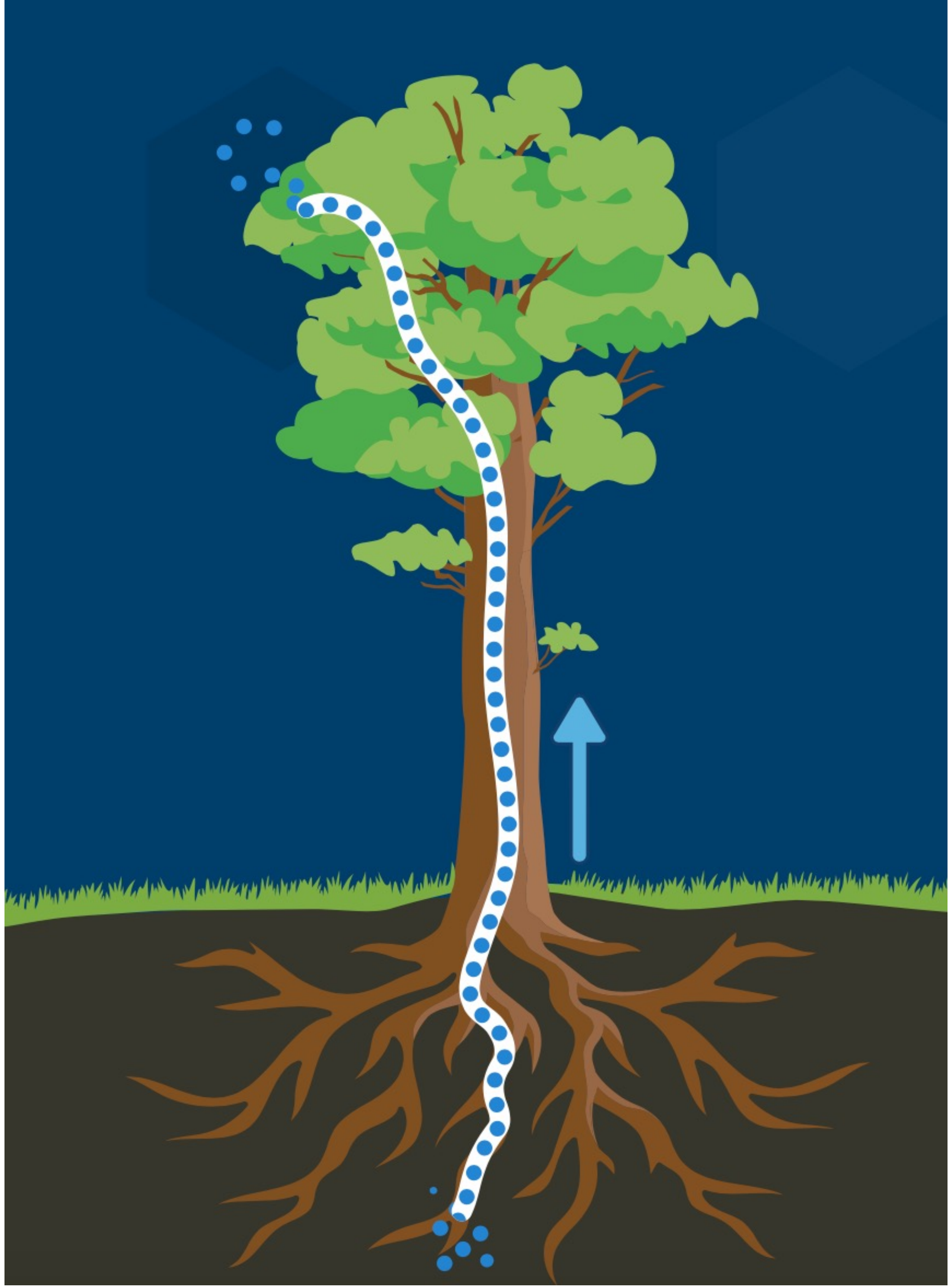
Plant Solutions for climate change

Lecture 2

ABIOTIC STRESS AND PLANT BIOLOGY

- how stress affects physiological and molecular processes and adaptation
- use our physiological and molecular knowledge to both predict the effect of climate change on plants and intervene to improve those outcomes, particularly in terms of ecosystem resiliency or crop yield
- how to move our knowledge from one scale to another
- How to link OMICS data to stress phenotypes “phenotype gap”
- What is stress resistance? ability to better survive a near-lethal stress or the ability to remain more productive during a moderate severity stress? agronomic versus ecophysiology perspective
- how plants perceive the stress at the molecular scale? No receptor–ligand; how to investigate downstream responses?
- how plants control the movement of water through the soil–plant–atmosphere continuum and how stress responses may be coordinated across different tissues. Hydraulic vs nonhydraulic/chemical signals?
- Growth-versus-defense” or water spender vs water saver trade-off (Saving water in the soil for later is less effective if your neighbor spends it first)

