Ecology

- Science of relations between living organisms and their environment (Ernst Haeckel – 1866)

- Ecosystem is the basic system of ecology, not only the organism-complex, but the also the whole complex of physical factors forming what we call the environment (Tansley – 1935)

Ecosystem has

- structure (parts) and
- function (processes) and is
- dynamic (orderly change called succession)

- Two main functions are
  - Transfer/Exchange of energy
  - Cycling of material (particularly nutrients)

Energy is the ability to do work

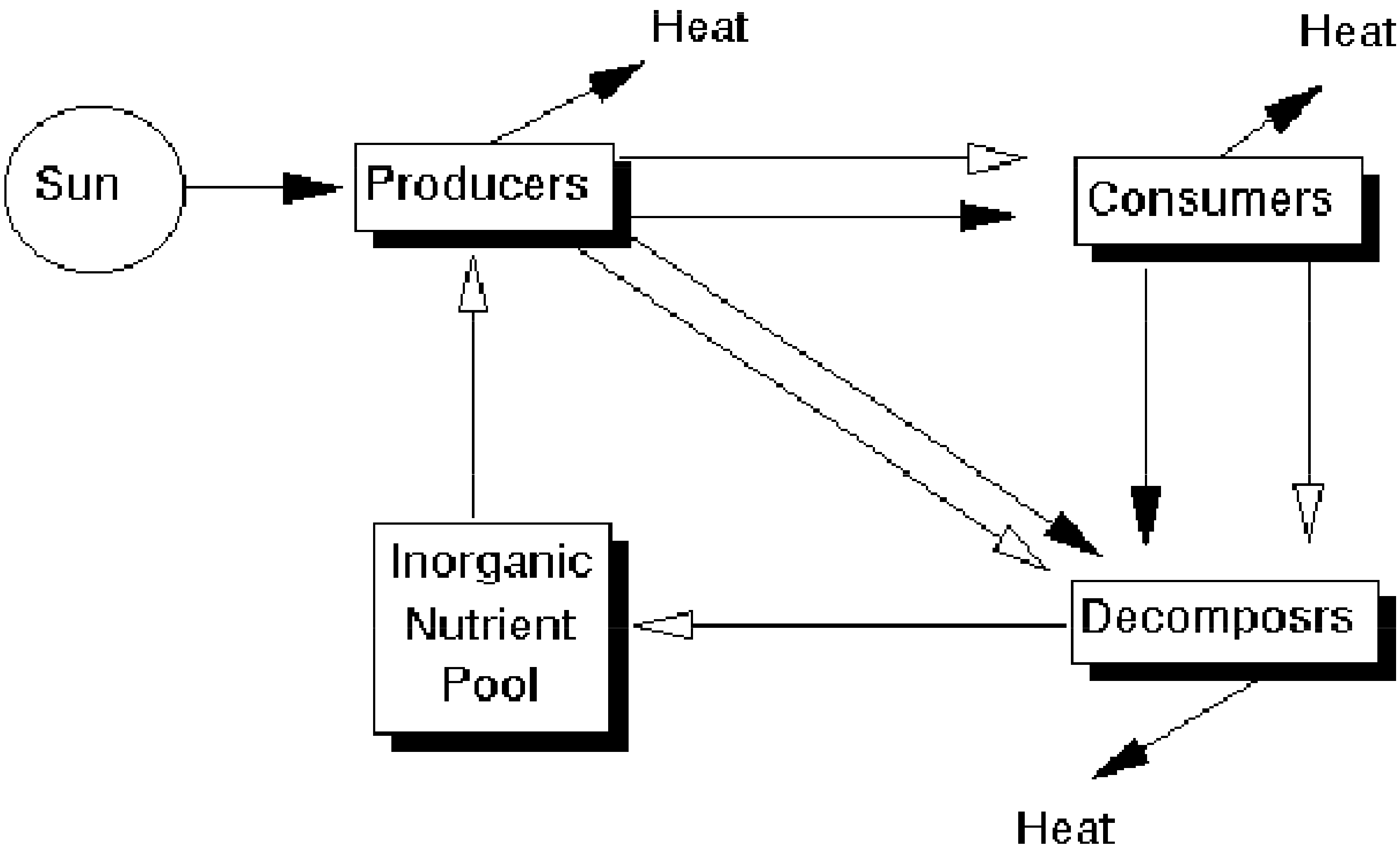
Forms of energy: potential, kinetic, thermal, chemical, electrical, etc.

1st Law of Thermodynamics:

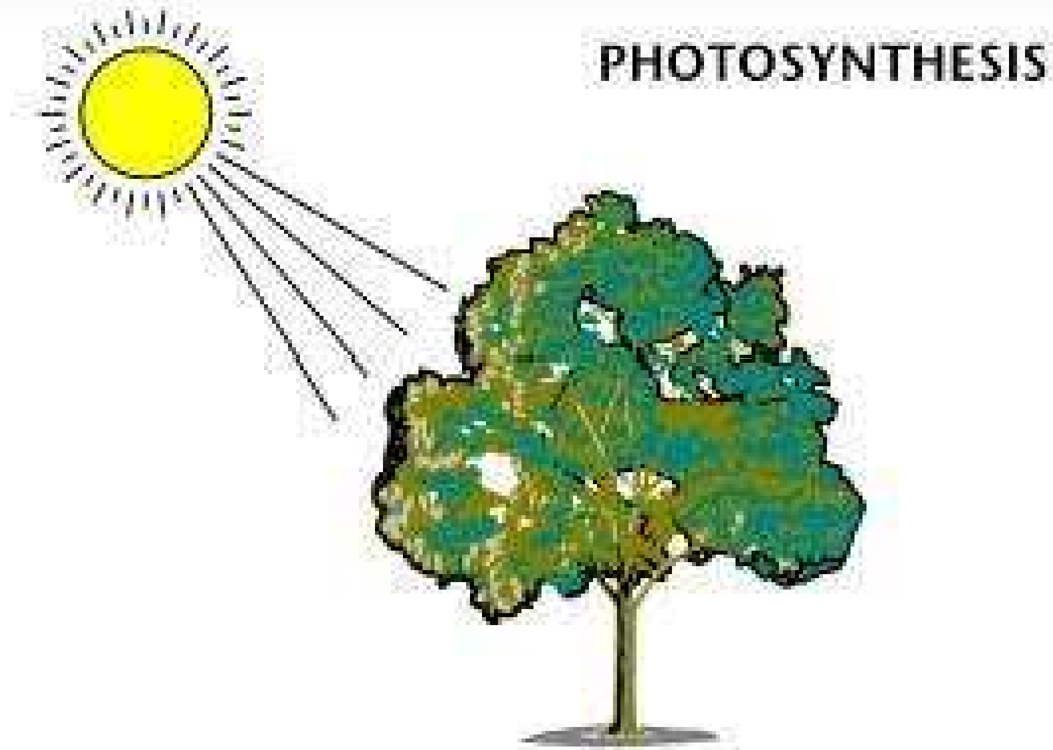
energy cannot be created or destroyed

2nd Law of Thermodynamics:

energy goes from a high quality to a lower quality during each energy transformation; while energy is conserved, it's ability to due work decreases


Heat
Heat
Sun
Producers
Consumers
Inorganic
Nutrient
Pool
Decomposrs
Heat

Photosynthesis

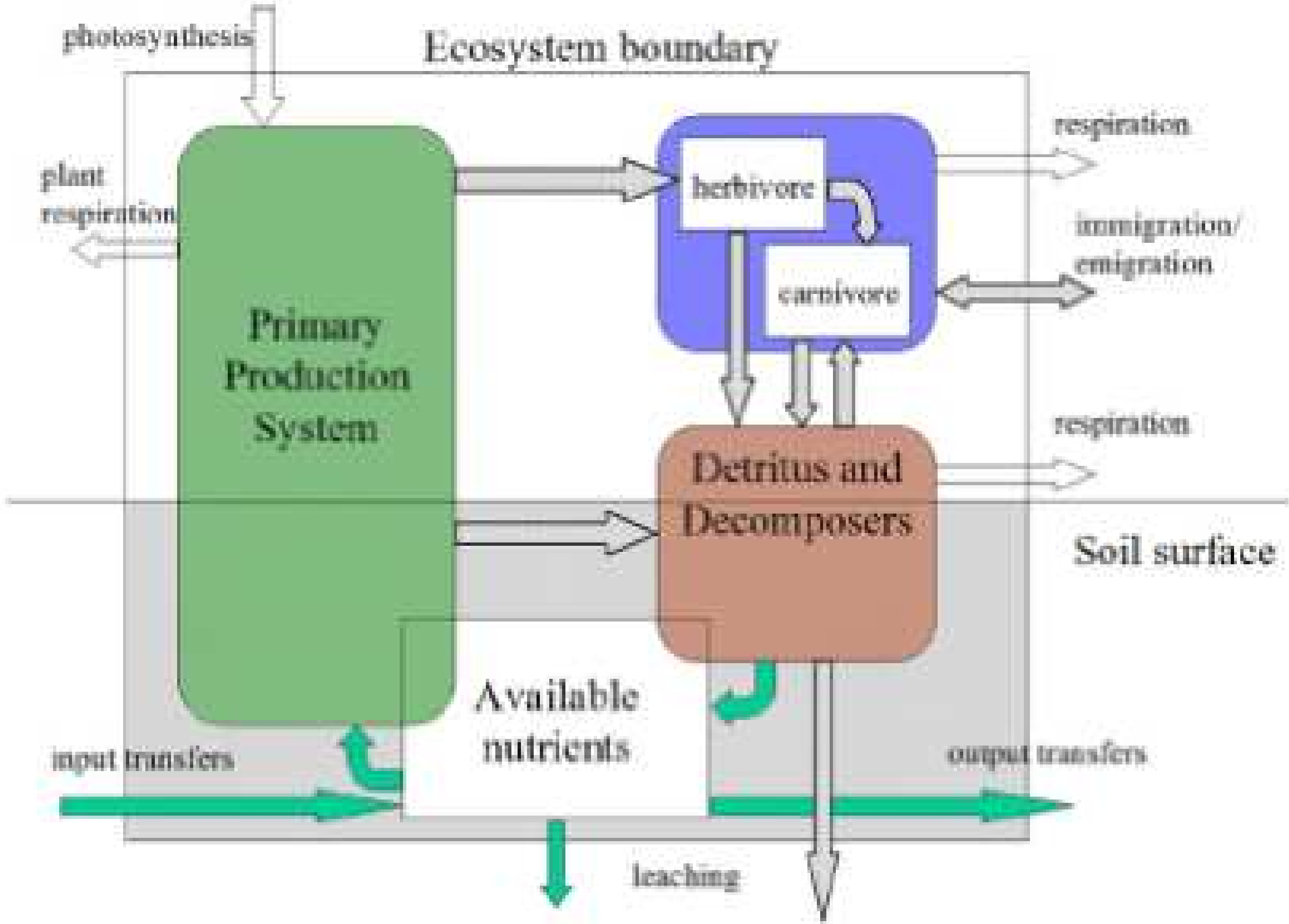


In the process of photosynthesis, plants convert radiant energy from the sun into chemical energy in the form of glucose - or sugar.

