Unit 03

Cells and Subcellular Organelles

STUDENTS LEARNING OUTCOMES (SLO's)

After studying this unit, the students will be able to

- Describe that cells are the basic unit of life with respect to seven properties of life (movement, respiration, homeostasis, growth, reproduction, excretion, nutrition).
- State cell theory (including how to validate it and exceptions to it).
- Compare and contrast the workings of a light microscope and electron microscope with focus on resolution and magnification and live vs dead samples.
- Identify the ultrastructure of animal and plant cells.
- Describe the structure and functions of cell wall, cell membrane and subcellular organelles (endoplasmic reticulum, ribosomes Golgi apparatus, vesicles, lysosomes, peroxisome, vacuoles, mitochondria, plastids, centrioles, nucleus)
- Differentiate between prokaryotic and eukaryotic cells with diagrams.
- Explain the structure of the cell membrane and the techniques that can be used to study it.
- Define cell signalling.
- Discuss the pathway of a signal from outside the cell to the inside. (protein signal and steroid signal).
- Explain the 4 membrane transport mechanisms with diagrams (simple diffusion, facilitated diffusion, osmosis, active transport).
- Describe endocytosis and exocytosis with diagrams.
- Compare and contrast simple and facilitated diffusion.
- Define stem cells and advantages of using stem cells
- Categorize different types of stem cells.
- Evaluate the advantages and disadvantages of using induced Pluripotent Stem Cells.

INTRODUCTION

Every living being is composed of cells. Cells are the basic unit of life because they form the structural and functional foundation of all living organisms.

In unicellular organisms such as amoebas and bacteria, a single cell is capable of carrying out all the essential functions necessary for life, including:

a. Movement
b. Respiration
c. Nutrition
d. Excretion
e. Growth
f. Reproduction
g. Maintaining internal stability (homeostasis)

These organisms depend on that one cell to sustain life. In multicellular organisms like plants and animals, numerous cells work together in a highly organized manner. These cells are specialized to perform particular tasks, such as transporting nutrients, generating energy and defending the body. Each cell contributes to the survival and proper functioning of the entire organism. Therefore, cells are rightly considered the basic unit of life because they perform all the vital activities that define living organisms.

3.1 CELLS-THE BASIC UNIT OF LIFE

1. Describe the seven basic properties of life and explain how these are performed at the cellular level.

Ans. All living organisms exhibit seven basic properties of life: movement, respiration, homeostasis, growth, reproduction, excretion, and nutrition. These properties not only define life but are also performed at the cellular level. Here's how each property functions through cells:

1. **Movement**:
   Cells can move in various ways. For example, sperm cells move using whip-like structures called flagella. White blood cells move through the bloodstream to fight infections. Even within cells, organelles shift positions to fulfill specific tasks, indicating that movement is an essential cellular activity.
2. **Nutrition**:
   Cells absorb nutrients from their surroundings. These nutrients are vital for producing energy, building cellular components, and facilitating various biochemical reactions essential for survival and development.
3. **Respiration**:
   Respiration is the process through which cells generate energy. By breaking down glucose molecules, cells release ATP (adenosine triphosphate), which is the primary energy currency of the cell. This energy powers all cellular processes.
4. **Excretion**:
   Cells produce waste as a byproduct of their metabolic activities. To prevent the accumulation of these toxic substances, cells expel waste materials through processes like diffusion and active transport.
5. **Homeostasis**: Cells maintain internal stability, or homeostasis, by regulating the movement of substances such as ions, water, and nutrients across their membranes. This ensures that the internal environment remains stable and balanced.
6. **Growth**:
   Cellular growth occurs when cells absorb nutrients and convert them into structural and functional components. As these components accumulate, the cell increases in size and becomes more complex.
7. **Reproduction**:
   Cells reproduce in two primary ways: mitosis and meiosis. Mitosis results in the formation of two identical daughter cells, used for growth, development, and tissue repair. Meiosis, on the other hand, is used in the production of gametes (sperm and egg cells) for sexual reproduction, ensuring genetic diversity.

MCQs

1. **What is considered the basic unit of life?**
   A) Atom
   B) Molecule
   C) Cell ✓
   D) Organ

2. **In unicellular organisms, how many cells perform life functions?**
   A) None
   B) A few
   C) One ✓
   D) Many

3. **Which of the following is an example of a unicellular organism?**
   A) Human B) Amoeba ✓
   C) Dog D) Tree

4. **What is a characteristic of multicellular organisms?**
   A) Made up of one cell
   B) Have no specialized cells
   C) Contain many specialized cells ✓
   D) Cannot reproduce

5. **Which of the following is NOT one of the seven basic properties of life?**
   A) Division ✓ B) Movement
   C) Homeostasis D) Respiration

6. **What enables sperm cells to move?**
   A) Cilia B) Arms
   C) Flagella ✓ D) Legs

7. **What do cells use for energy production?**
   A) Oxygen B) Water
   C) ATP ✓ D) Protein

8. **Through which processes do cells remove waste products?**
   A) Osmosis and diffusion
   B) Filtration and evaporation
   C) Diffusion and active transport ✓
   D) Respiration and excretion

9. **What is the function of homeostasis in cells?**
   A) Reproduction B) Movement
   C) Maintaining a stable internal environment ✓
   D) Making proteins

10. **How do cells reproduce for growth and repair?**
    A) Meiosis B) Binary fission
    C) Mitosis ✓ D) Budding

SQ

1. **What are cells and why are they considered the basic unit of life?**
Ans. Cells are the basic unit of life because they make up every living organism and carry out all the essential functions needed for life. In unicellular organisms such as amoebas and bacteria, a single cell performs all life processes. In multicellular organisms like plants and animals, different specialized cells work together to maintain life.

2. **How do unicellular and multicellular organisms differ in terms of cellular structure and function?**
Ans. In unicellular organisms, such as amoebas and bacteria, a single cell carries out all the functions necessary for life. In contrast, multicellular organisms, like plants and animals, consist of numerous specialized cells that work together to sustain life and perform various functions.

3. **What are the seven basic properties of life exhibited by all living organisms?**
Ans. The seven basic properties of life are:
1. Movement 2. Respiration 3. Homeostasis
4. Growth 5. Reproduction 6. Excretion
7. Nutrition 8. These properties define living organisms and are carried out by cells.

4. **What is the role of cells in performing life functions?**
Ans. Cells perform all the fundamental activities that characterize living organisms. These include movement, obtaining and utilizing nutrients, producing energy, removing waste, maintaining internal stability, growing, and reproducing.

5. **How do cells perform the function of movement?**
Ans. Cells are capable of movement in several ways:
- **Sperm cells** move with their **flagella**.
- **White blood cells** travel through the **bloodstream** to fight infections.
- **Organelles inside cells** also move to carry out vital internal cellular functions.

6. **How do cells carry out the function of nutrition?**
Ans. Cells obtain **nutrients** from their **environment**. These nutrients are used to:
- Produce **energy**
- Build **cellular structures**
- Drive **biochemical reactions**

7. **What is cellular respiration and how do cells perform it?**
Ans. Cellular respiration is the process by which cells generate **energy**. During this process, cells break down **glucose** to release **ATP (adenosine triphosphate)**, which is the **energy currency** that powers all cellular activities.

8. **How do cells excrete waste materials?**
Ans. Cells remove **waste products** through processes such as:
- **Diffusion**
- **Active transport**
- These mechanisms prevent the **buildup of toxic substances** inside the cell.

9. What is homeostasis and how do cells maintain it?

Ans. **Homeostasis** is the ability of cells to maintain a **stable internal environment**. Cells achieve this by **regulating the movement** of substances across their **cell membranes**.

10. How do cells grow?

Ans. Cells grow by:

- Taking in **nutrients**
- Converting them into various **cellular components**, which results in an increase in size and cellular content.

11. How do cells reproduce and what are the types of cell division involved?

Ans. Cells reproduce through two types of cell division:

1. **Mitosis** – Produces **identical daughter cells** used for **growth and repair**.
2. **Meiosis** – Produces **gametes** (sperm and egg cells) for **sexual reproduction**.

12. How do cells perform movement?

Ans. Cells move in various ways. For example, sperm cells use their flagella to swim, while white blood cells travel through the bloodstream to fight infections. Inside the cells, organelles also move to perform vital functions.

13. How do cells obtain and use nutrients?

Ans. Cells take in nutrients from their environment to produce energy, synthesize cellular components, and drive essential biochemical reactions necessary for life.

14. What is cellular respiration and why is it important?

Ans. Cellular respiration is the process by which cells break down glucose to release ATP (adenosine triphosphate), which is the energy currency that powers all cellular activities. This process is crucial for maintaining life functions.

15. How do cells remove waste products?

Ans. Cells eliminate waste through processes like diffusion and active transport, which help in preventing the accumulation of toxic substances inside the cell.

16. What is homeostasis in cells?

Ans. Homeostasis refers to the ability of cells to maintain a stable internal environment by regulating the movement of substances in and out through their membranes.

17. How do cells grow?

Ans. Cells grow by absorbing nutrients and converting them into new cellular material, which increases their size and enables them to perform their functions effectively.

18. What are the two types of cell reproduction, and how are they different?

Ans. Cells reproduce through **mitosis** and **meiosis**.

- **Mitosis** results in two identical daughter cells and is used for growth and repair.
- **Meiosis** produces gametes (sperm and egg cells) for sexual reproduction, resulting in genetic variation.

3.2 CELL THEORY

2. Explain the development and main points of the Cell Theory.

Ans. Introduction and Background

At the beginning of 17th century, many scientists began the use of microscopes to study very small objects. In 1665, English scientist Robert Hooke examined a thin slice of cork of oak tree under microscope. He observed that the cork was made of "many little boxes". Hooke also examined the pieces of stem and root of oak tree under microscope. He found that these were also made of similar little boxes. He concluded that the parts of plants were made of compartments. Hooke named these compartments as "cellulae".

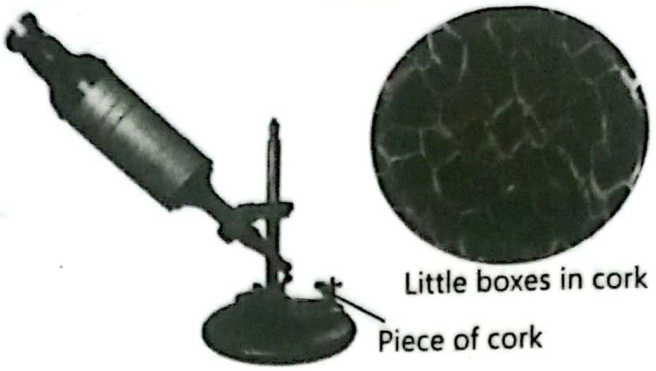


Fig. 3.1: Robert Hooke's microscope and observation

Further Discoveries

In 1673, a Dutch scientist Anton van Leeuwenhoek made a better microscope and observed living cells in pond water. He called these cells as animalcules.

In 1809, the French biologist Jean Baptiste de-Lamarck also observed cells when he examined the parts of animals and plants under microscope.

Later on, in 1831 the British botanist Robert Brown discovered nucleus in the cell.

Formation of the Cell Theory

After these studies, biologists began to organize information about cells. In 1838, the German botanist Matthias Schleiden observed many parts of plants under microscope. He concluded that all plants were composed of cells. The next year, the German zoologist Theodor Schwann concluded the same for animals.

In 1885, the German physician Rudolf Virchow (1821–1902) observed that all cells come from other cells. In 1862, Louis Pasteur provided the experimental proof of this idea. These observations were combined to form a basic theory about cells. It is called **cell theory**.

Main Points of the Cell Theory

It has three essential points:

1. All living organisms are composed of one or more cells.
2. Cells are the basic units of structure and function in an organism.
3. Cells come only from the division of pre-existing cells.

3. How is the cell theory validated through modern scientific methods?

Ans. Cell theory is validated by several modern scientific techniques:

1. **Microscopy** – Light and electron microscopes allow scientists to observe cell structures, confirming that all living things are made of cells.
2. **Live-cell imaging and genetics** – These methods track how cells grow and divide, proving that new cells come from existing cells.
3. **DNA sequencing** – Shows that all cells share common genetic materials and biochemical pathways.
4. **Cell culture and tissue engineering** – Demonstrate that cells can grow, differentiate, and reproduce under laboratory conditions, further supporting the cell theory.

4. What are the exceptions to cell theory, and how do they challenge the basic principles of the theory?

Ans. Although cell theory is one of the fundamental principles of biology and widely accepted, there are several notable exceptions that challenge its universality. These exceptions include viruses, prions, certain organelles, and specialized structures in some organisms. Below is a detailed explanation of these exceptions:

Viruses, Prions, and Viroids:

Viruses are a major exception to the cell theory. Unlike living cells, viruses are **not composed of cells** and **cannot perform life processes on their own**. They lack the structures needed for metabolism, energy production, and reproduction. Instead, they **require a host cell to replicate**, hijacking the host's cellular machinery to reproduce. Due to these characteristics, many scientists consider viruses to lie on the **borderline between living and non-living things**.

Other acellular entities like **prions** and **viroids** further challenge cell theory. Prions are made solely of proteins, while viroids consist only of **RNA**. Despite lacking cellular structures, these agents can cause diseases and exhibit certain characteristics of living systems, such as replication (in a host). However, since they are not made up of cells, they do not conform to the standard cell theory.

Mitochondria and Chloroplasts:

In eukaryotic cells, **mitochondria** and **chloroplasts** are organelles that contain **their own DNA** and are capable of **replicating independently** from the cell's nucleus. These features suggest that they may have evolved from **free-living prokaryotic cells**, which entered into a symbiotic relationship with early eukaryotic cells—a theory known as **endosymbiosis**. The ability of these organelles to reproduce independently and carry genetic information challenges the principle that the nucleus controls all aspects of the cell.

Coenocytic Structures in Fungi and Algae:

Certain **fungi** and **algae** possess a structure where **multiple nuclei exist within a shared cytoplasm**. These structures are known as **coenocytes** and lack the typical cell boundaries seen in other organisms. This multinucleate, continuous cytoplasmic mass defies the classical concept of individual cells functioning as the basic structural and functional units of life. These organisms function efficiently despite the absence of distinct cellular compartments, challenging the definition of a "cell" as an isolated and independent unit.

Multinucleated Muscle Fibers in Vertebrates:

In vertebrate animals, **muscle cells (myocytes)** may undergo fusion to form long, **multinucleated fibers**. These fibers function as single coordinated units despite containing **multiple nuclei**. This phenomenon challenges the idea that a single cell should have only one nucleus and function independently. Instead, these multinucleated structures operate as one functional unit, which complicates the definition of a cell as the smallest unit of structure and function in living organisms.

Conclusion:

These exceptions show that while cell theory provides a foundational understanding of life, biology is a complex science with certain organisms and structures that do not fit neatly into predefined rules. Studying these exceptions deepens our understanding of life and encourages continuous refinement of scientific theories.

MCQs

1. **Who coined the term "cellulae"?**
   A) Anton van Leeuwenhoek
   B) Matthias Schleiden
   C) Robert Hooke ✓
   D) Robert Brown
2. **What did Anton van Leeuwenhoek call the cells he observed in pond water?**
   A) Bacteria
   B) Organisms
   C) Protozoa
   D) Animalcules ✓
3. **Who discovered the nucleus in a cell?**
   A) Robert Hooke
   B) Robert Brown ✓
   C) Rudolf Virchow
   D) Louis Pasteur
4. **According to Schleiden and Schwann, all plants and animals are composed of:**
   A) Atoms
   B) Organs
   C) Cells ✓
   D) Tissues
5. **Which scientist proposed that all cells come from pre-existing cells?**
   A) Robert Hooke
   B) Louis Pasteur
   C) Rudolf Virchow ✓
   D) Anton van Leeuwenhoek
6. **Who gave experimental proof that cells arise from pre-existing cells?**
   A) Robert Brown
   B) Louis Pasteur ✓
   C) Schleiden
   D) Schwann
7. **Which of the following is NOT a point of the cell theory?**
   A) All living things are made of cells
   B) Cells come from pre-existing cells
   C) Cells form through crystallization ✓
   D) Cells are the basic units of structure and function
8. **Which tool helped in validating cell theory through direct observation?**
   A) Spectrometer
   B) Telescope
   C) Microscope ✓
   D) Calorimeter
9. **What method allows scientists to track cell replication?**
   A) Photosynthesis
   B) Live-cell imaging ✓
   C) Respiration
   D) Gel electrophoresis
10. **What does DNA sequencing reveal about cells?**
    A) They differ widely in metabolism
    B) They all have the same shape
    C) They share genetic material and metabolic pathways ✓
    D) They do not reproduce
11. **Which entity challenges the cell theory by not being made of cells?**
    A) Bacteria
    B) Amoeba
    C) Virus ✓
    D) Protozoa
12. **What is required by viruses in order to replicate?**
    A) Sunlight
    B) Host cell ✓
    C) Oxygen
    D) Water
13. **Viruses are often considered to be:**
    A) Fully living organisms

B) Inanimate chemicals
C) On the border of living and non-living ✓
D) Dead bacteria

14. Prions and viroids differ from cells because they are made of:
A) Cell membranes
B) DNA, RNA, or proteins only ✓
C) Organelles D) Cytoplasm

15. Which of the following is NOT made of cells?
A) Prions ✓ B) Algae
C) Fungi D) Plants

16. Which organelle contains its own DNA and can replicate independently?
A) Endoplasmic reticulum B) Golgi apparatus
C) Mitochondrion ✓ D) Ribosome

17. Chloroplasts are believed to have originated from:
A) Viruses B) Prokaryotic cells ✓
C) Multicellular organisms D) The nucleus

18. The fact that mitochondria and chloroplasts have their own DNA suggests:
A) They are dead parts of cells
B) They perform photosynthesis
C) They once were free-living organisms ✓
D) They don't perform any function

19. Some fungi and algae have structures where:
A) Each cell has a single nucleus
B) Multiple cells fuse to form one
C) Many nuclei share a single cytoplasm ✓
D) Nuclei disappear after division

20. The condition where many nuclei exist in a shared cytoplasm is:
A) Binary fission B) Cytoplasmic fusion
C) Multinucleated structure ✓
D) Cytokinesis

21. Which of the following cell types in vertebrates is often multinucleated?
A) Neurons
B) Myocytes (muscle cells) ✓
C) Red blood cells D) White blood cells

22. Multinucleated muscle fibers challenge the idea that:
A) Cells do not grow
B) Organelles are independent
C) A single cell has one nucleus ✓
D) Cells can't move

23. Cell theory states that:
A) All cells have one nucleus
B) All organisms are made of many cells
C) The cell is the basic unit of life ✓
D) Viruses are cells

24. What characteristic of prions makes them exceptions to cell theory?
A) They have multiple nuclei
B) They are composed only of protein ✓
C) They perform photosynthesis
D) They have cell membranes

25. Which of the following is not a part of the traditional cell theory?
A) All living things are made of cells
B) Cells come from pre-existing cells
C) All cells have organelles ✓
D) The cell is the basic unit of life

26. Which organelles are exceptions to cell theory due to their independent replication?
A) Ribosomes and lysosomes
B) Golgi apparatus and ER
C) Mitochondria and chloroplasts ✓
D) Nucleus and nucleolus

27. The ability of chloroplasts to replicate independently supports which theory?
A) Modern cell theory B) Germ theory
C) Endosymbiotic theory ✓
D) Atomic theory

28. The presence of many nuclei in a shared cytoplasm is common in:
A) Bacteria
B) Myocytes and some algae ✓
C) Viruses D) Red blood cells

29. Which structure in muscle tissue challenges the classic concept of the cell?
A) Sarcoplasmic reticulum
B) Mitochondria
C) Multinucleated fiber ✓
D) Actin filament

30. Which of the following is a structural feature of prions and viroids?
A) Organelles B) Single large cells
C) Nuclei and membranes
D) Only protein or nucleic acids ✓

SQ

1. Who first discovered cells, and how?
Ans. In 1665, English scientist **Robert Hooke** observed a thin slice of cork under a microscope and noticed it was made up of many little compartments, which he called **"cellulae"** (cells). He later observed similar structures in the stems and roots of oak trees.

2. What did Anton van Leeuwenhoek contribute to cell discovery?
Ans. In 1673, Dutch scientist **Anton van Leeuwenhoek** used an improved microscope to observe **living cells** in pond water. He called these microscopic organisms **animalcules**, which were actually single-celled organisms.

3. What was Jean Baptiste de Lamarck's role in the study of cells?
Ans. In 1809, French biologist **Jean Baptiste de-Lamarck** studied both animal and plant tissues under a microscope and also observed cells, further supporting the concept that cells are a basic part of living organisms.

4. Who discovered the nucleus and when?

Ans. In 1831, **Robert Brown**, a British botanist, discovered the **nucleus** inside plant cells, contributing significantly to the understanding of cell structure.

5. What did Matthias Schleiden and Theodor Schwann contribute to the cell theory?

Ans.

- In 1838, German botanist **Matthias Schleiden** concluded that all plants are made of cells.
- In 1839, German zoologist **Theodor Schwann** concluded that all animals are also composed of cells.
- Together, their work laid the foundation for the cell theory.

6. What was Rudolf Virchow's and Louis Pasteur's contribution to cell theory?

Ans.

- In 1855, **Rudolf Virchow** stated that all cells arise from pre-existing cells.
- In 1862, **Louis Pasteur** experimentally proved this by demonstrating that life does not spontaneously arise, confirming that cells come only from existing cells.

7. What are the three main points of cell theory?

Ans.

1. All living organisms are composed of one or more cells.
2. Cells are the basic units of structure and function in an organism.
3. All cells arise from the division of pre-existing cells.

8. Is cell theory universally applicable to all forms of life?

Ans. While cell theory is widely accepted and forms the foundation of modern biology, there are notable exceptions where certain biological entities and structures do not fully conform to its principles.

9. How do viruses challenge the cell theory?

Ans. Viruses challenge cell theory because they are **not made of cells** and **cannot carry out life processes independently**. They rely entirely on a **host cell to replicate**, which means they do not exhibit the autonomous characteristics of living cells. Because of this, many scientists consider viruses to exist **on the borderline between living and non-living entities**.

Additionally, other acellular infectious agents like **prions** and **viroids** also display some properties of living organisms but are not composed of cells. These agents are made solely of **DNA, RNA, or proteins**, further challenging the universality of the cell theory.

10. What is unique about mitochondria and chloroplasts that makes them an exception to cell theory?

Ans. Mitochondria and chloroplasts are eukaryotic organelles that contain **their own DNA** and have the ability to **replicate independently of the cell's nucleus**. This autonomy suggests that these organelles may have originated from **free-living prokaryotic cells** through a process known as **endosymbiosis**. Their unique features challenge the idea that all structures within a eukaryotic cell are entirely dependent on the nucleus for replication and genetic control.

11. How do certain fungi and algae challenge traditional cell theory?

Ans. Some **fungi and algae** possess structural features in which **multiple nuclei share a common cytoplasm**. This means that rather than being divided into distinct cells, the **cytoplasmic mass contains several nuclei** within a continuous boundary. Such **coenocytic structures** blur the boundaries of what is traditionally defined as an individual cell, thereby posing a challenge to the conventional definition upheld by cell theory.

12. Why are muscle cells (myocytes) in vertebrates considered an exception to the cell theory?

Ans. Muscle cells, or **myocytes**, in vertebrates have the ability to **fuse** together, forming long **multinucleated fibers**. This challenges the concept of a **single cell as the basic unit of structure and function**, especially in complex tissues. These multinucleated fibers function as a unit despite containing multiple nuclei, which defies the classical idea of cells as independent and individually nucleated units.

3.3 MICROSCOPY

5. What is microscopy, and how did it contribute to the discovery and study of cells? Describe the principle, advantages, and limitations of light microscopy.

Ans. Microscopy and Its Importance

Microscopy is the technique of using microscopes to observe and study objects that are too small to be seen with the naked eye. The discovery of cells and the exploration of their internal structures were only made possible through this technique.

Working Principle of Light Microscopy

Light microscopy, in particular, uses visible light to illuminate specimens. The light passes through the object and then through two glass lenses. The first lens produces an enlarged image, while the second lens magnifies it further. The resulting image is then seen by the viewer's eye.

Magnification and Resolving Power

The magnification of a light microscope can reach up to 1500 times (1500X), and its resolving power is 0.2 micrometres (μm), meaning it cannot distinguish objects smaller than 0.2 μm. One micrometre is equal to 1/1000 millimetre.

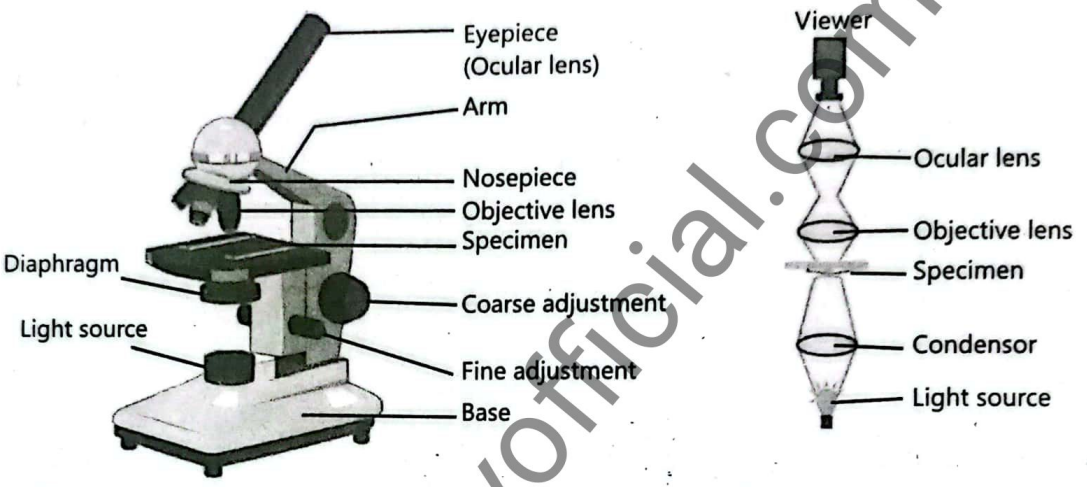


Fig. 3.2: (a) Major parts of light microscope; (b) Working Principle of Light Microscope

Uses and Limitations of Light Microscopes

Light microscopes are particularly useful for viewing living organisms. However, most cells are transparent, and their internal parts are not easily visible unless they are colored using special stains. These stains help to distinguish cellular structures, but the staining process typically kills the cells, making it unsuitable for observing live specimens. Thus, while light microscopes offer the advantage of observing living cells, their limited resolution and the need for staining are notable drawbacks.

Q 6. What is electron microscopy? Explain the types and uses of electron microscopes.

Ans. Electron microscopy is a powerful technique that uses a beam of electrons instead of light to produce highly magnified images of specimens. Unlike light microscopes that use glass lenses, electron microscopes use magnetic lenses to focus the electron beam onto a screen or photographic film. This produces a much more enlarged image than that provided by light microscopes. The resolving power of electron microscopes is significantly higher; they can clearly show objects as small as 0.2 nanometres (nm), where 1 nm equals 1/1,000,000 mm.

However, one major limitation of electron microscopes is that they cannot be used to observe living specimens. The preparation of samples involves procedures like fixing, dehydrating, and coating, which kill the specimen, making live observation impossible.

There are two primary types of electron microscopes:

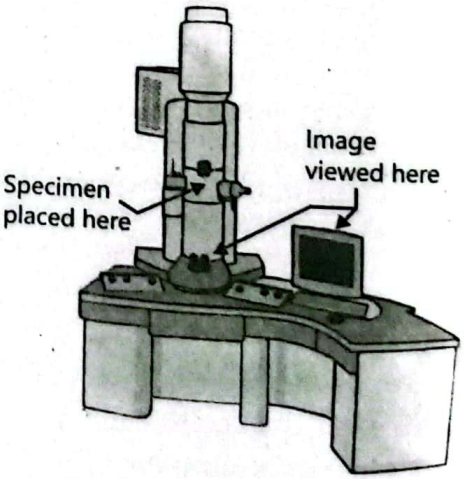


Fig. 3.3: Electron microscope

1. **Transmission Electron Microscope (TEM):**
   TEM is used to view the internal structures of cells. It passes a beam of electrons through an ultra-thin specimen and provides detailed images of the internal components of cells. TEM can magnify objects up to 250,000 times.
2. **Scanning Electron Microscope (SEM):**
   SEM is designed for studying the surfaces of cells or other materials. The sample surface is coated with a thin layer of metal. When the electron beam hits this metal surface, it is reflected to form an enlarged image of the surface. SEM can magnify objects up to 100,000 times.

Electron microscopes are invaluable in modern biology due to their high resolution and magnifying capabilities, though their use is limited to non-living specimens.

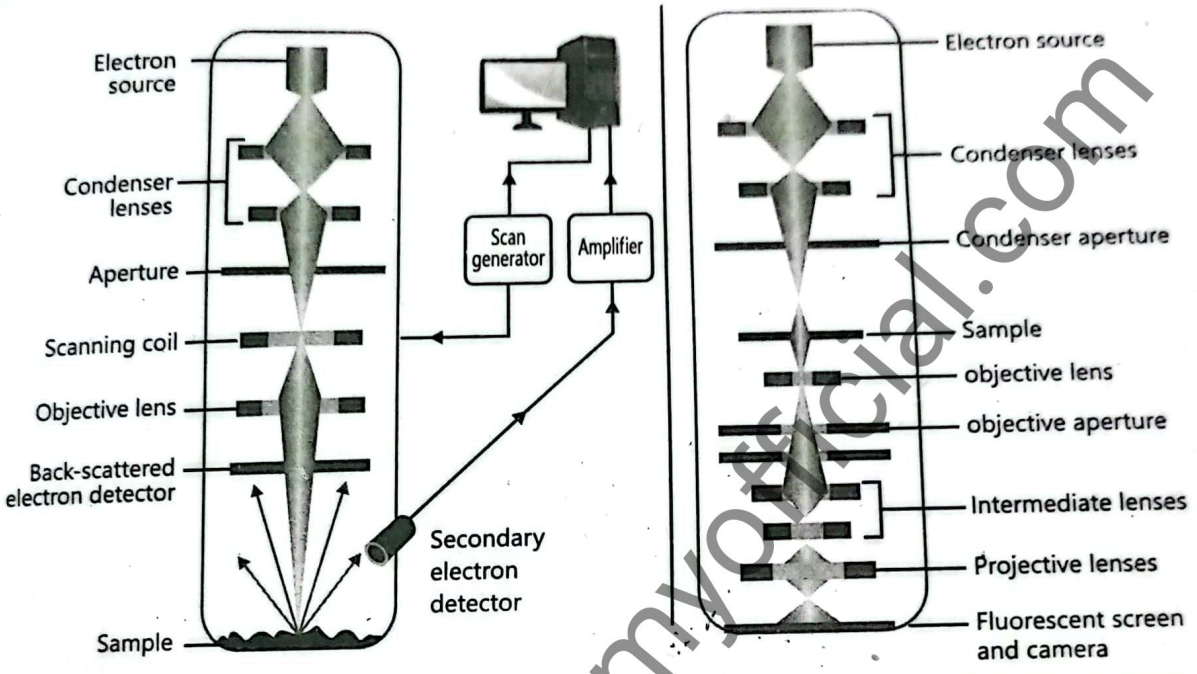


Fig. 3.4: Working principle of; (a) Scanning electron microscope; (b) Transmission electron microscope

7. Describe how will you compare the light microscope and electron microscope?

Ans. Light microscopes and electron microscopes are essential tools in biological research, each with unique features, advantages, and limitations. The key differences between these two types of microscopes are summarized in the table below:

Light Microscope	Electron Microscope
Uses light (approx. 400–700 nm) as an illuminating source	Uses electron beams (approx. 1 nm) as an illuminating source
Lower magnification (usually 500X to 1500X) than an electron microscope	Higher magnification (direct magnification is 16,000X and photographic magnification is 1,000,000X)
Low resolution (may be 0.2 µm)	High resolution (may be 0.2 nm)
Both live and dead specimens can be seen	Only dead and dried specimens can be seen
Specimen preparation takes about a few minutes or an hour	Specimen preparation takes several days
The image is seen through the ocular lens. No screen needed	The image is received on a zinc sulphate fluorescent screen

Conclusion:

While light microscopes are easier to use and allow the observation of living specimens, they are limited in magnification and resolution. Electron microscopes, on the other hand, provide much higher magnification and

resolution, enabling detailed study of cellular ultrastructure, but only with non-living specimens and more complex preparation procedures. Each has its own role depending on the requirements of the scientific investigation.

