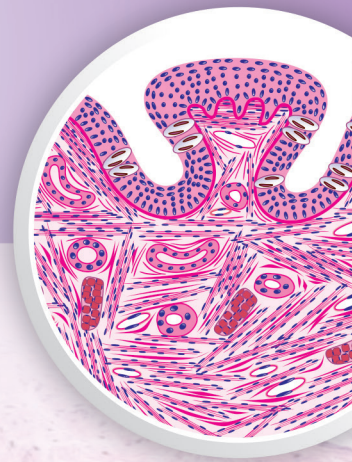




"God is a circle whose centre is everywhere but circumference is nowhere"

The basic unit of a tissue is the living cell. It consists of a cell membrane enclosing the cytoplasm with a nucleus usually in the centre. Its electron microscopic structure is described below.

ELECTRON MICROSCOPIC STRUCTURE

CELL MEMBRANE (STRUCTURE)

Accepted view of cell membrane is the fluid mosaic model. Characteristic features of the model are:

- Cell membrane comprises approximately 55% protein, 25% phospholipids, 13% cholesterol, 4% of other lipids and 3% carbohydrates. It is 7–10 nm in thickness.
- Cell membranes are composed of phospholipid bilayer with admixed protein molecule freely floating around it. The lipid bilayer consists of phospholipid molecules. The fatty portion of phospholipid is hydrophobic and faces the interior of the membrane while phosphate end is hydrophilic and faces the exterior.
- The proteins of cell membrane are:
 - i. Integral membrane proteins. Some of these span the full thickness of the cell membrane and are called transmembrane proteins. These proteins serve as membrane receptors for different hormones and have specific enzyme activity.
 - ii. Peripheral membrane proteins are not embedded within the cell membrane. These are anchored to the microfilaments of cytoskeleton.

Functions of Cell Membrane

1. It facilitates transport of substances across all membranes.
2. Protection of cell: It surrounds cytoplasm of cell and forms physical barrier between intracellular and extracellular components.
3. It maintains structural integrity.
4. The protein component of cell membrane acts as ligand receptors. The receptors located on cell membrane are sites for some hormones, immune proteins and neurotransmitters. Thus the cell receives and recognizes the signal and processes them.

5. Cell membrane takes in food and excretes waste product.
6. It aids in cell recognition.
7. The proteins in cell membranes act as enzymes and catalyze reactions and thus are involved in metabolic process.

CYTOPLASM

Control of the development and function of a cell resides mainly in the nucleus, while most of the responding metabolic synthetic activities are located in the cytoplasm. The cytoplasm consists of a cytoplasmic matrix with organelles, cytoskeleton and inclusions suspended in it. Organelles are living units while the inclusions are non-living entities.

Various cytoplasmic organelles seen with the electron microscope are the endoplasmic reticulum, Golgi apparatus, mitochondria, lysosomes peroxisomes, ribosomes and centriole.

Endoplasmic Reticulum

Endoplasmic reticulum may be in the form of rough surface or smooth surface vesicles / cisterns.

Granular or rough surface endoplasmic reticulum forms a network of membrane bound organelles spread in the whole of the cytoplasm.

In its typical form, it consists of an irregular network of branching and anastomosing flattened tubules and semi-flattened vesicles which form lamellar systems of parallel flat cavities. In addition to tubules, there are isolated vesicles which are also considered part of the endoplasmic reticulum.

The basophilia of these structures does not reside in the canalicular system of reticulum but in small particles of ribonucleoproteins called ribosomes. These are found in great numbers adhering to the outer surface of their limiting membranes and are found free in the cytoplasm as well as attached to the membranes.

The ribosomes are the sites of synthesis of new proteins in the cell. In protein secreting cells such as those of the pancreas, the endoplasmic reticulum is always of the granular type (Fig. 1.1).

