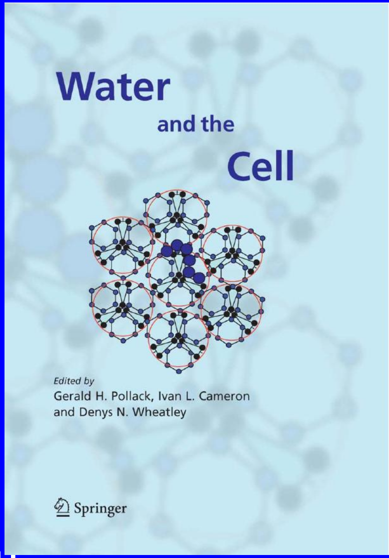
Concept of Metabolism

- Metabolism: A generic term of chemical changes that maintain all the activities of life.
- Assimilation: A process in which a plant absorbs simple inorganic matters from the environment, forms various kinds of complex organic matters through various changes, integrates them into a part of the plant and meanwhile converts solar energy into chemical energy and stores it in organic matters.
- Dissimilation: A process in which a plant decomposes complex organic matters in it into simple inorganic matters, releases the energy stored in it and uses the energy for life activities.
- Features of plant metabolism: It can directly synthesize simple inorganic matters in the environment into complex organic matters of the plant.

Chapter V Water Metabolism - Water Need of the Plant



I. Water Content of a Plant

1. How to determine the water content of a plant?
2. Water content varies remarkably with plants;
3. The water content of a same plant may be different when the growing environment is different;
4. In a plant, different organs and tissues may have remarkable difference in water content. Generally speaking, the locations with more vigorous life activities have higher water content.

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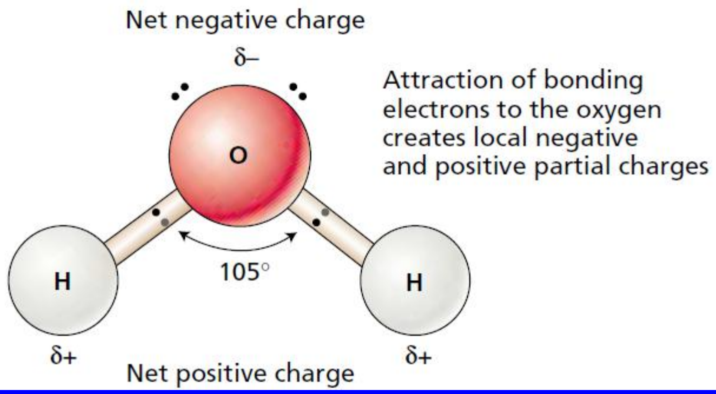
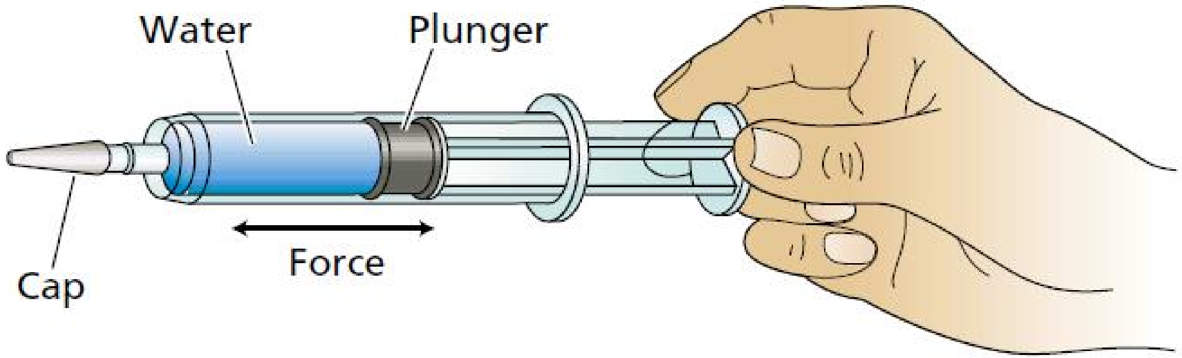
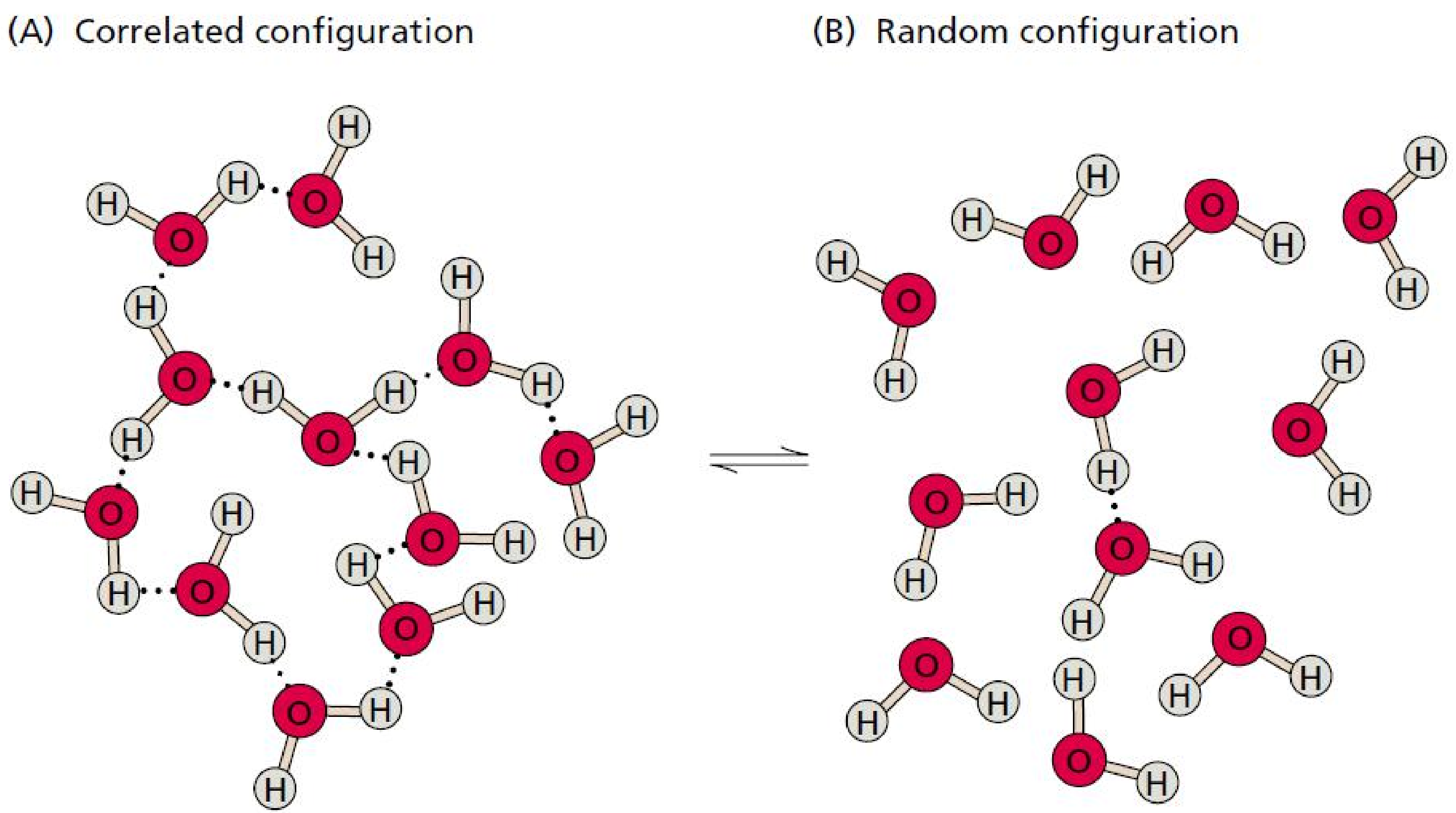






Physical and chemical properties of water molecules

II. Existent State of Water in a Plant

1. Existent state

Bound water: Water that is close to and adsorbed and constrained by micelles and can hardly flow freely.

