Wann und wo arbeiten die Wurzeln von Ackerpflanzen mit Pilzen und/oder mit Bakterien zusammen?

Wien, 14. 9. 2017

J. Záhora

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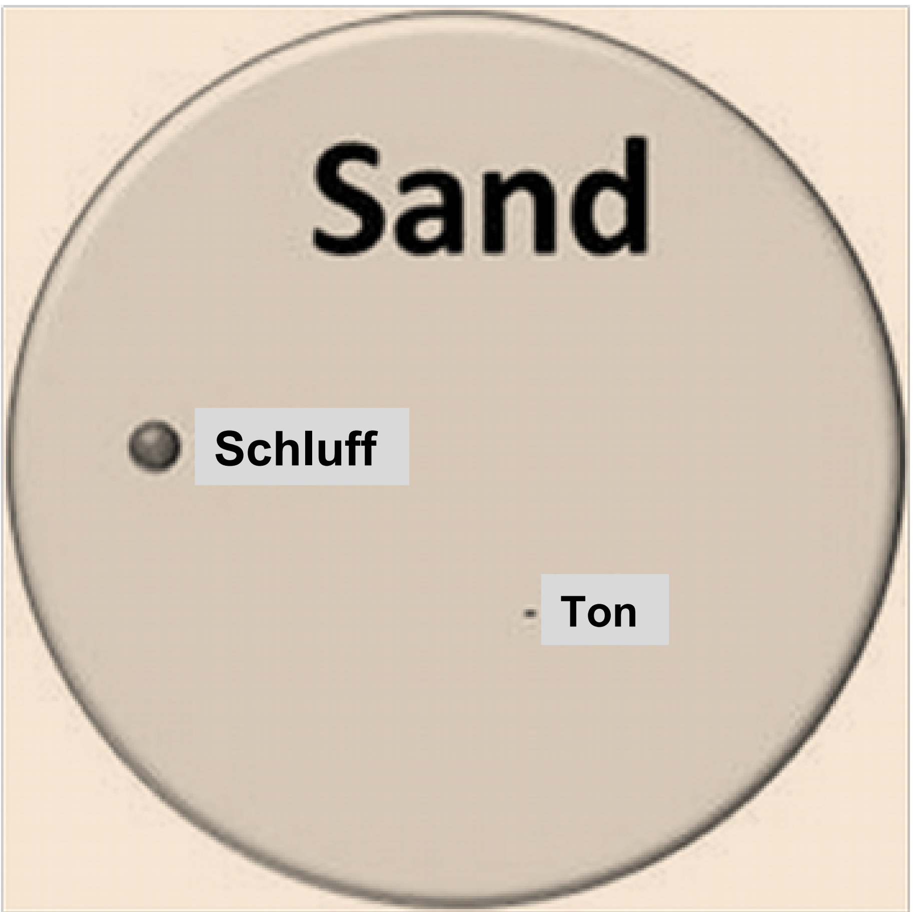
Ländliches Fortbildungs Institut LFI


