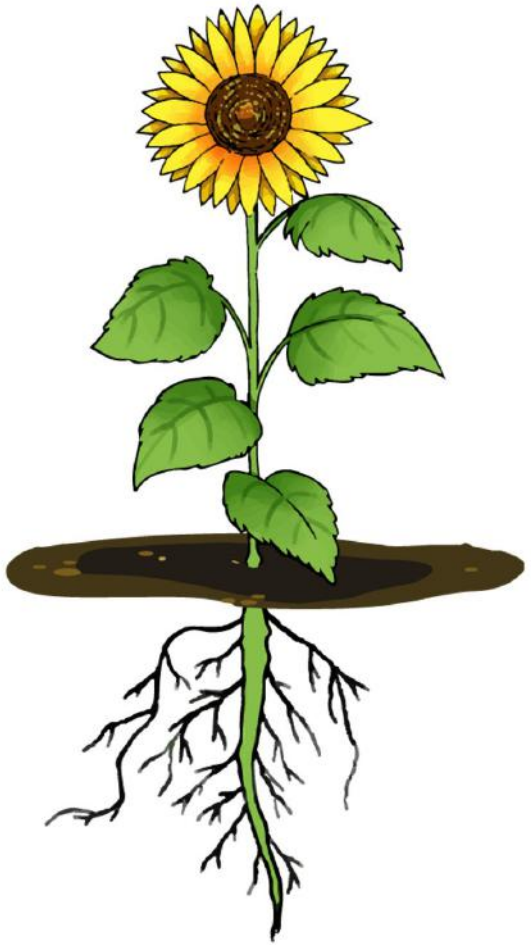
Mass Transport in Plants



Material Covered

Structure of Transport Tissues

1. Xylem
2. Phloem

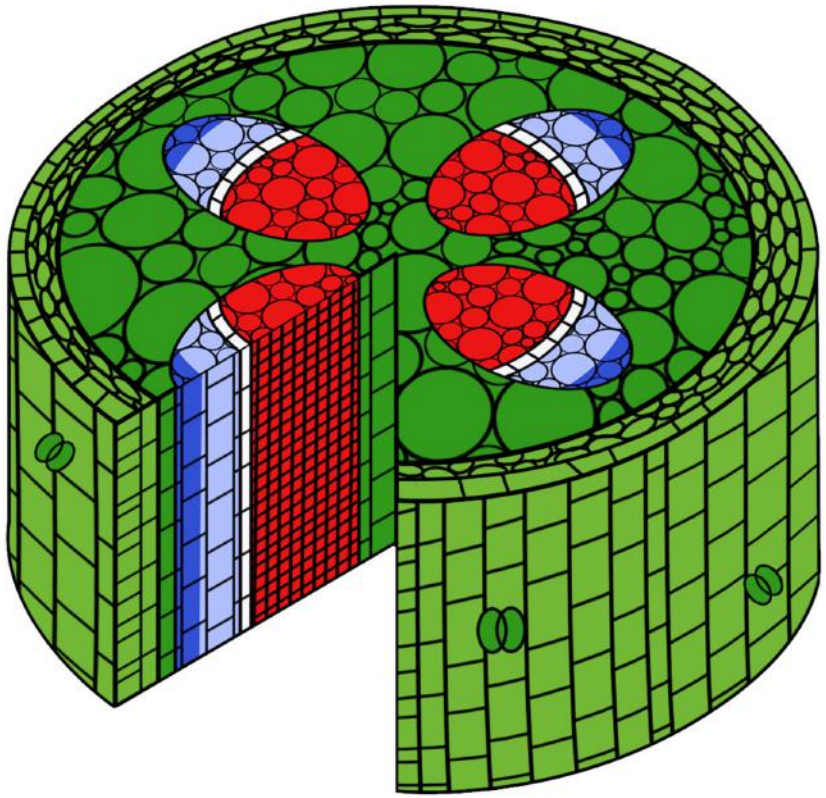
Transport of Water

1. Transpiration Stream
2. Measuring Rates of Transpiration

Translocation

1. Active Loading
2. Mass Transport in Phloem
3. Evidence for Mass-Flow and Cohesion-Tension

Structure of Transport Tissues



Specification Points

AQA

3.3.4.2 Mass transport in plants

Content	Opportunities for skills development
Xylem as the tissue that transports water in the stem and leaves of plants. The cohesion-tension theory of water transport in the xylem. Phloem as the tissue that transports organic substances in plants. The mass flow hypothesis for the mechanism of translocation in plants. The use of tracers and ringing experiments to investigate transport in plants. **Students should be able to:** • recognise correlations and causal relationships • interpret evidence from tracer and ringing experiments and to evaluate the evidence for and against the mass flow hypothesis.	**AT b** Students could set up and use a potometer to investigate the effect of a named environmental variable on the rate of transpiration.

OCR

3.1.3 Transport in plants

		Learning outcomes	Additional guidance
(a)		the need for transport systems in multicellular plants	To include an appreciation of size, metabolic rate and surface area to volume ratio (SA:V). *M0.1, M0.3, M0.4, M1.1, M2.1, M4.1* HSW1, HSW3, HSW5, HSW8
(b)	(i)	the structure and function of the vascular system in the roots, stems and leaves of herbaceous dicotyledonous plants	To include xylem vessels, sieve tube elements and companion cells.

Specification Points

Edexcel A

Topic 4: Biodiversity and Natural Resources

Students should:
4.11 Know the similarities and differences between the structures, position in the stem and function of sclerenchyma fibres (support), xylem vessels (support and transport of water and mineral ions) and phloem (translocation of organic solutes).

