Phloem structure and function

Pp. 140-152 (New Book pp.151-161)

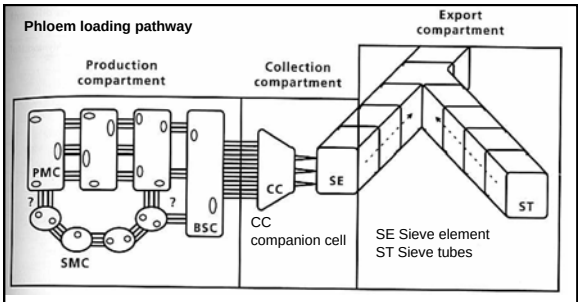
- Phloem function
- Phloem structure
- Symplastic pathway
- Apoplastic pathway
- Pressure-flow hypothesis
- Ecological distribution of phloem types

Goals

- Understand the critical significance of the phloem for vascular transport in plants
- Relate the structure of the phloem to its function
- Contrast apoplastic and symplastic phloem loading and unloading
- Explain the pressure flow hypothesis

Phloem function

- The phloem transports photosynthates (sugars, such as sucrose) and other organic substances (e.g., some plant hormones, amino acids and even messenger RNAs) manufactured in the cells of the plant.
- These substances enter “sieve tubes” of the phloem where they can be transported either up or down (depending on “sink strength”) to any region of the plant.

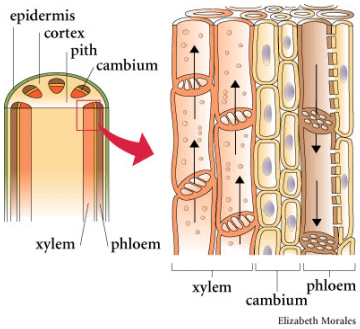


PMC palisade mesophyll cells

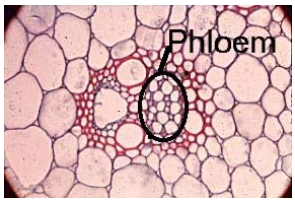
SMC spongy mesophyll cells

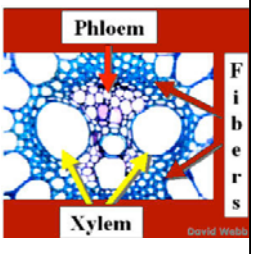
BSC bundle sheath cell

Phloem structure



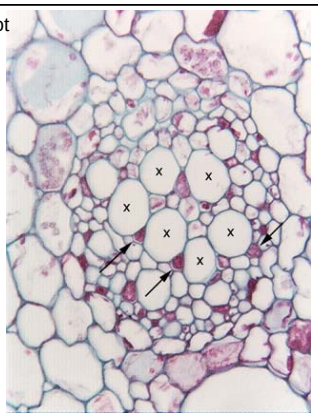
Vascular bundles in monocots





http://www.botany.org/plantimages/PhloemDevelopment.php

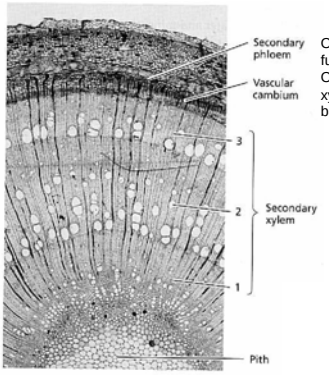
Dicot



Transverse section of water lily petiole (Nymphaea). The large round, empty-looking cells marked by Xs are **sieve tube members**. The small angular cells (three are indicated by arrows) that are almost filled with red contents are **companion cells**, which control the metabolism of the sieve tube members.

http://www.esb.utexas.edu/mauseth/weblab/webchap3par/3.5-2.htm

Woody dicot

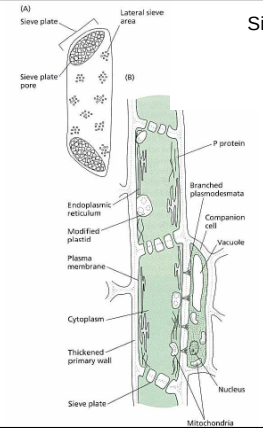


Only this year's phloem is functional;
Old phloem gets crushed by xylem expansion and becomes bark

