

Plant cells and cell walls

Revision notes · Plant cell ultrastructure compared with animal cells, starch and cellulose, and how wall structure gives xylem and fibres their properties.

For Pearson Edexcel International AS Biology XBI11 and International A Level Biology YBI11. **A Level only** is IA2 content (Units 4 to 6), not needed for the International AS.

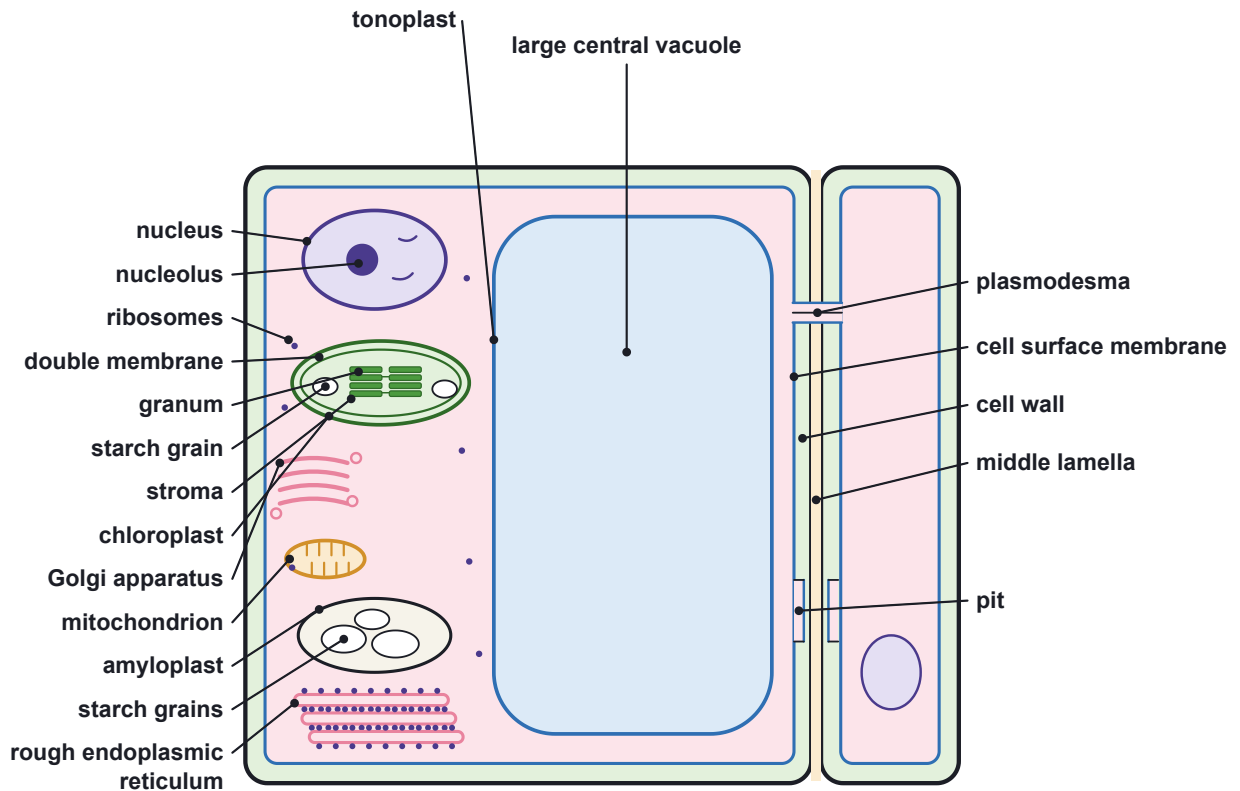
Plant cells and cell walls Spec 4.1-4.4

Plant cell ultrastructure and its functions Spec 4.1, 4.2

A plant cell has all the organelles of a eukaryotic cell (nucleus, mitochondria, rough endoplasmic reticulum, Golgi apparatus, ribosomes), plus several structures that animal cells lack. Learn the **structure** and the **function** of each one in the table, because both are examined.

