Introduction to Botany. Lecture 17

Alexey Shipunov

Minot State University

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Outline

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Monday test (3 points)

1. Name of cell layer in root which prevents apoplastic transport:

Monday test (3 points)

2. Name of cells which take water and minerals from soil:

Monday test (3 points)

3. What is the capillarity?

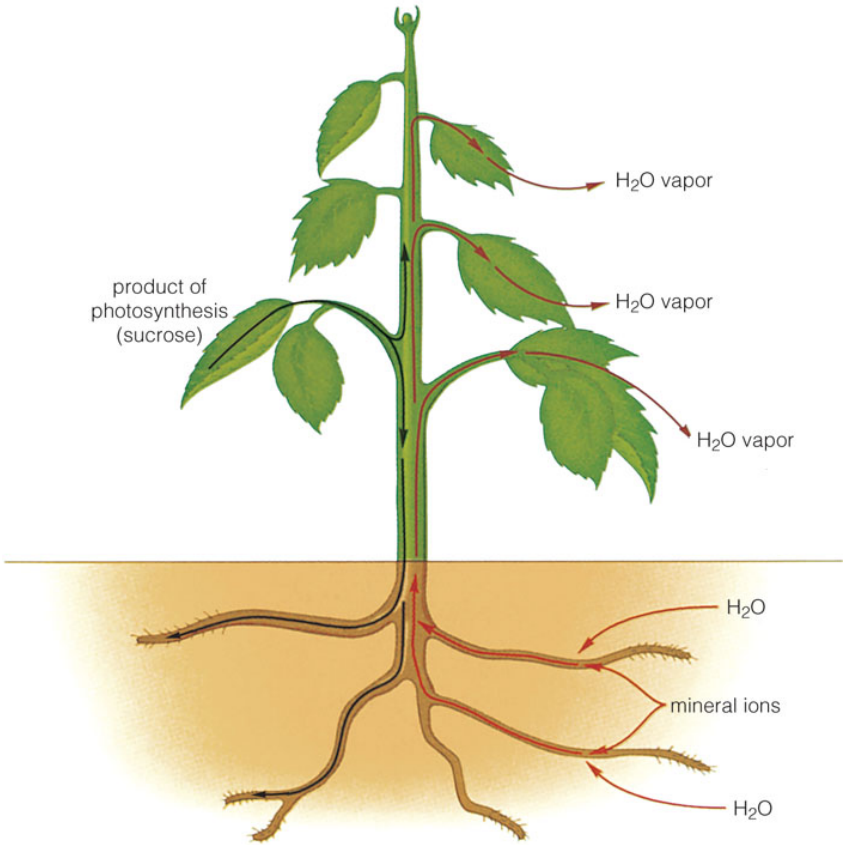
Exam 2, part II, question 4: 11 mistakes = 11 points

"... Carbon dioxide ~~C_2O_2~~ CO_2 enters the plant through ~~special cells—stomata~~ stomata located at the leaves ~~and bark~~. Stomata also perform another function—through the transpiration they protect the plant from overheating. Therefore, the ~~stomata are more dense on the upper side~~ on the lower side of the leaf blade ~~and opened wider than during the hottest time of day~~. This time of day is also the time of most intense photosynthesis. Photosynthesis results in ~~carbon~~ carbohydrates and ~~O^2~~ O_2. ~~Carbon can be converted into fats, proteins and carbohydrates~~. Sunlight supplies the energy for photosynthesis and picked up by the pigments. The ~~scattered light is absorbed by the subsidiary pigment~~ by chlorophyll located in the palisade tissue—carotene. Direct light is absorbed by chlorophyll located in the spongy tissue. The ~~color of chlorophyll may also depend on leaf color~~. So, in a bright green leaves, chlorophyll is green and ~~grayish leaves have gray chlorophyll~~..."

