

A close-up photograph of a small, vibrant green seedling with two leaves emerging from a crack in parched, greyish-brown soil. The soil is heavily cracked into irregular polygonal shapes, indicating extreme dryness. The background is a blurred continuation of the cracked earth, with warm, golden light suggesting a low sun position.

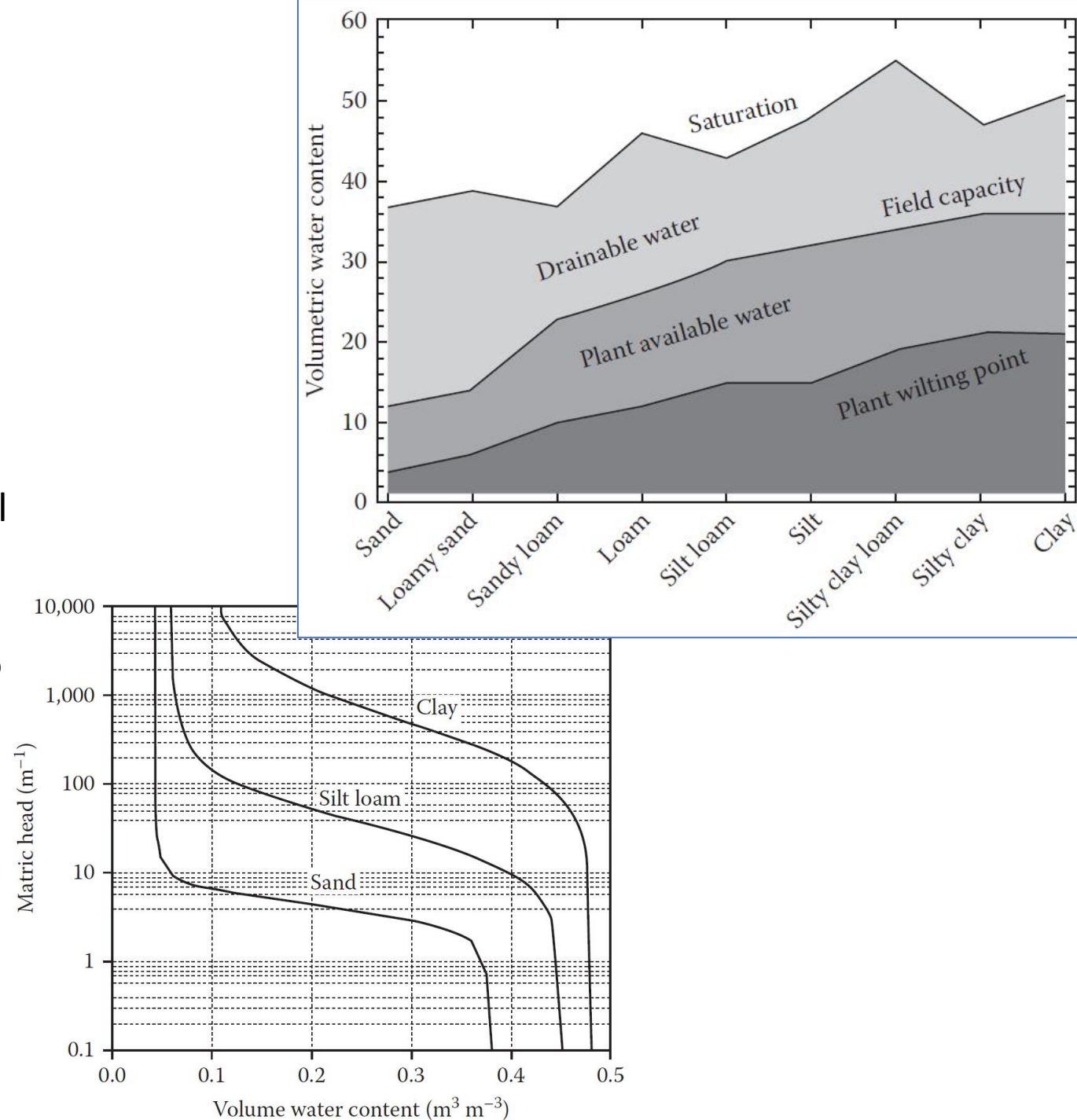
Soil water potential
(availability of water in soil)

The water status in soil

is defined by:

- (1) the amount of water in the soil or soil water content (θ), and
- (2) the force by which water is held in the soil matrix, soil energy content or soil water potential (ψ).

These two soil water attributes are related to each other through a function known as the soil water characteristic (SWC).



Soil water potential

- expresses the energy state of soil water – the force acting on water (in porous medium)
- it is given usually in pressure units – there are many of them: pascal (SI unit N/m^2), psi (Pounds per square inch, lb/in^2), atmosphere = 101.325 kPa (or 14.7 psi), bar = 100 kPa, torr = 1 mm of Hg, head (m)

Total soil water potential Ψ_T (is expressed as the sum of partial potentials)

- Ψ_m **matric** component results from capillary and adsorption forces
- Ψ_s **osmotic** component affected by the dissolved species in soil solution
- Ψ_p **pressure** component defined as pressure of created by water column situated above the point of interest
- Ψ_z **gravitational** component given by difference in elevation between reference point and point of interest

$$\Psi_T = \Psi_m + \Psi_s + \Psi_p + \Psi_z$$

Soil water potential

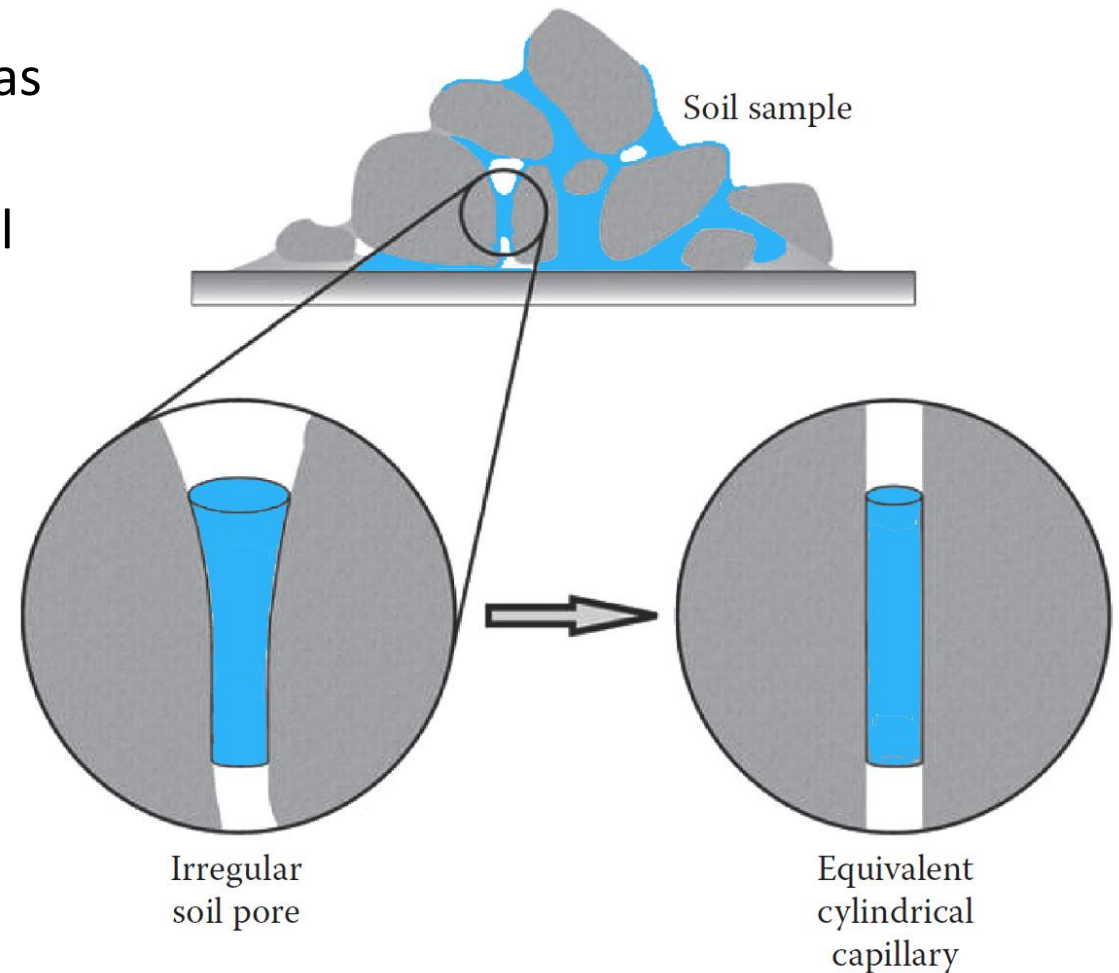
- Like all other matter, soil water tends to move from where the potential energy is high to where it is low, in its pursuit of a state known as equilibrium with its surroundings.
- The magnitude of the driving force behind such spontaneous motion is a difference in potential energy across a distance between two points of interest.
- At a macroscopic scale, one can define potential energy relative to a reference state.
- The standard state for soil water is defined as pure and free water (no solutes and no external forces other than gravity) at a reference pressure, temperature, and elevation, and is arbitrarily given the value of zero.

