Cell wall

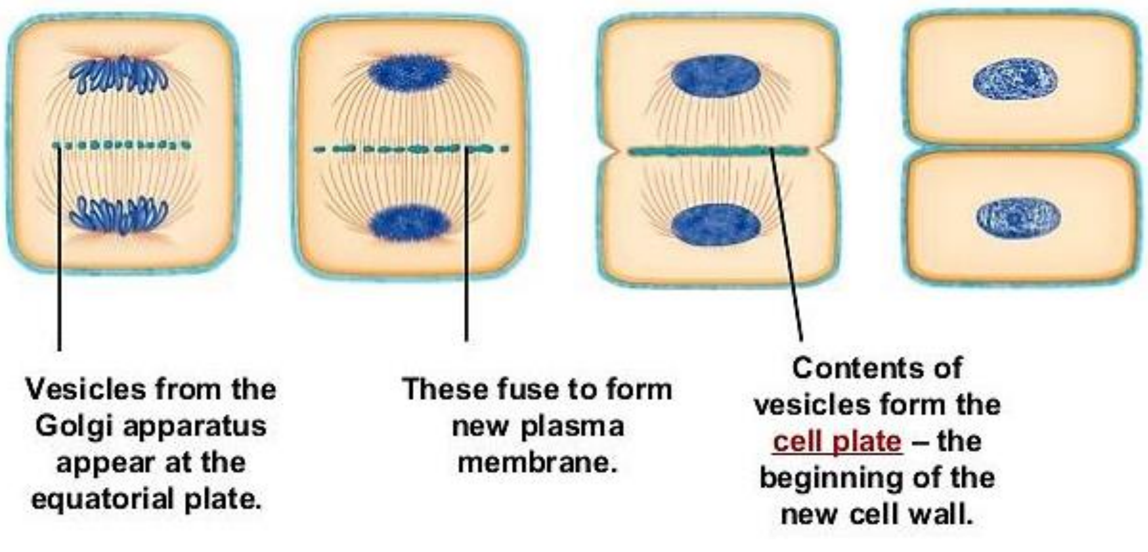
A cell wall is the non-living component, covering the outmost layer of a cell, present adjacent to the cell membrane, which is also called the plasma membrane. Its composition varies according to the organism and is permeable in nature. The cell wall separates the interior contents of the cell from the exterior environment. It also provides shape, support, and protection to the cell and its organelles. However, the cell wall is present exclusively in eukaryotic plants, fungi, bacteria, algae, and some archaea.

Formation of cell plate:

The presence of a wall in plants cells distinguishes them from animal cells. It is formed during the process of cell division. The presence of the nucleus is necessary for the formation of wall.

During mitosis at the telophase, the phragmoplast widens and becomes barrel shaped. At the same time, on the equatorial plane, the cell plate begins to form inside the phragmoplast. With the help of electron microscope it has been shown that cell-plate formation is initiated by the concentration and fusion of a large number of vesicles formed by dictyosomes (but ER vescicles may also be involved in this process). The microtubules of the phragmoplast seem to be involved in directing the vesicles towards the equatorial region. When the cell plate reaches all parts of the existing wall of the dividing cells, the phragmoplast disappears completely. At this stage the viscosity of the cell plate becomes higher. The cell plate gradually undergoes changes to form the intercellular substance referred to as the middle lamella. On both sides of these middle lamella then lamellae are gradually laid down by the daughter protoplasts. Formation of these lamellae is the initial stage in the development of the new walls of the daughter cells.

The chemical nature of the cell plate in the early stages of its development is not known, but it gives rise to middle lamella which is composed of pectic substances.



Cell plate formation

***Structure of cell wall*:**

The plant cell wall is generally arranged in 3 layers and composed of carbohydrates like pectin, cellulose, hemicellulose and other smaller amounts of minerals, which form a network along with structural proteins to form the cell wall. The three major layers from exterior to inner cell lumen are:

1. The Middle Lamella
2. Primary Cell Wall
3. The Secondary Cell Wall

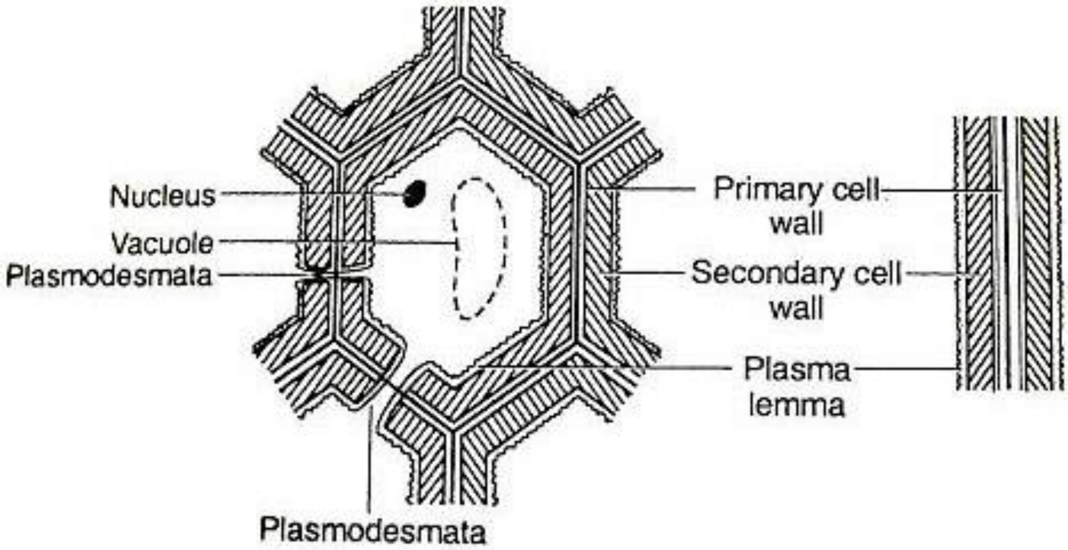
Middle Lamella

The middle lamella is the outermost layer and it acts as an interface between the other neighboring cells and glues them together. This layer primarily consists of pectins (calcium and magnesium pectates). However, other substances such as lignin and proteins can also be found.

Primary and Secondary Cell Wall:

The primary wall is the first formed wall that is formed by the cell and is deposited on either side of the middle lamella, by the adjacent cells. All meristematic cells have primary walls and also many mature cells which have living contents. The primary wall may not only undergo surface growth, but may also increase markedly in thickness.

The secondary cell wall is formed inside the primary cell wall once the cell is completely grown. Some types of cells (especially the cells of xylem tissues) consist of cellulose and lignin and these provide additional rigidity and waterproofing. Also, this layer provides the characteristic rectangular or square shape to a cell. It is also the thickest layer and permits permeability.



Secondary growth of cell wall

Secondary walls, pits & plasmodesmata

Generally secondary walls are usually formed after a cell has completed its elongation and therefore, do not normally extend to it is deposited on the inner side of the existing primary wall, next to the cell lumen. Secondary calls are present in cells which are non-living at maturity, such as sclereids, fibres and vessel elements. The secondary wall consists of three layers, so that a cell wall way consists of five layers, the middle lamella, the primary wall and threes of secondary wall. In the majority of tracheids and fibres, secondary walls are made up of the three layers (**s_1, s_2, s_3**), the central layer is usually the thickest. In some cells, however, the number of layers may be more.

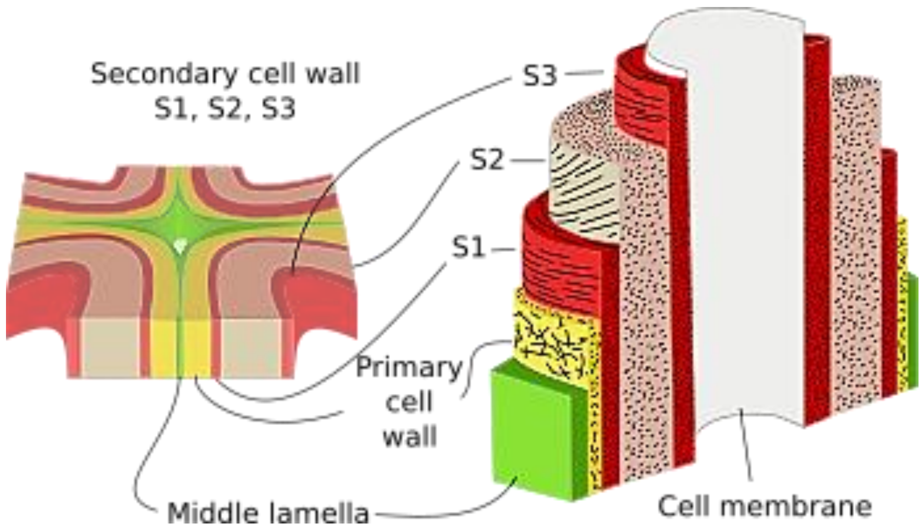
***Components and structure of cell wall*: -**

