

Source and Sink in Phloem Translocation

- ▶ It is the long distance movement of organic substances from the source or supply end (region of manufacture or storage) to the region of utilization or sink. But the source and sink may be reversed depending on the season or need of the plants.
- ▶ Sugar stored in roots may be mobilised to become a source of food in the early spring when the buds of trees act as sink and require energy for their growth and development. Since the source-sink relationship is variable, the direction of movement of organic solutes in phloem can be upwards or downwards i.e., bidirectional (c.f. unidirectional upwards in xylem).

Directions of Translocation of Organic Solutes

Translocation of organic solutes can occur in the following directions:

- 1. Downward Translocation:** It is the most common mode of translocation. The leaves manufacture food in excess of their own requirement. The excess food comes out of leaves and is translocated in the downward direction to stem (for storage, metabolism, maintenance of its cells and secondary growth, if any) and root system (for storage, growth, metabolism and maintenance).
- 2. Upward Translocation:** In deciduous plants renewal of growth and development of new foliage are dependent upon upward transport of food from reserves present in the roots and stems. Growth of the stem apices, formation of flowers, fruits, etc. require the movement of assimilates from leaves in an upward direction.
- 3. Lateral Translocation:** It is little except when source and sink lie on the opposite sides.
- 4. Bidirectional Translocation:** Rabideau and Burr (1945) found that labelled carbohydrates moved out of the leaves in both upward and downward directions. The two types of translocation are believed by many workers to occur in different sieve tubes.

Pathway of Translocation: The most common organic nutrient translocated in plants is sucrose. The channels of transport are sieve tubes (in flowering plants) and sieve cells (in non flowering vascular plants) of phloem. It was proved for the first time by Czapek (1897).

Evidences of translocation

The evidences are as follows:

- ▶ 1. There are only two paths for long distance translocation, tracheary elements and sieve tubes. The former are dead while the latter are living. Translocation of organic solutes seems to be through sieve tubes because it is inhibited by stem girdling which kills living cells.
- ▶ 2. In girdling or ringing experiments, a ring of bark is cut from the stem. It also removes phloem. Nutrients collect above the ring where the bark also swells up and may give rise to adventitious roots. Growth is also vigorous above the ring. The tissues below the ring not only show stoppage of growth but also begin to shrivel (Roots can be starved and killed if the ring is not healed after some time. Killing of roots shall kill the whole plant) clearly showing that bark or phloem is involved in the movement of organic solutes which occurs in one direction, i.e., towards root. Girdling experiments are performed in fruit trees to make more food available to fruits. However, the rings are kept narrow and cambium is not touched so that the incision heals up after some time. (Girdling experiments cannot be carried out in monocots and dicots with bi-collateral bundles because of the absence of a single strip of phloem).
- ▶ 3. Mason and Maskell (1928) inserted a wax paper between phloem and xylem. Parts of the bark were also removed except for a narrow strip. They found evidence that the organic solutes passed through the narrow strip of bark containing the phloem.
- ▶ 4. By means of aphid stylets, Weatherley (1959) found that sieve tubes contained a concentrated solution of organic substances under a pressure.
- ▶ 5. Radio-autographs show that assimilates with incorporated radioactive elements pass out of the leaves and travel towards the sink ends through phloem.

Evidences of translocation

- ▶ 6. Sieve tubes contain a high organic solute content— 5-10% soluble carbohydrates (mostly sucrose), about 1% nitrogenous compounds (mostly amino acids), organic acids besides traces of hormones and other organic solutes. Sucrose is most suitable form of carbohydrate translocation as it is non-reducing and chemically stable. It does not react with other substances during translocation.
- ▶ 7. Tonoplast is absent in sieve tube cells so that cytoplasm is in direct contact with vacuolar contents.
- ▶ 8. Sieve tube cytoplasm can tolerate high concentration of solutes without being plasmolysed.
- ▶ 9. Cytoplasm of one sieve tube cell is continuous with that of the adjacent sieve tube cells through sieve plates so as to form continuous filaments. The centre of sieve tube cells is empty with cytoplasmic strands being peripheral.
- ▶ 10. Sieve tube cells possess granules and filaments of P-protein with ATPase activity.
- ▶ 11. Relatively large amounts of organic solutes are trans-located. The rate of translocation of organic nutrients is such that a sieve tube must be refilled 3-10 times per second. Crafts and Lorenz (1944) found that a pumpkin fruit receives 5500 gm of the organic solution in 33 days with a rate of 0.61 gm. of dry weight or translocation of 110 cm per hour.
- ▶ 12. Lateral movement from phloem to living cells or from source to phloem occurs through transfer cells and symplasm.

