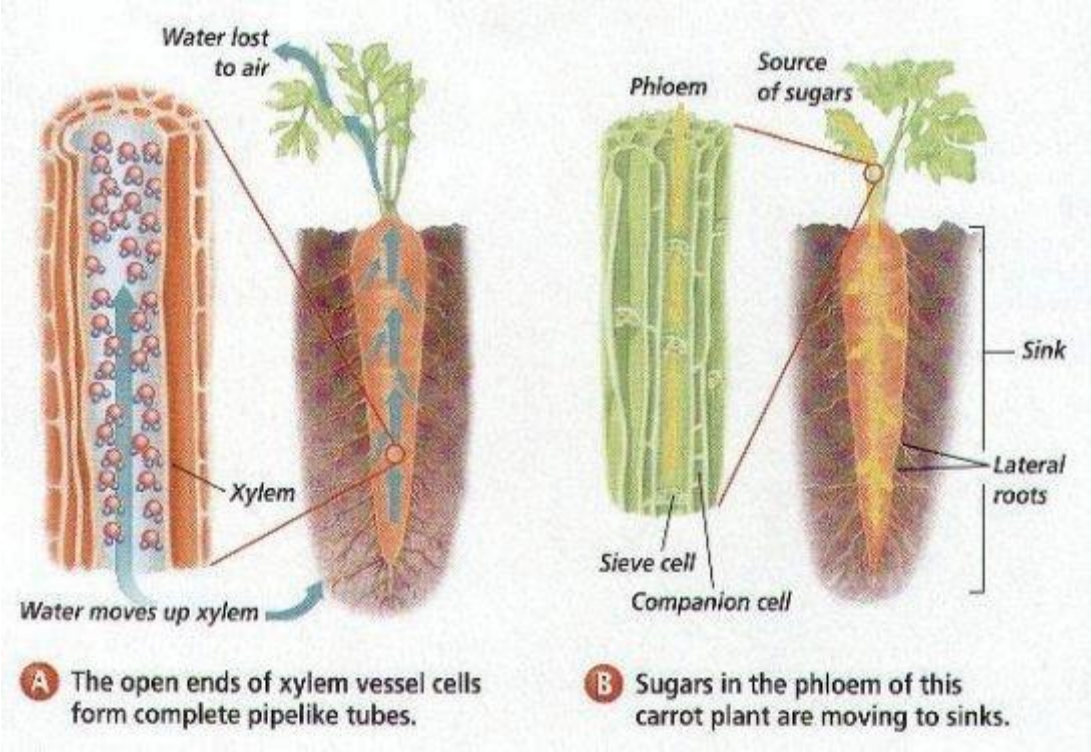
06 - Plant transport

#59 Transport in plants - functions of xylem and phloem

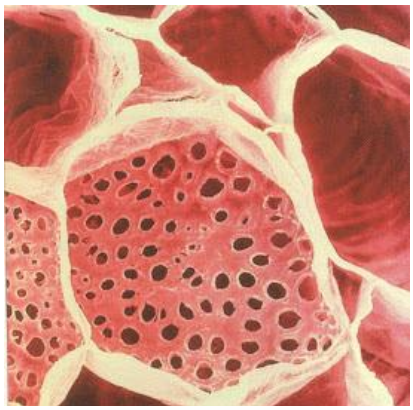


Plants have transport systems to move food, water and minerals around. These systems use continuous tubes called xylem and phloem:

- **Xylem vessels** carry **water** and minerals from the **roots** to the leaves.
- **Phloem** tubes carry **sugar** & other organic **nutrients** made by plant from the **leaves** to the rest of the plant.

Structure of the phloem tissue

This is a long tube that runs alongside the xylem tissue. They are made of long narrow tubes with **perforated sieve plates** along the thin length.



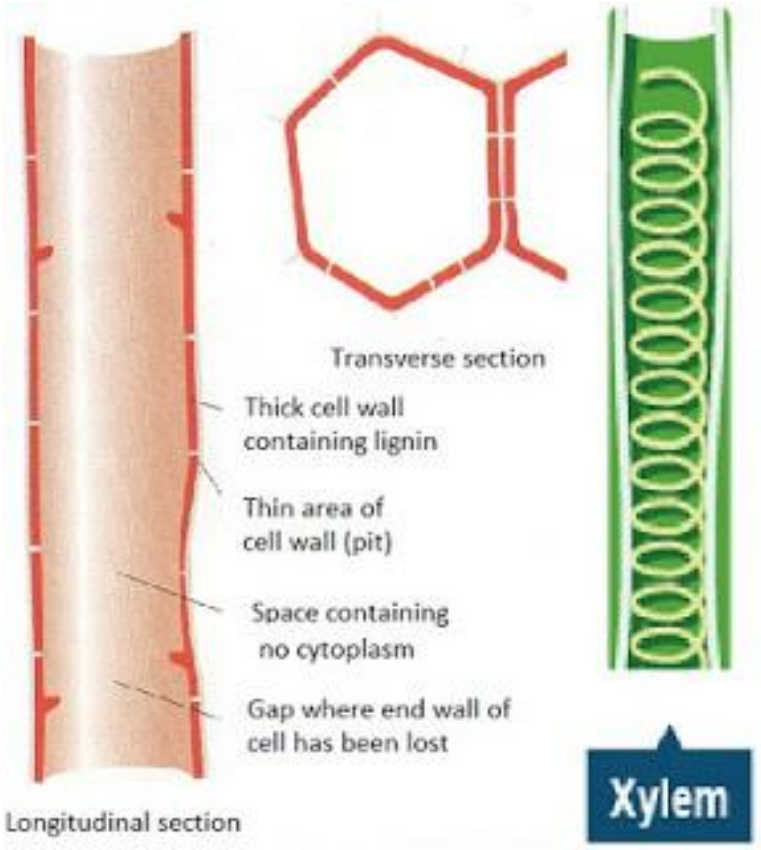
Scanning electron micrograph of a sieve plate in a phloem tube (x1300)

The function of the phloem tissue is to **transport** food nutrients such as **glucose** and **amino acids** from the leaves and to all other cells of the plant, this is called translocation.

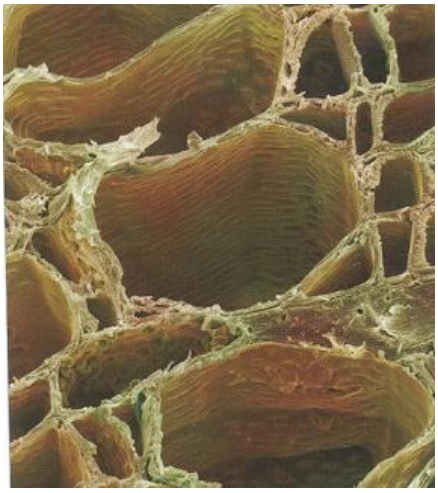
Unlike the xylem, the phloem tissue is made of columns of **living cells,** swhich contains a cytoplasm but no nucleus, and its activities are controlled by a **companion** cell next to it which has a nucleus, but companion cells have no function in translocation.

