SOIL WATER: CHARACTERISTICS AND BEHAVIOR

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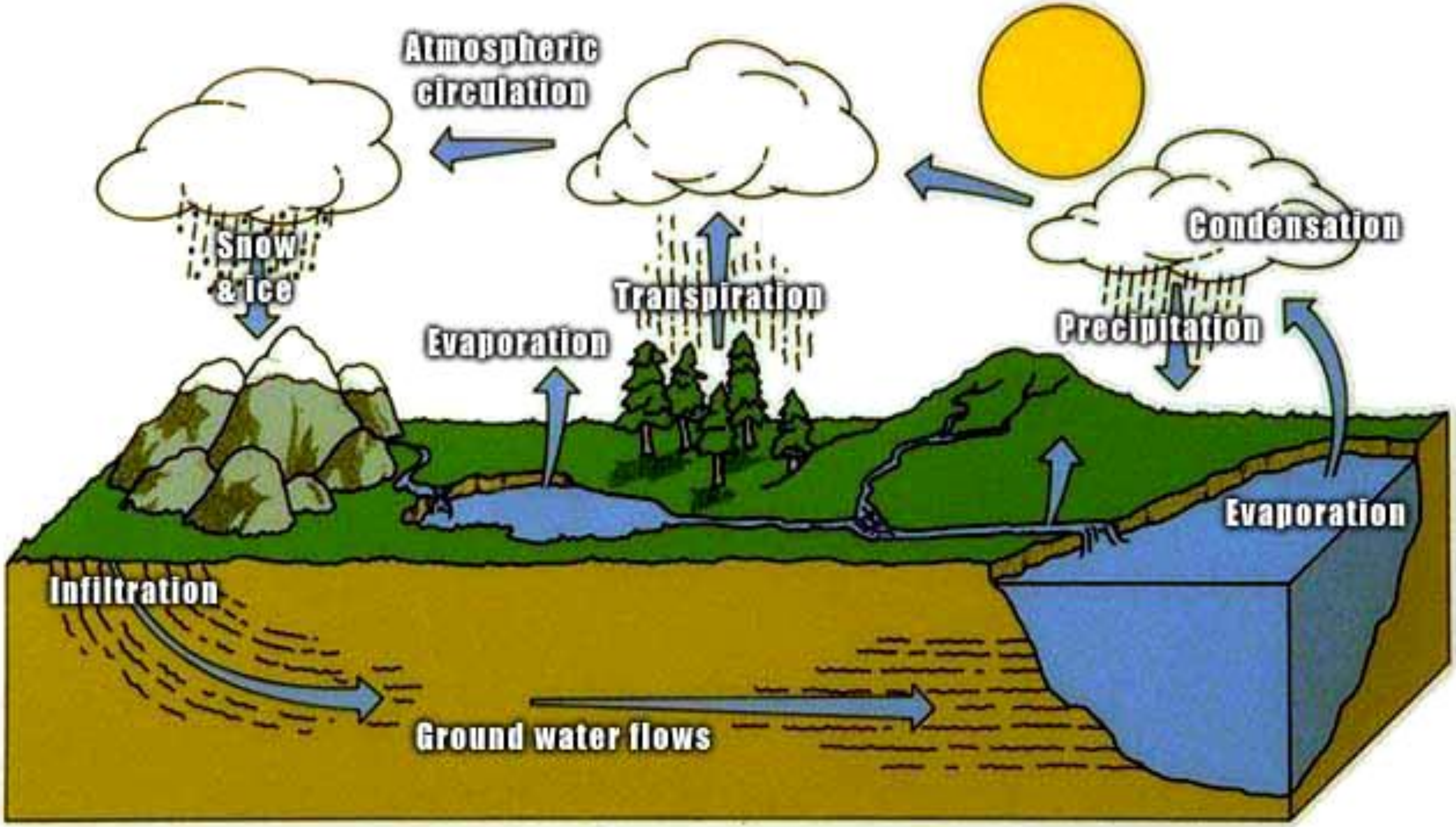


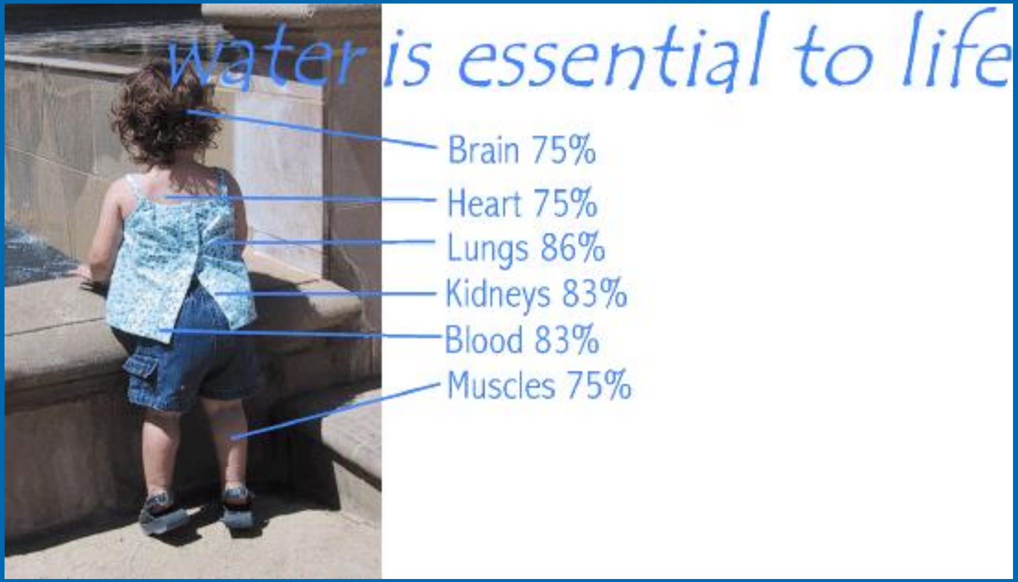
Water falls as precipitation and returns to the atmosphere as evaporation and transpiration. Over oceans, evaporation exceeds precipitation while over land precipitation may be stored in glaciers and icecaps, in rock and soil and vegetation, or may enter into lakes and streams before returning to the sea.

The Water Cycle

THE IMPORTANCE OF WATER

- Water is a vital component of all living things

- Soil water is intimately associated with solid particles



WATER AND SOIL PARTICLES

- Shrink and swell
- Adhere to each other
- Form **aggregates**

SOIL WATER AND ECOLOGY

- Amount of rainwater that runs into and through the soil

- Movement of chemicals in groundwater
- Rate of water loss via **leaching** and **evapotranspiration** (ET)


Groundwater contaminated from waste disposal site
Recharge area
Waste disposal site
Water table
Water
supply wells
Contaminated
groundwater

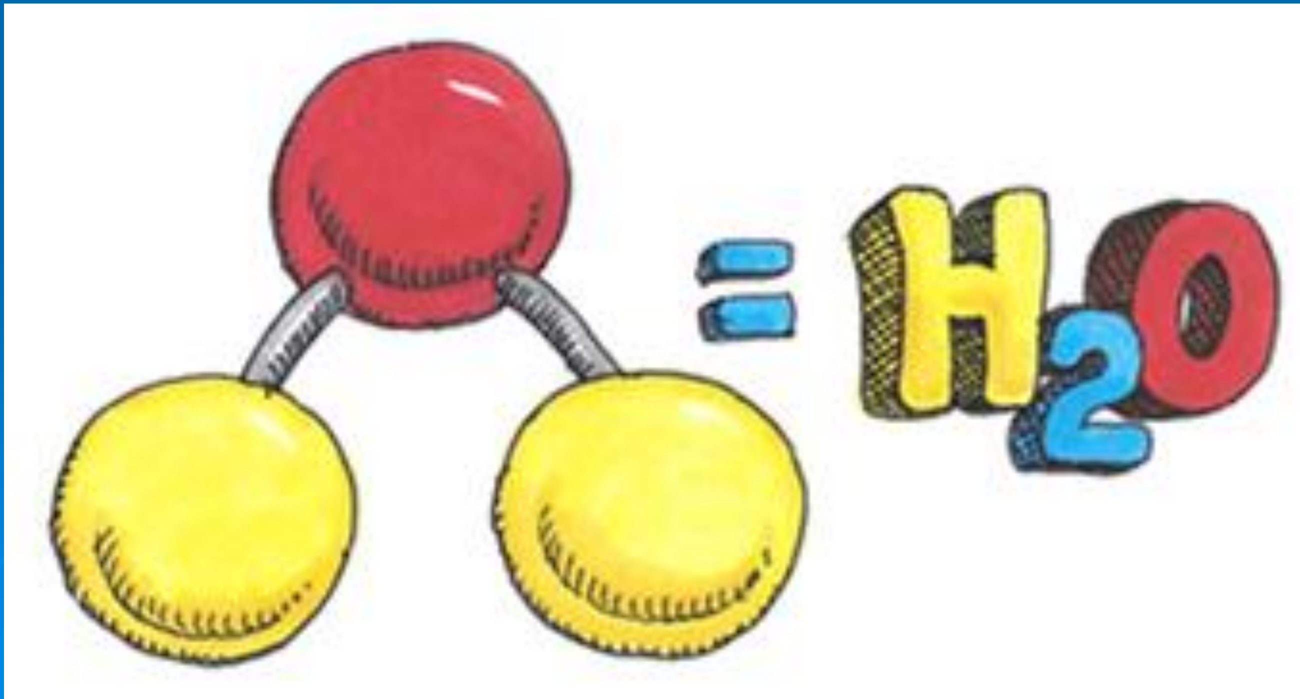
EFFECTS OF WATER AND SOIL RELATIONS

- Rate of change of soil temperature
- Rate and kind of metabolism of soil organisms
- Capacity of the soil to store and provide water for plant growth

- ***The characteristics and behavior of water is a common thread that interrelates with every aspect of soil science and the soil system*****!**

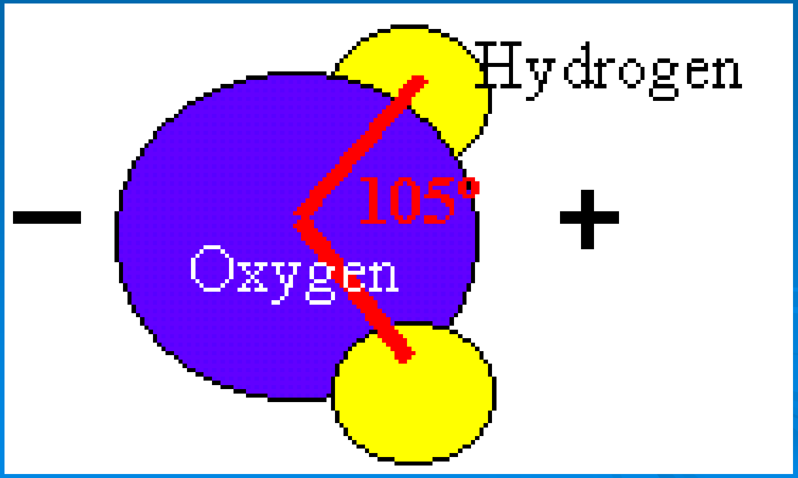
STRUCTURE AND PROPERTIES OF WATER

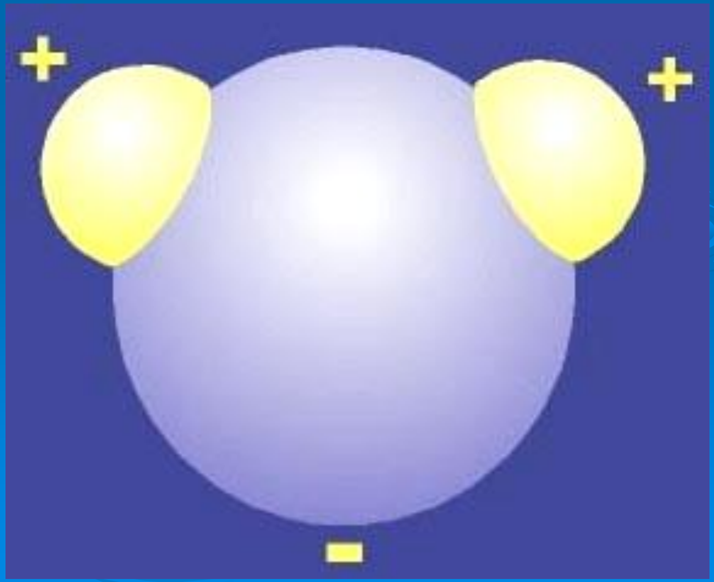
- **Liquid**, not a gas or vapor
- Only **inorganic liquid** found on earth (exception mercury)



STRUCTURE AND PROPERTIES OF WATER

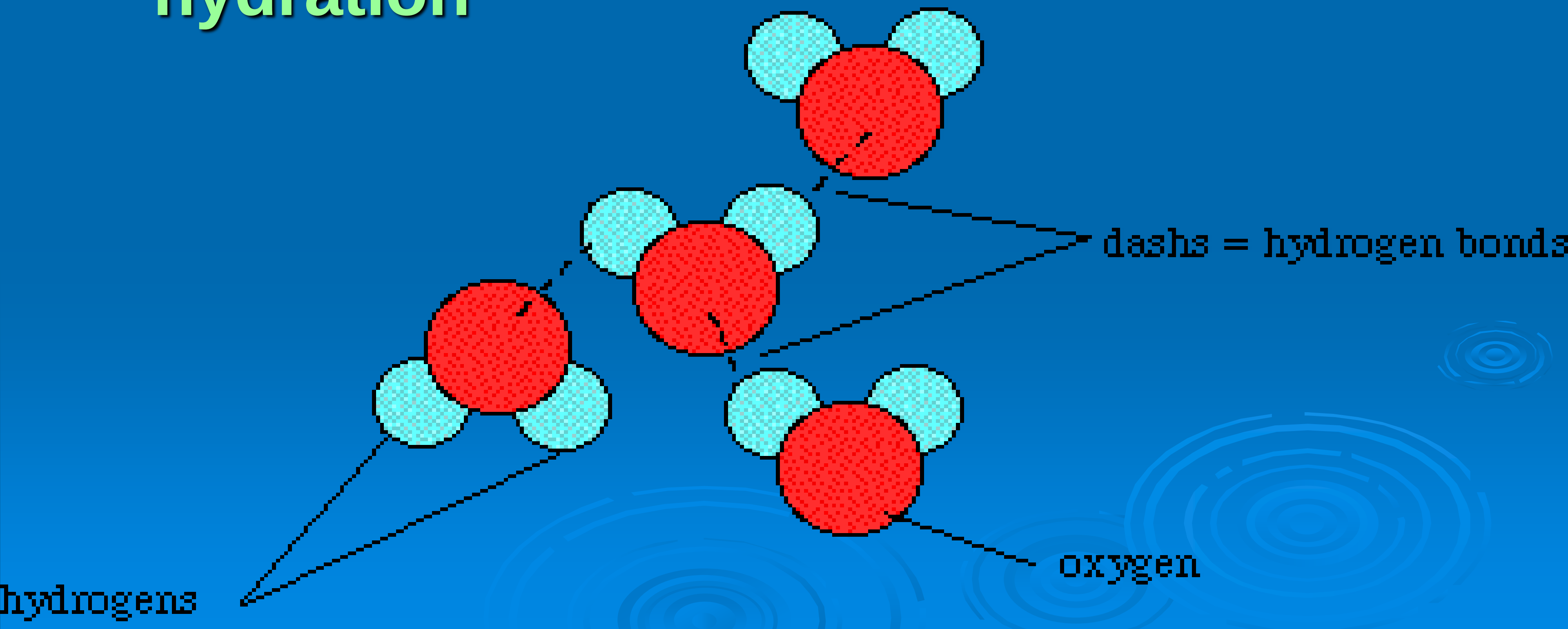
- **V-shaped arrangement** of water molecule
  - Angle of 105 degrees
- **Exhibits polarity** (charges are not evenly distributed)