Edexcel B

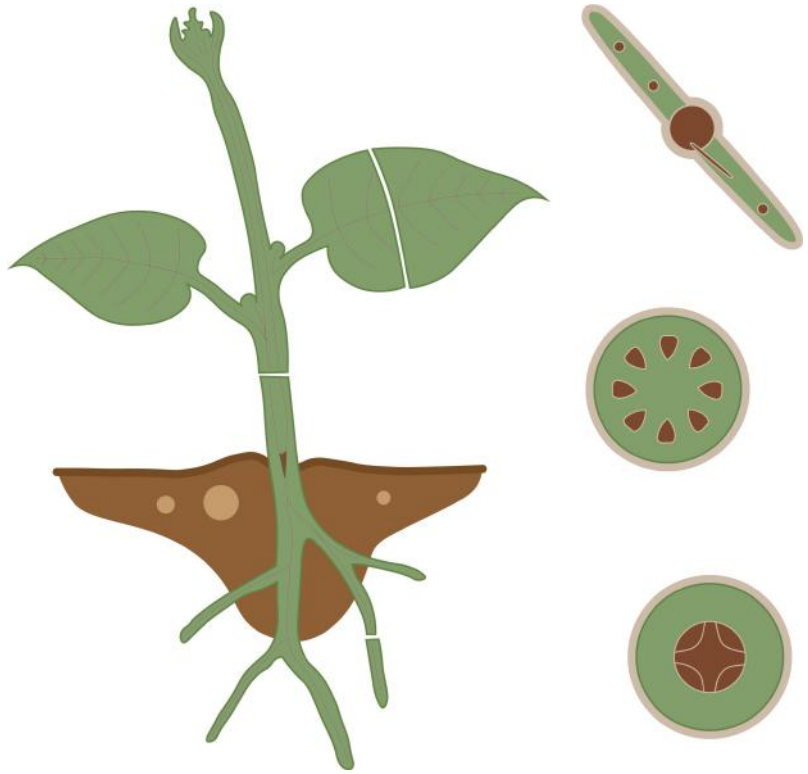
Topic 4: Exchange and Transport

Students should:	
4.7	**Transport in plants**
i	Understand the structure of xylem and phloem tissues in relation to their role in transport.

Plant Transport Systems

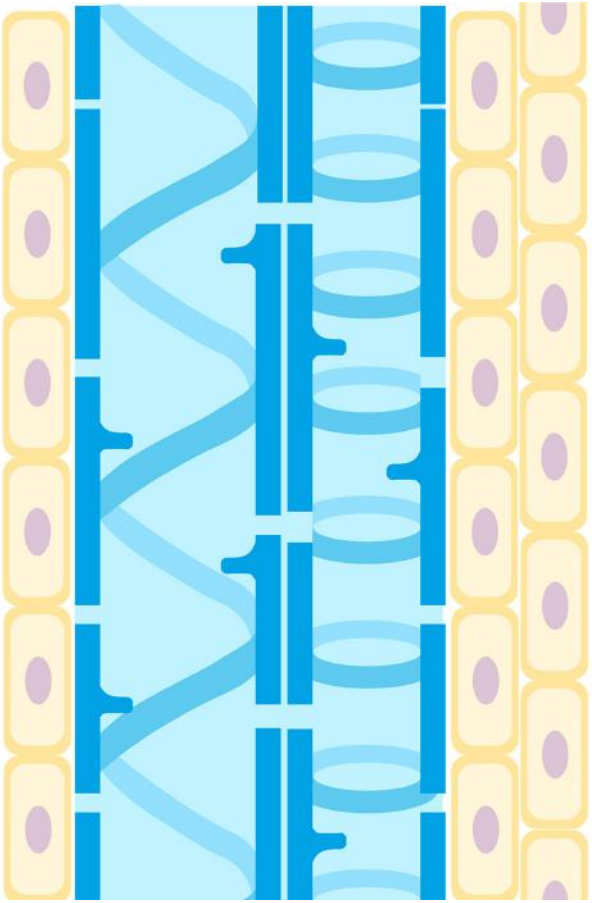
AQA: do not need to know about **xylem and phloem arrangement**

- Plants can **exchange gases** at their **leaves** using **diffusion** because leaves have a **high surface area** to **volume ratio**
- Other substances require **transport systems** because they are **taken in**/ **produced** in **one part** of the **plant** but **needed** in a **different part** of the **plant**
- **Water** and **nutrients** are taken in by the **roots** and **transported up** the **xylem**
- **Sap** (including **sucrose**) is **transported up** and **down** the **phloem**



Xylem Structure

- **Xylem vessels** are composed of **dead cells** containing **lignin**
- The polymer **lignin waterproofs** the xylem cells and also **strengthens** the xylem
- Xylem cells do not have **organelles** or **cytoplasm** and the end **cell wall** is broken down to form a **hollow tube**
- Xylem vessels run **continuously** from the **roots** to the **leaves**



Exemplar Exam Question – Calculation

1) A student is investigating the rate of water movement through xylem vessels in plants. They find that 2ml of water travels through the plant in 160 minutes.

Calculate the rate of water movement through the xylem in litres per hour. Give your answer in standard form.

[2 marks]

Command: numerical response

Direction: use correct units – litres per hour

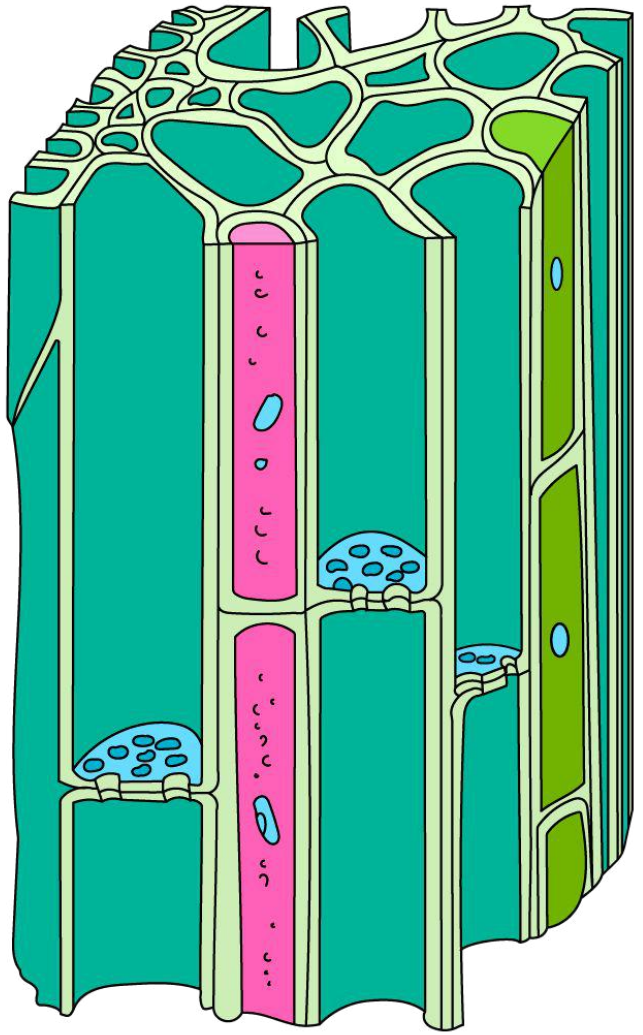
Context: volume and time given – change to rate

