# Stabilizing the unstable: The importance of ecological interactions in the process of recovery from mass extinctions

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The Field Museum

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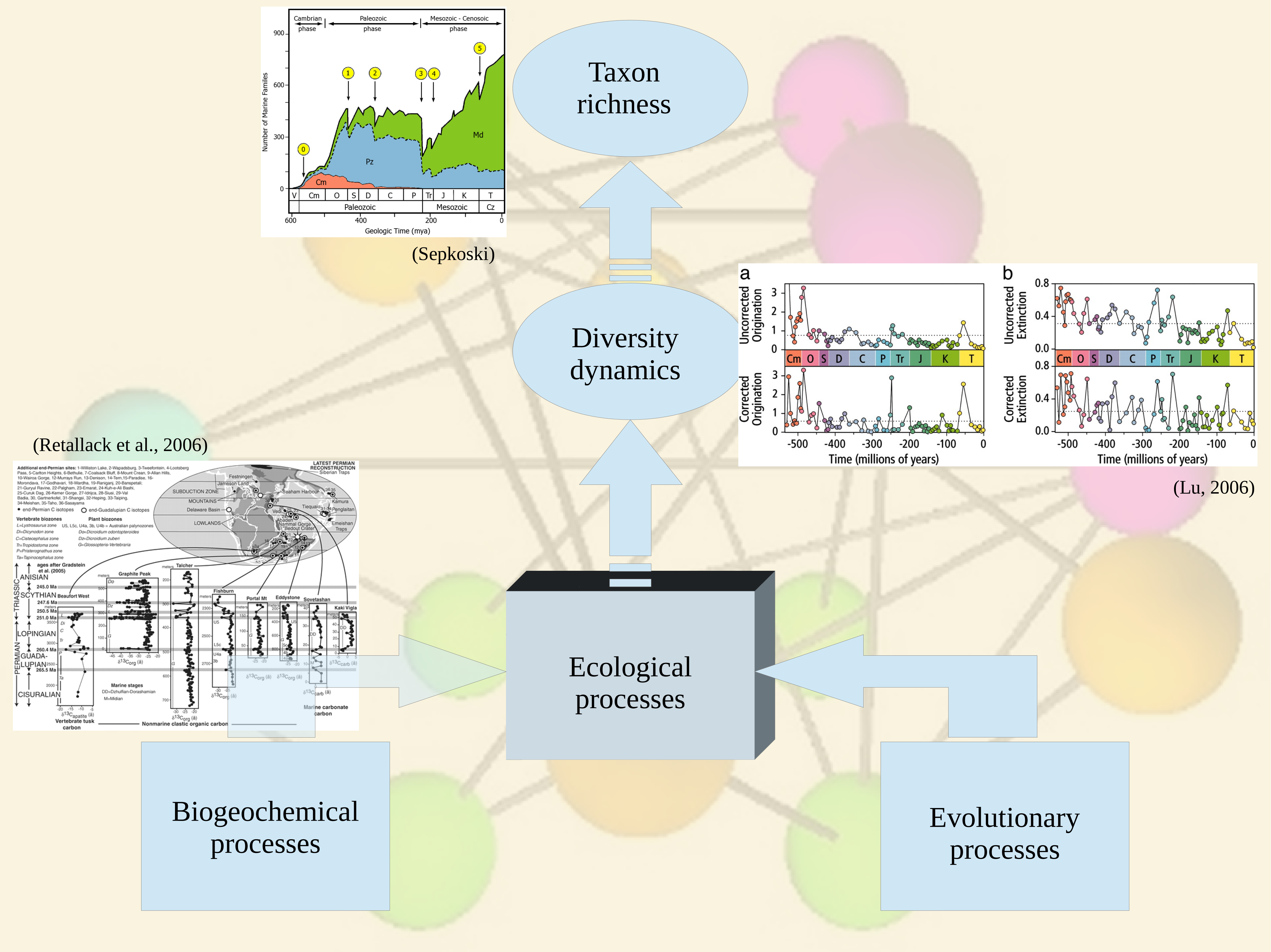
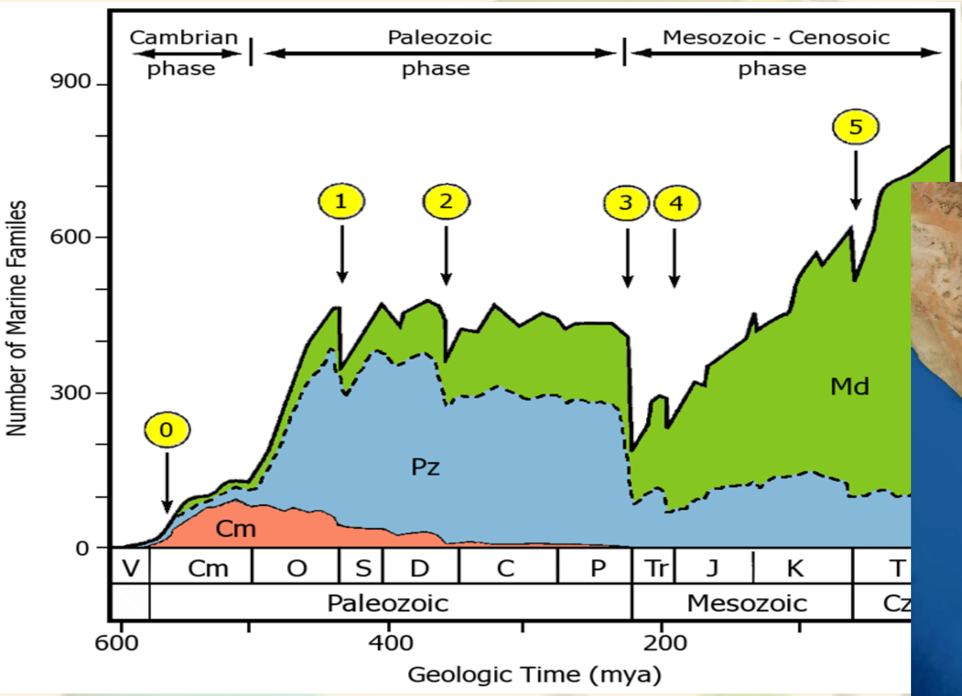
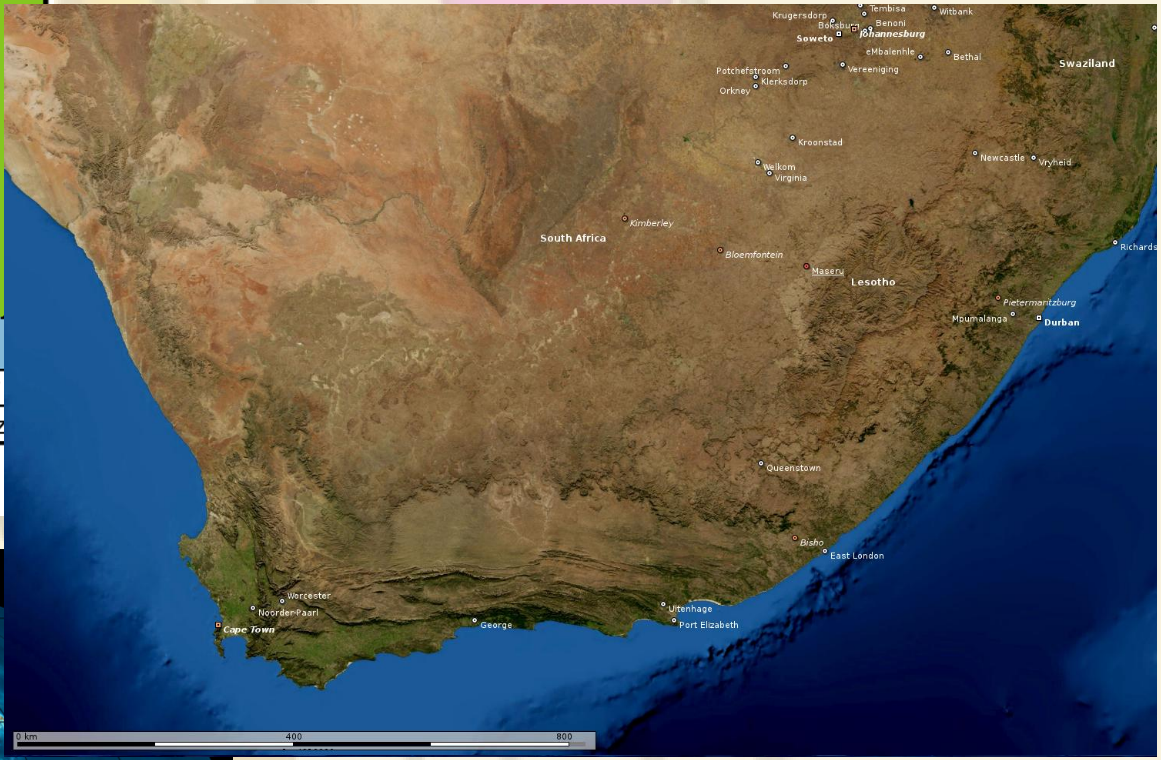
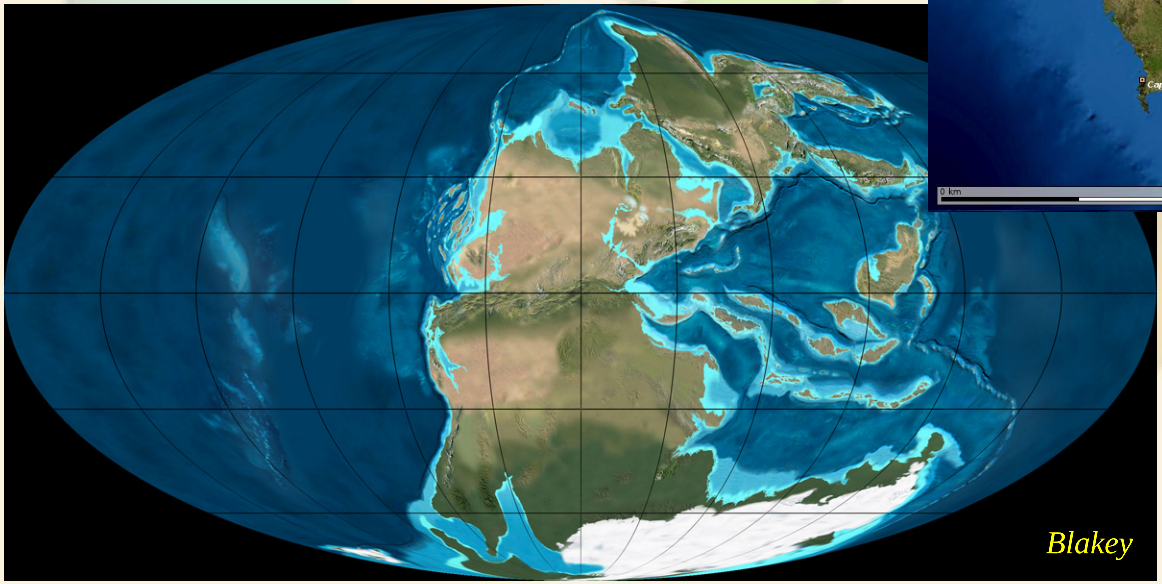


