

# Transport in Plants

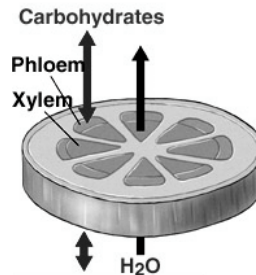
Two Transport Processes Occur in Plants

1. Carbohydrates carried from leaves (or storage organs) to where they are needed (from sources to sinks)
2. Water transported from roots to other parts

Plants move materials through the action of cells

Cells produce and use gradients in solute concentration and water availability for movement of water and solutes.

Water and minerals pass up through xylem along a gradient of successively lower water potentials.



## Water movement in the xylem

Water moves from roots to leaves through the xylem. But how?

Hypotheses:

1. Capillary action - water will move upward in a small tube through cohesion to walls of small tube - the smaller the tube the higher it will climb

However, capillary action has a limit of about 1 m and requires a tube that is open at the top.

2. Pressure generated by roots - if solutes are transported into xylem from soil, water will follow by osmosis, forcing water upwards in the xylem

This mechanism does work but to a limited extent. Water transport by root pressure is limited to a height of about 3 m.

“Root pressure” can result in water being extruded from leaves - a phenomenon called “guttation.”

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## Guttation



### 3. Water loss from leaves draws water up from roots

Removal of water from a continuous column of water can draw water to tremendous heights - limited only by the ability of water to be removed from the leaves by the air, and the physical force of gravity pulling downward on the column of water - the cohesion of water molecules makes it possible to draw a column of water to 130 m (the tallest redwood).

Water movement due to loss from the leaves is called **transpiration**

Evidence for mechanism of transpiration

- diameter of tree trunks decreases during day when water loss from leaves is high
- breakage of water column through introduction of air into the column stops upward flow of water

**Water potential:** the potential energy of water, the tendency of water to move

Two forces can cause water to move

physical pressure - creates “pressure potential”

osmotic differences - creates “solute potential”

water potential = pressure potential + solute potential

Water moves from areas of higher potential to areas of lower potential

e.g. from low solute to high solute concentration - solute potential

e.g. from areas where pressure is high (a tap) to areas where it is low (the end of the hose) - pressure potential

Dry air has a very low water potential. Moist soil has a relatively high water potential. Leaves in dry air are connected through a water filled conduit (the xylem) to the moist soil. Water moves upward through the xylem down a water potential gradient.

Transpiration slows when relative humidity is high.

### Transpiration at leaves

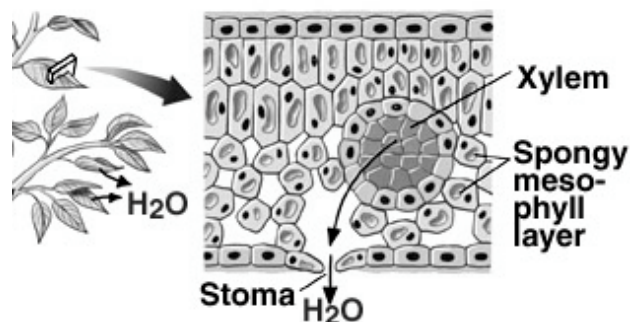
90% of all water taken up by roots is lost at leaves by evaporation

Water exits the leaves through the stomates

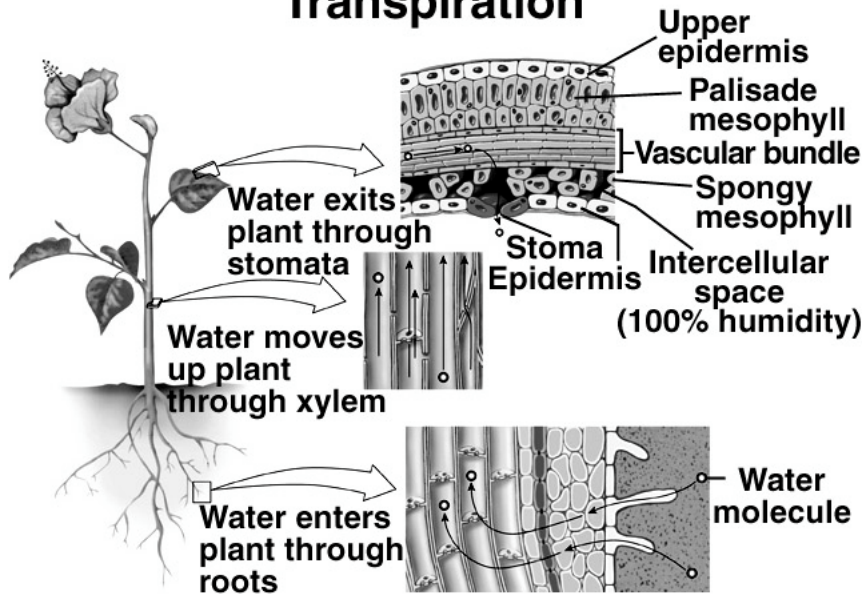
Water lost through stomates is replaced by water loss from mesophyll cells

Water lost from mesophyll cells is replaced by water from xylem

Difference in water potential causes water to move from xylem to mesophyll to air and exit from leaf



