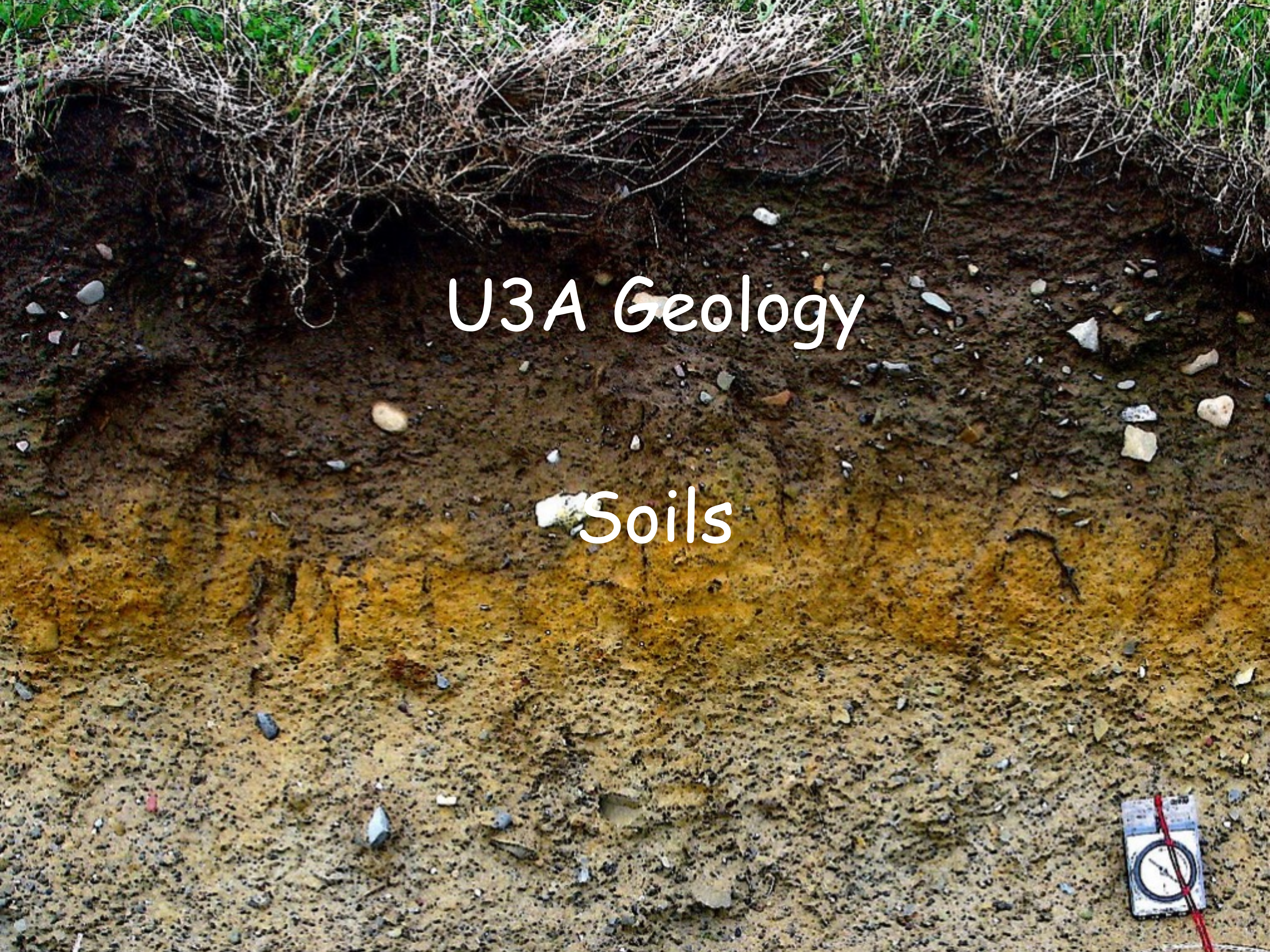

U3A Geology
Soils

Introduction

- Soil originates from the weathering of rock materials
- the rates at which the weathering processes occur, depend primarily on climate
- there are however, many other processes that produce the distinctive feature of soil
- of primary importance are the processes associated with plants, animals and micro-organisms that colonise the soil

The role of soils

1. Serve as media for growth of plants

2. modify the atmosphere by emitting and absorbing gases (CO_2, methane, water vapour)

3. provide habitat for animals and other organisms that live in the soil e.g. fungi, bacteria, rodents

4. absorb, hold, release, alter and purify water in terrestrial systems

5. process recycled nutrients so that living things can use them over again

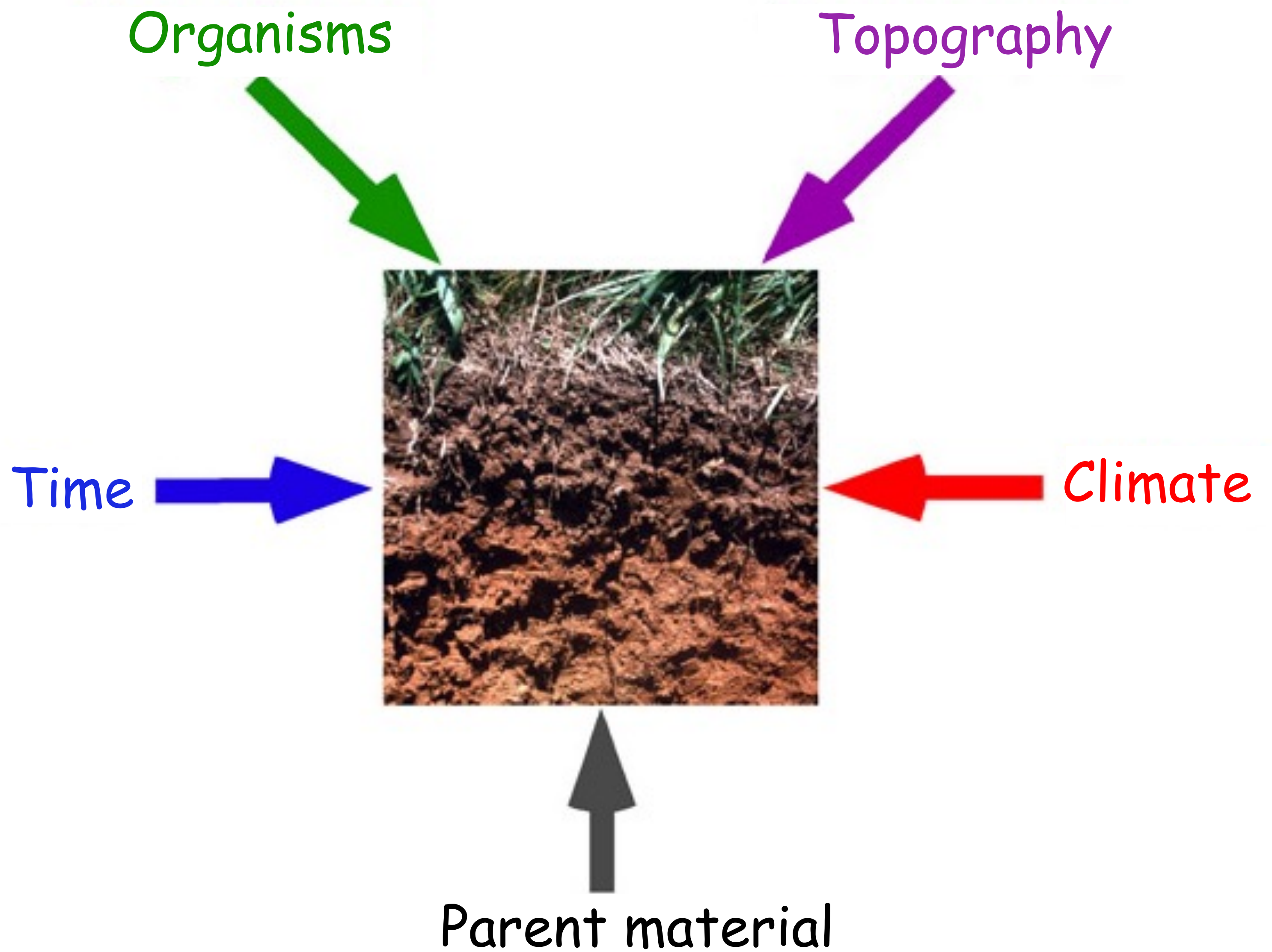
6. serve as engineering media for construction of foundations, road beds, dams and buildings

