Major Evolutionary Transitions and Cultural Evolution

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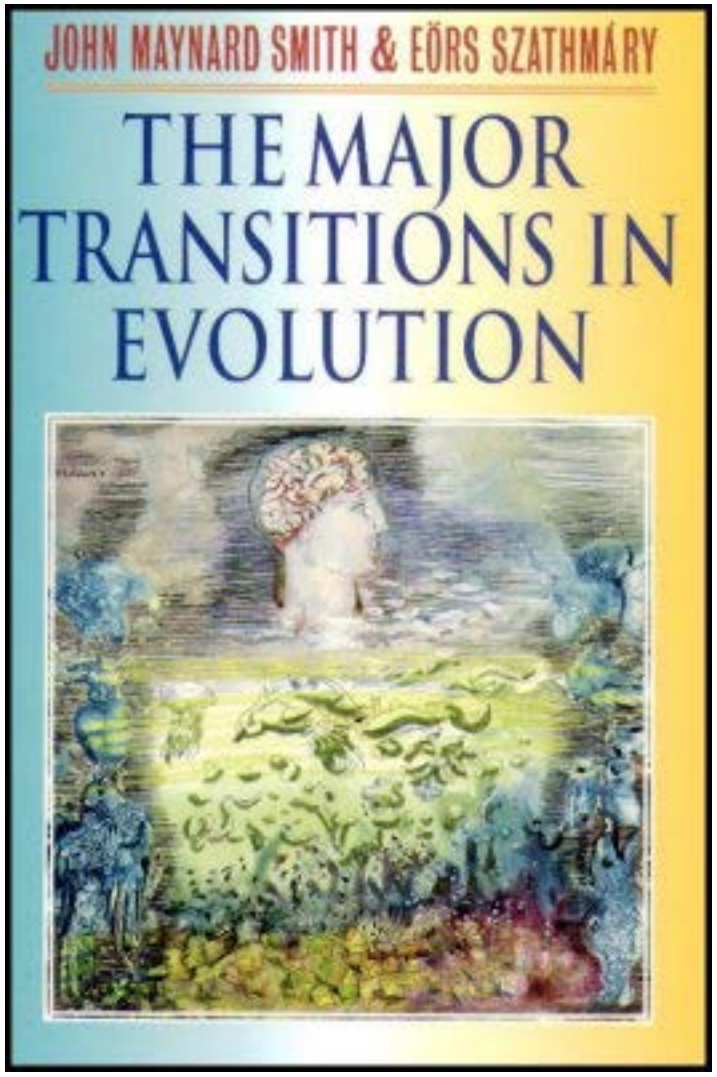
Outline

- Introduce Major Evolutionary Transitions
- Major Transitions in Individuality
- Nature of Individuals
- Alternative Approaches to Major Evolutionary Transitions
- Public Goods and Innovation
- Possible Implications for Cultural Evolution


JOHN MAYNARD SMITH & EÖRS SZATHMÁRY
THE MAJOR TRANSITIONS IN EVOLUTION

Major Evolutionary Transitions

Replicating molecules	→	Molecules in sacks
Independent replicators	→	Chromosomes
RNA	→	DNA + protein
Prokaryotes	→	Eukaryotes
Protist	→	Cellular differentiation
Solitary individuals	→	Colonies
Primate societies	→	Human Societies (language)

From Maynard Smith & Szahmary, 1995

Major Evolutionary Transitions: Information

- After each transition previously independent individuals can only reproduce as part of a larger whole.

- These transition involve a change in the division of labor

- Transitions involve a change in how genetic information is transmitted.

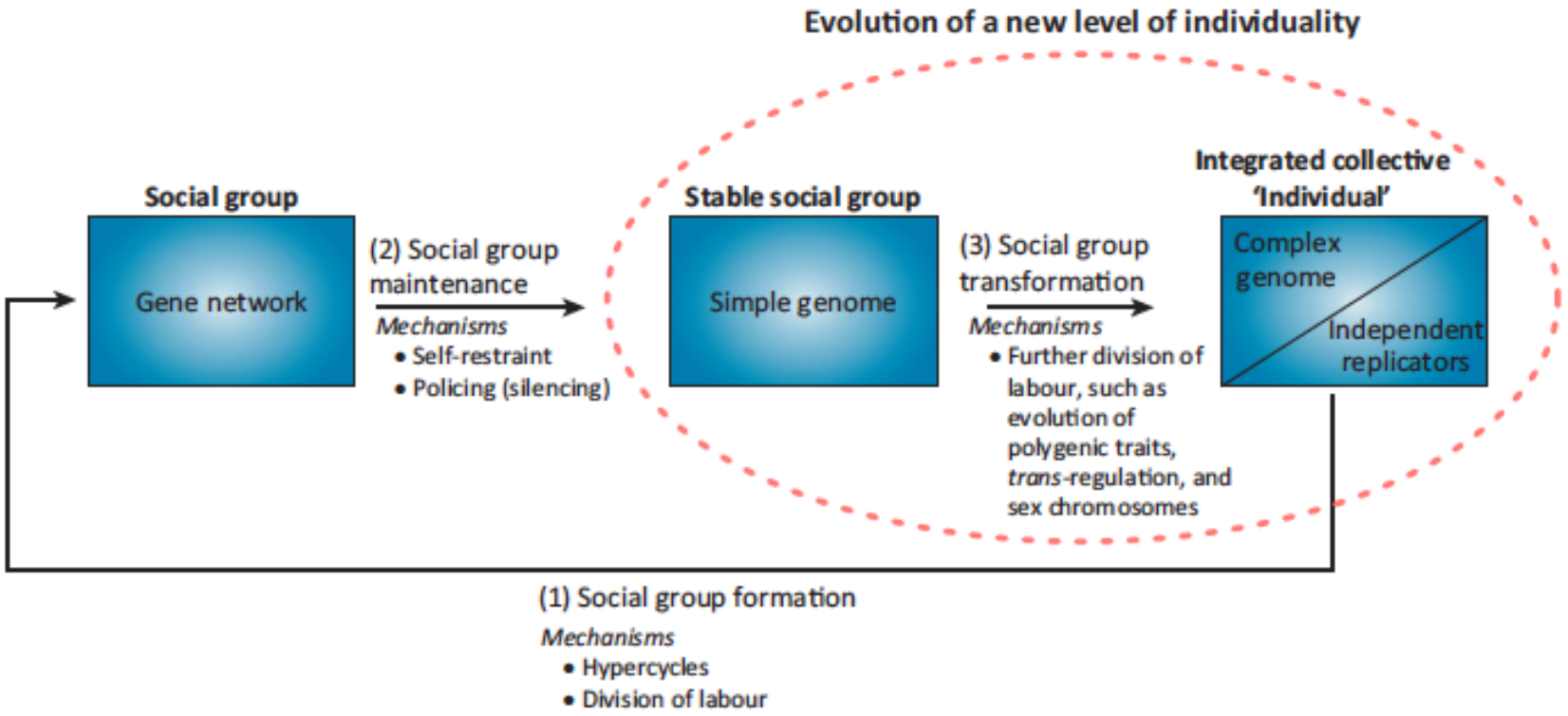
Transitions in Individuality

- Transitions involve the emergence of cooperation among independent units, leading to a new higher-level unit
- Transitions are associated with suppressing conflict among lower-level units
- Emergence of new levels Is contingent, not deterministic, and thus need to be explained (Griesemer, 2000; Okasha, 2005)

Evolutionary Individuals

- Traditional: spatially and temporally bounded, contiguous, physiologically discrete; genetically unique and homogeneous; division of labor between reproductive and somatic cells
  - Serve as evolutionary individuals
- Problem: most living things possess some but not all of these criteria
- Many ‘individuals’ have fuzzy boundaries

Transitions in Individuality



Focuses on suppressing conflict at lower levels and promoting cooperation

Agren, *Trends Ecol. Evol 2013*

Major Transitions in Evolution and Individuality

From	To	MET	ETI
Replicating Molecules	Populations of mol	Yes	Yes
Independent Replicators	Chromosomes	Yes	Yes
RNA as Gene & Enzyme	DNA + protein	Yes	No
Prokaryotes	Eukaryotes	Yes	Yes
Asexual clones	Sexual populations	Yes	Maybe
Protists	Cellular Differentiation	Yes	Yes
Solitary Individuals	Colonies	Yes	Yes
Primate societies	Human Societies (language)	Yes	No
Independent species	Interspecific mutualism	No	Yes

From Agren 2013, *TREE*

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Less Complex societies	"Human Institutions"	Maybe	Yes
Independent species	Interspecific mutualism	No	Yes

