Cytology

- Any cell consists of two main compartments: **Cytoplasm** and the **Nucleus**.
- The cytoplasm; composed of matrix (cytosol) in which various organic and non-organic substances are dissolved.
- Cytoplasm includes organelles and inclusions.
- Organelles are metabolically active structures carrying out specific functions, and are classified into membranous and non-membranous organelles.

-**Membranous organelles** such as; Cell membrane, RER, SER, Golgi, Lysosomes, Endosomes, Mitochondria…

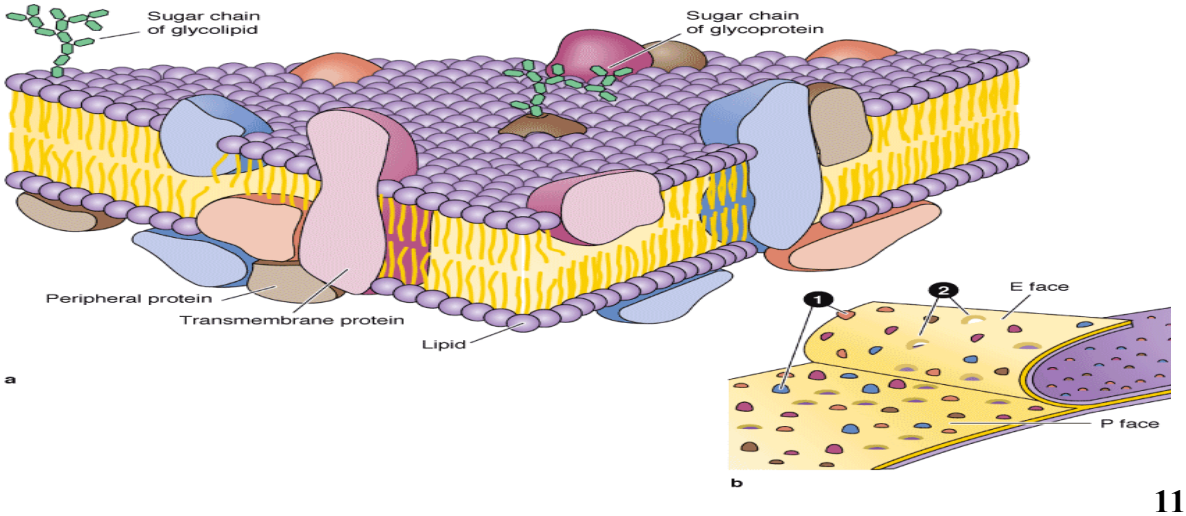
-**Non-membranous organelles** such as, Ribosomes, Centrioles, Microtubules, Glycogen inclusions, Cilia and Flagella…