MCQs

1. **What is microscopy?**
   A) Study of weather B) Study of planets
   C) Technique to magnify large objects
   D) Technique to observe tiny objects using microscopes ✓
2. **What do microscopes use to magnify specimens?**
   A) Magnets and chemicals
   B) Lenses and sound waves
   C) Lenses and light or electron beams ✓
   D) Radiation and mirrors
3. **Which type of microscope uses light to form an image?**
   A) Compound microscope
   B) Light microscope ✓
   C) Scanning microscope
   D) Projection microscope
4. **How many lenses are used in a light microscope to magnify the image?**
   A) One B) Two ✓
   C) Three D) Four
5. **What is the maximum magnification of a light microscope?**
   A) 200X B) 500X
   C) 1000X D) 1500X ✓
6. **What is the resolving power of a light microscope?**
   A) 0.1 mm B) 0.2 mm
   C) 0.2 µm ✓ D) 0.02 µm
7. **1 micrometre (µm) is equal to:**
   A) 1/10 mm B) 1/100 mm
   C) 1/1000 mm ✓ D) 1/10000 mm
8. **Light microscopes are most suitable for observing:**
   A) Bacteria only B) Living organisms ✓
   C) Rocks and minerals D) Fossils
9. **Why do biologists use special stains in light microscopy?**
   A) To make cells grow B) To kill bacteria
   C) To destroy cell membranes
   D) To distinguish transparent cell components ✓
10. **What is the disadvantage of staining cells in light microscopy?**
    A) It reduces resolution
    B) It increases size of image
    C) It kills the cells ✓
    D) It lowers magnification
11. **What does an electron microscope use to form an image?**
    A) X-rays B) Light rays
    C) Beams of electrons ✓ D) Heat waves
12. **Which component focuses the electron beam in an electron microscope?**
    A) Glass lenses B) Metal lenses
    C) Magnetic lenses ✓ D) Plastic lenses
13. **What is the minimum object size an electron microscope can clearly show?**
    A) 0.2 mm B) 0.2 µm
    C) 0.2 nm ✓ D) 2 µm
14. **Why can't electron microscopes be used for living specimens?**
    A) Because they produce heat
    B) Because of the preparation methods ✓
    C) Because they are not clear
    D) Because they use stains
15. **TEM stands for:**
    A) Total Electron Microscope
    B) Technical Electron Measurement
    C) Transmission Electron Microscope ✓
    D) Thin Electron Microscope
16. **TEM is used to observe:**
    A) Cell surface B) Nucleus shape only
    C) Internal structure of cells ✓
    D) Cell movement
17. **How much can TEM magnify an object?**
    A) 1000 times B) 25,000 times
    C) 100,000 times D) 250,000 times ✓
18. **SEM stands for:**
    A) Single Electron Microscope
    B) Scanning Electron Microscope ✓
    C) Sample Electron Machine
    D) Structured Electron Microscopy
19. **What does SEM study?**
    A) DNA sequencing B) Protein folding
    C) Internal nucleus
    D) Surface details of cells ✓
20. **What is done to the surface before using SEM?**
    A) It is cleaned with alcohol
    B) It is stained with dye
    C) It is coated with metal ✓
    D) It is heated
21. **What is the main function of microscopes in biology?**
    A) Measuring weight
    B) Observing large organisms
    C) Observing tiny objects invisible to the naked eye ✓
    D) Measuring temperature
22. **What are the two primary types of microscopes?**
    A) Solar and lunar microscopes
    B) Light and X-ray microscopes
    C) Optical and magnetic microscopes
    D) Light and electron microscopes ✓
23. **What does a light microscope use to illuminate specimens?**
    A) Laser light B) UV rays

C) Visible light ✓ D) Infrared rays

24. The wavelength of light used in a light microscope is approximately:
A) 1–5 nm B) 400–700 nm ✓
C) 100–200 µm D) 800–900 nm

25. Which type of specimens can be viewed under a light microscope?
A) Only dead specimens B) Only live specimens
C) Only metal-coated specimens
D) Both live and dead specimens ✓

26. Light microscopes are most suitable for:
A) Geological studies B) Nuclear research
C) Routine biological studies ✓
D) Viewing metals

27. One advantage of a light microscope is:
A) Needs no lenses B) High cost
C) Simple specimen preparation ✓
D) Requires vacuum chamber

28. Electron microscopes use:
A) Visible light B) UV light
C) Beams of electrons ✓ D) X-rays

29. What is the approximate wavelength of the electrons used in electron microscopes?
A) 400–700 nm B) 1 nm ✓
C) 10 µm D) 0.2 mm

30. Which microscope offers higher magnification and resolution?
A) Simple microscope B) Light microscope
C) Electron microscope ✓ D) Hand lens

31. What type of cellular structures can electron microscopes observe?
A) Only nuclei B) Ultra-fine structures ✓
C) Organs D) Macroscopic objects

32. What is a major limitation of electron microscopy?
A) Cannot observe dead specimens
B) Very low magnification
C) Preparation is quick
D) Preparation is complex and time-consuming ✓

33. Electron microscope specimens must be:
A) Frozen B) Live and moving
C) Dead and dehydrated ✓
D) Transparent and fresh

34. How is the image viewed in an electron microscope?
A) Through eyepiece B) Through magnifying glass
C) Through computer
D) On a zinc sulphate screen ✓

35. What is the direct magnification of an electron microscope?
A) 1500X B) 5000X
C) 16000X ✓ D) 1,000,000X

36. What is the photographic magnification of an electron microscope?
A) 1500X B) 16000X
C) 250000X D) 1,000,000X ✓

37. What is the resolution limit of a light microscope?
A) 0.2 nm B) 0.2 µm ✓
C) 0.1 mm D) 2 mm

38. What is the resolution of an electron microscope?
A) 0.2 mm B) 2 µm
C) 0.2 µm D) 0.2 nm ✓

39. In light microscopy, the image is viewed through:
A) A digital display B) A zinc-coated screen
C) The ocular (eyepiece) lens ✓
D) A mirror

40. Why are light microscopes widely used despite lower magnification?
A) More colorful images B) Easy to carry
C) More practical and easier for general use ✓
D) Use electricity

SQ

1. What is microscopy, and why is it important in the study of cells?

Ans. Microscopy is the technique of using microscopes to observe and study objects that are too small to be seen with the naked eye. The discovery of cells and further studies of their internal structures became possible only through the use of microscopes. Microscopes use lenses along with light or electron beams to **magnify** and **illuminate** specimens, allowing scientists to explore the world of microorganisms and cell structures in detail.

2. How does a light microscope work?

Ans. In a **light microscope**, visible light is used to produce an image of the object. The light first passes through the object and then through **two glass lenses**. The first lens creates an **enlarged image** of the object, and the second lens **further magnifies** that image. After passing through the object and lenses, the light forms an enlarged and clear image that is seen by the viewer's eye.

3. What is the magnification and resolving power of a light microscope?

Ans. A light microscope can **magnify objects up to 1500 times (1500X)**. Its **resolving power is 0.2 micrometre (µm)**, which means it cannot clearly distinguish objects smaller than that size. (Note: **1 µm = 1/1000 millimetre (mm)**). Thus, while useful for many observations, it has limitations in terms of resolution.

4. What are the advantages and limitations of light microscopes when studying cells?

Ans. Light microscopes are particularly advantageous for viewing **living organisms**, as they allow for real-time observation of life processes. However, most individual cells are **transparent**, making their internal components

indistinguishable unless they are **stained with special coloured chemicals**. Unfortunately, the **staining process usually kills the cells**, so living structures cannot be observed in stained preparations.

5. How does an electron microscope differ from a light microscope in its working principle?

Ans. An **electron microscope** uses a **beam of electrons** instead of light to produce images. Magnetic lenses are used to **focus the electron beam** onto a **screen or photographic film**, creating a **much more enlarged image** compared to what is possible with light microscopes. The **resolving power** of an electron microscope is **much greater**, allowing scientists to clearly observe objects as small as **0.2 nanometre (nm)**. (Note: **1 nm = 1/1,000,000 mm**).

6. Can electron microscopes be used to observe living specimens? Why or why not?

Ans. No, electron microscopes **cannot be used to view living material**. The preparation methods required for electron microscopy—such as fixing, dehydrating, and coating the samples—**kill the specimens**. Therefore, only **non-living, prepared samples** can be observed under an electron microscope.

7. What are the two main types of electron microscopes, and how do they differ in function?

Ans. There are **two main types** of electron microscopes:

1. **Transmission Electron Microscope (TEM):**
   TEM is used to view the **internal structure** of cells. It works by transmitting a **beam of electrons through a very thin specimen**, allowing scientists to see internal components at very high resolution. TEM can **magnify objects up to 250,000 times**.
2. **Scanning Electron Microscope (SEM):**
   SEM is used to study the **surface details** of cells or other objects. In this technique, the **surface of the specimen is coated with metal**. When the electron beam hits the metal coating, it is **reflected**, creating an **enlarged image** of the surface. SEM can **magnify objects up to 100,000 times**.

3.4 STRUCTURE OF CELL

There are two basic types of cells i.e., **prokaryotic and eukaryotic**.

- ✓ All **bacteria** are prokaryotes.
- ✓ **Yeast** and **Euglena** are examples of **unicellular eukaryotes**, while **plants and animals** are examples of **multicellular eukaryotes**.
- ✓ Eukaryotic cells are **more complex** than the prokaryotic cells.

In the following paragraphs, we study the **structures present in cells** and their **functions**.

CELL WALL

8. Describe the structure and functions of the cell wall in detail?

Ans. Structure of Cell Wall:

The **cell wall** is a more or less **solid layer surrounding a cell**. It is found in **bacteria, fungi, plants, and algae**.

- When a cell wall is removed using **cell wall degrading enzymes**, the remaining components of the cell are called a **protoplast**.

a) **Primary Cell Wall**

The **primary wall** is the actual cell wall of the cell.

- ✓ It is composed of **polysaccharides**, i.e., **cellulose, hemicellulose**, and **pectin**.
- ✓ The **cellulose microfibrils** are aligned at all angles and are held together by **hydrogen bonds**.
- ✓ Many **proteins** are also present in primary walls.

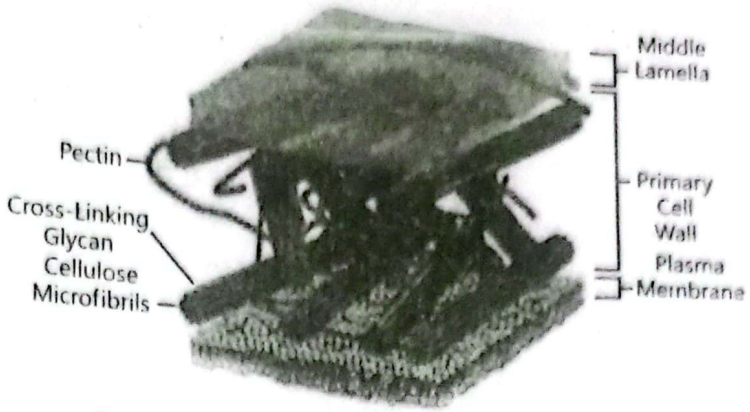


Fig. 3.5: The composition of primary cell wall

b) Middle Lamella

The **middle lamella** is a **gelatinous layer** that **separates and holds the primary walls of the neighbouring cells**.

- ✓ It is laid first, formed from the **cell plate during cytokinesis**, and the primary cell wall is then expanded inside the middle lamella.
- ✓ It contains **magnesium and calcium pectates** (salts of pectic acid).

c) Secondary Cell Wall

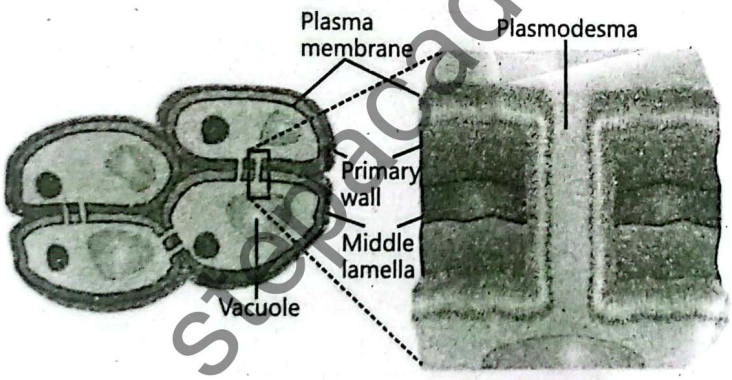
In some plant cells, after maturation, a **secondary wall** is made between the **protoplast** and **primary wall**.

- ✓ Secondary cell walls contain **lignin, cellulose**, and **hemicellulose**.
- ✓ Due to the presence of **lignin**, the **secondary wall is more rigid** than the primary wall.

Plasmodesmata:

Plasmodesmata (singular: **plasmodesma**) are **small channels** that directly connect the **cytoplasm of neighbouring plant cells** to each other.

- ✓ Plasmodesmata **penetrate both the primary and secondary cell walls**.
- ✓ They allow certain **molecules to pass directly** from one cell to another.
- ✓ So, they are important in **cellular communication**.
- ✓ Plasmodesmata are formed during **cell division** when parts of the **endoplasmic reticulum** of the parent cell get trapped in the new cell wall.



Plasmodesmata have caused debate among scientists regarding cell theory. Some scientists suggest that the cells of higher plants are not really cells since they are not physically separated or independent from one another.

Fig. 3 .6: The cell walls of two neighbouring cells showing a plasmodesma

The group of algae called diatoms synthesize their cell walls from silicic acid. The acid is polymerized inside cells, then the wall is extruded to protect the cell. The synthesis of Silica cell walls requires less energy. That is why there are higher growth rates in diatoms.

(a) Functions of Cell Wall:

Cell walls have a number of **functions**:

1. They provide **rigidity** to the cell for **structural and mechanical support**.
2. They **maintain cell shape** and the **direction of cell growth**, and ultimately the **architecture of the plant**.

3. The cell wall also **prevents expansion** when water enters the cell.
4. Cell walls **protect against pathogens** and the **environment**.
5. They are a **store of carbohydrates** for the plant.

The cell wall of algae contains cellulose and a variety of glycoproteins.
The cell wall of fungi is composed of chitin, the same carbohydrate that gives strength to the exoskeletons of insects.
The cell wall of prokaryotes (bacteria and cyanobacteria) is composed of peptidoglycan, that is a single large polymer of amino acids and sugar.
The cell wall of archaebacteria is composed of different polysaccharides and proteins, with no peptidoglycan.

MCQs

1. **Which of the following is an example of a prokaryotic organism?**
   A) Euglena B) Yeast
   C) Bacteria ✓ D) Plants
2. **Which of the following is a unicellular eukaryote?**
   A) Bacteria B) Yeast ✓
   C) Plants D) Algae
3. **Plants and animals are examples of:**
   A) Prokaryotes B) Viruses
   C) Unicellular organisms
   D) Multicellular eukaryotes ✓
4. **What makes eukaryotic cells more complex than prokaryotic cells?**
   A) Simpler structure B) Lack of organelles
   C) Presence of a nucleus and organelles ✓
   D) Smaller size
5. **The cell wall is found in all of the following EXCEPT:**
   A) Bacteria B) Algae
   C) Animals ✓ D) Fungi
6. **What is the term for the remaining components of a cell after the cell wall is removed?**
   A) Cytosol B) Plasmodesmata
   C) Protoplast ✓ D) Cell membrane
7. **The actual cell wall of a cell is called the:**
   A) Secondary wall B) Middle lamella
   C) Primary wall ✓ D) Outer membrane
8. **Which of the following is NOT a polysaccharide found in the primary cell wall?**
   A) Cellulose B) Hemicellulose
   C) Pectin D) Lignin ✓
9. **How are cellulose microfibrils in the primary wall held together?**
   A) Ionic bonds B) Hydrogen bonds ✓
   C) Covalent bonds D) Peptide bonds
10. **The gelatinous layer between primary walls of neighbouring plant cells is called:**
    A) Secondary wall B) Cell plate
    C) Middle lamella ✓ D) Cell junction
11. **Which salts are commonly found in the middle lamella?**
    A) Sodium and potassium pectates
    B) Magnesium and calcium pectates ✓
    C) Iron and zinc pectates
    D) Chloride and nitrate salts
12. **What is added between the primary wall and protoplast in some mature plant cells?**
    A) Plasma membrane B) Vacuole
    C) Secondary wall ✓ D) Middle lamella
13. **What is lignin's function in the secondary wall?**
    A) Makes the wall softer B) Reduces rigidity
    C) Provides flexibility D) Increases rigidity ✓
14. **Plasmodesmata are:**
    A) Fluid-filled vacuoles
    B) Membrane channels connecting nuclei
    C) Channels connecting cytoplasm of adjacent cells ✓
    D) Stains used for microscopy
15. **Plasmodesmata form during:**
    A) Photosynthesis B) Cell respiration
    C) Cytokinesis ✓ D) Protein synthesis
16. **During plasmodesmata formation, which organelle gets trapped in the new cell wall?**
    A) Nucleus B) Mitochondria
    C) Endoplasmic reticulum ✓
    D) Golgi apparatus
17. **One of the main functions of the cell wall is to:**
    A) Control cell division
    B) Provide structural support ✓
    C) Assist in protein synthesis
    D) Generate ATP
18. **The cell wall helps maintain:**
    A) Internal temperature B) Hormone levels
    C) Cell shape and direction of growth ✓
    D) DNA replication
19. **How does the cell wall help protect the plant?**
    A) By storing oxygen B) By neutralizing toxins
    C) By blocking sunlight
    D) By resisting pathogens and environmental stress ✓
20. **The cell wall also serves as a storage for:**
    A) Fats B) Proteins
    C) Enzymes D) Carbohydrates ✓

PLASMA MEMBRANE

Q. 9. What is the plasma membrane? Explain the fluid mosaic model of the plasma membrane.

Ans. The plasma membrane is a fundamental component of all prokaryotic and eukaryotic cells. It encloses the internal contents of the cell and serves as a semi-porous barrier that regulates the exchange of substances between the internal environment of the cell and the external surroundings. This selective barrier ensures proper cellular function by controlling the entry and exit of molecules.

The interior of lipid bilayer sheet is hydrophobic.
It repels water-soluble molecules that attempt to pass through it. If a cell was fully encased in pure lipid bilayer, it would be completely impermeable to water-soluble molecules e.g., sugars, polar amino acids etc. That is why, in addition to phospholipids molecules, the membranes also contain proteins that provide passageways across the membrane.

Fluid Mosaic Model

Introduction: The fluid mosaic model, proposed by S.J. Singer and Garth Nicolson in 1972, is the most widely accepted model explaining the structure and behavior of the plasma membrane.

Definition: According to this model, the plasma membrane is primarily composed of a lipid bilayer made up of phospholipids in which proteins are embedded in a mosaic manner.

These phospholipids have a phosphate-containing hydrophilic ("water-loving") head and hydrophobic ("water-fearing") tail regions consisting of hydrocarbon chains.

In the bilayer, the hydrophobic tails face inward, away from water, while the hydrophilic heads face outward, towards the aqueous environments inside and outside the cell. Within this bilayer, a mosaic of proteins is embedded or attached, allowing for dynamic movement and interaction, giving the membrane its "fluid" character.

Role of Cholesterol: In eukaryotic cells, cholesterol molecules are interspersed within the phospholipid bilayer of the plasma membrane. These molecules play a crucial role in modulating membrane fluidity. At low temperatures, cholesterol prevents the membrane from becoming too rigid by disrupting the close packing of phospholipid tails, thus maintaining appropriate membrane flexibility and function.

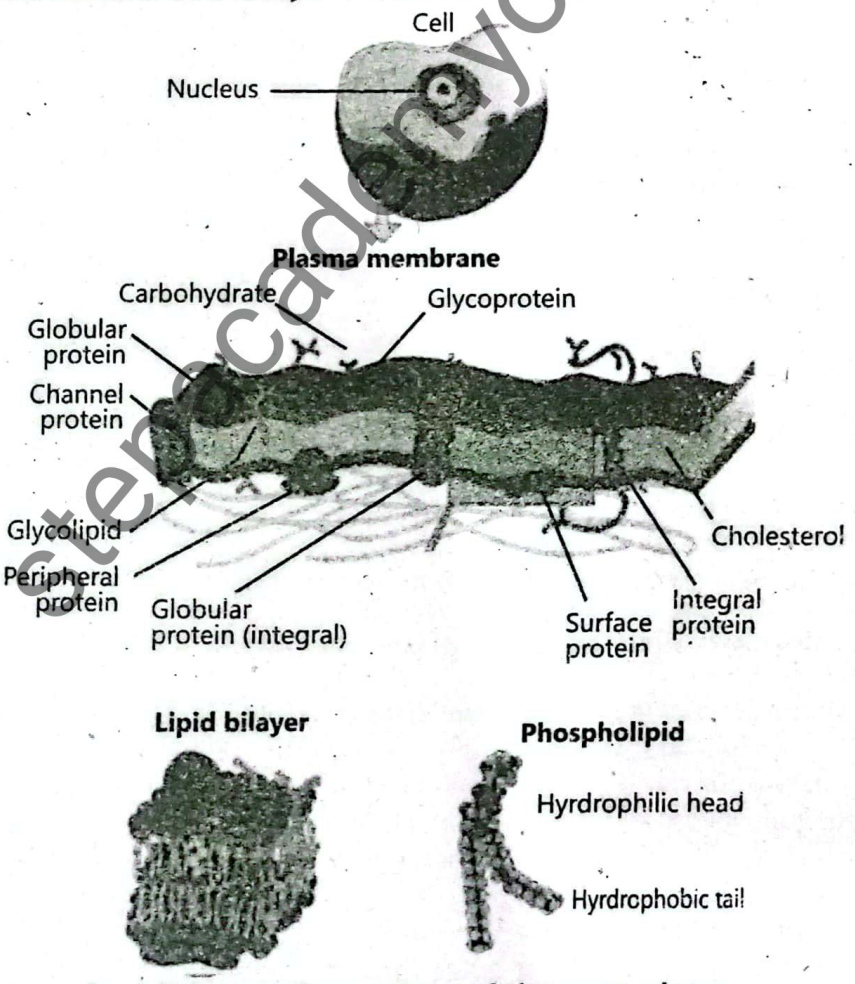


Fig. 3.7: Structural components of plasma membrane

Types and functions of proteins of plasma membrane.

Proteins within the plasma membrane serve various essential roles and are either embedded in the bilayer (integral proteins) or loosely attached to the surface (peripheral proteins). Their positioning is influenced by the organization of the cytoskeleton beneath the membrane. The major functions of these proteins include:

- **Selective transport:** Many proteins act as channels or carriers that regulate the movement of specific substances across the membrane.
- **Structural support:** Some proteins anchor the membrane to internal cytoskeletal elements and external extracellular fibers.
- **Cell recognition:** Certain proteins on the membrane surface bind with sugar molecules to form identification markers for cell-cell recognition.
- **Signal transduction:** Receptor proteins bind to messenger molecules like hormones and transmit signals into the cell.
- **Enzymatic activity:** Some proteins catalyze specific biochemical reactions at the membrane surface.

> The ability to distinguish among different cells is crucial to life. In allows cells in an embryo to sort themselves into tissues and organs. It also helps cells of the immune system to recognize and reject foreign cells, e.g., infectious bacteria.

Significance of Glycoproteins and Glycolipids in Plasma Membrane

Glycoproteins are proteins with carbohydrate chains attached, and glycolipids are lipids with attached carbohydrate chains. These molecules are located on the outer surface of the plasma membrane and collectively form the **glycocalyx**. The glycocalyx plays a critical role in cell recognition and communication. Its composition varies between species, individuals of the same species, and even among different cell types in the same organism. These variations allow cells to identify and interact with each other appropriately.

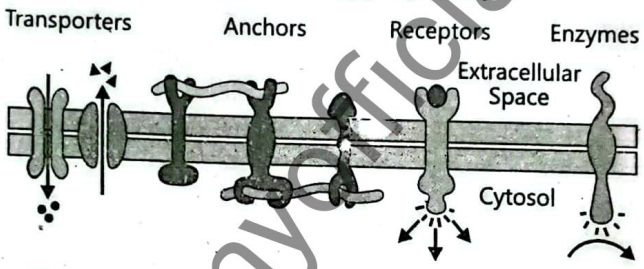


Fig. 3.8: Major types of plasma membrane proteins

10. Compare the percentage composition of proteins, lipids, and carbohydrates in the plasma membranes of various cells and organelles.

Ans. The plasma membrane composition varies depending on the type of cell or organelle. Below is a table showing the percentage by weight of proteins, lipids, and carbohydrates in the membranes of various biological structures:

Membrane	Protein (%)	Lipid (%)	Carbohydrate (%)
Human Red Blood Cell	49	43	8
Mitochondria (Outer Membrane)	52	48	0
Mitochondria (Inner Membrane)	76	24	0
Bacteria	75	25	0

These values reflect the specialized functions of each membrane. For instance, the inner mitochondrial membrane has a very high protein content (76%) due to its active role in electron transport and ATP production.

11. What are the major functions of the plasma membrane in cells? Explain in detail.

Ans. The **plasma membrane** plays a vital role in maintaining the integrity and functionality of both prokaryotic and eukaryotic cells. Its major functions include:

1. **Acts as a Semi-Porous Barrier:**
   The plasma membrane serves as a selective or semi-permeable barrier between the internal environment of the cell and its external surroundings. It ensures that the internal contents of the cell remain intact and protected.
2. **Boundary and Structural Support:**
   The membrane acts as a boundary that holds the entire cell together by enclosing the cytoplasm and all cellular organelles. It maintains the shape of the cell and offers mechanical support.

3. **Selective Permeability for Substance Exchange:**
The plasma membrane is selectively permeable to specific molecules. It allows **essential nutrients** and **other elements** to enter the cell while enabling **waste products** to leave. This is crucial for maintaining homeostasis.
4. **Free Movement of Small Molecules:**
Small molecules such as **oxygen (O_2)**, **carbon dioxide (CO_2)**, and **water (H_2O)** can easily pass through the membrane without assistance due to their small size and neutral charge.
5. **Regulated Transport of Large Molecules:**
Larger molecules like **amino acids**, **glucose**, and other **sugars** are not able to pass freely across the membrane. Their transport is **regulated** by specialized transport proteins, channels, or carriers.
6. **Membranes Around Organelles in Eukaryotes:**
In **eukaryotic cells**, the plasma membrane's function is mirrored by membranes surrounding some of the internal organelles (e.g., nucleus, mitochondria, endoplasmic reticulum). These internal membranes regulate the entry and exit of materials, ensuring functional separation and specialization within the cell.

12. Describe the major techniques used to study the structure of the plasma membrane.

Ans. To understand the complex structure and functions of the **plasma membrane**, several advanced techniques are employed in biological research. These include:

1. **Transmission Electron Microscopy (TEM):**
This method is used to obtain **high-resolution images** of the internal structure of the plasma membrane. TEM can **reveal detailed structural features** of the **lipid bilayer** and **associated proteins**, helping scientists to study the molecular organization at a very fine scale.
2. **Scanning Electron Microscopy (SEM):**
SEM is valuable for examining the **surface topology** of cells and their membranes. It provides **3D images** of the **outer surface** of cells, revealing textures, shapes, and surface patterns.
3. **Confocal Microscopy:**
This technique uses **laser scanning** and **fluorescent dyes** to produce **high-resolution and sharply focused images** of the plasma membrane. Confocal microscopy is particularly useful in cell imaging and localization of specific membrane components.
4. **Total Internal Reflection Fluorescence Microscopy (TIRFM):**
TIRFM allows for the visualization of events occurring at or near the **cell membrane**. It provides **high-resolution images** of the plasma membrane and is especially useful for studying **membrane-cytoskeleton interactions** and the behavior of **membrane proteins**.
5. **Atomic Force Microscopy (AFM):**
AFM is a powerful tool that generates **topographical images** of the plasma membrane at **nano-scale resolution**. It allows scientists to measure the surface roughness, texture, and elasticity of cell membranes.
6. **X-ray Crystallography:**
This technique is employed to determine the **atomic and molecular structure** of **membrane proteins**. Understanding the detailed structure of proteins helps in deciphering how they function in the membrane, such as in transport or signal reception.
7. **Lipidomics:**
Lipidomics involves the **comprehensive analysis of lipids** in the plasma membrane using tools such as **mass spectrometry**. This technique helps identify and quantify different types of lipids and understand their roles in membrane dynamics and cell signaling.
8. **Fluorescence Recovery After Photo-bleaching (FRAP):**
FRAP is used to study the mobility and dynamics of membrane lipids and proteins. A fluorescently labeled region of the membrane is bleached with a laser, and the recovery of fluorescence is monitored as unbleached molecules move into the bleached area. This helps in measuring diffusion rates and understanding membrane fluidity.

> The ability to distinguish among different cells is crucial to life. In allows cells in an embryo to sort themselves into tissues and organs. It also helps cells of the immune system to recognize and reject foreign cells, e.g., infectious bacteria.

