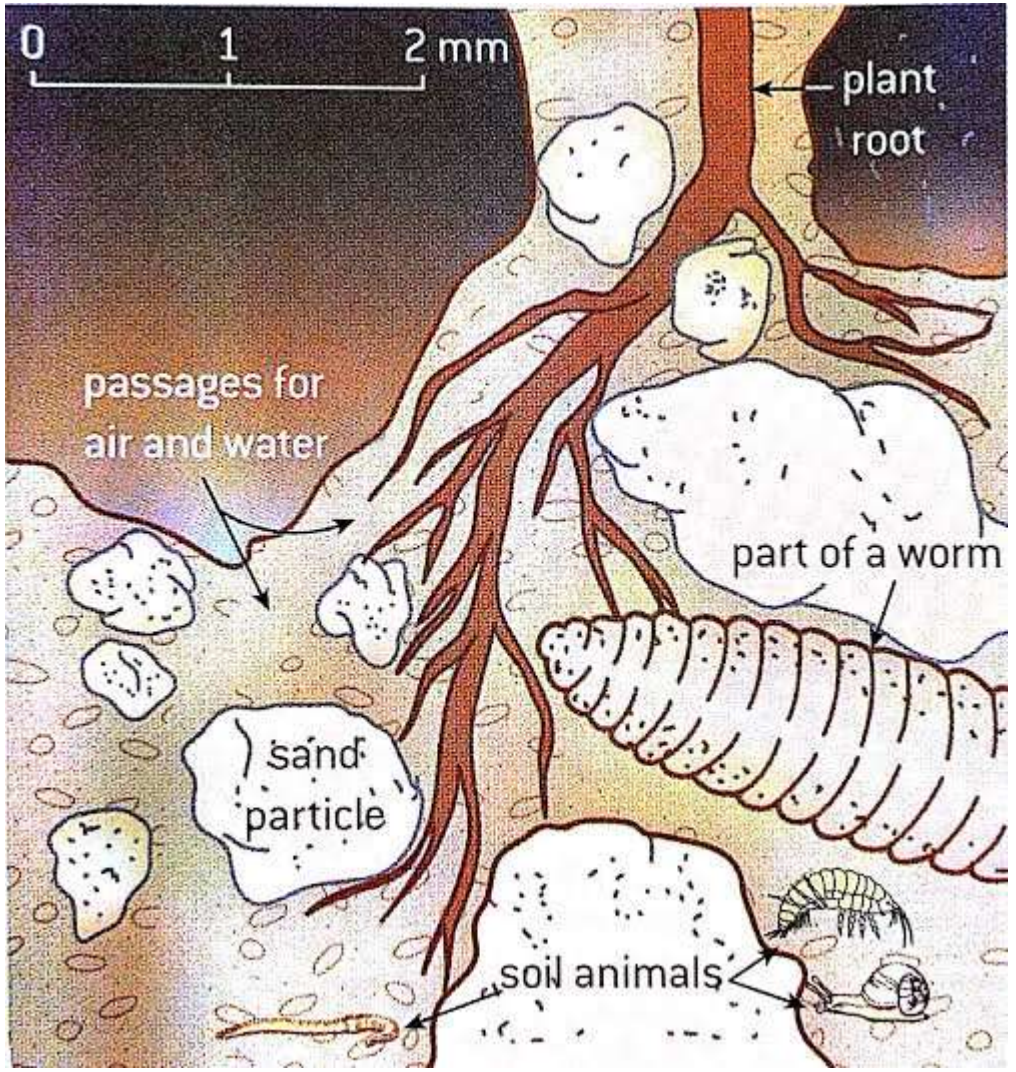
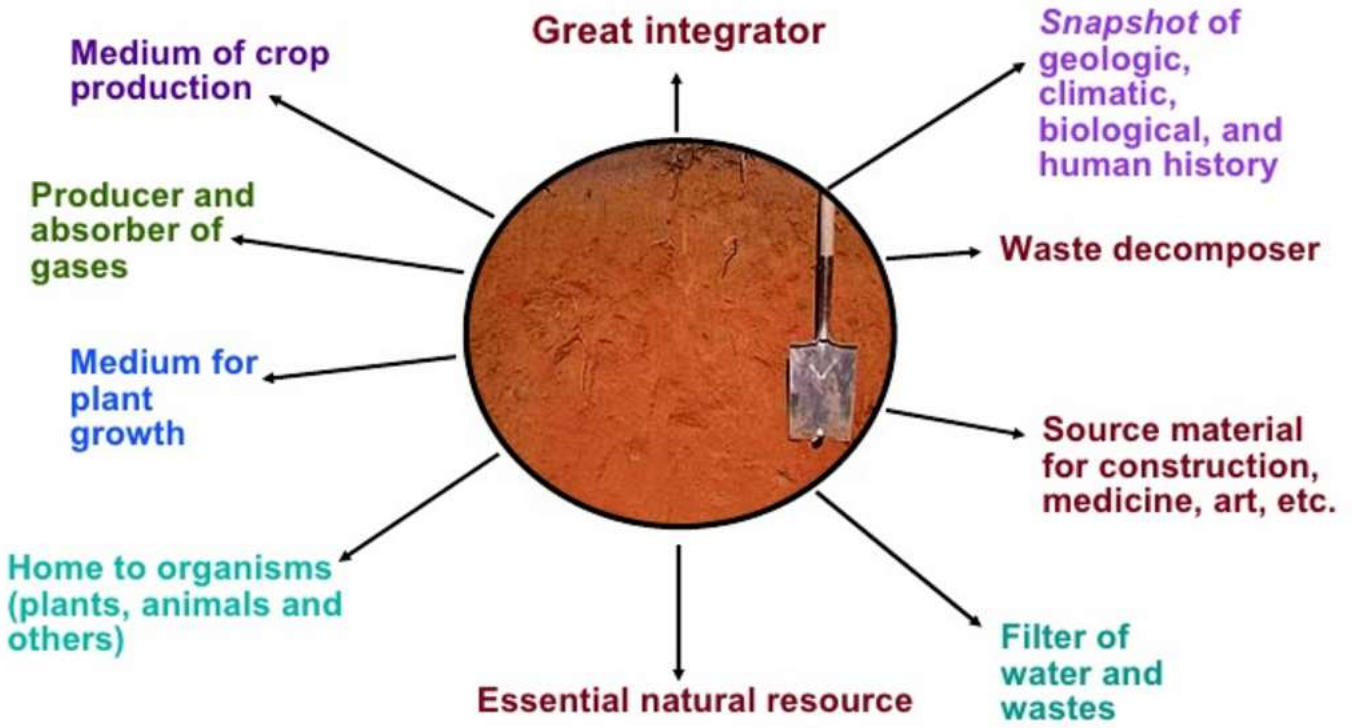
5.1 – Introduction to soil systems

- Soils are major components of the world's ecosystems.
- Soil forms the Earth's atmosphere, lithosphere (rocks), biosphere (living matter) and hydrosphere (water). Soil is what forms the outermost layer of the Earth's surface, and comprise weathered bedrock (regolith), organic matter (both dead and alive), air and water.

