TOPICS:1.Introductory knowledge about plant cell wall
2.Gross Structure and Ultrastructure of Cell Wall (With Diagram) | Plants

Cell Wall:

There are many forms of life on earth with a multitude of features and characteristics. Yet, when we look at the microscopic level, every single life on earth is composed of the same basic, structural and functional unit of life – the cell.

The types of cell, chemical composition, and its characteristics vary depending on the type of life. One of those important characteristics is the cell wall. Let us explore more about the cell wall, its types and where it is found.

What is a Cell Wall?

A cell wall is defined as the non-living component, covering the outmost layer of a cell. Its composition varies according to the organism and is permeable in nature. The cell wall separates the interior contents of the cell from the exterior environment. It also provides shape, support, and protection to the cell and its organelles. However, this cellular component is present exclusively in eukaryotic plants, fungi, and few prokaryotic organisms.

As stated above, fungi also possess cell walls, but they are made up of chitin, a derivative of glucose which is also found in the exoskeletons of arthropods. And just like the cell walls in plants, they provide structural support and prevents desiccation.

Prokaryotic organisms such as bacteria also contain cell walls. However, they are chemically different from the cell wall found in plants and fungi. The prokaryotic cell walls are composed of large polymers known as peptidoglycans. Cell walls in prokaryotes serve as a form of protection and prevent lysis (bursting of the cell and expulsion of cellular contents). Structurally, prokaryotic cell walls consist of two layers:

An inner layer that is made up of peptidoglycans

An outer layer that is composed of lipoproteins and lipopolysaccharides

Eukaryotic cells possess a definite nucleus along with a distinct nuclear membrane. It also contains membrane-bound organelles not found in prokaryotic cells. Another important point to note is that the cell wall is absent in other eukaryotic organisms such as animals, only plants possess cell walls.

Cell Wall Structure

The cell wall is the outer covering of a cell, present adjacent to the cell membrane, which is also called the plasma membrane. As mentioned earlier, the cell wall is present in all plant cells, fungi, bacteria, algae, and some archaea. An animal cell is irregular in their shape and this is mainly due to the lack of cell wall in their cells. The compositions of the cell wall usually vary along with organisms.

The plant cell wall is generally arranged in 3 layers and composed of carbohydrates, like pectin, cellulose, hemicellulose and other smaller amounts of minerals, which form a network along with structural proteins to form the cell wall. The three major layers are:

Primary Cell Wall

The Middle Lamella

The Secondary Cell Wall

Primary Cell Wall

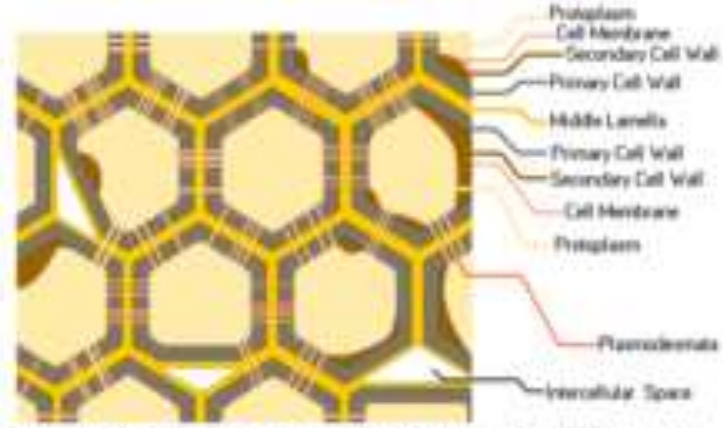
The primary cell is situated closest to the inside of the cell and is the first-formed cell wall. It is mainly made up of cellulose, allowing the wall to stretch for the purpose of growth. Several primary cells contain pectic polysaccharides and structural proteins. It is also comparatively permeable and thinner than the other layers.

