Cell Wall:

It is the outer rigid protective supportive and semi transparent covering of plant cells, fungi and some protists. Its thickness varies in different types of cells from 0.1 µm to 10 µm. Cell wall is a non-living extracellular secretion or matrix of the cell which is closely appressed to it. It is, however, metabolically active and is capable of growth.

Functions of Cell Wall:

- Provides rigidity and shape to the cell.
- Protects the protoplasm against mechanical injury.
- Protects the cell from attack of pathogens.
- Counteracts osmotic pressure.
- Gives strength to the land plants to withstand gravitational forces.
- By its growth the wall helps in cell expansion.
- Pits present in the wall help produce a protoplasmic continuum amongst cells.
- Walls prevent bursting of plant cells by inhibiting excessive endosmosis.
- Wall has some enzymatic activity connected with metabolism.
- Cutin and suberin of the cell wall reduce the loss of water through transpiration.
- Walls of sieve tubes, tracheids and vessels are specialised for long distance intercellular transport.
- Acts as a reservoir of food.

Gross Structure of Cell Wall:

Three layers can be distinguished in the cell wall. These are the middle lamella, the primary cell wall and the secondary cell wall.

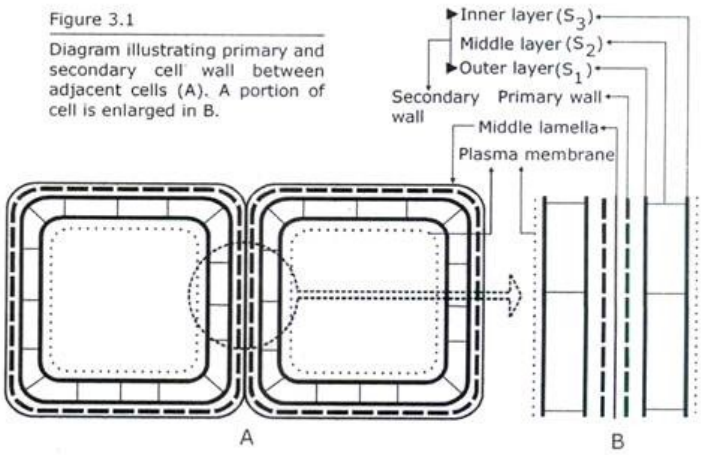

Figure 3.1
Diagram illustrating primary and secondary cell wall between adjacent cells (A). A portion of cell is enlarged in B.

1. **Primary Wall:**

The first formed wall of a cell is the primary wall. It usually grows in surface area. Primary wall is about 0.1 µm thick normally, but the walls of collenchyma may be 10 µm thick. The cuticularized epidermal cells may be thicker. Thick cellulosic primary cell walls are observed in the endosperm cells of *Phoenix dactylifera*, *Strychnos nux-vomica* etc. Thick primary wall, in contrast to secondary wall, is plastic and reversible. The meristem, cambium cell, parenchyma, collenchyma, root hairs etc. possess primary walls.

The components of primary wall are deposited on both the sides of middle lamella, which initially creates a boundary between two nuclei at the end of nuclear division.

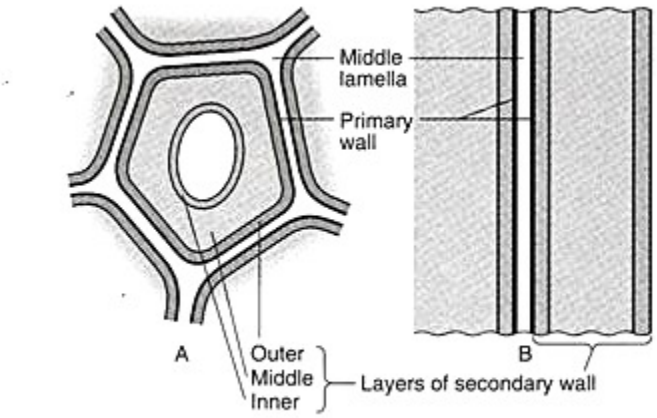

Fig. 2.28 : Wall-structure of a mature and lignified plant cell. A. In cross section, B. In longitudinal section

ii. Secondary Wall:

A secondary wall is one whose polysaccharide components are deposited over the primary wall. In contrast to primary wall, secondary wall is formed after the cessation of surface growth. Therefore, it causes growth in thickness only.

