Soil and Nutrient Network

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Welcome

Finavon Hotel
15th January 2020

Zach, David and Findlay
SAC Consulting

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This evenings agenda:

- Stones and soil

- What's in a soil?
- Micro, meso and macro fauna
- Improving soil health

- Slaking – open discussion

Please help yourselves to tea, coffee and cake!

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Stone and Soil – What's the difference?

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What's in a soil?

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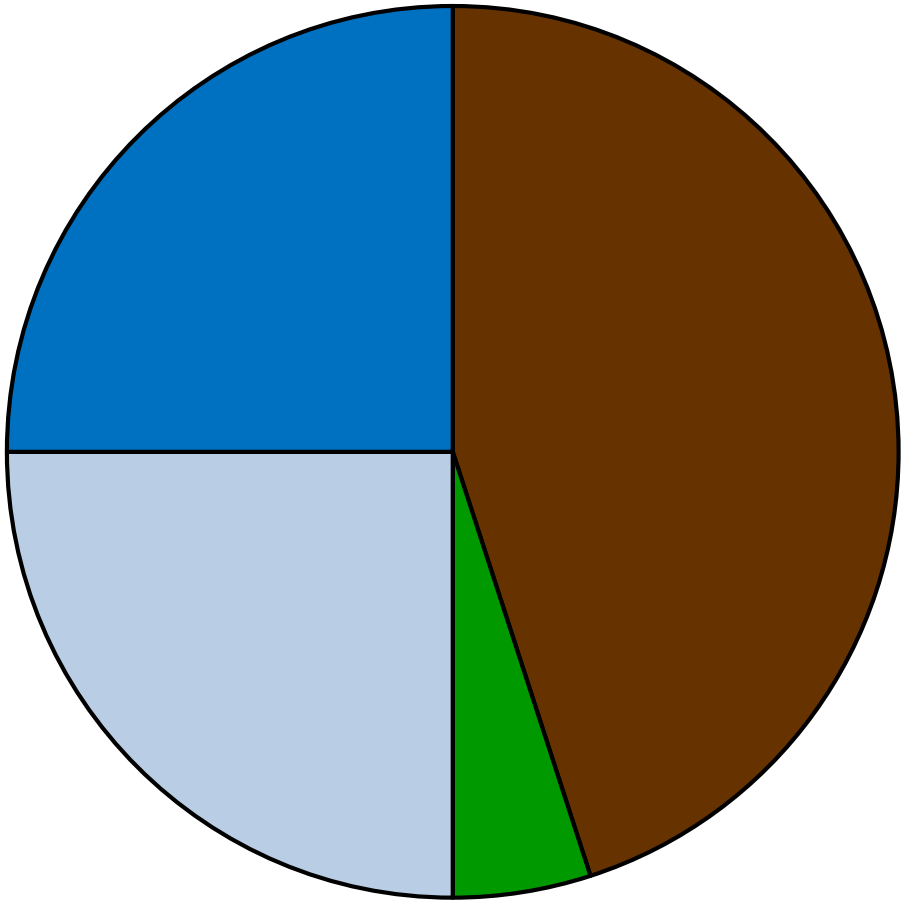

- Parent Material
- Organic Matter
- Air
- Water

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Organic Matter

- Dead and decomposing remains of plants, animals and microorganisms
- Residues and waste products from plants, animals and microorganisms
- Dead and decomposing remains of decomposer organisms
- Potential new substances formed during decomposition

What is in a soil?

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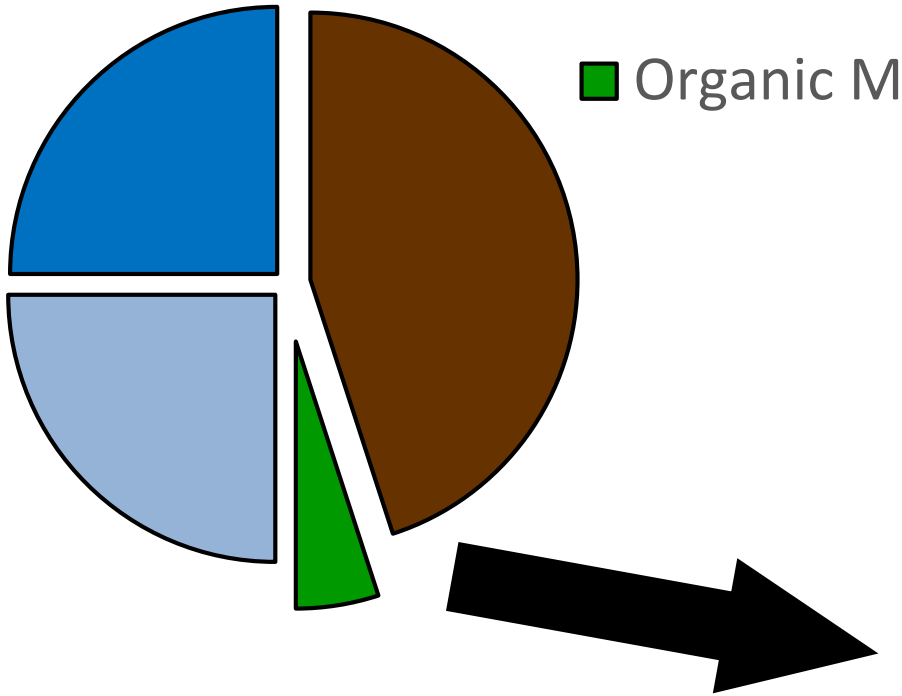

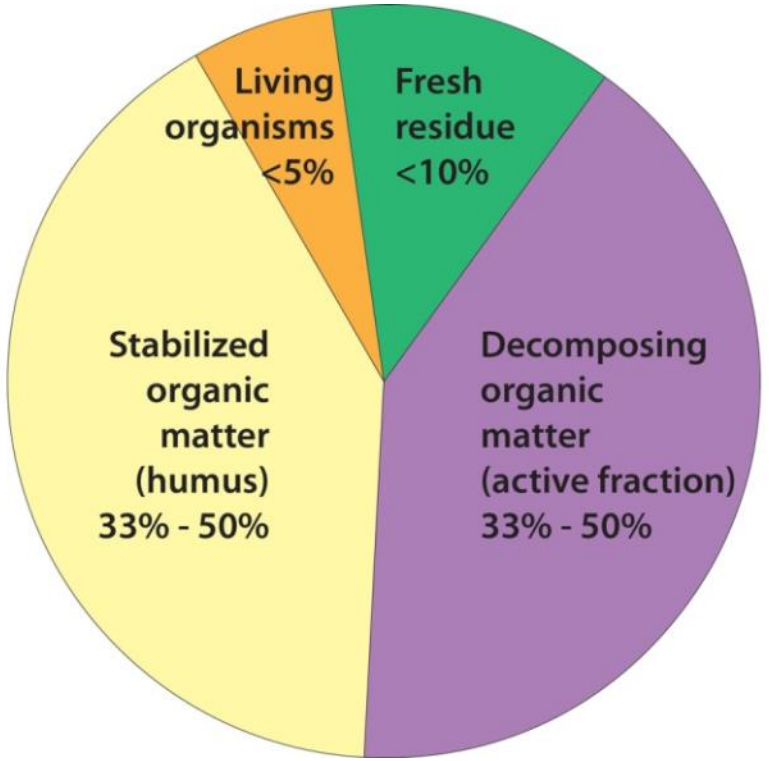

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Organic Matter

A mixture of organic substances and structures with:

- Different biological origins
- Different decomposition rates
- Different stages of decomposition and modification
- Different ages

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So, what determines turnover?

When organic matter is ‘turned over’ it either moves into another pool or is mineralised

- climate, vegetation type, nutrient availability, disturbance
- land use and management practices
- Organisms! (and their activity)

Soil Food Web

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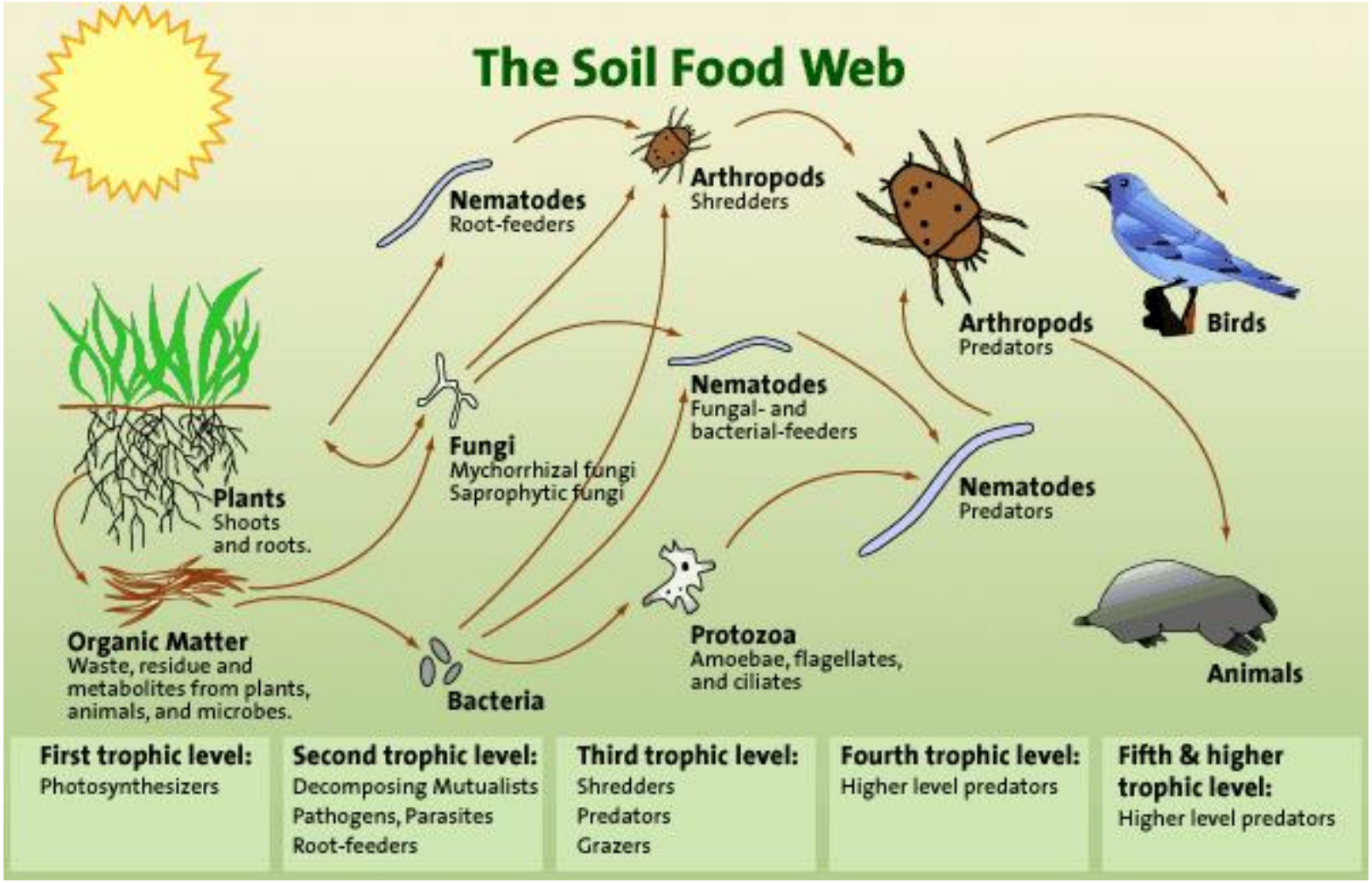

