Data-based questions

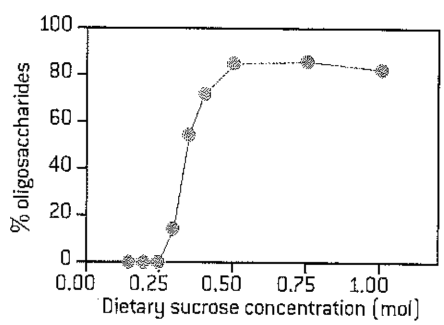
1 a) The only animals to consume phloem sap as the main part of their diet are insects belonging to a group called the Hemiptera. The data in this question comes from research into aphids.

The sugar content of phloem sap is very high – often greater than 1 mol dm^{-3}.

(i) Explain how plants increase the sugar concentration of phloem sap to such high levels. [1]

(ii) Explain how high sugar concentrations cause a high pressure to develop in the phloem. [2]

b) Aphids only ingest a small proportion of the sugar in phloem sap. The remainder passes out in the faeces, which is a liquid called honeydew. Because of the high sugar concentrations, phloem sap has a much higher solute concentration than aphid cells. Enzymes secreted into the aphid gut reduce the solute concentration of phloem sap by converting sugars into oligosaccharides. Figure 11 shows the relationship between the sucrose concentrations of phloem sap ingested by aphids and the oligosaccharide content of the honeydew.

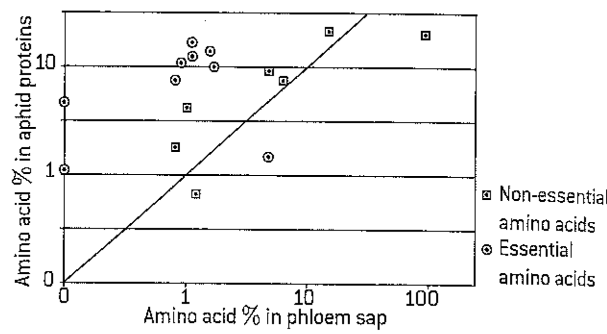


▲ Figure 10

(i) Describe the relationship between the sucrose concentration of phloem sap ingested by aphids and the percentage of oligosaccharides in the honeydew. [3]

(ii) Suggest reasons for aphids secreting enzymes to reduce the solute concentration of the fluid in the gut. [2]

c) Aphids ingest larger volumes of phloem sap than they need, to obtain sufficient sugar for cell respiration. This is because they also need to obtain amino acids and the concentration of amino acids in phloem sap is low. Figure 11 shows the percentages of individual amino acids in phloem sap and the percentages in aphid protein. Nine of the amino acids cannot be synthesized in aphid cells and so are called essential amino acids. The other amino acids can be synthesized from other amino acids and so are non-essential.



▲ Figure 11

(i) Evaluate phloem sap as a source of amino acids for aphids. [3]

(ii) Suggest reasons for the differences in amino acid content between phloem sap and aphid protein. [2]

d) Specialized cells have been discovered in aphids called bacteriocytes. These organisms contain bacteria called *Buchnera*, which synthesize essential amino acids from aspartic acid and sucrose. Aspartic acid is a non-essential amino acid that is found in much higher concentrations in phloem sap than any other amino acid. When aphids reproduce, they pass on *Buchnera* bacteria to their offspring.

(i) Explain how antibiotics could be used to obtain evidence for the role of *Buchnera* in aphids. [2]

(ii) Using the data in this question, discuss the reasons for few animals using phloem sap as the main part of their diet. [3]

Radioisotopes as important tools in studying translocation

Developments in scientific research follow improvements in apparatus: experimental methods for measuring phloem transport rates using aphid stylets and radioactively-labelled carbon dioxide were only possible when radioisotopes became available.

Carbon-14 is an isotope of carbon that is radioactive. Radioactively-labelled carbon within carbon dioxide can be fixed by plants during photosynthesis. It will release radiation that can be detected either using film or radiation detectors. As the carbon is metabolized, it will be found in different molecules within the plant. In other words, both the formation and movement of radioactive molecules can be traced. Figure 12 shows a device known as a Geiger counter measuring radiation levels in a crop of sunflowers. The sunflowers in the picture are being used for bioremediation of soil contaminated with radiation.

▲ Figure 12

Data-based questions: Radioactive labelling (1)

Source leaves were supplied with a pulse of radioactively-labelled carbon and the time taken for the radioactive carbon to be found in sink leaves was measured by radiophotography. The photosynthetic rate was varied, primarily, by altering the concentration of unlabelled carbon dioxide. The experiment was carried out at three different intensities of light (green squares are 20,000 lux; orange diamonds are 40,000 lux; purple circles are 80,000 lux).

