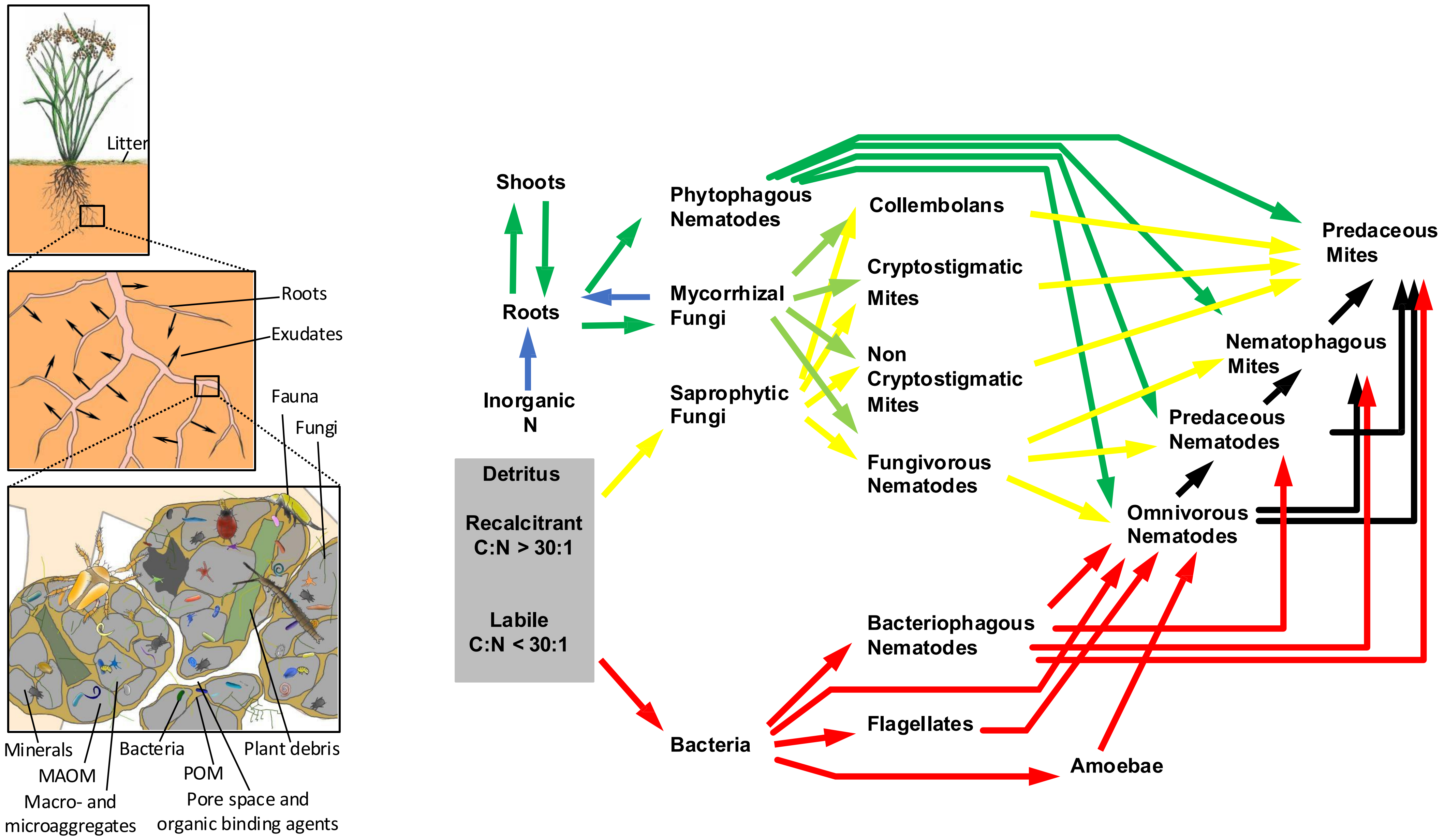
CHAPTER

6

The Biosphere

Biogeochemical Cycling on Land

OUTLINE



Litter
Roots
Exudates
Fauna
Fungi
Minerals
MAOM
Macro- and microaggregates
Bacteria
POM
Plant debris
Pore space and organic binding agents
Shoots
Roots
Inorganic N
Detritus
Recalcitrant C:N > 30:1
Labile C:N < 30:1
Phytophagous Nematodes
Mycorrhizal Fungi
Saprophytic Fungi
Bacteria
Collembolans
Cryptostigmatic Mites
Non Cryptostigmatic Mites
Fungivorous Nematodes
Bacteriophagous Nematodes
Flagellates
Amoebae
Predaceous Mites
Nematophagous Mites
Predaceous Nematodes
Omnivorous Nematodes

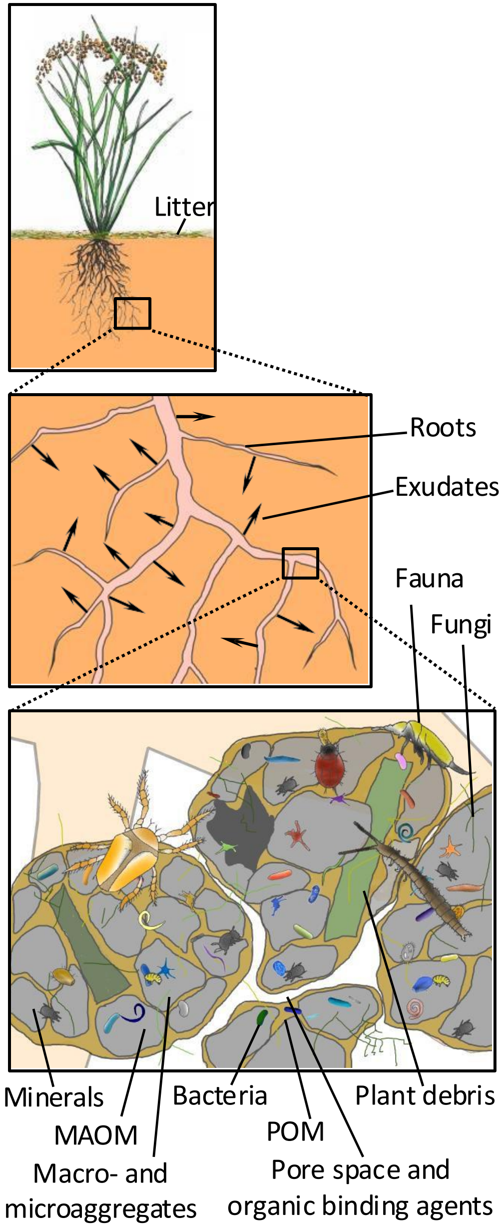
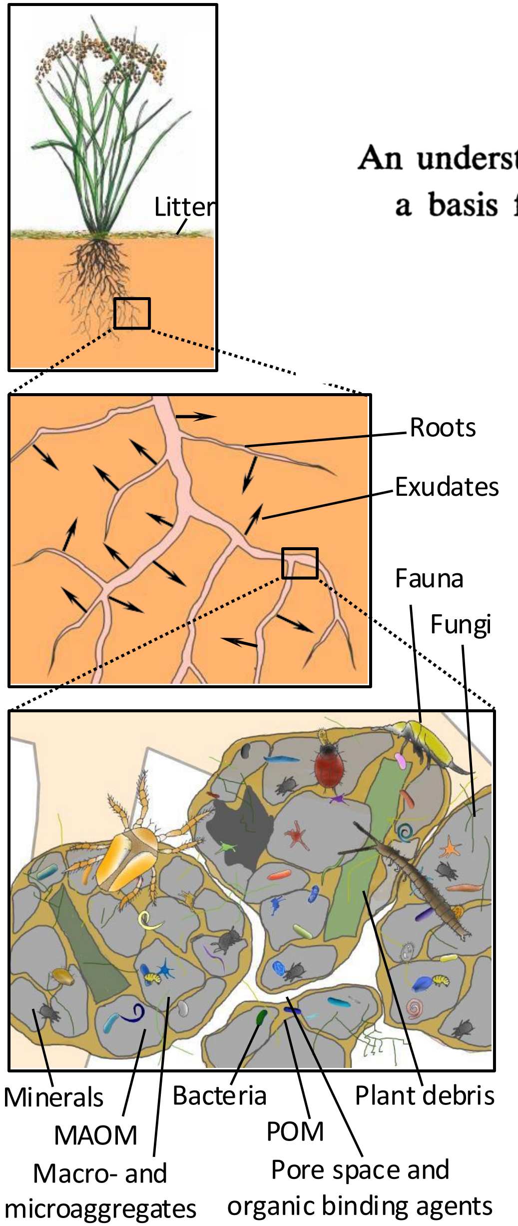