Free water: Water that is far from micelles and can flow freely.

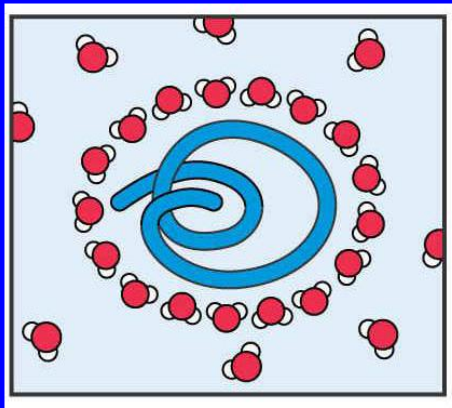
2. Relation between water and metabolism

The higher the percentage of free water to water content is, the more vigorous the plant metabolism will be. The content of bound water has a close relation with plant resistance.

3. State of cytoplasmic colloid

Sol: High water content

Gel: Low water content

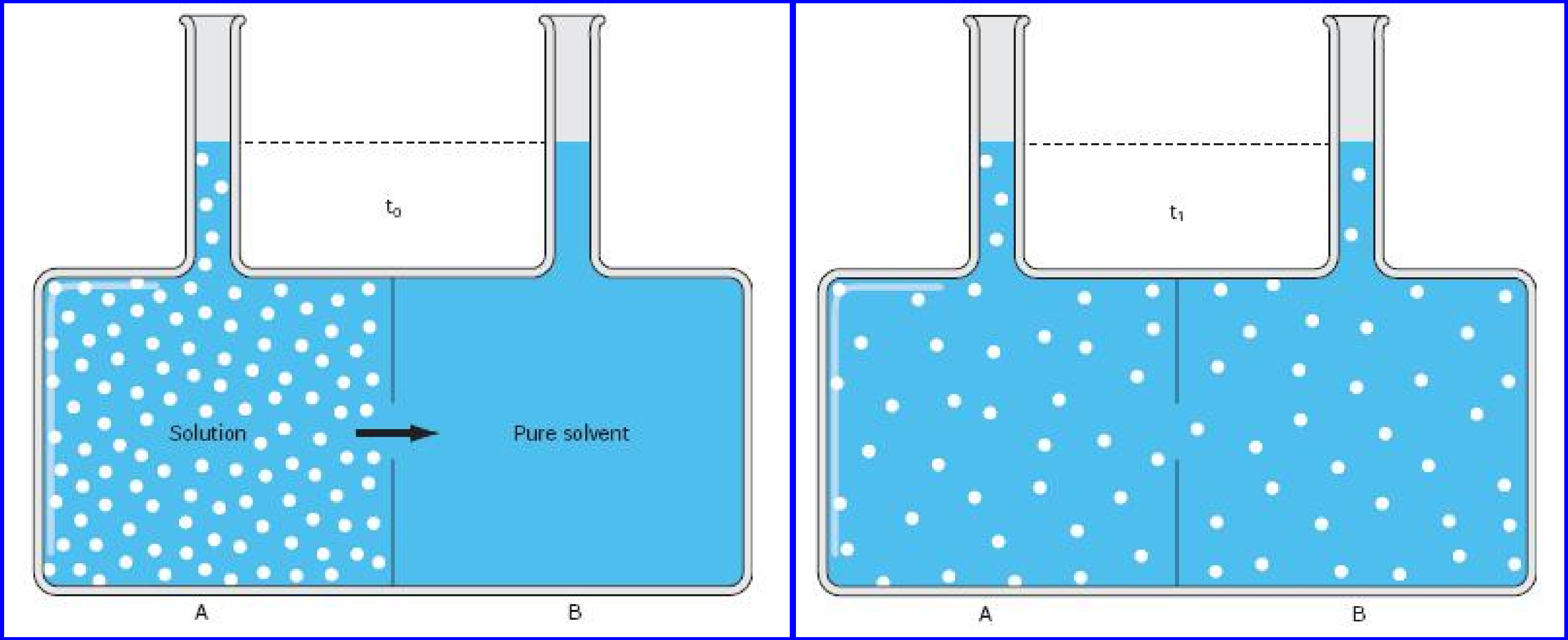


III. Effect of Water in Life Activities

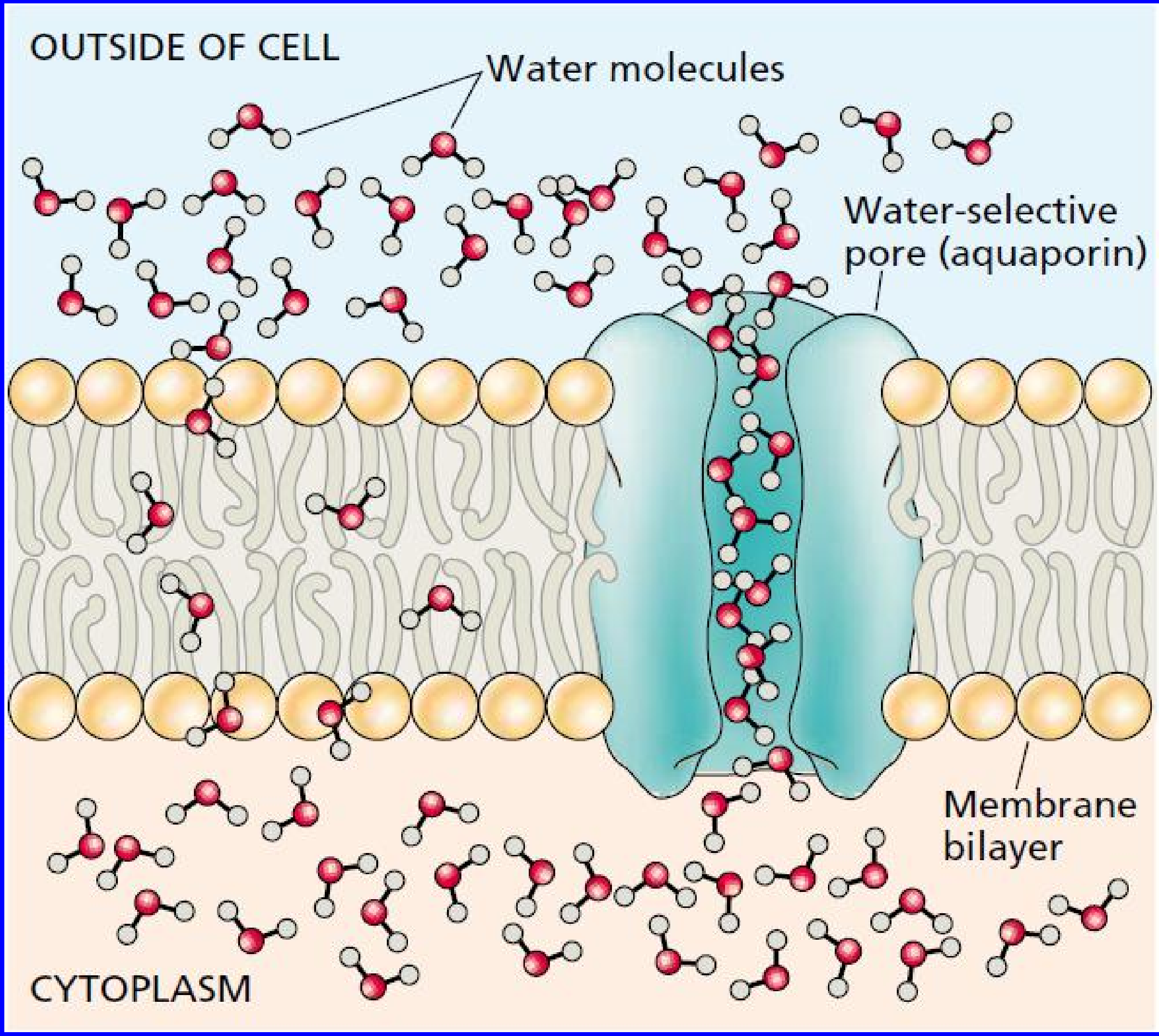
1. Water is a main component of cytoplasm and accounts for 70%-90% of the latter in general;
2. Water is a reactant of metabolic processes, such as photosynthesis, respiration, and organic synthesis and decomposition;
3. Water is a solvent in which plants absorb and transport substances;
4. Water can maintain the inherent postures of plants and the tensity of cells.