Mechanism of Phloem Translocation

Mechanism of Phloem Translocation: Several theories have been put forward to explain the mechanism of translocation of organic nutrients through the phloem e.g., diffusion, activated diffusion, protoplasmic streaming, interfacial flow, elect osmosis, trans cellular strands, contractile proteins, mass flow. Mass flow hypothesis is the most accepted one.

Mass Flow or Pressure Flow Hypothesis:

- ▶ It was put forward by Munch (1927, 1930). According to this hypothesis, organic substances move from the region of high osmotic pressure to the region of low osmotic pressure in a mass flow due to the development of a gradient of turgor pressure

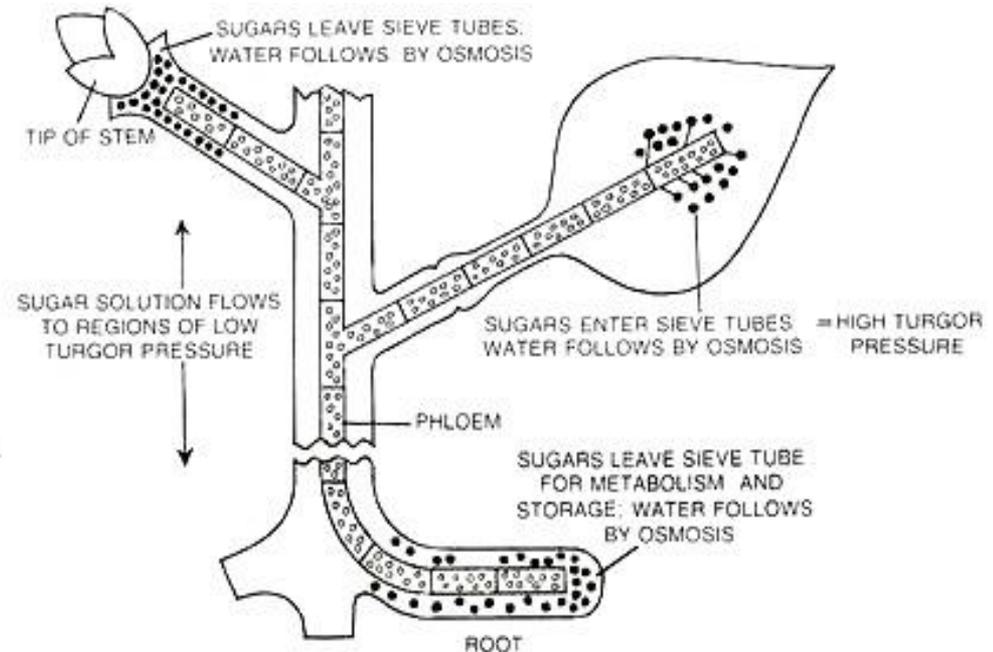


Fig. 11.41. Pathway and mechanism of phloem translocation.

