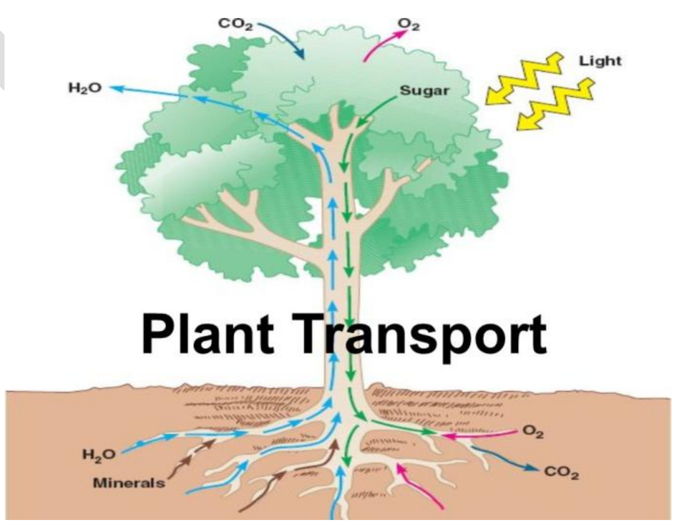
Cambridge
AS level
Biology

CODE: (9700)

Chapter 07
Transport in plants



The transport needs of plants

Transport systems are therefore needed for the following reasons.

■ To move substances from where they are absorbed to where they are needed

■ To move substances from where they are produced to where they are needed for metabolism

■ To move substances to a different part of the plant for storage

Unlike animals, plants do not have systems for transporting carbon dioxide and oxygen. Instead, these gases diffuse through air spaces within stems, roots and leaves.

■ Carbon dioxide - Photosynthetic plant cells require carbon dioxide during daylight, primarily found in leaves with thin, flat surfaces. They absorb this carbon dioxide through diffusion from the air.

■ Oxygen - Plant cells require oxygen for respiration, with photosynthesis cells producing more oxygen than non-photosynthesizing cells. Plants have lower energy demands and respiration rates, requiring less oxygen supply. Their branching shape and air spaces facilitate effective oxygen absorption.

Two systems: xylem and phloem

Plants have two transport systems: xylem and phloem. Xylem carries water and mineral salts from roots to above ground, while phloem transports substances made by photosynthesis from leaves to other areas. Both systems do not move fluids as rapidly as mammal blood or have an obvious pump like the heart.

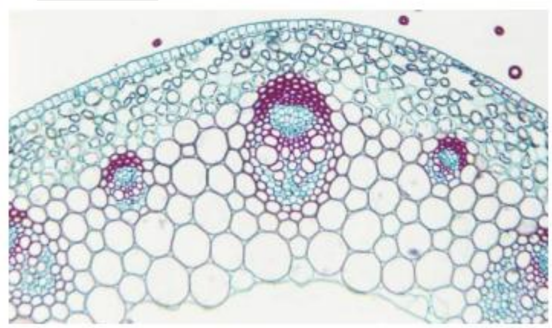


Figure 7.2 Light micrograph of part of a transverse section of a young *Ranunculus* (buttercup) stem (×60).

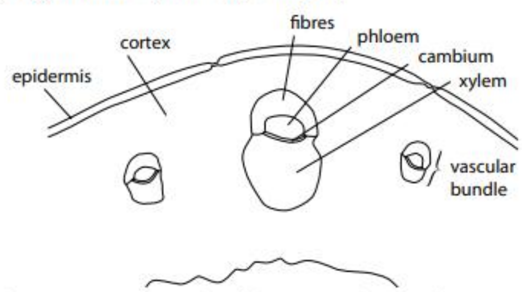


Figure 7.3 Low-power plan of the *Ranunculus* stem shown in Figure 7.2.

Structure of stems, roots and leaves

Stems, roots, and leaves are the main organs in plants for transport, composed of multiple tissues. Tissues are collections of cells specialized for a specific function. Studying these tissues is easy using transverse sections slides and microscope drawings. Structure is closely linked to function and following the advice in Box 7.1 is crucial.

Flowering plants (angiosperms) may be **monocotyledons** (monocots) or **dicotyledons** (dicots). Each type has its own characteristics.

Low-power plan diagrams

Transverse sections of a typical dicotyledonous stem, root and leaf are shown in Figures 7.2, 7.3 and 7.5–7.8. In each case a labelled photomicrograph from a prepared slide is shown, followed by a low-power, labelled drawing of the same organ.

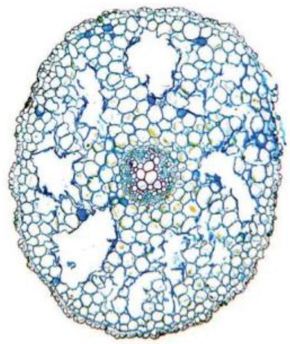


Figure 7.5 Light micrograph of a transverse section of *Ranunculus* (buttercup) root (×35).

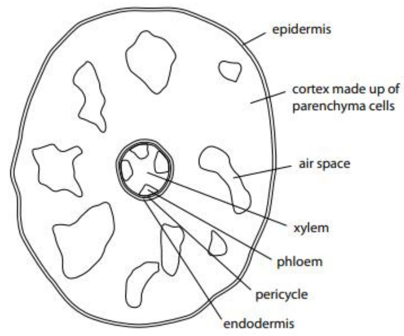


Figure 7.6 Low-power plan of the *Ranunculus* root shown in Figure 7.5.

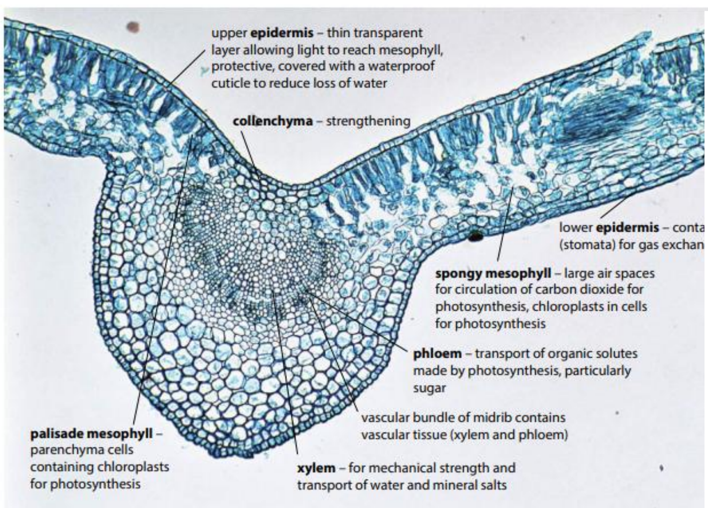


Figure 7.7 Transverse section through the midrib of a dicotyledonous leaf, *Ligustrum* (privet) (×50). Tissues are indic bold type.

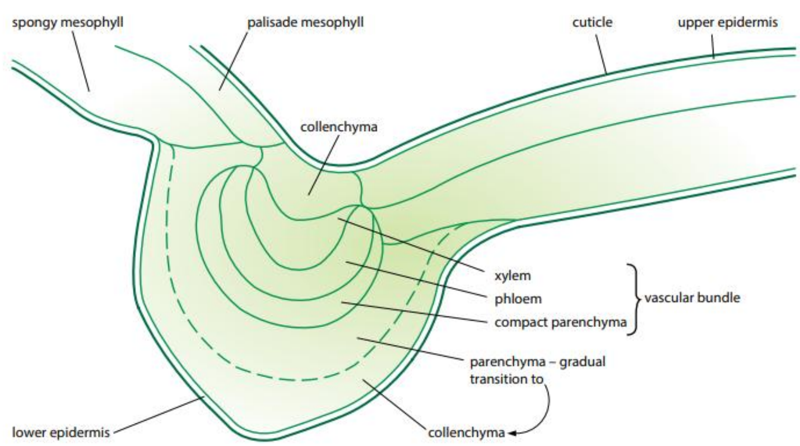


Figure 7.8 A plan diagram of the transverse section through a privet leaf shown in Figure 7.7. Parenchyma is a tissue made up of unspecialised cells. Collenchyma is made up of cells in which the walls are thickened with extra cellulose, especially at the corners, providing extra strength for support.

High-power detail diagrams

To accurately draw cells at high power, focus on two or three representative cells of each tissue, rather than trying to draw many to resemble the specimen on the slide. Use low-power plans to indicate cell locations. Figures 7.9-7.13 provide a brief description of tissues.