I. Diffusion

Refer to the movement of substances from a high concentration area to a low concentration area under the drive of the random thermal motion of molecules. It is a spontaneous process of substances along concentration gradient.



Water can cross plant membrane by diffusion of individual water molecules through the membrane bilayer, as shown on the left, and by microscopic bulk flow of water molecules through a water-selective pore formed by integral membrane proteins such as aquaporins.



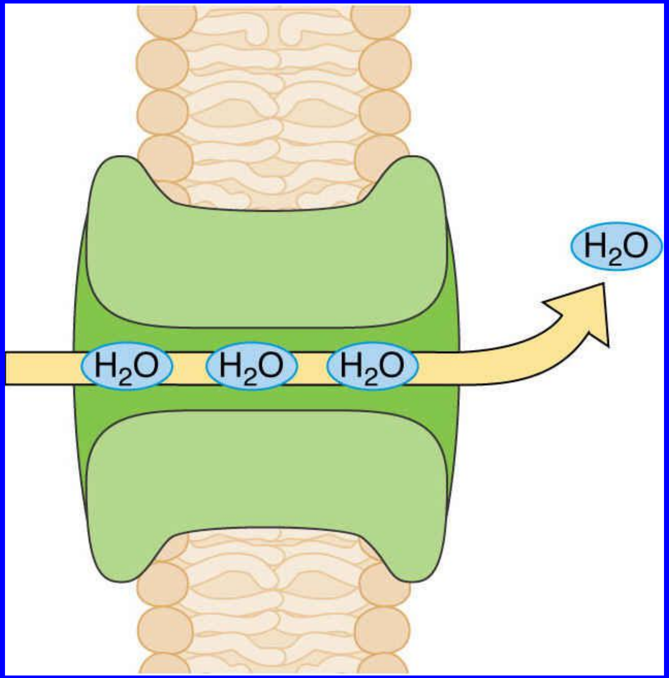
II. Bulk Flow

(I) Definition

Refer to the joint motion of atoms or molecules in groups in a liquid under a pressure gradient. The bulk flow of water is irrelevant with the concentration gradient of solute.

(II) Aquaporin

1. Properties: It is a kind of membrane channel protein that is selective and efficiently transports water. Only water can pass through it. Intrinsic protein has been found on tonoplast, plasma membrane and nodule symbiotic membrane.



2. Characteristics

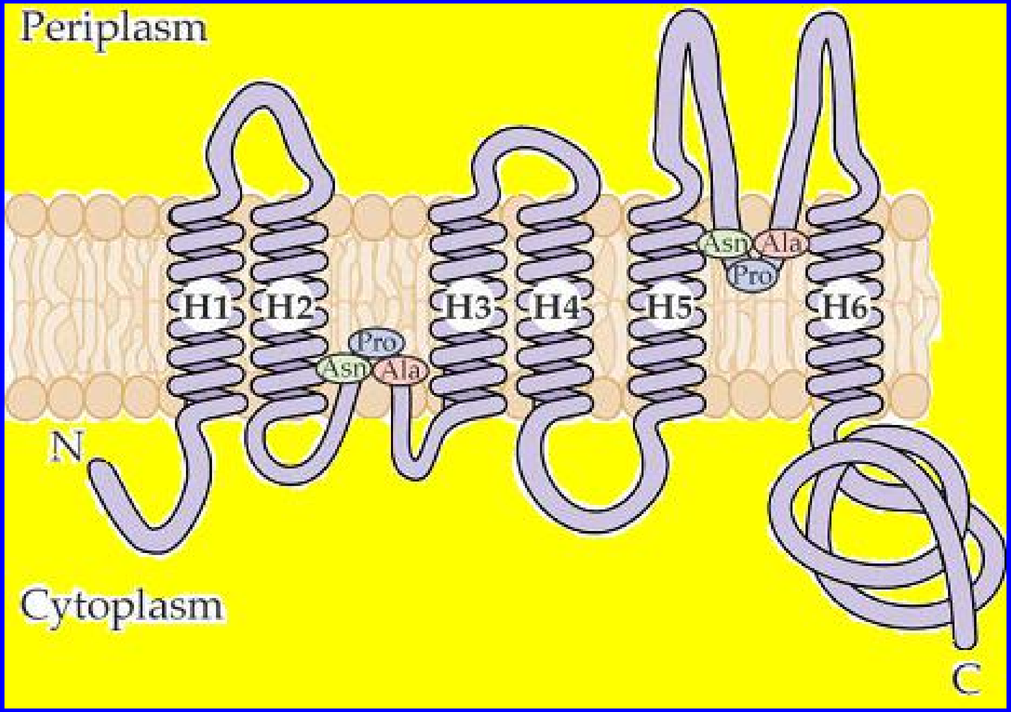
The monomer is a tetramer with a narrow middle part;

Speed regulation of active phosphorylation and aquaporin synthesis;

