Chapter 36. Transport in Vascular Plants

Key concepts of this chapter:

- Physical processes drive transport in plants.
- Roots absorb water and mineral nutrients from the soil.
- Water and mineral nutrients ascend from roots to shoots through the xylem.
- Stomata help regulate the rate of transpiration.
- Organic nutrients are transported through the phloem.

Some “review” from Chapters 6 and 7

- Adenosine triphosphate (ATP), p.66
- Membrane structure, Figure 7.3, p. 125
- Diffusion, Figure 7.11, p. 131
- Osmosis, Figure 7.12, p.132

ATP (adenosine triphosphate) is the main source of energy for cellular processes

Symbols:
- A = adenosine
- P = phosphate
- P-P-P-A = adenosine triphosphate, ATP
- P-P-A = adenosine diphosphate, ADP

(See p. 66 if you like chemical details)

The ATP cycle

- Releasing energy from ATP:
  P-P-P-A → P + P-P-A + energy
  ATP → ADP + energy
- Storing energy in ATP:
  P + P-P-A + energy → P-P-P-A
  P + ADP + energy → ATP
- Using the energy in ATP to build compounds (an example):
  glucose + fructose + ATP → sucrose + ADP + P
- All energy-requiring processes in cells use ATP as a source of energy.
Membranes are composed of a phospholipid bilayer in which protein molecules are embedded.

**Figure 7.3**

**Diffusion:** Molecules diffuse from regions of higher concentration to regions of lower concentration.

**Figure 7.11a**

Osmosis: diffusion of water across a selectively permeable membrane.

**Figure 7.12**

**Passive and Active Transport**

- Passive transport: molecules diffuse across membranes, from high to low concentration. This is "downhill transport."
- Active transport: molecules are pumped across membranes, against a concentration gradient. This is "uphill transport."

Two questions about plants, soil, and nutrients

- Is the concentration of nutrients (grams per cubic centimeter) higher in a plant or in the soil it came from?
- So, do nutrients enter plants by passive or by active transport?

Proton pumps establish the electrochemical gradients that result in active transport.

**Figure 36.3.** A hydrogen ion or proton is represented by $H^+$.
Uptake of potassium (K⁺) by active transport

Figure 36.4a. An ion is a charged atom, a cation is a positively charged ion.

Water moves from regions of higher water potential to regions of lower water potential

- Water potential depends on solute concentration and pressure.
- The units of water potential are pressure units, MPa, megapascals.

Ψ = Ψᵣ + Ψₚ

The solute and pressure components of water potential

Figure 36.5a

Flaccid, plasmolyzed and turgid cells

Figure 36.6

Cell compartments (Figure 36.8a)

- Cell wall
- Cytosol (cytoplasm)
- Plasma membrane (cell membrane)
- Vacuolar membrane (tonoplast)
- Vacuole
- Plasmodesma (plastid or plasmodesmata)

Transport routes between cells (Figure 36.8b)

- Transmembrane route
- Symplastic route
- Apoplastic route

Three transport routes:
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Is water *pushed* or *pulled* up stems?

Figure 36.11. Guttation resulting from positive root pressure

Lateral transport of water and mineral nutrients in roots (Figure 36.9)

• Water enters the root by osmosis.
• Water and nutrients travel from root hair through cortex by the symplastic and apoplastic routes.
• Casparian strips of the endodermis block the apoplastic route.
• This means that all nutrients must cross at least one membrane to enter the xylem. *The plant controls nutrient uptake.*
• The endodermis also prevents solutes from diffusing from the xylem back into the soil.

The answer: water is (usually) *pulled* up stems

Some facts about water and stems:
• Xylem sap (=water and nutrients) is under tension, not compression.
• Water has great tensile strength due to bonds between water molecules.
• Transpiration of water from leaves provides the “pull.”
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Photosynthesis and transpiration: good news and bad news

- High surface-to-volume ratios of leaves enhance absorption of light and photosynthesis.
- Stomata allow CO₂ to enter but H₂O to leave (transpiration).
- This means that plants cannot simultaneously maximize CO₂ uptake while minimizing loss of H₂O.
- "Guard cells arbitrate the photosynthesis-transpiration compromise" (p. 751)
Environmental factors affecting stomata

- Light (stomata open in light, close in dark).
- $\text{CO}_2$ in mesophyll (open when low, close when high).
- Water deficiency in mesophyll (close).
- Water deficiency in roots (close).

"Guard cells arbitrate the photosynthesis-transpiration compromise" (p. 751)

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Sugar is translocated in phloem, from source to sink

- Examples of sources:
  - Leaves
  - Tubers
  - Storage roots
- Examples of sinks:
  - Meristems
  - Tubers
  - Storage roots
  - Fruits

Pressure flow in a sieve tube (phloem element)

Pressure flow mechanism of phloem translocation

- Sugars are loaded (active transport) into phloem cells at sink.
- This decreases solute water potential ($\Psi_s$), resulting in osmotic uptake of water at sink.
- Water uptake produces positive pressure at sink.
- Sugars are unloaded (active transport) from phloem cells at source.
- This relieves pressure at sink.
- Pressure gradient (high at source, low at sink) causes phloem sap to flow from source to sink.

Phloem transport: Sugar is loaded and unloaded by active transport