Taxon richness
(Sepkoski)
Diversity dynamics
(Lu, 2006)
(Retallack et al., 2006)
Ecological processes
Biogeochemical processes
Evolutionary processes
Number of Marine Families
Geologic Time (mya)
Cambrian phase
Paleozoic phase
Mesozoic - Cenosoic phase
Cm
Pz
Md
Paleozoic
Mesozoic
Cz
Uncorrected Origination
Corrected Origination
Uncorrected Extinction
Corrected Extinction
Time (millions of years)
Cm O S D C P Tr J K T

# End Permian extinction

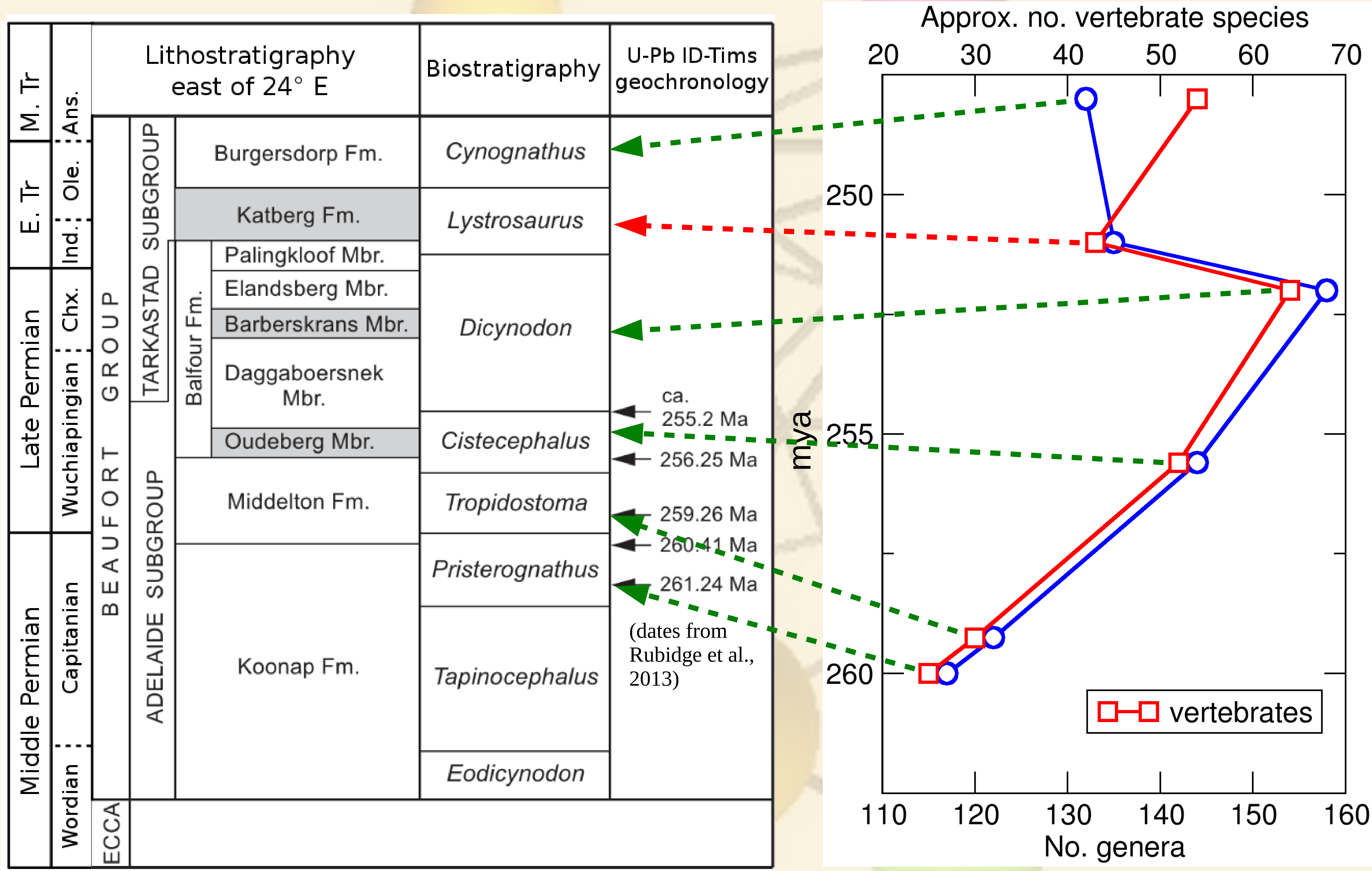


# Ecological processes

- Ecosystem structure
  - Taxon richness
  - Food web topology
  - Trophic level structure
- Community dynamics
  - Stability of food chains and energy pathways



Lithostratigraphy east of 24° E
Biostratigraphy
U-Pb ID-Tims geochronology
M. Tr
E. Tr
Late Permian
Middle Permian
Ans.
Ole.
Ind.
Chx.
Wuchiapingian
Capitanian
Wordian
BEAUFORT GROUP
ECCA
TARKASTAD SUBGROUP
ADELAIDE SUBGROUP
Balfour Fm.
Burgersdorp Fm.
Katberg Fm.
Palingkloof Mbr.
Elandsberg Mbr.
Barberskrans Mbr.
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Cynognathus
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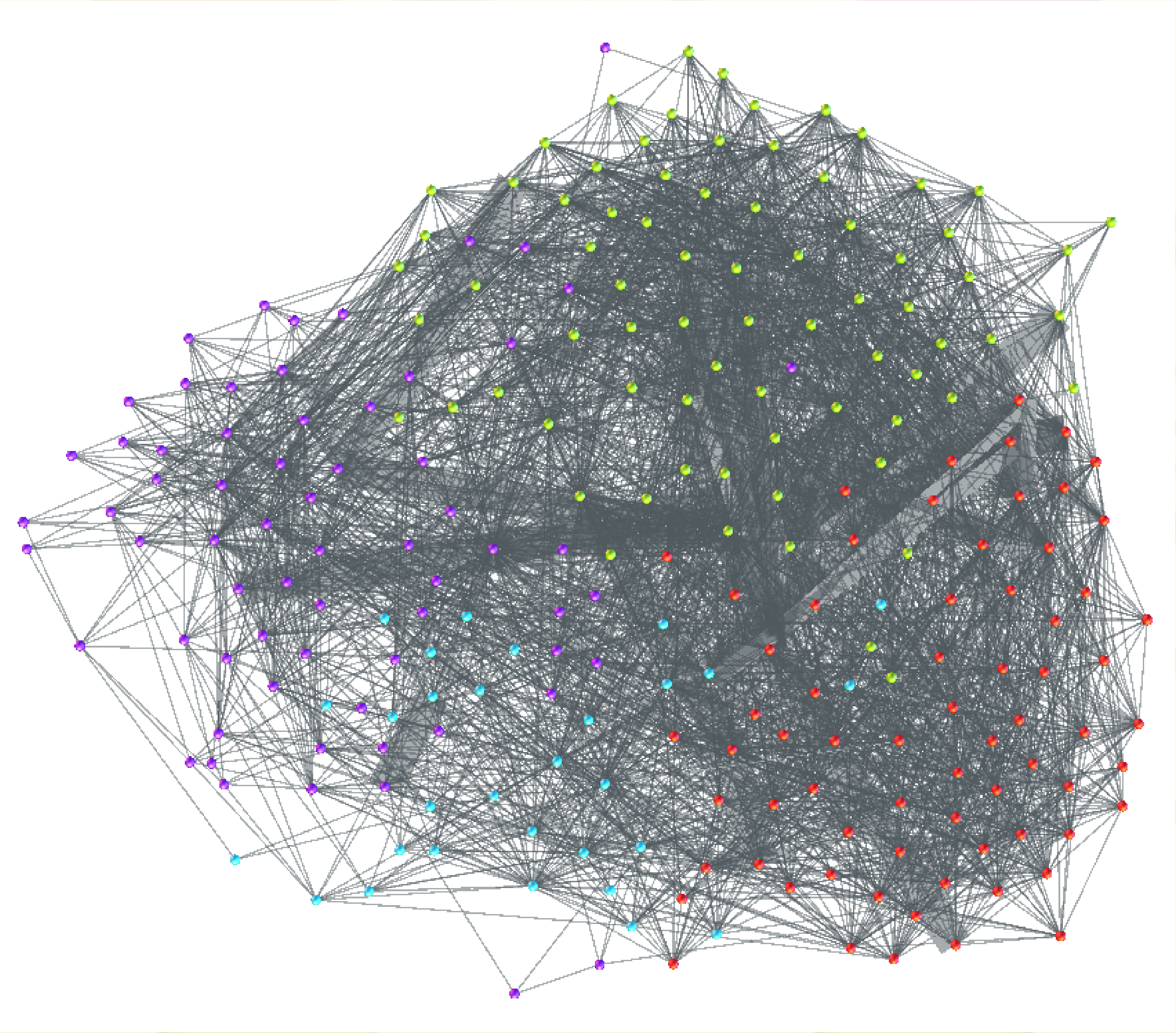
Cistecephalus
Tropidostoma
Pristerognathus
Tapinocephalus
Eodicynodon
ca. 255.2 Ma
256.25 Ma
259.26 Ma
260.41 Ma
261.24 Ma
(dates from Rubidge et al., 2013)
Approx. no. vertebrate species
20
30
40
50
60
70
250
255
260
mya
vertebrates
110
120
130
140
150
160
No. genera

