CHAPTER 2
Plant Cell Structure

Introduction

The cell is the structural and functional unit of all organisms. A scientist, Robert Hooke noted in 1665 that a cork is made up of small units which he called cells. Later in the late 17th and 18th centuries, other scientists: Schleiden, and Schwann noted the existence of cells in other organisms. This established the cell theory: "cells are the basic unit of life; all cells arise from the pre-existing ones". There are two basic classes of cells: prokaryotic cells (contain no distinct nucleus, found in bacteria), and the eukaryotic cells (contain distinct nuclei and other compartmentalized molecules called organelles, found in all higher organisms, example plants).

A plant cell is different from an animal cell because of the rigid cellulose cell wall, chloroplast for photosynthesis, other plants' pigments, for example anthocyanins (important for plants' fruit color) and large water vacuoles.

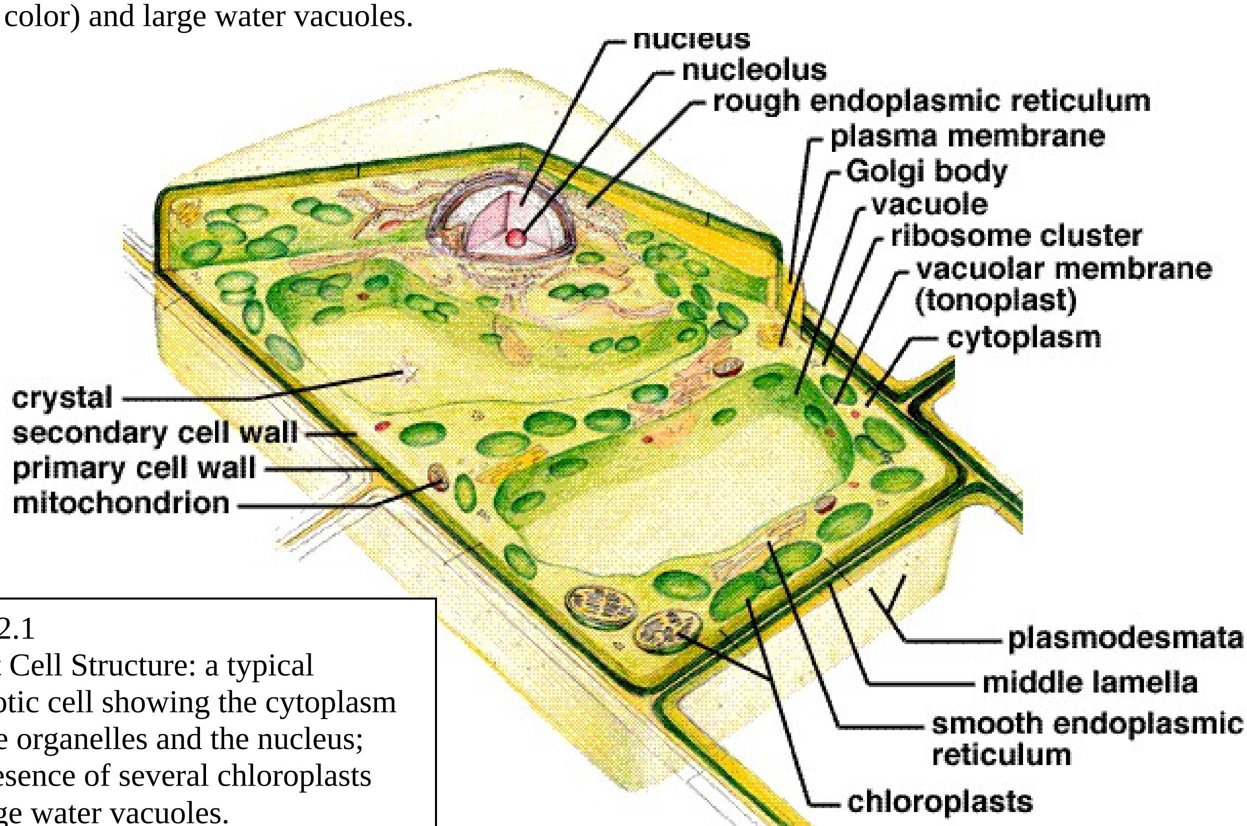


Figure 2.1
A Plant Cell Structure: a typical eukaryotic cell showing the cytoplasm with the organelles and the nucleus; also presence of several chloroplasts and large water vacuoles.