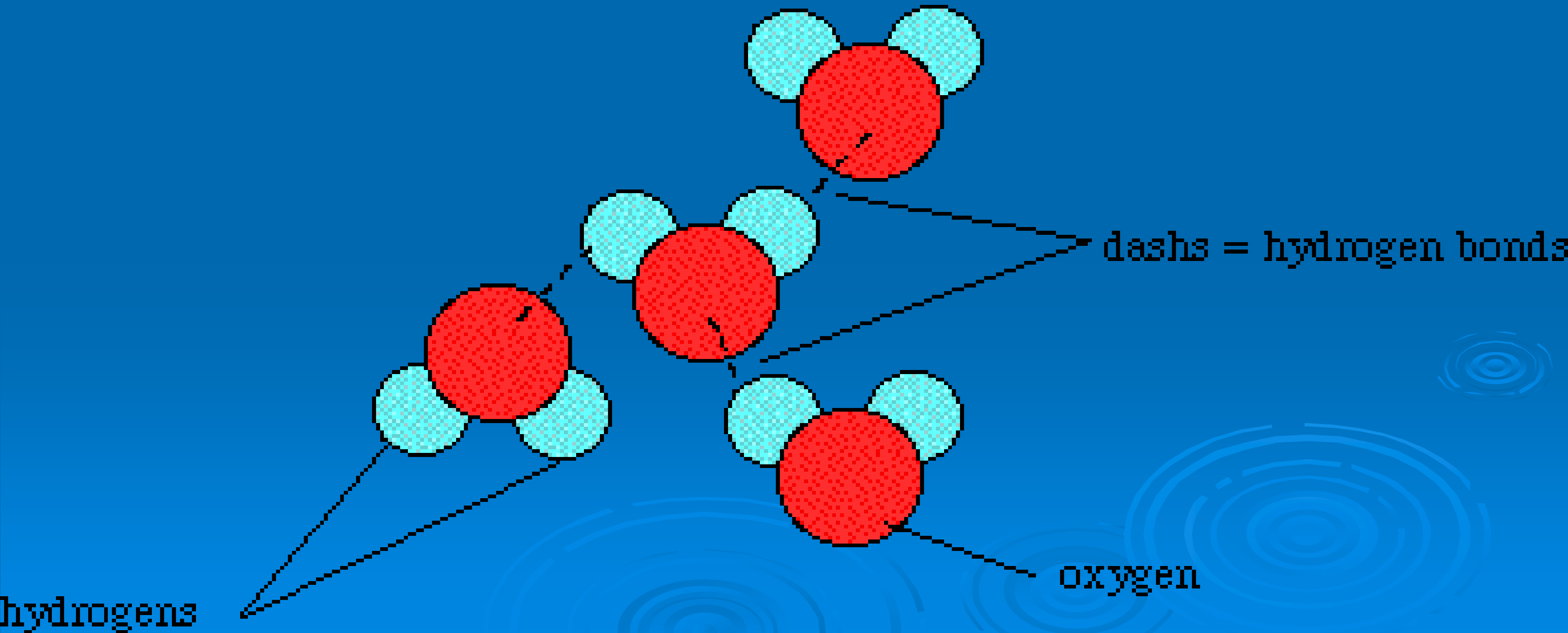
STRUCTURE AND PROPERTIES OF WATER

- **Negative** (oxygen) end is attracted to cations H, Na, K, and Ca resulting in **hydration**



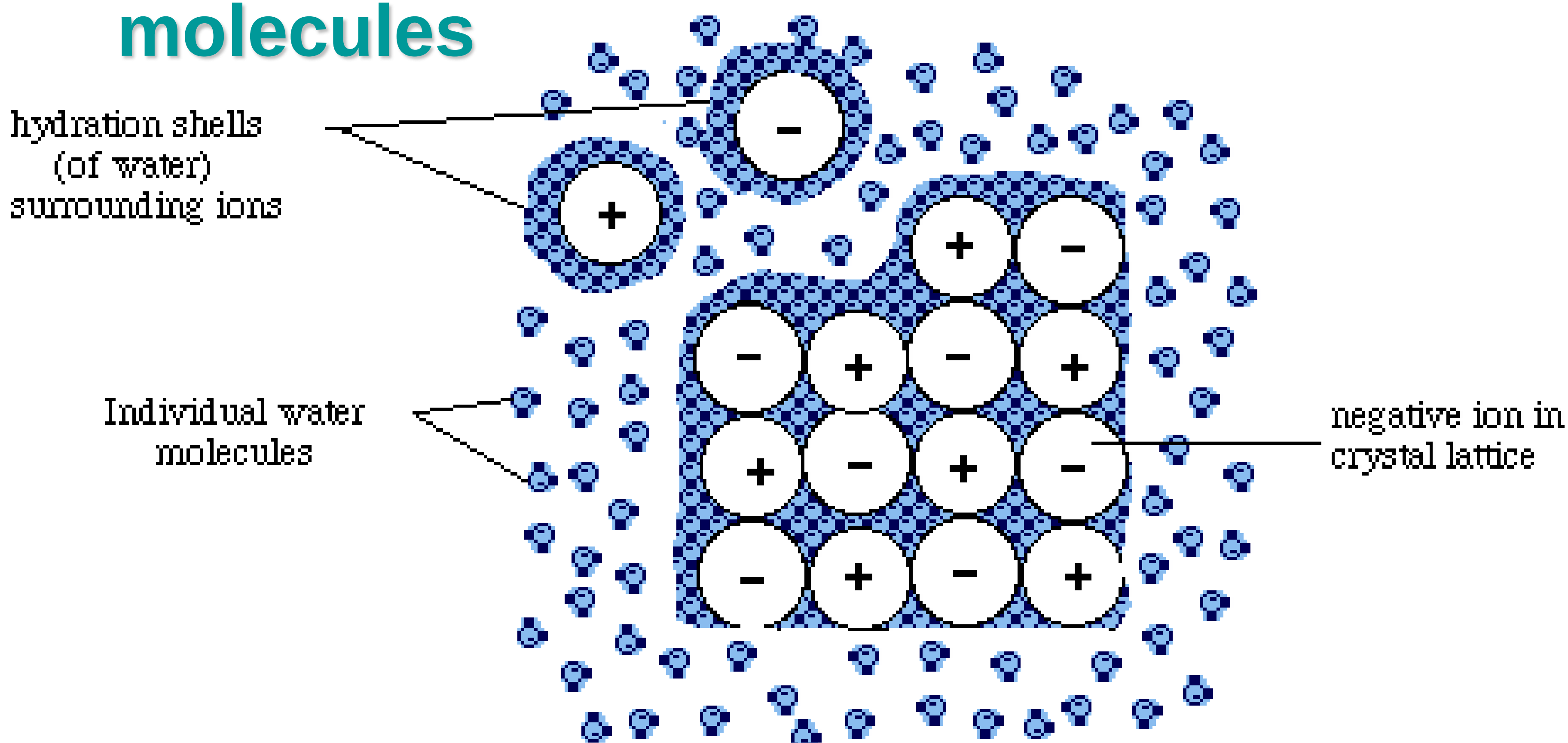
STRUCTURE AND PROPERTIES OF WATER

- **Positive** (hydrogen) end is attracted to negatively charged clay surfaces



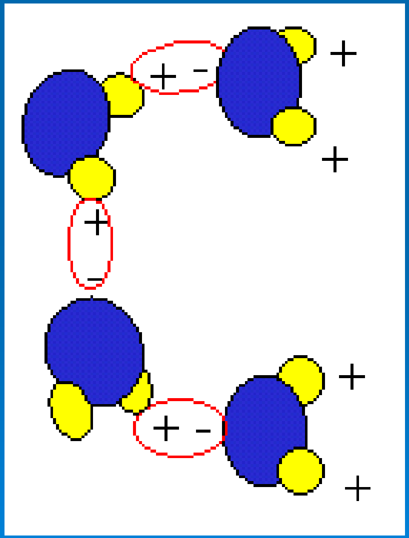
HYDRATION

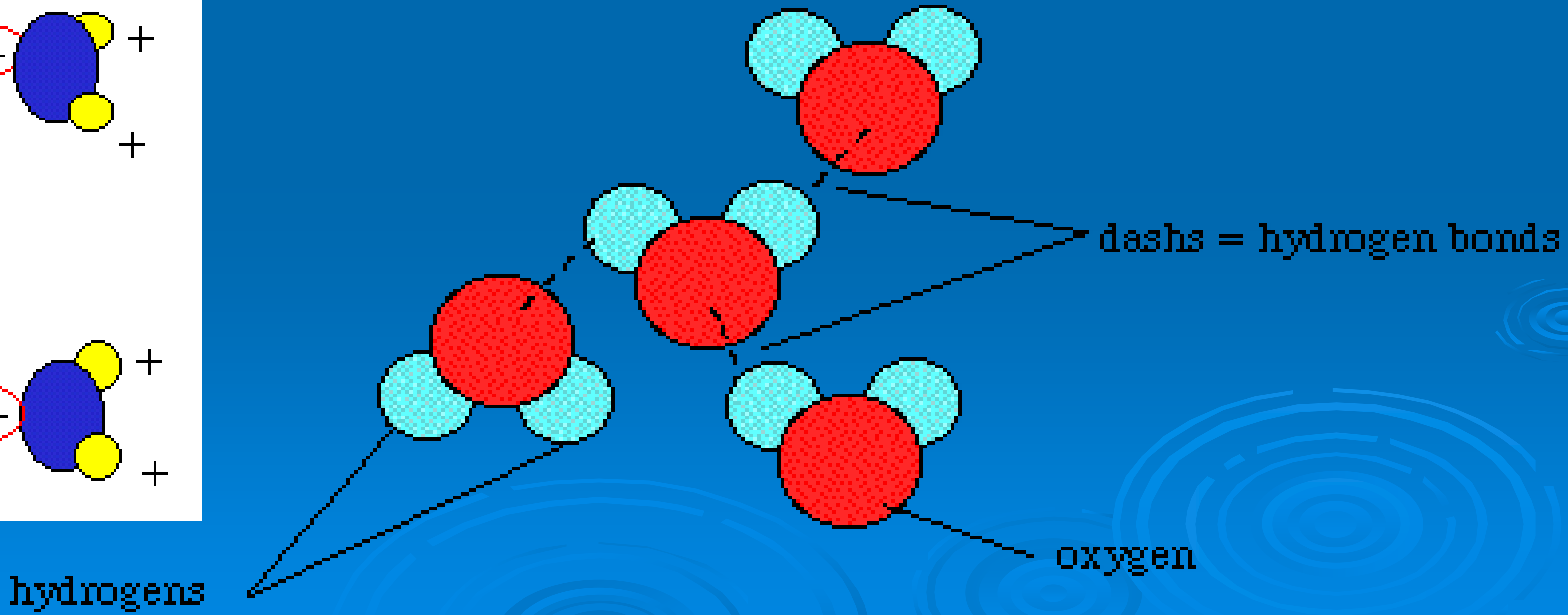
- Chemical union between an ion or compound and one or more water molecules



