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(A CONSTITUENT PG COLLEGE OF UNIVERSITY OF ALLAHABAD)

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Plant Morphology and Anatomy

Unit: I

Topic: Organization of cell wall

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ORGANIZATION OF CELL WALL

Each cell within a tissue has its own cell wall. The cell walls of plants very much in thickness in relation to age and type of cells. Generally, young cells have thinner cell walls than the fully developed ones, but sometimes the wall does not thicken much after the cell ceases to grow.

In mature thick-walled cells, a concentric layering is usually distinct in the cell wall. The layers differ from one another in physical and chemical nature. The cell wall is complex in its structure and usually consists of three layers, the primary wall, the intercellular substance or middle lamella, and the secondary wall.

The intercellular substance cements together the primary walls of two contiguous cells, and the secondary wall is laid over the primary, that is, next to the lumen of the cell. The primary wall usually consists of a single layer, whereas the secondary wall is made up of one to many layers, most frequently of three. The three most important layers of cell wall are listed below:

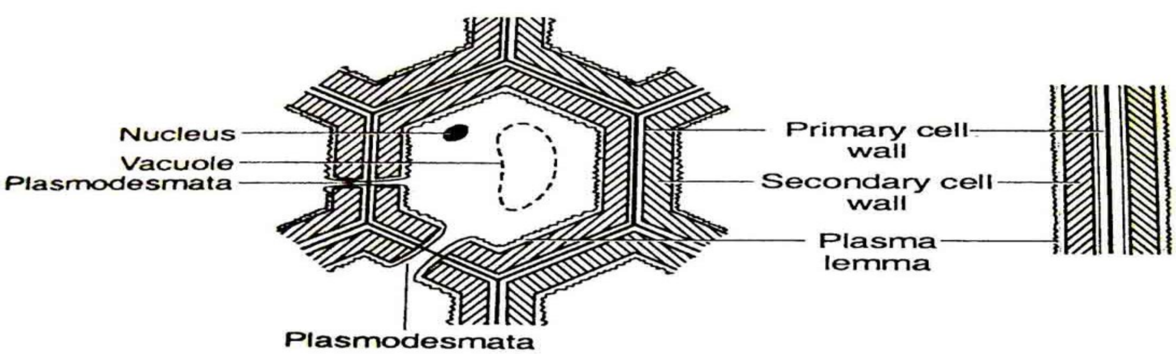


***Fig.* - Arrangement of various layers of cell wall in a mature plant cell.**

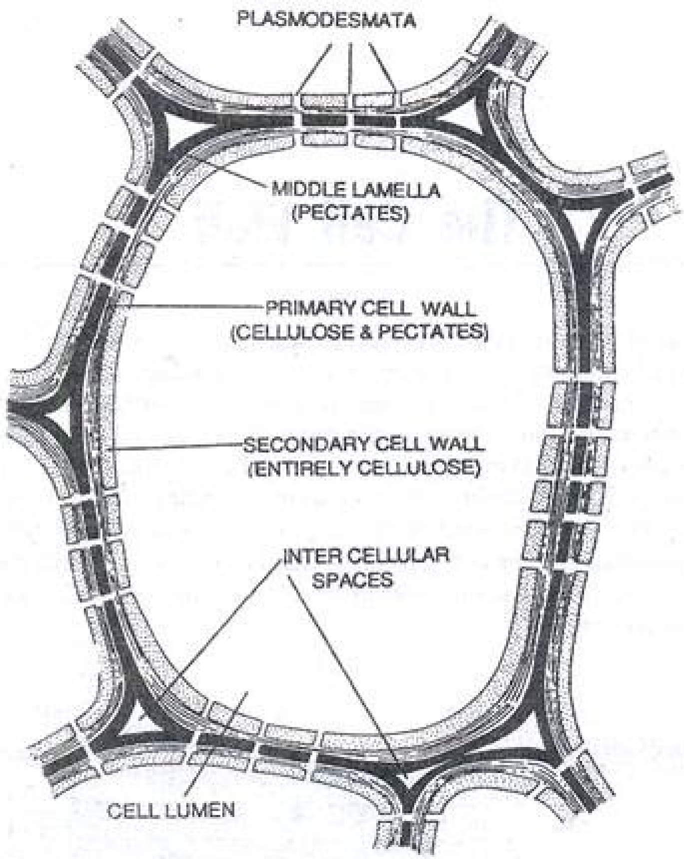


Fig. 34.2. The cell wall. Schematic representation of structure and composition of plant cell walls.