General overview

- **Water**—from root hairs to leaf stomata via xylem
- **Mineral ions**—from root hairs to all plant organs via xylem
- **Sucrose** and other products of photosynthesis—from leaf mesophyll to all plant organs via phloem

Overview of main flows inside a plant



Osmosis and capillarity

- **Osmosis** takes place in root hairs
- **Capillarity** is the result of water adhesion. In plant, it mostly occurs in xylem vessels and tracheids

Water potential

- **Water potential** is a virtual water pressure
- In plant, water always go from regions of higher water potential to regions with lower water potential

Water flow through soil

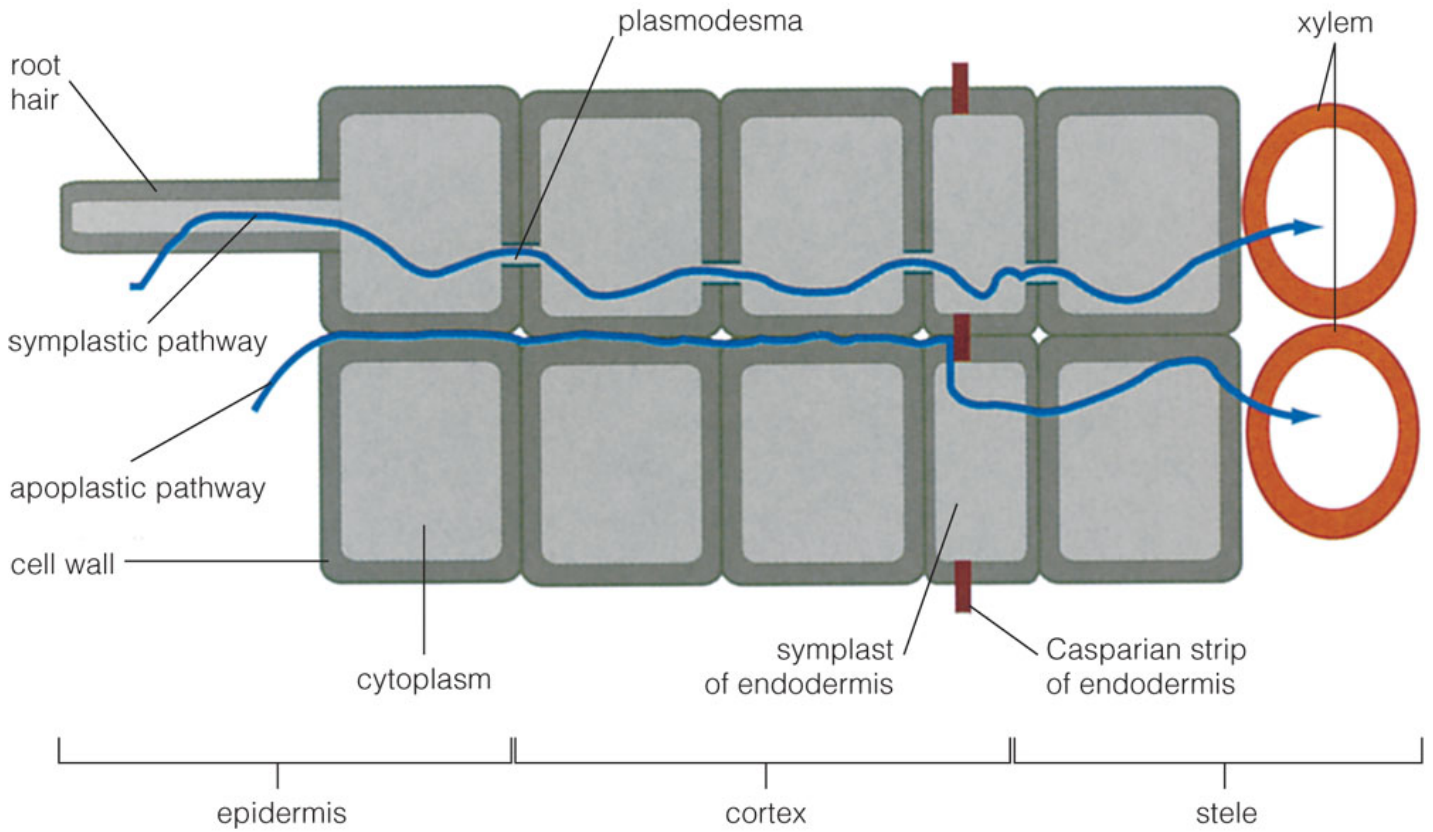
- Water moves through soil mostly via capillarity
- Compact, tough soil usually have high capillarity; loosen soil keeps water inside and do not transport it with capillarity

