GEOLOGY 408/508

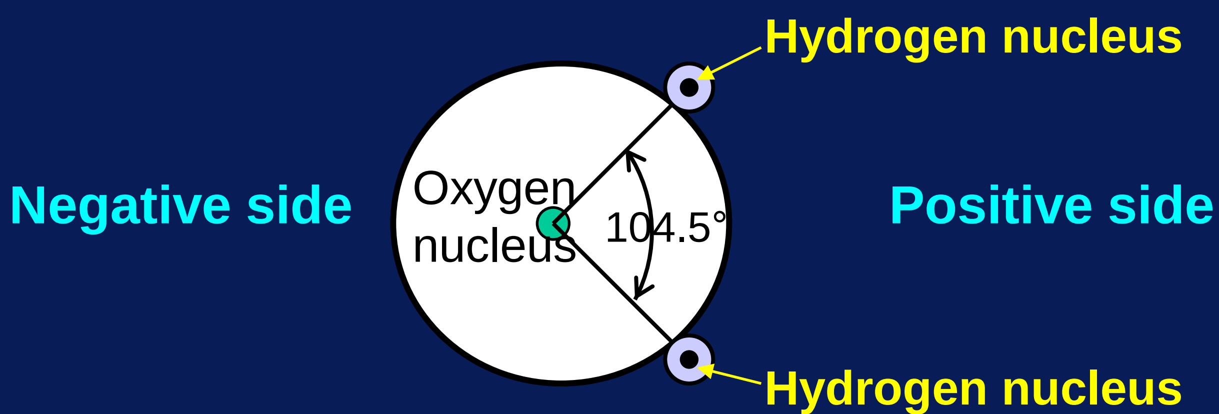
SOIL WATER: CHARACTERISTICS AND BEHAVIOR

CHAPTER 5

Brady & Weil, Rev. 14th ed.

SOIL WATER PROPERTIES

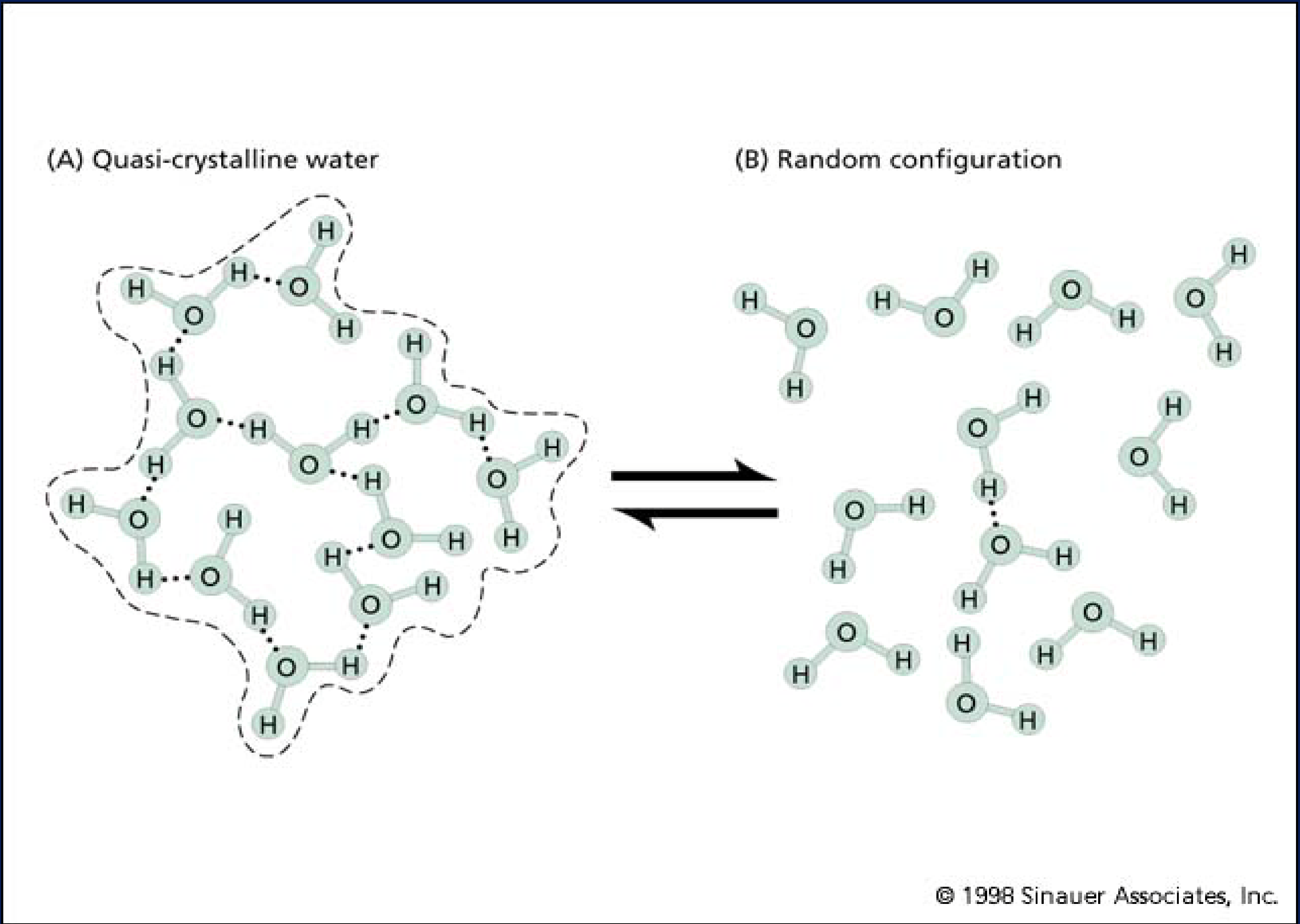
Polarity of the Water Molecule



Properties of:

- H-bonding - bonding of H^+ to O^{-2}
- Cohesion - like-to-like - H_2O to H_2O
- Adhesion - unlike - H_2O to (soil) solids
- Surface tension - H_2O to H_2O vs H_2O to air
- Capillarity - H_2O rise in capillary tube

SOIL WATER


(A) Quasi-crystalline water
(B) Random configuration
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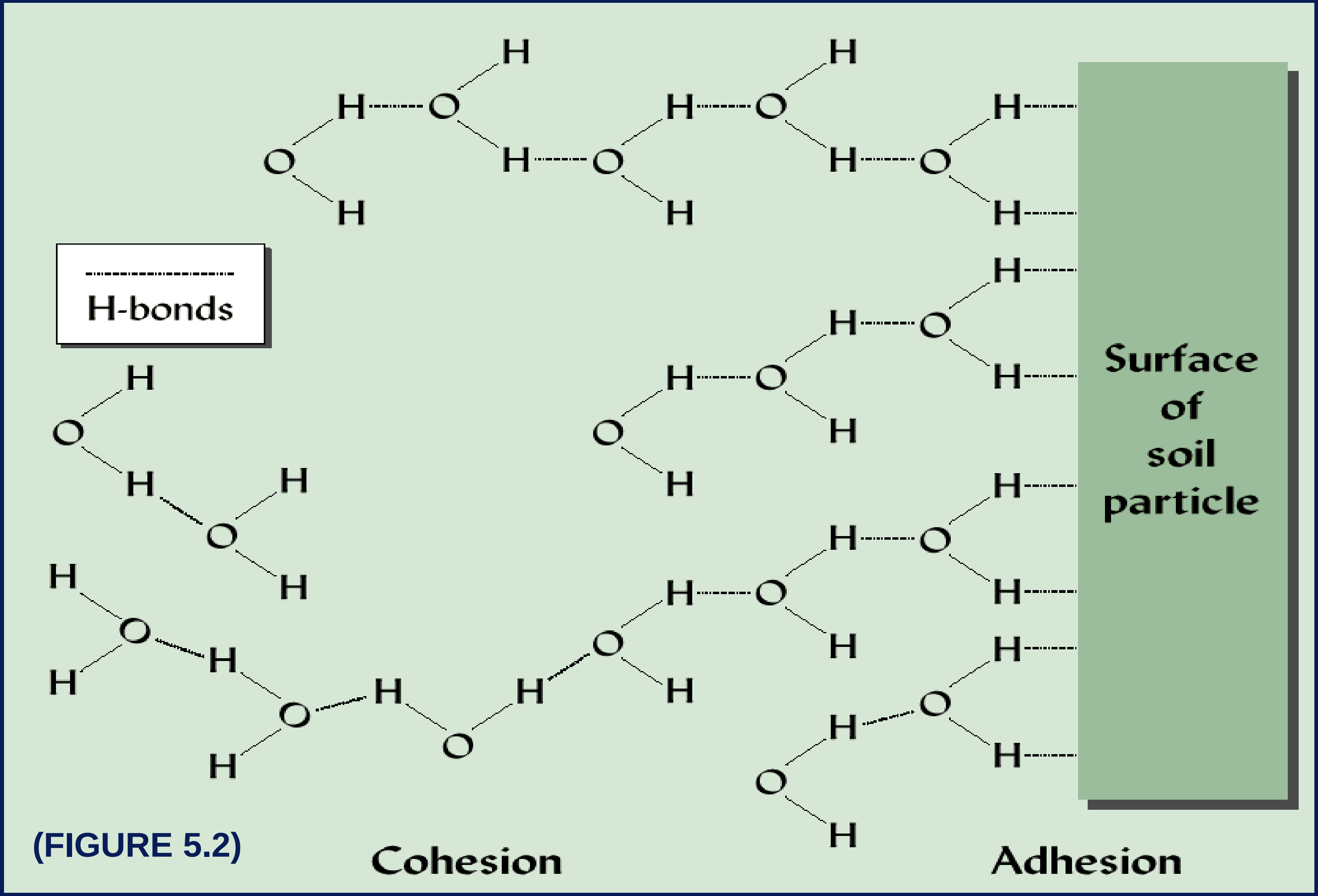
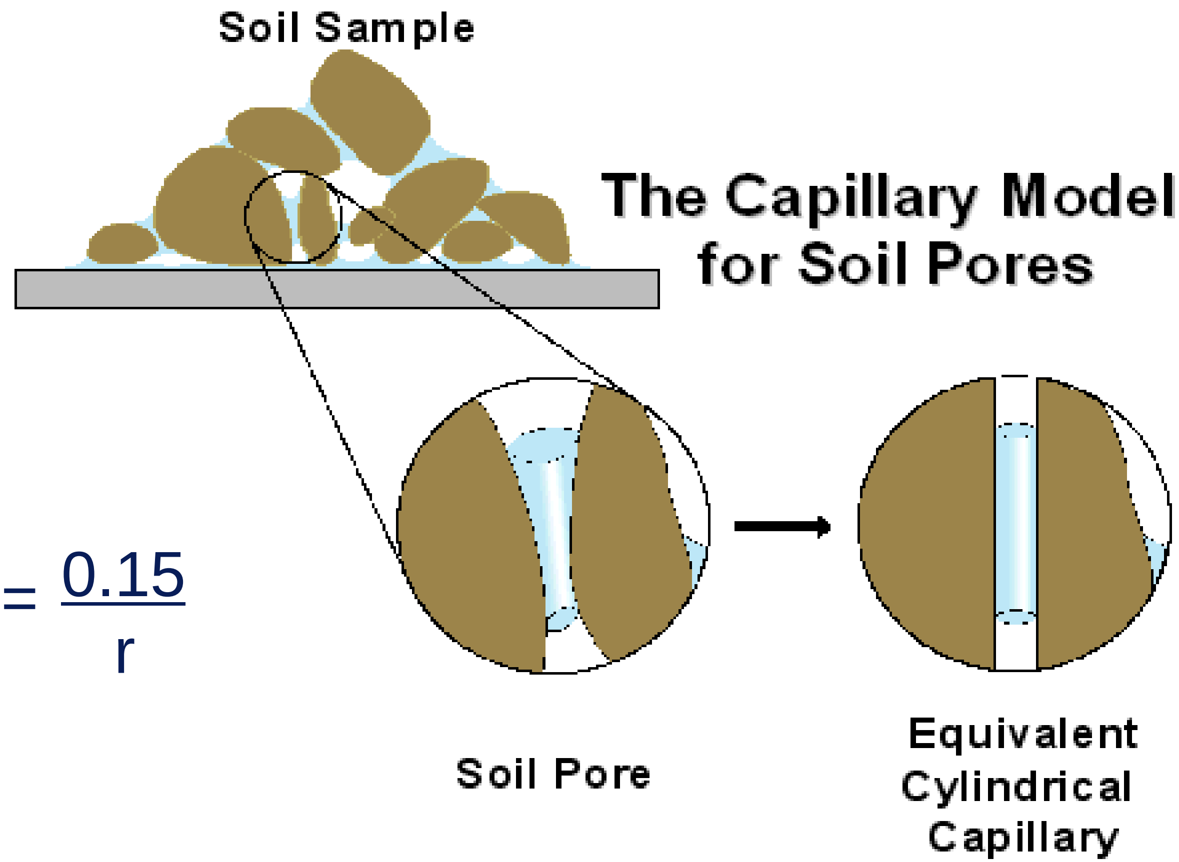
ADHESIVE AND COHESIVE FORCES IN A SOIL–WATER SYSTEM.



