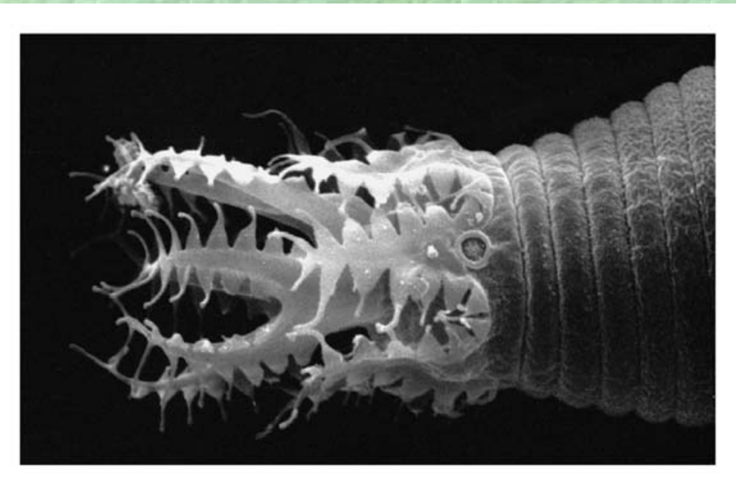


Soil Organisms and Functions

Martha Rosemeyer

Ecological Agriculture

January 12, 2006

Outline

Soil Food Web (BW Ch 11)

- The organisms- *Soil Biology Primer* (.http;//soils.usda.gov/sqi/concepts/soil_biology)
- The processes they perform
- Effect of management on the organisms and their functions: The WICST Trials

- For further information on earthworms, see posted lecture on masu

Food web concept

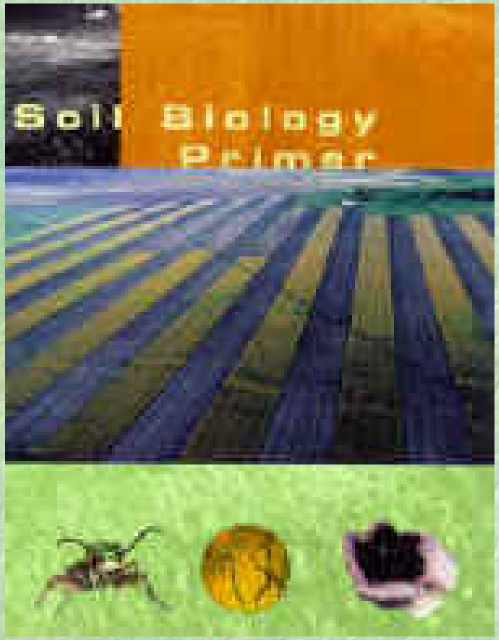
”Everything eats, everything excretes, and everything is food for something"

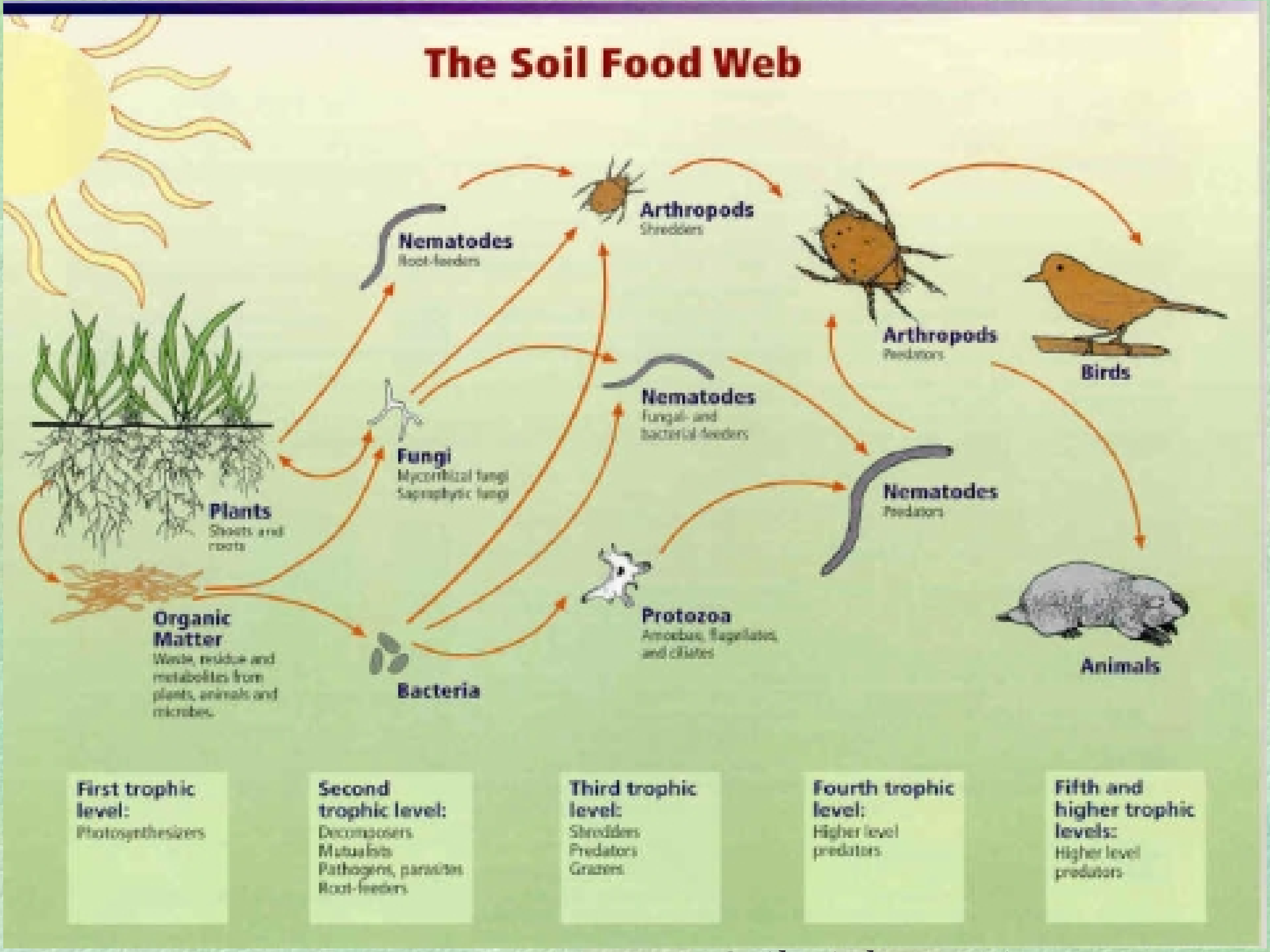
- Elaine Ingham, 2001

A great resource:

SWCS/NRCS,

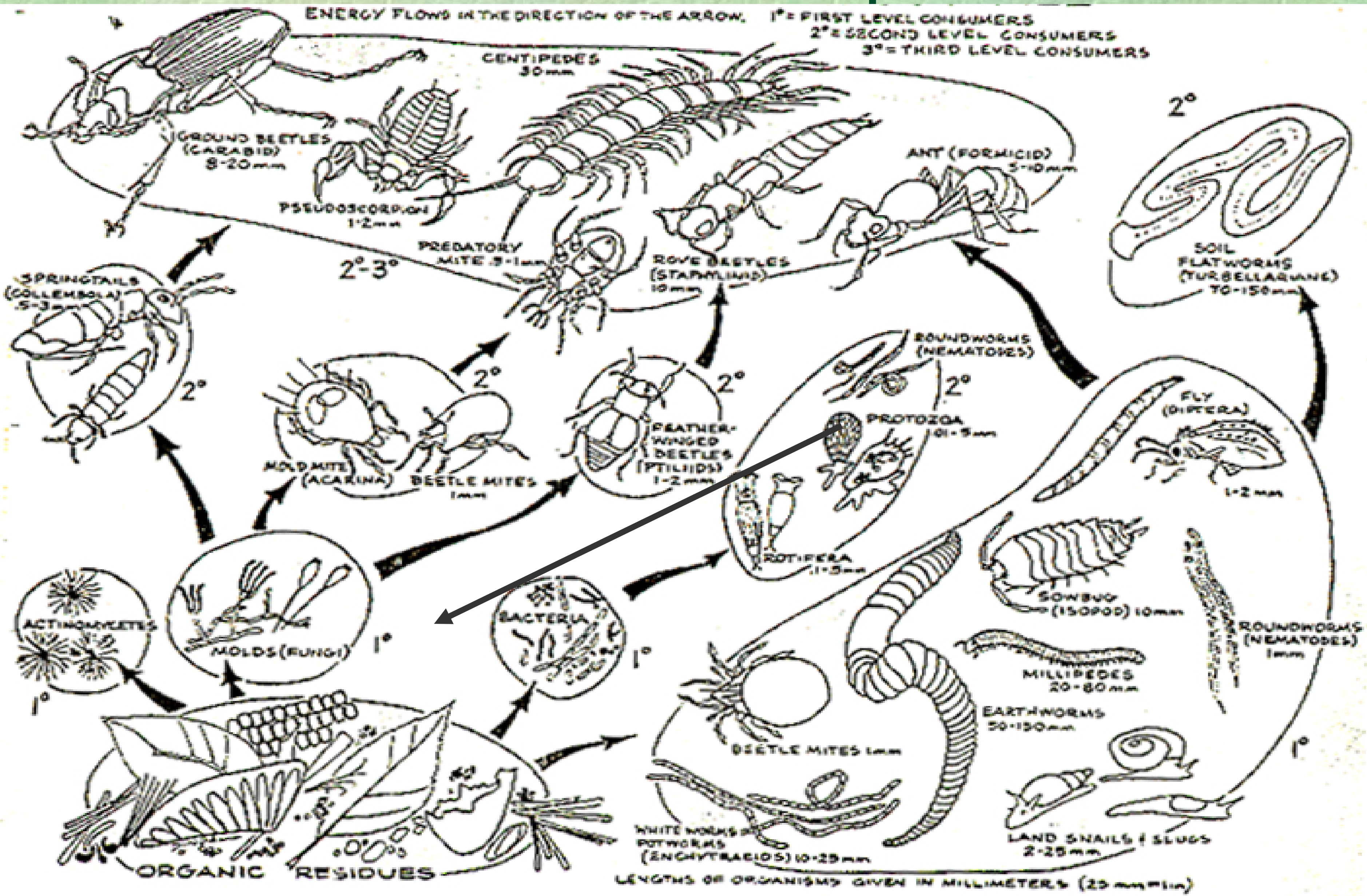
Soil Biology Primer





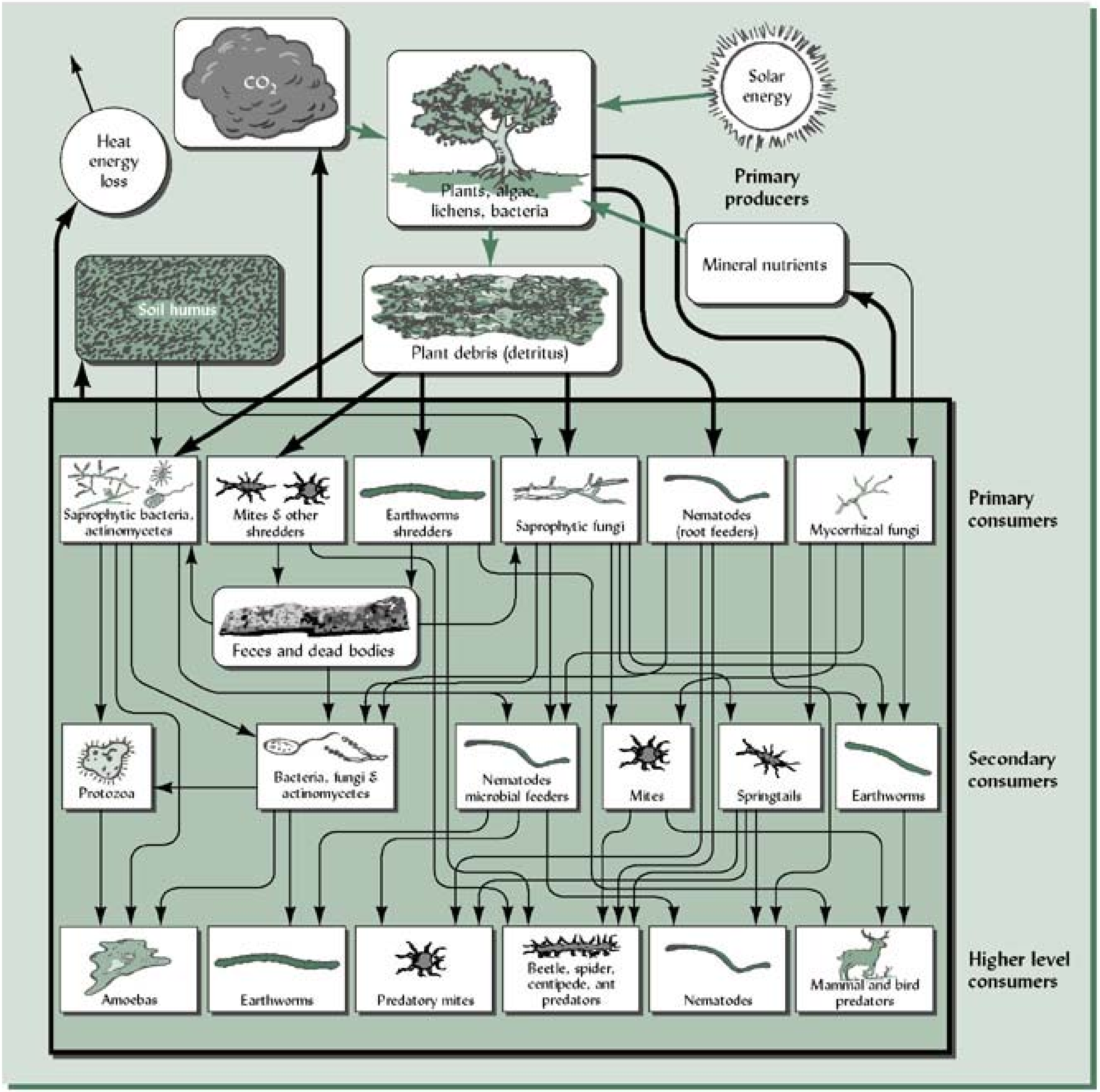
From: *Soil Biology Primer*

Food Web of the Compost Pile



Dindal, D. SUNY

BW Figure 11.1



Efficiency of soil food web vs. the above ground

- 10% of one trophic level passed on to next in above ground
- 30 (40-50)% of one trophic level passed on in below ground food web

Functional Groups of Soil Biota

- ***Ecosystem engineers***, e.g. macrofauna such as termites and earthworms, have major impact on soil physical and nutrient properties
- ***Decomposers***, e.g. microorganisms that have cellulose-degrading enzymes and are responsible for most of energy flow through decomposer food web
- ***Micro-regulators***, e.g. microfauna such as nematodes, protozoa that regulate nutrient cycles through microbial grazing an nutrient release
- ***Micro-symbiont***, e.g. Rhizobium and mycorrhizae associated with plant roots and enhance nutrient uptake
- ***Soil-borne pests and disease***, e.g. plant pathogens, invertebrate pests
- ***Bacterial transformers***, e.g. nitrifying bacteria, perform specific transformations of C, N, S

Mike Swift, TBSFH

Function of Soil Organisms

- Decomposition of organic matter
  - mixing and turnover of soil, increase macropores
  - mineralization - from organic to inorganic state
  - formation of humus
- Breakdown of toxic compounds
- Inorganic transformations
  - solubilization of P from Iron and Al compounds
    - *Bacillus meganthurium* increased yields 50-70% in USSR
  - oxidation of iron and manganese
- Nitrogen fixation
  - bacteria (cyanobacteria), actinomycetes

Classification according to size

TABLE 11.1 General Classification of Some Important Groups of Soil Organisms

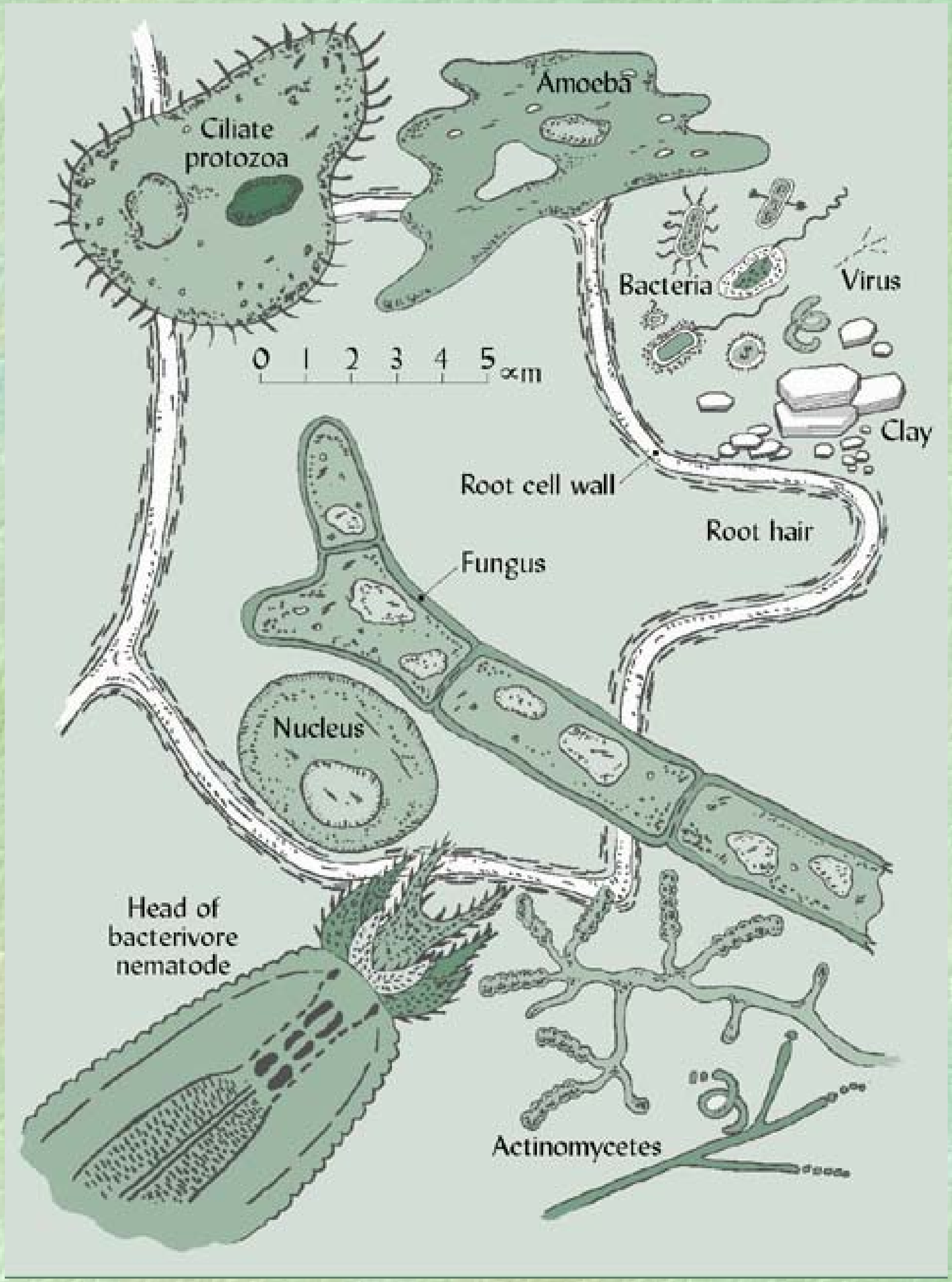
Some organisms subsist on living plants (herbivores), others on dead plant debris (detritivores). Some consume animals (predators), some devour fungi (fungivore) or bacteria (bacterivores), and some live off of, but do not consume, other organisms (parasites). Heterotrophs rely on organic compounds for their carbon and energy needs while autotrophs obtain their carbon mainly from carbon dioxide and their energy from photosynthesis or oxidation of various elements.