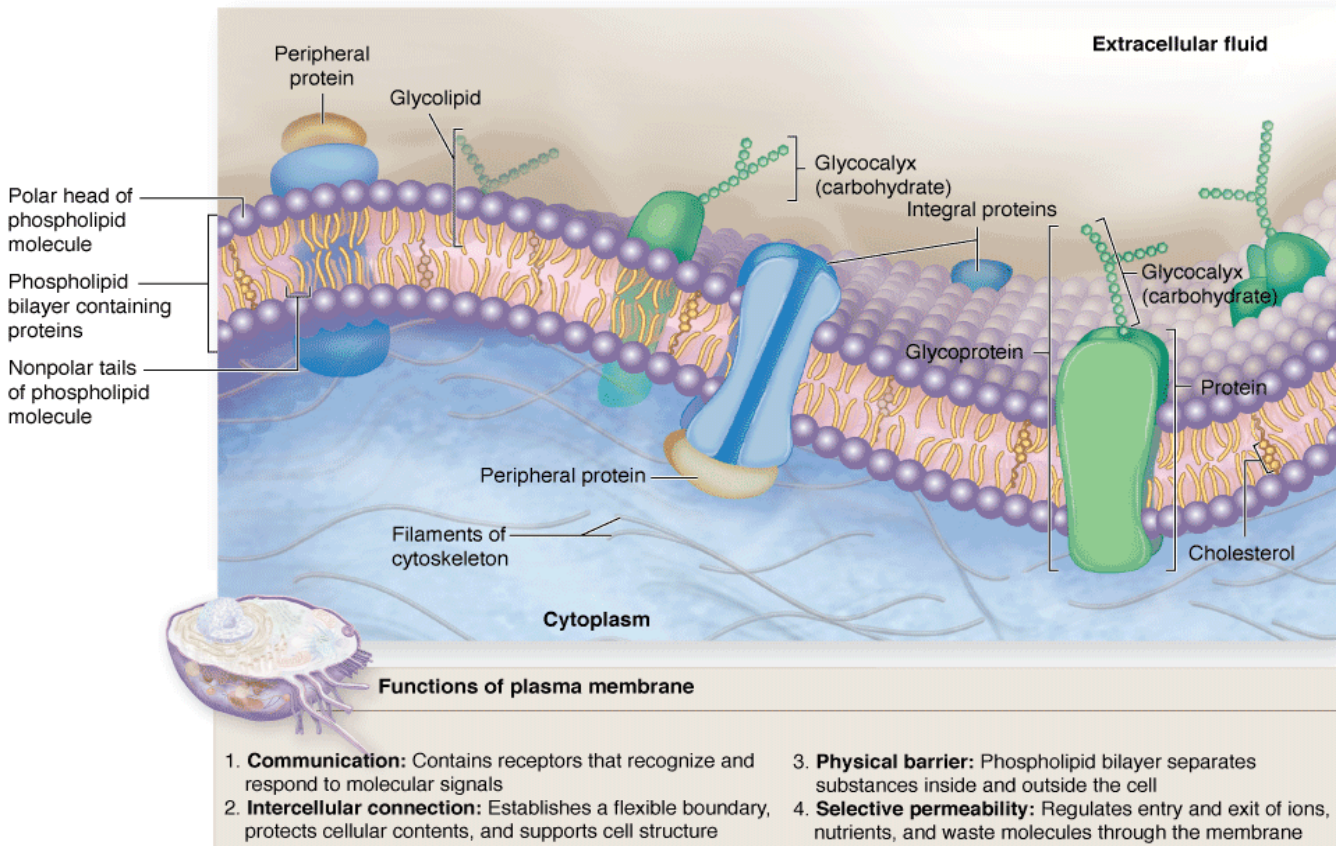
Plasma Membrane

All eukaryotic cells are enveloped by a limiting membrane composed of phospholipids, cholesterol, proteins, and chains of oligosaccharides covalently linked to phospholipid and protein molecules. The plasma, or cell, membrane functions as a selective barrier that regulates the passage of certain materials into and out of the cell and facilitates the transport of specific molecules. One important role of the cell membrane is to keep constant the ion content of cytoplasm, which is different from that of extracellular fluid. Membranes also carry out a number of specific recognition and regulatory functions.

-Maintain the structural integrity of the cell.
-Control movement of substances in and out the cell.
-Regulate cell – cell interaction.
-Act as interface between the cytoplasm and the external environment.

- Cell membrane is not visible by the light microscope, seen only by E/M. It can be recognized via receptors, antigens…





-It is 7.5-10 nm thick, and appears as a tri-laminar structure of two thin, dense lines, and a light line in between.

-The entire structure is called a unit membrane.

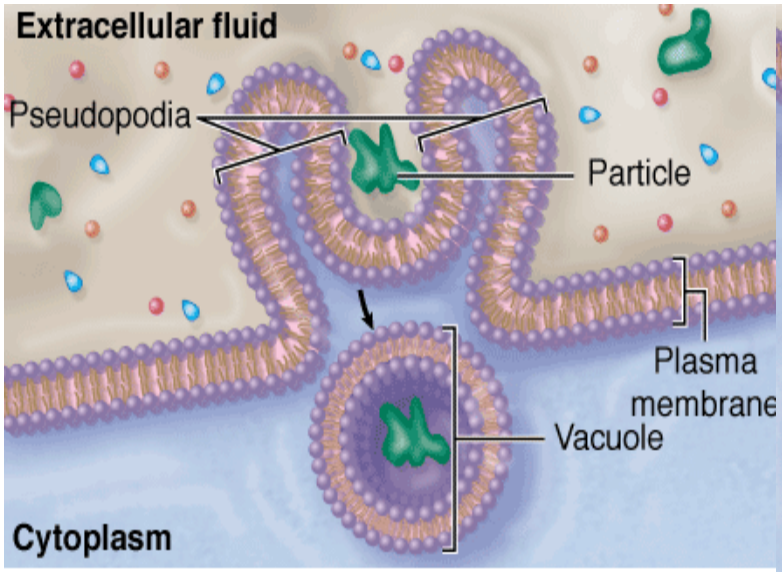
The outer layer is made of phospholipids molecules while the inner layer (light layer) is made of fatty acid side chains.

