Chapt. 36 – Transort in Plants

Plants require: [See Fig. 36.2]

CO_2, Light, H_2O } to make sugar

O_2

Minerals

Macronutrients (besides C, H, O): Ca, K, Mg, N, P, S

Micronutrients: B, Cl, Cu, Fe, Mn, Mo, Ni, Zn

BACKGROUND

Cell wall helps maintain a cell's shape, but the **plasma membrane** regulates the traffic of molecules into and out of a cell **[See Fig. 36.8]**

Plasmodesmata provide cytosolic connections among cells

Cytosol = **cytoplasm** minus **organelles**

Vacuoles often account for 90% of a plant's volume, but they are never shared by adjacent cells

Substances can move from cell to cell via the **symplastic**, **apoplastic**, or **transmembrane** routes

Solutes tend to diffuse down **concentration gradients**

Passive transport is diffusion across a membrane

Passive transport is generally slow, unless solutes travel through **transport proteins** in the membrane

Some **transport proteins** are **selective channels**

Some **selective channels** are "**gated**" – **environmental stimuli** open or close them

Active transport requires energy to move solutes up their **concentration or charge gradient**

E.g., **proton pumps** are very common **active transport proteins** **[See Fig. 36.3]**

Proton pumps create **membrane potentials**; **potential energy** can be used to perform cellular work

The **membrane potential** provides the energy to uptake some minerals, *e.g.*, K+ ions

The K+ ions pass through transport proteins **[See Fig. 36.4]**

The **membrane potential** provides the energy for **co-transport** of ions up their **concentration gradients**, as H+ ions move down theirs

The coupled ions pass through **[co-]transport proteins**

The **membrane potential** provides the energy for **co-transport** of some neutral molecules (*e.g.*, sugar) up their **concentration gradients**, as H+ ions move down theirs

Osmosis is diffusion of water across a membrane

To predict the movement of water across a membrane alone (*e.g.*, an animal cell), it is sufficient to know whether the inside solute concentration is < or > the outside solute concentration

To predict the movement of water across a membrane plus cell wall (*e.g.*, a plant cell), we must know both the solute concentration difference and the pressure difference

Water potential is a combined measure of **solute concentration** and **pressure**

Ψ (psi) → measured in **MPa** (**megapascals**; 1 **MPa** ≈ 10 **atmospheres**)
Pure water in an open container: $\Psi = 0$ MPa
Solutes reduce the value of Ψ
Pressure increases the value of Ψ
Negative pressure (**tension**) decreases the value of Ψ
Water potential = **pressure potential** + **solute** (**osmotic**) **potential**

$$\Psi = \Psi_P + \Psi_S$$

Ψ_P can be positive, 0, or negative
Ψ_S is always ≤ 0

Water will always move across a membrane from higher to lower Ψ

$$\Psi = \Psi_P + \Psi_S$$

Let's consider 4 examples **[See Fig. 36.5]**

Let's consider real cells **[See Fig. 36.6]**
Flaccid cell: $\Psi_P = 0$
If a cell loses water to the environment, it **plasmolyzes**
If a cell gains water from the environment, it becomes **turgid**

Turgor = pressure that keeps cell membrane pressed against cell wall

Aquaporins are transport proteins that form channels for water

How do roots absorb water and minerals? [See Fig. 36.9]

Solutes pass into roots from the dilute soil solution

Symplastic route:

Active transport occurs through proton pumps, that set up membrane potentials, that drive the uptake of mineral ions

Apoplastic route:

Some water and dissolved minerals passively diffuse into cell walls

Solutes diffuse through the cells (or cell walls) of the **epidermis** and **cortex** (the innermost layer of which is the **endodermis**)

At the endodermis, only the symplastic route is accessible, owing to the **Casparian strip**

Chapt. 35 observed that the endodermis regulates the passage of substances into the **vascular stele**

The final layer of live cells actively transports solutes into their cell walls

Solutes then diffuse into **xylem vessels** to be transported upward

The final layer may be an endodermal cell… or a cell of the **pericycle** (outermost layer of **stele**)

Mycorrhizal mutualism (fungus + roots)
Fungus helps plant obtain water and minerals (*e.g.*, P)
Plant feeds sugars to the fungus

Some species (including many legumes) have **root nodules** that house **N-fixing bacteria**
Bacteria convert N_2 to NH_4^+ (ammonium), providing plant with fixed N
Plant feeds sugars to the bacteria

How does xylem transport xylem sap? [See Fig. 36.13]

In some species of trees the process moves water and nutrients > 100 m upwards!

Nearly all of the energy to drive the process comes from the sun

Unbroken chains of water molecules (held together by **cohesive H-bonds**) fill **xylem vessels**

Evaporation at the top pulls water up from the bottom

The evaporation of water out of leaves is called **transpiration** **[See Fig. 36.12]**

Water vapor escapes through **stomata** **[See Fig. 36.15]**

Transpiration creates a **water pressure gradient**

Lower Ψ at the top is the **tension** that pulls water up from the bottom

Water flows upward through xylem vessels by **bulk flow** down the pressure gradient

The Transpiration-Cohesion-Tension Mechanism

How do plants regulate the transport of xylem sap?

Stomata

K^+ is actively transported into and out of **guard cells**
When $[K^+]$ is high, the amount of H_20 is high, and guard cells open stomata
When $[K^+]$ is low, the amount of H_20 is low, and guard cells close stomata
Light stimulates the uptake of K^+ by guard cells, opening stomata
Low $[CO_2]$ stimulates the uptake of K^+ by guard cells, opening stomata
Low H_2O availability inhibits the uptake of K^+ by guard cells, closing stomata

How does phloem transport phloem sap? **[See Fig. 36.17]**

Sugars manufactured in leaves diffuse to **phloem companion cells**

Companion cells actively transport sugars into **sieve-tube members (elements)**

Food (sugars) are then translocated from **sources** to **sinks** according to the **Pressure-Flow Theory:** **[See Fig. 36.18]**

1. At sources, sugars are actively transported into phloem
2. Water follows by osmosis from source cells and xylem; this creates high pressure
3. At the sink, sugars diffuse out of the phloem and water follows by osmosis; this creates low pressure
   Sugar solution flows from high to low pressure
4. Water may be taken up by the transpiration stream in the xylem

Not all **herbivores** chew leaves… some exploit sap
E.g., aphids tap sieve-tube elements for phloem sap