[STRUCTURE & FUNCTION OF PLANT CELL]

Overview

- The term cell is derived from the Latin ‘cella’ means storeroom or chamber.
- The term cell was first used by the English botanist Robert Hooke in 1665, to describe the individual units of the honeycomb-like structure in cork under compound microscope.
- Plants are multicellular organisms composed of millions of cells with specialized function.
- All plant cells have the same basic eukaryotic organization.

Cell Wall

- A fundamental difference between plant and animal cells is that the plant cell is surrounded by a rigid cell wall, mostly made of polysaccharides (cellulose, hemicellulose, pectin) and lignin.
- Plants have two types of cell walls, primary and secondary.
- Primary cell walls are thin and characteristic of young, growing cells.
- Secondary cell walls are thicker and stronger, and they are deposited when most cell enlargement has ended.
- Secondary cell walls have their strength and toughness due to lignin; a glue like material.
- The lignified secondary walls provide the plants the structural reinforcement necessary to grow vertically above the soil.
- Bryophytes which lack the lignified cell walls are unable to grow more than a few centimeters above the ground.
- In plants, the neighboring cells are cemented together by a middle lamella (intercellular layer).

![Diagram of cell wall](image)

**Plasma Membrane (Plasmalemma)**

- All cells are enclosed in a membrane that serves as their outer boundary, separating the cytoplasm from the external environment.
- This plasma membrane allows the cells to take up and retain certain substances while excluding others. Thus, plasmalemma accounts for selective traffic of solutes across membrane.
- All biological membranes consist of a double layer (bilayer) of phospholipids in which proteins are embedded.
- The membrane is not a static structure, but it is a dynamic structure. Both lipid and protein molecules are free to move and are usually in a constant motion. However, these molecules readily move in the plane of membrane, a process known as lateral diffusion.

![Diagram of plasma membrane](image)
Phospholipids

- Phospholipids are a class of lipids in which 2 fatty acids are linked to glycerol, which is linked to a phosphate group.
- A head group such as choline is also attached to phosphate group. Phosphatidylcholine is a phospholipid common to most membranes.
- The head groups are highly polar (hydrophilic) whereas the hydrocarbon chains of fatty acids are highly nonpolar (hydrophobic).
- Thus, phospholipids display both hydrophilic and hydrophobic properties, hence they are amphipathic.
- In the bilayer, the amphipathic lipids are arranged in such a way that their hydrophobic tails point toward each other and the hydrophilic heads make the surfaces.
- The bilayer is stable in aqueous environment because its surfaces readily associate with water.
Plant Biochemistry: BCH-350

- Plastid (chloroplast) membranes are made of glycosylglycerides instead of phospholipids.
- In glycosylglycerides, the polar head group consists of galactose, without a phosphate group.
- The fatty acid chains of phospholipids or glycosylglycerides contain 14-24 carbons.
- One of the fatty acid is saturated (no double bonds), whereas the other fatty acid chain is unsaturated containing one or more cis double bonds.
- The presence of cis double bond prevents the tight packing of phospholipids, hence increase the fluidity of membrane.
- Membrane fluidity is also influenced by temperature. Because plants generally cannot regulate their body temperature, plant phospholipids have a high percentage of unsaturated fatty acids such as oleic acid (1 double bond), linoleic acid (2 double bonds) and linolenic acid (3 double bonds) which increase the fluidity of their membranes.

Proteins

- The proteins which are embedded in lipid bilayer are globular.
- These proteins can be divided into two types, integral and peripheral.
- Integral proteins are deeply embedded in the lipid bilayer. Most integral proteins span the entire width of the lipid bilayer so one part of the protein interacts with the outside of cell, another part interacts with hydrophobic core and the third part interacts with interior of cell (cytosol).
- Ion channels are always integral proteins.
- Certain receptors that participate in signal transduction are integral proteins.
- Peripheral proteins are bound to polar surfaces of lipid bilayer by electrostatic (ionic) or hydrogen bonds.
- Peripheral proteins can be dissociated from membrane with high salt solutions or chaotropic agents, which break ionic and hydrogen bonds respectively.
- Peripheral proteins are involved in interactions between plasma membrane and the components of cytoskeleton.