1. The Primary Wall:

The membrane developed on the surface of the cell plate denotes the first stage of the primary wall. Generally the primary wall is formed in the developing cells, and in many types of cells it is the only wall. The primary wall consists of cellulose, pectic compounds, noncellulosic polysaccharides and hemicelluloses (Bonner, 1950).

Sometimes it becomes lignified. The primary walls are usually associated with living protoplasm. The walls of dividing and growing meristematic cells are primary. The primary wall may change its shape and volume according to the growth of young protoplast. This wall is not uniformly thickened and may maintain its thickness and unevenness, or be alternately thickened and thinned.

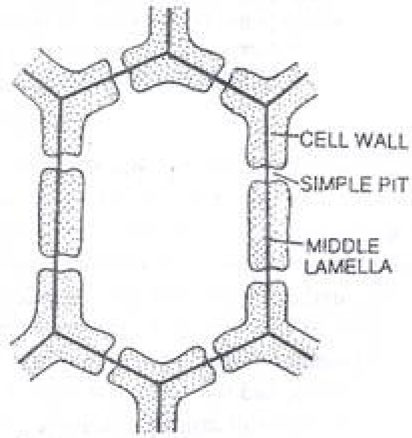


Fig. 34.3. The cell wall. Simple pits. A cell in sectional view showing simple pits in its wall.

As already mentioned, the walls of dividing and growing meristematic cells are primary, and so are those of most of the cells which retain living protoplast. The changes that occur in primary walls are therefore reversible. The wall may lose a thickening previously acquired and chemical substances may be removed or replaced by others.

For example, cambial walls show seasonal changes in thickness and in -colloidal properties (Kerr and Bailey, 1934). In other cases the thick primary walls of the endosperm in many seeds are digested during germination.

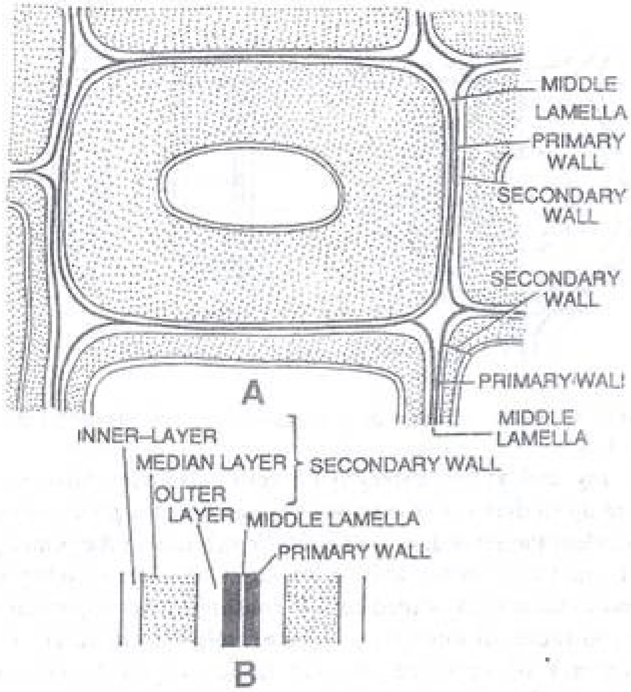


Fig. 34.4. The cell wall. The figure shows wall structure and middle lamella in wood fibres. A, T.S. of one wood fibre and parts of seven adjacent fibres; B, cross section of adjacent walls and middle lamella (highly magnified).