Exemplar Exam Question – Calculation

- 2ml of water travels through the plant in 160 minutes.
- Rate in litres per hour

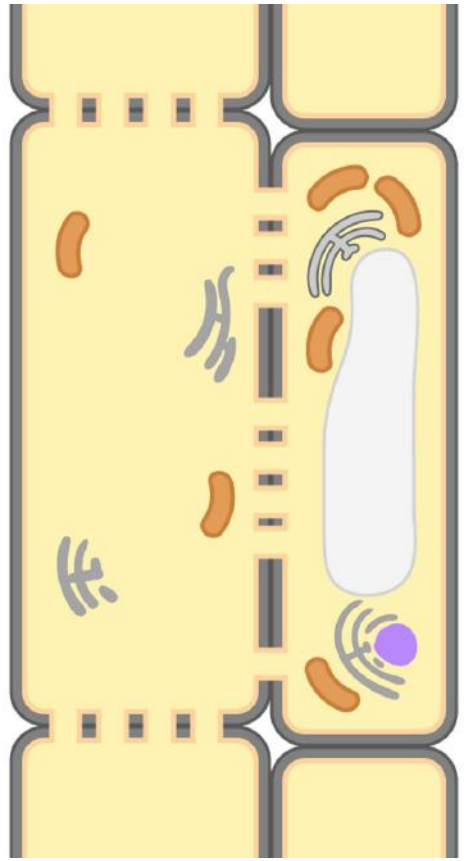
The Phloem

- The phloem is used to transport assimilates both **upwards** and **downwards**
- **Assimilates** are **organic molecules** (such as **sugars** or **amino acids**) which can be used by an organism
- Most assimilates are produced by the **leaves** and are required all over the **plant**
- Phloem tissue is formed from two types of cell: **sieve-tube elements** and **companion cells**



Phloem Tissue

- **Sieve-tube elements** are lined up end-to-end and are connect by **sieve plates**, which allow the flow of **sap**
- **Sieve-tube elements** have **little cytoplasm** and **have lost their nucleus** and some **other organelles** to **maximise space** for **sap**
- **Companion cells** control the **loading** of **sucrose**, the main component of sap, into the sieve tube elements
- Companion cells contain **many mitochondria** as the **loading** of **sucrose** requires **active transport**



Exemplar Exam Question – Extended Response

2) Plants contain two types of transport tissue: the xylem and the phloem. The xylem transports water and the phloem transports assimilates such as sucrose.

Explain how the structure of xylem vessels and sieve tube elements relates to their function.

[6 marks]

Command: Give reasons for how the structure helps the function

Direction: only focus on xylem vessels and sieve tube elements, not companion cells. Structure and function

Context: xylem, phloem and their function

Exemplar Exam Question – Extended Response

2) Explain how the structure of xylem vessels and sieve tube elements relates to their function.

[6 marks]

Xylem vessels are lignified which waterproofs them and also strengthens them, preventing them from collapsing under negative pressure. The end walls of the xylem vessels are broken down, and there is no cytoplasm or organelles, allowing the xylem vessels to form long, hollow tubes. This is essential for transporting water in a continuous stream. Sieve tube elements are connected by sieve plates, which create a long tube, allowing the flow of sap. Space is also maximised by reduced cytoplasm and few organelles.

Transport of Water

Specification Points

AQA

3.3.4.2 Mass transport in plants

Content	Opportunities for skills development
Xylem as the tissue that transports water in the stem and leaves of plants. The cohesion-tension theory of water transport in the xylem. Phloem as the tissue that transports organic substances in plants. The mass flow hypothesis for the mechanism of translocation in plants. The use of tracers and ringing experiments to investigate transport in plants. **Students should be able to:** • recognise correlations and causal relationships • interpret evidence from tracer and ringing experiments and to evaluate the evidence for and against the mass flow hypothesis.	**AT b** Students could set up and use a potometer to investigate the effect of a named environmental variable on the rate of transpiration.

OCR

3.1.3 Transport in plants

	Learning outcomes	Additional guidance
(d)	the transport of water into the plant, through the plant and to the air surrounding the leaves	To include details of the pathways taken by water **AND** the mechanisms of movement, in terms of water potential, adhesion, cohesion and the transpiration stream. HSW2, HSW8

Specification Points

Edexcel A

Topic 4: Biodiversity and Natural Resources

Students should:
4.11 Know the similarities and differences between the structures, position in the stem and function of sclerenchyma fibres (support), xylem vessels (support and transport of water and mineral ions) and phloem (translocation of organic solutes).