Generalized grouping (width in mm)	*Major specific groups*	*Examples*
Macrofauna (>2mm)		
All heterotrophs, largely herbivores and detritivores	Vertebrates	Gophers, mice, moles
	Arthropods	Ants, beetles and their larvae, centipedes, grubs, maggots, millipedes, spiders, termites, woodlice
	Annelids	Earthworms
	Mollusks	Snails, slugs
Macroflora		
Largely autotrophs	Vascular plants	Feeder roots
	Bryophytes	Mosses
Mesofauna (0.1–2 mm)		
All heterotrophs, largely detritivores	Arthropods	Mites, collembola (springtails)
	Annelids	Enchytraeid (pot) worms
All heterotrophs, largely predators	Arthropods	Mites, protura
Microfauna (<0.1 mm)		
Detritivores, predators, fungivores, bacterivores	Nematodes	Nematodes
	Rotifera[a]	Rotifers
	Protozoa[a]	Amoebae, ciliates, flagellates
Microflora (<0.1 mm)		
Largely autotrophs	Vascular plants	Root hairs
	Algae	Greens, yellow-greens, diatoms
Largely heterotrophs	Fungi	Yeasts, mildews, molds, rusts, mushrooms
	Actinomycetes	Many kinds of actinomycetes
Heterotrophs and autotrophs	Bacteria[b] (and Archaea[b])	Aerobes, anaerobes
	Cyanobacteria	Blue-green algae

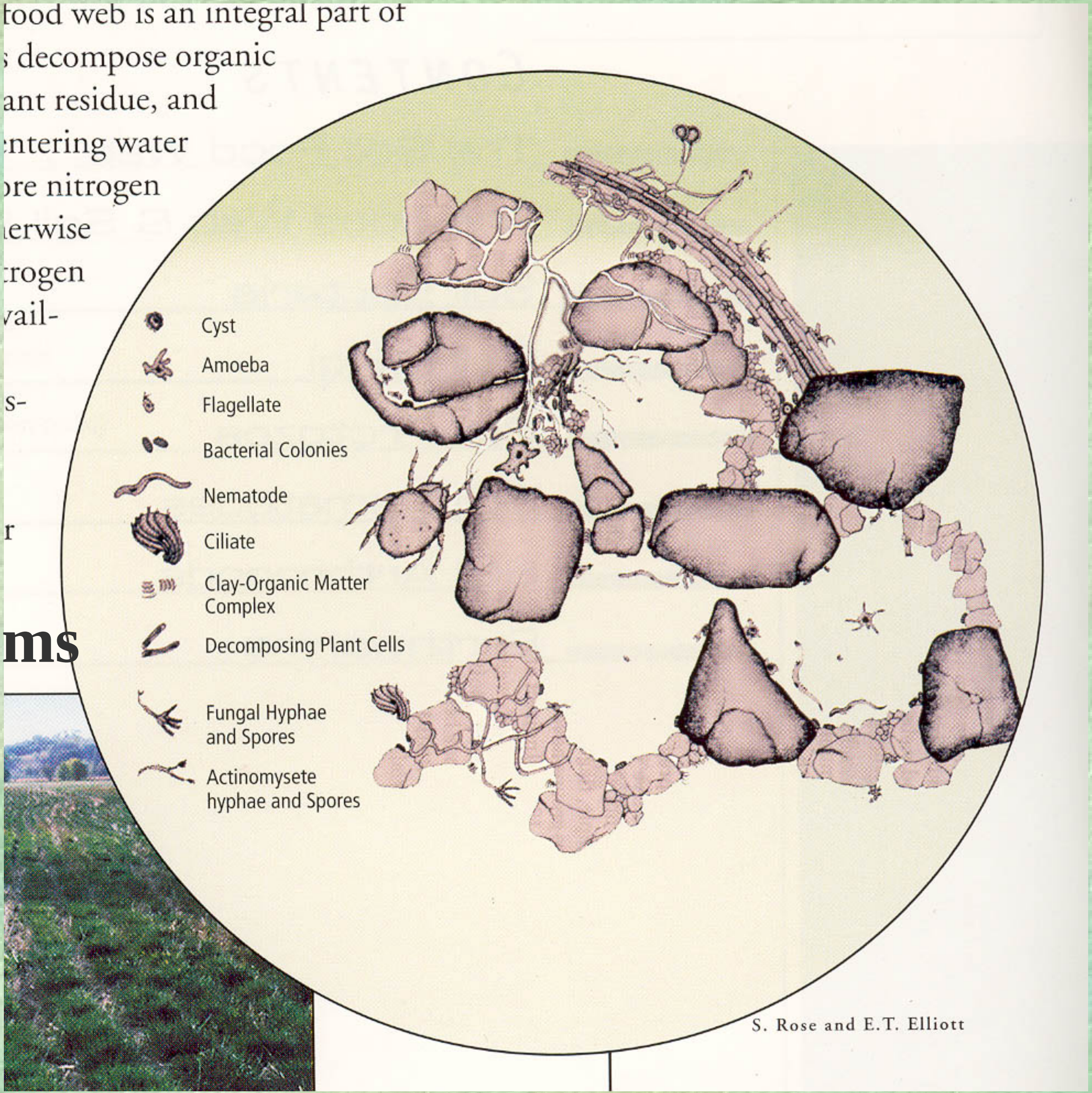
[a] Generally classified in the kingdom *Protista*.

[b] Traditionally classified together in the kingdom *Monera*, these organisms have prokaryotic cells but are classed in the domains Bacteria or Archaea based on differences in RNA.

Orders of magnitude difference in sizes of organisms



The soil is a heterogeneous environment for soil organisms



Microflora: cannot be seen without the aid of a microscope

Bacteria

Primary Consumers

Biomass: 400-500 kg/ha

No. individuals: 10^{13}-10^{14}/g

Metabolic activity

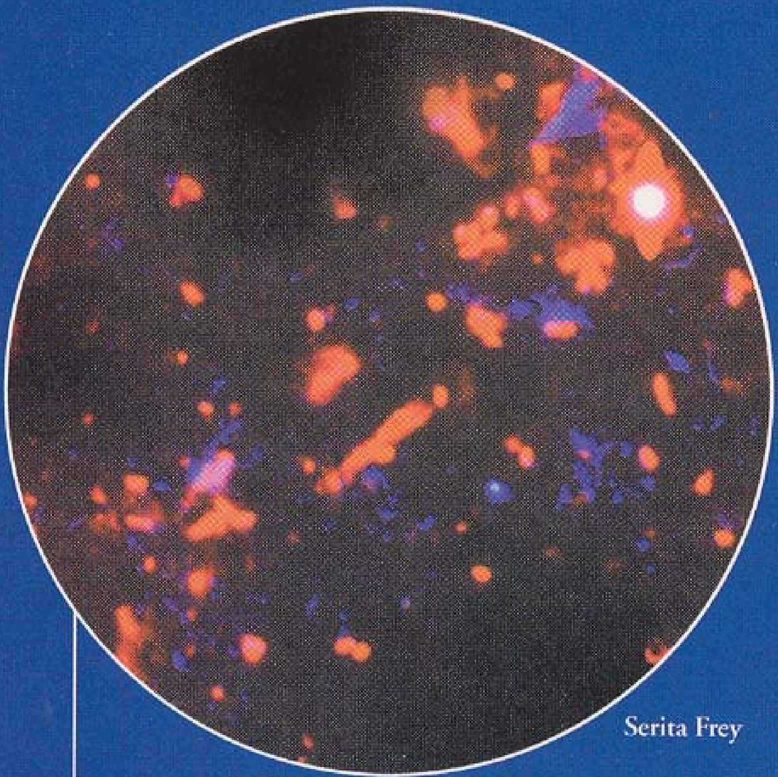


Figure 3: These bacteria have taken up a fluorescent stain, making them easier to count.

Metabolism

- Extremely resistant resting stages
- Rapid reproduction potential in response to food and environment
- In decomposition colonize easy to degrade substrates, especially with tillage
- Ability to use diverse substrates
  - some only catalyzed by bacteria, e.g. nitrifying
- Heterotrophic (parasitic or saprophytic) or Autotrophic
  - Photoautotrophic- energy from sunlight
  - Chemoautotrophic- energy from oxidation of inorganic substrates

Microbes are ancient!

- Responsible for all major processes on earth, including decomposition and photosysnthesis and nutrient cycling
- Major cycles of Earth could continue without plants and animals
- Most are beneficial!

Bacteria can be beneficial to plant growth:

Often sold as plant inoculants-- appears to be due to production of plant hormones

TABLE 11.9 Rice Plants Respond to Inoculation with Growth-Promoting Rhizobacteria

Rice plants were grown in pots with clay soil that was puddled and flooded with water. All pots were fertilized with adequate N fertilizer, but only some were inoculated with various strains of Rhizobia or Bradyrhizobia bacteria. The bacteria colonized the rice rhizosphere (hence the term rhizobacteria) and changed the physiology of the rice plant, partly by producing the plant growth hormone IAA. Inoculated roots were more efficient at nutrient uptake. Analysis of N isotope tracers showed that the rhizobacteria did not cause significant amounts of N fixation.

		Uptake of nutrients by rice plants, mg/pot				
Treatment	*Grain yield, g/pot*	*N*	*P*	*K*	*Fe*	*IAA[a] in the rhizosphere, mg/L*
Control—no inoculation	36.7	488	111	902	18.9	1.0
Inoculated with rhizobacteria	44.3	612	134	1020	23.6	2.1
Percent change	+21	+25	+21	+13	+25	+110

[a] IAA = inol-3-acetic acid, a plant growth hormone.
Data calculated from Biswas, et al. (2000)

Cyanobacteria (blue-green algae) can photsynthesize and fix N

Most bacteria (99%) cannot be cultured

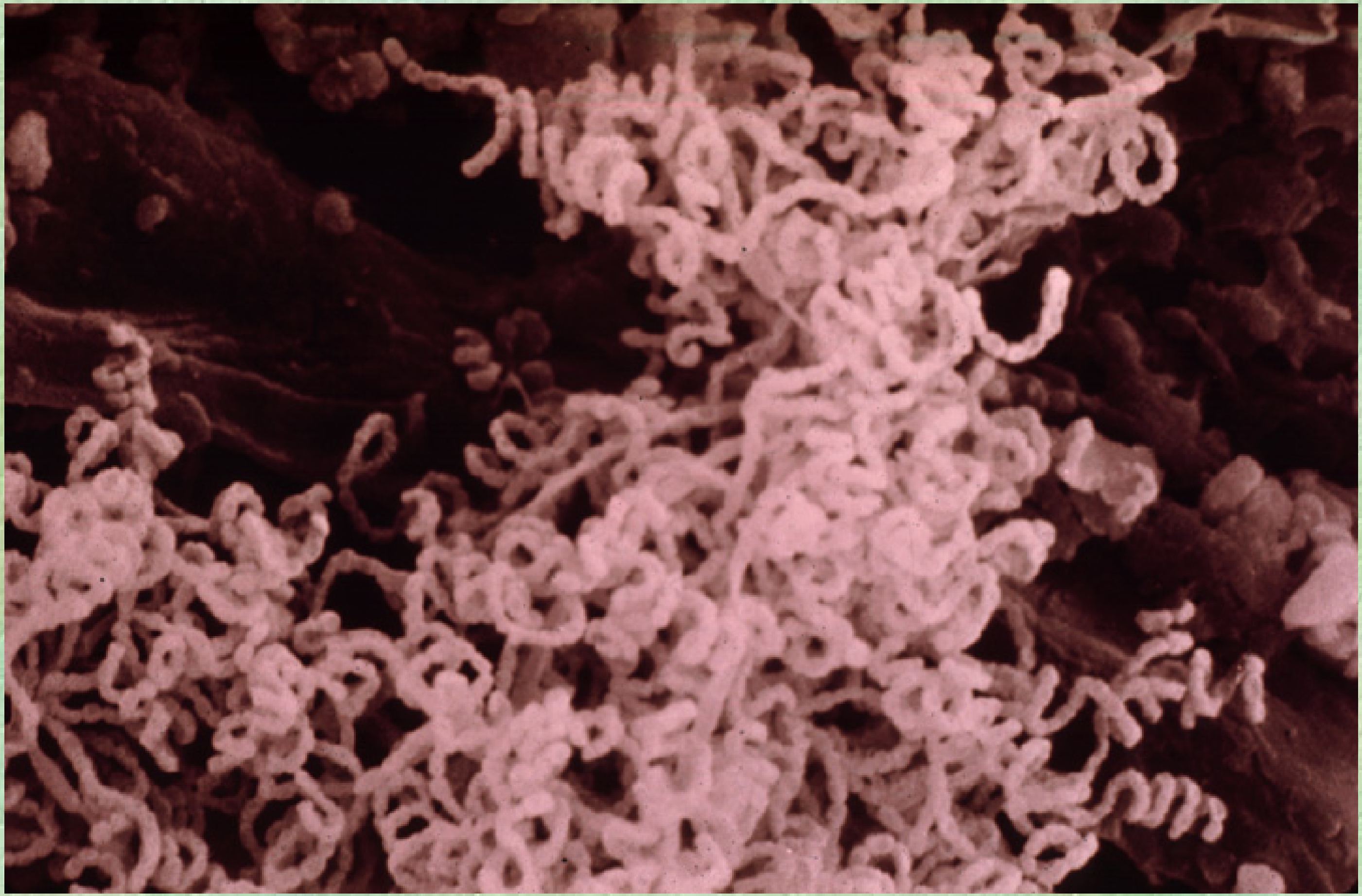
- How do we know?
  - Direct counts and genetic diversity (DNA assessment

A ton of microscopic bacteria may be active in each acre of soil.

Bacteria dot the surface of strands of fungal hyphae.

From: *Soil Biology Primer*

Actinomycetes: Filamentous bacteria



Actinomycetes, such as this *Streptomyces*, give soil and compost its "earthy" smell from *geosmins* a type of terpene.

Soil Microbiology and Biochemistry Slide Set. 1976. J.P. Martin, et al., eds. SSSA, Madison, WI From: *Soil Biology Primer*

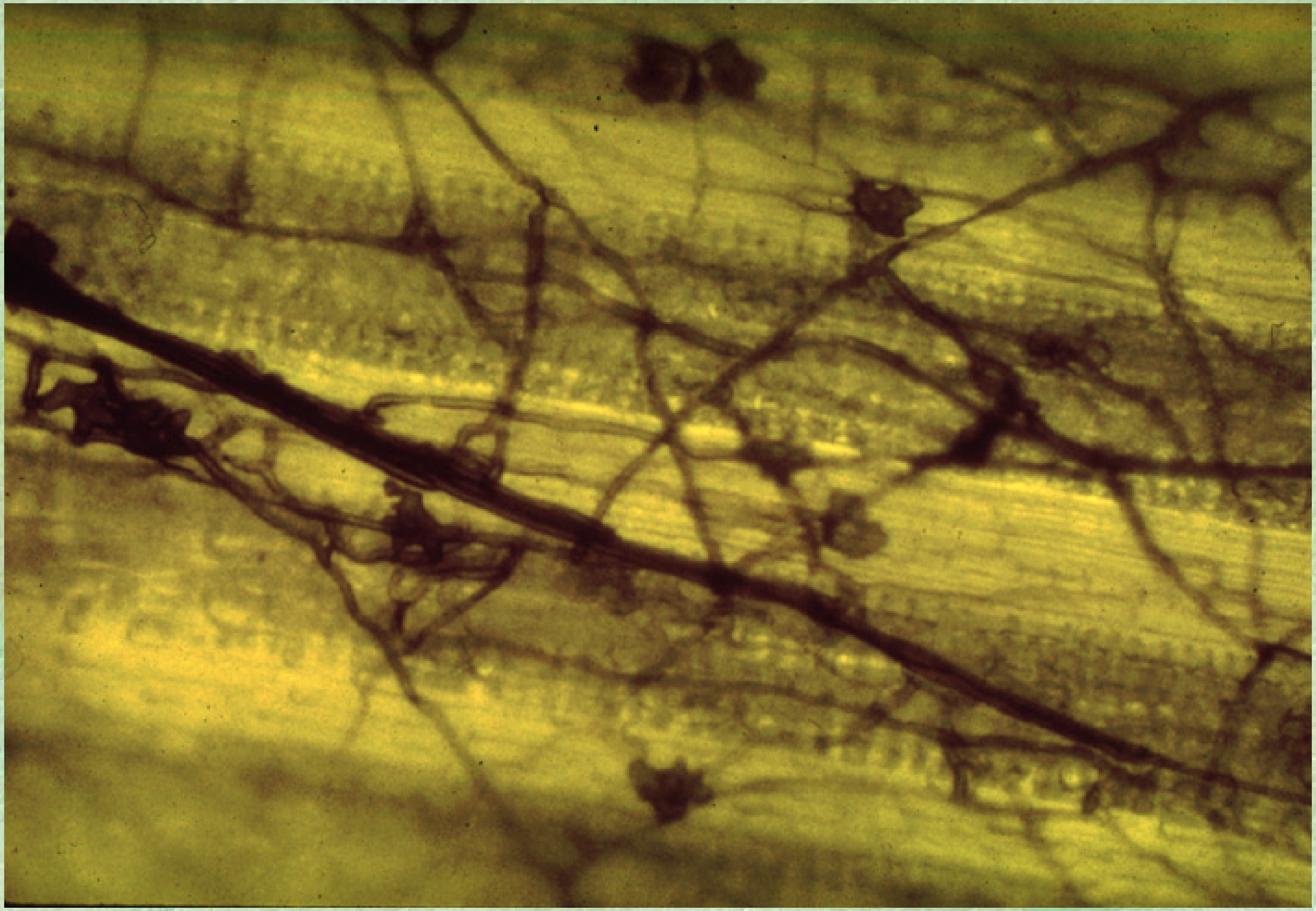
Actinomycetes

- Filamentous bacteria- filaments like fungi but finer. No nuclear membrane like bacteria (prokaryote) and spores resemble bacteria
- Decomposition of OM
- Some produce antibiotics- streptomycin, actinomycin and neomycin
- Some fix N, e.g. *Frankia* in red alder
- More drought tolerant than bacteria and fungi, acid sensitive

Actinomycetes

- Biomass 5000 kg/ha
- In numbers exceed all except bacteria
- Can degrade most resistant compounds such as cellulose, chitin and phospholipids
- Important later on in decay and therefore in “curing” process of compost
- Numerous in humus in old meadows and pastures

Fungi



Fungus beginning to decompose leaf veins in grass clippings.
Soil Microbiology and Biochemistry Slide Set.
1976. J.P. Martin, et al.,eds. SSSA, Madison WI.

From: *Soil Biology Primer*

Fungi

- Diverse group: 1 million await discovery?
- Numbers smaller than bacteria
- Dominate biomass at 1000 to 15,000 kg/ha in upper 15 cm
- Efficient- 50% of the substance decomposed can become fungal biomass
- Eukaryote with nuclear membrane and cell wall
- Yeasts- single celled, but rest are filamentous and some seen with naked eye
- Molds vs. mushrooms

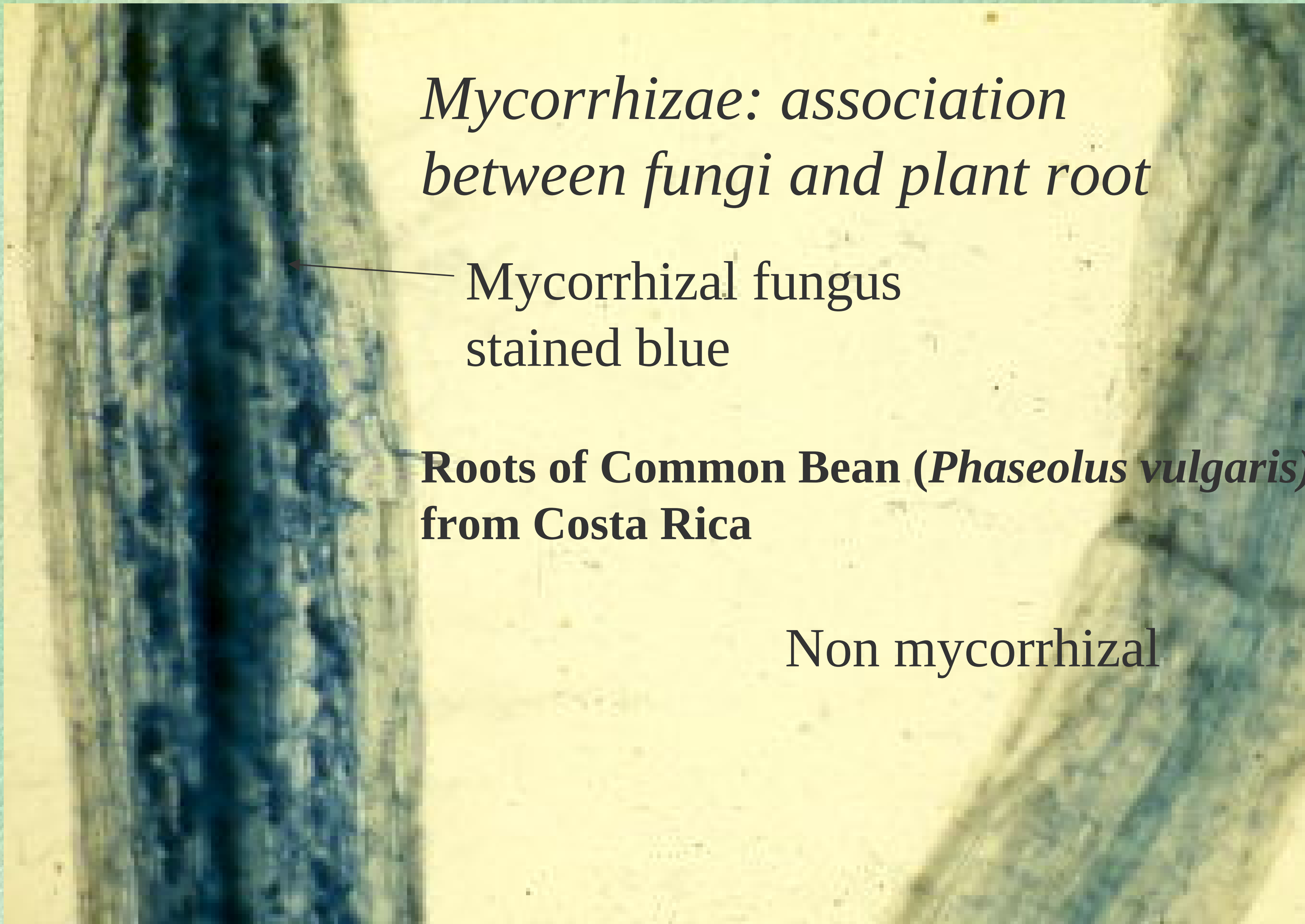
BW Figure 11.19

Fungal *hyphae* are often twisted together to form what appears like woven ropes forming the body of the fungus or *mycelium*.