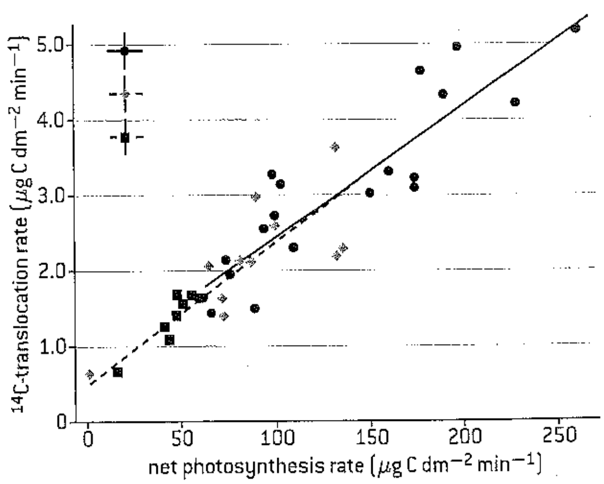
a) Outline the relationship between photosynthesis rate and translocation rate. [1]

b) (i) Deduce the relationship between light intensity and translocation. [2]

(ii) Suggest whether this is a correlation or a cause and effect relationship. [3]

c) Determine the ratio of translocation to net photosynthesis at two different points on the graph. [2]

d) Deduce, with a reason, whether the source leaf is a growing or mature leaf. [2]



▲ Figure 13

Data-based questions: Radioactive labelling (2)

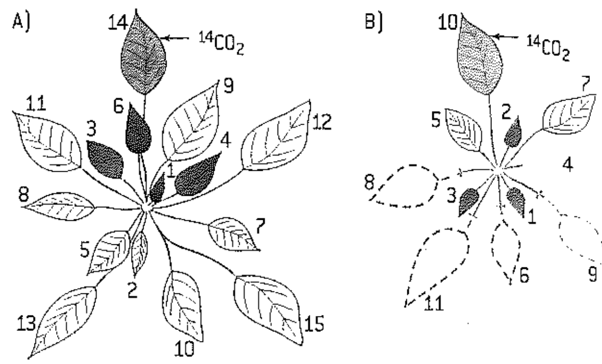
The distribution of radioactivity in leaves from a sugar beet plant (*Beta vulgaris*) was determined 1 week after $^{14}CO_2$ was supplied for 4 hours to a single source leaf (labelled with an arrow in figure 14). The degree of radioactive labelling is indicated by the intensity of shading of the leaves. Leaves are numbered according to their age; the youngest, newly emerged leaf is designated 1.

The purpose of the experiment was to determine the position of sink leaves in relation to the position of source leaves. The hypothesis was that leaves directly above and below the source leaf are most likely to receive photosynthate (the products of photosynthesis) and that pruning causes a rerouting of translocation pathways to include lateral leaves. Figure 14A shows the distribution of photosynthate in an intact plant. Figure 14B shows the pattern after several leaves have been removed.

(i) In figure 14A, identify the two leaves that received the most photosynthate. [2]

(ii) Using figure 14A, describe the location of the sink leaves receiving the most photosynthate in relation to the source leaf. [2]

(iii) Evaluate the hypothesis that leaves directly above and below the source leaf are most likely to receive photosynthate and that pruning causes a rerouting of translocation pathways to include lateral leaves. [3]

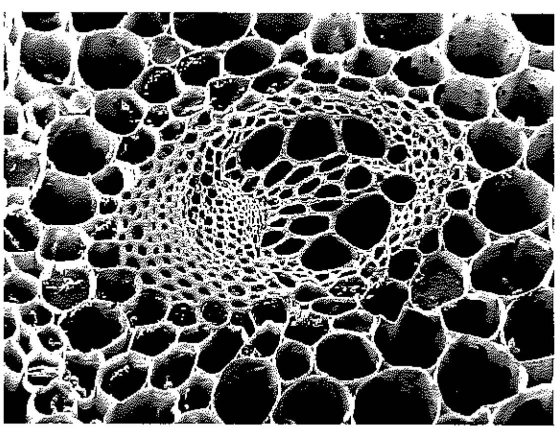


▲ Figure 14

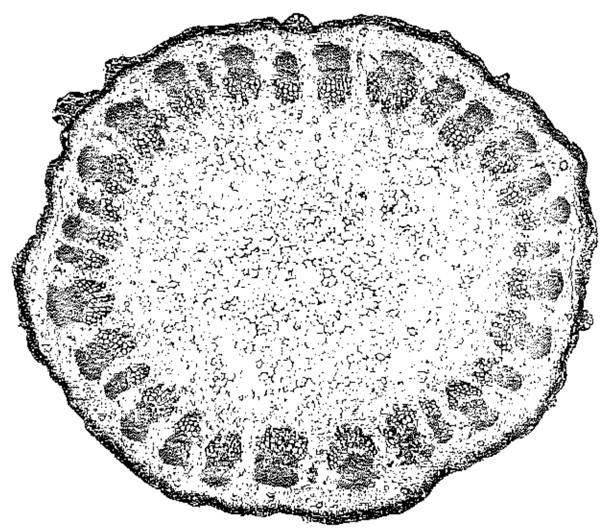
Identifying xylem and phloem in light micrographs

Identification of xylem and phloem in microscope images of stem and root.

Xylem cells are generally larger than phloem cells. Within one vascular bundle, phloem cells tend to be closer to the outside of the plant in stems and roots.



▲ Figure 15 Buttercup stem. Coloured scanning electron micrograph (SEM) of a transverse (cross) section through part of a stem of a buttercup, *Ranunculus repens*, showing a vascular bundle. This is a typical dicotyledon stem. At the centre is an oval vascular bundle embedded in the cortex cells of the stem. Some cells contain chloroplasts (green). The vascular bundle contains large xylem vessels (centre right) which serve to conduct water; the nutrient-conducting phloem is orange



▲ Figure 16 Light micrograph of a transverse section through the stem of a sunflower (*Helianthus annuus*)