Plasma Membrane

mcqs

1. **What is the function of the plasma membrane in all cells?**
   A. It produces energy
   B. It encloses cell contents and serves as a semi-porous barrier✓
   C. It forms genetic material
   D. It synthesizes proteins
2. **Who proposed the fluid mosaic model of the plasma membrane?**
   A. Watson and Crick
   B. Robert Hooke and Antonie van Leeuwenhoek
   C. S.J. Singer and Garth Nicolson✓
   D. Schleiden and Schwann
3. **What is the primary structural component of the plasma membrane?**
   A. DNA
   B. Phospholipids✓
   C. RNA
   D. Cellulose
4. **The phosphate end of a phospholipid is:**
   A. Hydrophobic
   B. Non-polar
   C. Hydrophilic✓
   D. Amphipathic
5. **What part of the phospholipid is hydrophobic?**
   A. Phosphate group
   B. Glycerol head
   C. Fatty acid tails✓
   D. All of the above
6. **In the bilayer of the plasma membrane, hydrophobic tails face:**
   A. Outward
   B. Toward cytoplasm
   C. Inward✓
   D. The nucleus
7. **What maintains the fluidity of the plasma membrane at low temperatures in eukaryotic cells?**
   A. Proteins
   B. Phospholipids
   C. Cholesterol✓
   D. Carbohydrates
8. **The positioning of membrane proteins is related to:**
   A. Golgi bodies
   B. DNA
   C. Cytoskeleton✓
   D. Ribosomes
9. **Proteins in the plasma membrane can function as all of the following EXCEPT:**
   A. Channels for transport
   B. Energy storage units✓
   C. Enzymes
   D. Receptors
10. **Which proteins are responsible for transmitting signals to the interior of the cell?**
    A. Channel proteins
    B. Carrier proteins
    C. Receptor proteins✓
    D. Enzymatic proteins
11. **Proteins that catalyze reactions related to the plasma membrane are called:**
    A. Channel proteins
    B. Structural proteins
    C. Enzymatic proteins✓
    D. Messenger proteins
12. **A protein with a sugar chain attached is known as a:**
    A. Glycolipid
    B. Glycoprotein✓
    C. Glycogen
    D. Glucose protein
13. **A lipid with a sugar chain attached is called:**
    A. Glycolipid✓
    B. Glycogen
    C. Lipoprotein
    D. Glucolipid
14. **What term describes the collection of glycoproteins and glycolipids on the plasma membrane?**
    A. Cytoskeleton
    B. Cell coat
    C. Glycocalyx✓
    D. Endomembrane system
15. **Which cell type has 49% protein in its plasma membrane by weight?**
    A. Bacteria
    B. Human red blood cell✓
    C. Mitochondrial inner membrane
    D. Plant cell
16. **What percentage of lipid is found in the outer mitochondrial membrane?**
    A. 24%
    B. 52%
    C. 48%✓
    D. 25%
17. **Which membrane has the highest percentage of protein?**
    A. Bacterial membrane
    B. Inner mitochondrial membrane✓
    C. Human red blood cell
    D. Outer mitochondrial membrane
18. **What is the carbohydrate percentage in bacterial membranes?**
    A. 0%✓
    B. 8%
    C. 10%
    D. 25%
19. **Which structure enables selective transport across the membrane?**
    A. Lipids
    B. DNA
    C. Proteins✓
    D. Carbohydrates
20. **Glycolipids and glycoproteins vary between:**
    A. Species
    B. Individuals of the same species
    C. Different cell types in the same individual
    D. All of the above✓

"FUNCTIONS OF PLASMA MEMBRANE" AND "TECHNIQUES TO STUDY ITS STRUCTURE"

mcqs

1. **What is the basic function of the plasma membrane?**
   A. Protein synthesis
   B. Energy production
   C. Acts as a semi-porous barrier✓
   D. DNA replication
2. **The plasma membrane holds which of the following together?**
   A. Nucleus only
   B. Cell wall
   C. Organelles
   D. Cell constituents✓
3. **The plasma membrane allows the movement of:**
   A. All molecules freely
   B. Only lipids
   C. Specific molecules✓
   D. Only large molecules
4. **Which of the following can freely pass through the plasma membrane?**
   A. Proteins
   B. Amino acids

C. Sugars D. Oxygen ✓

5. **Which of the following molecules is carefully regulated by the plasma membrane?**
A. Water B. Carbon dioxide
C. Amino acids ✓ D. Oxygen

6. **In eukaryotic cells, membranes are also found:**
A. Only outside the cell B. Around ribosomes
C. Around internal organelles ✓
D. Around DNA only

7. **The internal organelle membranes of eukaryotic cells serve to:**
A. Store water B. Destroy waste
C. Regulate material flow ✓
D. Create ribosomes

8. **Which technique reveals detailed structure of the lipid bilayer and proteins?**
A. Atomic Absorption Spectroscopy
B. Transmission Electron Microscopy ✓
C. Confocal Microscopy
D. X-ray Diffraction

9. **Scanning Electron Microscopy is mainly used to:**
A. View genetic material
B. Examine cell movement
C. Study surface topology ✓
D. Analyze protein synthesis

10. **What does confocal microscopy use for image creation?**
A. UV rays B. Magnetic waves
C. Laser scanning and fluorescence ✓
D. X-rays

11. **Total Internal Reflection Fluorescence Microscopy (TIRFM) provides high-resolution images of:**
A. Golgi bodies B. Mitochondria
C. Membrane and its interactions ✓
D. Ribosomes

12. **Atomic Force Microscopy provides:**
A. DNA sequences B. Topographical images ✓
C. Heat maps D. Genetic information

13. **Which technique determines the atomic structure of membrane proteins?**
A. Transmission EM B. X-ray Crystallography ✓
C. SEM D. FRAP

14. **Lipidomics primarily involves:**
A. Study of proteins B. Study of nucleotides
C. Analysis of lipids using mass spectrometry ✓
D. Measurement of RNA

15. **The technique that measures mobility of membrane proteins using laser bleaching is:**
A. Atomic Force Microscopy
B. Confocal Microscopy
C. Lipidomics
D. Fluorescence Recovery after Photobleaching (FRAP) ✓

16. **During FRAP, what occurs after bleaching a region of the membrane?**
A. It dies
B. Fluorescence remains absent
C. Fluorescence recovers ✓
D. Cell lyses

17. **Which molecules are able to pass freely through the plasma membrane?**
A. DNA and proteins B. Amino acids and sugars
C. Oxygen, CO_2, and water ✓
D. Lipids only

18. **Which of the following is NOT a technique used to study plasma membrane structure?**
A. Fluorescence Recovery after Photobleaching
B. X-ray Crystallography
C. Gram staining ✓
D. Lipidomics

19. **What is the role of the plasma membrane in waste removal?**
A. Prevents it entirely B. Stores waste
C. Regulates its exit from the cell ✓
D. Destroys it using lysosomes

20. **What type of microscopy provides sharp, detailed images using fluorescence and lasers?**
A. SEM B. Confocal Microscopy ✓
C. TIRF Microscopy D. Brightfield Microscopy

CYTOPLASM AND ORGANELLES

13. Describe the composition and functions of cytoplasm.

Ans. The cytoplasm is one of the three major components of a cell, the other two being the plasma membrane and the nucleus. It is a **semi-viscous and semi-transparent substance** present between the plasma membrane and nuclear envelope in **eukaryotic cells**, and fills the entire space beneath the plasma membrane in **prokaryotic cells**.

The cytoplasm comprises a liquid ground substance called **cytosol**, which is an aqueous solution containing water, organic compounds (such as proteins, carbohydrates, and lipids), and inorganic salts. It serves as the site for various metabolic reactions, including **glycolysis**, the breakdown of glucose during aerobic respiration. Furthermore, it **provides the medium and space** for the functioning of cellular organelles.

Within the cytoplasm, there are **discrete structures** known as **organelles**, which perform specialized cellular functions. Most of these organelles are **enclosed by membranes**, though exceptions like the **ribosome** exist, which are not membrane-bound.

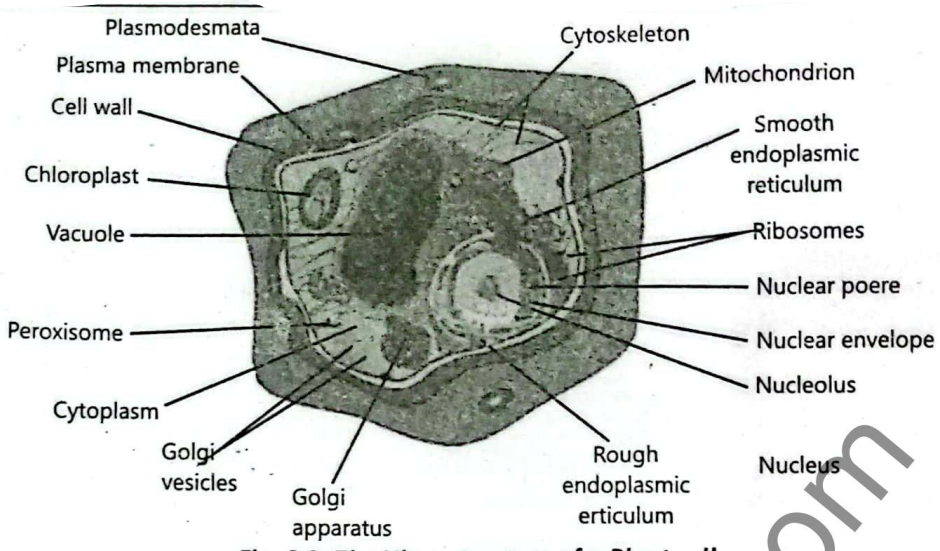


Fig. 3.9: The Ultra-structure of a Plant cell

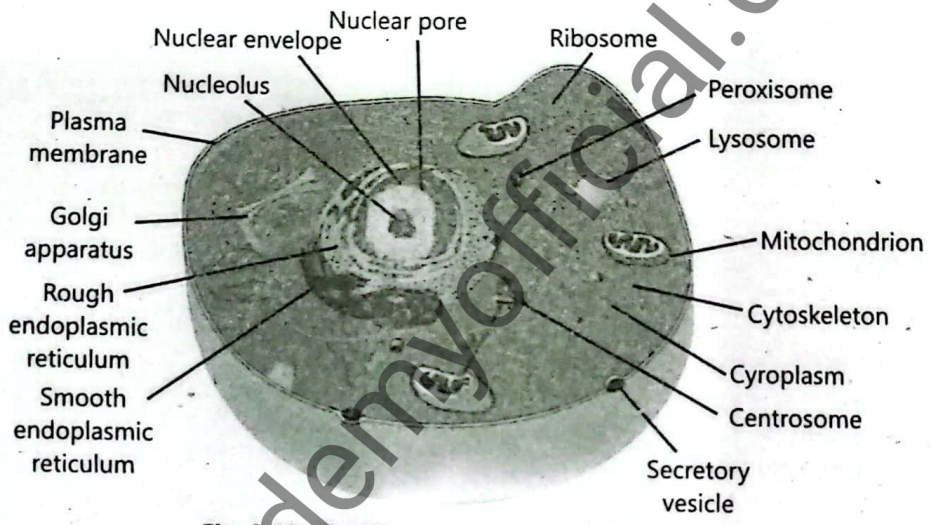


Fig. 3.10: The Ultra-structure of an Animal cell

Q 14. Describe the structure and function of nucleus, along with its associated components.

Ans. The **nucleus** is a central and highly significant organelle found in **eukaryotic cells**. It is typically located in the **center of animal cells**, while in **plant cells**, it is pushed to the side due to the presence of a large central vacuole. The nucleus usually occupies about **10% of the cell's volume** and functions as the **information processing** and **administrative center** of the cell.

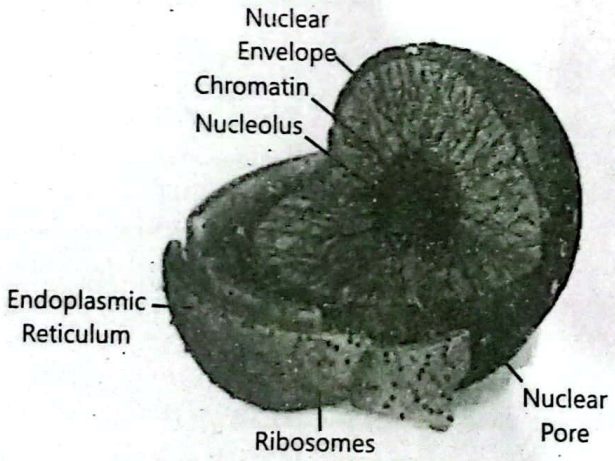


Fig. 3.11: The structure of nucleus

The two main functions of the nucleus are:

1. **Storage of the cell's genetic material (DNA)**
2. **Coordination of cellular activities**, including growth, protein synthesis, and cell division

The nucleus contains a semi-fluid matrix known as **nucleoplasm**, in which **chromatin** and **nucleoli** are suspended. Chromatin is a complex of DNA and proteins, and it organizes into **chromosomes** during cell division.

> Building blocks of DNA and RNA and ATPs are allowed to enter into the nucleus. Ribosomal subunits which are built in nucleoli are the examples of materials that are allowed to leave the nucleus and enter the cytoplasm

The **nucleolus** is a dense, darkly stained structure within the nucleoplasm that **manufactures ribosomal subunits**. Usually, one or two nucleoli are present in a nucleus. These are formed at specific regions on chromosomes called **Nucleolus Organizer Regions (NORs)**, where the DNA encodes **ribosomal RNA (rRNA)**.

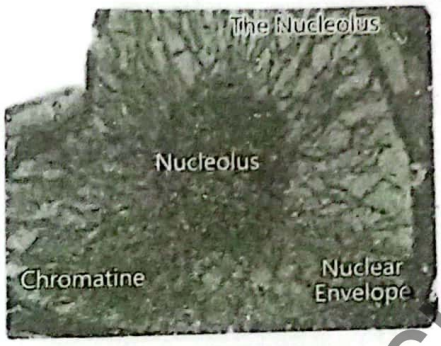


Fig. 3.13: The nucleolus within a nucleus

Structurally, the nucleolus contains:

- **Granular components**: composed of fully formed ribosomal subunits
- **Fibrillar components**: made up of rRNA molecules and associated proteins
- **DNA**: which directs the synthesis of rRNA

The **nuclear envelope** is a **double-layered membrane** that surrounds the nucleus. The space between the two layers is called the **perinuclear space** and is continuous with the **rough endoplasmic reticulum (RER)**. During **cell division**, the nuclear envelope **disassembles** and **reassembles** in the daughter cells.

On the inner surface of the nuclear envelope, there is a **protein lining** called the **nuclear lamina**, which binds to **chromatin** and provides **structural support**. The nuclear envelope is perforated by **nuclear pores**, which regulate the passage of molecules between the nucleus and cytoplasm. These pores allow **small molecules** and selectively permit **larger proteins** (e.g., histones) to enter.

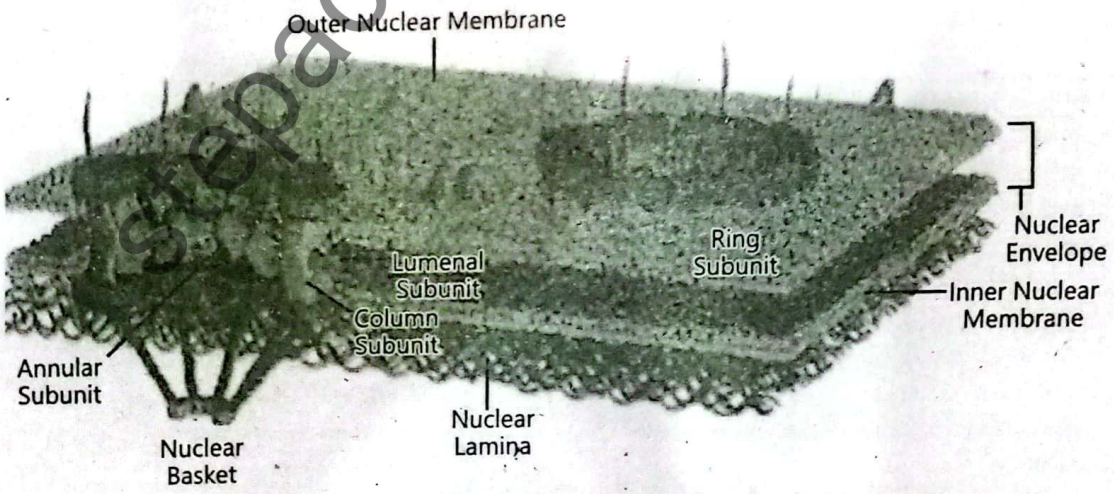


Fig. 3.12: The structure of nuclear envelope and nuclearp ore complex

Each **nuclear pore** is made of a **nuclear pore complex**, which includes:

- **Annular subunit**: surrounds the interior of the pore
- **Column subunit**: forms the walls of the complex
- **Ring subunit**: attaches to the column on the outer side

- **Lumenal subunit**: anchors the complex to the envelope

Tiny **fibrils** often extend from the complex and form a **basket-like structure** on the nuclear side, aiding in molecular transport.

Within the nucleus, **chromatin** appears as **thread-like fibers** composed of **DNA and proteins**. It is organized into structural units called **nucleosomes**, where DNA wraps around **histone proteins**. During **interphase**, chromatin is dispersed and active in various functions, but during **cell division**, it condenses into distinct structures called **chromosomes**. Each chromosome has **arms (chromatids)** and a **central point (centromere)**.

In cells that produce large amounts of protein, and thus require significant numbers of ribosomes, the size of the nucleolus is considerable.
At the onset of mitosis, the single nucleolus present in cell disappears, and after division new nucleolus is formed from the NORs.

The **number of chromosomes** is species-specific. For example:

- Humans have **46 chromosomes** in diploid (non-reproductive) cells
- Some ants and roundworms have as few as **2 chromosomes**
- The Indian fern (*Ophioglossum reticulatum*) has the highest known number, with **1,260 chromosomes**

Interestingly, the number of chromosomes **does not correspond to the complexity** of the organism.

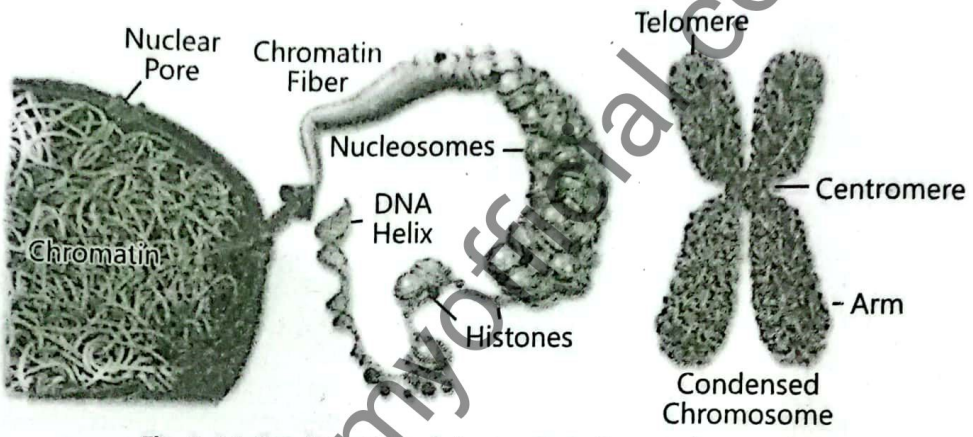


Fig. 3 .14: Condensation of chromatin to form a chromosome

Inside the nucleus of every human cell, there is a 6 feet long DNA. It is subdivided into 46 individual molecules (each 1.5 inches long), one for each chromosome.

There are two types of chromatin. **Euchromatin** is the genetically active chromatin involved in transcribing RNA to produce proteins. The other kind of chromatin is termed **heterochromatin**. Its DNA is genetically inactive.

MCQs

1. **What is the cytoplasm composed of?**
   A. Only water and salts B. Only organelles
   C. Cytosol, organelles, and inclusions ✓
   D. Plasma and DNA
2. **In eukaryotic cells, the cytoplasm is found between:**
   A. Cell wall and plasma membrane
   B. Nucleus and ribosome
   C. Plasma membrane and nuclear envelope ✓
   D. Mitochondria and nucleus
3. **What is the primary function of the cytoplasm?**
   A. DNA replication
   B. Protein transport only
   C. Providing space for organelles and metabolic reactions ✓
   D. Storing genetic material
4. **Which metabolic reaction occurs in the cytoplasm?**
   A. Photosynthesis B. Glycolysis ✓
   C. DNA replication D. Protein transcription
5. **Which organelle stores the genetic material of a eukaryotic cell?**
   A. Ribosome B. Cytoplasm
   C. Nucleolus D. Nucleus ✓
6. **What is the nucleoplasm?**
   A. A type of ribosome
   B. A nuclear envelope protein
   C. The semi-fluid matrix inside the nucleus ✓
   D. A type of chromatin
7. **What is chromatin made of?**
   A. RNA and sugars B. DNA and proteins
   C. Ribosomes and enzymes D. Lipids and DNA
8. **What is a nucleosome?**
   A. A type of ribosome

B. A bead-like structure made of DNA and histones ✓
C. A protein found in the cytoplasm
D. A nuclear pore complex

9. **What happens to chromatin during cell division?**
A. It disappears
B. It forms ribosomes
C. It condenses into chromosomes ✓
D. It becomes part of cytoplasm

10. **What is the nuclear envelope?**
A. A part of the nucleolus
B. A single-layered membrane
C. A double-layered membrane surrounding the nucleus ✓
D. The inner wall of the plasma membrane

11. **What connects the nuclear envelope to the endoplasmic reticulum?**
A. Chromosomes
B. Cytosol
C. Perinuclear space ✓
D. Nuclear pores

12. **What do nuclear pores regulate?**
A. Photosynthesis
B. Cell wall growth
C. Movement of molecules between nucleus and cytoplasm ✓
D. Ribosome attachment

13. **What is the nuclear lamina?**
A. A type of nuclear pore
B. A fluid in the nucleolus
C. A protein lining inside the nuclear envelope ✓
D. A chromosomal component

14. **What is the function of the nucleolus?**
A. DNA replication
B. Protein folding
C. Ribosome subunit synthesis ✓
D. ATP production

15. **Where are nucleoli formed?**
A. Inside the plasma membrane
B. In the mitochondria
C. At Nucleolus Organizer Regions (NORs) of chromosomes ✓
D. In Golgi bodies

16. **What type of RNA is synthesized in the nucleolus?**
A. mRNA
B. tRNA
C. rRNA ✓
D. snRNA

17. **Which of the following are components of the nuclear pore complex?**
A. Centrioles
B. Annular, column, ring, and lumenal subunits ✓
C. Ribosomes
D. Mitochondrial cristae

18. **What structure forms a basket-like structure on the nuclear side of the pore complex?**
A. Lipid vesicles
B. DNA loops
C. Tiny fibrils ✓
D. Histones

19. **What are the parts of a chromosome?**
A. Nucleotides only
B. Histones and enzymes
C. Chromatids and centromere ✓
D. Plasma and RNA
Explanation: Chromosomes consist of chromatids (arms) and a centromere (central point).

20. **Which of the following statements is true about chromosome numbers?**
A. All species have the same number
B. More chromosomes mean more complex organisms
C. Chromosome numbers vary by species and do not correlate with complexity ✓
D. Humans have the least number of chromosomes

ENDOPLASMIC RETICULUM

15. Describe the structure and functions of the Endoplasmic Reticulum (ER). Also differentiate between Rough and Smooth Endoplasmic Reticulum.

Ans. The Endoplasmic Reticulum (ER) is a vast network of flattened sacs and branching tubules, known as cisternae, that extend throughout the cytoplasm of plant and animal cells. These cisternae are interconnected and create a single, large internal space called the **cisternal space**, which accounts for more than 10% of the cell's volume. The ER is also connected to the nuclear envelope, providing a communication pipeline between the nucleus and cytoplasm.

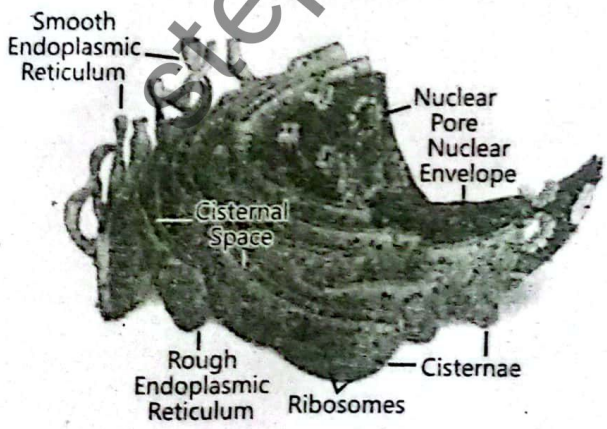


Fig. 3.15: Endoplasmic reticulum

Due to their physical membranous connection, the lumen of the endoplasmic reticulum and the space between the layers of the nuclear envelope comprise a single compartment. This close association enables the endoplasmic reticulum and the nucleus to share information in a very efficient manner.

Fig. 3.17: A fluorescence image of an endothelial cell showing ER (green)

The ER plays a crucial role in the synthesis, processing, and transport of various biochemical compounds necessary for cellular function. There are two types of ER:

- **Rough Endoplasmic Reticulum (RER):**

The surface of the RER is studded with ribosomes, giving it a rough appearance under a microscope. It is primarily involved in the **synthesis and processing of proteins**. During this process, the RER may attach other molecules such as sugars to the proteins, then transports them to required areas of the cell or sends them to the **Golgi apparatus** for further modification.

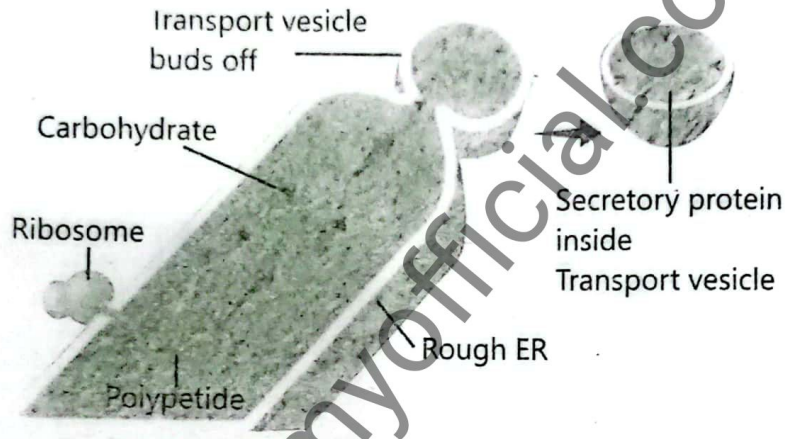


Fig. 3.16: The functioning of rough endoplasmic reticulum

- **Smooth Endoplasmic Reticulum (SER):**

The SER lacks ribosomes on its surface, appearing smoother under a microscope. It is **less extensive** than the RER in most cells and performs different functions, including **lipid synthesis**, **carbohydrate metabolism**, **detoxification** of harmful substances, and **calcium storage and metabolism**. In muscle cells, the SER is responsible for releasing calcium ions that trigger muscle contractions.

Thus, the ER is a multifunctional organelle vital to protein and lipid metabolism and maintaining cellular homeostasis.

MCQ's

1. **What are the structural units of the Endoplasmic Reticulum (ER)?**
   A. Vesicles B. Cristae
   C. Cisternae ✓ D. Granules
2. **The space enclosed by the cisternae of the ER is called:**
   A. Intermembrane space B. Nucleoplasm
   C. Matrix D. Cisternal space ✓
3. **The ER forms a connection between which two cell structures?**
   A. Nucleus and mitochondria
   B. Plasma membrane and Golgi body
   C. Nucleus and cytoplasm ✓
   D. Ribosomes and lysosomes
4. **What makes the Rough Endoplasmic Reticulum (RER) appear rough?**
   A. Lipid granules B. Enzyme coating
   C. Ribosomes on its surface ✓ D. Dense fluid
5. **What is the main function of the RER?**
   A. Lipid synthesis
   B. Protein processing and transport ✓
   C. Detoxification D. Carbohydrate storage
6. **Which organelle does RER send proteins to for further modification?**
   A. Ribosomes B. Nucleolus
   C. Golgi apparatus ✓ D. Lysosomes
7. **What is a major function of the Smooth Endoplasmic Reticulum (SER)?**
   A. Protein synthesis B. Photosynthesis
   C. Lipid production ✓ D. Chromosome replication
8. **In muscle cells, what does the SER release to trigger muscle contractions?**
   A. ATP B. Potassium
   C. Calcium ✓ D. Sodium

RIBOSOMES

16. What are ribosomes? Discuss their composition, location in different cell types, and role in protein synthesis.

Ans. Ribosomes are small, granular organelles found in all living cells. They are composed of approximately **60% ribosomal RNA (rRNA)** and **40% protein**. Unlike other organelles, ribosomes **lack a surrounding membrane** and are among the smallest cell structures.

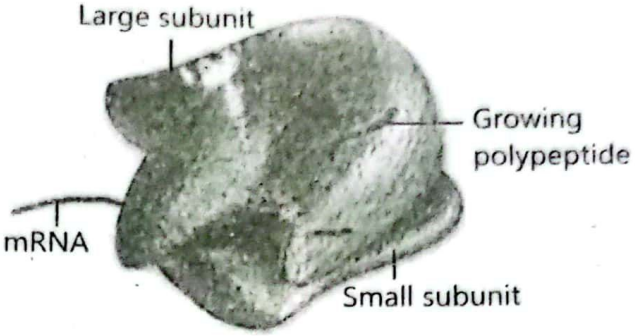


Fig. 3.18: Ribosome translating the mRNA

In **eukaryotic cells**, ribosomes are either:

- **Attached to the Rough Endoplasmic Reticulum**, forming the RER, or
- **Freely floating in the cytoplasm.**

In addition to the most familiar cellular locations of ribosomes, they can also be found inside mitochondria and the chloroplasts of plants. These ribosomes notably differ in size and makeup than the ribosomes found in cytoplasm, and are more like those present in prokaryotes.

In **prokaryotic cells**, ribosomes are **only found freely in the cytoplasm**. Regardless of location, ribosomes function as the **protein factories of the cell**, synthesizing proteins required for various cell functions. Cells involved in high levels of protein synthesis, like **pancreatic and brain cells**, contain a larger number of ribosomes.

In eukaryotes, ribosome subunits are **produced in the nucleolus**. Ribosomal proteins enter the nucleolus and combine with rRNA to form two subunits: a **small subunit (40S)** and a **large subunit (60S)**. These subunits exit the nucleus through nuclear pores and combine in the cytoplasm to begin **protein synthesis**. The complete eukaryotic ribosome is referred to as **80S**, based on its sedimentation rate during centrifugation.

In **prokaryotic cells**, ribosomes are slightly smaller, with a **70S** sedimentation rate, made up of **30S (small)** and **50S (large)** subunits.

The proteins that are synthesized by free ribosomes are for the cell's own internal use. While the proteins produced by the ribosomes bound to RER are transported outside of the cell.

Protein synthesis requires three types of RNA:

- **mRNA** (messenger RNA) brings genetic information from DNA,
- **tRNA** (transfer RNA) delivers amino acids to the ribosome, and
- **rRNA** forms the structural and enzymatic core of the ribosome.

Together, these components ensure the accurate translation of genetic instructions into functional proteins.

The Svedberg values are not additive i.e. the values of the two subunits of a ribosome do not add up to the Svedberg value of the complete ribosome. This is because the rate of sedimentation of a molecule depends upon its size and shape, rather than simply its molecular weight.

MCQs

1. **What are ribosomes made of?**
   A. DNA and protein B. mRNA and tRNA
   C. rRNA and protein ✓ D. Lipids and sugar
2. **Ribosomes are most abundant in cells that:**
   A. Do photosynthesis B. Synthesize proteins ✓
   C. Store fats D. Perform excretion
3. **Where are ribosomes made in eukaryotic cells?**
   A. Cytoplasm B. Golgi apparatus
   C. Nucleolus ✓ D. Nuclear envelope
4. **What type of RNA provides the instructions for protein synthesis?**
   A. tRNA B. rRNA
   C. mRNA ✓ D. sRNA
5. **What are the subunits of a eukaryotic ribosome?**
   A. 70S and 80S B. 60S and 40S ✓
   C. 50S and 30S D. 20S and 10S
6. **What is the complete sedimentation rate of prokaryotic ribosomes?**
   A. 50S B. 70S ✓
   C. 80S D. 60S
7. **Which molecule brings amino acids to the ribosome?**
   A. mRNA B. tRNA ✓
   C. DNA D. ATP

MITOCHONDRIA

17. What are mitochondria? Explain their structure, unique features, and role in energy production.

Ans. Mitochondria are rod-shaped organelles commonly known as the **powerhouses of the cell** because they generate **ATP (adenosine triphosphate)**, the primary energy currency of the cell. Each mitochondrion is surrounded by **two membranes**:

1. **Outer membrane** – smooth and acts like a filter to allow smaller molecules through.
2. **Inner membrane** – highly folded into **cristae**, which greatly increase surface area and house important enzymes and protein complexes involved in **cellular respiration**.

