

Should interaction strengths be at the individual or species level?

Peter C. de Ruiter, Anje-Margriet Neutel & John C. Moore



Trophic dynamics in ecosystems:
feeding interactions, species identity, and body size

SizeMic, Cambridge (UK) April 5, 2008

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...or at the functional group level?

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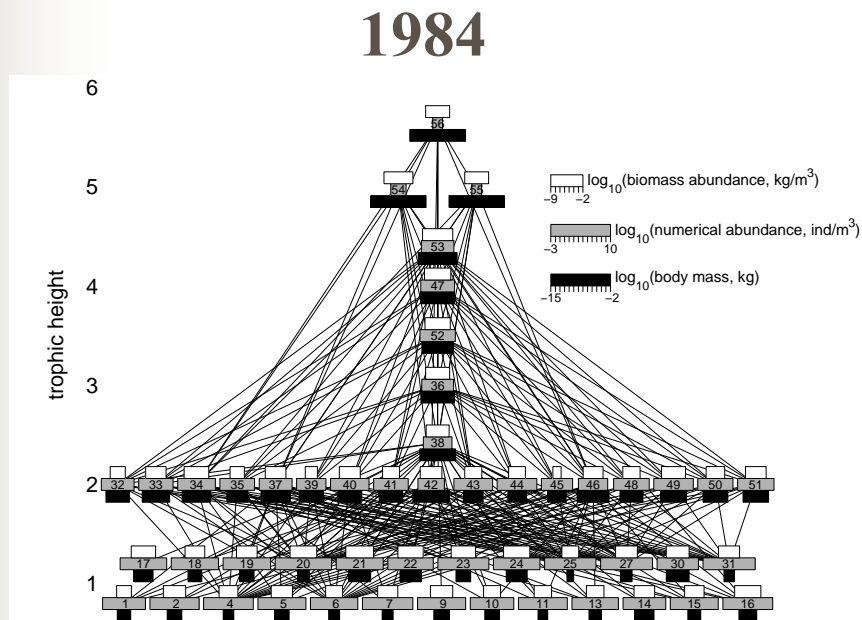
- Dynamics in species composition
- Energetic structures and stability
 - Energy budgets and ecosystem processes
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 - Food web stability and biomass pyramids in trophic loops
 - Biomass pyramids and physiological traits
- Dynamics in species composition

Dynamic food webs

Tuesday
Lake

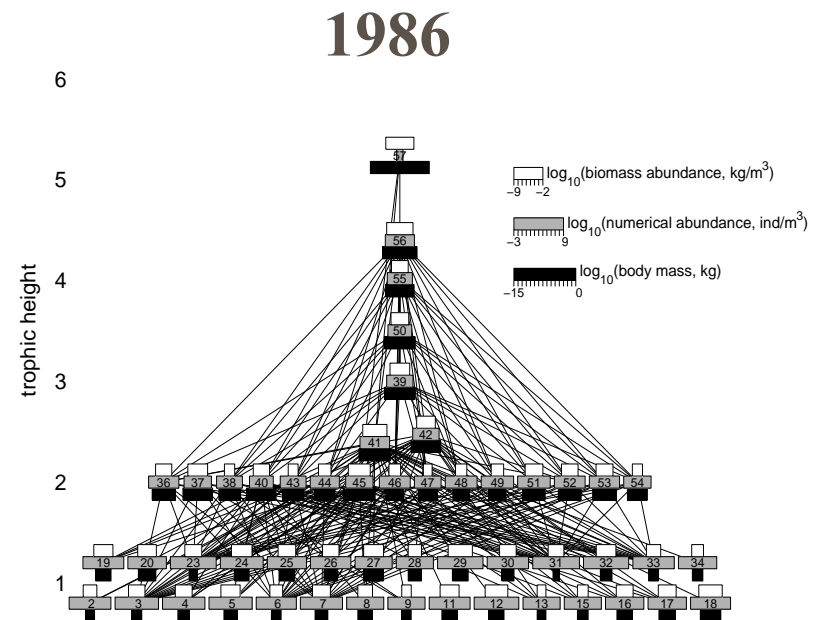


Dynamic food webs



Species

56 (23)



57 (24)

[Jonsson *et al.* Adv. Ecol. Res. 2005]



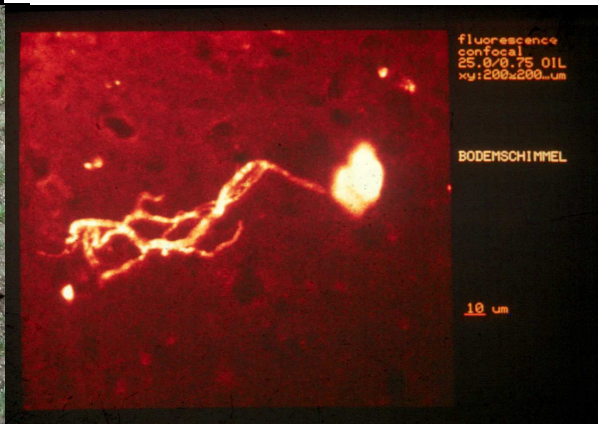
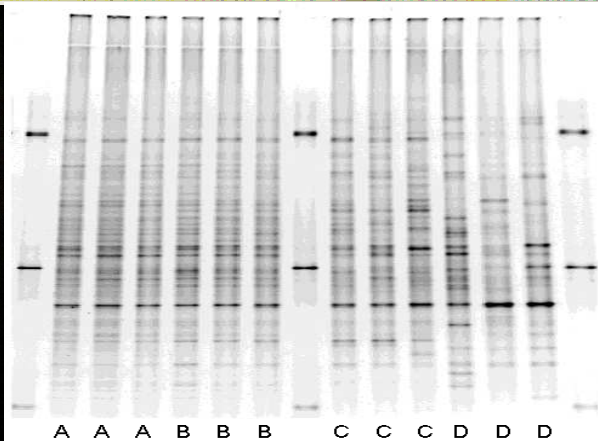
Should interaction strengths be at the individual or
species level? **...or at the functional group level?**

■ Soils









Soil Biodiversity and Ecosystem Functioning

Soil Biodiversity

- 150.000 sp.
- The majority of global biodiversity



Soil Ecosystem Functioning

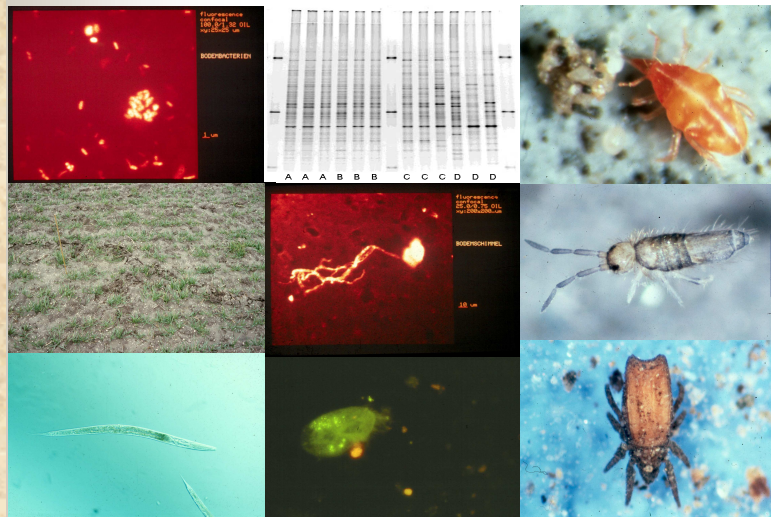
- Organic matter processed: $50.000 \text{ kg} \cdot \text{ha}^{-1} \cdot \text{yr}^{-1}$
- Production of CO_2 : $20 \text{ Mt yr}^{-1} \text{ (NL)}$



From Species to Functional Groups

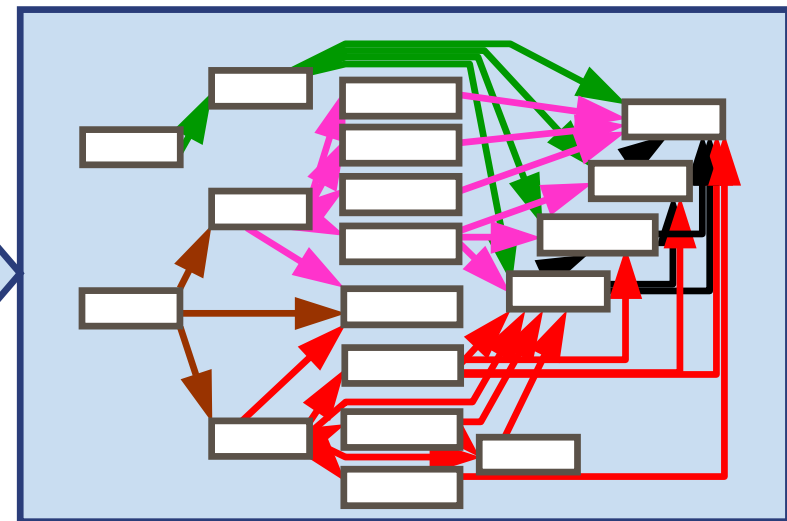
Soil Biodiversity

■ 150.000 sp.