2. The Middle Lamella:

The intercellular substance which cements together the primary walls of two contiguous cells very firmly is called middle lamella. This is a complex layer in its structure and morphology. It is amorphous, colloidal, and optically inactive. It is composed mainly of a pectic compound which appears to be a mixture of calcium and magnesium pectate.

In woody tissues the middle lamella is commonly lignified. The distinction between intercellular lamella and the primary wall is frequently obscured during the extension growth of the cell. In such cells as tracheids and fibres, which typically develop prominent secondary walls, the intercellular layer becomes extremely tenuous. As a result, the two primary walls of contiguous cells and the intervening middle lamella appear as a unit, particularly when all three become strongly impregnated with lignin. This triple structure is often known as middle lamella.

3. The Secondary Wall:

Usually in many fully developed cells further thickening of cell wall occurs. The wall then formed is the secondary wall. The secondary wall maybe considered a supplementary wall whose principal function is mechanical. Generally the cells with secondary walls are devoid of protoplasts at maturity. These walls are most characteristic of cells that are highly specialized and undergo irreversible changes in their development. However, cells with active, living protoplasts,

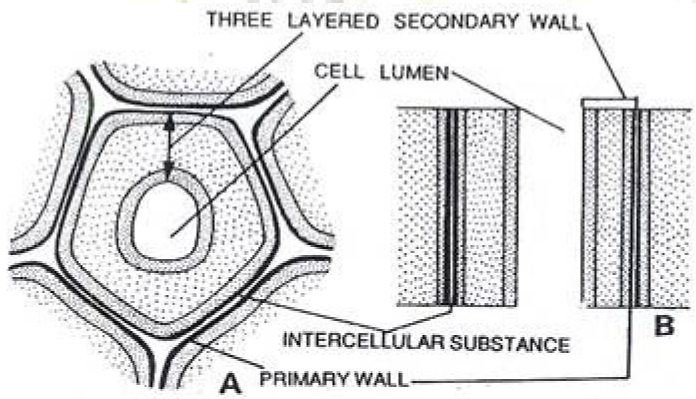


Fig. 34.5. A cell wall. A, cell with secondary wall layers in T.S.; B, cell with secondary wall layers in L.S.

such as the xylem ray and xylem parenchyma cells, also may have secondary walls. The secondary wall is laid down over the primary wall except over the pit membranes. In the tracheids and vessels of protoxylem the secondary wall covers much less of the primary wall; it forms only as rings, spiral bands and bars over the delicate primary wall.

The secondary wall is more massive than the primary, and in most thick-walled cells it constitutes the major part of the wall. Usually the secondary wall constitutes of three layers—inner, middle and outer. This wall may consist of cellulose or mixtures of cellulose, non-cellulosic polysaccharides and hemicelluloses.

Sometimes the number of layers of secondary wall may exceed three, and the innermost sometimes only of a helical band and such bands are called tertiary spirals or spiral thickenings (Eames and Mac Daniels, 1947).

