Soil Food Webs

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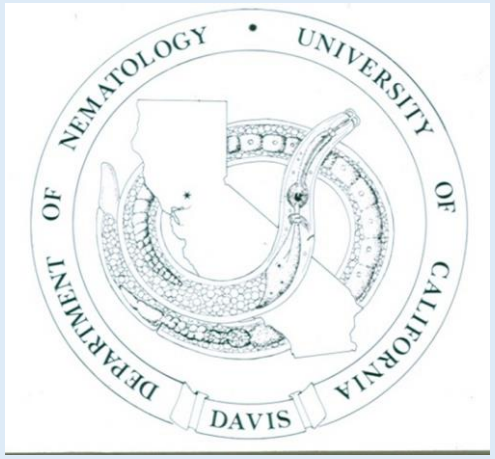
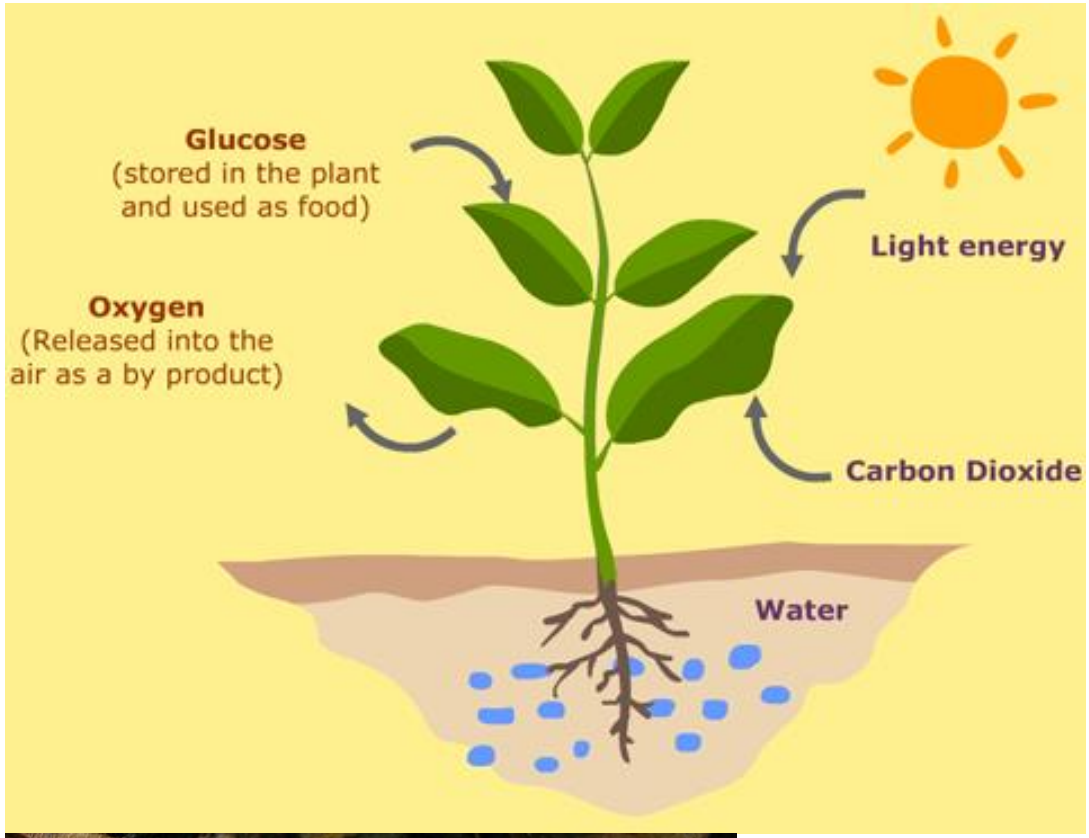


Photosynthesis

Plant makes:

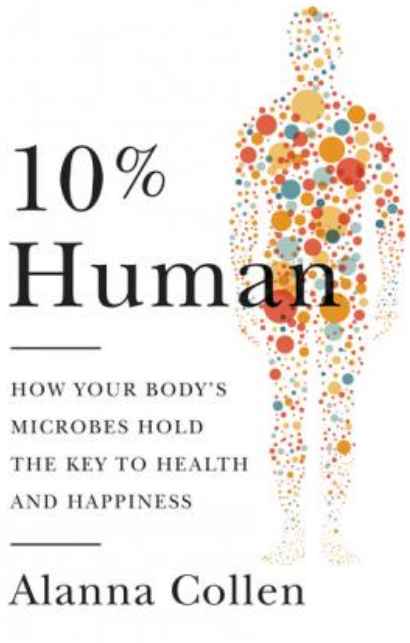
- Carbohydrates
- Amino acids/proteins
- Lipids (fats)
- Lignin
- Phenolics
- Vitamins

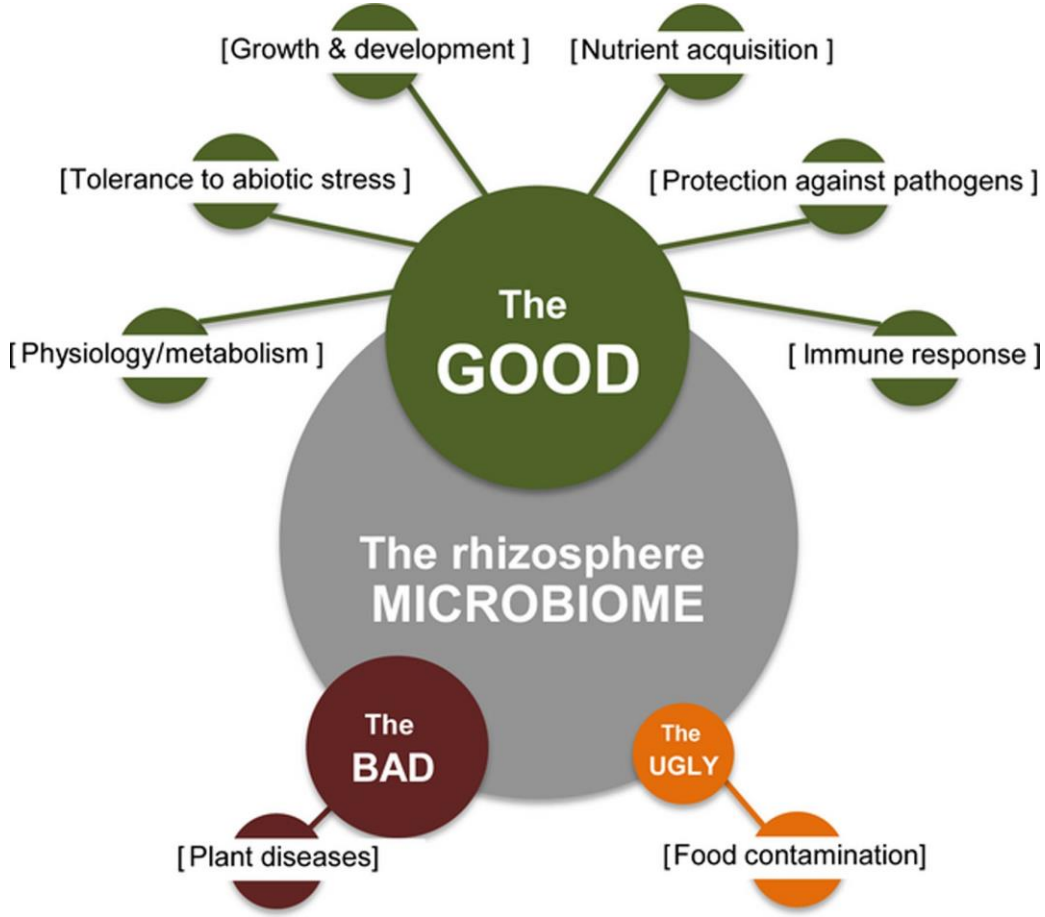
Then it dies and decomposes!



Microbiome

- the microorganisms in a particular environment (or their combined genetic material)

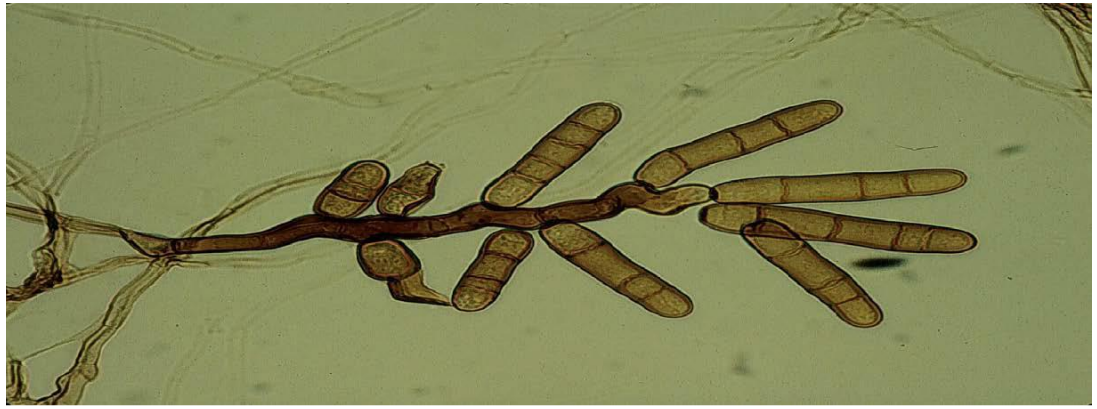




Mendes et al. 2013

Plant roots feed the Microbes!

- Plant roots use 25 to 40% of their root carbohydrate supplies to feed the microbes!
- Plants actively use hormones to attract and “farm” bacteria, fungus, and other organisms to help them recycle soil nutrients and water.

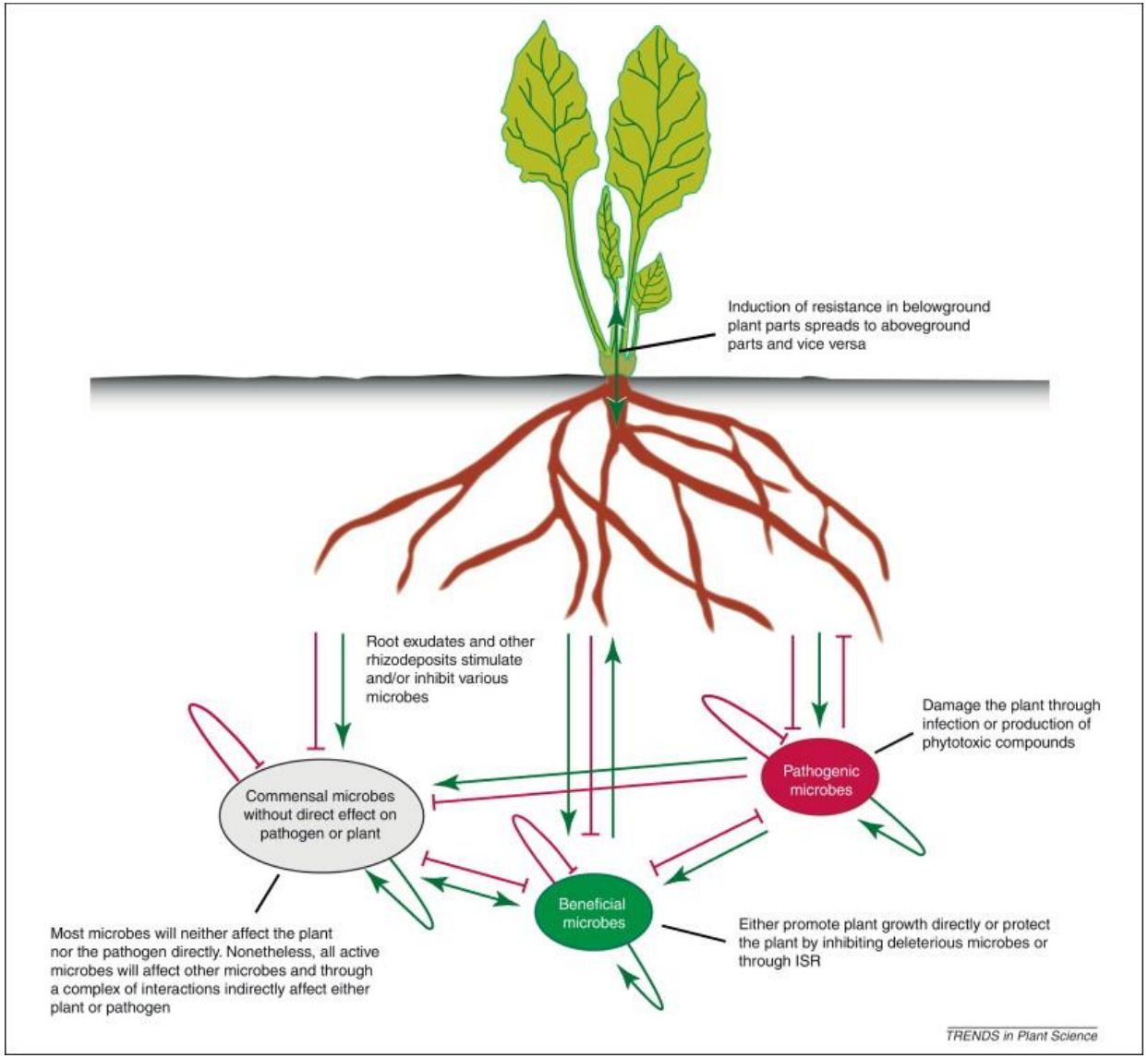


Rhizosphere

- Living roots release many types of organic materials into the rhizosphere within 50 µm of the surface of the root.
- There are over 1000-2000 times more microbes associated with a live root than in the bulk soil.