On the external layers (surface) of the cell membrane in animal cells there are many membrane of protein and some of lipid are conjugation with short chains of polysaccharide from glycoproteins and glycolipid which project from the surface of the cell formed outer cover of the cell called as **glycogalx**, which provide mechanical and chemical protection .

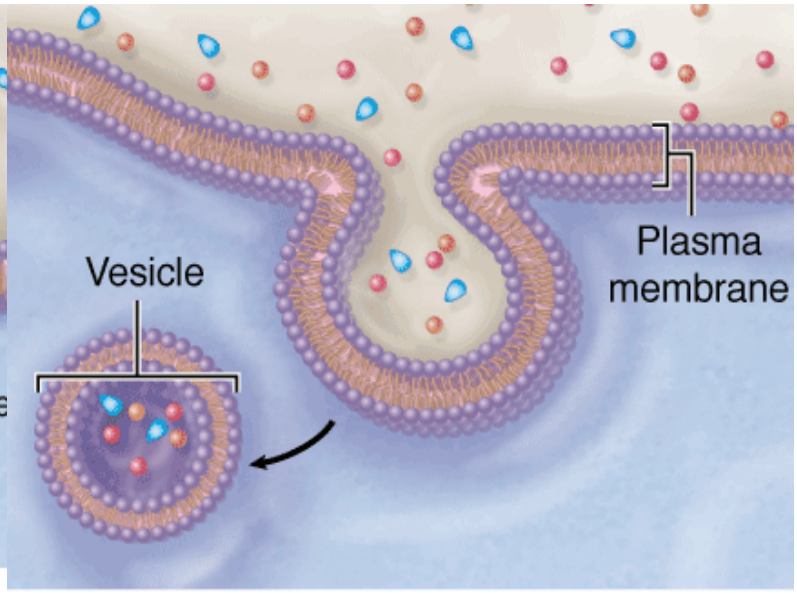
Membrane transport protein

- The hydrophobic components of the plasma membrane limit or prevent movement of polar molecules across it.
- The presence and activity of trans-membrane proteins will facilitate the transfer of these hydrophilic molecules across this barrier.
- The trans-membrane proteins form:

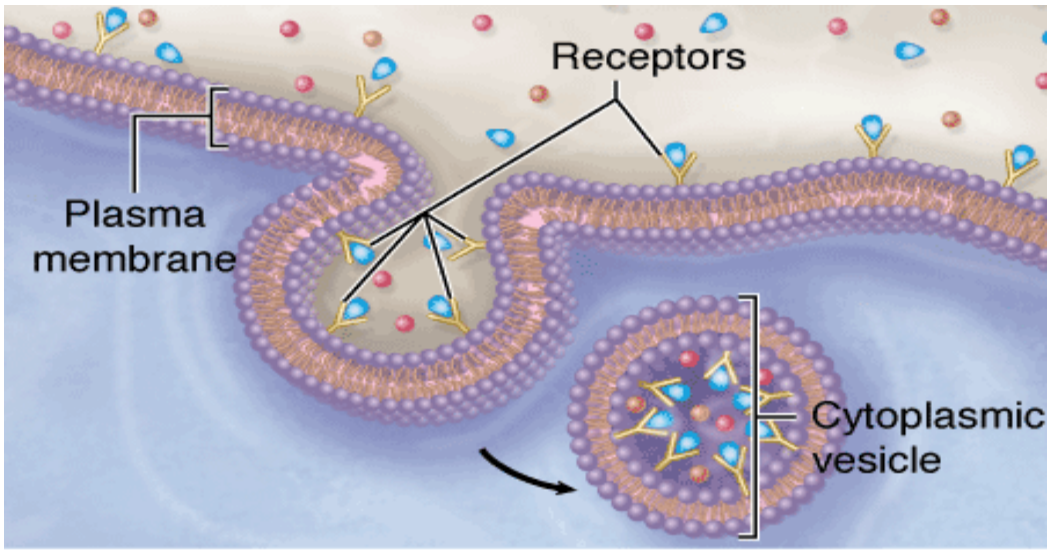
a- Channel proteins **b- Carrier proteins**