Fungal activities

- Decomposers of organic matter in soil
- Can decompose the difficult cellulose and lignins as well as proteins and sugars
- Important in humus formation and aggregate formation
- Form mycotoxins (aflatoxin by *Aspergillus flavus*– peanuts and corn, humanly toxic)
- Synthesize complex compounds: Antibiotic Penicillin from *Penicillium*
- Dominate in acid and sandy soils
- Appear to dominate in forest and no-tillage ag systems

Mycorrhizae: association between fungi and plant root



Roots of Common Bean (*Phaseolus vulgaris*) from Costa Rica

Photo: Rosemeyer

Predatory: Nematode trapping fungi

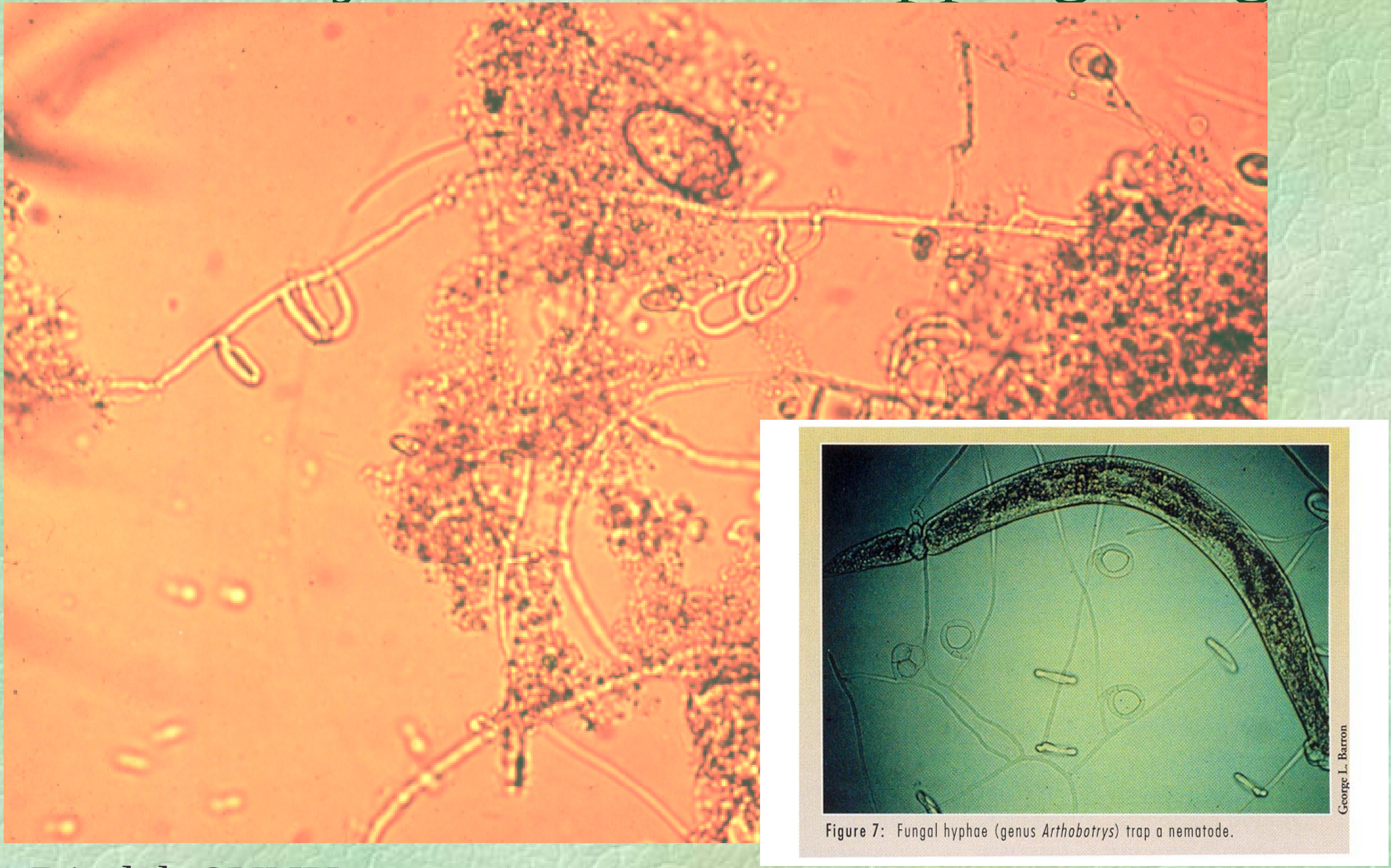
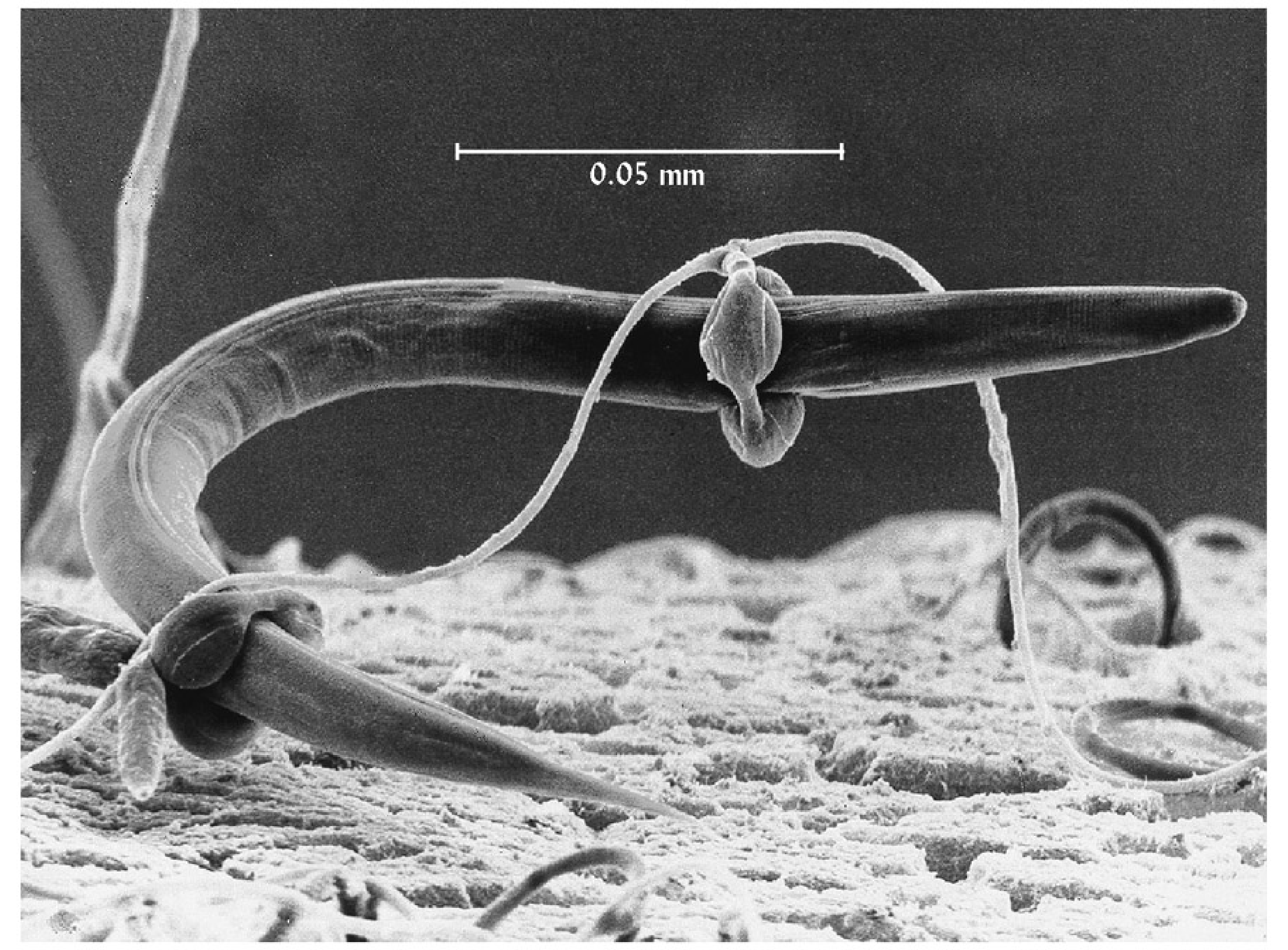


Figure 7: Fungal hyphae (genus *Arthobotrys*) trap a nematode.

Dindal, SUNY

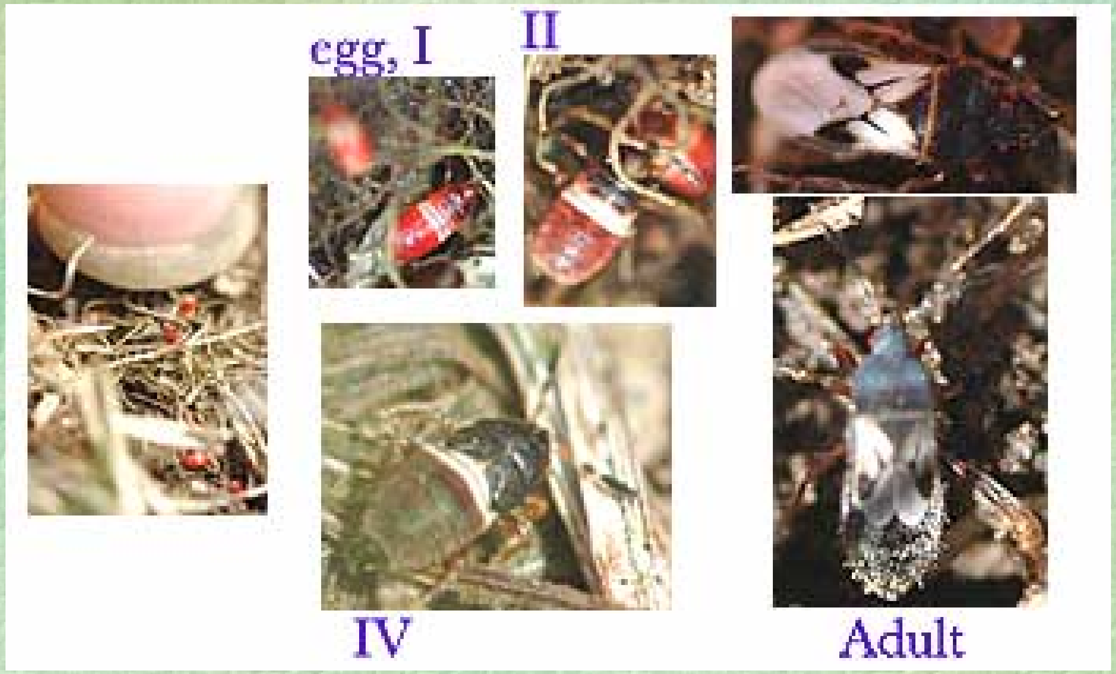
From: *Soil Biology Primer*

Ring three cells that swell and contract around the nematode



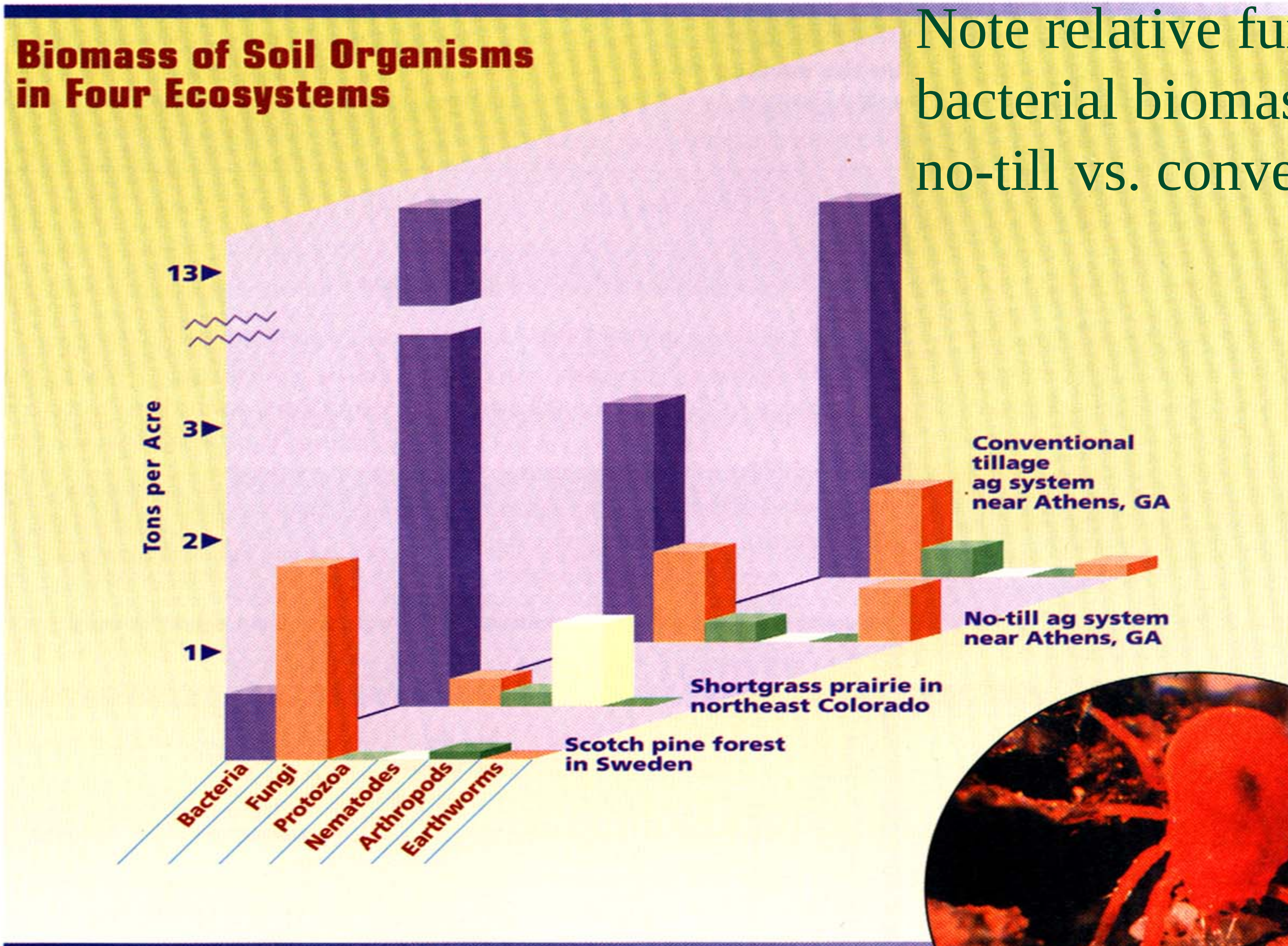
BW Ch 11 Fig 11.22

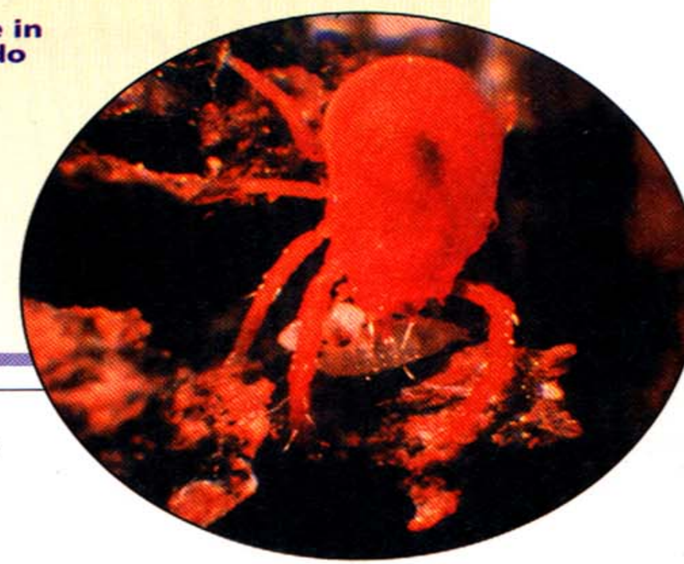
Fungi can be pathogens of insect and mite pests, and used as biocontrol e.g. *Beauvaria bassiana* on chinch bug, turf pest



George Barron
.www.versicolor. ca

Note relative fungal vs. bacterial biomass in no-till vs. conventional



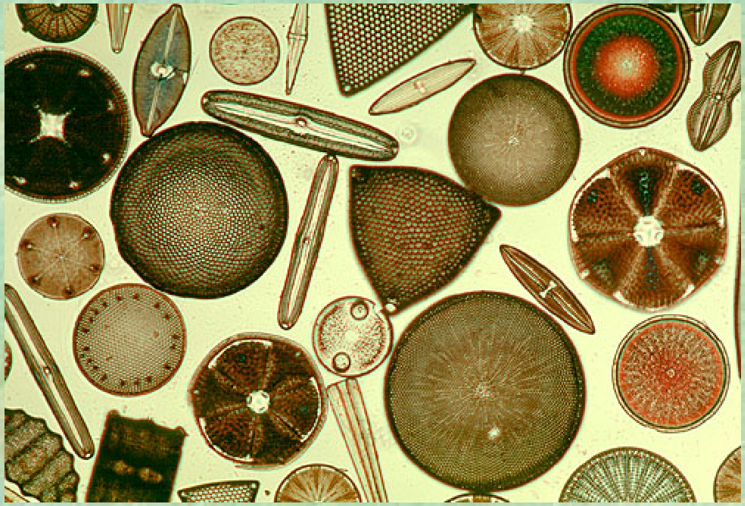


Roy A. Norton

Figure 1: A predacious mite feeds on a springtail. As the mite metabolizes the carbon in the springtail, excess nitrogen is excreted as feces and becomes available to plants. The interactions among organisms are important to soil health.

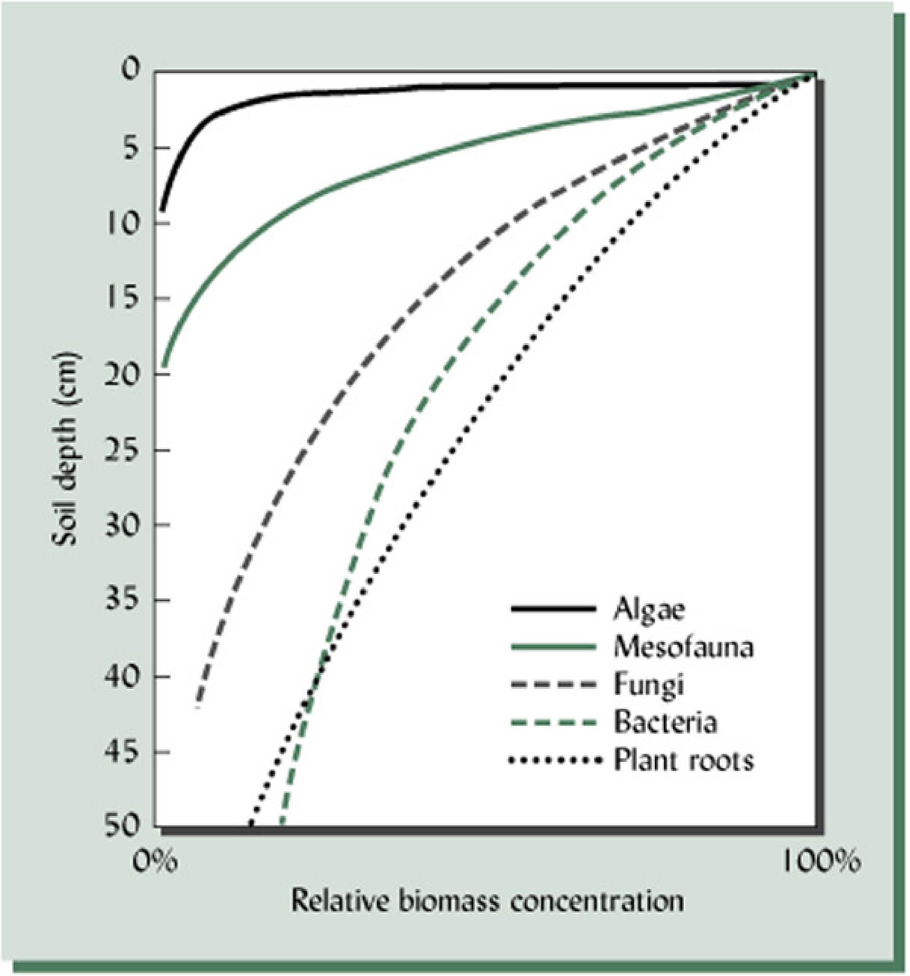
Algae

- 1 to 10 billion per m^2
  or 10,000 to 100,000/g
- 10 - 500 kg/ha
- Are eukarotes (nuclear membrane)
- Photosynthesize, so found on surface of soil
- Produce OM, polysaccharides
- Important form mat on soil surface, microbiotic crusts in desert and lichens (with fungi)



Diatoms, one type of soil algae

Algae found on surface

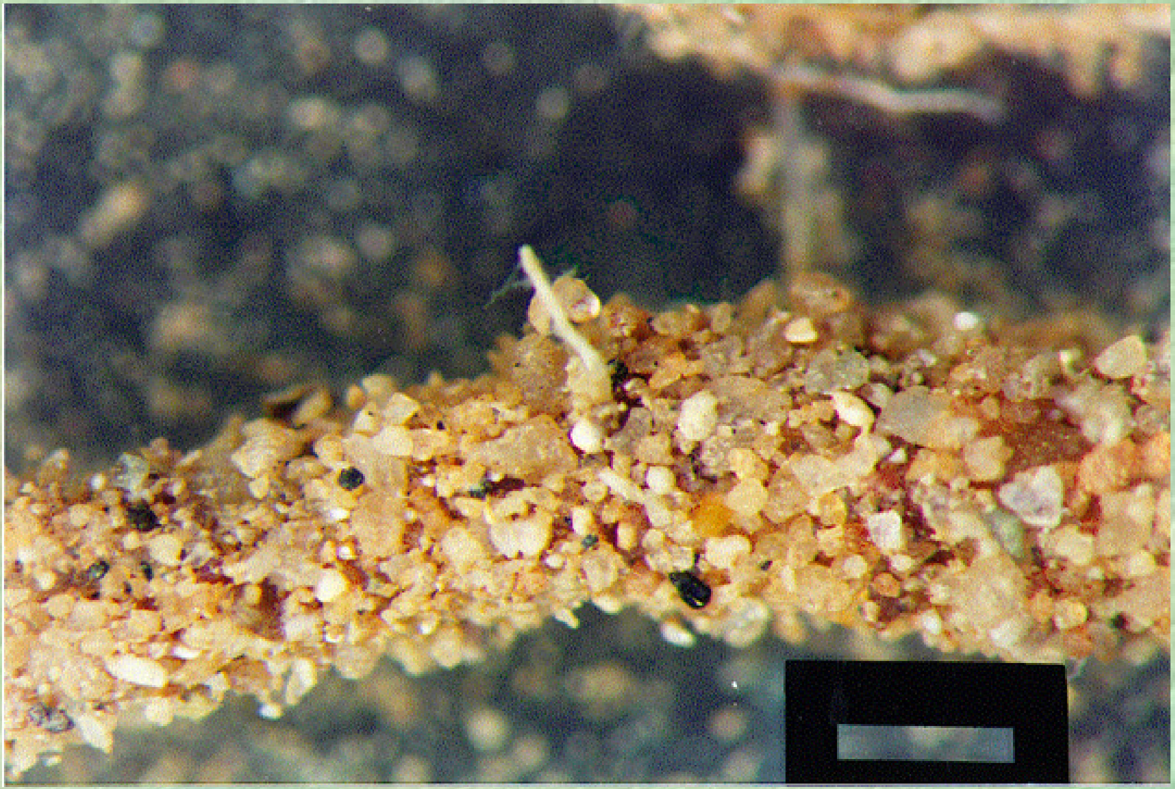


BW Figure 11.18

Roots of higher plants

- May be size of meso or microorganisms
- Roots grow and die and in text are soil orgs.
- Primary producers of organic matter
- About 1% of soil volume and 25-30% of respiration
- 50-60% of NPP in roots in grassland
- 40-70% of NPP in tree roots in forest

Rhizophere: zone of soil influenced significantly by the root, usually 2mm



In this photo, sand grains are bound to a root by hyphae from endophytes (fungi similar to mycorrhizae), and by polysaccharides secreted by the plant and the fungi, demonstrating the rhizosphere.