With thanks to Carl Simpson

Alternative views of Major Evolutionary Transitions

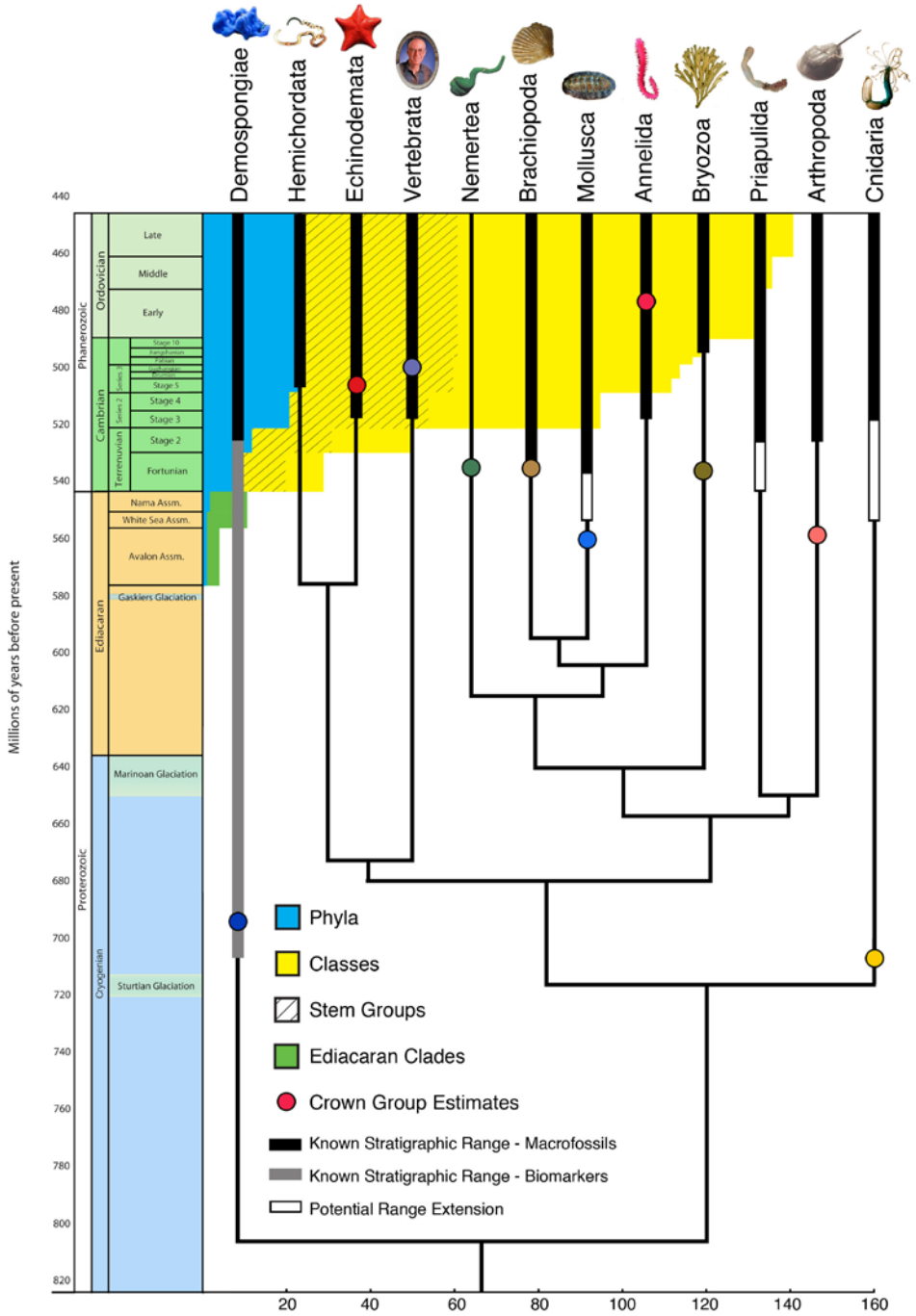




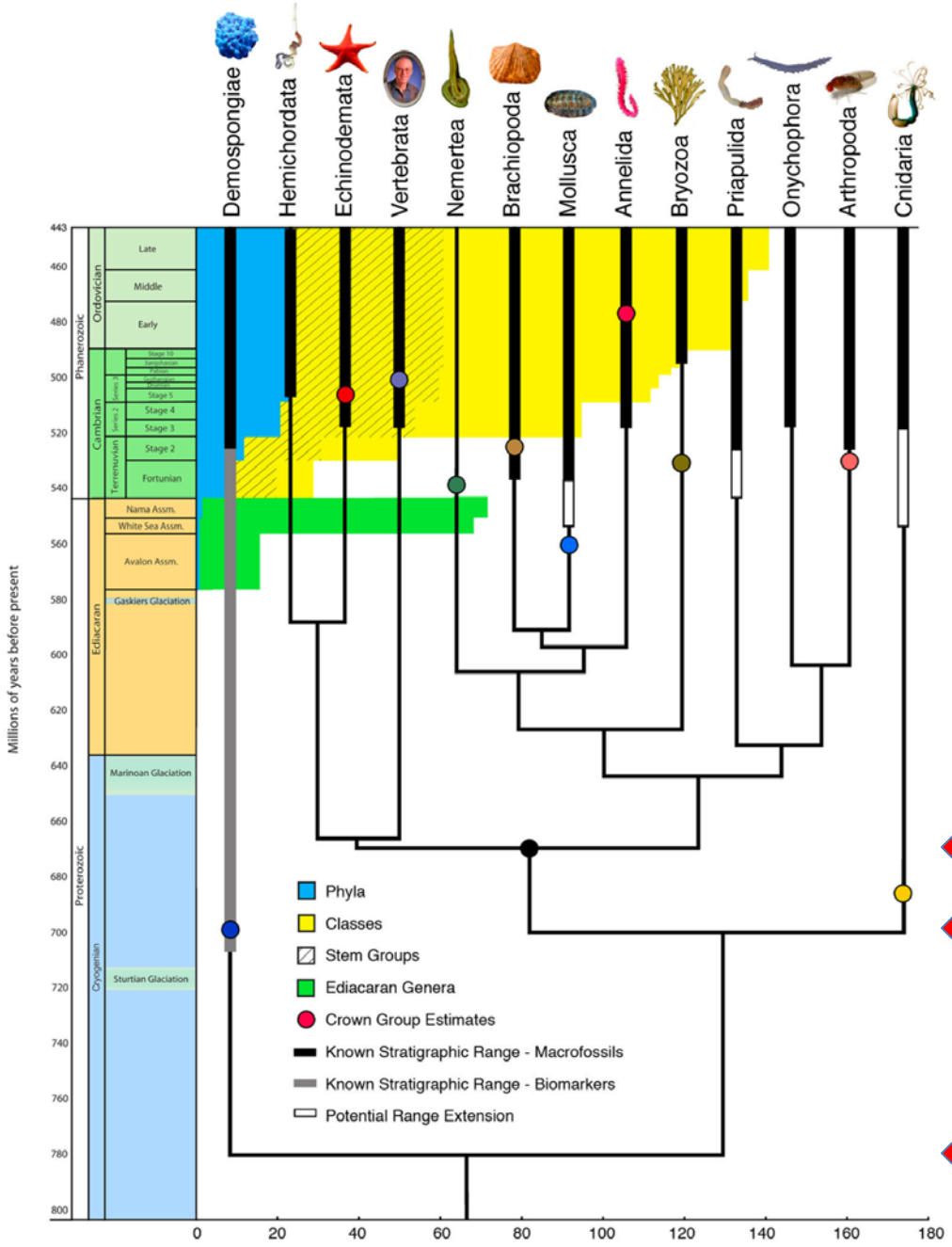








Erwin et al. *Science* 2011



Macroevolutionary lag between developmental and morphologic innovations

Origin of Developmental Toolkit

Origin of Eumetazoa

Most signaling pathways present

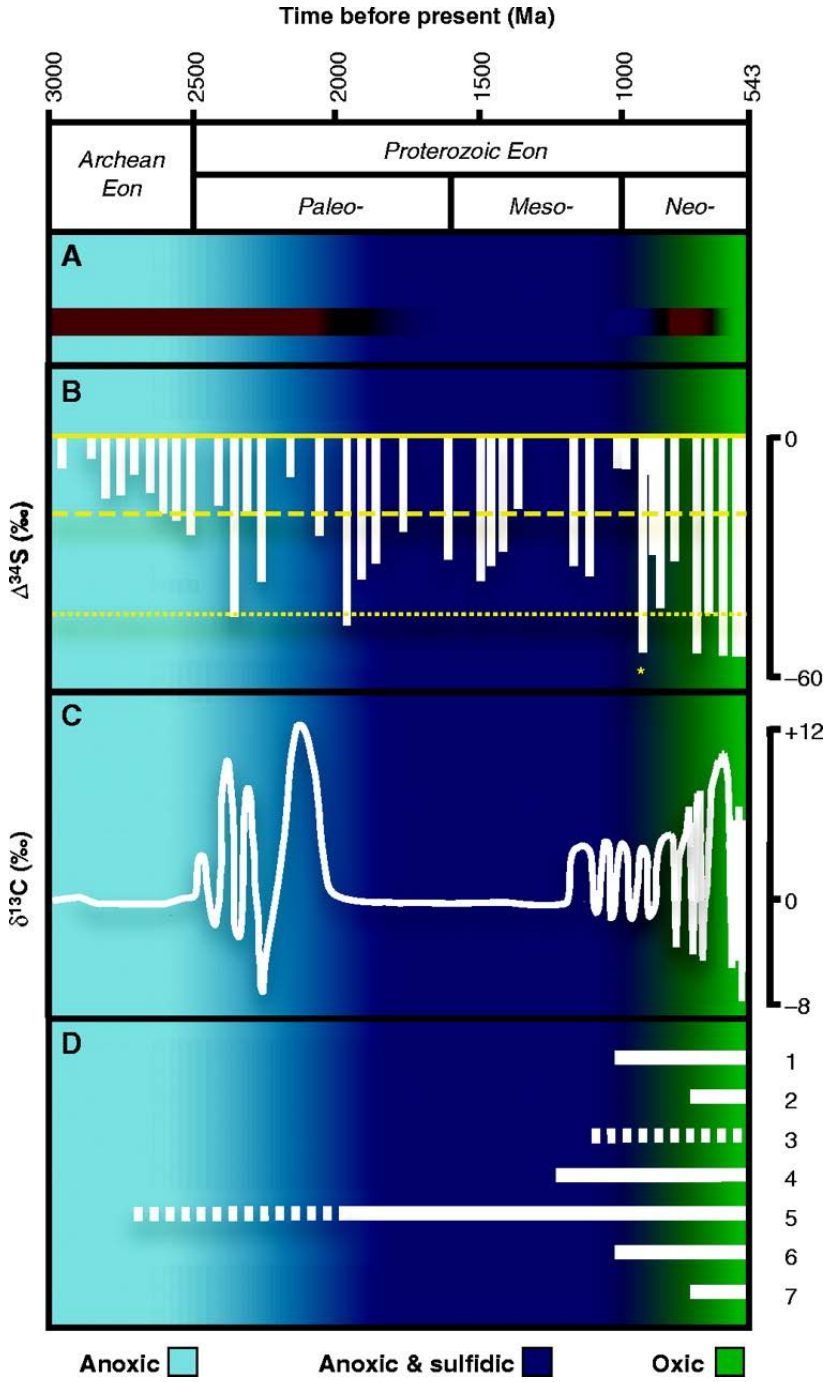
Invention & Innovation

