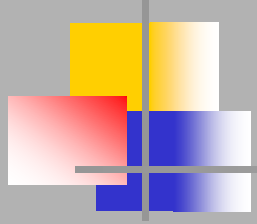


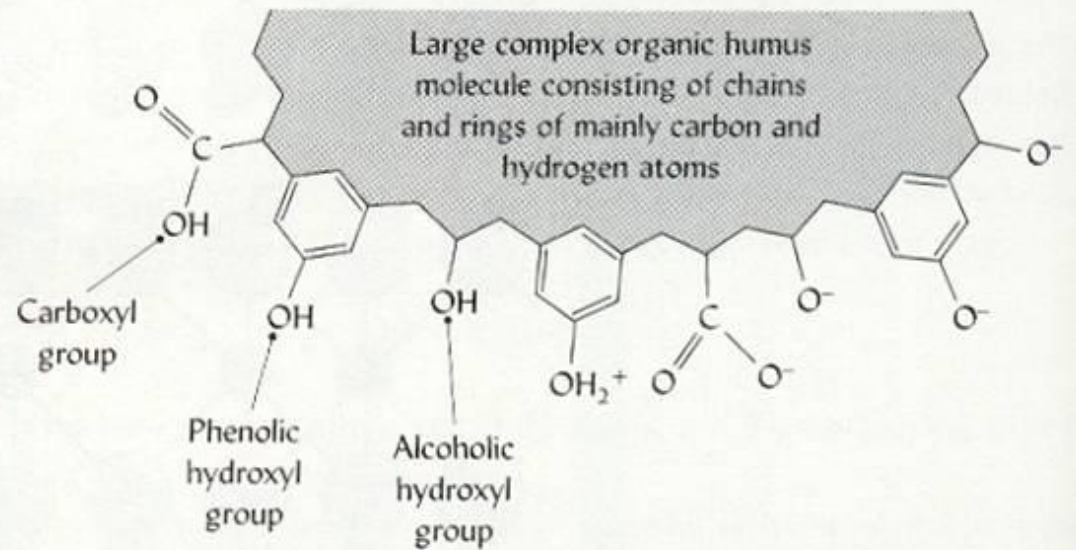
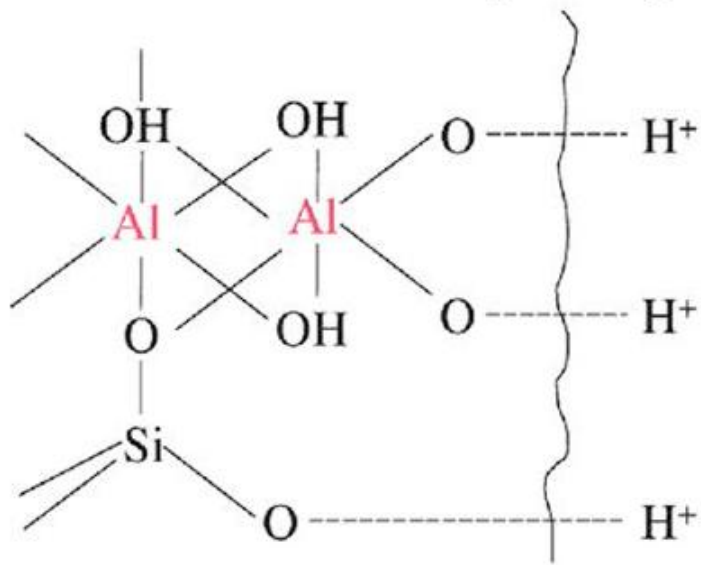
CHARGES ON SOIL COLLOIDS



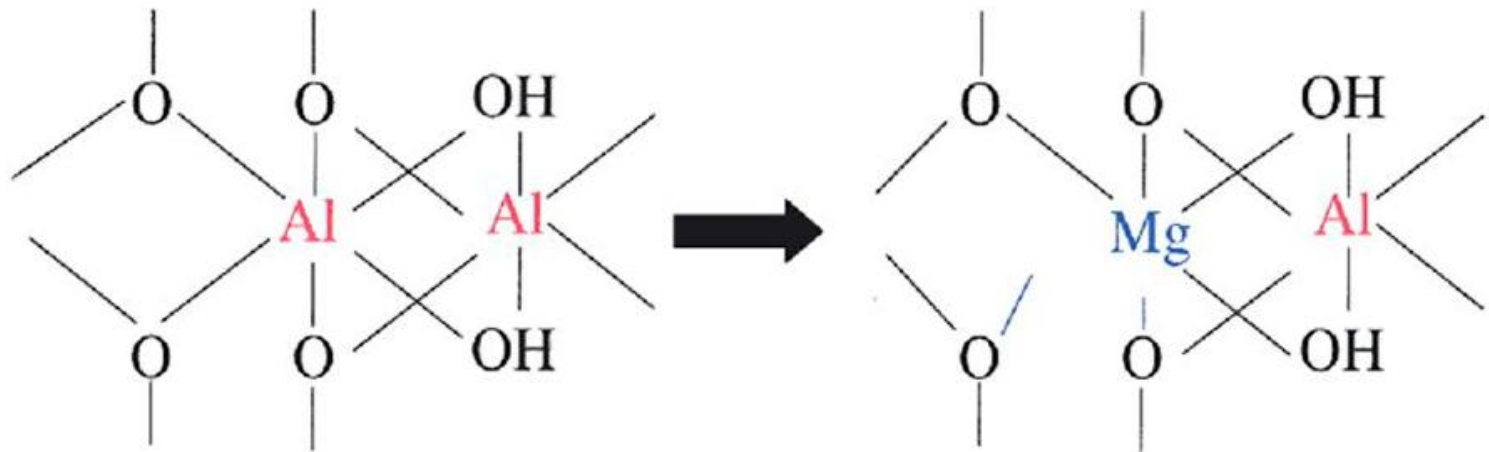
Sources of charges on soil colloids

- Hydroxyls and other functional groups on the surfaces of the colloidal particles that by releasing or accepting H^+ ions can provide either negative or positive charge
- Charge imbalance brought about by isomorphous substitution in some clay structures