The rhizosphere

- Plants influence their microbiome through exudates (fluids).
- These stimulate (green arrows) or inhibit (red blocked arrows) microbes.
- Microbes also affect plant health (for good or bad) and interact with each other.



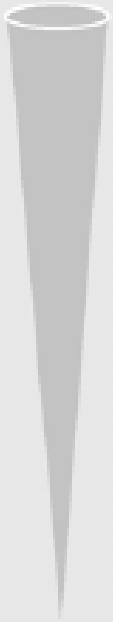
Berendsen et al. 2012 Cell

Relative amount of microbes in handful of soil

<u>In 100- 200 g soil:</u>

- Bacteria 50 billion
- Actinomycetes 2 billion
- Protozoa 50 million
- Fungus 100million
- Nematodes 10,000
- Arthropods 1000
- Earthworms 0 to 2

Table 1 – Estimated number of species of plants and of soil organisms organized according to body size (modified from Wall et al., 2001)

Size	Group	Known species	Estimated total species	% Known
	Vascular plants[a]	270000	300000	90
	Macrofauna			
	Ants	8800	15000	58.7
	Termites	1600	3000	53.3
	Earthworms	3600	No estimate	No estimate
	Mesofauna			
	Mites	20.000–30.000	900,000	2.2–3.3
	Collembola	6500	24,000	27.1
	Microfauna			
	Protozoa	1500	200,000	7.5%
	Nematodes	5000	400,000	1.3
	Microflora			
	Bacteria	13,000	1.000.000	1%
	Fungi	18000–35000	1.500.000	1–2%

[a] Estimates for Vascular plants (UNEP, 1995).

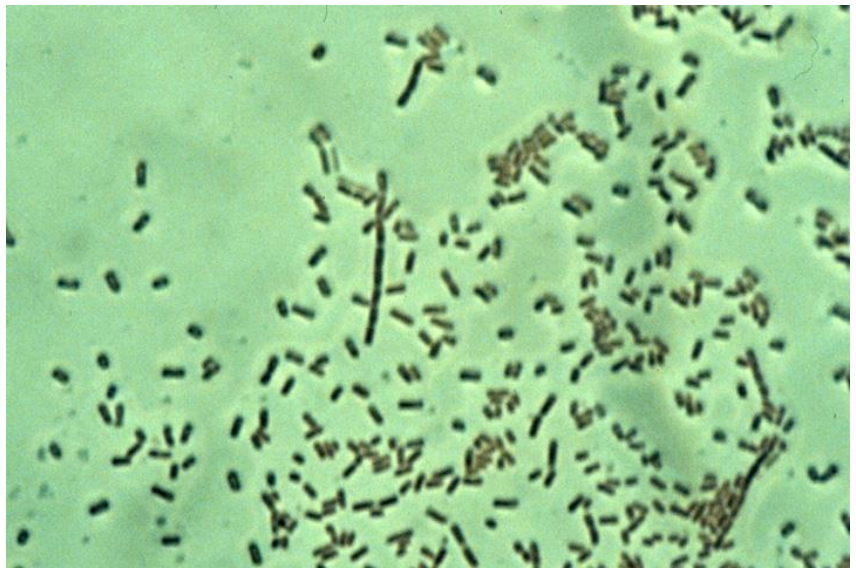
Soil animal categories

- Microflora and fauna (< 0.1 mm)
  - Bacteria
  - Fungi
- Mesofauna (< 2 mm)
  - Mites
  - Collembola
- Macrofauna (> 2 mm)
  - Insects, earthworms, rolly-pollies

Collembola on a leaf

Soil Microorganisms – bacteria and fungi

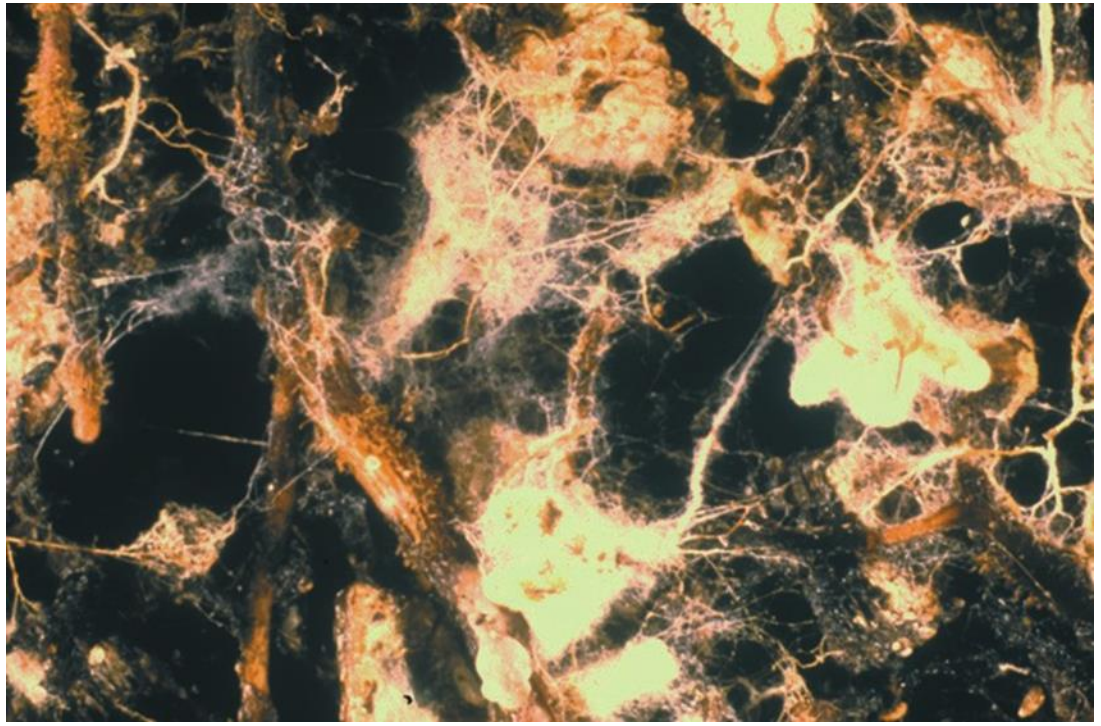
- Bacteria are tiny, one-celled organisms – generally 4/100,000 of an inch wide (1 µm)



- What bacteria lack in size, they make up in numbers.
- A teaspoon of productive soil generally contains between 100 million and 1 billion bacteria.
- That is as much mass as two cows per acre.

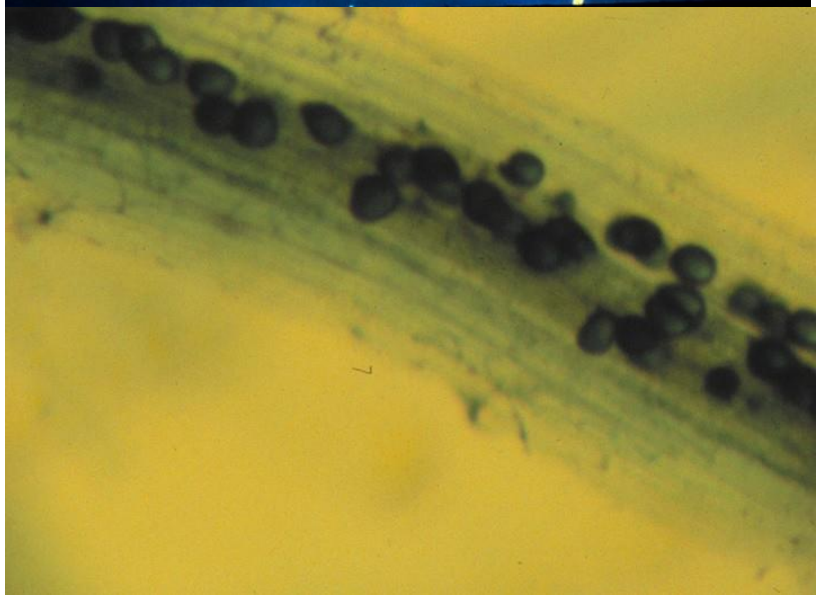
Fungi

- Fungi grow as long threads or strands called hyphae-several thousandths of an inch (a few micrometers) in diameter.
- These push their way between soil particles, roots, and rocks
- A single hyphae can span in length from a few cells to many yards.



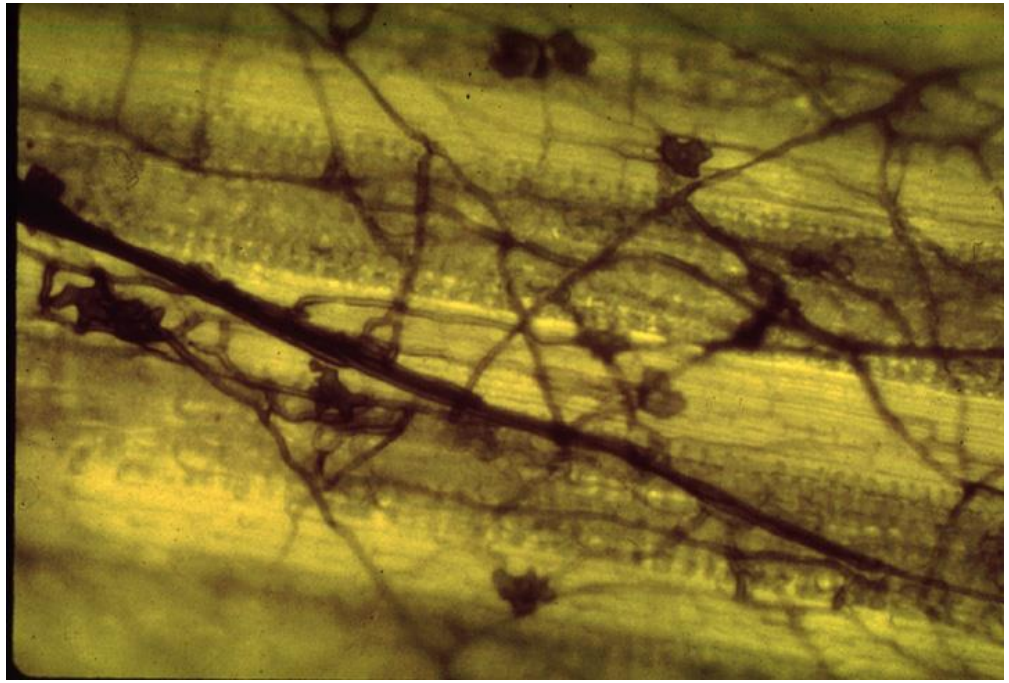
Mutualists

- mycorrhizal fungi – colonize plant roots.
- In exchange for carbon from the plant, make nutrients available.
- *ectomycorrhizae* grow on the surface layers of roots-commonly associated with trees.
- *endomycorrhizae* that grow within the root cells and are commonly associated with grasses, row crops, vegetables, and shrubs.



