# CAIE Biology A-level

## Topic 7: Transport in plants

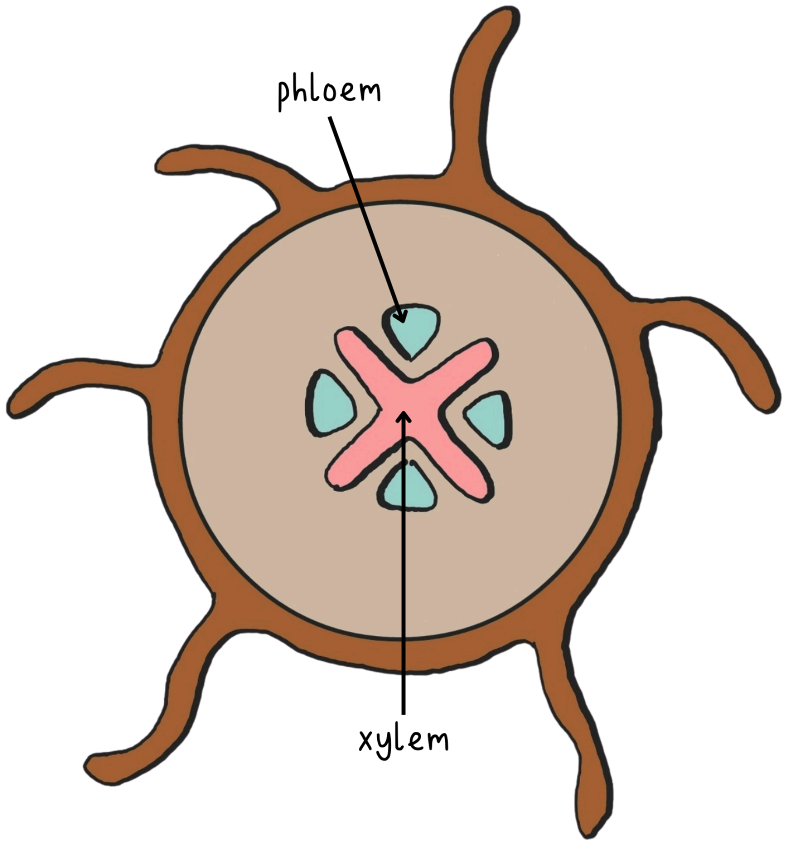
Notes

Plants require a transport system to ensure that all plant cells receive sufficient nutrients. This is achieved through the combined action of xylem tissue which enables water and minerals to travel passively up the plant in transpiration, and phloem tissue, which allows sugars to be transported between sources and sinks in the active process of translocation.