Epidermis

In stems and leaves it is covered with a waxy **cuticle** which is waterproof and helps to protect the organ from drying out and from infection. In leaves, it also has pores called **stomata** which allow entry of carbon dioxide for photosynthesis. In roots, it may have extensions called **root hairs** to increase the surface area for absorption of water and mineral salts.

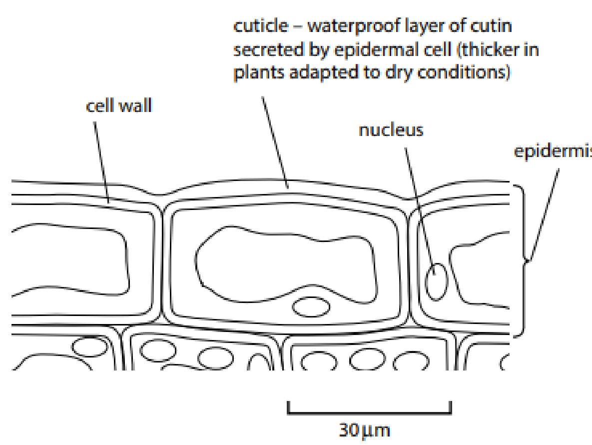


Figure 7.9 High-power detail of a transverse section of leaf epidermis.

Parenchyma

Parenchyma is a type of plant tissue composed of thin, metabolically active cells used for packing, food storage, and gas exchange. It forms the cortex in roots and stems, and the pith in stems. In leaves, it contains chloroplasts, which form the palisade and mesophyll. They also support the plant and facilitate gas exchange.

Collenchyma

Collenchyma is a modified form of parenchyma with extra cellulose deposited at the corners of the cells. This provides extra strength. The midrib of leaves contains collenchyma (figure 7.10)

Endodermis

The endodermis, like the epidermis, is one cell thick (Figure 7.11). It surrounds the vascular tissue in stems and roots. Its function in roots is explained later in this chapter.

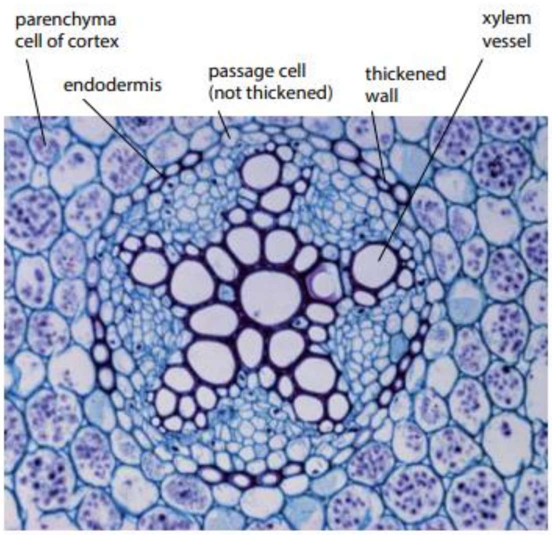


Figure 7.11 Light micrograph of part of a transverse section of a young dicotyledonous root. The endodermis with its thickened walls is shown. Note also the passage cell which allows the passage of water (×250).

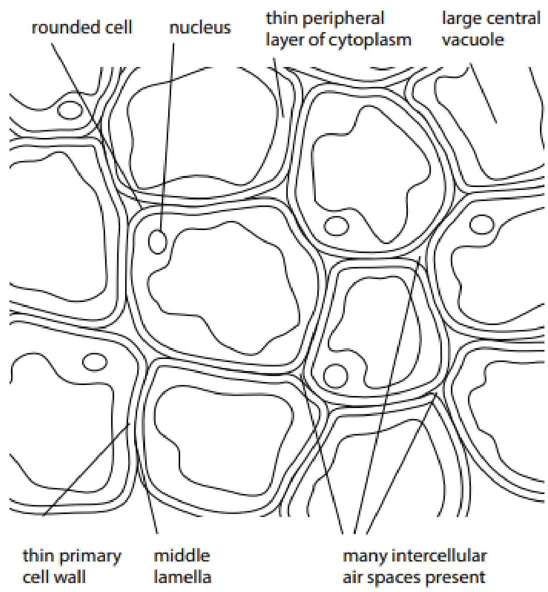


Figure 7.10 High-power detail of a transverse section of parenchyma. Cells are usually roughly spherical, though may be elongated. The average cell diameter is about 25 μm.

Mesophyll

'Meso' means middle and 'phyll' means leaf. The **mesophyll** is made up of specialised parenchyma cells found between the lower and upper epidermis of the leaf (Figure 7.12). They are specialised for photosynthesis and therefore contain chloroplasts. They are of two types, **palisade mesophyll** and **spongy mesophyll. '**

Pericycle

This is a layer of cells, one to several cells thick, just inside the endodermis and next to the vascular tissue. In roots, it is one cell thick and new roots can grow from this layer. In stems, it is formed from a tissue called **sclerenchyma** (Figure 7.13). This has dead, lignified cells for extra strength.

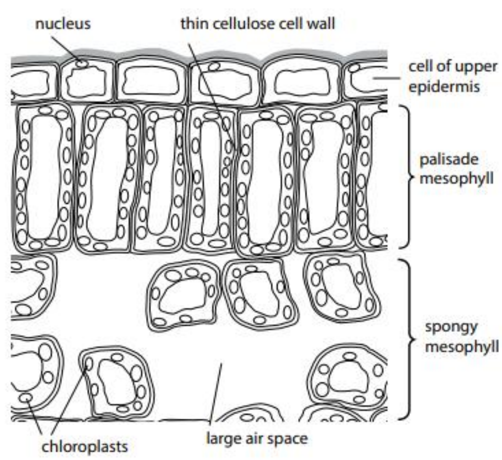


Figure 7.12 High-power detail of palisade and spongy mesophyll cells seen in transverse section.

Vascular tissue

Xylem and phloem both contain more than one type of cell and together they make the vascular tissue. 'Vascular' means having tubes for transporting fluids. Xylem contains tubes called vessels made from dead cells called **xylem vessel elements**. The walls of the cells are reinforced with a strong, waterproof material called lignin. Xylem allows long distance transport of water and mineral salts. It also provides mechanical support and strength. In roots, it is at the centre and has a series of 'arms' between which the phloem is found (Figures 7.5 and 7.6). In stems, the xylem and phloem are found in bundles called **vascular bundle**

Phloem contains tubes called sieve tubes made from living cells called **sieve tube elements**