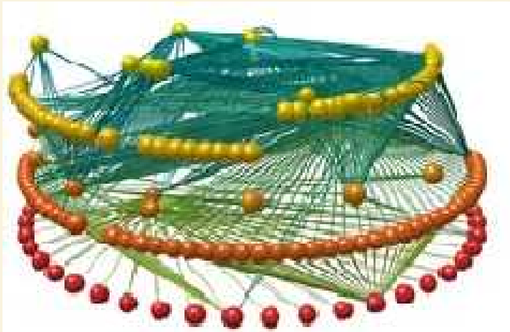
# Paleoecological process ← food webs

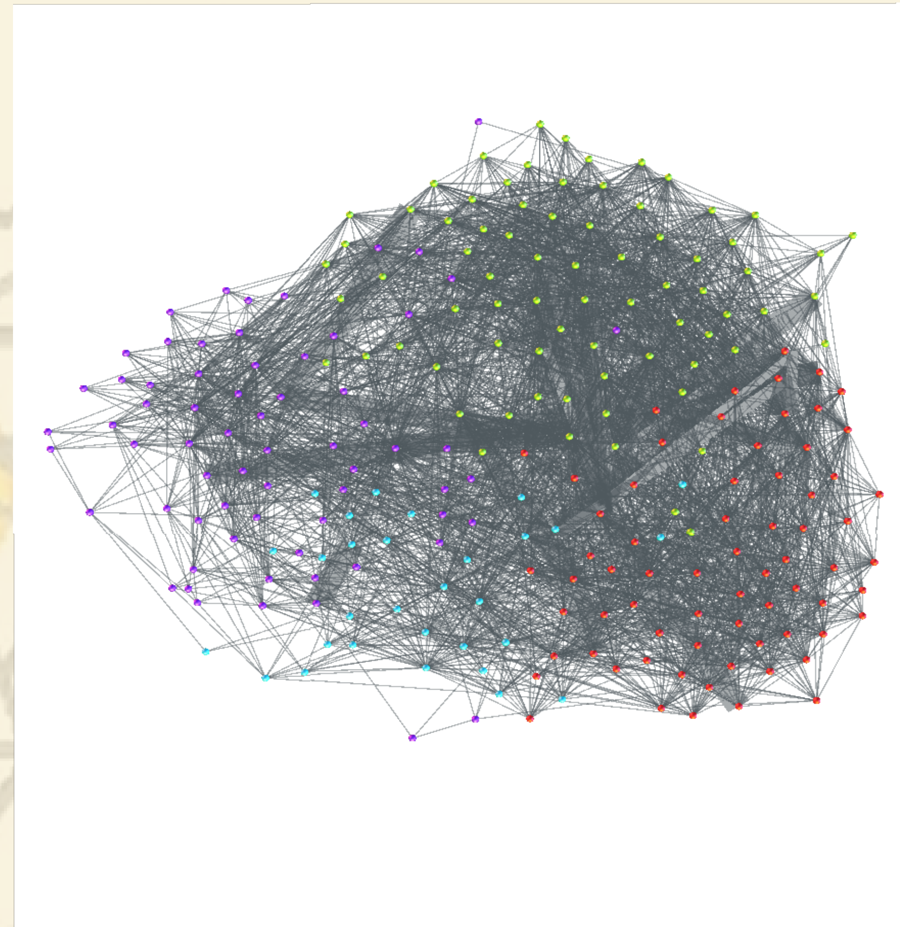
- Major conduits of energy through community.
- Trophic habits can be reconstructed for many fossil species.
- Trophic interactions can be
  - Observed
  - inferred

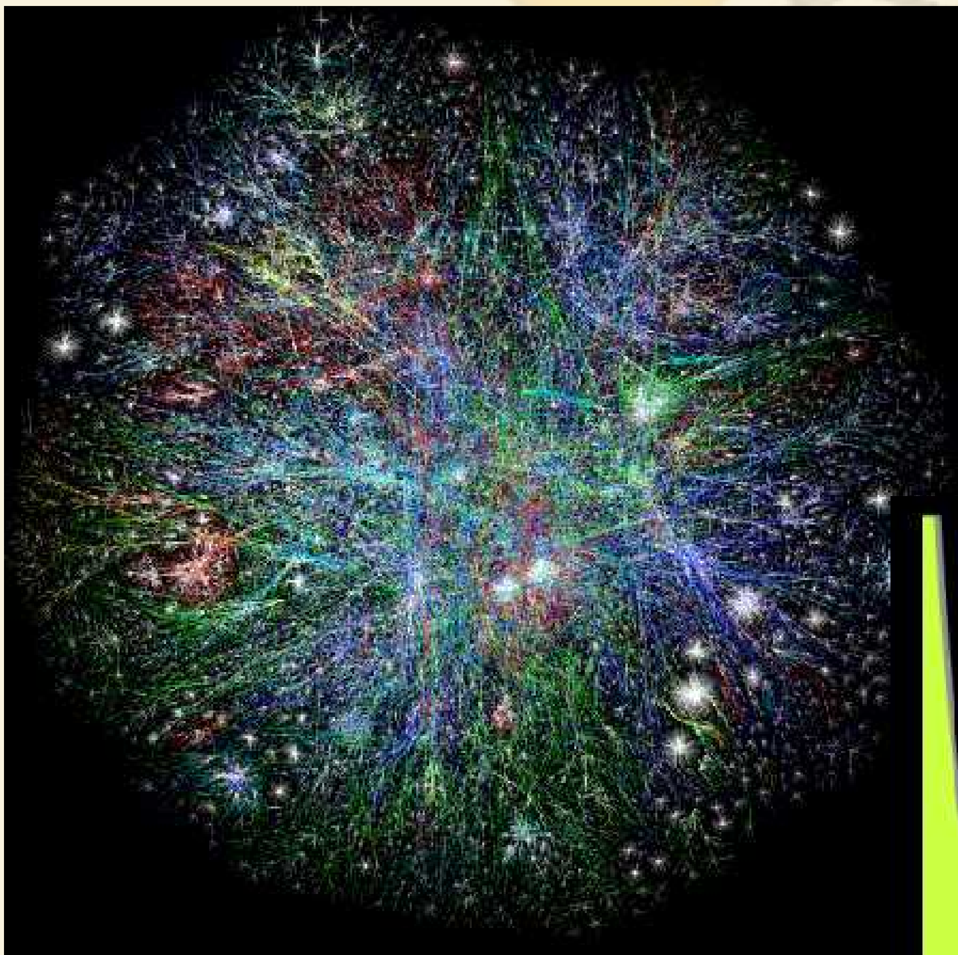
# Modern Cuban coral reef food web

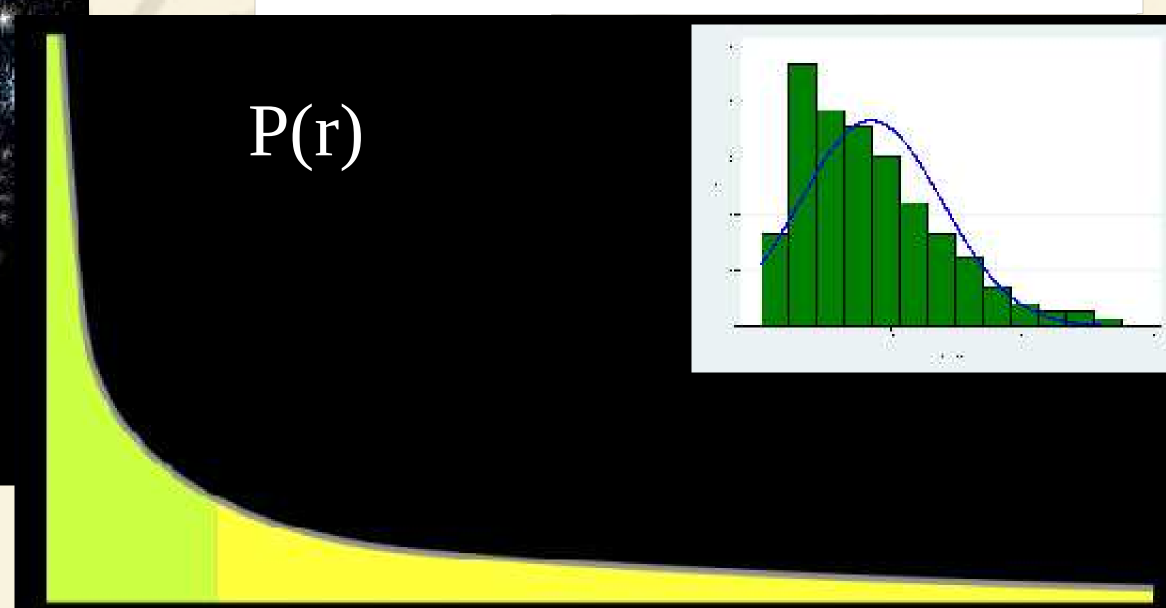


(Roopnarine and Hertog, 2012)