# The vascular bundle

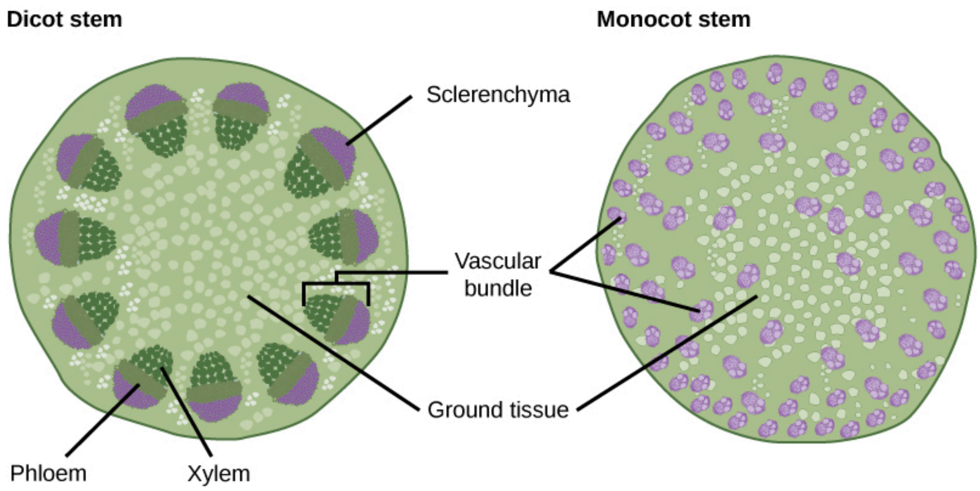
**The vascular bundle in the roots:**

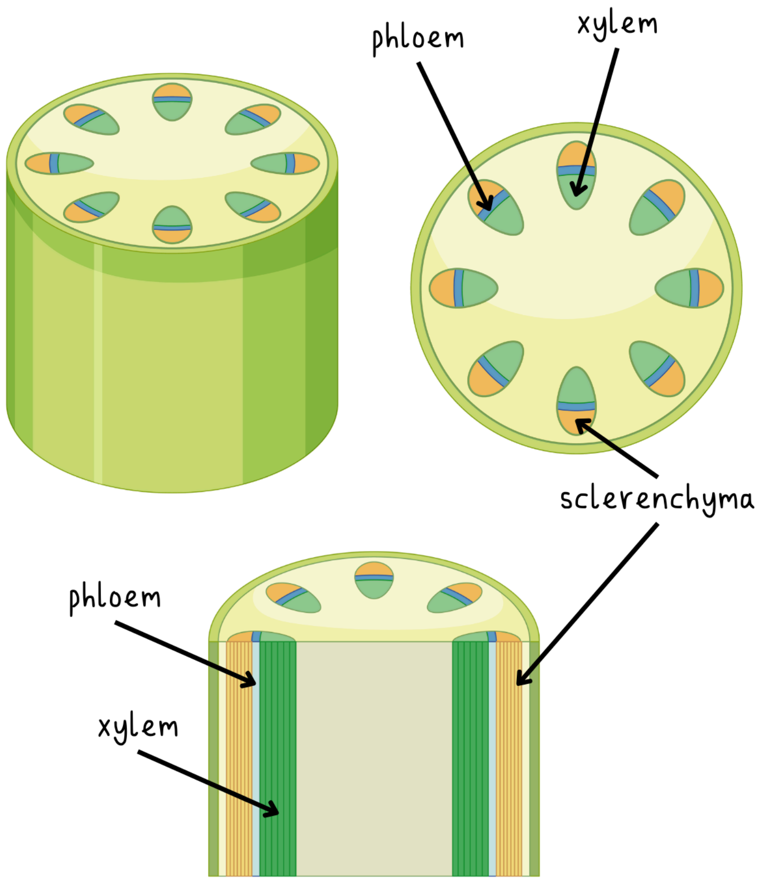
- Xylem and phloem are components of the vascular bundle, which serves to enable transport of substances as well as for structural support.
- The xylem vessels are arranged in an X shape in the centre of the vascular bundle. This enables the plant to withstand mechanical forces such as pulling.
- The X shape arrangement of xylem vessels is surrounded by endodermis, an inner layer of cortex cells that regulates the movement of water and mineral ions into the xylem.
- Just inside the endodermis is a layer of meristematic tissue known as the pericycle.



**The vascular bundle in the stem:**

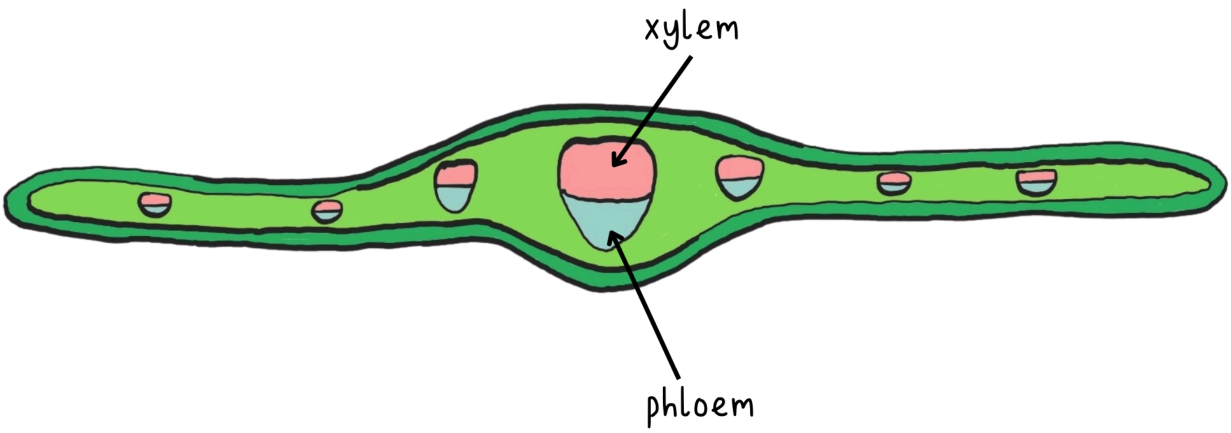
- In **dicotyledonous stems**, xylem is located on the inside of each vascular bundle to provide support and flexibility to the stem.
- Phloem is found on the outside of the vascular bundle.
- There is a layer of **cambium** between xylem and phloem; this consists of meristematic cells which are involved in production of new xylem and phloem tissue.



