Cell Physiology and Membrane Physiology

Dr Suman Ahuja

Associate Professor

Department of Kriya Sharir

PROGRAMME OUTCOMES

- PO1- Demonstrate comprehensive knowledge and application of the Trisutra concept to explore root causes, identify clinical manifestations of disease to treat ailments and maintain healthy status.
- PO2- Demonstrate knowledge and skills in Ayurveda, acquired through integration of multidisciplinary perspectives and keen observation of clinical and practical experiences.

COURSE OUTCOMES

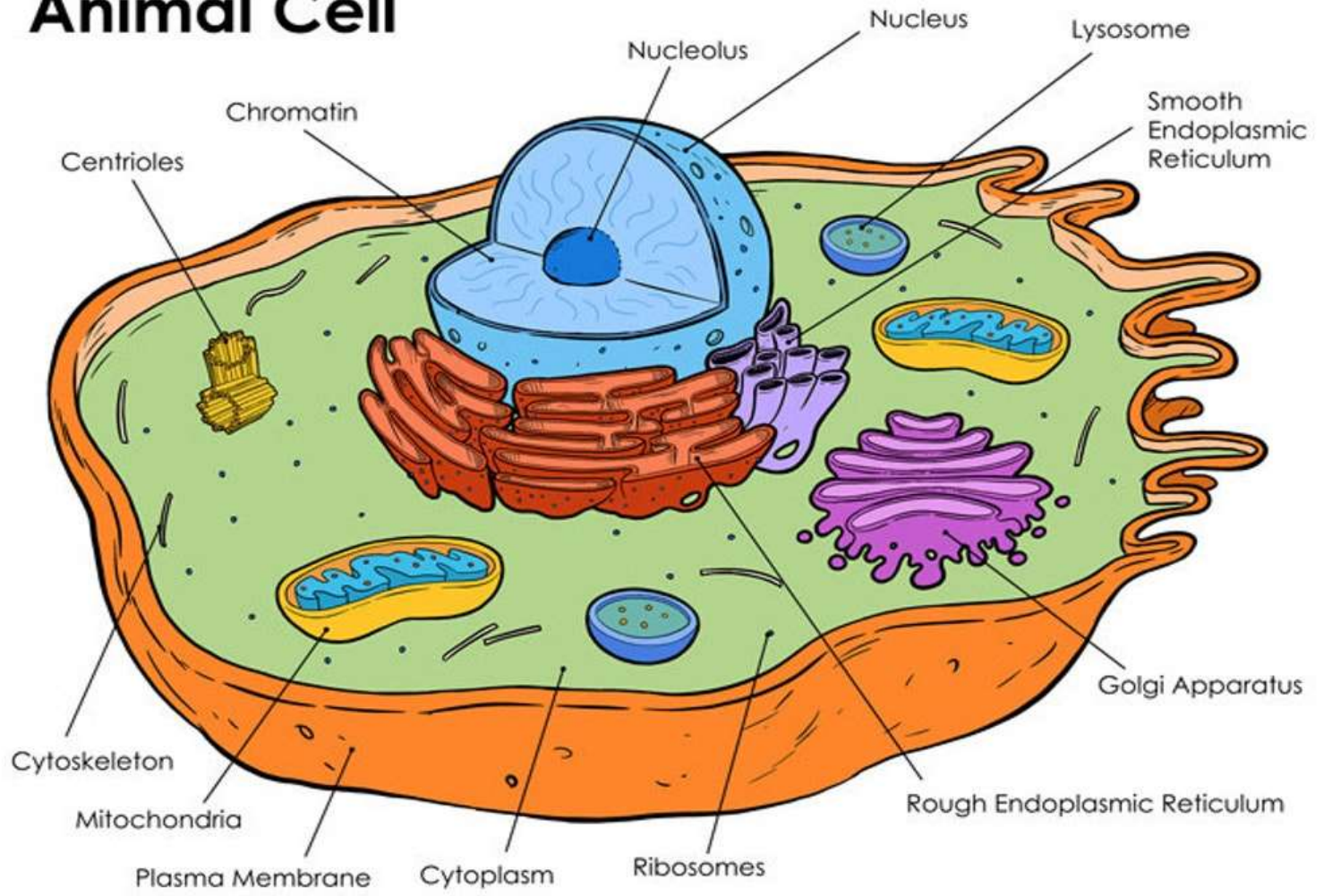
- CO1- Explain all basic principles & concepts of Kriya Sharir along with essentials of contemporary human physiology and biochemistry related to all organ systems.

