UNIT - 1

Cell Biology

CHAPTER 1

Cell and Organelles
(Introduction and General Features)

CHAPTER OUTLINE

INTRODUCTION AND GENERAL FEATURES

A cell is the structural and functional unit of body. It means that the body is composed of cells. The vast array of processes and functions of body occur in a correct manner due to 200 different types of cells, which are specialized to perform a particular function. They work in collaboration to maintain the homeostasis of the body. However, all cells have some common structural and functional features, which are necessary for proper execution of their activities. For this reason, cell has been defined from decades as a complete unit bound by a membrane which contributes to the structure and function of a living being, thus, also called structural and functional unit of life.

For proper understanding of various chemical and biological processes in the body, it is a necessity to have knowledge about the basic unit of life, cell. A study of structure and functions of cell is known as 'cell biology'. A cell is composed of different intricate components known as cell organelles, which work in association with one another to enable the cell to perform its functions. To study the cell in an easy way, the cell is segregated into following parts: the plasma membrane, cytoplasm and nucleus. They are discussed as under:

PLASMA MEMBRANE

It is a flexible membrane around the cytoplasm of a cell and it acts as a barrier between the outer and the internal environment of the cell. It selectively regulates the movement of substances to and fro the cell. The lipid components of the membrane allow lipid soluble molecules (non-polar) to pass through, but block the movement of substances polar (water soluble) in nature. This particular characteristic helps in establishing and sustaining a suitable environment for carrying out the cellular functions. Plasma membrane is also important for maintaining communication amongst the cells and the environment on the outside of the cell.

STRUCTURE OF PLASMA MEMBRANE (FLUID MOSAIC MODEL)

The structure of plasma membrane has been explained through the **'Fluid Mosaic Model'** as described by S. J. Singer and G. L. Nicolson (1972). The salient features regarding the structure of plasma membrane may be explained below **(Figure 1.1)**:

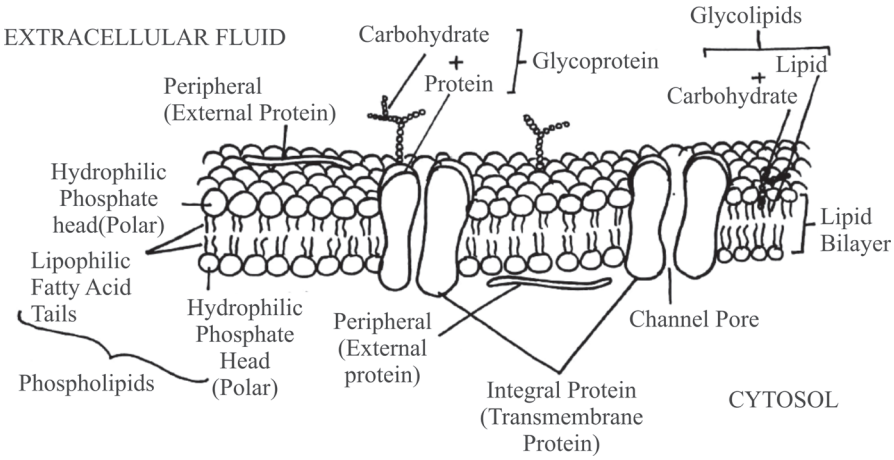

FIGURE 1.1 Fluid Mosaic Model explaining the structure of plasma membrane

1. According to this model, membrane is not rigid in nature; rather, it is fluid in nature. The structural constituents of membrane can float over the membrane.
2. Plasma membrane is mainly composed of lipids and proteins.
3. Phospholipid (75%) is the major lipid present in cell membrane. Phospholipid is amphipathic in nature as it has both hydrophilic phosphate heads and lipophilic tails.

4. Phospholipids form a lipid bilayer (two layers) in which hydrophilic phosphate heads face towards outside (face towards extracellular space) and inside (face towards intracellular space) of cell. On the other hand, two lipophilic tails face towards each other. Thus, lipophilic tails form the centre of membrane.
5. Other lipids of cell membrane include cholesterol (20%) and glycolipids (5%). Cholesterol helps in maintaining the membrane fluidity.
6. Within lipid bilayer, the membrane proteins are arranged.
7. Integral proteins (internal proteins) extend through into the bilayer and are embedded in the membrane. Most of the transmembrane proteins are integral proteins. They extend from extracellular fluid to the cytoplasm. These proteins cannot be isolated without breaking cell membrane. Most of these proteins function as ion channels through which molecules can enter inside or move outside **(Table 1.1)**.
8. Peripheral proteins (external proteins) are less firmly attached to the membrane. Mostly, these are located on the outer surface of plasma membrane. These can be easily removed from cell membrane without damaging the membrane. These mainly function as receptors **(Table 1.1)**.