**The vascular bundle in the leaf:**

- The vascular bundles form the **midrib and veins** of a leaf.
- **Dicotyledonous leaves** have a network of **veins**, starting at the midrib and spreading outwards which are involved in transport and support.
- In the leaf, xylem is located **closer to the upper epidermis**, while phloem lies nearer **the lower epidermis.**



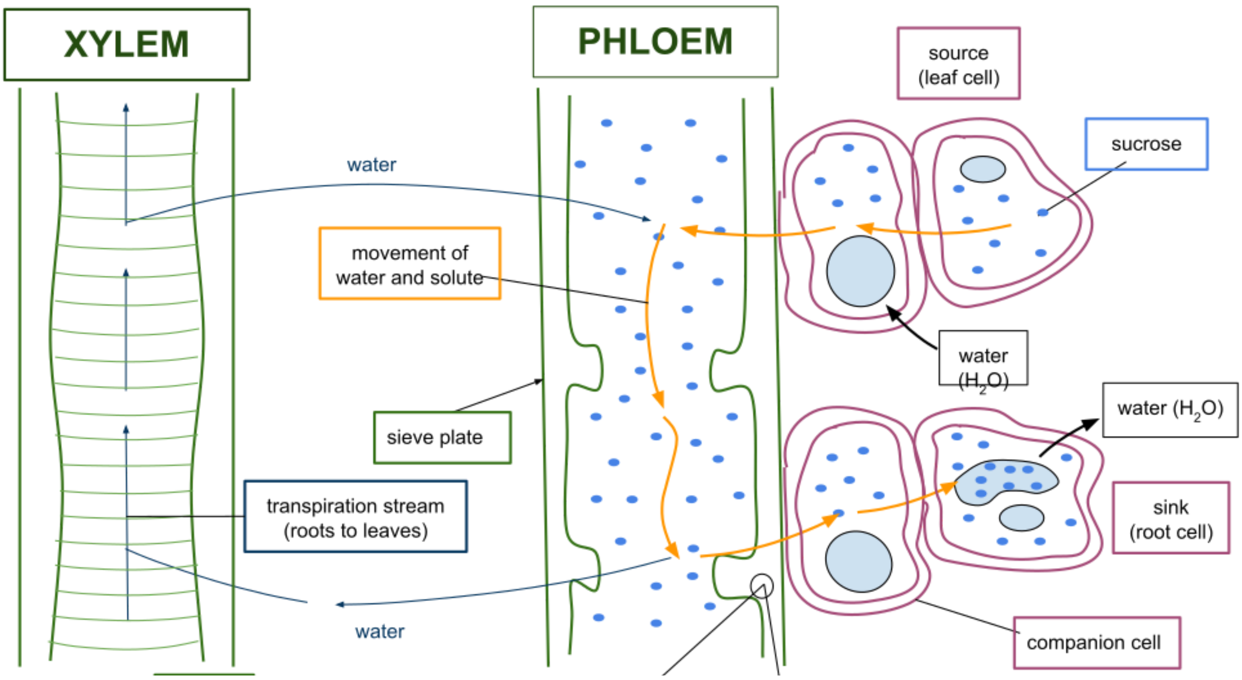
# Xylem and phloem

**Xylem vessels have the following features:**

- They transport water and minerals, and also serve to provide structural support.
- They are long cylinders made of **dead tissue** with **open ends**, therefore they can form a continuous column.
- Xylem vessels contain pits that enable lateral movement of water between vessels.
- They are thickened with a tough substance called **lignin** which is deposited in **spiral or annular patterns**, providing strength while allowing flexibility.

**The features of phloem vessels include:**

- They are tubes made of **living cells**.
- Involved in **translocation** which is the movement of nutrients to storage organs and growing parts of the plant.
- Consist of **sieve tube elements** and **companion cells.**
- Sieve tube elements form a tube to transport sugars such as sucrose, in the dissolved form of sap.
- Companion cells are involved in **ATP production** for active processes such as loading sucrose into sieve tubes.
- The cytoplasm of sieve tube elements and companion cells is linked by **plasmodesmata**, which allow communication and the movement of substances such as sucrose between cells.



