Bio Factsheet

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Phloem

This Factsheet describes the structure and function of phloem and concentrates on typical exam questions such as:

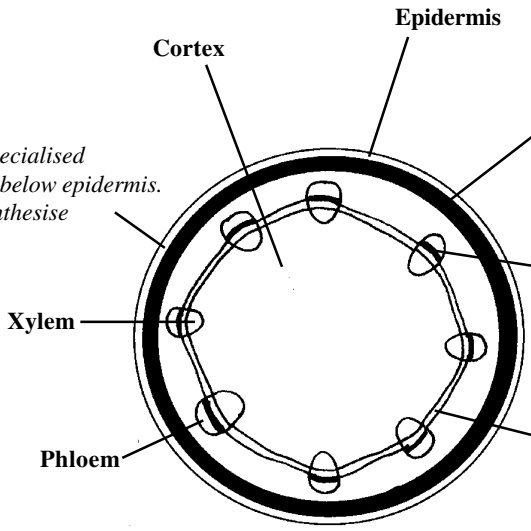
1. Labelling xylem and phloem in ts root sections
2. Describing the distribution of phloem in root, stems and leaves
3. Describing or labelling sieve tube elements and companion cells
4. Explaining the relationship between the structure and function of sieve tube elements and companion cells
5. Describing or interpreting the evidence that it is the phloem that transports sugars
6. Describing and analysing evidence for and against the mass flow hypothesis

Phloem is a tissue that contains several different types of cell. These include parenchyma, sclereids, fibres, sieve tube elements and companion cells. Phloem transports sucrose, amino acids, minerals such as phosphate and potassium and plant growth substances such as auxin. This process is called **translocation**.

The simplest type of exam question asks you to label the position of phloem (and usually xylem) on transverse sections of a stem and root (Fig 1).