Fraxinus excelsior

Taiz and Zeiger 1998

Sieve tube elements

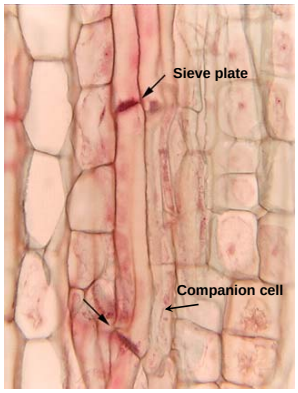


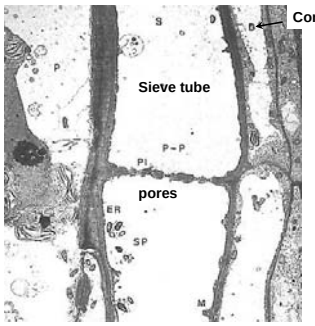
The plasma membrane of a sieve tube element is continuous with its neighboring STE and with the companion cells

Companion cell

Sieve tube

Longitudinal section of stem of milkweed (*Asclepias*). The long, wide cell in the center of the micrograph (marked by arrows) is a sieve tube member.





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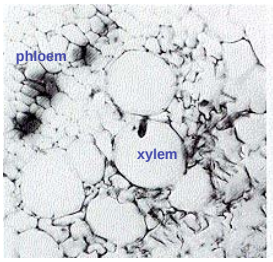


- Autoradiographs showing that the products of photosynthesis are transported in the phloem (cucumber leaf).
- Radioactive products of photosynthesis darkened the emulsion where it was in contact with the phloem (upper left in both photos), but not where it was in contact with the xylem vessels (center).

R. S. Gage and S. Aronoff

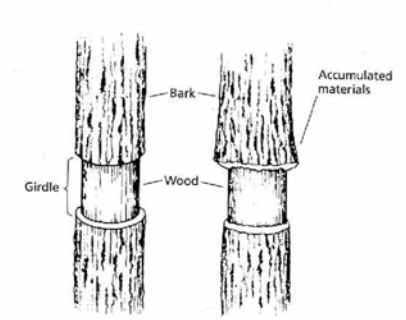


Figure 10.3 Tree trunk immediately after girdling (left) and later (right). Girdling is the removal of the bark of a tree in a ring around the trunk. At right, materials translocated from the leaves have accumulated in the region above the girdle and caused it to swell.

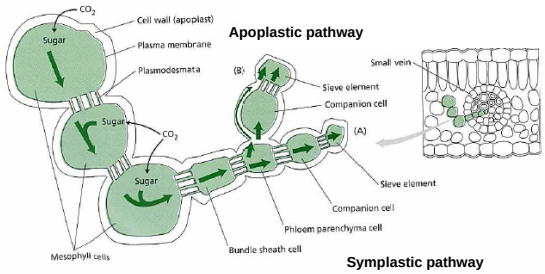
Phloem

- Conduits are **living cells**
  - **Sieve cells** in gymnosperms
  - **Sieve tube members** in angiosperms
- Used for transport of **carbohydrates** and other **organic compounds**
- **Bidirectional movement** (up or down, can change seasonally and depends on sink strength)
- **Slow** - maximum flow rate of 1 m/hr

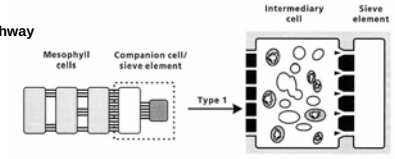
Xylem

- Conduits are **dead cells**
  - **Tracheids**
  - **Vessel elements**
- Used for transport of **water** and **minerals**
- **Unidirectional movement** (up, driven by water potential gradient)
- **Fast** - maximum flow rate of 15 m/hr

Symplastic and apoplastic pathways

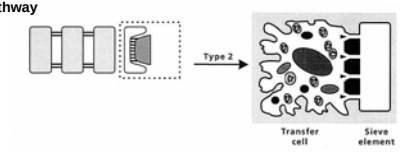


Symplastic pathway



Sucrose → rafinose synthesized (ATP required)
oligosaccharide trap

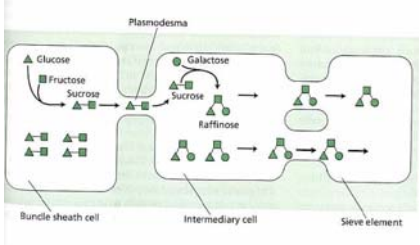
Apoplastic pathway



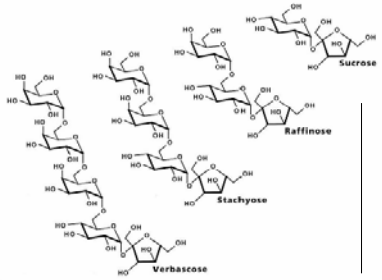
Sucrose → sucrose uploaded actively (ATP required)