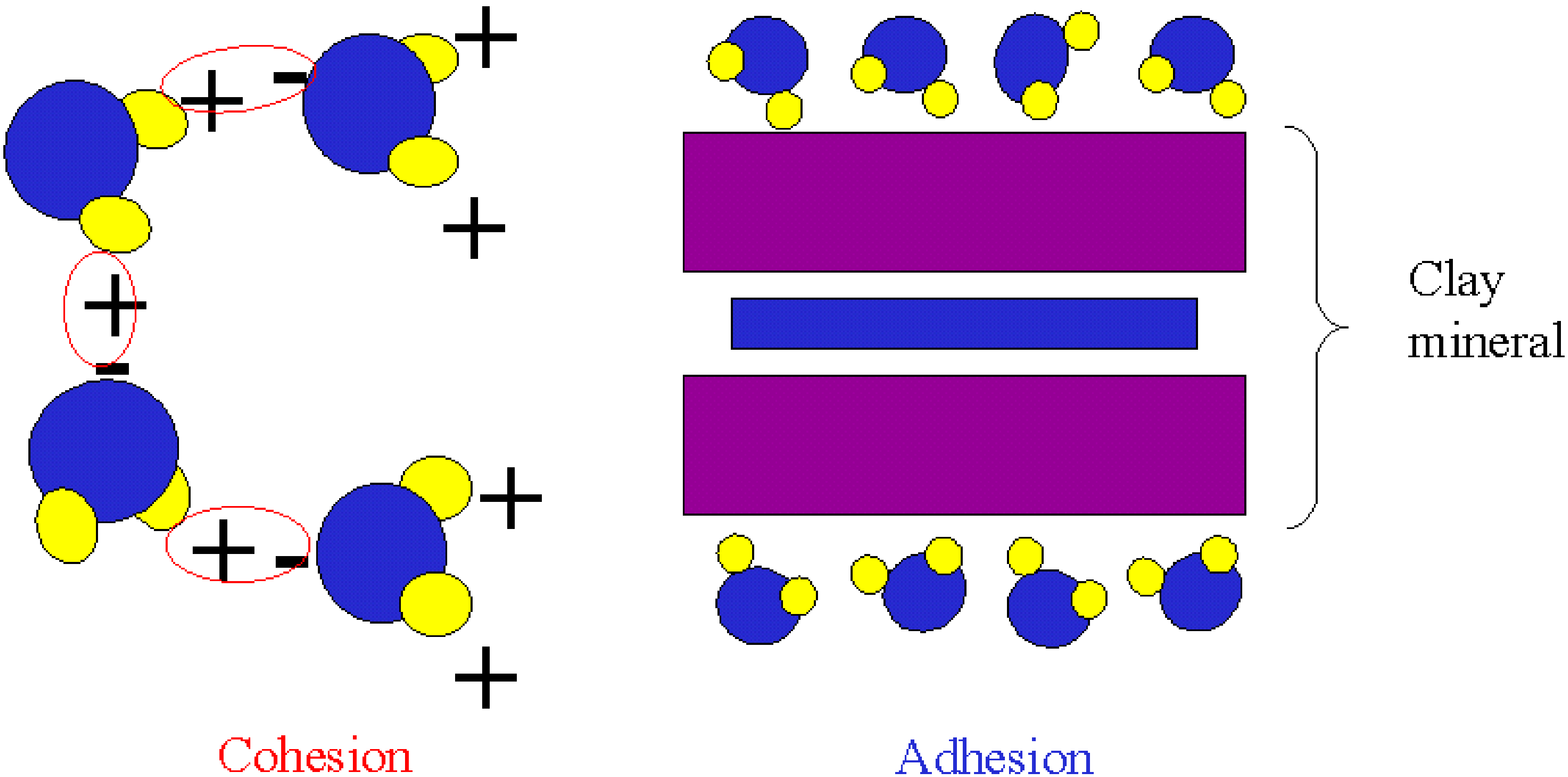
HYDROGEN BONDING

- Water retention
- Water movement in soils



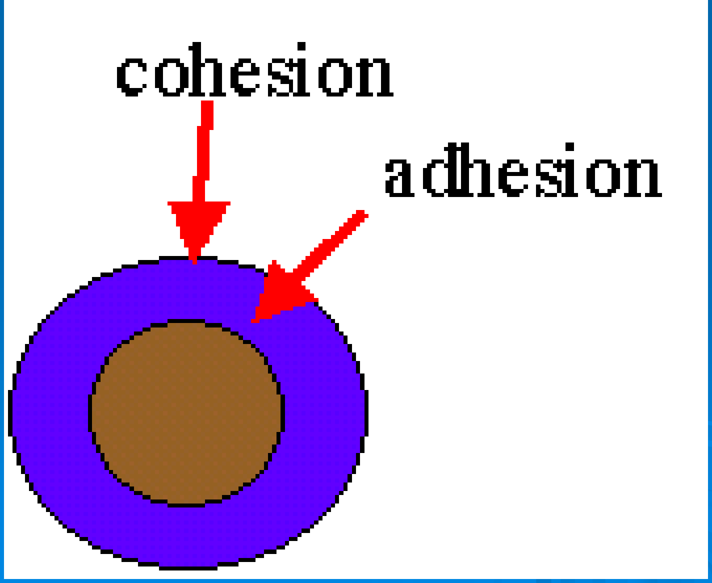


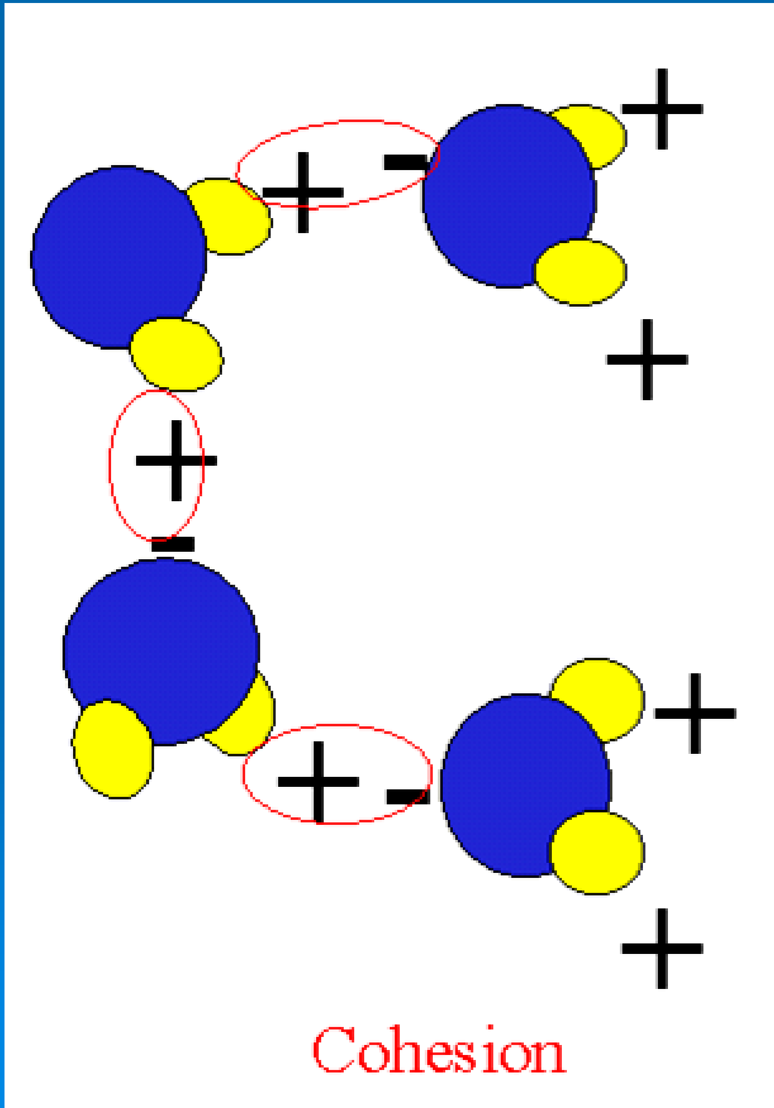
COHESION AND ADHESION OF WATER



COHESION OF WATER

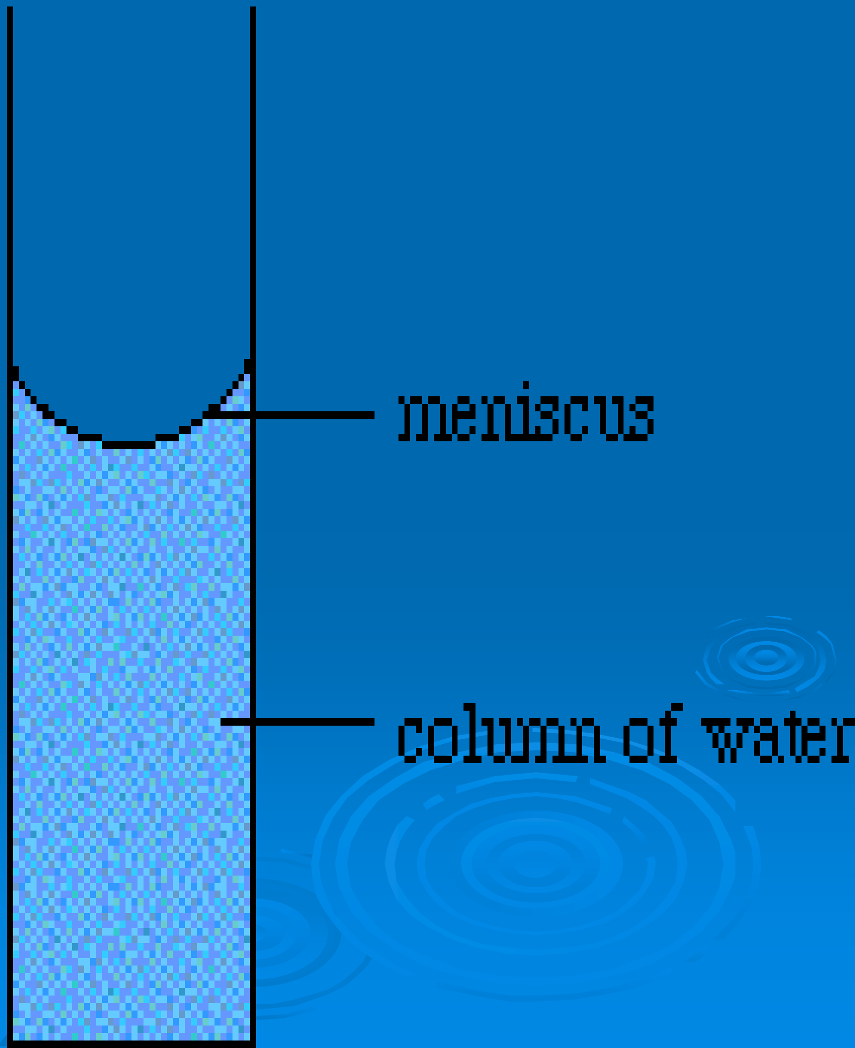
- **Attraction of water molecules for each other**



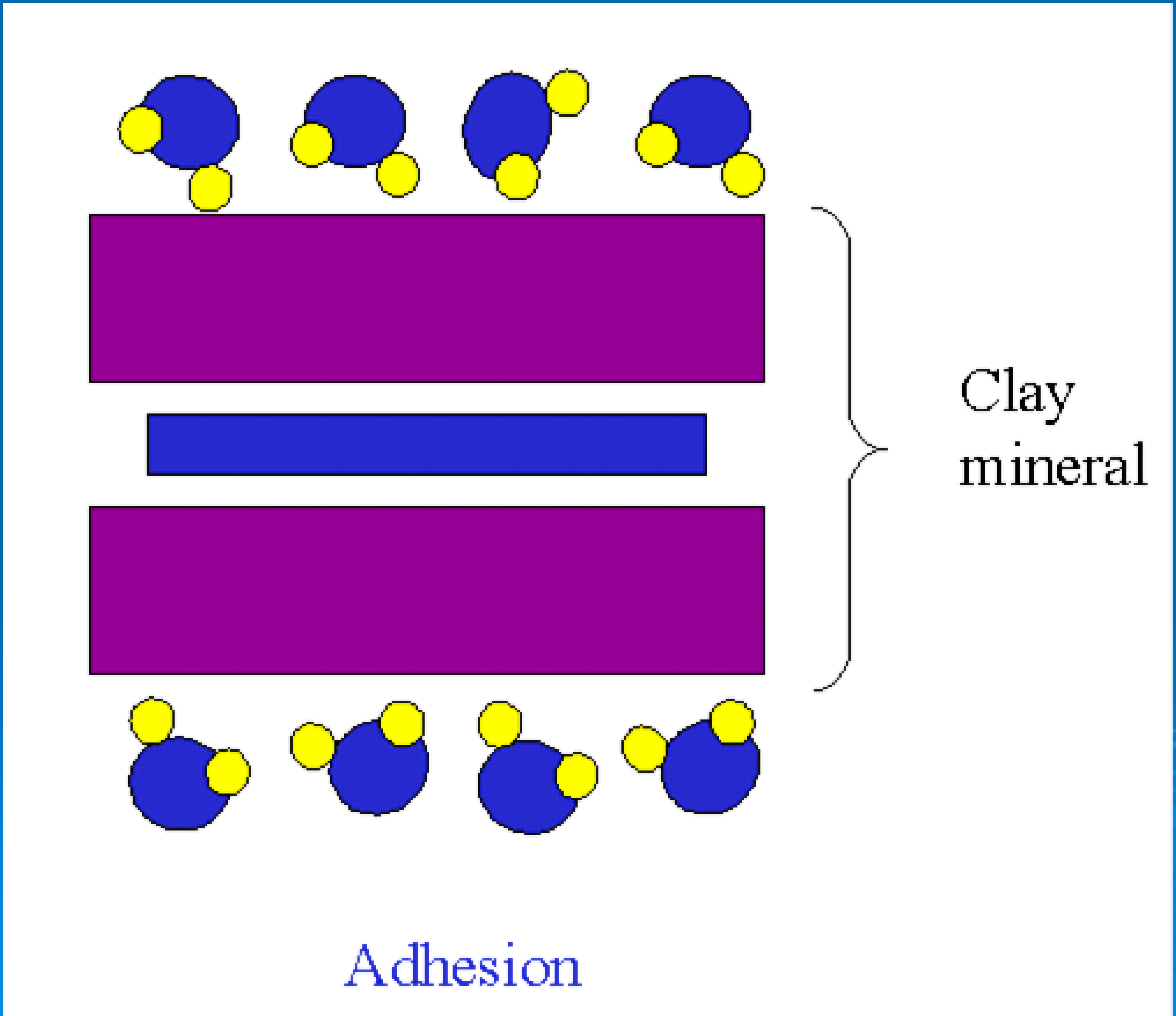


ADHESION OF WATER

- Attraction of water molecules for a solid surface

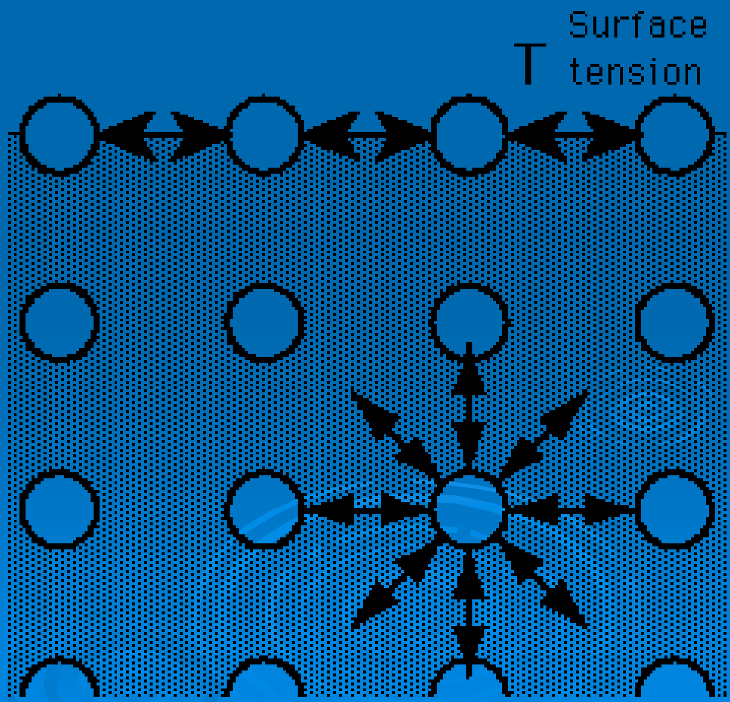


ADHESION OF WATER



SURFACE TENSION

- **Greater attraction of water molecules for each other (cohesion) than for the air above**
- Important factor in **capillarity**
- Determines how water moves and is retained in the soil



SURFACE TENSION

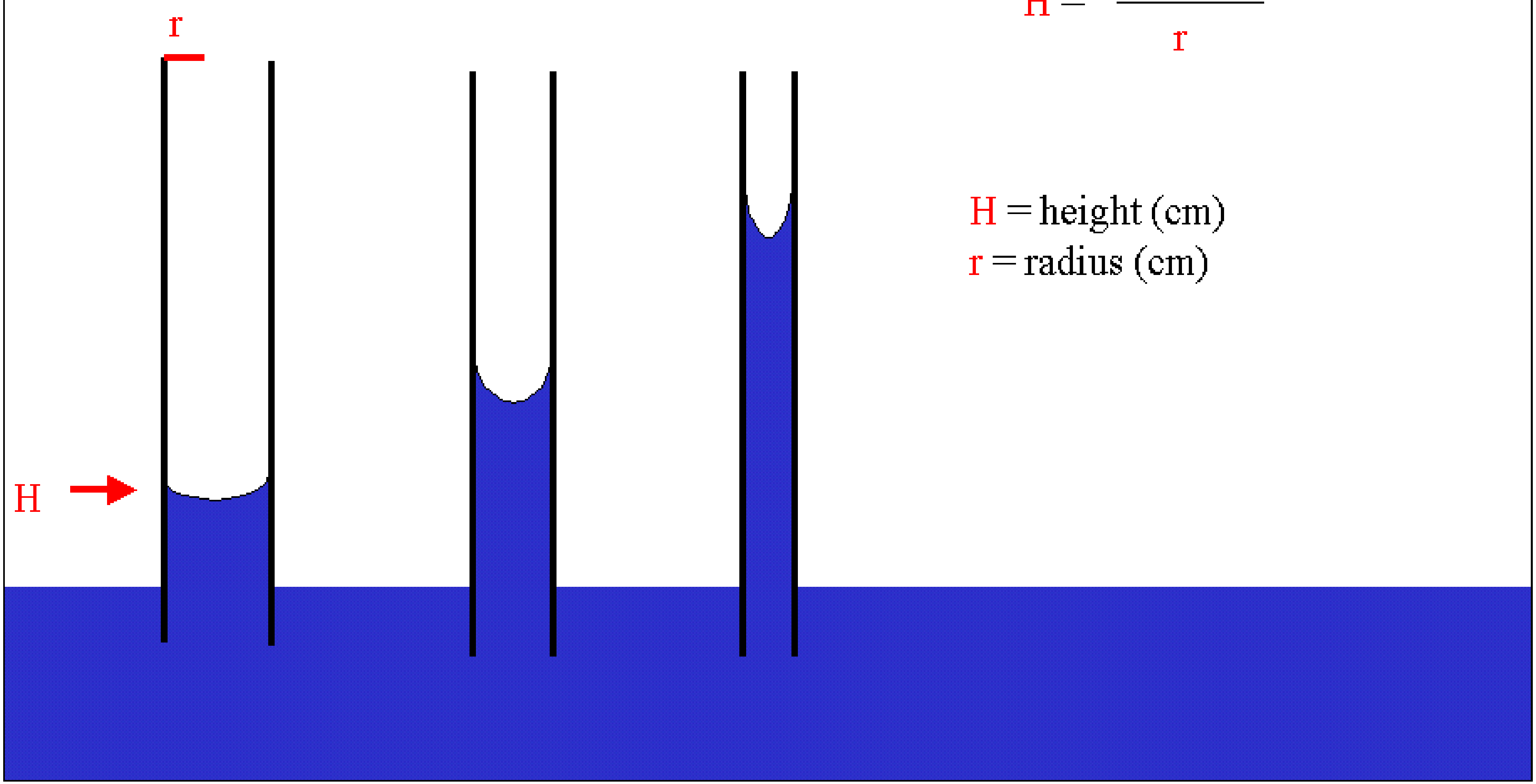
- **Water has a high surface tension**
  - 72.8 newtons for water
  - 22.4 newtons for alcohol

CAPILLARITY AND SOIL WATER

- **Capillarity** – movement of water up a wick
  - Attraction of water for a solid (**adhesion**)
  - Surface tension (**cohesion**)

