Cell wall

Cell: a cell may by defined as the basic structural and functional unit of a living organism;

A typically eukaryotic plant cell is composed of the following parts:

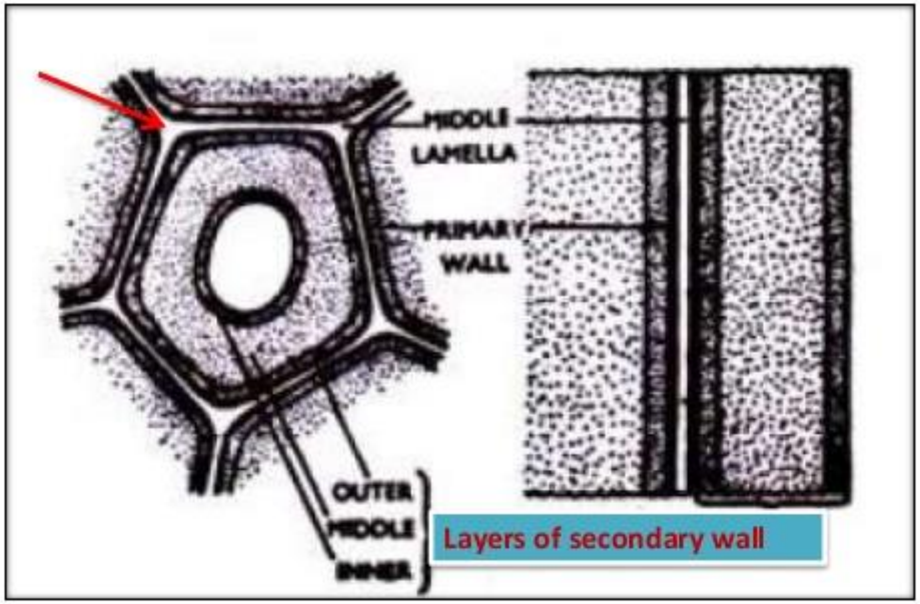
a) Cell wall and plasma membane;