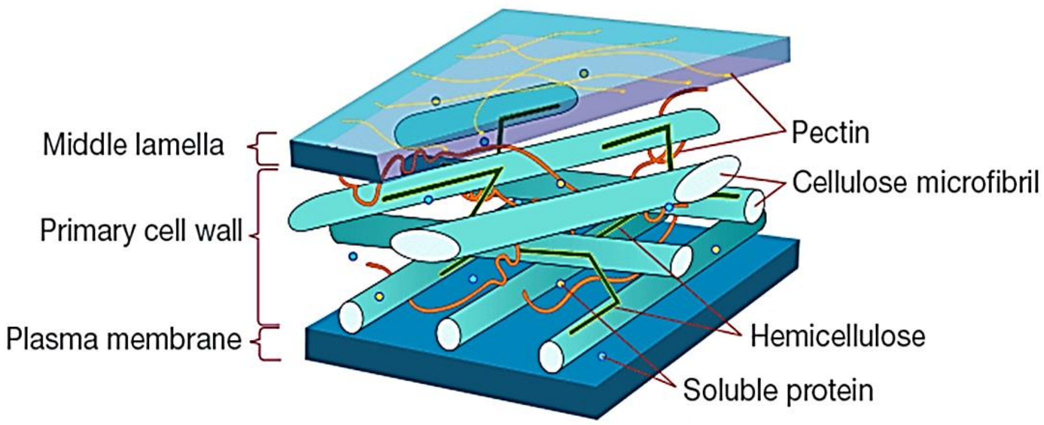
Cell wall may contain cellulose, hemicellulose, pectic compounds, lignin, suberin, protein etc***[1]**. The proportion of these substances differ both in different species. On a weight to weight basis the proportion of cellulose varies from 1-10% in primary walls of angiosperms to about 50% in secondary walls. Water is the most important components of the cell walls.

Cellulose in the cell walls acts as **a skeletal substance** and consists of many fine strands or microfibers which are approximately 100Å in diameter. Each microfibril is a bundle of a number of cellulose chain molecules. The molecules are generally arranged lengthwise with regard to the microfibril axis. Microfibrils are composed of smaller units called elementary fibrils. Each elemntary fibrils contains about 40 cellulose chains, 20 – 60 elementary fibrils are fasciculated to form a microfibril and about 20 microfibrils form a macrofibril. Between microfibrils there are inter-microfibrillar spaces, and within microfibrils there are intra-microfibrillar spaces. The microfibrils may be arranged randomly or in a more or less regular fashion. Smaller units are present within the microfibers; called micelles that lie parallel to one another. The spaces between the less regularly arranged molecules in microfibrils are filled with water, pectic substances, hemicelluloses and in secondary walls with lignin, cutin etc. The hemicelluloses are cross linked by pectic polymers, so that the microfibrils are interconnected. Proteins synthesized in the cytoplasm are regularly transported into the cell wall. These proteins may be involved in orientation of the fibrils. The wall proteins play an important role in cell extension and accordingly it has been given the name Extensins, a family of flexuous, rodlike, hydroxyproline-rich glycoproteins (HRGPs) of the plant cell wall.

The arrangement of microfibrils is not homogeneous within a cell wall. Differences in orientation help to distinguish the primary and the secondary walls of mature cells. Secondary wall is composed of three layers, which they designated as *outer (S1)*, *middle (S2)* and *inner (S3)* layer toward the cell lumen.

*[1] *Solubility properties of cell wall components*: **Cellulose**- insoluble in water; **Hemicelluloses**- partly soluble in water & mild alkalis; **Pectin**- water soluble; **Lignin**- insoluble in water and alcohol but soluble in weak alkaline solutions; **Cutin** and **Suberin**- water insoluble





Middle lamella has no special structure of microfibrils. There is no cellulose is mostly lignin and hemiceluloses.

The ***primary wall*** exhibits a loose weaving of microfibrils. This wall is very thin and does not show the lamellation observed in the secondary wall.