Crystal edge



- Due to isomorphous substitution



Octahedral sheet neutral

Net negative charge



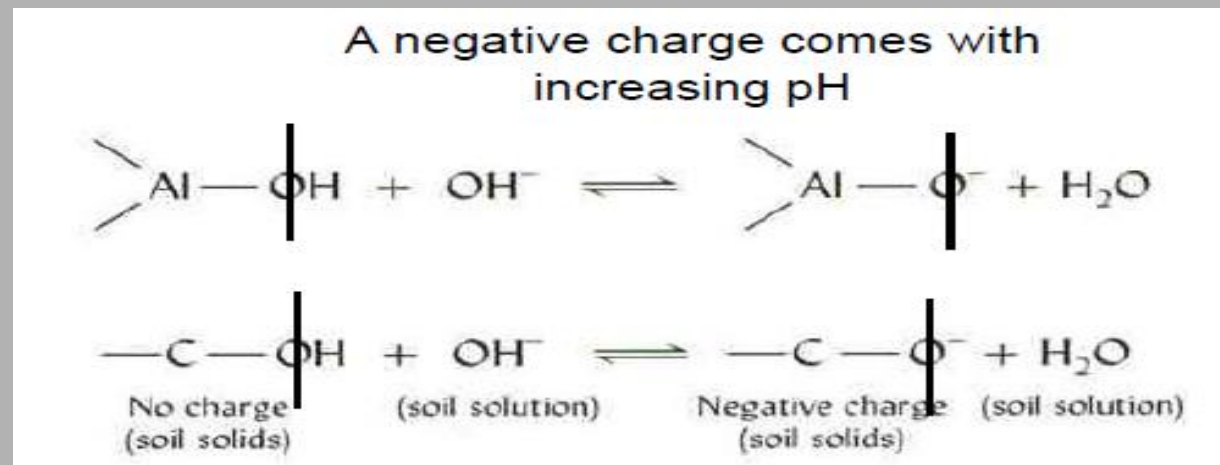
Permanent negative charges

- Isomorphic substitution in clay minerals
 - Si^{4+} replaced by Al^{3+} in tetrahedral sheets
 - Al^{3+} replaced by Mg^{2+} or Fe^{2+} in octahedral sheets

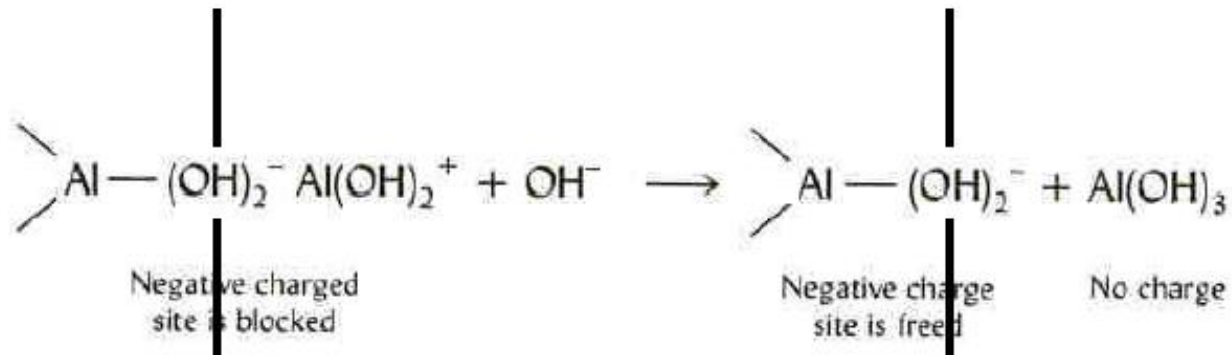
Variable or pH-Dependent Charges

■ pH dependent negative charges

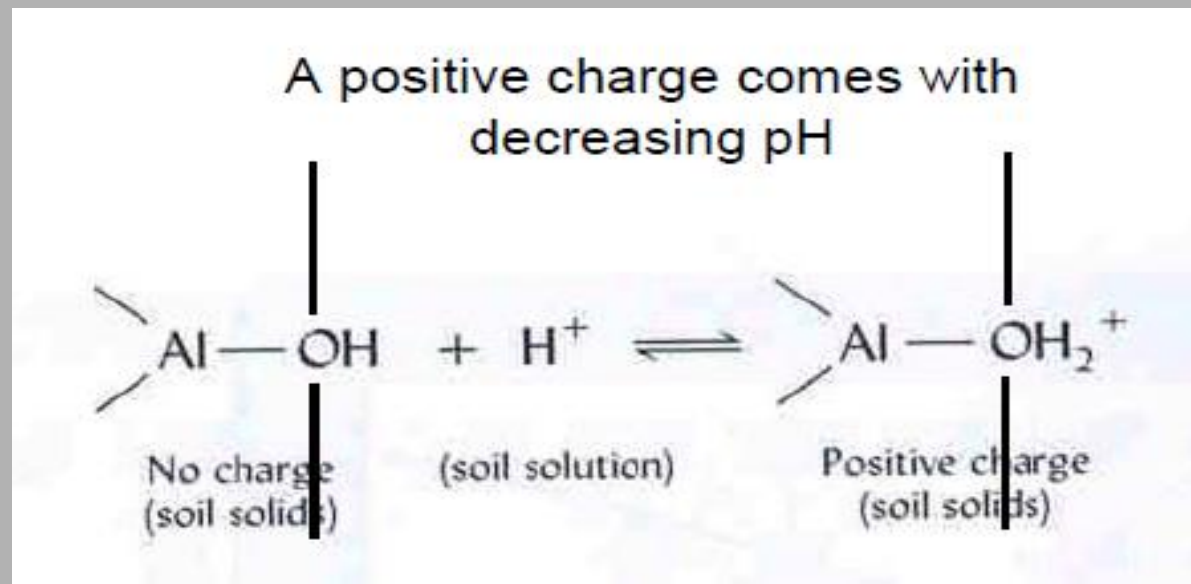
- Associated with hydroxyl (OH) groups on the edges and surfaces of the inorganic and organic colloids.
- Under moderately acid conditions there is little or no charge on these particles, but as the pH increases, the H dissociates from the colloid OH group and negative charges result.

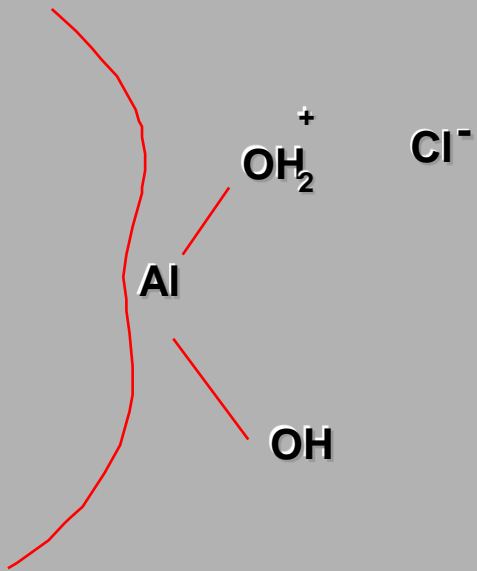
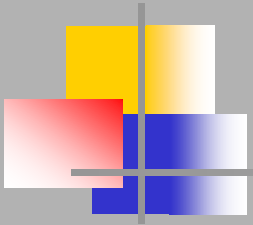


- Another source of increased negative charges as the pH is increased is the removal of positively charged complex Al hydroxy ions $\{Al(OH)_2^+\}$

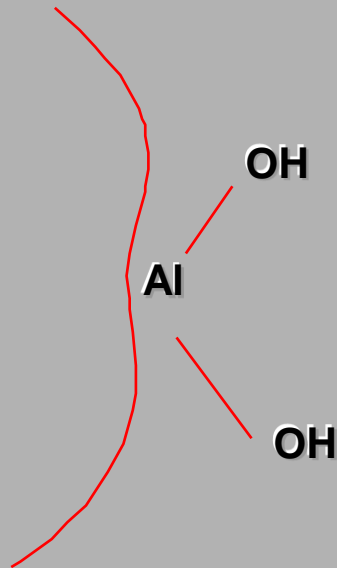


- pH dependent (variable) positive charges
- Under moderate to extreme acid soil conditions some silicate clays, iron and Al oxyhydroxides may exhibit positive charges
- Exposed OH groups are involved in this reaction.
- In this case, as the soils become more acid Protonation (the attachment of H^+ ions to the surface OH groups) takes place.