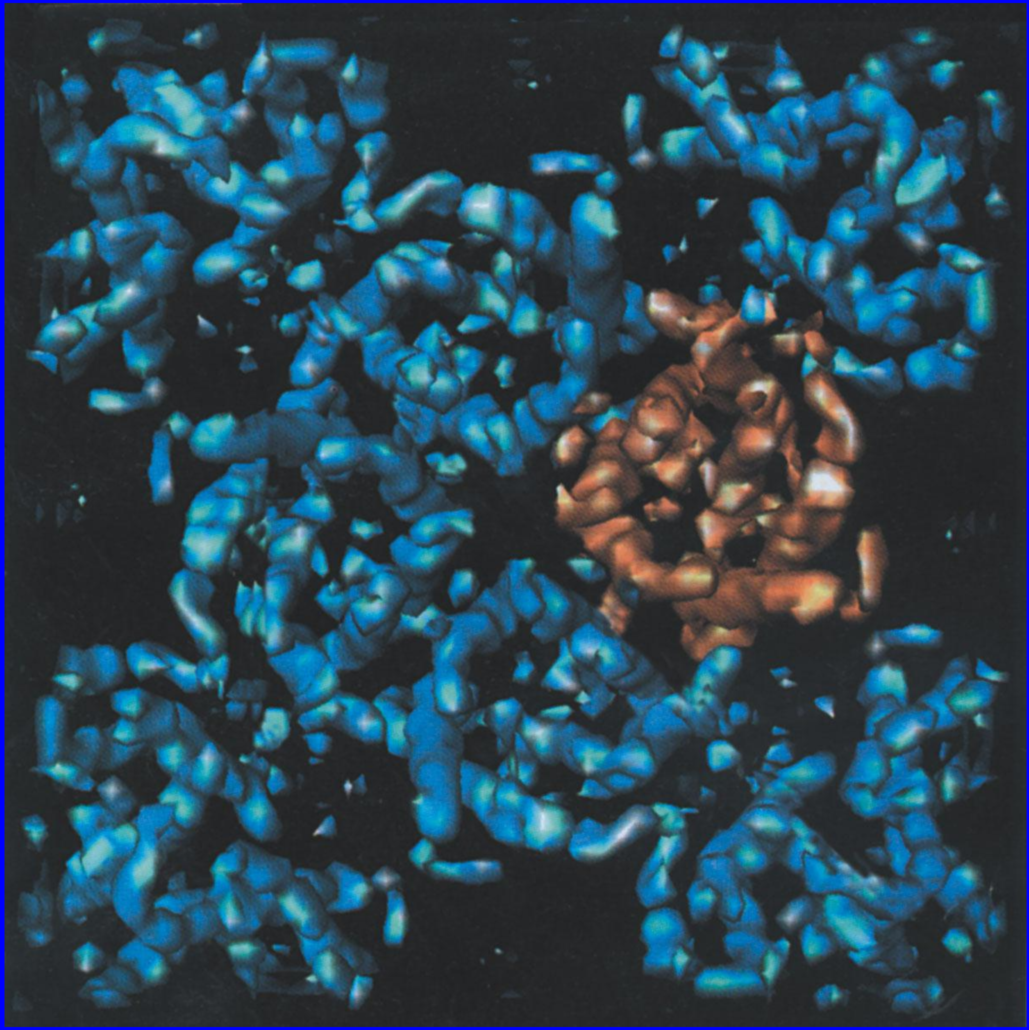
Molecular weight: 25-30 kD;

Highly conservative Asn-Pro-Ala (NPA) fragment with C & N terminals;

Hg^{2+} hinders its expression.



Three-dimensional structure of aquaporin-1 from human erythrocytes. Extracellular view of eight asymmetrical subunits that form two tetramers. One of the monomers of the central tetramer is colored gold.



3. Other effects

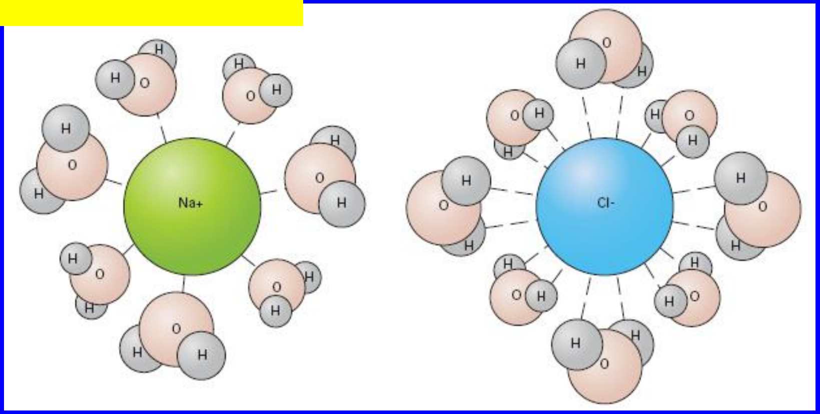
Participate in long-distance transport of water molecules (prioritized expression in parenchyma cells of vascular bundles)

Make for cell growth and differentiation (elongation region and meristem region of apex).

Relevant with reproduction (distributed in stamen and anther).

4. Inducing factor

Ambient (drought, low omission and blue light) and plant hormones (ABA, GA_3 and brassinolide) may induce gene expression of aquaporin.



III. Theory for Transmembrane Water Transport

(I) Free energy and water potential

1. Free energy: Energy used to do work at constant temperature.
2. Chemical potential: The free energy of 1 mol of substance is the chemical potential of this substance.
3. Water potential (ψ_w): Chemical potential of a partial molar volume of water. I.e. the difference ($\Delta\mu_w$) between the chemical potential of water solution (μ_w) minus the chemical potential of pure water in a same system at same temperature and pressure (μ_w^0), divided by the partial molar volume of water (V_w).

Chapter V Water Metabolism – Water Absorption of Plant Cells

4. Partial molar volume ($\bar{V}_w$): Refer to the effective volume of 1 mol of water at specific temperature and pressure after 1 mol of solution is added to 1 mol of water. In a dilute solution, $V_w \approx V_w$.

5. Unit of water potential: N/m^2=Pa

6. Properties of water potential:

   (1) Pure water has the largest free energy and the largest water potential as well.

   (2) The water potential of pure water is zero. The higher the concentration of a solution is, the lower the water potential will be.

   (3) Water flows from an area with high water potential to an area with low water potential along an energy gradient.

Comparison of units of pressure

1 atmosphere = 14.7 pounds per square inch
= 760 mm Hg (at sea level, 45° latitude)
= 1.013 bar
= 0.1013 Mpa
= 1.013×10^5 Pa

A car tire is typically inflated to about 0.2 MPa.

The water pressure in home plumbing is typically 0.2–0.3 MPa.

The water pressure under 15 feet (5 m) of water is about 0.05 MPa.

The water potential of seawater is -2.69 MPa.

The water potential of Hoagland culture solution is -0.05 MPa.

(II) Osmosis

A phenomenon that water moves from a system with high water potential to a system with low water potential via a semipermeable membrane.