- **Teaching learning methods-** lecture with power point presentation
  Domain- Cognitive/comprehension
  Must to know / desirable to know / Nice to know- Must to know
  Millers pyramid- Knows how(applied knowledge)
  Bloom taxonomy- Understand

STRUCTURE AND FUNCTION OF A CELL

- The fundamental or structural and functional unit of life is a cell, since virtually all tissues and any organised activity can be equated to the cellular level.
- A single cell is the smallest unit that has all the characteristics of life.
- Though no typical or generalised cell exists, it is convenient to create one to serve as a conceptual model within which most cell functions can be incorporated.
- Most cells in a human being have diameters of 10-20 µm (range 2-120 µm).

Animal Cell



- The three principal constituents of a cell are:

(A) Cell membrane

(B) Nucleus and its chromosomes

(C) Cytoplasm and its organelles

The clear fluid portion of the cytoplasm in which the particles are dispersed is called cytosol.

A. CELL MEMBRANE or PLASMA MEMBRANE or UNIT MEMBRANE

Thickness of the cell membrane varies from 70-100 Angstrom (A^0) or 7-10 nanometer (1 nm = 10^{-9} mts; I A^0 = 10^{-10} mts).

Structure (Fluid Mosaic Model)

1. All membranes consist of a double layer of lipid molecules in which proteins are embedded. The lipids normally constitute 20-40% of the dry weight of the membrane.

- **2.** Proteins make upto 60-70% of the dry weight of the membrane and are of 2 types:

(i) Lipoproteins (proteins containing lipids): function as enzymes and ion channels.

(ii) Glycoproteins (proteins containing carbohydrates constituting 1-5% of the dry weight): function as receptors for hormones and neurotransmitters.

According to location on cell membrane, proteins are of three types:

Proteins located in the inner surface of the membrane are **Intrinsic proteins.** These proteins serve mainly as 'enzymes'.

Proteins located in the outer surface of the membranes are Extrinsic and Peripheral proteins. These proteins contribute to the cytoskeleton (framework of the cell).

Proteins extend through the membrane are transmembrane proteins. These proteins serve as:

(a) Channels, through which ions or small water soluble substances can diffuse.

(b) Carriers, which passively or actively transport materials across the lipid layer .

(c) Pumps, which actively transport ions across the lipid layer.

(d) Receptors, which when activated initiate intracellular reactions. The number of receptors in a cell are not constant but their number increases and decreases in response to various stimuli, and their properties change with change in physiological condition.

For example, when a hormone or neurotransmitter is present in excess, the number of active receptors decreases (called down regulation); whereas during their deficiency, the number of active receptors increases (called up regulation).

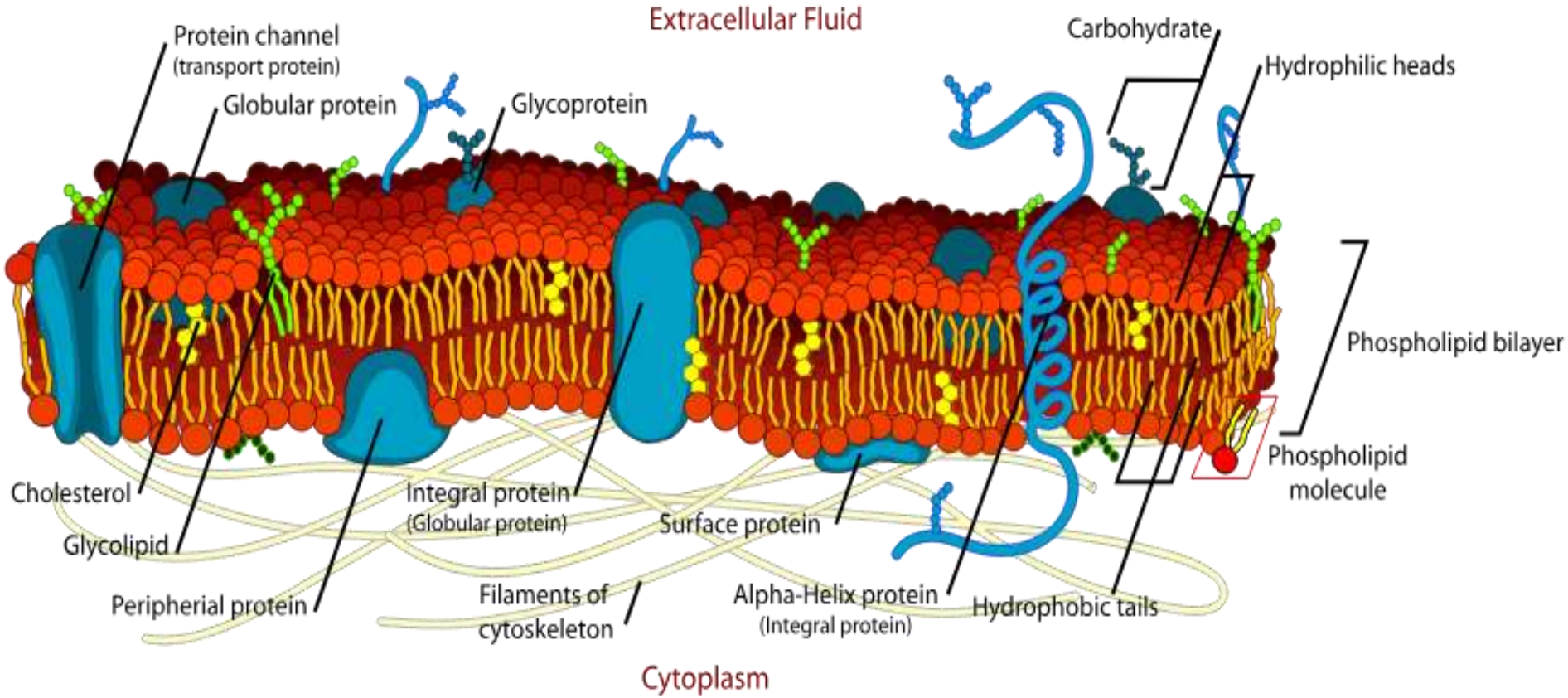
3. The clear area formed by bimolecular thickness of lipid molecules (phospholipids, cholesterol and glycolipids) is arranged as follows:

(i) Head end: contains phosphate portion, is positively charged and quite soluble in water (i.e. polar or hydrophilic). Polar groups of lipid molecules have affinity for water (water loving) and face the aqueous phase i.e. exterior of the cell on one side (ECF) and cytoplasm on the other (ICF).

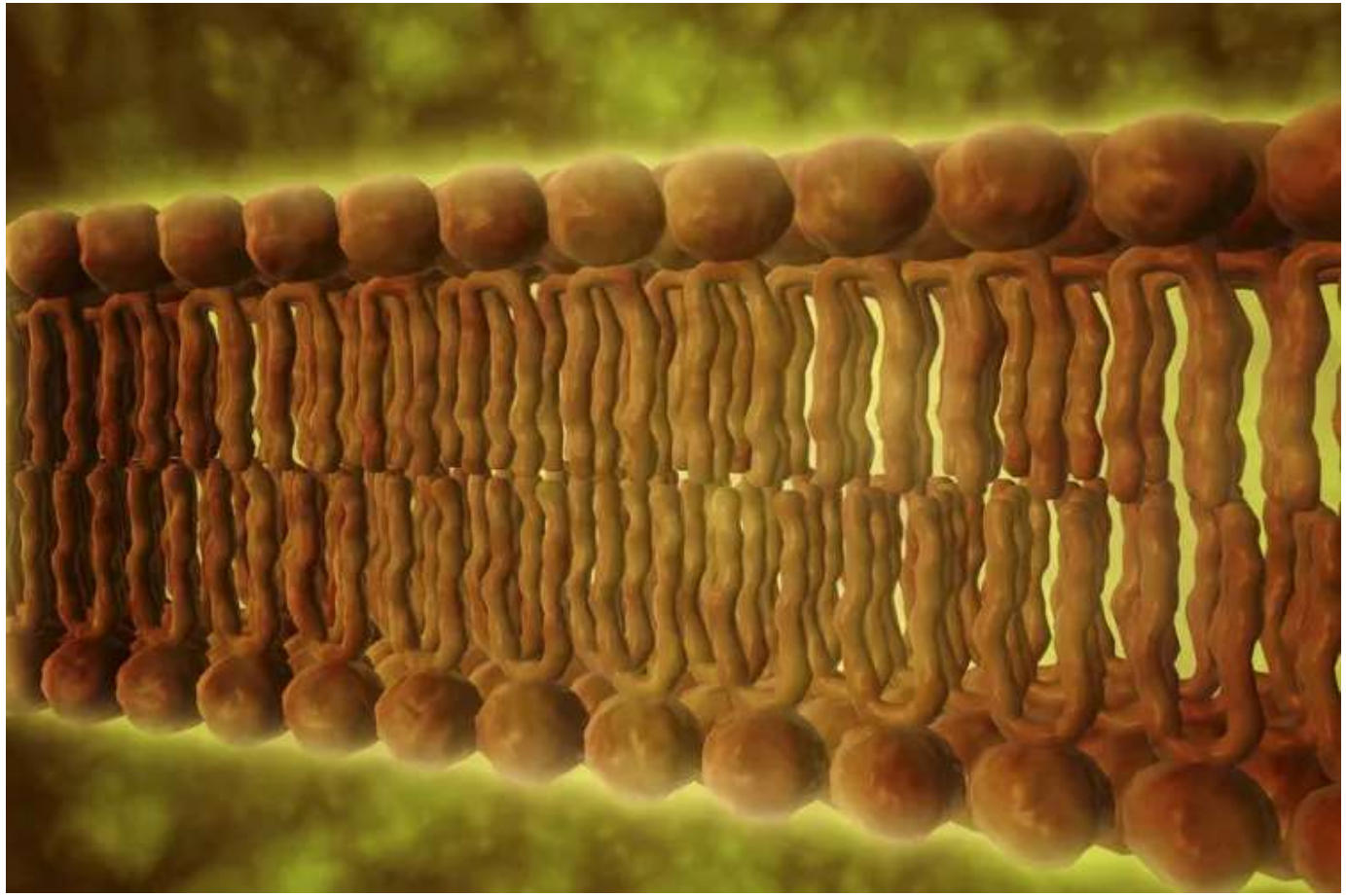
(ii) Tail end: quite insoluble in water (no affinity for water / water fearing) (i.e. non-polar or hydrophobic), contains two fatty acid chains. The hydrophobic ends facing each other meet in the water-poor interior of the membrane.

