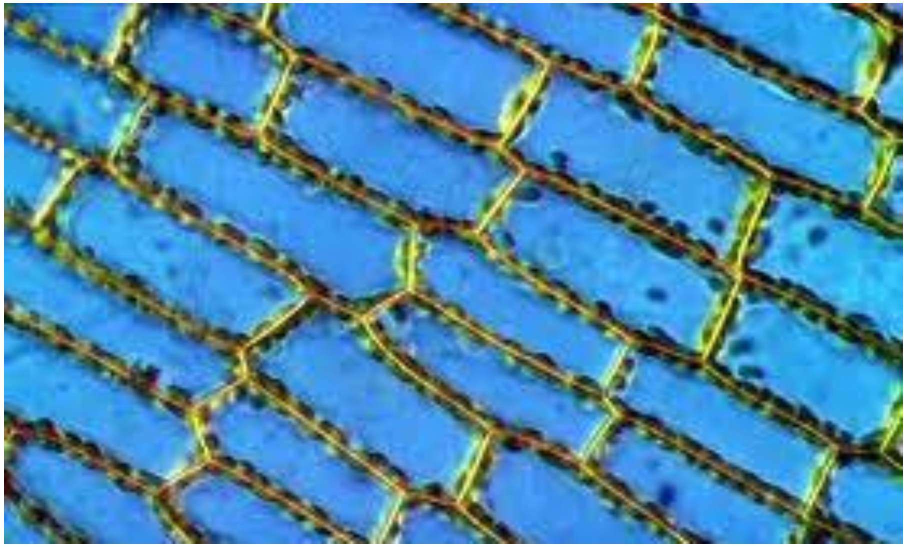
Chapter 1. Part III

The cell wall (or Pectocellulosic wall)

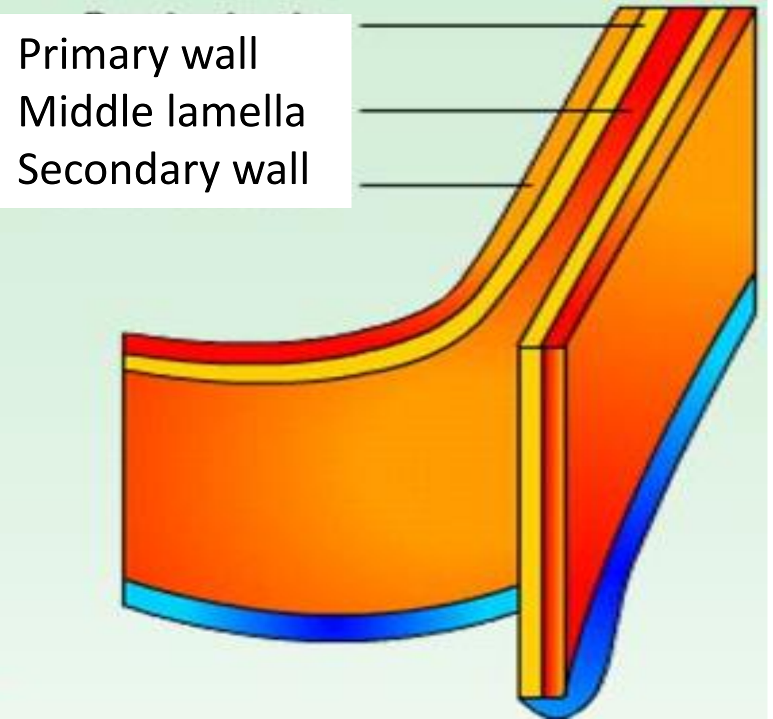
I. The plant cell

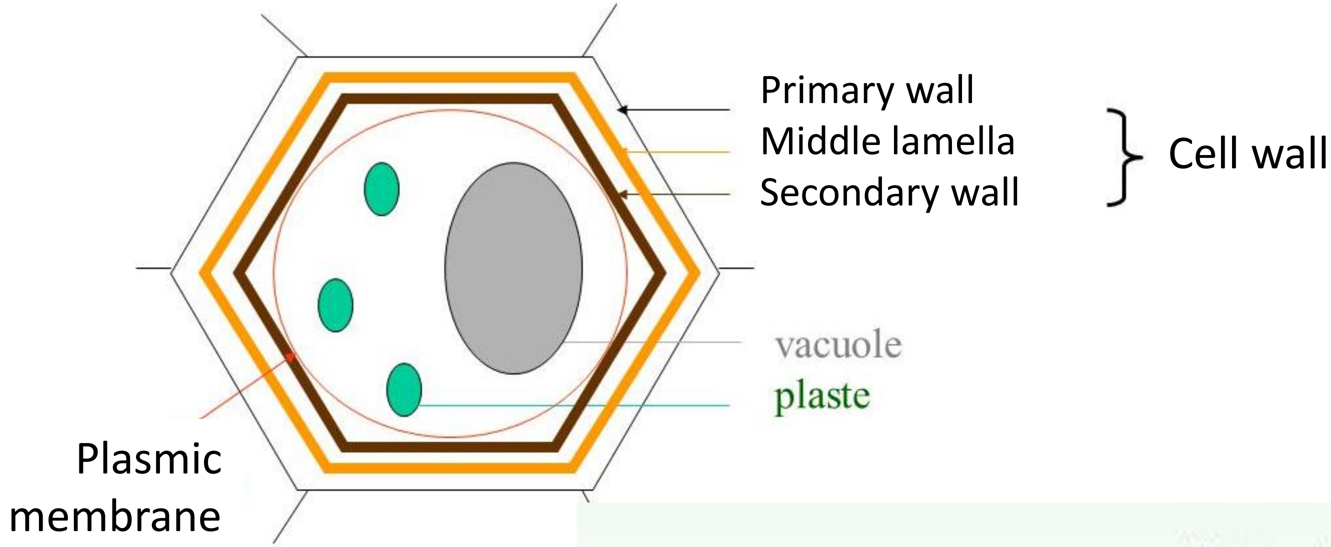
The cell wall is the external skeleton of plant cells.



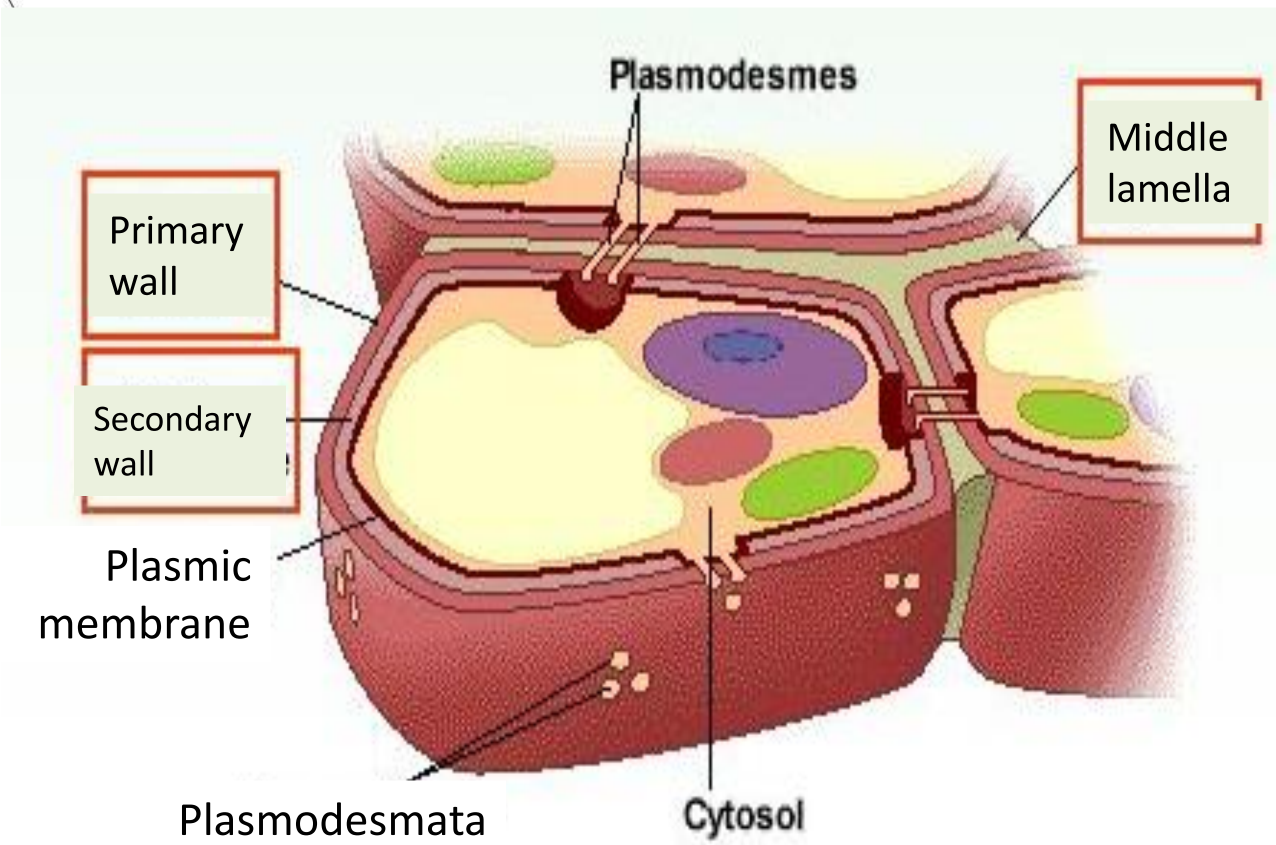
The cell wall

- The **cell wall** provides rigidity and support to the cell;
- All plant cells have a thin, flexible **primary cell wall**;
- At maturity, many cells produce a thicker, more rigid **secondary wall**;
- Cells are glued together to each other by **the middle lamella** rich in pectin.





