Water

Relation to Plants

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Properties of Water	Associated Uses of Water
Polar Solvent	Dissolves soil minerals, sugar, amino acids, widest range of any liquid!
Hydraulic Fluid	Does not compress, so turgor pressure supports plant tissue, permits flow of material in xylem (transpiration) and phloem (translocation)
Reactive	Reactant: $CO_2 + H_2O \text{ -> } O_2 + CH_2O$ Product: $CH_2O + O_2 \text{ -> } H_2O + CO_2$
High Specific Heat	Heat Buffer: 1 Calorie = 1 Liter 1°C

Water in plant life

- It is the most abundant constituents of most organisms (70 percent by weight of non-woody plant parts)
- The uptake of water by cells generates a pressure known as turgor
- The constant flow of water through plants is a matter of considerable significance to their growth and survival
- Photosynthesis requires that plants draw carbon dioxide from the atmosphere, and at the same time exposes them to water loss. To prevent leaf desiccation, water must be absorbed by the roots
- The thermal properties of water contribute to temperature regulation, helping to ensure that plants do not cool down or heat up too rapidly.
- Water has excellent solvent properties . Many of the biochemical reactions occur in water and water is itself either a reactant or a product in a large number of those reactions.

<u>Sources of Water</u>

Precipitation: Fog, Mist, Rain, Snow, Sleet, Hail

Runoff: Brook, Creek, Stream, River

Water Table: Puddle, Pond, Lake (Ocean not freshwater)

Soil Water: <u>Most useful for plants</u>

Aquifers: porous rock, wells, artesian wells, springs

The practice of crop irrigation reflects the fact that water is a key resource limiting agricultural productivity. Plants use water in huge amounts, but only small part of that remains in the plant to supply growth. About 97% of water taken up by plants is lost to the atmosphere, 2% is used for volume increase or cell expansion, and 1% for metabolic processes, predominantly photosynthesis. Water loss to the atmosphere appears to be an inevitable consequence of carrying out photosynthesis. The uptake of CO2 is coupled to the loss of water (**Figure**). Because the driving gradient for water loss from leaves is much larger than that for CO2 uptake, as many as 400 water molecules are lost for every CO2 molecule gained.