Structure of the xylem tissue

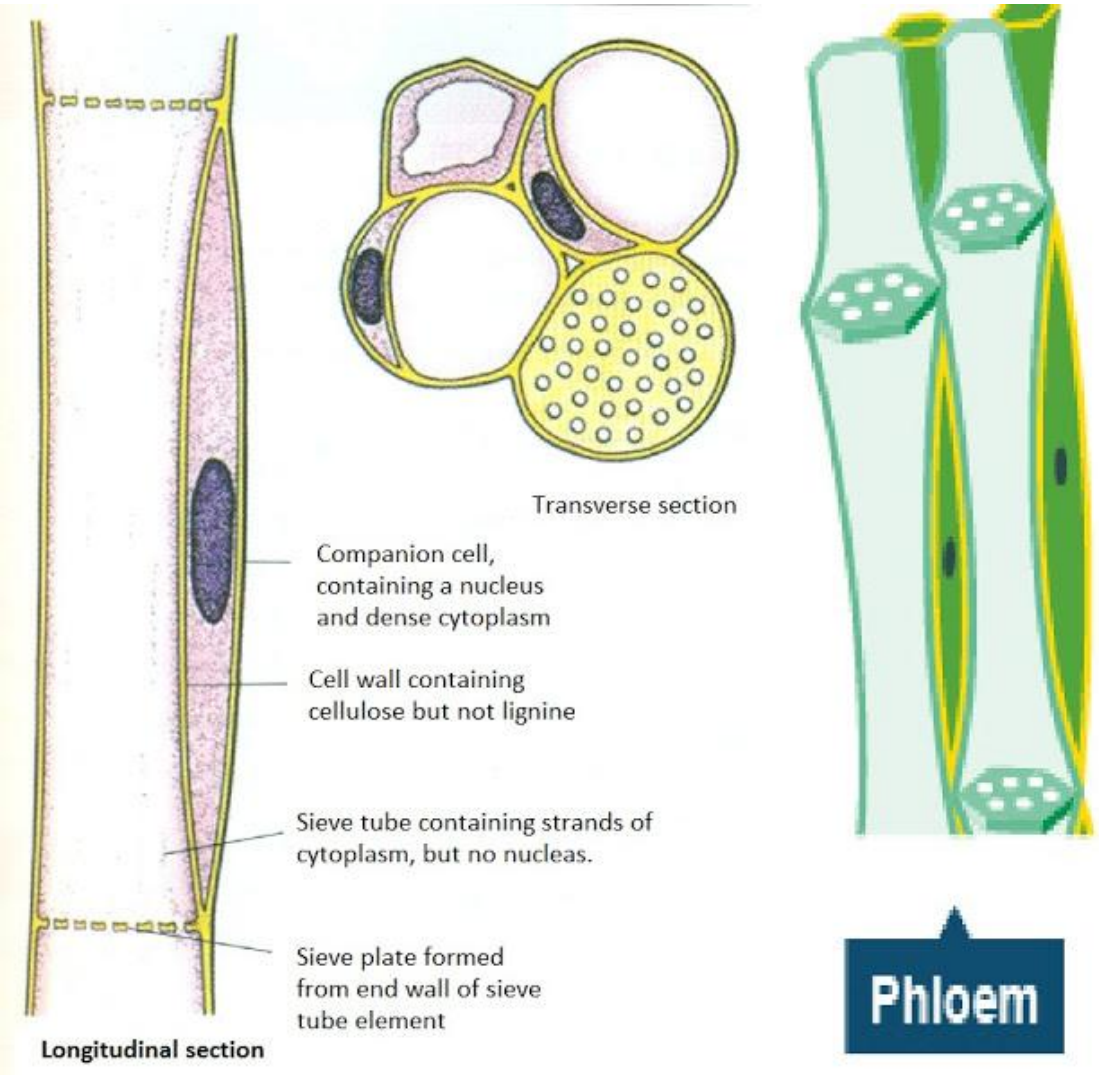
Xylem vessels consist of **dead cells**. They have a thick, strengthened cellulose cell wall with a hollow lumen. The end walls of the cells have disappeared, so a long, open tube is formed. The walls of the xylem vessel contains holes called **pits** which water enters through.



The xylem vessel is specialised to **transport** **water** and dissolved **minerals** from the root up to all the other parts of the plant, and also to helps **supporting** the stem and strengthening it.



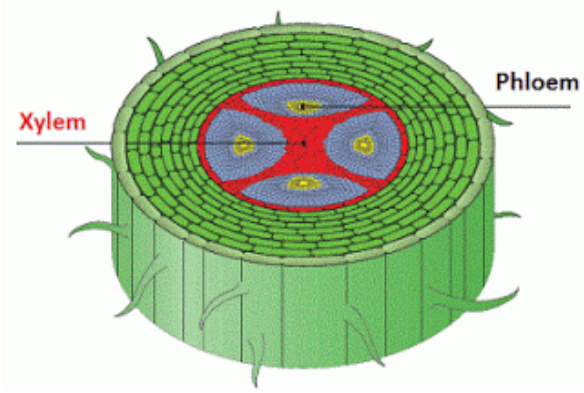
Scanning electron micrograph of xylem vessels (x1800)



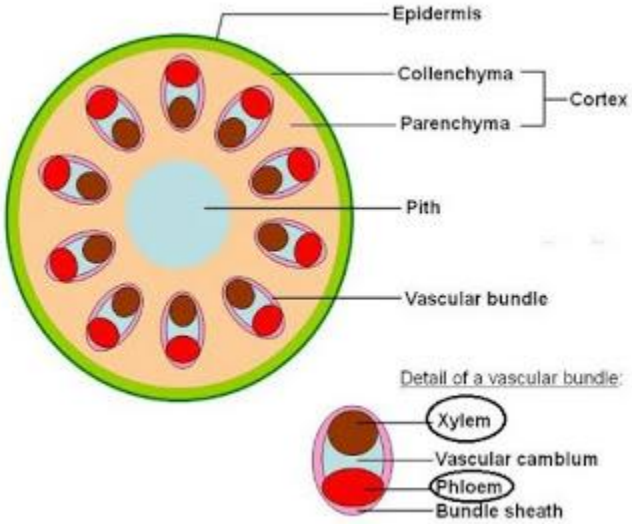
Additional resource: **xtremepapers.com**
acceleratedstudynotes.com

Related post: **Cell functions**

#60 Distribution of Xylem and Phloem in roots, stems and leaves

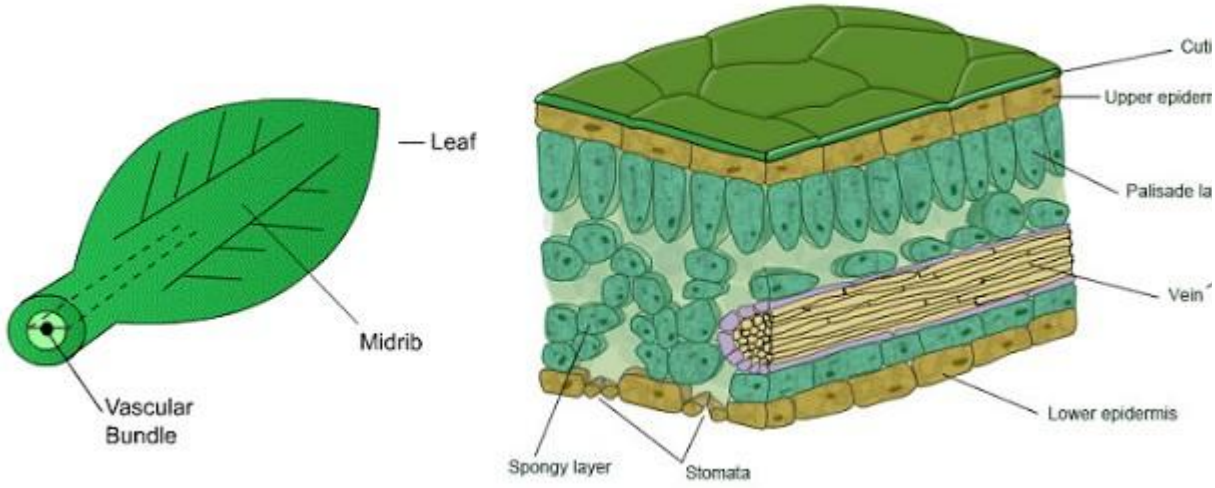


In the **roots** xylem and phloem are in the **centre** to withstand stretching forces.



