The Fundamental Unit of Life

Introduction

- ❖ What is a ***Cell*** ?
  - ➢ A cell is the smallest ***structural and functional unit of life.***
  - ➢ All living organisms are made up of cells.
  - ➢ It performs all vital functions such as respiration, digestion, excretion, etc.
  - ➢ Hence, the cell is called the "***building block of life***."
- ❖ Discovery of Cell :-
  - ➢ The cell was ***discovered by Robert Hooke in 1665.***
  - ➢ He observed thin slices of cork (dead plant tissue) under a microscope.
  - ➢ He saw tiny box-like structures and called them "cells" (meaning small rooms in Latin).
  - ➢ ***Antonie van Leeuwenhoek (1674)*** improved the microscope and ***observed living cells*** like bacteria and protozoa.
- ❖ Cell Theory :-

- Cell theory was developed by :
  - ➢ ***Matthias Schleiden (1838)*** – stated that all plants are made up of cells
  - ➢ ***Theodor Schwann (1839)*** – stated that all animals are made up of cells.
  - Together, they proposed the Cell Theory, which states:

- ❖ Main points of Cell Theory:
  - ➢ All living organisms are made up of cells.
  - ➢ The cell is the basic unit of life.
  - ➢ All cells arise from pre-existing cells – ***(added by Rudolf Virchow in 1855)***.

Types of Organisms Based on Number of Cells :-

- ➢ **Unicellular Organisms:**
  - Made up of only one cell.
  - That single cell performs all life processes (e.g., Amoeba, Paramecium, Bacteria).
- ➢ **Multicellular Organisms:**
  - Made up of many cells.
  - Different cells perform different functions (e.g., Humans, Plants, Animals).

Cellular Diversity

- Cellular diversity refers to the variety in the shape, size, structure, and function of cells found in different organisms.
- Though all cells perform similar life processes, they are not all identical.

1. Diversity in Cell Shape :-
   - the shape of cell may be ***flat*** (eg. Cheek cells), or ***cuboidal*** (eg. Germ cells), or ***columnar*** (eg. Intestine), or ***polygonal*** (eg. Liver cells), or ***rounded*** (eg. Fat cells), or ***slippers shapes*** (eg. Paramecium), ***oval shaped*** (eg. Hens cells), ***spindle shaped*** (eg. Smooth muscles), ***branched*** (eg. Chromatophores), or ***long thread like*** (eg. Muscles fibre and nerve fibre).
   - Shape of the cell mainly upon the specific function it perform.
2. Diversity in Cell Size :-
   - Cells also vary greatly in size. Some are very small, while others are very large.
   - Examples:
     - Smallest Cell: ***Mycoplasma*** (0.1 micrometer)
     - Largest Cell: ***Ostrich egg*** (15 cm long)
     - Longest Cell: ***Nerve cell*** (up to 1 meter in humans)

Prokaryotic and Eukaryotic Cells

- Cells are classified as Prokaryotic or Eukaryotic based on the presence or absence of a well-defined nucleus and membrane-bound organelles.

1. Prokaryotic Cells :

- These are primitive and simple cells.
- ***No true nucleus*** (genetic material is not enclosed in a membrane).
- No membrane-bound organelles (like mitochondria, Golgi, etc.).

📌 Key Features:

- ***DNA is present*** in a region called the ***nucleoid region*** (not a true nucleus).
- Mostly unicellular organisms.
- Very small in size (1–10 μm).
- Cell division by binary fission.
- ***Ribosomes are present*** (but small and scattered).

🔬 Examples :

- Bacteria, Blue-green algae (Cyanobacteria), Mycoplasma (smallest prokaryote)

2. Eukaryotic Cells :

- These are advanced and complex cells.
- Have a ***true nucleus*** (DNA enclosed in a nuclear membrane).
- Have ***membrane-bound organelles*** (like mitochondria, Golgi bodies, ER, etc.).

📌 Key Features:

- Can be unicellular (e.g., Amoeba) or multicellular (e.g., Humans, Plants).
- Larger in size (10–100 μm).
- Cell division by ***mitosis or meiosis.***
- Ribosomes are bigger and attached to the ER or free in cytoplasm.