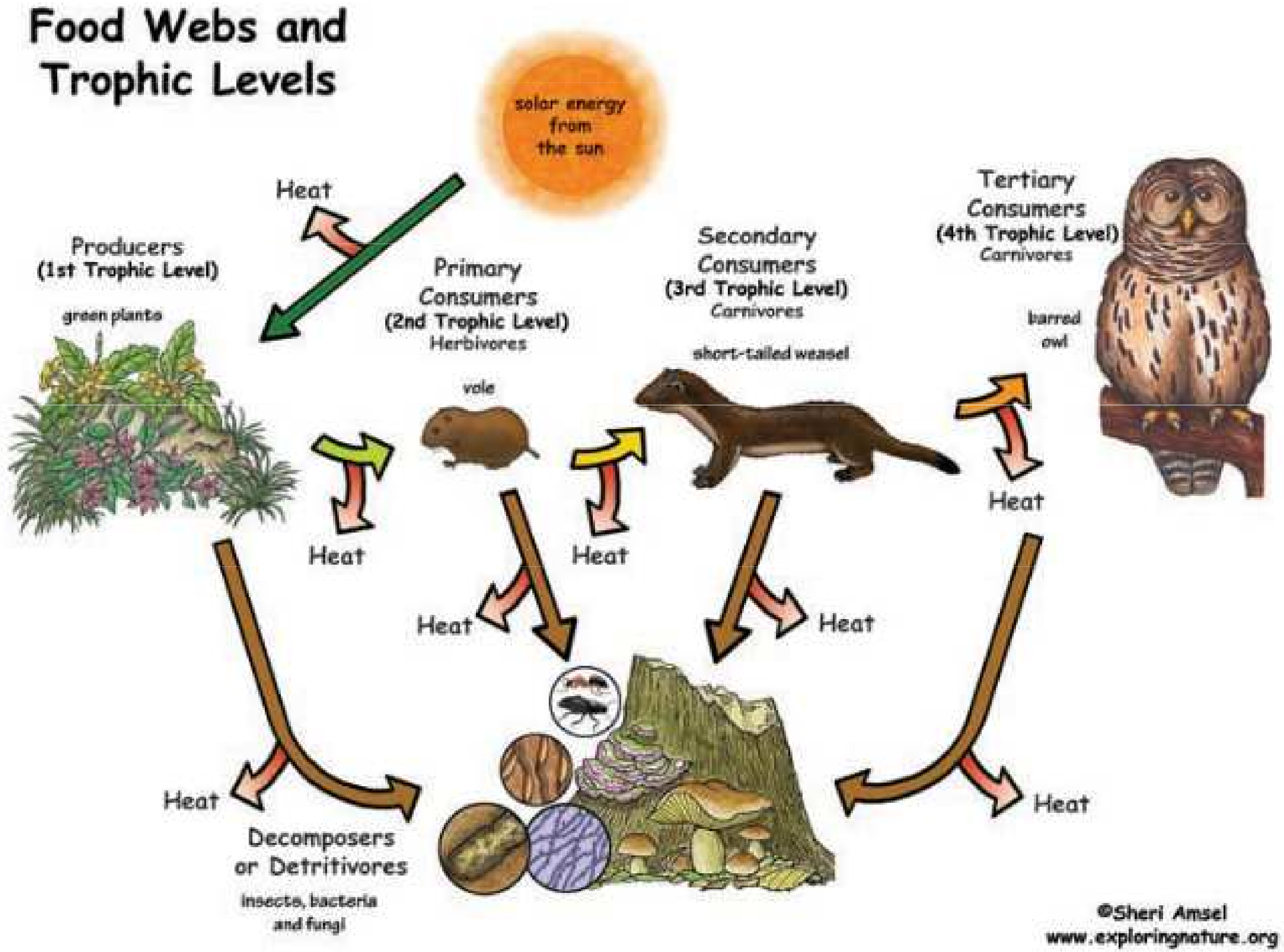
water + carbon dioxide + sunlight → glucose + oxygen

$6\ H_2O + 6\ CO_2 + \text{radiant energy} \rightarrow C_6H_{12}O_6 + 6\ O_2$

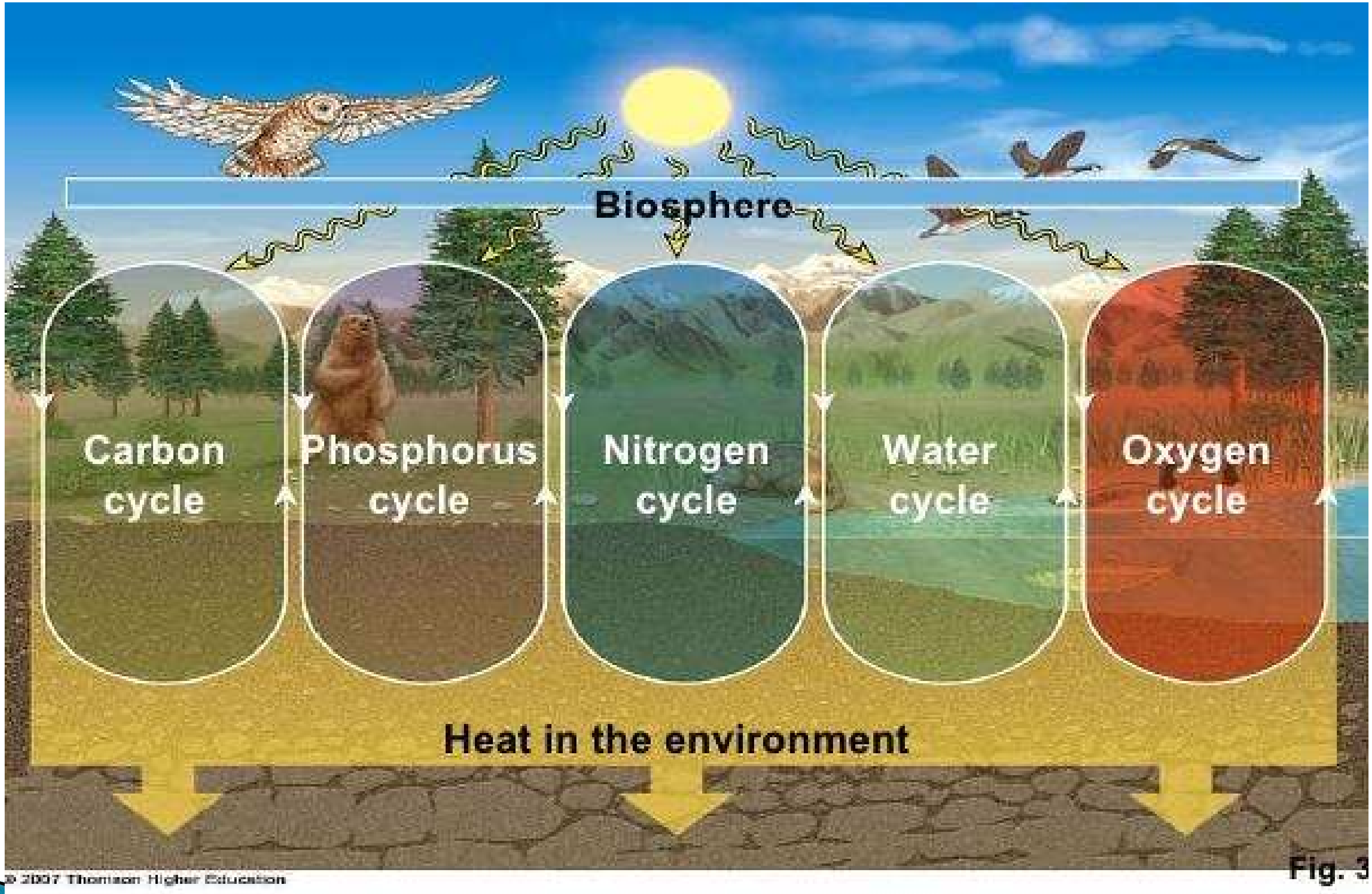
Ecosystem arranged by energy flow – food web



