The impact of inorganic fertilizers and pesticides on soil health – environmental issues of industrial agriculture

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Summary

Although fertilisers are used in agriculture to replenish soil nutrients the excessive use of inorganic industrial fertilizers in industrial agriculture results in biological, chemical and physical soil degradation such as loss of soil-biodiversity, nitrogen leaching, soil compaction, reduction in soil organic matter, and loss of soil carbon. Similarly, the use of pesticides due their xenobiotics characteristics may adversely affect beneficial, particularly nitrogen-fixing and phosphorus- solubilizing soil microorganisms and essential symbionts. Supporters of industrial agriculture based on heavy use of agrochemicals ferociously oppose the introduction of organic agriculture as economically non-viable production structures created by green idealists. However, the only way forward for healthy agro-ecosystems with healthy soils is a multi scale precision organic agriculture based on reuse of natural resources and the introduction of circular agro-economies, a compromise between permaculture and large-scale agricultural production. In a long term, there is no contradiction between profitability and sustainable use of ecosystem services in multifunctional agriculture, where soil nutrition, pest management, agroforestry, irrigation, core products, augmented and ancillary products and services, wastewater and solid waste management, renewable energy systems and regional/rural planning are treated in one integrated system.

Structure of the lecture

I. Basic concepts – the cornerstones of the sustainable system

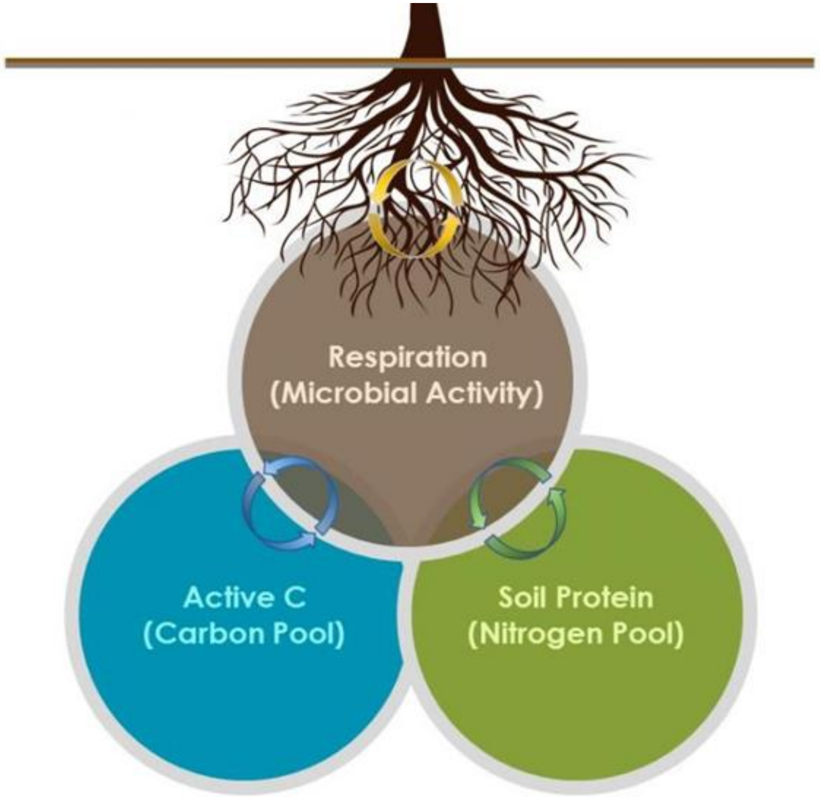
- Soil health and soil degradation
- Nutrients and nutrient cycling – soil biogeochemistry and biodiversity
- Cation Exchange Capacity (CEC)
- Soil pH and nutrient bio-availability
- Fertilizers, pesticides, POPs
- Agriculture definitions
  - Industrial agriculture
  - Precision agriculture
  - Urban agriculture
  - Organic agriculture
  - Permaculture
  - Multifunctional agriculture

II. Impact of artificial inorganic fertilizers & pesticides; ecological solutions

- Industrial mineral fertilizers
- Excess nitrate and acidification
- Excess nutrient toxicity
- Impact of pesticides on soils
- Ecological solutions
  - Natural mineral soil improvers
  - Multifunctional agriculture and ecocycles
  - System solutions for organic nutrient replenishment
  - Irrigation, wastewater reuse
- Viable circular rural economy: the universal Azienda Agricola Model

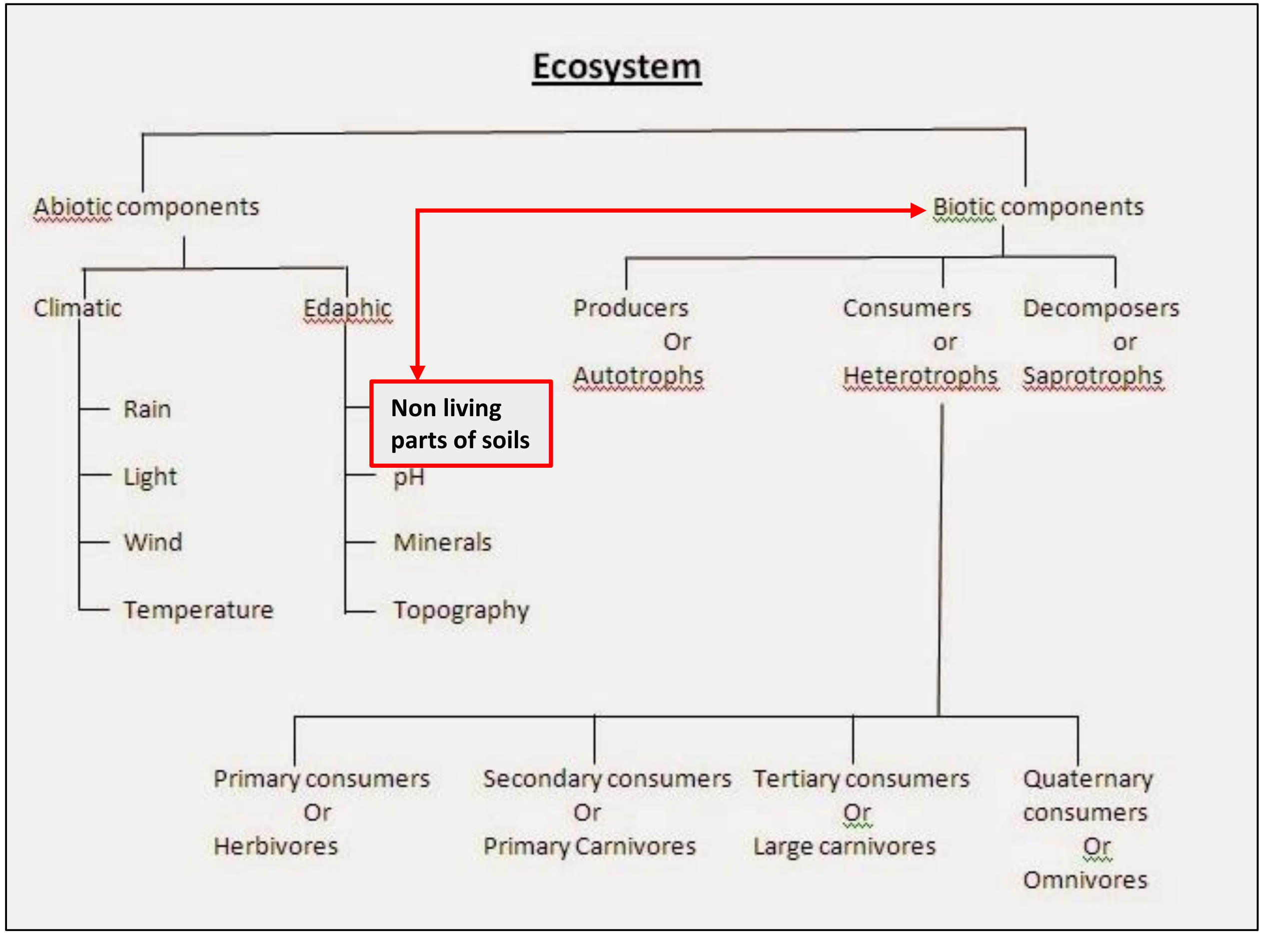
SOIL HEALTH

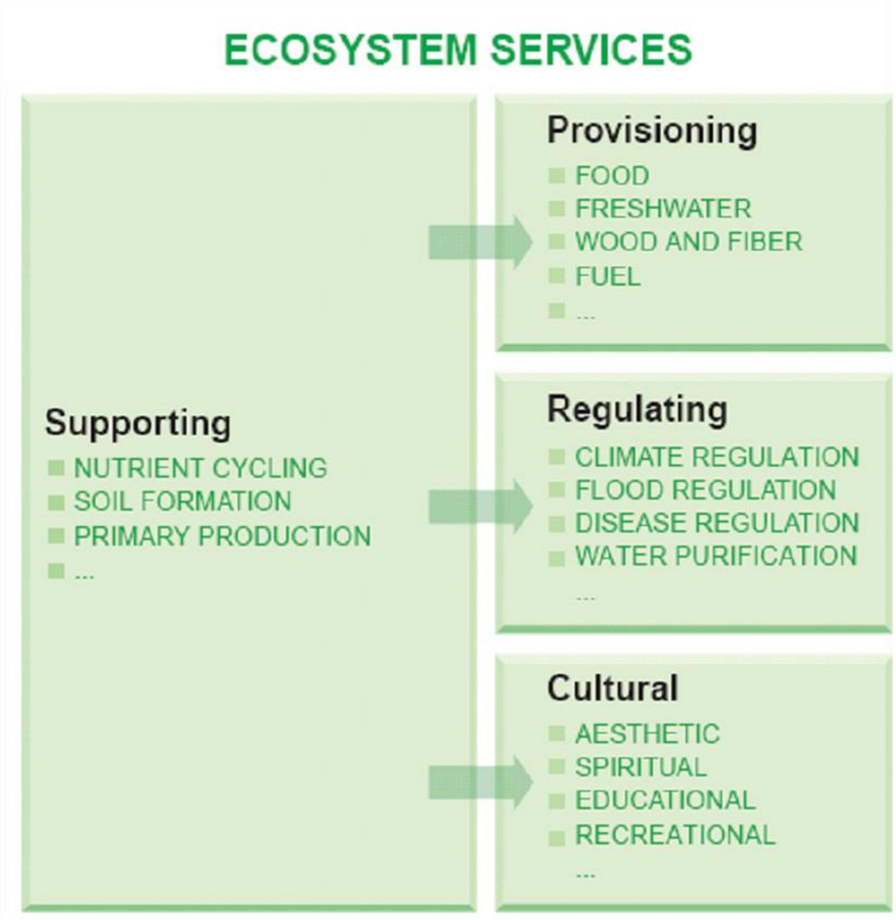
Healthy Soils Support Ecosystem Function
Water Storage + Filtration
Carbon Capture + Storage
Biological Function + Diversity
Productive Capacity



Respiration (Microbial Activity)
Active C (Carbon Pool)
Soil Protein (Nitrogen Pool)

Ecosystems & Ecosystem Services – Soils Are Ecosystems Providing Services





Source: modified after Mrinal Gour, 2015. http://mjcetenvsci.blogspot.com/2015/02/schematic-representation-of-structure.html

SOIL DEGRADATION

Soil degradation occurs where our activities (either directly or indirectly) cause it to become less vigorous or less healthy.

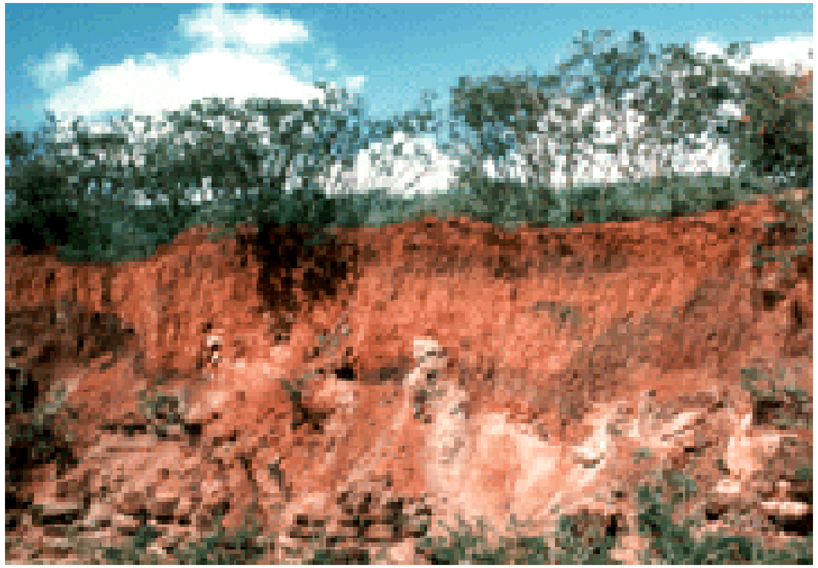
The ultimate degradation is the removal or loss of its physical components.

A soil can degrade in 3 ways:

1. Physical, chemical or biological run-down causing a reduction in vigour. This can result from excessive product removal (depleting soil nutrients), reduction in plant growth, lowered organic cycling, increasing soil temperatures, leaching, compaction and surface crusting.

2. Reduction in mass and volume through erosion. This reduces the physical size of the soil ecosystem.

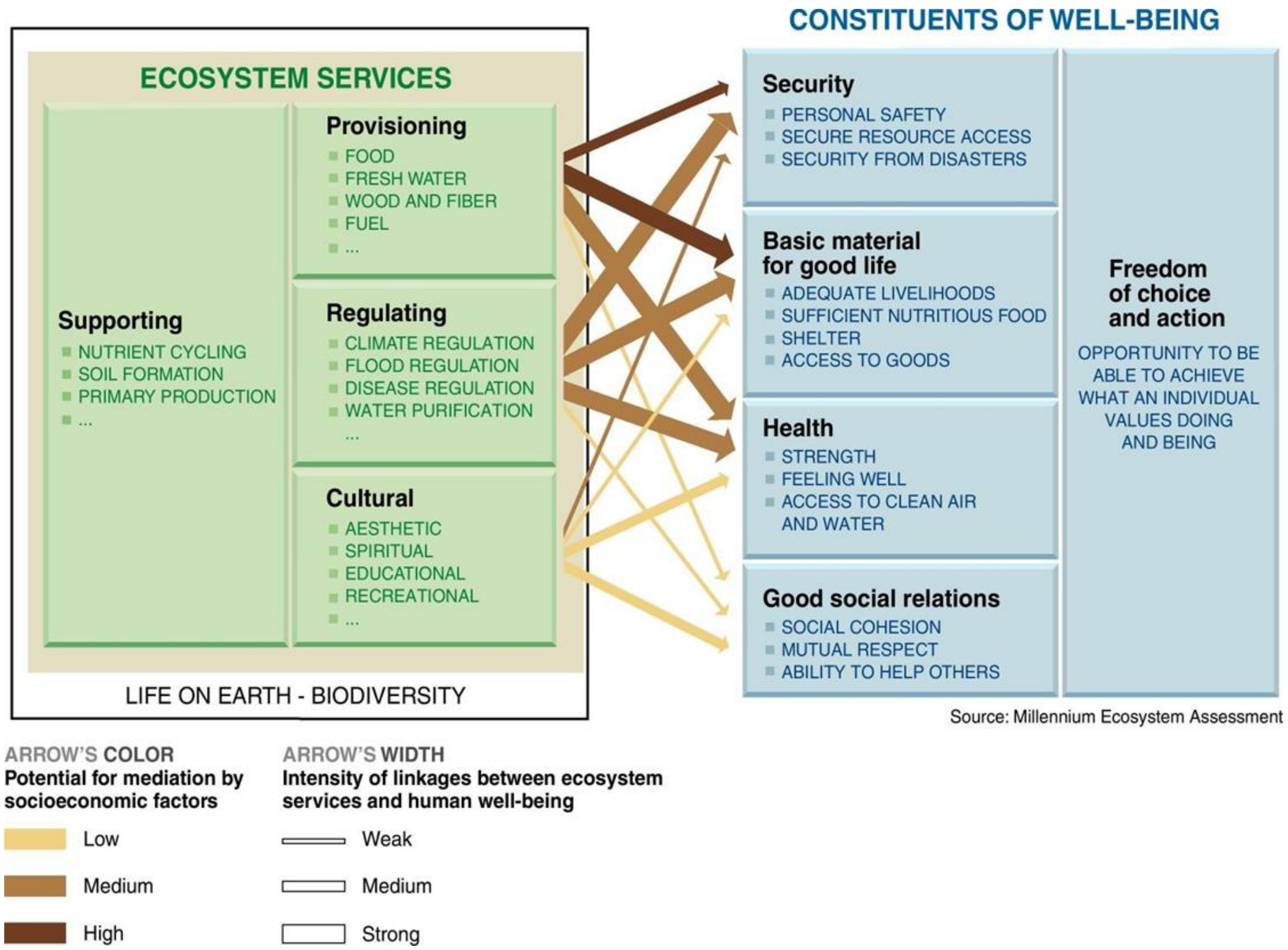
3. Accumulation of specific soil chemicals to levels that detrimentally effect plant growth. Such materials include soluble salts (causing salinity); hydrogen ions (causing acidification); and some chemicals from industrial, mining and agricultural activities (chemical contamination).



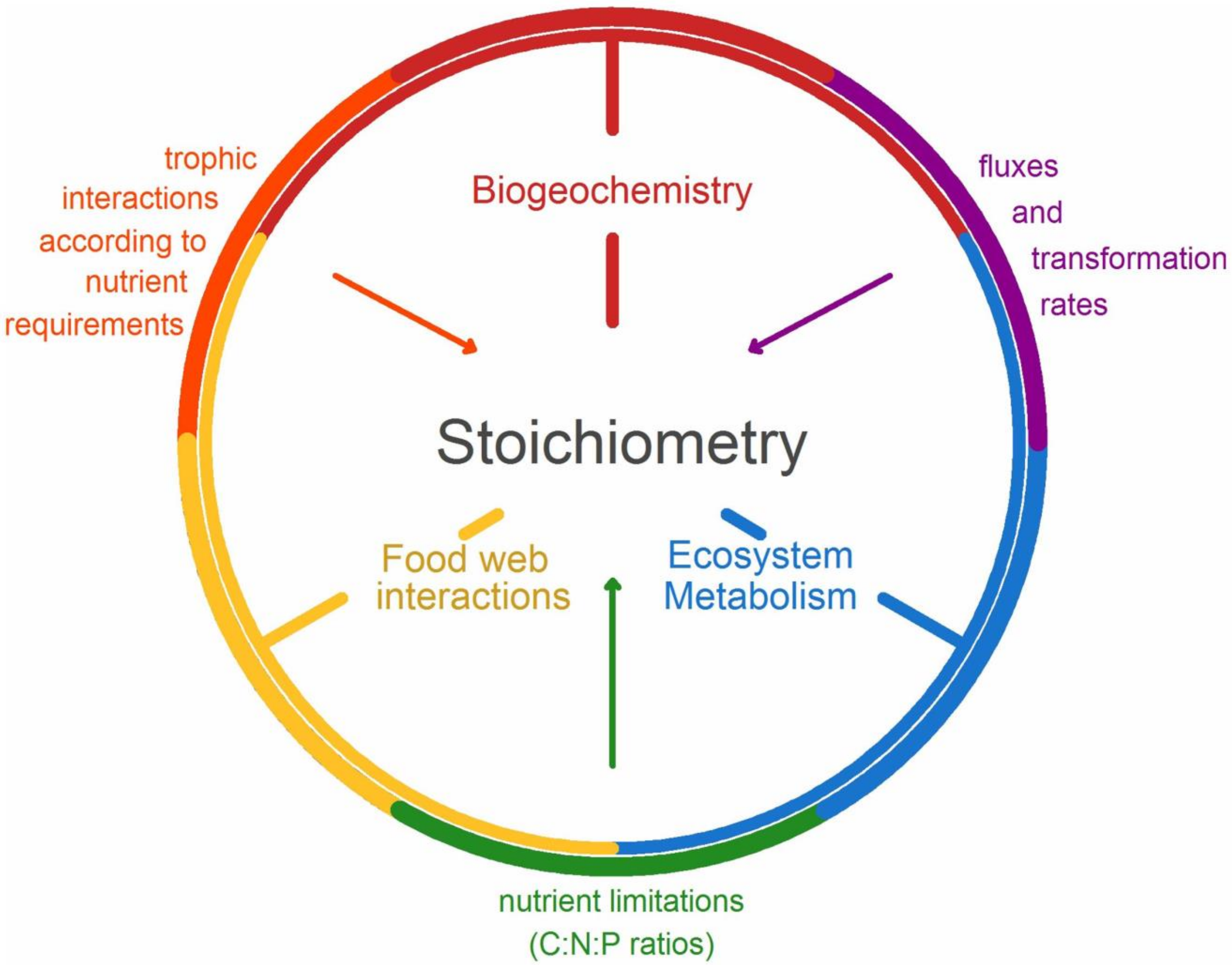
Forms of soil degradation:

- Acidification
- Salinity
- Organic depletion
- Compaction
- Nutrient depletion
- Chemical contamination
- Erosion
- Landslides

HOW TO PREVENT SOIL DEGRADATION? – BY PROTECTING ECOSYSTEM SERVICES



Nutrients and nutrient cycling – soil biogeochemistry & biodiversity



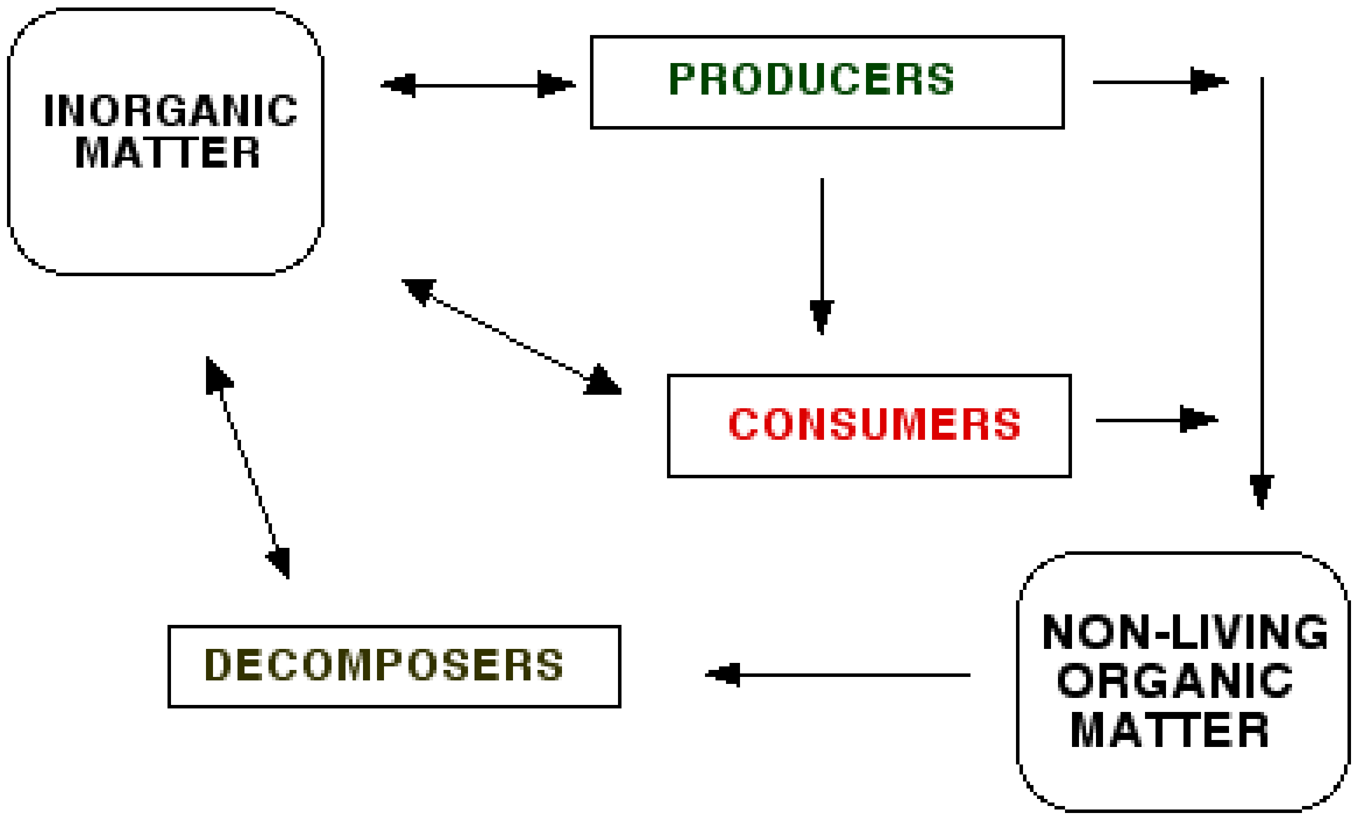
Nutrients: The Elements of Life

O OXYGEN	**K** POTASSIUM	**P** PHOSPHORUS
C CARBON	**Si** SILICON	**Cl** CHLORINE
H HYDROGEN	**Mg** MAGNESIUM	**Fe** IRON
N NITROGEN	**S** SULFUR	**Mn** MANGANESE
Ca CALCIUM	**Al** ALUMINUM	**Na** SODIUM

- Of the 50 to 70 elements that are found in living things, only about 15 account for the major portion of living biomass.

