Erhöhung der mikrobiellen Aktivitäten des Bodens - ein Schlüsselinstrument gegen Bodenerosion

Zvýšení mikrobiální aktivity půdy jako klíčový nástroj proti půdní erozi

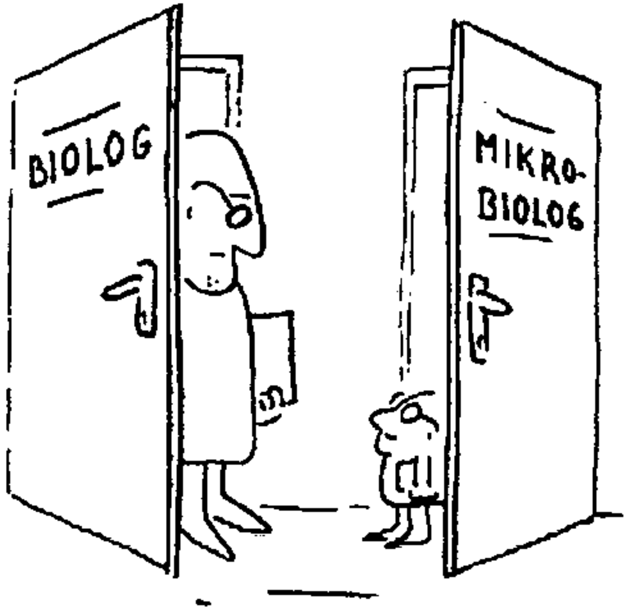
Mendelova univerzita v Brně

Záhora J., Tůma I., Hynšt J., Stroblová M., Elbl J., Plošek L., Kintl A., Urbánková O., Záhora J. (jr)

EUROPEAN UNION
European Regional Development Fund

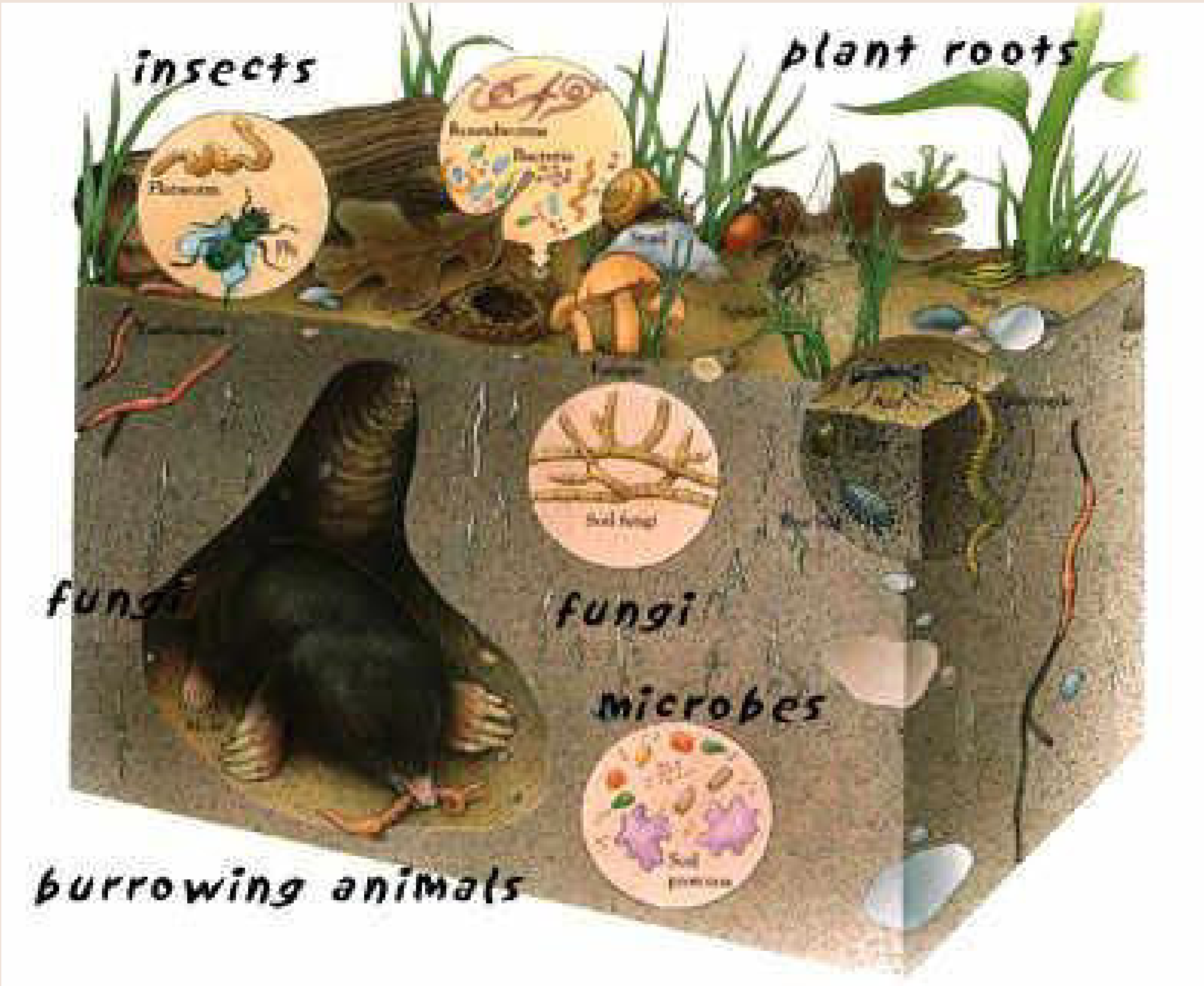
SONDAR CZ-AT
Soil Strategy Network in the Danube Region

SPOLUPRÁCE CZ - KOOPERATION AT
EUROPEAN TERRITORIAL CO-OPERATION
AUSTRIA-CZECH REPUBLIC 2007-2013
Gemeinsam mehr erreichen. Společně dosáhneme více.



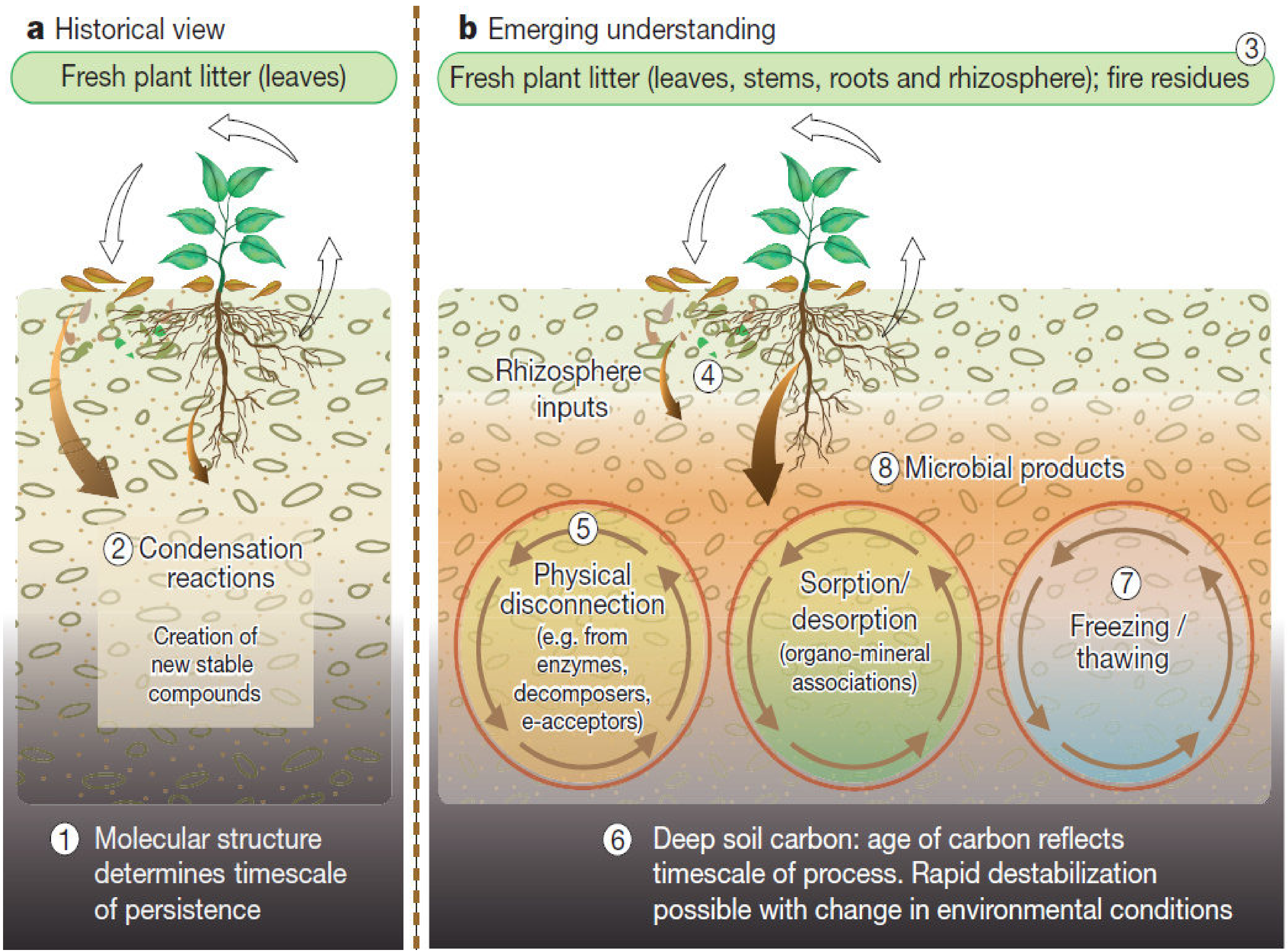
The laws of applied microbiology (David Perlman, 1980)

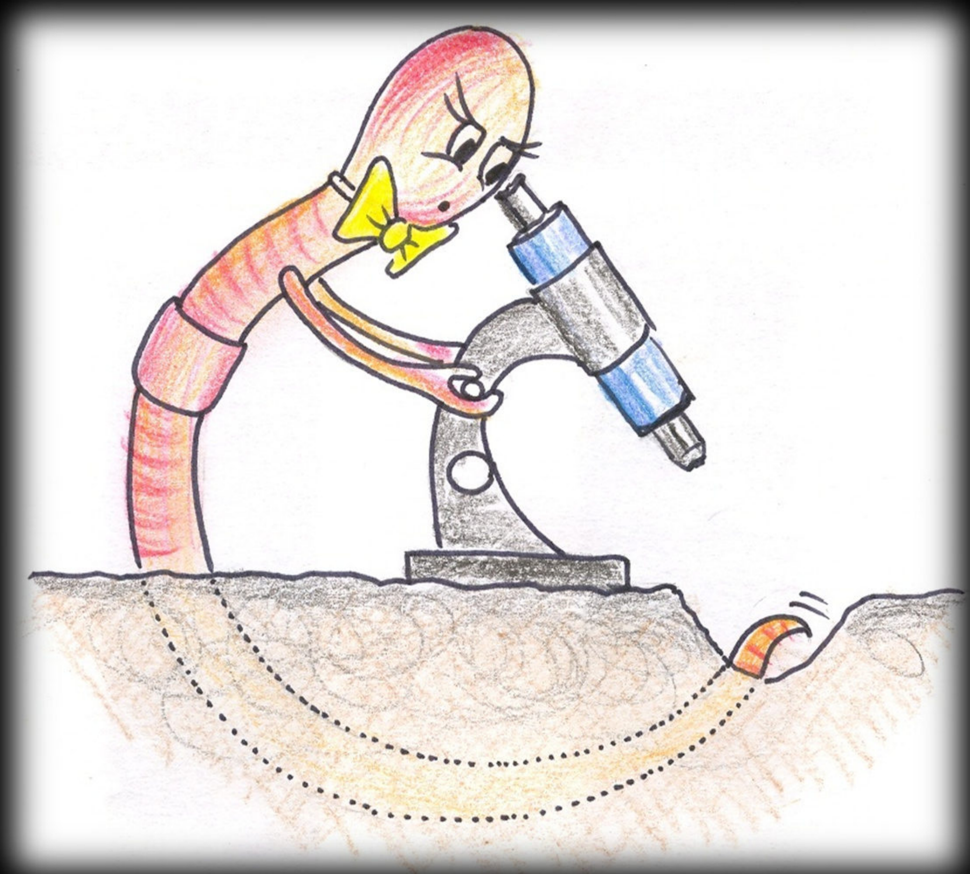
- The microbe is always right, your friend, and a sensitive partner;
- There are no stupid microbes;
- Microbes can and will do anything;
- Microbes are smarter, wiser, and more energetic than chemists, engineers, and others; and
- If you take care of your microbial friends, they will take care of your future.



„Soil is the most complicated biomaterial on the planet.
As with any material, the physical habitat is of prime importance in determining and regulating biological activity.“

(Young and Crawford, 2004: Interactions and Self-Organization in the Soil-Microbe Complex)


a Historical view
Fresh plant litter (leaves)
2 Condensation reactions
Creation of new stable compounds
1 Molecular structure determines timescale of persistence
b Emerging understanding
Fresh plant litter (leaves, stems, roots and rhizosphere); fire residues 3
Rhizosphere inputs
4
8 Microbial products
5 Physical disconnection (e.g. from enzymes, decomposers, e-acceptors)
Sorption/ desorption (organo-mineral associations)
7 Freezing / thawing
6 Deep soil carbon: age of carbon reflects timescale of process. Rapid destabilization possible with change in environmental conditions



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EW


INTERSPORT
MADE TO MOVE NATURALLY
INTERSPORT
POLO
TRIKO
Zahradní substrát

Microorganisms are the main decomposers, responsible for over 90% of the mineralisation occurring in soils (Lavelle & Spain 2001) and able to decompose any kind of natural substrate.

In optimal laboratory conditions, individuals can multiply extremely fast, increasing their biomass in short periods of time (in the order of days). However, in nature, the **turnover time of microbial biomass** generally varies between 6 and 18 months, that is 1,000 to 10,000 times slower than under laboratory conditions.

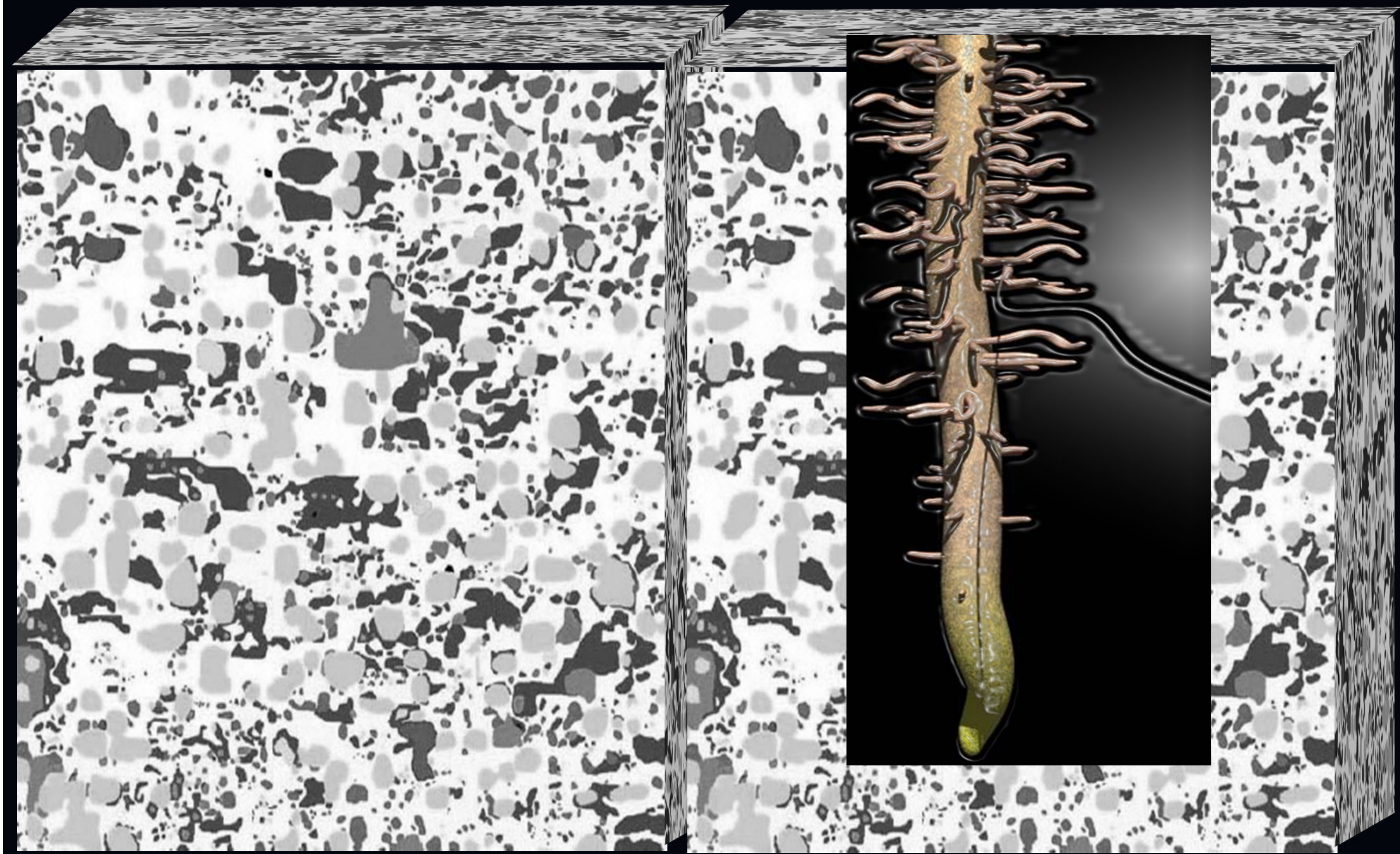
This indicates that in nature, micro-organisms are inactive most of the time. This inactivity may be due to **starvation**, resulting from their inability to move towards new substrates once their immediate surroundings are exhausted.

The apparent contradiction between laboratory and field observations has been named the '**Sleeping Beauty paradox**' (Lavelle, Lattaud et al. 1995).

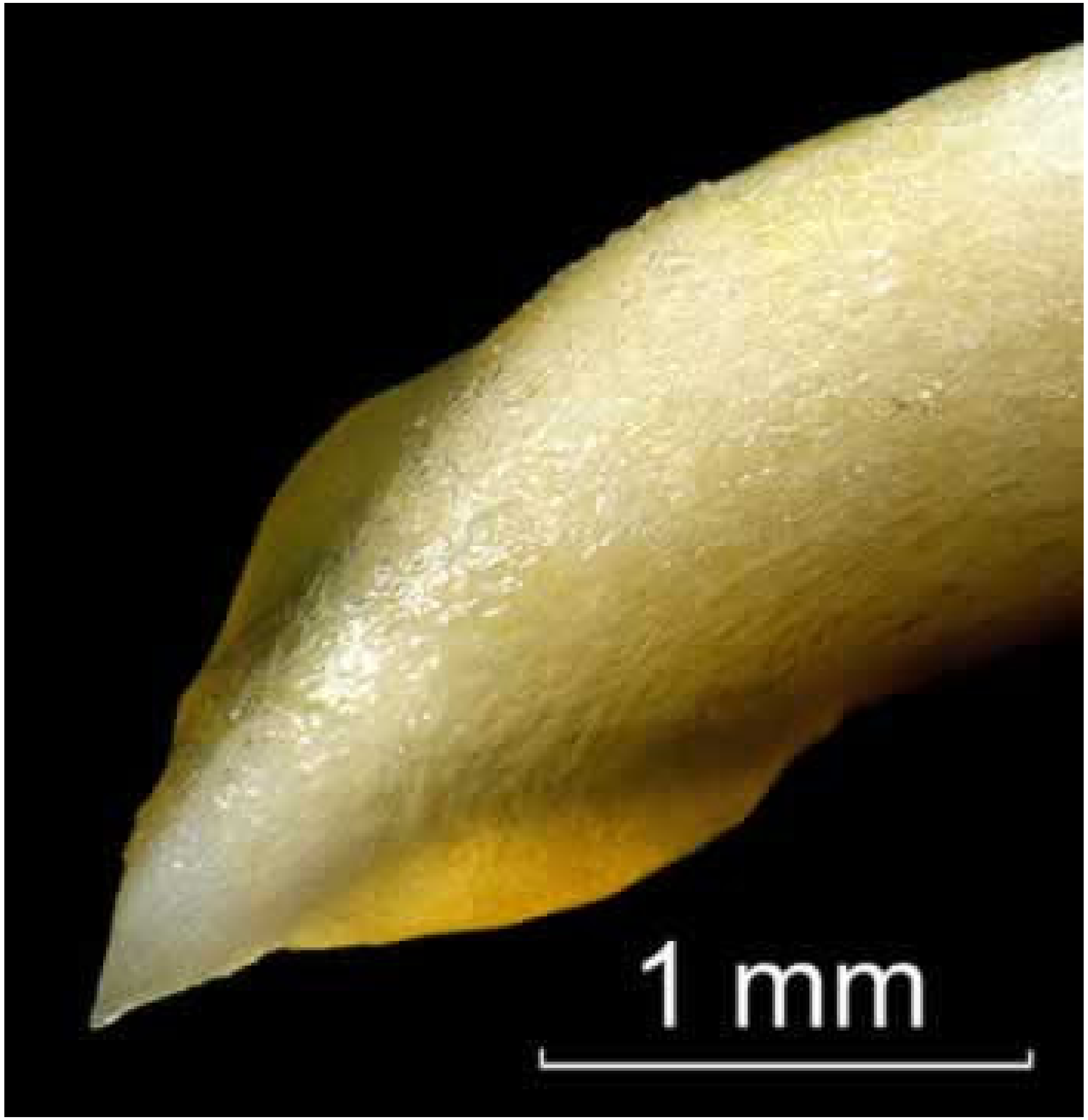
The '**Prince Charming**' of the story is any macro-organism, including plant roots, or physical process that may bring microorganisms in contact with new substrates to decompose, thereby activating them.