Ecosystem arranged by energy flow – food web

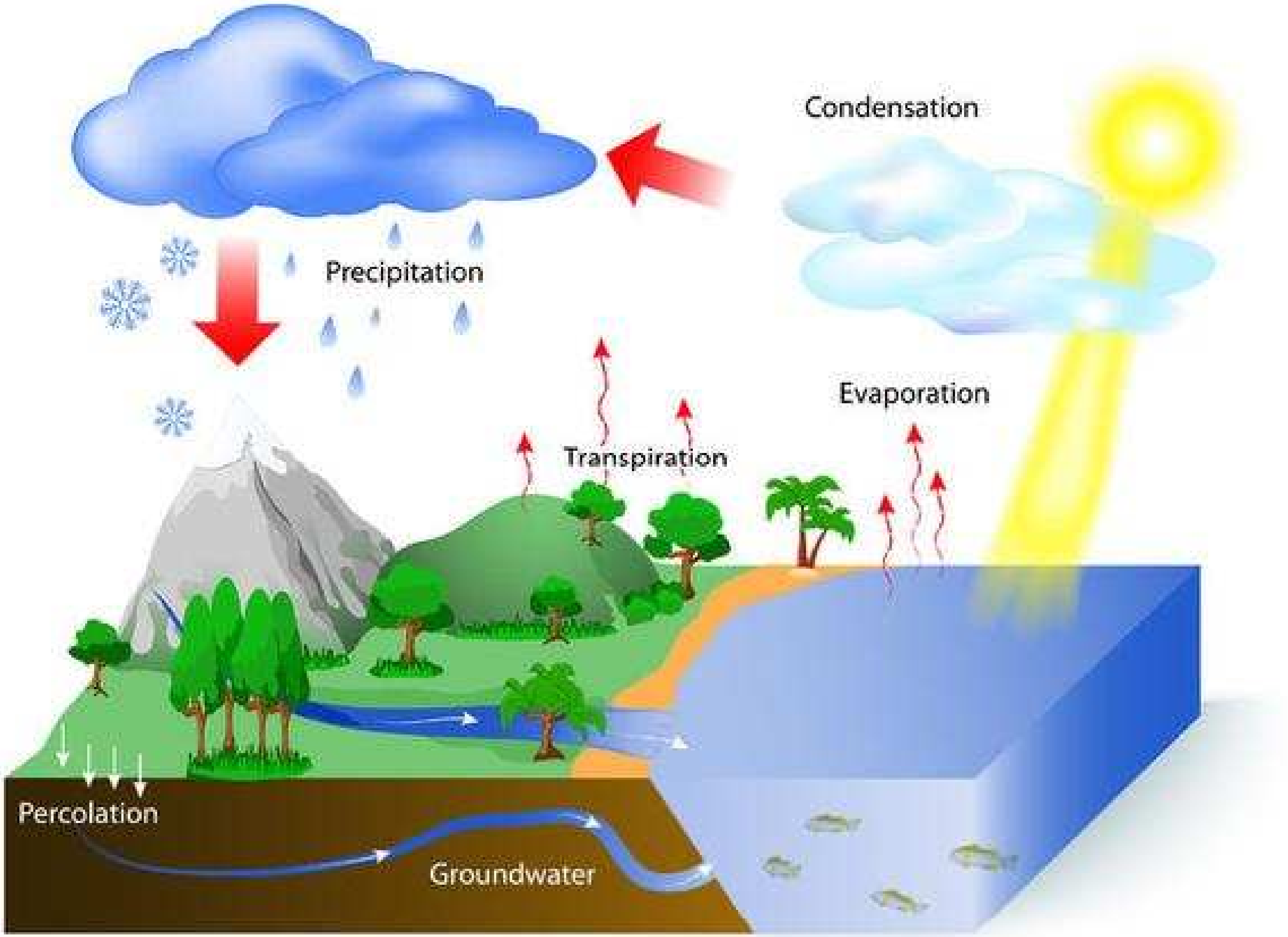


Biogeochemical Cycles

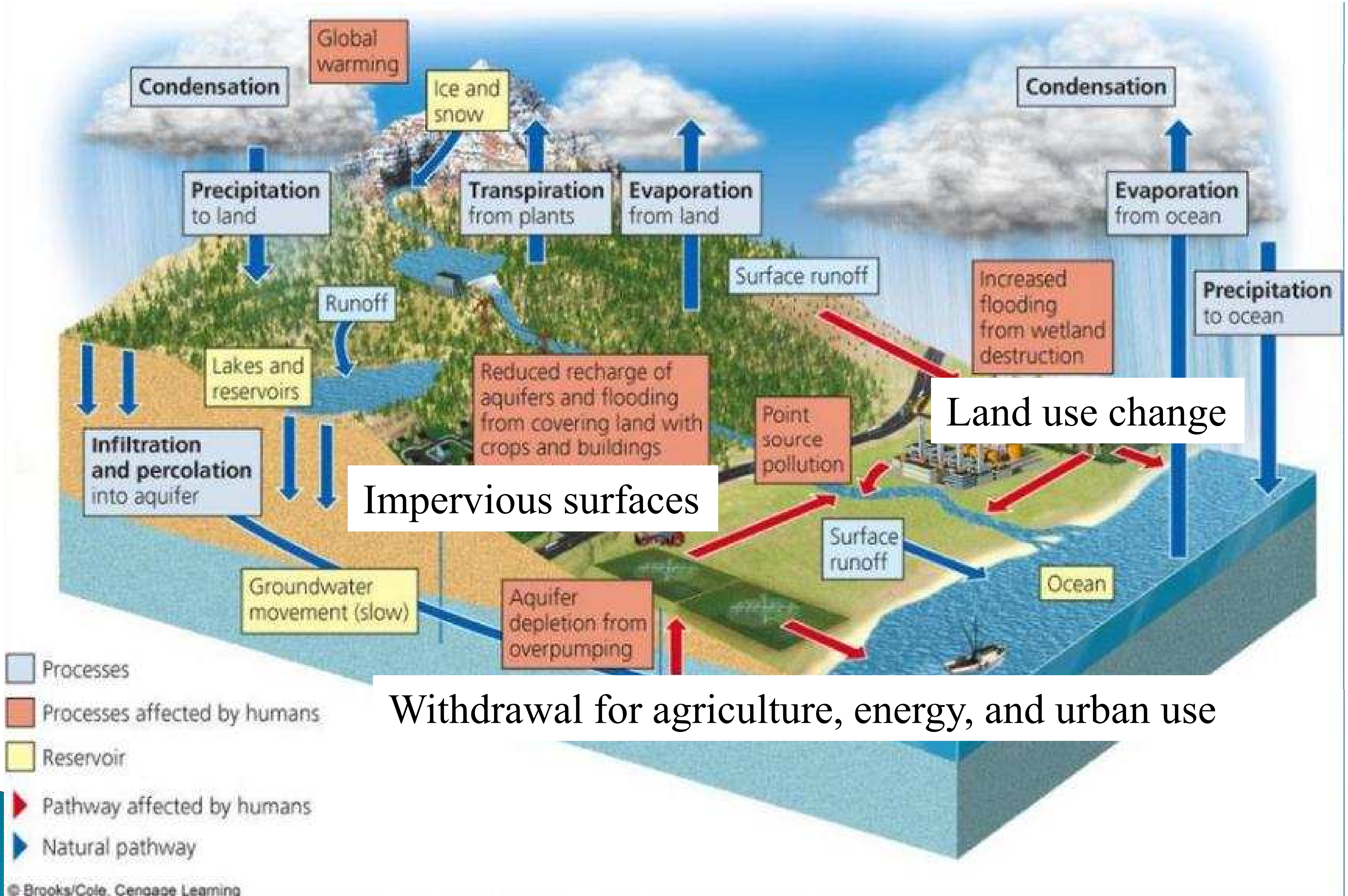


Tracing these cycles helps to understand how we have modified them

Hydrological Cycle – natural

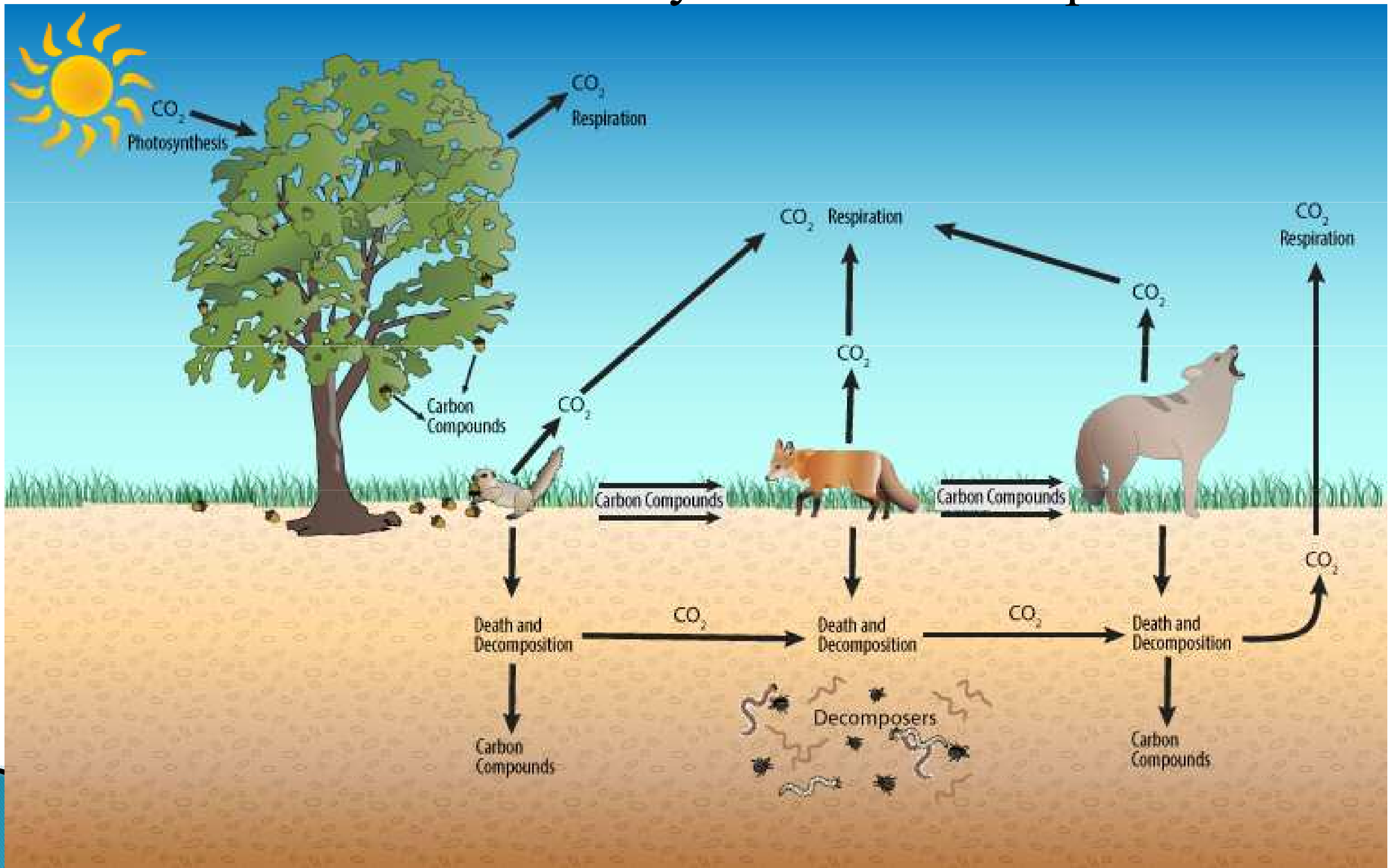