Decomposing fungi

- Saprophytic fungi
- Fungi can bridge gaps between pockets of moisture
- Can survive and grow when soil moisture is too low for most bacteria to be active.



What do soil fauna do?

Microorganisms

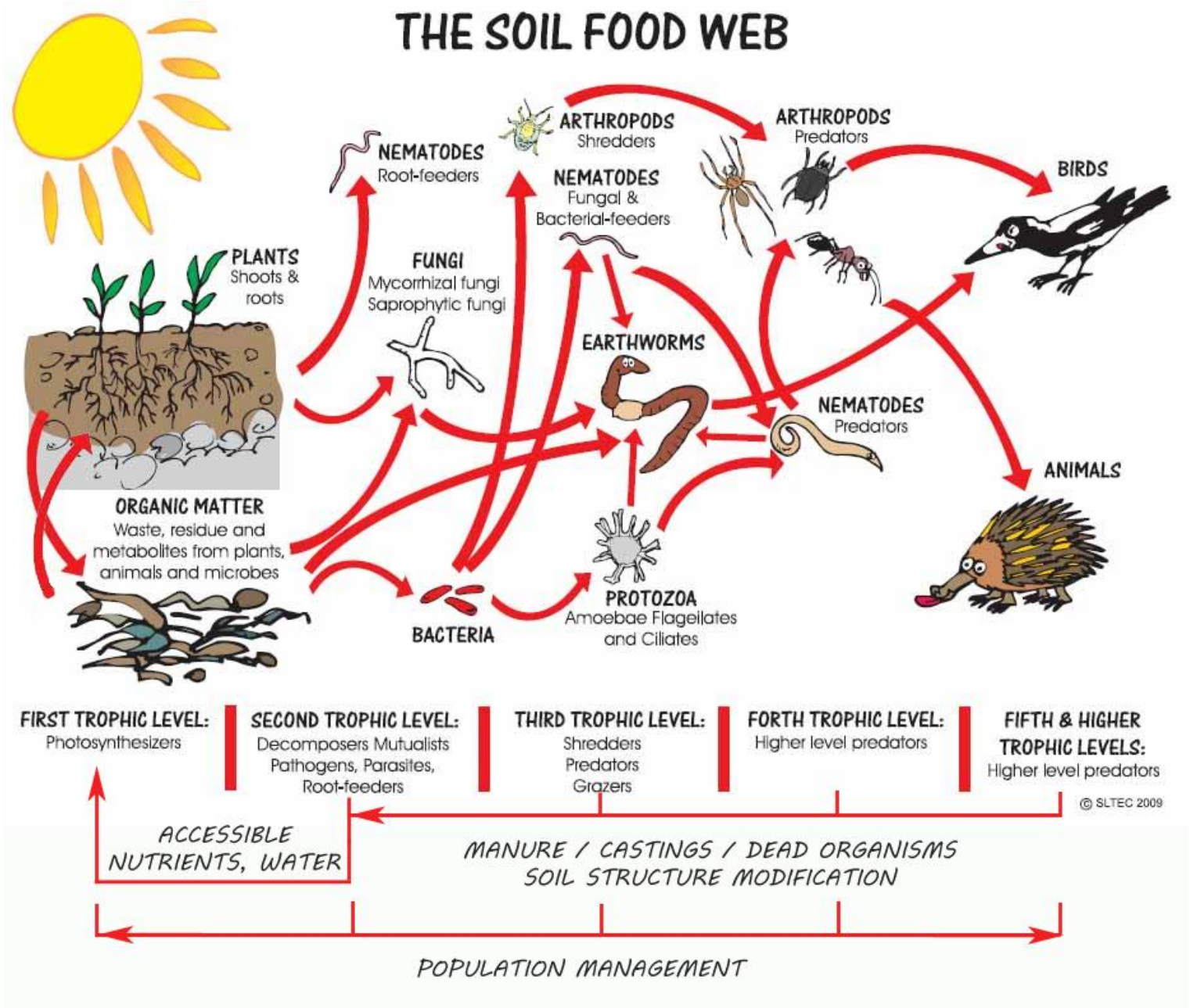
- Mineralize most C and N
- Binding of soil aggregates
- Detoxification
- Symbionts/disease

Soil Fauna

- Eat/fragment detritus
- Feces stimulate bacteria and fungi
- Increase soil porosity (burrows)
- Increase aggregate stability (casts)

What do soil fauna do?

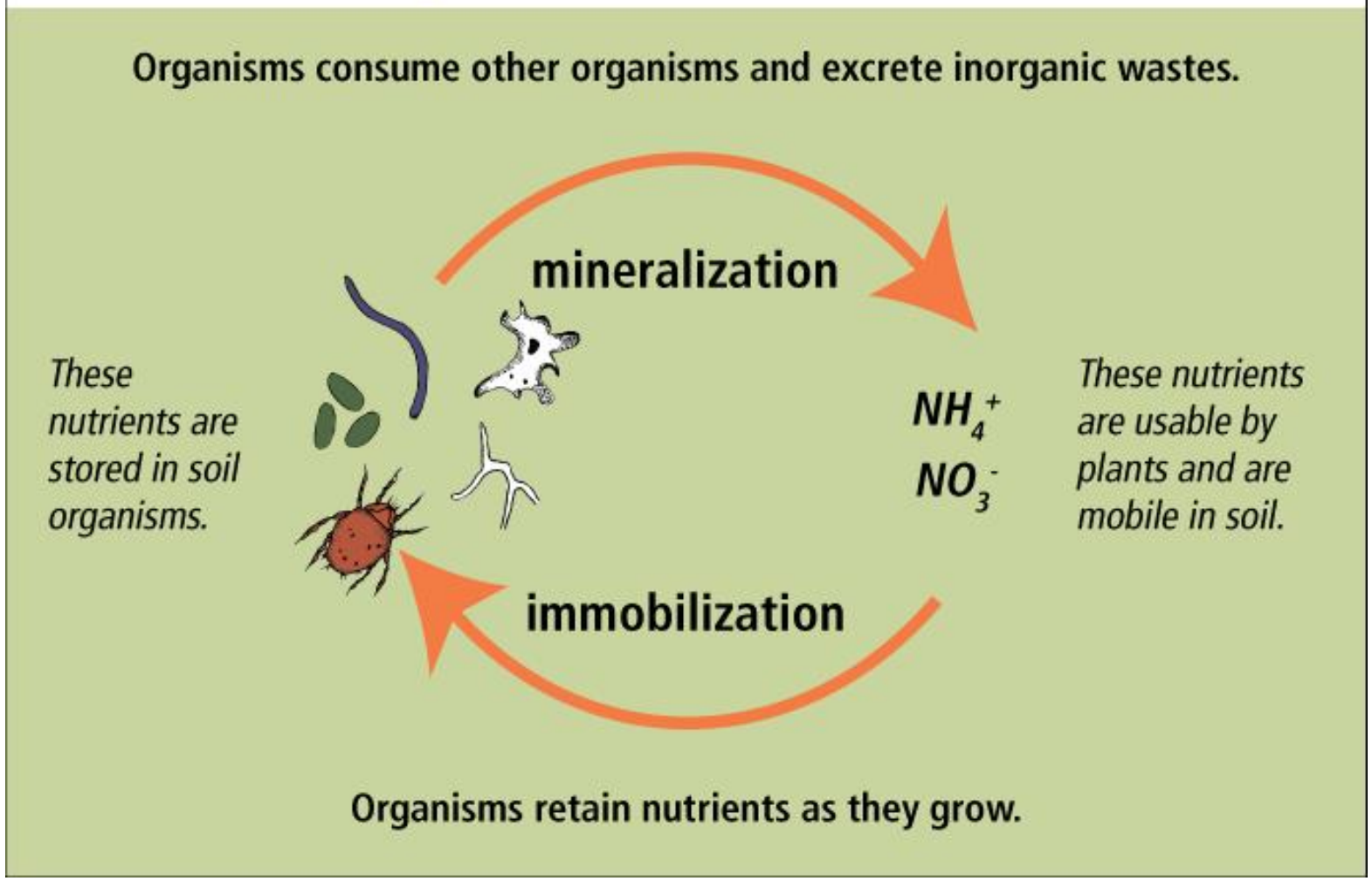
- Chemical Engineers—make nutrients accessible to the plants and other animals.
- Biological Regulators— population control, consume both flora and fauna.
- Ecosystem Engineers—modify soil structure, reduce compaction and create habitats.



https://thesoilhuggersjourney.wordpress.com/category/soil/

What Are Mineralization and Immobilization?

Soil nutrients generally occur in two forms: inorganic compounds dissolved in water or attached to minerals, and organic compounds part of living organisms and dead organic matter. Bacteria, fungi, nematodes, protozoa, and arthropods are always transforming nutrients between these two forms. When they consume inorganic compounds to construct cells, enzymes, and other organic compounds needed to grow, they are said to be "immobilizing" nutrients. When organisms excrete inorganic waste compounds, they are said to be "mineralizing" nutrients.