- Only around half of these 15 have been studied extensively as they travel through ecosystems or circulate on a global scale.

A GENERALIZED MODEL OF NUTRIENT CYCLING IN AN ECOSYSTEM

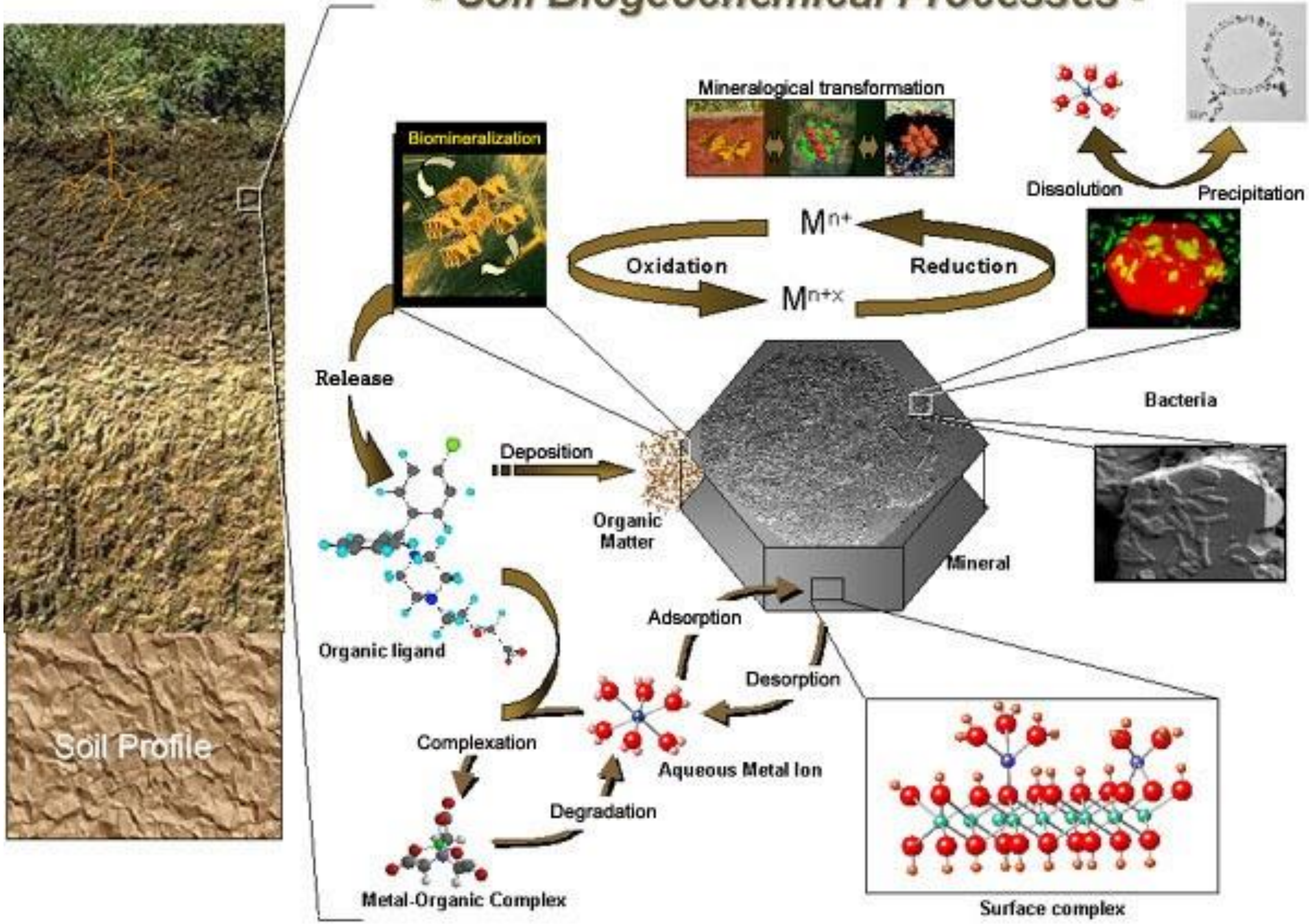


- The cycling of nutrients in an ecosystem are interlinked by a number of processes that move elements from and through organisms and to and from the atmosphere, soil and/or rocks, and water.
- Nutrients can flow between these compartments along a variety of pathways.

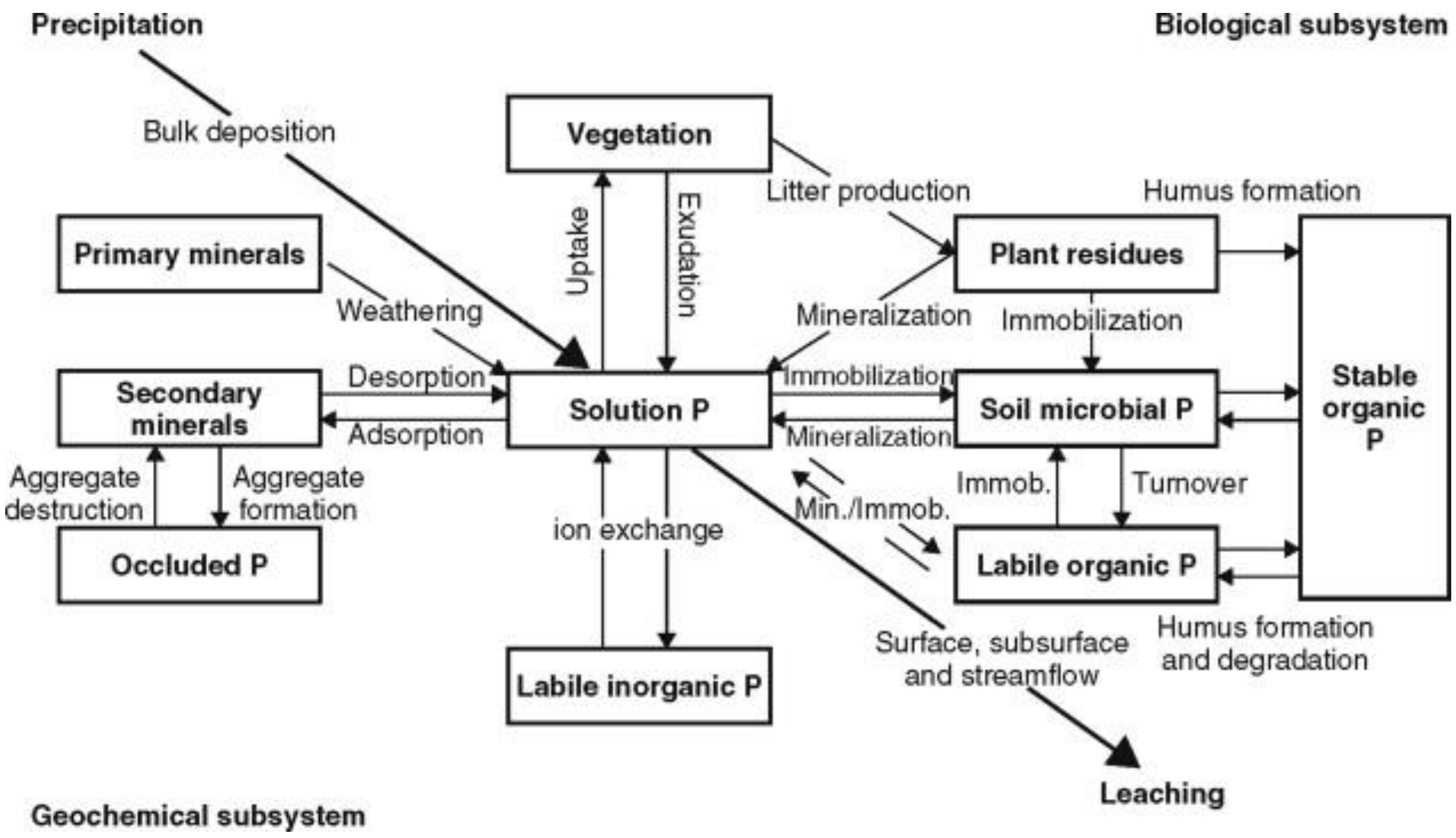
Nutrient Reservoirs in a Terrestrial Ecosystem

- The organic reservoir consists of the living organisms and their detritus.
- The available-nutrient reservoir consists of nutrients held to surface of soil particles or in solution.
- The third reservoir consists of nutrients held in soils or rocks that are unavailable to living organisms.
- The fourth reservoir is the air which can be found in the atmosphere or in the ground.

- Soil Biogeochemical Processes -

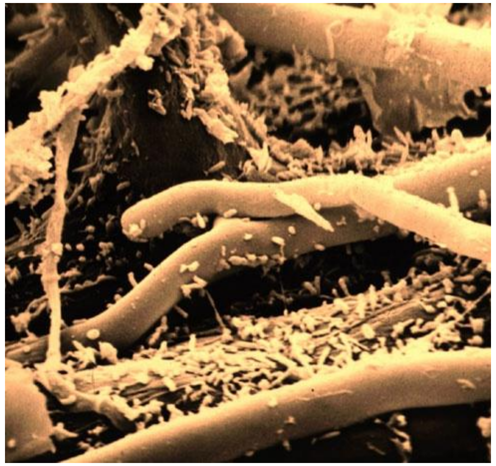


SOIL BIOGEOCHEMICAL CYCLING OF INORGANIC NUTRIENTS AND METALS



Soil microorganisms have a profound effect on the transformations involved in a large number of biogeochemical cycles other than carbon (C) and nitrogen (N), such as the macronutrients phosphorus (P) and sulfur (S), and various micronutrients and environmental pollutants.

Source: Plante, A.F. (2007): https://doi.org/10.1016/B978-0-08-047514-1.50019-6



The biodiversity of soils

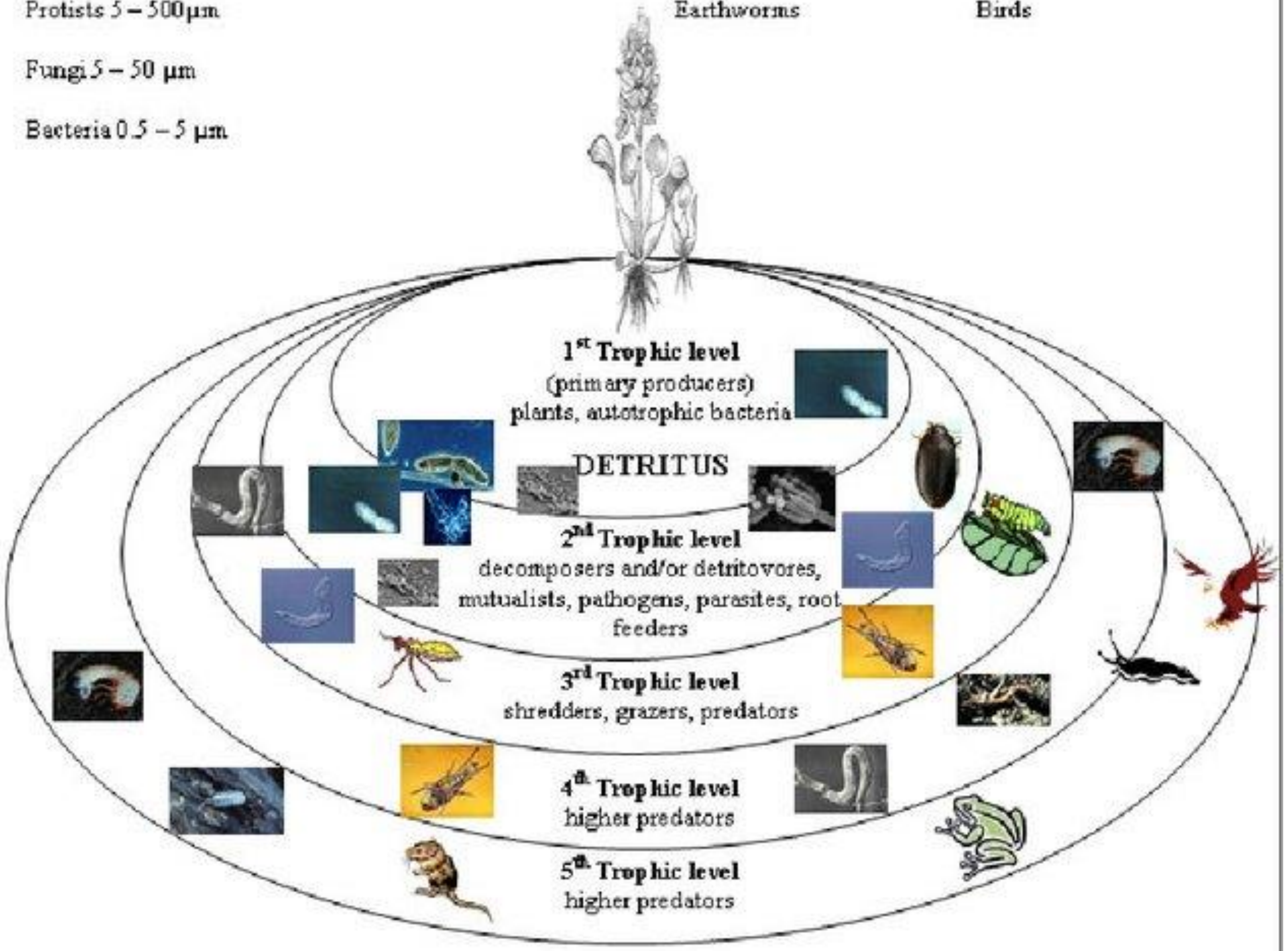
Over 1000 species of invertebrates may be found in a single m^2 of a European beech forest (Schaefer and Schauermann, 1990)

Many of the world's terrestrial insect species are soil dwellers for at least some stage of their life-cycle (Bater, 1996)

A single gram of soil may contain millions of individuals and several thousand species of bacteria (Torsvik *et al.*, 1994).

A typical, healthy soil might contain several species of vertebrate animals, several species of earthworms, 20-30 species of mites, 50-100 species of insects, tens of species of nematodes, hundreds of species of fungi and perhaps thousands of species of bacteria and actinomycetes.

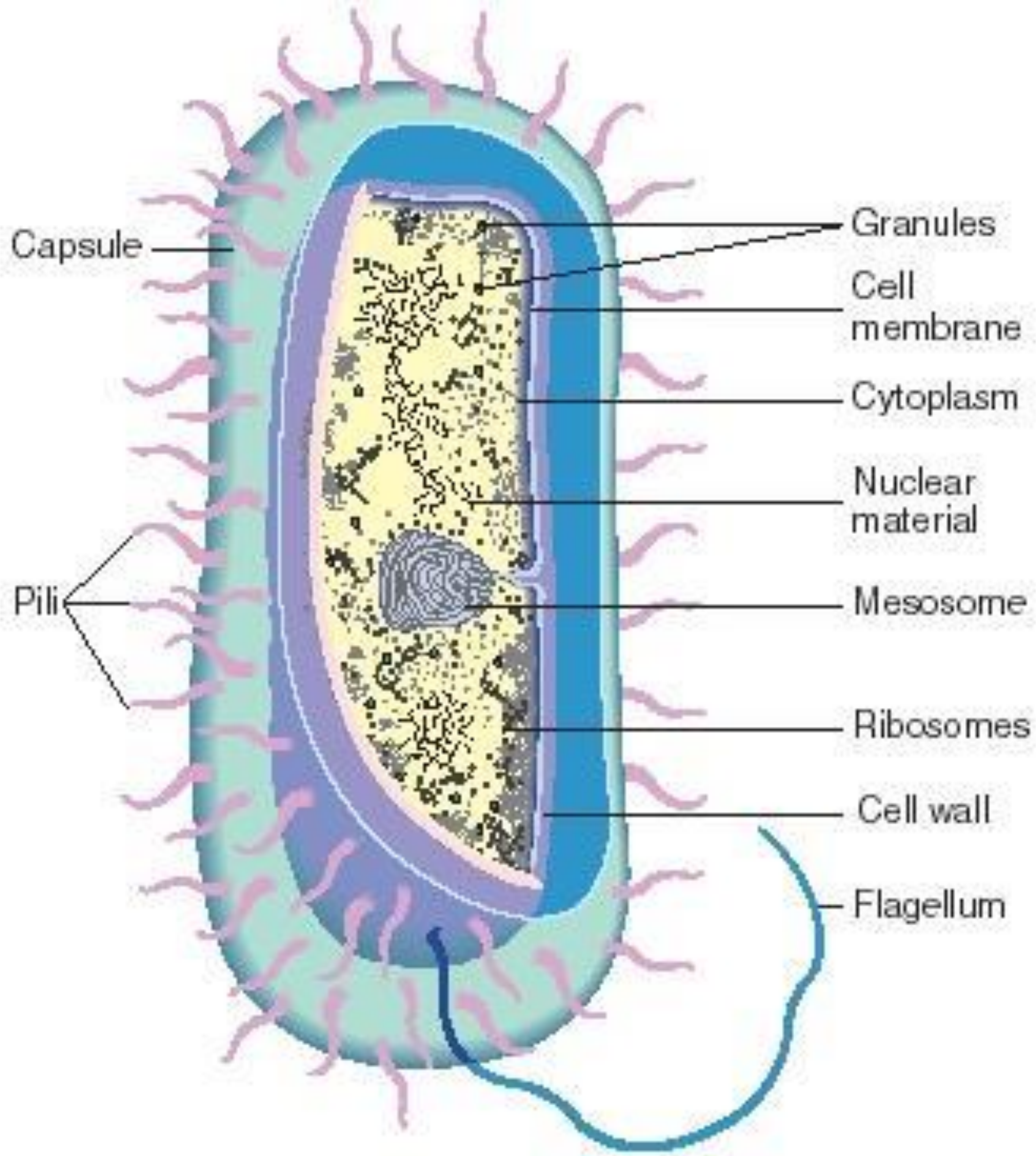
Microbiota (1 – 100 µm)	**Mesofauna (100 µm – 2 mm)**	**Macrofauna (2 – 20 mm)**	**Megafauna (>20 mm)**
Primary producers, herbivores, detritovores,	Detritovores and/or shredders bacterial and fungal feeders	Shredders and detrivores herbivores, predators	Herbivores, predators
Nematodes: 50 – 1000 µm	Tardigrades 0.1 – 1 mm	Enchytraeid worms	Arthropods
Predatory Bacteria and/or fungus	Collembola 0.2 – 6 mm	Arthropods	Molluscs
Plant feeders	Mites 0.5 – 2 mm	Molluscs	Mammals
Protists 5 – 500µm		Earthworms	Birds
Fungi 5 – 50 µm			
Bacteria 0.5 – 5 µm			



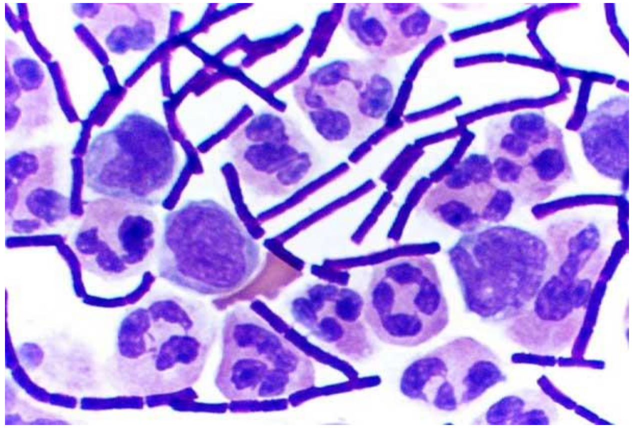
THE LIVING SOIL: BACTERIA

A ton of microscopic bacteria may be active in each acre of soil. 1 acre = 0.404686 hectar

Credit: Michael T. Holmes, Oregon State University, Corvallis.



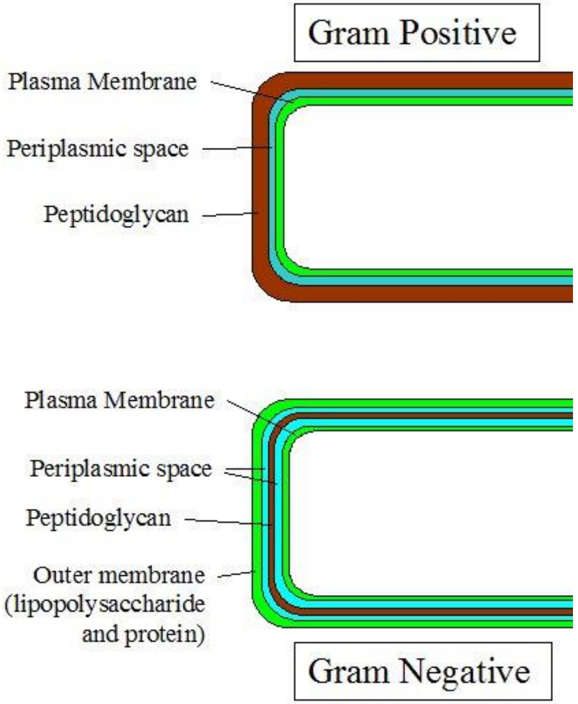
The anatomy of a typical bacterium



Gram-positive Bacillus anthracis bacteria (purple rods) in cerebrospinal fluid sample. The other cells are white blood cells

Gram staining (or **Gram's method**) is an empirical method of differentiating bacterial species into two large groups (Gram-positive and Gram-negative) based on the chemical and physical properties of their cell walls.

The method is named after its inventor, the Danish scientist Hans Christian Gram (1853–1938), who developed the technique in 1884 to discriminate between pneumococci and *Klebsiella pneumoniae* bacteria.

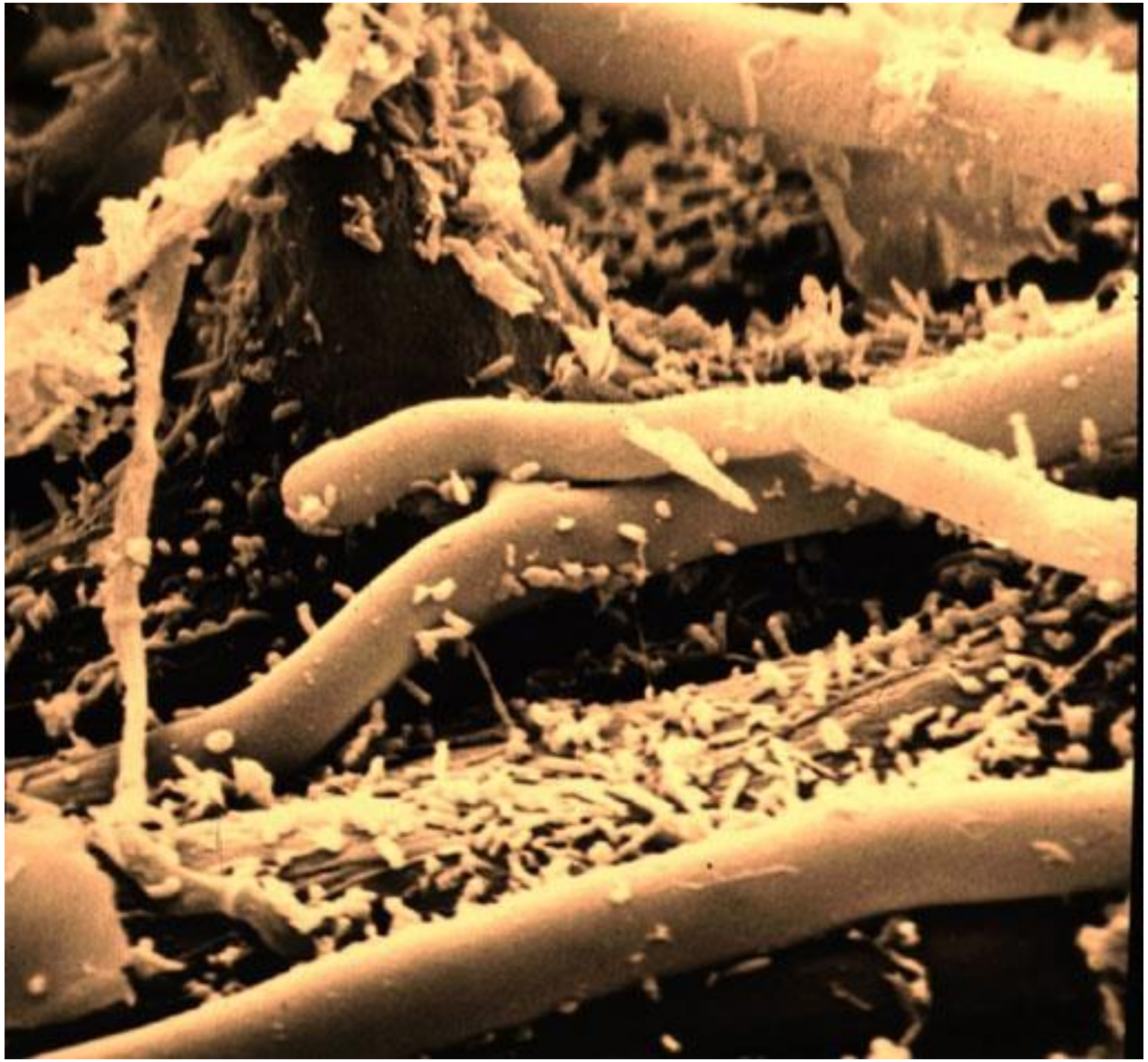


Gram-positive bacteria are those that retain a crystal violet dye during the Gram stain process.