Functions of organelles in a cell

The Cell Wall

This encloses all the protoplast that is the whole cell content, which includes the organelles and the cytoplasm. The cell wall is made up of 2 layers: primary wall and the secondary wall. In many plant cells can be found cellulose, lignin and other polysaccharides. Lignin a tough plant tissue, it provides strength to plant and also acts as a protective tissue to plants. Plant cell wall contains pits, which are pores that allow passage of molecules from cell to cell. Between cells are cytoplasmic connections known as **Plasmodesmata** (plasmodesma, singular). A middle lamella (made up of sticky substances secreted by the cell in the form of pectin) is usually present between adjacent cell walls.

Mitochondria

Energy releasing reactions occur here in the mitochondria. Mitochondria store energy in the form of ATP (adenosine triphosphate, energy molecule of a cell). It has a double membrane; the inner membrane is modified to form finger-like processes called **cristae**. On the surface membrane of cristae are located enzymes for **oxidative phosphorylation reactions** (ATP synthesis reaction using oxygen). Mitochondria can easily multiply because they have their own DNA.

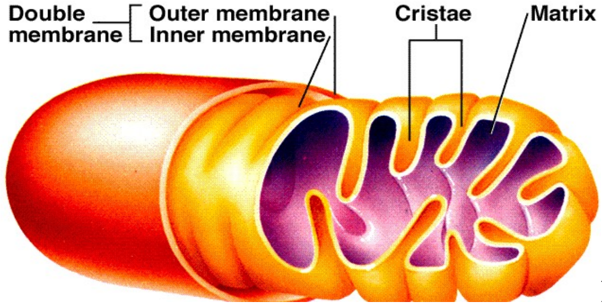


Figure 2.2. Mitochondria

Endoplasmic Reticulum (ER)

The ER is a double membrane channel -like organelle. This organelle can occur as smooth (no ribosomes on its membrane surface) or rough with ribosomes on its membrane surface. It functions in transporting and packaging of proteins; also it functions in lipid synthesis. Rough ER participates in protein synthesis.

Golgi Complex or Dictyosomes

This organelle is described as a pile of membranous sacs. It is important for the processing of molecules (glycolipids, glycoproteins and enzymes). It produces lysosomes (microbodies that contain hydrolytic enzymes).

Nucleus contains the DNA (Deoxyribonucleic acid and RNA (ribonucleic acid). DNA forms chromosomes for inheritance and continuation of life. RNA is formed from DNA and is important for protein synthesis. The nucleus is double membranous with openings or nuclear pores. When the cell is not dividing, the nucleus appears granular because the DNA and proteins are in the form of chromatin. Inside the nucleus is found the nucleolus.

Nucleolus makes ribosomes that later leave the nucleus and enter the cytoplasm of the cell. Some of the ribosomes remain free, while others attach themselves to ER to form the rough ER.

Ribosomes contain RNA and proteins. The ribosomes are the sites for protein synthesis. Ribosomes are found free in the cytoplasm or attached to Endoplasmic reticulum.

Vacuoles

Most plant cells have large water vacuoles. The vacuole can occupy about 90% of the cell and pushes the cytoplasm against the plasma membrane. The vacuole contains the cell sap that is a sugar solution with salts, amino acids, proteins and crystals. In most plants cell saps are acidic in nature, for example the lemon and lime juice are acidic. The vacuole also contains waste products. Some substances in the vacuole can accumulate to form crystals thereby making the sap toxic if eaten by man. Also in the vacuoles are found pigments such as **anthocyanins** that give colors to plant organs.

Chloroplasts
These are plants' pigments. Both chloroplasts and mitochondria have structures that are similar; they are both double membranous and they contain their on DNA and ribosomes. They can reproduce themselves. The chloroplast contains stacks of membranous sacs called grana. Inside these grana are chlorophyll pigments and enzymes for phtosynthesis.

Microbodies include **lysosomes, peroxisomes and glyoxisomes**. Lysosomes contain hydrolytic enzymes. Peroxisomes participate in photosynthesis and glyoxysomes function in conversion of stored fats into seeds.

Plasma Membrane
The plasma membrane is a lipid bilayer of phospholipid molecules. About 75% of the lipid is phospholipid. Generally about 50% of the molecules that make up the membrane is lipid, 45% is protein, and 5 % is carbohydrate. There are two groups of membrane proteins, surface bound proteins (peripheral) and proteins sandwiched in between the phospholipid bilayer (integral proteins). The carbohydrates are attached to proteins (glycoproteins) andor attached to lipids (glycolipids).