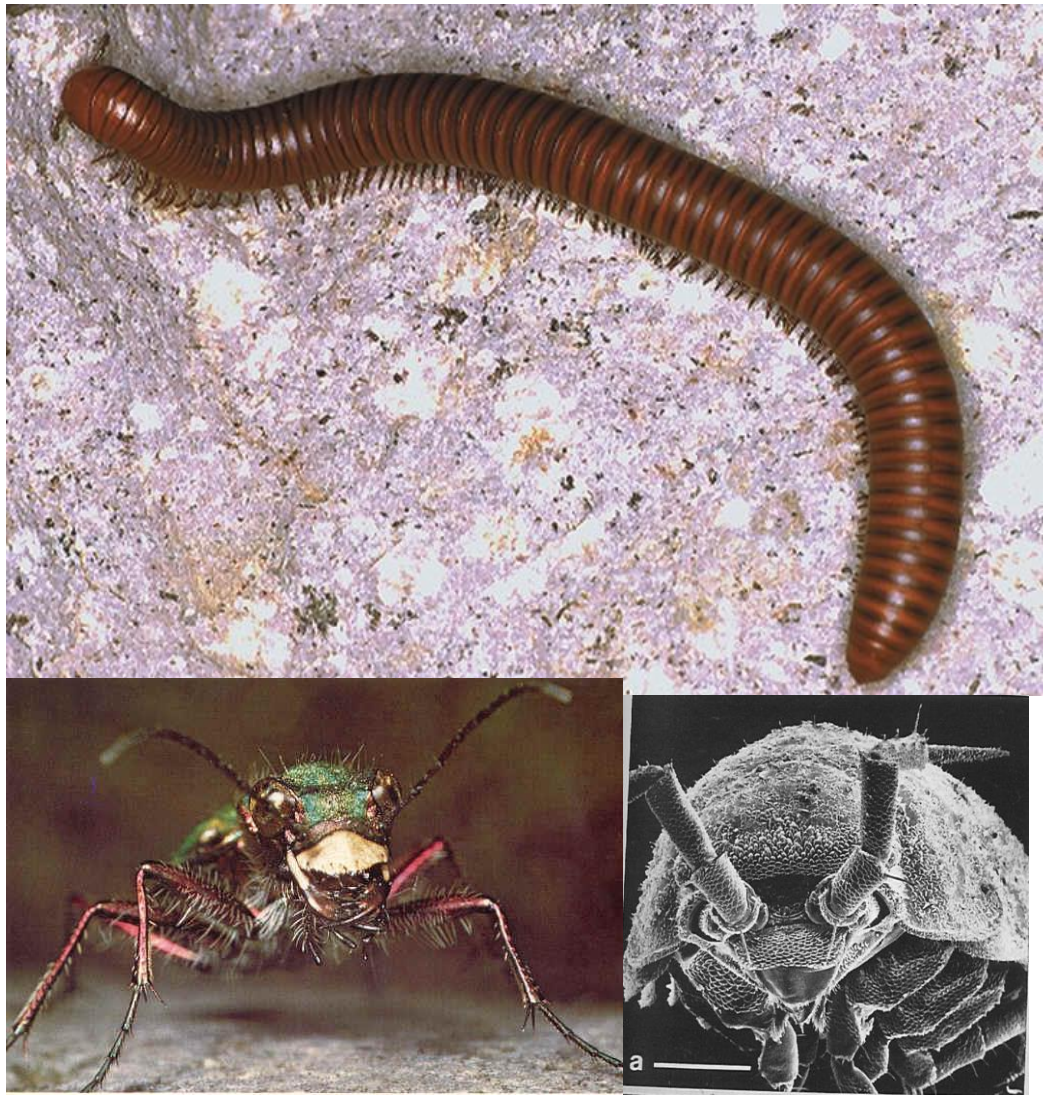


Macrofauna

- Macrofauna (>2mm) earthworms, pill bugs, millipedes

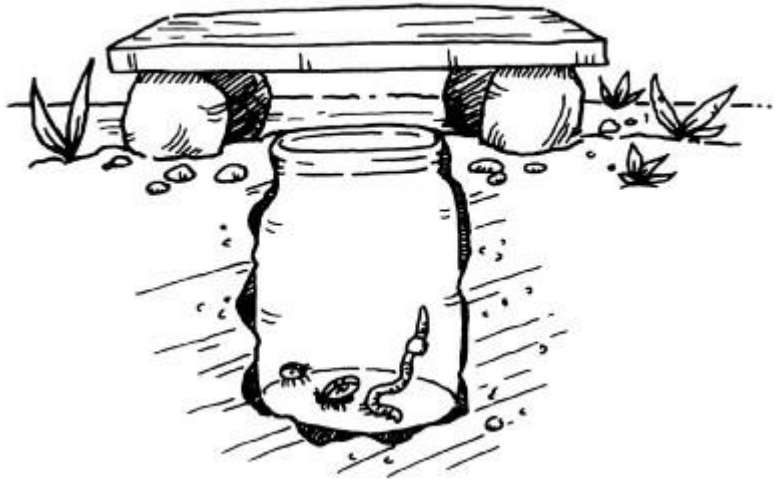
Arthropods

- Millipedes, sowbugs, certain mites, and roaches.
- Chew up dead plant matter as they eat bacteria and fungi on the surface of the plant matter.
- In agricultural soils, shredders can become pests by feeding on live roots if sufficient dead plant material is not present.



Surface dwelling marcofauna: Pitfall trap

- Sink a container (such as a yogurt cup) into the ground so the rim is level with the soil surface.
- Add 1/2 of an inch of non-hazardous antifreeze to the cup to preserve the creatures and prevent them from eating one another.
- Leave in place for a week and wait for soil organisms to fall into the trap.



Earthworms

- Eat organic matter “seasoned” with bacteria and fungi.
- Fragment and inoculate organic matter with more microbes- “sleeping beauty” hypothesis.
- Earthworm poop awakens the sleeping kingdom of microbes!
- Generate tons of casts per acre each year

Clive A. Edwards, The Ohio State University, Columbus

What Do Earthworms Do?

- Stimulate microbial activity.
- Mix and aggregate soil.
- Increase infiltration-burrows.
- Improve water-holding capacity-by fragmenting organic matter, and increasing soil porosity and aggregation.
- Provide channels for root growth.
- Bury and shred plant residue.

Where do earthworms live?

- Surface soil and litter
  - Epigeic species live in or near surface plant litter.
  - Compost worms
- Upper soil
  - Endogeic species feed primarily on soil organic matter.
- Deep-burrowing
  - Anecic species- more permanent deep (1 m) burrow systems
  - “night crawler,” Lumbricus terrestris
  - Feed mainly on surface litter that they pull into their burrows.

Soil and organic matter in a burrow. Clive A. Edwards, The Ohio State University, Columbus. Please contact the Soil and Water Conservation Society

Earthworms as “Ecosystem Engineers”

- Promote microbial activity by shredding and inoculation with gut microbes.
- Increasing the surface area of organic matter and makes it more available to small organisms.
- Change the amount and distribution of organic matter.
- Affect spatial distribution of soil microarthropod communities.

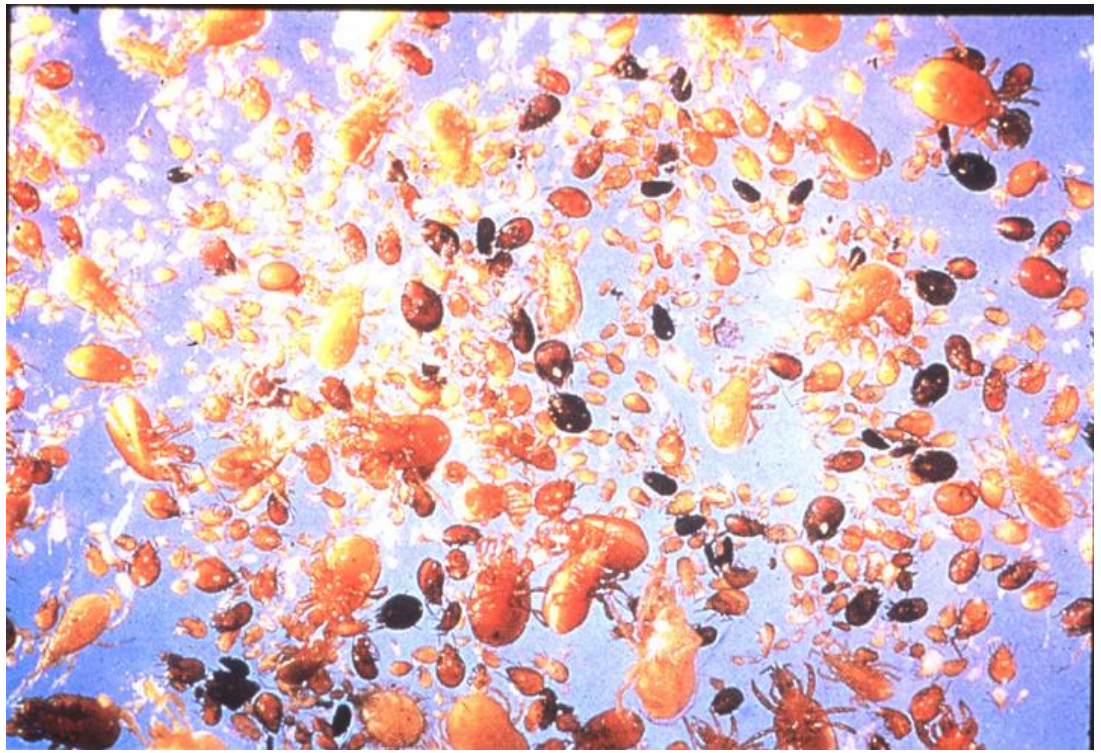
Earthworm casts at soil surface

Mesofauna

- Mesofauna (0.1-2mm) mites, collembolans (spring tails), enchytraeids

Arthropods - Mites

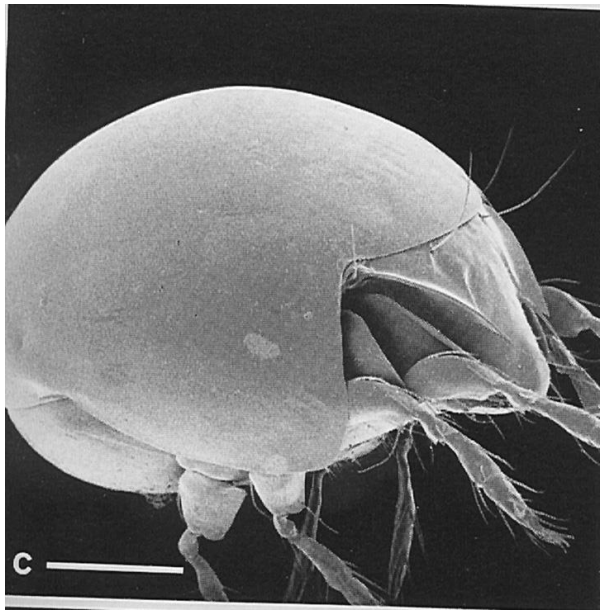
- 200 species of mites in this microscope view.
- Extracted from one square foot of the top two inches of forest litter and soil.
- Poorly studied, but enormously significant for nutrient release.



Val Behan-Pelletier, Agriculture and Agri-Food Canada

Mites

- Some prey on nematodes, springtails, other mites, and the larvae of insects.
- Others graze on microbes from root surfaces or dead leaves.



Gerhard Eisenbeis and Wilfried Wichard. 1987. Atlas on the Biology of Soil Arthropods. Pergamasus sp.

Collemebola

www.collebola.org

Collembola

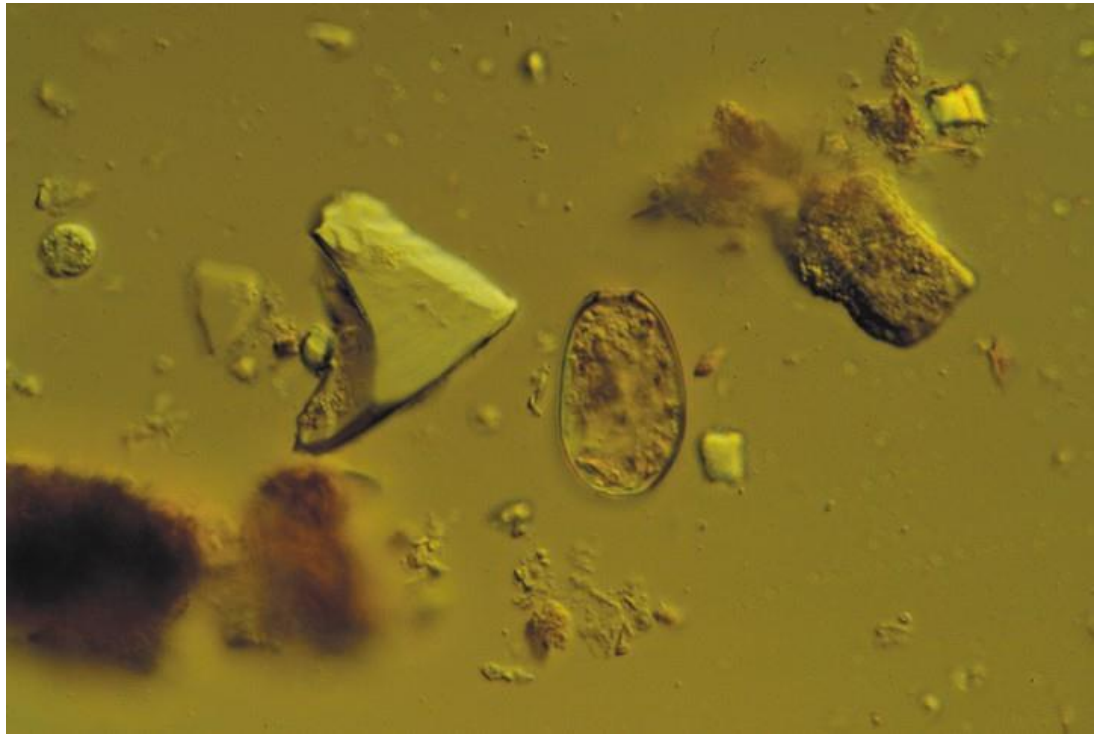
- ~8600 described species worldwide.
- Among the oldest known terrestrial animals.
- Fossils from the Devonian (ca 400 million years ago).
- Ubiquitous in terrestrial systems.
- One of the more successful arthropod lineages.