Gram-positive bacteria appear blue or violet under a microscope, while Gram-negative bacteria appear red or pink.

The Gram classification system is empirical, and largely based on differences in cell wall structure.

The purpose of Gram staining is to visually differentiate groups of bacteria, primarily for identification.



Bacteria dot the surface of strands of fungal hyphae.

Credit: *R. Campbell. In R. Campbell. 1985.* Plant Microbiology*. Edward Arnold; London. P. 149.*

Four functional groups of bacteria

1. **Decomposers: that consume simple carbon compounds, such as root exudates and fresh plant litter.**

    a. **A number of decomposers can break down pesticides and pollutants in soil.**

    b. **Decomposers are especially important in immobilizing, or retaining, nutrients in their cells, thus preventing the loss of nutrients, such as nitrogen, from the rooting zone.**

2. **Mutualists: that form partnerships with plants. The most well-known of these are the nitrogen-fixing bacteria.**

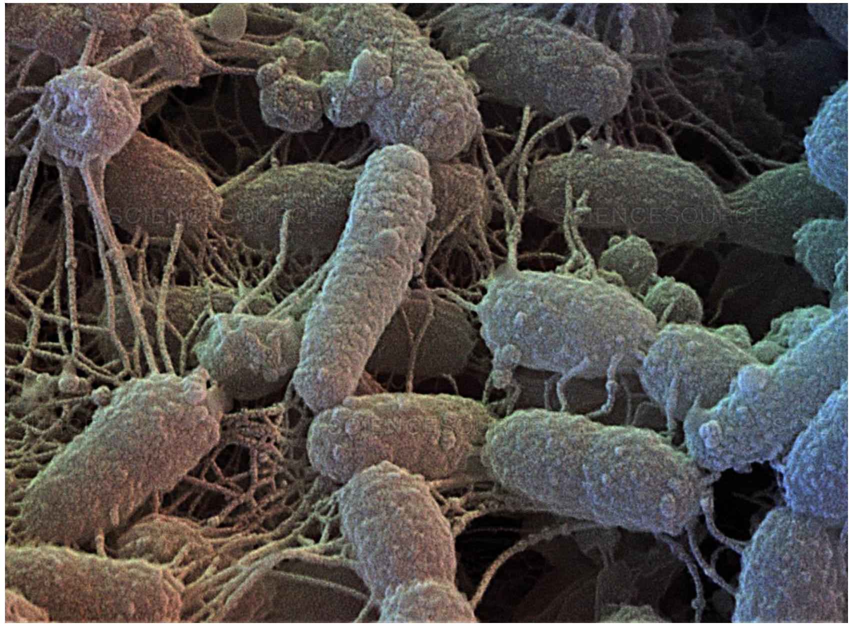
3. **Pathogens. Bacterial pathogens include *Xymomonas* and *Erwinia* species, and species of *Agrobacterium* that cause gall formation in plants.**

4. **Lithotrophs or chemoautotrophs: obtain their energy from compounds of nitrogen, sulfur, iron or hydrogen instead of from carbon compounds. Some of these species are important to nitrogen cycling and degradation of pollutants.**

WHAT DO BACTERIA DO?

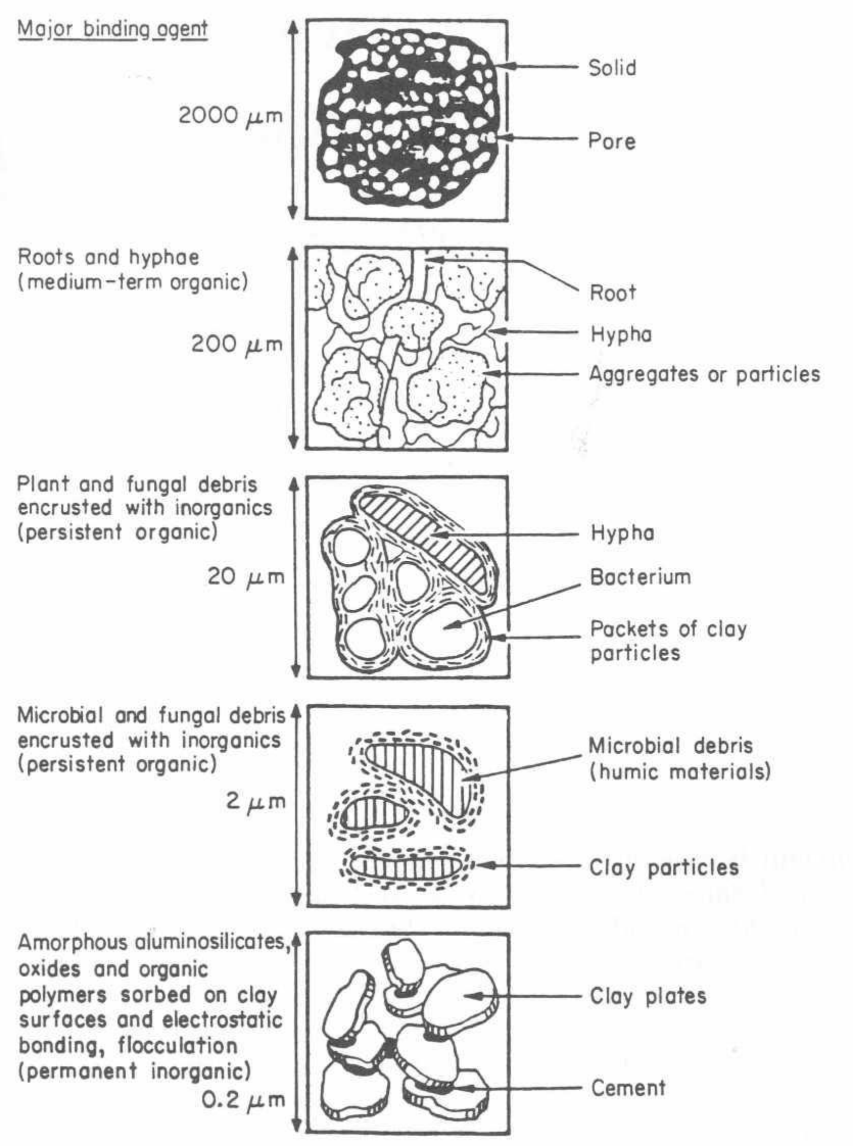
Bacteria from all four groups perform important services related to:

1. water dynamics
2. nutrient cycling
3. disease suppression



WHAT DO BACTERIA DO?

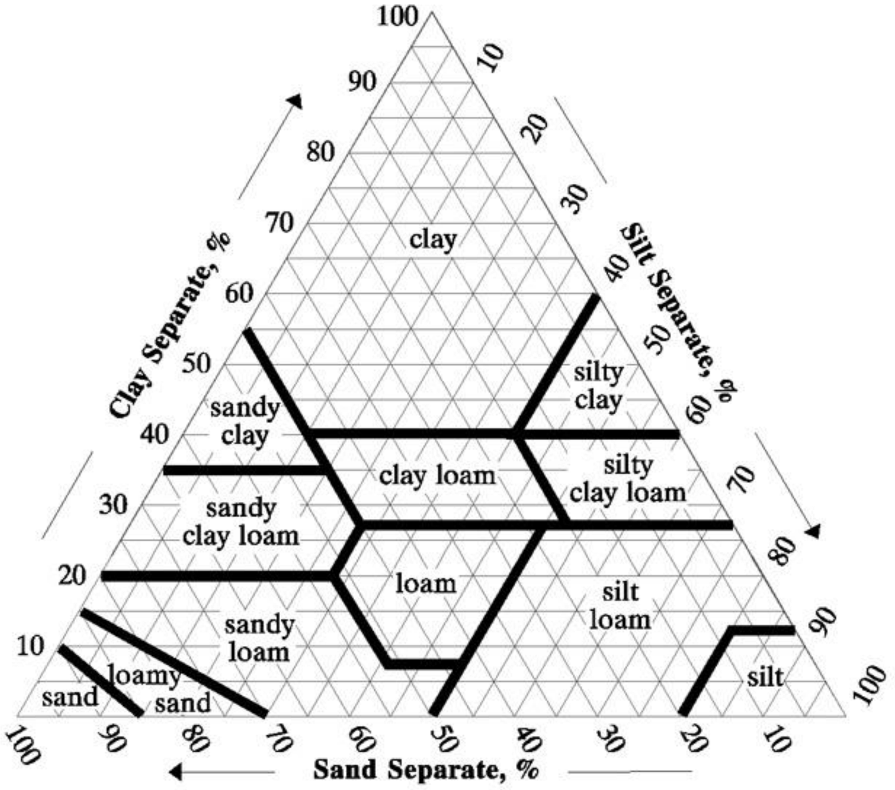
Aggregates

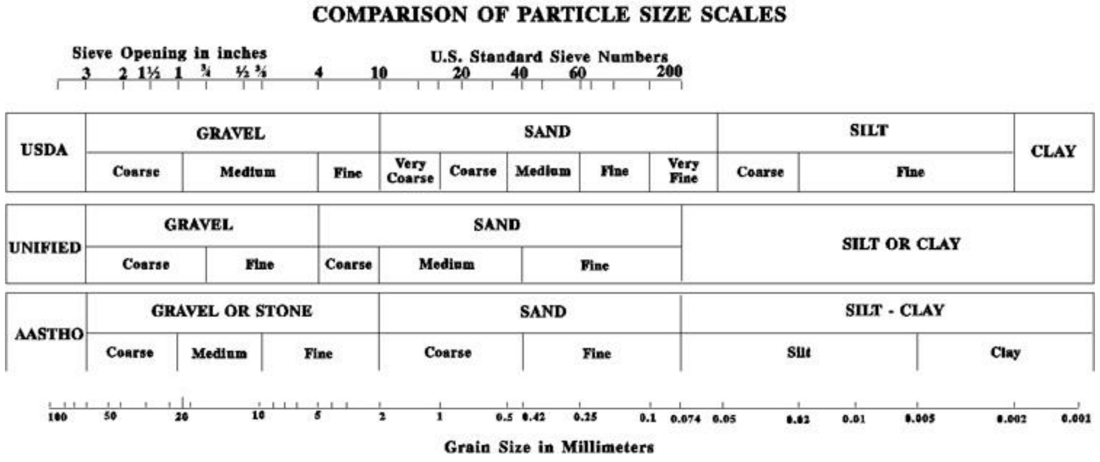


Some bacteria affect water movement by producing substances that help bind soil particles into small aggregates (those with diameters of 1/10,000-1/100 of an inch or 2-200µm).

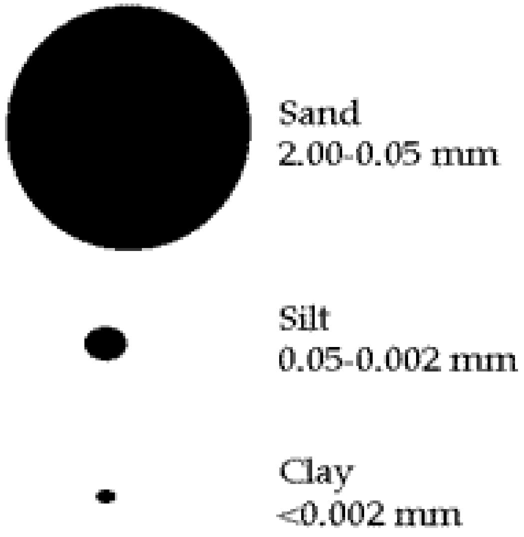
Stable aggregates improve water infiltration and the soil's water-holding ability.

In a diverse bacterial community, many organisms will compete with disease-causing organisms in roots and on aboveground surfaces of plants.





The texture is how the soil feels and is determined by the amount of sand (2.00-0.05 mm), silt (0.05-0.002 mm), and clay (<0.002) particles in the soil, each of which is a different size.



What can bacteria "use" for aggregate formation?

A FEW IMPORTANT BACTERIA

Scanning electron micrograph of wheat root-colonizing *Pseudomonas fluorescens* OE 28.3

Nitrogen – fixing bacteria

Nodules formed where Rhizobium bacteria infected soybean roots.

Credit: *Stephen Temple, New Mexico State University*

Nitrogen-fixing bacteria form symbiotic associations with the roots of legumes like clover and lupine, and trees such as alder and locust.

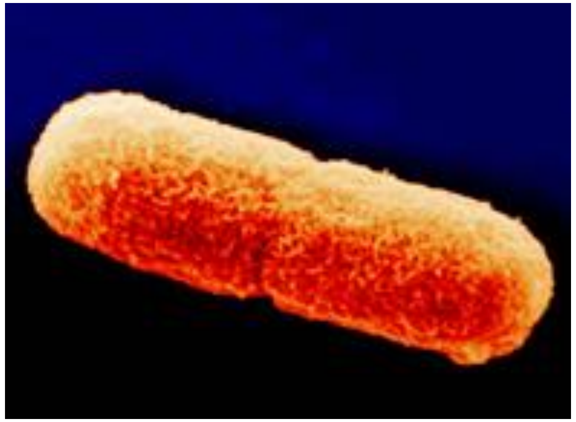
Visible nodules are created where bacteria infect a growing root hair.

The plant supplies simple carbon compounds to the bacteria, and the bacteria convert nitrogen (N_2) from air into a form the plant host can use.

When leaves or roots from the host plant decompose, soil nitrogen increases in the surrounding area.

Nitrogen – fixing bacteria

Azotobacter vinelandii



Azotobacter

Azotobacter vinelandii is a nitrogen-fixing bacterium, found in soils world-wide, with many features relevant to energy consumption and carbon sequestration. It has been studied for more than 90 years by hundreds of scientists throughout the world. Among its unique abilities are the capacity to fix, or reduce, atmospheric nitrogen gas (N2) to compounds of ammonium (NH4 +), by using one of three distinct but related nitrogenase enzymes which vary in metal content (molybdenum, Mo; vanadium, V; or iron, Fe) and which require a large amount of cellular energy for biosynthesis and activity.

Cyanobacteria

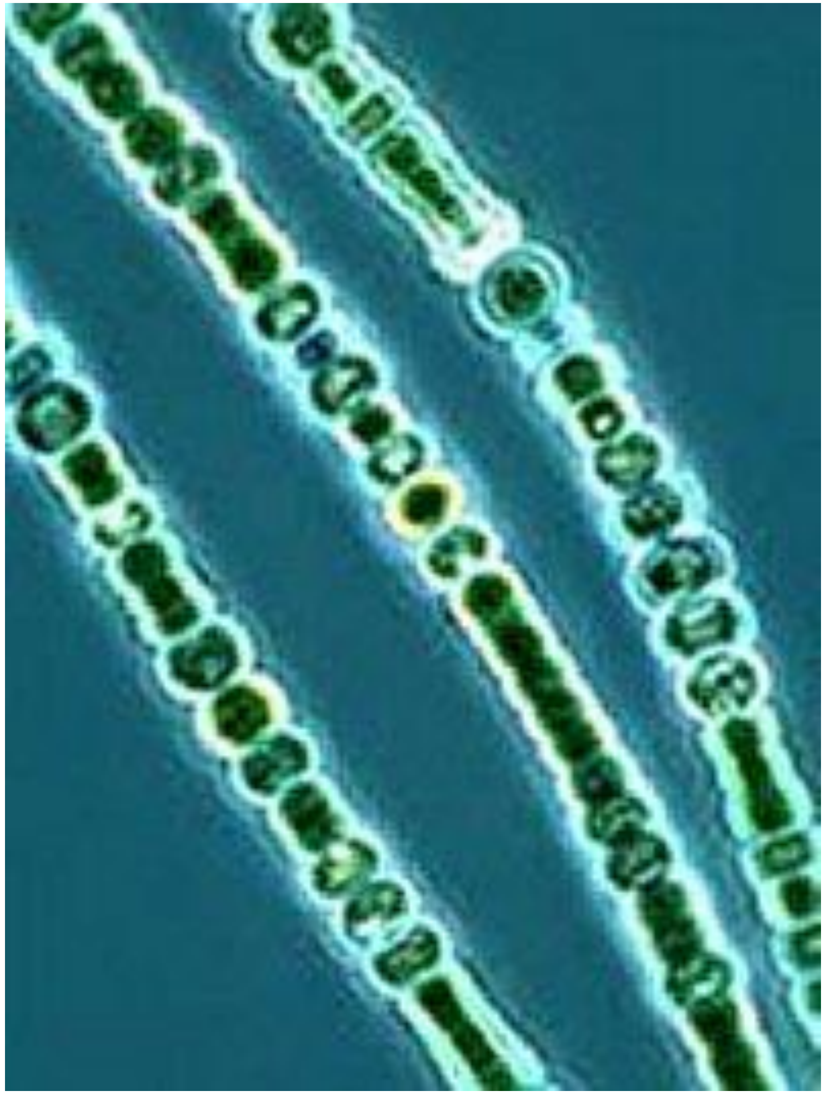
Cyanobacteria convert atmospheric nitrogen into a form that can be utilized by plants. In this conversion nitrogen, N2, from the air is fixed into biologically accessible forms such as nitrate or ammonia.

Cyanobacteria are very important in the formation of biological soil crusts.

They are photosynthetic and live within the first 25 cm of topsoil. Cyanobacteria help to reduce erosion by binding the particles of soil together.

When conditions are wet, they become active and move through the soil, leaving behind sticky filaments which particles of soil cling to.

When the filaments become wet, they absorb water and swell up to ten times their original size which helps to store moisture within the upper layer of soil where many plants root systems and other organisms live.



Cyanobacteria

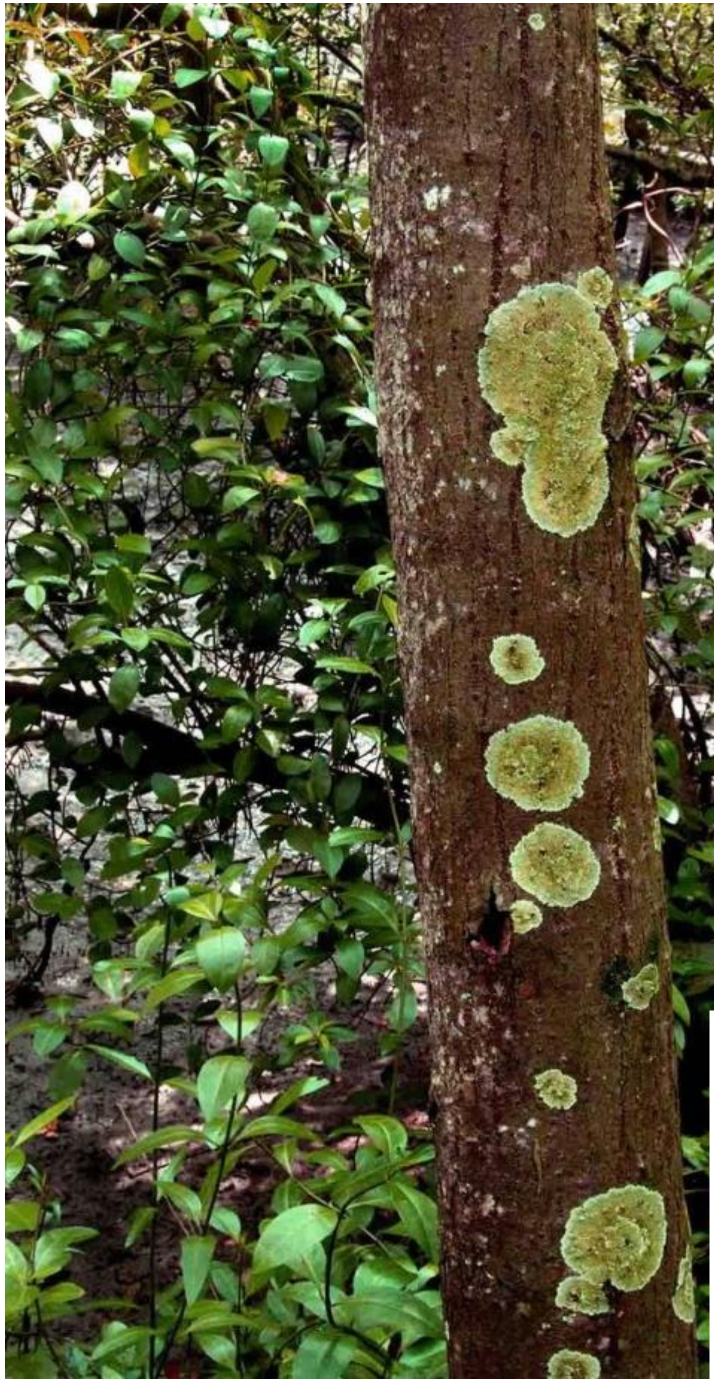
Many cyanobacteria have formed symbiotic relationships with other plants.

Cyanobacteria enables plants to photosynthesize and are responsible for the plants green color.

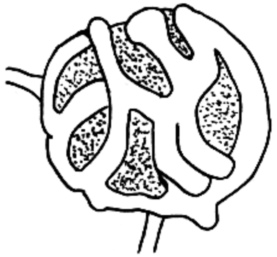
This relationship between plant and cyanobacteria is believed to have first occurred during the Precambrian era.

Cyanobacteria live in the roots of some plants such as legumes as well and provide nitrogen directly for plants to use.

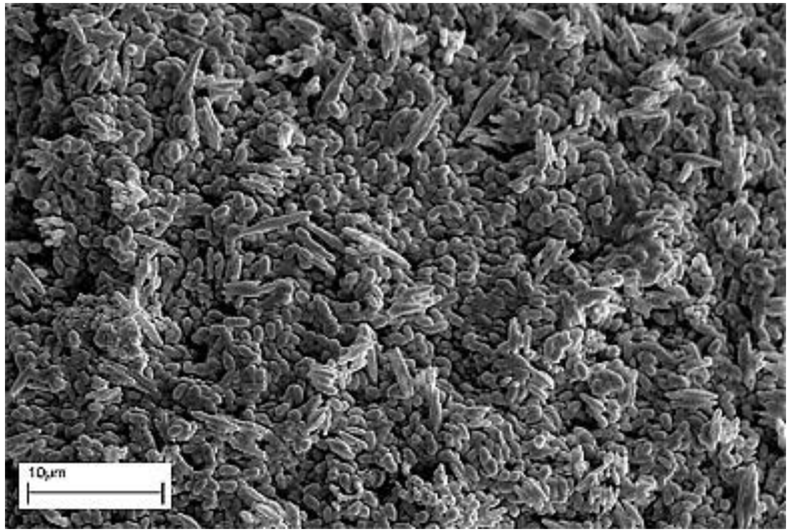
They have also formed symbiotic relationships with fungi and lichens.



Inside the thallus, clusters of one to several algal cells are tightly wrapped by fungal hyphae.