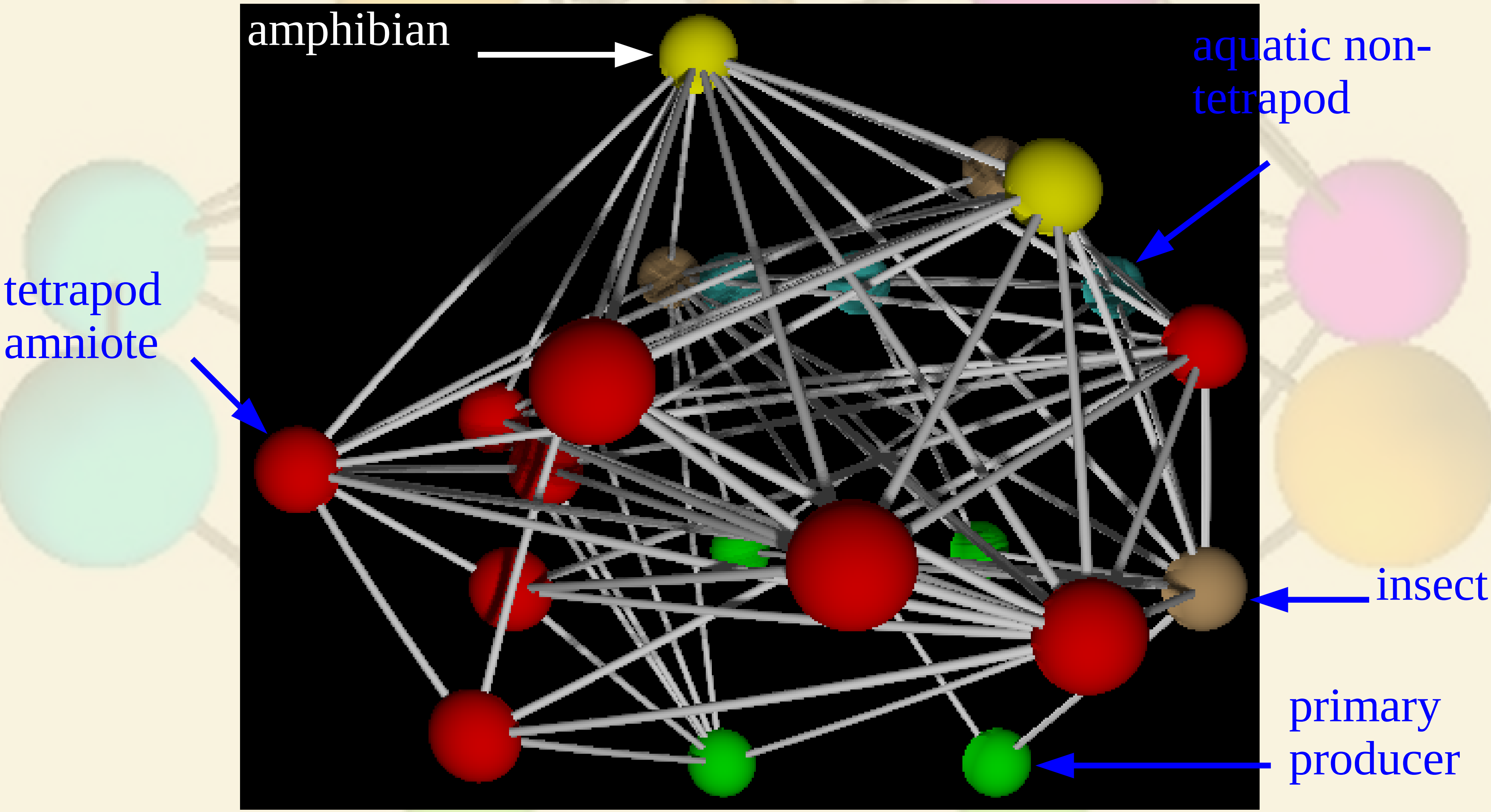




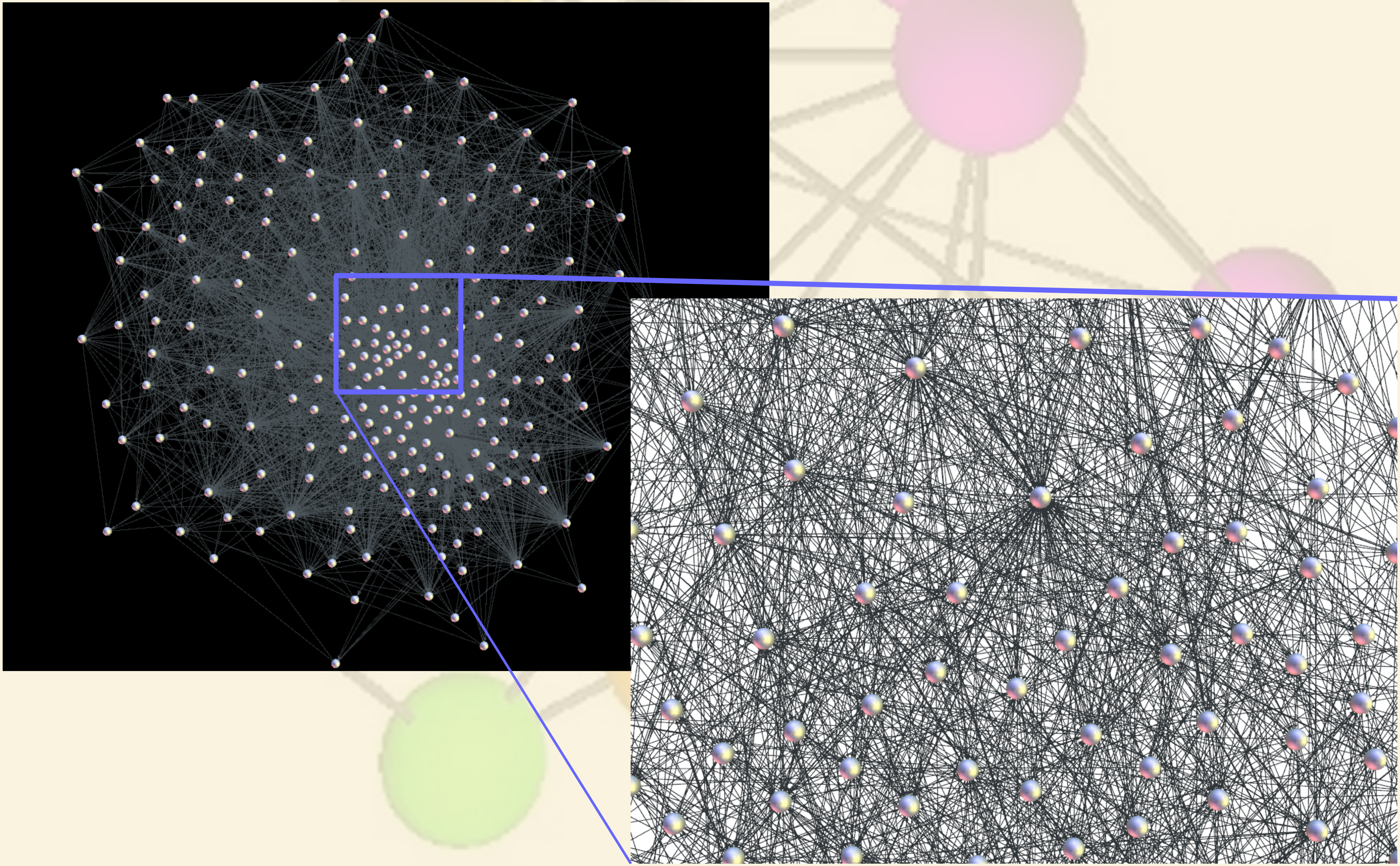



P(r)

# Functional food web

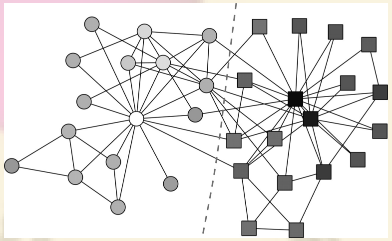


# Late Permian, Karoo Basin

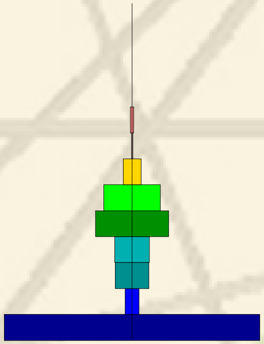


# Food web structure

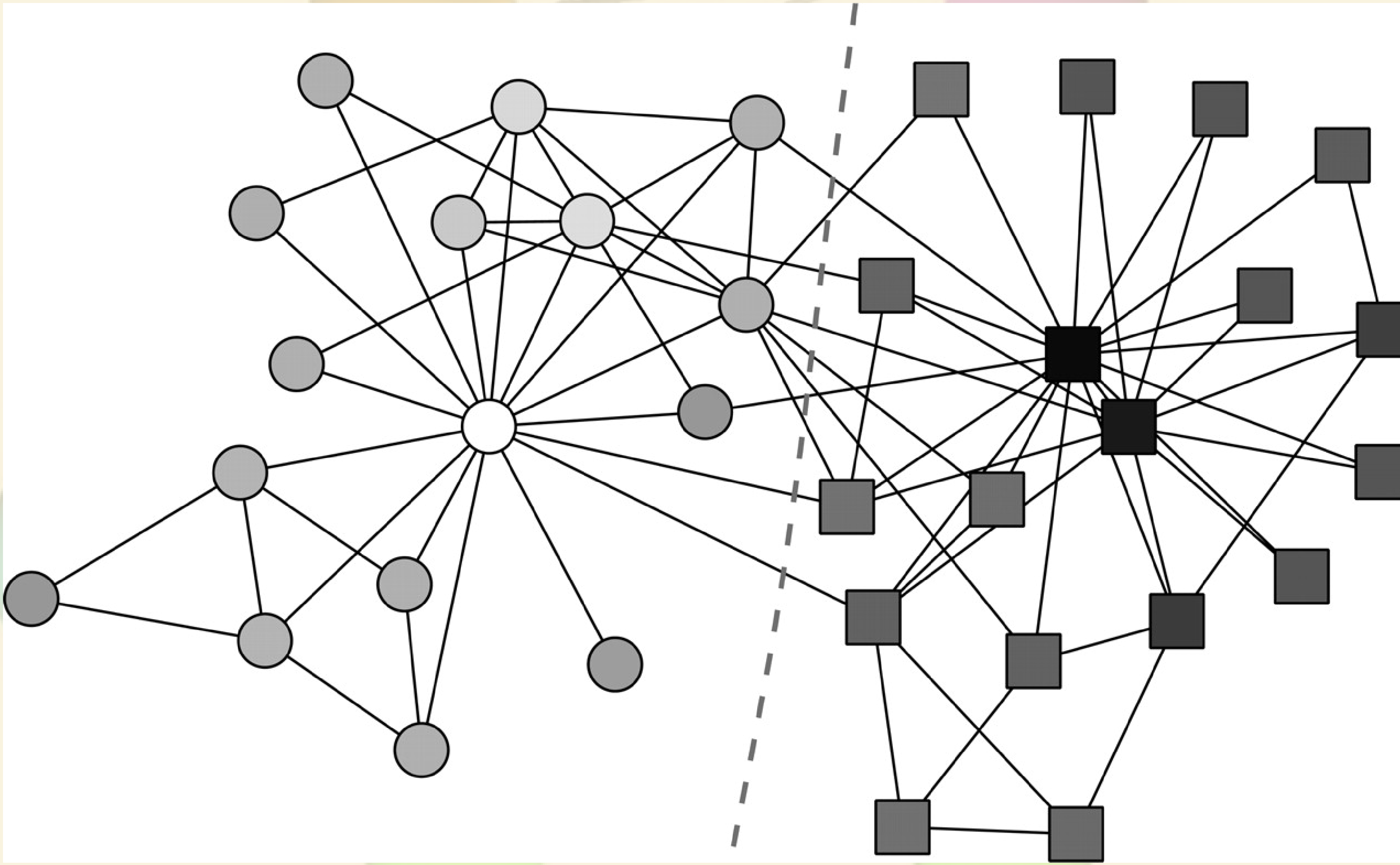
- Internal sub-structure
  - Modularity and sub-communities



