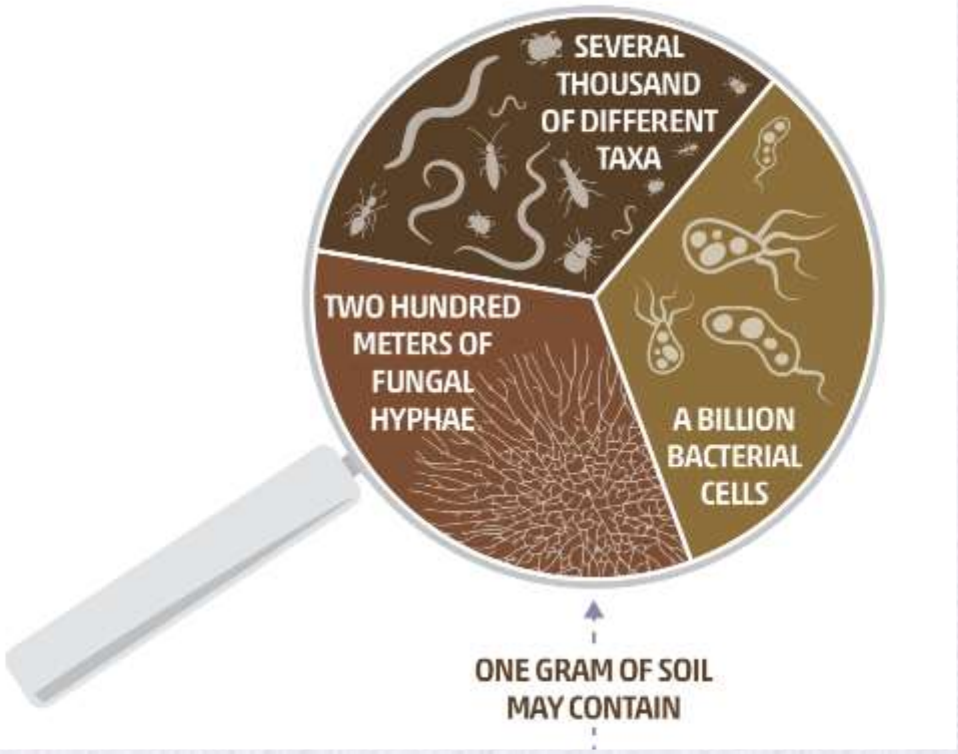
the soil microbiome

Sandra
Tuszynska
(PhD)

Dr. Elaine Ingham – Soil Food Web School

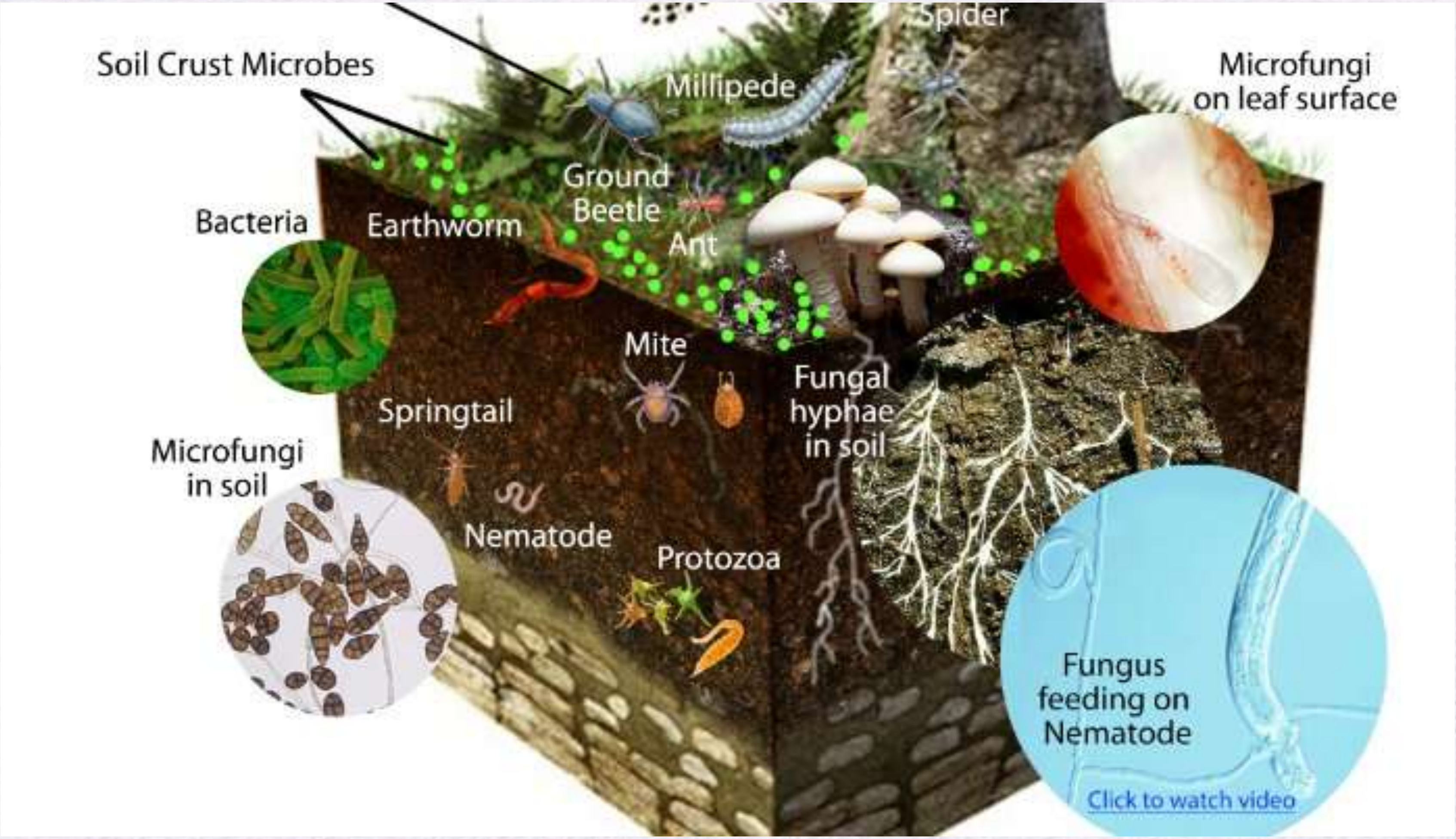
what is soil?

- Plants + associated microbes utilising sand, silt, clay and OM, solubilising and cycling nutrients



FAO, ITPS, GSBI, SCBD and EC. 2020. *State of knowledge of soil biodiversity - Status, challenges and potentialities*, *Report 2020*. Rome, FAO. https://doi.org/10.4060/cb1928en

it’s a living thing

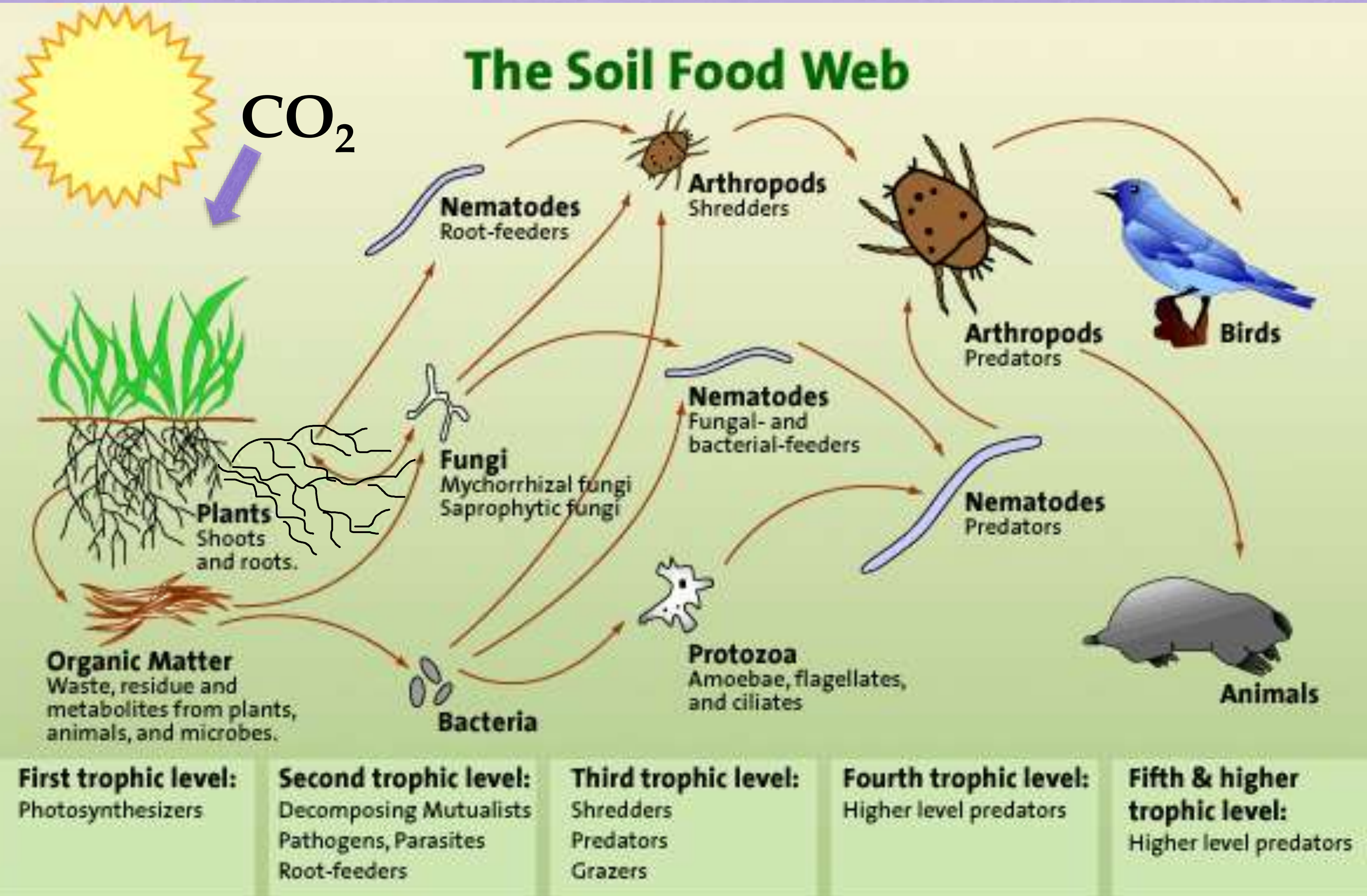


don’t treat it like dirt!

http://bluegrasslawn.com/everything-starts-soil/

plant services

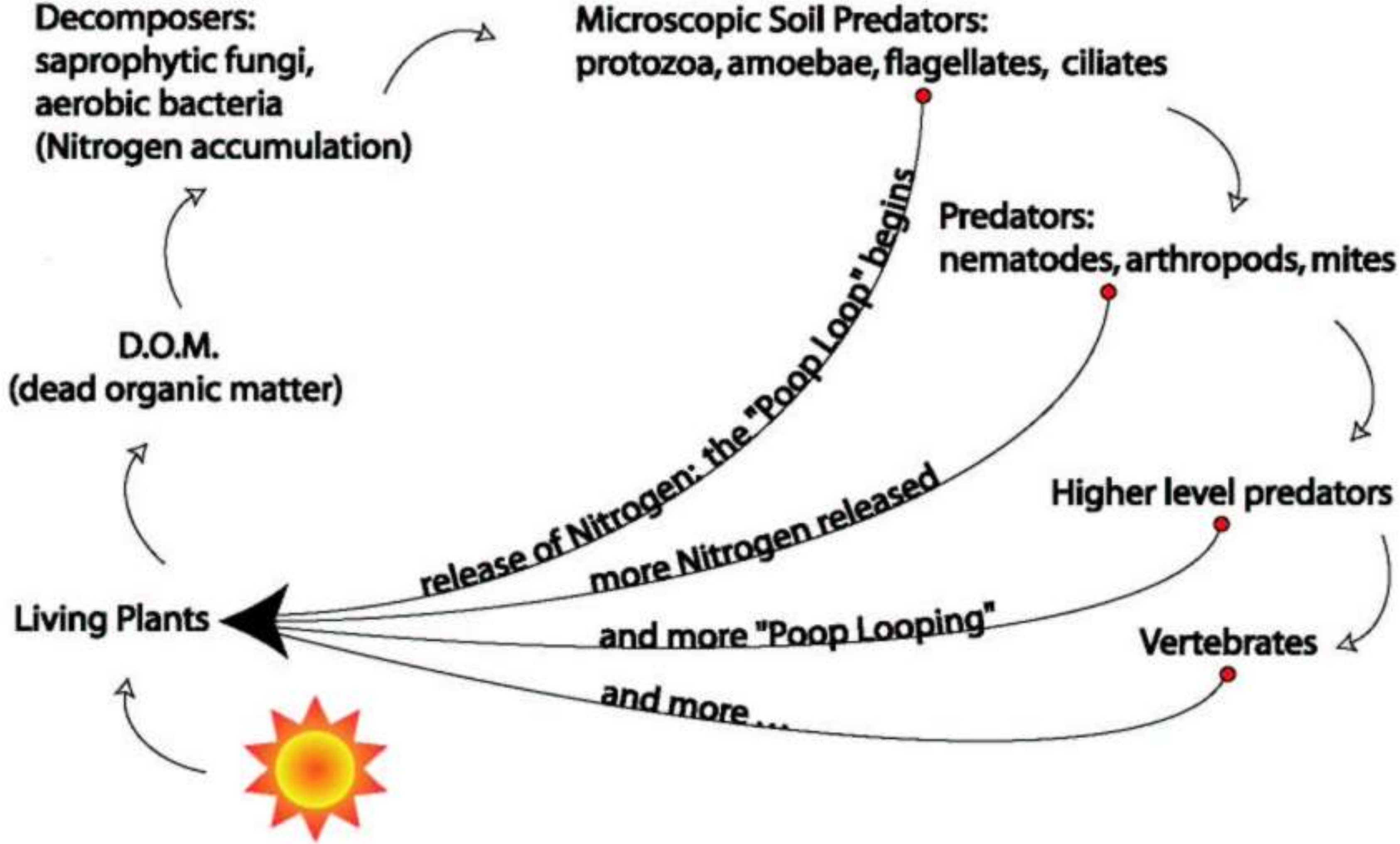
https://www.motherearthnews.com/organic-gardening/gardening-techniques/mycorrhizal-fungi-zm0z14aszkin



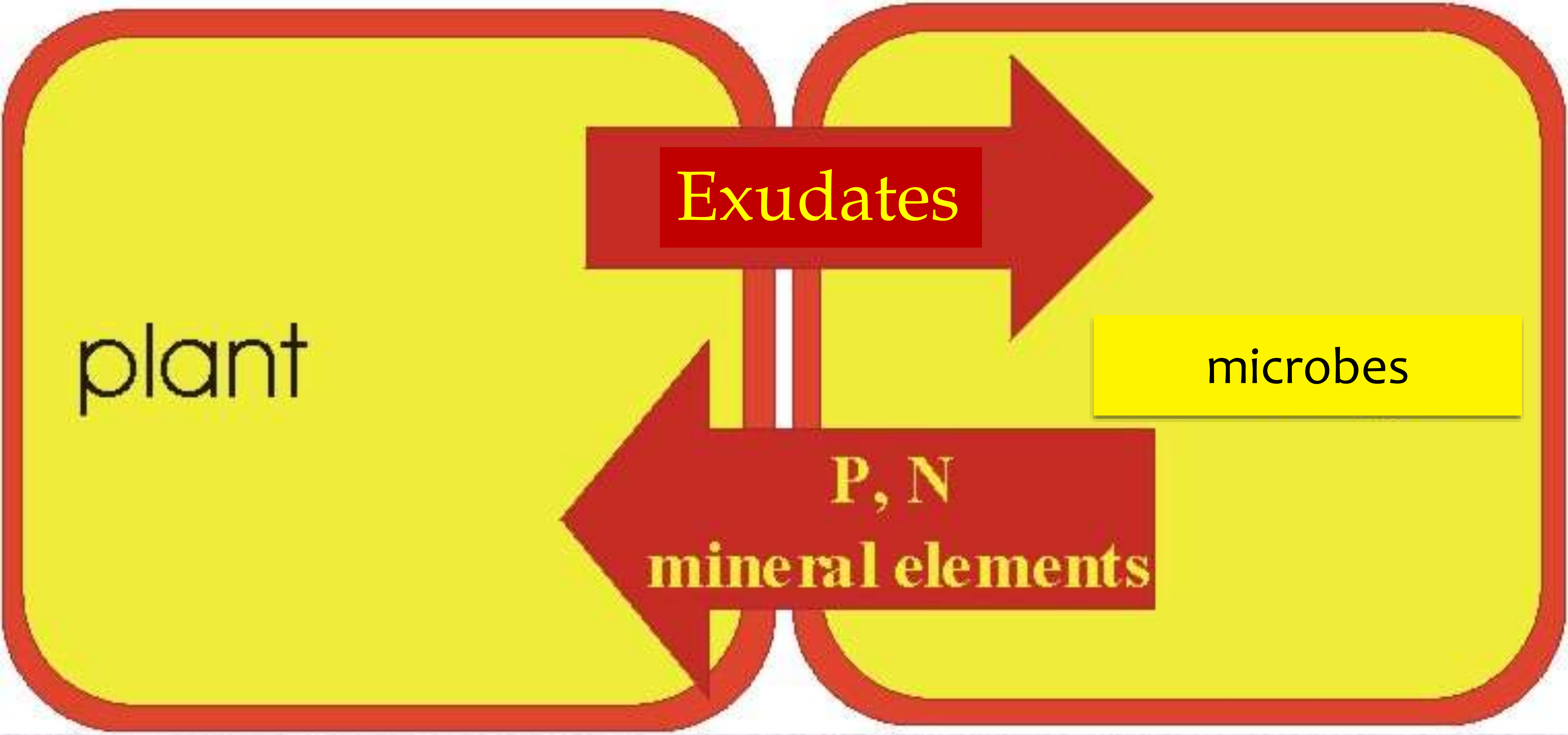
https://www.nuleaflawncare.com/what-is-wrong-with-chemical-fertilizers

THE POOP LOOP

Based on information from Dr. Elaine Ingham and Soil Foodweb, Inc.
by Alane O'Rielly Weber, Botanical Art
(c) 2004

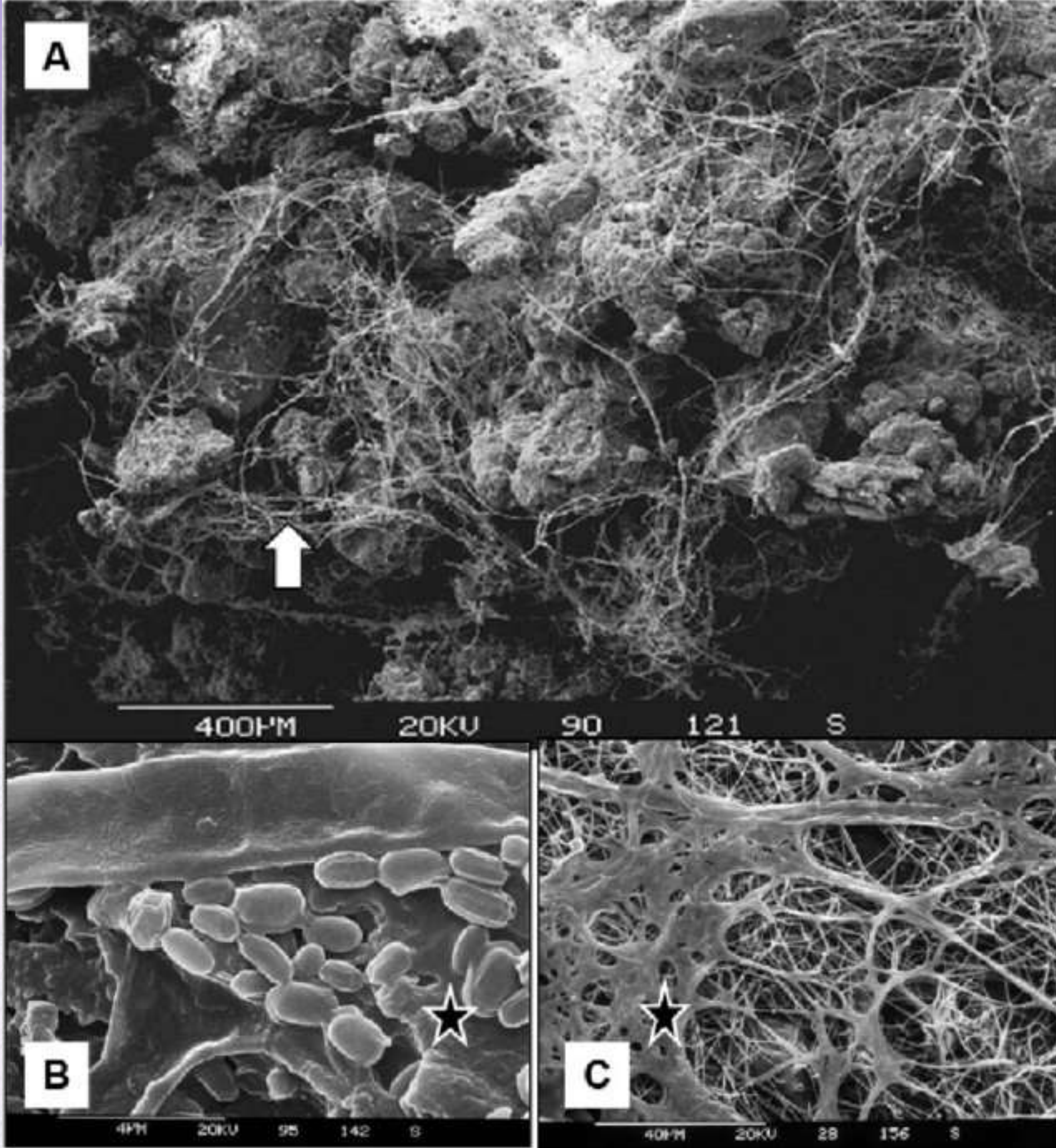


nutrient exchange



http://www-users.york.ac.uk/~fjm3/resmyco.html

rhizosheath



Vadakattu Gupta, Margaret Roper and John Thompson (2019) Harnessing the benefits of soil biology in conservation agriculture. In (Eds J Pratley and J Kirkegaard) "Australian Agriculture in 2020: From Conservation to Automation" pp 237-253 (Agronomy Australia and Charles Sturt University: Wagga Wagga)

(A) network of fungal hyphae holding soil particles to crop residues
(B) bacterial and fungal glues bind soil particles into
(C) stable aggregates