TABLE 6.1 Percentage of the Annual Requirement of Nutrients for Plant Growth in the Northern Hardwoods Forest at Hubbard Brook, New Hampshire, Which Could Be Supplied by Various Sources of Available Nutrients

Process	N	P	K	Ca	Mg
Growth requirement (Kg ha^{-1} yr^{-1})	115.4	12.3	66.9	62.2	9.5
Percentage of the requirement that could be supplied by:					
Intersystem inputs					
Atmospheric	18	0	1	4	6
Rock weathering	0	1	11	34	37
Intrasystem transfers					
Reabsorptions	31	28	4	0	2
Detritus turnover (includes return in throughfall and stemflow)	69	67	87	85	87

Note: Calculated using Eqs. 6.2 and 6.3.

Source: Reabsorption data are from Ryan and Bormann (1982). Data for N, K, Ca, and Mg are from Likens and Bormann (1995) and for P from Yanai (1992).



The Strategy of Ecosystem Development

An understanding of ecological succession provides a basis for resolving man's conflict with nature.

Eugene P. Odum

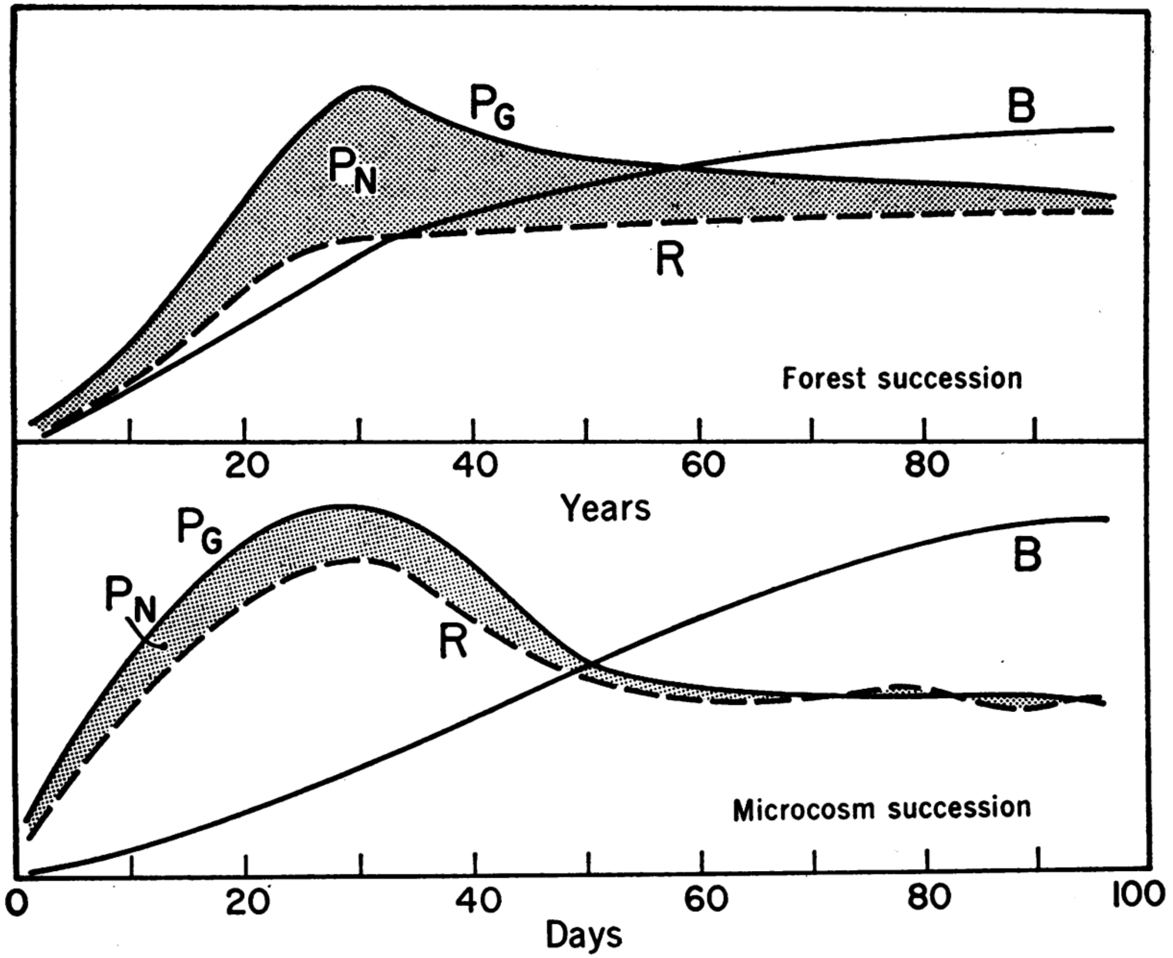
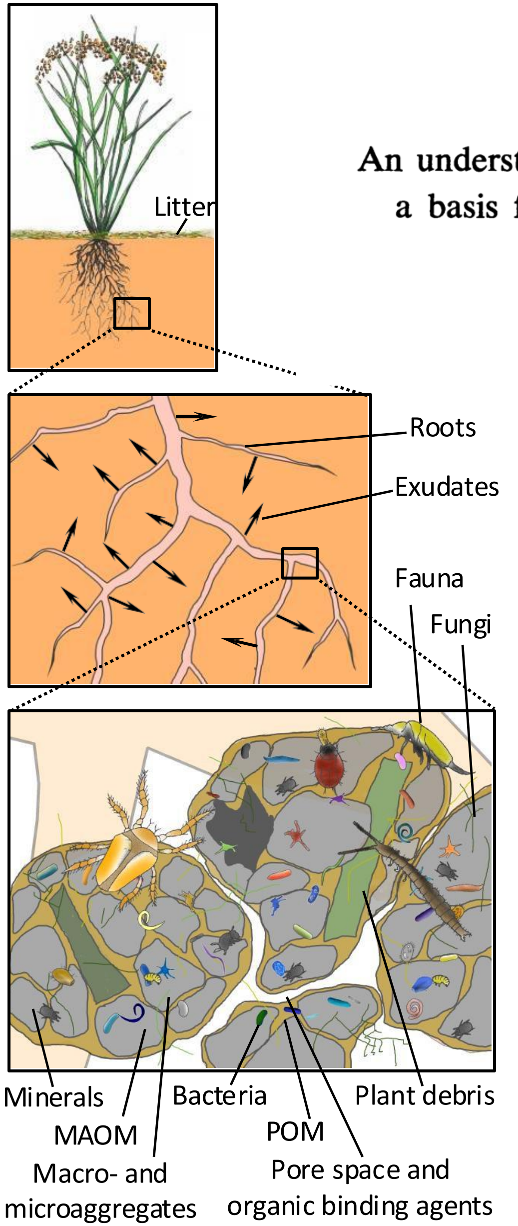