Fluid Mosaic Model of a cell membrane

The bimolecular lipid layer in the membrane has the characteristics of a fluid due to presence of cholesterol. This fluidity makes the membrane quite flexible, thus allows cells to undergo considerable changes in shape without disruption of their structural integrity.



Microscopic view of phospholipid layer



- **Functions**

1. Protective - it forms outermost boundary of the cell organelles.
2. Digestive - takes in food and excretes waste products.
3. Property of selective permeability:

(i) Non-polar molecules (gases like 0_2 , CO_2 and N_2 , lipids, steroid hormones, alcohol) can dissolve in the non-polar regions of the membrane and thus move rapidly across the membrane.

(ii) Polar molecules (water soluble substances: ions, glucose, urea etc.) have much lower solubility, therefore, penetrate the membrane much more slowly.

(iii) Chemical and physical characteristics of the membrane control the free passage of ions and molecules into and out of the cell.

This property of selective permeability of the cell membrane helps in maintaining the difference of composition between ECF and ICF.

4. Insulating properties: In electrophysiology we will see that the ion-impermeable lipid bilayer can be thought of as an electrical insulator. It allows a small charge imbalance across the membrane to generate an electrical potential difference across the membrane – the membrane potential. It act as the dielectric material (such as rubber) of a charged condenser, thus the cell membrane has a very high insulating value.

5. It provides a framework for the arrangement of an ordered sequence of protein molecules (enzymes, pumps, receptors, ions, channels, Co-factors, carriers) in a functionally meaningful pattern.

6. It links adjacent cells together by junctional complexes to form tissues.

B. **NUCLEUS AND ITS CHROMOSOMES**

Structure :

1. It is a spherical structure (10 µm diameter) surrounded by a relatively permeable membrane called nuclear membrane (or envelope). This is composed of two unit membranes and shows large pores of 1000 A^0 diameter which are closed by thin homogenous membrane. Therefore, passage of macromolecules like RNA can take place through these pores. The space between the two folds is 300 A^0 and is called perim1clear cistern.
2. It is made up of chromosomes on which genes are present. Gene is a portion of DNA molecule which carries a complete blue print for all the heritable species and individual characteristics of an animal. During cell division, the pairs of chromosomes become visible, but between cell divisions the irregular clumps of dark material called chromatin are the only evidence of their presence.

3. It contains a nucleolus which is densest of all the nuclear material i.e. a patch work of granules rich in Ribonucleic Acid (RNA). Nucleoli are most prominent and numerous in growing cells. They synthesize the RNA for the ribosomes.

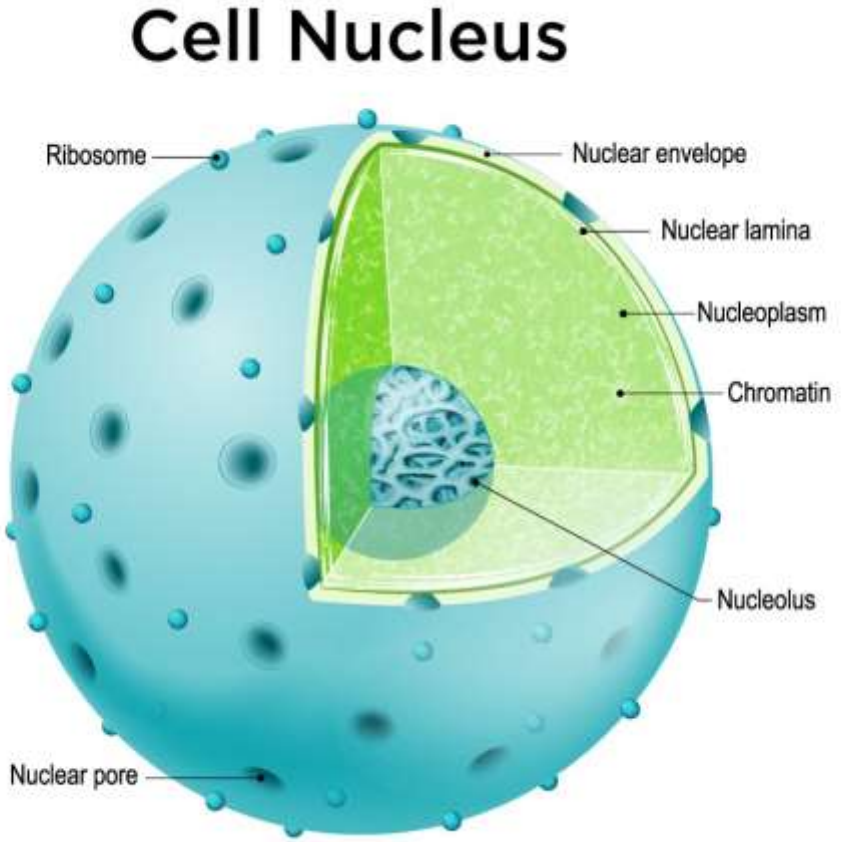
4. 80% of the dry weight of nucleus is protein, the remainder is made up by 18% DNA and 2% RNA.

