Summary
A plant is an integrated system which:
1. Obtains water and nutrients from the soil.
2. Transports them
3. Combines the H\textsubscript{2}O with CO\textsubscript{2} to make sugar.
4. Exports sugar to where it’s needed

Today, we’ll start to go over how this occurs

Transport in Plants – Outline
I. Plant water needs
II. Transport of water and minerals
   A. From Soil into Roots
   B. From Roots to leaves
   C. Stomata and transpiration

Why do plants need so much water?
The importance of water potential, pressure, solutes and osmosis in moving water...

Transport in Plants
1. Animals have circulatory systems.
2. Vascular plants have one way systems.

Transport of water and minerals in Plants
Water is good for plants:
1. Used with CO\textsubscript{2} in photosynthesis to make “food”.
2. The “blood” of plants – circulation (used to move stuff around).
3. Evaporative cooling.
4. Used for turgor pressure to hold plant erect.

Transport of water and minerals in Plants
Water (with minerals) - enters from the soil, travels through xylem exits the leaves (through stoma).

What makes it move?
Transport of water and minerals in Plants

What makes it move?
- Water potential = the tendency of water to move from one place to another across a membrane.
- Pure water (would have WP=0)

Water potential = the tendency of water to move

Water is usually a solution
- \( \Theta \) potential pulls water.
- \( \oplus \) potential pushes water.

- Thus, water flows toward more \( \Theta \) water potential.

Transport in Plants

Water potential \((\Psi, \text{Psi})\) = Pressure potential \((\Psi_p)\) + Solute Potential \((\Psi_s)\)

\[ \Psi = \Psi_p + \Psi_s \]

- Pressure potential, \( \Psi_p \) = hydraulic pressure.
  (like air pressure in tires).

How water potential works

\[ \Psi = \Psi_p + \Psi_s \]

In the tube:
- \( \Psi_s = -0.4 \)
- \( \Psi_p = 0 \)
- \( \Psi = ? \)

Beaker has distilled water with \( \Psi = 0 \)

Predictions?

Fig 36.2
How water potential works
\[ \Psi = \Psi_p + \Psi_s \]

- Difference in \( \Psi \) so –
- Beaker → Tube
- Pressure potential
  (from gravity on the column of water)
  increases
- Until it is equal and opposite to the osmotic pressure.

\[ \Psi_p = 0.15 \]
\[ \Psi_s = -0.15 \]

Water enters plant cells through osmosis

Fig 36.2

Water potential

\[ \Psi = \Psi_p + \Psi_s \]

This is how:
- Plants get support (pressure)
- Water moves into and out of plant cells

Summary of Water Potential

- Water potential = the tendency of a solution to absorb or release water
- Water flows towards?

Or -
\[ \Theta \text{ water potential wins the tug of war} \]

Turgor provides support and keeps plants from wilting

- Water enters cell by osmosis –
- \( \Theta \) pressure potential (turgor pressure) increases and balances the \( \Theta \) osmotic pressure (it is equal and opposite).
- Water stops moving - the cell is turgid.

Summary of Water Potential

Solute potential, \( \Psi_s \):

\[ \text{H}_2\text{O} \]

\[ \text{K} \]

\[ \text{K} \]

\[ \text{K} \]

\[ \text{K} \]

\[ \text{K} \]
Transport of water and minerals in Plants

- **Osmosis** has a major influence getting water from the soil to the root xylem.
- **Pressure potential** is responsible for moving water through the xylem to the leaves (and air).

From the soil to the root xylem

- Water moves freely through cell walls and intercellular spaces, but,
  - **Casparian strips** preventing water and ions flow
  - Has to goes thru cytoplasm of the endodermis cells.

Movement of minerals into the cells is through active transport

- Mineral ions move across membrane transport proteins.
- **Active transport** against a concentration gradient.

Transport in Plants

Mineral ion concentrations affects solute potential

Plants control:
- the concentration of mineral ions in living cells, hence
- they control osmosis in roots.

2 Control Points with Transport Proteins

- **Endodermis** – water from cortex → endodermis
- **Cells near xylem** create an osmotic gradient that moves water into the xylem.
Transport in Plants

Mineral ions move out of the cell (active transport)
Water potential is more negative outside
So water moves out of the cell (osmosis)

SO:
Minerals – active/direct
Water follows passively

Transport in Plants

• Xylem - movement is controlled by pressure potential (hydraulic pressure).

• Water and minerals are pulled (Θ pressure potential) through the xylem without expending energy. How?

How are water and minerals are pulled through the xylem?

• Transpiration – evaporation of water from leaves

• Tension – in the xylem sap from transpiration

• Cohesion – in the xylem sap along the plant

It’s like sucking on a straw......

Water diffuses out of leaf.

Water evaporates off leaf cells to replace it.

This pulls water from veins.

This tension pulls the water column up

Fig 36.8

Transport of water and minerals in Plants

• There is negative water potential in stems.

• What happens if you were to cut the base of a stem?

• Break the cohesion in the water column

It’s like sucking on a straw......

• In the xylem - movement is controlled by pressure potential (hydraulic pressure).

Because:
Dry air has very negative Ψ (Ψ = -95 MPa)
Soil is between -0.01 to -3 MPa
Transport in Plants

- With
  - high humidity
  - wet soils
  some plants will even have water pushed out of the leaves = "guttation"

- "root pressure": osmotic pressure due to higher solute concentration in root xylem sap than in the soil.

Summary of Root to Leaf Water Movement

- Osmosis = motor for getting water from the soil into the root xylem.
- Water only moves through cell sap.

- Endodermis cells control the osmotic gradient pulling water in (with energy and transport proteins)
- Xylem does the same: osmotically pulls water into the root xylem.

Summary of Root to Leaf Water Movement

- To get water to the top of tall plants...
- It is pulled by the evaporation of water from the leaves (like the pull generated by sucking on a straw).

Transpiration and the Stomata

- Transpiration (= evaporation of water from leaves) pulls water and minerals up stems AND provides evaporative cooling, but
- It results in tremendous loss of water, which must be controlled.

How do stomata work?

- The stoma (or pore): surrounded by two guard cells
- Guard cells control the opening and closing of the stoma thru...
  changes in the guard cell water potential

Transpiration and the Stomata

Plants manage costs and benefits (CO2 in for photosynthesis, H2O out) with:

- Epidermis — Flat cells covered by a waxy waterproof cuticle.

- Stomata — Pores that let CO2 in and H2O out when there’s not too much water stress. These are highly regulated by the plant
Mechanism of stomatal opening

- Light cues most plants to open stomata
- Active transport of potassium ions into the guard cells.

- What happens to the water potential of the guard cells?
- What will happen to water?

Mechanism of stomatal opening

- H2O moves into the guard cells to maintain osmotic balance.
- Stretching and turgidity of the guard cells.....
- **Stomata open.**

- (Closing is the reverse started by passive diffusion of potassium out of guard cells.)

Regulation of stomatal opening

- **Stomata** typically open in the day (in response to light) and close at night.
  - This provides CO2 for photosynthesis during the day, but saves water at night.

Signals for stomatal opening

- A **low level of CO2** in the leaf constrains photosynthesis and favors **stomatal opening**.
- If the plant is too dry:
  - mesophyll cells release **abscisic acid** \(\rightarrow\) stomata to close.