Nucleus

- The nucleus is surrounded by a double membrane called the nuclear envelope. The space between these two membranes is called the perinuclear space. The joining sites of the two nuclear membranes are called the nuclear pores.
- The material filled in the nucleus is called nucleoplasm (or nuclear sap).
- About 8% of the surface area of the nuclear membrane is occupied by pores. These pores allow the transport of substances between cytosol and nucleus.
• Nucleus is the site of storage and replication of chromosomes, composed of DNA and its associated proteins (histones). The DNA-protein complex is known as chromatin.
• Nucleus contains a densely granular region called the nucleolus, which is the site of ribosome (ribosomal RNA) synthesis.
• Ribosomal proteins are synthesized in cytosol and transported into nucleus via nuclear pores, where they bind with rRNA to form 40S and 60S subunits. These subunits pass into cytosol and aggregate to form 80S ribosomes.
• The genes are transcribed in nucleus to form mRNA, tRNA and rRNA. mRNA and tRNA pass from nucleus to cytosol where they are used for protein synthesis.
• The nucleotide sequence of mRNA is translated into amino acid sequence of proteins by ribosomes. tRNA assists by transferring amino acids to mRNA codons.

Endoplasmic Reticulum
• Cells have an elaborate network of internal membranes called endoplasmic reticulum (ER).
• ER is continuous with the outer membrane of nuclear envelope (but not plasmalemma).
• The ER lumen of one cell is connected to adjacent cell via plasmodesmata.
• There are 2 types of ER, smooth and rough, which are interconnected.
• Rough ER is covered with ribosomes which synthesize proteins to be delivered to lumen of ER.
• Smooth ER lacks ribosomes.
• Smooth ER is the site of lipid synthesis and membrane assembly.
• Both types of ER are involved in secretion.
Golgi Apparatus

- Golgi apparatus (or Golgi complex) is made of one or more dictysomes (or Golgi bodies) which are stacks of 3-10 flattened sacs (cisternae) and vesicles.
- Plant cells contain up to several hundred Golgi bodies dispersed in cytoplasm.
- The cisternae close to plasmalemma are called trans face, and the cisternae close to center of cell are called cis face. The medial cisternae are between trans and cis cisternae.
- Golgi body is a dynamic structure; new cisternae are continuously produced from endoplasmic reticulum at cis face while old cisternae are lost in the form of vesicle at trans face.
- Golgi apparatus has intermediary position between ER and extracellular space.
- It is involved in the transport and processing of many substances that are produced in ER and eventually discharged outside the cell via Golgi. It plays a key role in synthesis and secretion of complex polysaccharides and in processing of glycoproteins.
- Various proteins (including enzymes) are first synthesized in rough ER then they reach to Golgi via vesicles that bud off from ER and fuse with Golgi.
- Vesicles formed from membrane of outer face of Golgi apparatus move to different locations in cell. At plasma membrane they discharge their contents as secretions.

Ribosomes

- Ribosomes are composed of rRNA and protein.
- Ribosomes play an important role in protein synthesis.
- Plant cells contain 3 distinct types of ribosomes, which occur in cytoplasm, mitochondria and chloroplast.
- The mitochondrial and chloroplastic ribosomes are smaller (70 S) than cytoplasmic ribosomes (80 S).
- The cytoplasmic ribosomes may be found in cytosol or attached to endoplasmic reticulum.
- The rRNA molecules of cytoplasmic ribosomes are formed by transcription of nuclear genes in nucleolus. Whereas rRNA of mitochondrial and chloroplastic ribosomes are formed by transcription of mitochondrial and chloroplastic genes respectively.
- The proteins of cytoplasmic ribosomes are coded by nuclear genes and synthesized in cytosol. Most of the proteins of mitochondrial and chloroplastic ribosomes are also synthesized in cytosol by nuclear genes.
Mitochondria