Structures found in plant cells

Structure	Ultrastructure	Function
Cell wall	Outside the cell surface membrane. Cellulose microfibrils embedded in a matrix of other polysaccharides (such as hemicelluloses and pectins). Fully permeable.	Gives the cell strength and shape. Resists the pressure of water entering by osmosis, so the cell does not burst and becomes turgid.
Middle lamella	A thin layer between the walls of neighbouring cells, rich in pectins (calcium pectate).	Cements (sticks) adjacent cells together.
Chloroplast	Typically 3-10 μm long. Surrounded by a double membrane (envelope). Inside: stacks of thylakoid membranes (grana) joined by lamellae, containing chlorophyll; a fluid stroma containing enzymes, 70S ribosomes, circular DNA, lipid droplets and starch grains.	Site of photosynthesis. Light-dependent reactions occur on the thylakoid membranes; light-independent reactions occur in the stroma.
Amyloplast	A colourless organelle with a double membrane, packed with starch grains. No chlorophyll or thylakoids.	Stores starch, for example in potato tubers, roots and seeds.
Vacuole	A large, permanent, fluid-filled sac. The fluid is cell sap: a solution of water, sugars, amino acids, mineral ions, pigments and waste.	Stores solutes and water. Its water content helps keep the cell turgid, which supports non-woody plants.
Tonoplast	The single, partially permeable membrane surrounding the vacuole. Contains transport proteins.	Controls what enters and leaves the vacuole, for example by active transport of ions into the sap.
Plasmodesmata	Narrow channels through the cell walls, lined by the cell surface membrane and containing a thin strand of cytoplasm that links the cytoplasm of neighbouring cells.	Allow substances and chemical signals to pass directly from cell to cell.
Pits	Regions where the wall is thin because secondary thickening was not laid down there. Pits in neighbouring cells line up as pairs.	Allow water and dissolved substances to move between adjacent cells, for example from one xylem vessel to the next.



Ultrastructure of a plant cell and its junction with a neighbouring cell. The **middle lamella** lies between the two cell walls, and **plasmodesmata** pass through the walls.

Comparing plant and animal cells

Plant cells compared with animal cells		
Feature	Plant cell	Animal cell
Cell wall	Present, made of cellulose	Absent
Chloroplasts	Present in photosynthetic cells	Absent
Vacuole	One large permanent vacuole with a tonoplast	None, or small temporary vacuoles
Carbohydrate store	Starch (in amyloplasts and chloroplasts)	Glycogen (in the cytoplasm)
Shape	Fixed, often regular, because of the wall	Variable; no fixed shape
Centrioles	Absent in flowering plants	Present
Both have	Nucleus, cell surface membrane, mitochondria, ribosomes, rough endoplasmic reticulum, Golgi apparatus	Same

Exam tip: For compare questions give a similarity and a difference, and write about both cell types in the same sentence. "Plant cells have a cell wall" scores less than "plant cells have a cellulose cell wall but animal cells do not".

Recognising organelles in electron micrographs

- Chloroplast: oval, double membrane, internal stacks of discs (grana), often with pale starch grains.
- Amyloplast: rounded, double membrane, filled with large pale or dense starch grains, no internal stacks.

- Vacuole: very large, pale and featureless, bounded by a single thin line (tonoplast) and pushing the cytoplasm and nucleus to the edge.
- Cell wall and middle lamella: a thick layer outside the cell membrane; the middle lamella is the thin line between the walls of two neighbouring cells.
- Plasmodesmata: narrow gaps crossing the wall, joining the cytoplasm of two cells.

Common mistake: The tonoplast is the membrane around the vacuole. It is not the cell wall and it is not the cell surface membrane.

Starch and cellulose Spec 4.3

Both starch and cellulose are polysaccharides made by condensation reactions that join glucose monomers with glycosidic bonds. They differ in the type of glucose, the shape of the molecule and therefore the function.

Starch

Starch is the main energy store in plants and is made of α -glucose units. It is a mixture of two polysaccharides.

- **Amylose**: unbranched chain joined by α -1,4 glycosidic bonds. The chain coils into a helix, which makes it very compact.
- **Amylopectin**: α -1,4 chains with α -1,6 glycosidic bonds that make branches. Many free ends allow enzymes to hydrolyse it quickly, releasing glucose for respiration.