(FIGURE 5.2)

SOIL WATER



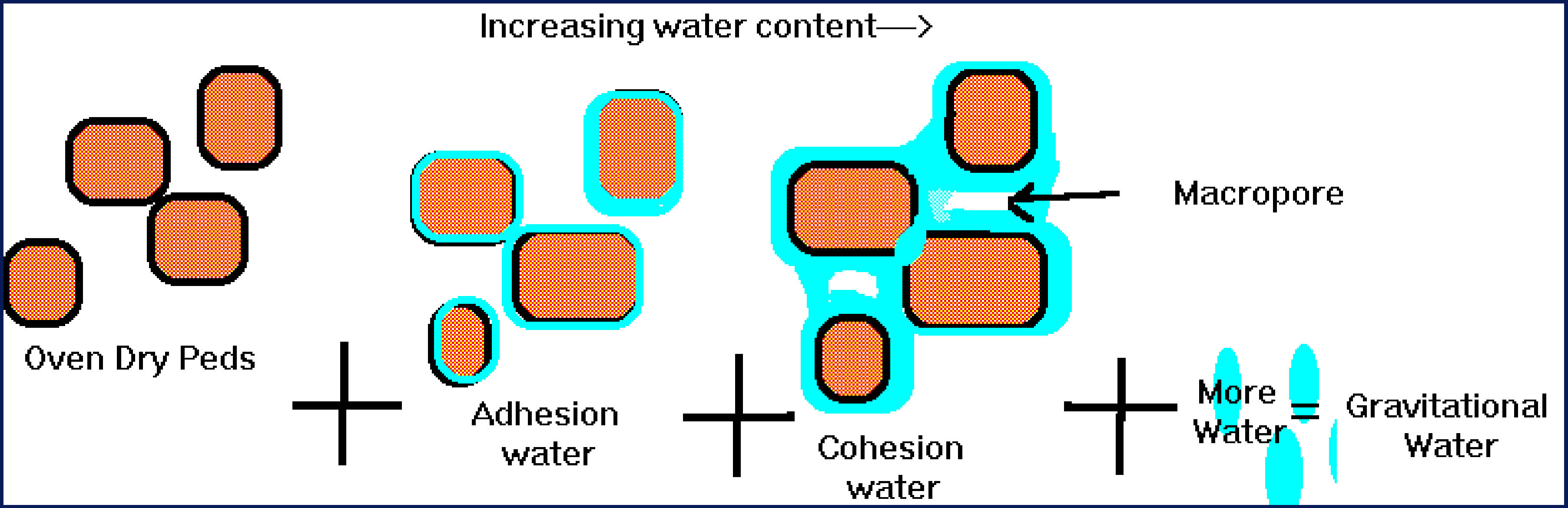
$$h = \frac{0.15}{r}$$

Conceptual representation of soil pores as equivalent capillaries. This concept is applied in many of our conceptual and mathematic/simulation models to describe and quantify soil hydraulic properties.

Source: Or and Wraith, 1999

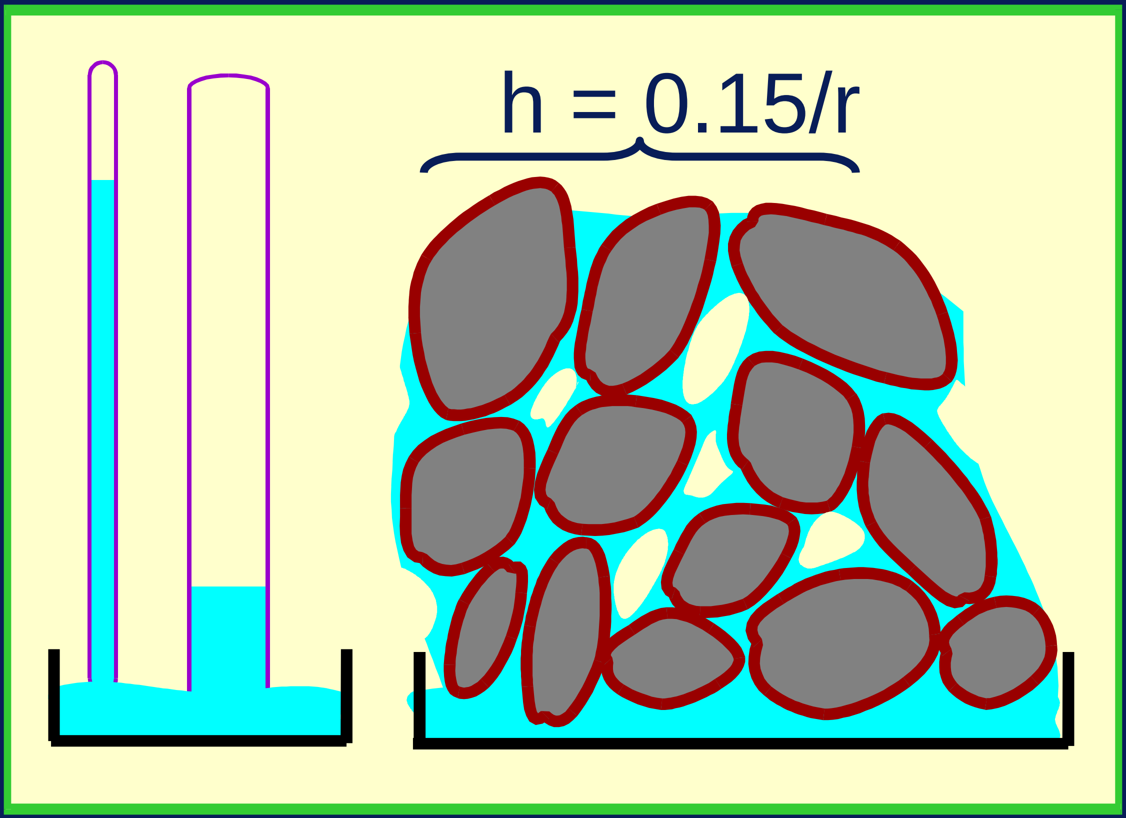
SOIL WATER

Soil Tension and Availability of Soil Water



CAPILLARY FORCES

$$h = \frac{2T \cos a}{r\,d\,g}$$



T = surface tension
a = wetting angle
r = radius of pore
d = density of water
g = gravity

