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Textbook of Biochemistry & Biophysics for Nurses

As per the Syllabus of Post Basic BSc Nursing of Indian Nursing Council (INC)



Suresh K Sharma

Foreword
Raj Kumar

JAYPEE

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CHAPTER

1

Introduction to Biochemistry and Cell

Suresh K Sharma, Navjot Kaur

Chapter Outline

- Definitions of Biochemistry
- Importance of Biochemistry in Nursing
- Structure of a Cell
- Various Components of a Cell

INTRODUCTION

Nursing is considered as oldest art and youngest science; therefore nursing professionals base their advanced nursing knowledge on the knowledge acquired from the basic sciences such as anatomy, physiology, biochemistry, pathology and so on. Biochemistry is one of the most important basic disciplines in the formation of healthcare professionals, including for nursing. It is concerned with the composition, characterization and transformation of matter. Thus, biochemistry can be defined as a science that tells us about the chemical constituents of the living cell and the reactions and processes that they undergo. Nurses take care of sick patients who cannot care for themselves with varying levels of medical conditions. Therefore, nurses need to be equipped with basic knowledge of biochemistry so that they understand the biochemical basis of disease condition and further understand the changes that occurred in the biochemical constitution of a patient's body during the course of illness so that they can inform about the disease progression and recovery of the patient.

DEFINITIONS OF BIOCHEMISTRY

- Biochemistry can be defined as the science concerned with the chemical basis of life. It is the study of biochemical changes that occur within the human body, during health and disease.
- Biochemistry constitutes the study of the chemistry of biomolecules and metabolic processes which constitute our body and are essential for life.
- Biochemistry is the study of structures and physical properties of biological molecules including protein, carbohydrates, lipids and nucleic acids, the mechanism of enzyme action, the chemical regulation of metabolism, the chemistry of nutrition, the molecular basis of genetics (inherence); the chemistry of vitamins, energy utilization in the cell and the chemistry of the immune response.

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IMPORTANCE OF BIOCHEMISTRY IN NURSING

Biochemistry deals with the chemical basis of living beings including human beings. Nurses are the largest group in healthcare organizations who are directly involved in promotive, preventive, curative and rehabilitative services. Biochemistry is of great use in the field of Nursing, with many practical applications that can assist in becoming a better nurse. Therefore, the study of biochemistry is significantly important for nurses and it facilitates the nurses to:

- **Understand the biochemical basis of health and illness:** With the knowledge of biochemistry, nurses understand the chemical aspects of different biological processes such as digestion, respiration, reproduction, excretion, the behavior of hormones, contraction, and relaxation of muscles, etc. Moreover, nurses will be able to understand that quite a large proportion of disorders have a biochemical basis. In addition, they will learn about:
  - Normal and abnormal biochemical processes and their regulations such as:
    - Composition and functions of fluid and electrolytes in the human body.
    - Enzymes and their role in digestion and absorption of carbohydrates, proteins and fats.
    - Metabolism, storage and catabolism of carbohydrates, proteins and fats.
  - Role of different biochemical processes in the maintenance of health or causation of illness.
  - Good or bad biochemical situations for health-illness continuum.
  - Biochemical factors playing role in an individual's health.
  - Biochemical contribution towards different diseases and disorders.
- **Interpret the biochemical diagnostics test reports:** The knowledge of clinical biochemistry will help the nurses to understand the needs of different biochemical tests and will also be able to interpret the biochemical reports of the patients with different disease conditions. The ability of nurses to interpret the biochemical diagnostic test reports will help them in early identification and prompt action during serious life-threatening situations, which may significantly affect the morbidity outcome among such patients. Therefore, it is essentially important for nurses to study biochemistry; so that they can become active resourceful members of the healthcare team. The common biochemical tests nurses generally encounter and may need to interpret in their day-to-day clinical practices are:
  - Serum electrolytes level
  - Glucose tolerance test
  - Blood sugar levels
  - Plasma protein levels
  - Renal function tests like urea, creatinine
  - Serum cholesterol and lipid profile
  - Serum enzyme levels such as amylase, lipase, etc.
  - Serum hormonal analysis such as TSH, T3, T4, and other hormones.
- **Contributes towards health promotion with biochemical aspect:** There are several biochemical tests that are carried out for screening purposes or to identify the risk of certain life-threatening illness such as cardiovascular diseases. For example, if a nurse is aware that increased level of serum cholesterol and lipid profile has a risk of cardiovascular disorders, then she may educate the people about maintaining the serum lipid level within the normal limits through dietary modification, regular exercises and medicines; so that future risk of coronary artery disease may be minimized. Thus through learning biochemistry, nurses may contribute towards health promotion with biochemical aspect.
- **Carryout effective assessment and planning for nursing needs:** It is the most essential function of a nurse to identify the priority needs of the patients. This may be further facilitated by the basic knowledge of biochemistry. For example, a nurse is assessing a diabetic patient

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admitted to the medical ward, her biochemistry knowledge facilitates her to interpret biochemical test reports such as blood sugar level that will help her in the identification of the nutritional needs of the patient and plan nursing interventions accordingly.

- **Implement the health education based on biochemical rationalization:** Health education is also one of the important roles of nurses; with knowledge of biochemistry, nurses will be able to understand the biochemical basis of illness and offer health education to clients based on biochemical rationalization when and where required so that their client can be more convinced and clear about their illness, treatment and prevention.

STRUCTURE OF A CELL

Introduction

The cell, discovered by Robert Hooke in 1665, is a basic, living, structural and functional unit of the body. They are often called the building block of life. "Cell is the structural and functional unit of all living organisms". Human body cells are of different types, sizes and shapes such as muscle cells, bone and cartilage cells, nerve cells, visual cells in the eye, etc. Division of work and distribution of various functions is the hallmark of a multicellular organism. The work assignment begins at the subcellular level and extends to the organ and tissue systems.