TABLE 1.1 Key differences between integral and peripheral proteins of cell membrane

S.No.	Integral Proteins	Peripheral Proteins
1.	These are present inside the lipid bilayer	These are located on the outer surface of plasma membrane
2.	These are firmly attached to membrane	These are less firmly attached to membrane
3.	These proteins cannot be isolated without breaking cell membrane.	These can be easily removed from cell membrane without damaging the membrane.
4.	Most of these proteins function as ion channels	Most of these proteins mainly function as receptors.

9. Glycoproteins are also membrane proteins and these carry carbohydrate groups at their ends. These are also present on the outer surface of membrane i.e., these extend into the extracellular fluid. These glycoproteins are important markers for cell identification (cell recognition) and antigenic determination.
10. The glycoproteins are present on the extracellular surface. Similarly, the carbohydrate portions of glycolipids are also exposed on the outer face of the plasma membrane. Accordingly, the surface of the cell is covered by a carbohydrate coat, known as the 'glycocalyx', which is formed by glycolipids and glycoproteins.

FUNCTIONS OF PLASMA MEMBRANE

Plasma membrane serves many functions and these include:

1. It protects the cell and organelles of the cell
2. The cell membrane supports the cell and helps in maintaining the shape of the cell.
3. The lipid bilayer is semi-permeable and it selectively regulates the movement of substances to and from the cell
4. It acts as a site for receptors, transporters, channels. These functions are performed by proteins of plasma membrane.
5. Glycocalyx helps in cell recognition and antigenic determination.

CYTOPLASM

It is clear, gel like material present in between the plasma membrane and nucleus of the cell. It serves as a space in which cell organelles are present and most of the cellular reactions take place in cytoplasm. Cytoplasm is composed of cytosol (fluid portion) and the organelles (solid part). The cell organelles are surrounded by cytosol.

CYTOSOL

It is also known as 'Intracellular fluid' and it makes up approximately 55% of total volume of the cell. The composition of the cytosol varies in different cells. It is mainly made up of water (75-90%) along with various other particles suspended in water such as electrolytes, amino acids, glucose, ions, ATP, lipids, fatty acids, waste products and proteins.

ORGANELLES

These are small, specialized components of cells with characteristic structures. These perform specific functions, which are vital for the cell either individually or in collaboration with other cells. These organelles are suspended in the cytosol. All organelles contain certain characteristic enzymes depending upon the function attributed to them. Their number in different cells depends on the function of

the particular cell. These organelles include endoplasmic reticulum, mitochondria, nucleus, ribosomes etc.

ENDOPLASMIC RETICULUM (ER)

The characteristic features of endoplasmic reticulum may be discussed as below:

1. The flattened sacs, tubules and vesicles exist in the form of a network in the cytoplasm to form endoplasmic reticulum **(Figure 1.2)**.

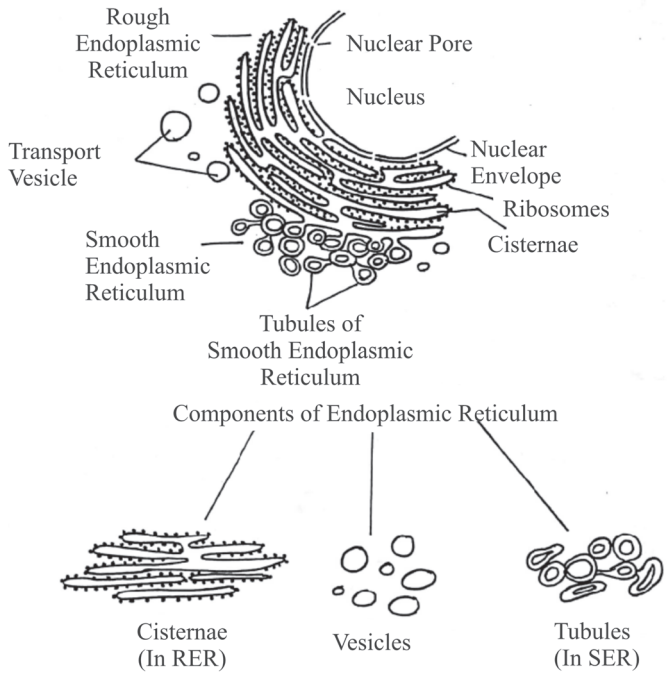

FIGURE 1.2 Structure of endoplasmic reticulum showing its different parts such as cisternae (present in RER), vesicles and tubules (present in SER)

2. The composition of its wall (membrane) is similar to that of the cell membrane i.e., lipid bilayer membranes containing large quantity of proteins.
3. Another characteristic feature of endoplasmic reticulum is its very large surface area and its total surface area may be more than that of plasma membrane of the cell. In hepatocytes, the surface area of endoplasmic reticulum may be even 30 to 40 times of the area of the cell membrane. Therefore, an extensive amount of area in cytoplasm is occupied by endoplasmic reticulum.