Primary wall
Middle lamella
Secondary wall
Cell wall
vacuole
plaste
Plasmic membrane



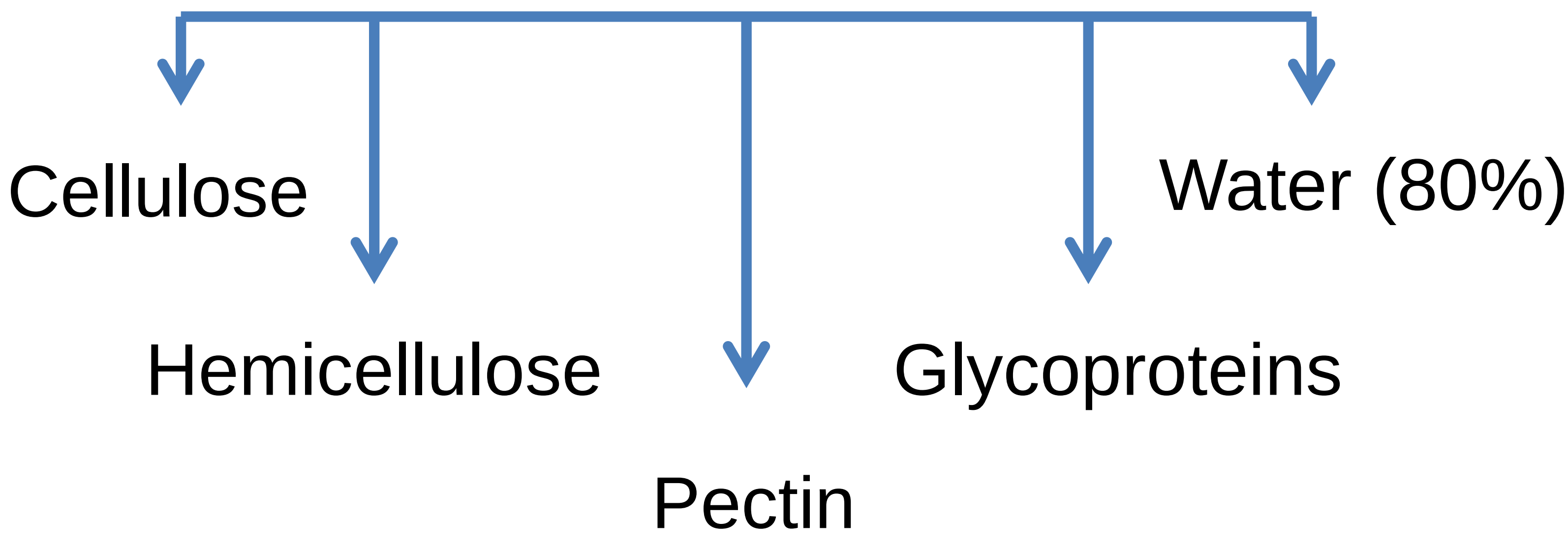
Plasmodesmes
Middle lamella
Primary wall
Secondary wall
Plasmic membrane
Plasmodesmata
Cytosol

1. The middle lamella

- It is formed at first and is made up of **pectic matter**. The cells are stuck together by the **middle lamella**. This cement, located on the outer region of the wall, allows the cells to join together to form tissues. It is a layer that separates two plant cells.

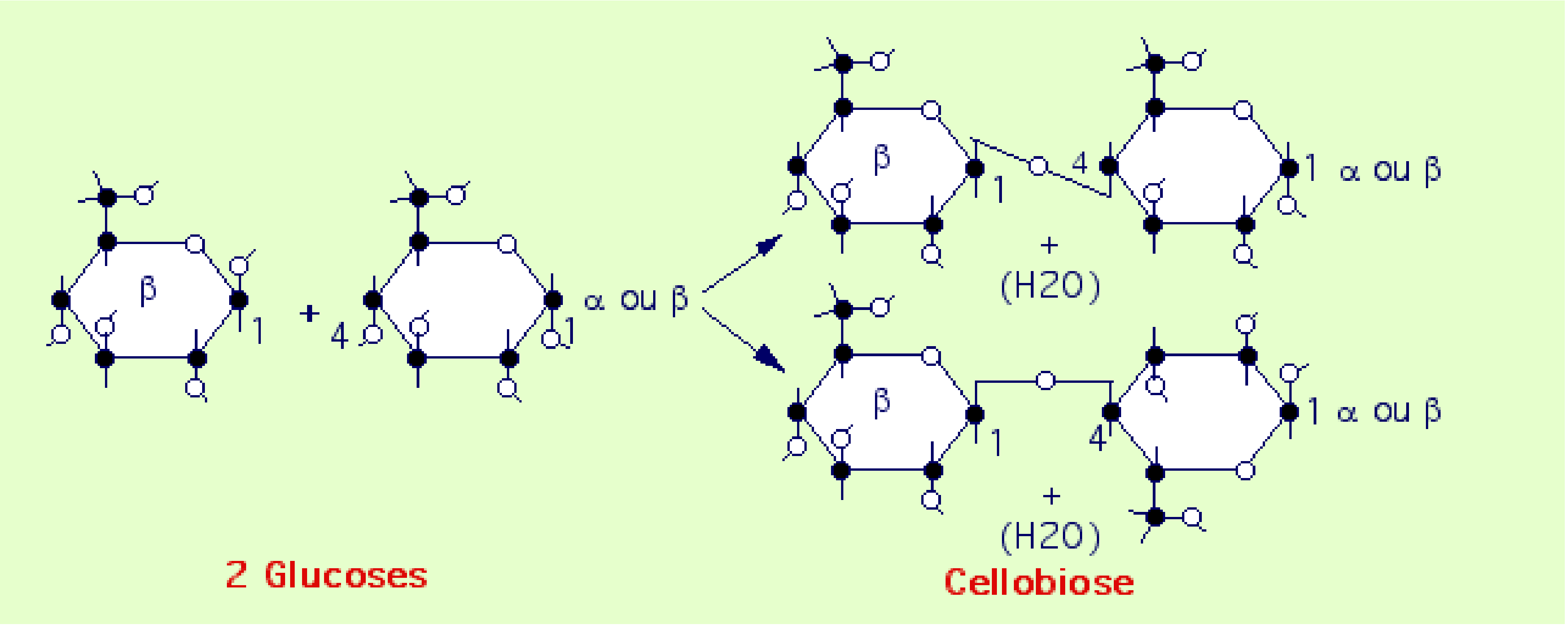
2. The first wall

It is **pectocellulosic** in nature and is found alone in juvenile cells. It is extensible, which allows cell growth (elongation).



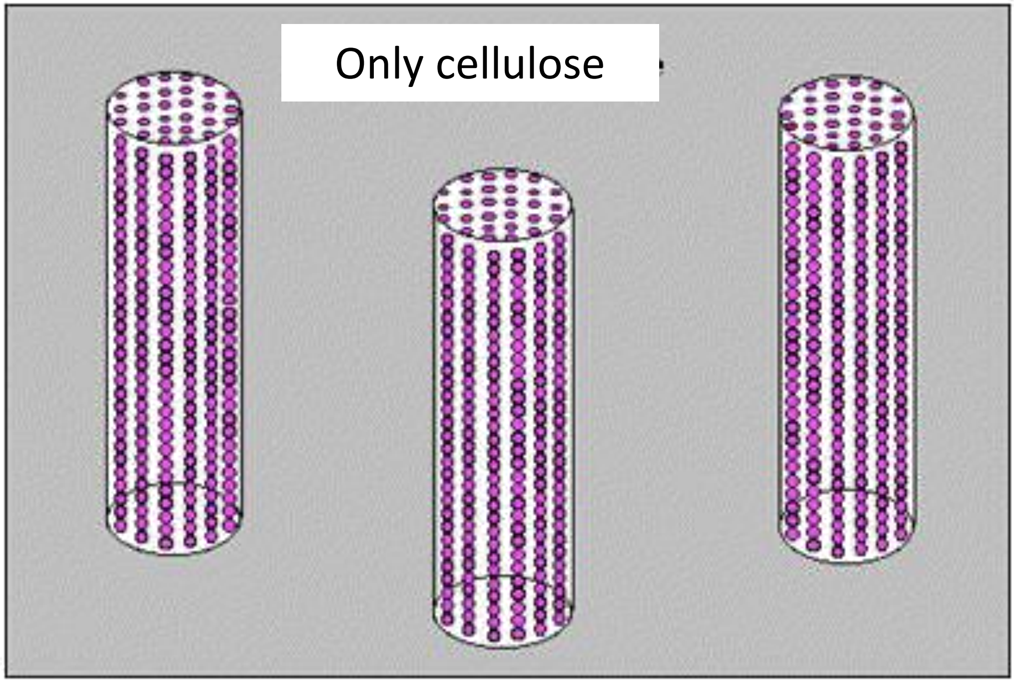
- *The cellulose*

Homopolysaccharide composed of glucose chains linked together by B-1-4 glycosidic bonds.



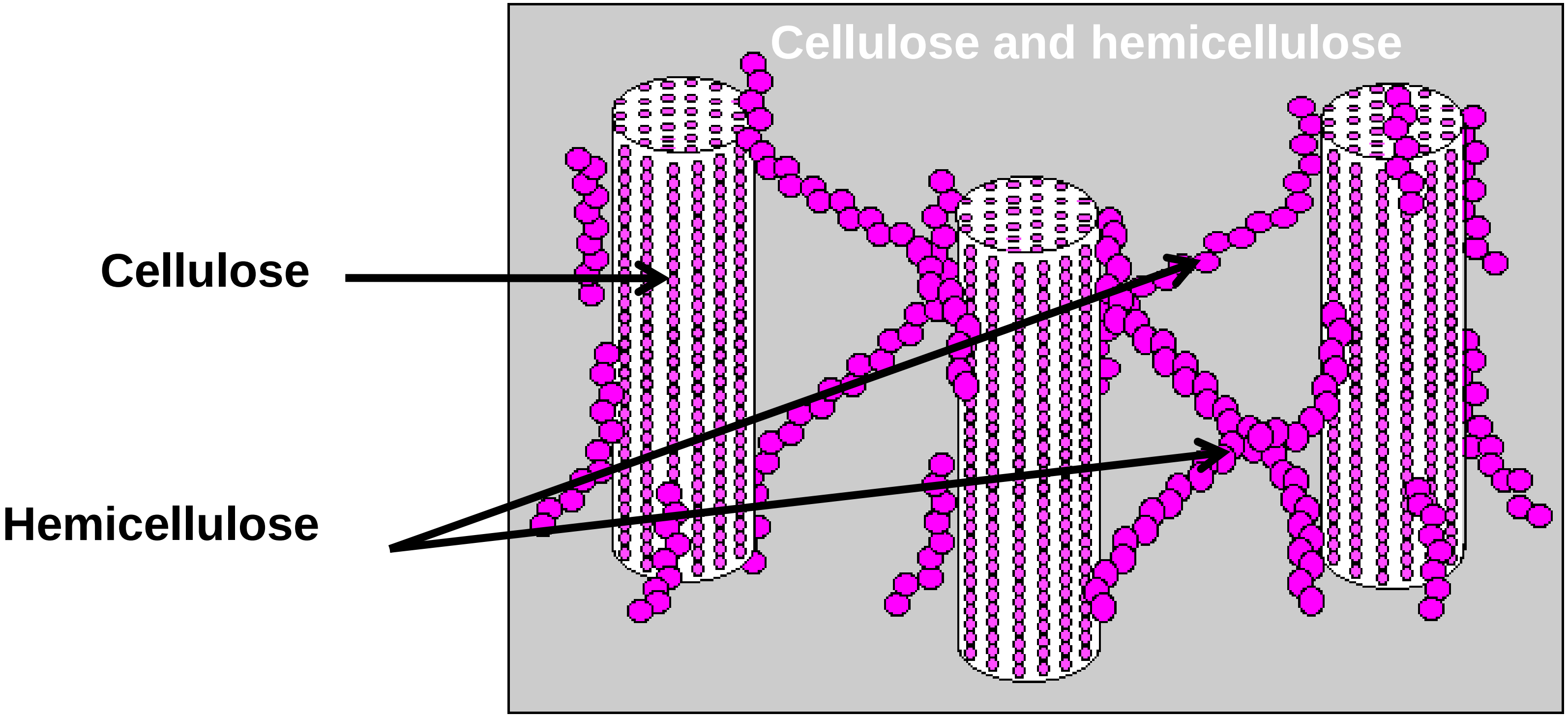
The **primary walls** contain cellulose molecules. These cellulose molecules (beta glucose chains) are associated in the form of microfibrils.