7. act as a living filter to clean water before it enters aquifer

Soil formation

- Soils are formed over a long period of time as a result of weathering and erosion of rock minerals in the Earth's crust
- solid bedrock exposed at the surface is broken up and its chemical composition altered substantially e.g. feldspars
- some fragmented rock material may remain in-situ → unconsolidated deposit
- weathering of soil involves variety of chemical, physical and biological processes → acting to breakdown rocks
- relative importance of different types of weathering processes determined by climate

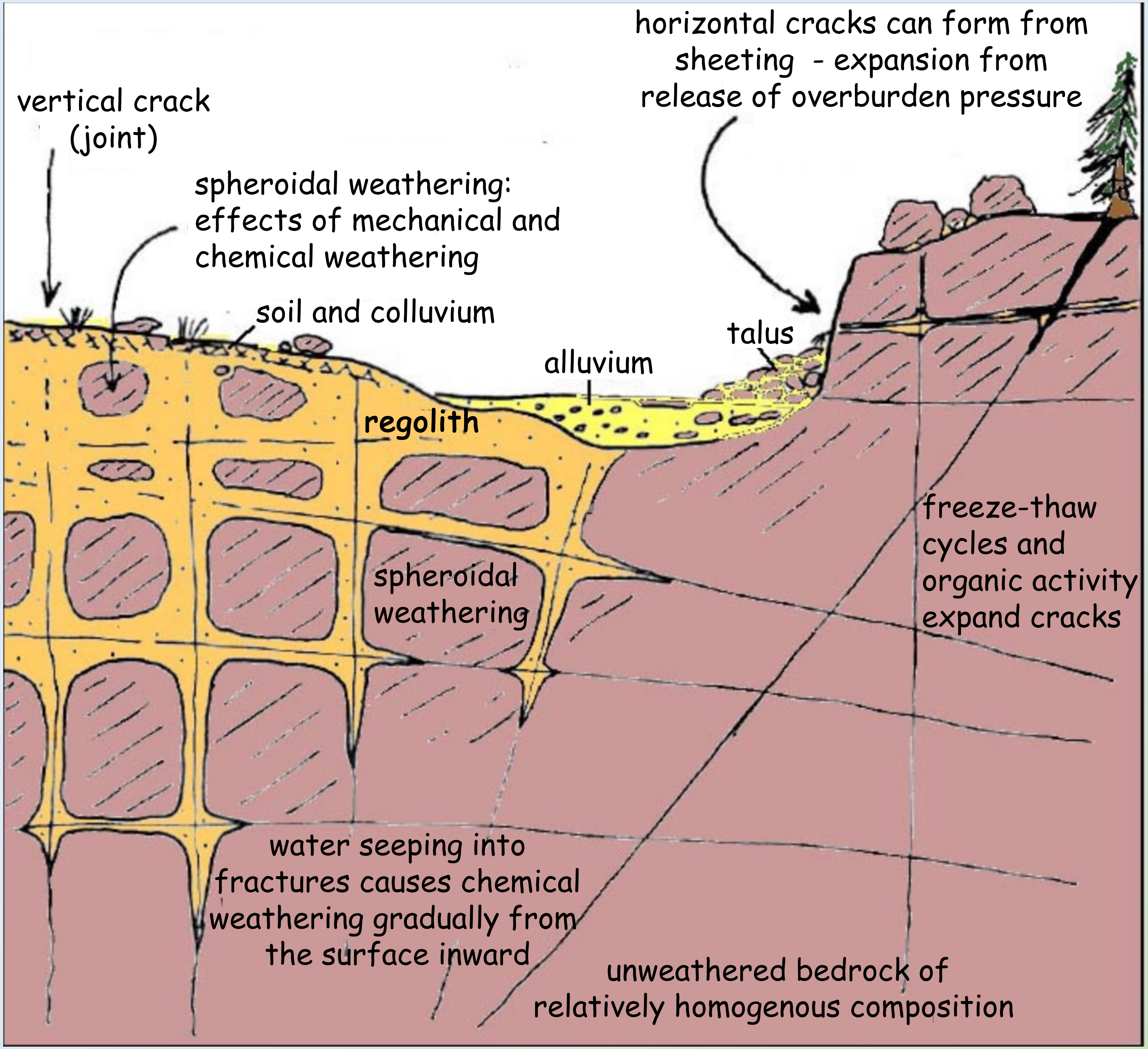
Soil formation



Mechanical weathering

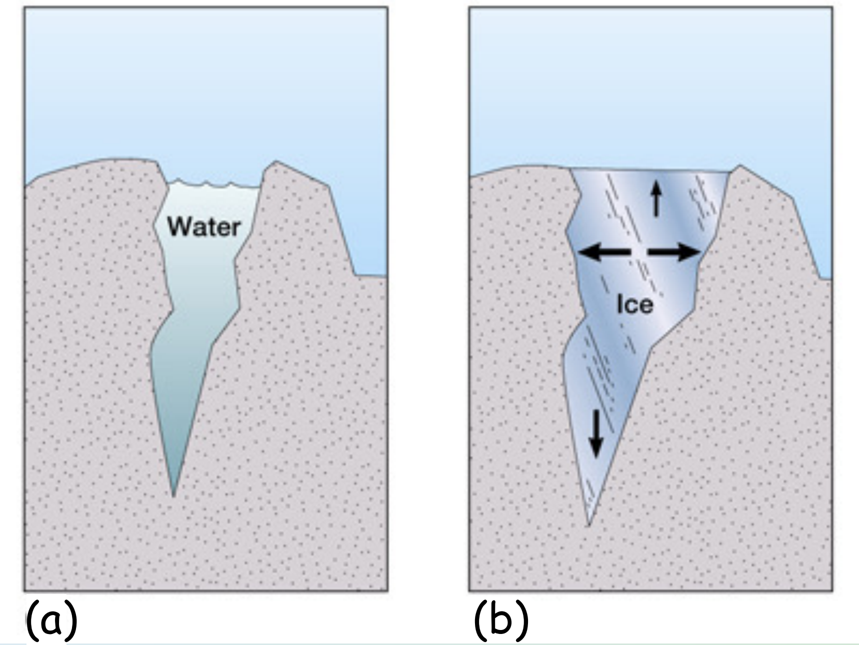
- Mechanical weathering → breakup of rocks without change in their composition
- in cold climates with temperatures that fluctuate above and below freezing → water enters cracks, repeatedly expands and contracts → breaks rocks into small fragments → ice wedging
- crystallising salts in cracks can have the same wedging effects
- in extreme climates, temperature contrast between day and night may cause enough stress to breakup fractured rocks

Weathering features



Ice wedging

- Water freezes and expands with 9% increase in volume
- successive freeze-thaw episodes propagates fracture downwards



Chemical weathering

- Chemical weathering → breakdown of minerals by chemical reaction with water, dissolved chemicals or gases in the air
- minerals differ in the kinds of reactions that they undergo
- calcite tends to dissolve completely leaving no other minerals behind in its place
- many natural waters are slightly acidic including rainwater that dissolves small amounts of CO_2 as it falls → H_2CO_3
- climate plays a major role in intensity of chemical weathering → warm, wet climates more conducive to weathering than cold ones