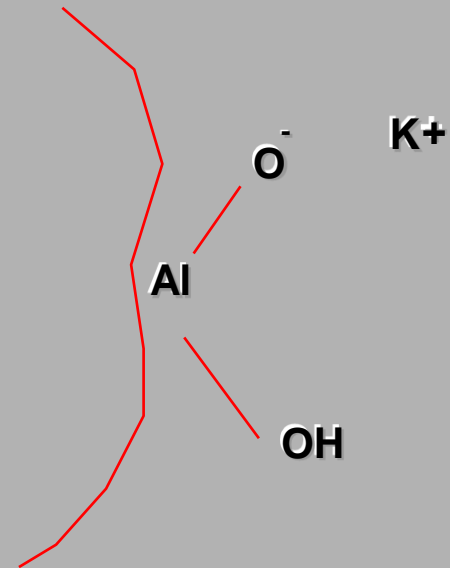




**Low pH (protonated,
anion exchange site)**



Zero Point of Charge



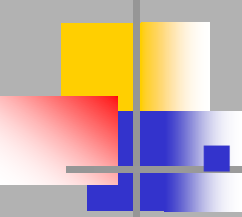
**High pH (deprotonated,
cation exchange site)**



ION EXCHANGE IN SOILS

- Ions are absorbed to the charges on the surfaces of the colloids.
 - **Negative charges: absorb cations**
 - **Positive charges: absorb anions**
- Absorbed cations: Ca^{2+} , Mg^{2+} , K^{+} , Al^{3+} , and Na^{+} .
 - Al^{3+} and H^{+} tend to dominate in humid regions.
 - In semi arid regions Ca^{2+} , Mg^{2+} , K^{+} , and Na^{+} tend to dominate.
- Absorbed anions: SO_4^{2-} , $\text{H}_2\text{PO}_4^{2-}$, MoO_4^{2-} , etc.

CATION EXCHANGE



Soil clay minerals and organic matter tend to be negatively charged, thus attracting positively charged ions (cations) on their surfaces by electrostatic forces.

- As a result, the cations remain within the soil root zone and are not easily lost through leaching.
- The adsorbed cations may easily exchange with other cations in the soil solution, hence the term “cation exchange.”
- The adsorbed cations replenish the ions in the soil solution when concentrations decrease due to uptake by plant roots.

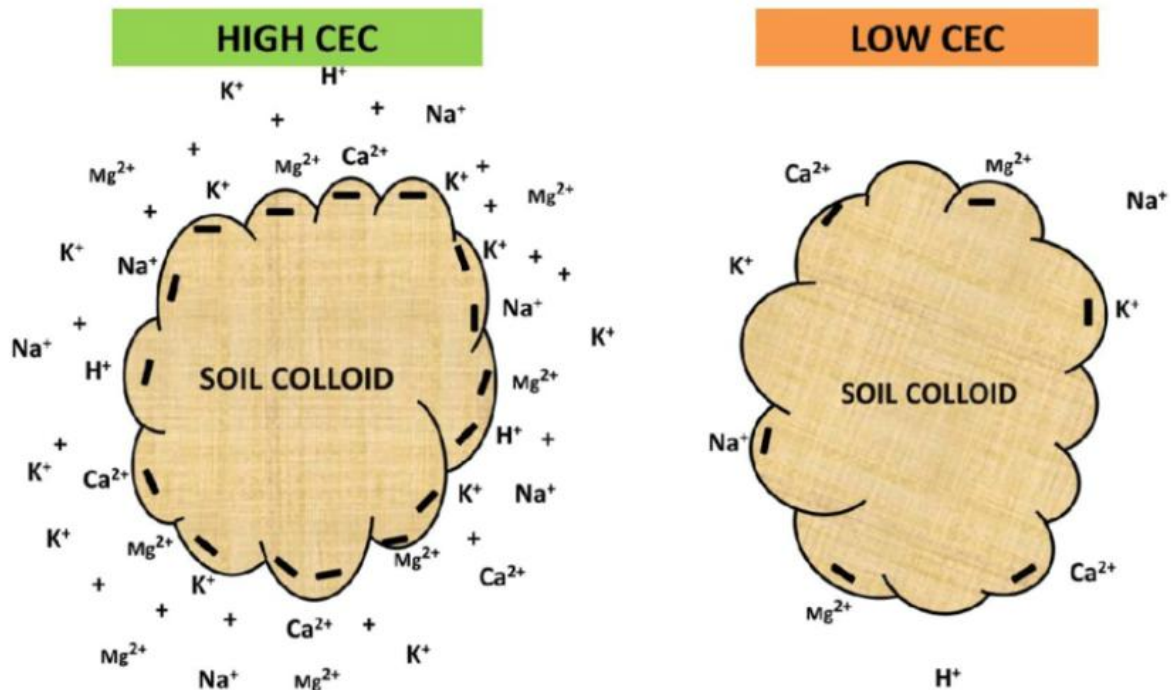
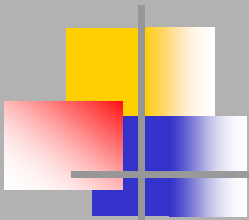
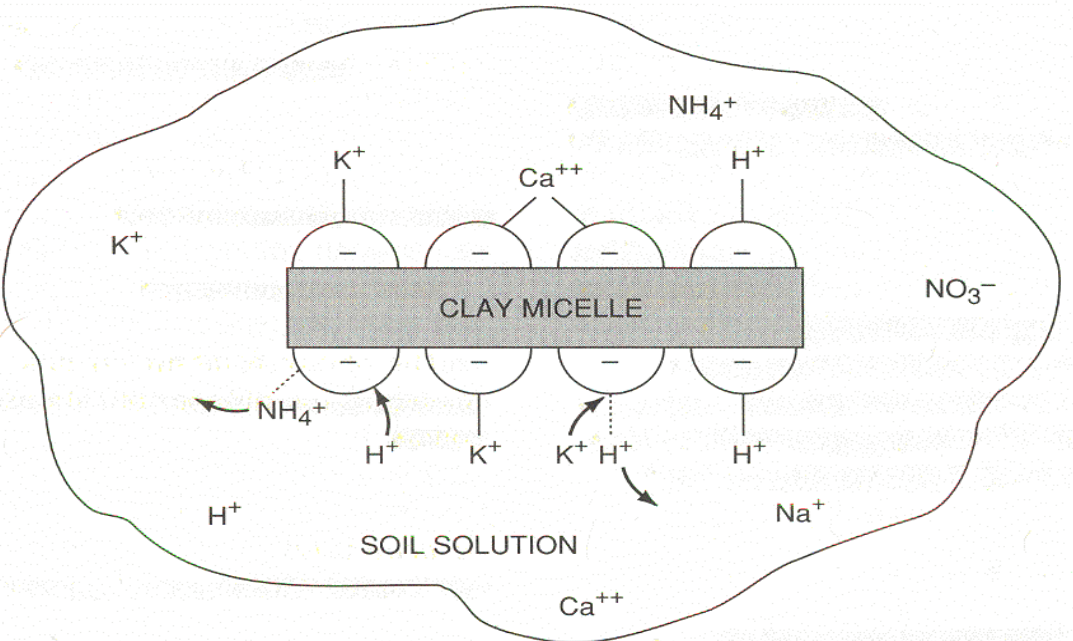
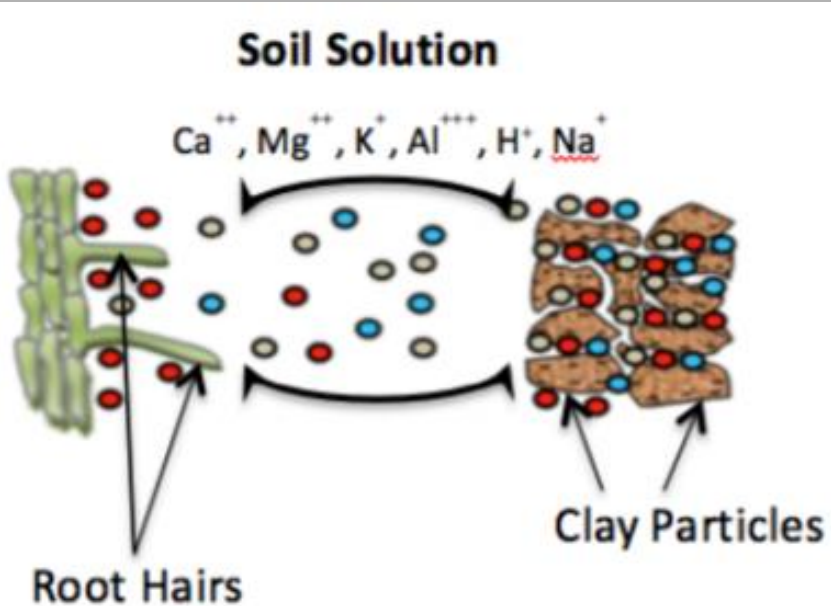


