Arboriculture 101
Tree – Soil Relationships

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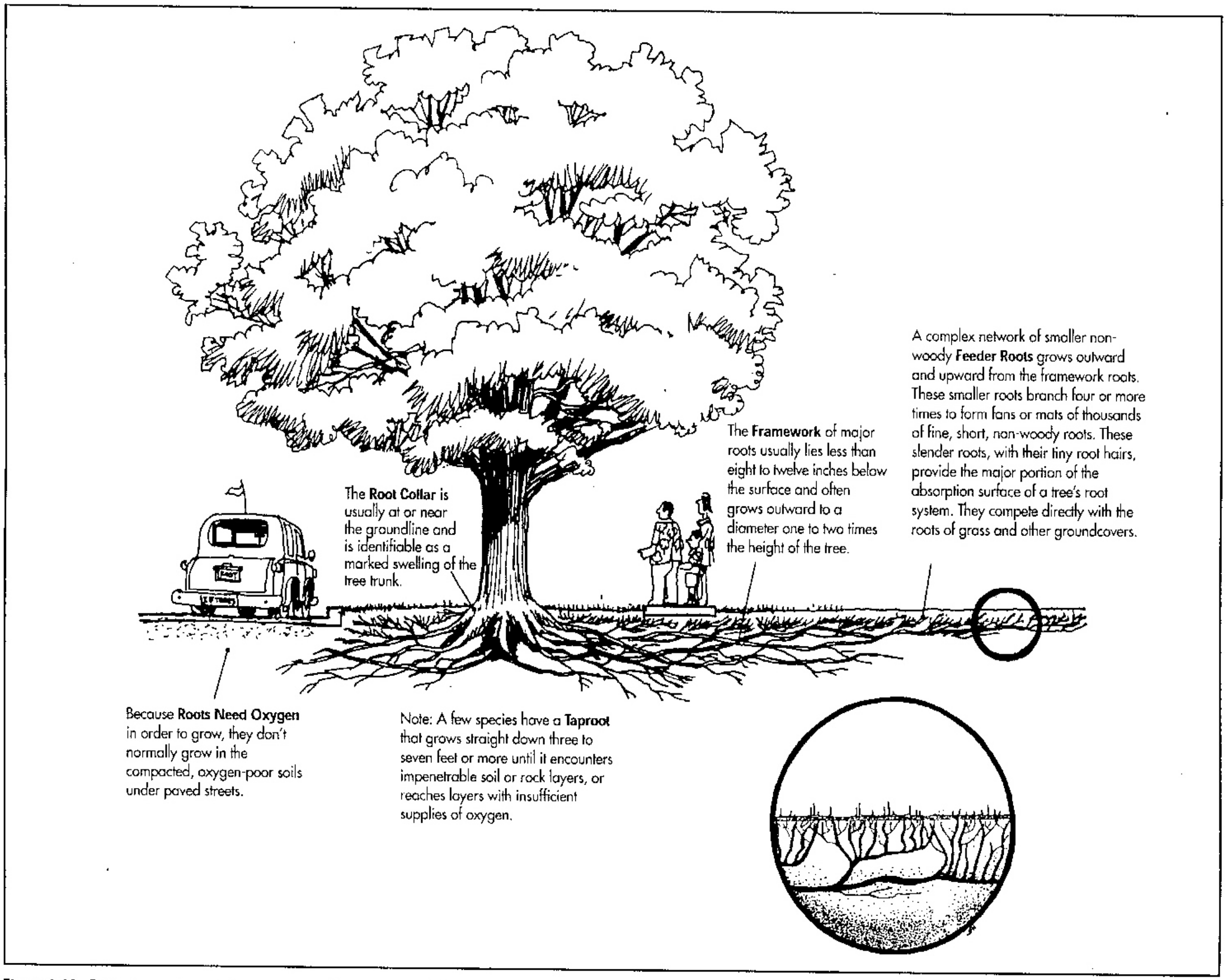


Figure 1.12 Roots grow where water, oxygen, and space are available.

Fraser firs planted in 2001
Treatments applied annually since 2002

Photos taken 3/8/06

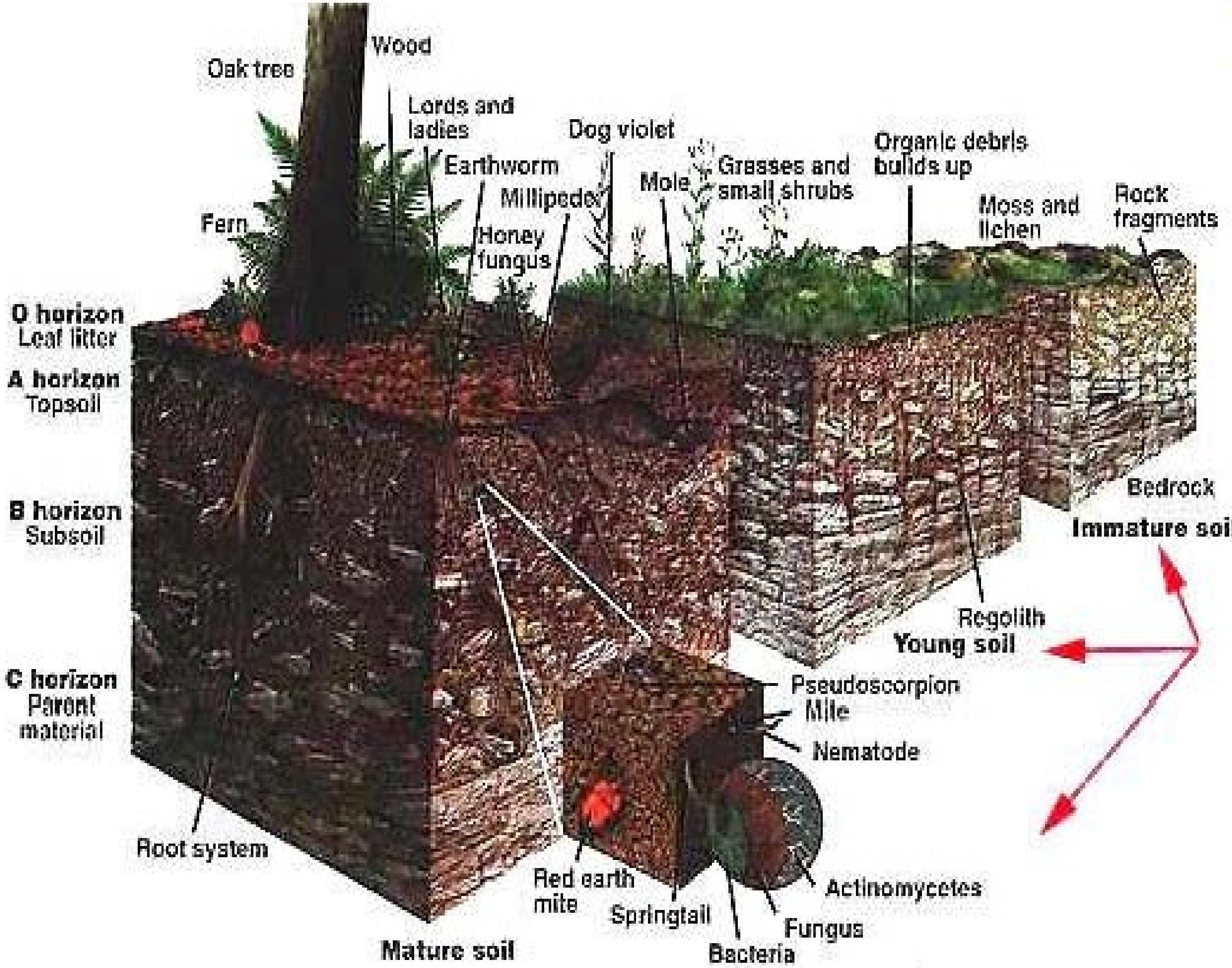
10-10-10 Fall

0-10-10 Spring

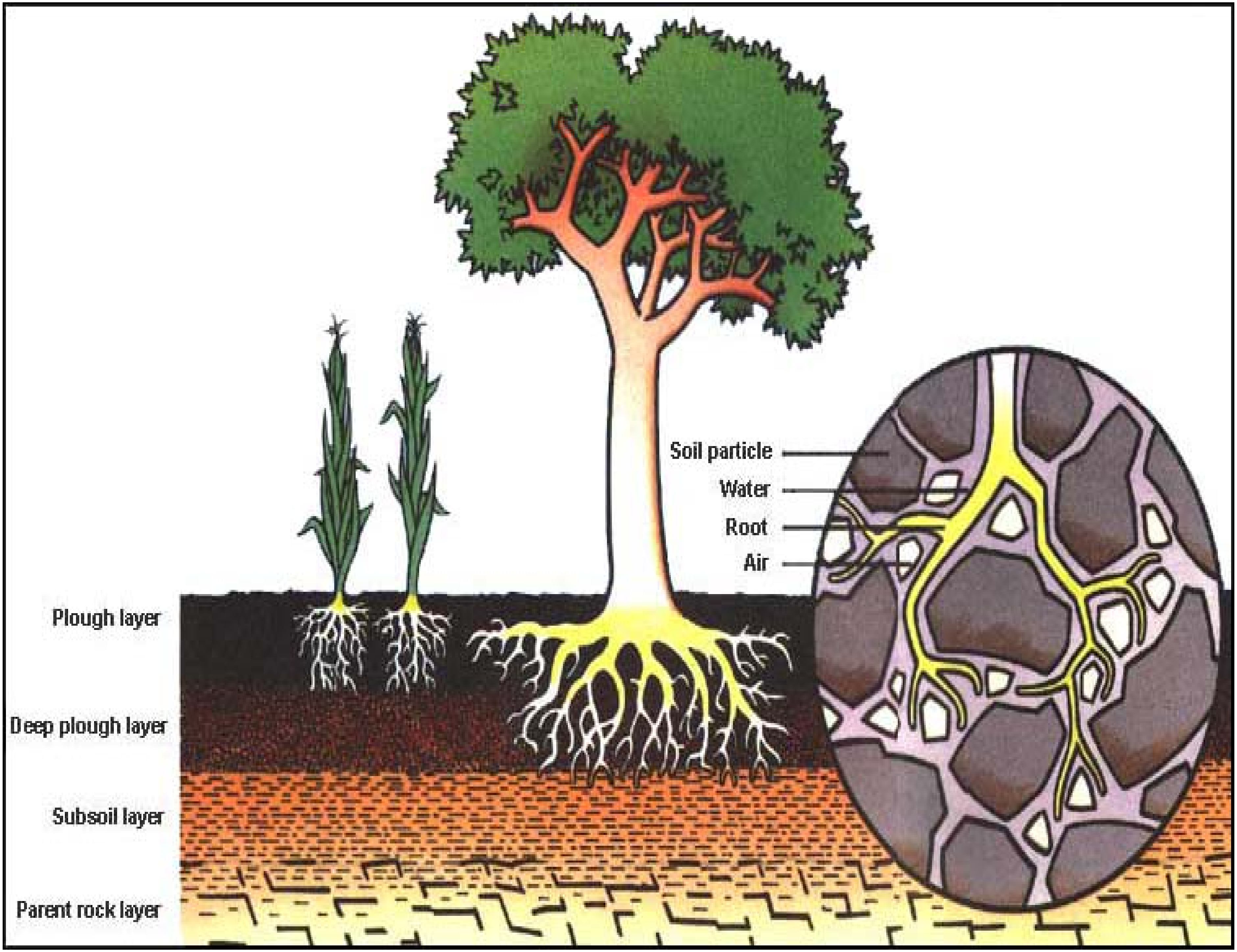
No Fertilization

10-10-10 Spring

10-10-10 Spring & Fall



Oak tree
Wood
Lords and ladies
Dog violet
Organic debris builds up
Earthworm
Mole
Grasses and small shrubs
Millipede
Moss and lichen
Rock fragments
Fern
Honey fungus
O horizon
Leaf litter
A horizon
Topsoil
B horizon
Subsoil
Bedrock
Immature soil
Regolith
Young soil
C horizon
Parent material
Pseudoscorpion
Mite
Nematode
Root system
Red earth mite
Springtail
Actinomycetes
Fungus
Bacteria
Mature soil



Soil particle
Water
Root
Air
Plough layer
Deep plough layer
Subsoil layer
Parent rock layer

Soil and Tree Fact 1

Trees take up moisture and soluble nutrients through their roots and those roots must continue to grow in order to continue functioning.

Soil and Tree Fact 2

In order to grow and function, roots must have a good supply of oxygen (for respiration) in balance with water.

Soil and Tree Fact 3

Tree roots grow in soil. Soil conditions must be appropriate for healthy root growth all year long or roots will fail.

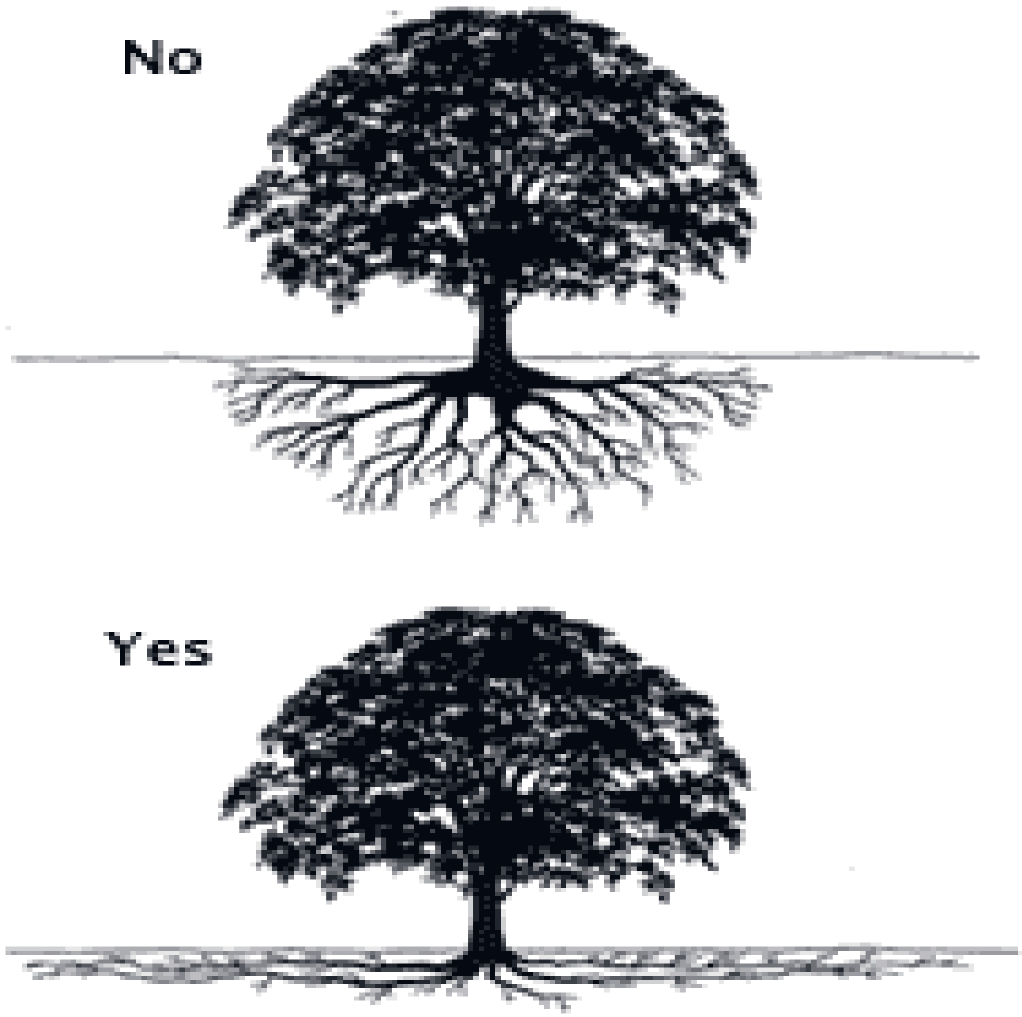
Soil and Tree Fact 4

In natural settings, tree roots are part of a community of decaying organic matter, micro-organisms and larger organisms that, together, provide enough nutrition for all.

Soil and Tree Fact 5

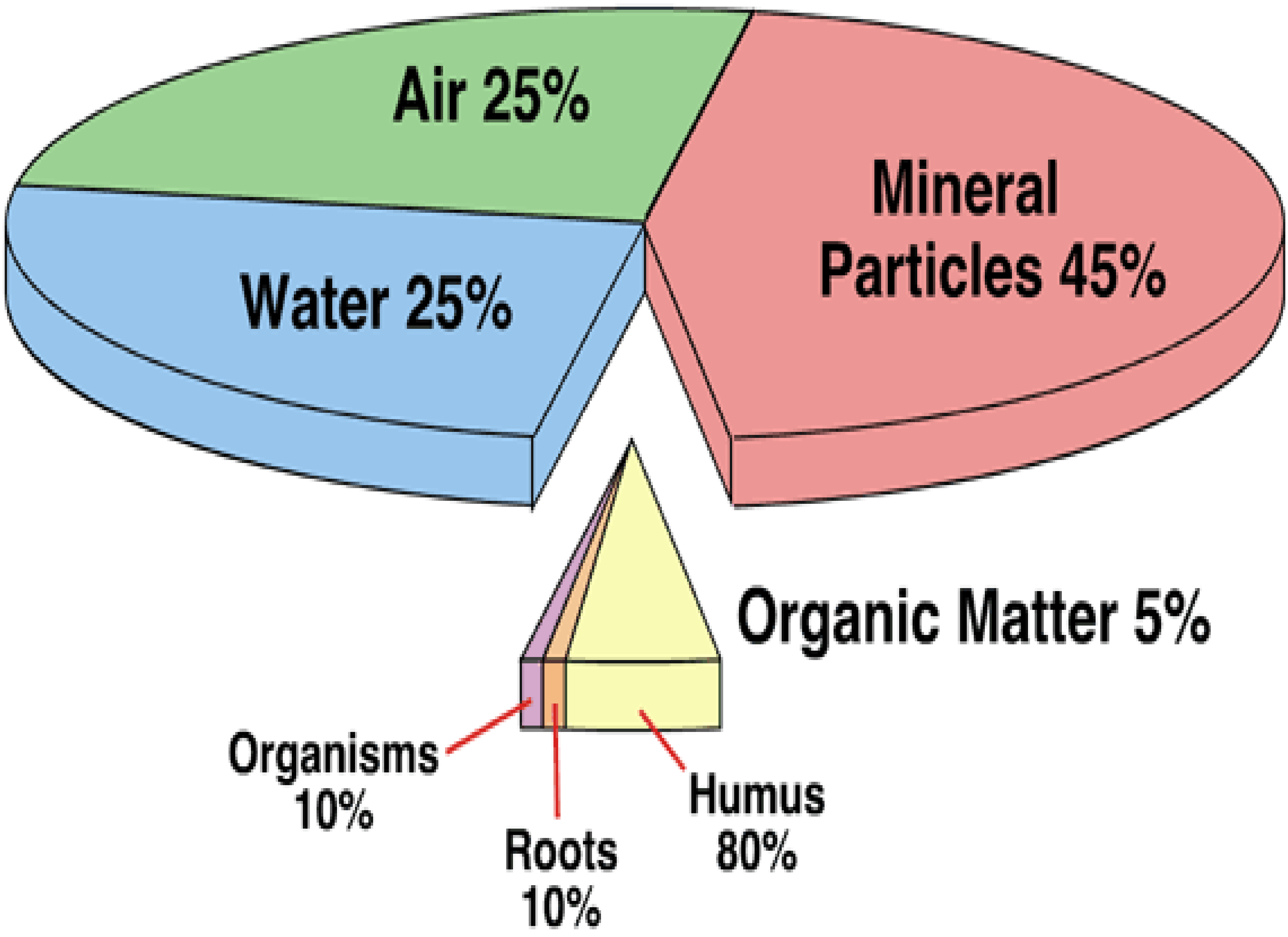
In most landscape settings, the value of the community of organisms is diminished. Care must be taken to create an environment that, at least, mimics some of the aspects of natural settings.

How a Tree Grows

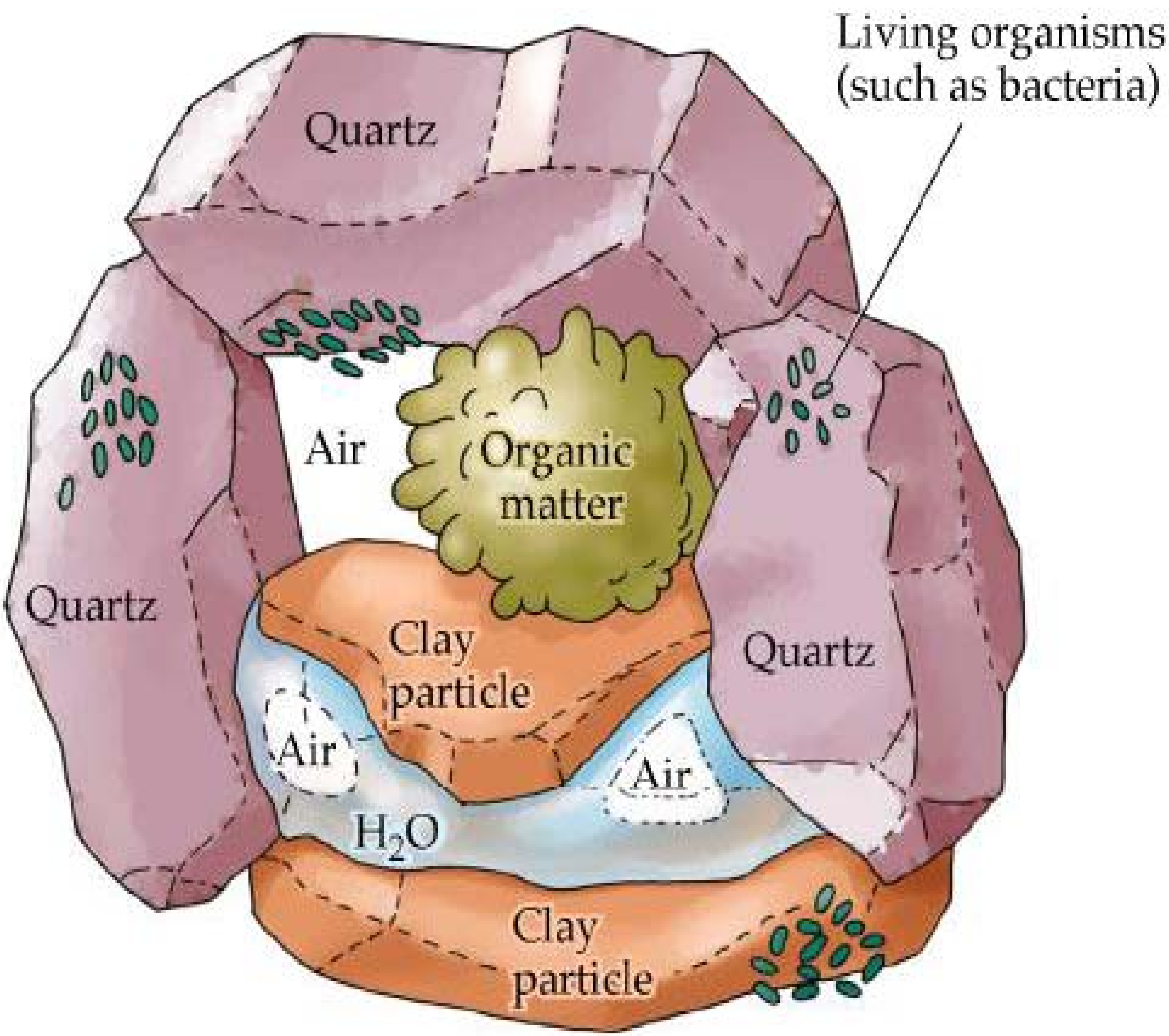


Soil

Soil is a dynamic, natural system synthesized in profile form at the earth's surface from a variable mixture of weathered minerals and decaying organic matter, under the influence of climatic and topographic conditions and living organisms; which supplies, when containing the proper amounts of air and water, mechanical support and, in part, sustenance for plants.



Air 25%
Mineral Particles 45%
Water 25%
Organic Matter 5%
Organisms 10%
Roots 10%
Humus 80%

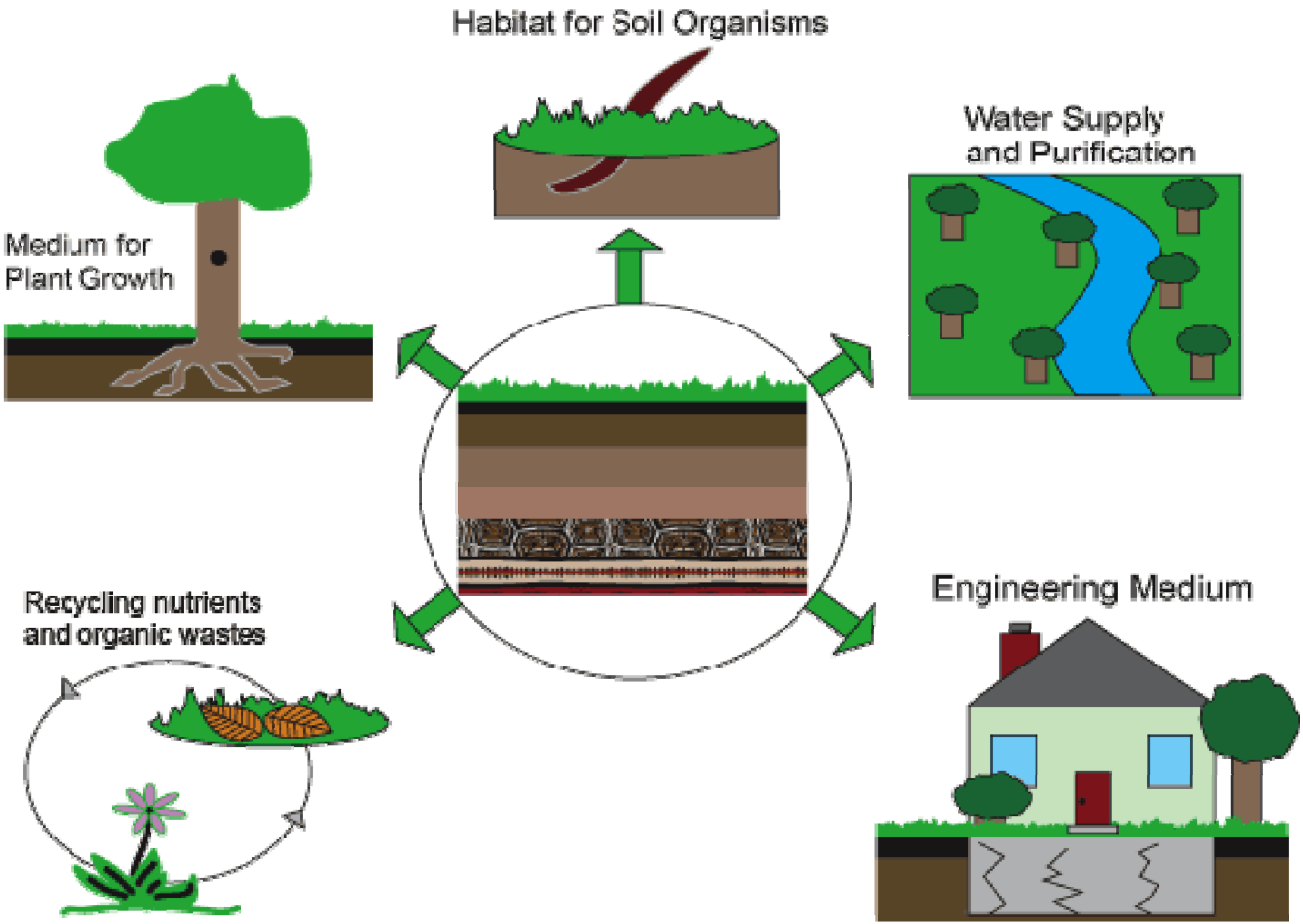


Living organisms
(such as bacteria)
Quartz
Quartz
Quartz
Air
Organic
matter
Clay
particle
Air
Air
H_2O
Clay
particle

Other soil uses

- Storehouse of water
- Structural base for houses and other buildings and roads
- Habitat for soil organisms
- Recycling nutrients and organic matter

The Five Functions of Soil

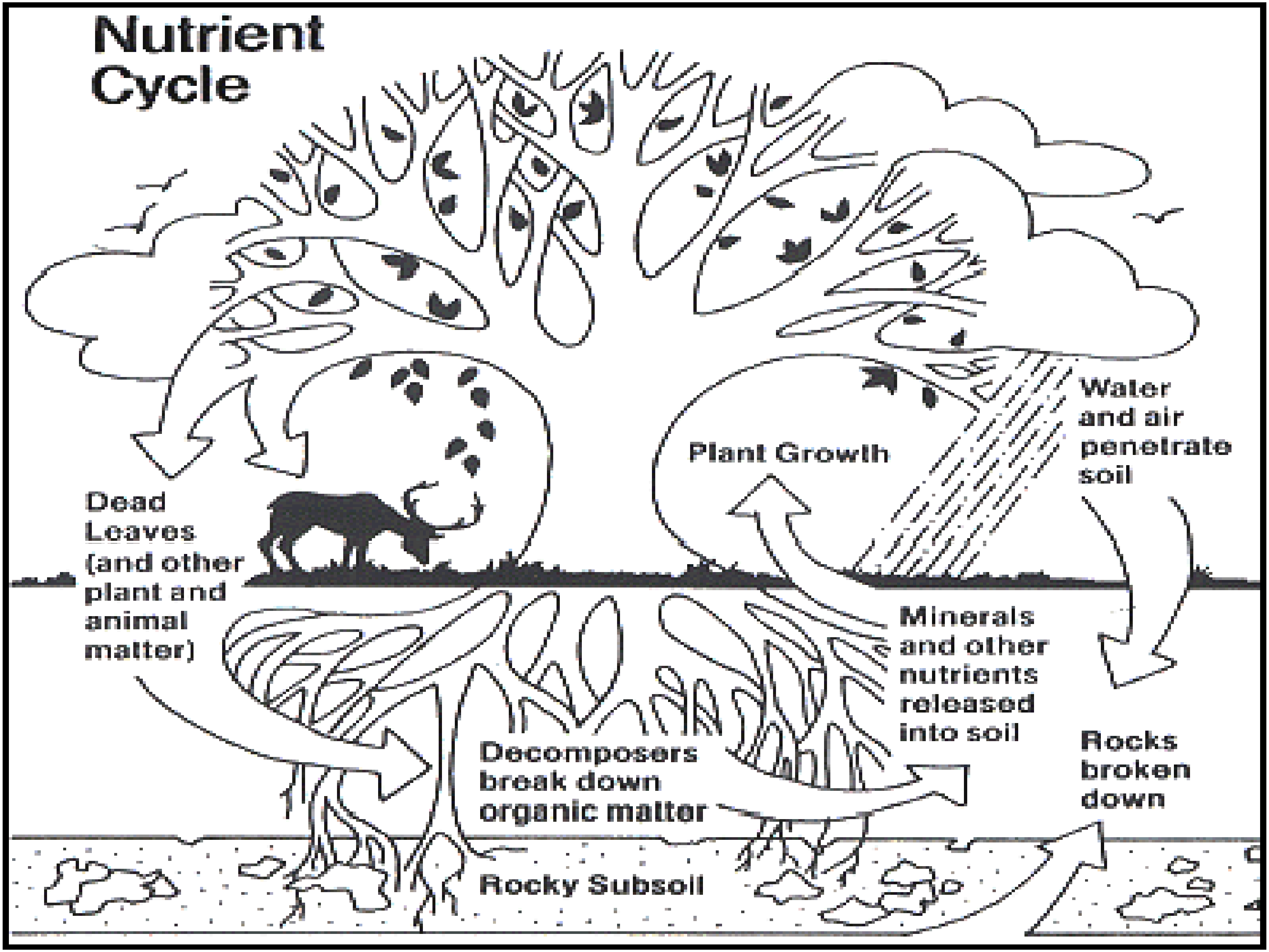


Rhizosphere

The zone of intense biological activity near actively growing roots. As roots grow through soil, root caps and external layers of cells fall off and organic compounds are released from the root tissue. This is a continuous source of organic matter that is food for microorganisms. Most important moisture and nutrient uptake activities by roots take place in the rhizosphere.

Nutrient Cycling

As a tree grows, roots absorb nutrient minerals from the soil solution and produce new woody material and leaves. As seasons pass, plants or plant parts die and fall to the soil surface where they weather and are gradually decomposed by soil organisms, releasing nutrients into the soil, available for root uptake again. This is how plants survive in natural settings, not in landscapes.