- **Height of rise in tube is inversely proportional to the tube radius (*r*)**

CAPILLARY ACTION



$$H = \frac{0.15}{r}$$

H = height (cm)
r = radius (cm)

CAPILLARITY AND SOIL WATER

- **Capillary rise** is **inversely proportional** to the density of the liquid

- **Capillary rise** is **directly proportional** to the liquid's surface tension and degree of adhesive attraction to the soil surface

CAPILLARITY FUNDAMENTALS AND SOIL WATER

- Water moves in the soil primarily by **capillarity** when soils are not saturated

- When soils are saturated, water moves primarily by gravity (**gravitational water**) until **field capacity** is reached

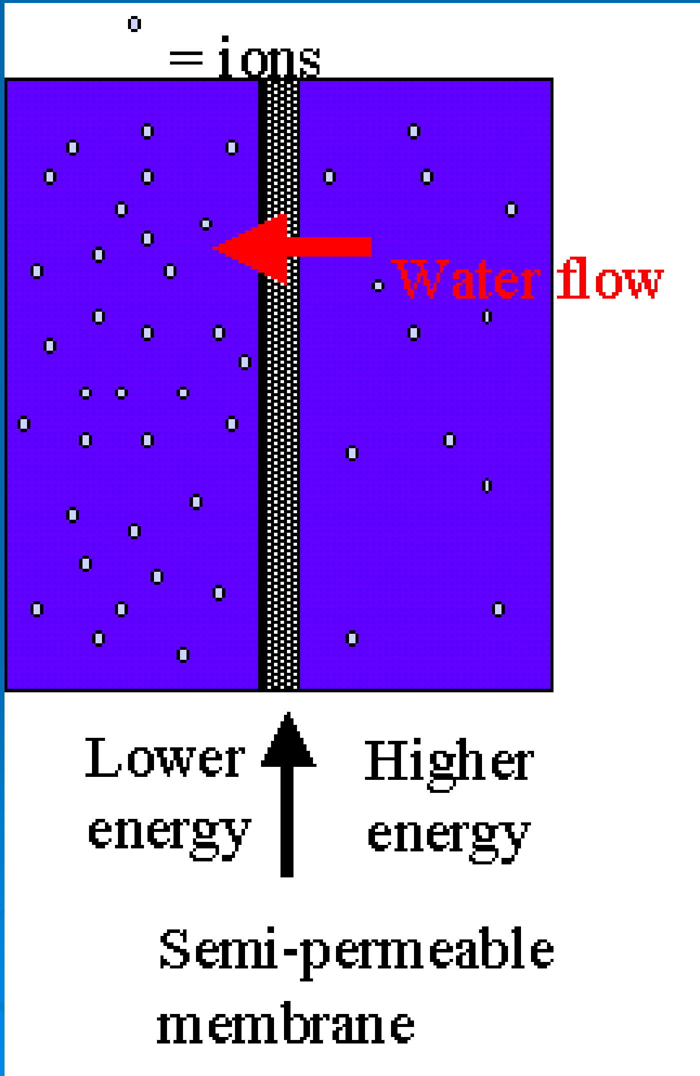
-

CAPILLARITY FUNDAMENTALS AND SOIL WATER

- Water will rise higher with fine textured soils, but at a slower rate
- Water will rise to a lower level in sandy soils, but at a faster rate
- **Capillary movement can take place in any direction**

SOIL WATER ENERGY

- **Water moves or changes from a higher to lower energy state**
- **Differences** in energy levels (**potential**) from one contiguous site to another that influences energy movement

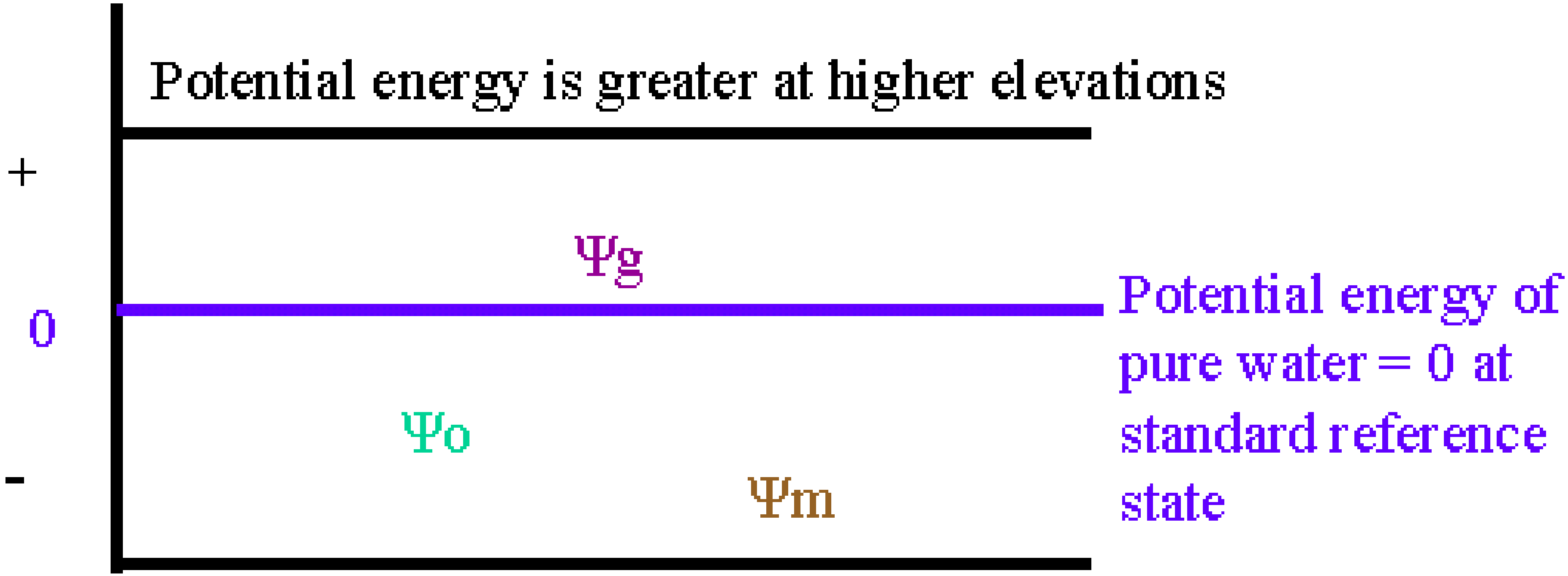


WATER POTENTIAL

- **Sum of:**
  - Matric potential (m)
  - Solute potential (s)
  - Pressure potential (p)
- **Does not include gravitational potential (g)**

TOTAL WATER POTENTIAL (TWP)

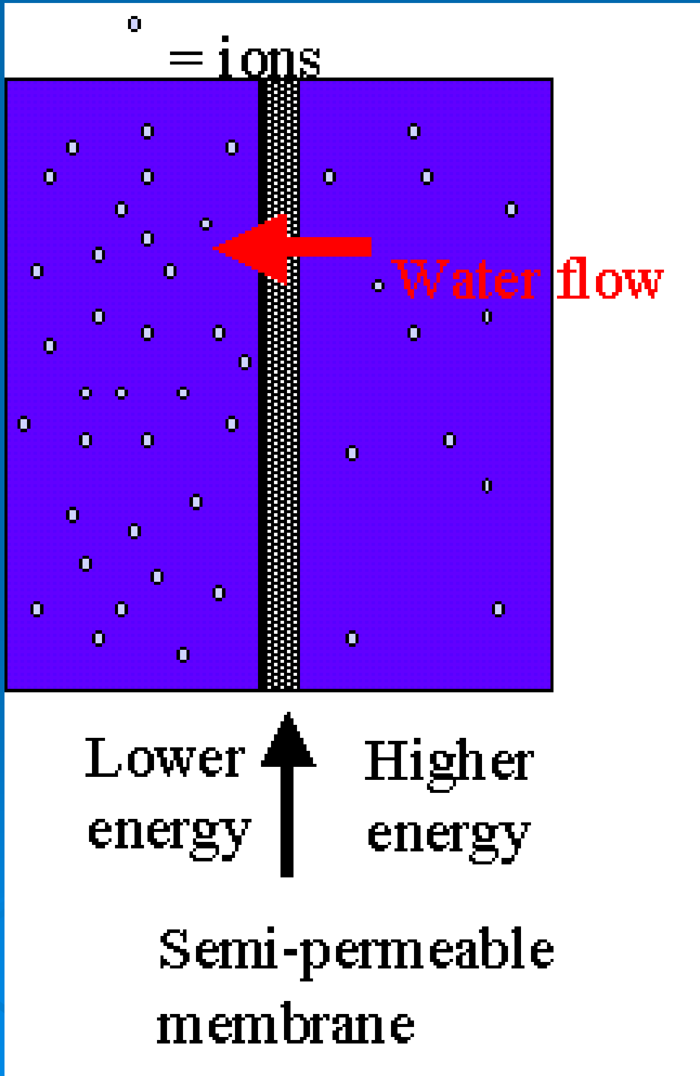
- Matric potential (m)
- Pressure potential (p)
- Solute potential (s)
- Gravitational potential (g)



SOIL WATER POTENTIAL (SWP)

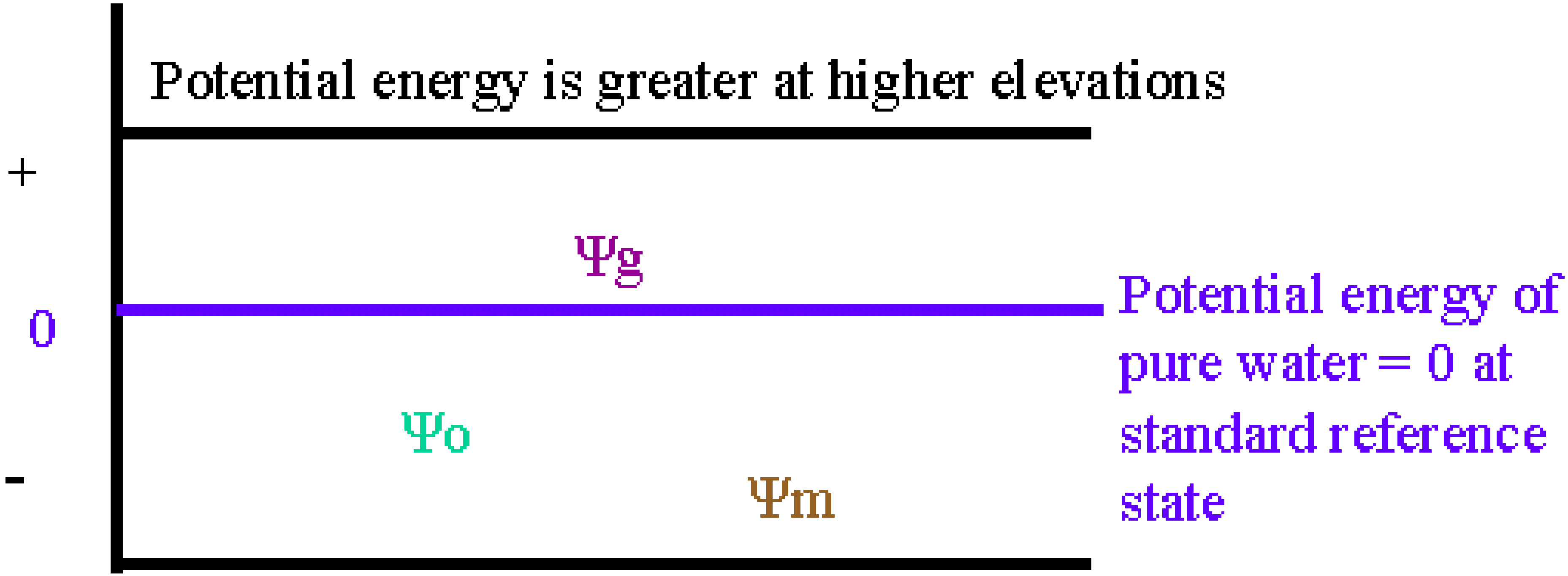
- **The work water can do as it moves from its present state to the reference state**

- **Difference in energy levels between *pure water* and soil water**



SOIL WATER POTENTIAL (SWP)

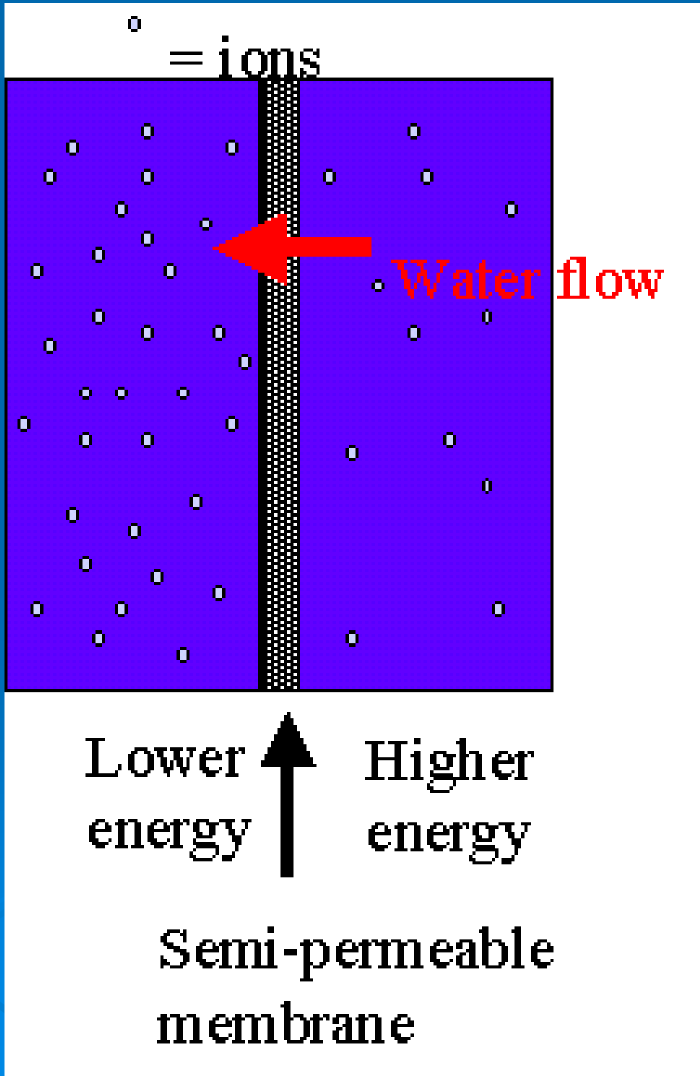
- **Reference state** is the energy state of pure water at a given elevation defined as **zero**



SOIL WATER POTENTIAL (SWP)