From: *Soil Biology Primer*Jerry Barrow, USDA-ARS Jornada Experimental Range, Las Cruces, NM.

Figure 11.17

Rhizosphere soil adheres as a ‘sheath’.

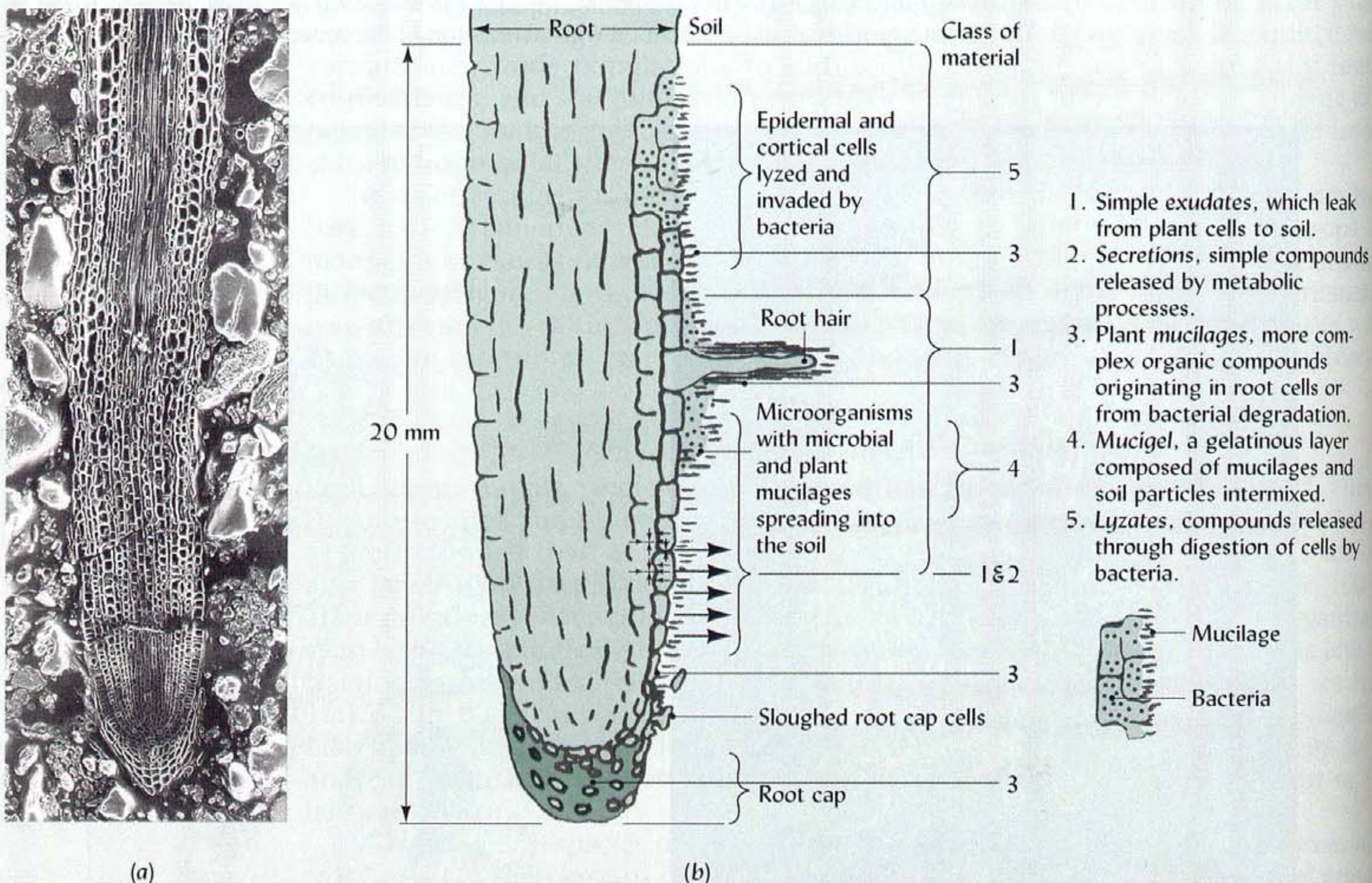


FIGURE 11.16 (*a*) Photograph of a root tip illustrating how roots penetrate soil and emphasizing the root cells through which nutrients and water move into and up the plant. (*b*) Diagram of a root showing the origins of organic materials in the rhizosphere. [(*a*) From Chino (1976), used with permission of Japanese Society of Soil Science and Plant Nutrition, Tokyo; (*b*) redrawn from Rovira, et al. (1979), used with permission of Academic Press, London]

11.16

- Carbon compounds exhuded from root
  - relatively simple sugars, proteins etc.
  - mucilage
  - roots cap cells themselves
- Nutrients taken up
- $[H^+]$ can be 10x different (one pH unit)
- Populations of organisms much higher in rhizosphere
  - Rhizosphere to soil or R/S ratio

Microfauna: nematodes, rotifers and protozoa

Nematodes

RKN of bean

- Predatory in general
  - bacteria, fungi algae, protozoa, other nematodes and insect larvae (biological control of corn rootworm)
- Release nutrients from feeding on bacteria and fungi
  - bacteria contain more N than nematodes need
  - can account for 30-40% of N released
- Beneficial but some plant parasitic

Nematode head structures indicate trophic group

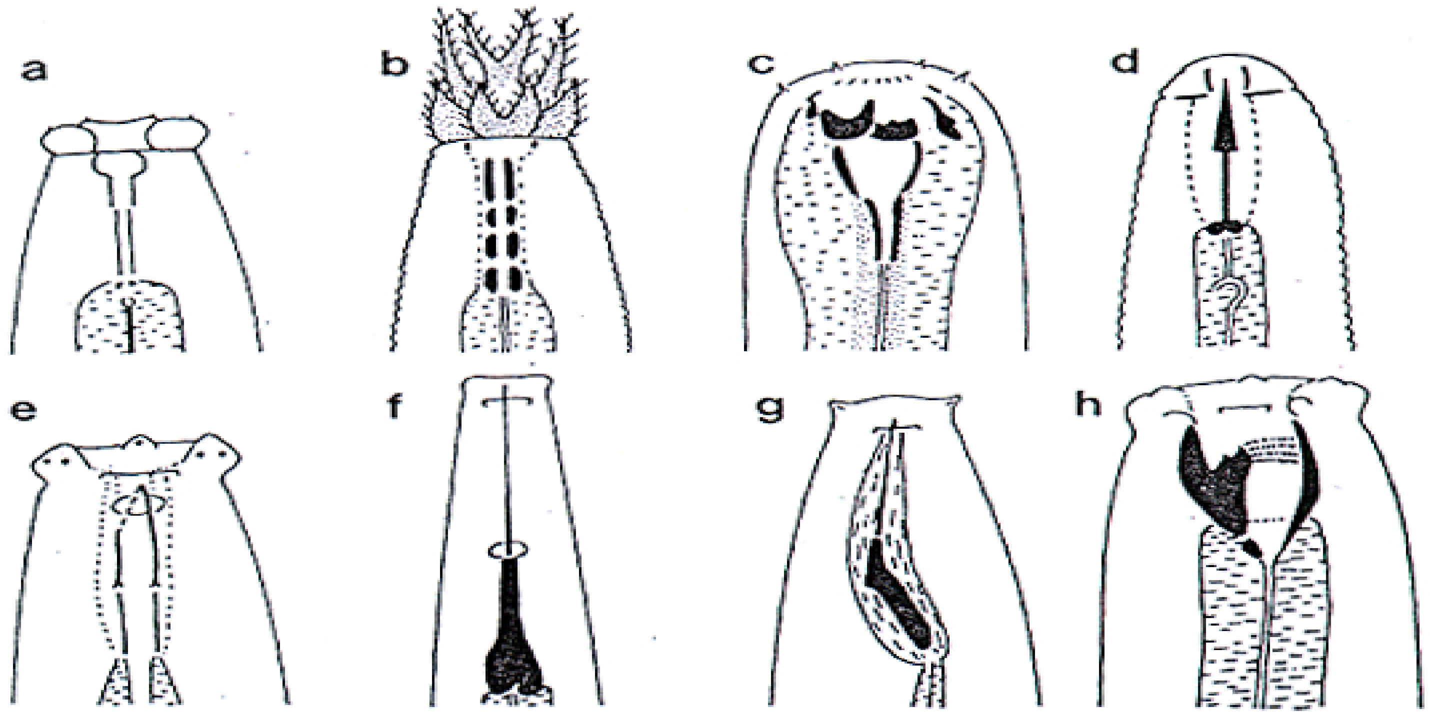
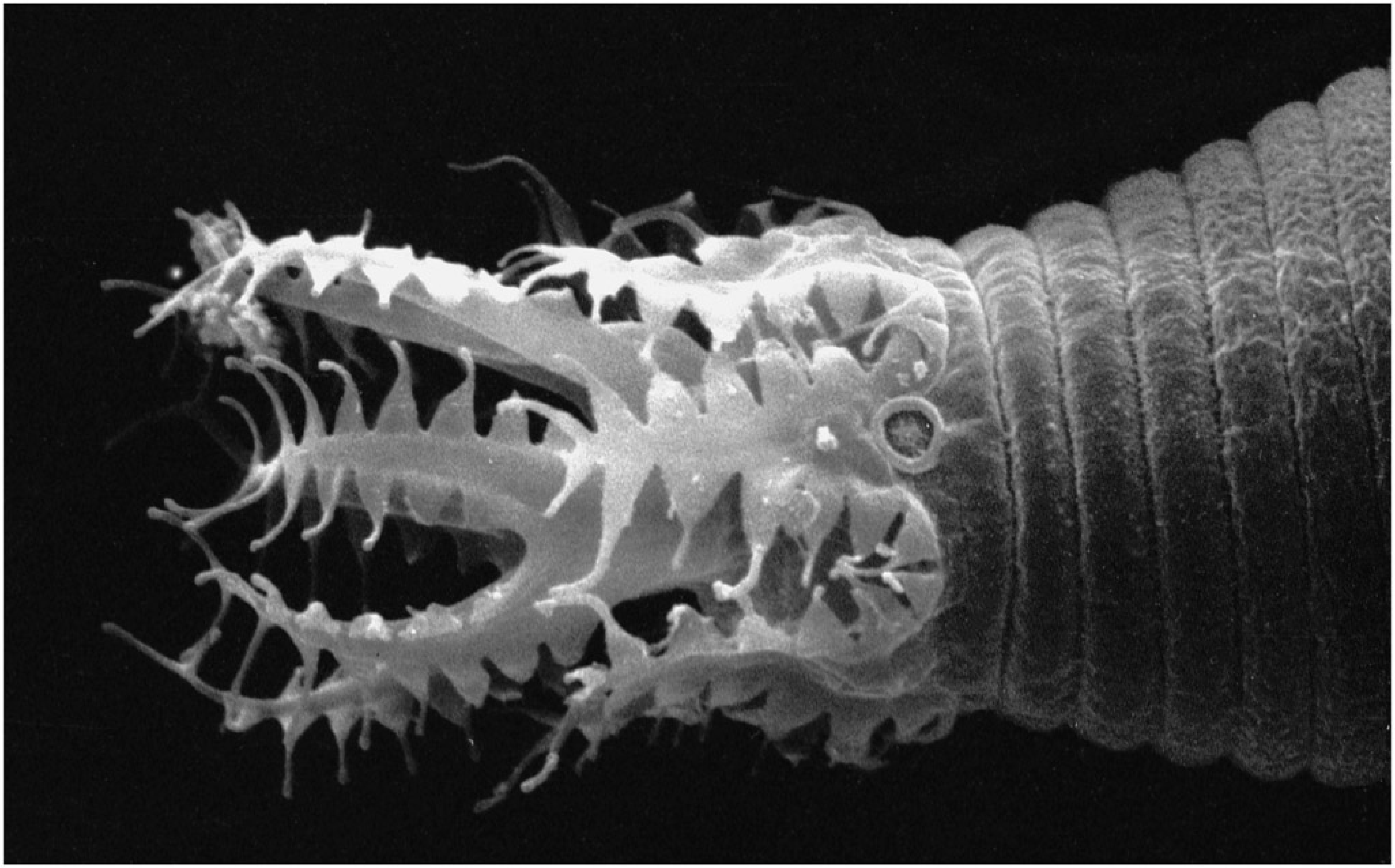


FIGURE 4.7 Head structures of a range of soil nematodes. (a) *Rhabditis* (bacterial feeding); (b) *Acrobeles* (bacterial feeding); (c) *Diplogaster* (bacterial feeding, predator); (d) tylenchid (plant feeding, fungal feeding, predator); (e) *Dorylaimus* (feeding poorly known, omnivore); (f) *Xiphinema* (plant feeding); (g) *Trichodorus* (plant feeding); (h) *Mononchus* (predator). [Reprinted from Yeates, G. W., and Coleman, D. C. (1982). Role of nematodes in decomposition. *In* "Nematodes in Soil Ecosystems" (D. W. Freckman, ed.), pp.55–80. Courtesy of the University of Texas Press, Austin.]

Bacterial feeding nematode



Characteristic nematode head structures

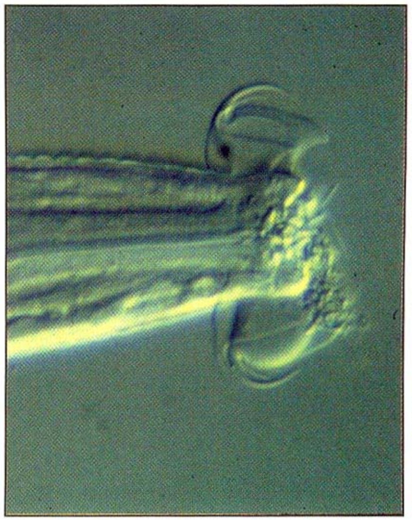


Figure 4: This bacterial-feeding nematod
Elaphonema, has ornate lip structures th
distinguish it from other nematodes.
Bacterial-feeders release plant-available
nitrogen when they consume bacteria.

Elaphonema, bacteria feeder

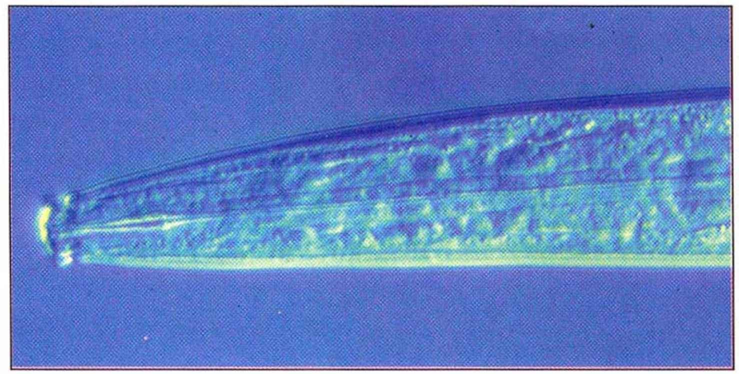


Figure 3: Fungal-feeding nematodes have small, narrow stylets, or spears, in their stoma (mouth) that they use to puncture the cell walls of fungal hyphae and withdraw the cell fluid. This interaction releases plant-available nitrogen from fungal biomass.

Fungal feeder

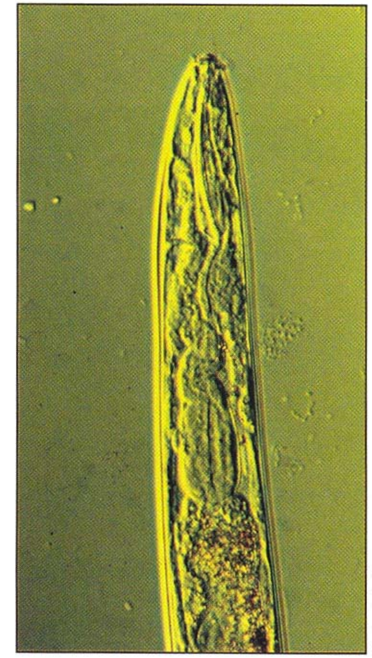


Figure 6: Root-feeding nematodes use their stylets to puncture the thick cell wall of plant root cells and siphon off the internal contents of the plant cell. This usually causes economically significant damage to crops. The curved stylet seen inside this nematode is characteristic of the genus *Trichodorus*.

Trichodorus plant feeder

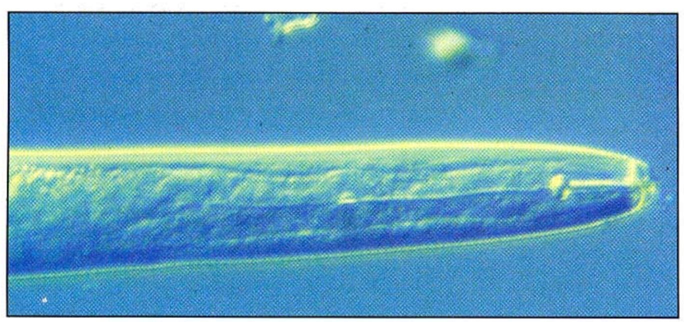
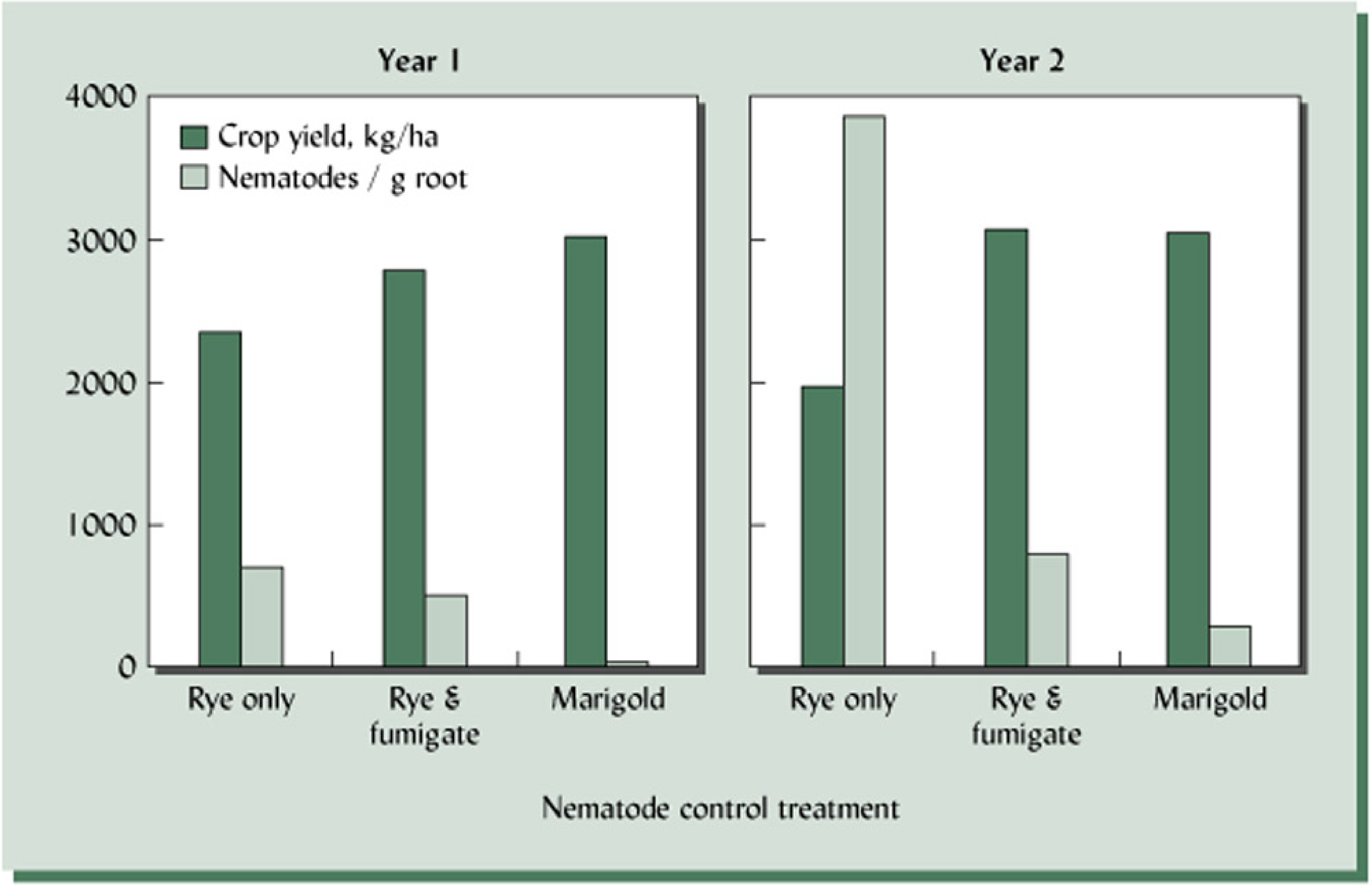


Figure 5: The *Pratylenchus*, or lesion nematode, has a shorter, thicker stylet in its mouth than the root feeder in Figure 6.