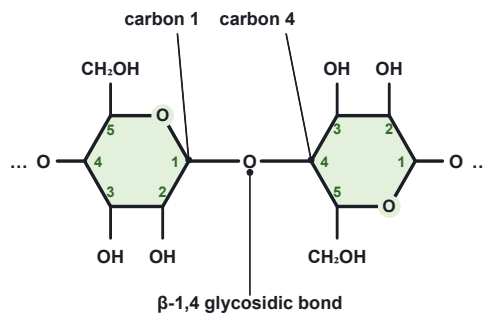
Starch is a good storage molecule because it is insoluble, so it does not change the water potential of the cell or leave the cell. It is also compact, so a lot of glucose is stored in a small space, and it is easily hydrolysed to α -glucose when energy is needed.

Cellulose

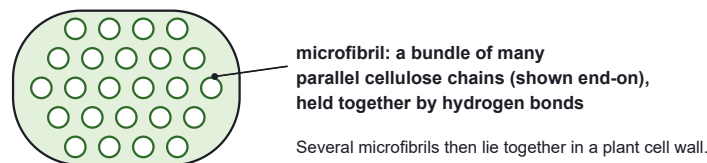
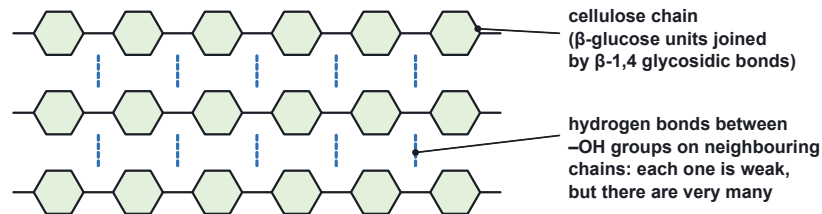
Cellulose is the main component of plant cell walls and is made of β -glucose units. In β -glucose the -OH on carbon 1 is above the ring. To form a β -1,4 glycosidic bond, every other glucose unit must be rotated through 180°. This gives a long, straight, unbranched chain.

1. Straight cellulose chains lie side by side.
2. Many hydrogen bonds form between the -OH groups on adjacent chains. Each bond is weak, but there are very many of them, so together they are strong.
3. Many chains held side by side in a bundle form a **microfibril**.
4. Microfibrils group into larger fibres. These have very high tensile strength and resist being pulled apart.

Starch compared with cellulose		
Feature	Starch	Cellulose
Monomer	α -glucose	β -glucose
Glycosidic bonds	α -1,4 (and α -1,6 in amylopectin)	β -1,4 only
Shape	Helical (amylose) or branched (amylopectin)	Straight, unbranched chains
Hydrogen bonds between chains	Few: the amylose helix is held by hydrogen bonds within the chain, not between chains	Yes, forming microfibrils
Function	Energy store	Structural: strengthens the cell wall



Every second β-glucose is rotated through 180°, so the chain is straight.



Cellulose: alternate **β-glucose** units are inverted and joined by β-1,4 glycosidic bonds. Many **hydrogen bonds** between parallel chains hold them together in a microfibril.

Common mistake: Do not say "cellulose is strong because it has strong bonds". Each hydrogen bond is weak. Strength comes from the very large number of hydrogen bonds between parallel chains.

Cell wall structure, secondary thickening and plant fibres Spec 4.4

The primary cell wall

In a growing cell, cellulose microfibrils are laid down in the **primary cell wall** in layers, with the microfibrils running at different angles. They are held in a matrix of other polysaccharides. This arrangement resists forces from every direction, including the outward pressure of the turgid cell, while the wall remains flexible enough to allow growth.