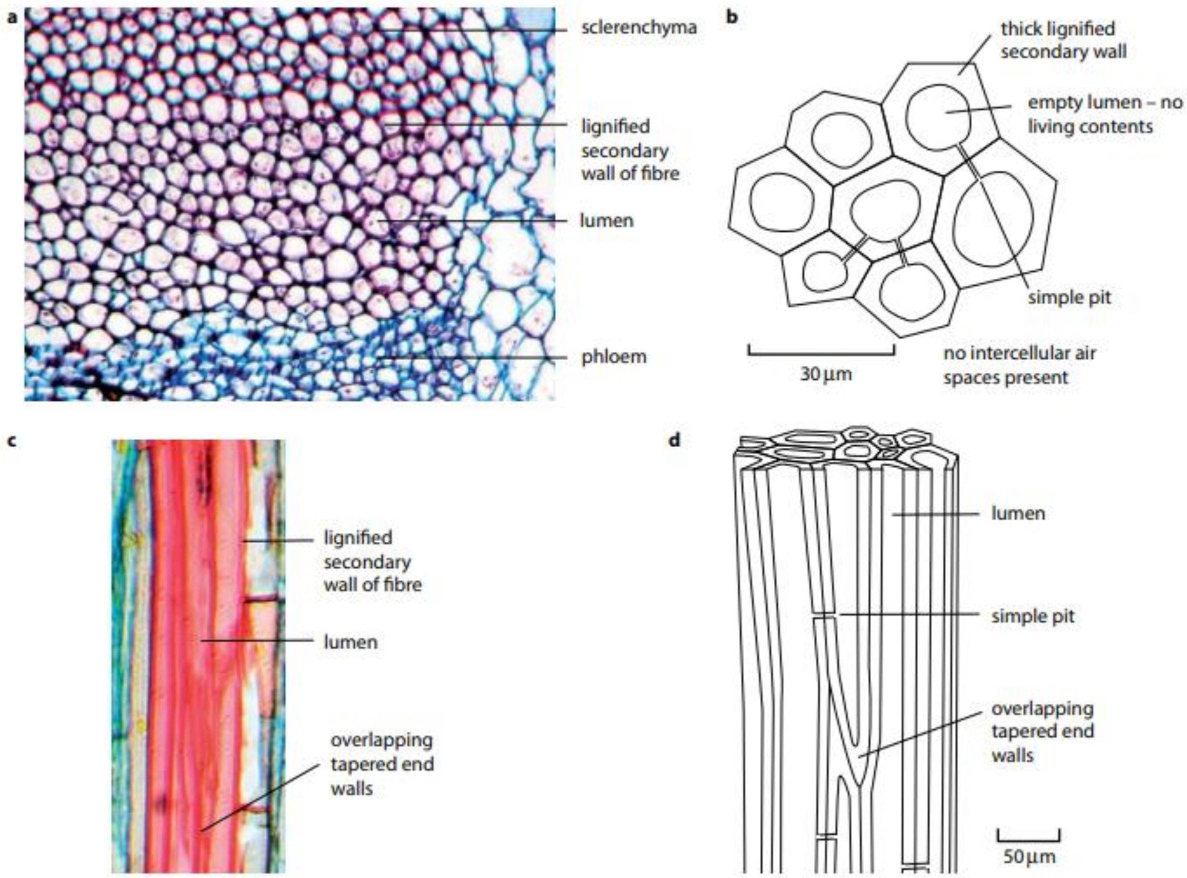


Figure 7.13 Structure of sclerenchyma cells. **a** light micrograph in TS (×100), **b** drawing in TS, **c** light micrograph in LS (×200) and **d** drawing in LS.

The transport of water

Figure 7.14 illustrates the water transport pathway in a plant, involving passive evaporation from leaves. The process begins with the Sun's energy, causing water to evaporate from leaves through transpiration. This reduces water potential in leaves, creating a water potential gradient throughout the plant. Water moves down this gradient, entering the plant through root hairs and xylem tissue in the center. The water then moves through the soil and into the plant's xylem tissue.

Once inside the xylem vessels, the water moves upwards through the root to the stem and from there into the leaves

From leaf to atmosphere – transpiration

Figure 7.15 shows the internal structure of a dicotyledonous leaf. The cells in the **mesophyll** ('middle leaf') layers are not tightly packed and have many spaces around them filled with air.

The air in the internal spaces of the leaf has direct contact with the air outside the leaf, through small pores called **stomata**.

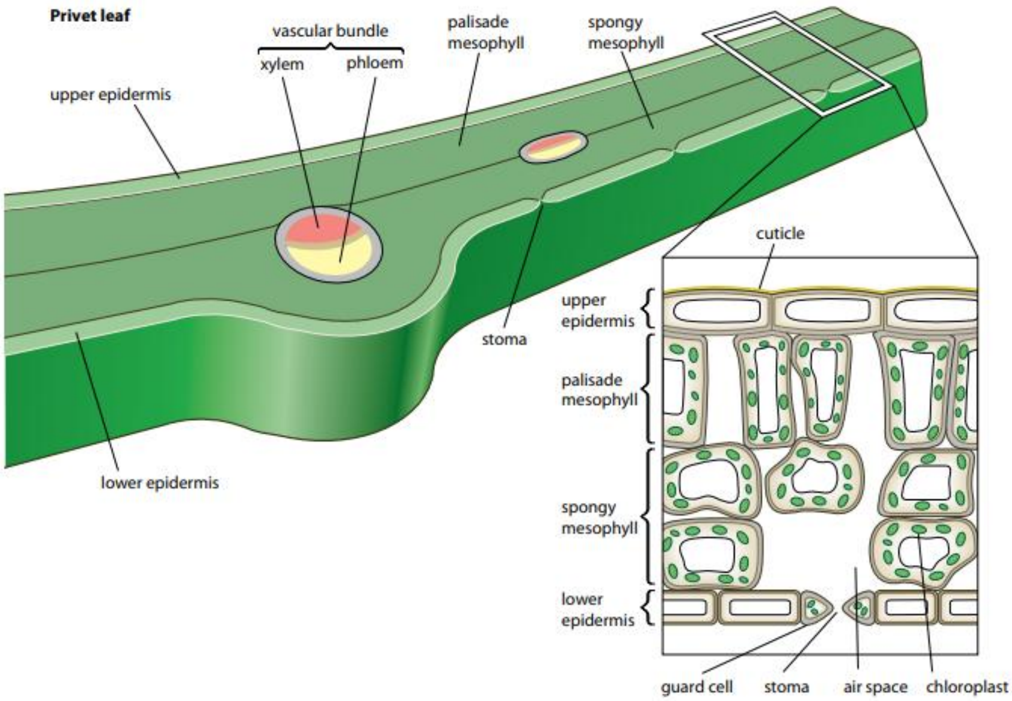
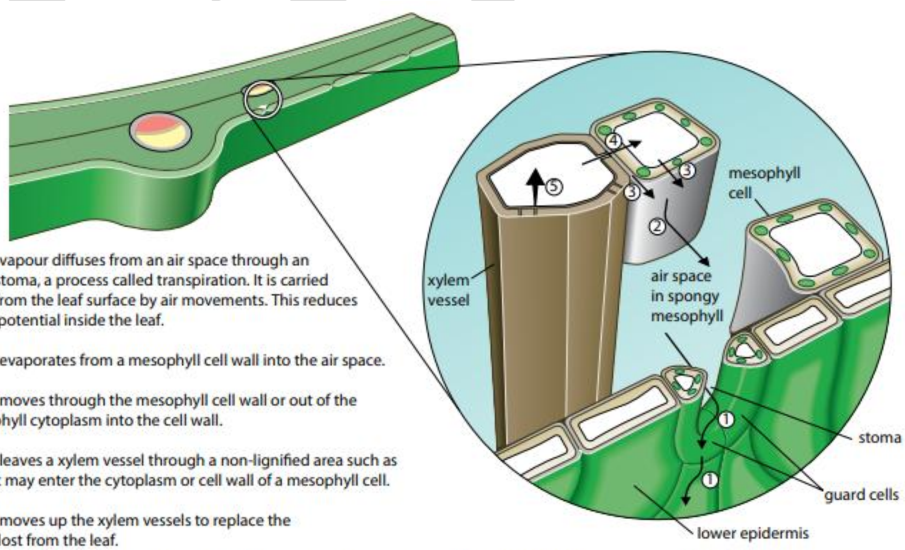


Figure 7.15 The structure of a dicotyledonous leaf. Water enters the leaf as liquid water in the xylem vessels and diffuses out as water vapour through the stomata.



1 Water vapour diffuses from an air space through an open stoma, a process called transpiration. It is carried away from the leaf surface by air movements. This reduces water potential inside the leaf.

2 Water evaporates from a mesophyll cell wall into the air space.

3 Water moves through the mesophyll cell wall or out of the mesophyll cytoplasm into the cell wall.

4 Water leaves a xylem vessel through a non-lignified area such as a pit. It may enter the cytoplasm or cell wall of a mesophyll cell.

5 Water moves up the xylem vessels to replace the water lost from the leaf.

Figure 7.16 Water movement through a leaf. Water is, in effect, being pulled through the plant as a result of transpiration and evaporation. Movement of water through the plant is therefore known as the transpiration stream.

Factors affecting transpiration

■■ Humidity. If the water potential gradient between the air spaces in the leaf and the air outside becomes steeper, the rate of transpiration will increase. In conditions of low humidity, the gradient is steep, so transpiration takes place more quickly than in high humidity.

■■ Wind speed and temperature. Transpiration may also be increased by an increase in wind speed or rise in temperature.

■■ Light intensity. In most plants, stomata open during the day and close at night. Most transpiration takes place through the stomata (although a little water vapour can escape through the epidermis if the cuticle is thin)

■■ Very dry conditions. In especially dry conditions, when the water potential gradient between the internal air spaces and the external air is steep, a plant may have to compromise by partially or completely closing its stomata to prevent its leaves drying out, even if this means reducing the rate of photosynthesis

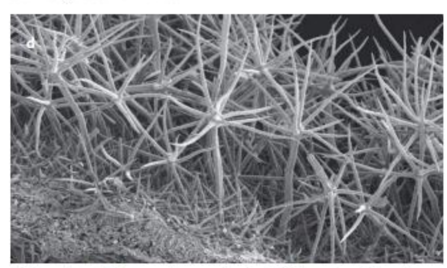
Figure 7.17 The *Fatsia* plant on the left has plenty of water and remains turgid. The plant on the right is wilted because it has lost more water by transpiration than has been taken up by its roots, and so does not have sufficient water to maintain the turgidity of its cells.