Cellulose microfibrils form the framework of the primary cell wall. They are held together by a matrix of pectins and hemicellulose.



- Hemicellulose

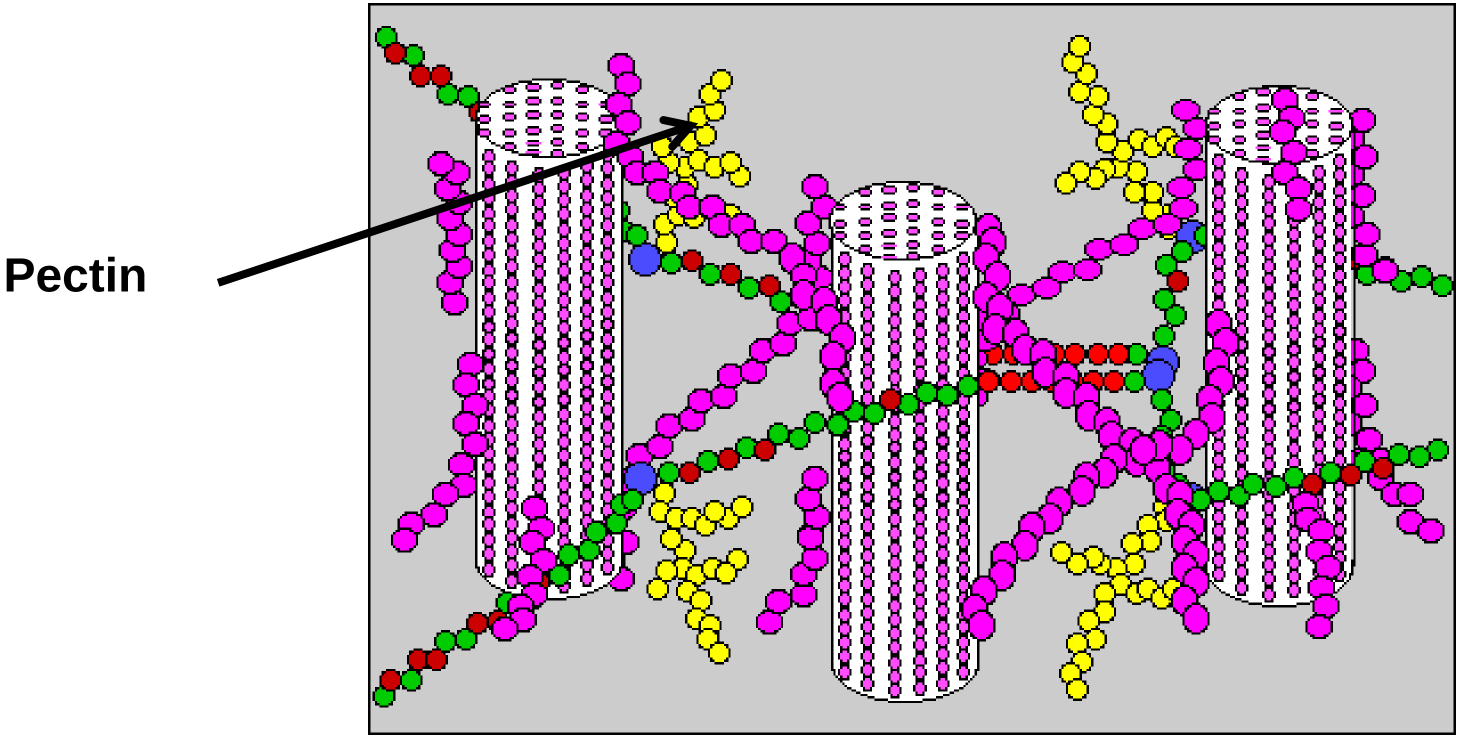
Hemicellulose can form H-bonds with cellulose. They play a fundamental role in maintaining an organised parietal architecture by binding the cellulose fibrils together.