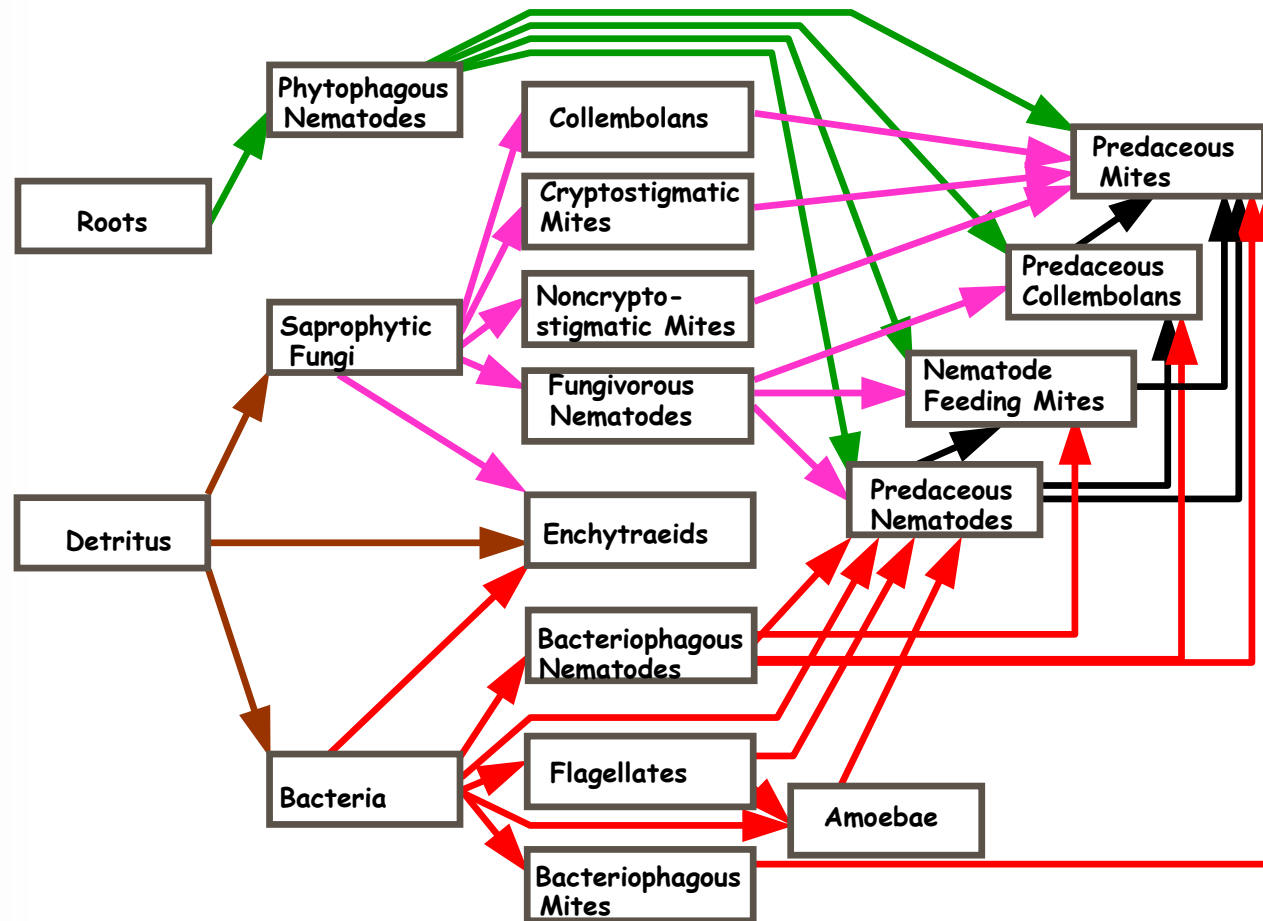


Soil Food Web

■ 18 functional groups



Lovinkhoeve food web





Should interaction strengths be at the individual or species level? **...or at the functional group level?**

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- Energy budgets and ecosystem processes

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- Biomass pyramids and physiological traits

- Dynamics in species composition

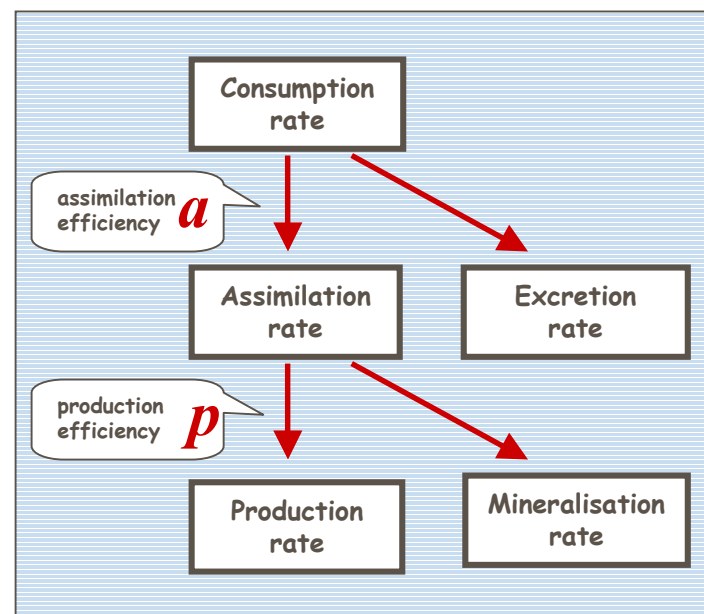
Modelling feeding rates

Steady state: production of a population balances the losses through natural death and predation:

$$F = \frac{dB + M}{ap}$$

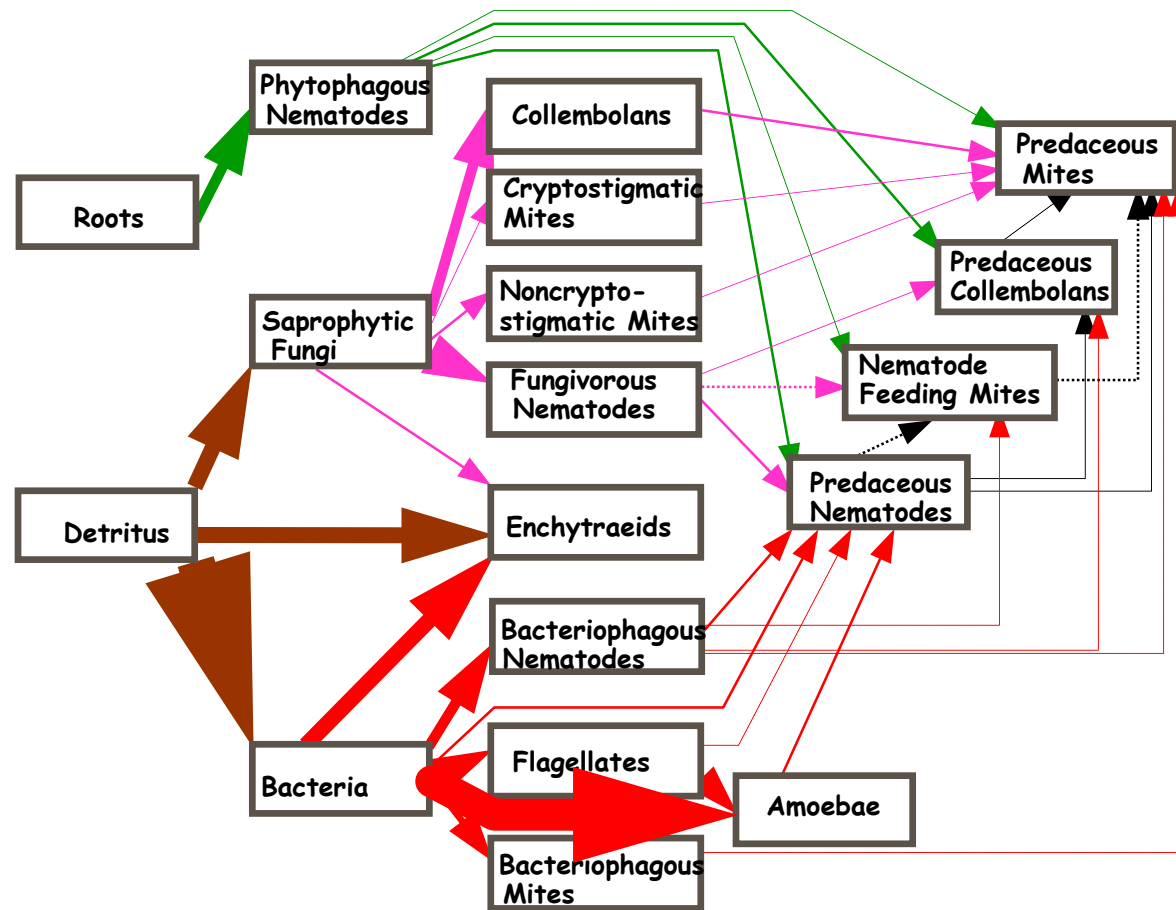
$$F_i = \frac{w_i B_i}{\sum_k w_k B_k} F$$