Bodenfruchtbarkeit kommt nicht aus dem Düngersack


und Enzym-
Andreas Bohner

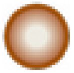



Relative Größen von Sand, Schlauff und Ton

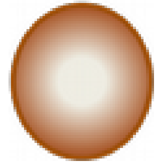
Relative Anteil

→ **Die Bodenarten**

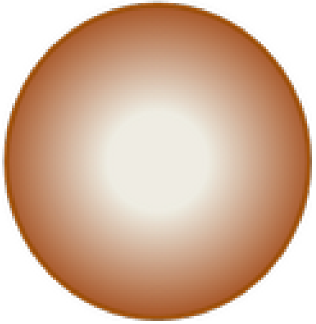
Die Bodenarten



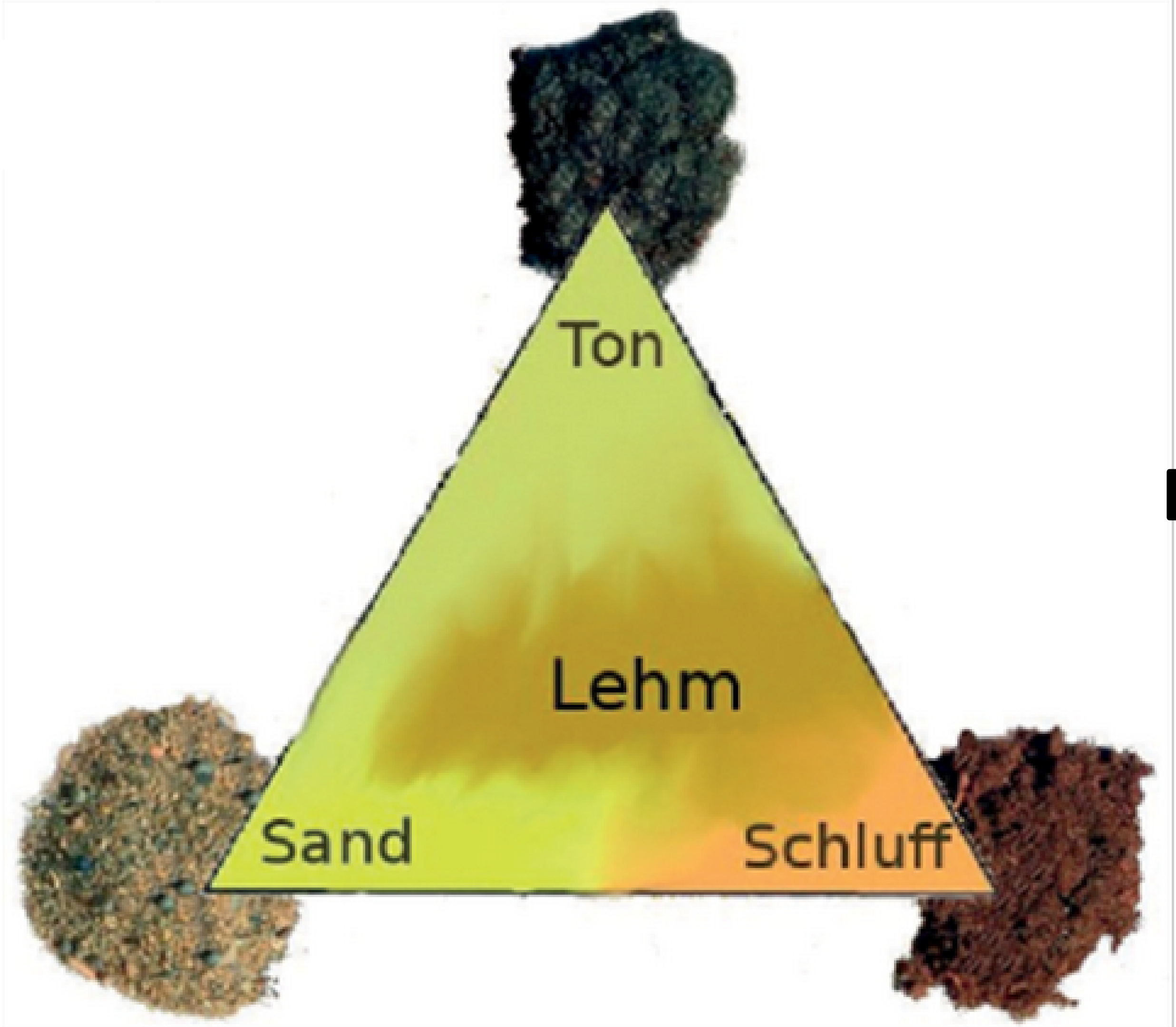
Ton
< 2 µm ø

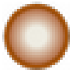


Schluff
2 – 63 µm ø

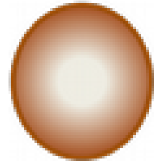


Sand
63 – 2 000 µm ø

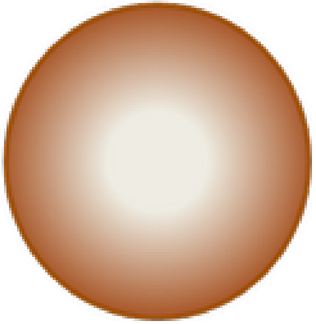




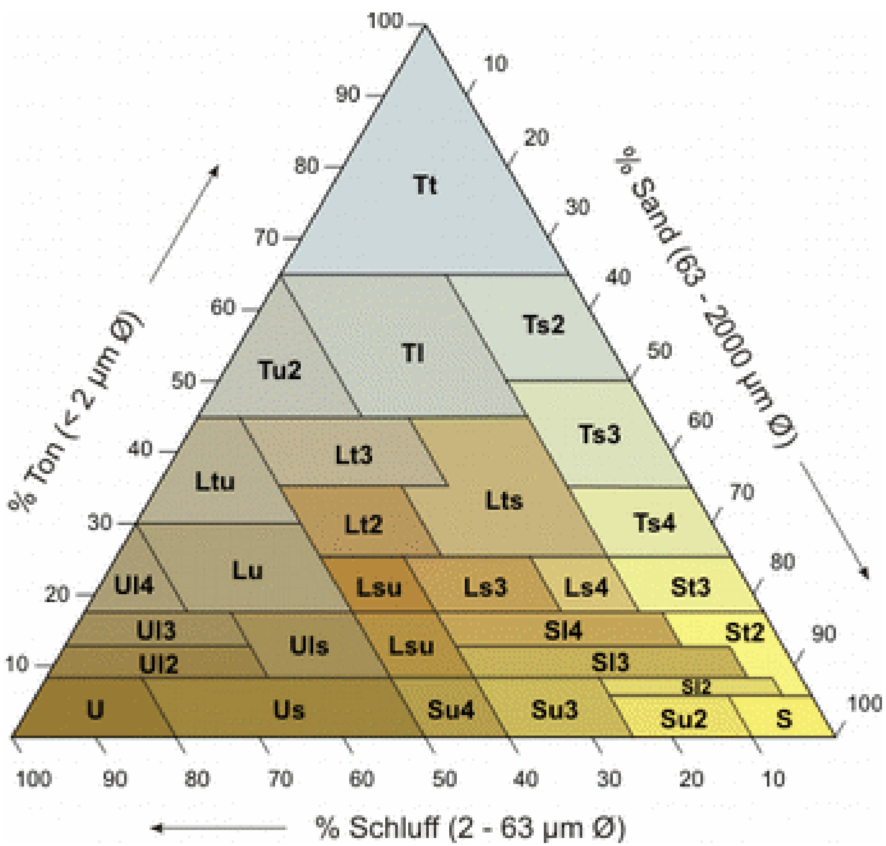
Ton
< 2 µm ø



Schluff
2 – 63 µm ø



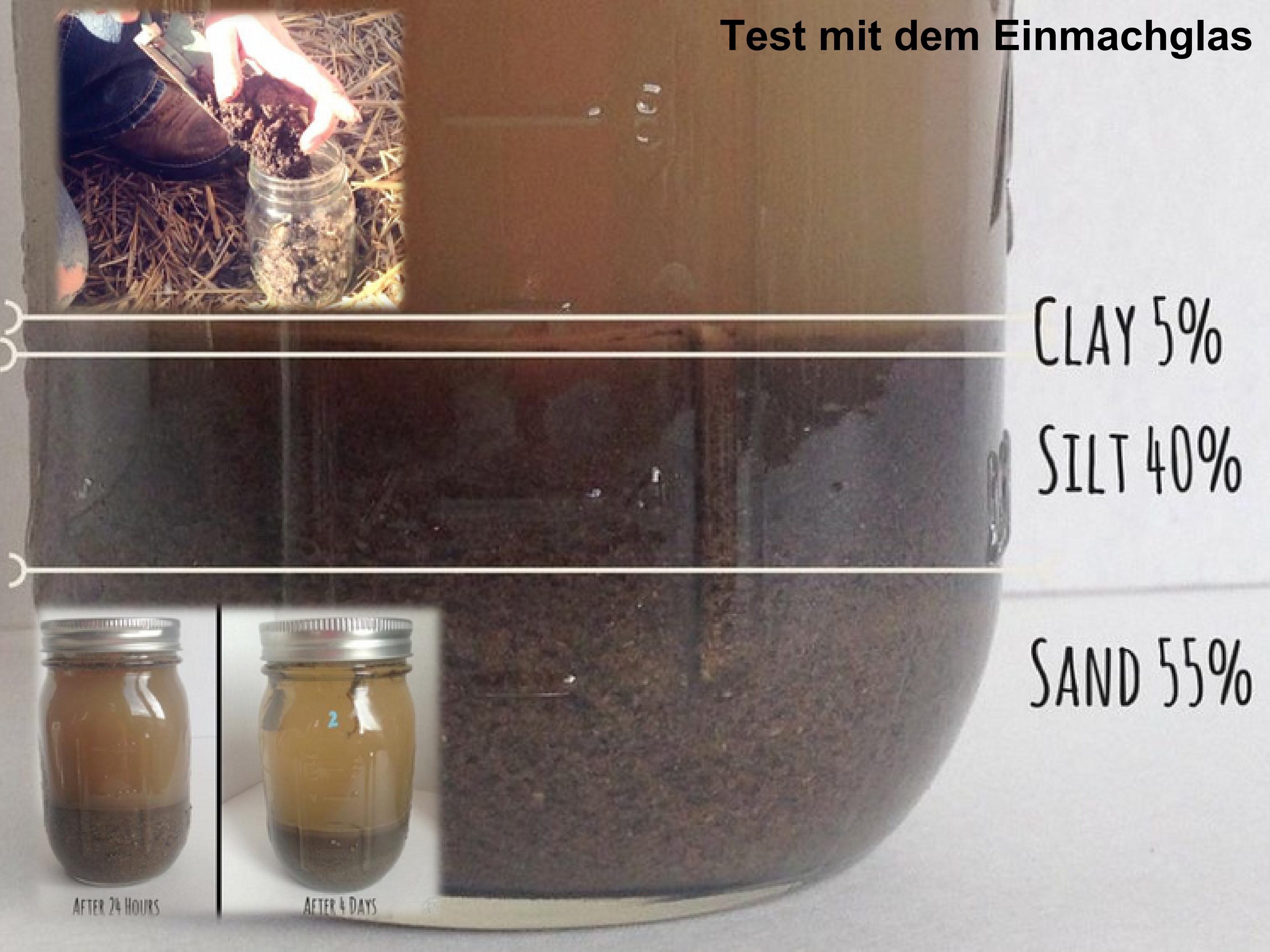
Sand
63 – 2 000 µm ø

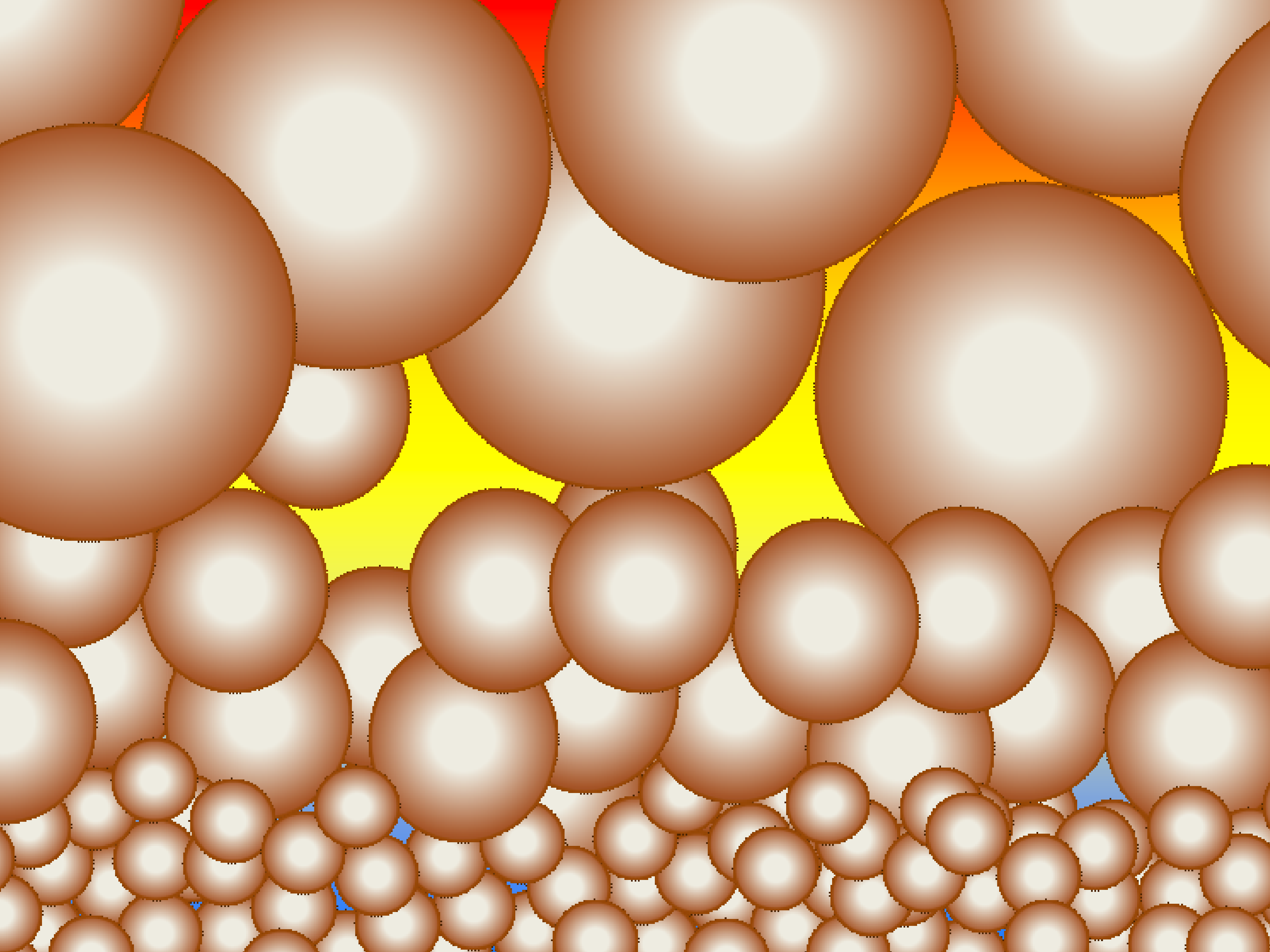


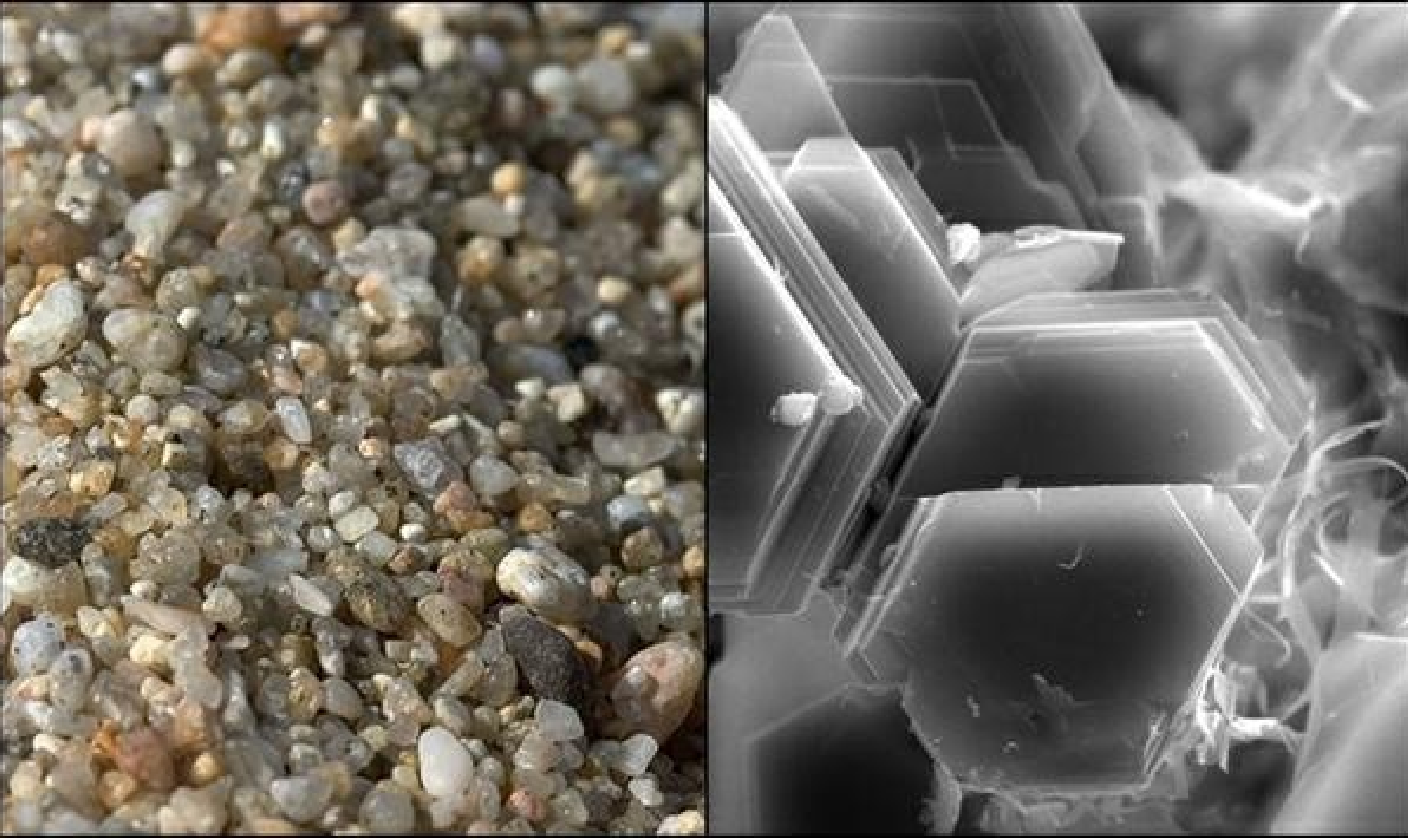
Die Bodenarten

das Diagramm zeigt sie in Abhängigkeit der Korngrößen-Anteile

Test mit dem Einmachglas

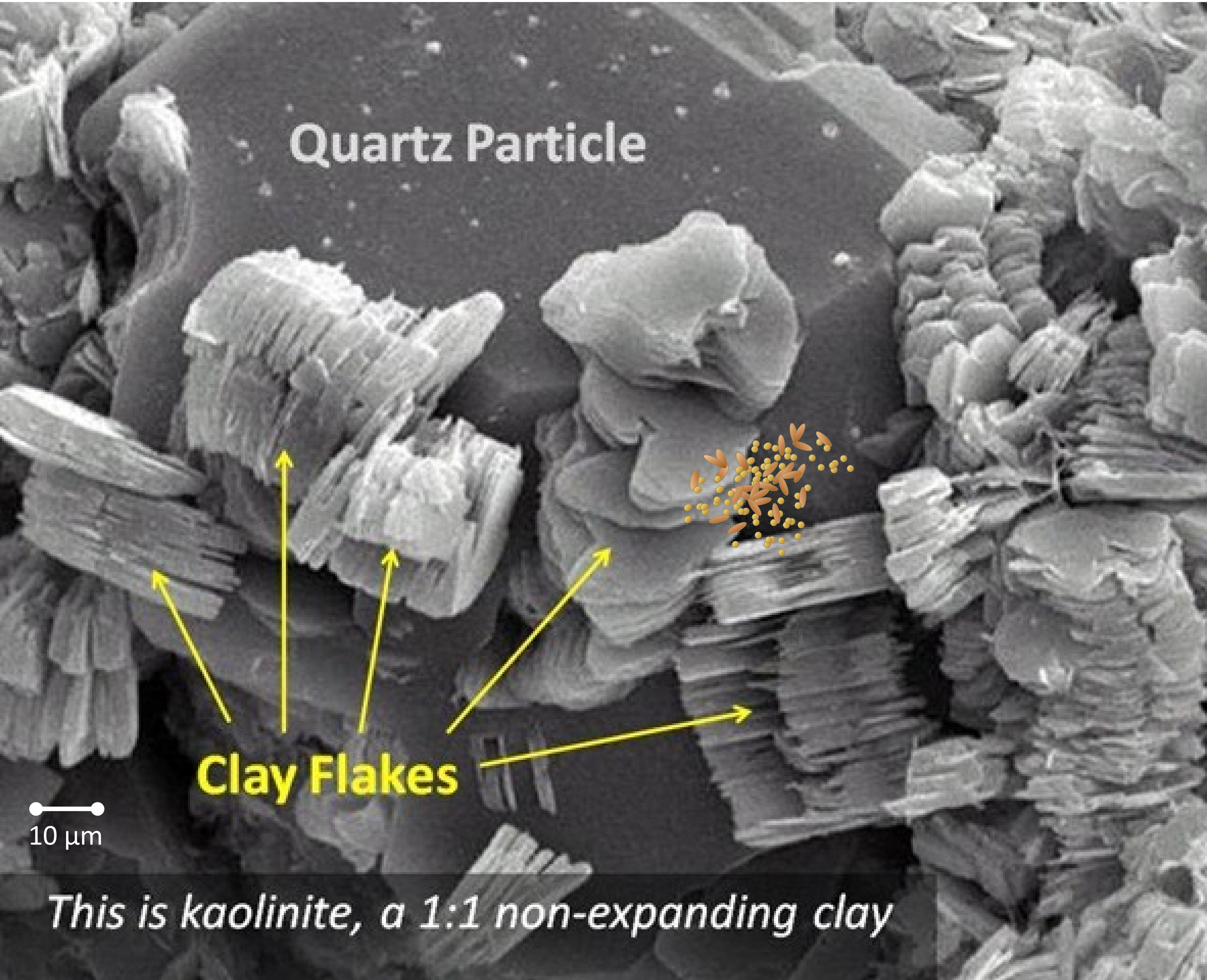






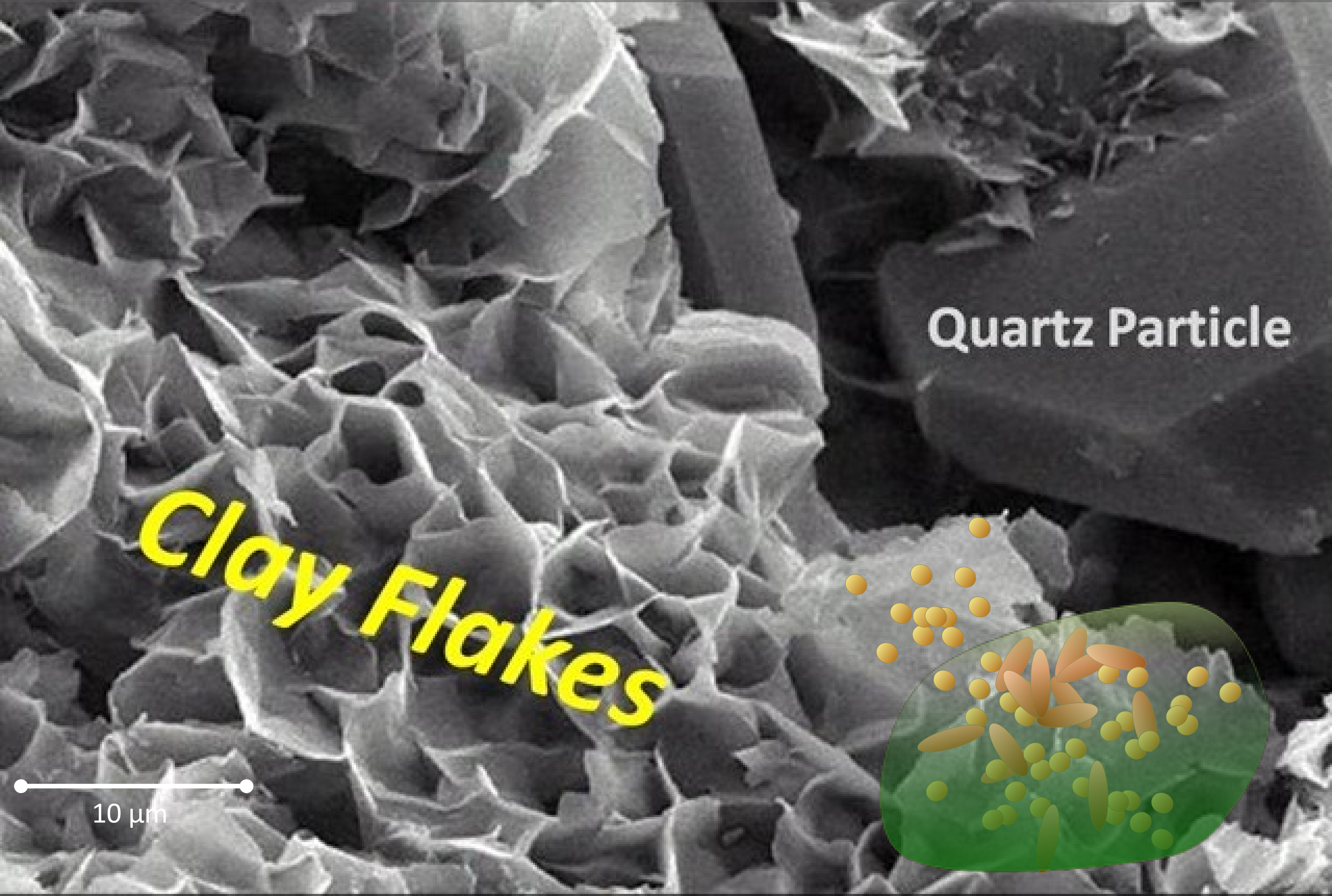
The image on the left shows a close-up of sand particles which appear grainy as seen by the naked eye. The right shows the plate-like texture of clay visible only under a microscope.

https://content.ces.ncsu.edu/media/images/particle%20size2.jpg

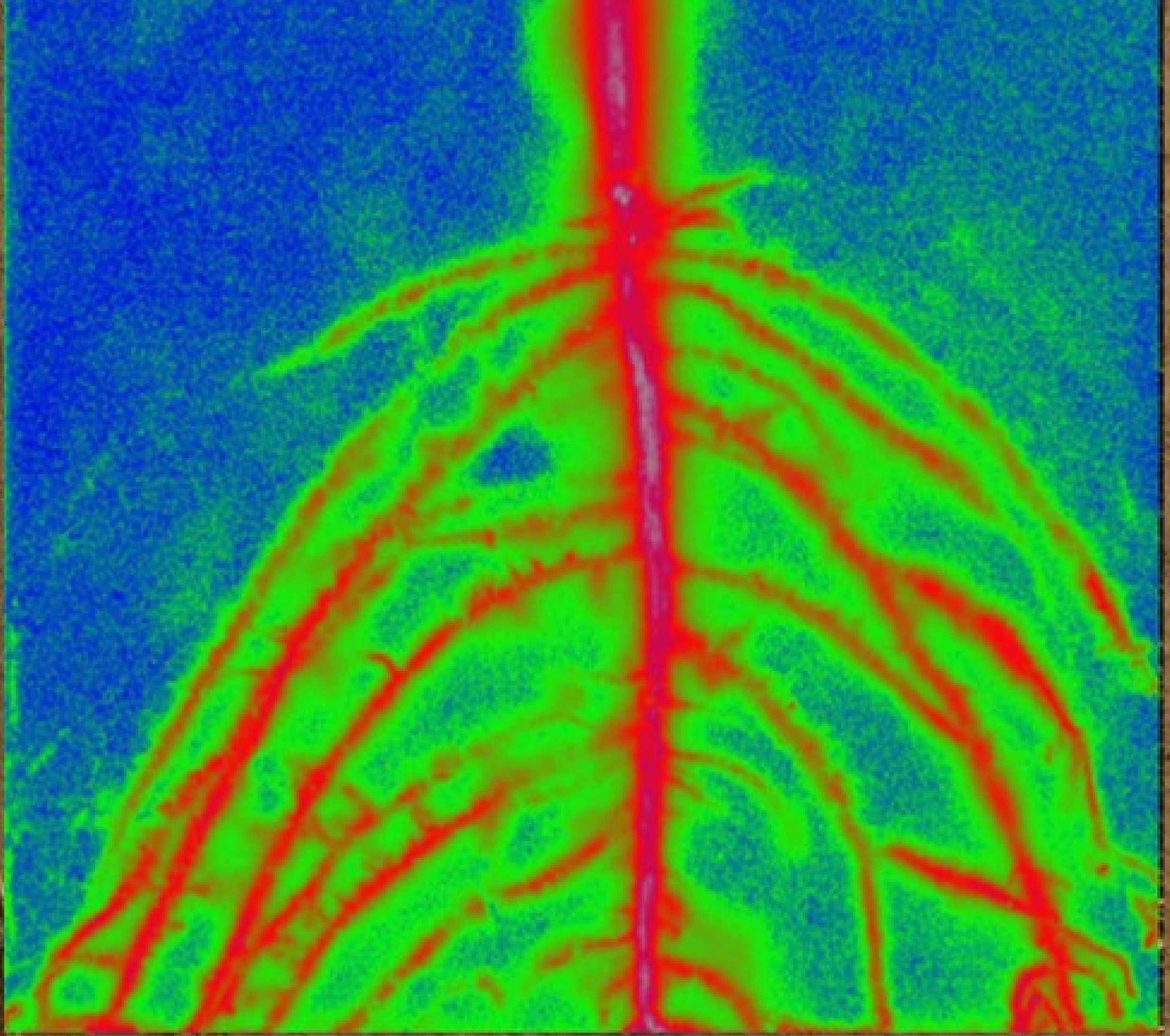


This is kaolinite, a 1:1 non-expanding clay

http://lh5.ggpht.com/_6LWjP0sZ22w/S4stSJjBMHI/AAAAAAAAHfQ/1-WpzNFDdCE/s1600/Kao%20electron%20view%5B9%5D.jpg http://lh6.ggpht.com/_6LWjP0sZ22w/S4stTAJy_rI/AAAAAAAAHfY/r8Palg6IaBA/s1600/Mont%20electron%20view%5B4%5D.jpg



This is smectite (specifically montmorillonite), a 2:1 expanding clay



Rhizodeposition assessed by ^{14}C imaging.

Kuzyakov et al. , University of Göttingen, Germany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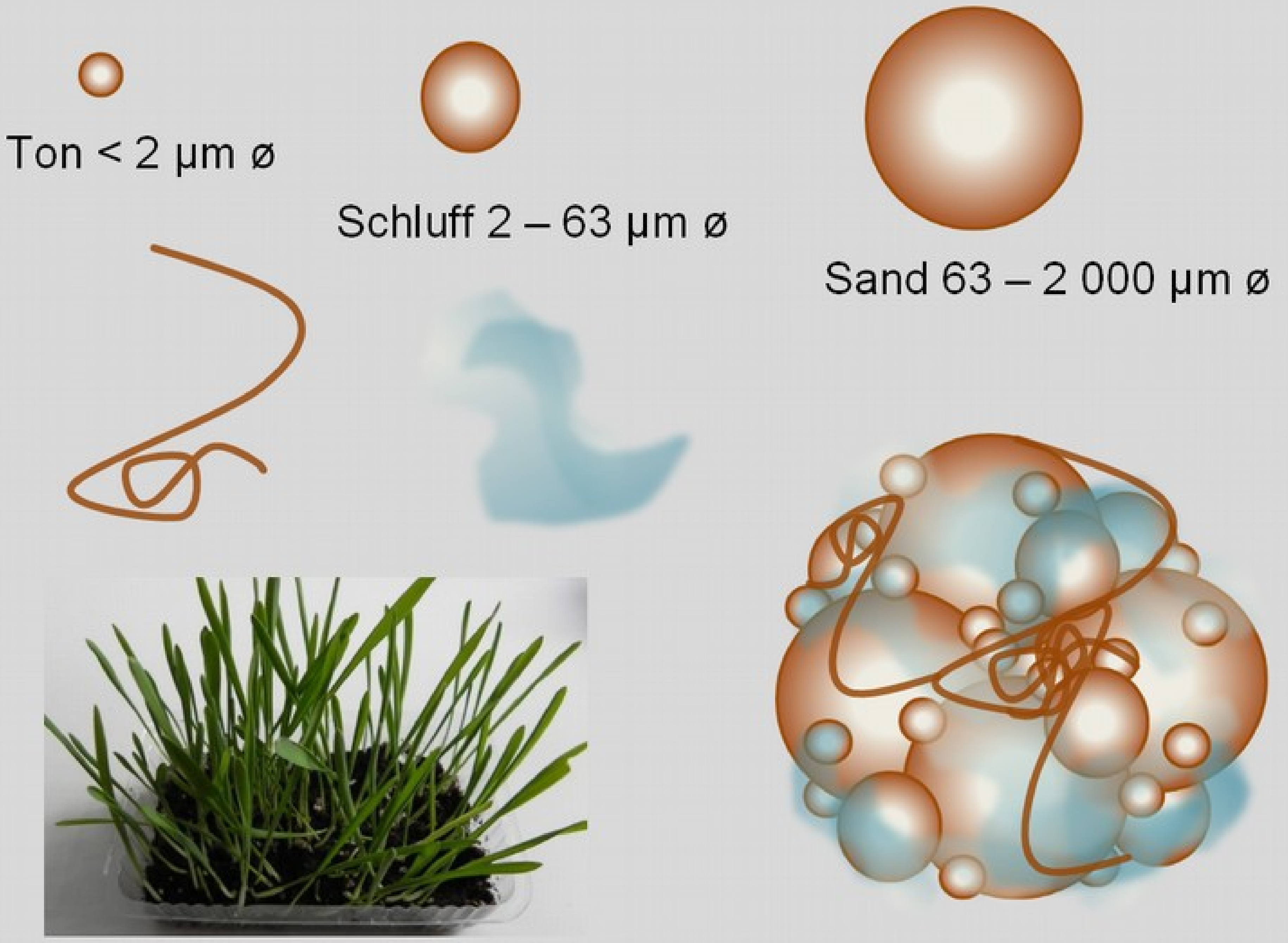
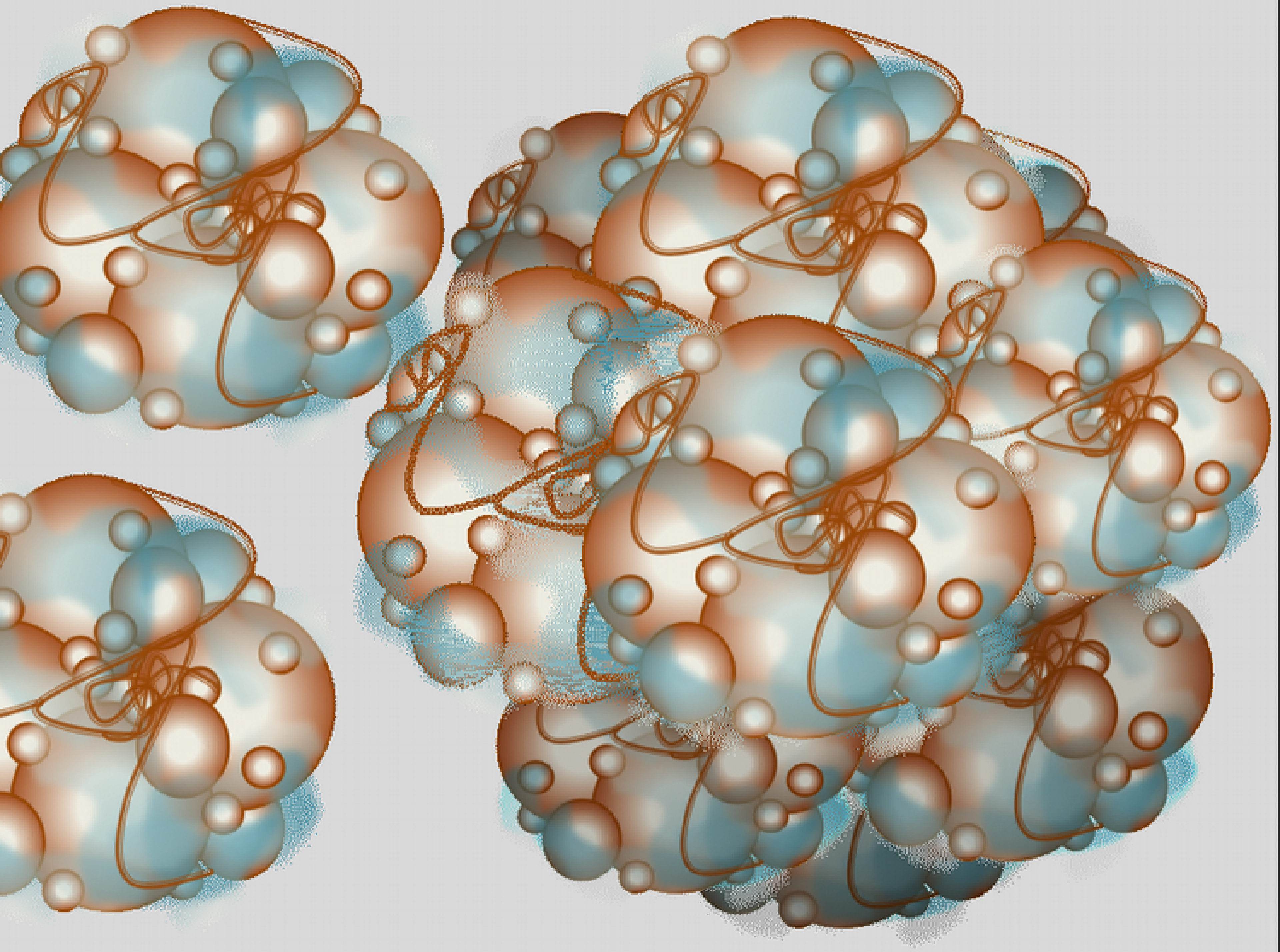
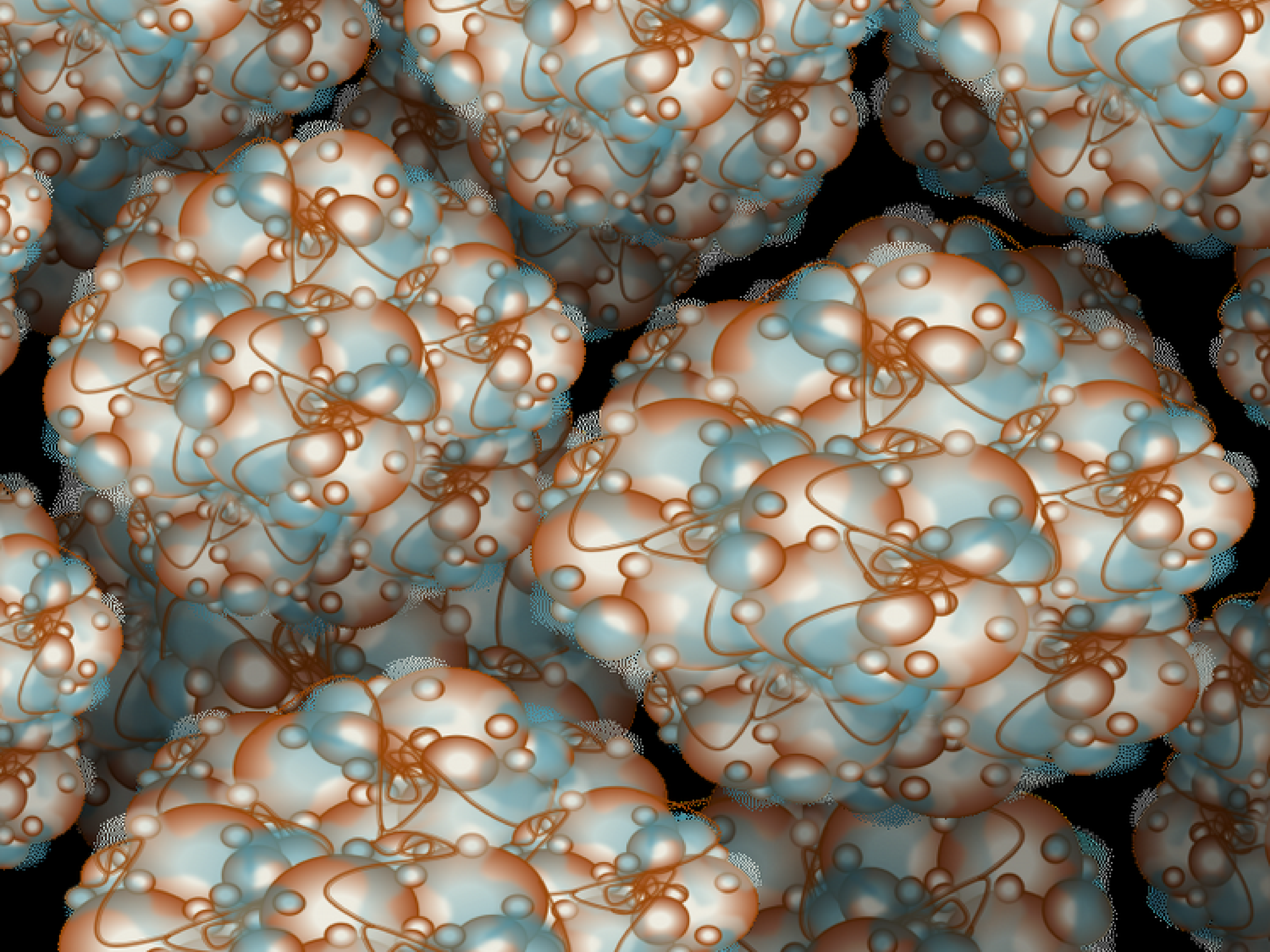
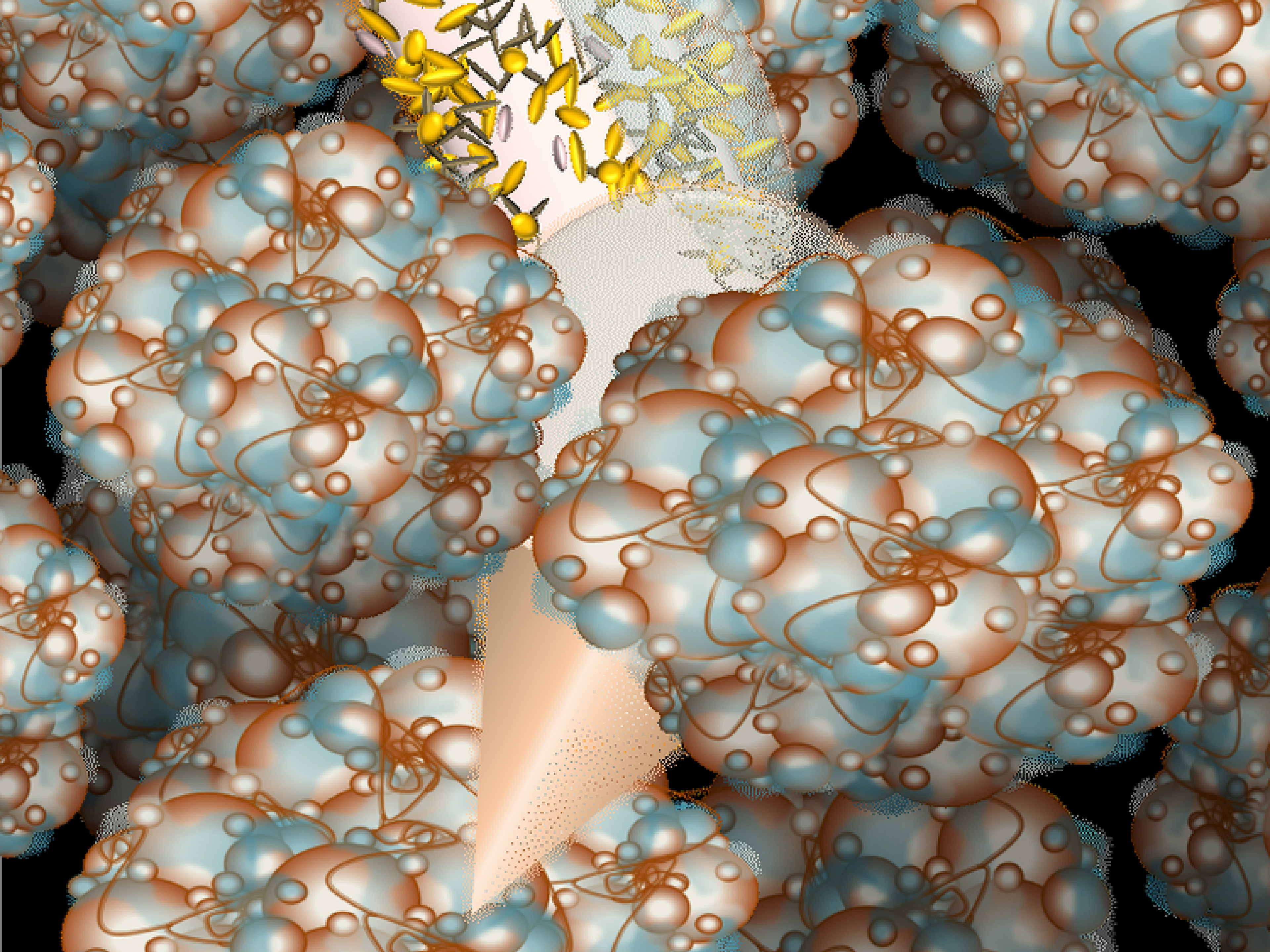
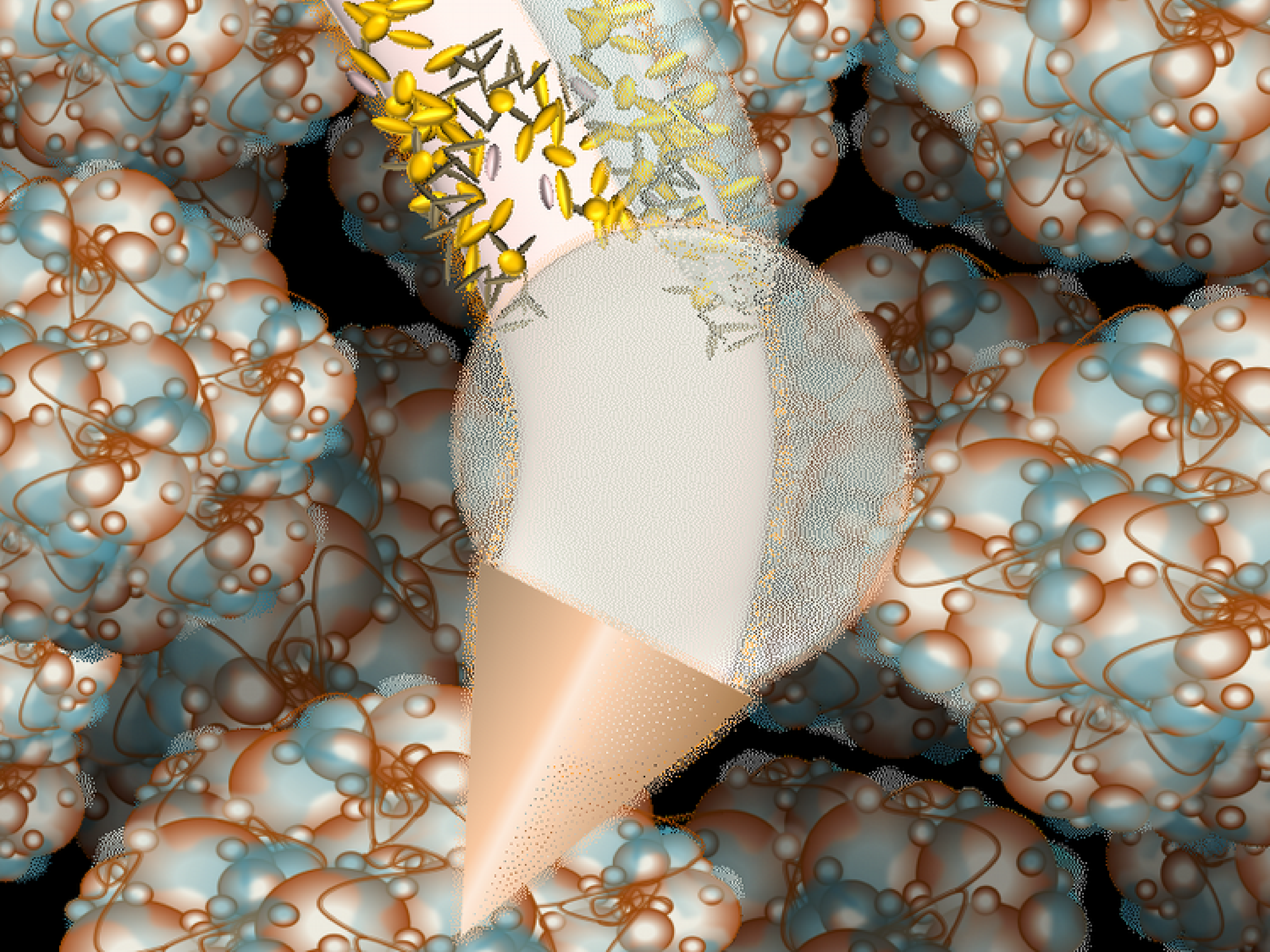
CUKOR
Rabio
CUKR / SUGAR
2017

