AQA Realising potential

# Teaching notes: Transport of organic substances in plants

These teaching notes relate to section 3.3.4.2 of our AS and A-level Biology specifications. This resource describes key teaching points in the accompanying PowerPoint presentation.

## Key points

Organic substances are moved from sources to sinks. Sources are the photosynthesising cells within leaves; sinks are growing regions (meristems), storage organs or seeds.

Two types of phloem cell are important in transporting organic substances from source to sink:

- sieve tube elements, which transport the organic compounds
- companion cells, which control the activities of the sieve tube elements.

Sieve tube elements and companion cells are well adapted for their roles.

The mass flow hypothesis of translocation consists of three stages:

- organic compounds are loaded into the sieve tube elements in the leaves, resulting in an increase in hydrostatic pressure caused by osmotic influx
- the increase in hydrostatic pressure pushes the contents of the sieve tube elements down a pressure gradient
- organic compounds are unloaded into cells at the sinks resulting in a decrease in hydrostatic pressure.

Evidence for the transport of organic substances within the phloem comes from the use of radioactive tracers, from ringing experiments and from the use of sap-sucking insects.

## PowerPoint presentation

### Overview (slide 2)

This slide provides an overview and introduces the terms **source** and **sink**.

You might ask students to identify which areas of a plant might be:

- actively growing (eg, shoot tips, root tips, new leaves, flower buds)
- storage organs which are common in their kitchen (eg, root tuber such as beetroot, stem tuber such as potato, tap root such as carrot, stem rhizome such as ginger, bulb such as onion, seed such as cumin).

## Location of phloem (slide 3)

Phloem tissue, introduced in the previous slide, is located alongside xylem tissue.

This diagram shows their location in the stem and in the root of a herbaceous plant. Students will have already learnt the position of the vascular bundles in a leaf when considering water transport.

[The intrafasicular cambium, shown in the diagram, is meristematic tissue that allows the plant to increase in girth (during secondary thickening) and is **not** specification content.]

In a woody stem, the phloem is located in the bark (the 'wood' being xylem). This is important in understanding the significance of ringing experiments (next slide).

## Evidence that transport of organic compounds occurs in the phloem (slide 4)

Evidence that phloem is the tissue that transports organic compounds includes:

- the use of $^{14}C$-labelled sucrose/amino acids followed by autoradiography
- ringing experiments (first performed in 1837 by a German forester named Theodor Hartig)
- experiments with aphids, though this is extension material and **not** specification content (see plantsinaction.science.uq.edu.au/book/export/html/23 for good photographs showing the process).

## Structure of phloem (slide 5)

Sieve tube elements are the cells in which translocation occurs. They are well adapted for mass transport having lost impediments to flow.

- They are stacked one on top of another.
- Their end walls (sieve plates) have large pores through which their cytoplasm can flow.
- During maturation they lose their nuclei and much of their cytoplasm.

Companion cells control the activities of the sieve tube elements.

- They have a nucleus and rough endoplasmic reticulum.
- They have relatively large numbers of mitochondria.

- There are many plasmodesmata in the lateral walls of the companion cells and their associated sieve tube elements.
- [Note the use of the term 'vacuole' indicates this is not a typical plant vacuole surrounded by a tonoplast.]

## Two sieve tube elements (slide 6)

This micrograph shows the sieve plate between two sieve tube elements.

## Sieve tube elements and a companion cell (slide 7)

This diagram represents the relationship between sieve tube elements and companion cells. The sieve plate and lateral sieve area, made of numerous plasmodesmata (singular, plasmodesma), are shown. These are important in aiding flow between cells (via the symplast route).

## A model of mass flow (slide 8)

This slide introduces the basic concepts of mass flow, using a well-known model.

Two 'cells', containing solutions of different concentration, are connected by tube **C**. Each 'cell' has a partially permeable membrane and is surrounded by distilled water. The two containers are themselves connected.

Water enters 'cell' **A** by osmosis because it has the more concentrated solution (lower/more negative water potential). This increases the volume within 'cell' **A** and, hence, the hydrostatic pressure within it. This increase in pressure pushes the solution from 'cell' **A** to 'cell' **B** through tube **C**. As the pressure increases in 'cell' **B**, water (and other small molecules) is forced through the partially permeable membrane surrounding it. Water flows back to the container holding 'cell' **A** as water finds its own level.