Nitrifying bacteria



Nitrifying bacteria isolated from landfill leakage

Bacterial systematics analysis of 16S rRNA has demonstrated that there are two phylogenetically distinct groups of autotrophic ammonium-oxidizing bacteria, both within the class Proteobacteria.

Nitrifying bacteria change ammonium (NH^{4+}) to nitrite (NO^{2-}) then to nitrate (NO^{3-}) – a preferred form of nitrogen for grasses and most row crops.

Nitrate is leached more easily from the soil, so some farmers use nitrification inhibitors to reduce the activity of one type of nitrifying bacteria.

Nitrifying bacteria are suppressed in forest soils, so that most of the nitrogen remains as ammonium.

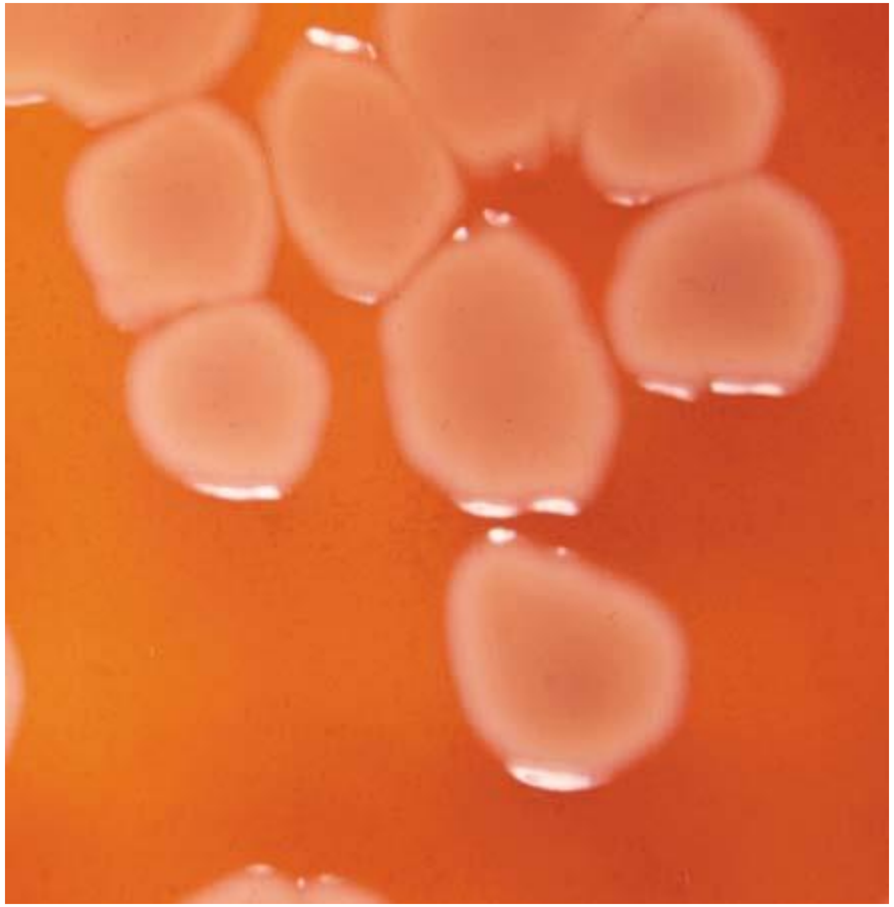
Nitrification

$$^{15}NH_4^+ \xrightarrow[*]{amoA} NH_2OH \longrightarrow NO_2^- \longrightarrow {}^{15}NO_3^-$$

$$H^{14}CO_3 + H_2O \longrightarrow {}^{14}CH_2O + O_2$$

Chemoautotrophy

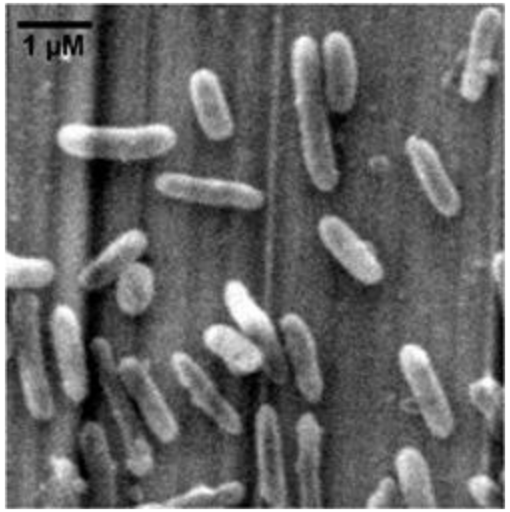
Denitrifying bacteria



Pseudomonas aeruginosa

Denitrifying bacteria convert nitrate to nitrogen (N_2) or nitrous oxide (N_2O) gas.

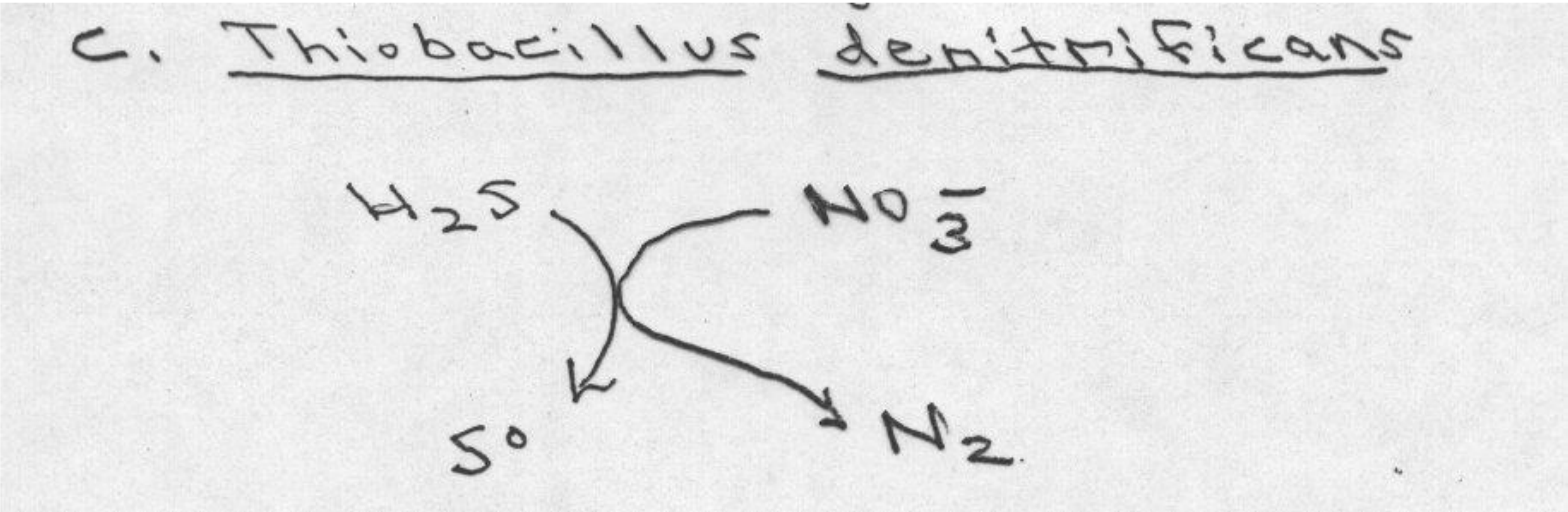
Denitrifiers are anaerobic, meaning they are active where oxygen is absent, such as in saturated soils or inside soil aggregates.

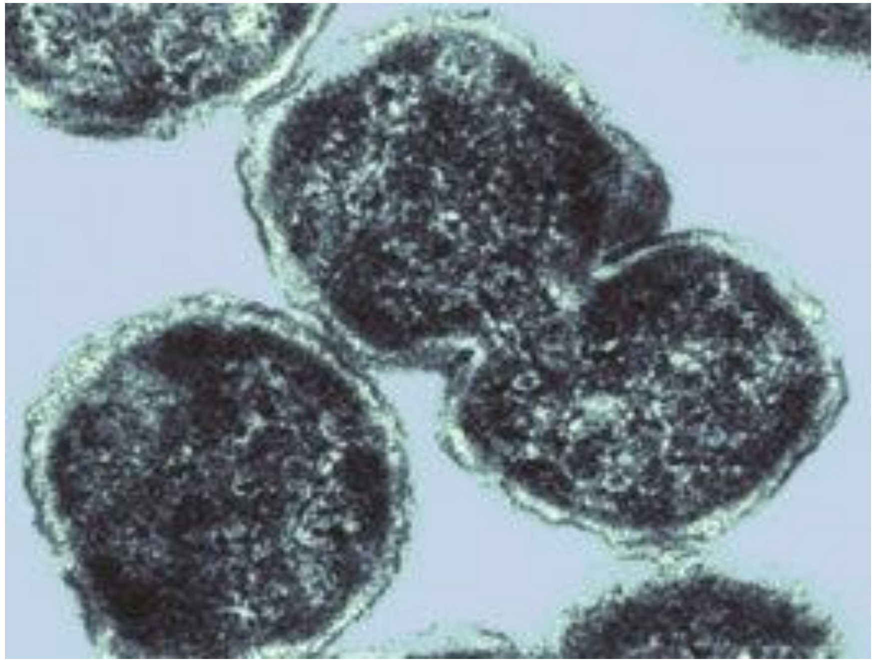


Thiobacillus denitrificans

T. denitrificans is best known for its ability to couple the oxidation of inorganic sulfur compounds (such as hydrogen sulfide and thiosulfate) to denitrification, although it was recently found to couple the anaerobic oxidation of Fe(II) to denitrification as well.

T. Denitrificans is a facultative anaerobe (it can respire aerobically or via denitrification) rather than an obligate aerobe and lives at circumneutral rather than acidic pH.





Paracoccus denitrificans

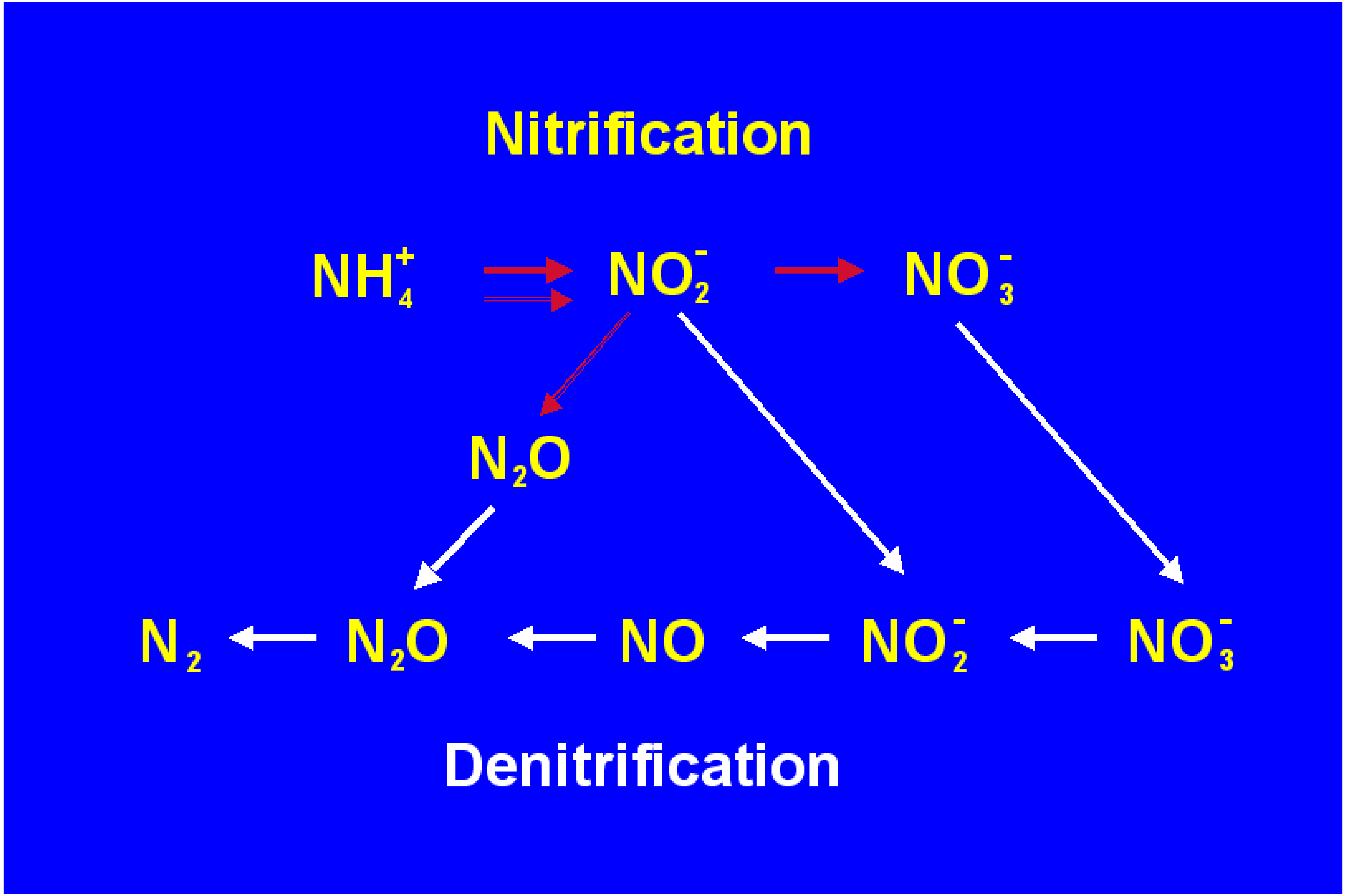
$$NO_3^{-} \rightarrow NO_2^{-}, N_2O, N_2$$

Paracoccus denitrificans, a Gram-negative, coccoid, nitrogen-oxidizing bacterium, formerly known as *Micrococcus denitrificans*, was first isolated in 1910 by Martinus Beijerinck.

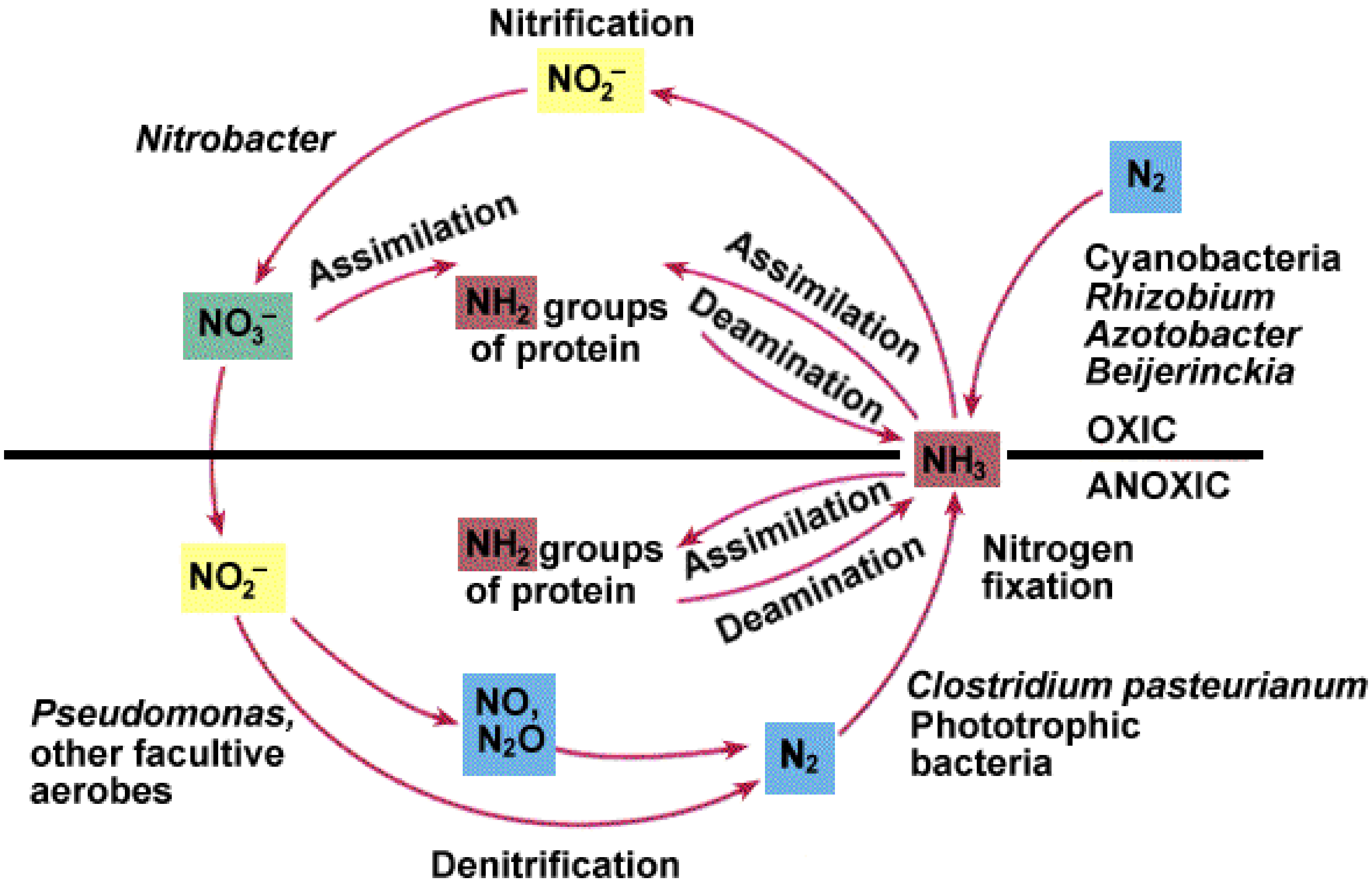
It was renamed in 1969 to *Paracoccus denitrificans* by Davis.

Paracoccus denitrificans harbors many features also found in mitochondria and because of this, *Paracoccus denitrificans* is thought to be a plausible ancestor of the eukaryotic mitochondrion (endosymbiotic theory).

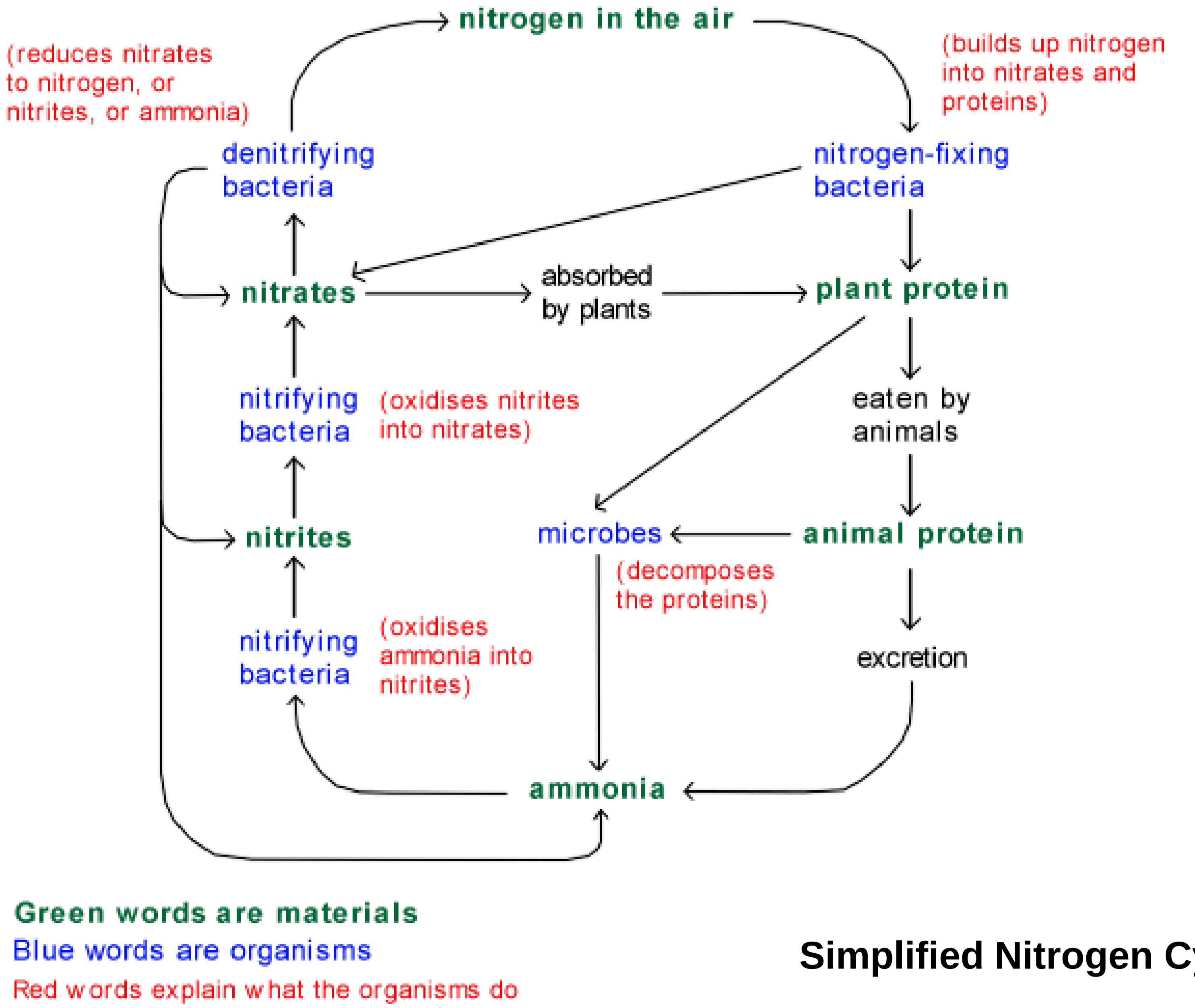
The genome of *P. denitrificans* was sequenced in 2004.



Nitrification
NH_4^+
NO_2^-
NO_3^-
N_2O
N_2
N_2O
NO
NO_2^-
NO_3^-
Denitrification

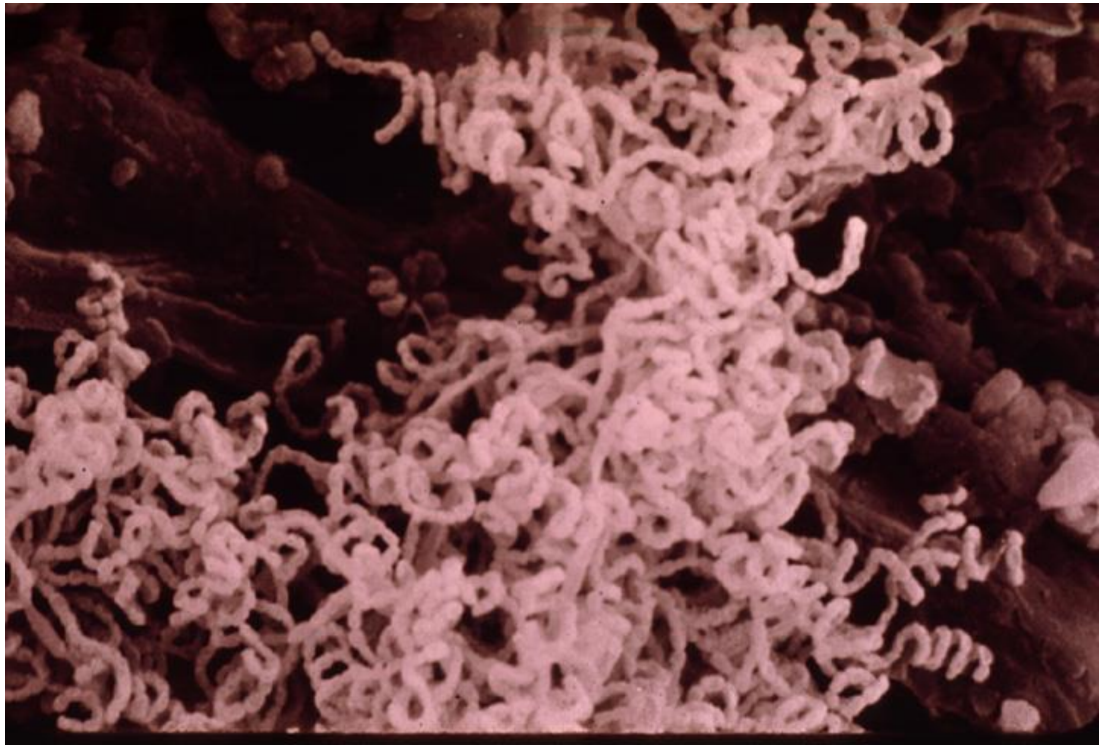


Nitrification
NO₂⁻
Nitrobacter
N₂
Assimilation
Assimilation
Deamination
NO₃⁻
NH₂ groups of protein
Cyanobacteria
Rhizobium
Azotobacter
Beijerinckia
OXIC
NH₃
ANOXIC
NH₂ groups of protein
Assimilation
Deamination
Nitrogen fixation
NO₂⁻
NO, N₂O
N₂
Pseudomonas, other facultive aerobes
Clostridium pasteurianum
Phototrophic bacteria
Denitrification



Simplified Nitrogen Cycle

Actinomycetes



Actinomycetes, such as this Streptomyces, give soil its "earthy" smell.