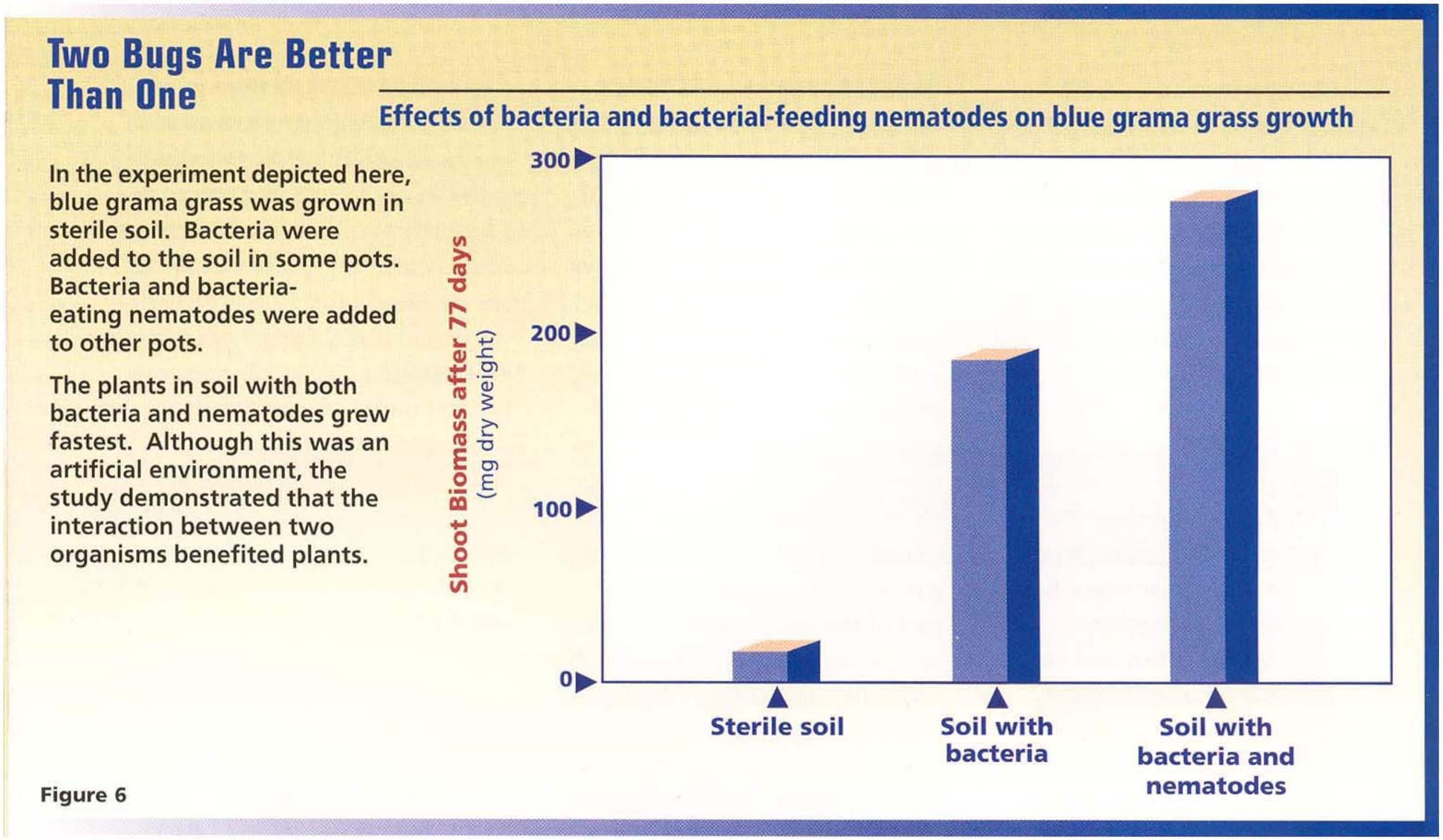
Pratylenchus, plant feeder

Figure 11.14



Marigolds planted previous year controlled plant parasitic nematodes of tobacco grown with rye cover crop equal or better than fumigants, and effect lasted 2 years

Nematode predation of bacteria increases plant growth via nutrients



Protozoa

Protozoa: Flagellates have one or two flagella which they use to propel or pull their way through soil. A flagellum can be seen extending from the protozoan on the left. The tiny specks are bacteria.

Credit: Elaine R. Ingham, Oregon State University

From: *Soil Biology Primer*

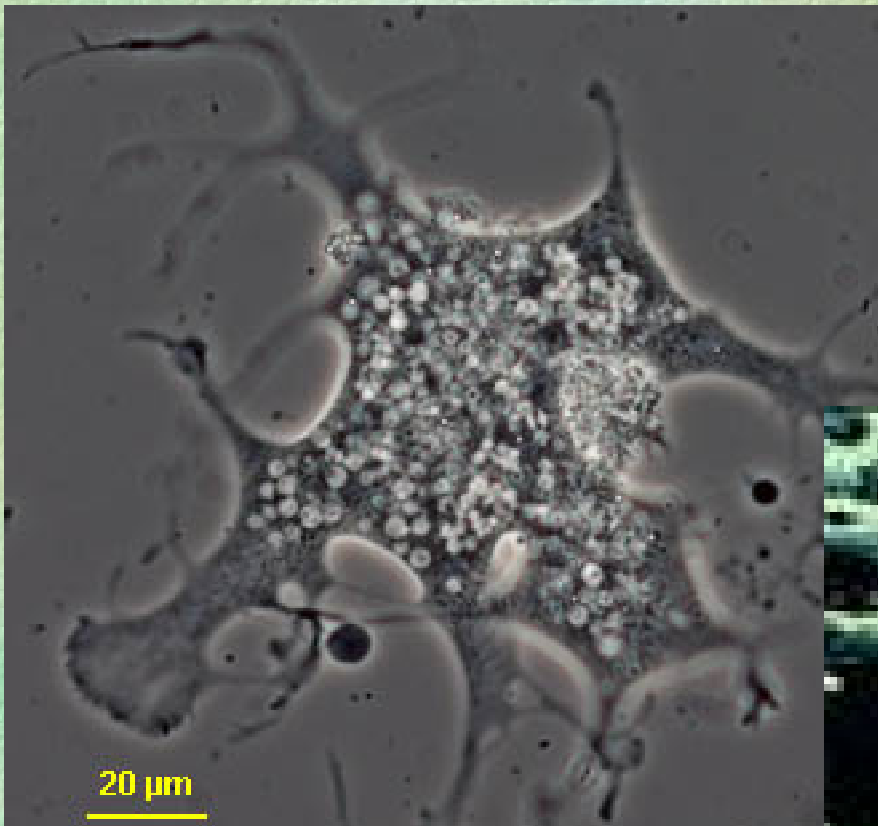
Protozoa: Ciliates are the largest of the protozoa and the least numerous. They consume up to ten thousand bacteria per day, and release plant available nitrogen. Ciliates use the fine cilia along their bodies like oars to move rapidly through soil

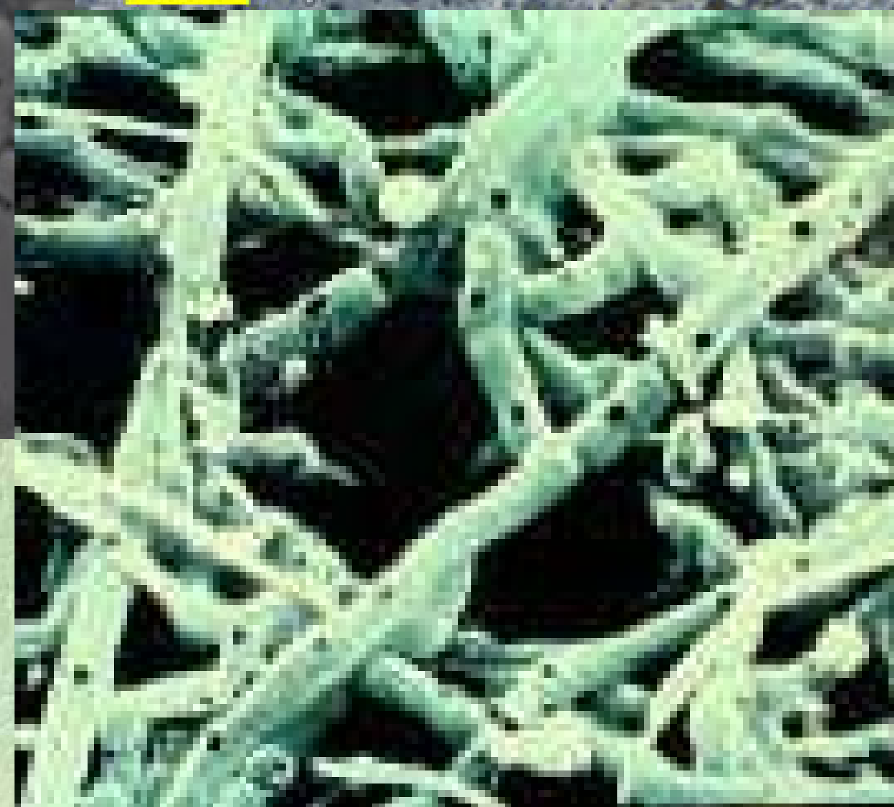
Credit: E. Ingham, Oregon State University, Corvallis From: *Soil Biology Primer*

Protozoa

- Single celled that capture and engulf their food
- Larger than bacteria
- Three groups: Amoebas, ciliates, flagellates
- 10,000-100,000 individual per gram
- 20-200 kg.ha
- Most prey on bacteria and can influence ppn like nematodes
- Found in rhizosphere

Interaction



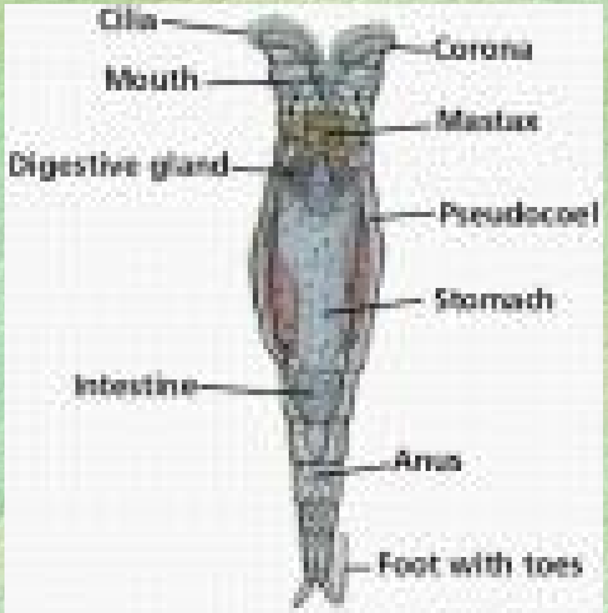


Vampyrellidae amoebae attack fungus “take all” of wheat

From: *Soil Biology Primer*

Rotifers

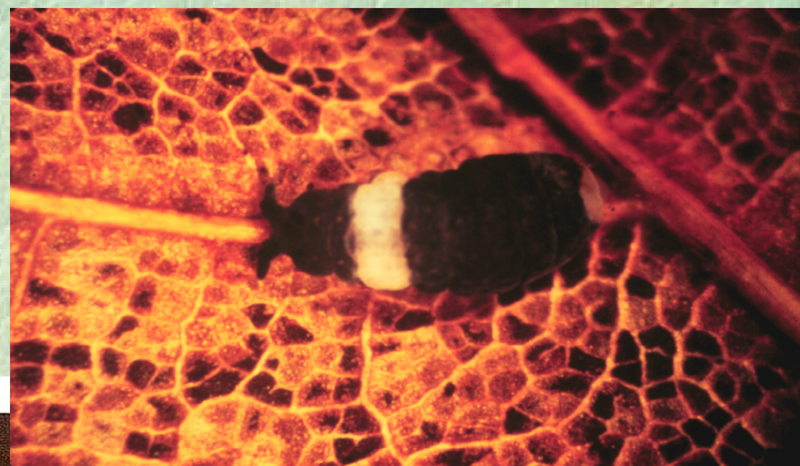
- Multicellular
- Live in soil water



http;//vivo.cornell.library.edu/entity

.www.emc.maricopa.edu/faculty/farabee

Mesofauna: mites, collembola, enchytraids and protura



Collembola
Or spring tails

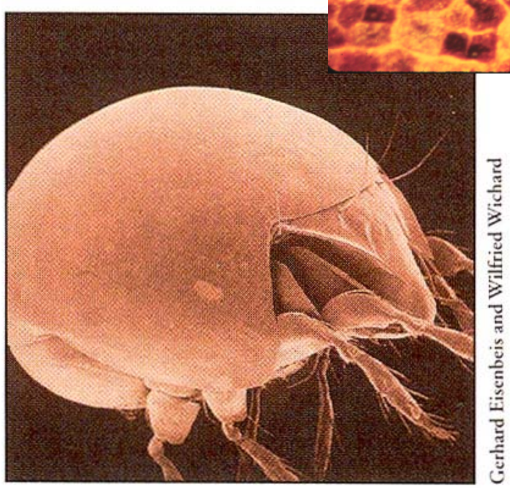


Figure 18: Oribatid turtle-mites are among the most numerous of the micro-arthropods. This millimeter-long species feeds on fungi.

Orabatid mite

Figure 17: This pale-colored and blind springtail is typical of fungal-feeding springtails that live deep in the surface layer of natural and agricultural soils throughout the world.

Collembola (Springtails)

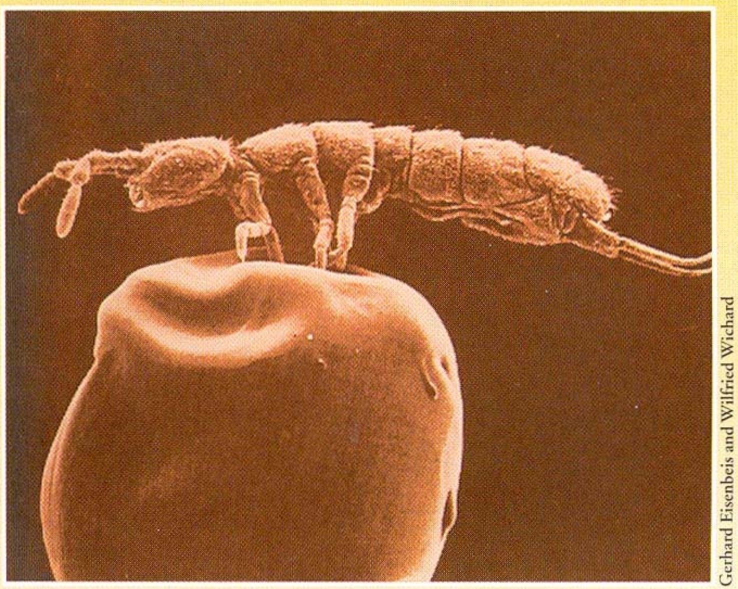
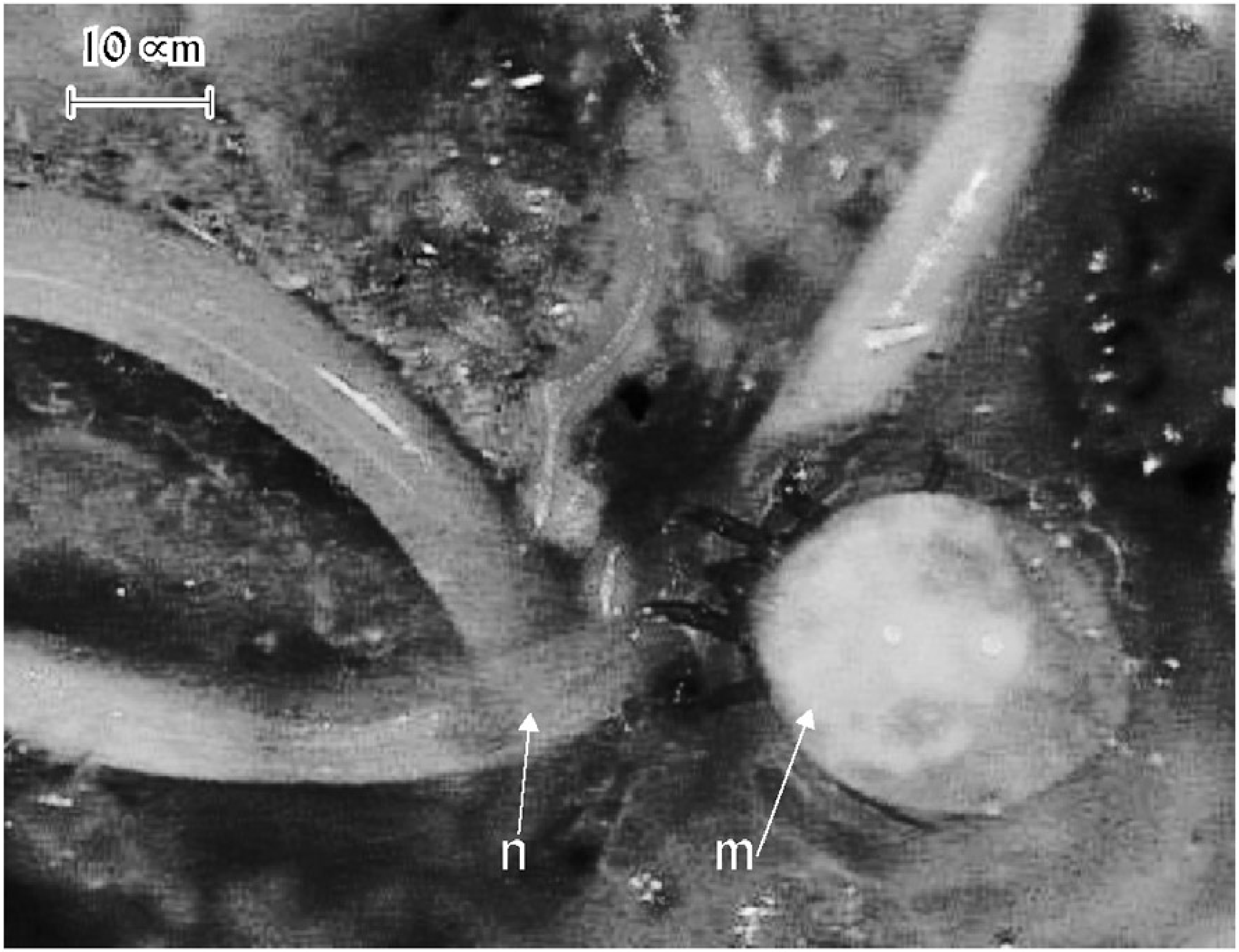


Figure 19 *Isotoma*

- Regulatory role of fungal and bacterial populations
- Springtail grazing can cause major changes in fungal species
- Use tail to jump
- Detritivores- breakup detritus stimulating bact. and fungal decomposition

Figure 11.2



A predatory mite dining on a nematode, keeping various populations under control and releases nutrients tied up in prey.

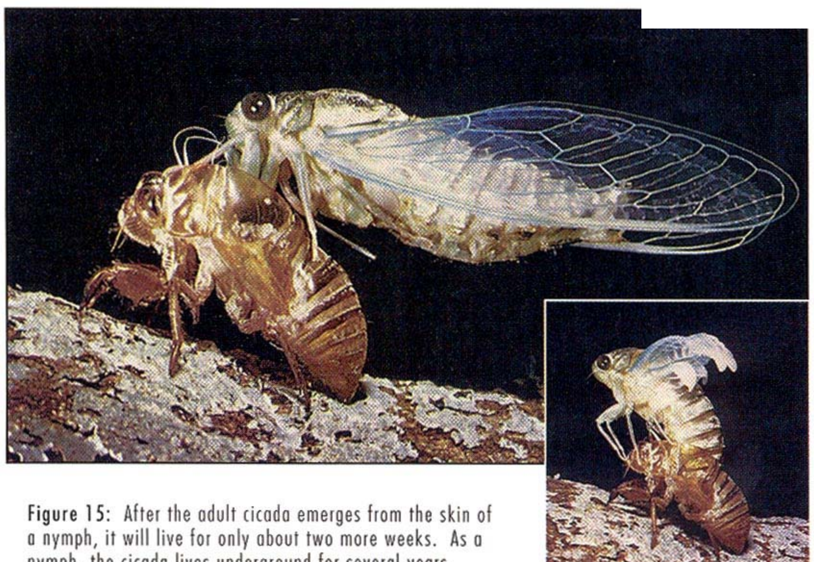
Macrofauna

- Ground beetles
- Arthropods
- Earthworms

D.I. McEwan/Aguila Wildlife Images

Figure 12: The powerful mouthparts on the tiger beetle (a carabid beetle) make it a swift and deadly ground-surface predator. Many species of carabid beetles are common in cropland.

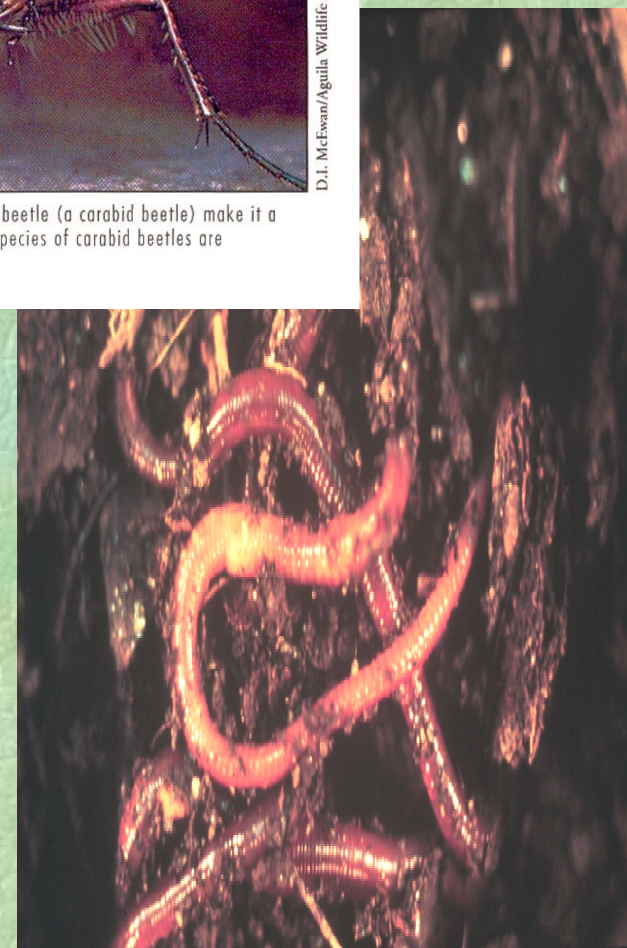
Carabid ground beetles



John Cooke

Figure 15: After the adult cicada emerges from the skin of a nymph, it will live for only about two more weeks. As a nymph, the cicada lives underground for several years, sucking plant fluids for nutrition. Cicadas occur primarily in forests and are important in aerating soils.