Functions

1. DNA in nucleus serves as a 'template' (block) for synthesis of RNA, which then moves to the cytoplasm where it regulates the synthesis of proteins by the cells. The information coded into the DNA molecules is conveyed from the nucleus to the cytoplasm by messenger RNA where actually the synthetic work of the cell takes place.

2. Genes are units of hereditary characteristics.

3. It is concerned with cellular reproduction and multiplication; the development of chromosomal threads form the network, being the first step towards cell division.



C. CYTOPLASM AND ITS ORGANELLES

1. Endoplasmic Reticulum (ER)

It is a complex series of tubules whose walls are made up of unit membrane. Through this network of tubules, substances may be delivered from the outer membrane of cell proper to the membrane of the nucleus or to other inclusion bodies of the cells e.g. mitochondria

Types

(i) Agranular or Smooth ER: Contains no granules.

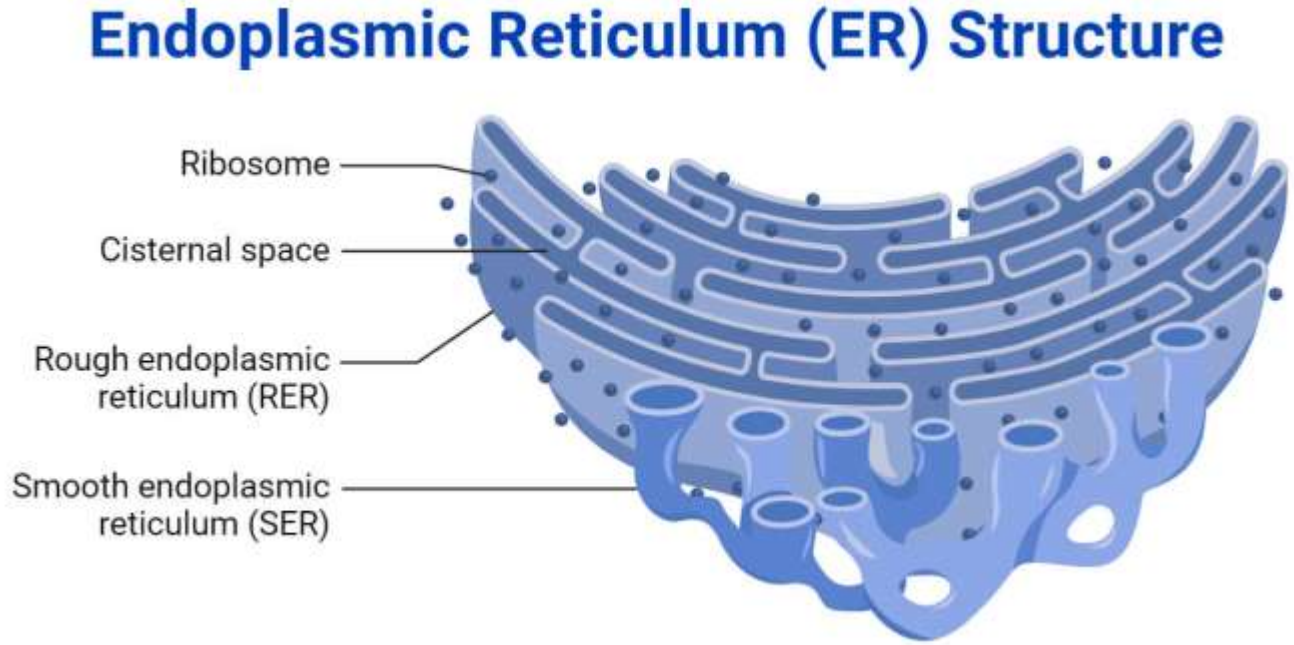
a. It is site of steroid (Adrenocortical hormone) synthesis in steroid secreting cells and the site of detoxification processes in other cells.
b. As the sarcoplasmic reticulum, it plays important role in skeletal and cardiac muscle

(ii) Granular or Rough ER or Ergastoplasm.

a. Contains granules called ribosomes (diameter 15 nm; contains 65% RNA and 35% protein: Ribonucleoprotein) which are attached to the cytoplasmic side of the membrane. 3-5 ribosomes clump together to form polyribosomes or polysomes.

b. It is the site of protein synthesis e.g., hormones that are secreted by the cell; and proteins that are found in enzymes.

c. Free ribosomes are also found in the cytoplasm, they synthesize cytoplasmic protein e.g., Haemoglobin.