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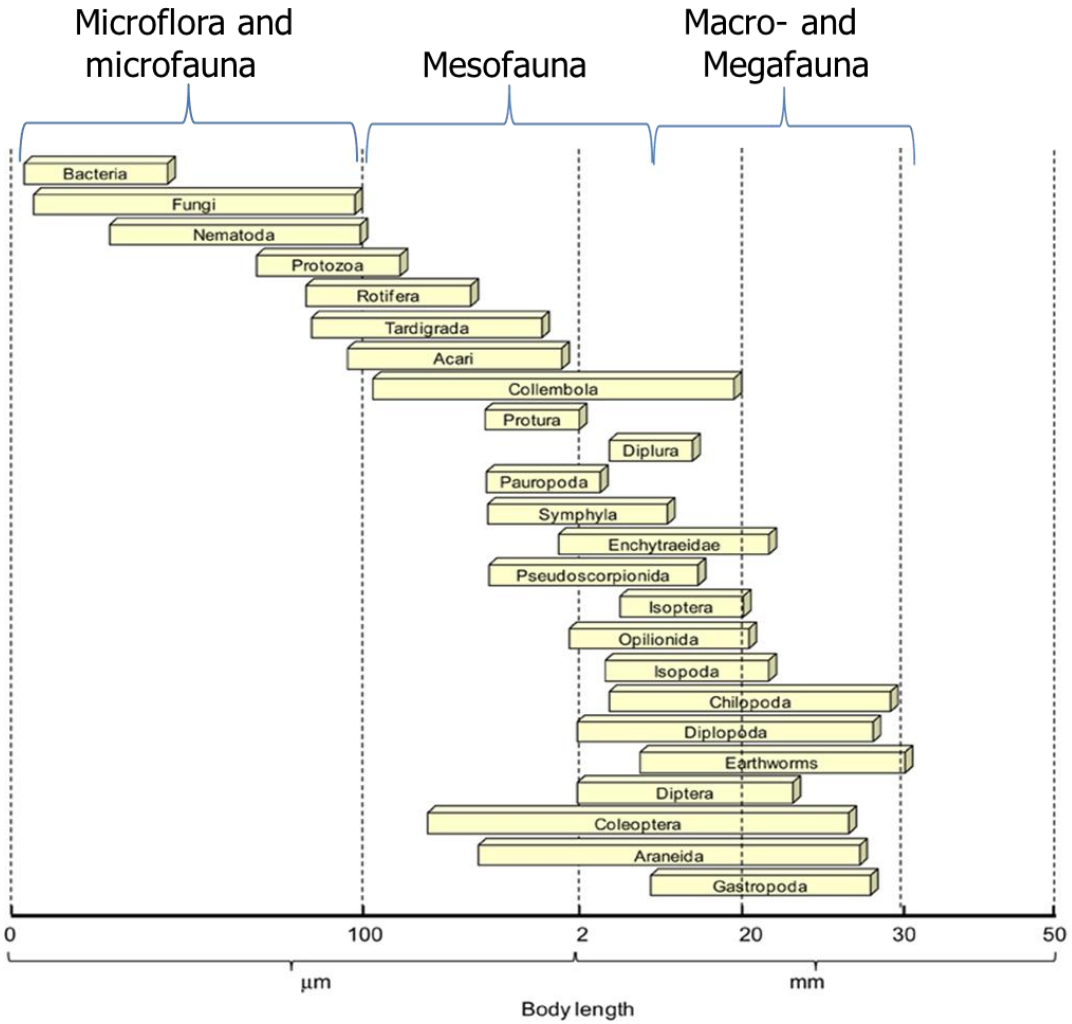
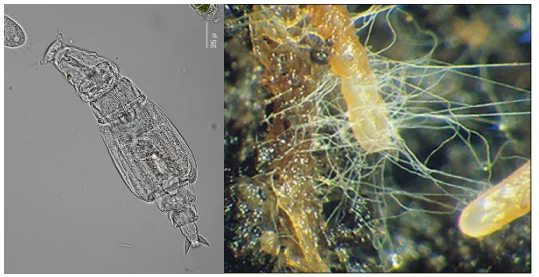
Soil Organisms





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Species

Organism	No of species	Abundance per square metre
Bacteria	9,000	200 trillion
All Fungi	200	1 million
Mycorrizal Fungi	20	800,000
Protists	1,200	10 million
Nematodes	100	9 million
Potworms	15	300,000
Springtails	20	50,000
Mites	150	100,000
woodlouse	100	10
millipedes	2,500	100
Earthworms	15	300

What do soil organisms do?

- Decompose OM
- Dissolve soil minerals
- Mineralise & immobilise nutrients
- Create humus (humification)
- Aerate the soil and increase permeability
- Strengthen and create soil structure
- Control harmful organisms
- Breakdown organic toxins
- Increase efficiency of nutrient uptake (mycorrhizae)
- Fix nitrogen (*Rhizobia*)

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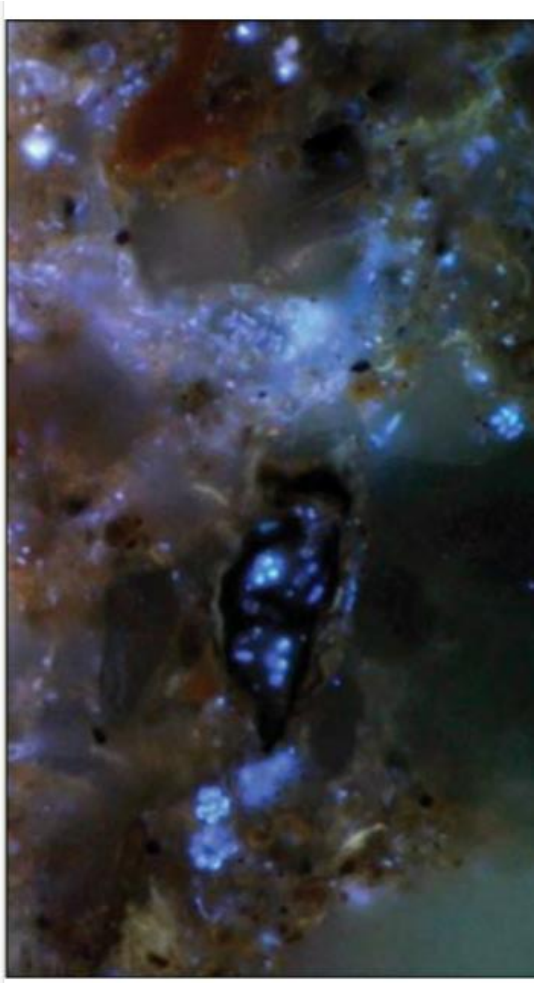
How do they do it?

- Most soil organisms are "chemo-heterotrophs" - they require organic matter for both energy and carbon
- Every time an organism eats another one, it excretes excess nutrients, making them plant available
- Some organisms excrete fluids which help bind soil, and others form associations with plants

Micro fauna – bacteria

- Tiny single celled organisms
- Decompose OM making nutrients available to other organisms
- Free living or symbiotic



- *Rhizobia* – limited by access to atmospheric N (aerated soil)
- *Actinobacteria* – fungi like, can decompose complex carbohydrates
- *Streptomyces* – earthy smell

Micro fauna – fungi

- Saprophytic fungi – decomposers (convert OM into fungal biomass, CO_2 and small molecules)

- Mutualistic fungi – form associations with plants to provide nutrients and water in exchange for C

What are Mycorrhizae?