Symplastic pathway

Polymer (oligosaccharide trap) model of phloem loading

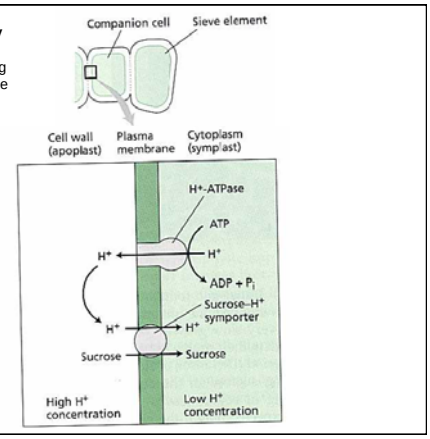


Chemical structure of sugars transported in sieve tubes



Apoplastic pathway

active phloem loading into symplast from the apoplast



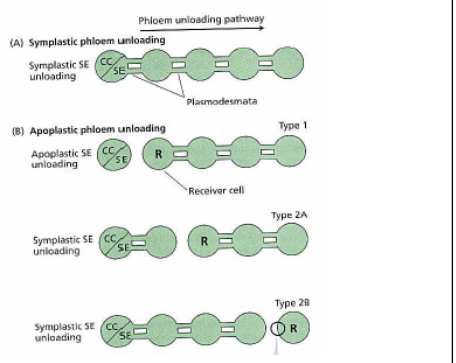
Leaves with the symplasmic pathway of phloem loading may have a lower capacity to export assimilates

Patterns in apoplastic and symplastic loading

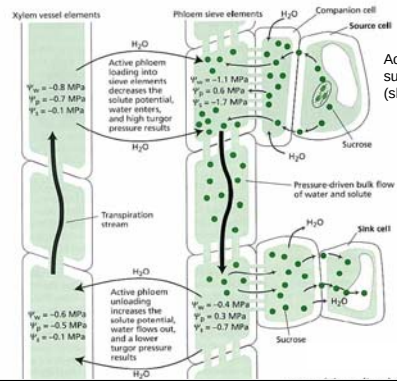
	Apoplastic loading	Symplastic loading
Transport sugar	Sucrose	Oligosaccharides in addition to sucrose
Type of companion cell in the minor veins	Ordinary companion cells or transfer cells	Intermediary cells
Number of plasmodesmata connecting the sieve elements and companion cells to surrounding cells	Few[a]	Abundant[a]

Source: Drawings after Van Bel et al. 1992.
Note: Some species may load both apoplastically and symplastically, since different types of companion cells can be found within the veins of a single species.
[a] CC, companion cell; IC, intermediary cell; PP, phloem parenchyma; SE, sieve element; XV, xylem vessel. Plasmodesmata are indicated by xxxx.

Phloem unloading

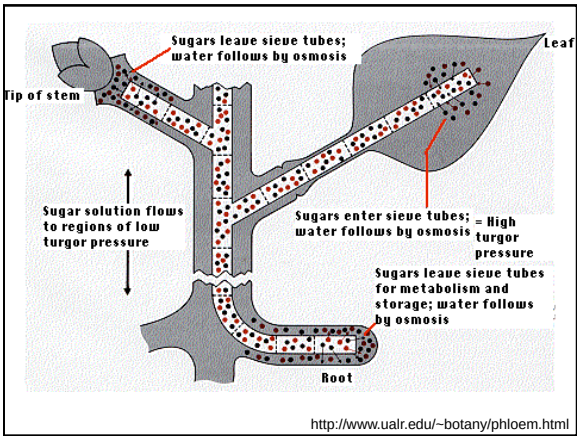


Pressure-flow model of translocation in the phloem

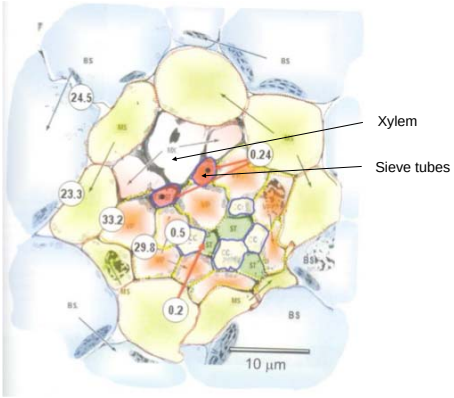


Active loading of sucrose (shown as apoplastic)

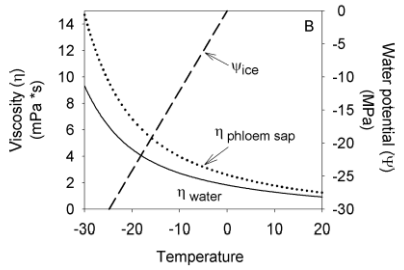
Active unloading of sucrose (shown as symplastic with an apoplastic step)



http://www.ualr.edu/~botany/phloem.html

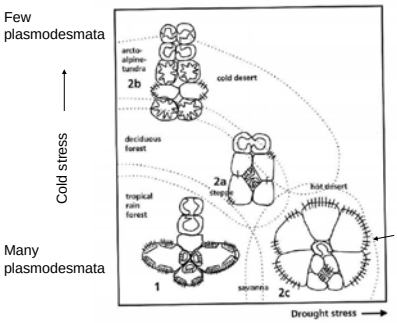


What happens to the phloem in the winter?