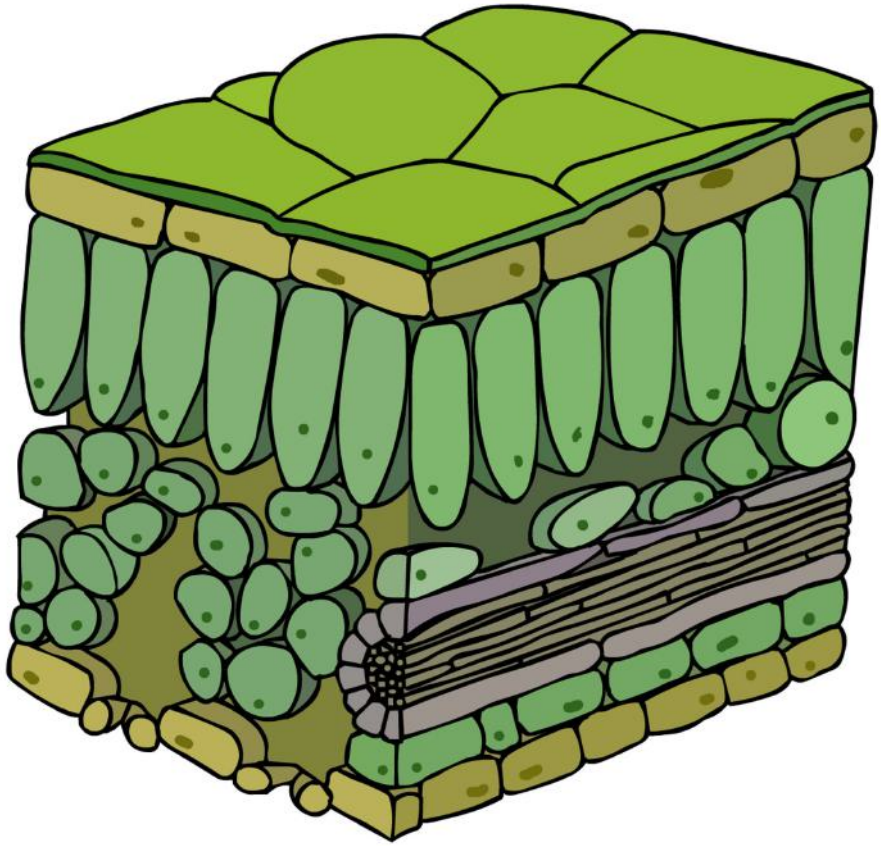
Edexcel B

Topic 4: Exchange and Transport

Students should:	
4.7	**Transport in plants**
iii	Understand how the cohesion-tension model explains the transport of water from plant roots to shoots.

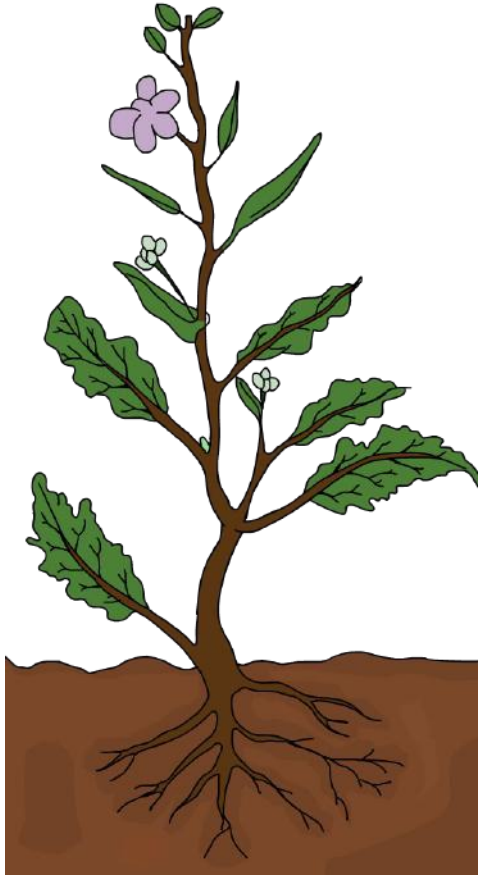
Water in Plant Leaves

- In the **leaf**, **water evaporates** into the **air spaces** between the **spongy mesophyll** cells
- Water then **exits** the **leaf** through the **stomata**, down a **water vapour potential gradient**
- The **loss** of **water** from **leaves** and other **aerial parts** of the **plant** is called **transpiration**
- The **lost water** is replaced from the **xylem**



The Transpiration Stream

- The **water lost** from the **xylem** to the **leaves** causes a **negative pressure** within the **xylem** – this is the **transpiration pull**
- **Water** is therefore **drawn up** the **xylem** from the **roots** to the **leaves** under **tension**
- **Water** can only be drawn up due to **adhesion** & **cohesion** between **water molecules** so the **stream** of **water** must be **continuous.**
- The **flow** of **water** up the **xylem** is known as the **transpiration stream**

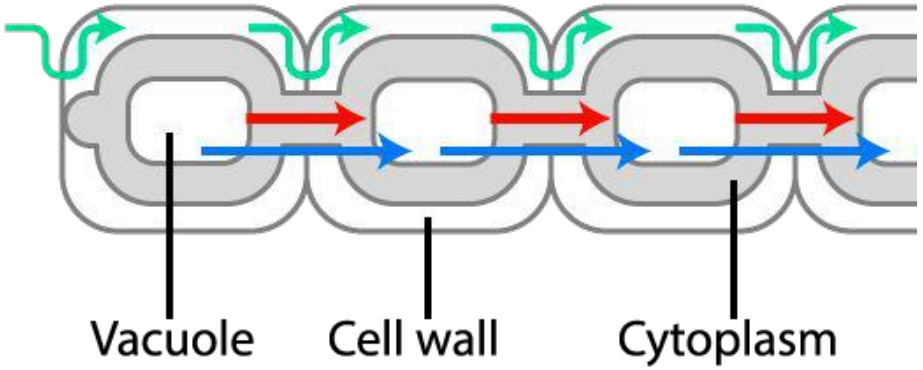


AQA & Edexcel A: do not need to know about **adhesion**

Water Movement in the Roots

AQA & Edexcel A: do not need to know about **the different pathways**

- **Water** enters the **roots** using **osmosis** from a **high water potential** to a **lower potential**
- **Water** can move through then move through **cell wall**, the **cytoplasm** or through **vacuoles**
- The **Casparian strip** stops **water** moving through **the cell wall forcing** it into the **cytoplasm**



Exemplar Exam Question – Simple Explanatory

3) The xylem vessels are responsible for transporting water through the plant. Water is drawn in at the roots and supplied to the leaves through the transpiration stream.