2. Golgi Complex (or Golgi Bodies)

It is a collection of membranous tubules and vesicles found always in the neighbourhood of the nucleus, prominent in actively secreting gland cells.

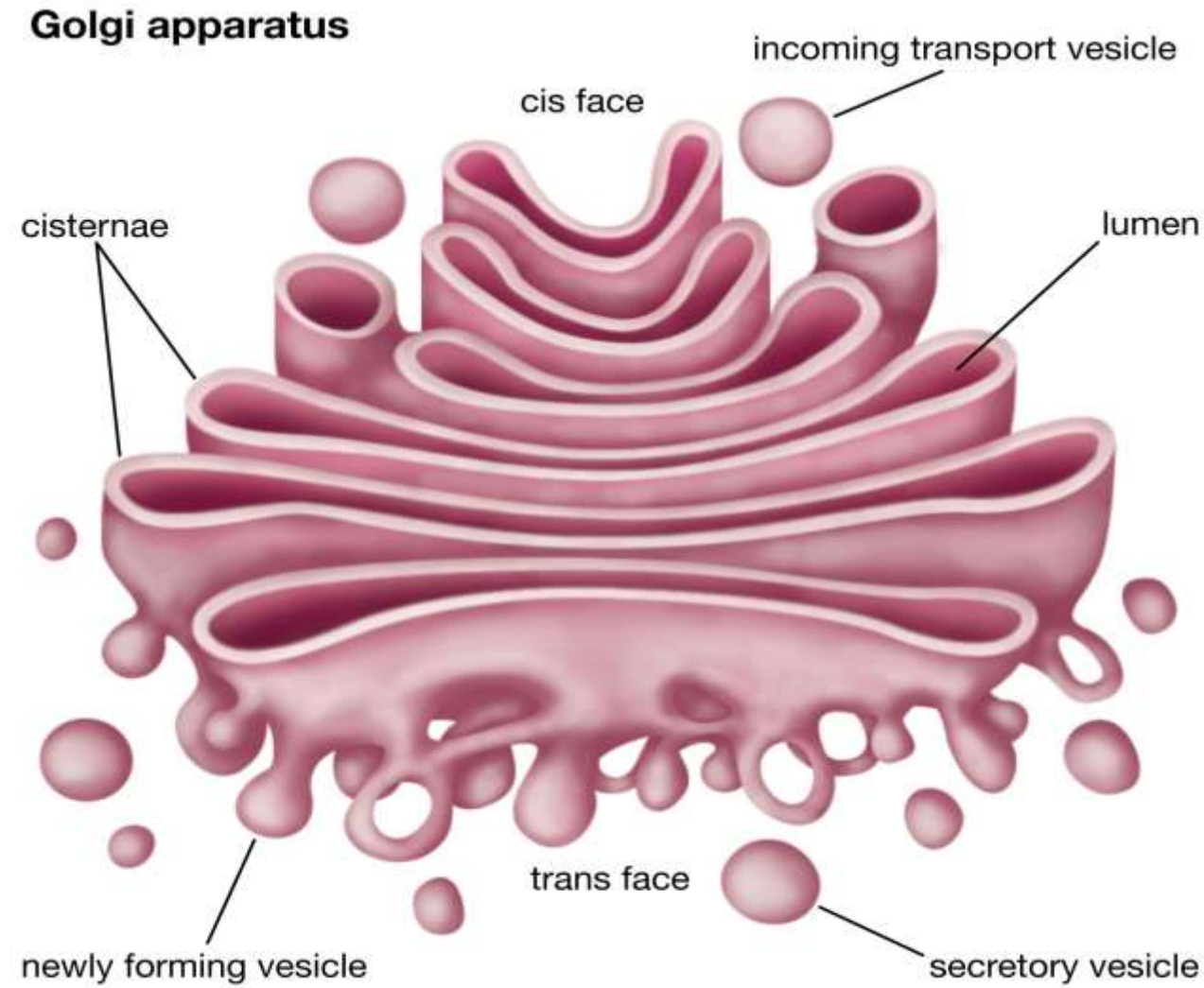
Functions

1. Wrapping and packaging department of the cell.

2. Produces secretion granules i.e. membrane enclosed complexes, which store hormones and enzymes in protein secreting cells; it packages proteins.