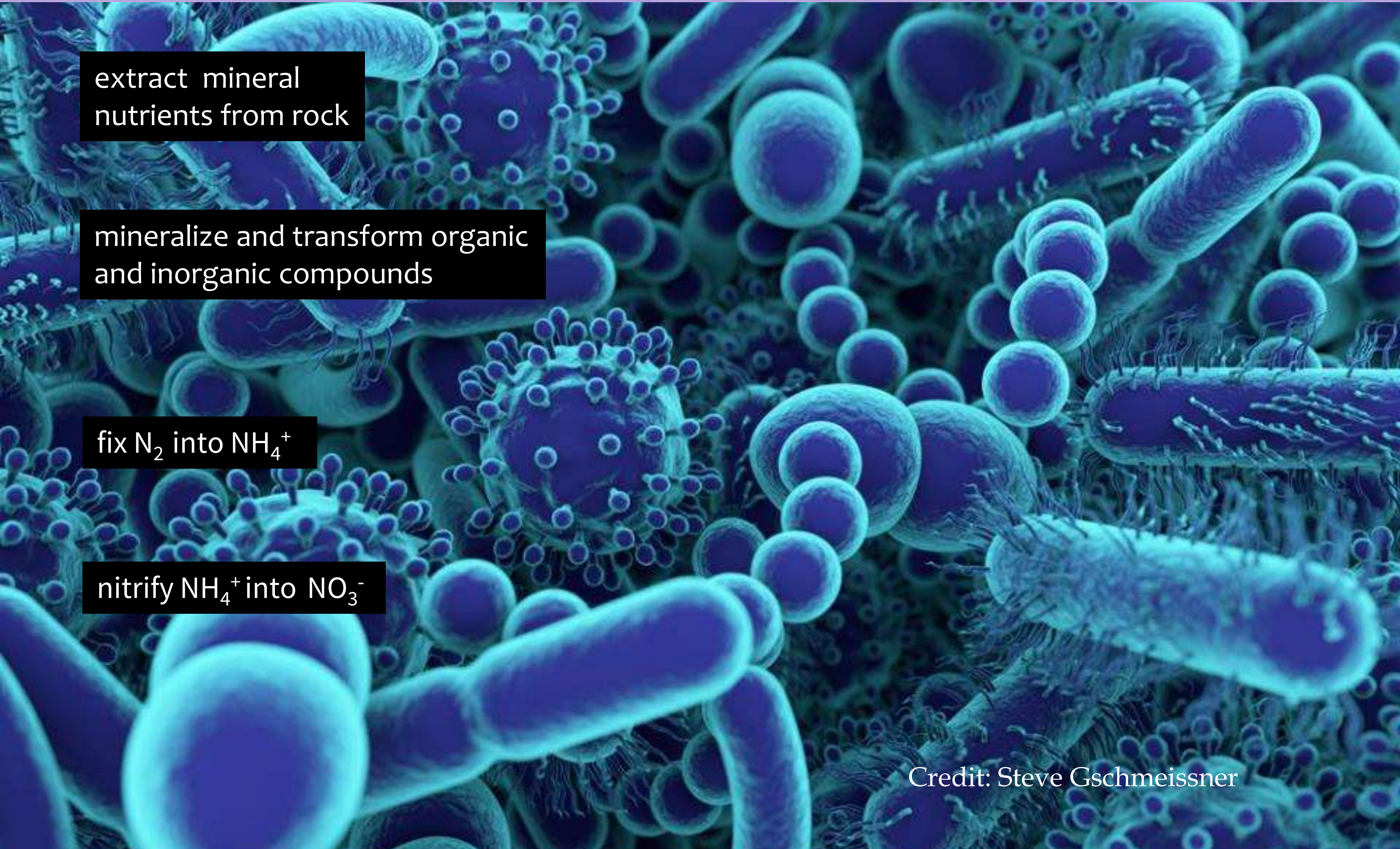
(Gupta VVSR, CSIRO)

meet the team






bacteria



extract mineral nutrients from rock

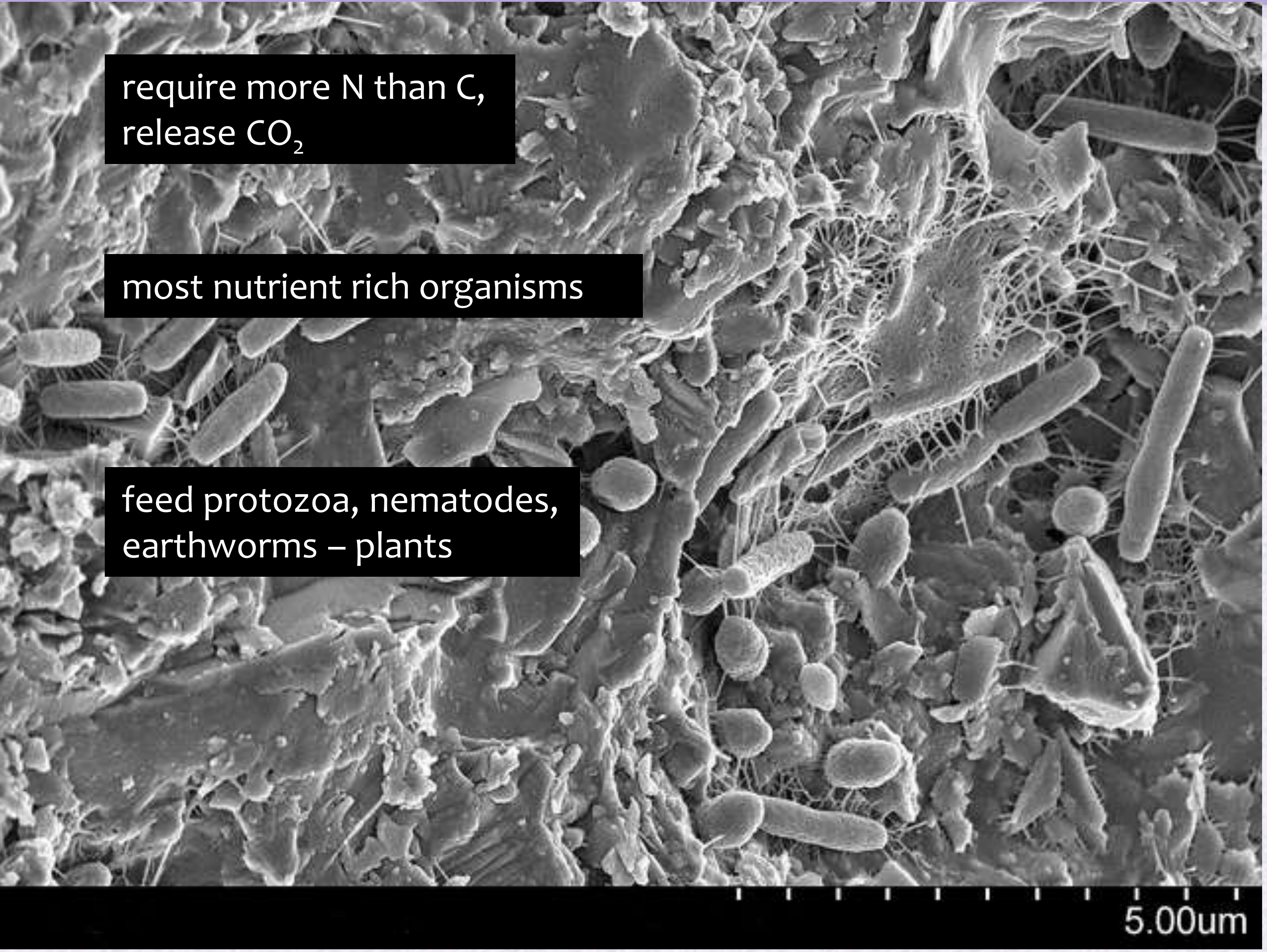
mineralize and transform organic and inorganic compounds

fix N_2 into NH_4^+

nitrify NH_4^+ into NO_3^-

Credit: Steve Gschmeissner

bacteria

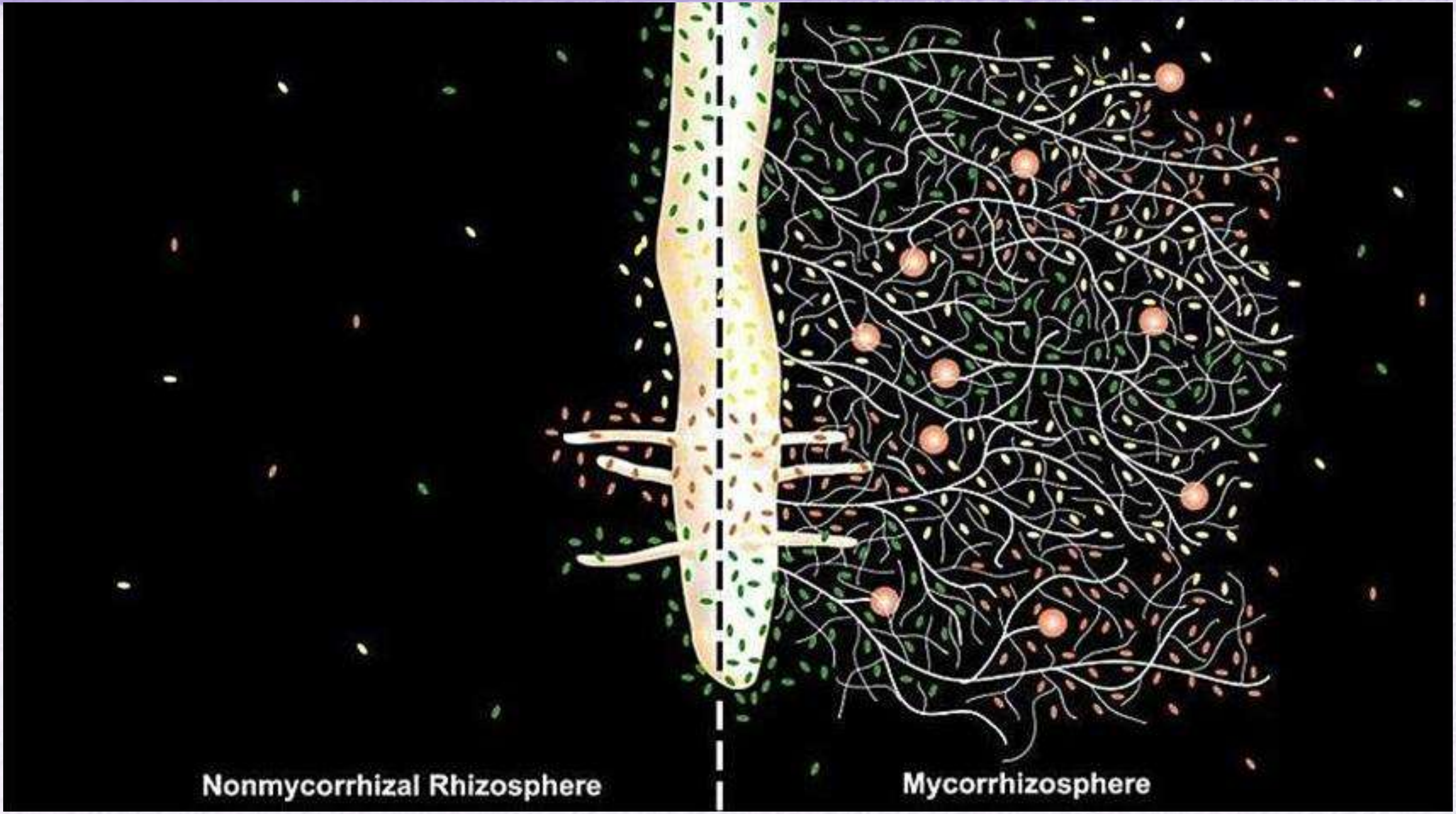


on a grain of sand form microaggregates

SEM image: Anthony D'Onofrio, William Fowle, Eric Stewart, and Kim, Northeastern University

https://soilsmatter.wordpress.com/2014/09/02/the-living-soil/

mycorrhizal microbiome



https://fungicultura.wordpress.com/2013/01/08/decoding-the-mycorrhizal-symbiosis-why-plants-like-fungi-so-much/

arbuscular mycorrhizal fungi

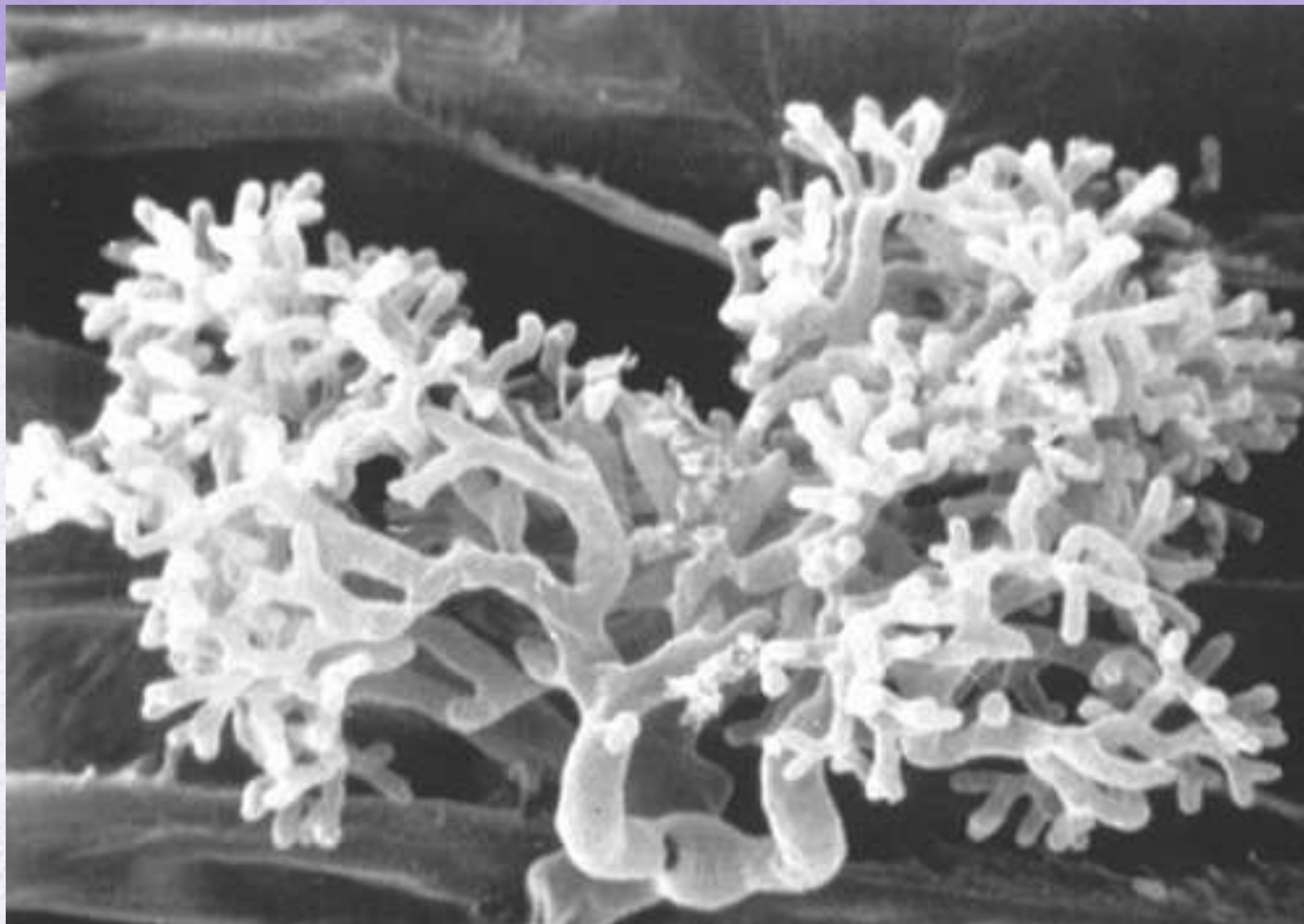
- symbiotic root extensions of ~80 - 92% of all plants (Wang & Qiu, 2006)
- 100 x more absorptive than roots
- 10-20% faster plant growth

https://www.westernsydney.edu.au/hie/topics/how_plants_benefit_from_partnerships_with_soil_fungi

Close-up of arbuscular mycorrhizal fungi connecting roots of plant hosts. Photo credit: Yoshihiro Kobae

arbuscule

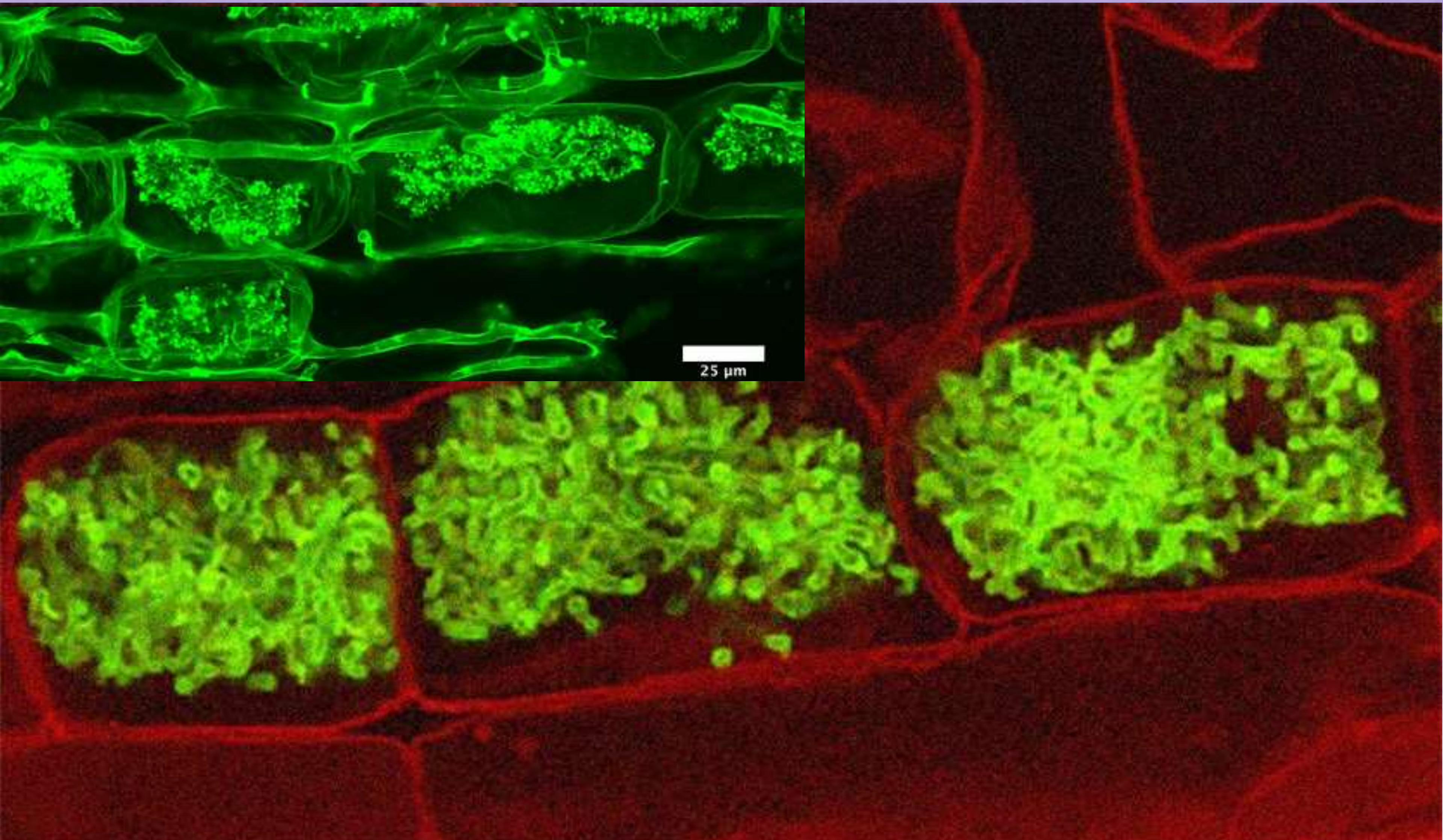
in root cortex



mycelium of $4m^2$ of perennial grassland can stretch around the equator

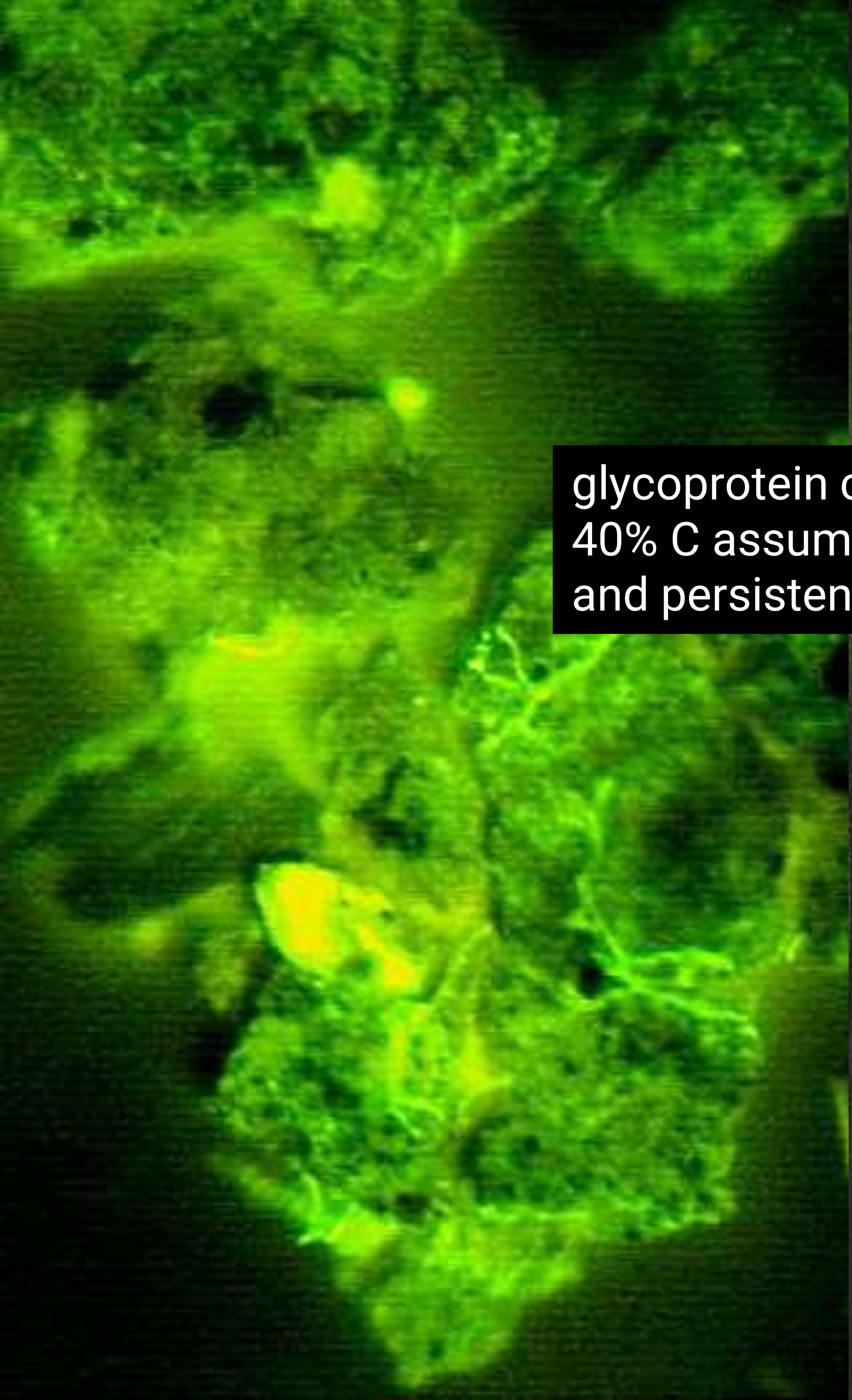
https://www.biooekonomie-bw.de/en/articles/news/mykotown-greentech-ag-uses-mycorrhiza-to-keep-plants-going/

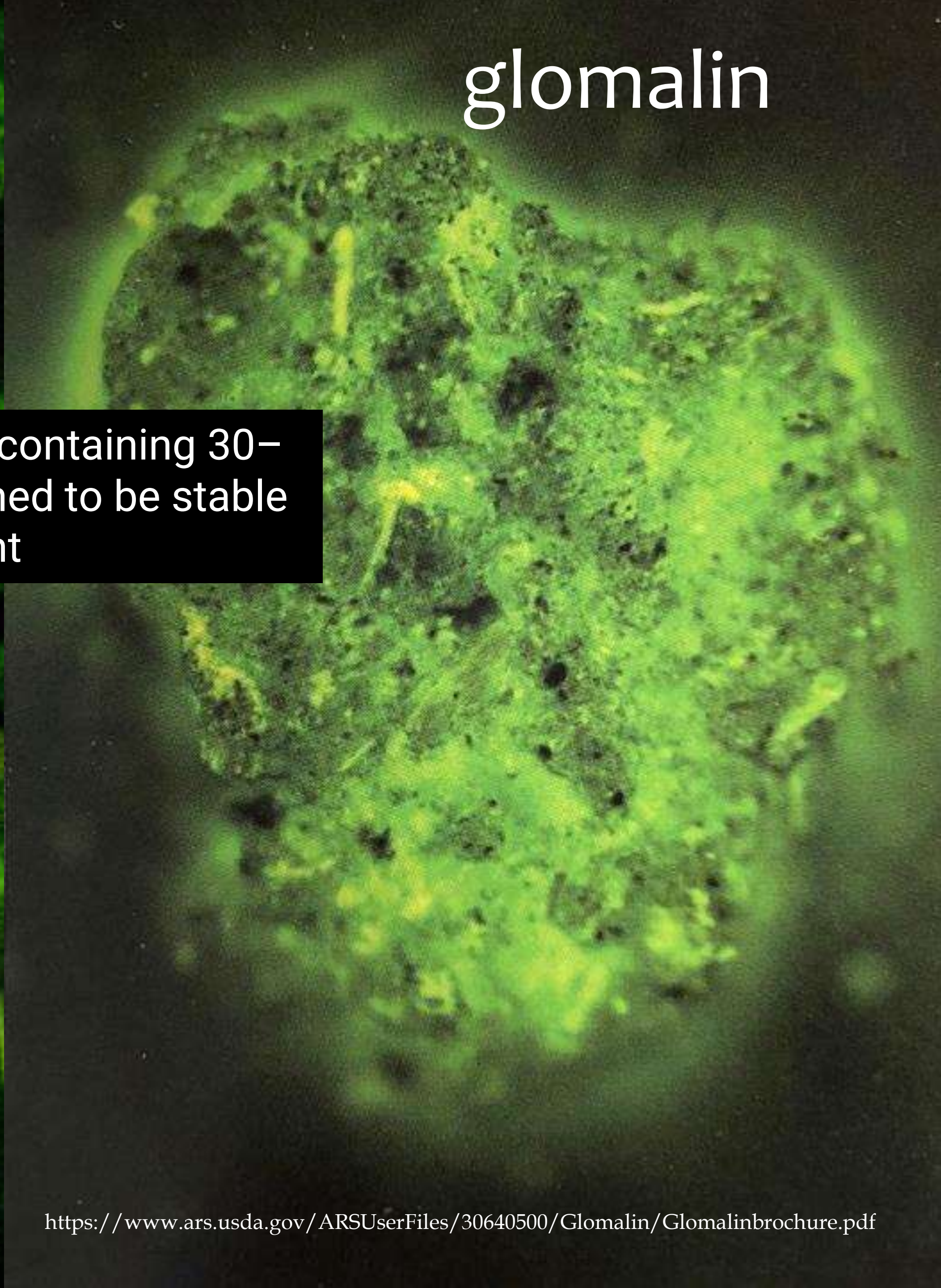
arbuscules



Arbuscules in root cells: Maria J Harrison, BTI (https://cosmosmagazine.com/biology/symbiotic-connections-of-plants-and-fungi)