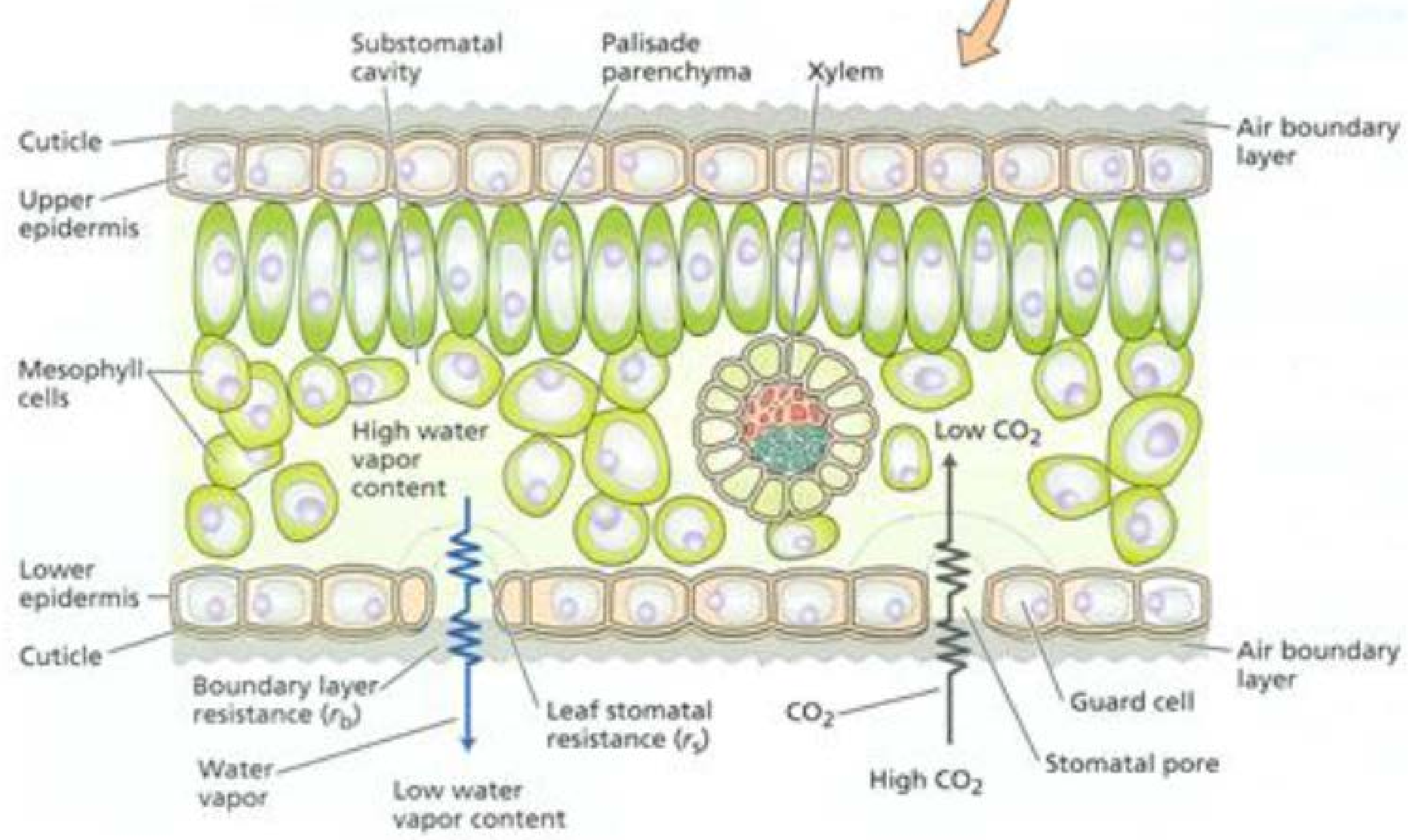


Figure 1.2 Water pathway through the leaf (*source: Taiz L., Zeiger E., 2010*)

The structure and properties of water

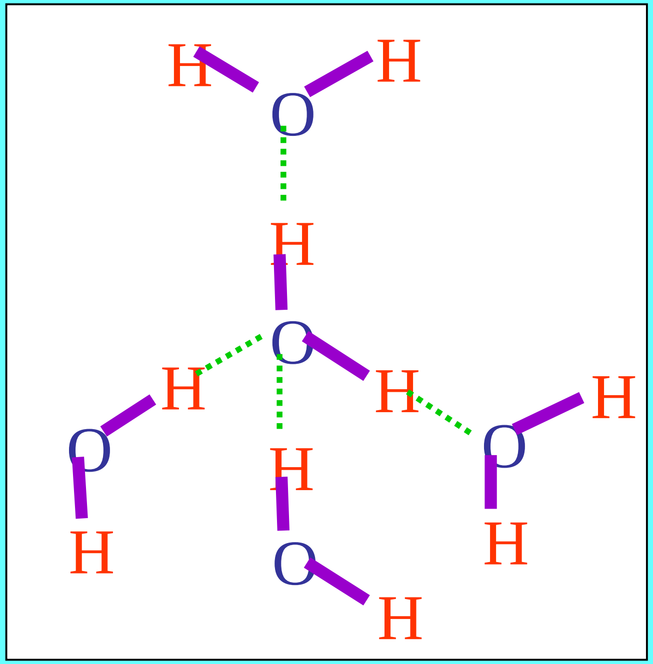
Water consists of an oxygen atom covalently bonded to two hydrogen atoms

Water molecules have a weak negative charge at the oxygen atom and weak positive charge at the hydrogen atoms

The positive and negative regions are attracted to the oppositely-charged regions of nearby molecules. The force of attraction, dotted line, is called a hydrogen bond.

Each water molecule is hydrogen bonded to four others.