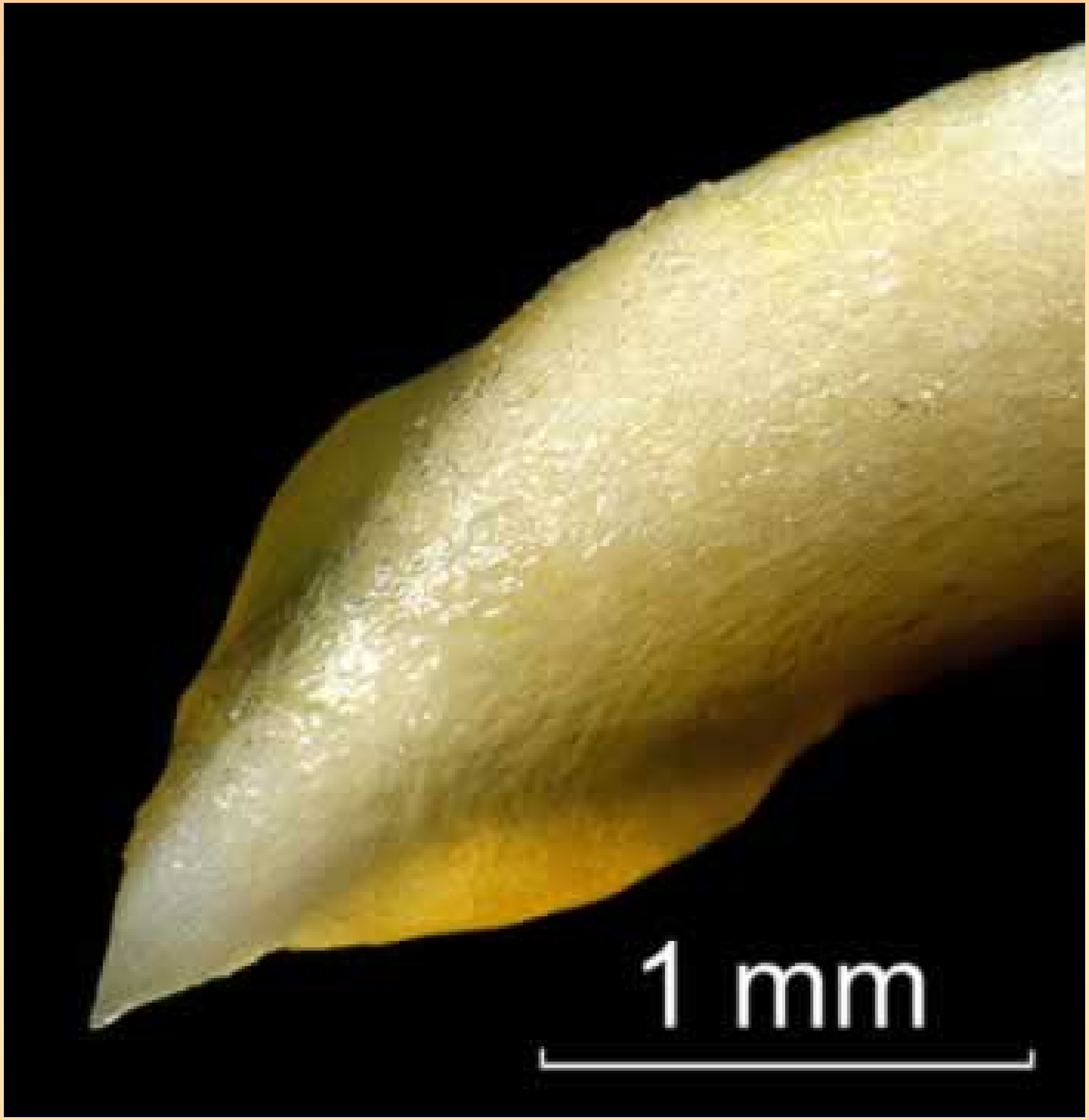

Ton < 2 µm ø
Schluff 2 – 63 µm ø
Sand 63 – 2 000 µm ø











Mikrographie der Wurzelkappe mit mucilage (Mais)

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

Die Rhizosphäre (Boden-Hotspots

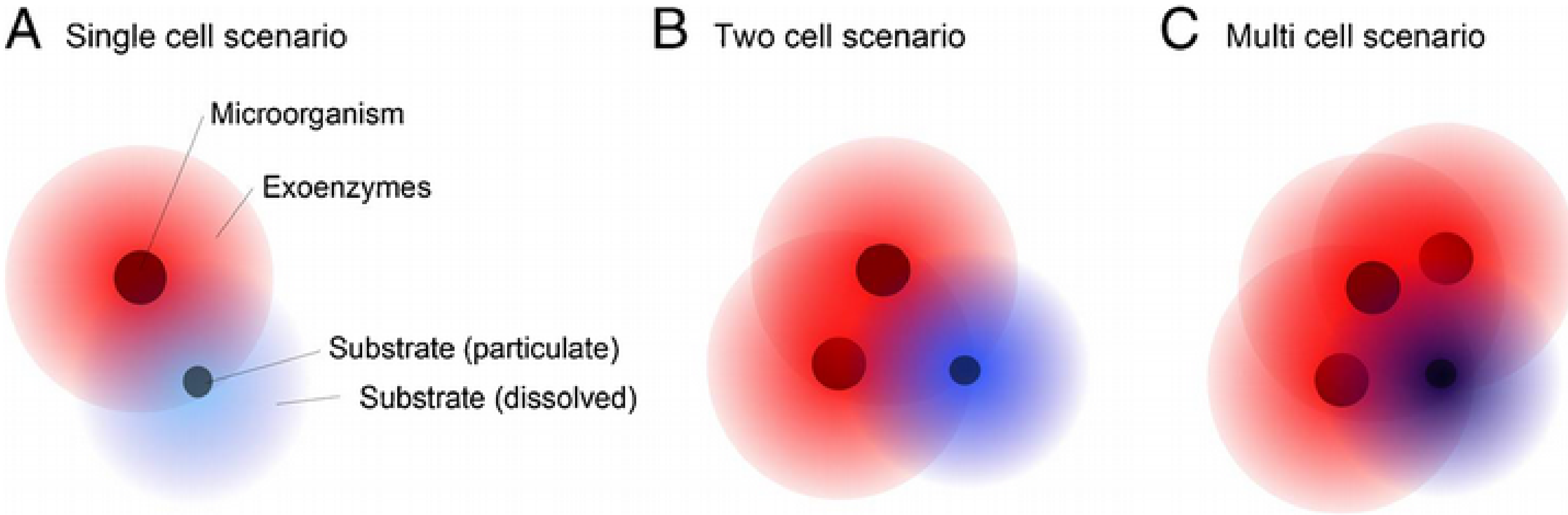
Lebende Wurzeln reichlich leicht verfügbare Monomere wie Monosaccharide und Aminosäuren freisetzen,

und, während Rhizodepositionen einen kontinuierlichen Fluss von Substanzen während des Pflanzenwachstums darstellen.

Die Wurzel-Detritusphäre (Boden-Hotspots)

Der Tod von Wurzeln ist ein zeitlich **konzentrierter C-Eingang**, hauptsächlich makromolekulare Verbindungen wie Cellulose und Xylan.

Wegen des konzentrierten Inputs der verfügbaren organischen Stoffe aus toten Wurzeln ist es allgemein anerkannt, dass Mikroorganismen häufiger sind und dass die Hotspots-Bereiche der Enzymaktivität in der Wurzel-Detritusphäre größer sind als in der Rhizosphäre.



Hypothesized concept of synergistic interactions of exoenzyme - producing soil microorganisms. In bulk soil, a high proportion of exoenzymes released by a soil microorganism is lost without any benefit for it (a). With increasing number of exoenzymes the concentration of products of enzymatically catalyzed reactions increases (as indicated by the increase in the intensity of the blue color, b). Thus, exoenzyme-producing microorganisms can benefit from each other, which might contribute to the high microbial activity at hotspots of enzyme activity (c)

Spohn, M. et Kuzyakov, Y. / Plant Soil (2014) 379:67–77

Biofilms: an emergent form of bacterial life

Hans-Curt Flemming[1], Jost Wingender[1], Ulrich Szewzyk[2], Peter Steinberg[3], Scott A. Rice[4] and Staffan Kjelleberg[4]

NATURE REVIEWS | MICROBIOLOGY VOLUME 14 | SEPTEMBER 2016 | 563

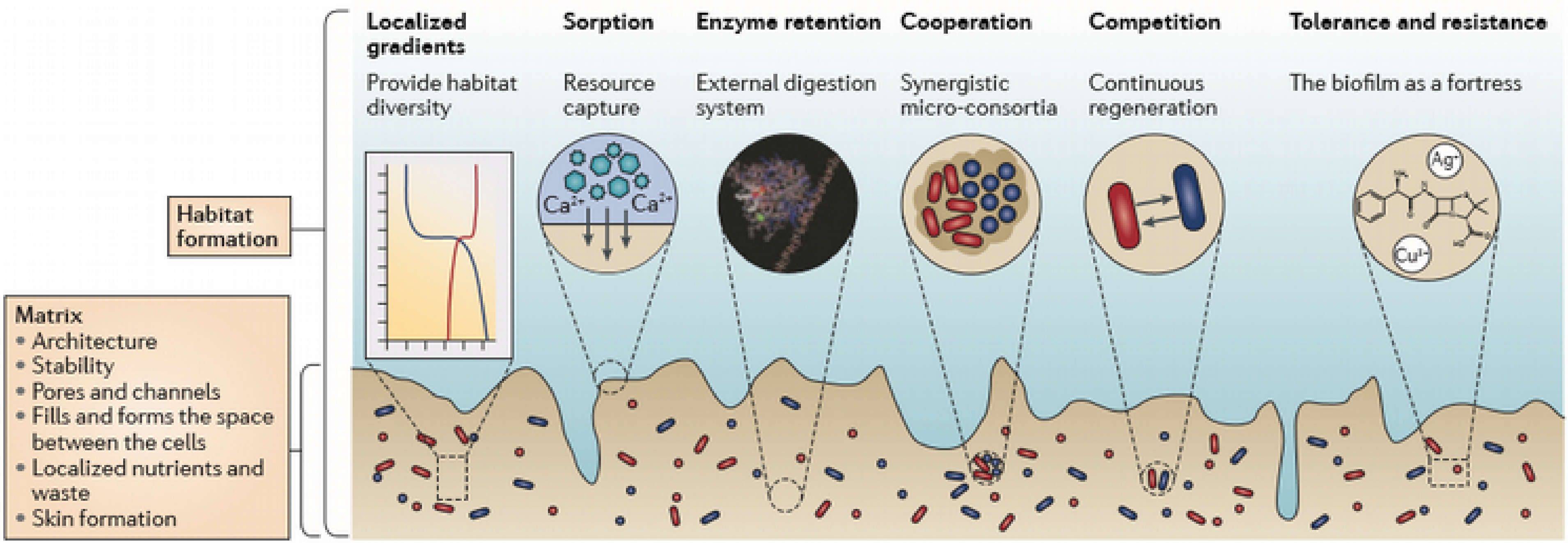


Figure 1 | **Emergent properties of biofilms and habitat formation.** Bacterial cells in biofilms can be considered to be habitat formers, owing to their generation of a matrix that forms the physical foundation of the biofilm. The matrix is composed of extracellular polymeric substances (EPS) that provide architecture and stability to the biofilm. Nutrients and other molecules can be trapped both by sorption to EPS molecules and to the pores and channels of the matrix, whereas skin formation by hydrophobic EPS molecules enhances the ability of the biofilm to survive desiccation. Biofilms derive several emergent properties — that is, properties that are not predictable from the study of free-living bacterial cells — from the EPS matrix. These properties include localized gradients that provide habitat diversity, resource capture by sorption, enzyme retention that provides digestive capabilities, social interactions and the ability, through tolerance and/or resistance, to survive exposure to antibiotics.

Nanowires
Electrically conductive structures that are produced by microorganisms.

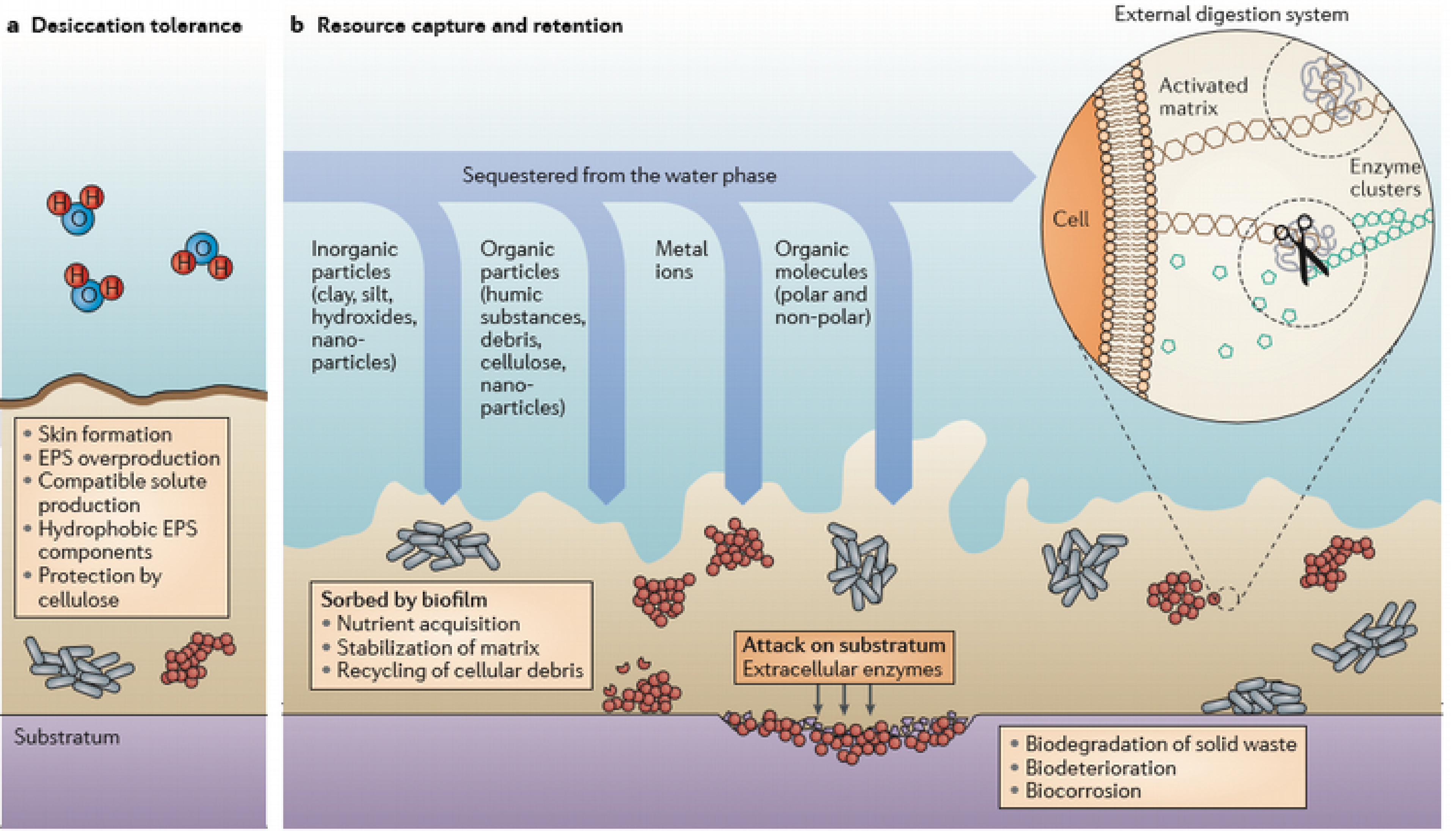
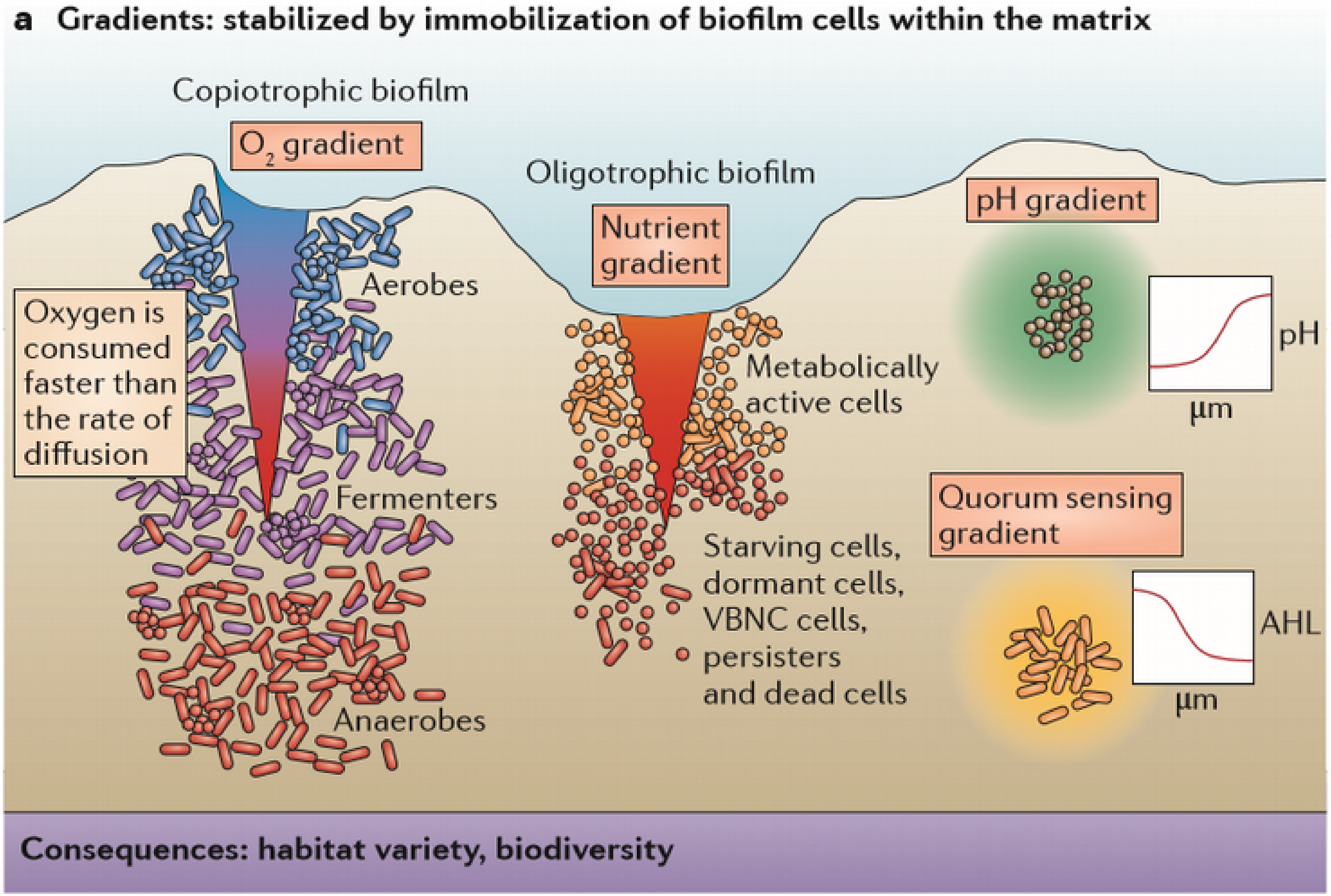
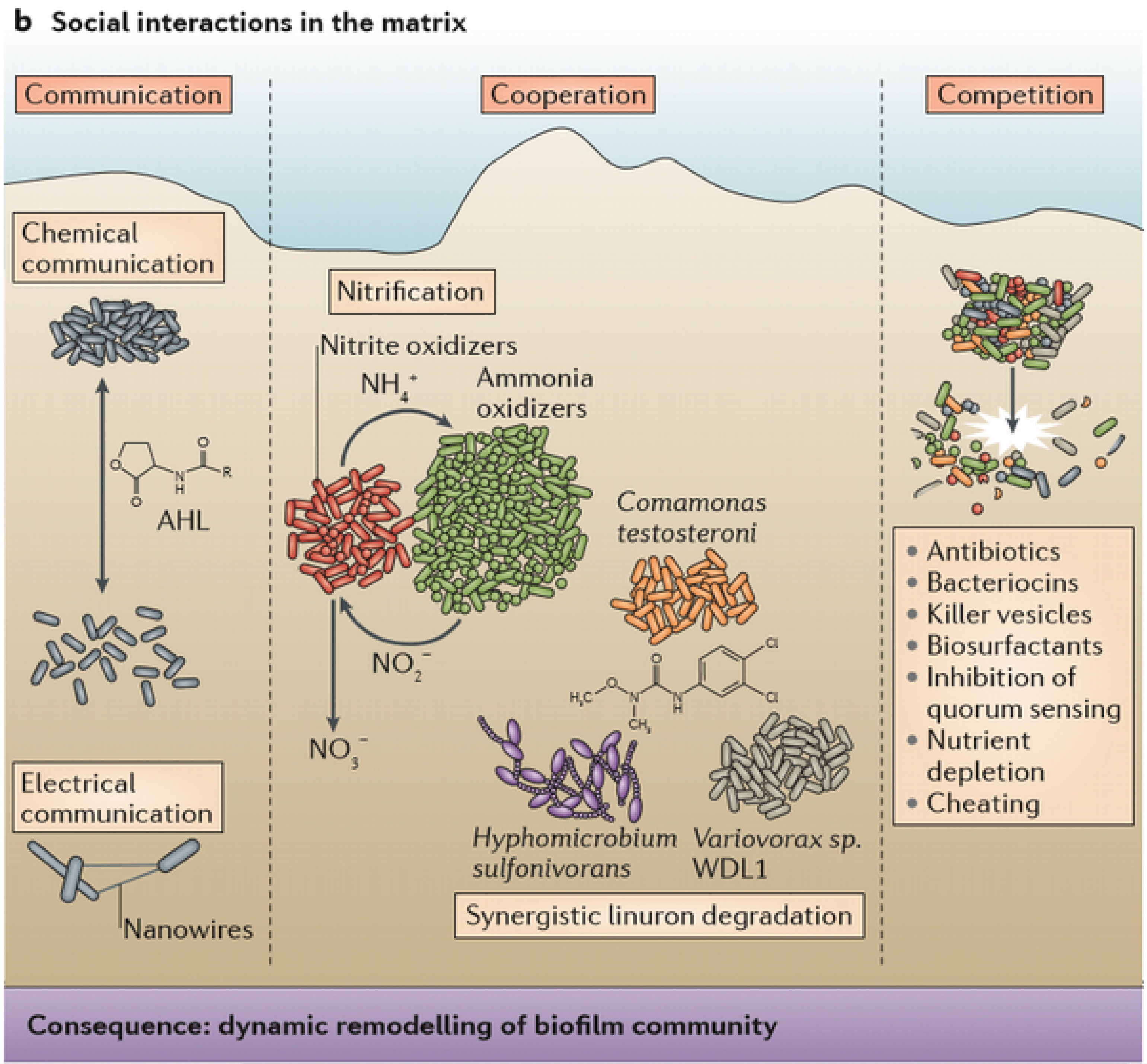
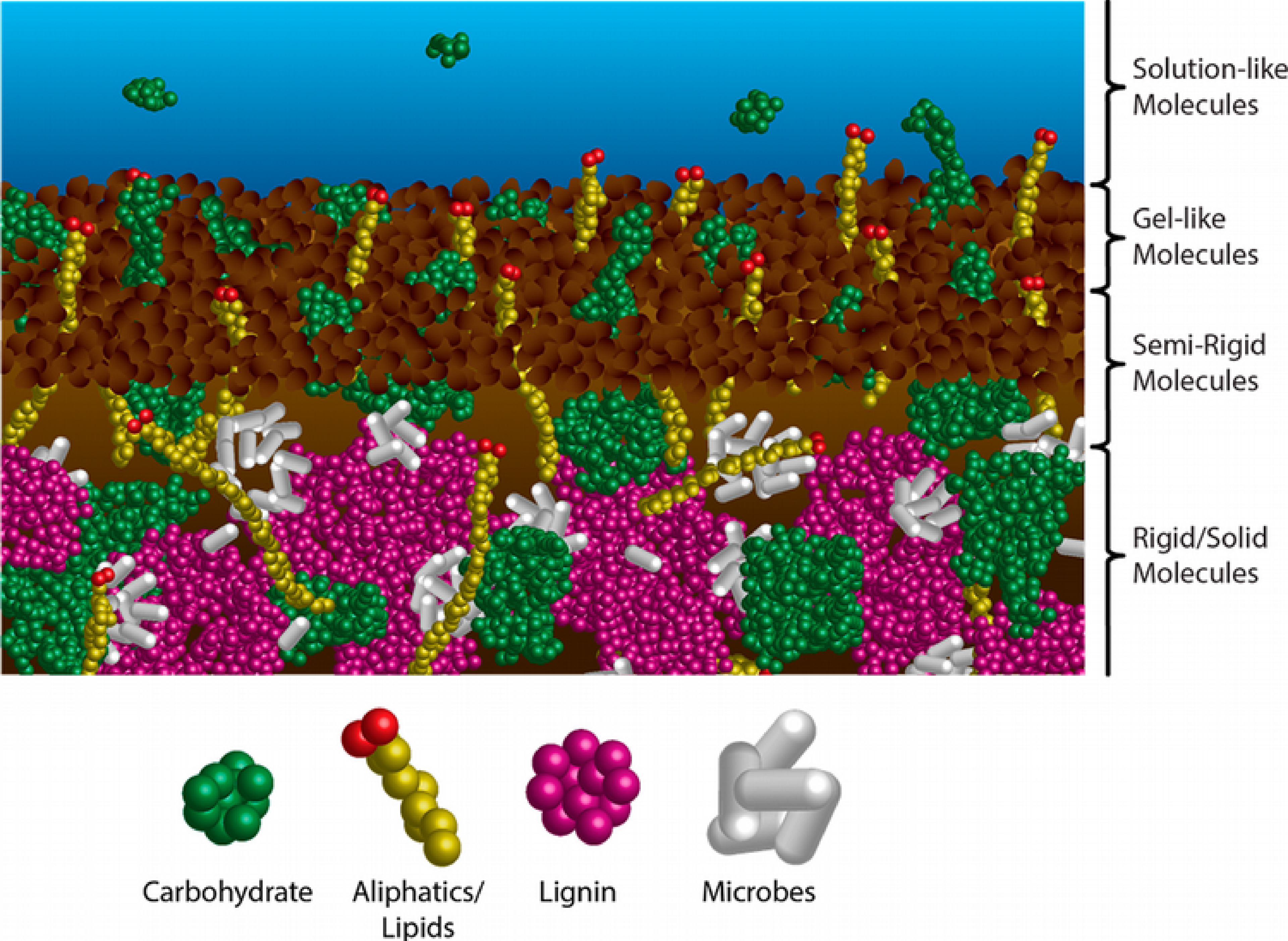