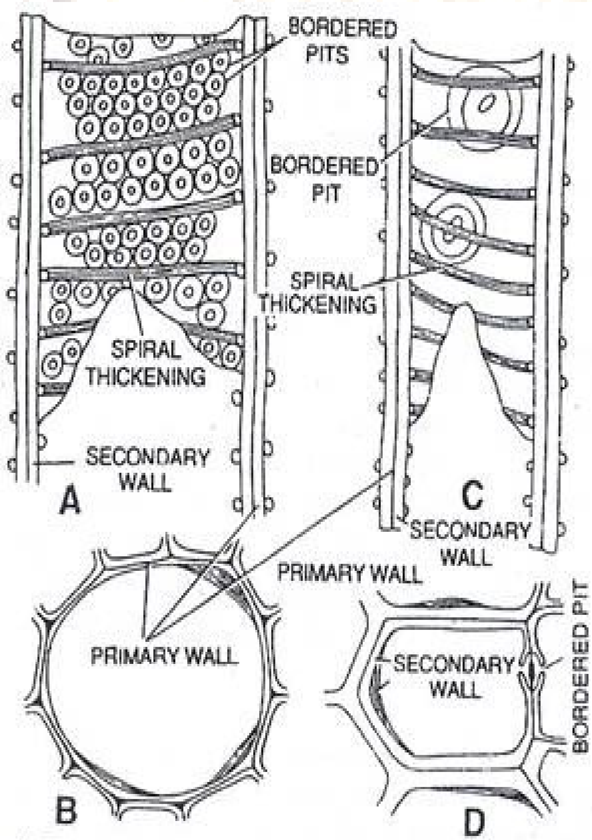


Fig. 34.6 The cell wall. This figure shows the primary wall and secondary wall with tertiary spirals. A and B, L.S. and T.S. of vessel of *Tilia;* C and D, L.S. and T.S. of tracheid of *Taxus* (a gymnosperm).

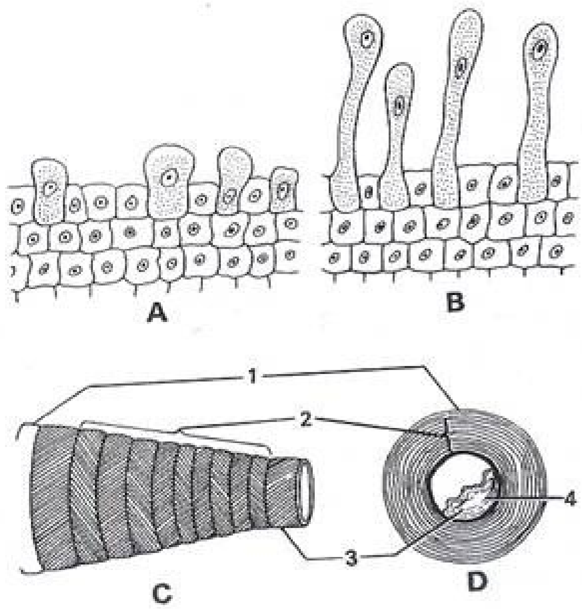


Fig. 34.7. Structure and growth of cotton fibre. A, outer layer of cells of young cotton seed showing the beginning enlargement of the fibre on the day of flowering; B, same after 24 hours, C, diagram of the various layers of the cellulose laid down in a mature cotton fibre (1) outer primary wall (2) concentric inner layers revealing the different orientation of the cellulose in the secondary thickenings, (3) last inner layer of the secondary wall, (4) remains of cell contents.