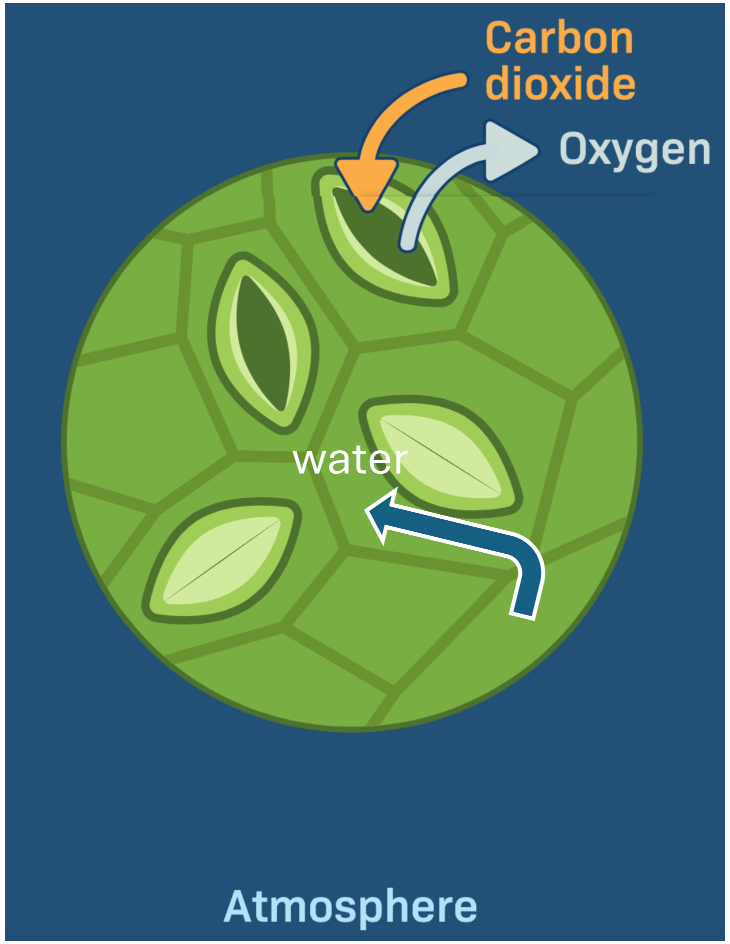
(from the Introduction to Burning questions for a warming and changing world: 15 unknowns in plant abiotic stress)