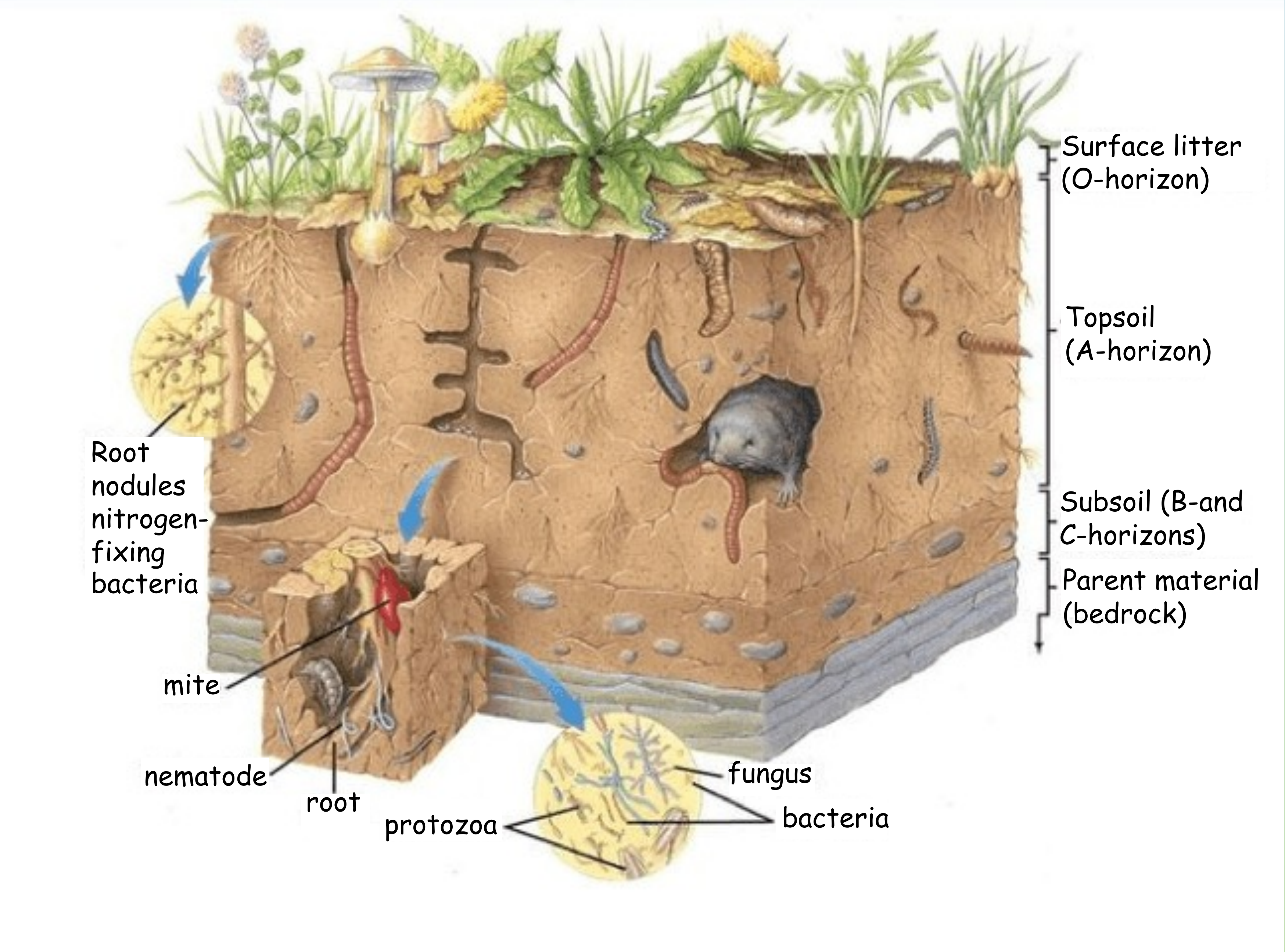
Role of animals and bacteria in soil formation

- Earthworms and other burrowing animals e.g. rodents, termites play an important role in preparing material for removal by rain-wash or wind
- worms consume large quantities of soil to extract food → indigestible particles passed out as worm casts
- on average → there may be 400,000 worms per hectare → raise 10-15tonnes of material to the surface over one year
- water containing bacteria attacks minerals and soils
- dead remains of organisms decay in the soil mainly due to activities of fungi and bacteria

Role of plants in soil formation

- Growing rootlets of shrubs and trees exert pressure on rocks as they work their way into crevices wedging off large rocks
- plants of all kinds including fungi and lichen contribute to chemical weathering → extract certain elements from rock materials
- CO_2 and organic acids together with traces of ammonia and nitric acid are liberated → increase solvent power of soil water
- chief organic product is humus → water charged with humic acid can dissolve certain substances that are ordinarily insoluble

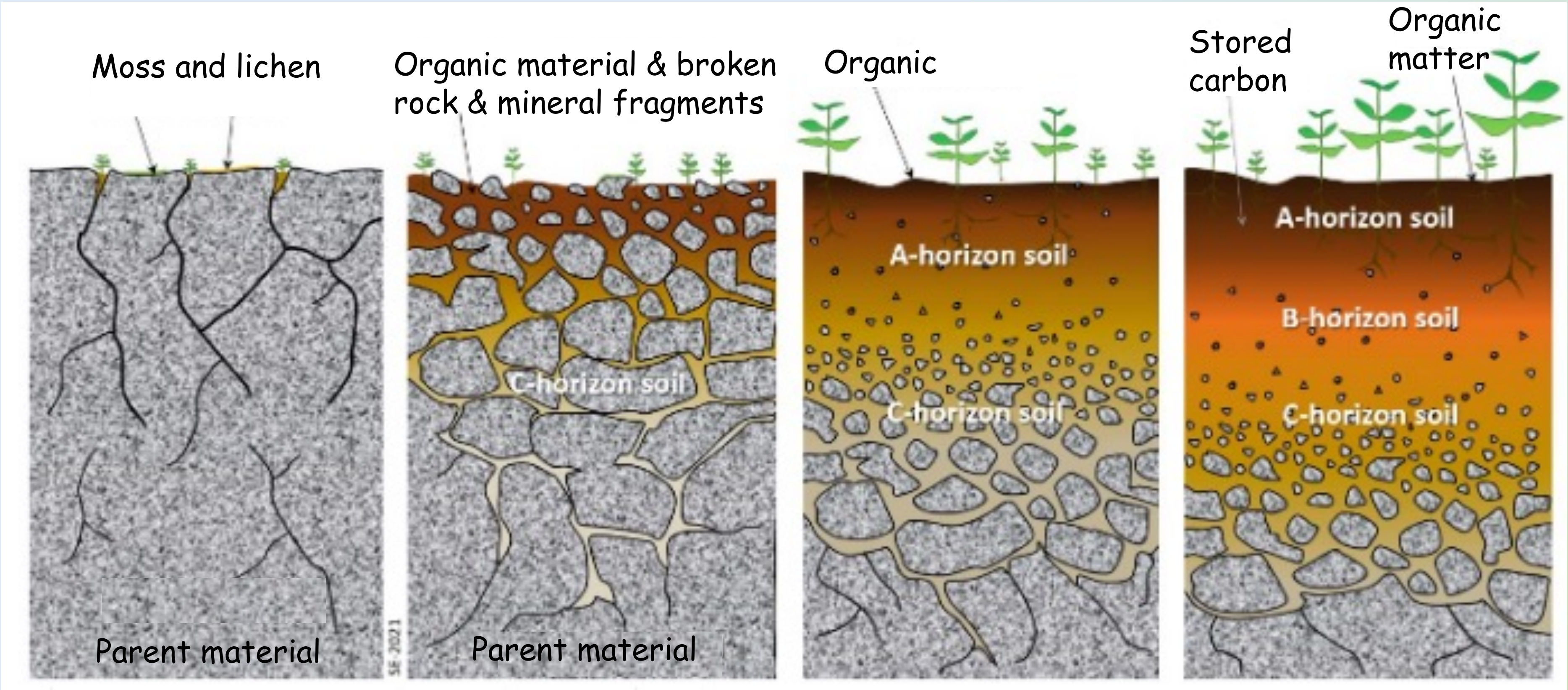
Role of plants and animals in soil formation