Types of Cells

Some organisms are unicellular such as bacteria, while some are multicellular, e.g., human cells are of many types. On the basis of structural differences, cells are divided as eukaryotes and prokaryotes **(Table 1.1)**. Prokaryotes are simple and usually independent cells, while eukaryotes are often found in multicellular organisms.

- **Prokaryotic cells:** The most primitive cell structure where there is an absence of nuclear membrane, nucleolus and membrane-bound organelles. The genetic material in them is stored in the form of nucleoids, found freely distributed in the cytoplasm. Generally, this genetic material is made-up of one or more folded DNA strands without the presence of histone proteins. The bacteria, viruses and some of the fungi are good examples of prokaryotic cells, which are significant in health sciences.
- **Eukaryotic cells:** It is the most advanced cell with well-developed nucleus with nucleic membrane, nucleolus and genetic material in the form of chromosomes. These cells are found in the higher organism such as human beings. Structurally and functionally eukaryotic cells are larger in size, advanced, developed and complex **(Fig. 1.1)**.

VARIOUS COMPONENTS OF A CELL

The cells are too small to be seen with naked eyes. However, a microscope is used to view a cell and its components after staining with appropriate dyes. Cell and its components absorb the dye and their structure and size may be clearly differentiated using a microscope. A typical eukaryotic cell consists of the following components:

- **Plasma membrane:** Outer, limiting membrane separating the cell's internal components from the extracellular materials and external environment.
- **Cytosol:** The thick intracellular fluid is termed cytosol. The cytosol contains many dissolved proteins and enzymes, nutrients, ions and other small molecules, which all participate in various phases of metabolism. Organelles and inclusions are suspended in the cytosol.
  - The term cytoplasm includes cytosol, all organelles (except nucleus) and inclusions.
- **Organelles:** Highly organized structures with characteristic shapes that are specialized for specific cellular activities. The organelle with the largest volume is the nucleus, which contains

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Table 1.1: Difference between prokaryotic and eukaryotic cells.

Features	*Prokaryotic cells*	*Eukaryotic cells*
Cell size	Size of prokaryotic cell varies between 0.1 and 10 micron in diameter	Typically eukaryotic cell is between 10 and 100 micron in diameter
Cell membrane	Prokaryotic cells are covered by a cell envelop, which generally is made-up of muramic acid.	Eukaryotic cells are covered with a complex structure cell wall made-up of phospholipids, glycolipid, cholesterol and proteins.
Cell wall appendages	Simple structured flagella are present on cell envelop, which are not differentiated into axoneme and sheath.	Complex structure flagella, cilia and microvilli are present on cell wall. Flagella if present are differentiated into axoneme and sheath.
Nucleus	Nucleus is not present, no nucleic membrane and nucleolus; simple chromosomes are directly suspended in cytoplasm.	Most of the cells have a nucleus, which is covered with double layered nucleic membrane, complex-structured chromosomes and nucleolus is present in nucleus.
Genetic material	Simple structure chromosomes without presence of histone proteins.	Complex structure chromosomes are presented associated with histone proteins.
Cytoplasm and cell components	Cytoplasm is present without major cell components such as mitochondria, endoplasmic reticulum, etc.	Cytoplasm is present and most of the cells contain major cell components such as mitochondria, endoplasmic reticulum, etc.
Ribosomes	Cell contains ribosomes of only one size.	Cell contains two types of ribosomes, one in cytoplasm and smaller type is in mitochondria.
Cell division	Cell division does not involve meiosis; reproduce sexually by the transfer of DNA fragments through conjugation. They are generally fast-multiplying cells	Cell division involves mitosis and meiosis and relatively slow multiplying but versatile

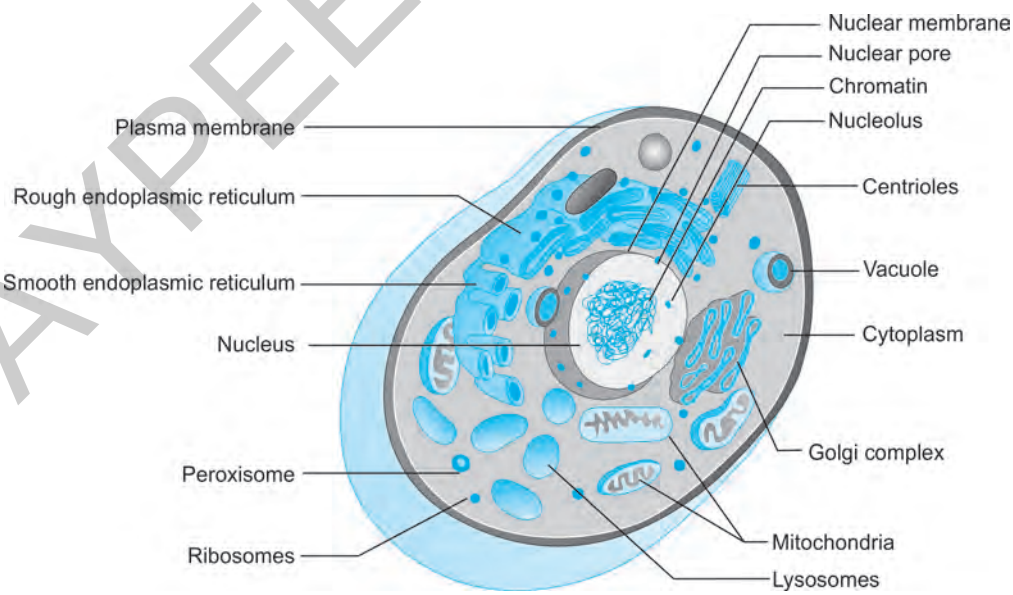

Fig. 1.1: Basic structure and components of an eukaryotic cell.

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most of the cell genetic material. The other major organelles are mitochondria, endoplasmic reticulum, golgi apparatus, lysosomes, ribosomes and vacuoles and peroxisomes.