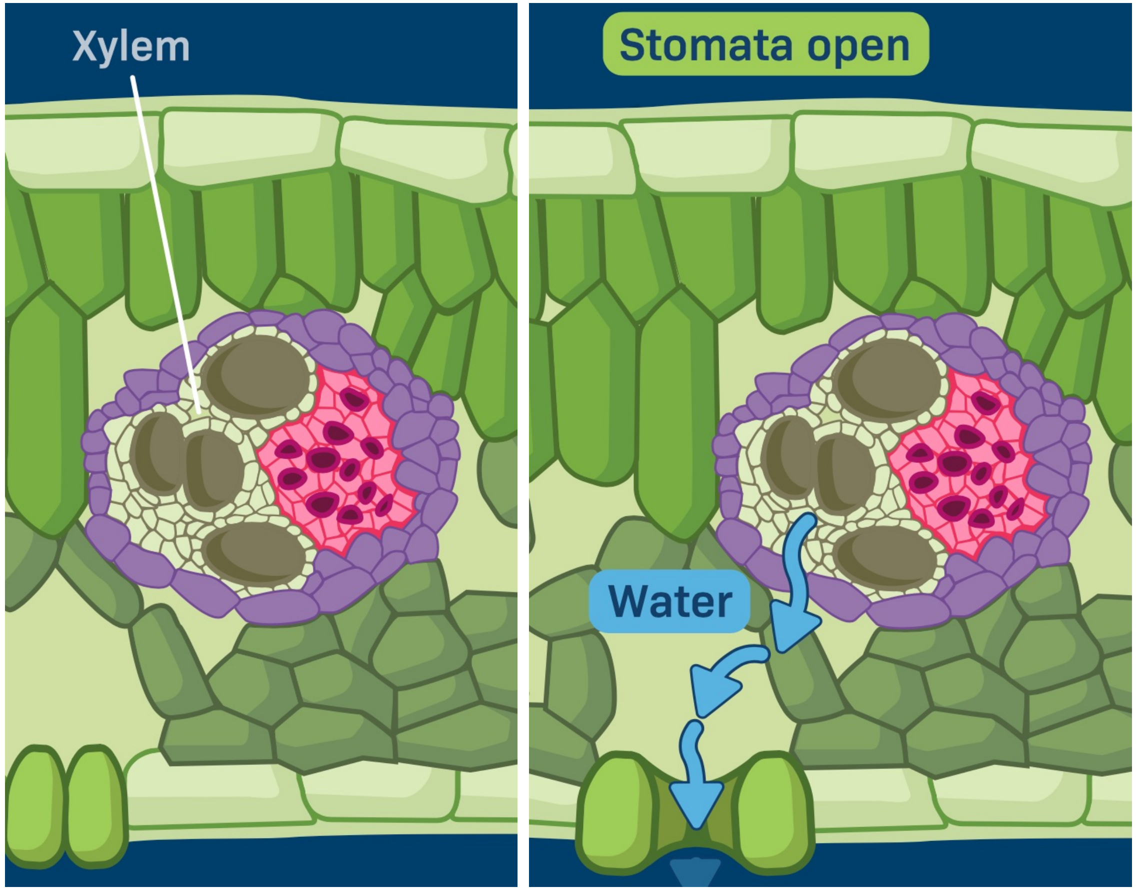


WATER TRANSPIRATION IN PLANTS

Plants absorb water from the soil to replace the water that is lost by transpiration. The continuous upward movement of water from the soil to the leaves is known as the transpiration stream.

A tall tree, like an 80-meter giant redwood, can lose up to 114 liters (L) of water to the atmosphere every day.



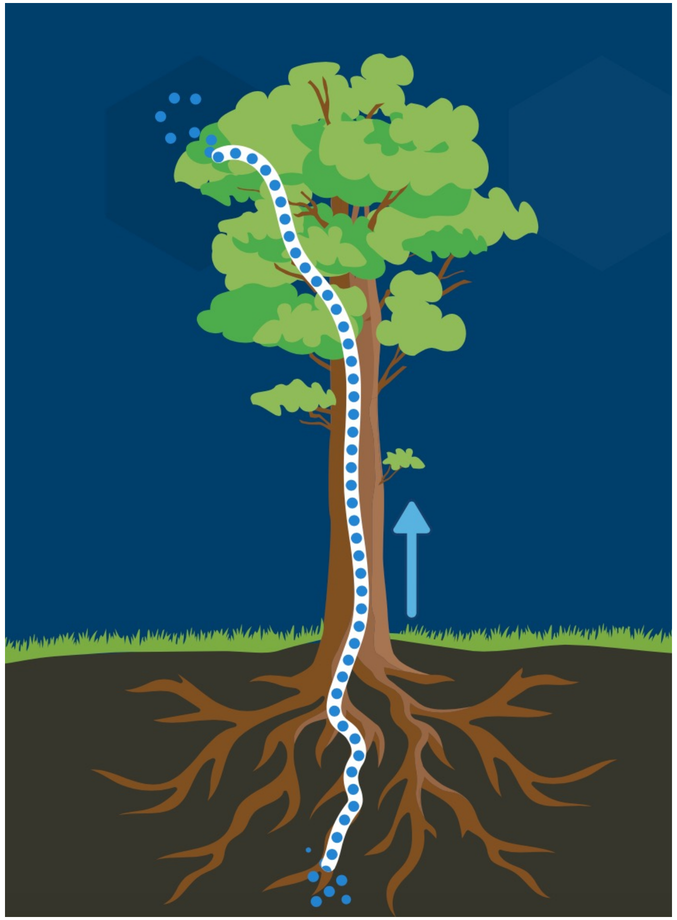


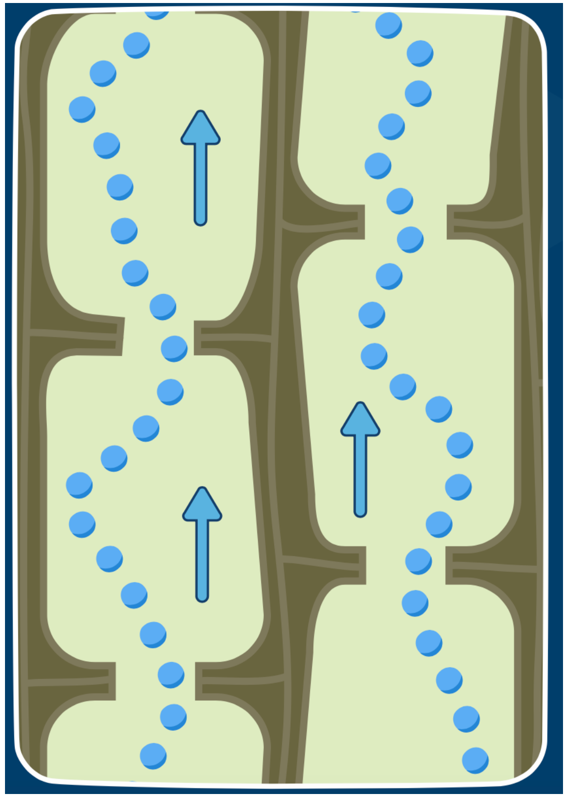
During photosynthesis, oxygen is released and **carbon dioxide** is consumed. Water also evaporates into the atmosphere through the open stomata

inside the leaf, the **xylem** bring the water required for photosynthesis up from the soil to the leaf. When stomata open to allow for the gaseous exchange of carbon dioxide and oxygen that is associated with photosynthesis, water in the leaf **evaporates** into the atmosphere

What is water potential?