Can students identify which parts of the plant are represented by the components of this model? [Cell **A** = source; cell **B** = sink; tube **C** = phloem; water = xylem]

## Transport in the phloem (1) (slide 9)

Loading of organic molecules occurs from cells in the chlorenchyma into the companion cells and then into the sieve tube elements.

Transport through the mesophyll is largely via the symplast route, but into the sieve tube element is also via the apoplast route. For 'stretch and challenge' students, you might like to:

- extend the latter point by explaining it involves the active transport of hydrogen ions into the cell wall of the sieve tube elements and from there the co-transport back into the cytoplasm of sucrose and hydrogen ions down a hydrogen ion concentration gradient through sucrose transport proteins in the surface membranes of the sieve tube elements

- tell them that most of the carbohydrate is loaded and transported as non-reducing sugar and ask them to suggest an advantage of this (answer: less reactive than reducing sugar, so likely to last longer during transport). You could extend this idea by explaining that, initially, the loading involves sucrose but that, in the sieve tube elements, this is often converted to larger non-reducing sugars, such as the trisaccharide raffinose (sucrose + galactose) and the tetrasaccharide stachyose (sucrose + galactose + galactose), which are too large to leave the cells.

## Transport in the phloem (2) (slide 10)

The basic concepts here should be familiar to students and were introduced in slide 8.

- Loading of solutes into sieve tube elements reduces (makes more negative) the water potential of these cells.
- As a result water enters by osmosis; in this case from the adjacent xylem vessels (hence the importance of the closeness of these tissues shown in slide 3).
- The influx of water results in an increase in (hydrostatic) pressure, pushing materials down a pressure gradient.

## Transport in phloem (3) (slide 11)

Some organic substances are lost from the phloem to surrounding cells during transport.

At the sink, they are transported into the tissues, water follows by osmosis and the hydrostatic pressure falls.

The water enters the xylem and is pulled back up the plant in the transpiration stream.

[The mechanism of unloading is complicated by the fact that different sinks within a single plant and different species of plants use different methods: some apoplastic and some symplastic.]

## Mass flow hypothesis (slide 12)

A pictorial representation of the mass flow hypothesis.

An animation of transport in the xylem and in the phloem is available at uic.edu/classes/bios/bios100/f06pm/transport.htm

## Contents of phloem / mg $cm^{-3}$ (slide 13)

This slide provides information about the approximate content of phloem sap.

The data are for illustrative purposes only; students should **not** commit them to memory. They do show that most of the sap comprises non-reducing sugars.

Students could be asked about this, to suggest, for example, that sugars can be hydrolysed in the sinks and used in respiration or to produce other useful compounds, such as amino acids. The latter could be linked to basic biochemistry, eg, what other components would plants need to make amino acids or DNA (nitrate for amino acids and nucleic acid bases, sulfate for some amino acids, phosphate for nucleotides etc).

# Questions for students

1. During translocation, organic substances are transported from sources to sinks. Give **two** ways in which these organic substances might be used in these sinks.

[2 marks]

2. Give **one** piece of evidence that shows translocation occurs in phloem tissue.

[2 marks]

3.

3.1. Most carbohydrate carried by phloem tissue is non-reducing sugar. Suggest **one** advantage of transporting non-reducing sugar, rather than reducing sugar.

[2 marks]

3.2. Given a sample of sap from phloem tissue, describe how you would test for the presence of non-reducing sugar.

[4 marks]

4. Phloem tissue is found in close association with xylem tissue. Explain the importance of this close association.

[2 marks]

5. Sieve tube elements and companion cells are two types of cell found in phloem tissue.

5.1. Give **two** ways in which the contents of sieve tube elements are different from those of companion cells.

[2 marks]

5.2. Explain the importance of plasmodesmata between the sieve tube elements and the companion cells.

[2 marks]

5.3. Sieve plates are important in translocation. Explain why.

[2 marks]

6. Describe and explain how organic substances are transported in plants.

[6 marks]

**The guide mark scheme for these student questions is available in [e-AQA](e-AQA) through Secure Key Materials.**