Nutrient Cycle
Water and air penetrate soil
Plant Growth
Dead Leaves (and other plant and animal matter)
Minerals and other nutrients released into soil
Rocks broken down
Decomposers break down organic matter
Rocky Subsoil

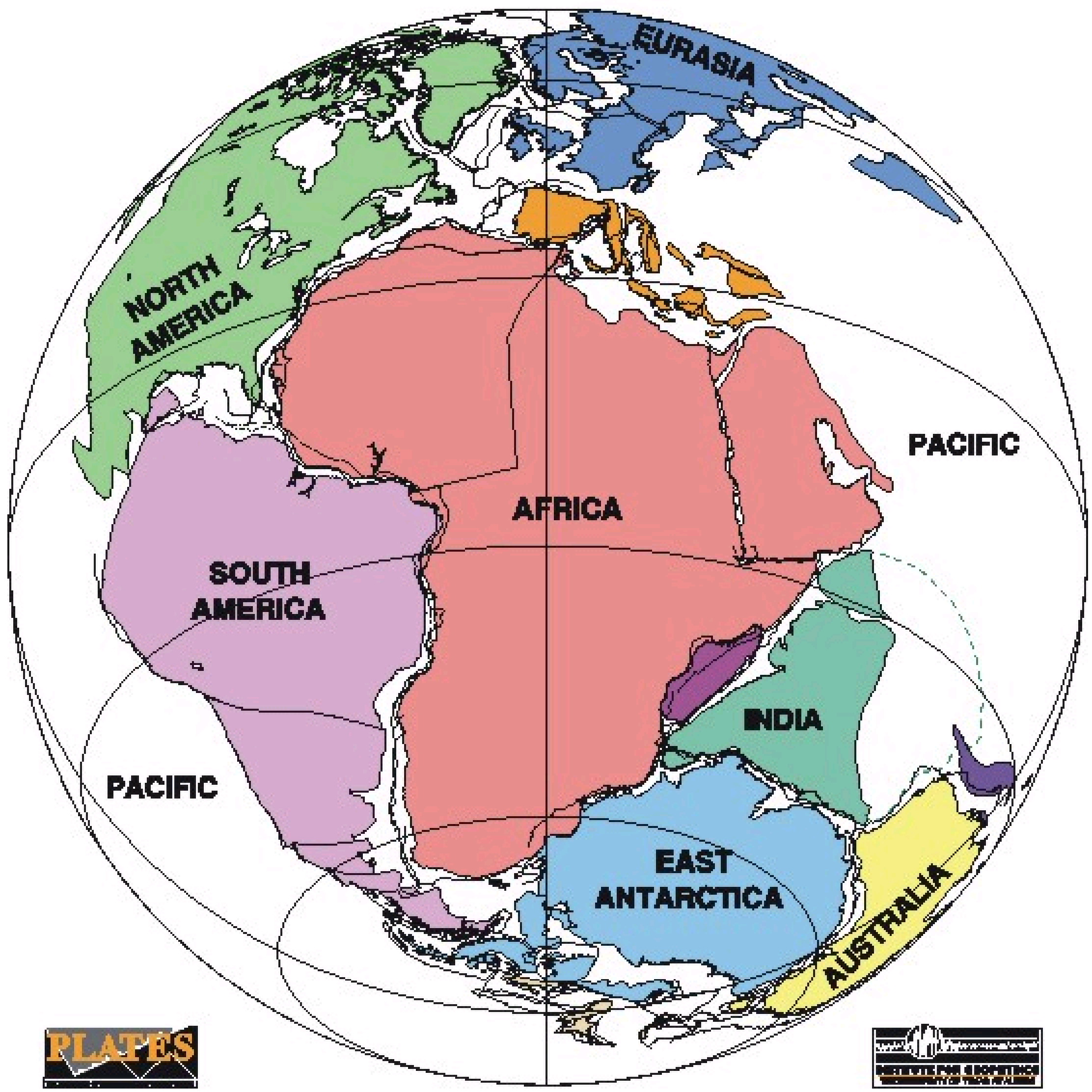
Practical tree/soil health care

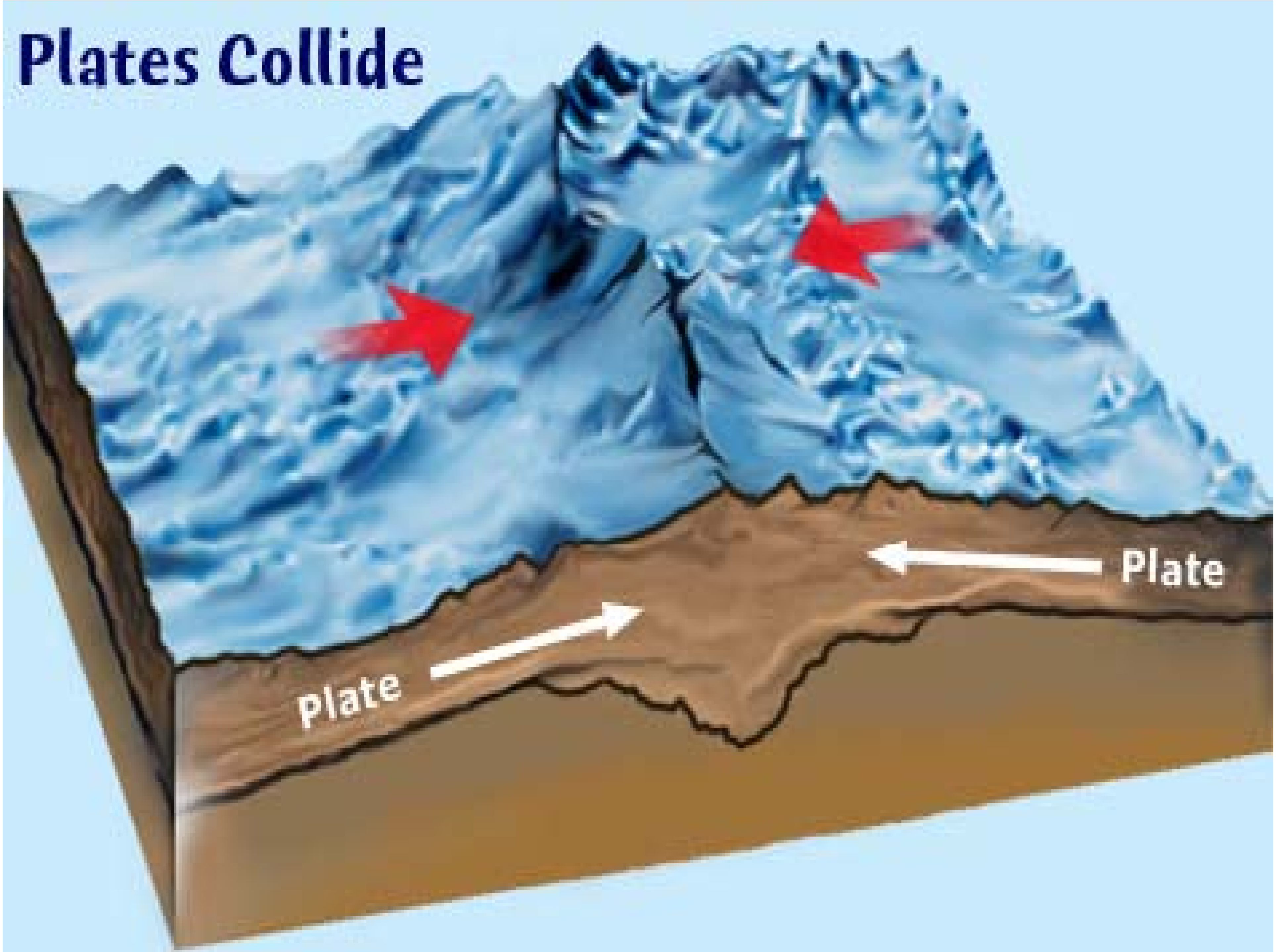
- Develop and carry out methods that optimize healthy root environments
- Duplicate nutrient cycling whenever possible
- Understand that healthy soils can provide most of tree’s nutrition without fertilization
- Understand how soil affects water and air availability

Soil Science

- Physical characteristics
- Chemical characteristics
- Biological characteristics

PANGEA


EURASIA
NORTH AMERICA
AFRICA
PACIFIC
SOUTH AMERICA
INDIA
PACIFIC
EAST ANTARCTICA
AUSTRALIA

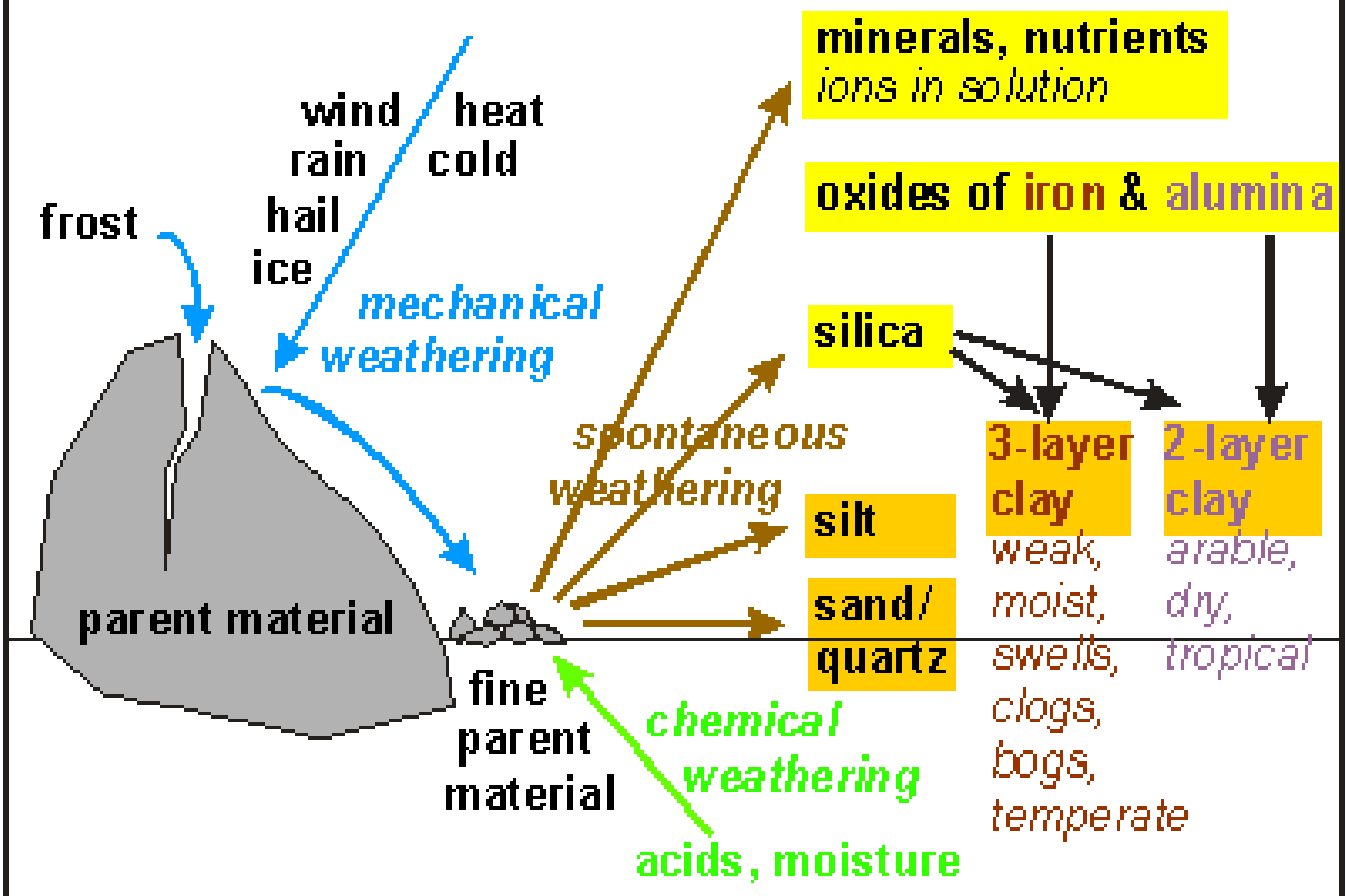

Plates Collide
Plate
Plate

Mineral soils are formed by weathering of rocks

Physical weathering
- water (erosion)
- freezing/thawing
- wind
- vegetation

Chemical weathering
- oxidation/reduction
- hydration/hydrolysis
- solubility
- carbonation

How is soil made? - weathering

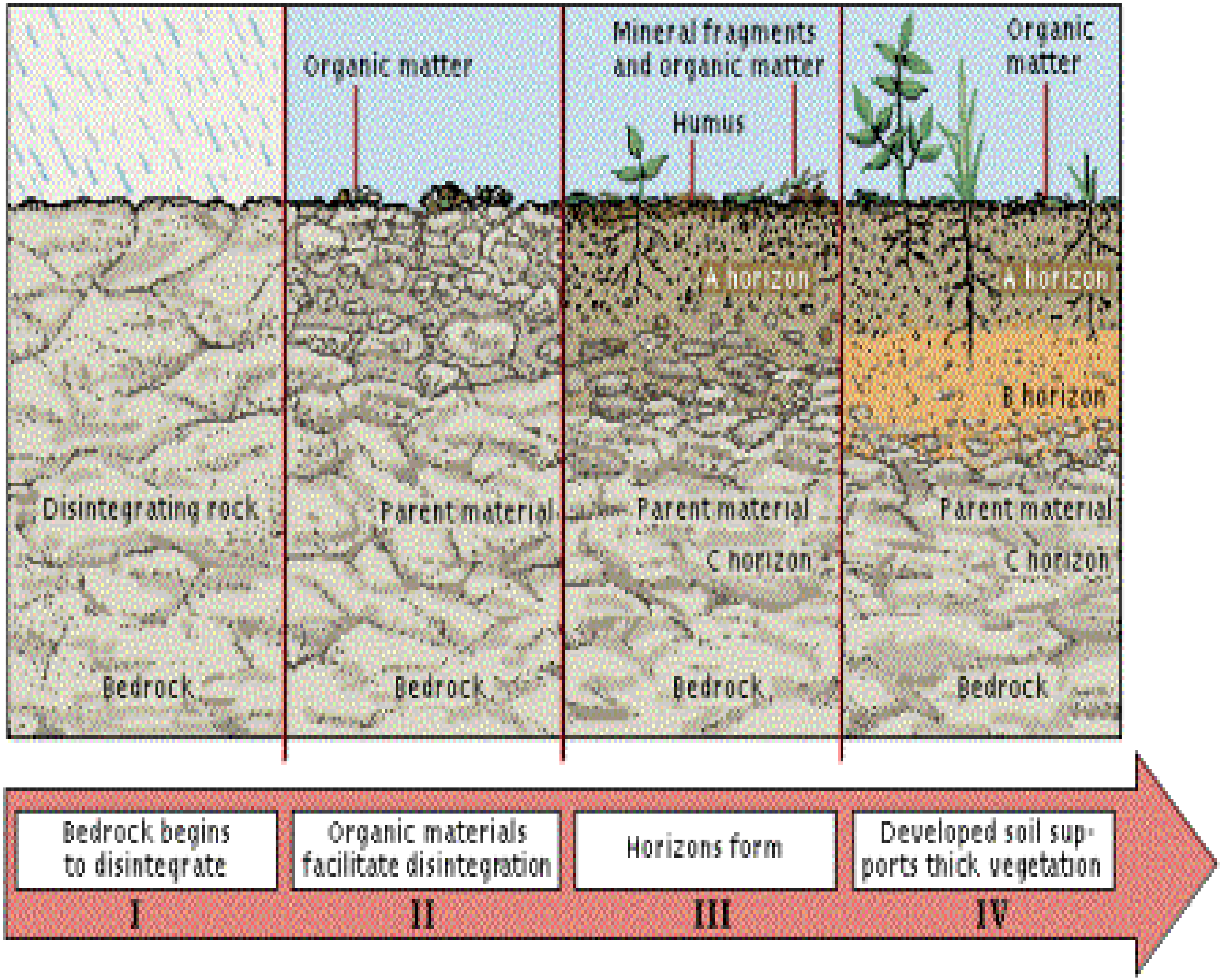


Parent material

- Rocks that are the source of the mineral portion of soil
- Weather at different rates
- Bedrock beneath soil is often the parent material (though not always, thanks to glaciers)
- Sedimentary (sandstone, shale); igneus (basalt); metamorphic (marble, granite, quartz)

Soil and rock are interchangeable

- Over millions of years, rock becomes soil and soil becomes rock again
- Same total amount since earth was formed
- Continental drift
- Most CT soils are where they are because of glacial activity

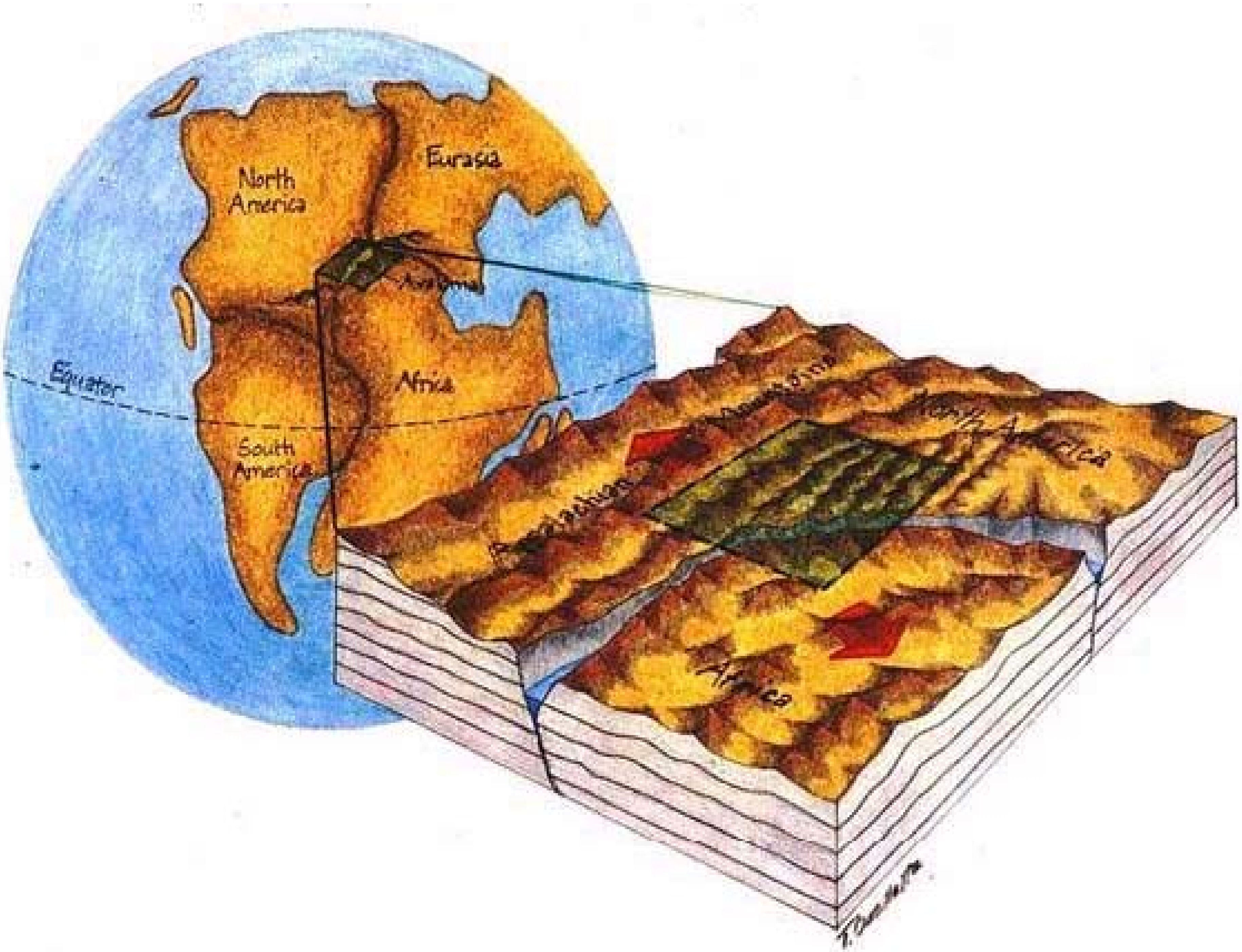

Organic matter
Mineral fragments and organic matter
Humus
Organic matter
A horizon
A horizon
B horizon
Disintegrating rock
Parent material
Parent material
Parent material
C horizon
C horizon
Bedrock
Bedrock
Bedrock
Bedrock
Bedrock begins to disintegrate
I
Organic materials facilitate disintegration
II
Horizons form
III
Developed soil supports thick vegetation
IV

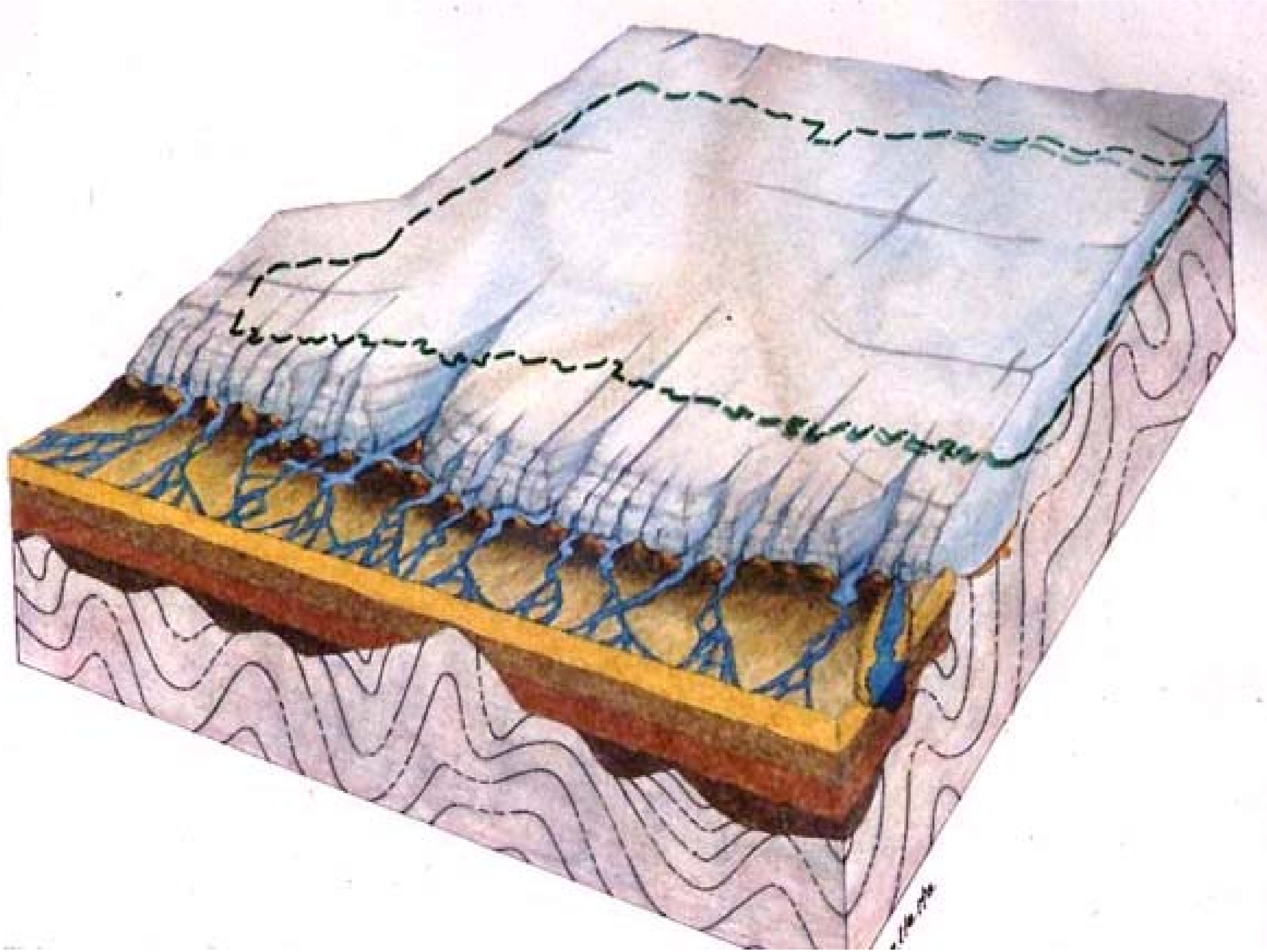
Soil weathering influences

- Climate
- Vegetation
- Parent material

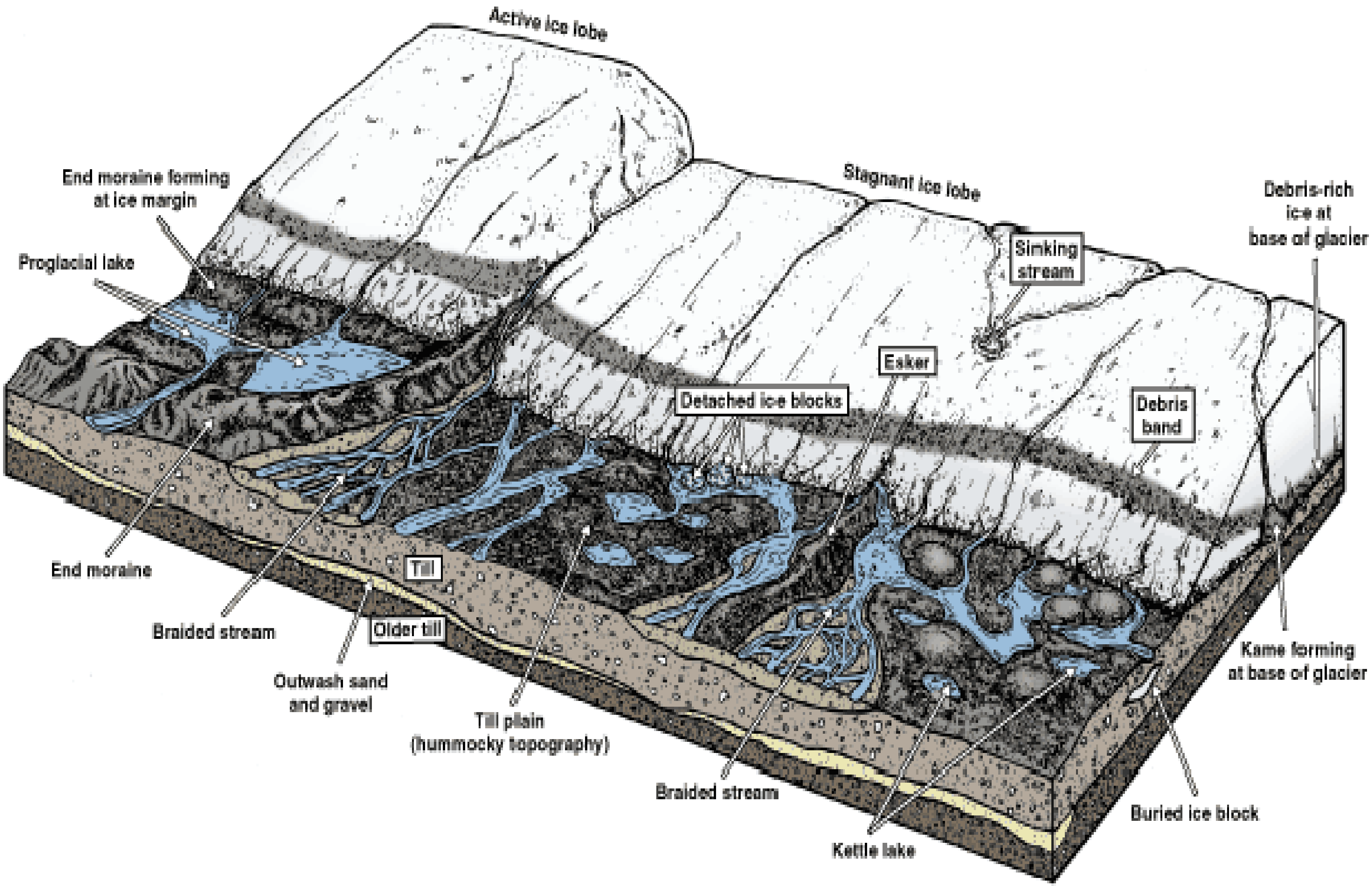
How glaciers moved soil

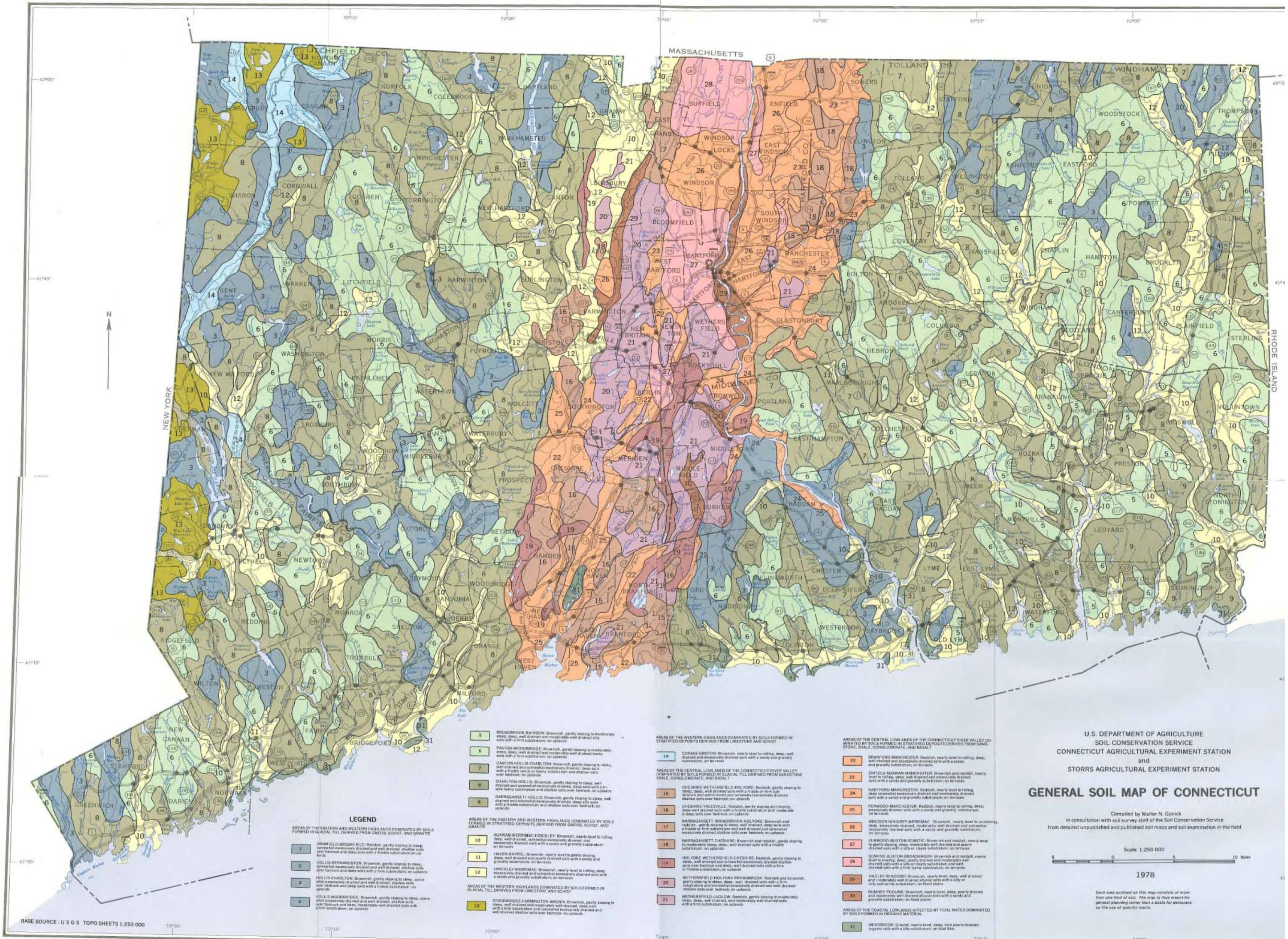
- Glacial till – mixed/plowed up, left in profile
- Stratified drift/glacial outwash – caught in flow/meltdown
- Alluvial – carried in water, left behind when dried
- Organic deposits – bogs, mucks