Middle Lamella

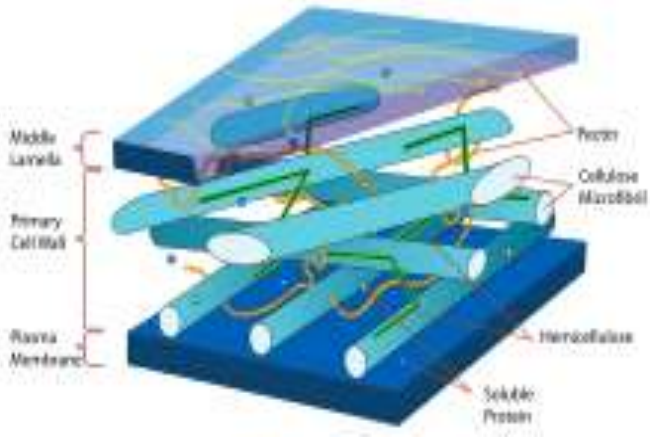
The middle lamella is also the outermost layer and it acts as an interface between the other neighbouring cells and glues them together. This layer primarily consists of pectins. However, other substances such as lignin and proteins can also be found.

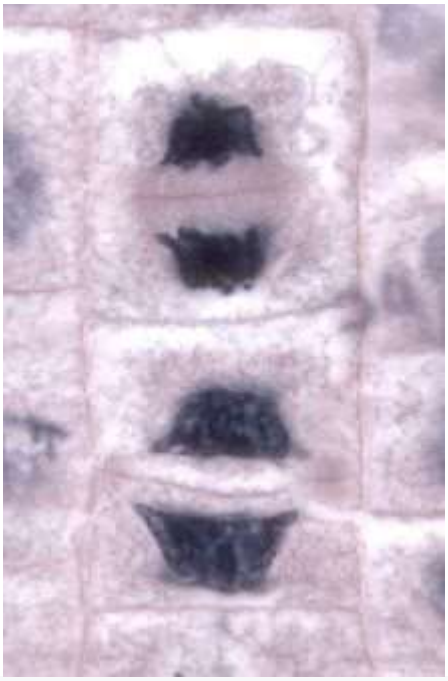
Secondary Cell Wall

The secondary cell wall is formed inside the primary cell wall once the cell is completely grown. Some types of cells (especially the cells of xylem tissues) consist of cellulose and lignin and these provide additional rigidity and waterproofing. Also, this layer provides the characteristic rectangular or square shape to a cell. It is also the thickest layer and permits permeability.



Placement of plant's cell wall (extracellular matrix) and its major parts (highly diagrammatic)





Photomicrograph of onion root cells, showing the centrifugal development of new cell walls (phragmoplast)

What is the Function of the Cell Wall

The cell wall is an integral component of the plant cell and it performs many essential functions. Following are some of the major cell wall functions observed:

The plant cell wall provides definite shape, strength, rigidity

It also provides protection against mechanical stress and physical shocks

It helps to control cell expansion due to the intake of water

Also helps in preventing water loss from the cell

It is responsible for transporting substances between and across the cell

It acts as a barrier between the interior cellular components and the external environment

1. What is a Cell Wall?

A cell wall is defined as a rigid, external layer that is specifically designed to provide structural support and rigidity. It also keeps the interior components of the cell intact and safe from the external environment.

2. What is the function of the cell wall?

The main function of the cell wall is to provide structural strength and support, and also provide a semi-permeable surface for molecules to pass in and out of the cell.

3. Name other organisms besides plants to have a cell wall.

Besides plants, prokaryotic organisms such as bacteria sport a cell wall. However, its cell wall is made up of peptidoglycan, which is composed of sugars and amino acids. Fungi also possess cell walls and they are composed of chitin, a complex carbohydrate.

4. What are the 3 layers of the cell wall?

A typical plant cell wall is composed of 3 layers namely the primary cell wall, the secondary cell wall, and the middle lamella.

5. Why are bacterial cell walls important?

The cell wall in bacteria is essential for survival as it helps to keep the contents of the cell intact. Antibiotics usually work on this principle by targeting the bacterial cell wall and causing lysis. This leads to the expulsion of cellular contents and the eventual death of the cell.

In this article we will discuss about the ultrastructure of cell wall in plants.

The cell wall is a biphasic structure consisting of cellulose microfibril embedded in gel-like non-cellulosic matrix. The microfibrillar phase consists of cellulose (β1, 4-glucan) only and the ultrastructure of cell wall is based on it. The microfibrillar phase is readily visible in Electron microscope and is crystalline, i.e. its molecules are arranged in a definite way. Moreover, it is homogeneous in chemical composition.