b) Cytoplasm;
c) Nucleus

CELL WALL: The non-living outer boundary of a plant cell is called the cell wall.

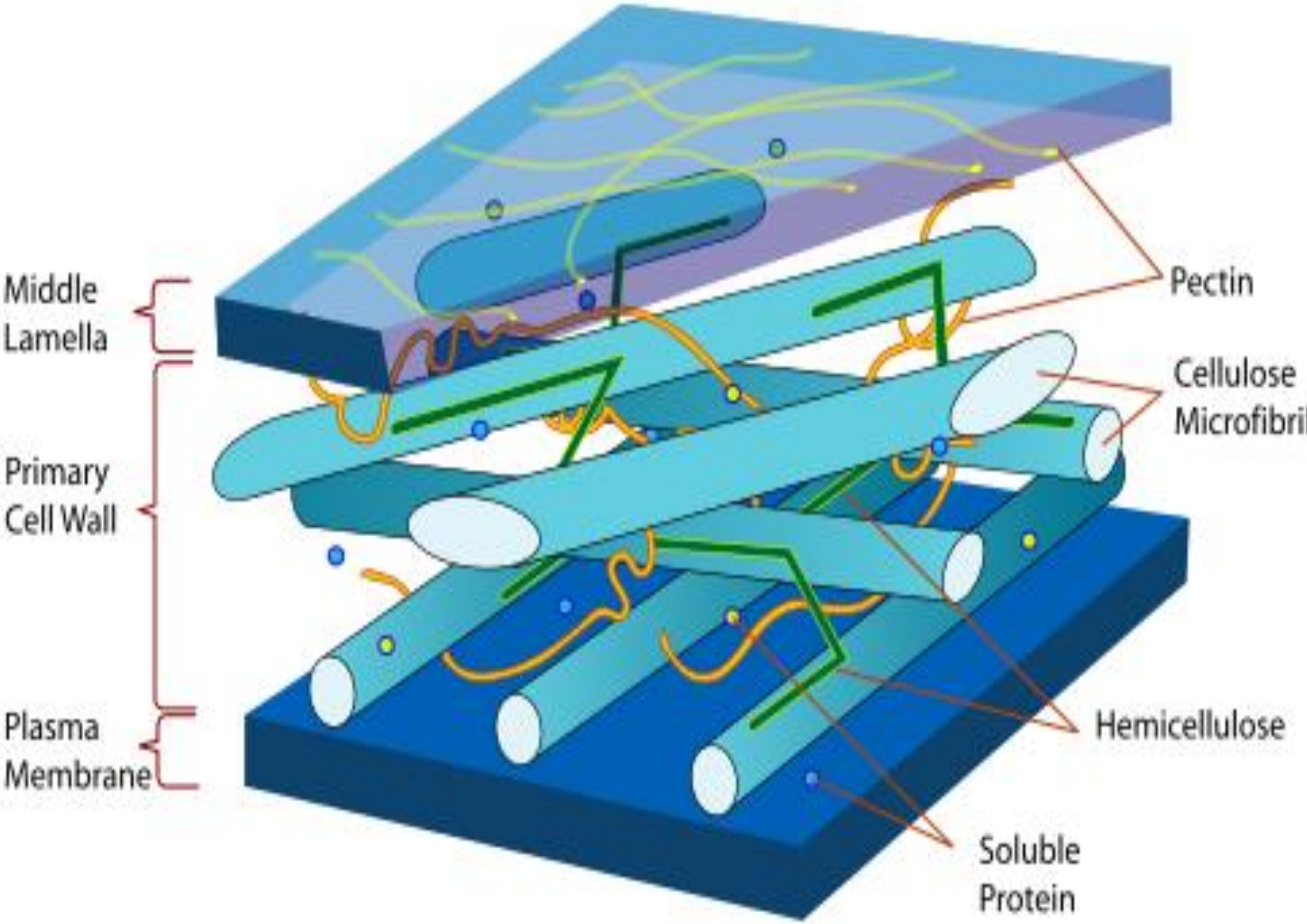
The cell wall is a semi-rigid, laminafied, external covering of the cell.