North
America
Eurasia
Equator
Africa
South
America
North America
Africa



Continental Glacier



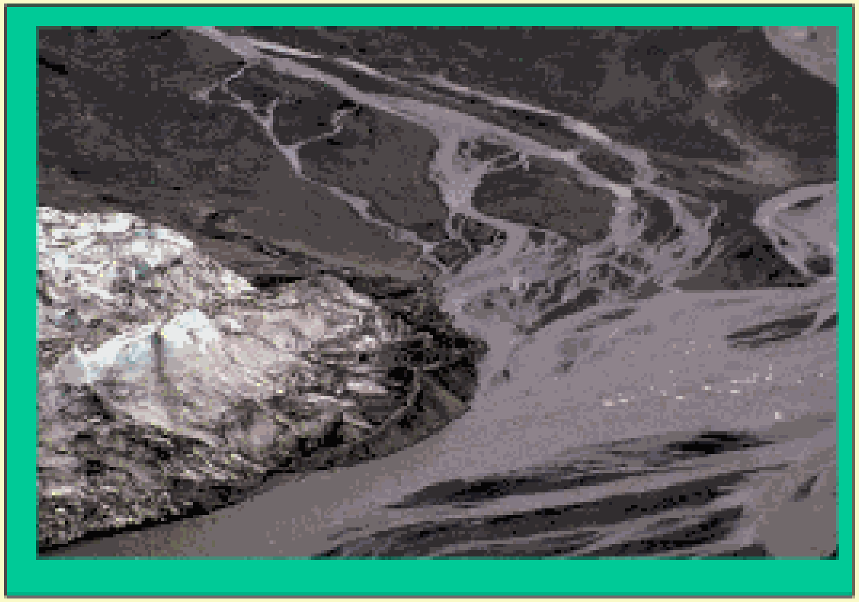

MASSACHUSETTS
NEW YORK
RHODE ISLAND
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
CONNECTICUT AGRICULTURAL EXPERIMENT STATION
and
STORRS AGRICULTURAL EXPERIMENT STATION
GENERAL SOIL MAP OF CONNECTICUT
Compiled by Walter N. Gonick
in consultation with soil survey staff of the Soil Conservation Service
from detailed unpublished and published soil maps and soil examination in the field
Scale: 1:250 000
5 0 5 10 Miles
1978
Each area outlined on this map consists of more than one kind of soil. The map is thus meant for general planning rather than a basis for decisions on the use of specific tracts.
LEGEND
AREAS OF THE EASTERN AND WESTERN HIGHLANDS DOMINATED BY SOILS FORMED IN GLACIAL TILL DERIVED FROM GNEISS, SCHIST, AND GRANITE
1 BRIMFIELD-BROOKFIELD: Reddish, gently sloping to steep, somewhat excessively drained and well drained, shallow soils over bedrock and deep soils with a friable substratum; on uplands
2 HOLLIS-BERNARDSTON: Brownish, gently sloping to steep, somewhat excessively drained and well drained, shallow soils over bedrock and deep soils with a firm substratum; on uplands
3 HOLLIS-CHARLTON: Brownish, gently sloping to steep, somewhat excessively drained and well drained, shallow soils over bedrock and deep soils with a friable substratum; on uplands
4 HOLLIS-WOODBRIDGE: Brownish, gently sloping to steep, somewhat excessively drained and well drained, shallow soils over bedrock and deep, moderately well drained soils with a firm substratum; on uplands
5 BROADBROOK-RAINBOW: Brownish, gently sloping to moderately steep, deep, well drained and moderately well drained silty soils with a firm substratum; on uplands
6 PAXTON-WOODBRIDGE: Brownish, gently sloping to moderately steep, deep, well drained and moderately well drained loamy soils with a firm substratum; on uplands
7 CANTON-HOLLIS-CHARLTON: Brownish, gently sloping to steep, well drained and somewhat excessively drained, deep soils with a friable sandy or loamy substratum and shallow soils over bedrock; on uplands
8 CHARLTON-HOLLIS: Brownish, gently sloping to steep, well drained and somewhat excessively drained, deep soils with a friable loamy substratum and shallow soils over bedrock; on uplands
9 NARRAGANSETT-HOLLIS: Brownish, gently sloping to steep, well drained and somewhat excessively drained, deep silty soils with a friable substratum and shallow soils over bedrock; on uplands
AREAS OF THE EASTERN AND WESTERN HIGHLANDS DOMINATED BY SOILS FORMED IN STRATIFIED DEPOSITS DERIVED FROM GNEISS, SCHIST, AND GRANITE
10 AGAWAM-MERRIMAC-HINCKLEY: Brownish, nearly level to rolling deep, well drained, somewhat excessively drained, and excessively drained soils with a sandy and gravelly substratum on terraces
11 HAVEN-RAYPOL: Brownish, nearly level to gently sloping, deep, well drained and poorly drained soils with a sandy and gravelly substratum; on terraces
12 HINCKLEY-MERRIMAC: Brownish, nearly level to rolling, deep excessively drained and somewhat excessively drained soils with a sandy and gravelly substratum; on terraces
AREAS OF THE WESTERN HIGHLANDS DOMINATED BY SOILS FORMED IN GLACIAL TILL DERIVED FROM LIMESTONE AND SCHIST
13 STOCKBRIDGE-FARMINGTON-AMENIA: Brownish, gently sloping to steep, well drained and moderately well drained, deep soils with a firm substratum and somewhat excessively drained and well drained shallow soils over bedrock; on uplands
AREAS OF THE WESTERN HIGHLANDS DOMINATED BY SOILS FORMED IN STRATIFIED DEPOSITS DERIVED FROM LIMESTONE AND SCHIST
14 COPAKE-GROTON: Brownish, nearly level to rolling, deep, well drained and excessively drained soils with a sandy and gravelly substratum; on terraces
AREAS OF THE CENTRAL LOWLANDS OF THE CONNECTICUT RIVER VALLEY DOMINATED BY SOILS FORMED IN GLACIAL TILL DERIVED FROM SANDSTONE SHALE, CONGLOMERATE, AND BASALT
15 CHESHIRE-WETHERSFIELD-HOLYOKE: Reddish, gently sloping to steep, deep, well drained soils with a friable or firm substratum and well drained and somewhat excessively drained shallow soils over bedrock; on uplands
16 CHESHIRE-YALESVILLE: Reddish, gently sloping and sloping, deep well drained soils with a friable substratum and moderately deep soils over bedrock; on uplands
17 NARRAGANSETT-BROADBROOK-HOLYOKE: Brownish and reddish, gently sloping to steep, well drained, deep soils with a friable or firm substratum and well drained and somewhat excessively drained shallow soils over bedrock; on uplands
18 NARRAGANSETT-CHESHIRE: Brownish and reddish, gently sloping to moderately steep, deep, well drained soils with a friable substratum; on uplands
19 HOLYOKE-WETHERSFIELD-CHESHIRE: Reddish, gently sloping to steep, well drained and somewhat excessively drained shallow soils over bedrock and deep, well drained soils with a firm or friable substratum; on uplands
20 WETHERSFIELD-HOLYOKE-BROADBROOK: Reddish and brownish, gently sloping to steep, deep, well drained soils with a firm substratum and somewhat excessively drained and well drained shallow soils over bedrock; on uplands
21 WETHERSFIELD-LUDLOW: Reddish, gently sloping to moderately steep, deep, well drained, and moderately well drained soils with a firm substratum; on uplands
AREAS OF THE CENTRAL LOWLANDS OF THE CONNECTICUT RIVER VALLEY DOMINATED BY SOILS FORMED IN STRATIFIED DEPOSITS DERIVED FROM SANDSTONE, SHALE, CONGLOMERATE, AND BASALT
22 BRANFORD-MANCHESTER: Reddish, nearly level to rolling, deep, well drained and excessively drained soils with a sandy and gravelly substratum; on terraces
23 ENFIELD-AGAWAM-MANCHESTER: Brownish and reddish, nearly level to rolling, deep, well drained and excessively drained soils with a sandy and gravelly substratum; on terraces
24 HARTFORD-MANCHESTER: Reddish, nearly level to rolling, deep somewhat excessively drained and excessively drained soils with a sandy and gravelly substratum; on terraces
25 PENWOOD-MANCHESTER: Reddish, nearly level to rolling, deep, excessively drained soils with a sandy and gravelly substratum; on terraces
26 WINDSOR-NINIGRET-MERRIMAC: Brownish, nearly level to undulating, deep, excessively drained, moderately well drained and somewhat excessively drained soils with a sandy and gravelly substratum; on terraces
27 ELMWOOD-BUXTON-SCANTIC: Brownish and reddish, nearly level to gently sloping, deep, moderately well drained and poorly drained soils with a silty or clayey substratum; on terraces
28 SCANTIC-BUXTON-BROADBROOK: Brownish and reddish, nearly level to sloping, deep, poorly drained and moderately well drained soils with a silty or clayey substratum and well drained soils with a firm loamy substratum; on terraces
29 HADLEY-WINOOSKI: Brownish, nearly level, deep, well drained and moderately well drained alluvial soils with a silty or silty and sandy substratum; on flood plains
30 RUMNEY-PODUNK: Brownish, nearly level, deep, poorly drained and moderately well drained alluvial soils with a sandy and gravelly substratum; on flood plains
AREAS OF THE COASTAL LOWLANDS AFFECTED BY TIDAL WATER DOMINATED BY SOILS FORMED IN ORGANIC MATERIAL
31 WESTBROOK: Grayish, nearly level, deep, very poorly drained organic soils with a silty substratum; on tidal flats
BASE SOURCE: U S G S TOPO SHEETS 1:250 000

Glacial Till

- Unsorted/stratified material deposited beneath and within glacial ice.
- Heterogeneous mixture of all particle sizes (boulder to clay).
- Oldest surficial deposit.

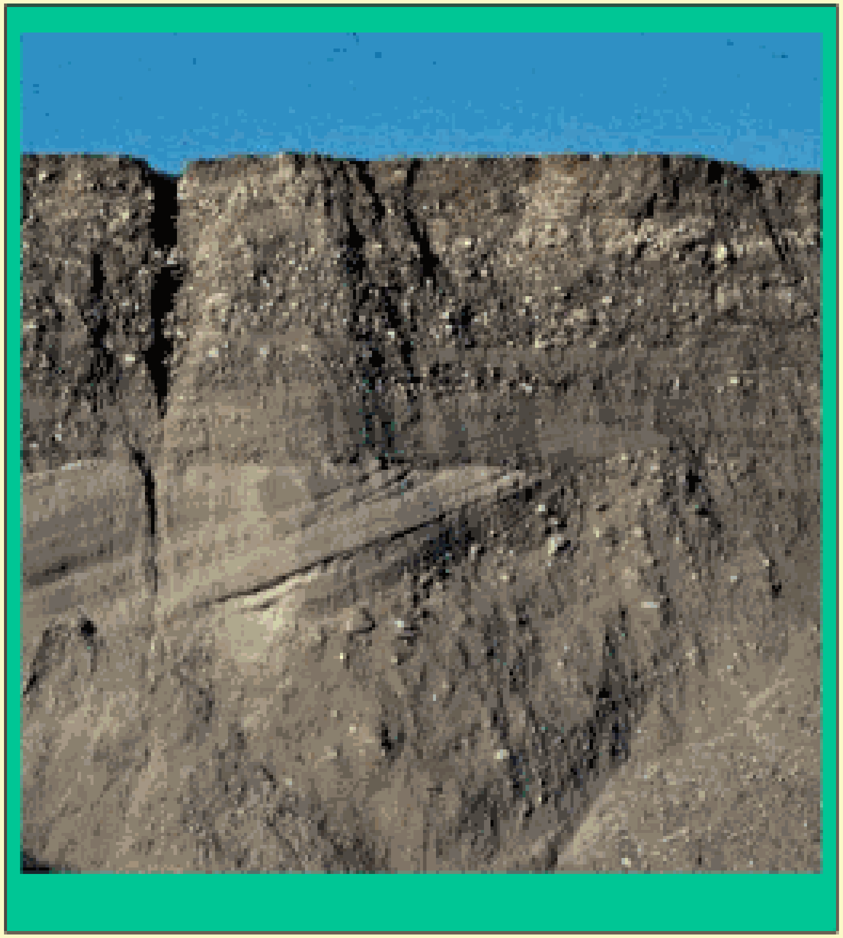
Glacial Fluvial (Outwash)

- Sediments deposited by glacial meltwater.
- Stratified layers of sand, gravel, and fines.
- Types: Proglacial and Proximal (ice contact).
- Landforms: Plains, eskers, kames, deltas.



Outwash Properties

- Dominantly sand and gravel sized particles.
- Rapid water movement, associated with aquifers.
- Apparent watertable.
- Few limitations for most uses.

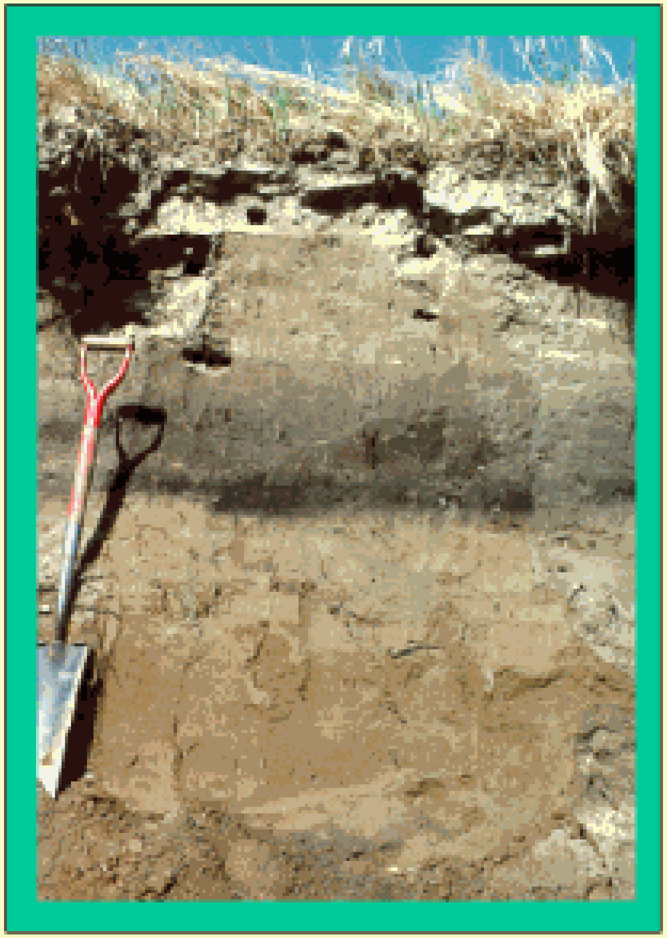


Post-Glacial Deposits

- Material deposited after glacier left (Holocene-10K BP).
- Eolian - wind deposited sand to silt sized particles.
- Most upland soils in NE have a thin 18-36 inch eolian cap. Deposited rapidly after ice left.

Post-Glacial Deposits

- Organic deposits - swamps, bogs, marshes.
- Alluvial deposits - modern day floodplains.
- Anthro-transported material.

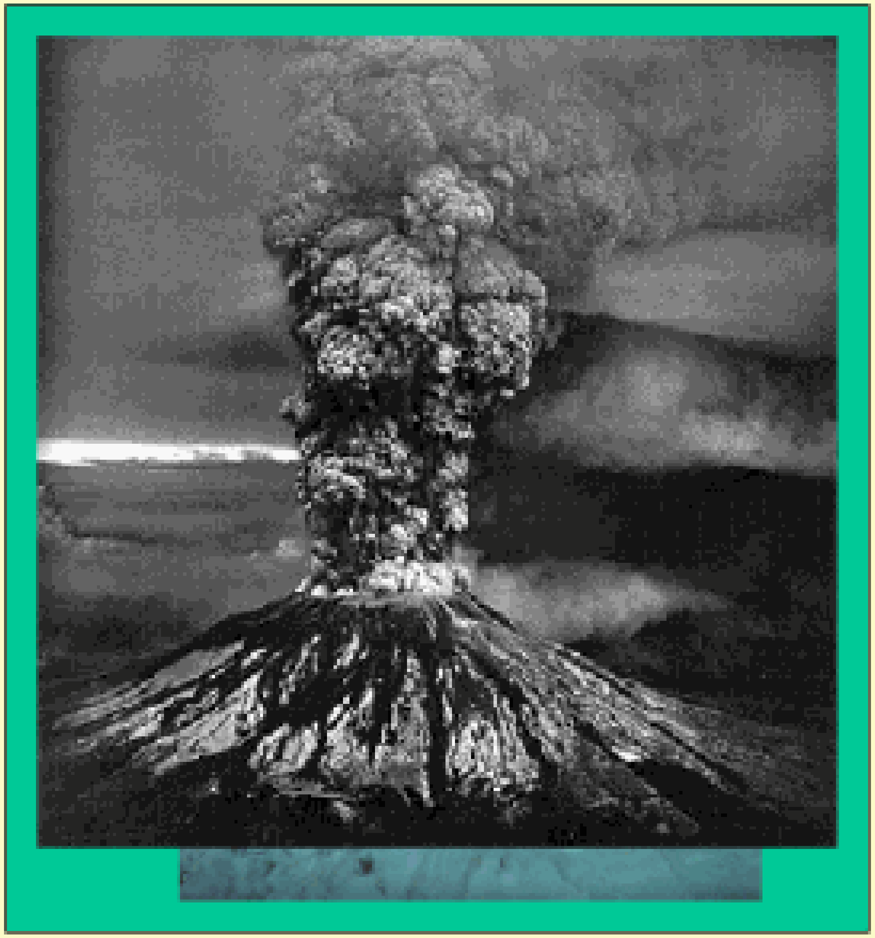


Parent Material

Geologic Material Soil Formed From.

- Types of minerals.
- Reaction of soil.
- Soil Color.

Types of PM: Glacial, Volcanic, Organic, Loess, Colluvium,



New England Parent Materials

- Pleistocene Epoch (Ice Age) - 1.8 MYBP to 8 KYBP.
- 4 Major advances.
- Last- Wisconsinan advance covered all of NE.
- Soil parent materials - glacial & post glacial

Soil physical characteristics

- Soil is the interface between the atmosphere and the lithosphere
- Most soils in the US are at least 8000 years old
- Many soils as old as 600,000 years
- Some soils are forming as we speak
- Soil is unconsolidated rock

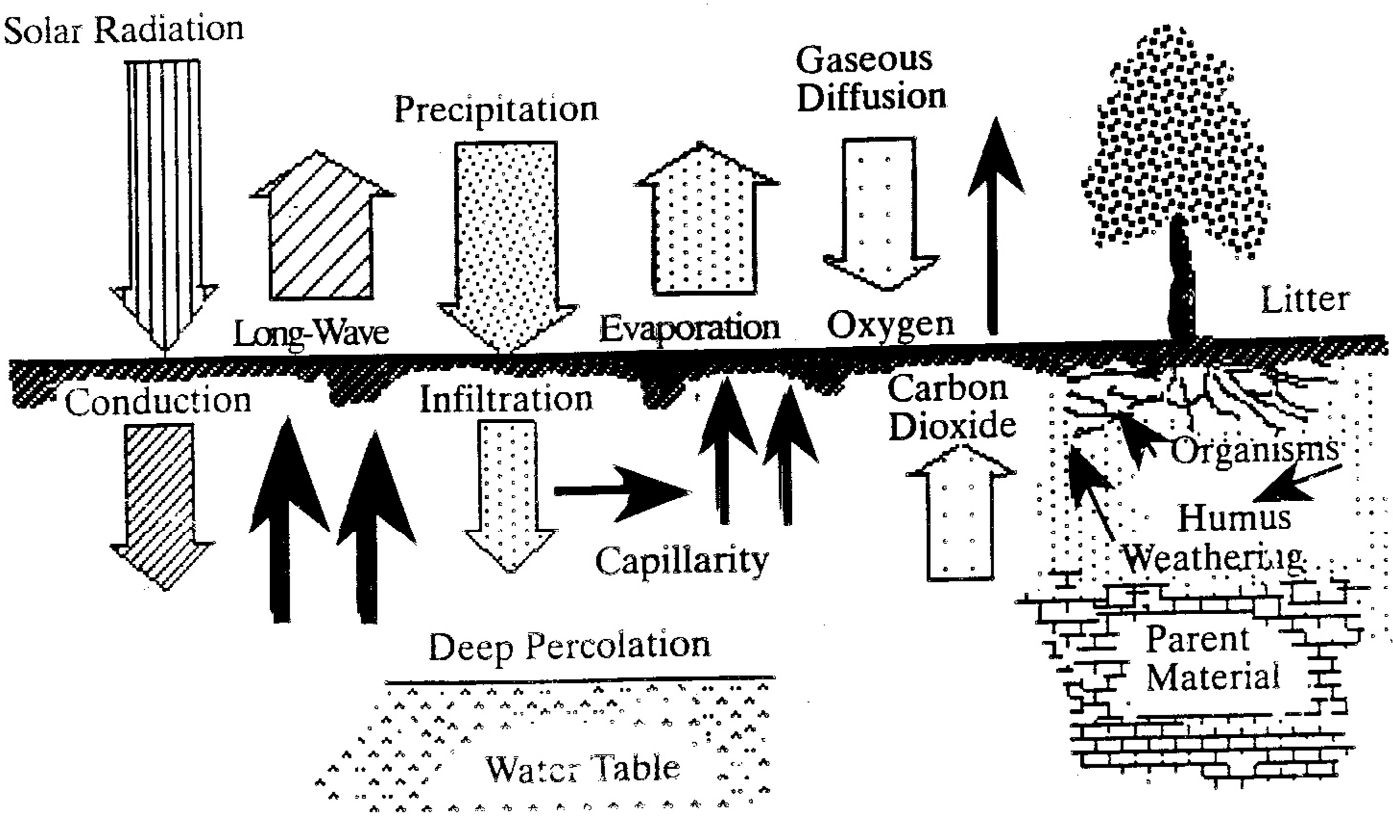
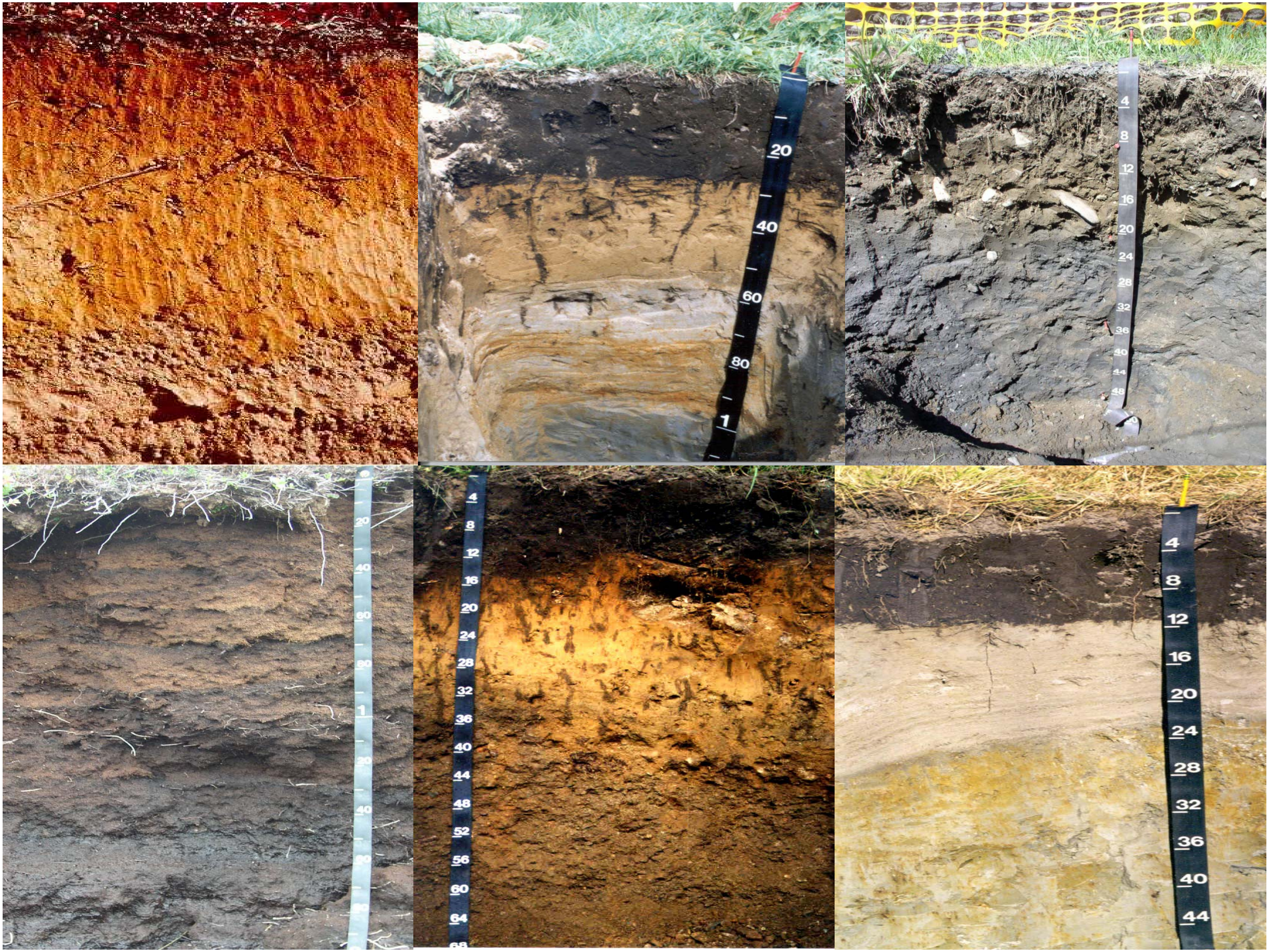
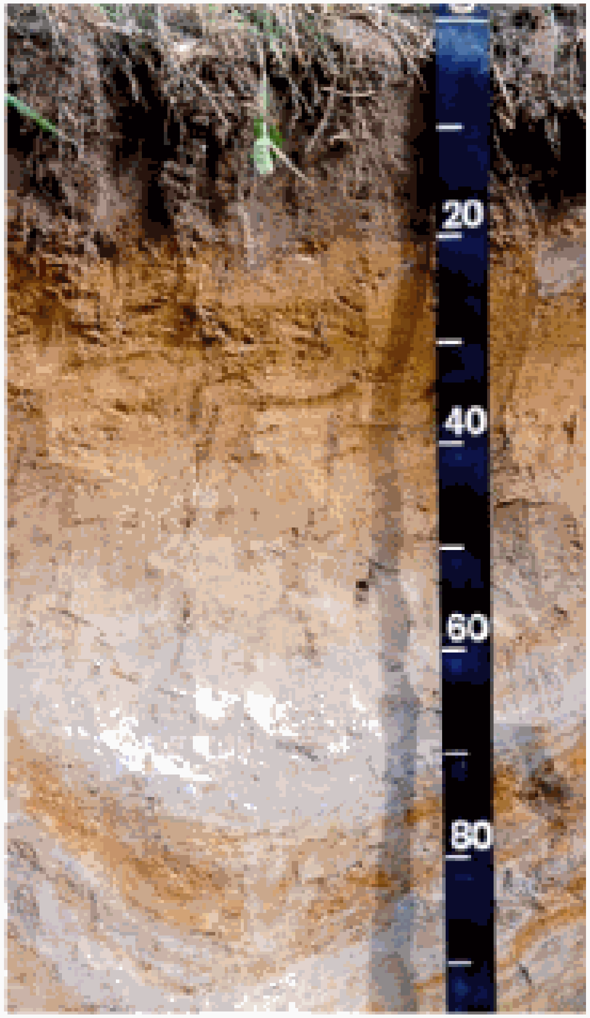


Fig. 1.1. The soil as the interface between the atmosphere and the lithosphere.


20 40 60 80 1
4 8 12 16 20 24 28 32 36 40 44 48
4 8 12 16 20 24 28 32 36 40 44 48 52 56 60 64
4 8 12 16 20 24 28 32 36 40 44

Soil Color

- Easily identified property.
- Used to relate chemical/physical properties such as watertable depth, drainage, chemical constituents, formation, horizons.



Soil Profile

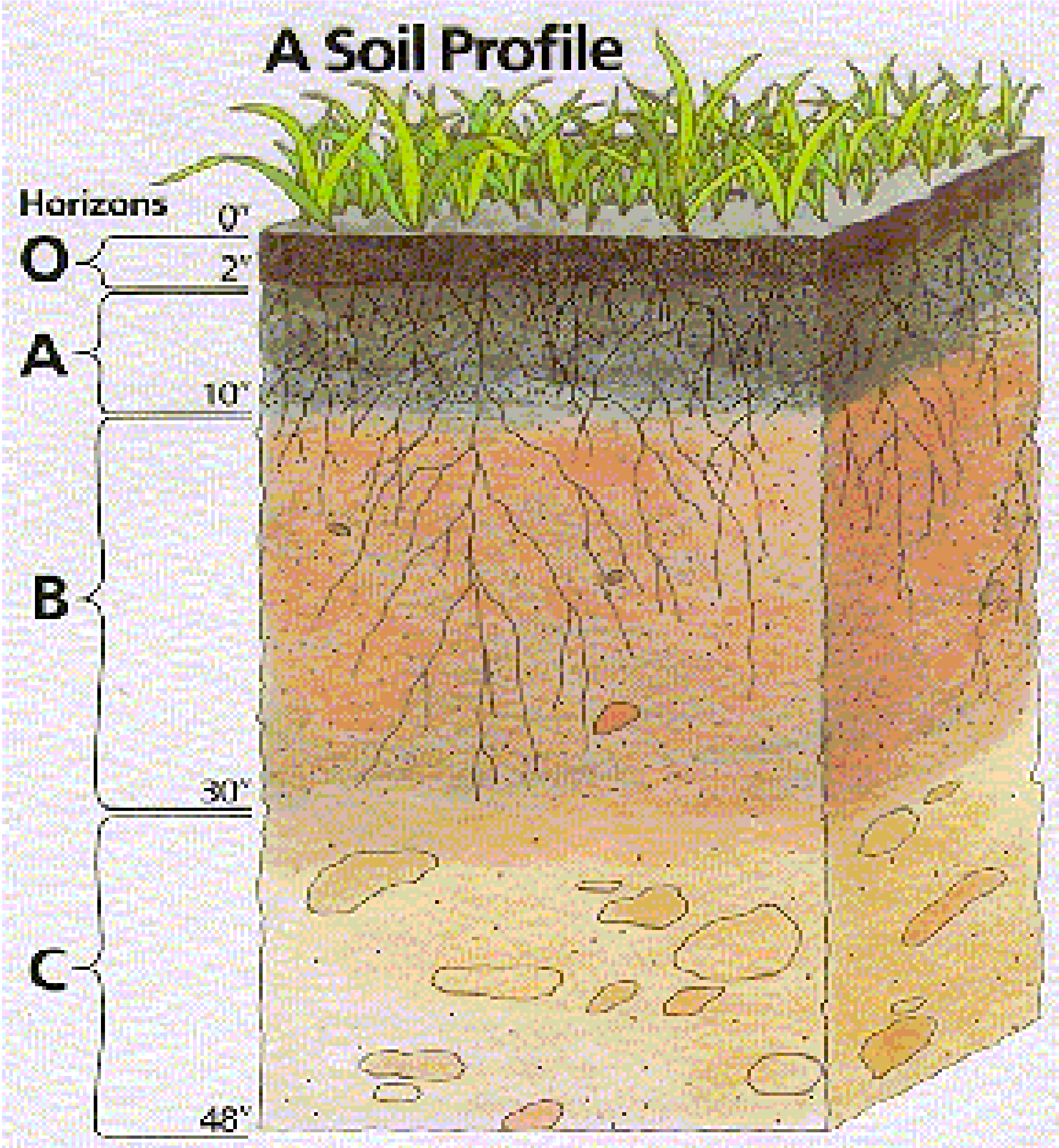
- Layers develop over time – influenced by physical, chemical, biological factors
- Horizons