Mechanism of Phloem Translocation

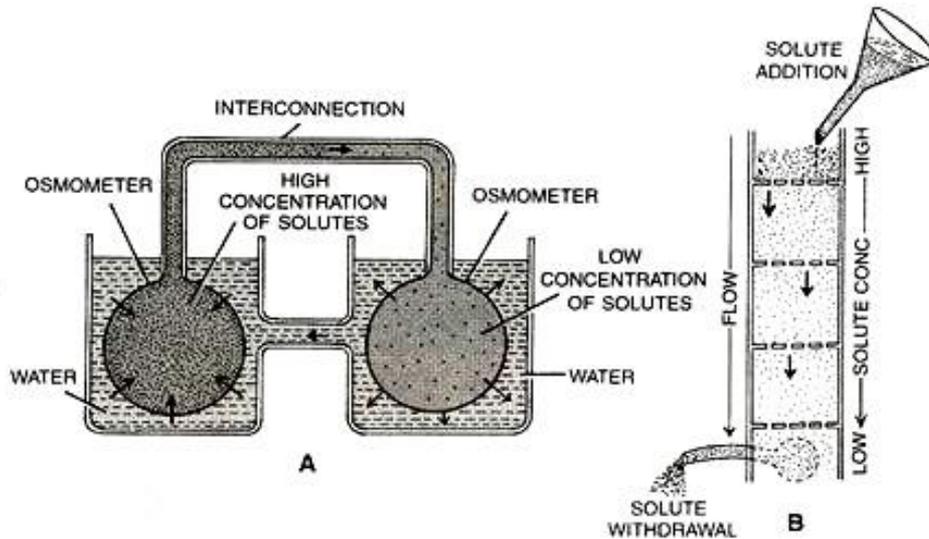


Fig. 11.42. A, mass flow or pressure flow of fluids from high to lower osmotic or turgor pressure. B, diagrammatic representation of continuous flow of solutes in one direction.

This can be proved by taking two interconnected osmometers, one with high solute concentration and the other with little osmotic concentration. The two osmometers of the apparatus are placed in water. More water enters the osmometer having high solute concentration as compared to the other.

It will, therefore, come to have high turgor pressure which forces the solution to pass into the second osmometer by a mass flow. If the solutes are replenished in the donor osmometer and immobilised in the recipient osmometer, the mass flow can be maintained indefinitely.

Mechanism of Phloem Translocation

Mass Flow or Pressure Flow Hypothesis

- ▶ Sieve tube system is fully adapted to mass flow of solutes. Here the vacuoles are fully permeable because of the absence of tonoplast. A continuous high osmotic concentration is present in the source or supply region, e.g., mesophyll cells (due to photosynthesis).
- ▶ The organic substances present in them are passed into the sieve tubes through their companion cells by an active process. A high osmotic concentration, therefore, develops in the sieve tubes of the source. The sieve tubes absorb water from the surrounding xylem and develop a high turgor pressure.
- ▶ It causes the flow of organic solution towards the area of low turgor pressure. A low turgor pressure is maintained in the sink region by converting soluble organic substances into insoluble form. Water passes back into xylem.