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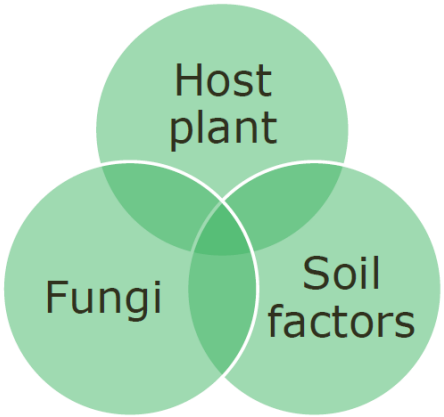
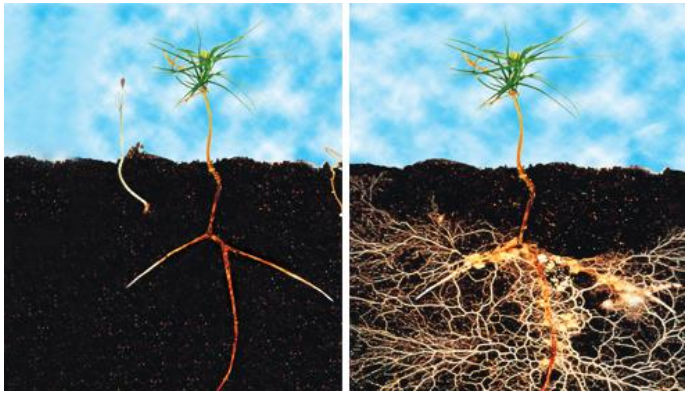
- Mycorrhizae fungi form a key beneficial soil symbiosis, establishing mutualistic associations with the roots of 80% of plant species.
- Both the plant and the fungus benefit from the association
- The fungus takes over the role of the plant's root hairs and acts as an extension of the root system





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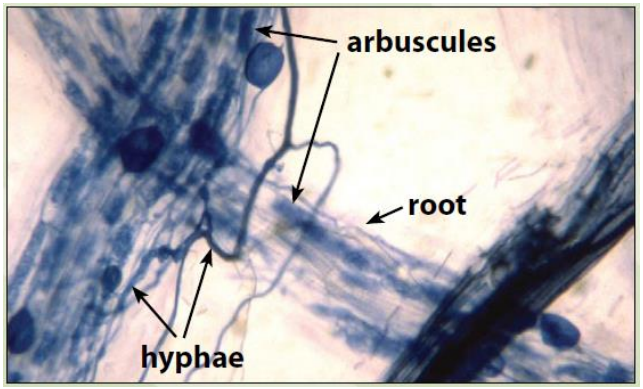
Types of Associations

- **<u>Ectomycorrhizal fungi:</u>**
  - Found in the roots of 10% of plant families – mainly trees.
  - The hyphae does not penetrate individual cells within the root
- **<u>Endomycorrhizal Fungi:</u>**
  - Found in the majority of cereals, legumes, vegetables and fruit
  - The fungi's hyphae penetrates the cortial cells within the root for nutrient exchange



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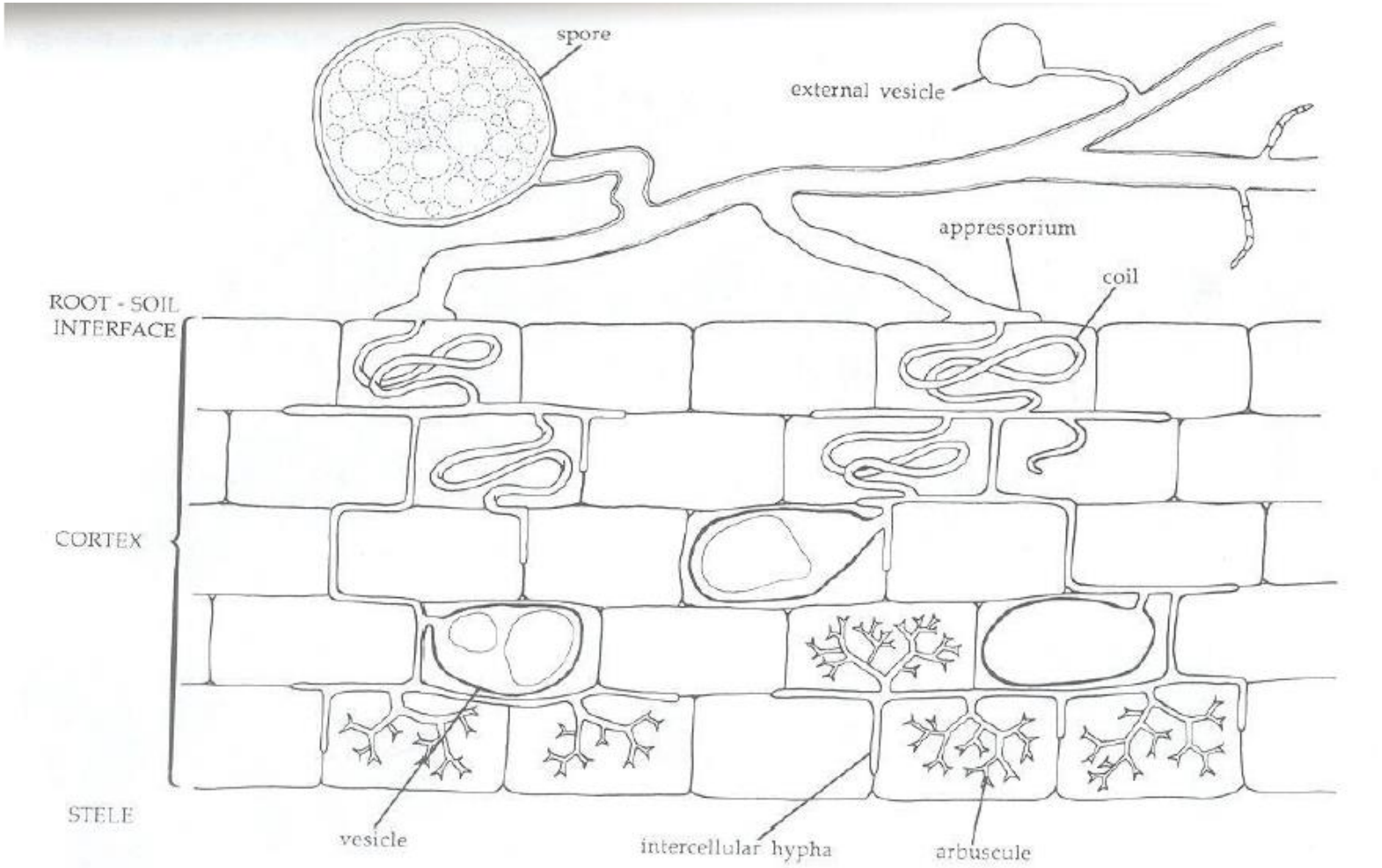

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What Makes up Mycorrhizal Fungi?