Hydrological Cycle – human impact



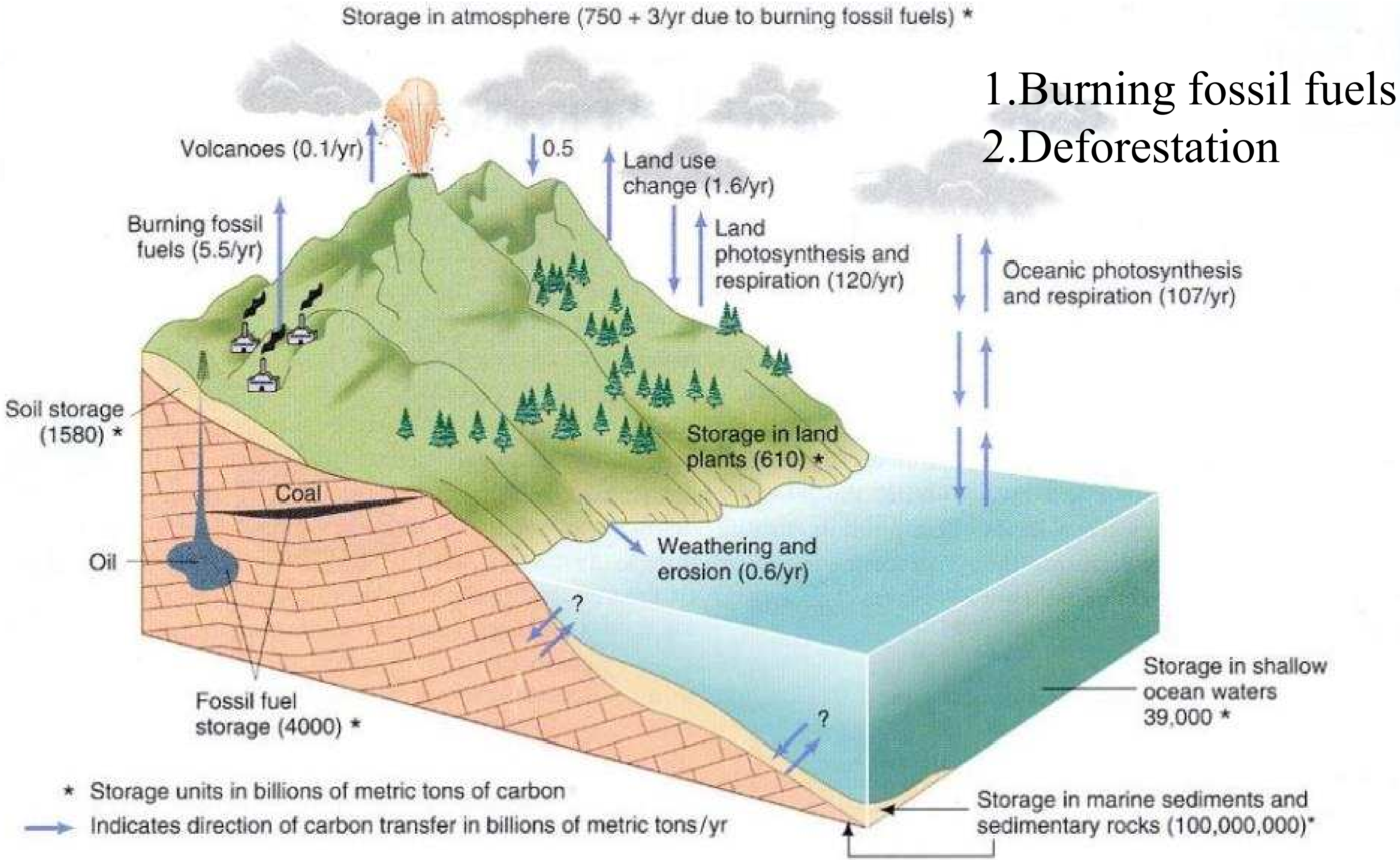
Carbon Cycle – natural

Photosynthesis ←→ respiration

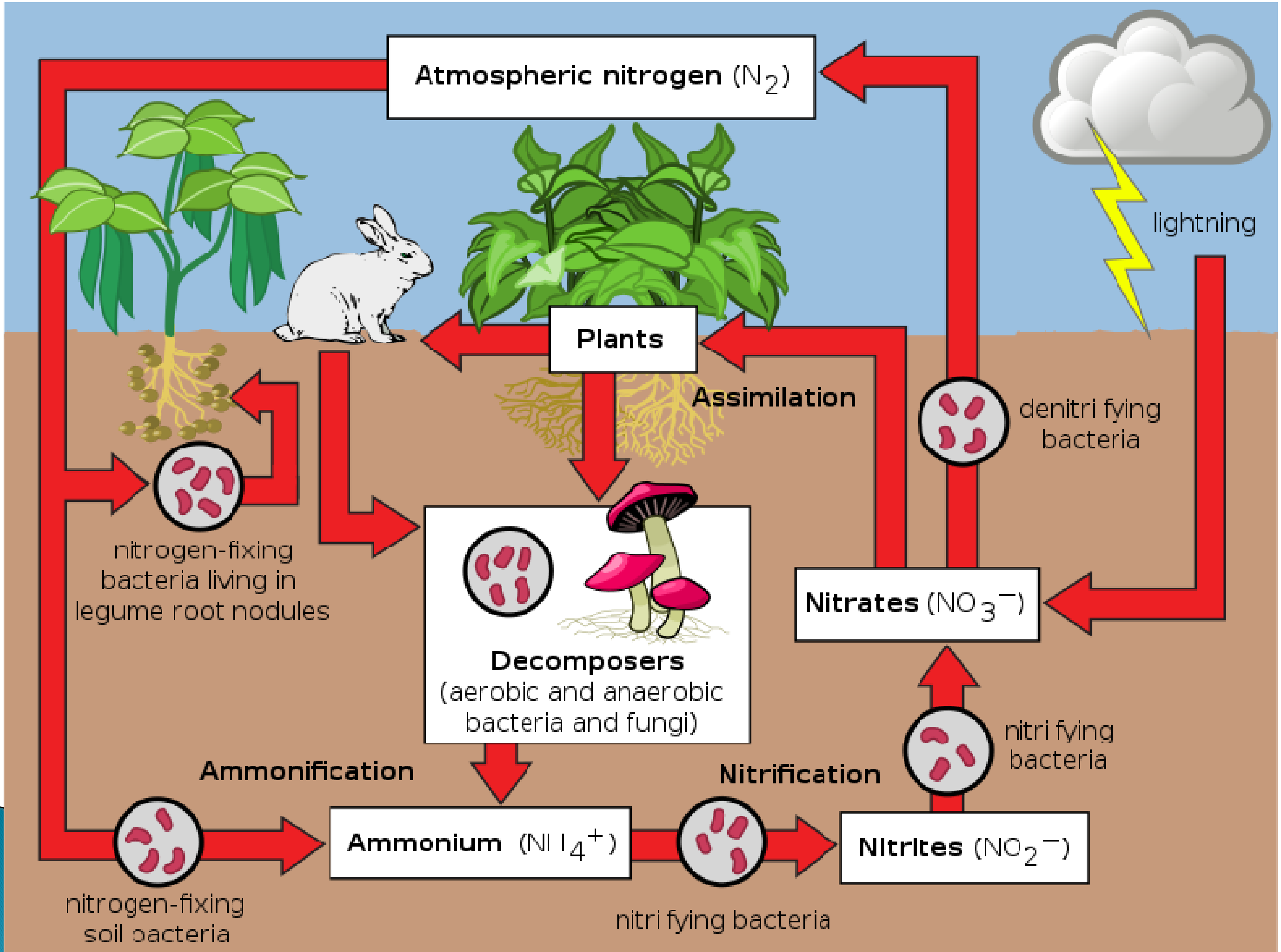


Carbon Cycle – human impact

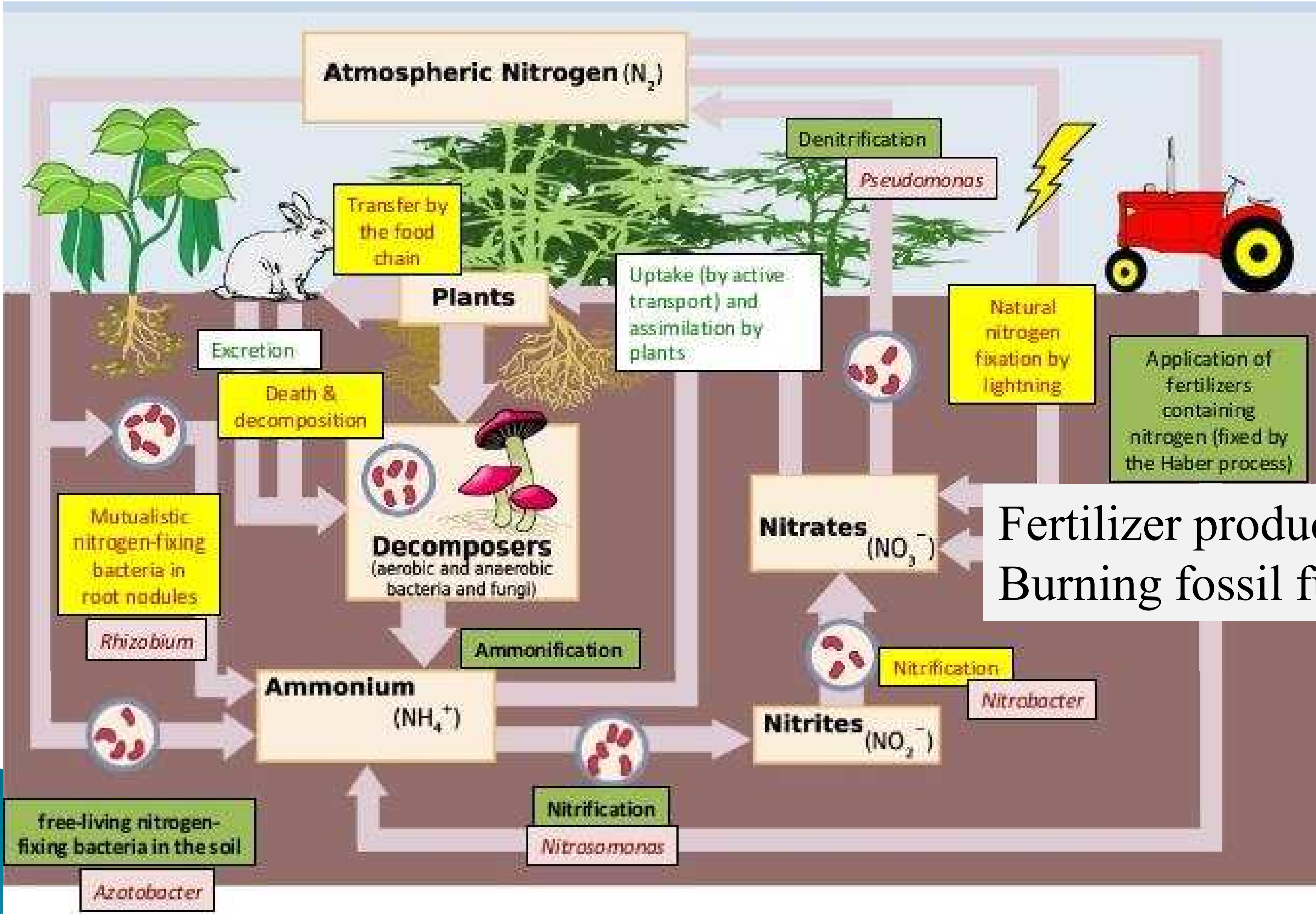
1. Burning fossil fuels
2. Deforestation