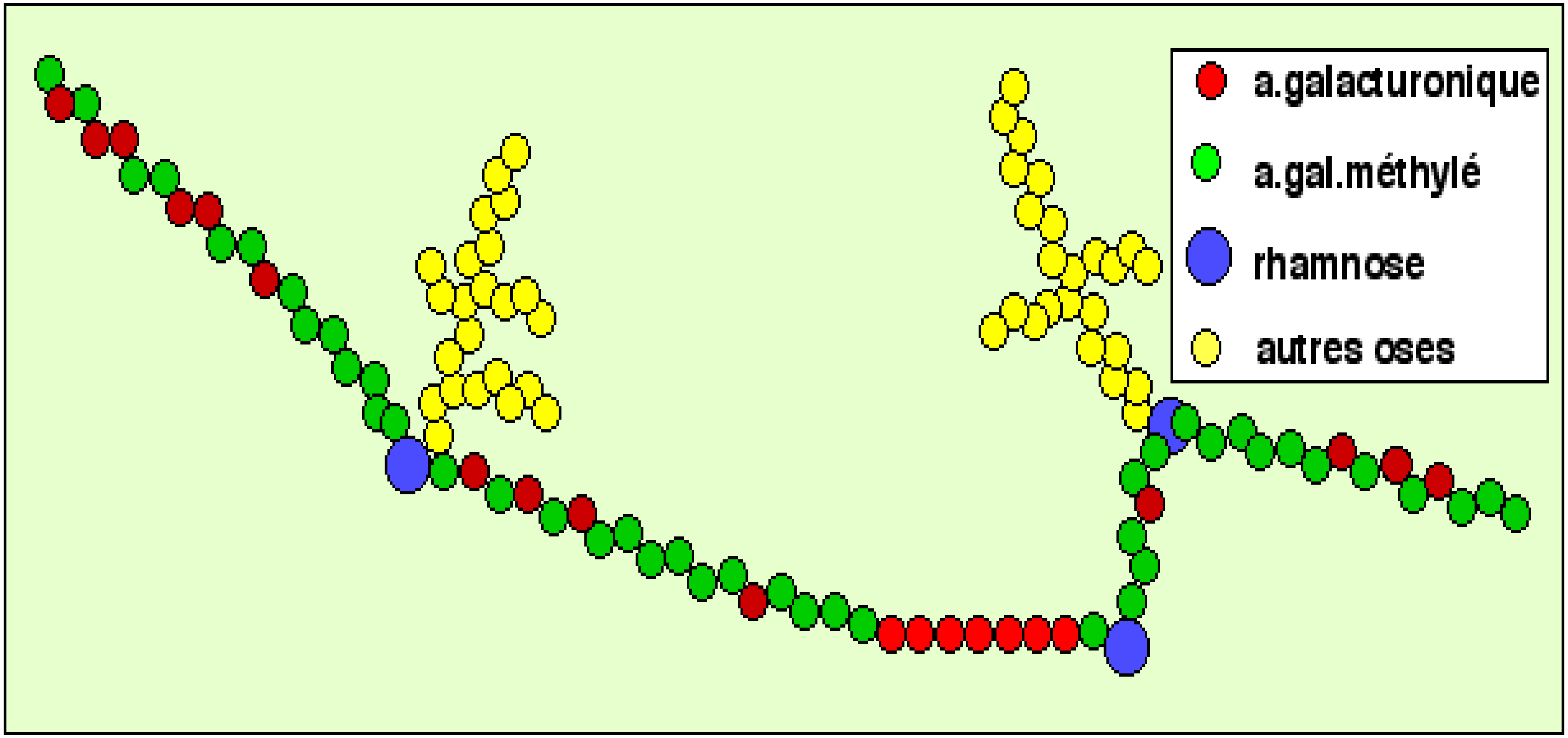
- Pectins or pectic compounds

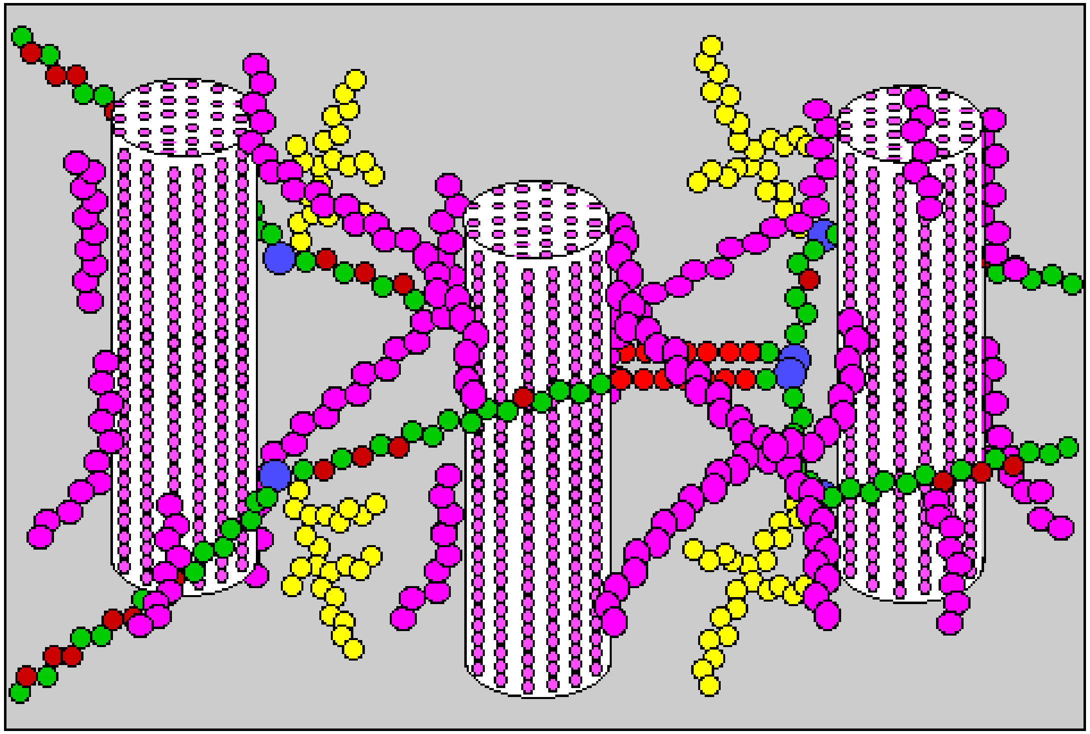
Pectins are a complex set of macromolecules. Pectins increase the complexity of the matrix.

Cellulose, hemicellulose and pectin



Pectins : The main chain is made up of galacturonic acid and rhamnose. The side chains form branches.





Cellulose, hemicelluloses and pectins

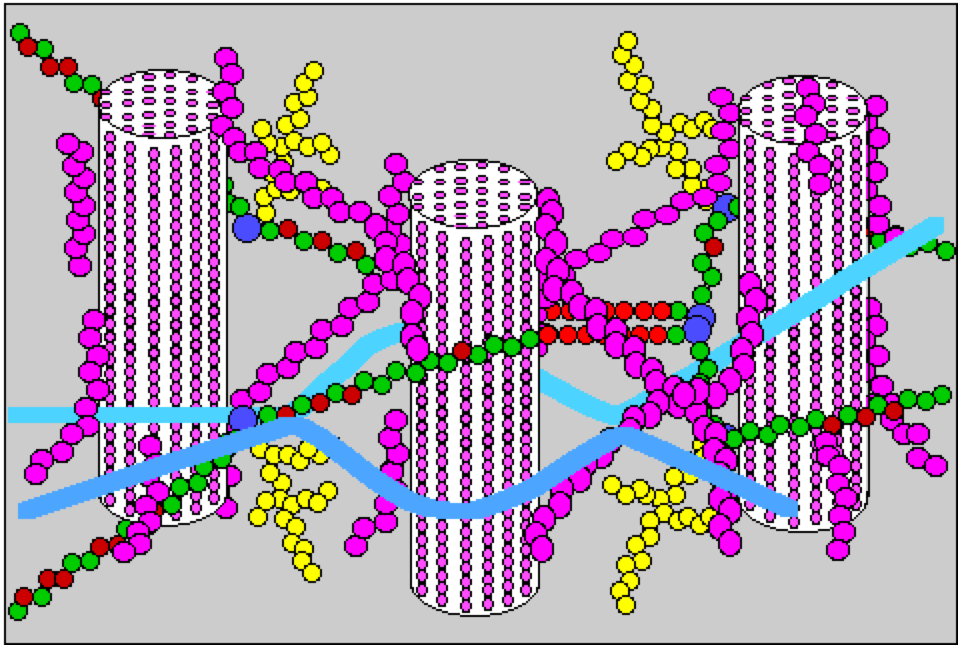
An additional network of pectins increases the complexity of the matrix.

- The glycoproteins

- The **HRGP network** acts as a stabilising element by consolidating the fibrillar network of the wall (cellulose).

- It blocks the plasticity properties of the polysaccharide network of the plant wall.

At the end of growth, the protein network can stiffen (become more rigid) the matrix by creating a secondary network.



- *Water*

- The polysaccharide constituents are hydrophilic and the cell wall contains a very high percentage of water (80%).

- When the **younger is the cell**, the more water it contained.

3. The secondary wall

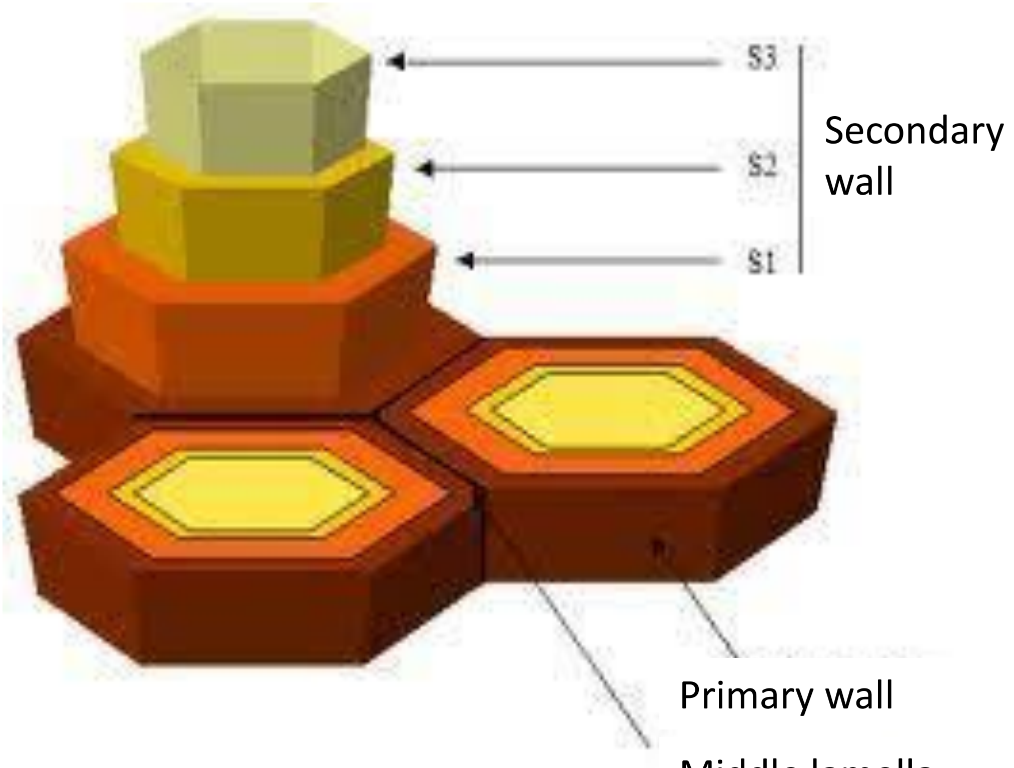
- It is located between the cytoplasmic membrane and the primary wall.
- It has the same composition as the primary wall, but in different proportions :

  - Richer in cellulose;

  - Lower in water and hemicellulose;

  - Lacking pectins and glycoproteins.

The cellulose microfibrils are arranged in a regular pattern. These microfibrils have been arranged in successive strata in which the direction of orientation changes abruptly from one stratum to the next.



II. Exchanges between cells

Intercellular communication

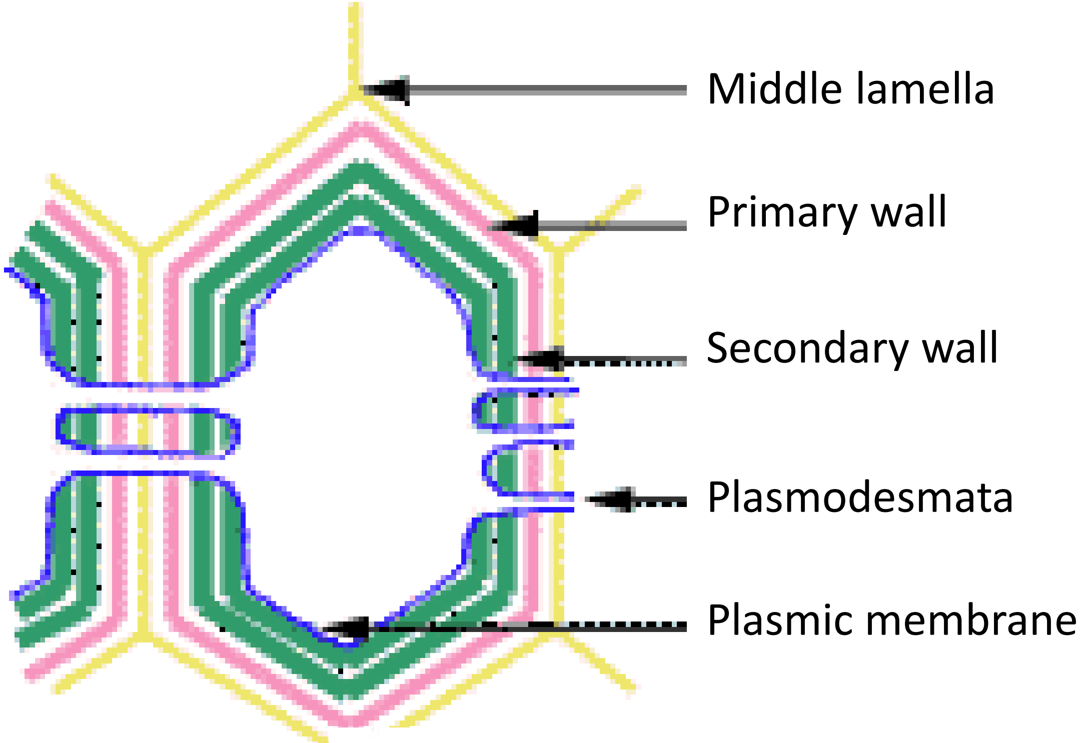
There are two communication structures:

1) plasmodesmata

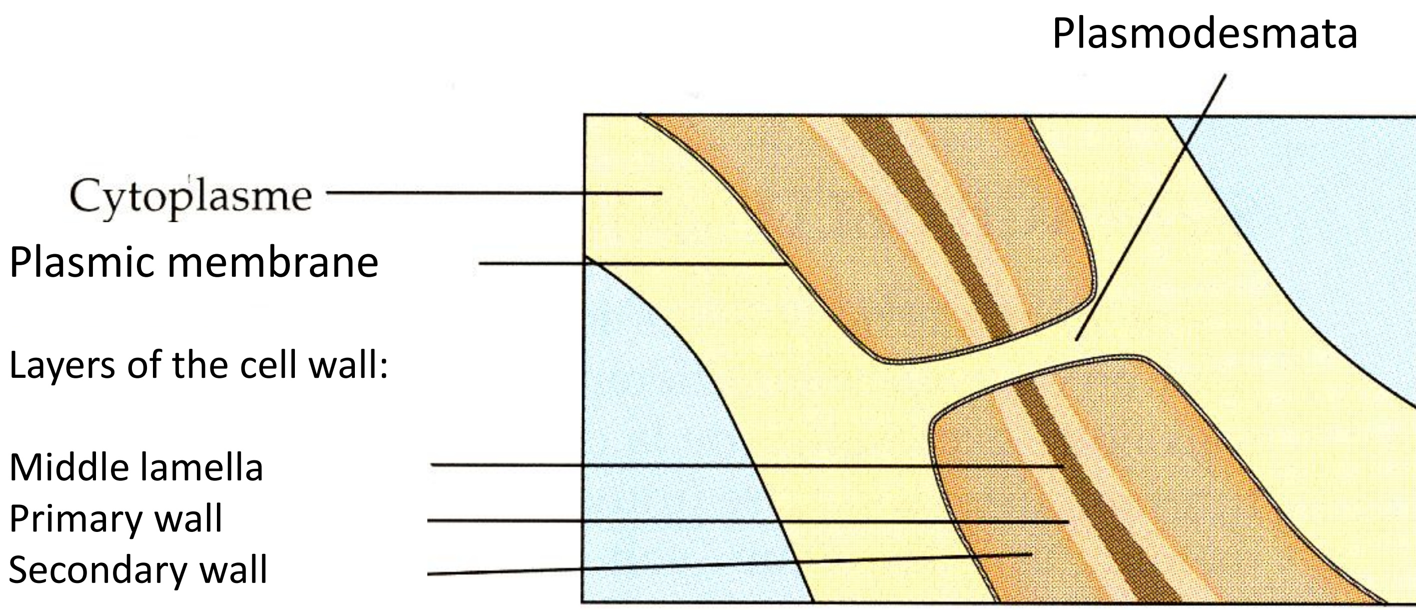
2) Punctuations

1. The plasmodesmata

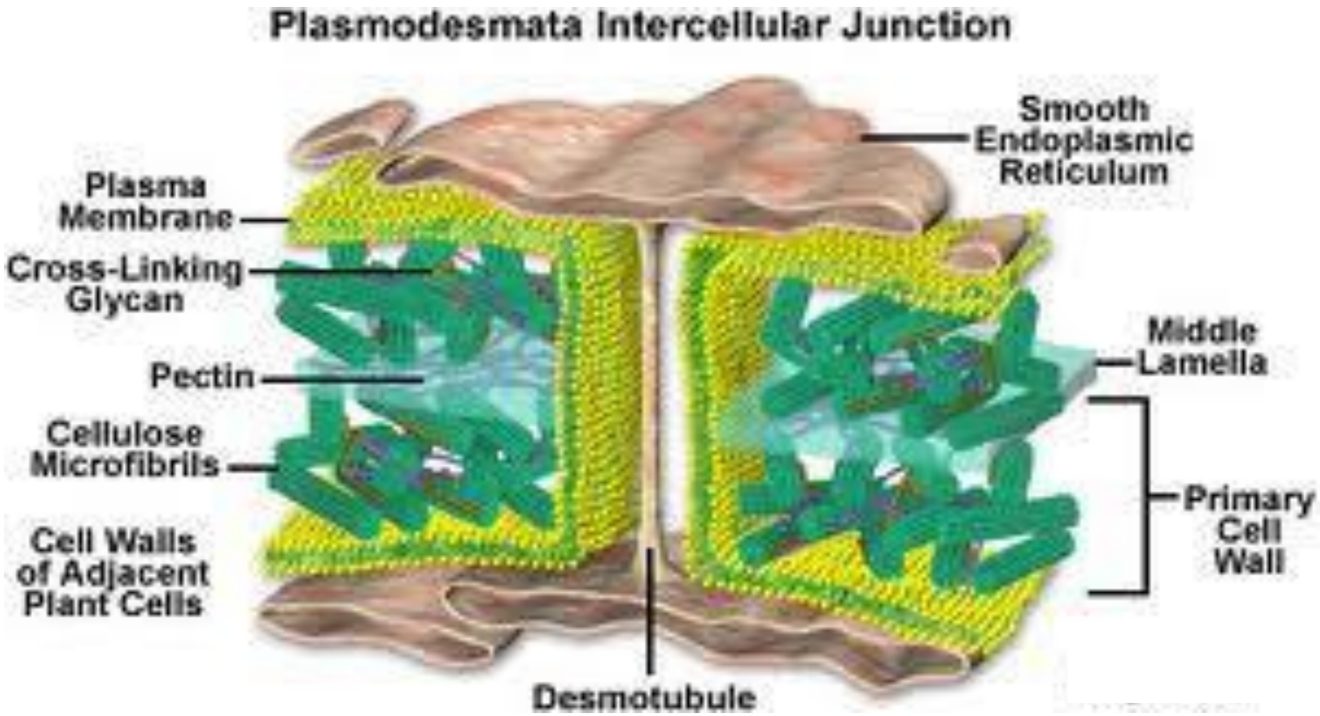
- **Plasmodesms** are structures of 20 to 40 nm in diameter, that interrupt the cell wall and bring the cytosol of two adjacent cells together.
- This allows water and small solutes to circulate freely from one cell to another one.



The **plasma membranes** of plant cells fuse to form a continuous channel, the ring



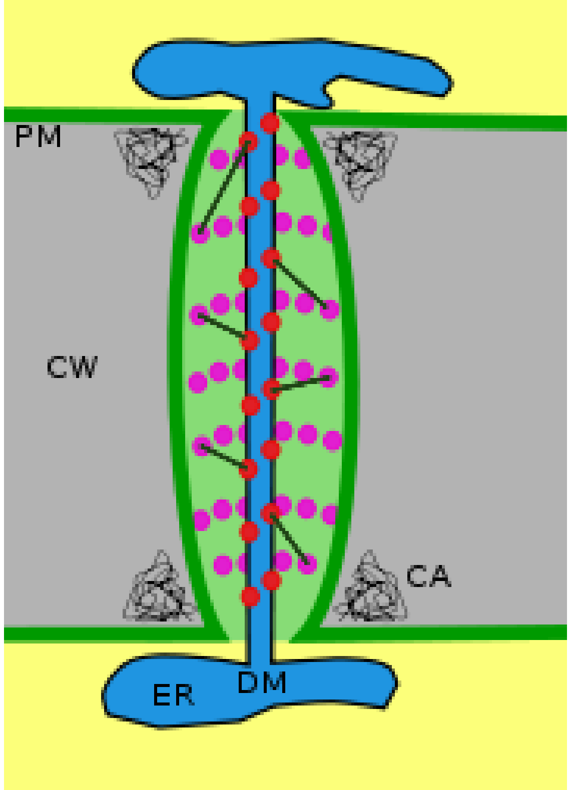
- The center of the plasmodesmata is occupied by the desmotubule.
- The channel formed inside the desmotubule **allows the controlled passage of molecules between adjacent cells.**



The desmotubule

- The **desmotubule** is surrounded by a ring of globular proteins throughout the thickness of the plasmodesm.

- It is linked to the smooth endoplasmic reticulum on either side of the wall.



2. The punctuations

There are two types of punctuations :

2.1. Simple punctuation

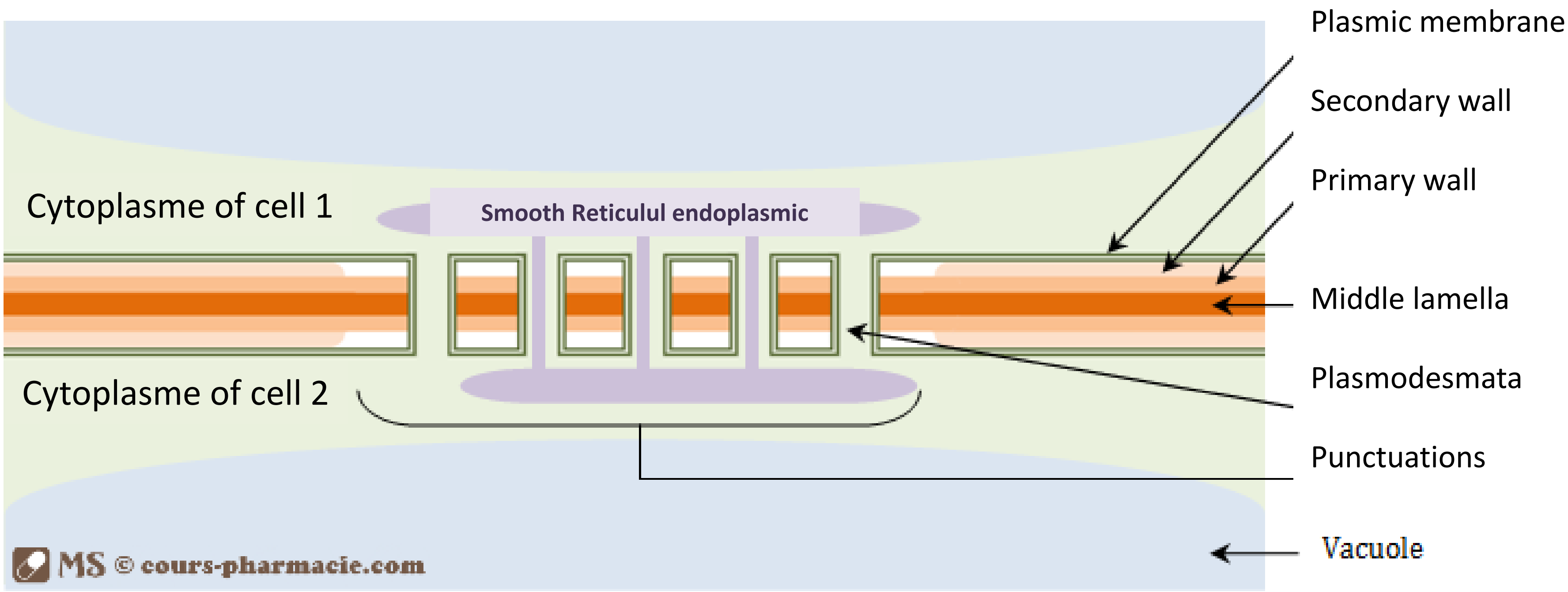
2.2. Areolated punctuation

- Simple punctuation

- When cells develop walls, communication between them takes place via **simple punctuations**.
- These gaps are visibles under a light microscope, at the bottom of which ten or even hundreds of plasmodesmata are gathered.