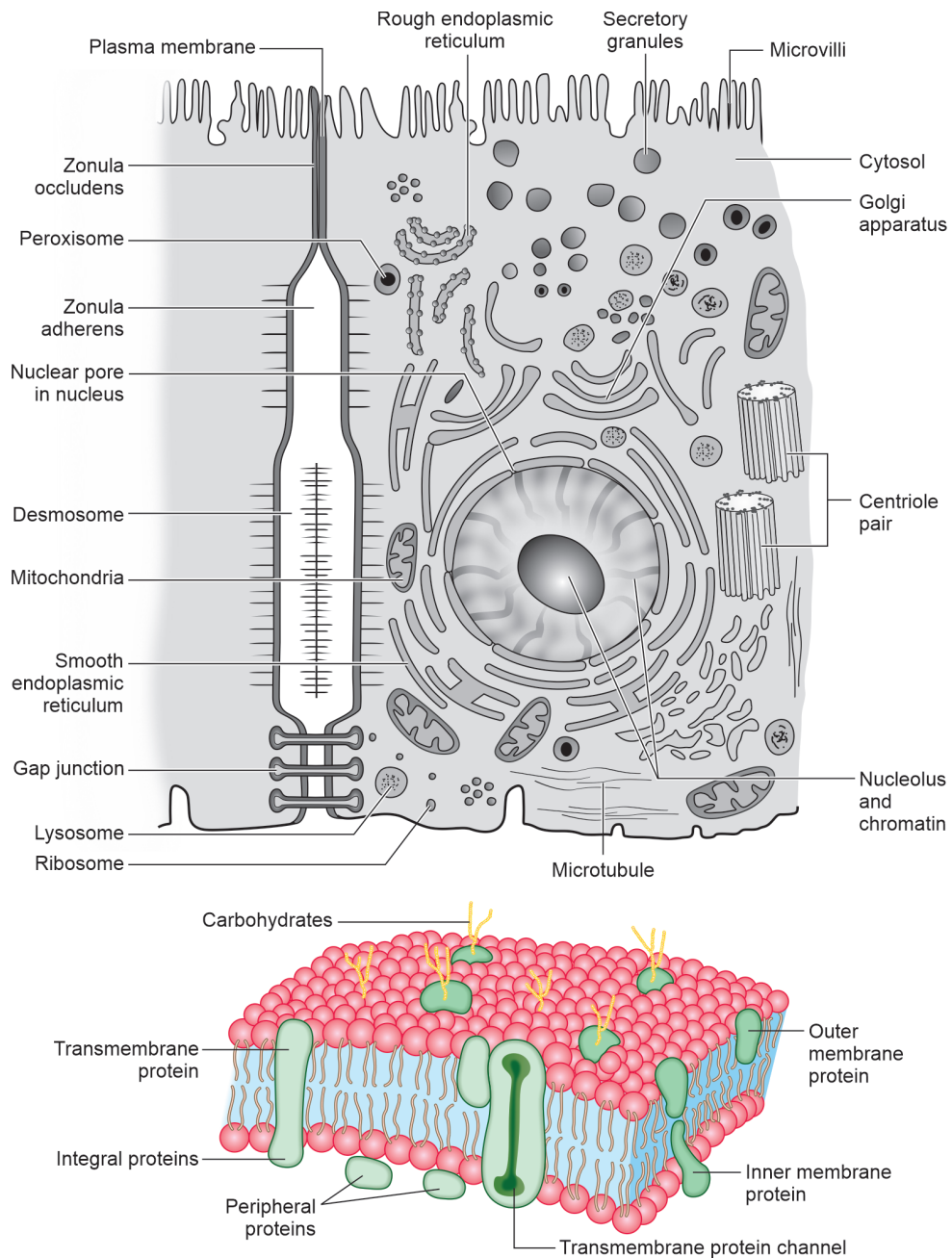
Agranular or smooth endoplasmic reticulum is seen in some cell types. The tubules comprising the endoplasmic reticulum lack the associated ribosomes. In such cells the cytoplasm is usually acidophilic. Agranular endoplasmic reticulum is usually a close meshwork of tubules.

In muscle, the endoplasmic reticulum is mainly of the smooth surface variety and is concerned with release and recapture of calcium ions in the cycle of contraction and relaxation. In liver, both rough and smooth surface endoplasmic reticulum are present and are involved in cholesterol and lipid metabolism.

Golgi Apparatus

Golgi apparatus can be seen in routine histological preparations. However, in tissues subjected to impregnation with osmium or silver, it can be demonstrated as a blackened network usually in the juxtanuclear region.

Electron microscopically it is seen to consist of a lamellar membranous structure consisting of curved arrays of flattened saccules often expanded at each end. These are usually present between the nucleus and the apical part of the cell.