In the ***secondary wall*** the microfibrils are closely packed. The amount of lignin is low (10 – 20 %), cellulose content ranged from about 50 % to over 60 %.

The ***S1 layer*** is thin and consists of a few lamellae. It has a crossed microfibrillar texture, with its lamellae exhibiting an alternating left-hand and right-hand helical arrangement. In each lamella, the helical angle is about 50 – 90º, as measured from the longitudinal axis of the cell.

The ***S2 layer*** is thick, especially in latewood tracheids and thick-walled fibers. It is composed of 30 – 150 lamellae. Adjoining lamellae were observed to exhibit a similar (not crossed) microfibrillar orientation. The microfibrils show a high degree of parallelism in all lamellae, and they run approximately parallel to cell axis, usually not exceeding an angle of about 30º.

The ***S3 layer*** is usually thinner than the *S1* and it is lamellate (up to 6 lamellae). The angle of microfibrils lekewise varies from about 50 to 90º. The *S3* layer may sometimes be missing.

Pits and Plasmodesmata

Secondary cell walls are commonly characterized by the presence of cavities called **pits**. A pit in a cell wall usually occurs opposite a pit in the wall of an adjoining cell, and the two opposing pits constitute a **pit-pair**. The middle lamella and the two primary walls between the two pit cavities are called the **pit membrane**. Pits arise during ontogeny of the cell and result from differential deposition of secondary wall material. Pits are the areas on the cell wall on which the secondary wall is not laid down so the pits are actual discontinuities in the secondary wall.

Pits vary in size and detailed structure but two principal types are recognized in cells with secondary walls: **simple pits** and **bordered pits**. The basic difference between the two kinds of pit is that, in the bordered pit, the secondary wall arches over the pit cavity and narrows down its opening to the lumen of the cell. The overarching secondary wall constitutes the border. In simple pits, no such overarching occurs. In bordered pits, the part of the cavity enclosed by the border is called the **pit chamber**, and the opening in the border is the aperture. A combination of simple pits is termed a **simple pitpair,** and of two opposing bordered pits a **bordered pit-pair**. Combinations of simple pits and bordered pits, called **half-bordered pit-pairs**, are found in the xylem. A pit may have no complementary structure, for example, as when it occurs opposite an intercellular space. Such pits are called **blind pits**. In addition two or more pits may oppose a single pit in an adjoining cell, a combination that has been named **unilaterally compound pitting**.