Microfauna

- Microfauna (<0.1 mm diam) – nematodes, protozoa

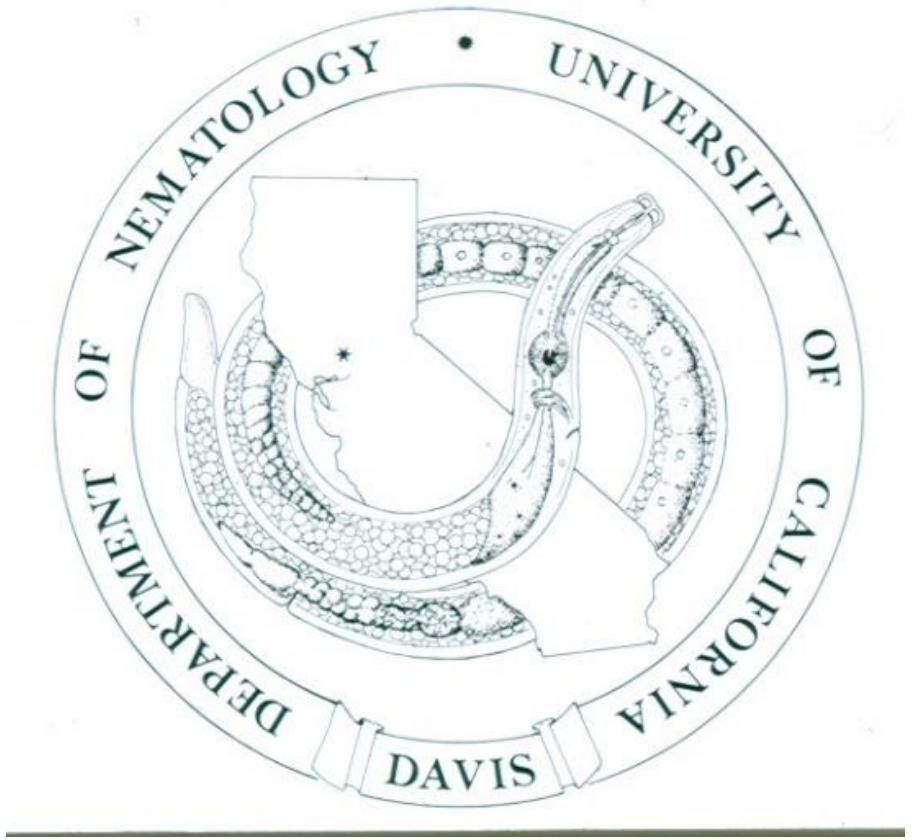
Protozoa

- Single-celled animals
- Feed primarily on bacteria
- Ranging from 1/5000 to 1/50 of an inch (5 to 500 µm) in diameter.
- As they eat bacteria, protozoa release excess nitrogen that can then be used by plants and other members of the food web.



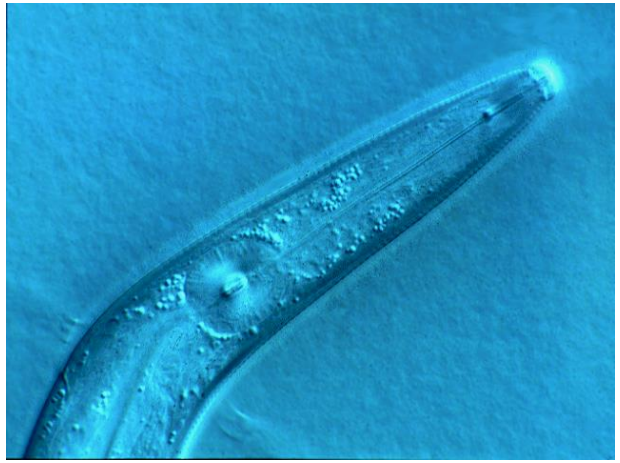
What is a nematode?

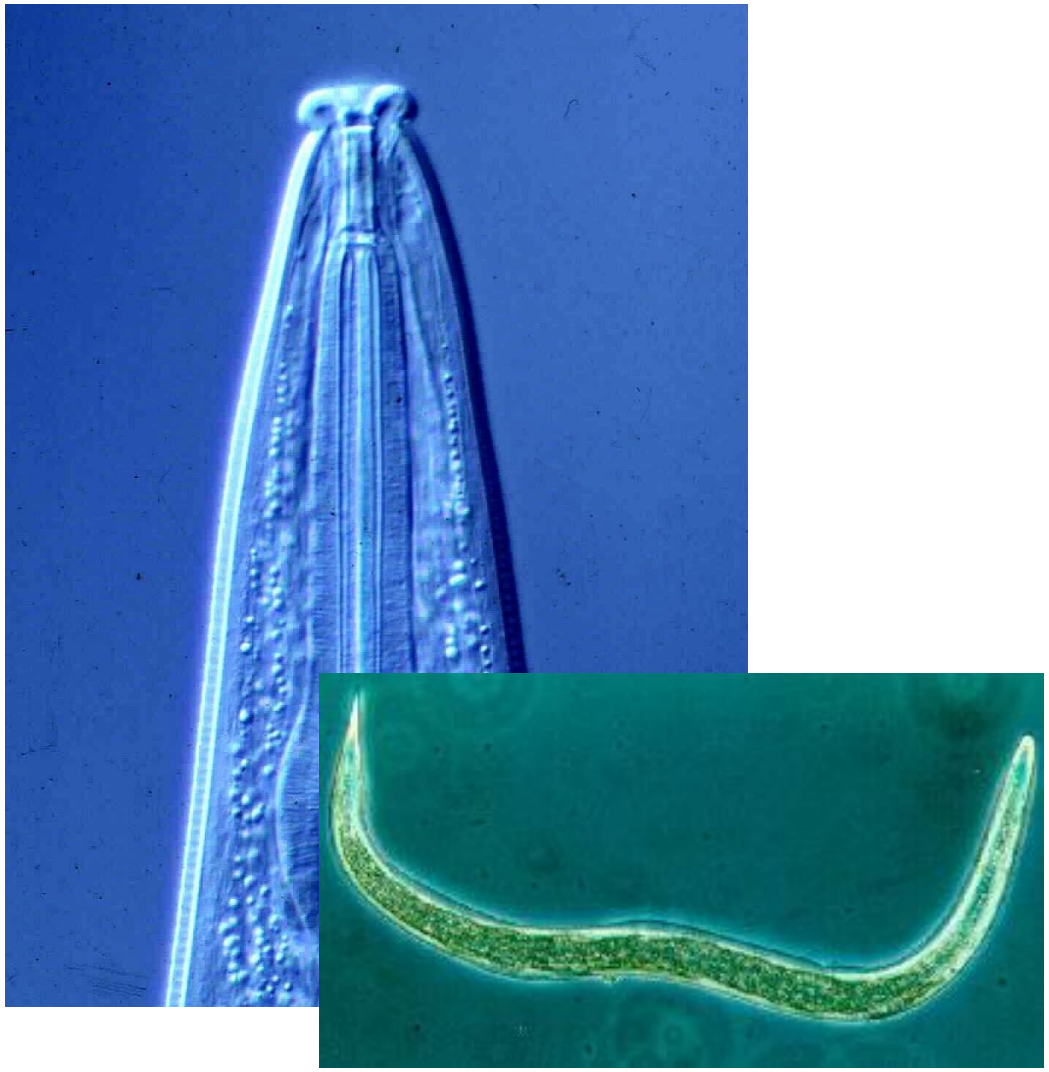
- Microscopic roundworms, phylum Nematoda.
- Most numerous multicellular animals on earth.
- A handful of soil will contain thousands—many of them parasites of insects, plants or animals.
- Free-living species include nematodes that feed on bacteria, fungi, and other nematodes.
- The vast majority of species encountered are poorly understood biologically. There are nearly 20,000 described species.



Nematode life history strategies

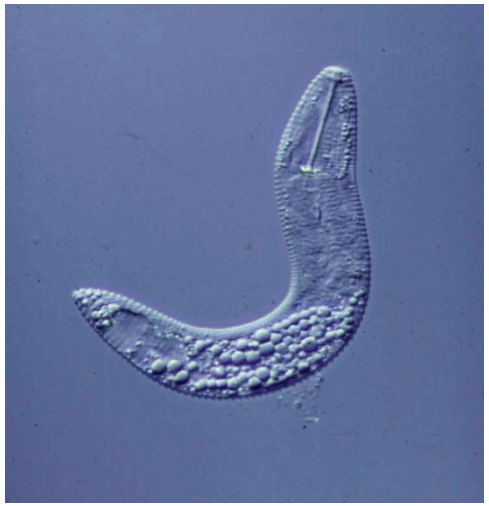
- Bacterial feeders—C. elegans
- Insect parasites—Entomopathogenic nematodes (EPNs)
- Fungal feeders
- Omnivores
- Predators
- Plant Parasites

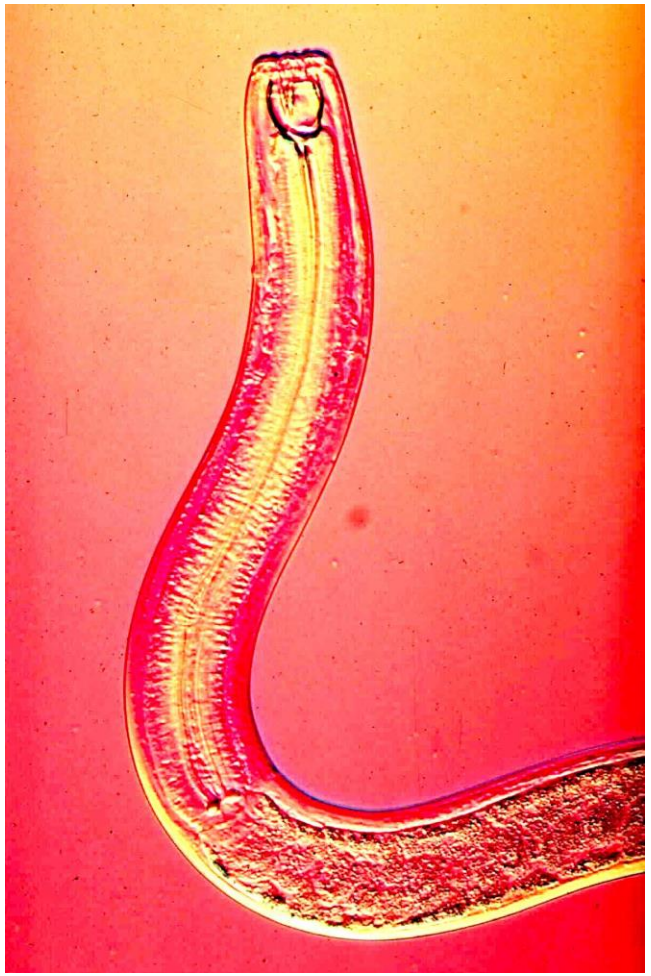




Nematodes as Bio-indicators

- Key positions in soil food webs
- Clear relationship between structure and function
- Abundant and ubiquitous
- Each soil sample has high intrinsic information value

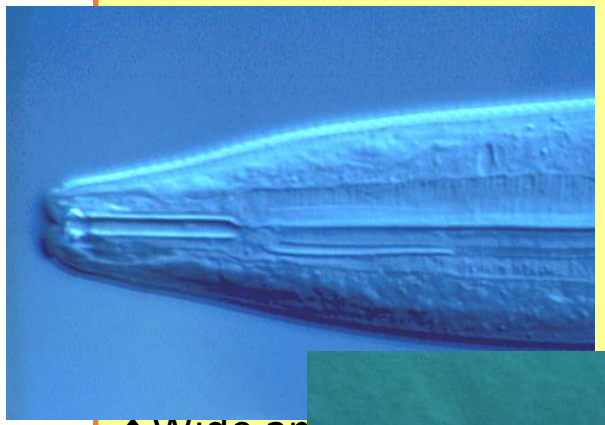




Enrichment Indicators

Structure Indicators

Rhabditidae
Panagrolaimidae



♦ Wide an
♦ Opportu
♦ Disturbe

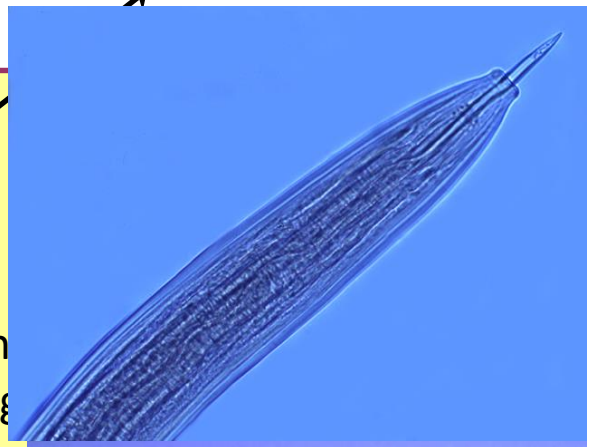
Basal Fauna

halobidae
nchidae, etc.