- **Smaller pores hold water with greater energy**
- **nondirectional**

WATER MOVEMENT BY CAPILLARY ACTION

ENERGY CONCEPT

Water moves from *high to low free energy*

wet soil → dry soil

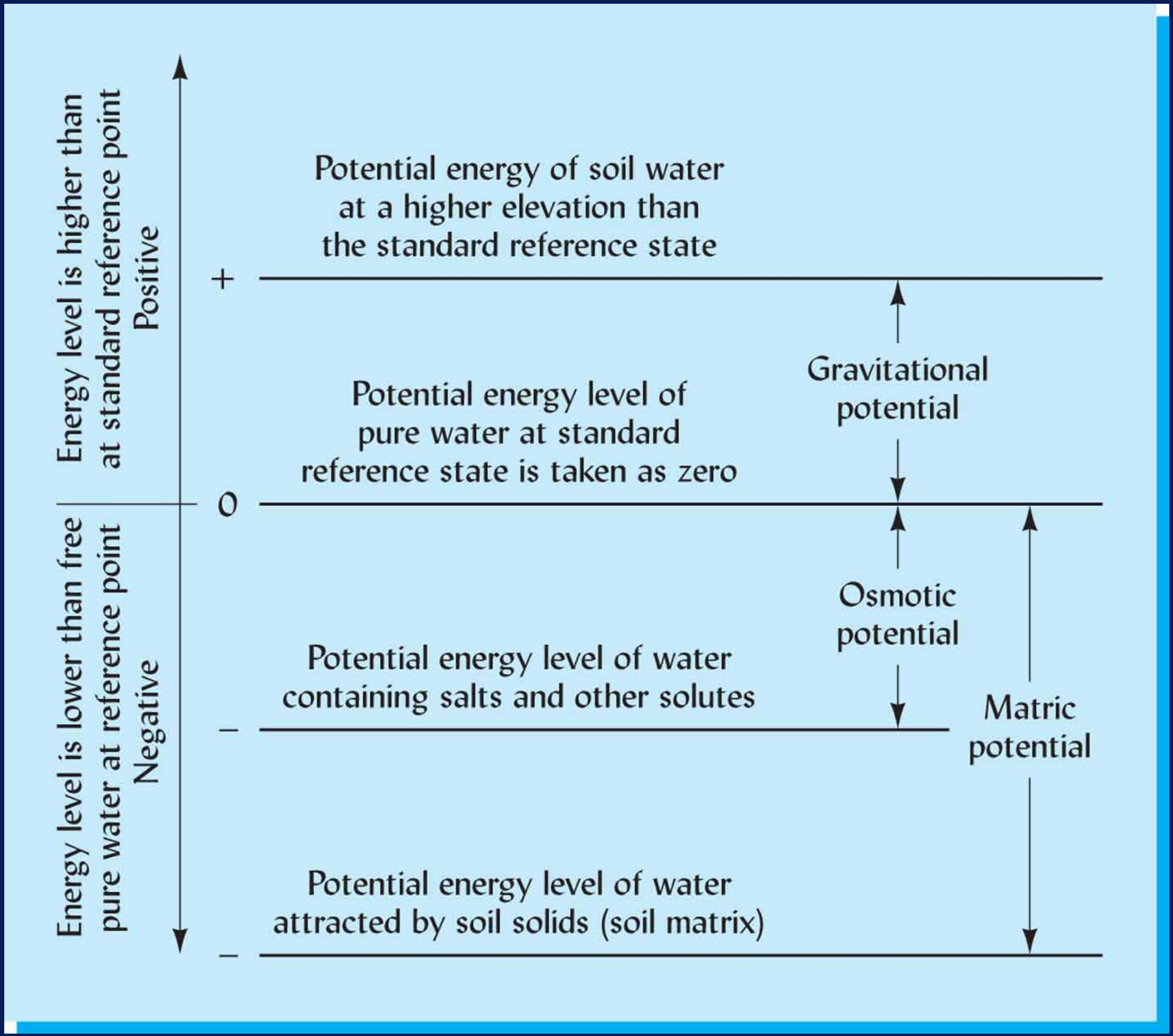
Large Pores | **H_2O movement** | **Small Pores**

H_2O free energy is higher

H_2O free energy is lower

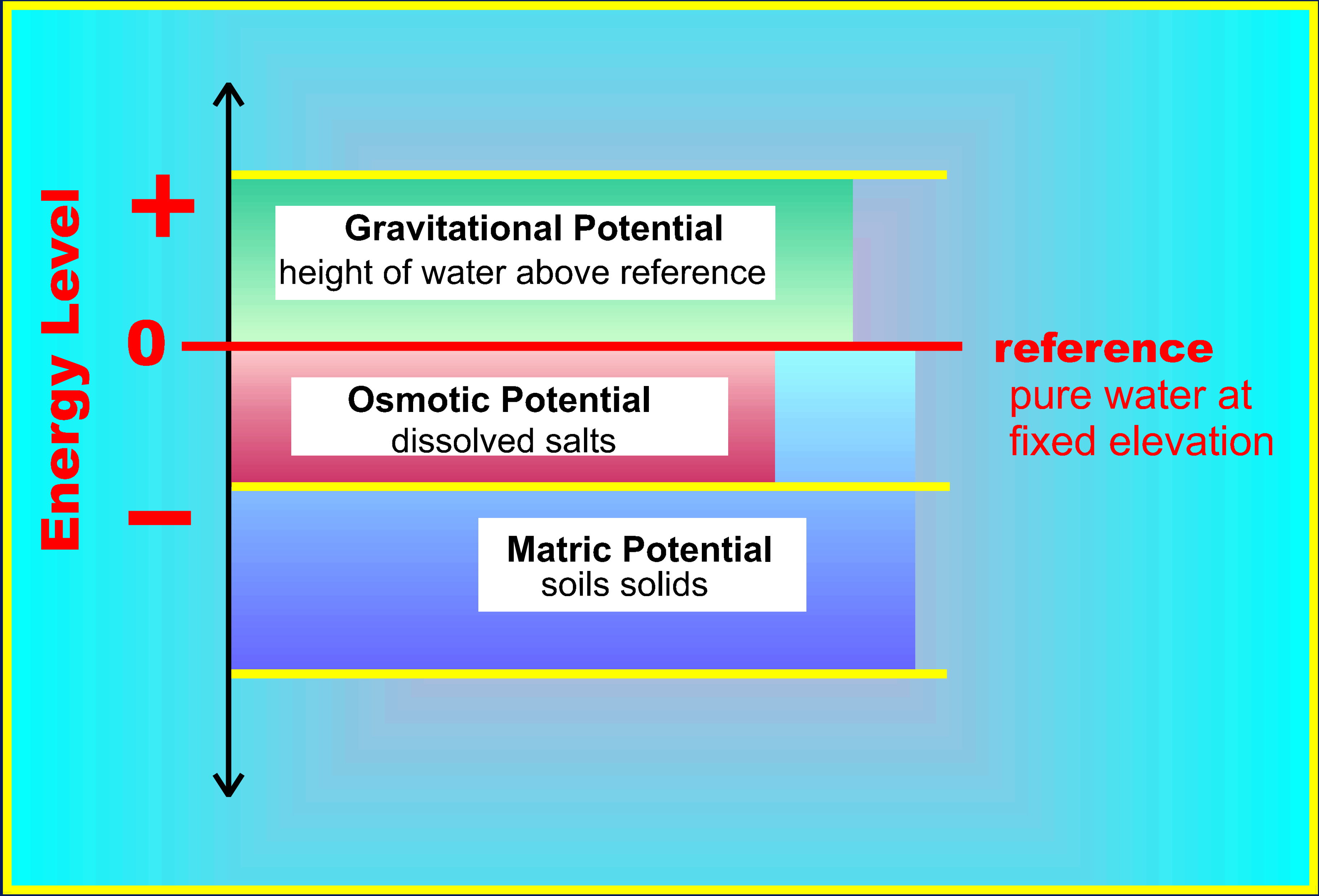
- difference in free energy causes H_2O to move

Relationship between the potential energy of pure water at a standard reference state (pressure, temperature, and elevation) and that of soil water



(FIGURE 5.7)