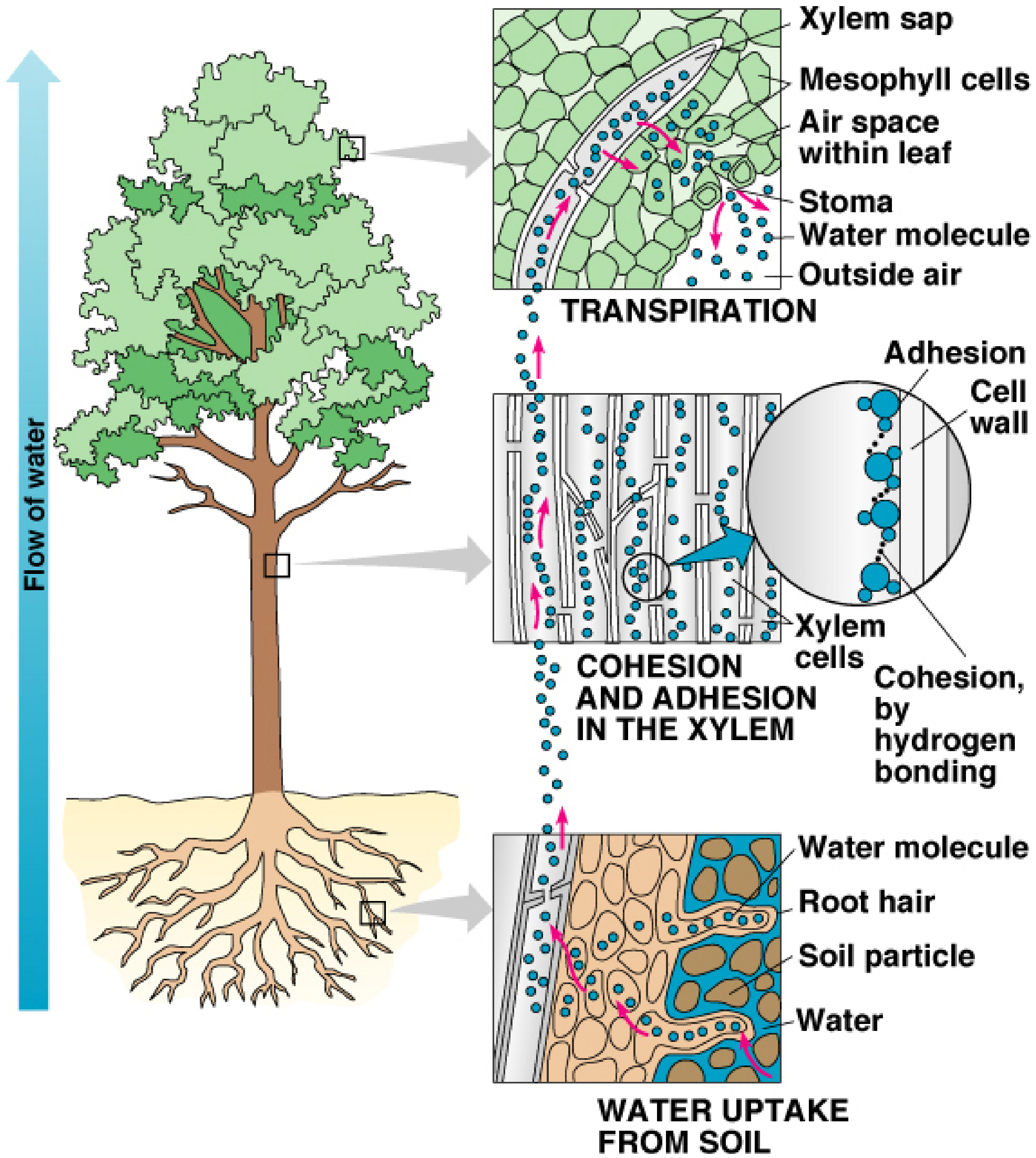
The hydrogen bond has ~ 5% of the strength of a covalent bond. However, when many hydrogen bonds form, the resulting union can be sufficiently strong as to be quite stable.



The hydrogen bonding ability of water and its polar structure make it a particularly good solvent for ionic substances and for molecules such as sugars and proteins. The hydration shells that form around biologically important macromolecules are often referred to as bound water. Bound water prevents protein molecules from approaching close enough to form aggregates large enough to precipitate.

The extensive hydrogen bonding between water molecules results in water having both a high **specific heat capacity** and a high **latent heat of vaporization**. Because of its highly ordered structure, liquid water also has a high **thermal conductivity**. This means that it rapidly conducts heat away from the point of application. The combination of high specific heat and thermal conductivity enables water to absorb and redistribute large amounts of heat energy without correspondingly large increases in temperature. The heat of biochemical reactions may be quickly dissipated throughout the cell. Compared with other liquids, water requires a relatively large heat input to raise its temperature. This is important for plants, because it helps buffer temperature fluctuations.

