Cell Biology

Chapter (3): Type of cells and structures of the cell

1. Prokaryotic cell
   - Parts and organelles

2. Eukaryotic cell: Animal cell
   - Cell membrane
   - Organelles: Nucleus, Endoplasmic reticulum, Golgi apparatus, Lysosomes, Ribosomes, Mitochondria, Microbodies, and Centrioles.
   - Cytoskeletons
   - Junctions between cells

Type of cells

- The presence or absence of the nucleus is used as a basis for classification of cells.
- There are two primary types of cells: prokaryotic cells and eukaryotic cells.

Prokaryotic Cell

- They are very small in size.
- No membrane bound nucleus.
- Single chromosome present.
- Nucleolus is absent.
- Membrane bound organelles are absent.
- Multiplication of cell is by binary fission or budding.
- Cell wall present.
- Unicellular.
- Cell size is 1-10µm

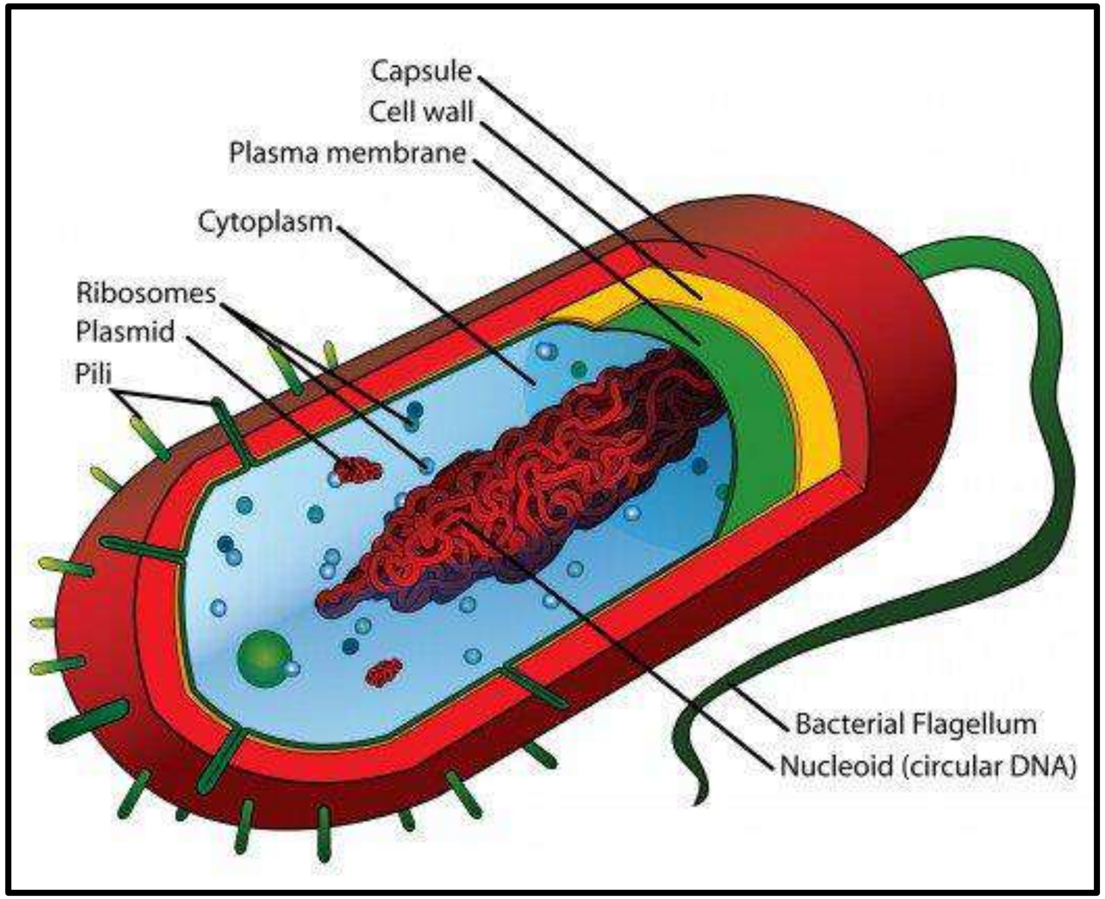
Eukaryotic Cell

- They are comparatively larger in size.
- Nucleus is surrounded by a double membrane layer.
- More than one chromosome are present.
- Nucleolus is present.
- Membrane bound organelles are present.
- Cell division by mitosis or meiosis.
- Cell wall seen in only plant cells.
- Unicellular and multicellular cells.
- Cell size 10 - 100µm.

Type of cells

1. Prokaryotic cell: Bacteria

- Bacteria are the simplest living organisms.
- Bacteria lack nucleus and membrane bound organelles.
- They are unicellular organisms.

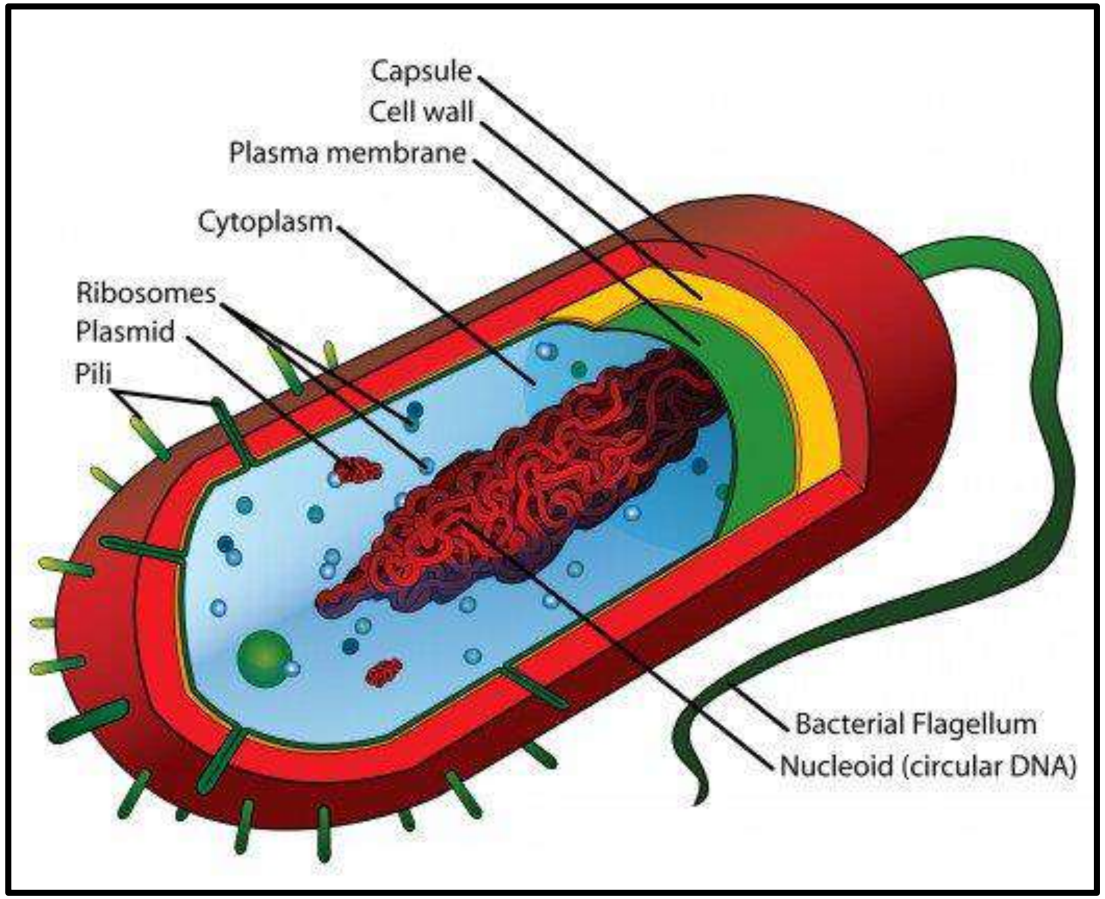


Structure of bacteria

Structures of bacterial cell

1. Plasma membrane

- It surrounds the cytoplasm so it is also known as cytoplasmic membrane.
- It is a bilayer composed of phospholipids, proteins and carbohydrates.
- Its main components are phospholipids, so it is called phospholipids bilayer.
- It regulates the flow of substances in and out of the cell.



Structure of bacteria

Structures of bacterial cell

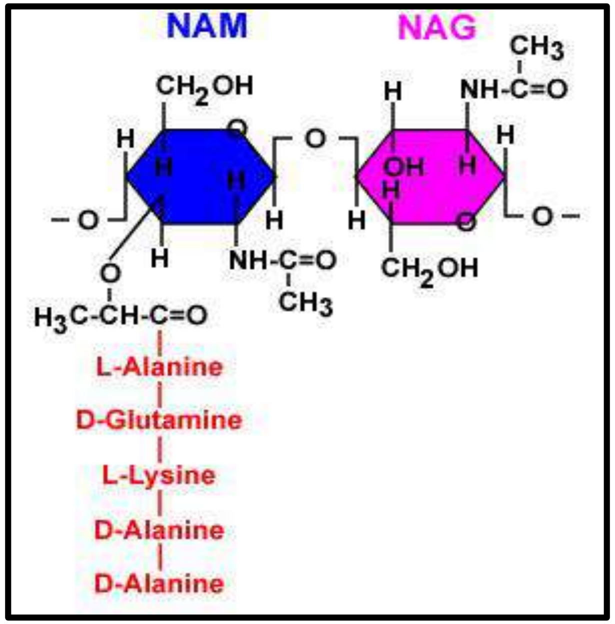
2. Cell wall

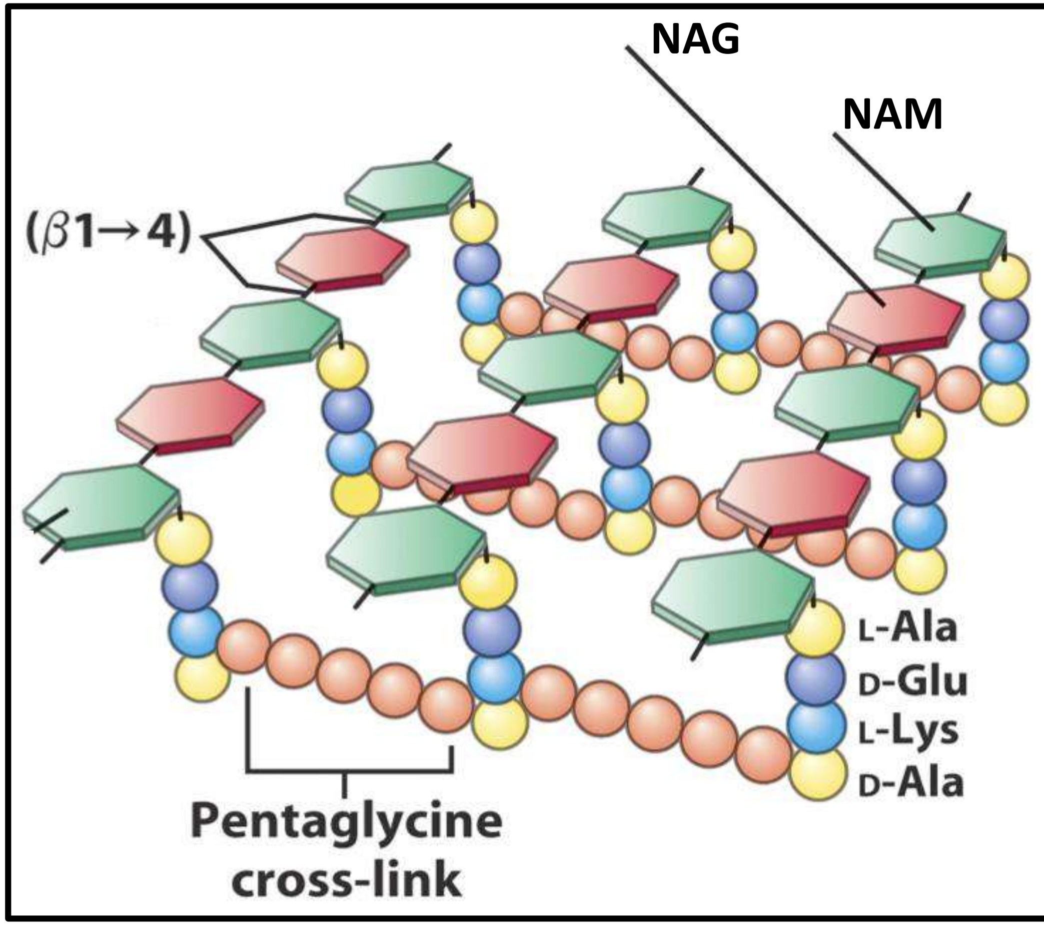
- It is a rigid layer surrounds the plasma membrane, composed of peptidoglycan (glycoprotein) molecules.
- Peptidoglycan is made up of:

  a. Polysaccharide chain consisting of alternating N-Acetylmuramic acid (NAM) and N-acetylglucosamine (NAG) which is linked together by β-(1,4) glycosidic bond.

  b. Peptide chain consisting of 3-5 amino acids linked to NAM.

- Its main function is providing support, and rigidity to the cell.





Structures of bacterial cell

3. Capsule

- It is the third protective layer in some bacteria surrounding the cell wall and plasma membrane.
- It is made up of polysaccharides, so it is called sugar coat or glycocalyx.
- It protects the bacterium from dryness and from chemicals.
- It also protects the bacterium from phagocytosis (engulfing) by white blood cells.

4. Flagella (Flagellum)

- They are rigid rotating tails made up of proteins.
- They help the bacterium to move toward nutrients; away from toxic chemicals.

Structures of bacterial cell

5. Pili (Pilus)

- They are small hair-like projections made up of proteins.
- They allow bacteria to attach to other cells and surfaces.
- They are used for bacterial conjugation, where genetic material can pass through them.

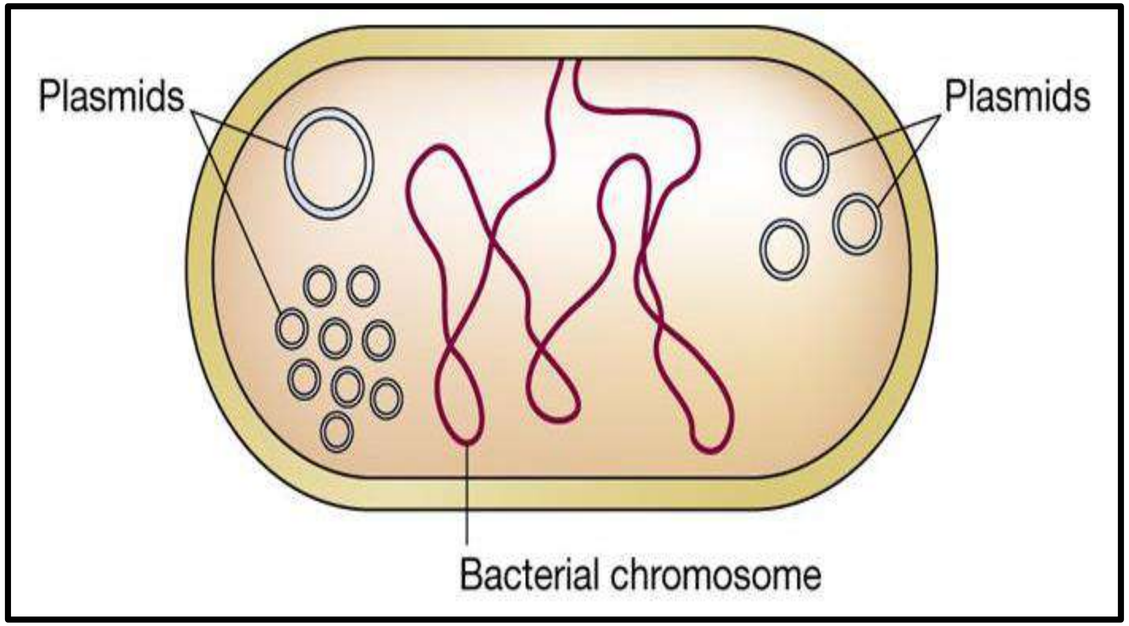
6. Cytoplasm

- It is a gel-like matrix composed of water, enzymes, nutrients, and chemical molecules.
- It contains cell structures such as ribosomes, DNA and plasmids.

Structures of bacterial cell

7. DNA

- In most bacteria, DNA is a single circular molecule, localized in a region of cytoplasm called the nucleoid without surrounding membrane.