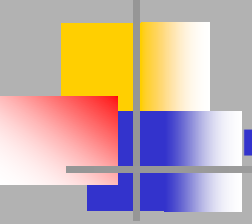
Diagram showing soil colloids with high and low negative charges corresponding high and low CEC respectively

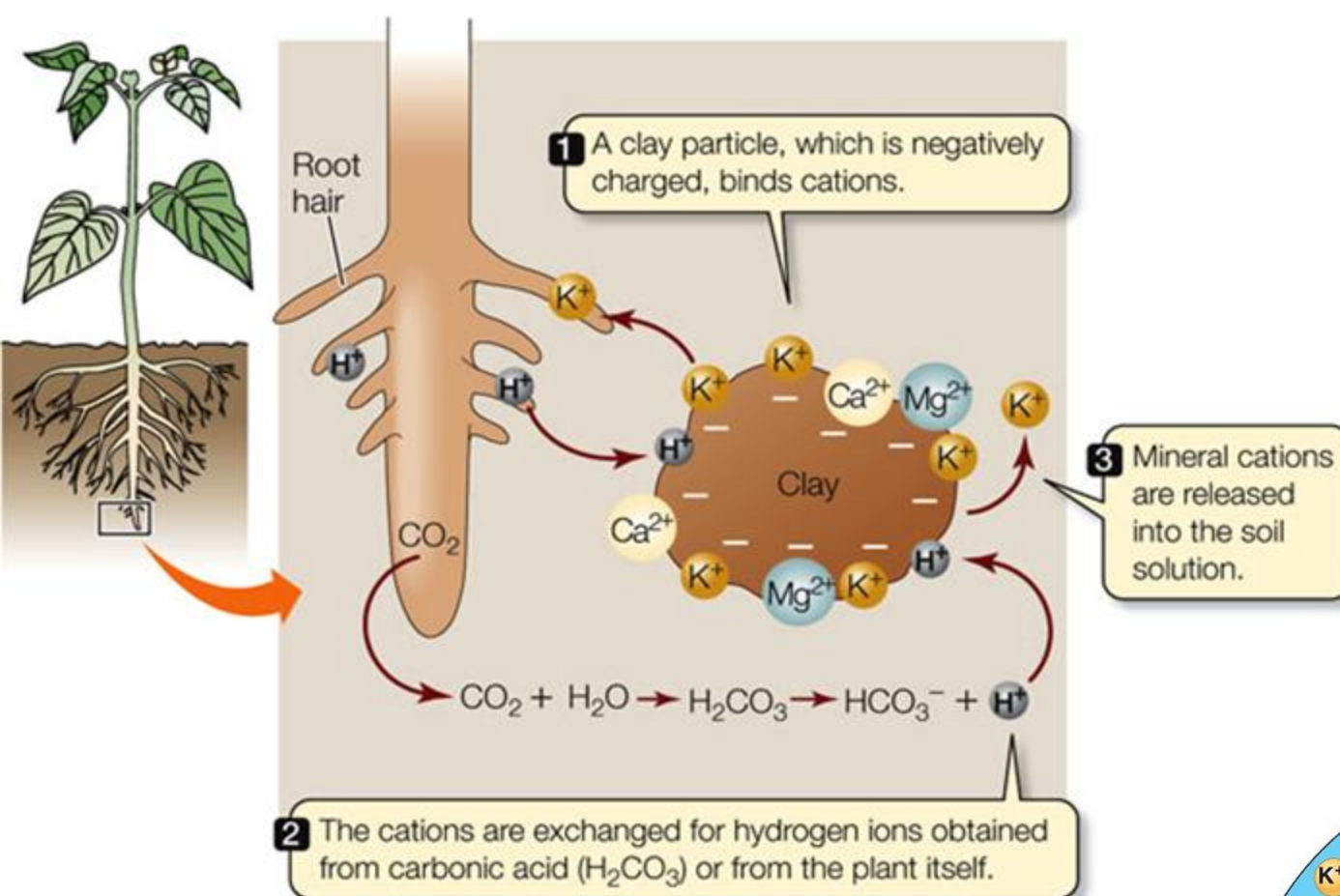


Exchange of cations between Soil surfaces and the soil solution, and the movement of these cations from soil solution to roots (rhizosphere) for uptake