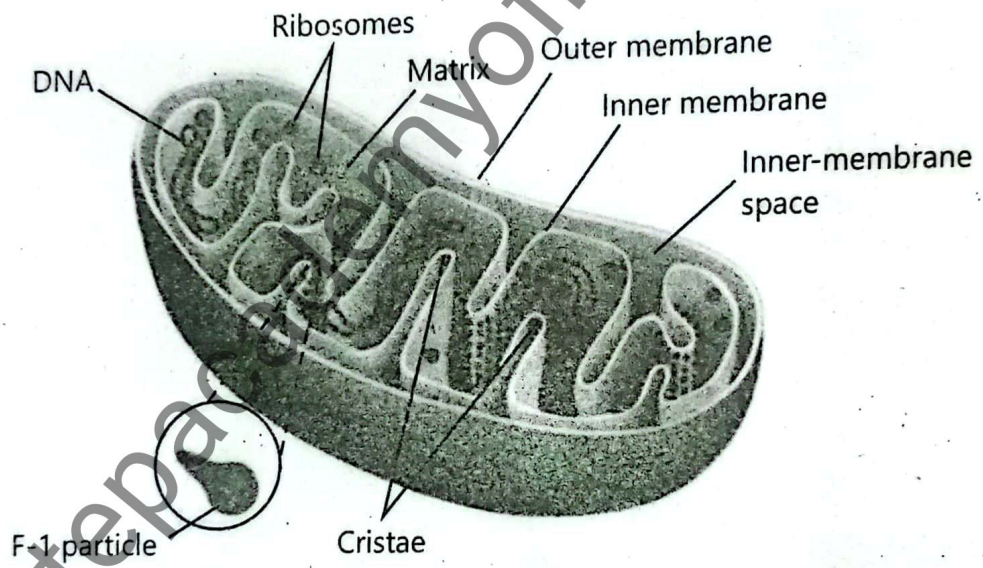


Fig. 3.19: Structure of a mitochondrion

Between these membranes lies the **intermembrane space**, and inside the inner membrane is the **matrix**, a fluid-filled area containing enzymes for the **Krebs cycle** and other steps of respiration.

> Scientists hypothesize about the origin of mitochondria. According to them, millions of years ago small, free-living prokaryotes were engulfed, but not consumed, by larger prokaryotes. The two organisms developed a symbiotic relationship over time, the larger organism providing the smaller with ample nutrients and the smaller organism providing ATP molecules to the larger

A unique feature of mitochondria is that they contain their **own circular DNA**, similar to prokaryotic DNA. They also have their own **ribosomes (70S type)** and RNA types, allowing them to **replicate independently** of the cell's nucleus.

The **inner membrane** contains special protein complexes that serve as **electron carriers** in the **electron transport chain**, a critical phase of aerobic respiration. The **cristae** are embedded

> The number of mitochondria present in a cell depends upon the metabolic requirements of that cell, and may range from one to thousands. Mitochondria are found in nearly all eukaryotes, including plants, animals, fungi, and protists, and are large enough to be observed with a light microscope.

with **F1 particles** or **ATP synthase enzymes**, which synthesize ATP using the energy derived from the electron transport chain.

The **matrix** hosts enzymes that catalyze reactions in the **Krebs cycle**, where carbohydrates, fats, and proteins are broken down to release energy.

In summary, mitochondria are essential for producing the energy required for cellular activities, and their semi-autonomous nature and complex structure make them distinct among organelles.

MCQs

1. **What is the primary function of mitochondria?**
   A. DNA replication B. Protein degradation
   C. Energy (ATP) production ✓ D. Lipid transport
2. **The inner membrane of mitochondria is folded into:**
   A. Cristae ✓ B. Cisternae
   C. Vesicles D. Microvilli
3. **The enzymes on the inner mitochondrial membrane involved in ATP synthesis are called:**
   A. RNA polymerase B. F-1 particles ✓
   C. Histones D. Lysosomes
4. **Which feature makes mitochondria semi-autonomous?**
   A. Double membrane only
   B. Presence of Golgi body
   C. Own DNA and ribosomes ✓
   D. Fixed position in cytoplasm
5. **Which type of ribosomes are present in mitochondria?**
   A. 80S B. 60S
   C. 70S ✓ D. 40S

CHLOROPLASTS

18. What are chloroplasts? Explain their structure and function in photosynthesis with proper detail.

Ans. ***Introduction***

One of the most important characteristics of plants is their ability to conduct **photosynthesis**, which means they can make their own food by converting **light energy into chemical energy**. This process occurs in almost all plant species and is carried out in specialized organelles known as chloroplasts.

> Mitochondria are similar to chloroplasts. Both organelles convert energy for the cell. Mitochondria perform aerobic respiration. They generate chemical energy in the form of ATP by metabolizing sugars, fats and other chemical fuels with the assistance of oxygen.
> Chloroplasts perform photosynthesis. They convert energy from the sun into the biosynthesis of organic nutrients using carbon dioxide and water. Like mitochondria, chloroplasts also contain their own DNA and are able to grow and reproduce independently of the cell.

Presence of Chloroplasts in Plant Structures

All green structures in plants, including stems and unripened fruits, contain chloroplasts. However, the majority of photosynthetic activity takes place in the leaves. On average, the **chloroplast density** on the surface of a leaf is about one-half million per square millimetre.

Role of Chlorophyll Pigments

Chloroplasts contain the pigments **chlorophyll "a"** and **chlorophyll "b"**, which are capable of absorbing the light energy required for photosynthesis to take place.

Structure of a Chloroplast

The chloroplast is **ellipsoid-shaped** and enclosed by **two membranes**. The area between these two membranes is called the **inter-membrane space**. Inside the inner membrane, a semi-fluid substance called **stroma** is present. The stroma contains **dissolved enzymes** and makes up most of the chloroplast's internal volume. It is important to note that the outer membrane is **more permeable** than the inner one.

Thylakoids, Grana, and Lamellae

The inner membranes of the chloroplast lie closely together and fuse along their edges. This arrangement forms **disk-shaped compartments** called **thylakoids**. Multiple thylakoids stack together to form structures called **grana** (singular: granum). The **lamellae** are **non-green compartments** that connect different grana together. Each granum may contain a few to several thylakoids, and a single chloroplast may have a hundred or more grana.

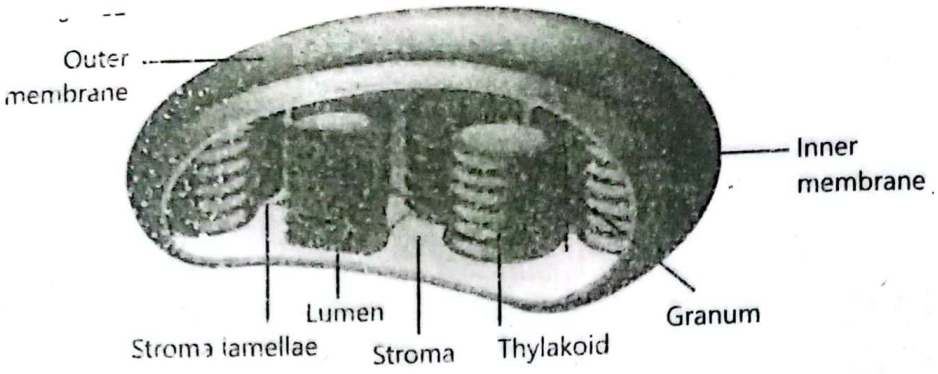


Fig. 3.20: Structure of chloroplast

Unique Features and Function of Chloroplasts

Much like mitochondria, chloroplasts are unique among organelles because they have their **own DNA** and can **reproduce independently** of the cell in which they exist.

Light is absorbed by chlorophyll molecules embedded in the thylakoid disks. When these chlorophyll molecules absorb light, they **emit electrons**, which leads to the formation of **ATP (adenosine triphosphate)**.

Using the ATPs produced, the **stroma** then facilitates the conversion of **low-energy carbon dioxide (CO_2)** into a **high-energy compound such as glucose**. This is the key function of chloroplasts: the production of food for the plant through the process of photosynthesis.

MCQs

1. **What is the primary function of chloroplasts?**
   A) Respiration B) Protein synthesis
   C) Photosynthesis ✓ D) Digestion
2. **Chloroplasts are mainly found in which part of the plant?**
   A) Roots B) Bark
   C) Leaves ✓ D) Flowers
3. **What pigments are found in chloroplasts that help in absorbing light?**
   A) Melanin and Keratin
   B) Carotene and Xanthophyll
   C) Chlorophyll "a" and Chlorophyll "b" ✓
   D) Haemoglobin and Myoglobin
4. **What is the shape of a chloroplast?**
   A) Round B) Spiral
   C) Ellipsoid ✓ D) Rectangular
5. **The fluid inside the inner membrane of the chloroplast is called:**
   A) Plasma B) Matrix
   C) Cytosol D) Stroma ✓
6. **The outer membrane of a chloroplast is:**
   A) Impermeable B) Selectively permeable
   C) Less permeable than the inner
   D) More permeable than the inner ✓
7. **What are the disk-shaped compartments formed by fused inner membranes in chloroplasts called?**
   A) Vesicles B) Thylakoids ✓
   C) Lamellae D) Granum
8. **Stacks of thylakoids are known as:**
   A) Lamellae B) Cisternae
   C) Grana ✓ D) Mitochondria
9. **What connects two grana in the chloroplast?**
   A) Ribosomes B) Nucleus
   C) Lamellae ✓ D) Vacuoles
10. **What is produced when chlorophyll absorbs light energy?**
    A) Oxygen B) ATP ✓
    C) Water D) Nitrate

GOLGI APPARATUS

Q 19. What is the Golgi apparatus? Describe its structure, occurrence, and role in cellular processes.

Ans. ***Introduction***

The **Golgi apparatus** consists of **five to eight cup-shaped, membrane-covered sacs** called **cisternae**, which are **stacked** over each other. It is found in the cells of **plants, animals, and unicellular eukaryotes**.

Recalling:
Golgi apparatus was discovered by Camillo Golgi.

In some **unicellular flagellates**, the Golgi apparatus may consist of as many as **60 cisternae**. The number of Golgi apparatuses in a cell **varies according to its function**. For example, **animal cells** generally contain **between ten and twenty Golgi stacks**. This entire complex is typically **located close to the nucleus**.

Structural Polarity: Cis and Trans Faces

Each **Golgi stack** has **two distinct faces**.

- The **'cis' face**, which is found near the **endoplasmic reticulum (ER)**.
- The **'trans' face**, which is positioned near the **plasma membrane**.

Function of Golgi Apparatus in Transport and Processing

The **Golgi apparatus** serves as the **distribution and shipping department** of the cell for its chemical products. It **modifies proteins and lipids** that have been built in the **endoplasmic reticulum** and prepares them for:

- **Export outside the cell**, or
- **Transport to other locations within the cell**.

Vesicle Transport and Chemical Modification

Small vesicles containing **proteins, carbohydrates, phospholipids**, and other molecules **bud off from the ER**. These vesicles move through the **cytoplasm** and reach the **'cis' face** of the Golgi apparatus. Upon arrival, the vesicles **fuse with the Golgi body** and **release their molecular contents**.

Inside the Golgi lumen, **enzymes** further process these molecules. They are converted into **glycoproteins** and **glycolipids**, which are crucial components of the cellular structure and function.

Camillo Golgi was investigating the nervous system by using a new staining technique (known as Golgi staining). He observed a structure inside cells and named it as reticular apparatus. He publicly announced his discovery in 1898 and the structure was named after him as the Golgi apparatus. Many scientists did not believe that what Golgi observed was a real organelle and instead argued that the apparent body was a visual distortion caused by staining. The invention of the electron microscope in the twentieth century finally confirmed that the Golgi apparatus is a cellular organelle.

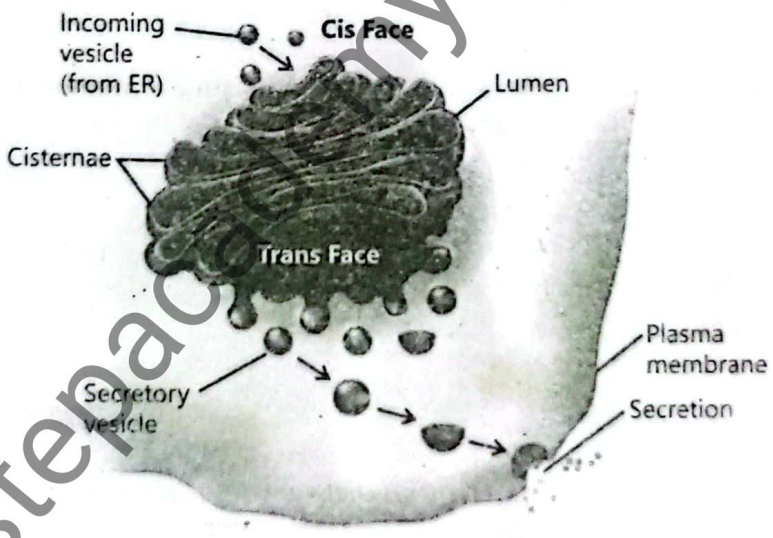


Fig. 3.21: Structure of Golgi apparatus and its functioning

Final Product and Secretion

The final product is **extruded from the 'trans' face** of the Golgi in the form of a **vesicle** and is directed to its **final destination**, either **inside or outside the cell**.

The products that are sent outside the cell are known as **secretions**. Other products may be:

- **Returned to the endoplasmic reticulum**, or
- **Undergo maturation** to become **lysosomes**.

Special Functions in Plant Cells

In **plant cells**, the **Golgi apparatus** also produces **pectin** and other **polysaccharides** that are **specifically required for plant structure and metabolism**. These substances are vital for maintaining cell wall strength and overall plant development.

MCQs

1. **What are the stacked membrane-bound sacs of the Golgi apparatus called?**
   A) Cisternae ✓ B) Grana
   C) Vesicles D) Thylakoids
2. **Where is the Golgi apparatus typically located in a cell?**
   A) Near the mitochondria
   B) Inside the nucleus
   C) Close to the plasma membrane
   D) Near the nucleus ✓
3. **The face of Golgi nearest to the endoplasmic reticulum is called:**
   A) Trans face B) Cis face ✓
   C) Outer face D) Inner face
4. **The function of the Golgi apparatus is best described as:**
   A) DNA replication B) Cell respiration
   C) Distribution and shipping ✓
   D) Protein translation
5. **What type of vesicles fuse with the cis face of the Golgi apparatus?**
   A) Lysosomal vesicles B) Vacuoles
   C) Vesicles from the ER ✓ D) Ribosomes
6. **In the Golgi lumen, enzymes convert proteins into:**
   A) Amino acids B) Lipids
   C) Glycoproteins ✓ D) DNA
7. **Products leaving the trans face of the Golgi are transported via:**
   A) Ribosomes B) Vacuoles
   C) Vesicles ✓ D) ER tubes
8. **Secretions are the products that:**
   A) Remain in the cytoplasm
   B) Enter the nucleus
   C) Are sent out of the cell ✓
   D) Stay in the Golgi apparatus
9. **What may happen to products that are not secreted?**
   A) Destroyed by ribosomes
   B) Sent to vacuoles
   C) Become or return to ER ✓
   D) Become thylakoids
10. **What special substances does the Golgi apparatus produce in plant cells?**
    A) Proteins only B) Nucleic acids
    C) Pectin and polysaccharides ✓
    D) Glucose and starch

LYSOSOMES

Q 20. What are lysosomes and what are their major functions in the cell?

Ans. Structure and Location

Lysosomes are **spherical organelles** that are bounded by a **single membrane**. They are present in most **eukaryotic cells**. These organelles function as **digestive compartments** of the cell.

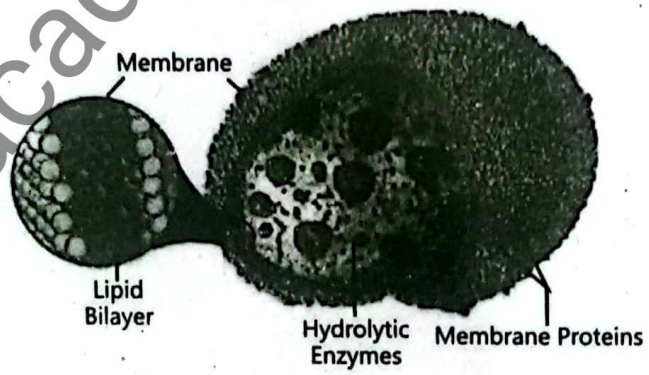


Fig. 3 .22: Structure of lysosome

Abundance in White Blood Cells

Lysosomes are particularly **numerous in animal cells**, especially in **disease-fighting cells** such as **white blood cells**. This is because white blood cells must **digest bacteria, viruses**, and other **foreign intruders** that enter the body.

Recalling:
Lysosomes were discovered by a Belgian scientist Christian René de Duve. They contain strong dige enzymes.

Role in Autophagy

Lysosomes are also involved in breaking down **cellular materials** that hav **xceeded their lifetime** or are no **longer useful**. This function is called **autophagy**, in which the cell digests it wn components to recycle useful materials.

Cellular Recycling Function

Lysosomes break down **cellular waste products**, **fats**, **carbohydrates**, **proteins**, and other **macromolecules** into **simple compounds**. These simple compounds are then **transferred back into the cytoplasm** where they are reused to make **new materials** needed by the cell.

> The cell is safe from the enzymes of lysosomes. These enzymes require acidic environment (of pH of about 4.8). The lysosomal matrix is acidic but cytosol is a neutral environment. So, even if a lysosome is ruptured, its digestive enzymes become inactive and the cell remains uninjured.

Enzymatic Composition

Lysosomes contain about **40 different hydrolytic enzymes**, all of which are **manufactured in the endoplasmic reticulum** and then **modified in the Golgi apparatus** before being sent to the lysosomes.

Protective Membrane

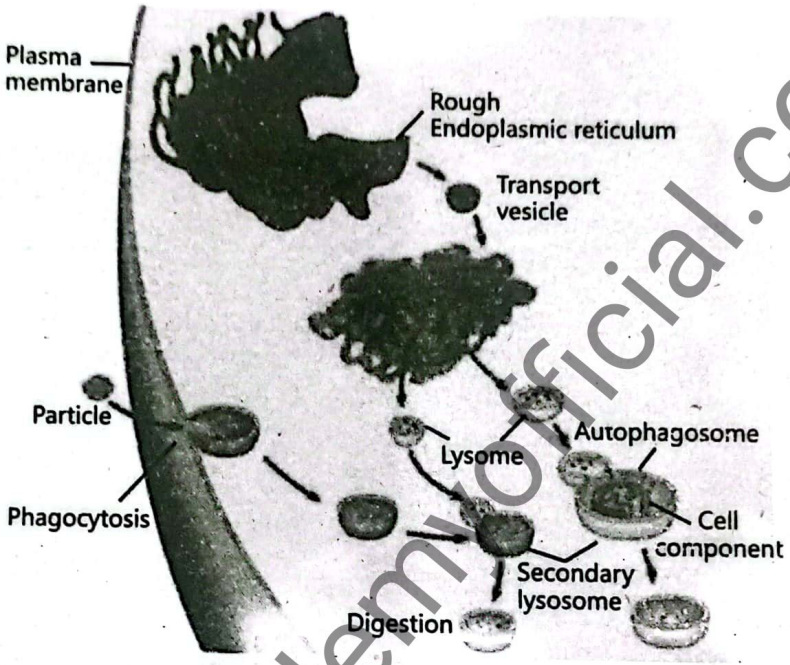


Fig. 3.23: Role of lysosome in the breakdown of the phagocytosed particle and cellular component

The membrane surrounding the lysosome plays a critical role in **protecting the rest of the cell** from the **harsh digestive enzymes** it contains. Without this protective barrier, these enzymes could **cause significant damage** to the cell.

> In the mid-18th century, Belgian scientist Christian René de Duve was investigating carbohydrate metabolism in liver cells. He observed that when cells are damaged in the centrifuge, they release acid phosphatase. He suggested that this digestive enzyme was encased in some membrane bounded organelle within the cell, which he named as lysosome.

Role in selective cell death (apoptosis)

Lysosomes also play a role in the **elimination of whole cells** through a process known as **selective cell death** or **programmed cell death (apoptosis)**. This mechanism is used by **multicellular organisms** during their development.

> Many cells in your brain die during development. This directed suicide is accomplished by the rupture of the lysosomes within the cells that are being eliminated.

For instance, when a **tadpole develops into a frog**, the **tail of the tadpole** is no longer needed. The **cells in the tail** are destroyed by the **enzymes of lysosomes**, demonstrating their role in the **developmental remodeling** of organisms.

21. What are lysosomal storage diseases and what are their effects on the body?

Ans. Lysosomal Storage Diseases

Lysosomal storage diseases occur when a patient lacks one of the **hydrolytic enzymes** needed by the lysosome. As a result, the **abnormal lysosomes** fill with **indigestible substances**, which interfere with the **normal cellular functions**.

Examples of Lysosomal Diseases

- **Pompe's Disease:** The lysosome lacks a **glycogen-digesting enzyme**, leading to the **accumulation of glycogen** in **liver cells**. This buildup can disrupt liver function.
- **Tay-Sachs Disease:** A **lipid-digesting enzyme** is missing, causing **lipids to accumulate** in the **nerve cells of the brain**. This results in **damage to the nervous system**, **mental retardation**, and **early death in childhood**.

MCQs

1. **What is the primary function of lysosomes in the cell?**
   A) Protein synthesis B) DNA replication
   C) Digestion of cellular materials ✓ D) Photosynthesis
2. **Lysosomes are most numerous in which type of cells?**
   A) Red blood cells B) Muscle cells
   C) White blood cells ✓ D) Nerve cells
3. **The process in which lysosomes digest old or damaged cellular parts is called:**
   A) Phagocytosis B) Pinocytosis
   C) Autophagy ✓ D) Exocytosis
4. **How many hydrolytic enzymes are typically found in lysosomes?**
   A) 10 B) 20
   C) 30 D) 40 ✓
5. **Where are lysosomal enzymes initially synthesized?**
   A) Mitochondria B) Golgi apparatus
   C) Endoplasmic reticulum ✓ D) Ribosomes
6. **Which disease is caused by a deficiency of a glycogen-digesting enzyme in lysosomes?**
   A) Tay-Sachs disease B) Zellweger syndrome
   C) Pompe's disease ✓ D) Parkinson's disease
7. **In Tay-Sachs disease, what accumulates in the nerve cells due to enzyme deficiency?**
   A) Proteins B) Lipids ✓
   C) Glycogen D) Water
8. **What protects the cell from the digestive enzymes in lysosomes?**
   A) Cell wall B) Cytoskeleton
   C) Lysosomal membrane ✓ D) Mitochondrial matrix
9. **What role do lysosomes play in the development of a tadpole into a frog?**
   A) Tissue regeneration B) Tail cell destruction ✓
   C) Nerve cell formation D) Blood cell production
10. **Lysosomal storage diseases are caused by the absence of:**
    A) Ribosomes B) Mitochondria
    C) Hydrolytic enzymes ✓ D) Chlorophyll

PEROXISOMES

Q 22. What are peroxisomes and how do they function in a cell?

Ans. Peroxisomes

Introduction

Peroxisomes are single membrane-bounded organelles present in all eukaryotic cells. They were discovered by **Christian de Duve**, the same scientist who discovered lysosomes.

Enzymatic Functions

Peroxisomes contain a variety of **enzymes**, many of which are **oxidative enzymes**. These enzymes perform **oxidation reactions**, which involve the **removal of electrons and hydrogen atoms** from toxic substances.

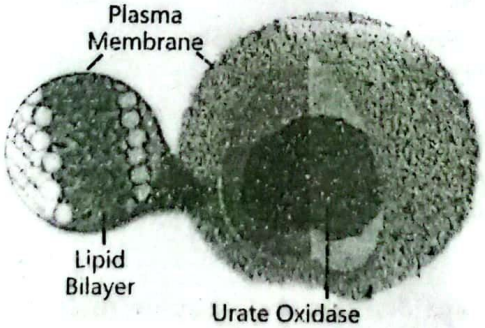


Fig. 3.24: Structure of peroxisome

Detoxification Role

The main function of peroxisomes is to **detoxify harmful substances** in the cell. For example, peroxisomes in **liver cells** help to **detoxify alcohol** and other **harmful compounds** by **oxidizing them**.

Role of Catalase

Some peroxisomes also contain **catalase enzymes**, which break down **hydrogen peroxide**, a toxic by-product of metabolism. Catalase converts hydrogen peroxide into **water and oxygen**, thereby **neutralizing its toxicity** and **protecting the cell**.

Effects of defects in peroxisomes?

Defects in peroxisomes lead to various **metabolic disorders**. The most serious among them is **Zellweger syndrome**.

Zellweger Syndrome

Zellweger syndrome is a **congenital disorder** (present at birth) characterized by the **absence or reduced number of peroxisomes** in the cells. It has **no cure or effective treatment** and usually results in **death within the first year of life**.

MCQs

1. **Peroxisomes were discovered by:**
   A) Robert Hooke B) Antonie van Leeuwenhoek
   C) Christian de Duve ✓ D) Theodor Schwann
2. **Which of the following is NOT a function of peroxisomes?**
   A) Alcohol detoxification
   B) Hydrogen peroxide breakdown
   C) Lipid digestion ✓
   D) Oxidation of harmful substances
3. **What type of enzyme is commonly found in peroxisomes?**
   A) Digestive enzymes B) Oxidative enzymes ✓
   C) Photosynthetic enzymes D) Transport enzymes
4. **Which organ contains many peroxisomes for detoxifying alcohol?**
   A) Kidney B) Heart
   C) Liver ✓ D) Lungs
5. **What toxic substance do some peroxisomes break down?**
   A) Ammonia B) Carbon dioxide
   C) Hydrogen peroxide ✓ D) Urea
6. **Which enzyme breaks hydrogen peroxide into water and oxygen?**
   A) Peroxidase B) Hydrolase
   C) Catalase ✓ D) Lipase
7. **Zellweger syndrome is characterized by:**
   A) Missing mitochondria
   B) Reduced ribosomes
   C) Absence or reduction of peroxisomes ✓
   D) Enlarged nucleus

GLYOXYSOMES

Q 23. What are glyoxysomes and what is their role in plant cells?

Ans. Structure and Function

Glyoxysomes are organelles that are **similar to peroxisomes** but are **found only in plant cells**. These organelles contain **enzymes that convert lipids into carbohydrates**.

Occurrence in Seeds

Glyoxysomes are most abundant in the **cells of lipid-rich seeds**, such as **castor beans** and **soybeans**. During **germination**, these organelles convert **stored lipids into carbohydrates**.

Energy Supply during Germination

The **converted carbohydrates** serve as the **primary energy source** for the **germinating seed**. This energy is essential for the **initial stages of plant growth**, before the seedling can perform **photosynthesis** on its own.

MCQs

1. **Glyoxysomes are found only in:**
   A) Animal cells B) Bacteria
   C) Plant cells ✓ D) Fungi
2. **What is the main function of glyoxysomes during seed germination?**
   A) DNA replication
   B) Conversion of carbohydrates into fats
   C) Conversion of lipids into carbohydrates ✓
   D) Formation of chlorophyll
3. **In which type of seeds are glyoxysomes most abundant?**
   A) Starch-rich seeds B) Water-rich seeds
   C) Protein-rich seeds D) Lipid-rich seeds ✓

VACUOLES

24. What are vacuoles and what are their functions in plant and animal cells?

Ans. Vacuoles are membrane-bounded sacs that serve a variety of functions in cells. Their roles differ slightly in plant and animal cells.

> **Recalling:**
> Vacuoles are fluid filled single membrane bounded organelles. Cells have many small vacuoles in their cytoplasm. However, when a plant cell matures its small vacuoles fuse to form a single large vacuole.

In Plant Cells:

In mature plant cells, vacuoles are usually large and central. A single large vacuole often develops by the fusion of smaller vacuoles and can occupy up to **80 percent or more** of the cell's volume. This central vacuole is enclosed by a membrane known as the **tonoplast**, and the material inside the vacuole is called **cell sap**. The cell sap is chemically different from the surrounding cytoplasm.

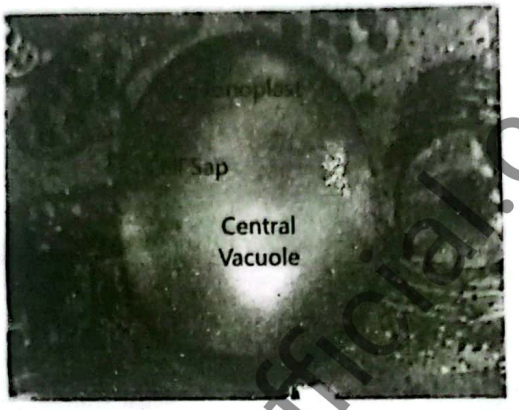


Fig. 3.25: Structure of vacuole in plant cell

The central vacuole in plant cells plays a significant **structural role** by maintaining **turgor pressure**. Turgor pressure is the pressure of the cell contents against the cell wall, which keeps the cell rigid. When a plant receives adequate water, the central vacuoles swell, increasing turgor pressure and thereby maintaining the **structural integrity** of the plant, supported further by the **cell wall**.

> Several materials commonly stored in plant vacuoles have been found to be useful for humans, such as opium, rubber, and garlic flavouring.

In addition to structural support, vacuoles in plant cells perform **several other functions**:

- **Storage** of essential and waste materials
- **Waste disposal**
- **Protection** by storing toxic compounds that deter insects and herbivores
- **Pigment storage**, which contributes to flower coloration to attract pollinators like bees

In Animal Cells:

Vacuoles in animal cells are **much smaller** than those in plant cells. They are primarily involved in the **temporary storage** of materials and the **transport of substances** within the cell.

MCQs

1. Which membrane surrounds the central vacuole in plant cells?
A) Cell wall B) Plasma membrane
C) Tonoplast ✓ D) Chloroplast membrane

2. What is the main substance inside a vacuole called?
A) Cytosol B) Cell sap ✓
C) Plasma D) Matrix

3. Which of the following is NOT a function of vacuoles in plant cells?
A) Turgor pressure maintenance
B) Protein synthesis ✓ C) Storage of pigments
D) Defense against herbivores

4. Vacuoles help in maintaining plant structure by regulating:
A) Osmosis B) Turgor pressure ✓
C) Diffusion D) Photosynthesis

5. Which cells contain smaller, temporary vacuoles for storage and transport?
A) Plant cells B) Fungal cells
C) Animal cells ✓ D) Algal cells

6. What role do vacuoles play in flower coloration?
A) Store water B) Store starch
C) Store pigments ✓ D) Produce light

7. What do vacuoles release to deter herbivores?
A) Sugars B) Water
C) Pigments D) Poisonous molecules ✓

CENTRIOLES

25. What are centrioles and what is their role in animal and protist cells?

Ans. Centrioles are **organelles** found in the cells of **animals** and most **protists**. They are associated with the **assembly and organization of cytoskeletal fibres**, especially **microtubules** including **spindle fibres**, which play a key role during cell division.

> **Recalling:**
> Centrioles are hollow and cylindrical organelles. A centriole is made of nine triplets of microtubules.

Structure and Arrangement:

In **eukaryotic cells**, centrioles occur in **pairs**, located at **right angles** to one another near the **nuclear envelope**. These paired centrioles form a structure known as the **centrosome**.

Role in Cilia and Flagella Formation:

In cells that are **ciliated** or **flagellated**, centrioles are essential for the formation of these structures. Each **cilium** and **flagellum** is anchored by a **centriole**, which in this context is called a **basal body**.

Absence in Plants and Fungi:

Interestingly, **plant** and **fungal cells** lack centrioles and basal bodies. In these cells, the organization of **microtubules** and **spindle fibres** occurs from **other structures within the cytoplasm**, not from centrioles.

