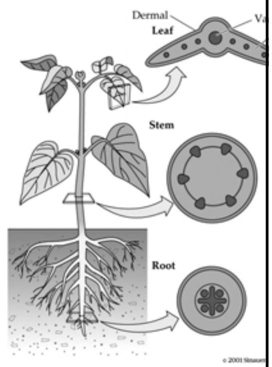
Summary

A plant is an integrated system which:

1. Obtains water and nutrients from the soil.
2. Transports them
3. Combines the H_2O with CO_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 in Plants

- One way systems: plants need ***a lot more water*** than same sized animals.
- A sunflower plant "drinks" and "perspires" 17 times as much as a human, per unit of mass.

Transport of water and minerals in Plants

Water is good for plants:

1. Used with CO2 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

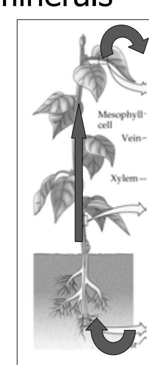
Water (with minerals) -

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)

Transport of water and minerals in Plants

Water potential = the tendency water to move

Water is usually a solution

- ⊖ potential pulls water.
- ⊕ potential pushes water.

- Thus, **water flows toward more ⊖ water potential.**

Transport in Plants

Water potential (Ψ Psi) =
Pressure potential + Solute Potential

$\Psi = \Psi_p + \Psi_s$

- **Pressure potential, Ψ_p** = hydraulic pressure.

(like air pressure in tires).

Transport in Plants

Water potential (Ψ Psi)

has 2 parts, $\Psi = \Psi_p + \Psi_s$

- **Pressure potential, Ψ_p** = hydraulic pressure.

(like in a car's brake line, or like air pressure in tires).

Transport in Plants

- **Water potential (Ψ)** has 2 parts,

[redacted]

potential (unless resisted by ⊕ pressure potential).

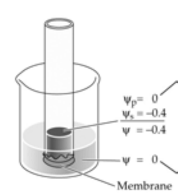
How water potential works

$\Psi = \Psi_p + \Psi_s$

In the tube:

Ψ_s = -0.4
Ψ_p = 0
Ψ = ?

Beaker has distilled water with
Ψ = 0



Predictions?

Fig 36.2

How water potential works

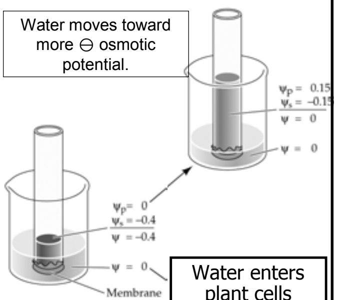
$\Psi=\Psi_p+\Psi_s$

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

Ψ_p = 0.15

Ψ_s = -0.15

Water moves toward more ⊖ osmotic potential.



Water enters plant cells through **osmosis**

Fig 36.2

How water potential works

$\Psi=\Psi_p+\Psi_s$

Or

Resistance to entry of water

E.g. Cell walls (Here a piston)

Ψs doesn't change

But water still leaks in to raise Ψp until balanced water potentials

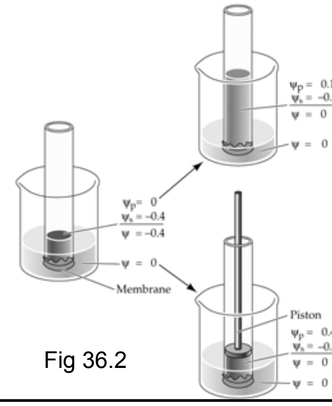


Fig 36.2

Water potential

$\Psi=\Psi_p+\Psi_s$

This is how:

- Plants get support (pressure)
- Water moves into and out of plant cells

Turgor provides support and keeps plants from wilting

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

Summary of Water Potential

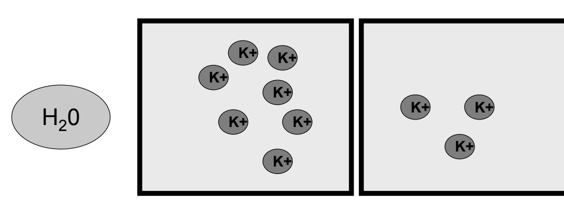
- **Water potential** = the tendency of a solution to **absorb** or **release** water
- **Water flows towards?**

Or -

⊖ water potential wins the tug of war

Summary of Water Potential

Solute potential, Ψs:



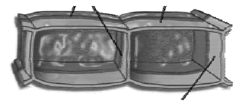
Transport of water and minerals in Plants

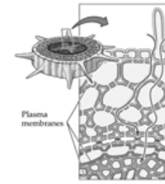
- **Osmosis** has a major influence getting water from the soil to the root xylem.
- **Pressure potential** is responsible for moving water through the xylem to the leaves (and air).

Transport in Plants

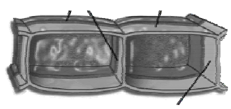
- Osmosis - water movement between living cells.
- Soil → root xylem, water passes through living cells

Why?