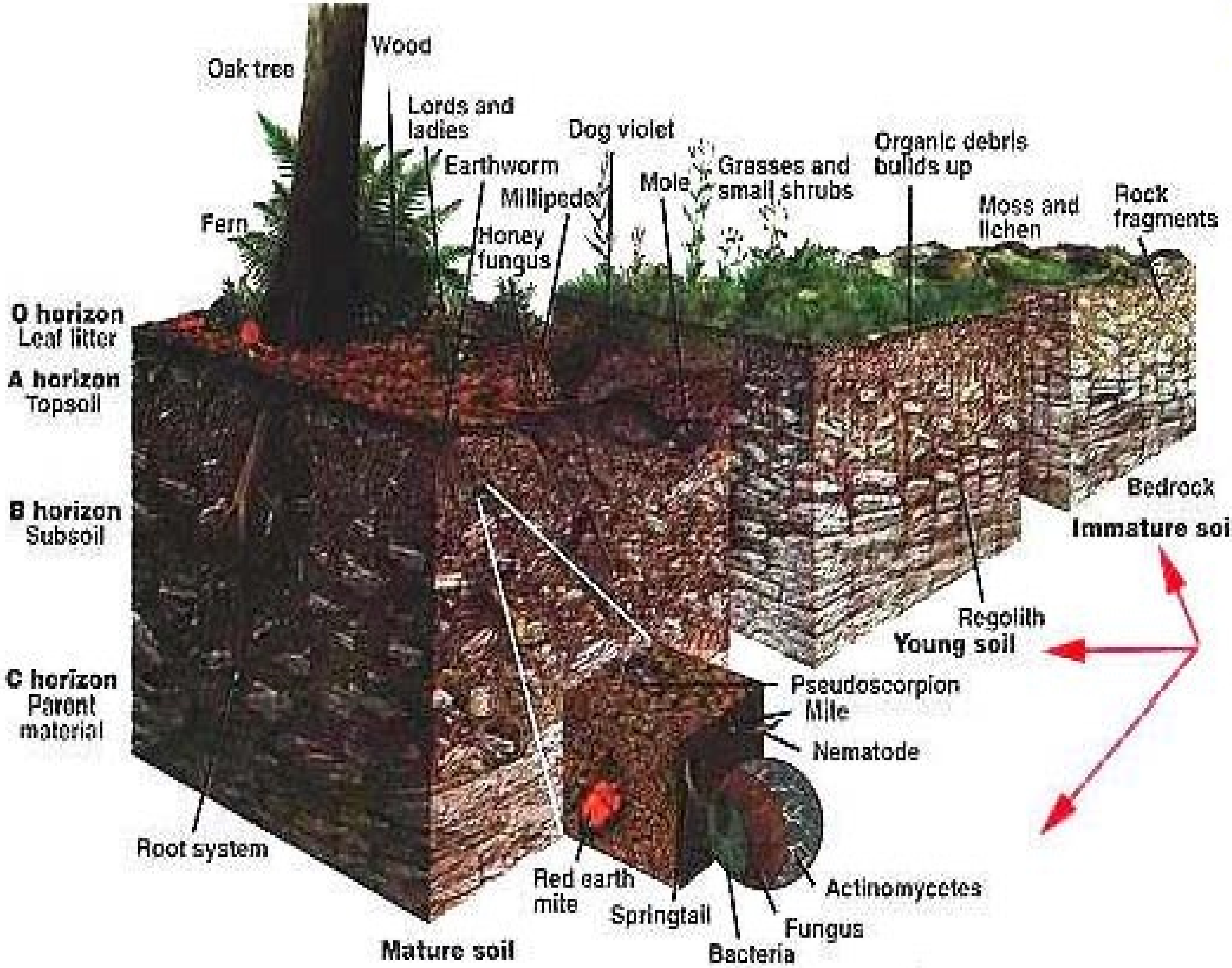
  organic layer

  A – topsoil

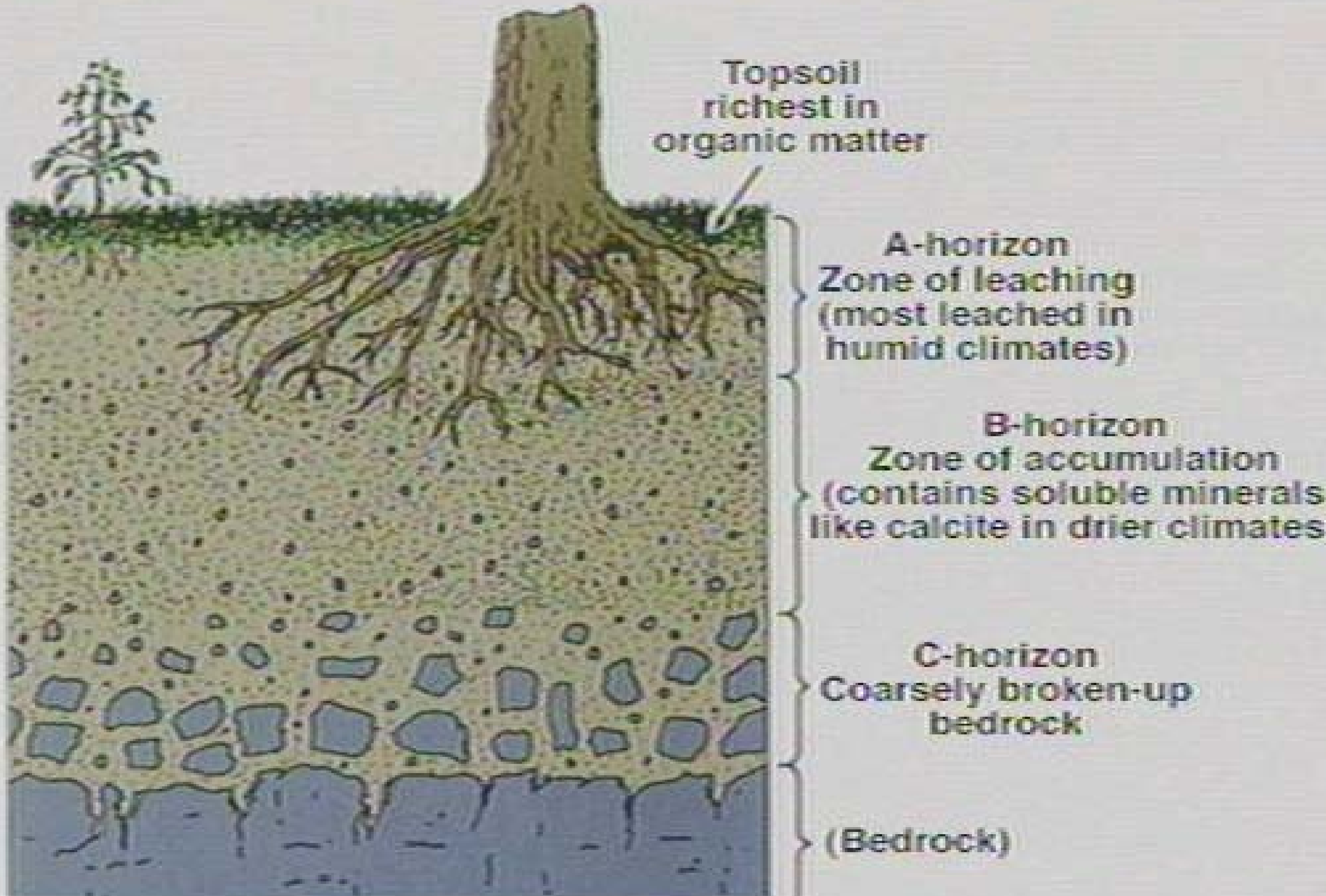
  B – subsoil

  C - subsoil

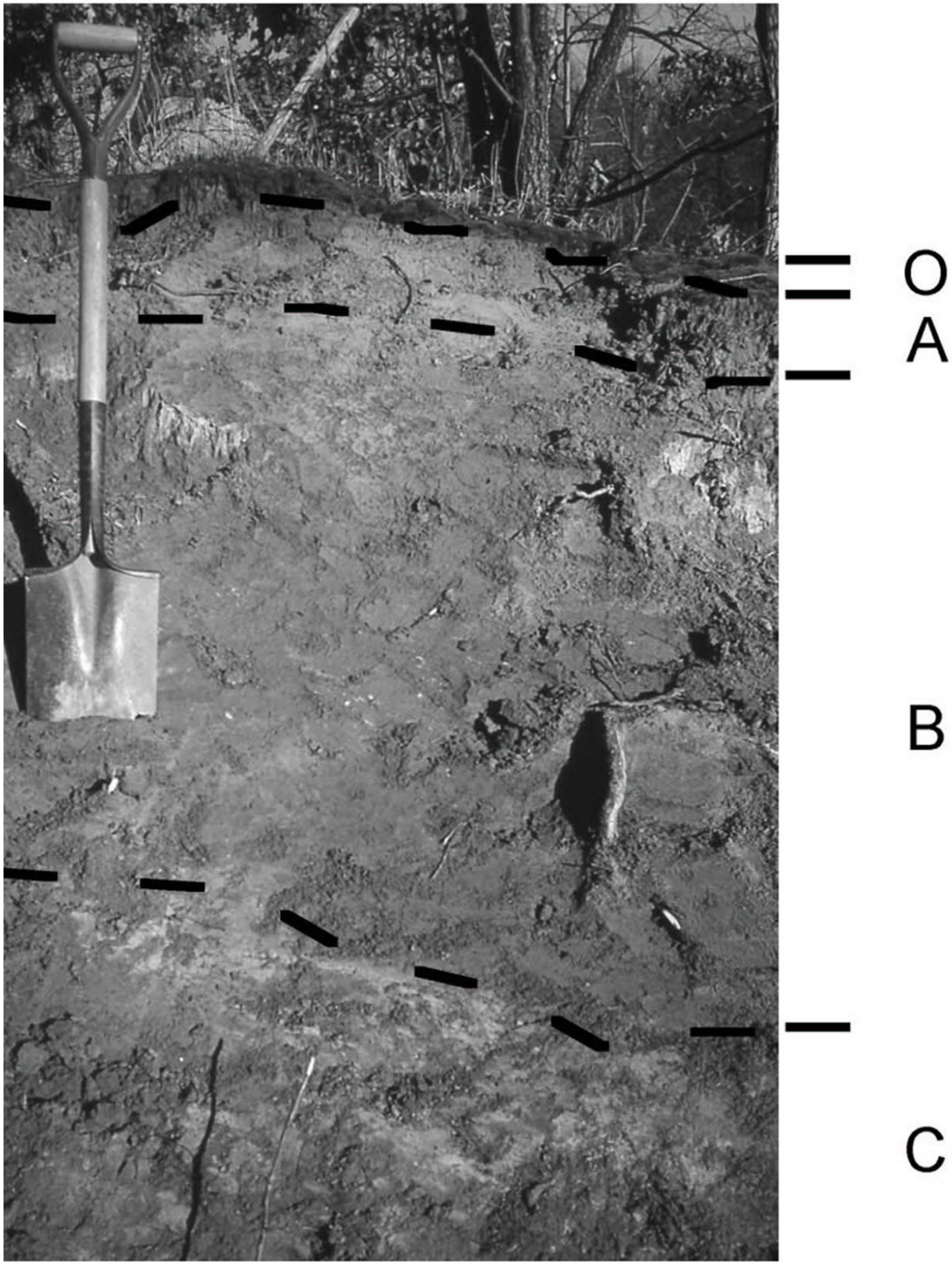

A Soil Profile
Horizons
O
A
B
C
0"
2"
10"
30"
48"



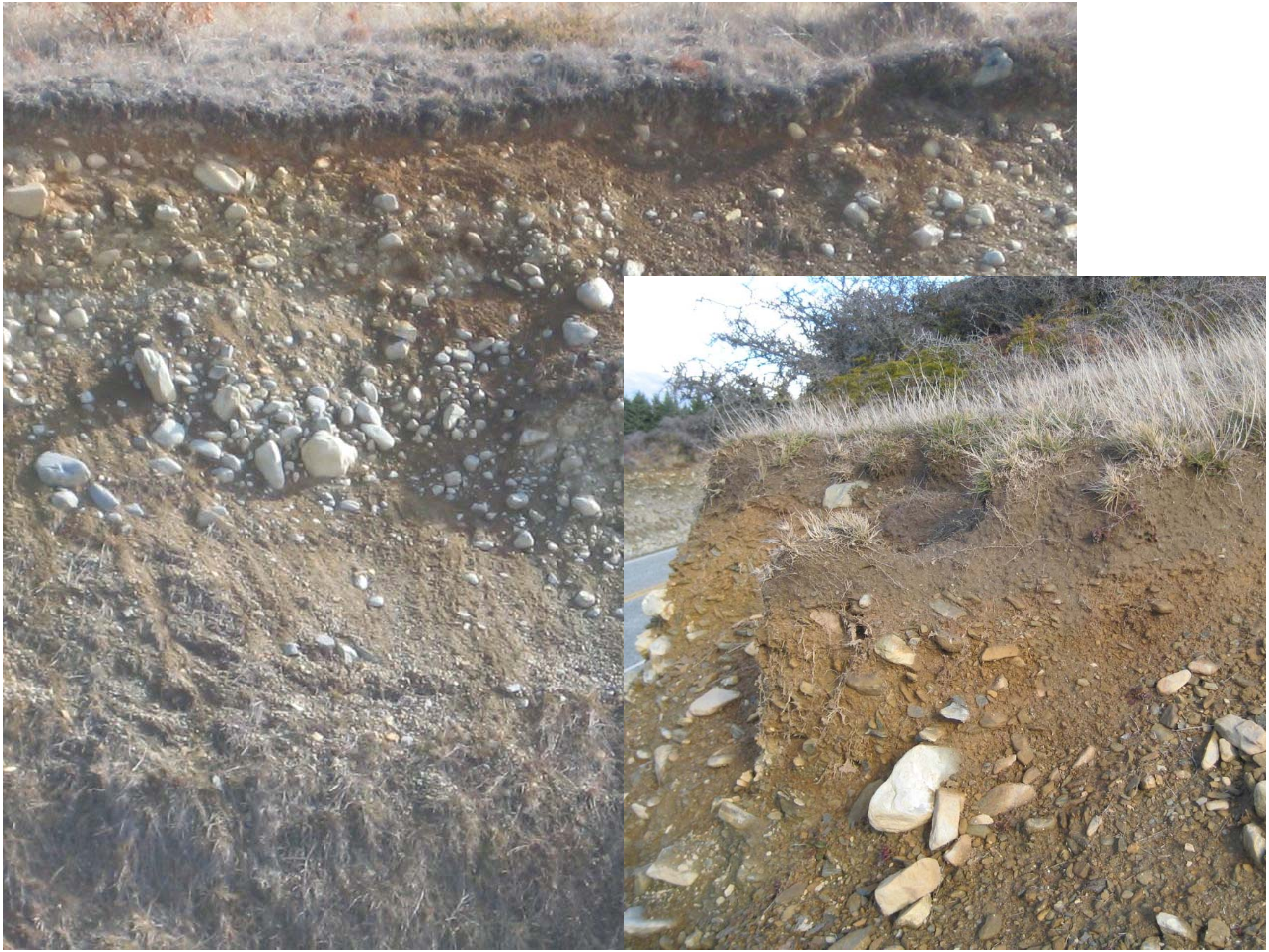
Oak tree
Wood
Lords and ladies
Dog violet
Earthworm
Millipede
Mole
Grasses and small shrubs
Organic debris builds up
Fern
Honey fungus
Moss and lichen
Rock fragments
O horizon
Leaf litter
A horizon
Topsoil
B horizon
Subsoil
C horizon
Parent material
Bedrock
Immature soil
Regolith
Young soil
Pseudoscorpion
Mite
Nematode
Root system
Red earth mite
Springtail
Actinomycetes
Fungus
Bacteria
Mature soil



Generalized relationship of soil horizons in soil development

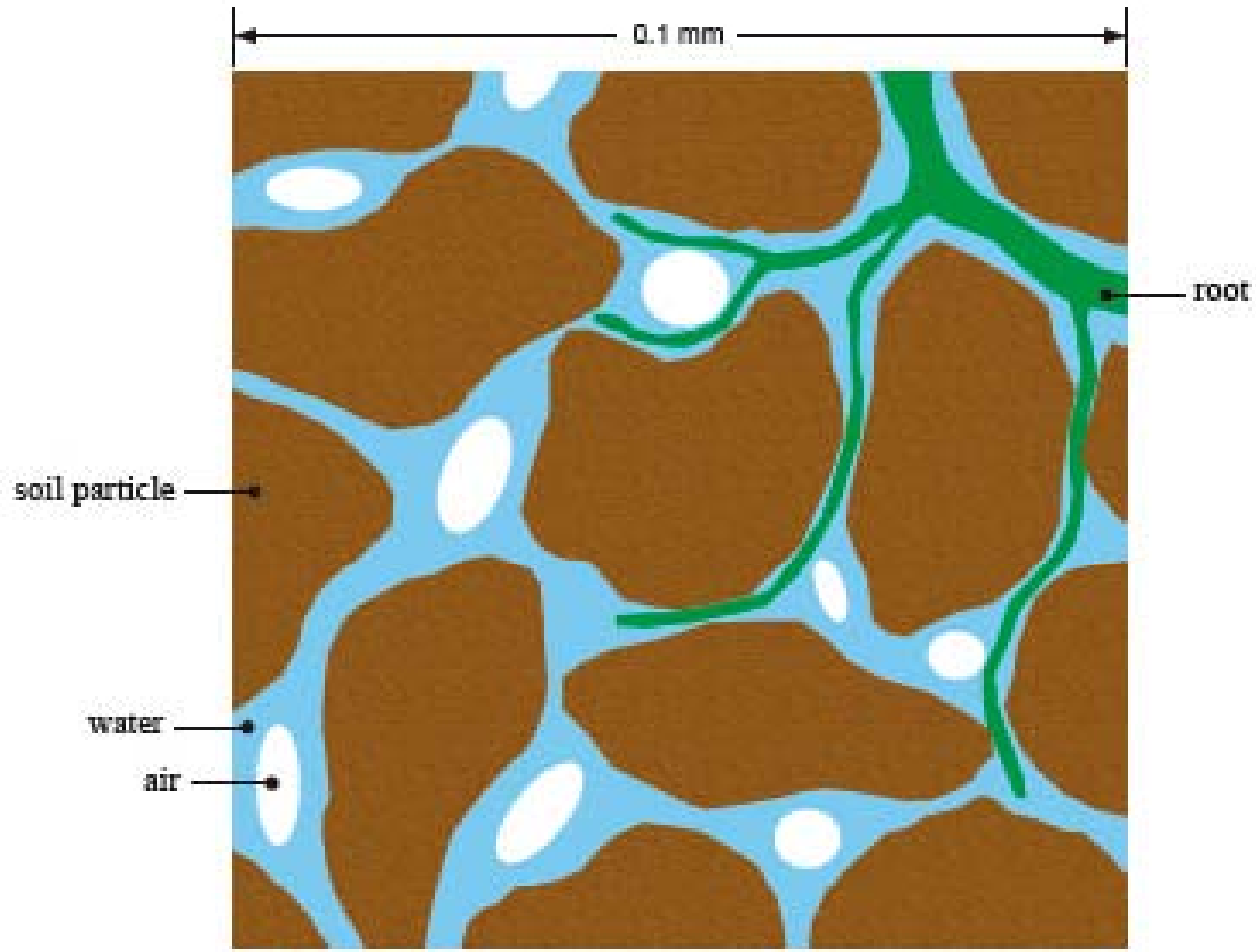


Soil Profile



Soil pore space

- Pore space = space between all soil particles
- Macropores – larger spaces normally occupied by air
- Micropores – smaller spaces usually filled with water



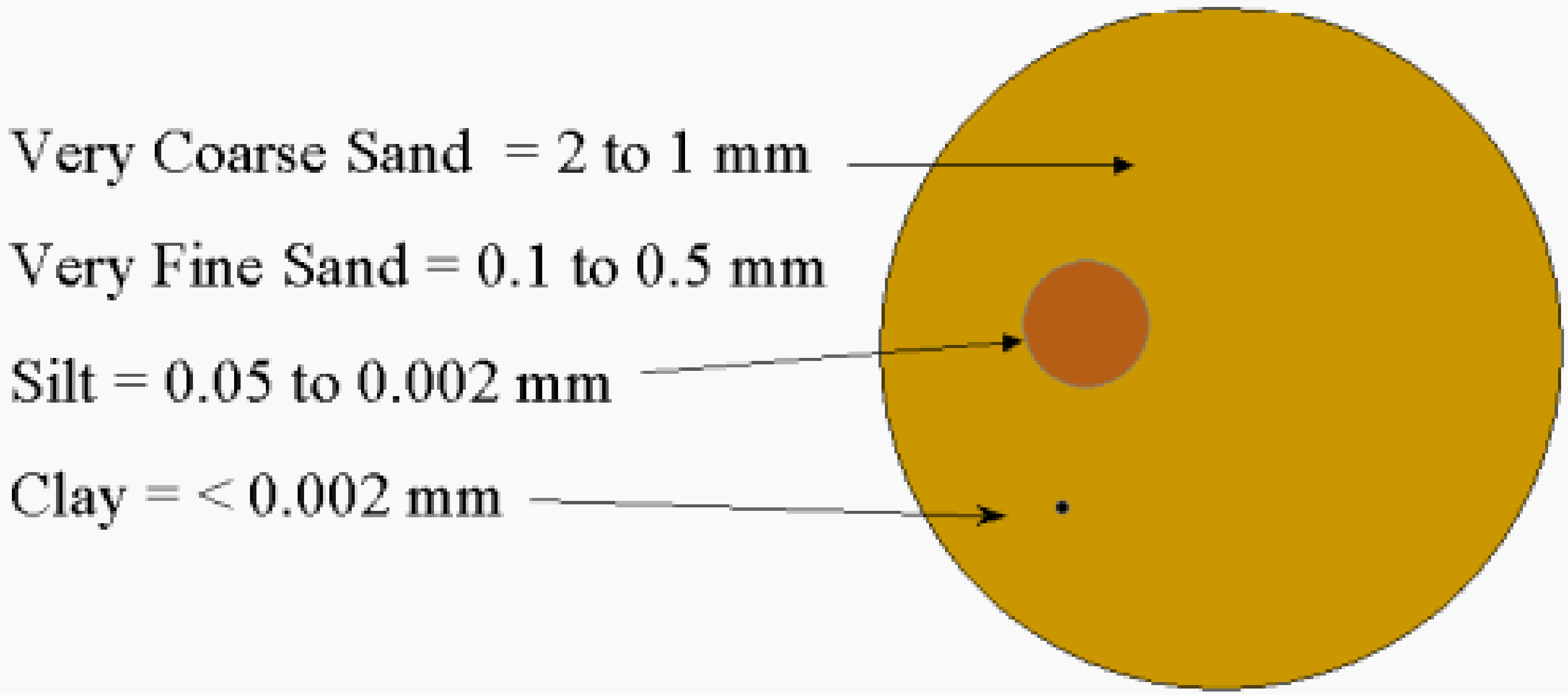
0.1 mm
root
soil particle
water
air

Soil texture

- Relative proportion of sand to silt to clay – based on particle size and reactivity
- Particle sizes arbitrarily chosen
- Applies only to portion of soil smaller than 2mm
- Doesn't include gravel, stones, boulders, etc.

Soil Properties: Texture

Soil Texture: The relative proportions of sand, silt, and clay particles in a mass of soil (material less than 2mm in size).



100
80
20
CLAY
Percent Clay
60
40
Percent Silt
40
60
sandy
clay
clay loam
silty
clay
20
loam
80
sandy loam
silt loam
SAND
SILT
100
80
60
40
20
100
Percent Sand

Sand

- Particle size 0.05mm – 2.0mm
- Skeleton/backbone of soil
- Chemically inert
- Non-porous
- Formed by physical weathering
- Low water holding ability
- Good aeration
- Poor fertility

Silt

- Particle size 0.002mm – 0.05mm
- Chemically inert
- Non-porous
- Formed by physical weathering
- Good water holding ability
- Poor aeration
- Poor to moderate fertility

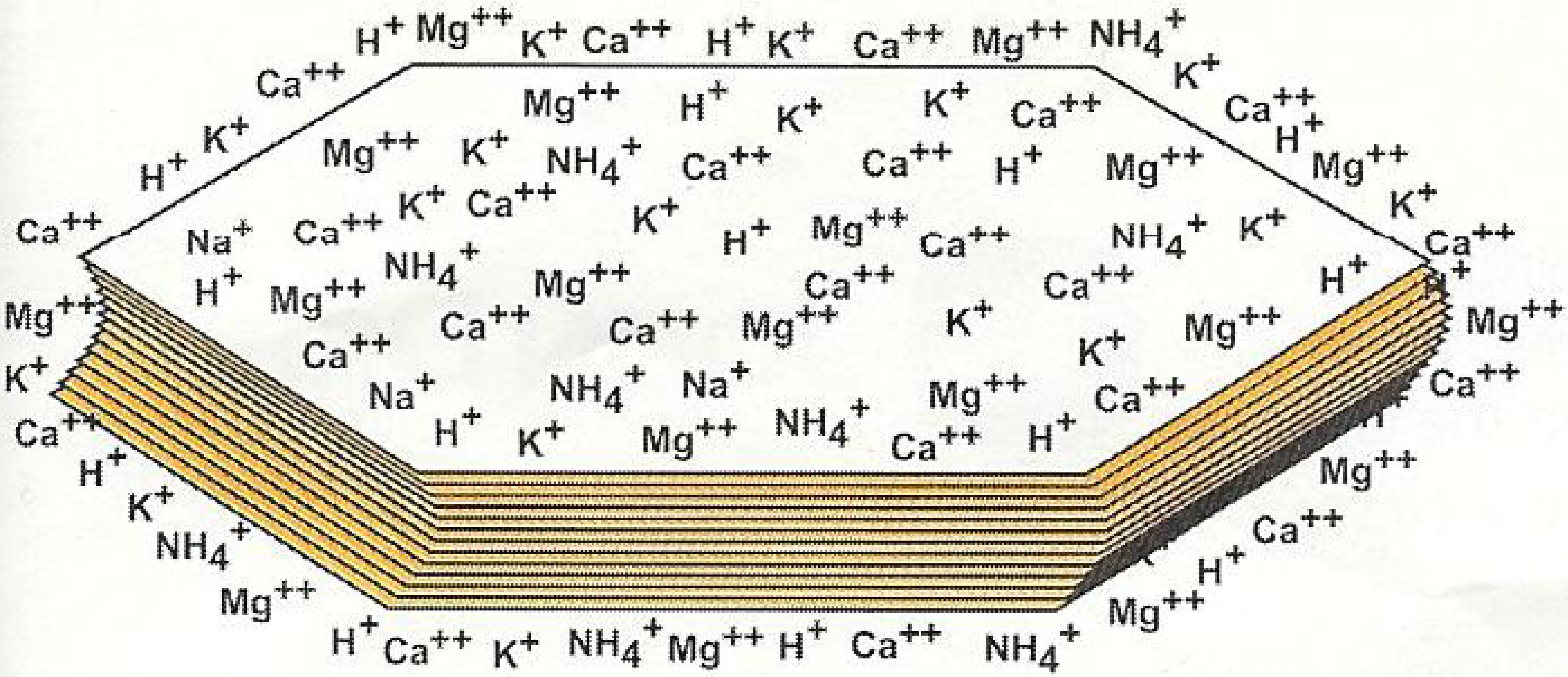
Clay

- Particle size <.002mm (lots of surface area)
- Chemically active
- Porous, flat crystals
- Formed by chemical/freeze-dry weathering
- Expands/contracts when wet/dry
- Great water holding ability
- Poor aeration
- Good fertility
- Negatively charged active sites

Figure 1

Paul Marks

CLAY PARTICLES

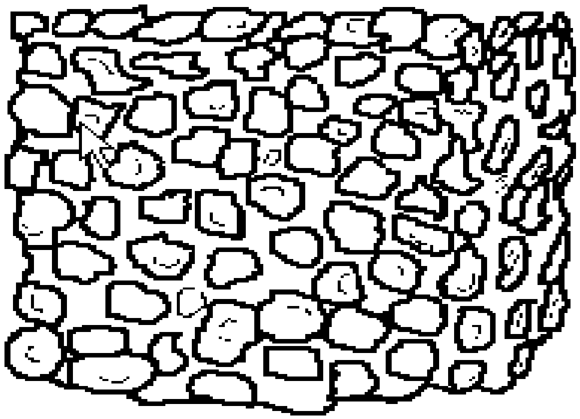
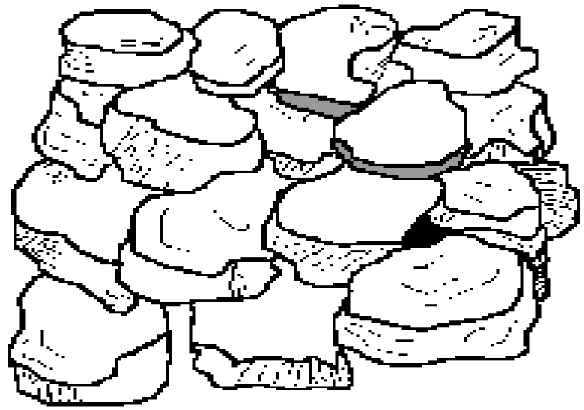
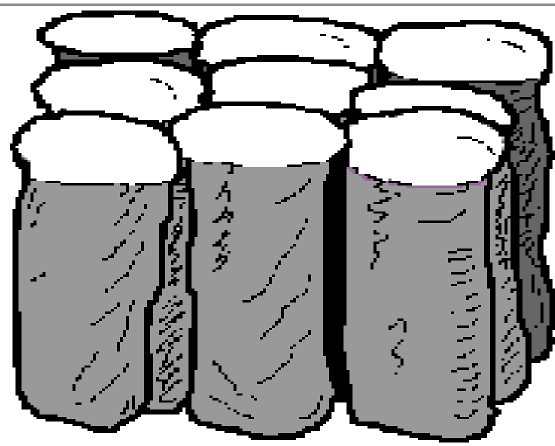
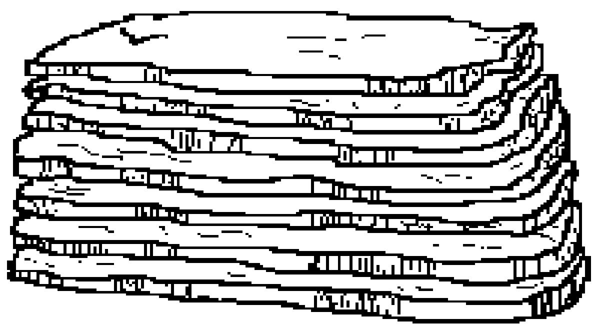
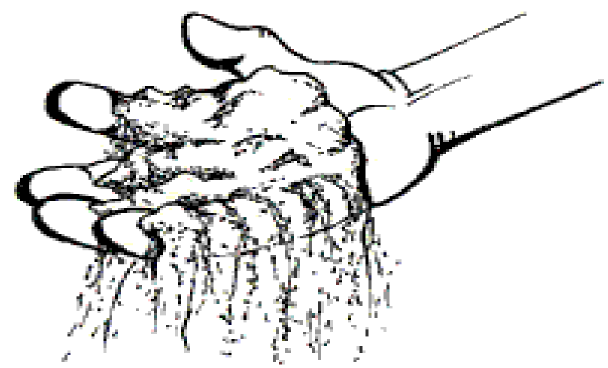


Negatively charged clay particles
shown with typical plate-like
appearance and swarm of adsorbed cations

Soil structure

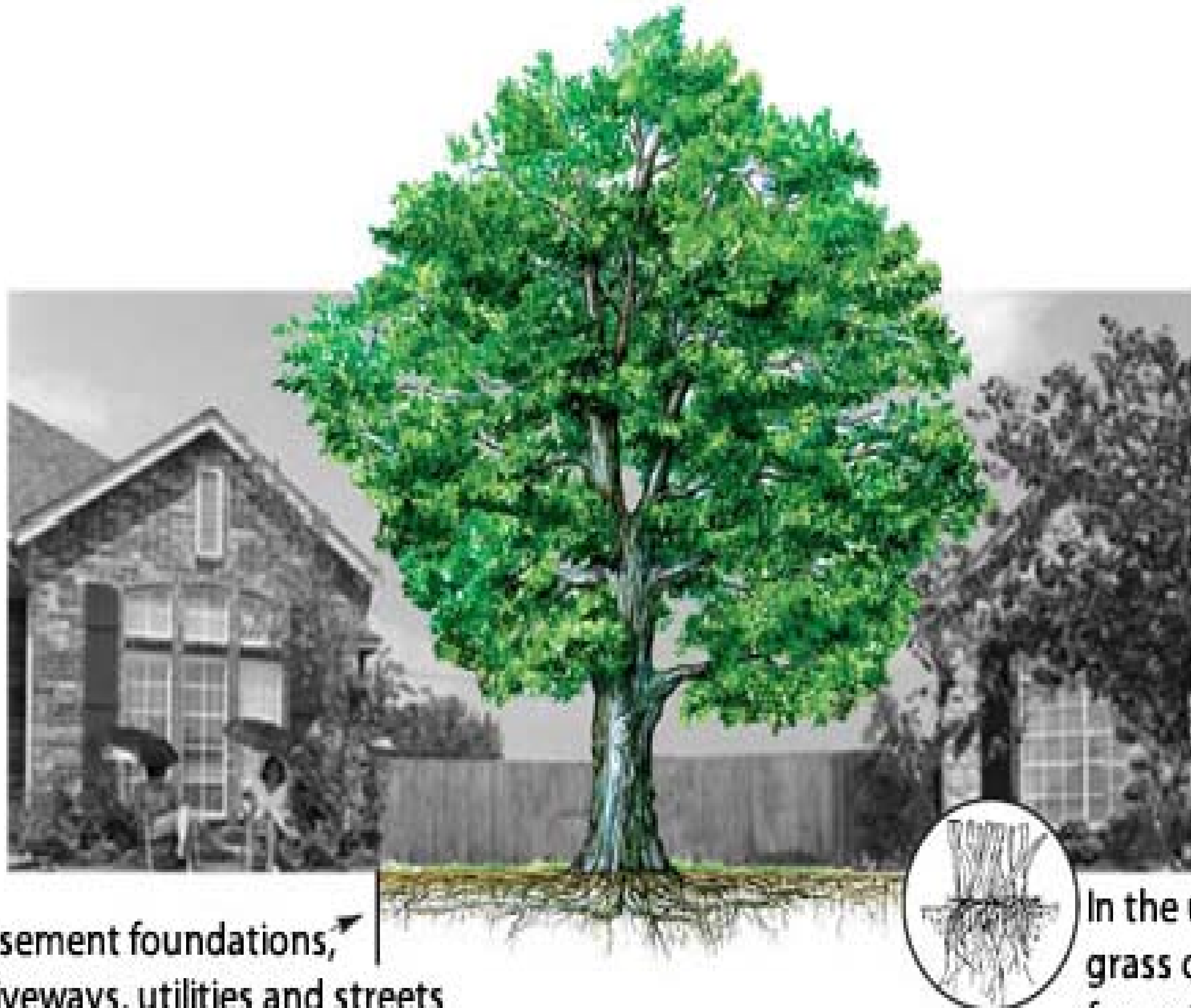
- Arrangement of soil particles into aggregates
- Each soil has characteristic shape/structure
- Sand, silt, clay and organic matter all clumped together by cementing by microorganisms


Jim Urban

		
Granular: Resembles cookie crumbs and is usually less than 0.5 cm in diameter. Commonly found in surface horizons where roots have been growing.	**Blocky**: Irregular blocks that are usually 1.5 - 5.0 cm in diameter.	**Prismatic**: Vertical columns of soil that might be a number of cm long. Usually found in lower horizons.
		
Columnar: Vertical columns of soil that have a salt "cap" at the top. Found in soils of arid climates.	**Platy**: Thin, flat plates of soil that lie horizontally. Usually found in compacted soil.	**Single Grained**: Soil is broken into individual particles that do not stick together. Always accompanies a loose consistence. Commonly found in sandy soils.