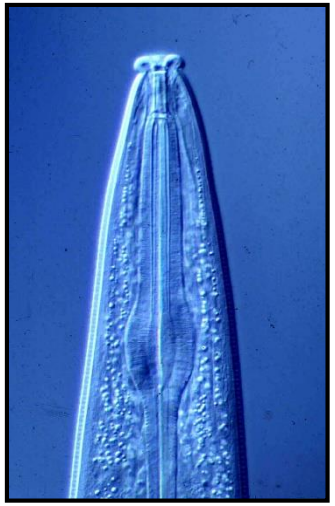
lifecycle

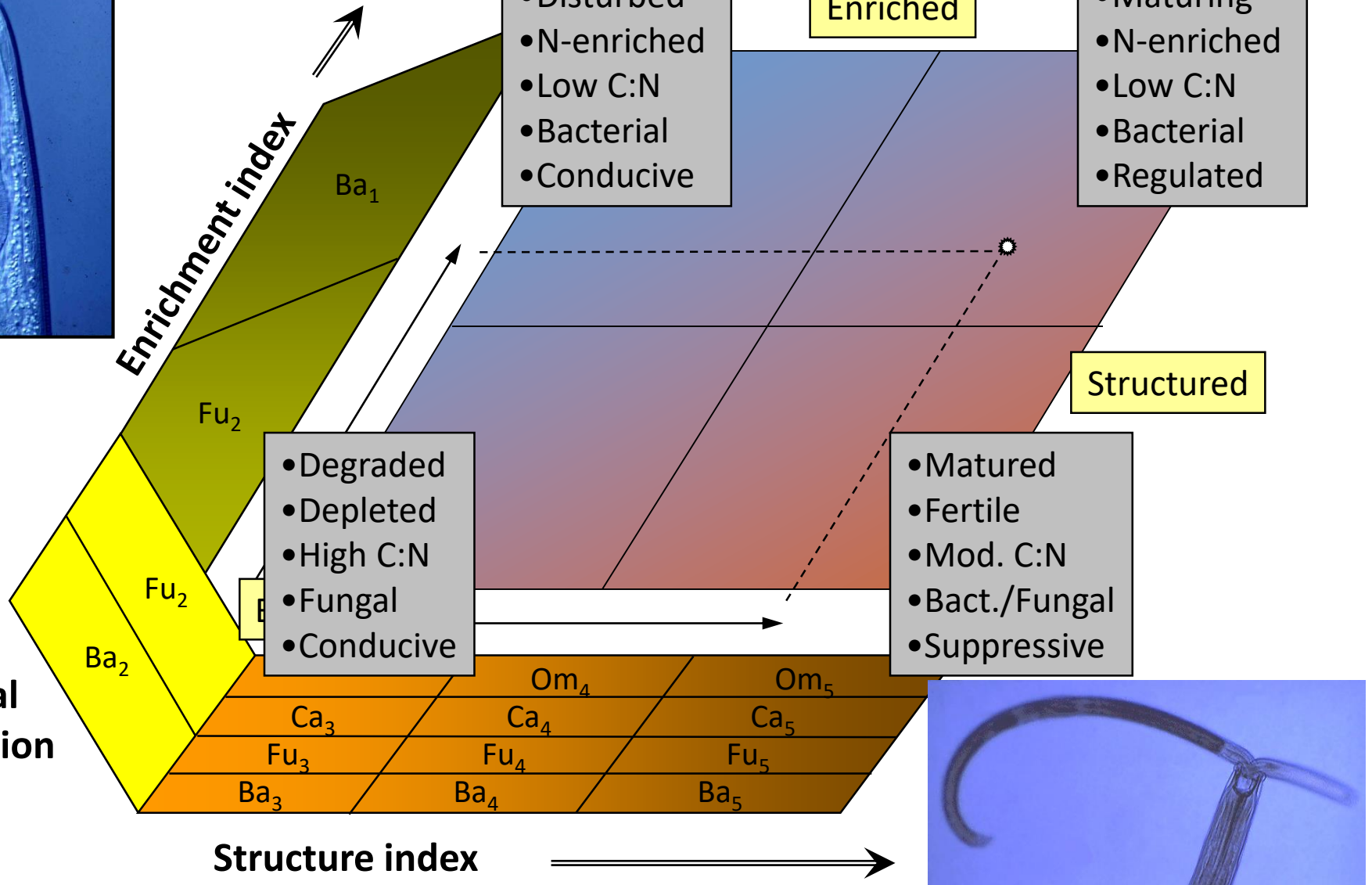
♦ Feeding a
♦ Present ir

♦ Lon
♦ Larg
♦ Low
♦ Large
♦ Stres
♦ Narr
♦ Undi



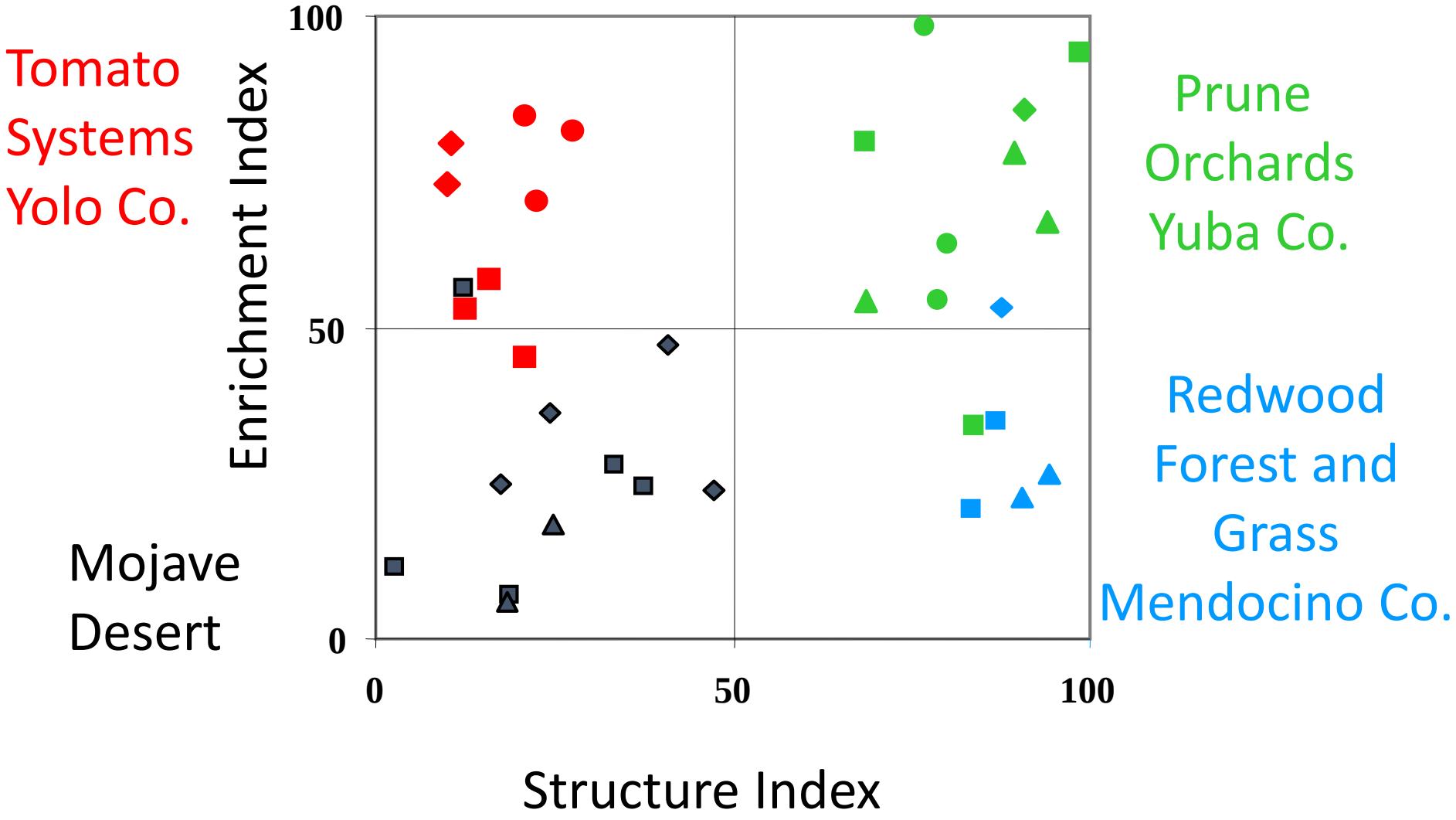
Testable Hypotheses of Food Web Structure and Function





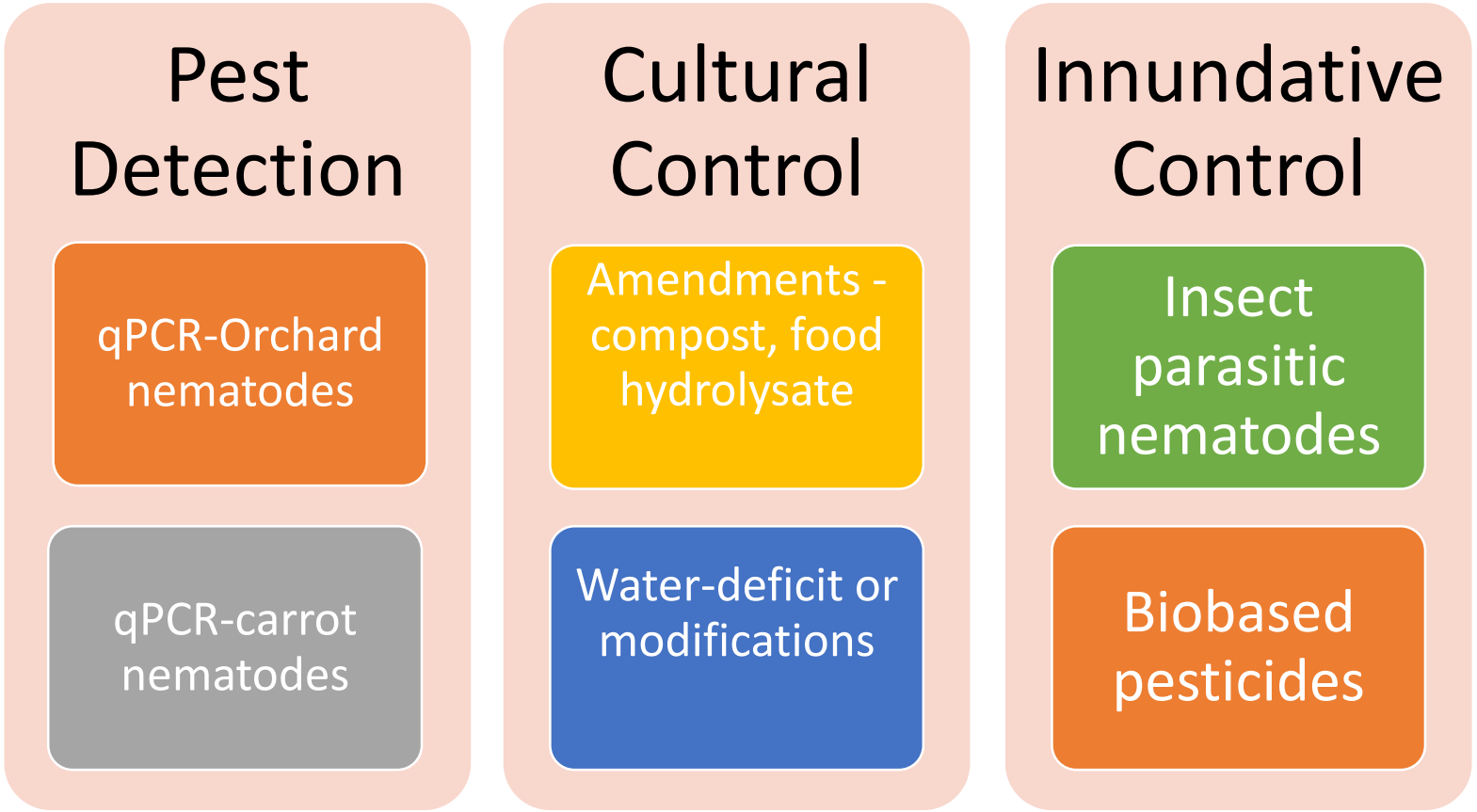
Ferris et al. (2001)