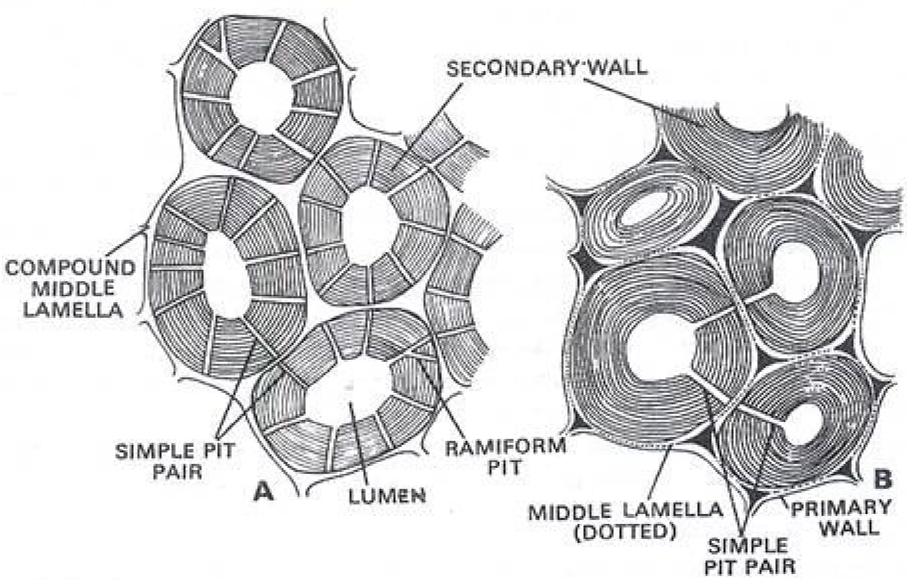
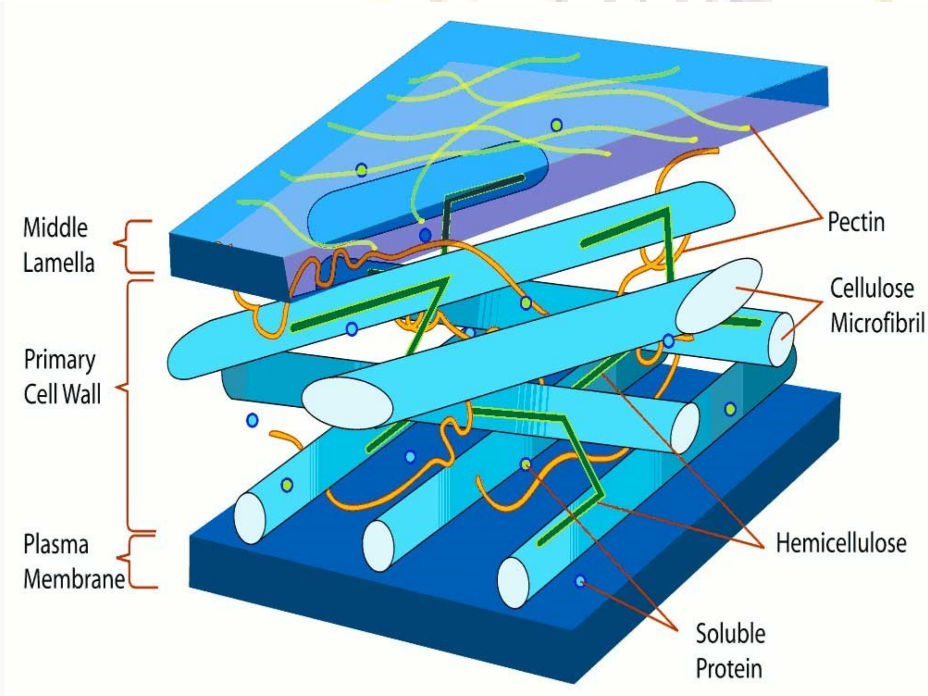


Fig. 34.8. The cell wall. Secondary cell wall sclereids from a T.S. of *Cydonia* fruit; B, phloem fibres from a transection of *Nicotiana* stem.

Microscopic and Sub microscopic Structure of Cell Walls – Explained!

The chemical substances of cell walls remain combined physically and chemically with each other. Several physical and chemical methods have been employed for such investigations. At first the secondary wall was the main object of study, but with the refinement of methods the primary wall has been also investigated successfully.



The significance of the study of primary walls is that it yields information on the methods of growth of cell walls in surface area. Investigators combine observations on differential staining; differential solubilities; coarse and fine structure variations; reaction to polarized and fluorescent light, to X-rays, and to dark-field illumination; refractive indices; and composition of ash. In modern days, the electron microscope is the main tool for the study of cell walls.

Micellar and Intermicellar Systems:

The organization of the structure of the cell walls is based on cellulose. The fundamental units of the system are the chain-like cellulose molecules of different lengths. These chains are not dispersed at random but occur in aggregates and generally known as micelles. The chain molecules possess a parallel arrangement in a micelle and the glucose residues within a chain are spaced at uniform distances from each other.

Thus, a bundle of cellulose molecules, the micelle, may be compared to a crystal in that its units are arranged symmetrically. This way, the bundles of cellulose molecules are interconnected by means of the lower chain molecules and from a porous coherent system, the Micellar system, interpenetrated by an equally coherent intermicellar system in which various wall substances other than the cellulose are present.