Different pressure units:

To convert from	General pressure units					Head units		Others	
	bar	Pa	atm	PSI	kg/cm ²	ft H ₂ O	m H ₂ O	in Hg	mmHg/Torr [#]
	Multiply by:								
bar	1	100000	0.9869	14.504	1.0197	33.4562	10.1974	29.5301	750.06
Pa	1 x 10 ⁻⁵	1	9.87x 10 ⁻⁶	1.45x 10 ⁻⁴	1.02 x 10 ⁻⁵	3.34 x 10 ⁻⁴	1.02 x 10 ⁻⁴	2.95 x 10 ⁻⁴	0.0075
atm	1.01325	101325	1	14.7	1.03	33.9	10.333	29.9	760
psi	0.06895	6894.8	0.0680	1	0.0703	2.307	0.7031	2.036	51.715
kg/cm ²	0.9807	98066.5	0.968	14.22	1	32.809	10.0003	28.959	735.56
ft (H ₂ O)	0.02989	2989.0	0.0295	0.4335	0.03048	1	0.3048	0.883	22.419
m (H ₂ O)	0.09806	9806.4	0.09678	1.4223	0.099997	3.281	1	2.8958	73.554
in Hg	0.03386	3386.4	0.03342	0.4911	0.03453	1.133	0.3453	1	25.4
mm Hg/Torr [#]	0.00133	133.32	0.001316	0.0193	0.00136	0.0446	0.0136	0.03937	1

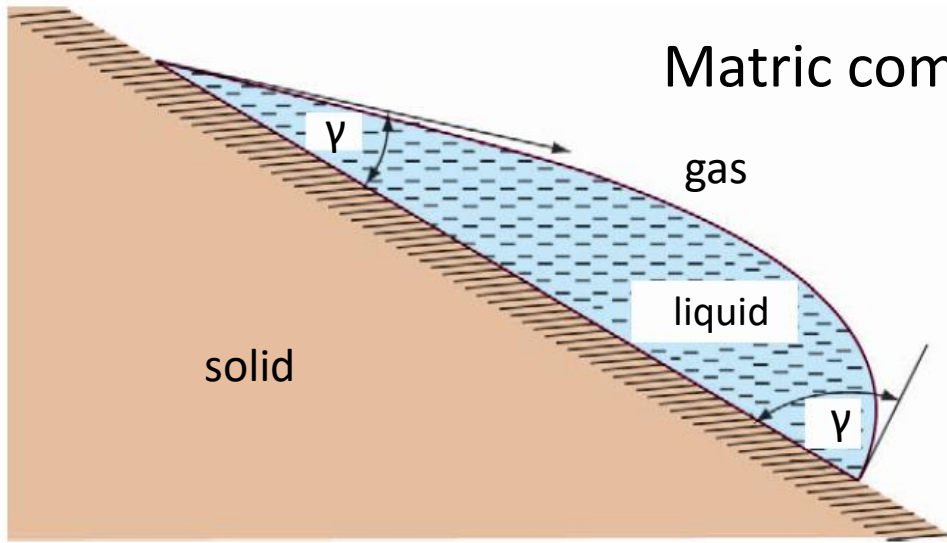
Pore system simplification

- In many cases we think of soil pores simply as straight tubes varying in radius (diameter)
- this simplistic idea is implemented in several soil water retention models



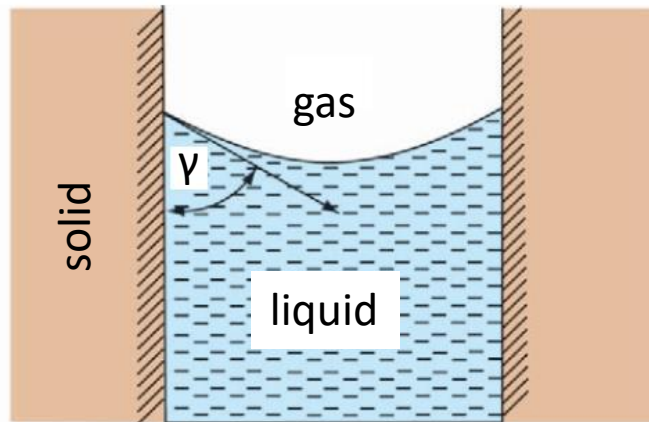
Matrix component of water potential

$$\Psi_T = \Psi_m + \Psi_s + \Psi_p + \Psi_z$$



matric potential is controlled by:

- soil porosity (size, distribution and geometry)
- surface tension at solid/air/liquid interface



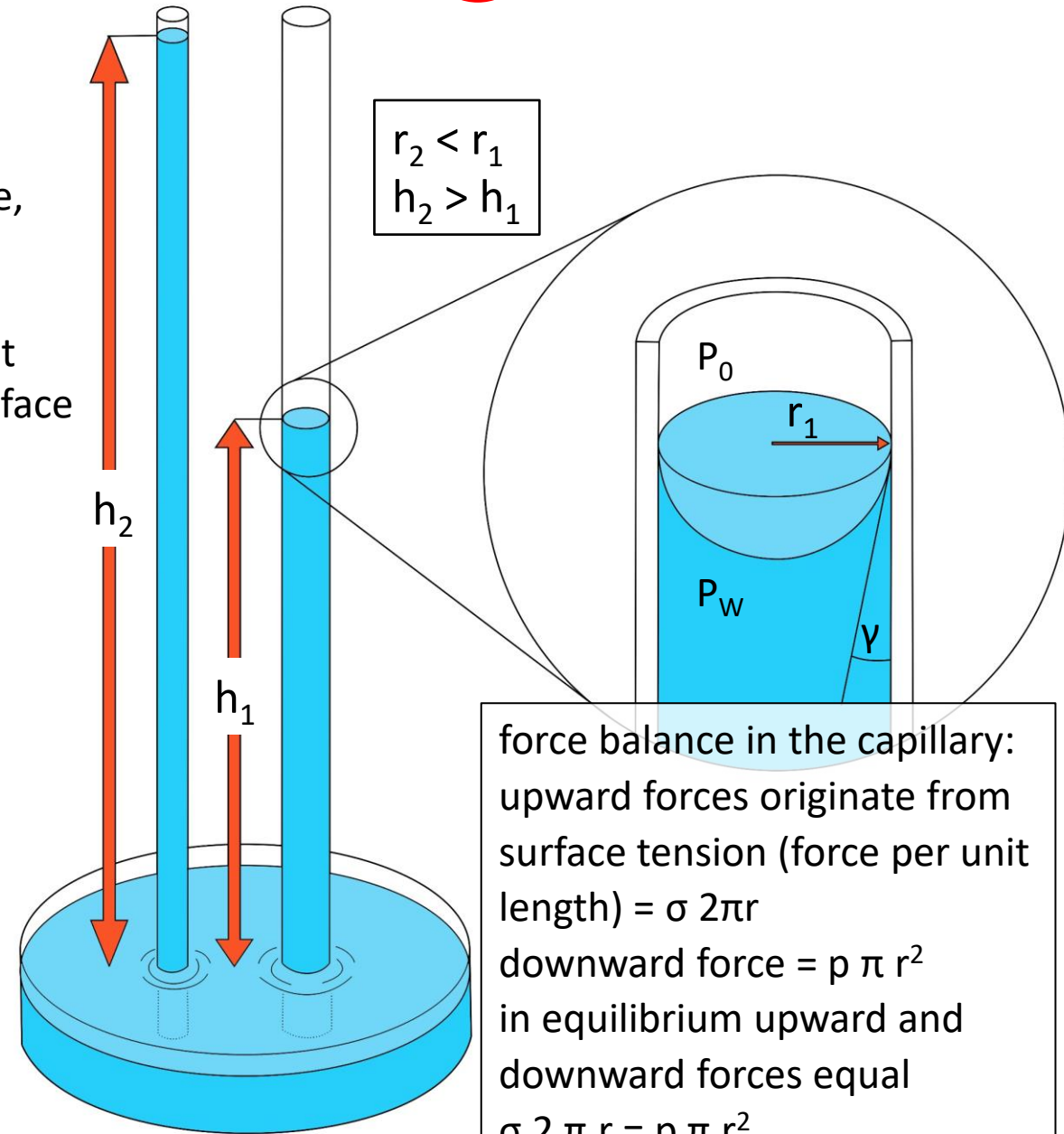
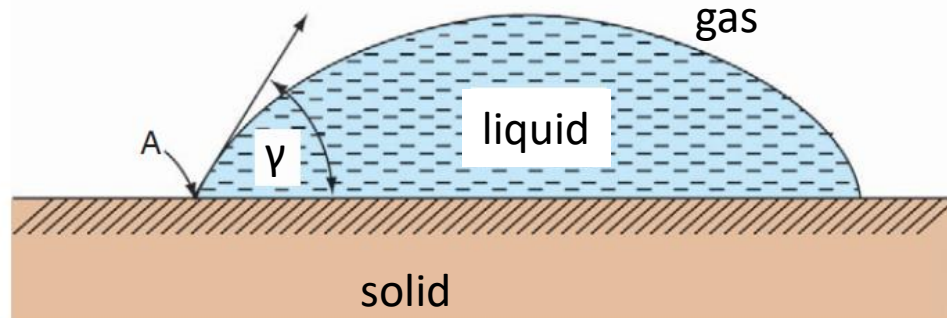
contact angle