  The soil interacts with the atmosphere, lithosphere, biosphere and hydrosphere.
- The water cycle moves through the soil by infiltration and water may evaporate from the surface.
- The atmosphere may contain particulate matter that is deposited on the soils and particles may blow up into the atmosphere.
- Rocks in the lithosphere weather to form soils, and soils at depth and pressure may form rocks.
- Plants in the biosphere may extract nutrients from the soils and dead plants may end up forming parts of the soil.

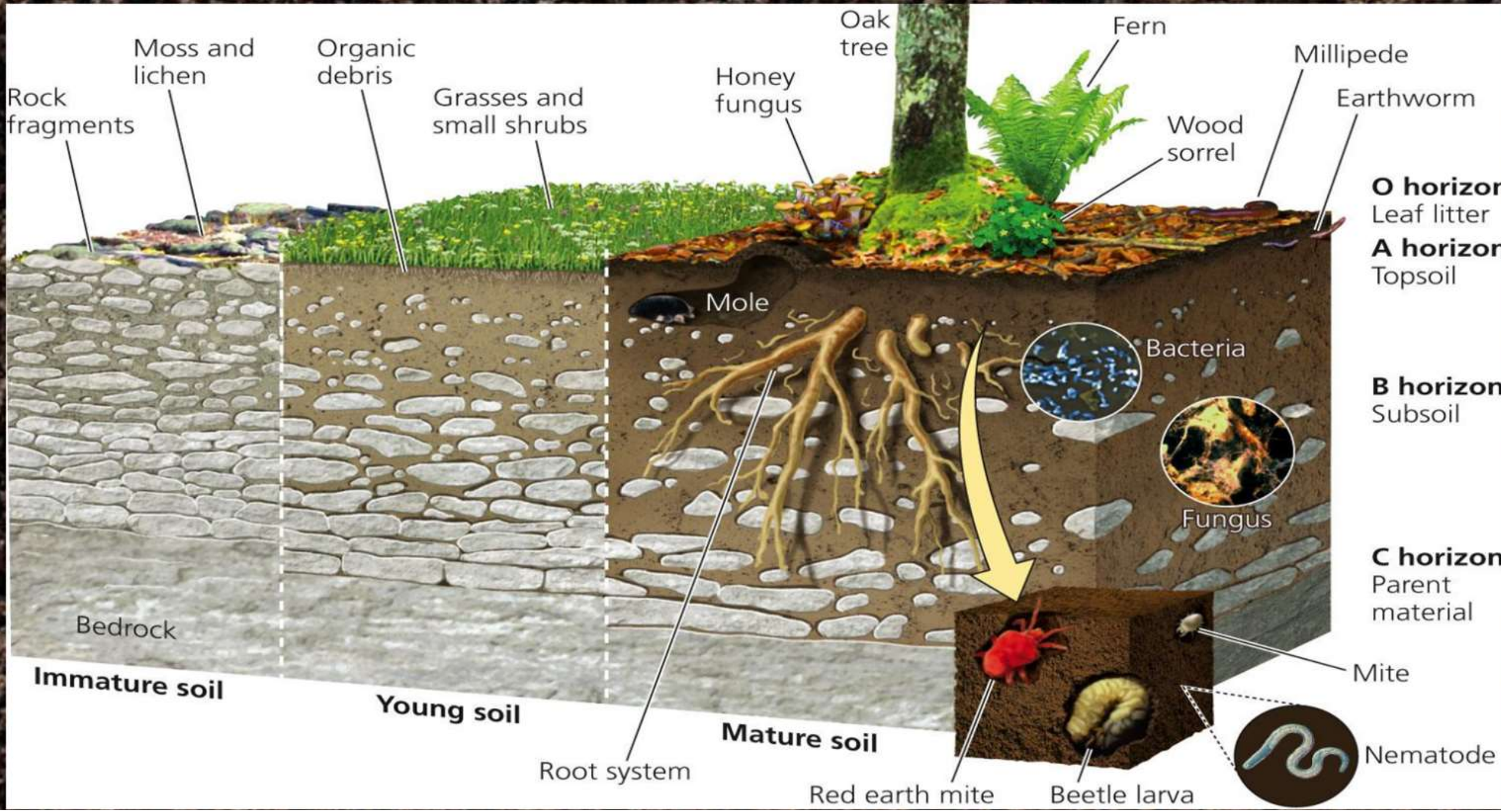


- **Soils are important to humans in many ways:**
- soil is the medium for plant growth, which most of foods for humans are grown in
- soil stores freshwater, 0.005% of world's freshwater
- soil filters materials added to the soil, keeping quality water
- recycling of nutrients takes place in the soil when dead organic matter is broken down
- soil is the habitat for billions of micro-organisms, as well as other larger animals
- soil provides raw material in the forms of peat, clay, sands, gravel and minerals



How does soil form?

Very Slow Process
1. Weathering of rock (mechanical)
2. Deposition of sediments by erosion (mechanical)
3. Decomposition of organic matter (chemical)


Oak tree
Fern
Millipede
Earthworm
Moss and lichen
Organic debris
Rock fragments
Grasses and small shrubs
Honey fungus
Wood sorrel
O horizon
Leaf litter
A horizon
Topsoil
Mole
Bacteria
B horizon
Subsoil
Fungus
C horizon
Parent material
Bedrock
Mite
Nematode
Root system
Red earth mite
Beetle larva
Immature soil
Young soil
Mature soil

The soil system may be illustrated by a soil profile that has a layered structure (horizons)