Frey Wyssling (1959) graphically described these structural elements and their interrelations on the basis of the secondary wall of the fibre of Boehmeria. Here one cellulose molecule is 8 A wide. Cellulose molecules are combined into an elementary microfibril which has a widest diameter of 100 A and is discernible with the electron microscope. It contains 100 cellulose molecules in a transverse section. Both the cellulose molecules and the elementary fibrils are ribbon like structures.

Elementary fibrils form a bundle known as microfibril which is 250 A wide and contains 2,000 cellulose molecules in a transverse section. Electron microscope studies on cell walls are connected mainly with this unit. Microfibrils are combined into macrofibrils 0.4 micron (|i) wide and containing 500,000 cellulose molecules in transverse section. Finally, 2,000,000,000 cellulose molecules make up a transverse section of the secondary wall of the fibre.

Microfibrillar and Microcapillary Structure:

As mentioned earlier the cellulose of plant cell walls is being interpreted as a combination of two interpenetrating systems, the Micellar and the intermicellar. They are submicroscopic. The walls contain a porous matrix of cellulose consisting of very fine coalesced fibrils, the microfibrils and an interfibrillar system of microcapillaries containing various noncellulosic wall constituents.

However, within the microfibrils the micelles and consequently also the chain molecules occur approximately parallel to the long axis of the fibrils. The microcapillaries within the cellulose framework may contain liquids, waxes, lignin, cutin, hemicelluloses, suberin, pectic substances, other less common organic compounds, and even crystals and silica.

Microfibrillar Orientation in the Cell Wall:

In the three layered walls of certain vessels, tracheids and wood fibres the fibrillar orientations of the inner and outer layers vary between transverse and helical, the helices being of comparatively low pitch, and those of the central layer fluctuate between longitudinal and relatively steeply pitched helical. Characteristic patterns occur about the large bordered pits of the early wood tracheids.