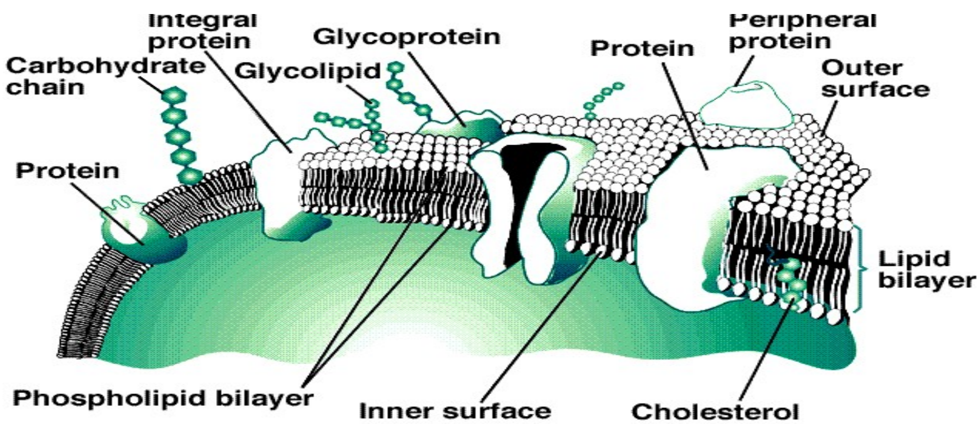


Figure 2.3. Plasma Membrane Structure

Plasma Membrane Transport
The membrane allows selective permeability of molecules in and out of the cell. A plant cell, placed in an isotonic solution has equal movement of molecules in and out of the cell. When the plant cell is placed in pure water (distilled water, or hypotonic solution), water molecules diffuse into the cell much more than out of the cell, the cell becomes turgid. When the plant cell is placed in a 1.5% or higher salt solution (hypertonic solution), water molecules diffuse out of the cell much more than into the cell, the cell shrinks, this is known as plasmolysis. Plant cells remain in the same physiological state when placed in a solution isotonic (0.9% salt solution) to their cells.

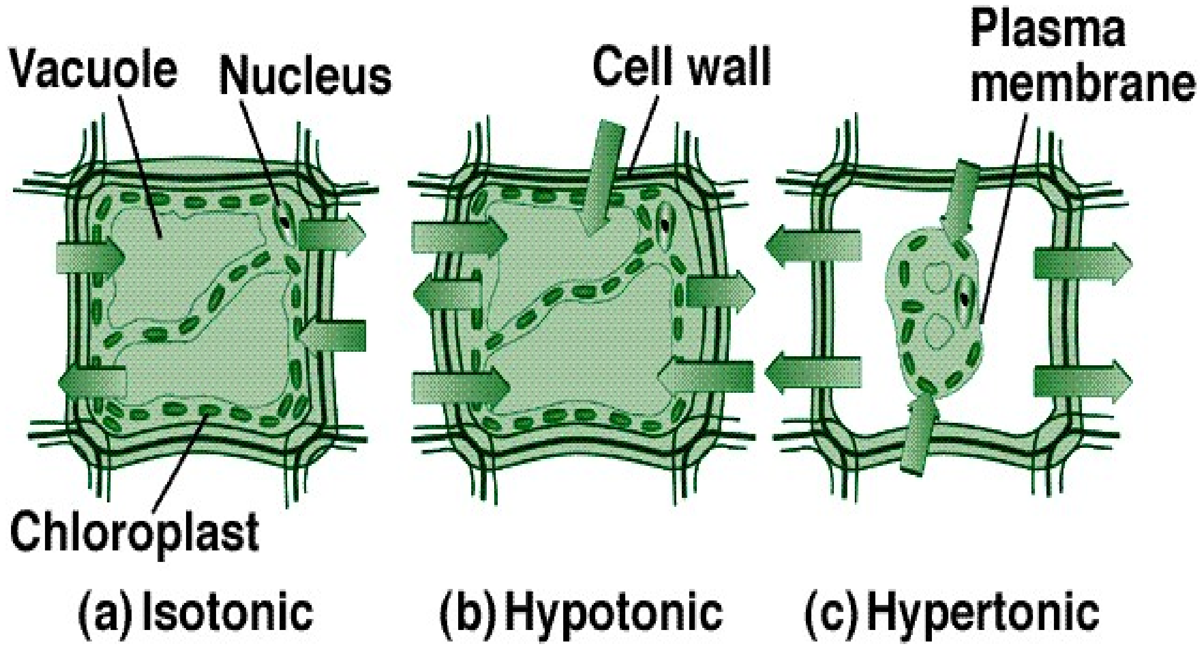


Figure 2.4 Osmosis / Plasmolysis in a plant cell

The transport of molecules across the membrane could be passive, where no energy is required, or active where energy in the form of ATP is required for molecules to be transported across the membrane.