Nitrogen Cycle –natural

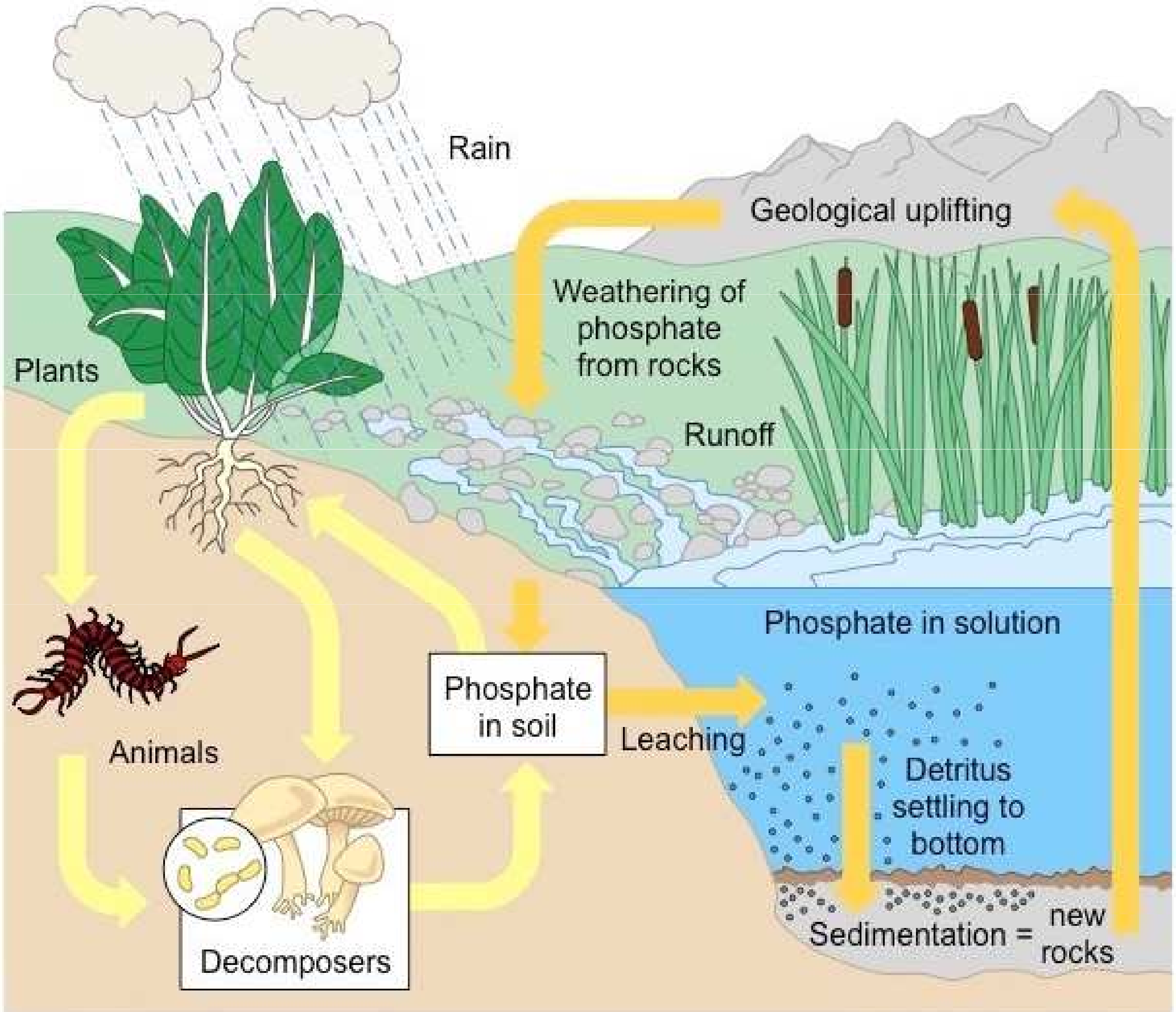


Nitrogen Cycle – human impact



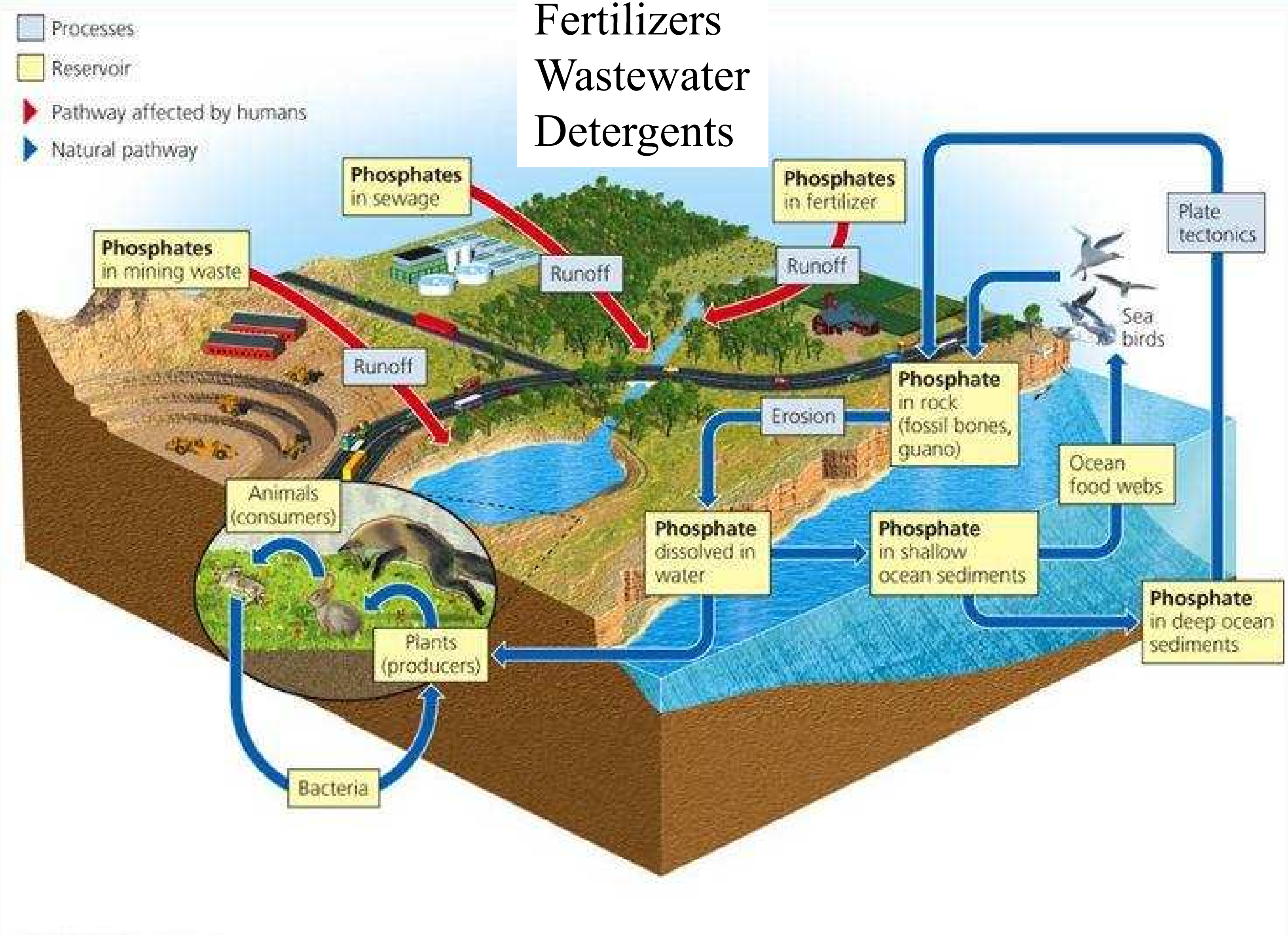
Fertilizer production
Burning fossil fuels

Phosphorus Cycle – natural



Phosphorus Cycle – human impact

Fertilizers
Wastewater
Detergents

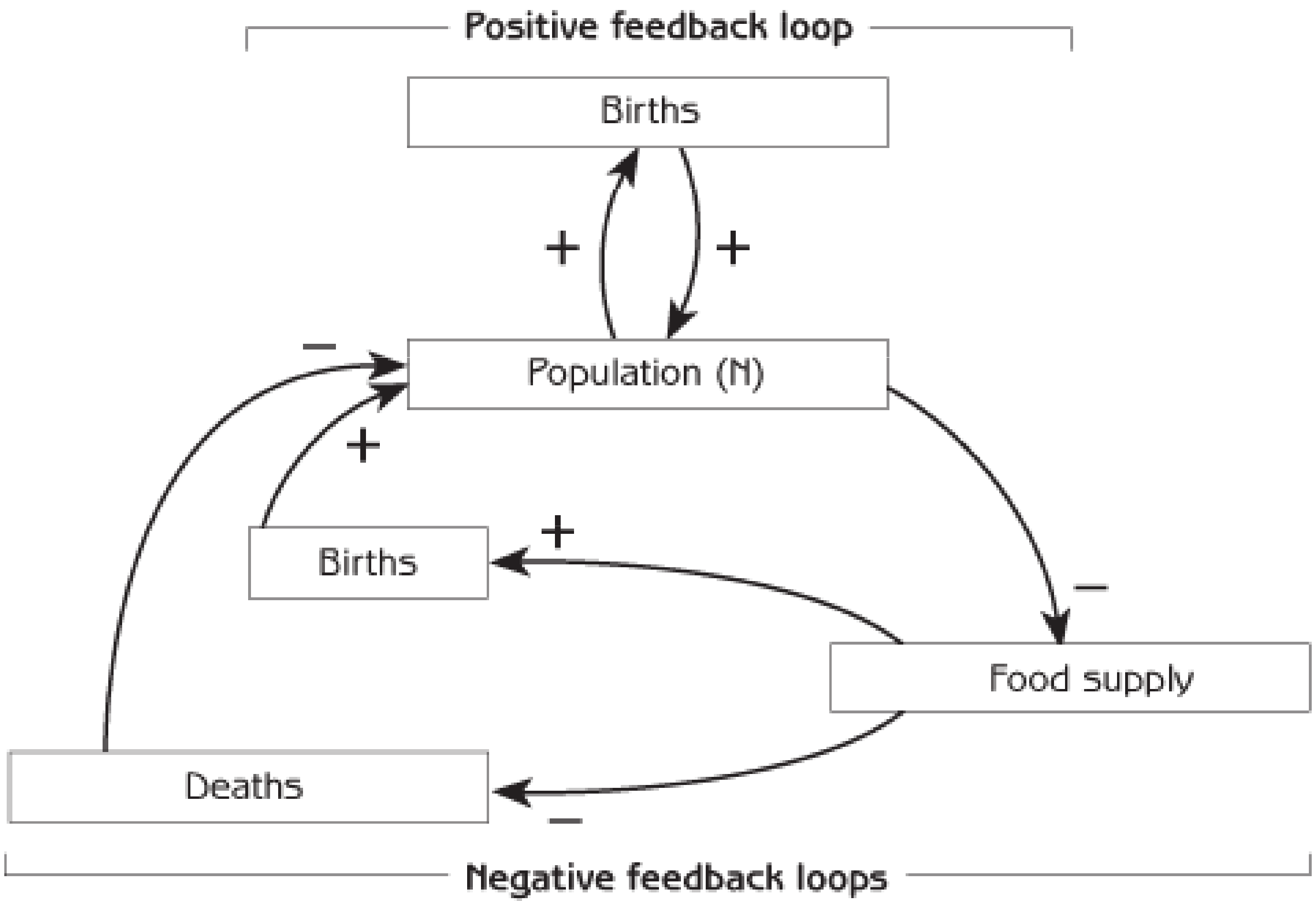


FEEDBACK as a consequence of interconnections

Ecological Systems possess capacity for

(a) self-regulation: negative feedback - deviation damping, stabilizing

(b) self-adaptation: positive feedback - deviation-amplifying, destabilizing



Ecosystems are dynamic

Biological systems are characterized by a capacity for *directional change* – the cumulative manifestation of positive feedback.

Succession – ordered pattern of growth and development

Increase in complexity and order as the result of controlled growth – decrease internal entropy

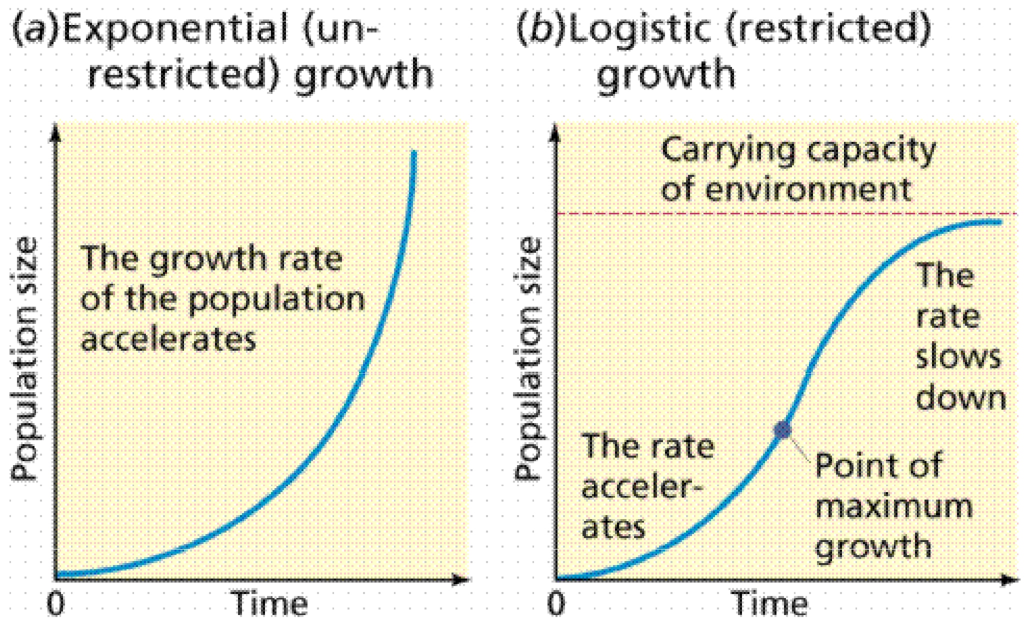
Population dynamics

Unconstrained Growth

$$\frac{dx}{dt} = rx$$

Constrained Growth
(environmental resistance)

$$\frac{dx}{dt} = rx\left(1 - \frac{x}{K}\right)$$

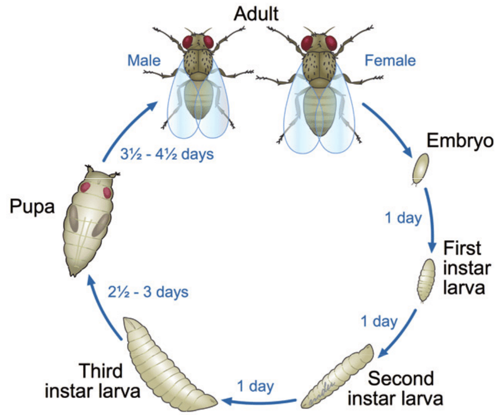


Density dependent mechanisms (negative feedback)