Cicada forms macropores



Earthworms

B. Earthworms: Ecosystem Engineers

- Effect the substrate for many other organisms
- Indicators of soil quality

  -25/ft^3 excellent

Zimmer, G. 2000. *The Biological Farmer: A Complete Guide to the Sustainable and Profitable System of Farming.*

Three "Lifestyles" of Earthworms

- Epigeic or litter (compost) dwellers
  - e.g. CA red worm (worm bins)
- Endogeic horizontal burrowers
  - often grey or blue-ish
- Anecic vertical burrowers
  - e.g. nightcrawlers

Anecic earthworms (nightcrawlers)

Middens

Vertical burrows

TABLE 11.7 Improvements in Soil Ecosystem Quality Nine Years After Inoculating Restored Coal-Mine Land with Earthworms

Earthworms were initially absent from the soils being restored. The mine site in Wales (U.K.) was covered with clay loam surface horizon material that had been pushed aside and stored for four months during the coal-mining operation. Earthworms of several indigenous species were added (70/m^2) to certain experimental plots, but not to the control plots. Without inoculation, normal populations of earthworms may take 20 to 30 years to recolonize such soils.

	Earthworm population,[a] *number/m^2*	*Carbohydrate content in soil,*[b] *g/100 g soil*	*Clay dispersed by wetting soil,*[c] *g/100 g soil*	*Metabolic quotient,*[d] *mg CO_2-C g^{-1} h^{-1}*
Control (no earthworms added)	8	0.90	23.7	15.3
Earthworms added	106	1.28	16.9	10.9
Percent change	+1200	+42	−29	−29

[a] Earthworm populations were measured 6 years after restoration began.
[b] Carbohydrates were mainly polysaccharides, which may have been produced by the earthworms themselves or by bacteria stimulated by the earthworms.
[c] Clay dispersed when dry soil aggregates are shaken in water is a measure of the stability of the aggregate structure and the soil's resistance to erosion. More dispersed clay indicates weaker structure.
[d] Metabolic quotient is the amount of respiration occurring per g of microbial biomass. A higher value indicates a stressed ecosystem in which microorganisms must devote increased energy to survival rather than growth. The units are mg of C respired in the form of CO_2 per g of microbial biomass per hour. See also Table 20.11. Data from Scullen and Malik (2000).

Reduces understory because loss of litter, plants can't get established

Without worms in MN

With worms in MN

Native habitats may not have worms due to glaciation
Native worms can be more vulnerable to habitat disturbance and invasion by exotics through moving of plants and soil, bait industries.
Change species composition, reproduction of forests and ecosystem function.

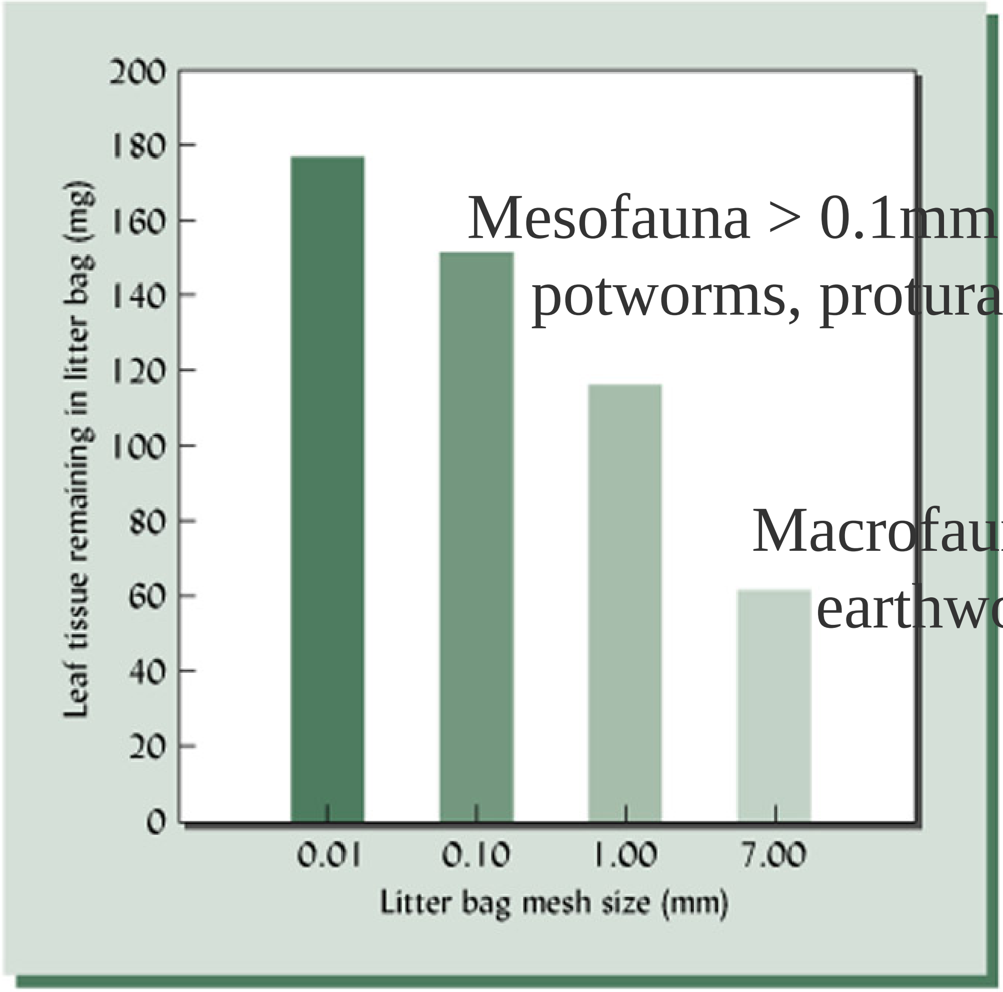
Arthropods (Insects and Spiders)

- Break up organic matter
- Feed on fungi (Springtails (Collembola)
- Predators (spiders)
- Make macropores in soil
- Can be pests

Spiders

Wolf spider, D. Dindal

Macrofauna and mesofauna speed decomposition



Mesofauna > 0.1mm: mites, springtails, potworms, protura

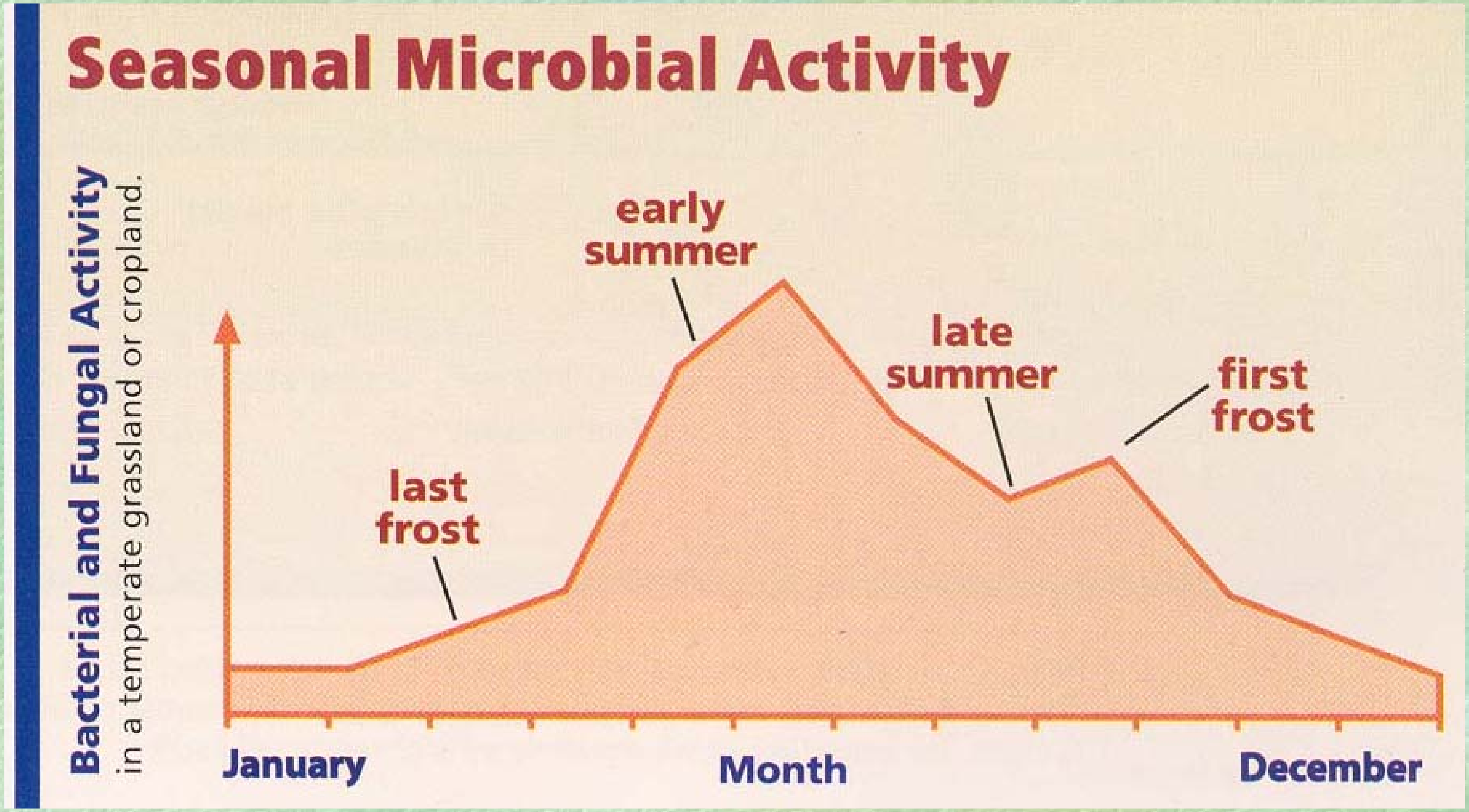
Macrofauna > 2mm: beetles, earthworms, ants

BW Figure 11.4

Conditions that affect soil organisms

- Presence of organic matter
- Oxygen content of soil
- Moisture and temperature
- Calcium and pH
- Pesticides

Microbial activity dependent on temperature and moisture



System effect on soil biology is a composite of many manage-ment actions

Table 8. General responses of some soil biotic and abiotic parameters to management.

\+ positive – negative o neutral +/– variable , () slight effect

	Temperature	Moisture content	Porosity/ aeration	Organic matter	Microbial Activity	Microfaunal Activity	Mesofaunal Activity	Macrofaunal Activity	Decomposition Rate
GRASSLAND									
Mowing	+	–	o	–	+	o	–	+	+
Grazing	+	–	–	–	+	o	–	+	+
Inorganic fertilizers	o	o	o	–	+	(+)	(–)	+/–	+
Organic fertilizers	–	+	o	+	+	+	+	+	+
Burning	+	–	o	–	+	–	–	–	+
Irrigation	–	+	o	o	+	+	+	+	+
Drainage	+	–	+	–	+	+	+	+	+
ARABLE LAND									
Plowing	+	–	+	–	+	+/–	–	–	+
Minimum cultivation	(+)	(–)	–	(–)	(+)	o	(–)	(–)	(+)
Inorganic fertilizers	o	o	o	–	+	+	(+)	(+)	+
Organic fertilizers	–	+	o	+	+	+	+	+	+
Surface crop residues	–	+	o	+	+	(+)	(+)	+	(+)
Incorporated residues	(–)	(+)	o	+	+	+	(+)	(+)	+
Residue removal	+	–	o	–	–	–	–	–	–
Herbicides	o	o	o	o	(–)	o	o	o	(–)
Fungicides	o	o	o	o	–	o	o	(–)	–
Fumigants	o	o	o	o	–	–	–	–	–
Insecticides	o	o	o	o	o	–	–	–	–
Heavy metals	o	o	o	o	–	–	–	–	–

Curry, J. 1986. The Effects of Soil Management on Soil Decomposers and Decomposition Processes in Grasslands and Croplands, in M. Mitchell and J.P. Naleas (eds.) *Microfloral and Faunal Interations in Natural and Agroecosystems.* Nijoff and Junk Publishing.

TABLE 11.10 The Generalized Effects of Major Soil-Management Practices on the Overall Diversity and Abundance of Soil Organisms

Note that the practices that tend to enhance biological diversity and activity in soils are also those associated with efforts to make agricultural systems more sustainable.

Decreases biodiversity and populations	*Increases biodiversity and populations*
Fumigants	Balanced fertilizer use
Nematicides	Lime on acid soils
Some insecticides	Proper irrigation
Compaction	Improved drainage and aeration
Soil erosion	Animal manures and composts
Industrial wastes and heavy metals	Domestic (clean) sewage sludge
Moldboard plow–harrow tillage	Reduced or zero tillage
Monocropping	Crop rotations
Row crops	Grass–legume pastures
Bare fallows	Cover crops or mulch fallows
Residue burning or removal	Residue return to soil surface
Plastic mulches	Organic mulches

Complexity of the Soil Food Web in Several Ecosystems

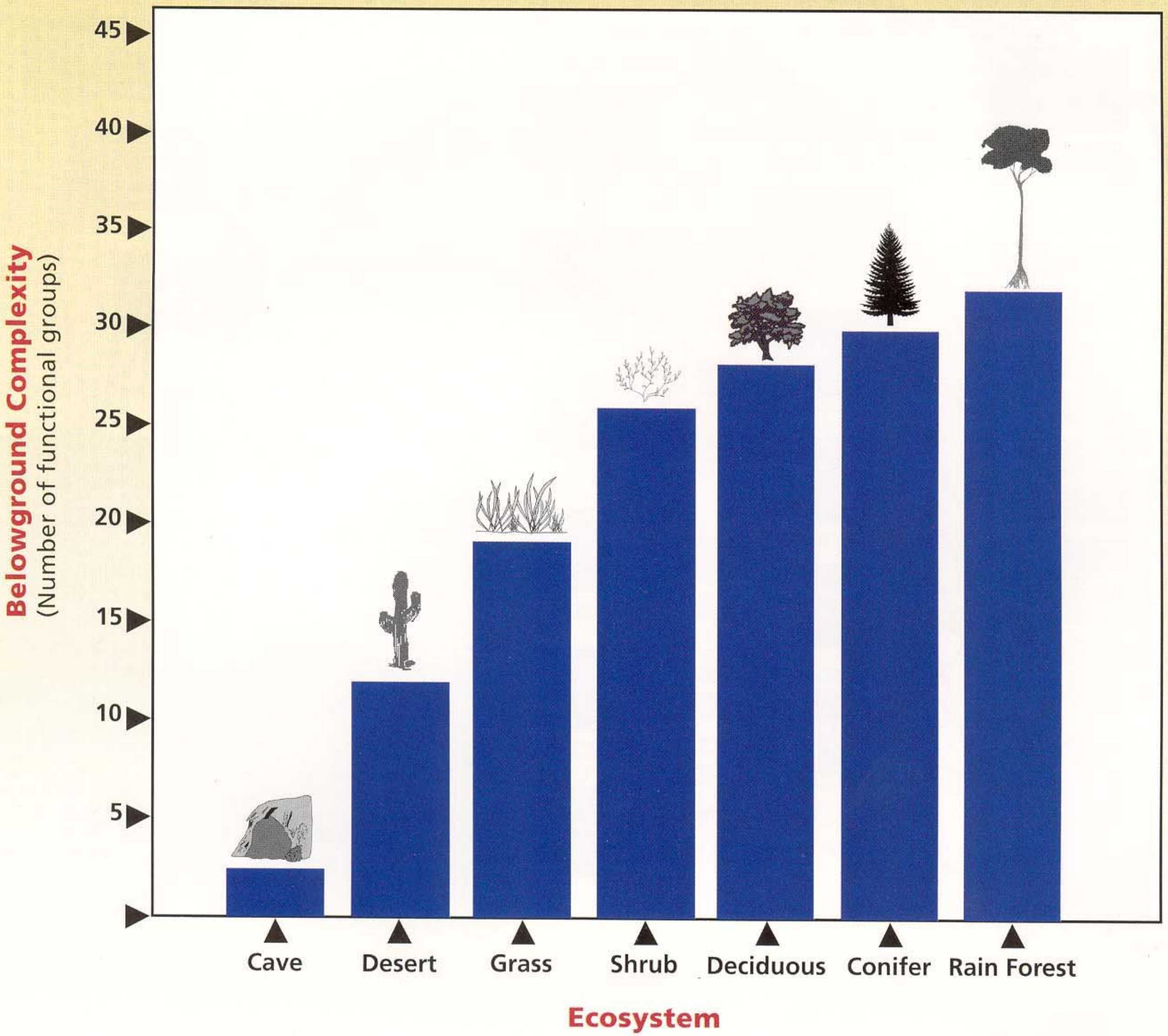


Figure 5

Elaine Ingham

Biodiversity: Case study of the Wisconsin Integrated Cropping System Trials (WICST) 1990-2001

Department of Agronomy
University Wisconsin-Madison

Acknowledgements:

- J. Posner (UW- Madison), J. Hall (MFAI), J. Baldock (Agstat)
- *Microbial*: V. Gollwitzer, B. Hickey, P. Selbach, A. Yuroff
- *Nematode*: A. MacGuidwin, T. Lim
- *Insect/Spider*: E. Rebek, D. Young, D. Hogg, T. Lim
- *Earthworm*: J. Simonsen
- *Nitrate*: J. Stute (MFAI), S. Kung

WICST Sites

Arlington Research Station
Columbia Co.

Lakeland Agricultural Complex
Walworth Co.

WICST Cropping Systems

	Cash Grain	Forage
High input	C-C-C-C	C-A-A-A
Medium input	C-Sb-C-Sb	C-O/A-A
Low input	C-Sb-W/RC	Rotational grazing

WICST cropping systems with low/medium input management

Corn-soybean-wheat/red clover

Corn-oat/alfalfa-alfalfa

Agroecological Questions: Are conventionally-managed soils dead?

- Are soil organisms more abundant in low input systems?
- Are soil organisms more diverse in low input systems?
- How does does abundance and diversity of soil organisms affect agroecological processes?

Microbial biomass at Arlington Research Station 1993-1997

Figure 5. Microbial Biomass in Corn phases. ARS 1993 - 1997.

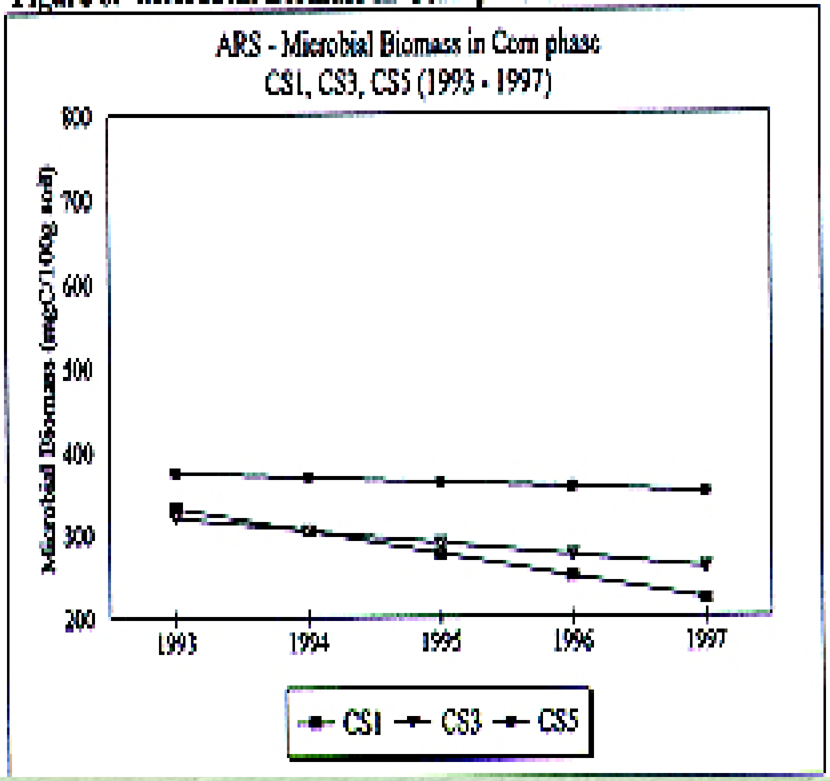
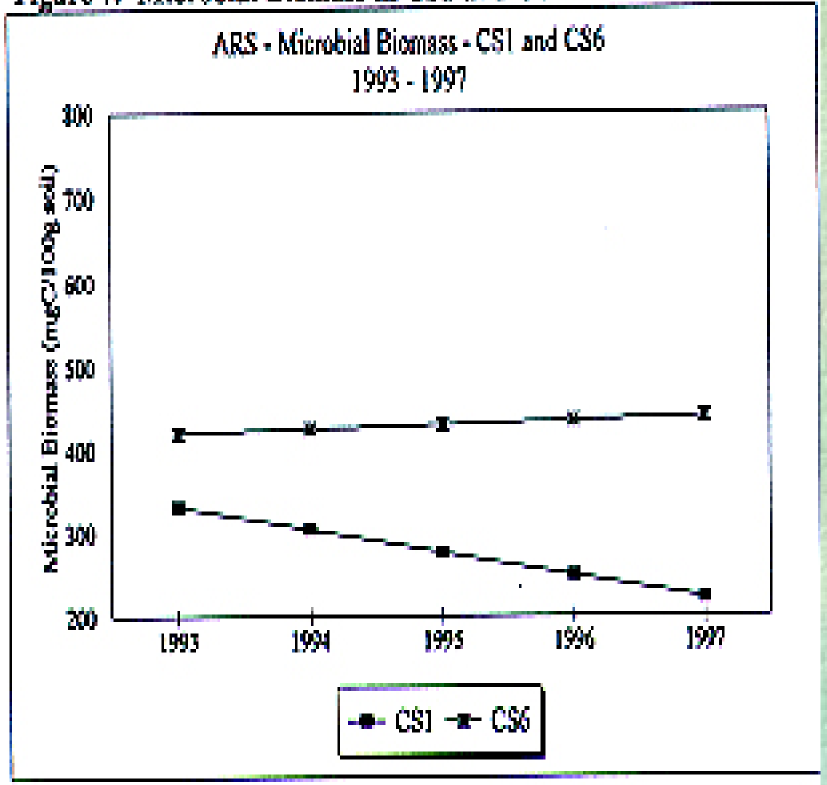
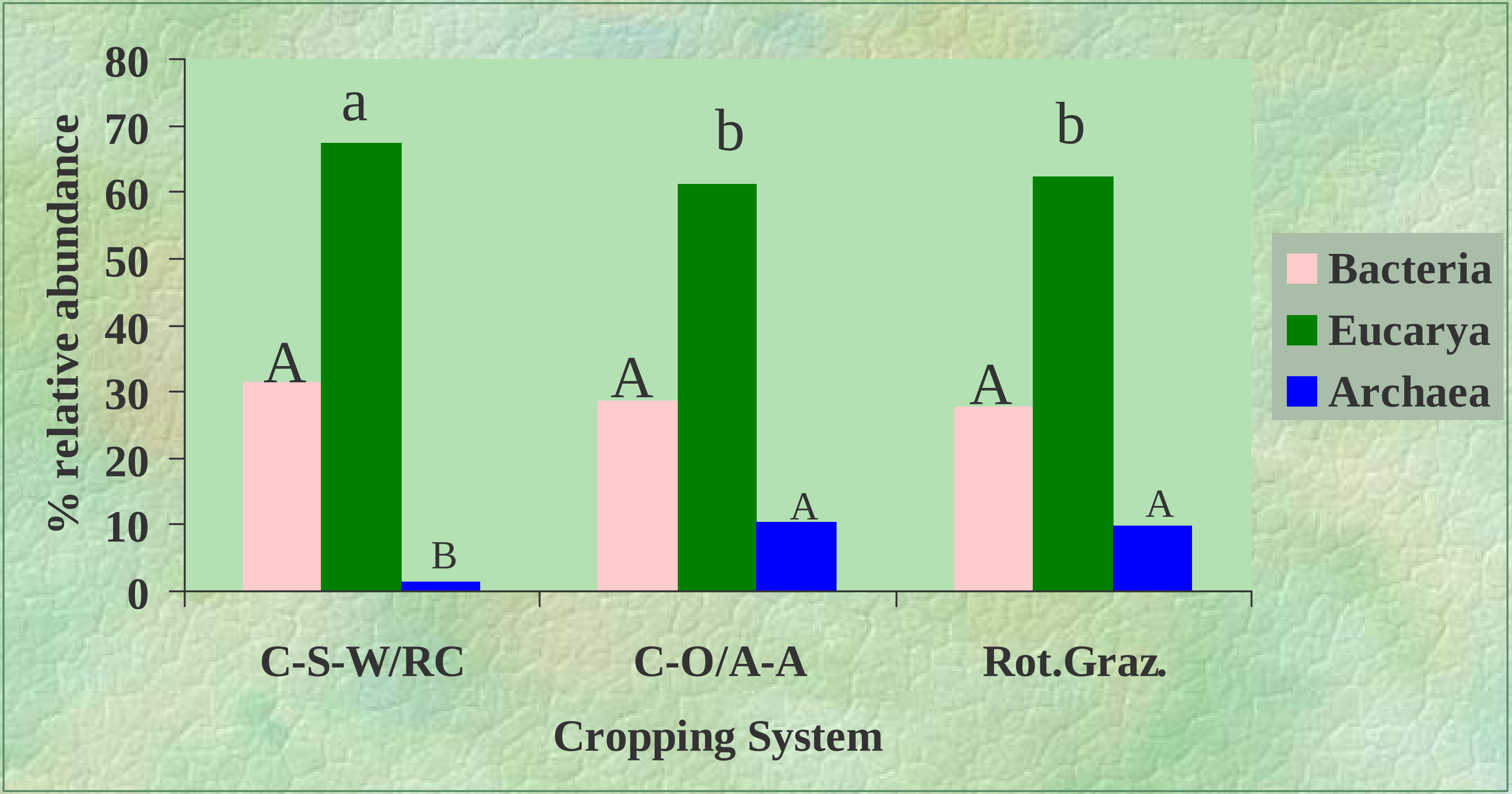