🔬 Examples :

- Animals (e.g., Humans), Plants (e.g., Mango tree), Fungi (e.g., Yeast), Protists (e.g., Amoeba, Paramecium)

Structural Organisation of a Eukaryotic Cell

- Eukaryotic cell is divided into three main functional regions:
  - ***Plasma Membrane (Cell Membrane)***
  - ***Cytoplasm***
  - ***Nucleus***

Now let's understand each region in full detail — Position, Structure, and Function

I. Plasma membrane :-

Position:

- ***Outermost layer of an animal cell.***
- In plant cells, it lies just beneath the cell wall.

Structure:

- Made up of ***lipids and proteins*** (called lipid bilayer).
- It is a ***selectively permeable membrane*** — allows only some substances to pass.
- Has ***tiny pores*** for transport.
- Model: ***Fluid Mosaic Model*** (Singer and Nicolson, 1972)

Function:

- ***Controls entry and exit*** of substances (like oxygen, water, nutrients).
- ***Protects the internal parts*** of the cell.
- Helps in cell communication.
- Maintains homeostasis (***balance inside cell)***.

Plasma Membrane – Types of Transport Mechanism :

- Plasma membrane is selectively permeable, and substances can pass through it in two main ways:
  - Passive transport
  - Active transport

1. Passive transport:

- Movement of molecules from ***higher concentration to lower concentration.***
- ***No energy*** (ATP) is required.

- These involve process like :
    - Diffusion
    - Osmosis

a. Diffusion:-

- ***Movement of solids or gases*** (like O_2 or CO_2) from high to low concentration
- Oxygen entering the cell

b. Osmosis :-

- ***Movement of water molecules through a selectively permeable membrane*** from high to low water concentration
- Water entering plant root cells

2. Active Transport :

- Active transport is the movement of substances against the concentration gradient — i.e., from ***lower concentration to higher concentration*** — by ***using energy (ATP)***.
- Key Features:
    - Always ***requires energy*** in the form of ATP
    - Needs ***carrier proteins*** in the plasma membrane
    - Movement is from ***low to high concentration*** (opposite of diffusion/osmosis)
    - Helps in absorbing important nutrients and removing wastes even if they are in low concentration outside

a. Endocytosis :-

- ***(endo = inside, cytosis = cell process)***
- The process by which a cell takes in ***materials from its surroundings by engulfing them with the plasma*** membrane.
- Energy required: ***Yes*** (ATP)
- How it works:
    - Plasma membrane folds inward, forming a vesicle around the material.
    - The vesicle then moves inside the cell.
- Types of Endocytosis:-
    - ***Phagocytosis*** (Cell Eating)
    - ***Pinocytosis*** (Cell Drinking)
- Phagocytosis (Cell Eating)
    - Cell ***engulfs solid particles*** (like food, bacteria).
    - Forms a food vacuole.
    - Example: WBCs engulf bacteria.
    - 🔬 Seen in amoeba, macrophages, etc.

- Pinocytosis (Cell Drinking) :
  - Cell ***engulfs liquid or fluid*** droplets.
  - Forms small vesicles containing fluid.
  - 🔬 Occurs in many animal cells.

b. Exocytosis :-

- (exo = outside)
- The process by which a cell removes materials by packaging them into vesicles which fuse with the plasma membrane and release their contents outside.
- Energy required: Yes (ATP)
- How it works:
  - Materials (like hormones, enzymes, waste) are packed in vesicles inside the cell.
  - The vesicle moves to the plasma membrane, fuses with it, and releases the material outside the cell.

Effect of Hypertonic, Hypotonic and Isotonic Solutions on a Cell

I. Cell in Hypertonic Solution :

- Condition:
  - Cell is placed in a ***hypertonic solution*** (more solute less solvent)
- Observation:
  - ***Cell shrinks in size***
  - In plant cell, cytoplasm pulls away from the cell wall (called ***plasmolysis***)
- Explanation (Why it happened?):
  - In hypertonic solution, the ***outside has less water and more solute than inside the cell***
  - So, water moves out of the cell through osmosis
  - Due to water loss, cell becomes ***shrinked*** and ***dehydrated***

II. Cell in Hypotonic Solution :

- Condition:
  - Cell is placed in a ***hypotonic solution*** (more solvent less solute)
- Observation:
  - ***Cell swells up***
  - In animal cell, it may even burst
  - In plant cell, it becomes ***turgid*** (tight and swollen)
- Explanation (Why it happened?):
  - Hypotonic solution has ***more water and less solute than the inside of the cell***
  - So, water enters the cell by osmosis
  - Cell swells due to water intake