- The *primary wall* may be thinned or completely interrupted.

- If the cell has a *secondary wall*, this is also interrupted.



Simplified diagram of the structural organisation of the plant wall

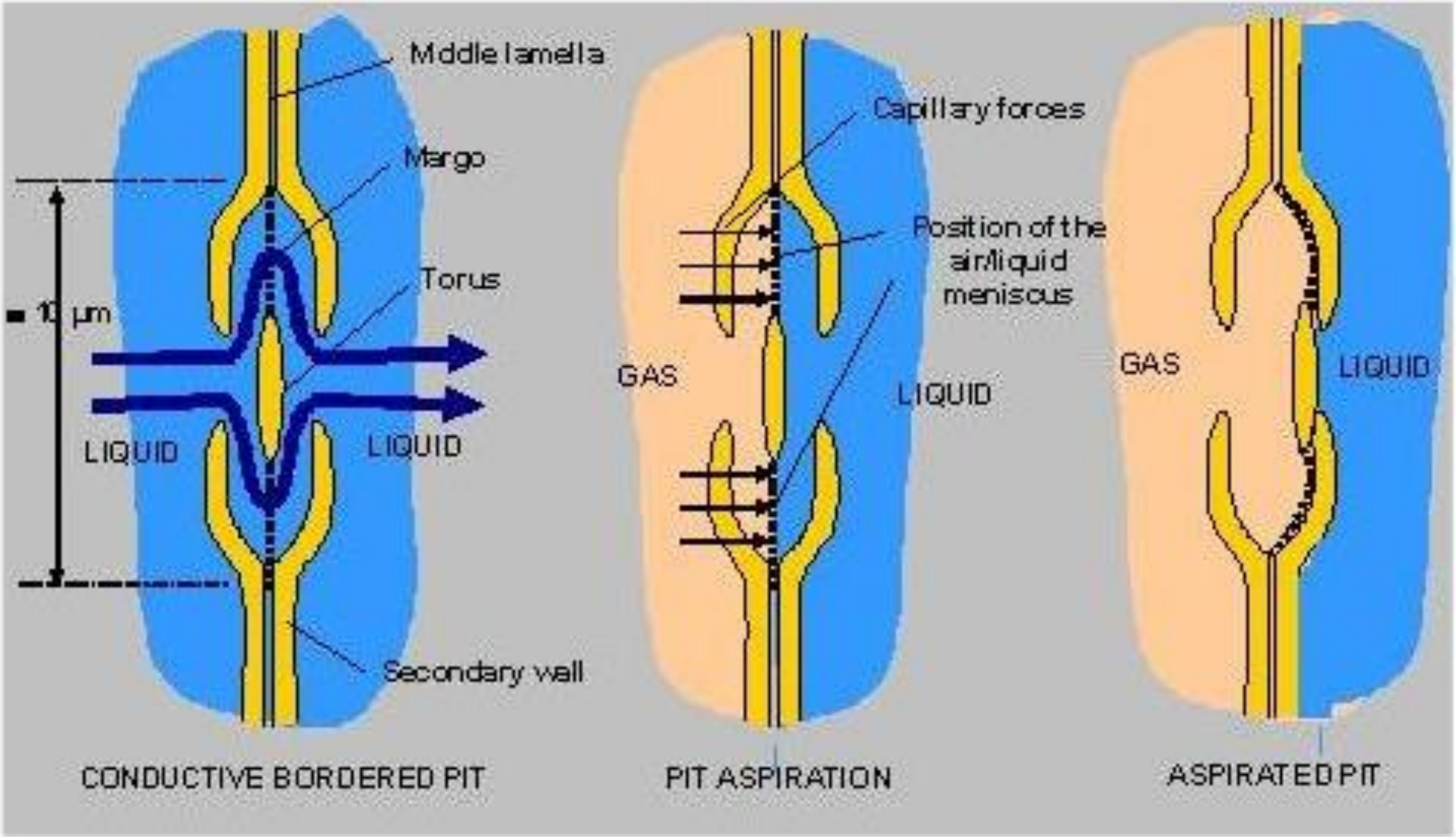
- Areolated punctation

These punctuations are characteristic of gymnosperms.

- The primary wall forms a central thickening called a **torus**, which is often lignified;

- The primary wall is partially hydrolysed and allows exchanges between adjacent cells;

- The lignified secondary wall is interrupted, detached and lifted.



Aspiration process of punctuation between two tracheids (Perré 2007)

Chemical modifications of the cell wall

Chemical changes in the cell wall are linked to the function of the cell.

A. Modification to ensure rigidity

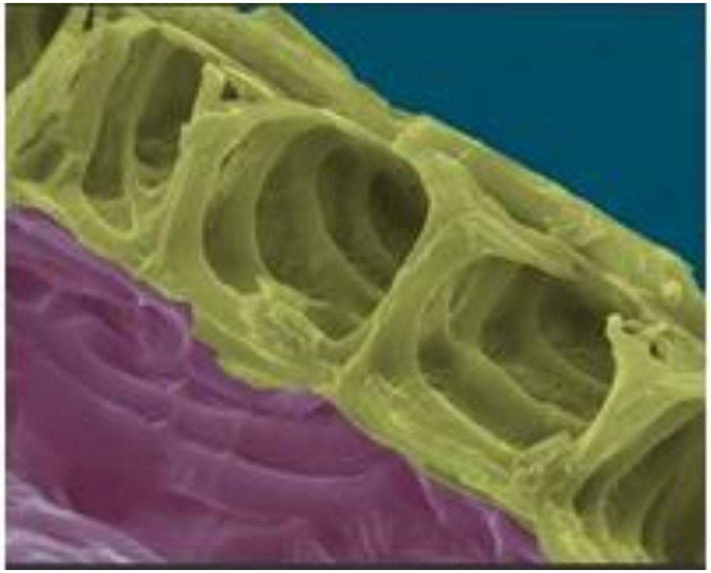
1. Lignification or sclerification

It is an impregnation of the wall **by lignin** which provides great rigidity and resistance in the supporting tissues.

Lignin is a hydrophobic molecule, which is important for sap conduction: it prevents the sap from sticking to the canals, enabling it to be transported more efficiently and more quickly.

- Since the lignified wall is impermeable to water, the cell generally dies after synthesizing its secondary wall.
- These dead cells play an important role in supporting the plant and conducting sap.

These dead cells have a thick secondary wall impregnated with wood-forming lignin. They act as “canals" to allow the sap to rise and give the plant great rigidity.

2- Mineralization

- Mineralization refers to the deposition of mineral elements in the walls of certain plant cells.

- A distinction is made between calcification, which is the addition of calcium carbonate ($CaCO_3$) ;

- Silicification, which is the addition of silica oxide (SiO_4).

- The calcification process

Ex. Cystolythians

Accumulation of calcium carbonates ($CaCO_3$) deposited inside the cell walls of the epidermis of fruits of the cucurbitaceae family.

- The silicification

The epidermal walls of the leaves of certain **grasses** (graminea, Maize) are reinforced by silica, which makes them sharp.

The **Nettle** (*Ortica dioica*) **hairs** is ended by a **cilium cap**.

B- Modification to ensure impermeability

- These are **appositions** of lipid substances such as **cutin**, **wax** (cire) and **suberin**.
- These compounds are polymers of long-chain fatty acids acides gras) responsible for hydrophobicity.
- Depending on the substance, these affixations are called

  – Cutinisation;

  - Cerification;

  - Suberification.

1. Cutinization and cerification

- They involve the protective tissues of the airborne organs, with the outer walls of the epidermal cells covered by a cuticle.
- This cuticle is composed of either cutin only, or cutin and wax, known as intracuticular wax.

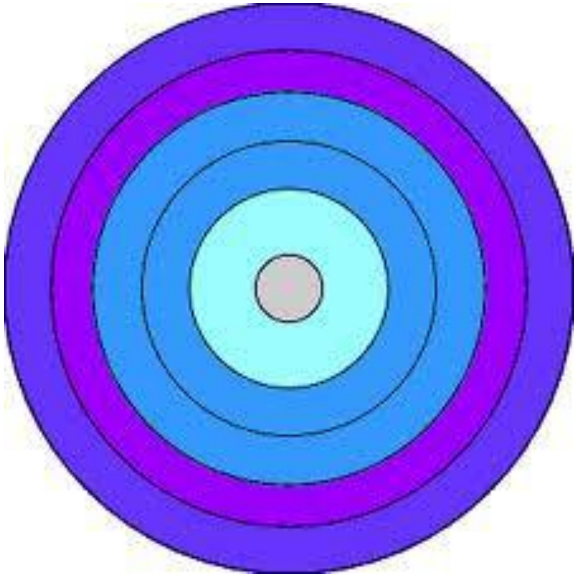
Cuticle on the surface of a leaf. The cuticle makes the leaf waterproof and therefore prevents water loss through evaporation.

In **xerophytes**, the wax layer is very important and constitutes the **epicuticular wax**.