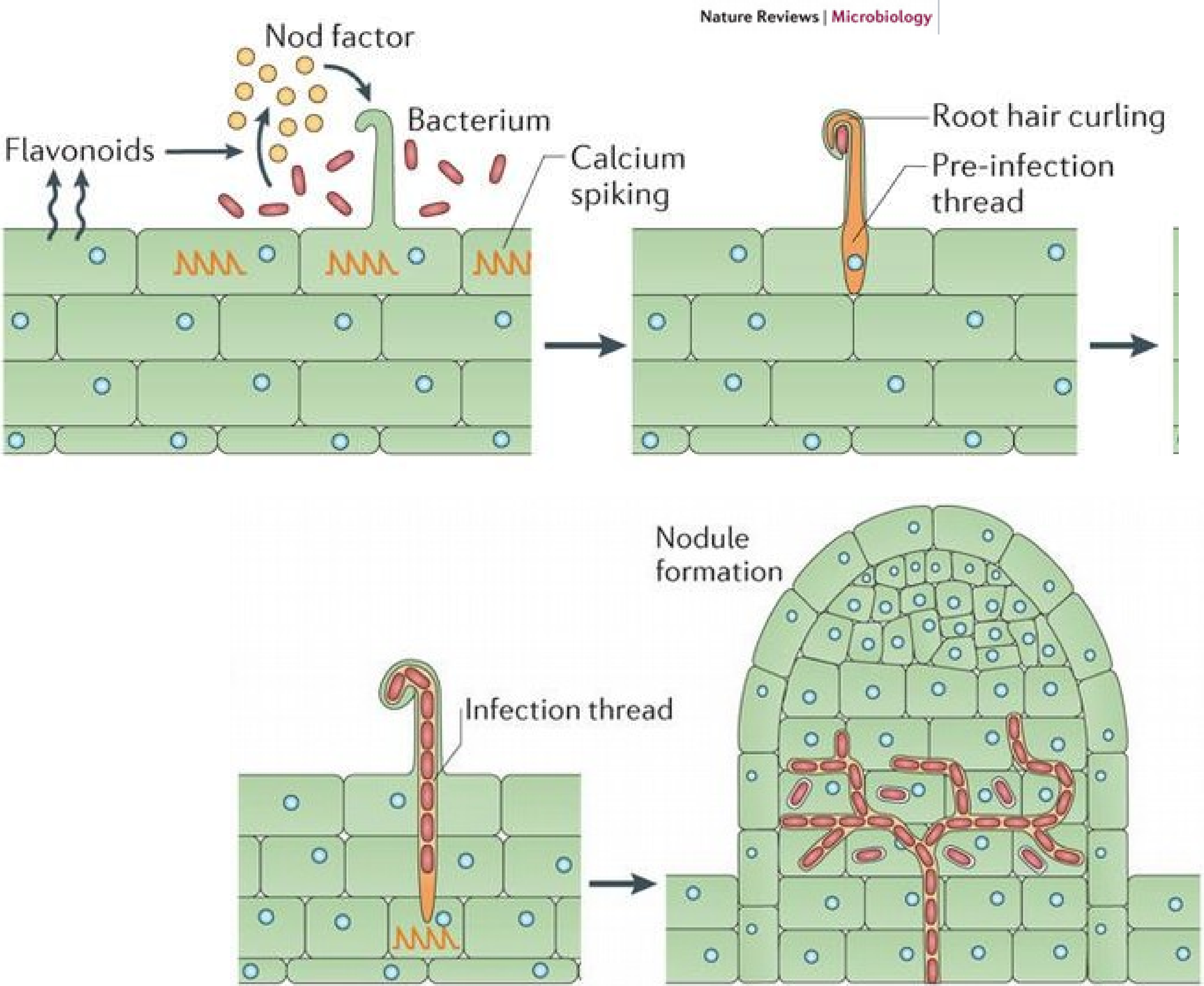
Figure 2 | **Physical and chemical properties of the biofilm matrix. a** | The biofilm can be viewed as a fortress that, through several properties of the matrix, enables constituent cells to survive desiccation. **b** | The biofilm is a sponge-like system that provides surfaces for the sorption of a diverse range of molecules that can be sequestered from the environment. This confers several benefits to the biofilm, such as nutrient acquisition and matrix stabilization. Similarly, the physicochemical properties of the matrix enable biofilms to retain and stabilize extracellular digestive enzymes that are produced by biofilm cells, which turns the matrix into an external digestive system. Surface-attached biofilms are not only able to take up nutrients from the water phase but can also digest biodegradable components from the substratum, which is exposed to enzymes in the matrix.


a Gradients: stabilized by immobilization of biofilm cells within the matrix
Copiotrophic biofilm
O_2 gradient
Oligotrophic biofilm
Nutrient gradient
pH gradient
Aerobes
Oxygen is consumed faster than the rate of diffusion
Metabolically active cells
pH
µm
Fermenters
Starving cells, dormant cells, VBNC cells, persisters and dead cells
Quorum sensing gradient
AHL
µm
Anaerobes
Consequences: habitat variety, biodiversity

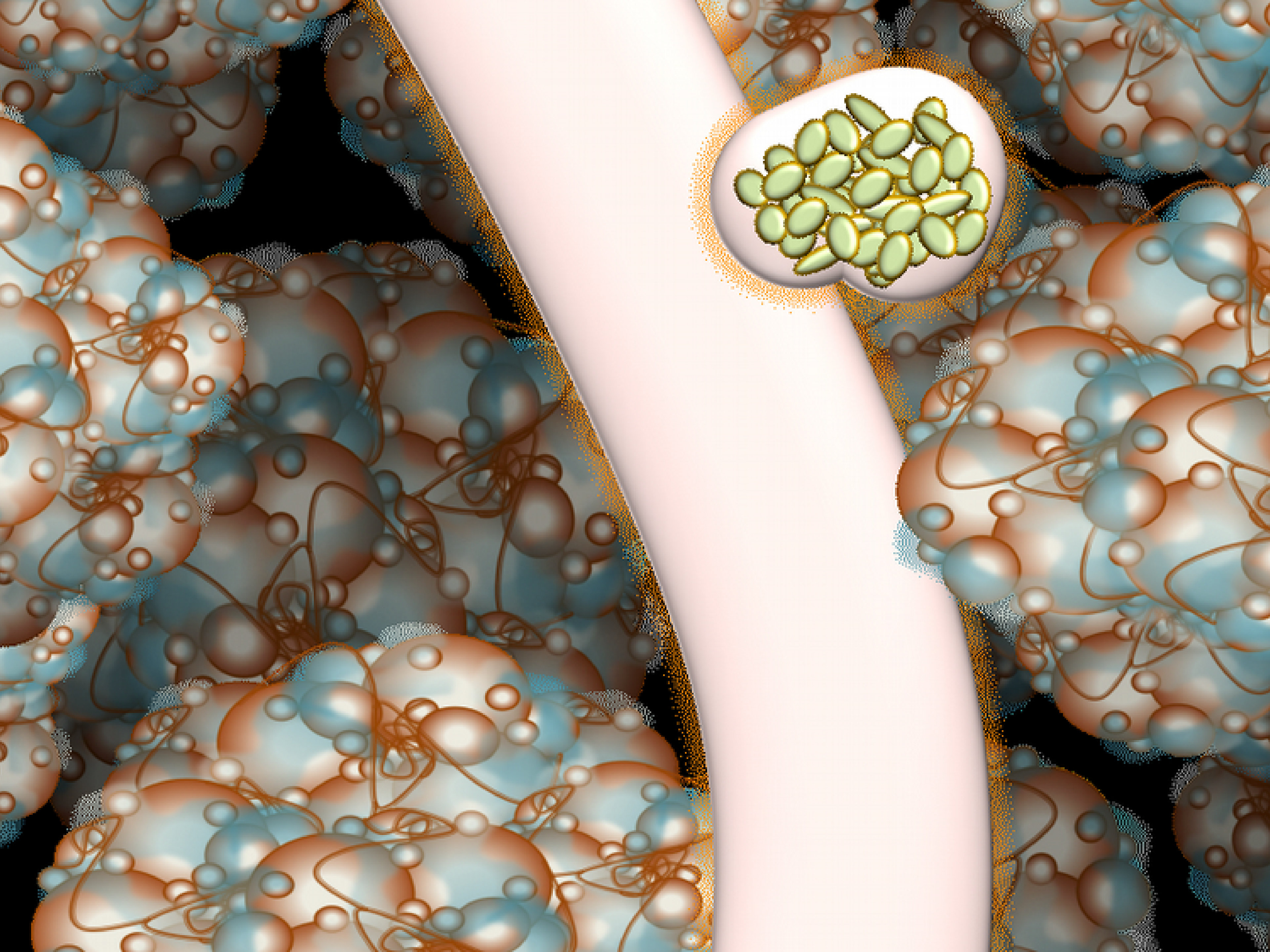

b Social interactions in the matrix
Communication
Cooperation
Competition
Chemical communication
AHL
Electrical communication
Nanowires
Nitrification
Nitrite oxidizers
NH4+
Ammonia oxidizers
NO2−
NO3−
Comamonas testosteroni
Hyphomicrobium sulfonivorans
Variovorax sp. WDL1
Synergistic linuron degradation
Antibiotics
Bacteriocins
Killer vesicles
Biosurfactants
Inhibition of quorum sensing
Nutrient depletion
Cheating
Consequence: dynamic remodelling of biofilm community

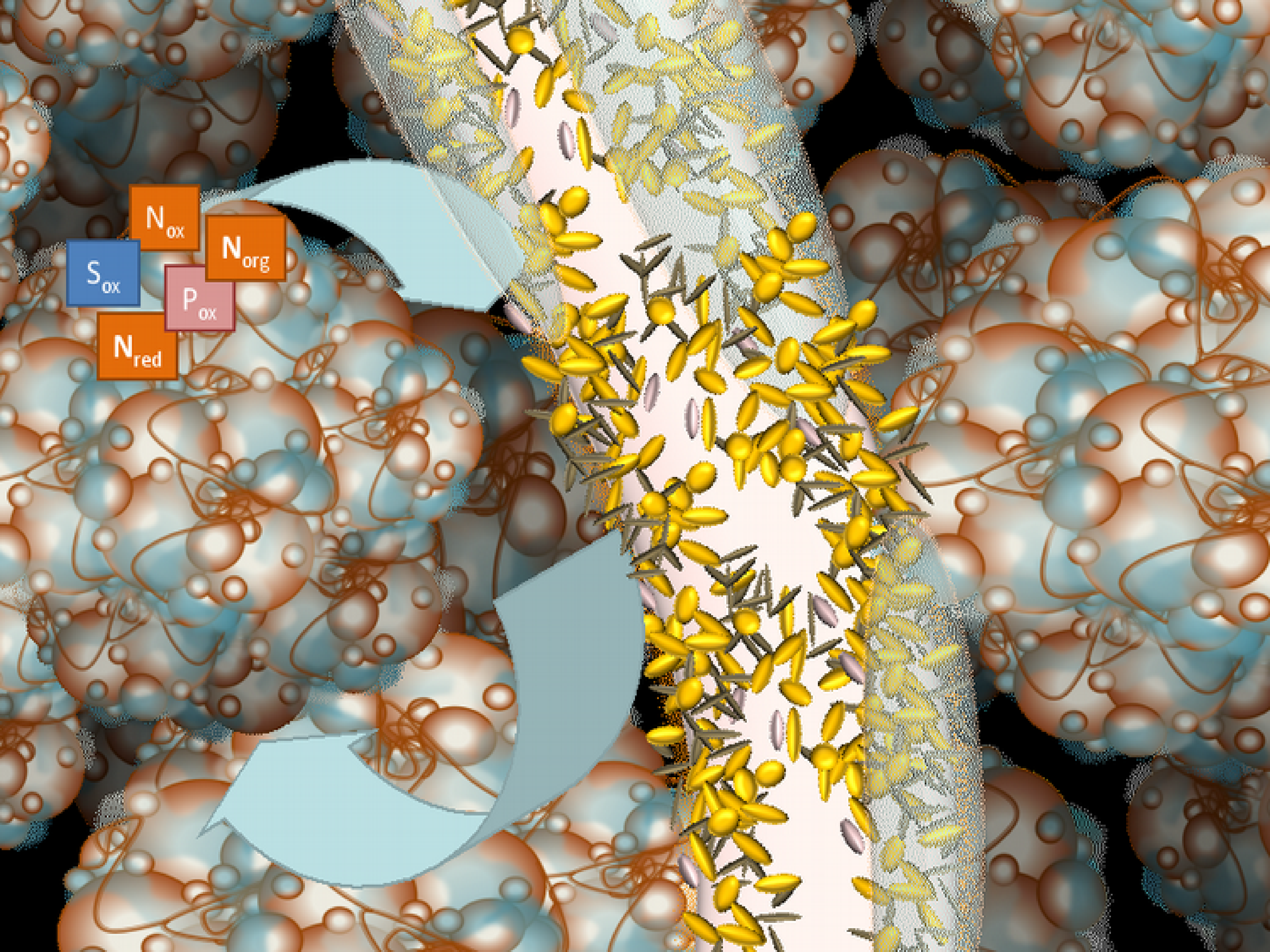


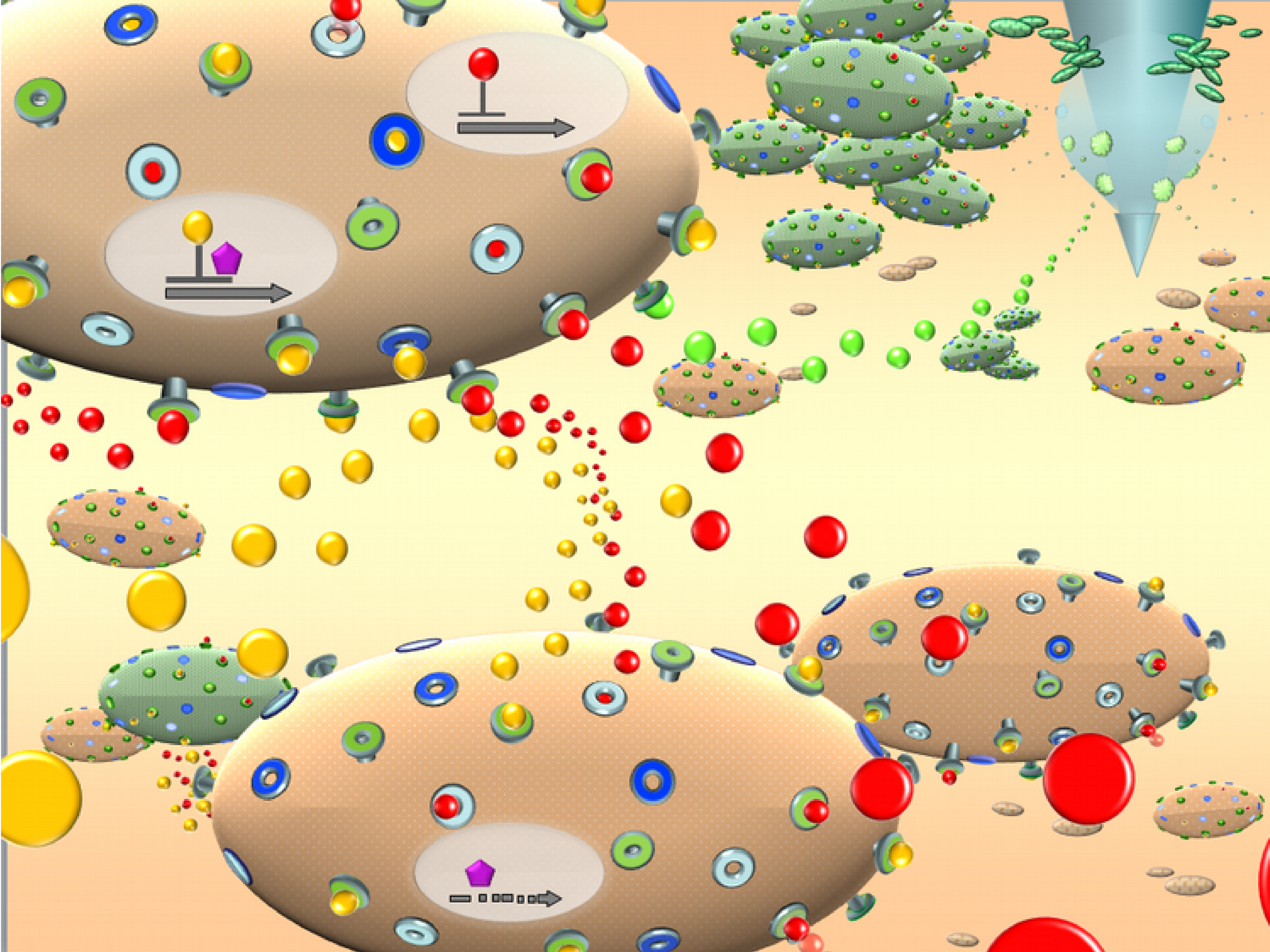
Masoom Hussain et al., Environ. Sci. Technol. 2016, 50, 1670−1680

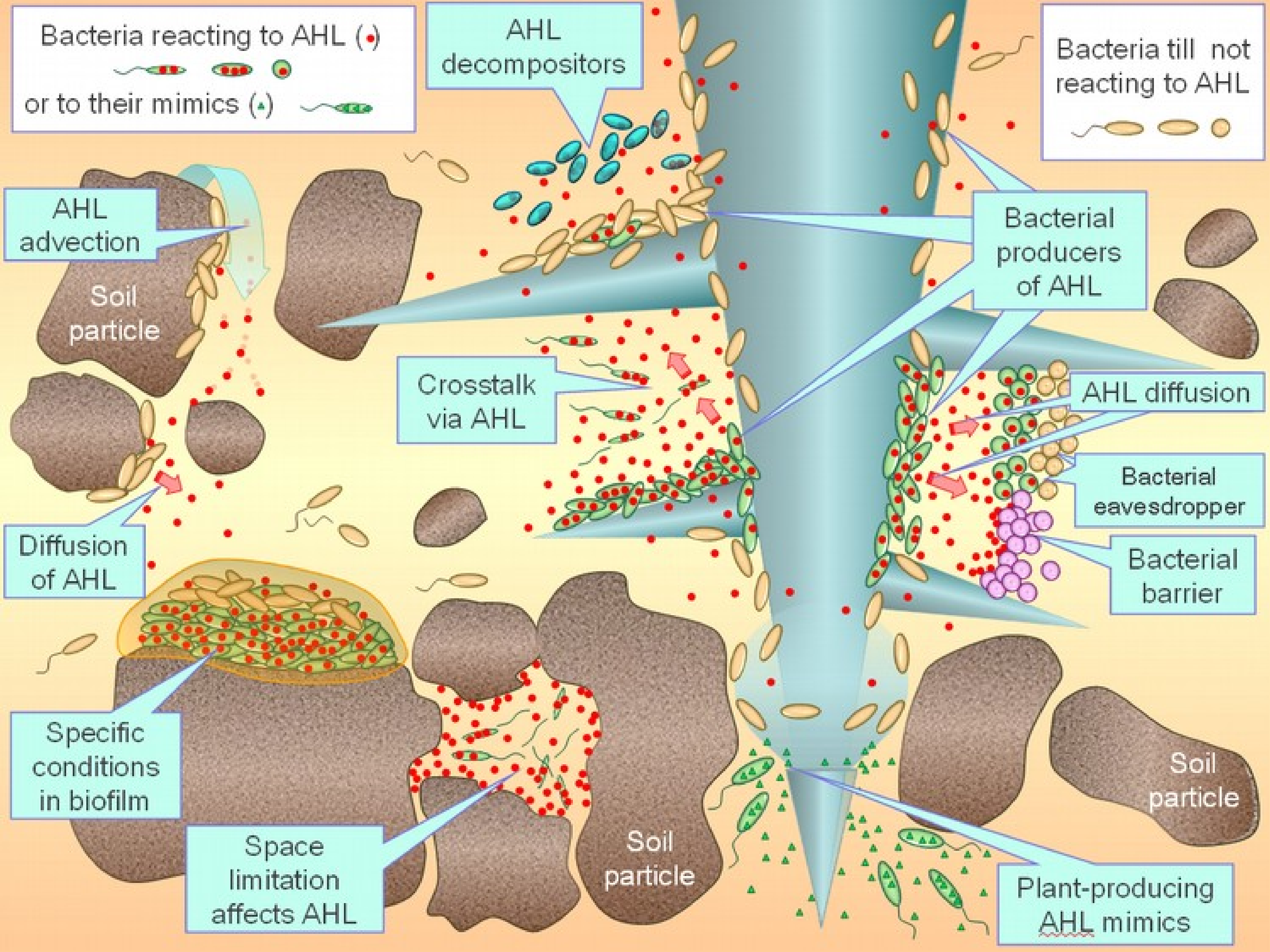


Oldroyd G.E.D. 2013: Speak, friend, and enter: signalling systems that promote beneficial symbiotic associations in plants; Nature Reviews Microbiology 11, 252-263.