- Mitochondria are cytoplasmic organelles.
- Mitochondria are the sites of oxidative phosphorylation (ATP synthesis).
- Mitochondria are surrounded by two membranes. The outer membrane is smooth and the inner membrane is highly convoluted. The folds of inner membrane are called ‘cristae’.
- The components of respiratory electron transport chain are found in inner membrane.
- The inner membrane is also characterized by the presence of stalked particles with spherical heads containing ATPase. ATPase catalyses the synthesis of ATP.
- The inner membrane is highly impermeable to the passage of protons (H⁺), which allows the formation of electrochemical gradient necessary for ATP synthesis.
- The compartment enclosed by inner membrane is called ‘matrix’. Matrix contains the enzymes of Krebs cycle (TCA cycle or citric acid cycle).
- Mitochondria contain their own protein synthesizing machinery (ribosomes, tRNA etc.).
- Mitochondrial ribosomes are smaller (70 S) than those found in cytosol (80 S).
- Mitochondria contain circular, histone-free DNA molecule, similar to those of bacteria.
- Mitochondrial genome of plants consists of about 200 kb (200,000 base pairs), which is much larger than animal mitochondria.

Plastids

- Plastids are the organelles which are peculiar to plant cells.
- Plastids that contain high concentration of carotenoid pigments are called ‘chromoplasts’. They give yellow, orange and red colors to many fruits (tomato), roots (carrot) and flower petals.
- Nonpigmented plastids are called ‘leucoplasts’. An important type of leucoplast is ‘amyoplast’ which is a starch-storing plastid.
- Chloroplasts are the plastids that contain green pigment, chlorophyll. They are found in green tissues of plant, especially leaf. They are absent in roots.
The chloroplast is surrounded by the inner and outer membranes.

- Chloroplasts also contain third system of membrane called thylakoid. All the chlorophyll is contained within this membrane, which is the site of light reactions of photosynthesis.
- Thylakoid membranes are highly folded and appear like stacked coins. These stacked membranes are known as grana lamellae (or grana thylakoid). The membranes without stacking are known as stroma lamellae (or stroma thylakoid).
- Each stack is called granum.
- The inner space within a thylakoid is known as lumen.
- The region of the chloroplast that is inside the inner membrane and surrounds thylakoids is known as stroma. The carbon reactions take place in stroma.
- Chloroplasts contain their own DNA and protein-synthesizing machinery.
- Chloroplast genome is smaller (145 kb) than mitochondrial genome (200 kb).
- Chloroplast DNA is circular and histone-free.
- Ribosomes occur free in stroma or bound to the outer surface of thylakoid membrane.
- As is mitochondria, most of the chloroplast’s proteins are encoded by nuclear genes, synthesized in cytosol and transported to organelle.

**Central Vacuole**

- Mature plant cells contain large, water-filled central vacuole (usually one or two).
- Central vacuole can occupy 80-90% of the total volume of cell.
- Each vacuole is surrounded by a vacuolar membrane or tonoplast.
- The vacuole contains water, inorganic ions, organic acids, sugars and enzymes.
- Like animal lysosomes, plant vacuoles contain hydrolytic enzymes including proteases, ribonucleases and glycosidases.
- Vacuole has storage function as well as to provide rigidity to plant cell.
Microbodies

- Plant cells also contain microbodies, which are spherical organelles surrounded by a single membrane.
- The two main microbodies are peroxisomes and glyoxysomes.
- Peroxisomes are present in photosynthetic cells of plant leaf. Their function is the removal of potentially toxic hydrogen peroxide ($H_2O_2$) using the enzyme catalase.

$$\text{Catalase}$$

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H_2O_2 \rightarrow H_2O + \frac{1}{2} O_2
\]

- Glyoxysomes are present in oil-storing seeds. They can convert stored fatty acids into sugars that can be translocated in the plant to provide energy for growth.

Cytoskeleton

- The cytosol in organized into a 3-dimensional network of filamentous proteins called 'cytoskeleton'.
- Cytoskeleton serves as scaffolding for the movement of organelles and other components.
- Cytoskeleton plays an important role in maintenance of cell shape as well as in cell division.
- Basically 2 types of cytoskeletal elements are found in plant cells; microtubules and microfilaments.
- Microtubules are hollow cylinders with an outer diameter of 25 nm.
- Microtubules are composed of polymers of the globular protein ‘tubulin’.
- A single microtubule consists of thousands of tubulin monomers arranged in 13 columns called protofilaments.
- Microfilaments are solid with 7 nm diameter.
- Microfilaments are composed of protein globular actin (or G-actin).
- A microfilament consists of two chains of polymerized actin subunits that interwind in a helical fashion.