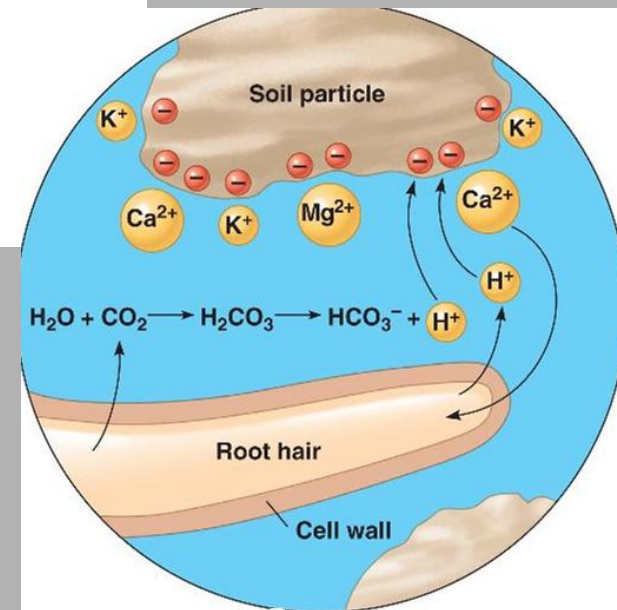
CATION EXCHANGE CAPACITY

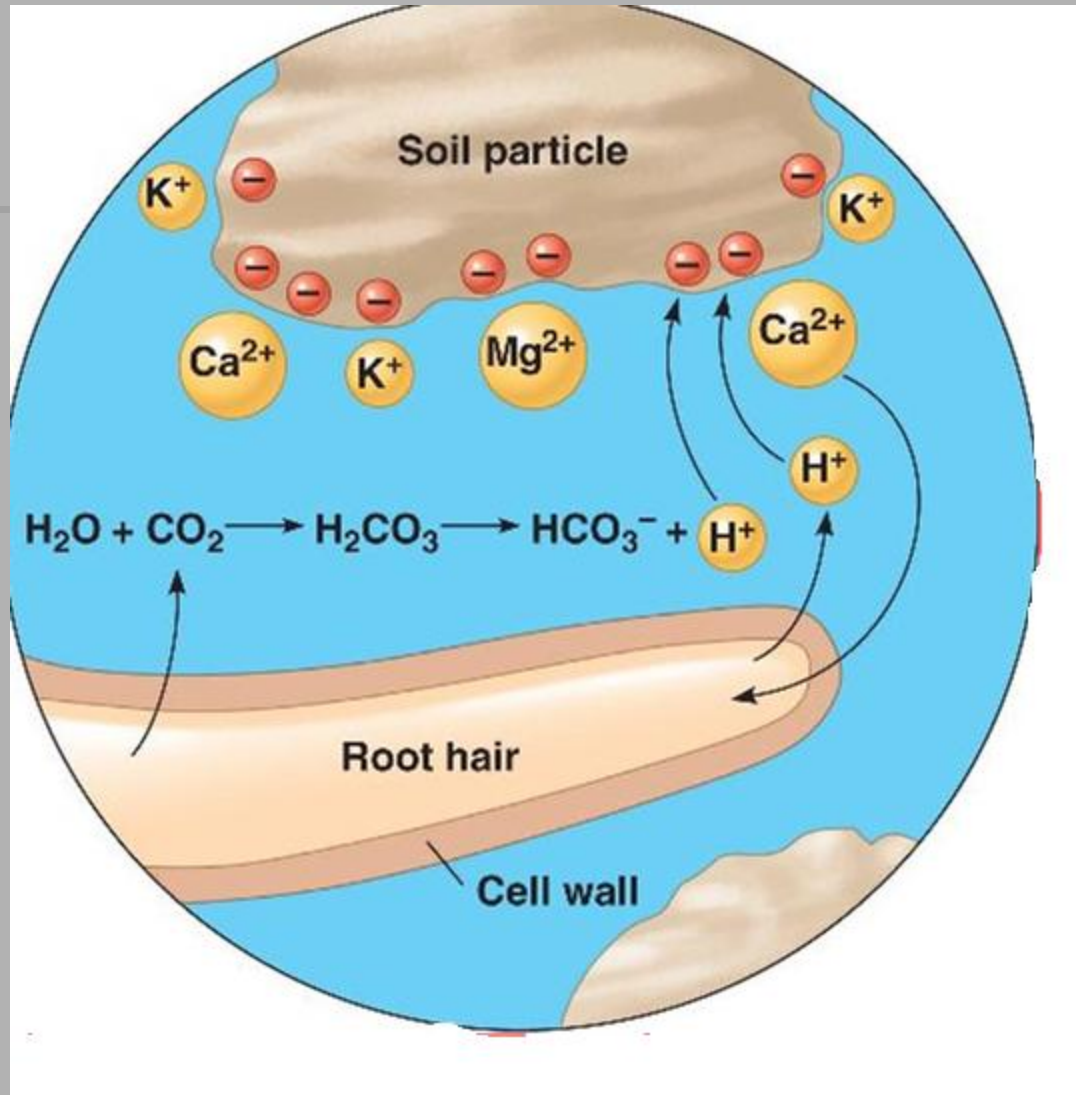
- 
- Cation exchange capacity (CEC) is a measure of the total negative charges within the soil that adsorb plant nutrient cations such as calcium (Ca^{2+}), magnesium (Mg^{2+}) and potassium (K^{+}).
 - As such, the CEC is a property of a soil that describes its capacity to supply nutrient cations to the soil solution for plant uptake.
 - Units: **centimoles_c /kg of soil or meq/100g of soil**