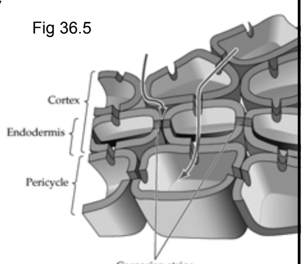


From the soil to the root xylem



- 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**.

Fig 36.5



Movement of minerals into the cells is through active transport

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

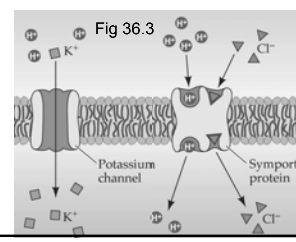


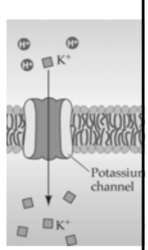
Fig 36.3

Transport in Plants

Mineral ion concentrations affects solute potential

Plants control:

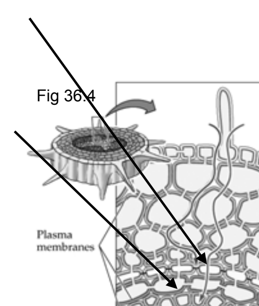
- the concentration of mineral ions in living cells, hence
- they control osmosis in roots.



2 Control Points with Transport Proteins

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

Fig 36.4



Transport in Plants

Mineral ions move out of the cell (active transport)

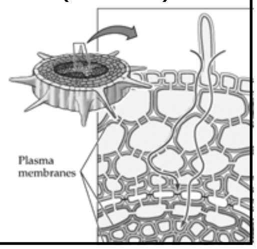
Water potential is <u>more negative outside</u>

So water moves out of the cell (osmosis)

SO:

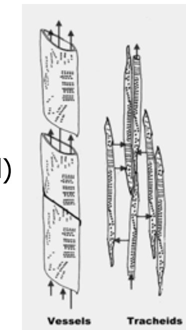
Minerals – active/direct

Water follows passively



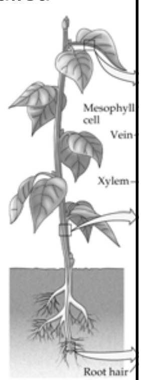
Transport in Plants

- Xylem - movement is controlled by **pressure potential** (hydraulic pressure).
- Water and minerals are **pulled** (⊖ pressure potential) through the xylem without expending energy. **How?**

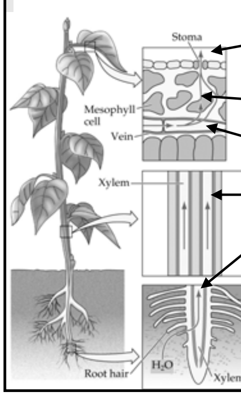


How are water and minerals are pulled through the xylem?

- 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.

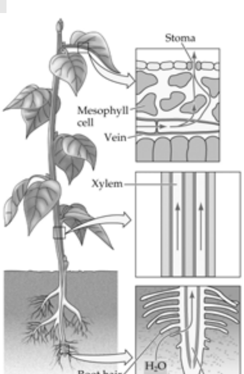
Water evaporates off leaf cells to replace it.

This pulls water from veins.

This tension pulls the water column up

Fig 36.8

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 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

Transport in Plants

- With
  - high humidity
  - wet soils

some plants will even have water *pushed out* of the leaves = **"guttation"**

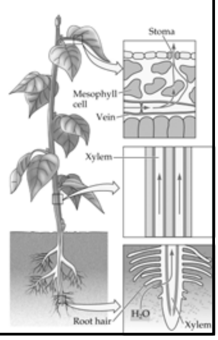
- **"root pressure":** osmotic pressure due to higher solute concentration in root xylem sap than in the soil.

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 <u>control</u> 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.

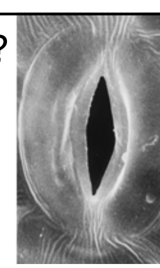
Transpiration and the Stomata

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

How do stomata work?



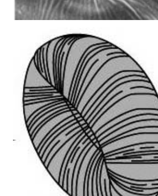
- The **stoma** (or pore):

surrounded by two **guard cells**

- Guard cells <u>control</u> the opening and closing of the stoma

  thru…

  changes in the guard cell water potential



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?

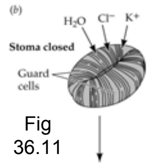
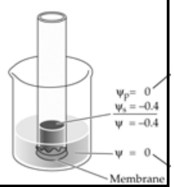


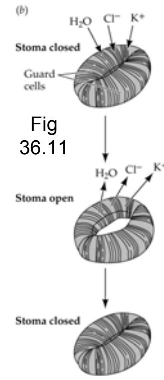
Fig 36.11



Mechanism of stomatal opening

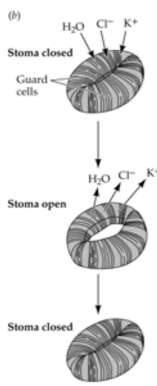
- $H2O$ moves into the guard cells to maintain **osmotic** balance.
- Stretching and turgidity of the guard cells…..
- **Stomata open.**
- (Closing is the reverse started by passive diffusion of potassium out of guard cells.)

Fig 36.11



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** → stomata to close.