- **Inclusions:** These are the temporary structures in the cytoplasm that contain secretions and storage products of the cell.

Plasma Membrane

The plasma membrane is the gatekeeper that regulates the passage of substances into and out of the cell. In other words, the plasma membrane is a lipid bilayer of phospholipids that separate the cytoplasm from the environment. Within the phospholipid bilayer, cholesterol, glycolipids, proteins and glycoproteins are interseparated **(Fig. 1.2)**. The structure of the plasma membrane can be explained with the help of *Fluid Mosaic Model.*

The **fluid mosaic model** of membrane structure describes the molecular arrangement of the plasma membrane and other membranes in living organisms. A mosaic is a pattern of many small pieces fitted together. According to this model, the membrane is a mosaic of proteins floating like icebergs in a sea of lipids.

Plasma membrane like the other membranes is composed of lipids and proteins. These two major components arrange themselves in a manner to form plasma membrane. There are the following three *types of lipids* involved in the formation of the plasma membrane.

- ***Phospholipids:*** About 75% of the lipids are phospholipids that contain phosphorus.
  - Phospholipids are arranged in two parallel layers forming a phospholipid bilayer. So, this model is also known as the phospholipid bilayer model. This arrangement occurs because phospholipids are amphipathic in nature, each molecule consisting of polar and nonpolar regions. The polar part is the phosphate-containing "head", which is hydrophilic and the nonpolar parts are two fatty acid "tails", which are hydrophobic. The head faces outward on either side, towards the watery cytosol and extracellular fluid.
- ***Glycolipid:*** About 5% of lipids are gycolipids with attached sugar groups. Glycolipids are also amphipathic in nature. They only appear in the layer that faces extracellular fluid (ECF).
- ***Cholesterol:*** The remaining 20% of plasma membrane lipids are cholesterol molecules, which are located among the phospholipid in animal cells. However, plant cells lack cholesterol in the cell membrane.

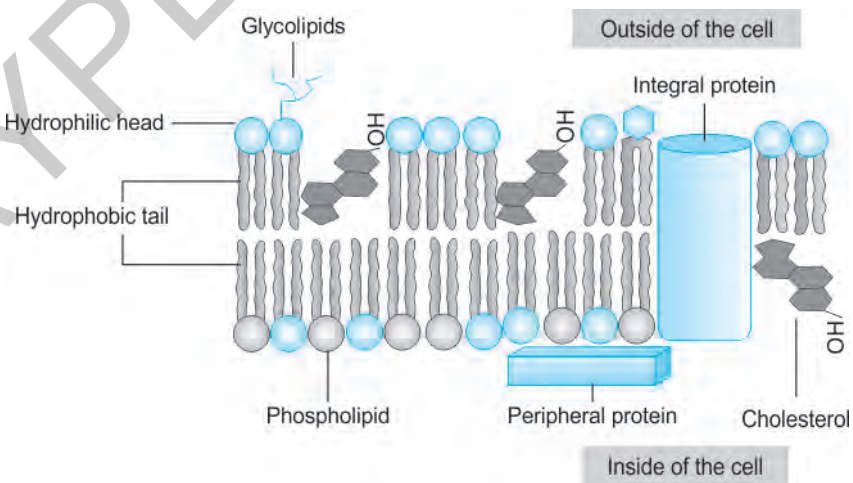

Fig. 1.2: Basic structure of plasma membrane.

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The plasma membrane also contains two types of proteins; which are discussed as follows:

- ***Integral proteins:*** These are extended across the phospholipid bilayer among the fatty acids tails. The most integral proteins are glycoproteins, which are proteins with attached sugar groups.
- ***Peripheral proteins:*** These are proteins that do not extend across the phospholipid bilayer. They are loosely attached to the inner and outer surfaces of the membrane and are easily separated.

The molecular composition of plasma membranes also differs from tissue to tissue and this change in the composition is partly, responsible for the functional differences in the tissues.

Appendages of Plasma Membrane

Following are the main appendages of a plasma membrane, i.e., cilia, flagellum and microvilli, etc.

- ***Cilia:*** These are the extensions of the plasma membrane containing parallel microtubules, 10 micrometers in length. The main function of the cilia is to move materials over the surface of the cells.
- ***Flagellum:*** These are the extensions of the plasma membrane containing parallel microtubules, 55 micrometers in length. In human cells, flagella are responsible for the movement of spermatozoa.
- ***Microvilli:*** These are the extensions of the plasma membrane containing microfilaments. The main functions of the microvilli are to increase the surface area of the plasma membrane for absorption and secretion and modified to form sensory receptors.

Functions of Plasma Membrane

Following are the major functions of the plasma membrane of a cell:

- ***Semipermeable:*** The plasma membrane regulates the entry and exit of materials inside the cell. It permits the passage of certain substances and restricts the passage of others. This property of membrane is known as "selective permeability."
- ***Receptor:*** The plasma membrane proteins can identify and attach to a specific molecule such as hormones, neurotransmitters or a nutrient that is important for some cellular function.
- ***Communication:*** The plasma membrane functions in cellular communication. This includes interactions with the other body cells, foreign cells, hormones, neurotransmitters, enzymes, nutrients and antibodies in extracellular fluid.
- ***Electrochemical gradient:*** The membrane maintains an electrical and chemical gradient, called an electrochemical gradient, between the inside and outside the cell. The electrochemical gradient and the resulting membrane potential are important for the proper functioning of most cells.
- ***Physical barrier:*** The plasma membrane surrounds all cells and physically separates the cytoplasm, from the extracellular fluid outside the cell. This protects all the components of the cell from the outside environment and allows separate activities to occur inside and outside the cell. The plasma membrane provides structural support to the cell. It tethers the cytoskeleton, which is a network of protein filaments inside the cell that hold all the parts of the cell in place. This gives the cell its shape.
- ***Endocytosis and exocytosis:*** Endocytosis is when a cell ingests relatively larger contents than the single ions or molecules that pass through channels. Through endocytosis, a cell can take in large quantities of molecules or even whole bacteria from the extracellular fluid. Exocytosis is when the cell releases these materials. The cell membrane plays an important role in both of these processes. The shape of the membrane itself changes to allow molecules to enter or exit the cell.