III. Cell in Isotonic Solution

- Condition:
  - Cell is placed in an ***isotonic solution*** (same water concentration as inside the cell)
- Observation:
  - ***No change*** in the shape or size of the cell
  - Cell remains normal
- Explanation (Why it happened?):
  - Isotonic solution has ***equal water concentration*** as the cell
  - So, there is no net movement of water
  - Water enters and exits equally — ***balance is maintained***

Cell wall :-

- The cell wall is a ***rigid outer covering*** found only in plant cells, fungi, and some bacteria, which lies ***outside the plasma membrane*** and gives shape, strength, and protection to the cell.
- Position :
  - It is the ***outermost layer*** in a plant cell.
  - Lies above (outside) the plasma membrane.
- Present In:
  - Plant cells
  - Fungi 🍄
  - Bacteria 🦠
  - Not present in animal cells ❌
- Composition:

Organism	Cell wall made of :
Plant	Cellulose (carbohydrates /fibre)
Fungi	Chitin
Bacteria	Peptidoglycan (also called murine)

- Structure:
  - ***Made up of cellulose*** fibers arranged in layers.
  - It is ***rigid*** but porous, allowing materials like water and gases to pass through.
  - In plant cells, the middle lamella (made of calcium pectate) helps stick adjacent cells together.
- Functions of Cell Wall:
  - Gives shape to the plant cell
  - Provides strength and rigidity
  - Protects the inner cell from mechanical injury and pathogens

    - Prevents bursting of the cell in hypotonic solutions (supports plant cells when water enters)
    - Allows free movement of substances due to its porous nature
    - Helps in ***plasmolysis*** and turgidity
- Special Terms Related to Cell Wall:
    - ***Turgid Cell:*** When water enters a plant cell (hypotonic solution), the cell becomes swollen but does not burst due to the ***rigid cell wall***.
    - **Plasmolysis**: When a plant cell is placed in a hypertonic solution, water leaves the cell and the ***plasma membrane shrinks*** away from the cell wall.

Nucleus

- The nucleus is a ***large, membrane-bound cell organelle*** found in eukaryotic cells that contains the cell's genetic material (DNA) and controls all the activities of the cell.
- It is also called the "***Control Centre***" or "***Brain of the Cell.***"

Position :

- Usually found in the ***central region*** of the animal cell.
- In plant cells, it is often pushed to the ***side due to a large central vacuole***.

Present In:

- All eukaryotic cells (plants, animals, fungi, protists)
- ❌ ***Absent in prokaryotic cells*** (they have nucleoid instead)
- ❌ ***Not present in mature red blood cells*** (RBCs)

Structure of Nucleus :

- The nucleus has four main parts:

1. **Nuclear Envelope** (Nuclear Membrane)
    - A ***double-layered membrane*** that surrounds the nucleus.
    - Contains ***nuclear pores*** that allow the exchange of materials between the nucleus and cytoplasm.
2. **Nucleoplasm** (Nuclear Sap)
    - ***Jelly-like fluid inside*** the nucleus.
    - Suspends the ***chromatin*** and nucleolus.
3. **Nucleolus**
    - ***Small, dense, round*** body inside the nucleus.
    - ***Makes ribosomes***, which help in protein synthesis.
4. **Chromatin / Chromosomes**
    - Chromatin: ***Thread-like structure*** made of ***DNA + proteins*** (seen when cell is not dividing).
    - During cell division, ***chromatin condenses to form chromosomes***.
    - Chromosomes carry genes, which ***control hereditary characters.***

Chromosomes : Basic structure and Number

- Chromosomes are ***thread-like structures made up of DNA and proteins (histones),*** found inside the nucleus of a cell.
- They ***carry genetic information*** in the form of genes and are responsible for heredity, growth, and cell functions.

When Are They Visible?

- Chromosomes are visible only ***during cell division.***
- When the cell is not dividing, they appear as long, ***thin chromatin threads.***

Basic Structure of a Chromosome :-

- Each chromosome has the following parts:
    1. ***Chromatid***
        - Each chromosome has ***two identical arms*** called sister chromatids
        - These ***chromatids are joined together***
    2. ***Centromere***
        - It is the central point where the ***two chromatids are attached***
        - It helps in the movement of ***chromosomes during cell division***
    3. ***Telomere***
        - The end parts of chromosomes
        - They protect the chromosome from damage
    4. ***Genes***
        - ***Small segments*** on chromosomes made of DNA
        - Each ***gene controls a particular*** trait or protein

In Humans:

46 chromosomes = 23 pairs

→ 22 pairs = Autosomes

→ 1 pair = Sex Chromosomes

(XX in female, XY in male)

Functions of Chromosomes:

- Carry ***genetic information*** through genes
- Help in ***inheritance*** of traits from parents to offspring
- Control all ***life processes*** (growth, reproduction, repair)
- Responsible for cell division and ***proper distribution of DNA***

Cytoplasm

- Cytoplasm is the ***jelly-like, semi-fluid substance*** found between the plasma membrane and the nucleus in all eukaryotic and prokaryotic cells.
- It ***contains organelles*** and is the site for many biochemical reactions.