Fig. 1. Comparison of the energetics of succession in a forest and a laboratory microcosm. P_G, gross production; P_N, net production; R, total community respiration; B, total biomass.



The Strategy of Ecosystem Development

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Eugene P. Odum

Table 1. A tabular model of ecological succession: trends to be expected in the development of ecosystems.

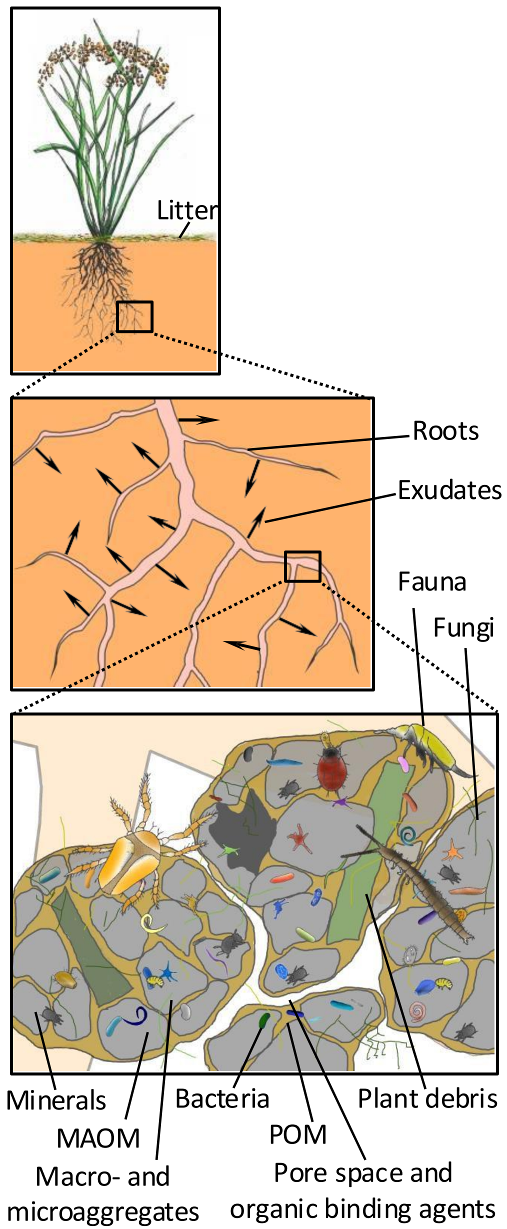
Ecosystem attributes	Developmental stages	Mature stages
Community energetics		
1. Gross production/community respiration (*P/R* ratio)	Greater or less than 1	Approaches 1
2. Gross production/standing crop biomass (*P/B* ratio)	High	Low
3. Biomass supported/unit energy flow (*B/E* ratio)	Low	High
4. Net community production (yield)	High	Low
5. Food chains	Linear, predominantly grazing	Weblike, predominantly detritus
Community structure		
6. Total organic matter	Small	Large
7. Inorganic nutrients	Extrabiotic	Intrabiotic
8. Species diversity—variety component	Low	High
9. Species diversity—equitability component	Low	High
10. Biochemical diversity	Low	High
11. Stratification and spatial heterogeneity (pattern diversity)	Poorly organized	Well-organized
Life history		
12. Niche specialization	Broad	Narrow
13. Size of organism	Small	Large
14. Life cycles	Short, simple	Long, complex
Nutrient cycling		
15. Mineral cycles	Open	Closed
16. Nutrient exchange rate, between organisms and environment	Rapid	Slow
17. Role of detritus in nutrient regeneration	Unimportant	Important
Selection pressure		
18. Growth form	For rapid growth ("*r*-selection")	For feedback control ("*K*-selection")
19. Production	Quantity	Quality
Overall homeostasis		
20. Internal symbiosis	Undeveloped	Developed
21. Nutrient conservation	Poor	Good
22. Stability (resistance to external perturbations)	Poor	Good
23. Entropy	High	Low
24. Information	Low	High

Oxidized $\longrightarrow$ Reduced

Reduced $\longrightarrow$ Oxidized

	H_2O/O_2	C	N	S
H_2O/O_2	X	Photosynthesis $CO_2 \longrightarrow C$ $H_2O \longrightarrow O_2$		
C	Respiration $C \longrightarrow CO_2$ $O_2 \longrightarrow H_2O$	X	Denitrification $C \longrightarrow CO_2$ $NO_3 \longrightarrow N_2$	Sulfate-Reduction $C \longrightarrow CO_2$ $SO_4 \longrightarrow H_2S$
N	Heterotrophic Nitrification $NH_4 \longrightarrow NO_3$ $O_2 \longrightarrow H_2O$	Chemoautotrophy (Nitrification) $NH_4 \longrightarrow NO_3$ $CO_2 \longrightarrow C$	Anammox $NH_4 + NO_2 \rightarrow N_2 + 2H_2O$	?
S	Sulfur Oxidation $S \longrightarrow SO_4$ $O_2 \longrightarrow H_2O$	Chemoautotrophy (Sulfur-based Photosynthesis) $S \longrightarrow SO_4$ $CO_2 \longrightarrow C$	Autotrophic Denitrification $S \longrightarrow SO_4$ $NO_3 \longrightarrow N_2/NH_4$	X