$$\cos \gamma = \left(\frac{\sigma_{GS} - \sigma_{SL}}{\sigma_{LG}} \right)$$

$$h = \frac{2\sigma \cos \gamma}{\rho_w g r}$$

capillary rise

$$h(m) = \frac{14.84}{r(\mu m)}$$



$$\Psi_T = \Psi_m + \Psi_s + \Psi_p + \Psi_z$$

Osmotic component of water potential

Osmotic pressure in the diluted solution is proportional to concentration of osmotically active substance and temperature

$$\Pi = MRT \text{ (Pa)}$$

Π is osmotic pressure

M molar concentration

T temperature in Kelvins

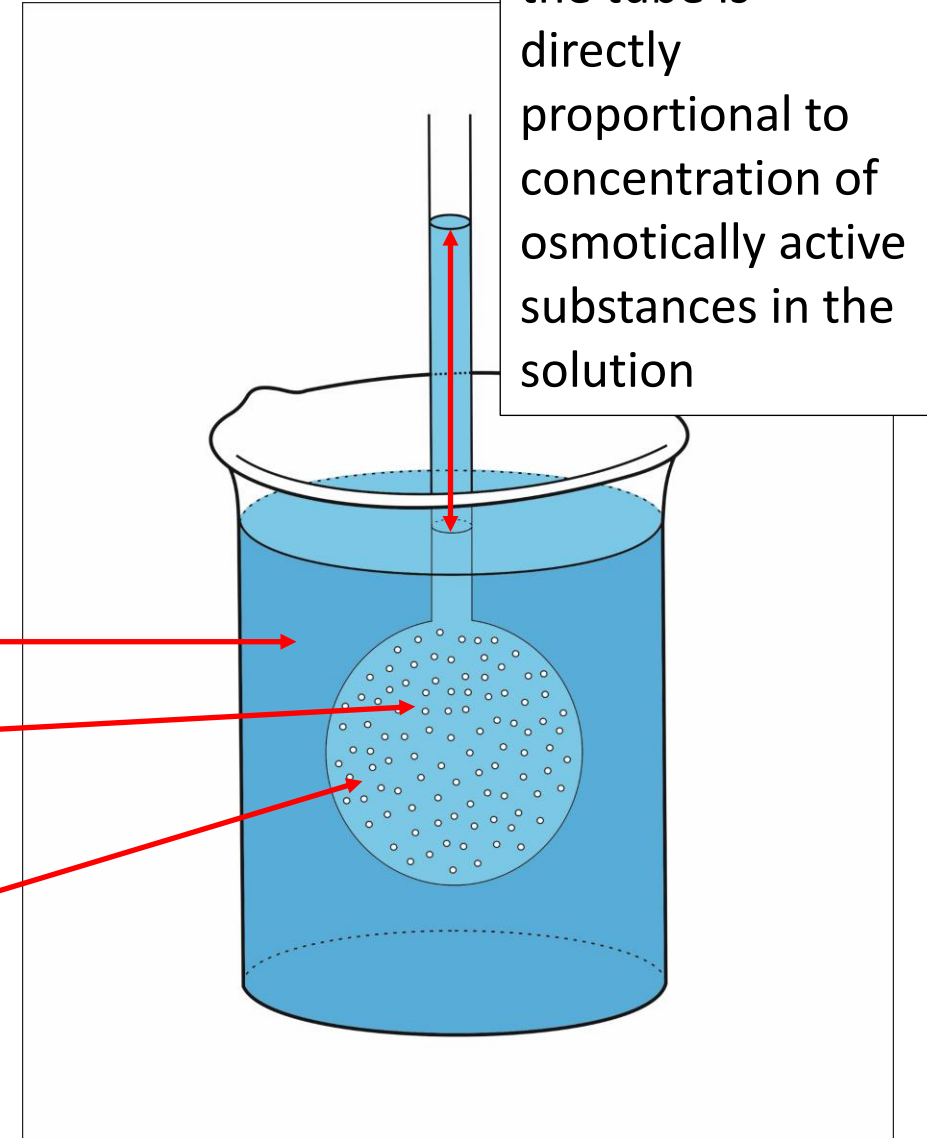
R gas constant = 0.08205 L atm/mol K

the rise of level in the tube is directly proportional to concentration of osmotically active substances in the solution

water

solution

membrane with selective permeability



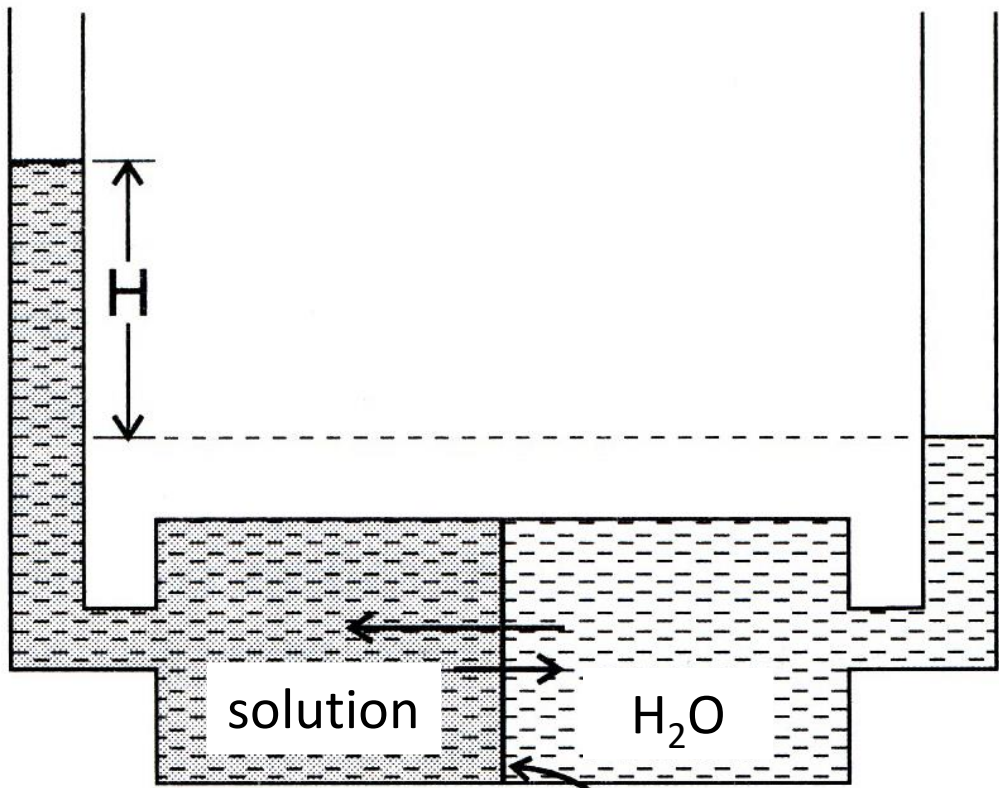
Soil salinity and sodicity

The accumulation of highly soluble (sodium) salts in near-surface part of the soil, such as NaCl , Na_2SO_4 , NaHCO_3 , $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$, $\text{Na}_2\text{CO}_3 \cdot \text{NaHCO}_3 \cdot 2\text{H}_2\text{O}$

- the occurrence of these soils is conditioned by partially by climate – annual evapotranspiration exceeds the precipitation; another factors increasing probability of soil salinity occurrence is higher mineralization of soil water and shallow water table level
- therefore, saline soils are occurring predominantly in lowlands and arid climatic zones
- it is estimated that app. 932 mil. ha of soils are significantly affected either by soil salinity or sodicity