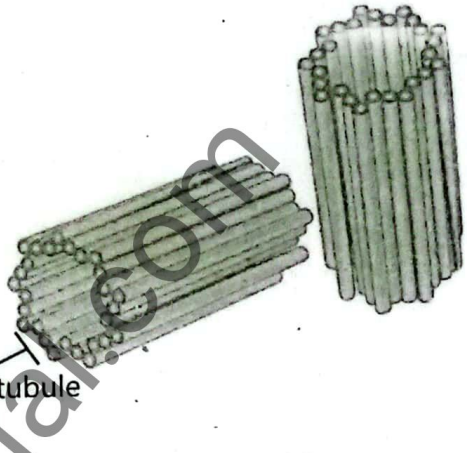


Fig. 3.26: Two centrioles

MCQs

1. **What is the function of centrioles in animal cells?**
   A) DNA replication B) Photosynthesis
   C) Spindle fiber formation ✓
   D) Protein transport
2. **How are centrioles arranged in the cell?**
   A) Parallel to each other B) In a triangle
   C) Randomly scattered
   D) At right angles to each other ✓
3. **In which cells are centrioles absent?**
   A) Animal cells B) Protist cells
   C) Plant and fungal cells ✓
   D) Insect cells
4. **What structures are formed by centrioles in ciliated and flagellated cells?**
   A) Golgi bodies B) Nucleoli
   C) Basal bodies ✓ D) Ribosomes

CYTOSKELETON

26. What is the cytoskeleton and what are its major components and functions in the cell?

Ans. The **cytoskeleton** is a **network of protein fibres** that extends throughout the **cytoplasm** of a cell. It provides structural support, enables movement, and is involved in various cellular processes. The cytoskeleton is made up of **three main types of fibres**:

1. Microfilaments:

- Found in all **eukaryotic cells.**
- Composed of **actin**, a **globular protein**, forming **solid rods.**
- Capable of **assembling and disassembling**, allowing cells to **change shape and move.**
- Important during **cell division**, enabling the dividing cell to **pinch off into two daughter cells**
- In association with **myosin**, microfilaments help in **cellular contraction**.

2. Microtubules:

- Straight, **hollow cylinders** made up of subunits composed of **alpha-tubulin** and **beta-tubulin**
- Provide **structural support** and **shape** to the cell
- Act as **tracks or highways** for the **transport of organelles**
- Major components of **cilia and flagella**, contributing to their structure and movement
- Play a crucial role in **forming spindle fibres** during **cell division**

3. Intermediate Filaments:

- Present only in some **higher animal groups**

- Composed of various **proteins**, the most common being **vimentin**
- In certain cells, other proteins like **keratin** (in skin cells) may form intermediate filaments
- Function to **maintain cell shape and rigidity**
  Help **anchor organelles**, such as the **nucleus**, in place

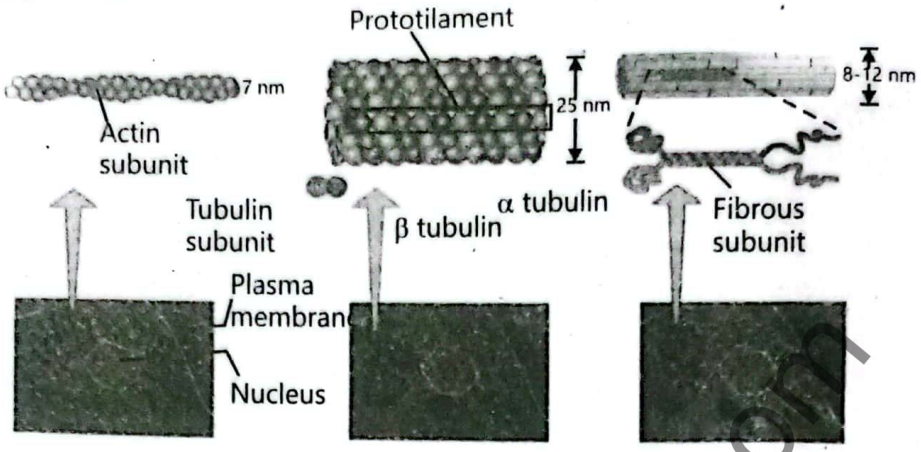


Fig. 3.27: Components of cytoskeleton

MCQs

1. **Which of the following is NOT a part of the cytoskeleton?**
   A) Microfilaments B) Microtubules
   C) Endoplasmic reticulum ✓ D) Intermediate filaments
2. **What are microfilaments made of?**
   A) Myosin B) Tubulin
   C) Actin ✓ D) Keratin
3. **Which cytoskeletal fibre is involved in cell movement and contraction?**
   A) Microfilaments ✓ B) Microtubules
   C) Intermediate filaments D) Ribosomes
4. **Microtubules are composed of which two proteins?**
   A) Actin and Myosin
   B) Alpha-tubulin and Beta-tubulin ✓
   C) Keratin and Collagen
   D) Myosin and Vimentin
5. **What is the function of microtubules?**
   A) Protein synthesis
   B) Chromosome replication
   C) Organellar transport and structure ✓
   D) DNA repair
6. **Which fibres are involved in forming spindle fibers during cell division?**
   A) Microfilaments B) Ribosomes
   C) Microtubules ✓ D) Tonoplasts
7. **Intermediate filaments are mainly found in:**
   A) All prokaryotes B) Plant cells only
   C) Some higher animal cells ✓
   D) Fungal cells
8. **The protein most commonly found in intermediate filaments is:**
   A) Keratin B) Actin
   C) Myosin D) Vimentin ✓
9. **Which cytoskeletal component helps anchor organelles like the nucleus?**
   A) Microfilaments B) Microtubules
   C) Intermediate filaments ✓ D) Actin filaments

CILIA AND FLAGELLA

27. What are cilia and flagella, and how are they structured and functionally important in eukaryotic and prokaryotic cells?

Ans. Cilium (plural: cilia) and flagellum (plural: flagella) are the locomotor appendages that protrude from certain cells. They are thin, tail-like projections extending from the cell body. **Cilia** are short in length and are usually **numerous**, while **flagella** are **longer** but **less numerous**.

Cilia are rare in plants. However, many protozoans, particularly ciliates, possess cilia. Larger eukaryotes such as mammals have cilia on some cell surfaces. For example, in humans, cilia are found in the lining of the trachea, where they sweep mucus and dirt out of the breathing tubes.

The core of eukaryotic cilia and flagella is called the **axoneme**. It contains **two central microt**les surrounded by an **outer ring of nine doublet microtubules**. **Dynein molecules** are located arou**n**e circumference of the axoneme. These dynein molecules bridge the gaps between adjacent microtubule double**t**his arrangement is referred to by biologists as the "**9 + 2 structure**."

A **plasma membrane** surrounds the entire axoneme. At the base of the cilium is its organizing center called the **basal body**. The basal body has the same basic structure as the outer ring of the axoneme, but **each of the nine sets of outer filaments is composed of three microtubules**, rather than a doublet. The basal body is, in fact, a **centriole** and **do not contain microtubule triplets.**

In contrast, **prokaryotic flagella** have a completely different structure. They are built from the protein **flagellin**

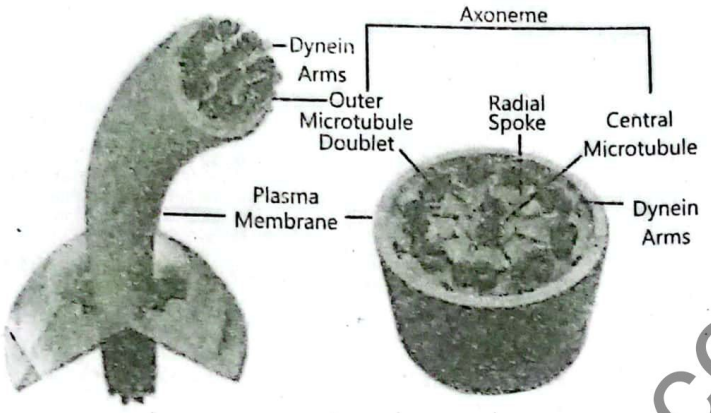


Fig. 3.28: Structure of eukaryotic cilium and flagellum

MCQs

1. **Which of the following correctly differentiates cilia from flagella in eukaryotic cells?**
   A) Cilia are longer and less numerous than flagella
   B) Cilia are shorter and more numerous than flagella ✓
   C) Both are of equal length and number
   D) Cilia are found in all types of plant cells

2. **Where in the human body can you find functional cilia?**
   A) Inside liver cells B) On skin surface
   C) In the lining of the trachea ✓
   D) In red blood cells

3. **What is the structural core of eukaryotic cilia and flagella called?**
   A) Centriole B) Basal body
   C) Axoneme ✓ D) Pili

4. **How are the microtubules arranged in a eukaryotic flagellum's axoneme?**
   A) 9 + 0 B) 8 + 1
   C) 9 + 2 ✓ D) 2 + 9

5. **What surrounds the axoneme in cilia and flagella?**
   A) Protein coat B) Capsule
   C) Plasma membrane ✓ D) Cell wall

6. **The basal body of a cilium is structurally the same as which cellular organelle?**
   A) Ribosome B) Nucleolus
   C) Centriole ✓ D) Peroxisome

7. **Which protein makes up the prokaryotic flagella?**
   A) Dynein B) Tubulin
   C) Actin D) Flagellin ✓

8. **Which of the following is absent in prokaryotic cells?**
   A) Plasma membrane B) DNA
   C) Mitochondria ✓ D) Ribosomes

9. **What term describes the region where DNA is located in a prokaryotic cell?**
   A) Nucleolus B) Chromatin zone
   C) Nucleoid ✓ D) Plasmid

10. **What is the size range of most prokaryotic cells?**
    A) 10–100 µm B) 1–10 nm
    C) 0.1–1 µm D) 2–8 µm ✓

11. **Which organelle is present in eukaryotic cells but absent in prokaryotic cells?**
    A) Plasma membrane B) Ribosome
    C) Endoplasmic reticulum ✓
    D) Nucleoid

12. **Which is a function of dynein in cilia and flagella?**
    A) Protein synthesis
    B) Energy storage
    C) Connecting microtubule doublets ✓
    D) DNA replication

SQ

1. What are the two basic types of cells, and how are they different?

Ans. The two basic types of cells are **prokaryotic** and **eukaryotic**.

- **Prokaryotic cells** are simpler and do not have membrane-bound organelles. All bacteria are examples of prokaryotes.
- **Eukaryotic cells** are more complex and contain membrane-bound organelles. Examples of unicellular eukaryotes include **Yeast** and **Euglena**, while **plants and animals** are examples of multicellular eukaryotes.

2. What is a cell wall, and in which organisms is it found?

Ans. A **cell wall** is a more or less solid outer layer that surrounds a cell. It is found in **bacteria, fungi, plants, and algae**. It provides support and protection to the cell. When the cell wall is removed using cell wall-degrading enzymes, the remaining part of the cell is called a **protoplast**.

3. What is the primary cell wall made of, and what is its structure?

Ans. The **primary cell wall** is the main structural component of a cell wall and is composed of **polysaccharides** such as **cellulose, hemicellulose, and pectin**.

- The **cellulose microfibrils** are arranged at various angles and are held together by **hydrogen bonds**.
- Additionally, many **proteins** are also present in the primary walls to support its function.

4. What is the middle lamella, and what role does it play in plant cells?

Ans. The **middle lamella** is a **gelatinous layer** located between the primary walls of neighboring plant cells.

- It is the first layer to form from the **cell plate during cytokinesis**.
- It holds adjacent cells together and contains **magnesium and calcium pectates**, which are salts of **pectic acid**.
- The primary wall expands inward from this middle lamella.

5. What is the secondary cell wall, and how is it different from the primary cell wall?

Ans. The **secondary cell wall** forms **after the cell has matured** and is located **between the primary wall and the protoplast**.

- It contains **lignin, cellulose**, and **hemicellulose**.
- Due to the presence of **lignin**, the secondary wall is **more rigid** than the primary wall, providing extra mechanical strength to the cell.

6. What are plasmodesmata and what function do they perform?

Ans. **Plasmodesmata** (singular: **plasmodesma**) are **small channels** that directly connect the **cytoplasm of neighboring plant cells**.

- They **penetrate both the primary and secondary cell walls**.
- They allow certain **molecules to pass** directly from one cell to another, making them important for **cellular communication**.
- Plasmodesmata are formed during **cell division**, when parts of the **endoplasmic reticulum** of the parent cell become trapped in the new cell wall.

7. Outline some main functions of the cell wall?

Ans. The **cell wall** performs several critical functions:

- Provides **rigidity** to the cell for **structural and mechanical support**
- Maintains **cell shape** and controls the **direction of cell growth**, which contributes to the **overall architecture of the plant**
- Prevents the **cell from bursting** when water enters
- Offers **protection** against **pathogens** and **environmental stress**
- Acts as a **storage site for carbohydrates** used by the plant

PLASMA MEMBRANE

SQ

1. What is the plasma membrane and which types of cells possess it?

Ans. All prokaryotic and eukaryotic cells have a plasma membrane. It encloses their contents and serves as a semi-porous barrier to the outside environment.

2. What is the structure of the plasma membrane according to the fluid mosaic model?

Ans. The fluid mosaic model is a widely accepted concept that describes the dynamic nature of the plasma membrane. It was proposed by two American biologists, S.J. Singer and Garth Nicolson, in 1972. According to this model, the basic foundation of the plasma membrane is a lipid bilayer, made of phospholipids. A collection of proteins floats within the lipid bilayer.

3. What are phospholipids and how are they arranged in the plasma membrane?

Ans. Phospholipids have a phosphate group at one end of each molecule. They are hydrophilic ("water-lov... at their phosphate ends and hydrophobic ("water-fearing") along their tail regions containing C-H chains. ...he lipid bilayer, the hydrophobic tails are oriented inwards, and the hydrophilic phosphate groups are ...ed outwards, either toward the cytoplasm or the extracellular environment.

4. **What role does cholesterol play in the plasma membrane of eukaryotic cells?**

Ans. In eukaryotes, cholesterol molecules are wedged into the phospholipid bilayer. They help maintain the fluidity of the membrane at low temperatures.

5. **How are proteins positioned in the plasma membrane, and what determines their positioning?**

Ans. Many proteins float within the phospholipid bilayer, while some others simply adhere to the surfaces of the bilayer. The positioning of proteins is related to the organization of the cytoskeleton.

6. **What are the different functions of plasma membrane proteins?**

Ans. Plasma membrane proteins have several functions:

- Many function in the **selective transport** of substances, acting as channels or active transport molecules.
- Some help in **attachment** of the plasma membrane to the cytoskeleton and external fibres.
- Some proteins attach with sugars to form **identification marks**.
- Others act as **receptors**, binding to messenger molecules (e.g., hormones) and transmitting signals to the cell's interior.
- Some proteins also perform **enzymatic activity**, catalyzing reactions related to the plasma membrane.

7. **What are glycoproteins and glycolipids, and where are they found?**

Ans. The outside surface of the plasma membrane has chains of sugars bonded to proteins and lipids.

- A **protein with attached sugar** is called a **glycoprotein**.
- A **lipid with attached sugar** is called a **glycolipid**.

8. **How do glycoproteins and glycolipids vary and what is their function?**

Ans. Glycoproteins and glycolipids vary from species to species, from individual to individual within the same species, and even among different cell types in the same individual. They collectively form the **glycocalyx**, which functions as **cell identification marks** recognized by other cells.

Table: Membrane Composition by Weight

Membrane	Protein	Lipid	Carbohydrate
Human Red Blood Cell	49%	43%	8%
Mitochondria (Outer membrane)	52%	48%	0%
Mitochondria (Inner membrane)	76%	24%	0%
Bacteria	75%	25%	0%

FUNCTIONS OF PLASMA MEMBRANE

SQ

1. **What is the primary role of the plasma membrane in cells?**

Ans. The plasma membrane serves as a semi-porous barrier to the outside environment. It acts as a boundary that holds the cell constituents together and separates the interior of the cell from its external surroundings.

2. **How does the plasma membrane manage the transport of substances into and out of the cell?**

Ans. The plasma membrane is selectively permeable to specific molecules. It allows essential nutrients and elements to enter the cell and facilitates the removal of waste materials. This selective transport ensures that only needed substances pass through while harmful or unnecessary substances are excluded.

3. **Which molecules can pass freely across the plasma membrane, and which are regulated?**

Ans. Small molecules such as oxygen, carbon dioxide, and water can pass freely across the plasma membrane. However, larger molecules like amino acids and sugars are carefully regulated and cannot cross the membrane without specific transport mechanisms.

4. **Do eukaryotic cells contain membranes around their internal organelles? What is the function of these membranes?**

Ans. Yes, eukaryotic cells have membranes surrounding some of their internal organelles. These internal membranes function similarly to the exterior plasma membrane by regulating the flow of materials into and out of the organelles, thus maintaining internal cellular organization and compartmentalization.

TECHNIQUES TO STUDY THE STRUCTURE OF PLASMA MEMBRANE

5. **What is the purpose of Transmission Electron Microscopy in the study of plasma membranes?**

Ans. Transmission Electron Microscopy (TEM) is used to reveal the detailed structures of the lipid bilayer and the proteins associated with it. This technique allows for high-resolution imaging of the internal components of the plasma membrane.

6. How does Scanning Electron Microscopy contribute to membrane studies?

Ans. Scanning Electron Microscopy (SEM) is useful for examining the surface topology of cells and their membranes. It provides detailed three-dimensional images of the cell surface.

7. What is the function of Confocal Microscopy in analyzing plasma membranes?

Ans. Confocal Microscopy uses laser scanning and fluorescence to create sharp, detailed images of the cell membrane. It helps visualize the spatial arrangement of membrane components with high clarity.

8. For what purpose is Total Internal Reflection Fluorescence Microscopy (TIRFM) used?

Ans. Total Internal Reflection Fluorescence Microscopy is used to obtain high-resolution images of the plasma membrane and its interactions with the cytoskeleton and other cellular structures. It is especially useful for studying processes occurring at or near the membrane surface.

9. What does Atomic Force Microscopy reveal about the plasma membrane?

Ans. Atomic Force Microscopy provides topographical images of the plasma membrane at very high resolution. It helps in studying the physical surface and structural features of the membrane in fine detail.

10. How is X-ray Crystallography used in the context of plasma membrane research?

Ans. X-ray Crystallography is employed to determine the atomic structure of membrane proteins. This technique is crucial for understanding the detailed molecular architecture of proteins embedded in or associated with the plasma membrane.

11. What is lipidomics and how is it used to study plasma membranes?

Ans. Lipidomics involves the comprehensive analysis of lipids present in the cell membrane. Using techniques such as mass spectrometry, it helps identify and quantify various lipid molecules and understand their roles in membrane structure and function.

12. What does Fluorescence Recovery after Photo-bleaching (FRAP) measure, and how does it work?

Ans. FRAP is used to study the mobility and dynamics of membrane proteins and lipids. In this technique, a fluorescently labeled region of the membrane is intentionally bleached using a laser. The recovery of fluorescence is then observed as unbleached fluorescent molecules move into the bleached area, indicating molecular mobility within the membrane.

CYTOPLASM AND ORGANELLES

SQ

1. What are the main components and chemical nature of cytoplasm?

Ans. A cell consists of three major components: the **plasma membrane**, **cytoplasm**, and **nucleus**. The **cytoplasm** is a semi-viscous and semi-transparent substance. In **eukaryotic cells**, cytoplasm is found between the plasma membrane and nuclear envelope, while in **prokaryotic cells**, it occupies the entire space beneath the plasma membrane.

It is made up of an aqueous ground substance known as **cytosol**, which contains various **organelles** and other **inclusions**. Cytosol is primarily composed of water, in which many **organic compounds** (such as proteins, carbohydrates, and lipids) and **inorganic salts** are dissolved, either completely or partially.

2. Outline functions of cytoplasm.

Ans. The cytoplasm serves two key purposes:

1. It **provides space** for the proper functioning of cell organelles.
2. It acts as the **site for numerous biochemical (metabolic) reactions**, such as **glycolysis**, which is the breakdown of glucose during aerobic respiration.

3. What are cell organelles and how are they generally structured?

Ans. The cytoplasm contains discrete structures known as organelles, each with specific cellular functions. Most organelles are membrane-bound, which helps in compartmentalizing different biochemical processes. An exception to this is the ribosome, which is not enclosed by a membrane.

1. NUCLEUS

SQ

1. Write a short note on the structure of nucleus.

Ans. The nucleus is a prominent organelle present in all eukaryotic cells. It is centrally located in animal cells, whereas in plant cells, it is usually pushed to the side due to the presence of a large vacuole. The spherical nucleus typically occupies about 10% of the cell's volume. Inside the nucleus is a semi-fluid matrix called nucleoplasm, where most of the nuclear material exists as chromatin. During cell division, chromatin condenses to form chromosomes. The nucleus also contains one or more nucleoli, which are responsible for synthesizing ribosomes.

2. **Outline the functions of nucleus.**

Ans. The nucleus serves as the information processing and administrative center of the cell. It performs two major functions:

1. It **stores the cell's hereditary material (DNA)**.
2. It **coordinates the cell's activities**, such as growth, protein synthesis, and cell division.

3. **Write a short not on envelope.**

Ans. The **nuclear envelope** is a **double-layered membrane** that encloses the contents of the nucleus during most of the cell's life cycle. The **space between the two layers** is known as the **perinuclear space**, which is continuous with the **rough endoplasmic reticulum (RER)**.

During **cell division**, the nuclear envelope **disintegrates** and later **reforms** in daughter cells. On the inner side of the nuclear envelope lies a **protein lining** called the **nuclear lamina**, which binds to chromatin and provides **structural support**.

4. **Give brief description of nuclear pore complex.**

Ans. The nuclear envelope contains small openings known as **nuclear pores**, which regulate the **exchange of materials between the nucleus and cytoplasm**. These pores are **permeable to small molecules** and allow the selective passage of larger molecules such as **histone proteins**.

A **nuclear pore** is a complex structure made of several subunits:

- **Annular subunit**: surrounds the inside of the pore
- **Column subunit**: forms the wall of the complex
- **Ring subunit**: located on the outer side of the column
- **Lumenal subunit**: anchors the pore complex into the nuclear envelope

Additionally, **tiny fibrils** extend from the complex and form a **basket-like structure** on the nuclear side.

5. **write a short note on structure and function of nucleolus.**

Ans. The **nucleolus** is a **darkly stained** and **prominent structure** found within the **nucleoplasm**. A nucleus may contain **one or two nucleoli**. The main function of the nucleolus is to **manufacture the subunits of ribosomes**, which later assemble into functional ribosomes.

Nucleoli form at specific sites on chromosomes called **Nucleolus Organizer Regions (NORs)**. The DNA in these regions encodes **ribosomal RNA (rRNA)**.

The nucleolus is composed of:

- **Granular components**: made of **ribosomal subunits** that are already formed
- **Fibrillar components**: consist of raw materials like **rRNA molecules** and associated proteins
- **DNA**: related to the synthesis of rRNA

6. **What is chromatin, and how does it relate to chromosomes?**

Ans. The **nucleus** contains **string-like fibers** called **chromatin**, which is made up of **DNA and proteins**. Under microscopic observation, chromatin appears as a series of **bead-like structures**, called **nucleosomes**. Each nucleosome consists of a DNA strand **wrapped around histone proteins**.

During **interphase** (the phase when the cell is not dividing), chromatin is **dispersed** throughout the nucleus as a tangled network of fibers. However, as the cell prepares to divide, chromatin **condenses into well-defined structures** known as **chromosomes**.

A **chromosome** consists of two **arms**, called **chromatids**, joined at a **central point** known as the **centromere**.

7. **How does chromosome number vary across species, and does it relate to organism complexity?**

Ans. The **number of chromosomes** in the nucleus of a cell is **species-specific**. For example:

- **Human diploid cells** (non-reproductive cells) contain **46 chromosomes**.
- Some **ants and roundworms** may have as few as **2 chromosomes**.
- The **Indian fern (Ophioglossum reticulatum)** has the highest known number, with **1,260 chromosomes**.

Importantly, the **number of chromosomes is not correlated with the complexity of the organism**. For instance, a plant like the Indian fern has far more chromosomes than humans but is not necessarily more complex.

2. ENDOPLASMIC RETICULUM (ER)

SQ

1. **What is the endoplasmic reticulum (ER)?**

Ans. The endoplasmic reticulum is a network of flattened sacs and branching tubules that extends

throughout the cytoplasm in both plant and animal cells. These sacs and tubules are called cisternae (singular: cisterna). All cisternae are interconnected, forming a single, large, highly convoluted lumen known as the cisternal space.

2. What is the significance of the cisternal space in the ER?

Ans. The cisternal space makes up more than 10% of the total volume of a cell, providing a large internal area for various cellular processes.

3. How is the ER connected to other cellular structures?

Ans. The cisternae of the ER are connected to the double-layered nuclear envelope, forming a pipeline between the nucleus and the cytoplasm.

4. What are the functions of the ER in the cell?

Ans. The ER manufactures, processes, and transports a wide variety of biochemical compounds for use inside and outside the cell.

5. What are the two types of endoplasmic reticulum, and how do they differ in structure?

Ans.

- **Rough Endoplasmic Reticulum (RER):** Its surface is covered with ribosomes, giving it a bumpy appearance.
- **Smooth Endoplasmic Reticulum (SER):** It lacks ribosomes on its surface, making it appear smoother and more even under a microscope. SER is generally less extensive than RER.

6. What are the main functions of the rough endoplasmic reticulum (RER)?

Ans.

- Production and processing of proteins
- Addition of other chemicals (e.g., sugars) to proteins
- Transportation of processed proteins to different areas of the cell or to the Golgi apparatus for further modification

7. Enlist the main functions of the smooth endoplasmic reticulum (SER)?

Ans.

- Production of lipids
- Building blocks for carbohydrate metabolism
- Detoxification of drugs and poisons
- Storage and metabolism of calcium
- In muscle cells, it releases calcium to trigger muscle contractions

3. RIBOSOMES

SQ

1. What are ribosomes made of?

Ans. Ribosomes are tiny, granular structures composed of approximately **60% ribosomal RNA (rRNA)** and **40% protein**.

2. Are ribosomes bound by a membrane?

Ans. No, ribosomes are **not membrane-bound** and are much smaller than other organelles.

3. Where are ribosomes found in eukaryotic and prokaryotic cells?

Ans.

- **Eukaryotic cells:** Found attached to rough ER and freely scattered in the cytoplasm
- **Prokaryotic cells:** All ribosomes are freely scattered in the cytoplasm

4. What is the primary function of ribosomes?

Ans. Ribosomes serve as the **protein production machinery** of the cell. They are most abundant in cells actively involved in protein synthesis, such as those in the pancreas and brain.

5. Where are ribosomes produced and assembled in eukaryotic cells?

Ans. In eukaryotic cells, ribosomes are produced and assembled in the **nucleolus**. Ribosomal proteins enter the nucleolus and combine with rRNA to form the **small and large subunits**, which then leave the nucleus through nuclear pores.

6. What happens to ribosomal subunits in the cytoplasm?

Ans. In the cytoplasm, the two ribosomal subunits combine to synthesize proteins. When not in use, they remain separated.

7. **Which types of RNA assist in protein synthesis?**

Ans.
- **rRNA (ribosomal RNA):** Makes up the ribosome structure
- **mRNA (messenger RNA):** Brings instructions from DNA
- **tRNA (transfer RNA):** Brings amino acids to the ribosome

8. **What is the Svedberg (S) value of ribosomal subunits in eukaryotic and prokaryotic cells?**

Ans:
- **Eukaryotic ribosomes:** 80S (composed of 40S and 60S subunits)
- **Prokaryotic ribosomes:** 70S (composed of 30S and 50S subunits)

4. MITOCHONDRIA

SQ

1. **What are mitochondria and what is their primary function?**

Ans. Mitochondria are rod-shaped organelles known as the **power generators of the cell**. They produce ATP (adenosine triphosphate) from oxygen and nutrients through **cellular respiration**, supplying energy for the cell's metabolic activities.

2. **What is the structure of a mitochondrion?**

Ans.
- **Two membranes**: outer and inner
- **Intermembrane space**: narrow gap between the membranes
- **Matrix**: large internal space beneath the inner membrane
- The **outer membrane** is smooth and acts as a filter
- The **inner membrane** is highly folded into structures called **cristae** to increase surface area.

3. **What are F1 particles and where are they found?**

Ans: F1 particles are knob-like enzyme complexes called **ATP synthase** located on the inner surface of the cristae. These enzymes are involved in synthesizing ATP.

4. **What are some unique features of mitochondria?**

Ans.
- Mitochondria have their own **circular DNA**, similar to prokaryotic DNA
- Contain all types of RNA and **70S ribosomes**
- Can replicate **independently** of the cell

5. **What are the major functions of enzymes and proteins found in mitochondria?**

Ans.
- Enzymes in the **matrix** catalyze steps of cellular respiration such as the **Krebs cycle**
- Proteins in the **inner membrane** participate in the **electron transport chain** to generate ATP.

5. CHLOROPLASTS

SQ

1. **What is the main function of chloroplasts in plant cells?**

Ans. Chloroplasts enable plants to perform photosynthesis, which is the process of converting light energy into chemical energy. This allows plants to make their own food.

2. **Where does photosynthesis occur in plants, and what parts contain chloroplasts?**

Ans. Photosynthesis occurs in chloroplasts found in all green structures of plants, including stems and unripe fruits. However, the majority of photosynthetic activity takes place in the leaves, where the chloroplast density is about one-half million per square millimetre.

3. **What pigments do chloroplasts contain, and what is their function?**

Ans. Chloroplasts contain pigments chlorophyll "a" and chlorophyll "b", which absorb the light energy required for photosynthesis.

4. **What is the structure and shape of a chloroplast?**

Ans. A chloroplast is ellipsoid-shaped and enclosed by two membranes. The space between these membranes is known as the intermembrane space.

5. **What is the stroma, and what does it contain?**

Ans. The stroma is a semi-fluid substance inside the inner membrane of the chloroplast. It contains dissolved enzymes and occupies most of the chloroplast's volume.

6. What is the difference between the outer and inner membranes of the chloroplast?

Ans. The outer membrane is more permeable than the inner membrane. The inner membranes are tightly associated with each other and fuse along their edges to form compartments.

7. What are thylakoids, and how are they organized?

Ans. Thylakoids are disk-shaped compartments formed by the fusion of adjacent inner membranes. Multiple thylakoids stack to form grana (singular: granum), and each chloroplast can have hundreds of grana.

8. What are lamellae in chloroplasts?

Ans. Lamellae are non-green structures that connect two grana within a chloroplast.

9. How is the chloroplast similar to the mitochondrion in terms of genetic material?

Ans. Like mitochondria, chloroplasts have their own DNA and can reproduce independently of the cell.

10. How is light energy converted into chemical energy in chloroplasts?

Ans. Light energy is absorbed by chlorophyll molecules in the thylakoids, which emit electrons. This leads to the formation of ATP. These ATP molecules are then used in the stroma to convert low-energy carbon dioxide into high-energy compounds like glucose.

6. GOLGI APPARATUS

SQ

1. What is the structure of the Golgi apparatus?

Ans. The Golgi apparatus consists of five to eight cup-shaped, membrane-bound sacs called cisternae, which are stacked on top of each other. In some organisms like unicellular flagellates, there can be up to 60 cisternae.