FIGURE 1.4 A matrix showing how cellular metabolisms couple oxidation and reduction reactions. The cells in the matrix are occupied by organisms or a consortium of organisms that reduce the element at the top of the column, while oxidizing an element at the beginning of the row. *Source: From Schlesinger et al. (2011).*



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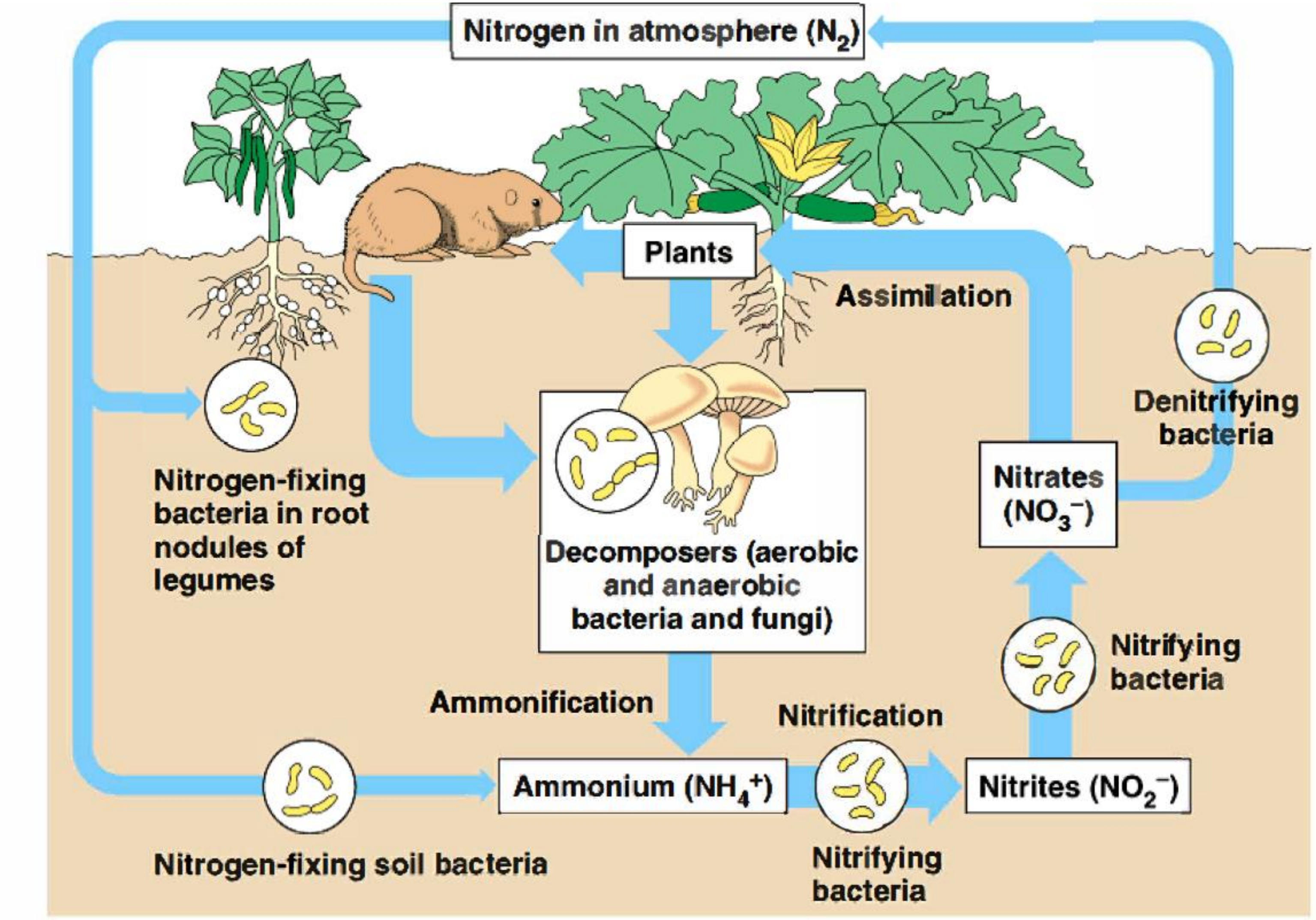
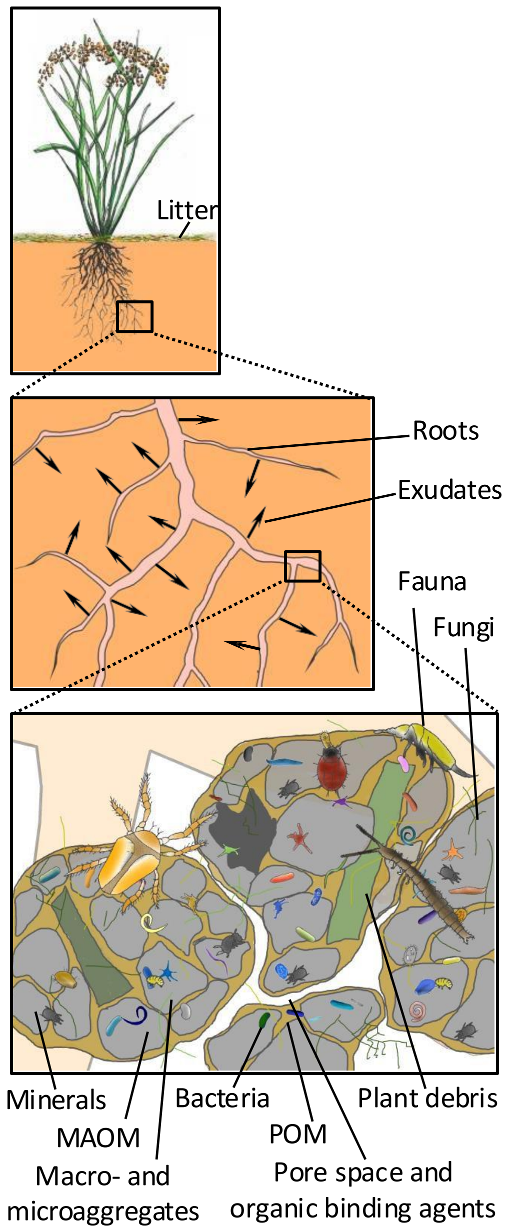


