

OCR (A) Biology A-level

Topic 3.3: Transport in plants

Notes

Plants require a **transport system** to ensure that all the cells of a plant receive a sufficient amount of **nutrients**. This is achieved through the combined action of **xylem tissue** which enables water as well as **dissolved minerals** to travel up the plant in the passive process of transpiration, and **phloem tissue** which enables **sugars** to reach all parts of the plant 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 various** mechanical forces such as pulling.
- The X shape arrangement of xylem vessels is surrounded by **endodermis**, which is an **outer layer of cells which supply xylem vessels with water**.
- An inner layer of **meristem cells known as the pericycle**

The vascular bundle in the stem:

- Xylem is located on the **inside in non-wooded plants** to provide **support and flexibility** to the stem
- Phloem is found on the **outside of the vascular bundle**
- There is a **layer of cambium** in between xylem and phloem, that is **meristem 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**

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 also contain **pits** which enable water to **move sideways** between the vessels.
- They are **thickened with a tough substance called lignin**, which is deposited in **spiral patterns** to enable the plant to remain flexible
- Water can only flow upwards

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**. **This transport can be upwards or downwards.**
- Companion cells are involved in ATP production for active processes such as **loading sucrose into sieve tubes**
- Cytoplasm of sieve tube elements and companion cells is linked through structures known as **plasmodesmata which are gaps between cell walls which allow communication and flow of substances such as minerals between the cells**

Transpiration

Transpiration is the process where plants **absorb water through the roots**, which then moves up through the plant and is **released into the atmosphere** as **water vapour** through pores in the leaves. Carbon dioxide enters, while water and oxygen exit through a leaf's stomata.

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**.

Transpiration involves **osmosis**, where water moves from the **xylem to the mesophyll cells**. Transpiration also involves evaporation from the surface of mesophyll cells into intercellular spaces and diffusion of water vapour down a **water vapour potential gradient** out of the stomata.

The rate of transpiration can be investigated with the help of a **potometer** where water vapour lost by the leaf is replaced by water in the capillary tube. Therefore, **measuring the movement of the meniscus can be used to determine 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 **smaller leaves** which reduce the surface area for water loss. Both **densely packed mesophyll and thick waxy cuticles prevent water loss via evaporation**. Moreover, xerophytes respond to low water availability by **closing the stomata to prevent water loss**. Apart from this, they contain **hairs and pits which serve as a means of trapping moist air**, thus reducing the water vapour potential. Xerophytes also **roll the leaves** to reduce the exposure of lower epidermis to the atmosphere, thus trapping air.

Hydrophytes are plants that actually live in water such as water lillies. As such they need their own adaptations for this environment. They have a **very thin or absent waxy cuticle** as they don't need to conserve water. **Many constantly open stomata** are found on the upper surfaces of leaves to **maximise gas exchange**. **Wide, flat leaves** give a **large surface area** for light absorbtion. **Air sacs** are found in some hydrophytes to enable leaves to stay **afloat**. **Many large air spaces** to make leaves and stems more **buoyant**.

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 the movement of water to occur.

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 doesn't 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 cannot be penetrated by water.

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.

Once it has moved across the endodermis, the water continues down the water potential gradient from cell to cell until it reaches a pit in the xylem vessel which is the entry point of water.

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 push of water upwards is aided by the **root pressure** which is where the action of the endodermis moving minerals into the xylem by active transport, drives water into the xylem by osmosis, thus pushing it upwards.

The flow of water is also maintained with the help of **surface tension of water** and the attractive forces between water molecules known as **cohesion**. The action of these two forces in combination is known as the **tension-cohesion theory**, which is further supported by **capillary action** where the forces involved in cohesion cause the water molecule to adhere to the walls of xylem, thus pulling water up.

Translocation

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

Sucrose enters the phloem in a process known as **active loading** where companion cells use **ATP to transport hydrogen ions** into the surrounding tissue, thus creating a **diffusion gradient**, which 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.

Therefore, in summary the mass flow of water from the source to the sink down the **hydrostatic pressure gradient** is a means of supplying assimilates such as sucrose to where they are needed.