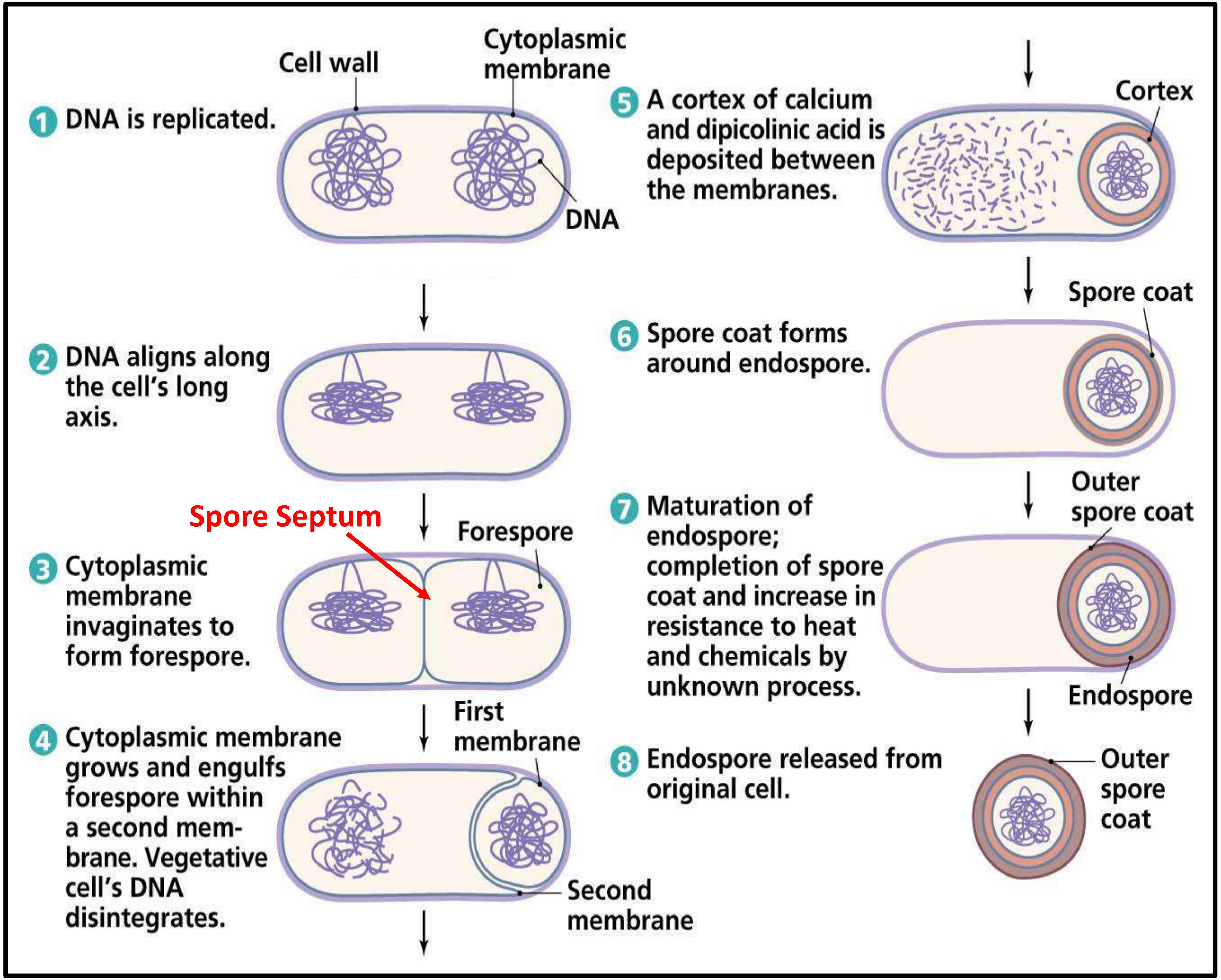


8. Plasmid

- Plasmid is small circular double strands of bacterial DNA.
- It is not necessary for growth, metabolic processes, reproduction of bacteria.
- It carries genes required for antibiotics resistance or genes to cause a disease.

Endospores

- They are thick-walled, resistant and non-reproductive structure produced by certain bacteria.
- They protect bacteria from drying, high temperature, chemicals, and radiation.
- They allow bacteria to survive in an environment that would be lethal for them in their normal form.
- Endospores are formed by the bacteria in a process called sporulation.

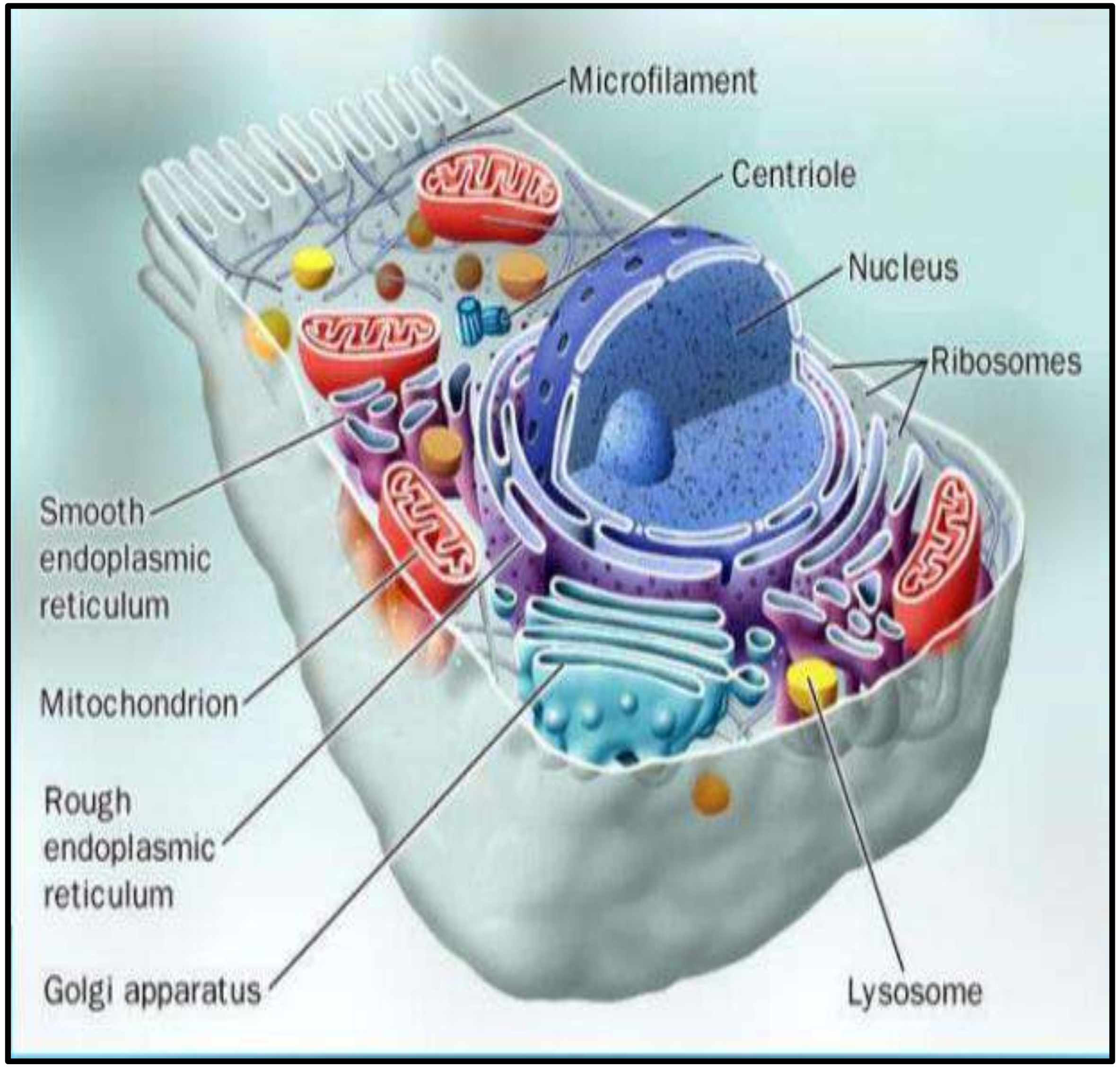


Type of cells

2. Eukaryotic cell

- Eukaryotic cell is complex and larger than the prokaryotic cell.
- Eukaryotic cell can be easily distinguished through a membrane-bound nucleus.
- Eukaryotic cells are membrane-bound organelles, which have a multiple membrane-bound organelles to carry out specific cell functions.
- Most of eukaryotic cells are multicellular organisms.
- Example: Animal cell, Plant cell, Fungi

Structures of animal cell



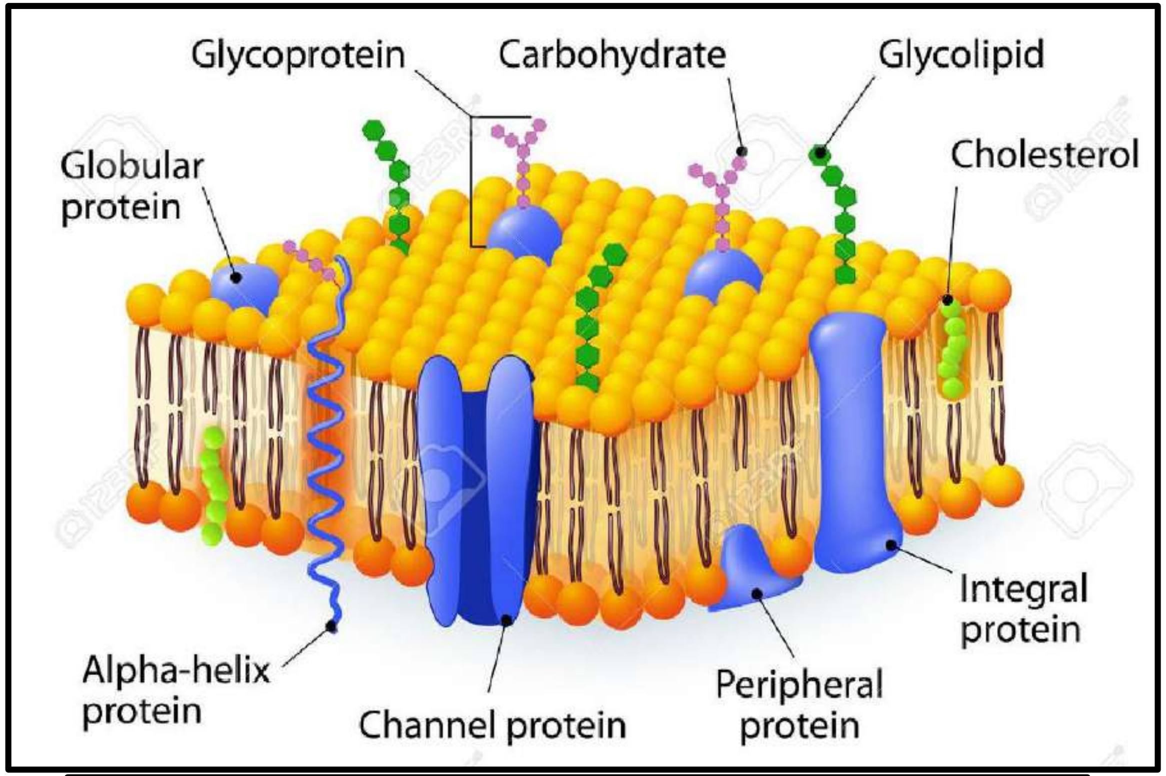
Structures of animal cell

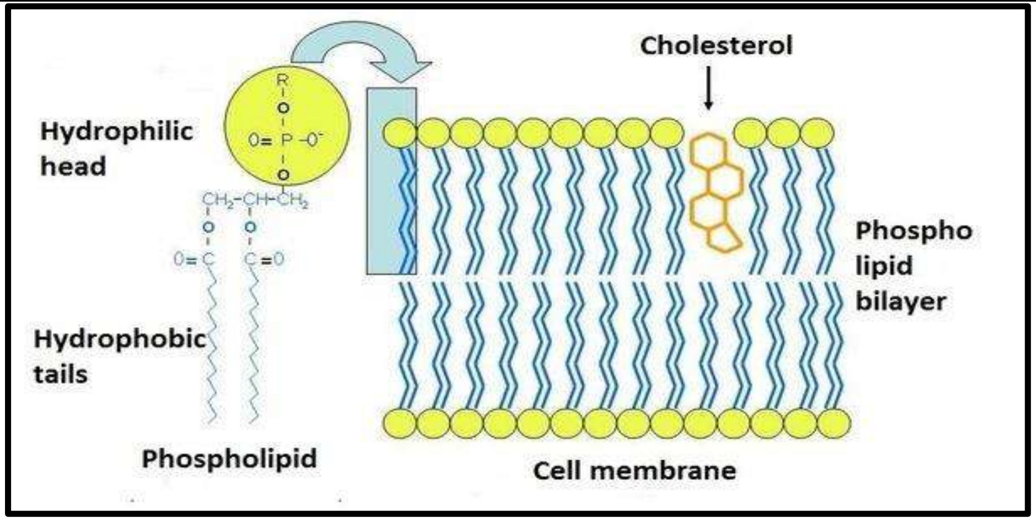
1. Plasma membrane

- It surrounds the cytoplasm so it is also known as cytoplasmic membrane.
- The plasma membrane separates the internal contents of the cell from its surrounding environment.
- It regulates the flow of substances into and out of the cell. It also allows wastes to leave the cell.
- It is a bilayer composed of:

A. Lipids:

- Phospholipids: are the main components, so it is called phospholipid bilayer.
- Cholesterol: is located between the tails of phospholipids to stabilize the membrane mainly at temperature variations.





Structures of animal cell

1. Plasma membrane

B. Proteins: There are large group of proteins with different functions attached to the membrane surface or embedded in the phospholipid *bilayer.*

- Transporter proteins: help substances to move through the membrane.
- Receptor proteins: induce changes in the cell when they bind with specific molecules called ligands.
- Markers: usually they are glycoproteins which identify the cell and distinguish it from other cells like the markers of immune cells and the markers which characterize red blood cells.
- Enzymes: control the chemical reactions that may carry out in the membrane.
- Adhesion proteins: help the cells to attach to other cells.
- Proteins attached to the cytoskeleton to maintain the cell shape.

C. Carbohydrates: plasma membrane usually contains carbohydrates as glycoproteins and glycolipids which play an important in cell recognition.

Structures of animal cell

1. Plasma membrane

Fluid Mosaic Model

- **A model that describes the structure of cell membrane and its components.**

HOW?????

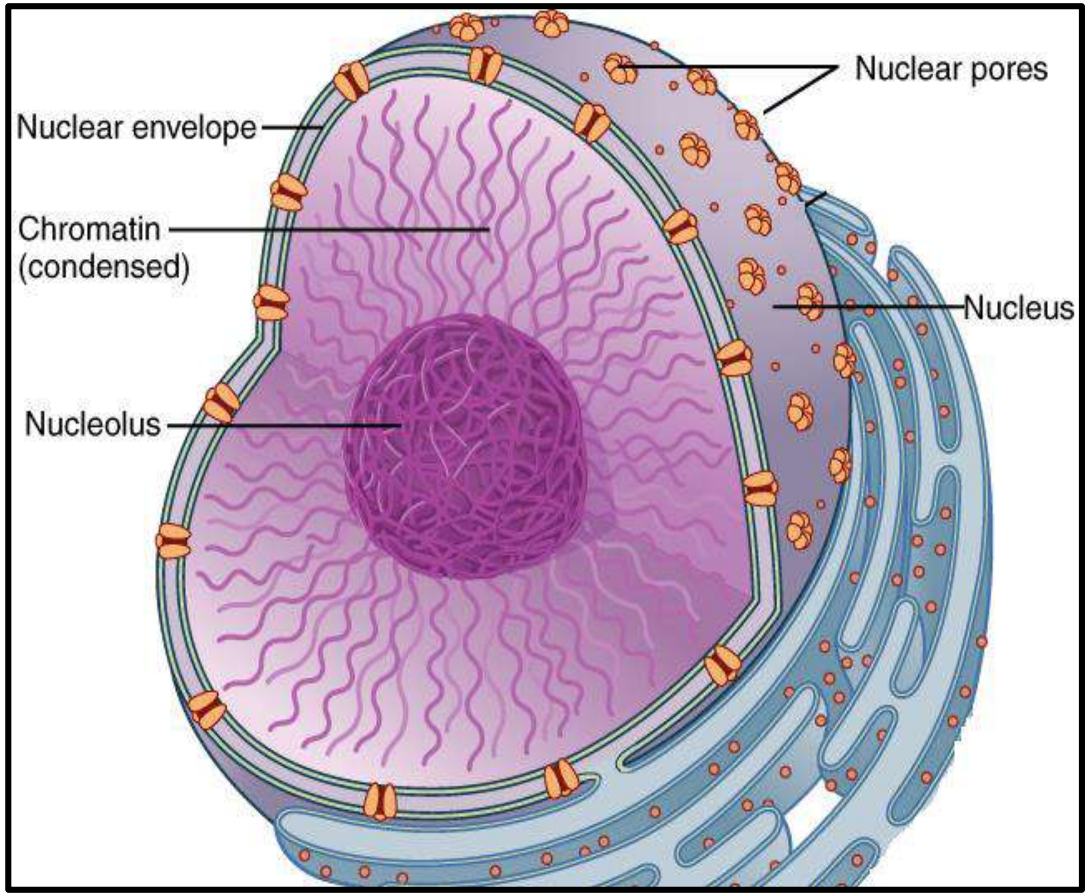
Structures of animal cell

2. Nucleus

- It is the most prominent organelle in a cell because it is the store of genetic material (DNA).
- It is a roughly spherical organelle located in the center of the cell.
- Most of eukaryotic cells have a single nucleus: Fungi have more than one, while RBCs have no nucleus.
- Structural components of nucleus:

A. Nuclear envelope:

- It is a double-membrane surrounding the nucleoplasm.
- Both the inner and outer membranes of the nuclear envelope are phospholipid bilayers.
- The outer membrane is connected with the endoplasmic reticulum.