Xerophytes

Xerophytes (or xerophytic plants) are plants that live in places where water is in short supply. Many xerophytes have evolved special adaptations of their leaves that keep water loss down to a minimum. Some examples are shown in Figure 7.21.

a A scanning electron micrograph of a TS through part of a rolled leaf of marram grass, *Ammophila arenaria*. This grass grows on sand dunes, where conditions are very dry. The leaves can roll up due to shrinkage of special 'hinge cells', exposing a thick, waterproof cuticle to the air outside the leaf. The cuticle contains a fatty, relatively waterproof substance called cutin. The stomata are found only in the upper epidermis and therefore open into the enclosed, humid space in the middle of the 'roll'. Hairs help to trap a layer of moist air close to the leaf surface, reducing the steepness of the diffusion gradient for water vapour.

c False colour scanning electron micrograph of a needle from a Sitka spruce (×1265), a large tree native to Canada and Alaska. Its leaves are in the form of needles, greatly reducing the surface area available for water loss. In addition, they are covered in a layer of waterproof wax and have sunken stomata, as shown here.



d Scanning electron micrograph of a TS through a *Phlomis italica* leaf showing its trichomes (×20). These are tiny hair-like structures that act as a physical barrier to the loss of water, like the marram grass hairs. *Phlomis* is a small shrub that lives in dry habitats in the Mediterranean regions of Europe and North Africa.

It is useful to observe the xerophytic features of marram grass (Figure 7.21a) for yourself by examining a transverse section with a light microscope and making an annotated drawing using Figure 7.22 to help you. Note the sunken stomata on the inner surface (upper epidermis) – they are at the bottoms of grooves in the leaf. Note also that the outer surface (lower epidermis) has no stomata.

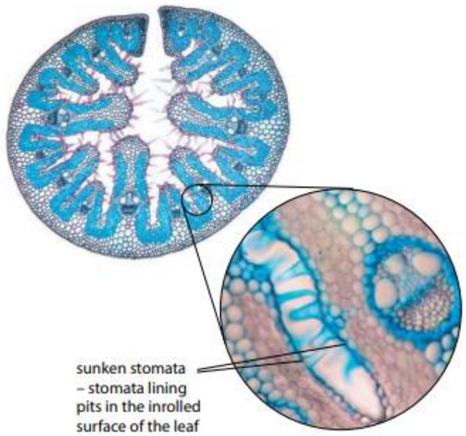


Figure 7.22 Light micrograph of a transverse section of a rolled marram grass leaf.

e The cardon *Euphorbia canariensis* grows in dry areas of Tenerife. It has swollen, succulent stems that store water and photosynthesise. The stems are coated with wax, which cuts down water loss. The leaves are extremely small.

From xylem across the leaf

The water then moves down a water potential gradient from cell to cell in the leaf along two possible pathways. In one pathway, known as the **symplastic pathway,** water moves from cell to cell via the plasmodesmata. In the other pathway, known as the **apoplastic pathway,** water moves through the cell walls.

Xylem tissue

To understand how water moves into the xylem from the root, up the stem and into the leaves, scientists first had to understand the structure of xylem tissue. Of particular interest were the xylem vessels, which have certain unusual characteristics:

■They are made from cells joined end to end to form tubes

■The cells are dead

■The walls of the cells are thickened with a hard, strong material called lignin

Xylem tissue (Figure 7.23) has two functions, namely support and transport. It contains several different types of cell. In flowering plants, xylem tissue contains vessel elements, tracheids, fibres and parenchyma cells.

■■ Vessel elements and tracheids are the cells that are involved with the transport of water. Unlike other plants, flowering plants rely mostly on the vessel elements for their water transport, so only these are described in detail below.

■■ Sclerenchyma fibres are elongated cells with lignified walls that help to support the plant. They are dead cells; they have no living contents at all.

■■ Parenchyma cells .

Xylem vessels and vessel elements

Figure 7.23 shows the structure of typical xylem vessels. Vessels are made up of many elongated cells called **vessel elements**, arranged end to end.

Each vessel element begins life as a normal plant cell in whose wall **lignin** is laid down.

As lignin builds up around the cell, the contents of the cell die, leaving a completely empty space, or **lumen**, inside.

The non-lignified areas can be seen as 'gaps' in the thick walls of the xylem vessel and are called **pits**.

Th e end walls of neighbouring vessel elements break down completely, to form a continuous tube rather like a drainpipe running through the plant. Th is long, non-living tube is a **xylem vessel.**

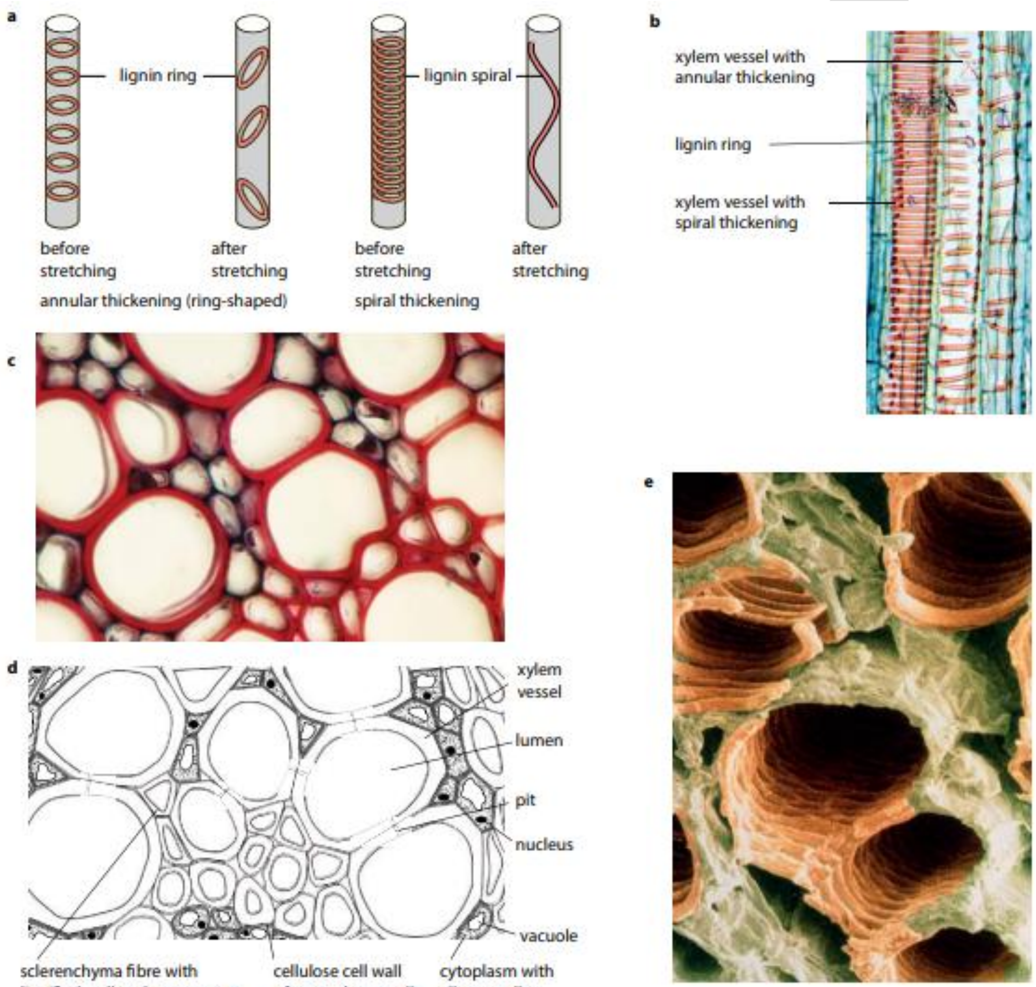


Figure 7.23 Structure of xylem. **a** Diagrams to show different types of thickening. **b** Micrograph of xylem as seen in longitudinal section. Lignin is stained red (×100). **c** and **d** Micrograph and diagram of xylem as seen in transverse section; lignin is stained red. Small parenchyma cells are also visible between the xylem vessels (×120). **e** Scanning electron micrograph of mature xylem vessels, showing reticulate (net-like) pattern of lignification (×130).

The movement of water up through xylem vessels is by **mass flow.** This means that all the water molecules (and any dissolved solutes) move together, as a body of liquid, like water in a river. This is helped by the fact that water molecules are attracted to each other by

hydrogen bonding. this attraction is called **cohesion**. They are also attracted to the cellulose and lignin in the walls of the xylem vessels, and this attraction is called **adhesion.**

Air bubbles cannot pass through pits. Pits are also important because they allow water to move out of xylem vessels to surrounding living cells. The xylem tissue in dicotyledonous stems is arranged in a series of rods around the centre of the stem, as shown in Figure 7.24. These strong rods help to support the stem.