SOIL WATER POTENTIAL



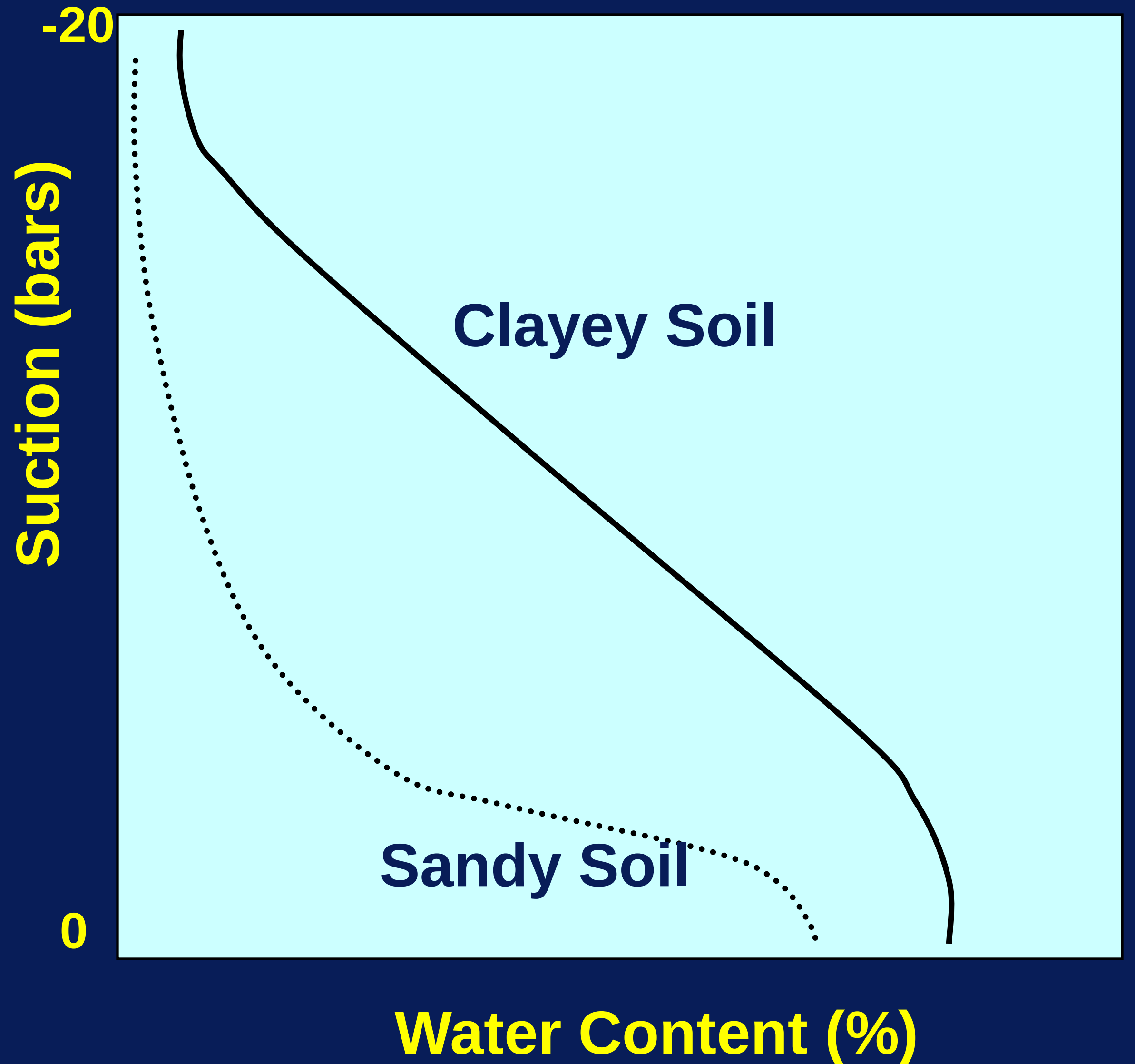
SOIL WATER POTENTIAL UNITS

1 atm = 760 mm Hg = 1020 cm H_2O = 1 bar = 100 KPa

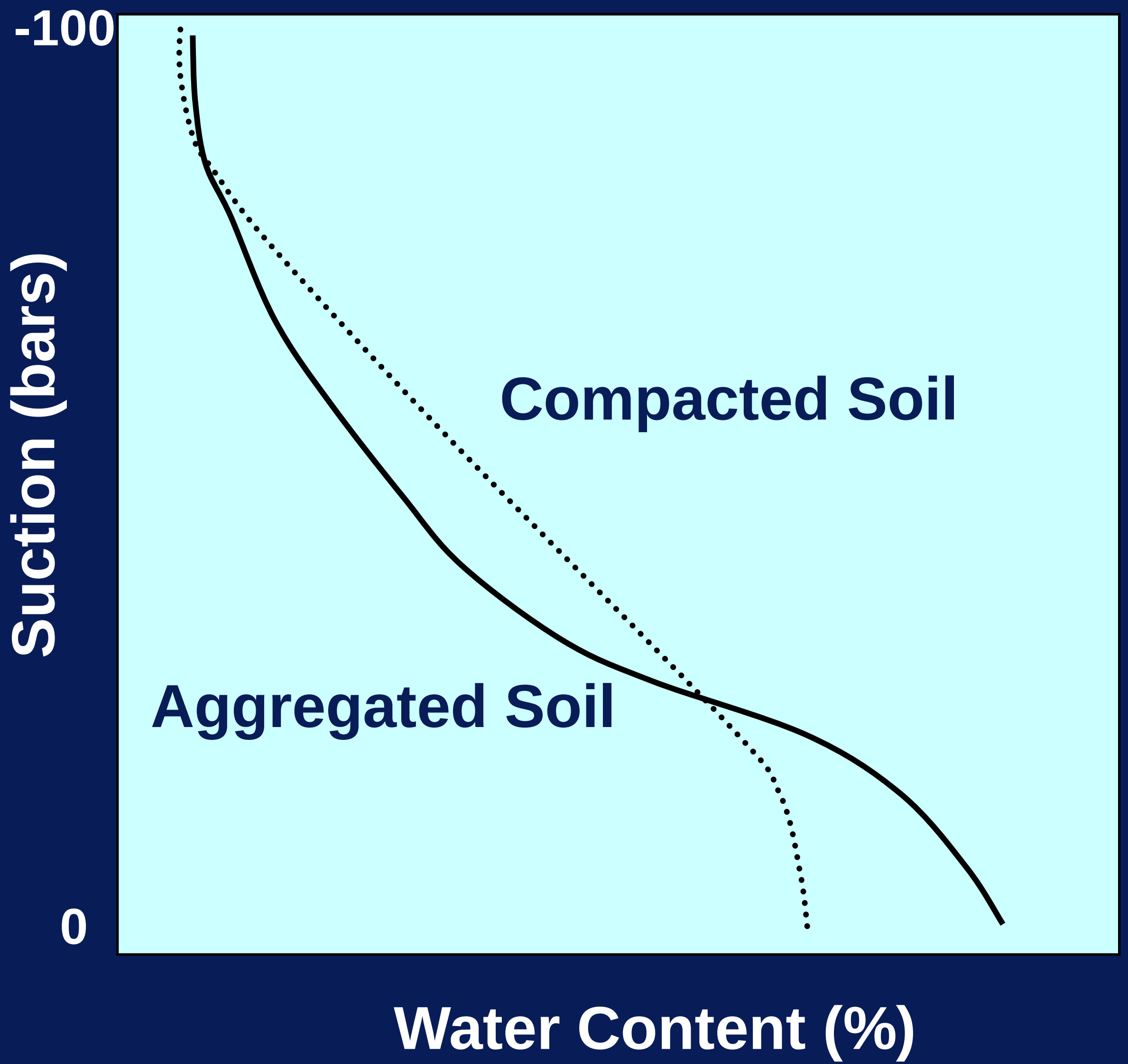
cm H_2O	bars	kPa
300	-0.3	-30
1,000	-1	-100
10,000	-10	-1000
15,000	-15	-1500

see Table 5.1 in text

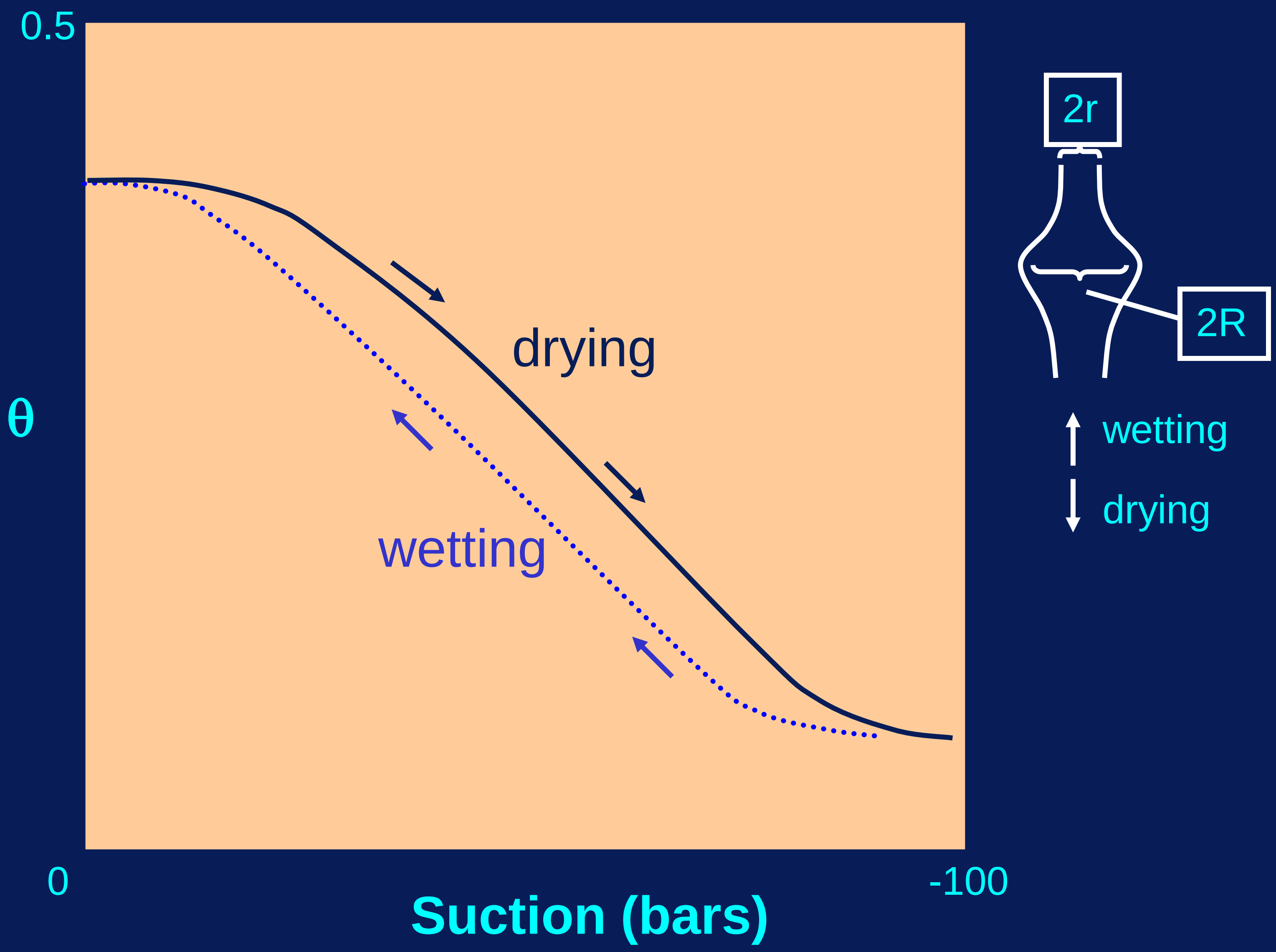
WATER RETENTION CURVES



WATER RETENTION CURVES



HYSTERESIS



MEASURING SOIL WATER CONTENT

Volumetric water content, θ, is the volume of water associated with a given volume of dry soil

Mass water content, θ_m, is the mass of water associated with a given mass of dry soil

Gravimetric method: remove sample, weigh moist, dry, weigh dry

Resistance blocks: place into soil, calibrate and obtain *in situ* measurements

MEASURING SOIL WATER CONTENT

Neutron Scattering: uses fast neutron which lose energy after colliding with water molecules
- there is a positive interference from OM

Time-Domain Reflectometry:

Measures:
- (1) travel time of electromagnetic impulse down two parallel metal rods buried in the ground

- (2) degree of dissipation of the impulse as it impacts soil at the end of the lines

Both moisture content & salinity can be measured

MEASURING SOIL WATER POTENTIALS

Tensiometers - measure the attraction of water by soil solids.

Field tensiometer - a plastic tube with a porous ceramic cup at the bottom and sealed at the top with a vacuum measuring device

- water in tube equilibrates with soil matric potential through porous cup

Electrical Resistance Blocks - porous gypsum, nylon or fiberglass with electrodes