Credit: No. 14 from Soil Microbiology and Biochemistry Slide Set*. 1976. J.P. Martin, et al., eds. SSSA, Madison, WI*

Actinomycetes are a large group of bacteria that grow as hyphae like fungi.

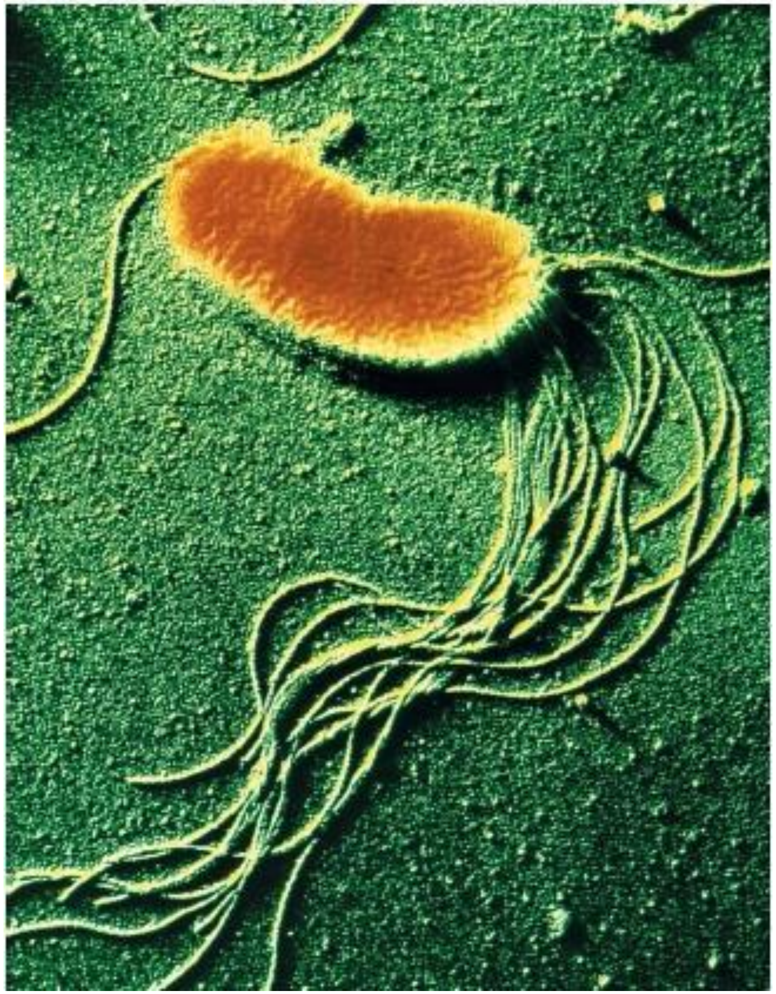
They are responsible for the characteristically “earthy” smell of freshly turned, healthy soil.

Actinomycetes decompose a wide array of substrates but are especially important in degrading recalcitrant (hard-to-decompose) compounds, such as chitin and cellulose, and are active at high pH levels.

Fungi are more important in degrading these compounds at low pH.

A number of antibiotics are produced by actinomycetes such as Streptomyces.

Bacteria That Promote Plant Growth



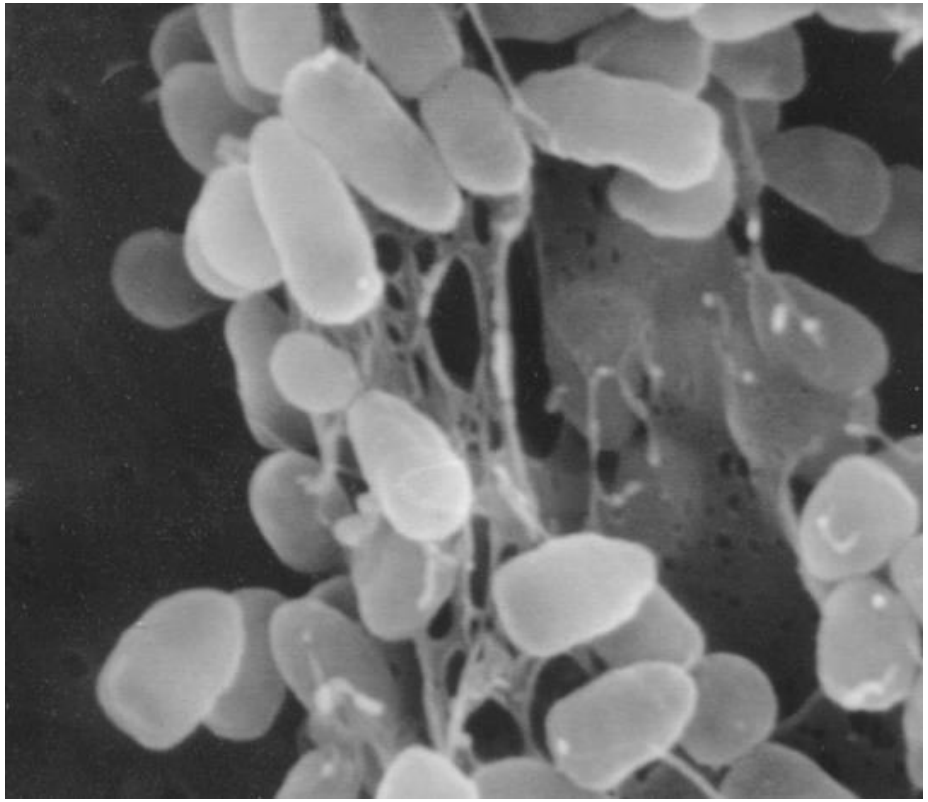
Pseudomonas fluorescens (Photo Researchers Inc.)

Certain strains of the soil bacteria Pseudomonas fluorescens have anti-fungal activity that inhibits some plant pathogens.

P. fluorescens and other Pseudomonas and Xanthomonas species can increase plant growth in several ways.

They may produce a compound that inhibits the growth of pathogens or reduces invasion of the plant by a pathogen.

Bacteria That Promote Plant Growth



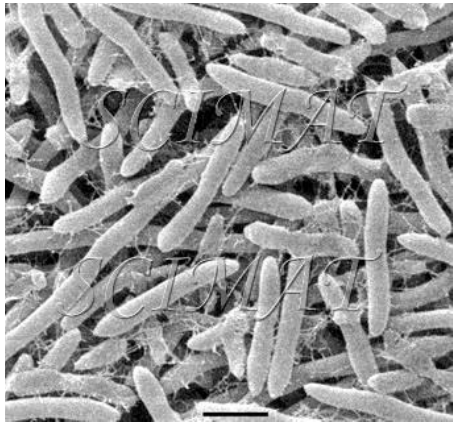
They may also produce growth factors, compounds that directly increase plant growth.

These plant growth-enhancing bacteria occur naturally in soils, but not always in high enough numbers to have a dramatic effect.

In the future, farmers may be able to inoculate seeds with anti-fungal bacteria, such as P. fluorescens, to ensure that the bacteria reduce pathogens around the seed and root of the crop.

Carbonate biomineralization in soils

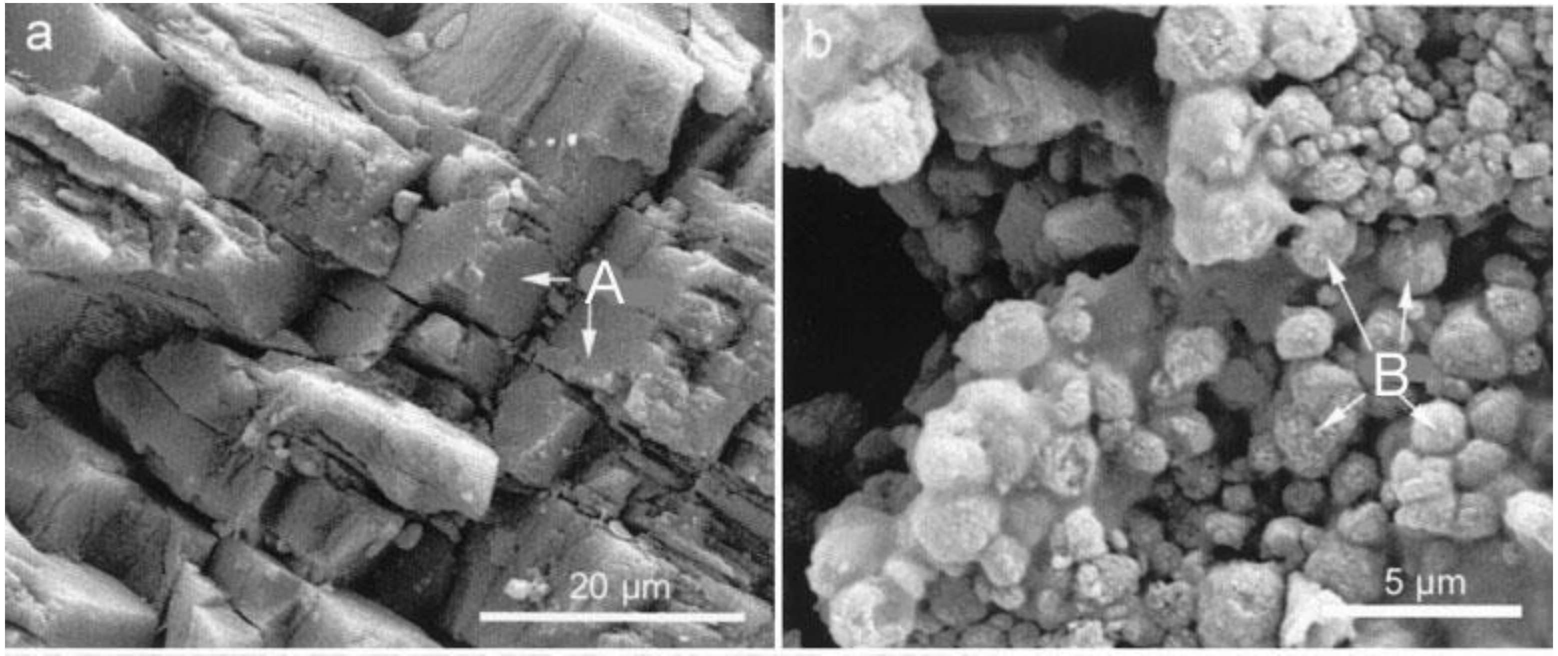
Bar: 5 µm



Bar: 1 µm

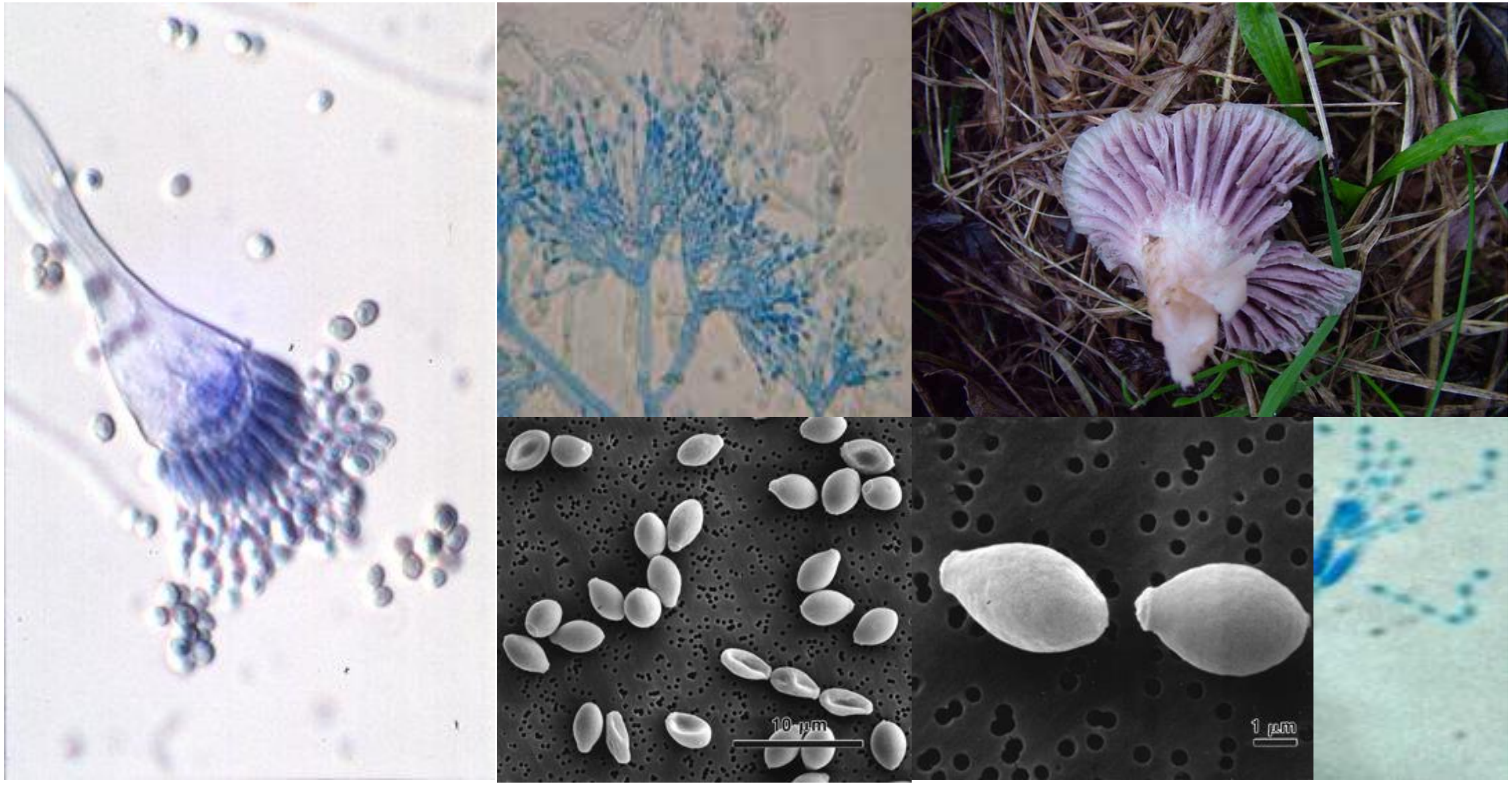
Carbonate biomineralization mediated by the bacterium *Bacillus megaterium*, a dominant strain separated from a loess profile in China

Microbiologically Mediated Soil Improvement



SEM photomicrographs of samples subjected to Myxococcus xanthus-induced calcite precipitation. (a) Control (i.e., calcium-rich slab stone not submitted to biomineralization) showing spalling and fissuring of calcite crystals along planes (see zone A), (b) Calcified bacteria blanketing stone samples (see zone B). (After Rodriguez-Navarro et al. 2003). The process aimed to replicate is the natural process that occurs when calcium carbonate precipitates in granular soil, resulting in a strongly cemented soil.

Fungi



Aspergillus fumigatus

Aspergillus fumigatus

The moulds such as *Aspergillus fumigatus* are filamentous fungi. They are especially prevalent growing on the nonliving organic materials in the soil. They disperse their non-sexual spores called conidia in the air.

Paecilomyces

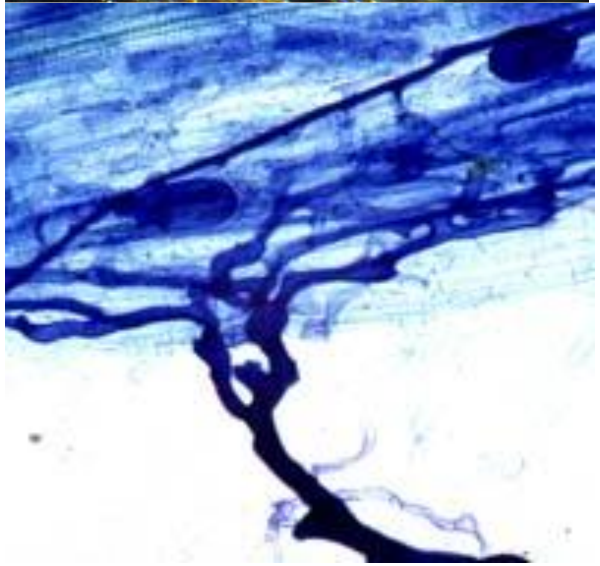
Paecilomyces carneus

Paecilomyces carneus **is found on a wide range of material, and especially in soil. It is sometimes isolated from insects, though it appears to be a weak insect pathogen. Some isolates produce several metabolites of the antibiotic group cephalosporins.**

Paecilomyces farinosus

Paecilomyces farinosus **is also commonly isolated from soil. It is a well-known insect pathogen, and there has been interest in its use as an agent of biological control.**

Paecilomyces species are common environmental moulds. They are widespread in soils, composts, and food products. In an indoor environment, *Paecilomyces* species have been isolated from air, damp walls, wet plaster work, carpet dust and HVAC fans.



Mycorrhiza

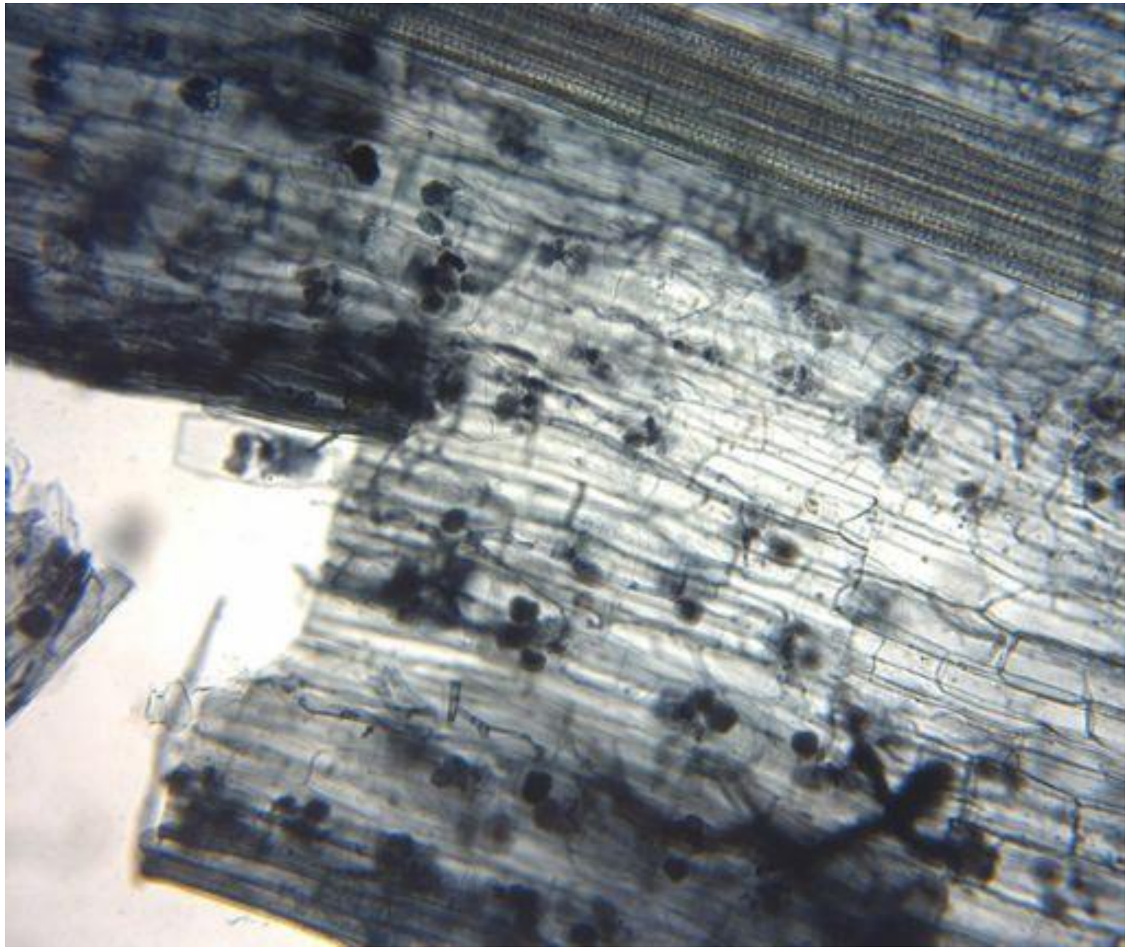
A mycorrhiza is a symbiotic (occasionally weakly pathogenic) association between a fungus and the roots of a plant.

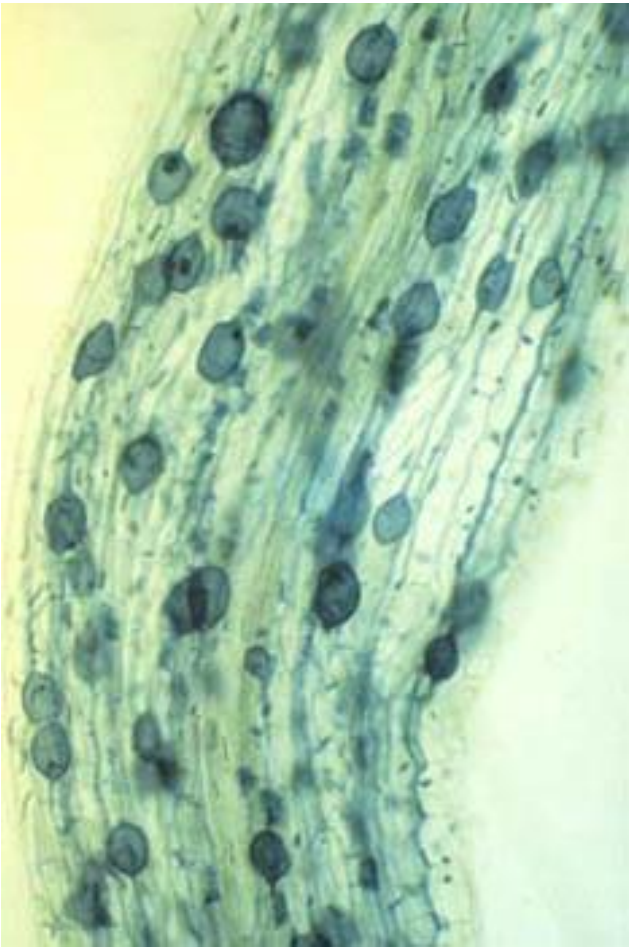
In a mycorrhizal association the fungus may colonize the roots of a host plant either intracellularly or extracellularly.

This mutualistic association provides the fungus with relatively constant and direct access to mono- or dimeric carbohydrates, such as glucose and sucrose produced by the plant in photosynthesis.

The carbohydrates are translocated from their source location (usually leaves) to the root tissues and then to the fungal partners. In return, the plant gains the use of the mycelium's very large surface area to absorb water and mineral nutrients from the soil, thus improving the mineral absorption capabilities of the plant roots.