Nitrogen in atmosphere (N_2)
Plants
Assimilation
Denitrifying bacteria
Nitrogen-fixing bacteria in root nodules of legumes
Decomposers (aerobic and anaerobic bacteria and fungi)
Nitrates (NO_3^-)
Nitrifying bacteria
Ammonification
Nitrification
Ammonium (NH_4^+)
Nitrites (NO_2^-)
Nitrogen-fixing soil bacteria
Nitrifying bacteria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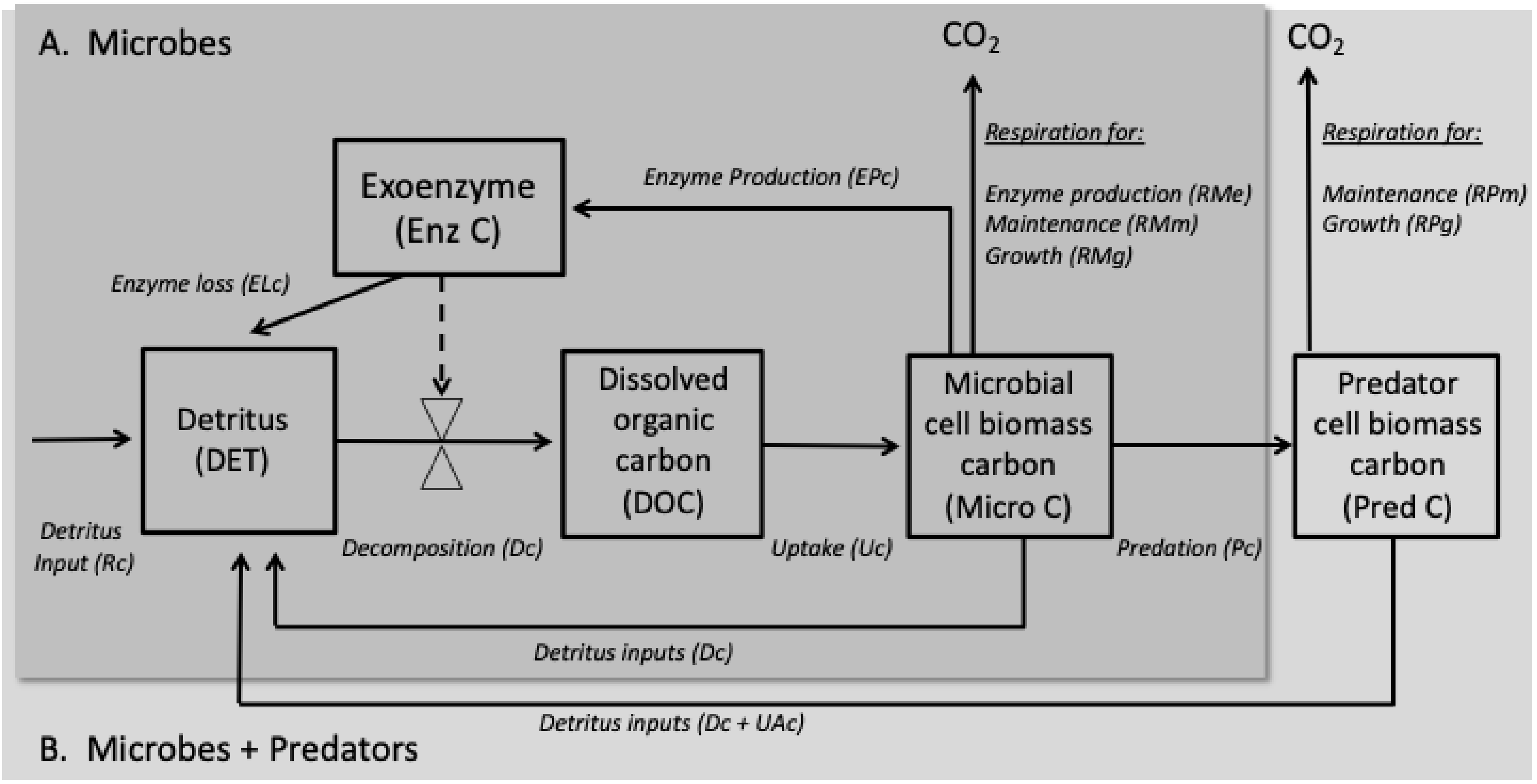
A. Microbes
CO_2
CO_2
Respiration for:
Enzyme production (RMe)
Maintenance (RMm)
Growth (RMg)
Respiration for:
Maintenance (RPm)
Growth (RPg)
Enzyme Production (EPc)
Exoenzyme (Enz C)
Enzyme loss (ELc)
Detritus (DET)
Dissolved organic carbon (DOC)
Microbial cell biomass carbon (Micro C)
Predator cell biomass carbon (Pred C)
Detritus Input (Rc)
Decomposition (Dc)
Uptake (Uc)
Predation (Pc)
Detritus inputs (Dc)
Detritus inputs (Dc + UAc)
B. Microbes + Predators

LETTERS | FOCUS
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Soil-carbon response to warming dependent on microbial physiology

Steven D. Allison[1]*, Matthew D. Wallenstein[2] and Mark A. Bradford[3]

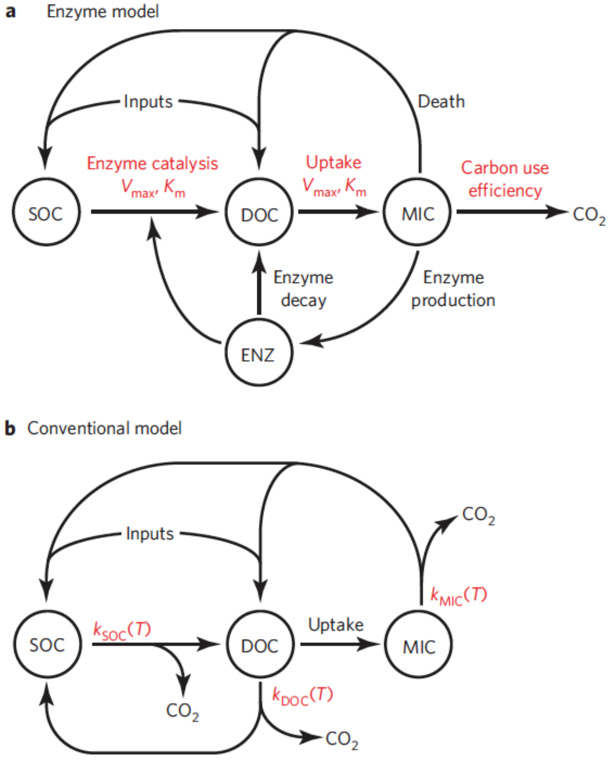
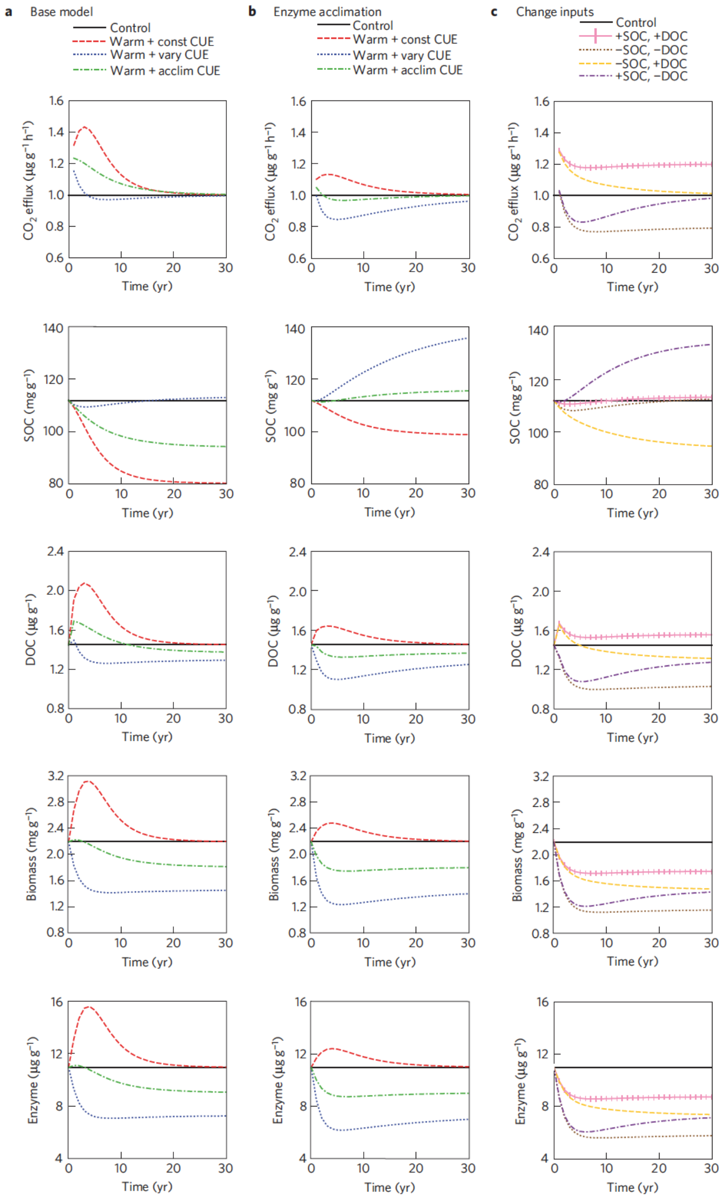