Importantly, earthworms provide the suitable temperature, moisture and organic resources within their guts for microbes to be activated (Brown, Barois et al. 2000).

… 'Sleeping Beauty paradox' ….

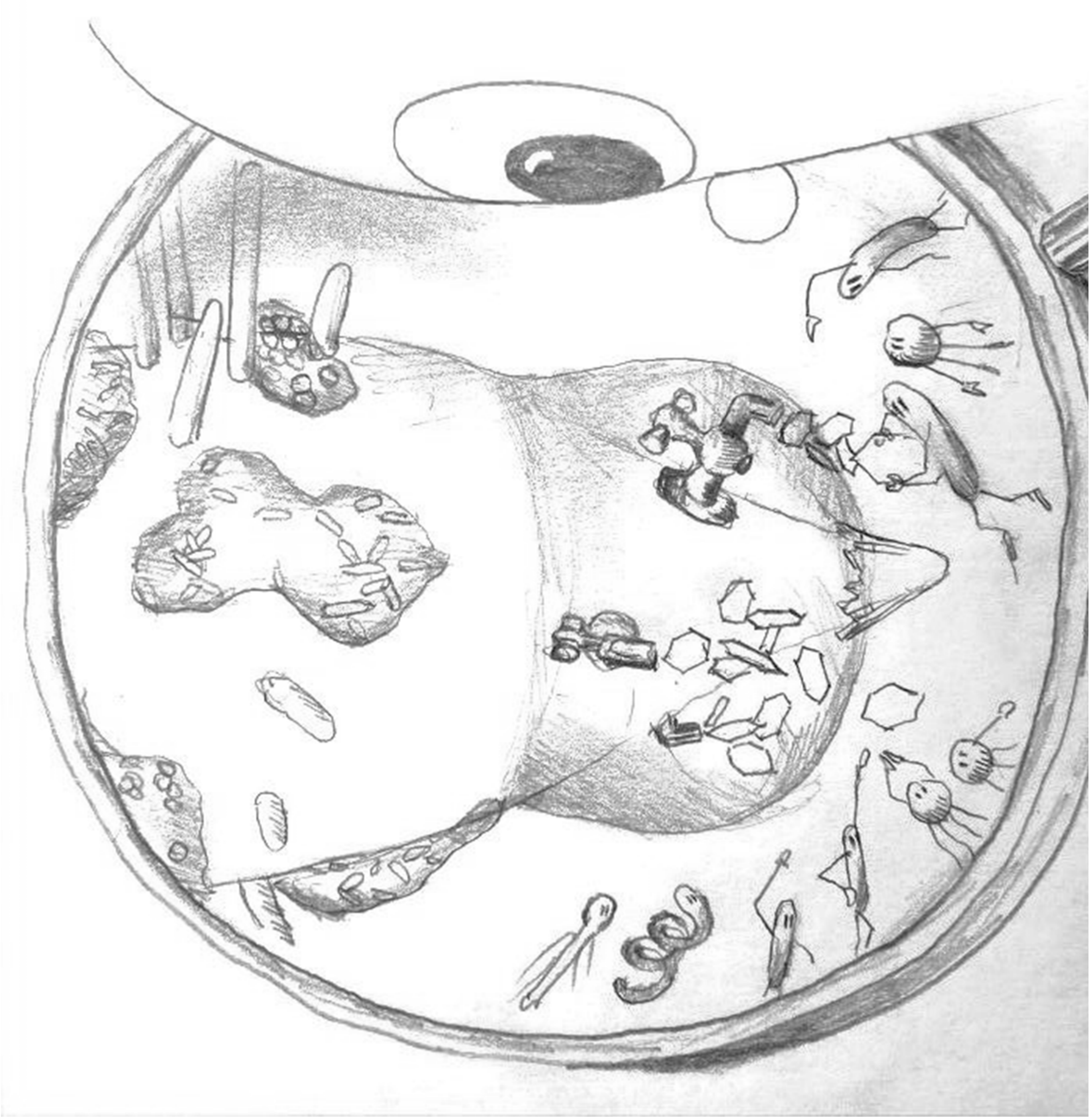


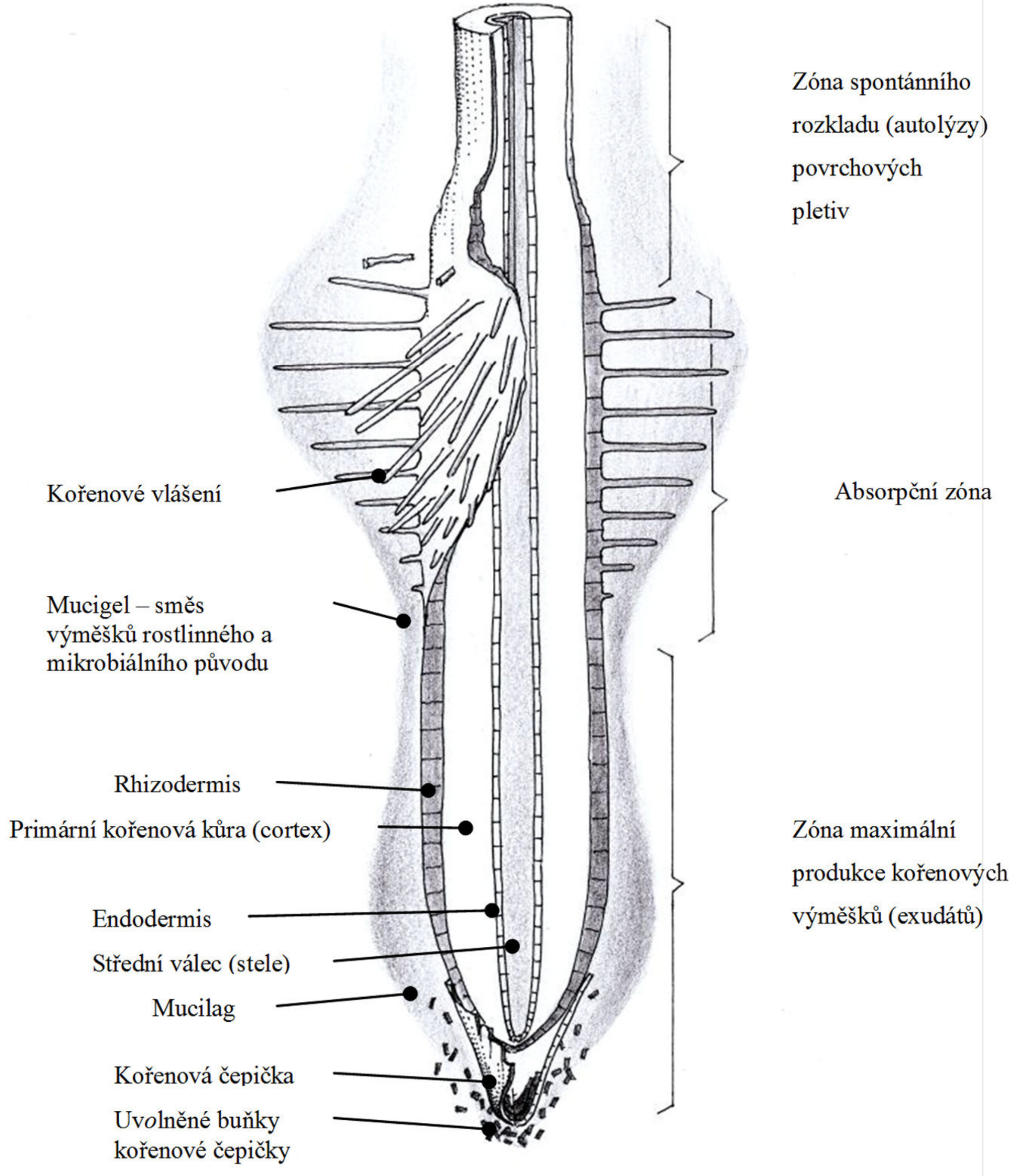

PLEASE
DO NOT
DISTURBE
WE ARE
STARVING

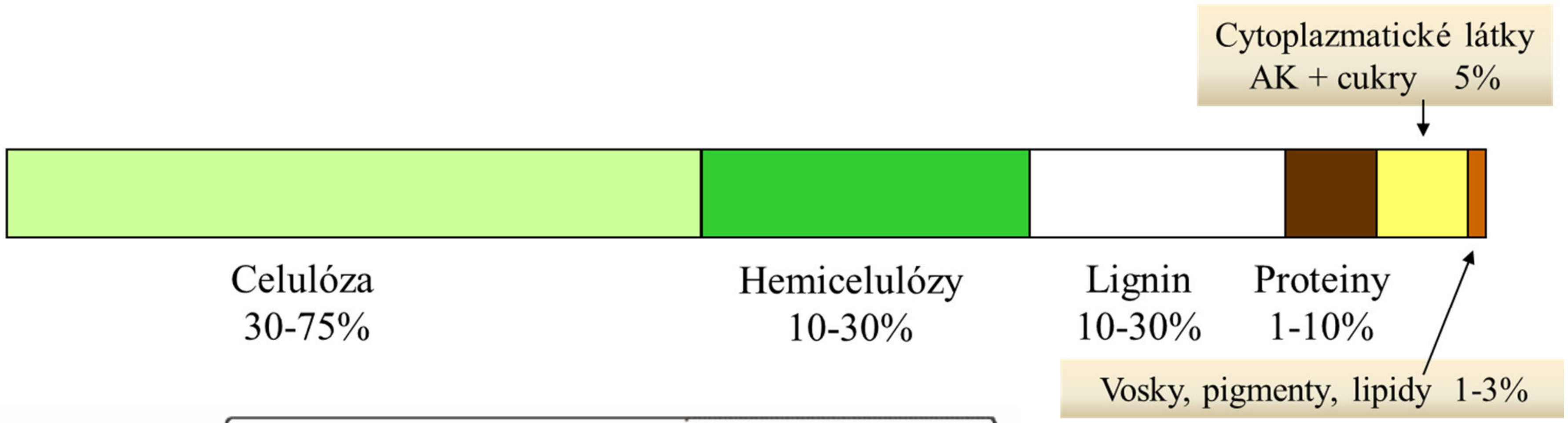


Micrograph of root cap with mucilage produced by the plant (maiz)

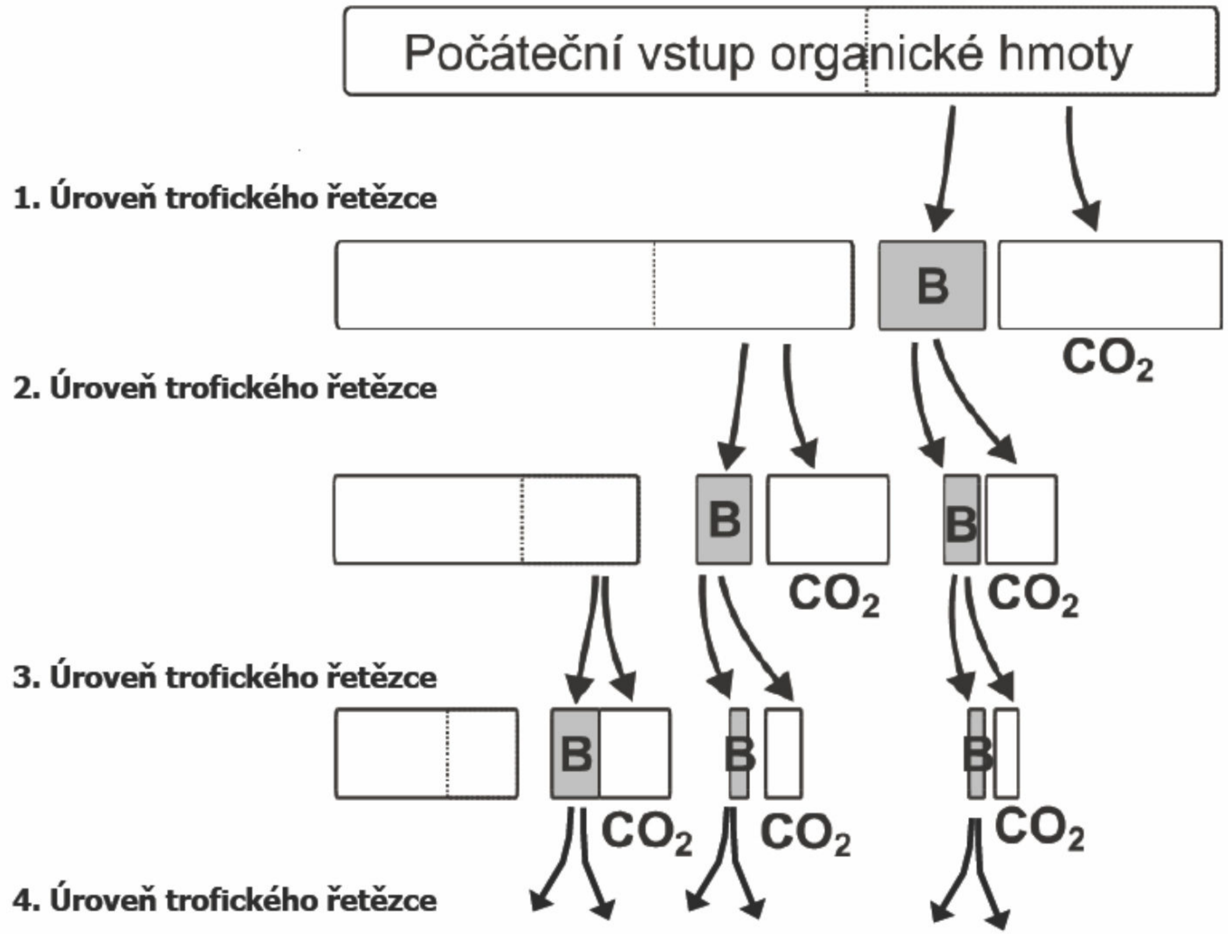
(Source: V. Sobolev, Agricultural Research Service, United States Department of Agriculture - ARS USDA)



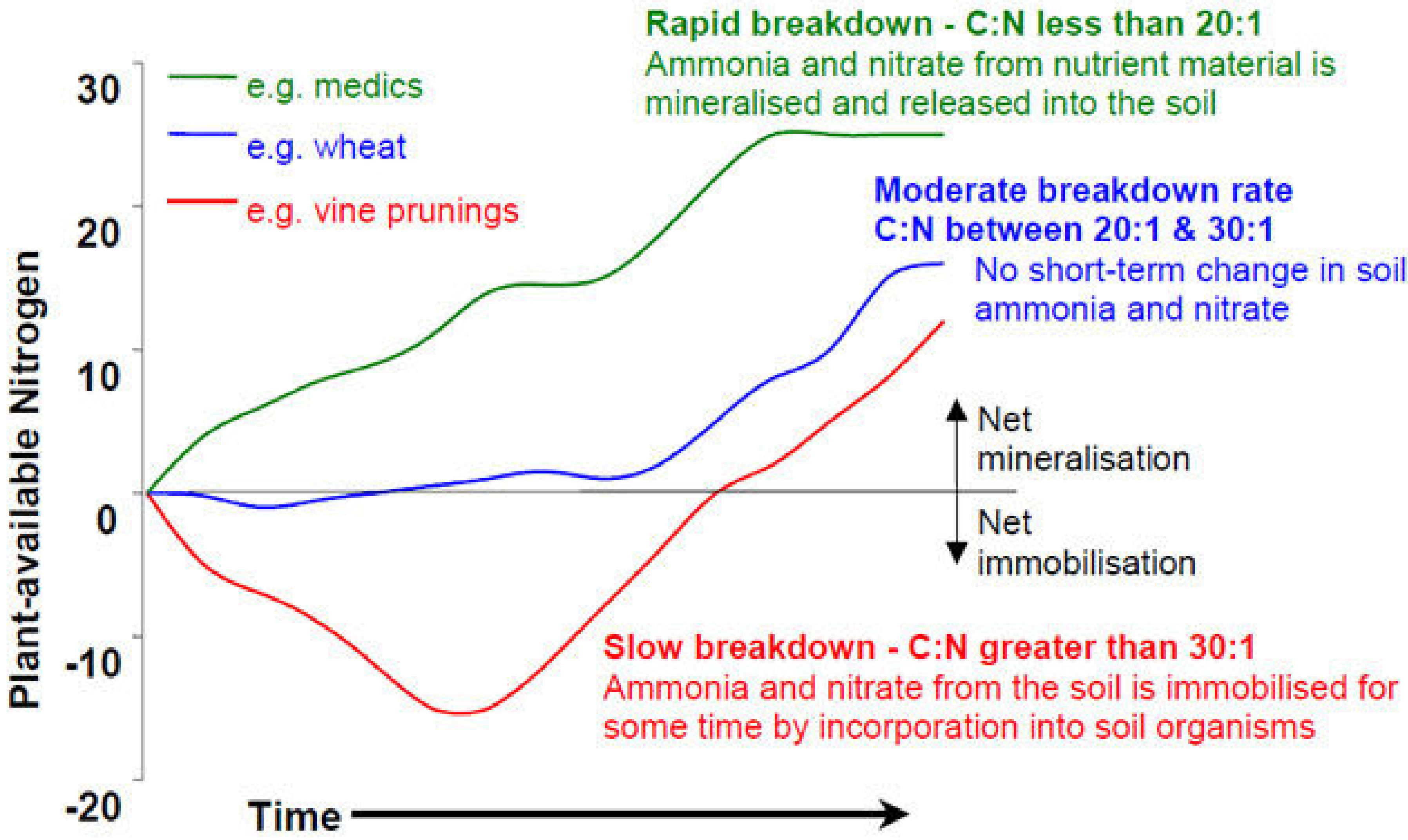

Zóna spontánního
rozkladu (autolýzy)
povrchových
pletiv
Absorpční zóna
Zóna maximální
produkce kořenových
výměšků (exudátů)
Kořenové vlášení
Mucigel – směs
výměšků rostlinného a
mikrobiálního původu
Rhizodermis
Primární kořenová kůra (cortex)
Endodermis
Střední válec (stele)
Mucilag
Kořenová čepička
Uvolněné buňky
kořenové čepičky