The time factor

- Characteristics and properties of soils require much time for development
- mineral matter like clean sorted sand in a dune may take hundreds or thousands of years to acquire the properties of a sandy soil
- a warm, moist environment is conducive to soil development
- soil develops from sediments relatively quickly and from bedrock relatively slowly
- soil scientist's rule of thumb → it takes 500 years to form 2.5cm of topsoil

Stages in soil formation



Stage 1 Stage 2 Stage 3 Stage 4

Soil profiles and soil horizons

- As a result of mechanical, chemical and biological weathering with decayed remains of organisms → formation of blanket of soil between bedrock and atmosphere (regolith)
- cross-section of soil blanket → usually reveal a series of zones of different colours and different properties
- the number of recognisable zones and thickness of each vary
- at the top is the A horizon, mostly weathered rock material → most exposed to surface processes
- unless local water table is exceptionally high, precipitation infiltrates through A horizon dissolving and dispersing soluble minerals → zone of leaching

Soil profiles and soil horizons

- In dry climates many of the leached minerals accumulate in the layer below the A horizon → B horizon
- below the B horizon → zone of broken up bedrock and little else → C horizon
- boundaries between adjacent soil horizons may be sharp or indistinct (maybe divided into subhorizons)
- e.g. the A horizon may consist of topsoil rich in organic matter → O horizons
- overall soil thickness → partly a function of rate of soil formation and partly a function of rate of soil erosion

Soil horizons

Soil horizons

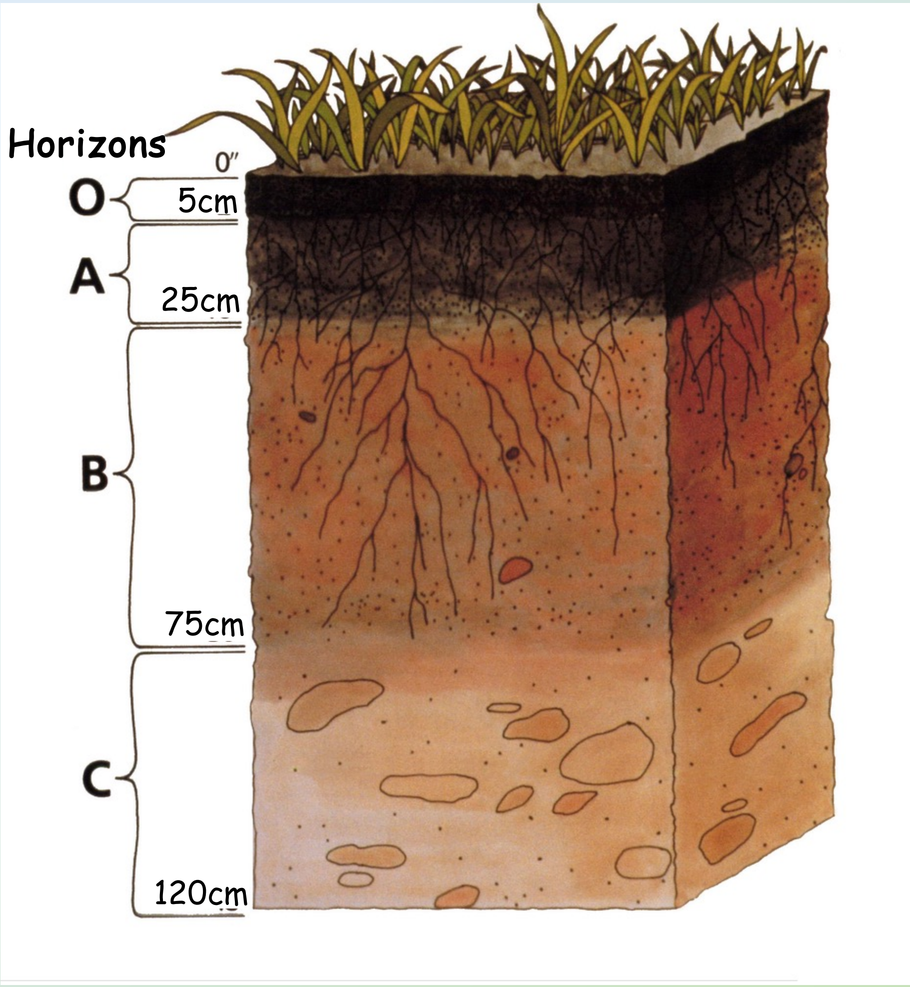
O – (humus or organic) Mostly organic matter e.g. decomposing leaves.

A – (topsoil) Mostly minerals from parent material with organic matter

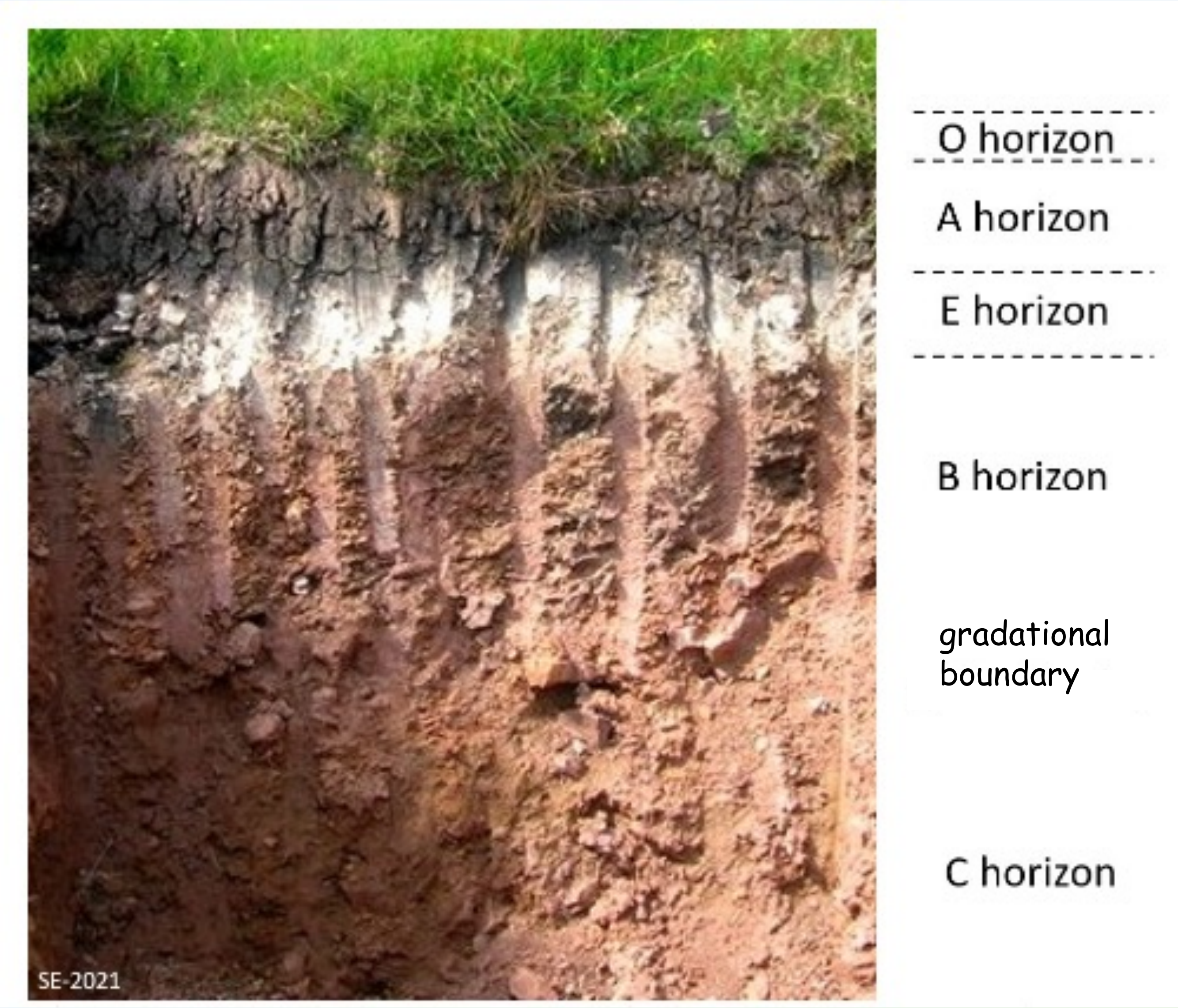
E – (eluviated) Leached of clay minerals and organic matter, leaving concentration of sand and silt