4. Endoplasmic reticulum is connected to the nuclear envelope all around the nucleus. Sometimes, it may extend even up to the cell membrane.
5. The vesicles and tubules of endoplasmic reticulum contain a fluid of watery consistency called endoplasmic matrix.
6. There are two types of endoplasmic reticulum depending on their structure and function. Rough ER (RER) and smooth ER (SER) **(Table 1.2)**.

TABLE 1.2 Key differences between RER and SER

S. No	Rough endoplasmic reticulum	Smooth endoplasmic reticulum
1.	The outer surface is covered with ribosomes.	The outer surface is not covered with ribosomes.
2.	The outer surface is rough due to presence of ribosomes	The outer surface is smooth due to absence of ribosomes
3.	It is responsible for production and processing of proteins.	It synthesizes of fatty material, detoxifies drugs and acts as calcium store

7. Rough endoplasmic reticulum (granular ER) is covered with granular structures called ribosomes, which are present on its outer membrane. Ribosomes are made up of RNA and proteins and these are exclusively responsible for synthesizing proteins. The proteins synthesized by the ribosomes move inside the rough ER, where it undergoes processing for becoming functional. For example, proteins formed from ribosomes move inside the ER, where proteins are attached to carbohydrates to form glycoproteins.
8. The major function of RER includes production and processing of various proteins essential for carrying out different functions in the cells such as, secretory proteins, organelle proteins, membrane associated proteins, etc.
9. Smooth ER (agranular ER) does not possess ribosomes on its membrane and these are called smooth because of its appearance.
10. The functions of SER include:
    (i) Synthesis of fatty acids and steroids (estrogen, testosterone)
    (ii) Detoxification of drugs or substances in SER of hepatocytes
    (iii) Smooth ER present in skeletal muscles is called as 'Sarcoplasmic reticulum'. It is store house of calcium and it releases Ca^{2+} ions from its stores during muscle contraction.

RIBOSOMES

The characteristic features of ribosomes may be described as follows:

1. These are the minute, spherical structures present in the cells for the synthesis of proteins. Therefore, these are also termed as protein factories. Indeed, ribosomes link amino acids in a specific order as specified by messenger RNA (mRNA). In other words, these are involved in the process of translating mRNA into protein.
2. It is made up from ribosomal RNA (rRNA) and protein. Therefore, it is also termed as 'ribonucleoprotein'.
3. The unit of measurement of ribosomes is the 'Svedberg' unit, which measures the rate of sedimentation in centrifugation.
4. Eukaryotic ribosomes are of 80 S type, which is in contrast to 70 S type of ribosomes in prokaryotes. In eukaryotes, 80 S ribosomes have a small (40S) and large (60S) subunit. The smaller ribosomal subunit reads the mRNA, and the large subunit joins amino acids to form a polypeptide chain.
5. Ribosomes may be present on the outer surface of the ER as in RER. However, these may also exist independently in the cytosol.
6. During active protein synthesis, a number of ribosomes may be attached over mRNA to form 'polysomes'.

GOLGI APPARATUS OR GOLGI COMPLEX

The characteristic features of Golgi apparatus may be discussed below:

1. It is a cup-like membranous organelle consisting of tubules, vesicles and flattened sac like structures called 'cisternae'. These cisternae are stacked over one another.
2. They are generally found in vicinity of nucleus. However, in case of secretory cells Golgi apparatus are more prominent and are located more towards the boundary of the cell from where the secretion from the cell takes place. Structurally, it is comprised of different cisternae depending on the shape, position and enzymatic activity **(Figure 1.3).**
3. The Golgi complex works in collaboration with the Rough ER. The proteins synthesized and modified in the RER are passed towards the Golgi apparatus. In the Golgi apparatus, the proteins are appropriately processed, and packaged to form 'membrane or secretory vesicles'.
4. Thus, packaging is main function of Golgi apparatus and it packages the proteins after receiving from endoplasmic reticulum. The packaged proteins are released into the extracellular fluid in the form of secretory vesicles **(Figure 1.4)**.