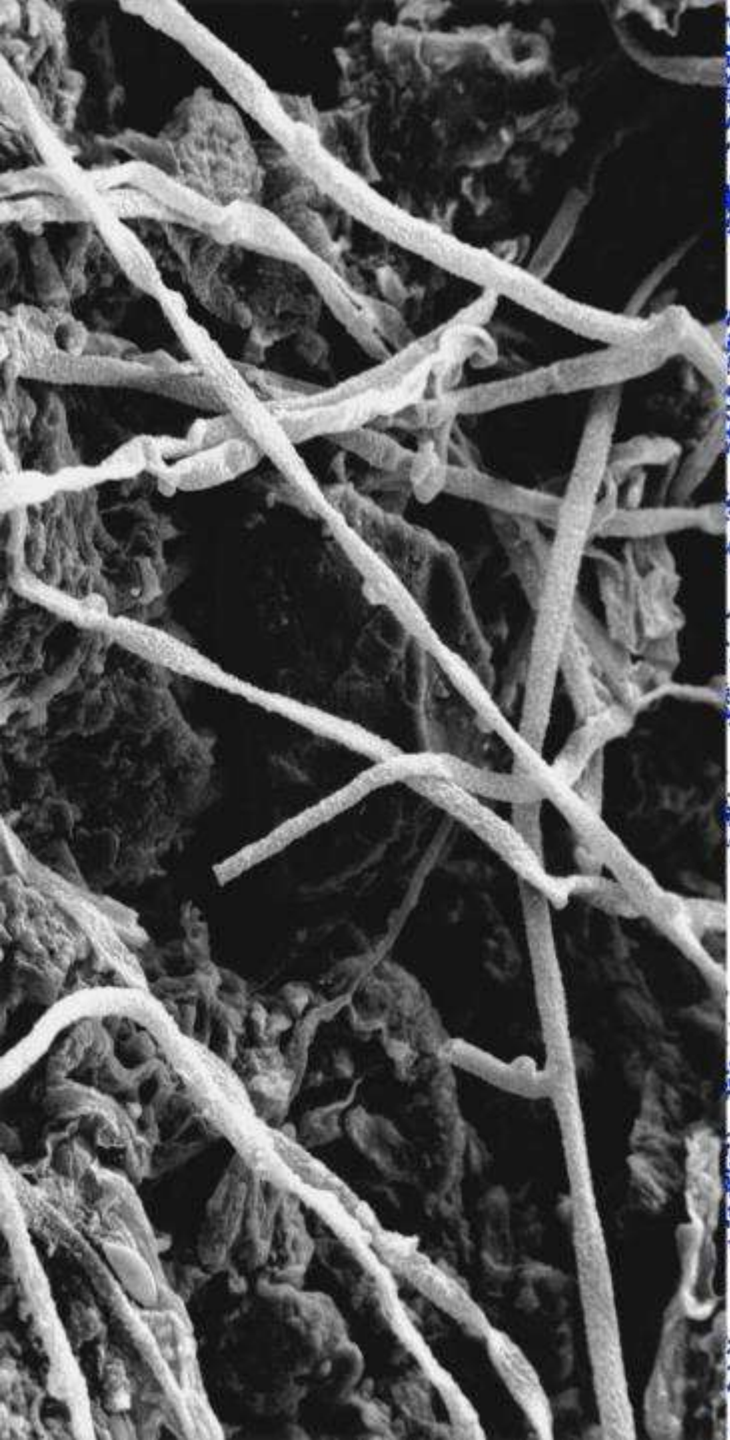
glomalin

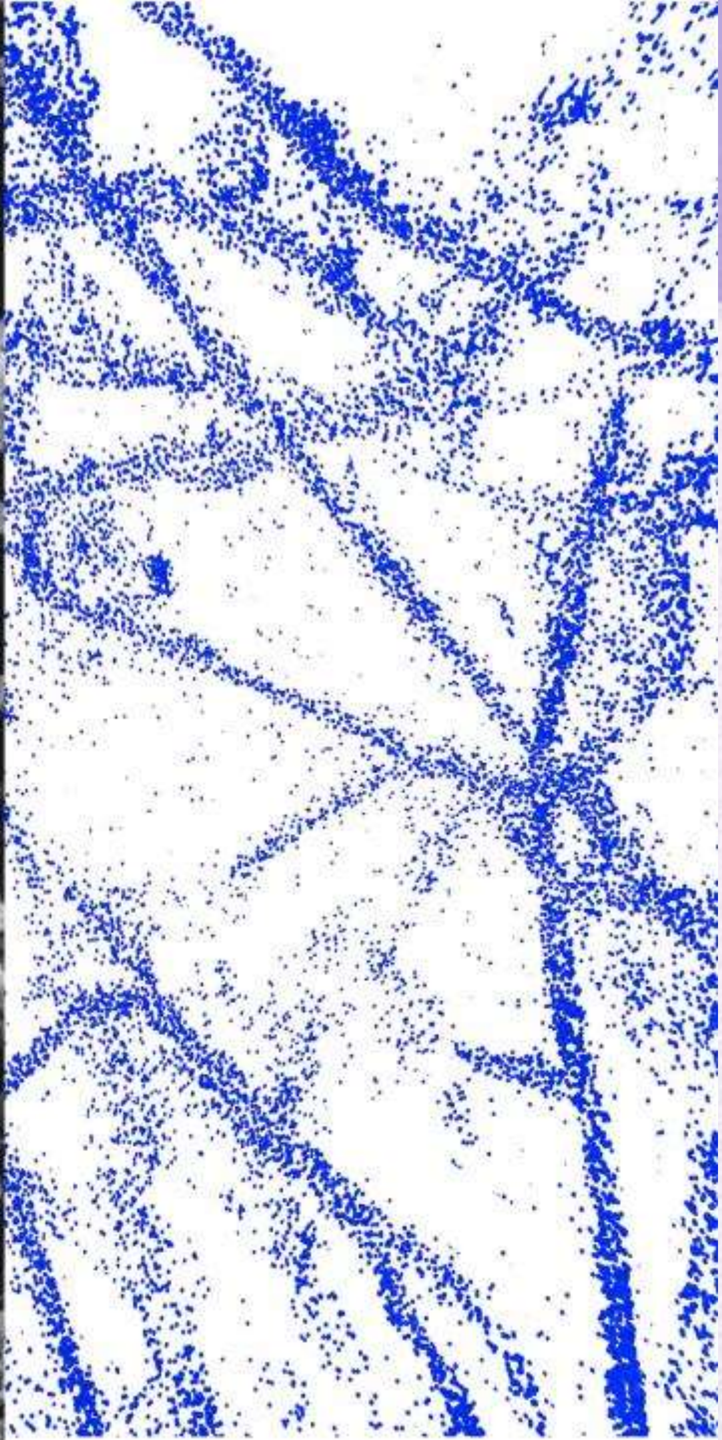




glycoprotein containing 30–40% C assumed to be stable and persistent

https://www.ars.usda.gov/ARSUserFiles/30640500/Glomalin/Glomalinbrochure.pdf





carbon
in hyphae

http://www.microped.uni-bremen.de/SEM_index.htm

fungi bind
micro-aggregates
into
macro-aggregates

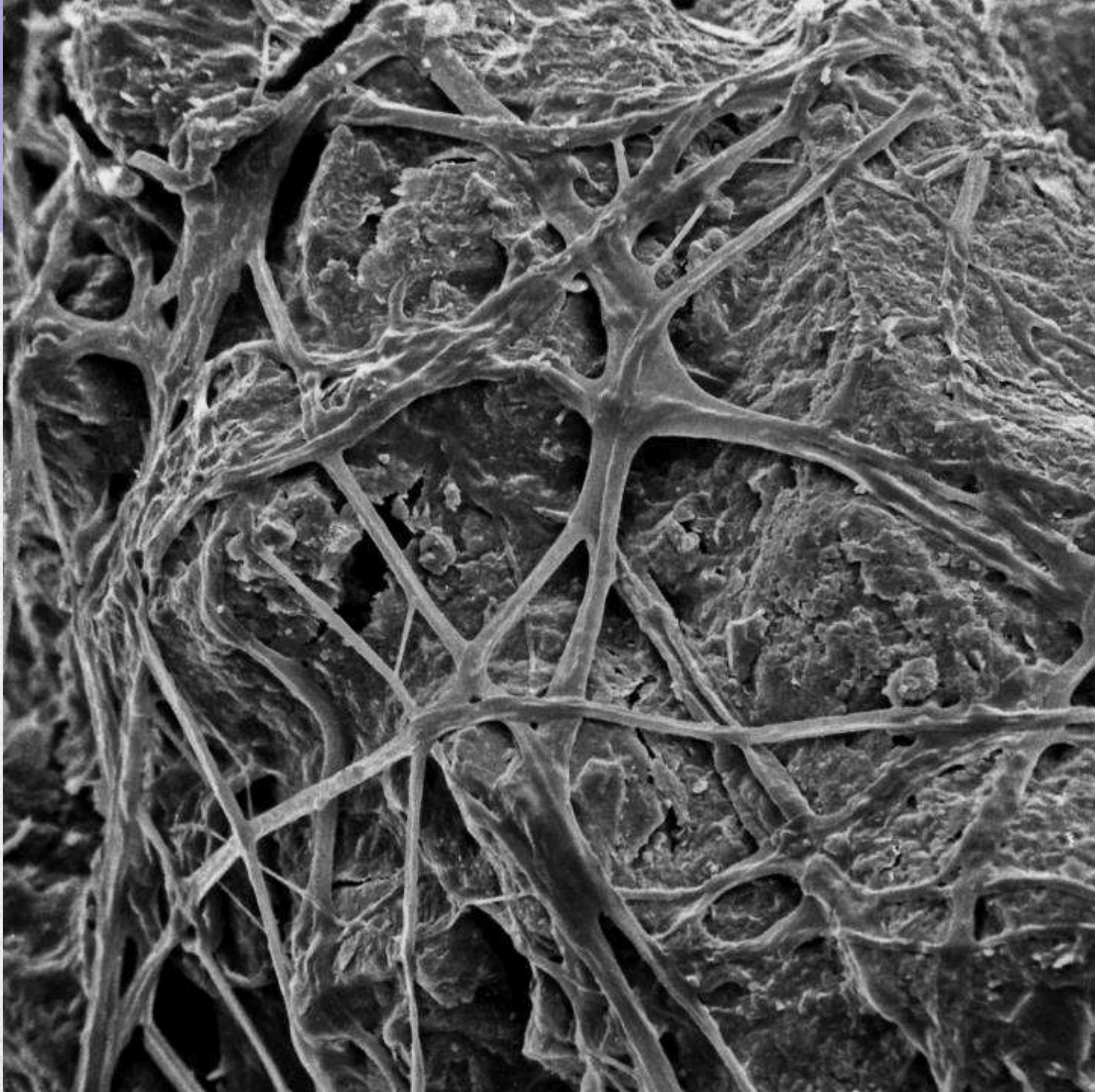


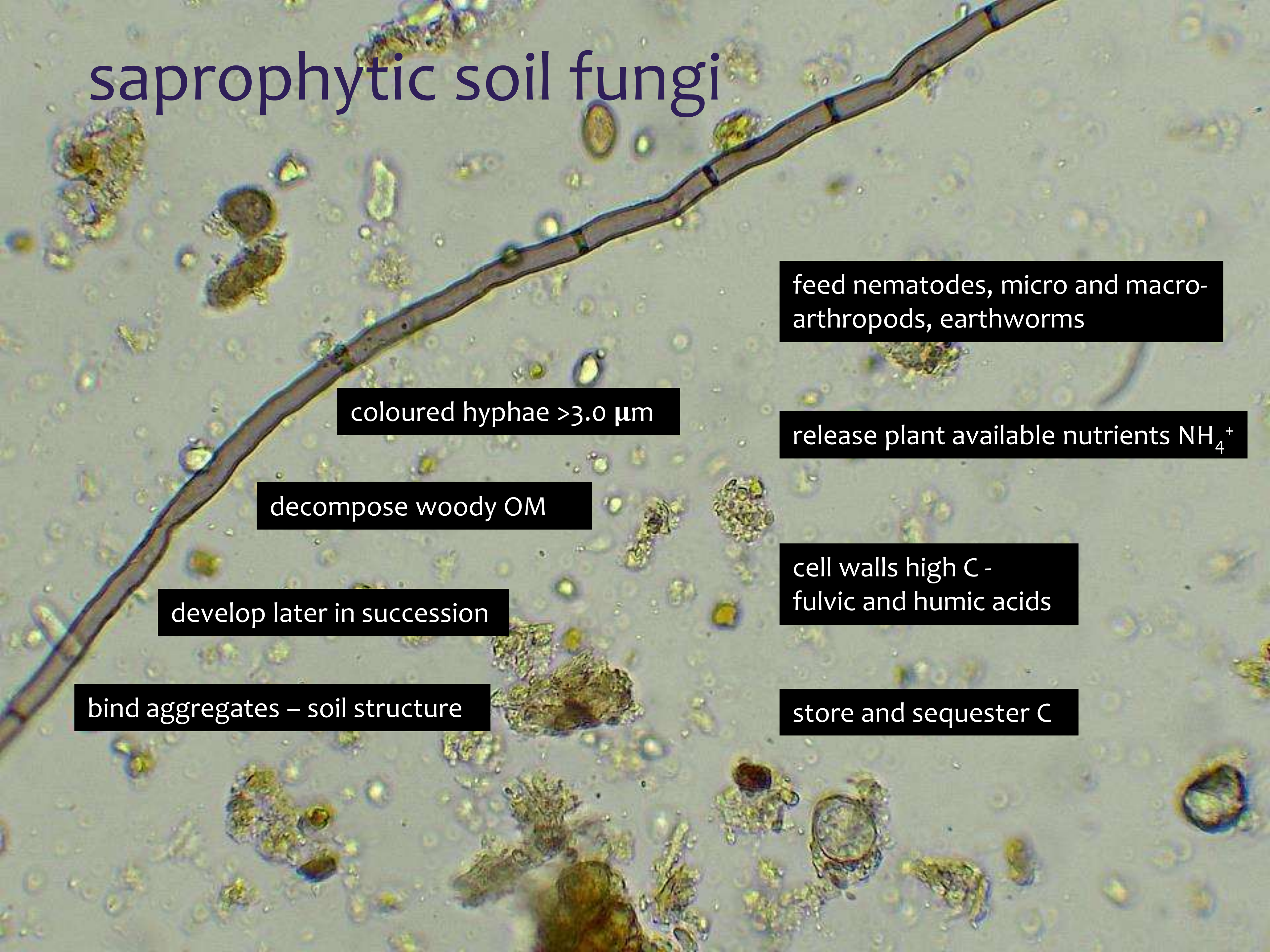
Image courtesy of Soil Microbial Ecology, University of Bremen. http://www.microped.uni-bremen.de

mycorrhizal crops

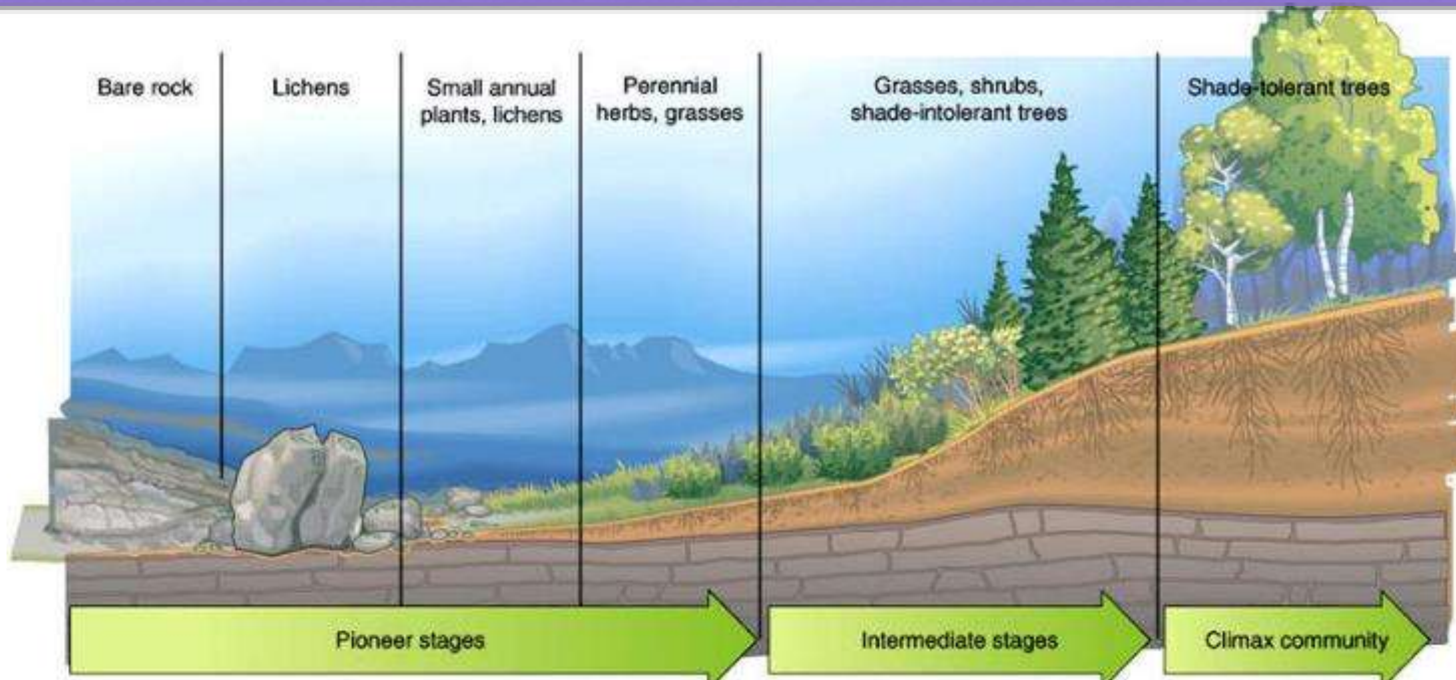
http://mycorrhizae.com/info-by-industry/agriculture/agriculture-image-gallery/

difference between potatoes from untreated plants (l) and treated plants (r). *Photo: Premier Tech Agriculture*

saprophytic soil fungi



fungal:bacterial biomass determines plant succession

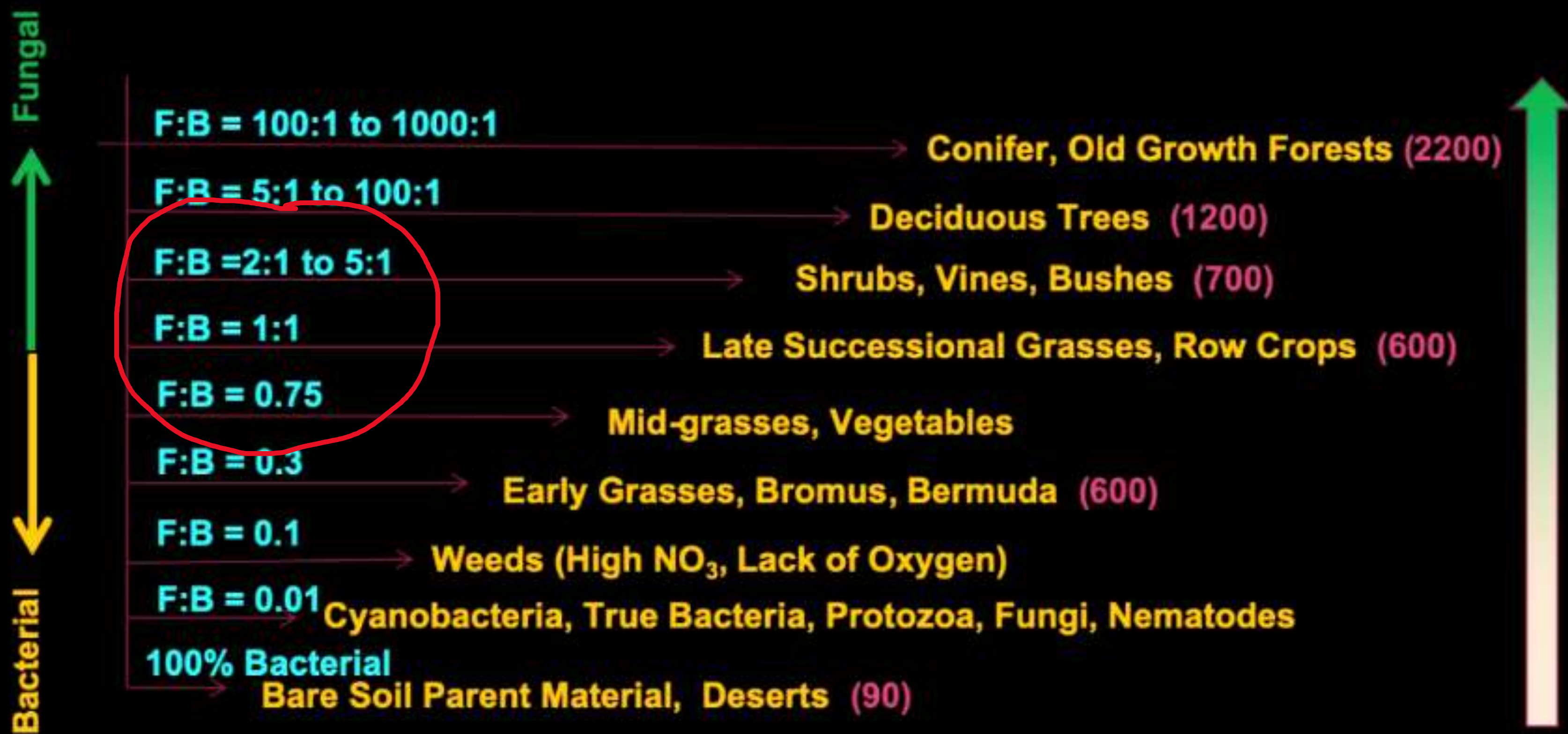


All units are µg/g

Bacteria → A Few Fungi → Balanced → More Fungi → Fungi

Bacteria:	10	100	500	600	650	700
Fungi:	0	10	250	600	8,000	70,000

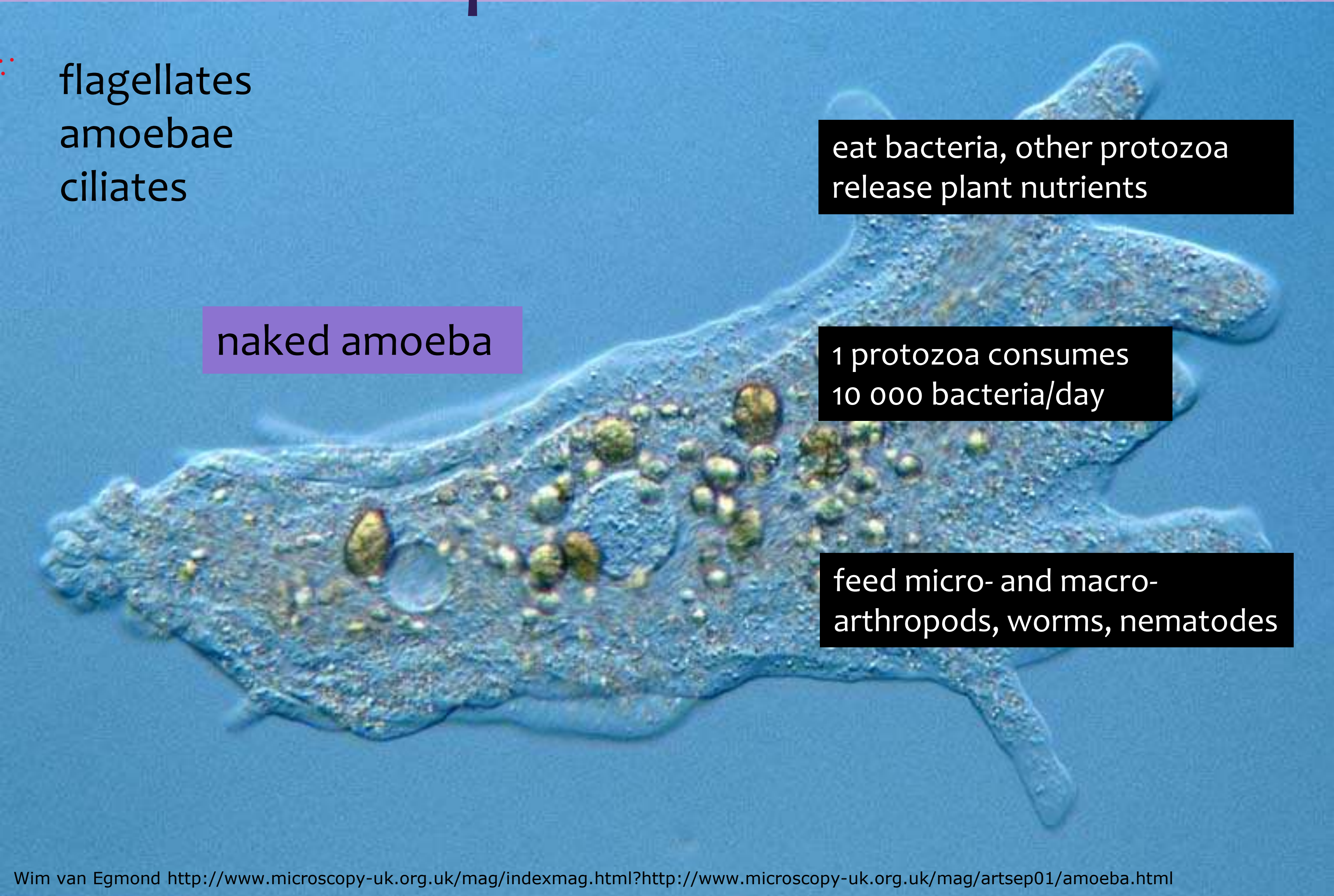
Plant Succession Ladder as a Function of Fungal:Bacterial Ratio (F:B)