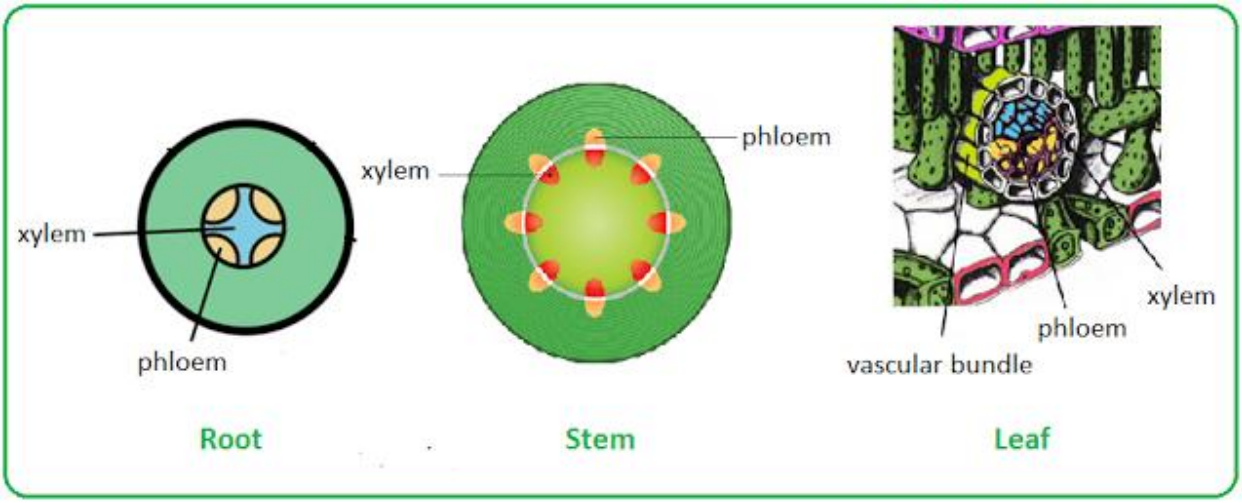
In the **stems**, they are arranged in bundles near the **edge** to resist compression and bending.

They are grouped together into **veins** and **vascular bundles** as they pass through **leaves**.

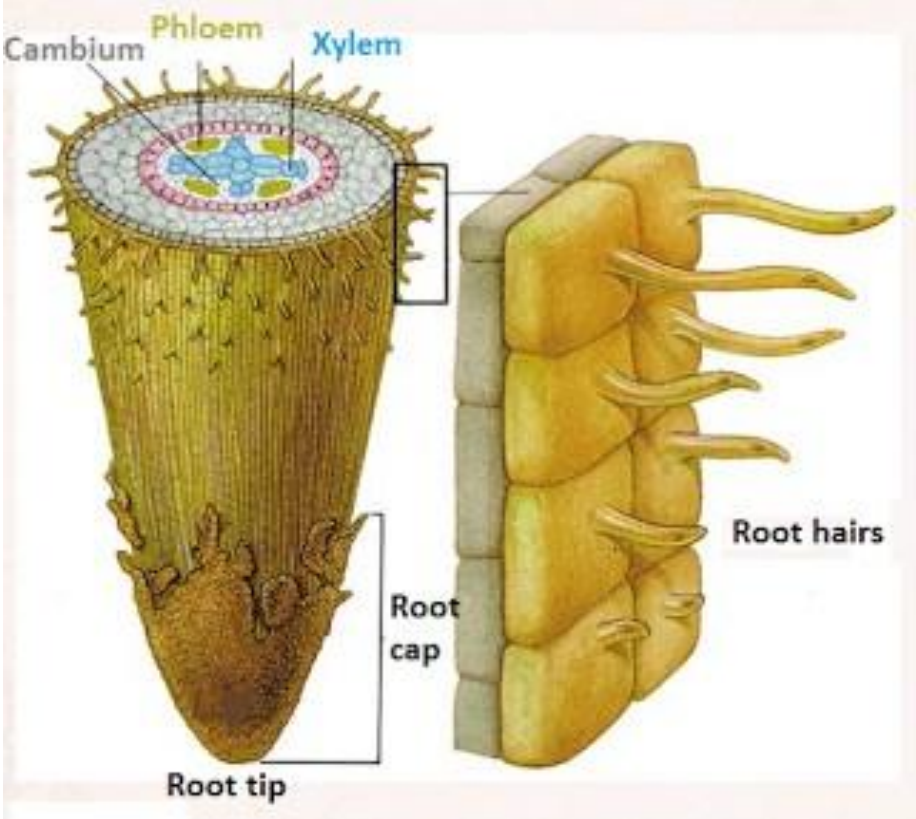


Leaf

The positions of xylem and phloem tissues as seen in transverse sections of unthickened, herbaceous, dicotyledonous roots, stems and leaves:



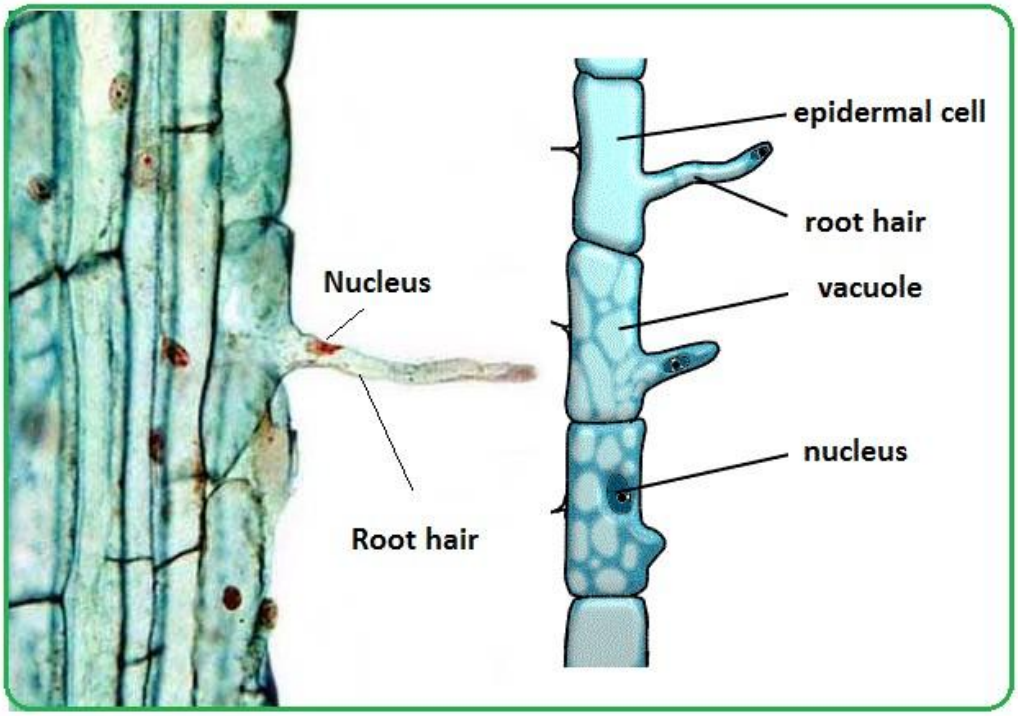
#61 Root hairs and water uptake by plants



Plants take in **water** from the soil, through their **root hairs:**

- At the very tip is a **root cap**. This is a layer of cells which protects the root as it grows through the soil.
- The rest of the root is covered by a layer of cells called the **epidermis**.
- The **root hairs** are a little way up from the root tip. Each root hair is a **long epidermal cell**. Root hairs do not live for very long. As the root grows, they are replaced by new ones.

Root hair cells, as seen under the light microscope:



*The **hair** is an **extension** of the cell and not a separate cellular structure.*

Functions of root hair cells

- **Increase** the external **surface area** of the root for **absorption** of **water** and **mineral ions** (the hair increases the surface area of the cell to make it more efficient in absorbing materials).
- Provide **anchorage** for the plant.