- *Invention* is the creation of something new and distinct (contrast with variation on established themes)
- *Innovation* occurs when inventions become economically or ecologically significant
- *Macroevolutionary lags* emphasize the importance of this distinction

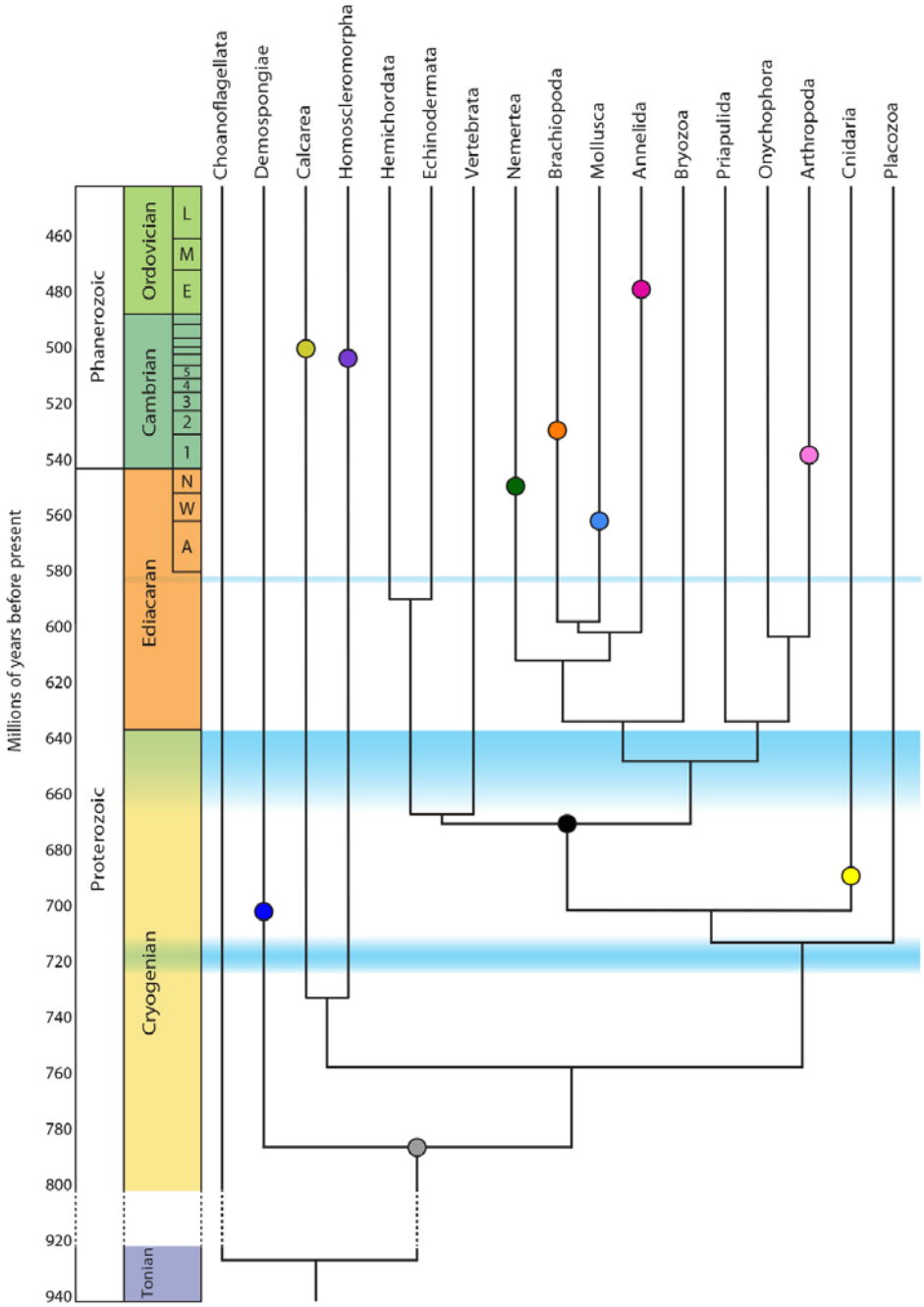
Joseph Schumpeter (1883-1950

Alternative Views of Major Evolutionary Transitions

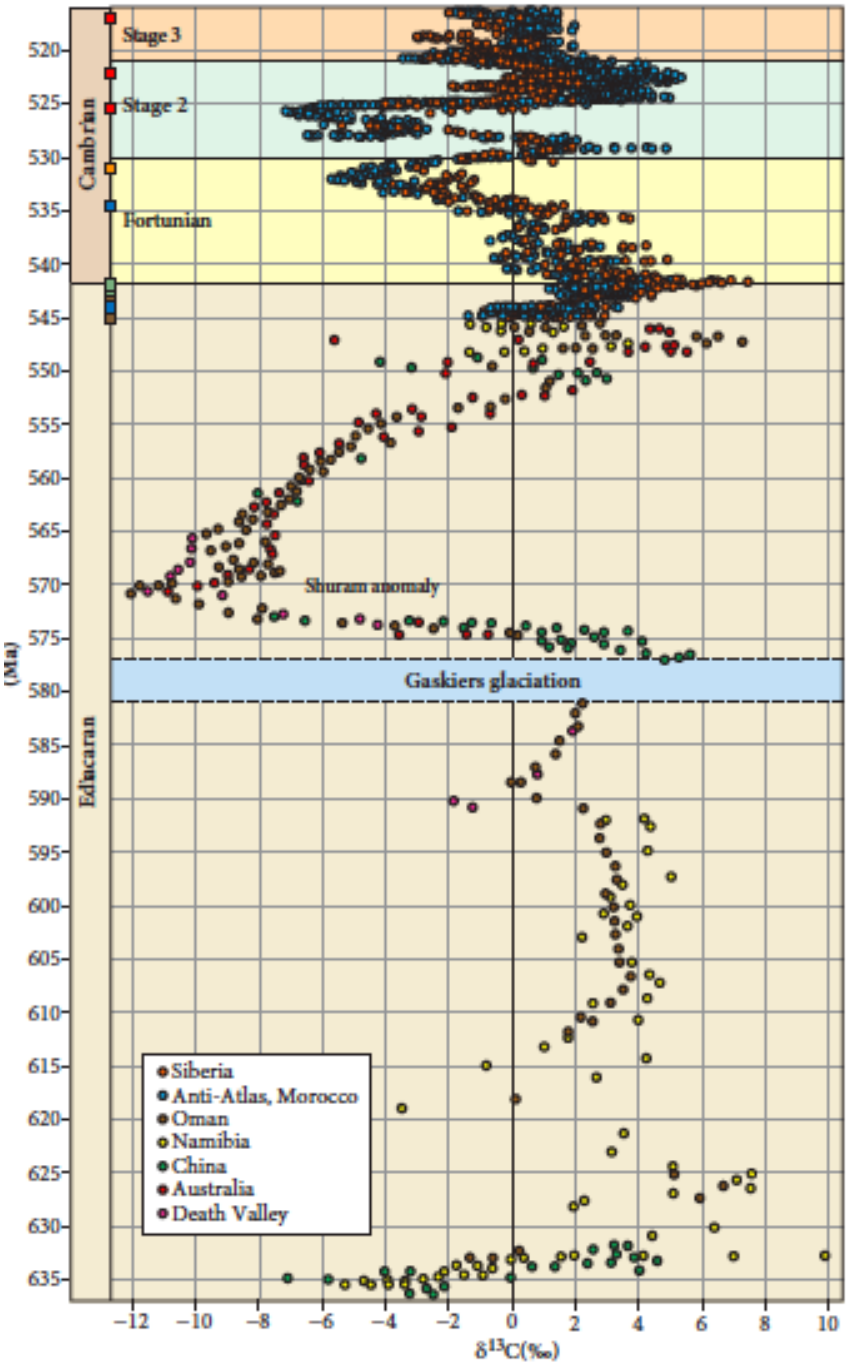
- Hierarchical expansion of information
- Driven by environmental drivers
- Expansion of ecospace