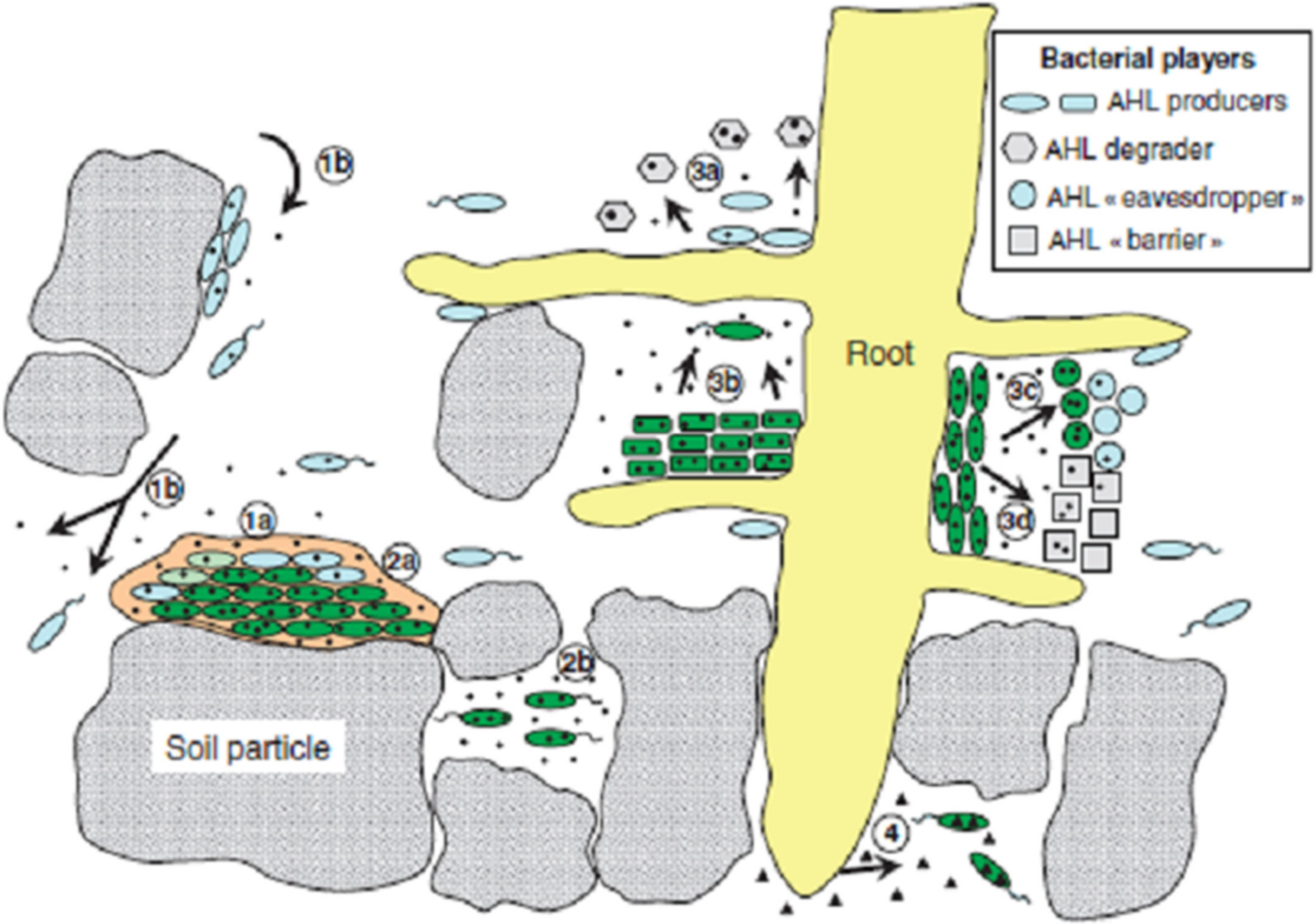
Cytoplazmatické látky
AK + cukry 5%
Celulóza
30-75%
Hemicelulózy
10-30%
Lignin
10-30%
Proteiny
1-10%
Vosky, pigmenty, lipidy 1-3%



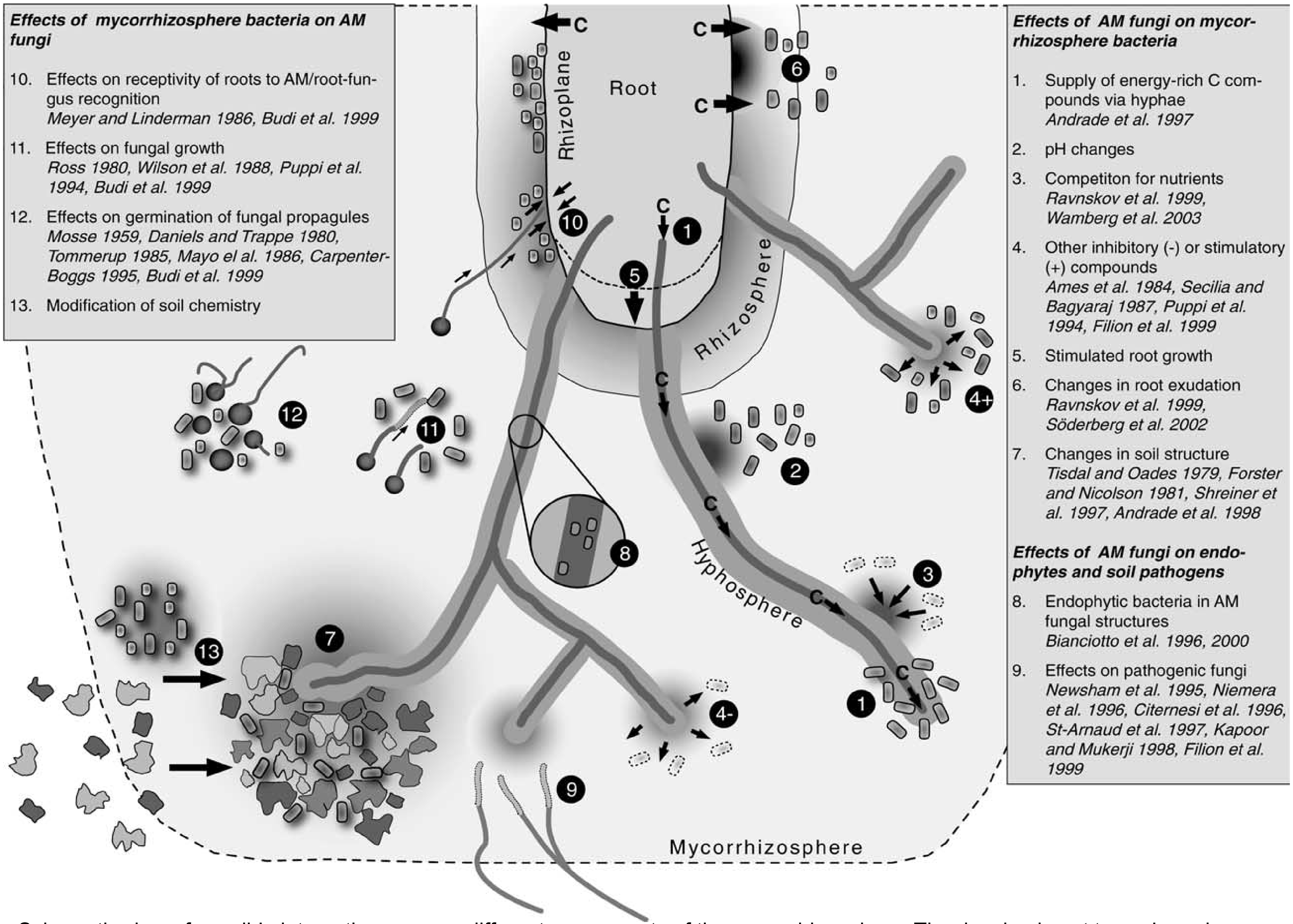
Počáteční vstup organické hmoty
1. Úroveň trofického řetězce
2. Úroveň trofického řetězce
3. Úroveň trofického řetězce
4. Úroveň trofického řetězce
B
CO_2



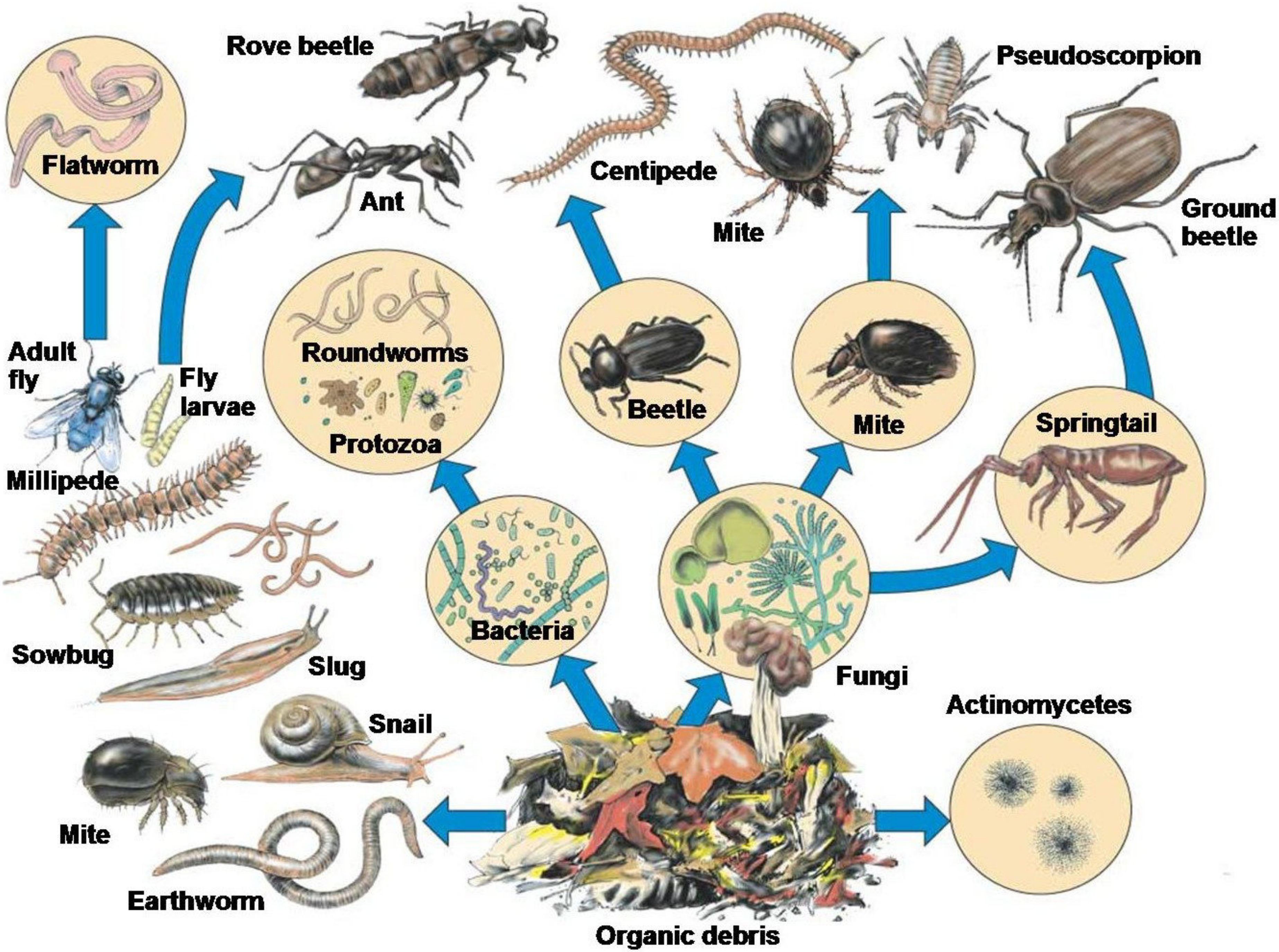
C:N ratio and plant available nitrogen (Treeby et Goings, 2001)



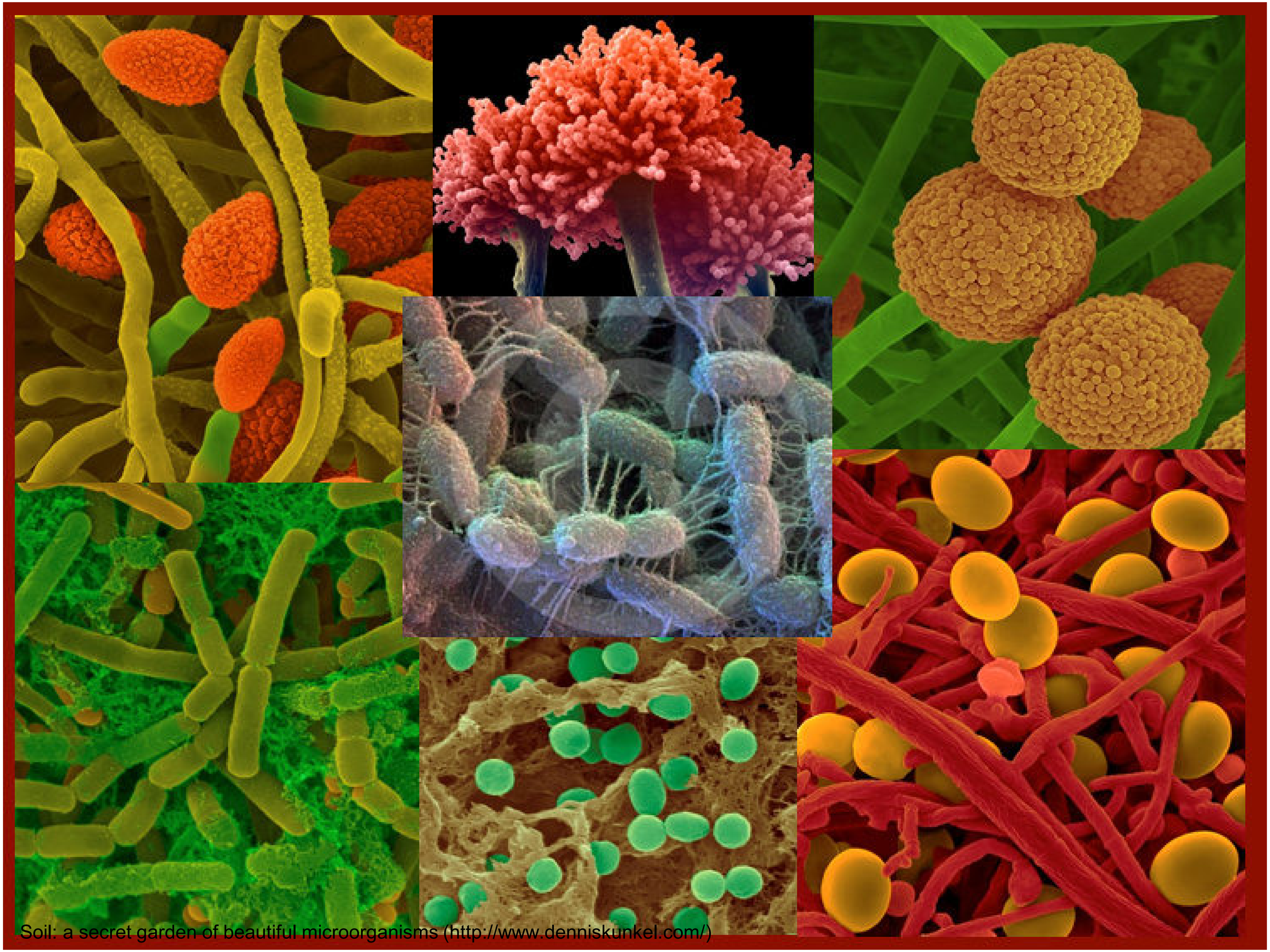
Bacterial players
AHL producers
AHL degrader
AHL « eavesdropper »
AHL « barrier »
Root
Soil particle
1a
1b
1b
2a
2b
3a
3b
3c
3d
4



Schematic view of possible interactions among different components of the mycorrhizosphere. The drawing is not to scale and underestimates the relative surface area of the external mycorrhizal mycelium. /Johanson et al., FEMS Microbiology Ecology 48

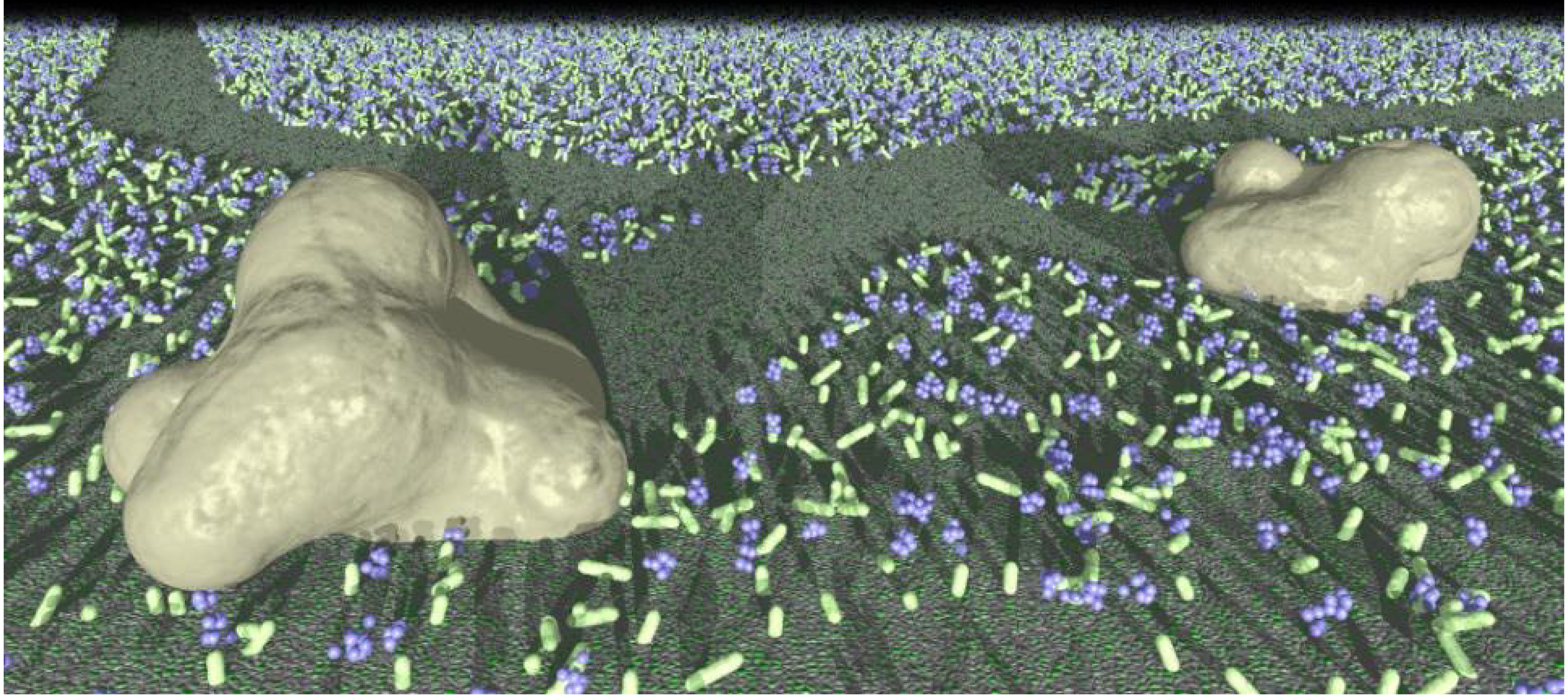


http://www.wunderground.com/blog/gardencoach/comment.html?entrynum=14



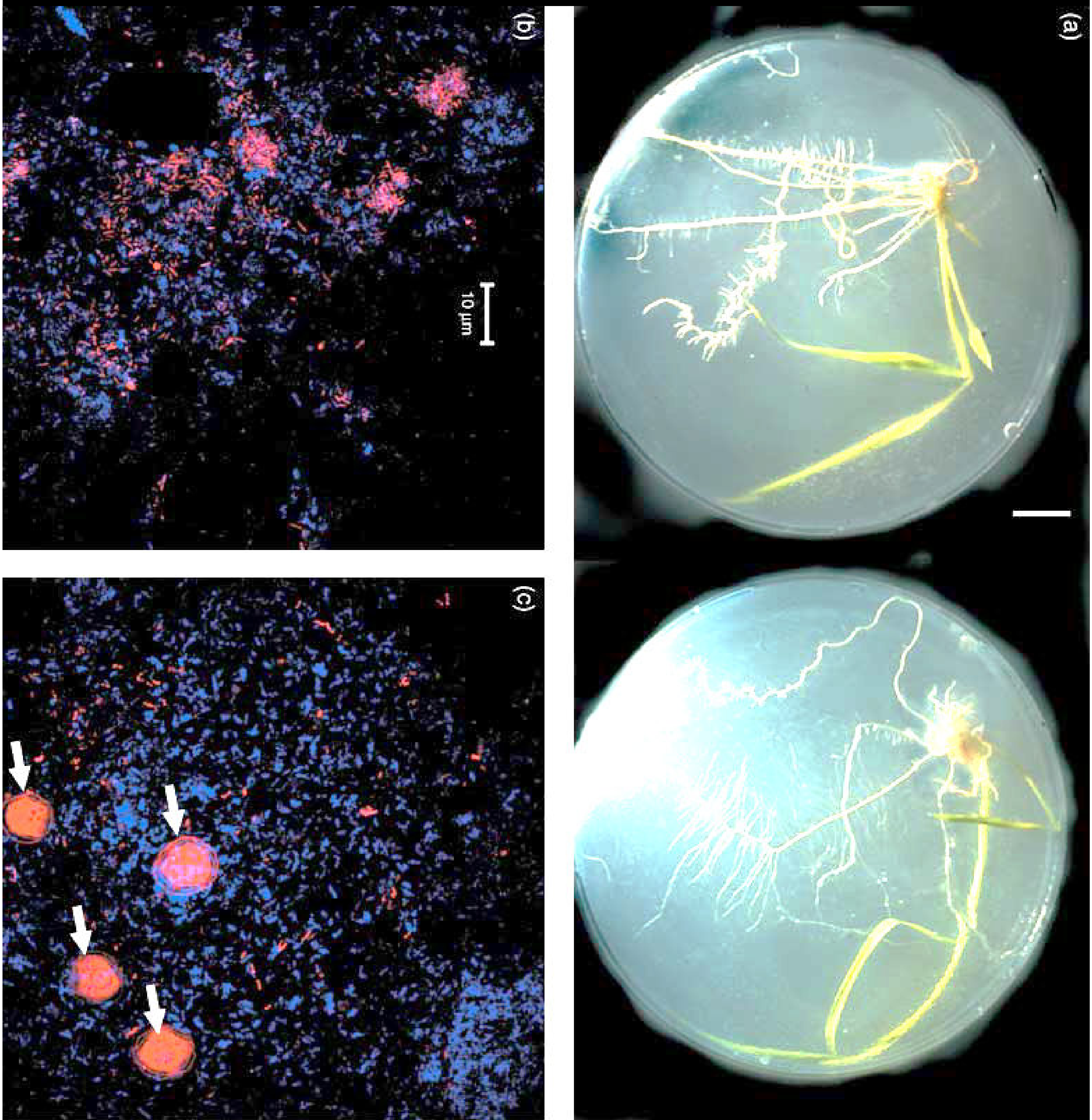
Soil: a secret garden of beautiful microorganisms (http://www.denniskunkel.com/)