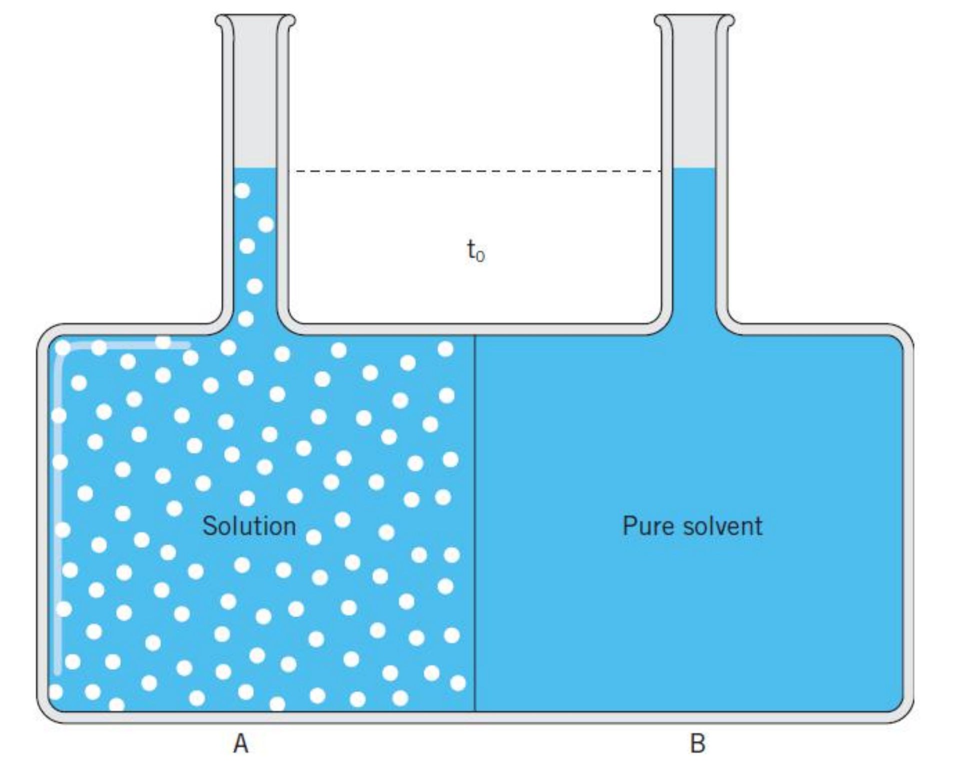
(III) Plant cell is a permeable system

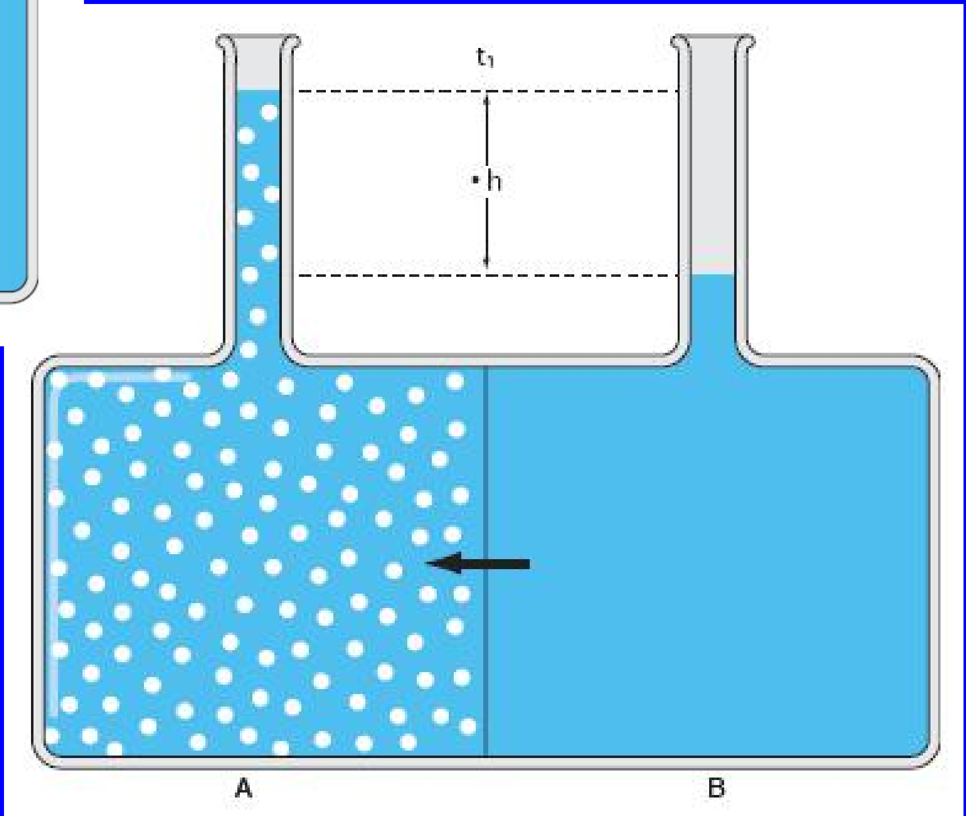
Cell wall - permeable membrane .

Protoplasm (containing plasma membrane, cytoplasm and tonoplast) - semipermeable membrane.

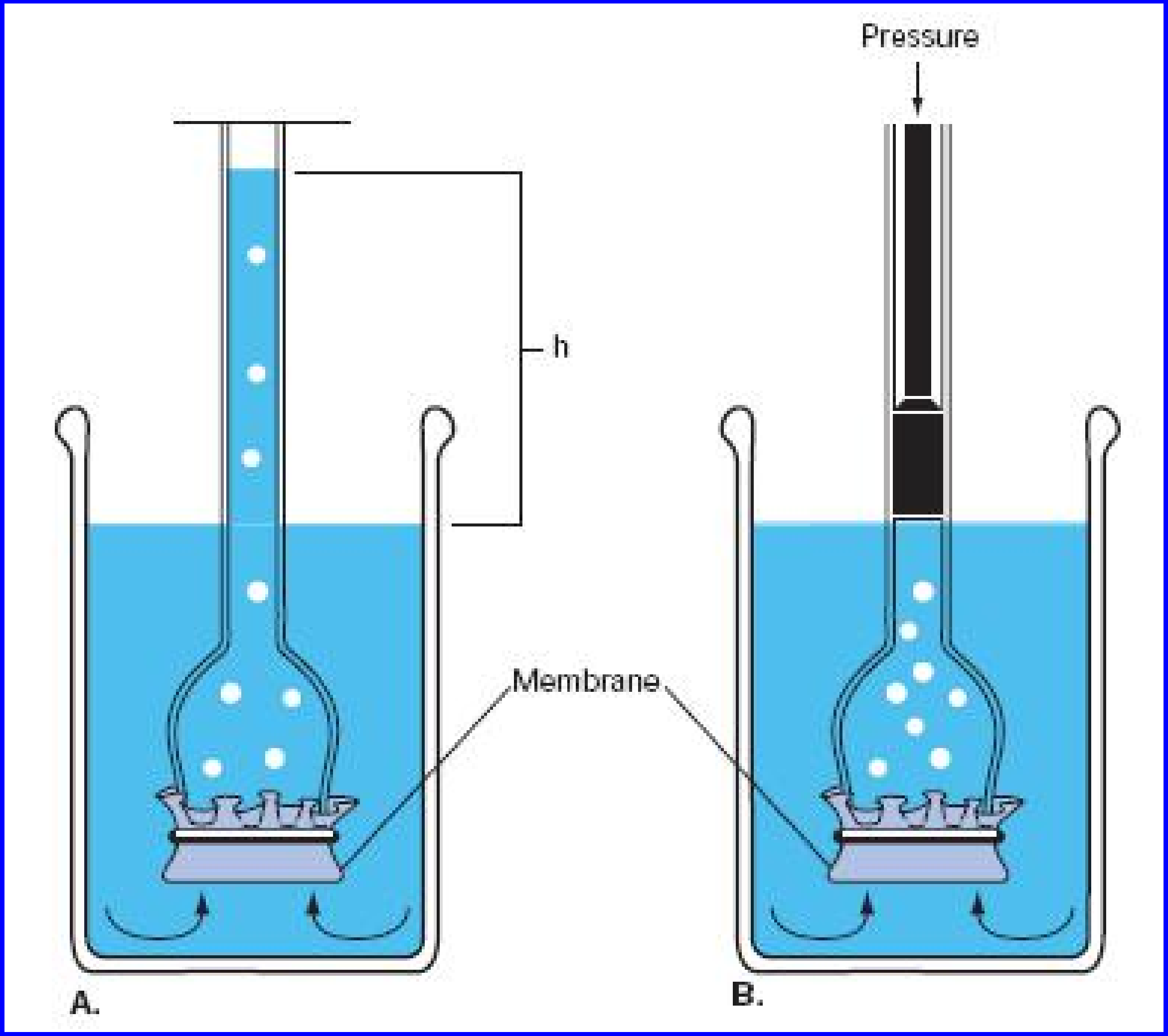
A plant cell with a vacuole and the solution around it jointly form a permeable system .