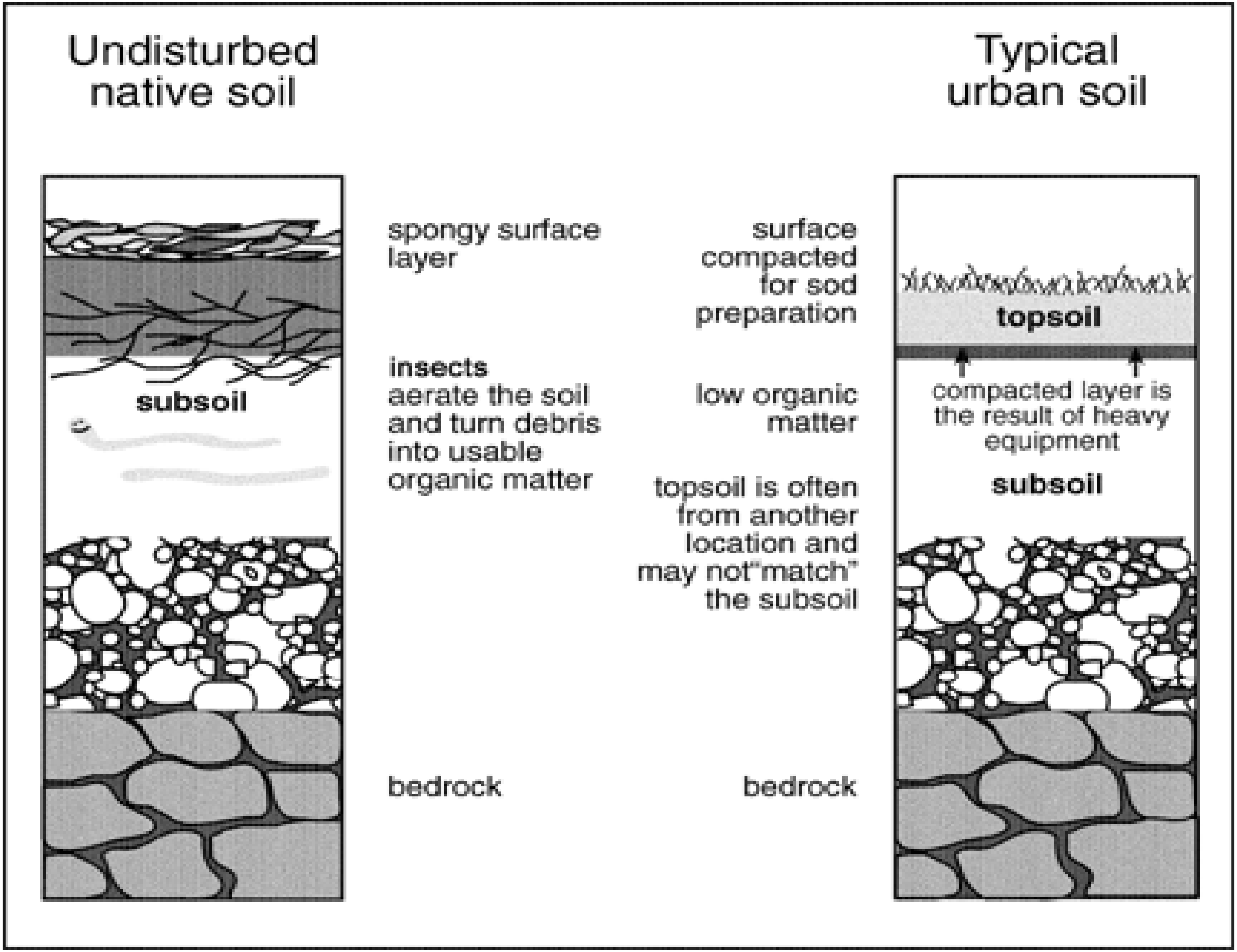
Bulk Density

- Weight/volume (g/cm^3 or lb/ft^3)
- Used to assess pore space adequacy
- Reflects degree of soil compaction

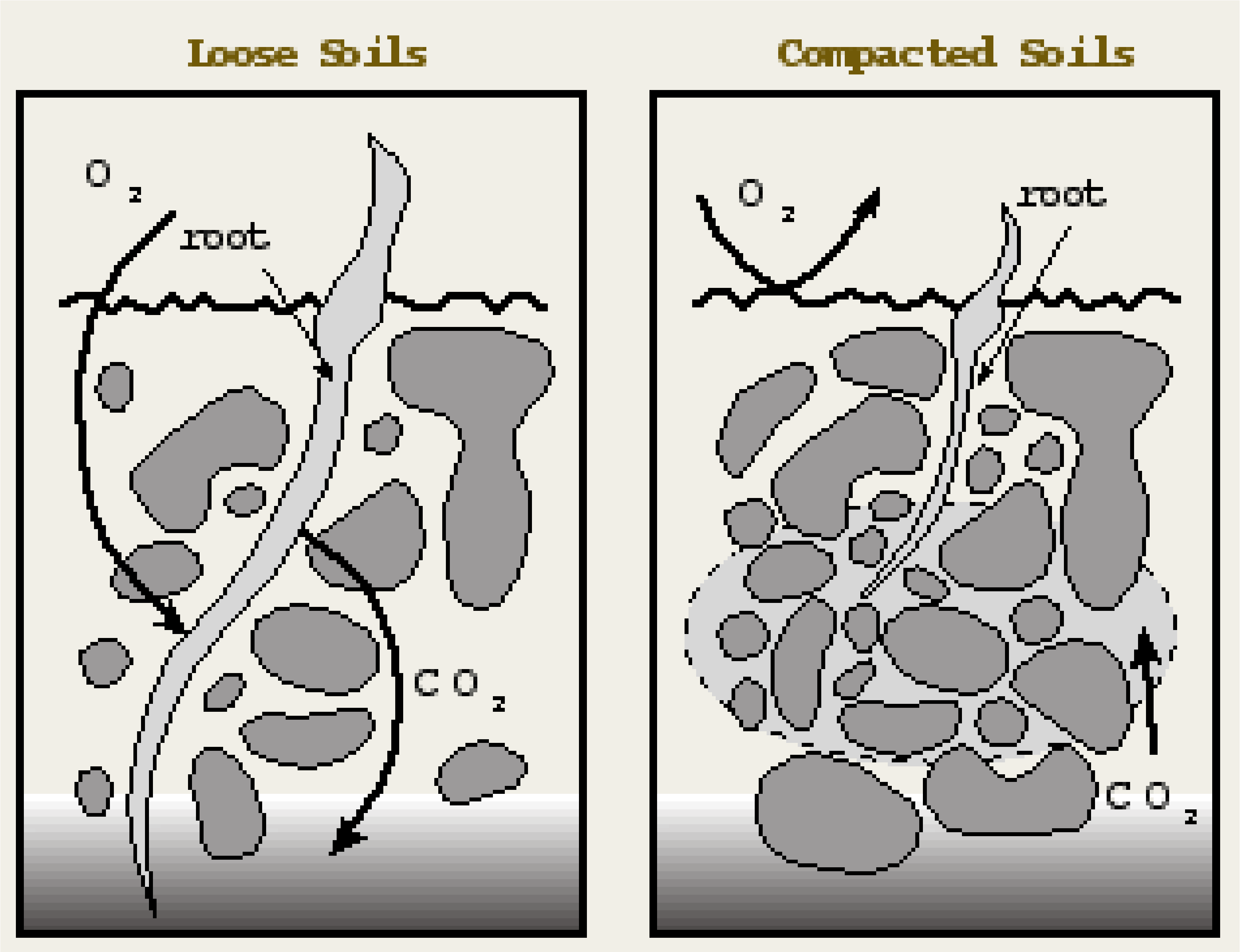

Basement foundations, driveways, utilities and streets restrict the root system and limit available resources.
In the urban environment grass competes with trees for water and minerals. This significantly reduces the capacity of a yard to support a tree.

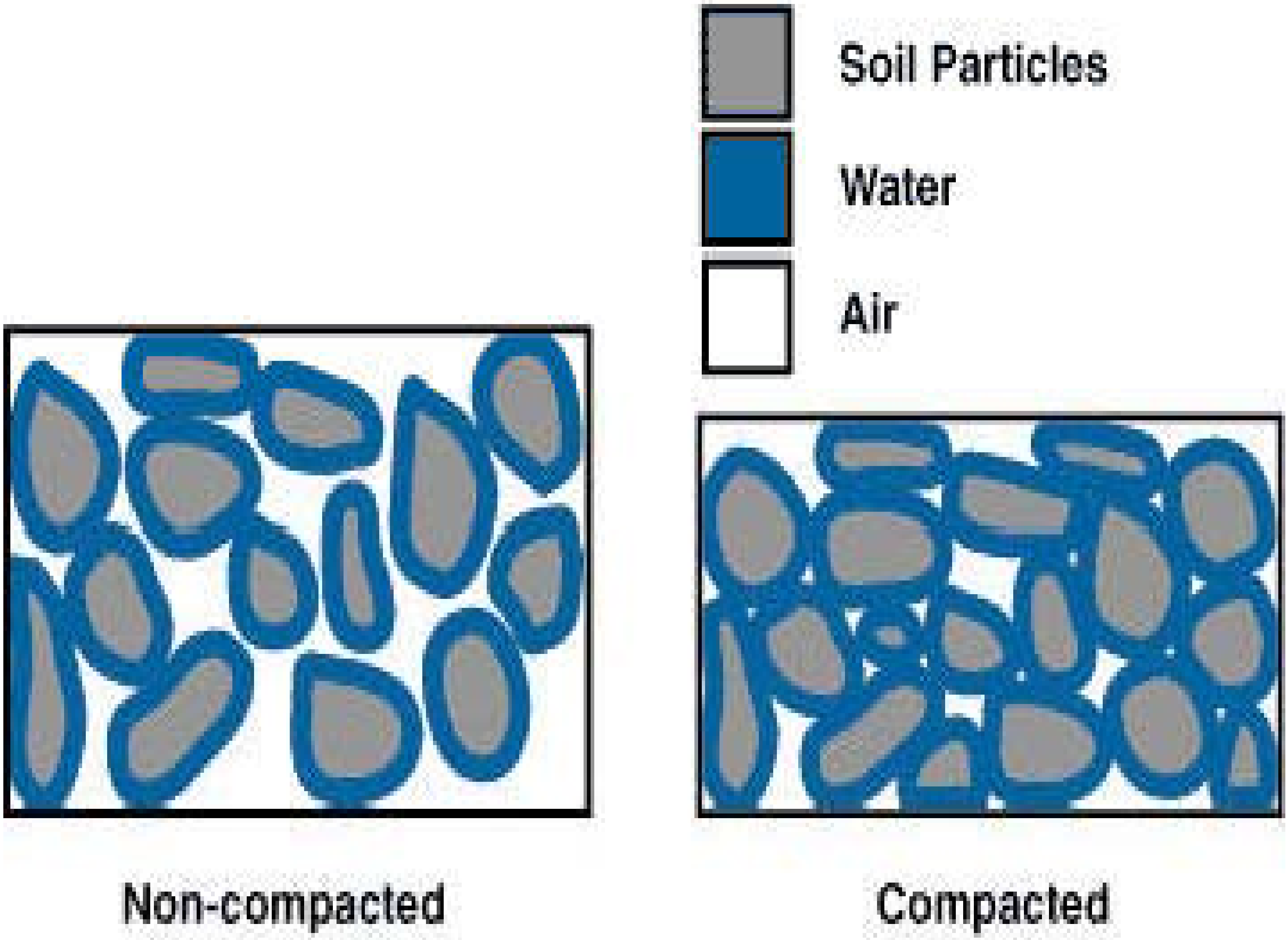
Compaction

- Disruption of soil particles, aggregates and accompanying pore spaces
- Increase in bulk density and decrease in total pore space
- Typically the result of traffic (foot & vehicular)
- Clay soils are more easily compacted then sandy soils
- Moist soils more easily compacted then dry soils

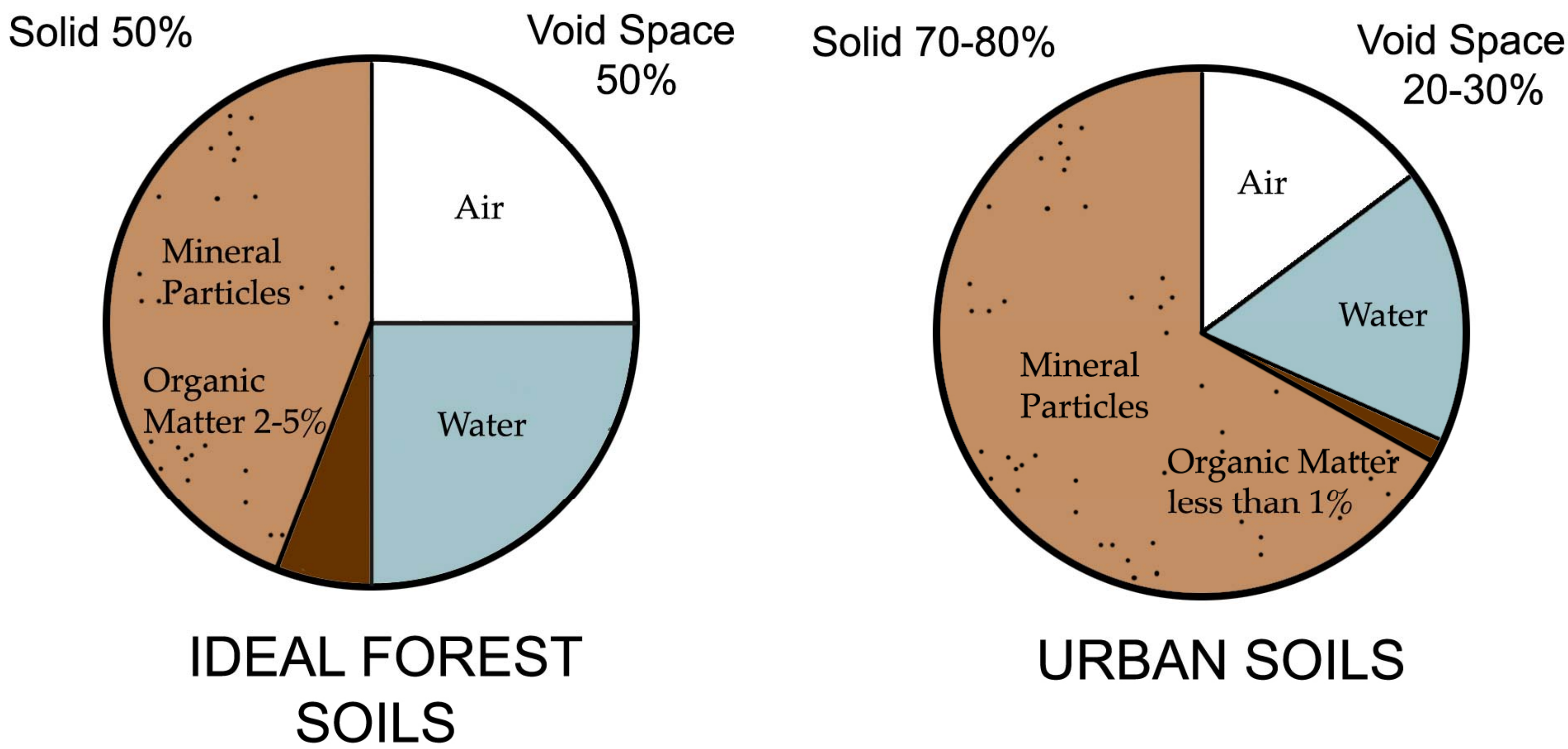


Undisturbed native soil
Typical urban soil
spongy surface layer
subsoil
insects aerate the soil and turn debris into usable organic matter
bedrock
surface compacted for sod preparation
topsoil
low organic matter
compacted layer is the result of heavy equipment
subsoil
topsoil is often from another location and may not"match" the subsoil
bedrock


Loose Soils
Compacted Soils
O2
root
CO2
O2
root
CO2

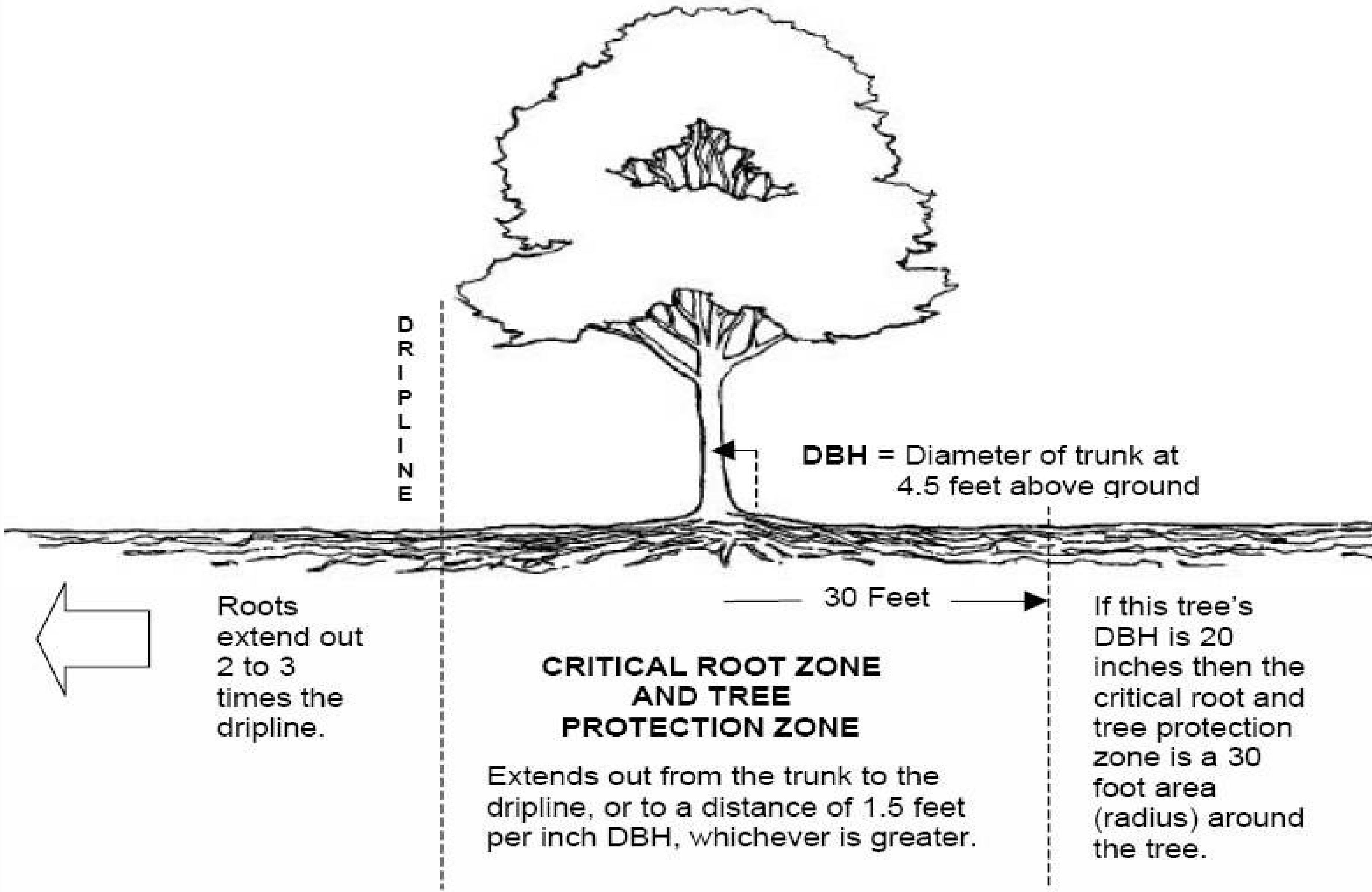

Soil Particles
Water
Air
Non-compacted
Compacted


Jim Urban



As compaction increases, pore space for water and air decreases

Figure 1. CRITICAL ROOT ZONE



Organic matter

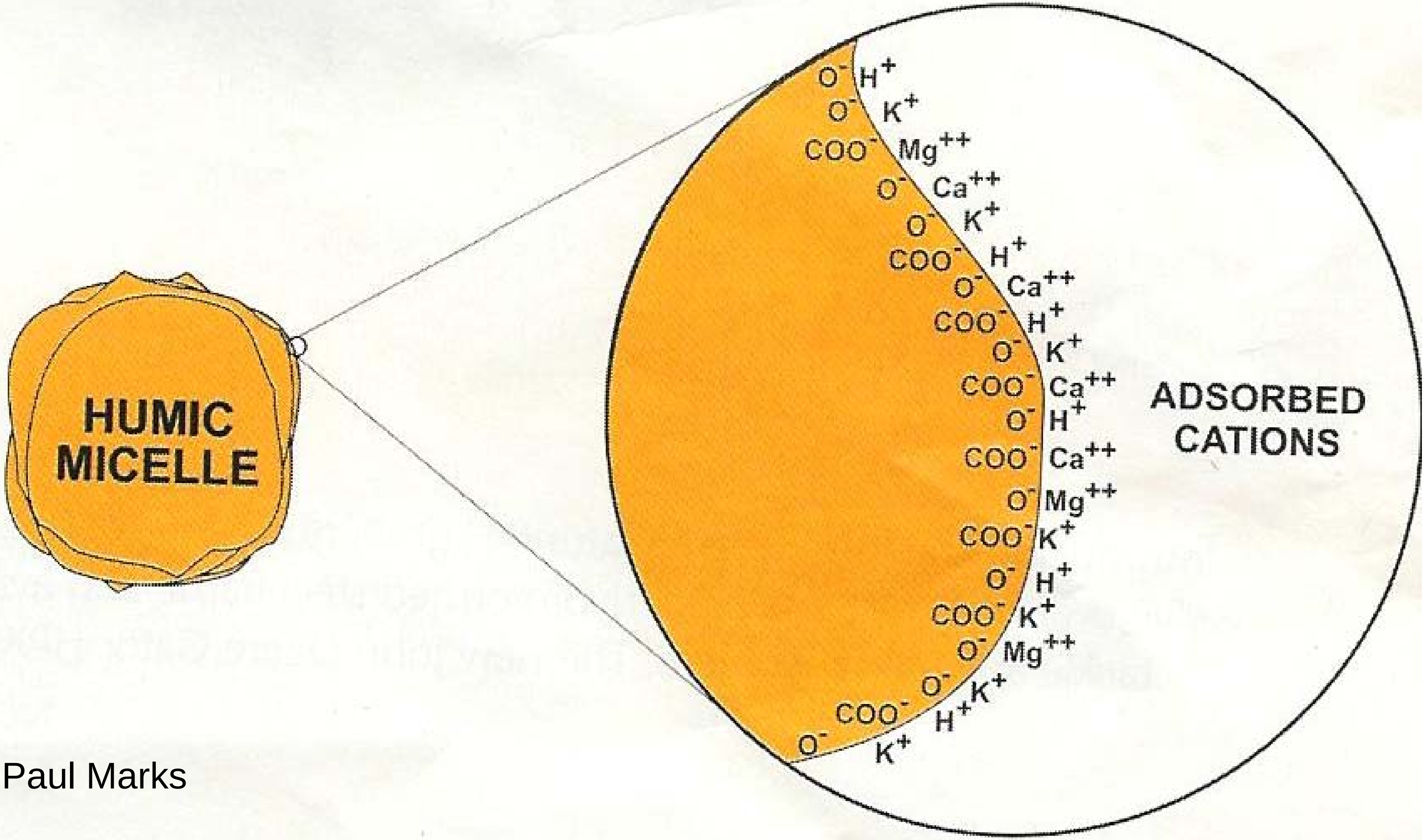
- Accumulated decomposition products of dead plants and animals
- Carbohydrates, nitrogenous compounds (proteins, amino acids), lignin, fats/resins/waxes
- End stage of decomposition is humus

Humus

- Chemically active
- Porous
- Improves water/nutrient holding capacity of coarse textured soils
- Reduces or moderates water/nutrient holding capacity of fine textured soils

Figure 3

ORGANIC COLLOID



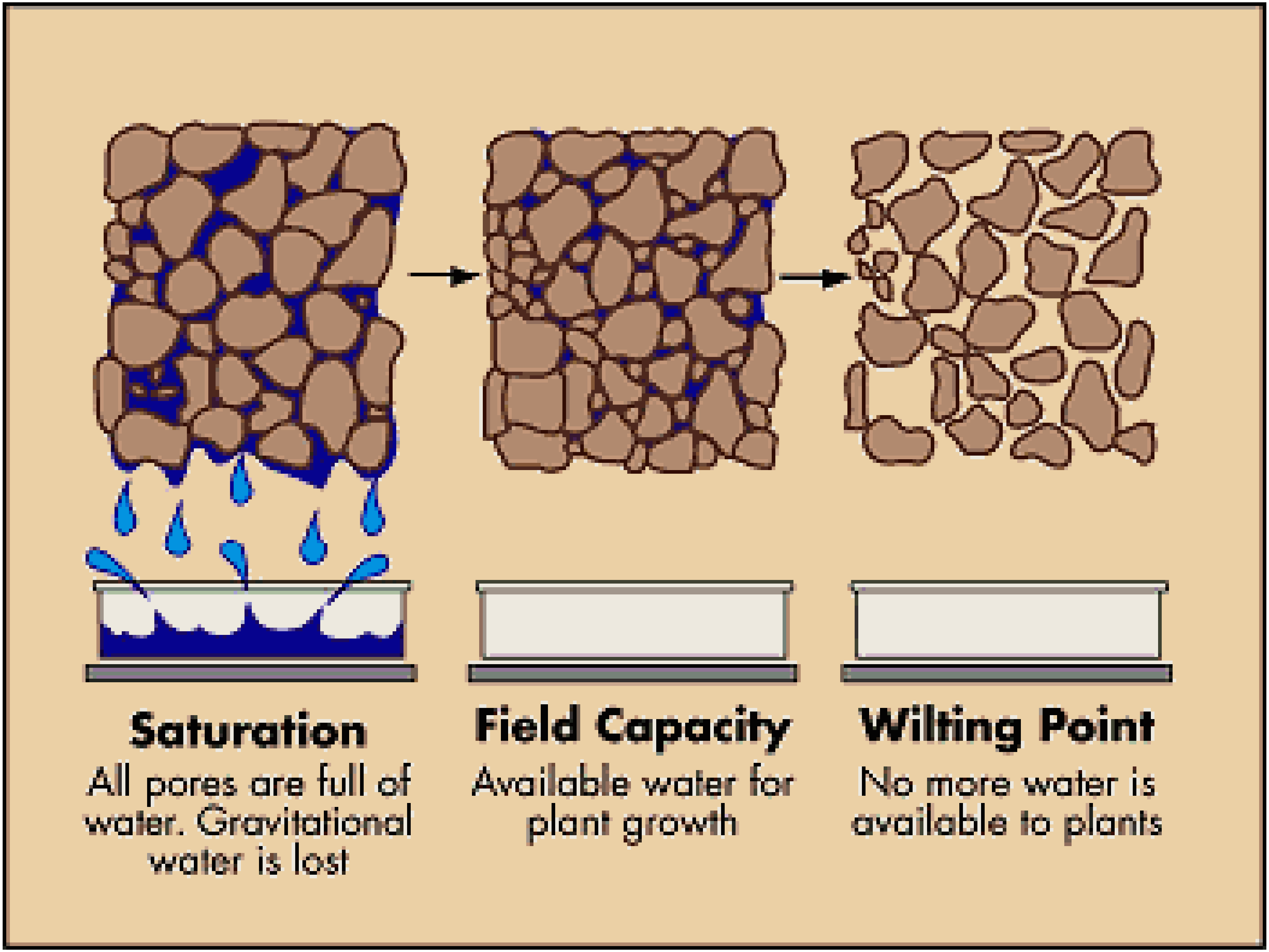
Paul Marks

Soil water

- Ability to hold or leach water varies from soil to soil
- Influenced by soil texture, vegetation, cultivation, amendments, cultural methods (mulching, etc.)
- Volume occupied by water = volume not occupied by air
- Important because all soil chemistry takes place in solution

Soil water

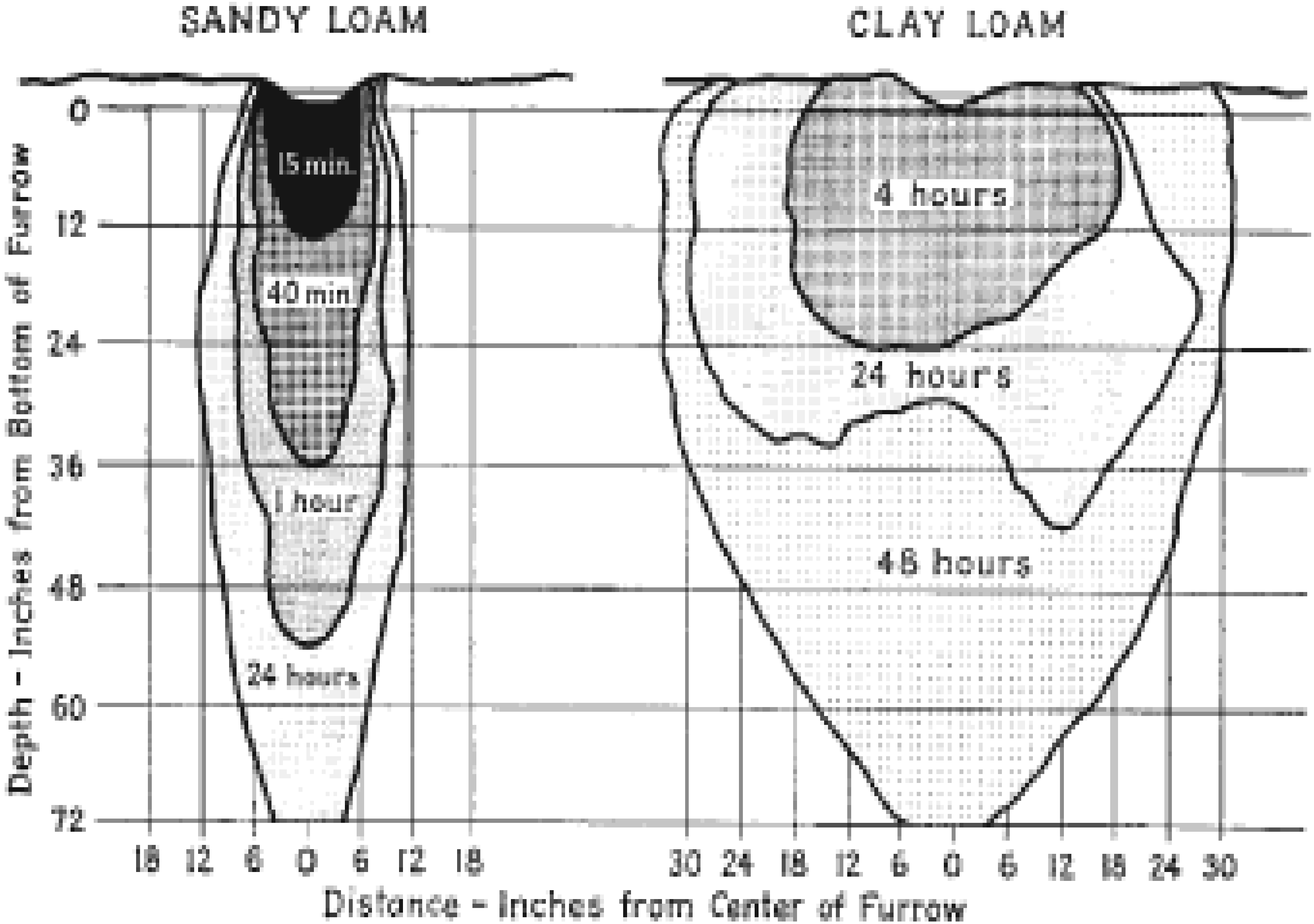
- Gravitational – drains from macropores under force of gravity
- Capillary – remains in micropores after gravitational effects – available for plant use
- Hygroscopic – exists as vapor – unavailable to plants


Saturation
All pores are full of water. Gravitational water is lost
Field Capacity
Available water for plant growth
Wilting Point
No more water is available to plants

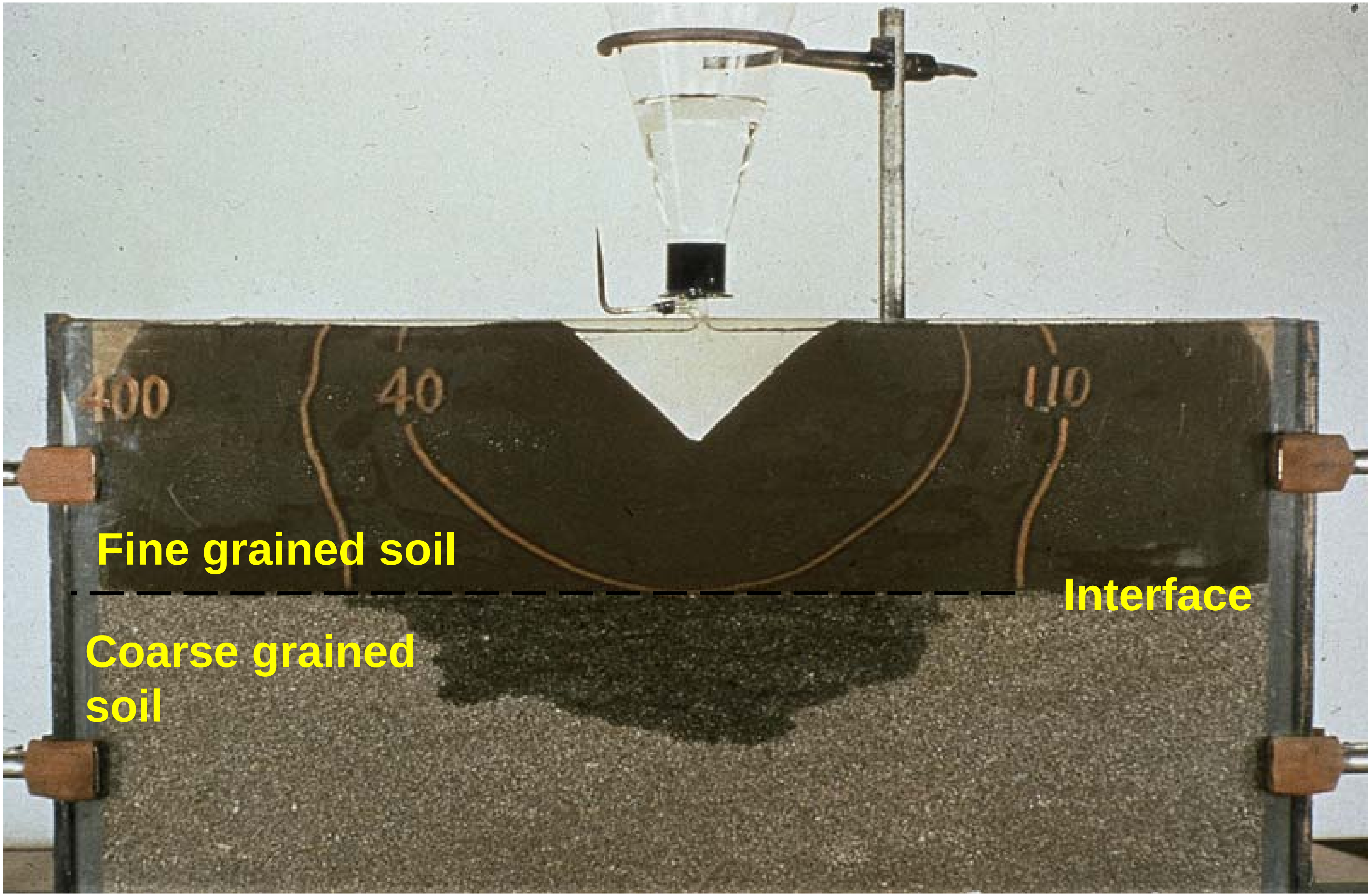
Soil water

- Saturation – all pore space occupied by water – flooding can occur
- Field capacity – after gravitational water has passed through profile
- Wilting point – no water left for plant use – plants begin to wilt
- Infiltration rate – speed with which water moves through a soil profile
- Evapotranspiration – moisture loss from soil and plants