Video

Root absorption

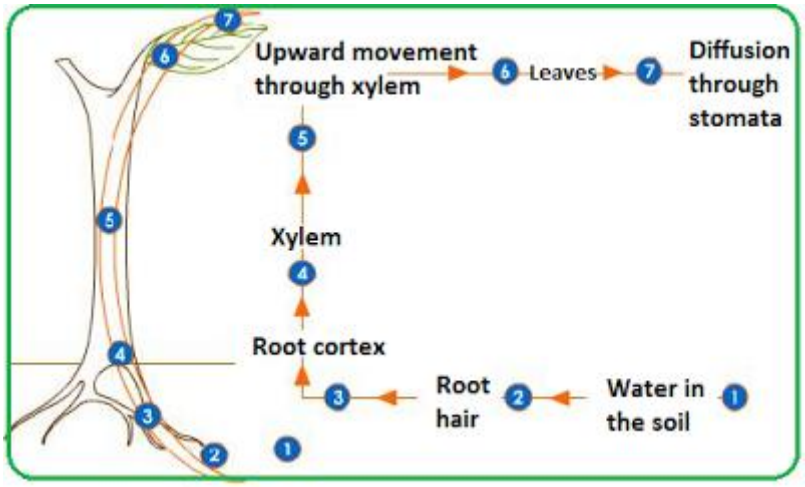
https://www.youtube.com/watch?v=o32jqyIpoHg

Water Uptake by plants

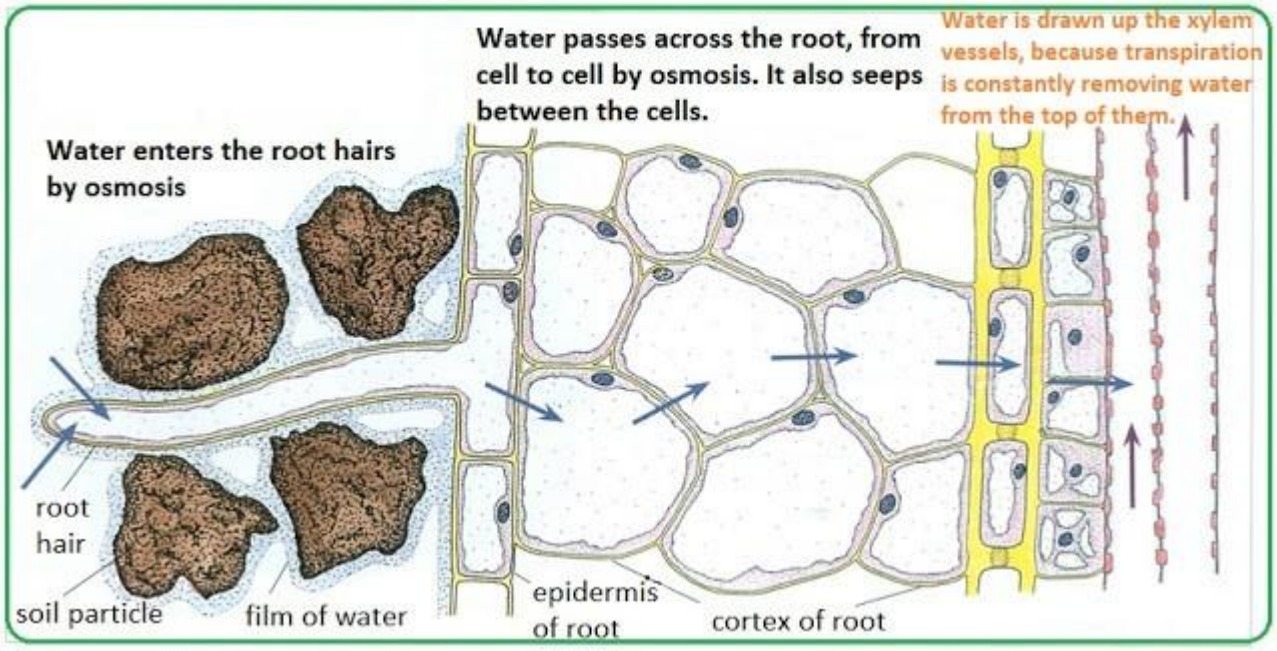
https://www.youtube.com/watch?v=g7HbmUnqGlM

#62 Passage of water through root, stem and leaf

Water enters **root hair** cells by **osmosis**. This happens when the water potential in the **soil** surrounding the root is higher than in the cell à water diffuses from the soil into the root hair, **down** its **concentration gradient.**



- As the water enters the cell, its water potential becomes higher than in the cell next to it, e.g. in the **cortex**. So water moves, by **osmosis**, into the next cell. Some of water may also just **seep** through the spaces between the cells, or through the cell walls, never actually entering a cell.



- Water vapour evaporating from a leaf crates a kind of **suction**, its pressure at the top of the vessels is lower than that at the bottom à water move up the **stem** in the xylem, more water is drawn into the leaf from the xylem. This creates a **traspiration stream**,

pulling water up from the root. Mature xylems cells have no cell contents, so they act like open-ended tubes allowing free movement of water through them. Roots also produce a root pressure, forcing water up xylem vessels.

- Water moves from xylem to enter **leaf** tissues **down** water **potential gradient**. In the leaves, water passes out of the xylem vessels into the surrounding cells.

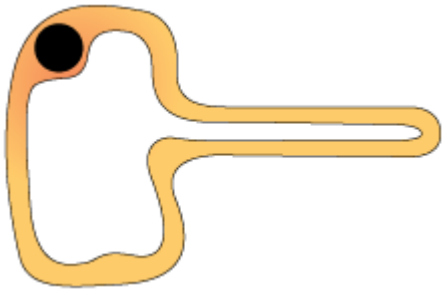
Common misconceptions

Water does not travel through xylem vessels by osmosis. Osmosis involves the movement of water across cell membranes – xylem cells do not have living contents when mature, so there will be no membranes.

Try this

Describe how the structure of xylem tissue is adapted to its functions.
The cells join together to make a long tubular structure.
There are no cross-wall and no living contents so the water and mineral salts can pass through freely.

Describe the mechanism of water movement through the xylem.
Water moves by the pull from the leaves caused by the transpiration.
Xylem vessels are very thin, so they act like a capillary tube helping to withdraw water upward.



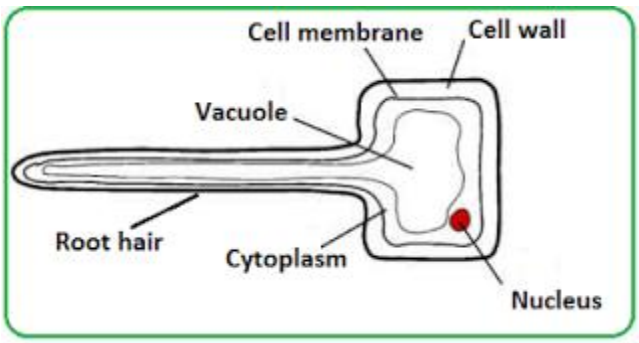
1. a) Labell all parts of the root hair cell (5 mark)

b) Which plant cell part is missing from this cell? (1 mark)
c) Name the process by which the cell absorbs:

i)Water (1 mark)

ii)Minerals (1 mark)

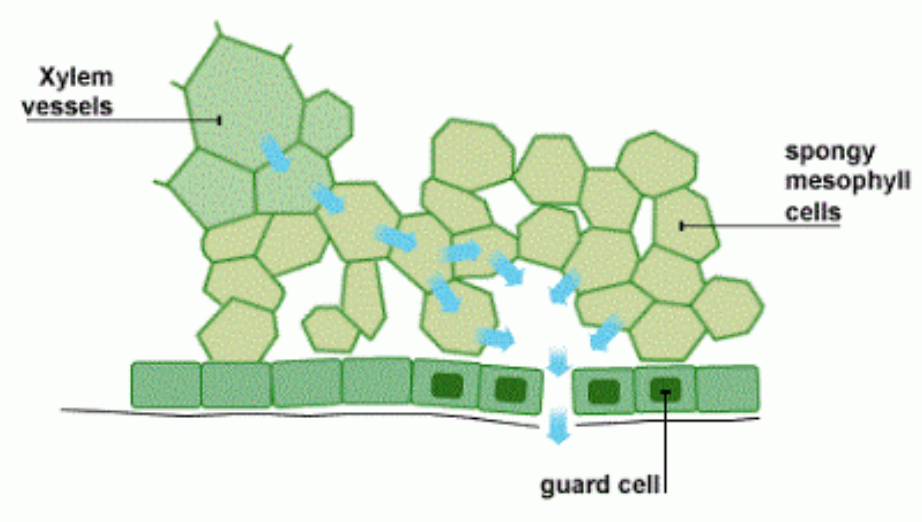
Answer:
a)



b) Chloroplast

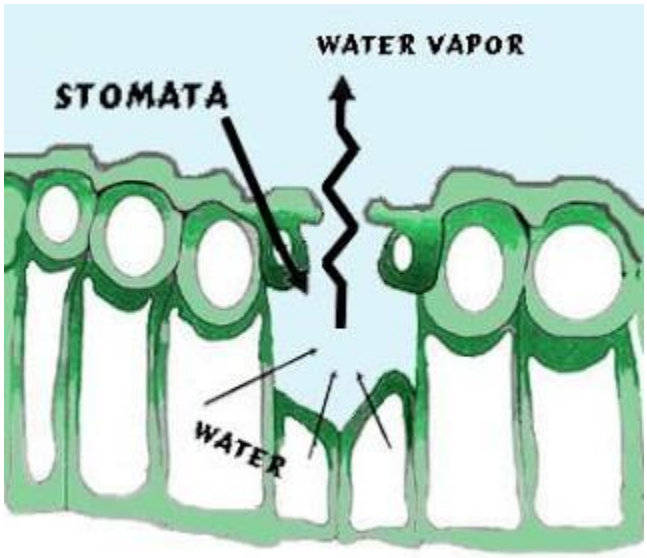
c) i) osmosis
ii) diffusion or active transport (or active uptake)