Plasmolysis and deplasmolysis experiments can prove it.

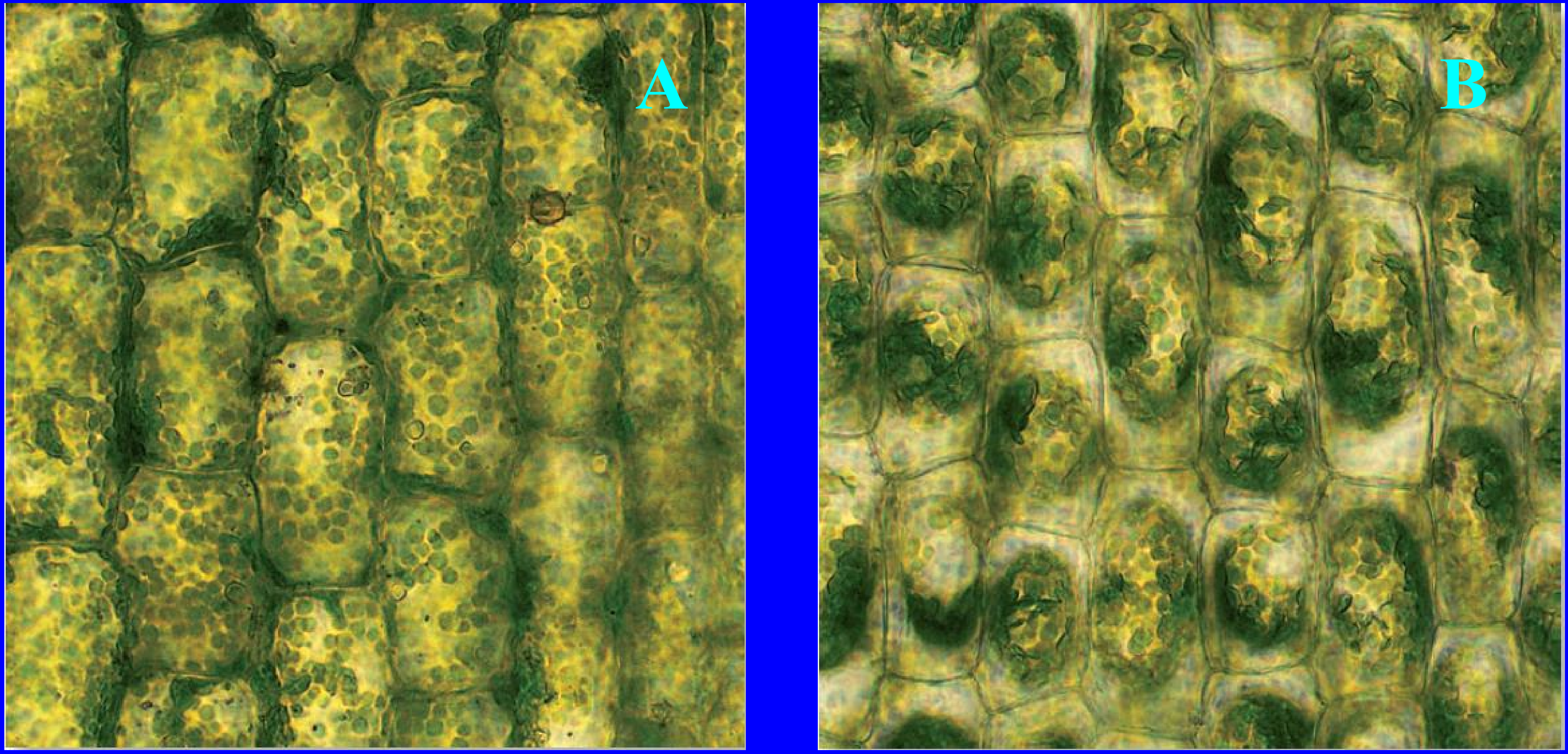




Osmosis is the directed movement of the solvent molecule (usually water) across a selectively permeable membrane.



A demonstration of hydrostatic pressure.



A portion of a leaf of the water weed *Elodea*. *A*. Normal cells. *B*. Plasmolyzed cells.