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Hyphal Network:

There are 2 types of hyphae:

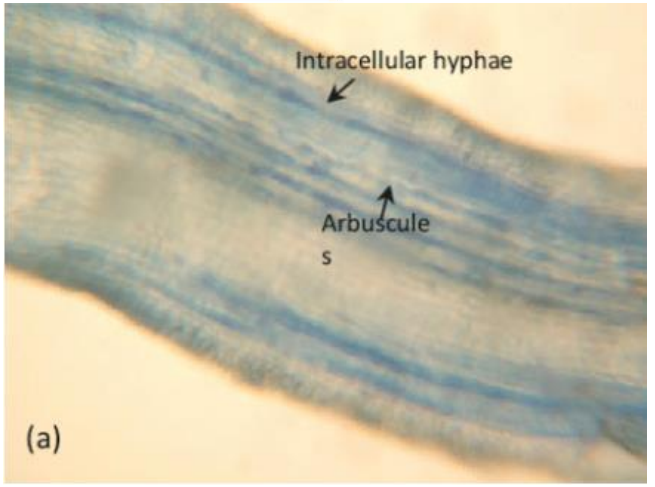
Intracellular Hyphae:

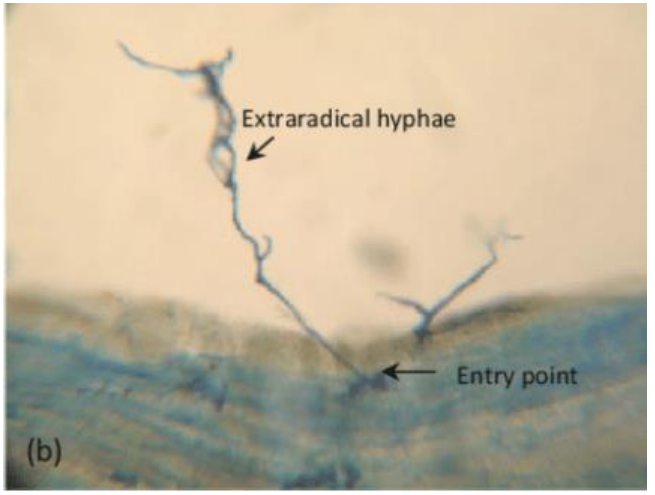
- These grow within the cortex of the root to form a colony.
- They go on to develop Arbuscles and vesicles.

Extracellular Hyphae:

- Responsible for:
  - Nutrient acquisition
  - Spore production
  - Initiating the association with the host plant

- Both can survive in the soil for months if not years





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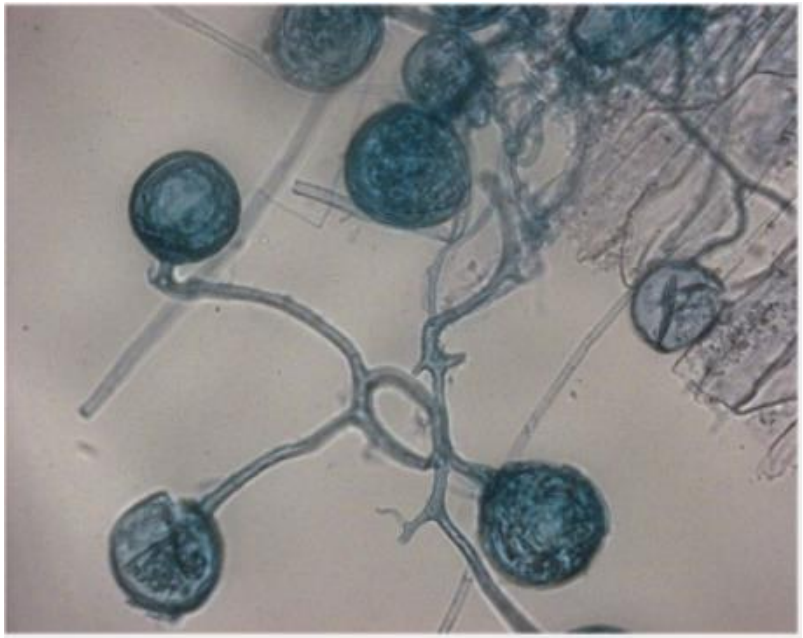
Spores:

- The germination of a spore is the start of the fungi's lifecycle.
- Spores form when nutrients are re-mobilised from the roots were associations are senescing
- These structures contain lipids, cytoplasm and many neculi



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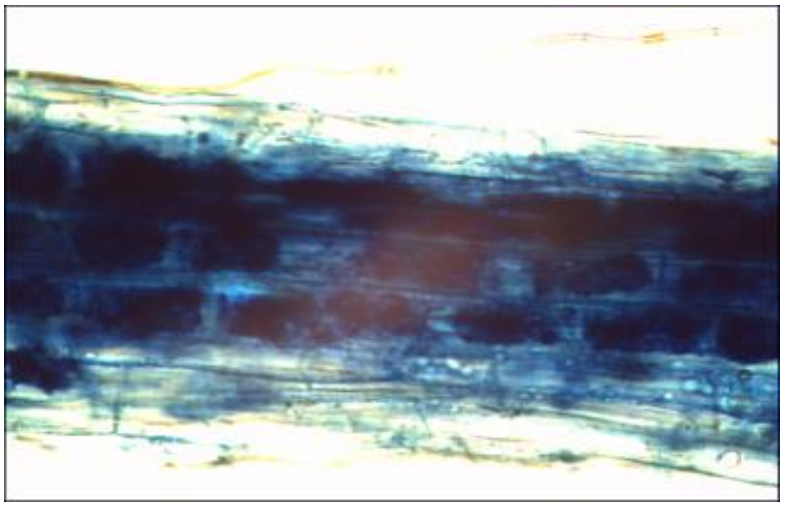
Arbuscles:

- Found within an individual cell surrounded by the plant cell membrane
- Typically disintegrate after around 2 weeks
- This is the site of nutrient exchange between the plant and the fungus
- Arbuscles begin to from approximately 2 days after root infection