Fig 1. Transverse sections of a stem and root

Stem



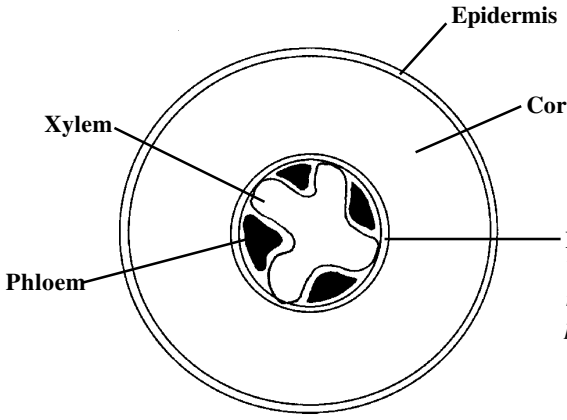
Root

No sclerenchyma - not needed, soil provides support

No collenchyma - not needed, soil provides support

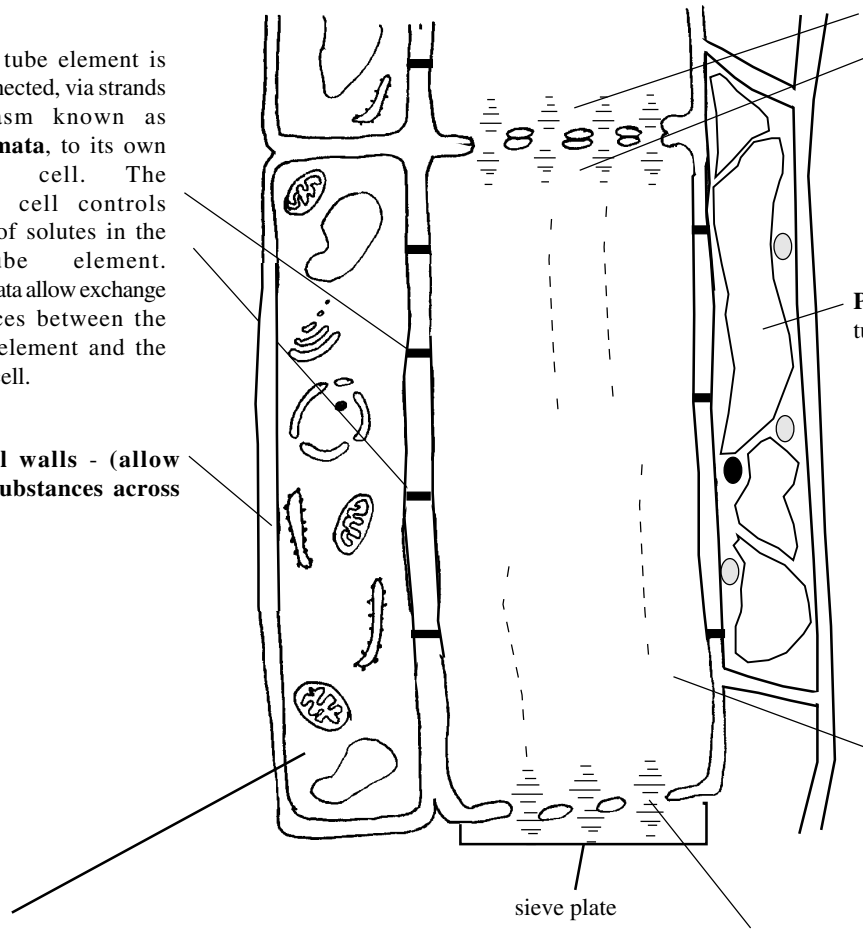
No chlorenchyma - roots not exposed to sun therefore could not photosynthesise

No stomata or lenticels - gaseous exchange occurs via root hairs



Another common exam question asks you to explain how the organisation of the sieve tube element and companion cell enables efficient translocation (Fig 2). The key principle is that the sieve tube elements have thin cytoplasm and few organelles so that the flow of substances through them is rapid and efficient (peak flow rate = $2mh^{-1}$). The companion cell on the other hand has many organelles, chief of which are mitochondria, that provide ATP for active transport in the adjacent sieve tube element.

Fig 2. Sieve tube element



Why is sucrose transported and not glucose?

Sucrose is a non – reducing sugar, it is less reactive and less liable to enzyme breakdown than glucose.

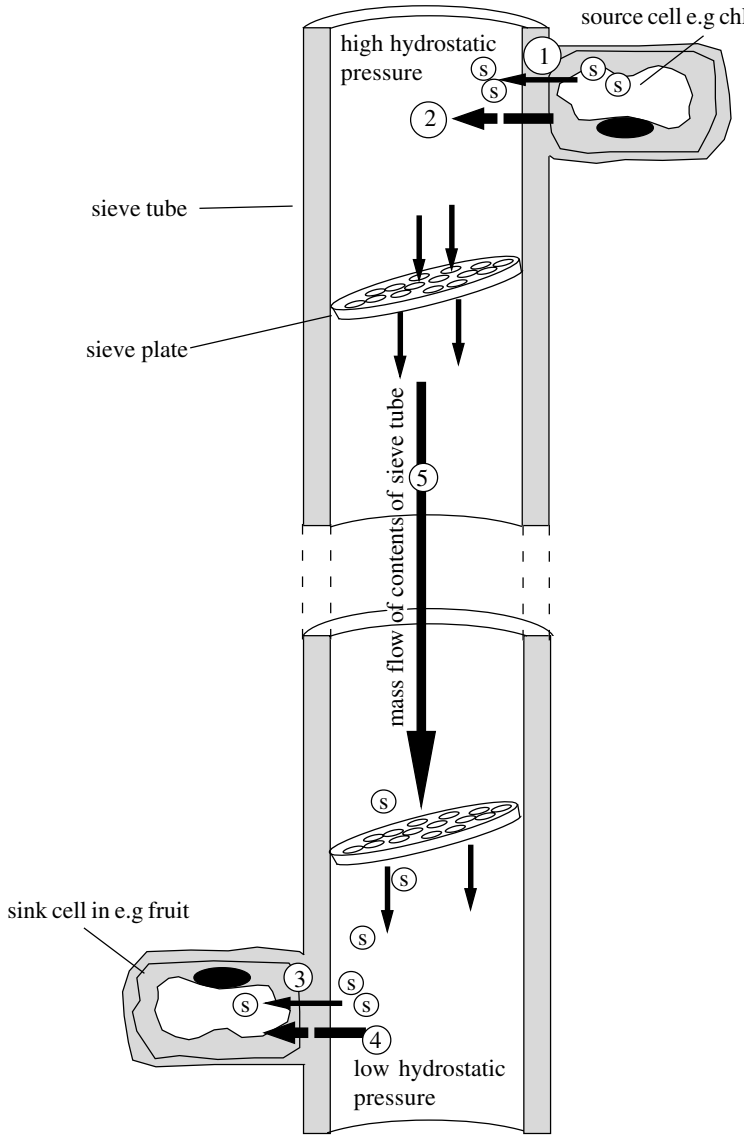
Evidence that the phloem transports sugars