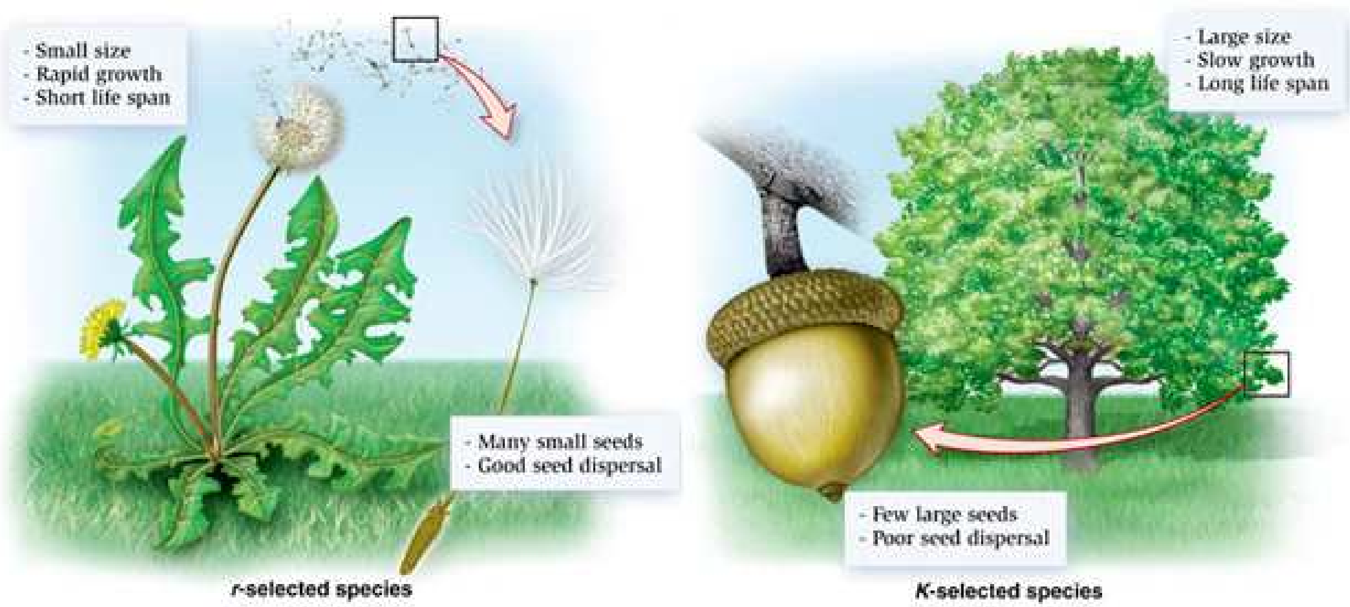
As population ↑, increasing mortality or decreasing birth rate
As population ↓, decreasing mortality or increasing birth rate

Community and Ecosystem Dynamics

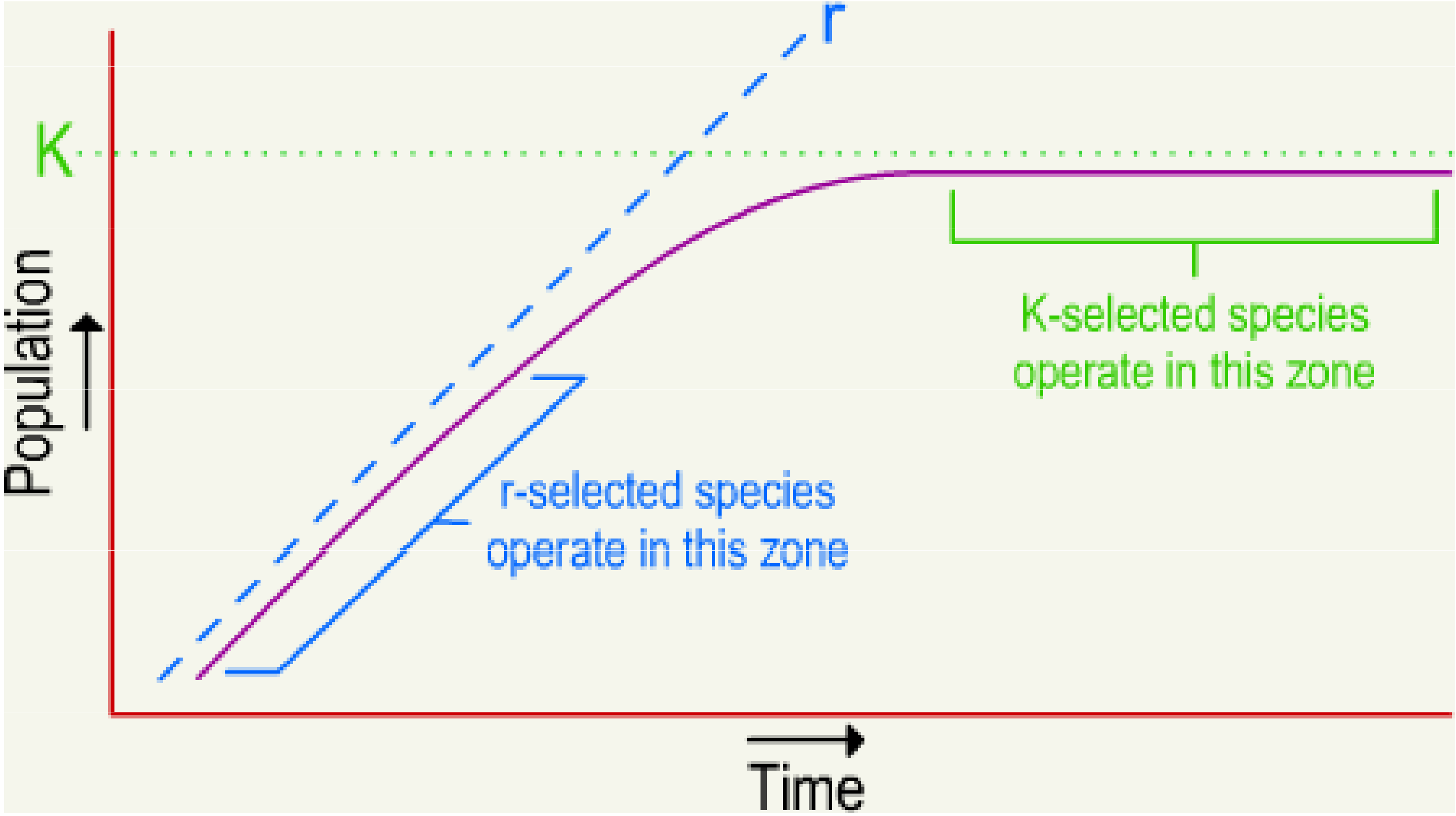
r species (ability to reproduce rapidly), fast growing, effective dispersal mechanisms, wind borne seeds, short lived, vegetative or asexual reproduction, do not compete well with other species, numbers fluctuating widely, strong influence of density-independent factors



K species (ability to maintain populations at their carrying capacity) species, slow growing, low reproductive rates, low dispersal rates, time lag to sexual maturity, diverting production or energy to defense.



Succession



Early stage

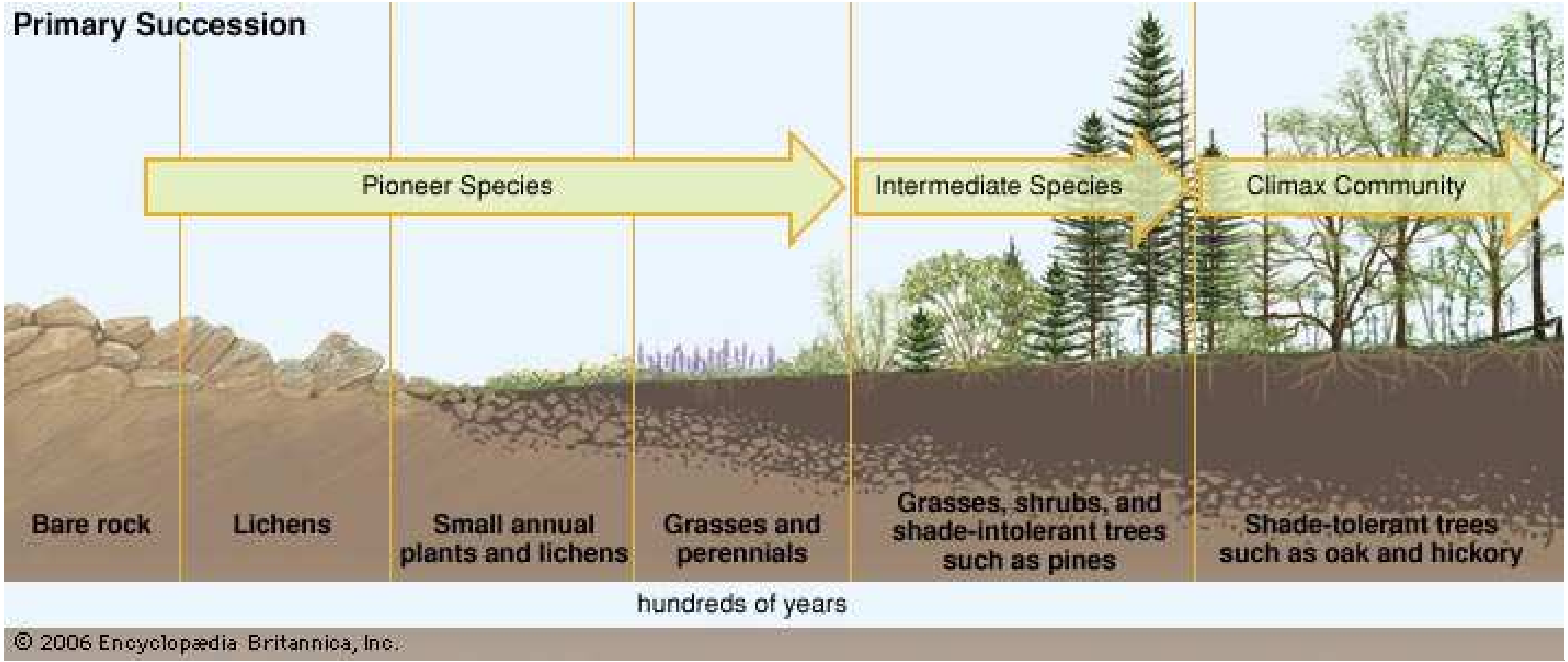
Late stage

These are paralleled by two distinct environments:
r-selecting environments – ephemeral, extreme, unpredictable
K-selecting environments – equable, predictable, stable.

Succession

Mature communities with the highly developed interdependence of their constituent species and their complex network of interaction with the environment are the result of inherent processes of change – directional change akin to the growth and development of the organism.

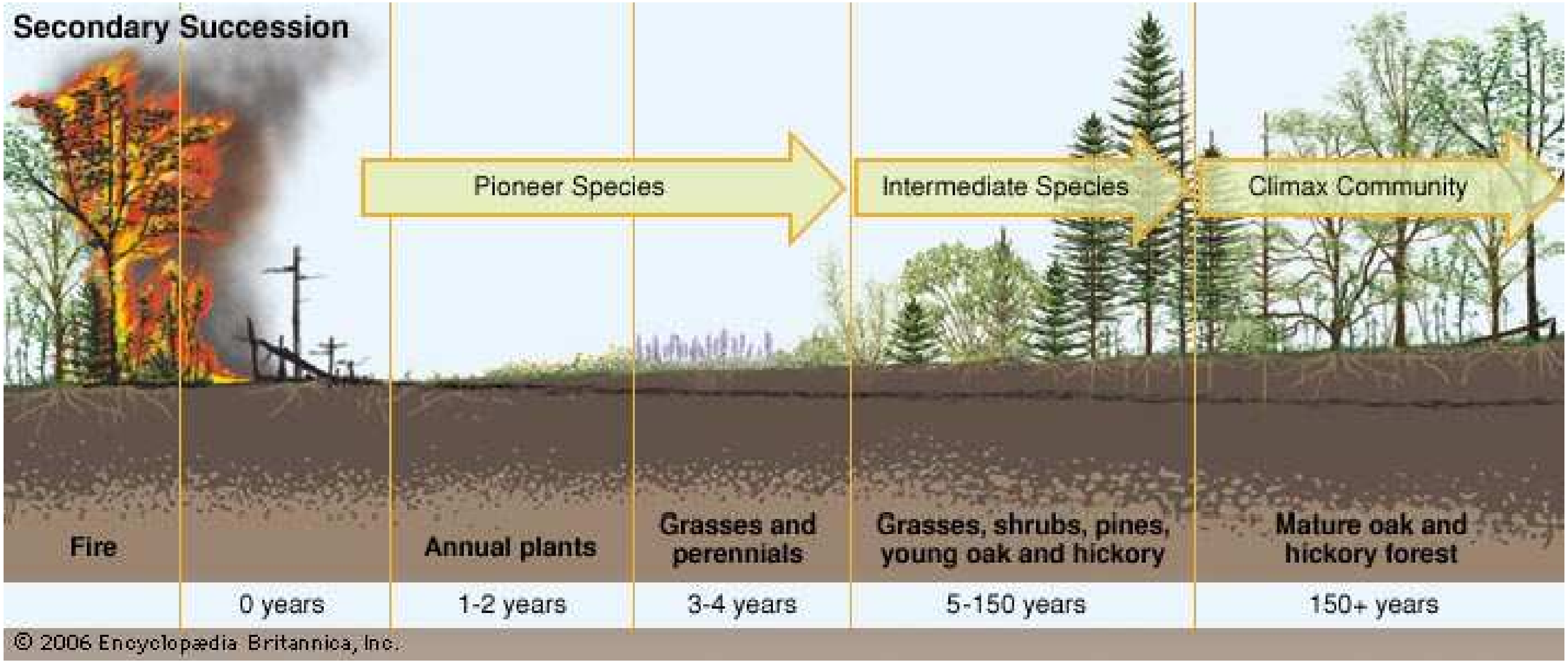
Organisms modify their environment, but in such a way as to allow other species to enter the community. This is the facilitation model of succession, a positive feedback process reinforcing change.