- Hierarchical structure
  - Trophic levels

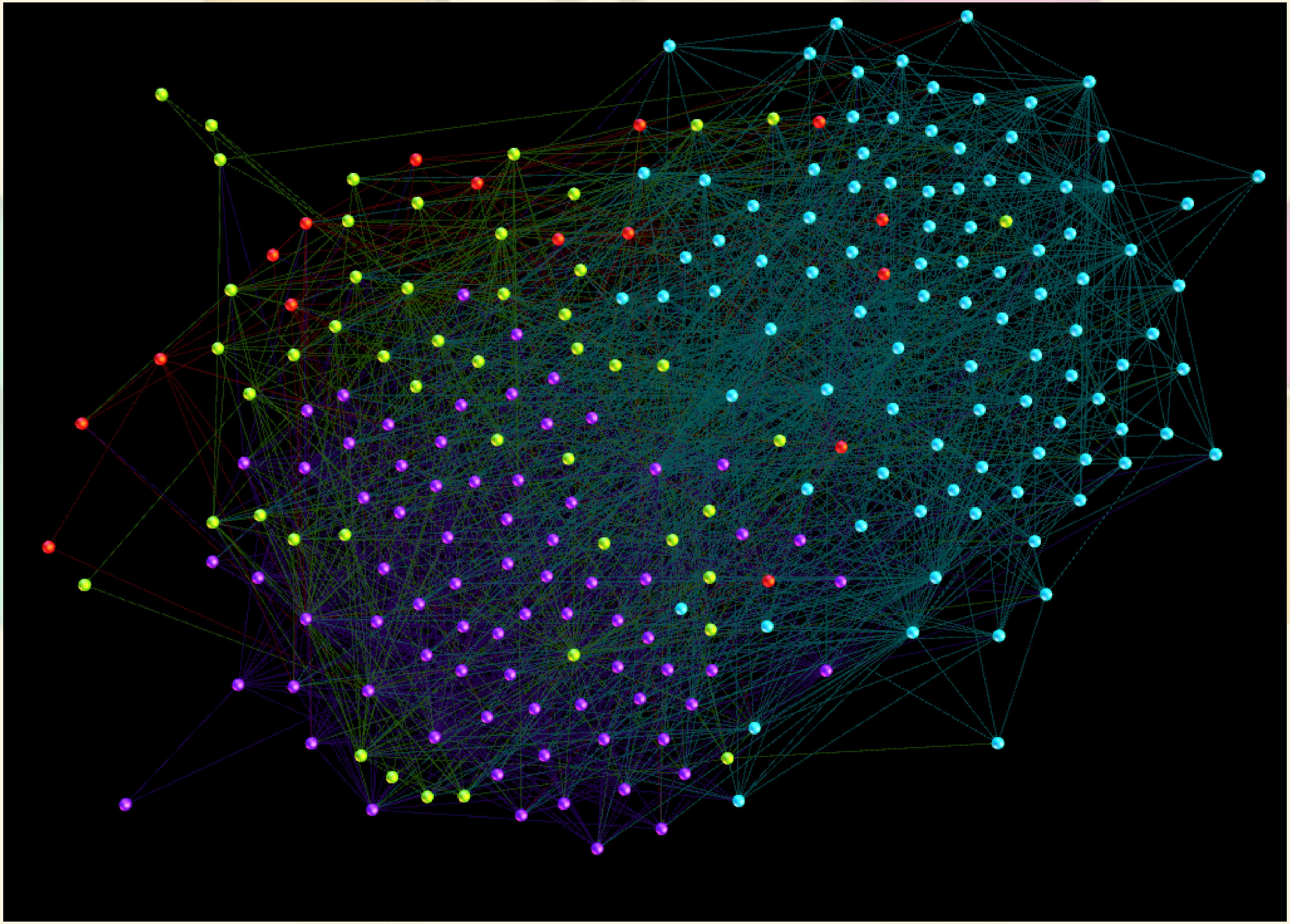


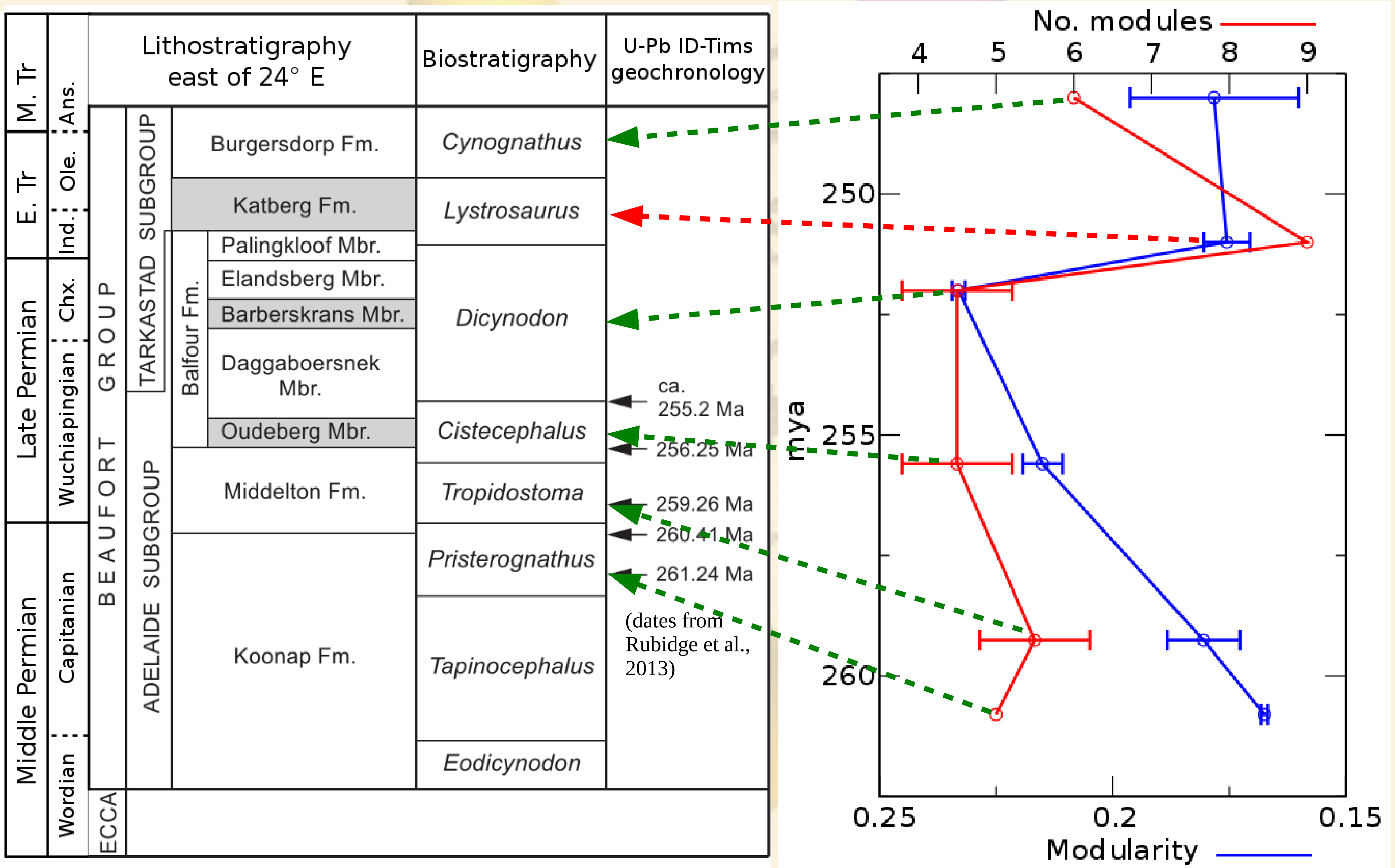
# Modularity



(Newman, 2006)

# Modularity; end Permian *Dicynodon* Assemblage Zone





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ca. 255.2 Ma
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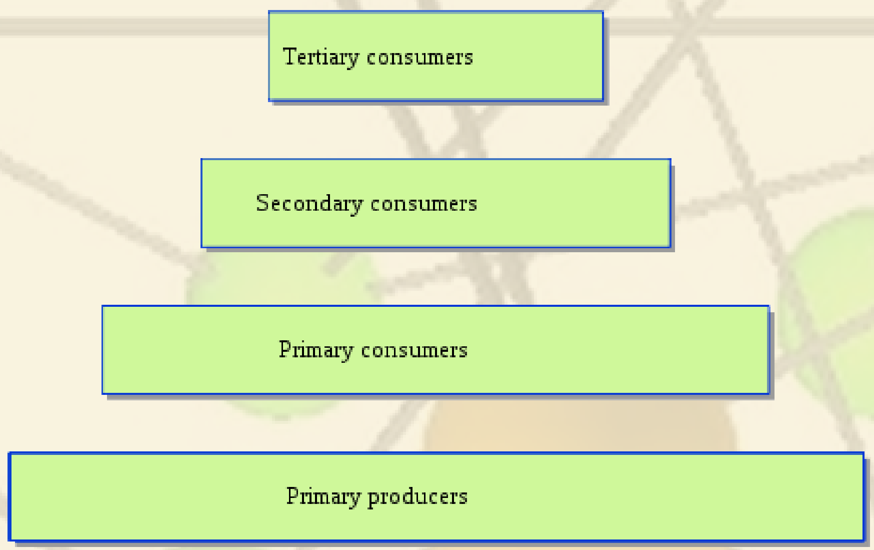
259.26 Ma
260.41 Ma
261.24 Ma
(dates from Rubidge et al., 2013)
No. modules
4
5
6
7
8
9
mya
250
255
260
0.25
0.2
0.15
Modularity

# Trophic level

- No. of steps between producer and consumer
  - Energy transfer efficiency, biomass



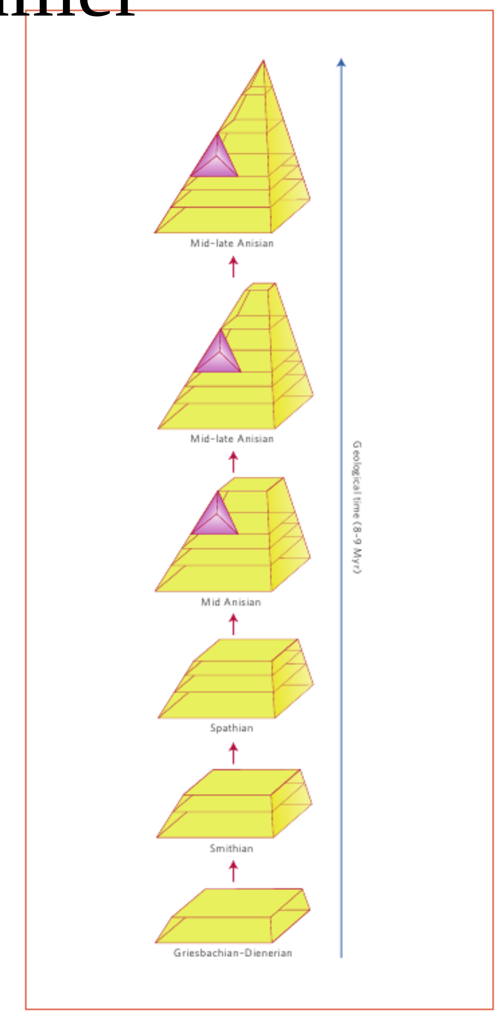
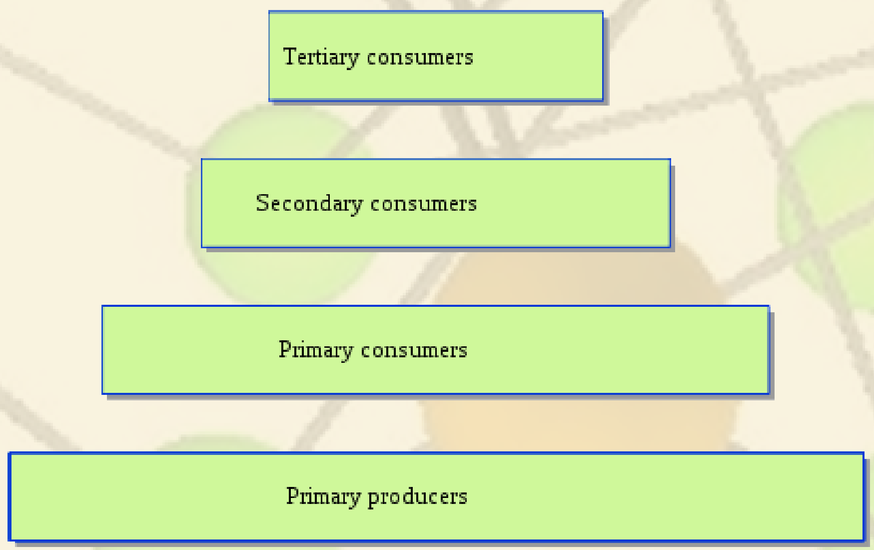




**Figure 4 | Stepwise rebuilding pattern of marine ecosystems from low to top trophic levels in the aftermath of the EPME.** Immediate post-extinction ecosystems in the Griesbachian–Dienerian show only the lowest trophic level. Further levels are added from Smithian to Anisian, with the topmost level, of reptiles and large fishes that fed on other vertebrates, fully achieved only by the mid-late Anisian, 8–9 Myr after the mass extinction event.