Since the secondary wall materials are deposited outside the plasma membrane, it is present internal to primary wall surrounding the cell lumen. In addition to cellulose, hemicelluloses and other polysaccharides, the secondary wall contains lignin.

When lignification occurs, it may begin at either the primary wall or middle lamella. In the deposition of secondary wall materials layering can be observed. The lignified tracheid and fibre show three layers in their secondary wall the outer layer (S_1) the central layer (S_2) and the inner layer (S_3), among which the central (S_2) is the thickest. The S_1 and S_3 layers lie adjacent to primary wall and cell lumen respectively.

Cells with secondary wall consist of five layers a three layered secondary wall, the primary wall and the middle lamella. In contrast to primary wall, secondary walls are irreversible and provide

mechanical strength. Usually secondary walls are present in those cells, which are devoid of active protoplast.

iii. Middle Lamella:

This layer lies in between the two primary walls of adjacent cells. It is the cementing material that fastens or binds cells to their neighbours; therefore, the cells are held together by their primary walls. The middle lamella is very thin (less than 30nm thick) and thickest at the cell corners. It consists of pectic substances, in association with calcium and others.

Ultrastructure of Cell Wall

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.

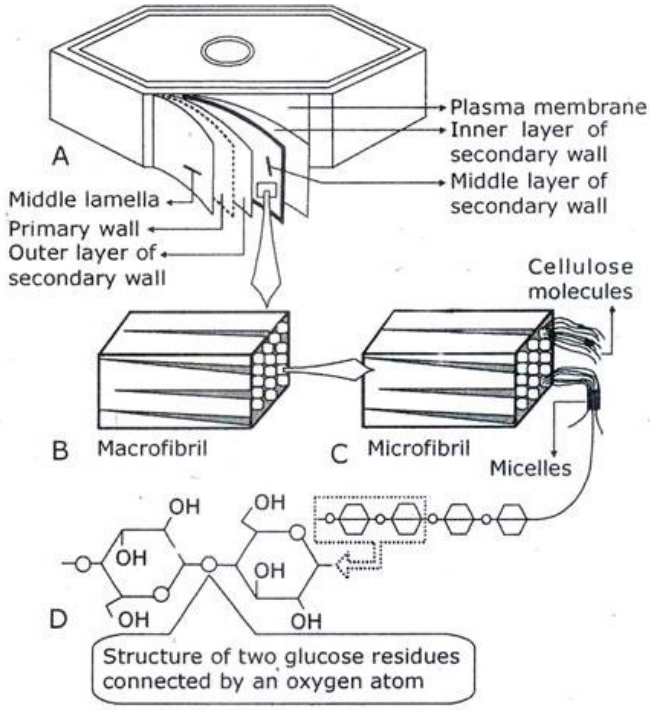

Figure 3.4

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.

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^{-9}m) in higher plants.
The microfibrils are made up of cellulose molecules, which are polymers of 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).
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.
The cellulose molecules form chains, which 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.