B – (subsoil) Rich in minerals leached from A and E horizons

C – (parent material) Deposit at Earth's surface from which soil developed



Soil horizons

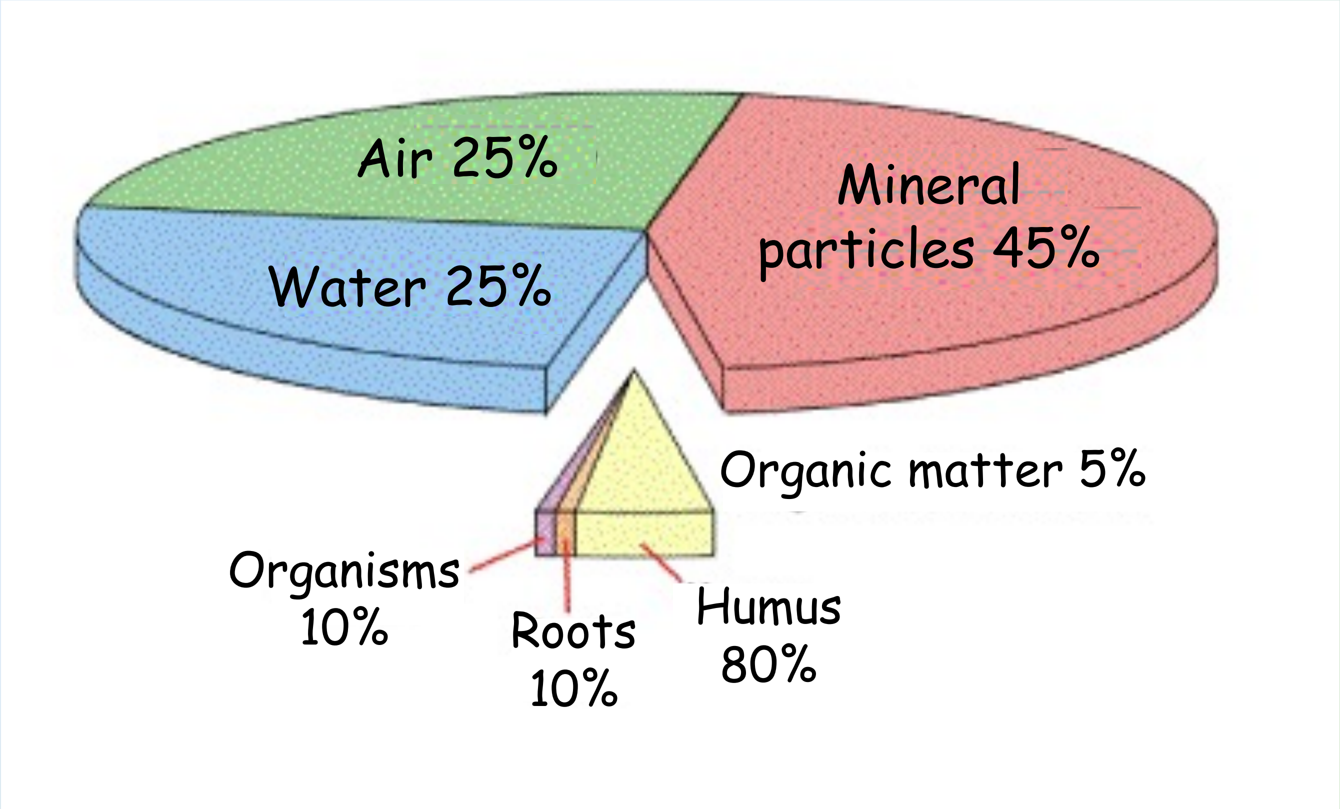


Soil composition

- Soil contains both abiotic and biotic factors, air, water and minerals as well as plant and animal matter both living and dead
- in absence of pollution, wind and rainwater rarely add many chemicals. Runoff water may carry away some leached minerals in solution
- chemical weathering tends to result in net subtraction of elements from rock or soil
- weathering processes also influence the mineralogy of the soil
- physical properties of soil are affected by mineralogy, texture of mineral grains and any organic matter present

Composition

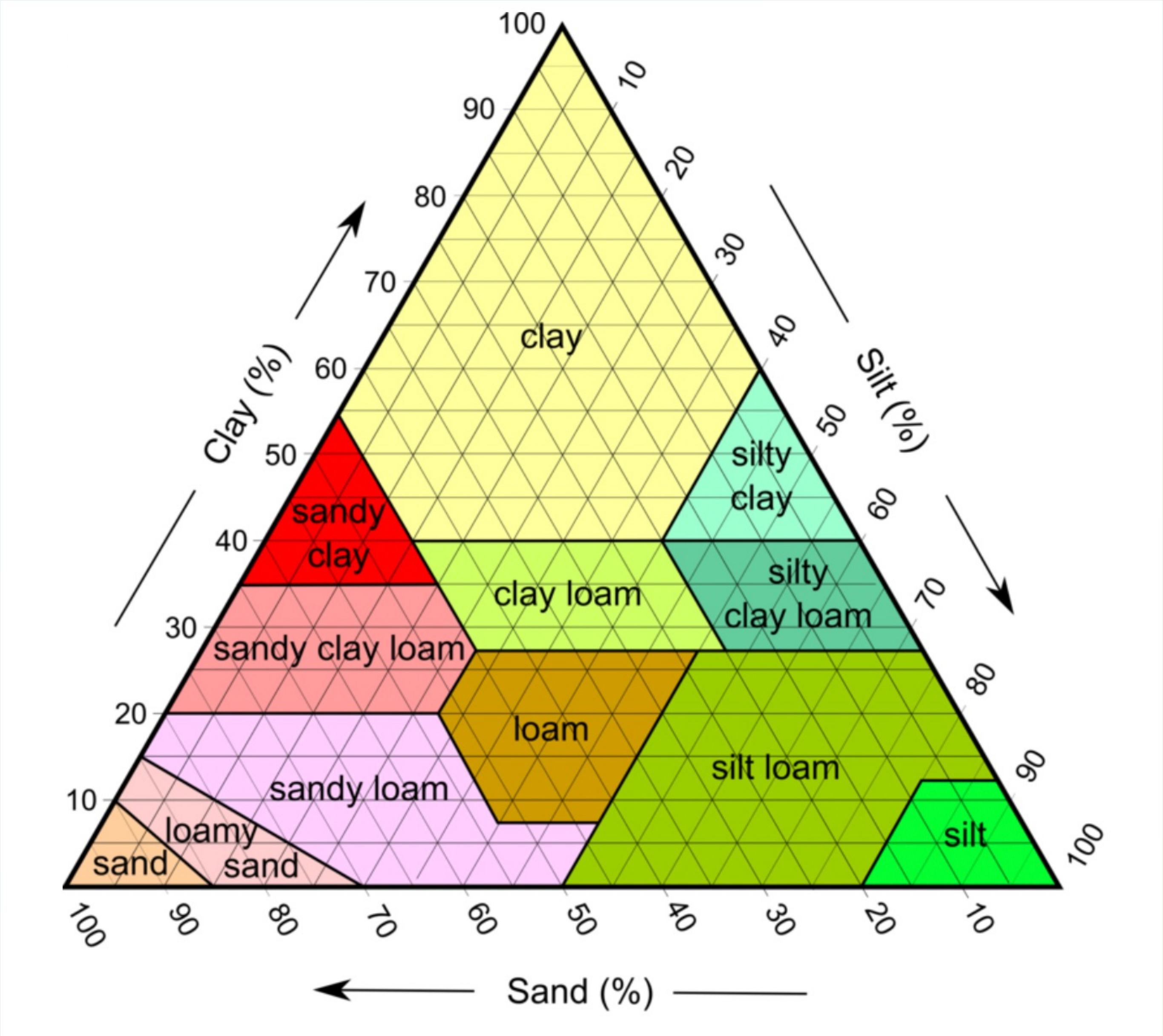
- Most common elements in soil are P, K and N
- less common elements include Ca, Mg and S