Figure 1 | Diagram of soil C models. Structure of the microbial-enzyme (**a**) and conventional (**b**) models of soil C decomposition under warming. Temperature-sensitive parameters are shown in red. The distinguishing feature of the enzyme model is that microbial biomass (MIC) affects the conversion of SOC to DOC through the production of extracellular enzymes (ENZ). In the conventional model, microbial processes are not explicitly coupled to soil C turnover, so changes in microbial biomass and enzyme production cannot feed back on decomposition.



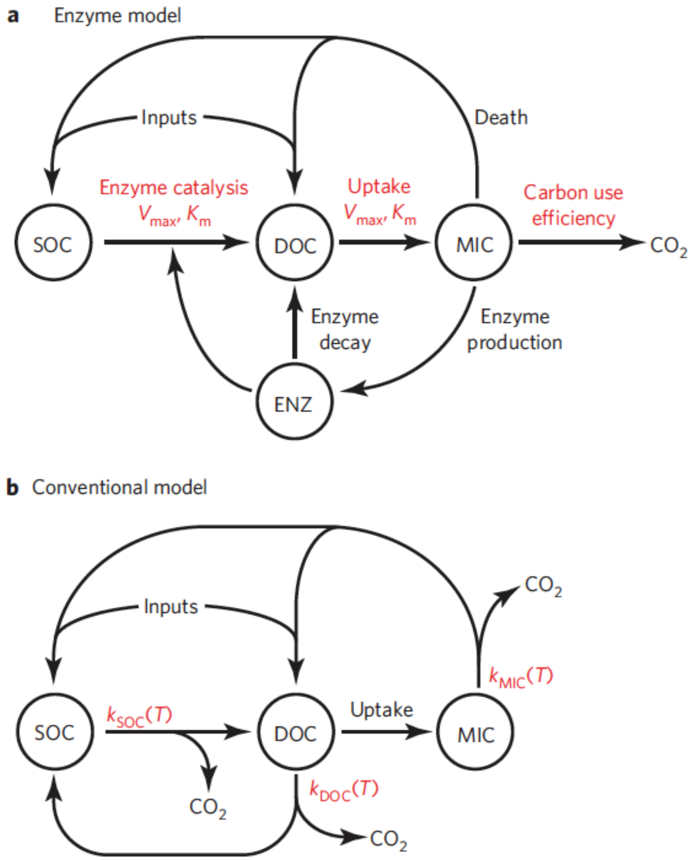


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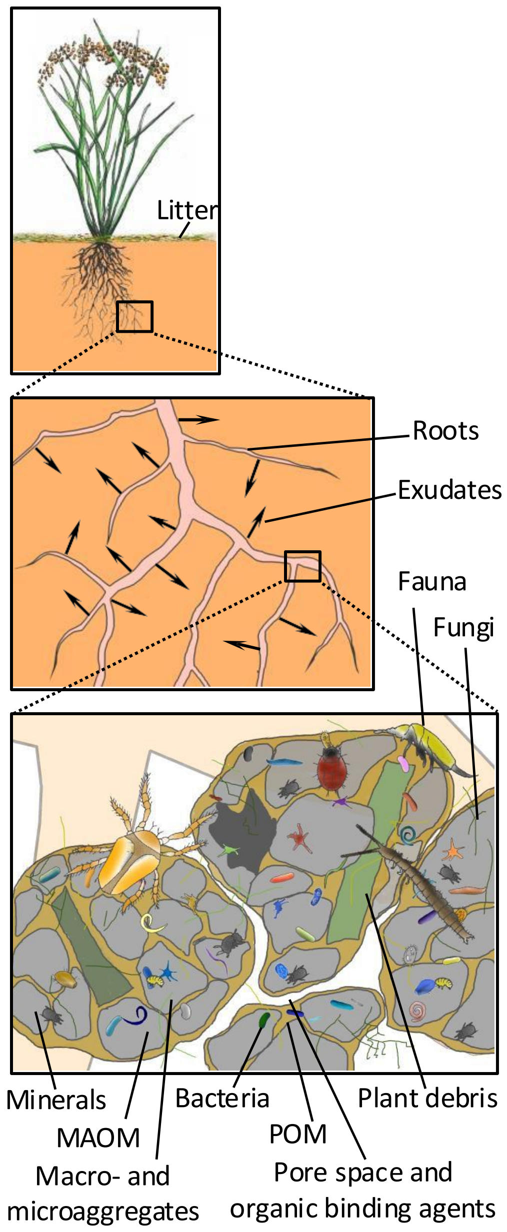
Table 1 | Modelled changes in SOC pool size.

