

# Introduction to Botany. Lecture 23

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# Outline

- 1 Questions and answers
- 2 Water transport
  - Water transport in roots
  - Water transport in stems
  - Water transport in leaves
- 3 Minerals
  - Primary and micro- elements



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## Previous final question: the answer

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Photorespiration increases when concentration of oxygen grows. Why is photorespiration so intensive at high temperatures?

- When temperature is high, light stage makes more oxygen
- When temperature is high, plants closes stomata to avoid water loss. As a sideway result, concentration of oxygen in leaf tissues grows

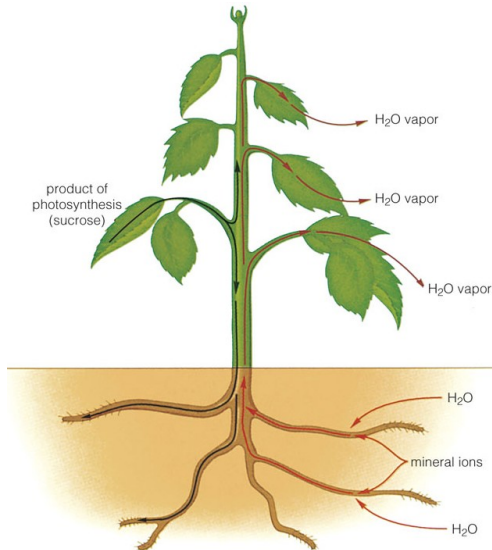


# Water transport

## Water transport in roots



# Overview of main flows inside a plant



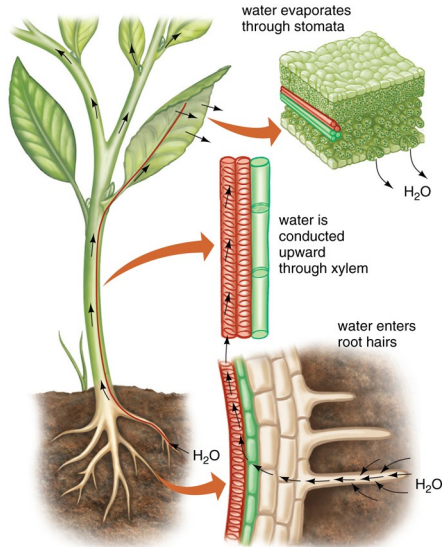


# General overview

- **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 water flow inside a plant



# Rhizoderm and osmosis

- The existence of root hairs dramatically increases the surface of absorption
- Every root hair cell increase the internal concentration of large molecules, typically organic acids
- Process of concentration requires ATP
- As a result, osmosis water flow starts from soil to root cells

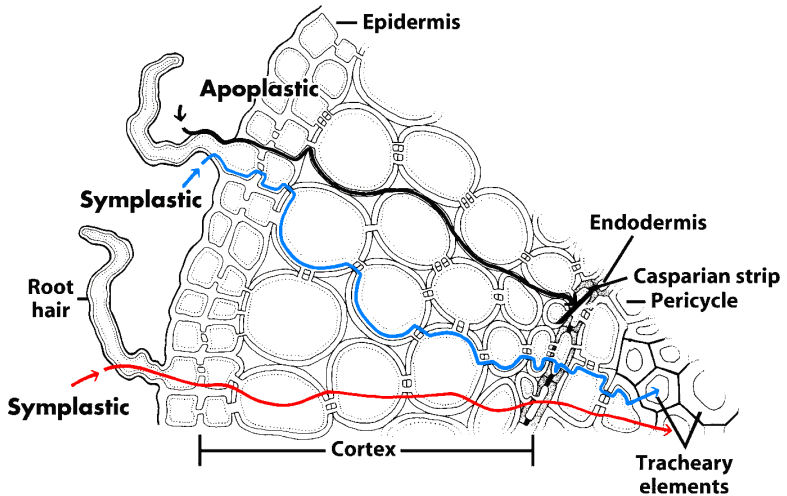


# Endoderm and root pressure

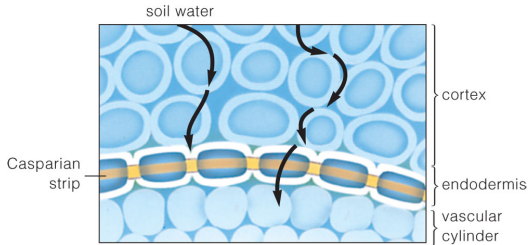
- From rhizoderm to endoderm, transport of water is both symplastic and apoplastic
- In the endoderm cells, Caspari stripes stop apoplastic transport and therefore forced symplastic transport
- This is a high-energetic process requires ATP
- As a result, water will be pushed up from root: this is the root pressure