University of Arizona. Credit: John C. Palumbo



SANDY LOAM
CLAY LOAM
15 min.
40 min.
1 hour
24 hours
4 hours
24 hours
48 hours
0
12
24
36
48
60
72
18 12 6 0 6 12 18
30 24 18 12 6 0 6 12 18 24 30
Depth - Inches from Bottom of Furrow
Distance - Inches from Center of Furrow


400
40
110
Fine grained soil
Interface
Coarse grained soil

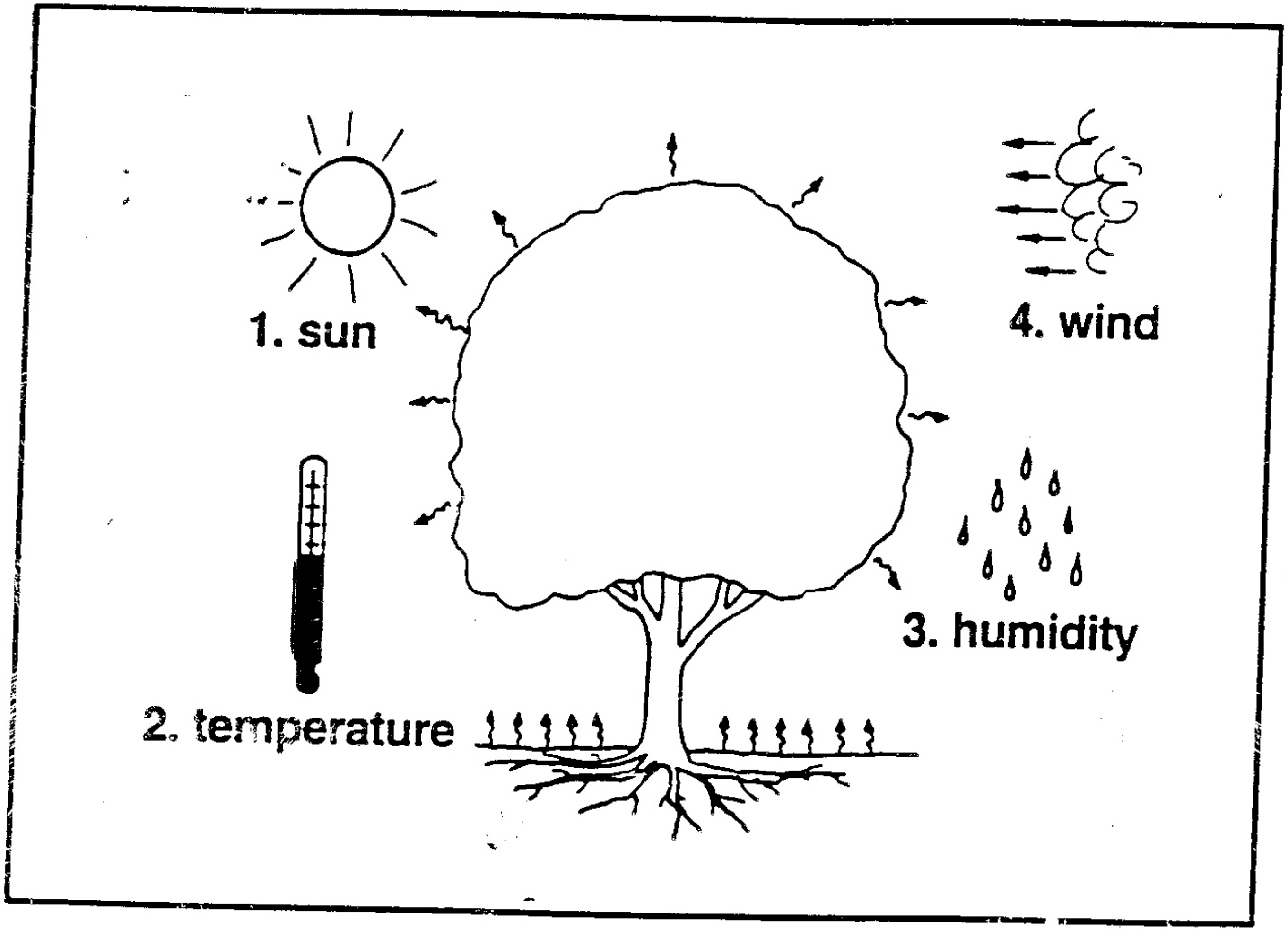


Fig. 4.6 Evapotranspiration rates are dependent on environmental conditions including light, temperature, wind, and humidity.

Percolation test

- Dig one foot deep pit
- Fill pit with water and allow to drain (to saturate soil before the actual test)
- Within 24 hours, refill pit and record time needed for each inch of water to drain

  poorly drained = < 1 in/hr

  moderately drained = 1 – 6 in/hr

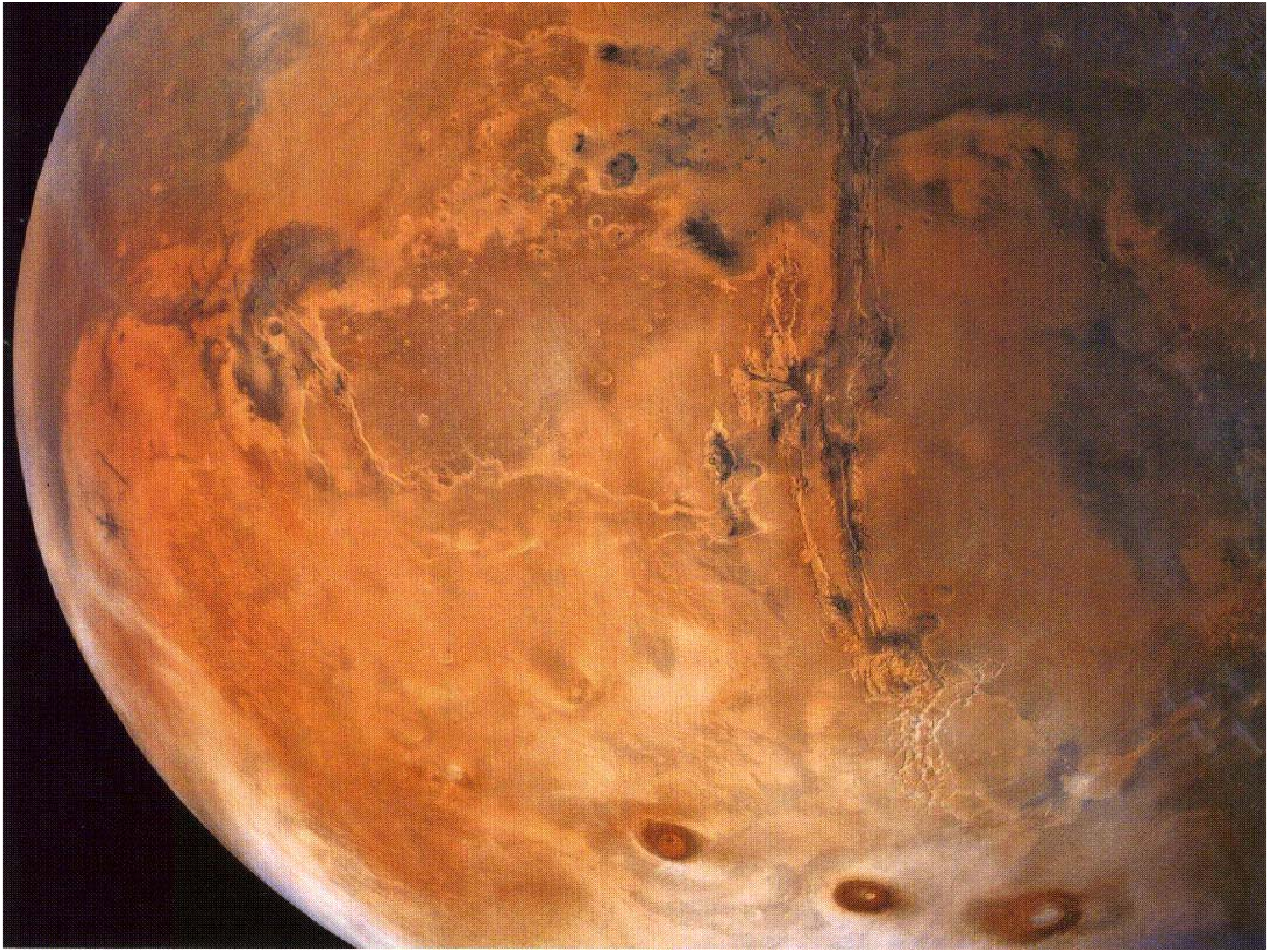
  excessively drained = > 6 in/hr

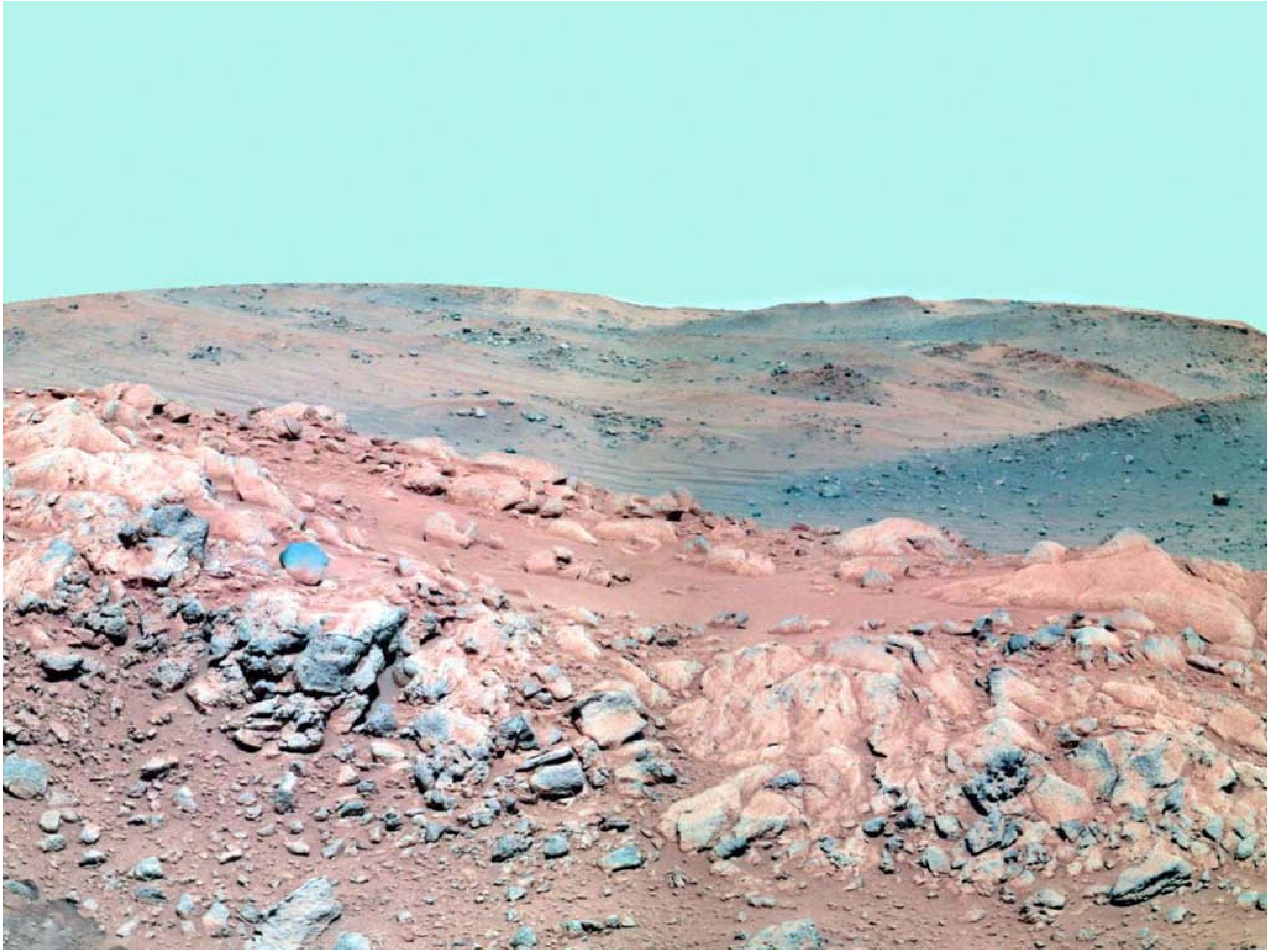
Irrigation

- Sprinkler irrigation – most common method; long duration/infrequent intervals is best strategy; greater risk for evaporation
- Drip irrigation – low volumes applied over time directly to soil; helps conserve water
- Minimum irrigation – least amount of water needed to maintain plants; plant/soil dependant

Irrigation terms

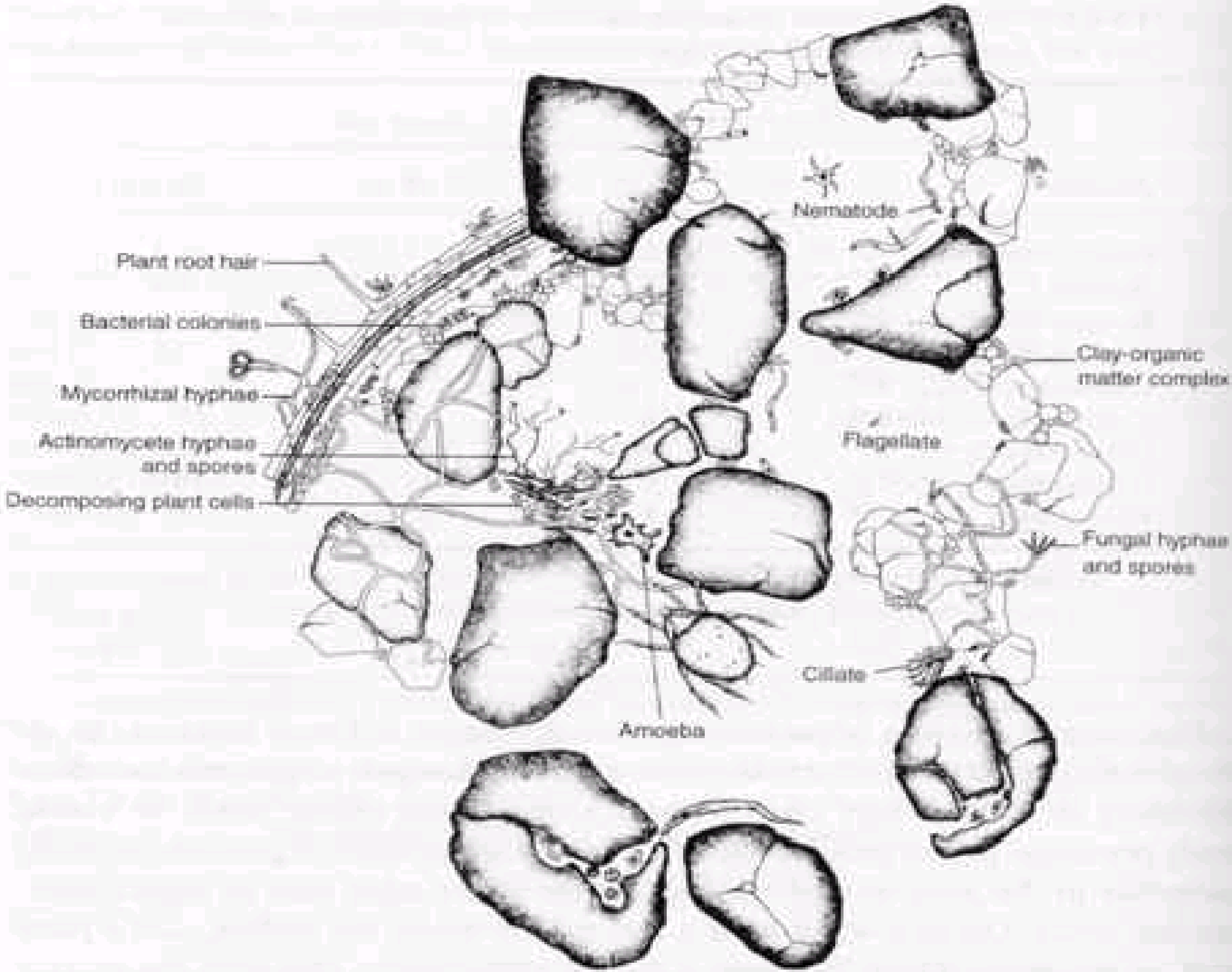
- Tensionometer – device that senses soil moisture; helpful for irrigation scheduling
- Hydrogels – polymeric crystals that absorb and slowly supply water when incorporated in soil
- Antitranspirants – applied to foliage to limit moisture loss
- Mulches – placed on soil surface to limit moisture loss
- Desiccation – plants drying to death
- Phytotoxic – poisonous to plants



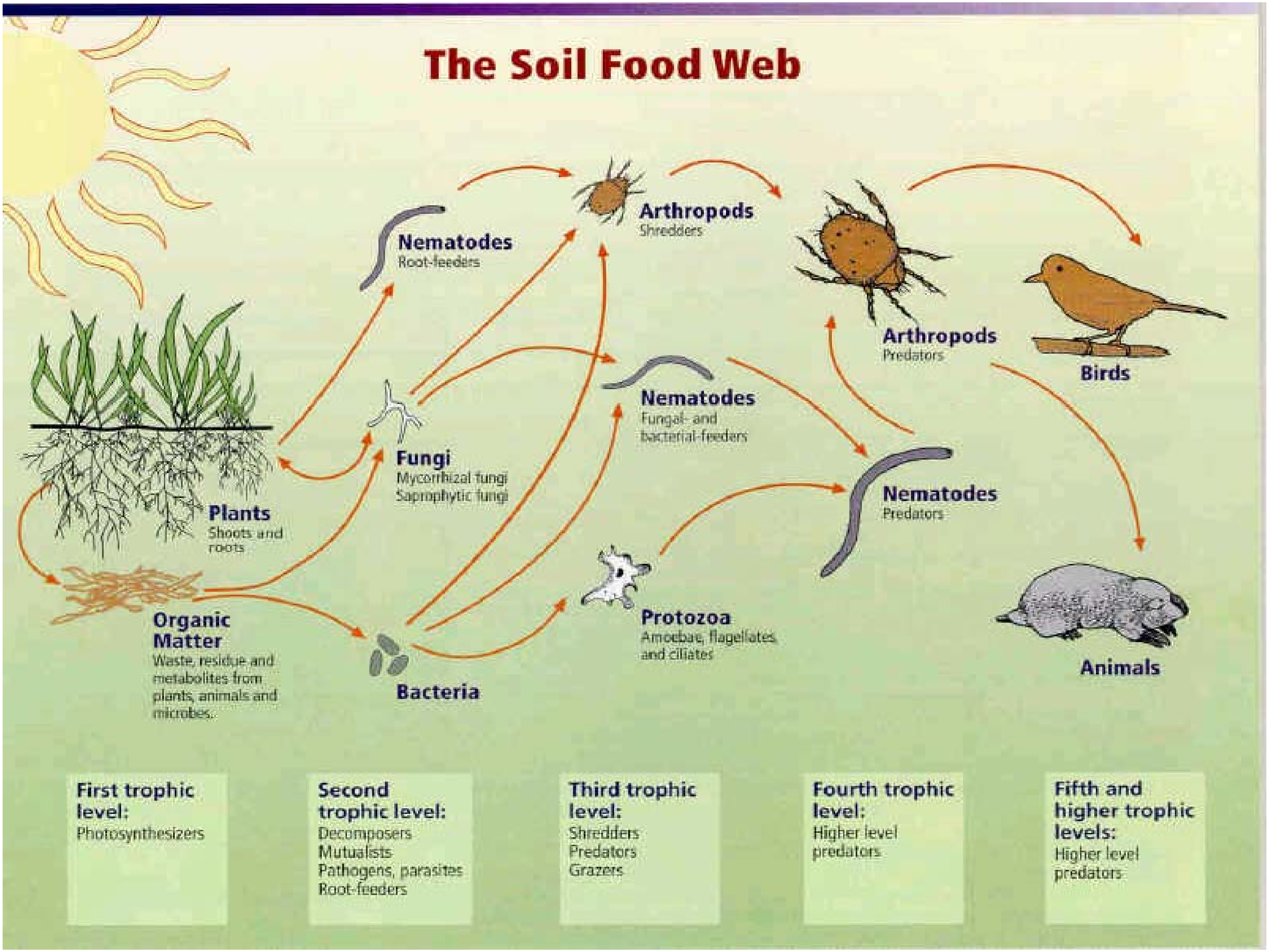


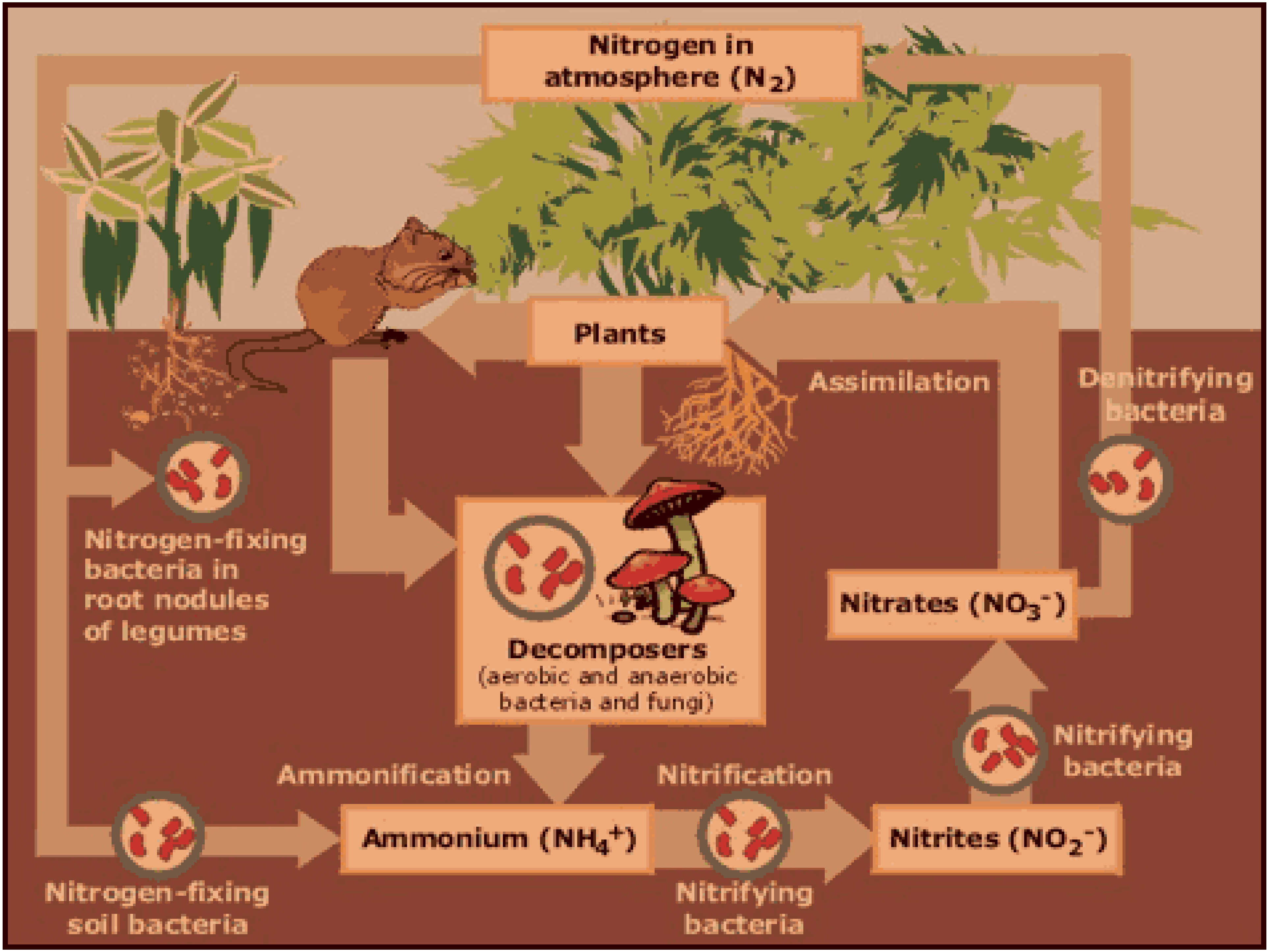
Soil biology

- Microfauna
  - bacteria
  - fungi
  - algae
  - protozoans
  - nematodes
- Macrofauna/flora
  - insects
  - mites
  - earthworms
  - rodents
  - myccorhizae
  - plant roots

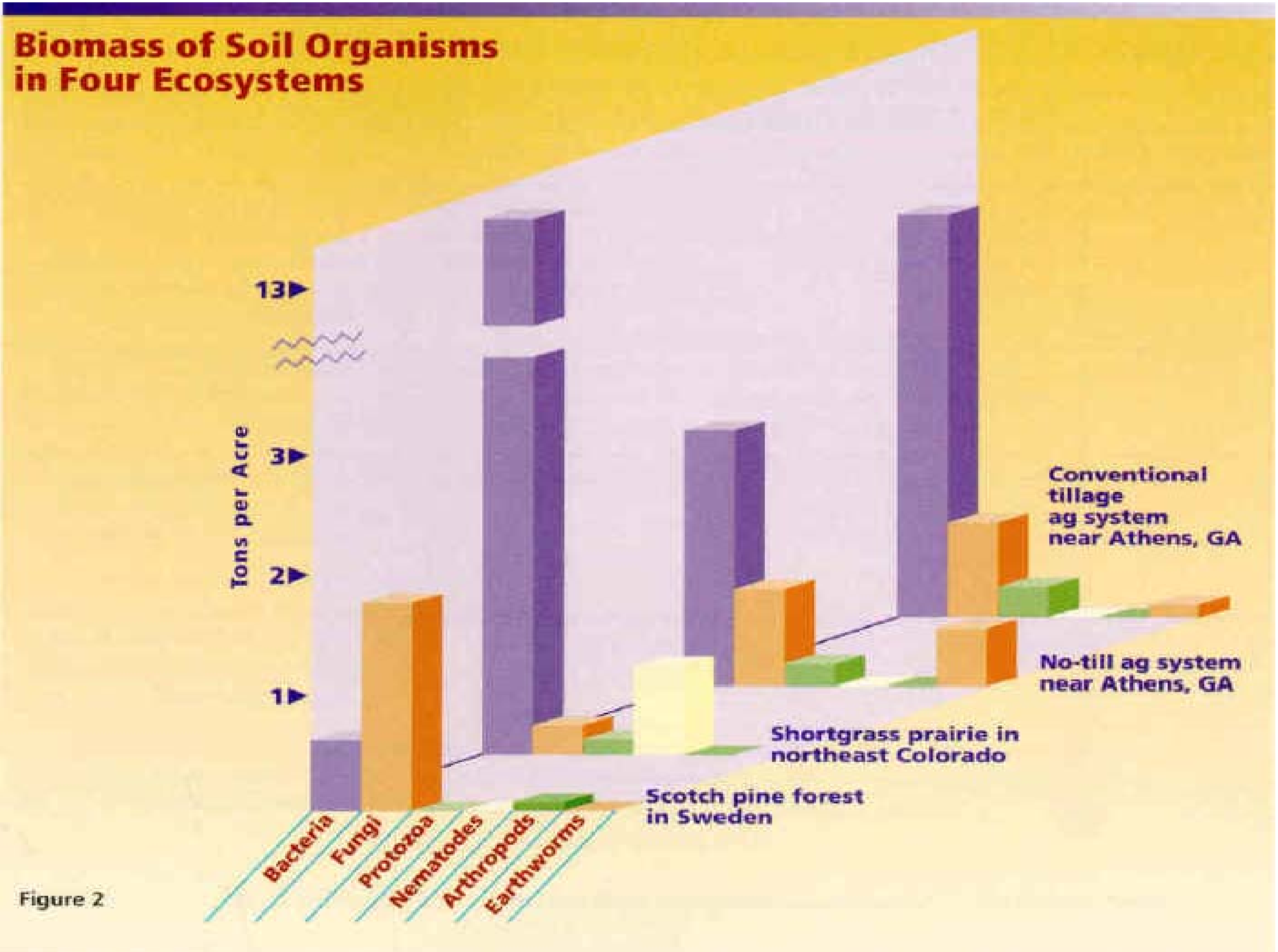


Plant root hair
Bacterial colonies
Mycorrhizal hyphae
Actinomycete hyphae
and spores
Decomposing plant cells
Nematode
Clay-organic
matter complex
Flagellate
Fungal hyphae
and spores
Ciliate
Amoeba


The Soil Food Web
Nematodes
Root-feeders
Arthropods
Shredders
Arthropods
Predators
Birds
Nematodes
Fungal- and bacterial-feeders
Fungi
Mycorrhizal fungi
Saprophytic fungi
Plants
Shoots and roots
Nematodes
Predators
Organic Matter
Waste, residue and metabolites from plants, animals and microbes.
Bacteria
Protozoa
Amoebae, flagellates, and ciliates
Animals
First trophic level:
Photosynthesizers
Second trophic level:
Decomposers
Mutualists
Pathogens, parasites
Root-feeders
Third trophic level:
Shredders
Predators
Grazers
Fourth trophic level:
Higher level predators
Fifth and higher trophic levels:
Higher level predators



Nitrogen in atmosphere (N_2)
Plants
Assimilation
Denitrifying bacteria
Nitrogen-fixing bacteria in root nodules of legumes
Decomposers
(aerobic and anaerobic bacteria and fungi)
Nitrates (NO_3^-)
Nitrifying bacteria
Ammonification
Nitrification
Ammonium (NH_4^+)
Nitrites (NO_2^-)
Nitrogen-fixing soil bacteria
Nitrifying bacteria


Biomass of Soil Organisms
in Four Ecosystems
13
3
2
1
Tons per Acre
Conventional
tillage
ag system
near Athens, GA
No-till ag system
near Athens, GA
Shortgrass prairie in
northeast Colorado
Scotch pine forest
in Sweden
Bacteria
Fungi
Protozoa
Nematodes
Arthropods
Earthworms
Figure 2

Microbial activity

- Breakdown complex organic substances
- Consume carbon, nitrogen
- Nitrogen cycle carried out by microorganisms

Mycorrhizae – fungal roots

- Myco = fungal
- Rhizae = roots
- Exist in many natural settings
- Parasitize plant roots
- Improve roots’ ability to take up moisture and nutrients (especially P)
- Example of symbiosis = mutually beneficial

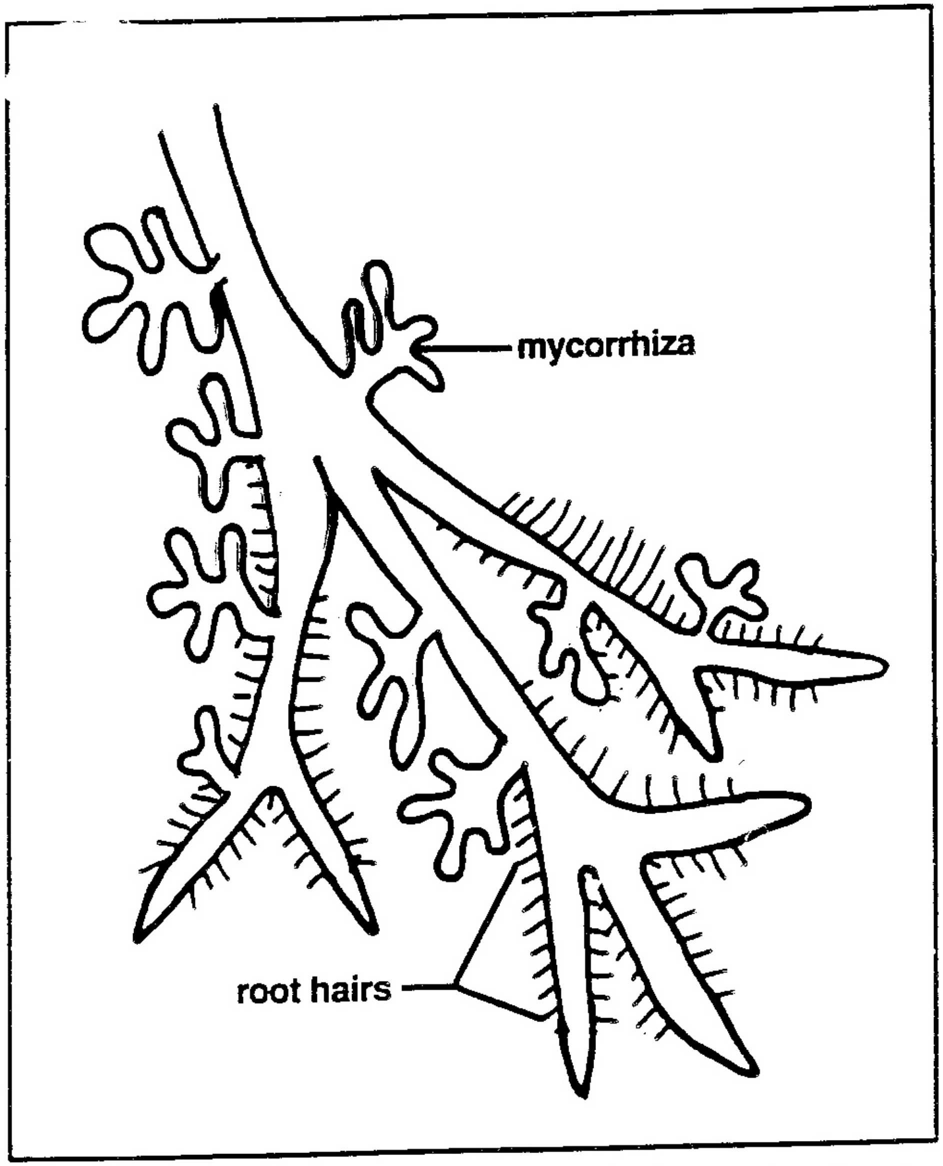
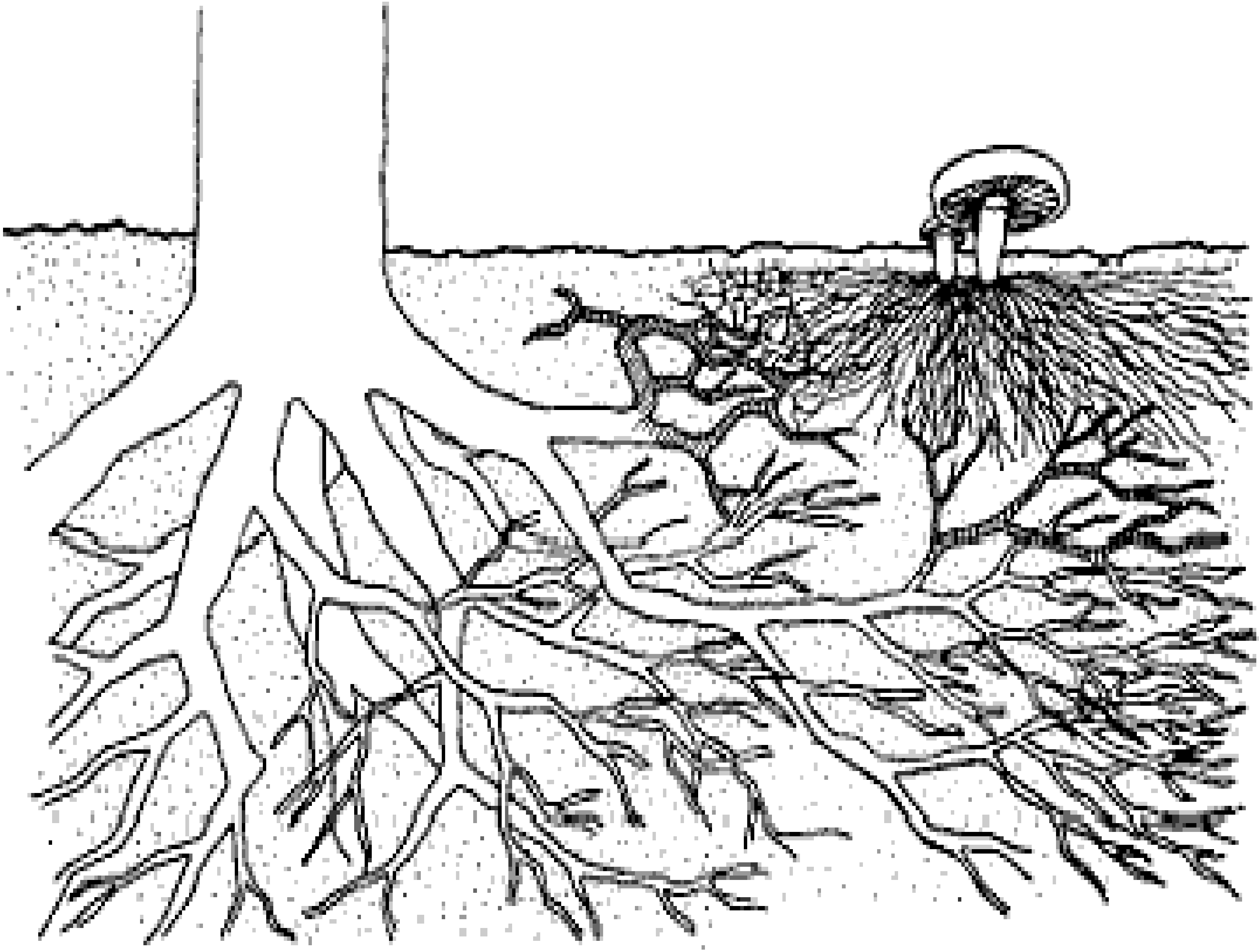


Fig. 3.6 Mycorrhizal roots aid the tree in the uptake of water and minerals.