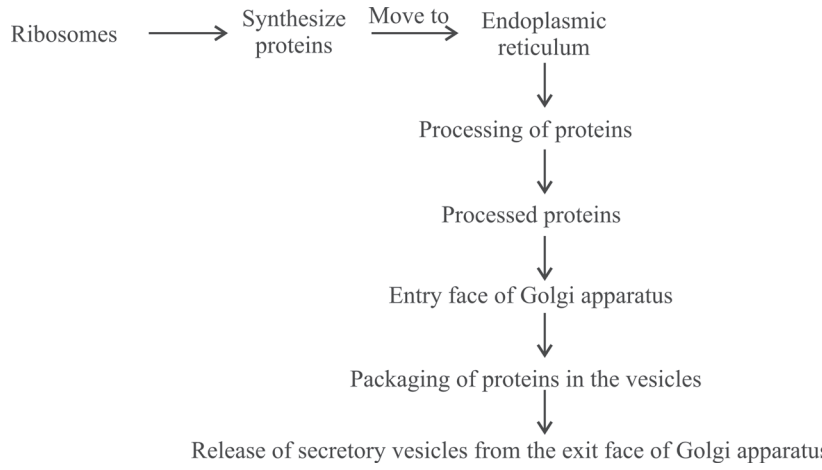

FIGURE 1.3 Key structural features of Golgi Apparatus

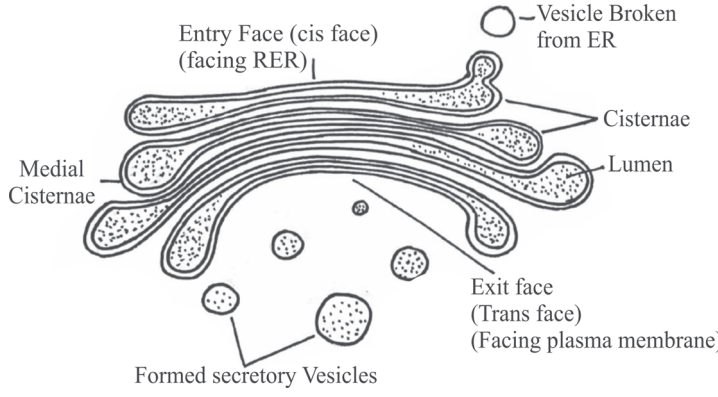

FIGURE 1.4 Golgi apparatus works in association with ribosomes and endoplasmic reticulum to form secretory vesicles

MITOCHONDRIA

1. This organelle is also referred to as the "powerhouse of the cell" because the most of the ATP (energy) required for cell to function is produced by mitochondria. In their absence, all cellular activities come to a halt due to unavailability of energy to work.
2. Their number in a cell depends on the metabolic activity of the cell. More active a cell, more is the number of mitochondria present in the cell such as in skeletal muscles and liver cells.
3. Structurally, mitochondrion has two membranes: outer membrane and inner membrane. The structure of these membranes is similar to that of lipid bilayer of plasma membrane. **(Figure 1.5)**

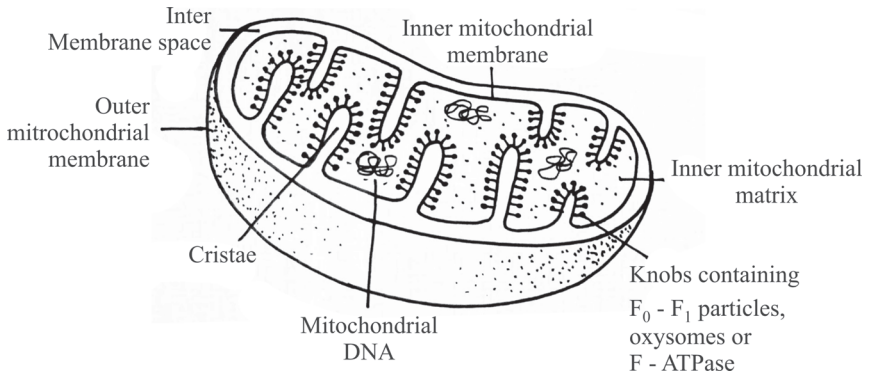

FIGURE 1.5 Ultra-structure of mitochondria showing different components.

4. The outer membrane is smooth. However, the inner membrane is folded to form finger like structures called 'cristae'. On these cristae, enzymes known as 'F_0-F_1 particles' or 'oxysomes' or 'F-ATPase' are present. These enzymes are involved in ATP synthesis.
5. The inner cavity of mitochondria is called as 'mitochondrial matrix' and is formed by inner mitochondrial membrane. The matrix contains a large amount of enzymes (dissolved in it) that are responsible for carrying out oxidative phosphorylation and ATP production.
6. Mitochondrion has its own independent genome (DNA), which shows a lot of similarity to bacterial genome. With increase in ATP demand, mitochondria can self replicate to meet the increasing demand. Therefore, it is also termed as 'semi-autonomous'.