Describe what happens to the transpiration stream if the xylem vessels are broken.

[2 marks]

Command: state changes that occur – no explanation

Direction: focus on the effect on the transpiration stream only – not plant

Context: xylem, transpiration and the transpiration stream

Exemplar Exam Question – Simple Explanatory

3) The xylem vessels are responsible for transporting water through the plant. Water is drawn in at the roots and supplied to the leaves through the transpiration stream.

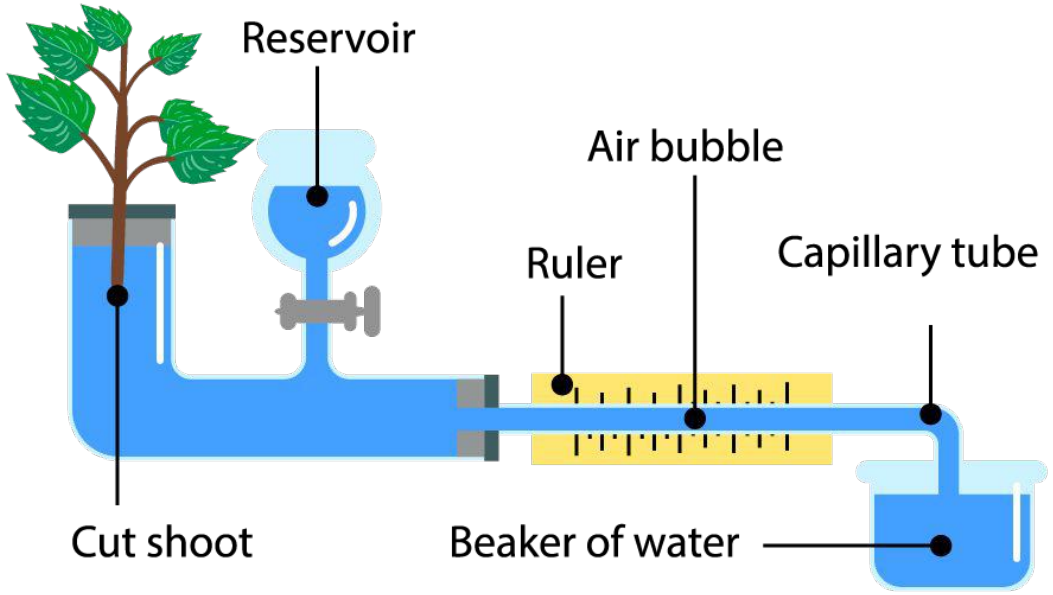
Describe what happens to the transpiration stream if the xylem vessels are broken.

[2 marks]

Cutting the xylem vessels will allow air into the xylem, disrupting the transpiration stream and breaking the cohesive forces between the water molecules.

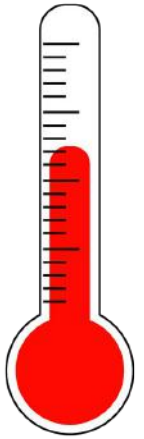
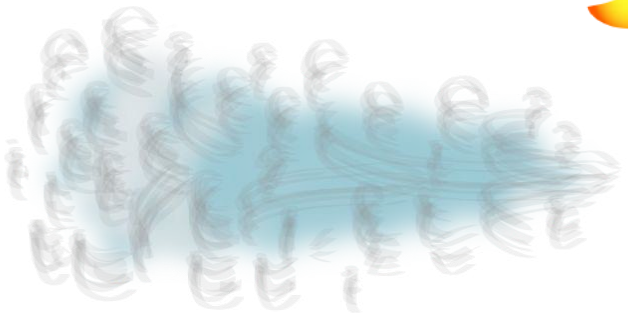
Measuring the Rate of Transpiration

- A **potometer** is used to **measure** the **rate** of **transpiration** in plants
- It is almost **impossible** to collect all the water vapour leaving the leaves, so **water uptake** is measured instead
- When using a **potometer** it is important to ensure **no air bubbles** enter the apparatus – other than the measurement bubble



Factors Affecting the Rate of Transpiration

- When using a **potometer**, **factors** that affect **transpiration** must be **controlled**:
  - **Light intensity**
  - **Temperature**
  - **Relative humidity**
  - **Air movement**
  - **Water availability**

Exemplar Exam Question – Data Analysis

4) A student was using a potometer to investigate the impact of total leaf area on the rate of transpiration. His results are shown in the table.

Describe and explain what is shown by the student's results.

Number of Leaves on Plant	Mean rate of Bubble Movement / au
0	6
1	17
2	29
4	52
8	95

Command: use figures when describing and give reasons

Direction: focus on results, give reasons from own knowledge

Context: Data on effect of leaf area on transpiration rate

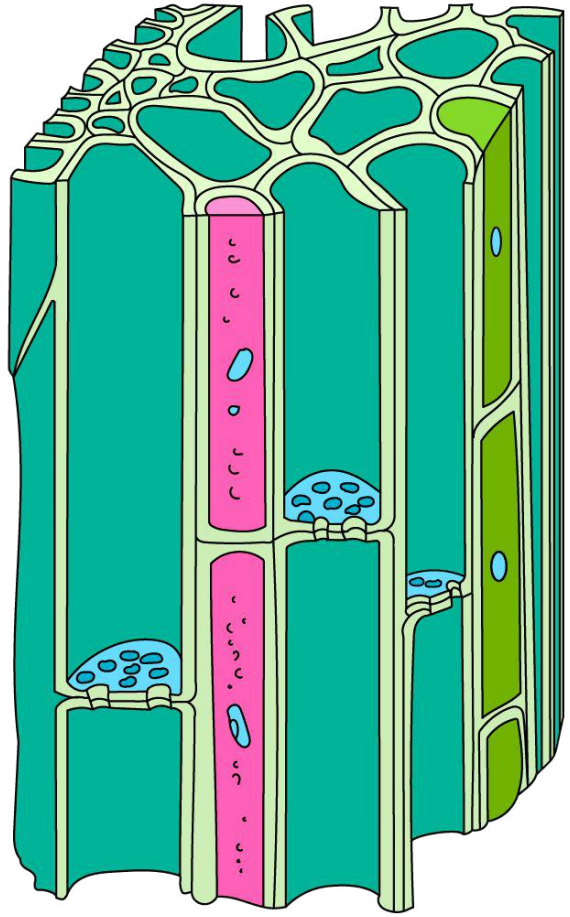
[3 marks]