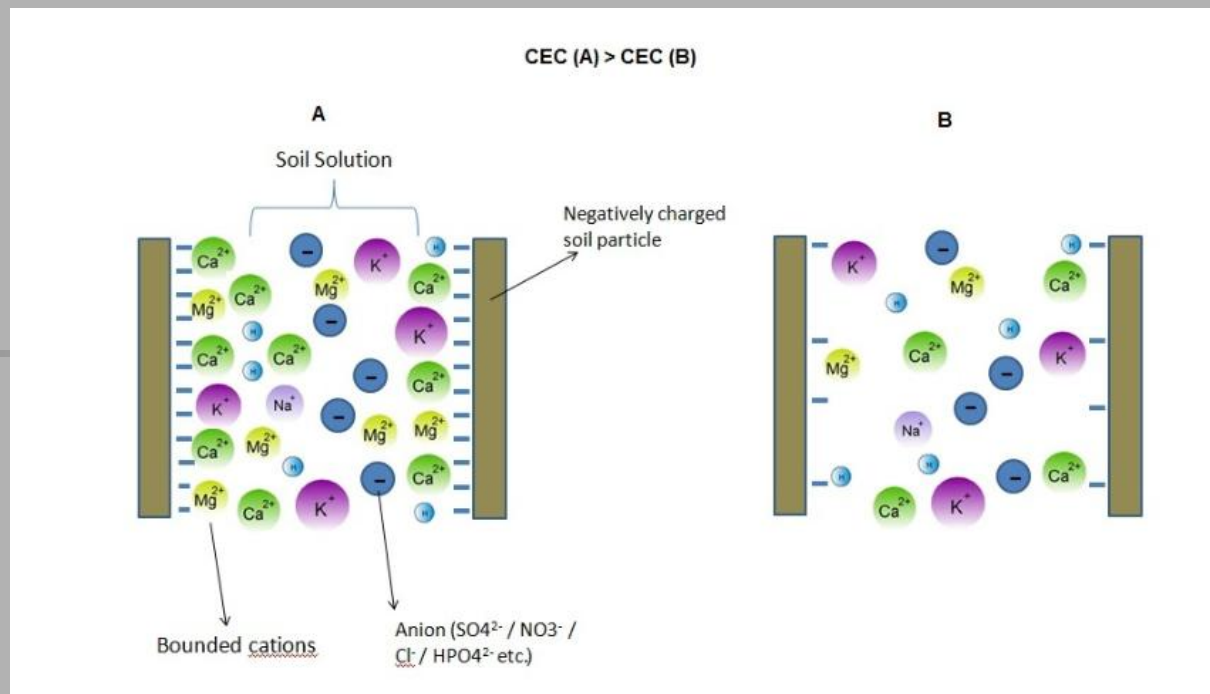


CO_2 reacts with H_2O to form carbonic acid (H_2CO_3) in the soil, which dissociates to add H^+ to the soil.

Plants obtain some mineral nutrients through ion exchange between the soil solution and the surface of clay particles.

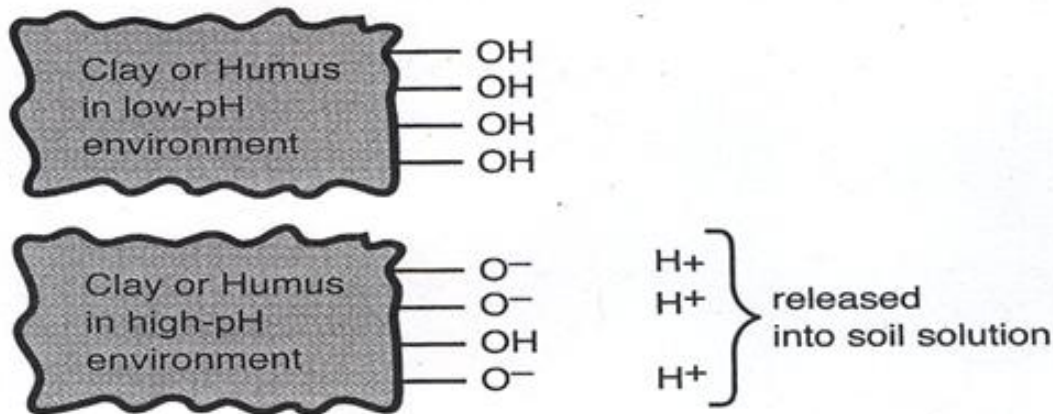




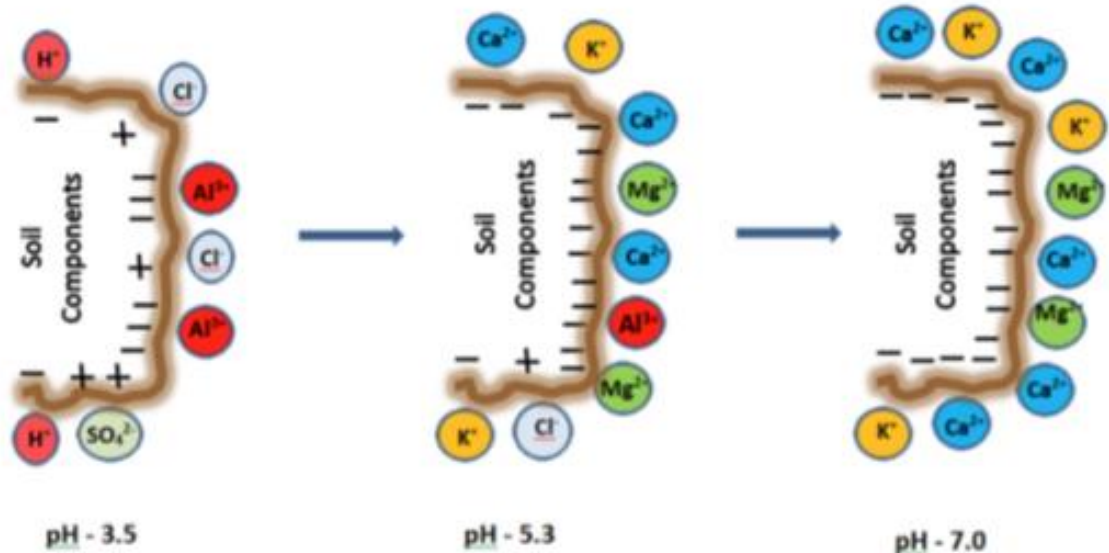


- Soils with high CEC typically have a high clay and organic matter content.
- These soils are considered to be more fertile, as they can hold more plant nutrients.
- Sandy soils typically have a lower CEC and require more frequent fertilizer applications.

- The CEC of soil organic matter and some clay minerals varies with pH.
- The CEC is lowest at soil pHs of 3.5 to 4.0 and increases as the pH is increased by liming an acid soil.