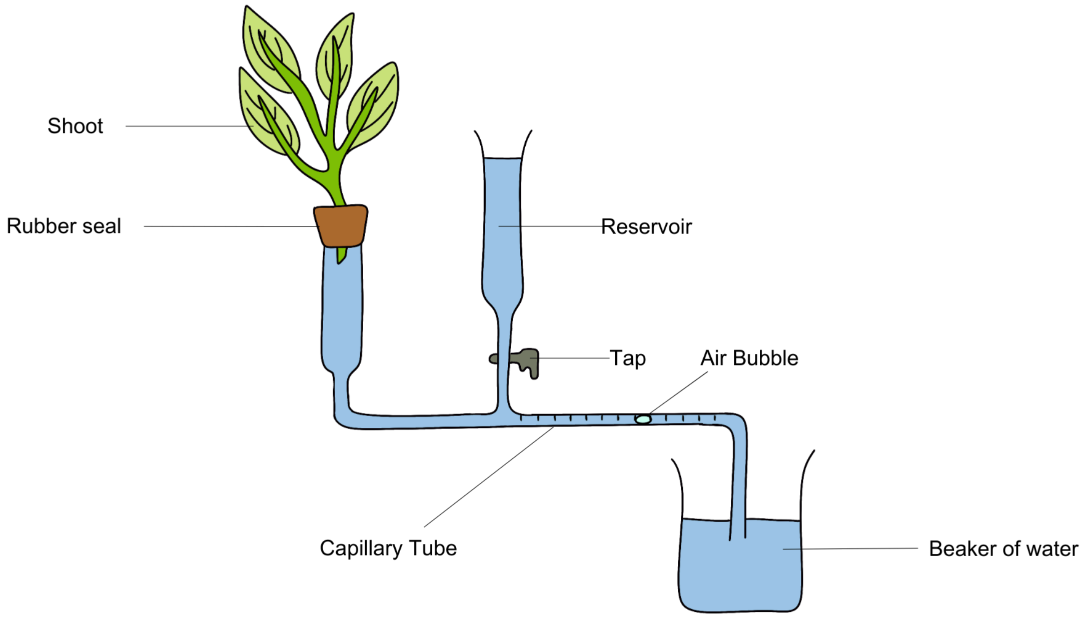
# Transpiration

**Transpiration** is the loss of water vapour from the aerial parts of a plant, mainly through the stomata of the leaves. Water evaporates from the surface of the leaf and then moves into the atmosphere via diffusion as water vapour. Carbon dioxide enters, while water vapour and oxygen exit through a leaf's stomata by diffusion.

The **transpiration stream,** which is the movement of water up the stem, enables processes such as photosynthesis, growth and elongation as it supplies the plant with water which is necessary for all these processes. Apart from this, the transpiration stream supplies the plant with the required minerals, whilst enabling it to control its temperature via evaporation of water.

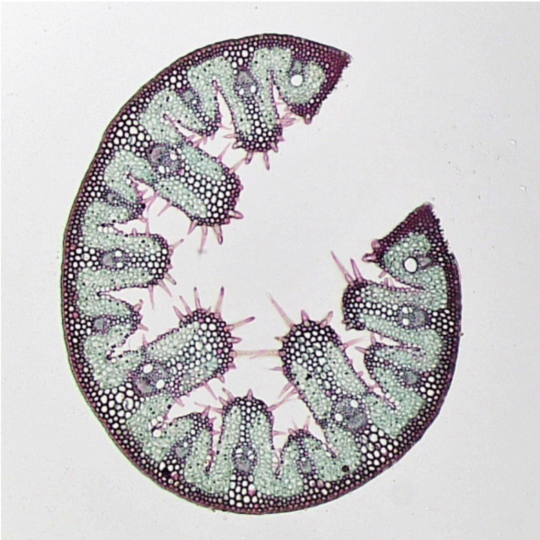
Osmosis is involved in the uptake of water by root hair cells and movement between living cells. Transpiration also involves **evaporation** from the surface of mesophyll cells into intercellular spaces and diffusion of water vapour down a water potential gradient out of the stomata.

The rate of transpiration can be investigated with the help of a **potometer** where water lost by the leaf is replaced by water in the capillary tube. Therefore, measuring the movement of the meniscus can be used to estimate the rate of transpiration. Factors which affect the rate of transpiration include **number of leaves, number/size or position of stomata, presence of waxy cuticle, the amount of light present, the temperature, humidity, air movement and water availability.**



**Xerophytes** are plants adapted to living in **dry conditions**. They are able to survive in such conditions because of various adaptations which serve to **minimise the water loss**. The adaptations include:

- Small leaves which reduce the surface area for water loss
- Densely packed mesophyll reduces air spaces, while a thick waxy cuticle reduces evaporation.
- Moreover, xerophytes respond to low water availability by closing the stomata to prevent water loss.
- They contain hairs and pits which serve as a means of trapping moist air, thus reducing the water vapour potential.
- They also roll their leaves to reduce the exposure of lower epidermis to the atmosphere, thus trapping air.
- Leaf loss helps decrease the number of leaves to reduce water loss via transpiration
- Water is stored in parenchyma tissue
- Large extensive roots to increase water uptake