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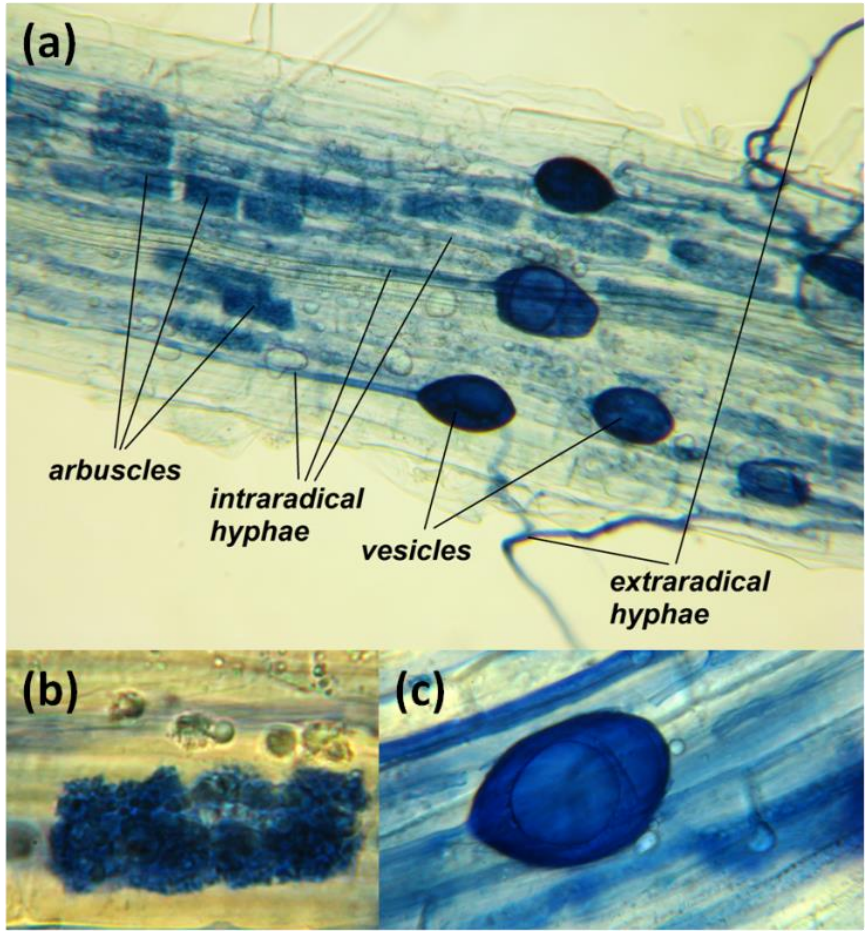
Vesicles:

- Intercellular hyphae may also form large swellings
- Can be found within or in-between cells
- Can be very rich in lipids and are involved in nutrient storage and propagation
- Not to be confused with spores



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Effect of Tillage on Mycorrhiza and Colonisation

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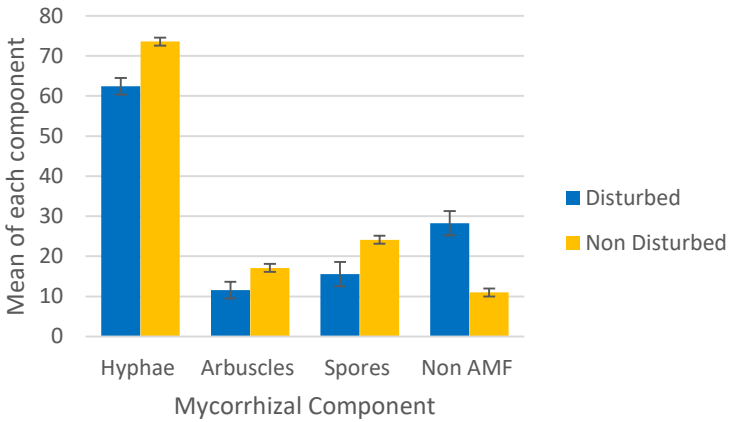
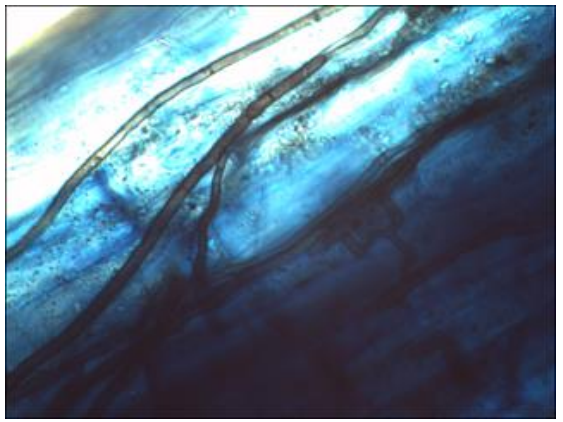
- The deeper the cultivation the greater the damage to the mycorrhizae
  - A No-till system is best for increasing mycorrhizae numbers
- The Benefits of no-till farming far outnumber those of heavy tillage-based systems.
- Maintaining the Extracellular hyphae is key
  - Soil disturbance will decrease the prevalence of the hyphal networks due to it becoming dismantled
- Different tillage regimes will select for different species of mycorrhiza
- Mycorrhiza can play a key part in disease suppression of fungal soil borne diseases





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Pesticides and Mycorrhizae

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Herbicides:

- Glyphosate has an indirect long term consequence on mycorrhizae
  - Specifically the Arbuscles
- Glyphosate residues within the soil change the microbial community or change microbial activity rather than limit resource allocation to the mycorrhizae

Fungicides:

- Systemic Fungicides have a more negative impact due to accumulation of fungicide in the root tissue.
  - Roots of fungicide treated plants are not susceptible to colonisation for up to 3 weeks after the application

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Micro/meso – protozoa

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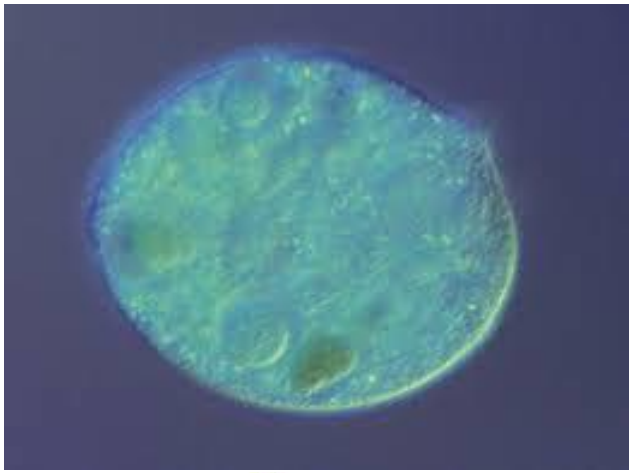
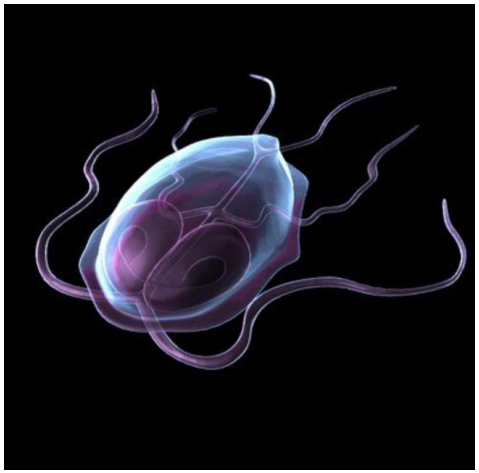
- Soil ‘space’ for living/ feeding required
- Feed primarily on bacteria
- Responsible for a large proportion of the nutrient cycling