Composed of complex polysaccharide carbohydrate, the cellulose, lignin and many salts and fatty acid substances.

Cell wall

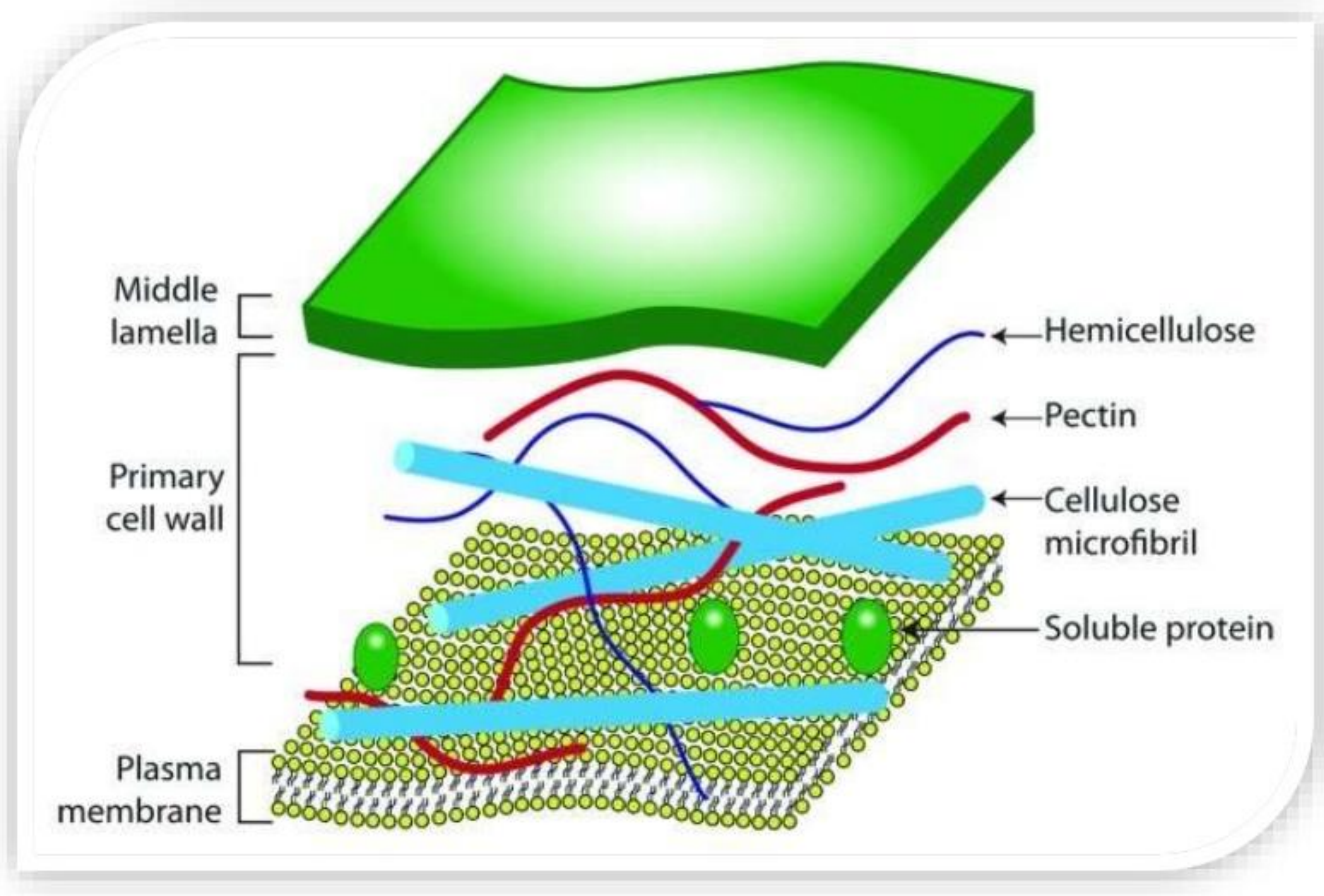


MIDDLE LAMELLA
PRIMARY WALL
OUTER
MIDDLE
INNER
Layers of secondary wall



Middle
Lamella
Primary
Cell Wall
Plasma
Membrane
Pectin
Cellulose
Microfibril
Hemicellulose
Soluble
Protein

Structure of primary call



Property:

- The cell wall serves a similar purpose in organisms that posses them
- .
- The wall gives cells rigidity and strength, offering protection against mechanical stress.

- The cell wall also limits the entry of large molecules that may be toxic to the cell

The middle lamella:

•It is common structure between adjacent cells and therefore, binds them with each other,

•It is an amorphuos layer and is composed of calcium and magnesium pectate,

•The middle lamella remains unlignified in case of softer living tissues namely parenchyma, collenchyma and arenchyma, but in woody tissues sclerenchyma it becomes highly lignified

Primary cell wall:

Chemical composition-consists of cellulose(45%),hemicellulose(25%),pectins(35%) and structural proteins(upto8%) on basis of dry weight

The backbone of the primary wall is formed by the cellulose fibrils.

The matrix is composed of hemicellulose, pectin, gums, tanins, resins, silica, waxesetc and small structural proteins.

Cellulose:
It has a very high molecular weight
It is linear polymers of glucose molecules

Cell wall ultrastructure:

Cell wall is biphasic structure-

a) Gel like non-cellulosic matrix and
b) microfibrillar phase

The microfibrillar phase consists of cellulose**(**β1-4-glucan**)** only and 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^{-9}m) in higher plants.

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).