1. Removing a ring of bark from around the stem causes swelling above the ring and the eventual death of the plant. Removing the ring of bark will remove the phloem, which unlike the xylem, lies immediately below the bark (Fig 1). ***Inference: the swelling is the accumulated sugars that cannot move any further. The plant dies because the sugars etc cannot reach any part of the plant below the ring – the roots for example.***
2. Aphids feed by inserting their needle-like mouthparts (stylets) into sieve tubes. If feeding aphids are killed and their body cut off – leaving the stylets inserted into the sieve tubes - sucrose, minerals and plant growth substances leak out. ***Inference: the sieve tubes are the cells in which these substances are normally transported***
3. A plant is exposed to the radioactive isotope ^{14}C. This isotope becomes incorporated in sucrose made in photosynthesis. A ts section of the stem is then cut and placed on an x-ray film. The film blackens where it is exposed to radioactivity. It is found that the blackened area corresponds exactly to the position of the phloem in the stem section. ***Inference: the radioactive carbon, incorporated in a sucrose molecule, is in the phloem***

The mass flow hypothesis

Phloem transports substances made in the leaves to all the other parts of the plant that need them. For example, sugars made in photosynthesising leaves have to be transported to root hair cells. This could be a distance of over 50 m in a large tree.
The mass flow hypothesis tries to explain how this transport occurs (Fig 3).

Fig 3. Mass flow hypothesis



1. Sucrose produced in photosynthesis in source cell leaf is actively transported into sieve tube
2. This lowers the water potential in the cytoplasm of the sieve tube. Water moves by osmosis from a region of high water potential to low water potential. This influx of water into the sieve tube raises the hydrostatic pressure in the sieve tube
3. Sucrose moves into sink cell where it is going to be used
4. This reduces the water potential of the sink cell so water moves by osmosis from the sieve tube element into the sink cell. This reduces the hydrostatic pressure in the sieve tube.
5. There is a difference in hydrostatic pressure in the source and sink ends of the sieve tube. This difference in pressure causes the fluid inside the sieve tube to flow from source to sink

Evidence for the mass flow hypothesis

1. The solute concentrations of sieve tubes have been measured in many plants. The concentration of sucrose in sieve tubes is higher nearer the source than the sink and these differences in concentration are large enough to account for the measured rates of movement
2. The rate of solute transport is usually proportional to the difference in solute concentrations
3. Water potential gradients exist between the source and sink cells and the adjacent sieve tube elements

However, this is still a hypothesis and exam questions can ask you for evidence against the hypothesis

Evidence against mass flow?