LYSOSOMES

1. These are minute, membranous vesicles present throughout the cytosol. These are formed from the combined and coordinated actions of rough ER and Golgi complex.
2. These lysosomes contain large number of (at least 40-60) different types of digestive enzymes. These enzymes require acidic pH for optimum activity. The membrane of lysosomes prevents these powerful digestive and hydrolytic enzymes from coming in contact with the organelles. These enzymes perform digestion of
   (i) Intracellular worn out, damaged and un-repairable cell organelles
   (ii) Food material ingested by cell
   (iii) Foreign material in the cell
   (iv) Sometimes, whole cell itself. Therefore, these are also known as 'suicidal bags of the cell'

3. Apart from intracellular digestion, these are also involved in extracellular digestion. For example, the lysosomal enzymes released from the sperm head helps in dissolving the outer membrane of the oocyte and help in fertilization.

Digestion of worn-out organelles/Cell

The worn-out organelles are engulfed by the lysosomes, where these are digested with the help of lysosomal enzymes. The digested material is returned back to the cytosol for re-use. This process of auto-digestion is termed as 'autophagy'. In this process, the worn out organelles are entrapped in an ER-derived membrane to form 'autophagosome'. This structure then fuses with the membrane of the lysosome, leading to digestion of the organelle inside the lysosome (Explained in chapter 3 necrosis and autophagy, Figure 3.2). The whole cell may also be destroyed with the help of lysosomes. This process of degradation of the entire cell is called 'autolysis'. It generally occurs in certain pathological conditions and is responsible for cell death.

PEROXISOMES

These are small sized organelles, also known as 'microbodies'. They are rich in enzymes called 'oxidases' which oxidize various organic and toxic substances. The oxidation process leads to the formation of hydrogen peroxide (H_2O_2), reactive oxygen species. Catalase enzyme present in the peroxisome neutralizes H_2O_2 to form water and protect the cell from the harmful effects of hydrogen peroxide. The peroxisomes may enlarge in size and ultimately divide to give rise to new peroxisomes. The main function of peroxisome is detoxification of harmful substances using oxidation.

PROTEASOMES

Proteasomes are minute structures and these appear like four rings placed one over the other. These are rich in large number of protein digesting enzymes termed as 'proteases'. Their major function is to degrade proteins which are not required, damaged or faulty. These proteins are disposed/digested with the help of proteases present in the proteasomes. These proteases cleave the proteins into peptides, which are further degraded into amino acids. The resulting amino acids are recycled to produce new proteins. The dysfunction of the proteasomes may cause development of various diseases such as Parkinson disease and Alzheimer's disease.

CYTOSKELETON

1. Cytoskeleton refers to structures that provide support to cell as bones provides support to body. These structures mechanically support the cell and the organelles to help maintain their shape.
2. These are mainly composed of protein filaments that form a network and are present throughout the cytosol. These protein filaments include microfilaments, intermediate filaments and microtubules.

(i) Microfilaments

(a) These have the smallest diameter of all three types of protein filaments. These are mostly found at the cell boundary. They are mainly made up of protein called as 'actin'. The diameter of actin microfilaments is around 7 nm.

(b) Actin is globular proteins. These proteins assemble and form a linear filamentous structure **(Figure 1.6).**

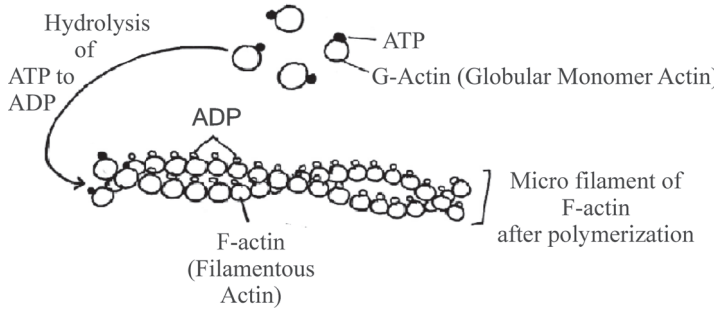

FIGURE 1.6 Structure of microfilaments made up of actin protein

(c) Apart from providing support and shape to cell, microfilaments composed of actin also helps in movement of the cell; contraction of skeletal muscles through actin-myosin interaction, endocytosis, exocytosis and cell division.

(ii) Intermediate filaments (IF)

(a) These have a diameter larger than that of the microfilaments but less than that of microtubules. The diameter of these filaments is around 10 nm.