Passive transport system utilizes various processes, among them include: simple diffusion, and osmosis, and filtration, where molecules move along the concentration gradient.

Osmosis: Movement of water molecules from higher to lower concentrations through a selectively permeable membrane.

Simple Diffusion: Movement of molecules from higher to lower concentrations.

Filtration: Movement of molecules can occur through a selectively permeable membrane with the help of a pressure gradient.

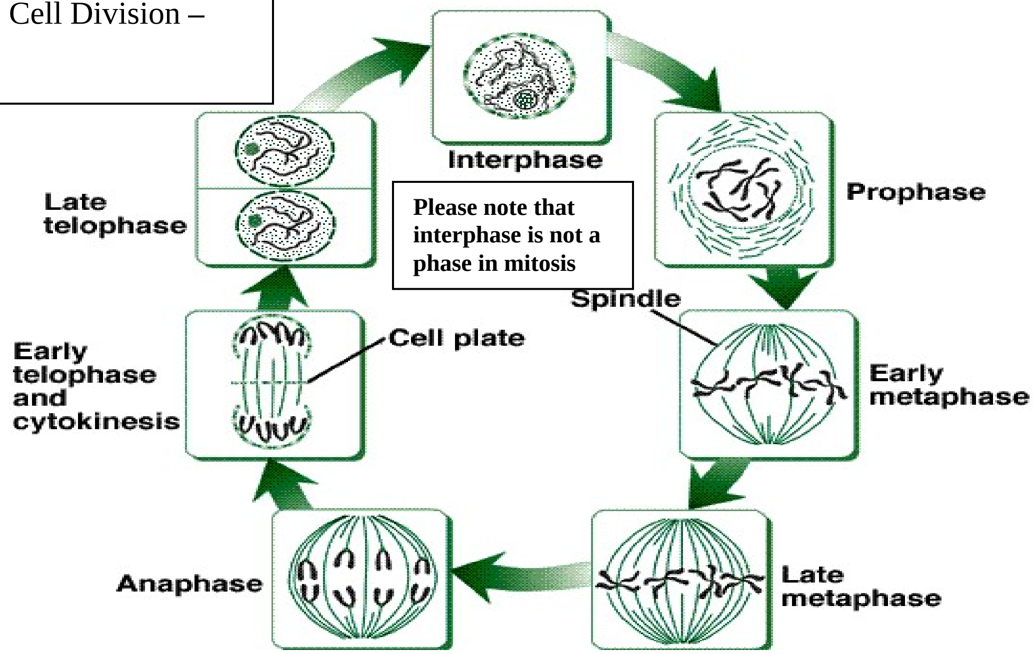
Active transport processes include phagocytosis (cell eating processes), pinocytosis (cell drinking processes). **Phagocytosis** can be divided into endocytosis (cell engulfing solid materials or other cells), and exocytosis (cell secreting molecules, or pinching off of cellular fragments). Molecules can move against the concentration gradient in this process.

CELL DIVISION

The cell cycle

The life of a cell within 24 hours is divided into 2 phases: M phase or mitosis (division phase), interphase (non-division phase). Interphase is subdivided into three phases: G_1 phase, S-phase, and G_2 phase. During G_1 and G_2 phases, proteins, and enzymes are synthesized. Centrioles also divide during these phases of interphase. During the S phase, DNA is synthesized. The cell enters the M phase where division occurs. The M phase is subdivided into 4 phases: **prophase, metaphase, anaphase, and telophase.**

Figure 2.4. Cell Division – Mitosis



Prophase

In this phase, the DNA and proteins that appeared as chromatin in the nucleus during interphase condense, thicken, and form chromosomes. Each chromosome is made up of two sister chromatids held together at the center by the centromere (is like two bow-shaped ribbons joined at the center). The nuclear membrane disintegrates, the centrioles that had divided during the G1 and G2 phases of the interphase produce spindles.