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Cytosol

Chemically, cytosol is 75–90% water plus solid components. Proteins, carbohydrates, lipids and inorganic substances comprise most of the solids. Inorganic substances and smaller organic substances, such as simple sugars and amino acids are soluble in water and are present as solutes. Larger organic compounds like proteins, polysaccharides, glycogen, are found as colloid particles that remain suspended in the surrounding medium although they are not dissolved. The colloids bear electrical charges that repel each other and thus remain suspended and separated.

The cytosol contains enzymes that catalyze catabolic and anabolic reactions, ATP is produced in glycolysis reactions.

Organelles

The main organelles present in the cell are nucleus, endoplasmic reticulum, Golgi complex, mitochondria, ribosomes, lysosomes, peroxisomes, centrioles, and spindle fibers, etc.

1. Nucleus

It occupies a central position in the cell. It is spherical or oval and much denser than the cytoplasm. It is the governing organelle of the cell that controls the functions, growth, and multiplication of the cell. It is generally situated in center of the cell, covered with a double-layered membrane called a nuclear membrane and contains chromosomes, nucleoplasm and nucleolus. Chromosomes carry the genetic material of the cell and nucleolus serves as a site for ribosome synthesis.

Most of the cells contain a single nucleus, but few may have more such as some of the liver cells have more than one nucleus and long muscle cells do have hundreds of nuclei. However, red cell during their maturation lose their nucleus.

The main parts of the nucleus are **(Fig. 1.3)**:

- ***Nuclear membrane:*** It is a double membrane enclosing the nucleus. The outer membrane is continuous with the endoplasmic reticulum; nuclear pores extend through the nuclear envelope. The nuclear membrane helps to maintain the shape of the nucleus and assists in regulating the flow of molecule including RNA into and out of the nucleus through nuclear pores.
- ***Chromatin:*** The mass of DNA and proteins inside a chromosome is referred to as chromatin. Thin strands of DNA, histones and other proteins condenses to form chromosomes during cell division.

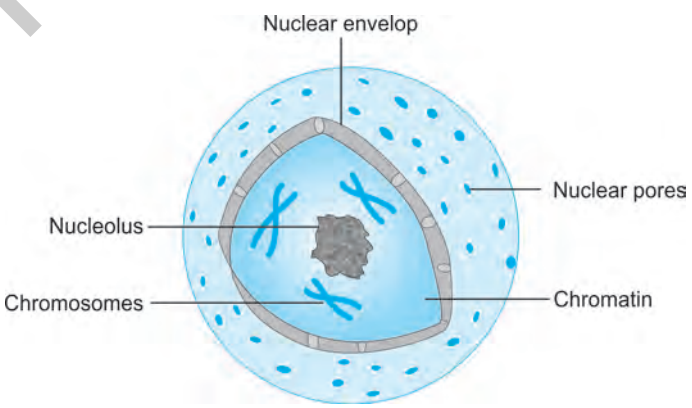

Fig. 1.3: Structure of nucleus.

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- ***Nucleolus:*** When a nucleus is not dividing, a structure called a nucleolus becomes visible which is the most prominent structure within the nucleus. Usually there is only a single nucleolus present, but some nuclei have multiple nucleoli. It is a mass of granules and fibers attached to chromatin. It consists of ribosomal RNA and proteins and the nucleolus serves as a site for ribosome synthesis.

Functions of Nucleus

Following are the main functions of the nucleus in a cell:

- It is the seat of all metabolic activities of the cell.
- The nuclear membrane helps in separating the nucleus from the cytoplasm and regulates the movement of material into and out of the nuc leus.
- All cells in the human body contain a nucleus except mature RBCs in circulation.
- The nucleus contains DNA, the chemical basis of the genes, which governs all the functions of the cell. It contains the cell's hereditary information and controls the cell's growth and reproduction.
- DNA replication and RNA synthesis are taking place inside the nucleus.
- The nucleolus is the area for RNA processing and ribosome synthesis.

2. Endoplasmic Reticulum

It is a network of tubular channels traversing the cytosol. The individual tubules are called as cisterns which vary in size, shape and connectivity with various subcellular organelles. Endoplasmic reticulum is connected to the plasma membrane and surrounds the nucleus and other organelles **(Fig. 1.4)**. On the basis of appearance as well as function, the endoplasmic recticulum can be divided into:

- ***Rough endoplasmic reticulum:*** It is also known as granular endoplasmic reticulum. These are studded with ribosomes on its outer surface. The rough endoplasmic reticulum is involved in active protein synthesis with the help of ribosomes, synthesizes secretory proteins like digestive enzymes, protein sorting and initial post-translational modification such as glycosylation, sulfation, phosphorylation and hydroxylation of proteins and also