(b) These are composed of several very strong proteins. They are mainly found in the organelles and regions of the cell, which are exposed to higher mechanical stress

(c) These are various types and some of examples of intermediate filaments include 'keratin' that makes up hair, nails; 'desmin' that

forms sarcomere in skeletal muscles; 'Glial Fibrillary Acidic Protein' (GFAP) that is found in astrocytes; 'peripherin' which is found in peripheral neurons; 'vimentin' which is widely distributed in fibroblasts, leukocytes, and endothelial cells.

(iii) Microtubules

(a) These have the largest diameter (25 nm) amongst all protein filaments. These are also the longest protein filaments.

(b) Microtubules are long, hollow cylinders and made up of α- and β-tubulin proteins. α- and β-tubulin proteins form a dimer. The dimer of α- and β-tubulin proteins polymerize to form microtubules **(Figure 1.7)**.

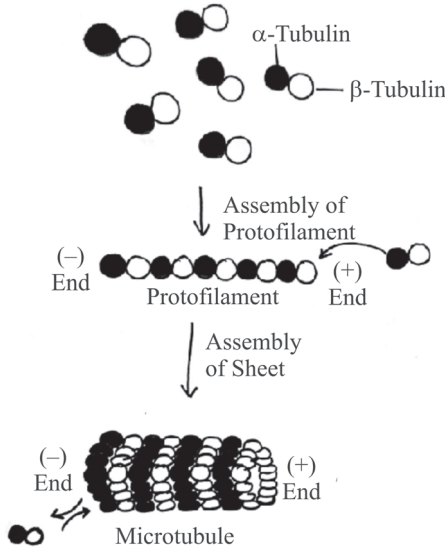

FIGURE 1.7 Structure of Microtubules made of α and β-tubulin proteins

(c) These play an important role in cell division and chromosomes move apart towards two ends through microtubules. Indeed, these are assembled in centrosome, from where they grow towards the boundary of the cell. These are the major constituents of mitotic spindles.

(d) Other functions of microtubules include maintaining the shape of the cell, movement of cell organelles, movement of cilia and flagella and movement of secretory vesicles.

NUCLEUS

1. Nucleus is the center of the cell and it controls all the vital functions of the cell. Therefore, it is one of the most prominent organelles in a cell. The genetic material of cell is present in nucleus.
2. Generally, one nucleus is present in each cell. However, cells composing skeletal muscle contain multiple nuclei, while mature RBCs do not have any.
3. Structurally, nucleus is composed of nuclear membrane, nucleoplasm, nucleolus and chromosomes **(Figure 1.8)**.

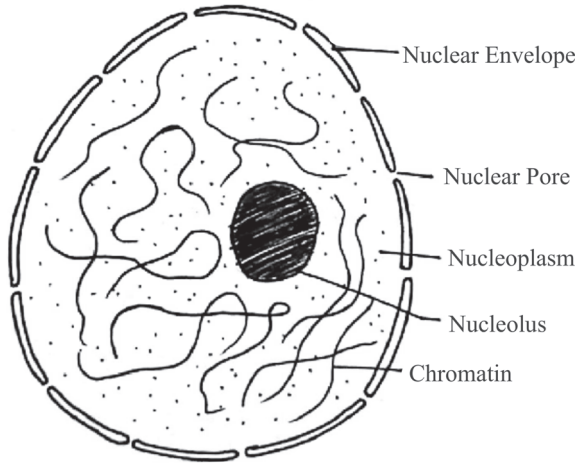

FIGURE 1.8 Structural features of nucleus

4. A nucleus is covered with a double membrane called **'nuclear envelope'** or 'nuclear membrane'. Small perforations are present in the nuclear and these are called as 'nuclear pores'. These pores regulate the movement of different substances in and out of the nucleus. Through the process of diffusion small sized molecules and ions pass through the nuclear pores. While large sized bulky molecules like proteins and RNAs are unable to pass through the small pores of the nuclear membrane by the simple process of diffusion. For their transportation, active process of transportation is used.
5. The nucleus is filled with a jelly like material called **'nucleoplasm'**, which is the site for the chemical reactions taking place inside the nucleus.
6. **'Nucleolus'** is a prominent, dark structure present in nucleus, whose major function is to produce rRNA, which in turn helps in formation of ribosomes. It is composed of proteins, deoxyribonucleic acid (DNA), and ribonucleic

acid (RNA). The cells which need more amounts of proteins have much more prominent nucleoli, for example, cells of muscles and liver.