Anbar & Knoll, 2002, *Science*



Tweedt & Erwin, submitted



Erwin and Valentine, *2013*

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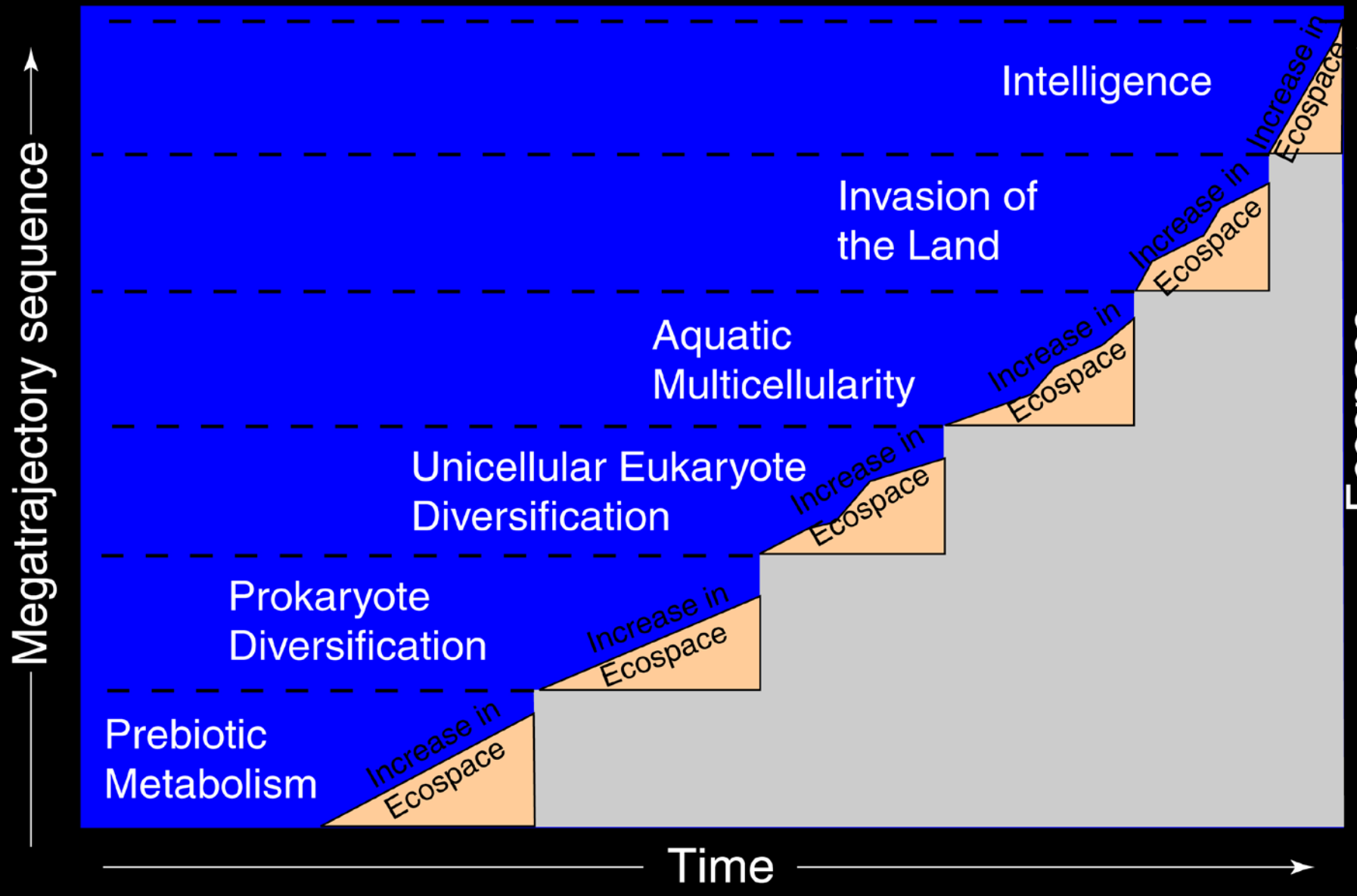
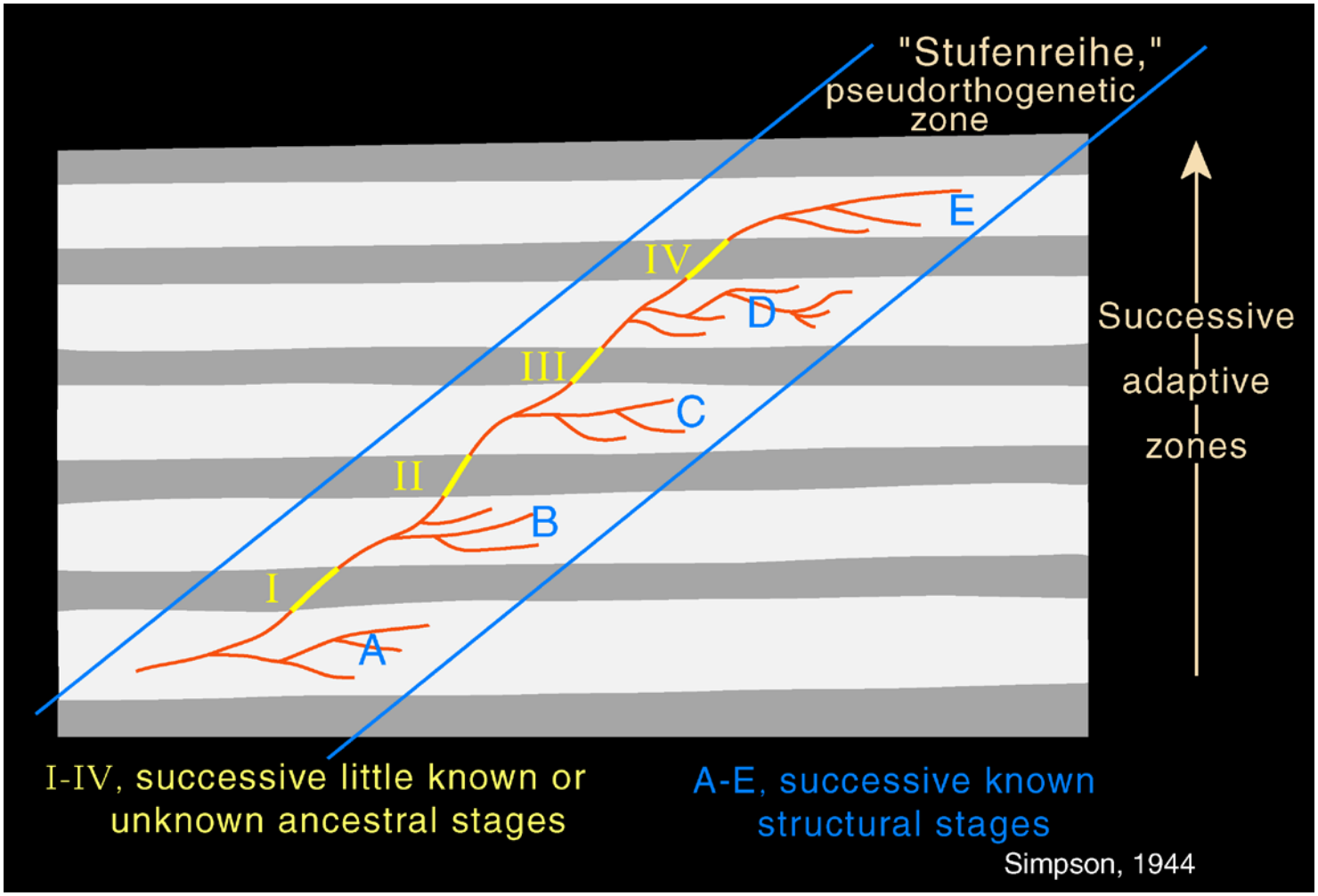
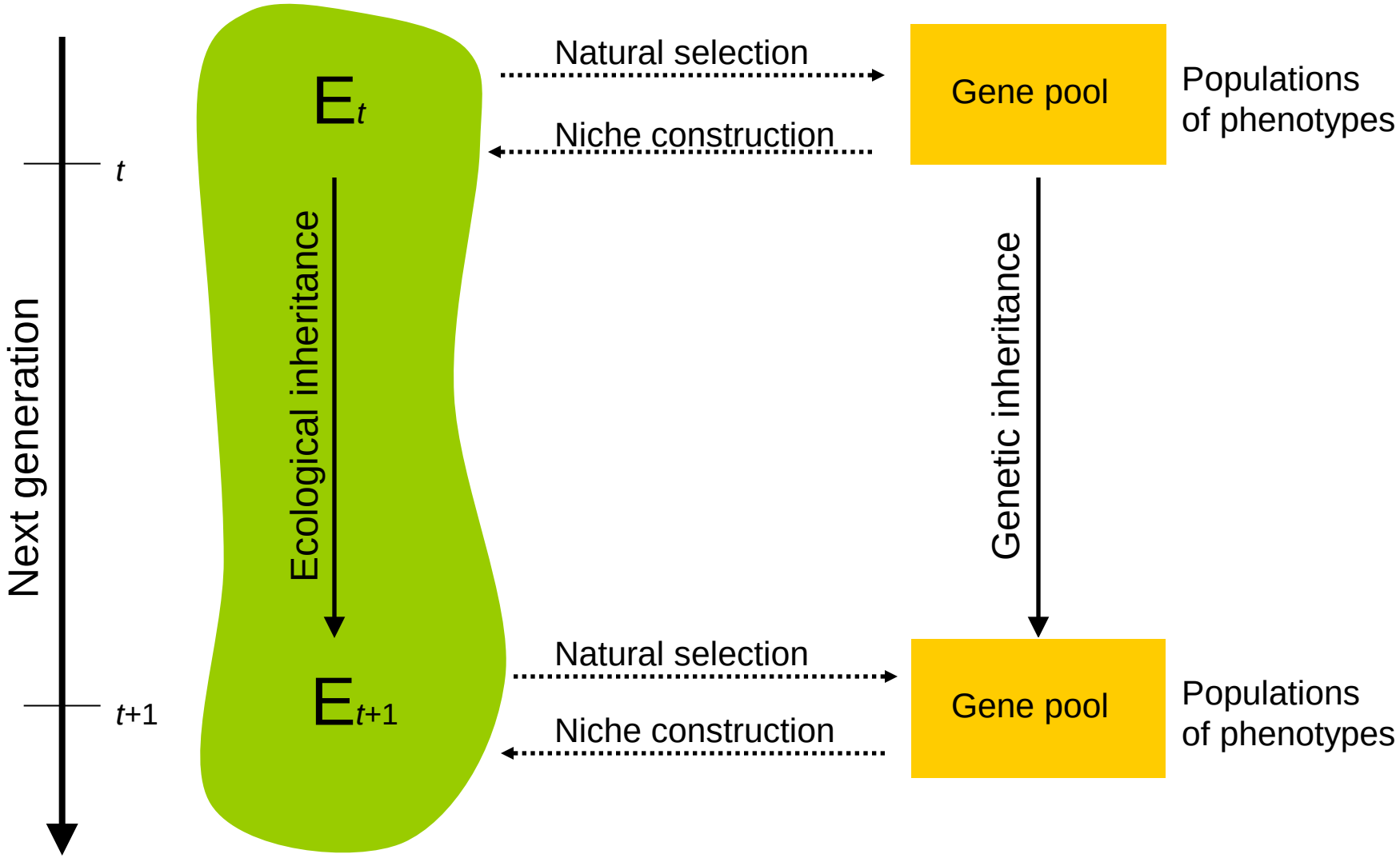