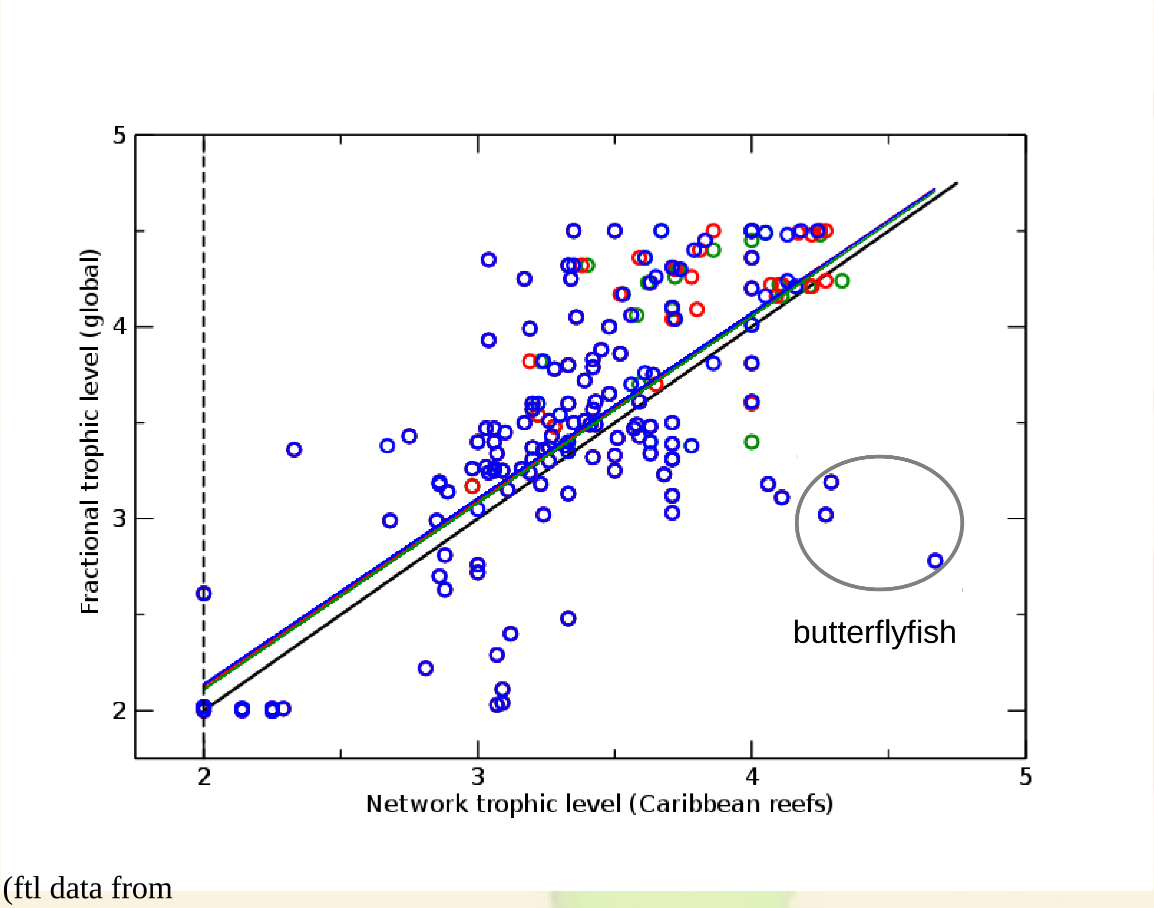
(Chen and Benton, 2012)

# Trophic pyramid collapse? Unlikely

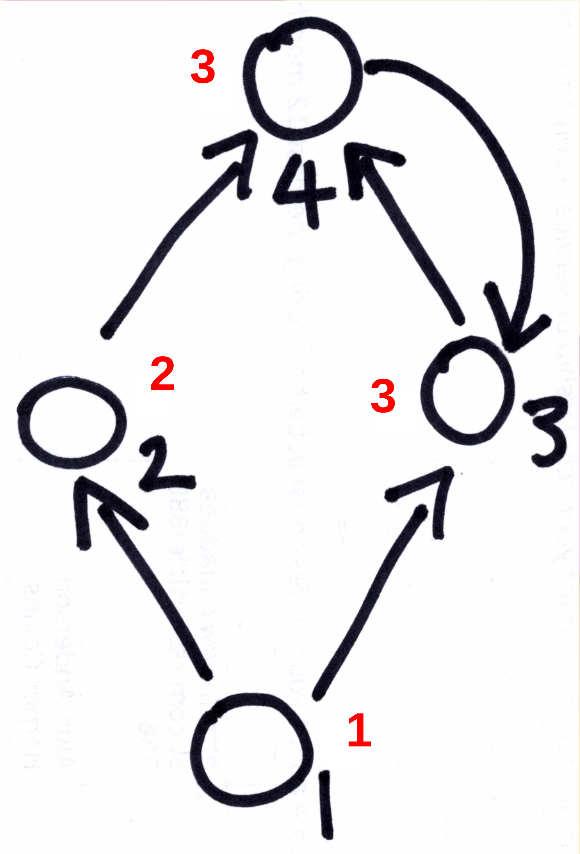
- Massive attenuation of energy flow through ecosystem
- Nutrient re-mobilization requires re-evolution of energy pathways. Time?

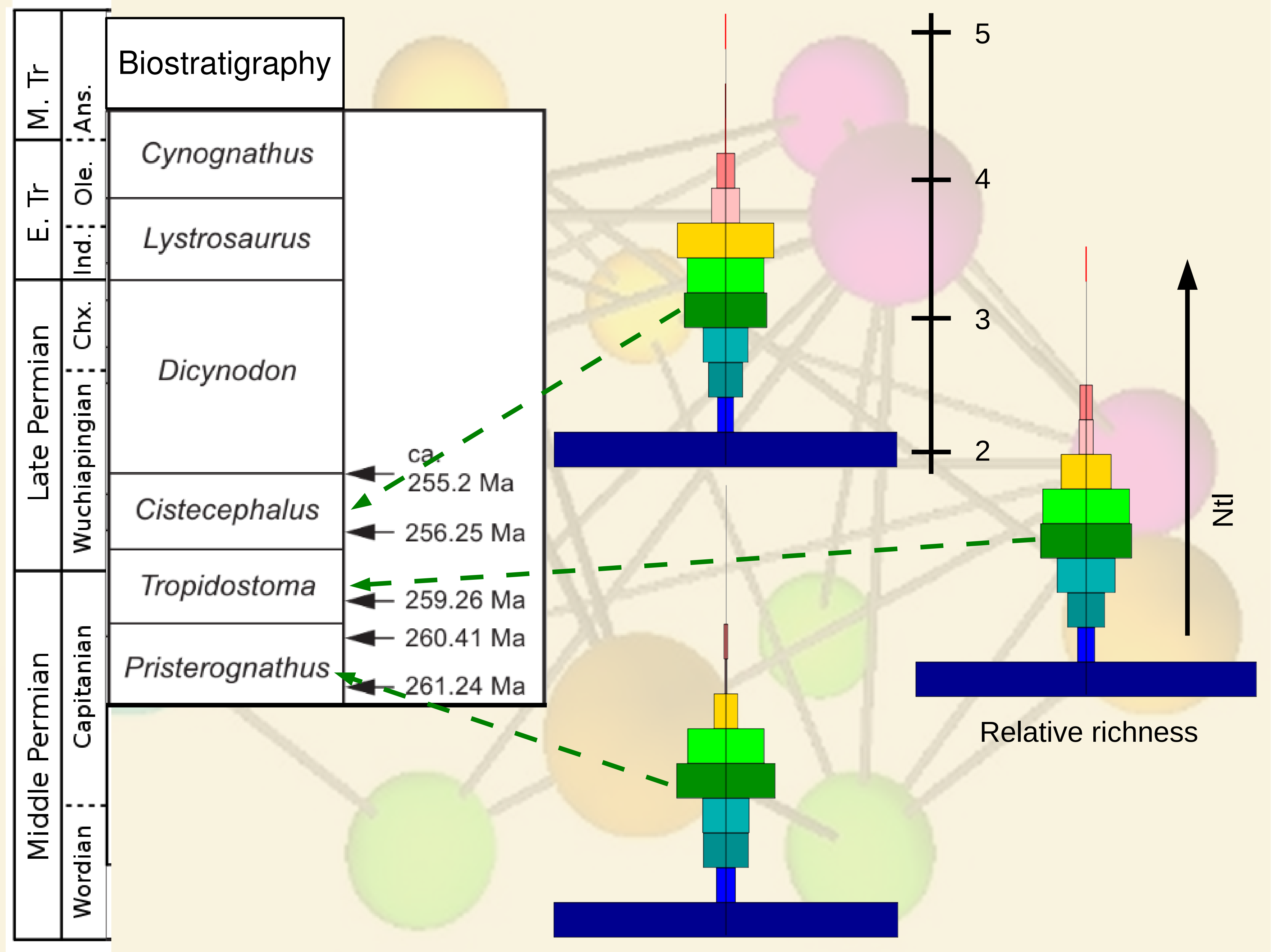


# Network trophic level




(ftl data from
Romanuk et al., 2011)





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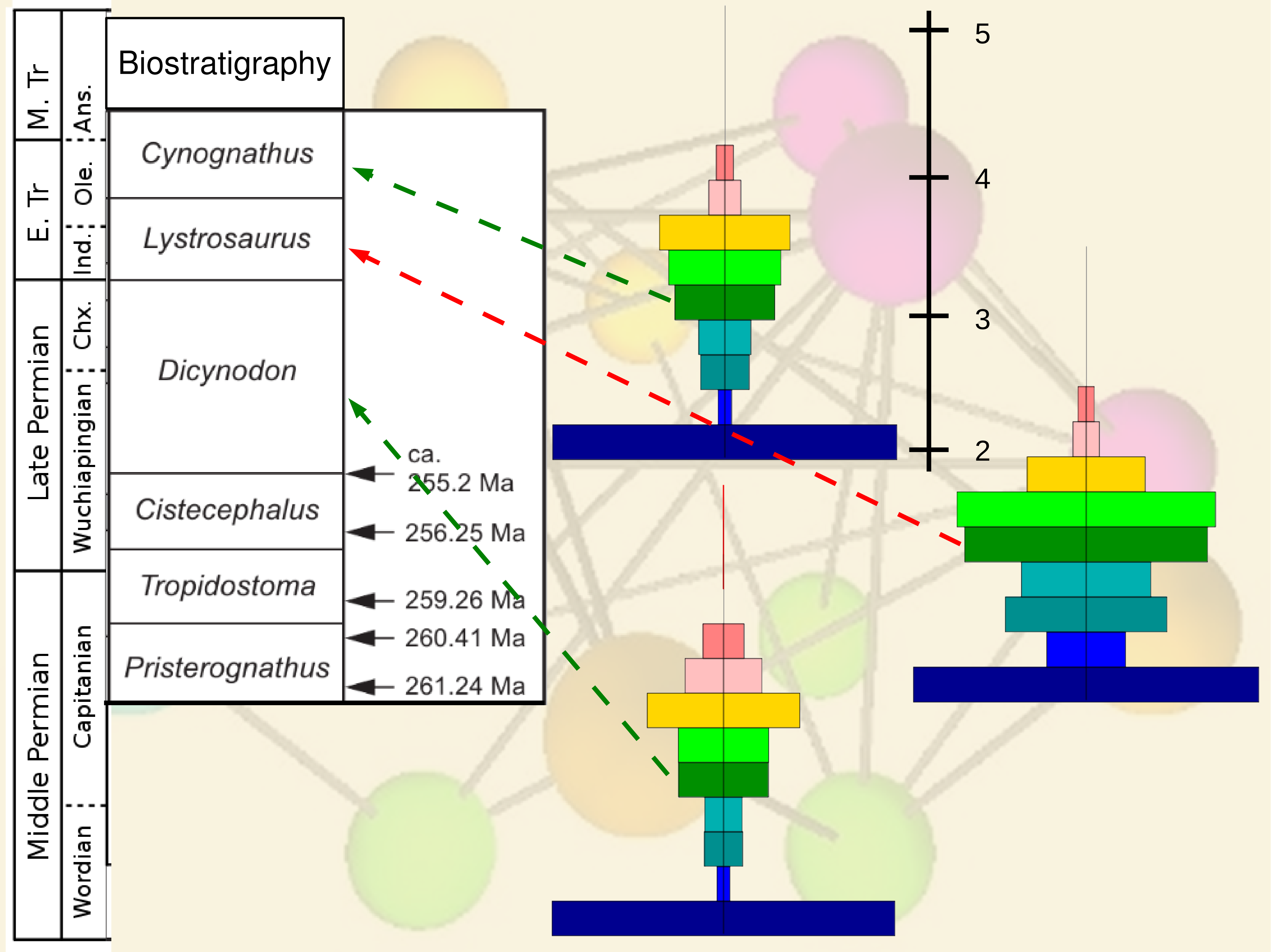
Cynognathus
Lystrosaurus
Dicynodon
Cistecephalus
Tropidostoma
Pristerognathus
ca. 255.2 Ma
256.25 Ma
259.26 Ma
260.41 Ma
261.24 Ma
5
4
3
2
NtI
Relative richness