Exemplar Exam Question – Data Analysis

4) Describe and explain what is shown by the student's results. **[3 marks]**

As the number of leaves on the plant increases, the rate of bubble movement through the potometer increases. For example, with 0 leaves the bubble moves at 6 au, versus with 8 leaves the bubble moves at 95 au. The rate of transpiration increases with the number of leaves, as there are more stomata for water vapour to diffuse out of, and therefore the rate of water uptake by the roots is also increased.

Translocation



Specification Points

AQA

3.3.4.2 Mass transport in plants

Content	Opportunities for skills development
Xylem as the tissue that transports water in the stem and leaves of plants. The cohesion-tension theory of water transport in the xylem. Phloem as the tissue that transports organic substances in plants. The mass flow hypothesis for the mechanism of translocation in plants. The use of tracers and ringing experiments to investigate transport in plants. **Students should be able to:** • recognise correlations and causal relationships • interpret evidence from tracer and ringing experiments and to evaluate the evidence for and against the mass flow hypothesis.	**AT b** Students could set up and use a potometer to investigate the effect of a named environmental variable on the rate of transpiration.

OCR

3.1.3 Transport in plants

	Learning outcomes	Additional guidance
(f)	the mechanism of translocation.	To include translocation as an energy-requiring process transporting assimilates, especially sucrose, in the phloem between sources (e.g. leaves) and sinks (e.g. roots, meristem) **AND** details of active loading at the source and removal at the sink. HSW2, HSW8

Specification Points

Edexcel A

Topic 4: Biodiversity and Natural Resources

Students should:
4.11 Know the similarities and differences between the structures, position in the stem and function of sclerenchyma fibres (support), xylem vessels (support and transport of water and mineral ions) and phloem (translocation of organic solutes).

Edexcel B

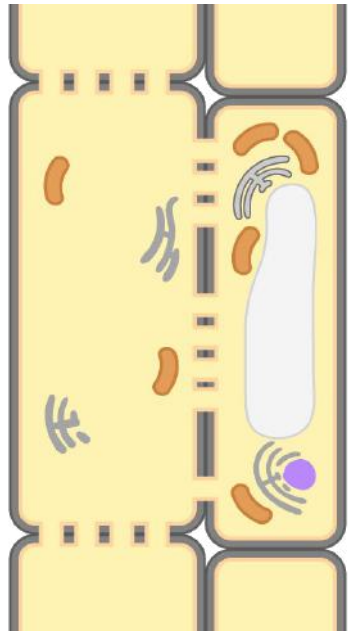
Topic 4: Exchange and Transport

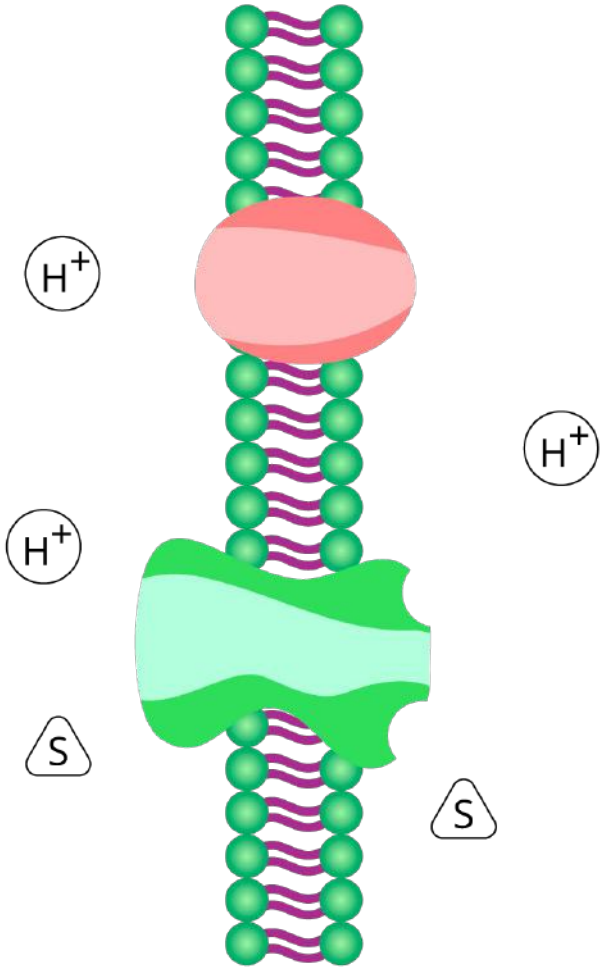
Students should:	
4.7	**Transport in plants**
v	Understand the strengths and weaknesses of the mass-flow hypothesis in explaining the movement of sugars through phloem tissue.

Active Loading

Edexcel A: do not need to know about **H^+ ions**

- **Sucrose** is loaded into **sieve tube elements** using **active/cotransport**
- **H ions** are **actively transported out** of the **companion cells**
- **H ions diffuse back in**, through **cotransporter proteins**, bringing **sucrose** with them **against** its **concentration gradient**
- **Sucrose** then **diffuses** down the **concentration gradient** from **companion cells** to **sieve tube elements**





Exemplar Exam Question – Simple Explanation

5) Companion cells actively load sucrose into phloem tissue using the mechanism of cotransport.

Explain why cotransport is a type of secondary active transport.