FACTS TO REMEMBER

1. The cell membrane is a lipid bilayer
2. The cell organelles are mitochondria, endoplasmic reticulum, Golgi apparatus and lysosomes, etc. Nucleus is surrounded by nuclear membrane
3. The adjacent cells are joined together by zonula occludens, zonula adherens, desmosome and gap junctions

Fig. 1.1: Electron microscopic structure of cell with cell junctions

The Golgi apparatus is concerned with aggregation, condensation and elaboration of the secretion of the cell. It also actively participates in synthesis of secretory products rich in complex polysaccharides, the carbohydrate moiety, which replenishes the cell membranes as and when required. The secretory vesicles leave the apical aspect of the cell in the form of zymogen granules (Fig. 1.1).

Mitochondria

Mitochondria can be seen in light microscopy as minute granules or filaments spread throughout the cytoplasm and can be stained in the living cell by the supravital dye, e.g. Janus green. The mitochondria show brownian movements and symbiosis. They divide by binary fission and are self replicating.

With the electron microscope, they are seen to have a complex sausage shaped structure being enclosed by two membranes.

The outer membrane is a smooth continuous limiting membrane and the inner membrane is thrown into folds called **cristae**.

The interior of the mitochondria have a dense fluid called the mitochondrial matrix which may show granules of iron or calcium in it.

The mitochondria contain the enzymes responsible for oxidation of foodstuffs which give energy to the cell. The enzymes **flavoprotein** and **cytochromes** are attached to the membrane and are important for respiratory processes of the cell.

The **dehydrogenase enzymes** which are responsible for Krebs citric acid cycle and for protein and lipid synthesis, are present in the mitochondrial matrix.

Lysosomes

Lysosomes are dense bodies, limited by a membrane containing a number of hydrolytic enzymes termed **acid hydrolases**. The enzymes play a role in the breakdown of an injured cell. These also take part in the intracellular digestion of foreign matter. The lysosomes are rich in glycoproteins.

Peroxisomes: Are smaller than lysosomes and are abundant in cells of liver and kidney where toxic substances are removed. Peroxisomes contain enzymes which oxidise organic substances to form hydrogen peroxide. Catalase, another enzyme, breaks hydrogen peroxide into oxygen and water molecules. These enzymes protect other parts of the cell.

Ribosomes

Ribosomes are granules lying on the surface of endoplasmic reticulum, making it rough. They are also collected in the cytoplasm in the form of polyribosomes which are active sites for the synthesis of proteins.

The Cytoskeleton

Microfilaments: Most of the cells contain microfilaments 6–8 nm comprising protein actin. These are seen in microvilli of intestinal epithelium. In the skeletal muscle the presence of actin and myosin microfilaments are responsible for the contraction of muscle.

Intermediate filaments: These are thicker than microfilaments 8–10 nm, e.g. keratin in epithelial cells of skin (Fig. 1.2).