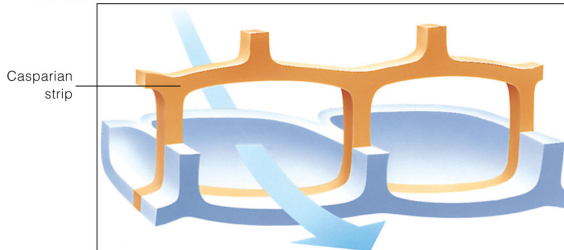
# Apoplastic and symplastic transport in the root



# Casparian strips



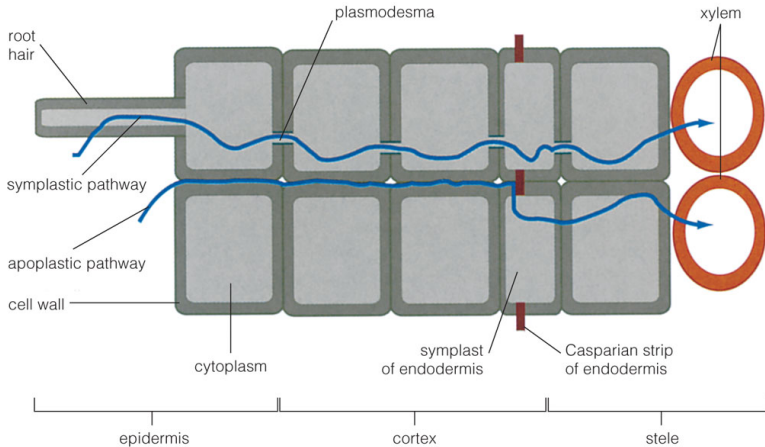
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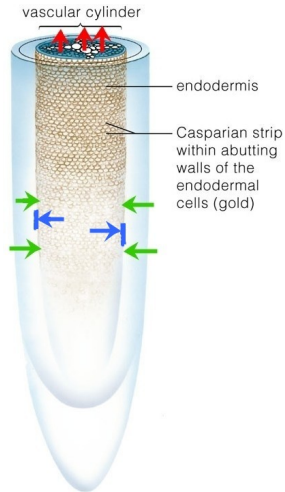
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# How Casparian strips are working



# Origin of root pressure





# 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 transport

## Water transport in stems

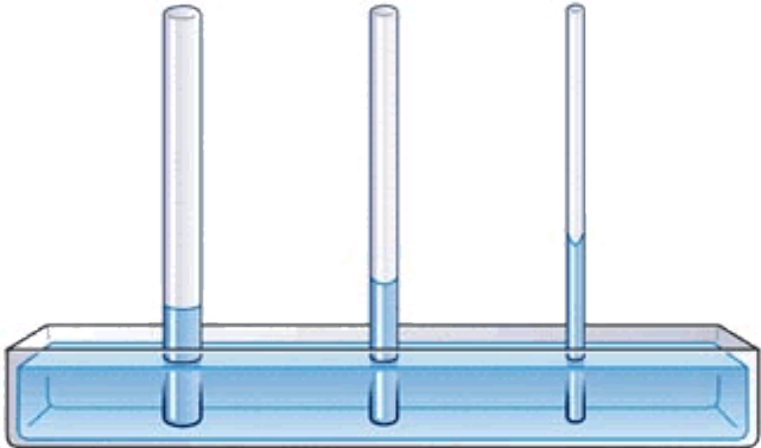


# Water flow through xylem

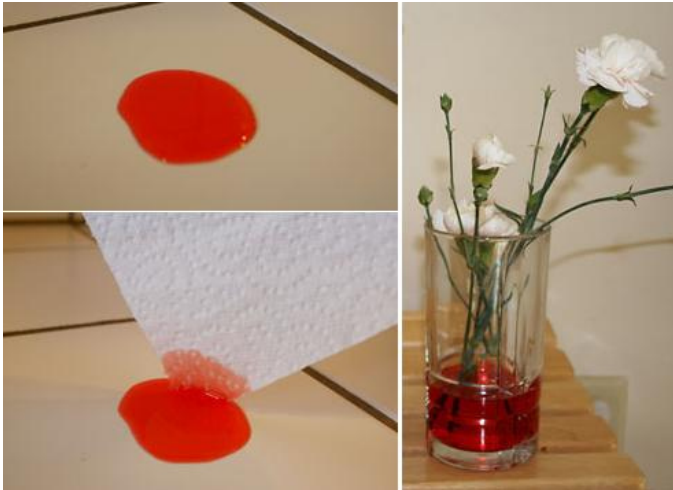
- Continuous water flow through xylem is the result of **capillarity**—adhesion of water molecules to the walls of xylem vessel elements; and also cohesion of water molecules to each other
- As a result, pulling one water molecule from xylem will move all water molecules
- The more narrow vessel elements are, the higher is capillarity
- However, wide vessel elements could take much more water. As a result, there is a trade-off between wide and narrow vessel elements.
- Bubble in xylem cell will stop transport; tracheids have less chances to form bubbles than vessels
- Two other forces: **root pressure** and pulling the “water molecule chain” by leaf **transpiration**