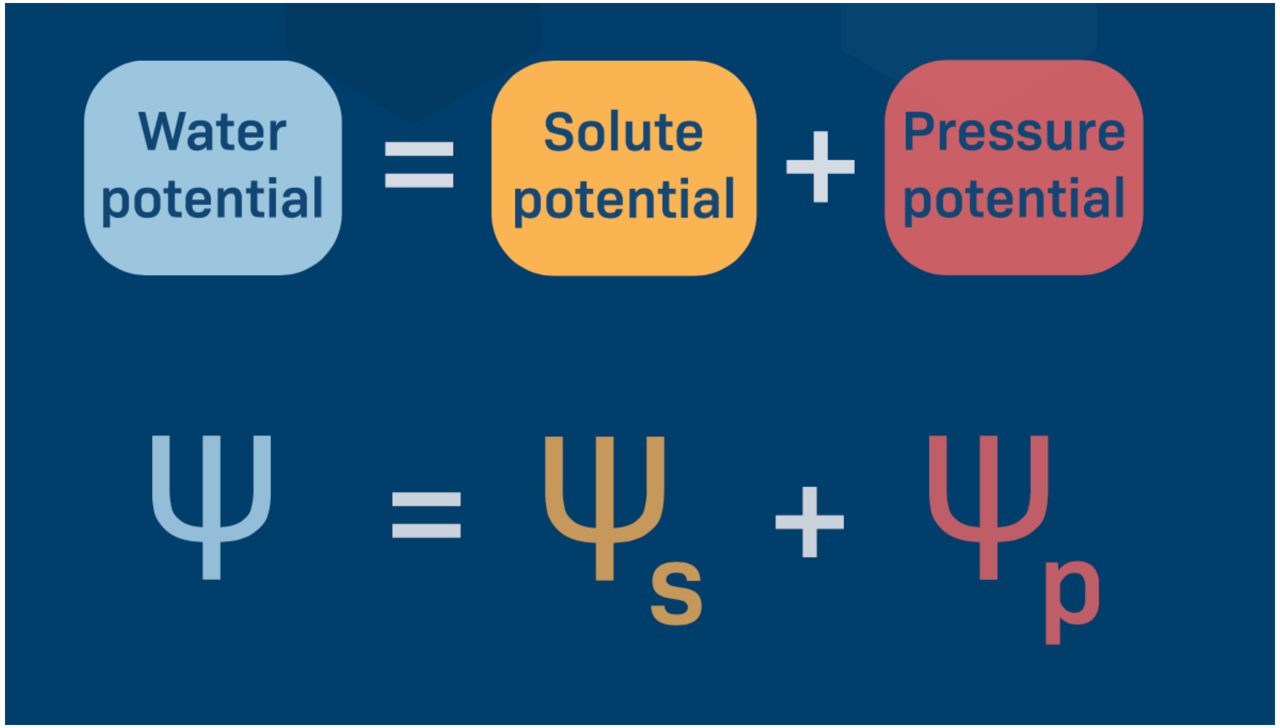
In the xylem, water molecules are strongly bonded to each other. This forms an unbroken string of water molecules that are being pulled upwards by a negative pressure (or tension). In this case, the negative pressure is evaporation from the leaf.