Root pressure

- Root pressure (high water potential) is the result of forced symplastic transport in the endoderm
- When root pressure is too high, plant starts **guttation** (water droplets come through special openings which is much bigger than stomata, **hydatodes**)

Guttation

Origin of root pressure (again)



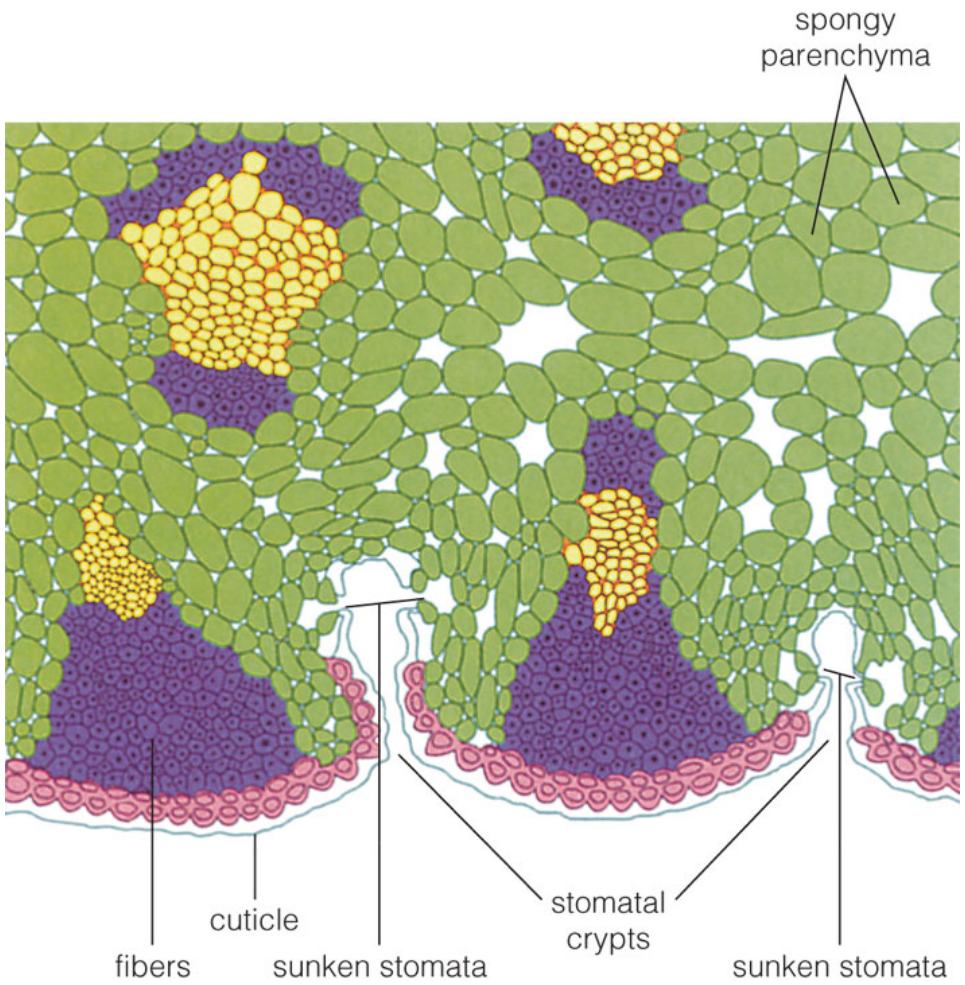
Water flow through xylem

- Continuous water flow through xylem is the result of capillarity—adhesion of water molecules to the walls of xylem vessel elements; and also cohesion of water molecules to each other
- As a result, pulling one water molecule from xylem will move all water molecules
- Bubble in xylem cell will stop transport; tracheids have less chances to form bubbles than vessels

Water flow through leaves

- Xylem cells of leaf veins have apoplastic contact with mesophyll
- When stomata are open, water vapor constantly moves from the leaf causing other water molecules to follow
- Stomatal crypts form a bouyndary layer which slows down the transpiration