- electrical current flow proportional to water sorbed by blocks

MEASURING SOIL WATER POTENTIALS

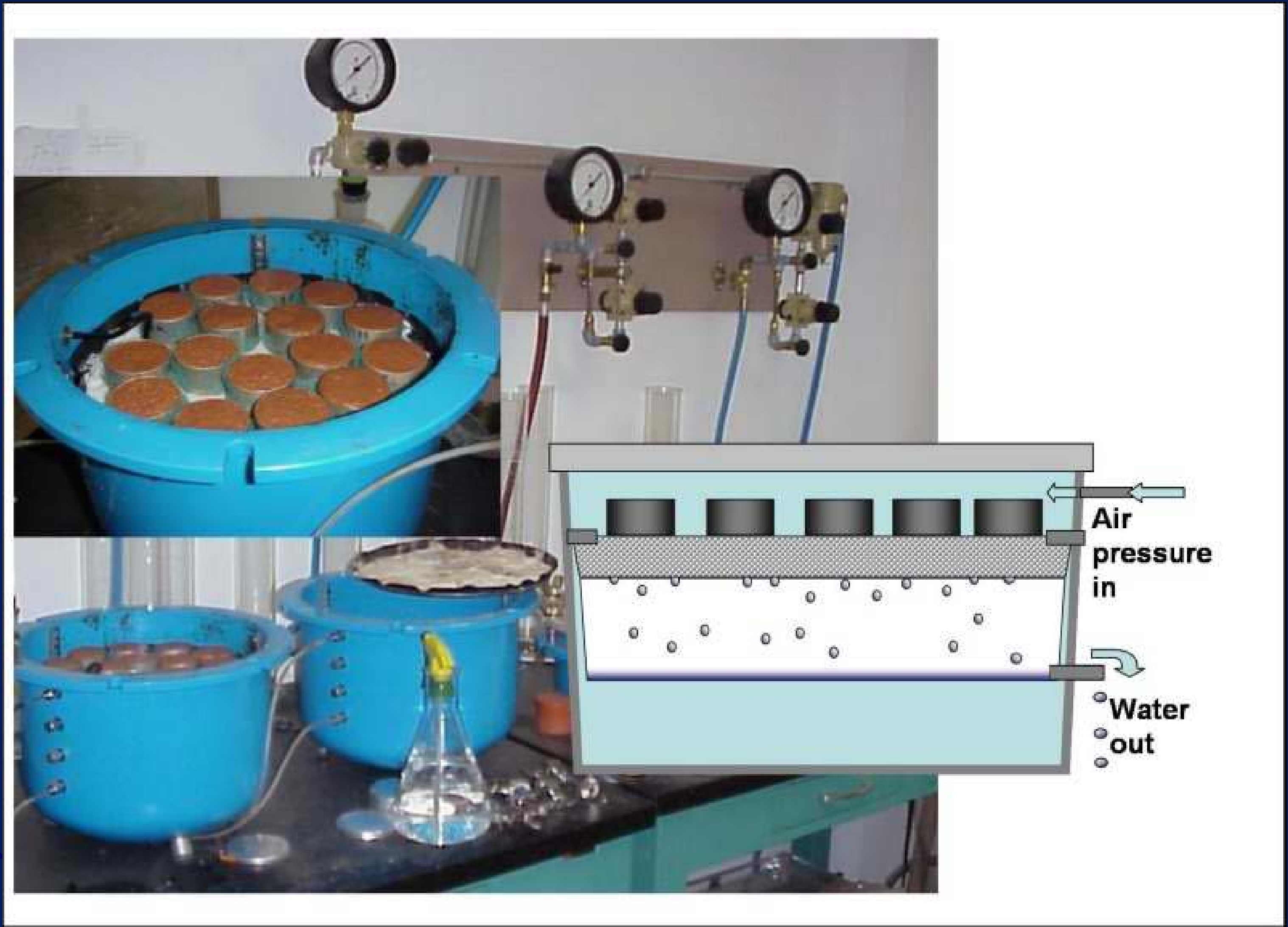
Thermocouple Psychrometer:

- measures both osmotic & matric potentials
- thermocouple junction inside small porous ceramic chamber uses cooling to condense a drop of water which is then allowed to evaporate
- evaporation rate is related to rel. humidity of soil air which is related to soil water

Pressure Membrane Apparatus:

- apply pressure to saturated soil samples
- can use range of pressures
- determine moisture remaining gravimetrically
- can measure matric potentials at -10,000kPa

Pressure membrane apparatus used to determine relationships between water content and matric potential in soils



Fig

SATURATED FLOW THROUGH SOILS

- All pores filled with water
- Occurs in poorly drained soils, above clay pans, after rain & irrigation

Saturated hydraulic conductivity:

$$Q = \frac{K_{sat} A \Delta P}{L}$$

K_{sat} - saturated hydraulic conductivity
A - cross sectional area of column through water flows
ΔP - hydrostatic pressure difference: top/bottom of col.
- hydraulic gradient or driving force
L - length of column

SATURATED FLOW THROUGH SOILS

Factors Influencing the Hydraulic Conductivity of Saturated Soils:

- Factors which influence size & configuration of soil pores
- Macropores account for most of saturated water flow
- Texture and structure
- OM and nature of inorganics (type of clay)

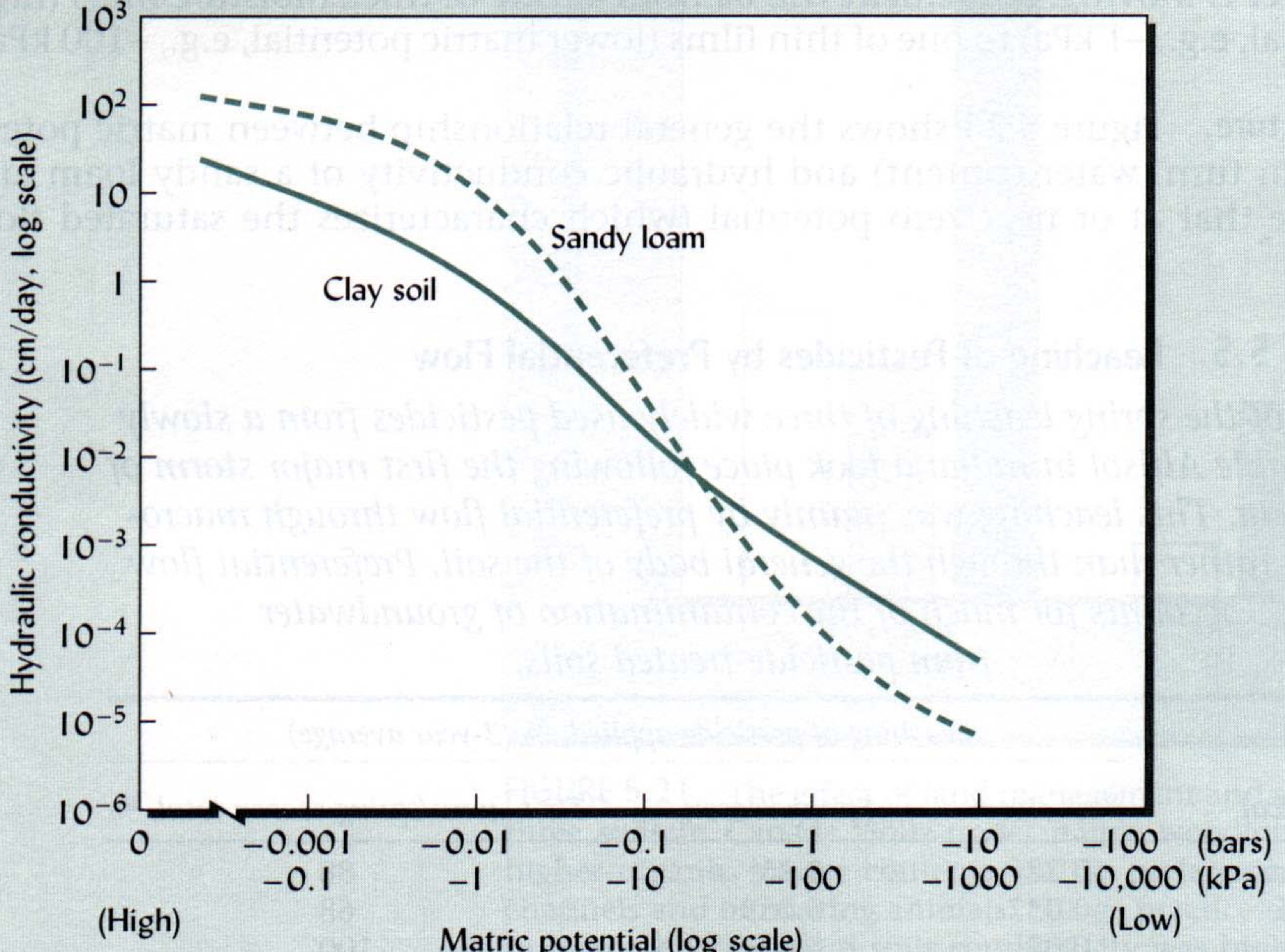
Preferential Flow:

- Sandy soils - fingering through textural channels
- Clayey soils - network of cracks, fissures, old root channel

UNSATURATED FLOW THROUGH SOILS

- Most soil water movement occurs as unsaturated flow, through capillary pores
- Movement is slow due to irregularity of pores and air in pores
- More unsaturated flow in clay soil than sandy soil
- Matric potential gradient is driving force

MATRIC POTENTIAL AND HYDRAULIC CONDUCTIVITY



(FIGURE 5.22)

INFILTRATION AND PERCOLATION

Infiltration:

- The process by which water enters the soil pore spaces
- Infiltration capacity is the rate at which water can enter the soil (cm h^{-1})
- Infiltration capacity generally decreases during a rainfall or irrigation episode
  - pores, especially in subsoil, fill with water; pores in subsoils smaller than in surface soil
  - clays may swell upon wetting, reducing pore size

INFILTRATION AND PERCOLATION

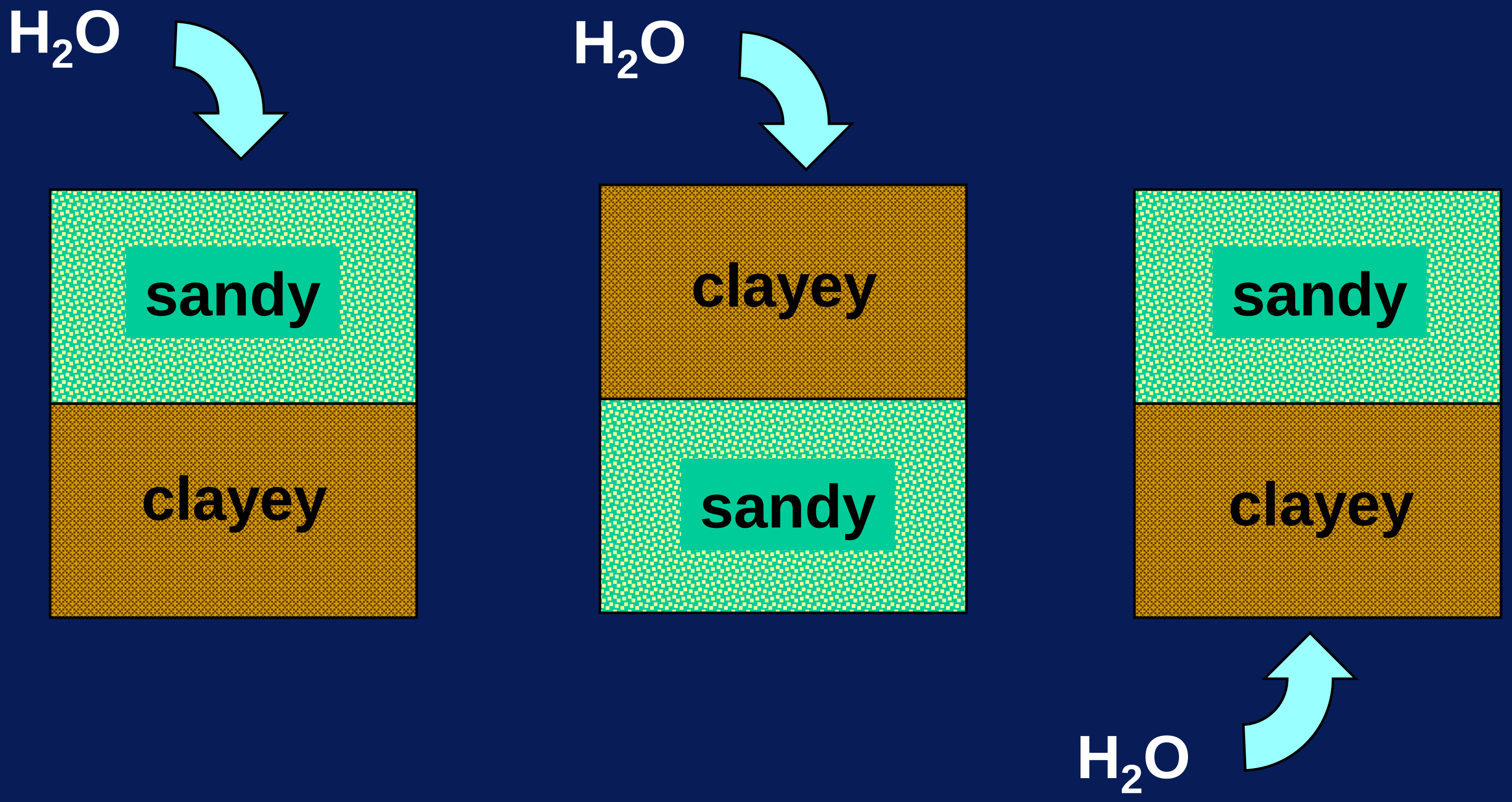
Percolation:

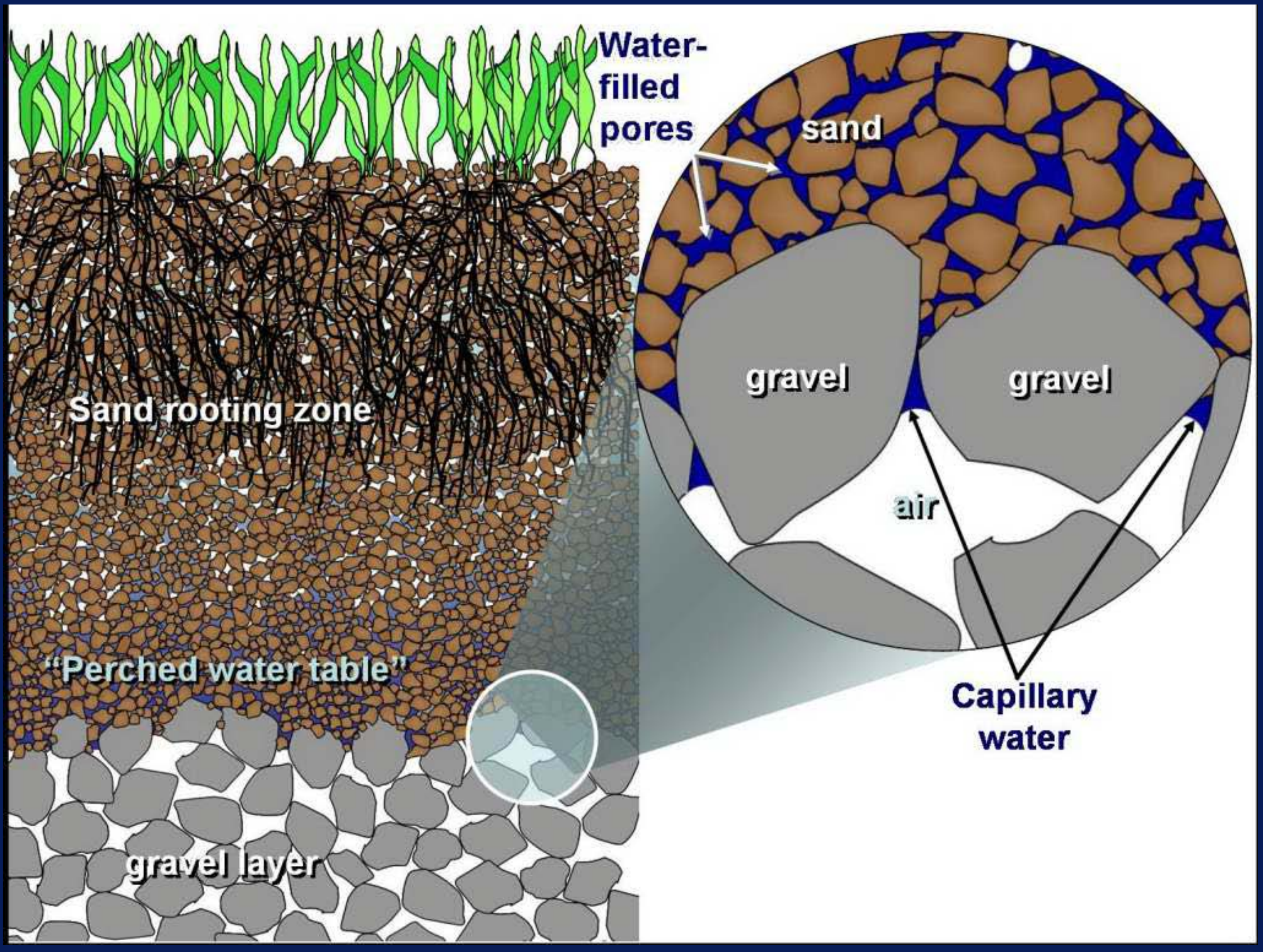
- Downward movement of water into the profile
- Involves both saturated and unsaturated flow
- Usually appears to be a sharp boundary, wetting front, between wet and dry soil
- Percolation rate generally decreases with depth
- Percolation rate generally decreases during a rainfall or irrigation episode

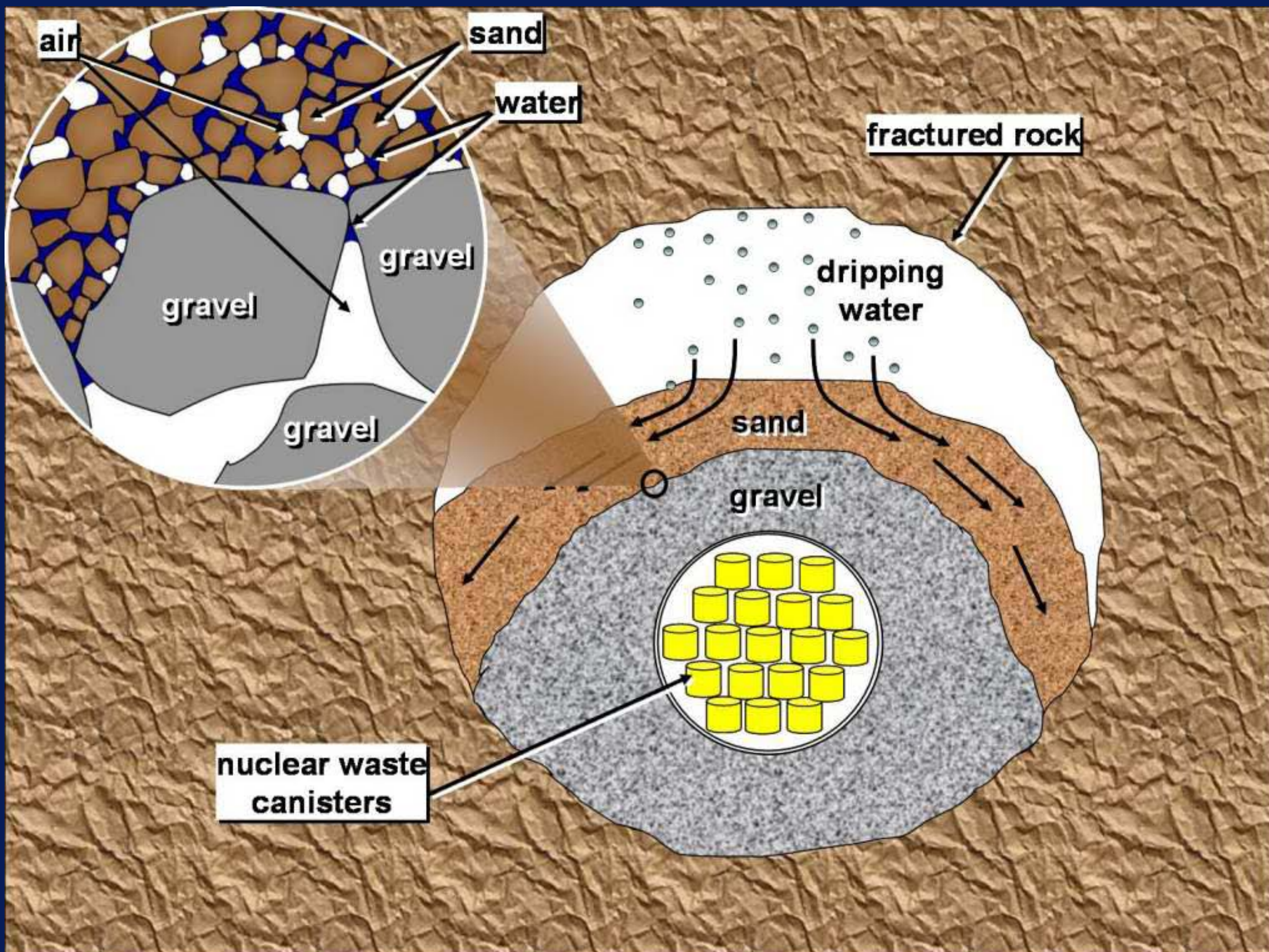
WATER MOVEMENT IN STRATIFIED SOILS

- Most downward water movement is by unsaturated flow
- Stratified layers have a very profound influence on water movement
- Effect is usually that of a barrier to downward (and upward!) water movement
- Impervious clay or silt pans hinders downward movement
- Sand or gravel layer will also act as barrier to water flow - due to differences in matric potential in the fine vs. coarse layers
- Causes soil to be unexpectedly wet for longer period

