Chapter 3 - Cell

3.1. Cell

In 1665, Robert Hooke discovered a cell when he examined a thin slice of cork tissue under a compound microscope. A cell is the smallest, basic **structural and functional unit** of life. Two types of cells; Eukaryotic cells have a nucleus (e.g.: plant cells and animal cells) Prokaryotic cells without a nucleus, only containing loosely stranded DNA (e.g.: bacterial cells and amoebae)

Cell Membrane

A flexible outer layer that surrounds the cell. It controls what goes in and out of the cell, like a security gate.

- Semi-permeable.

A cell membrane is a thin sheet-like covering of the cell. Chemically it is composed of proteins 60-80 %, phospholipids 20-40% and traces of carbohydrates. The structure of the cell membrane is explained according to the **fluid mosaic model**. It postulates that the cell membrane consists of a double layer of phospholipids in which proteins are incorporated in a mosaic fashion.

Cytoplasm

A jelly-like substance inside the cell that holds all the cell parts. It also helps transport materials within the cell. Between the cell membrane and nucleus of the cell is an aqueous substance called cytoplasm. It is about 90% water having many dissolved and suspended materials. It is the site for many biochemical processes.

Nucleus

The “brain” of the cell, which stores DNA and controls cell activities. It tells the cell what to do and when to do. The nucleus is surrounded by two membranes which collectively form the nuclear envelope. The nuclear envelope bears nuclear pores at points where both membranes fuse with each other. The nucleus contains a fluid called nucleoplasm. Nucleolus is a round darkly stained area in the nucleus. Ribosomes are assembled at this point. Hereditary material in the nucleus is actually in the form of chromatin. Chromatin consists of DNA fibres coiled on histone proteins. DNA is organised into chromosomes, which consist of tightly coiled threads of DNA fibres bound to proteins (histone proteins). The chromosomal set of each species is different and is actually what sets them apart, 46 chromosomes, 23 pairs

Mitochondria

Known as the **powerhouse** of the cell, mitochondria make energy from food for the cell to use. Aerobic respiration takes place in mitochondria. Mitochondria are found in all aerobic eukaryotic cells. They are double membrane bound structures; the outer membrane is smooth and inner membrane forms finger-like projections called cristae. They increase the surface area for the respiration. The fluid inside the mitochondrion is called matrix. Mitochondria have their own DNA and ribosomes.

Ribosomes

Small structures that make proteins, which the cell needs to grow and repair itself. They are tiny granular structures found both in prokaryotic and eukaryotic cells. They are not bound by any membrane. They are composed of roughly equal amount of proteins and ribosomal RNA (rRNA). The prokaryotic ribosomes, however, are smaller in size. A large number of ribosomes are scattered in the cytoplasm. In eukaryotes many ribosomes are also attached on the surface of RER.

Endoplasmic Reticulum

It is a system of membranes present throughout the cytoplasm of eukaryotic cells. Flattened sacs of the endoplasmic reticulum are called cisternae which form a network of interconnected channels. Rough ER : Has ribosomes on its surface, making it look bumpy, and helps make and transport proteins. Smooth ER : Lacks ribosomes and is smooth. It helps make and transport fats and detoxifies harmful substances. SER synthesize lipids including steroids.

Golgi Apparatus

Acts like a packaging centre. It modifies, sorts, and packages proteins and fats for transport to other parts of the cell or outside. Golgi apparatus was discovered by Camillo Golgi. It is present in all eukaryotic cells. Golgi apparatus and many cisternae are stacked over each other. They are constantly formed at one end and break up into vesicles at the other end. Golgi apparatus store and modify materials into finished form before packing into vesicles. Some of these vesicles settle in cytoplasm as organelles like lysosomes.

Lysosomes

Small structures filled with enzymes that break down waste materials and old cell parts. They're the cell's "clean-up crew." They are single membrane bound small sac like structures. They contain a variety of digestive enzymes. Lysosomes then bud off from Golgi apparatus with their processed enzymes. One important role of lysosome is Intracellular digestion. In this process lysosomes digest materials taken up by the cell from outside as food vacuole. They also engulf and digest unwanted cell organelles. This process is termed as autophagy.

Vacuole

A storage sac for water, nutrients, and waste. Plant cells usually have one large vacuole, while animal cells have smaller ones. Some freshwater organisms like amoeba and sponges have contractile vacuoles which collect and pump out extra water and other wastes. Some cells ingest food by forming food vacuoles which are then digested into simple molecules. Foop vacuoles also store food. The membrane of plant vacuole is called tonoplast. It contains a liquid called cell sap.

Plant-specific Structures

Some structures are found in plant cells, specifically, but not in animal cells, including:

- **Cell Wall** : A rigid layer outside the cell membrane in plant cells that provides support and protection. It is **fully permeable**.
- **Chloroplasts** : Organelles in plant cells where photosynthesis occurs, allowing plants to make their own food using sunlight.