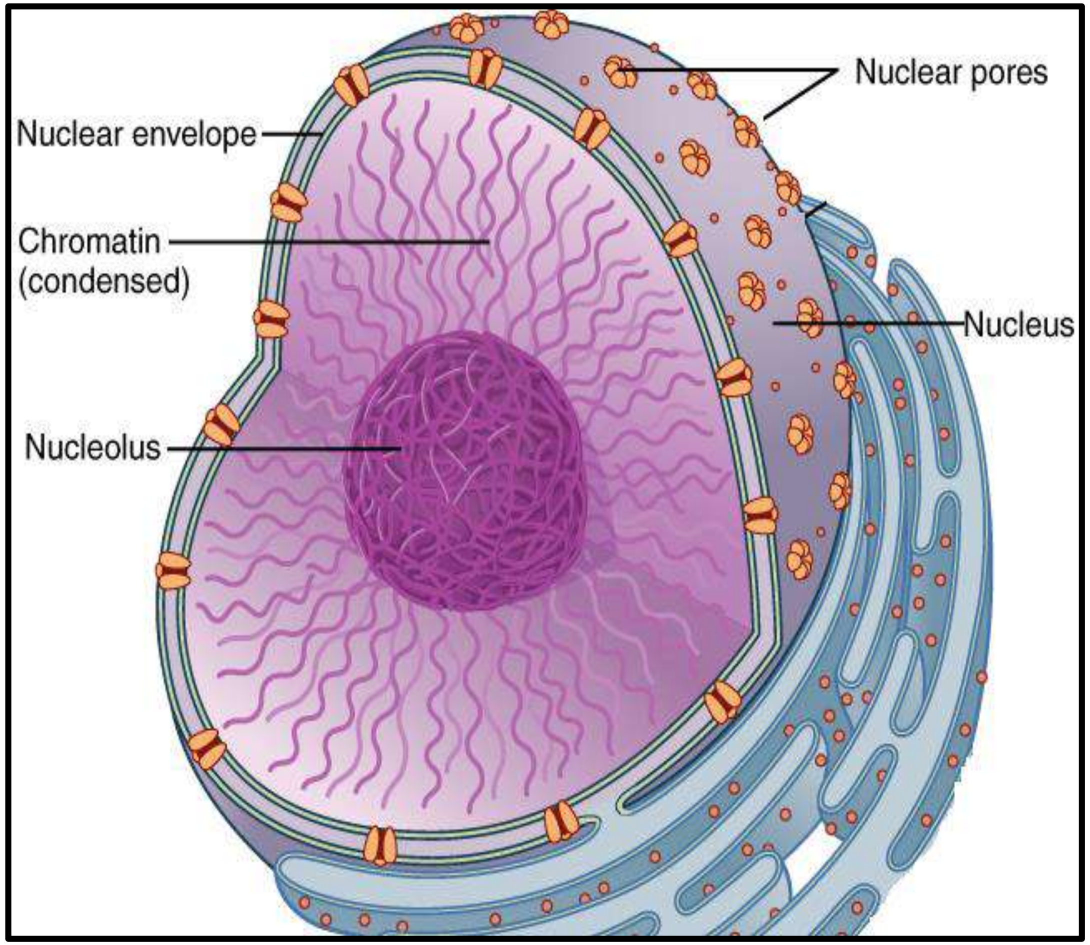
- The nuclear envelope contains pores made of a protein called nucleoporin that control the passage of ions, molecules, and RNA between the nucleoplasm and cytoplasm.

Structures of animal cell

2. Nucleus

B. Nucleolus:

- It is a roughly spherical structure located in the nucleus.
- It contains the ribosomal RNAs which are associated with proteins to form the ribosomal subunits that are then transported out to the cytoplasm through the pores in the nuclear envelope.



C. DNA

- It is the genetic material of the cell, where each human cell contains roughly two meters of DNA.
- In the nucleus, the DNA is found in a coiled form known as chromatin which is a complex of DNA and a protein called histone.
- The histone is a protein consisting many lysine and arginine amino acids.
- When the cell prepare itself for division, the chromatin coil up to form well-defined structures called chromosomes.

Structures of animal cell

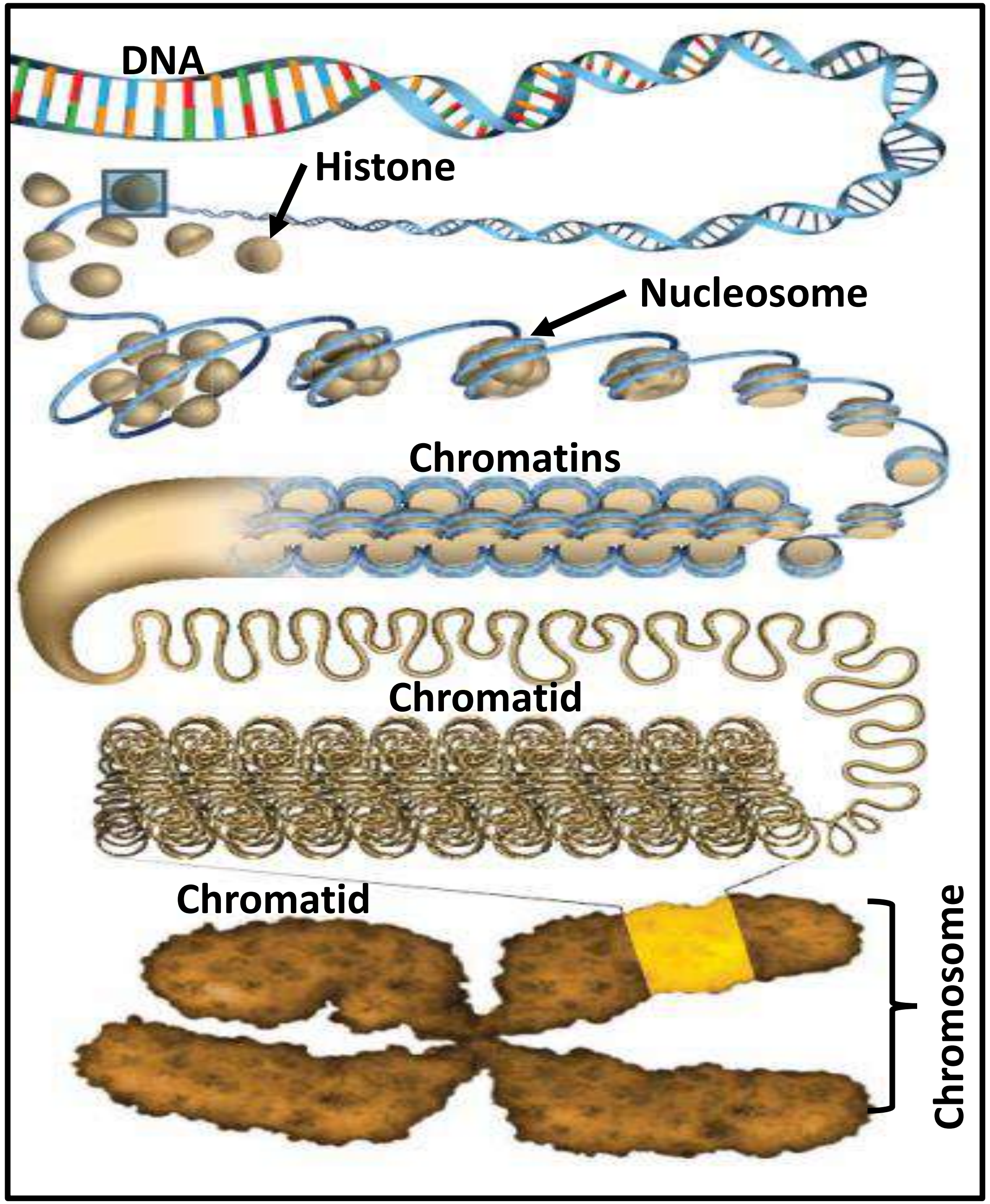
Formation of chromosomes

1. Each 200 nucleotides of DNA are coiled around 8 histone proteins forming a complex called a nucleosome.

2. Nucleosome complexes condense together forming chromatin fibres.

3. The chromatin fibres condense together forming chromatids.

4. Each two sister chromatids bind together through a centromere forming a chromosome.

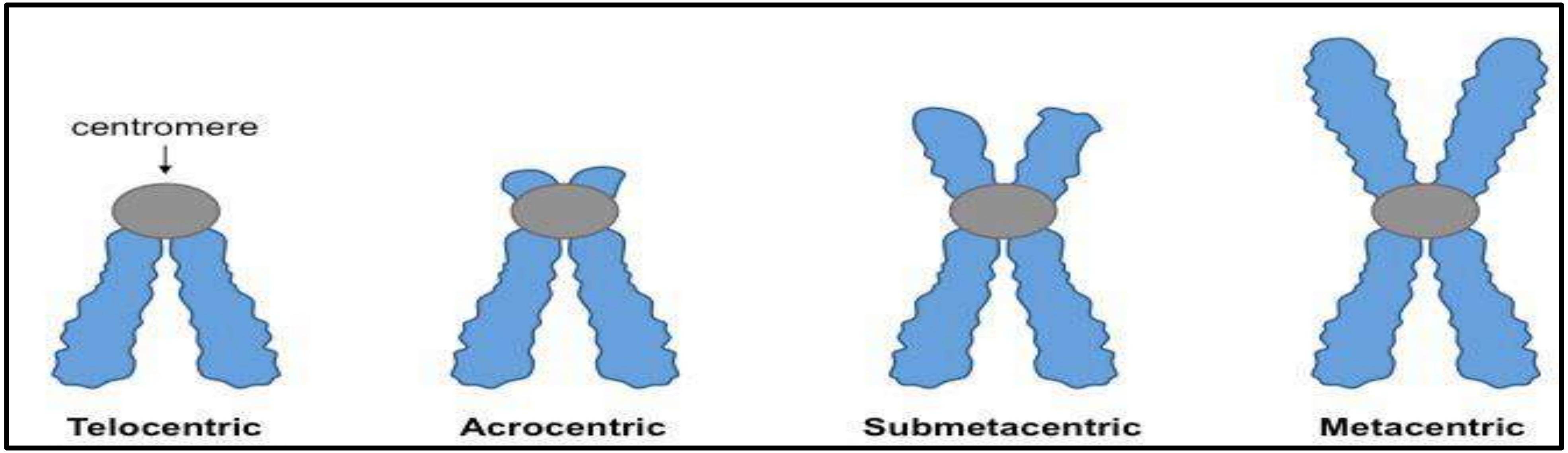


Structures of animal cell

Types of chromosomes

- Based on the position of the centrosome, there are four types of chromosomes:

1. Metacentric chromosome: the centrosome is found in the centre and all the segments of chromatids are equal.
2. Submetacentric chromosome: the centrosome is little away from the centre, so chromatids from one side are slightly longer than the other side.
3. Acrocentric chromosome: the centrosome is found closer to one end of chromatid, so the chromatids on the opposite side are very long.
4. Telocentric chromosome: the centrosome is found at one end of the chromatid, so there is one arm only.



Structures of animal cell

3. Endoplasmic Reticulum (ER)

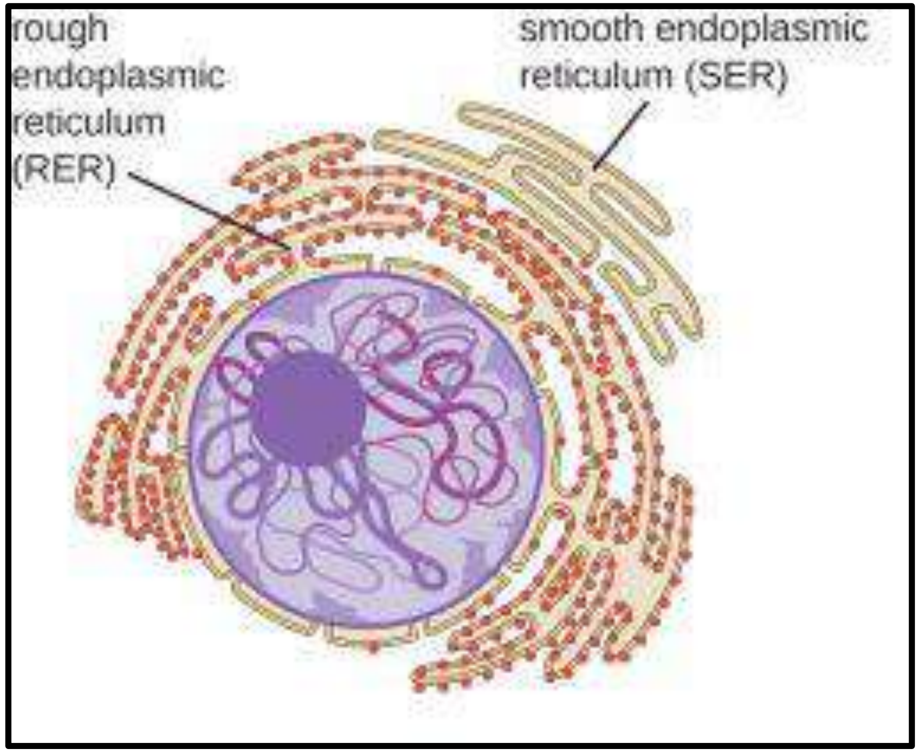
- **It is a connected network of flattened sacs or tube-like structures called cisternae that coils through the cytoplasm.**
- **There are two types of ER that differ in both structure and functions.**

A- Granular or rough endoplasmic reticulum (RER):

- **It is flattened connected sacs which has ribosomes attached to its membrane.**
- **It extends directly from the outer membrane of the nuclear envelope.**

B- Agranular or smooth endoplasmic reticulum (SER)

- **It is flattened connected sacs and lacks the attached ribosomes to its membrane.**



Structures of animal cell

General functions of ER

1. It a suitable site for different metabolic reactions because it contains many enzymes and due to its large surface area.

2. Transport the message from the genetic material in the nucleus to the various organelles in cytoplasm.

3. Some organelles are developed from ER such as nuclear envelop, Golgi apparatus and lysosomes.

4. It acts as secretory or transporting system mainly for proteins and mRNA as the following:

   a. The rough ER synthesizes the secreted proteins by its surface ribosomes, then the smooth ER packages the secretory products into transport vesicles, which move to the Golgi apparatus.

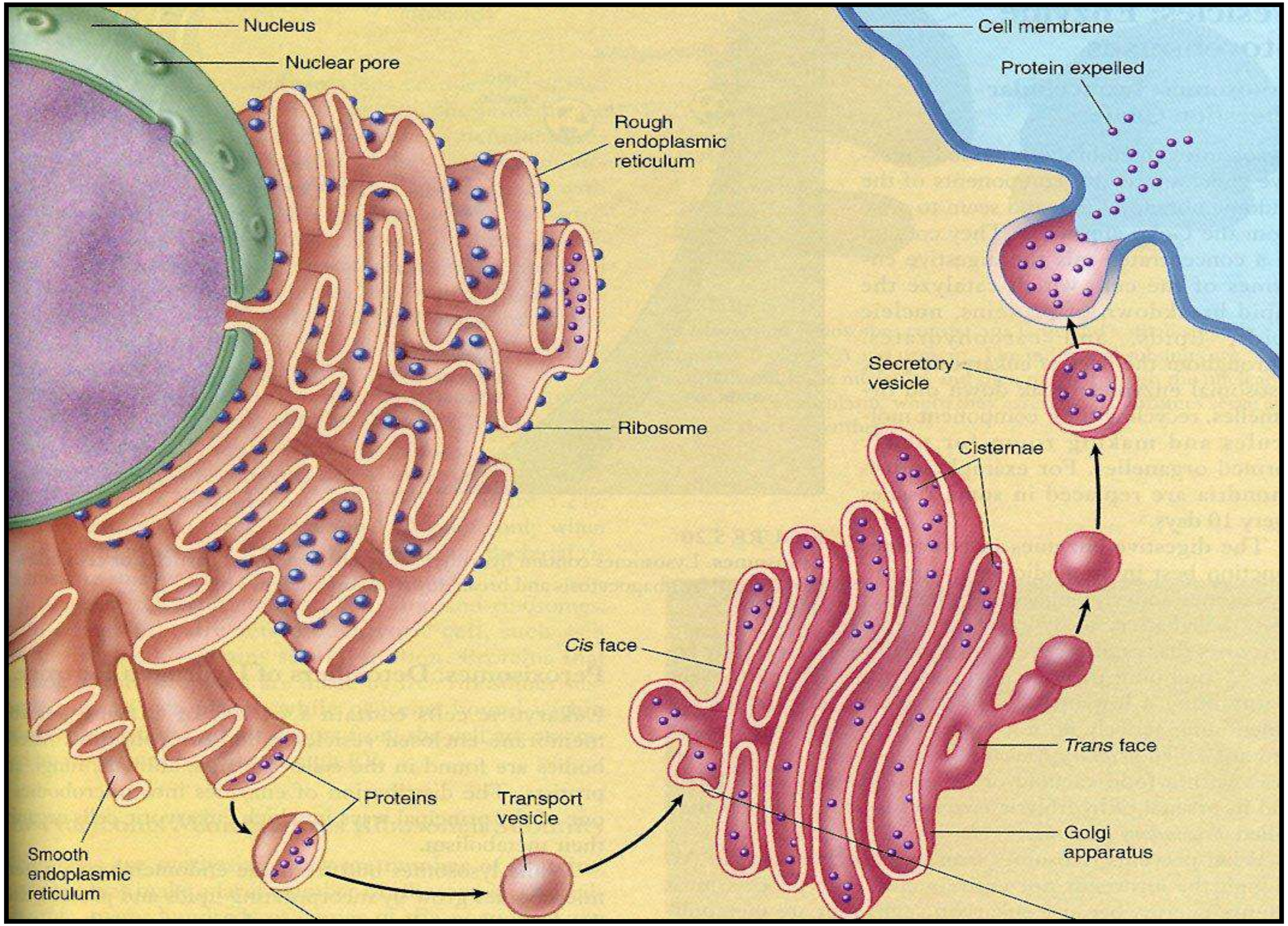
   b. The transport vesicles fuse with the Golgi apparatus, and empty their contents into it.

   c. The secreted products move through the layers of Golgi apparatus to modify into the final form, then packaged again as secretory vesicles.

   d. The secretory vesicles containing the end products leave Golgi apparatus and remain in the cytoplasm until reaching a signal to empty their contents by exocytosis process.

Structures of animal cell

General functions of ER



Structures of animal cell

Functions of RER

1. Production of secreted proteins and membrane proteins.

2. Production of lysosomal enzymes.

NOTE: Proteins that function in the cytoplasm are made by the free ribosomes.