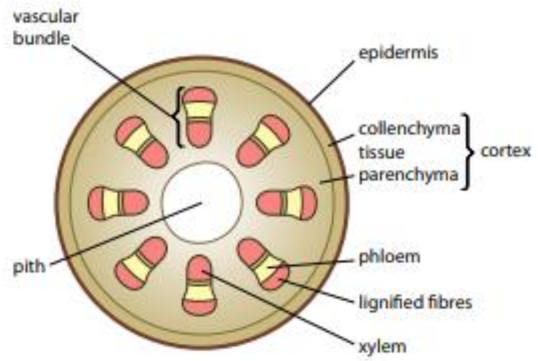


Figure 7.24 TS of a young sunflower (*Helianthus*) stem to show the distribution of tissues. The sunflower is a dicotyledonous plant.

Root pressure

You have seen how transpiration **reduces** the water (hydrostatic) pressure at the top of a xylem vessel compared with the pressure at the base, so causing the water to flow up the vessels. Plants may also increase the pressure difference between the top and bottom by **raising** the water pressure at the **base** of the vessels

Water transport in plants is largely a **passive** process, driven by transpiration from the leaves. The water simply moves down a continuous water potential gradient from the soil to the air.

From root hair to xylem

Figures 7.25 and 7.26 depict transverse sections of a young root, showing xylem vessels in the center, unlike stems' ring arrangement. Water taken up by root hairs crosses the root cortex and enters the xylem due to lower water potential inside the vessels compared to the root hairs. This water potential gradient moves water down the root.

Water can soak into these walls, rather as it would soak into blotting paper, and can seep across the root from cell wall to cell wall without ever entering the cytoplasm of the cortical cells. Th is is called the **apoplastic pathway** (Figure 7.27a).

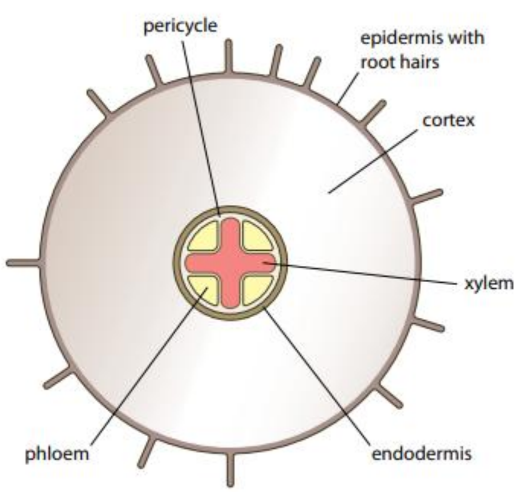


Figure 7.26 TS of a young dicotyledonous root to show the distribution of tissues.

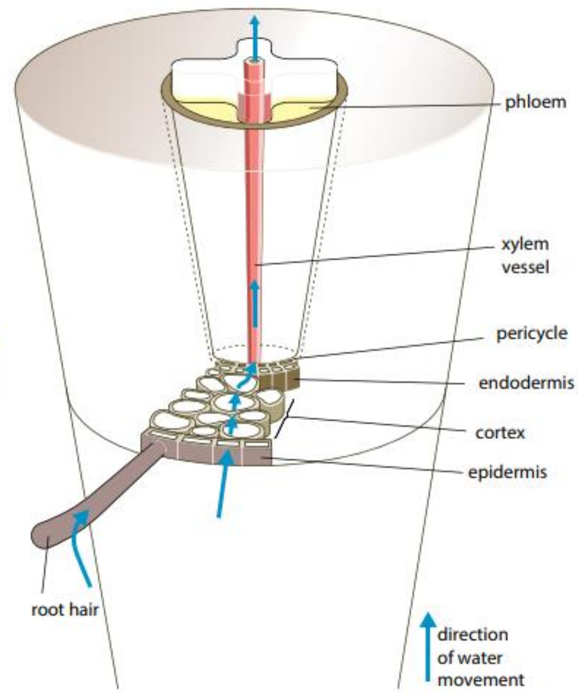
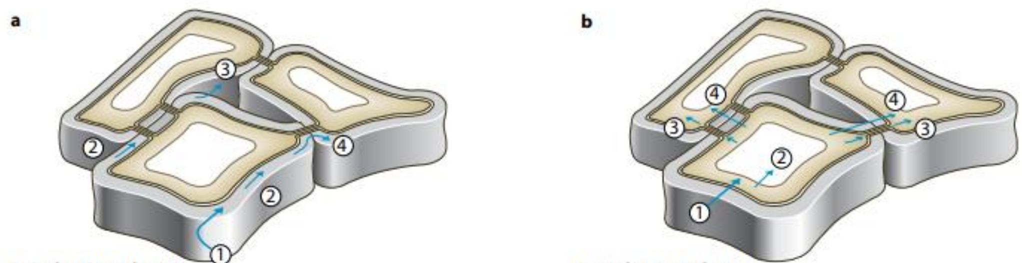


Figure 7.25 The pathway of water movement from root hair to xylem.

Another possibility is for the water to move into the cytoplasm or vacuole of a cortical cell by osmosis, and then into adjacent cells through the interconnecting plasmodesmata. Th is is the **symplastic pathway.**

Once the water reaches the **endodermis** (Figures 7.25 and 7.26), the apoplastic pathway is abruptly blocked. Th e cells in the endodermis have a thick, waterproof, waxy band of **suberin** in their cell walls (Figure 7.28). Th is band, called the **Casparian strip.**

As the endodermal cells get older, the suberin deposits become more extensive, except in certain cells called **passage cells,**



Apoplastic pathway

1. Water enters the cell wall.
2. Water moves through the cell wall.
3. Water may move from cell wall to cell wall through the intercellular spaces.
4. Water may move directly from cell wall to cell wall.

Symplastic pathway

1. Water enters the cytoplasm by osmosis through the partially permeable cell surface membrane.
2. Water moves into the sap in the vacuole, through the tonoplast by osmosis.
3. Water may move from cell to cell through the plasmodesmata.
4. Water may move from cell to cell through adjacent cell surface membranes and cell walls.

Figure 7.27 **a** Apoplastic and **b** symplastic pathways for movement of water from root hairs to xylem.

From soil into root hair

Figure 7.29a shows a young root. Th e tip is covered by a tough, protective root cap and is not permeable to water. However, just behind the tip some of the cells in the outer layer, or **epidermis**, are drawn out into long, thin extensions called **root hairs.**

Many plants, especially trees, have fungi located in or on their roots, forming associations called **mycorrhizas,** which serve a similar function to root hairs.

Some trees, if growing on poor soils, are unable to survive without these fungi. In return, the fungi receive organic nutrients from the plant. The name given to a relationship such as this, in which two organisms of different species both benefits, is mutualism.

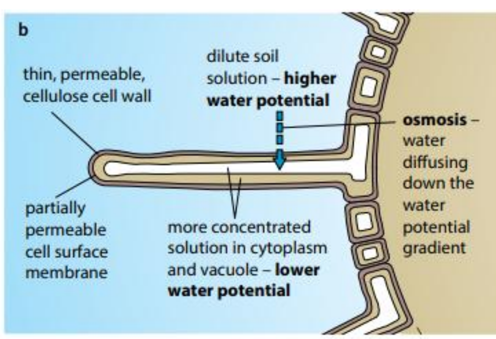


Figure 7.29 **a** A root of a young radish (*Raphanus*) plant showing the root cap and the root hairs. **b** Water uptake by a root hair cell. Mineral ions are also taken up, mostly by active transport against the concentration gradient via carrier proteins, but also by diffusion.

Transport of mineral ions

Plants require a supply of mineral ions, such as nitrate, phosphate, sulfate, potassium, magnesium, and calcium, in addition to carbohydrates produced in photosynthesis. These ions are absorbed by roots, particularly by root hairs, and their route through the plant is like water, crossing the root through apoplastic and symplastic pathways before moving in mass flow of xylem sap up the xylem to the rest of the plant. From the xylem, they enter apoplastic and symplastic pathways again. Mineral ions can also move by diffusion and active transport, such as diffusion into the root's apoplastic pathway and diffusion into cells. Cells can control ions' entry or exit, with the root endodermis being an important control point, where the Casparian strip forces ions to pass through living cells before entering the xylem.