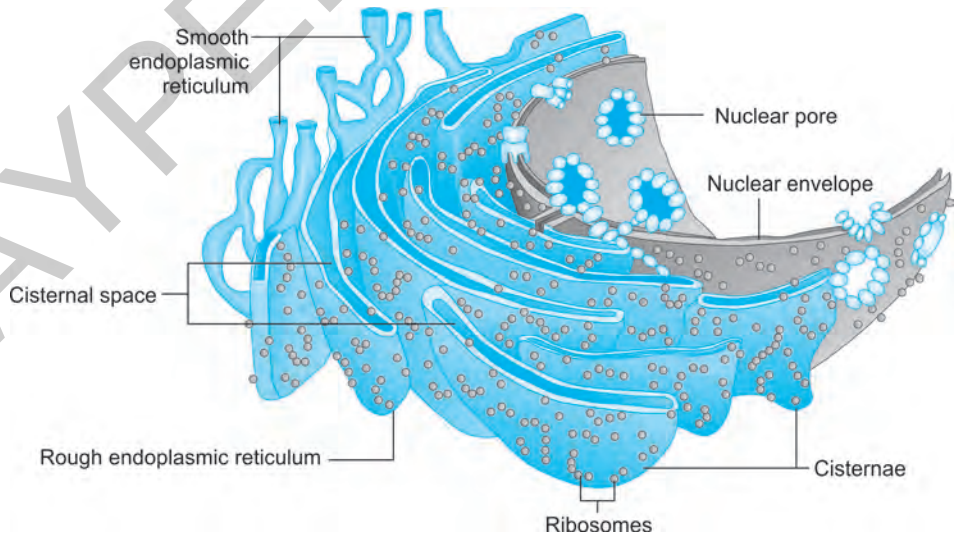

Fig. 1. 4: Structure of endoplasmic reticulum.

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the synthesis of phospholipids. Protein sorting involves several factors and a sequence of events.

- ***Smooth endoplasmic reticulum:*** It is also known as the agranular endoplasmic reticulum. These are not studded with ribosomes on their outer surface. The smooth endoplasmic reticulum is found abundant in cells. The smooth ER has a wide range of functions including carbohydrate and lipid synthesis. It serves as a transitional area for vesicles that transport ER products to various destinations. In liver cells, the smooth ER produces enzymes that help to detoxify certain compounds and foreign substances like drugs and toxins and glycogen metabolism. In muscle cells, it stores calcium that assists in the contraction of muscle cells. In the adrenal cortex and gonad cells, it synthesizes steroid hormones. It is also involved in lipid metabolism and membrane formation. It carries enzymes for the modification of proteins synthesized in the rough endoplasmic reticulum.

Functions of Endoplasmic Reticulum

Following are the main functions of endoplasmic reticulum:

- Ribosomes associated with the rough ER synthesize proteins destined for insertion into the plasma or export from the cell.
- Rough ER serves as a temporary storage area for newly synthesized molecules and may add sugar groups to certain proteins, thus forming glycoproteins.
  Smooth ER is the site of fatty acid, phospholipid and steroid synthesis. It is also responsible for the metabolism of carbohydrates.
- Also within certain cells, enzymes within the smooth ER can inactivate or detoxify a variety of chemicals, including alcohol, pesticides and carcinogens. The endoplasmic reticulum is also considered a cell skeletal system and helps to keep cell organelle in position. The smooth ER stores and releases calcium ions. These are quite important for the nervous system and muscular systems.
- The endoplasmic reticulum also helps in the formation of vacuoles.

3. Golgi Complex

It is derived from endoplasmic reticulum. It is an organelle located near the nucleus. It consists of flattened sacs called cisterns. Associated with the cisterns are small golgi visicles, which cluster along the expanded edges of cisterns **(Fig. 1.5)**. The golgi complex can be divided into three regions:-

a. **Proximal or cis region:** This is the immediate extension of the endoplsmic reticulum and receives proteins synthesized from it.
b. **Medial region:** Most of the post-translational modifications of synthesized proteins take place in this region.
c. **Distal or trans region:** This region of the golgi apparatus is primarily associated with secretory activity.

Functions of Golgi Complex

- Golgi complex processes, sorts, packages and delivers proteins and lipids to the plasma membrane and forms lysosomes and secretory vesicles.
- As mentioned above the primary function of golgi complex is the formation of secretory vesicles and lysosomes.
- Golgi complex helps the endocrine cells in the secretion of hormones.
- It is also involved in the formation of acrosomes, during the maturation of sperms.
- Golgi complex also activates mitochondria to produce ATP.
- It also helps in the modification of proteins by adding certain prosthetic groups.

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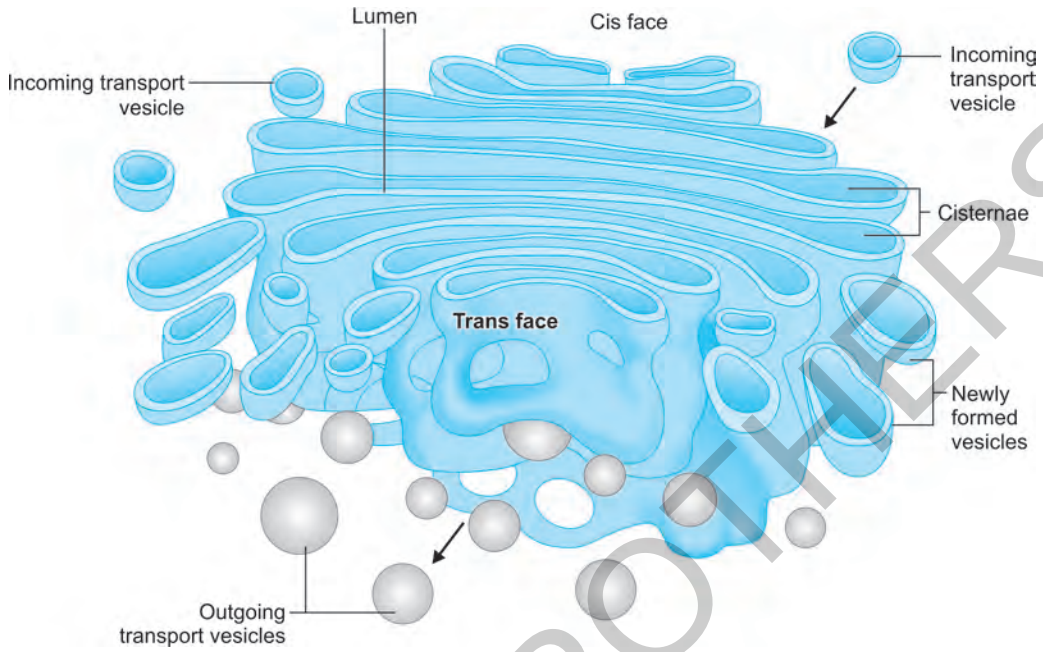

Fig. 1.5: Structure of golgi complex.