63 Transpiration in plants and factors affecting transpiration rate



In the leaves, **water** molecules leave the **xylem vessels** and move from cell to cell. They move through the **spongy mesophyll** layer by **osmosis** along a concentration gradient. Water then **evaporates** into **spaces** behind the stomata and diffuses through the **stomata** into the surrounding air.

Transpiration is the **evaporation** of **water** at the surfaces of the **mesophyll** cells, followed by loss of water vapour from plant leaves, through the **stomata.**



Water in the leaf cells forms a thin layer on their **surface**. The water evaporates into the **air spaces** in the spongy **mesophyll**. This creates a **high** concentration of water molecules. They diffuse out of the leaf into the surrounding air, through the **stomata**, by **diffusion**.

Mechanism of water movement through a plant

Water molecules are attracted to each other (cohesion) à water vapour evaporating from a leaf crates a kind of suction, pressure of water at the top of the vessels is lower than that of the bottom à water move up the **stem** in the xylem, more water is drawn into the leaf from the xylem. This creates a **traspiration stream**, pulling water up from the root.

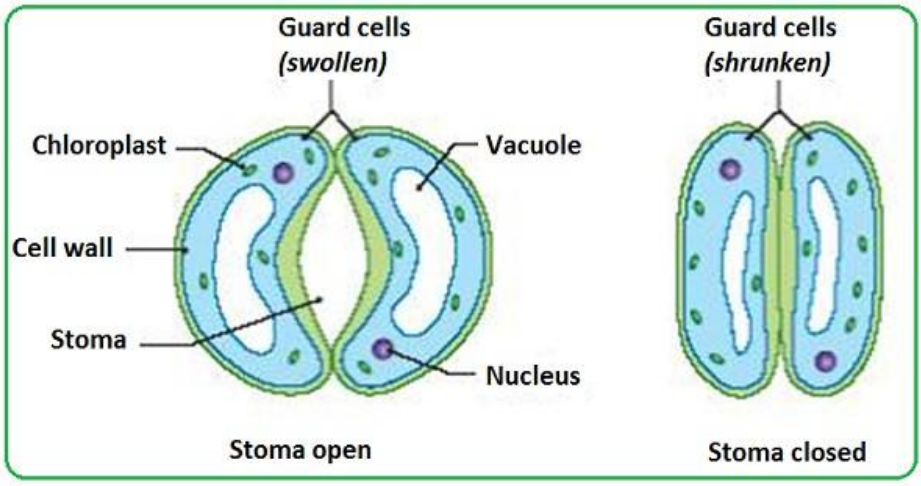
The rate of transpiration can be affected by several factors:

Factors affecting transpiration rate

Factor	Explanation
↑ temperature	↑ the kinetic (movement) energy of water molecules → they diffuse faster.
↑ air movement (wind…)	Removes water molecules as they pass out of the leaf → maintaining a steep concentration gradient for diffusion.
↓ humidity	↓ the concentration of water molecules outside the leaf → steeper concentration gradient for diffusion.
↑ light intensity	Stomata open to allow gas exchange for photosynthesis → water vapour can diffuse out of the leaf.

The opening and closing of the **stomata** is controlled by the **guard cells**.

- In **light**, guard cells **take up** water by osmosis and become **turgid**. Because their inner walls are rigid they are pulled apart, **opening** the pore.
- In **darkness** water is **lost** and the inner walls move together **closing** the pore.



Because of this, the transpiration rate is increased by an increase in light intensity.

* Most of the factors that result in a change in transpiration rate are linked to **diffusion**. When writing explanation, try to include references to the **concentration gradient** caused by a change in the factor.

How wilting occurs

Young plant stems and leaves rely on their cells being **turgid** to keep them rigid. If the amount of **water lost** from the leaves of a plant is > than the amount **taken** into the roots à the plant will have a **water shortage** à cells become **flaccid** (soft) and will no longer press against each other à Stems and leaves lose their rigidity, and **wilt**.

#64 Adaptations of the leaf, stem and root to different environments

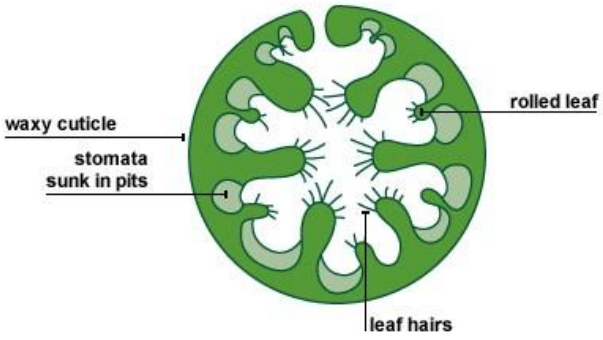
Plants which live in extreme environments have **adaptations** to control their transpiration rate. Most modifications are adaptations to very **dry** (arid) **environments.**

Water plants have no problems of water shortage. They do not need adaptations to conserve water as desert plants.

Plants modified to cope with a lack of water are called **xerophytes**. Living in **deserts** where water is scarce and evaporation is rapid, or in **windy** habitats where evaporation can also be rapid, they have to **cut down water loss.**

1. Marram grass (Ammophila)

- Very **long roots** to search for water deep down in sand dunes.
- **Leaves** that **roll up** in dry weather to increase humidity around stomata, reducing transpiration.
- **Sunken stomata** to create high humidity and reduce transpiration.
- **Fine hairs** around stomata, reducing air movement so humidity builds up and transpiration is reduced.

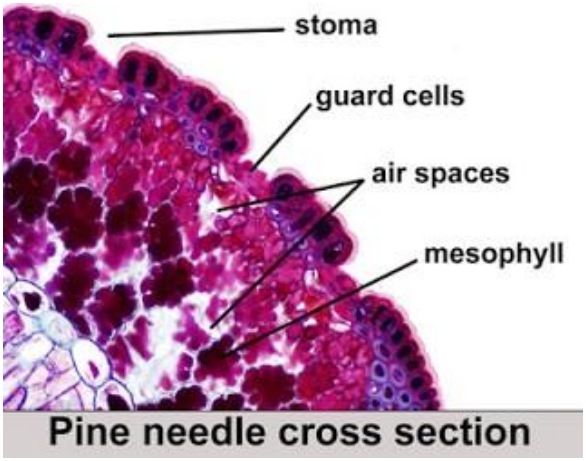


2. **Prickly pear cactus** (Opuntia)

- **Leaves** reduced to **spines** – this reduces the surface area for transpiration and also acts as a defence against herbivores.
- **Reduces** number of **stomata**.
- Stomata **cloesed** during the **day**- when conditions for transpiration are most favourable.
- **Fleshy stem** - to store water.

3. **Pine tree** (Pinus)

- **Leaves needles-shaped** to reduce surface area for transpiration and to resist wind damage.
- **Sunken stomata** to create high humidity and reduce transpiration.
- **Thicsk waxy cuticle** on the epidermis to prevent evaporation from leaf surface.