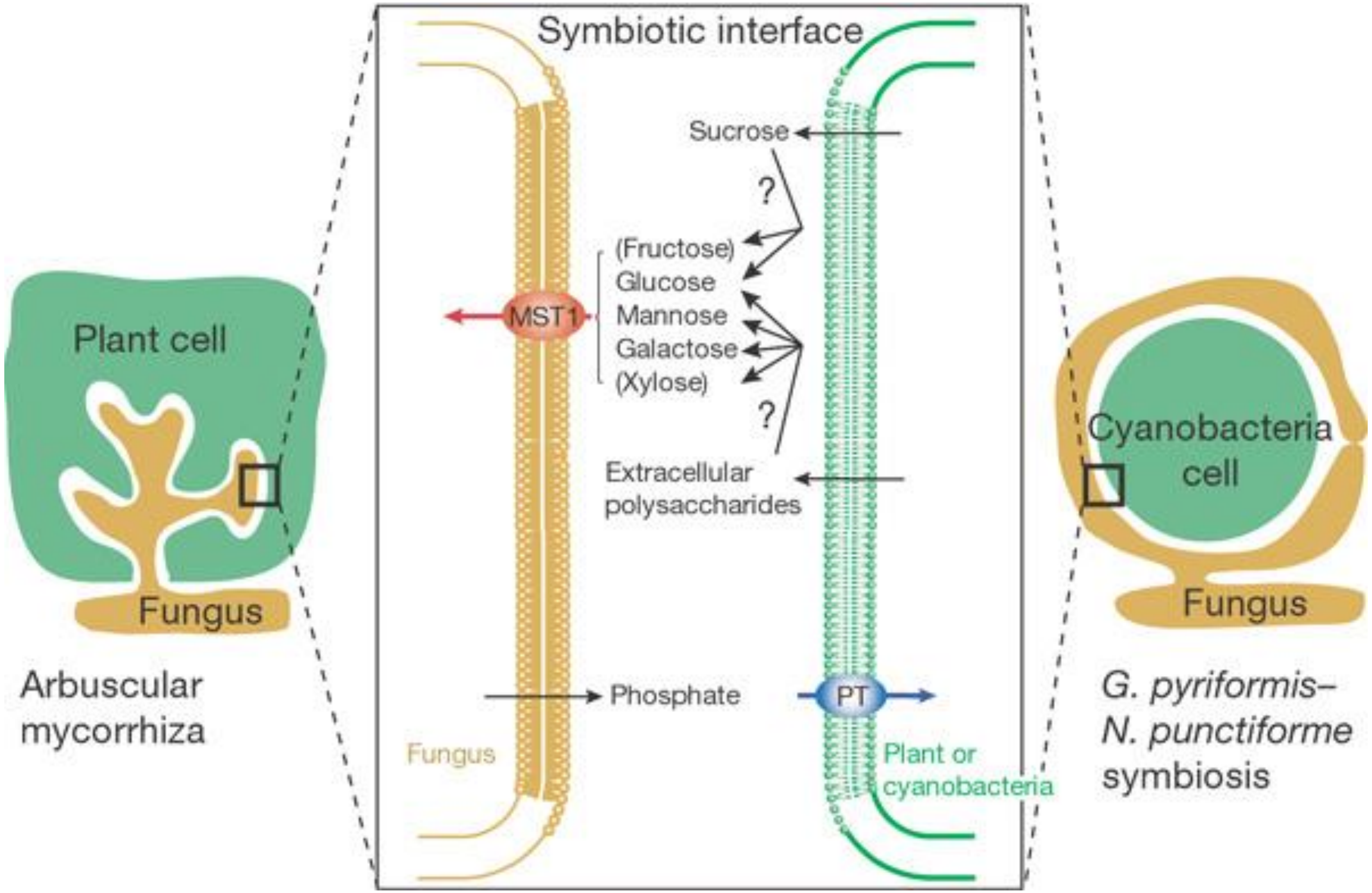
Plant roots alone may be incapable of taking up phosphate ions that are immobilized, for example, in soils with a basic pH. The mycelium of the mycorrhizal fungus can however access these phosphorus sources and make them available to the plants they colonize.



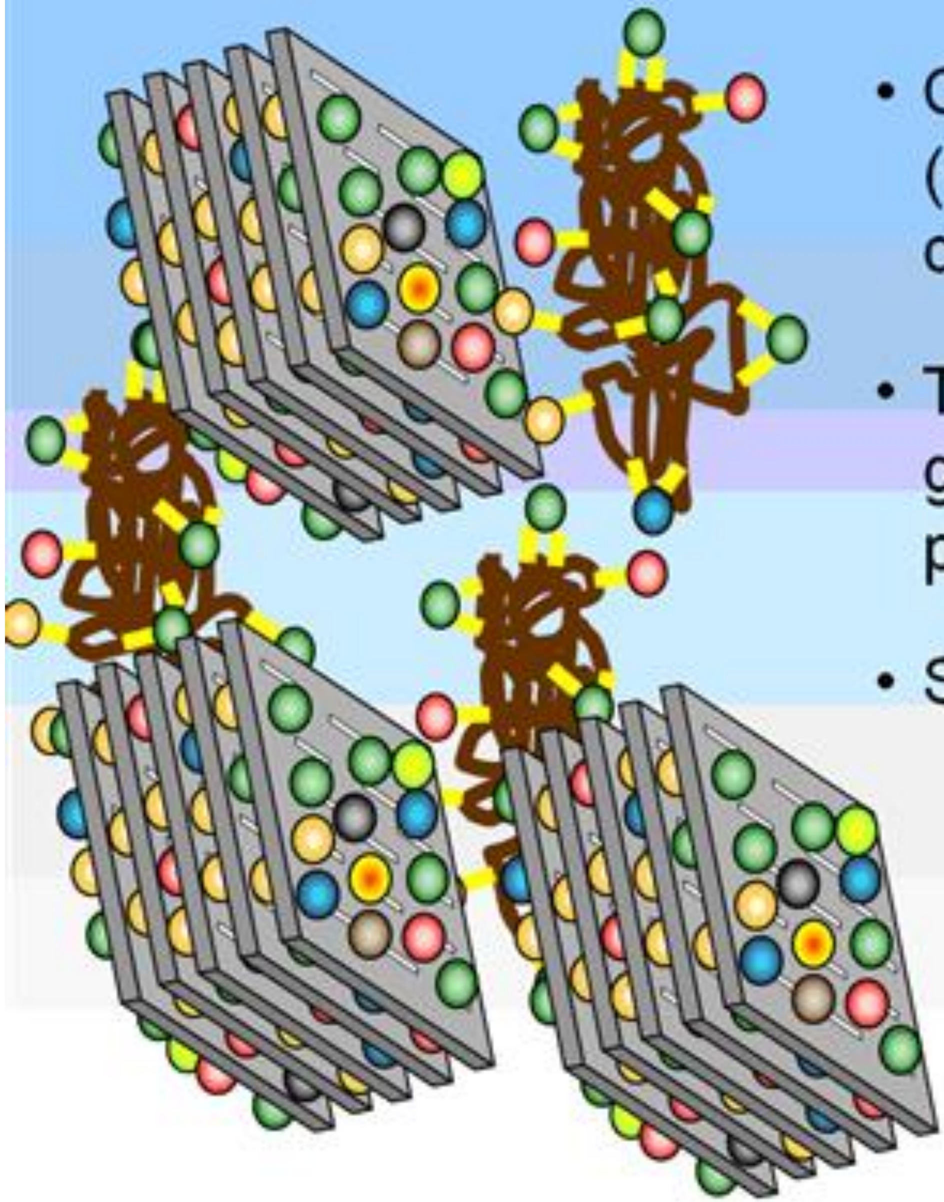


An **arbuscular mycorrhiza** (plural **mycorrhizae** or **mycorrhizas**) is a type of mycorrhiza in which the fungus penetrates the cortical cells of the roots of a vascular plant. Arbuscular mycorrhizal fungi belong to the division Glomeromycota.

Despite inverted relative dimensions of macro- and microsymbiont the interface and nutrient exchange in the *Geosiphon pyriformis – Nostoc Punctiforme* symbiosis correspond to that in the arbuscular mycorrhiza.



Cation Exchange Capacity

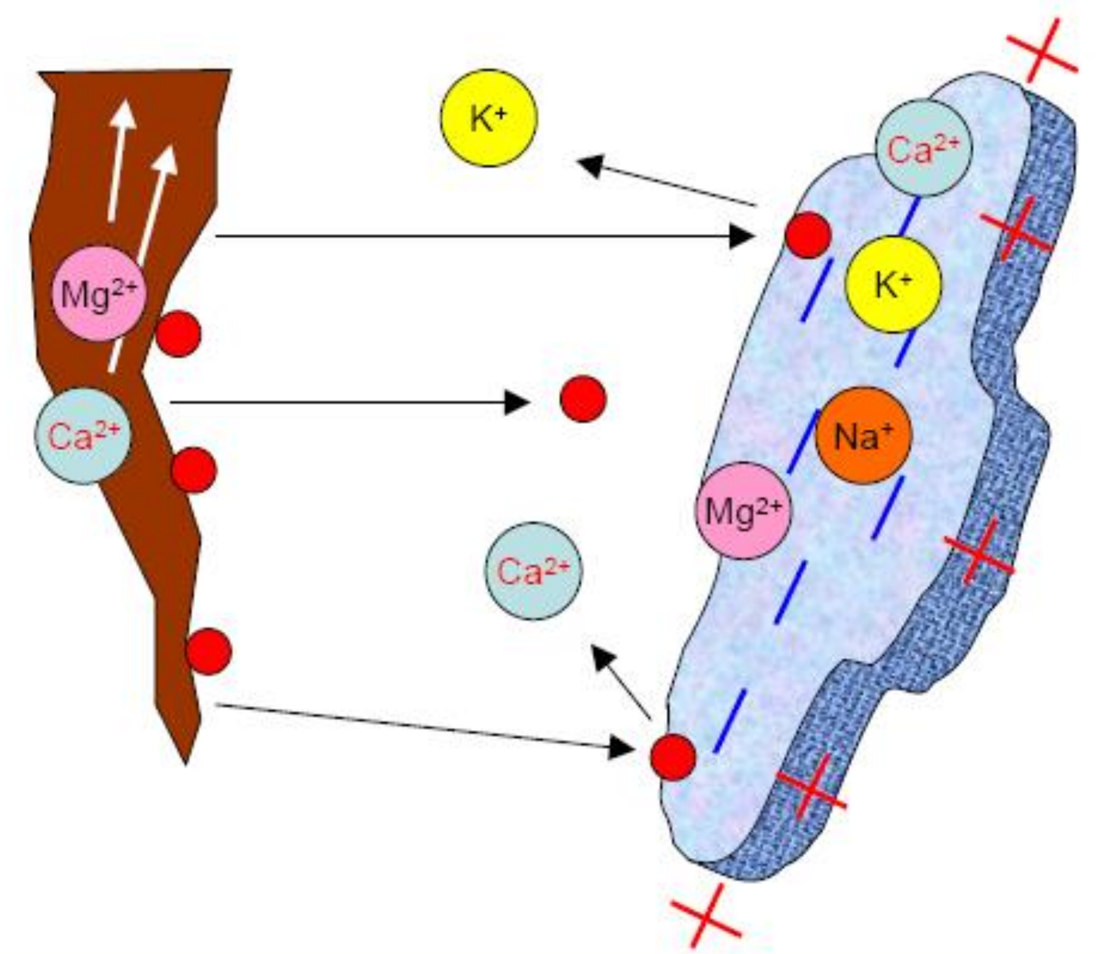


- Cation exchange capacity (CEC) is the total amount of cations that a soil can retain
- The higher the soil CEC the greater ability it has to store plant nutrients
- Soil CEC increases as
  - **The amount of clay increases**
  - **The amount of organic matter increases**
  - **The soil pH increases**

Ion Exchange

The Chemical Warfare of the Plants Against the Soil

- H^+- ions (●) are excreted by the plants



- **Nutrient uptake**
- **Chemical exchange between soil/water and the grapevine**

Soil pH and nutrient bio-availability

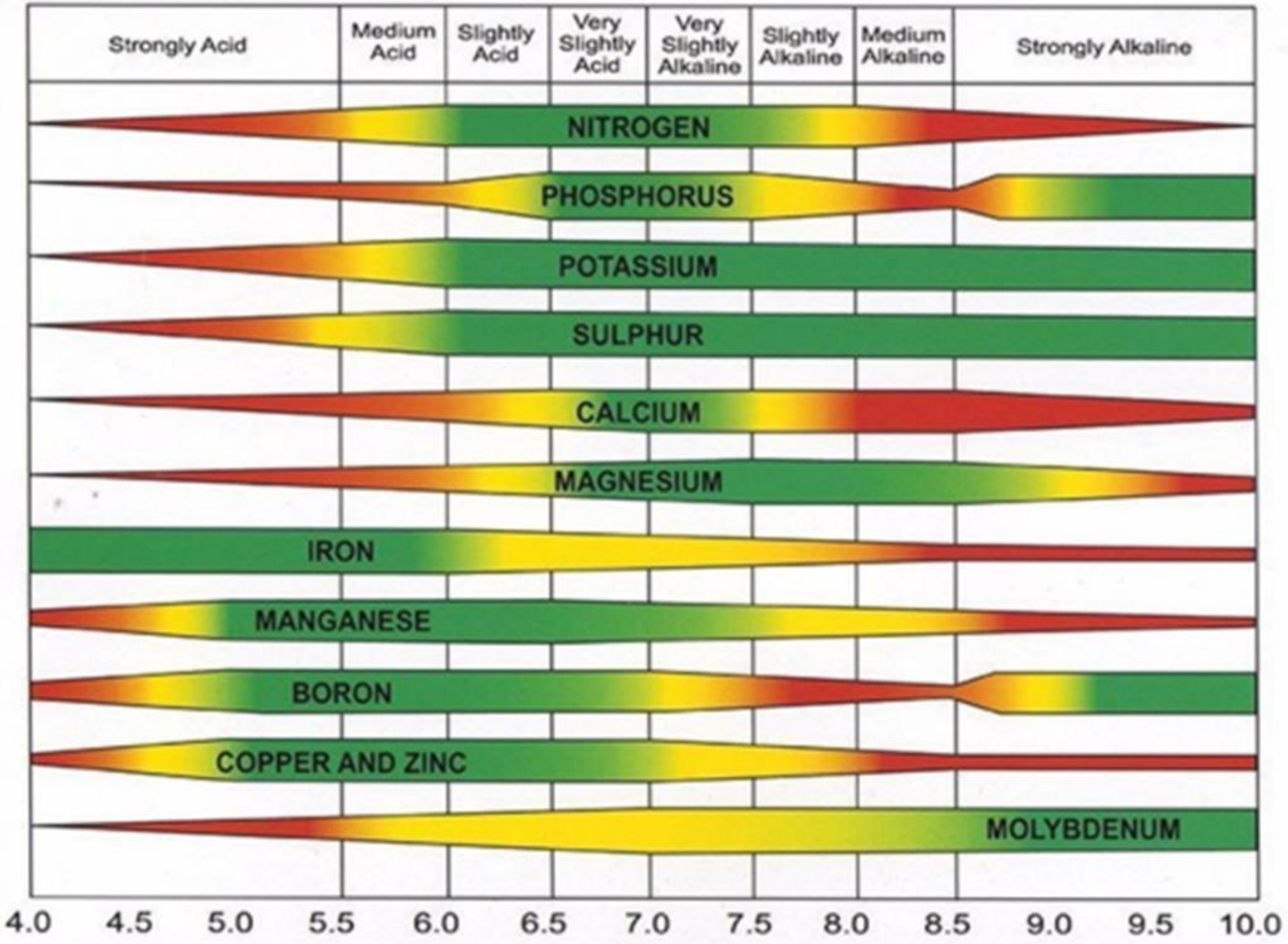
Soil pH is a characteristic that describes the relative acidity or alkalinity of the soil. Soil pH is important because it affects the availability of nutrients to plants. Generally, soil pH 6.0-7.5 is acceptable for most plants as most nutrients become available in this pH range.

Nitrogen (N), Potassium (K), and Sulphur (S) are major plant nutrients that appear to be less affected directly by soil pH than many others, but still are to some extent. Phosphorus (P), however, is directly affected. At alkaline pH values, greater than pH 7.5 for example, phosphate ions tend to react quickly with calcium (Ca) and magnesium (Mg) to form less soluble compounds.

At acidic pH values, phosphate ions react with aluminium (Al) and iron (Fe) to again form less soluble compounds. Most of the other nutrients (micronutrients especially) tend to be less available when soil pH is above 7.5, and in fact are optimally available at a slightly acidic pH, e. g. 6.5 to 6.8. The bio-availability of aluminium increases at low pH – results in Al-toxicity.

The exception is molybdenum (Mo), which appears to be less available under acidic pH and more available at moderately alkaline pH values.

How soil pH affects availability of plant nutrients.



SOURCE: https://www.emporiumhydroponics.com/what-is-ph-1-to-14

Fertilisers, pesticides, POPs

Generally, fertilisers are defined as natural or artificial substances containing the chemical elements that improve growth and productiveness of plants. Fertilizers enhance the fertility of the soil or replace the chemical elements taken from the soil by previous crops.

Although manufactured fertilisers contain precisely the same plant nutrients in the chemical forms that are provided in nature, it is important that the timing and rate of fertilizer or manure application are correct, calculated to optimize crop production and minimize adverse environmental pollution from nutrient losses.

The nitrate ion is particularly mobile in soil and problems occur if excessive amounts of nitrogen fertilisers or animal manures are used. This is because any unused nitrate remains in the soil and there is a risk that it will leach into the water courses.

Phosphate ions applied in fertiliser and manure become tightly bound to soil particles and are not normally leached. Some phosphate ions however are found in rivers and they come from soil which has been eroded into the water course.

Pesticides

A pesticide is any substance used to kill, repel, or control certain forms of plant or animal life that are considered to be pests.

Pesticides include:

- herbicides for destroying weeds and other unwanted vegetation,
- insecticides for controlling a wide variety of insects,
- fungicides used to prevent the growth of moulds and mildew,
- disinfectants for preventing the spread of bacteria,
- compounds used to control rodents.

POPs - Persistent organic pollutants are carbon-based compounds that:

- remain intact in the environment for a long time;
- become widely distributed throughout the environment;
- accumulate in fatty tissue of living organisms; and
- are toxic to humans and wildlife.

The initial list of 12 POPs

Chemical	Pesticides	Industrial Chemicals	By-products
Aldrin	+		
Chlordane	+		
DDT	+		
Dieldrin	+		
Endrin	+		
Heptachlor	+		
Mirex	+		
Toxaphene	+		
Hexachlorobenzene	+	+	+
PCBs		+	+
Chlorinated dioxins			+
Chlorinated furans			+

Agriculture definitions

- Industrial agriculture
- Precision agriculture
- Urban agriculture
- Organic agriculture
- Permaculture
- Multifunctional agriculture

Industrial agriculture

The concept of industrial agriculture implies increased use of farmlands to produce the highest yields possible to gain profit and support human food needs.

The maximization is achieved through typical intensive farming practices like increased use of fertilizers, insecticides, abundant irrigation, heavy machinery land treatment, planting high-yield species, expansion of new areas, among others.

High inputs in industrial agriculture condition result in higher yields. Intensive agriculture is the most typical method of soil cultivation with strong and often extreme land exploitation and often extreme inputs.

Precision agriculture

Precision agriculture can be defined as “the application of modern information technologies to provide, process and analyze multisource data of high spatial and temporal resolution for decision making and operations in the management of crop production”. (National Research Council, UK).

Urban agriculture

Urban agriculture, urban farming, or urban gardening is the practice of cultivating, processing, and distributing food in or around urban areas. Urban agriculture is also the term used for animal husbandry, aquaculture, urban beekeeping, and horticulture. These activities occur in peri-urban areas as well.

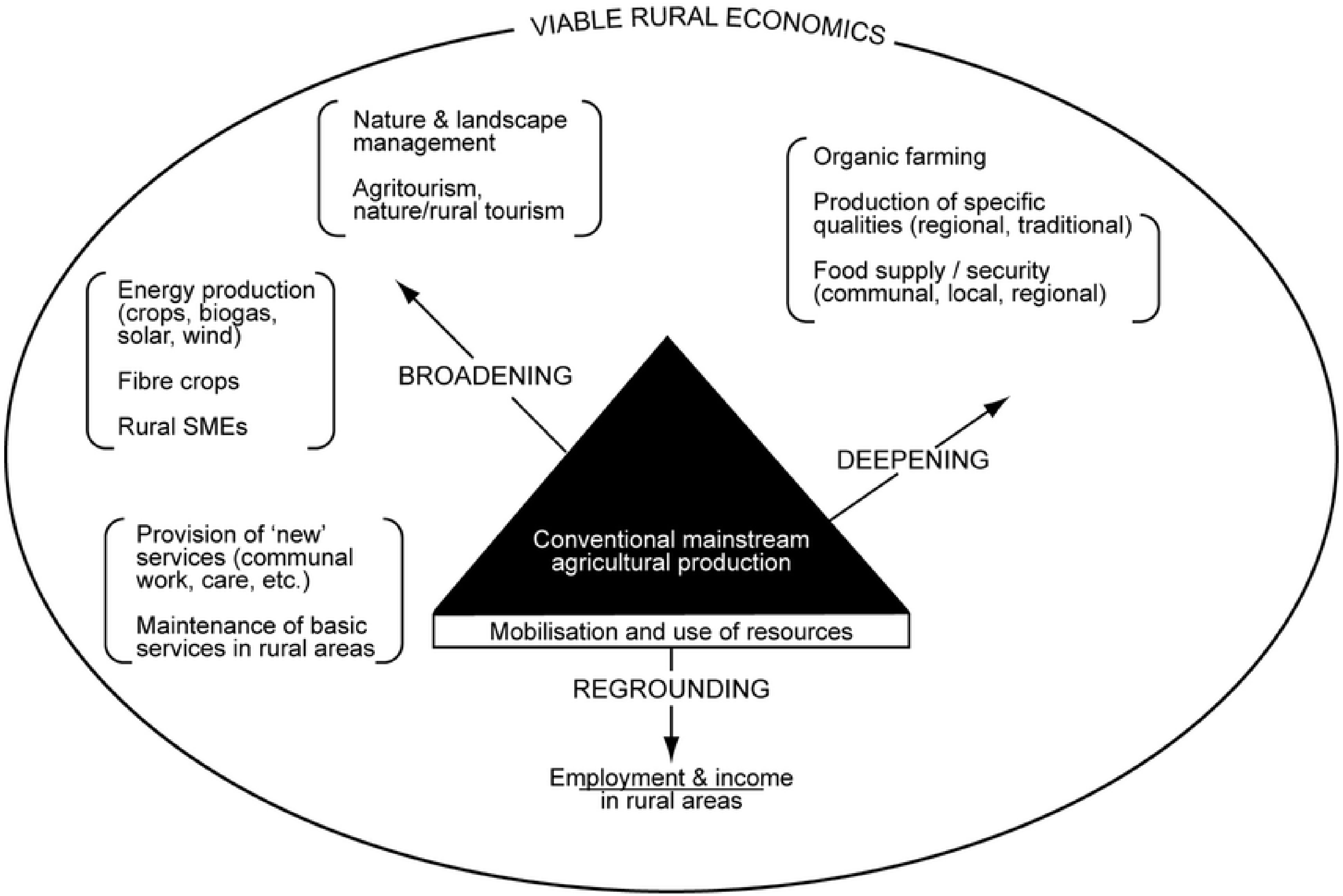
Organic farming – complex systems – ecological, economic and social viability

1. Based on the carrying capacity of ecosystem services:
   - New definition of carrying capacity: ecological, socio-economic, cultural (social marketing)
2. Knowledge regarding natural and anthropogenic cycle processes: biogeochemical cycles
3. Nutrient replenishment by recycling – linking farming, waste management and production and use of renewable energy
4. Maintaining soil fertility by protecting soil biodiversity using only natural fertilizers (such as minerals) in harmony with soil ecosystems
5. Crop rotation and ecosystem planning instead of long-term monoculture – crop diversity – using cover crops when appropriate
6. Biological pest control: new definition of Integrated Pest Management systems – biological methods or, if very much needed: only natural pesticides
7. Applying phytoremediation of soils (often combined with mineral based soil improvers) when needed

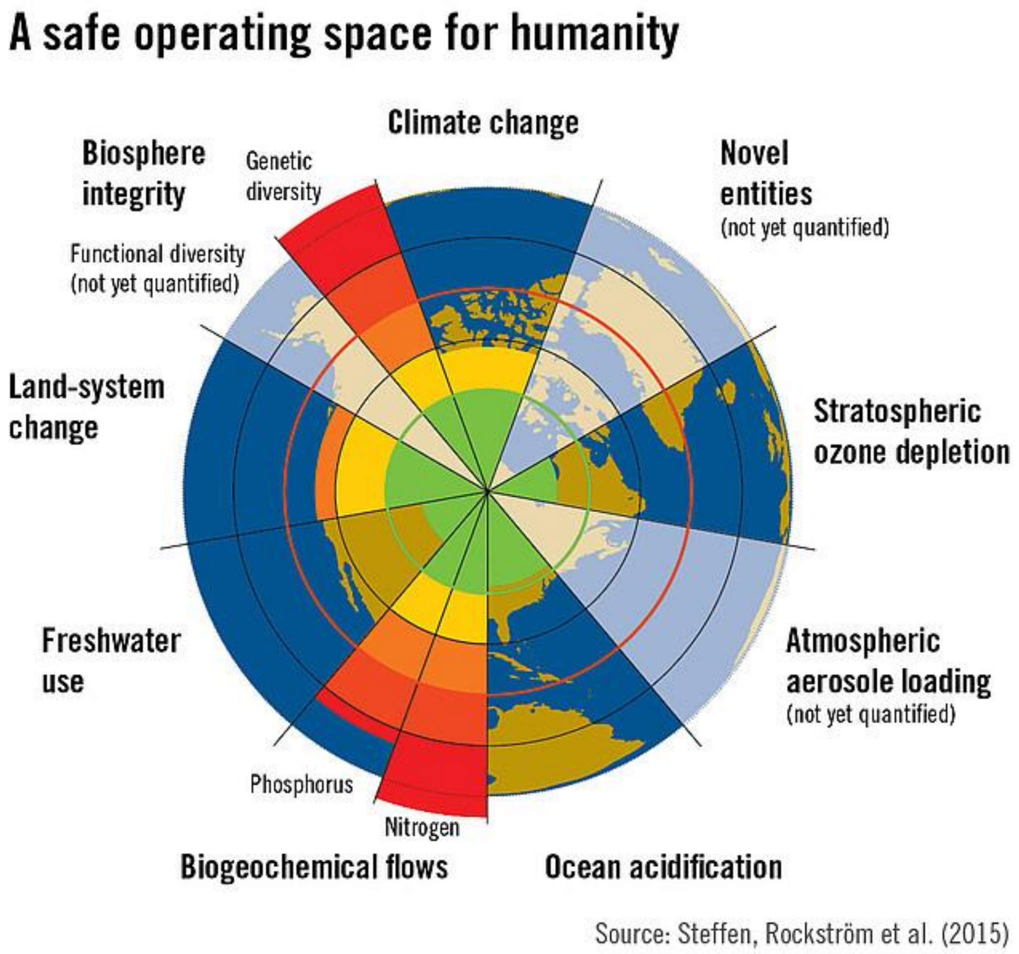
PERMACULTURE

Source: https://bcfarmsandfood.com/profitable-ecological-small-scale-farming/

Multifunctional agriculture



Impact of artificial inorganic fertilisers & pesticides; ecological solutions



Industrial multinutrient mineral fertilizers

Multinutrient fertilizers contain two or more of the nutrients N, P and K and in some cases small amounts of sulphur, magnesium and trace elements like boron may be added. There are two types of multinutrient fertilizers:

1. Blended fertilizer, is simply a mixture of individual fertilizers. Because the individual fertilizers are used in their commercially produced form, they may be of different sizes and densities and after blending may separate out during transport and spreading. This results in an uneven distribution of the nutrient elements and uneven crop growth.