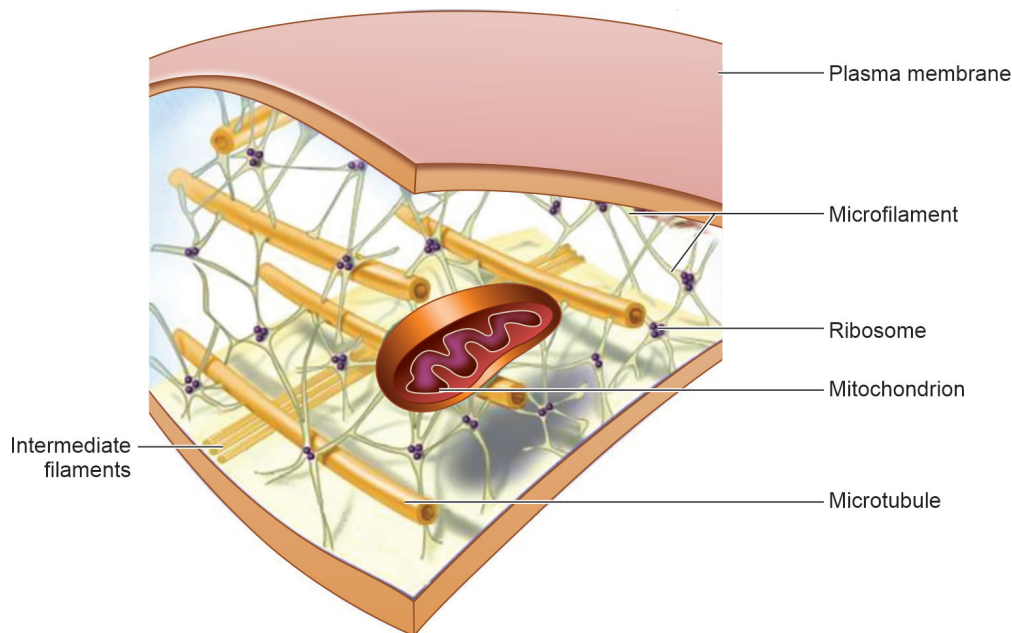


Fig. 1.2: Microfilament, intermediate filaments and microtubule

Microtubules: These are pipe/rod like structures of 18–20 nm length in all cell types except mature red blood cells and microvilli. These are rigid bodies which give shape to the cell. These help in axoplasmic transport in neurons and also in melanin dispersion.

Cilia and flagella: These are motile processes 5–10 μm extending from the surfaces of the cells. In their cores are the microtubules (9 + 2). These are composed of 'a' and 'b' tubules. Dynein protein uses ATP for ciliary movement. Flagellum or cilium comprises nine pairs of microtubules around the circumference and a pair of tubule in the centre. These 9 microtubules are connected to central doublet by radial spokes. Basal body, the anchor of cilium contains 9 triplets (**Fig. 1.3a and b**).

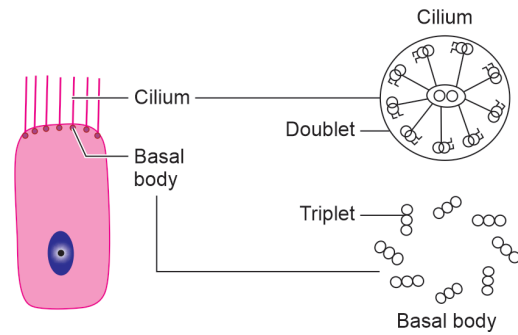
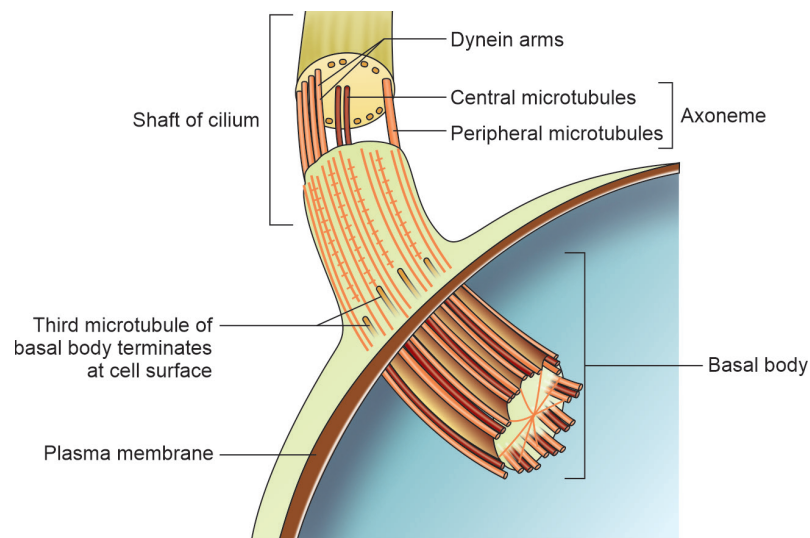
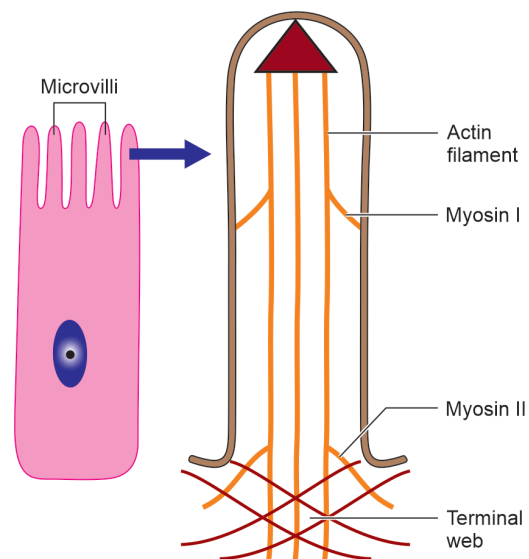
In human, only one type of cells, the spermatozoa contains single flagellum.