The extensive hydrogen bonding in water gives a new property known as **cohesion**, the mutual attraction between molecules. A related property, called **adhesion**, is the attraction of water to a solid phase, such as cell wall. The water molecules are highly cohesive. One consequence of cohesion is that water has exceptionally high **surface tension**, which is the energy required to increase the surface area of a gas-liquid interface. Surface tension and adhesion at the evaporative surfaces in leaves generate the physical forces that pull water through the plant's vascular system. Cohesion, adhesion and surface tension give rise to a phenomenon known as **capillarity**. These combined properties of water help to explain why water rises in capillary tubes and are exceptionally important in maintaining the continuity of water columns in plants. (collum of 10 µm in diameter ad 3000 m in height)



Cohesion and adhesion in the transpiration stream

Mechanisms for translocation may be classified as:
either active or passive.

It is sometimes difficult to distinguish between active and passive transport, but the **translocation of water is clearly a passive process**.

Passive movement of most substances can be accounted for by **bulk flow** or **diffusion**.

Bulk flow accounts for some water movement in plants through the **xylem tissues** of plants.

Movement of materials by **bulk flow** (or **mass flow**) is **pressure driven**.

Bulk flow occurs when an **external force**, such as gravity or pressure, is applied. As a result, all of the molecules of the substance move in mass.

Bulk flow is pressure-driven, **diffusion** is driven principally by **concentration differences**.

Diffusion results in the net movement of molecules from regions of high concentration to regions of low concentration.

Diffusion in solutions can be effective **within cellular dimensions** but is far too slow to be effective over long distances.
(The average time required for a glucose molecule to diffuse across a cell with a diameter of 50 µm is 2.5 s. However, the average time needed for the same glucose molecule to diffuse a distance of 1 m in water is approximately 32 years).

The net movement of water across a selectively permeable barrier is referred to as **osmosis**.