## Transpiration



### The Absorption of Water and Minerals by Roots

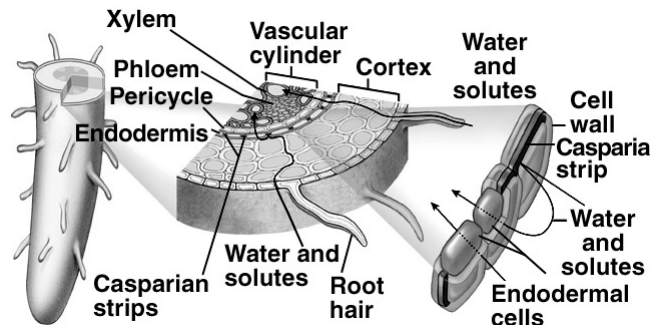
Most water enters through root hairs

Root hairs always turgid due to solute potential

Transport of minerals into root by active transport - using proton pumps in the root hair plasma membrane to accumulate minerals against the concentration gradient

Active transport creates solute potential in the roots and water follows

Because of the **Casparian strip**, all water and minerals must pass through cells of endodermis - allows for selective uptake of minerals



## **Conflicting requirements of photosynthesis and water retention**

Plants require water for photosynthesis and they require minerals that must come with water from roots. Thus, water uptake by roots and loss from leaves through stomates is a necessity for active production of carbohydrates.

Plants require CO<sub>2</sub> for photosynthesis. CO<sub>2</sub> can only enter when stomates are open. Thus, open stomates are required for active photosynthesis.

If water loss from leaves is greater than uptake from roots, stomates close, or worse, wilting can result and photosynthesis stops.

The rate of transpiration from leaves must be regulated.

The opening and closing of stomates regulates the rate of transpiration.

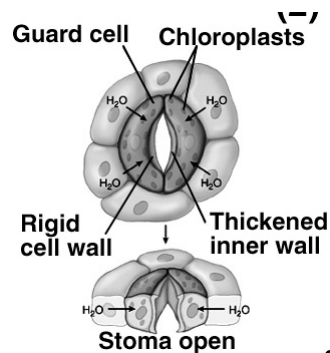
## **Stomatal opening**

Stomates are open when guard cells are turgid (full of water)

When water potential in guard cells is lower than in cells of the mesophyll, water enters guard cells.

When turgid, guard cells deform and stomates open

Guard cells can become hypertonic to the mesophyll cells by increasing their sugar concentration through active photosynthesis, or by pumping K<sup>+</sup> ions into their cytoplasm.

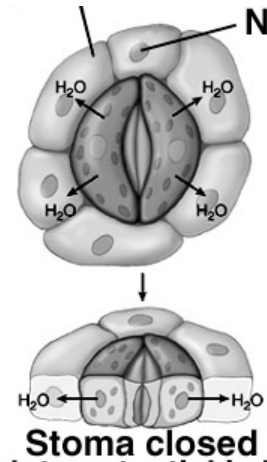


## Stomate closing

Stomates are closed when guard cells are flaccid

If mesophyll cells lose excessive amounts of water, they become hypertonic to guard cells and water leaves guard cells.

Plants under stress produce abscisic acid. Abscisic acid results in opening of  $K^+$  channels in guard cell plasma membrane. Loss of solutes causes water loss and stomate closing.



## Other Factors Regulating and Affecting Transpiration Rate

Guard cells become flaccid with high concentrations of  $CO_2$

Stomates close because there is sufficient  $CO_2$  in the leaf

In many plants, stomates close when temperature is above 30 to 34 C to reduce potential for water loss

CAM photosynthesis allows plants to conserve water by taking in

$CO_2$  at night and making carbohydrates during the day

Seasonal dormancy regulates water loss

Deciduous plants lose leaves during dry seasons, including winter

Leaf morphology regulates water loss

Thick, hard leaves with few stomates lose less water

Woolly trichomes trap humid layer of air near the leaf surface and the leaf loses less water

Stomates in pits in the leaf surface lose less water

Annual plants common in deserts - seed is resistant resting stage

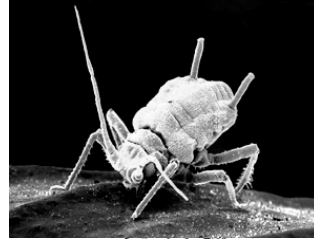
## Carbohydrate Translocation in Phloem

Carbohydrates manufactured in leaves or released from storage organs are distributed through phloem by a process called translocation.

Translocation has been studied through the use of aphids

Sucrose comprises most of dry matter of phloem liquid

Movement may be as rapid as 50 to 100 centimeters per hour



## Translocation Mechanism: Mass Flow

Source: where sugars are manufactured or released from storage

Sink: where sugars are consumed

At the source, sugars are pumped, by active transport, into the phloem sieve tubes. Water from neighboring xylem follows by osmosis. This creates pressure and forces water and sugars into the next sieve tube in series and so on down the line.

At the sink, sugars are taken out of the sieve tubes, and water follows. Sugars are used at the sink, remaining water enters the xylem, creating continuous flow in the phloem.

Phloem transport is potentially bidirectional