Figure 7. Microbial Biomass in CS1 and CS6. ARS 1993 - 1997.

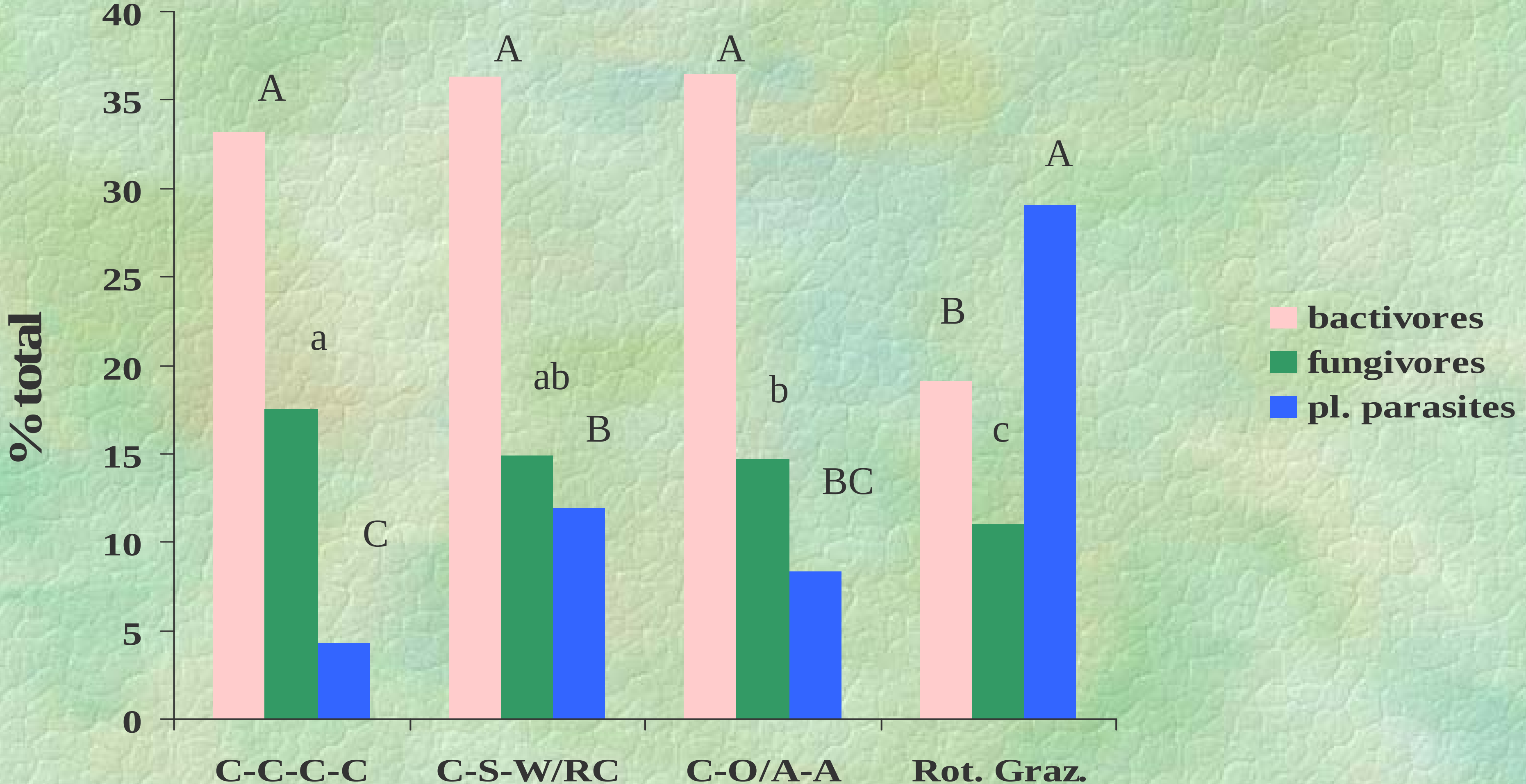


Microbial community structure in WICST soils



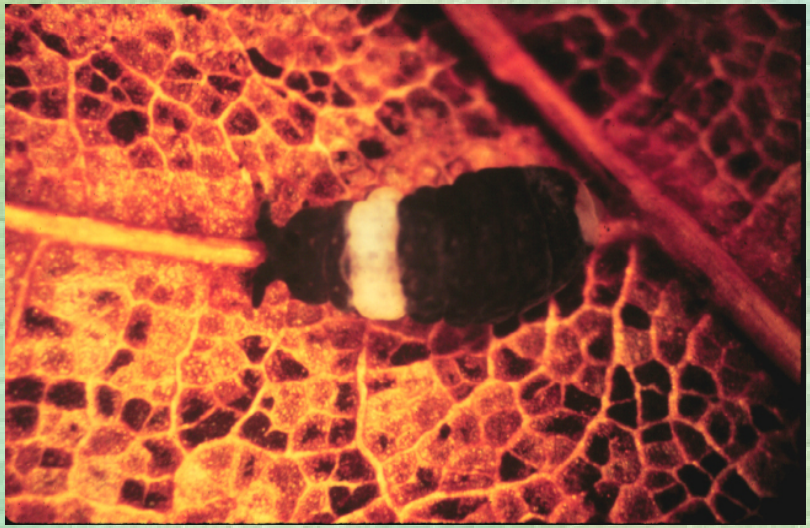
From: Selbach, Yuroff and Hickey, msc submitted

Nematode functional group community structure in WICST, ARS, 1997



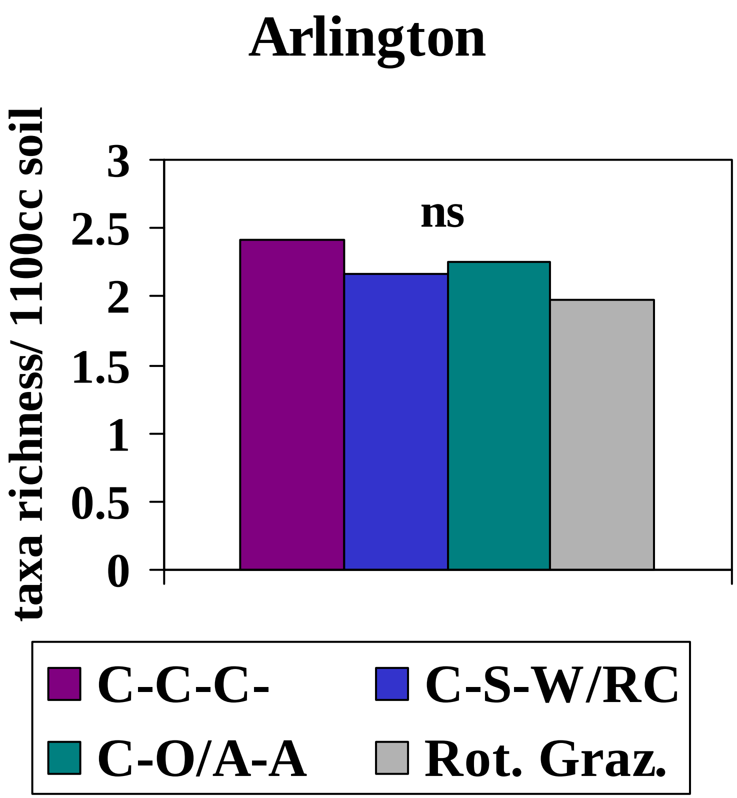
From: MacGuidwin, Rosemeyer and Lim msc in preparation

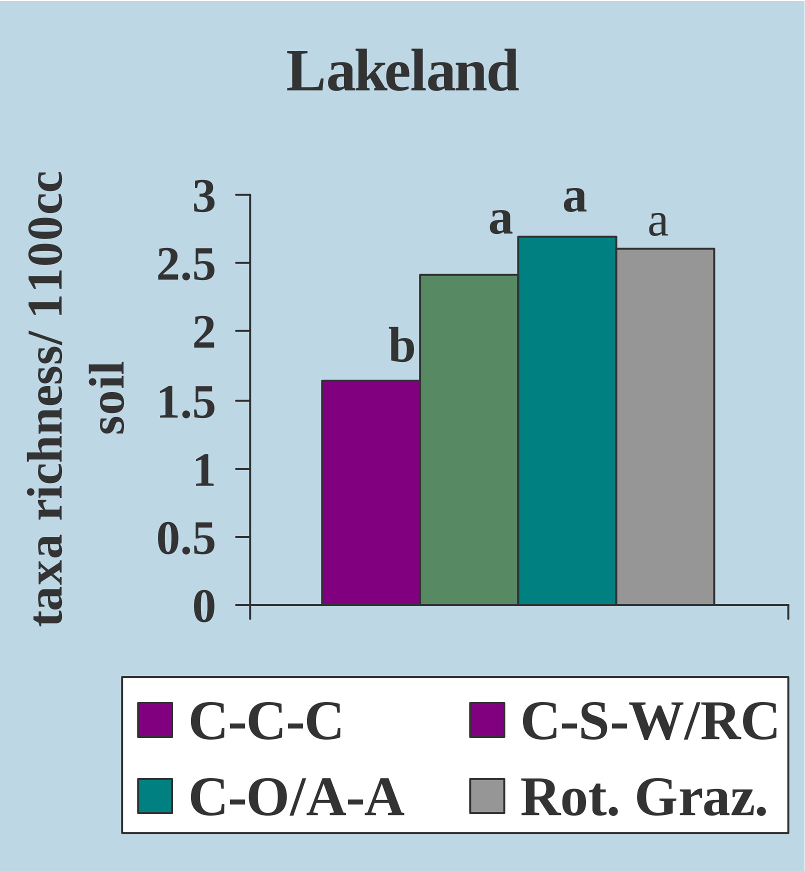
Diversity of Collembola (Springtails) in the WICST



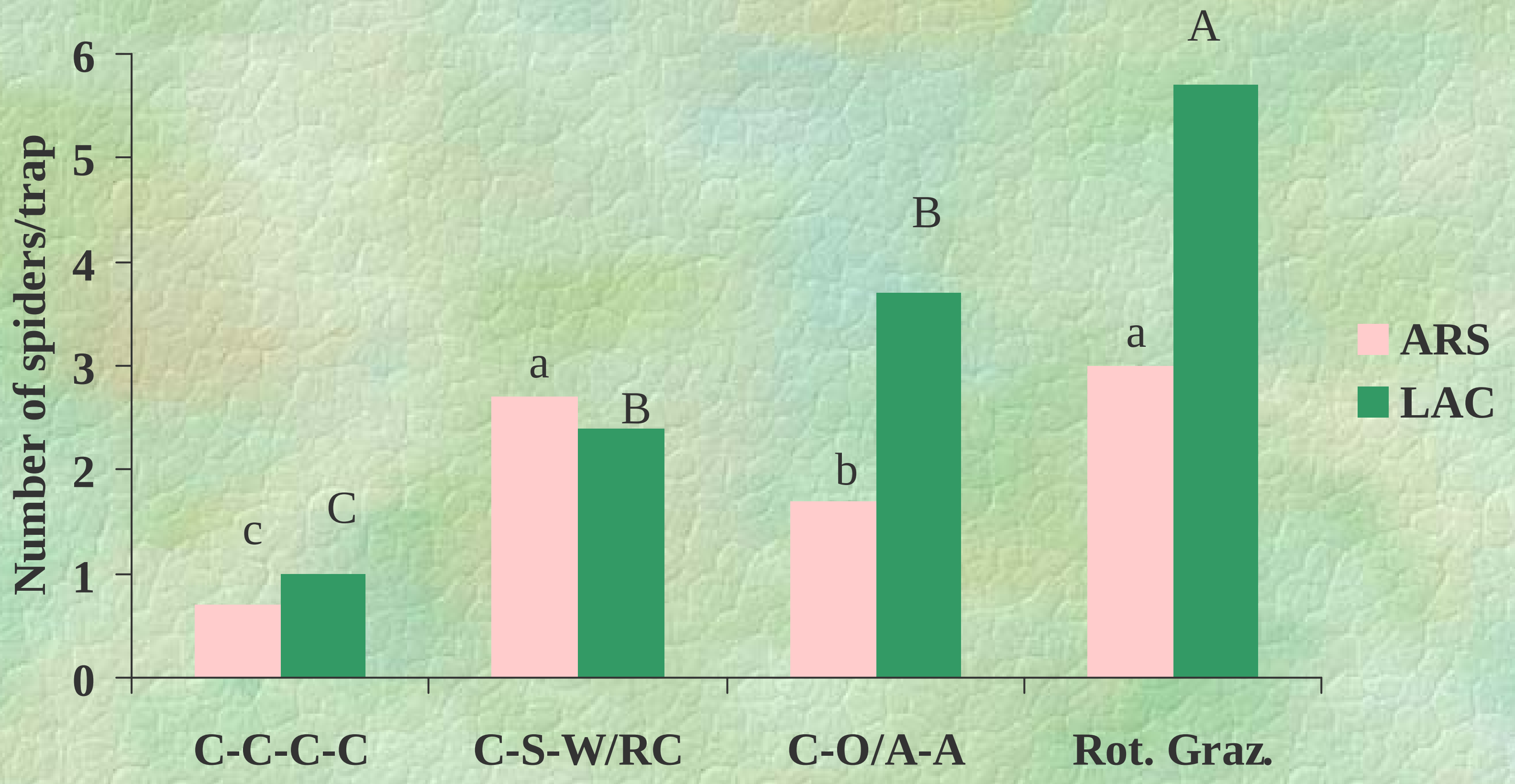
- Twenty range extensions of Collembola species found in Wisconsin
- One species new to science found in a Wisconsin cornfield!!!
- -Rebek, Young and Hogg 1999

Wisconsin WICST arthropod taxa species richness (diversity) in soil cores over 2 sites, 1997

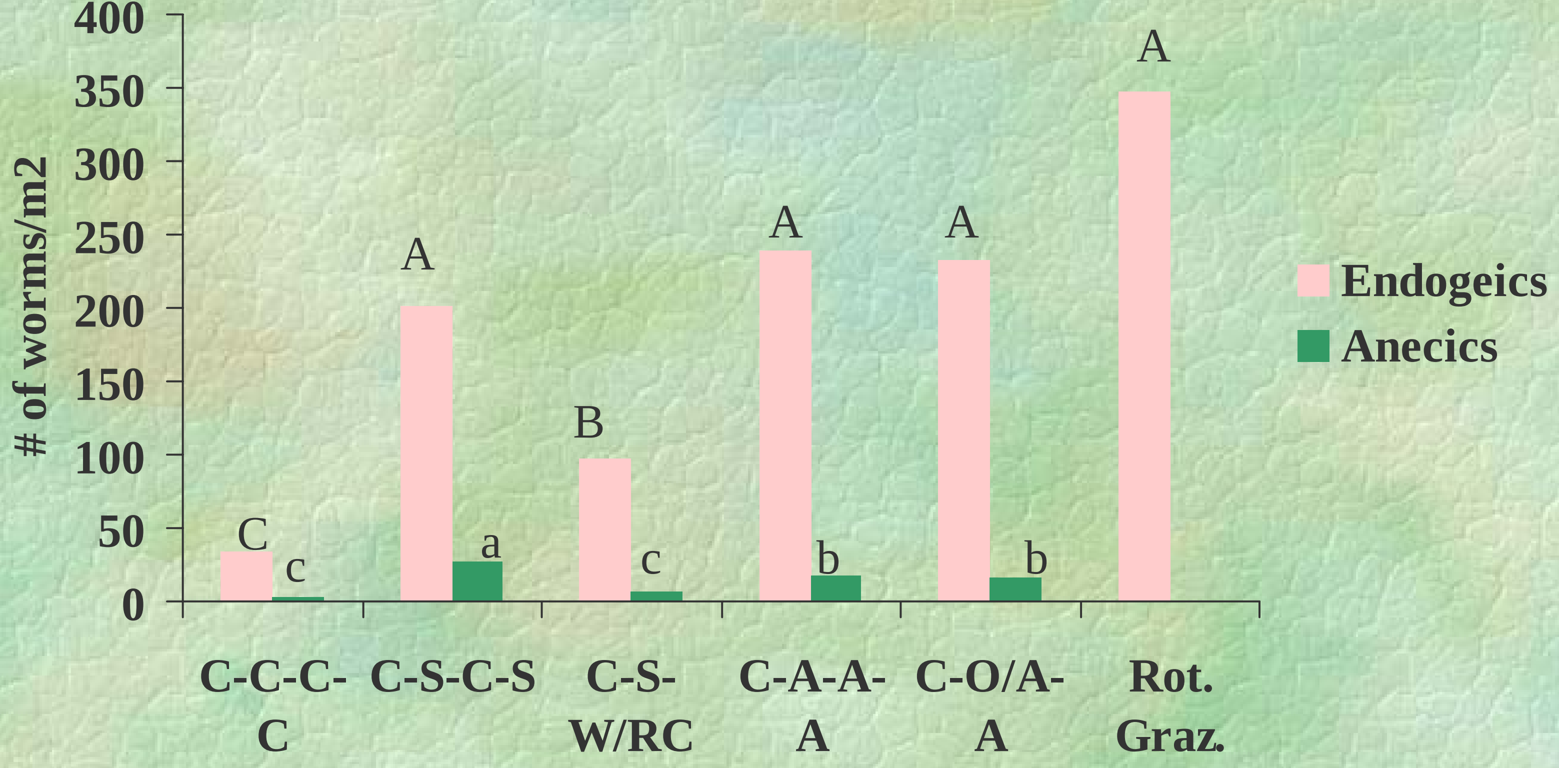




Spiders caught in pitfall traps in corn phase at ARS and LAC, 1996



Earthworm functional groups respond to different cropping systems



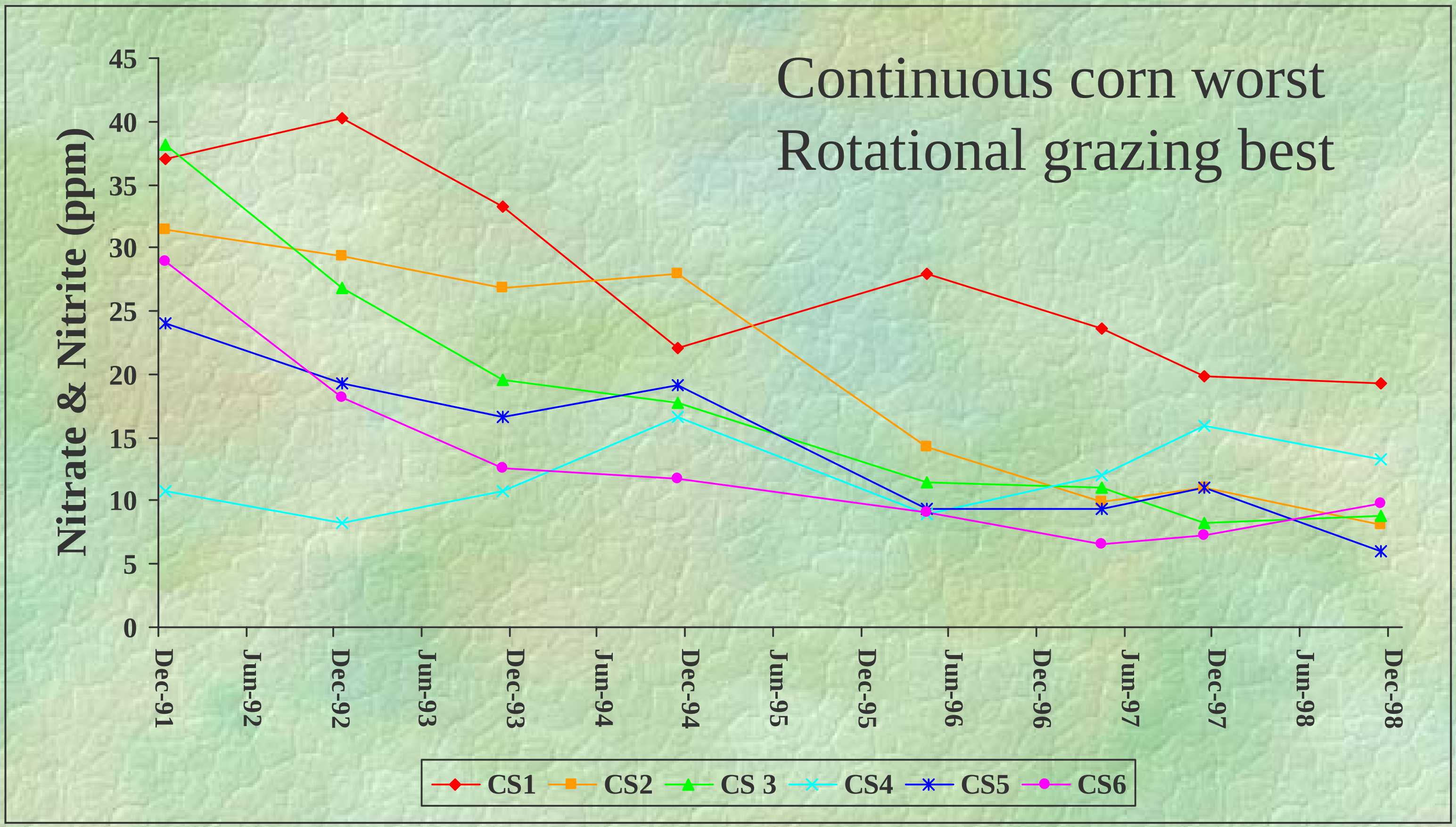
Soil Biodiversity Summary

- In WICST, microbial biomass diverging over time between system extremes
- Microbes, nematodes, arthropods, earthworms exhibit changed community structure under different cropping systems, though abundance and diversity variable
- Response appears to tillage, manure and legumes--could be different with heavy biocide use and on less fertile soils
- Does the change in belowground community structure alter soil processes?