True cilia are present in the epithelial cells of respiratory mucous membrane. The cilia help in the movement of mucus laden with dust particles towards the pharynx.

Microvilli: These are non-motile 1–2 μm long finger-like projection on cell surface. Plasma membrane forms the outer covering with inner cytoplasmic core of actin filaments. Terminal web lies at apical part of cells with horizontally obliquely placed actin filaments. When actin filaments of terminal web contract, microvilli spread and surface area for absorption increases. The microvilli also contain myosin I and myosin II filaments.

Microvilli form brush border (if irregular) and striated appearance (if regular). These increase the surface area of cell for absorption (**Fig. 1.4**).

Stereocilia: These are long thick non-motile microvilli 100 μm long with core of actin filament and terminal web at the apical part of the cell. Present in inner ear receptor cells and epididymis epithelium. These cause signal generation in inner ear hair cell (**Fig. 1.5**) and increase the cell surface area in epithelium of epididymis.

**Fig. 1.3a:** Cilia**Fig. 1.3b:** Ultrastructure of cilium**Fig. 1.4:** Microvilli and its ultrastructure

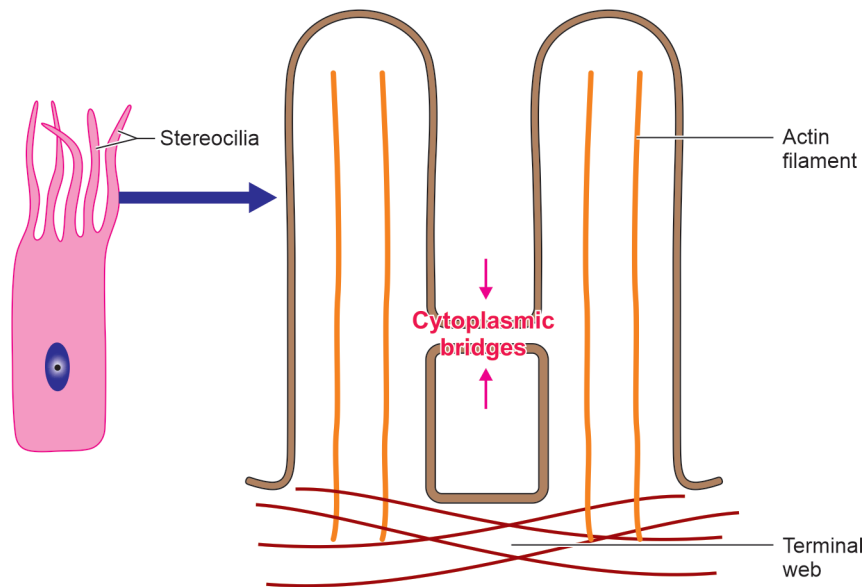


Fig. 1.5: Stereocilia with terminal web

Centrioles

The centrioles are short cylinders located near the nucleus. In transverse section of centriole, 9 triplets are seen around the circumference. Centrioles are concerned with movement of chromosomes during cell division (Fig. 1.1).

Junctional Complexes

These are ultramicroscopic structures joining the adjacent sides of two epithelial cells. The important junctional complexes from apical end to the basal end of cells are:

- i. Zonula occludens
 - ii. Zonula adherens/fascia adherens
 - iii. Desmosome/macula adherens
 - iv. Gap junction (*see Fig. 1.6*)
- i. **Zonula occludens/tight junctions:** These are seen in the epithelia of renal tubules, gallbladder and intestines. Near the apical margin, the two cell membranes fuse completely over a short distance. Tight junction helps to bind the adjacent cells to each other. These prevent movement of molecules and ions across the intercellular spaces. The claudin and occludin transmembrane proteins cause the fusion of outer plasma membranes of adjacent cells to form a barrier. These provide attachment to intracellular actin filaments via zona occludens (ZO) proteins.
 - ii. **Zonula adherens:** The plasma membranes below the apical parts are separated by a gap of 15–20 nm. Deposited proteins on inner side of cell membranes are seen as thickening. Actin filaments are attached to these proteins. Fascia adherens is like zonula adherens, except that it does not surround the whole cell. It is present in intercalated discs of myocardium and in smooth muscles.