a Phagocytosis



b Pinocytosis



c Receptor-mediated endocytosis

<u>Endocytosis</u> the process by which a cell ingests macromolecule, particulate matter, and other substances from the extra-cellular space.Then, endocytosis material is engulfed in a vesicle.

-If the vesicle is large (>250 nm in diameter): the method is called phagocytosis (cell eating). The membranes of these processes meet and fuse, enclosing the bacterium in an intracellular vacuole, a **phagosome**.

-If the vesicle is small (<150 nm in diameter): the method is called pinocytosis (cell drinking), and a vesicle is called a **pinocytotic vesicle**.

- **Phagocytosis**; the process of engulfing large particles, or even cells by phagocytic cells such as monocytes, neutrophils, macrophages.

- Membrane trafficking; the cycle of membrane shuffling during exocytosis and endocytosis (membrane recycling).

Receptors mediated endocytosis (coated vesicle) (cytoplasmic vesicle)

-Many cells specialize in pinocytosis of specific macro- or micro-molecules.

-The most efficient form of capturing these substances depends on the presence of receptors proteins (cargo protein) in the cell membrane.

- Cargo proteins are trans-membrane proteins associated with a particular macro-molecules (ligand) extracellulary, and with a clathrin coat intracellular.

Mitochondria

They are flexible, rod-shape organelles; with diameter of 0.5 µ width and ~7.0 µ length.

Their number are variable in human cells; e.g. they are abundant in hepatocytes (~2000) and muscles.

-**Mitochondria are self-replicating and possess their own DNA**, and perform oxidative phosphorylation and lipid synthesis.

The mitochondrion is bounded by a double membrane, each mitochondrion possesses a smooth outer membrane and folded inner membrane (Cristae) with a narrow space between them is called **inter-membrane space**.

- The mitochondrial matrix is homogenous and many granular and fibrous structures are surrounded in it. It contains ribosomes, nucleic acids and proteins.

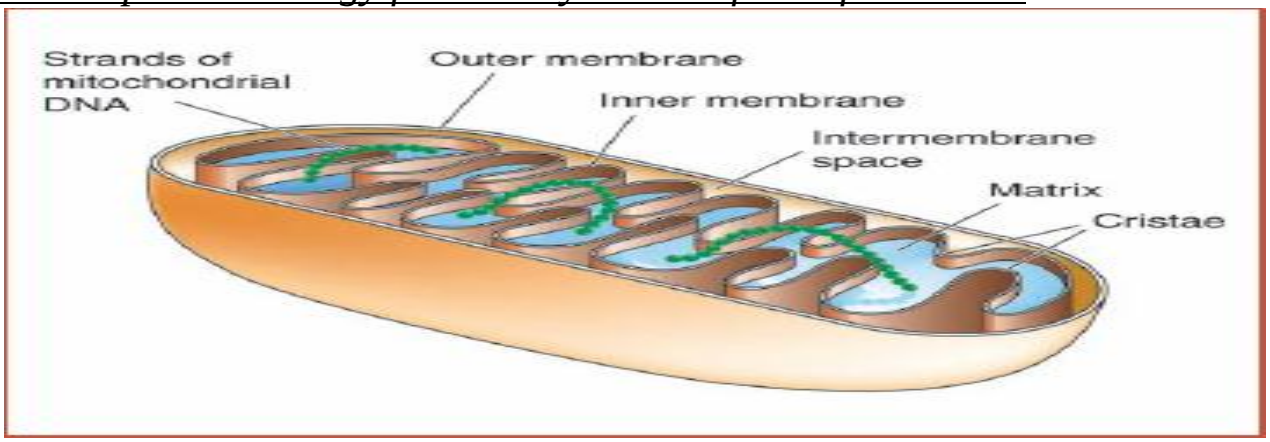
-Cristae increase the surface area of the inner membrane for ATP synthase and the respiratory chain; and also their number are related directly to the energy requirement of the cell.