[2 marks]

Command: Give reasons

Direction: focus on what determines secondary active transport

Context: cotransport in companion cells

Exemplar Exam Question – Simple Explanation

5) Explain why cotransport is a type of secondary active transport.

[2 marks]

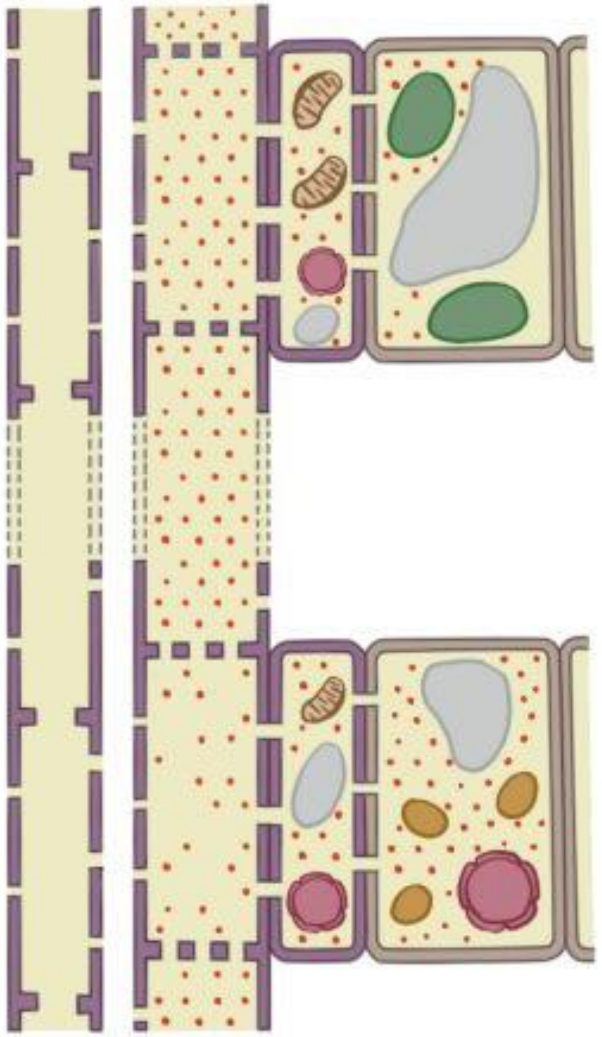
The energy needed to move sucrose against its concentration gradient into companion cells is coupled with the diffusion of hydrogen ions down their concentration gradient. However, the concentration gradient of hydrogen ions is first set up by actively transporting hydrogen ions against their concentration gradient, using ATP hydrolysis as energy.

Mass Transport in Phloem

- **Sources** are locations in the plant where **assimilates** are **produced** and **loaded** into the **phloem**
- **Sinks** are locations where **assimilates** are **used** and/or **stored** and where **assimilates** are **removed** from the **phloem**
- The **movement** of **assimilates** in the **phloem** from **sources** to **sinks** is called **translocation**

Mass Flow

- Loading of **assimilates** into the **phloem** at the **source lowers** the **water potential**
- **Water** from the **xylem** therefore **enters** the **phloem** by **osmosis**, **increasing** the **hydrostatic pressure**
- **Unloading** of **assimilates** at **sinks reduces** the **water potential** of **surrounding cells**
- **Water** therefore **leaves** the **phloem** by **osmosis**, **decreasing** the **hydrostatic pressure**
- This creates a **hydrostatic pressure difference** which **pushes sap** to the location it is required by **mass flow**



Exemplar Exam Question – Explanation/Qualitative

6) Plants have developed a mechanism to ensure assimilates are transported to where they are most needed.

Describe how assimilates are transported through the plant.

[4 marks]

Command: Describe process, no need to explain why

Direction: only assimilates, not water

Context: Translocation in the phloem and mass flow

Exemplar Exam Question – Explanation/Qualitative

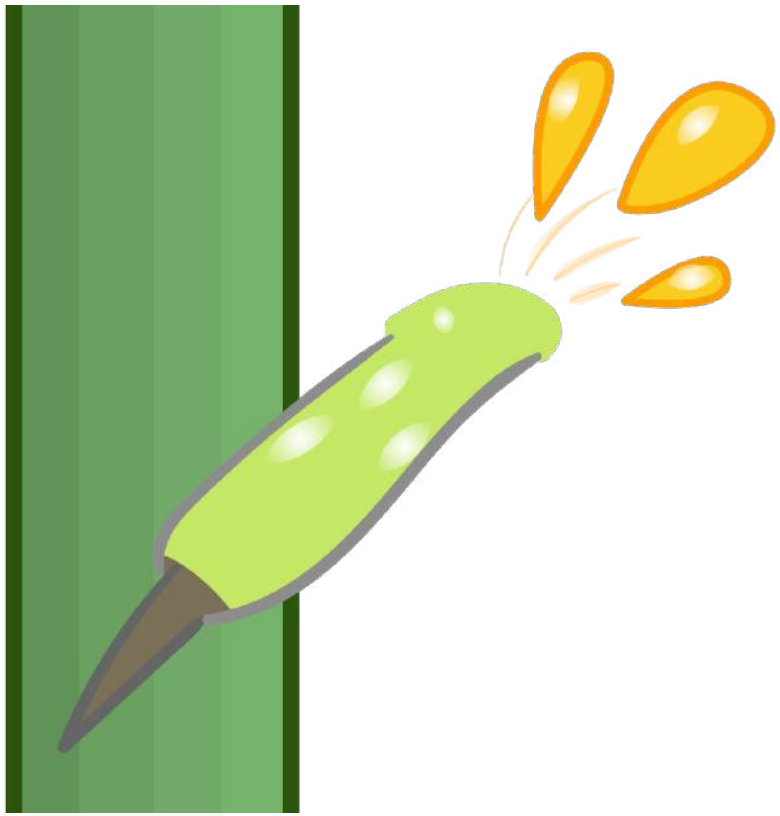
6) Describe how assimilates are transported through the plant. **[4 marks]**

Assimilates are loaded into the sieve tube elements (STEs) of the phloem at the source. This decreases the water potential of the STEs and water from the xylem moves into the phloem by osmosis, increasing the hydrostatic pressure of the phloem at the source. At the sink, assimilates are unloaded and water follows, decreasing the hydrostatic pressure. This difference in pressure between source and sink transports assimilates by mass flow.