- F : feeding rate ($\text{kg ha}^{-1} \text{ yr}^{-1}$)
 d : natural death rate (yr^{-1})
 B : biomass (kg ha^{-1})
 M : mortality due to predation ($\text{kg ha}^{-1} \text{ yr}^{-1}$)
 a : assimilation efficiency (-)
 p : production efficiency (-)
 w_{ij} : preference of predator j for prey i (-)



[O'Neill, JTB 1969]

Lovinkhoeve food web: feeding rates



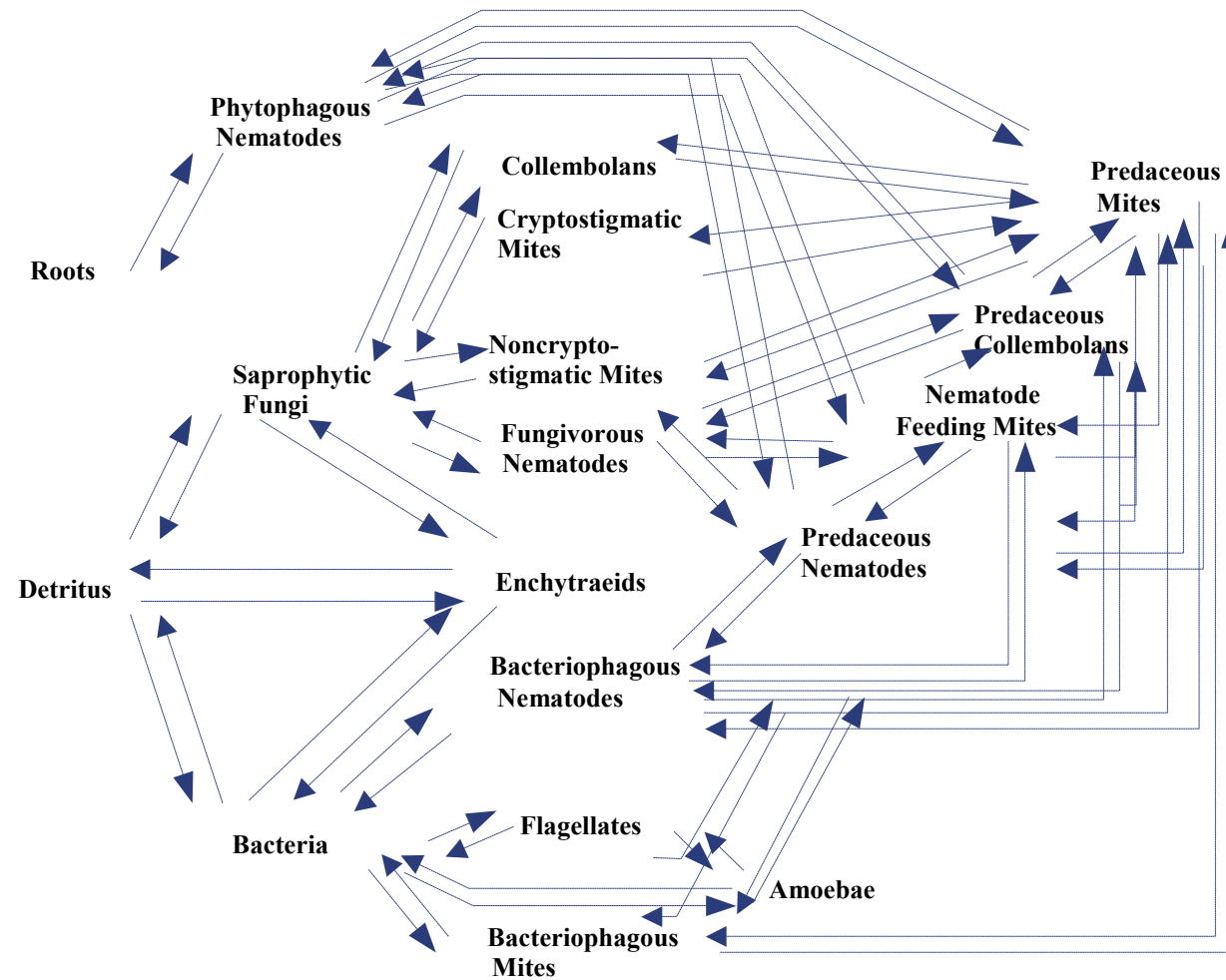


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- Dynamics in species composition

- 
- From feeding rates to interaction strengths

Trophic Interaction Web



From feeding rates to interaction strengths

Interaction strengths are 'per capita effects', calculated cf. May (1972) as partial derivatives

$$\alpha_{ij} = [\partial \dot{X}_i / \partial X_j]^*$$

Substitutions:

$$F_{ij} = c_{ij} X_i X_j$$

$$B_i = X_i^* \text{ and } B_j = X_j^*$$

Per capita effect of predator j on prey i :

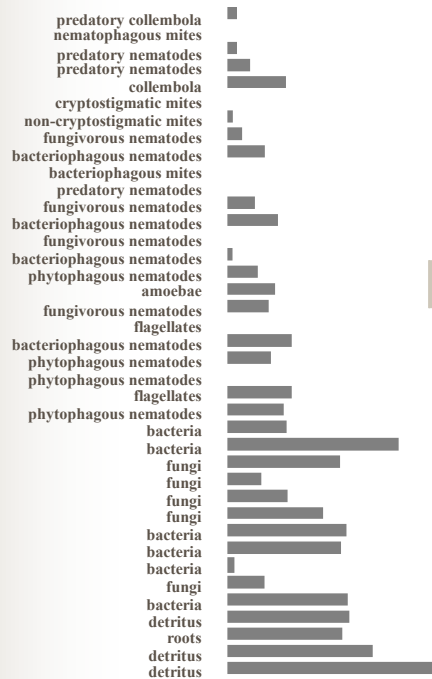
$$\alpha_{ij} = - c_{ij} X_i^* = - F_{ij} / B_j$$

Per capita effect of prey i on predator j :

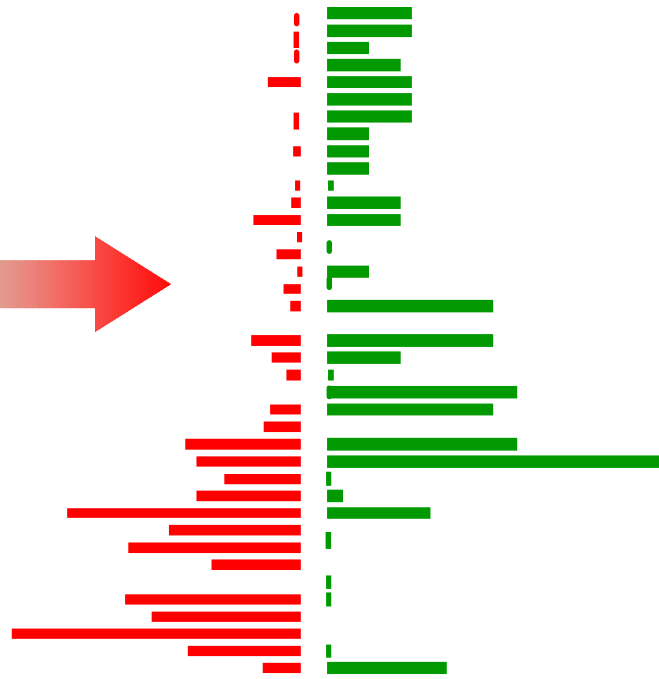
$$\alpha_{ji} = e_j c_{ij} X_j^* = e_j F_{ij} / B_i$$