Feeding Protozoa

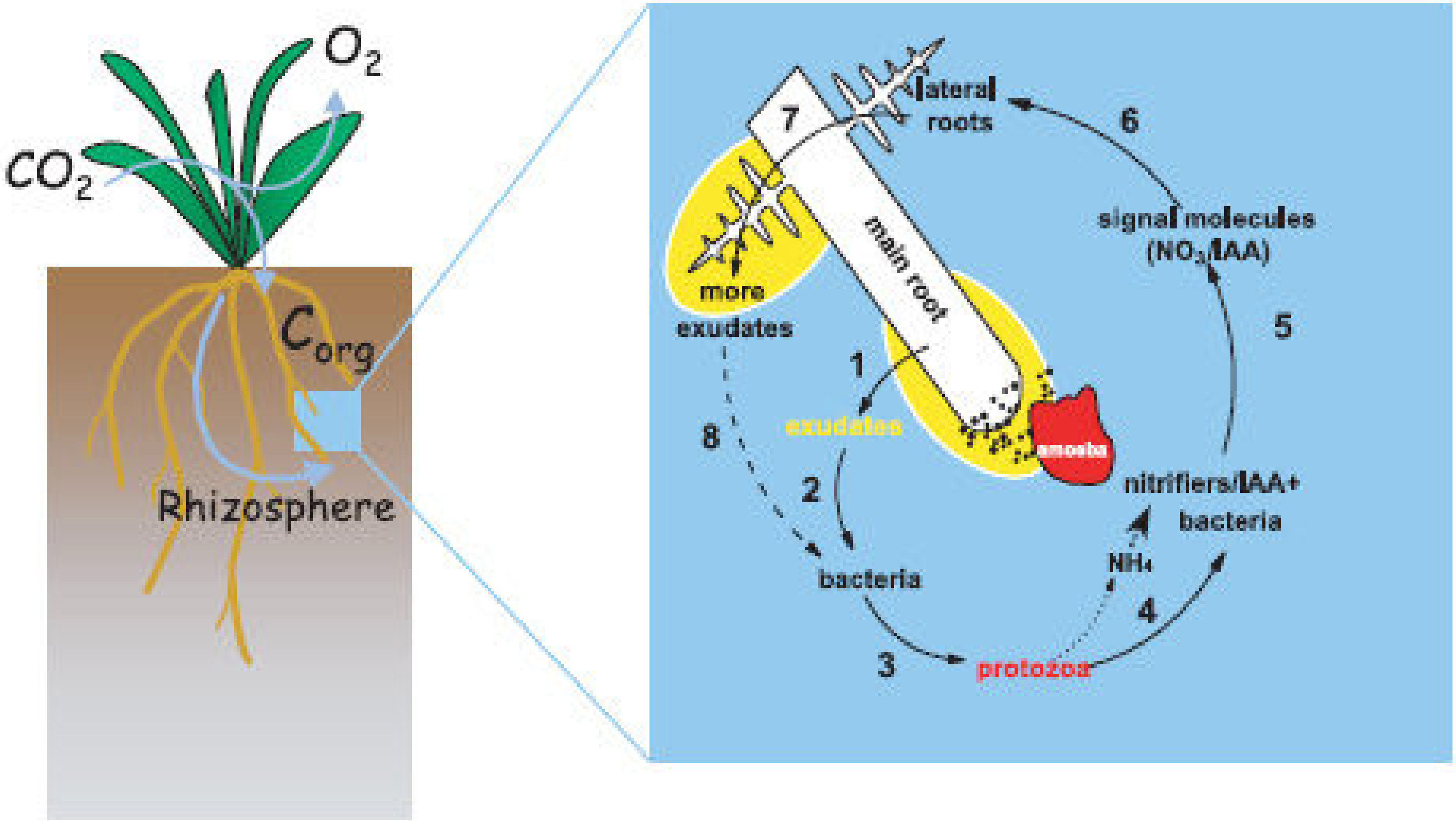


(*Acanthamoeba castellanii*)

Protozoa and plant growth: the microbial loop in soil revisited. M. Bonkowski New Phytologist (2004)



Protozoa and plant growth: the microbial loop in soil revisited. M. Bonkowski. New Phytologist (2004)



Protozoa and plant growth: the microbial loop in soil revisited. M. Bonkowski. New Phytologist (2004)

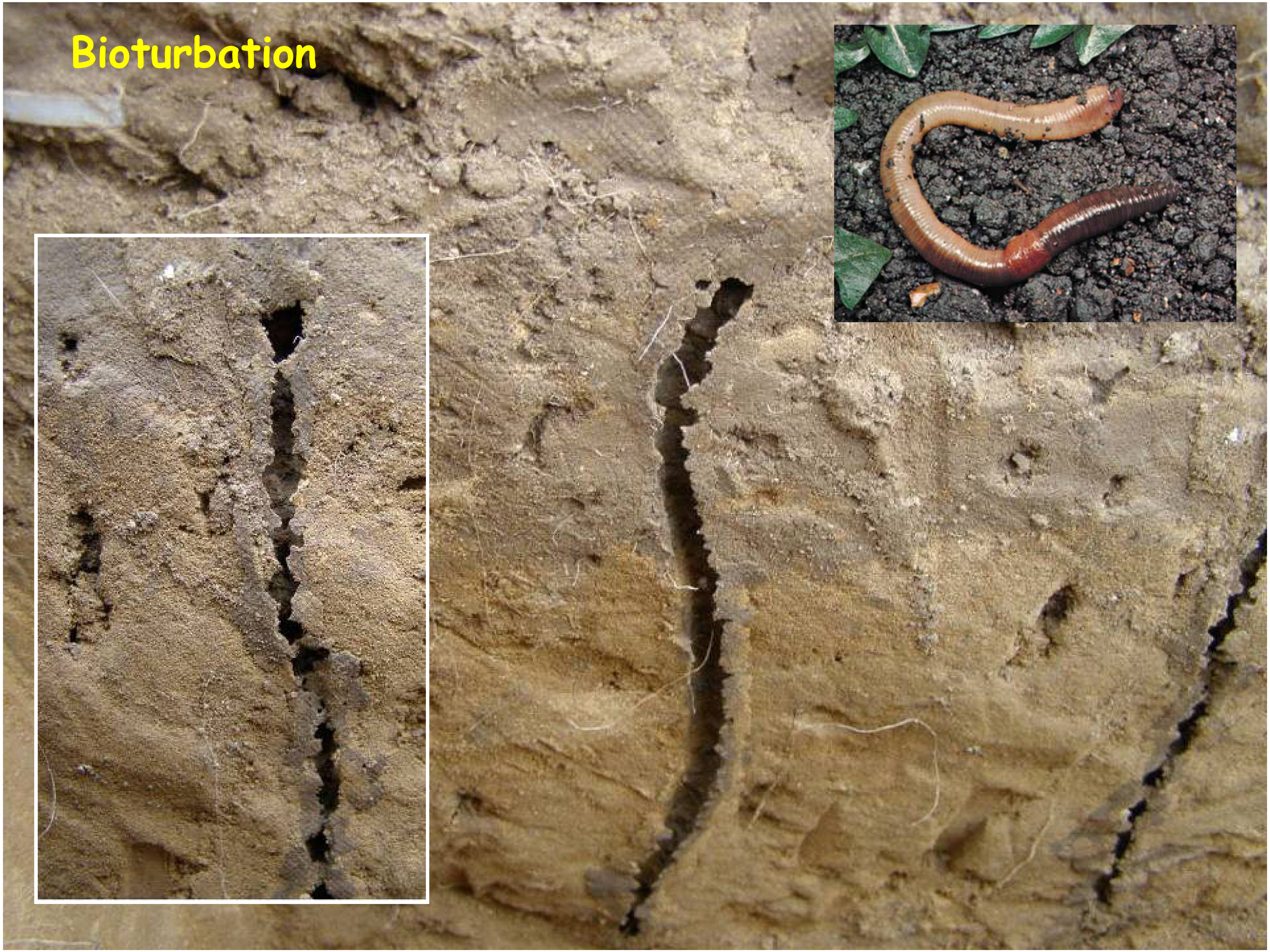
Predatory mite eating a springtail (body size: 0.5^{-2} mm)

Image from: www.prairieecosystems.pbworks.com/Dennis-NaturalistGuide

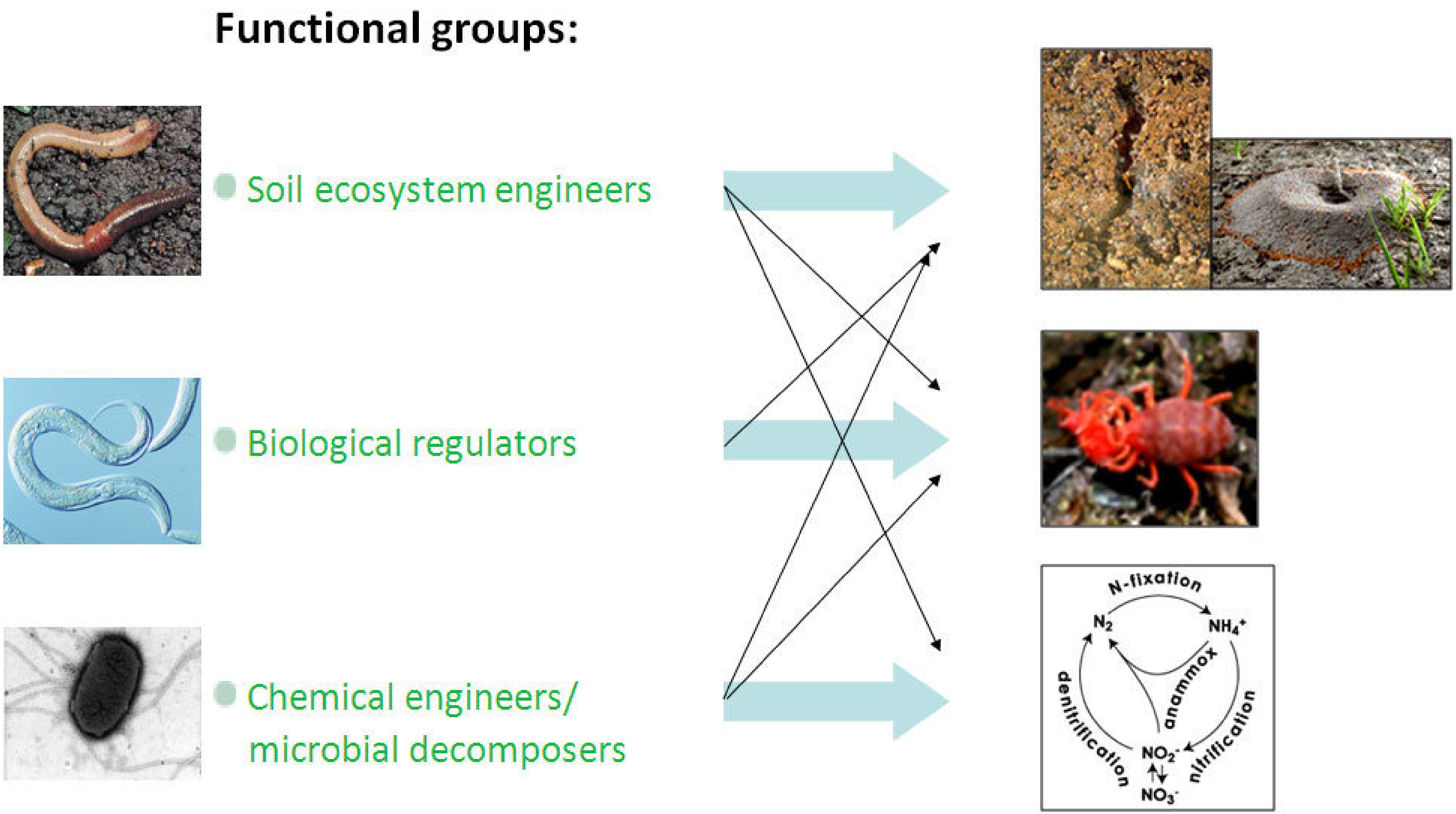
Examples of the common red mite and and other soil microarthropods

Image from: www.prairieecosystems.pbworks.com/Dennis-NaturalistGuide

Bioturbation



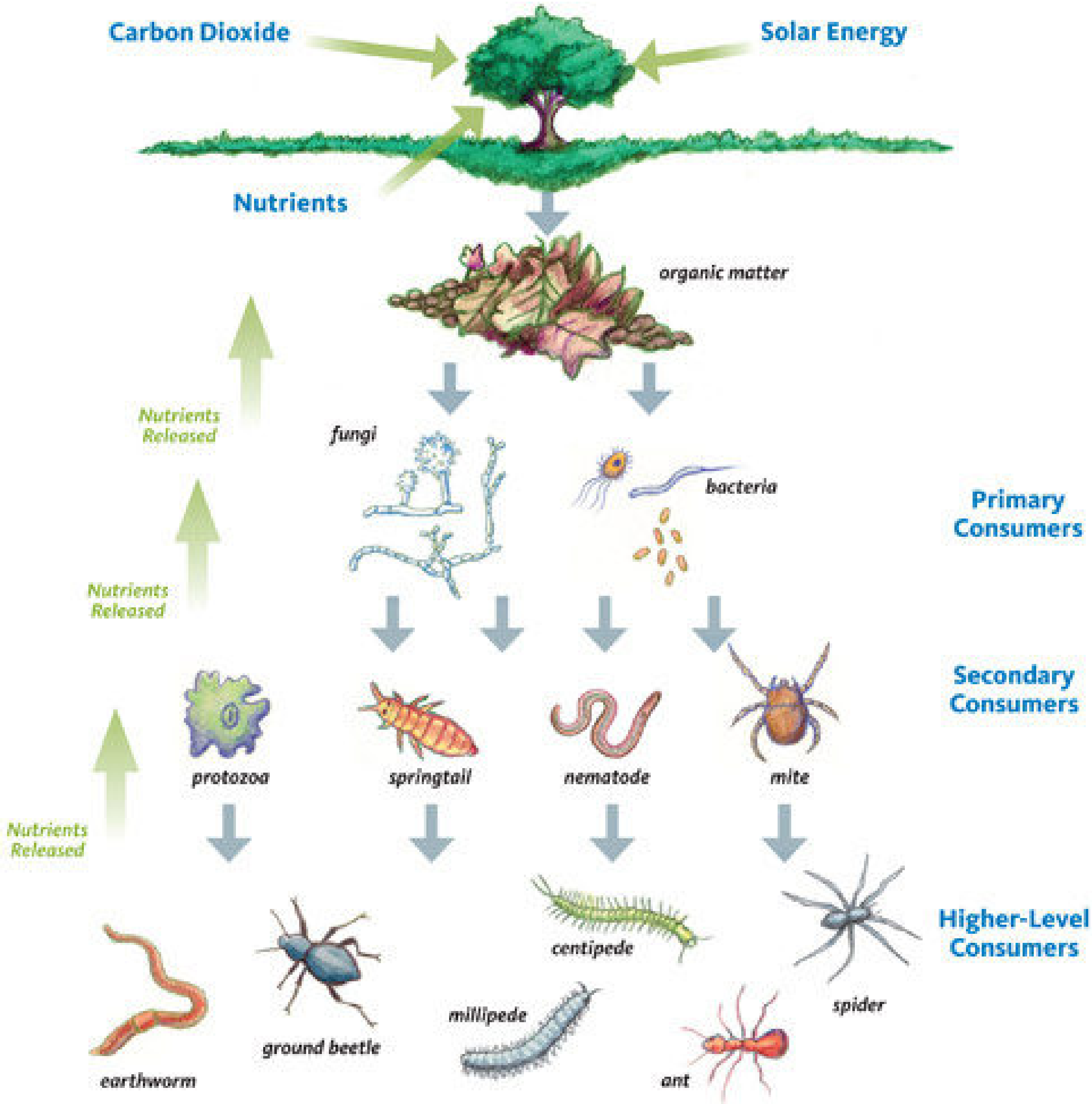

European mole (www.cornwallwarrener.co.uk/Moleman_devon_cornwall.htm


Functional groups:
Soil ecosystem engineers
Biological regulators
Chemical engineers/
microbial decomposers
N-fixation
N_2
NH_4^+
anammox
denitrification
nitrification
NO_2^-
NO_3^-

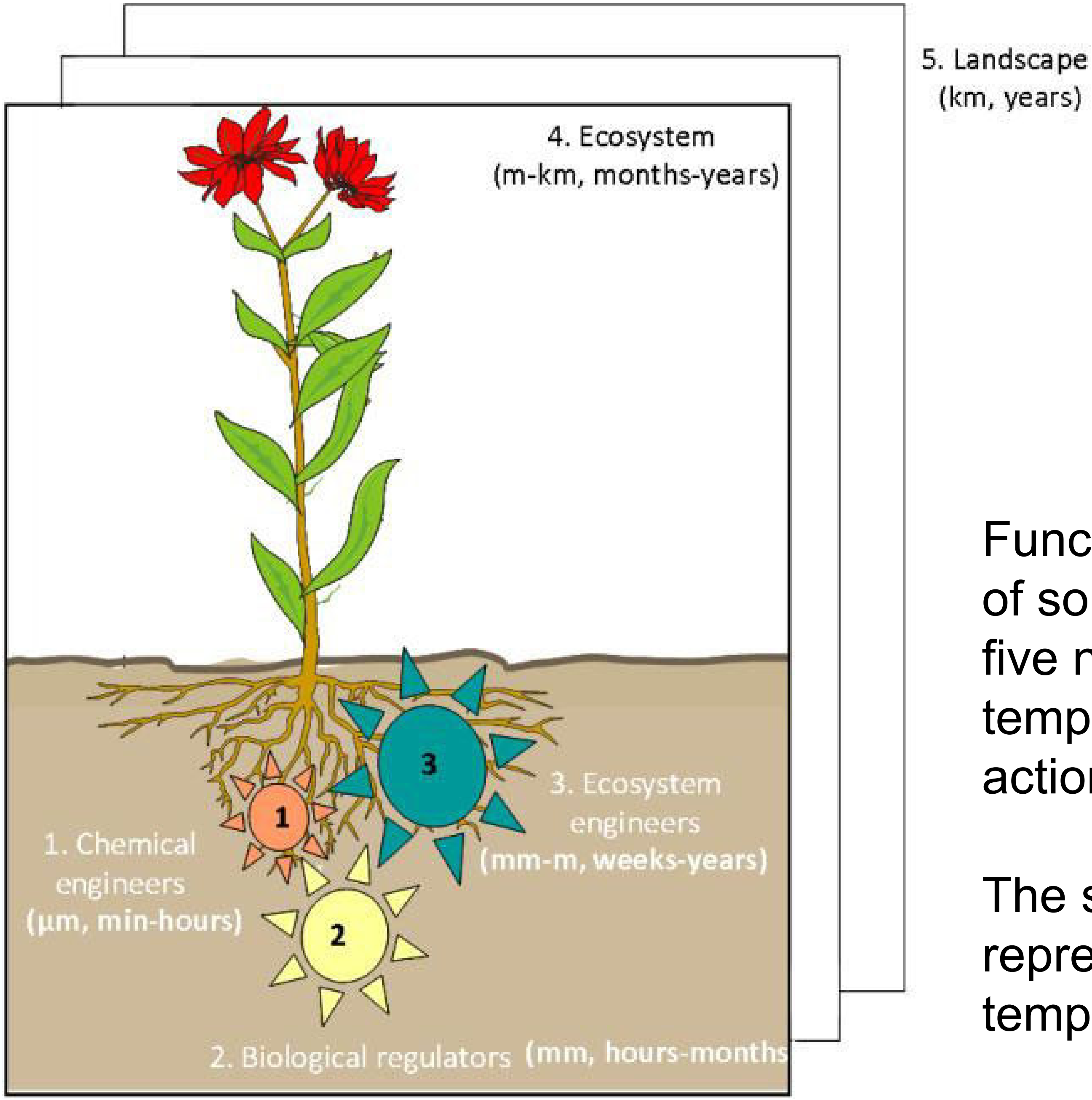
- **Chemical engineers** (transformers and decomposers): organisms responsible for carbon transformation through the decomposition of plant residues and other organic matter, and for the transformation of nutrients (e.g. nitrogen, phosphorus, sulphur)

- **Biological regulators**: organisms responsible for the regulation of populations of other soil organisms, through grazing, predation or parasitism, including soilborne pests and diseases.