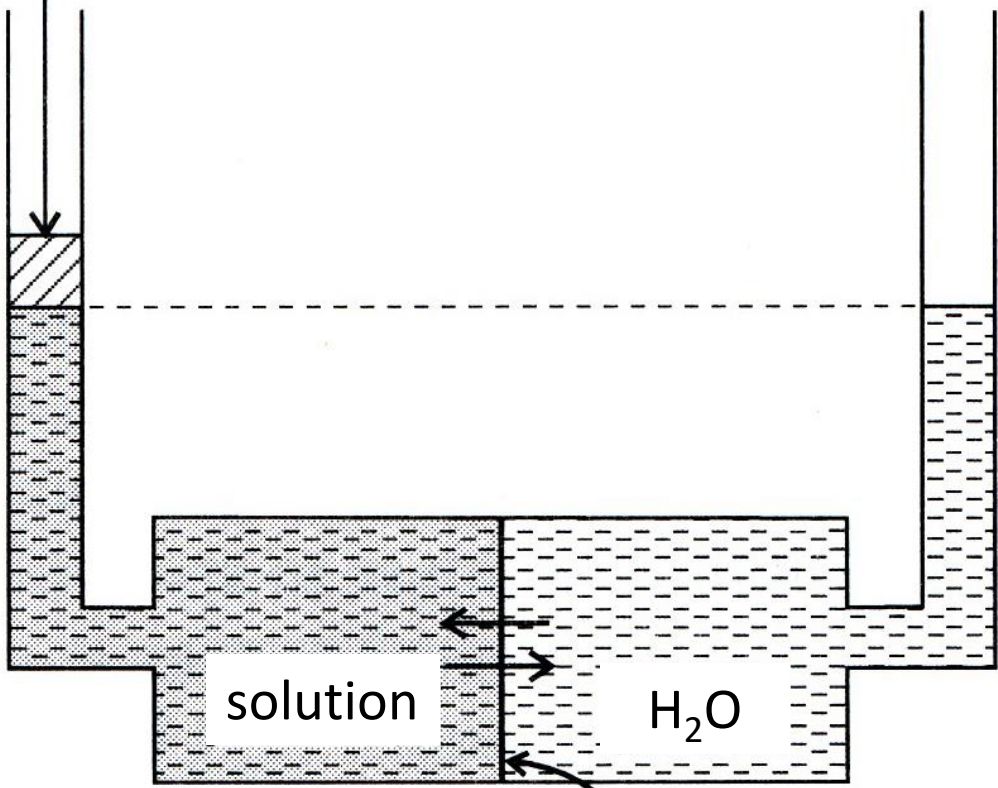


pressure



membrane

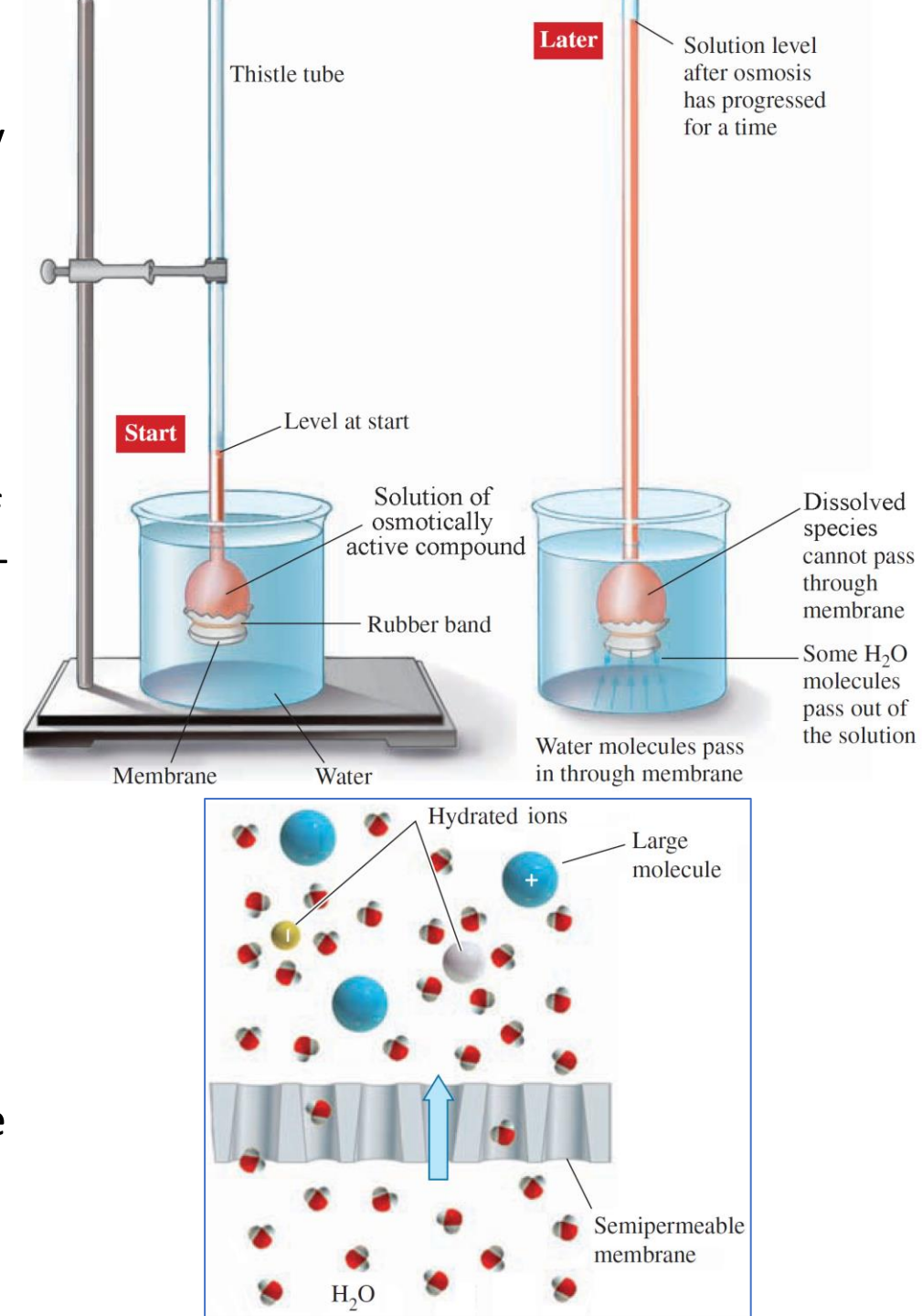
a.

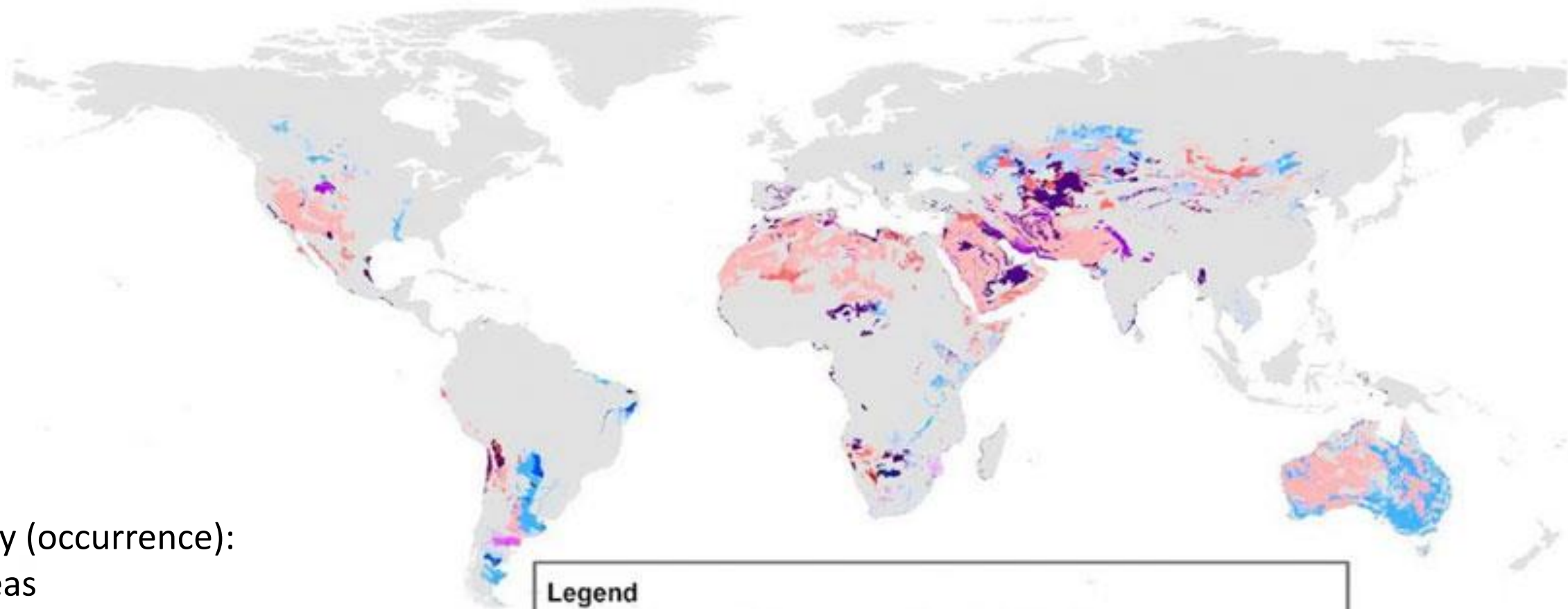


membrane

b.