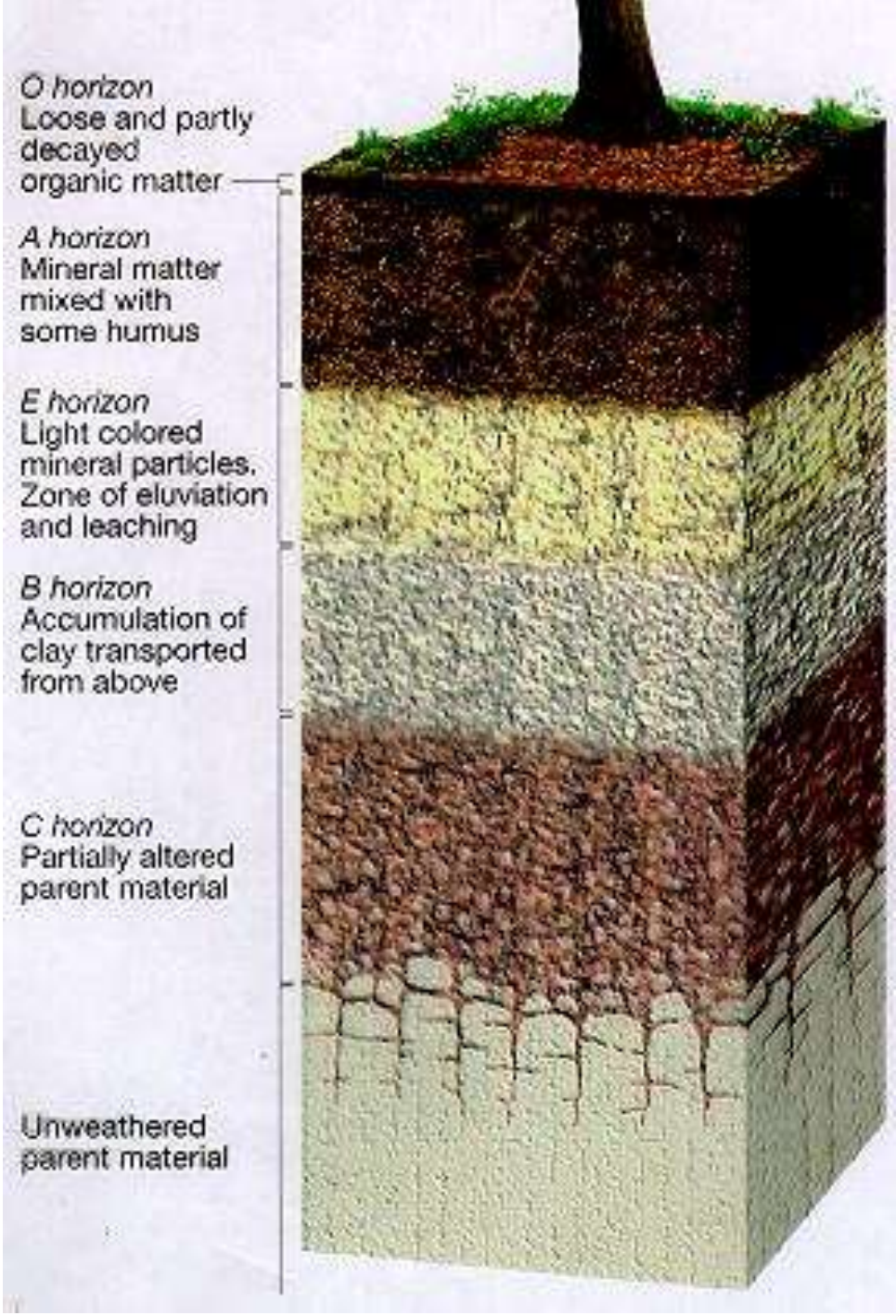
- O) Organic matter: Litter layer of plant residues in relatively undecomposed form.

- A) Surface Soil: Layer of mineral soil with most organic matter accumulation and soil life. This layer eluviates (is depleted of) iron, clay and calcium, organic compounds, and other soluble constituents. When eluviation is pronounced, a lighter colored "E" subsurface soil horizon is apparent at the base of the "A" horizon. A-horizons may also be the result of a combination of soil bioturbation and surface processes that separates fine particles from biologically mounded topsoil. In this case, the A-horizon is regarded as a "biomantle".

- B) Subsoil: This layer accumulates iron, clay, aluminum and organic compounds, a process referred to as illuviation.

- C) Parent Rock: Layer of large unbroken rocks. This layer may accumulate the more soluble compounds.

- R) Bedrock: The parent material in bedrock landscapes. This layer denotes the layer of partially weathered bedrock at the base of the soil profile. Unlike the above layers, R horizons largely comprise continuous masses of hard rock that cannot be excavated by hand. Soils formed *in situ* will exhibit strong similarities to this bedrock layer. These areas of bedrock are under 50 feet of the other profiles.



O horizon - Leaf litter and other organic debris

A horizon – A surface mineral horizon showing coloration due to organic matter accumulation

B horizon – A subsurface horizon showing depletion of organic matter and an accumulation of clay. Clay is typically iron and aluminum based compounds

C horizon – A subsurface layer of soil forming parent materials. Could be weathered rock, unconsolidated floodplain sediments or loose sands

R horizon – Hard bedrock

- Soil has matter in all three states: organic and inorganic matter form the solid state
- soil water(from precipitation, groundwater and seepage) form the liquid state
- soil atmosphere forms the gaseous state

