
- glycosylation of proteins (adding sugar to proteins).



- **Mitochondria**

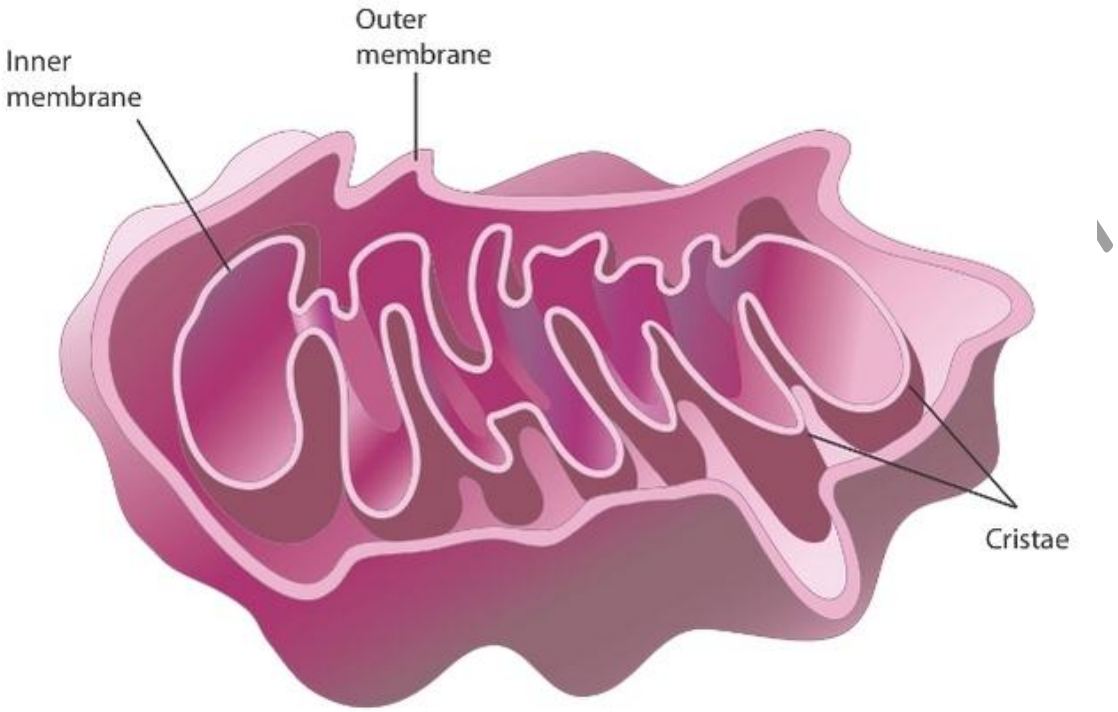
i- it is a bean-shaped structure found in both plant and animal cells.

ii- it has inner membranes or cristae.

iii- cells with high activity levels contain more mitochondria,

such as liver, and muscle cells, whereas low activity level cells such as sperm cell contain low number of mitochondria.

iv- enzymes attached in the inner membrane of mitochondria concerned for cellular respiration and producers of energy ATP via oxidative phosphorylation. Whereas, enzymes of the outer membrane of mitochondria are used for biological oxidation of CHO, fats and proteins to produce Co_2 and H_2O.



- **Lysosome:** is a small spherical vesicles which contain hydrolytic enzymes to break down various biomolecules that engulfs, including peptides, nucleic acids, carbohydrates, and lipids. Also digestion of invading microorganisms and old cell parts.
- **Peroxisomes :**

  i- it contain oxidative enzymes, such as D-amino acid oxidase and uric acid oxidase.

  ii- some enzymes within the peroxisome, by using molecular oxygen, can producing hydrogen peroxide H2O2 (it is toxic substance) that is hydrolysed by catalase enzymes.
- **Nucleus** – is a large, oval structure found in both plant and animal cells. It controls and regulates all cell activities. It contains genetic material DNA. **Nucleolus** - is the structure within the nucleus and helps in synthesis of ribosomes.