Soil texture classes

- Major soil textures → defined by 12 classes on a ternary diagram
- classification of textures based on particle size distribution
- one side of triangle represents percentage sand, the second clay and the third silt
- textures are classified by fraction of each soil separate (sand, silt and clay)
- fourth term → loam → equal separates of sand, silt and clay in soil sample
- most commonly used classification → USDA system

Soil texture classes (USDA)



Soil classification based on climate

- Classification of soil into two broad categories is basically based on climate
- Pedalfer soils → moderately leached soils rich in Fe and Al minerals → characteristic of more humid regions
- where climate is very wet, more extensive leaching of soil → what remains are less soluble oxides and hydroxides of Fe and Al with clays accumulated in B horizon

Soil classification based on climate

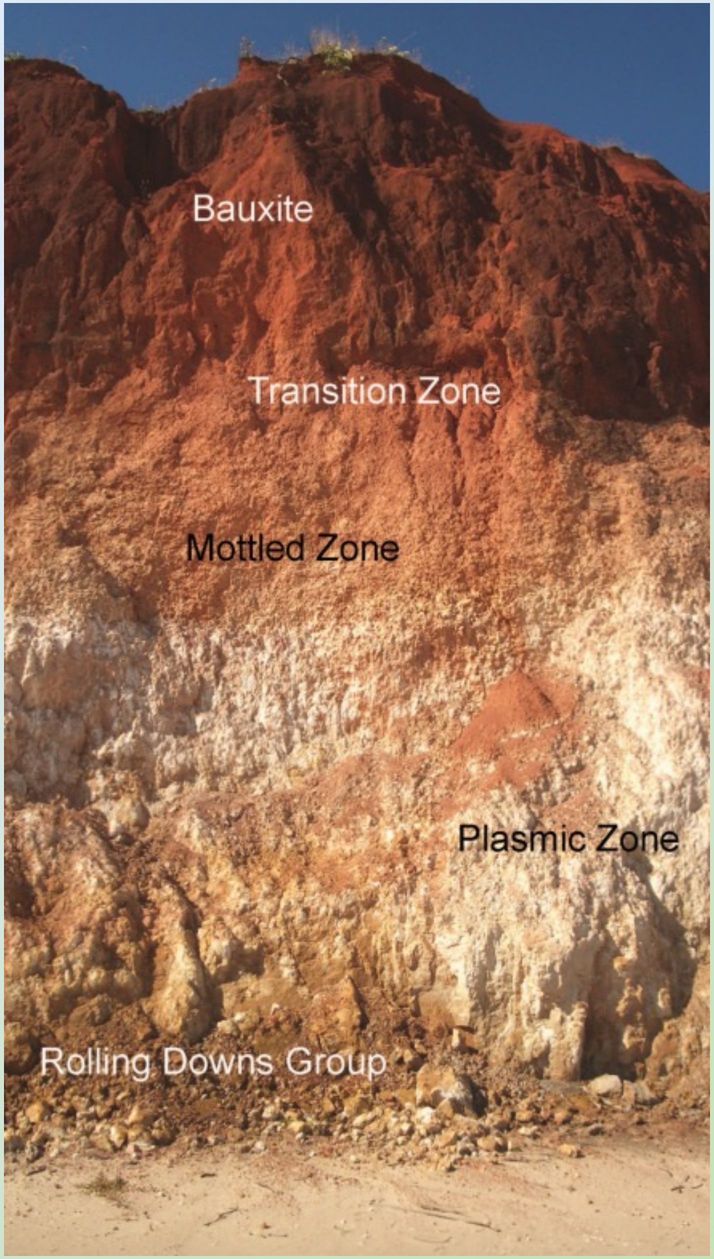
- Where climate is drier → leaching much less extensive → even quite soluble compounds like $CaCO_3$ remain in the soil, particularly in B horizon
- These soils are called pedocal soils → presence of carbonate make them more alkaline
- a problem with this classification being strictly applied → soils it describes must have formed over bedrock
- bedrock poor in Fe and Al e.g. limestone does not leave Fe and Al-rich residue no matter how extensively it is leached

Regolith

- Regolith → superficial deposits that lie on foundation of older more coherent bedrock
- cuttings through the regolith show a surface layer of soil passing gradually downward through a zone of shattered and partially decomposed rock → subsoil
- below the subsoil is parental rock → relatively fresh and unbroken by weathering
- bedrock can also be overlain by other material transported in by wind, water or moving ice

Regolith profile, Weipa, Qld

- Uppermost zone is lateritic and consists largely of pisolitic bauxite
- transition zone is iron-rich ferricrete
- mottled zone → predominantly hematite or goethite cemented kaolinite
- plasmic zone → mainly quartz and kaolinite
- base is Rolling Downs Group bedrock



Lateritic soil

- Laterite → extreme type of pedalfer → develop in tropical climates with high temperature and heavy rainfall → heavily leached
- lateritic soil may contain very little other than Fe and Al compounds
- soils of lush tropical rain forest are commonly lateritic → suggests great farmland potential → however, opposite is true
- first problem → highly leached soils, forest holds huge reserve of nutrients → no corresponding reserve in soil
- second problem → when forest vegetation is cleared and exposed to baking sun → lateritic soil hardens → bricklike, resists infiltration by water and penetration by crop roots