2. Granular fertilizer where each granule contains the nutrients in the ratio required. They are made by mixing the individual nutrient salts, like ammonium nitrate, an ammonium phosphate and potassium chloride to create a slurry in a large vessel, known as a granulator. On drying, the granules have a moisture content of approximately 0.5% and may then be coated with a water-repelling material to prevent further moisture absorption. This improves storage life and enhances flow of the granules when they are being spread mechanically. These fertilizers are known as compound or sometimes as complex fertilizers.

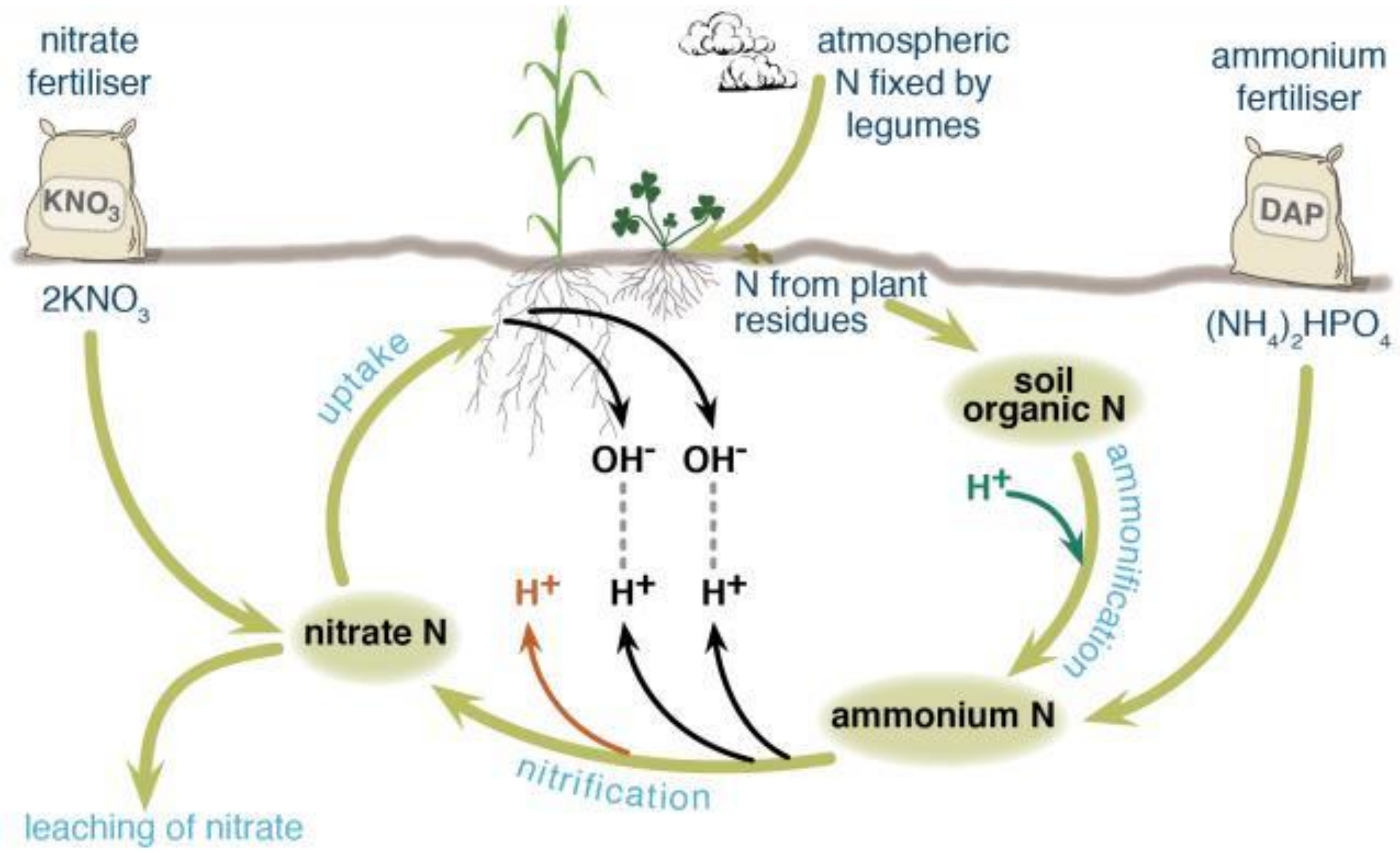
Excess nitrate and soil acidification

Soil acidification occurs naturally very slowly as soil is weathered, but this process is accelerated by productive agriculture. Soil acidification occurs because the concentration of hydrogen ions in the soil increases.

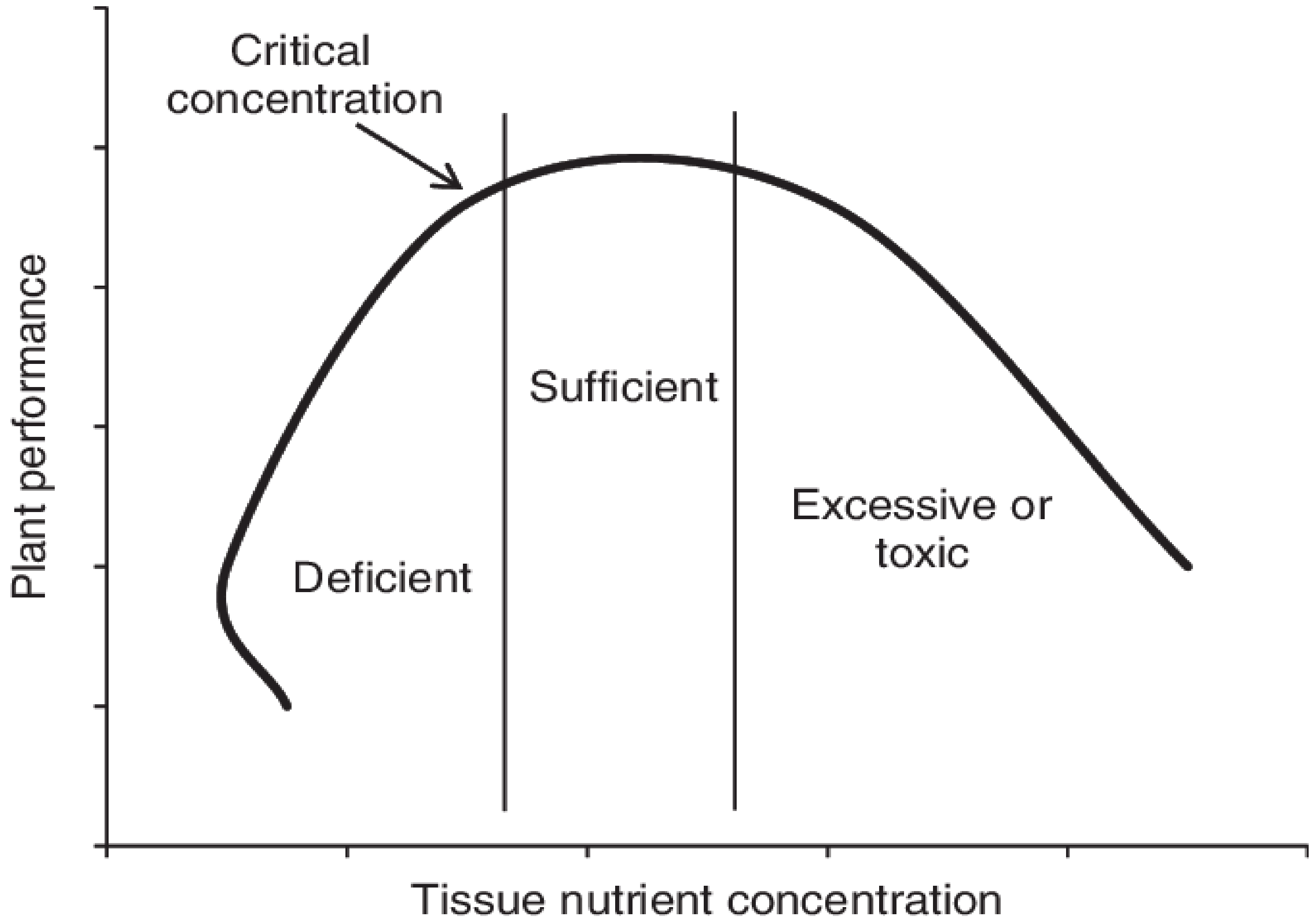
Ammonium-based fertilisers are the major contributors to soil acidification, especially if the nitrogen is leached rather than taken up by plants. Only if the nitrogen is returned to the soil again when the plant dies is there no acidification. Many ammonium fertilisers contribute to soil acidification even if the nitrogen is taken up by plants.

Ammonium nitrogen from fertiliser or soil organic matter is readily converted to nitrate and hydrogen ions by bacteria in the soil. This contributes different amounts of hydrogen ions to the soil, depending on the fertiliser.

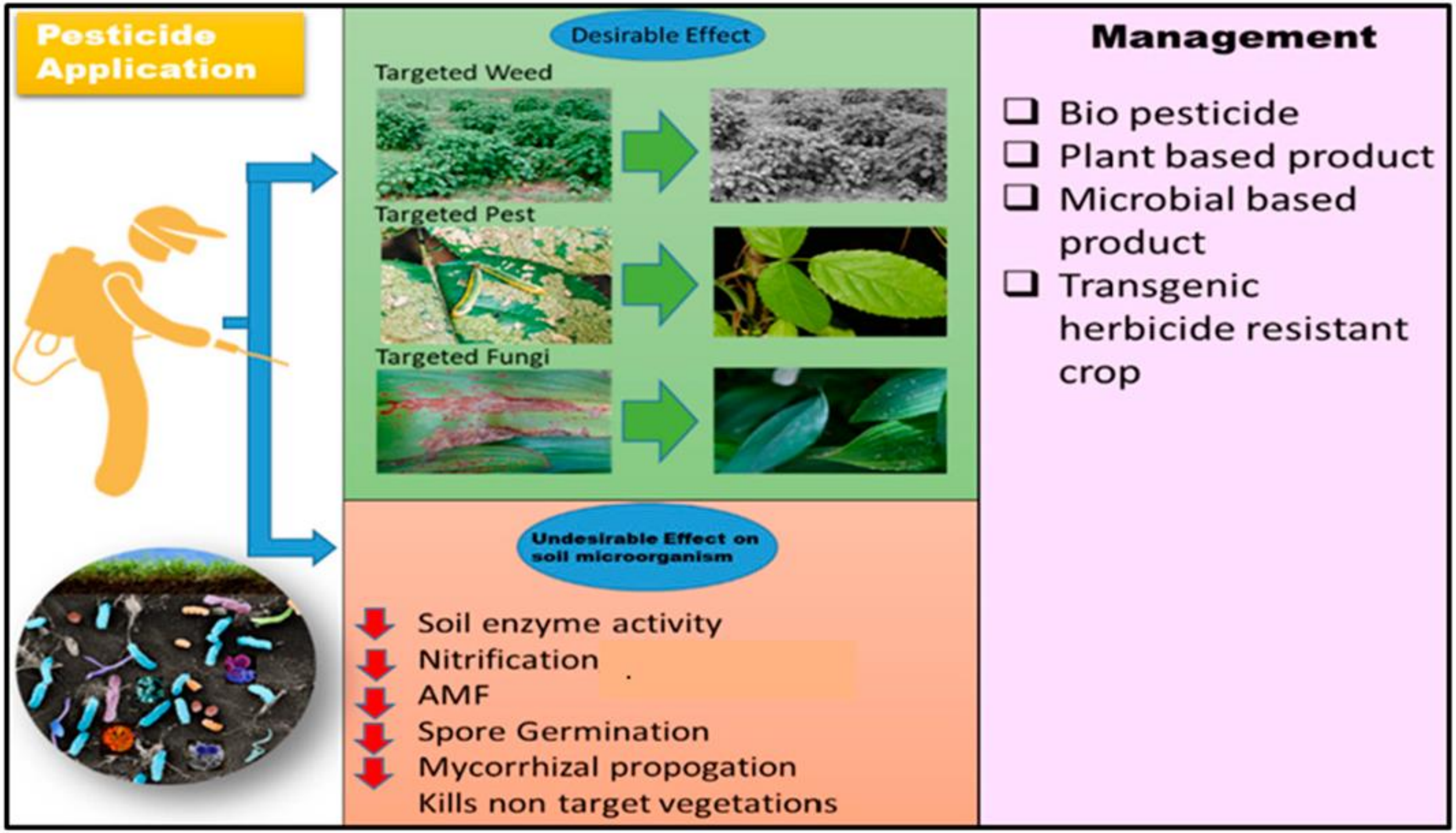
When nitrate, which is negatively charged, is taken up by plants, a hydroxide ion, also negatively charged, is released from the plant to maintain electrical balance. This hydroxide ion combines with a hydrogen ion in the soil to form water (the hydrogen ion is no longer contributing to soil acidity). Depending on the fertiliser, all hydrogen ions released by nitrification may be neutralised or there may be a net increase in hydrogen ions. If nitrate is not taken up by plants, it can leach away from the root zone, meaning that no hydroxide ion is released from the plant to bind with a hydrogen ion.

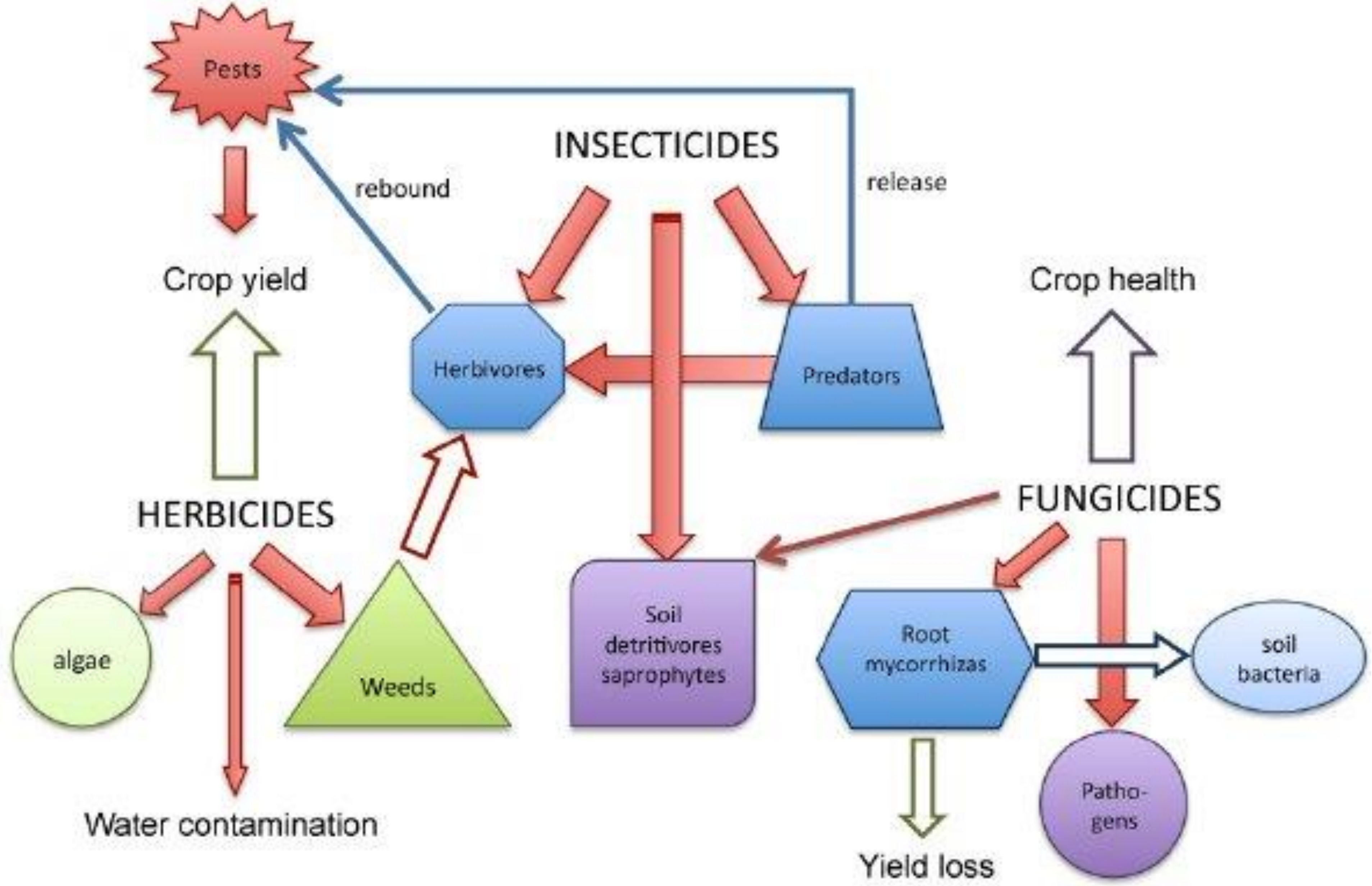

nitrate fertiliser
KNO3
2KNO3
atmospheric N fixed by legumes
ammonium fertiliser
DAP
(NH4)2HPO4
N from plant residues
soil organic N
uptake
OH-
OH-
H+
ammonification
H+
H+
H+
nitrate N
ammonium N
nitrification
leaching of nitrate

Excess nutrient toxicity



Impact of pesticides on soils





Francisco Sánchez-Bayo, 2011

Ecological solutions

Natural pest control can be less expensive than buying & applying commercial pesticides that are filled with toxic chemicals. It's also safer for your garden, your family, and the environment.

Mineral based soil improvers – revival of sustainable practices

1. In the past fifty years, the nutrient supply of soils has been severely weakened in agricultural areas, mainly due to large-scale monoculture and intensive cultivation methods based on short-term synthetic fertilizers.

2. Soil minerals have many functions, including increasing the nutrient absorption capacity of plants, adjusting the pH of soils, and providing nutrients to plants.

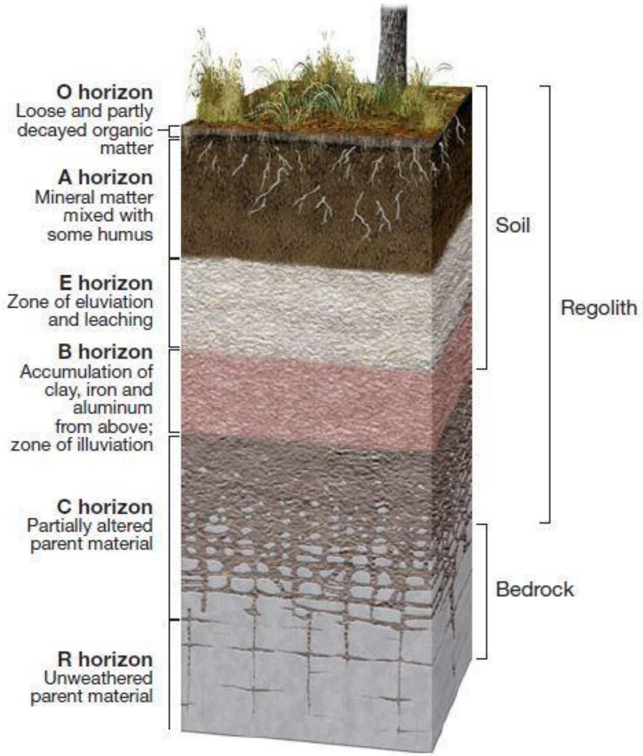
3. Improving the soil's mineral content is an important part of healthy plant cultivation and essential for modern organic farming.

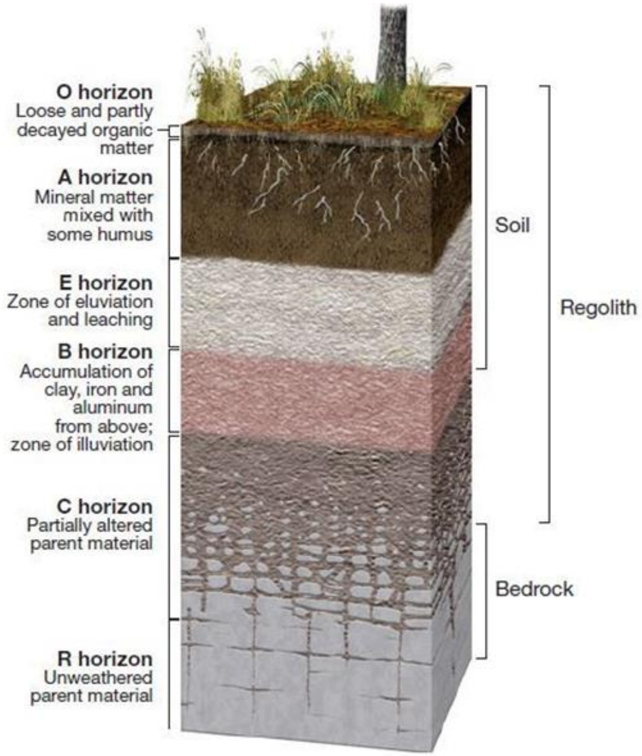
4. Research on the use of mineral soil improvers and rock powder fertilizers have been developed in connection with their abilities and utilization possibilities for domestic agricultural areas in Hungary.