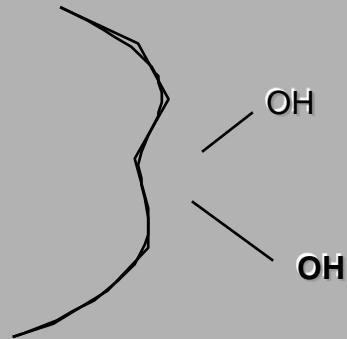


**Influence of pH
On the surface
Charge of soil and
its components**



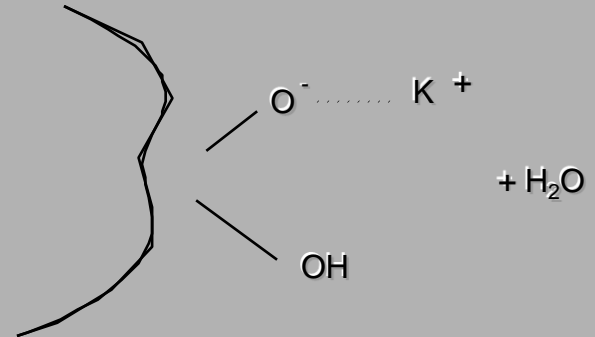


Organic matter : pH-dependent CEC

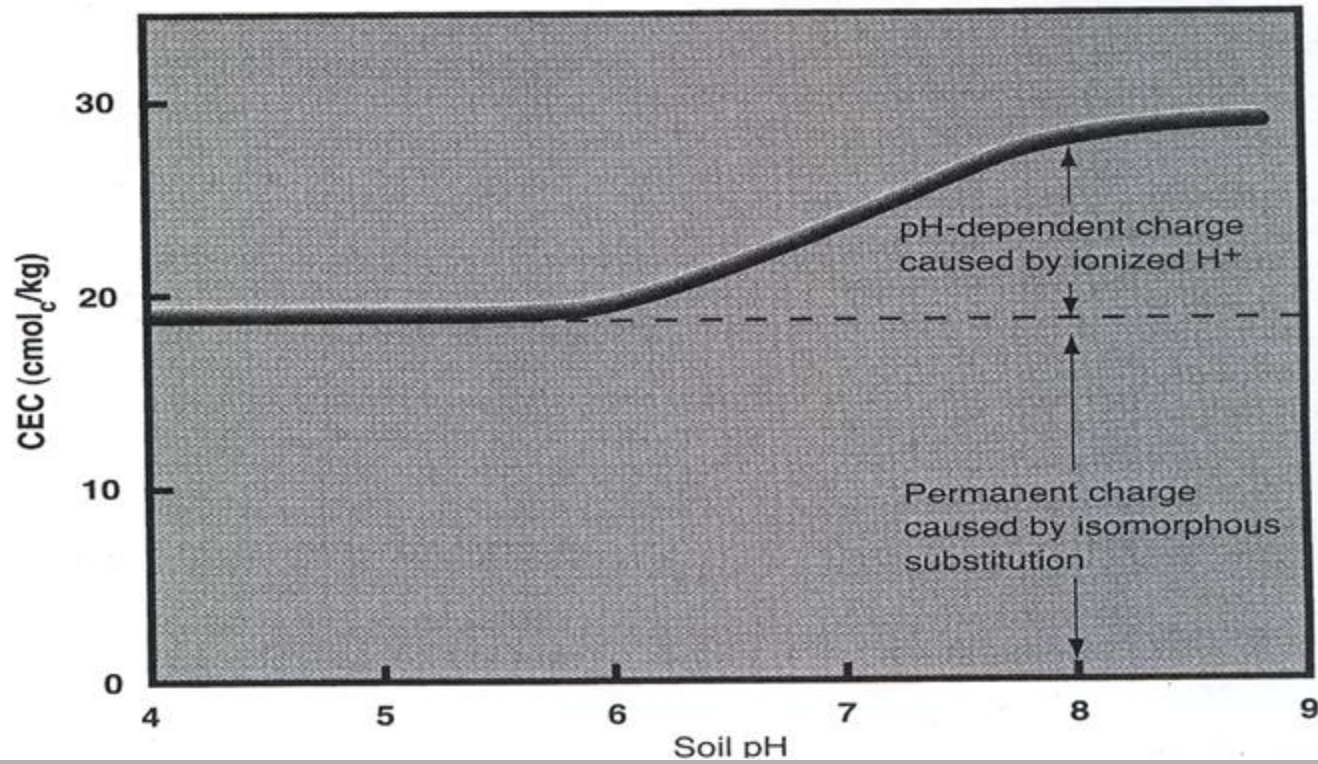


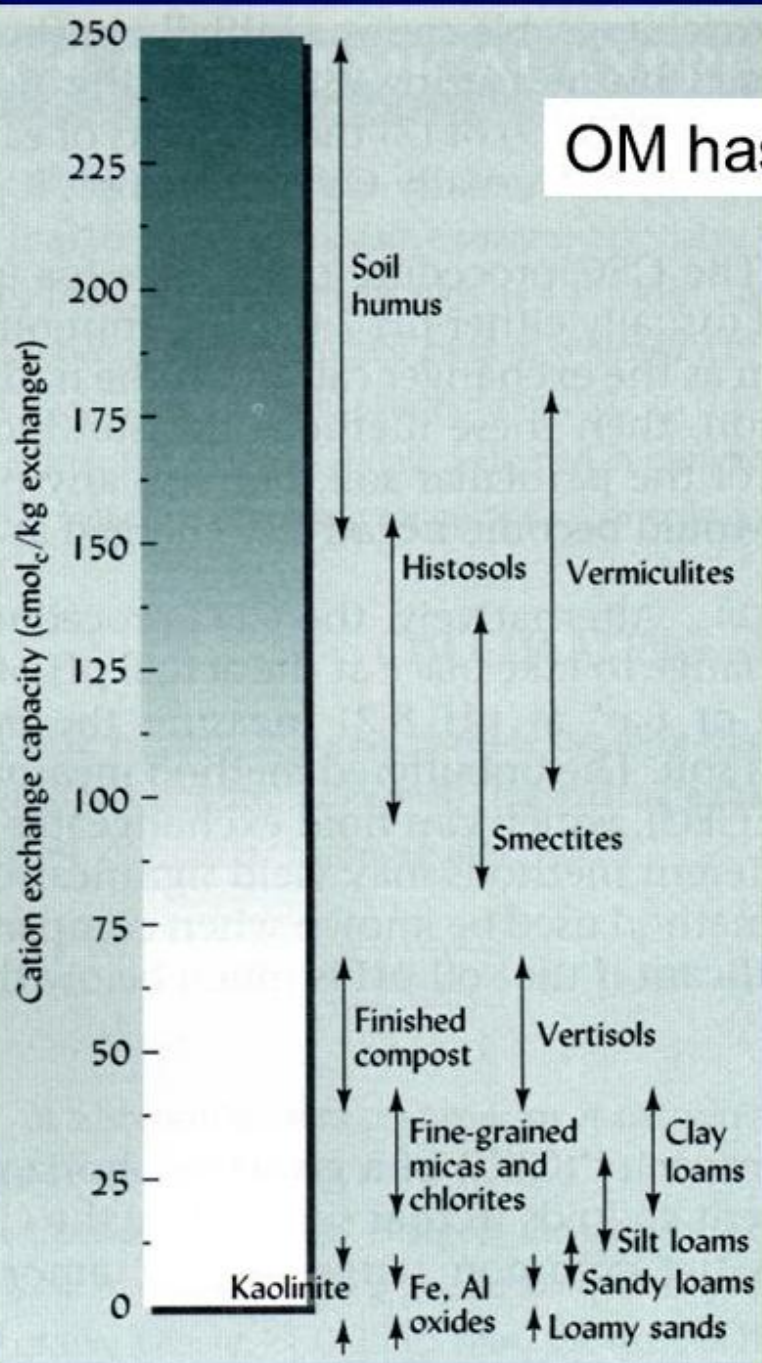
Low pH, sites protonated
no CEC

+ OH⁻



High pH (deprotonated,
cation exchange site)