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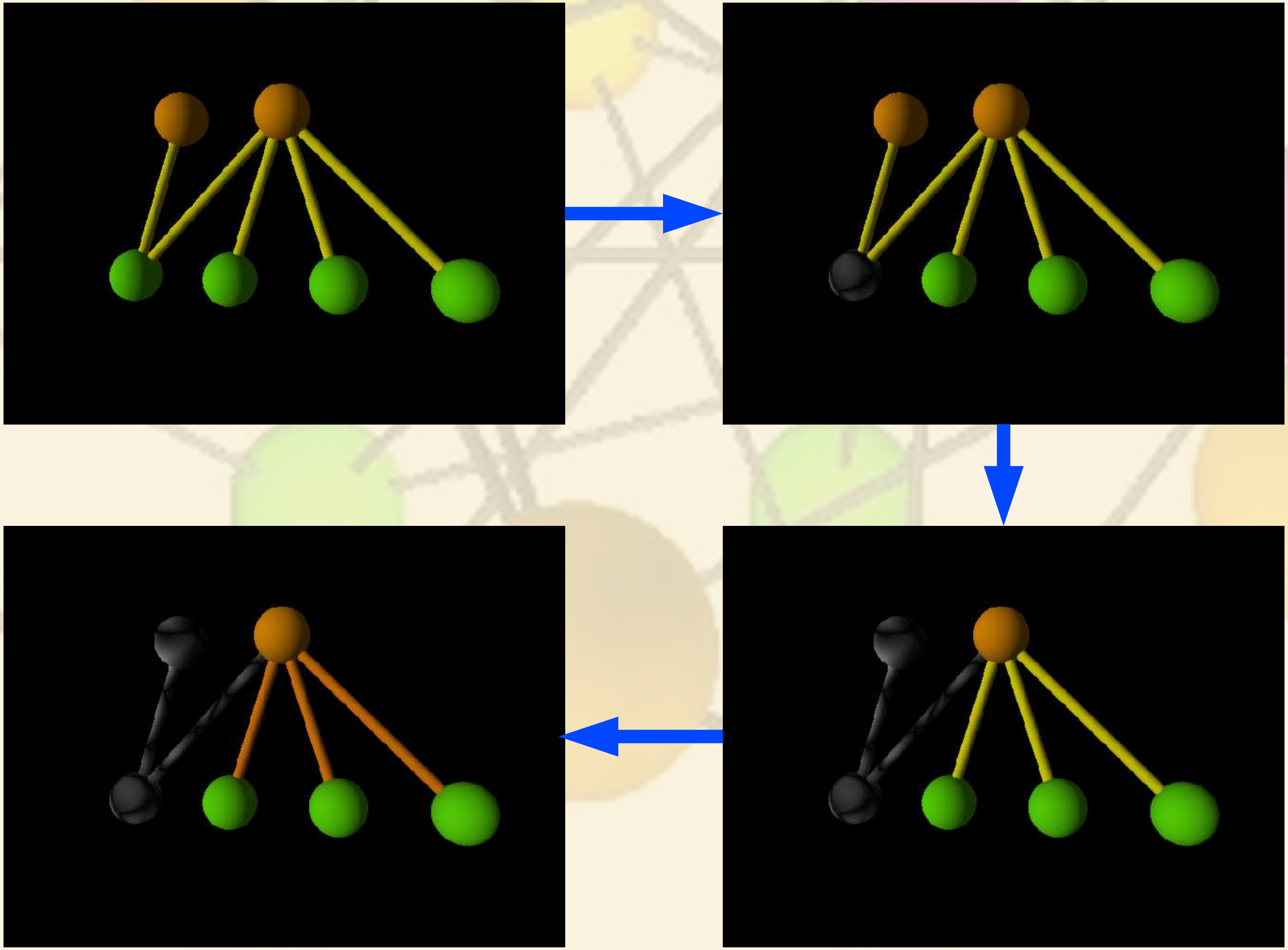
5
4
3
2