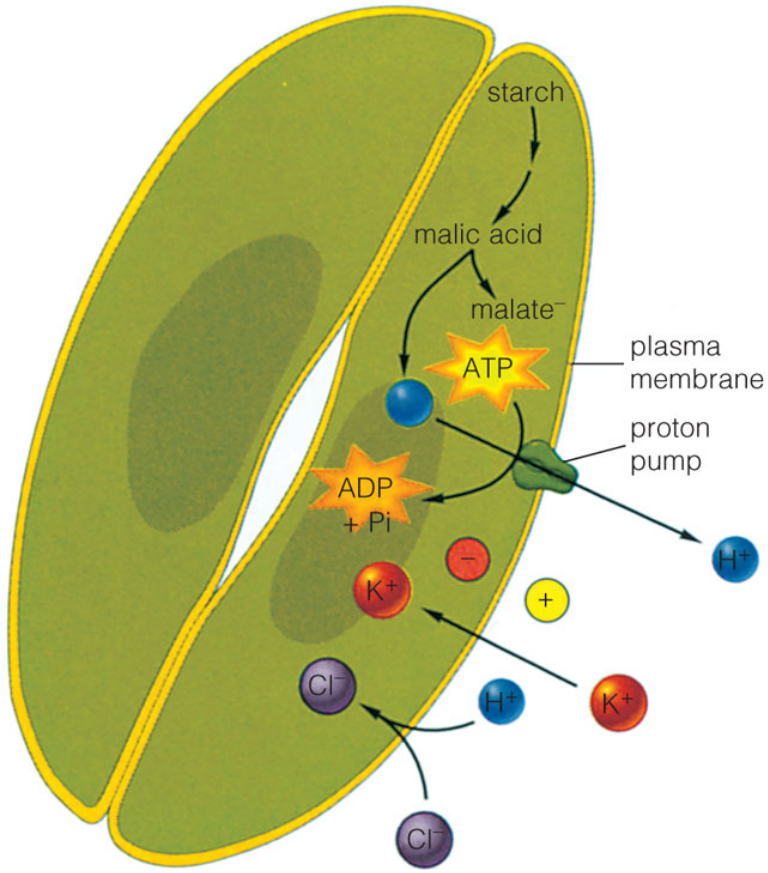
Stomatal crypts



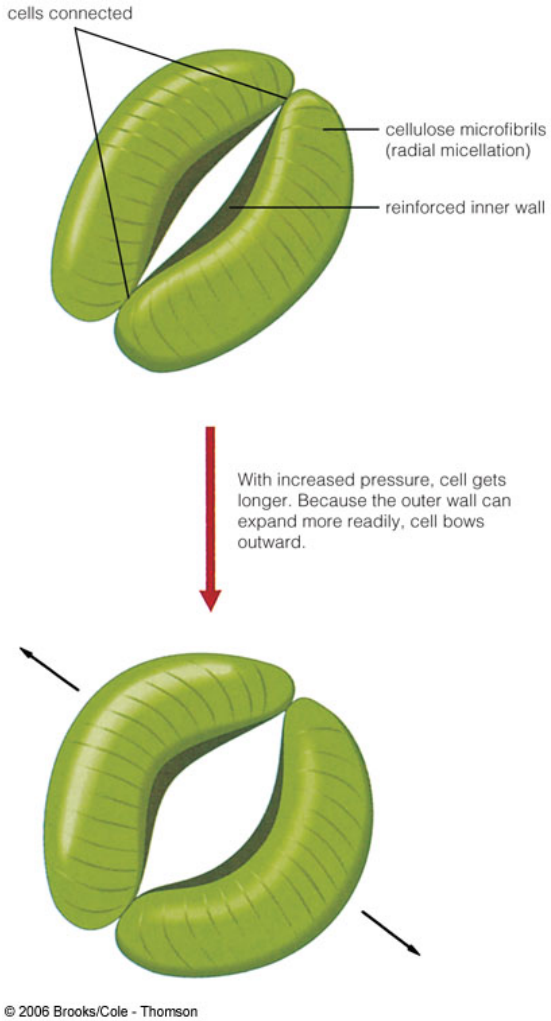
Opening and closing stomata

- Stomata are opening when guard cells accumulate potassium (K^+) and malic acid ($malate^-$) ions which results in the osmotic flow inside guard cells, bloating of guard cells and finally opening of stoma.