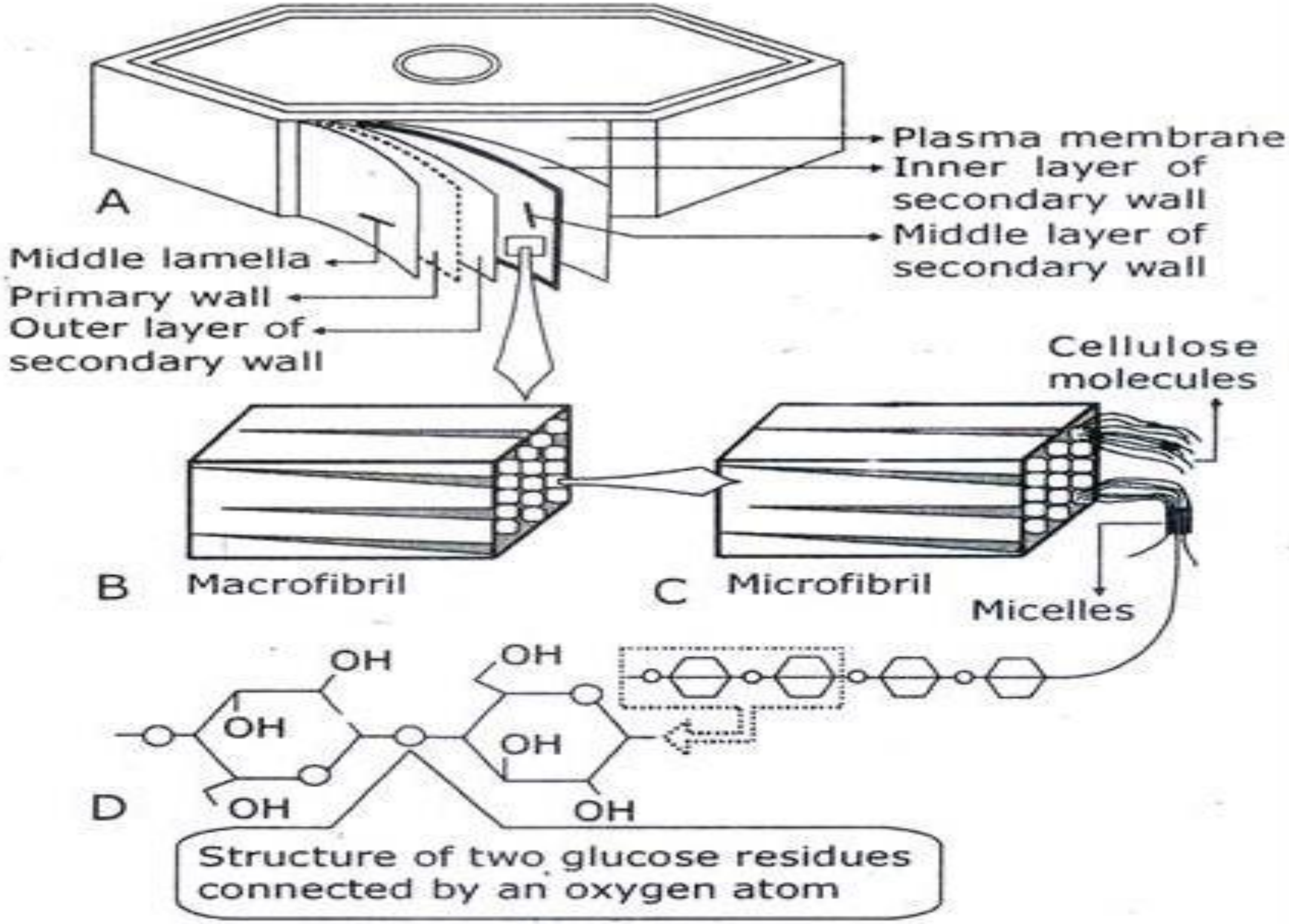


Figure 3.4

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 (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).

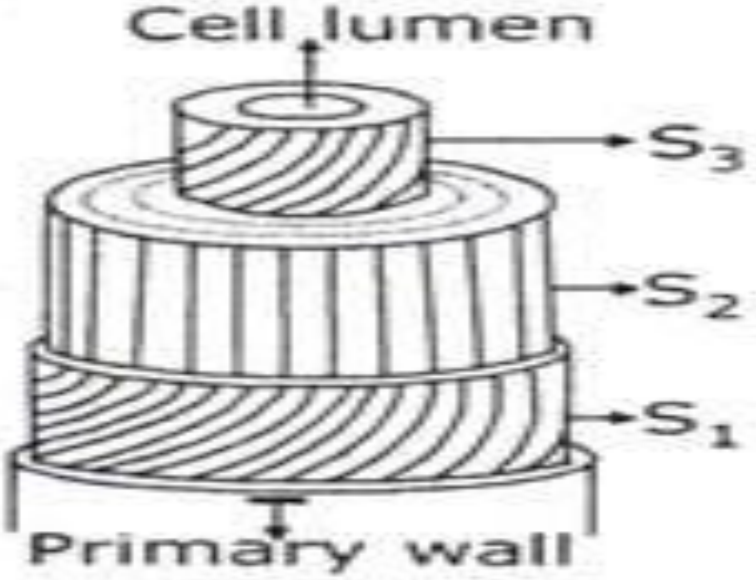


Figure 3.5

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.

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.