# Community dynamics - the CEG model

- Model propagation of perturbation through food web



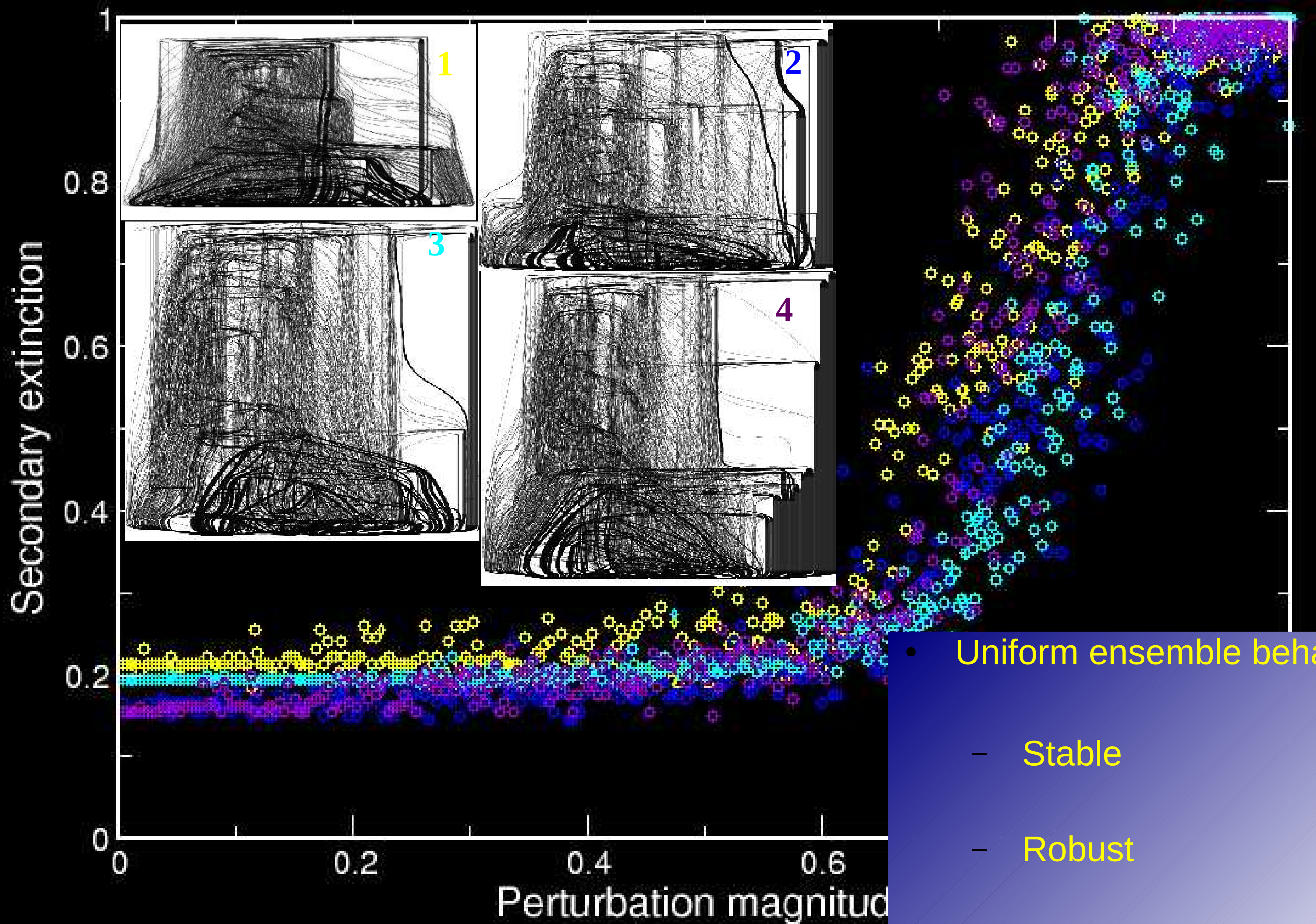
# CEG equation

*species* *prey* *predator*

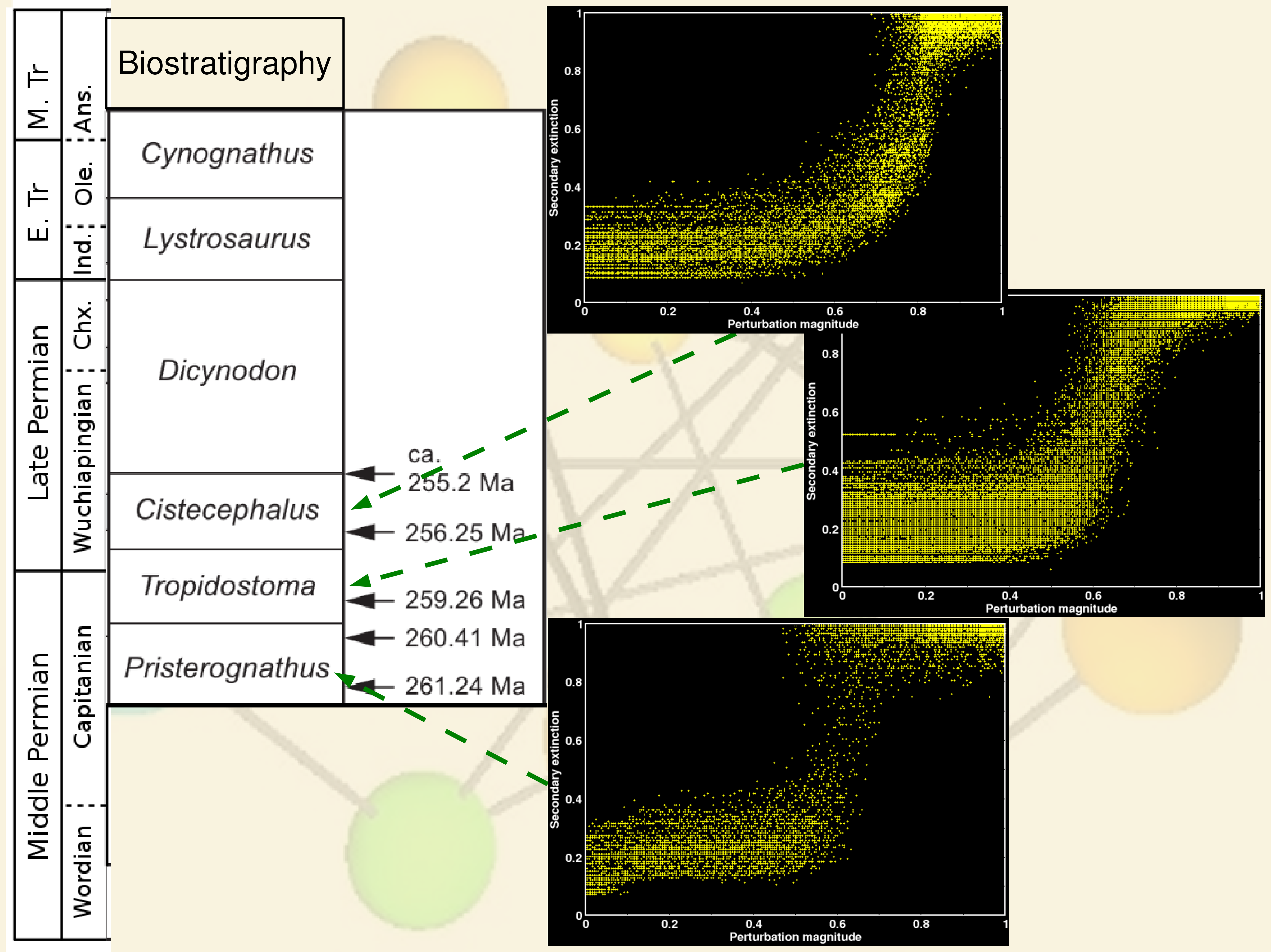
$$\frac{dX_i}{dt}=\sum_{j=1}^{S}\left(a_{ij}\frac{1}{r_X}Y_j\right)-\sum_{k=1}^{S}\left(a_{ki}\frac{1}{r_Z}Z_k\right)$$

*interaction strength*

- Energy in via prey minus energy out via predation
- Interaction strength=function of no. of prey
- No self-regulating term




- Uniform ensemble behaviour
  - Stable
  - Robust
  - Collapse threshold



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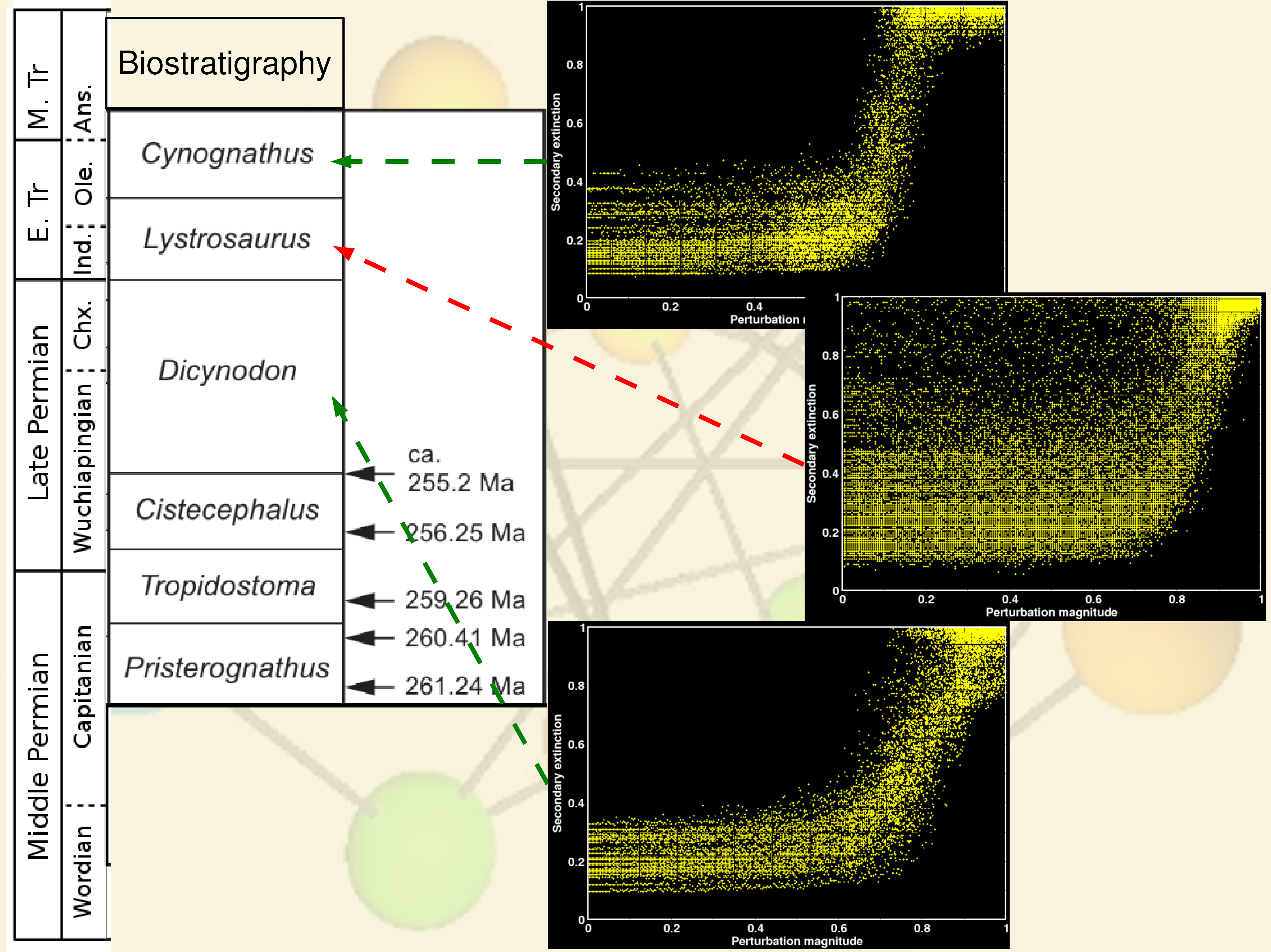
Secondary extinction
Perturbation magnitude



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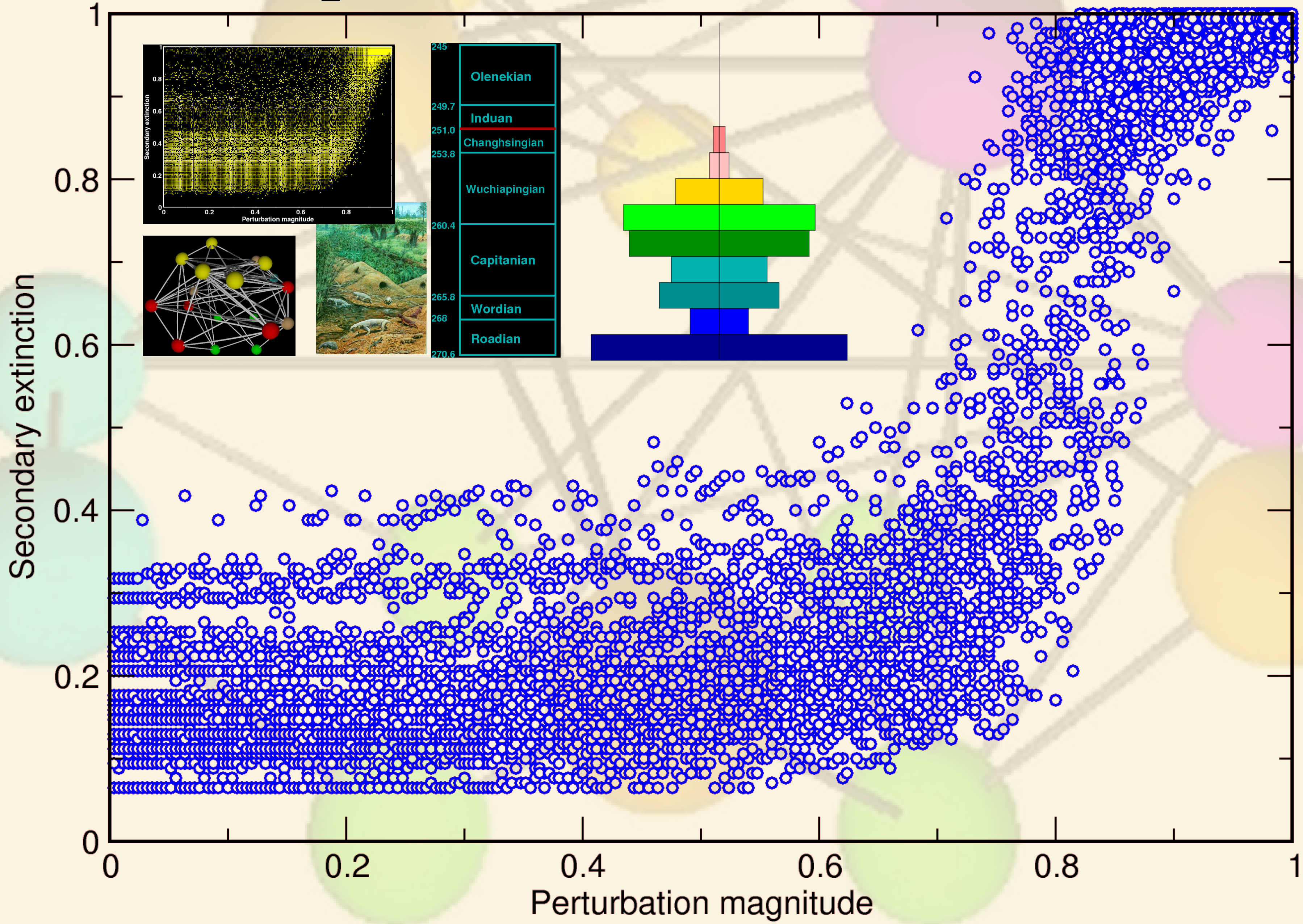
Secondary extinction
Perturbation magnitude

# Reduce p(interaction)
# Specialized carnivores



# Summary

- E. Triassic taxon richness in Karoo not indicative of ecological recovery.
- E. Triassic communities were poorly integrated.
- Trophic pyramid remained intact, but hierarchical structure was anomalous.
- Food webs were possibly energetically unstable.
  - Stability possible if mid-level consumers were highly specialized.
  - Increased rates of evolution, speciation and extinction.
- Acknowledgments: Hugo Bucher, Rachel Hertog, Jon Mitchell, NSF-ARC 0530828

National Science Foundation
WHERE DISCOVERIES BEGIN