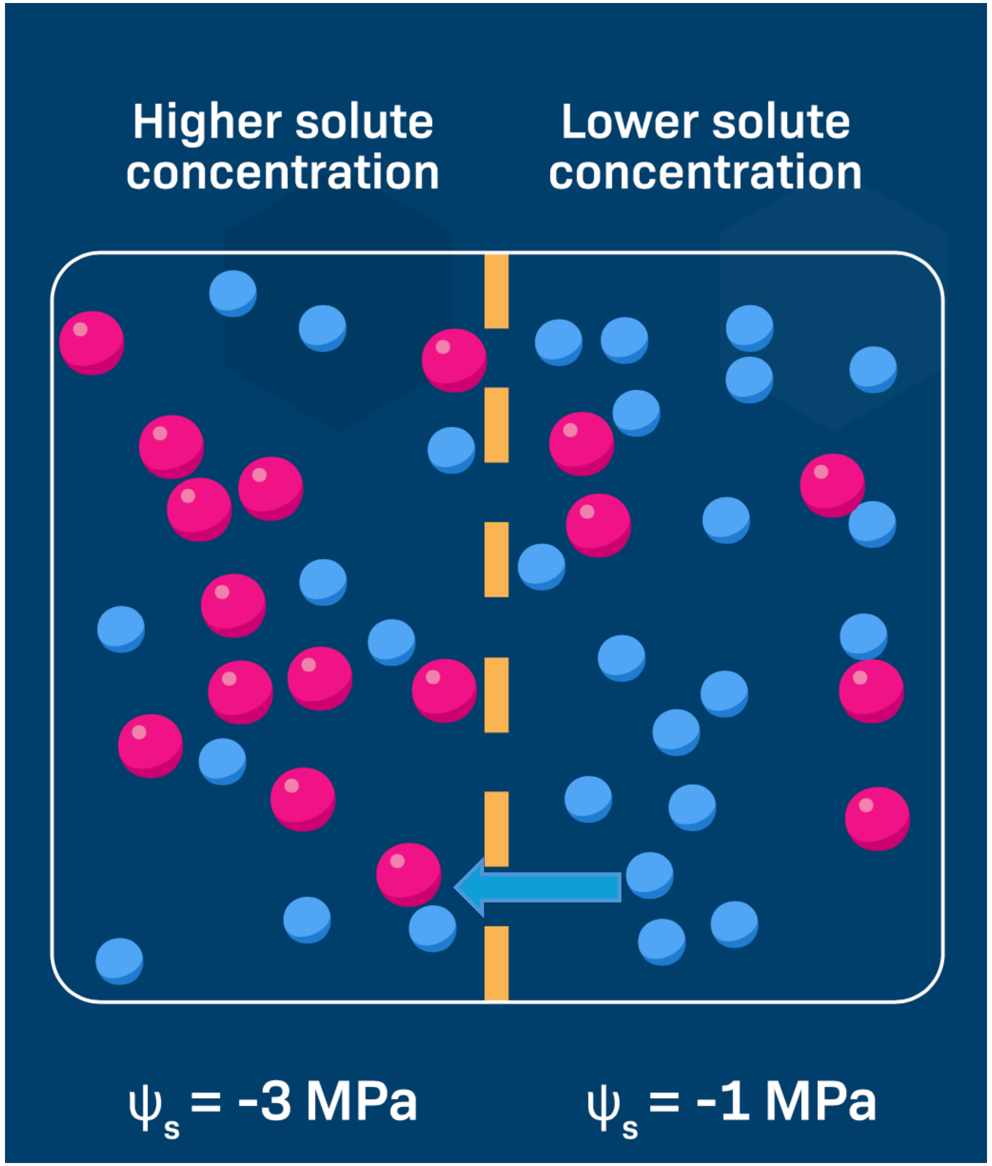
Water potential is a property that helps us predict where water will flow (or move). Water always moves from an area of higher water potential to an area of lower water potential. Water potential is measured in megapascals (MPa), a unit of pressure.

Water potential is calculated by adding solute (or osmotic) potential (ψ_s) and pressure potential (ψ_p).