-The outer mitochondrial membrane possesses a large number of porins (Multipass trans-membrane proteins).

- Porins form large aqueous channels through which water soluble molecules can pass.

-The outer membrane is relatively permeable to small molecules, so the contents of the inter-membrane space resemble the cytosol.

The chief function of Mw is to supply energy the oxidation of nutrient within the cell to provide energy from the synthesis of ATP from ADP.



-The inner membrane display a large number of protein complexes such as ATP synthase and Respiratory chains, so mitochondria can be regarded as the power house of the cell.
-The matrix space contains also mitochondrial ribosomes, mRNA, tRNA, and dense spherical matrix granules.
-Moreover, matrix contains the double-stranded circular DNA (cDNA) and enzymes necessary for expression of the mitochondrial genome.

Protein Synthetic and Packaging Machinery of the Cell The protein synthetic machinery of the cell composed of-:
-Ribosomes, and polyribosomes
-Endoplasmic reticulum
-Golgi apparatus

Ribosomes

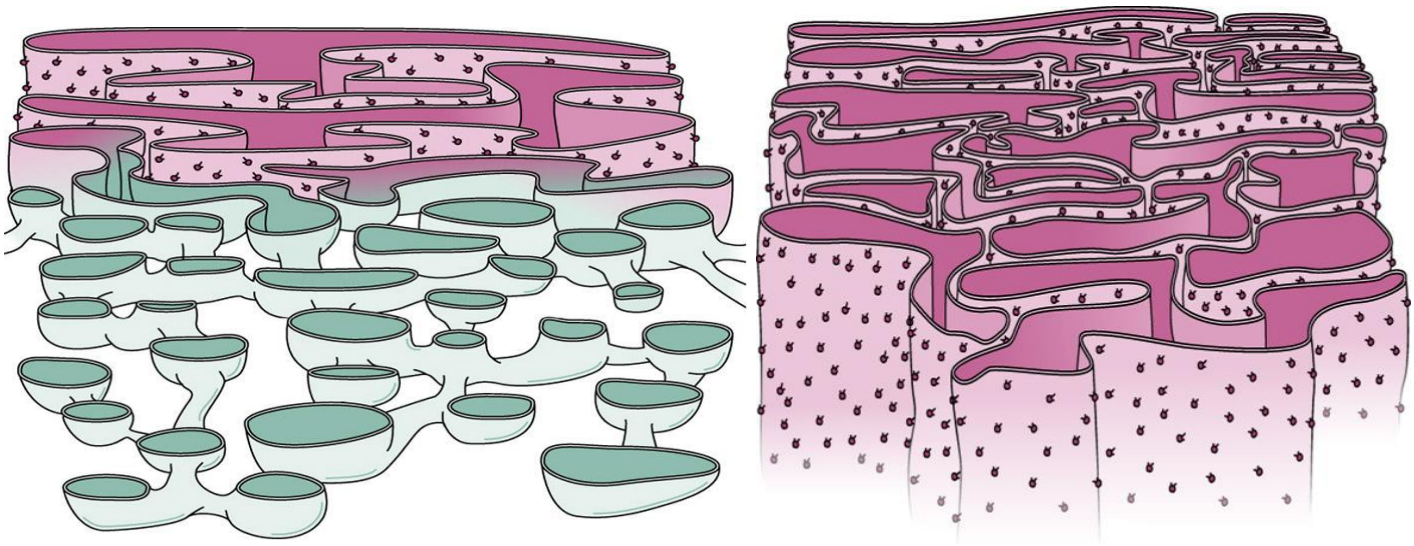
-They are small spherical part non-membranous particles composed of protein and ribosomal RNA.
-Each ribosome is composed of large subunit and small subunit.
-Composite of 40-60% of RNA and the reminder protein. The ribosomes presented in long number of cells which secret protein. The ribosomes (R) found either single particles or clusters free in the cytoplasm or associated with E.R. the free R. synthesis protein to use intercellular while the R. associated with E.R. synthesis protein and use for secret outside of the cell.