Structures of animal cell

Functions of SER

- SER contains many proteins as a part of its membranes which act as enzymes which catalyze reactions involved with the following processes:

1. Cholesterol synthesis

2. Synthesis of steroid-based hormones such as sex hormones

3. Absorption, synthesis and transport of fats (in intestinal cells)

4. Detoxification of drugs (in liver and kidneys)

5. Breakdown of glycogen to form free glucose (in liver cells)

6. Skeletal and cardiac muscles have a modified SER called *sarcoplasmic reticulum* that plays an important role in calcium ion storage and release during muscle contraction

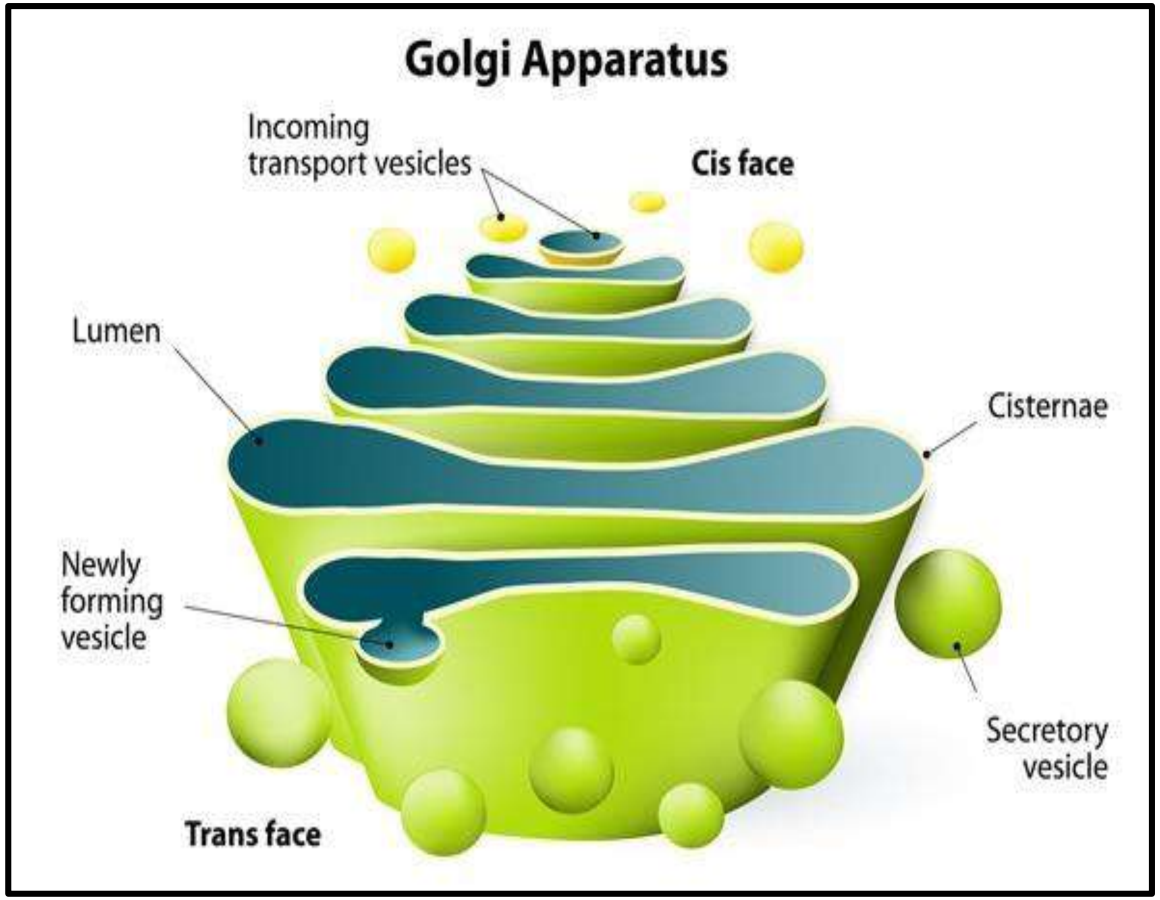
Structures of animal cell

4. Golgi Apparatus (Golgi body)

- **It is an organelle made up of many flattened membranous sacs called cisternae which originate from ER.**
- **It is known as the packaging center.**
- **It has two functional regions:**

A- Cis face (receiving side)

B- Trans face (Discharging or shipping side)

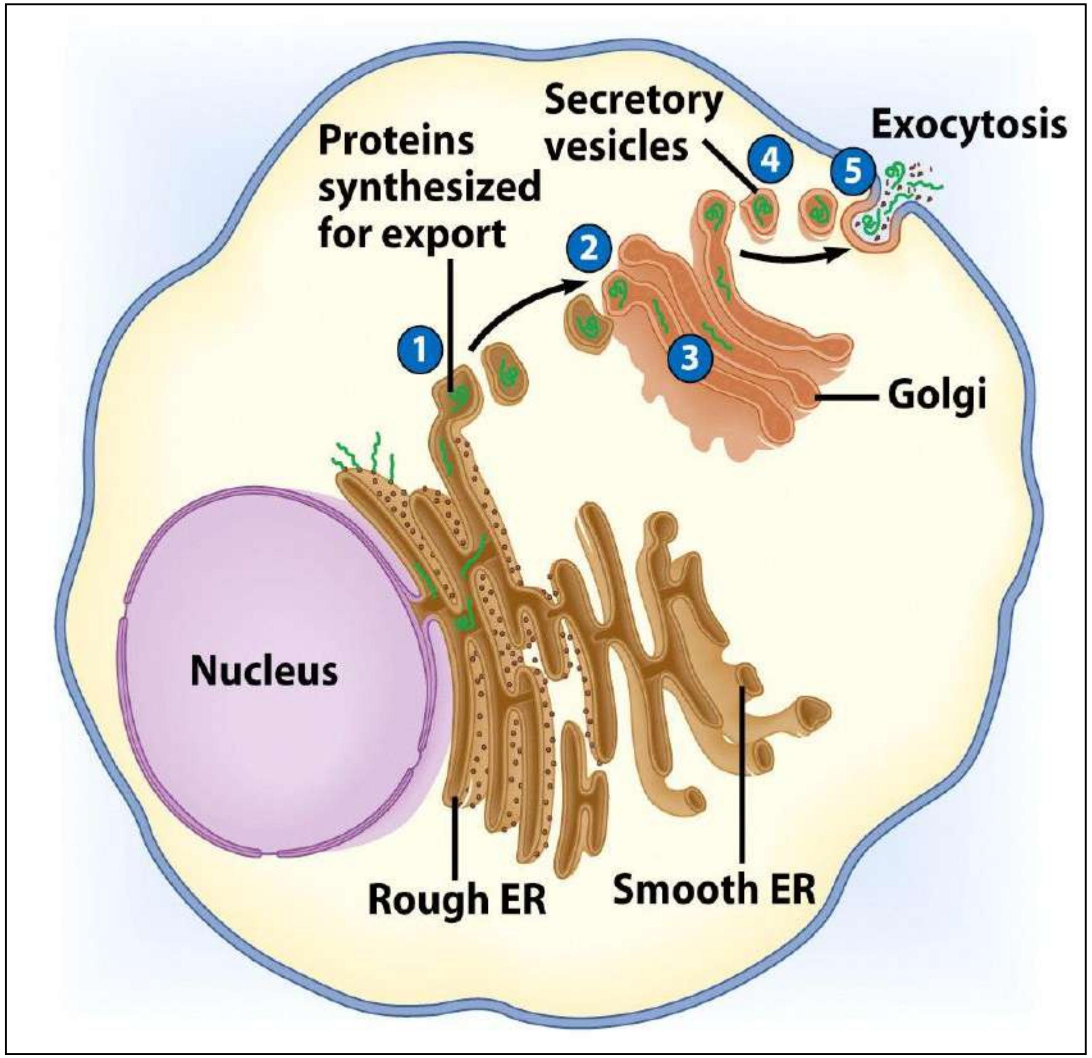


Structures of animal cell

Functions of Golgi apparatus

- It is involved in formation of lysosomes.
- Its major function is modification and packaging the proteins and lipids synthesized in ER.

1. The vesicles containing proteins or lipids that bud off from the ER move to and fuse with Golgi apparatus at its cis face.
2. The vesicles discharge their contents inside Golgi body in a process called endocytosis.
3. Inside Golgi body, the proteins and lipids are modified by adding sugar groups and in some cases, phosphate groups.
4. Then, the modified molecules are packaged and sorted in vesicles (secretory vesicles) that bud off from the trans face of Golgi.
5. Finally, some of the secretory vesicles leaving the cytoplasm and discharge their contents outside the cell in a process called exocytosis.



Structures of animal cell

5. Lysosomes

- Lysosomes are small spherical organelles made by the Golgi bodies.

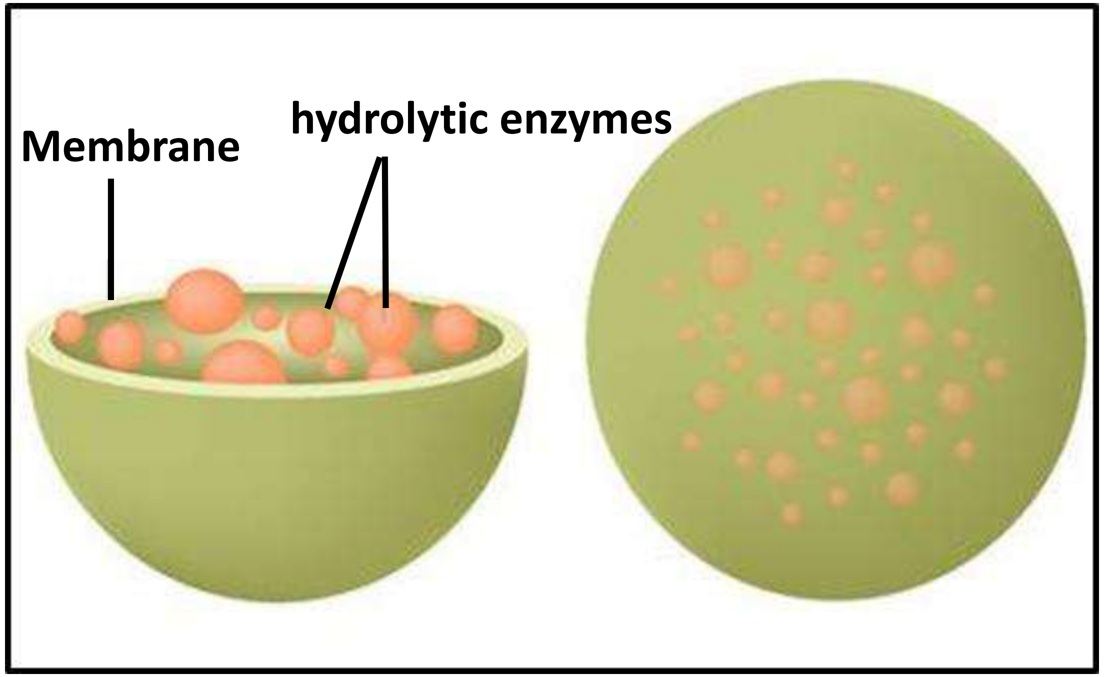
- The cell contains about 300 lysosomes.

- Each lysosome contains more than 30 different hydrolytic enzymes that are synthesized in the rough ER, then transported to Golgi apparatus for packaging as lysosome.

- They are also known as the digestive system of the cell or cell's recycling center.

- Their main function is breaking down organic molecules as proteins, nucleic acids, carbohydrates and lipids, and dead cells which are taken into the cell through the process of phagocytosis.

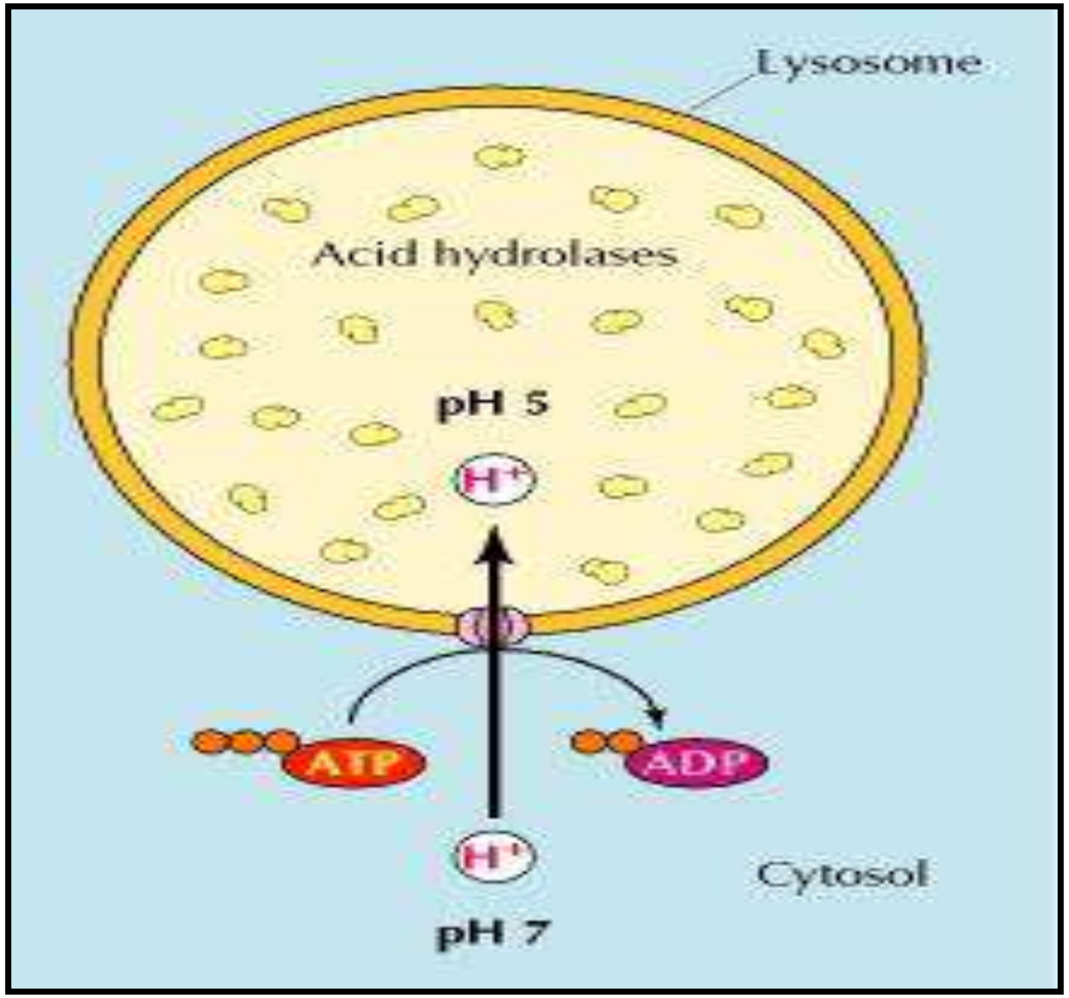
Lysosome



Structures of animal cell

5. Lysosomes

- All lysosomal enzymes are acidic enzymes, which are active at acidic pH (about 4-5) that is maintained within lysosomes but not at the neutral pH of the cytoplasm.
- So if the lysosomal membrane are broken down, the contents of the cytoplasm would not be digested by the lysosomal enzymes because the released acidic enzymes would be inactive at the neutral pH of the cytoplasm.
- To maintain their acidic internal pH, lysosomes must actively concentrate H^+ ions by a proton pump in the lysosomal membrane, which actively transports protons into the lysosome from the cytoplasm.



Structures of animal cell

Types of Lysosomes

1. Primary lysosomes

- They are freshly synthesized organelles by Golgi apparatus, where these vesicles contain inactive lysosomal enzymes.

2. Secondary lysosomes

- They are formed by fusion of the primary lysosomes with food vesicles and/or damaged organelles.
- They are also called phagosomes and contain active enzymes.
- There are two types of secondary lysosomes:-

A- Heterophagosomes

They are formed by fusion of primary lysosomes with extracellular substances as bacteria and food brought into the cell by endocytosis process.

B- Autophagosomes

They are formed by fusion of primary lysosomes with damaged intracellular organelles as mitochondria.