(IV) Water potential of cells

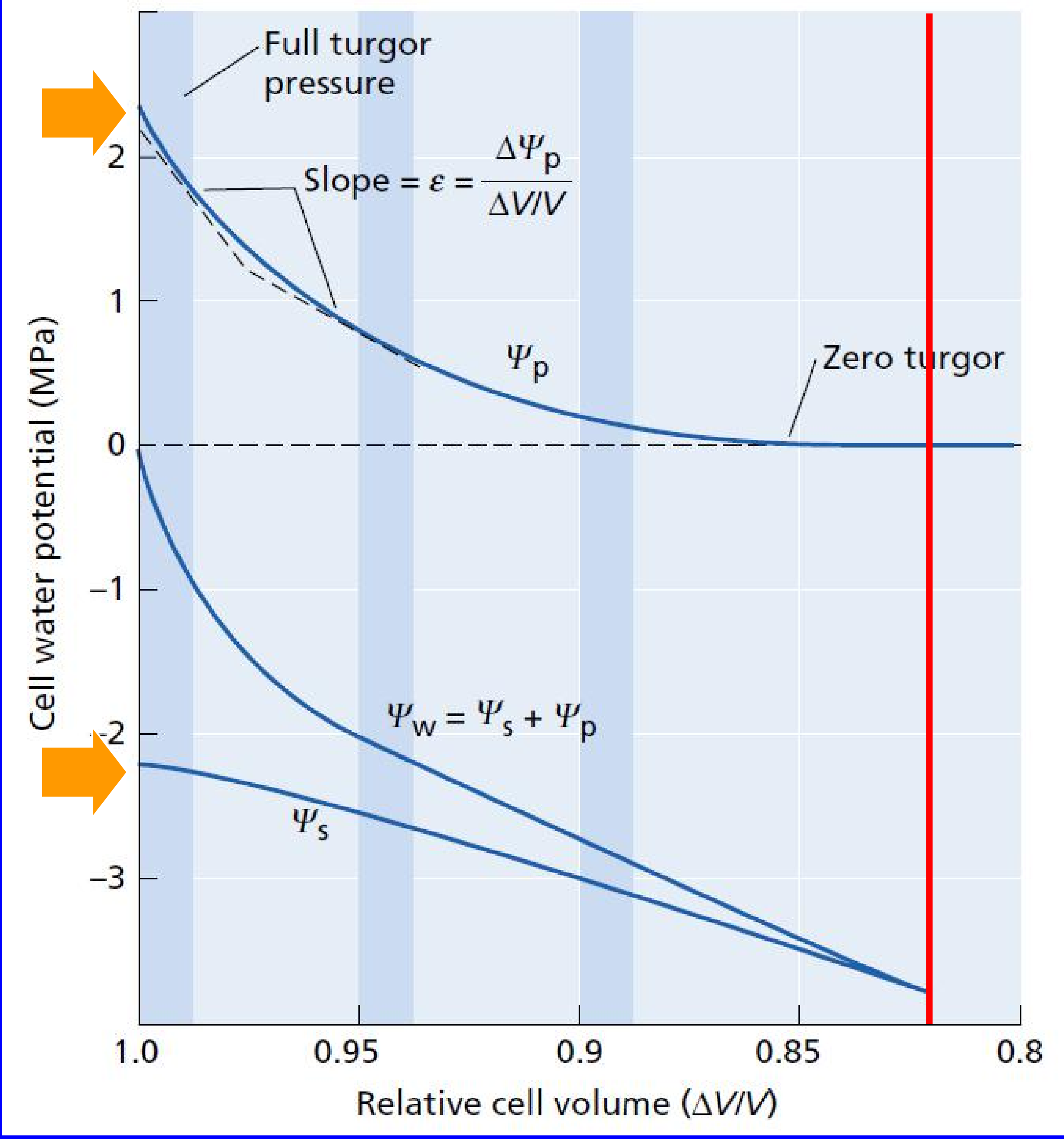
1. Osmotic potential (ψ_s): The existence of solute particles reduces the free energy of water. The osmotic potential of a solution is equal to the water potential of the solution and decided by the total number of solute particles (molecules or ions). It is the sum of the osmotic potentials of all particles. $\psi_s = -RTic_\pi$.

2. Turgor pressure (ψ_p): The protoplast of a cell is expanded after absorption of water, generating an acting force on the cell wall and inducing the cell wall to generate a counterforce against the expansion of the protoplast. As a result, the water potential is increased. It is a positive value.

3. Gravitational potential (ψ_g): Refer to the force that tends to make water move downwards due to gravity. It raises water potential. $\psi_g = \rho_w gh$. As water moves horizontally on cells, ψ_g is usually omitted in comparison with ψ_π and ψ_p. Therefore, $\psi_w = \psi_\pi + \psi_p + \psi_m$.

4. Matric potential (ψ_m): Refer to the value of water potential reduced due to the constraint of hydrophilic colloidal substances and capillaries of the cell to free water. After formation of vacuole, ψ_m only accounts for a tiny portion of water potential and is often omitted, so $\psi_w = \psi_\pi + \psi_p$.

Relation between cell water potential (ψ_w) and its components (ψ_p and ψ_π), and relative cell volume ($\Delta V/V$).



(V) Intercellular water movement

1. The direction of water movement between two neighboring cells is decided by the water potential difference between the two cells. The water in the cell with higher water potential will flow to the cell with lower water potential.
2. The larger the water potential difference between two cells is, the faster the water will flow, vice versa
3. The water flowing direction between plant organs also follows the law of water potential gradient.
4. Water potential is changed remarkably among different cells or tissues: Above ground <underground, higher leaves <lower leaves, inside of root<outside of root.