- **Water usually has a SWP that is less than zero (negative)**

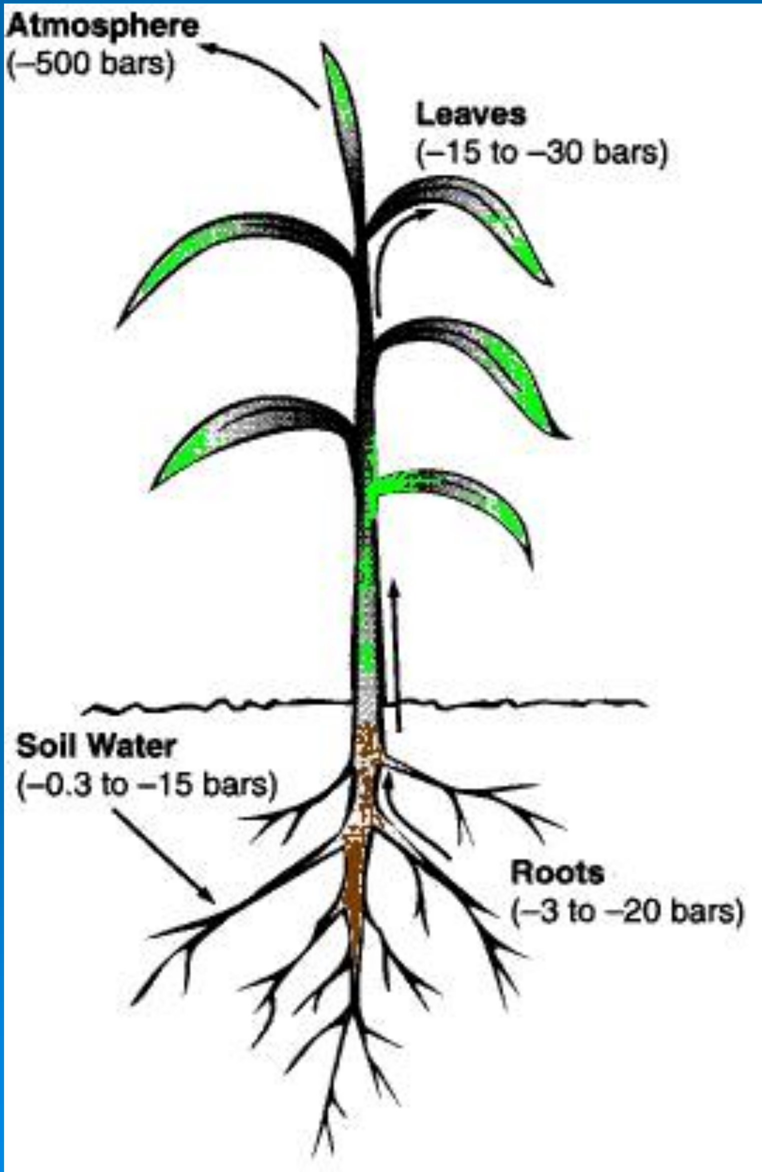
- **Negative potential** means work is required on the water to move it from the soil to a pool of water at the zero state



SOIL WATER POTENTIAL (SWP)

- **Water will move from a soil zone having a high SWP (wet) to a zone with a low SWP (dry)**

- **Direction** and **rate** of water movement



SOIL WATER POTENTIAL (SWP)

- **The tighter water is held the more negative the potential**

- **Expressed in units of energy per mass of water**
  - Mass (joules/kg)
  - Volume (newtons/m^2)
  - **Pa or kilopascales** (kPa) = 1 newton (N) acting over an area of $1m^2$

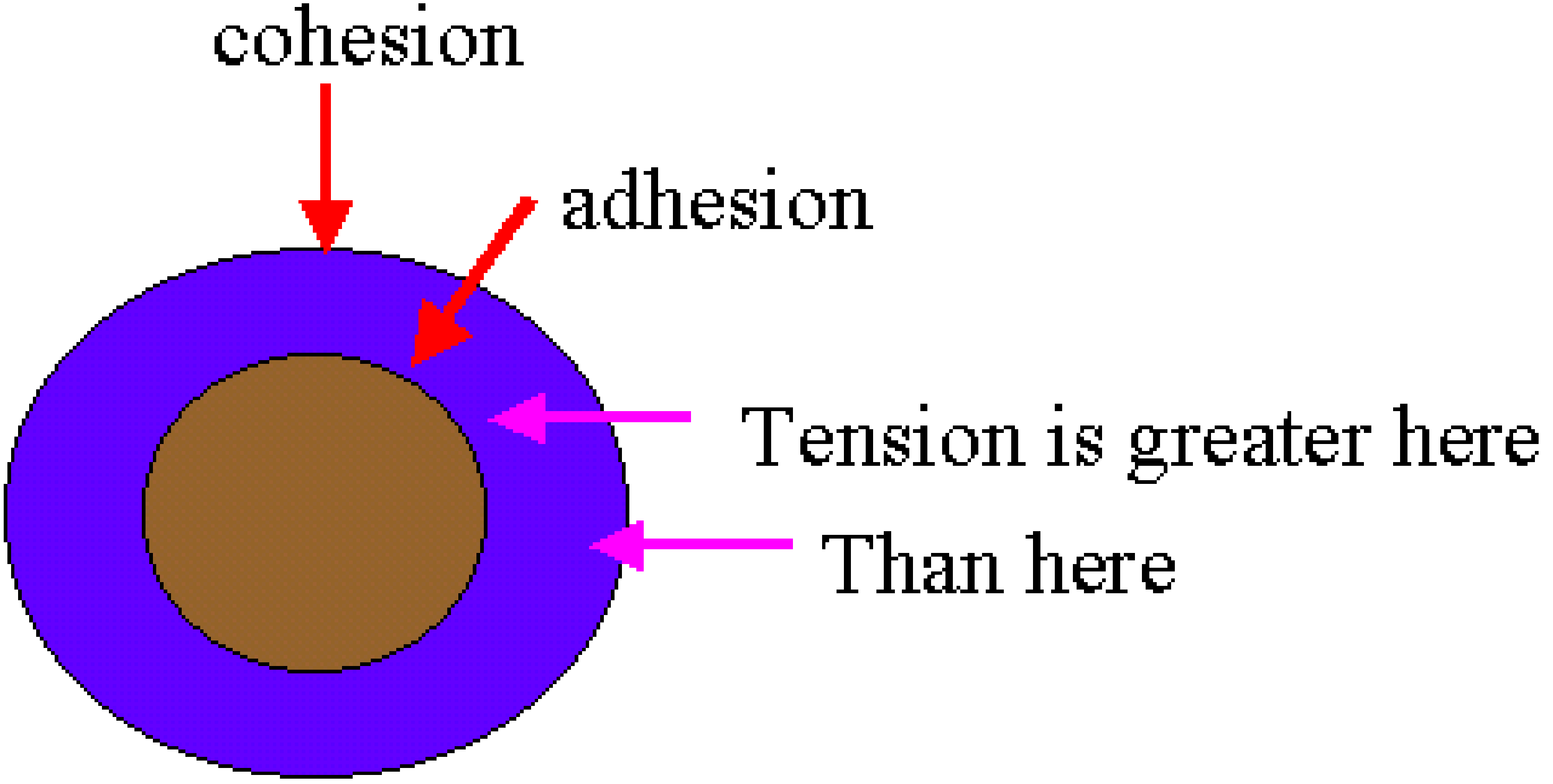
MATRIC POTENTIAL

- **Effect of surface adsorption on the ability of water to do work or adhesion or attraction of water to soil solids (matrix) (*Value is always negative*)**

- Responsible for adsorption and capillarity

- Reduces the energy state of water near particle surfaces

MATRIC POTENTIAL

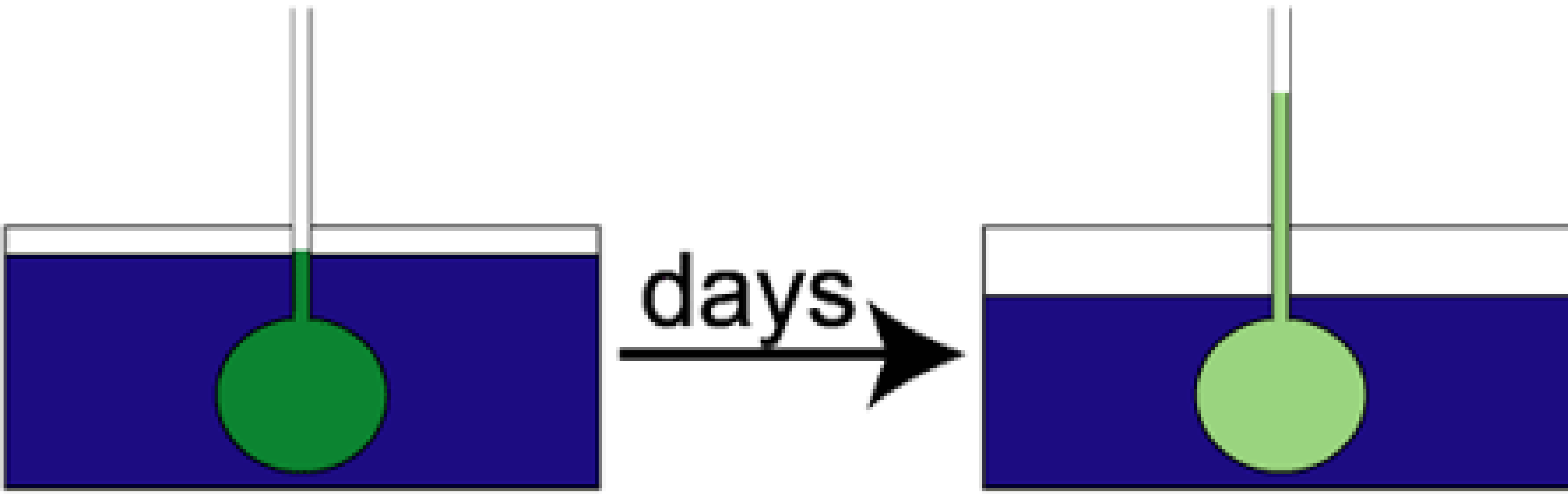


SOLUTE OR OSMOTIC POTENTIAL

- **Effect of dissolved substances on the ability of water to do work or attraction of water to ions and other solutes** (**Values are always negative**)

- Illustrated by movement of pure water across a semi-permeable membrane into a solution (**osmosis**)

SOLUTE OR OSMOTIC POTENTIAL



Sugar water solution enclosed in a semi-permeable membrane and placed in a water bath. An open glass tube sticks out of the end of the semi-permeable membrane. Over a period of days water will diffuse into the sugar water solution, forcing the solution up the glass tube, diluting the solution, and lowering the water level in the bath.

PRESSURE POTENTIAL

- **Effect of pressure from gases or from overhead water on the ability of soil water to do work (Values are zero or positive)**
- Pressurized water flows farther and faster
- Water can be under pressure due to gas pressures or overhead water

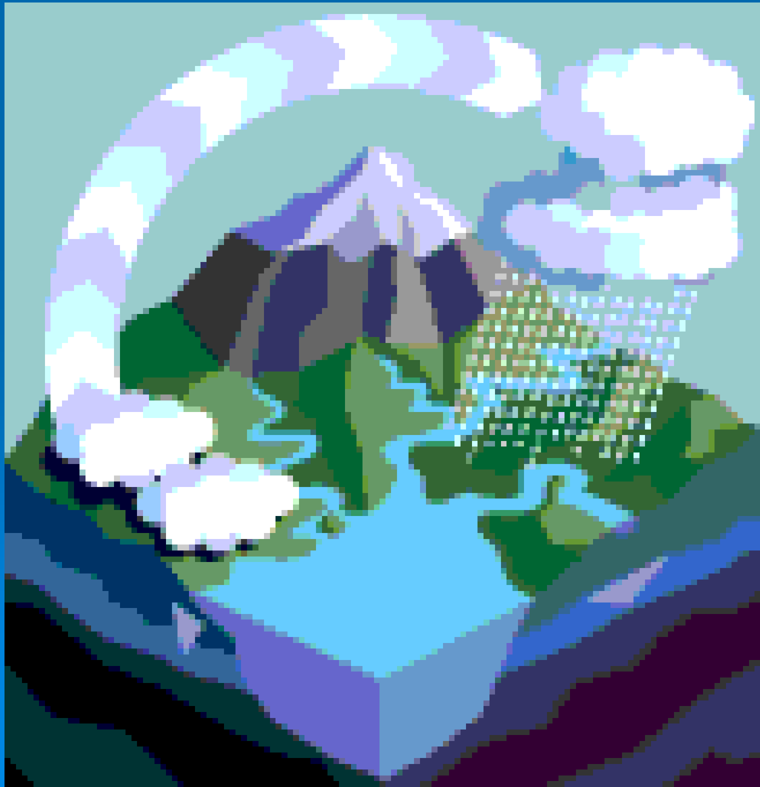
PRESSURE POTENTIAL

- **Overhead water** is encountered under three conditions:
- 1. Water is located below the water table
- 2. Soil surface has **ponded** or stationary water
- 3. Soil surface is flooded or covered with flowing water

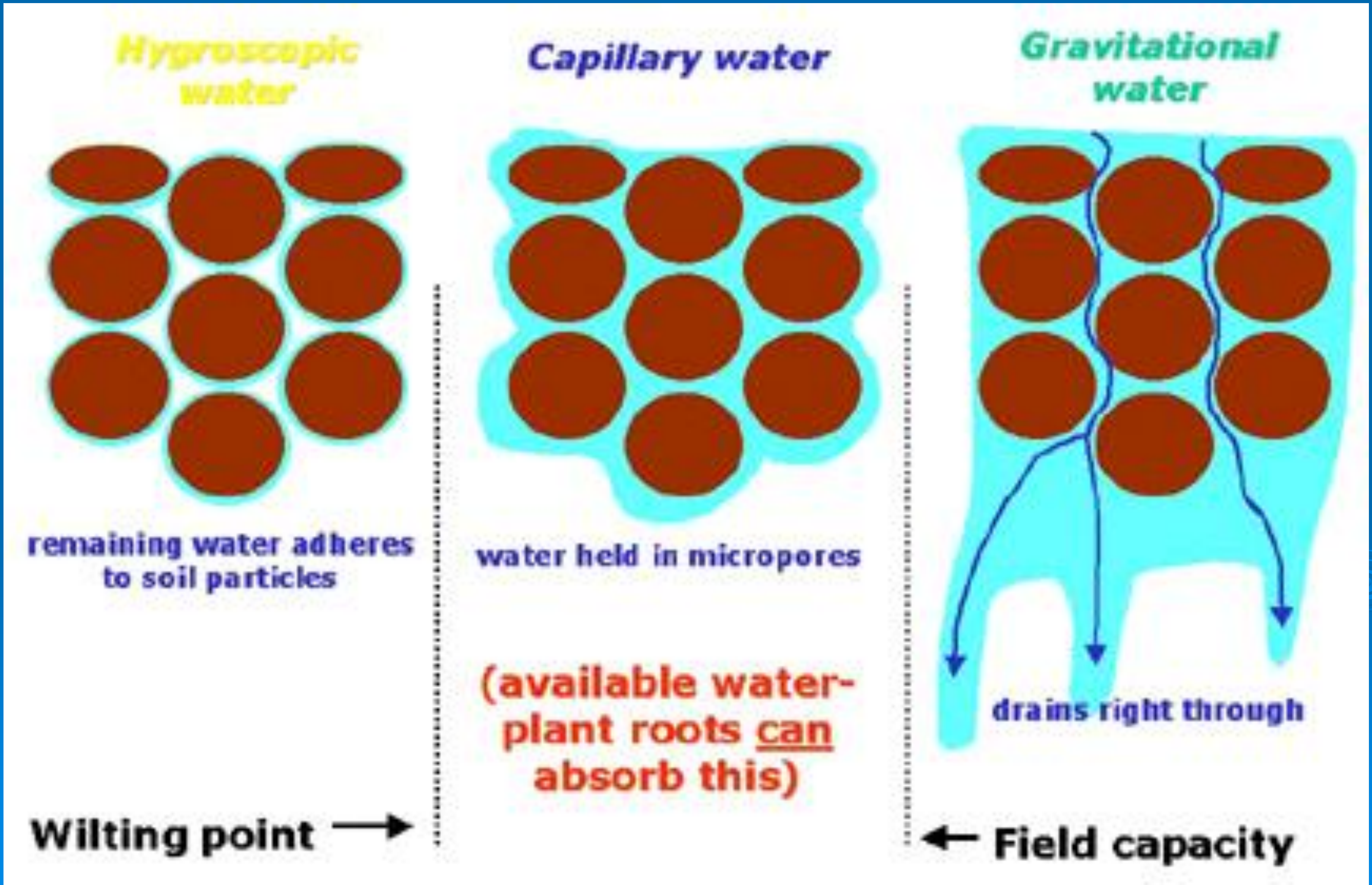
GRAVITATIONAL POTENTIAL

- **Effect of vertical position on the ability of water to do work or pulls water downward (Values +/-)**