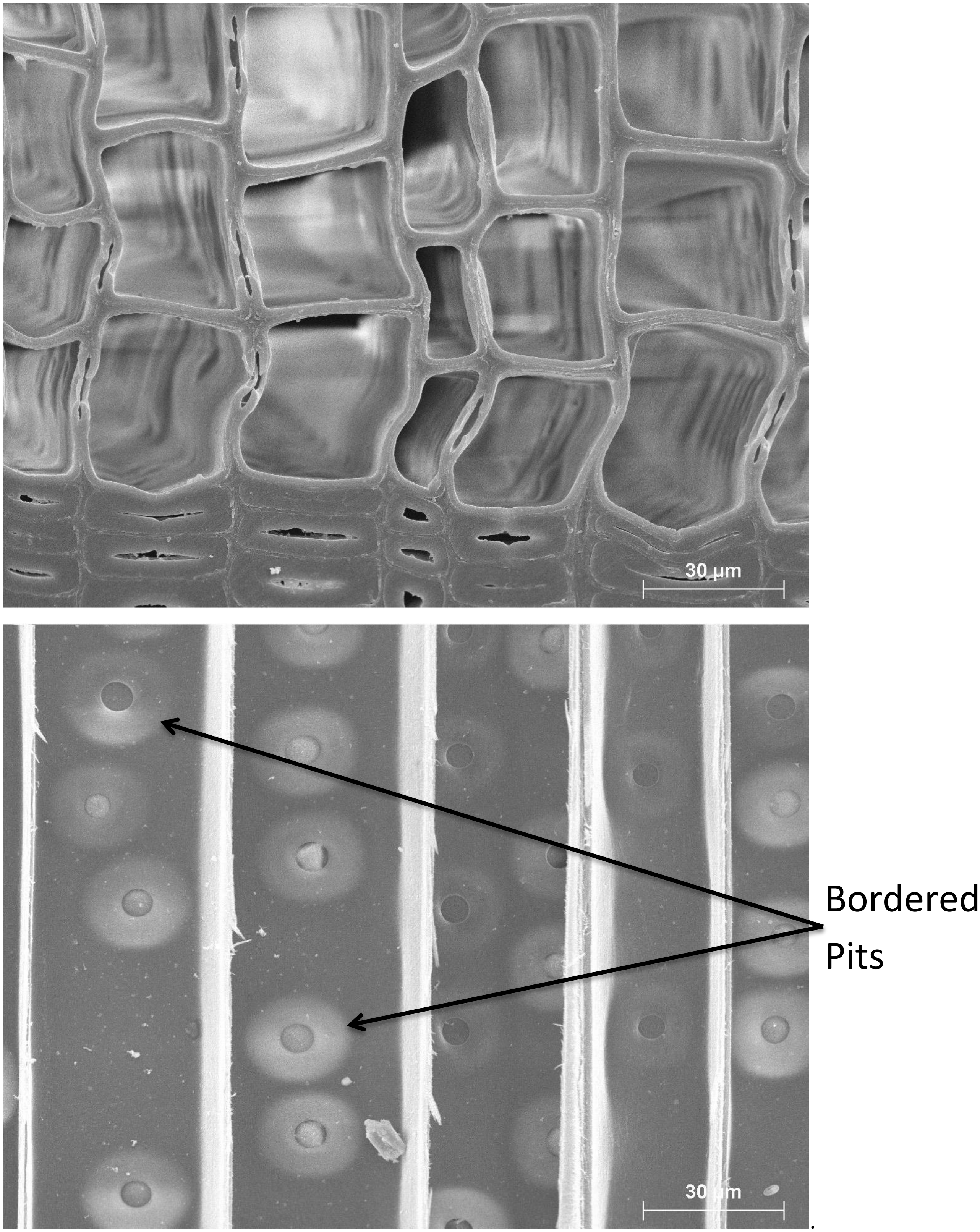
Depending on the thickness of the secondary wall, the simple pit may be shallow or it may form a canal extending from the cell lumen toward the pit membrane. Pits may coalesce as the wall increases in thickness and form **branched** or **ramiform pits.**

Simple pits are found in certain parenchyma cells, in extraxylary fibers, and in sclereids. Both simple and bordered pits occur in the secondary walls of tracheary elements. In conifer tracheids, the bordered pit-pairs have an especially elaborate structure.

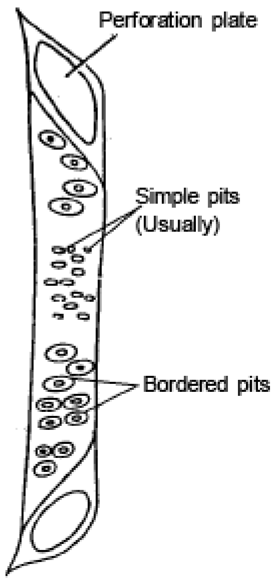
Plasmodesmata are microscopic channels that connect the cytoplasm of neighbouring plant cells with each other. They form intercellular cytoplasmic bridges called **symplast.** It consists of a canal, lined by plasma membrane. It has a simple or branched tubule known as **desmotubule.** Desmotubule is an extension of endoplasmic reticulum. Structurally, plasmodesmata are tube-like structures. There are desmotubules in the space of plasmodesmata. Desmotubules consist of a tightly packed endoplasmic reticulum. Moreover, there is a cytoplasmic sleeve between the membrane and the desmotubules. It is a fluid-filled space which is an extension of the cytosol. Transfer of molecules occurs via the cytoplasmic sleeve. Small molecules diffuse through the sleeve without the use of energy. The sleeve contains protein fibres such as actin and myosin, which provide contractile forces to transport substances across the plasmodesmata. On the basis of origin plasmodesmata are of two types- (i) primary plasmodesmata (ii) secondary plasmodesmata. On the basis of branching they are of two types- (i) branched plasmodesmata (ii) unbranched plasmodesmata

Plasmodesmata are present in almost all plant cells. They are abundant in pits. Plasmodesmata are vital in nutrient transportation via the vascular tissue.

Bordered pits in the wood of *Picea abies*.