Elaine Ingham- www. soilfoodweb.com

protozoa

flagellates
amoebae
ciliates



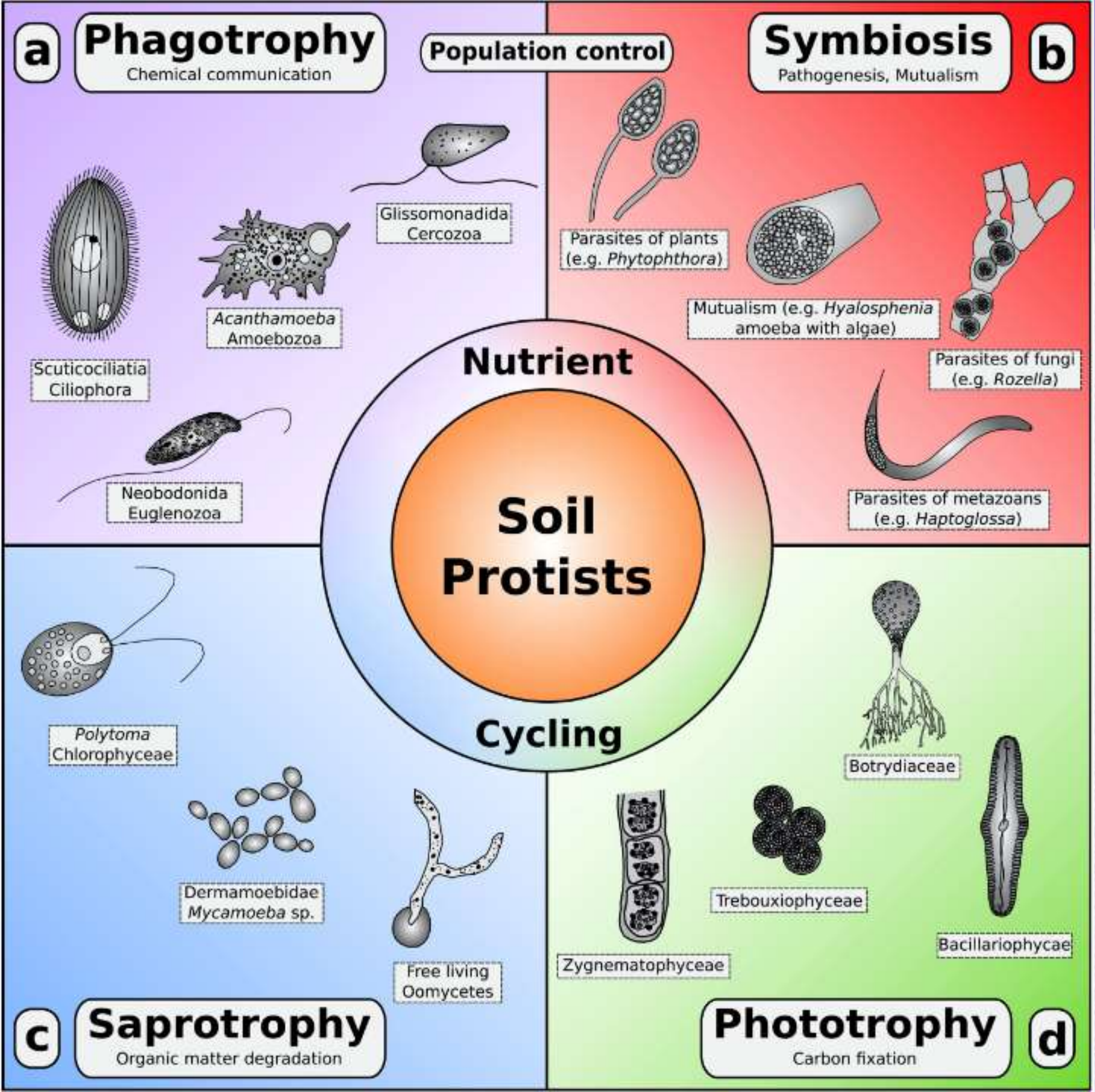
naked amoeba

eat bacteria, other protozoa
release plant nutrients

1 protozoa consumes
10 000 bacteria/day

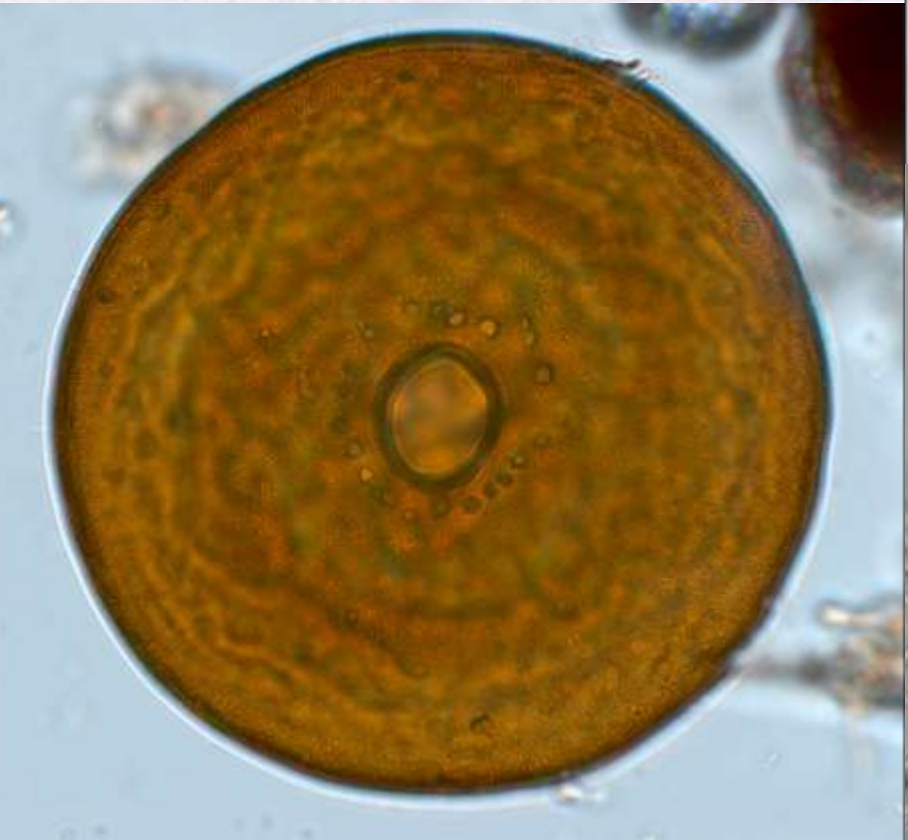
feed micro- and macro-
arthropods, worms, nematodes

Wim van Egmond http://www.microscopy-uk.org.uk/mag/indexmag.html?http://www.microscopy-uk.org.uk/mag/artsep01/amoeba.html



Geisen et al., **Soil protists: a fertile frontier in soil biology research**
FEMS Microbiology Reviews, 42, 2018, 293–323

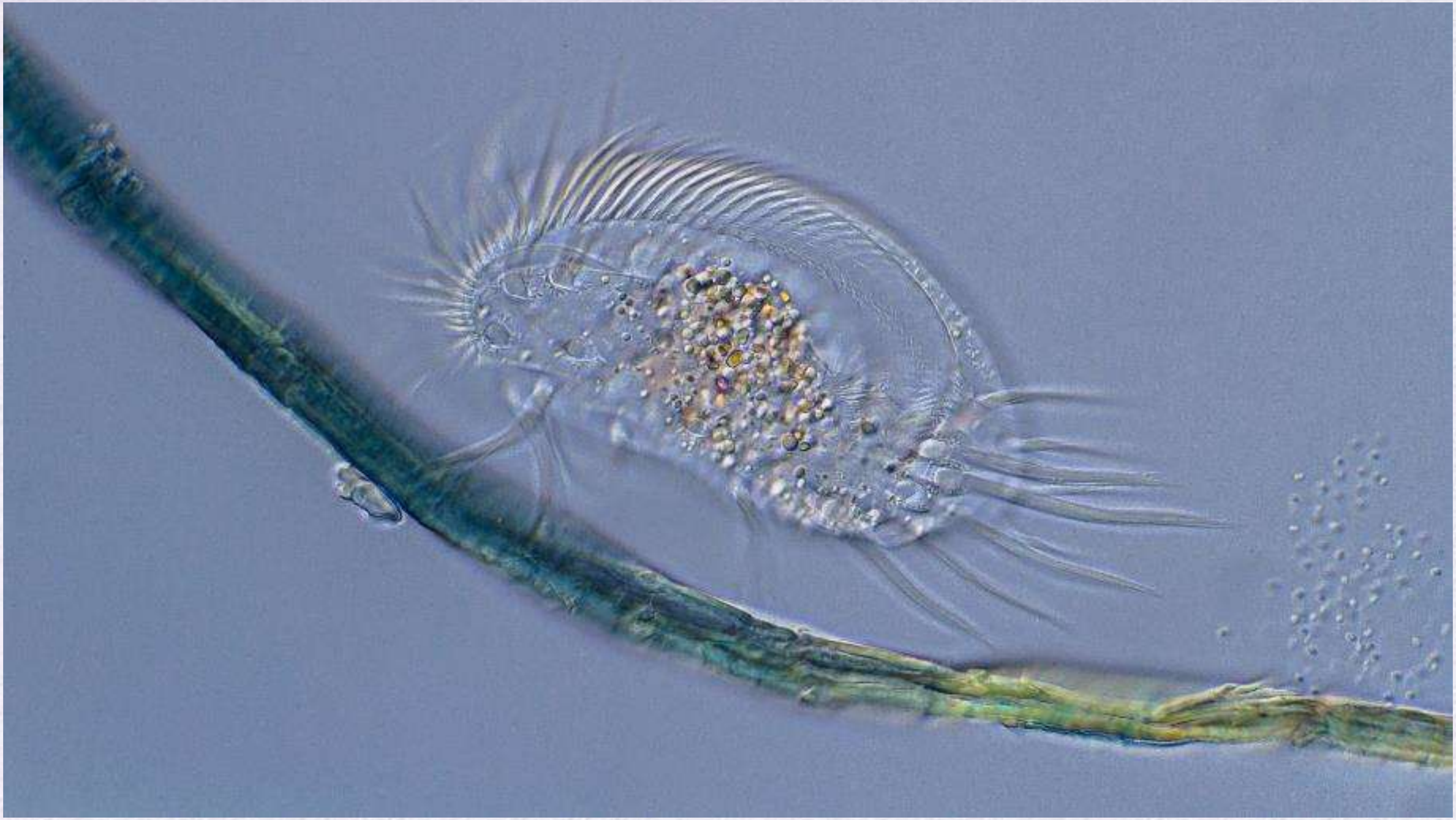
testate amoebae



https://bogology.org/how-we-do-it/biological-methods/testate-amoebae/

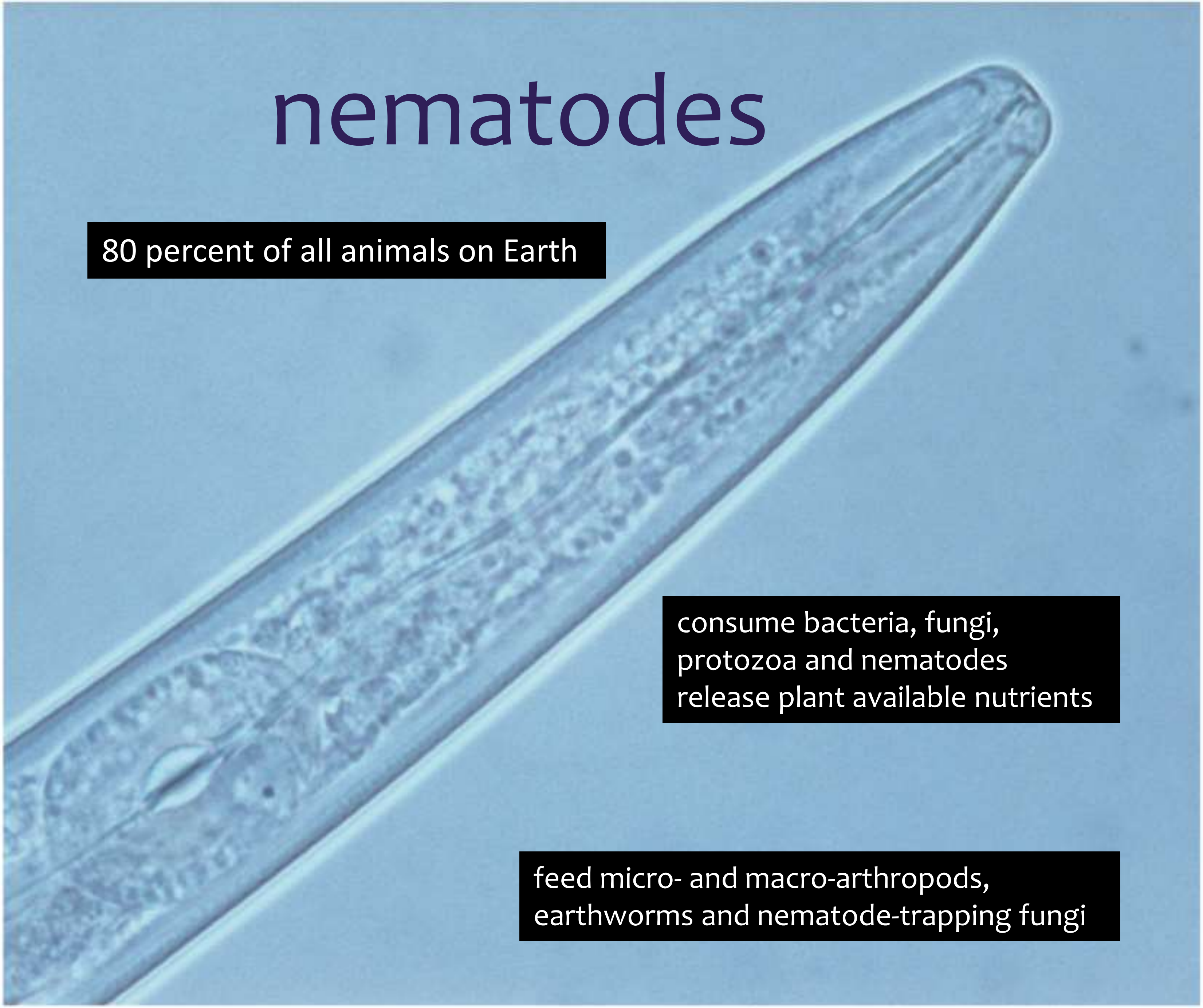
flagellates

ciliates: reduced oxygen/anaerobic



https://www.micropia.nl/en/discover/microbiology/Ciliates_en/

nematodes

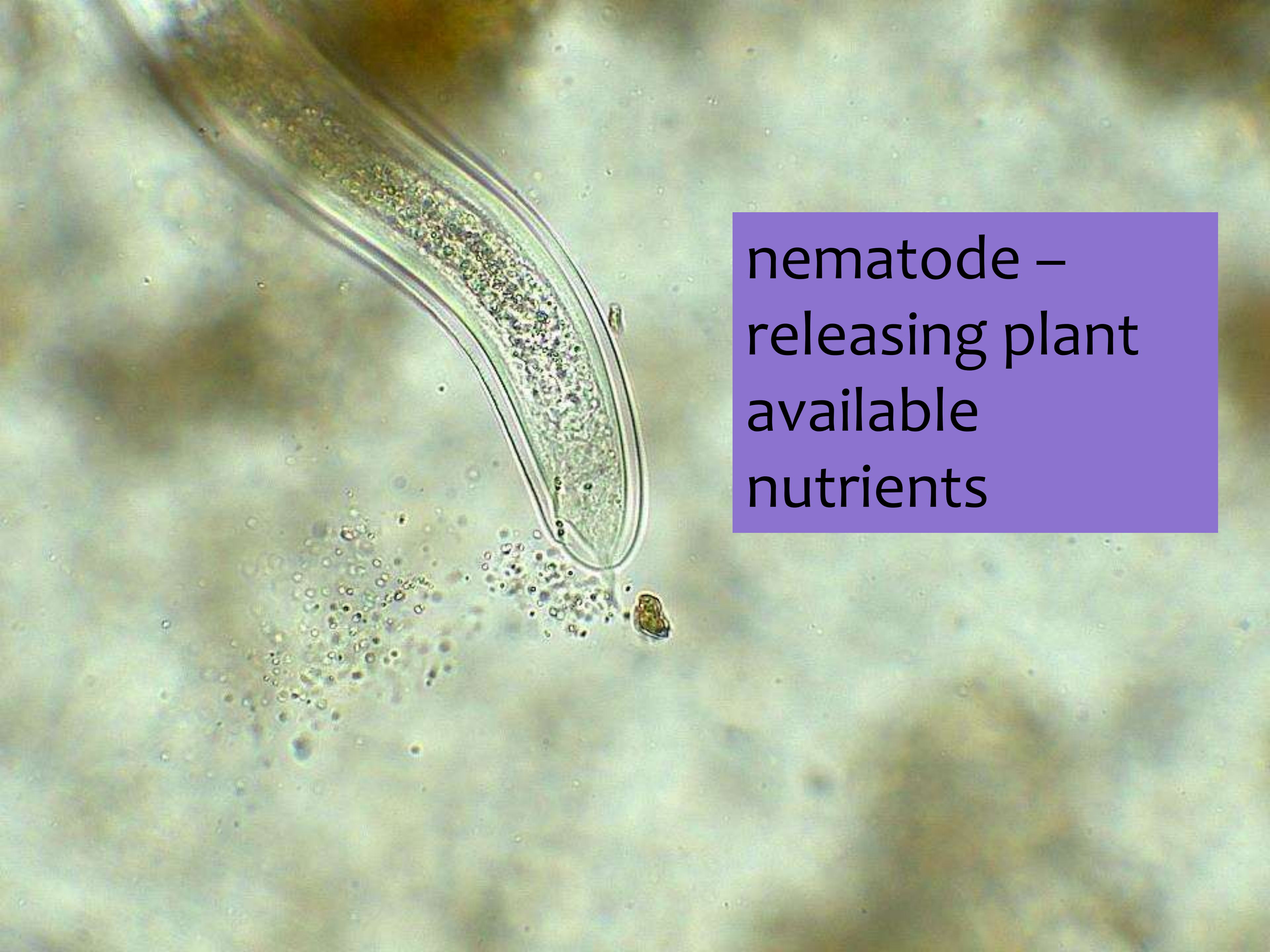


80 percent of all animals on Earth

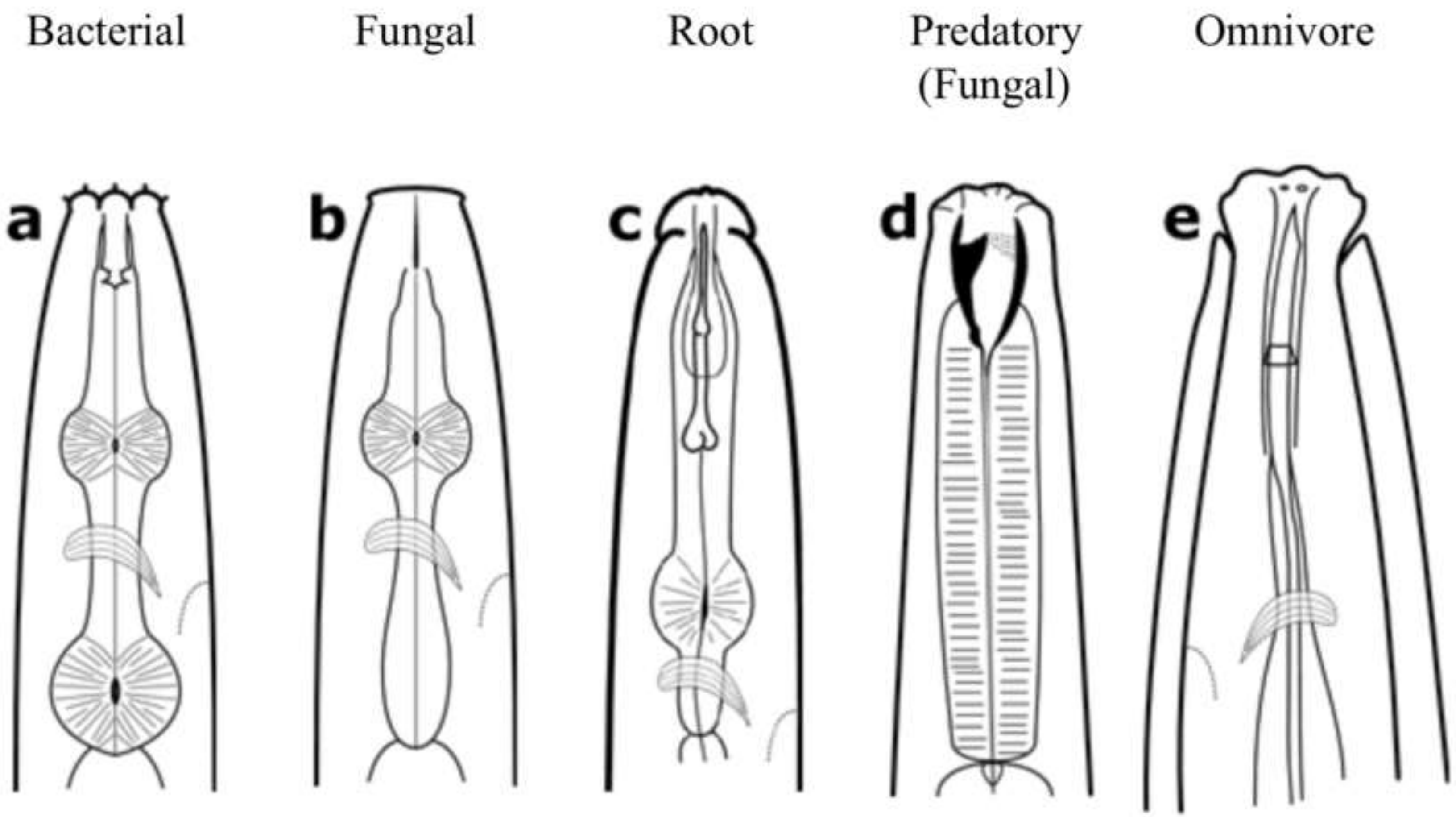
consume bacteria, fungi,
protozoa and nematodes
release plant available nutrients

feed micro- and macro-arthropods,
earthworms and nematode-trapping fungi

Fungal-feeding nematodes, such as *Aphelenchus* sp., have a tiny spear to pierce fungal hyphae. (HM, HH, JGB)


nematode –
releasing plant
available
nutrients

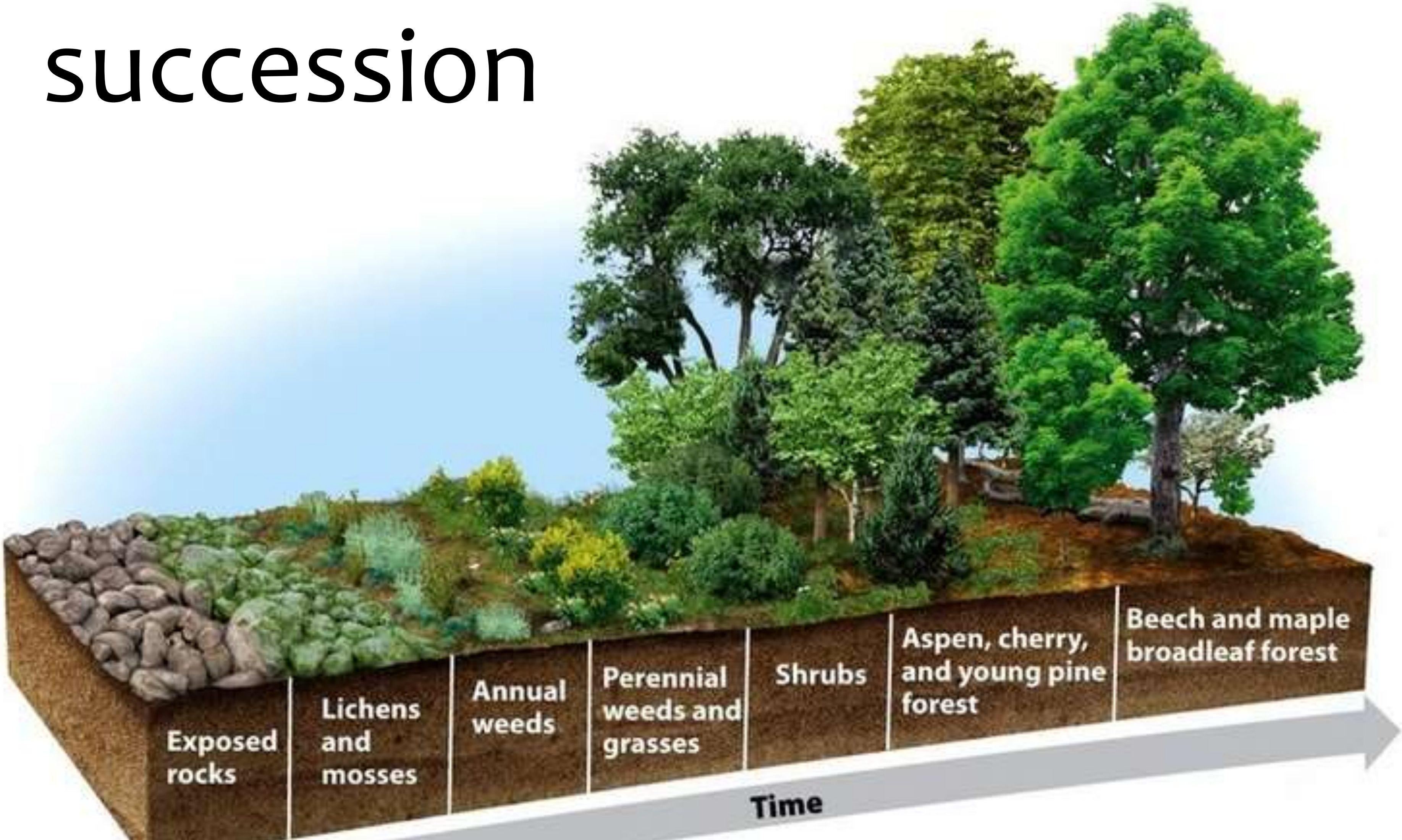
nematodes



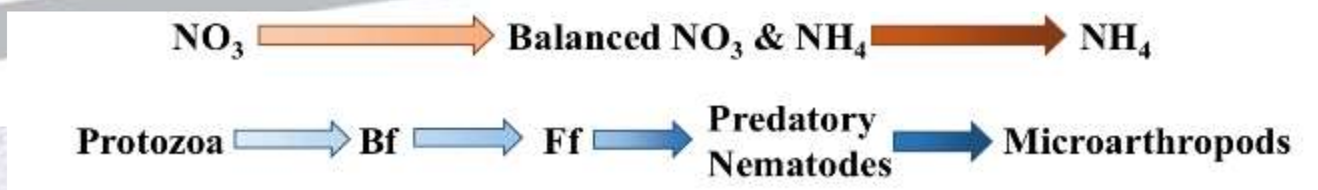
root feeding nematode

https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/soils/health/biology/?cid=nrcs142p2_053866

succession



Exposed rocks
Lichens and mosses
Annual weeds
Perennial weeds and grasses
Shrubs
Aspen, cherry, and young pine forest
Beech and maple broadleaf forest
Time