Membranes of plant cells are selectively permeable. The diffusion of water directly across the lipid bilayer is facilitated by **aquaporins**, which are integral membrane proteins that form water-selective channels across membrane.
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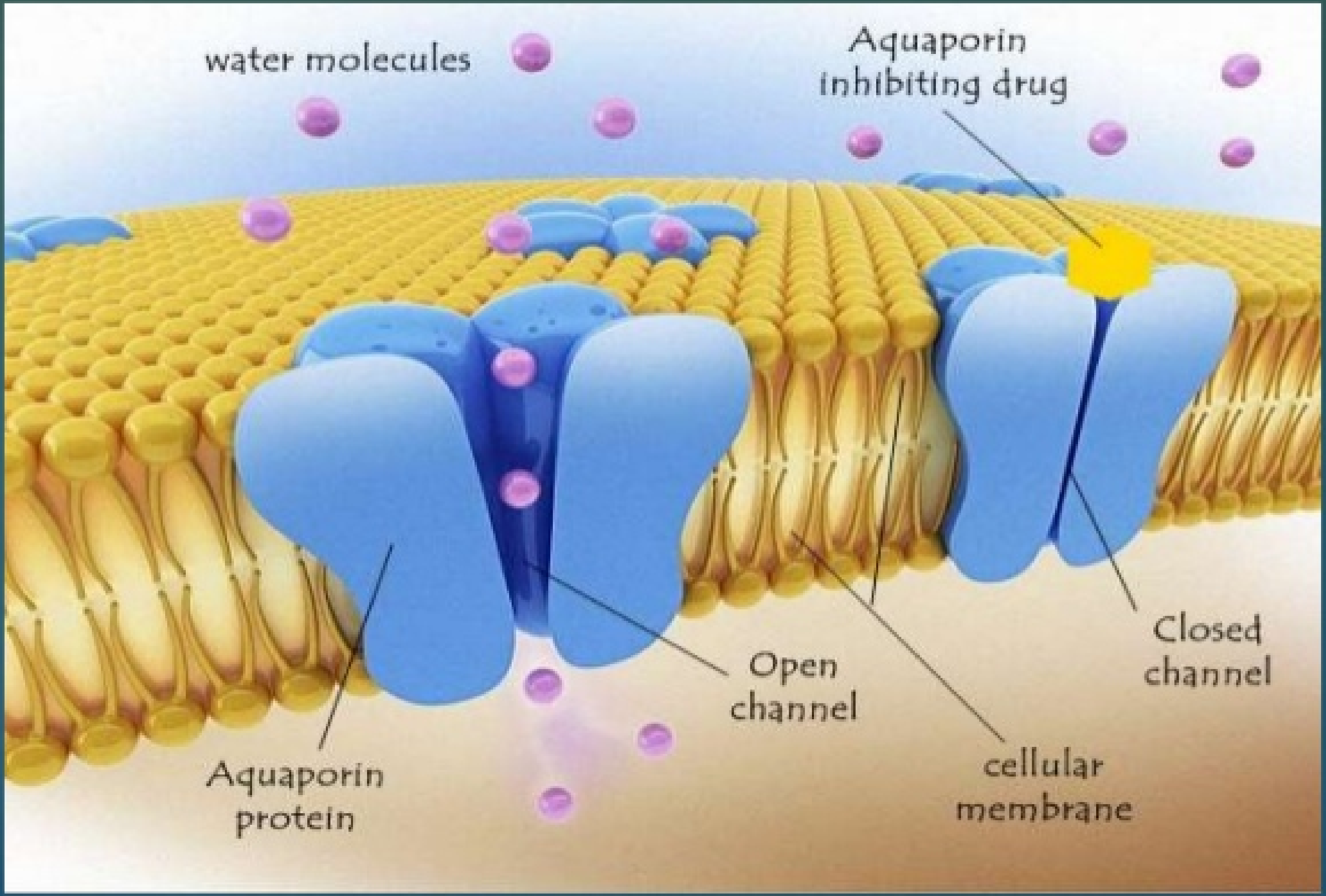
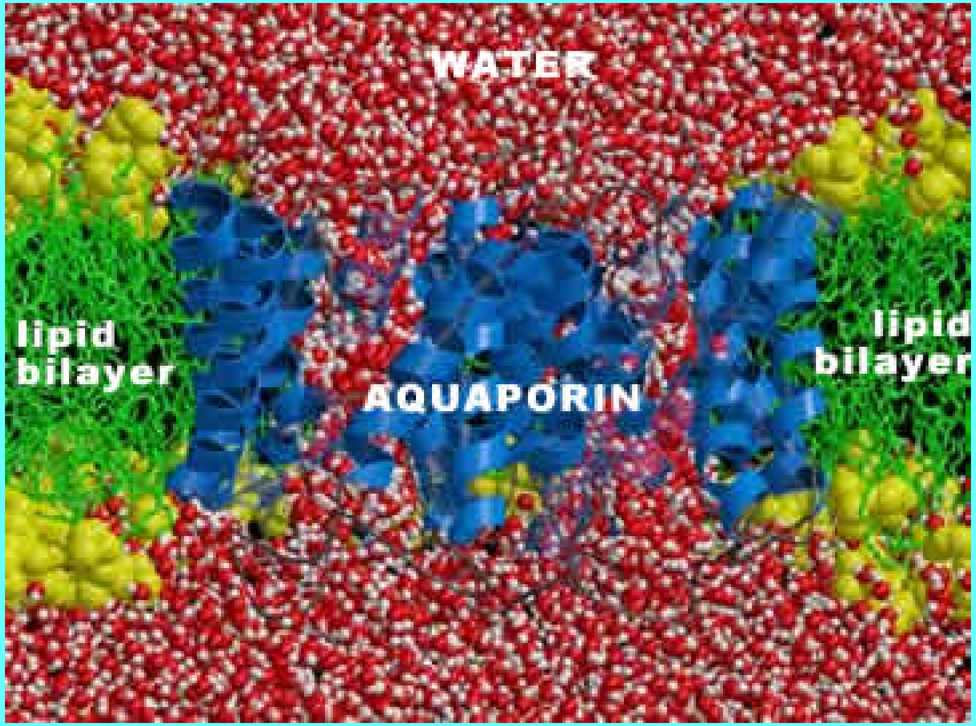

water molecules
Aquaporin
inhibiting drug
Open
channel
Closed
channel
cellular
membrane
Aquaporin
protein


WATER
lipid
bilayer
AQUAPORIN
lipid
bilayer