Osmosis is a phenomenon (process) that occurs if water and solution (for example $\text{H}_2\text{O} + \text{NaCl}$) are separated from each other by membranes with selective permeability. This pertains also to more concentrated and less concentrated solutions. The membrane freely passes solvent (H_2O) molecules, but it is almost impermeable for the ions of the dissolved substance. Depending on the concentration, as well as the solubility of the given substance, water molecules flow through the membrane into the solution, which causes the rise to a certain level. The hydrostatic pressure of the resulting column will equal the value of the osmotic pressure of the given solution. A similar situation occurs in plant/microbial cell - soil solution system. In the picture, the left part of the connected vessels represents a hypertonic environment, while the right part represents a hypotonic environment (the reason is the different concentration of osmotic active substances). If the cell is in a hypotonic environment, water flows into the cells → the cell increases its volume, relatively strong cellulose cell walls prevent it from increasing. If (on the contrary) the cell is present in a hypertonic environment, the cell loses water - it flows into the solution that surrounds it, and if the H_2O losses are too great, the so-called plasmolysis (detachment of the plasmalemma from the cell wall) → the cell dies. In addition to the plasmalemma, the salt content in the cytoplasm is regulated by the vacuole, which in some cases can occupy up to 90% of the cell volume. If the cytoplasm is hypertonic, the vacuole releases water into it and vice versa.





Soil salinity (occurrence):

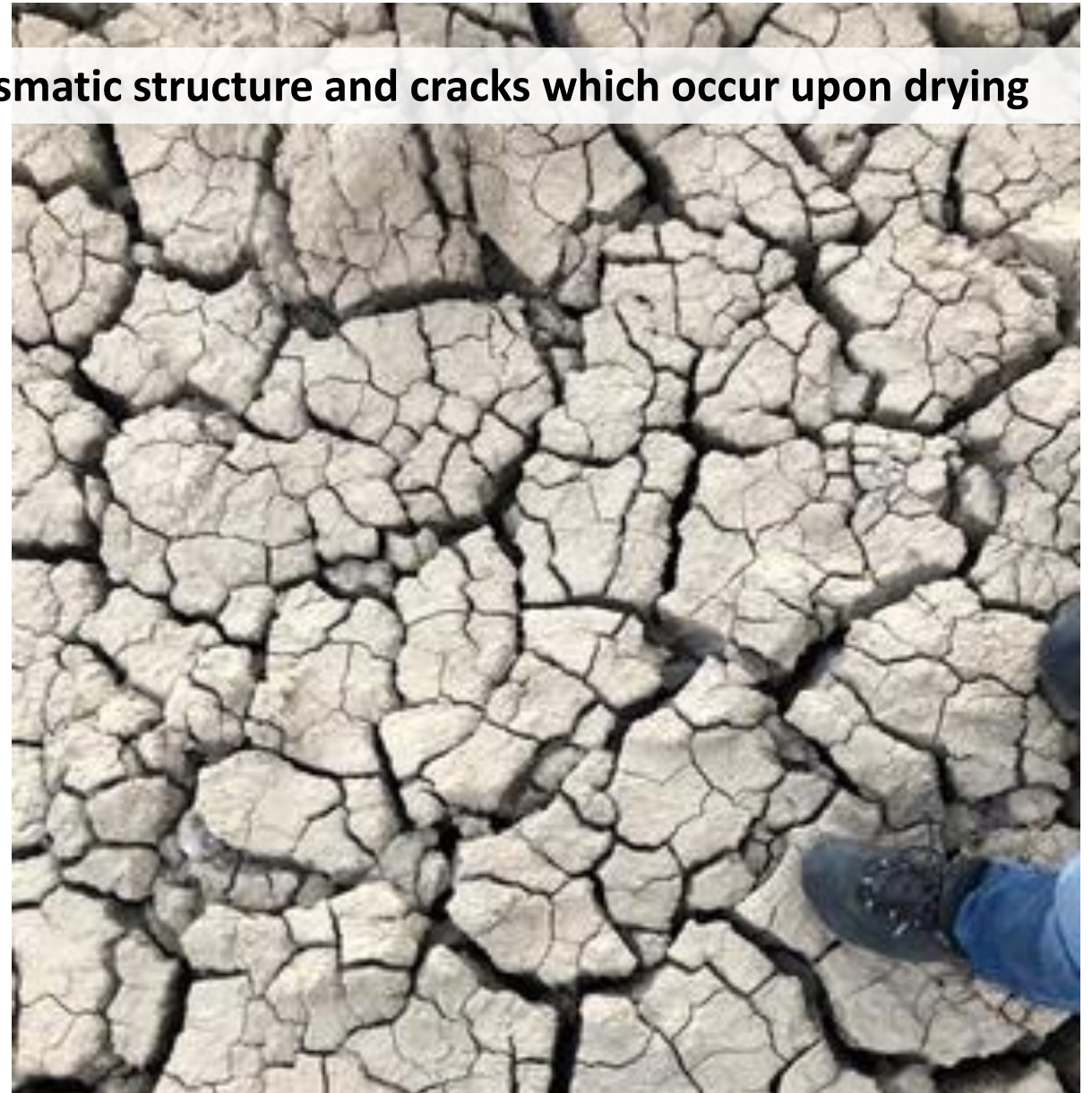
- arid areas
- low altitudes, plain terrain
- shallow water table
- higher concentration of dissolved salts in the groundwater (especially Na salts)

Legend

Type and severity levels of salt-affected soils

	saline slight		sodic slight		saline-sodic slight
	saline moderate		sodic moderate		saline-sodic moderate
	saline high		sodic high		saline-sodic high
	saline extreme		sodic extreme		saline-sodic extreme

soils intensively affected by sodicity often exhibit prismatic structure and cracks which occur upon drying



this however doesn't mean that soil cracks are symptoms of salinity/sodicity; many soils shrink during drying process, which is caused by the presence of certain clay minerals (smectites)

How to determine risk of soil salinity

- **electrical conductivity** - EC (mS cm^{-1})
- exchangeable sodium percentage (ESP) in %
- sodium absorption ratio = SAR

$$\text{SAR} = [\text{Na}^+]/([\text{Ca}^{2+}] + [\text{Mg}^{2+}])^{1/2}$$

- concentrations are given in mmol L^{-1}

salinity vs. sodicity (difference)

- **salinity**: caused by accumulation of highly soluble salts in soil
- **sodicity**: caused by accumulation of highly soluble **sodium** salts in soil → high ESP and SAR values

Occurrence of saline soils in the world

Climatic conditions	Salinity is	Water mineralization (g L ⁻¹)			Amounts of salts in surface horizon (%)
		Rivers	Subsurface	Lakes	
deserts	common	20-90	200-350	350-400	25-75
semi-desert	frequent	10-30	100-150	300-350	5-8
steppes	occasional	3-7	50-100	100-250	2-5
forest steppes	very rare	0,5-1	1-3	10-100	0,5-1
forests	-	0,1-0,2	0-1	0	0