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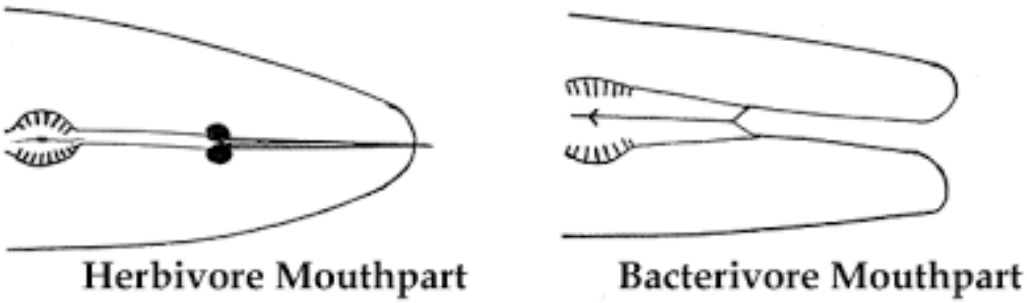
Micro/ meso – nematodes

- Feed on: plants, bacteria, fungi, protozoa and each other
- Again, help to cycle nutrients
- Healthy soils will have a diverse mix of nematodes
- Can replace earthworms in acidic or compact soil (with limited effects)



Macro – earthworms

- Epigeic – surface dwellers, reproduce rapidly, consume high amounts of compost, reddish colour
- Endogenic – burrow horizontally in the top soil, pale colours
- Anecic – largest worms in UK, and often absent from arable soils

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Macro – anecic earthworms

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- Can grow to the size of a pencil
- Burrows can be 2m deep and identified by surface casts
  - drainage, root penetration, aeration, nutrient cycling
- Reproduce on weight not age – are you feeding them?

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The carbon cycle

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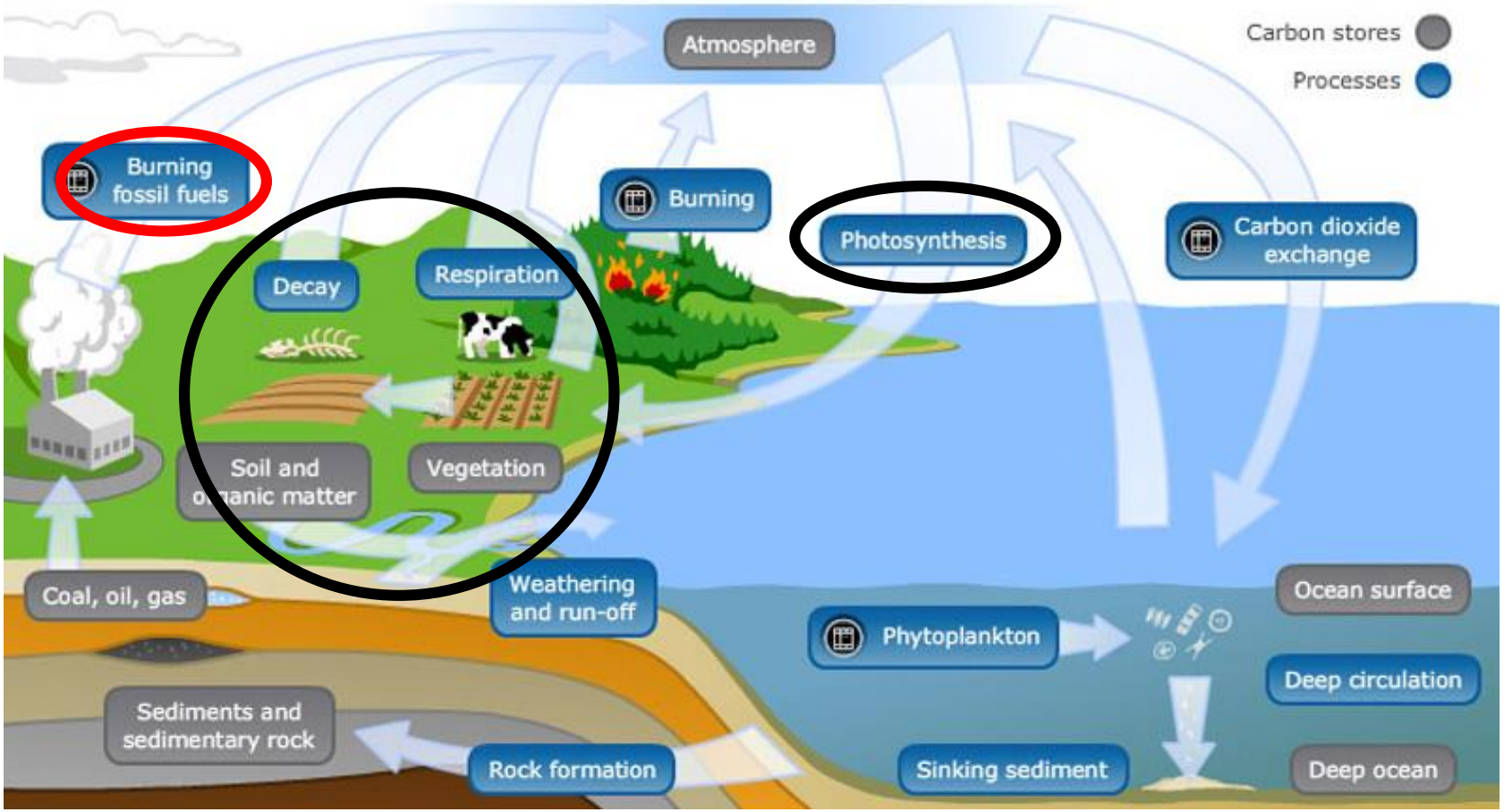