From feeding rates to interaction strengths

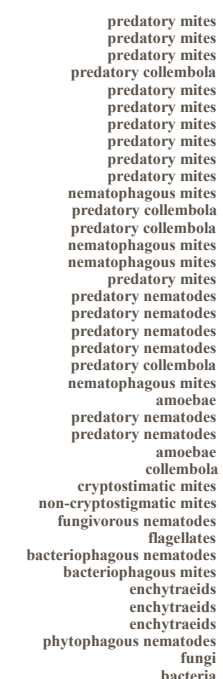
resource



top predators



consumer

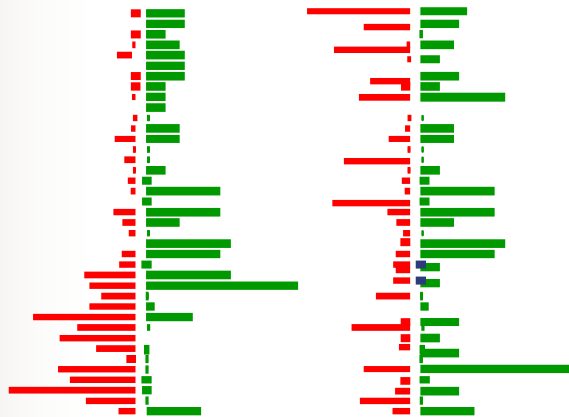


Patterned interaction strengths and stability

Interaction strengths

Patterned

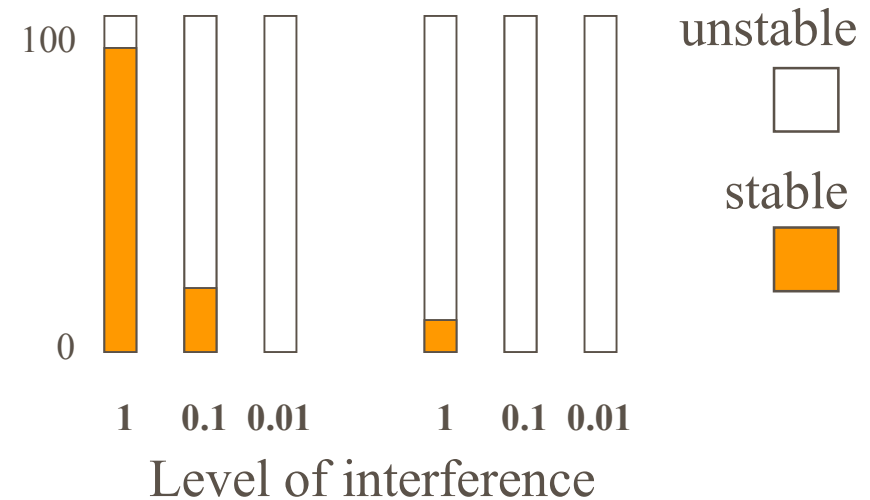
Random



Probability of community matrix stability (%)

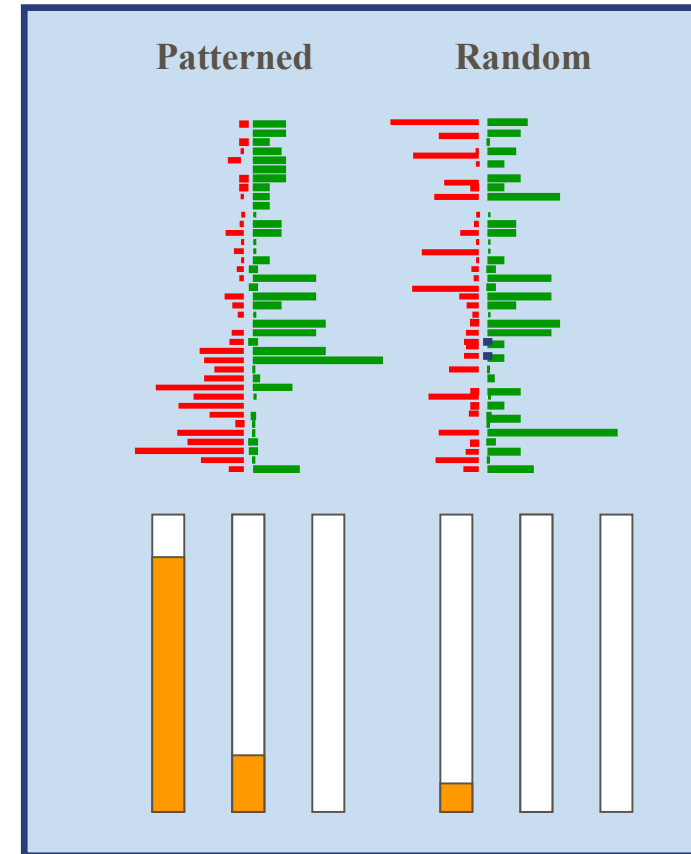
Patterned

Random



Summary...

- The energetic organization in soil food webs (feeding rates, biomasses) generates a pattern of interaction strengths that enhances stability.





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 - Biomass pyramids and physiological traits
- Dynamics in species composition