OM has highest CEC

2:1 clays

1:1 clays

Non-clayey soils

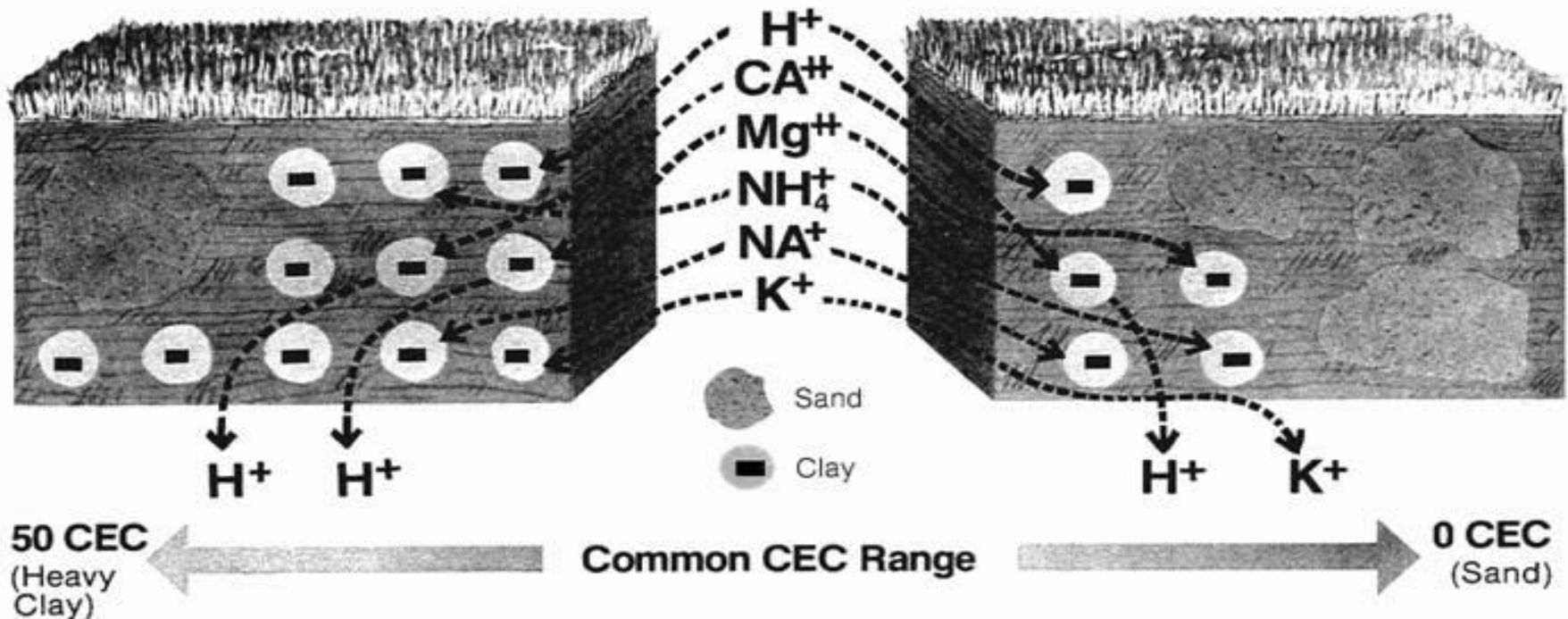
A SCHEMATIC LOOK AT CATION EXCHANGE

CEC 25

MORE CLAY, MORE POSITIONS
TO HOLD CATIONS

CEC 5

LOW CLAY CONTENT,
FEWER POSITIONS TO HOLD CATIONS



SOME PRACTICAL APPLICATIONS

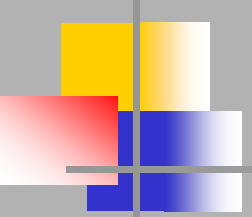
Soils with CEC 11-50 Range

- High clay content
- More lime required to correct a given pH
- Greater capacity to hold nutrients in a given soil depth
- Physical ramifications of a soil with a high clay content
- High water-holding capacity

Soils with CEC 1-10 Range

- High sand content
- Nitrogen and potassium leaching more likely
- Less lime required to correct a given pH
- Physical ramifications of a soil with a high sand content
- Low water-holding capacity

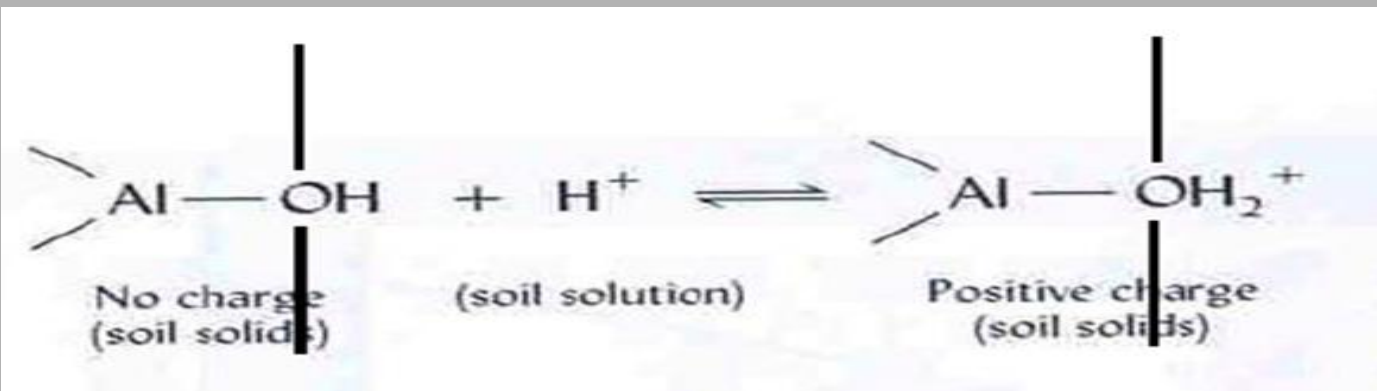
IMPORTANCE OF CEC

- 
-
- Storage of nutrients - Cation exchange sites hold fertilizers and so reduce their mobility
 - Buffering capacity - The amount of lime required to neutralize a soil increases as CEC increases
 - Adsorption of other material
Ex :Trace metals Pb, Ni, pesticides *etc*




ANION EXCHANGE

- Soils in which the predominant colloids are sesquioxides (oxides of Fe and Al) may have a net positive charge.
- This creates opportunities for anion adsorption and exchange.
- clay-size particle of hydrous aluminum oxide has a positive charge under acidic conditions



BASE SATURATION (BS)

- 
- Base forming cations: (Ca^{2+} , Mg^{2+} , K^{+} , and Na^{+})
 - How many cation exchange sites are occupied by base forming cations (Nutrients)
 - **Base Cation Saturation Percentage (BCSP)** (often stated as simply base saturation)

BCSP is the sum of exchangeable base cations divided by CEC. It is usually expressed as a percentage of CEC :

- $$\text{BCSP (\%)} \text{ (or \%BS)} = \frac{\text{Ca} + \text{Mg} + \text{K} + \text{Na}}{\text{CEC}} \times 100$$