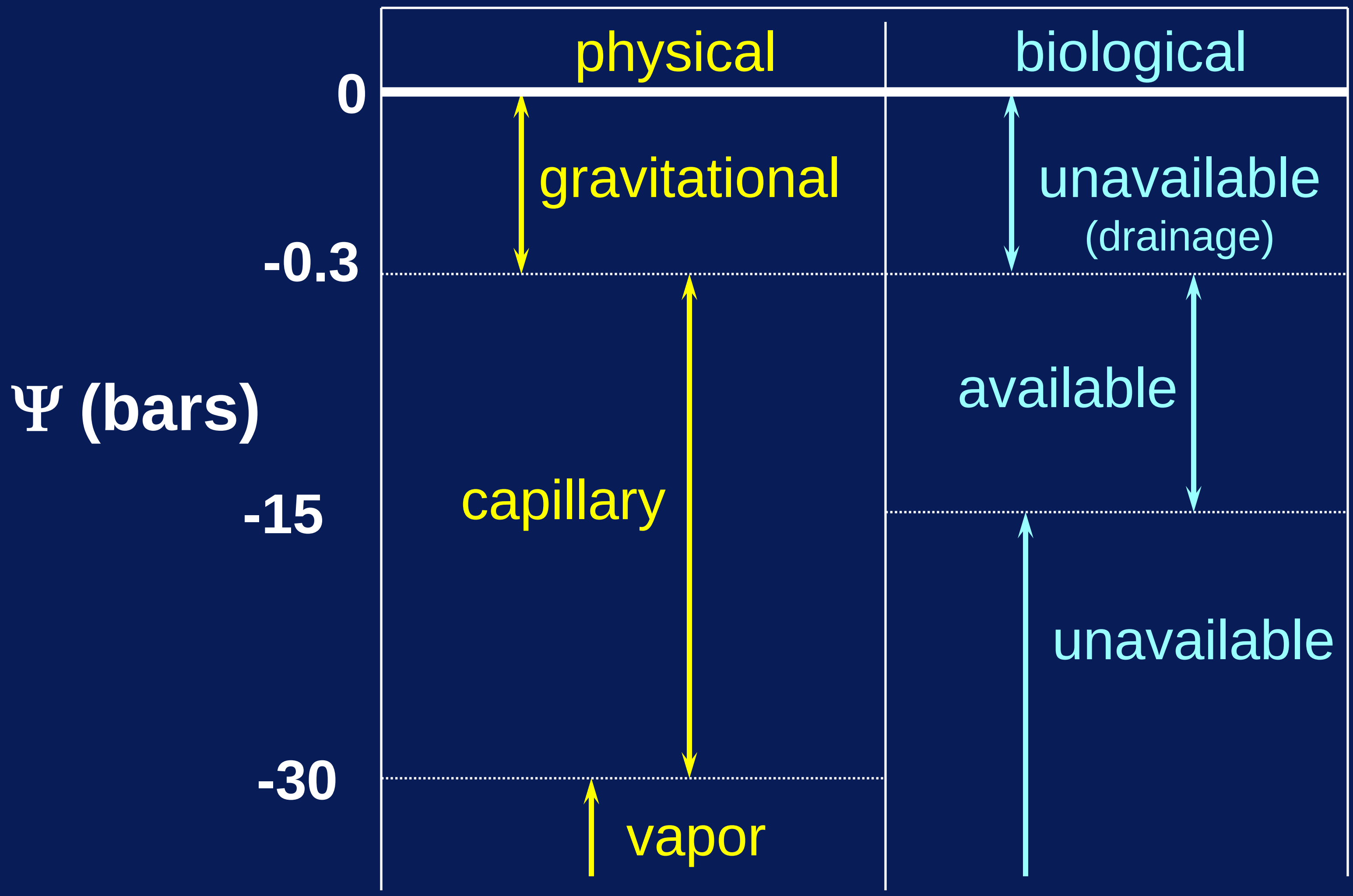
CONCEPTS OF MOVEMENT




Water-
filled
pores
sand
gravel
gravel
air
Capillary
water
Sand rooting zone
"Perched water table"
gravel layer

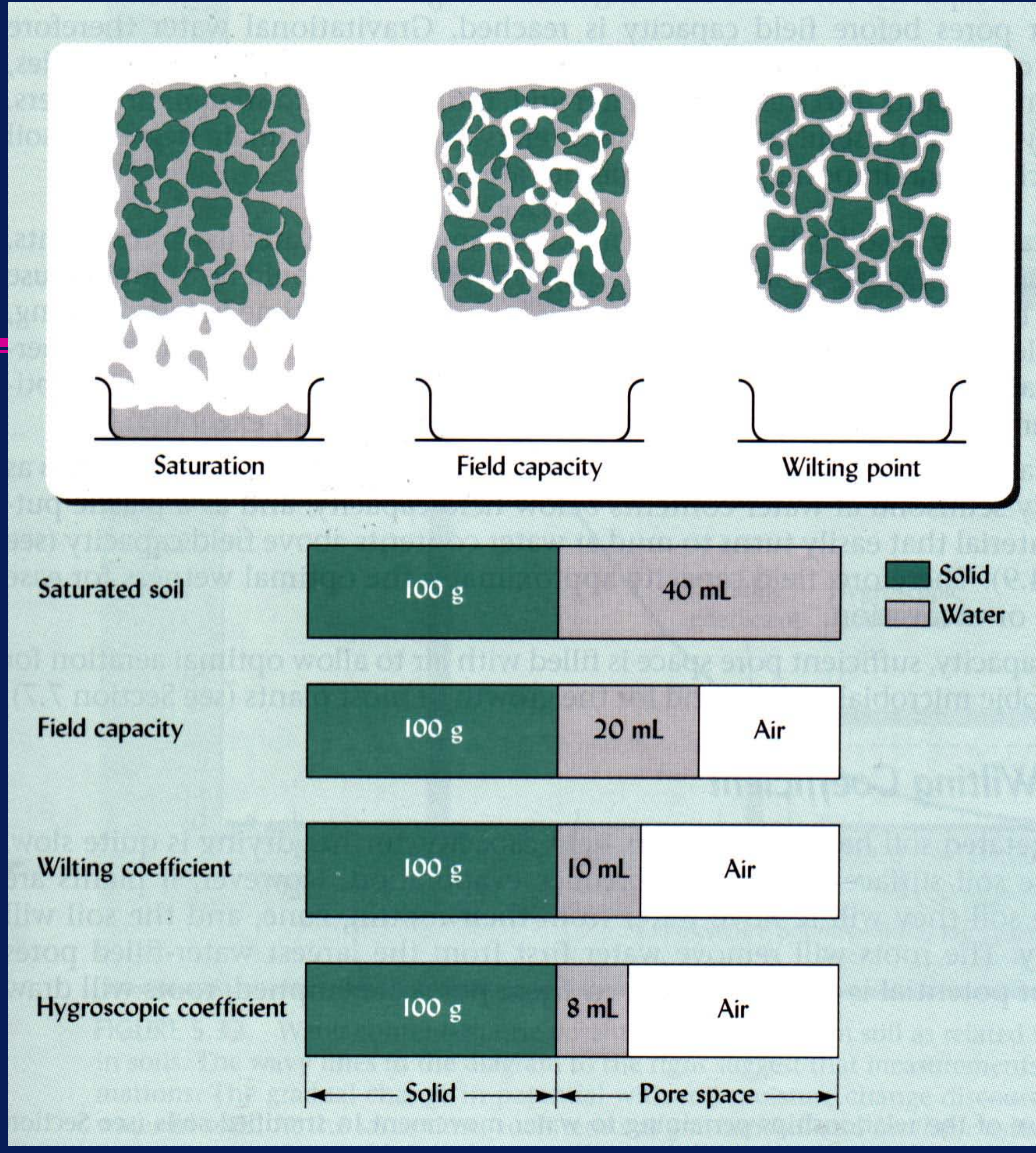

air
sand
water
fractured rock
gravel
gravel
gravel
dripping
water
sand
gravel
nuclear waste
canisters

SOIL WATER: Classification and Availability



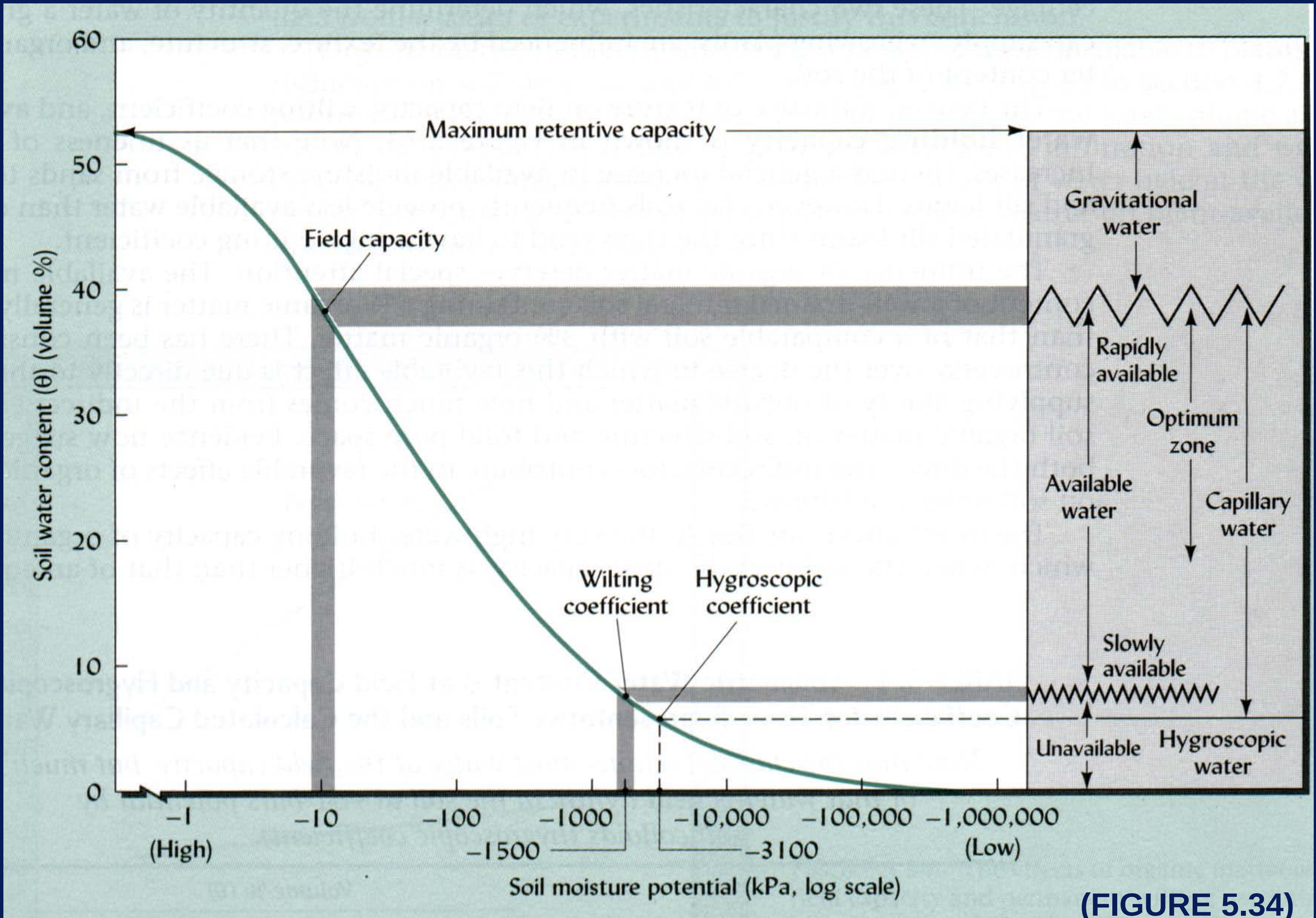
values are only semiquantitative

QUALITATIVE DESCRIPTION OF SOIL WETNESS



(FIGURE 5.32)