- Trophic interaction loops

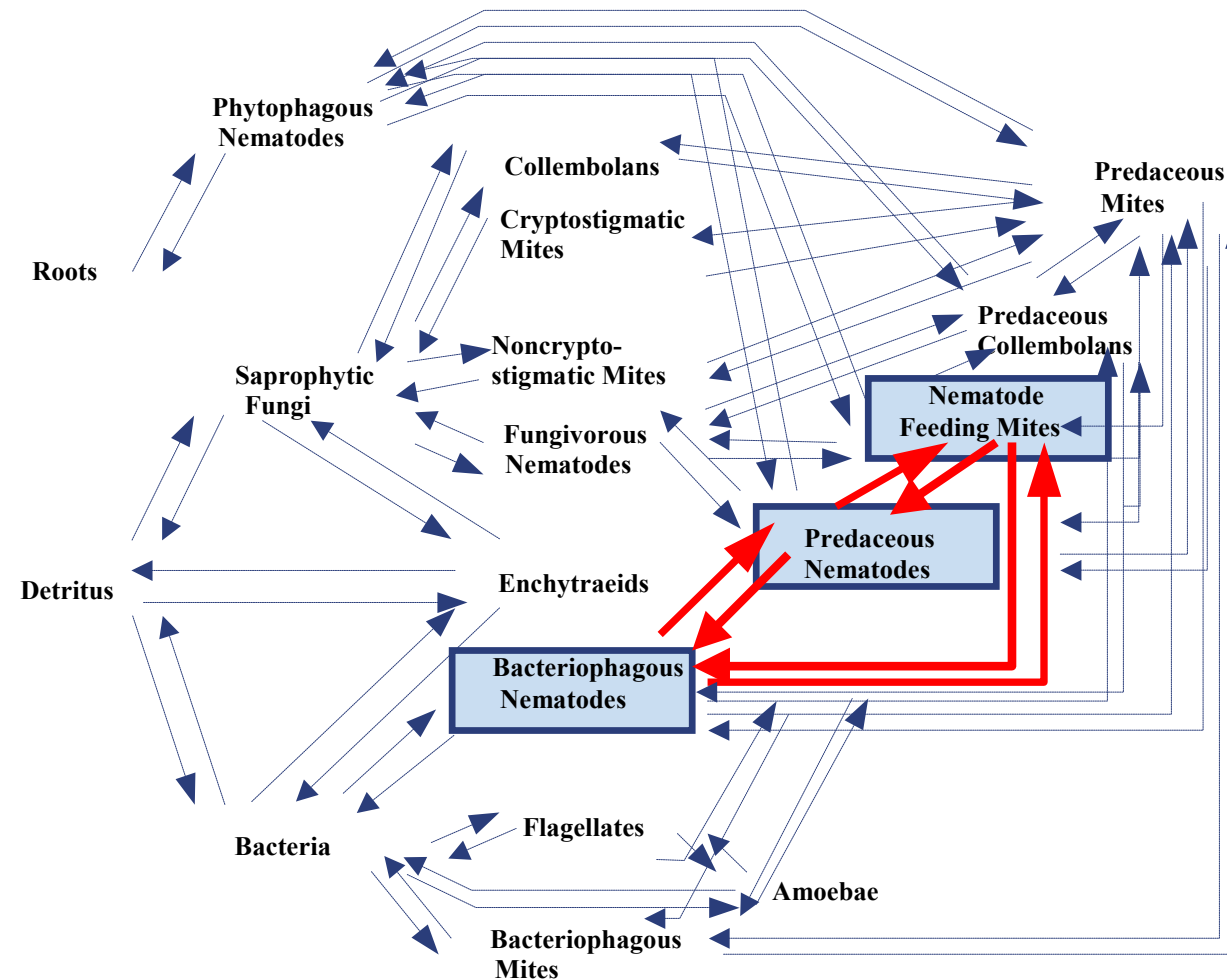


Trophic interaction loops

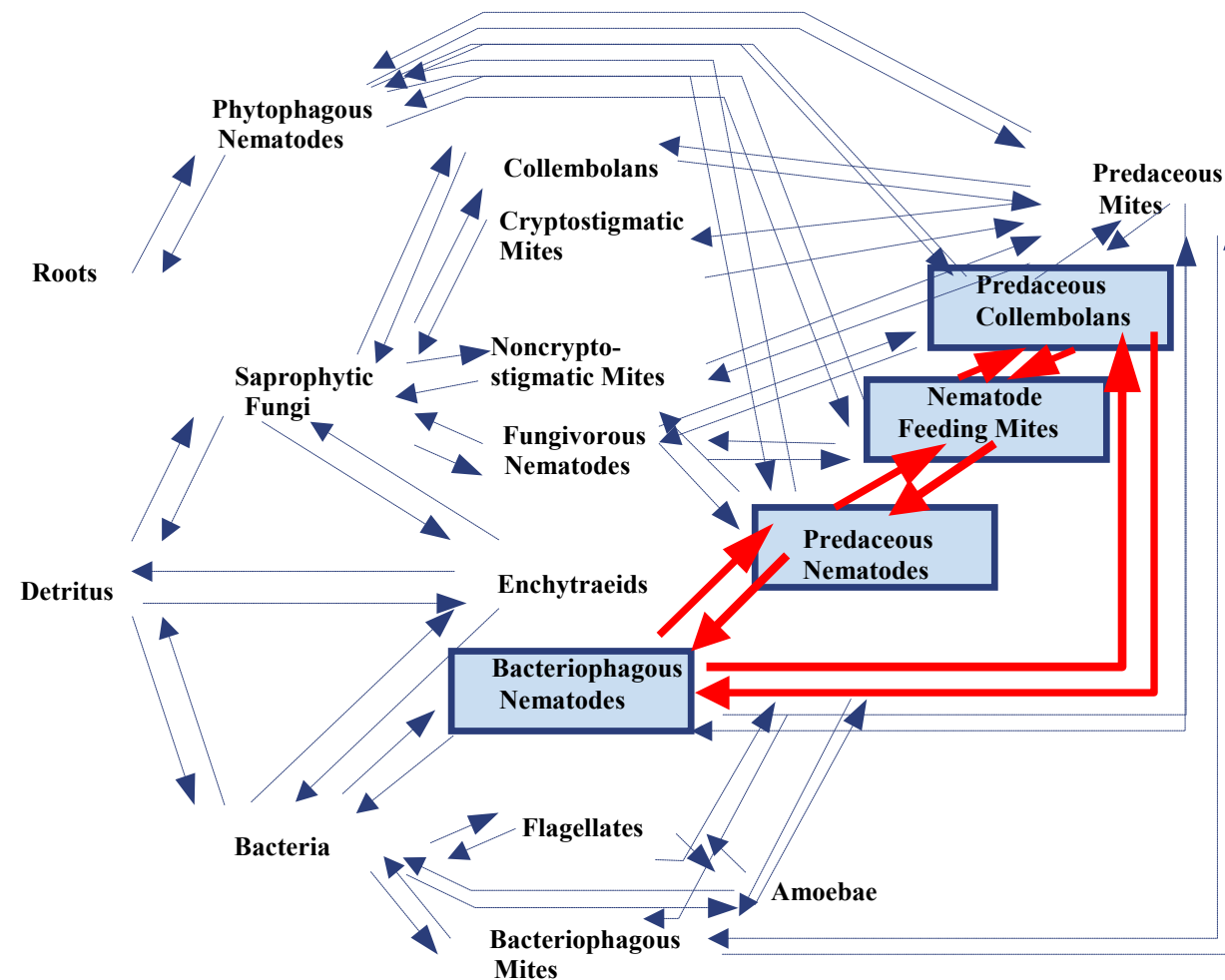
- Trophic interaction loops are closed chains of interactions.
- The loop length is the number of groups in the loop.
- The loop weight is the geometric mean of the strengths of the interactions in the loop.
- The loop with the maximum loop weight is critical to food web stability.

[Neutel *et al.* Science 2002]

Trophic Interaction Loop (length 3)

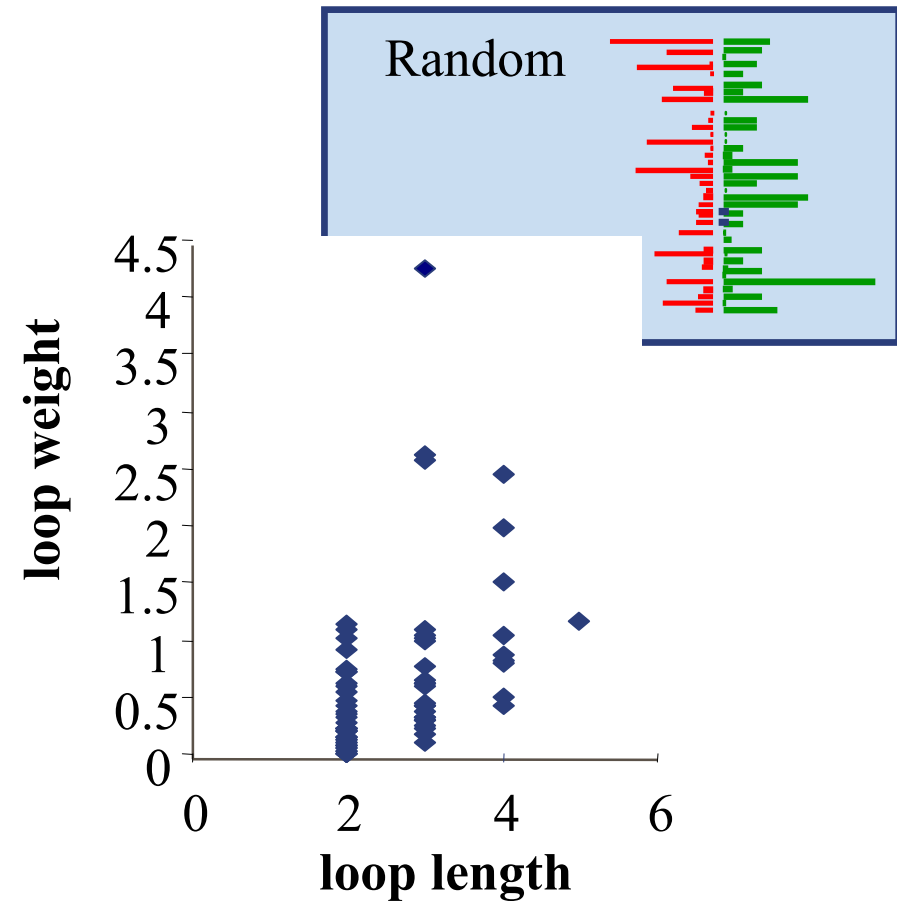
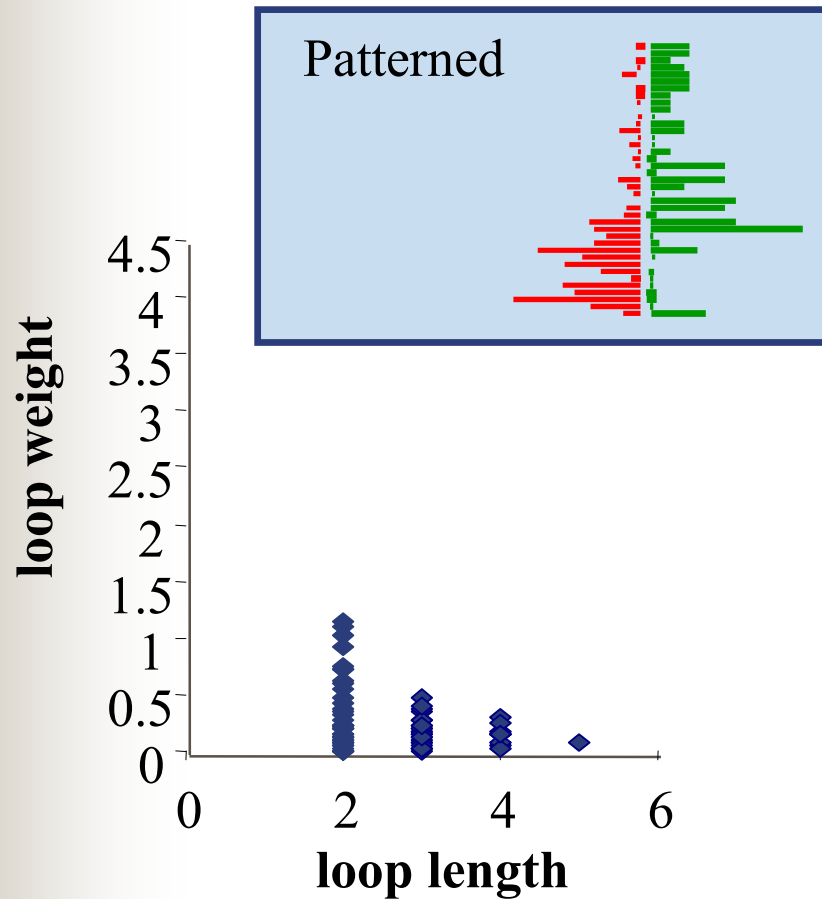