NO_3 → Balanced NO_3 & NH_4 → NH_4
Protozoa → Bf → Ff → Predatory Nematodes → Microarthropods

functional soil food web

organisms	minimal requirements/g soil
bacteria	135ug
actinobacteria	<16ug
fungi	135ug
protozoa (flagellates and amoebae) ciliates	10 000 <100
nematodes	>100

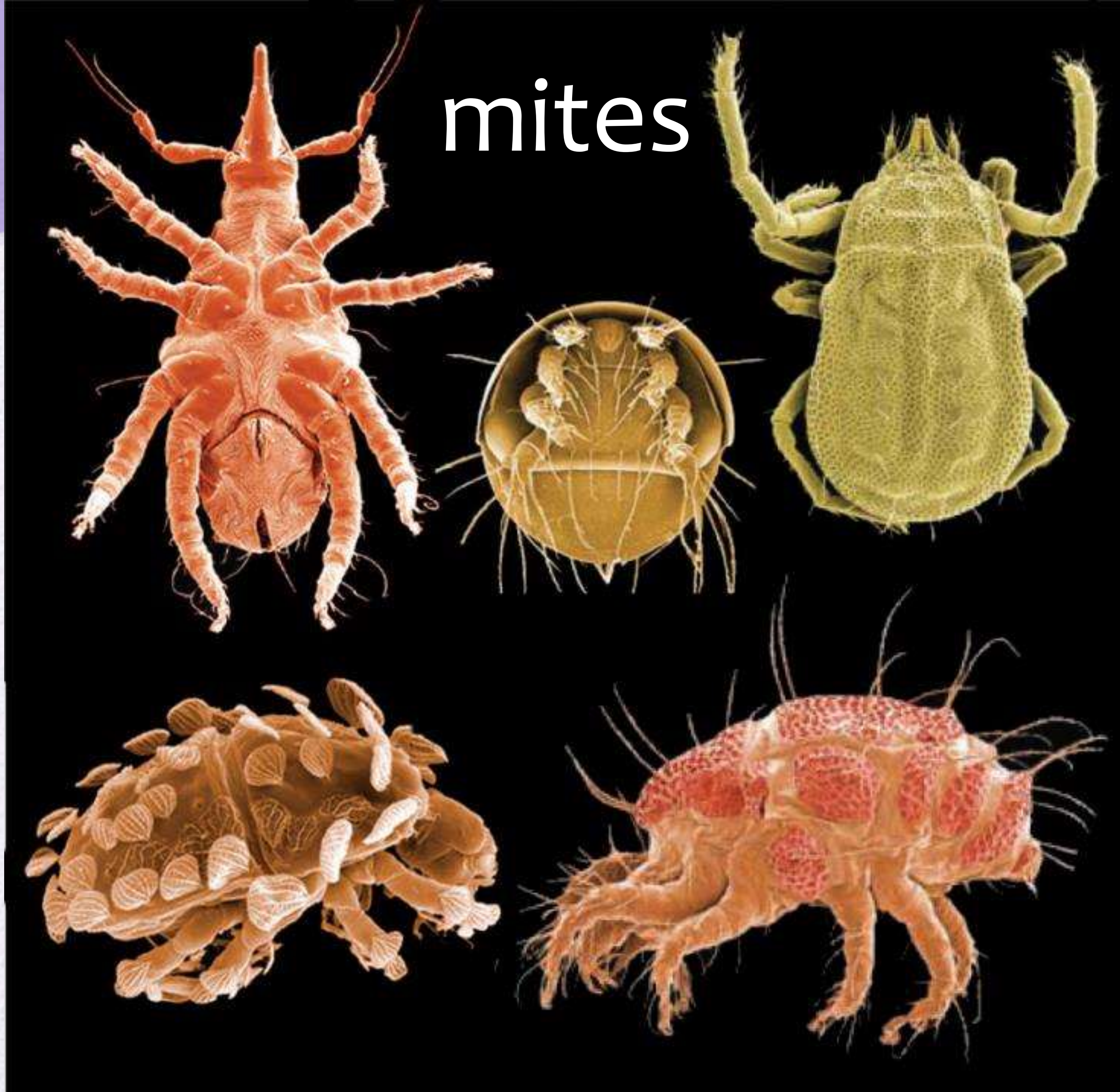
application results

Organisms	Agricultural Field	BioComplete™ Compost (1 ton/ac)	Two weeks later
Total bacteria (µg/g dry soil)	135	900	360
# bacterial sp/g soil (DNA)	5,000	75,000	75,000
Total fungi (µg/g dry soil)	2 (i.e., dirt)	428	293
# fungal species /g soil (DNA)	500	25,000	25,000
Protozoa: F, A **C**	0, 0 1,450	12,000, 31,000 29	6,000, 17,000 67

earthworms

consume, cultivate and disseminate microbes

soil nutrition – 7x N, 11x P


mites


springtails

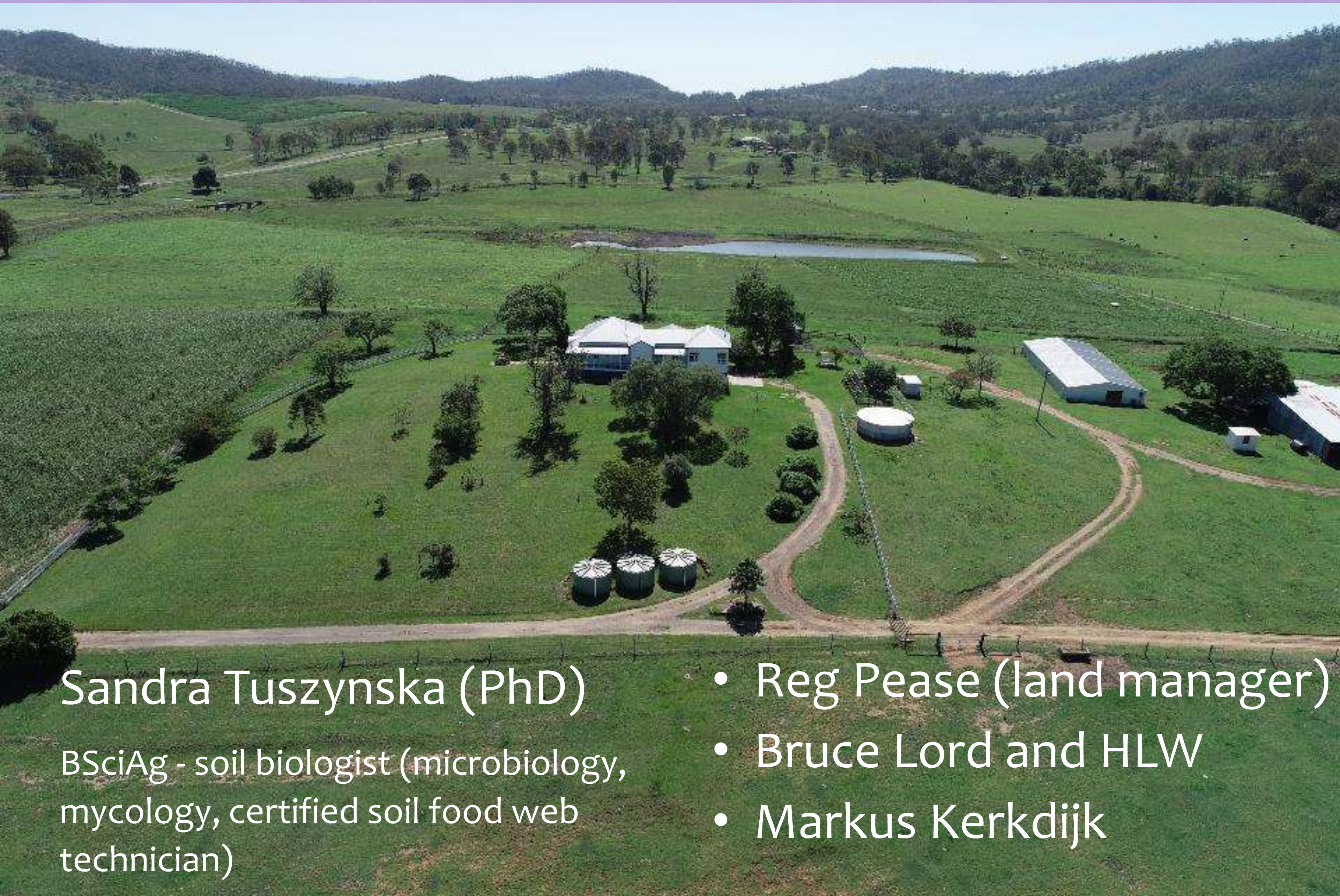
soil restoration

using biocomplete compost amendments
- vermicompost
- hot compost
- Johnson-Su bioreactor

Mycorrhizal Planet – Michael Phillips

beneficial cultivation practices

Jacaranda Hill soil biology and multispecies cover crop trial report

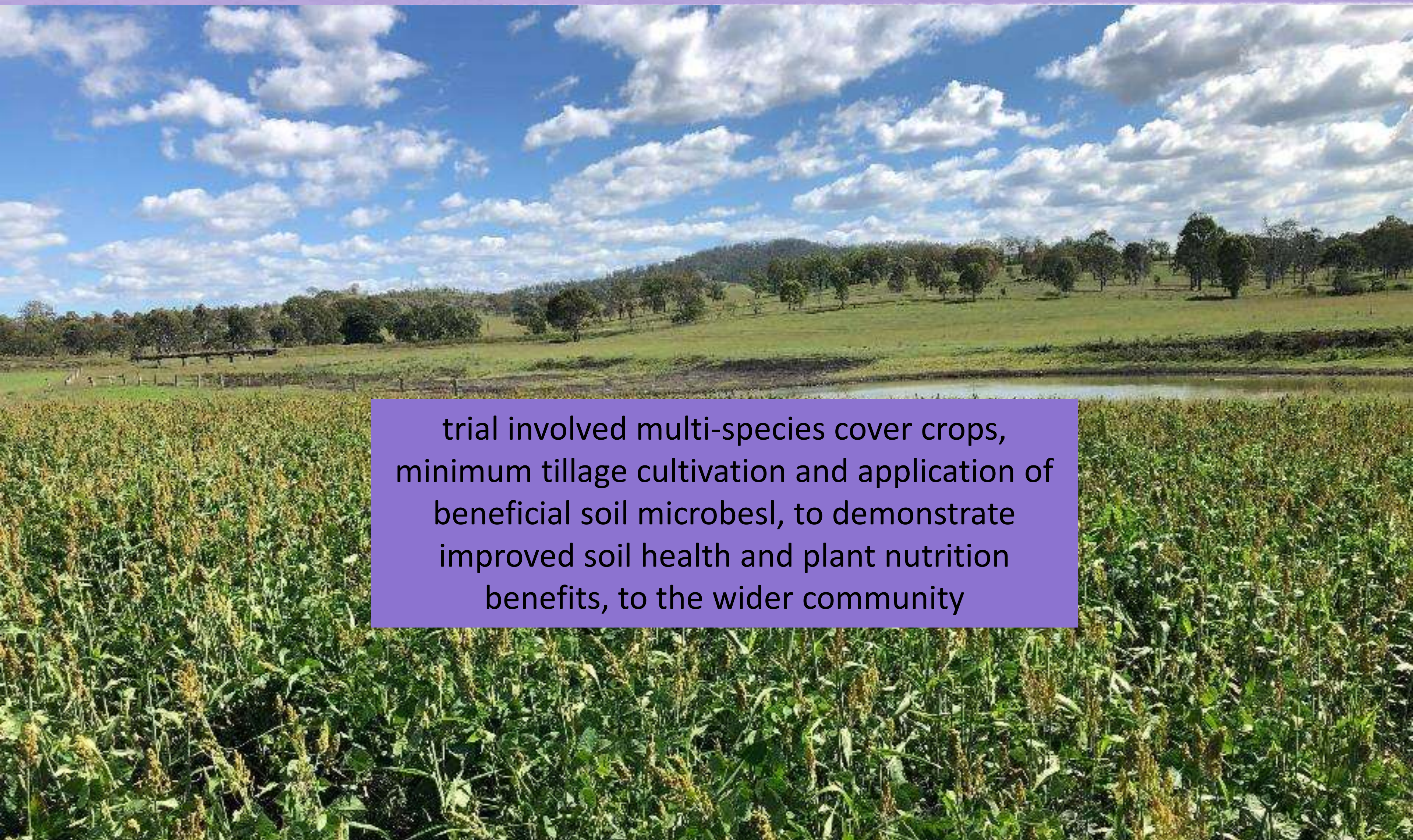


Sandra Tuszynska (PhD)

BSciAg - soil biologist (microbiology, mycology, certified soil food web technician)

- Reg Pease (land manager)
- Bruce Lord and HLW
- Markus Kerkdijk

On-farm soil microbiome restoration and cover crop trial
Brisbane Valley Kilcoy Landcare project
Supported by Healthy Land and Water, Community NRM Activity Support Grants



trial involved multi-species cover crops, minimum tillage cultivation and application of beneficial soil microbesl, to demonstrate improved soil health and plant nutrition benefits, to the wider community

trial aims

to improve soil

- biodiversity
- structure
- water holding capacity
- resistance to drought, pests and diseases

summary of activities and observations

- Thermal compost and worm farm cultivation of beneficial soil microbes
- Millet vs multispecies cover crop (8 species mix)
- November - application of compost and castings extract to seeds and soil, post sowing (hot, dry weather, minimal irrigation)
- December and March - additional extract applications to treatment crop
- Crops struggle without rain, millet monocrop poor growth, eventually strip grazed
- Multispecies cover crop takes off after March rains, especially treatment plot
- Marked difference observed in biomass and photosynthetic output of treated crop vs control
- Biological assessment did not reveal a marked soil food web organism increase, however active rhizobium nodules and root symbiotic fungi present on roots of treated crop
- Bacterial diversity increase and quorum sensing is likely to have increased and presence of bacterial predators indicates nutrient cycling

biocomplete compost preparation

cow manure

cow manure

mixerbin: cow manure, chicken manure, wood chip, silage, straw in correct proportions

loading mixerbin :
to achieve desired C:N ratio

welding compost bioreactor cage

compost bioreactor on a pallet

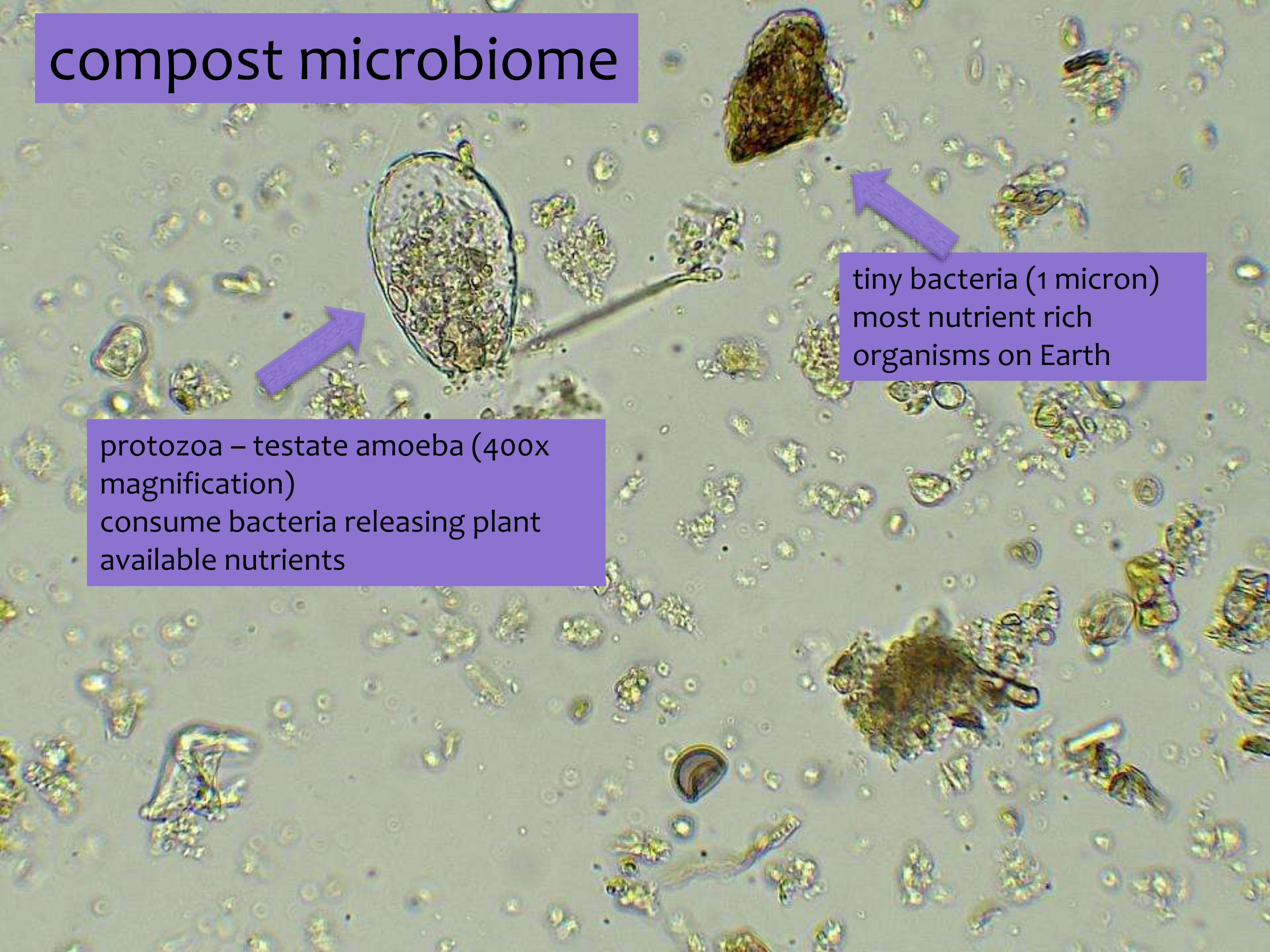
regular temperature testing of compost to prevent overheating and anaerobic conditions

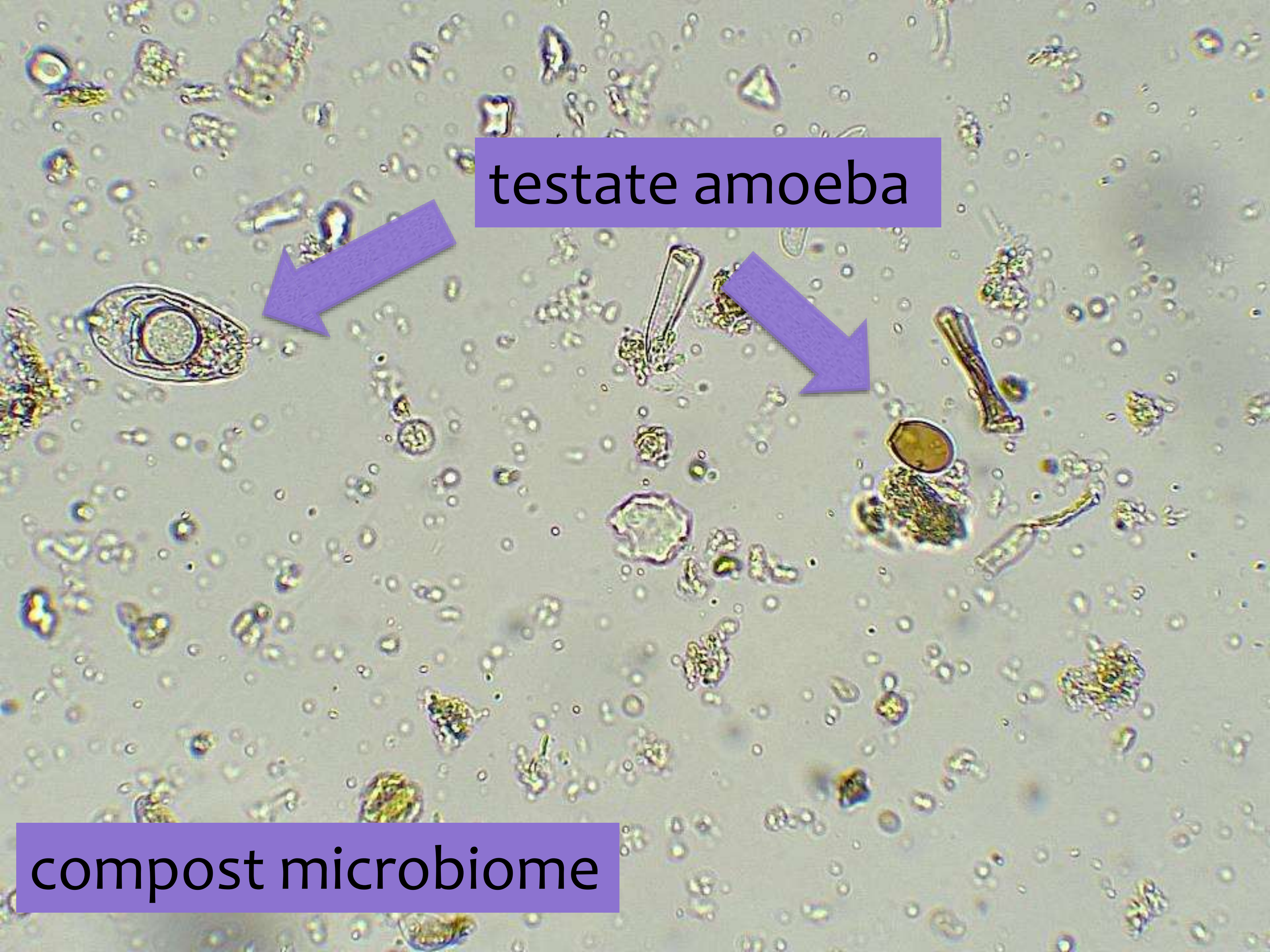
when compost reaches 75Cº it must be turned

turning hot compost while monitoring moisture

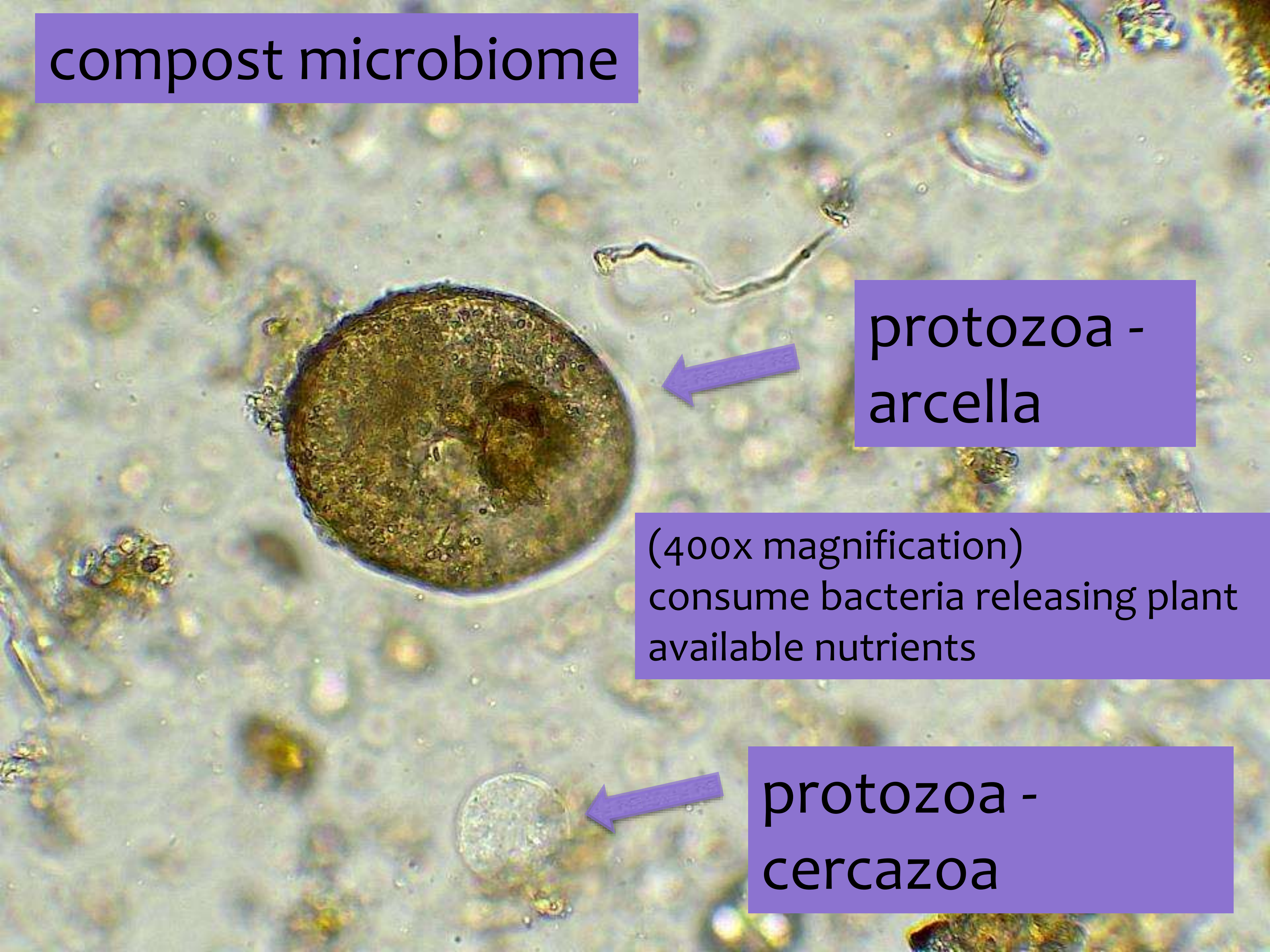
chimneys added to prevent anaerobic conditions forming from bacterial overgrowth