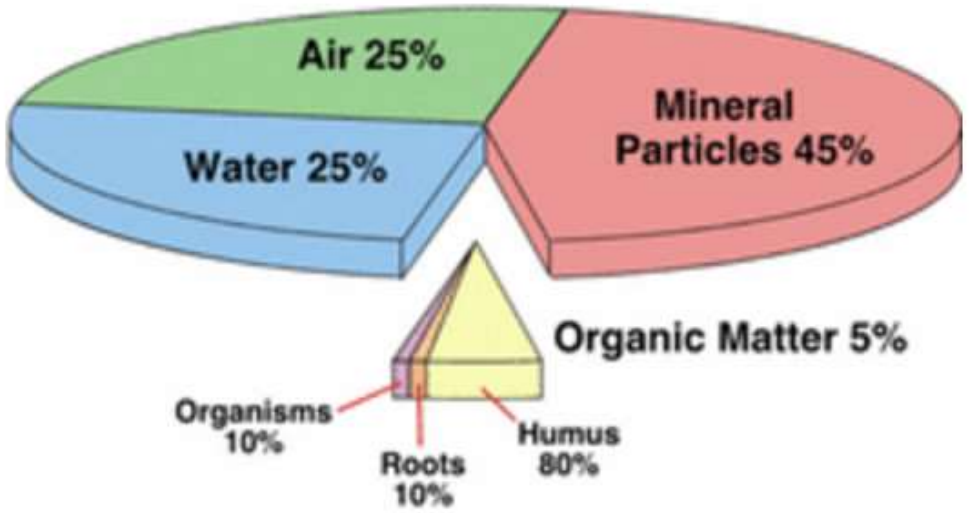
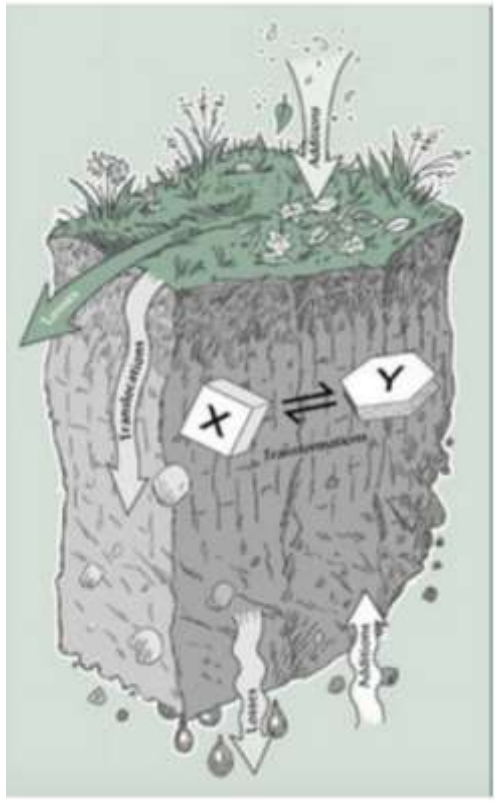
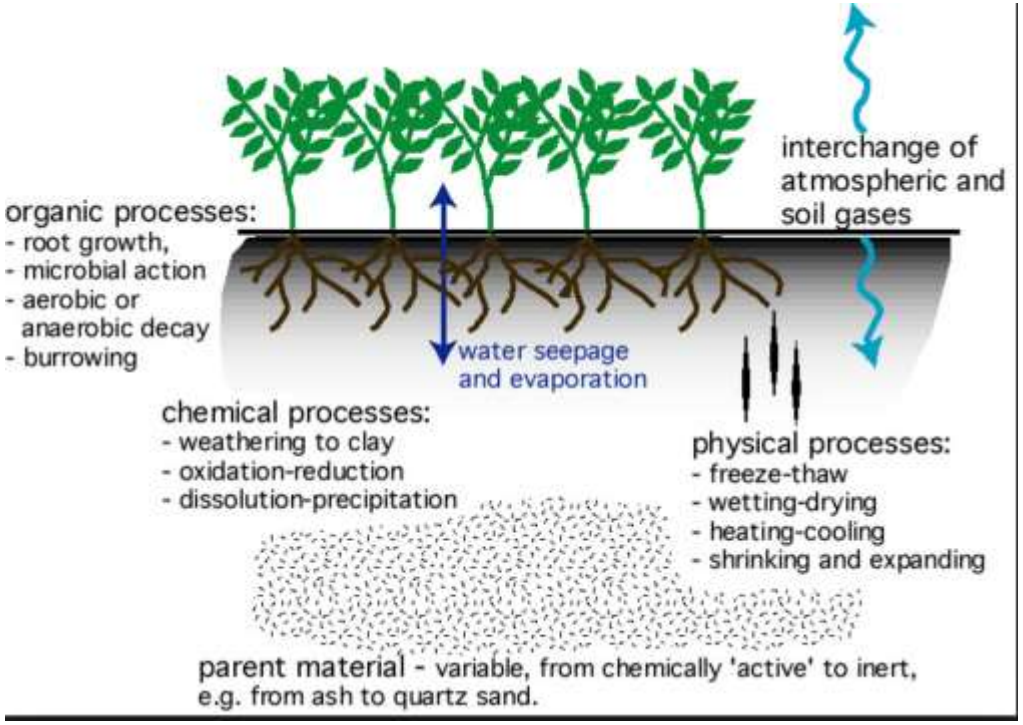


image from www.eoearth.org

- **There are four basic processes that occur in the formation of soils:**

1. inputs - physical movement of material within soil.
2. outputs - occur both from the surface and from the deep subsoil. Water lost by evapotranspiration
3. translocations - translocation of materials within the soil profile is primarily due to gradients in water potential and chemical concentrations within the soil pores.
4. transformations - change of some soil constituent without any physical displacement.





The two driving forces for these processes are climate (temperature and precipitation) and organisms, (plants and animals).

Parent material is usually a rather passive factor in affecting soil processes because parent materials are inherited from the geologic world.

Topography (or relief) is also rather passive in affecting soil processes, mainly by modifying the climatic influences of temperature and precipitation.

There are inputs of organic material including leaf litter and inorganic matter form parent material, precipitation and energy. Outputs include uptake by plants and soil erosion

Inputs

1. Weathering

Rock weathering is one of the most important long-term sources for nutrients. However, this process adds nutrients to ecosystems in relatively small quantities over long periods of time. Important nutrients released by weathering include: Calcium, magnesium, potassium, sodium, silicon, iron, aluminum, and phosphorus.

INPUTS	OUTPUTS
Soil	
Fertilizer	Crop Removal
N Fixation	Leaching Loss
Plant & Animal Residues	Denitrification
Precipitation	Volatilization
Available pool	
Mineralization	Immobilization

image from www.gov.mb.ca

2. Atmospheric Input

Large quantities of nutrients are added to ecosystems from the atmosphere. This addition is done either through precipitation or by a number of biological processes.
Carbon - absorbed by way of photosynthesis.
Nitrogen - produced by lightning and precipitation.
Sulfur, chloride, calcium, and sodium - deposited by way of precipitation.

3. Biological Nitrogen Fixation

Biological nitrogen fixation is a biochemical process where nitrogen gas from the atmosphere is chemically combined into more complex solid forms by metabolic reactions in an organism. This ability to fix nitrogen is restricted to a symbiotic associations with legumes and other microorganisms.

Outputs

1. Erosion

Soil erosion is probably the most import means of nutrient loss to ecosystems. Erosion is very active in agricultural and forestry systems, where cultivation, grazing, and clearcutting leaves the soil bare and unprotected. When unprotected, the surface of the soil is easily transported by wind and moving water. The top most layers of a soil, which have an abundance of nutrient rich organic matter, are the major storehouse for soil nutrients like phosphorus, potassium, and nitrogen.

2. Leaching

Leaching occurs when water flowing vertically through the soil transports nutrients in solution downward in the soil profile. Many of these nutrients can be completely lost from the soil profile if carried into groundwater and then horizontally transported into rivers, lakes, or oceans. Leaching losses are, generally, highest in disturbed ecosystems. In undisturbed ecosystems, efficient nutrient cycling limits the amount of nutrients available for this process.

3. Gaseous Losses

High losses of nutrients can also occur when specific environmental conditions promote the export of nutrients in a gaseous form. When the soil is wet and anaerobic, many compounds are chemically reduced to a gas from solid forms in the soil. This is especially true of soil nitrogen.