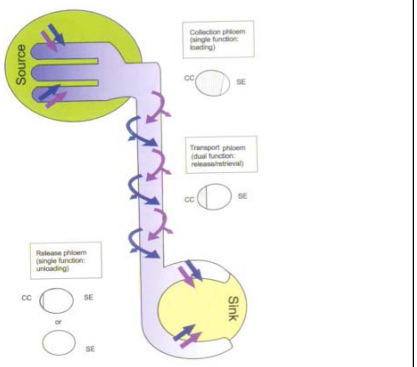


Cavender-Bares 2005

Distribution of phloem types over terrestrial ecosystems



C4 plant with many plasmodesmata between mesophyll and bundle sheath



What are the disadvantages of the symplastic pathway?

- Lower capacity to export assimilates from leaves
  - (due to limited capacity of intermediary cells to make polysaccharides?)
- Detrimental build-up of carbohydrate levels in leaves under high CO_2?
- At cold temperatures, low solubility of raffinose; high viscosity of sugar solutions

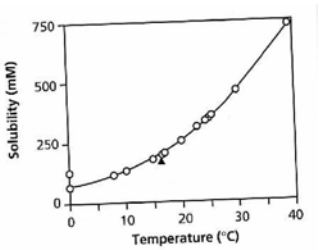
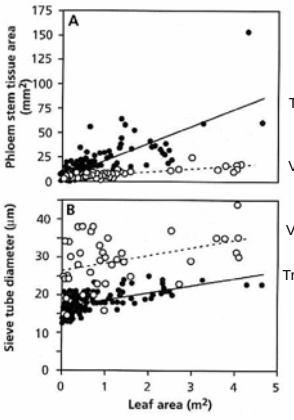


FIGURE 5. Solubility of raffinose at different temperatures. The solubility in artificial phloem sap is indicated by the triangle (Turgeon 1995). Copyright American Society of Plant Physiologists.



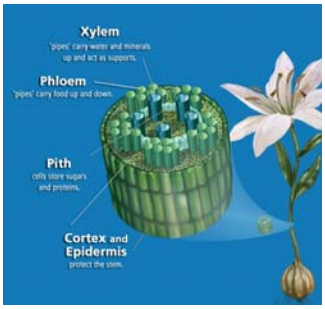
Trees/shrubs

Vines

Vines

Trees/shrubs

Vines have wider xylem vessels and sieve tubes - need less xylem and phloem tissue to support the same leaf area as a tree because they don't have to support themselves/allows them to weigh less



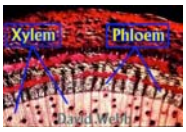


FIGURE 6. The distribution of the minor vein types over various terrestrial ecosystems. Type 2c is similar to type 2a with regard to the symplasmic connections between the sieve element/companion cell complex and the neighboring cells, but has many conspicuous plasmodesmata between the mesophyll and the bundle sheath (C_3-plants). Typical dicotyledonous 2c-families include the Portulacaceae and Amaranthaceae (Van Bel & Gamalei 1992). Copyright Blackwell Science Ltd.

FIGURE 1. The phloem-loading pathway comprises three compartments with separate functions. The photosynthates move from the production compartment, comprising the palisade (PMC) and spongy (SMC) mesophyll and bundle sheath (BSC), to the collection compartment. The site of the collection compartment is the phloem in the minor vein ends; it includes companion cells (CC) and sieve elements (SE). Companion cells occur in all species, but they differ widely in their ultrastructure and biochemistry. The collection compartment is connected via plasmodesmata with the export compartment. In the production compartment the palisade mesophyll cells are connected via plasmodesmata, just like the spongy mesophyll cells. The absence of sound information on plasmodesmatal connections between the two types of mesophyll cells is indicated by the questions marks. The frequency of plasmodesmatal connections between the production compartment and the collection compartment differs enormously, as outlined in this chapter. The sieve tubes (ST) of the export compartment comprise both sieve elements and companion cells (Van Bel 1996).