2. In which types of cells is the Golgi apparatus found?

Ans. *The Golgi apparatus is present in plant cells, animal cells, and unicellular eukaryotes.*

3. How many Golgi stacks are typically present in an animal cell?

Ans. *Animal cells generally contain between ten and twenty Golgi stacks.*

4. Where is the Golgi apparatus usually located in the cell?

Ans. *It is usually located near the nucleus of the cell.*

5. What are the 'cis' and 'trans' faces of the Golgi apparatus?

Ans. *The 'cis' face is located near the endoplasmic reticulum (ER), while the 'trans' face is oriented toward the plasma membrane.*

6. What is the primary function of the Golgi apparatus?

Ans. It acts as the distribution and shipping center for the cell's chemical products. It modifies proteins and lipids from the ER and prepares them for export or transport to other locations within the cell.

7. How do materials reach the Golgi apparatus from the ER?

Ans. Small vesicles containing proteins, carbohydrates, and other molecules bud off from the ER and move through the cytoplasm to the 'cis' face of the Golgi apparatus, where they fuse and release their contents.

8. What kind of processing occurs in the Golgi lumen?

Ans. Enzymes in the Golgi lumen modify the molecules and convert them into glycoproteins and glycolipids.

9. What happens to the processed products in the Golgi apparatus?

Ans. The processed products are released from the 'trans' face in vesicles, which then transport them to their final destinations inside or outside the cell. Exported products are called secretions, while others may return to the ER or become lysosomes.

10. What additional substances are produced by the Golgi apparatus in plant cells?

Ans. In plant cells, the Golgi apparatus also produces pectin and other polysaccharides that are essential for plant structure and metabolism.

7. LYSOSOMES

SQ

1. What are lysosomes, and what is their primary function?

Ans. Lysosomes are spherical organelles bounded by a single membrane. They serve as digestive compartments within the cell, breaking down various cellular materials, waste products, fats, carbohydrates, proteins, and other macromolecules into simpler compounds.

2. **In which types of cells are lysosomes most abundant, and why?**

Ans. Lysosomes are most numerous in disease-fighting cells, such as white blood cells, because these cells need to digest foreign invaders like bacteria, viruses, and other harmful substances.

3. **How do lysosomes help in autophagy?**

Ans. Lysosomes are involved in breaking down cellular materials that have surpassed their useful lifespan or are no longer needed by the cell, a process known as autophagy.

4. **What happens to the breakdown products of lysosomes?**

Ans. The breakdown products, such as simple compounds, are transferred back into the cytoplasm, where they are used to create new materials for the cell.

5. **How many enzymes do lysosomes contain, and where are they made?**

Ans. Lysosomes contain about 40 different hydrolytic enzymes. These enzymes are produced in the endoplasmic reticulum and are modified in the Golgi apparatus.

6. **What is the role of the membrane surrounding lysosomes?**

Ans. The membrane surrounding lysosomes protects the rest of the cell from the harsh digestive enzymes inside the lysosomes, preventing potential damage to the cell.

7. **What happens in lysosomal storage diseases?**

Ans. In lysosomal storage diseases, a patient lacks one of the hydrolytic enzymes needed in the lysosome. This causes the lysosome to fill with indigestible substances, interfering with cellular functions.

8. **Can you provide an example of a lysosomal storage disease and its effects?**

Ans. An example is Pompe's disease, where the lysosome lacks an enzyme that digests glycogen. This leads to the accumulation of glycogen in liver cells, causing harmful effects. Another example is Tay-Sachs disease, where a missing enzyme prevents the digestion of lipids in nerve cells, leading to brain damage and early death.

9. **How do lysosomes contribute to the elimination of whole cells?**

Ans. Lysosomes are involved in selective cell death, a mechanism used in the development of multicellular organisms. For example, during the development of a frog, lysosomes destroy the cells in the tail of the tadpole.

8. PEROXISOMES

SQ

1. **What are peroxisomes and what is their primary function?**

Ans. Peroxisomes are single membrane-bound organelles found in all eukaryotic cells. They contain enzymes that primarily carry out oxidation, removing electrons and hydrogens to rid the cell of toxic substances.

2. **How do peroxisomes detoxify harmful substances?**

Ans. Some peroxisomes, especially in liver cells, detoxify alcohol and other harmful compounds by carrying out oxidative reactions.

3. **What is the role of catalase enzymes in peroxisomes?**

Ans. Catalase enzymes in peroxisomes break down hydrogen peroxide, a by-product of cellular metabolism, into water and oxygen.

4. **What happens when there are defects in peroxisomes?**

Ans. Defects in peroxisomes can lead to metabolic disorders, with one of the most serious being Zellweger syndrome, a congenital disorder that causes a lack or reduction of peroxisomes. This disorder has no effective treatment and often leads to death within the first year of life.

9. GLYOXYSOMES

SQ

1. **What are glyoxysomes, and where are they found?**

Ans. Glyoxysomes are organelles similar to peroxisomes but are found only i plant cells. They contain enzymes that convert lipids into carbohydrates.

2. **What is the role of glyoxysomes in plant cells?**

Ans. Glyoxysomes are most abundant in lipid-rich seeds, such as those of castor beans and soybeans. During seed germination, glyoxysomes convert stored lipids into carbohydrates, providing energy for the growth of the seedling.

3. **Why are glyoxysomes important for seed germination?**

Ans. Glyoxysomes are essential for converting stored lipids into carbohydrates, which are vital for providing energy during the early stages of seed germination.

10. VACUOLES

SQ

1. What is a vacuole?

Ans. A vacuole is a membrane-bounded sac found in cells that serves functions like storage, waste disposal, protection, and structural support.

2. What is the main function of the central vacuole in plant cells?

Ans. It maintains structural support by regulating turgor pressure and stores water, pigments, waste, and defensive compounds.

3. What is tonoplast?

Ans. Tonoplast is the membrane that encloses the central vacuole in plant cells.

4. What is cell sap?

Ans. Cell sap is the fluid inside the vacuole, chemically different from cytoplasm.

5. How do vacuoles help in plant protection?

Ans. They store poisonous compounds that deter herbivores and insects.

6. How do vacuoles assist in flower coloration?

Ans. They store pigments that give color to flowers and attract pollinators.

7. How are vacuoles different in animal and plant cells?

Ans. Plant cells have a large central vacuole, while animal cells have smaller vacuoles used for temporary storage and transport.

11. CENTRIOLES

SQ

1. What are centrioles?

Ans. Centrioles are cylindrical organelles involved in organizing microtubules and forming spindle fibres.

2. Where are centrioles located in the cell?

Ans. Near the nuclear envelope, usually at right angles to each other.

3. What is the role of centrioles in flagellated or ciliated cells?

Ans. They help in the formation of cilia and flagella and serve as basal bodies.

4. Do plant and fungal cells have centrioles?

Ans. No, they lack centrioles and basal bodies.

5. What are spindle fibres and how are they related to centrioles

Ans. Spindle fibres are structures that help in cell division; centrioles organize their formation.

12. CYTOSKELETON

SQ

1. What is the cytoskeleton?

Ans. A network of protein fibres in the cytoplasm that supports cell shape, movement, and organelle positioning.

2. What are the three main components of the cytoskeleton?

Ans. Microfilaments, microtubules, and intermediate filaments.

3. What protein makes up microfilaments?

Ans. Actin.

4. What is the function of microfilaments?

Ans. They help in cell movement, shape changes, and cellular division.

5. What are microtubules made of?

Ans. Subunits of alpha-tubulin and beta-tubulin.

6. Name two functions of microtubules.

Ans. They provide structure to the cell and act as pathways for organelle transport.

7. What is the role of microtubules in cell division?

Ans. They form spindle fibres that help separate chromosomes.

8. What is the funct n of intermediate filaments?

Ans. They maintain cell shape and anchor organelles like the nucleus.

13. CILIA AND FLAGELLA

1. What are cilia and flagella?

Ans. Cilium (plural cilia) and flagellum (plural flagella) are locomotor appendages that protrude from certain cells. They are thin, tail-like projections extending from the cell body.

2. How do cilia differ from flagella in terms of structure and number?

Ans. Cilia are shorter and usually numerous, while flagella are longer but fewer in number.

3. Are cilia common in plant cells?

Ans. No, cilia are rare in plants.

4. Which organisms commonly possess cilia?

Ans. Many protozoans (ciliates) have cilia, and larger eukaryotes such as mammals also have cilia on the surface of some cells.

5. Where are cilia found in the human body, and what is their function?

Ans. In humans, cilia are found in the lining of the trachea, where they sweep mucus and dirt out of the breathing tubes.

6. What is the core of eukaryotic cilia and flagella called, and what is its structure?

Ans. The core is called the axoneme. It contains two central microtubules surrounded by an outer ring of nine doublet microtubules.

7. What are dynein molecules and where are they located in cilia and flagella?

Ans. Dynein molecules are located around the circumference of the axoneme and bridge the gaps between adjacent microtubule doublets.

8. What is the "9 + 2" structure in cilia and flagella?

Ans. It refers to the organization of the axoneme with 9 outer doublet microtubules and 2 central microtubules, all surrounded by a plasma membrane.

9. What is found at the base of a cilium and what is its role?

Ans. The base of a cilium contains a basal body, which is the organizing center of the axoneme.

10. How does the structure of the basal body differ from the axoneme?

Ans. In the basal body, each of the nine sets of outer filaments is composed of three microtubules (triplets), instead of the doublets found in the axoneme.

11. What is the basal body structurally equivalent to?

Ans. The basal body is actually a centriole.

3.5 PROKARYOTIC AND EUKARYOTIC CELLS

28. How do prokaryotic and eukaryotic cells differ in structure and function? Include major similarities and differences.

Ans. Bacteria and archaea are composed of prokaryotic cells, whereas all other forms of life, including animals, plants, fungi, and protozoans, are composed of eukaryotic cells.

Similarities between Prokaryotic and Eukaryotic Cells

Despite differences, both prokaryotic and eukaryotic cells share certain similarities. Both have DNA as their genetic material, plasma membranes as their outer coverings, and ribosomes for protein synthesis.

Simplicity of Prokaryotic Cells

However, prokaryotic cells are much simpler than eukaryotic ones. Most prokaryotic cells range from 2 to 8 μm in length, making them about one-tenth the size of a typical eukaryotic cell. A prokaryotic cell lacks a nucleus. Instead, its less extensive DNA is found in a more or less central region called the nucleoid (nucleus-like).

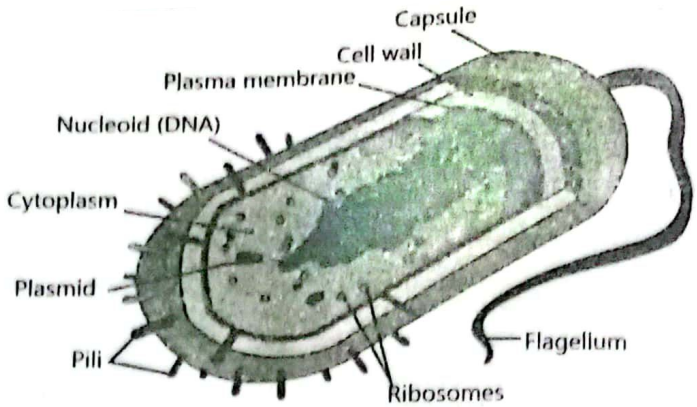


Fig. 3.29: Structure of a generalized prokaryotic cell

Absence of Membrane-Bound Organelles

Furthermore, a prokaryotic cell lacks membrane-bounded organelles such as the endoplasmic reticulum, mitochondria, chloroplasts, Golgi apparatus, lysosomes, and peroxisomes. Its cytoplasm is a single unit with no internal support structures.

Prokaryotic Ribosomes and Their Characteristics

Ribosomes are present in prokaryotic cells, but they are smaller than those in eukaryotic cells. The Svedberg values (sedimentation rates) of the smaller and larger subunits of prokaryotic ribosomes are 30S and 50S, respectively, while the complete ribosome has a value of 70S.

Cell Wall and External Structures

Surrounding the plasma membrane of most prokaryotic cells is a cell wall, but unlike plant cells, it does not contain cellulose. Instead, it is composed of peptidoglycan, a single large polymer of amino acids and sugars. In bacteria, the cell wall may also be surrounded by a capsule and have extensions for attachment called pili (singular pilus).

Structure of Prokaryotic Flagella and Cell Division

Prokaryotic flagella are made of repeating units of the protein flagellin and lack microtubule triplets. Also, mitosis and meiosis are absent in prokaryotic cells. They divide through a process called binary fission or direct division.

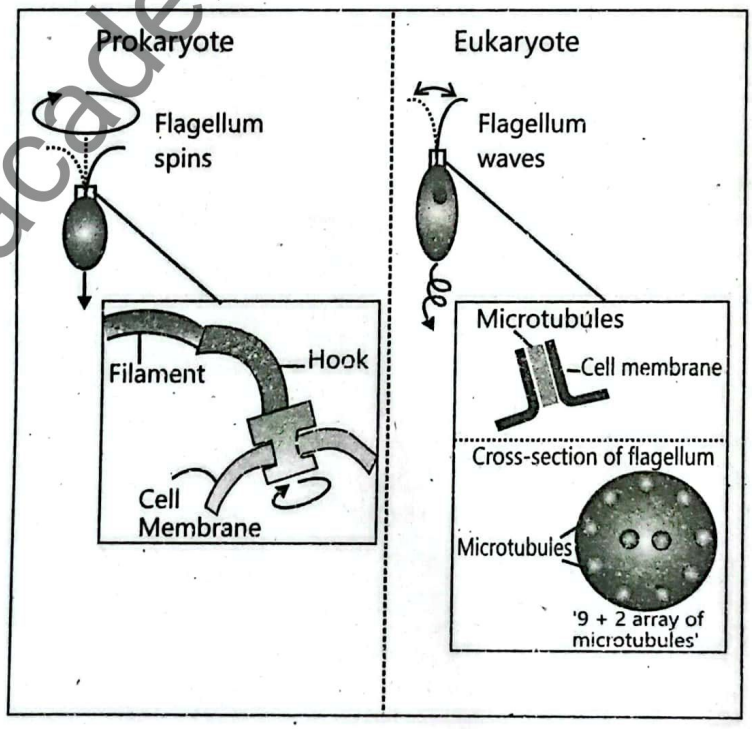


Fig. 3.30: Difference between the structures of prokaryotic and eukaryotic flagella

Comparison Table: Eukaryotic VS Prokaryotic Cells

Characteristics	Eukaryotic Cell	Prokaryotic Cell
Distinct Nucleus	Present	Absent
Number of chromosomes	More than one	One – but not true chromosomes; plasmids
Cell Type	Usually multicellular	Usually unicellular (some cyanobacteria may be multicellular)
Example	Protozoans, Algae, Fungi, Animals, Plants	Bacteria and Archaea
Lysosomes and peroxisomes	Present	Absent
Microtubules	Present	Absent or rare
Endoplasmic reticulum	Present	Absent
Mitochondria	Present	Absent
Cytoskeleton	Present	May be absent
Vacuoles	Present	Absent
Ribosomes	Larger	Smaller
Golgi apparatus	Present	Absent
Chloroplasts	Present (in plants)	Absent; chlorophyll scattered in cytoplasm
Cell Division	Mitosis or meiosis	Binary fission; mitosis and meiosis absent
Flagella	Membrane-bound; 9+2 microtubule arrangement	Not membrane-bound; made of flagellin; no microtubules
Cell Wall	Only in plant cells and fungi; chemically simpler	Composed of peptidoglycan
Cell Size	10–100 µm	1–10 µm

MCQs

1. **Which of the following structures is involved in direct cell division in prokaryotes?**
   A) Mitosis B) Meiosis
   C) Binary fission ✓ D) Budding
2. **Which of the following correctly describes prokaryotic ribosomes?**
   A) 80S, composed of 40S and 60S
   B) 60S, composed of 30S and 30S
   C) 70S, composed of 30S and 50S ✓
   D) 90S, composed of 45S and 45S
3. **What is the major structural component of the prokaryotic cell wall?**
   A) Cellulose B) Lignin
   C) Peptidoglycan ✓ D) Glycoprotein
4. **Which cells contain membrane-bound flagella with a 9 + 2 microtubule arrangement?**
   A) Bacterial cells B) Plant root cells
   C) Eukaryotic sperm cells ✓
   D) All animal cells
5. **Which of the following structures are found in bacteria but not in eukaryotic cells?**
   A) Cilia B) Pili ✓
   C) Mitochondria D) Golgi apparatus
6. **What feature is commonly absent in the cytoplasm of prokaryotic cells?**
   A) Enzymes B) Support structures ✓
   C) Water D) RNA
7. **What distinguishes the basal body from the axoneme in microtubule structure?**
   A) The basal body has a 9 + 0 doublet structure
   B) The basal body has triplets of microtubules instead of doublets ✓
   C) The axoneme lacks any organized microtubules
   D) The basal body contains DNA
8. **In which of the following organisms would you most likely find scattered chlorophyll rather than membrane-bound chloroplasts?**
   A) Algae B) Fungi
   C) Bacteria ✓ D) Plants

1. How do prokaryotic flagella differ from eukaryotic ones?

Ans. Prokaryotic flagella have a completely different structure built from the protein flagellin and do not contain microtubule triplets.

2. Which organisms are made of prokaryotic cells and which are made of eukaryotic cells?

Ans. Bacteria and archaea are made of prokaryotic cells, whereas all other forms of life are composed of eukaryotic cells.

3. What are the similarities between prokaryotic and eukaryotic cells?

Ans. Both have DNA as their genetic material, plasma membranes as coverings, and ribosomes for protein synthesis.

4. What are the major structural differences between prokaryotic and eukaryotic cells?

Ans. Prokaryotic cells are simpler, smaller (2–8 μm), lack a nucleus, and do not have membrane-bound organelles like mitochondria or ER.

5. Where is the DNA located in prokaryotic cells?

Ans. In a central region known as the nucleoid (nucleus-like), without a membrane.

6. Are ribosomes present in prokaryotic cells? How do they compare with those in eukaryotic cells?

Ans. Yes, ribosomes are present but are smaller. The Svedberg values for the subunits are 30S and 50S, with the complete ribosome being 70S.

7. What is the composition of the prokaryotic cell wall?

Ans. It is made of peptidoglycan, a polymer of amino acids and sugars, and does not contain cellulose.

8. What additional structures may surround the prokaryotic cell wall?

Ans. A capsule and pili (singular: pilus), which help in attachment.

9. How do prokaryotic cells divide, and what cellular processes are absent in them?

Ans. They divide by direct division (binary fission). Mitosis and meiosis are absent.

3.6 CELL SIGNALLING

Q 29. What is meant by cell signaling? What are the main steps involved in cell signaling?

Ans. Cell signaling is the ability of cells to respond to stimuli from their environment by producing specific cellular responses. It involves the transmission of signals between cells through a series of molecular events that often lead to a cellular response.

The main steps of cell signaling include:

1. **Signal Reception:**
   Cell signaling begins when a signal molecule (ligand) binds to a receptor on the membrane of a target cell. These receptors are typically proteins embedded in the cell membrane, but some may also be located inside the cell. Each receptor is specific to a particular ligand.
2. **Signal Transduction:**
   After the ligand binds to the receptor, the receptor undergoes a conformational change that activates an intracellular signaling pathway. This usually involves a series of interactions and modifications that create a signaling cascade, amplifying the signal. Small molecules like **cyclic AMP (cAMP)**, **calcium ions**, and **inositol triphosphate (IP3)** act as **second messengers**, transmitting the signal from the receptor to the target molecules inside the cell.
3. **Cellular Response:**
   The signal transduction pathway can lead to changes in gene expression, turning specific genes on or off. This may result in various cellular responses such as **cell growth**, **division**, **differentiation**, or **apoptosis** (programmed cell death). Other responses include changes in metabolism, enzyme activity, or the opening and closing of ion channels.

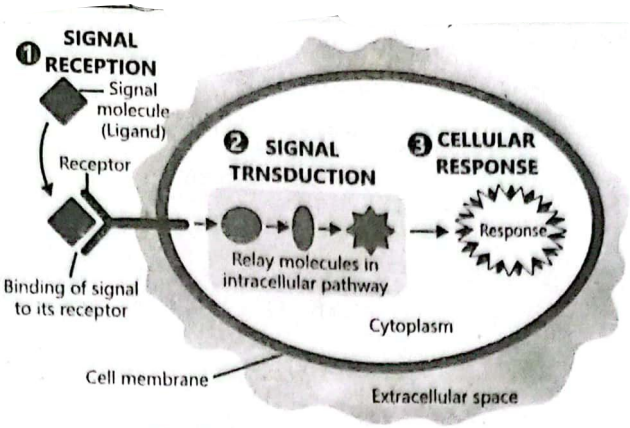


Fig. 3.31: Steps of cell signalling

Q 30. Describe different pathways by which cell signals are transmitted from outside to inside of a cell?

Ans. Cell signaling pathways transmit signals from the outside of the cell to its interior, resulting in specific cellular responses. There are two main types of signaling pathways:

Protein/peptide signaling

It involves water-soluble signaling molecules that cannot pass through the plasma membrane. When a peptide or protein ligand approaches the cell surface, it binds to a specific receptor on the plasma membrane. This binding causes a **conformational change** in the receptor protein, activating it. The activated receptor then triggers a series of reactions inside the cell. These reactions generate **second messengers** like **cyclic AMP (cAMP)**, which initiate changes such as alterations in **gene expression**, **metabolism**, **cell growth**, **division**, or **apoptosis**.

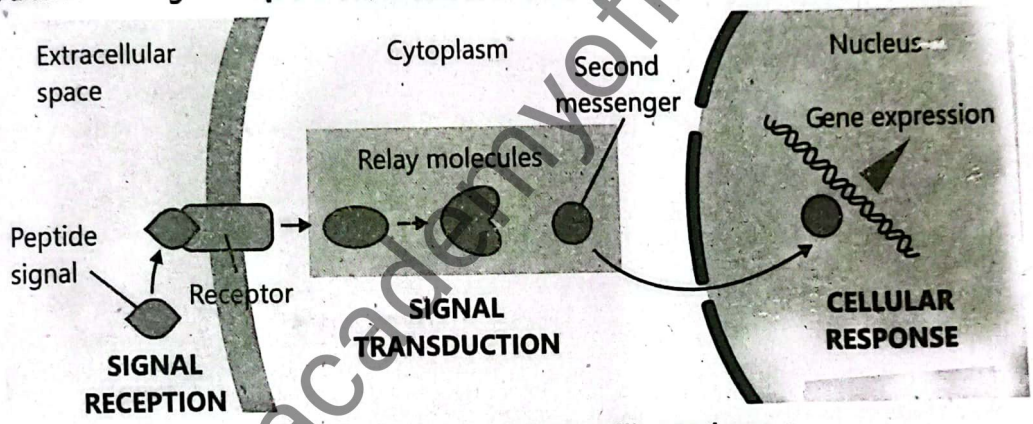


Fig. 3.32: Protein/peptide signalling pathway

Steroid signaling

It involves **lipophilic (fat-loving)** hormones that can **diffuse through the plasma membrane** of the target cell. Once inside the cell, these steroid molecules bind to specific **intracellular receptors** located in the **cytoplasm or nucleus**. This forms an **active receptor-hormone complex**. If the complex forms in the cytoplasm, it moves into the nucleus. Inside the nucleus, the complex binds to specific DNA sequences in the **target genes**. This interaction regulates the **transcription** of these genes, leading to either an **increase or decrease in the production of specific proteins**.

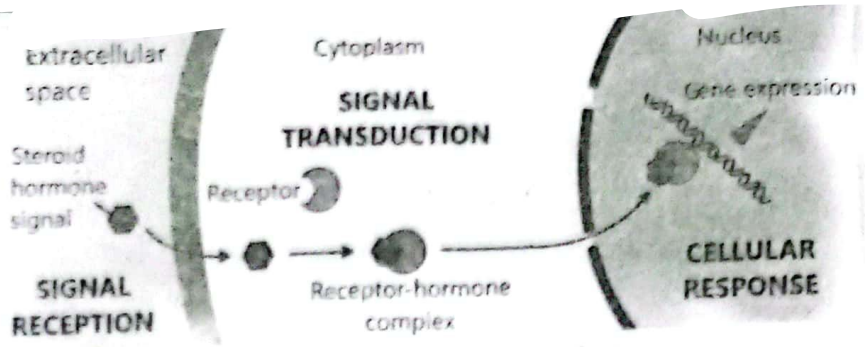


Fig. 3.33: Steroid signalling pathway

MCQs

1. **What is the primary purpose of cell signaling?**
   A) To destroy harmful cells
   B) To transport nutrients
   C) To respond to environmental stimuli ✓
   D) To store energy
2. **What is a ligand in cell signaling?**
   A) A type of enzyme
   B) A signal molecule that binds to a receptor ✓
   C) A transport protein
   D) A type of cell organelle
3. **Where are most cell signaling receptors located?**
   A) In the nucleus
   B) On the plasma membrane ✓
   C) In the mitochondria
   D) In the ribosomes
4. **What happens during signal reception?**
   A) The cell divides
   B) The ligand binds to its specific receptor ✓
   C) Proteins are broken down
   D) DNA is replicated
5. **What is the next step after signal reception?**
   A) DNA replication B) Protein synthesis
   C) Signal transduction ✓ D) Cell death
6. **What change occurs in the receptor during signal transduction?**
   A) It becomes inactive
   B) It changes shape (conformational change) ✓
   C) It is digested
   D) It moves outside the cell
7. **Which of the following is a second messenger in cell signaling?**
   A) DNA B) RNA
   C) cAMP ✓ D) ATP
8. **What is the role of second messengers?**
   A) Destroy the ligand
   B) Amplify and transmit the signal inside the cell ✓
   C) Block the receptor
   D) Repair the cell membrane
9. **What may result from the final step of cell signaling?**
   A) Cell membrane rupture
   B) Change in gene expression ✓
   C) Chromosome duplication
   D) Ribosome formation
10. **Which of the following is NOT a possible result of cell signaling?**
    A) Apoptosis B) Cell division
    C) Muscle contraction D) Protein denaturation ✓
11. **What type of signaling molecules are proteins or peptides?**
    A) Lipid-soluble B) Water-soluble ✓
    C) Non-polar D) Steroid-based
12. **Why can't protein/peptide signals pass through the plasma membrane?**
    A) They are too small
    B) They are charged and water-soluble ✓
    C) They are already inside the nucleus
    D) They are lipid-soluble
13. **What happens when a protein signal binds to its receptor?**
    A) The ligand enters the cell
    B) The receptor is destroyed
    C) The receptor activates internal signaling ✓
    D) The cell shrinks
14. **What are steroid hormones made of?**
    A) Water B) Lipids ✓
    C) Proteins D) Carbohydrates
15. **How do steroid hormones enter the target cell?**
    A) Through protein channels
    B) By endocytosis
    C) By diffusion across the membrane ✓
    D) With the help of ATP
16. **Where do steroid hormones bind inside the cell?**
    A) Cell membrane B) Mitochondria
    C) Intracellular receptors in the cytoplasm or nucleus ✓
    D) Ribosomes
17. **What forms when a steroid hormone binds to its receptor?**
    A) An enzyme B) A hormone transport
    C) A receptor-hormone complex ✓
    D) A DNA molecule
18. **What is the function of the receptor-ho complex in the nucleus?**
    A) Breaking down proteins
    B) Activating enzymes

C) Binding to DNA to regulate transcription ✓
D) Transporting glucose

19. **Which type of signaling uses second messengers like cAMP?**
A) Steroid signalling B) Direct DNA signaling
C) Protein/peptide signaling ✓
D) Passive transport

20. **What cellular processes can be affected by cell signaling?**
A) Only movement
B) Growth, division, differentiation, or apoptosis ✓
C) Digestion only D) Osmosis only

SQ

1. **What is cell signaling?**
Ans. Cell signaling is the process by which cells respond to stimuli from their environment, leading to specific cellular responses. It involves signal transmission between cells through a series of molecular events.

2. **What is the first step in cell signaling?**
Ans. The first step is signal reception, where a signal molecule (ligand) binds to a specific receptor on the membrane of a target cell.

3. **What are receptors in cell signaling, and where are they found?**
Ans. Receptors are usually proteins that are either embedded in the cell membrane or located inside the cell. Each receptor binds specifically to a particular ligand.

4. **What happens during signal transduction?**
Ans. After the ligand binds to the receptor, the receptor changes shape and activates an intracellular signaling pathway. This involves a chain of interactions called a signaling cascade that amplifies the signal.

5. **What are second messengers, and what is their role in signal transduction?**
Ans. Second messengers such as cyclic AMP (cAMP), calcium ions, and IP3 transmit signals from the receptor to target molecules inside the cell, helping carry the message deeper into the cell.

6. **What is the final step of cell signaling, and what occurs during it?**
Ans. The final step is the cellular response, which may involve changes in gene expression, resulting in cell growth, division, differentiation, apoptosis, changes in metabolism, enzyme activity, or ion channel behavior.
Pathways of Cell Signals from Outside to Inside

7. **What is the purpose of signaling pathways in cells?**
Ans. These pathways transmit signals from the cell's exterior to its interior, leading to specific cellular responses.

8. **What are protein or peptide signaling molecules?**
Ans. They are water-soluble signaling molecules that cannot pass through the plasma membrane.

9. **How do protein/peptide signaling molecules transmit signals into the cell?**
Ans. They bind to specific receptors on the plasma membrane, causing a shape change in the receptor that activates it. This starts a series of internal reactions, producing second messengers like cAMP.

10. **What are the possible results of protein/peptide signaling?**
Ans. It can lead to changes in gene expression, metabolism, cell growth, cell division, or apoptosis.

11. **What are steroid hormones, and how do they enter cells?**
Ans. Steroid hormones are lipophilic (fat-soluble) and can diffuse through the plasma membrane of target cells.

12. **What happens after a steroid hormone enters the cell?**
Ans. It binds to a specific receptor in the cytoplasm or nucleus, forming a receptor-hormone complex.

13. **How does the receptor-hormone complex affect the cell?**
Ans. It enters the nucleus (if not already there) and binds to specific DNA sequences in target genes, regulating their transcription and changing the production of certain proteins.

3.7 MEMBRANE TRANSPORT MECHANISMS

Q

31. What are membrane transport mechanisms, and why are they important for cellular functions?

Ans. Membrane transport mechanisms are processes that regulate the movement of substances in and out of cells. These movements are crucial for various cellular functions such as nutrient uptake, waste elimination, gas exchange, and signal transduction.

While exchanging matter with cells' environment, plasma membranes maintain equilibrium inside the cell as well as outside.

The plasma membrane plays a key role in this regulation. It acts as a selective barrier, allowing specific substances to enter or leave the cell, thereby maintaining the internal environment of the cell—also known as homeostasis.

Through membrane transport, the cell can acquire essential nutrients, remove harmful waste products, and communicate with its surroundings. This ensures that the cell can function efficiently and respond to environmental changes.

Membrane transport is divided into two major types:

1. **Passive Transport** – which does not require energy.
2. **Active Transport** – which requires energy (usually in the form of ATP).

32. What is passive transport? Describe its types with examples.

Ans. Passive transport is the movement of molecules across the plasma membrane without any energy input from the cell. It relies on the natural motion of particles and occurs along the concentration gradient, meaning substances move from areas of higher concentration to areas of lower concentration.

There are two main types of passive transport:

Diffusion

Diffusion is the net movement of a substance (usually a liquid or gas) from a region of higher concentration to one of lower concentration. Since this movement does not require any energy and occurs naturally along the concentration gradient, it is categorized as passive transport. For example, oxygen and carbon dioxide gases move across cell membranes through diffusion.