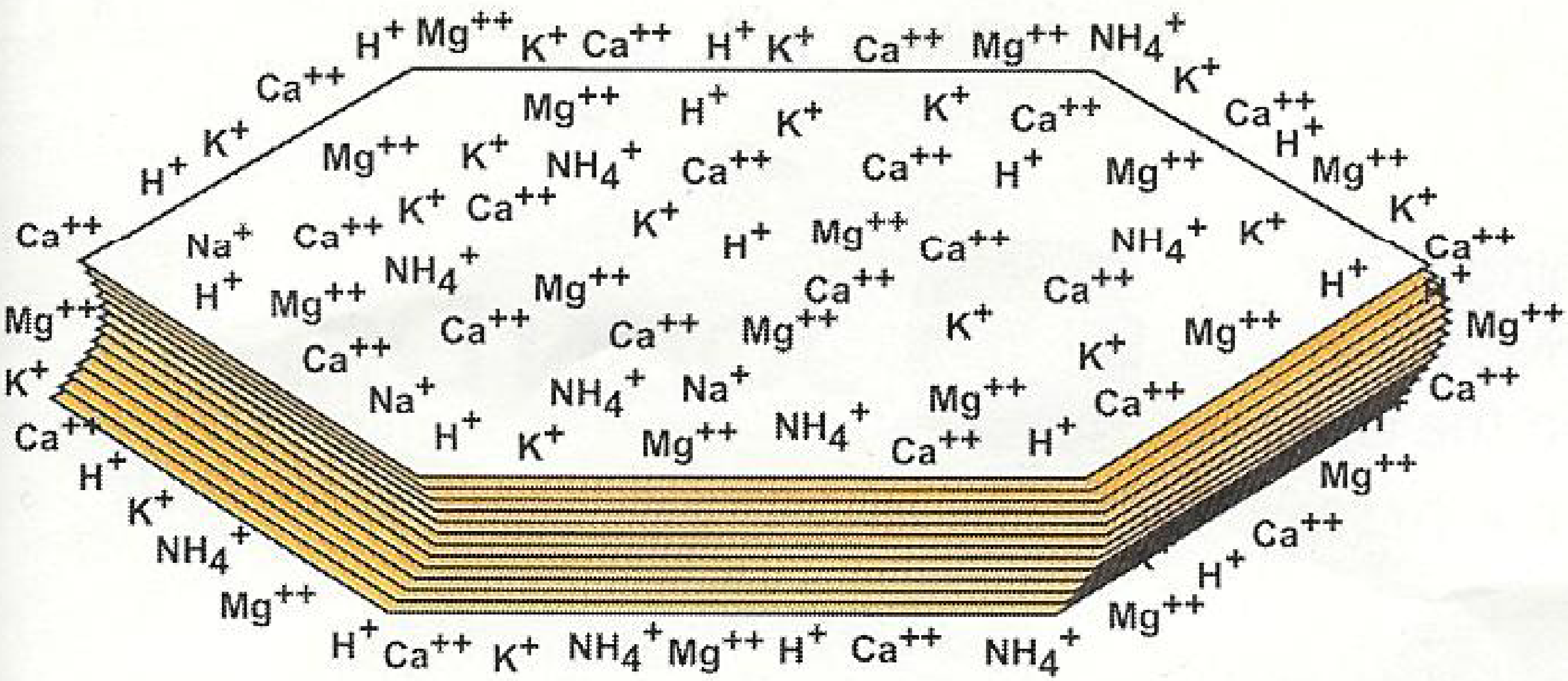
Soil chemistry – surface reactivity

- Plants take up nutrients only in ionic form
- Ions = elements or collection of elements in solution and are positively or negatively charged
- Cations – positively charged ions (Ca, Mg, K, Na, NH_4, H; attached to soil (- charge)
- Anions – negatively charged ions (Cl, CO_3, NO_3, SO_4); not attached to soil - at mercy of gravity

Figure 1

Paul Marks

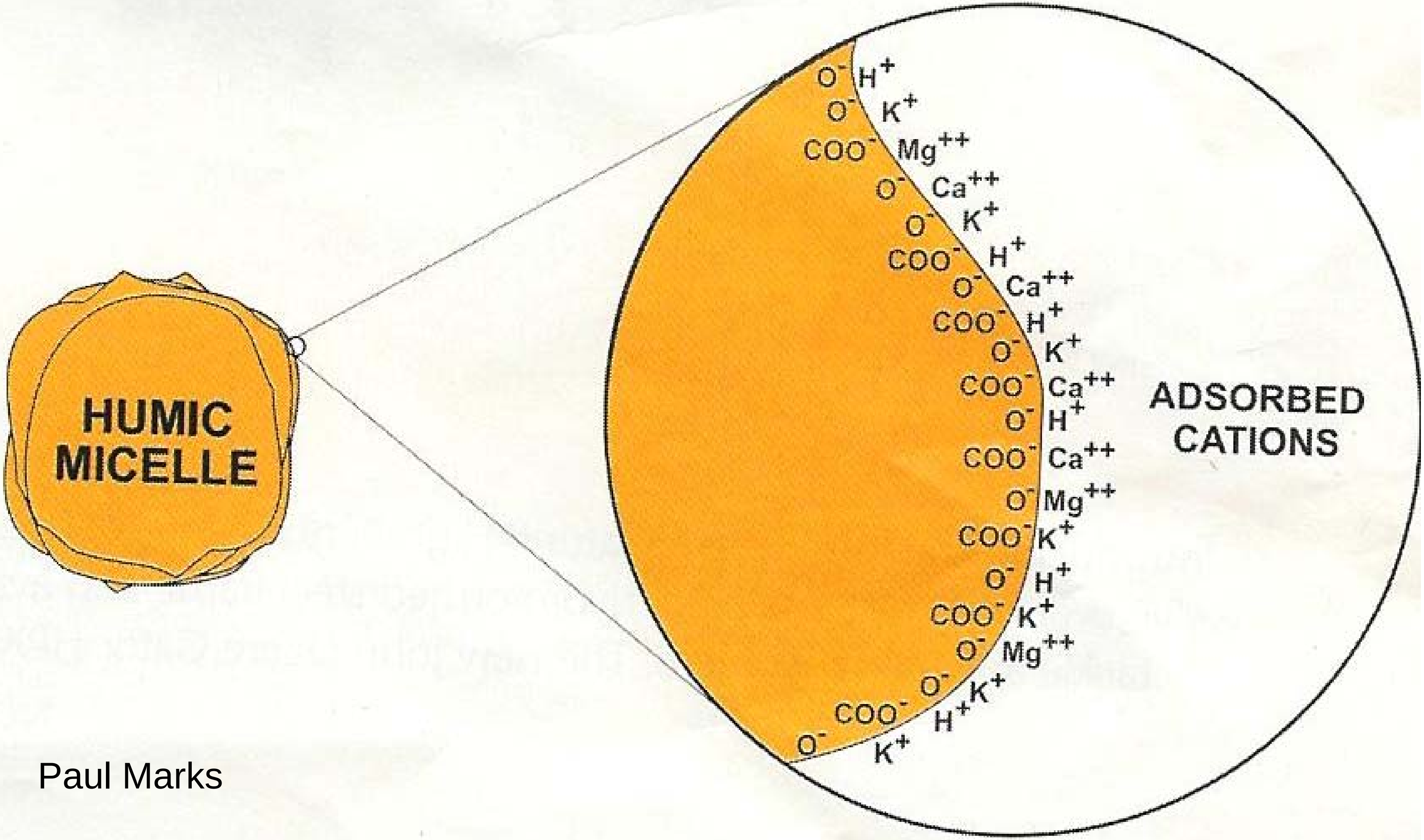
CLAY PARTICLES



Negatively charged clay particles
shown with typical plate-like
appearance and swarm of adsorbed cations

Figure 3

ORGANIC COLLOID



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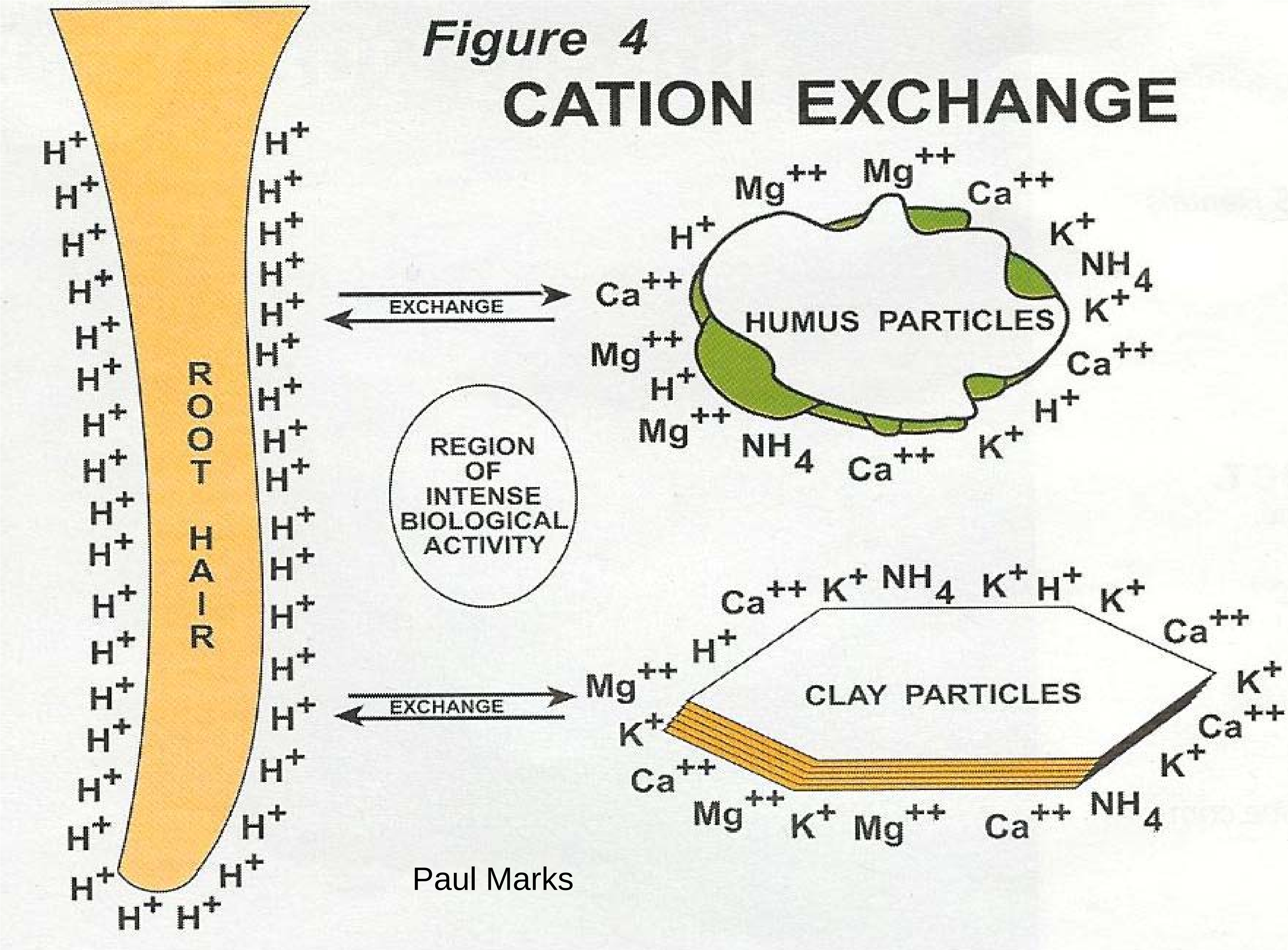
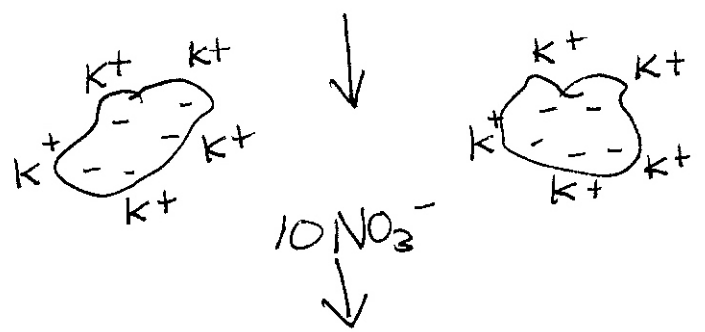


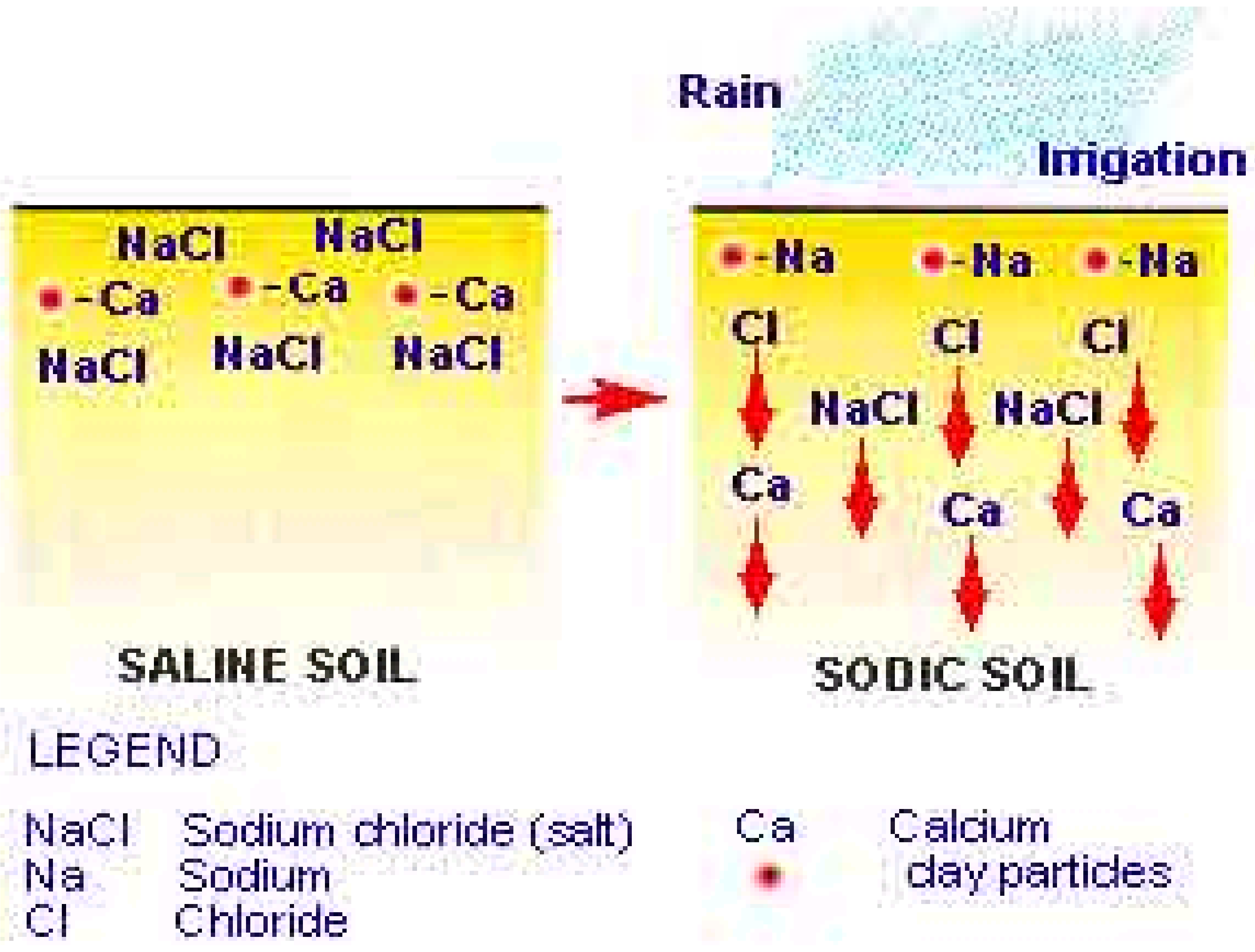
Figure 4
CATION EXCHANGE
ROOT HAIR
H^+
EXCHANGE
EXCHANGE
REGION OF INTENSE BIOLOGICAL ACTIVITY
HUMUS PARTICLES
CLAY PARTICLES
Mg^{++}
Ca^{++}
K^+
NH_4
H^+
Paul Marks

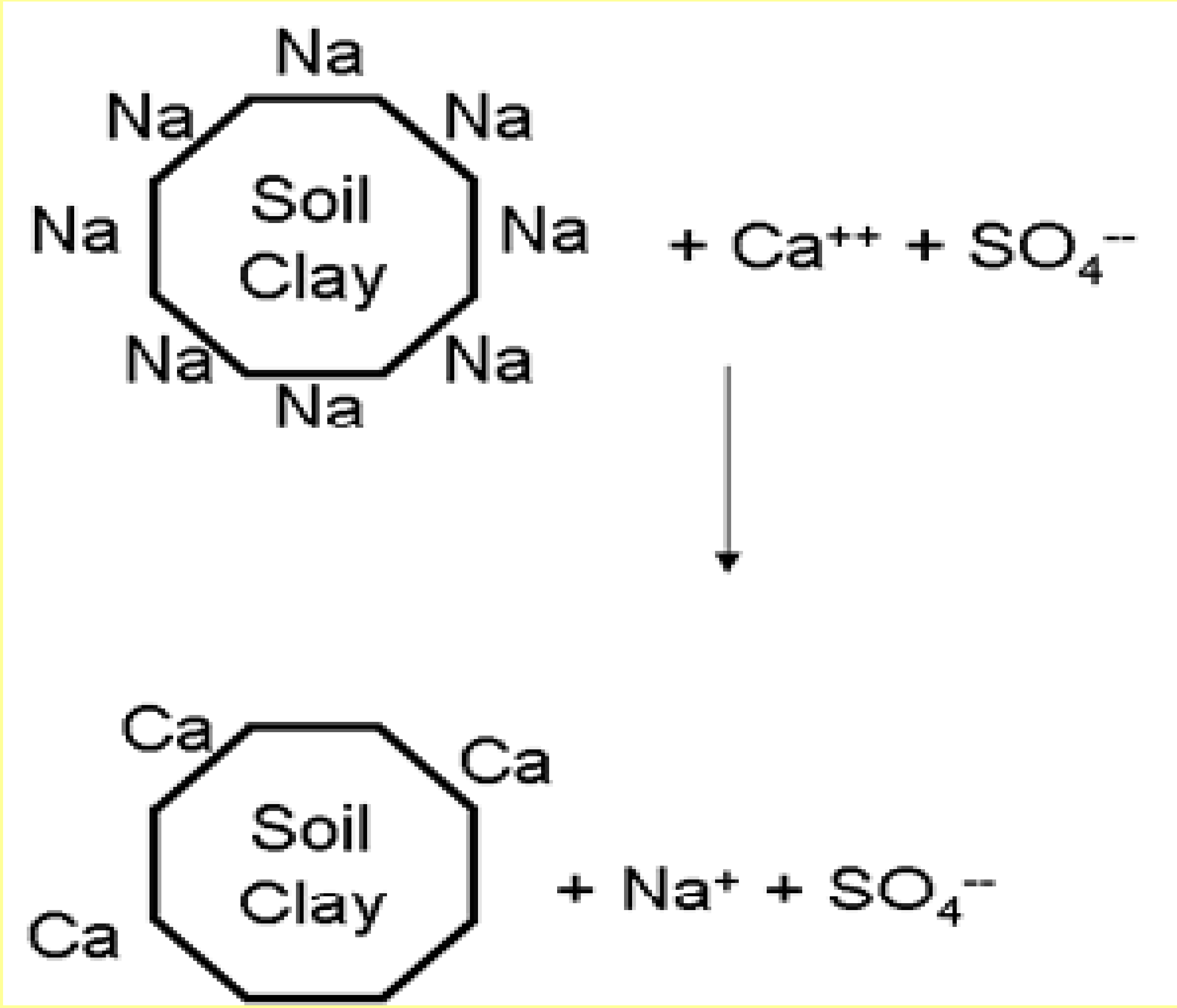
Potassium Nitrate

KNO_3

$$\underset{\text{molecule}}{10\,KNO_3} \; \underset{\text{remove } H_2O}{\overset{\text{add } H_2O}{\rightleftharpoons}} \; \underset{\text{cation}}{10\,K^+} + \underset{\text{Anion}}{10\,NO_3^-}$$




Rain
Irrigation
NaCl
NaCl
-Ca
-Ca
-Ca
NaCl
NaCl
NaCl
SALINE SOIL
-Na
-Na
-Na
Cl
Cl
Cl
NaCl
NaCl
Ca
Ca
Ca
SODIC SOIL
LEGEND
NaCl Sodium chloride (salt)
Na Sodium
Cl Chloride
Ca Calcium
day particles



Na
Na
Na
Na
Soil
Clay
Na
Na
Na
Na
+ Ca++ + SO4--
Ca
Ca
Soil
Clay
Ca
+ Na+ + SO4--

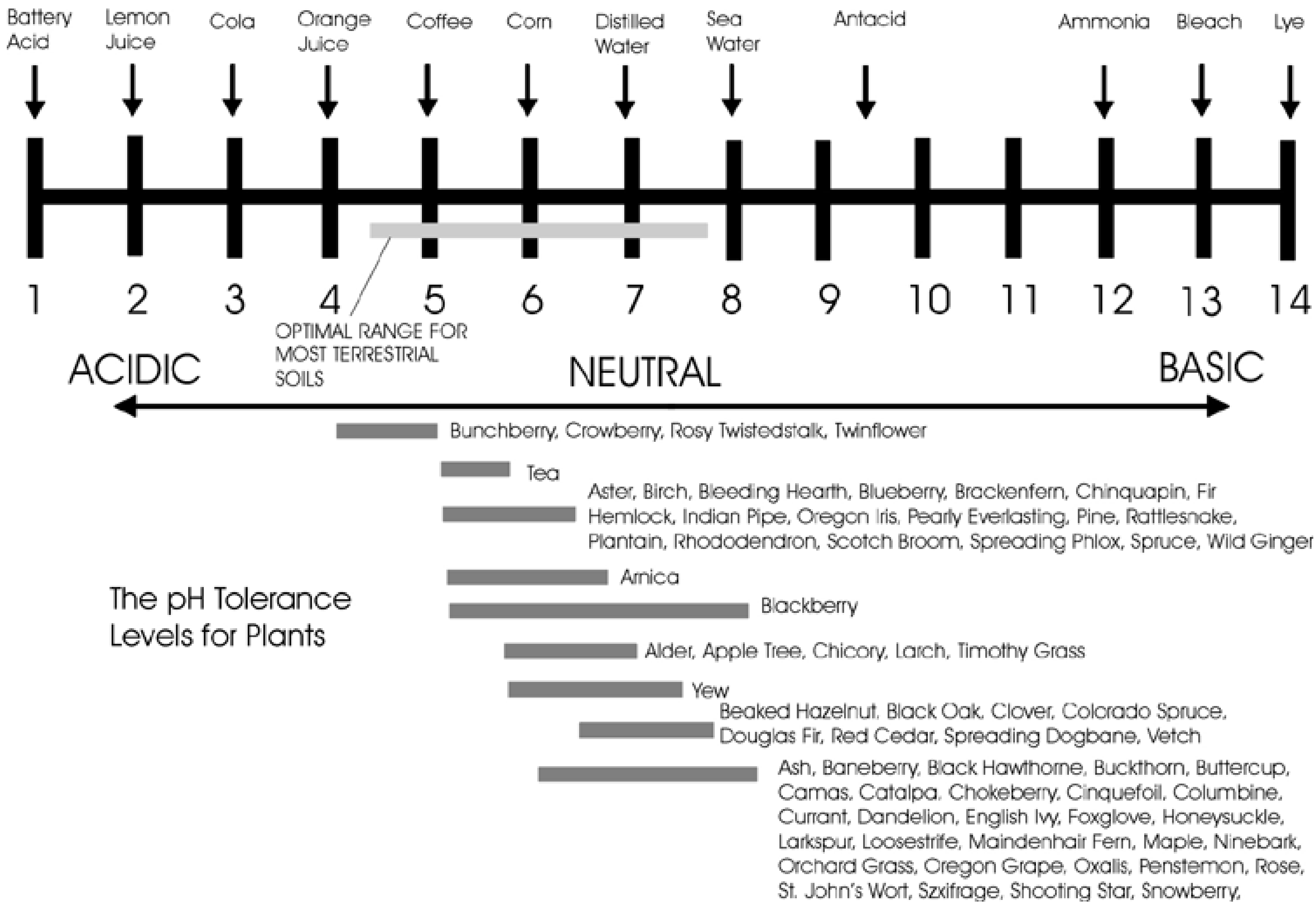
Cation exchange capacity

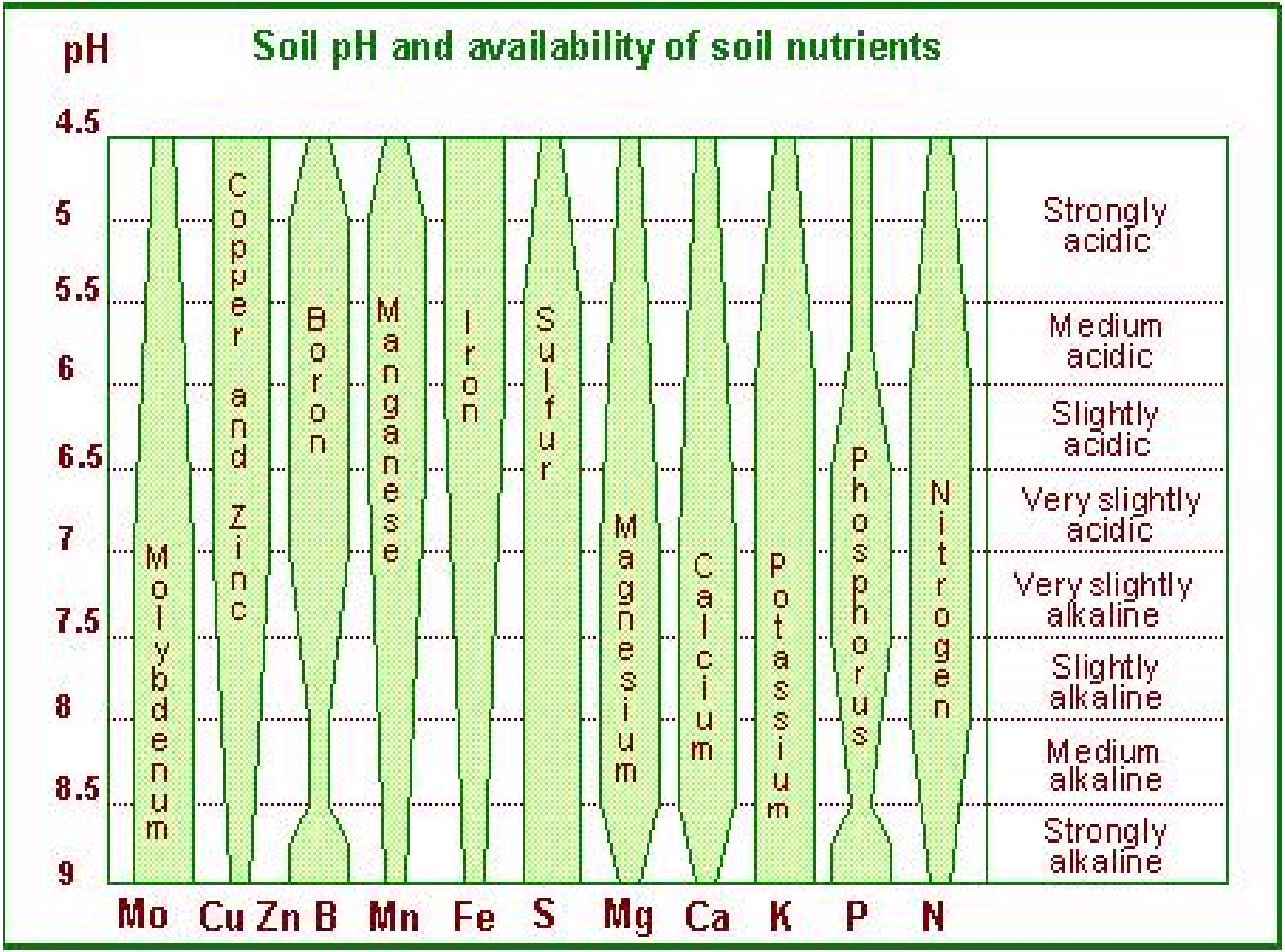
- Soil ability to attract, retain and exchange cations
- Indirect measurement of clay content because clays have more active (-) sites
- Coarser soils with fewer active sites less able to hold cations