Transformations include decomposition, weathering and nutrient cycling

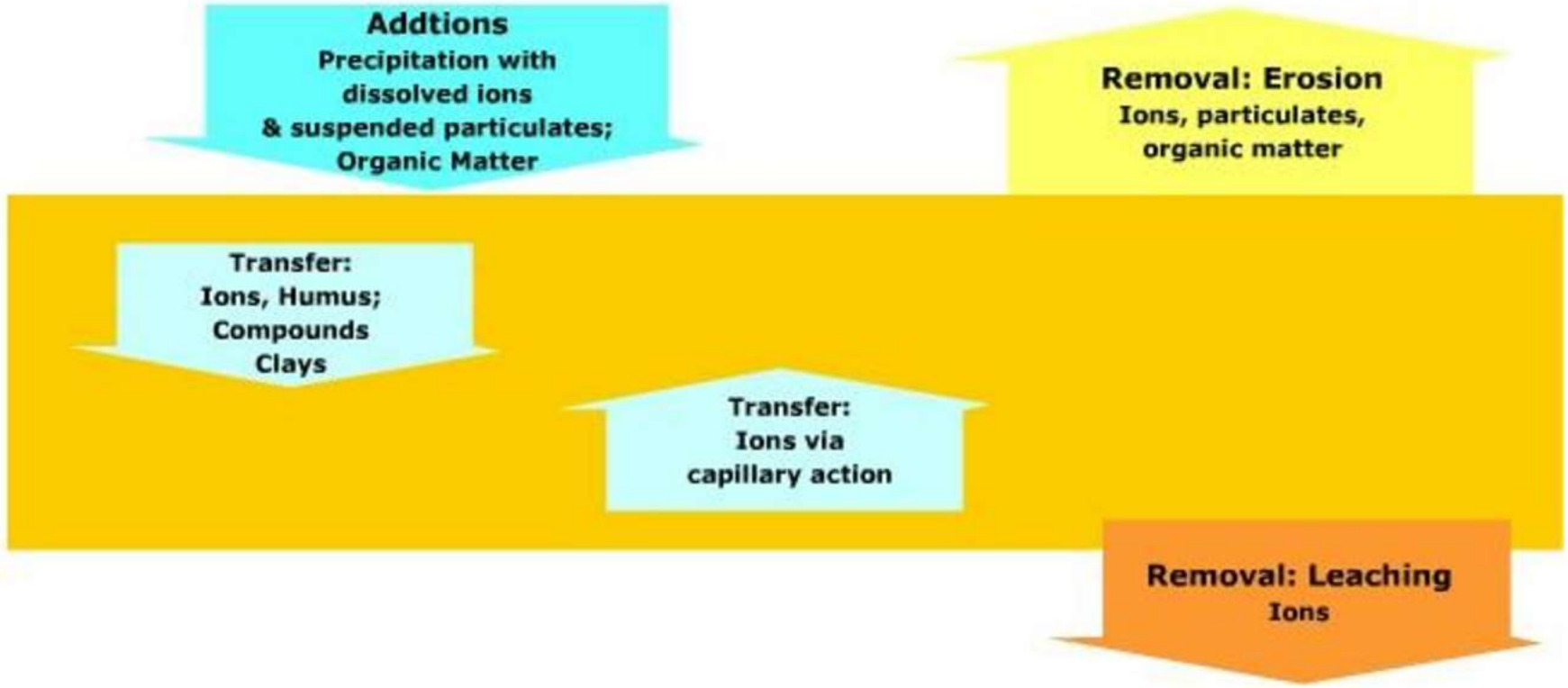


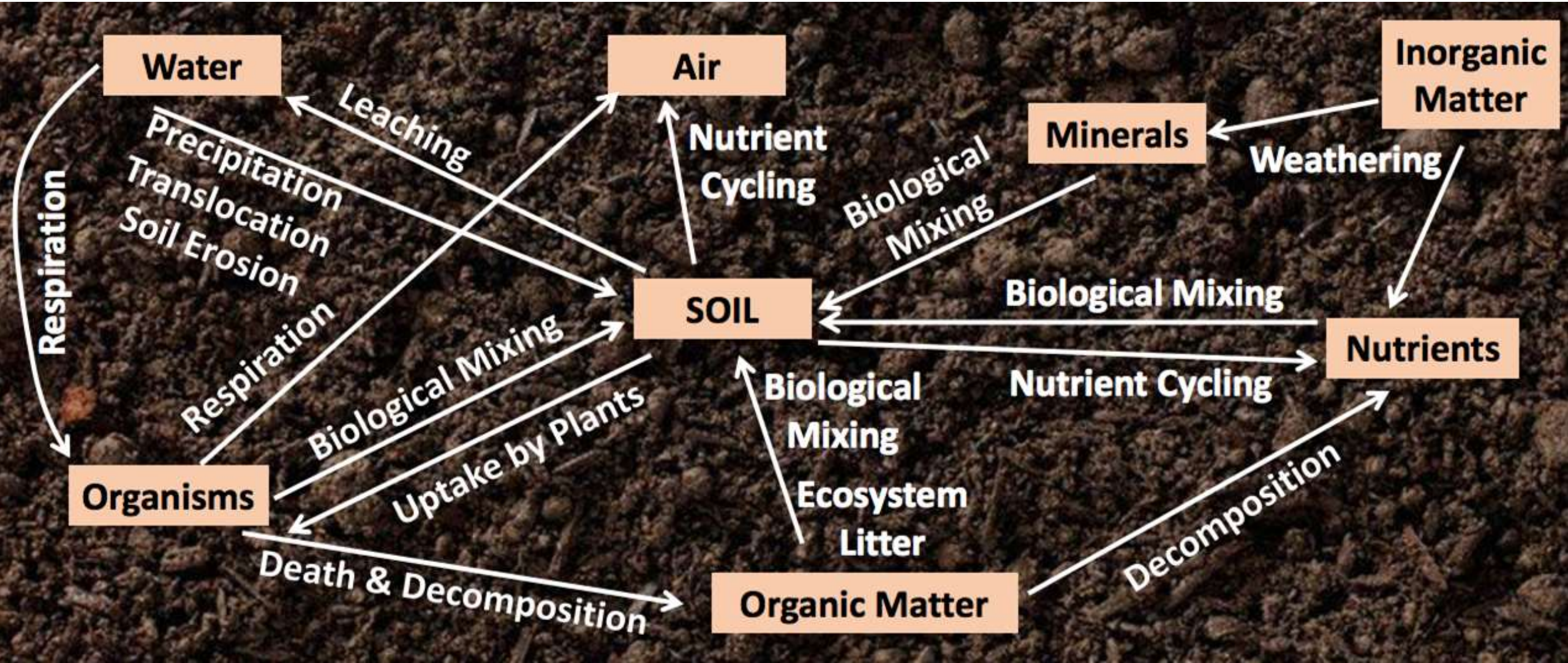
image from earthonline.com

- The transformation and movement of materials within soil organic matter pools is a dynamic process influenced by climate, soil type, vegetation and soil organisms.
- All these factors operate within a hierarchical spatial scale.
- Soil organisms are responsible for the decay and cycling of both macronutrients and micronutrients, and their activity affects the structure, tilth and productivity of the soil.