Structure Of The Cell Wall:

Made up of **cellulose**

- **Middle lamella:** The middle lamella is the outermost layer that lies between two plant cells, sort of like the **cement** between bricks in a wall. It acts like a **glue** that holds adjacent plant cells together. Without the middle lamella, plant cells wouldn't be tightly bound to each other, and the plant structure wouldn't be strong. It's made mostly of **pectin**, a sticky carbohydrate that helps bind cells.
- **Primary Cell Wall:** Just inside the middle lamella, the primary cell wall is the first wall that forms around the plant cell. It's thin and flexible.
- **Secondary Cell Wall:** The secondary cell wall is formed inside the primary cell wall once the cell is completely grown. This is a thicker and stronger wall, which provides extra strength and support. The secondary wall is important for cells that need extra support, like wood cells in trees or xylem vessels. The secondary wall has layers, each making the cell even stronger, like layering multiple bricks on top of each other.
- **Plasmodesmata -** the pore connecting neighboring cells together with cytoplasmic connections
- **Lignin:** is a key part of the secondary cell wall, and it makes the wall extremely strong and waterproof. It's like the concrete that solidifies and reinforces the cell wall, making it tough.
- **Pectin:** is a sticky, gel-like substance that helps hold the middle lamella and the primary cell wall together. Pectin keeps the cells bound together while still allowing for some flexibility.

Structure of Cell Membrane:

Acts as a semi-permeable barrier for the cell, allowing some molecules to pass while blocking others. The cell membrane is a double-layered structure (called a **phospholipid bilayer**) made up of phospholipids, proteins, cholesterol, and carbohydrates. The phospholipids have a hydrophilic (water-loving) head and two hydrophobic (water-repelling/hating) tails. They arrange themselves so the heads face outward toward the watery environment inside and outside the cell, while the tails face inward, away from water. **Fluid Mosaic Model:** This model explains that the cell membrane is flexible (fluid) and has many components like proteins, cholesterol, and carbohydrates embedded within or on it (mosaic). The components can move around within the membrane layer, providing flexibility and allowing cells to change shape. Proteins embedded in the membrane serve as **channels**, **carriers**, or **receptors** for different molecules, while cholesterol adds stability by keeping the membrane from being too fluid or too rigid.

Plastids

Double membrane-bound organelles found in both plants and algae, responsible for functions like photosynthesis and storage. Three types: chloroplast, chromoplast and leucoplast.

Chloroplast

It has its own DNA and ribosomes, so can multiply on its own. The main organelle involved in carrying out photosynthesis is the chemical energy. **Structure:**

- **Outer and Inner Membranes** : Form the chloroplast envelope.
- **Thylakoids** : (system of membranes) Coin-like structures that contain chlorophyll, the green pigment that captures light energy.
- **Granum** : Stack of thylakoids.
- **Stroma** : The fluid surrounding the thylakoids, where the light-independent phase of photosynthesis occurs. Contains enzymes, DNA and ribosomes, which are necessary for photosynthesis
- **Lumen** : the space inside thylakoid membranes, which is filled with a fluid that is crucial for light-dependent reactions.

Chromoplast

Stores pigments in colours other than green, such as red, yellow, and orange, which attract insects for pollination and animals for seed dispersal. **Location** : Often found in flower petals and fruit skins.

Leucoplasts

Non-pigmented plastids Mainly involved in storing food, so they are found in the non-photosynthetic parts of plants like roots, bulbs and stem tubers. Store starch, lipids and proteins

Centrioles

Hollow, cylindrical structures found in animal cells Made up of microtubules arranged in triplets Exist as pairs near the nucleus and are important in cell division for forming spindle fibres Also aids in the formation of cilia and flagella

Cytoskelton

A network of protein fibres within the cell that maintains its shape and aids in movement. **Types of Fibres** :

- **Microtubules** : Unbranched, hollow tubes made of tubulin protein; they provide structural support and form structures like spindle fibres, cilia, and flagella.
- **Microfilaments** : Thin strands made of actin protein; they enable movement within the cell and help the cell maintain its shape.
- **Intermediate Filaments** : Thicker than microfilaments and provide strength to the cell. They form a stable framework that helps keep cells connected.

Cilia and Flagella:

Hair-like projections on the surface of the cell Enable movement by beating and moving in a coordinated manner

- **Cilia:** Short and numerous Move in a coordinated wave-like motion The main function is in creating currents in moving substances, e.g., respiratory tract cells
- **Flagella:** Long and usually present in smaller numbers Whip-like motion, propelling the cell forward Helps in cell motility, allowing it to swim through fluids. E.g. sperm cells

Structural Advantages and Disadvantages of Plant and Animal Cells

Plant Cells

Advantages:

- **Cell Wall** : Provides structural support and connects cells to create a sturdy overall plant structure.
- **Transport Channels** : Formation of xylem and phloem for water and nutrient transport due to the cell wall.
- **Osmotic Pressure Tolerance** : Can withstand high osmotic pressure, allowing for better water storage.
- **Turgidity** : Becomes turgid (firm), helping plants maintain structure and stay upright.

Disadvantages:

- **Rigid Structure** : Prevents movement; plants cannot change location to seek better environmental conditions.
- **Slower Division Rate** : The rigid cell wall slows down cell division and reproduction processes.