- **Ecosystem engineers**: organisms responsible for maintaining the structure of soil by the formation of pore networks and bio-structures, and aggregation, or particle transport.



http://www.wunderground.com/blog/gardencoach/comment.html?entrynum=14

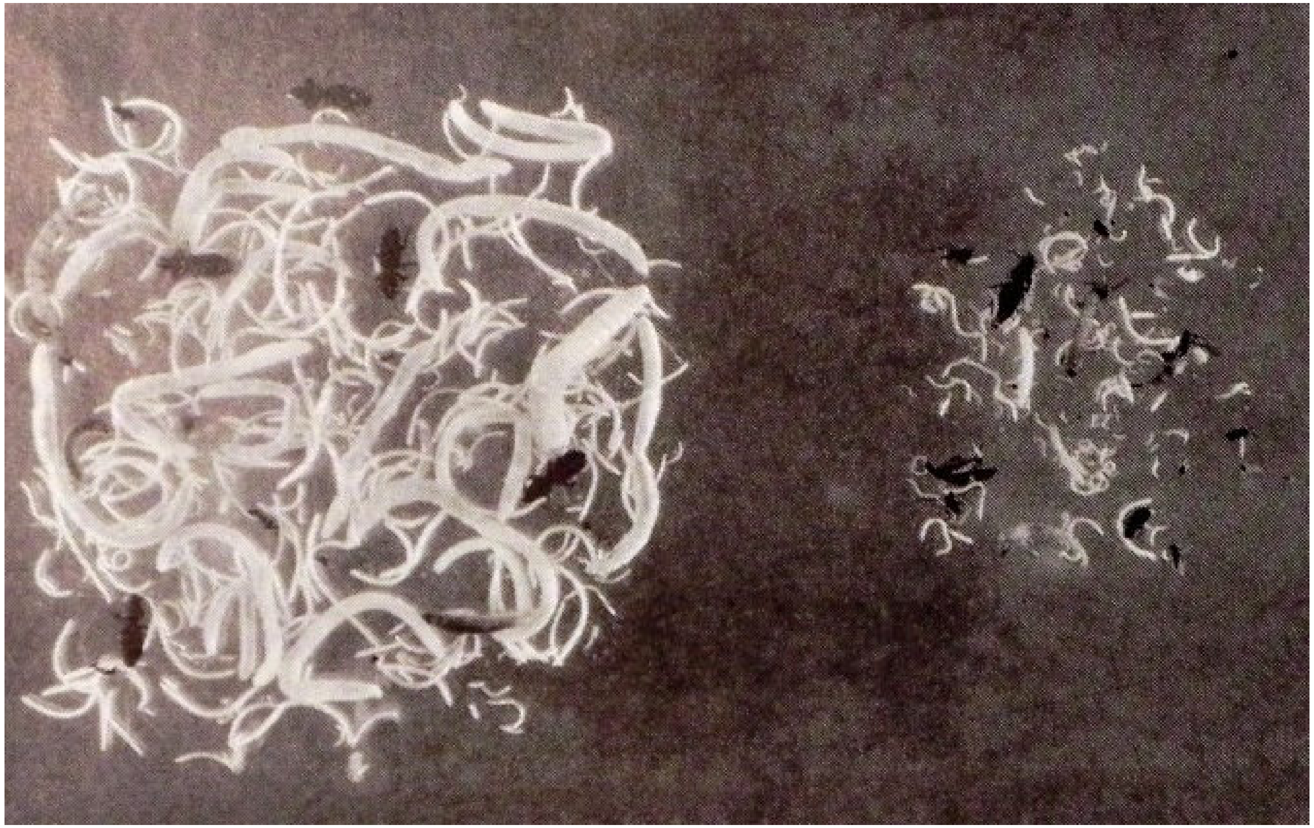


Functional organisation of soil communities over five nested spatio-temporal scales of action.

The size of the wheels represents the spatio-temporal scale.

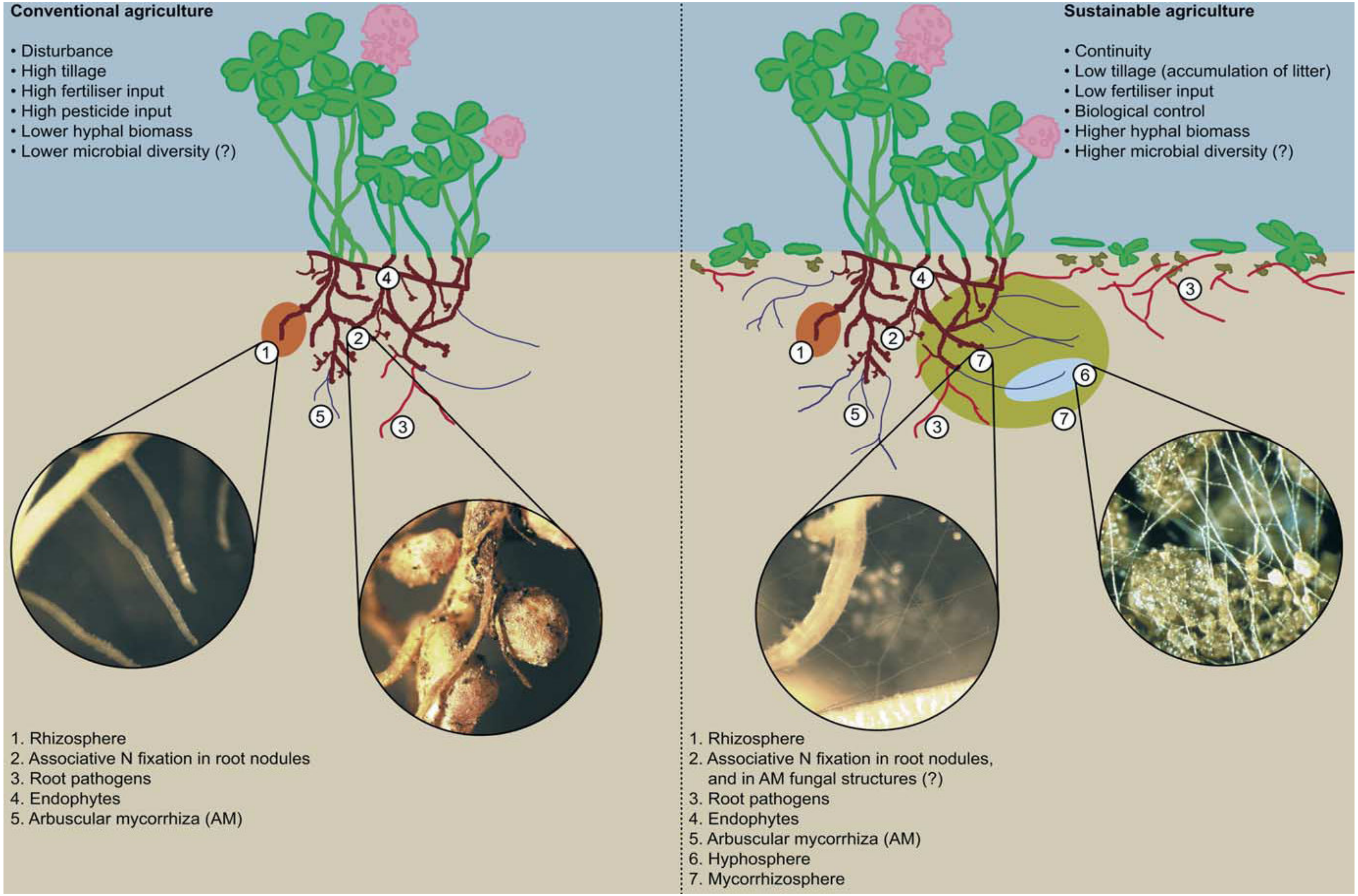
Soil, how are you …… with human?

biological agriculture



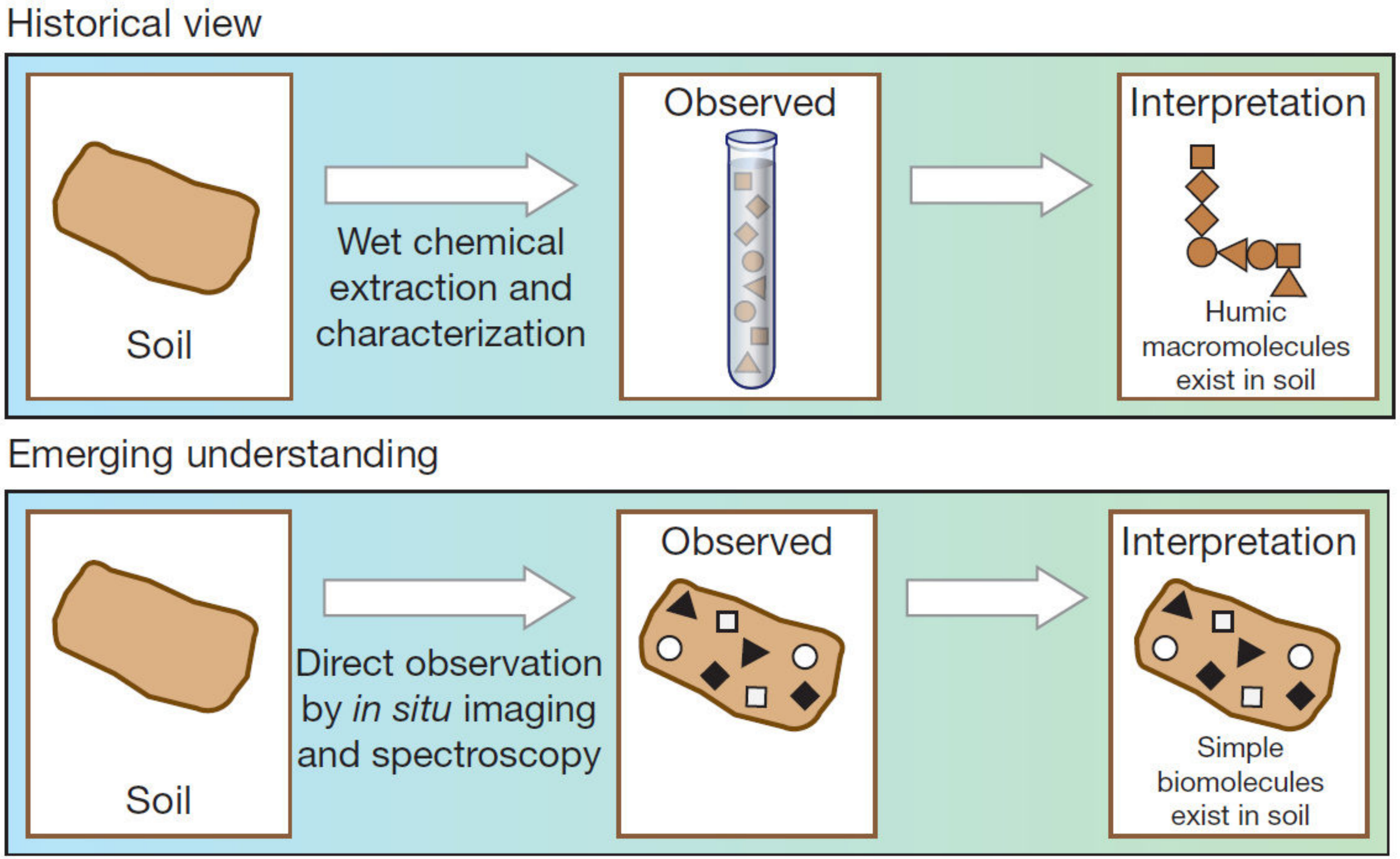
conventional agriculture

Comparison of two extractions of the soil fauna: similar soils (CALCISOLS), similar altitudes (500 m), similar climates (oceanic temperature of then Switzerland Plateau), identical crop (wheat). At the left, under conditions of **biological agriculture**; at right, under conditions of **conventional agriculture**. Life in the soil ….soils are poorly developed and have a limited capacity to store N inputs /Gobat et al., 2003: The Living Soil/

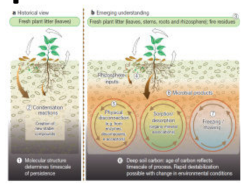


Schematic view of the mycorrhizosphere concept in contrast to the rhizosphere concept: Features of conventionally managed agricultural soils versus sustainably managed agricultural soils are indicated.

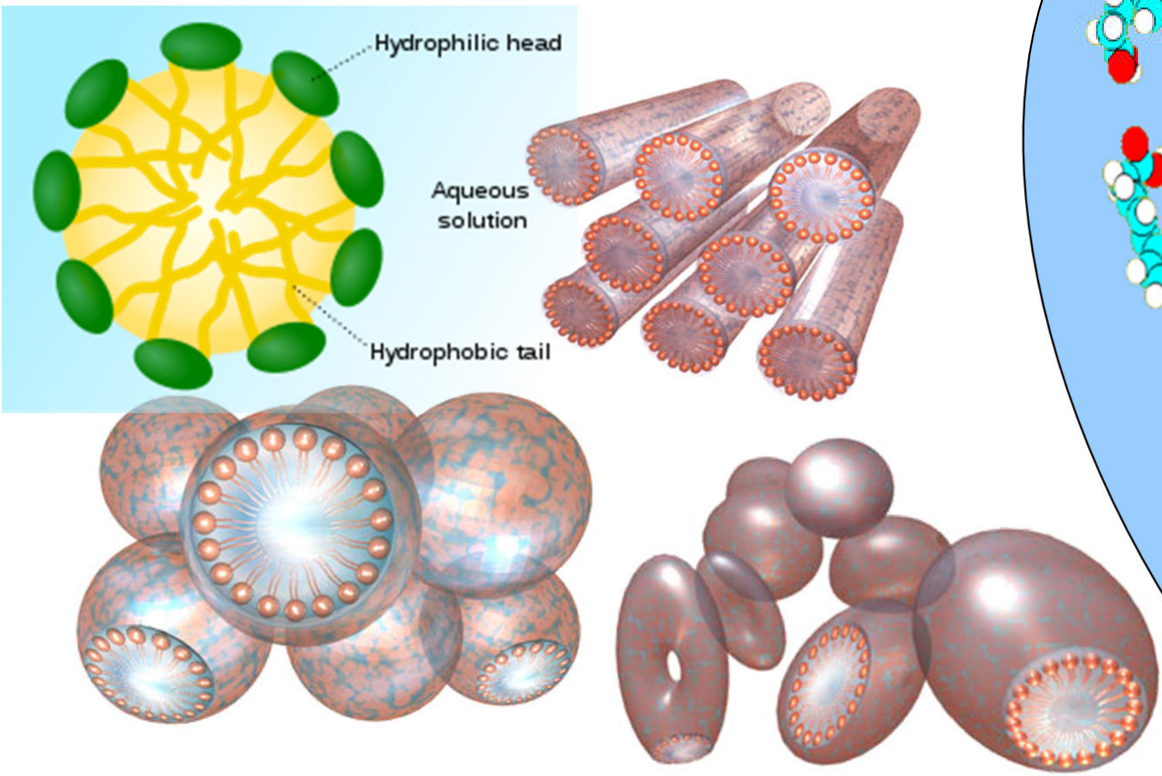
/Johanson et al., FEMS Microbiology Ecology 48 (2004) 1–13/.

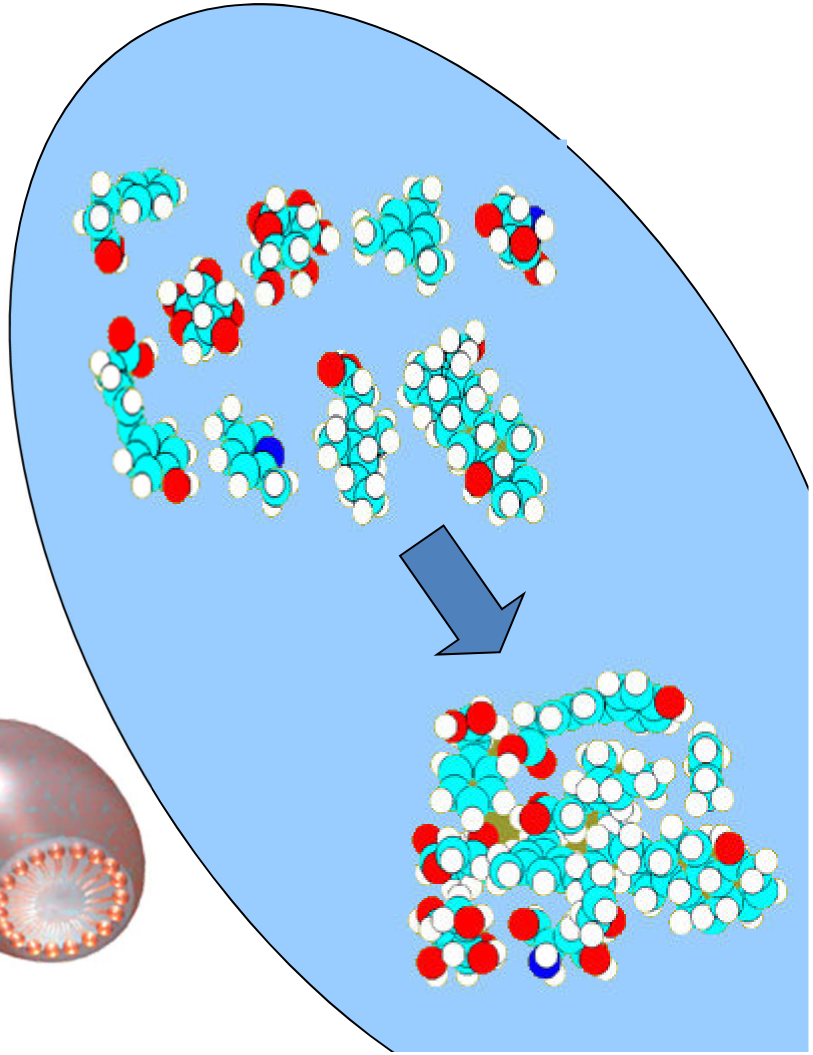


Direct high-resolution *in situ* observations with non-destructive techniques have been able to explain the functional group chemistry of the extracted humic substances as relatively simple biomolecules without the need to invoke the presence of unexplainable macromolecules.