Scenario*	30 yr change in SOC pool size (%)
Control	0
CUE varies	+1
CUE acclimates	−16
CUE acclimates + enzyme acclimation	+3
Low SOC, high DOC inputs + CUE varies	−15
LH inputs + CUE varies + enzyme acclimation	+2
LH inputs + CUE acclimates	−29
LH inputs + CUE acclimates + enzyme acclimation	−13

*Control run and model scenarios predicting an ephemeral rise in soil respiration and reduced microbial biomass in response to 5 °C warming, consistent with empirical observations[3-5,14]. LH inputs = Low SOC, high DOC inputs.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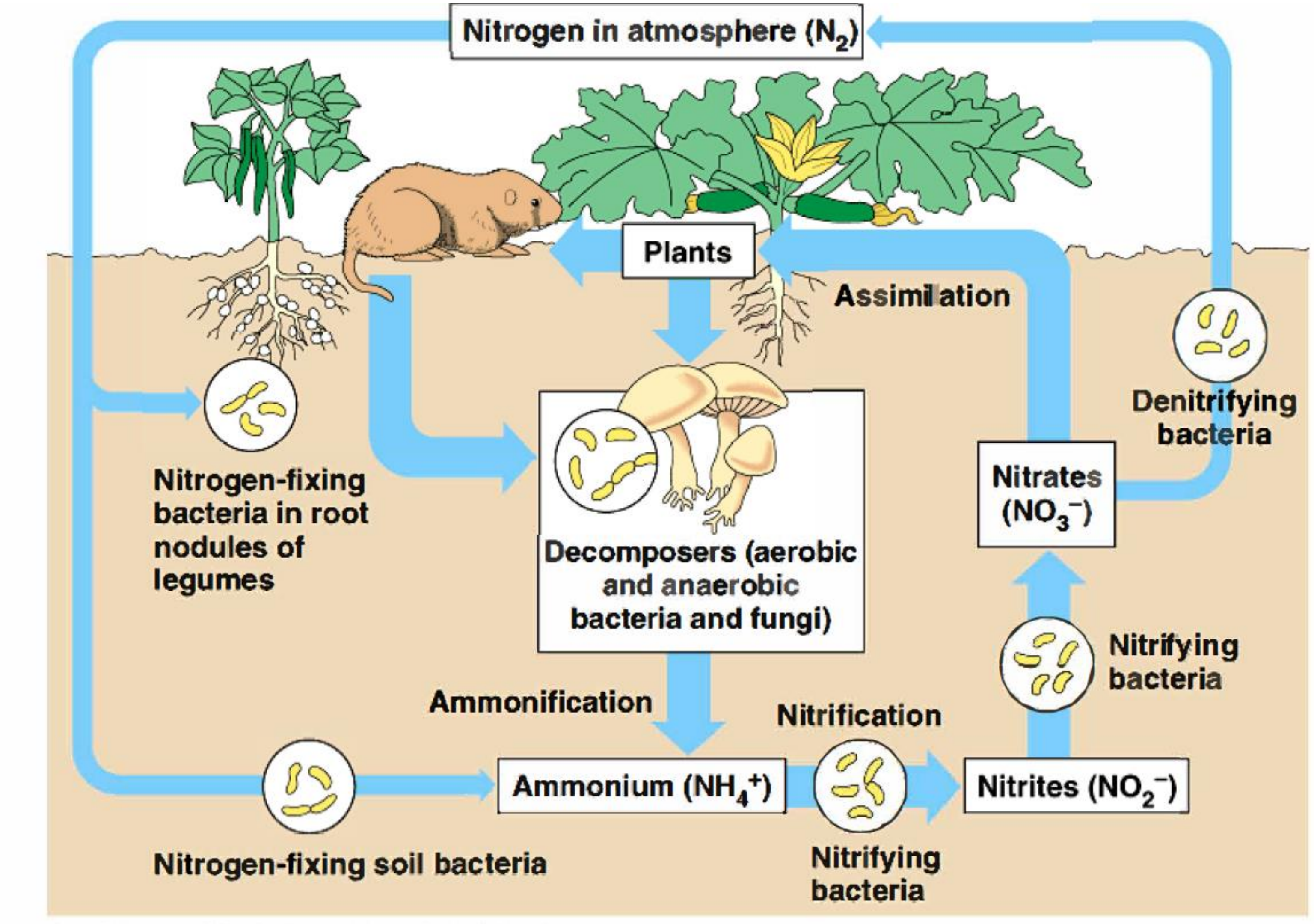
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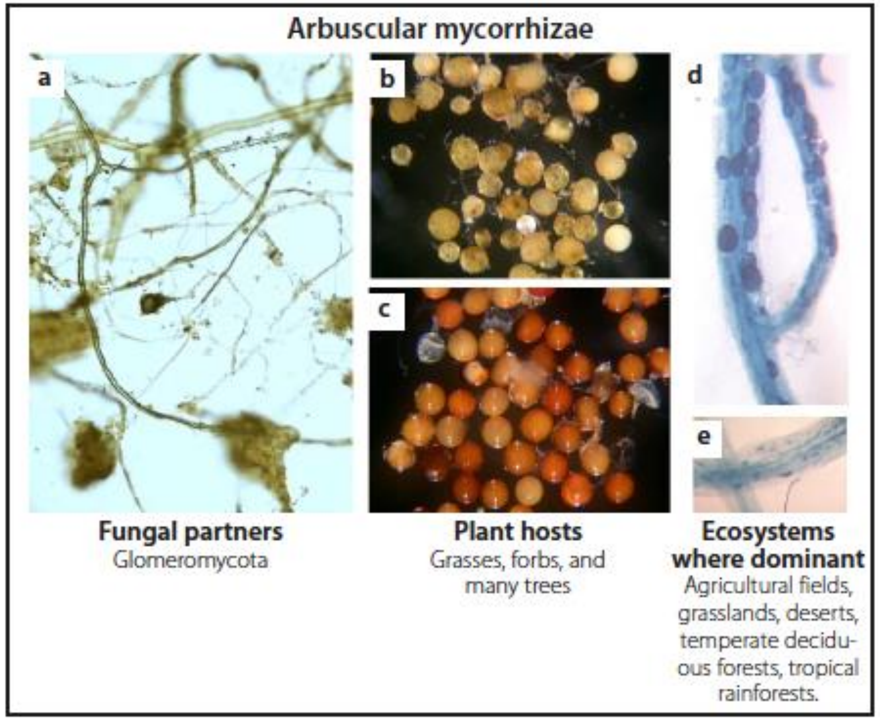
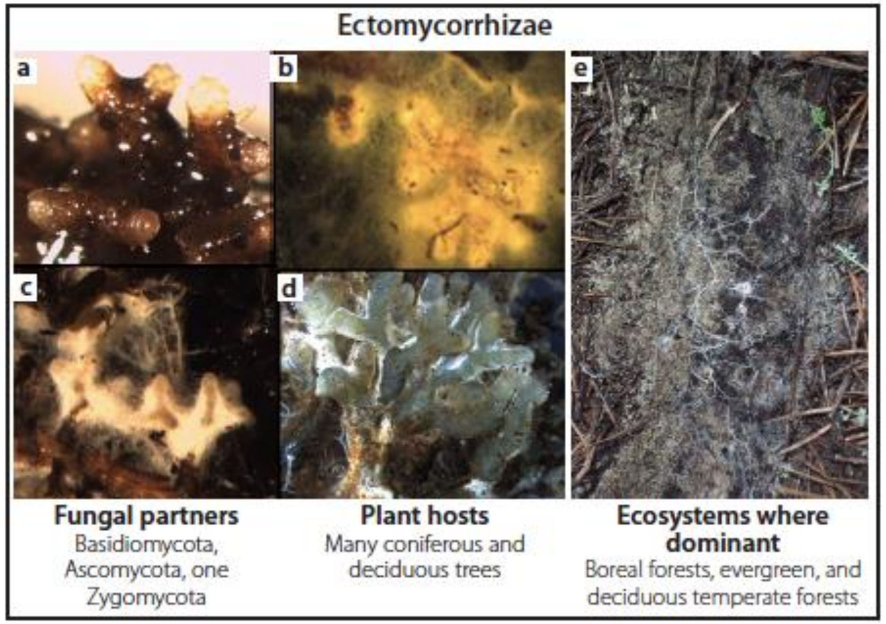
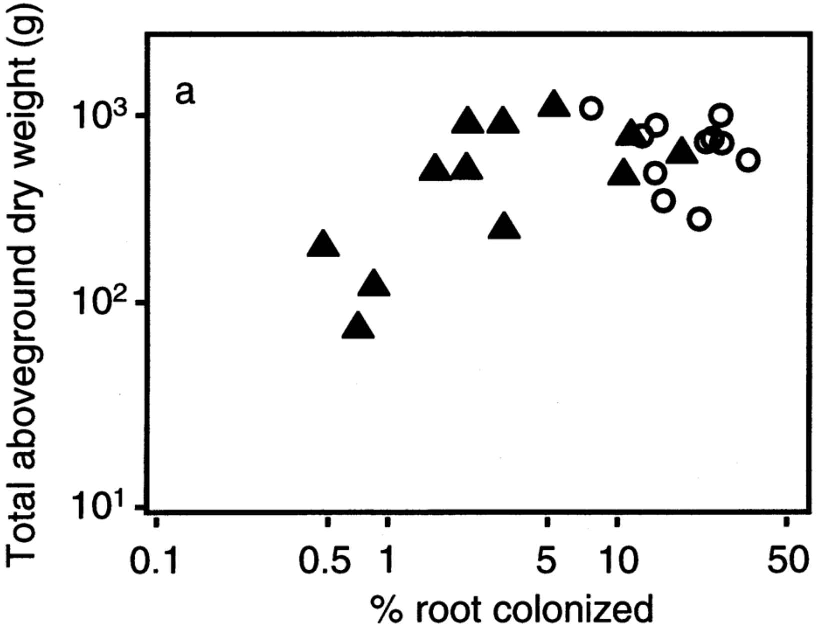