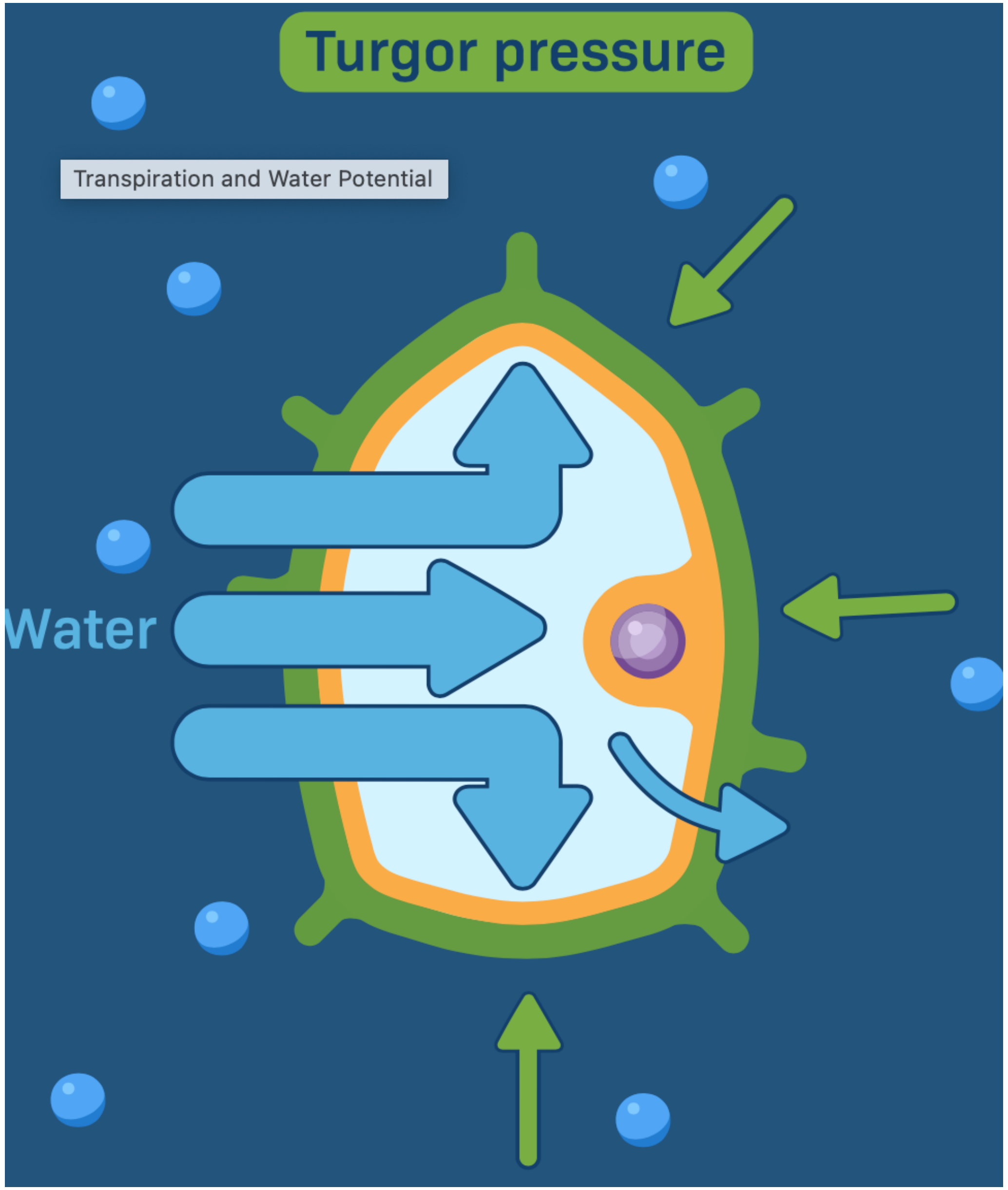
Osmotic (solute) potential

- Pure water has a solute potential of zero because there are no solutes in the solution.
- **solute molecules** (such as sugar) cannot pass through a selectively permeable membrane, but the water molecules can.
- The value of the solute potential (ψs) decreases on the left because there is a higher concentration of solutes. This makes the left half of the solution more negative than the right.
- The difference in solute potential causes the water molecules to passively move, by osmosis, through the selectively permeable membrane to the side with a lower solute potential.
- Solute potential is negative as long as there are solute molecules in a solution. It depends on the number of ions of the solution, the solute molar concentration, pressure and temperature



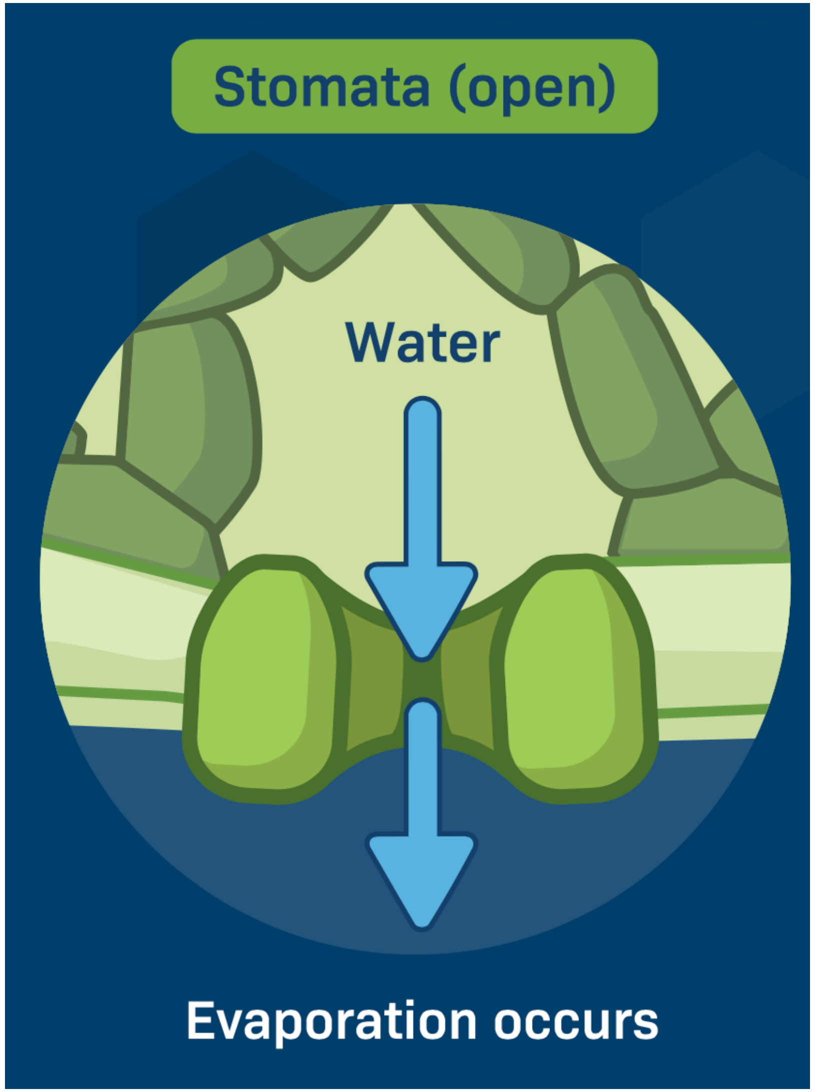
Pressure potential

- Pressure potential (ψ_p) is the movement of water in response to a physical pressure. An example of this is turgor pressure, which is exerted by a plant's cell wall on its cell membrane.
- In the case of plant cell surrounded by water, as water flows into the cell, a small amount can flow out of the cell, but the remaining water causes the cell to swell. As water continues to flow into the cell, the cell membrane swells out towards the cell wall. The cell wall applies pressure to the cell membrane, which prevents the cell from expanding and bursting.
- The pressure which the cell wall exerts to resist the movement of excess water into the cell is called **turgor pressure**.