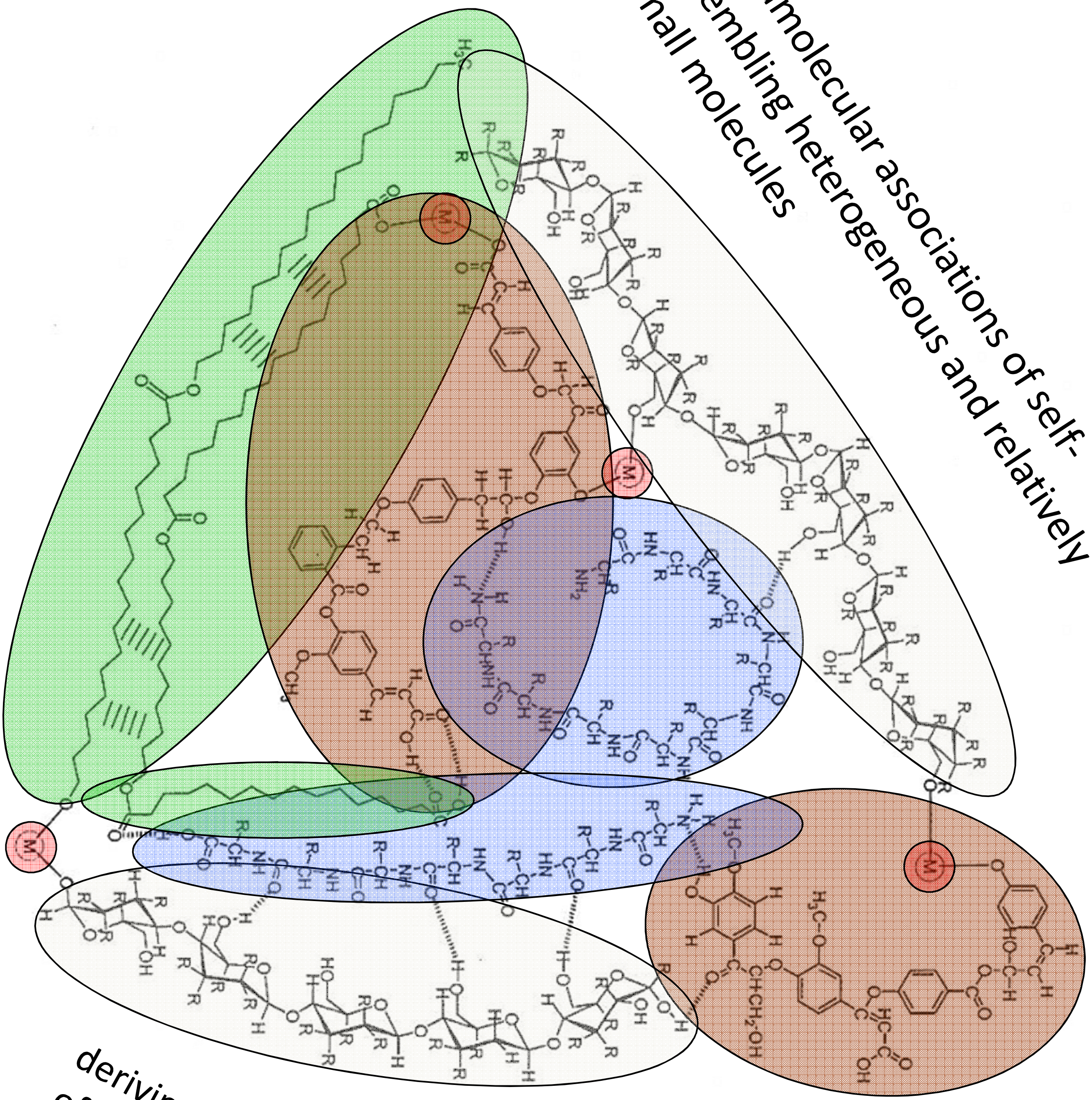


A major aspect of the humic supramolecular conformation is that it is stabilized predominantly by weak dispersive forces instead of covalent linkages (Piccolo, 2001).



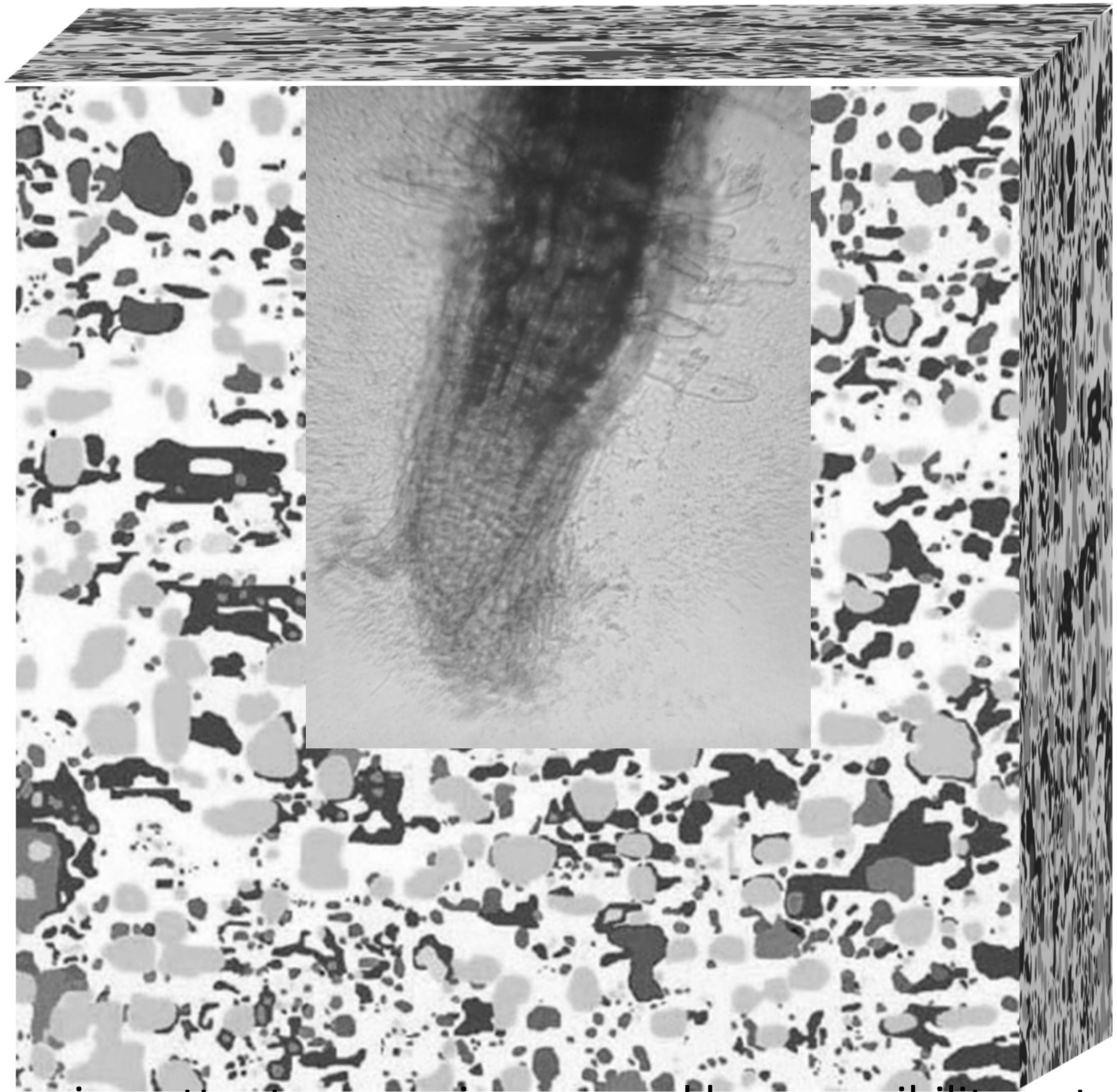


Supramolecular associations of self-assembling heterogeneous and relatively small molecules



deriving from the degradation and decomposition of dead biological material.

What is the source of the 'Trigger organic Molecules'? Fresh inputs of plant litter and rhizodeposits? Metabolites from decomposing microorganisms? Others? (Dungait et al., 2012)

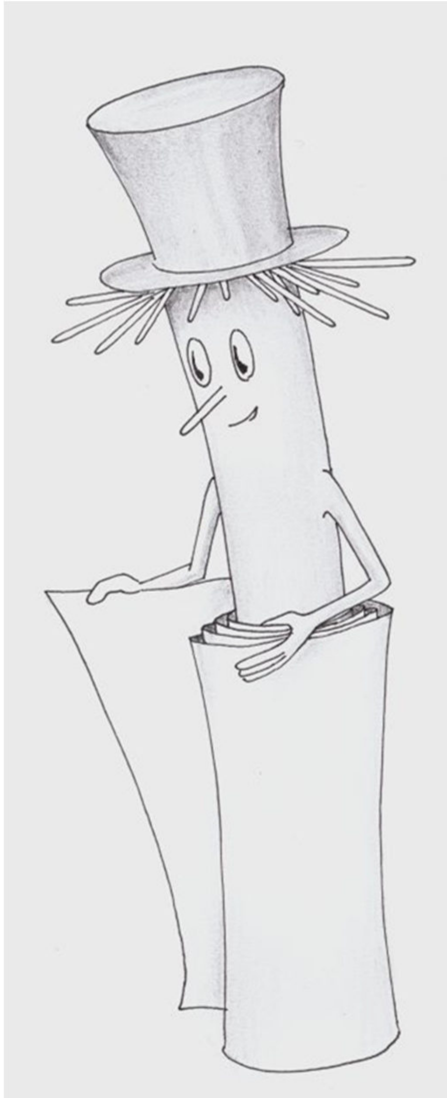


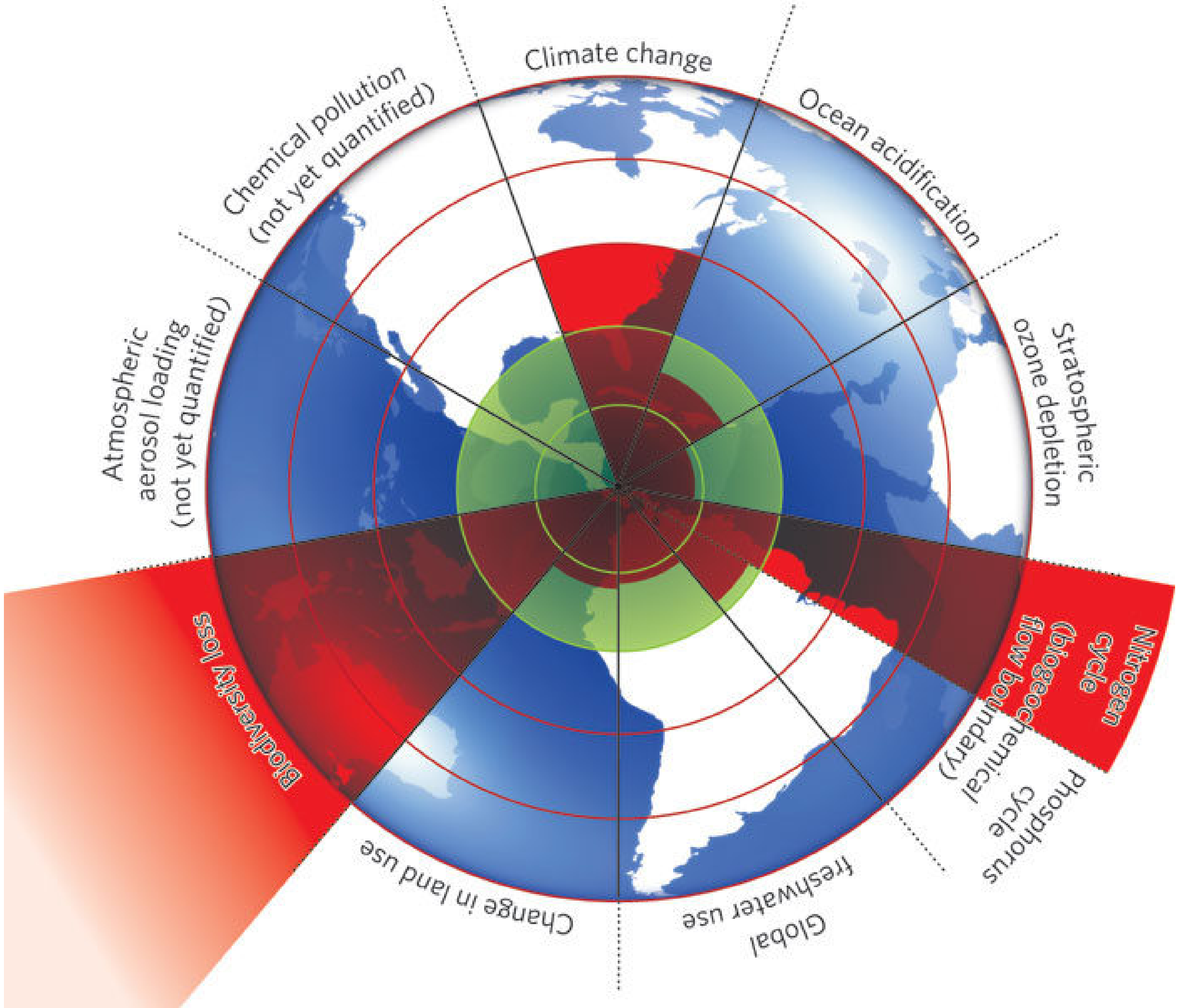
Soil organic matter turnover is governed by accessibility not recalcitrance

It appears, based on the emerging understanding, that part of SOM is a special kind of extracellular microbial reservoir of key biogenic nutrients (N, P, S, ...), well preserved against the spontaneous microbial activities („**Sleeping Beauty**“) without the additional source of carbohydrates but well prepared for explosive microbial activities after the stimulation with rhizodeposits.

In other words, the major reservoir of soil nitrogen must be first activated by delivery of well accesive plant rhizodeposits and the rate of nitrogen availability will be directly proportional to the supply of plant carbohydrates.

The pictures show a plant roots "dressed up" to the active surface represented by exchangeable surface structures (plasma membranes) of microorganisms, which are proliferated in the vicinity due to the production of root exudates.
Otherwise unavailable biogenic nutrients are released from SOM by extracellular enzymes produced by microorganisms as a result of an excess of carbonaceous compounds and the lack of these nutrients. From this phenomenon is ultimately benefiting the plant in proportion to their carbonaceous “investment”.





The inner green shading represents the proposed safe operating space for nine planetary systems. The red wedges represent an estimate of the current position for each variable. The boundaries in three systems (rate of biodiversity loss, climate change and human interference with the nitrogen cycle), have already been exceeded.

A safe operating space for humanity Johan Rockström et al., Nature 461, 472-475(24 September 2009)

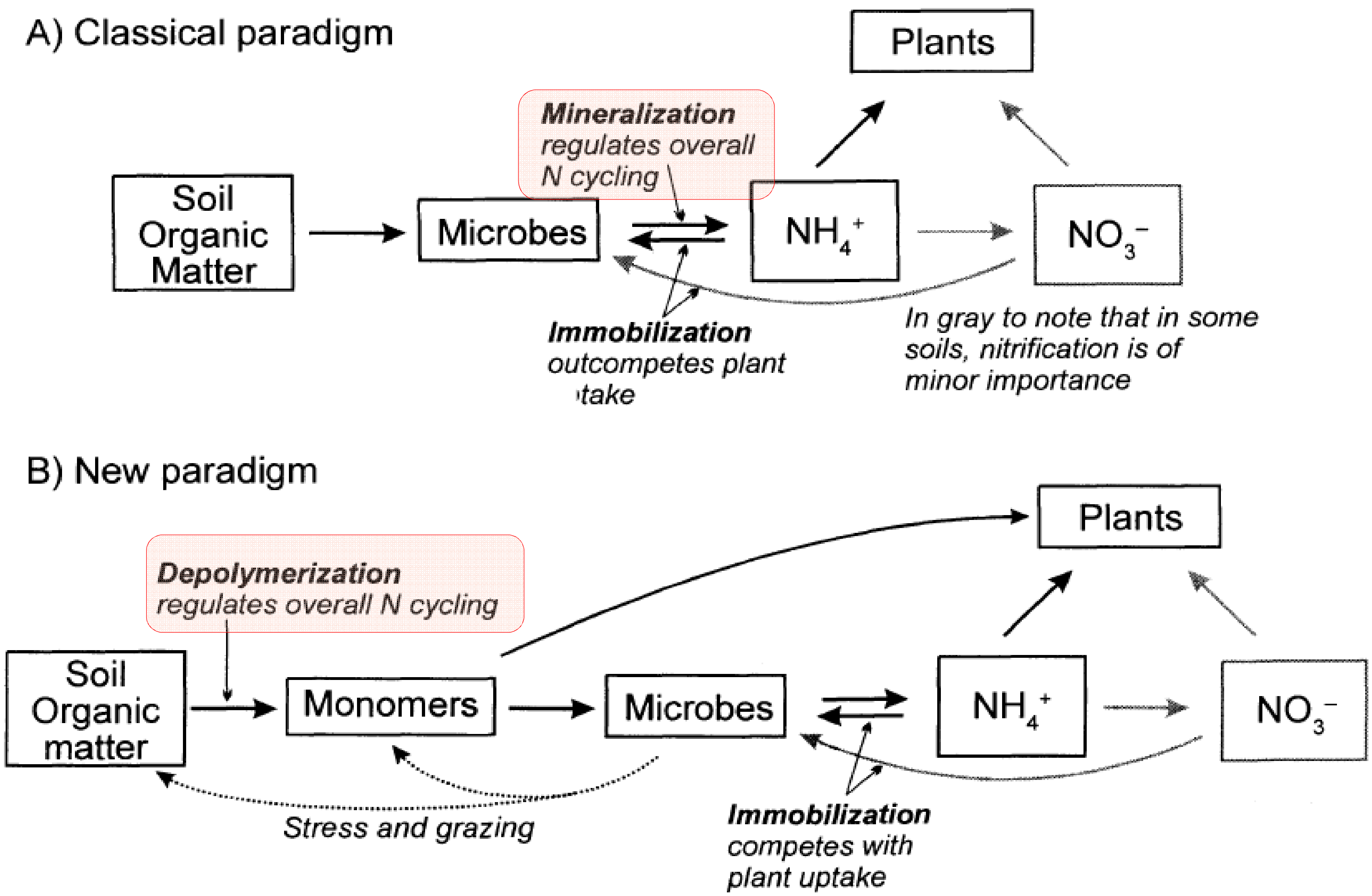
PLANETARY BOUNDARIES

Earth-system process	Parameters	Proposed boundary	Current status	Pre-industrial value
Climate change	(i) Atmospheric carbon dioxide concentration (parts per million by volume)	350	387	280
	(ii) Change in radiative forcing (watts per metre squared)	1	1.5	0
Rate of biodiversity loss	Extinction rate (number of species per million species per year)	10	>100	0.1–1
Nitrogen cycle (part of a boundary with the phosphorus cycle)	Amount of N_2 removed from the atmosphere for human use (millions of tonnes per year)	35	121	0
Phosphorus cycle (part of a boundary with the nitrogen cycle)	Quantity of P flowing into the oceans (millions of tonnes per year)	11	8.5–9.5	~1
Stratospheric ozone depletion	Concentration of ozone (Dobson unit)	276	283	290
Ocean acidification	Global mean saturation state of aragonite in surface sea water	2.75	2.90	3.44
Global freshwater use	Consumption of freshwater by humans (km^3 per year)	4,000	2,600	415
Change in land use	Percentage of global land cover converted to cropland	15	11.7	Low
Atmospheric aerosol loading	Overall particulate concentration in the atmosphere, on a regional basis	To be determined		
Chemical pollution	For example, amount emitted to, or concentration of persistent organic pollutants, plastics, endocrine disrupters, heavy metals and nuclear waste in, the global environment, or the effects on ecosystem and functioning of Earth system thereof	To be determined		

nitrogen cycle)

Boundaries for processes in red have been crossed. Data sources: ref. 10 and supplementary information

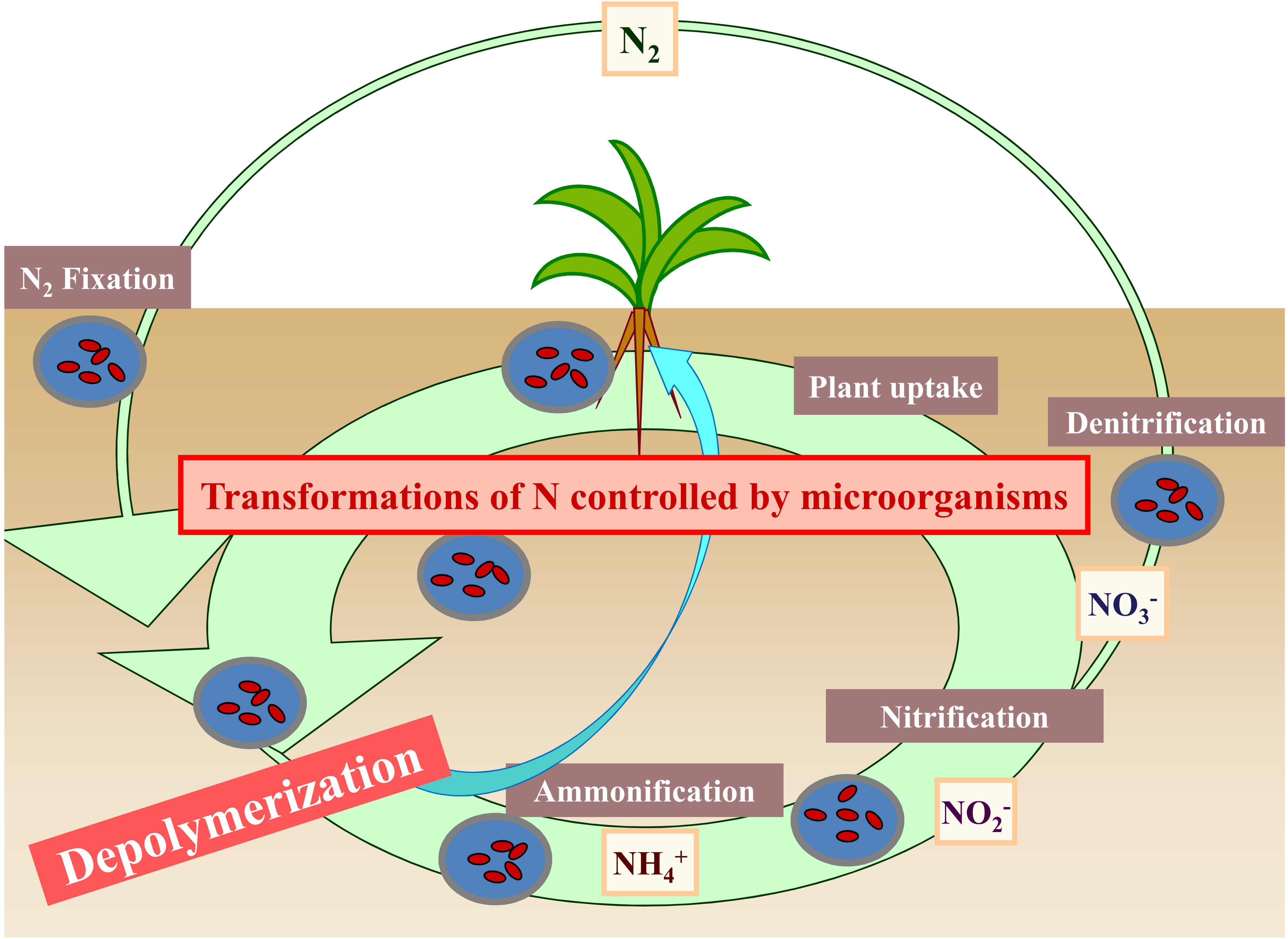
A safe operating space for humanity Johan Rockström et al., Nature 461, 472-475(24 September 2009)