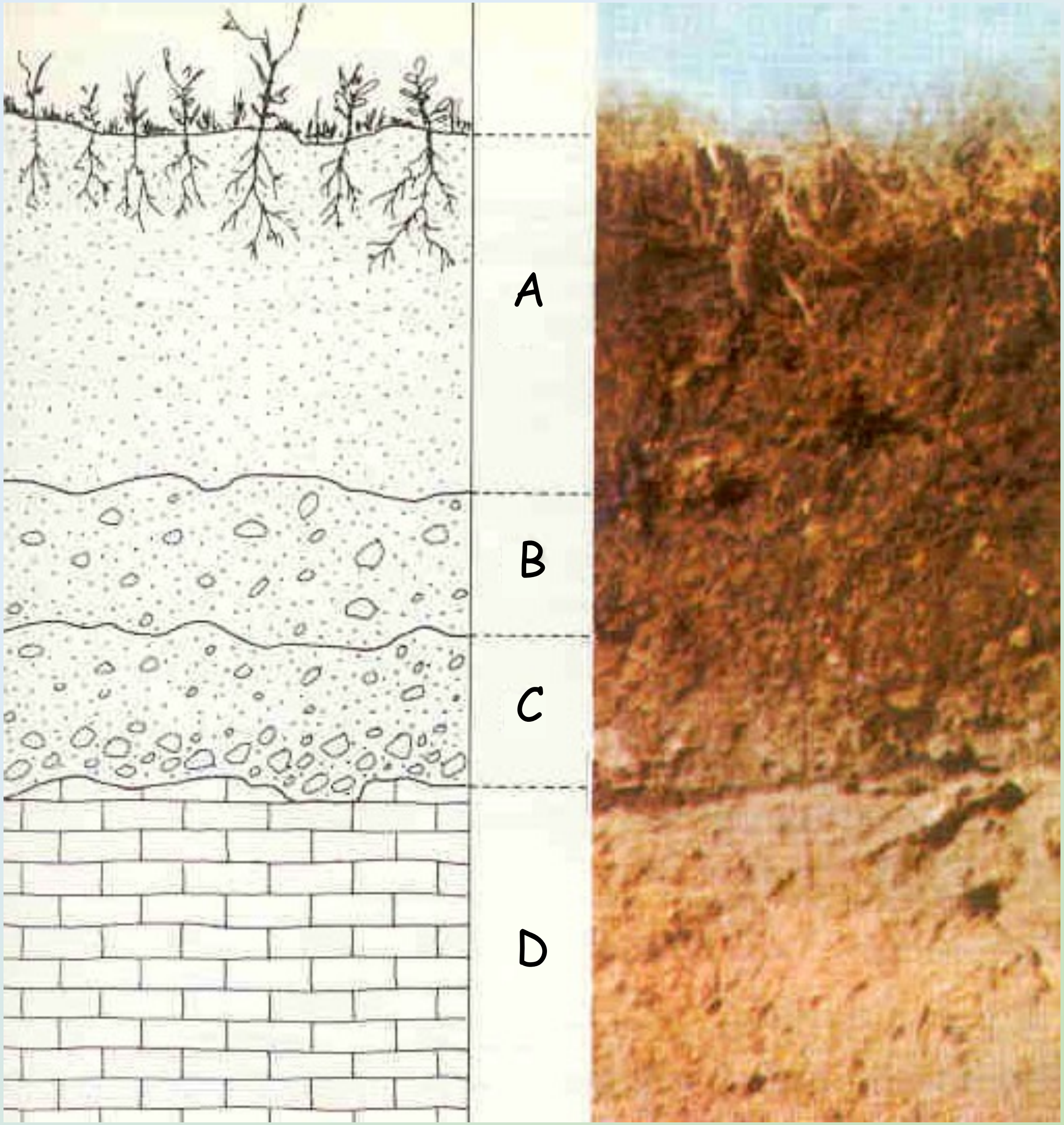
Laterite soil profile

A – soil

B – laterite

C – saprolite

D - bedrock



Laterite soil profile

Laterite soil profile Weipa

Soil erosion

- Erosion involves physical removal of materials from one place to another
- soil erosion → caused by action of water and wind → rain hitting ground helps to breakup soil
- runoff water and wind carry away loosened soil
- the faster wind and water travel the larger the particles they transport → greater the load that they move
- steep and unobstructed slopes more susceptible to erosion by water. Flat exposed land more vulnerable to wind erosion
- physical properties of soil also influence vulnerability to erosion

Soil erosion

Soil deposits transported by gravity

- Colluvium refers to sediments on or at the base of slopes as a result of gravity creep and downslope wash
- such material arises from buildup of unconsolidated material → eventually becomes unstable → moves downslope
- original accumulation of material may be due to weathering of rocks in-situ
- movement of deposits may be a gradual process or take place in short catastrophic events
- colluvium often shows evidence of successive periods of deposition layering

Colluvium

Water transported deposits

- Alluvium refers to sediments deposited by streams and rivers
- particle size varies → large rocks and boulders to fine silts and clays
- alluvial deposits often consist of layers of different textured materials e.g. sand and silt overlying coarse gravel
- sediments deposited by streams draining glaciers → fluvio-glacial deposits

Fluvial deposits

Wind and ice transported deposits

Wind transported deposits

- Wind transported deposits are called loess and are dominated by silt-sized particles that have been blown by the wind from mountains, glacial outwash plains and flood plains
- these deposits blanket and smooth pre-existing topography
- vary in depth from several cm to several metres

Ice transported deposits

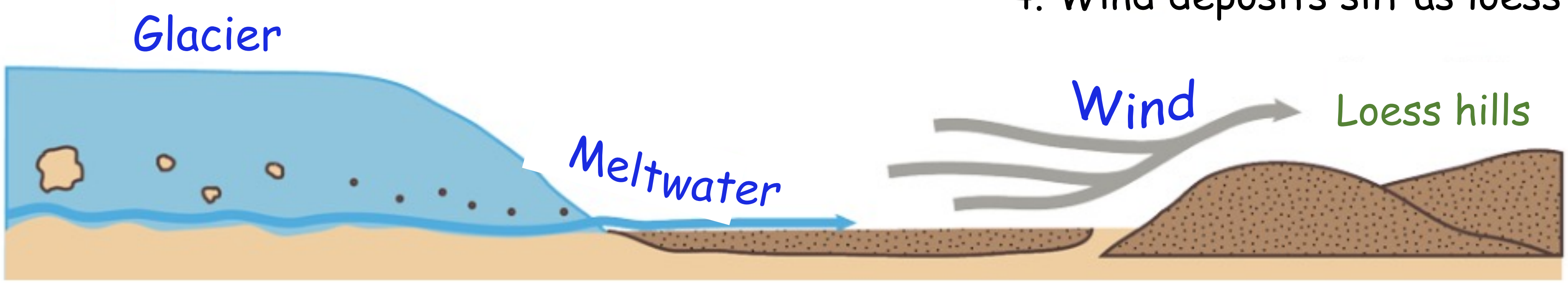
- soils transported by ice movement and erosion are called till
- till is compacted, poorly sorted material, usually consisting of large rocks in a gravelly sand matrix

Loess deposits, Palouse hills, Washington State, USA

Formation of Palouse loess

- Palouse hills of eastern Washington State are composed of loess
- glacial erosion produces large volumes of sediment
- glacial silt deposited south of a continental ice sheet by wind

1. Glacier grinds transported material into silt
2. Meltwater deposits silt downstream
3. Wind picks up exposed silt
4. Wind deposits silt as loess