7. '**Chromosomes'** are thread like structures present in the nucleus. These are more prominent during the process of cell division. In resting state of cell (interphase), chromatin is visualized in nucleus. Indeed, chromosomes are the condensed forms of chromatin. Chromosomes are made up of a long stretch of DNA molecule and histone proteins (explained in chapter 2 genome, Figure 2.1). Humans have 2n number of chromosomes in each cell of the body i.e., 46 chromosomes except in gametes, which contain n number of chromosomes i.e., 23. The chromosomes have specifically arranged sequence on them known as "genes". They are also known as cell's hereditary units and are responsible for transmitting the genetic information from one generation to the next. The compilation of the genetic material carrying the genetic information of an organism is known as genome. The information carried by genes is decoded by a process known as gene expression (explained in chapter 2 genome).
8. The major function of chromosomes include
   (a) These act as a carrier to transfer the genetic information from generation to generation.
   (b) Several proteins are formed from genes present on the DNA by the process known as transcription and translation. This complete process is known as gene expression.

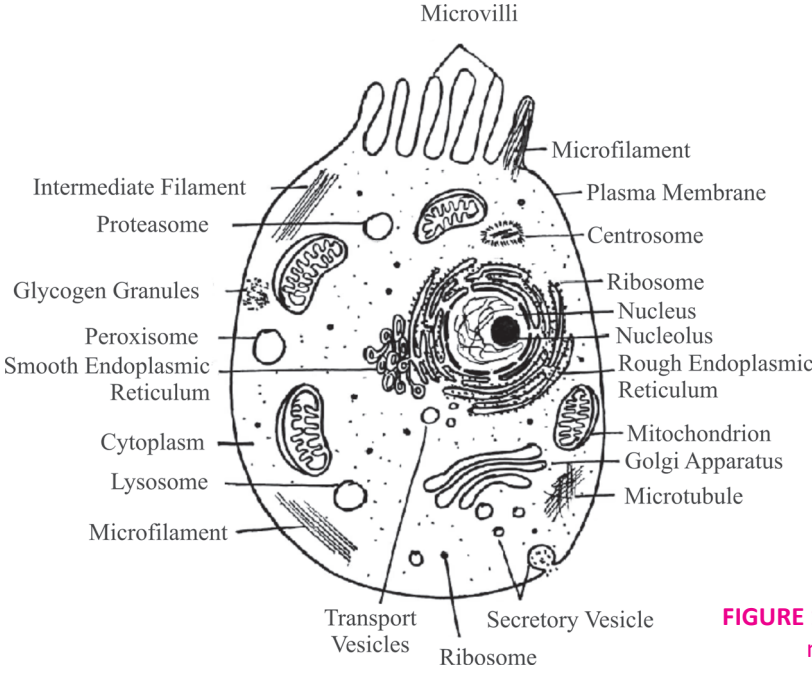

FIGURE 1.9 Typical structure of mammalian cell

TABLE 1.3 Summarized description and functions of different parts of cell

Component of cell	Description of the cell component	Functions performed
Plasma membrane	Flexible semi-permeable membrane covering the cytoplasm. Composed of phospholipids, cholesterol, glycolipids and proteins arranged in the form of fluid mosaic model.	(a) Protection of substances and organelles of the cell (b) Selective regulation of movement of substances to and from the cell (c) Site for receptors, transporters, channels, etc
Cytoplasm	Clear gel like material in between the plasma membrane and nucleus. Composed of cytosol and organelles.	Site for most of the cellular reactions
Cytosol	Intracellular fluid. Composed of different electrolytes, amino acids, glucose, ions, ATP, lipids, fatty acids, waste products and proteins suspended in 75-90% of water.	(a) Have organelles suspended in it (b) Site for many cellular reactions
Organelles	Small specialized components having characteristic structures suspended in the cytosol	Perform all the vital functions of cell
Endoplasmic reticulum	A membranous organelle containing flattened sacs, tubules and vesicles in the form of a network	
RER	Endoplasmic reticulum containing miniscule granular structures called ribosomes embedded in the outer membrane. Therefore, called rough ER.	Production and processing of various proteins
SER	Extension of RER, but lacks ribosomes on its surface. Therefore, called smooth ER.	- Synthesis of fatty acids and steroids - Detoxification of drugs or harmful substances - Storage house for Ca^{2+} ions in the form of sarcoplasmic reticulum