Knoll and Bambach, 20000, *Paleobiology*

Simpson's Adaptive Zones

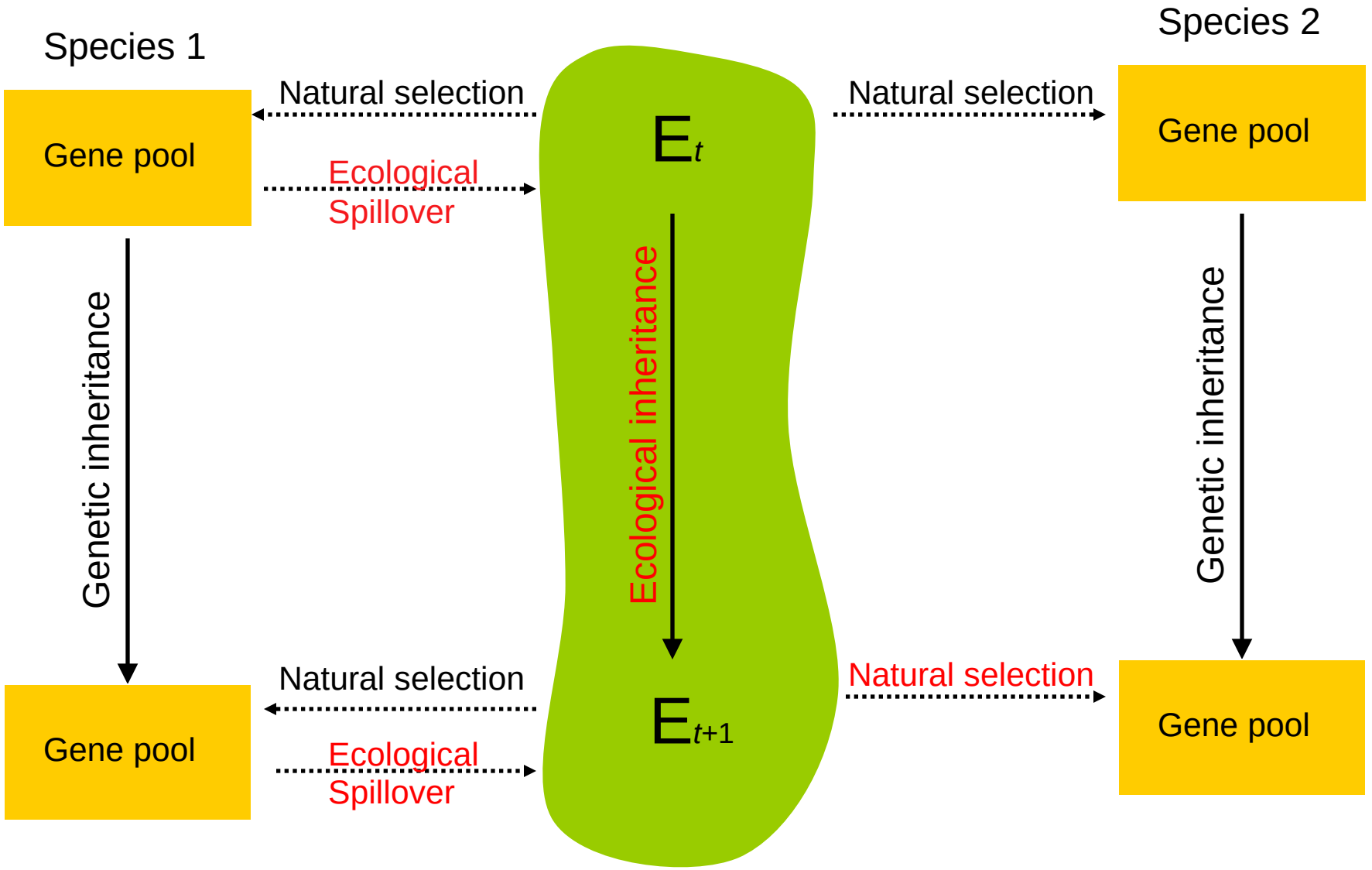


Niche inheritance



Odling-Smee et al.

Ecosystem Engineering



Cambrian Ecosystem Engineering

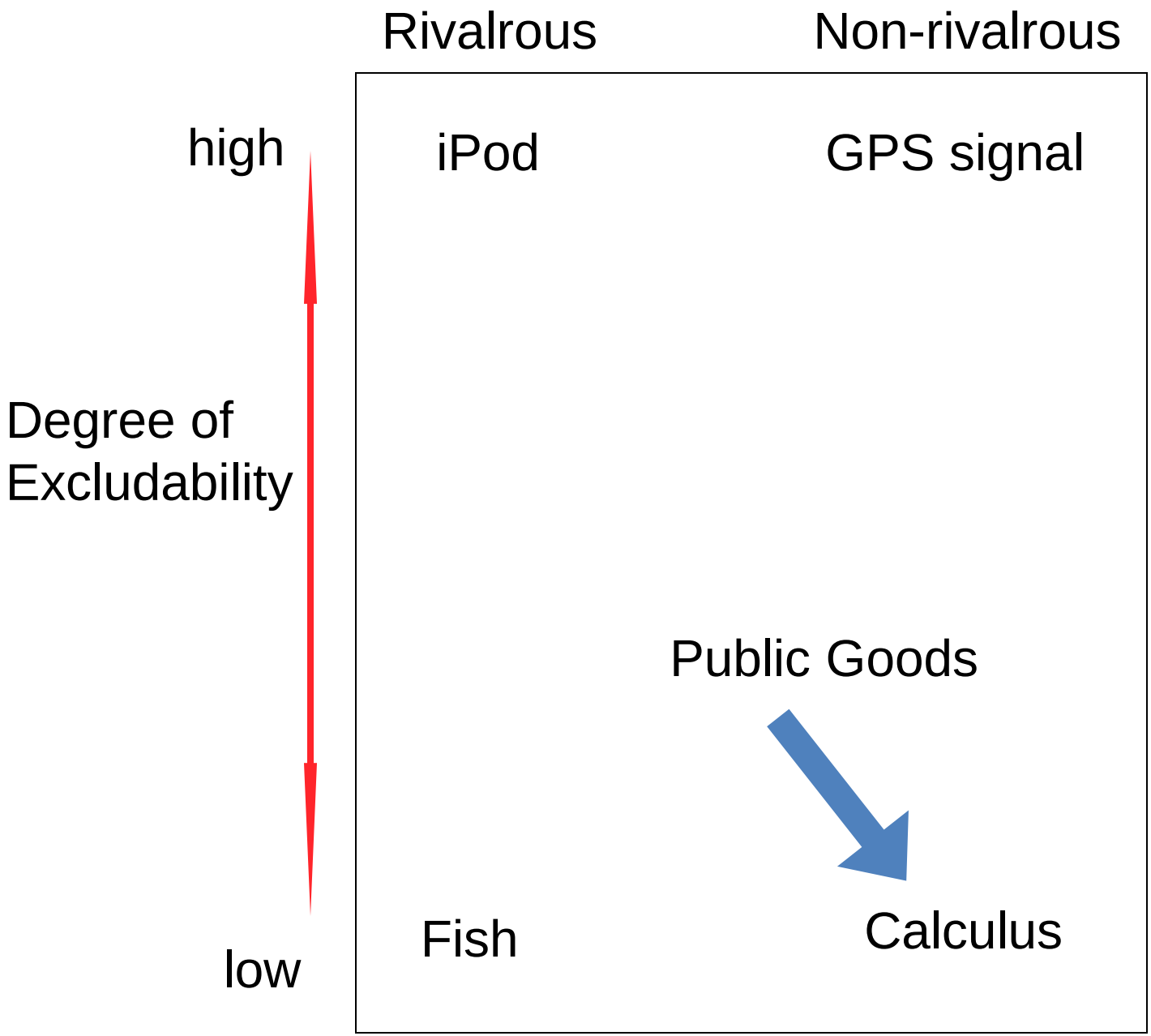
- Archaeocyathid reefs (+)
- Sponges & other filter feeders (+)
- Burrowed sediments (+/-)
- Shelly substrates (+)
- Mesoozooplankton