Trophic Interaction Loop (4)



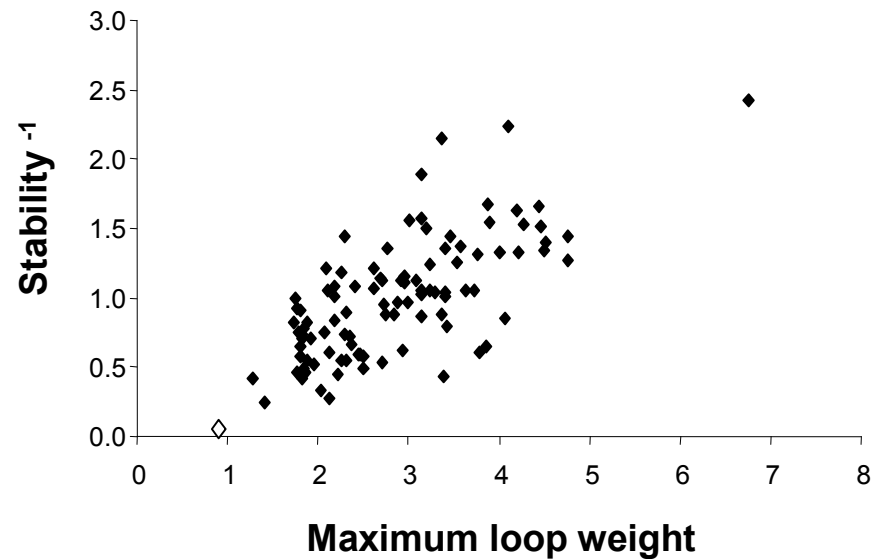
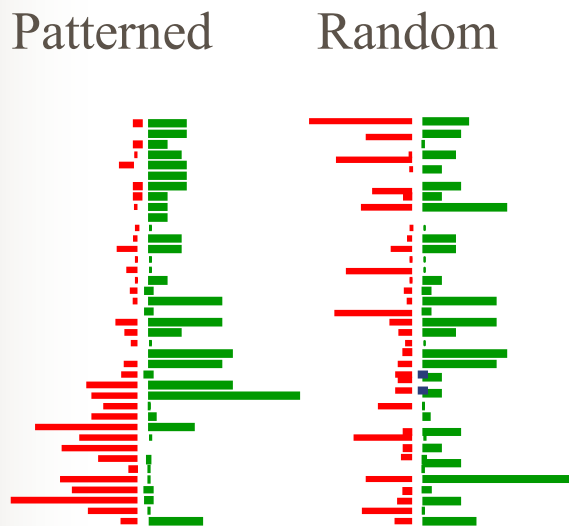
- 
- Long loops with many negative effects are potentially the heaviest loops.

Food web stability and the weight of trophic loops



[Neutel *et al.* Science 2002]

Food web stability and the weight of trophic loops



[Neutel *et al.* Science 2002]

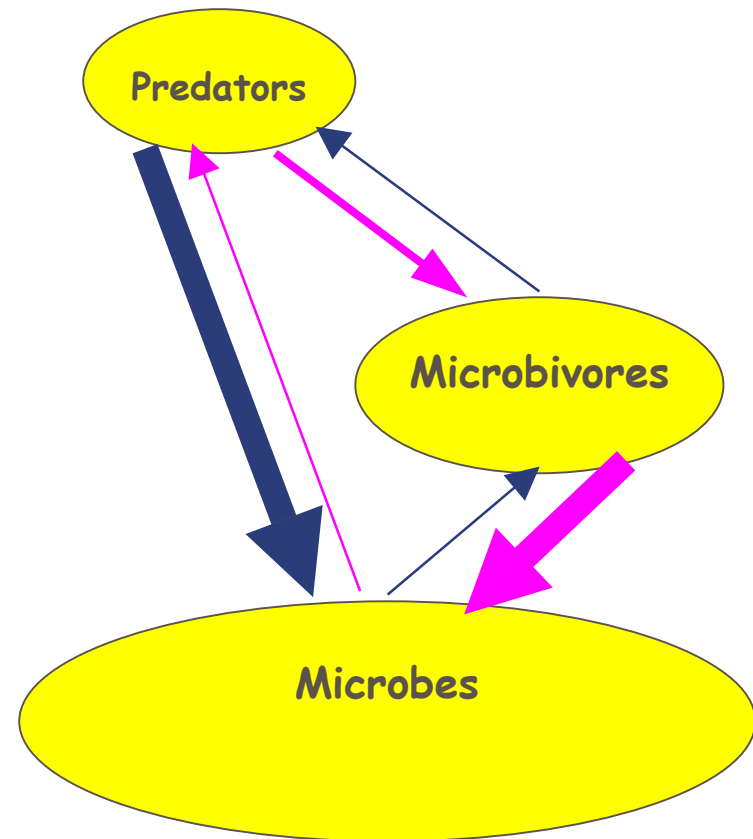
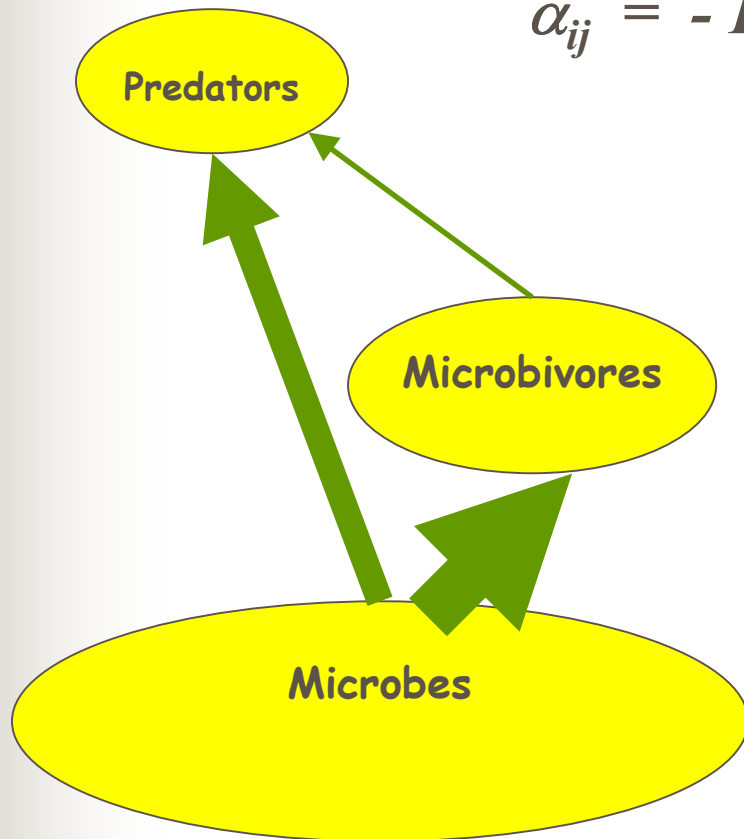