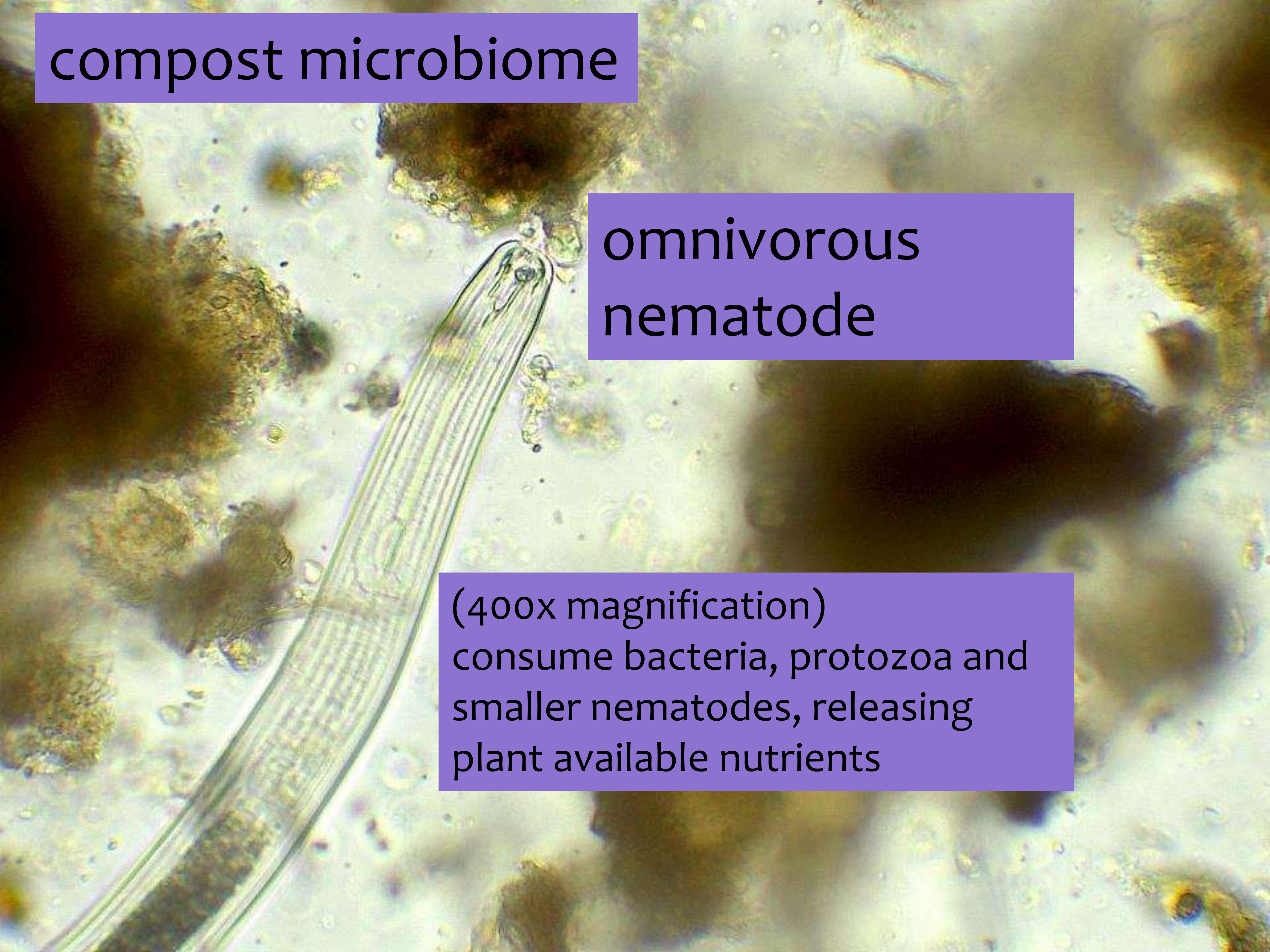
microscopy analysis of maturing compost

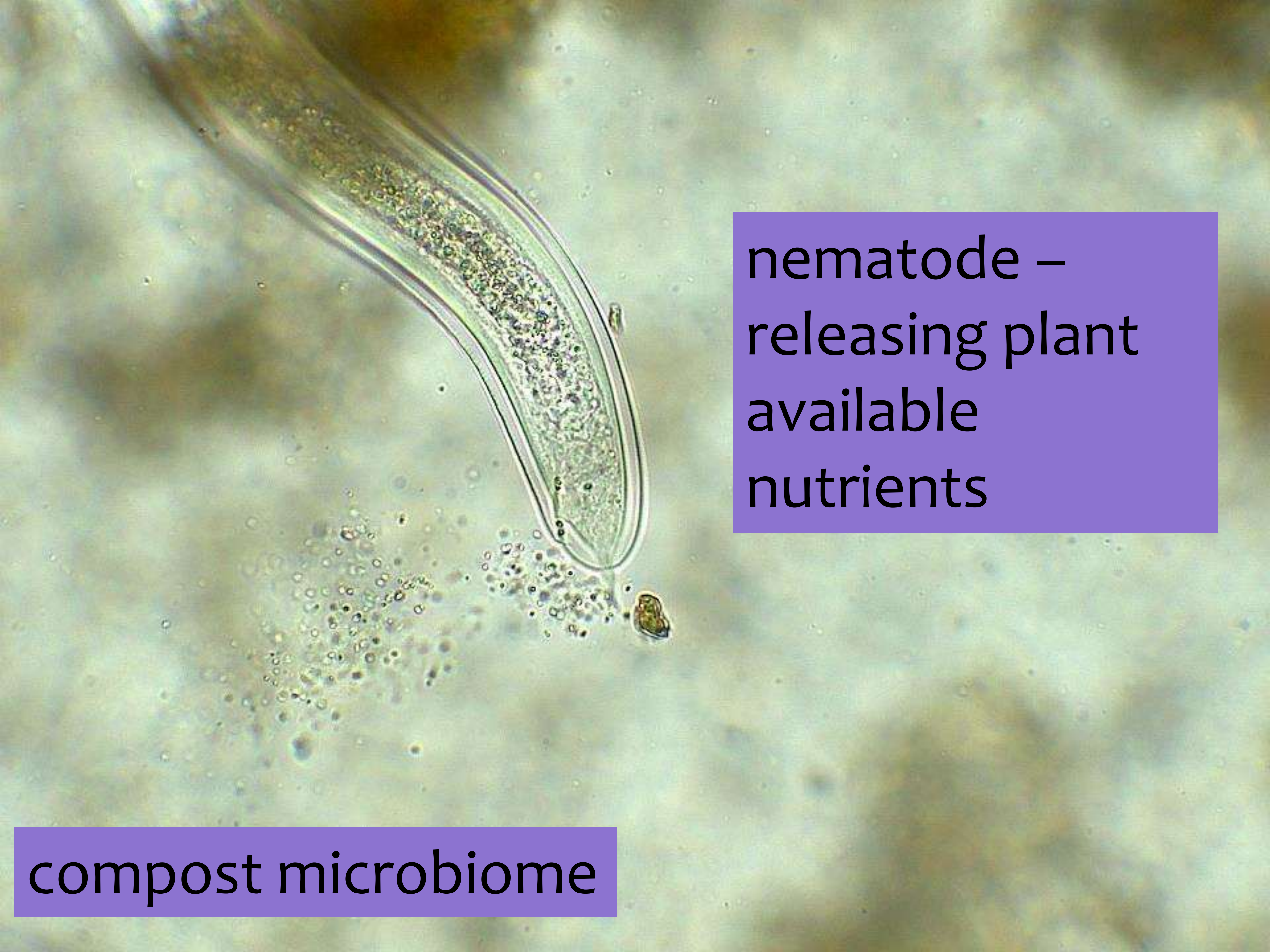

compost microbiome
tiny bacteria (1 micron)
most nutrient rich
organisms on Earth
protozoa – testate amoeba (400x
magnification)
consume bacteria releasing plant
available nutrients

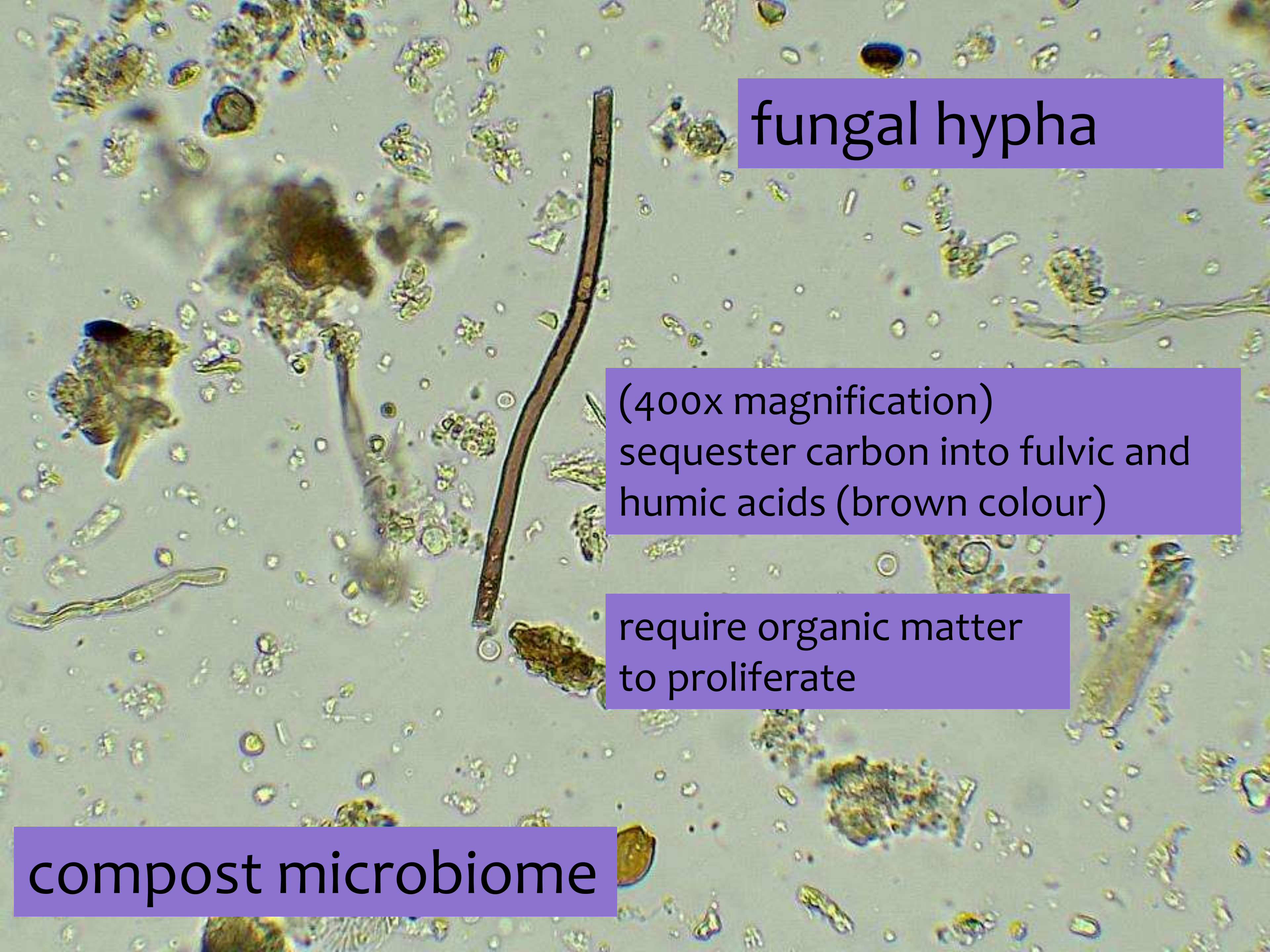

testate amoeba
compost microbiome

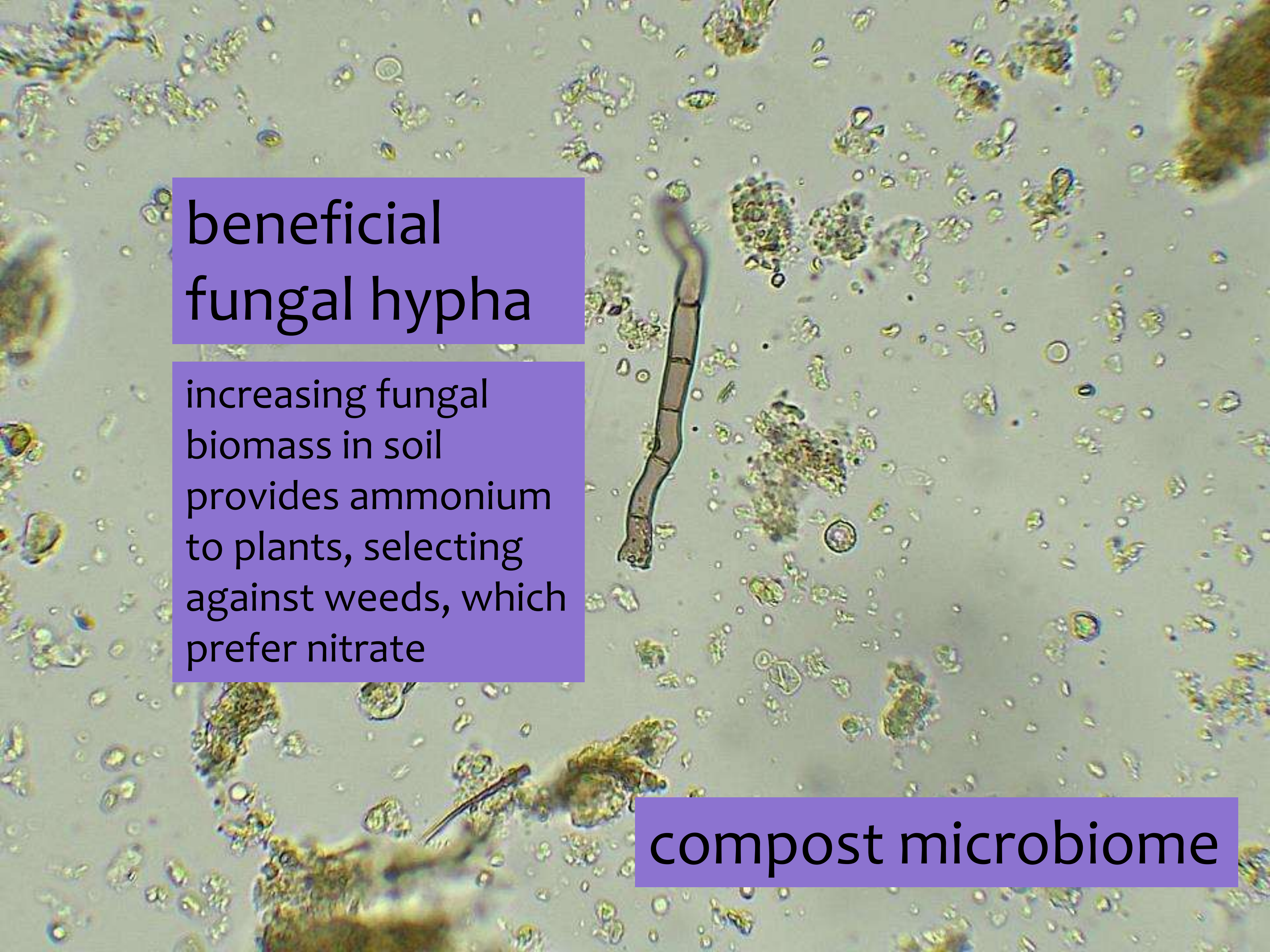
compost microbiome




compost microbiome
omnivorous nematode
(400x magnification)
consume bacteria, protozoa and smaller nematodes, releasing plant available nutrients


nematode –
releasing plant
available
nutrients
compost microbiome


fungal hypha
(400x magnification)
sequester carbon into fulvic and humic acids (brown colour)
require organic matter to proliferate
compost microbiome


beneficial fungal hypha
increasing fungal biomass in soil provides ammonium to plants, selecting against weeds, which prefer nitrate
compost microbiome

functional soil food web

organisms	minimal requirements/g soil
bacteria	135ug
actinobacteria	<16ug
fungi	135ug
protozoa (flagellates and amoebae) ciliates	10 000 <100
nematodes	>100

Our compost surpassed these minimal values

soil food web microbial analysis report of compost

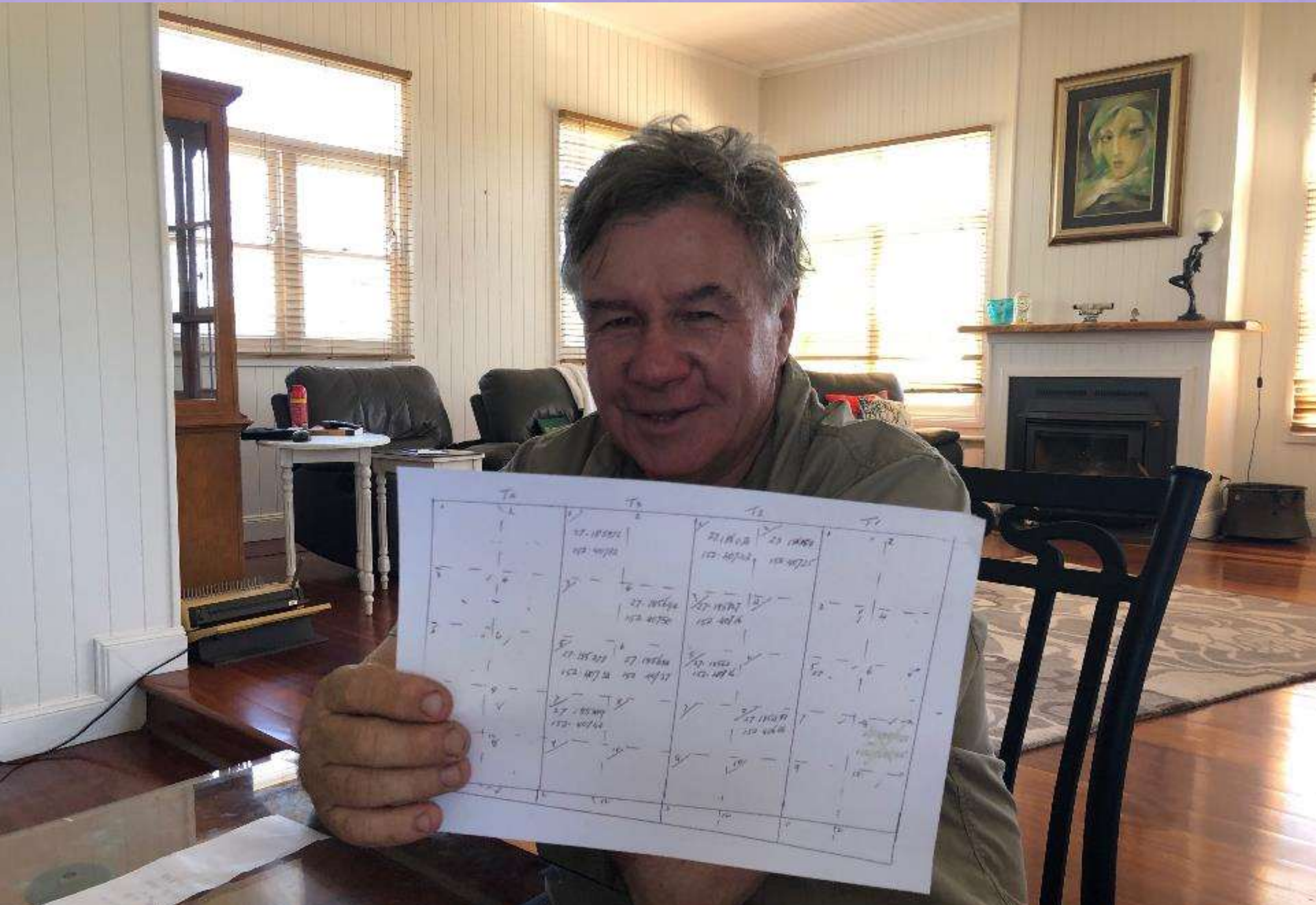
Beneficial Microorganisms	Sample Results
Bacterial Biomass (µg/g)	416.884
Bacterial Standard Deviation Biomass (µg/g)	98.912
Bacterial Standard Deviation as Percentage of Mean	23.70%
Actinobacterial Biomass (µg/g)	0.707
Actinobacterial Standard Deviation Biomass (µg/g)	0.585
Actinobacterial Standard Deviation as Percentage of Mean	82.70%
Fungal Biomass (µg/g)	969.841
Fungal Standard Deviation Biomass (µg/g)	437.203
Fungal Standard Deviation as Percentage of Mean	45.10%
Fungal Average Diameter - Weighted Mean (um)	4.872
F:B Ratio	2.322
Total Beneficial Protozoa (number/g)	520065.0
Total Beneficial Protozoa Standard Deviation (number/g)	314915.0
Total Beneficial Protozoa Standard Deviation as Percentage of Mean	60.60%
Flagellates (number/g)	187223.0
Flagellates Standard Deviation (number/g)	174392.0
Flagellates Standard Deviation as Percentage of Mean	93.10%
Amoebae (number/g)	332842.0
Amoebae Standard Deviation (number/g)	154276.0
Amoebae Standard Deviation as Percentage of Mean	46.40%
Bacterial-feeding Nematodes (number/g)	630.0
Fungal-feeding Nematodes (number/g)	105.0
Predatory Nematodes (number/g)	105.0

Detrimental Microorganisms	Sample
Oomycetes Biomass (µg/g)	54.563
Oomycetes Standard Deviation Biomass (µg/g)	25.787
Oomycete Standard Deviation as Percentage of Mean	47.30%
Oomycetes Average Diameter - Weighted Mean (um)	1.615
Ciliates (number/g)	62408.0
Ciliates Standard Deviation (number/g)	56970.0
Ciliates Standard Deviation as Percentage of Mean	91.30%
Root-feeding Nematodes (number/g)	0

fungal to bacterial biomass ratio of 1:1 is enough to grow healthy crops

Export | Soil Biology Report | Help | Exit

27th November, 2020 – trial map and planning



modifying machinery to suit compost extract application

modifying sprayer positions to deliver extract onto dropped seed


compost and worm farm castings
for seed and soil inoculation

8 x seed cover crop mix

seed inoculant prep (molasses, water and milk mix)

seed inoculation and mixing

seed spreading

seed drying

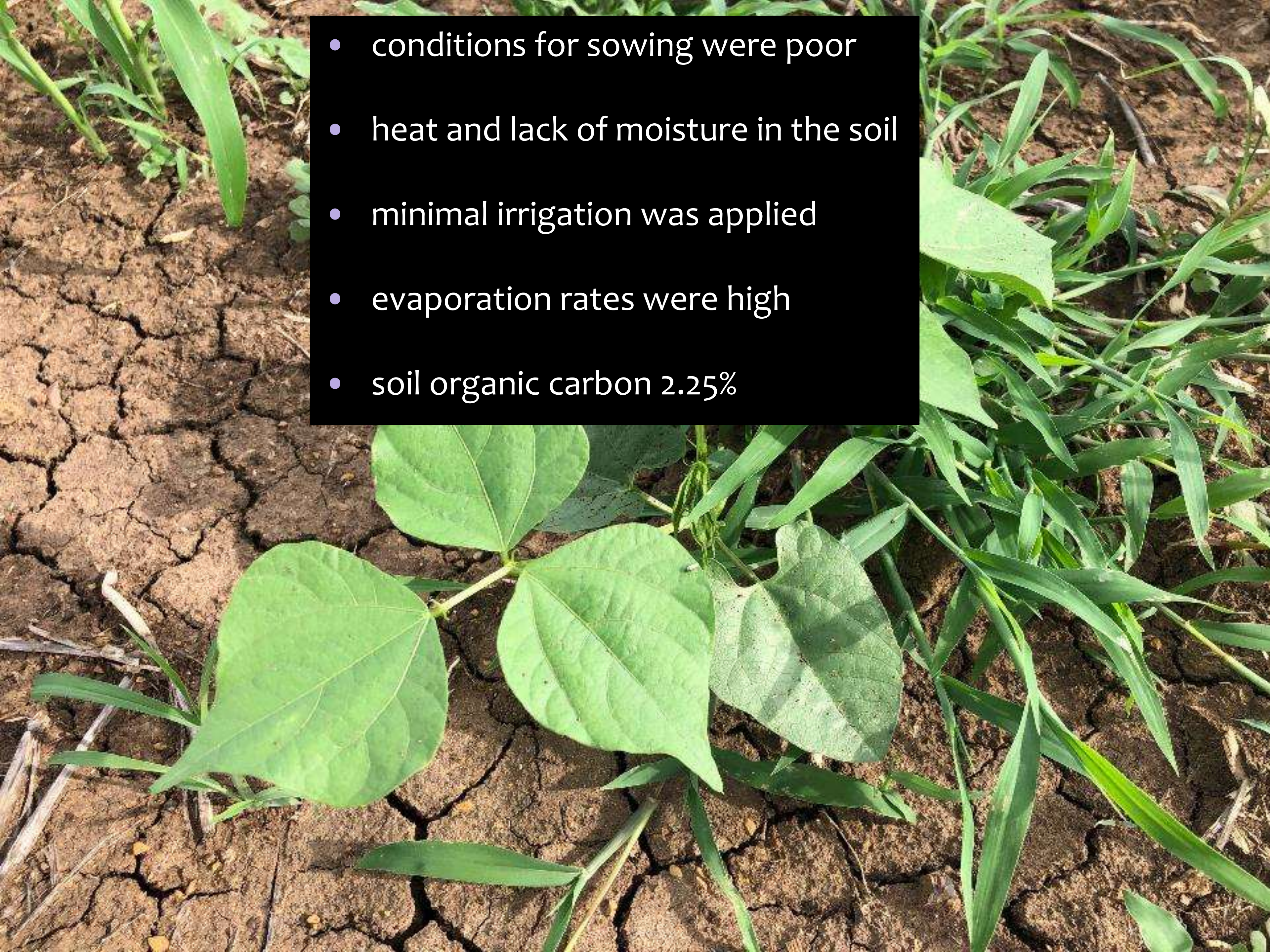
we hand extracted microbes from the compost
but compost tea brewers can be used

lack of soil moisture and ~40C° were unfavorable for sowing

Rainfall Registration For Jacarandahill 2020

From 9 am to 9 am daily

January mm	Febuary mm	March mm	April mm	May mm	June mm	July mm	August mm	September mm	October mm	November mm	December mm	Date
												1
												2
	5											3
	11											4
	20			1								5
	44						13					6
											22	7
	22											8
	12	33										9
	40	34										10
2		40									8.5	11
	27										6	12
	10									1		13
											27	14
					7	8.5					7	15
23							2.5		6			16
				9.5								17
18					4							18
2											6	19
			4									20
7					7				15			21
15												22
												23
									16			24
30												25
						13			26			26
									9			27
									20			28
												29
									5			30
									2			31
97	191	107	4	10.5	18	21.5	15.5	0	99	1	76.5	Monthly Total
												YEARLY
97	288	395	399	409.5	427.5	449	464.5	464.5	563.5	564.5	641	641