- Located ***between the plasma membrane and the nucleus.***
- All living cells — both plant and animal cells
- Even in prokaryotes (though they ***lack membrane-bound organelles***)

composition :

1. ***Cytosol***
    - ***Jelly-like fluid*** part of cytoplasm
    - Made mostly of water, some salts, and enzymes
    - It is the medium in which other cell parts float
2. Cell Organelles
    - All important organelles like:
        - ***Mitochondria***
        - ***Endoplasmic Reticulum***
        - ***Golgi Apparatus***
        - ***Ribosomes***, etc.
    - These organelles are suspended in cytosol
3. Stored Substances
    - Temporary ***materials*** like:
        - ***Starch*** (in plant cells)
        - ***Glycogen*** (in animal cells)
        - ***Fats and oils***
    - Stored as ***reserve food or energy***

Functions of Cytoplasm :

- Acts as a ***medium for movement of materials inside*** the cell
- ***Provides space*** for organelles to remain suspended
- Site for many chemical reactions like glycolysis
- Helps in ***transport of materials between organelles***
- Stores enzymes and nutrients
- Gives ***shape and structure*** to the cell

Cell organelles

- Cell organelles are the specialized parts of a cell that ***perform specific functions*** to keep the cell alive and working.
- They are ***found in the cytoplasm of eukaryotic cells.***

Endoplasmic Reticulum (ER) :-

- Endoplasmic Reticulum (ER) is a ***well-developed, electron microscopic network*** found in the cytoplasm.
- It is ***made up*** of :

    - ***Tubules*** – branched and without ribosomes
    - ***Cisternae*** – flattened, two-layered, and studded with ribosomes
    - ***Vesicles*** – oval-shaped structures, may have ribosomes
- ER is absent in :
    - Prokaryotic cells
    - Mature RBCs of mammals
- Chemically, the ER is ***lipoproteinaceous*** (made of lipids and proteins).
- It was ***discovered by Porter and coworkers*** in 1945.

Function :-

- ER provides a ***large surface area for various chemical reactions inside the cell.***
- ER acts like a ***transport system*** by carrying materials (like proteins and lipids) from one part of the cell to another.
- Rough ER, which has ribosomes on it, helps in the ***formation of proteins.***
- Smooth ER is involved in the ***synthesis of fats (lipids) and steroids.***
- ***Detoxification*** (by Smooth ER in liver cells), Smooth ER helps in ***removing harmful substances*** (toxins) from the body, especially in liver cells.

Ribosomes :-

- There are smallest known, ***membrane-less*** electron microscopic, ***ribonucleoprotein*** particles (as formed of RNA and proteins) found in both prokaryotic & eukaryotic cells.
- Structure :
    - Each ribosomes is formed of to unequal components.
    - ***70S ribosome*** is formed of 50S and 30S subunits, while ***80S ribosomes*** is formed of 60S and 40S subunits.
- Function :
    - Ribosomes are ***sites of protein synthesis*** so are called ***protein factory*** or ***engines of cells.***

Golgi apparatus :-

- The Golgi apparatus is a cell organelle ***found in all eukaryotic cells.***
- It is ***not found in prokaryotic cells*** like bacteria.
- It is usually located ***near the nucleus and endoplasmic reticulum.***
- Discovered by ***Camillo Golgi in 1898.***

Structure :

- The Golgi apparatus is made up of a series of ***flattened, membrane-bound sacs called cisternae***.
- A typical Golgi body contains ***4 to 8 cisternae*** arranged in parallel.
- The cisternae are curved like a stack of plates or a ribbon.
- Vesicles are small, ***bubble-like structures*** that bud off from the edges of cisternae.
- Golgi is surrounded by cytoplasm and often located near nucleus and ER.