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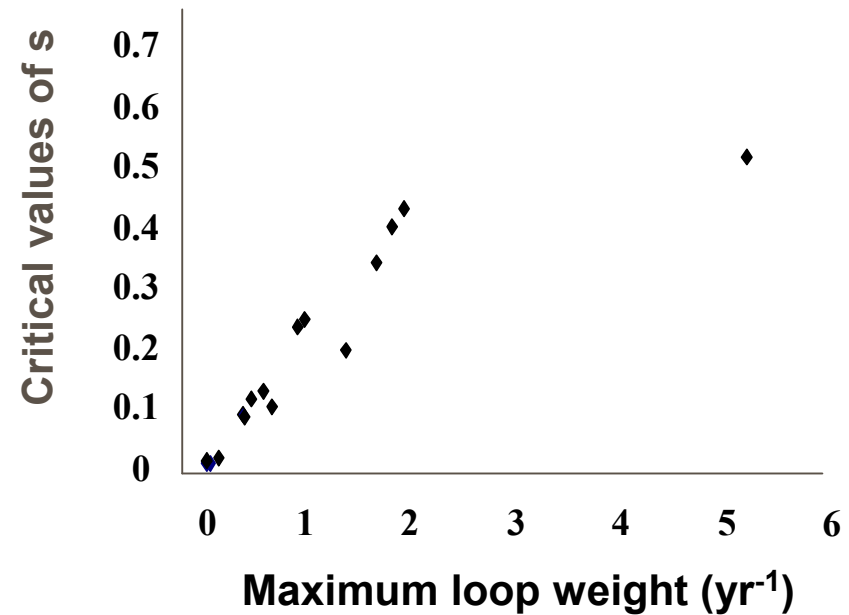
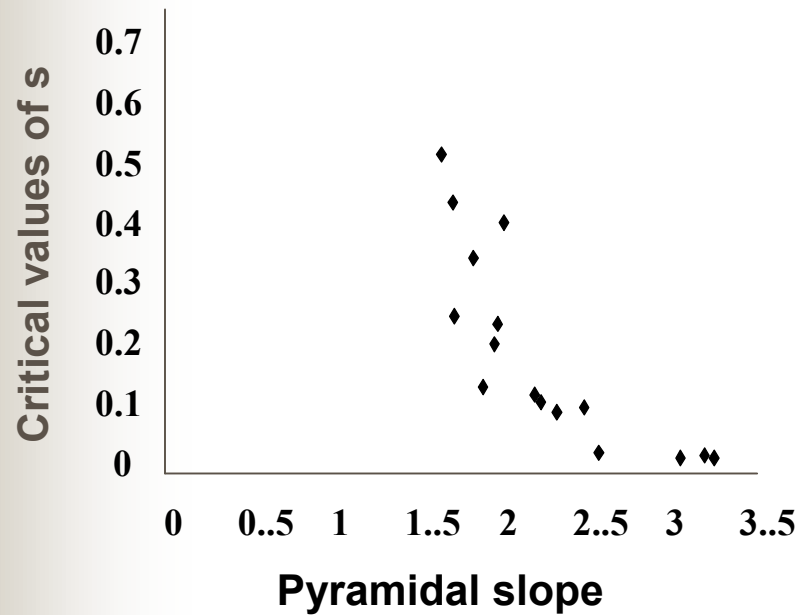
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Biomass pyramids and loop weight

$$\alpha_{ij} = -F_{ij} / B_j$$

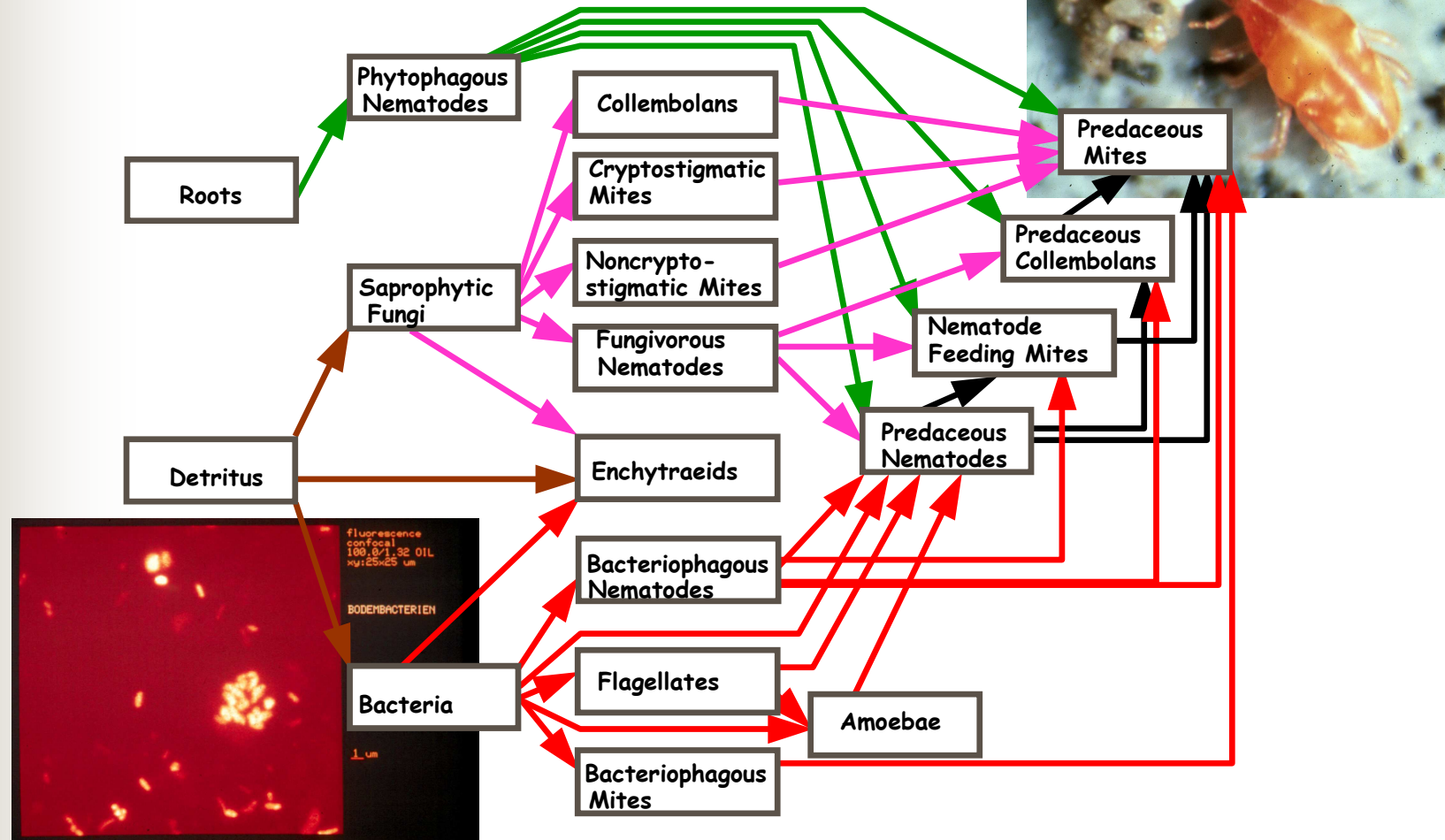


Pyramidal slope, loop weight and stability



[Neutel *et al.* Nature 2007]

Lovinkhoeve food web



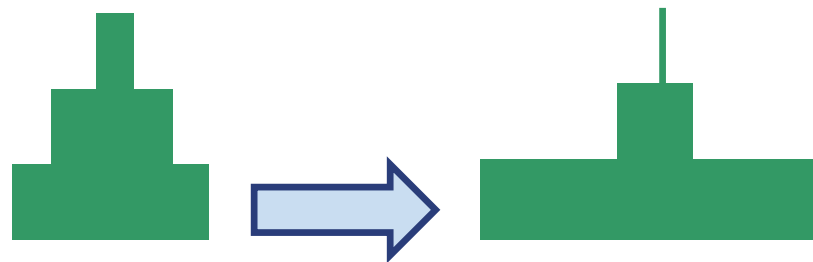
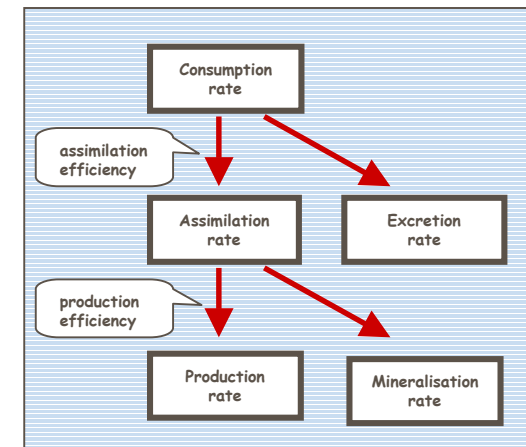
Body-size and trophic biomass pyramids

- Biomass distributions are the outcome of:

- d : natural death rate
- a : assimilation efficiency
- p : production efficiency
- w : preference

- d , a , p and w are functions of body-size:

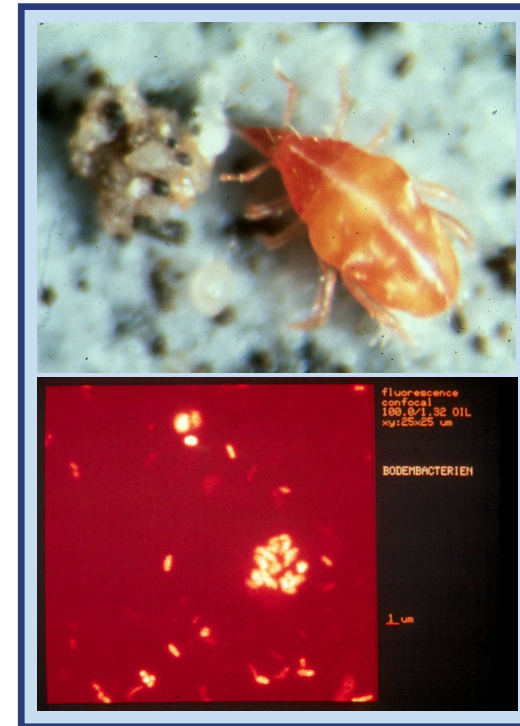
- Trends in body-size over trophic levels make that:



[Neutel *in prep*]

Loop weight links body-size to food web stability

- Body-size related physiological traits lead to
 - Strong biomass pyramids in trophic loops
 - a low maximum loop weight,
 - and a high food web stability



[Neutel *in prep*]



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 Dynamics in species composition

Island Schiermonnikoog

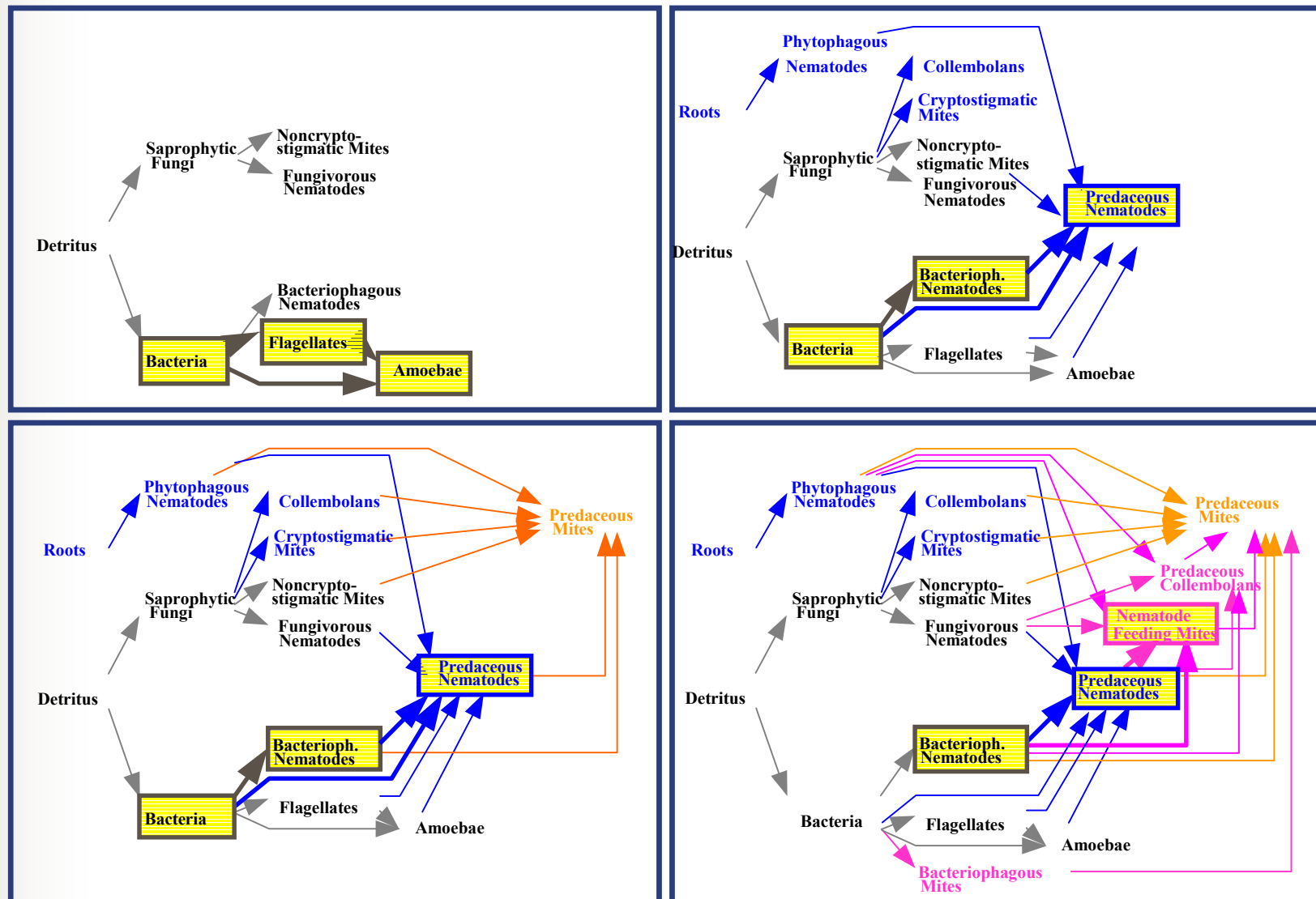


Hulshorsterzand



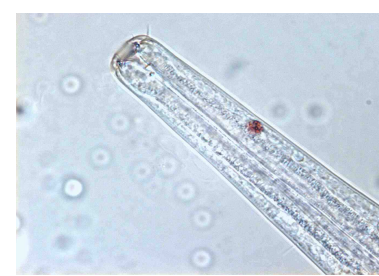
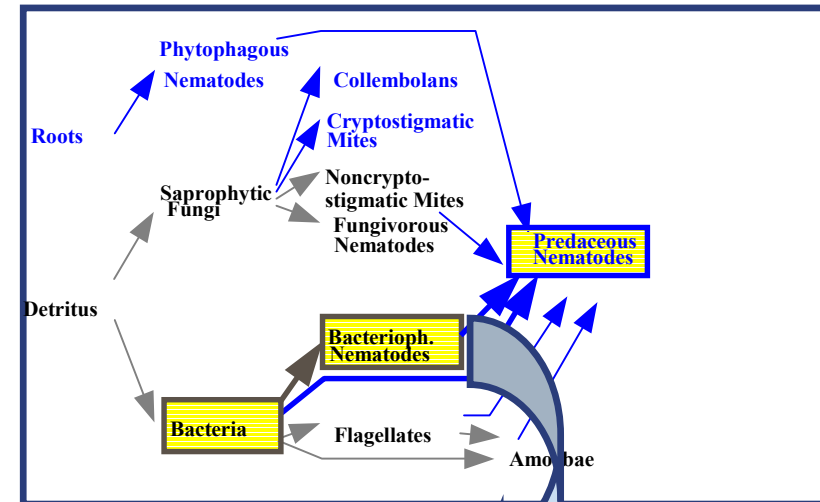
[Neutel *et al.* Nature 2007]

Critical loops during succession stage 1-4



Dynamic food webs

Stage 2

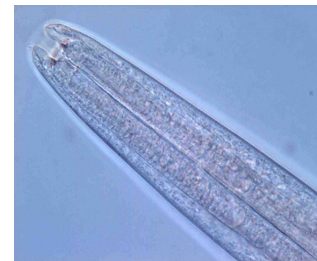
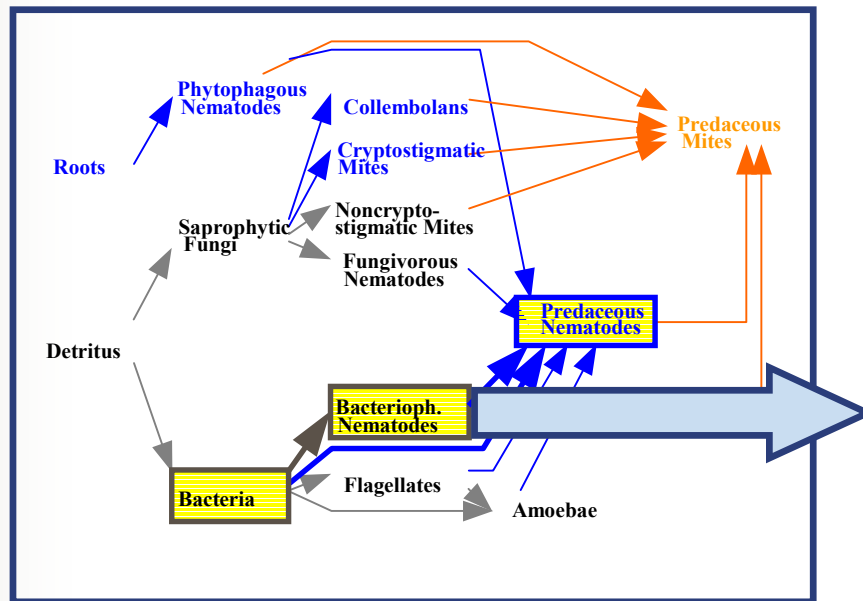


Acroboloides apiculatus

Monhystrera

Dynamic food webs

Stage 3



Panagrolaimus paetzoldi



Plectus armatus

Should interaction strengths be at the individual or species level? ...or at the functional group level?

■ Energetic structures

- govern stability
- provide niches for dynamic species compositions