Translocation

Translocation refers to the movement of soluble organic substances within a plant, such as sugars produced by photosynthesis in the leaves, from one place to another, often referred to as **assimilates**, which are substances the plant itself has created. This term is commonly used in both xylem and phloem.

Assimilates are transported in sieve elements. **Sieve elements** are found in phloem tissue, along with several other types of cells including **companion cells**, parenchyma and fibres (Figures 7.30 and 7.31)

Sieve tubes and sieve elements

Phloem contains unique tube-like structures called **sieve tubes**. Unlike xylem vessels, sieve tubes are made of **living** cells. Figure 7.30 shows the structure of a **sieve tube** and its accompanying companion cells.

Perhaps the most striking feature of sieve elements is their end walls. Where the end walls of two sieve elements meet, a **sieve plate** is formed.

Companion cells

Companion is closely associated with each sieve element, with a cellulose cell wall, cell surface membrane, cytoplasm, small vacuole, and nucleus. These cells have a larger number of mitochondria and ribosomes than normal and are metabolically active. They are considered a single functional unit, with numerous plasmodesmata passing through their cell walls, making direct contact between the cytoplasm of the companion cell and the sieve element.

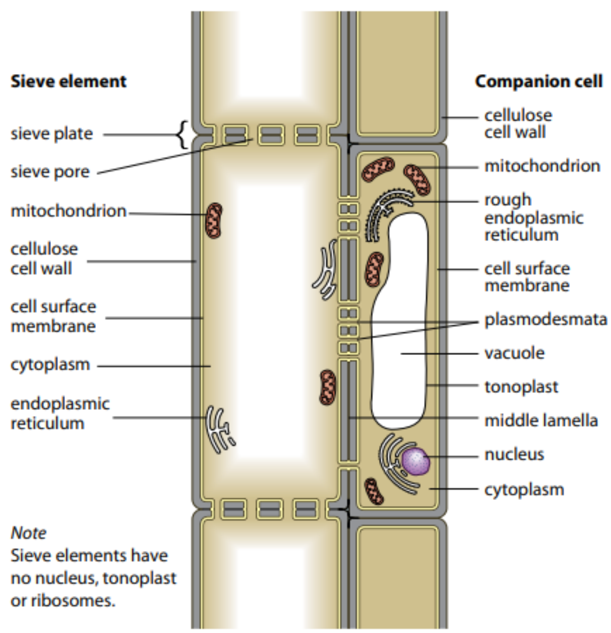


Figure 7.30 A phloem sieve tube element and its companion cell.

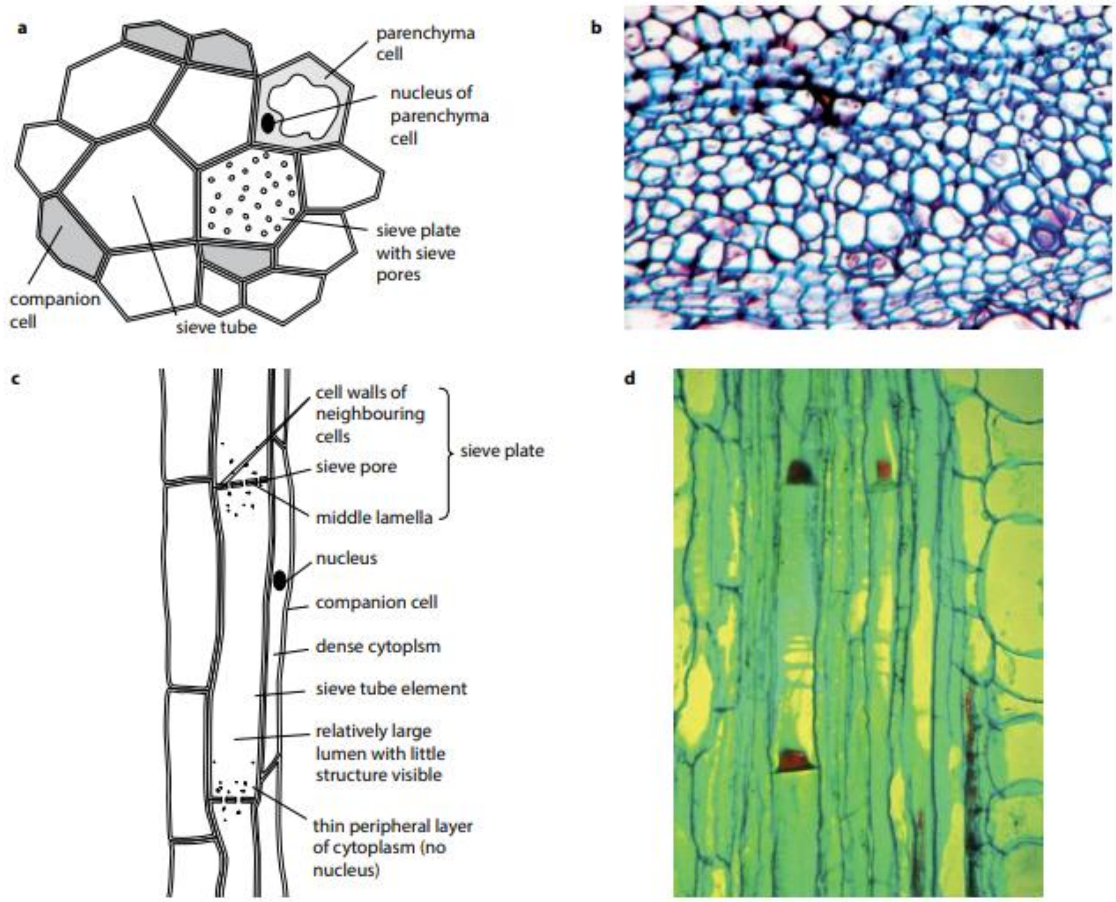


Figure 7.31 Structure of phloem. **a** Diagram in TS, **b** light micrograph in TS (×300), **c** diagram in LS, **d** light micrograph in LS (×200). The red triangles are patches of callose that formed at the sieve plates between the sieve tube elements in response to the damage done as the section was being cut. You can see companion cells, with their denser cytoplasm, lying alongside the sieve tube elements. On the far right are some parenchyma cells.

The contents of phloem sieve tubes

The liquid inside phloem sieve tubes is called **phloem sap,** or just sap. Table 7.3 shows the composition of the sap of the castor oil plant, Ricinus communis.

Collecting enough phloem sap for analysis is challenging due to high pressure in sieve tubes. When cut, pressure surges, blocking the sieve plate to prevent escape.

is helps to prevent escape of the contents of the sieve tube. Then, within minutes, the sieve plate is properly sealed with a carbohydrate called **callose**, a process sometimes called '**clotting'.**

Aphids, like greenfly, feed on sap using stylets, which are tubular mouthparts inserted into the plant's stem or leaves. The sap flows through the stylet, but its small diameter prevents rapid sap flow.

Solute	Concentration / mol dm^{-3}
sucrose	250
potassium ions	80
amino acids	40
chloride ions	15
phosphate ions	10
magnesium ions	5
sodium ions	2
ATP	0.5
nitrate ions	0
plant growth substances (e.g. auxin, cytokinin)	small traces

Table 7.3 Composition of phloem sap.

How translocation occurs

Phloem sap, like the contents of xylem vessels, moves by **mass flow,** as the aphid experiment shows.

To create the pressure differences needed for mass flow in phloem, the plant must use energy. Phloem transport is therefore an **active** process, in contrast to the **passive** transport in xylem.

The pressure difference is produced by **active loading** of sucrose into the sieve elements at the place from which sucrose is to be transported. Any area of a plant in which sucrose is loaded into the phloem is called a **source.**

Any area where sucrose is taken out of the phloem is called a **sink**.