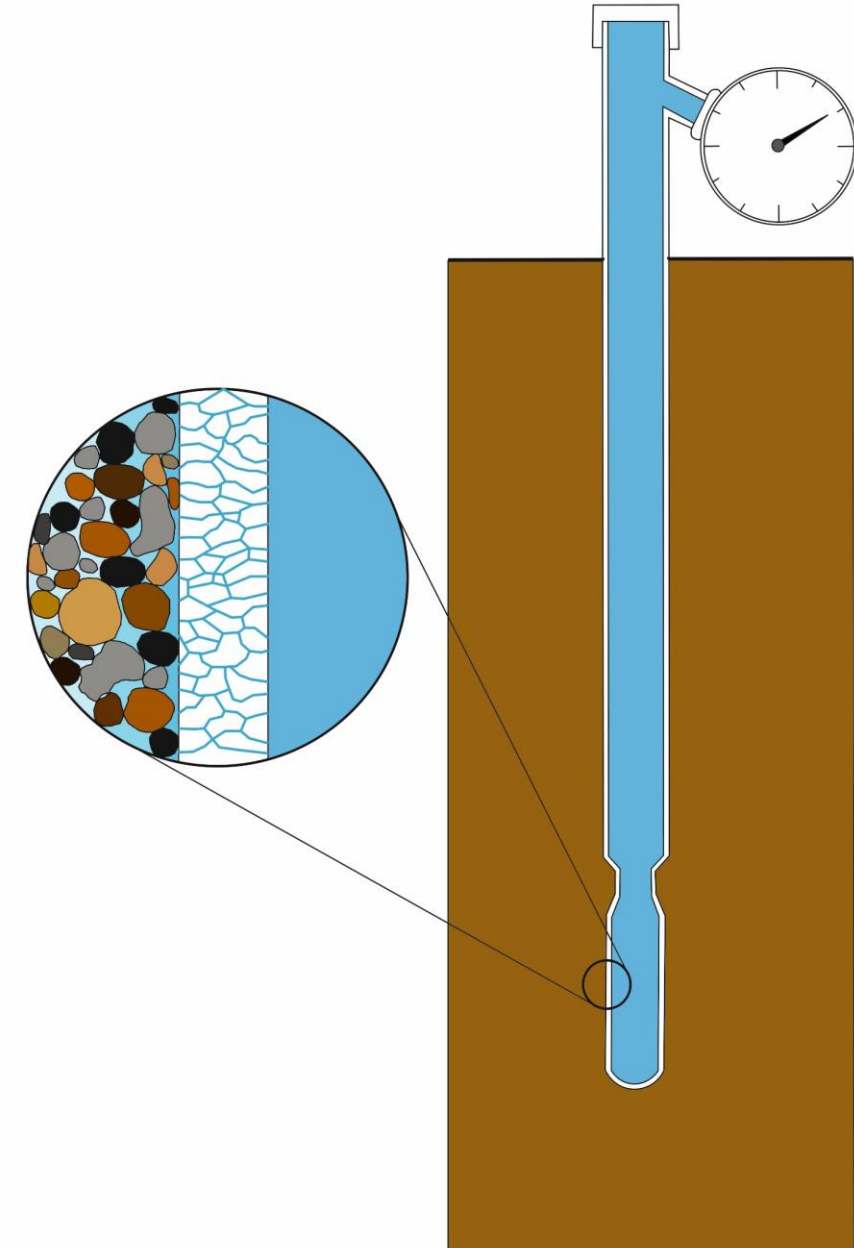
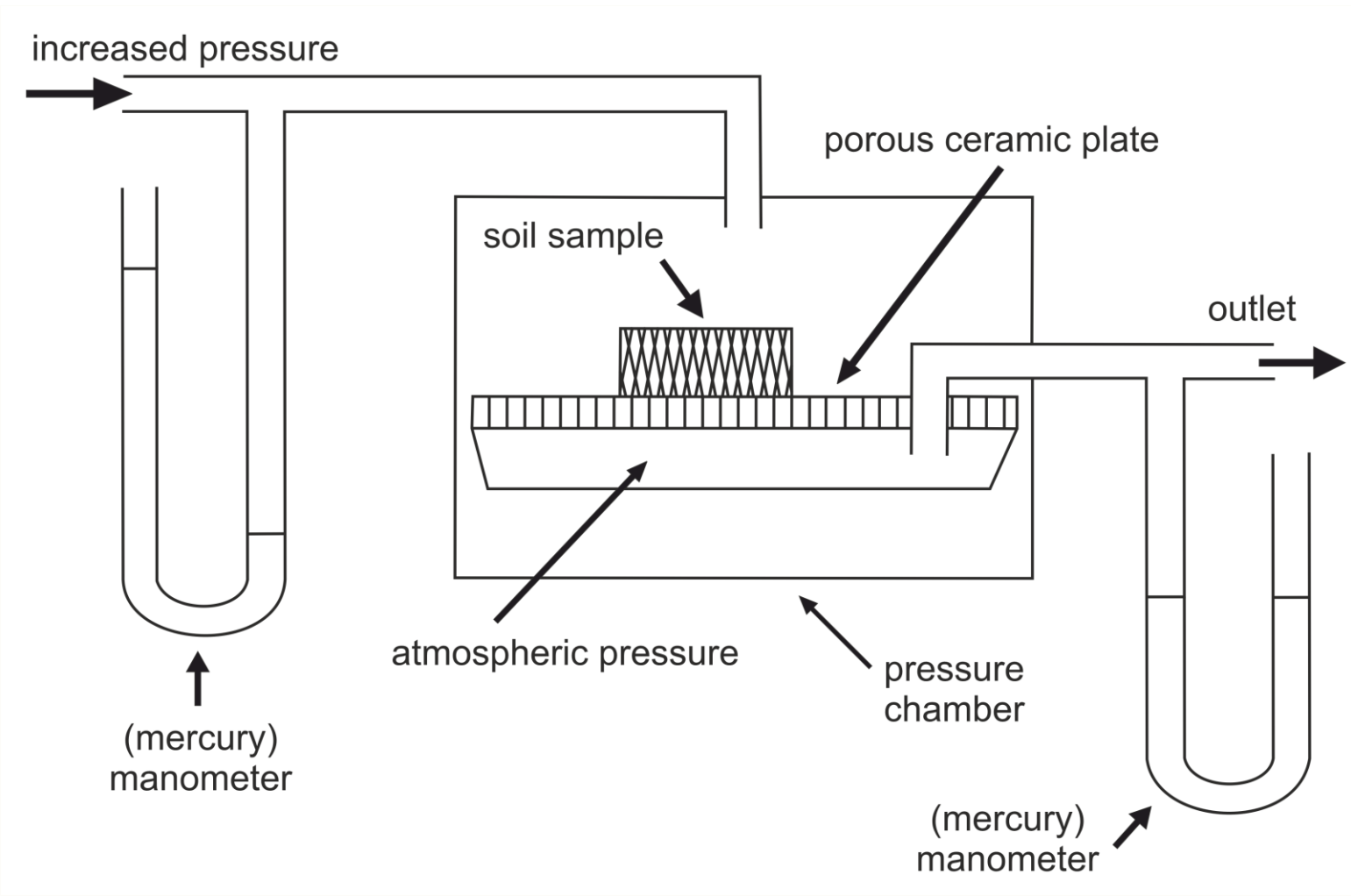
Occurrence of saline soils in the world

Continent	Estimated area of saline soils (thousands ha)
Africa	80 538
Asia (south)	87 608
Asia (north - middle)	211 686
Europe	50 804
North America	15 755
Middle America (Mexico included)	1 965
South America	129 163
Australia plus part of south-east Asia	357 330
Total	854 311
Total in the world	954 832