- conditions for sowing were poor
- heat and lack of moisture in the soil
- minimal irrigation was applied
- evaporation rates were high
- soil organic carbon 2.25%

November 27, 2020 sowing inoculated seed

hot (~40C°), dry summer's day

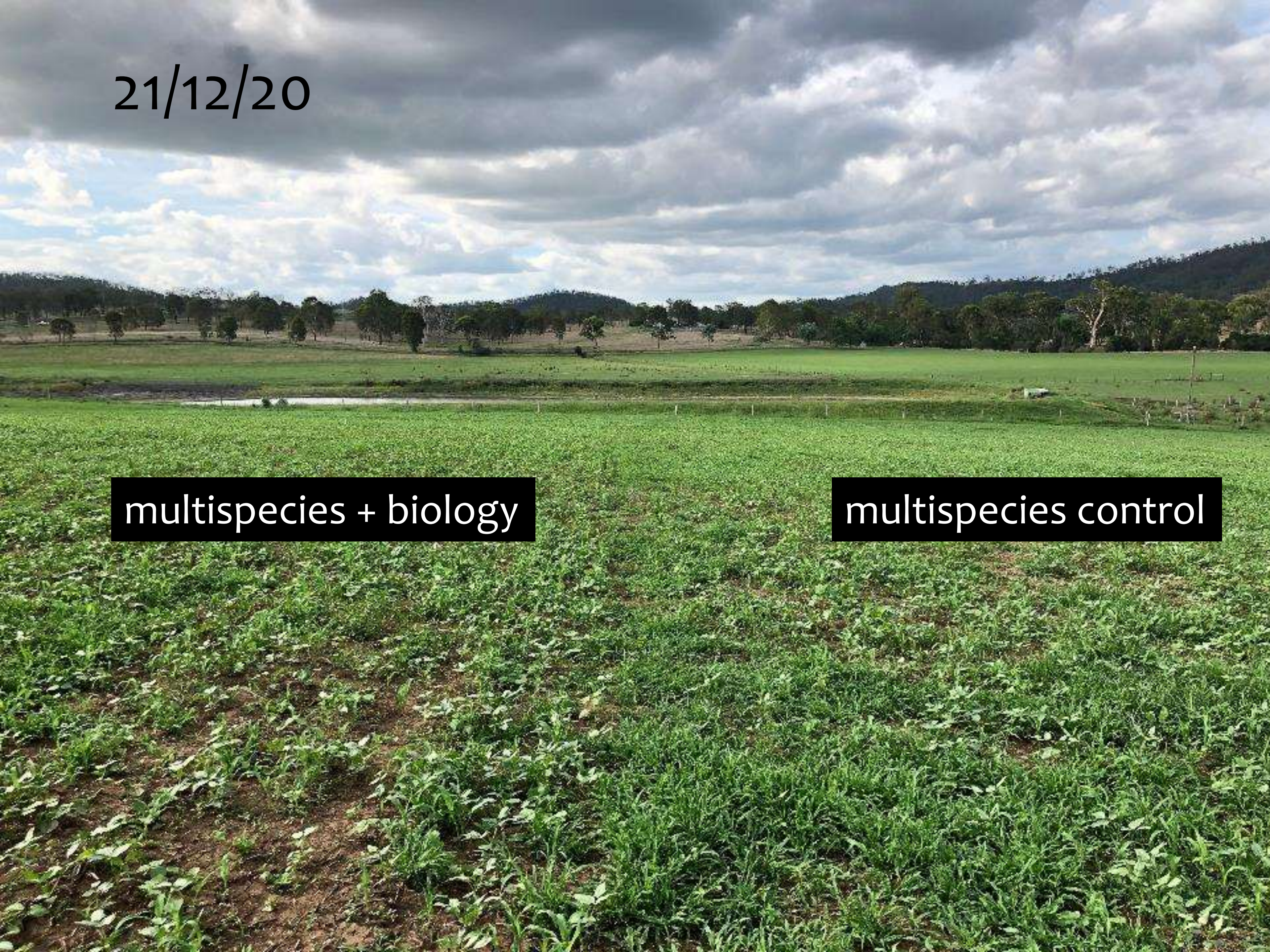
compost extract application trouble shooting

tank-pump connection failed, only parts of field received compost extract


21/12/20
millet
(mostly weedy grass)
multispecies

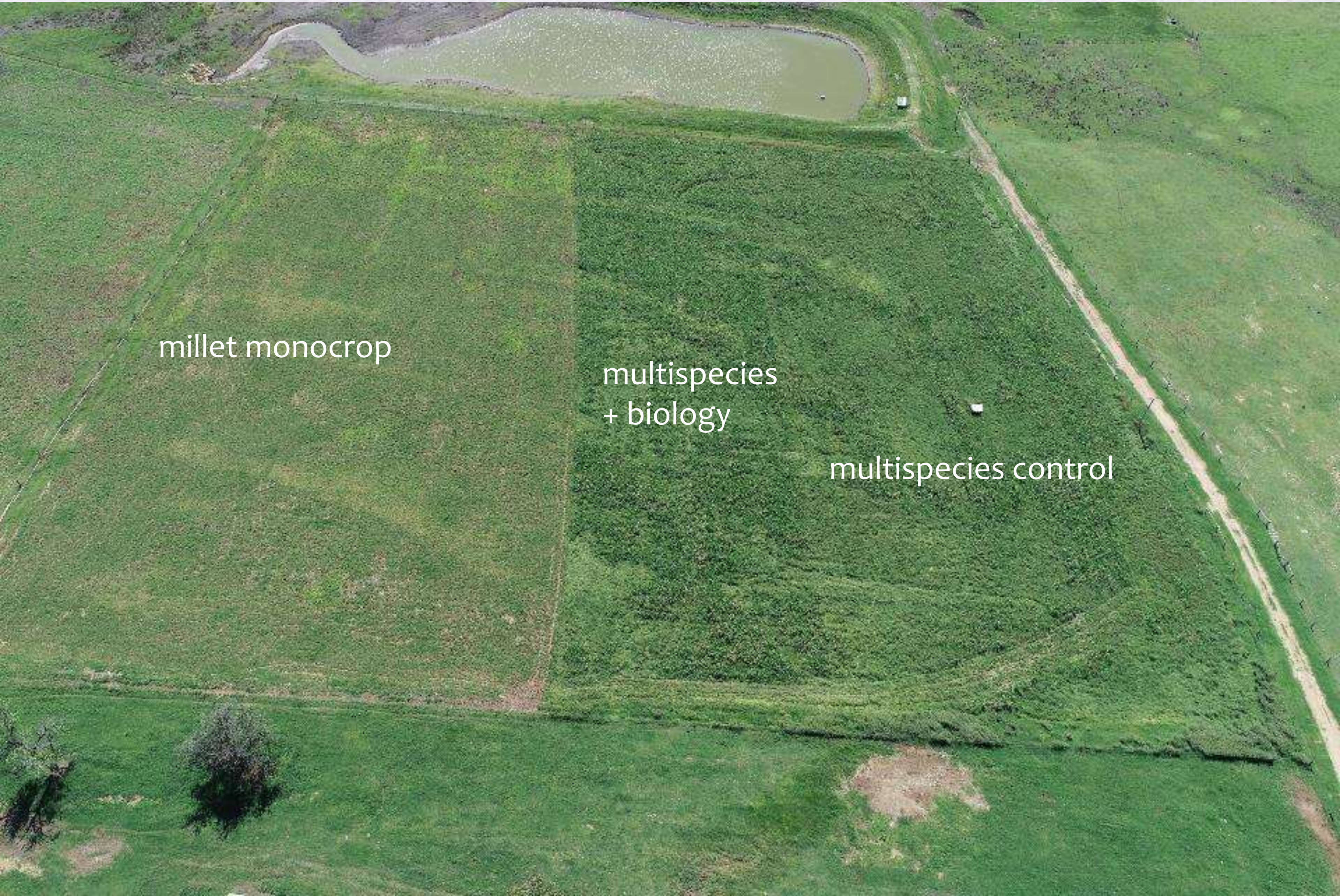

21/12/20
millet crop (mostly other grass took over) potentially sown too deep
multispecies


21/12/20
multispecies
millet/grass


21/12/20
multispecies + biology
multispecies control

December 2020 – before rainfall

millet crop failed and was strip grazed



a bit of rain in March got the crop growing

Rainfall Registration For Bolena 2021

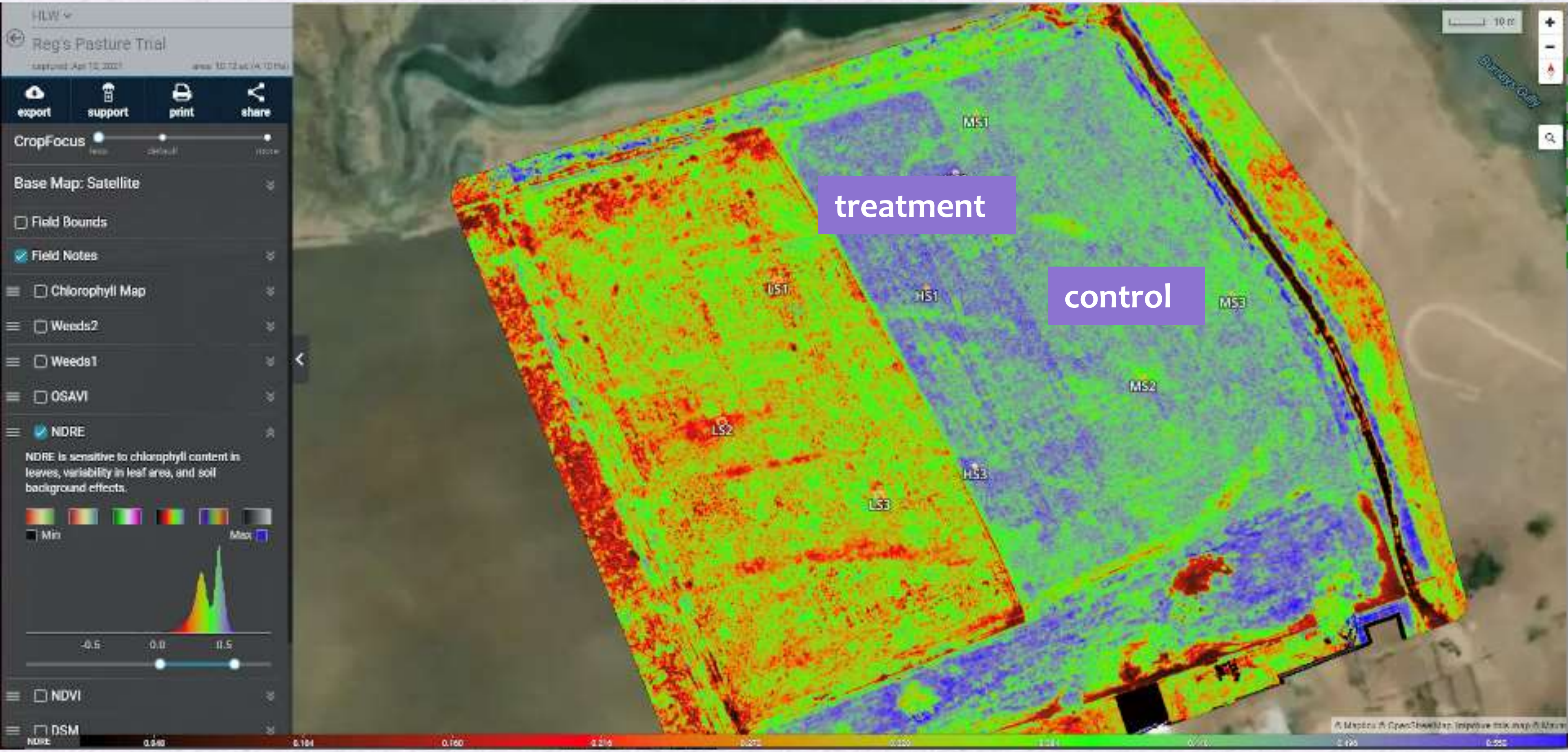
From 8 am to 8 am daily

Date	January mm	Febuary mm	March mm	April mm	May mm	June mm	July mm	August mm	September mm	October mm	November mm	December mm	Date
1	4.5				14								1
2			5										2
3						10							3
4			7.5	8									4
5	2.5			13	32								5
6	14			4									6
7				1									7
8		2											8
9	8.5		11.5			10							9
10			2										10
11					27								11
12					25								12
13		4											13
14			12		51								14
15			12										15
16		5	17										16
17	4.5	9	22										17
18													18
19													19
20													20
21			24										21
22			21.5										22
23													23
24			25										24
25		3											25
26													26
27													27
28	4.5												28
29													29
30													30
31													31
Monthly Total	34	23	159.5	26	149	20	0	0	0	0	0	0	Monthly Total
Running													YEARLY
411.5	34	57	216.5	242.5	391.5	411.5	411.5	411.5	411.5	411.5	411.5	411.5	411.5

April 2021 – multispecies cover-crop biomass measurements

Normalised Difference Red Edge (NDRE) –
NDRE is sensitive to chlorophyll content in leaves, variability in leaf area for pasture assessment.
This is calculated using the red edge and near infrared bands, light reflectance humans cannot see

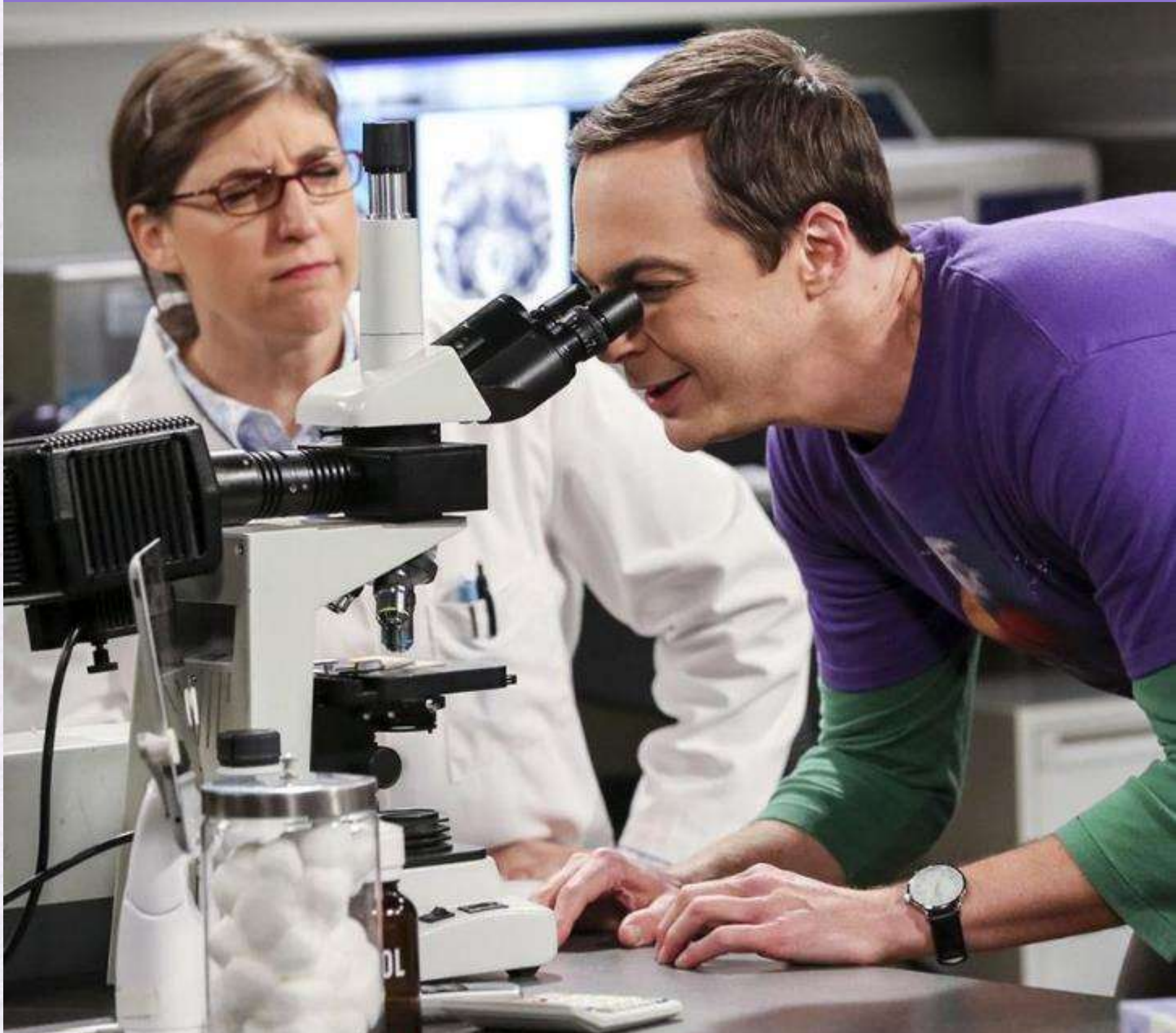
Treatment plot demonstrates higher chlorophyll content in multispectral capture data