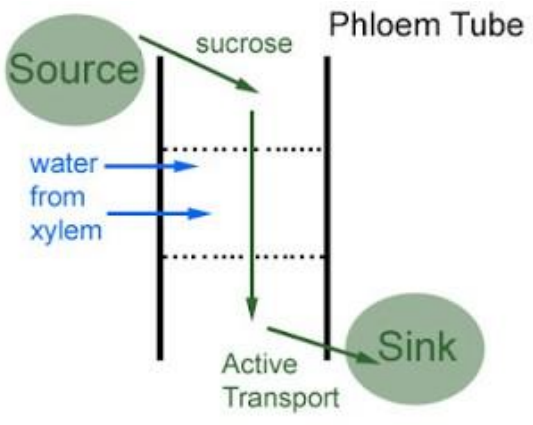
Pine needle cross section

Water plants may have stomata on the tops of their leaves

Water hyacinth (Ecichhornia csassipes)

- **Roots** do not attach to to the bed of the river or pond where they grow, but just float freely in the water.
- The **stems** and **leaf stalks** have hollow spaces in them, filled with air à help to float on the top of the water where they can get plenty of light for photosynthesis.
- **Leaves** and **stomata** are on **both surfaces**, not just on the underside as in most plant à allow to absorb CO_2 from the air, for photosynthesis.
- The **cuticle** on the upper and lower surfaces of the leaves is much **thinner** than in plants that don't live in water, there is no need to prevent water loss from the leaves.

#65 Translocation of organic foods in plants



Translocation is the movement of organic food such **sucrose** and **amino acids** in **phloem**; from regions of production to regions of storage OR regions of utilisation in respiration or growth.

1. Glucose the product of **photosynthesis** is very important as it makes many other important nutrients, e.g. **sucrose**.

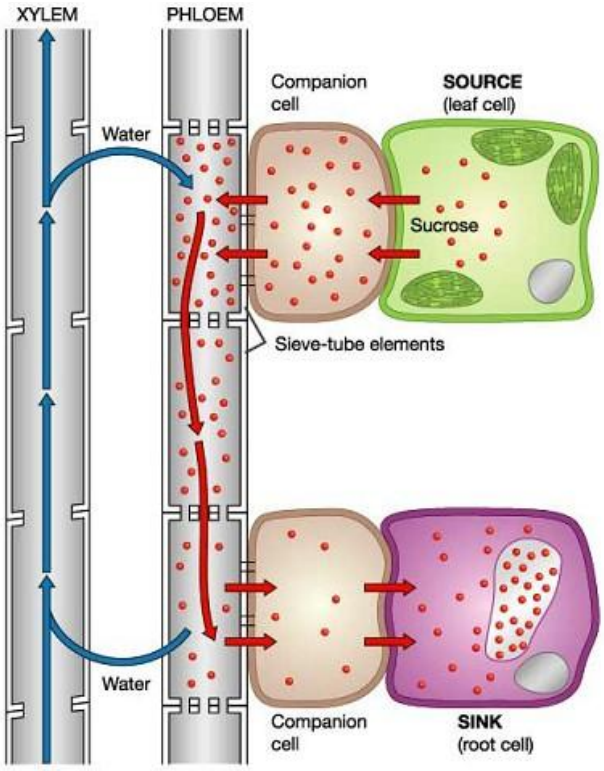
- Sucrose in the leaves then enters the **phloem** vessels.
- The phloem transports the sucrose all **across the leaf** where it can be made used of.

2. Amino acids are also transported in the phloem.

Sucrose and amino acids are transported to every tissue of the plant, each cell use it in a different way.

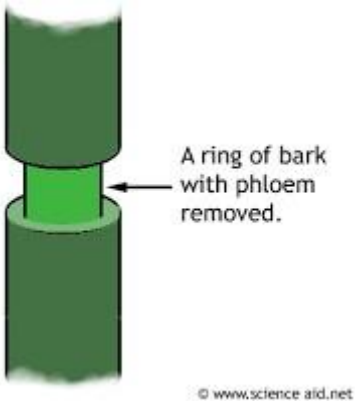
- **Root cells** convert sucrose into glucose for **respiration** and **store** it.
- **Growing cells** make cellulose for **cell walls** from sucrose and use the amino acids to make **proteins** for growth.
- And **fruits** use the sucrose to make the attractive **scent** and **tasty nectar** to attract insects.

The areas of the plant where sucrose is made, are called **sources**, and where they are delivered to and made use of are called **sinks**.



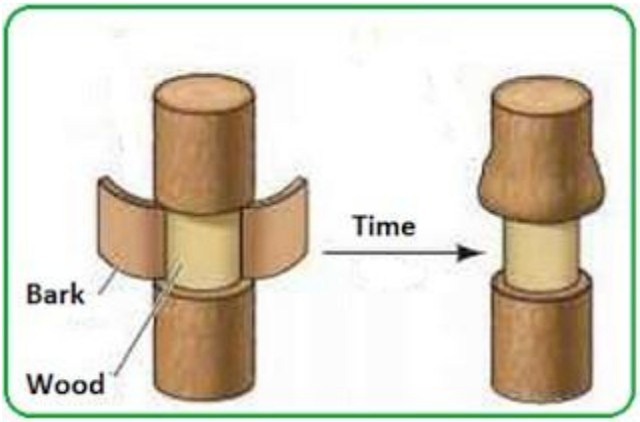
Ringing Experiment

The **phloem** vessels are situated nearer to the bark in comparison with xylem à they can be selectively removed by cutting a **ring** in a stem just deep enough to cut the phloem but not the xylem.



After a week there is:

- a **swelling above** the ring
- **reduced growth below** the ring
- the **leaves** are unaffected.



This was early evidence that **sugars** were transported downwards in the phloem.

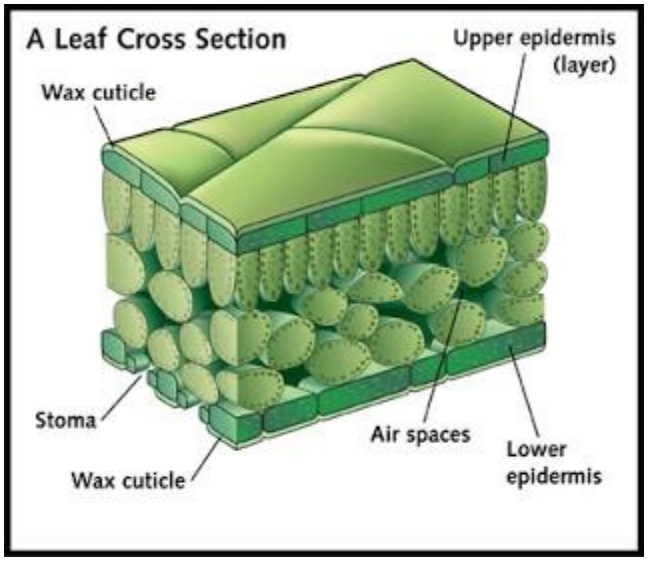
Grey squirrels and other small mammals gnaw the bark and destroy the phloem that is in the inner bark region.

#66 Translocation of applied chemicals (pesticides) throughout the plant

People who grow crops for food sometimes need to use chemicals called **pesticides**. Pets such as **insects** that eat the crop plants, or **fungi** that grow on them, can greatly reduce the yield of the crop. Pesticides are use to kill the insects or fungi.

Some pesticides kill only the insects or fungus that the spray touches. They are called **contact pesticides**. They can be very effective if they are applied properly, but they also kill insects and pests that are useful to the plant.