Ion pumps inside guard cells



Opening of stomata (again)



Primary (biogenic) elements

- Main three biogenic elements: carbon (C), hydrogen (H), oxygen (H): used as gases
- Slightly less important are nitrogen (N) and phosphorus (P) which are usually taken as anions: NH_4^+ or NO_3^- and HPO_4^{2-}
- Potassium (K), calcium (Ca), magnesium (Mg): used as cations, namely K^+, Ca^{2+}, Mg^{2+}
- Iron (Fe), sulfur (s): also used as ions, but in less amounts, typically as Fe^{3+} and SO_4^{2-}

Microelements

- Play a lesser roles and used in lesser amounts
- These are: manganese (Mn), boron (B), molybdenum (Mo), copper (Cu) , zinc (Zn) and chlorine (Cl)
- Microelements are also taken from the soil as ions

Roles of some biogenic elements and microelements

Table 11.1 Roles of Mineral Elements in Plants

Element	Primary Roles
Potassium (K)	Osmotic solute, activation of some enzymes
Nitrogen (N)	Structure of amino acids and nucleic acid bases
Phosphorus (P)	Structure of phospholipids, nucleic acids, adenosine triphosphate
Sulfur (S)	Structure of some amino acids
Calcium (Ca)	Structure of cell walls, transmission of developmental signals
Magnesium (Mg)	Structure of chlorophyll, activation of some enzymes
Iron (Fe)	Structure of heme in respiratory, photosynthetic enzymes
Manganese (Mn)	Activation of photosynthetic enzyme
Chloride (Cl)	Activation of photosynthetic enzyme, osmotic solute
Boron (B), cobalt (Co), copper (Cu), zinc (Zn)	Activation of some enzymes

Soil types

- Every soil have (1) granular part like sand, (2) clay part (microscopic particles) and (3) humus part (decayed organic matter)
- The most important capacities of different soil types are: water-holding, aeration, pH (acidity), salinity/toxicity and biota
- Most soils have three layers (horizons): (A) topsoil, (B) subsoil and (C) parent material

Horizons of soil

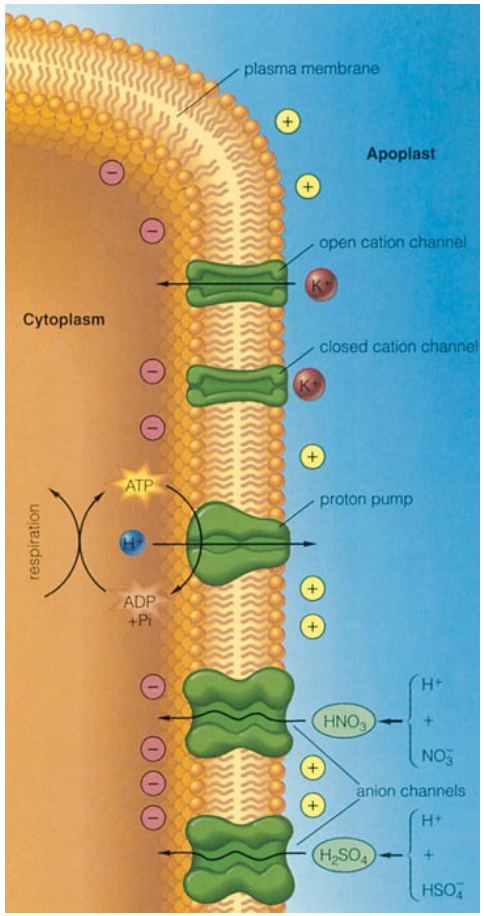
Nitrogen fixation

- Plants cannot take N_2 from air: it is an exceedingly stable molecule.
- However, some soil bacteria (nitrogen-fixing bacteria mostly from *Rhizobium* genus) can do that, they convert N_2 to ammonia (NH_4^+)
- Legume plants (Leguminosae, or Fabaceae), alders (*Alnus*) and members of silverberry family (like buffaloberry, *Schepherdia*) have root nodules inhabited with nitrogren-fixing bacteria.