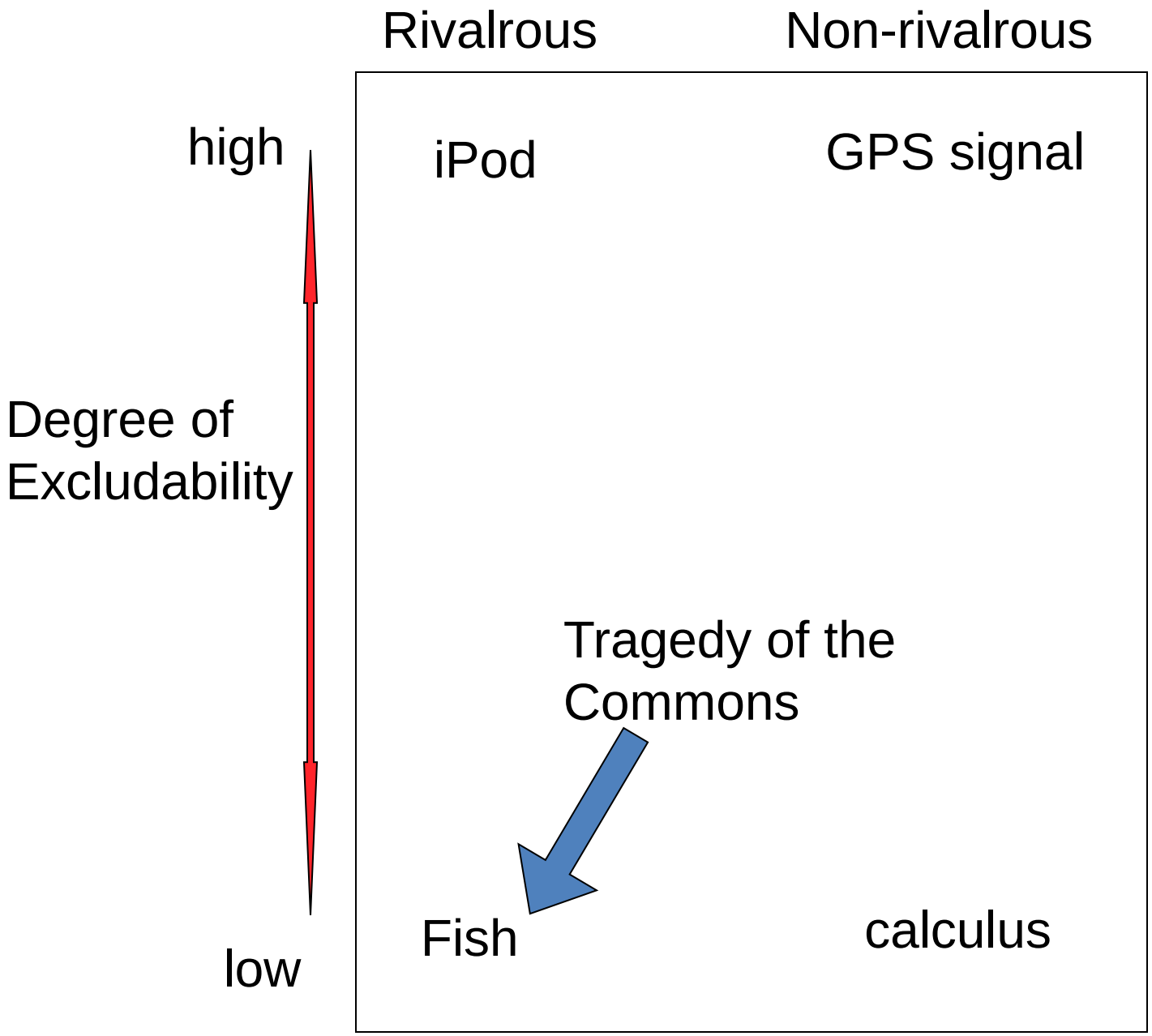
Alternative Views of Major Evolutionary Transitions

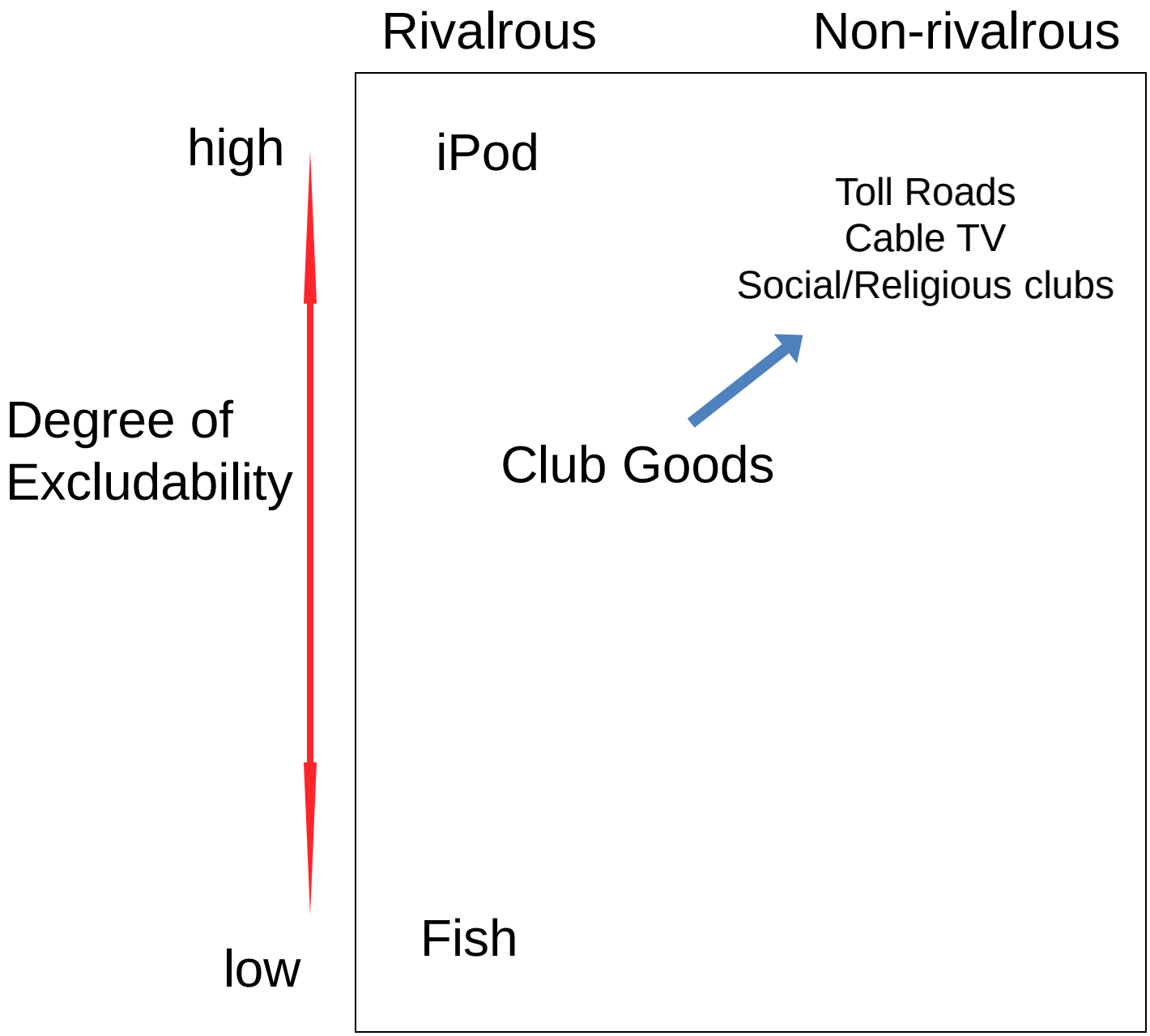
- Hierarchical expansion of information
- Driven by environmental drivers
- Expansion of ecospace
- Appearance of public goods

What is a 'Public Good'?