Endoplasmic Reticulum (ER)

-It is the largest membranous system in the cell.
-It is a system of interconnection tubules and vesicles whose lumen is referred as cistern.
-ER has 2 types; smooth and rough ER.
-Their Functions are-:
-Manufacture of all membranes of the cell.
- Protein synthesis and modification.
- Lipid and steroid synthesis.
- Detoxification of certain toxic compounds.

Smooth Endoplasmic Reticulum (SER)

-SER is a system of anastomosing tubules and flattened membrane-bound vesicles.
-The lumen of SER is assumed to be continuous with that of RER.
-They are abundant in cells that active in synthesis of steroids, cholesterol, triglycerides, and also in cells that are functioning in detoxification.
- Their surface is not attached to ribosomes, and so, it is called smooth.



Rough Endoplasmic Reticulum (RER)

-Their membranes possess integral proteins that function in recognizing and binding ribosomes to their surfaces and maintain their flattened shape.
-RER participates in the synthesis of all proteins that are packaged and delivered to the plasma membrane.

-RER also manufactures lipid and integral proteins of the cell membrane.
The cisternae of RER are continuous with the peri-nuclear cisterna (the space between the inner and the outer nuclear membrane).

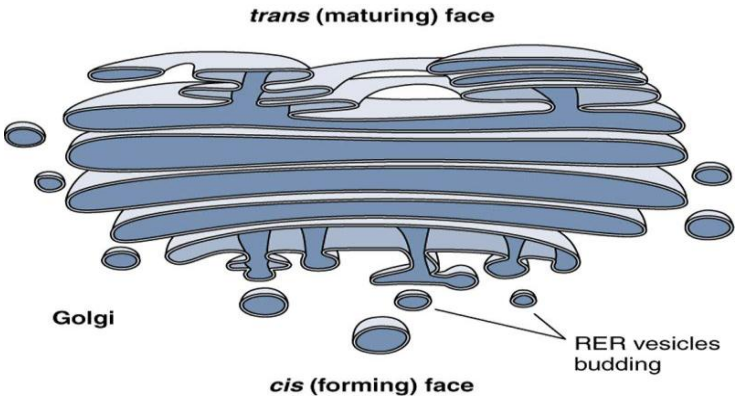
Golgi complex

-Proteins manufactured in the RER go to Goli apparatus for post-translational modification and packaging.

-Golgi is composed of one or more series of flattened, slightly curved membrane-bound cisternae.

-Each Golgi stack has three levels of cisternae:- the cis-face, the medial-face, and the trans-face, and then smooth or coated vesicles.

-this organelles is consisting of different numbers of flatten sacs aggregated like plates or cups, at the periphery of the sac there are Golgi cisternae . Golgi (G) found near the nucleus and it is very well develop in secretory cell and its appearance differs depend on the cell type and activity. The function of Golgi apparatus is a source of membrane unit for the cells and also provide membrane unit for the packaging or branching the secretory granules.



Lysosomes

-Lysosomes are small rounded or polymorphic in shape, with a diameter of 0.3- 0.8µ.

-Lysosomes have an acidic pH, and contain hydrolytic enzymes (~ 40 different types of acid hydrolases).

-Lysosomal membranes contain proton pumps that transport H+ ions into the lysosomes to maintain its luminal pH at 5.0.

-Lysosomes help in digesting macromolecules, phagocytosed micro-organisms, cellular debris, cells, and senescent organelles such as mitochondria & RER.

-The L. are originated from golgi apparatus as small particles called primary L. the foreign particles which inter the cell by endocytosis . Surrounded by