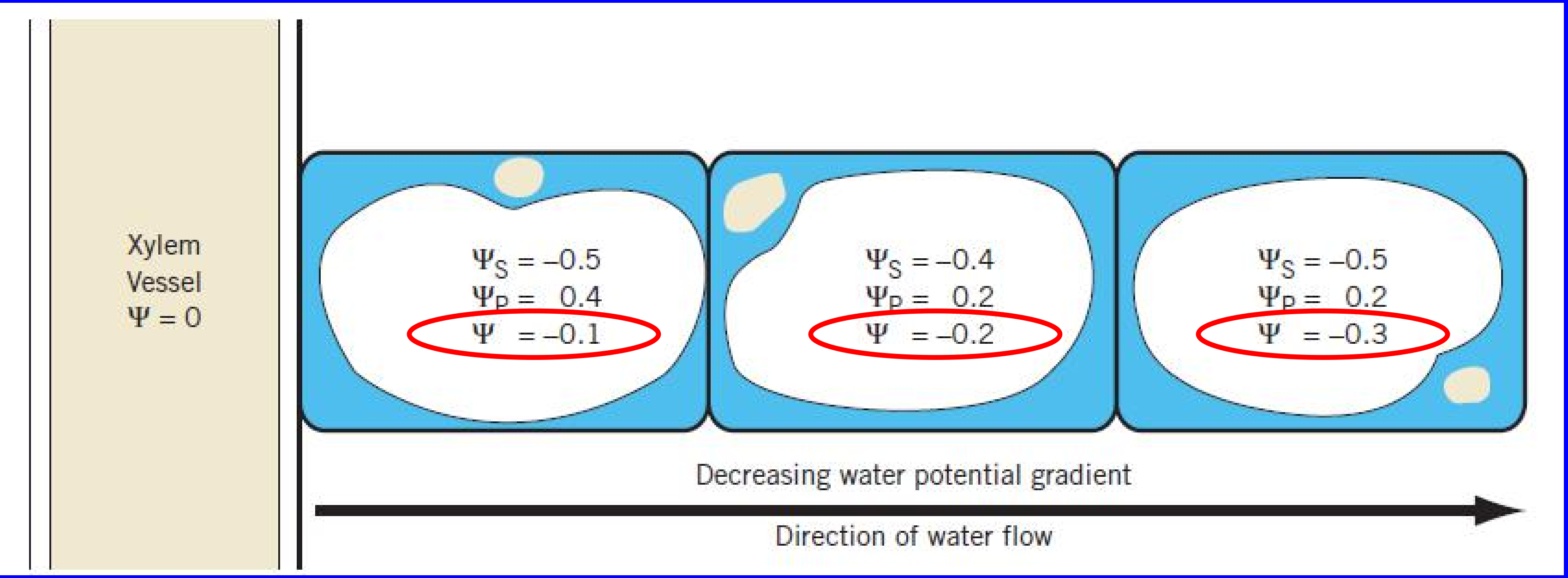
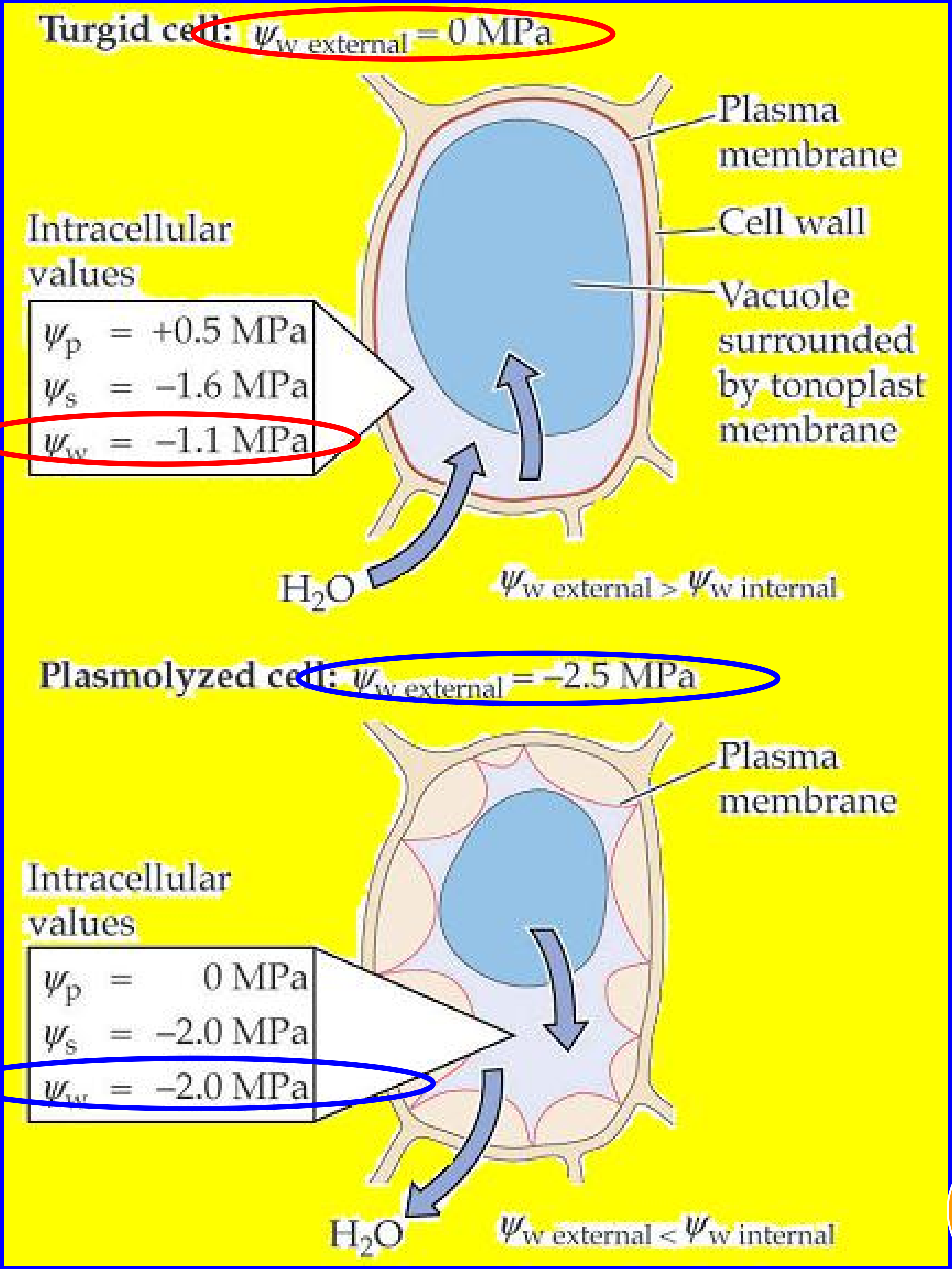
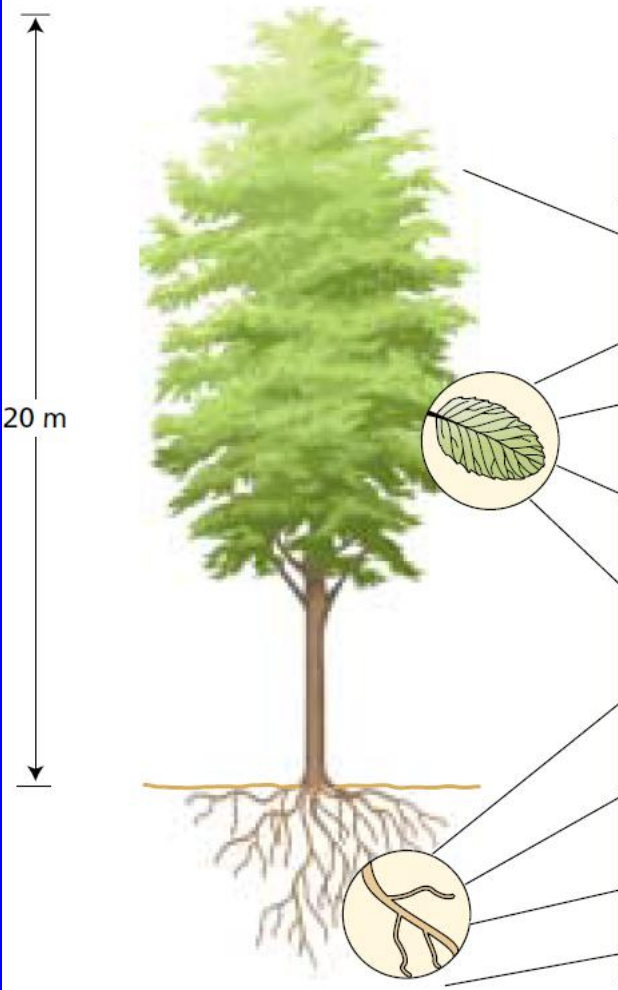


Diagram illustrating the contributions of osmotic potential (ψ_s), turgor pressure (ψ_p), and water potential (ψ_w) to water movement between cells. The direction of water movement is determined solely by the value of the water potential in adjacent cells.

Movement of water into or out of a cell depends on the water potential gradient across the plasma membrane.



Representative overview of water potential and its components at various points in the transport pathway from the soil through the plant to the atmosphere.



Location	Water potential and its components (in MPa)				
	Water potential (Ψ_w)	Pressure (Ψ_p)	Osmotic potential (Ψ_s)	Gravity (Ψ_g)	Water potential in gas phase $\left(\frac{RT}{\bar{V}_w}\ln[RH]\right)$
Outside air (relative humidity = 50%)	–95.2				–95.2
Leaf internal air space	–0.8				–0.8
Cell wall of mesophyll (at 10 m)	–0.8	–0.7	–0.2	0.1	
Vacuole of mesophyll (at 10 m)	–0.8	0.2	–1.1	0.1	
Leaf xylem (at 10 m)	–0.8	–0.8	–0.1	0.1	
Root xylem (near surface)	–0.6	–0.5	–0.1	0.0	
Root cell vacuole (near surface)	–0.6	0.5	–1.1	0.0	
Soil adjacent to root	–0.5	–0.4	–0.1	0.0	
Soil 10 mm from root	–0.3	–0.2	–0.1	0.0	

IV. Imbibition of Cells

1. Concept: A phenomenon that hydrophilic colloid is expanded after absorption of water. Water molecules are bound with hydrogel through hydrogen bonds to make the colloid expanded. Protein >starch>cellulose.

2. Mechanism of imbibition: Water absorption of air-dried seed, i.e.: before formation of a vacuole, $\psi_s=0$, $\psi_p=0 \rightarrow \psi_w=\psi_m \rightarrow$cellular water potential<water potential of pure water or solution $\rightarrow$water flows to the imbibant.

Assignment after class

- When a plant cell with ψ_s –0.732 Mpa, which has just completed plasmolysis, is put into a sucrose solution with ψ_s –0.244 MPa, will this cell absorb or lose water? Why?

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