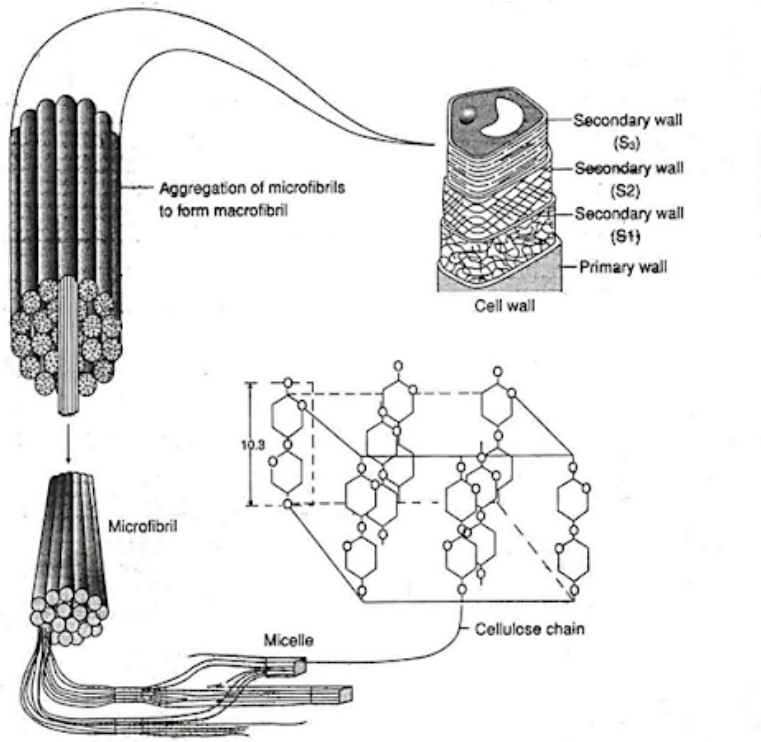

Fig. 5.18 : Paracrystalline arrays of several dozen. 1, 4 β-D-glucan chains tightly linked by numerous hydrogen bonds in cellose microfibrils

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 (S_1), the central layer (S_2) and the inner layer (S_3), among which the central (S_2) is the thickest.
The S_1 and S_3 layers lie adjacent to primary wall and cell lumen respectively. These layers S_1, S_2 and S_3 may be distinguished by their respective orientation of cellulose microfibrils. In S_1 and S_3, the microfibrils are in the form of a lax helix and in S_2, it is a steep one (Fig 3.5).

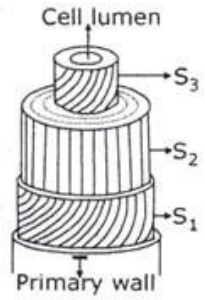

Figure 3.5
Diagrammatic illustration of the orientation of microfibrils in the secondary wall of a cell.

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.

In a schematic way,

8000 – 15,000 glucose monomers (β1, 4-Glucan) per **cellulose molecule**
(0.25- 0.5 µm long)
↓
Cellulose molecule chain arranged parallel into 3-dimensional lattice (**micelle**)
↓
40 – 70 chains of cellulose molecules form **microfibril**
(10 nm)
↓
microfibril aggregate (5,00,000 cellulose molecules in transaction) form **macrofibrils** (0.4 µm)
↓
Several macrofibrils together form **cell wall**

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.

Lamport and Epstein, 1983, explained 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.

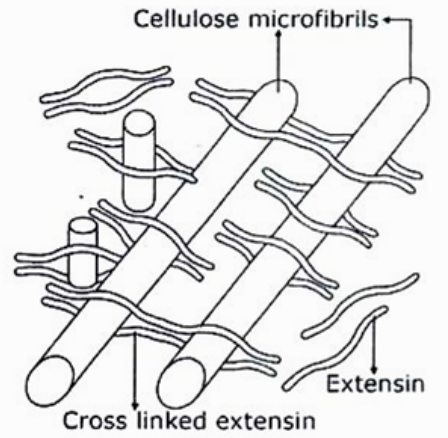

Figure 3.6
Diagram representing Lamport and Epstein model.

Reference Books:
Plant Anatomy- Pijush Ray
Plant Anatomy – A. Fahn
Plant Anatomy – B. P. Pandey

1) Please note that, this is only a study material for the topic. Please refer to the mentioned books.
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