# Capillarity



# Experiment with capillarity



# Water transport

## Water transport in leaves



# From vascular tissues to mesophyll

- Vascular bundles become leaf traces, and leaf traces become veins
- Vein xylem cells transfer water apoplastically to mesophyll cells



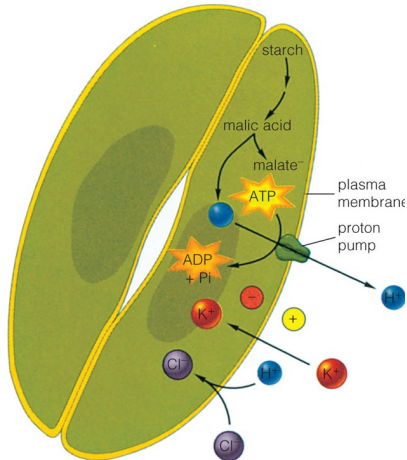
# From mesophyll to stomata and leaf surface

- Mesophyll cells and stomata control transpiration
- When stomata are open, water vapor constantly moves from the leaf causing other water molecules to follow
- Stomatal chambers, crypts and epidermis hairs will hold water because they provide spaces with higher humidity
- Common epidermal cells also transpire, even with cuticle. In stems, lenticels will transpire.





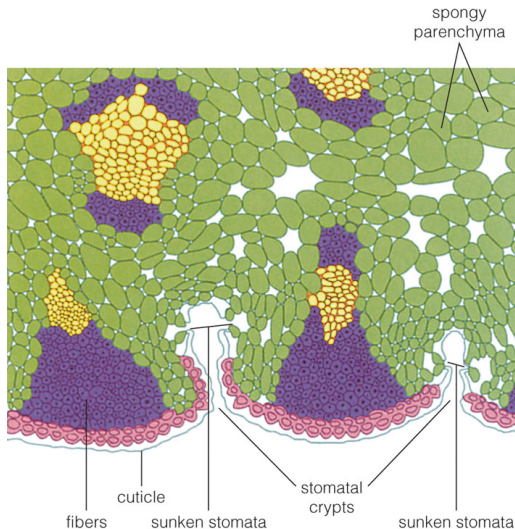
# Opening and closing stomata



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



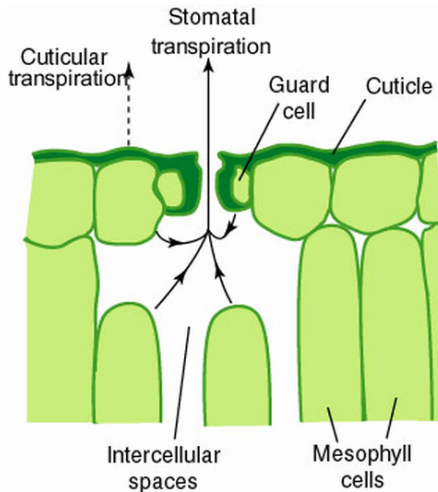
# Stomatal crypts



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# Transpiration



# Guttation



When root pressure is too high, plant starts **guttation** (water droplets come through special openings which is much bigger than stomata, **hydathodes**)



# Minerals

## Primary and micro- elements



# Primary (biogenic) elements

- Main three biogenic elements: carbon (C), hydrogen (H), oxygen (O): used as gases
- Slightly less important are nitrogen (N) and phosphorus (P) which are usually taken as anions:  $\text{NH}_4^+$  or  $\text{NO}_3^-$  and  $\text{HPO}_4^{2-}$
- Potassium (K), calcium (Ca), magnesium (Mg): used as cations, namely  $\text{K}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$
- Iron (Fe), sulfur (S): also used as ions, but in less amounts, typically as  $\text{Fe}^{3+}$  and  $\text{SO}_4^{2-}$



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



## Final question (2 points)





## Final question (2 points)

What is guttation?



# Summary

- Taking nutrients to roots is the result of **osmosis**.
- **Root pressure** is the result of forced symplastic transport (due to Caspari strips) in endoderm cells
- The height of trees is controlled mostly by the **capillarity** of xylem vessel elements
- **Water transport** in plants regulates by: (1) osmosis in root hairs, (2) root pressure in endoderm, (3) capillarity in vessels or tracheids and (4) transpiration in leaves
- Biogenic elements (except three gases) and microelements are taken from the soil as ions



## For Further Reading



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Th. L. Rost, M. G. Barbour, C. R. Stocking, T. M. Murphy.  
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