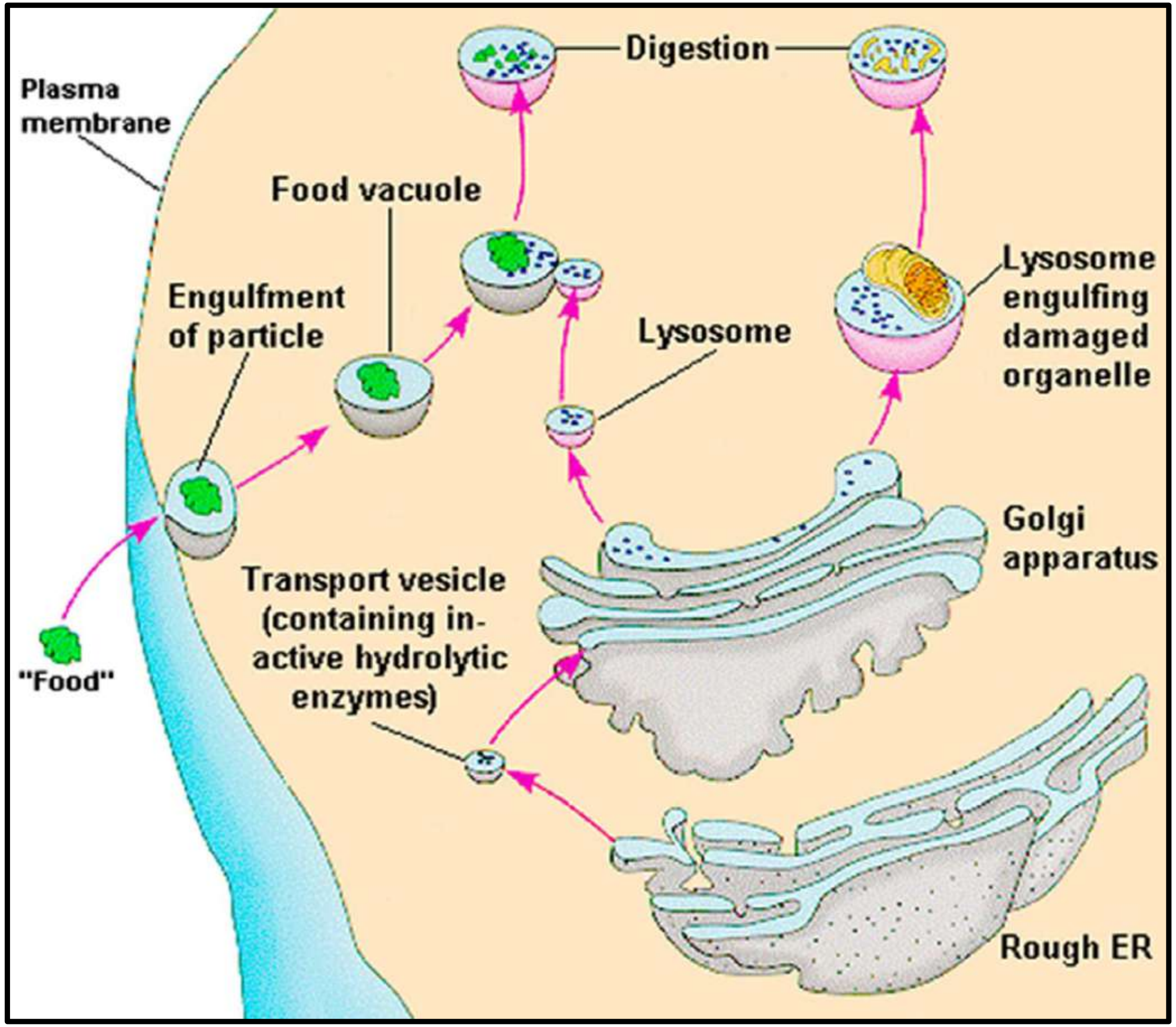
Structures of animal cell

Functions of Lysosomes

1. Digestion of large extracellular particles as bacteria and food.

2. Digestion of intracellular substances as proteins, lipids and carbohydrates.

3. Autolysis of dead cells and organelles.



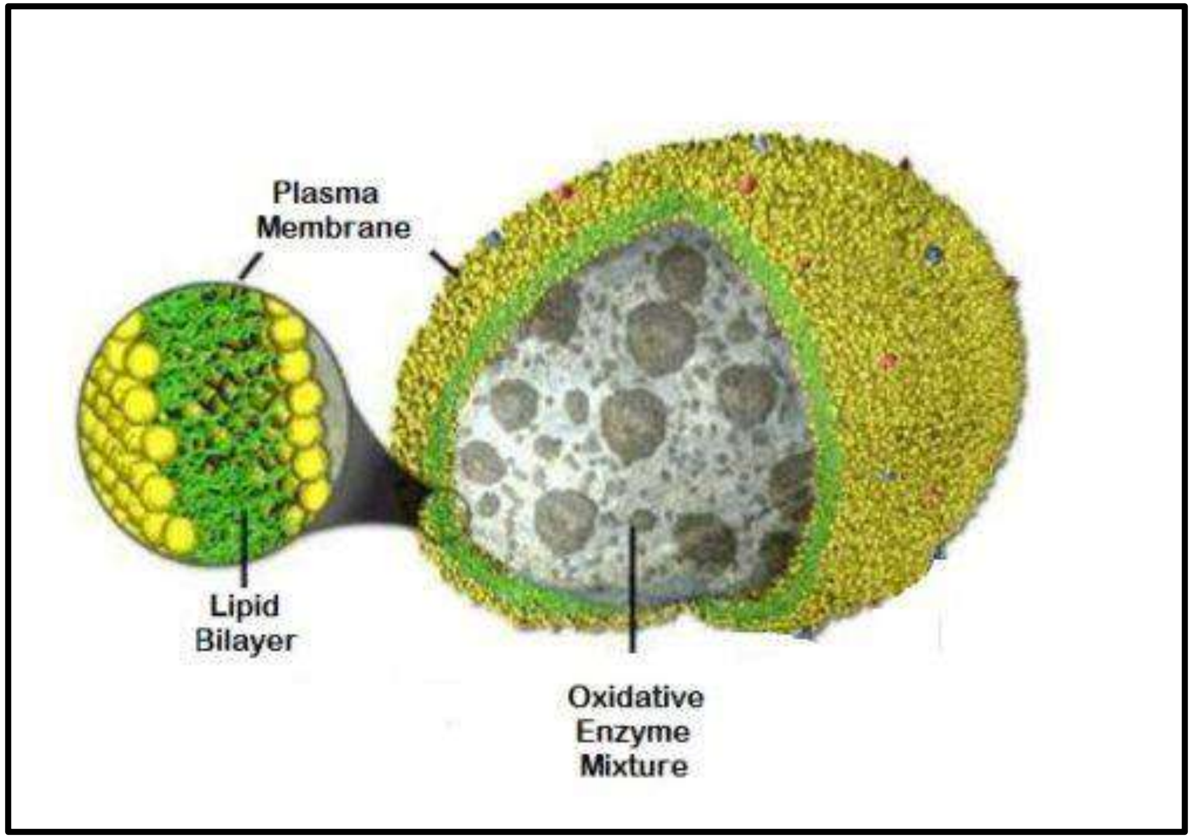
Structures of animal cell

6. Peroxisomes (Microbodies)

- They are small organelles found in all eukaryotic cells that involved in catabolism of many substances as long fatty acids, alcohols and phenols by oxidation process.

- They resemble lysosomes in being filled with enzymes, but their enzymes are oxidative enzymes.

- Peroxisomes bud off from the endoplasmic reticulum and their enzymes are synthesized in cytoplasm.



Function of Peroxisomes

1. The main function of peroxisomes is the breakdown of long chain fatty acids through beta-oxidation to short chain fatty acids, which are broken down by mitochondria to carbon dioxide and water.

2. Breakdown of hydrogen peroxide (H_2O_2), a dangerous product, by catalase enzyme.

Structures of animal cell

7. Mitochondrion (plural Mitochondria)

- **They are double membraned organelles found in eukaryotic cells which contain their own ribosomes and DNA.**

- **They are known as "power houses of the cell " because they generate adenosine triphosphate (ATP), the main form of energy in the cell in a process called cellular respiration.**

A. Aerobic cellular respiration: it requires O2 in order to generate 38 molecules of ATP with a single molecule of glucose.

B. Anaerobic cellular respiration: O2 is not present, so it generates 2 molecules of ATP with a single molecule of glucose.

- **Their number in the cell depends on what the cell needs to do.**

For example, nerve cells have fewer mitochondria than muscle cells that need large amount of energy.

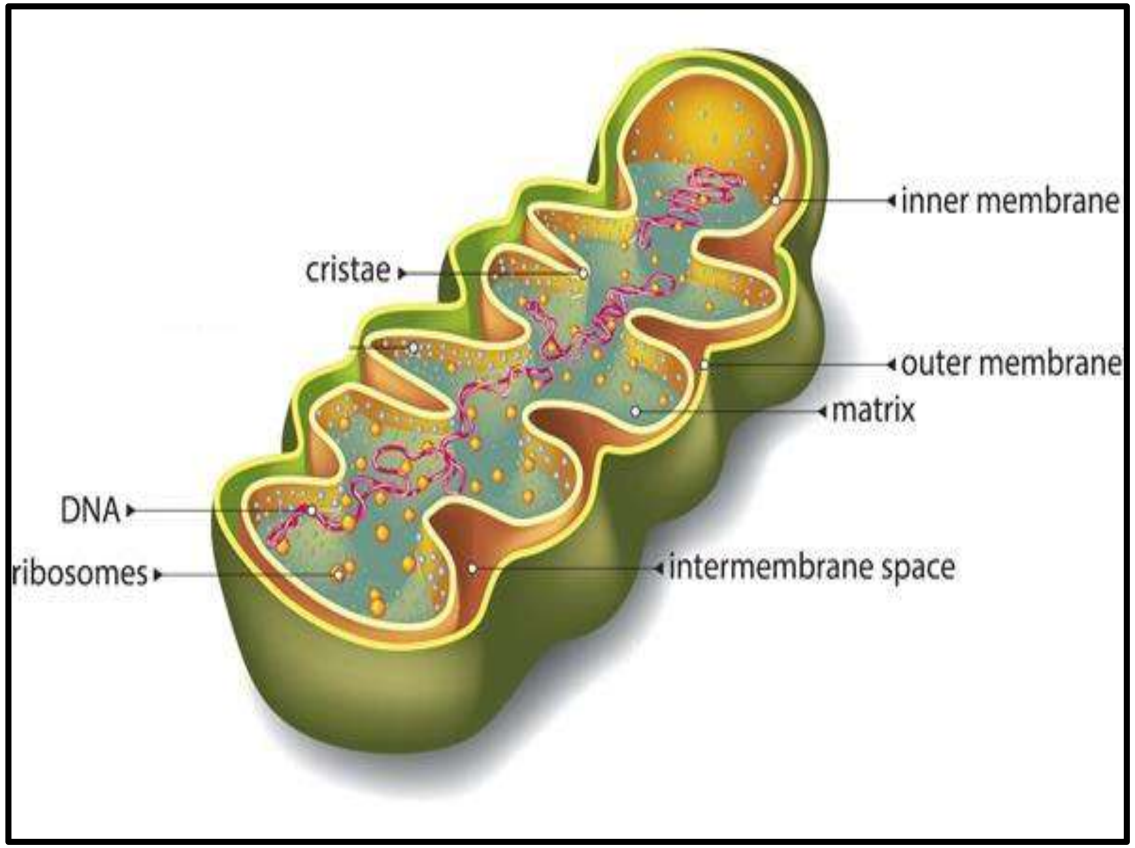
Structures of animal cell

Structure of Mitochondrion

- It is composed of outer membrane, intermembrane space, inner membrane, cristae and matrix.

A- The outer membrane

- It has a protein-to-phospholipid ratio about 1:1 by weight.
- Most of its proteins are called porins which form channels to allow small molecules to freely diffuse from one side of the membrane to the other.



B- Intermembrane space

- It is the space between the outer membrane and the inner membrane.
- Because the outer membrane is freely permeable to small molecules, the concentrations of small molecules such as ions and sugars in the intermembrane space is the same concentration as the cytoplasm.

Structures of animal cell

Structure of Mitochondrion

C- The inner membrane

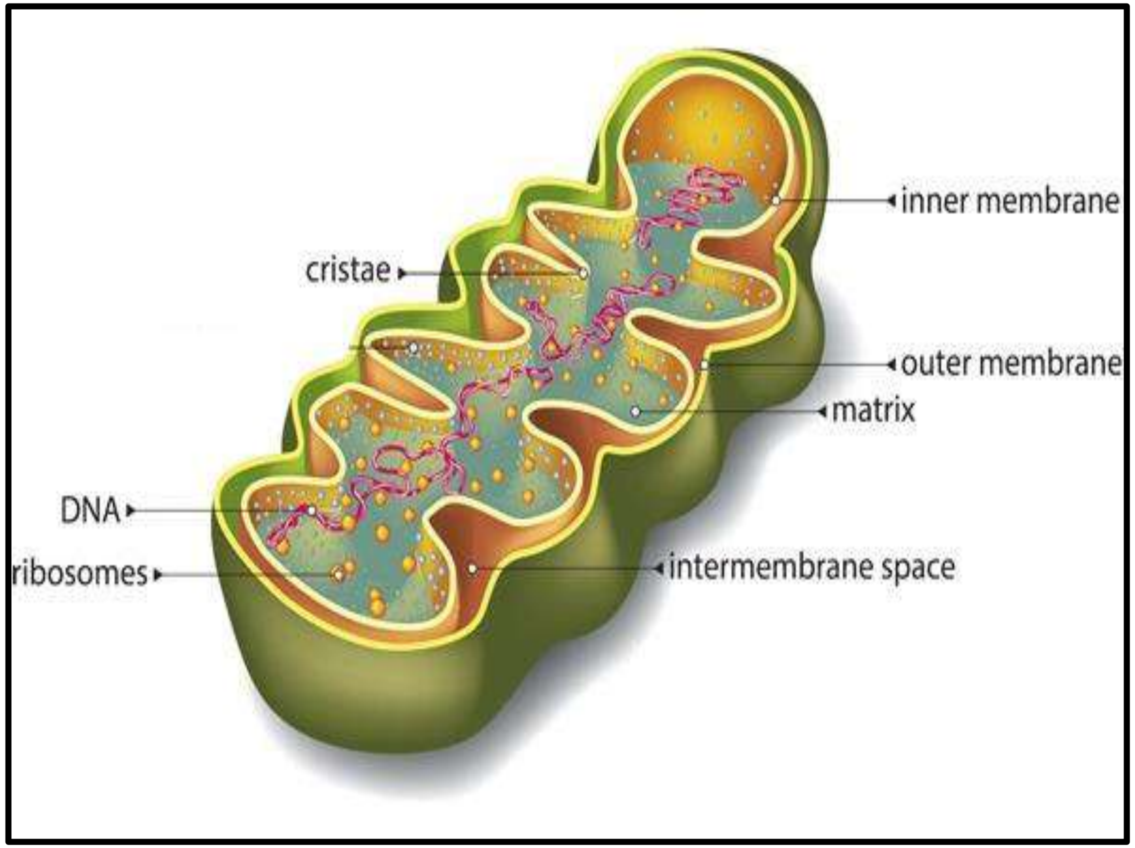
- **It has a very high protein-to-phospholipid ratio (more than 3:1 by weight).**
- **Unlike the outer membrane, the inner membrane doesn't contain porins, and is highly impermeable to all molecules.**
- **It contains many types of proteins as:**

1. Enzymes for redox reactions.

2. ATP synthase to generate ATP.

3. Transport proteins to regulate the passage of ions and molecules into and out of the matrix

4. Support proteins

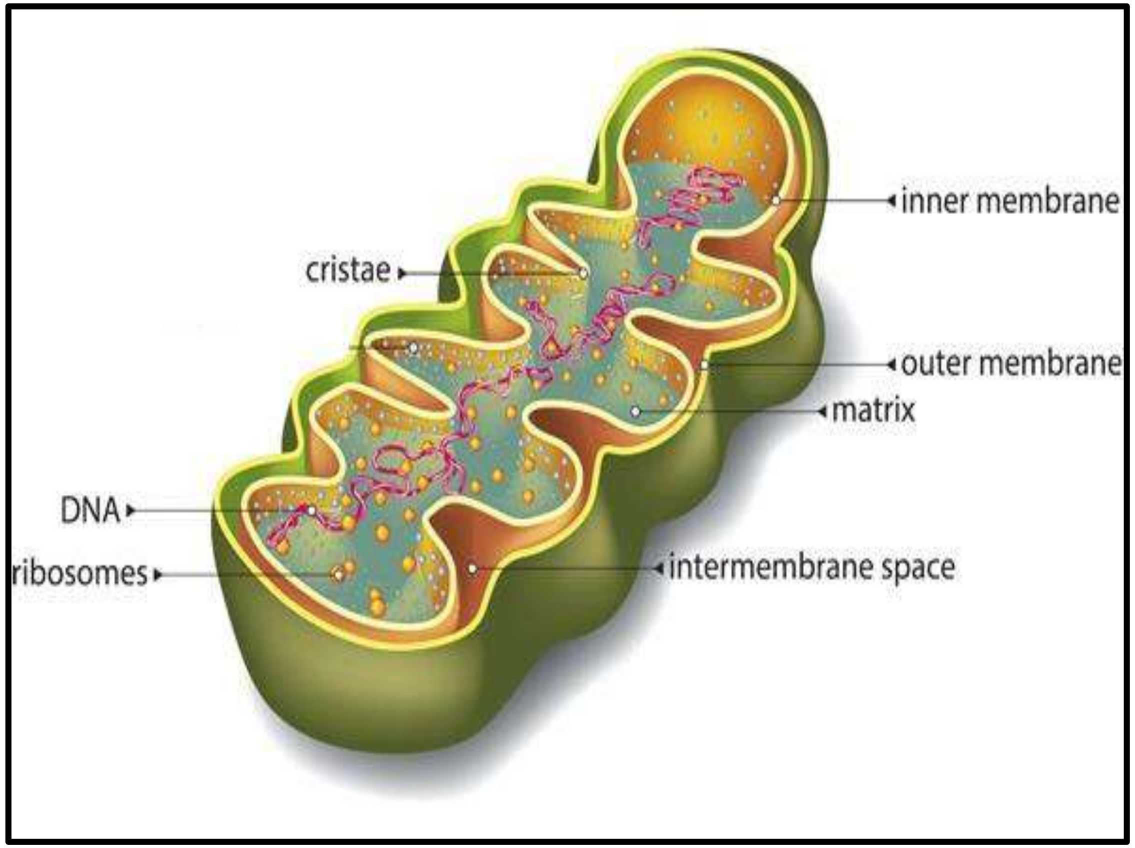


Structures of animal cell

Structure of Mitochondrion

D. Cristae

- **They are the folds in the inner membrane of mitochondria.**
- **They give the inner membrane a large surface area to perform the chemical reactions.**
- **They are rich in ATP synthase.**



E. Matrix

- **The matrix is the space enclosed by the inner membrane and it contains about 2/3 of the total protein in the mitochondrion.**
- **The matrix is the place of cellular respiration that produce ATP.**
- **It contains a highly concentrated enzymes, mitochondrial ribosomes and copies of mitochondrial DNA, so mitochondria have their own genetic material to manufacture their own RNA and proteins.**

Structures of animal cell

ATP: Adenosine triphosphate

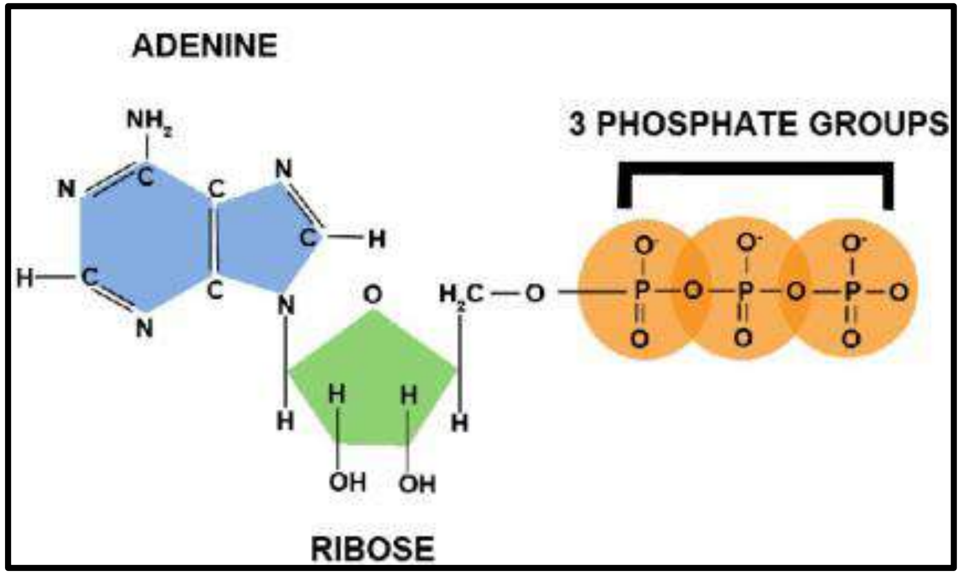
- It is the main form of energy in the cell produced by mitochondria.
- ATP consists of adenine ring, ribose sugar and three phosphate groups (triphosphate).