Guard cells and turgor pressure

- Guard cells regulate the opening and closing of stomata in response to changing turgor pressure. This is done by pumping solutes, like potassium ions, into or out of the guard cells.
- If plant cells have too much water, they actively pump out solute molecules. The water molecules then passively follow the solute molecules out of the cell.
- If they have too little water, they actively pump solute molecules into the cell. Water molecules then passively flow into the cell. Once the guard cells swell, stomata open and water evaporates through the stomata into the atmosphere

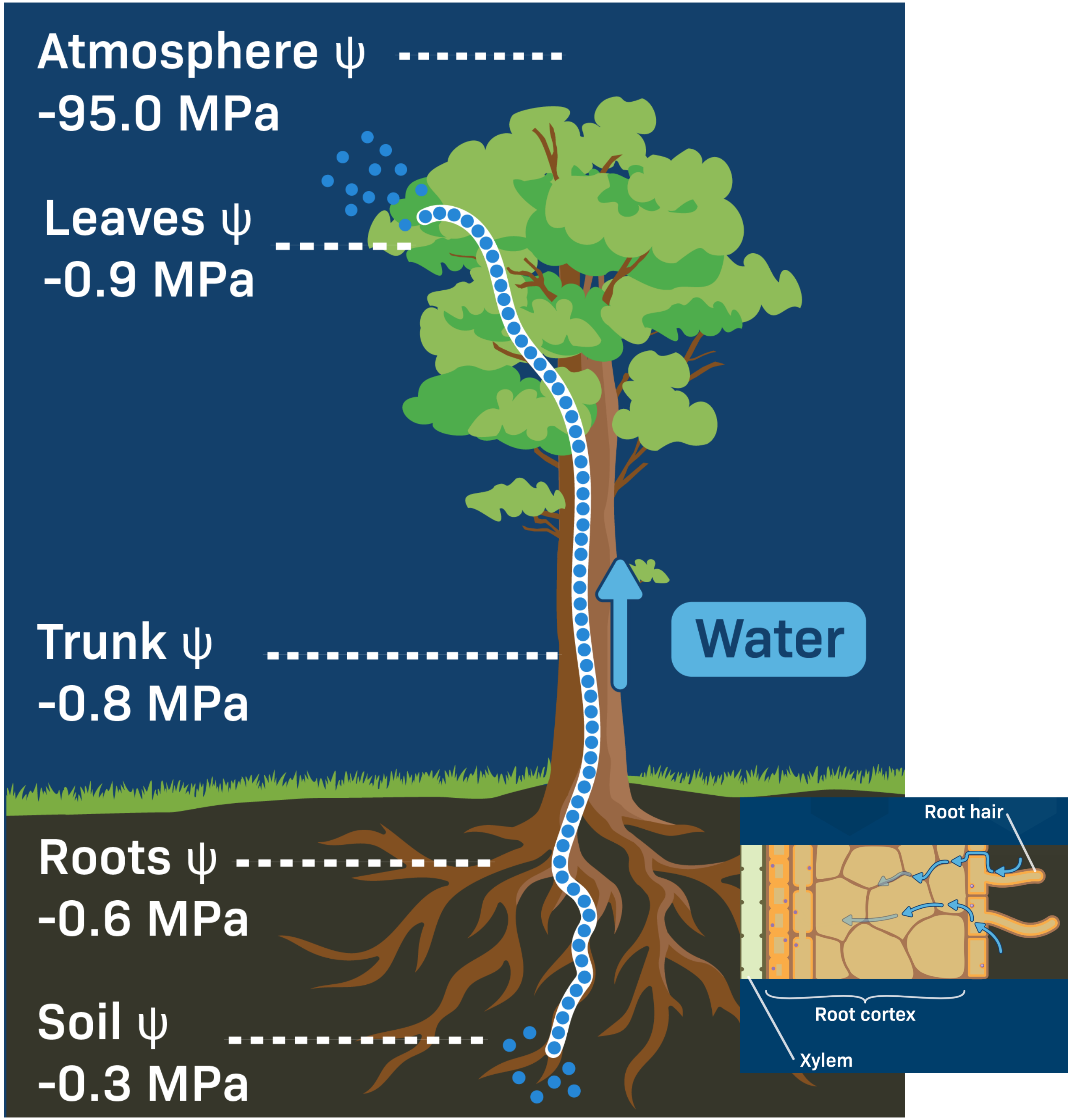


The string of water molecules is pulled upwards and out of the leaves because of a difference in water potential between the leaves (-0.9 MPa) and the atmosphere (-95.0 MPa).