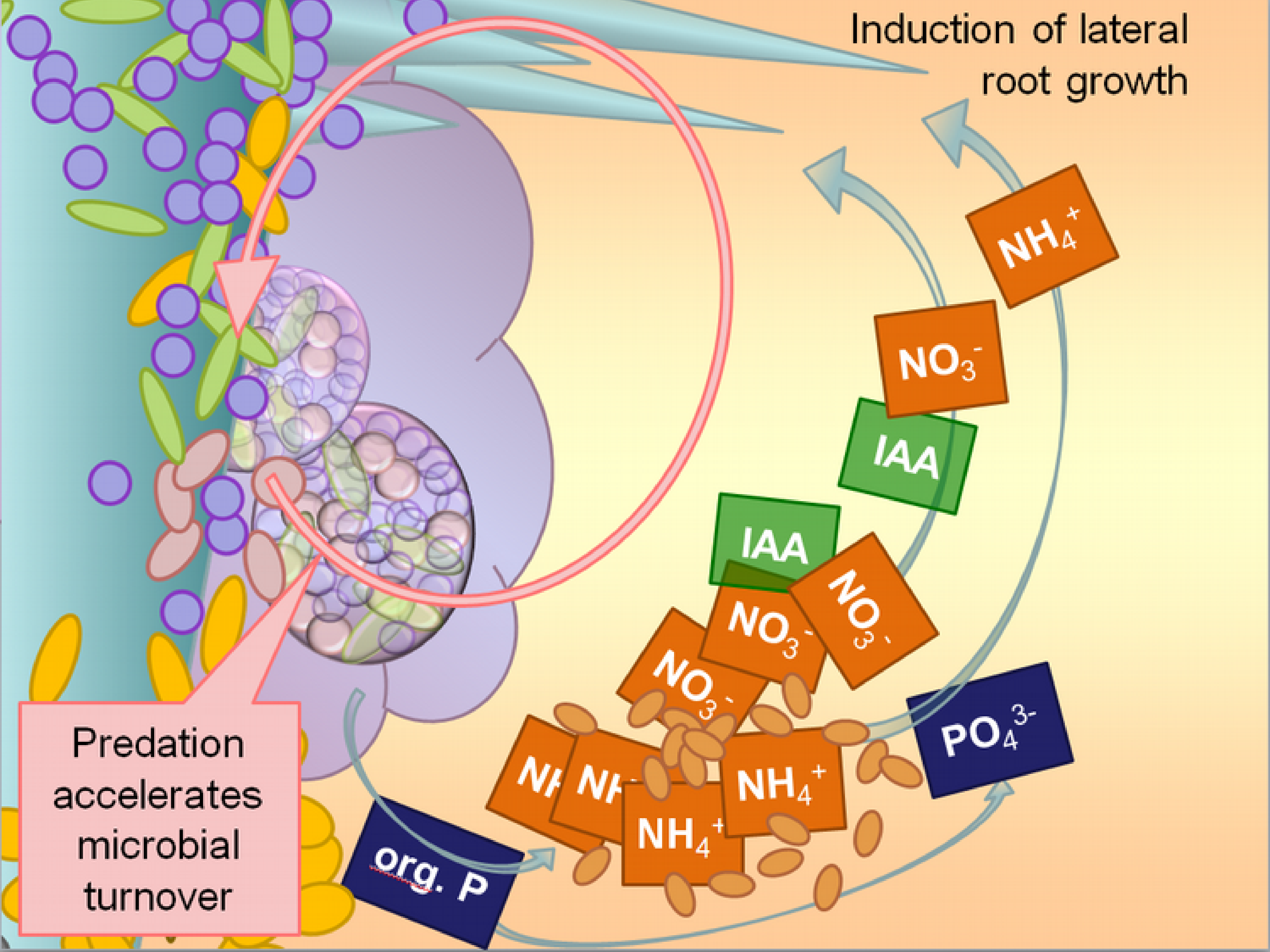


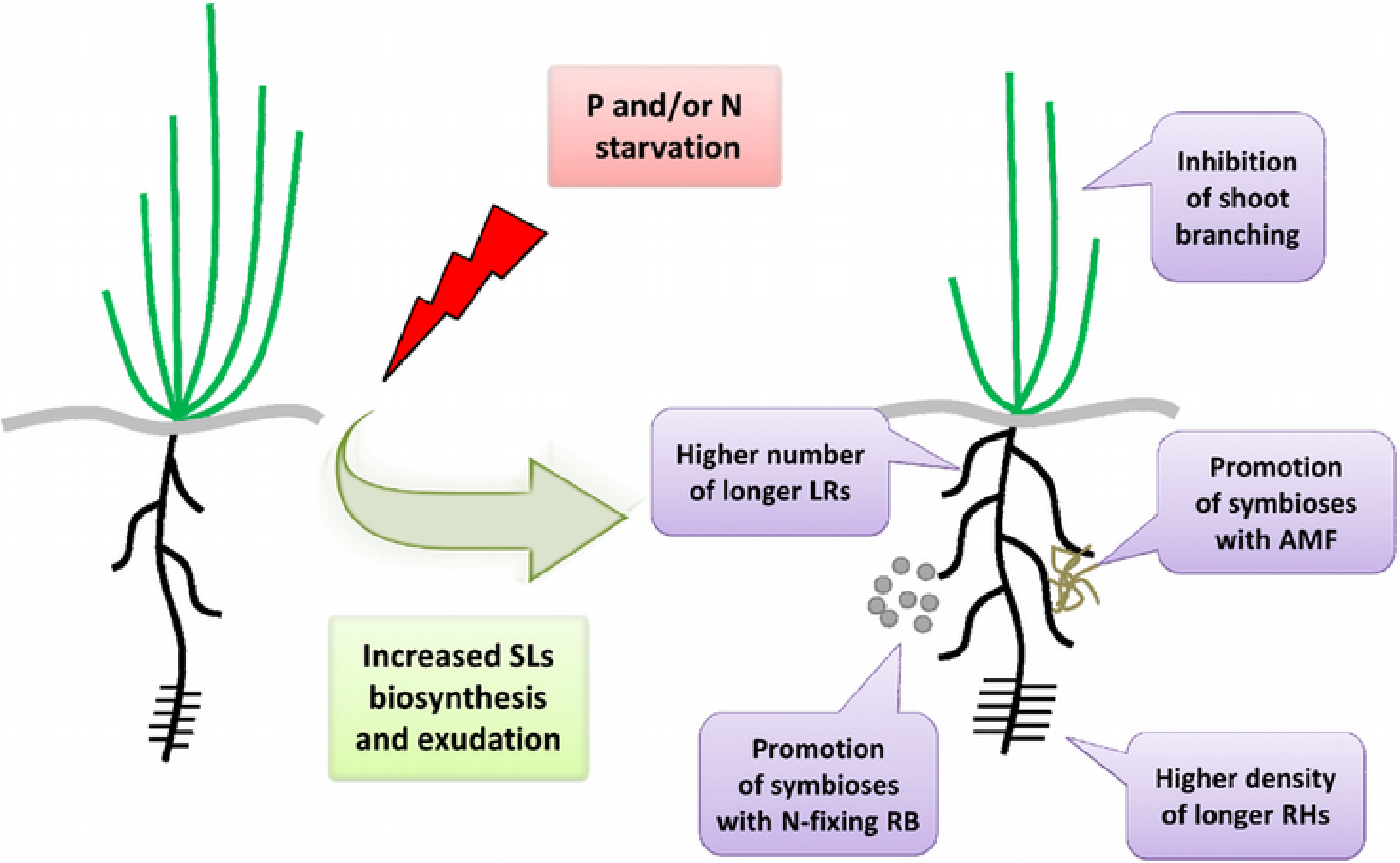


N_{ox}
N_{org}
S_{ox}
P_{ox}
N_{red}



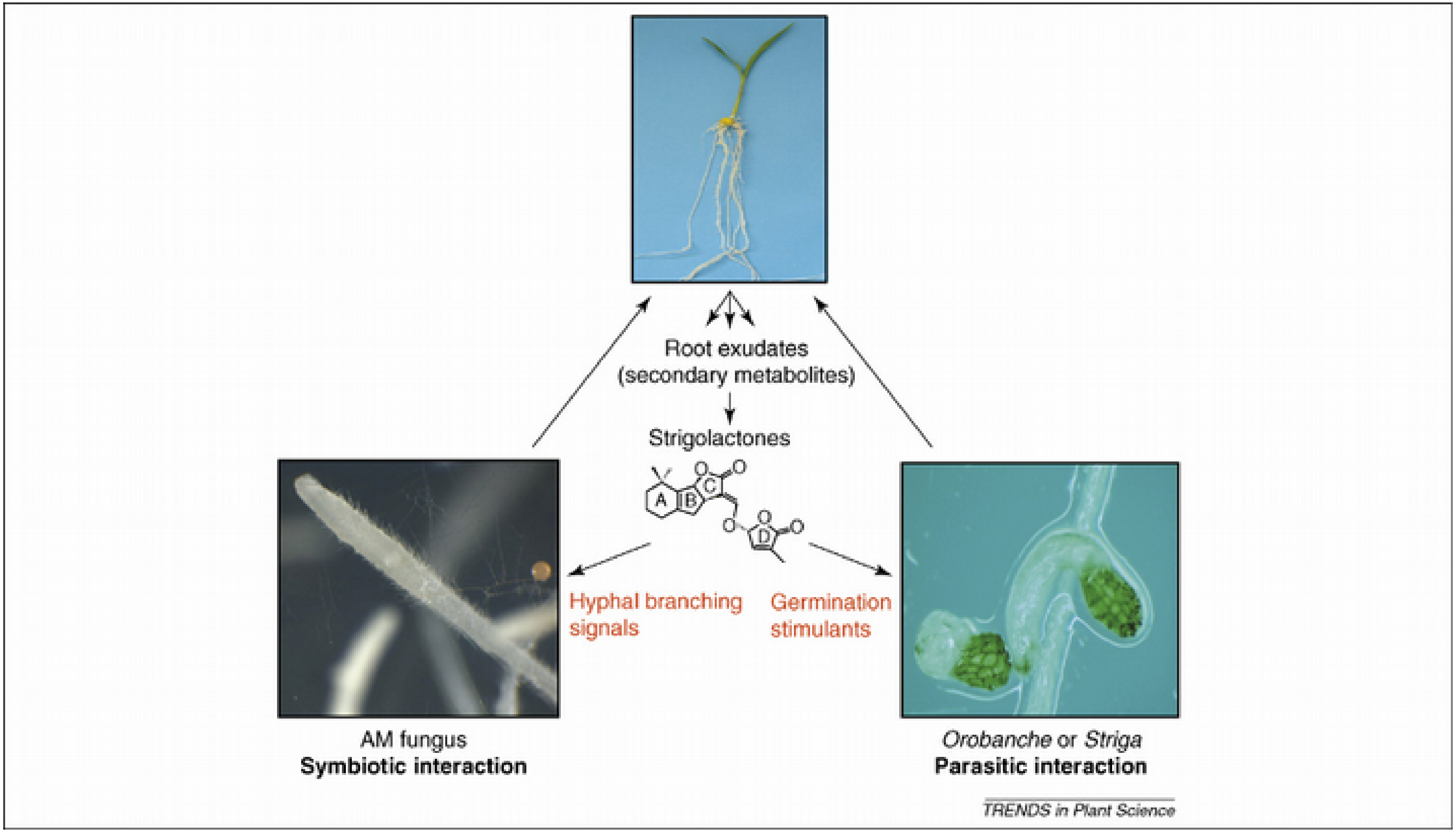


Bacteria reacting to AHL (•)
or to their mimics (▲)
AHL decompositors
Bacteria till not reacting to AHL
AHL advection
Soil particle
Bacterial producers of AHL
Crosstalk via AHL
AHL diffusion
Bacterial eavesdropper
Diffusion of AHL
Bacterial barrier
Specific conditions in biofilm
Soil particle
Space limitation affects AHL
Soil particle
Plant-producing AHL mimics


Induction of lateral root growth
NH4+
NO3-
IAA
IAA
NO3-
NO3-
NO3-
NH4+
NH4+
PO4 3-
org. P
Predation accelerates microbial turnover



Marzec , M., Muszynska, A., Gruszka, D.: Review. The Role of Strigolactones in Nutrient-Stress Responses in Plants. Int. J. Mol. Sci. 2013, 14(5), 9286-9304.



Podzemní komunikace mezi rostlinami, arbuskulárními (AM) houbami a parazitickými rostlinami. Rostliny produkují a uvolňují sekundární metabolity do rhizosféry k zavedení komunikace s dalšími organismy. Strigolaktony jsou důležitou třídou signálních molekul. Dříve byly izolovány jako stimulanty klíčení semen parazitických rostlin, ale později se ukázalo, že také indukují hyfální větvení AM hub. Nepřímá komunikace mezi AM houbami a parazitickými rostlinami – jako zjevná z redukce infekce.

Brewer et.al., 2013 Diverse role of strigolactones in plant development

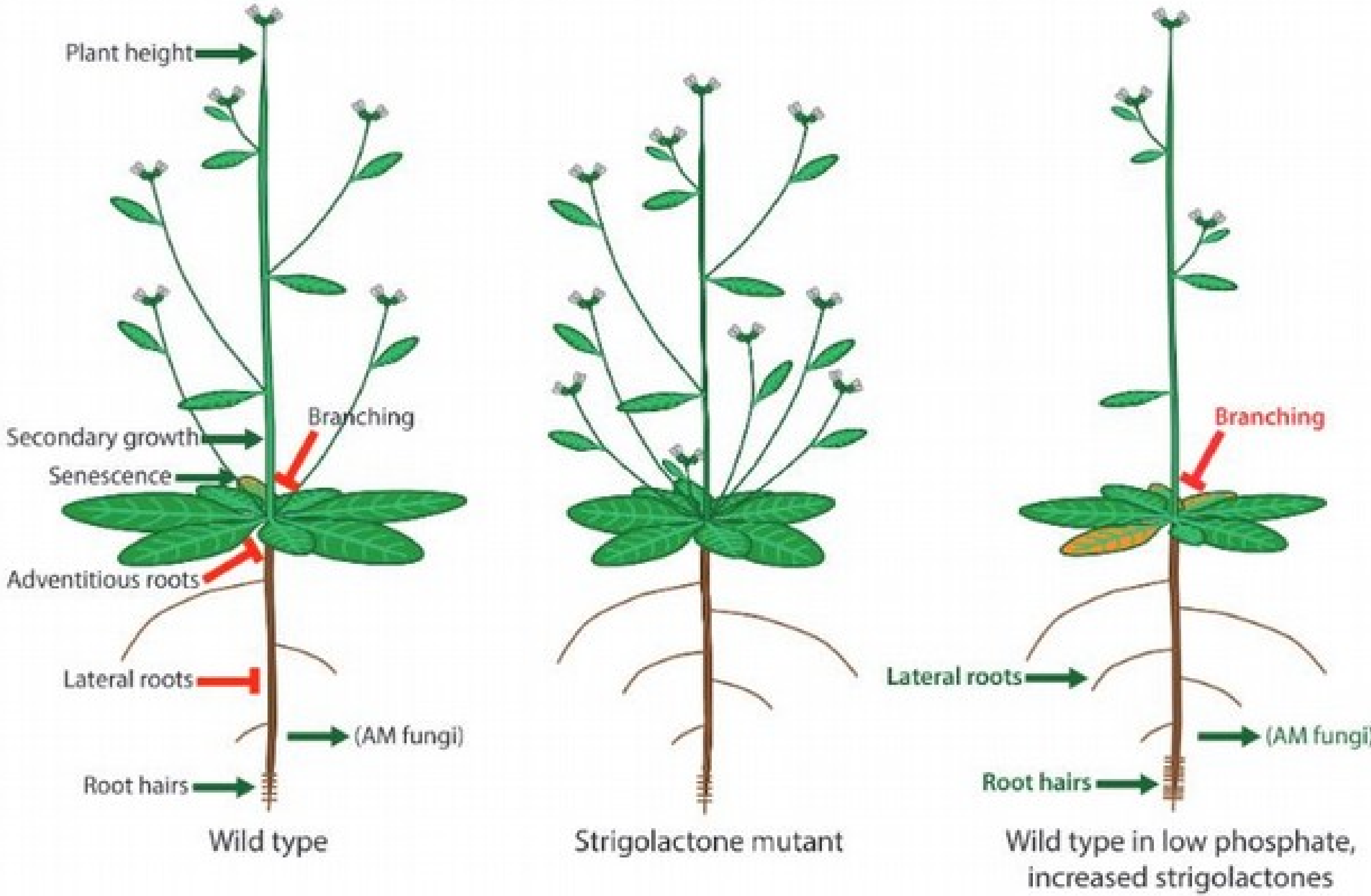


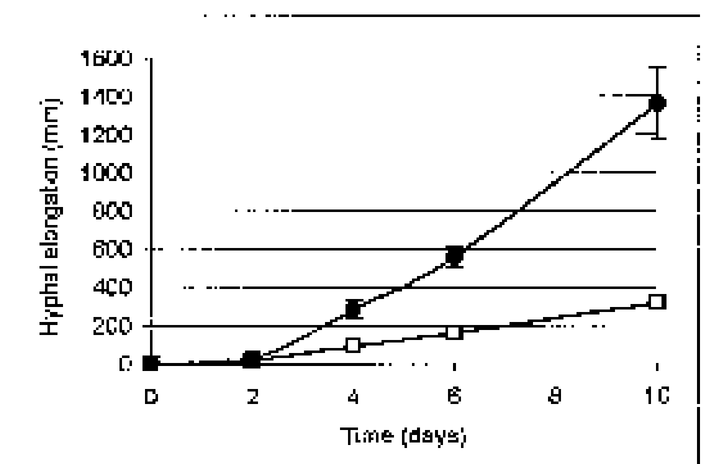
Figure 1. The Proposed Roles of Strigolactones in Adult Plant Growth and Development.

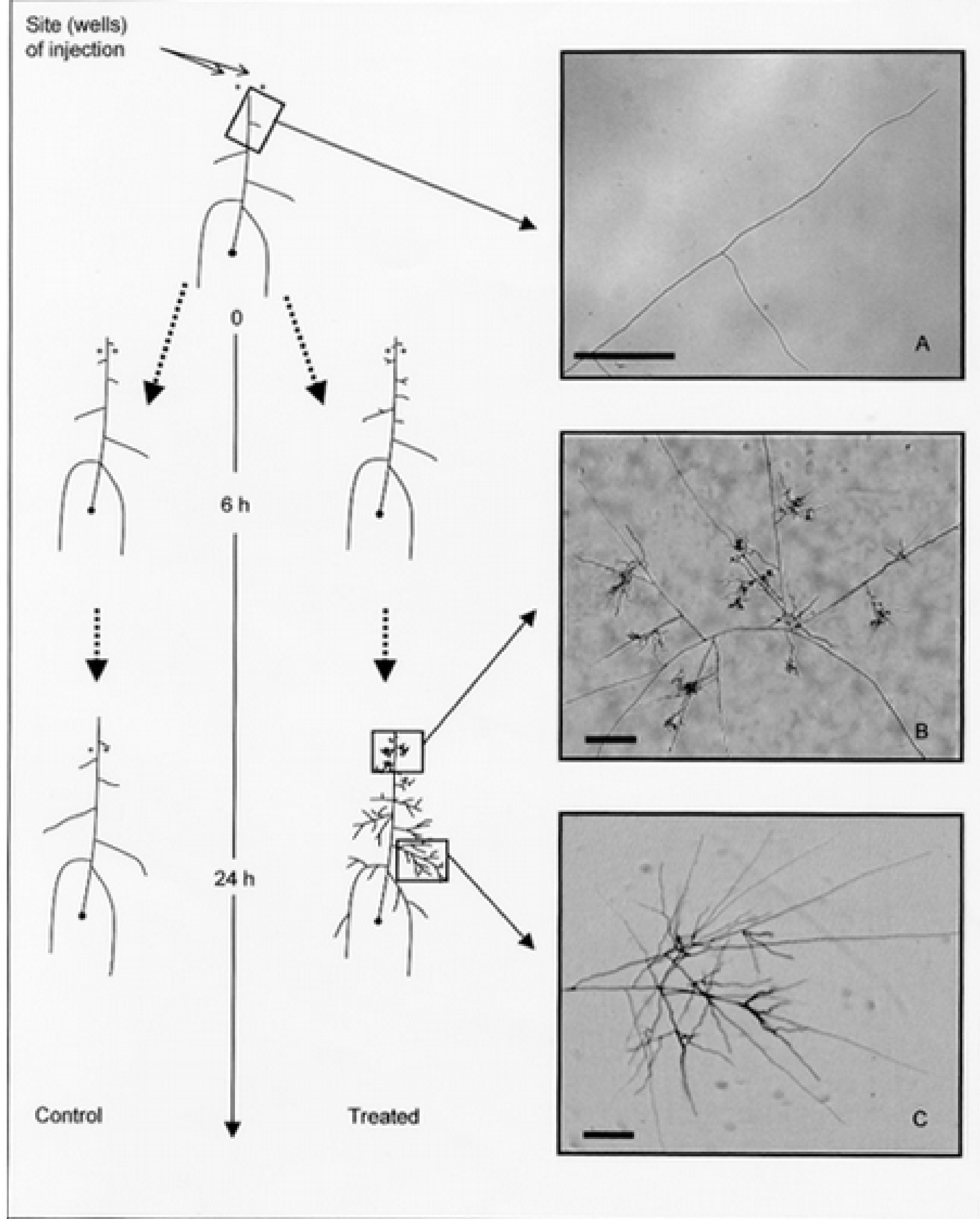
(A) Under normal conditions, a basal level of strigolactone production in a wild-type plant reduces lateral shoots and roots, but enhances plant height, secondary growth, senescence, and root hairs.

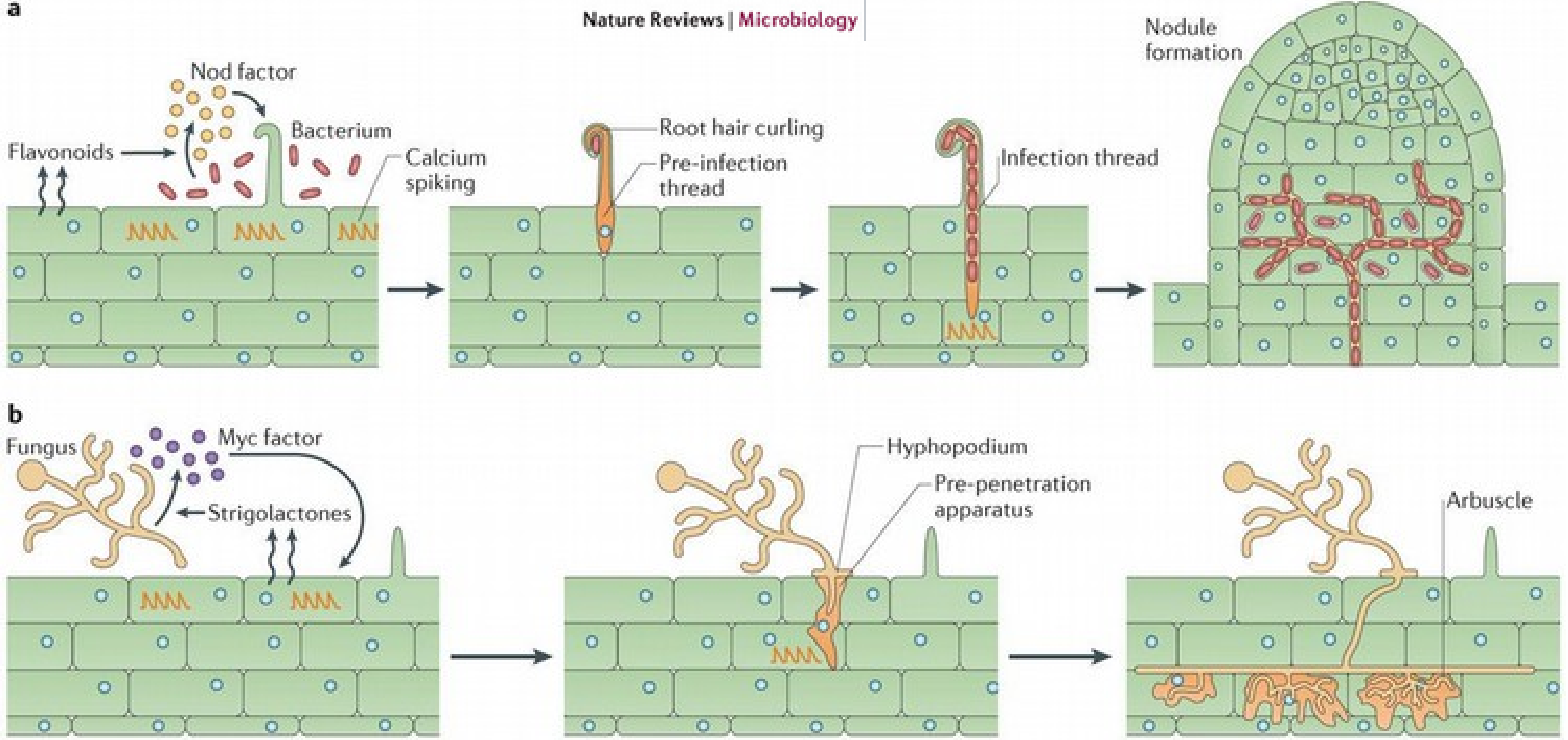
(B) Much of this influence of strigolactones can be seen in mutants that are unable to make or respond to strigolactones. They display more lateral branches and lateral roots, and less secondary growth and arbuscular mycorrhizal (AM) fungi symbiosis (in compatible species).

(C) Reduced phosphate triggers increased strigolactone production. This leads to greater branch repression and, initially, to enhanced lateral roots and root hairs, and enhances AM fungi symbiosis. Other phenotypes like plant height, secondary growth, senescence, reproduction, biomass, germination, shading responses, and leaf shape have yet to be fully characterized, especially with regard to low-phosphate-induced strigolactone production.