(Schimel et Bennett, 2004)

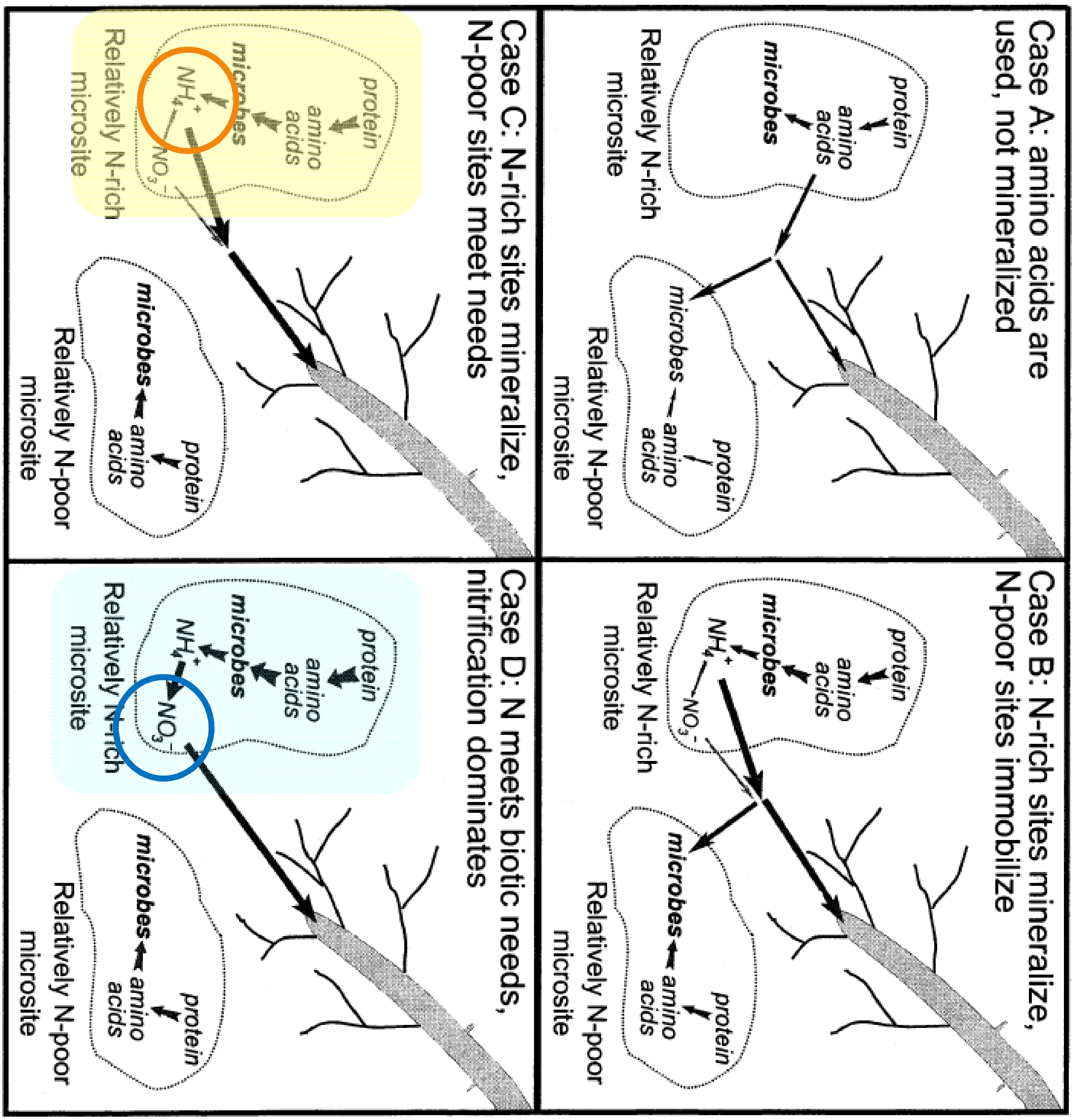
The changing paradigm of the soil N cycle.

N cycling is now seen as being driven by the depolymerization of N-containing polymers by microbial extracellular enzymes.

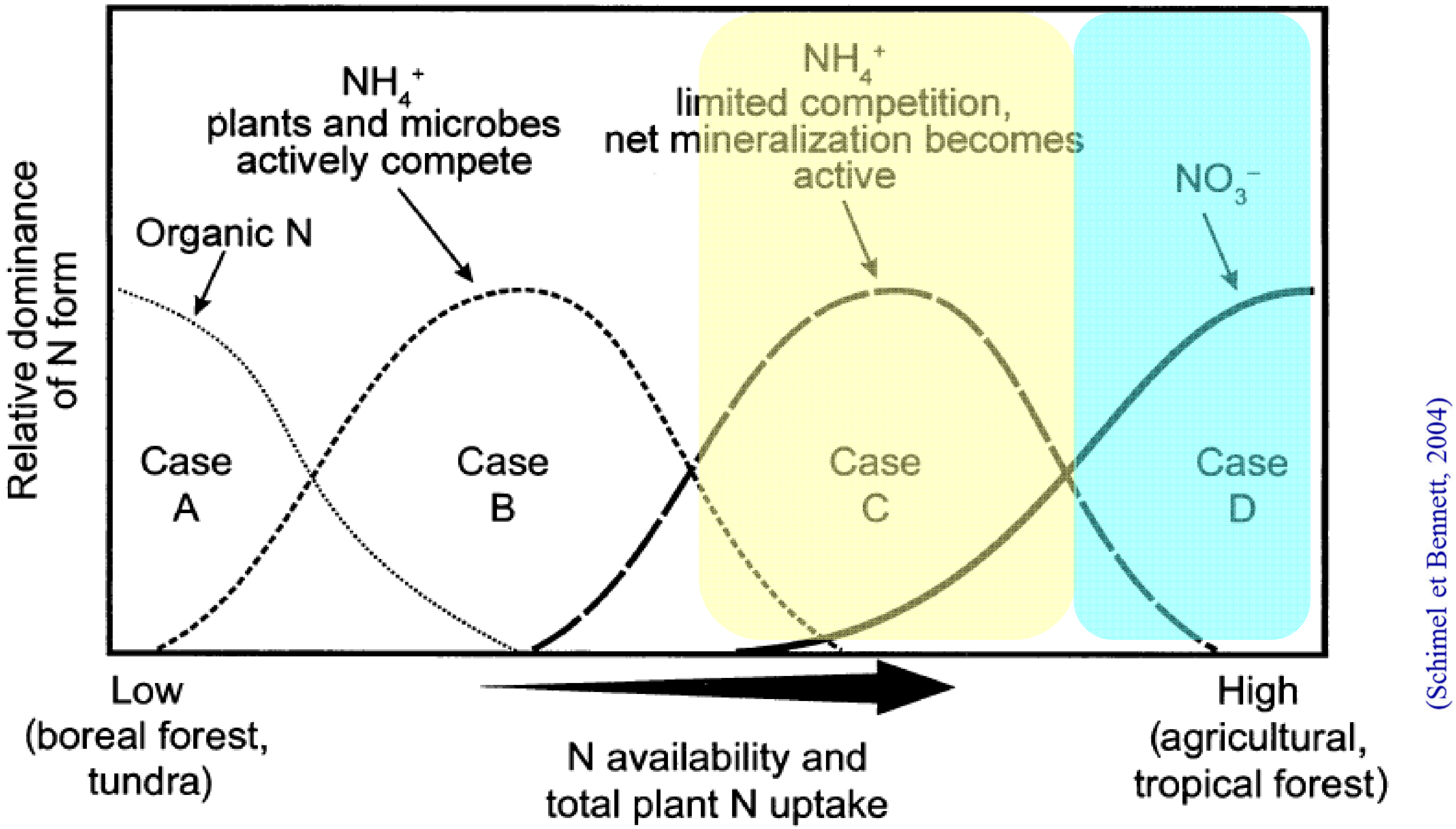


N_2
N_2 Fixation
Plant uptake
Denitrification
Transformations of N controlled by microorganisms
NO_3^-
Nitrification
NO_2^-
Ammonification
NH_4^+
Depolymerization

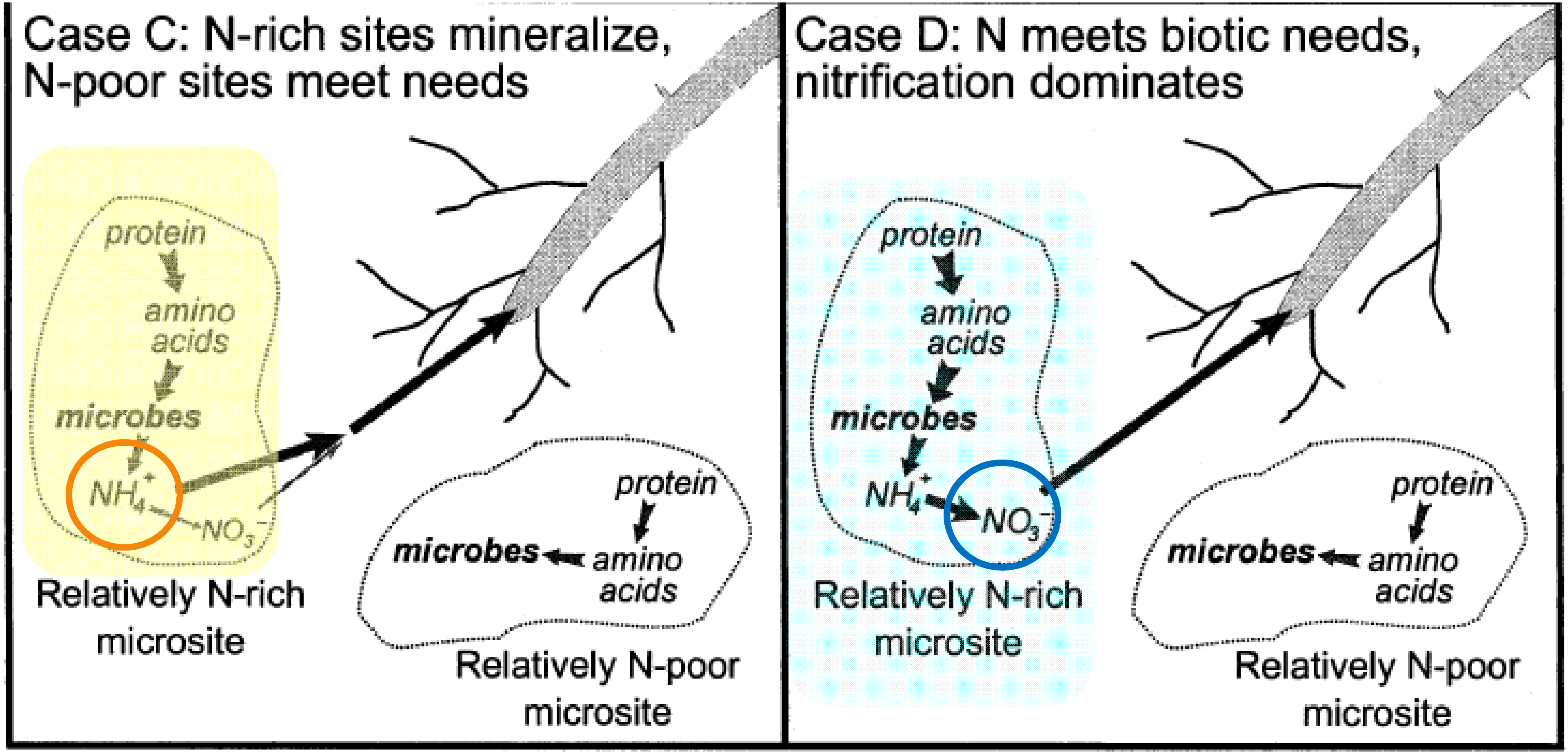
The diagrams specify that the polymers are protein, but only as a representative organic N-containing polymer.



(Schimel et Bennett, 2004)



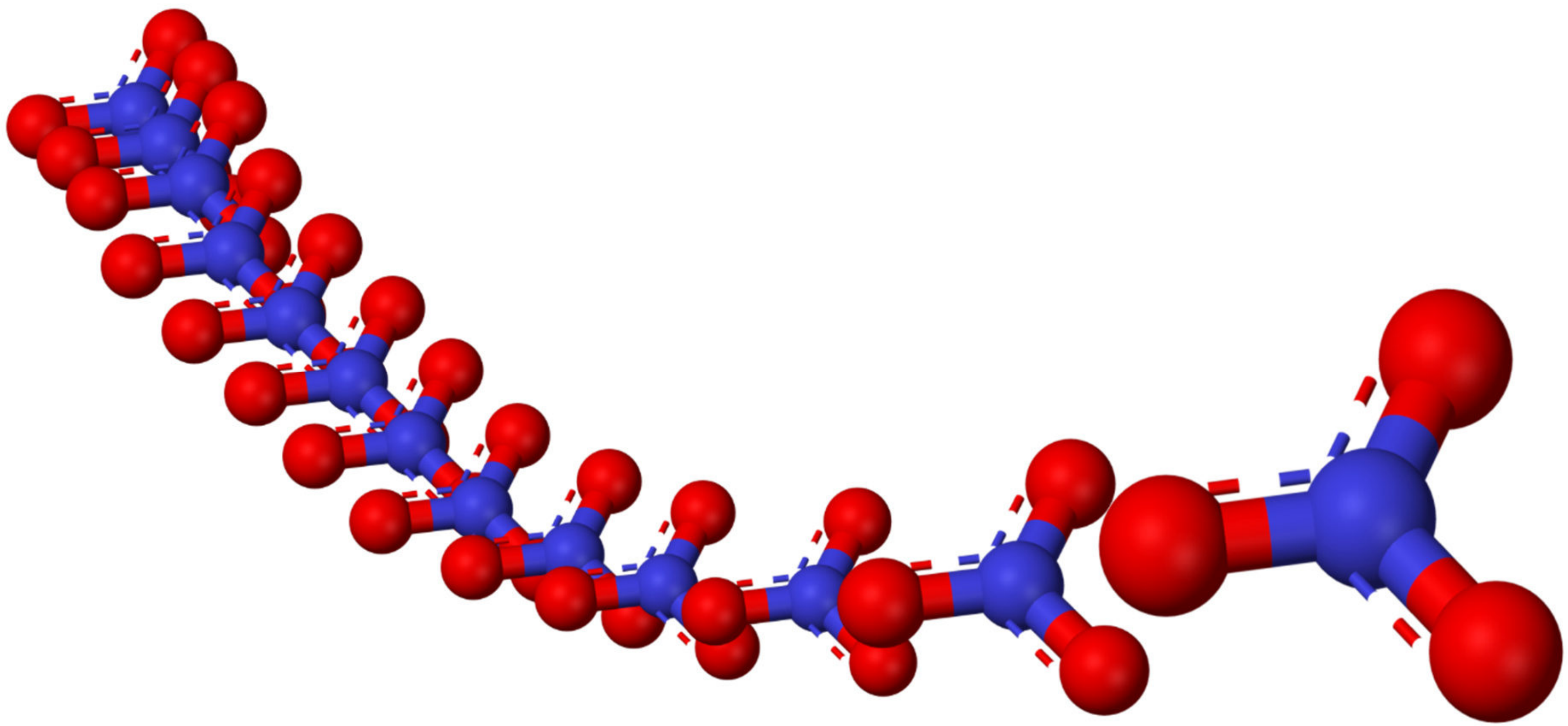
The shifting dominance of N forms along a gradient of N availability and the soil processes that regulate N availability to plants under different N-availability regimes. Total N availability and plant uptake both increase along the hypothetical gradient.



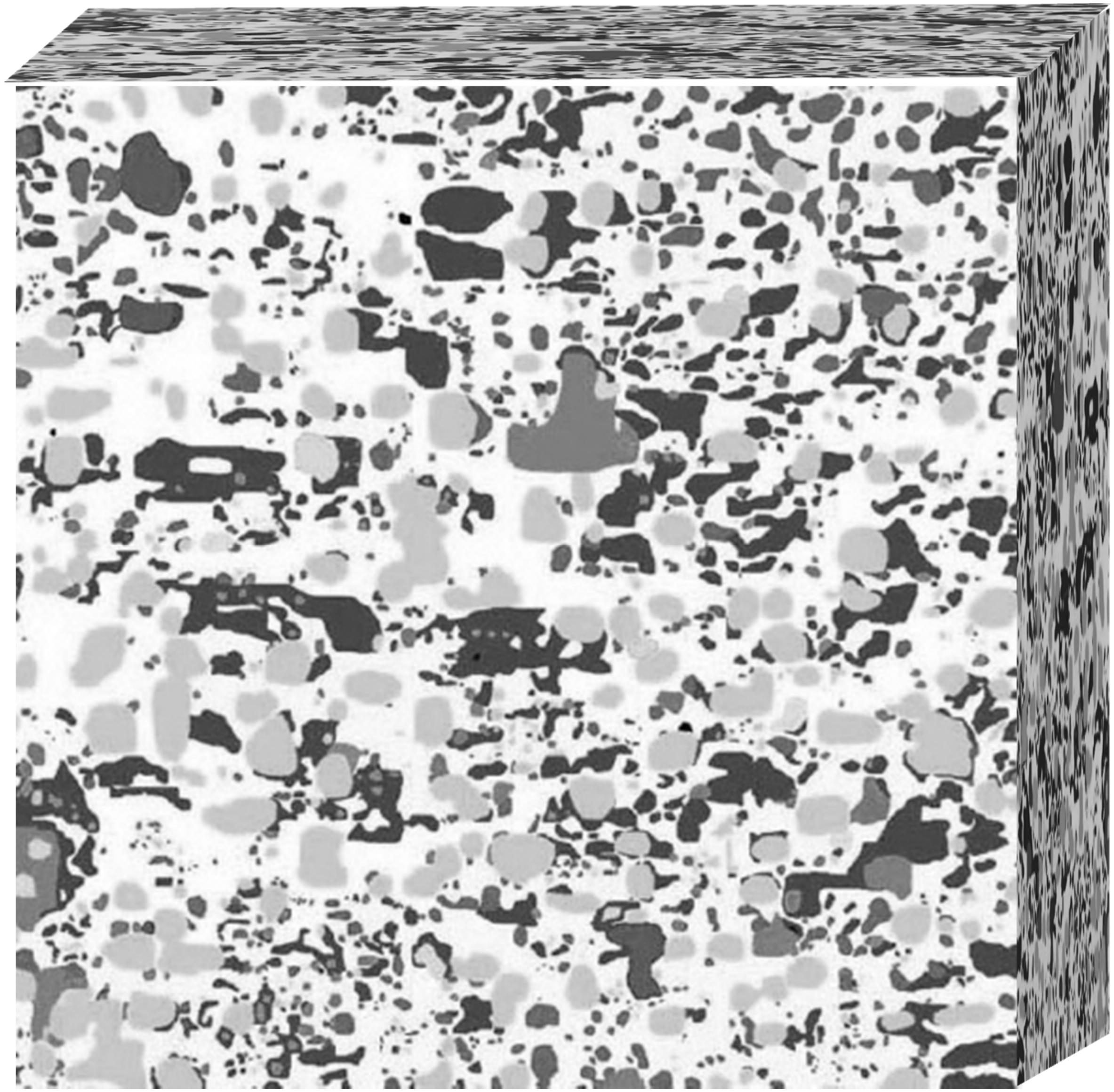
If we (farmers) add some more mineral nitrogen, then the aboveground plant production increased, but the plants do not need to release their carbohydrates into the soil environment. Therefore the process of carbon sequestration in soil will be discriminated.