Functions :

- The Golgi body ***receives proteins and lipids*** from the Endoplasmic Reticulum and ***modifies, sorts, and packages them for delivery*** to other parts of the cell or outside.
- Golgi forms small vesicles (bubble-like sacs) that ***transport materials inside or outside*** the cell.
- Golgi body helps in the ***formation of lysosomes,*** which are digestive organelles.
- Golgi body ***secretes substances like enzymes, mucus, and hormones in secretory cells.***

Lysosome :-

- Lysosomes are small, ***membrane-bound organelles*** found in eukaryotic cells.
- They are ***present in the cytoplasm***, floating freely.
- ***Maximum number of lysosomes are found in WBCs and liver cells.***
- Lysosomes are ***formed by Golgi apparatus.***

Structure :

- Lysosomes are ***single membrane-bound*** organelles.
- The membrane is made of ***lipoproteins*** and is similar to the plasma membrane
- They are ***spherical*** or oval in shape.
- The inner part is filled with ***hydrolytic enzymes*** (digestive enzymes).
- Enzymes are made in rough ER and packed by Golgi apparatus.

Function :

- Lysosomes ***digest worn-out organelles,*** food particles, and bacteria that enter the cell.
- Lysosomes help White Blood Cells to ***kill and digest invading bacteria.***
- ***If the cell is damaged beyond repair, lysosomes burst and digest the whole cell.***
- In organisms like frogs, lysosomes help remove tail cells during transformation (tadpole to frog).

Mitochondria :-

- Mitochondria are ***double membrane-bound*** organelles found in almost all eukaryotic cells.
- It is ***absent in prokaryotic cells*** (like bacteria).
- Their ***number varies depending on the energy requirement of the cell.***
- Mitochondria are called the "***powerhouse of the cell***."
- Discovered by ***Richard Altmann in 1890*** (called them bioblasts).

Structure :

- Mitochondria is a ***double membrane-bound*** organelle.
- The ***outer membrane is smooth and permeable.***
- The ***inner membrane is folded into finger-like structures called cristae.***
- ***Cristae increase surface area for ATP*** (energy) production.
- The inner ***space filled with gel-like fluid is called the matrix.***
- Mitochondria contains its ***own circular DNA and ribosomes.***

Function :-

- Mitochondria ***produces ATP*** (Adenosine Triphosphate), the energy currency of the cell, through aerobic respiration.
- The ***complete breakdown of glucose using oxygen*** (aerobic respiration) takes place in mitochondria.
- During energy production, mitochondria also ***releases heat to maintain body temperature.***
- Mitochondria ***provides energy needed for mitosis and meiosis*** (cell division processes).

Plastids :-

- Plastids are ***found only in plant cells*** and ***some algae.***
- They are located ***in the cytoplasm***.
- Plastids are ***absent in prokaryotic*** cells.
- Plastids are ***found in large numbers in leaf cells, flower cells, and fruit cells.***
- Plastids were ***discovered by Ernst Haeckel.***
- Types of Plastids :
    - ***Leucoplasts*** -
        - Leucoplasts are ***colorless plastids*** found mainly in underground parts of plants like roots, seeds, and tubers.
        - Type :
            - ☐ ***Amyloplasts*** – Store Starch (Carbohydrates)
            - ☐ ***Elaioplasts*** – Store Fats and Oils (Lipids)
            - ☐ ***Aleuroplasts*** (or Proteinoplasts) – Store Proteins
    - ***Chromoplast*** -
        - Chromoplasts are ***colored plastids (except green)*** found in flowers and fruits that contain pigments like carotene and xanthophyll to attract pollinators.
    - ***Chloroplasts*** -
        - Chloroplasts are ***green plastids found in plant cells*** that contain chlorophyll and perform photosynthesis.

Cell Division

- Cell division is the process by which a cell ***divides into two or more daughter cells.***
- It helps in ***growth, repair, reproduction***, and replacement of old cells.
- Types of Cell Division :
    - ***Mitosis*** -
        - In mitosis, ***one parent cell divides*** to form two identical daughter cells.
        - Number of ***chromosomes remains the same in daughter cells*** as in parent cell.
        - It occurs in somatic (body) cells.
        - Purpose: ***growth, repair of tissues, wound healing.***
        - Mitosis has 4 stages: Prophase, Metaphase, Anaphase, Telophase.

- ***Meiosis*** -
  - In meiosis, ***one parent cell divides to form four non-identical daughter cells.***
  - Each daughter cell has ***half the number of chromosomes.***
  - It occurs in reproductive cells (testes and ovaries).
  - Purpose: ***formation of gametes (sperm & egg) for sexual reproduction.***