3. Site of formation of lysosomes i.e. large irregular structures surrounded by membrane which are present in the cytoplasm.

4. It adds certain carbohydrates to proteins to form glycoproteins, which play an important role in the association of the cells to form tissues.



3. Mitochondrion

Structure

(i) Length 5--12 µm; diameter 0.5-1 µm; filamentous or globular in shape; occur in variable numbers from a few hundred to few thousands in different cells.

(ii) Made up of outer membrane and inner membrane. Inner membrane folded to form cristae (shelves) which project into the interior of the mitochondrion.

(iii) Outer membrane: Studded with the enzymes concerned with biological oxidation (oxidation being catalyzed by enzymes).

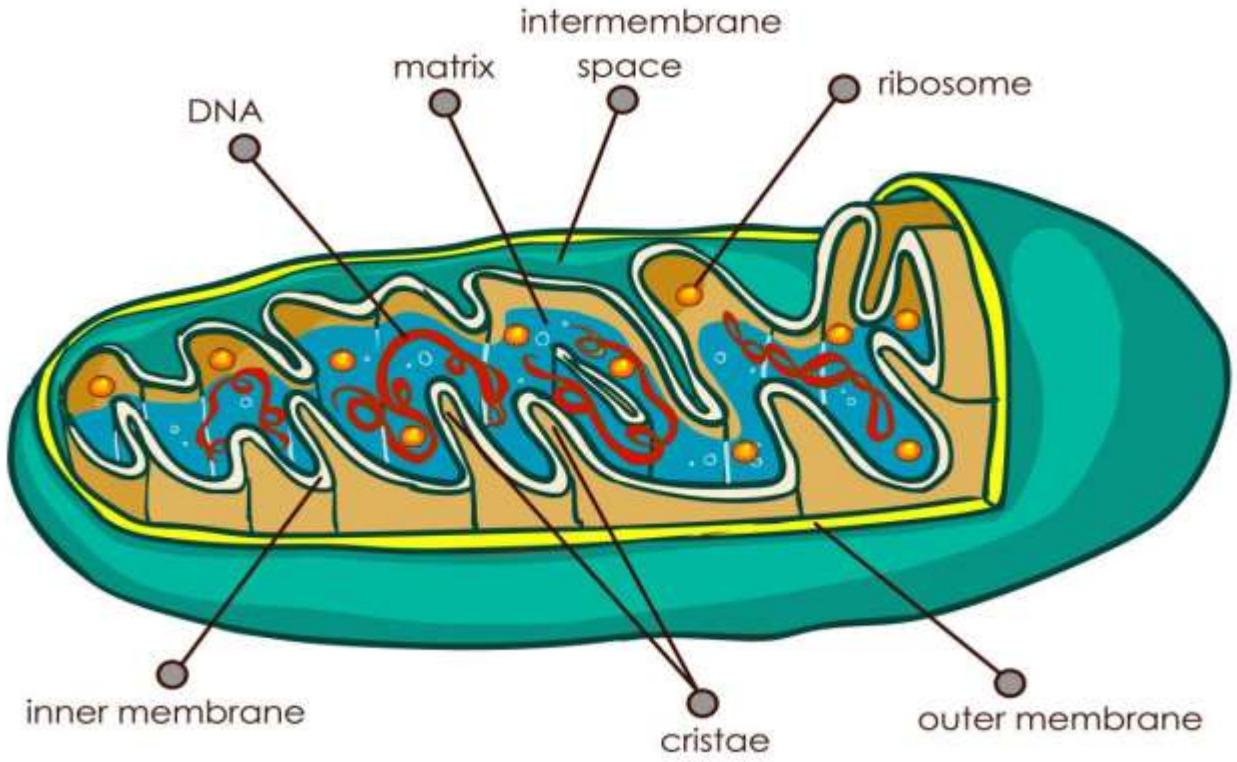
(iv) Interior (matrix) of mitochondrion contains enzymes concerned with 'citric acid cycle' and 'respiratory chain oxidation’.

(v) Inner membrane contains adenosine triphosphatase (ATPase) and other enzymes concerned with synthesis and metabolism of ATP.

Functions

(i) Mitochondria are power generating units of the cells and are plentiful and best developed in parts of cells where energy requiring processes take place e.g. rapidly contracting skeletal muscles where they comprise 40-50% of the cell volume.

(ii) Also contain DNA and can synthesize proteins.



4. Lysosomes Structure

1. These are large irregular structures surrounded by unit membrane and are found in the cytoplasm; 250-750nm in diameter. A typical cell may contain several hundred lysosomes.

2. It is filled with large number of small granules, 5-8 run in diameter which contain variety of enzymes, called lysozymes

3. The interior is kept acidic (near pH 5.0) by the action of proton pump or H+ or ATPase. Lysozymes are all acid hydrolases as they function best at the acidic pH

Functions

(i) Acts as a form of digestive (lytic) system for the cell, because enzymes present in it can digest essentially all macromolecules

(ii) Engulf worn out components of the cells in which they are located.