Strigolactone

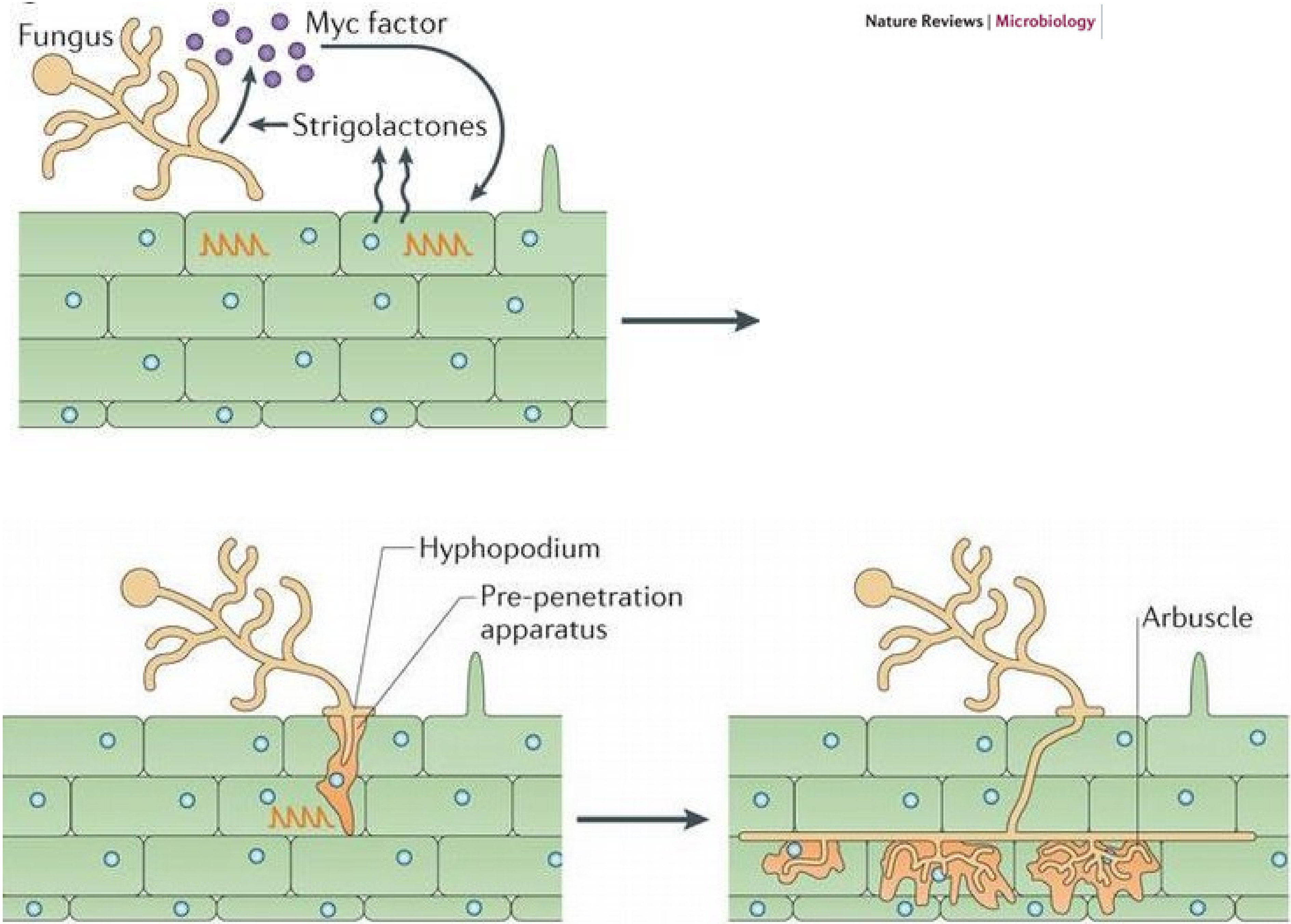






a | Flavonoids released by the plant root signal to rhizobia in the rhizosphere, which in turn produce nodulation factors (Nod factors) that are recognized by the plant. Nod factor perception activates the symbiosis signalling pathway, leading to calcium oscillations, initially in epidermal cells but later also in cortical cells preceeding their colonization. Rhizobia gain entry into the plant root by root hair cells that grow around the bacteria attached at the root surface, trapping the bacteria inside a root hair curl. Infection threads are invasive invaginations of the plant cell that are initiated at the site of root hair curls and allow invasion of the rhizobia into the root tissue. The nucleus relocates to the site of infection, and an alignment of ER and cytoskeleton, known as the pre-infection thread, predicts the path of the infection thread. Nodules initiate below the site of bacterial infection and form by de novo initiation of a nodule meristem in the root cortex. The infection threads grow towards the emergent nodules and ramify within the nodule tissue. In some cases, the rhizobia remain inside the infection threads, but more often, the bacteria are released into membrane-bound compartments inside the cells of the nodule, where the bacteria can differentiate into a nitrogen-fixing state. b | Strigolactone release by the plant root signals to arbuscular mycorrhizal fungi (AMF) in the rhizosphere. Perception of strigolactones promotes spore germination and hyphal branching. AMF produce mycorrhizal factors (Myc factors), including lipochitooligosaccharide (LCOs) and, possibly, signals that activate the symbiosis signalling pathway in the root, leading to calcium oscillations. AMF invasion involves an infection peg from the hyphopodium that allows fungal hyphal growth into the root epidermal cell. The route of hyphal invasion in the plant cell is predicted by a pre-penetration apparatus, which is a clustering of ER and cytoskeleton in a zone of the cell below the first point of fungal contact[135]. The fungus colonizes the plant root cortex through intercellular hyphal growth. Arbuscules are formed in inner root cortical cells from the intercellular hyphae. Part b image is modified, with permission, from Ref. 136

Oldroyd G.E.D. 2013: Speak, friend, and enter: signalling systems that promote beneficial symbiotic associations in plants; Nature Reviews Microbiology 11, 252-263.

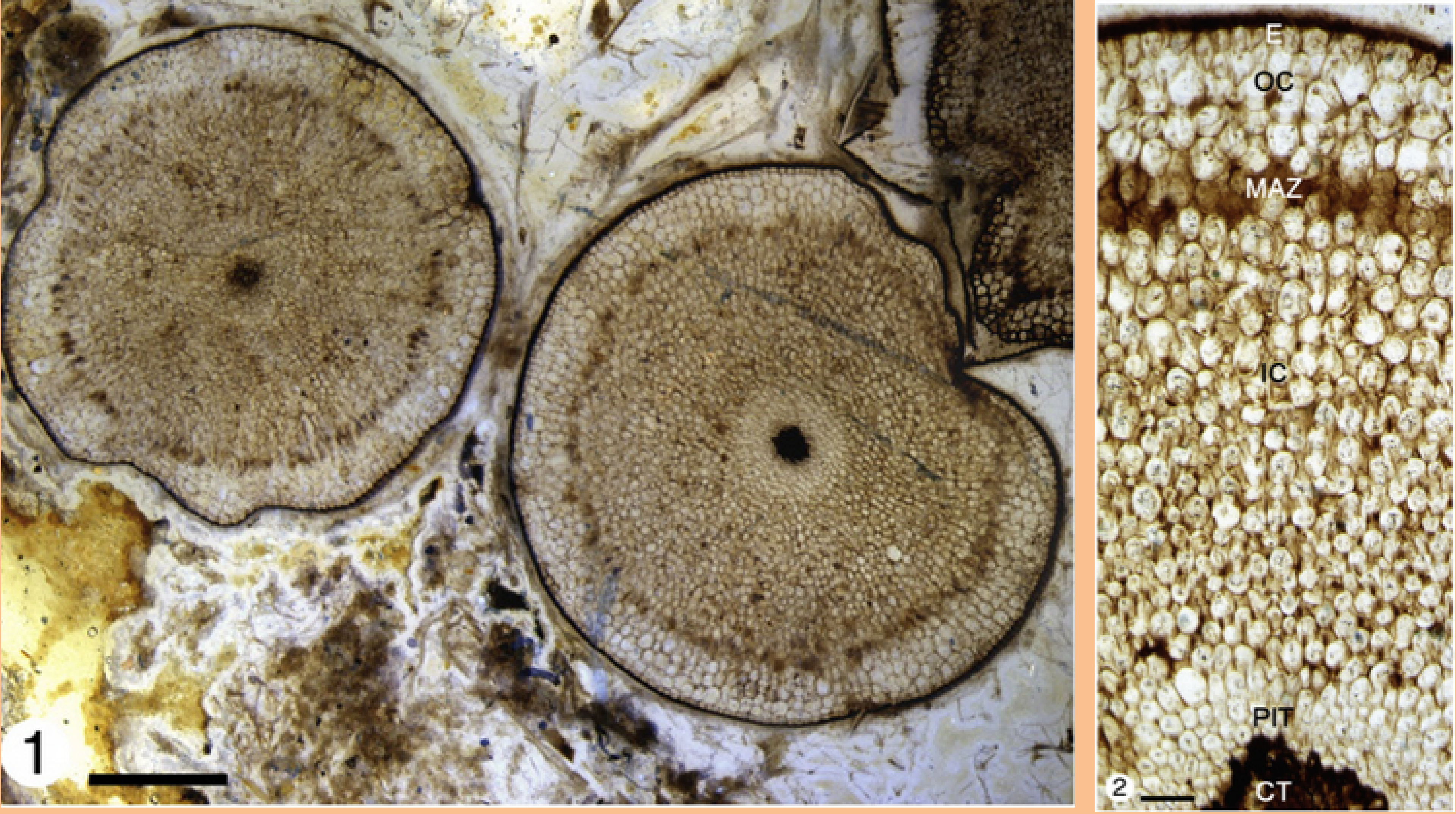


Oldroyd G.E.D. 2013: Speak, friend, and enter: signalling systems that promote beneficial symbiotic associations in plants; Nature Reviews Microbiology 11, 252-263.

Aglaophyton major

These were early plants of the Lower Devonian, **approx 410 million years ago**. They grew to about 15cm in height and had a prostrate habit, spreading as they grew. Fossils of these plants are found in Rhynie chert in Aberdeenshire, Scotland. They grew close to silica-rich hot springs.

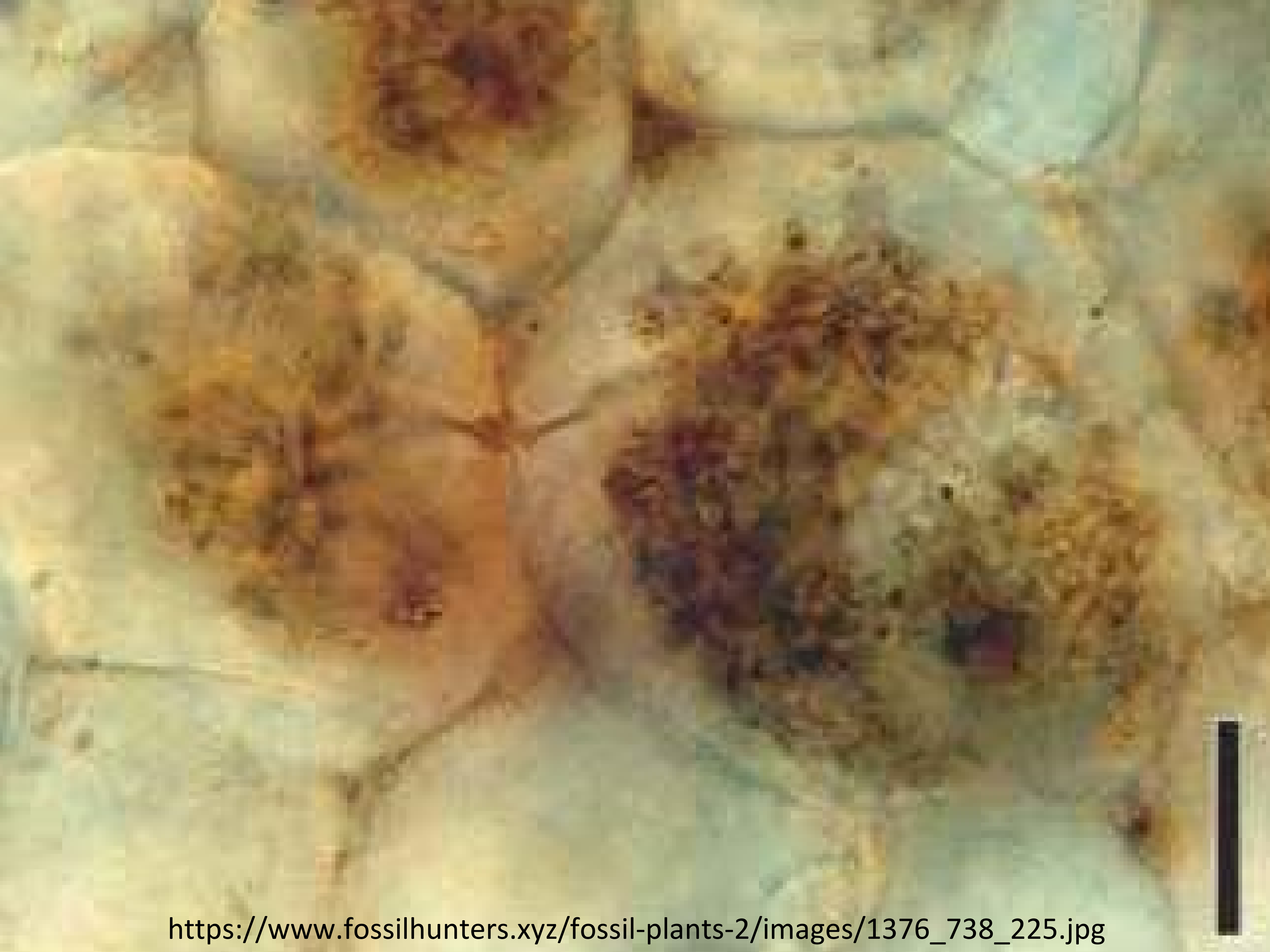
http://www.bizleyart.com/gallery/image?view=image&format=raw&type=img&id=333



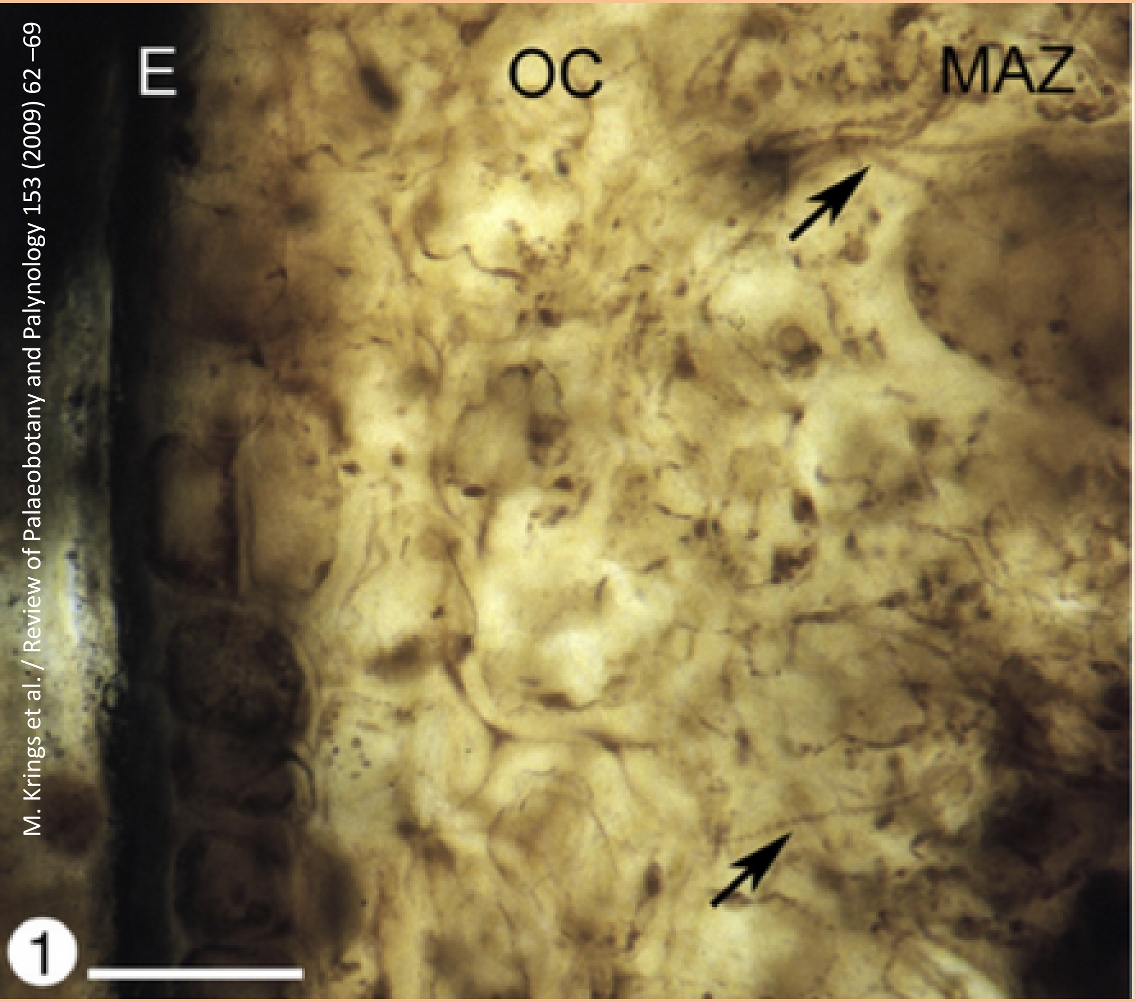
Anatomy of ***Aglaophyton major***

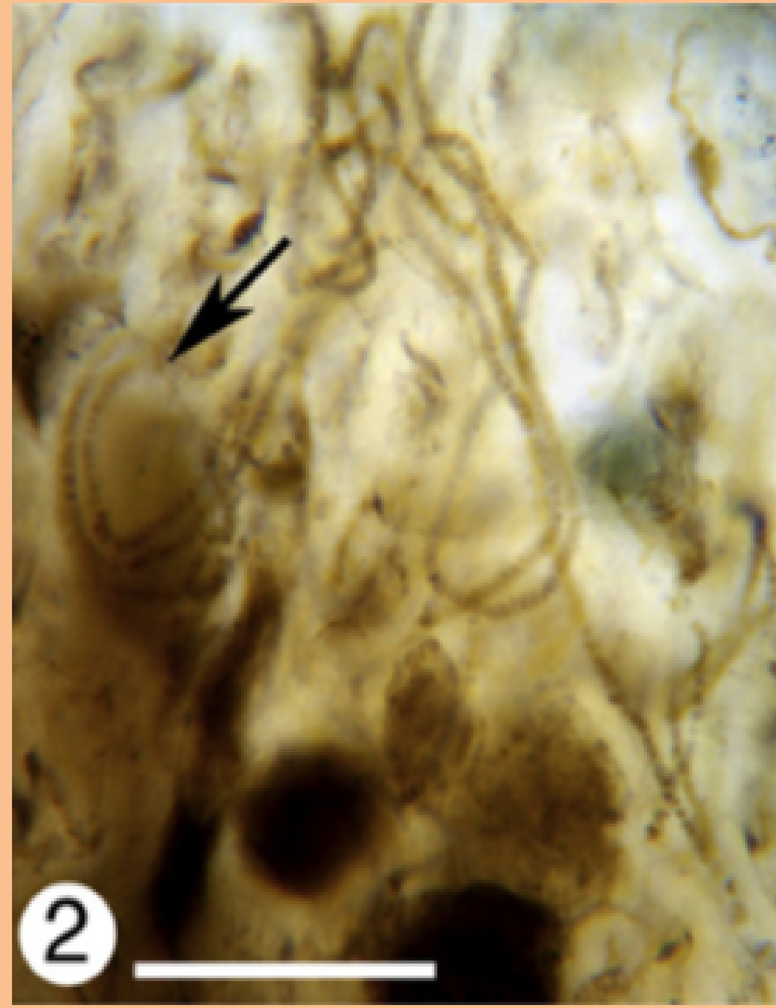
1. Transverse section through two typical axes showing the simple internal organization; slide P1828; bar=1 mm. 2. Anatomy of the prostrate mycorrhizal axis (E = epidermis; OC = outer cortex; MAZ = mycorrhizal arbuscule-zone; IC = inner cortex; PIT = phloem-like tissue; CT = conducting tissue); slide P1612; bar=150 µm.

M. Krings et al. / Review of Palaeobotany and Palynology 153 (2009) 62 –69



https://www.fossilhunters.xyz/fossil-plants-2/images/1376_738_225.jpg

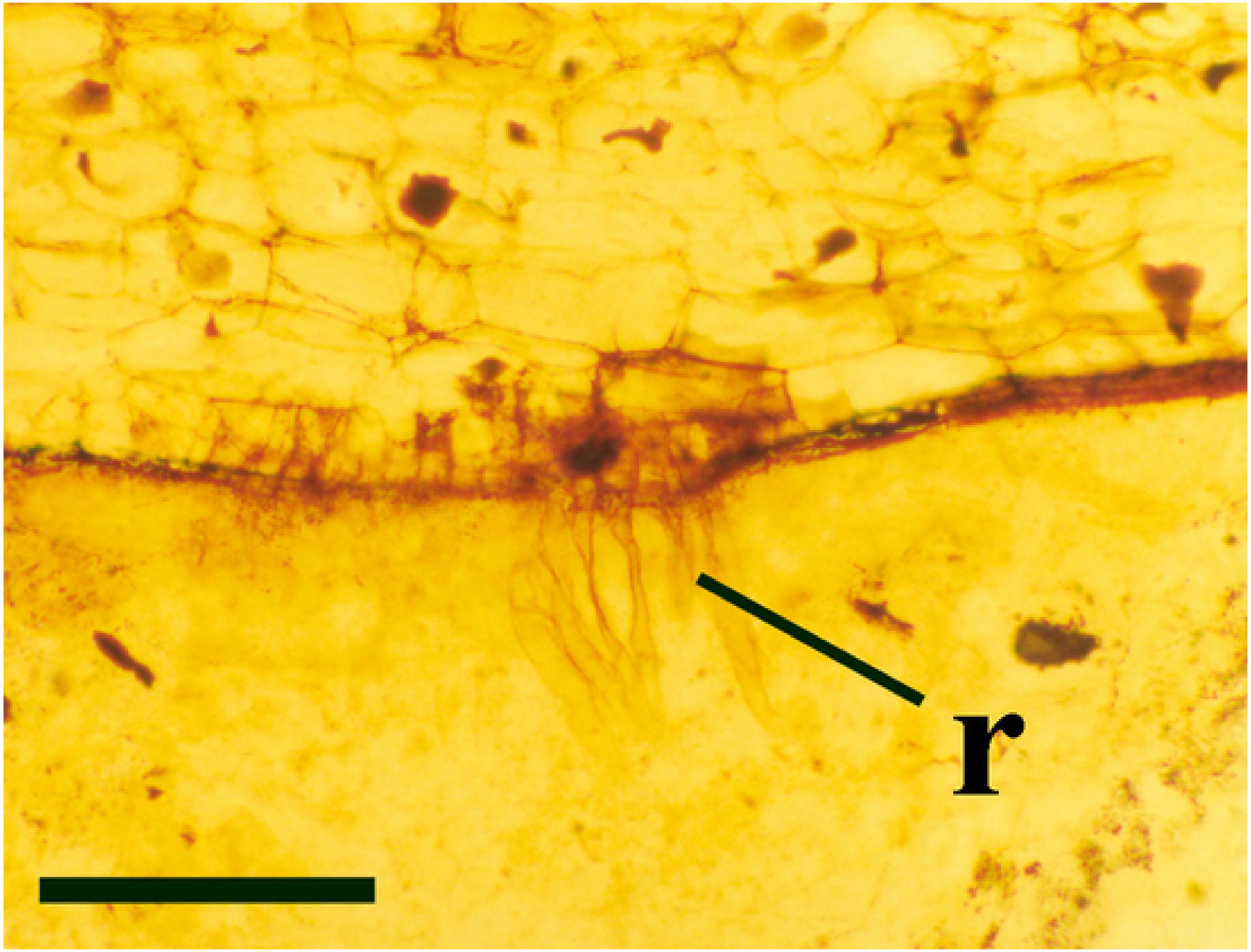




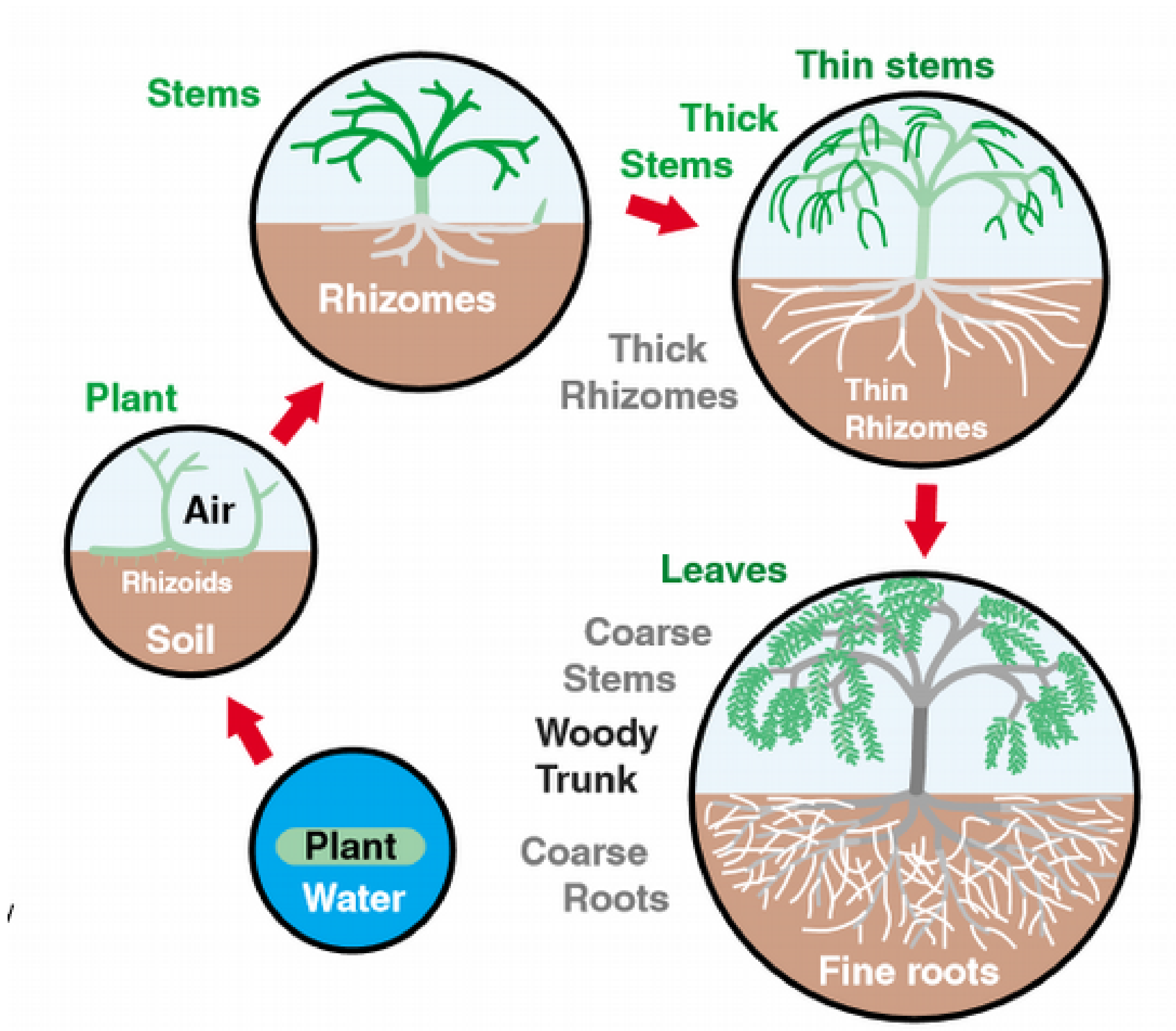
Endophytic filamentous cyanobacteria in ***Aglaophyton major*** prostrate axes.