The microfibrillar phase is composed of microfibrils which are long, thin structure with oval or circular in cross section and have uniform width of about 10nm (1 nm = 10-9m) in higher plants.
The cambium cells have narrow width (± 3 nm). The microfibrils are made up of cellulose molecules, which are precisely defined polymer composed of purely glucose molecules linked to each other by β1, 4 bond and are unbranched 1, 4-glucan. The glucose residues $C_6H_{10}O_5$ are linked together with oxygen atoms (Fig. 3.4).

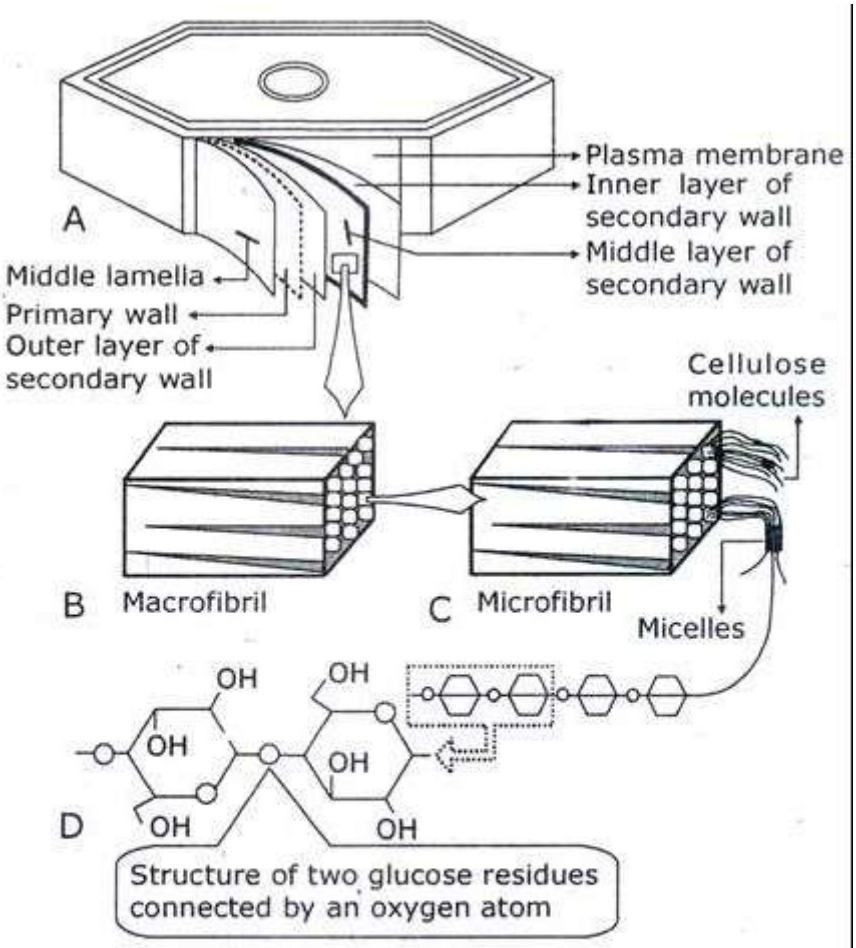


Figure 3.4

Diagram illustrating the structure of cell wall of a fibre. A. Diagrammatic representation of cross section of fibre in three dimensional view showing middle lamella, the primary wall and three layers of secondary wall. B. Macrofibril from a portion of the middle layer of secondary wall. C. Microfibril from a portion of macrofibril.

There are at least 8000 to 15,000 glucose monomers per cellulose molecule and are 0.25 to 0.5 µm long. The molecules are flat and ribbon like, and lie parallel to each other. Hydrogen bonding occurs between the molecules, thus crystallizing and producing aggregates. These aggregates are called microfibril.

Each microfibril contains 40 to 70 chains, which lie side by side, and these can be seen in Electron micrographs. Electron microscopic study reveals that about 40 cellulose molecules are grouped together to an elementary fibril of about 3.5 nm in diameter. Later the idea of elementary fibril is considered as misconception.