Table 1.3 *Contd...*

Component of cell	Description of the cell component	Functions performed
Ribosomes	Minute spherical factories for the synthesis of proteins. Made up of two subunits, a large and a small. May be attached to the surface of ER as in RER, or independently suspended in the cytosol	(a) Ribosomes on the ER for production of proteins for various processes. (b) Free or independent ribosomes for synthesis of proteins used for certain processes in the cytosol.
Golgi apparatus	Cuplike membranous organelle consisting of tubules, transport vesicles and flattened sac like structures called **cisternae.**	(a) Processing, sorting and packaging of proteins received from the ER (b) Formation of membranous vesicles to transport the modified proteins to the plasma membrane (c) Release of modified proteins into the extracellular fluid via secretory vesicles.
Mitochondria	Sausages like double membranous organelles commonly called "powerhouse of the cell". Inner membrane is folded to form finger like structures called **cristae**.	Generation of ATP via oxidative reactions of aerobic portion of cellular respiration.
Lysosomes	Minute membranous vesicles dispersed throughout the cytosol. Formed by detaching from the Golgi complex. Also called 'suicidal bags of the cell'.	(a) Digestion of foreign particles entering the cell (b) Autophagy of worn out cell organelles (c) Autolysis after death or in certain pathological conditions (d) Extracellular digestion
Peroxisomes	Structurally similar to lysosomes, but smaller in size	(a) Oxidize organic substance (b) Detoxify harmful substances (c) Degradation of hydrogen peroxide
Proteasomes	Structures resembling four rings stacked one on the other	Degradation of cytosolic proteins which are not required anymore, are damaged or faulty

Table 1.3 *Contd...*

Component of cell	Description of the cell component	Functions performed
Cytoskeleton	Protein filaments which form a network covering whole of the cytosol.	Movement of cell, provide mechanical support to cell and organelles, attachment to proteins, define and maintain shape of cell.
Nucleus	Prominent body in cell. Also known as the brain of cell.	Controls all the vital functions of the cell.
Nuclear membrane	Contains small pores called nuclear pores.	Regulate the movement of substances in and out of the nucleus
Nucleoplasm	Jelly like substance inside the nucleus	Site for chemical reactions in nucleus
Nucleolus	A prominent dark structure in the nucleus	Synthesis of rRNA
Chromosomes	Thread like structures present in the nucleus	Transfer of genetic material from one generation to other.

REVIEW QUESTIONS

TWO MARKS QUESTIONS

1. What are the functions of smooth endoplasmic reticulum?
2. What is the role of Golgi apparatus in formation of secretory vesicles?
3. Differentiate smooth and rough endoplasmic reticulum.
4. What are the difference between chromatin and chromosomes?
5. What is the role of glycoproteins on cell membrane?
6. Differentiate intrinsic and extrinsic proteins on cell membrane.
7. What are the functions of ribosomes?
8. What are the functions of mitochondria?
9. What are microtubules? Enlist any two functions of microtubules?
10. Write functions of microfilaments?

FIVE MARKS QUESTIONS

1. Explain fluid mosaic model of plasma membrane structure.
2. Explain the structure of endoplasmic reticulum, including its types and functions
3. Explain different components of nucleus with their functions.
4. What are lysosomes? What are their functions?

TEN MARKS QUESTIONS

1. What do you understand by cytoskeletal system? What are different structures that constitute cytoskeleton? Explain their structure and functions?
2. Draw and label different parts of a mammalian cell? Explain their characteristic structural features along with their functions.

MULTIPLE CHOICE QUESTIONS

1. Which of the following organelles is involved in steroid production?
   (a) SER (b) Peroxisomes
   (c) Microtubules (d) Proteasomes
2. Which of following organelles is involved in autophagy?
   (a) SER (b) Peroxisomes
   (c) Lysosomes (d) Proteasomes
3. Which of following is involved in antigen recognition?
   (a) Phospholipids (b) Cholesterol
   (c) Glycoproteins (d) Intrinsic proteins
4. Which of following is intracellular storage organelle of calcium?
   (a) SER (b) Peroxisomes
   (c) Microtubules (d) Proteasomes
5. Which of following organelles is involved in production of free radicals?
   (a) SER (b) Peroxisomes
   (c) Microtubules (d) Proteasomes
6. Actin is a constituent of following
   (a) Microtubules (b) Microfilaments
   (c) Intermediate filaments (d) None of above
7. The formation of secretory vesicles is a function of
   (a) Golgi Apparatus (b) Peroxisomes
   (c) Lysosomes (d) Proteasomes
8. F_0-F_1 particles are present in
   (a) Golgi Apparatus (b) Mitochondria
   (c) Lysosomes (d) Proteasomes
9. The faulty and degraded proteins are removed by
   (a) Golgi Apparatus (b) Mitochondria
   (c) Lysosomes (d) Proteasomes
10. DNA is present in
    (a) Mitochondria (b) Cytoplasm
    (c) Endoplasmic reticulum (d) Golgi apparatus