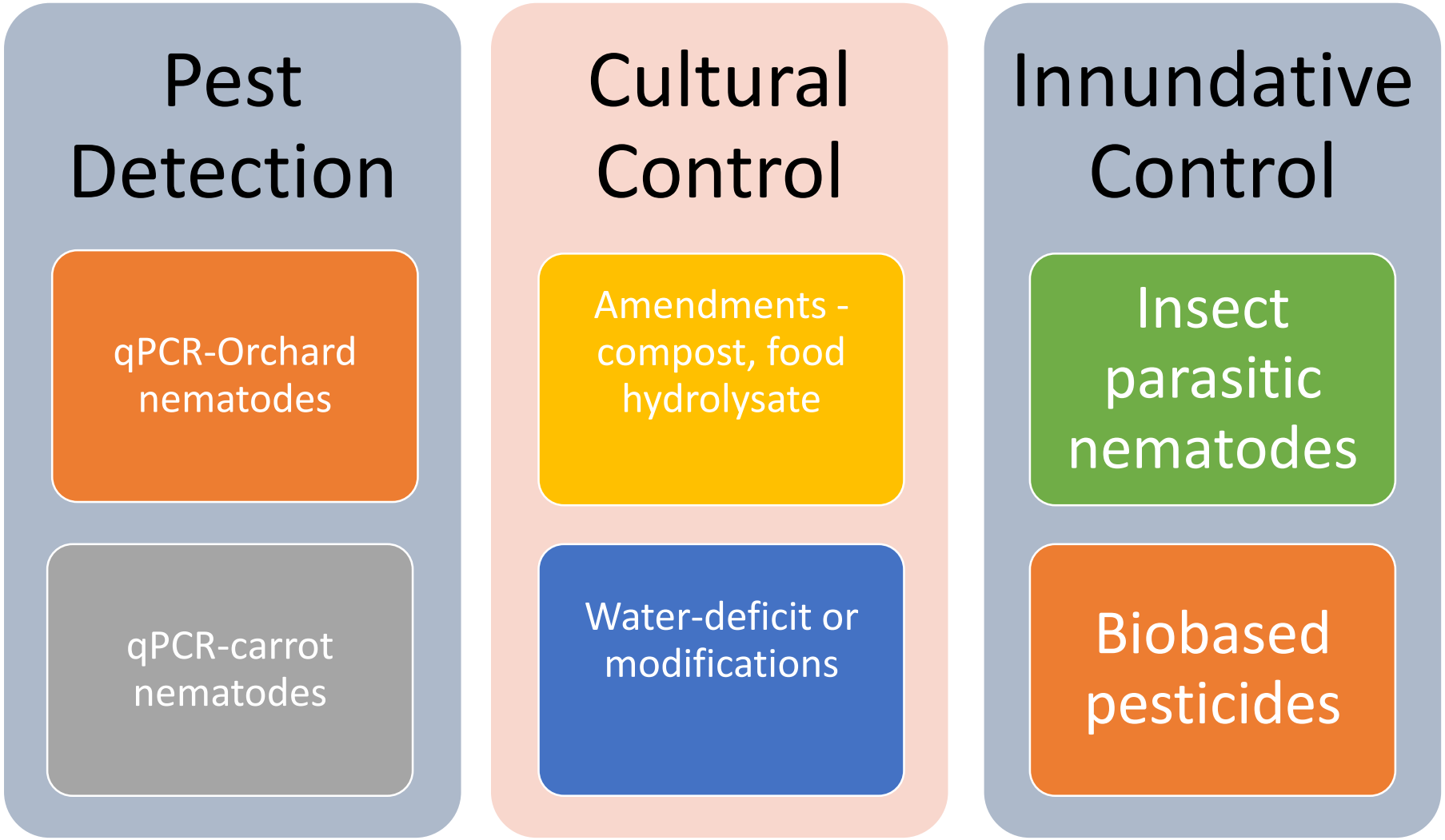
Food Web Analyses



Lewis Lab: Soil Ecology and Biological Control

The main scientific goal of our lab is to learn how to more sustainably manage agroecological systems to control pests and improve soil health. In particular, we study soil ecology, plant pest interactions, and biological control—both independently and through collaborations with industry and other laboratories.

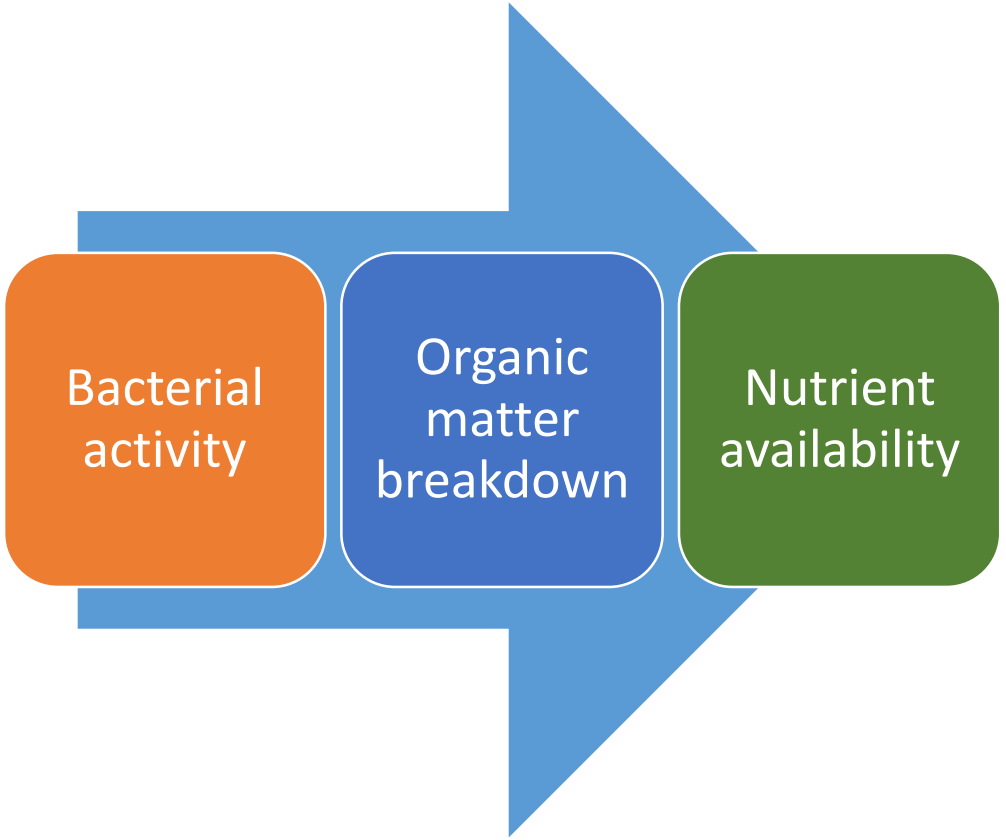



Pest Detection
qPCR-Orchard nematodes
qPCR-carrot nematodes
Cultural Control
Amendments - compost, food hydrolysate
Water-deficit or modifications
Innundative Control
Insect parasitic nematodes
Biobased pesticides

Applied nematode ecology: Ecological effects of an organic Amendment - stabilized food hydrolysate

- Unsold food collected from supermarkets in California.
- Digested with enzymes to produce a stabilized product consisting of amino acids, simple sugars, fatty acids, and minerals
- Marketed as a liquid fertilizer product to improve soil health.
  - *Does it improve plant growth?*
  - *Does it influence soil biology?*