Evidence for Mass Flow Hypothesis

Scientists have found **evidence** that supports the **mass-flow hypothesis** for **translocation**:

- **Companion cells** contain **many mitochondria**, with **translocation stopping** when **mitochondria** are **poisoned**
- The **rate** of **flow** of **assimilates** in the **phloem** is **much faster** than could occur by **diffusion**
- **Sap** is **released** when the **phloem** is **cut** showing that the **phloem** is under **positive pressure**

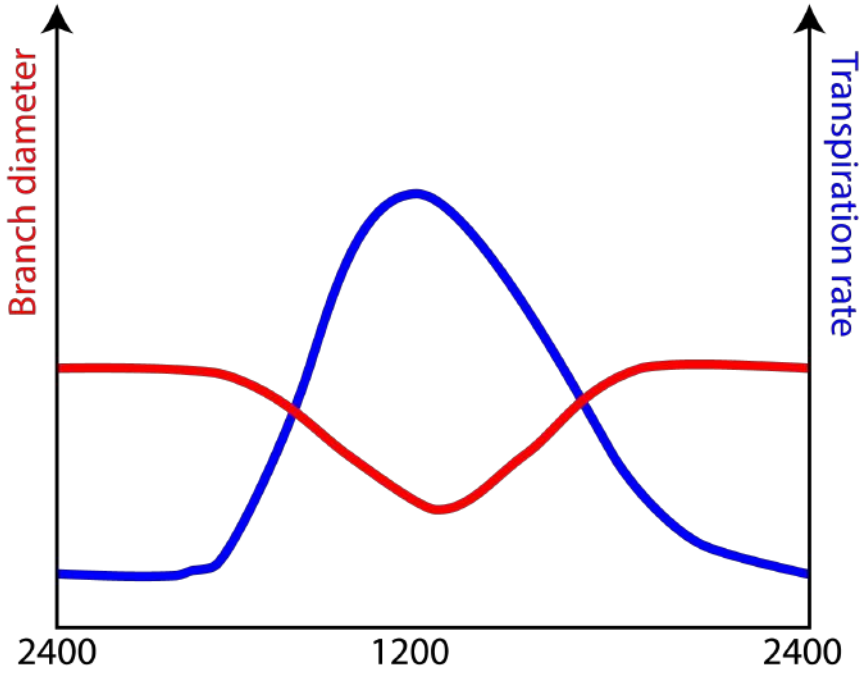


OCR & Edexcel A: do not need to know this

Evidence for Cohesion-tension Theory

Scientists have found **evidence** that supports the **cohesion-tension theory** of **water transport**:

- The **diameter** of **tree trunks decrease** in the **day** and **increase** at **night**, suggesting **negative pressure increases** when **water flow** is **highest**
- **Cut xylem vessels draw air** into the xylem rather than water dripping out
- If an **air bubble enters** the **xylem vessel**, this **prevents** any **water** from then being **carried** in the vessel



Exemplar Exam Question – Data Analysis

7) A scientist was investigating the mechanism involved in loading sucrose into the sieve tube elements. They isolated the companion cells and conducted some experiments, making the following observations:

1. Companion cells became negatively charged compared to their surroundings
2. The pH within the companion cells increased, whilst the pH of the surrounding solution decreased
3. Addition of cyanide prevented the change in pH occurring

What conclusions can be drawn from these observations? **[3 marks]**

Command: analyse and evaluate data

Direction: use only provided data

Context: mechanism of active loading by companion cells

Exemplar Exam Question – Data Analysis

It can be concluded that positively charged hydrogen ions are being moved out of the companion cells, into the surrounding solution increasing the pH inside companion cells. This process requires active transport – as addition of cyanide inhibits its process. Cyanide prevents production of ATP by blocking the electron transport chain from function – stopping respiration.

SNAPREVISE

Mini Mock Paper

Mini Mock Paper

a) What direction(s) is/are water and sugars transported in the plant?

[1 mark]

_____

_____

Mini Mock Paper

b) Sodium fluoride is a metabolic inhibitor of plant cells.

Explain why treatment of a plant with sub-lethal concentrations of sodium fluoride (NaF) prevented translocation occurring.

[2 marks]

Mini Mock Paper

c) A student used a mass potometer to measure the rate of transpiration from a plant. The student calculated mass of the plant at the start and end of the experiment and then worked out the change in mass. The balance scales used had an absolute uncertainty of +/-0.2g.
The initial measurement taken by the student was 113.4g.
The final measurement taken by the student was 108.2g.

Calculate the percentage error. Show your working.

[2 marks]

SNAPREVISE

Mini Mock Paper Answers

Mini Mock Paper

a) What direction(s) is/are water and sugars transported in the plant?

[1 mark]

Water: Up the plant (from the roots to the leaves)

Sugars: Up and down the plant (from sources to sinks)

Mini Mock Paper

b) Sodium fluoride is a metabolic inhibitor of plant cells.

Explain why treatment of a plant with sub-lethal concentrations of sodium fluoride (NaF) prevented translocation occurring.

[2 marks]

Translocation is an active process which requires ATP. If metabolism is stopped by addition of an inhibitor, respiration cannot occur and ATP cannot be produced, meaning Hydrogen ions cannot be pumped out of companion cells preventing sucrose loading.

Mini Mock Paper

c) A student used a mass potometer to measure the rate of transpiration from a plant. The student calculated the mass of the plant at the start and end of the experiment and then worked out the change in mass. The balance scales used had an absolute uncertainty of +/- 0.2g.
The initial measurement taken by the student was 113.4g.
The final measurement taken by the student was 108.2g.

Calculate the percentage error. Show your working.

[2 marks]

Mini Mock Paper

c) Calculate the percentage error. Show your working.

[2 marks]