- Energy of water at a given elevation is higher than at a lower elevation



GRAVITATIONAL POTENTIAL



APPLICATION OF TOTAL SOIL WATER POTENTIAL

SWP IN WET SOILS

- Water is retained in large pores and are not close to particle surface
- Not held tightly by soil solids (matrix)
- **Water molecules have freedom of movement and energy levels approach pure water**

SWP IN DRY SOILS

- Water is retained in small pores
- Water molecules held tightly to particle surface
- Water molecules have little freedom of movement
- **Energy level much lower than water in wet soils**

OSMOTIC POTENTIAL

- Due to solutes in the soil solution
  - Inorganic salts
  - Organic compounds
- Solutes reduce the freedom of movement of water molecules
- **The greater the solute concentration the lower the osmotic potential**

SOILS HIGH IN SOLUBLE SALTS

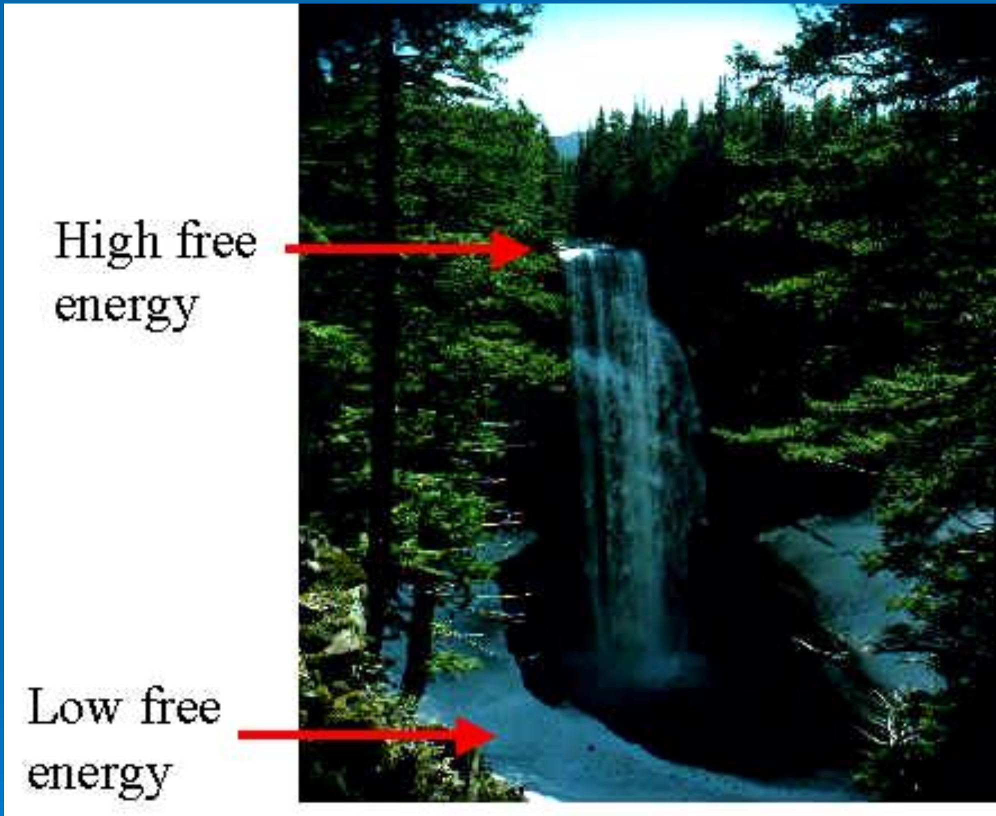
- Lower OP in soil solution than in root cells

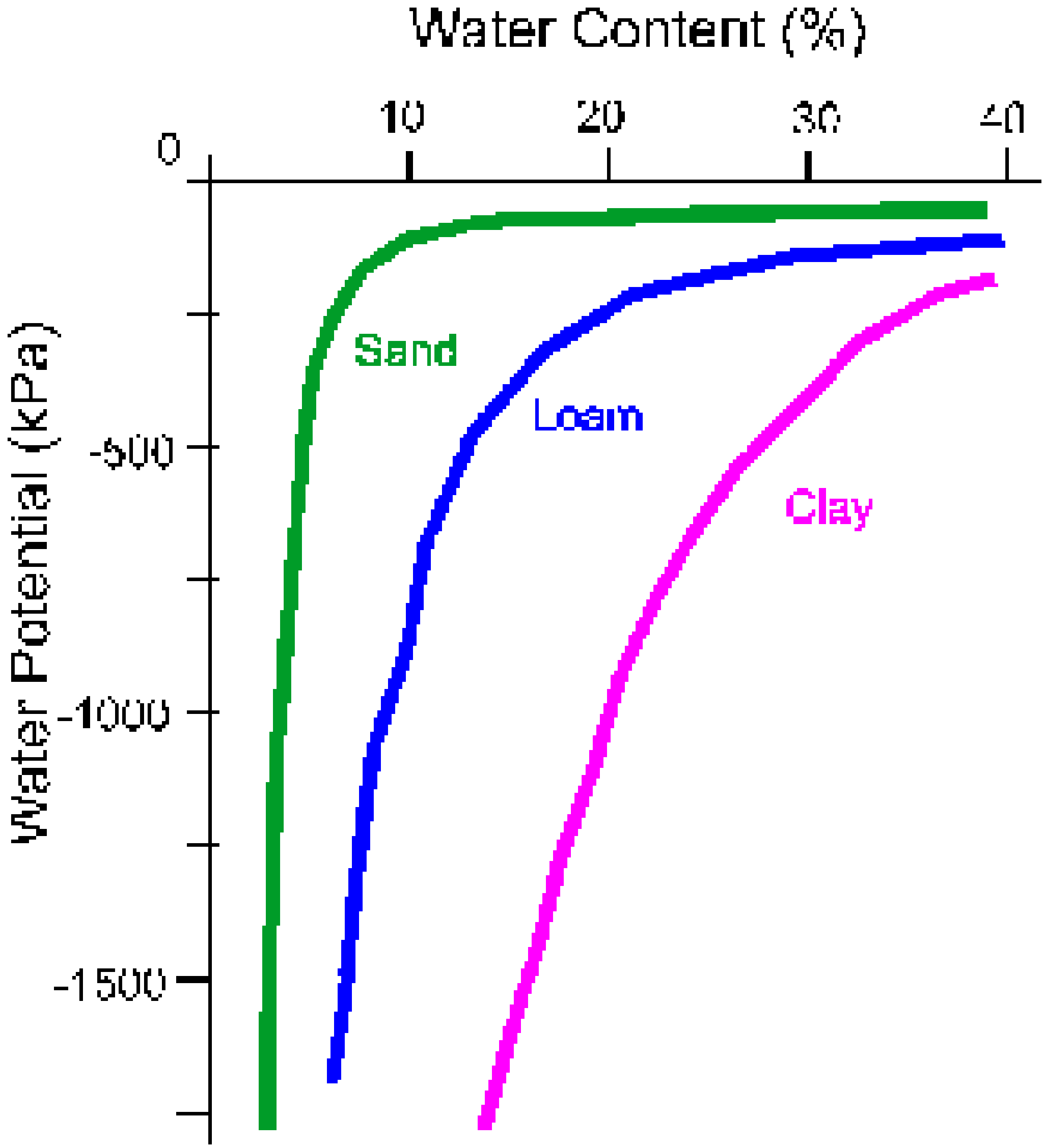
- Limits uptake of water by plant

- Plant cells may collapse and water moves from cells to surrounding soil

GRAVITATIONAL POTENTIAL

- Includes acceleration due gravity
- Height of the soil water above a reference elevation




Water Content (%)
10
20
30
40
0
-500
-1000
-1500
Water Potential (kPa)
Sand
Loam
Clay

GRAVITATIONAL POTENTIAL

- Important in removing excess water from upper horizons

- Helps in the recharging of groundwater supplies

MEASURING SOIL WATER STATUS

- Amount of water present (water content)
- Energy status (soil water potential)
- **Water behavior is most related to energy status of the water, not to the water content in the soil**

MEASURING WATER CONTENT

- **Volumetric water content:** volume of water associated with a give volume (1 m^3) of dry soil
- Expressed a depth ratio or depth of water per unit depth of soil

MEASURING WATER CONTENT

- **Gravimetric method:** calculates the grams of water per gram of dry soil

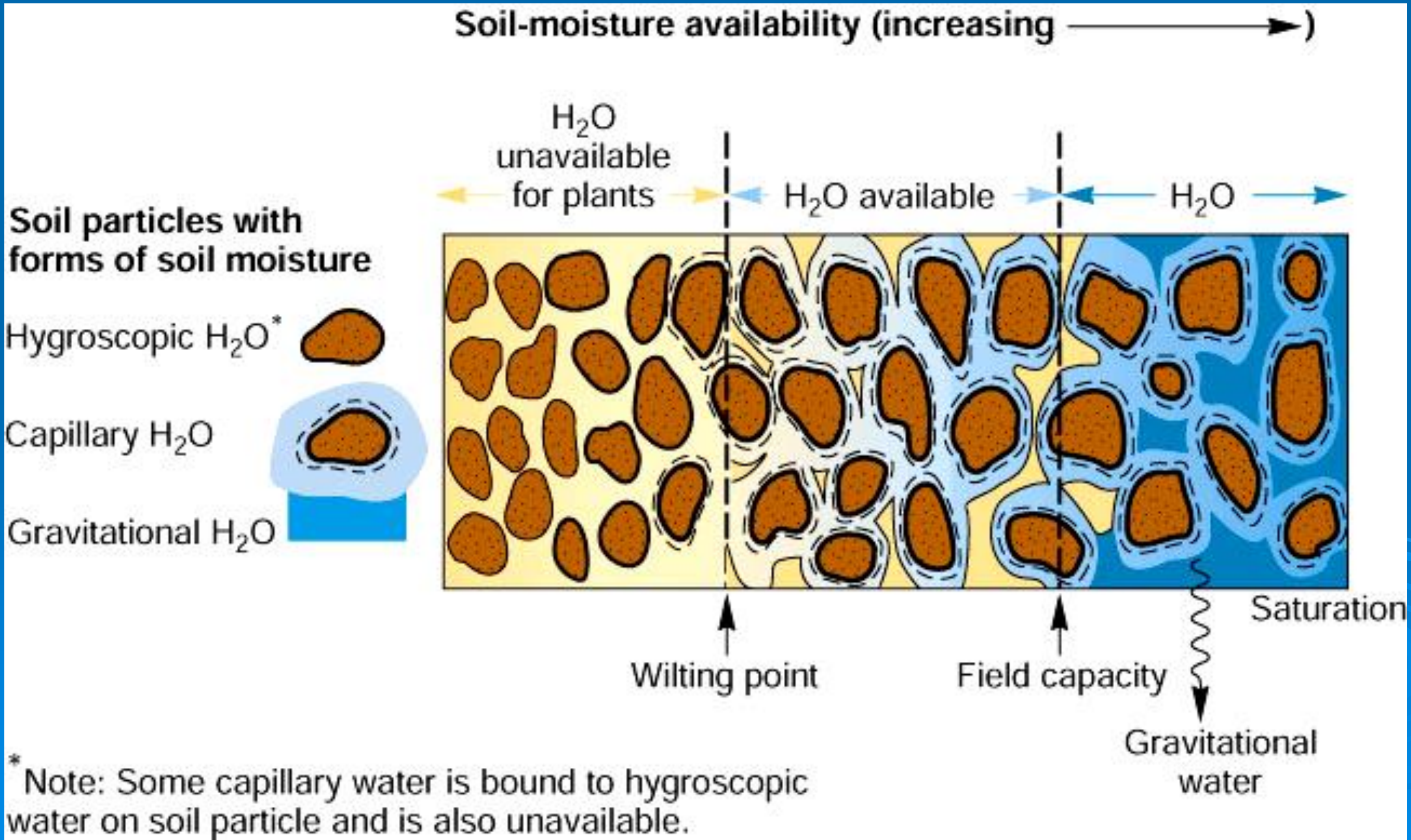
- **Tensiometer**

FLOW OF SOIL WATER IN SOIL

- **Saturated flow**
  - Occurs when soil pores are completely filled with water
- **Unsaturated flow**
  - Larger pores in soil are filled with air and smaller pores filled with water
- **Vapor movement**
  - Differences in vapor pressure in dry soils