1. Cross-section through an axis, showing the epidermis (E), outer cortex (OC), mycorrhizal arbuscule-zone (MAZ), and cyanobacterial filaments (arrows); bar=100 µm. 2. Cyanobacterial filaments within the arbuscule-zone; bar=100 µm. 3. Cyanobacterial filaments in the intercellular system; bar=25 µm.

https://www.abdn.ac.uk/rhynie/images/plants/aglao/aglao2.jpg



Rhizoids (**r**) on an *Aglaophyton* rhizomal axis (scale bar = 200µm).



Mark C. Brundrett, New Phytologist (2002) 154: 275–304

Probable stages in the evolution of stems, rhizomes, leaves and roots from the thallus of an early bryophyte-like land plant, using a hypothetical final example with a woody trunk.

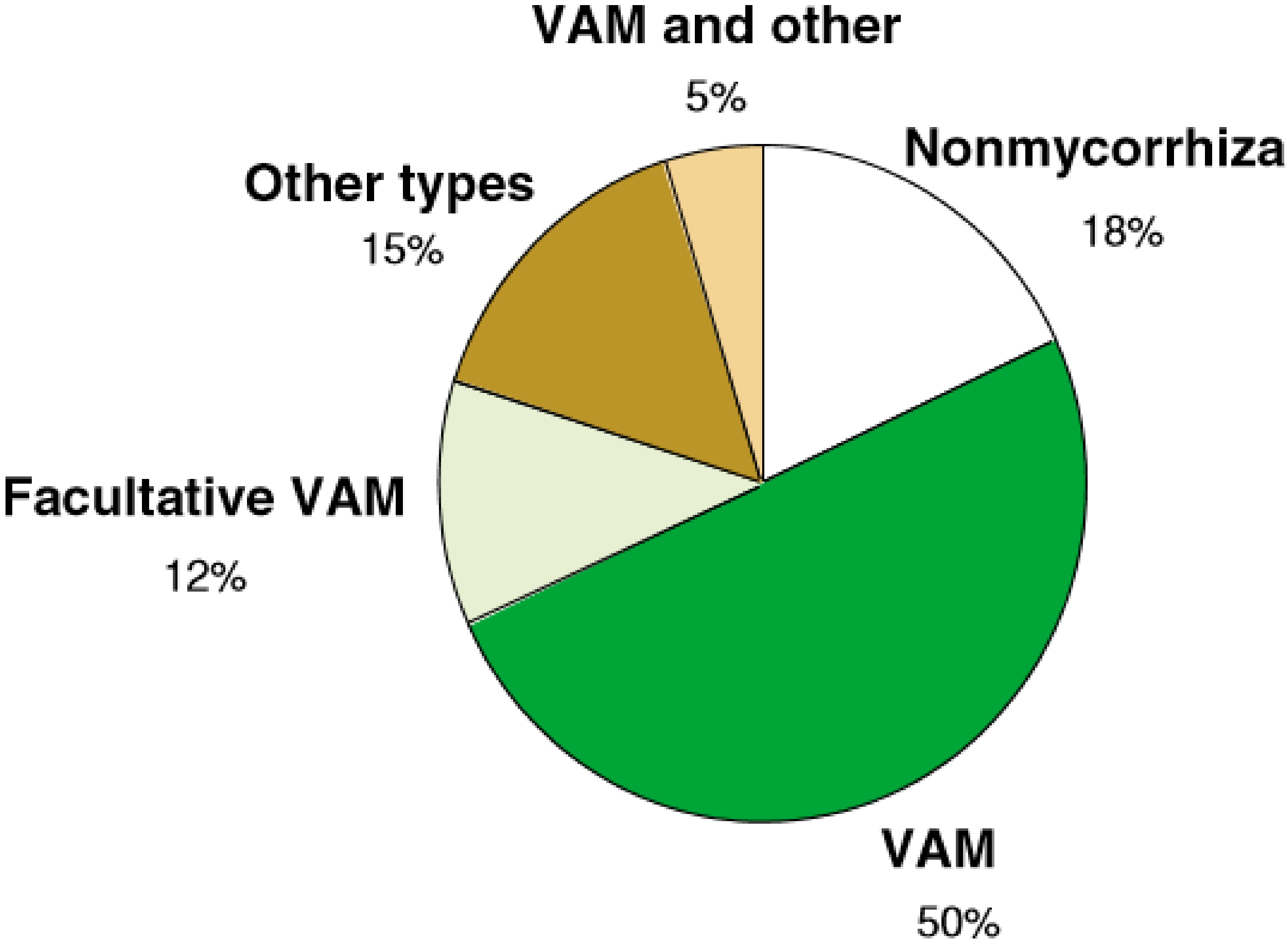
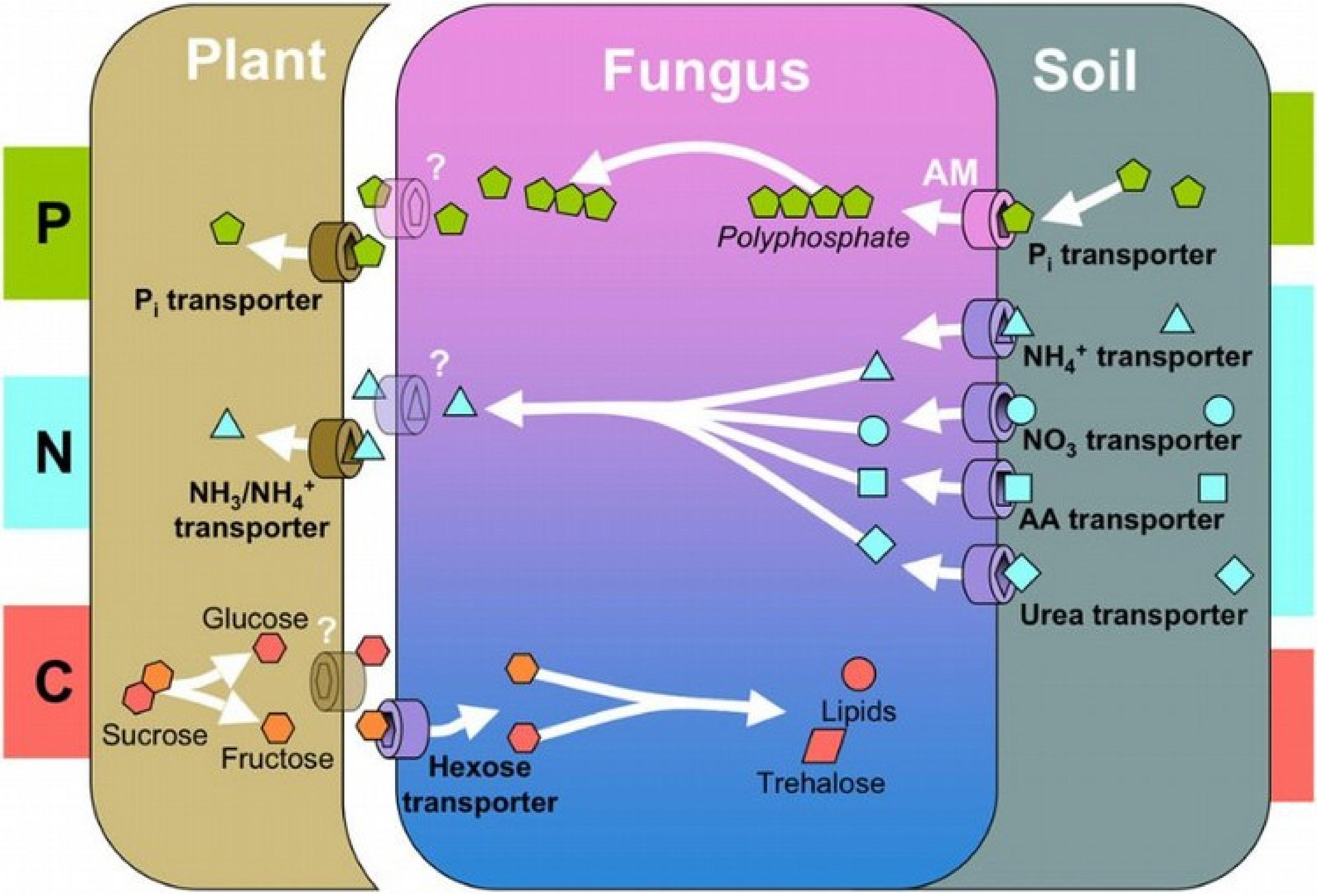
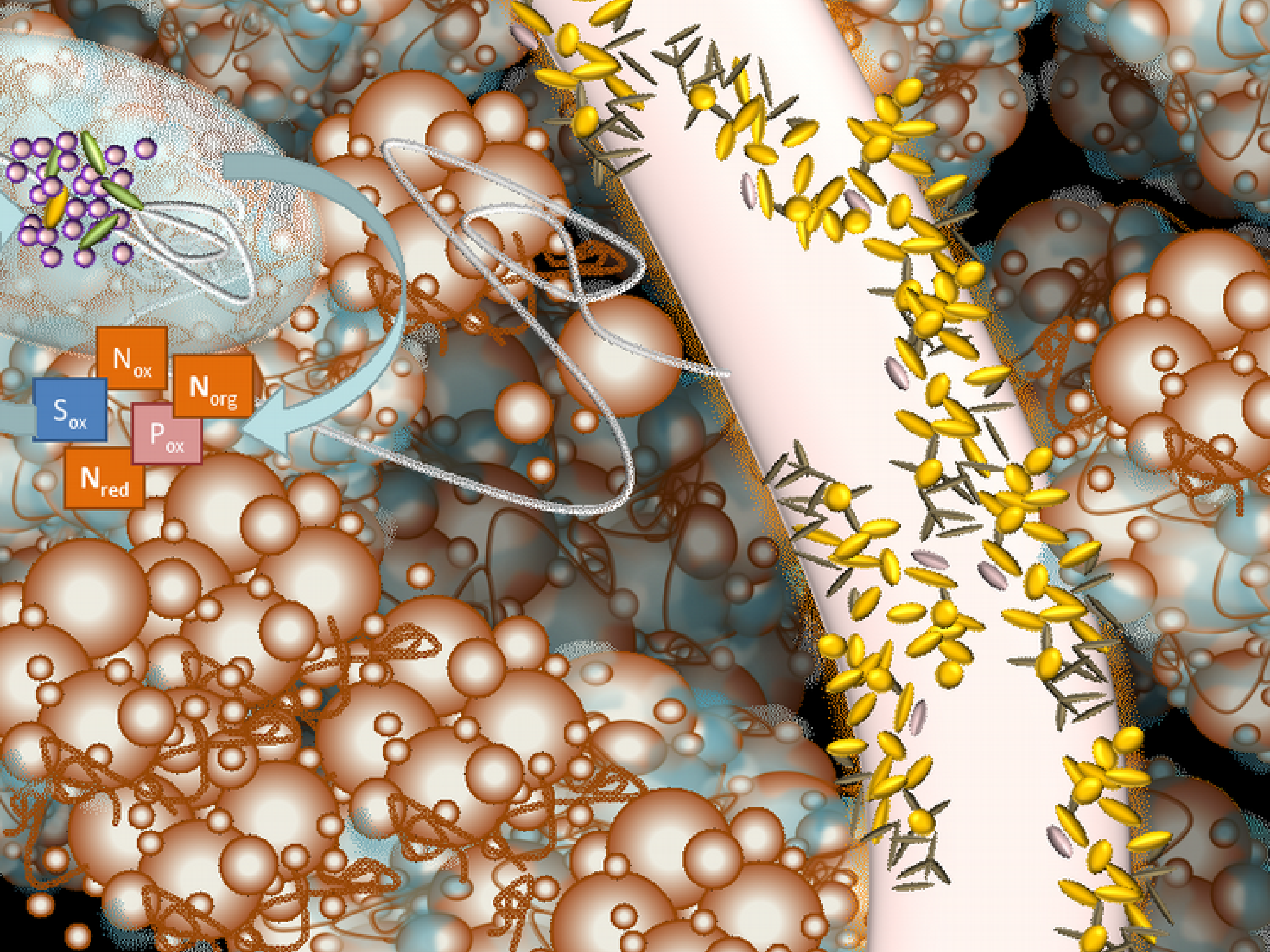


Fig. 2 Proportion of angiosperm species with different categories of mycorrhizal associations using data from Trappe (1987).

Mark C. Brundrett, New Phytologist (2002) 154: 275–304


Plant
Fungus
Soil
P
N
C
AM
?
Polyphosphate
P_i transporter
P_i transporter
NH_4^+ transporter
NO_3 transporter
AA transporter
Urea transporter
NH_3/NH_4^+ transporter
Glucose
Sucrose
Fructose
Hexose transporter
Lipids
Trehalose



N_{ox}
N_{org}
S_{ox}
P_{ox}
N_{red}

Biologia **67**/4: 673—680, 2012
Section Botany
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Different nutrient use strategies of expansive grasses *Calamagrostis epigejos* and *Arrhenatherum elatius*

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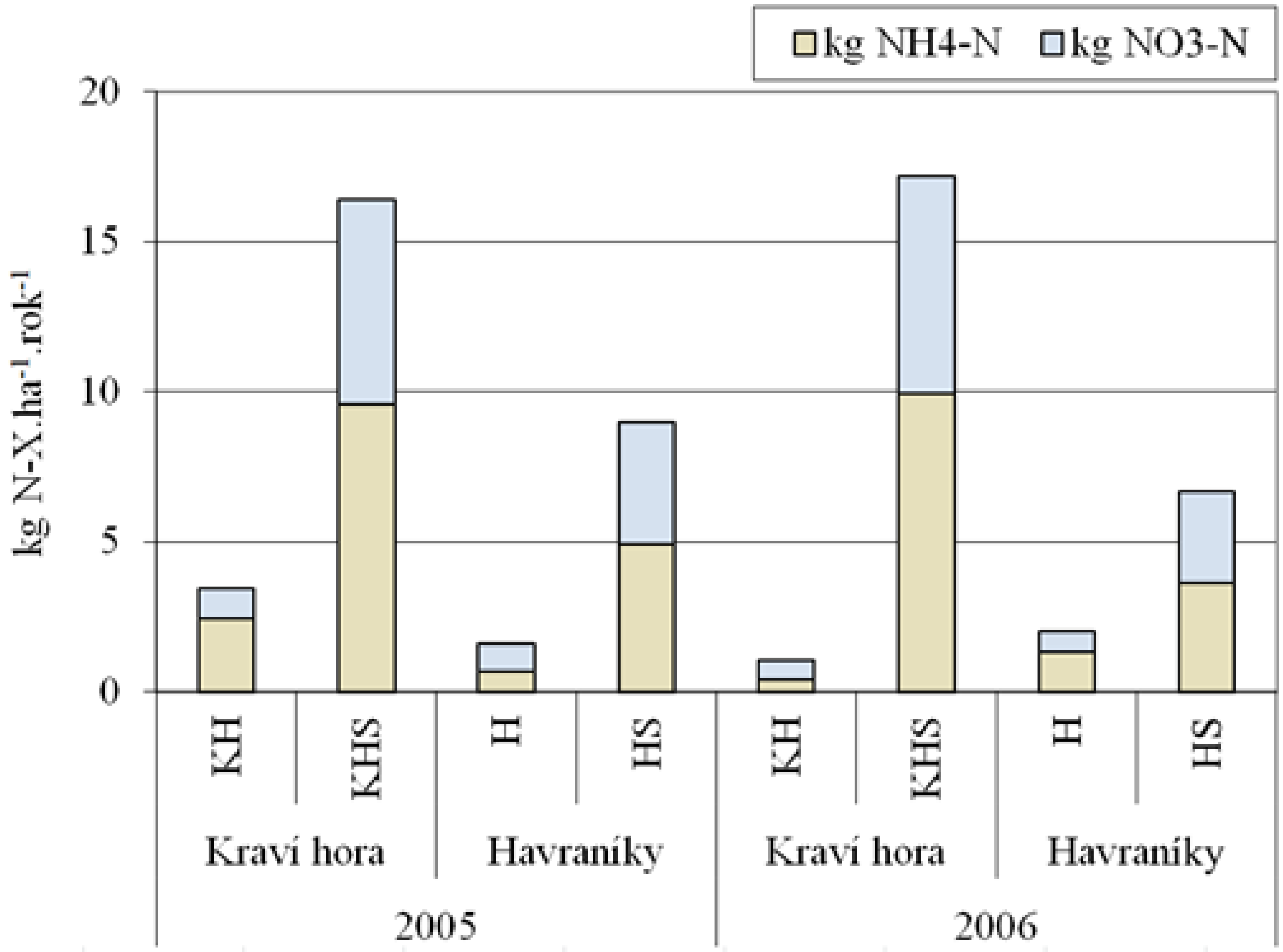
JAROSLAV ZÁHORA, MILAN CHYTRÝ, PETR HOLUB, KAREL FIALA, IVAN TŮMA,
JANA VAVŘÍKOVÁ, MARTINA FABŠIČOVÁ, IVA KEIZER, LENKA FILIPOVÁ

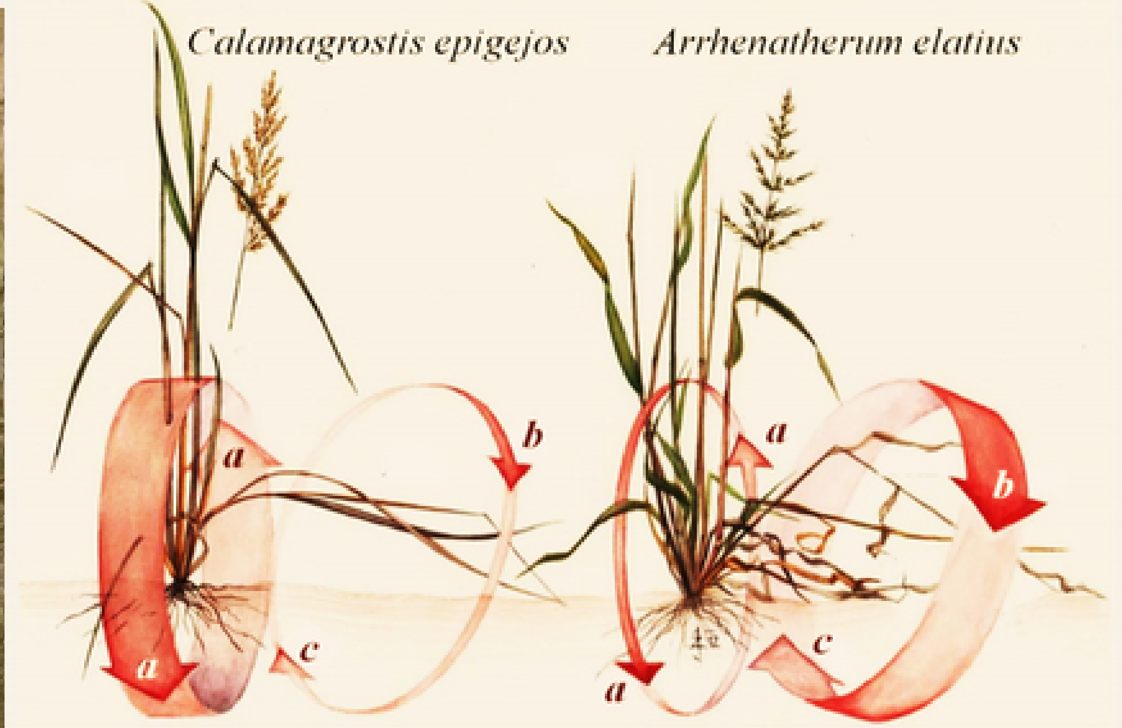
Vliv akumulace dusíku na vřesoviště a suché trávníky v Národním parku Podyjí

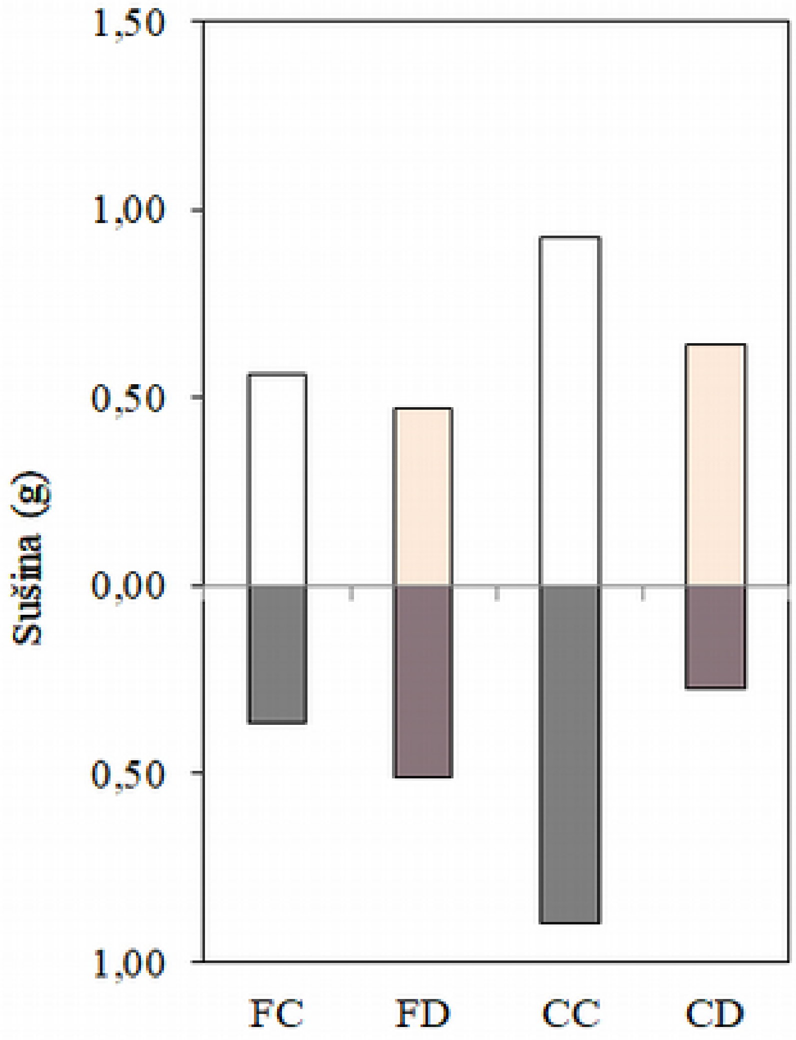
Záhora, J., Chytrý, M., Holub, P., Fiala, K., Tůma, I., Vavříková, J., Fabšičová, M., Keizer, I., Filipová, L.: The Effect of Nitrogen Accumulation on Heathlands and Dry Grasslands in the Podyji National Park. Životné prostredie, 2016, 50, 2, p. 97 – 107.



Obr. 3. Souhrnný záchyt amonného (žlutě) a nitrátového dusíku (modře) z atmosférického spadu v letech 2005 a 2006 na lokalitách Kraví hora a Havraníky v jednoduchých nádobách v úrovni vegetace (označeno KH a H) a v nádobách opatřených svazkem nylonové síťoviny (KHS, HS). Je patrný výrazně vyšší záchyt v nádobách se síťovinou, která imitovala vegetaci, přičemž toto množství dusíku nebylo možno vysvětlit pouze nárůstem množství srážek (sběrné nádoby ve výřezu).