- Golgi complex also helps in the regulation of cellular fluid balance by expelling extra fluid from the cell.

4. Mitochondria

It is known as the "powerhouse" of the cell. A typical mammalian cell carries between 800 and 2500 mitochondria. The highest number of mitochondria is found in neurons and muscle cells. About 10% of body weight of a human adult is mitochondria. Mitochondria consist of two membranes, each of which is similar in structure to plasma membrane: (a) outer mitochondrial membrane which is smooth and (b) inner mitochondrial membrane which is arranged in series of folds called cristae. The central cavity of mitochondria, enclosed by the inner membrane and cristae is called the matrix. The mitochondrial membrane divides the mitochondria into two chambers **(Fig. 1.6)**:

- ***Outer chamber:*** The outer chamber is formed between outer smooth membrane and inner mitochondrial membrane, which is arranged in series of folds. It is lipid-rich membrane composed of phospholipids and cholesterol.
- ***Inner chamber:*** The inner chamber is formed by the inner membrane, which is arranged in a series of folds named as matrix. This inner chamber contains semifluid matrix. It is a protein-rich membrane with a protein: lipid ratio is about 3.7: 1. The matrix has protein particles, ribosomes, RNA, DNA, enzymes of Krebs cycle, amino acid synthesis and fatty acid metabolism, etc.

Functions of Mitochondria

Following are the main functions of the mitochondria:

- It is the main site for the generation of ATP.

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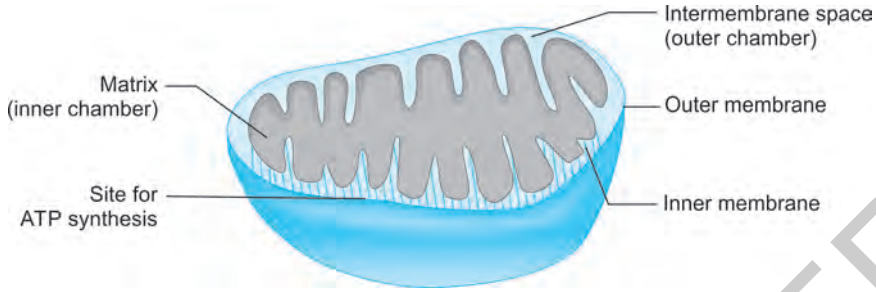

Fig. 1.6: Structure of mitochondria.

- The elaborated folds of the cristae provide an enormous surface area for a series of chemical reactions, known as "cellular respiration", which provides most of a cell's ATP. Enzymes that catalyze these reactions are located in the matrix and on the cristae.
- Active cells such as muscles, liver and renal tubule, have a large number of mitochondria and use ATP at a high rate.
- Mitochondria self-replicate, they divide to increase in number. Their replication is controlled by the genes within the mitochondria. Self-replication usually occurs in response to the increased cellular need for ATP and at the time of cell division.
- Mitochondrial matrix contains various enzymes for the synthesis of fatty acids.
- Cell death, also called apoptosis, is an essential part of life. As cells become old or broken, they have cleared away and destroyed. Mitochondria help decide which cells are destroyed.
- Mitochondria help in storing calcium by quickly absorbing calcium ions and holding them until they are needed.
- Mitochondria can generate heat to keep the body warm through non-shivering thermogenesis.

5. Ribosomes

Ribosomes are tiny granules that contain ribosomal RNA (rRNA) and many ribosomal proteins. Structurally, ribosome consists of two subunits, one about half the size of the other **(Fig. 1.7)**. They are made up of ribonucleic acid and protein, so-called ribonucleoprotein particles. Ribosomes are popularly known as 'protein factories'. They produce proteins from amino acids through the process called 'translation'. Ribosomes have four sites that help in protein synthesis, i.e., (a) mRNA-binding site, (b) A (Aminoacyl) site, (c) P (Peptidyl) site (d) E (Exit) site.

Some ribosomes called 'Free Ribosomes' float in the cytosol, they have no attachments to other organelles. The free ribosomes occur singly or in clusters. Other ribosomes attach to a cellular structure called the endoplasmic reticulum. Further ribosomes may occur singly as monosomes or in groups named polyribosomes.

Types of Ribosomes

Based on the size and sedimentation coefficient, ribosomes are classified into two main types:

1. ***70S Ribosomes:*** These are smaller in size and found in prokaryotic cells, mitochondria and chloroplast of eukaryotic cells. 70S ribosome consists of large (50S) and smaller (30S) subunits.
2. ***80S Ribosomes:*** These ribosomes are larger in size and found in eukaryotic cells. They consist of larger (60S) and smaller (40S) subunits. A tunnel occurs between the larger and smaller subunit for the passage of mRNA during protein synthesis.

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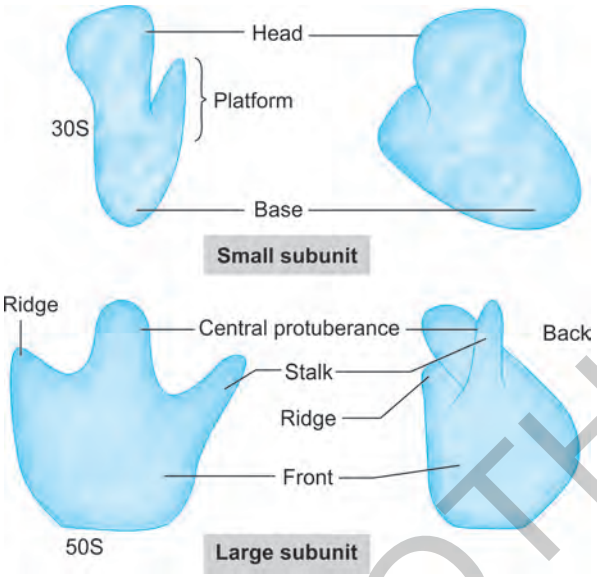

Fig. 1.7: Structure of ribosome.