WATER CONTENT-MATRIC POTENTIAL CURVE



(FIGURE 5.34)

FACTORS AFFECTING AMOUNT OF PLANT-AVAILABLE SOIL WATER

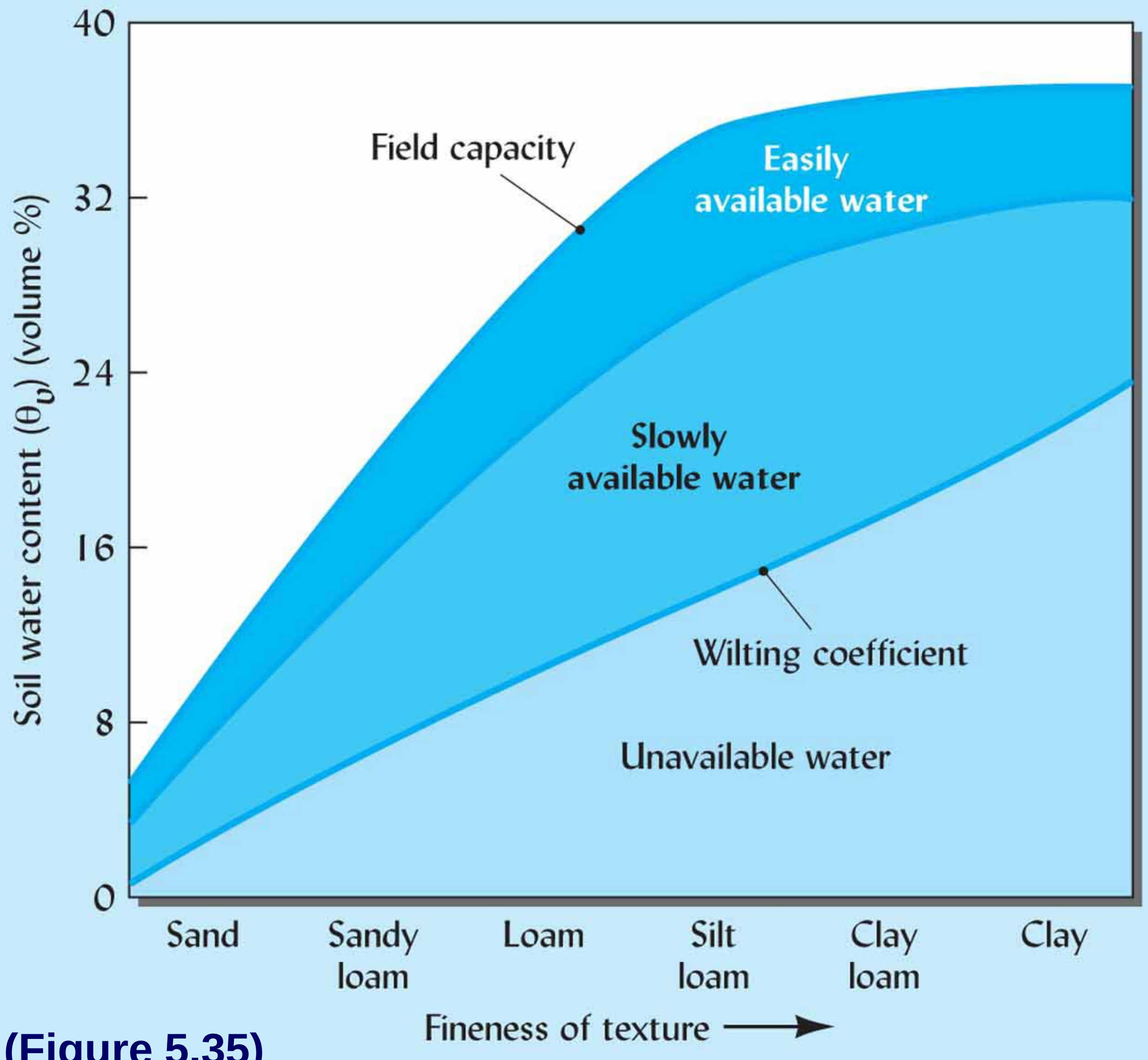
Matric potential:

- **Affects amounts of water at FC and PWP**
- **Clay soils strongly affected by matric potential (Fig 5.35)**
- **Organic matter especially important with respect to available moisture (Fig. 5.36)**
  - **direct effect of OM**
  - **indirect effect on soil structure**
- **Compaction causes grater amounts of soil water to be more strongly affected by the matric potential**

Osmotic potential:

- **High potential reduces the amount of available moisture**

SOIL WATER CHARACTERISTICS VS SOIL TEXTURE



(Figure 5.35)

MECHANISMS BY WHICH PLANTS ARE SUPPLIED WITH WATER

Rate of capillary movement:

- Sandy soils - rate is relatively rapid at moisture near FC
- Clay soils - rate is slow; greater total amount delivered than for sandy soils
- With high amount of root distribution, may be significant

Rate of root extension:

- May be rapid enough to supply most water needs
- Small proportion of soil is contacted at any one time
- Contribution by root hairs difficult to measure

MECHANISMS BY WHICH PLANTS ARE SUPPLIED WITH WATER

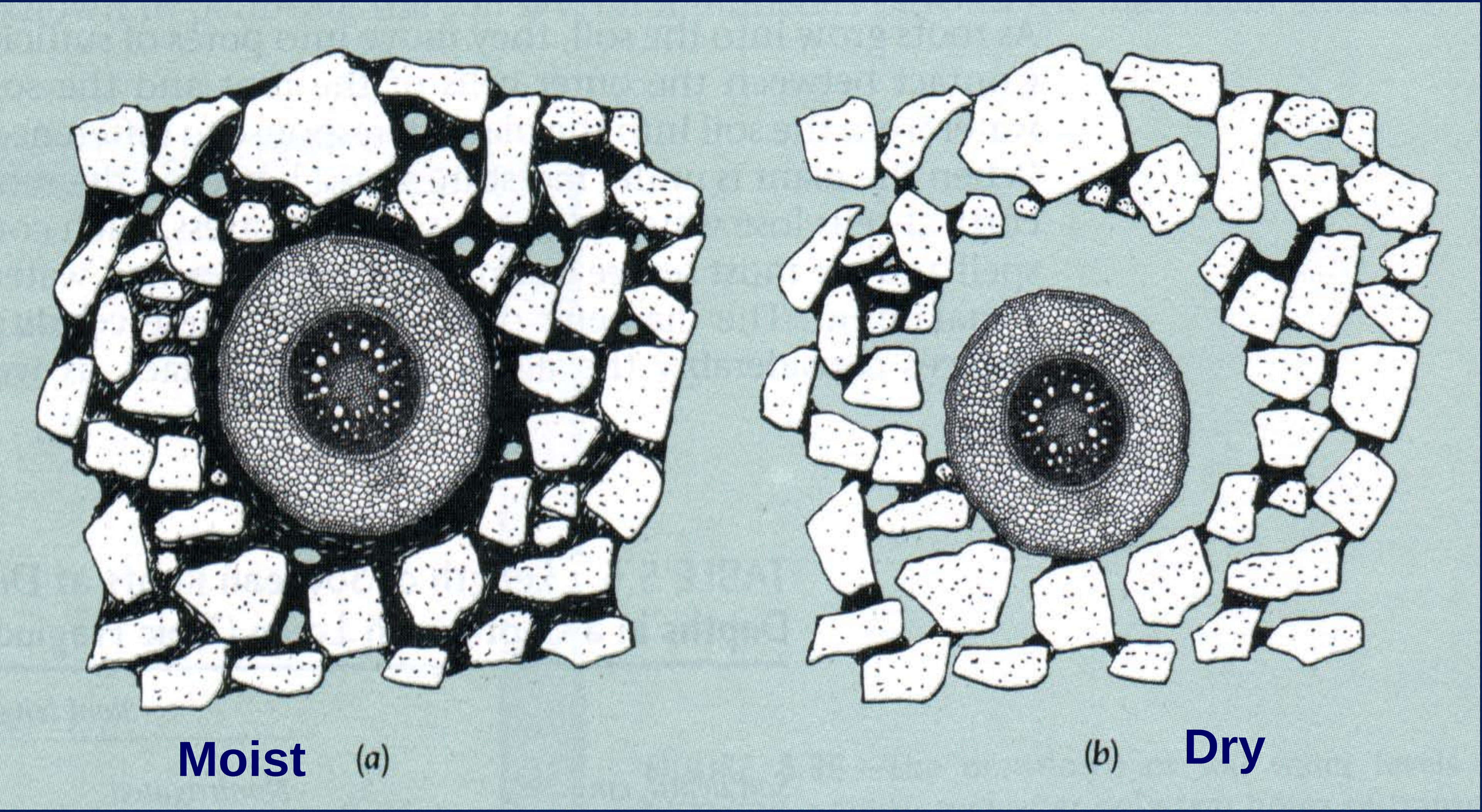
Root distribution:

- Most are roots within upper 25-30 cm of profile
- Deep rooted plants (trees, alfalfa, etc) may obtain a considerable proportion of water from subsoil
- Many annual plants (corn, soybeans) may obtain much water from subsoil

Root-soil contact:

- Generally, roots are well hydrated and in contact with surrounding soil
- Under moisture stress, roots may shrink by 30%

CROSS-SECTION OF ROOT SURROUNDED BY SOIL



(FIGURE 5.44)