Nitrates, where are you coming from and where are you going?

Nitrate is a critical signaling molecule in regulating plant growth, little is know about plant nitrate signaling at molecular level and even less about the role of nitrate signaling for interactions between key players in soils.



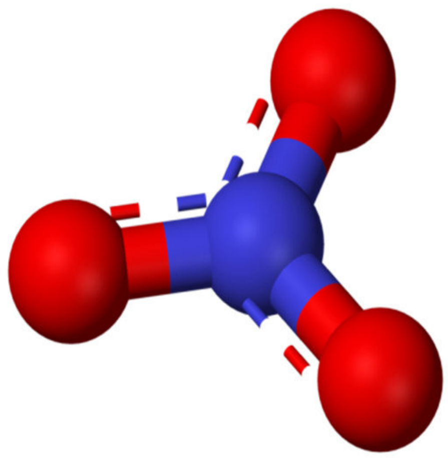
In the natural ecosystems can nitrates as movable compounds balance nitrogen availability in heterogeneous soil environment



What kind of information constitutes the presence of nitrate-N in soils?

- for plants?
- for microbes?
- for ecosystem?

- prolonged oxidative conditions and lack of interest about ammonium-N from plants or microbes
- nitrogen saturation (oversaturation?)
- rainfall event and its consequences,
- ……



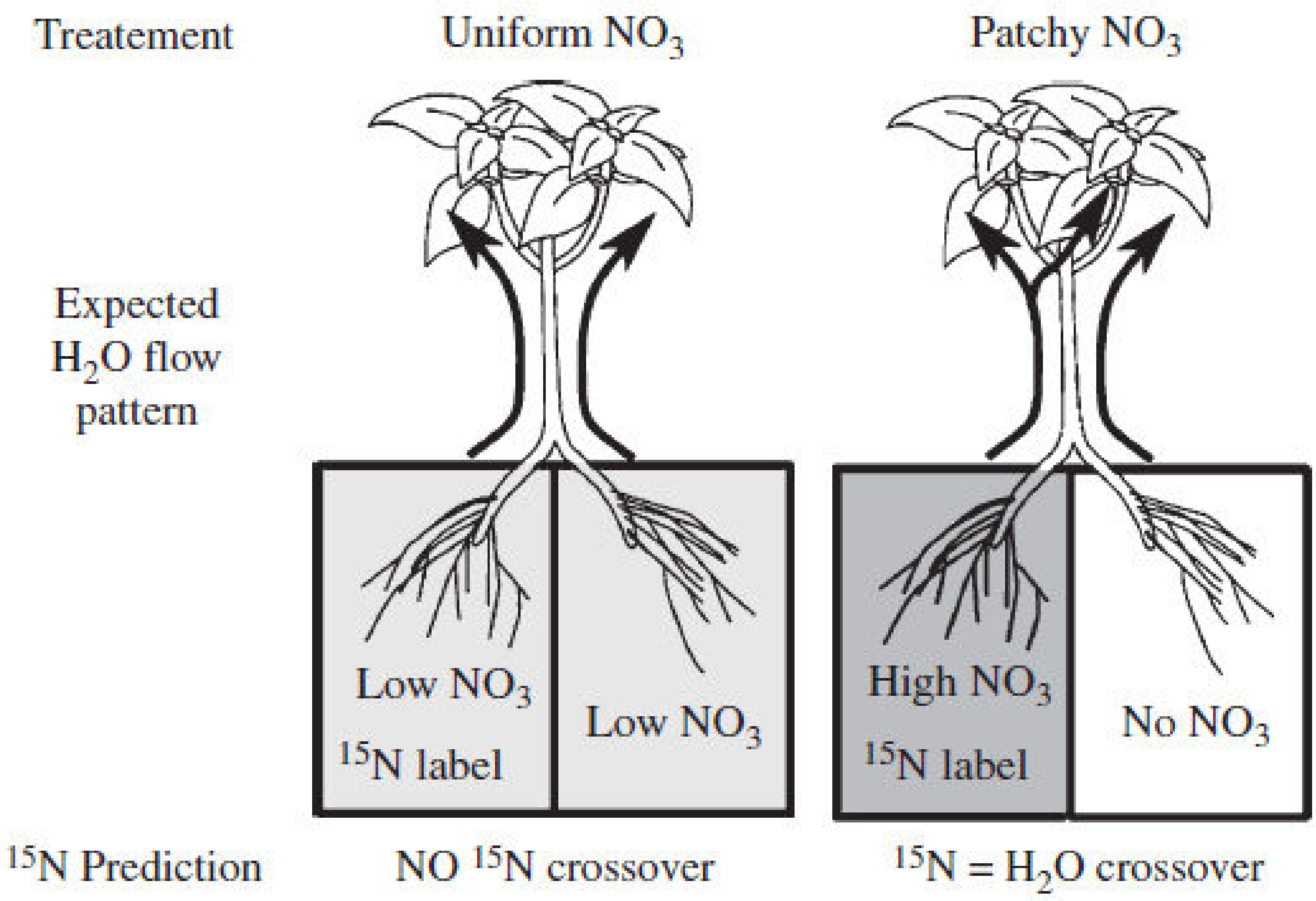
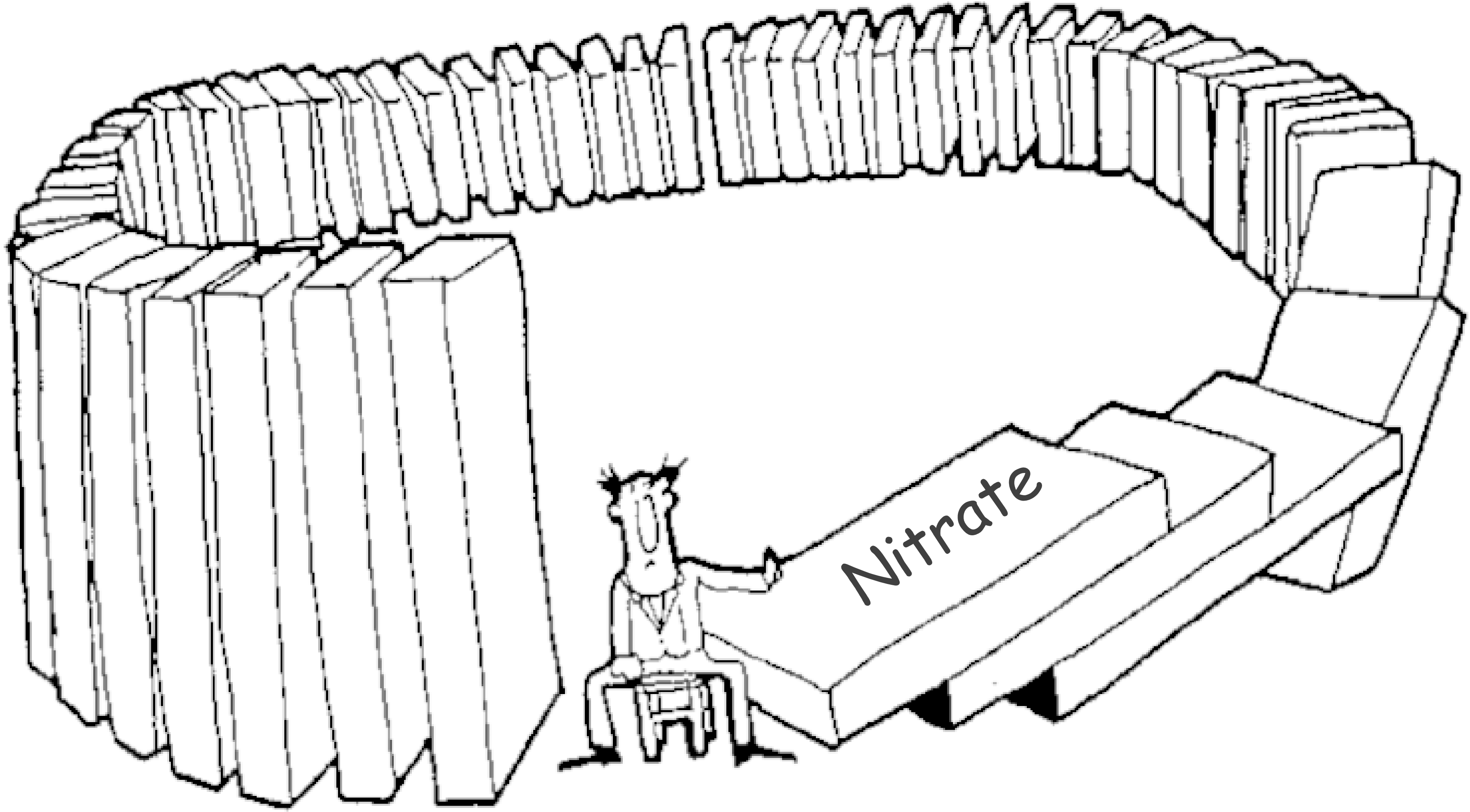


Diagram of qualitative predictions for how water and nutrient movement will be affected if roots in a nutrient patch have lower resistance than roots in the background nutrient environment (Thorn et Orians, 2011).



In a complex system are the causes and consequences temporally and spatially separated but if farmers apply nitrates, they should take care of their fates ….

Soil Indicators: - „*in situ*“ soil respiration; „*in situ*“ leaching of mineral nitrogen; above- and below- ground primary production

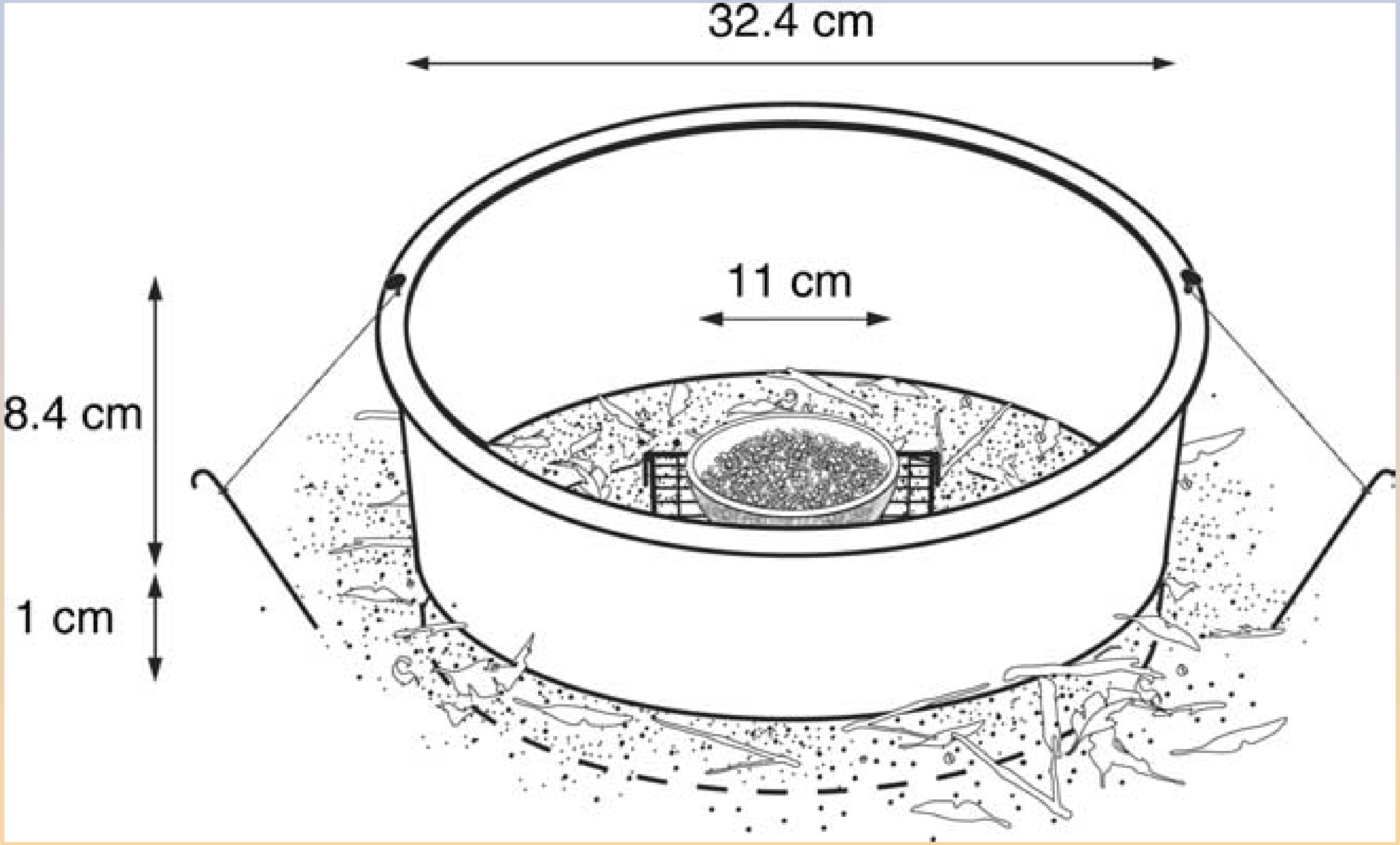
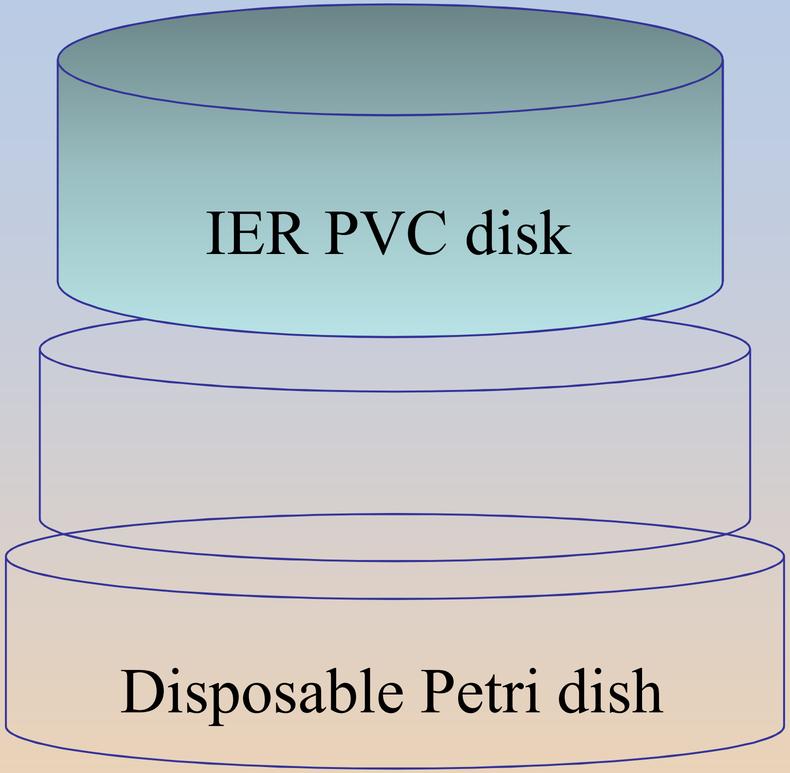
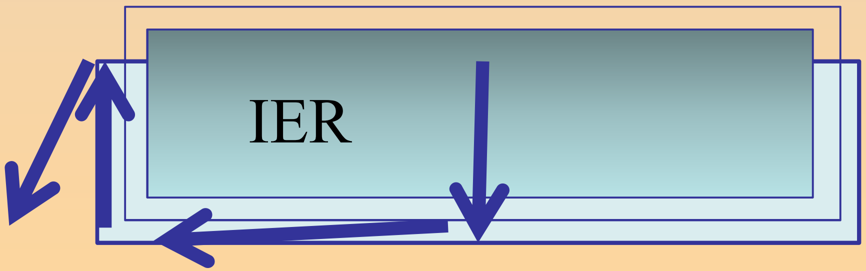


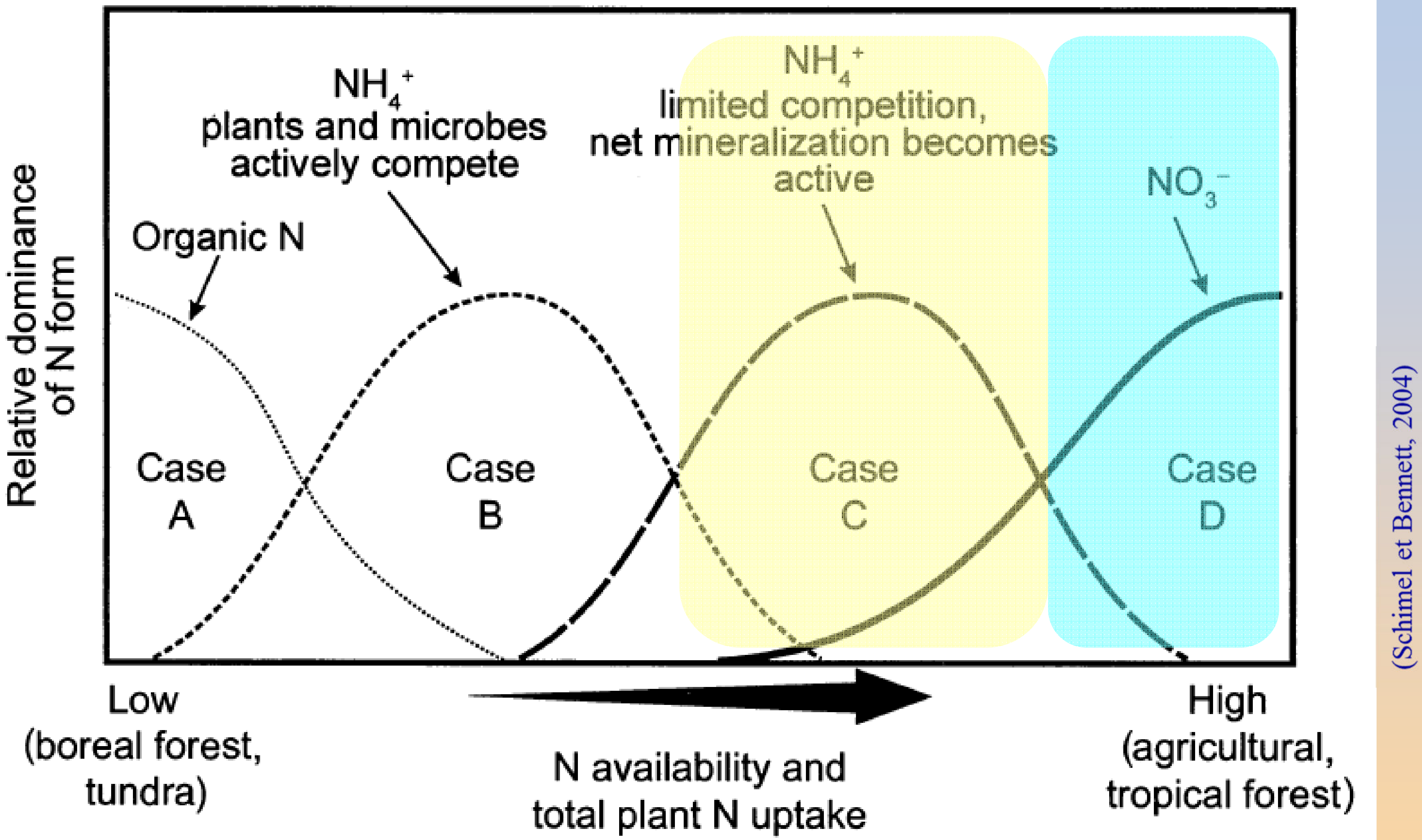
Diagram illustrating the chamber design inserted in the soil, with petri dish of soda lime on wire stand. A lid is fitted on the chamber during incubation periods.

H. Keith, S.C. Wong / Soil Biology & Biochemistry 38 (2006) 1121–1131



Percolating soil solution





If we were able to capture an excess of NH_4^+ and NO_3^- ions from soil solution, then we will be able to assess at what stage is the current N-load of the ecosystem.


min N