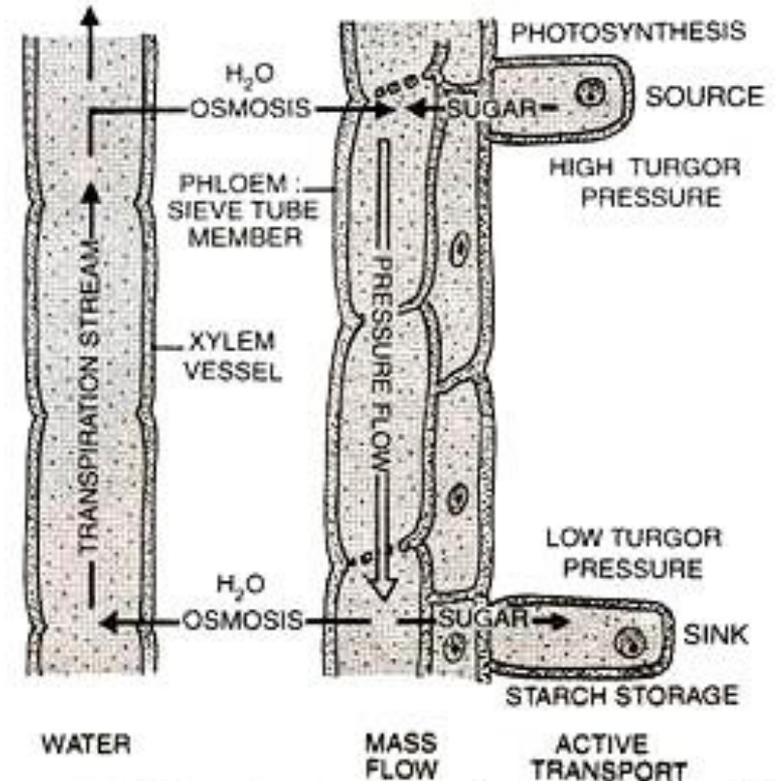
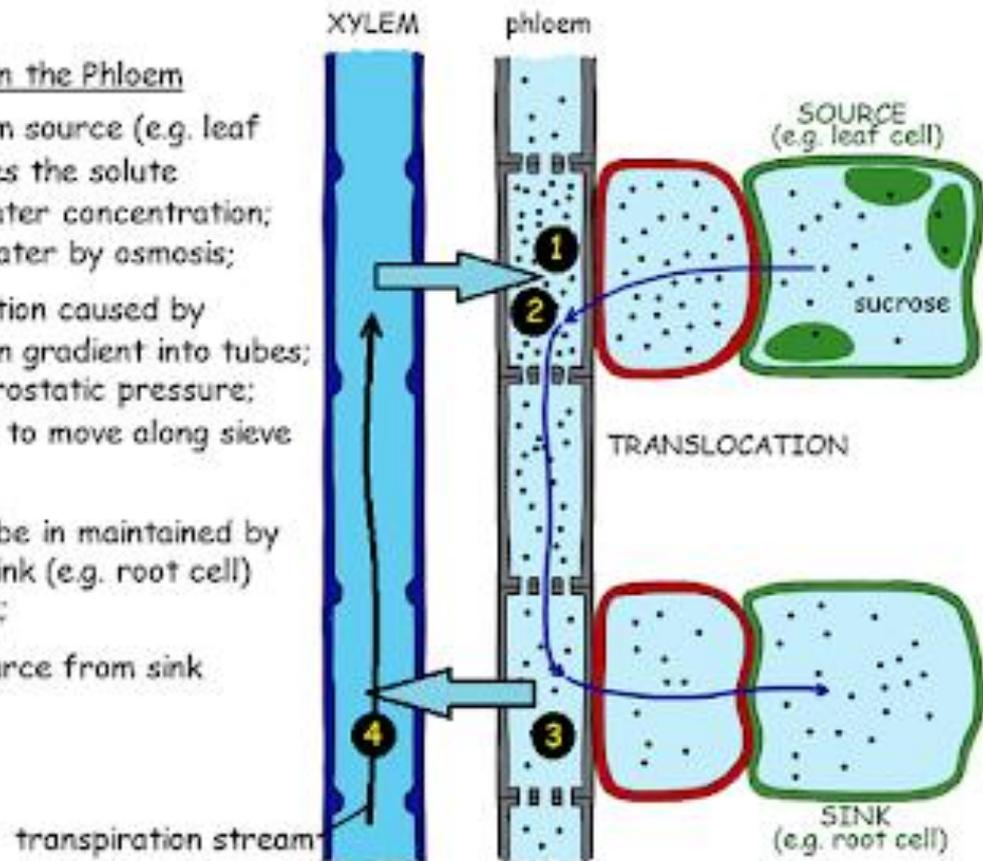
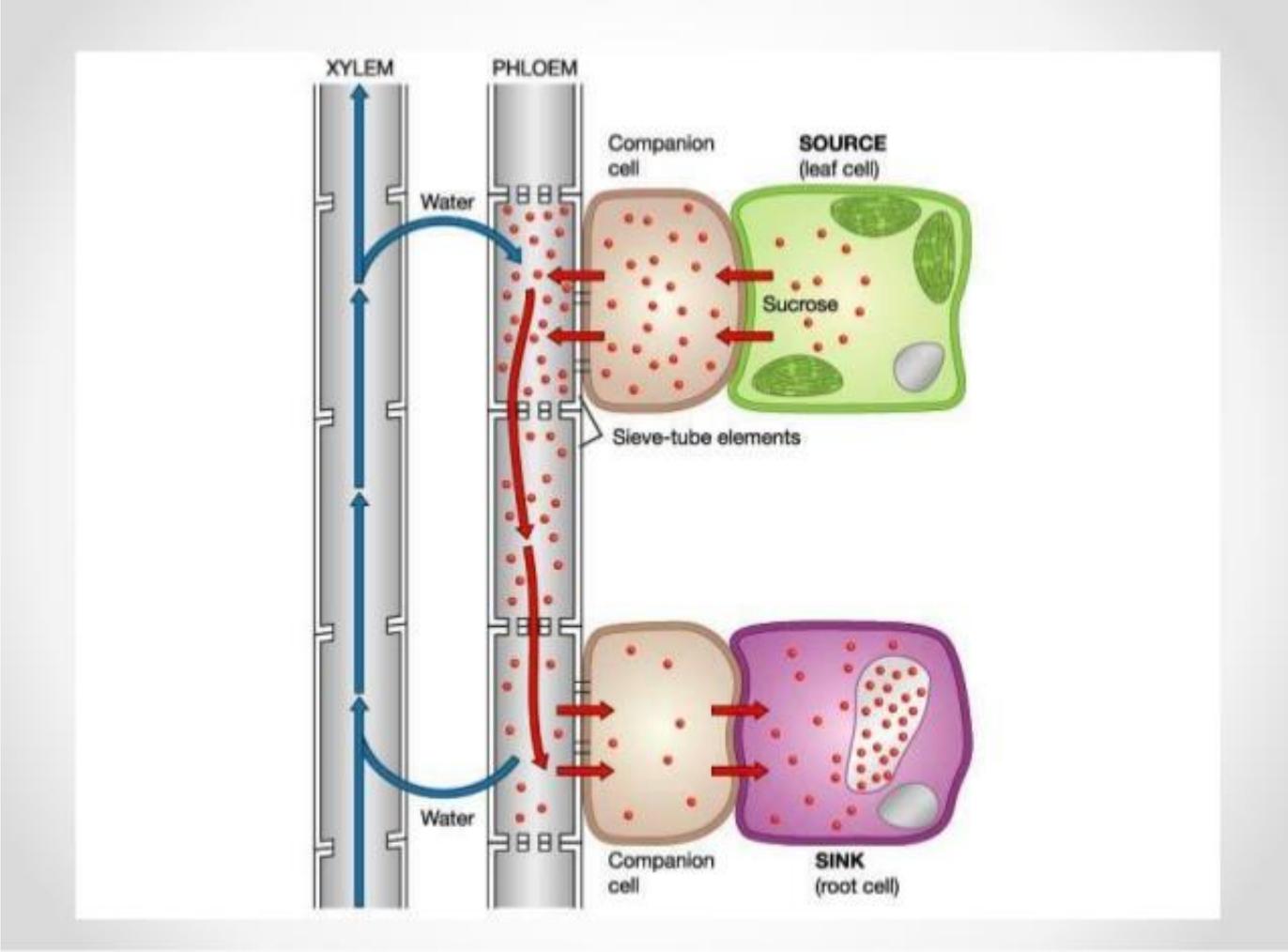