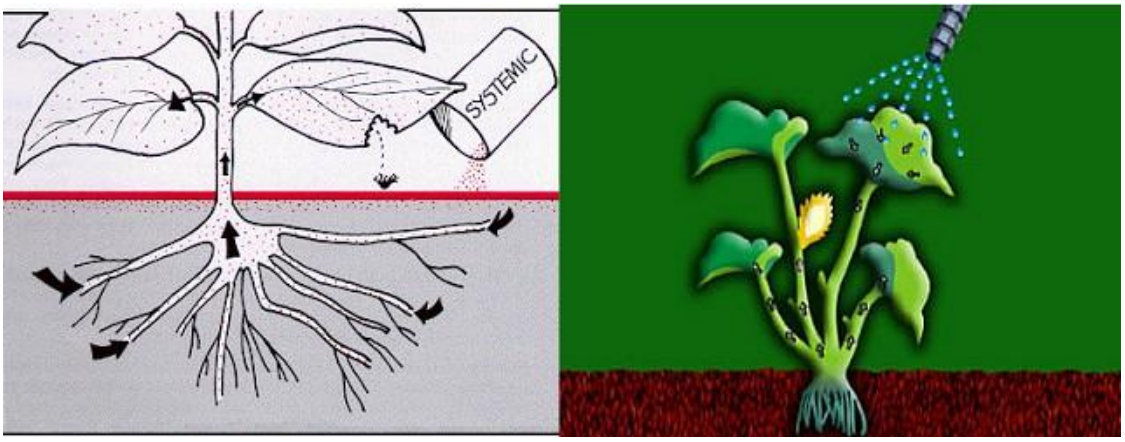
Systemic pesticides are more effective because when sprayed onto the leaves of the plant, they are **absorbed** by it through the **cuticle** or **stomata** and into the phloem tubes. They move through the plant in the **phloem** (**translocation**) and are taken in by any insect eating the plant or sucking up phloem sap.



So any insect feeding on the plant, even if it was hidden under the leaf

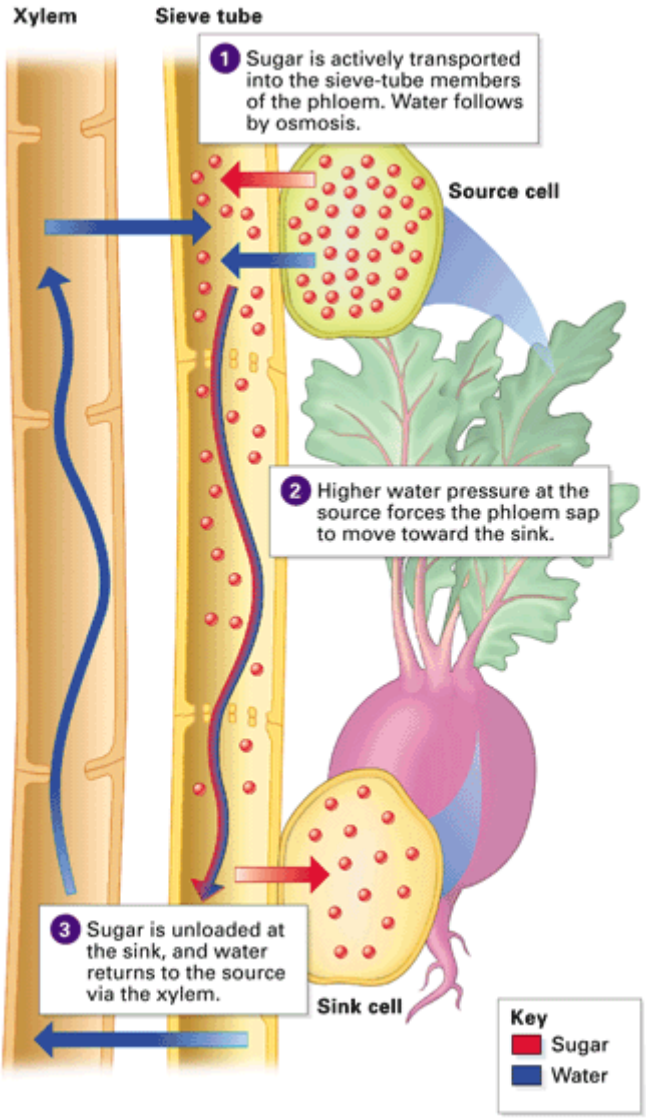
where the spray could not reach it, will eventually end up feeding on pesticide. The same is true for fungi; no matter where they are growing on the plant, the pesticide will eventually reach them. Once an insect has ingested enough pesticide it will die, meanwhile the harmless insects remain safe.

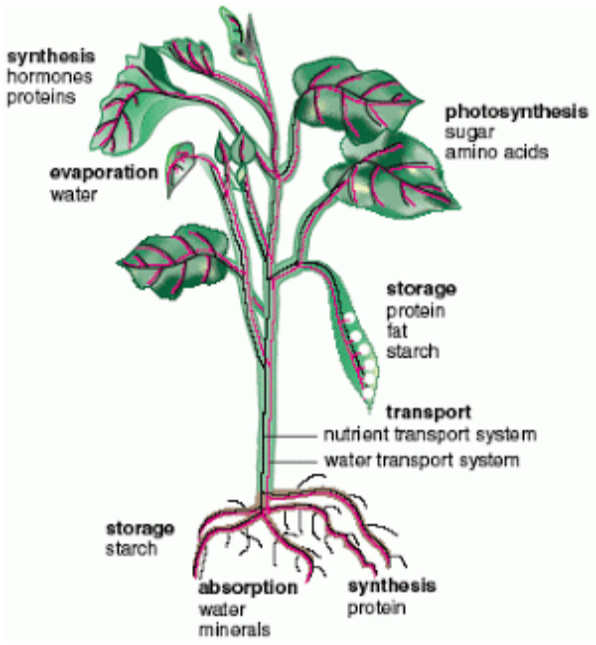
The disadvantages of systemic pesticides are that they may accumulate in the food chain.



Systemic pesticides may need to be taken up by roots or through the leaves.

#67 Transport of materials from sources to sinks at different seasons





'**Source**' is the part of a plant where substances are **produced** (e.g. leaves for sucrose, amino acids) or **enter the plant**.

'**Sink**' refers to the part of the plant where the substrate can be **stored** (e.g. roots or stem for starch).

Examples:

Sources:

Leaves - sucrose is produced here.

Root hairs - Nitrates are absorbed here.

Sinks:

Roots/Stems - starch is stored here.

Root tips - amino acids are stored here.

When a plant is actively photosynthesising and growing, the **leaves** are generally the major **sources** of translocated materials. They are constantly **producing sucrose**, which is carried in the phloem to all other parts of the plant.

These parts - the **sinks** - include the **roots,** the **flowers** and the **fruits**:

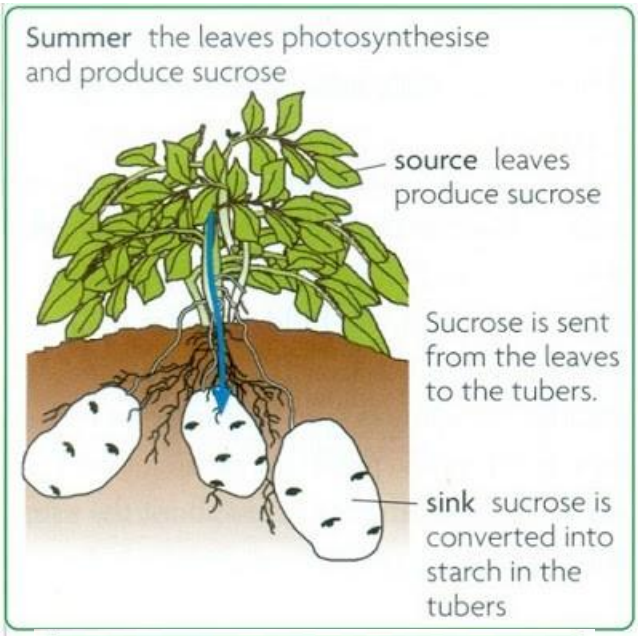
- The **roots** may change some of the sucrose to starch and store it.
- The **flowers** use the sucrose to make fructose.
- Later, when the **fruits** are developing, quite large amounts of sucrose may be used to produce sweet, juicy fruit ready to attract animals.

But many plants have a time of year when they become **dormant**. During this stage, they wait out harsh conditions in a state of reduced activity.