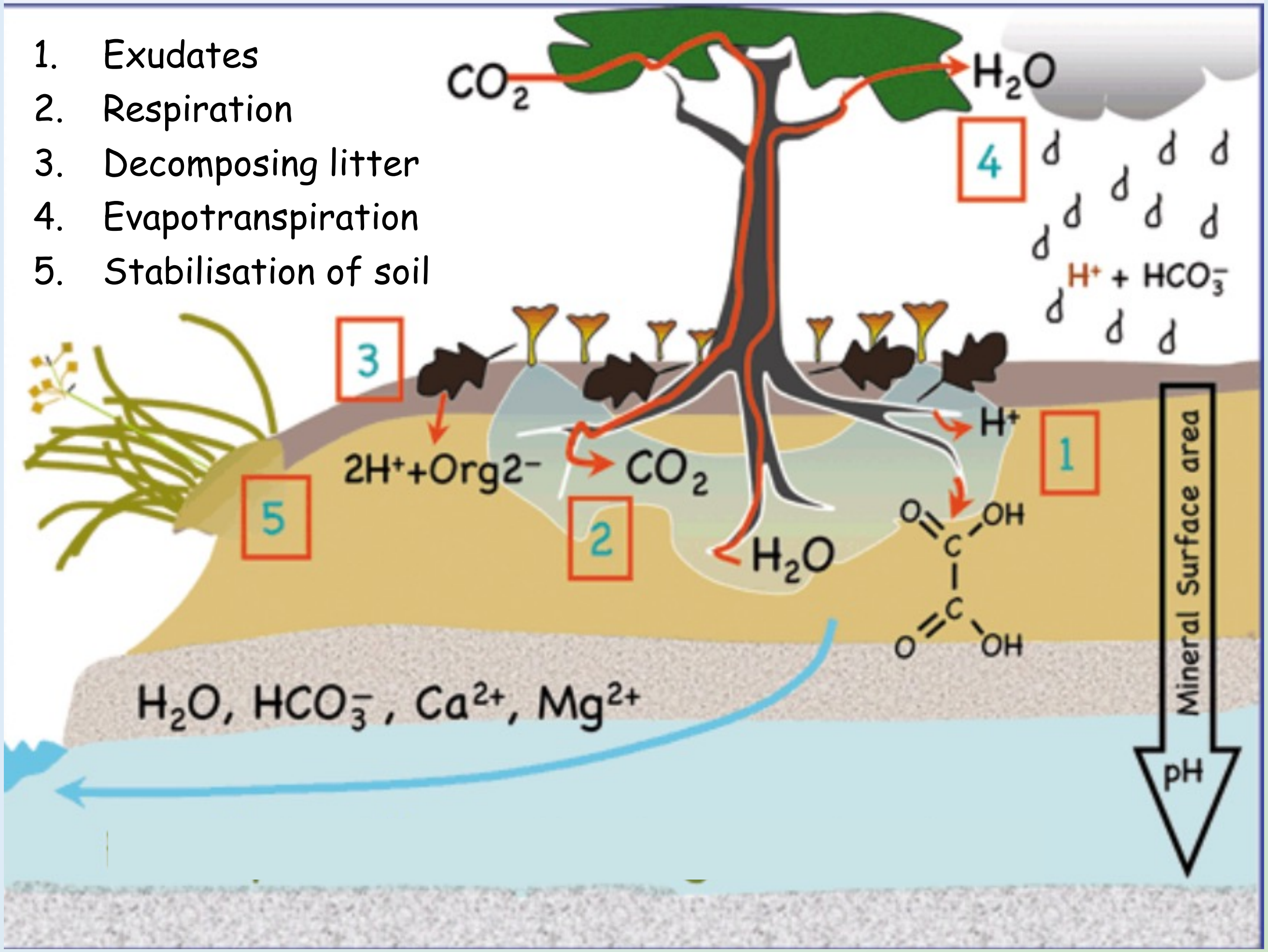
From Washington State Geological Survey

Glacial till, St Marys, Montana, USA

Soil aeration and plant growth

- Most plants and soil organisms need O_2 for respiration and growth photosynthesis produces carbohydrates that store energy
- a small proportion of carbohydrates transported to plant roots → respiration breaks them down → releases some of the energy
- soil bacteria and other micro-organisms also use carbohydrates produced by plants either from breakdown of dead plant material, exudates or from microbial residue
- for optimum plant growth → soil must supply sufficient O_2 at a fast rate → meet combined demands of plants, soils and other microbial tissue

Soil aeration and plant growth



Growth and nature of the soils

- The purely mineral matter of the residual or transported deposits is first colonised by bacteria, lichen and mosses
- rootlets work down, burrowing animals bring up inorganic particles → growing mass becomes porous → can retain water and allow passage of air
- soil is the base of pyramid of life, its fertility depends on proper balance of air, water, minerals, trace elements, humus and bacteria
- sand makes too light a soil for many plants → too porous to hold water
- clay by itself is too impervious. Mixture of clay and sand makes loam → excellent soil

Growth and nature of the soils

- Limestone cannot make soil unless it contains impurities
- clay may be lightened by mixing it with limestone to form marl that is a good soil
- in most climates, granite decomposes very slowly and yields its plant foods very gradually, basalt much quicker
- as soil ages, certain ingredients are leached out, others concentrated, compositions approach a certain characteristic type
- colours of soil are almost wholly due to abundance (or paucity) of various Fe compounds and humus

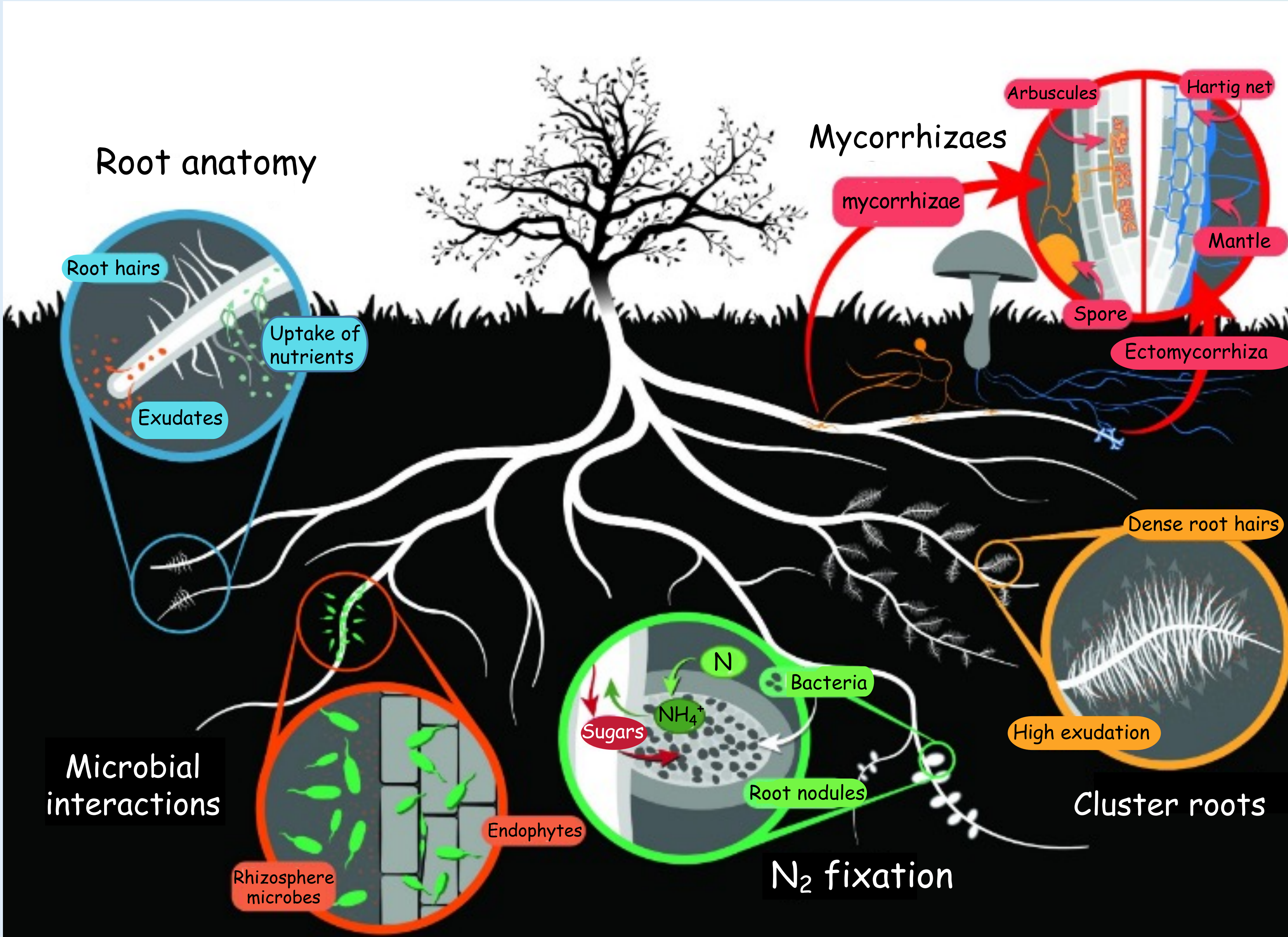
Soil organic matter

- Soil organic matter → that fraction of the soil that consists of plant and animal tissue in various stages of break down
- most productive agricultural soils have between 3 and 6% organic matter (living plant roots, stubble, leaves, mulch, animal manures)
- earthworms and microbes decompose these materials → release nutrients that can be taken up by plant roots
- end product is humus → black crumbly material resistant to further decomposition
- humus → complex chemical substance that stores nutrients, improves soil structure

Breakdown of soil organic matter

- Rate of decomposition depends on soil temperature, moisture, aeration, pH and nutrient levels
- warmer and wetter the climate → faster the break down
- cooler areas have higher levels of soil organic matter → does not break down as quickly at low temperature
- waterlogged organic material breaks down very slowly → micro-organisms cannot exist where there is no oxygen
- soils formed from waterlogged organic matter are called peat

Soil organic matter



Benefits of organic matter

- Improve soil structure → decays to humus, humus molecules, particles of sand, silt clay and organic matter into aggregates that don't break down in water
- aggregates effective in holding moisture for use by plant roots
- provide nutrients – organic matter important source of N, P and S as organic matter is decomposed by micro-organisms
- improves cation exchange capacity – humus molecules → negatively charged structures with large surface areas → hold huge quantities of positively charged Ca, Mg and K til plant needs them