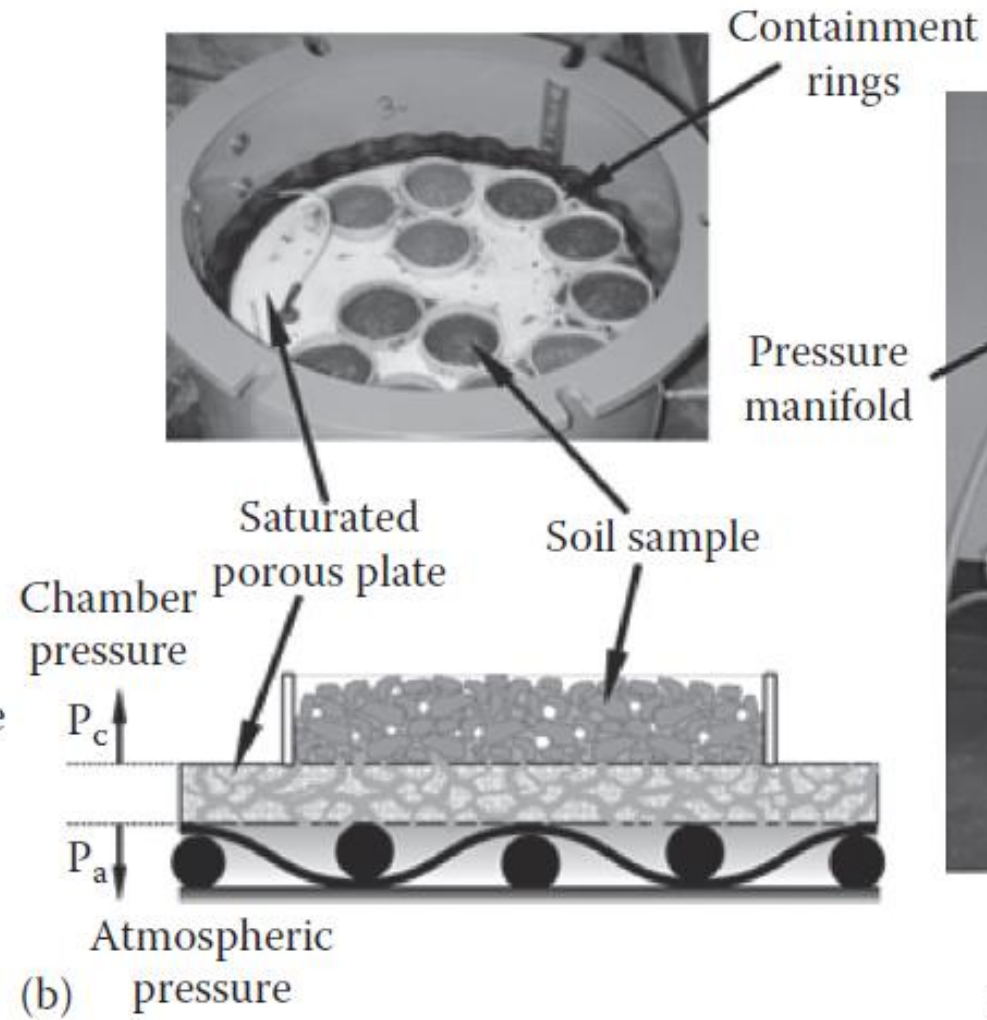
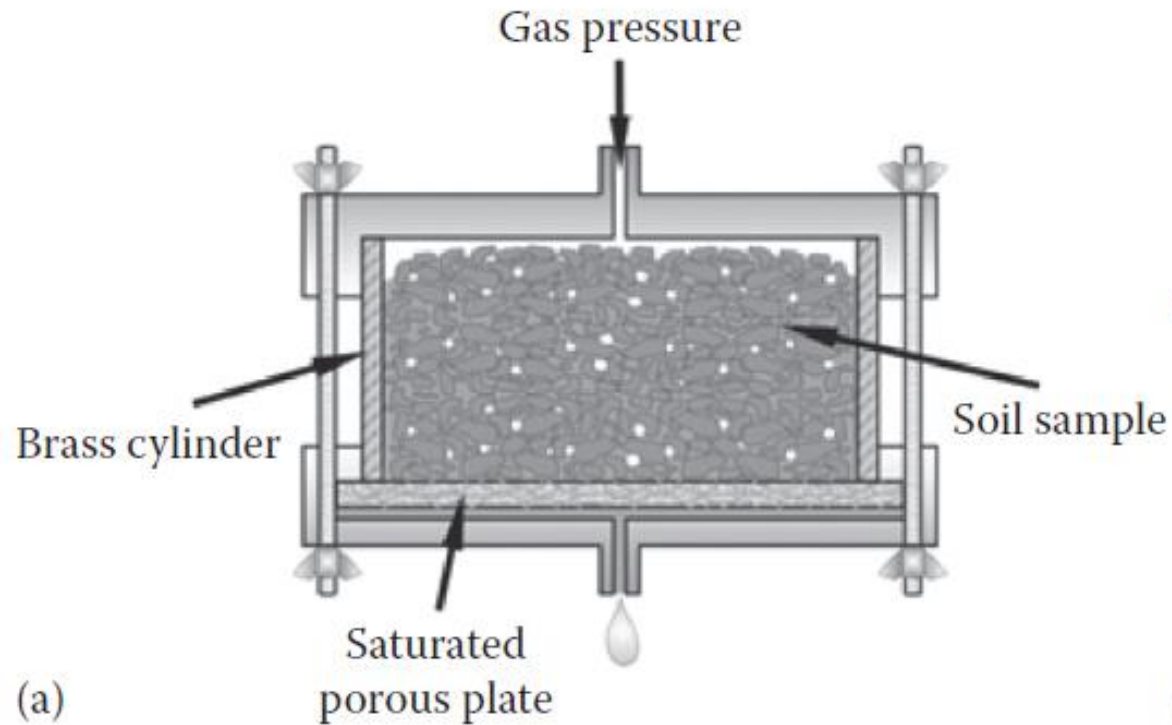
Soil water potential (the measurement)

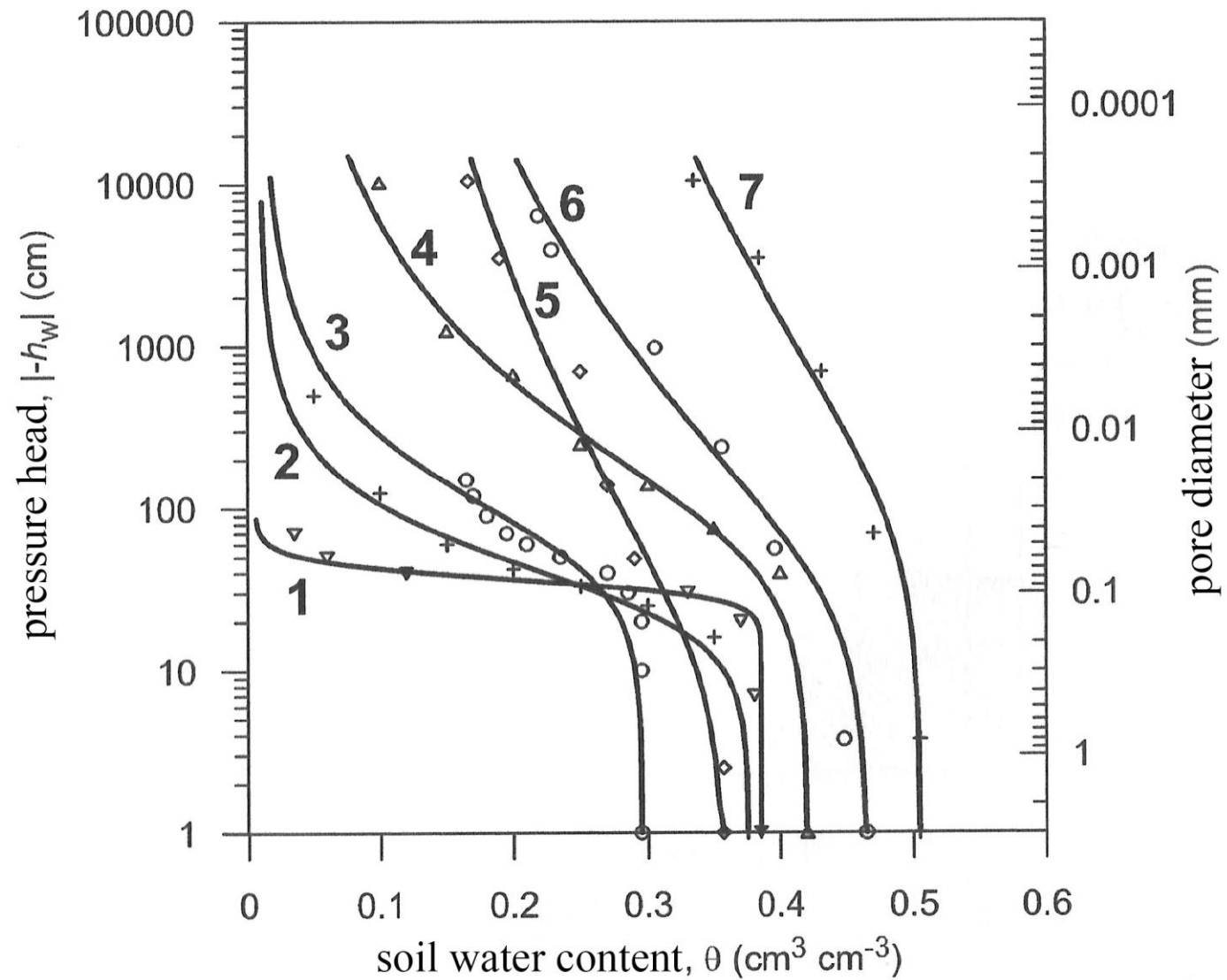
2. in the field – using tensiometers

1. in the laboratory: saturation of sample with water followed by its gradual dewatering in pressure chamber