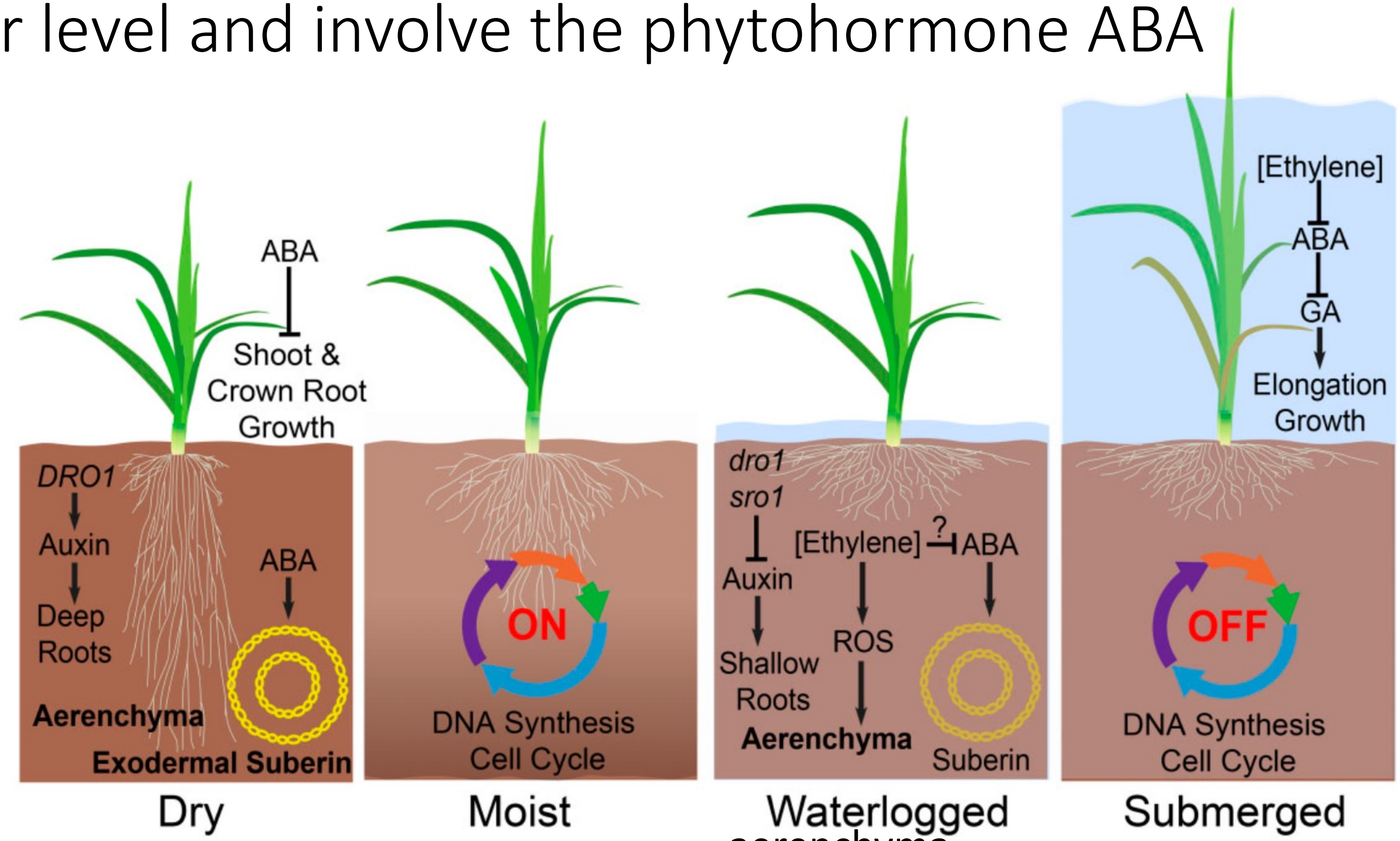
The leaves have an even lower water potential (-0.9 MPa) than the tree trunk (-0.8 MPa), so water molecules move from the tree trunk into the leaves.

The water molecules move upwards in the xylem since the tree trunk has a lower water potential (-0.8 MPa) than the roots (-0.6 MPa).

Root hair cells have a high solute concentration compared to the surrounding soil, generating a water potential gradient. The soil has a higher water potential than the root hair cells. Water molecules move from the soil into the root hair cells by osmosis. Root hair cells do not actively pump water in. Once they pump in the solutes, the water passively follows.



Regulatory processes governing long-term adjustments and stomata responses to changes in water status are well understood on a molecular level and involve the phytohormone ABA



water loss limited by by deposition of a suberin barrier, on the exodermis

compact root architecture, limited exodermal suberization

aerenchyma proliferation near the soil surface and suberin prevent oxygen loss by radial diffusion

cell division activity in root systems is rapidly switched off and leaf elongation is enhanced, promoting escape to the air

How is the change in water potential in the plant perceived?

- Changes in hydraulic parameters serve as a fast long-distance signal and can be perceived by a a mechano-sensitive mechanism (ex. touch-induced leaf closure of the Venus flytrap)
- No water-deficit sensing receptors
- How is ABA production induced?
- Monitoring cell wall integrity/