Outline the transfers, transformations, inputs, outputs, flows and storages within soil ecosystems

Storages	Organic matter, organisms, nutrients, minerals, air, and water
Transfers within soil	Biological mixing (organism living in soil mix nutrients & minerals in with organic matter), translocation (movement of soil particles in suspension,
Inputs	Organic material including leaf litter, inorganic matter from parent rock, precipitation, energy
Outputs	Uptake by plants, soil erosion
Transformations	Decomposition, weathering, nutrient cycling

Transfers of materials within the soil including biological mixing, leaching (minerals dissolved in water moved through soil) contribute to the organization of the soil

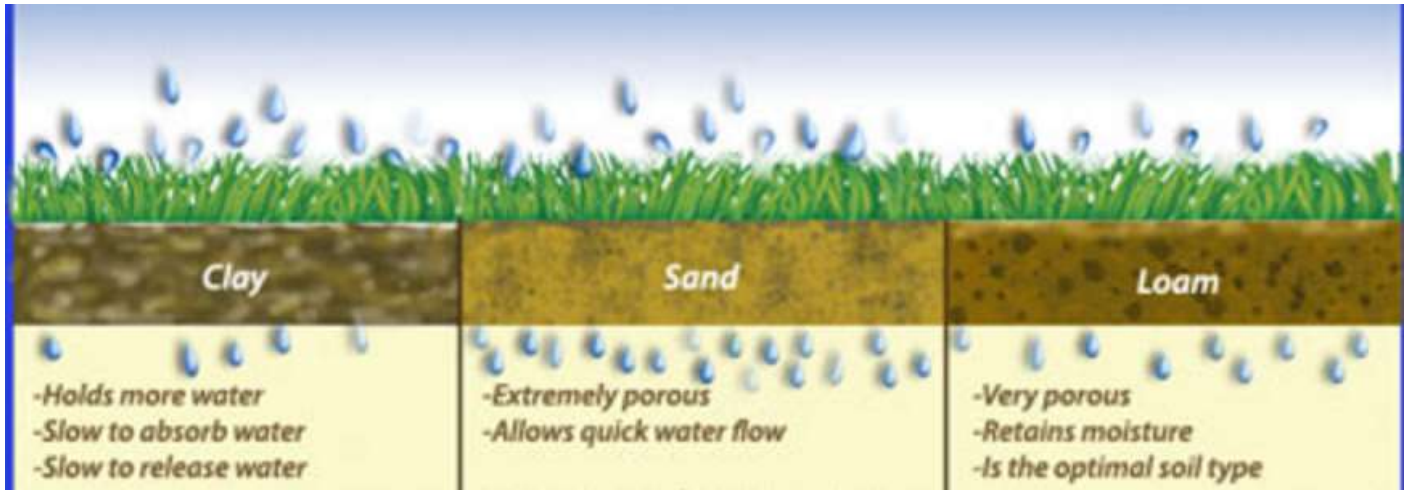


	Water retention and availability	Nutrient storage capacity	Air Space	Primary Production
Clay	Sticky and easily waterlogged	High	Low	Medium/Low
Sand	Fast draining soils that dry easily	Low	High	Low
Loam	High to medium	Medium	Medium	Medium

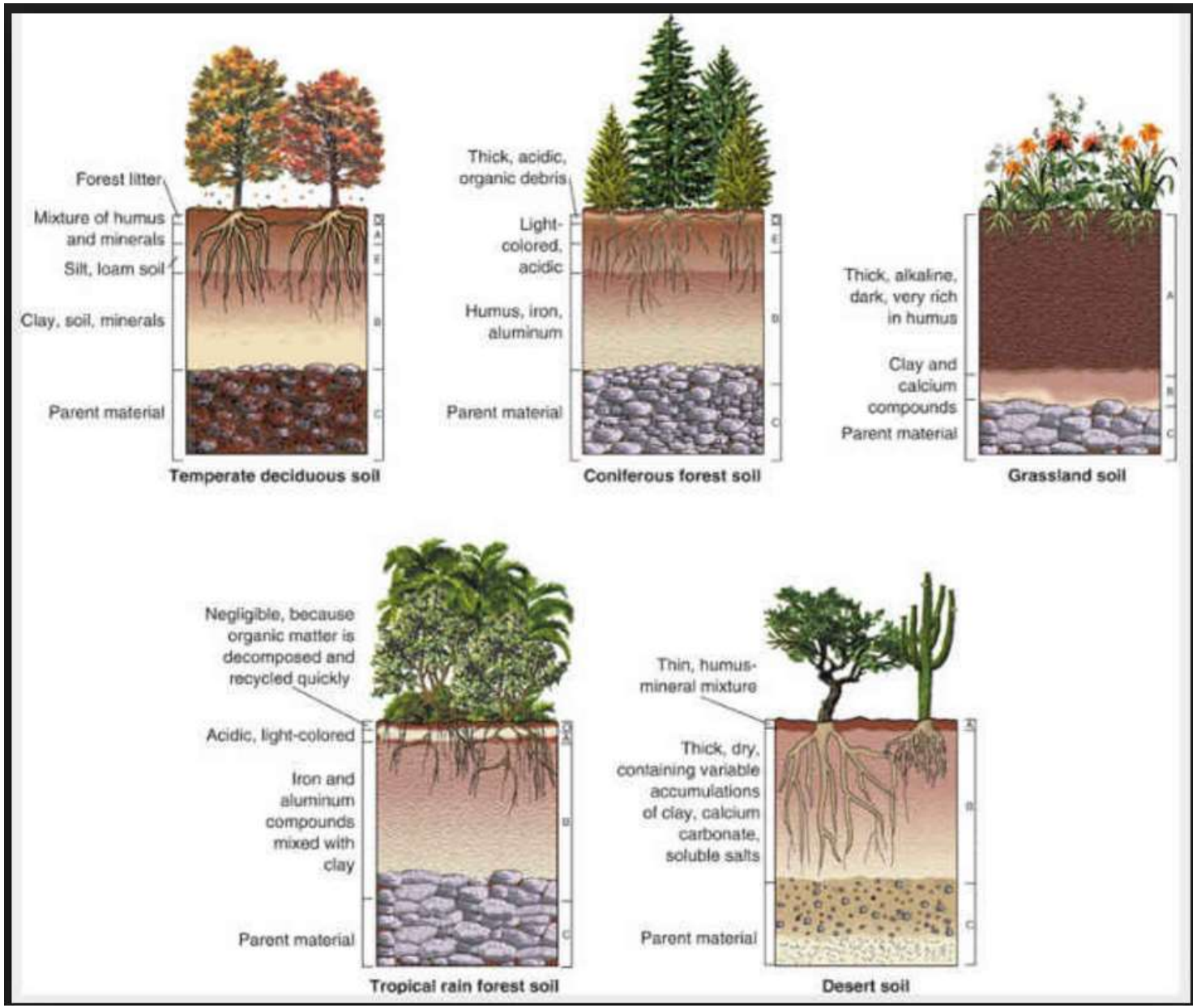
Soil structure affects aeration, water-holding capacity, drainage, and penetration by roots and seedlings, among other things.