- Public goods are those where the use of the good does not preclude use by others (non-excludability) and the inability to prevent others from using the good (non-rivalry).
- May be local or global

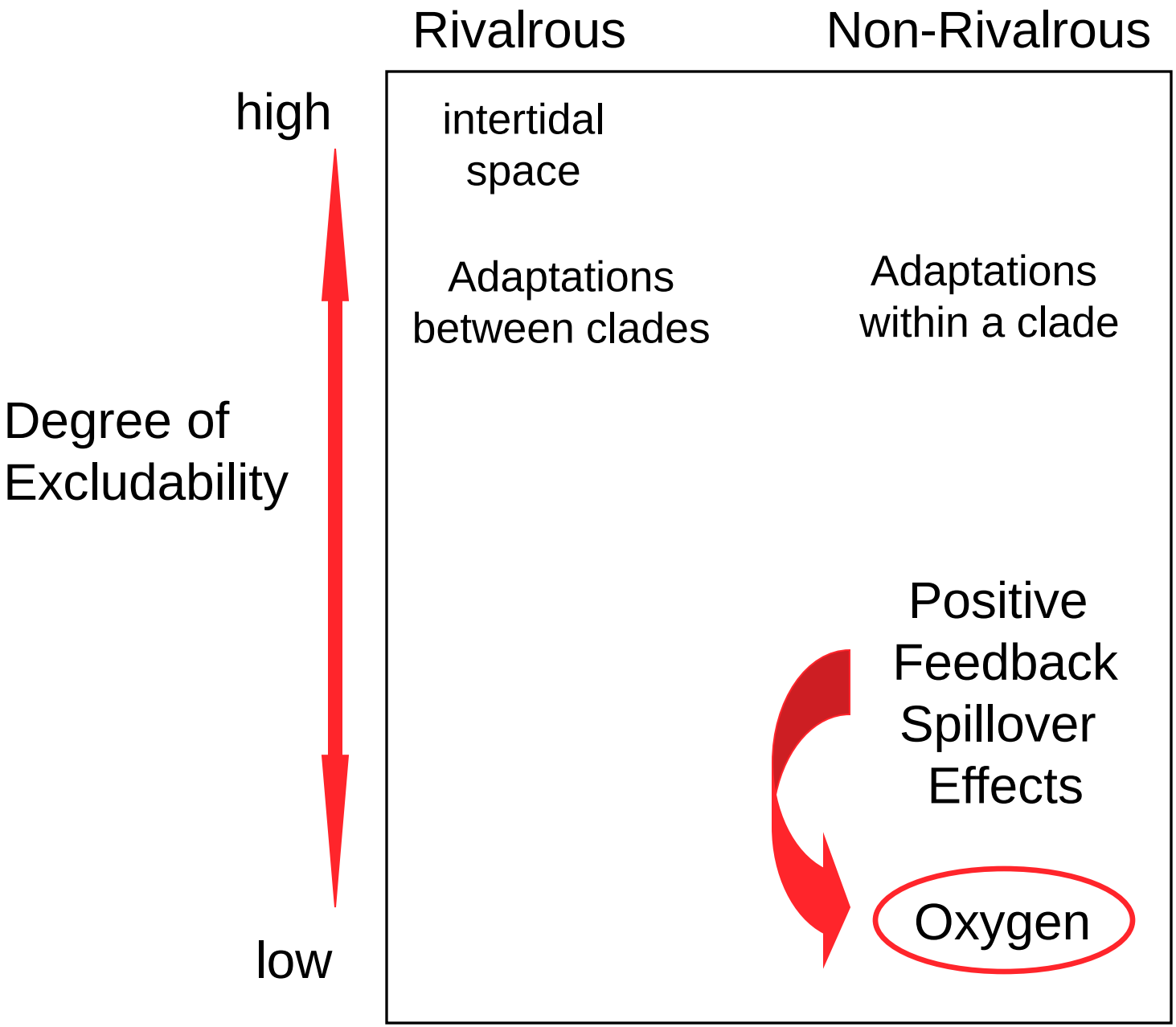

Rivalrous
Non-rivalrous
high
iPod
GPS signal
Degree of
Excludability
Public Goods
Fish
Calculus
low


Rivalrous
Non-rivalrous
high
iPod
GPS signal
Degree of Excludability
Tragedy of the Commons
Fish
calculus
low

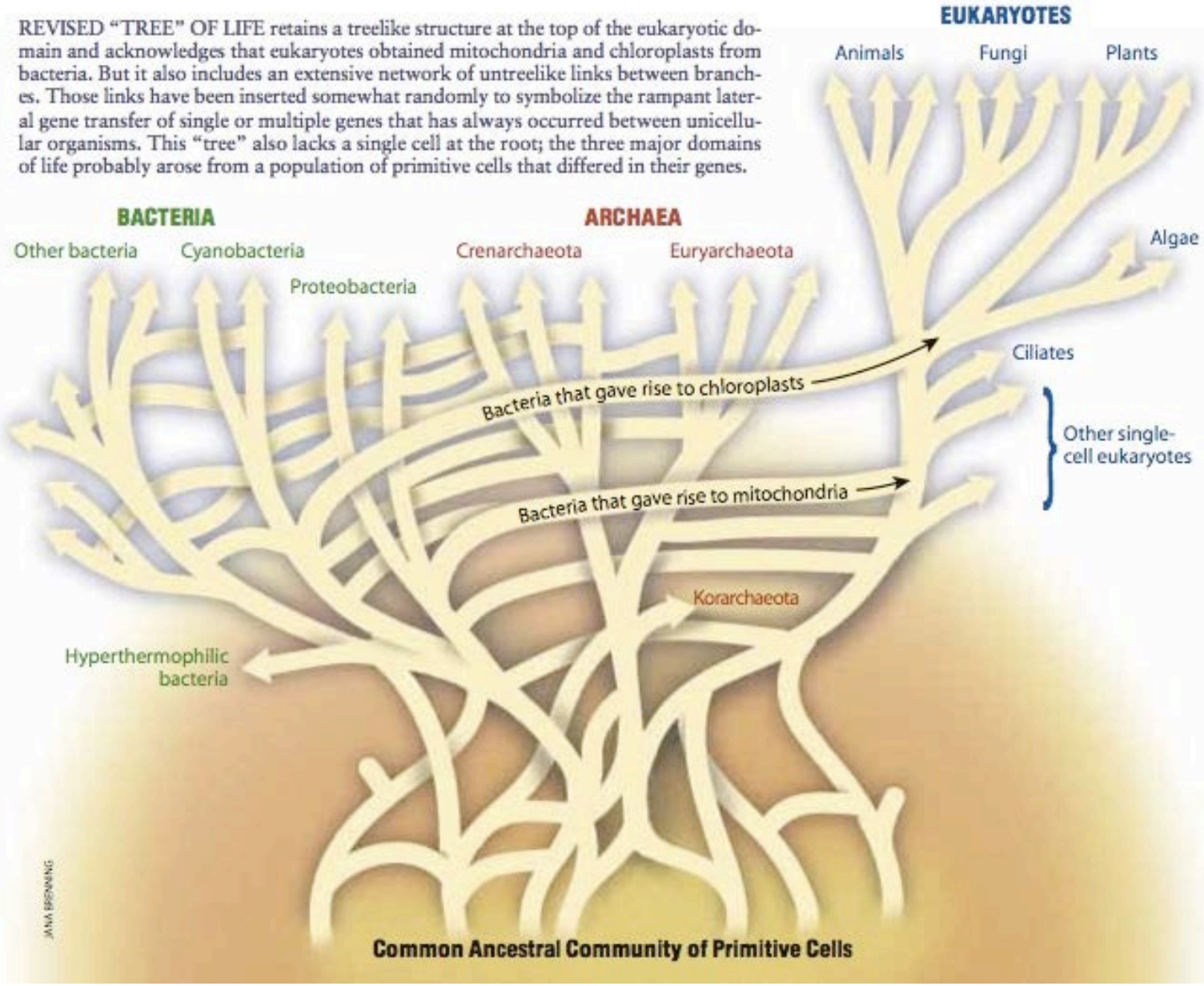

Rivalrous
Non-rivalrous
high
iPod
Toll Roads
Cable TV
Social/Religious clubs
Degree of
Excludability
Club Goods
Fish
low

Public/Club Goods and Major Evolutionary Transitions

- Origin of Life: sequences, replication machinery and lipid bilayers
- Early microbial life: gene sequences (HGT)
- Origin of Eukaryotes: symbionts (with ecological spillover resulting
- Multicellularity: ecosystem engineering