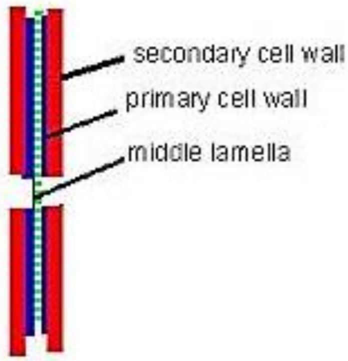


Bordered pits in the wood of *Picea abies*.

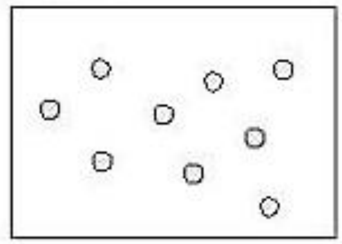


Vessels

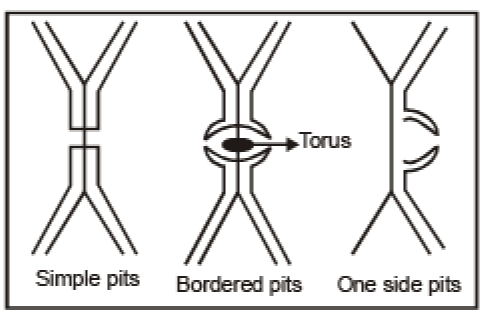
SIMPLE PITS (middle lamella + thin primary cell wall)