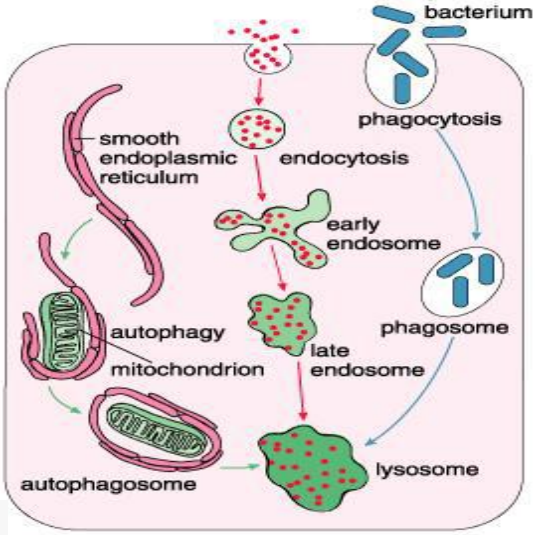
membrane unit as phagosomes . When the primary L. come close content with phagosomes and these membrane fuse and the continent of two organelles mix. The new body called as secondary L. this body exposes the engulfed material to the L. enzymes. When digestion is complete the L. membrane rupture and discharge it's contain to the cytoplasm and undigested material may remain within the membrane called Residual body.

Substances subjected for degradation within lysosomes pass through 3 ways-:

-**Phagosomes** either join lysosomes or late indosomes. The hydrolytic enzymes digest most the contents of phagosomes except lipid which resist complete digestion and changed into residual body.

-**Pinocytotic vesicles**.

-**Autophagosomes**: Organelles that no longer required by the cell become surrounded by elements of SER, and then enclosed in vesicles called autophagosomes.

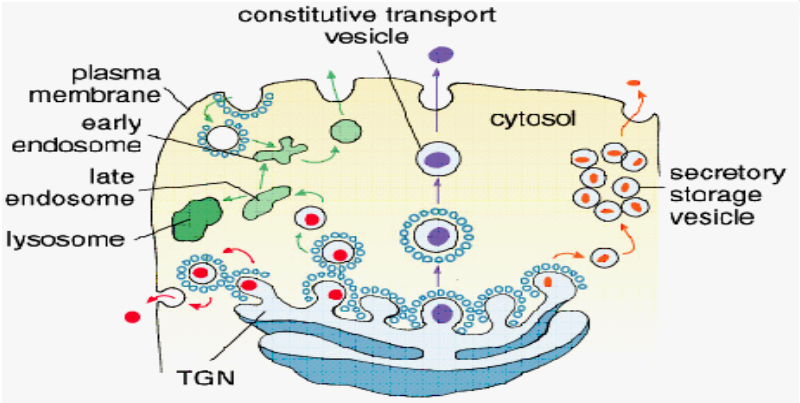


Endosomes

-Endosomes are divided into early and late compartments:

-Early endosomes are situated near the periphery of the cell near the Golgi apparatus.

- Late endosomes are situated deeper in the cytoplasm.



Cell Inclusions

-They are non-living components of the cell that do not possess metabolic activity and are not bounded by membranes.

-The most common inclusions are-:

-Stored food:

-Glycogen: abundant in liver and muscle cells

-Lipid droplets; stored mainly in adipocytes, and present also in other cells.

-**Pigments**: could be endogenous or exogenous.

-Exogenous pigments as carotene, carbon, and dust.

-Endogenous pigments such as; Hemoglobin, Melanin, lipofuscin or lipochrom.

-Crystals: are not commonly seen. Present in Sertoli cells as (Crystals of Charcot-Bottcher) and in interstitial cells as (Crystals of Reink.

Cytoskeleton

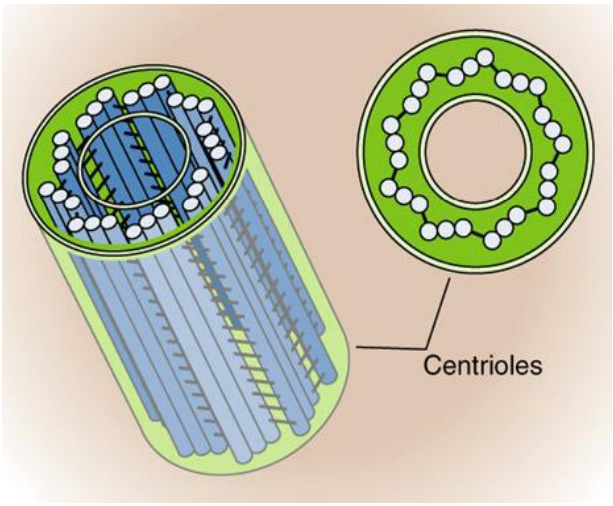
-They are meshwork of protein filaments responsible for maintenance of cellular morphology, and participate in cellular motion,

- The cytoskeleton has three major components; 1- Thin filaments 2- Intermediate filaments 3- Microtubules

Centromere and Centrioles

-Centromere is present in all dividing cells near the nucleus, and is composed of 2 perpendicular centriols. The centriols duplicated during cell division.