Animal Cells

Advantages:

- **No Cell Wall** : Flexible structure allows movement and adaptation to the environment.
- **Support Systems** : Tissues, organs, and skeletal systems provide support without needing a cell wall.
- **Mobility** : Allows animals to move for better environmental conditions, food sources, shelter, and reproduction opportunities.

Disadvantages:

- **Osmotic Pressure Sensitivity** : Lacks the cell wall, making animal cells more sensitive to osmotic pressure and limiting water storage capacity.
- **No Turgidity** : Cannot become turgid, so structural support depends on other systems rather than cell rigidity.

3.2. Cell Specialization

In multicellular organisms, cells undergo differentiation after mitosis, altering in the structure, size, metabolic activities, and physiological responses. This process helps cells become specialized for specific functions. For example, a muscle cell cannot perform functions a brain cell performs because it's not **specialised** for it. **Specialised Cells** : Cells in plants and animals adapt structurally and functionally to perform specific roles (e.g., root hair cells in plants for water absorption, guard cells for stomatal regulation).

Examples of specialised cells:

Epidermal cells:

Forms a protective layer of covering over roots, stems and leaves. Flattened shape and tight packing create a continuous protective barrier Some types are modified so can perform additional roles **Example: root hair cells** - extensions in the cell to absorb water and minerals from the soil, and **guard cells -** found in places where they can manage stomatal opening and closing

Mesophyll cells:

Photosynthetic cells in plants, specifically in the leaves of the plant Contains numerous chloroplasts filled with chlorophyll and other pigments Chlorophyll in the chloroplasts' membranes absorbs light energy used to produce food through photosynthesis.

Red Blood Cells:

Transports oxygen throughout the body Biconcave disc shape, which increases the surface area for oxygen absorption and release Lacks nucleus, mitochondria and endoplasmic reticulum to maximise space for haemoglobin and oxygen uptake Highly flexible, so it can pass through narrow capillaries The average age is 120 days Hb - HbO2

Neurons:

Neurons are the cells of the nervous system, responsible for coordinating body functions Composed of a cell body, dendrites and axons (cytoplasmic fibres) Dendrites conduct nerve impulses towards the cell body Axons, however, conduct these nerve impulses away from the cell body Dendrites and axons allow neurons to communicate with distant cells in the body.

Muscle cells:

Also called muscle fibres, and have the ability to contract and relax Enables various essential body functions such as locomotion, breathing, blood pumping, change in the size of the pupil, speech and peristalsis. **Structure: elongated shape** allowing efficient contractions, and is filled with the **contractile protein** called **actin**, enabling contraction and relaxation for body movements.

Liver cells:

Also called **'hepatocytes'** Round-shaped cells with prominent nuclei and cytoplasmic organelles, making them some of the most metabolically active cells in the body **Functions:**

- Storage of glycogen, iron, vitamins and essential substances necessary as nutritional reserves
- Detoxification of toxic material, keeping the body free from harmful substances
- Production of proteins necessary for blood clotting, preventing excessive bleeding
- Recycling old red blood cells to manage waste

3.3. Division of Labour

In a cell, each organelle has its own and unique functions based on the structure they have and where it is placed Mitochondria act as the powerhouse of the cell, producing energy Ribosomes are engaged in protein synthesis Chloroplasts utilise light energy for organic food production through photosynthesis. Therefore, division of labour is when different organelles of a cell perform their specified jobs, contributing to the cell's survival and overall functioning. In **unicellular** organisms, a single cell acts as the organism, performing all life functions independently. In **multicellular** organisms, numerous cells form the body and cannot perform all tasks alone. Cells form groups, called **tissues**, to specialise in particular functions Cells originating from the same zygote differentiate to perform specific roles:

- **Muscle Cells** : Elongated for contraction.
- **Neurons** : Form fibres to transmit signals.
- **Red Blood Cells (RBCs)** : Transport oxygen.
- **Mesophyll Cells** (in plants): Conduct photosynthesis.
- **Phloem Cells** (in plants): Transport food.

3.4. Stem Cells

Stem cells are **unspecialized** cells that can differentiate into various cell types. All cell types in the body develop from stem cells. Around 220 types of cells are identified in human body. A zygote is the most basic form of stem cell which has this ability to produce all kinds of organisms Stem cells have the capacity for self-renewal and differentiation. In multicellular organisms, stem cells contribute to tissue repair and growth. Stem cells by themselves are not differentiated and are un-specialized. Each daughter cell produced by division of a stem cell has capacity to remain un-specialized stem cell or differentiate into mature cell of some tissue. So stem cells divide, renew themselves and daughter cells differentiate into distinct cell type. **Hematopoietic stem cells:** These stem cells produce all the different types of blood cells, including:

- Red blood cells: Carry oxygen throughout the body.
- White blood cells: Fight infections and protect the body from disease.
- Platelets: Help with blood clotting to stop bleeding.

Whereas other stem cells help produce specific types of cells based on their location in the body, assisting in the repair and maintenance of tissues like bone, skin, muscles, or nerves.