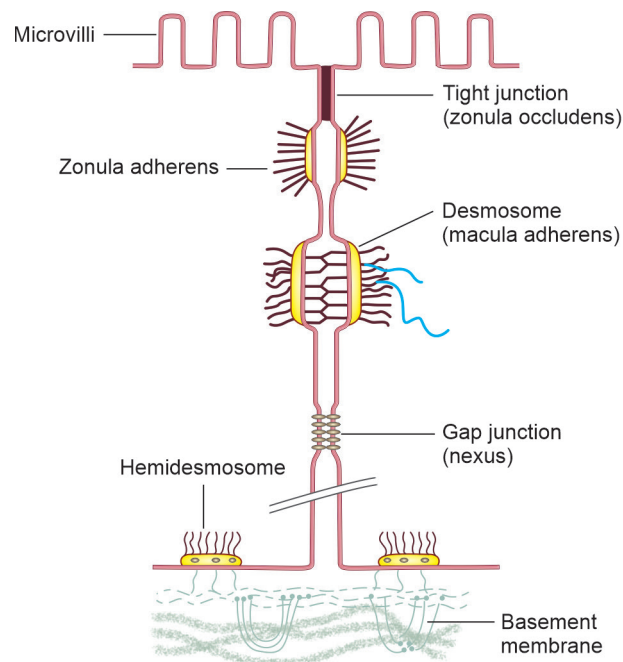


Fig. 1.6: Ultrastructure of junctional complexes

- iii. **Desmosome/macula adherens:** Desmosomes connect only the lateral surfaces of cells. The cells are separated by 30 nm distance. On inner aspect of cell membrane lies a dense thick disc. Intermediate filaments of cell get attached to this disc. Transmembrane proteins, e.g. cadherin, connect the dense thick discs of adjacent cells. These provide adhesion and stability to the cells.

Hemidesmosomes are present at the basal border of the epithelial cells. These help to attach the epithelial cells firmly to the underlying basement membrane/ basal lamina. The basal lamina shows thickenings (disc) to which intermediate filaments are attached. These are seen in epithelium of skin, cornea.

- iv. **Gap junctions** are typically seen in cardiac muscle and smooth muscle. These consist of proteinaceous tubes, which permit ions to travel from one cell to the next adjacent cell without passing through the cell membrane. These tubes are called 'connexons'. Gap junctions are areas with very low electrical resistance. So electrical impulses or action potentials can easily spread from one cell to the next cell through the gap junctions, which is less than 3 nm. These junctions regulate transport of ions and also maintain pH of cells.

Basement Membrane (Basal Lamina)

It is a thin homogeneous layer on which the basal epithelial cells rest. It is comprised of **lamina densa** (type IV collagen fibrils) derived from epithelial cells and a **reticular lamina** derived from the subjacent connective tissue.

Lamina densa and reticular lamina are anchored by type VII collagen fibrils.

Basal lamina is periodic acid-Schiff (PAS) positive.

Cytoplasmic Inclusions

Cytoplasmic inclusions are non-living entities and do not take part in the metabolism of the cell, e.g. stored food which may be seen in the form of glycogen and fat. Pigments may be of exogenous origin like dust, tattoo marks or endogenous origin which include haemoglobin of blood, melanin pigment of skin, hair, iris and lipofuscin pigment found in the heart muscle and in some nerve cells.