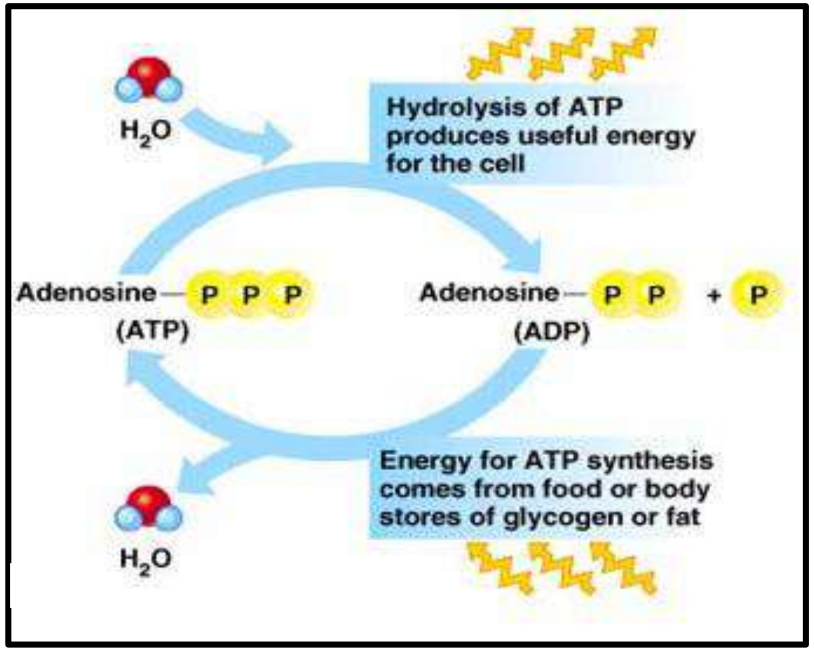
Note: adenine ring and ribose sugar is called adenosine .

- ATP is an unstable molecule in water, in which it hydrolyses to ADP and phosphate producing a large amount of energy.

$$ATP + H2O \rightarrow ADP + P_i \quad \Delta G^{\circ} = -30.5\ kJ/mol\ (-7.3\ kcal/mol)$$

ATP molecule





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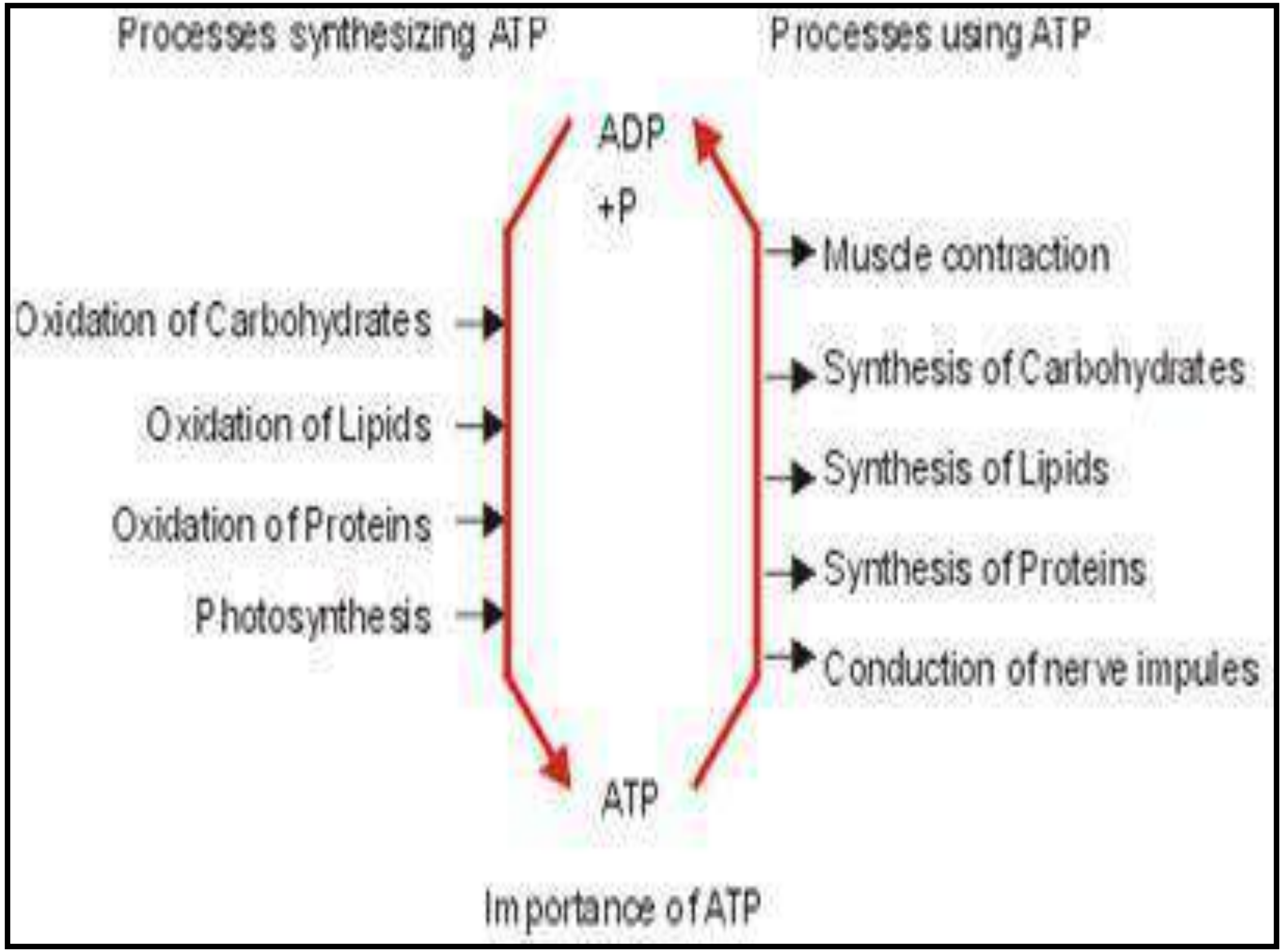
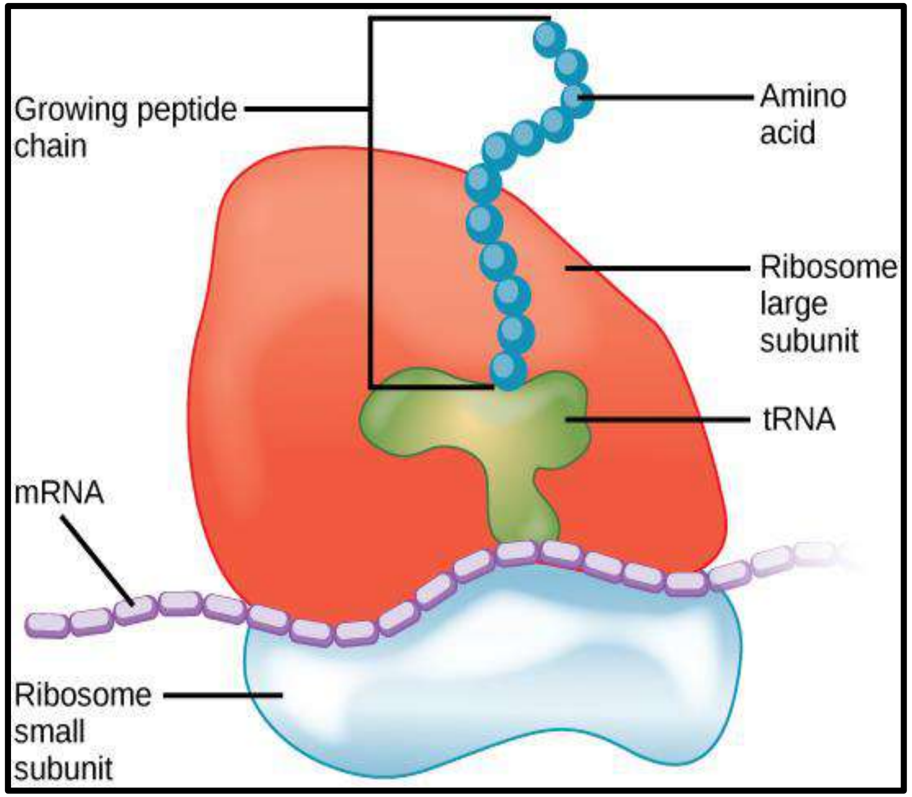
Production and utilization of ATP



Structures of animal cell

8. Ribosomes

- They are tiny organelles present in large numbers in all living cells and serve as the site of protein synthesis in a process called mRNA translation.
- Ribosomes are typically composed of two subunits: large subunit and small subunit.
- Each subunit is made up of RNA called ribosomal RNA (rRNA) and ribosomal proteins which are synthesized in the nucleolus.
- Both subunits must join together in the cytoplasm when attach to mRNA during protein synthesis.
- There are two types of ribosomes, 70S and 80S, where S is the measurement unit and refers to Svedberg unit, the sedimentation rate during centrifugation.

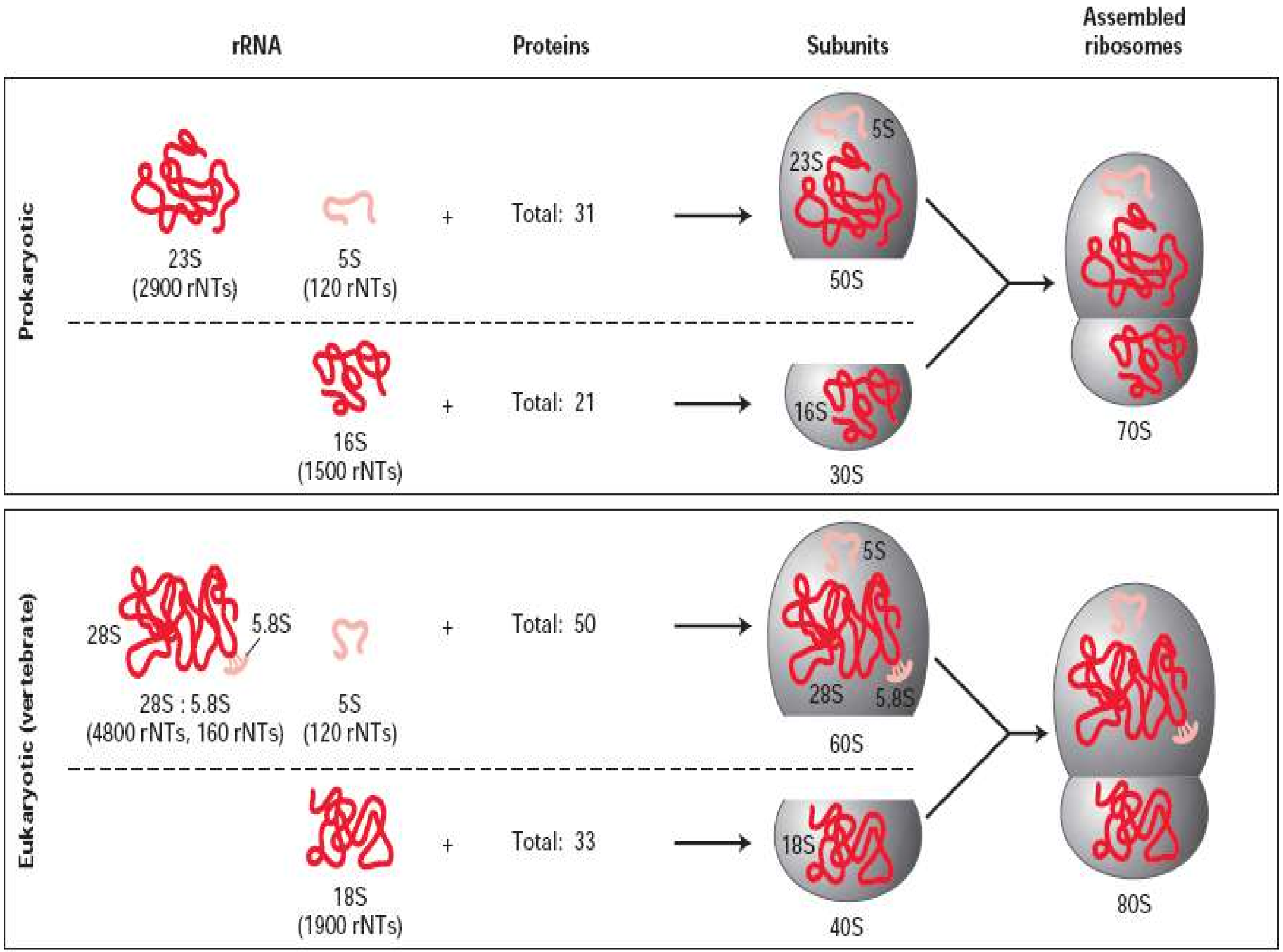


Structures of animal cell

8. Ribosomes

- **In prokaryotics, ribosomes are found free in the cytoplasm and their type is 70S consisting of a small (30S) and a large (50S) subunits.**

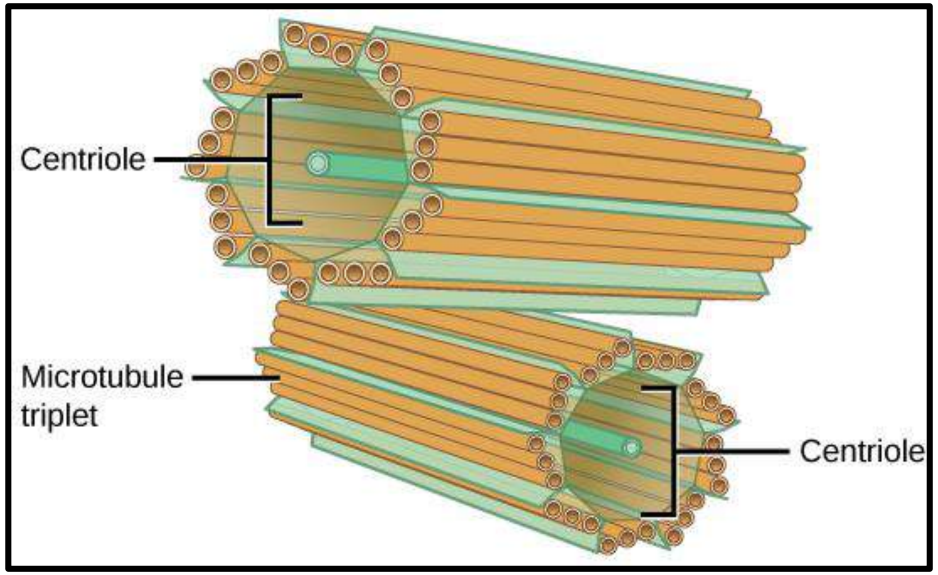
- **In eukaryotics, they are found as free particles in the cytoplasm or attached to rough ER and their type is 80S consisting of a small (40S) and a large (60S) subunits.**

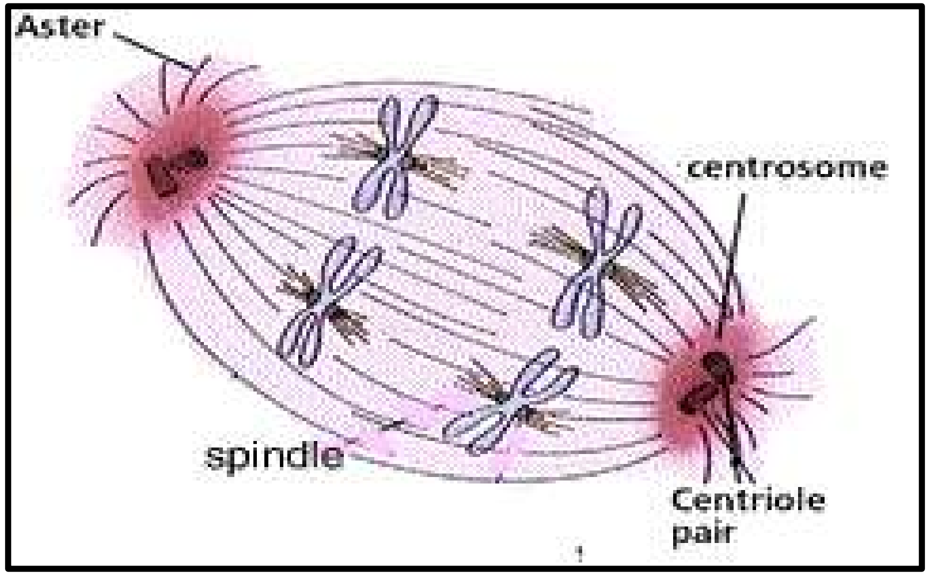


Structures of animal cell

9. Centrioles

- A centriole is a cylindrical cell structure composed of tubulin protein that is found in eukaryotic cells, where each cell has two centrioles that lie perpendicular to each other.
- The pair of centrioles is called centrosome.
- Each centriole is a cylinder of nine triplets of microtubules (9 + 3 pattern).
- The centrosome plays an important role in cell division because it is involved in the organization of the mitotic spindle fibers during cell division.