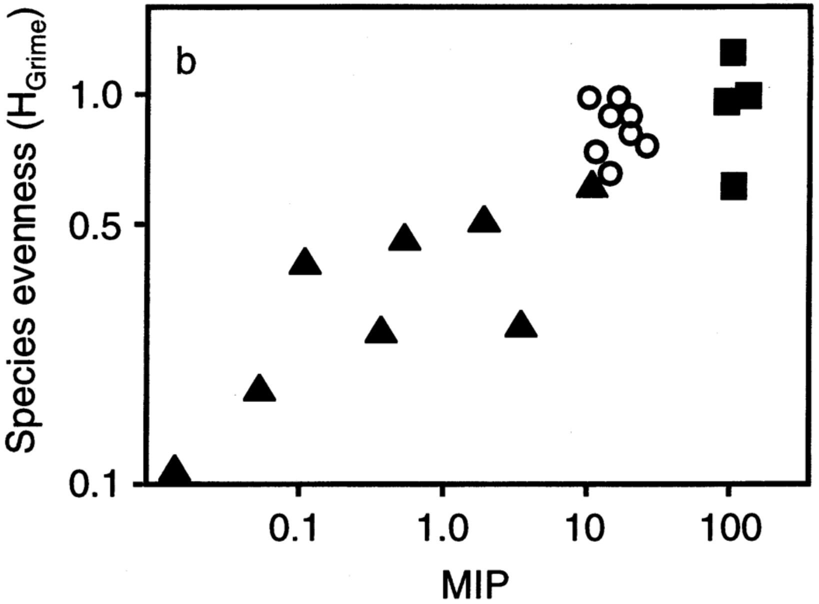
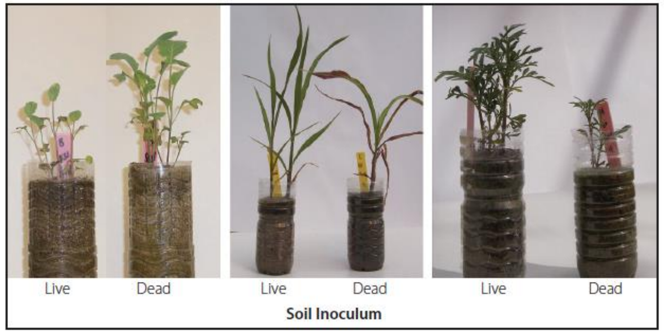


Figure 3. Results of the experiment can be illustrated with photographs. These pictures show that after eight weeks in a warm greenhouse, broccoli (left) grew better without mycorrhizal fungi and other organisms in the living soil, while corn and marigolds (middle and right) grew better with these soil organisms.



Biological Invasion by Myrica faya Alters Ecosystem Development in Hawaii

Peter M. Vitousek; Lawrence R. Walker; Louis D. Whiteaker; Dieter Mueller-Dombois; Pamela A. Matson

Science, New Series, Vol. 238, No. 4828 (Nov. 6, 1987), 802-804.

Table 1. Diameter increment (in millimeters per year, with standard errors in parentheses) of control and fertilized individuals of the native tree *Metrosideros polymorpha* in young, intermediate-aged, and old sites. Fertilizer treatments, application rates, and statistical design are in (*11*). No *Myrica faya* was present on any plot.

Site	Control	Nitrogen-fertilized	Significance level	Effect of other nutrients
1959 ash	6.6 (0.8)	11.6 (0.9)	$P < 0.001$	NS*
1790 ash	0.4 (0.1)	0.8 (0.1)	$P < 0.01$	NS*
Old ash	4.4 (0.7)	5.5 (0.9)	NS*	
Open canopied†	0.6 (0.1)	2.4 (0.3)	$P < 0.001$	

*NS, not significant ($P > 0.05$). †Many canopy trees and all of the understory were eliminated by volcanic cinder from a 1959 eruption; measurements were made on the surviving canopy trees.

Table 2. Sources of nitrogen (in kilograms per hectare per year) in open-canopied sites with and without populations of the exotic nitrogen-fixer *Myrica faya*.

Source	No *Myrica*	With *Myrica*
Rainfall (*16*)	5	5
Native nitrogen fixation (*17*) by		
Leaf litter	0.2	0.3
Decaying wood	0.1	<0.1
Lichens	0.2	0.2
Bryophyte mats	<0.1	<0.1
Nitrogen fixation by *Myrica faya* (*14*)	0	18
Total	5.5	23.5