Mineral based soil improvers can be divided into two main groups according to their use and recoverability:

1. In the soil zone (in the depth of the soil profile)

2. Below the soil zone (deeper situated materials)





1. In the soil zone (in the depth of the soil profile)

a. Materials of marshland soils (peat, marshes, moss, lime mud)

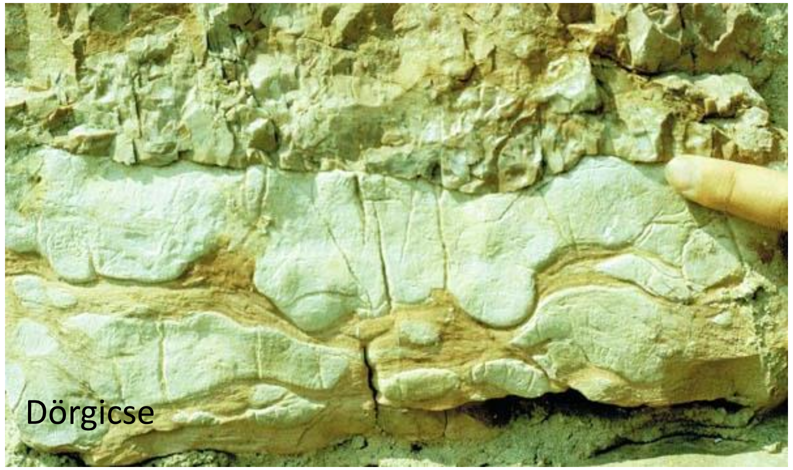
b. Top layers of meadow soils (containing clay minerals and humus)

c. Loess, calcareous formations in the subsoil of higher lying fields of the saline lowland areas

2. Below the soil zone (deeper situated materials)

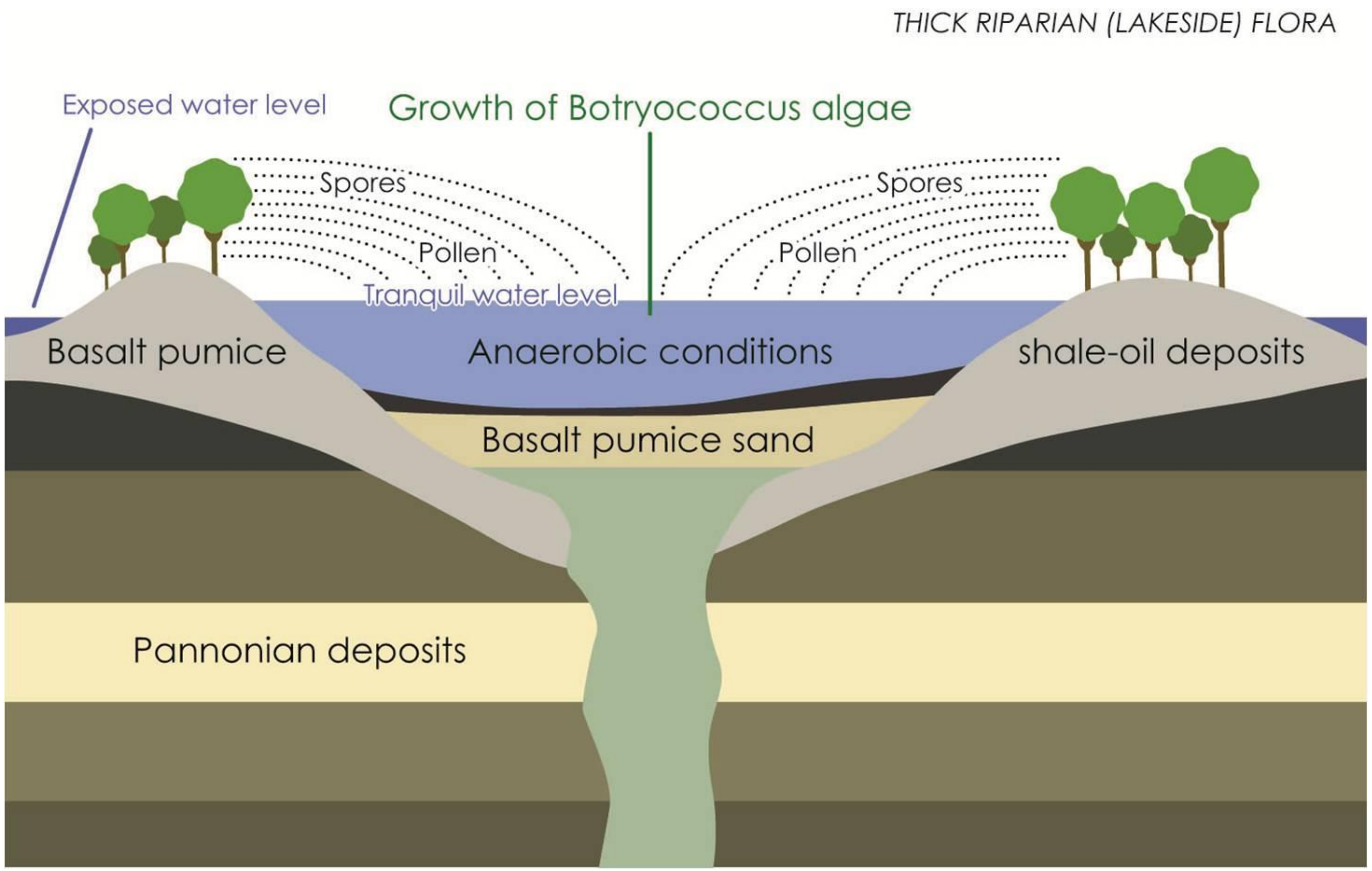
a. **Limestone (monomineral, mostly biogenic, sometimes chemical sedimentary rock, calcium carbonate content at least 90%, mostly calcite)**

b. **Dolomite (calcium-magnesium carbonate trigonal crystalline mineral)**



c. **Alginite (sedimentary rock composed of algae biomass and volcanic tuff)**

ALGINITE



Alginite is a mineral containing in high concentration components such as humus, limestone, Nitrogen (N), potassium (K), magnesium (Mg) and other macro- and micro elements, these among 62 different components so far identified in it, all deriving from the region of Gérce, Hungary.

4-5 million years ago green algae a relatively rare species (*Botryococcus braunii*) proliferated in the closed ring-shaped volcanic crater crater-cone which arose from the Pannonian sea.

The sea algae settled down with other floating particles on the bottom of the interior hollow. The mineral resource originated from this settled and fossillised algal-biomass is known as alginite. It developed in aerobic conditions.

Alginite belongs to the category of oil shales but it has got unique and individual attributes which can cause an alteration to the oil shales not only in physico-chemical characteristics but in the potential usage of the product.

So far alginite was discovered exclusively in Hungary, or more precisely in the Carpatian Basin. It can be found and mined solely in this area of the world.

Alginite quarry in Pula, Hungary

2. Below the soil zone (deeper situated materials) cont.

d. Zeolites (sodium calcium aluminosilicates, spacious, hollow, porous)

e. Rhyolitic tuff (volcanic, high silica, sour, contain pumiceous, glassy fragments and small scoriae with quartz, alkali feldspar and biotite)

f. Perlite (high-water, felsic, by heating heavily swollen glass rock)

Bodrogkeresztúr – rhyolitic tuff quarry

2. Below the soil zone (deeper situated materials) cont.

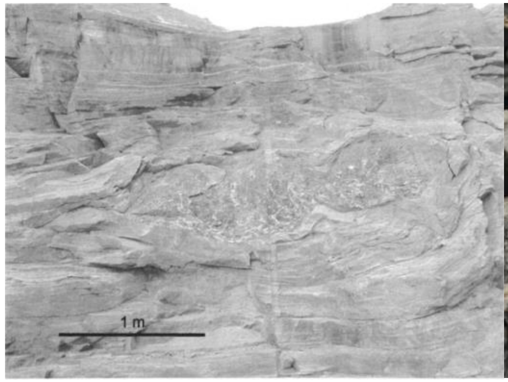
g. Marl (sedimentary, clay-carbonate rock)

h. Bentonite (a clay-type, dominant elements may be aluminum, potassium, calcium and sodium, with a water retaining capacity of 15 – 20 times its volume).

i. Potassium trachyte (high potassium spillage rock with white, sanidine crystals). Sanidine is the high temperature form of potassium feldspar with a general formula $K(AlSi_3O_8)$.

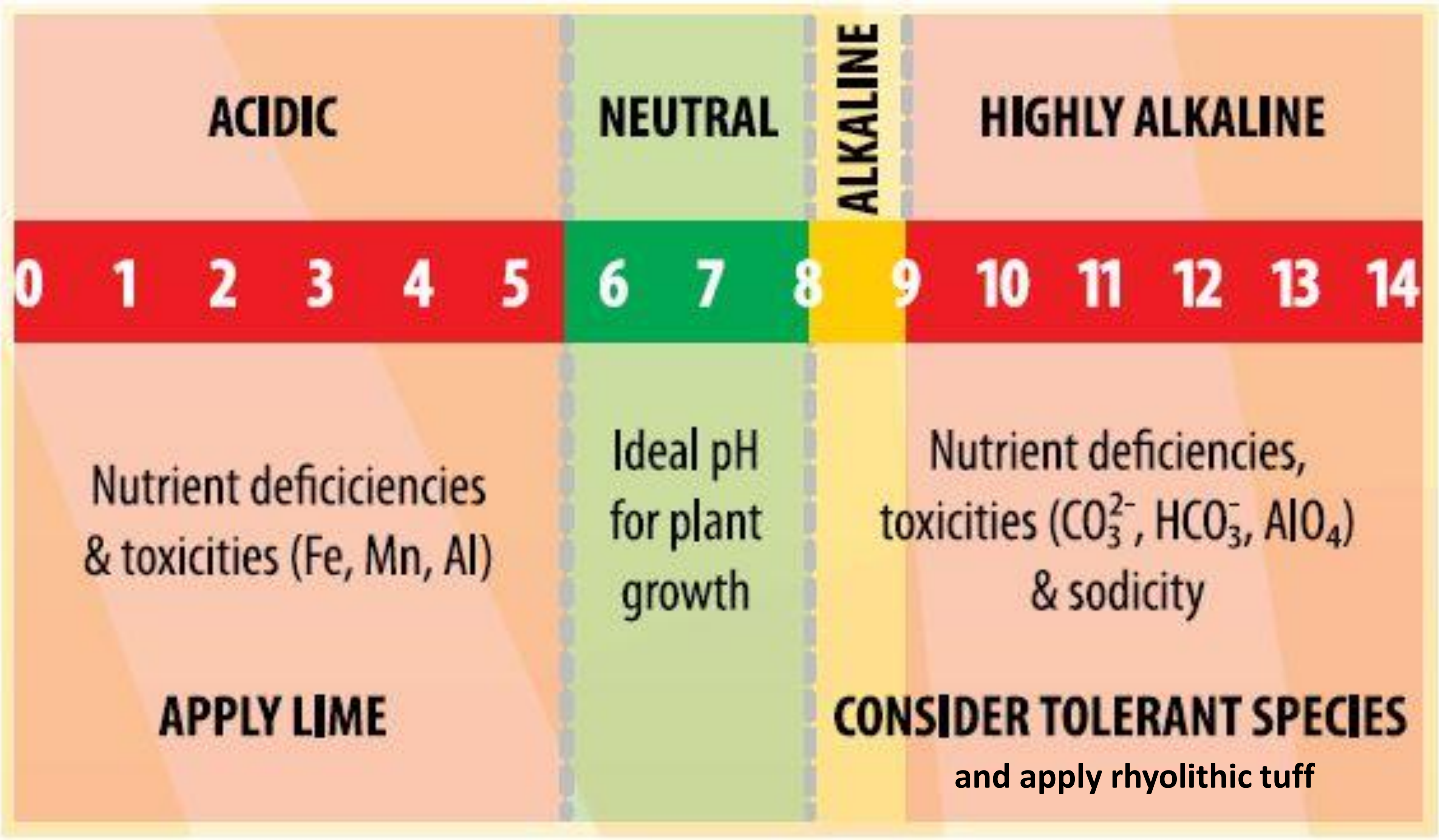
2. Below the soil zone (deeper situated materials) cont.

j. Mixture of gypsum anhydrite (anhydrous alkali sulphate) and lignite powder

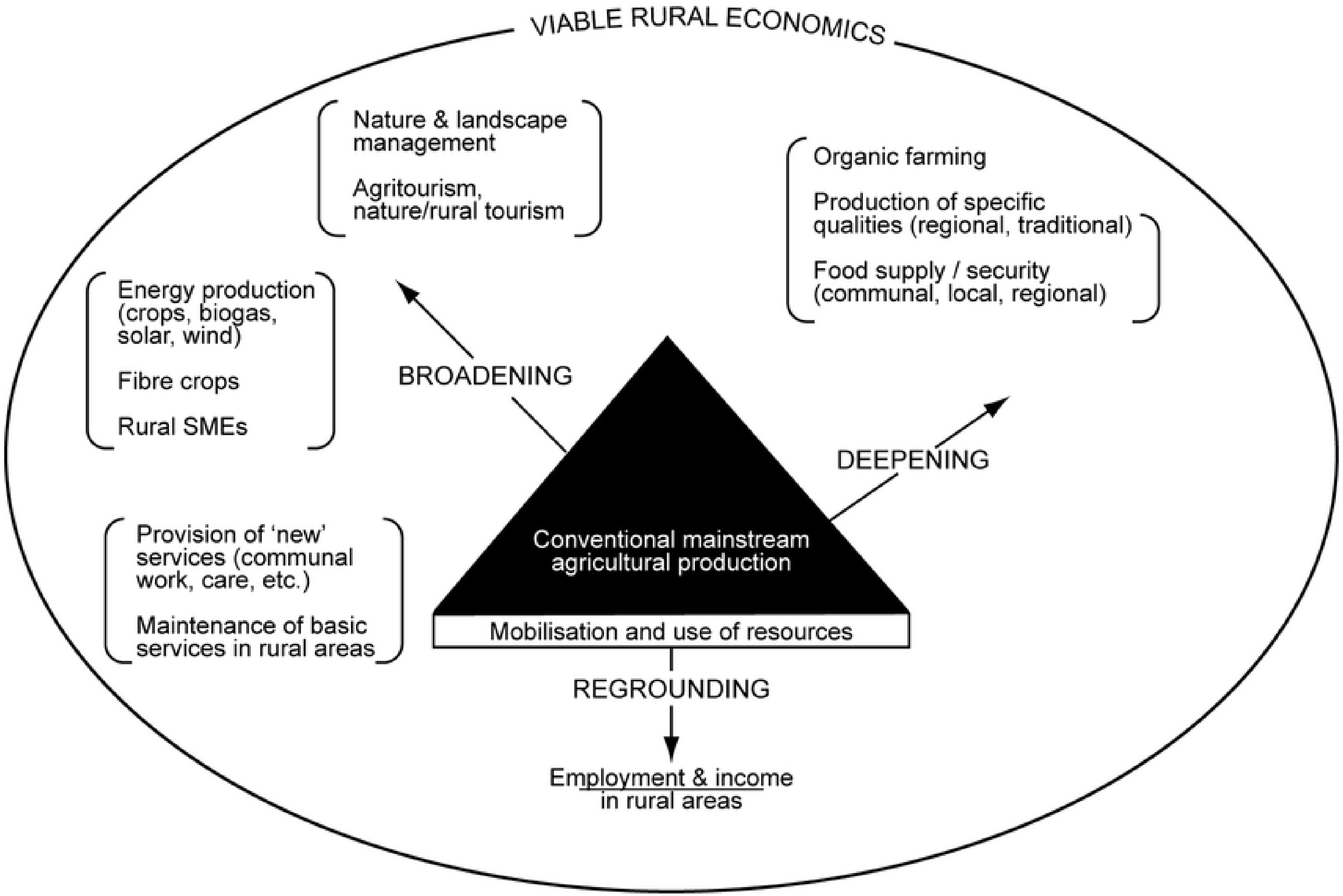


k. Dudarit NPK (brown coal-based soil enhancer with more than 60% humic acid content mined in the Dudar area, Hungary)

Soil pH – one of the most important factors – one of the functions of mineral based soil improvers



Multifunctional agriculture

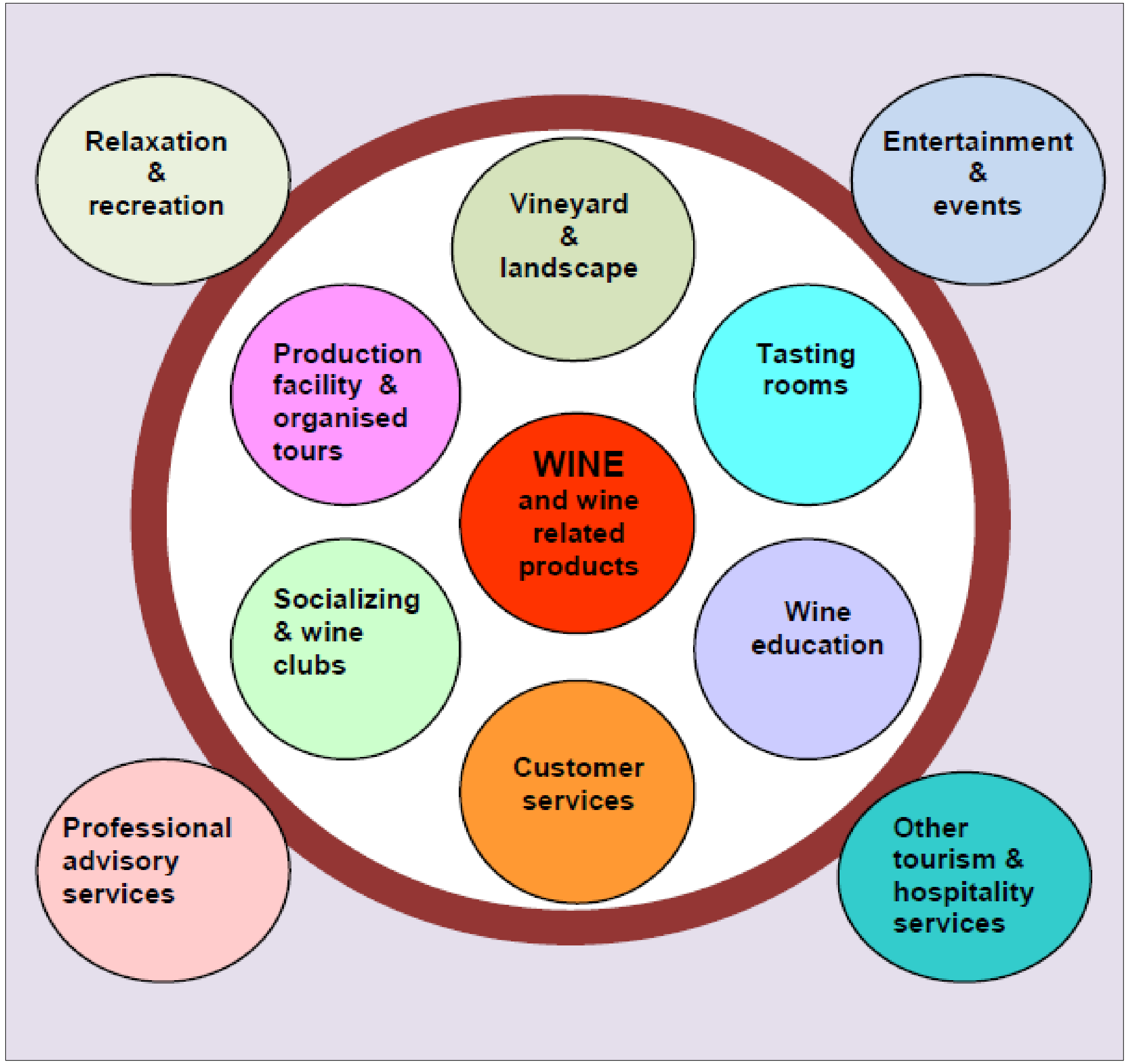


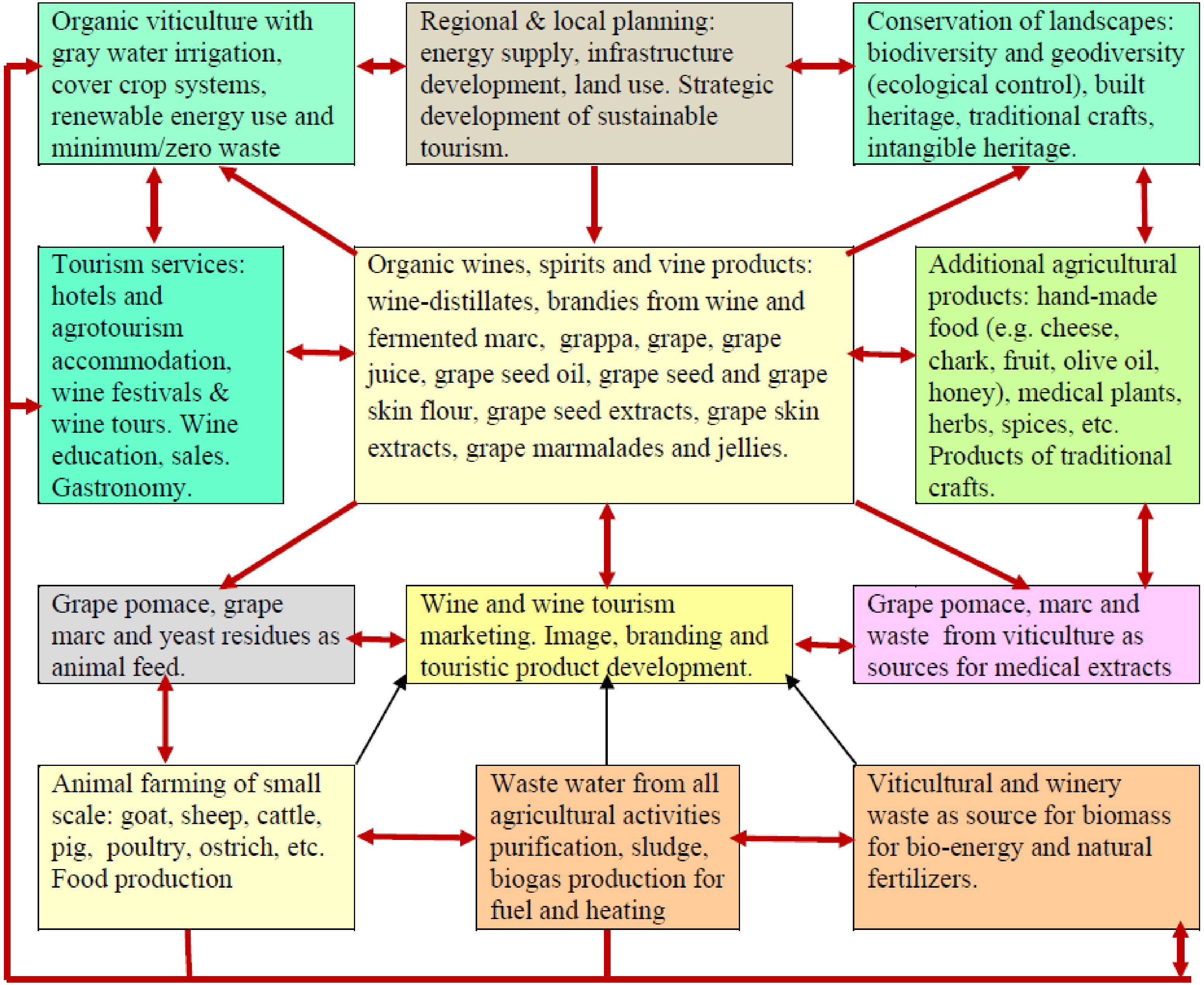
The Azienda Agricola Model

Holistic approach

1. Originally developed for the wine sector- the grapevine is a multifunctional crop
2. Based on organic multifunctional agriculture
3. Energy – Product – Service – Zero Waste Principle
4. Ecological sustainability
5. Economic viability
6. Landscape stewardship
7. Heritage conservation – built and intangible heritage
8. Sustainable tourism
9. Revitalization of traditional trades and crafts
10. Viable local economies

Core, augmented and ancillary services in a wine region




Organic viticulture with gray water irrigation, cover crop systems, renewable energy use and minimum/zero waste
Regional & local planning: energy supply, infrastructure development, land use. Strategic development of sustainable tourism.
Conservation of landscapes: biodiversity and geodiversity (ecological control), built heritage, traditional crafts, intangible heritage.
Tourism services: hotels and agrotourism accommodation, wine festivals & wine tours. Wine education, sales. Gastronomy.
Organic wines, spirits and vine products: wine-distillates, brandies from wine and fermented marc, grappa, grape, grape juice, grape seed oil, grape seed and grape skin flour, grape seed extracts, grape skin extracts, grape marmalades and jellies.
Additional agricultural products: hand-made food (e.g. cheese, chark, fruit, olive oil, honey), medical plants, herbs, spices, etc. Products of traditional crafts.
Grape pomace, grape marc and yeast residues as animal feed.
Wine and wine tourism marketing. Image, branding and touristic product development.
Grape pomace, marc and waste from viticulture as sources for medical extracts
Animal farming of small scale: goat, sheep, cattle, pig, poultry, ostrich, etc. Food production
Waste water from all agricultural activities purification, sludge, biogas production for fuel and heating
Viticultural and winery waste as source for biomass for bio-energy and natural fertilizers.

Thank you for your attention!