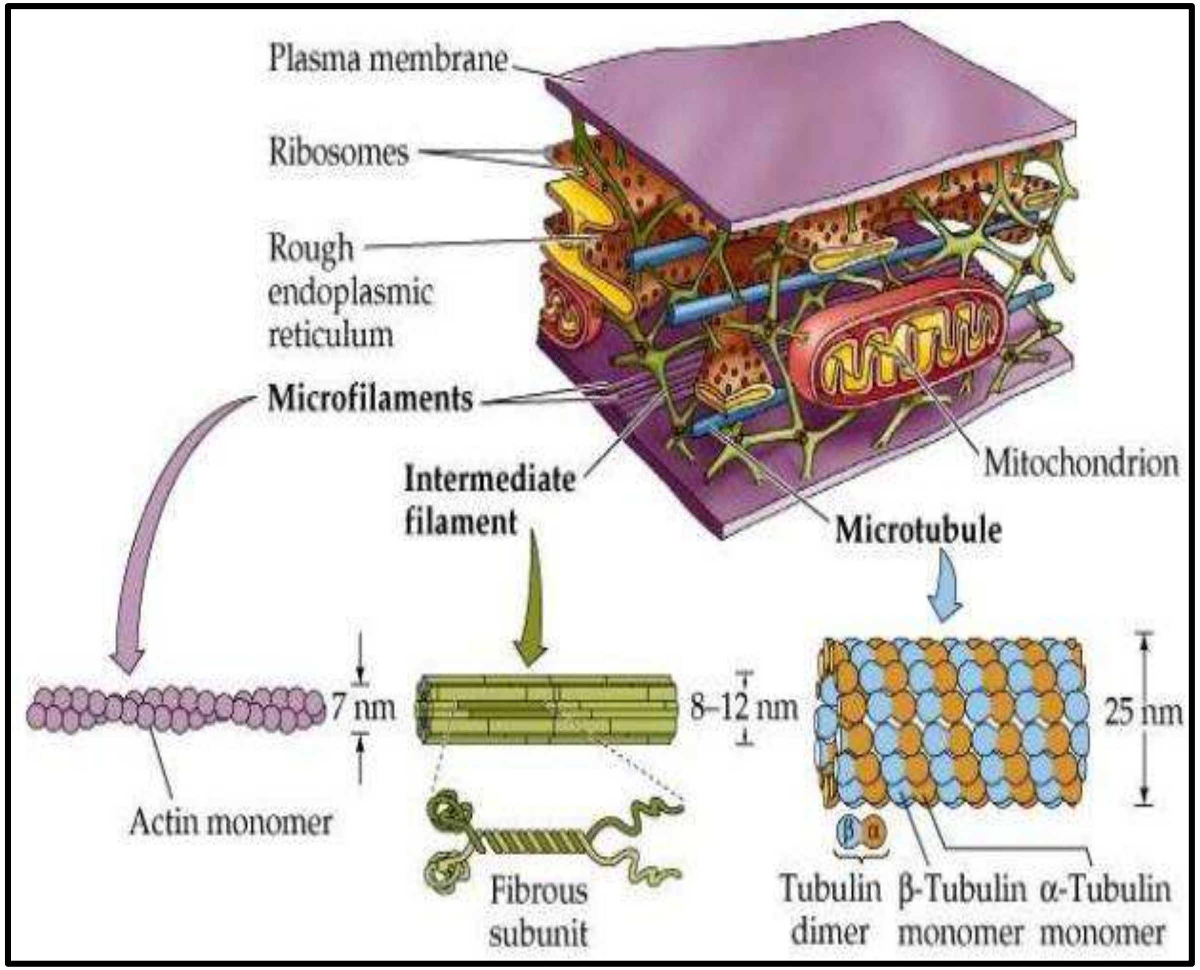




Structures of animal cell

10. Cytoskeleton

- **It is a network of tubes and filaments made of proteins distributed in the cytoplasm.**
- **It acts as the "bone and muscle" of the cell by supporting its components and controlling their movements.**
- **Cytoskeleton has three main structural components: microfilaments, intermediate filaments and microtubules.**



A. Microfilaments

- **They are the smallest component of the cytoskeleton (about 7 nm in diameter) and composed of actin proteins that assemble into two strands twisted around each other in a helical shape.**
- **They serve two functions:**

1. play a vital role in various contractile systems of the cell.

2. maintain the cell shape.

Structures of animal cell

10. Cytoskeleton

B. Intermediate filaments

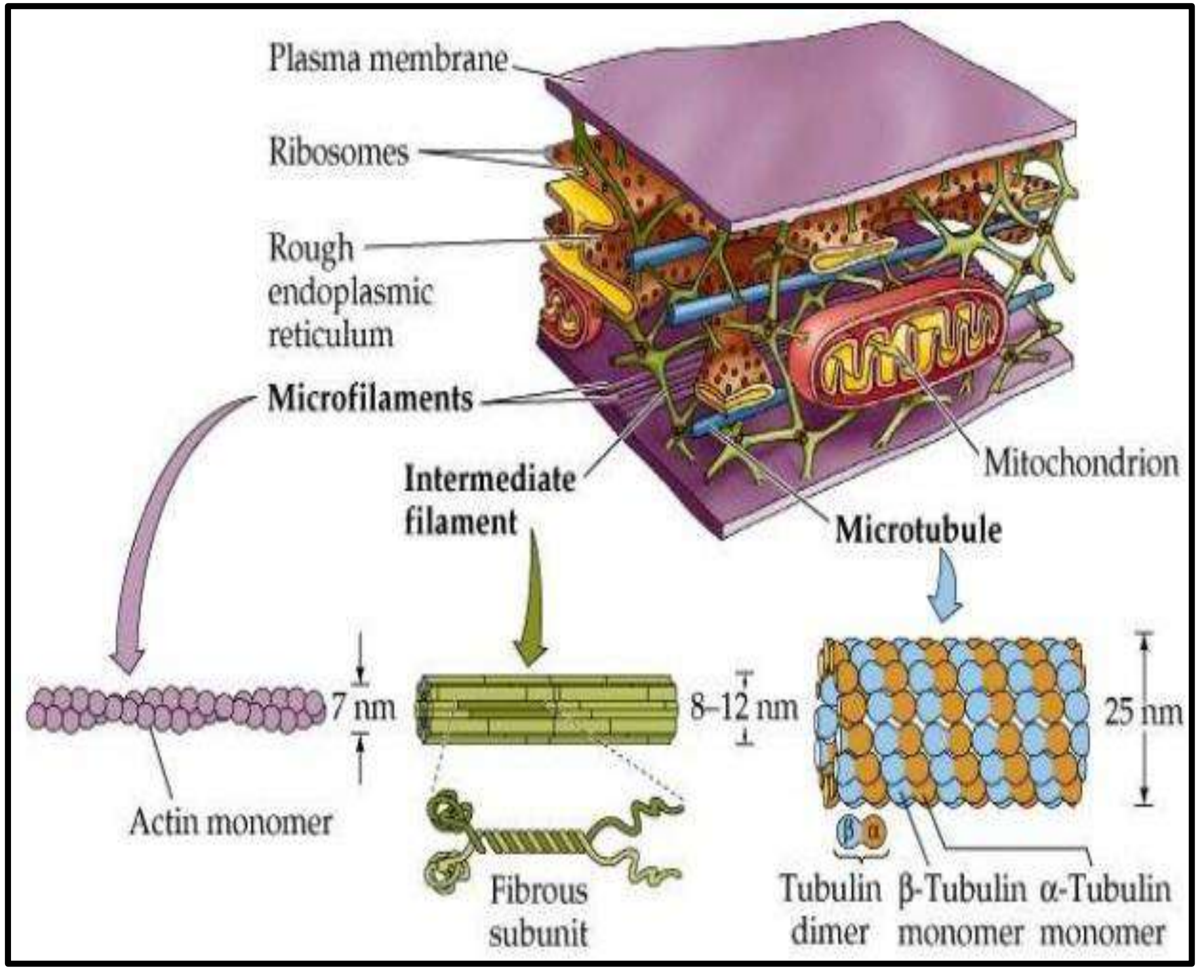
- **They are 8-12 nm in diameter and are twisted together in a cord shape, so they are more stable than actin filaments.**

- **They play a central role in maintaining the structural integrity of the cell and in resisting mechanical stress applied to it.**

- **There are several types of intermediate filaments as:**

1. **Keratins: which are found in epithelial cells, hair and nails.**

2. **Neurofilaments which support the long axons of neurons.**

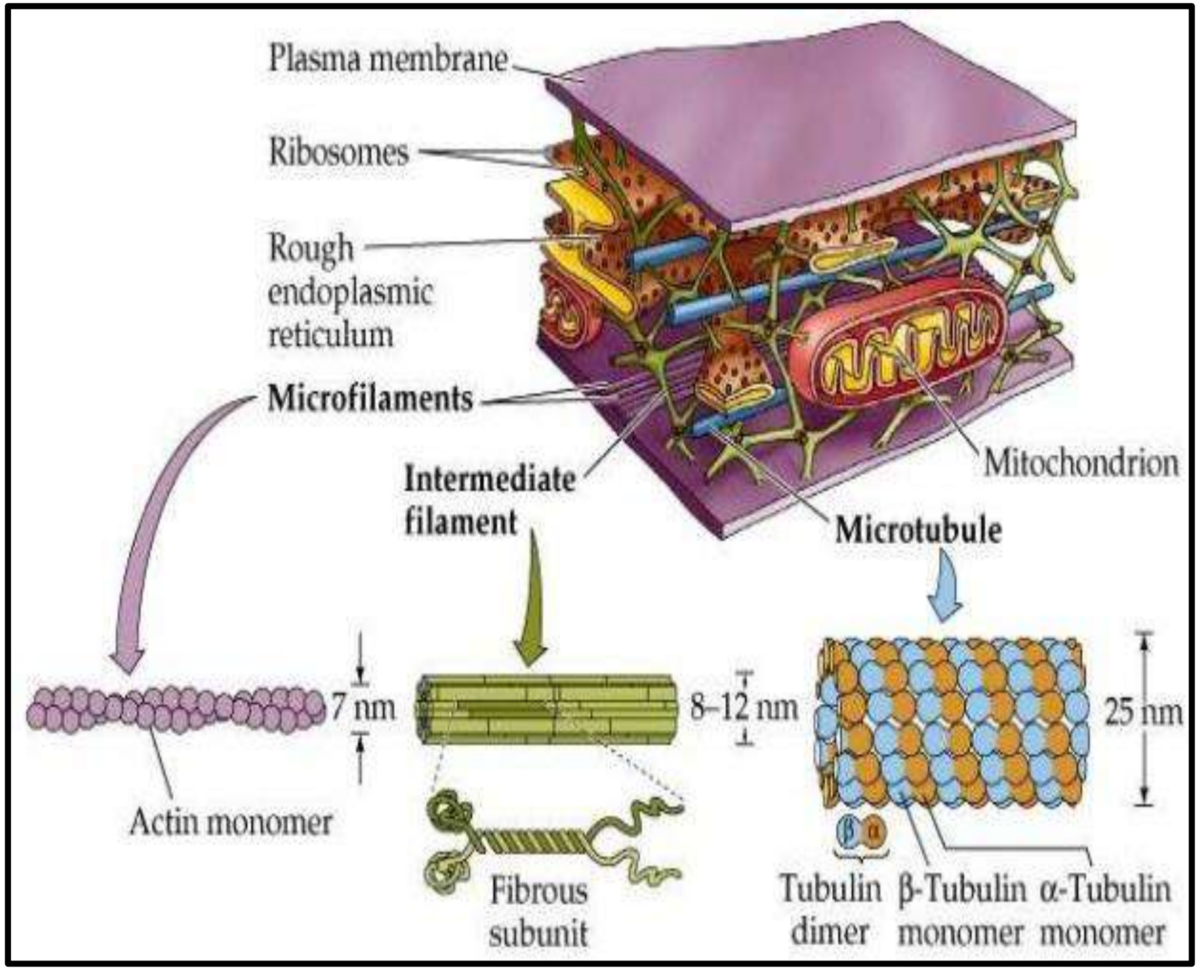


Structures of animal cell

10. Cytoskeleton

C. Microtubules

- They are hollow cylinders about 25 nm in diameter having 13 subunits or called protofilaments arranged to each other.
- Each protofilament is composed of proteins subunits called α-tubulin (negative end) and β- tubulin (positive end).
- So, microtubules are polar where the negative end is found toward the nucleus, while the positive end toward the cell membrane.



Functions of Microtubules

1. Movement of centrioles spindle fibers during cell division.

2. Formation and movement of cilia and flagella.

3. Movement of secretory vesicles inside the cell by using specific transporter called:
   - Dyneins which move vesicles to the negative end
   - Kinesins which move vesicles to the positive end

Structures of animal cell

Unique features of plant cells

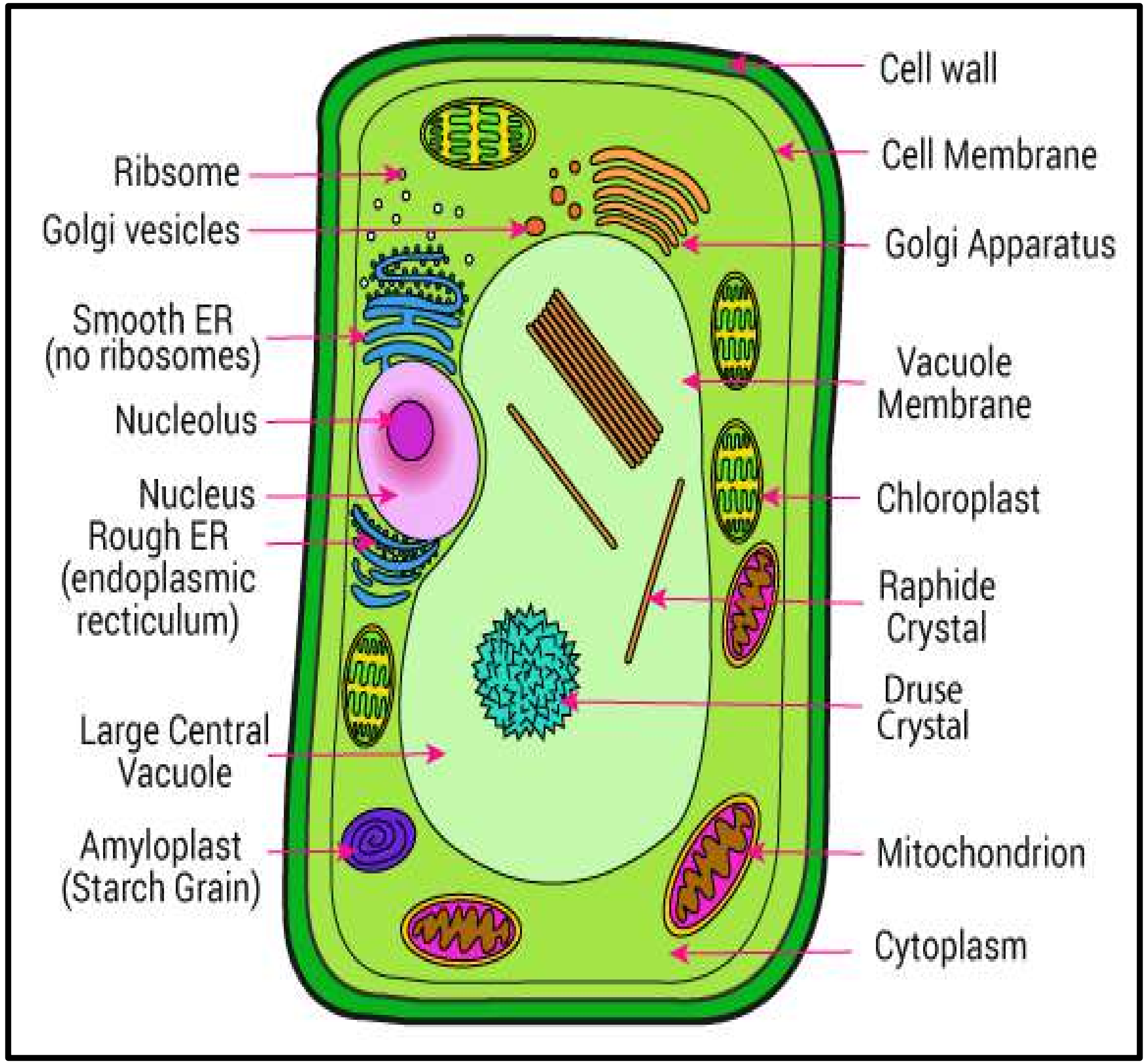
- **Plant cells differ from other eukaryotic cells in several features as: Cell wall, Plastids, Central vacuole and Glyoxysomes.**