(iii) Engulf exogenous substances e.g. bacteria etc. and degrade them.

(iv) When a cell dies, lysosomal enzymes cause autolysis of the remnant i.e. why lysosomes are called as suicidal bags.

5. Peroxisomes

(i) Its structure is similar to that of lysosomes but with a different chemical composition. It contain oxidases (enzymes that produce H_20_2) rather than hydrolases.

(ii) They consume oxygen in small amounts that is not used in the chemical reactions associated with ATP formation.

(iii) They destroy certain products formed from oxygen, especially hydrogen peroxide, that can be toxic to the cells, hence the name peroxisomes.

(iv) The alcohol, a person drinks is mainly detoxified by the peroxisomes of the liver cells.

6. Centrioles or Centrosomes

Structure

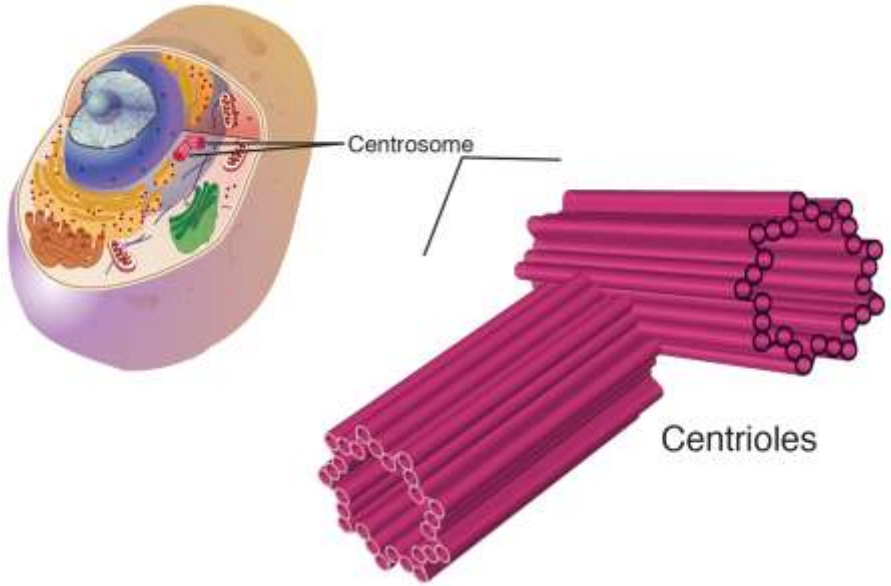
(i) These are two short cylinders called 'centrioles' visible only during cell division.

(ii) They are located at each pole near the nucleus and are so arranged such that they are at right angles to each other.

(iii) Tubules in group of three (triplets) run longitudinally in the walls of the centrioles. There are nine of these triplets spaced at regular intervals around the circumference.

Function

They are concerned with the movement of the chromosomes during cell division.



7. Microtubules and Microfilaments

- Microtubules are long hollow structures approx. 25 nm in diameter; make up structures or tracts on which, chromosomes, mitochondria and secretion granules move from one part of the cell to another.
- Microfilaments are long solid fibers 4-6 nm in diameter. They comprise the contractile protein actin and are responsible for the cell motion.
- All cells have a system of fibers called cytoskeleton that maintains the structure of the cell. It allows a cell to change shape and also permits its movement. The cytoskeleton comprises of microtubules and microfilaments, along with proteins that bind them together .

Functions

These are involved in the:

(i) movements of the chromosomes;

(ii) cell movement;

(iii) processes that move secretion granules in the cell; and

(iv) movement of proteins within the cell membrane.

Assessment

Study Questions

1.Give the electron microscopic structure of the cell membrane.

2.List the prominent cell organelles. Briefly describe the structure and functions of any one of them.

MCQ

(i) One major function of the cell membrane is:

(a) Protective (b) Property of selective permeability

(c) Digestive (d) Links adjacent cells together to form tissues

(ii) Main function of nucleus is:

(a) To control chemical and physical characteristics of the cell

(b) To bring about cellular reproduction and multiplication

(c) To synthesize protein for the cell

(d) To help in cellular movement

(iii) Peroxisomes:

(a) Their structure and chemical composition is similar to that of lysosomes

(b) They destroy products formed from oxygen, especially hydrogen peroxide

(c) They engulf exogenous substances and degrade them

(d) They consume oxygen in large amounts, hence the name peroxisomes

(iv) Cytoskeleton comprises:

(a) Microtubules and microfilaments

(b) Golgi complex

(c) Cell membrane

(d) Cell junctions

(v) Which of the following moves rapidly across the cell membrane?

(a) CO_2 (b) Water (c) Glucose (d) Urea

THANKS