Metaphase

The spindles produced at prophase rearrange themselves at each pole of the cell. The chromosomes also arrange themselves at the center of the cell. The spindles are made up of filamentous proteins called microtubules, some spindles stretch out to attach themselves to the centromeres in the chromosomes (kinetichore microtubules); others stretch across to opposite pole of the cell (non-kinetichore microtubules), and a third group of the spindles (aster microtubules) remain at each pole of the cell.

Anaphase

The proteins in the microtubule of the spindles condense retracting the spindles. These spindles while retracting back to the poles, pull the centromere that held together the sister chromatids of each chromosome causing each sister chromatid to separate from each other. These chromatids move to opposite poles of the cell. This is followed by cytokinesis, a process where the cytoplasm of the cell divides as the sister chromatids move to opposite poles of the cell. This is followed by a cell plate formation.

Telophase

At telophase, the cytokinesis is completed, the nuclear membrane is re-formed around the chromatids, and the cell divides into two.

Key Points

1. All organisms are made up of cells. The cell is the structural & functional unit of organisms, this is known as the cell theory. This theory was established by Schleiden and Schwann.
2. There are 2 main groups of cells: prokaryotic and eukaryotic cell; bacteria and blue green algae are prokaryotic. The prokaryotic cells are very simple with no organelles, while in the eukaryotic cells are organelles.
3. The organelles in the eukaryotic cell include nucleus, mitochondria, endopasmic reticulum, golgi complex, lysosomes, and ribsomes. Specifically in the plant cells are found chloroplasts, large water and vacuoles.
4. The nucleus of a cell contains the choromosomes, DNA and RNA and some ribosomes. These factors allow genetic inheritance during cell division / reproduction.
5. The mitochondria is like the "Power house" of the cell. It is where most metabolic reactions which require the release of energy using oxygen occur, a process known as oxidative phosphorylation. Mitochondria contain their own DNA, so they can multiply. Mitochondria stores cellular energy in the form of adensine triphosphate or ATP.
6. The chloroplasts contain chlorophyll, the green plant pigment. Other plant pigments are anthocyanin which give color to the fruits. Chloroplasts like mitochondria have their own DNA and ribosomes, and they can reproduce themselves.
7. Endoplasmic Reticulum (ER) is an organelle that functions in lipid a protein synthesis. Some ER carry ribosomes (rough or granular ER) so they assist the ribosomes in protein synthesis, other ER do not carry ribosomes (smooth ER or granular ER) and function only in the lipid synthesis
8. The Golgi complex functions in processing of lipids, carbohydrates, and proteins formed by the ER. The golgi produces gylcoproteins and glycolipids, and also enzymes. The golgi forms lysosomes.
9. Lysosomes contain digestive enzymes (or hydrolytic enzyme) in the cell.
10. The plant cell has a cellulose cell wall which makes the plant rigid; also in addition to the cellulose cell wall, the cell has a plasma membrane. The plasma membrane is selectively permeable to molecules. This plasma membrane is made up of a high % of phospholipid, some proteins and a small amount of carbohydrates.
11. The plasma membrane of a cell can allow both passive (diffusion, filtration, osmosis) transport processes that require no energy, and active transport processes that require energy to occur.
12. Plant cells have to be in isotonic solution (a solution which has equal salt concentration as the cell) to maintain normal physiological cell conditions. A plant cell placed in a hypotonic solution (a solution with less salt concentration in the cell) gains too much water and becomes turgid. A plant cell placed in a hypertomic solution (a solution with more salt concentration than the cell) loses water and shrinks (a process known as plasmolysis). (See the illustration of a plant cell structure, and plasmolysis in the text)

Study questions

- **Cell**
  State the cell theory.
- Name 3 scientists associated with the cell theory.
- State the difference between a prokaryotic cell and a eukaryotic cell.
- State 3 differences between a plant and an animal cell.
- Describe all the organelles that can be found in a plant cell, and state the functions of each.
- Describe the plasma membrane structure.
- What is a passive transport? Give examples of passive transports.
- Define osmosis, simple diffusion, and filtration.
- What is an active transport? Give 2 examples of active transport processes in the cell.

Cell Division

What is mitosis? Describe the events that occur at each phase of mitosis.
Interphase is a phase in the cell cycle; it has 3 sub phases (S, G1, and G2); describe what occurs during each of the sub-phases S, G1, and G2

Cell Structure

State the function of each of the organelles:

- Chloroplasts
- Mitochondria
- Ribosomes
- RNA
- Endoplasmic reticulum
- Perioxisomes
- Glyoxisomes
- Vacuole
- Cell wall
- Plasma membrane
- Golgi
- Nucleus / Nucleolus