Primary succession – initial establishment and development of an ecosystem in an area devoid of an ecological community

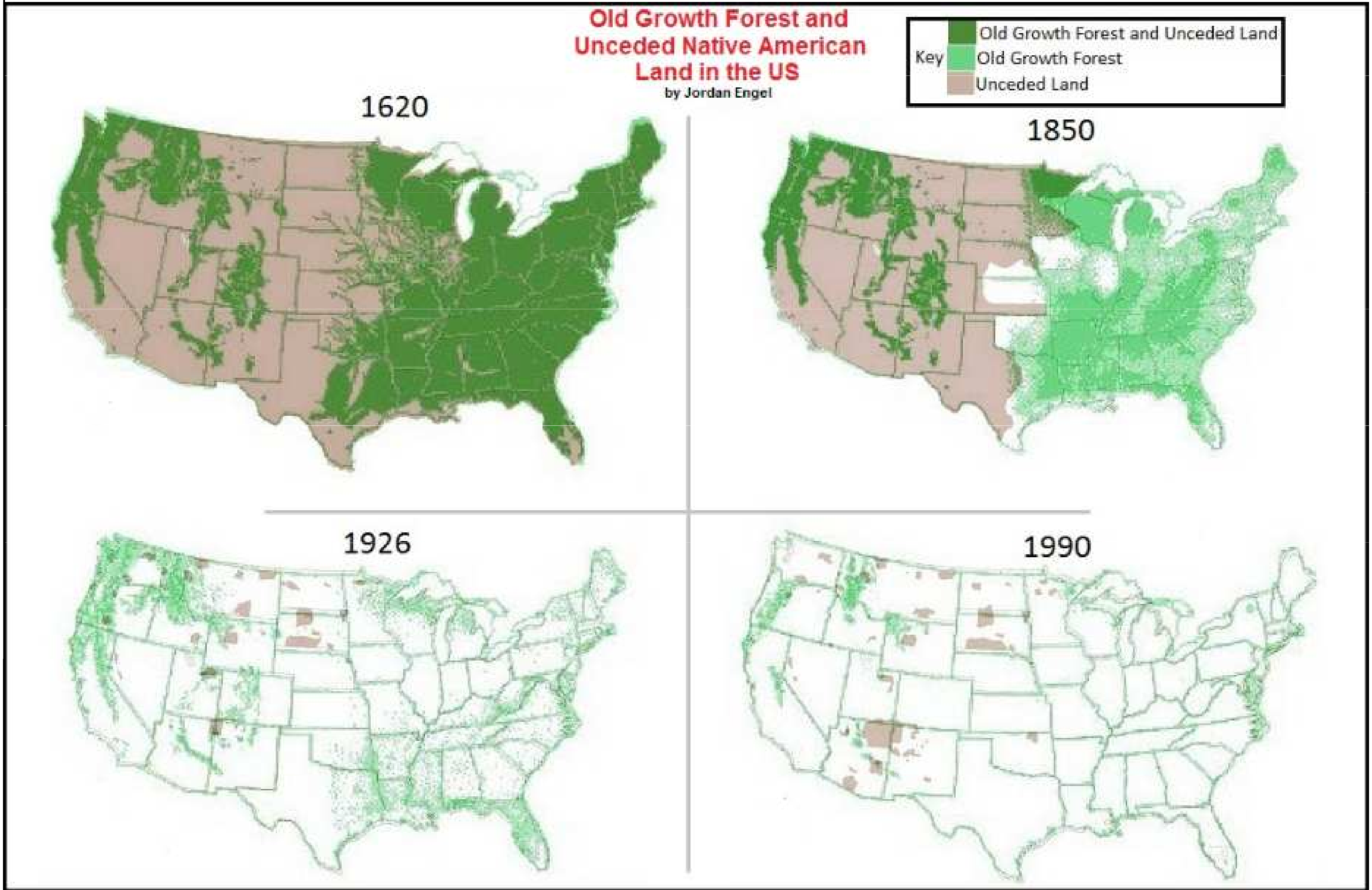
Primary succession

Island formation; dune formation, glacier retreat



Secondary succession – reestablishment of an ecosystem from the remnants of a previous biological community following disturbance

Almost all old growth forests have been cleared in the US



Boreal forest one year and two years after a wildfire

a. During the first year, only the remains of corn plants are seen.

b. During the second year, wild grasses have invaded the area.

c. By the fifth year, the grasses look more mature, and sedges have joined them.

d. After twenty years, the juniper trees are mature, and there are also birch and maple trees in addition to the blackberry

Secondary succession

Secondary succession

Human induced succession – agriculture, forestry, plowing, mining, fisheries, damming rivers, war, etc.

Towards establishment of a climax state

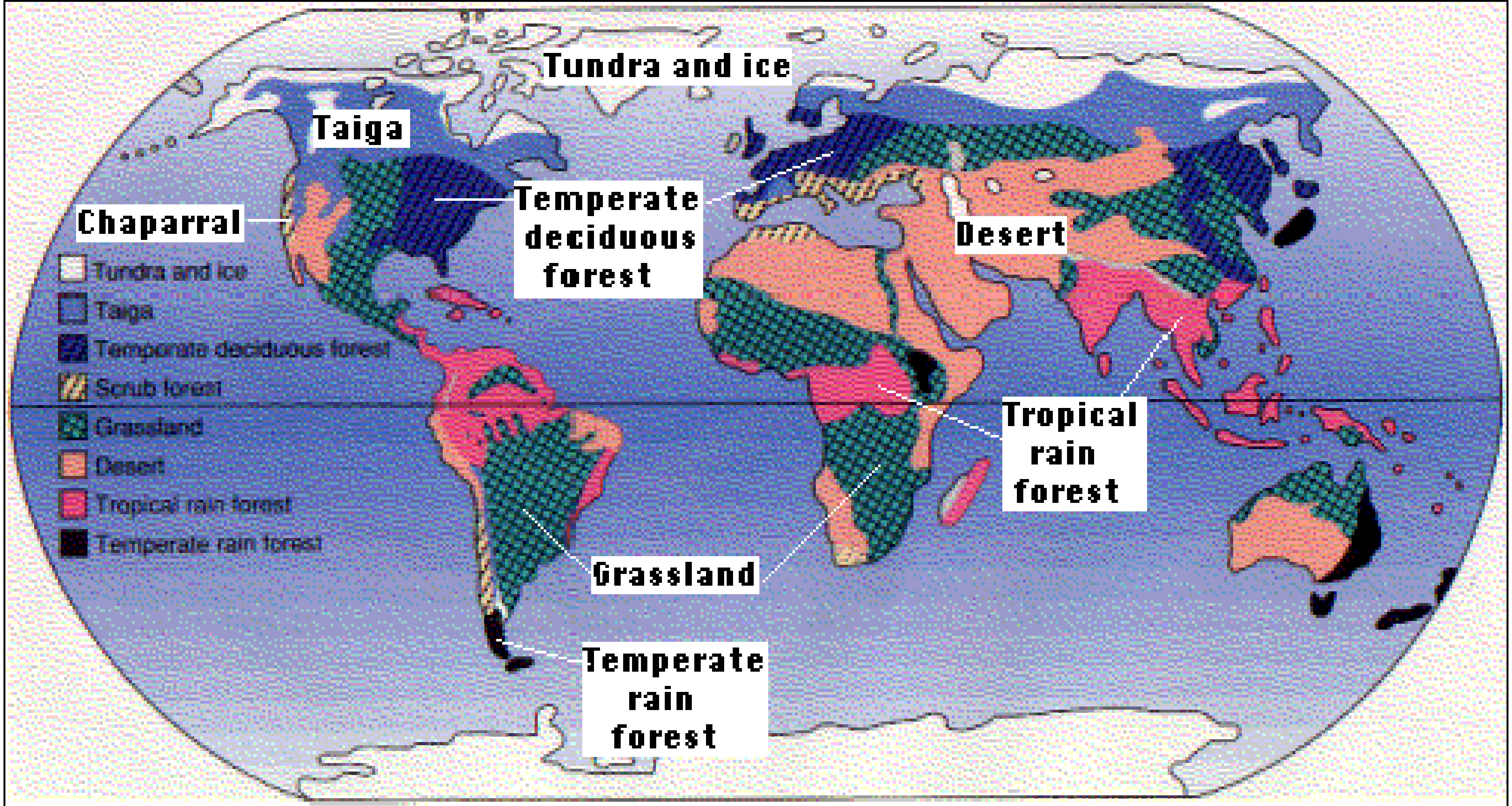
- organic matter increases
- development of soil
- balancing of weathering
- soil chemistry reaches a balance
- water and drainage patterns established
- climate is modified by microclimate
- diversification and segregation of ecological niche
- development of negative feedback loops

During Succession – how nature restores itself

Organisms modify their environment in such a way as to allow other species to enter the community. A positive feedback process reinforcing change.