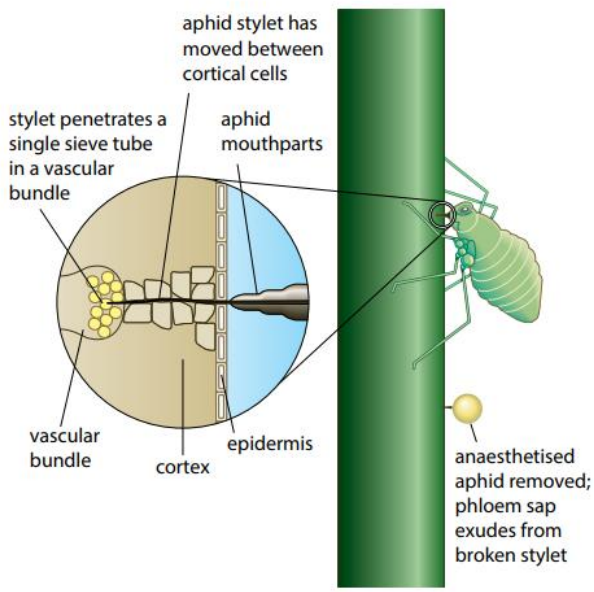
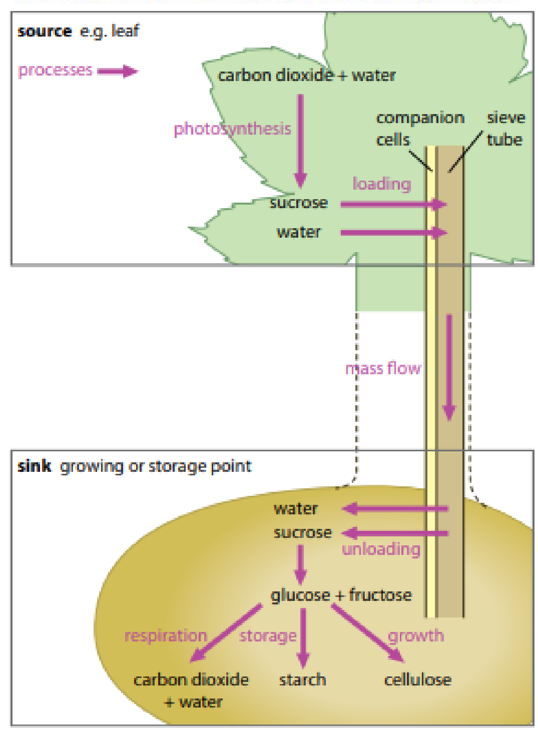


Figure 7.32 Using an aphid to collect phloem sap.

Figure 7.33 The phloem sap of the sugar maple (*Acer saccharum*) contains a high concentration of sugar and can be harvested to make maple syrup. Taps are inserted into each



The sink is a growing point, e.g. young leaf, bud, flower or root, or a storage point, e.g. seed, fruit or tuber.

Figure 7.34 Sources, sinks and mass flow in phloem.

Sinks can be anywhere in the plant, both above and below the photosynthesising leaves. Thus, sap flows both upwards and downwards in phloem (in contrast to xylem, in which flow is always upwards). Within any vascular bundle, phloem sap may be flowing upwards in some sieve tubes and downwards in others, but it can only flow one way in any sieve tube at any one time.

Loading sucrose into phloem

Photosynthesis in leaf mesophyll cells produces triose sugars, some of which are converted into sucrose. Sucrose moves from the mesophyll cell to the phloem tissue via the symplastic pathway or the apoplastic pathway. The symplastic route is more important for species. Sucrose is loaded into a companion cell or directly into a sieve element by active transport, where hydrogen ions are pumped out of the companion cell and transported through a **co-transporter molecule.**

Unloading sucrose from phloem

Unloading occurs into any tissue which requires sucrose. It is probable that sucrose moves out of the phloem into these tissues using both symplastic and apoplastic routes, as with loading. Phloem unloading requires energy, and similar methods to those used for loading are probably used. Once in the tissue, the sucrose is converted into something else by enzymes, so decreasing its concentration and maintaining a concentration gradient. One such enzyme is invertase, which hydrolyses sucrose to glucose and fructose.

Differences between sieve tubes and xylem vessels

Phloem sieve tubes differ from xylem vessels in structure due to active loading of sucrose at sources, forming sieve plates. This allows for a steep positive pressure gradient and quick equilibration of pressures at source and sink. Phloem vessels have lignified cell walls, allowing cells to be dead and empty, allowing water to flow unimpeded. Sieve tubes also reduce resistance to flow by having only a thin layer of cytoplasm and no nuclei. The 'clotting' of phloem sap may also prevent the entry of microorganisms that might feed on it or cause disease.

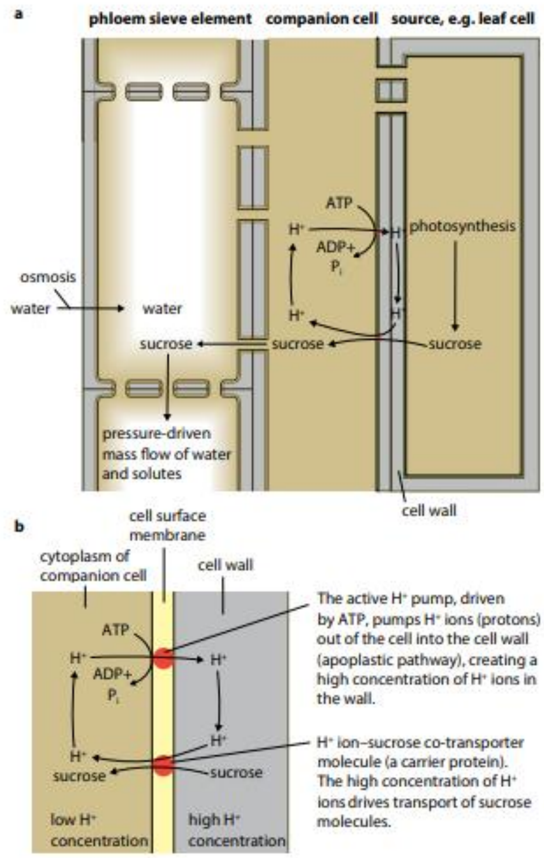
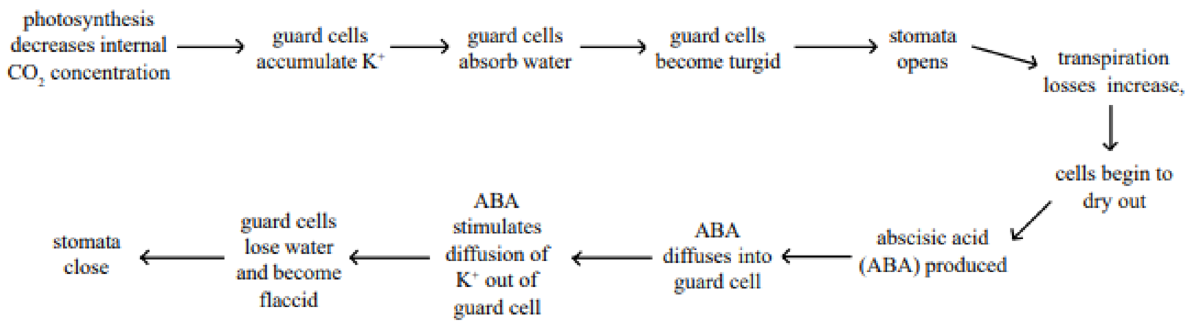


Figure 7.35 Loading phloem. **a** One of the possible methods by which sucrose is loaded and a pressure gradient generated. **b** Detail of the H^+ ion-sucrose co-transporter system.

Revision questions

(1) The diagram shows a proposed mechanism to explain the regulation of the opening and closing of stomata



(a) Explain why:

(i) the accumulation of K+ in guard cells causes them to absorb water.

(ii) stomata open when guard cells become turgid.

(b) Using information in the diagram, explain the term negative feedback.

(c) Why is transpiration sometimes called 'a necessary evil'?

(2) The table below shows the mean number of stomata on the upper and lower sides of leaves from two species of herbaceous plant.

Species	Mean number of stomata / cm^{-2}	
	Upper surface	Lower surface
A	820	2712
B	5500	5800

(a) Suggest a method which you could use to obtain the data in the table

(b)(i) Which of the two species, A or B is likely to be a monocotyledon? Explain your answer.

(ii) Which of the two species, A or B, is likely to live in the driest conditions? Explain your answer.