# Movement of water in the root

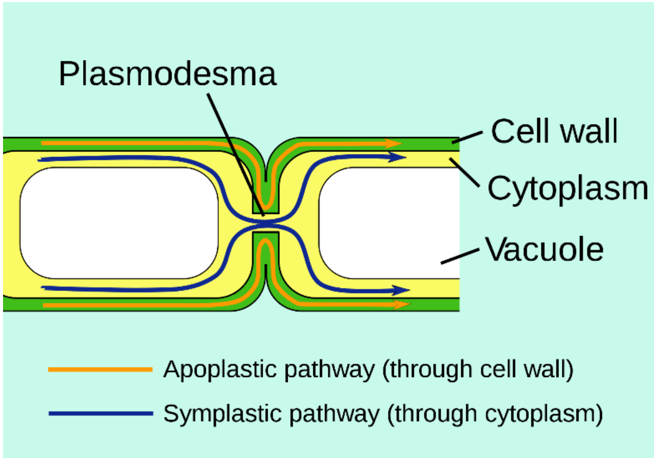
Water enters through **root hair cells** and moves into the xylem tissue located in the centre of the root. This movement occurs as a result of a **water potential gradient**, as the water potential is higher inside the soil than inside the root hair cells, due to the dissolved substances in the **cell sap.**

Therefore, the purpose of **root hair cells** is to provide a large surface area for water uptake.

Minerals are also absorbed through the root hair cells by **active transport**, as they need to be pumped against the concentration gradient.

**There are two ways the water taken up by the root hair cells can move across the cortex of the root into xylem:**

- It can either occur via the **symplast pathway** where water enters the cytoplasm through the plasma membrane and passes from one cell to the next through plasmodesmata, the channels which connect the cytoplasm of one cell to the next.
- The other pathway is the **apoplast pathway** where the water moves through the water-filled spaces between cellulose molecules in the cell walls. In this pathway, water does not pass through any plasma membranes; therefore, it can carry dissolved mineral ions and salts.
- When the water reaches a part of the root called the endodermis, it encounters a layer of suberin which is known as the **Casparian strip**, which blocks the apoplast pathway.
- Therefore, in order for the water to cross the **endodermis**, the water that has been moving through the cell walls must now enter the symplast pathway via the plasma membrane.
- Once it has moved across the endodermis, the water continues down the water potential gradient from cell to cell until it enters the xylem vessel via pits in the vessel wall.



## Water moving in the xylem up the stem

The water is removed from the top of the xylem vessels into the mesophyll cells down the **water potential gradient.** The upward movement of water is aided by **root pressure**, which results from active transport of mineral ions into the xylem. This drives water into the xylem by **osmosis**, contributing to the upward movement of water. Root pressure contributes to water movement but is insufficient alone to account for transpiration in tall plants.

The flow of water is also maintained with the help of **surface tension** of water and the attractive forces (hydrogen bonding) between water molecules known as **cohesion**. The action of these two forces in combination is known as the **cohesion-tension theory**, with **capillary action** playing a minor supporting role, where adhesion between water molecules and the cellulose cell walls, together with cohesion between water molecules, helps maintain a continuous water column.

## Translocation

**Translocation** is an energy requiring process which serves as a means of transporting assimilates (such as sucrose) dissolved in water in the phloem between sources which release sucrose such as leaves and **sinks** e.g. roots and meristems which remove sucrose from the phloem.

Sucrose enters the phloem in a process known as **active loading.** The **proton pumps** of **companion cells** use ATP to transport hydrogen ions into the surrounding tissue, creating a **diffusion gradient**. This causes the H+ ions to diffuse back into the companion cells. It is a form of **facilitated diffusion** involving cotransporter proteins which allows the returning H+ ions to bring sucrose molecules into the companion cells, thus causing the concentration of sucrose in the companion cells to increase. As a result of that, the sucrose diffuses out of the companion cells down the **concentration gradient** into the sieve tube elements through links known as **plasmodesmata**.

As sucrose enters the sieve tube elements, the **water potential** inside the tube is reduced, therefore causing water to enter via **osmosis**, as a result increasing the **hydrostatic pressure** of the sieve tube. Therefore, water moves down the sieve tube from an area of higher pressure to an area of lower pressure. Eventually, sucrose is removed from the sieve tube elements by diffusion or active transport into the surrounding cells, thus increasing the water potential in the sieve tube. This in turn means that water leaves the sieve tube by osmosis, as a result **reducing the pressure in the** phloem at the sink.

In summary, the mass flow of phloem sap from the source to the sink down a **hydrostatic pressure gradient** supplies assimilates such as sucrose to where they are needed.