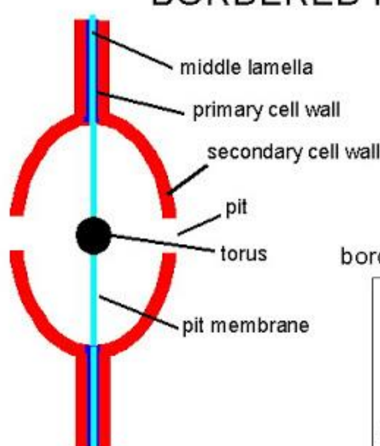


simple pits in cell wall



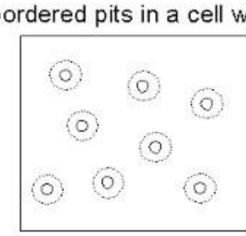
BORDERED PITS

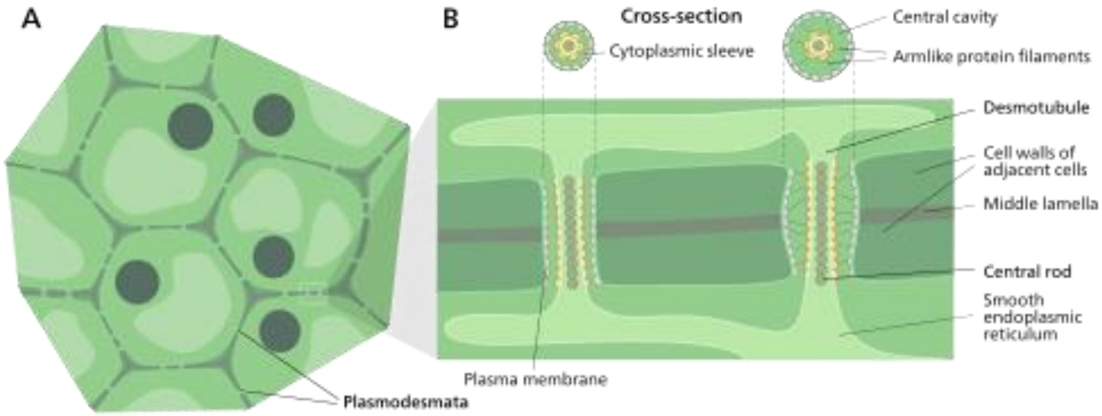


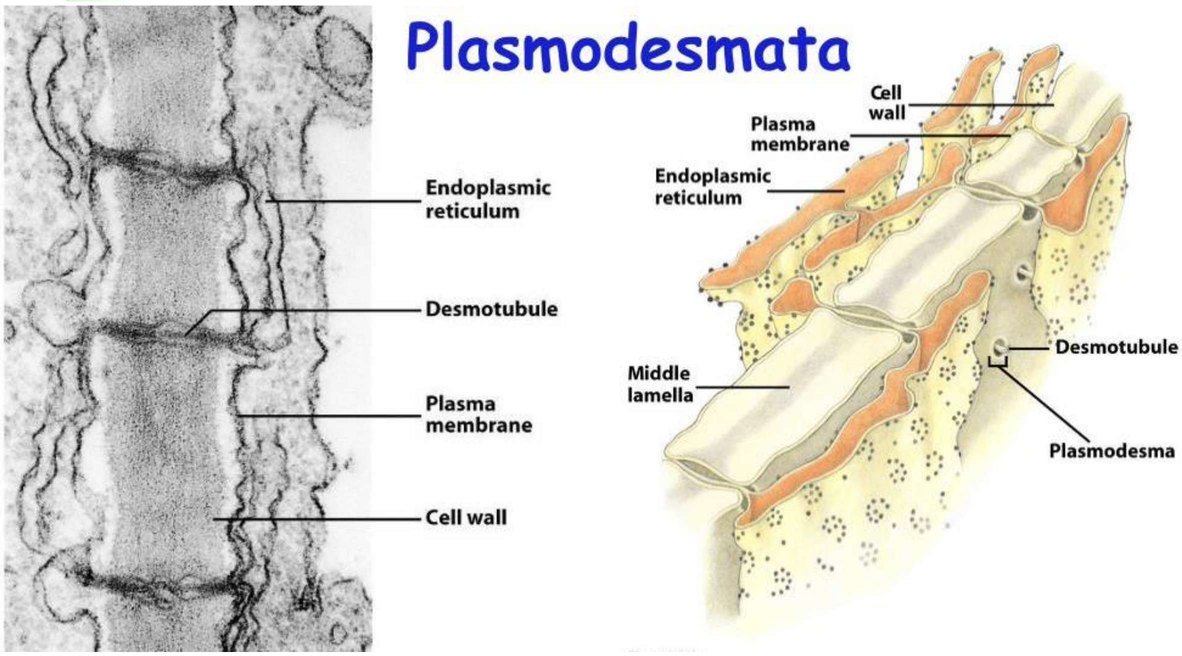


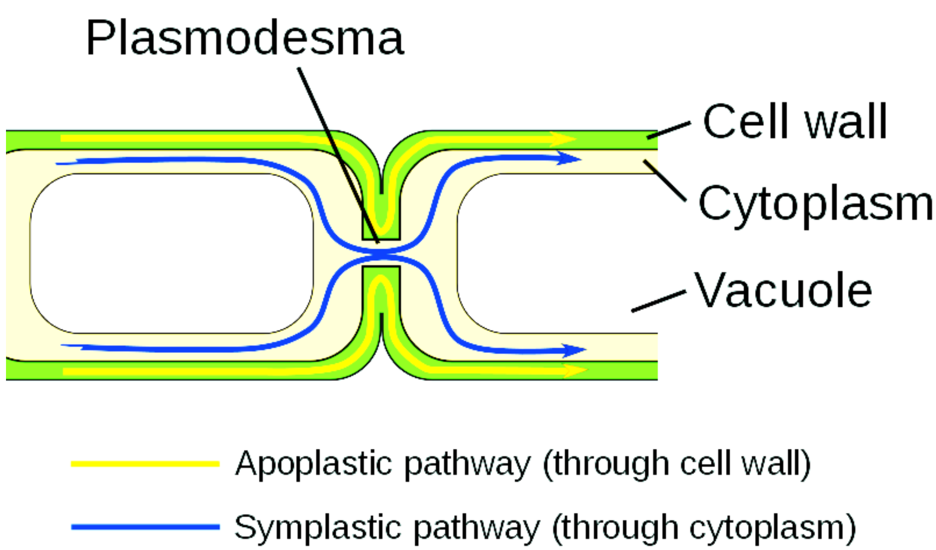
PIT PAIR

bordered pits in a cell wall




A
B
Cross-section
Cytoplasmic sleeve
Central cavity
Armlike protein filaments
Desmotubule
Cell walls of adjacent cells
Middle lamella
Central rod
Smooth endoplasmic reticulum
Plasma membrane
Plasmodesmata


Plasmodesmata
Endoplasmic reticulum
Desmotubule
Plasma membrane
Cell wall
Cell wall
Plasma membrane
Endoplasmic reticulum
Middle lamella
Desmotubule
Plasmodesma


Plasmodesma
Cell wall
Cytoplasm
Vacuole
Apoplastic pathway (through cell wall)
Symplastic pathway (through cytoplasm)