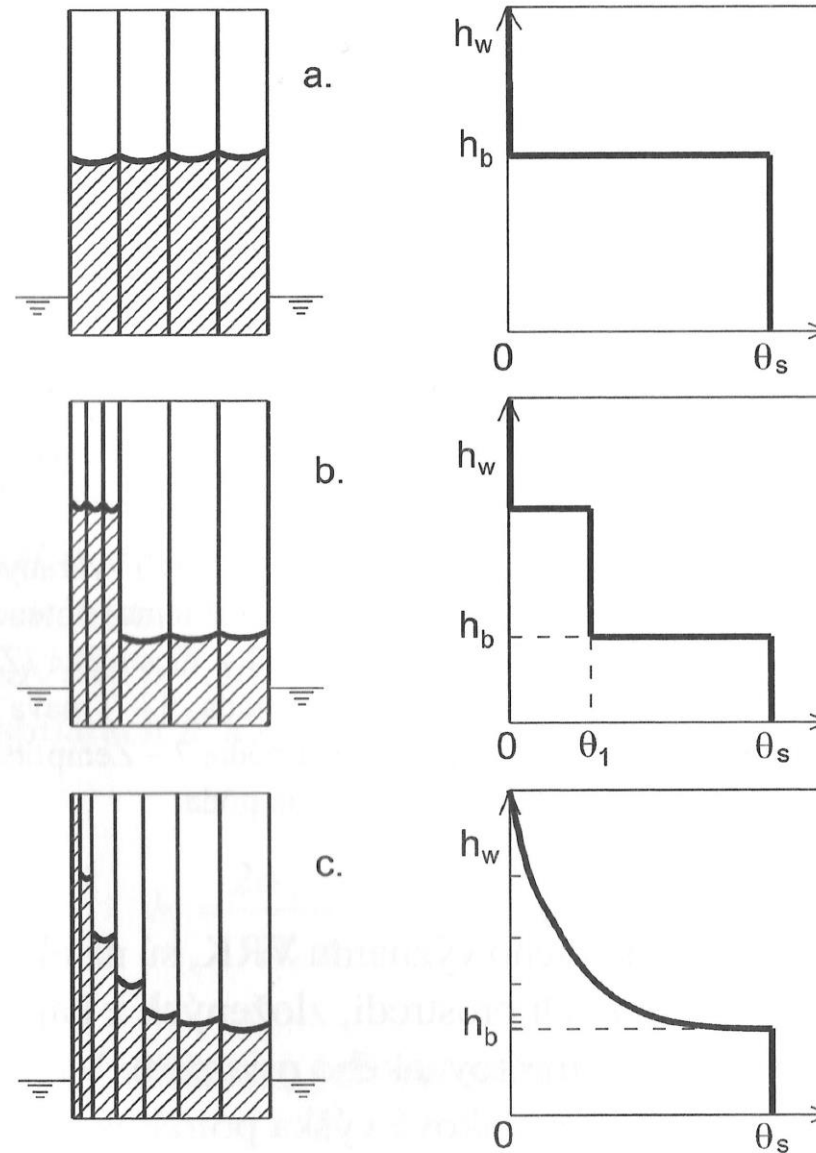
The measurement can be carried out using either undisturbed or disturbed samples..



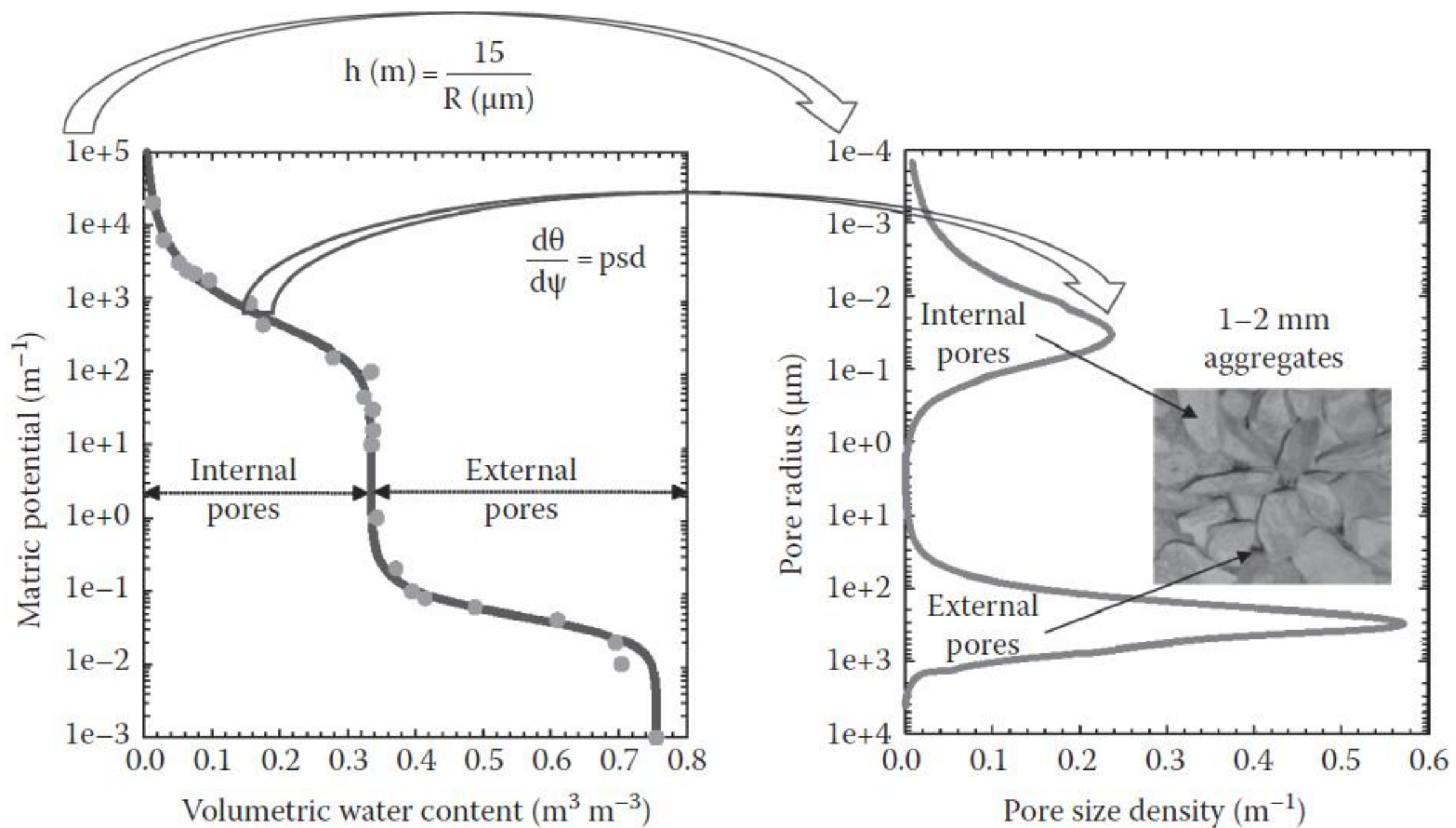


water retention curves of selected soils with differing texture (particle size distribution) and porosity: 1. sand, 2. silty sand soil, 3. sandy soil, 4 - 6. loamy soils, 7. clay soil

when moist soil is
subjected to drying the
larger pores are emptied
first



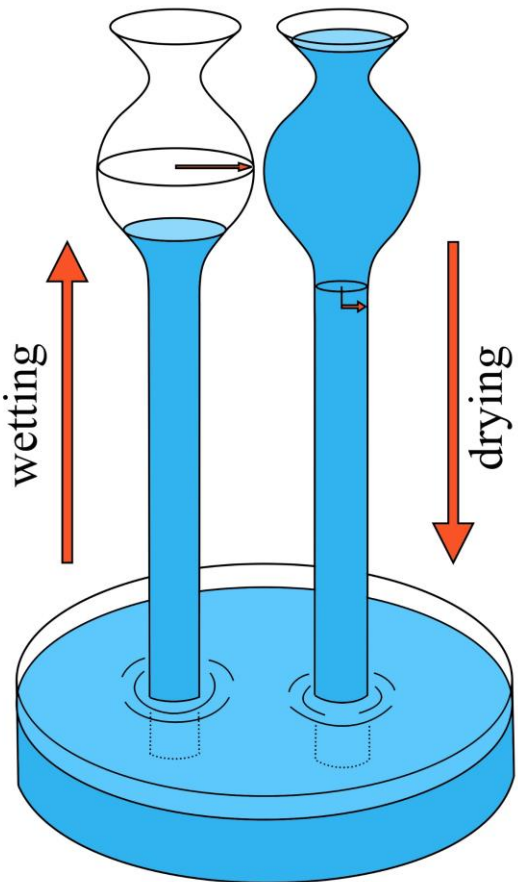
Models of hypothetic porous environments differing in pore size distribution and associated water retention “curves”: in the first one, all pores have same diameter and therefore the water is lost in one abrupt step; the model in the middle has pores with two diameters and the third one in the bottom shows model with more diverse pore size distribution, which results in more continuous dewatering.



SWC of dual-porosity aggregates (1–2 mm) mapped to a corresponding pore-size distribution using Equation 4.25.

Hysteresis of soil water

- same amount of water will be held by soil more strongly in case of drying as in the case of wetting
- given soil potential value will be associated with higher moisture level in case drying compared to wetting



causes:

- differences in contact angle between wetting and drying
- differences in trajectory of moving water in case of wetting in comparison to drying