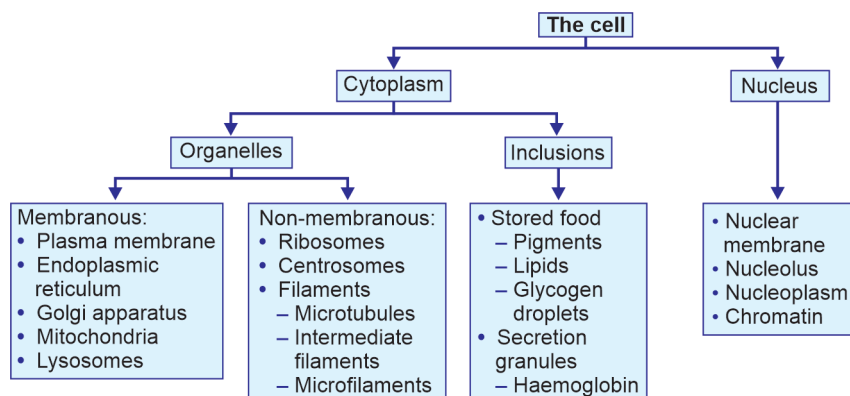
NUCLEUS

It is an essential component of nearly all cell types. These are absent in mature RBC. Its components are:

- i. **Nuclear membrane:** It consists of two cell layers enclosing a narrow perinuclear space. The outer layer may have ribosomes adherent to its surface. The inner layer may have peripheral chromatin adherent to it.
The nuclear membrane has small circular openings called nuclear pores, 8 Angstrom in diameter closed by a thin membrane around which the two membranes fuse. This area of fusion is referred to as the nuclear pore complex. The nuclear pore controls the movement of substances between cytoplasm and nucleus. One of the X-chromosomes of the females is seen adherent to the nuclear membrane and is known as the **Barr body**.
- ii. **Nuclear sap:** It is semifluid and lies within the nucleus. It stains poorly and is rich in proteins.
- iii. **Nucleolus:** It is present in most of the nuclei. The number of nucleoli varies from one to five in each nucleus. The nucleolus consists of a dark and light component. The light component forms the canals which course through the dark substance. The dark components form the granular or fibrillar material in the nucleolus. It acts as an auxiliary chromosome and is rich in RNA (Fig. 1.1).
- iv. **Chromatin:** It forms the bulk of the nucleus. In interphase some chromatin is adherent to the surface of the inner layer of nuclear membrane and is called peripheral chromatin. Some chromatin is distributed as strands in the nuclear sap. The rest of the chromatin surrounds the nucleolus. During the prophase of mitosis, chromatin gets collected into small rod-like bodies known as the chromosomes.

Flowchart 1.1 shows the components of the cell.

Flowchart 1.1: Components of the cell



 Multiple Choice Questions

1. Which of the following cell organelle provides energy for functions of the cell?
 - a. Lysosomes
 - b. Centriole
 - c. Cilia
 - d. Mitochondria
2. Intracellular digestion is done by one of the following organelles:
 - a. Centriole
 - b. Lysosome
 - c. Endoplasmic reticulum
 - d. Golgi apparatus
3. Steroid synthesis is done by:
 - a. Golgi apparatus
 - b. Lysosome
 - c. Smooth endoplasmic reticulum
 - d. Mitochondria
4. Microtubules are not present in:
 - a. Centriole
 - b. Flagella
 - c. Cilia
 - d. Microvilli

Viva Voce Questions

1. What is the structure of cell membrane?
2. Where are the transmembrane proteins located?
3. Name the function of transmembrane protein.
4. Name the components to which cell membrane is permeable.
5. How do larger molecules enter the cell membrane?
6. Which cells are devoid of mitochondria?
7. Name the substances attached to the mitochondrial membrane. What enzyme is present in its matrix?
8. Which cells contain rough endoplasmic reticulum?
9. What is the function of free ribosomes?
10. Which cells contain smooth endoplasmic reticulum?
11. What are the functions of Golgi apparatus?
12. Name the enzyme present in lysosomes.
13. What is the function of lysosomes?
14. Which cells contain peroxisomes?
15. What is the function of peroxisomes?
16. What is the function of microfilaments?
17. Name the sites where microfilaments are present.
18. What is the size of the intermediate filaments? Where are they present?
19. Where are the microtubules present?
20. When does the centrosome function?
21. How many centrosomes are there in one cell?
22. What does the centriole form during cell division?
23. What are the components of a nucleus?
24. What are the functions of nuclear pore?
25. What changes occur at zonula occludens?
26. Where is zonula adherence located?
27. Where are desmosomes situated?
28. Where are hemidesmosomes present?
29. Where are the gap junctions present and what is their location?
30. Does zonula occludens permit passage of solubles between adjacent cells?
31. What is the function of gap junctions in cardiac muscle fibres?