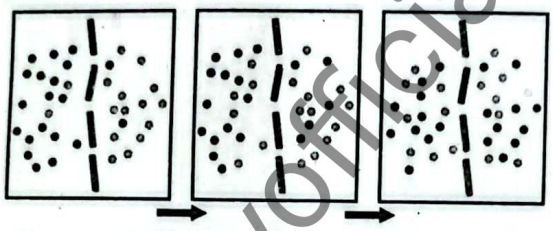


Fig. 3.34: Diffusion of two types of molecules

Facilitated Diffusion

In facilitated diffusion, specific molecules are transported in or out of the cell with the help of transport proteins present in the plasma membrane. These transport proteins assist the molecules in moving down their concentration gradient (from high to low concentration), and no energy is used in the process.

The rate of facilitated diffusion depends on the availability of transport proteins in the membrane. There are two main types of transport proteins involved:

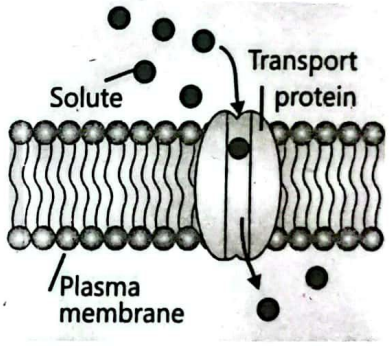


Fig. 3.35: Facilitated diffusion

Channel Proteins:

These proteins create hydrophilic channels through the membrane, allowing certain molecules or ions to pass. They may be gated (open or close in response to stimuli like voltage, ligand binding, or mechanical stress) or non-gated (always open). Examples include:

- Ion channels for Na^+ (sodium), K^+ (potassium), Ca^{2+} (calcium), and Cl^- (chloride).
- Aquaporins that enable rapid movement of water molecules.

Carrier Proteins (Transporters):

These proteins bind to specific molecules and change their shape (conformational change) to carry the molecules across the membrane. They are highly selective for the substances they transport. Carrier proteins can become saturated, which means their rate of transport reaches a maximum when all binding sites are occupied. Examples include:

- Glucose transporters for transporting glucose.
- Amino acid transporters for moving specific amino acids.

Thus, passive transport plays a vital role in moving essential substances like gases, water, glucose, and ions in and out of the cell without using cellular energy.

33. Describe the different types of transport across the plasma membrane in detail.

Ans.

1. Simple and Facilitated Diffusion

Cells often need to move substances in and out through the plasma membrane. Two important passive transport mechanisms involved in this process are **simple diffusion** and **facilitated diffusion**. Both allow substances to move from a region of higher concentration to a region of lower concentration without using energy, but they differ in their mechanisms and the types of molecules they transport.

Here is a detailed comparison:

Difference	Simple Diffusion	Facilitated Diffusion
Mechanism	Substances move from higher concentration to lower concentration directly through the lipid bilayer of the plasma membrane.	Substances move from higher concentration to lower concentration through specific transport proteins embedded in the plasma membrane.
Energy Requirement	It is a passive transport mechanism, requiring no energy input from the cell.	It is also a passive transport mechanism and does not require energy.
Types of Molecules	Typically involves small, nonpolar molecules such as oxygen, carbon dioxide, and lipid-soluble substances.	Primarily involves polar or charged molecules, such as glucose, amino acids, and ions, which cannot easily pass through the hydrophobic core of the lipid bilayer.
Rate of Movement	The rate depends on the concentration gradient, temperature, and the permeability of the membrane.	The rate can be affected by the number and availability of transport proteins and can reach a maximum rate when all transport proteins are saturated.

2. Osmosis

Osmosis is the passive transport of **water molecules** across a selectively permeable membrane. In this process, water diffuses from an area of **higher water concentration** (or lower solute concentration) to an area of **lower water concentration** (or higher solute concentration). This movement does **not require energy**.

The term **tonicity** refers to the relative concentration of solutes in the solutions.
Hypertonic solutions are those in which more solute is present.
Hypotonic solutions are those with less solute.
Isotonic solutions have equal concentrations of solutes.

- **Direction of Water Movement**: Water moves from a **hypotonic solution** (low solute concentration) to a **hypertonic solution** (high solute concentration).
- **Selectively Permeable Membrane**: Osmosis occurs through membranes that allow only certain substances, such as water, to pass through while restricting others.
- **Importance of Osmosis**: It is essential for maintaining **cell turgor** in plant cells and **balancing internal water content** in all cells.
- **Aquaporins**: These are special **membrane proteins** that **facilitate rapid water transport** across the membrane. They help regulate the **hydration and volume** of cells efficiently.
- **Factors Influencing Osmosis**: The **osmotic gradient** (difference in solute concentration) and the **membrane's permeability to water** determine the rate and direction of osmosis.

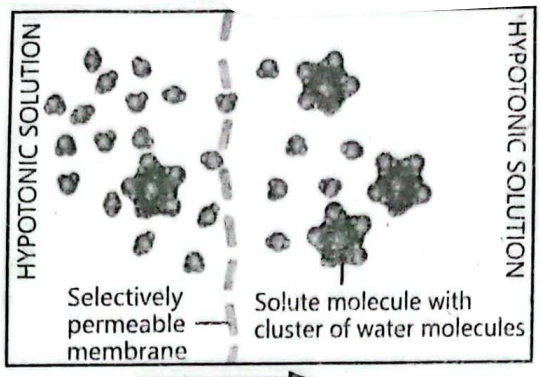
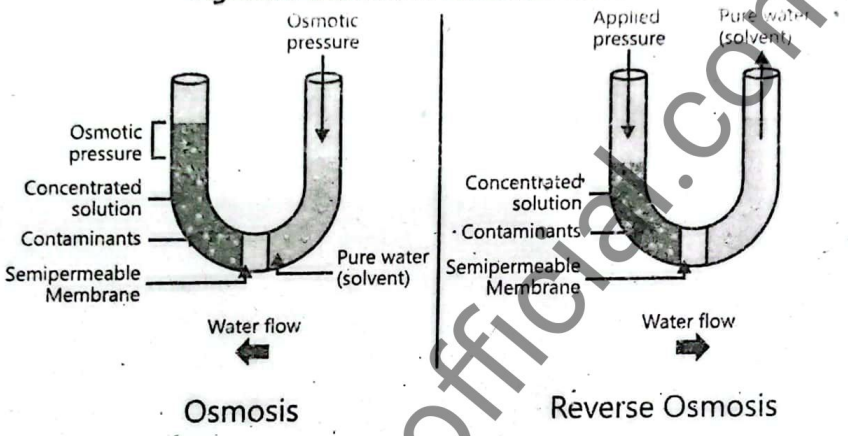


Fig. 3.36: Osmosis at molecular level



Reverse osmosis
It is a widely used technology for purifying water by removing contaminants and impurities. Unlike natural osmosis, which moves water from a lower to a higher solute concentration, reverse osmosis applies external pressure to push water through a semi-permeable membrane from a higher to a lower solute concentration. This process effectively filters out dissolved salts and other impurities, providing clean and safe drinking water. Reverse osmosis is commonly used in water treatment plants, desalination facilities, and even in household water purification systems.

3. Active Transport

Active transport refers to the movement of substances **against the concentration gradient**, i.e., from **lower concentration to higher concentration**, and it **requires energy** (usually in the form of ATP).

- **Carrier Proteins**: Specialized proteins in the plasma membrane **use energy** to transport molecules.
- **Sodium-Potassium Pump**: This is a well-known example found in nerve cells.
  - In a **resting nerve cell**, the pump **actively transports** sodium ions (Na^+) out of the cell and potassium ions (K^+) into the cell.
  - This helps maintain **higher concentrations of K^+ inside** and **lower concentrations of Na^+ inside** the cell.
  - This process uses **ATP (adenosine triphosphate)** as an energy source.

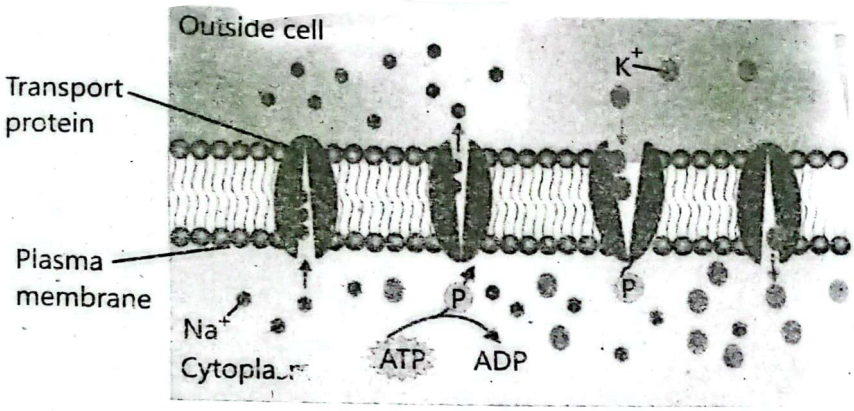


Fig. 3.37: Active transport through carrier proteins

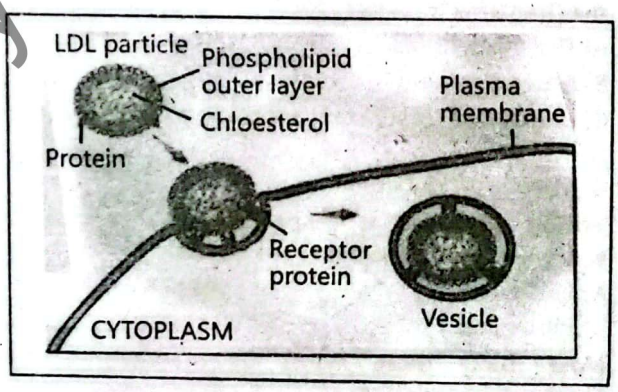
4. *Endocytosis*

Endocytosis is a type of active transport used to move **large or bulky materials** into the cell.

- **Mechanism**:
  - The plasma membrane **invaginates** (bends inward) and forms a pouch around the material.
  - The ends of this pouch then **seal** to form a **vesicle**.
  - The vesicle **detaches** from the plasma membrane and moves into the cytoplasm.
- **Types of Endocytosis**:
  - **Phagocytosis**: The cell takes in **solid material** (often referred to as "cell eating").
  - **Pinocytosis**: The cell takes in **liquids in the form of droplets** (also called "cell drinking").

Endocytosis allows the cell to **ingest nutrients, remove debris**, and **interact with its external environment** effectively.

Receptor-mediated endocytosis
Specific receptor proteins of plasma membrane pick up material from outside and pinch inside to form a vesicle. For example, the cells of liver have receptor proteins for cholesterol. Cholesterol circulates in our blood in the form of low-density-lipoproteins (LDLs). The receptor proteins of plasma membrane of liver cells, recognize and take up LDLs from the blood by receptor-mediated endocytosis



Exocytosis

Exocytosis is the process through which bulky materials are exported out of the cell. In this process, the material is first packed inside a membrane-bound vesicle. This vesicle then moves toward the plasma membrane, fuses with it, and releases its contents into the extracellular environment. Exocytosis helps the cell get rid of waste materials or secrete useful substances such as hormones and enzymes.

Conclusion

All these transport mechanisms—**simple diffusion**, **facilitated diffusion**, **osmosis**, **active transport**, and **endocytosis**—play a vital role in regulating what enters and exits the cell. These processes ensure that cells maintain proper **internal conditions**, which is essential for their **survival and functioning**.

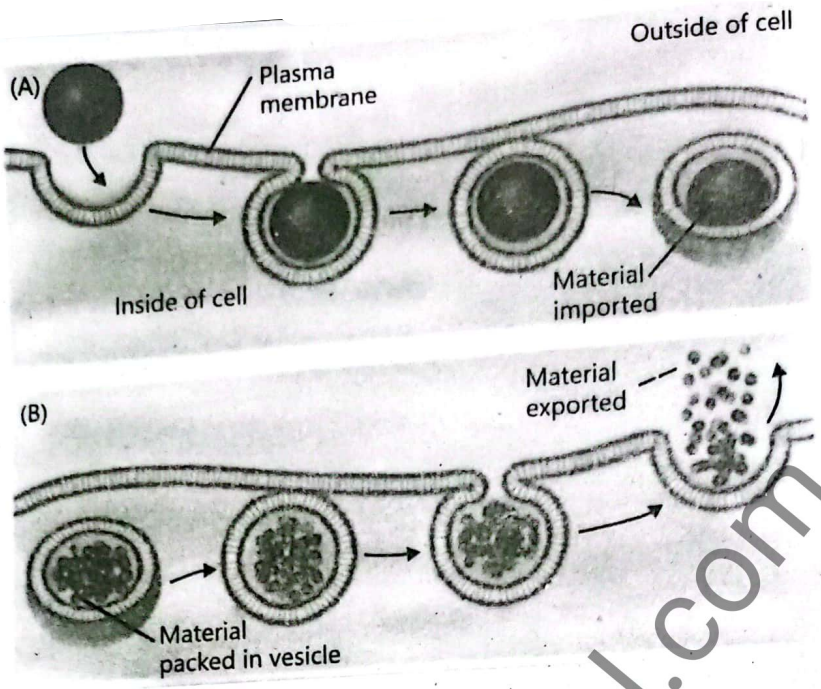


Fig. 3.38: (A) Endocytosis, (B) Exocytosis

MCQs

1. **What is the primary function of membrane transport mechanisms in cells?**
   A) Protein synthesis
   B) Movement and locomotion
   C) Regulation of substance movement in and out of cells ✓
   D) Energy production

2. **Which structure is responsible for regulating the entry and exit of substances in the cell?**
   A) Nucleus B) Cytoplasm
   C) Ribosome D) Plasma membrane ✓

3. **How many main types of membrane transport mechanisms are there?**
   A) One B) Two ✓
   C) Three D) Four

4. **Which type of transport requires cellular energy?**
   A) Passive transport B) Osmosis
   C) Facilitated diffusion D) Active transport ✓

5. **What is passive transport?**
   A) Movement with energy
   B) Movement of proteins only
   C) Movement without energy ✓
   D) Movement with enzymes

6. **In diffusion, molecules move from:**
   A) Low to high concentration
   B) High to low concentration ✓
   C) Neutral to acidic environment
   D) Membrane to nucleus

7. **Diffusion is a type of:**
   A) Active transport B) Facilitated transport
   C) Passive transport ✓ D) Osmotic process

8. **Facilitated diffusion involves:**
   A) Direct energy usage
   B) Movement through cytoplasm
   C) Use of transport proteins ✓
   D) Endocytosis

9. **Facilitated diffusion differs from simple diffusi because it:**
   A) Requires more ATP
   B) Involves transport proteins ✓
   C) Is slower
   D) Moves against concentration

10. **The rate of facilitated diffusion depends on:**
    A) Temperature B) pH level
    C) Number of transport proteins ✓
    D) Cell age

11. **Channel proteins form:**
    A) ATP B) Hydrophilic channels ✓
    C) Protein fibers D) DNA strands

12. **What do gated channel proteins respond to?**
    A) DNA changes B) Hormone levels only
    C) Specific stimuli ✓ D) Light exposure

13. **Aquaporins are specific for transporting:**
    A) Proteins B) Ions
    C) Water molecules ✓ D) Glucose

14. **Which is an example of ions transported via ion channels?**
    A) Glucose B) Sodium (Na^+) ✓
    C) Oxygen D) Lipids

15. **Carrier proteins transport substances by:**
    A) Filtering through the nucleus

B) Changing their shape ✓
C) Destroying toxins
D) Breaking them down

16. **Carrier proteins are highly:**
A) Non-selective B) Specific ✓
C) Slow D) Random

17. **Saturation of carrier proteins means:**
A) All proteins are inactive
B) Protein has melted
C) Maximum transport rate is reached ✓
D) pH is too high

18. **Glucose is transported into cells by:**
A) Osmosis B) Aquaporins
C) Glucose transporters ✓ D) Ion pumps

19. **Amino acid transport is carried out by:**
A) Lipid channels B) Aquaporins
C) Amino acid transporters ✓
D) Lysosomes

20. **Which of the following is NOT involved in passive transport?**
A) Diffusion B) Facilitated diffusion
C) Channel proteins D) ATP usage ✓

21. **Which of the following is a passive transport mechanism?**
A) Endocytosis B) Active transport
C) Simple diffusion ✓ D) Sodium-potassium pump

22. **Facilitated diffusion uses which of the following components?**
A) Lipid bilayer only B) Vesicles
C) Carrier proteins ✓ D) Ribosomes

23. **Which molecule typically uses simple diffusion to cross the plasma membrane?**
A) Glucose B) Amino acids
C) Sodium ions D) Oxygen ✓

24. **In osmosis, water moves from:**
A) Hypertonic to hypotonic solution
B) Higher solute to lower solute concentration
C) Hypotonic to hypertonic solution ✓
D) Inside to outside of the cell always

25. **Which type of transport moves substances against the concentration gradient?**
A) Simple diffusion B) Facilitated diffusion
C) Osmosis D) Active transport ✓

26. **Which of these processes does not require ATP?**
A) Sodium-potassium pump
B) Endocytosis
C) Osmosis ✓ D) Phagocytosis

27. **What type of molecules are usually transported by facilitated diffusion?**
A) Lipid-soluble molecules
B) Small nonpolar gases
C) Polar or charged molecules ✓
D) DNA fragments

28. **What affects the rate of simple diffusion?**
A) Number of transport proteins
B) DNA concentration
C) Concentration gradient and temperature ✓
D) Ribosomal activity

29. **Which protein helps in rapid transport of water across membranes?**
A) Enzyme B) Ribosome
C) Aquaporin ✓ D) Myosin

30. **Which of the following best defines phagocytosis?**
A) Transport of ions
B) Engulfing of solid particles ✓
C) Movement of gases D) Diffusion of liquids

31. **What forms during endocytosis to carry materials inside the cell?**
A) Nucleus B) Vesicle ✓
C) Ribosome D) Mitochondrion

32. **Which process is described as "cell drinking"?**
A) Phagocytosis B) Pinocytosis ✓
C) Exocytosis D) Active transport

33. **Sodium-potassium pump is a type of:**
A) Facilitated diffusion B) Osmosis
C) Simple diffusion D) Active transport ✓

34. **Which solution has a lower solute concentration?**
A) Hypertonic B) Hypotonic ✓
C) Isotonic D) Acidic

35. **Which factor can limit the rate of facilitated diffusion?**
A) Membrane cholesterol
B) Number of available transport proteins ✓
C) ATP concentration D) pH value

36. **What best describes the plasma membrane during osmosis?**
A) Completely permeable B) Selectively permeable ✓
C) Impermeable D) Rigid

37. **Which process requires invagination of the plasma membrane?**
A) Simple diffusion B) Endocytosis ✓
C) Osmosis D) Facilitated diffusion

38. **Which of these is a form of bulk transport?**
A) Osmosis B) Endocytosis ✓
C) Facilitated diffusion D) Aquaporin activity

39. **Which ions are involved in the sodium-potassium pump?**
A) H^+ and Cl^- B) Na^+ and K^+ ✓
C) Ca^{2+} and Mg^{2+} D) O^{2-} and Fe^{3+}

40. **Which of the following processes help plant cells maintain turgor pressure?**
A) Active transport B) Pinocytosis
C) Osmosis ✓ D) Simple diffusion

41. **What is the main purpose of exocytosis?**
A) To import nutrients into the cell
B) To divide the cell
C) To export bulky materials out of the cell ✓
D) To transport DNA

42. **During exocytosis, where is the bulky material initially stored?**

A) In the nucleus
B) In the mitochondria
C) In a vesicle ✓
D) In the cytoskeleton

43. What happens when the vesicle reaches the plasma membrane in exocytosis?
A) It dissolves inside the cytoplasm
B) It replicates
C) It fuses with the membrane and releases contents ✓
D) It forms ribosomes

44. What is released during exocytosis?
A) Chromosomes
B) ATP molecules
C) Bulky cellular contents ✓
D) Nucleic acids

45. Where are the contents released during exocytosis?
A) Into the nucleus
B) Into the mitochondria
C) Into the extracellular environment ✓
D) Into the endoplasmic reticulum

SQ

1. Why is the movement of substances in and out of cells important?
Ans. The movement of substances is crucial for nutrient uptake, waste elimination, gas exchange, and signal transduction, which are essential for proper cellular function.

2. Which structure controls the movement of substances in and out of the cell?
Ans. The plasma membrane regulates the movement of substances in and out of the cell.

3. What is the main purpose of membrane transport mechanisms?
Ans. Membrane transport mechanisms help the cell maintain homeostasis, acquire nutrients, remove waste products, and communicate with its environment.

4. What are the two main types of membrane transport mechanisms?
Ans. The two types are passive transport (does not require energy) and active transport (requires energy).

PASSIVE TRANSPORT

5. What is passive transport?
Ans. Passive transport is the movement of molecules across the plasma membrane without using cellular energy.

6. What are the types of passive transport?
Ans. The main types are diffusion and facilitated diffusion.

7. What is diffusion?
Ans. Diffusion is the net movement of a substance (usually a liquid or gas) from an area of higher concentration to an area of lower concentration, along its concentration gradient.

8. Does diffusion require energy from the cell? Why or why not?
Ans. No, diffusion does not require energy because it occurs naturally along the concentration gradient.

9. What is facilitated diffusion?
Ans. Facilitated diffusion is the movement of substances across the membrane with the help of transport proteins, from higher to lower concentration, without energy usage.

10. Why is facilitated diffusion still considered passive transport?
Ans. Because it does not use cellular energy, even though it requires transport proteins.

11. What does the rate of facilitated diffusion depend on?
Ans. It depends on the number of transport protein molecules available in the membrane.

12. What are the two main types of transport proteins involved in facilitated diffusion?
Ans. The two main types are channel proteins and carrier proteins (transporters).

CHANNEL PROTEINS

13. What do channel proteins do?
Ans. Channel proteins form hydrophilic channels across the membrane, allowing specific molecules or ions to pass through.

14. What is the difference between gated and non-gated channel proteins?
Ans. Gated channels open or close in response to specific stimuli, while non-gated channels remain open continuously.

15. What are some examples of substances that pass through channel proteins?
Ans. Examples include ions like Na^+ (sodium), K^+ (potassium), Ca^{2+} (calcium), Cl^- (chloride) and water (through aquaporins).

16. What are aquaporins?
Ans. Aquaporins are special channel proteins that facilitate the rapid transport of water molecules.

CARRIER PROTEINS (TRANSPORTERS)

17. **How do carrier proteins transport substances?**

Ans. They bind to a specific molecule, change their shape (conformational change), and move the molecule across the membrane.

18. **Are carrier proteins specific to the molecules they transport?**

Ans. Yes, carrier proteins are highly specific to the molecules they transport.

19. **What does it mean that carrier proteins can become saturated?**

Ans. It means there is a maximum rate of transport when all carrier proteins are occupied and no more molecules can be transported at that moment.

20. **What are examples of substances transported by carrier proteins?**

Ans. Examples include glucose (via glucose transporters) and amino acids (via amino acid transporters).

SQ

1. **What is simple diffusion?**

Ans. Simple diffusion is a passive transport process in which substances move from an area of higher concentration to an area of lower concentration directly through the lipid bilayer of the plasma membrane.

2. **What is facilitated diffusion?**

Ans. Facilitated diffusion is also a passive transport process where substances move from higher concentration to lower concentration with the help of specific transport proteins embedded in the plasma membrane.

3. **Does simple diffusion require energy?**

Ans. No, simple diffusion does not require any energy input from the cell as it is a passive transport mechanism.

4. **Does facilitated diffusion use energy?**

Ans. No, facilitated diffusion is also a passive process and does not require energy.

5. **What types of molecules move through simple diffusion?**

Ans. Simple diffusion typically involves small, nonpolar molecules such as oxygen, carbon dioxide, and lipid-soluble substances.

6. **What types of molecules move through facilitated diffusion?**

Ans. Facilitated diffusion primarily involves polar or charged molecules like glucose, amino acids, and ions that cannot easily pass through the hydrophobic part of the membrane.

7. **What factors affect the rate of simple diffusion?**

Ans. The rate of simple diffusion depends on the concentration gradient, temperature, and the permeability of the membrane.

8. **What affects the rate of facilitated diffusion?**

Ans. The rate of facilitated diffusion is influenced by the number and availability of transport proteins, and it can reach a maximum rate when all transport proteins are saturated.

9. **What is osmosis?**

Ans. Osmosis is the process by which water molecules diffuse across a cell membrane from a region of higher concentration to a region of lower concentration. It is a type of passive transport and does not require energy.

10. **On what does the direction of osmosis depend?**

Ans. The direction of osmosis depends on the concentration of solutes on both sides of the membrane. Water moves from a hypotonic solution (low solute concentration) to a hypertonic solution (high solute concentration).

11. **What type of membrane does osmosis occur through?**

Ans. Osmosis occurs through a selectively permeable membrane that allows water to pass while restricting many solutes.

12. **Why is osmosis important for cells?**

Ans. Osmosis is crucial for maintaining cell turgor in plant cells and for regulating the internal water balance in all cells.

13. **What factors influence the direction and rate of osmosis?**

Ans. The osmotic gradient and the permeability of the membrane to water influence the direction and rate of osmosis.

14. What are aquaporins and what is their function?

Ans. Aquaporins are specialized proteins that facilitate the rapid transport of water molecules across the cell membrane, helping in the regulation of cellular hydration and volume.

15. What is active transport?

Ans. Active transport is the movement of substances across the plasma membrane from a region of lower concentration to a region of higher concentration using energy (ATP).

16. How does active transport occur through carrier proteins?

Ans. Carrier (transport) proteins in the plasma membrane use energy to move molecules against the concentration gradient. An example is the sodium-potassium pump in nerve cells.

17. What does the sodium-potassium pump do in nerve cells?

Ans. In resting nerve cells, the sodium-potassium pump uses ATP to maintain higher concentrations of K^+ and lower concentrations of Na^+ inside the cell by actively moving Na^+ out and K^+ into the cell.

18. What is endocytosis?

Ans. Endocytosis is the process in which bulky materials are moved into the cell by the invagination of the plasma membrane, forming a vesicle that carries the material into the cytoplasm.

19. What happens during endocytosis?

Ans. During endocytosis, a portion of the membrane folds inward, traps material from outside, and forms a sealed vesicle that detaches and moves into the cytoplasm.

20. What are the types of endocytosis and how do they differ?

Ans. The two types of endocytosis are:

Phagocytosis, where the cell takes in solid materials.

Pinocytosis, where the cell takes in liquid in the form of droplets.

SQ

1. What is exocytosis?

Ans. Exocytosis is the process through which bulky material is exported out of the cell.

2. What type of materials are transported through exocytosis?

Ans. Bulky materials such as proteins, waste products, and secretory substances are transported through exocytosis.

3. How is the bulky material prepared for exocytosis?

Ans. The bulky material is packed inside a membrane-bound vesicle.

4. What happens to the vesicle during exocytosis?

Ans. The vesicle moves toward the plasma membrane and fuses with it.

5. What happens after the vesicle fuses with the plasma membrane?

Ans. After fusion, the vesicle releases its contents into the extracellular environment.

6. Why is exocytosis important for the cell?

Ans. Exocytosis is important for removing waste, releasing hormones and enzymes, and maintaining cell surface area.

3.8 STEM CELLS

Q

34. What are stem cells? Describe their types, uses, and categories based on origin.

Ans. Definition and Characteristics of Stem Cells

Stem cells are special cells in the body with the remarkable ability to develop into many different types of specialized cells. They are undifferentiated cells, which means they have not yet developed into specific cell types. When a stem cell divides, each new cell can either remain a stem cell or become a specialized cell like a muscle cell, red blood cell, or brain cell.

Types of Stem Cells Based on Differentiation Potential

Stem cells are classified into different categories based on how many types of cells they can become:

1. **Totipotent Stem Cells**
   These stem cells can differentiate into **all possible cell types**, including both embryonic and extra-embryonic tissues (like placenta). For example, a **zygote** and the cells from its **first few divisions** are totipotent.
2. **Pluripotent Stem Cells**

These cells can develop into **almost any type of cell** in the body, excluding extra-embryonic tissues. An example of pluripotent stem cells is the **cells from an early embryo**.

3. **Multipotent Stem Cells**
   These stem cells can become **a limited range of related cells**. For instance, **hematopoietic stem cells** (found in bone marrow) can differentiate into red blood cells, white blood cells, or platelets.
4. **Oligopotent Stem Cells**
   These stem cells can produce **a few different types of cells**, usually within a specific tissue type. Examples include **adult lymphoid or myeloid stem cells**.
5. **Unipotent Stem Cells**
   These cells can form **only one type of cell**, which is their own type. However, they still qualify as stem cells because they can **self-renew**. An example is **adult muscle stem cells**.

Uses of Stem Cells

Stem cells are highly valuable in medicine and research for various purposes:

1. **Regenerative Medicine**
   Stem cells can be used to **repair or replace damaged tissues and organs**. They are being studied for treating conditions such as **spinal cord injuries, type 1 diabetes, Parkinson's disease**, and **heart disease**.
2. **Drug Testing and Development**
   Scientists can differentiate stem cells into specific types of cells and use them to **create models of human diseases**. This helps in testing how drugs affect human tissues and **reduces the use of animals in testing**.
3. **Personalized Medicine**
   By using stem cells derived from a patient's own body, doctors can develop **personalized treatments**. This **minimizes the risk of immune rejection** and makes the therapy safer and more effective.