Secondary thickening

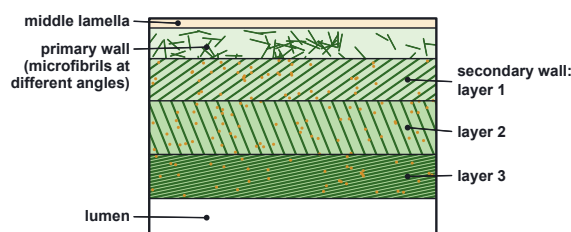
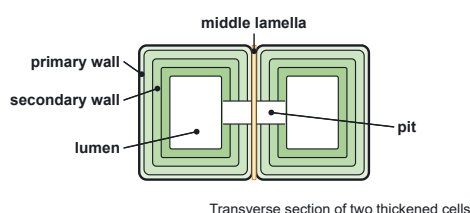
In some cells, extra layers are added on the inside of the primary wall after the cell has stopped growing. This is **secondary thickening**. The new layers contain cellulose microfibrils, and in xylem vessels and sclerenchyma fibres they are impregnated with **lignin**, a rigid, waterproof polymer. The cell contents then die, leaving a dead, hollow cell with a strong wall.

How wall structure gives xylem vessels and sclerenchyma fibres their properties

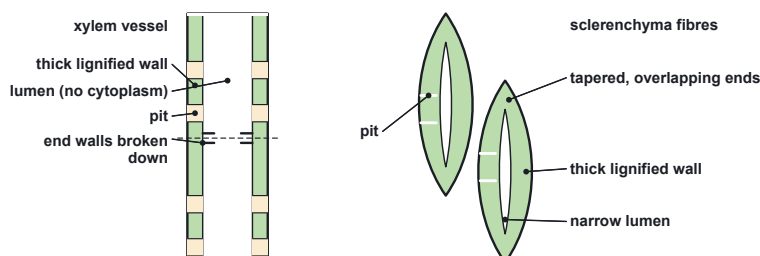
Tissue	Wall features	Physical properties
Xylem vessels	Thick secondary walls with cellulose and lignin, in rings, spirals or almost continuous layers with pits left unthickened. No end walls between vessel elements.	Lignin makes the wall waterproof, so water does not leak out. The thick, rigid wall resists collapse under the negative pressure (tension) caused by transpiration pull and gives the stem support. Pits allow sideways movement of water.
Sclerenchyma fibres	Very long, narrow cells with tapered ends, overlapping their neighbours. Thick, heavily lignified secondary walls built of layers of parallel cellulose microfibrils; in the thickest layer the microfibrils run almost along the length of the cell. Dead at maturity with a narrow lumen.	Very high tensile strength and some flexibility, so they support the plant and resist bending and stretching.

Properties exploited by humans

The long cells and tightly bound microfibrils of sclerenchyma fibres make plant fibres strong, flexible and light. Humans extract them from stems and leaves, for example flax, hemp, jute and sisal, to make rope, string, textiles, paper, packaging and fibre-reinforced composite materials. Xylem tissue in wood is used for timber because its thick lignified walls are strong in compression and bending.



Within a layer the microfibrils are parallel; the angle changes from layer to layer.
Amber dots: lignin impregnating the secondary wall.



Longitudinal sections: xylem vessel (left) and sclerenchyma fibres (right)

Walls of xylem vessels and sclerenchyma fibres: the **secondary wall** is built of layers of microfibrils, each at a different angle, and is impregnated with **lignin**.

Exam tip: Link structure to property to use: "microfibrils in layers and lignin give high tensile strength, so fibres can be used for rope".

Quick check

- 1 . Name the membrane that surrounds the plant vacuole.
- 2 . State the function of plasmodesmata.
- 3 . Which type of glucose is cellulose made from?
- 4 . Why does amylopectin release glucose faster than amylose?
- 5 . Name the polymer in secondary walls that makes them waterproof and rigid.

Quick check answers

Plant cells and cell walls

- 1 . The tonoplast.
- 2 . They are channels through cell walls, lined by the cell surface membrane, that link the cytoplasm of adjacent cells and allow substances and signals to pass between them.
- 3 . β -glucose, with alternate units rotated through 180° , joined by β -1,4 glycosidic bonds.
- 4 . It is branched, so it has many free ends where enzymes can hydrolyse glycosidic bonds at the same time.
- 5 . Lignin.