Stabilized food hydrolysate



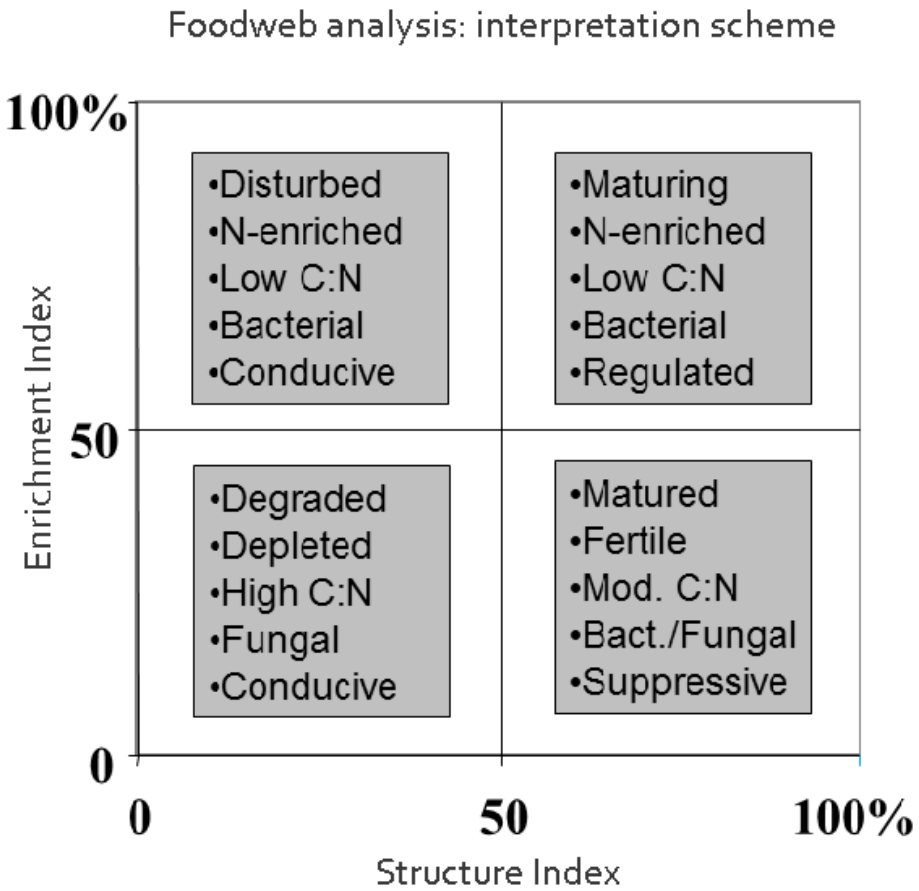
Food waste products in almonds

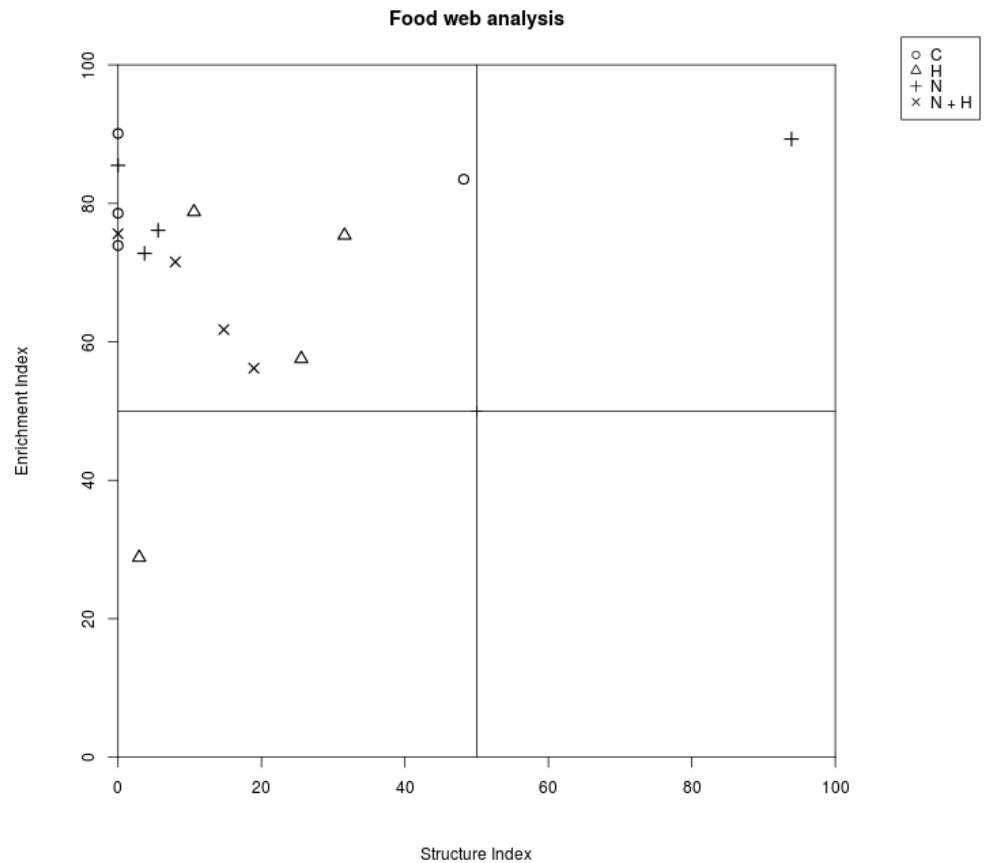
- *Can composted food waste and food hydrolysate increase soil carbon stocks?*
- *How do these nutrient sources differ in their ability to provide plant nutrition and increase growth?*
- *How do they differ in their potential for nitrate leaching, especially compared to chemical fertilizer?*
- *What changes do these products cause in soil biological communities?*

Treatments	
●	Nitrogen fertilizer (UAN32)
*	H2H
●/*	50 % H2H + 50% fertilizer
O	Control

Raised bed experiment

Family	Genus	Feeding habit
Rhabditidae	*Rhabditis*	bacterivores
	Diploscapter	bacterivores
Diplogasteridae	*Diplogaster*	bacterivores
Cephalobidae	*Cephalobus*	bacterivores
	Eucephalobus	bacterivores
	Acrobeles	bacterivores
	Acrobeloides	bacterivores
	Cervidellus	bacterivores
Plectidae	*Plectus*	bacterivores
	Anoplectus	bacterivores
Monhysteridae	*Monhystera*	bacterivores
Prismatolaimidae	*prismatolainus*	bacterivores
Alaimina(Alaimdae)	*Alaimus*	bacterivores
Aphelenchoididae	*Aphelenchoides*	fungivores
Aphelenchidae	*Aphelenchus*	fungivores
Dorylaimidae	*Dorylaimus*	Omniovores
Tylenchidae	*Tylenchus*	Herbivores
	Filenchus	Herbivores
	Tetylenchus	Herbivores
Paratylenchidae	*Paratylenchus*	Herbivores
Tylenchorhynchidae	*Tylenchorhynchus*	Herbivores
Pratylenchidae	*Pratylenchus*	Herbivores
Heteroderidae	*Meloidogyne*	Herbivores


Foodweb analysis: interpretation scheme
100%
50
0
Enrichment Index
•Disturbed
•N-enriched
•Low C:N
•Bacterial
•Conducive
•Maturing
•N-enriched
•Low C:N
•Bacterial
•Regulated
•Degraded
•Depleted
•High C:N
•Fungal
•Conducive
•Matured
•Fertile
•Mod. C:N
•Bact./Fungal
•Suppressive
0
50
100%
Structure Index

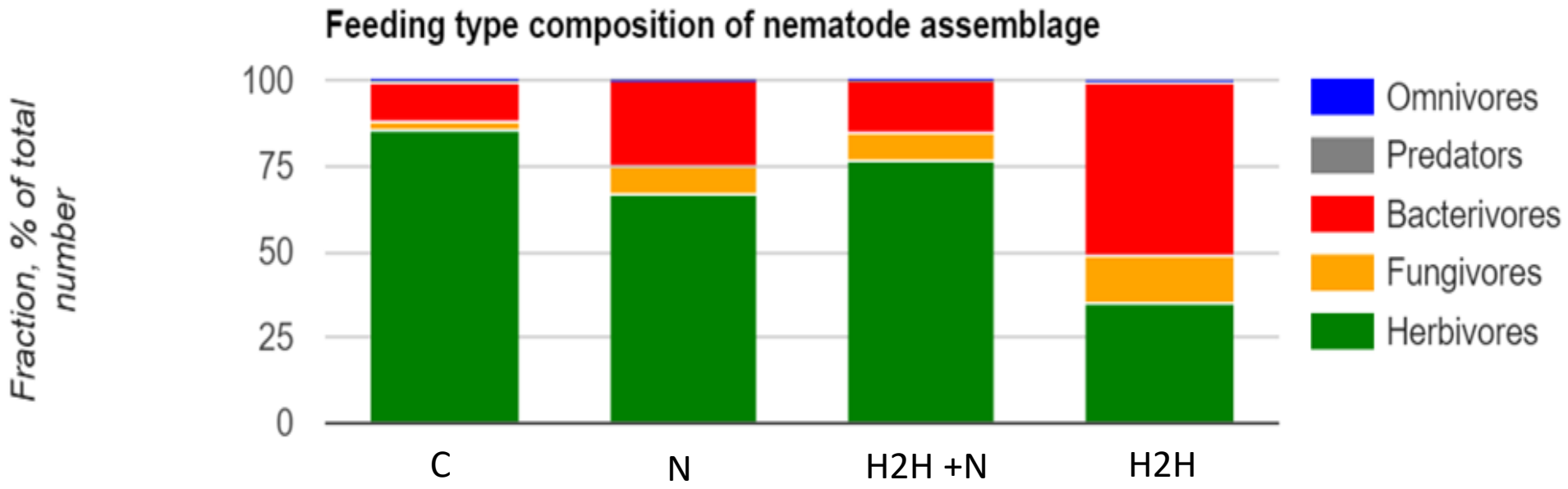

Food web analysis
C
H
N
N + H
Enrichment Index
0
20
40
60
80
100
Structure Index

Effects on soil biology

- Decreased pest root knot nematodes in H2H treated plots compared to controls (P=0.03)

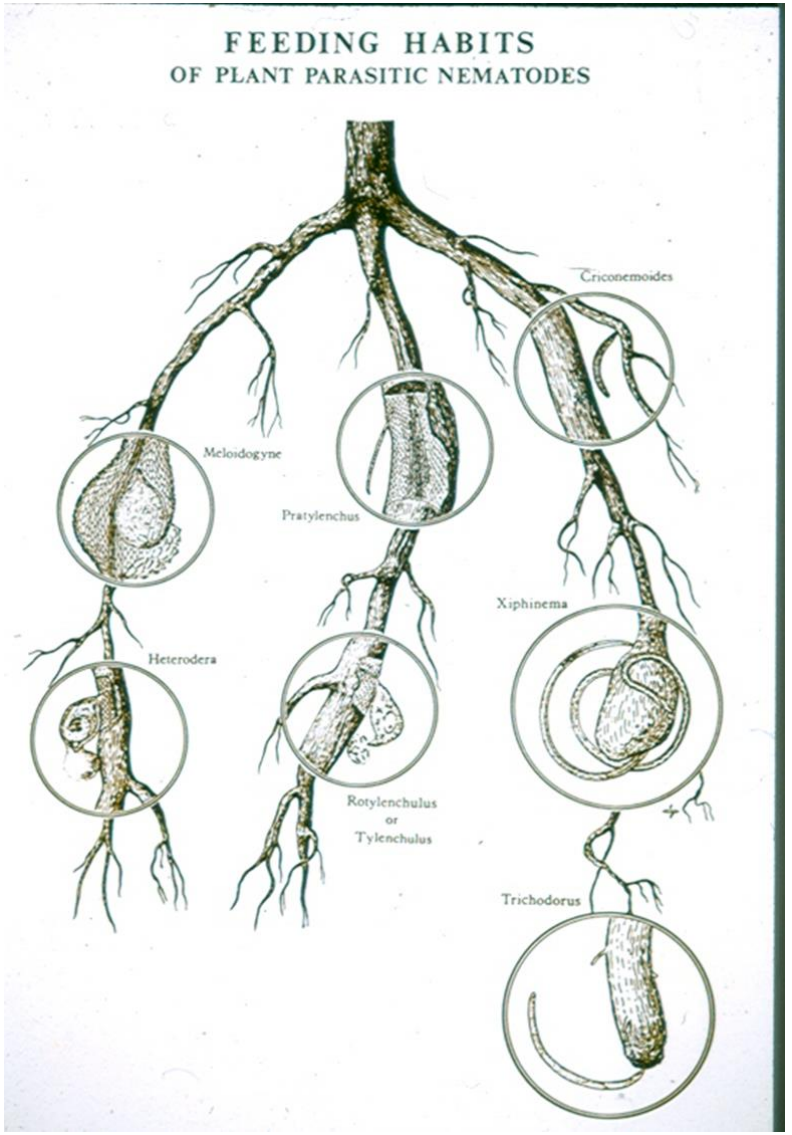
Effects on soil biology

- Increased beneficial bacterial feeding nematodes compared to controls (P=0.03).



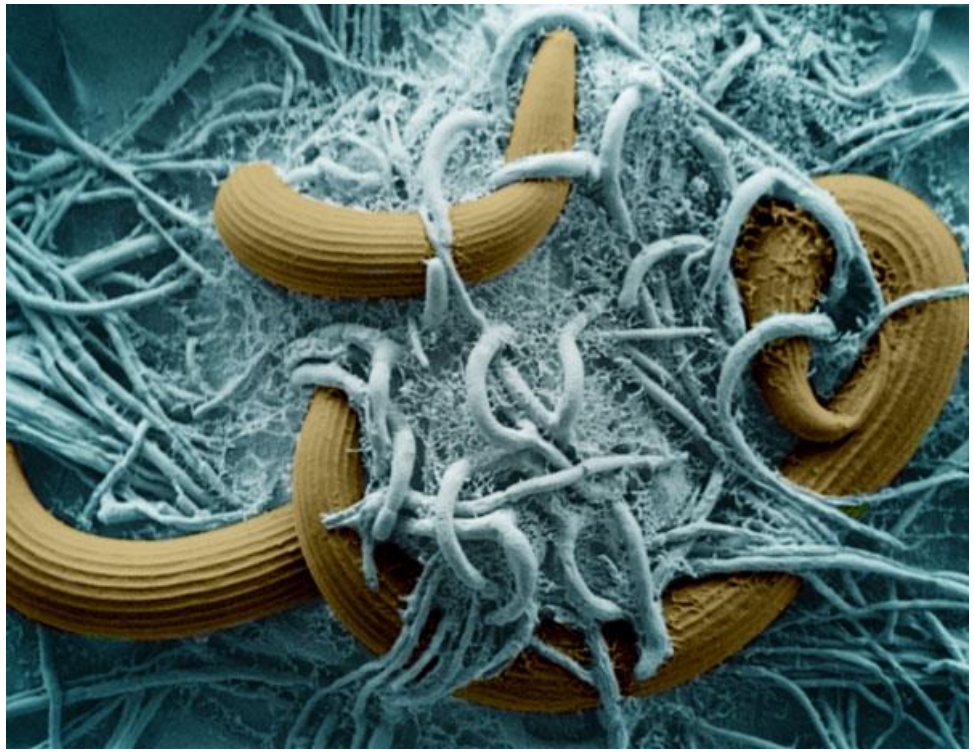
Managing for pest suppressive soils

- General suppression – protective community
- Specific suppression—targeted
- Inoculation—natural enemies are released directly via soil, seeds or planting materials



Mechanisms of Biological Control

- Predation Parasitism
- Competition for food/space –consortia?
- Antibiosis/toxic compounds



Thank you very much!!!

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