Chemical composition of the 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:

1) relatively **rigid cellulosic microfibril** consisting of only cellulose (β1, 4-glucan)
2) **gel-like non-cellulosic matrix** composed of non-cellulosic polysaccharides and pectins, hemicelluloses, proteins and phenolics.

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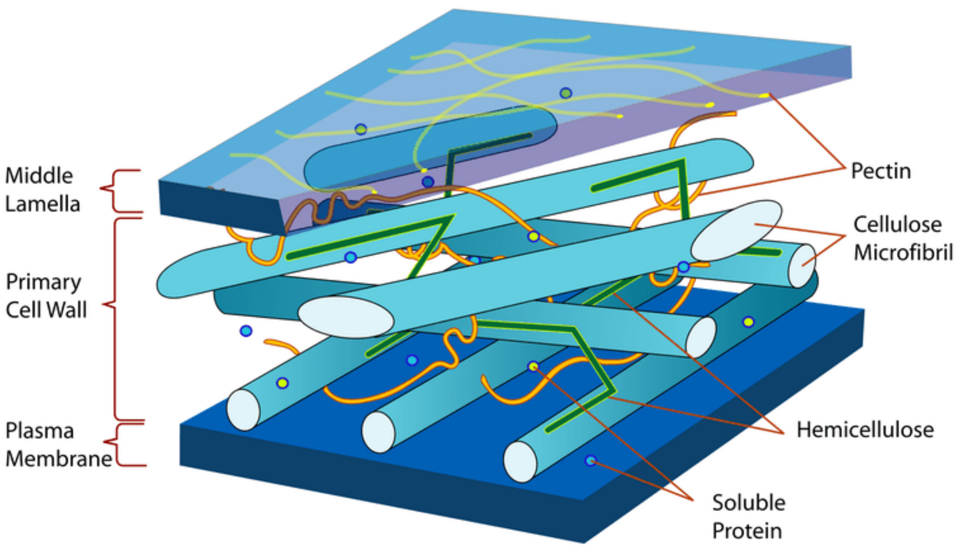
The rigid cellulose microfibrils are embedded in the gel like matrix and readily visible in Electron Microscope. The microfibrillar phase is crystalline (its molecules are arranged in a definite way) and relatively homogeneous in chemical composition. Matrix is non-crystalline and non homogeneous in chemical composition compared to microfibrils.



- **Cellulose:**

The microfibrils are long, thin structure with oval or circular in cross section and have uniform width of about 10 nm (1 nm = 10^{-9}m) in higher plants. The cellulose molecules consist of long chain of linked glucose residues. It is a polymeric carbohydrate with the general formula $(C_6H_{10}O_5)n$. The glucose residues $C_6H_{10}O_5$ are linked together with oxygen atoms.

There are at least 8000 to 15,000 glucose monomers per cellulose molecule. The microfibrils are aggregated to form macrofibrils that are composed of about 500,000 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.

Matrix

The non-crystalline and non-cellulosic phase of cell wall is the matrix. It is made up of polysaccharides, proteins and phenolic compounds whose composition differs in different species, in different types of cells, in different parts of cell wall and even at different stages of the cell growth.

The matrix polysaccharides are partitioned into two classes:

1) pectin and
2) hemicellulose.

Growing primary wall contains about 65% water, almost of which is in the matrix. Water is an important structural component of the matrix.

- **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, rhamnogalacturonan. 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.

- **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.

- **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.

- **Hemicelluloses:**

They are flexible polysaccharides that characteristically bind to the surface of cellulose. These matrix polysaccharides are **branched and built up of different types of sugars**. They differ in different species and in different cell types.

The principal hemicelluloses are the followings:

a) **Xylan** (polymer of xylose)**:**
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.

b) **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.

c) **Mannan and Galactomannan**):

Mannan consists of mannose in the backbone and galactomannan is a polymer containing galactose and mannose in the backbone. These hemicellulosic polysaccharides are found in the walls of endosperm. These cells function as food reserves.

d) Glucuronomannan:

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

e) Xyloglucan:

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.
It is storage polysaccharide. Xyloses are the major components of the thick storage walls of some seeds, e.g. Nasturtium and tamarind. They may be present in some primary walls but appear to be absent from most secondary walls.

f) Callose:

Callose is β1, 3-Iinked glucan. 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.

g) β1, 3, β1, 4-glucan:

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

h) **Arabinogalactan II:**

This polysaccharide is found in the walls of gymnospermous cells.

- **Proteins:**

Different types of protein are present in the cell wall, linked with carbohydrate, forming glycoprotein. The cell wall glycoprotein extensin contains an unusual aminoacid hydroxyproline (about 40%), generally absent from the protoplast. In addition to hydroxyproline valine, tyrosine, serine and lysine are present in large amounts. Histidine is also found in some extensins. Extensins are present in the primary cell walls of dicots while secondary walls are devoid of extensins.
The control of cell extensibility is attributed to wall proteins and accordingly these proteins are named as extensin. It regulates the orientation of cellulose microfibrils, forms the skeletal construction and controls the growth of cell wall. It also resists the invading pathogens.
Arabinogalactan-proteins are another protein component of the cell wall. The protein portion contains a high proportion of hydroxyproline, serine, alanine and glycine.

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.

- **Phenolic Compounds:**

a) Lignin

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.

Lignin is a phenolic polymer and contains **three subunits** namely-**coumaryl, guiacyl and sinapyl-propane**. Cell wall lignin of monocots contains all the three subunits more or less in equal amounts. The dicots contain about equal amount of guiacyl and sinapyl-propane subunits in their cell wall lignin while in gymnosperm guiacyl subunits predominate.

Wood contains about 30% lignin.

Lignin deposits to fill up the spaces present between the macromolecules of cell walls. Thus, it cements the wall components and forms a very strong structure. As a result, the cell wall loses the capability of plastic extension and hence growth ceases. Moreover, lignified walls form a waterproof system of xylem and resist the pathogens. It forms the mechanical cells of plants.

b) Cutin:

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

c) 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.

- **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.

- **Wax:**

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

- **Mineral Substances:**

Mineral substances like silica and calcium carbonate may deposit on cell wall. Silica is present 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.

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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