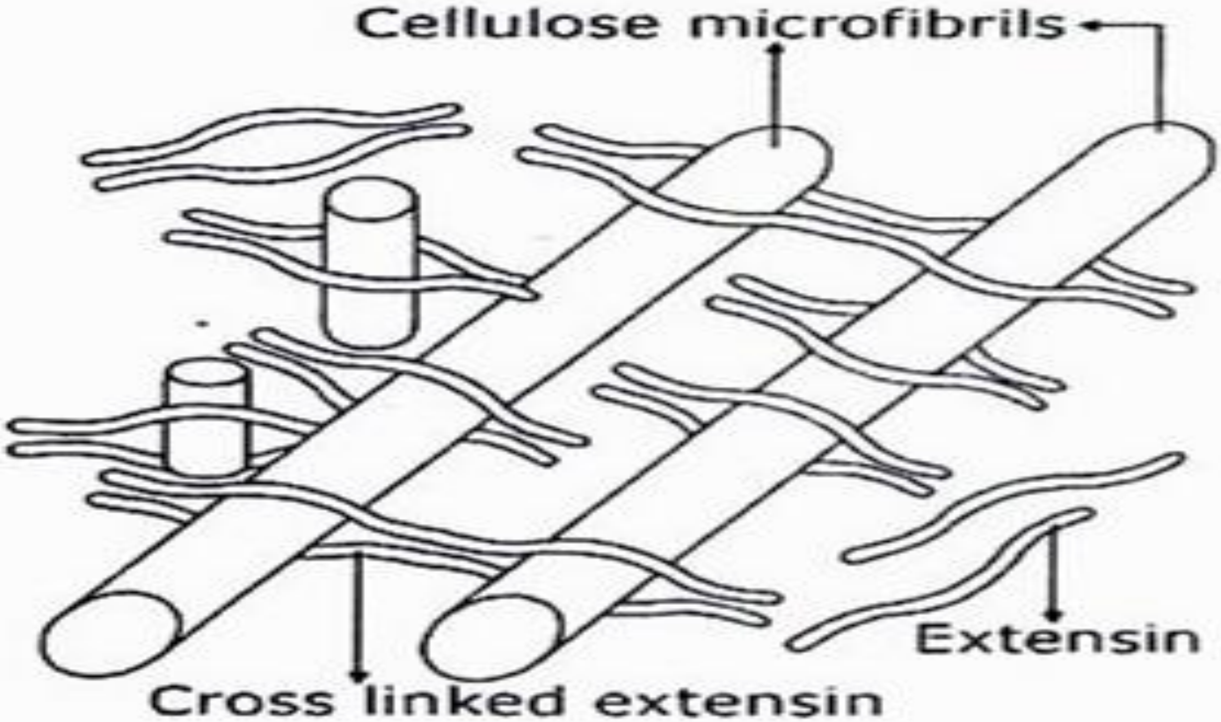


Figure 3.6

Diagram representing Lamport and Epstein model.

Chemical composition of cell wall:

The cell wall is mainly composed of carbohydrate rich materials. The major components of cell wall are cellulose, pectins, hemicelluloses, proteins and phenolics. The cell wall is a biphasic structure consisting of relatively rigid cellulosic microfibril embedded in gel-like non-cellulosic matrix.

The microfibrillar phase consists of only cellulose (β1, 4-glucan) and the matrix is composed of non-cellulosic polysaccharides and other substances, which include pectins, hemicelluloses, proteins and phenolics.

The microfibrillar phase is readily visible in Electron Microscope and is crystalline, i.e. its molecules are arranged in a definite way and the matrix is non-crystalline. Moreover, it is relatively homogeneous in chemical composition than matrix.

i. Cellulose:

It provides shape and strength to the cell wall. It composes 20-30% of the dry weight of primary wall and accounts 40-90% of the dry weight of secondary wall. Cellulose is an unbranched β1, 4-glucan. The microfibrils are made up of cellulose molecules. It is clear from x-ray diffraction and chemical studies that the bulk of microfibril is made up of crystalline β1, 4-glucan.

ii. Pectins:

These are a group of polysaccharides, which are rich in galacturonic acid, rhamnose, arabinose and galactose. The other pectin polysaccharides are arabinan, galactan, arabinogalactan I and homogalacturonan. Pectic polysaccharides may be linked covalently to cellulose, proteins and phenols. Pectins are present in much larger amount in primary walls than the secondary walls, suggesting a role in growth.

They are highly hydrophilic polysaccharides, and the water that they introduce into the matrix may loosen the wall enabling the cellulose microfibrils to separate — necessary for wall expansion. Pectins are present in high concentration in the middle lamella where they presumably serve the function of cementing adjacent cells together.

iii. Gum:

It is the collective term of the disintegration products of the cell wall carbohydrate especially of starch. Gums are colloidal plant products, which either dissolve or swell in water.