Functions of Ribosome

- The main function of the ribosomes is the sites of protein synthesis. They assemble amino acids to form proteins that are essential to carry out cellular functions.
- The ribosomes contain rRNAs for providing attaching points to mRNA and tRNAs.

6. Lysosomes

They are membrane-enclosed vesicles that form in the golgi complex. They originate by budding off from the membrane of the trans-golgi network. They are tiny sac-like granules bounded by a single membrane containing hydrolytic enzymes in it. They are also known as 'Suicide Bags' because of a number of digestive enzymes in them. Lysosomes contain as many as 40 kinds of powerful digestive enzymes capable of breaking down a wide variety of molecules. The structure and functions of the lysosome are depicted in **Fig. 1.8**.

Functional Polymorphism of Lysososome

On functional basis lysosomes at different stages present with polymorphism and these functional stages of polymorphism are of three types, i.e., primary lysosomes, secondary lysosomes and residual bodies.

- *The primary lysosome:* They are small size tiny sac-like bodies bounded by a single membrane containing many hydrolytic enzymes and popularly known as storage granules. They are present in silent form but ready to act whenever the need for autodigestion within the cell is desired.
- *The secondary lysosomes:* They are active digestive vacuoles containing the foreign material and enzymes within the membrane for the auto-digestion. When a liquid foreign material is ingested in these vacuoles for the auto-digestion process of cells, they are known as pinosomes and the process is called pinocytosis or cell drinking. On another hand when a solid foreign material is ingested in these vacuoles for the auto-digestion process of the cell, they are known as phagosomes and the process is called phagocytosis or cell eating.

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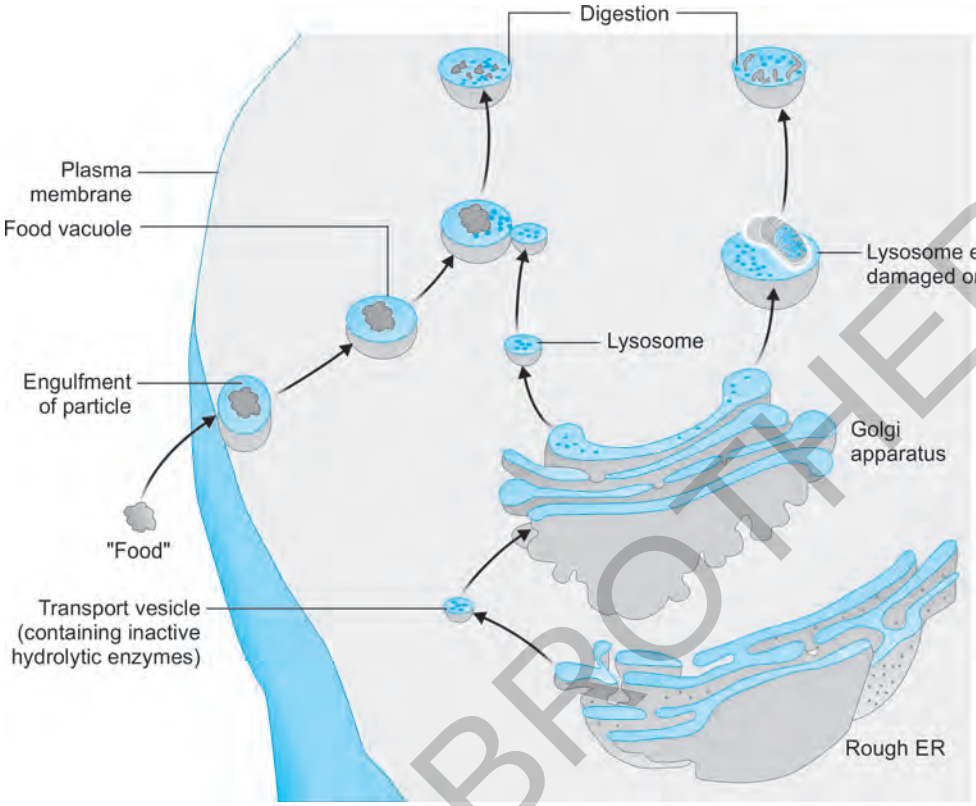

Fig. 1.8: Illustration depicting structure and functions of lysosome.

- *The residual body:* After the process of pinocytosis or phagocytosis, an undigested material is left in the cell. A residual body of lysosomes is formed which attach to the plasma membrane and are thrown out of the cell by ephagy.

Functions of Lysosomes

- Lysosomal enzymes digest bacteria and other substances that enter the cell in phagocytic vesicles during phagocytosis, pinocytic vesicles during pinocytosis.
- Lysosomes take part in the natural defence of the body.
- They also help in breaking down of the aging cells and dead cells. Therefore, they are involved in programmed cell death.
- Lysosomes also help in intracellular scavenging by removing old or useless organelles.

7. Peroxisomes

These are single membrane-bound organelles found free in the cytosol. They are similar in structure to lysosomes but smaller in size. They are so named because they usually contain one or more enzymes that use molecular oxygen to oxidize (remove hydrogen atoms from) various organic substances. Perxisomes are minute, somewhat spherical and single unit membrane particles with diameter varying from 0.5 to 1.0 μm **(Fig. 1.9)**. The shape and size is variable from cell to cell. They are present in abundant numbers in parenchyma of liver and kidney.