2. The suberification

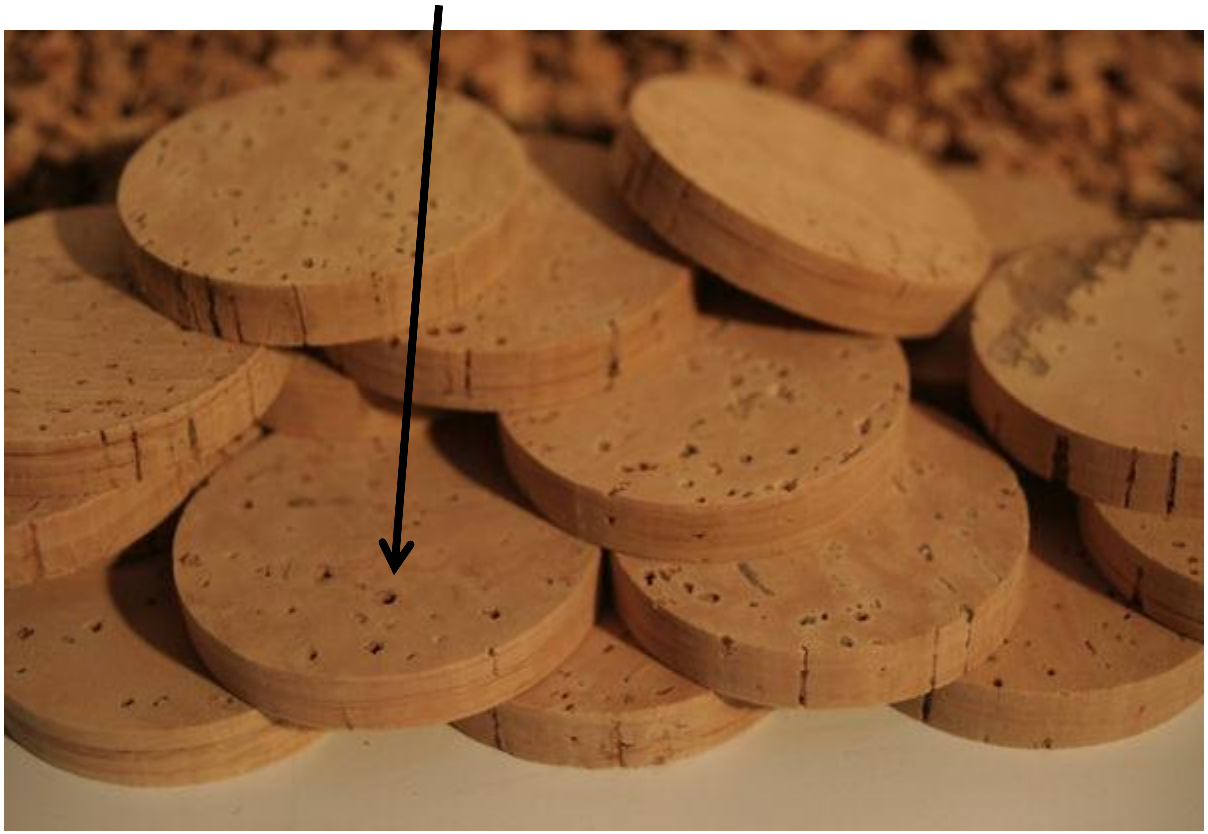
It takes place in the protective tissues of aerial and underground (souterrains) organs.

The cell wall may be impregnated with **suberin**, an **impermeable** hydrophobic substance that is deposited on the inside of the cell wall in **concentric** layers.



Concentric layers

It leads to impermeabilisation of the cell walls and cell death following degeneration of the cytoplasm.



C. The gelification

- This can be observed in the hydrolysis (destruction) of the polygalacturonic chains of the middle lamella by pectinase enzymes : - When the fruit is ripening,

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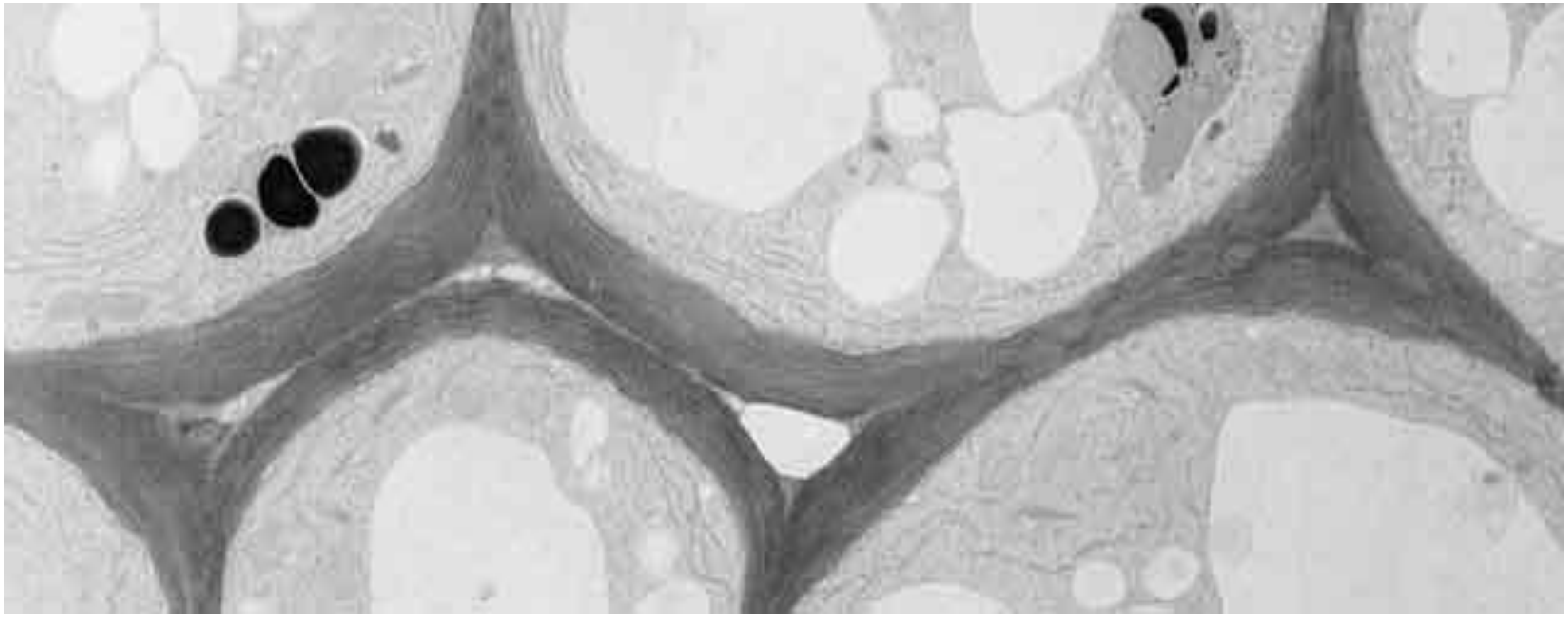
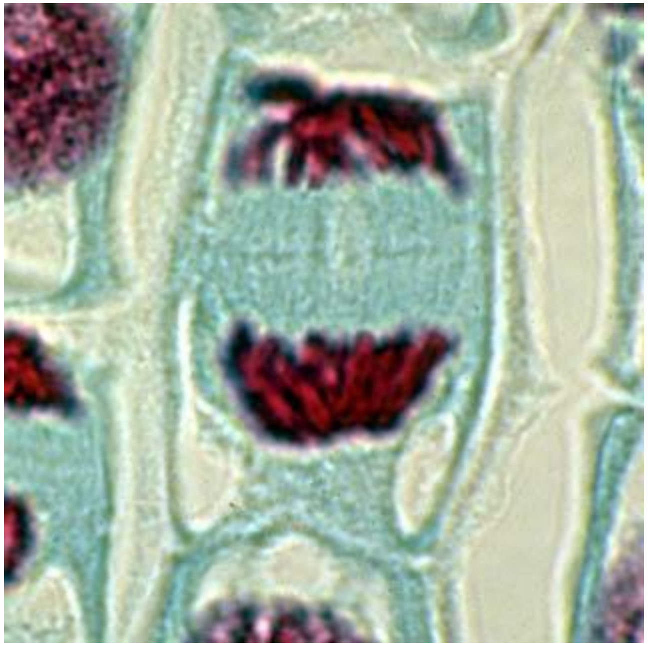
- In the formation of meats and gaps



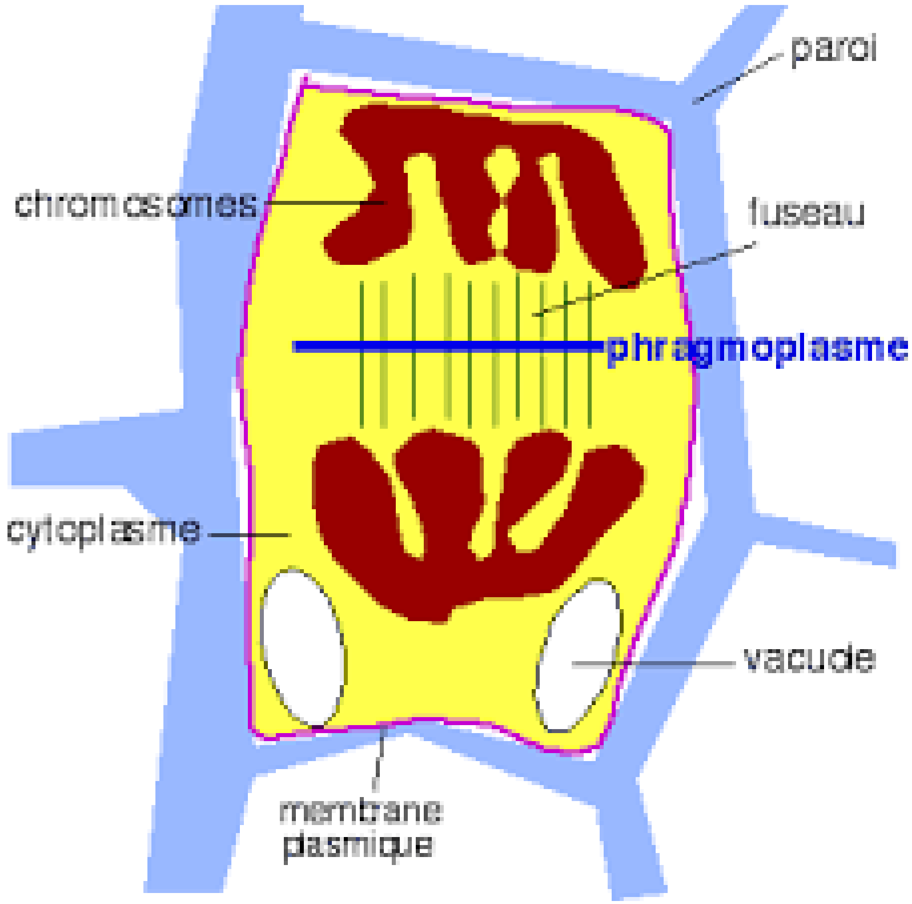
- In the fall of deciduous organs, such as leaves, petals and fruits (abscission).