They are related to pectic compounds and on hydrolysis give pentoses, hexoses and complex organic acids. Gums appear as a result of breakdown of walls, which are often caused by physiological or pathological disturbances, diseases, insect or mechanical injury.

iv. Mucilages:

It is the polymer of galactan and related to pectic compounds. Mucilages are found in seed coats and outer cell layers of plant bodies of many aquatic plants. They apparently increase the water holding capacity of the wall.

v. Hemicelluloses:

These are matrix polysaccharides built up of a variety of different sugars. They differ in different species and in different cell types.

The principal hemicelluloses are the followings:

Xylan: It typically makes up roughly 5% of primary cell wall and 20% of secondary wall in dicots. This hemicellulosic polysaccharide is linked with xylose and arabinose. Other sugars may also be present.

The primary wall of dicotyledonous cells contains glucuronic acid and arabinose. In dicots, the secondary walls contain glucuronoxylan as hemicellulose with small amount of arabinose. The secondary walls of monocot cells also contain arabinoxylan with more glucuronic acid.

Glucomannan:

This polysaccharide forms the major hemicellulose of secondary wall of gymnosperm and angiospermous cells. It contains glucose and mannose in a ratio of approximately 1: 3.

Mannan and Galactomannan:

These hemicellulosic polysaccharides are found in the walls of endosperm. These cells function as food reserves.

vi. Glucuronomannan:

This polysaccharide is found in low proportion in the cell walls. It contains mannose, glucuronic acid, xylose and arabinose.

vii. Xyloglucan:

It is storage polysaccharide. Xyloses are the major components of the thick storage walls of some seeds, e.g. Nasturtium and tamarind. They typically make up about 20% of the primary cell walls of dicots, and one to five percent of the primary walls of grasses. They appear to be absent from most secondary walls.

Xyloglucans have a backbone identical with cellulose. Xyloglucans contain glucose and xylose residues. Some xyloses are substituted by fucose, galactose and arabinose. Fucose is absent from the storage polysaccharides of endosperm cell walls.

viii. Callose:

It normally occurs in small amounts in healthy cell walls, where it has been suggested to form a thin layer between the plasma membrane and the wall proper.

It is also found lining the sieve pores of sieve tubes, microfibrils of pollen tube walls and secondary walls of cotton fibres. Callose may be formed on the surface of protoplasts in response to wounding or on the surface of stigma in response to incompatible pollen. Callose is β1, 3-linked glucan.

ix. β1, 3, β1, 4-glucan:

This hemicellulose polysaccharide is found in the cell wall component of barley, cereals and other grasses.

Arabinogalactan II:

This polysaccharide is found in the walls of gymnospermous cells.

x. Proteins:

Different varieties of protein are present in the cell wall, most of which are linked with carbohydrate forming glycoprotein. The cell wall glycoprotein extensin contains an unusual aminoacid hydroxyproline (about 40%), which is generally absent from the protoplast. In addition to hydroxyproline valine, tyrosine, serine and lysine are present in large amounts.

In addition to above glycoproteins, the following enzyme proteins are present in the cell wall: invertase, peroxidase, pectinase, cellulase, pectin methylesterase, acid phosphatase and malate dehydrogenase.

xi. Lignin and Other Phenolic Compounds:

Lignin is the cell wall component of sclerenchyma, which includes fibres and sclereids. It is also found in the tracheids and vessels of xylem. In some cells, lignin deposits in response to attack of microorganisms.

xii. Cutin:

It is present in the epidermal walls of roots, root hairs, stems and leaves. It may be found in growing walls also. It is indigestible polymer and composed of polyester of hydroxy-fatty acids. Cutinized walls and cuticle contain the phenol — ferulic acid.

xiii. Suberin:

It is found in the cell walls of seed coats, cork and casparian strips of endodermis. In contrast to cutin, it contains more phenolic materials.

xiv. Tannin:

It is present in condensed form. Tannins of the proanthocyanidin type seem to be linked to polysaccharides. It is not known whether the walls of living cells contain tannins.

xv. Wax:

It is a fatty substance and occurs in and upon the cell wall. It is usually noted on the surfaces of leaves and fruits. It may occur either above or below the surface of cuticle. It may be present within cutin also.

xvi. Mineral Substances:

Mineral substances like silica and calcium carbonate may deposit on cell wall. Silica is commonly noted in the epidermal walls of Equisetum, leaves of grasses etc.

In conclusion, it can be stated that the cell wall can be visualized as a network of polymer, which on superimposition forms the overall complex structure.

Refenceses:
https://en.m.Wikipedia.org/cellwall.
https://sciencing.com