- Centriol is cylindrical in shape.
- Each centriol composed of nine sets of triplet microtubules.



Cilia and Flagella

-Cilia (cilium) are hair-like motile processes extend from the free surface of ciliated cells.

-Flagellated cells (sperm) has only one flagellum.

-Both cilium and flagellum composed of the same core organization (axoneme.(
-The axoneme is formed of nine pairs (doublets) and 2 central (singlet) microtubules.

Nucleus

- All human cells contain nucleus except the mature red blood corpuscles.

- Normally each cell contains a single nucleus, but sometimes contains two as liver cells or more (multinucleated) as skeletal muscle cells, and osteoclasts.

- Nucleus could be spherical, oval, flattened, or lobulated.

- Also, nucleus could be central, basal or peripheral.

Structure of the nucleus - Nucleus composed of:
- Nuclear membrane (Envelop) - Chromatin - Nucleolus - Nucleoplasm

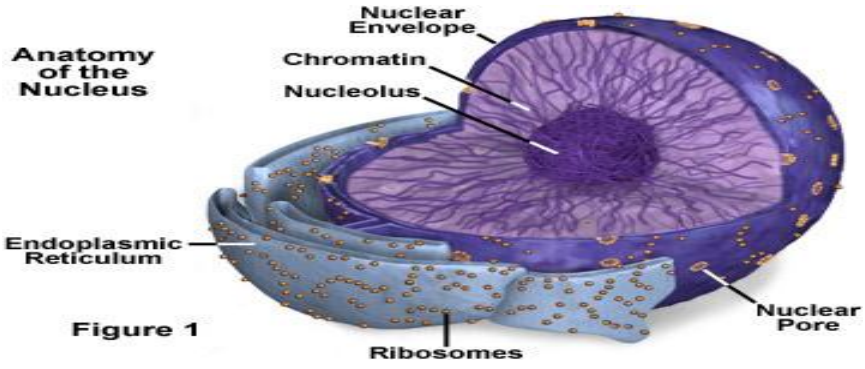


Figure 1

1- Nuclear Envelop

- Nuclear envelop is composed of two parallel unit membranes; the outer and the inner membranes separated from each other by a 10-30 nm space called **perinuclear cisterna**.
- The two membranes fuse with each other at certain regions known as **nuclear pores** that permit communication between cytoplasm and nucleus.
- The nuclear pores are surrounded by a non- membranous structure called **pore complex.**

2- Chromatin

- Chromatin is a complex basophilic structure formed of DNA associated with histone and non-histone proteins.
- Depending on its transcriptional activity chromatin can be divided into:
- **Euchromatin**; uncoiled or not condensed, stained lightly basophilic, gene rich, and early transcript.

- **Heterochromatin**; highly coiled or condensed, stained deeply basophilic, gene poor, and late transcript.

***Chromosomes**, the most highly condensed form of chromatin, are visible during mitosis. The human cells contain 46 chromosomes, 44 (the somatic chromosomes), the other pair (sex chromosomes) consists of dissimilar chromosomes (XY) in males and similar ones (XX) in females. In females, only one X chromosome is active; the inactive X chromosome is often visible as a clump of heterochromatin termed sex chromatin.

3- Nucleolus

-Nucleolus is a non-membranous deeply stained structure located in the nucleus.
-It present during interphase and disappear during cell division.
-It contains ribosomal RNA, some proteins and small amount of DNA.

4- Nucleoplasm: composed of the following
I- **Interchromatin Granules:** They are located in clusters scattered throughout the nucleus among the chromatin material.
II- **Perichromatin Granules:** They are located at the margin of the heterochromatin, and are composed of:
a- **Heterogeneous nuclear ribo-nucleo-proteins**
b- Small nuclear ribo-protein particles
III- **Nuclear Matrix:** Contain DNA, RNA, Proteins, and nuclear phosphate.