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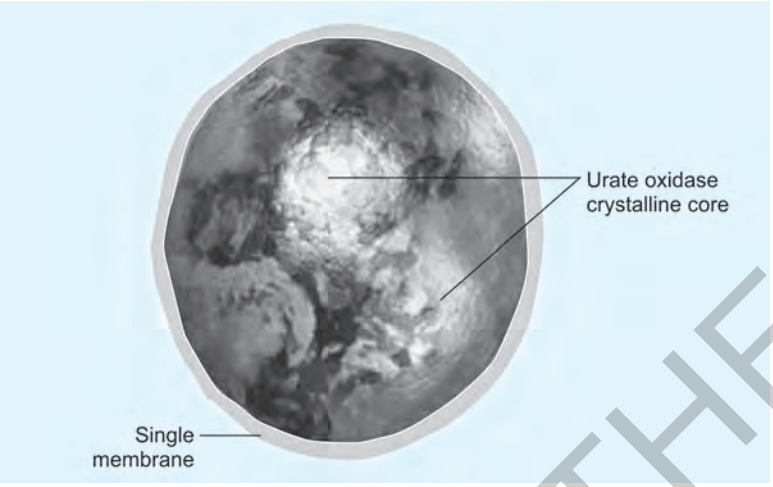

Fig. 1.9: Structure of peroxisomes.

Functions of Peroxisomes

- They detoxify harmful molecules such as ethanol, phenols, formic acid, etc.
- They contain oxidase and catalase that helps in oxidation and removal of hydrogen peroxide.
- The chief function is to help in the metabolism of glycolate during photosynthesis.
- The long-chain and branched fatty acids are catabolized by peroxisomes.
- The substances which cannot be catabolized by normal enzymes are generally catabolized by peroxisomes.

8. Centrioles

These are the pair of cylindrical organelles in the centrosome, consisting of triplets of parallel microtubules **(Fig. 1.10)**. These are made of tubulin protein. These are located very close to the nucleus of the cell.

Functions of Centrioles

Following are the main functions of the centrioles:

- It is the center for microtubule formation.
- The main function of centriole is to help with cell division. It determines cell polarity during cell division.
- The centrioles also help in the formation of the spindle fibers that separate the chromosomes during cell division (mitosis).
- It forms the basal bodies of cilia and flagella.

9. Spindle Fibers

These are the microtubules extending between the two centrosomes, where chromosomes are arranged at middle of the cell during a cell division, which are called spindle fibers **(Fig. 1.11)**. Spindle fibers only appear during cell division; therefore, they cannot be seen during time other than cell division. Spindle fibers form a protein structure that divides the genetic material in a cell. The spindle is necessary to equally divide the chromosomes in a parental cell into two daughter cells during both types of nuclear division: mitosis and meiosis. During mitosis, the

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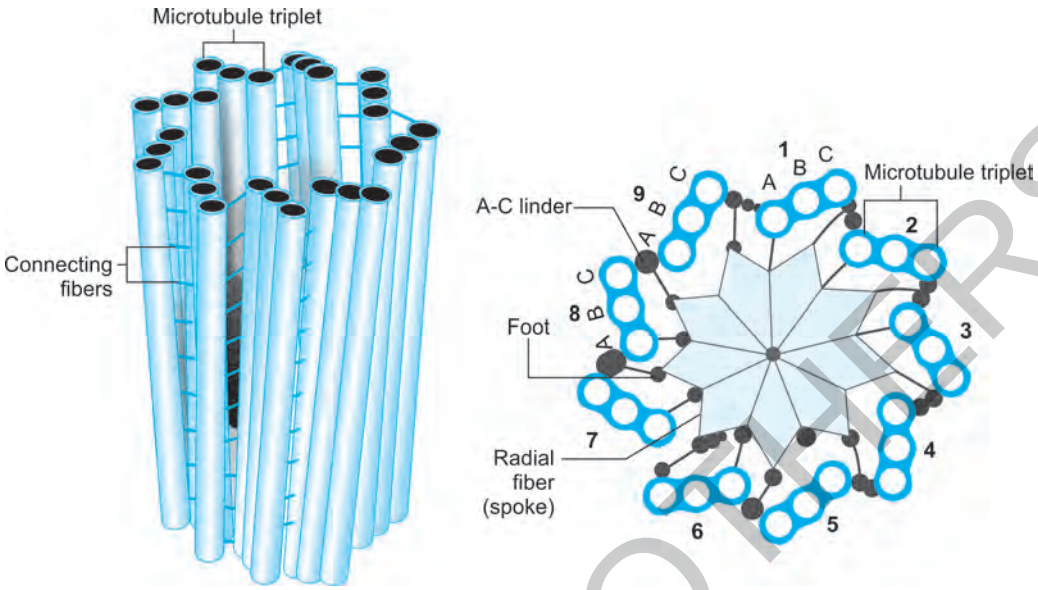

Fig. 1.10: Structure of centrioles.

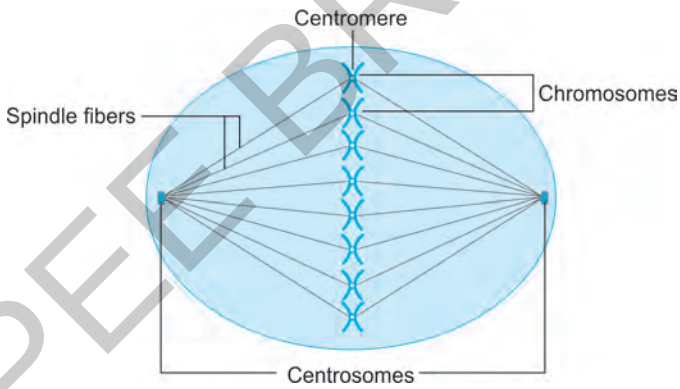

Fig. 1.11: A cell division depicting appearance of spindle fibers.

spindle fibers are called the mitotic spindle. Meanwhile, during meiosis, the spindle fibers are referred to as the meiotic spindle.

Functions of Spindle Fibers

- These assist in the separation of chromosomes during cell division. Spindle fibers help in the division of genetic component of the cell during division.
- Spindle fibers get attached to kinetochores and arms of chromosomes and help in the segregation and movement of chromatids.
- During metaphase, chromosomes get aligned in the middle with the help of the spindle and then move to the opposite poles during the anaphase stage.

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