1. Cell wall

- **It is a rigid layer located outside the cell membrane of plant cells which is mainly composed of cellulose.**
- **It provides the cell with structural support and protection, and maintains its shape.**
- **In addition, it prevent over-expansion when water enters the cell.**

2. Glyoxysomes

- **They are special peroxisomes found in plant cells (particularly in the fat storage tissues).**
- **In glyoxysomes, the fatty acids are hydrolyzed by β-oxidation enzymes for energy production.**



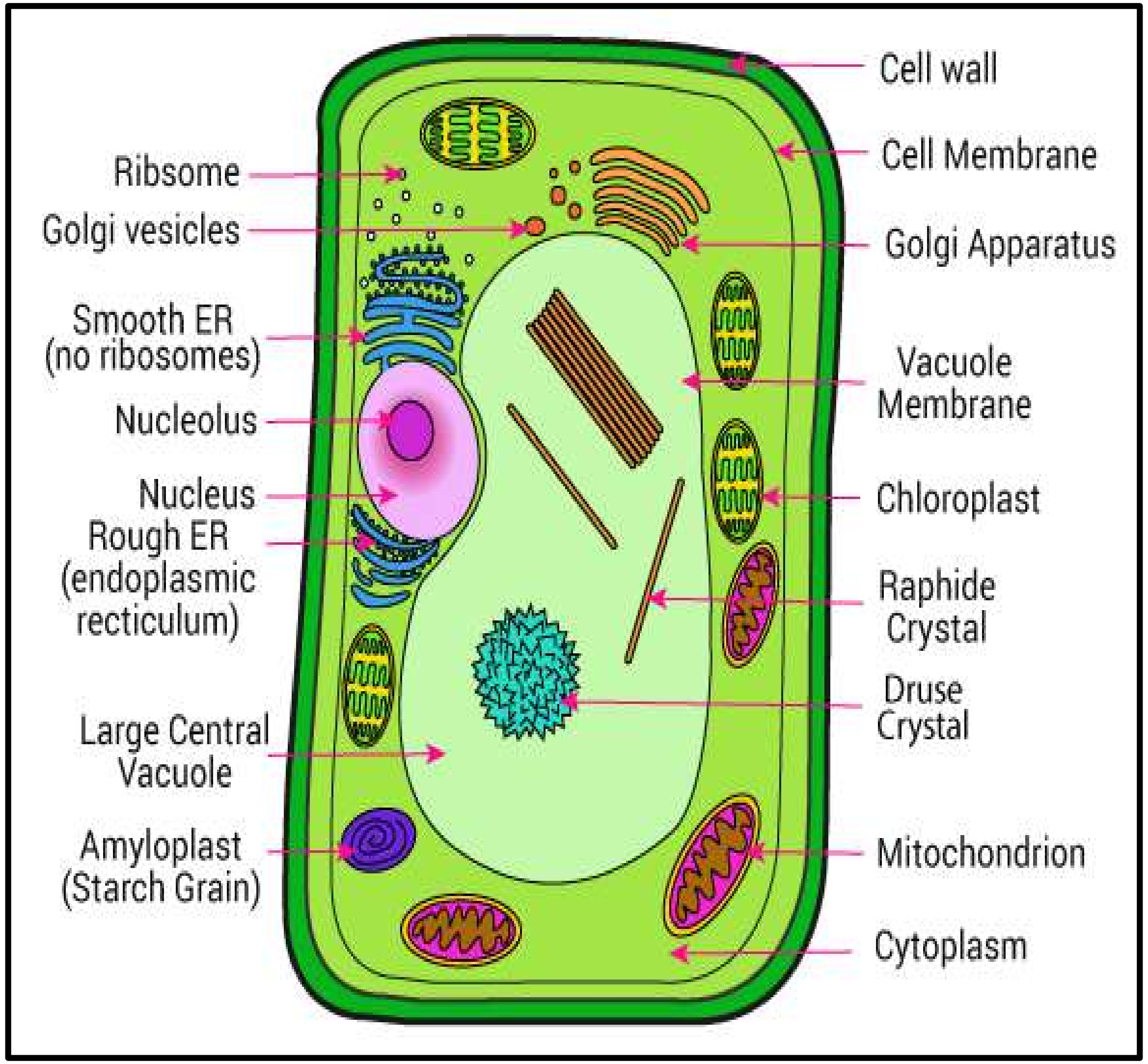
Structures of animal cell

Unique features of plant cells

3. Central vacuole

- It is a large fluid-filled membrane sac which is present in all plant cells.
- It contains large amount of water, proteins, enzymes, and inorganic substances.
- In general, the functions of the vacuole are:

1. Isolating and exporting unwanted substances from the cell.
2. Maintaining internal turgor pressure against the cell wall.
3. Maintaining the cell's concentration of water in changing environmental conditions.



Structures of animal cell

Unique features of plant cells

4. Plastids

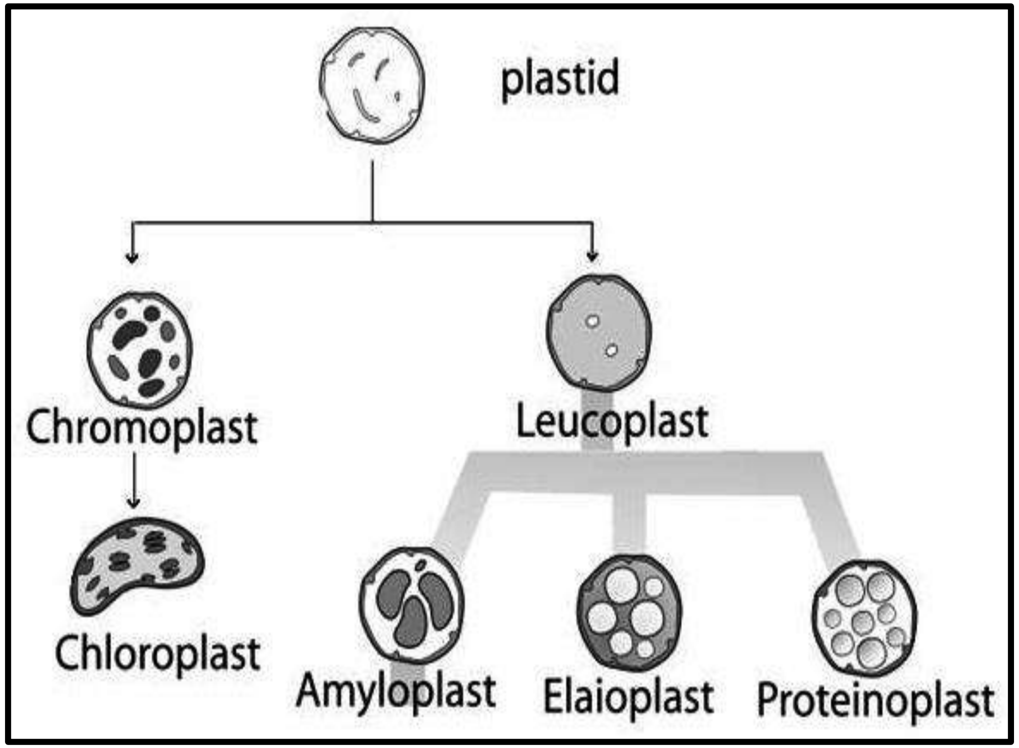
- **They are the major organelles found in the plant cells, where they are the site of manufacture and storage of important chemical compounds used by the cell.**
- **They often contain pigments used in photosynthesis and pigments that can change or determine the cell's color.**
- **Plastids can differentiate into several forms, depending upon the function they play in the cell as the following:**

1. Chromoplasts: **They are colored plastids where pigments are synthesized and stored.**

2. Chloroplasts: **They are double membrane organelles, green plastids because they contain chlorophyll that is required for photosynthesis.** **(They are the mitochondria of the plant cell)**

3. Leucoplasts:

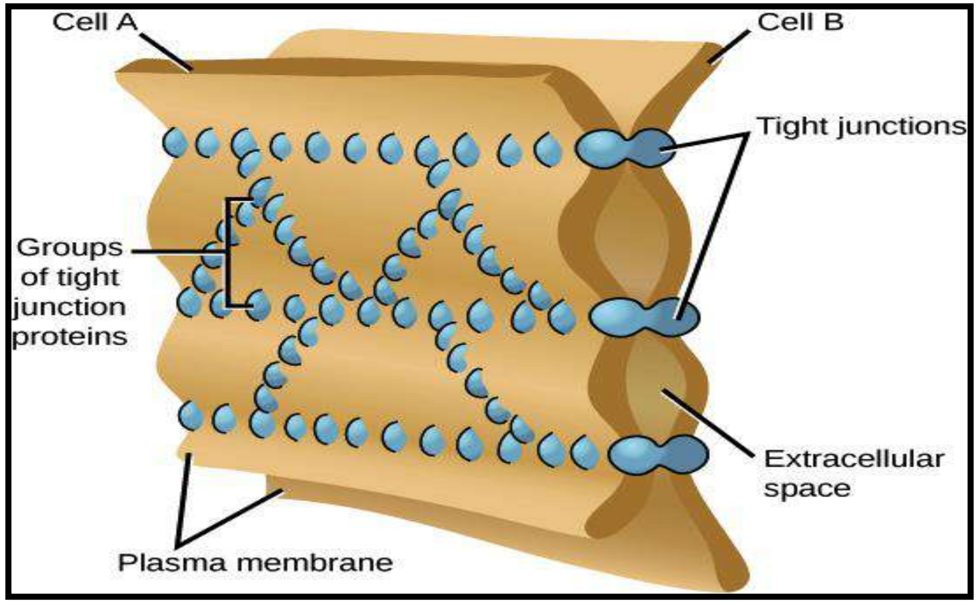
- **They are colorless plastids located mainly in roots and non-photosynthetic tissues.**
- **They are the main storage for starch (Amyloplast), lipids (Elaioplast), and proteins (Proteinoplast).**



Cell junctions

1. Tight junctions (impermeable junctions)

- In tight junction two adjacent plasma membranes appear to be fused at a series of points forming a seal , there is no intercellular space.
- Each tight junction sealing strand is composed of a long row of transmembrane adhesion proteins embedded in each of the two interacting plasma membranes.
- The extracellular domains of these proteins join directly to each other to occlude the intercellular space.
- This type of connection is found in the region surrounding the lumen of organs, it prevents the transport of the contents of organs into the blood and surrounding tissue.

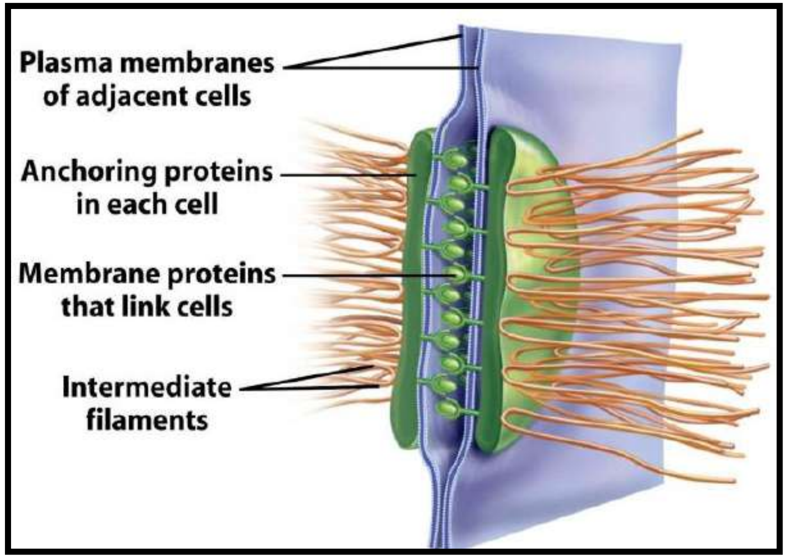


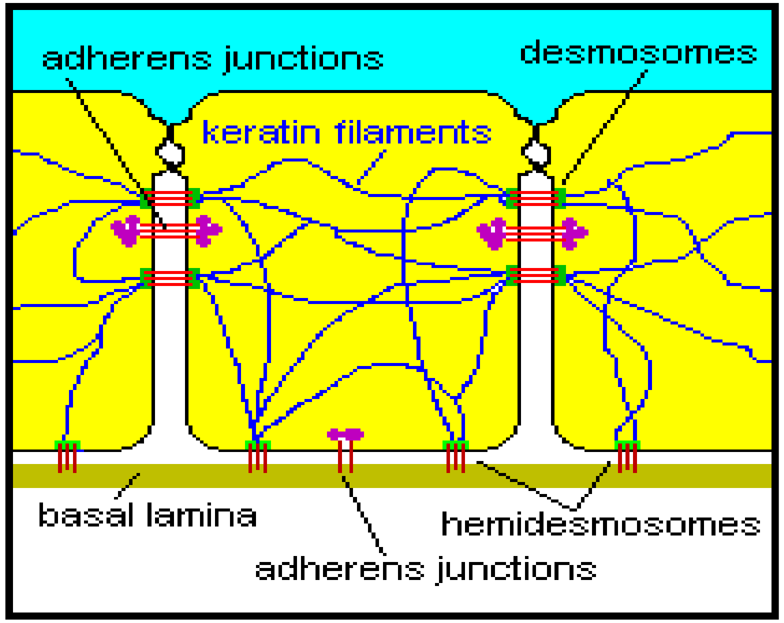
Cell junctions

2. Anchoring junctions

- Anchoring junctions mechanically attach the cytoskeleton of a cell to the cytoskeleton of other cell. They are common in tissue subject to mechanical stress such as muscles and skin epithelium.

- Anchoring junctions are two types:
  - Desmosomes which connect the cytoskeletons of adjacent cells.
  - Hemidesmosomes which connect epithelial cells to basement membrane.





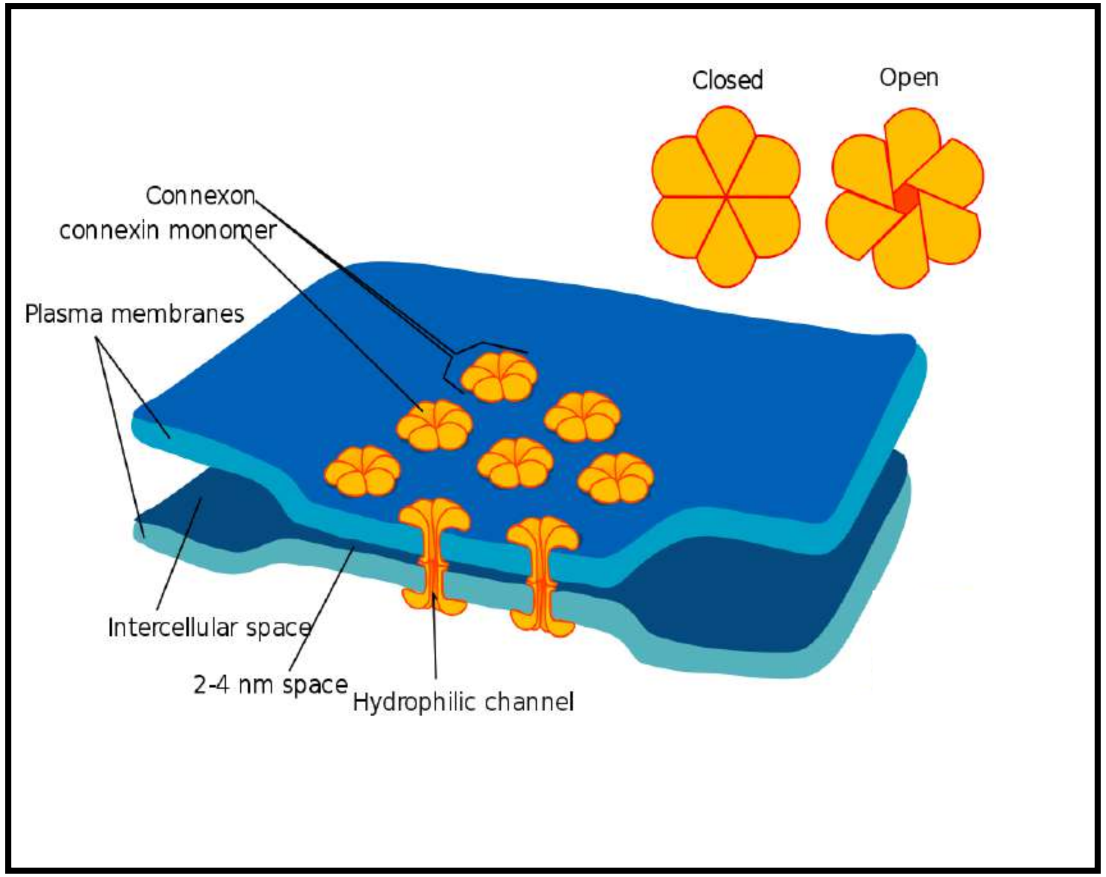
Cell junctions

3. Gap junction

- **Gap junctions are intercellular connection that directly connect the cytoplasm of two cells, which allows free passage of ions , small molecules as sugar and amino acids but prevent passage of large molecules as proteins, nucleic acids and polysaccharide.**

- **Each gap junction is a channel composed of two connexons of two cells align perfectly creating an open channel spanning the plasma membranes of both cells.**

- **Connexon is six identical transmembrane proteins that are arranged in a circle to form a channel.**



Cell junctions in plant cells

Plasmodesmata

- In plant tissue, the plasma membrane of each cell is continuous with that of adjacent cells, through opening in the cell wall called plasmodesmata.

- The function of plasmodesmata in plant cell is similar to jap junction function in animal cell.

- It permits the passage of ions, small molecules and even large molecules.