The cellulose molecules form chains, which are at some regions of microfibrils, are arranged in parallel into 3-dimensional crystalline lattices termed micelles. The lattices are connected with each other by intra and inter molecular hydrogen bonds. The spaces between the microfibrils are filled up with lignin, cutin, pectic substances, hemicellulose, water etc. Thus, the microfibril gains considerable strength.

In primary cell wall, the orientation of microfibril is transverse to the long axis, and during growth the arrangement may be longitudinal. The orientation in secondary wall may differ from primary wall. Tracheids and fibres show three layers in their secondary wall the outer layer (S1), the central layer (S2) and the inner layer (S3), among which the central (S2) is the thickest.

The S1 and S3 layers lie adjacent to primary wall and cell lumen respectively. These layers S1, S2 and S3 may be distinguished by their respective orientation of cellulose microfibrils. In S1 and S3, the microfibrils are in the form of a lax helix and in S2, it is a steep one (Fig 3.5).

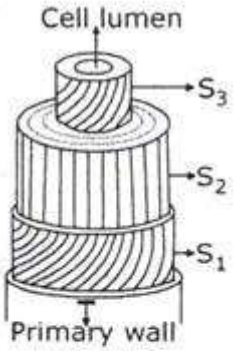


Figure 3.5
Diagrammatic illustration of the orientation of microfibrils in the secondary wall of a cell.

The microfibrils are aggregated to form macrofibrils, which are composed of about 5,00,000 cellulose molecules in transection. The macrofibrils are about 0.4 µm wide and can be visible under light microscope. Several macrofibrils are combined together to form the cell wall. Preston suggested that microtubule directs the arrangement of microfibrils.

It is certain from chemical analysis and X-ray diffraction studies that the major bulk of microfibril is composed of crystalline β1, 4-Glucan. Later evidences suggest that α-cellulose fraction of cell wall contains mannose and xylose in addition to glucose. The microfibrils may consist of a central core of crystalline cellulose micelle.

Major components of the cell walls are cellulose, pectins, hemicellulose, proteins and phenolics whose presence has extremely complicated the overall structure of cell wall. So, a number of models were proposed to explain the arrangement of the (cell wall) components in the wall.

Mention may be made of the model of (Fig. 3.6) Lamport and Epstein, 1983, which explains the interrelationships between matrix molecules and cellulose microfibrils. According to this model the protein molecules lie perpendicular to cell surface through which the microfibril passes. There are covalent links between protein and cellulose microfibrils, and between the proteins.

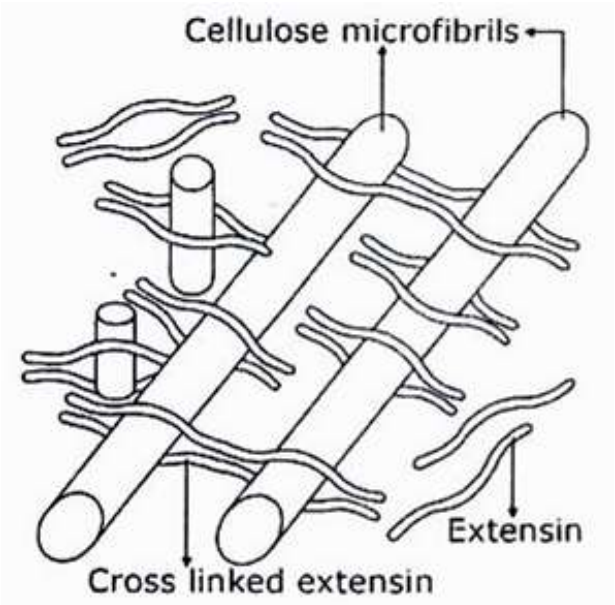


Figure 3.6
Diagram representing Lamport and Epstein model.

REFERENCES:

1.https://www.biologydiscussion.com/plants/cell-wall/ultrastructure-of-cell-wall-with-diagram-plants/68833
2.https://byjus.com/biology/cell-wall/
3. https://en.wikipedia.org/wiki/Cell_wall

(All the above mentioned description including figures are taken for the above mentioned references and are solely used for teaching and learning purposes.)