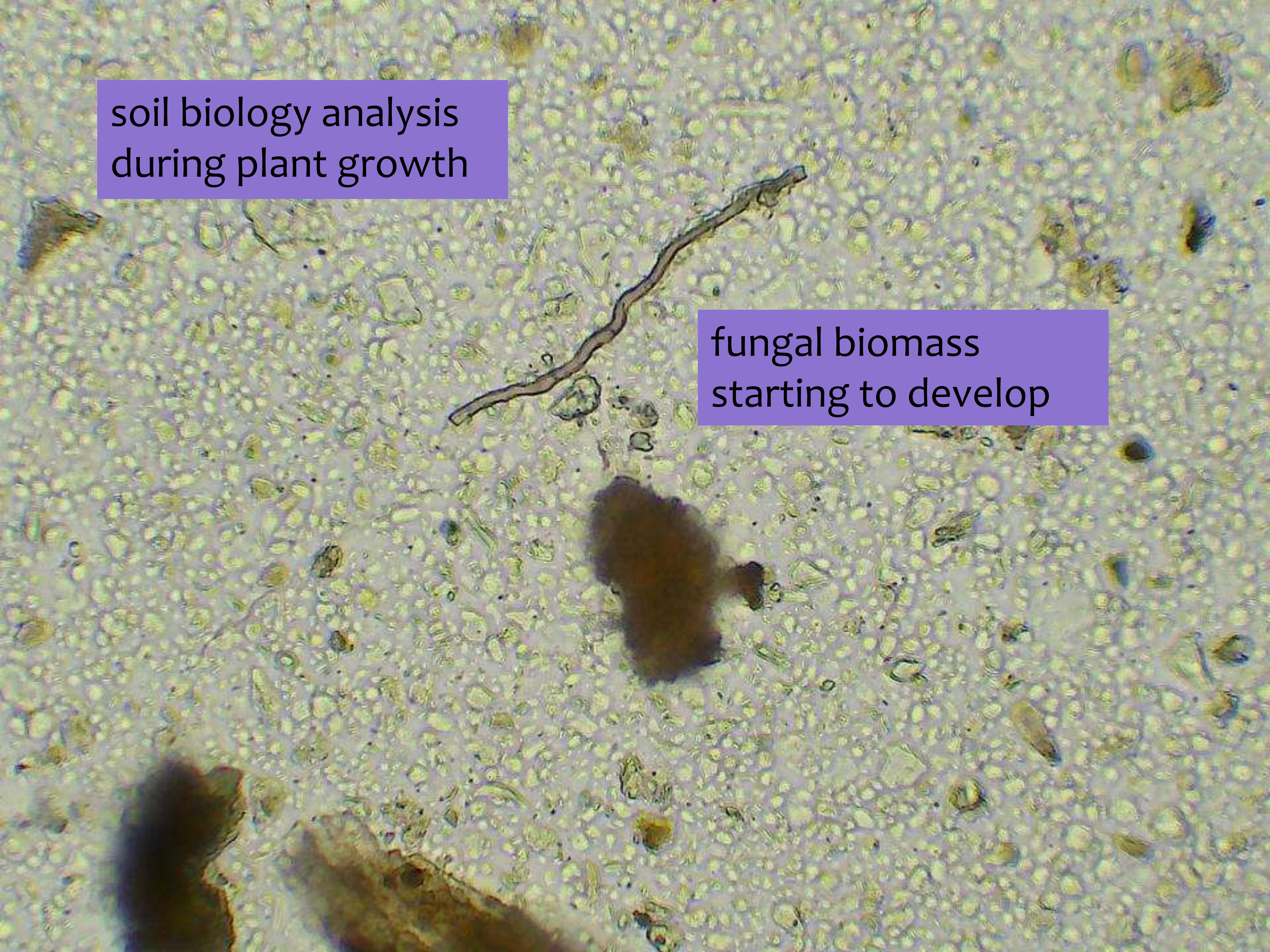


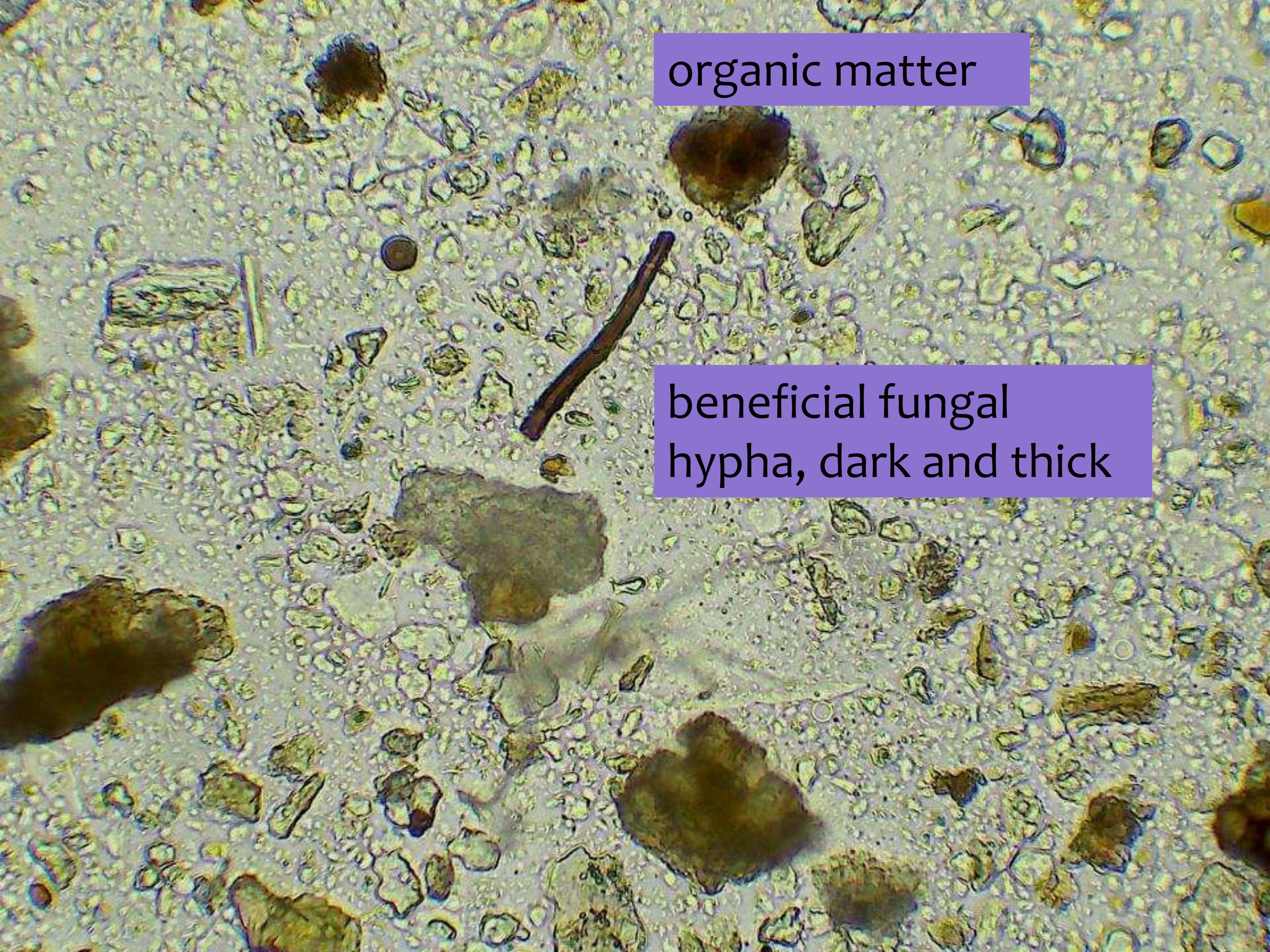
AirBorn Insight Pty Ltd

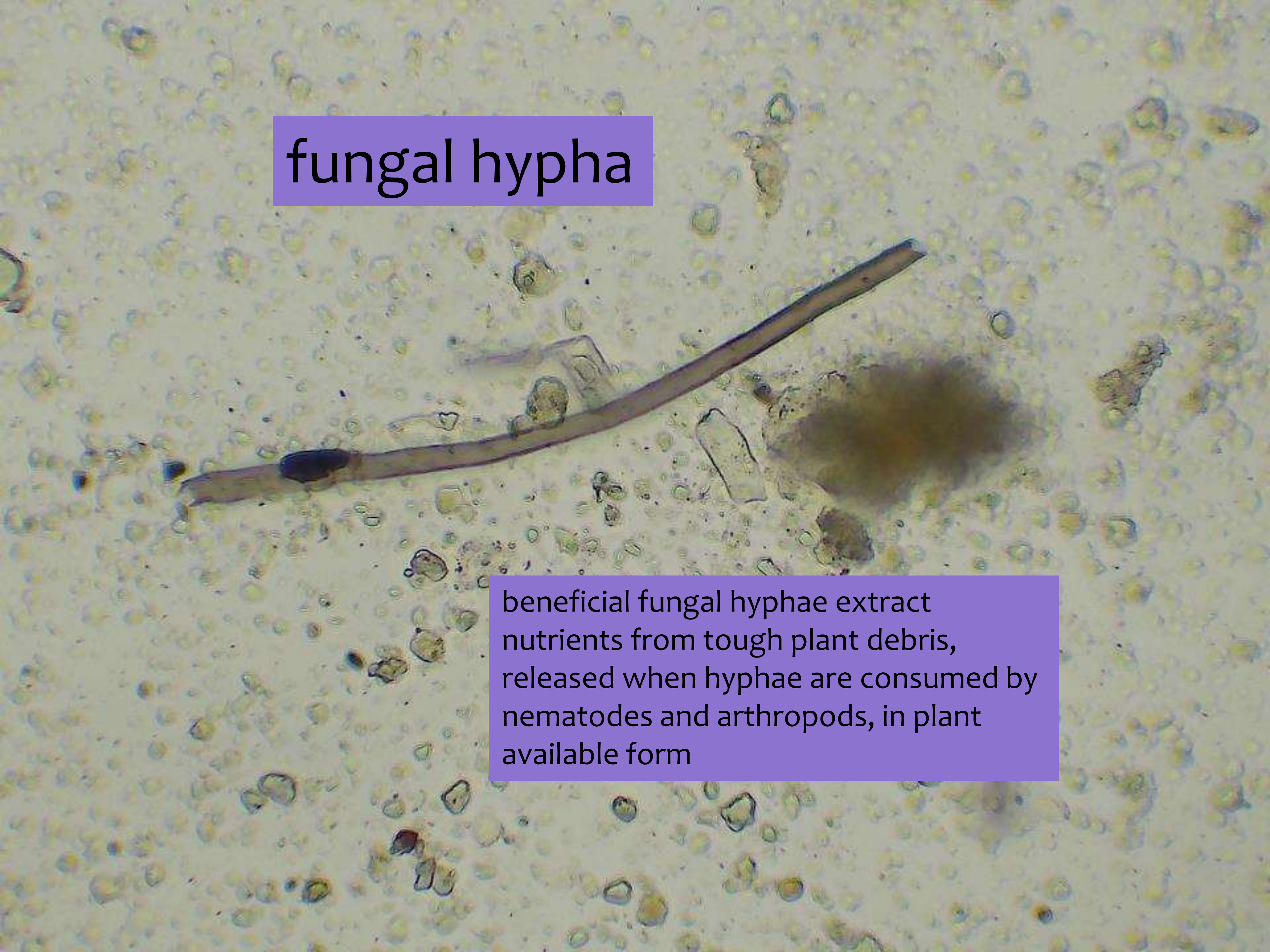
microscopy of soil microbiology

microscopy analysis continued as crop developed and compost matured




soil biology analysis
during plant growth
fungal biomass
starting to develop


organic matter
beneficial fungal hypha, dark and thick



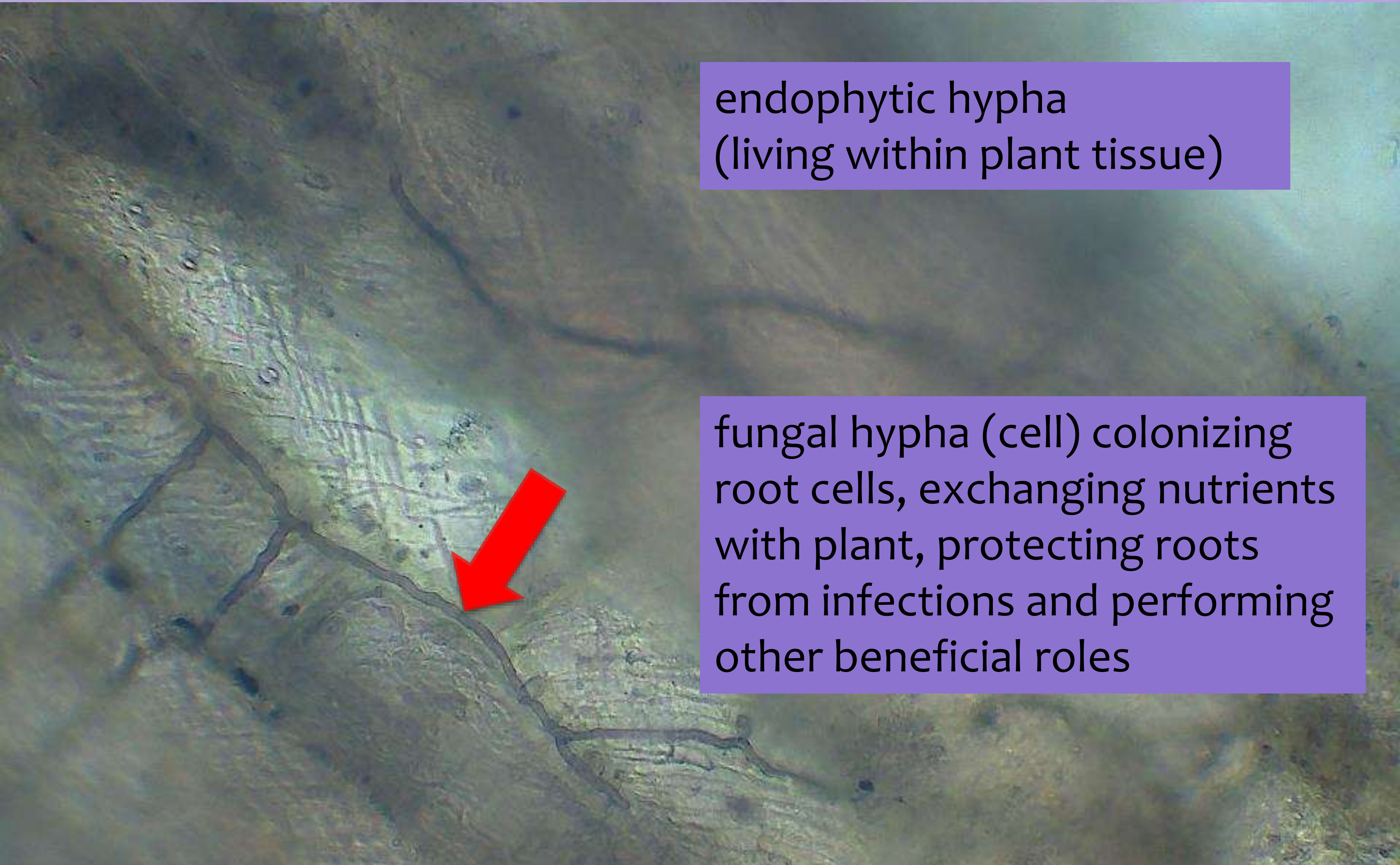
fungal hypha

beneficial fungal hyphae extract nutrients from tough plant debris, released when hyphae are consumed by nematodes and arthropods, in plant available form

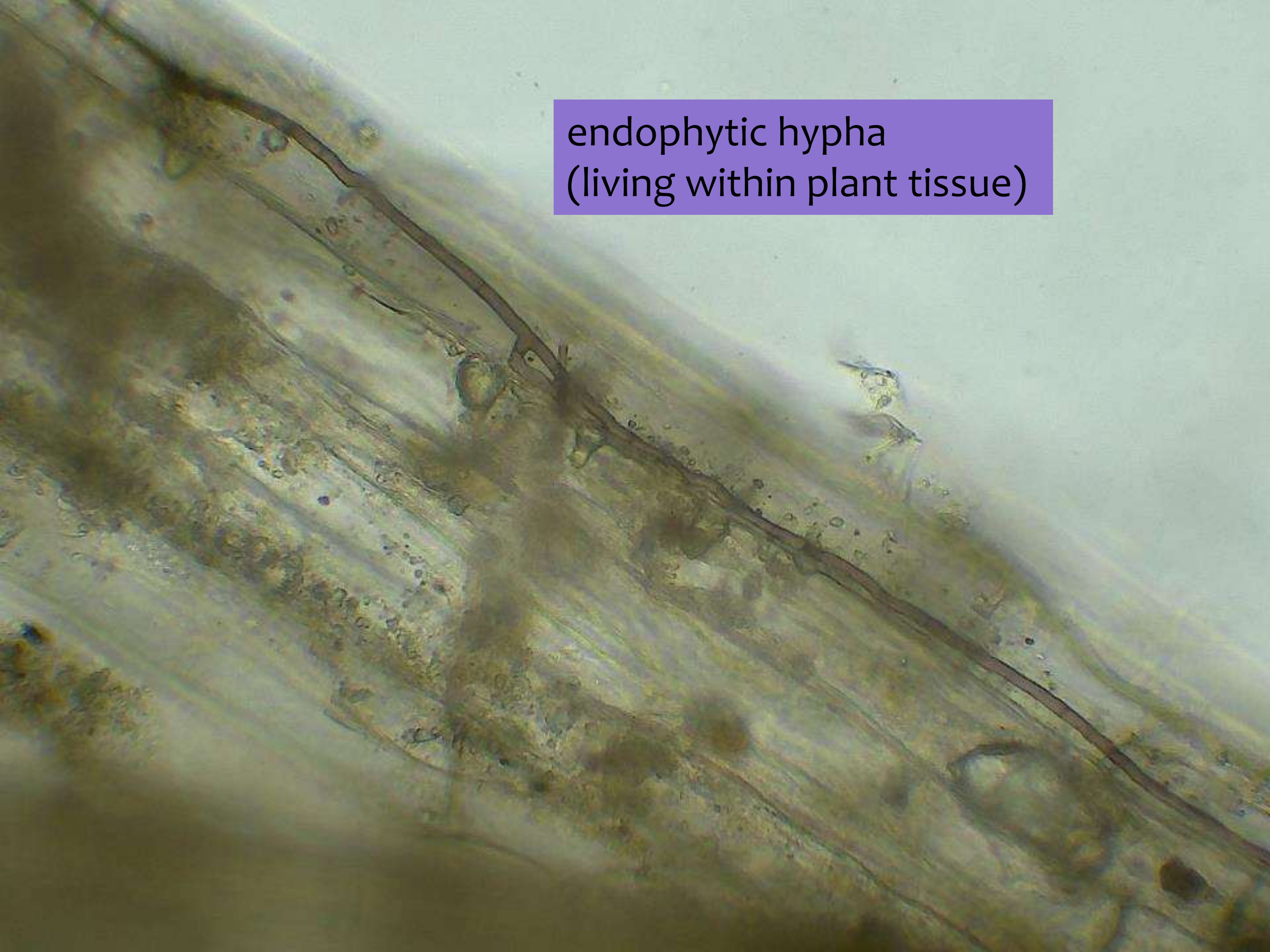

fungal hypha
when beneficial fungal hyphae die, containing chitin, fulvic and humic acids which are recalcitrant humus building blocks, they build soil carbon and soil structure

roots and rhizosphere microscopy analysis

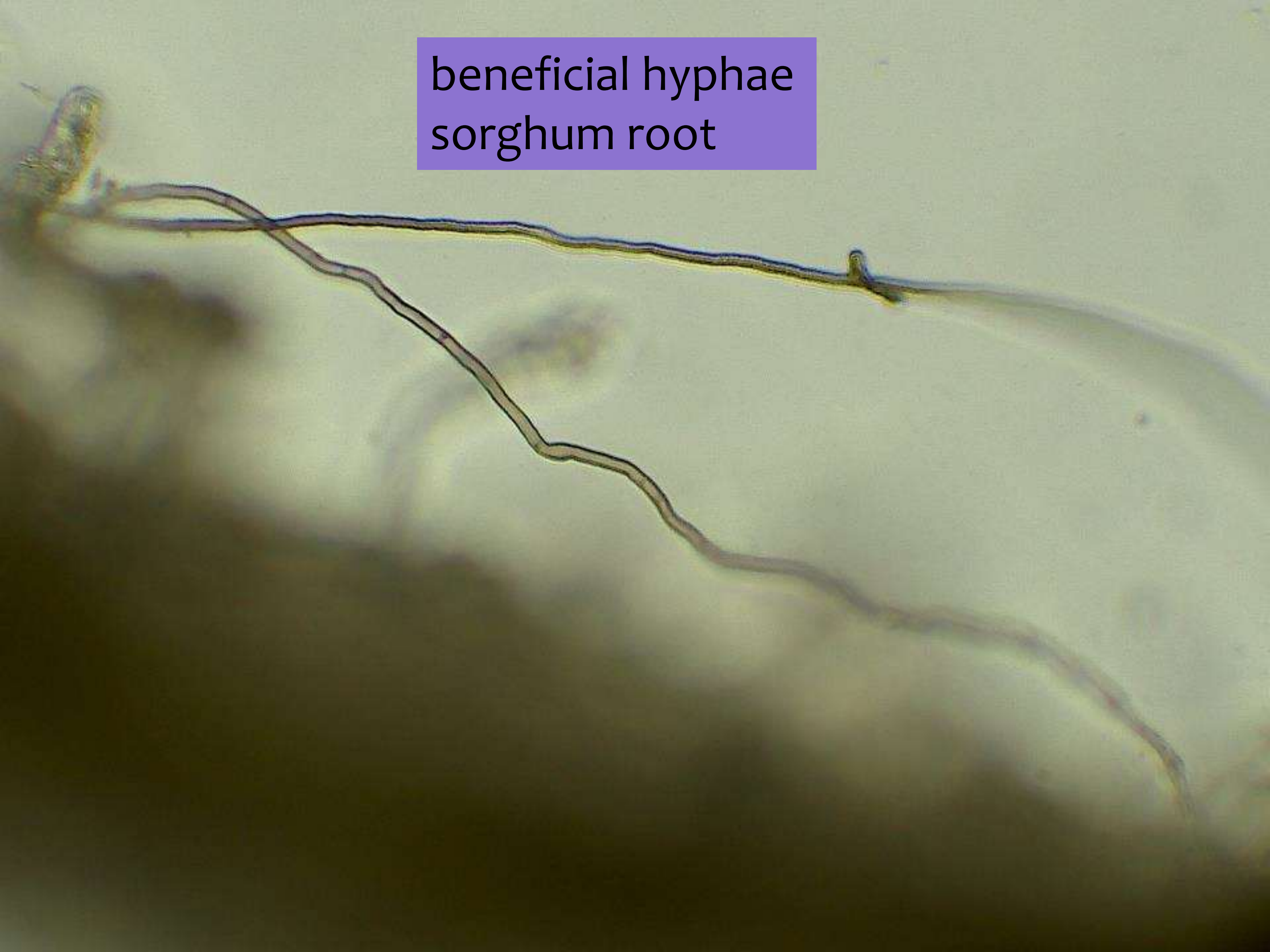
sorghum root associated fungi



beneficial hypha infection within sorghum root


endophytic hypha
(living within plant tissue)

endophytic hypha branching (living within plant tissue)


beneficial hyphae
sorghum root


beneficial hypha
sorghum root

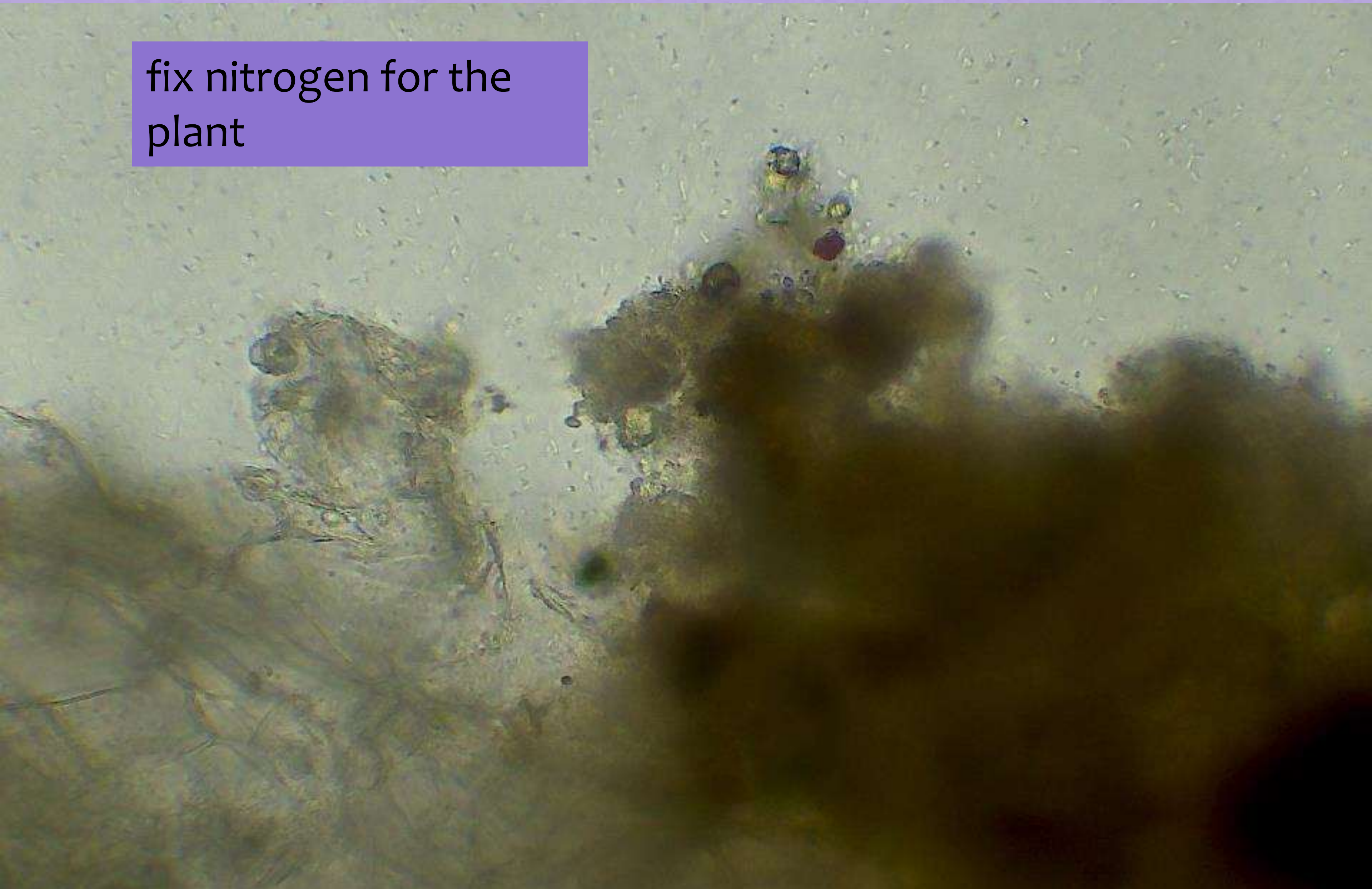

fungal feeding nematode, releases plant available nutrients like ammonium, selecting against weed proliferation, as weeds prefer nitrate


arcella, protozoan: consume bacteria in large amounts, releasing plant available nutrients

Rhizobium nodule on cowpea roots

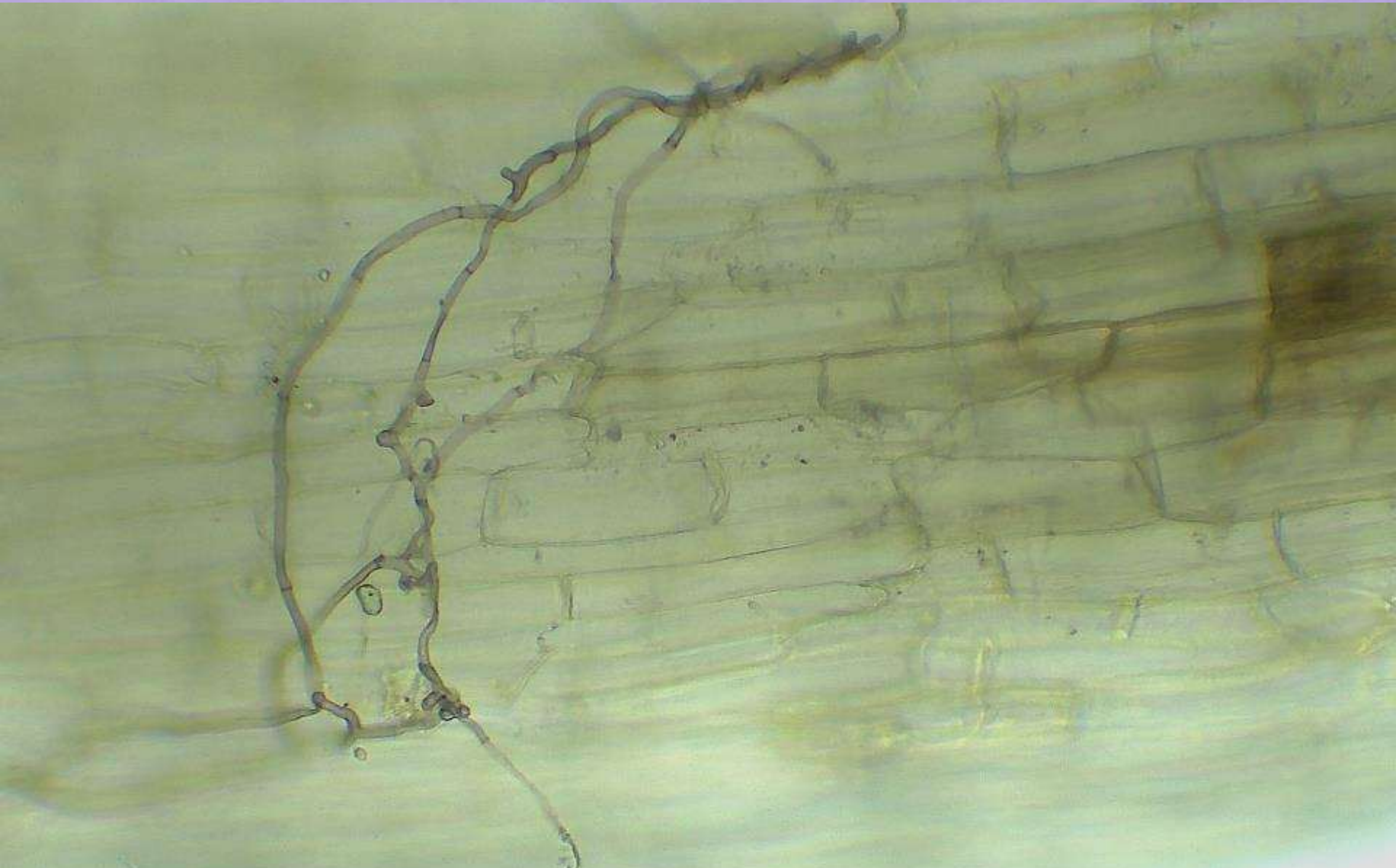
Rhizobium nodules fix nitrogen in legumes

Rhizobium bacteria (rods) from squashed nodule



fungal hypha in cowpea root

branching fungal hyphae within cowpea root



fungal hypha from cowpea rhizosphere

fungal hypha, thick and dark is what we want

May 2021 – crimper-roller trial

5th of May open field day

~40 members of the community attended an open field day to learn about the trial

presentation on the trial and the role of beneficial soil microbe cultivation for improved plant nutrition, immunity and soil health

AirBorn presented on the use of multispectral capture in plant health assessment

direct drill demo


cowpea and sorghum thriving

goals

diversity of plant families : diverse exudates improve nutrient cycling and plant immunity

minimise/avoid soil disturbance: direct drill to ensure survival of microbes

provide perennial ground cover to feed beneficial microbes

increase:
soil moisture, structure
drought resistance,
carbon sequestration,
nutrient availability/cycling,
plant immunity/vigour,
animal/human nutrition

eliminate weeds, fertilizer and pesticide costs, reduce work-load

ensure soil moisture

create compost

check for microbial diversity and apply extract/tea to soil/plants

retain crop residue and mulch to increase soil organic matter and fungal biomass

Giving Soil

https://www.patreon.com/givingsoil

- Community cultivated soil microbiome
- Given to producers
- Applied to land dedicated to biological restoration
- Food tested for nutritional value and sold at a premium

- Chemical free
- Restorative and regenerative
- No till
- Perennial cover cropping

flow through worm farm

Johnson-Su Bioreactor

Dr. David C. Johnson, molecular biologist and research scientist at the University of New Mexico, has developed a system that brings lifeless soils back to life by reintroducing beneficial microorganisms to the soil with biologically enhanced compost.

For more info contact:

Sandra Tuszynska
loveoursoils@gmail.com
0459 228 575

services:

- soil microscopy
- consultancy
- worm farm and compost set up and analyses
- community education
- https://www.patreon.com/givingsoil








Thank you