Soil structure refers to the arrangement of soil particles into aggregates (or peds) and the distribution of pores in between.

It is not a stable property and is greatly influenced by soil management practices.



Soil profiles vary from ecosystem to ecosystem

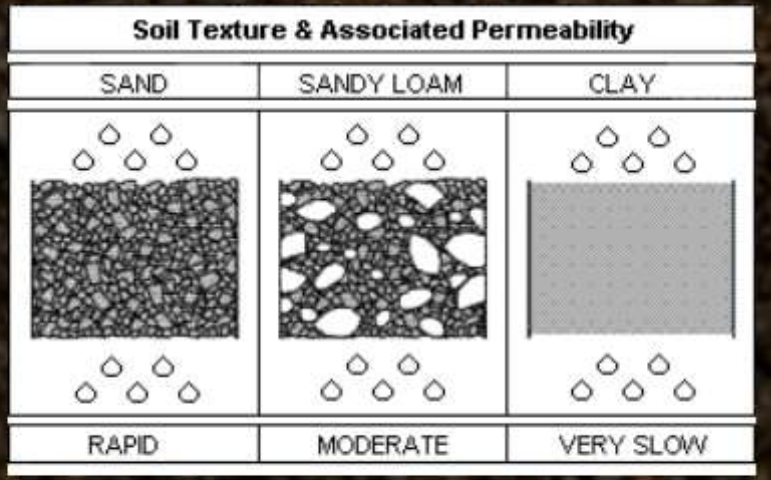


The structure and properties of sand, clay and loam soils differ in many ways, including; mineral and nutritional content, drainage, water holding capacity, air spaces, biota and potential to hold organic matter. Each of these variables is linked to the ability of the soil to promote primary productivity

SOIL TYPE	SOIL TEXTURE	SOIL COMPONENTS	INTAKE RATE	WATER RETENTION	DRAINAGE EROSION
Sandy soil	Coarse texture	Sand	Very high	Very low	Low erosion Good drainage
		Loamy sand	High	Low	
Loamy soil	Moderately coarse	Sandy loam	Moderately high	Moderately low	Low erosion Good drainage
		Fine loam	Moderately high	Moderately low	
	Medium texture	Very fine loam	Medium	Moderately high	Moderate drainage
		Loam	Medium	Moderately high	Moderate drainage
		Silty loam	Medium	Moderately high	Moderate drainage
		Silt	Medium	Moderately high	Moderate drainage
	Moderately fine	Clay loam	Moderately low	High	
		Sandy clay loam	Moderately low	High	
		Silty clay loam	Moderately low	High	
Clay soil	Fine texture	Sandy clay	Low	High	Drainage
		Silty clay	Low	High	Severe erosion
		Clay			

Soil Permeability

- The rate at which air and water can flow from upper layers of soil to lower layers of soil
- Clay: particles are small, have low permeability and lock minerals in place so makes inaccessible to plants
- Sand: has large pore space which allows drainage but may allow minerals to leach through the soil.
- Loam soils are ideal for agriculture because they have good permeability and have good nutrient content