Do we see differences in soil processes in the different cropping systems?
Diversity effects on soil processes?

- Drilling shallow wells at LAC to test leaching
- nitrates
- atrazine

Nitrate and nitrate concentration in shallow wells LAC, 1991-98



- In moderate rainfall event, tracer reached tile drainage in 16 minutes!
- -S. Kung et al., unpublished data

Nightcrawlers causing nitrate leaching?

- No correlation between high nightcrawler populations and high nitrate in shallow wells in WICST data

Context

- There may be restrictions in nutrient use by farmers in Midwest
- Farmers have limited financial means for inputs
- Sustainable agriculture relies on soil biological processes to release plant available nutrients more slowly

Importance of biodiversity in soil function

TABLE 11.2 The Relationship Between Biodiversity and Ecosystem Function in a Soil Under Grazed Grassland Vegetation

The researchers adjusted the species diversity in a set of soil samples by fumigating[a] the soil for different lengths of time (0, 0.5, 2, and 24 hours). The longer the fumigation time, the fewer the number of species and individuals that survived. The soils were then incubated for 5 months, during which time the total soil biomass and total numbers of organisms rebounded to prefumigation levels, but consisted only of those species that had survived the fumigation treatments. Soil functions were then measured. Note that specialized ecological functions declined consistently with the decrease in biodiversity. In contrast, the more general types of functions fluctuated somewhat, but were not significantly affected by the differences in species diversity. Thus, by manipulating the level of biodiversity, the researchers were able to use the soil as a model ecosystem with which to test a major tenet of general ecology.

	Hours of initial fumigation			
	0	*0.5*	*2*	*24*
Examples of Biodiversity Measures				
Bacterial-feeding nematode groups present	8	7	1	0
Flagellate protozoa groups present	23	18	10	5
Examples of General Decomposition Functions[b]				
Microbial respiration rate (∝g CO_2/g per h)	0.87	0.37	0.29	0.83
Assimilation of added amino acid, pmol/g per h	90	114	113	159
Examples of Specialized Ecosystem Functions[c]				
Methane oxidation pg/g per h	77	16	4	–14[d]
Nitrate formation, ∝g N/g	45	42	24	6

[a] With chloroform.
[b] General functions are those that most types of soil organisms can carry out.
[c] Specialized ecosystem functions can be carried out by only a small number of species or groups.
[d] Negative value indicates oxidation activity so low that the net result is methane production rather than oxidation (see Section 12.11).

Data compiled from Griffiths, et al. (2000).

WICST Summary and Conclusion

- Soil biota community structure different under different cropping systems
- Ecological processes are different under low input treatments, e.g. nitrate leaching
- Linking belowground community structure to agroecosystem process is a current research challenge

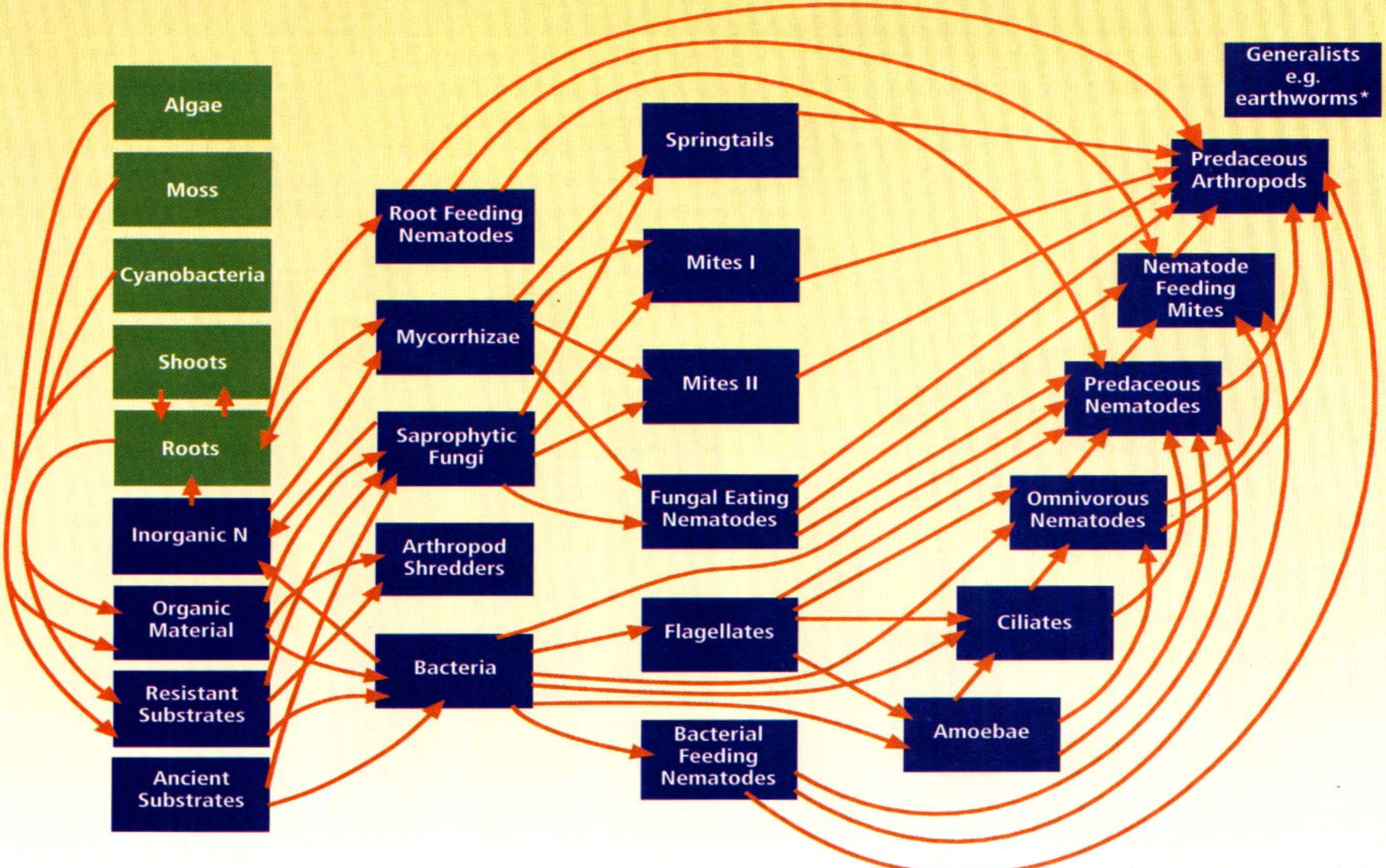
Final comments and summary

- The decomposer = detritus=soil food chain appears to be longer and more complex due to efficiency of conversion between trophic levels
- Tendency for redundancy
- Soil microfauna, though account for 5-10% of respiration can have important regulatory role, esp. nematodes and protozoa
- Soil management (cropping systems) affect organism populations
- Soil ecology is young as a discipline, potential for pest, pathogen control restoration enormous

Study questions

- Soil Ecology Worksheet of glossary terms sheet with questions (on Masu in Winter Handouts folder)
- BW Ch 11 #1, 2, 3 (also change mesofauna to microfauna and answer the question), 8
- This lecture is in Winter Lectures folder

A Complex Food Web



* Earthworms are generalists that feed on many smaller soil organisms.

Typical Numbers of Soil Organisms in Healthy Ecosystems

		Agricultural Soils	Prairie Soils	Forest Soils
Bacteria	Per teaspoon of soil (one gram dry)	100 million to 1 billion.	100 million to 1 billion.	100 million to 1 billion.
Fungi		Several yards. [Dominated by arbuscular myc-orrhizal (AM) fungi].	Tens to hundreds of yards. [Dominated by arbuscular myc-orrhizal (AM) fungi].	Several hundred yards in decid-uous forests. One to 40 miles in coniferous forests (dominated by ectomy-corrhizal fungi).
Protozoa		Several thousand flagellates and amoebae, 100 to several hundred ciliates.	Several thousand flagellates and amoebae, 100 to several hundred ciliates.	Several hundred thousand amoebae, fewer flagellates.
Nematodes		Ten to 20 bacterial-feeders. A few fungal-feeders. Few preda-tory nematodes.	Tens to several hundred.	Several hundred bacterial- and fungal-feeders. Many predatory nematodes.
Arthropods	Per square foot	Up to 100.	Five hundred to 2,000.	Ten to 25,000. Many more species than in agricultural soils.
Earthworms		Five to 30. More in soils with high organic matter.	Ten to 50. Arid or semi-arid areas may have none.	Ten to 50 in deciduous wood-lands. Very few in coniferous forests.

Figure 2

Soil Biology Primer. 2000. Soil and Water Conservation Society.

Functions of Soil Organisms

Type of Soil Organism		Major Functions
Photosynthesizers	• Plants • Algae • Bacteria	**Capture energy** • Use solar energy to fix CO_2. • Add organic matter to soil (biomass such as dead cells, plant litter, and secondary metabolites).
Decomposers	• Bacteria • Fungi	**Break down residue** • Immobilize (retain) nutrients in their biomass. • Create new organic compounds (cell constituents, waste products) that are sources of energy and nutrients for other organisms. • Produce compounds that help bind soil into aggregates. • Bind soil aggregates with fungal hyphae. • Nitrifying and denitrifying bacteria convert forms of nitrogen. • Compete with or inhibit disease-causing organisms.
Mutualists	• Bacteria • Fungi	**Enhance plant growth** • Protect plant roots from disease-causing organisms. • Some bacteria fix N_2. • Some fungi form mycorrhizal associations with roots and deliver nutrients (such as P) and water to the plant.
Pathogens **Parasites**	• Bacteria • Fungi • Nematodes • Microarthropods	**Promote disease** • Consume roots and other plant parts, causing disease. • Parasitize nematodes or insects, including disease-causing organisms.
Root-feeders	• Nematodes • Macroarthropods (e.g., cutworm, weevil larvae, & symphylans)	**Consume plant roots** • Potentially cause significant crop yield losses.
Bacterial-feeders	• Protozoa • Nematodes	**Graze** • Release plant-available nitrogen (NH_4^+) and other nutrients when feeding on bacteria. • Control many root-feeding or disease-causing pests. • Stimulate and control the activity of bacterial populations.
Fungal-feeders	• Nematodes • Microarthropods	**Graze** • Release plant available nitrogen (NH_4^+) and other nutrients when feeding on fungi. • Control many root-feeding or disease-causing pests. • Stimulate and control the activity of fungal populations.
Shredders	• Earthworms • Macroarthropods	**Break down residue and enhance soil structure** • Shred plant litter as they feed on bacteria and fungi. • Provide habitat for bacteria in their guts and fecal pellets. • Enhance soil structure as they produce fecal pellets and burrow through soil.
Higher-level predators	• Nematode-feeding nematodes • Larger arthropods, mice, voles, shrews, birds, other above-ground animals	**Control populations** • Control the populations of lower trophic-level predators. • Larger organisms improve soil structure by burrowing and by passing soil through their guts. • Larger organisms carry smaller organisms long distances.

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Organic Matter as Food Sources

"Soil organic matter" includes all the organic substances in or on the soil. Here are terms used to describe different types of organic matter.

Living

Living organisms: Bacteria, fungi, nematodes, protozoa, earthworms, arthropods, and living roots.

Fresh

Dead plant material; organic material; detritus; surface residue: All these terms refer to plant, animal, or other organic substances that have recently been added to the soil and have only begun to show signs of decay. Detritivores are organisms that feed on such material.

Decomposing

Active fraction organic matter: Organic compounds that can be used as food by microorganisms. The active fraction changes more quickly than total organic matter in response to management changes.

Labile organic matter: Organic matter that is easily decomposed.

Root exudates: Soluble sugars, amino acids, and other compounds secreted by roots.

Particulate organic matter (POM) or Light fraction (LF) organic matter: POM and LF have precise size and weight definitions. They are thought to represent the active fraction of organic matter, which is more difficult to define. Because POM or LF is larger and lighter than other types of soil organic matter, they can be separated either from soil by size (using a sieve) or by weight (using a centrifuge).

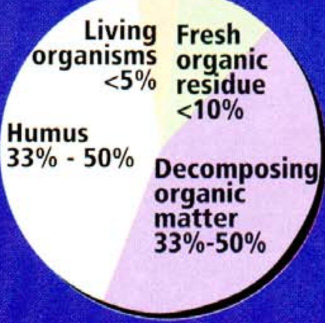
Lignin: A hard-to-degrade compound that is part of the fibers of older plants. Fungi can use the carbon ring structures in lignin as food.

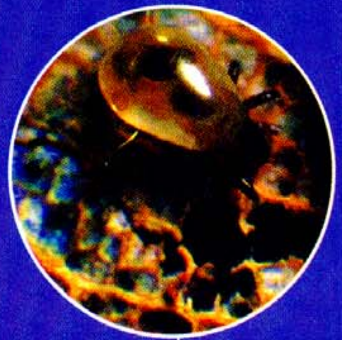
Humus

Recalcitrant organic matter: Organic matter, such as humus or lignin-containing material, that few soil organisms can decompose.

Humus or humified organic matter: Complex organic compounds that remain after many organisms have used and transformed the original material. Humus is not readily decomposed because it is either physically protected inside of aggregates or is chemically too complex to be used by most organisms. Humus is important in binding tiny soil aggregates; it also improves water and nutrient-holding capacity.

Components of Soil Organic Matter





Roy A. Norton

Figure 2: These microshredders, immature oribatid mites, skeletonize plant leaves. This starts the nutrient cycling of carbon, nitrogen, and other elements.

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A Soil Food Web Glossary

Arthropods	Invertebrate animals with jointed legs. They include insects, crustaceans, sowbugs, arachnids (spiders), and others.
Bacteria	Microscopic, single-celled organisms that are mostly non-photosynthetic. They include the photosynthetic cyanobacteria (formerly called blue-green algae) and actinomycetes (filamentous bacteria that give healthy soil its characteristic smell).
Fungi	Multi-celled, non-photosynthetic organisms that are neither plants nor animals. Fungal cells form long chains called hyphae and may form fruiting bodies such as mold or mushrooms to disperse spores. Some fungi, such as yeast, are single-celled. **Saprophytic fungi:** Fungi that decompose dead organic matter. **Mycorrhizal fungi:** Fungi that form associations with plant roots. These fungi get energy from the plant and help supply nutrients to the plant.
Grazers	Organisms, such as protozoa, nematodes, and microarthropods, that feed on bacteria and fungi.
Microbes	An imprecise term referring to any microscopic organism. Generally, "microbes" includes bacteria, fungi, and sometimes protozoa.
Mutualists	Two organisms living in an association that is beneficial to both, such as the association of roots with mycorrhizal fungi or with nitrogen-fixing bacteria.
Nematodes	Tiny, usually microscopic, unsegmented worms. Most live free in the soil. Some are parasites of animals or plants.
Protozoa	Tiny, single-celled animals, including amoebas, ciliates, and flagellates.
Trophic levels	Levels of the food chain. The first trophic level includes photosynthesizers that get energy from the sun. Organisms that eat photosynthesizers make up the second trophic level. Third trophic level organisms eat those in the second level, and so on. It is a simplified way of thinking about the food web. In reality, some organisms eat members of several trophic levels.

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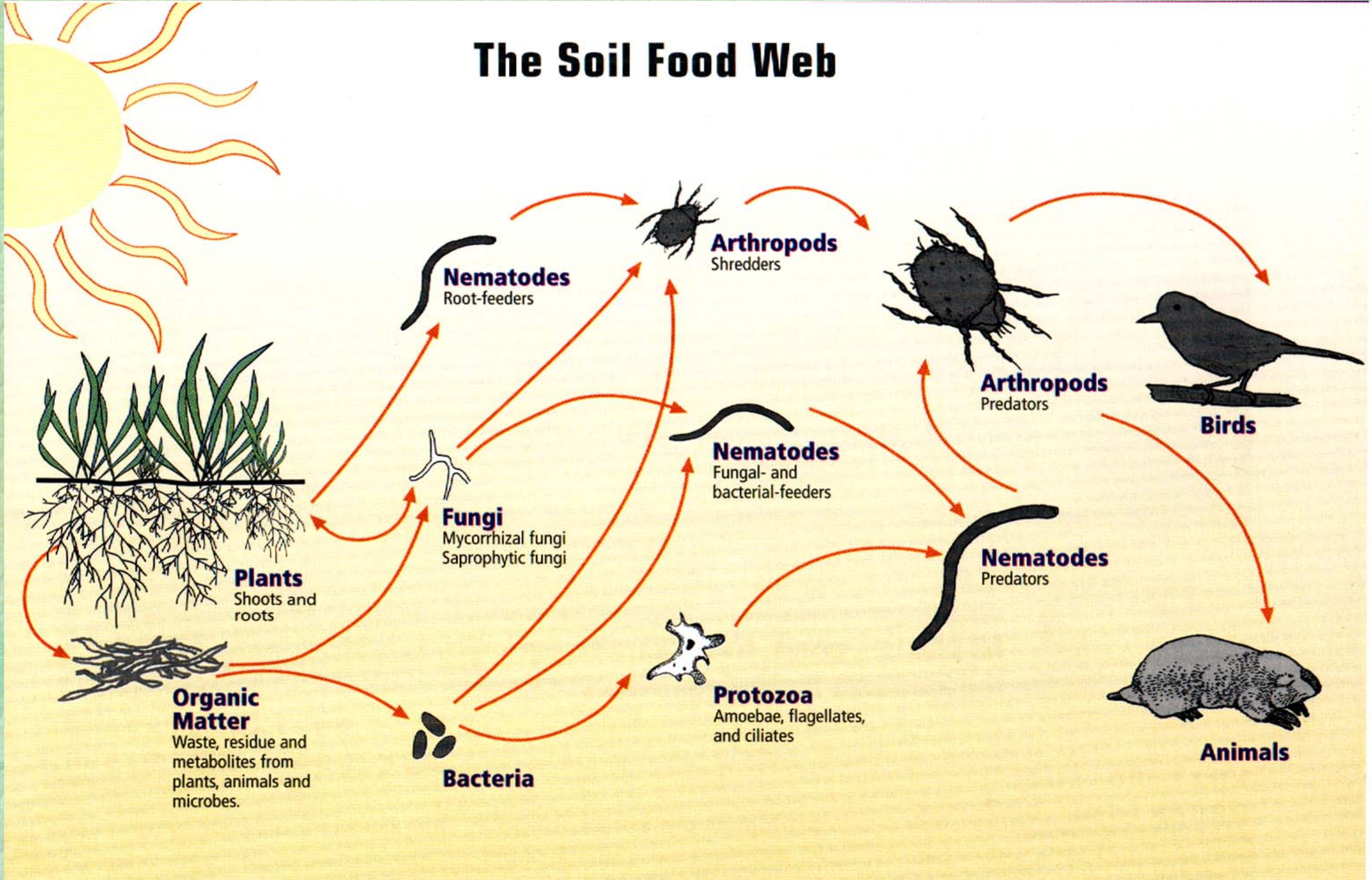
The Soil Food Web



First trophic level:	Second trophic level:	Third trophic level:	Fourth trophic level:	Fifth and higher trophic levels:
Photosynthesizers	Decomposers Mutualists Pathogens, Parasites Root-feeders	Shredders Predators Grazers	Higher level predators	Higher level predators