Potentillo arenariae–Agrostietum vinealis
(Carici humilis-Callunetum)
a
a
c
b


Calamagrostis epigejos
Arrhenatherum elatius
a
b
a
c
a
b
c
a

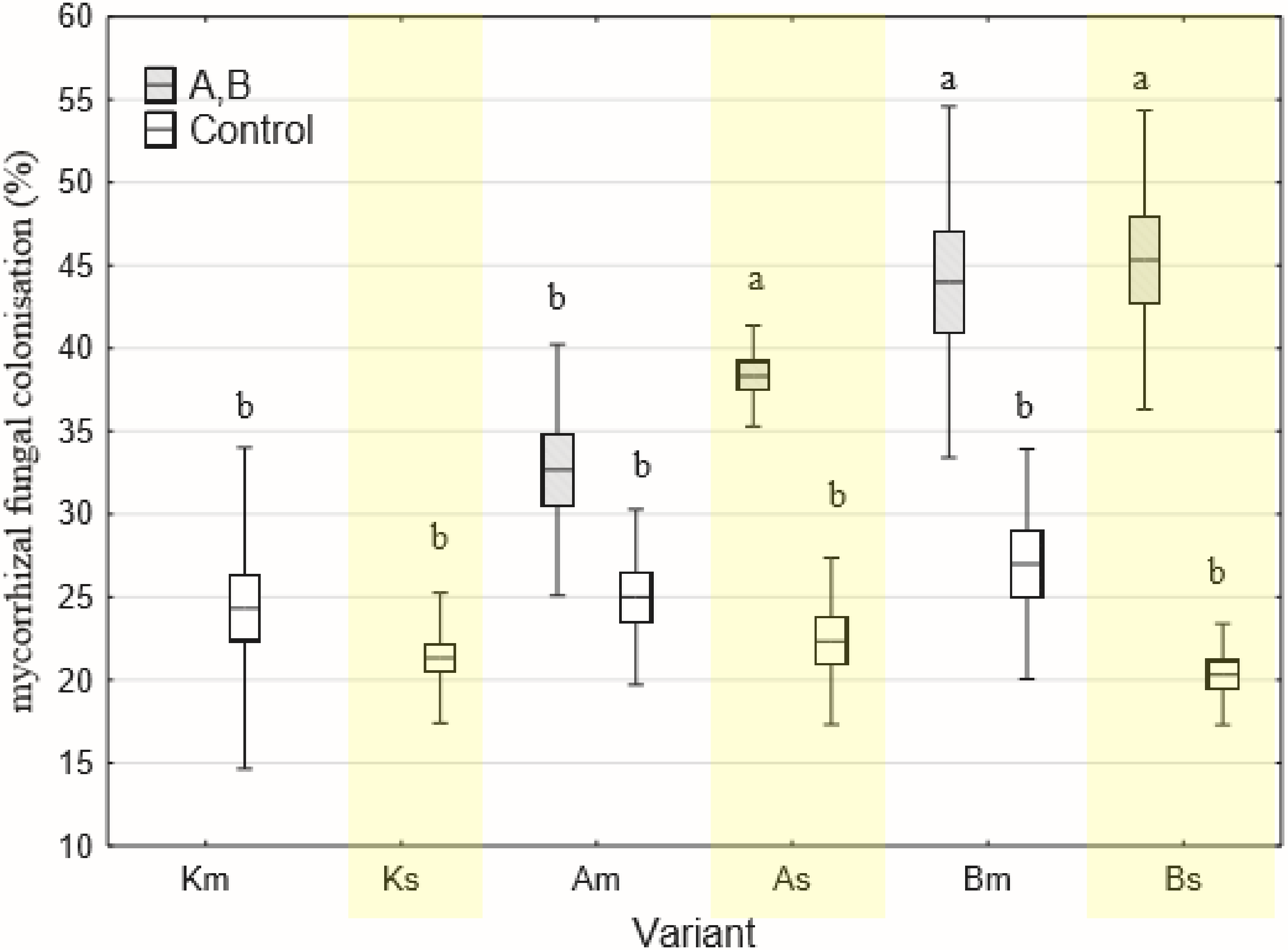


Obr. 6. Sušina nadzemní (nad osou x) a podzemní (pod osou x) biomasy semenáčků kostřavy ovčí (*F.* ovina) pěstované po dobu jednoho roku v nádobovém pokusu v půdě odebrané z původního krátkostébelného trávníku (FC a FD) a v půdě degradované třtinou křovištní (CC a CD). Stres suchem byl navozen polovičním množstvím zálivky (FD a CD). Napravo je ukázka schopnosti produkce nadzemní a podzemní biomasy po čtyřech letech pěstování semenáčku kostřavy v pouhém sterilním písku.


B2

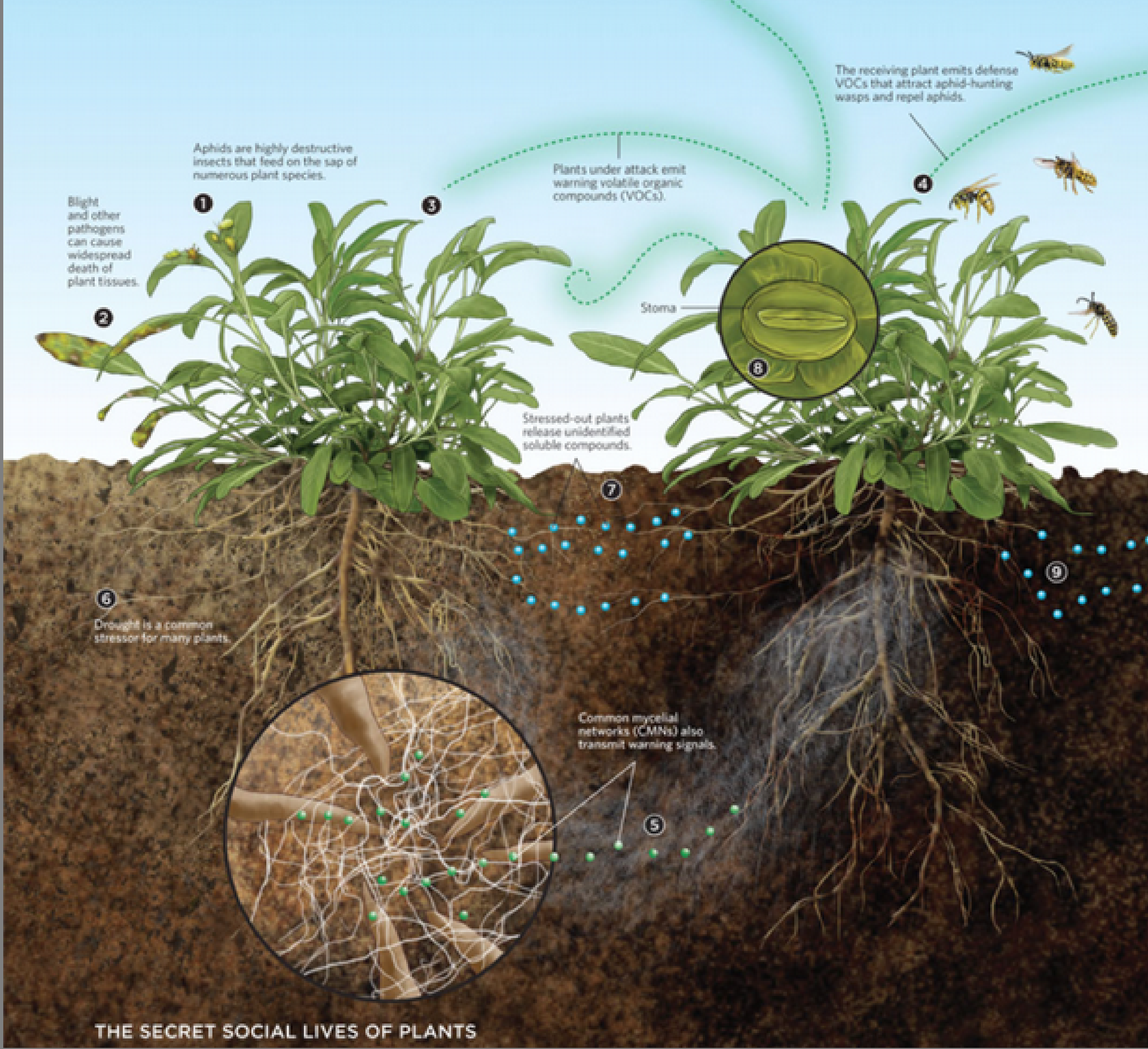

2
1

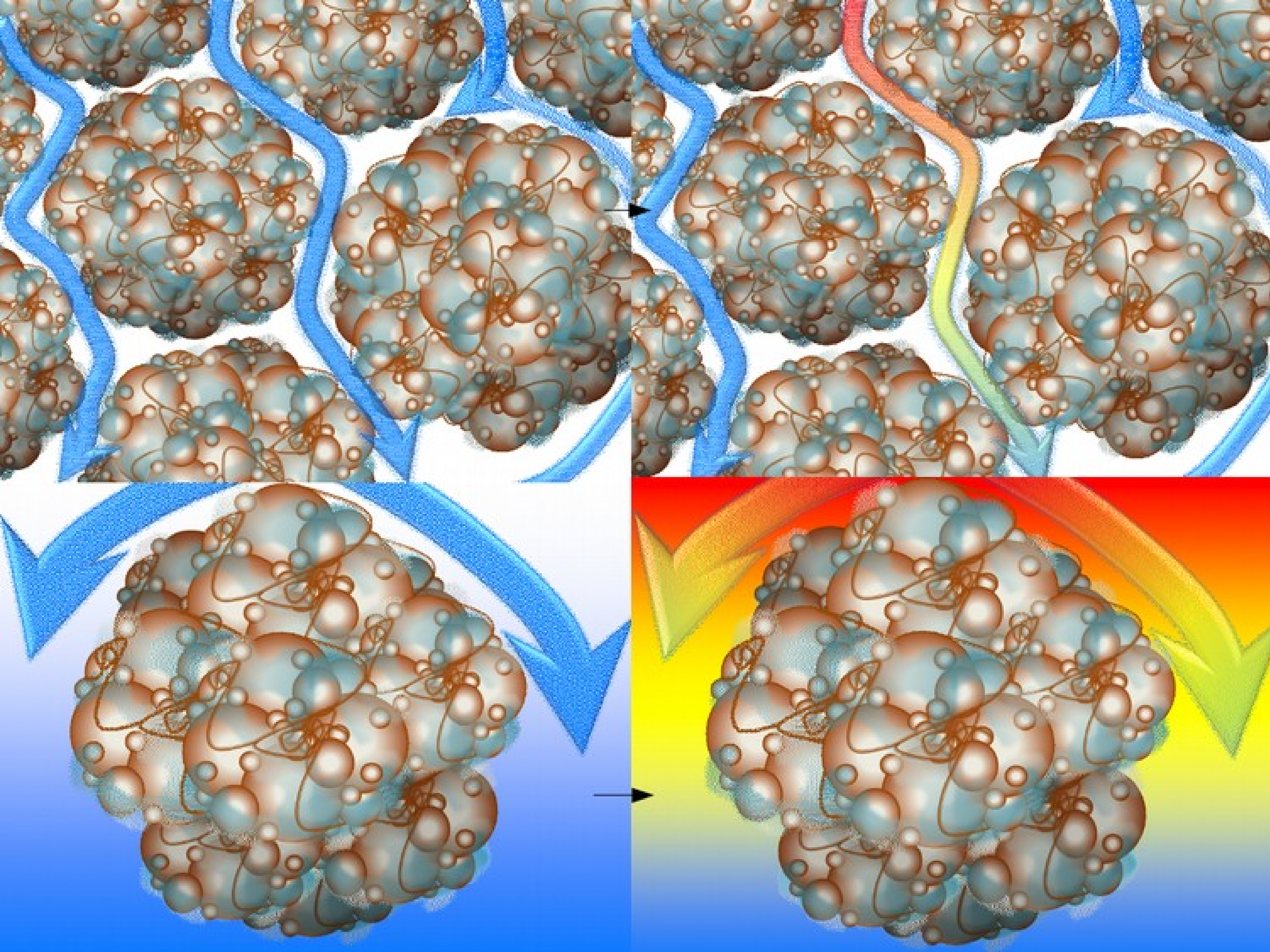

665241
HTM 40 zátka

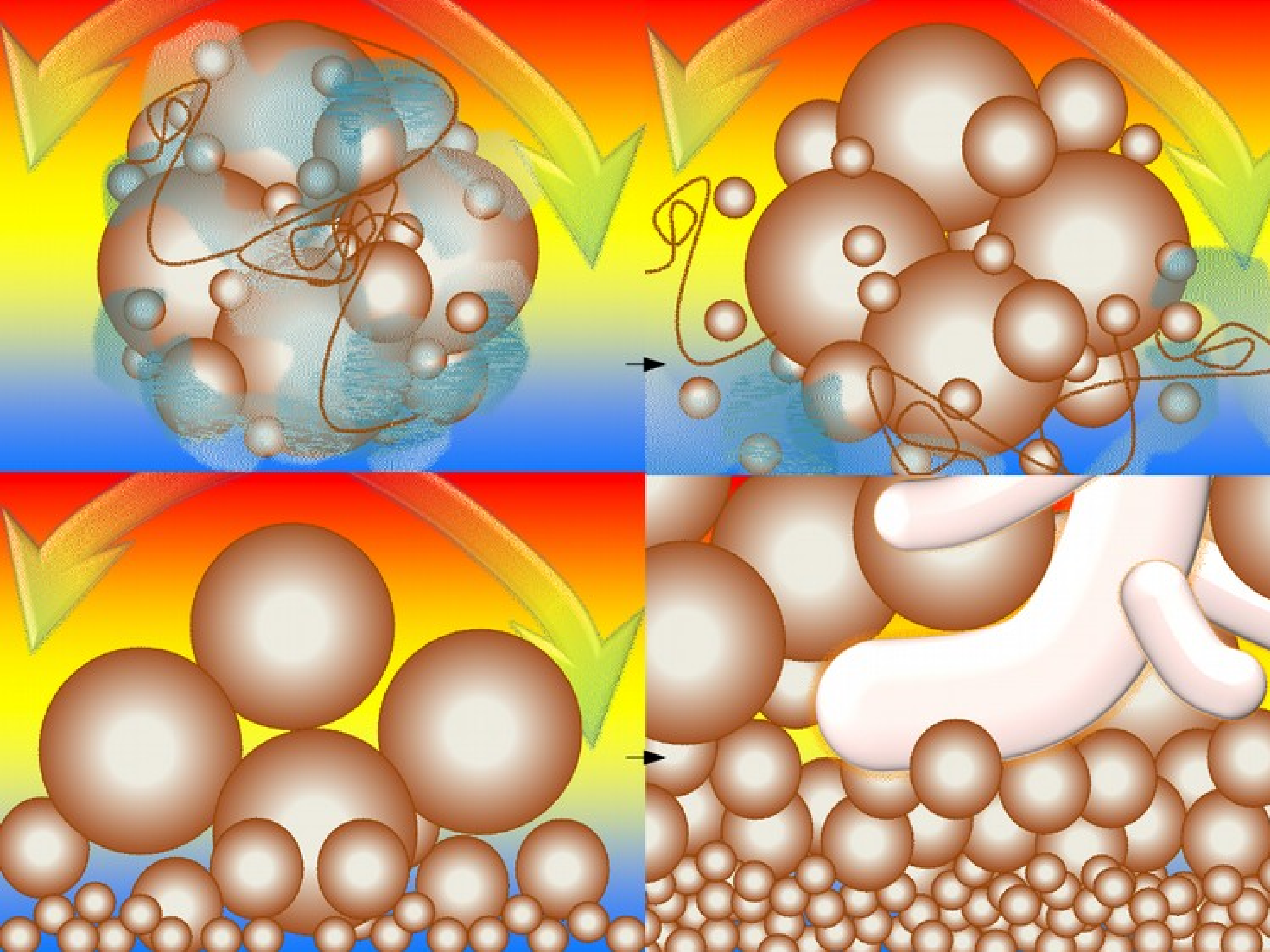


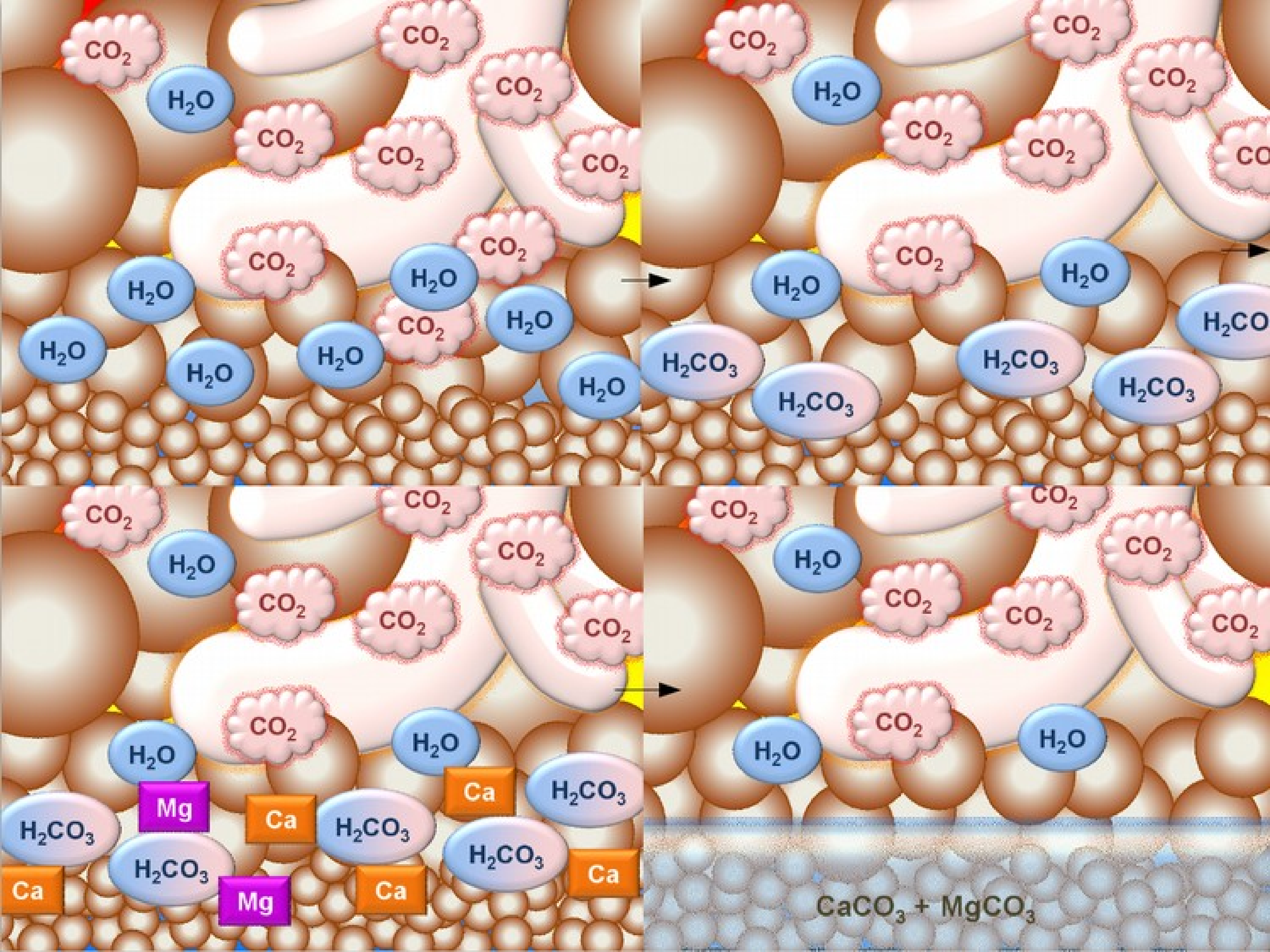
3: *Graph of mycorrhizal fungal colonisation; Midpoint represents average, box indicates standard error and error lines indicates standard deviation, treatment means with different letters are significantly different (P < 0.05).*

Svoboda, Z., Záhora, J., Dvořáčková, H. 2017 EFFECTS OF BIOCHAR APPLICATION ON WINTER WHEAT (TRITICUM AESTIVUM L.) ROOTS UNDER LONG-TERM DROUGHT CONDITIONS (in press)

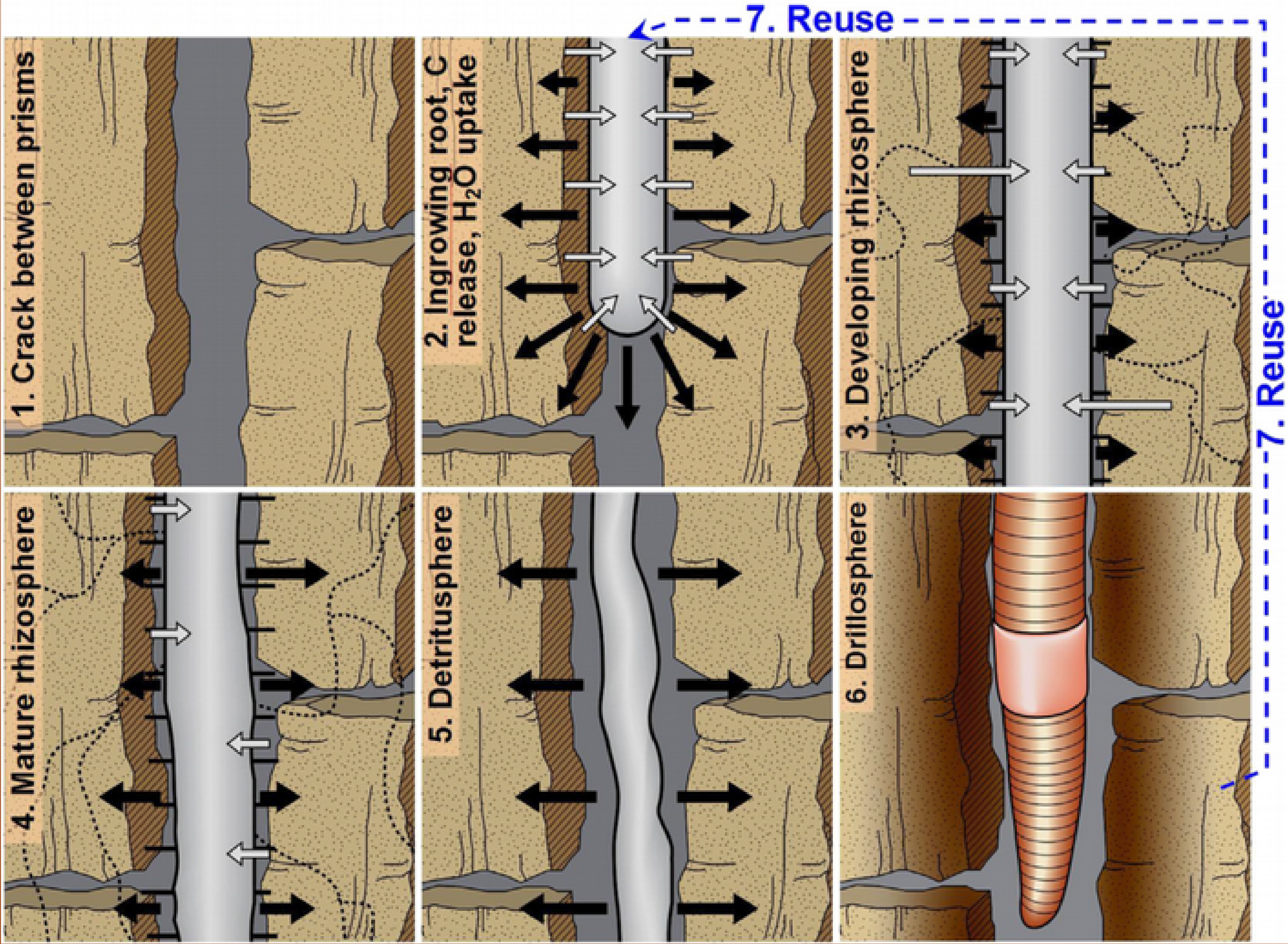

The receiving plant emits defense VOCs that attract aphid-hunting wasps and repel aphids.
Aphids are highly destructive insects that feed on the sap of numerous plant species.
Plants under attack emit warning volatile organic compounds (VOCs).
Blight and other pathogens can cause widespread death of plant tissues.
1
2
3
4
Stoma
8
Stressed-out plants release unidentified soluble compounds.
7
9
6
Drought is a common stressor for many plants.
Common mycelial networks (CMNs) also transmit warning signals.
5
THE SECRET SOCIAL LIVES OF PLANTS






CO_2
CO_2
CO_2
CO_2
CO_2
CO_2
CO_2
CO_2
CO_2
H_2O
H_2O
H_2O
H_2O
H_2O
H_2O
H_2O
H_2O
CO_2
CO_2
CO_2
CO_2
CO_2
CO_2
H_2O
H_2O
H_2O
H_2CO_3
H_2CO_3
H_2CO_3
H_2CO_3
CO_2
CO_2
CO_2
CO_2
CO_2
CO_2
CO_2
H_2O
H_2O
H_2O
Mg
Mg
Ca
Ca
Ca
Ca
Ca
H_2CO_3
H_2CO_3
H_2CO_3
H_2CO_3
H_2CO_3
CO_2
CO_2
CO_2
CO_2
CO_2
CO_2
CO_2
H_2O
H_2O
H_2O
$CaCO_3 + MgCO_3$

Biologická degradace vede ke zhutnění půdy, které urychluje půdní erozi



Y. Kuzyakov, 186 E. Blagodatskaya / Soil Biology & Biochemistry 83 (2015) 184-199

Vielen Dank für Ihre Aufmerksamkeit