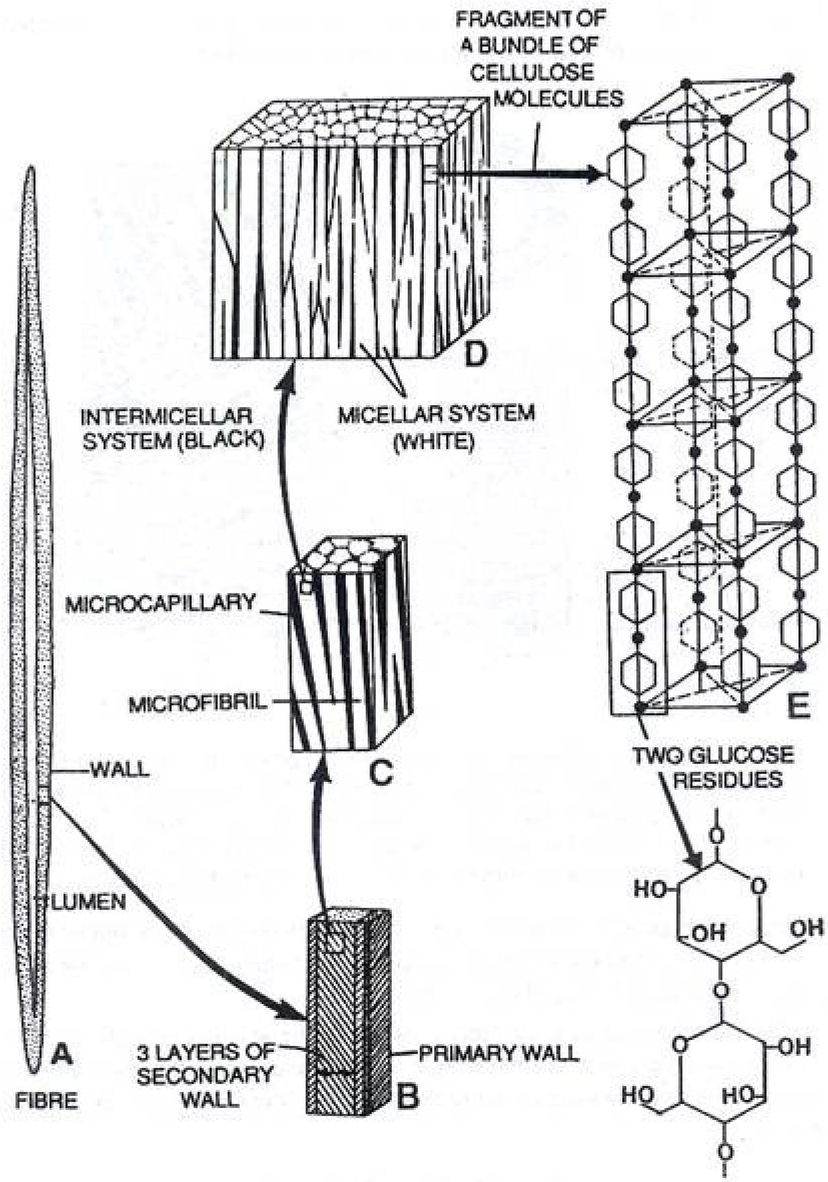


Fig. 34.18. Diagrams illustrating the common concept of microscopic and submicroscopic structure of secondary cellulose wall. Fibre (A) has a three layered secondary wall (B), In a fragment of the central layer of this wall (C), the microfibrils of cellulose (white), the other of micro capillaries (black) containing various noncellulosic wall materials. Microfibrils consist of inter micellar (black) and micellar (white) systems (D). The intermicellar system contains noncellulosic wall constituents, whereas the micellar system is composed of bundles of chain like cellulose molecules (E). The bundles of cellulose chains, the micelles, show an orderly arrangement of the glucose residues (F) that make the basic units of the cellulose molecules.

In the cotton fibre the bulk of the secondary wall consists of microfibrils oriented at an angle of 45 degrees and less with respect to the longitudinal axis of the fibre.

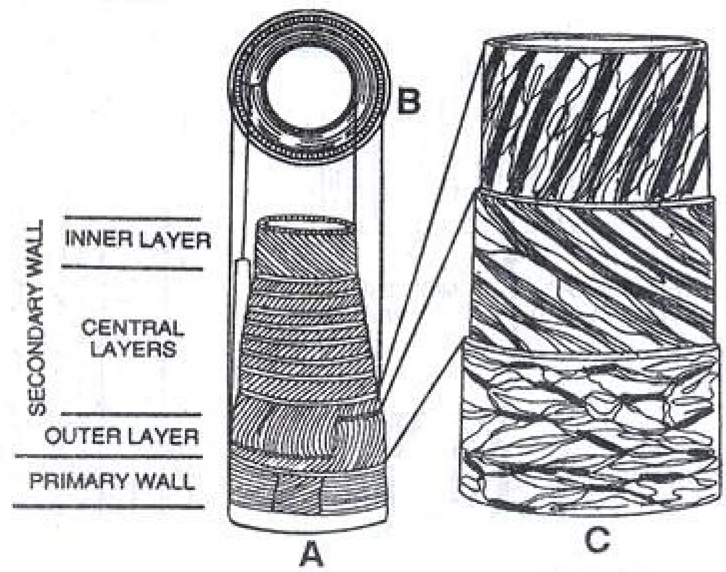


Fig. 34.19. Cotton fibre's wall structure. A, telescoped segment; B, T.S. of fibre showing spatial relation of the various layers and orientation of microfibrils; C, showing the primary wall with its reticulate microfibrillar structure the outer layer of the secondary wall combining a reticulate a parallel orientation of microfibrils, and the first central layer of secondary wall with predominantly parallel microfibrillar structure.

In the consecutive lamella of the flax fibre the helices are wound in opposite directions. In tracheary cells with annular and scalariform secondary thickenings the crystalline regions of these thickenings have a horizontal, ring-like orientation.

The pitch of the helices of microfibrils varies in the secondary walls of different cells. However, among the layers of the same wall, within a given layer the microfibrils are usually parallel to one another and always parallel to the surface of the cell. The secondary walls possess a parallel texture.