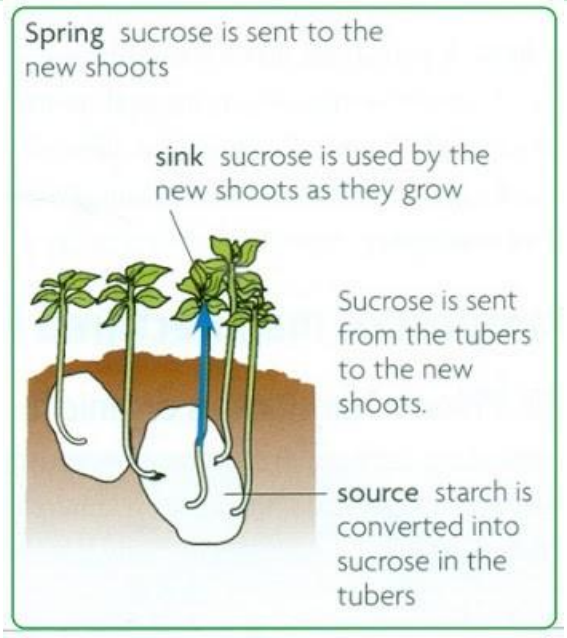
Dormant plants do not photosynthesise, but survive on their stored starch, oils and other materials. When the seasons change, they begin to grow again. Now the stored materials are converted to sucrose and transported to the growing region.

For example, potato plants are not able to survive the cold frost of winter.

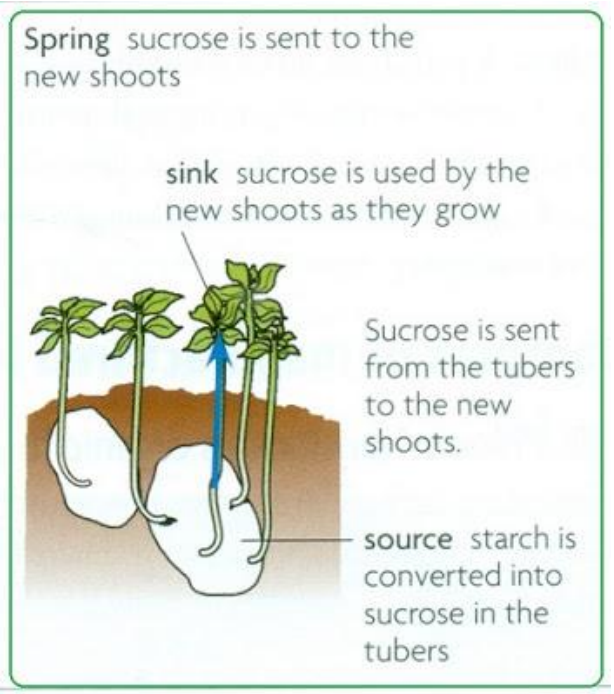
- During the **summer**, the leaves photosynthesise and send sucrose down into underground stems. Here, swellings called **tubers** develop. The cells in the root tubers change the **sucrose to starch** and store it.



- In **winter**, the leaves die. Nothing is left of the potato plant above ground - just the stem tubers beneath the soil.



- In **spring**, they begin to grow new shoots and leaves. The **starch** in the tubers is changed back to the **sucrose**, and transported in the phloem the growing **stems and leaves**. This will continue until the leaves are above ground and photosynthesise.



to

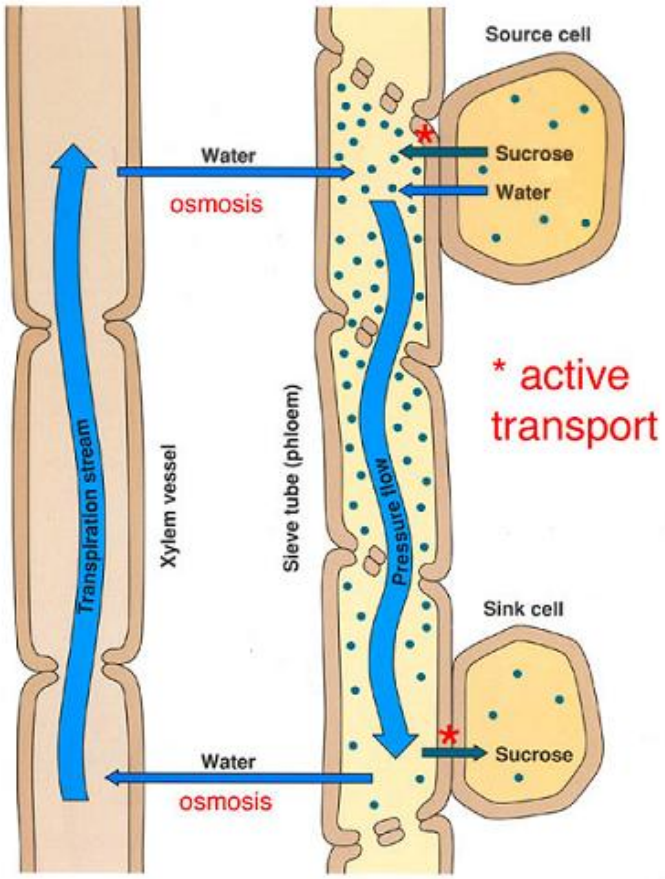
So in **summer**, the **leaves** are **sources** and the growing stem **tubers** are **sinks**. In **spring**, the stem **tubers** are **sources** and the growing **leaves** are **sinks**.

Conclusion:

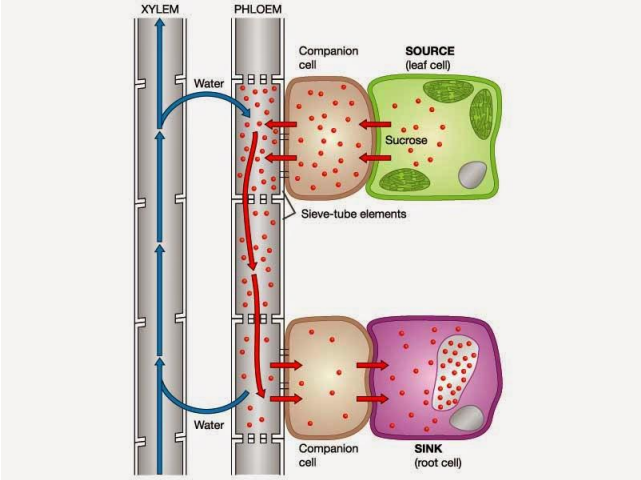
Phloem can transfer sucrose in **either direction** - up or down the plant. This isn't true for the transport of water in the **xylem** vessels. That can only go **upwards**, because transpiration always happens at the leaf surface, and it is this that provides the 'pull' to draw water up the plant.

Comparison of transpiration and translocation

	Transport	From	To	Mechanism	High rate
Transpiration	H_2O, Mineral irons	Soil	Leaves, Flowers Fruits	**Passive** process using a **tension** in the xylem produce by **evaporation** of water.	on **hot**, **sunny**, **windy** and **dry** days
Translocation	Sucrose, Amino acids	Leaves	Shoot,root tips, root cortex, seeds, flowers, fruits	**Active** process, the **water** enters the tubes to build up a head of pressure that forces the phloem sap to the **sinks.**	on **warm**, **sunny** days when plants are producing more sugar


Source cell
Water
osmosis
Sucrose
Water
* active transport
Transpiration stream
Xylem vessel
Sieve tube (phloem)
Pressure flow
Sink cell
Sucrose
Water
osmosis

#68 Summary of plant transport



- In plants, **xylem** vessels transport **water** and **mineral** ions from the roots upwards to the leaves. **Phloem** tubes transport **sucrose** and other organic nutrients, from the leaves where they are made to all parts of the plant. This is called **translocation**.
- **Xylem** vessels are made of **dead**, empty **cells** with strong lignin in their walls. As well as transporting water, they help to **support** the plant.
- Water is drawn up xylem vessels by the evaporation of water from the leaves, called **transpiration**. Transpiration happens fastest when it is hot, dry, windy and sunny.
- Water enters root hairs by **osmosis**, and then moves across the cortex of the root into the xylem.
- Root hairs take up mineral ions by **active transport**, using energy supplied by respiration to move them against their concentration gradient.
- **Phloem** is made of **living cells** with sieve plates at their ends. A companion cell is associated with each phloem sieve tube element.
- Systemic **pesticides** are translocated in phloem.
- **Sucrose** is translocated from sources to sinks. Different parts of a plant may become sources and sinks in different seasons.