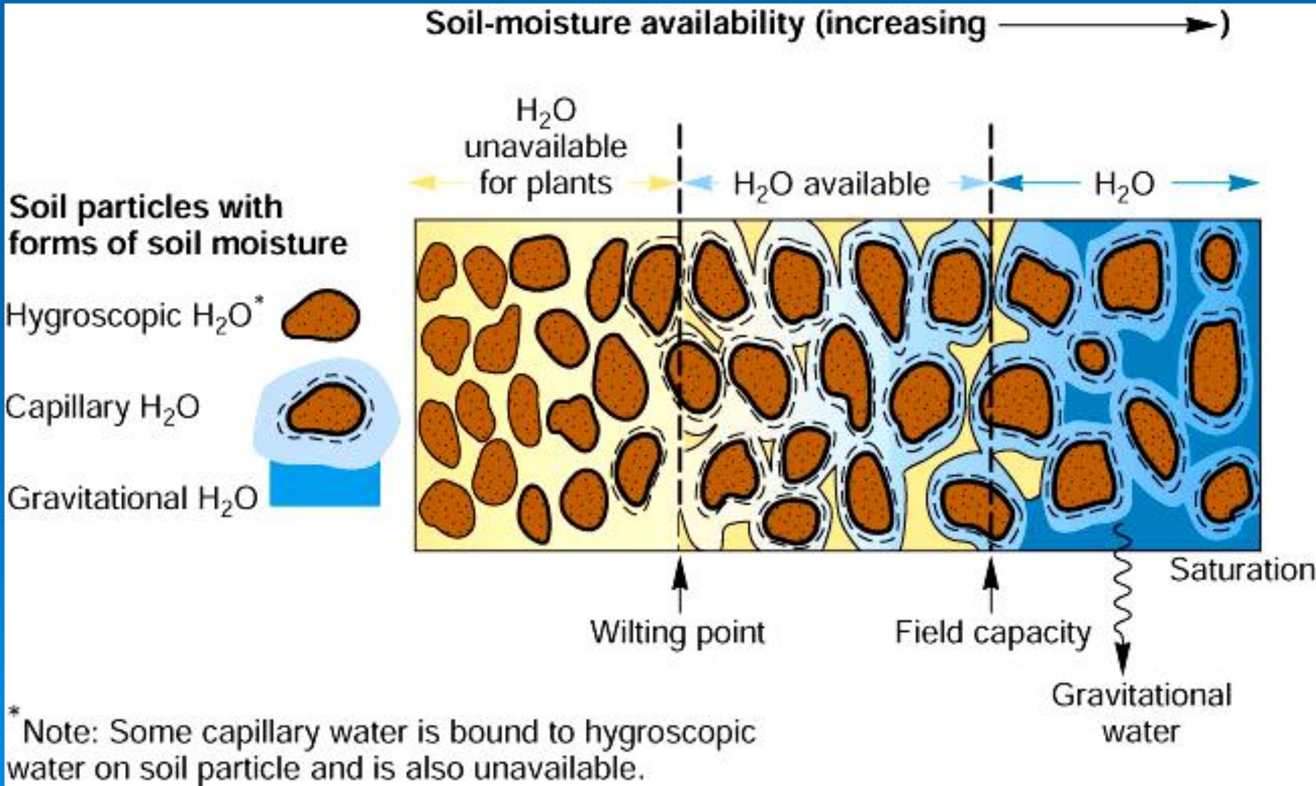
UNSATURATED FLOW

- Macropores are filled with air
- Driving force is the matric potential



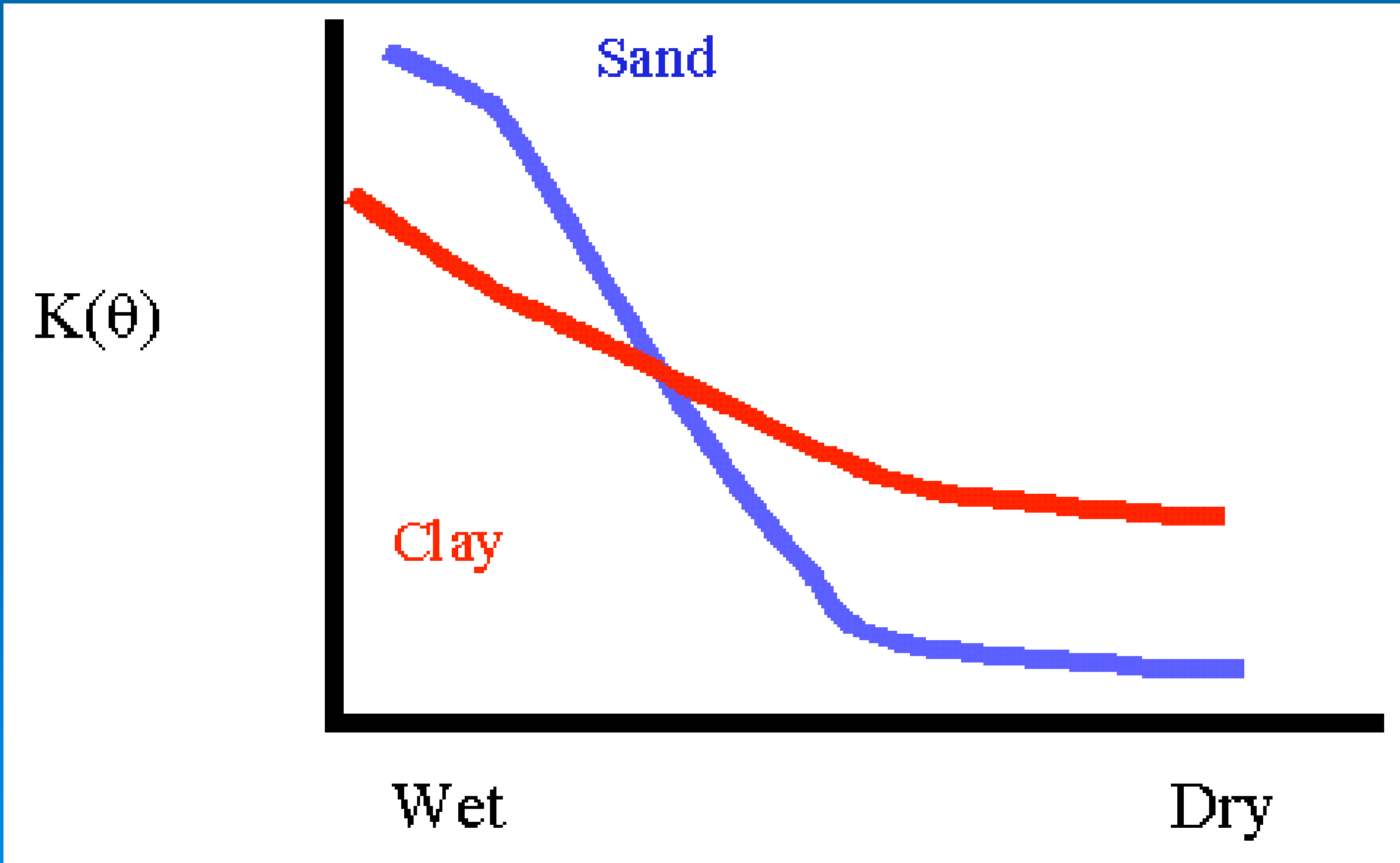
UNSATURATED FLOW

- Water movement is from a zone of thick moisture films (**high matric potential**) to thin moisture films (**lower matric potential**)



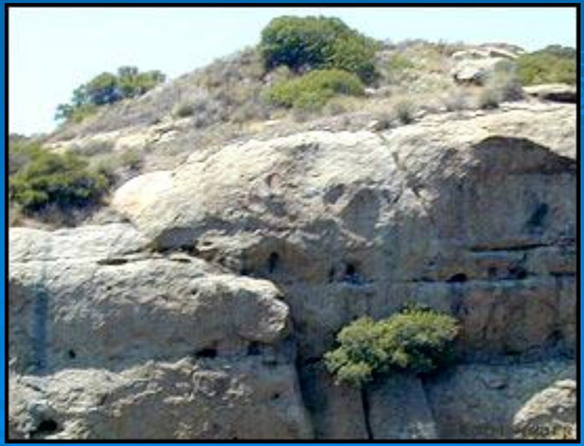
UNSATURATED FLOW

- Sandy soils are less likely to "participate" in unsaturated flow as compared to clay soils



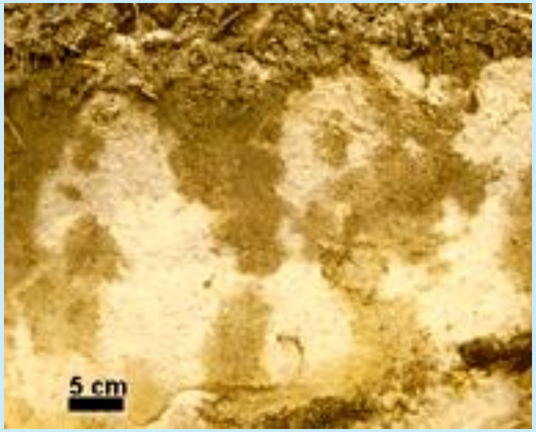
PREFERENTIAL FLOW

- Water may flow rapidly through certain pathways
  - May increase the likelihood of groundwater pollution
  - Cracks, earthworm burrows, old root channels



INFILTRATION

- Process by which water enters soil pore spaces and becomes soil water



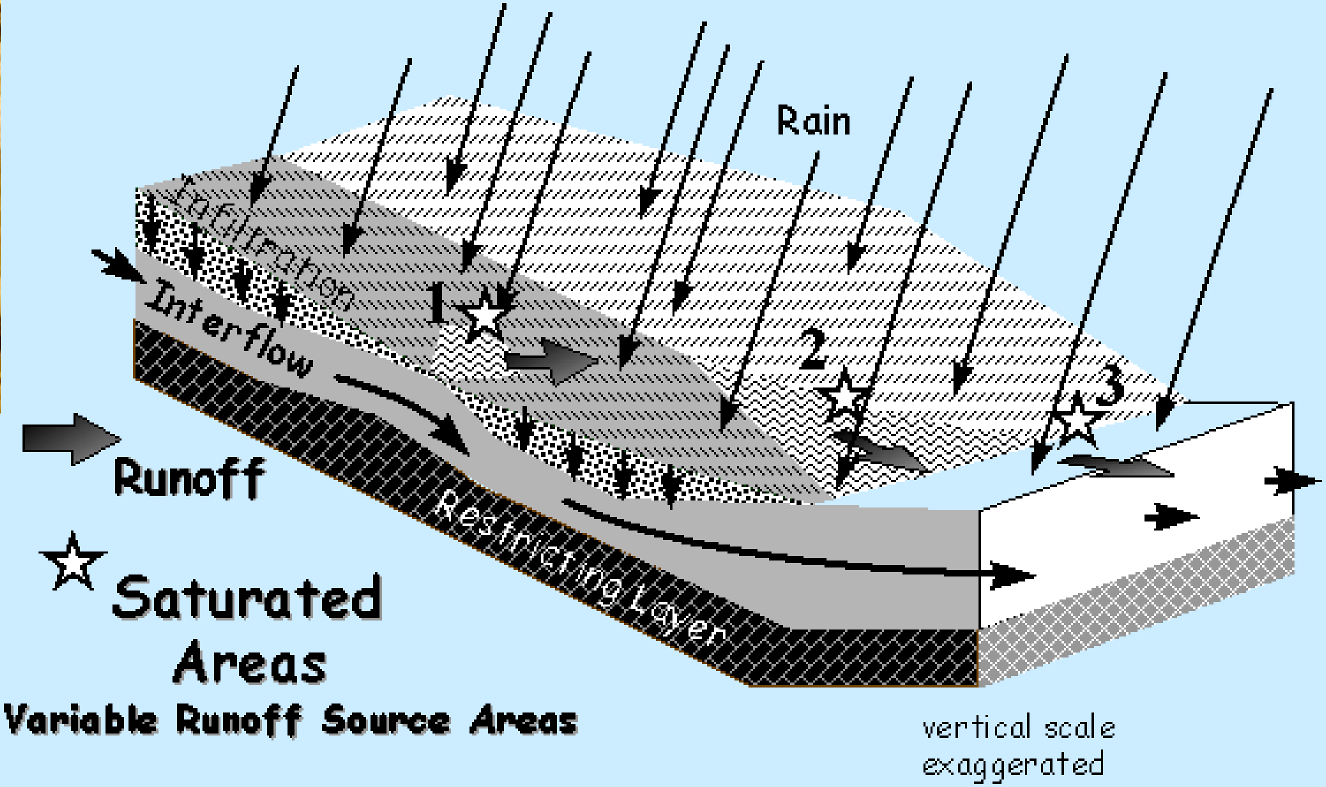
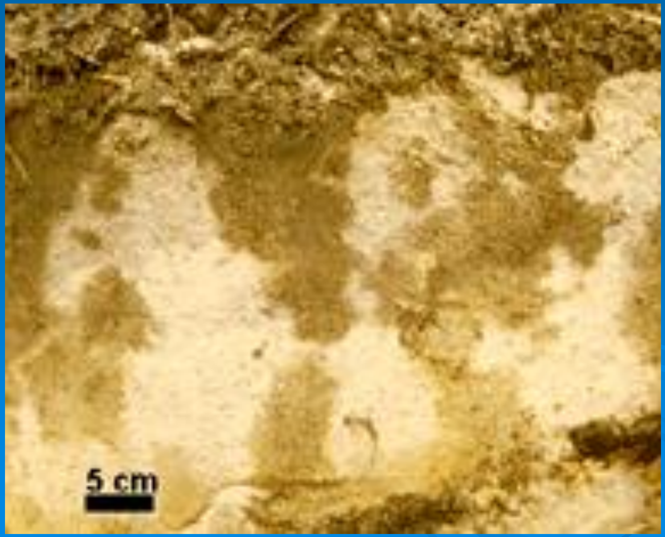


Figure 3: Incidents of saturation excess hydrology: 1) shallow soil, 2) convergence area, 3) downhill slope decreases

INFILTRATION

- Depends on soil texture and structure

- Measured using a double ring **infiltrometer**



INFILTRATION CAPACITY

- **Rate at which water enters the soil** (mm/s or cm/h)
- Decreases with time as the soil become saturated

PERCOLATION

- **Downward movement of water in the soil profile**

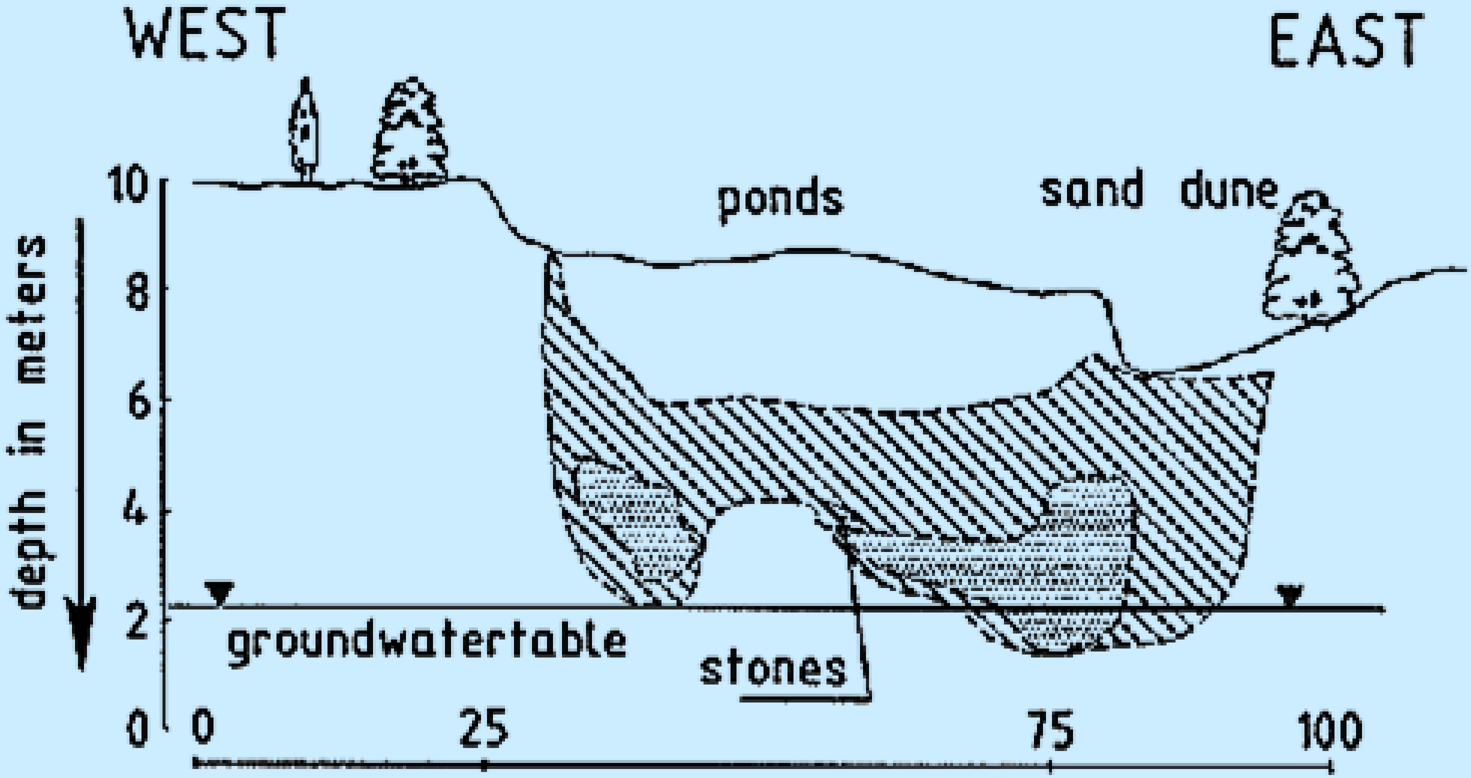
- Includes saturated and unsaturated flow

PERCOLATION

- **Wetting front** – boundary between the dry underlying soil and the soil already wetted
- Soil surface water movement is via saturated flow
- Wetting front water movement is in response to matric potential gradients

PERCOLATION

- **Stratification** may hinder downward or upward movement of water



QUALITATIVE DESCRIPTION OF SOIL WETNESS

- **Maximum retentive capacity** is the condition when soil is saturated

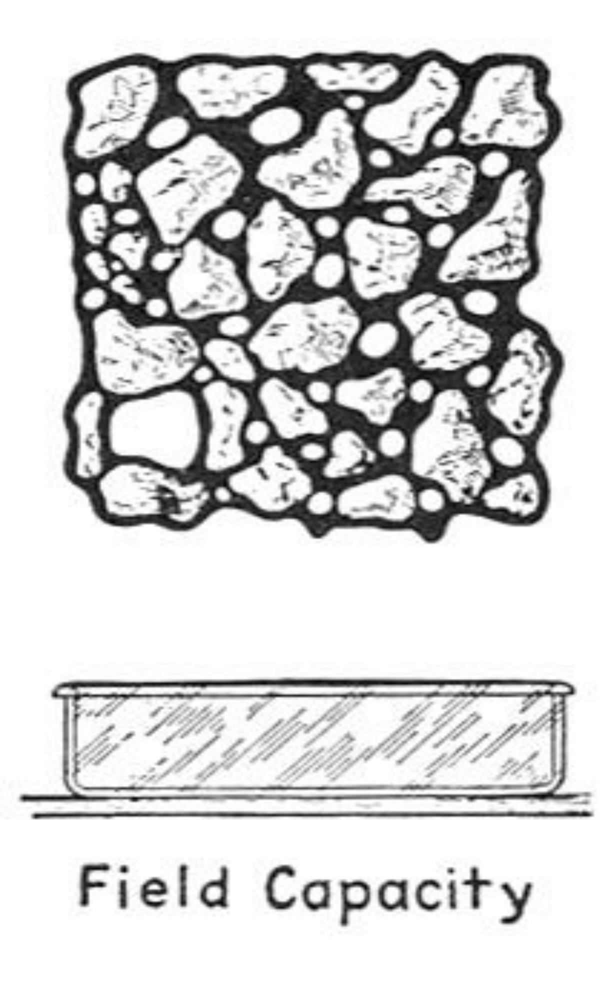
- **Gravitational water** is water that percolates downward due to gravity