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Nitrogen Cycle

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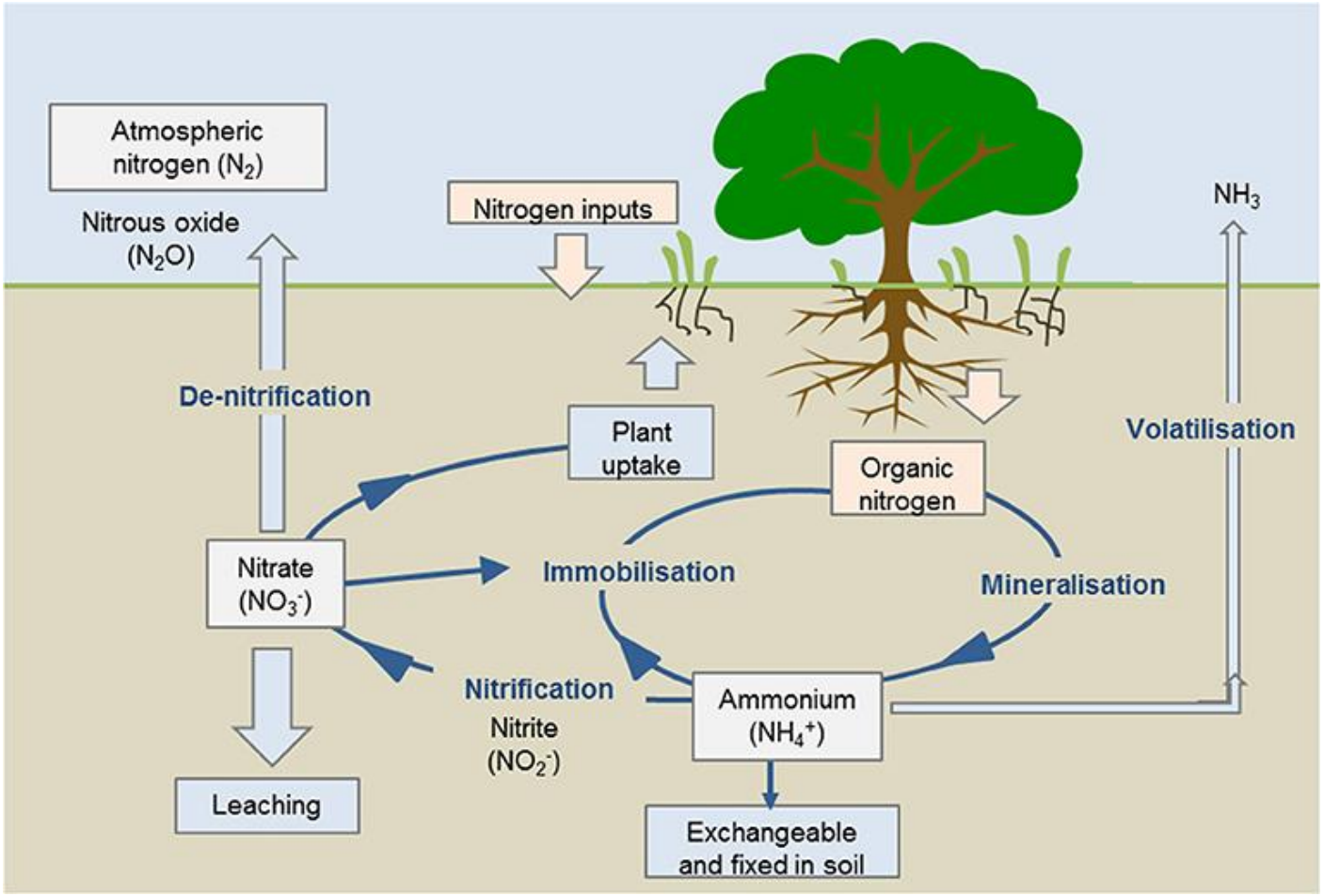

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Improving soil health

A healthy soil smells good, looks good, feels good

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Symptoms of an dysfunctional soil…

- Compaction
- Wind erosion
- Water erosion
- Slumping
- Capping
- Diffuse pollution

Soil health

1. Less soil disturbance
2. More plant diversity
3. Living roots
4. Soil cover

If you are not meeting one of these factors, can the others compensate?

Soil disturbance

- Tillage affects SOM in 2 ways:
  - Physical disturbance and mixing of soil
  - Incorporation and disturbance of plant residue in soil profile
- Intensive tillage:
  - enhances SOM decomposition
  - reduces total C and N concentrations
  - reduces microbial biomass
  - simplifies microbial communities structure (lower stability or resiliency in function)

Soil disturbance

- Usually species diversity of microfaunal groups is unchanged by tillage, whereas macrofaunal groups can be more affected:
  - *Bacteria and fungi*: mildly inhibited
  - *Nematodes and protozoa*: mildly to moderately inhibited
  - *Collembola and mites*: moderately inhibited
  - *Earthworms and beetles*: moderately to extremely inhibited

Plant diversity

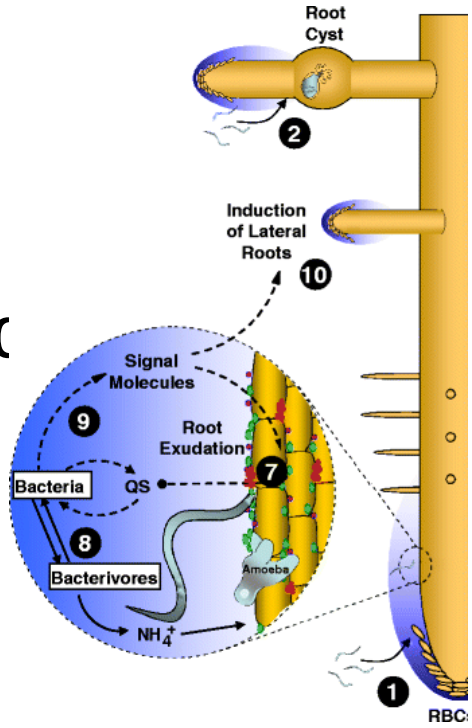
- Eat cake for one month or eat carrots for one month – neither are healthy…
- Ecosystems require diversity – as much as possible

- Plants feed the soil, and soil feeds the plants

- Look at the native ecosystem and match the number of species?

Living roots

- The most easily accessible energy form for soil microbes
- Different rooting structures and plant species key
- Mycorrhiza need a living plant to survive



Soil cover

- If you cant see the soil that's a good thing!
- Living and dead armour
- Reduce erosion and increase infiltration

Key points

- Think beyond ‘total Organic Matter’
  - Quality and turnover of OM

- Remember each part of the SFW has a different function

- Assess your own system and challenge yourself to improving soil health

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Soil slaking – open discussion

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