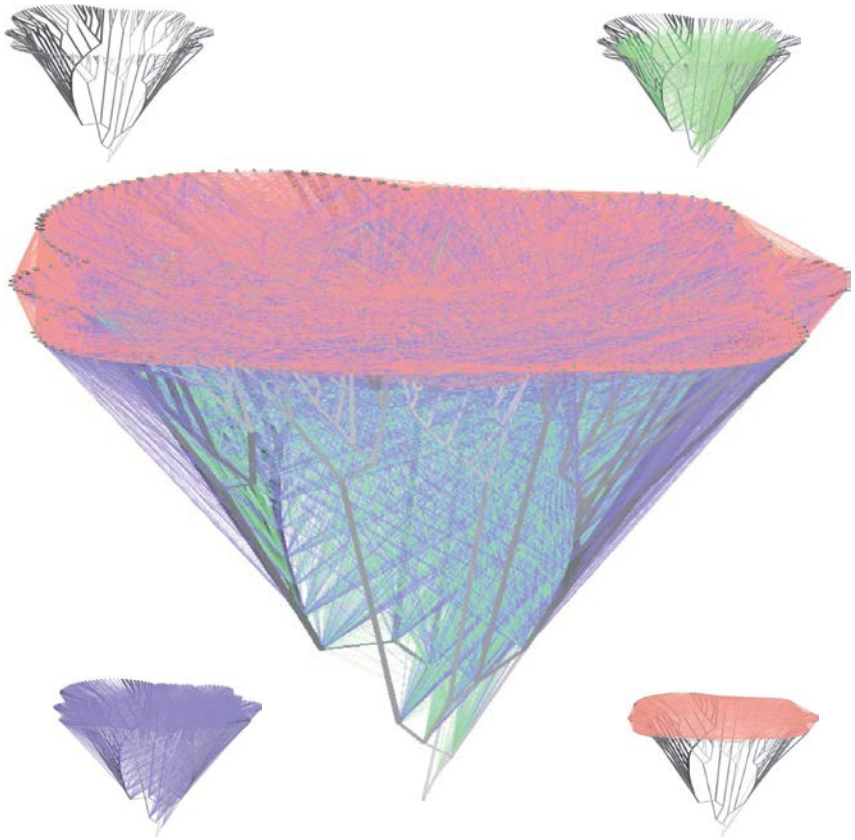

Rivalrous
Non-Rivalrous
high
low
Degree of Excludability
intertidal space
Adaptations between clades
Adaptations within a clade
Positive Feedback Spillover Effects
Oxygen

REVISED "TREE" OF LIFE retains a treelike structure at the top of the eukaryotic domain and acknowledges that eukaryotes obtained mitochondria and chloroplasts from bacteria. But it also includes an extensive network of untreelike links between branches. Those links have been inserted somewhat randomly to symbolize the rampant lateral gene transfer of single or multiple genes that has always occurred between unicellular organisms. This "tree" also lacks a single cell at the root; the three major domains of life probably arose from a population of primitive cells that differed in their genes.



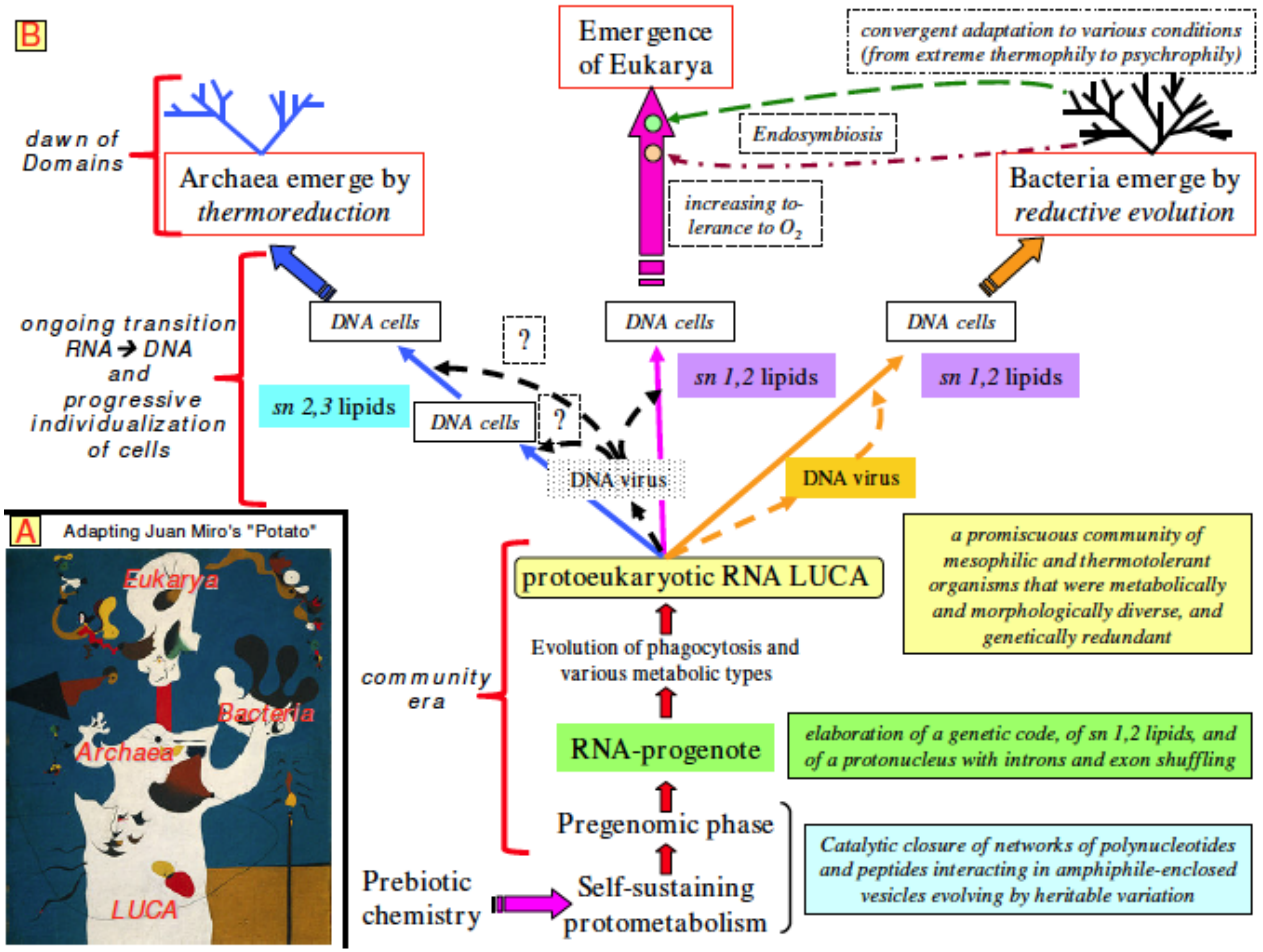
Gene sequences

- Network representation of vertical inheritance and lateral gene transfer among eubacteria and archaea
- Based on 539 723 protein coding genes among 181 taxa
- Infers extensive LGT
- Coding genes serve as information that has been readily transferred between lineages



Dagan & Martin, 2009, *Phil. Trans R. Society B*

LUCA as a diverse community



Glansdorff et al. 2008 *Biology Direct*

Public/Club Goods and Major Evolutionary Transitions

- Origin of Life: sequences, replication machinery and lipid bilayers
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- Origin of Eukaryotes: symbionts (with ecological spillover resulting
- Multicellularity: ecosystem engineering

Major Evolutionary Transitions

- Many, and perhaps all, of the major evolutionary transitions involved the origin and spread of public goods
- Some of these public goods involved ecological spillovers that constructed new niches for other taxa, providing positive feedback for increased diversity

Major Transitions in Social Evolution

From	To
Emergence of culture	Emergence of culture
Prelinguistic culture	Linguistic culture
Undifferentiated cultural groups	'Tribes' (increased hierarchy and division of labor)
	Symbolic systems of information storage and transmission
	Legal system
Protists	Institutionalization of science and technology

Focus on evolution of systems of information replication

From Hodgson & Knudsen Darwin's Conjecture

Major Transitions in Social Evolution

- Each transition generates complexity by nesting prior social adaptations within more complex structures
- Each major information transition in social evolution is accompanied by new forms of generative replicators
- Importance of '*habits*' in the evolution of culture

Major Transitions in Social Evolution

- *Customs* as generative replicators
  - *Conditional generative mechanisms*
  - *Copied customs are similar to original*
  - *Information is transferred*
  - *As with other METs, customs require lower level functions to operate*

From Hodgson & Knudsen, Darwin's Conjecture

Key Points

- METs involve the construction of new evolutionary individuals
- Selection happens on multiple levels: populations, species, clades,
- Multiple kinds of inheritance: genetic, epigenetic (non-DNA cellular transmission), ecologic (niche construction)

This is not 'Universal Darwinism' which suffers from a number of conceptual problems (not least of which is a restricted view of biological evolution)

How are new evolutionary spaces created?

- *Potentiated* by broader environmental setting (physical, genetic, ecologic*)*
- *Actualized* by genetic and developmental innovations leading to a new clade
- *Refined* by further developmental and ecological changes
- *Realized* as innovations by ecological expansion and evolutionary success

Evolutionary Uniformitarianism

The assumption that the evolutionary rates, mechanisms and processes that can be observed experimentally today are sufficient to explain the sweep of evolutionary patterns through geologic time.