Biogenesis of the cell wall

The wall comes into place during telophase, when the two formed cells are separated.

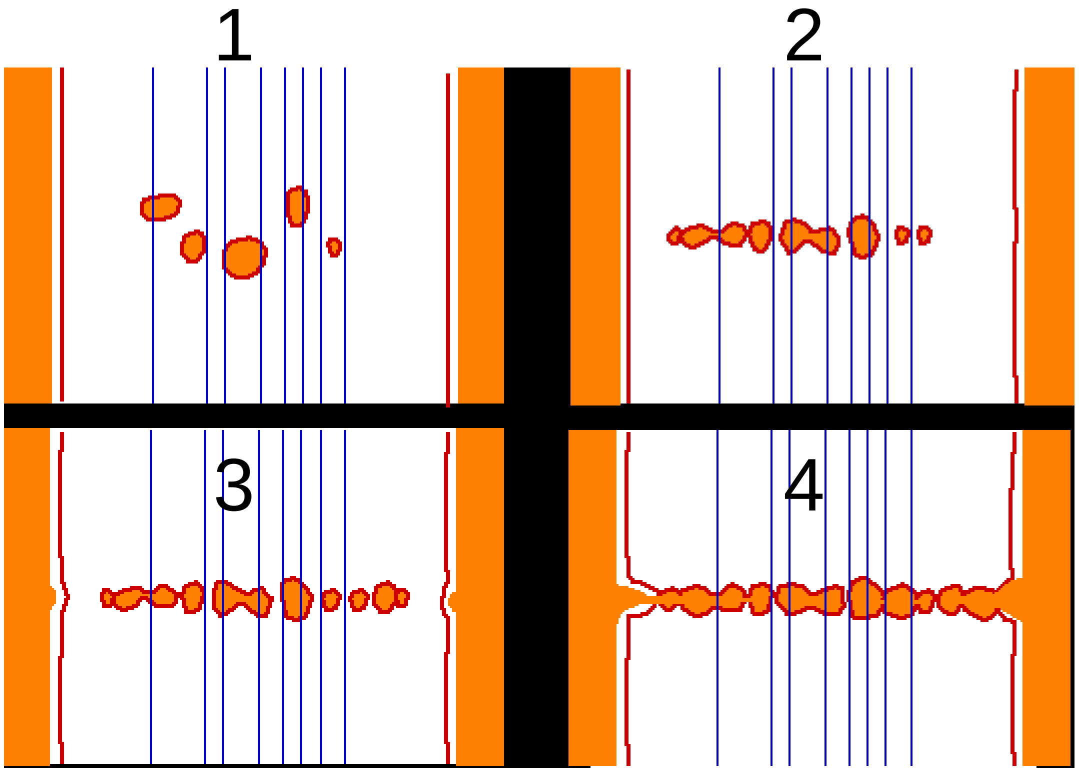


At the end of cell division (telophase), **the microtubules are assembled to form the phragmoplast**.

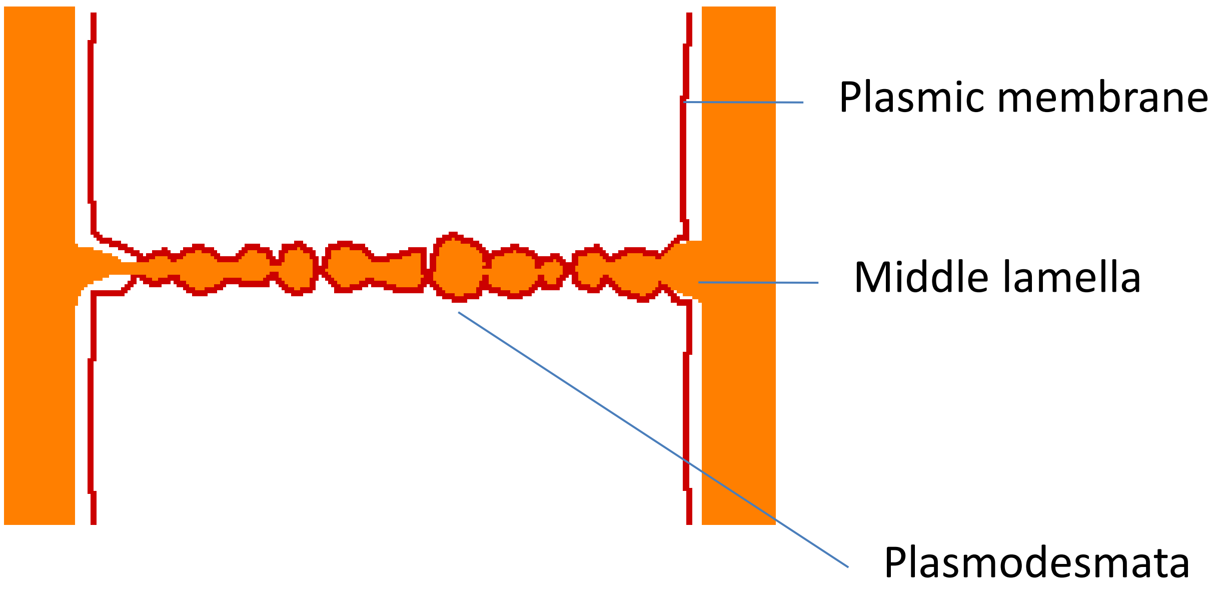


The phragmoplast, at the beginning, directs the pectin-rich golgitic vesicles towards the equatorial plate, forming the cell plate.

Four schematic stages in the formation of the new intercellular wall.



The golgenic vesicles fuse together to form the plasma membrane of each cell daughter, after which the pectins organise themselves to form the middle lamella.



Formation of the primary cell wall :

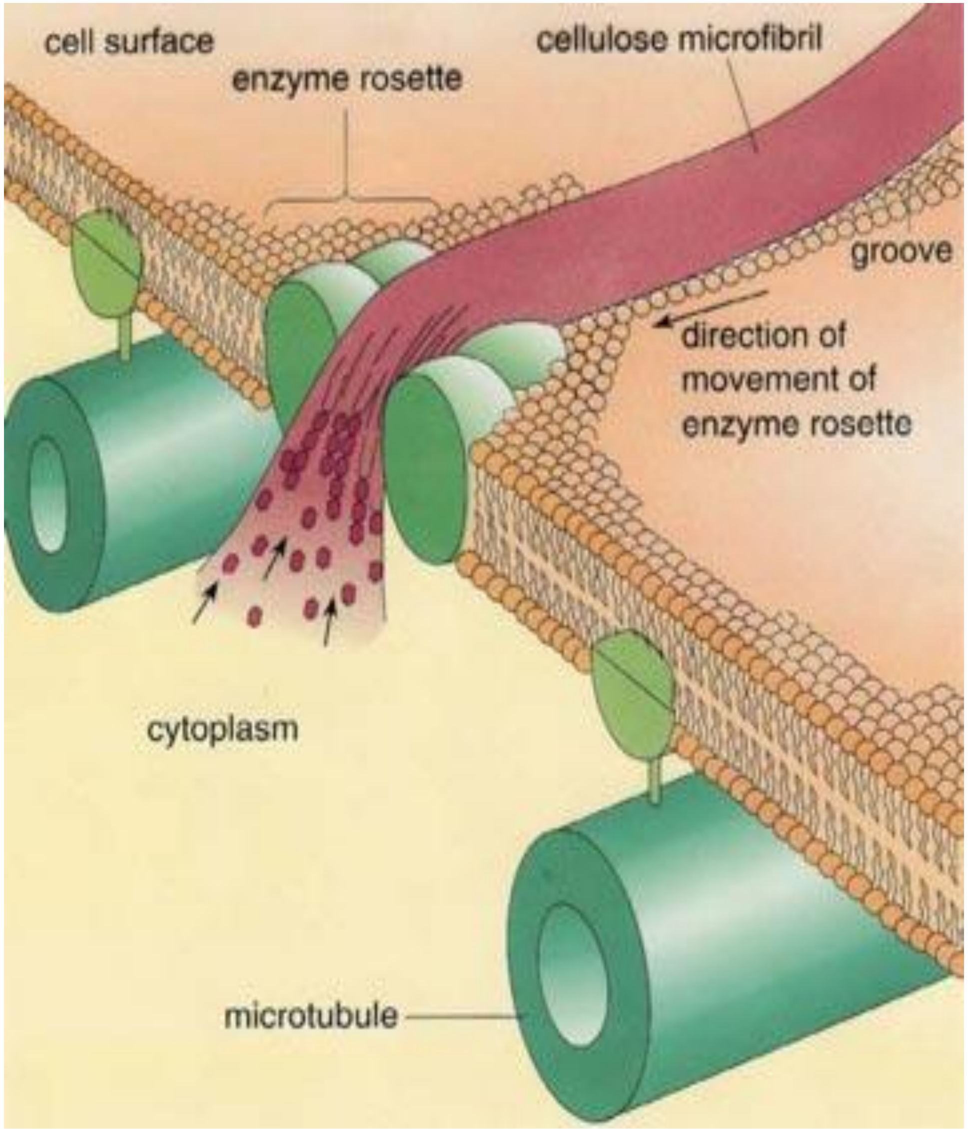
- The golgi apparatus synthesises **pectins and hemicelluloses**.

- **Exocytosis** causes the vesicles to release their contents on either side of the **middle lamella**.

- **Glycoproteins** originate from the **REG** and **golgi**, they are also secreted by exocytosis.

For cellulose microfibrils, the polymerisation of B-glucoses takes place at the level of enzyme complexes called **cellulose synthetase** located in the lipid bilayer.

The cellulose microfibril, polymerized by **cellulose synthetase** (the rosette enzyme), emerges through the canal of this enzyme.



Formation of the secondary wall :

The secondary wall is formed on top of the primary wall, except at the points.