Fig. 11.43. Translocation of organic substances (assimilates) according to mass flow or pressure flow hypothesis.

Pressure-Flow Hypothesis: Transport in the Phloem

- * loading of solutes (e.g. sucrose) from source (e.g. leaf cell) into phloem sieve tube increases the solute concentration and decreases the water concentration;
- 1 * causes the sieve tubes to take up water by osmosis;
- * sieve tube cell walls resist deformation caused by
- 2 water movement down concentration gradient into tubes;
- * creates a build up of a positive hydrostatic pressure;
 - * forces contents of phloem (i.e. sap) to move along sieve tubes (bulk flow);
- 3 * gradient of pressure in the sieve tube is maintained by active unloading of sucrose at the sink (e.g. root cell) and loss of water by osmosis at sink;
- 4 * xylem recycles the water back to source from sink through the transpiration stream.





Mass Flow or Pressure Flow Hypothesis

Evidences:

- ▶ (i) Sieve tubes contain organic solutes under a pressure because an injury causes exudation of solution rich in organic solutes
- ▶ (ii) Direction of flow of organic solutes is always towards concentration gradient. A fall of 20% concentration was observed by Zimmermann (1957) over a distance of eight metres
- ▶ (iii) Defoliation of shoots causes disappearance of concentration gradient in its phloem
- ▶ (iv) Bennet (1937) observed viruses to move in phloem in a mass flow in the direction of movement of organic solutes at a rate of about 60 cm/hr
- ▶ (v) All the substances dissolved in sieve tubes are found to move with the same velocity with minor differences
- ▶ (vi) The hypothesis can be simulated experimentally.

Mass Flow or Pressure Flow Hypothesis

Objections:

- ▶ (i) Vacuoles of the adjacent sieve tube cells are not continuous. The cytoplasm present near the sieve plates exerts resistance to the mass flow
 - ▶ (ii) Catalado (1972) have observed that the rate of flow of water (72 cm/hr.) and solutes (35 cm/hr.) to be different in the same sieve tube
 - ▶ (iii) Phloem transport is not influenced by water deficit
 - ▶ (iv) The cells at the source end of mass flow should be turgid but they are often found to be flaccid in case of germinating tubers, corms, etc..
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