Soil pH

- Measure of the acidity or alkalinity of soil.
- Measures concentration of H in soil
- pH scale ranges from 0 – 14
- 0 – 7 = acidic; 7 = neutral; 7-14 = alkaline
- Negative logarithmic function – each whole number is a factor of 10 different from the next – 4.0 is 10 times more acidic than 5.0, 100 times more than 6.0, 1000 times more than 7.0

pH Scale for Soils





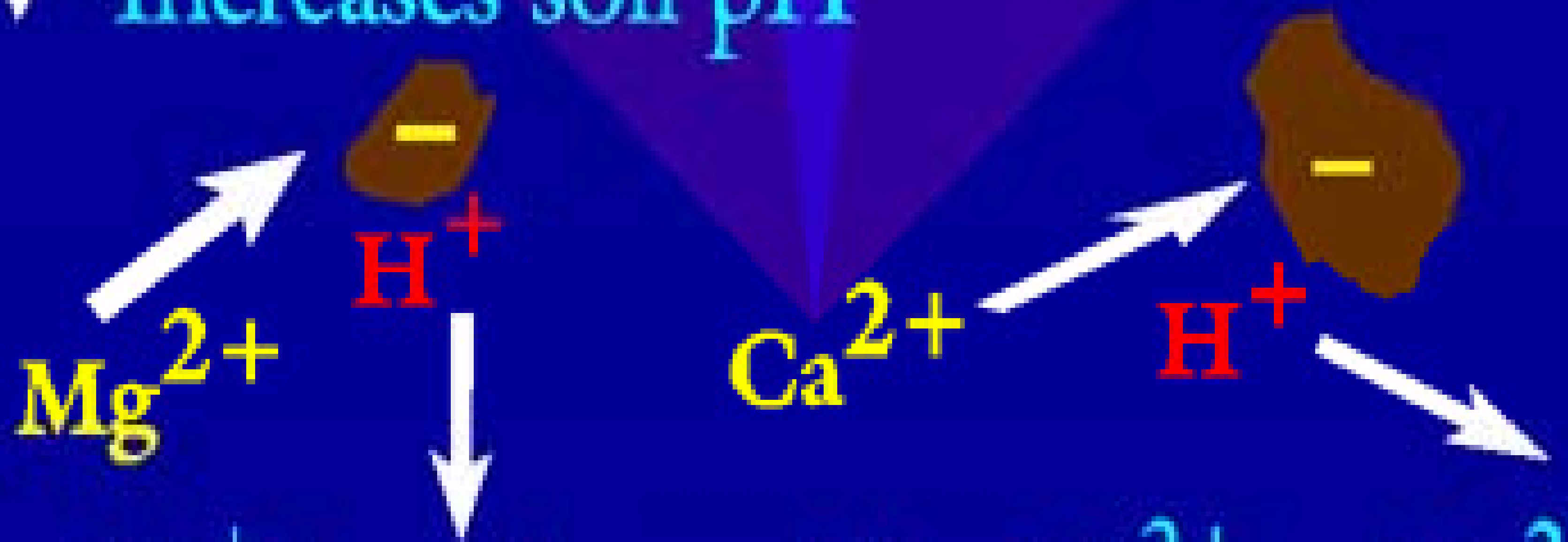
pH
Soil pH and availability of soil nutrients
4.5
5
5.5
6
6.5
7
7.5
8
8.5
9
Molybdenum
Copper and Zinc
Boron
Manganese
Iron
Sulfur
Magnesium
Calcium
Potassium
Phosphorus
Nitrogen
Strongly acidic
Medium acidic
Slightly acidic
Very slightly acidic
Very slightly alkaline
Slightly alkaline
Medium alkaline
Strongly alkaline
Mo
Cu Zn B
Mn
Fe
S
Mg
Ca
K
P
N

Soil pH

- Most plants have a soil pH preference range that mirrors the soil conditions where the plant evolved
- Soil pH can be manipulated by additions of limestone (Ca and Mg oxides and carbonates to raise pH) or sulfur (lower pH)
- Buffering capacity – ability of soil to resist a change in pH – clays are better than sands

Liming

- ✓ Increases soil pH



- ✓ H^+ is exchanged for Ca^{2+} or Mg^{2+} on cation exchange sites and the acidity of the soil is neutralized

18 essential elements

- Macronutrients – N, P, K, Ca, Mg, S – usually in 0.25% - 2.0% of woody plant dry matter
- Micronutrients – Fe, Mn, Cu, Zn, B, Mo, Cl, Co, Ni – content in woody plant dry matter usually in ppm range

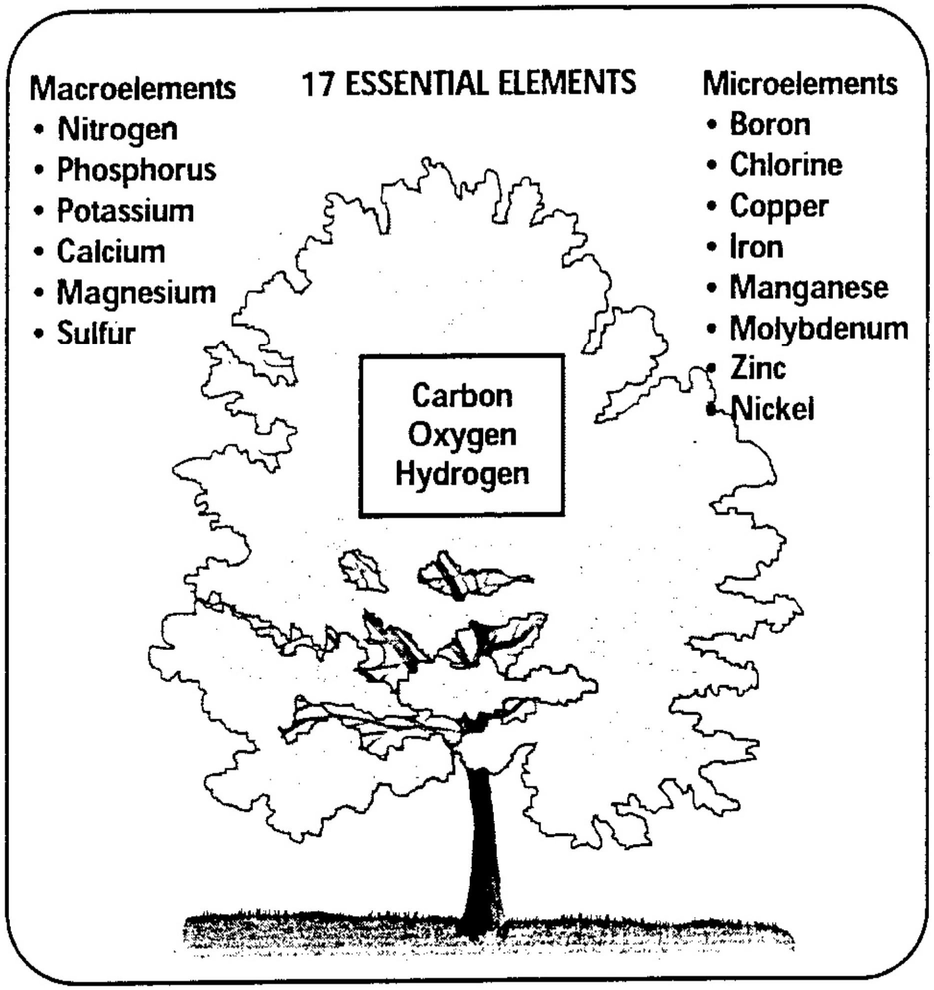


Figure 5.1 Trees require 17 essential elements.

Carbon, hydrogen and oxygen

- The basics for carbohydrates – the building blocks of plant tissue
- Make up 95 – 98% of most plants
- Derived from air (to roots and foliage) and water
- Availability depends on soil and root health

Soil – a storehouse for nitrogen

- Organic N average 0.15% in US soils
- Over 3000 lb N/A (6 inch depth)
- 68 lb N/1000 sq ft
- Slow availability
- Provides the bulk of the N taken up by woody plants in natural settings and landscapes

10-10-10 Fall

0-10-10 Spring

Fraser firs planted in 2001
Treatments applied annually since 2002

Photos taken 3/8/06

No Fertilization

10-10-10 Spring

10-10-10 Spring & Fall

Fertilization

- Most nutrients supplied by soil in survival amounts but often not enough to meet modern landscape standards
- Fertilization is done to supplement nature's supply, often making the difference between thriving and surviving landscapes

Fertilizer terms

- Complete fertilizer – contains nitrogen, phosphorus and potassium
- Fertilizer analysis – relative percentage of each element supplied and guaranteed on the label – a product with a 5-10-10 analysis has 5% N, 10% P (P_2O_5) and 10% K (K_2O)
- Fertilizer burn – presence of excess fertilizer salts in root zone, pulling water out of roots by osmosis, causing scorched foliage or plant death

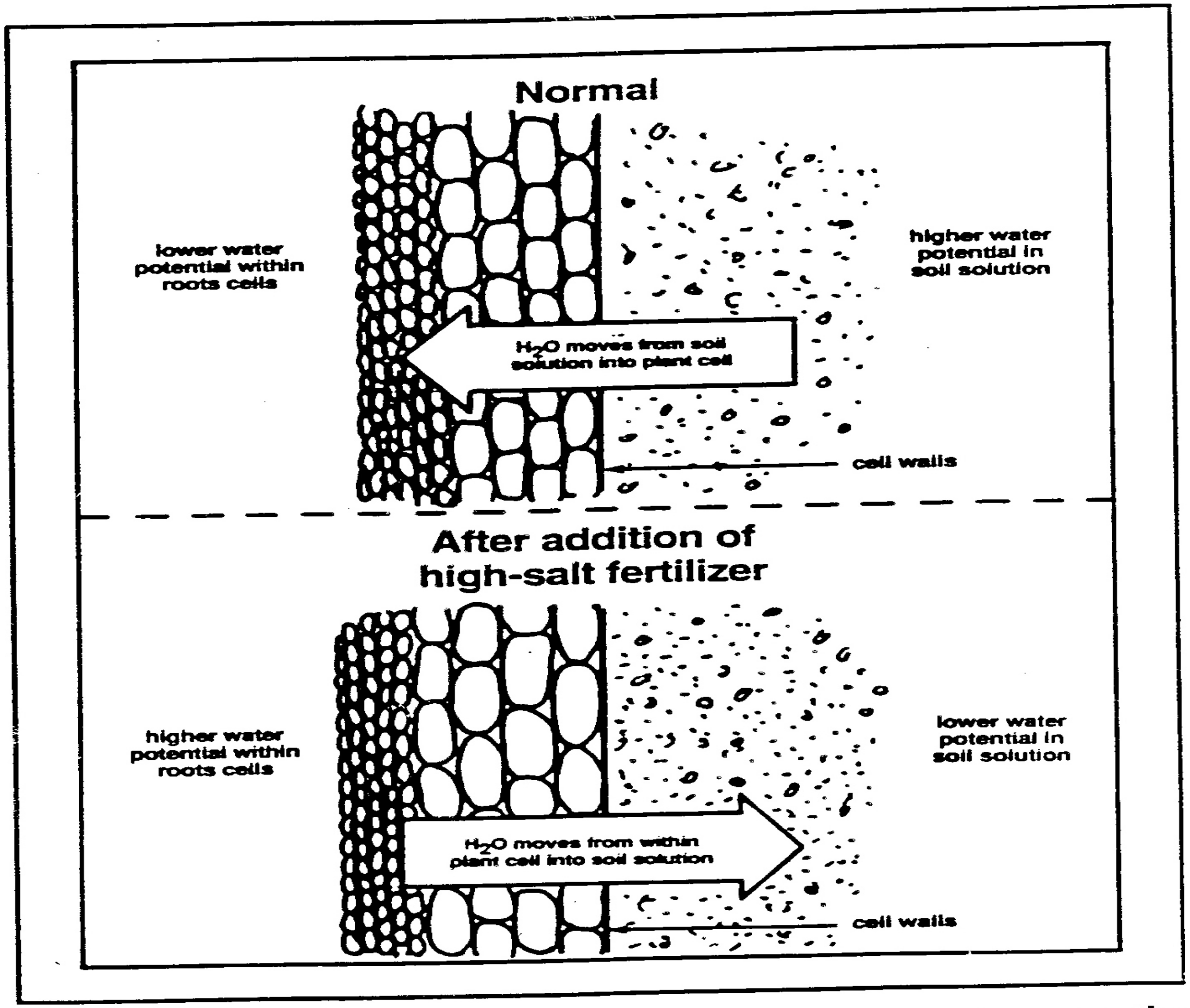
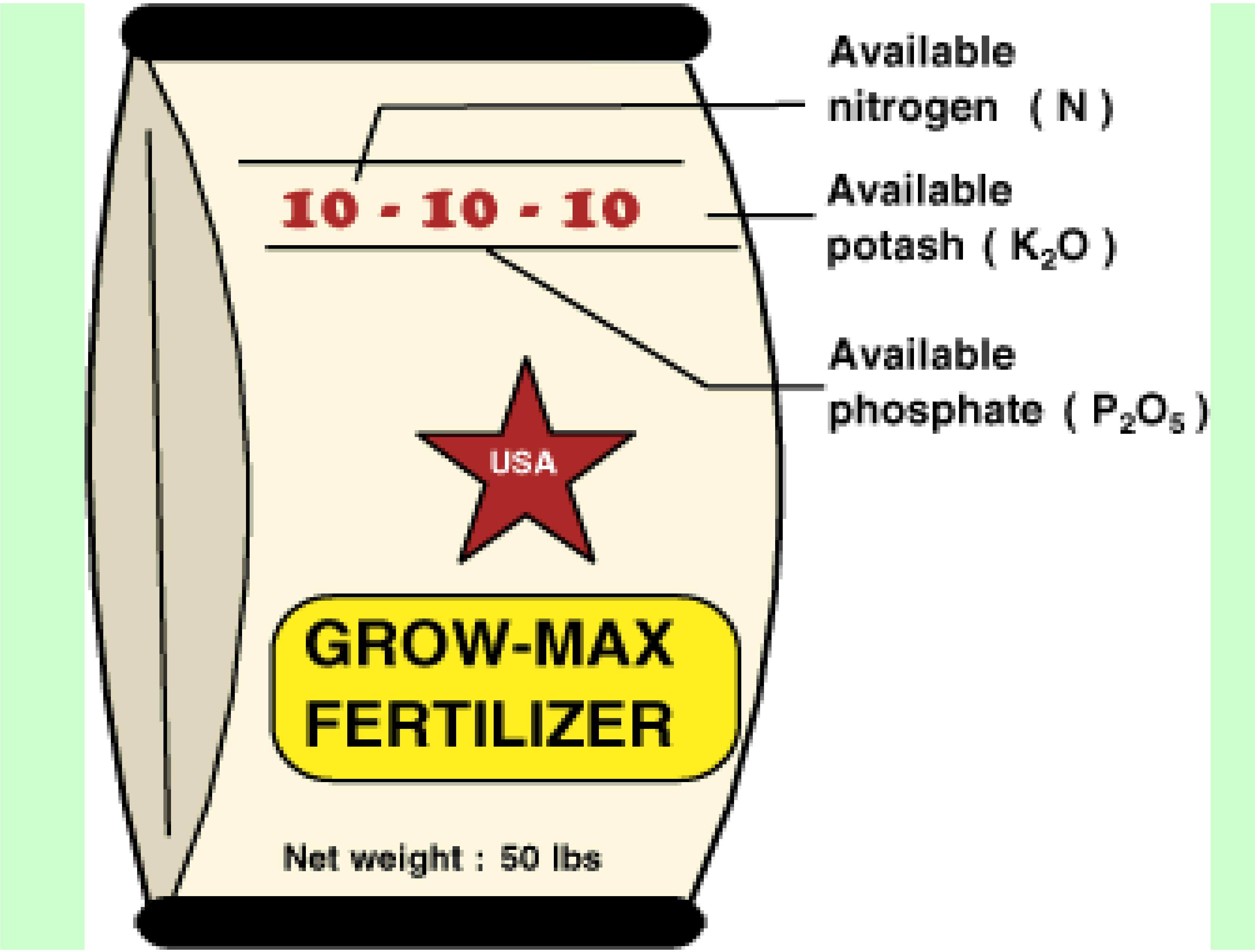


Fig. 5.8 Excessive soluble salts in the root zone can reverse the osmotic process, drawing water out of the roots.


10 - 10 - 10
USA
GROW-MAX
FERTILIZER
Net weight : 50 lbs
Available nitrogen (N)
Available potash (K_2O)
Available phosphate (P_2O_5)

Fertilizer terms

- Inorganic fertilizer – release their essential elements when they contact water – quick, short term availability
- Controlled release fertilizer – releases essential elements over extended period; the release mechanism may be slow solubility, dependant on microbial degradation or coated with a permeable material
- Water insoluble nitrogen – 20-30% dissolution rate of N

Organic fertilizer

- Chemical definition – Any fertilizer composed of carbon based molecules, synthetic or natural; chemical or biological decomposition needed to make essential elements available
- Traditional definition – any non-synthetic product derived from natural biological or geologic sources; can be chemically organic or inorganic

Fertilization frequency

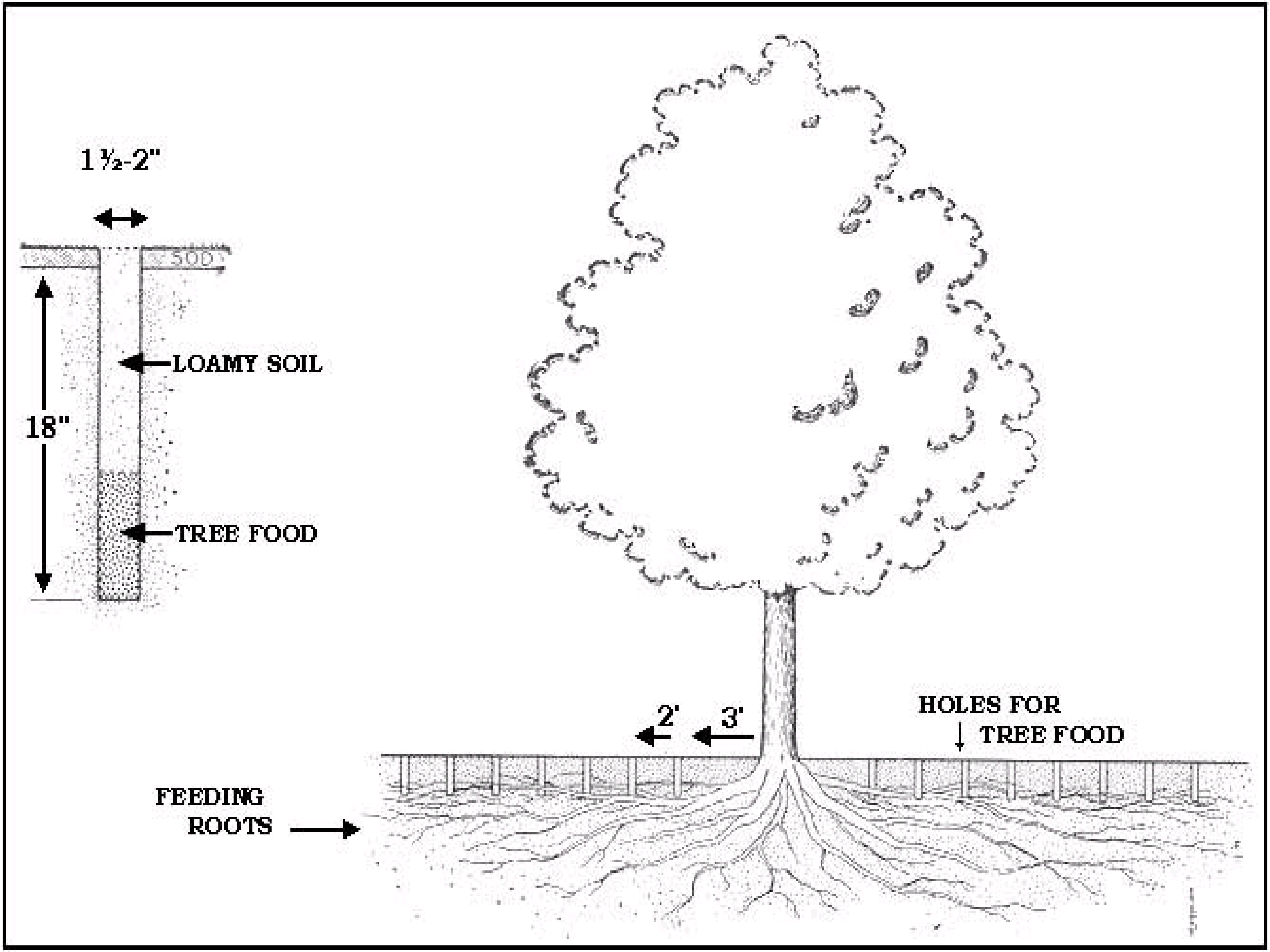
- Dependant on soil conditions
- Fine textured soils can hold nutrients longer – larger amounts can be applied less frequently
- Coarse textured soils can not hold nutrients for very long – smaller, more frequent applications are more appropriate

Fertilization methods

- Broadcast – easiest and least expensive; usually, granular fertilizer products are spread uniformly over soil surface – may interfere with other plantings/turf
- Drill hole method – concentric grid pattern of drill holes into which granular fertilizers are poured – affects trees but not other plants/turf

Fertilization methods

- Subsurface injection (deep root feeding) – pressurized injection of dissolved or suspended fertilizer into the root zones of woody plants – little effect on other plants
- Foliar feeding – low concentration of soluble fertilizer in a fine mist directly to foliage – impractical for general fertilization but can be useful for temporary deficiency remedy
- Implants and tree injection – in capsule or solution injected directly into xylem – can work for some deficiencies or to stimulate local growth


1½-2"
SOD
18"
LOAMY SOIL
TREE FOOD
2'
3'
HOLES FOR
TREE FOOD
FEEDING
ROOTS

Fertility related analyses

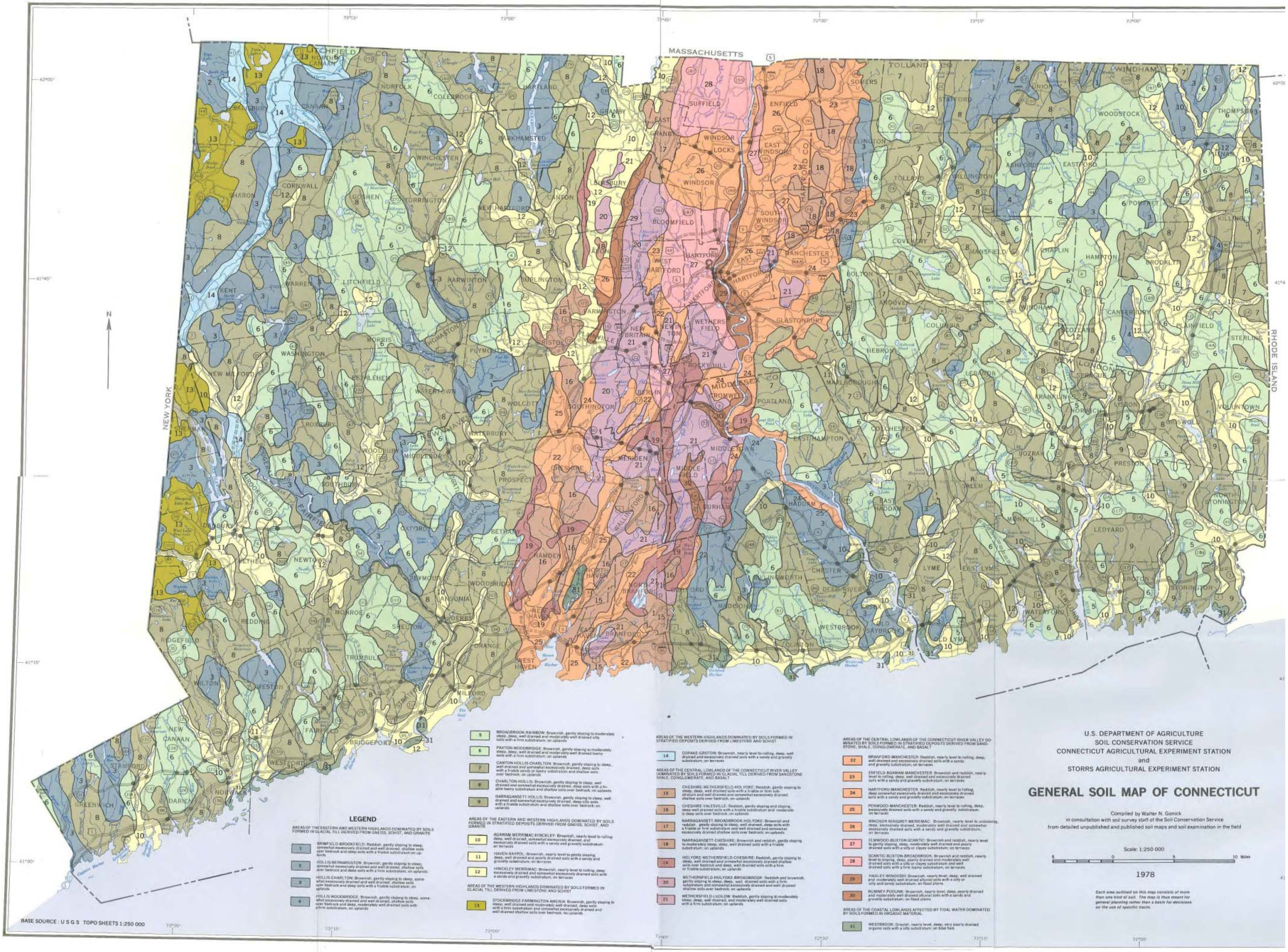
- Soil analysis – info on physical and chemical characteristics; soil pH, soil texture, organic matter content and major nutrients; limestone and fertilizer suggestions made – very useful to monitor over time; sampling method critical
- Foliar analysis – useful in conjunction with soil analysis; can accurately reflect how tree uses nutrition; sampling method critical


Adult exit hole
Oviposition sites

The Emerald Ash Borer

Serpentine Galleries


HOBBY LOBBY
Jim Urban


MASSACHUSETTS
NEW YORK
RHODE ISLAND
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U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
CONNECTICUT AGRICULTURAL EXPERIMENT STATION
and
STORRS AGRICULTURAL EXPERIMENT STATION
GENERAL SOIL MAP OF CONNECTICUT
Compiled by Walter N. Gonick
in consultation with soil survey staff of the Soil Conservation Service
from detailed unpublished and published soil maps and soil examination in the field
Scale: 1:250 000
5 0 5 10 Miles
1978
Each area outlined on this map consists of more than one kind of soil. The map is thus meant for general planning rather than a basis for decisions on the use of specific tracts.
LEGEND
AREAS OF THE EASTERN AND WESTERN HIGHLANDS DOMINATED BY SOILS FORMED IN GLACIAL TILL DERIVED FROM GNEISS, SCHIST, AND GRANITE
1 BRIMFIELD-BROOKFIELD: Reddish, gently sloping to steep, somewhat excessively drained and well drained, shallow soils over bedrock and deep soils with a friable substratum; on uplands
2 HOLLIS-BERNARDSTON: Brownish, gently sloping to steep, somewhat excessively drained and well drained, shallow soils over bedrock and deep soils with a firm substratum; on uplands
3 HOLLIS-CHARLTON: Brownish, gently sloping to steep, somewhat excessively drained and well drained, shallow soils over bedrock and deep soils with a friable substratum; on uplands
4 HOLLIS-WOODBRIDGE: Brownish, gently sloping to steep, somewhat excessively drained and well drained, shallow soils over bedrock and deep, moderately well drained soils with a firm substratum; on uplands
5 BROADBROOK-RAINBOW: Brownish, gently sloping to moderately steep, deep, well drained and moderately well drained silty soils with a firm substratum; on uplands
6 PAXTON-WOODBRIDGE: Brownish, gently sloping to moderately steep, deep, well drained and moderately well drained loamy soils with a firm substratum; on uplands
7 CANTON-HOLLIS-CHARLTON: Brownish, gently sloping to steep, well drained and somewhat excessively drained, deep soils with a friable sandy or loamy substratum and shallow soils over bedrock; on uplands
8 CHARLTON-HOLLIS: Brownish, gently sloping to steep, well drained and somewhat excessively drained, deep soils with a friable loamy substratum and shallow soils over bedrock; on uplands
9 NARRAGANSETT-HOLLIS: Brownish, gently sloping to steep, well drained and somewhat excessively drained, deep silty soils with a friable substratum and shallow soils over bedrock; on uplands
AREAS OF THE EASTERN AND WESTERN HIGHLANDS DOMINATED BY SOILS FORMED IN STRATIFIED DEPOSITS DERIVED FROM GNEISS, SCHIST, AND GRANITE
10 AGAWAM-MERRIMAC-HINCKLEY: Brownish, nearly level to rolling deep, well drained, somewhat excessively drained, and excessively drained soils with a sandy and gravelly substratum; on terraces
11 HAVEN-RAYPOL: Brownish, nearly level to gently sloping, deep, well drained and poorly drained soils with a sandy and gravelly substratum; on terraces
12 HINCKLEY-MERRIMAC: Brownish, nearly level to rolling, deep excessively drained and somewhat excessively drained soils with a sandy and gravelly substratum; on terraces
AREAS OF THE WESTERN HIGHLANDS DOMINATED BY SOILS FORMED IN GLACIAL TILL DERIVED FROM LIMESTONE AND SCHIST
13 STOCKBRIDGE-FARMINGTON-AMENIA: Brownish, gently sloping to steep, well drained and moderately well drained, deep soils with a firm substratum and somewhat excessively drained and well drained shallow soils over bedrock; on uplands
AREAS OF THE WESTERN HIGHLANDS DOMINATED BY SOILS FORMED IN STRATIFIED DEPOSITS DERIVED FROM LIMESTONE AND SCHIST
14 COPAKE-GROTON: Brownish, nearly level to rolling, deep, well drained and excessively drained soils with a sandy and gravelly substratum; on terraces
AREAS OF THE CENTRAL LOWLANDS OF THE CONNECTICUT RIVER VALLEY DOMINATED BY SOILS FORMED IN GLACIAL TILL DERIVED FROM SANDSTONE SHALE, CONGLOMERATE, AND BASALT
15 CHESHIRE-WETHERSFIELD-HOLYOKE: Reddish, gently sloping to steep, deep, well drained soils with a friable or firm substratum and well drained and somewhat excessively drained shallow soils over bedrock; on uplands
16 CHESHIRE-YALESVILLE: Reddish, gently sloping and sloping, deep well drained soils with a friable substratum and moderately deep soils over bedrock; on uplands
17 NARRAGANSETT-BROADBROOK-HOLYOKE: Brownish and reddish, gently sloping to steep, well drained, deep soils with a friable or firm substratum and well drained and somewhat excessively drained shallow soils over bedrock; on uplands
18 NARRAGANSETT-CHESHIRE: Brownish and reddish, gently sloping to moderately steep, deep, well drained soils with a friable substratum; on uplands
19 HOLYOKE-WETHERSFIELD-CHESHIRE: Reddish, gently sloping to steep, well drained and somewhat excessively drained shallow soils over bedrock and deep, well drained soils with a firm or friable substratum; on uplands
20 WETHERSFIELD-HOLYOKE-BROADBROOK: Reddish and brownish, gently sloping to steep, deep, well drained soils with a firm substratum and somewhat excessively drained and well drained shallow soils over bedrock; on uplands
21 WETHERSFIELD-LUDLOW: Reddish, gently sloping to moderately steep, deep, well drained, and moderately well drained soils with a firm substratum; on uplands
AREAS OF THE CENTRAL LOWLANDS OF THE CONNECTICUT RIVER VALLEY DOMINATED BY SOILS FORMED IN STRATIFIED DEPOSITS DERIVED FROM SANDSTONE, SHALE, CONGLOMERATE, AND BASALT
22 BRANFORD-MANCHESTER: Reddish, nearly level to rolling, deep, well drained and excessively drained soils with a sandy and gravelly substratum; on terraces
23 ENFIELD-AGAWAM-MANCHESTER: Brownish and reddish, nearly level to rolling, deep, well drained and excessively drained soils with a sandy and gravelly substratum; on terraces
24 HARTFORD-MANCHESTER: Reddish, nearly level to rolling, deep somewhat excessively drained and excessively drained soils with a sandy and gravelly substratum; on terraces
25 PENWOOD-MANCHESTER: Reddish, nearly level to rolling, deep, excessively drained soils with a sandy and gravelly substratum; on terraces
26 WINDSOR-NINIGRET-MERRIMAC: Brownish, nearly level to undulating, deep, excessively drained, moderately well drained and somewhat excessively drained soils with a sandy and gravelly substratum; on terraces
27 ELMWOOD-BUXTON-SCANTIC: Brownish and reddish, nearly level to gently sloping, deep, moderately well drained and poorly drained soils with a silty or clayey substratum; on terraces
28 SCANTIC-BUXTON-BROADBROOK: Brownish and reddish, nearly level to sloping, deep, poorly drained and moderately well drained soils with a silty or clayey substratum and well drained soils with a firm loamy substratum; on terraces
29 HADLEY-WINOOSKI: Brownish, nearly level, deep, well drained and moderately well drained alluvial soils with a silty or silty and sandy substratum; on flood plains
30 RUMNEY-PODUNK: Brownish, nearly level, deep, poorly drained and moderately well drained alluvial soils with a sandy and gravelly substratum; on flood plains
AREAS OF THE COASTAL LOWLANDS AFFECTED BY TIDAL WATER DOMINATED BY SOILS FORMED IN ORGANIC MATERIAL
31 WESTBROOK: Grayish, nearly level, deep, very poorly drained organic soils with a silty substratum; on tidal flats
BASE SOURCE: U S G S TOPO SHEETS 1:250 000