Saturation

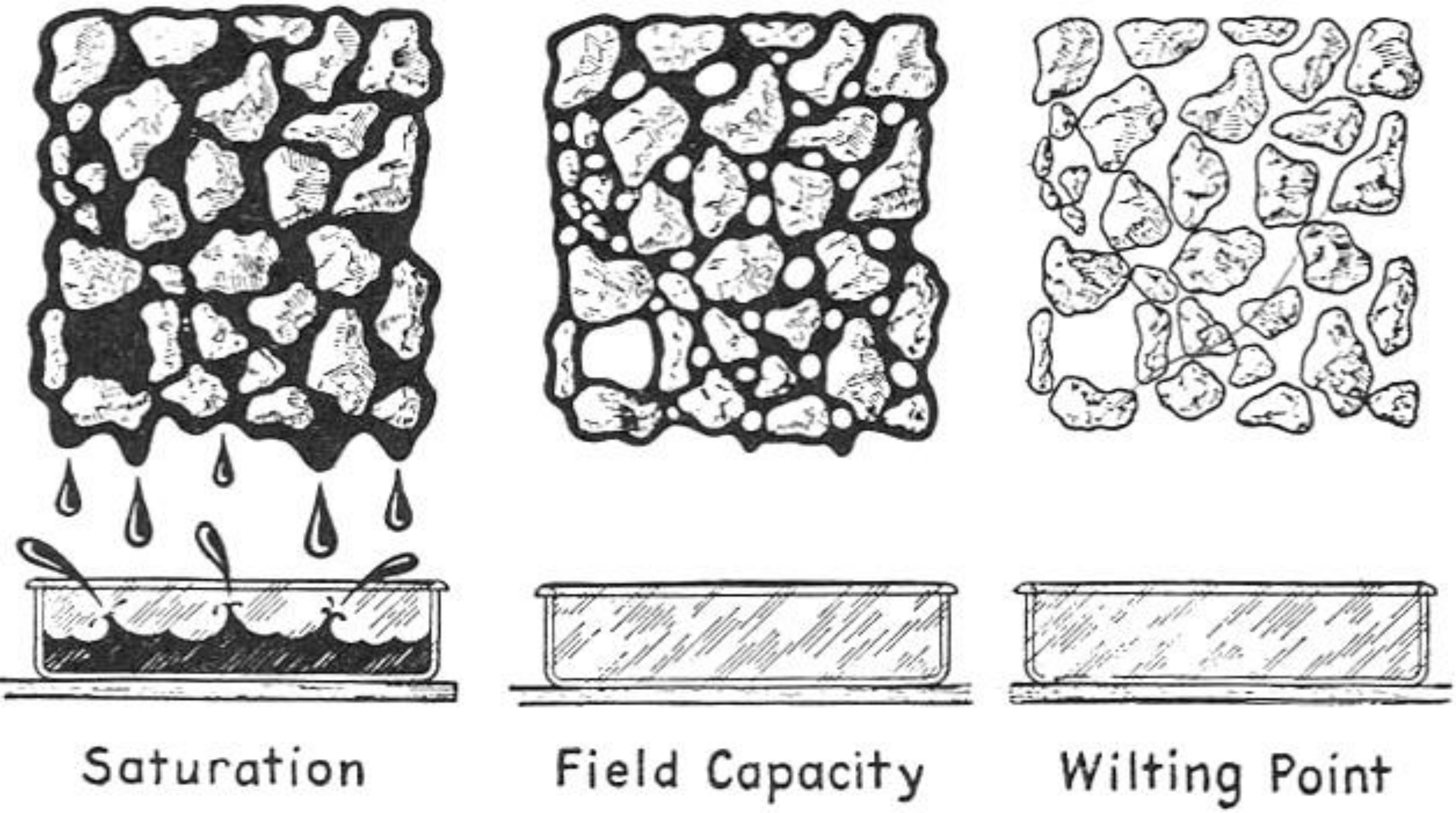
FIELD CAPACITY

- **Water left in pores after gravity has acted**
  - **Macropores** are filled with air
  - **Micropores** contain water

- **Soil holds maximum amount of water useful to plants**

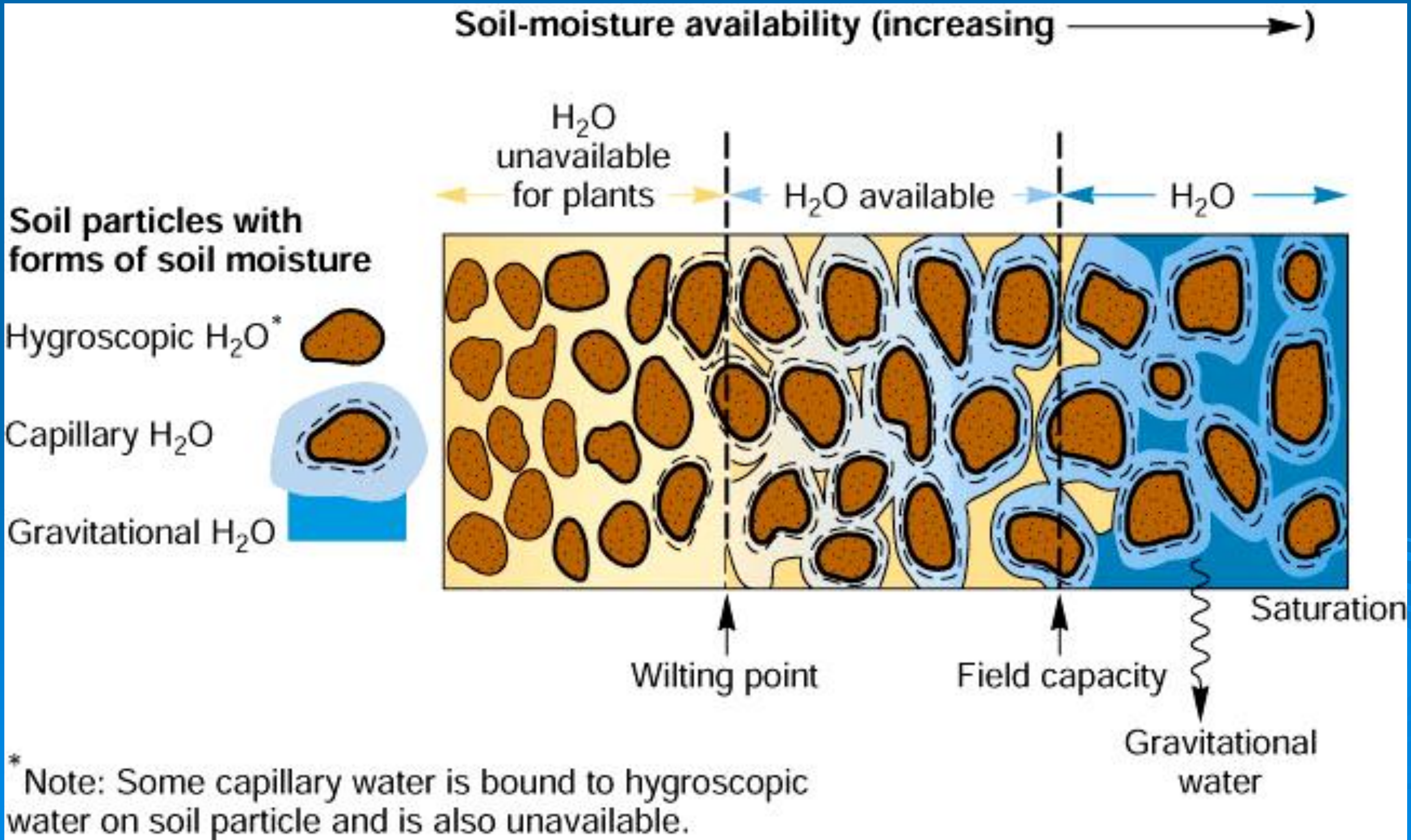


FIELD CAPACITY



CAPILLARY WATER

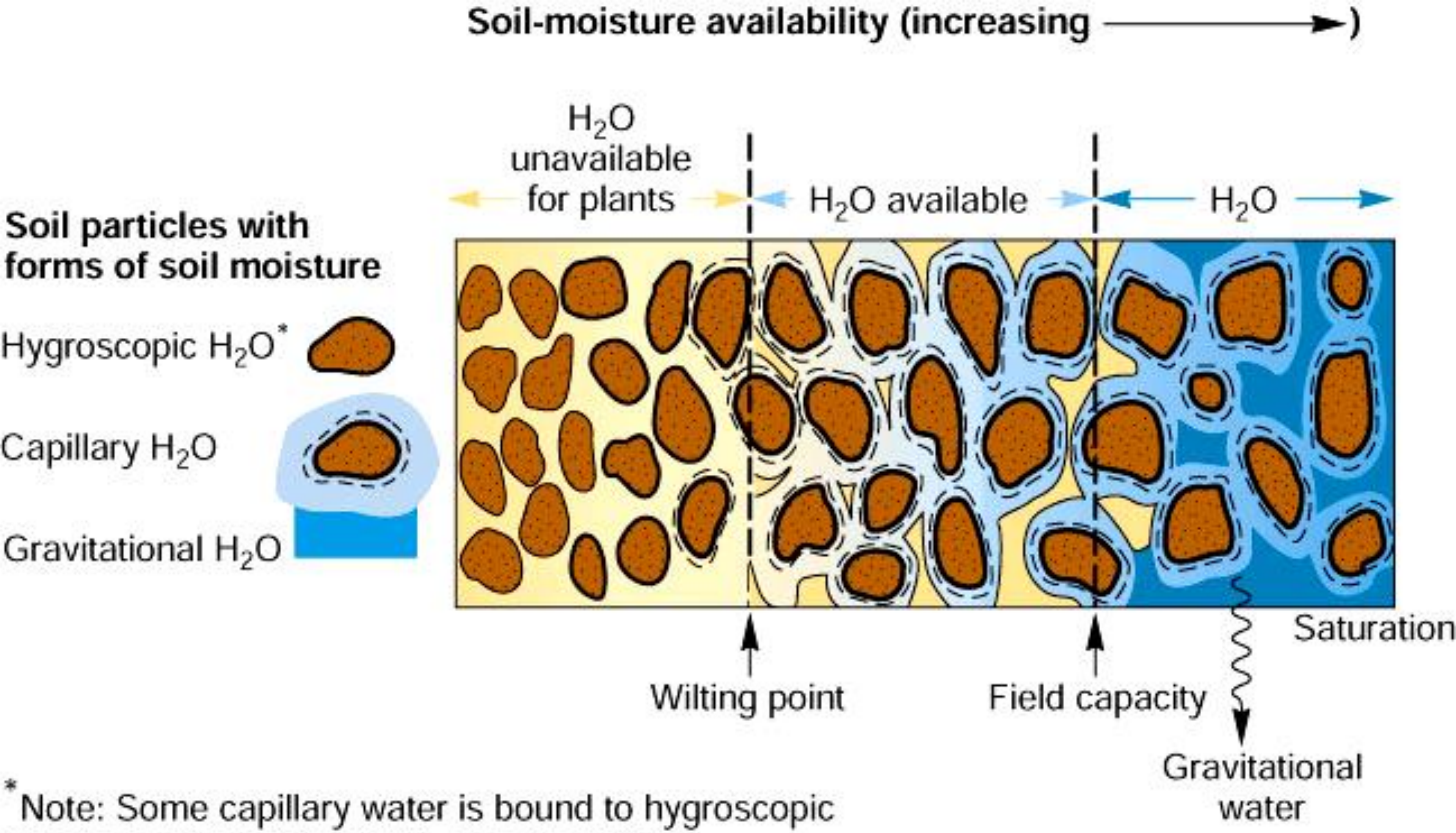
- **Water that moves out of micropores and is available to plant roots**



PERMANENT WILTING PERCENTAGE

- **Wilting coefficient or permanent wilting percentage** – soil will appear dry and dusty, but some moisture is still held in micropores

- **Plant available water** – water that is held between field capacity and wilting coefficient



*Note: Some capillary water is bound to hygroscopic water on soil particle and is also unavailable.

FACTORS AFFECTING AVAILABLE WATER TO PLANTS

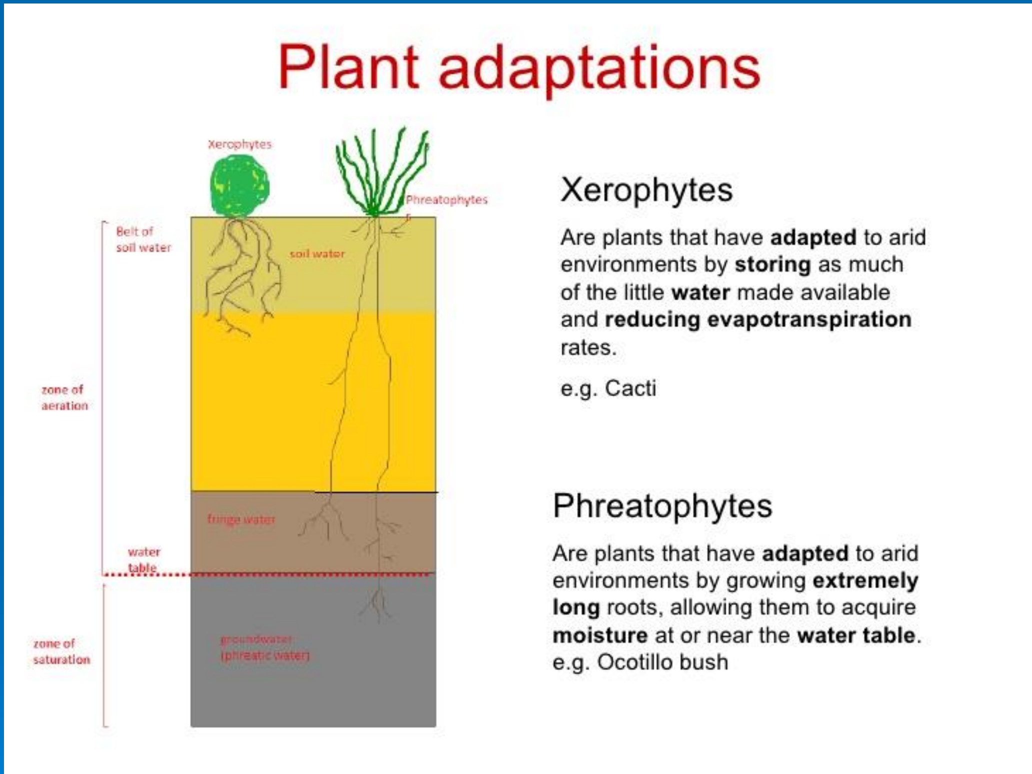
- **Soil texture and organic matter**
  - Greatest in silt loam soils

- **Compaction**
  - Reduces available water

- **Soil depth and layering**
  - Different textures can impede percolation and availability (***soil interface issue***)

HOW PLANT ROOTS ARE SUPPLIED WITH WATER

- Water moves to roots by capillary flow
- Plant roots extend into wetter soil areas
  - Deep rooting
  - Extensive rooting



END OF PRESENTATION