1. Sieve tube elements have cytoplasm but this is not needed if transport is simple mass flow. Why are the sieve tubes not hollow and empty like xylem vessels?
   Similarly, why do sieve tubes have sieve plates between them? Why are they not continuous? (***Botanists have suggested that these features help prevent rapid loss of valuable solutes if sieve tubes are damaged***)
2. Solutes have been found to be moving in opposite directions in phloem tissue. (***Botanists point out that solutes may easily be moving in different directions in adjacent sieve tubes – all that is needed is that the adjacent tubes have different sources and sinks. Bi-directional flow has not been recorded in the same sieve tube***)

Typical Exam Questions

1 (a) Suggest explanations for the following observations:

(i) Fruit growth is suppressed if a ring of bark between the fruit and mature leaves is removed. **2**

(ii) Translocation in the phloem may be stopped by metabolic inhibitors. **2**

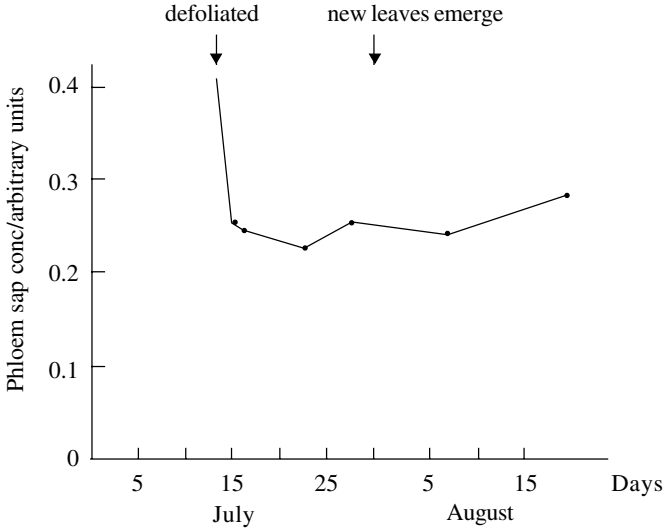
2. The table shows the destination (sink) of translocated carbohydrates in a mature tomato plant.

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. **3**

(b) Outline how phloem tissue is structurally adapted for its role in carbohydrate transport. **3**

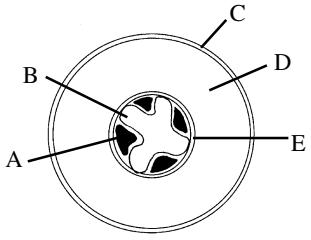
3. The graph below show the effect of defoliation (removal of all leaves) of a white ash tree on the sugar content of the phloem.



(a) Explain what these results suggest about the source of sugars in the phloem. **2**

(b) Outline the 'mass flow hypothesis'. **4**

4. The diagram shows a transverse section of a plant organ.



(a) Identify the organ **1**

(b) Label the tissues shown A-E. **5**

Answers

1. (a) (i) removal of bark removes phloem;
responsible for transport of sugars to fruit;
to enable fruit development/formation of food store in fruit;
max 2

(ii) movement/uptake/loading of sucrose from mesophyll cells to phloem is active/requires ATP;
metabolic inhibitors stop respiration/prevent ATP manufacture; **2**

TOTAL 4

2. (a) for storage;
to provide energy for fruit/tomato development;
to make fruits/tomatoes attractive to animals;
for animal dispersal; **max 3**

(b) end walls of sieve tube elements are perforated/ref to sieve plates;
cytoplasm of sieve tube element is thin/peripheral/contains few organelles/has no nucleus;
cellulose cell walls allow exchange of substances across them;
ref to elongated sieve tubes; **max 3**

TOTAL 6

3. (a) defoliation causes sugar concentration to fall;
suggests the source is the leaves; **2**

(b) sugars move from sources/leaves to sinks/storage areas/main stems;
sugars actively taken up by phloem companion cells;
and passed to sieve tubes;
water follows osmotically/along water potential gradient;
creates hydrostatic pressure;
sugars removed from phloem at sink and water follows;
hydrostatic pressure difference between source and sink creates mass flow; **max 4**

TOTAL 6

4. (a) root; **1**

(b) A = Phloem
B = Xylem
C = Epidermis
D = Cortex
E = Endoderm **5**

TOTAL 6

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