(3) The table shows some of the characteristics of two types of plant cell

	Cell X	Cell Y
Structure	Hollow and dead when mature. Ends of cells overlapping. Have bordered pits.	Hollow and dead when mature. Form long cylinder as end cell walls break down.
Length	Up to 10 mm	Stacked end to end, units stretch up to 1 metre
Width	10 – 15 µm	40 – 80 µm

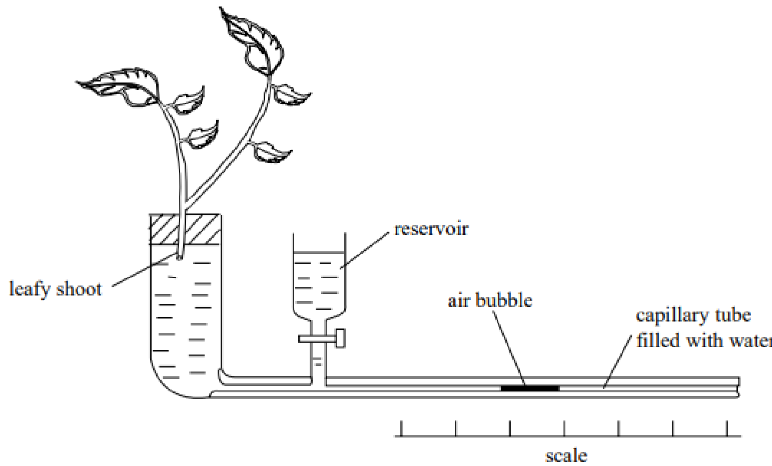
(a) Identify cells X and Y

(b) Explain why angiosperms possess large amounts of tissue formed from cell Y rather than from cell X

(c) (i) Name the plant tissue in angiosperms where sugars and amino acids are transported, and name the two main types of cell found in that tissue

(ii) Sugars and amino acids are transported in the plant by a mass flow method. Outline the process of mass flow

(4) A student used the apparatus below to estimate the rate of transpiration of a leafy shoot



(a) (i) Name this piece of apparatus

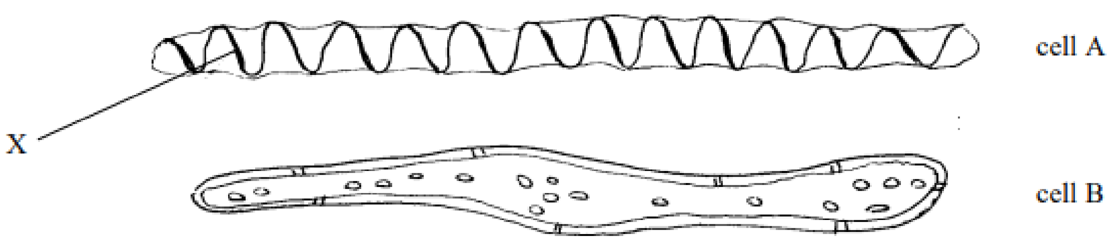
(ii) What does this piece of apparatus measure?

(iii) What is the purpose of the air bubble?

(b)(i) State three precautions which must be taken when setting up this apparatus

(ii) How would you use the apparatus to measure the effect of wind speed on transpiration rate?

(5) The diagram below shows two types of cell from a tissue of a flowering plant



(a) (i) Name cells A and B

(ii) From what plant tissue do these cells come?

(iii) Name two other types of cell which would be present in the tissue you have named

(iv) What is X made of and why is it in a spiral form?

(b)(i) State two functions of this tissue

(ii) State three ways in which cell A is suited for its functions

(6) (a) Suggest explanations for the following observations:

(i) In summer, angiosperms may lose a much greater volume of water via transpiration than gymnosperms.

(ii) Fruit growth is suppressed if a ring of bark between the fruit and mature leaves is removed.

(iii) Translocation in the phloem may be stopped by metabolic inhibitors

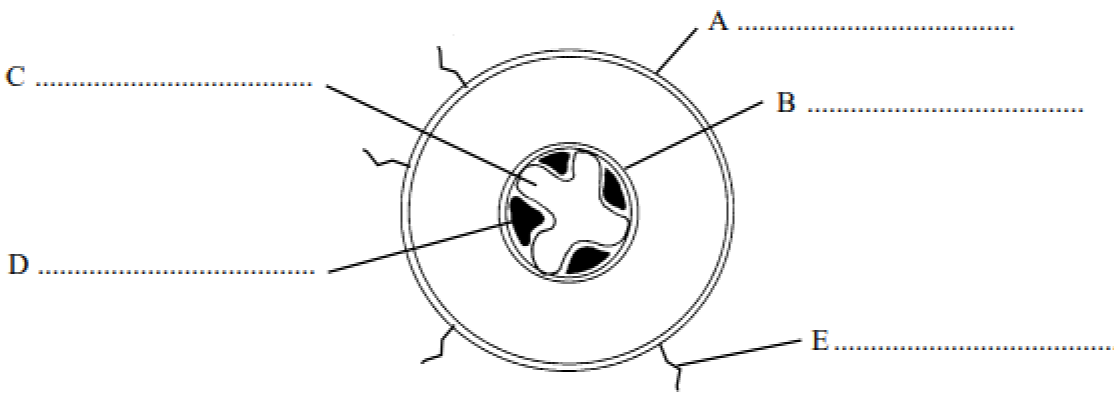
(7) The table shows the destination (sink) of translocated carbohydrates in a mature tomato plant

Destination	% of total translocated carbohydrate
Roots	26
Stem	22
Leaves	12
Tomatoes	40

(a) Suggest an explanation for the percentage of carbohydrate translocated to the tomatoes.

(b)Outline how phloem tissue is structurally adapted for its role in carbohydrate transport.

(c) The diagram below shows a transverse section of a root.



(a) On the diagram label A,B,C, D and E.

(b)For each of the following root structures, state their functions and outline one way in which they are structurally adapted for their function:

(i) B Function: ....

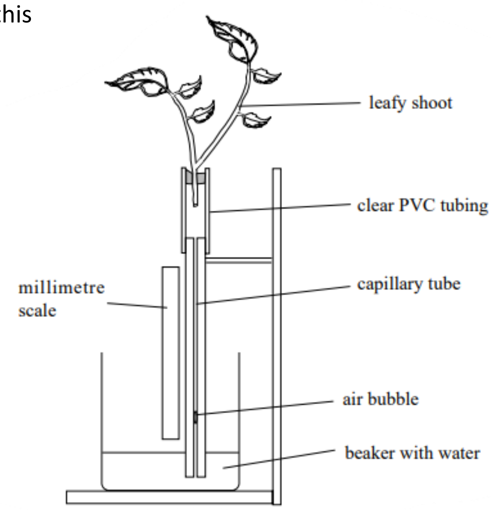
Adaptation: ....

(ii) E Function: ....

Adaptation: ....

(8) The diagram shows a simple potometer.

(a) Suggest two precautions which should be taken when setting up this apparatus.



This potometer was used to investigate the effect of leaf area on water uptake. The potometer was initally set up as above and the distance moved by the bubble in ten minutes was recorded. One of the leaves was then detached from the plant. The potometer was adjusted appropriately and the distance moved by the bubble was measured over a second 10 minute period. The investigation was repeated until only one leaf remained. The table below shows the result which were obtained.

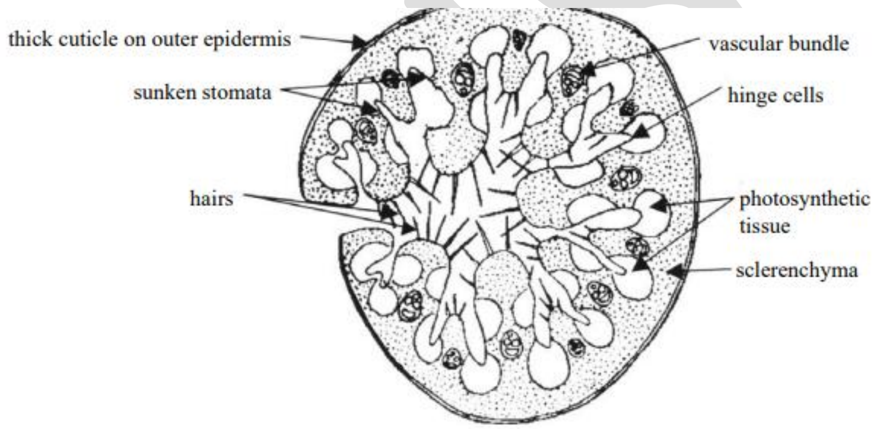
Number of leaves on shoot	Distance moved by bubble in ten minutes (mm)
5	83
4	60
3	44
2	10
1	6

(b)(i) Using a suitable scale, plot this data on graph paper.

(ii) Describe and explain the trend shown

(iii) What assumption is made in using the apparatus in this way?

(9) The diagram below shows a transverse section of the leaf of the xerophytic plant Marram grass (Ammophila arenaria)



(a) Describe and explain two xerophytic features shown in the diagram.

(b) Outline the connection between the loss of water from the leaves and the movement of water through the plant

(c) The graph below shows the effect of defoliation (removal of all leaves) of a white ash tree on the sugar content of the phloem

(a) Explain what these results suggest about the source of sugars in the phloem

(b)Outline the 'mass flow hypotheses.