Pumps and channels in root cells

- Membrane of root cells have specific channels and pumps almost for every ion

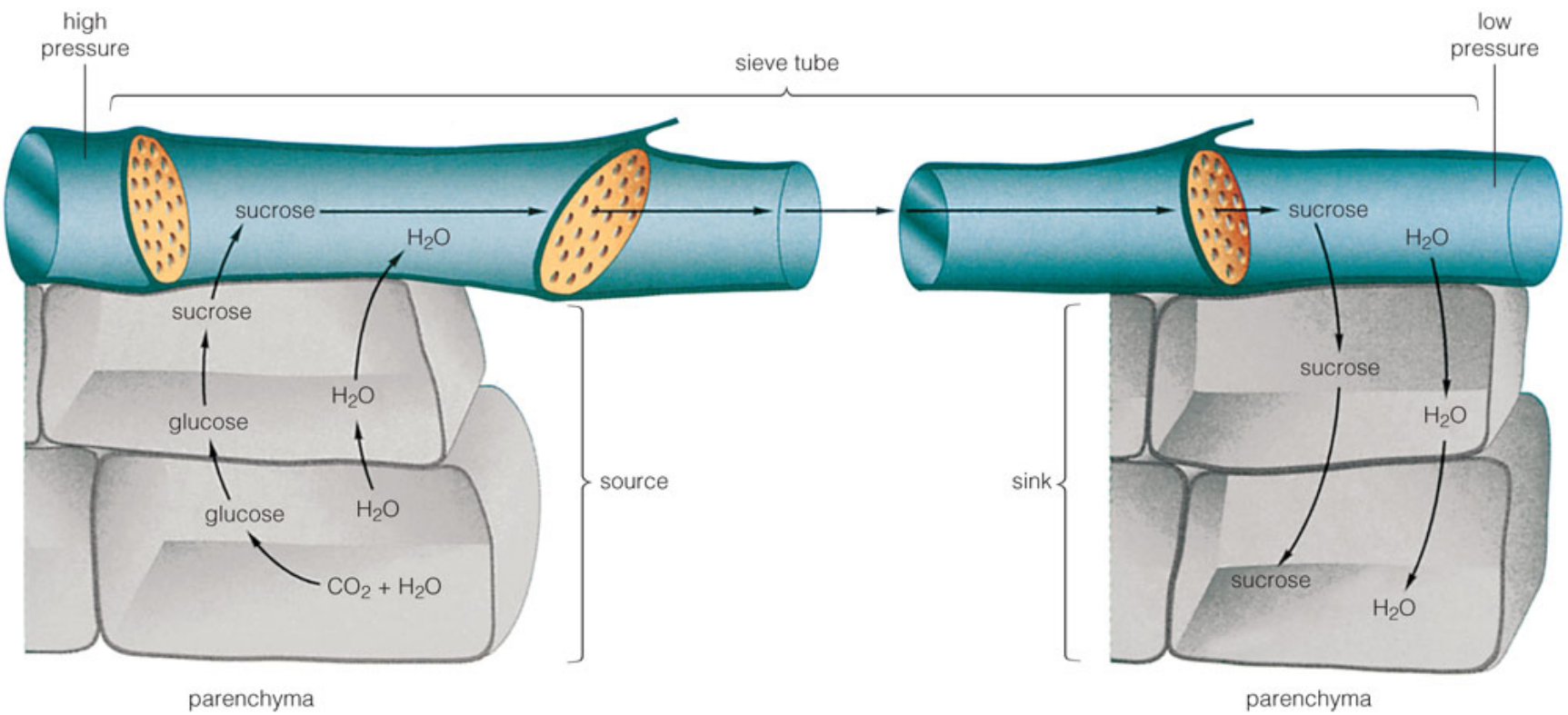
Ion pumps and channels in the rhizoderm cell membrane



Phloem osmotic pump

- Phloem transport is the result of osmotic pump from regions with higher concentration of sucrose to regions with lower concentration of sucrose
- Therefore, sucrose is transported only with water
- Phloem transport is purely symplastic
- As a consequence of above, phloem transport is usually much less directed than xylem transport

Phloem pump



Summary

- Biogenic elements (except three gases) and microelements are taken from the soil as ions
- High root pressure often results in a **guttation**
- Phloem transport is the result of **osmotic pump**

For Further Reading

Th. L. Rost, M. G. Barbour, C. R. Stocking, T. M. Murphy.
Plant Biology. 2nd edition.
Thomson Brooks/Cole, 2006.
Chapter 11.