Soil Particles

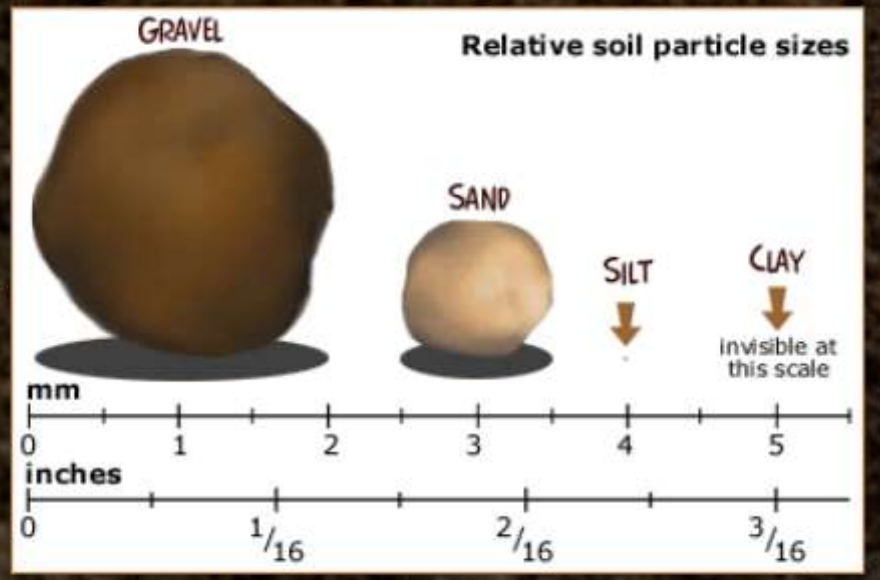
Smallest

Clay < 0.002 mm in diameter

Silt 0.002 – 0.05 mm in diameter

Sand 0.05 – 2 mm in diameter

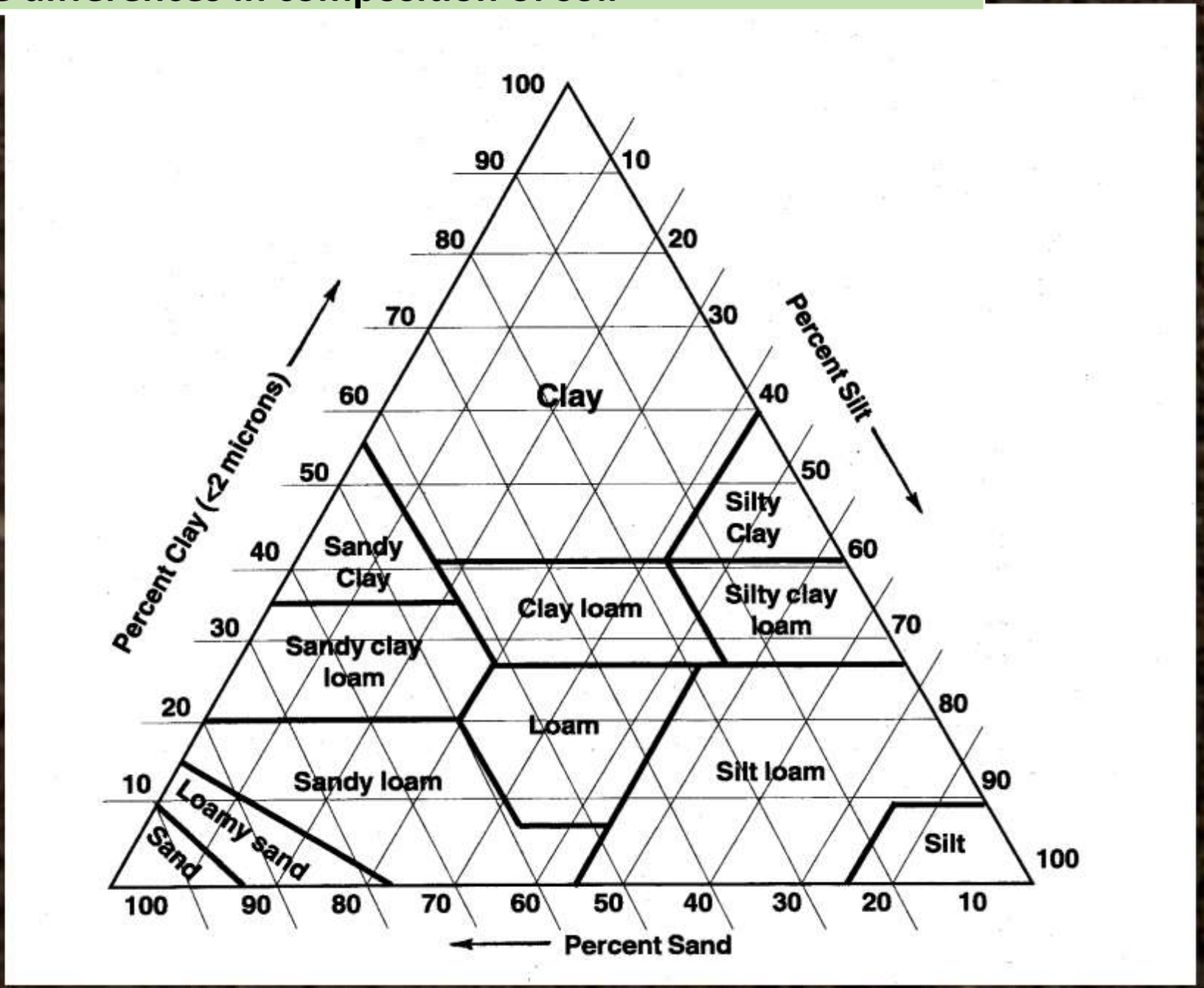
Largest



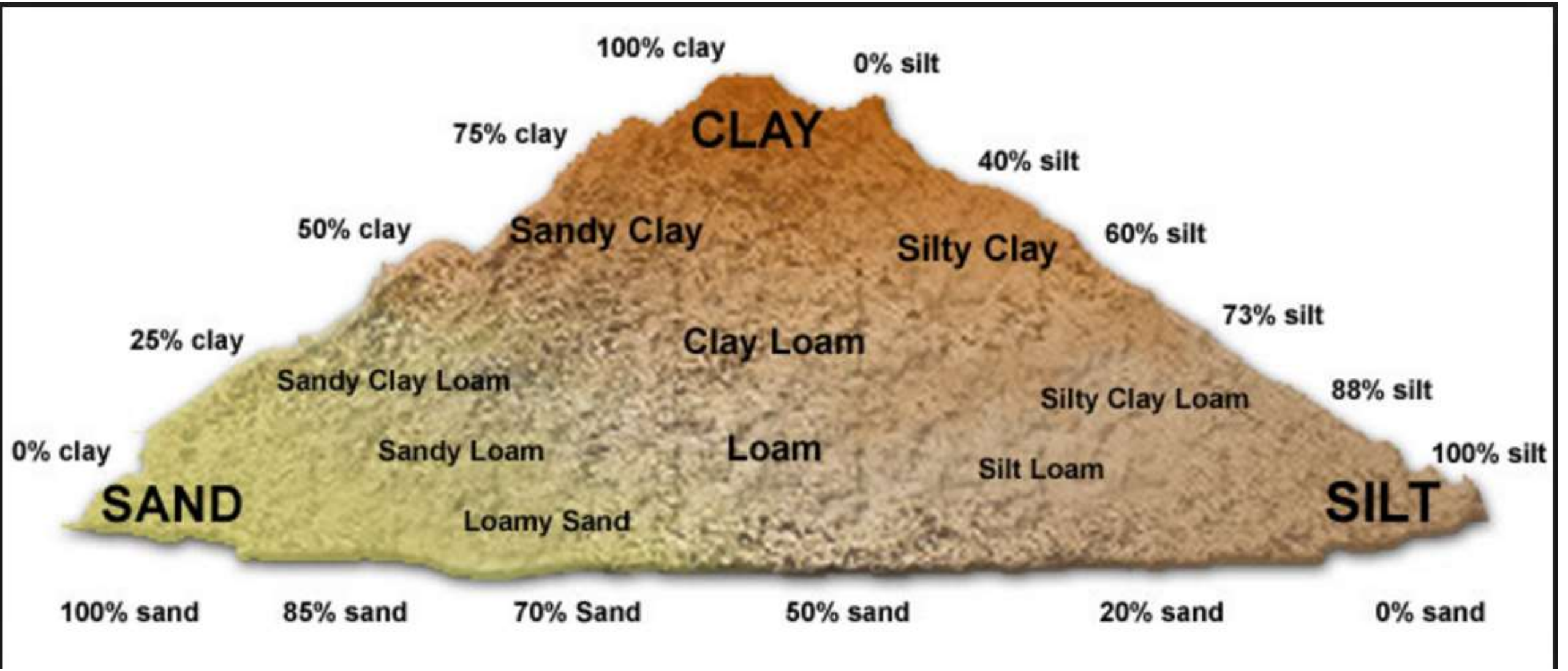
- **Soil Texture** is determined by the relative amounts of the different types and sizes of mineral particles
- If fairly equal portions of each soil are present the soil is said to be a **loam**
- **Soil texture affects the fertility and primary productivity of an ecosystem**

A soil texture triangle illustrates the differences in composition of soil

Soil Texture Triangle



Compare and contrast the structure and properties of sand, clay and loam soils, with reference to a soil texture diagram, including their effect in primary productivity



Acidification of Soils

- Acid precipitation due to industrial pollution has increased the acidity of many soils near urban areas
- Clay soils often have high acidity due to the absorption of water
- Acidified soil causes leaching of potassium, magnesium and ammonium (removing these minerals from the ecosystem)
- A decrease in pH causes aluminum and iron to become more available to plants which is toxic to most plants, especially evergreen plants which lose their needles.

Soil Sustainability

- Fertile Soil is a non-renewable resource – it takes a LONG time for soil to form
- Fertile soil has enough nutrients (nitrates, phosphates, and potassium NPK) for healthy plant growth.
- Nutrients are leached from soil as water is moving through
- Nutrients are also lost when crops are harvested
- To replace nutrients, chemical fertilizers are often used
- More sustainable methods of replacing nutrients include crop rotation, planting legumes, and using organic fertilizers (compost, manure)