35. How are stem cells categorized based on their origin? Also elaborate their advantages and disadvantages.

Ans. Categories of Stem Cells Based on Origin

Stem cells are also categorized based on where they come from:

1. **Embryonic Stem Cells (ESCs)**
   ESCs are obtained from the **inner cell mass of blastocysts** (an early-stage embryo). These cells are **pluripotent** and can differentiate into nearly all types of body cells. They are highly versatile for research and therapy.
   Ethical Concerns: Their use involves the destruction of human embryos, which raises ethical issues. They also have a **risk of forming tumors (teratomas)** and **immune rejection**.
2. **Adult Stem Cells (ASCs)**
   These stem cells are found in **various body tissues**, such as **bone marrow, fat, and blood**. They are **multipotent**, meaning they can become a limited range of cells related to their tissue of origin.
   Advantages: Less ethical controversy and **lower risk of immune rejection**, especially when taken from the patient's own tissues.
   Disadvantages: They are **harder to isolate, difficult to grow**, and have **limited potential** compared to embryonic stem cells.
3. **Induced Pluripotent Stem Cells (iPSCs)**
   These stem cells are created in the lab by **reprogramming adult somatic cells** using specific transcription factors to make them behave like pluripotent stem cells. They are **similar in function to ESCs**.
   Advantages of iPSCs:
   - No destruction of embryos, so no ethical controversy
   - Can be made from a patient's own cells → **low immune rejection risk**
   - Can help regenerate tissues (e.g., **heart or nerve cells**) for treatment of serious diseases

   Disadvantages of iPSCs:
   - Reprogramming can cause **genetic changes**
   - May lead to formation of **tumors (teratomas)**
   - It is difficult to **control and guide their differentiation**
   - Ensuring proper **functionality** of the new cells remains a challenge

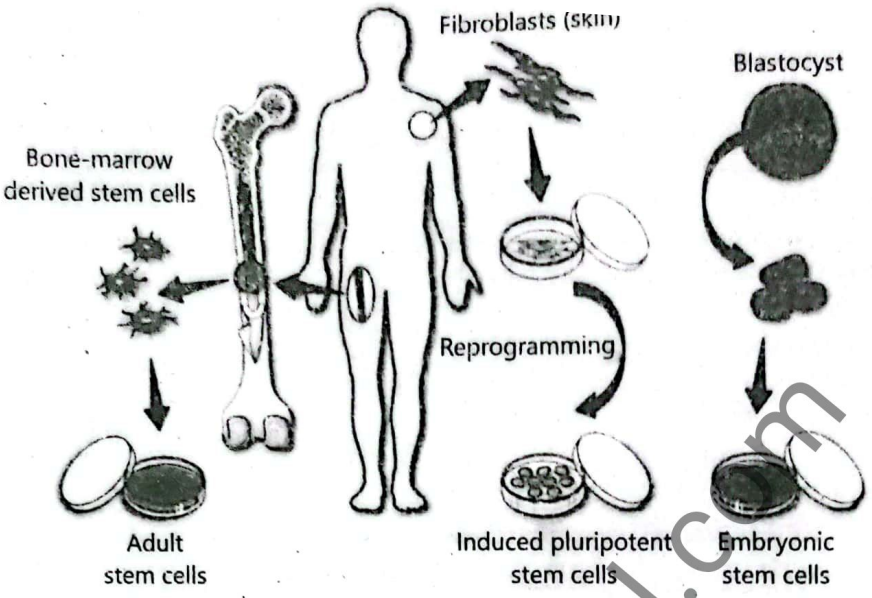


Fig. 3.39: Stem cells - Sources and types

MCQs

1. **What is the main characteristic of stem cells?**
   A. They cannot divide
   B. They always become muscle cells
   C. They can develop into many different cell types ✓
   D. They only produce red blood cells

2. **Which type of stem cell can differentiate into all possible cell types?**
   A. Unipotent B. Multipotent
   C. Totipotent ✓ D. Pluripotent

3. **The zygote is an example of a:**
   A. Multipotent cell B. Totipotent cell ✓
   C. Unipotent cell D. Oligopotent cell

4. **Which stem cells can become almost any type of cell, but not extra-embryonic cells?**
   A. Totipotent B. Pluripotent ✓
   C. Multipotent D. Oligopotent

5. **Hematopoietic stem cells are an example of:**
   A. Unipotent stem cells B. Pluripotent stem cells
   C. Multipotent stem cells ✓ D. Totipotent stem cells

6. **Which stem cells can produce only one specific type of cell?**
   A. Oligopotent B. Unipotent ✓
   C. Pluripotent D. Multipotent

7. **Which stem cells are derived from early embryos?**
   A. Adult stem cells B. Pluripotent stem cells
   C. Embryonic stem cells ✓
   D. Induced pluripotent stem cells

8. **What is a major ethical concern of using embryonic stem cells?**
   A. Expensive process
   B. Requires destruction of embryos ✓
   C. Cannot differentiate D. No medical use

9. **Adult stem cells are found in:**
   A. Only the brain B. Only in embryos
   C. Bone marrow, fat, and blood ✓
   D. Umbilical cord only

10. **Which stem cells are multipotent and found in adults?**
    A. ESCs B. ASCs ✓
    C. iPSCs D. Totipotent

11. **Which stem cells are created by reprogramming adult cells in the lab?**
    A. Pluripotent B. Embryonic
    C. Induced pluripotent ✓ D. Oligopotent

12. **A benefit of using iPSCs is that they:**
    A. Are multipotent B. Avoid ethical concerns ✓
    C. Cannot divide D. Are found in embryos

13. **Which stem cells can cause teratomas if not properly controlled?**
    A. ASCs B. ESCs and iPSCs ✓
    C. Unipotent D. Totipotent only

14. **Which is a use of stem cells in medicine?**
    A. Cooking B. Fuel generation
    C. Regenerative therapy ✓ D. Photography

15. **Which of the following is NOT a category based on differentiation potential?**
    A. Totipotent B. Dormant ✓
    C. Pluripotent D. Oligopotent

16. **What is a disadvantage of adult stem cells?**
    A. Easily available B. Pluripotent nature
    C. Hard to isolate and culture ✓
    D. Derived from embryos

17. **Stem cells are useful for drug development because they:**
    A. Destroy tissues B. Form zygotes

C. Can model diseases✓ D. Can't divide

18. **What makes personalized medicine using stem cells possible?**
A. Their ability to change color
B. Their shape
C. Deriving them from a patient's own cells✓
D. Availability of robots

19. **Which transcription factors are used in creating iPSCs?**
A. Enzymes B. Hormones
C. Specific reprogramming factors✓
D. Vitamins

20. **What is the function of pluripotent stem cells?**
A. Become one type of cell only
B. Cannot divide
C. Become almost any cell in the body✓
D. Die quickly

SQ

1. **What are stem cells?**

Ans. Stem cells are unique cells with the remarkable ability to develop into many different types of cells in the body. When a stem cell divides, it can either remain a stem cell or become a specialized cell such as a muscle cell, red blood cell, or brain cell.

Categories of Stem Cells Based on Differentiation Potential

2. **What are the major categories of stem cells based on their ability to form different types of cells?**

Ans. The categories are:
Totipotent: Can become all cell types (e.g., zygote and early divisions of zygote).
Pluripotent: Can turn into almost any cell (e.g., cells from the early embryo).
Multipotent: Can become a closely related family of cells (e.g., hematopoietic stem cells).
Oligopotent: Can differentiate into a few different types (e.g., lymphoid or myeloid stem cells).
Unipotent: Can produce only one type of cell but can self-renew (e.g., adult muscle stem cells).

Uses of Stem Cells

3. **How are stem cells used in regenerative medicine?**

Ans. Stem cells are used to repair or replace damaged tissues and organs. They are being tested or used to treat spinal cord injuries, type 1 diabetes, Parkinson's disease, and heart disease.

4. **How are stem cells used in drug testing and development?**

Ans. Researchers use differentiated stem cells to create disease models for more accurate drug testing and to reduce the use of animal models.

5. **What is the role of stem cells in personalized medicine?**

Ans. Stem cells can be derived from a patient's own cells, which reduces the risk of immune rejection and makes therapies safer and more effective.

Categories of Stem Cells Based on Origin

6. **What are embryonic stem cells (ESCs)?**

Ans. ESCs are derived from the inner cell mass of blastocysts. They are pluripotent, meaning they can differentiate into nearly all cell types. However, their use raises ethical concerns and carries the risk of tumor formation and immune rejection.

7. **What are adult stem cells (ASCs)?**

Ans. ASCs are found in various tissues like bone marrow, fat, and blood. They are multipotent and can become certain related cell types. They involve fewer ethical issues and lower immune rejection risk but have limited potential and are harder to isolate.

8. **What are induced pluripotent stem cells (iPSCs)?**

Ans. iPSCs are created by reprogramming adult somatic cells in a lab to become pluripotent using transcription factors. They behave similarly to embryonic stem cells.

Advantages and Disadvantages of iPSCs

9. **What are the advantages of using iPSCs?**

Ans. iPSCs avoid ethical issues related to embryos, can be made from a patient's own cells (reducing immune rejection), and can potentially regenerate tissues and organs.

10. **What are the disadvantages of using iPSCs?**

Ans. The reprogramming process can introduce genetic changes. iPSCs may form tumors (teratomas), and it is still difficult to guide them to become fully functional, specific cell types that work correctly in the body.

SOLVED EXERCISE

MULTIPLE CHOICE QUESTIONS

Tick (✓) the correct answer.

1. **Which one of the following eukaryotic cell structures does not contain DNA?**
   (a) Nucleus
   (b) Mitochondrion
   (c) Endoplasmic reticulum ✓
   (d) Chloroplast

2. **Which of the following is not an accurate description of a chromosome?**
   (a) It is a coloured body localized in the nucleus
   (b) It is a protein and nucleic acid complex
   (c) It is the cellular structure that contains the genetic material
   (d) In eukaryotes, it is composed of many DNA molecules attached end to end ✓

3. **A centriole is an organelle that is:**
   (a) Present in the centre of a cell's cytoplasm
   (b) Composed of microtubules and important for organizing the spindle fibres ✓
   (c) Surrounded by a membrane
   (d) Part of a chromosome

4. **The rough endoplasmic reticulum is:**
   (a) An intracellular double-membrane system to which ribosomes are attached ✓
   (b) b) An intracellular membrane that is studded with microtubular structures
   (c) c) A membranous structure found within mitochondria
   (d) d) Only found in prokaryotic cells

5. **In the nucleus of eukaryotic cells, the genetic material is complexed with protein and organized into linear structures called:**
   (a) Centrioles
   (b) Histones
   (c) Chromosomes ✓
   (d) Plasmi

6. **Which of the following statements does not apply to the nuclear envelope?**
   (a) It is a double membrane
   (b) It is continuous with the endoplasmic reticulum
   (c) It has pores through which material enters and leaves
   (d) It has infoldings to form cristae ✓

7. **Lysosomes are formed by budding from which cellular organelle?**
   (a) Smooth endoplasmic reticulum
   (b) Golgi apparatus ✓
   (c) Rough endoplasmic reticulum
   (d) Nucleus

8. **All peroxisomes carry out this function:**
   (a) Break down fats and amino acids into smaller molecules that can be used for energy production by mitochondria ✓
   (b) Digest macromolecules using the hydrolytic enzymes they contain
   (c) Synthesize membrane components such as fatty acids and phospholipids
   (d) Control the flow of ions into and out of the cell

9. **How would the absence of peroxisomes in a cell affect its metabolism, and what would be the likely symptoms?**
   (a) The cell would be unable to carry out oxidative phosphorylation, leading to reduced ATP production.
   (b) The cell would accumulate hydrogen peroxide, leading to oxidative stress and potential cellular damage. ✓
   (c) The cell would have impaired protein synthesis, leading to muscle weakness.
   (d) The cell would fail to produce lipids, causing membrane instability

10. **Which of the following does not apply to chloroplasts?**
    (a) They contain chlorophyll and the enzymes required for photosynthesis.
    (b) They contain an internal membrane system consisting of thylakoids.
    (c) They synthesize ATP.

(d) They are bounded by two membranes, the inner of which is folded into the cristae.✓

11. What is the correct sequence of membrane compartments through which a secretory protein moves from synthesis to release from the cell?

(a) SER → Golgi apparatus → RER → Cell membrane
(b) Cell membrane → Golgi apparatus → RER → SER
(c) RER → Golgi → Cell membrane → SER
(d) RER → SER → Golgi apparatus → Cell membrane✓

12. How does the process of facilitated diffusion differ from active transport?

(a) Facilitated diffusion requires energy, active transport does not
(b) Facilitated diffusion does not require energy, active transport does ✓
(c) Both processes require energy
(d) Both processes do not require energy

SHORT ANSWER QUESTIONS

1. Compare the resolution and magnification of light microscope and electron microscope?

Ans. A **light microscope** uses visible light and lenses, offering up to **1500X magnification** with a **resolution of 0.2 micrometres (µm)**. It is suitable for viewing living cells but cannot show very fine details. An **electron microscope** uses electron beams, providing magnification up to **1,000,000X** and a **resolution of about 0.001 micrometres (1 nanometre)**, allowing detailed observation of cell structures, but it requires non-living, specially prepared specimens.

2. State the cell theory. How we can validate it? What are the exceptions to cell theory?

Ans. Cell Theory states that:

1. All living organisms are made up of one or more cells.
2. The cell is the basic unit of structure and function in living organisms.
3. All cells arise from pre-existing cells.

Validation:

Cell theory is validated through extensive observations using microscopes and experiments showing that all organisms consist of cells and that new cells form by the division of existing ones.

Exceptions to Cell Theory:

1. **Viruses, prions, and viroids** are not made of cells and cannot carry out life processes independently.
2. **Mitochondria and chloroplasts** have their own DNA and replicate independently.
3. **Multinucleated cells** like some fungi, algae, and muscle fibers challenge the idea of one nucleus per cell.

3. The table below compares the process of diffusion, facilitated diffusion and active transport. Fill in the blank cells, using the words "YES" or "NO".

	Process		
Description	**Simple Diffusion**	**Facilitated Diffusion**	**Active Transport**
Is ATP required?	No	No	Yes
Are carrier proteins involved?	No	Yes	Yes
Is direction of transport always from higher to lower concentration?	Yes	Yes	No

4. Categorize the organelles as (i) single membrane bounded, (ii) double membrane bounded and (iii) lacking any membrane.

Ans. (i) Single Membrane Bounded Organelles:

Endoplasmic Reticulum (Smooth and Rough)
Golgi Apparatus
Lysosomes
Peroxisomes
Vacuoles (in plant and fungal cells)

(ii) Double Membrane Bounded Organelles:

Mitochondria

Chloroplasts (in plant cells)
Nucleus

(iii) Organelles Lacking Any Membrane:

Ribosomes
Centrioles
Cytoskeleton (microtubules, microfilaments, intermediate filaments)
Nucleolus (within nucleus)

These classifications are based on the structural features of each organelle and are important for understanding their functions and origins.

5. State two functions of the proteins in the plasma membrane.

Ans. Transport: Some proteins act as channels or carriers to help move substances (like ions, glucose, or amino acids) across the membrane.

Cell Signaling: Receptor proteins in the membrane receive chemical signals (like hormones) from outside the cell and transmit them into the cell to trigger a response.

6. State two features that mitochondria have in common with prokaryotes.

Ans. Two features that mitochondria have in common with prokaryotes are:

1. **Presence of circular DNA:** Like prokaryotes, mitochondria contain their own circular DNA, which is not enclosed within a nucleus.
2. **Independent replication:** Mitochondria can replicate independently of the cell's nucleus, similar to how prokaryotic cells divide.

7. List three ways in which prokaryotic cells differ from eukaryotic cells.

Ans. Three ways in which prokaryotic cells differ from eukaryotic cells are:

1. **Nucleus:** Prokaryotic cells lack a true nucleus; their DNA is located in a region called the nucleoid, whereas eukaryotic cells have a membrane-bound nucleus.
2. **Organelles:** Prokaryotic cells do not contain membrane-bound organelles (e.g., mitochondria, ER, Golgi apparatus), while eukaryotic cells have well-defined membrane-bound organelles.
3. **Size:** Prokaryotic cells are generally smaller (2–8 µm) compared to the larger eukaryotic cells.

8. List the structures and molecules, which can cross the nuclear envelope.

Ans. The following structures and molecules can cross the nuclear envelope:

1. **RNA molecules** (e.g., mRNA, tRNA, rRNA) – exit the nucleus to participate in protein synthesis.
2. **Proteins** (e.g., enzymes, histones, transcription factors) – enter the nucleus to perform various nuclear functions.
3. **Ribosomal subunits** – synthesized in the nucleolus and transported to the cytoplasm.
4. **Ions and small molecules** – pass through nuclear pores by passive diffusion.
5. **Signal molecules** – such as steroid hormones, which influence gene expression inside the nucleus.

9. Distinguish each of the following pairs.

a- exocytosis and endocytosis
b- phagocytosis and pinocytosis
c- peroxisome and glyoxysomes

Ans.

a) Exocytosis vs Endocytosis

Feature	Exocytosis	Endocytosis
Definition	Expelling materials out of the cell	Taking materials into the cell
Mechanism	Vesicles fuse with plasma membrane	Plasma membrane engulfs material forming vesicles
Purpose	Secretion of substances (e.g., hormones)	Uptake of nutrients, fluids, or particles

b) Phagocytosis vs Pinocytosis

Feature	Phagocytosis	Pinocytosis
Type of material taken	Large particles or microorganisms	Extracellular fluid and dissolved substances
Process name	"Cell eating"	"Cell drinking"
Vesicle formed	Large vesicles called phagosomes	Small vesicles

c) Peroxisome vs Glyoxysome

Feature	Peroxisome	Glyoxysome
Function	Break down fatty acids, detoxify hydrogen peroxide	Convert stored lipids into carbohydrates during seed germination
Organism	Found in most eukaryotic cells	Found in plants and some fungi
Enzymes present	Catalase and oxidases	Enzymes of glyoxylate cycle

10. **What are the main functions of lysosomes?**

Ans: Lysosomes are membrane-bound organelles that contain digestive enzymes to break down macromolecules, damaged organelles, and foreign particles. They play a key role in intracellular digestion and recycling of cellular components, often referred to as the cell's "suicide bags" due to their role in autolysis.

11. **Describe the role of the Golgi body in forming lysosomes.**

Ans: The Golgi body is responsible for modifying, packaging, and sorting proteins and lipids. It plays a key role in forming lysosomes by enclosing hydrolytic enzymes in vesicles, which then bud off as lysosomes used for intracellular digestion.

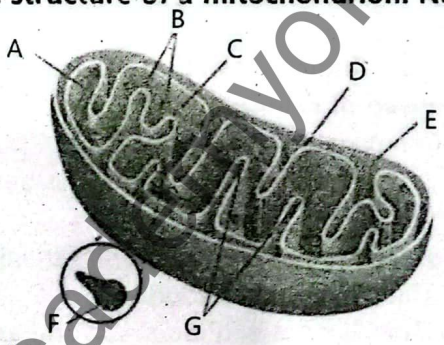
12. **What are histones? Where are these found in eukaryotic cells?**

Ans: Histones are positively charged proteins that help in the organization and packaging of DNA into structural units called nucleosomes. They are found in the nucleus of eukaryotic cells and are essential for the condensation of DNA into chromatin.

13. **What do you mean by "stem cell"? What are the main usages of stem cells?**

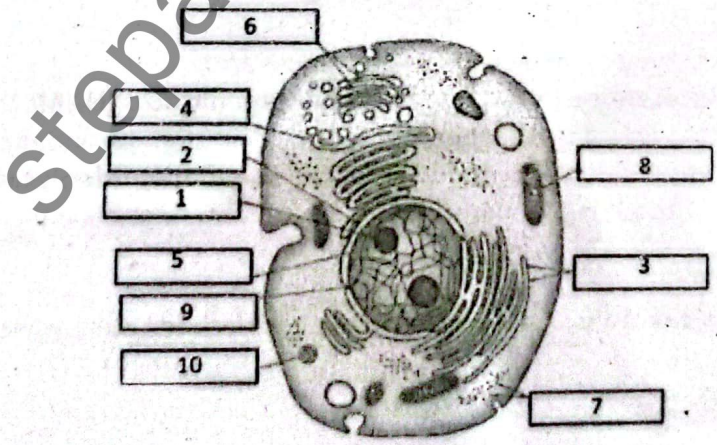
Ans: Stem cells are undifferentiated cells that have the potential to develop into different types of specialized cells. They are widely used in regenerative medicine, tissue repair, and the treatment of diseases such as leukemia and Parkinson's due to their ability to divide and replace damaged cells.

14. **The following diagram shows the structure of a mitochondrion. Name structures A to G.**



Ans: See Diagram 3.19 Topic 4 Mitochondria

15. **The diagram below shows an electron micrograph of a cell.**



Label the parts of the cell.

Ans: **Label the Parts of the Cell (based on the image):**

This is a **typical animal cell**. The structures are identified as follows (Match the numbering):

1. **Nucleolus**

2. **Nucleus**
3. **Rough Endoplasmic Reticulum (RER)**
4. **Smooth Endoplasmic Reticulum (SER)**
5. **Nucleoplasm**
6. **Golgi Apparatus**
7. **Ribosomes**
8. **Mitochondrion**
9. **Nuclear Pore**
10. **Lysosome**

b- What evidence can be seen in the diagram that suggests that the cell is metabolically active and involved in secretion of enzymes?

Ans: b. Evidence of Metabolic Activity and Enzyme Secretion:

- The **presence of numerous mitochondria** indicates high energy demands, suggesting that the cell is metabolically active.
- The **well-developed Rough Endoplasmic Reticulum (RER)** and **Golgi Apparatus** show that the cell is actively synthesizing and processing proteins, including enzymes.
- The **presence of vesicles and lysosomes** indicates intracellular transport and enzyme secretion or digestion.

These features collectively suggest that the cell is involved in **protein synthesis, modification, packaging, and secretion of enzymes**, which are all signs of high metabolic activity.

LONG QUESTIONS

Q1. Write details of the structure and the chemical composition of cell walls of eukaryotes and prokaryotes.

Ans. Cell Wall of Prokaryotes

Structure:

- Most **prokaryotes** (like bacteria) have a **rigid cell wall** that surrounds the plasma membrane.
- The bacterial cell wall is **not composed of cellulose** like in plants but of a unique molecule called **peptidoglycan** (also known as murein).
- The wall is **porous** and allows the passage of nutrients and waste but provides **mechanical strength** and **protection**.
- Two types of bacterial cell walls are recognized based on Gram staining:
  - **Gram-positive bacteria**: Thick layer of peptidoglycan.
  - **Gram-negative bacteria**: Thin layer of peptidoglycan and an **outer membrane** containing **lipopolysaccharides** (LPS).

Chemical Composition:

- **Peptidoglycan**: A complex polymer made of sugars and amino acids.
  - Sugars: **N-acetylglucosamine (NAG)** and **N-acetylmuramic acid (NAM)** form alternating chains.
  - These chains are cross-linked by **short peptides**, providing strength and rigidity.
- In **archaea**, the cell wall lacks peptidoglycan and may contain **pseudopeptidoglycan**, **polysaccharides**, **glycoproteins**, or **proteins**, depending on the species.

Cell Wall of Eukaryotes

Note: **Not all eukaryotic cells have cell walls**. For example, animal cells lack cell walls, while plant cells, fungi, and some protists have them.

1. Plant Cell Wall

Structure:

- The cell wall is **rigid** and **multi-layered**.
  - **Primary cell wall**: Thin and flexible, formed during cell growth.
  - **Secondary cell wall** (in some cells): Thicker, formed after the cell stops growing.
- The wall lies **outside the plasma membrane**.

Chemical Composition:

- **Cellulose**: Main structural component – a polysaccharide made of β-1,4 linked glucose units.
- **Hemicellulose**: Branched polysaccharides that bind with cellulose fibers.
- **Pectin**: A gel-like polysaccharide that helps in adhesion and hydration.
- **Lignin** (in secondary walls): Provides rigidity and water resistance.
- **Proteins** and **enzymes** are also embedded in the wall matrix.

2. Fungal Cell Wall

Structure:

- Rigid and multilayered, surrounds the plasma membrane.

Chemical Composition:

- **Chitin**: Main component – a polysaccharide made of N-acetylglucosamine.
- **Glucans**: Branched polysaccharides (β-glucans).
- **Proteins** and **glycoproteins**.

3. Algal Cell Wall

Structure and Composition:

- Similar to plant cell walls but may contain **additional polysaccharides** such as:
  - **Agar, carrageenan, alginate, silica**, or **calcium carbonate**, depending on the species.

Summary

Organism Type	Main Cell Wall Component
Bacteria	Peptidoglycan (murein)
Archaea	Pseudopeptidoglycan or proteins
Plants	Cellulose, hemicellulose, pectin
Fungi	Chitin, glucans
Algae	Cellulose + other polysaccharides

Q2. Explain the chemical composition and the functions of plasma membrane.

Ans. See Question number 9, 10 and 11

Q3. Identify the role of glycolipids and glycoproteins as the cell surface markers.

Ans. Role of Glycolipids and Glycoproteins as Cell Surface Markers

1. Glycolipids:

- **Structure**: Glycolipids are molecules composed of a **lipid** and one or more **carbohydrate chains** attached.
- **Location**: They are found on the **outer leaflet of the plasma membrane**, with the carbohydrate portion extending into the extracellular space.
- **Function as Cell Surface Markers**:
  - **Cell Recognition**: Glycolipids act as **identification markers** that help cells recognize each other, especially during tissue formation and immune responses.
  - **Cell Communication**: They participate in **cell signaling** by interacting with other cells or with external molecules.
  - **Stability and Protection**: They contribute to **membrane stability** and can help protect the cell from harsh environmental conditions.

2. Glycoproteins:

- **Structure**: Glycoproteins consist of a **protein** core with one or more **carbohydrate (sugar) chains** attached.
- **Location**: These are also found on the **outer surface of the plasma membrane**.
- **Function as Cell Surface Markers**:
  - **Immune Response**: Many glycoproteins act as **antigens** (such as blood group antigens), enabling the immune system to distinguish self from non-self.
  - **Cell Adhesion**: They play a key role in **cell-to-cell adhesion**, allowing cells to bind to one another and form tissues.
  - **Receptor Functions**: Some glycoproteins function as **receptors**, helping cells respond to hormones, neurotransmitters, or pathogens.

Q4. Explain the structure, chemical composition and function of ribosomes.
Ans. *See Question number 16*
Q5. Explain the structure, and functions of Golgi complex.
Ans. *See Question number 16*
Q6. Describe the structure, chemical composition and function of chromosome.
Ans. *See Question number 19*
Q7. Discuss nuclear envelope and nuclear pore complex in detail.
Ans. *See Question number 19*
Q8. Explain how Golgi apparatus is involved in making cell secretions.
Ans. *See Topic No.16*
Q9. Describe the structure and functions of smooth and rough endoplasmic reticulum.
Ans. *See Question number 15*
Q10. Explain the role of lysosomes and peroxisomes in regulating the amounts of cellular contents.
Ans. *See Question number 20*
Q11. Describe the structures of the three fibres that make the cytoskeleton.
Ans. *See Question number 26*
Q12. Describe the formation and functions of lysosomes.
Ans. *See Question number 20*
Q13. Compare mitochondria and chloroplasts as the organelles that are involved in cellular energetics.
Ans.

Feature	Mitochondria	Chloroplasts
Function	Site of **aerobic respiration**: converts glucose into ATP (energy)	Site of **photosynthesis**: converts solar energy into chemical energy (glucose)
Presence	Found in **all eukaryotic cells** (plants, animals, fungi, protists)	Found only in **plant cells and some protists** (e.g., algae)
Energy Conversion	Convert **chemical energy** from food into **ATP**	Convert **light energy** into **chemical energy** (glucose)
nergy Output	Produces **ATP** through **oxidative phosphorylation**	Produces **glucose** and **oxygen** during photosynthesis
Pigments	Does **not contain pigments**	Contains **chlorophyll** and other pigments
Structure	Double membrane, with inner membrane folded into **cristae**	Double membrane, with internal stacked membranes called **grana** (thylakoids) in the **stroma**
Matrix or Internal Space	Contains **matrix**, where Krebs cycle occurs	Contains **stroma**, where the Calvin cycle occurs
DNA and Ribosomes	Contains **its own DNA and ribosomes** (semi-autonomous)	Contains **its own DNA and ribosomes** (semi-autonomous)
Key Enzymes	Enzymes for **Krebs cycle** and **electron transport chain**	Enzymes for **light and dark reactions** of photosynthesis
Origin (Endosymbiosis)	Believed to have originated from **aerobic bacteria**	Believed to have originated from **photosynthetic bacteria (cyanobacteria)**

Q14. Describe the basic structure of a mitochondrion, from outside inward.
Ans. See long question number 17
Q15. Describe the pathway of protein signal and steroid signal from outside of a cell to inside.
Ans. See long question number 30
Q16. Categorize and explain different types of stem cells.
Ans. See long question number 34
Q17. What are the advantages and disadvantages of using Induced Pluripotent Stem Cells?
Ans. See long question number 35

INQUISITIVE QUESTIONS

1. If a researcher observes that a certain cell type has an exceptionally large Golgi apparatus, what can be inferred about the function of this cell?

Ans. The cell is heavily involved in **secretion or modification and packaging of proteins and lipids**.

Justification:

The Golgi apparatus functions in modifying, sorting, and packaging proteins and lipids for delivery to targeted destinations, including secretion outside the cell. An enlarged Golgi typically indicates a high rate of processing and exporting materials, as seen in glandular cells (e.g., pancreatic cells that secrete digestive enzymes or endocrine cells secreting hormones).

2. If a signaling molecule is lipid-soluble, like a steroid hormone, what is the most likely mechanism for its action within the target cell?

Ans. It **diffuses through the plasma membrane** and binds to **intracellular receptors**, often in the cytoplasm or nucleus.

Justification:

Lipid-soluble molecules can pass through the lipid bilayer of the cell membrane without the need for surface receptors. Once inside, they bind to specific intracellular receptors, and the resulting complex often acts as a transcription factor to regulate gene expression directly.

3. Why do we categorize endocytosis and exocytosis in active transport?

Ans. Because they **require energy in the form of ATP** to move large particles or volumes **against a concentration gradient or across the membrane**.

Justification:

Endocytosis and exocytosis involve the remodeling of the cell membrane and the movement of materials in bulk (e.g., vesicles). This process needs cellular energy (ATP) to change membrane structure and transport vesicles, qualifying it as a form of active transport.

4. Justify why the membrane may be described as fluid.

Ans. The membrane is described as **fluid** because **phospholipids and proteins move laterally within the layer**, giving it flexibility and dynamic behavior.

Justification:

According to the **Fluid Mosaic Model**, the lipid bilayer is not rigid; lipids and proteins can drift laterally. This fluidity is essential for membrane function, including the movement of materials, membrane fusion, and the functioning of embedded proteins. Cholesterol and the types of fatty acids also influence this fluidity.

Self-Assessment Unit 3

Max. Marks: 28 Time allowed 60 Mins

Q1. Each of the following question has four options. Select the correct answer. (10x1=10)

1. **Which of the following eukaryotic cell structures lacks DNA?**
   (a) Nucleus (b) Mitochondrion (c) Endoplasmic reticulum (d) Chloroplast
2. **Which of the statements below is incorrect regarding chromosomes?**
   (a) They are colored bodies located inside the nucleus
   (b) They are complexes made of proteins and nucleic acids
   (c) They carry the genetic information of the cell
   (d) In eukaryotic cells, they consist of multiple DNA strands linked together
3. **What accurately describes a centriole within a cell?**
   (a) Found at the center of the cytoplasm
   (b) Built from microtubules and helps organize spindle fibers during division
   (c) Enclosed within a membrane
   (d) Functions as a part of a chromosome
4. **The rough endoplasmic reticulum (RER) can be best described as:**
   (a) A membrane-bound system inside the cell with ribosomes attached
   (b) An organelle containing microtubules
   (c) A folded membrane found within mitochondria (d) Present only in prokaryotic organisms
5. **Inside the eukaryotic nucleus, DNA and protein are organized into:**
   (a) Centrioles (b) Histones (c) Chromosomes (d) Plasmids
6. **Which feature is not true about the nuclear envelope?**
   (a) It is made of two membranes (b) It connects to the endoplasmic reticulum
   (c) It contains pores that allow transport in and out (d) It has folds that form cristae
7. **Lysosomes originate by budding off from which cellular organelle?**
   (a) Smooth endoplasmic reticulum (b) Golgi complex
   (c) Rough endoplasmic reticulum (d) Nucleus
8. **Which of the following functions is carried out by all peroxisomes?**
   (a) Degradation of fats and amino acids for mitochondrial energy production
   (b) Hydrolysis of large molecules using enzymes
   (c) Synthesis of phospholipids and fatty acids
   (d) Regulation of ion transport across membranes
9. **What would likely happen if a cell lacked peroxisomes?**
   (a) ATP generation via oxidative phosphorylation would fail
   (b) Hydrogen peroxide would accumulate, causing oxidative damage
   (c) Protein synthesis would be disrupted, leading to muscle issues
   (d) Lipid production would stop, weakening the cell membrane
10. **Which of the following is not a correct feature of chloroplasts?**
    (a) They perform photosynthesis using chlorophyll and enzymes
    (b) They have thylakoid membranes inside
    (c) They produce ATP
    (d) Their inner membrane forms cristae-like folds

Q2. Write short answers to the following questions. (5x2=10)

1. Compare the resolution and magnification of light microscope and electron microscope?
2. State the cell theory. How we can validate it? What are the exceptions to cell theory?
3. State two functions of the proteins in the plasma membrane.
4. State two features that mitochondria have in common with prokaryotes.
5. What are histones? Where are these found in eukaryotic cells?

Q3. Write detailed answer to the following question. (4+4=8)

1. Identify the role of glycolipids and glycoproteins as the cell surface markers.
2. Describe the pathway of protein signal and steroid signal from outside of a cell to inside.