Development leads to co-development

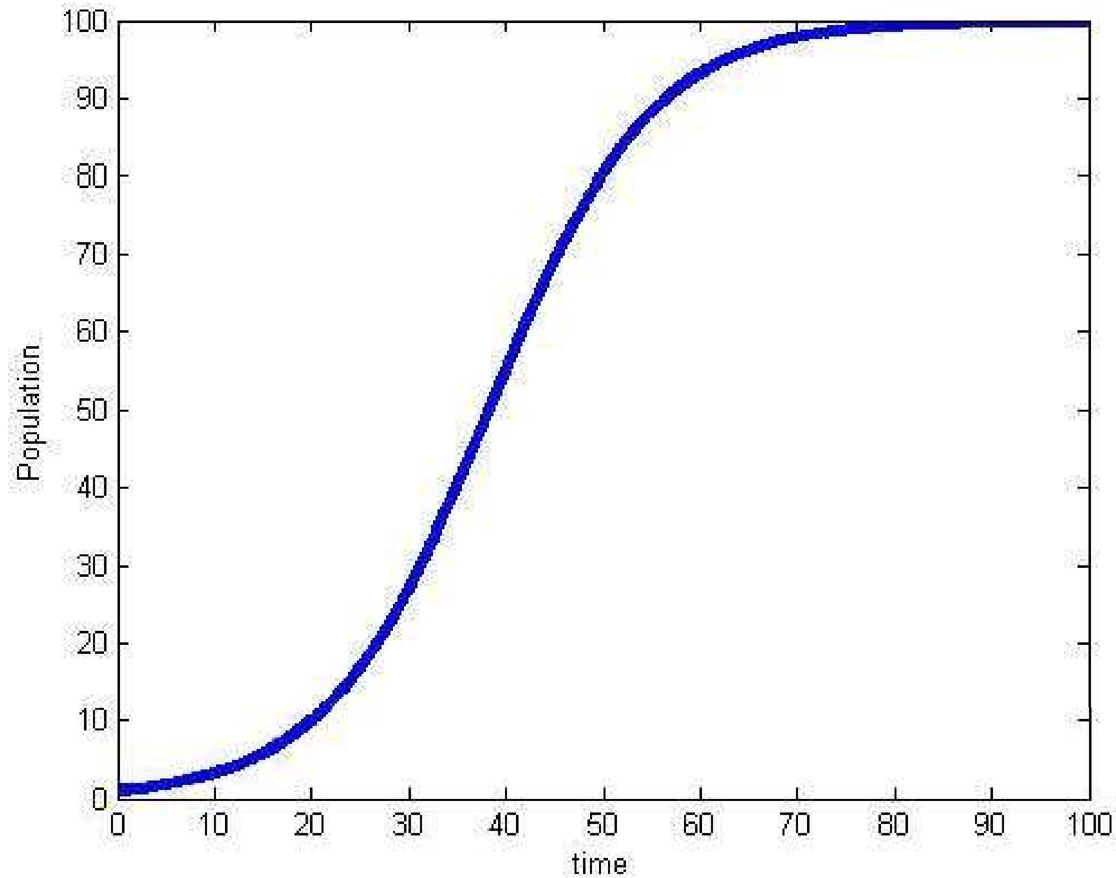
Biodiversity begets biodiversity – the tree is habitat for many more organisms



Biomes of the world

How do systems change over time?

Logistic growth from early to late successional stages



Trends to be expected in ecosystem development (Odum 1969)

Ecosystem Attribute	Developmental Stage	Mature Stage
<u>Community energetics</u>		
Gross production/community respiration (P/R ratio)	>1	~1
Gross Production/standing crop biomass (P/B ratio)	high	low
Biomass supported/unit energy flow (B/E ratio)	low	high
Food chains	linear	weblike
<u>Nutrient cycling</u>		
Mineral cycles	open	closed
Nutrient exchange rate	rapid	slow
Nutrient conservation	poor	good
<u>Overall homeostasis</u>		
Stability (resistance to external perturbations)	poor	good
Entropy	high	low
Information	low	high

Bioenergetic model of succession

In early stages of succession, P>R and excess is channeled into growth and accumulation of biomass.

Increase capacity and complexity of the energy storage compartments (total biomass of all species and trophic levels) as well as the complexity of energy transfer pathways.

In late stages of succession, P=R as maintenance costs increase respiration

Negative feedback maintains steady state, with little or no change in biomass (network, feedback, cycling).

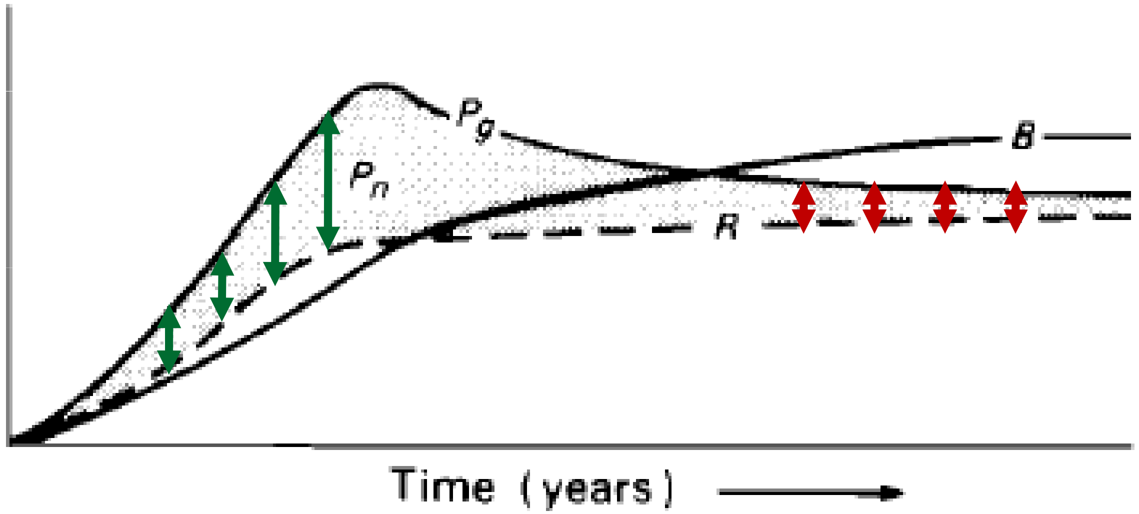


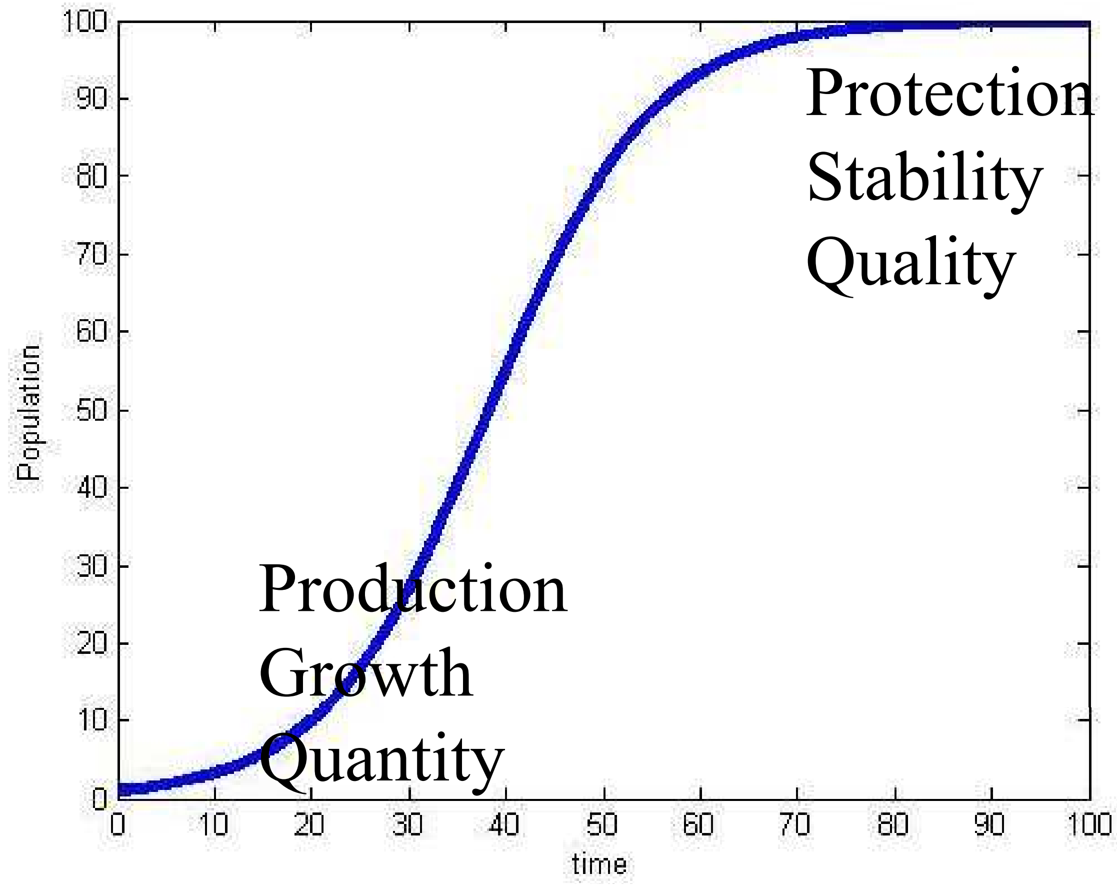
Fig. 25.17 Changes in gross (P_g) and net (P_n) production, respiration (R) and biomass (B) through succession.

Odum, EP 1969
Strategy of Ecosystem Development

Table 2. Contrasting characteristics of young and mature-type ecosystems.

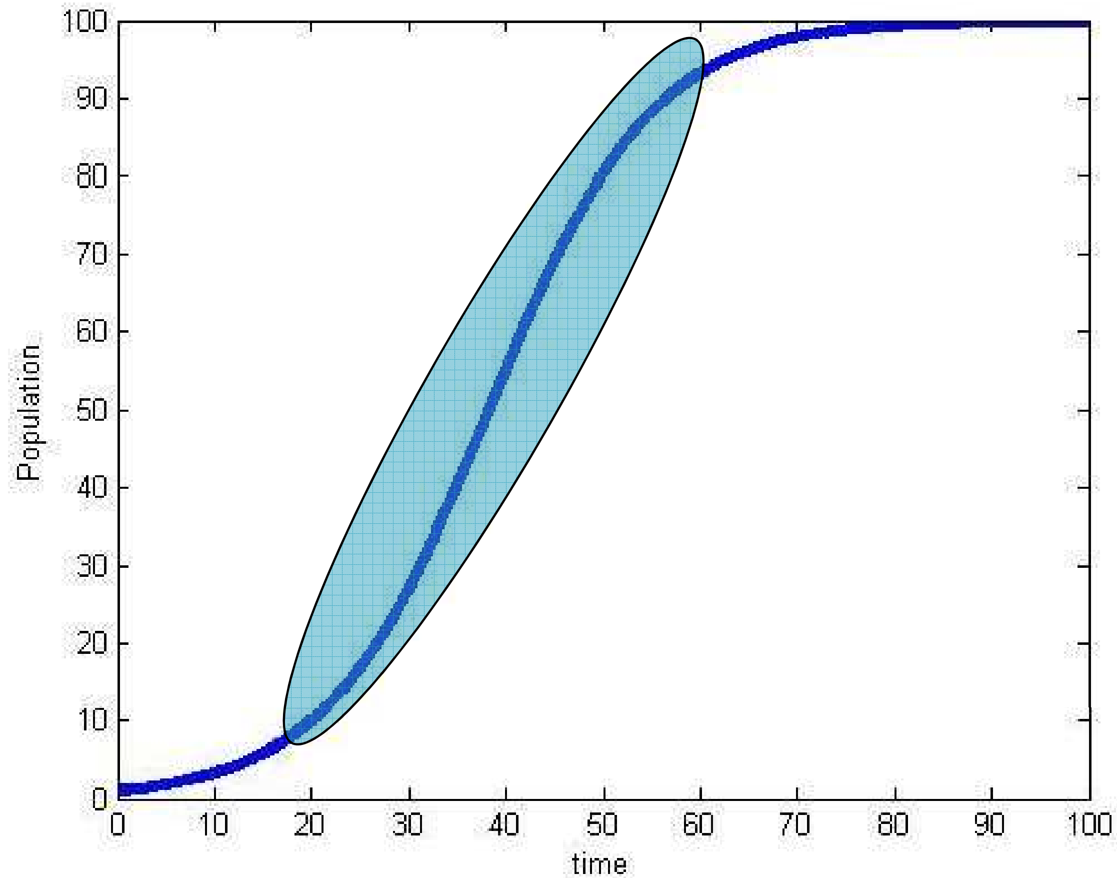
Young	Mature
Production	Protection
Growth	Stability
Quantity	Quality

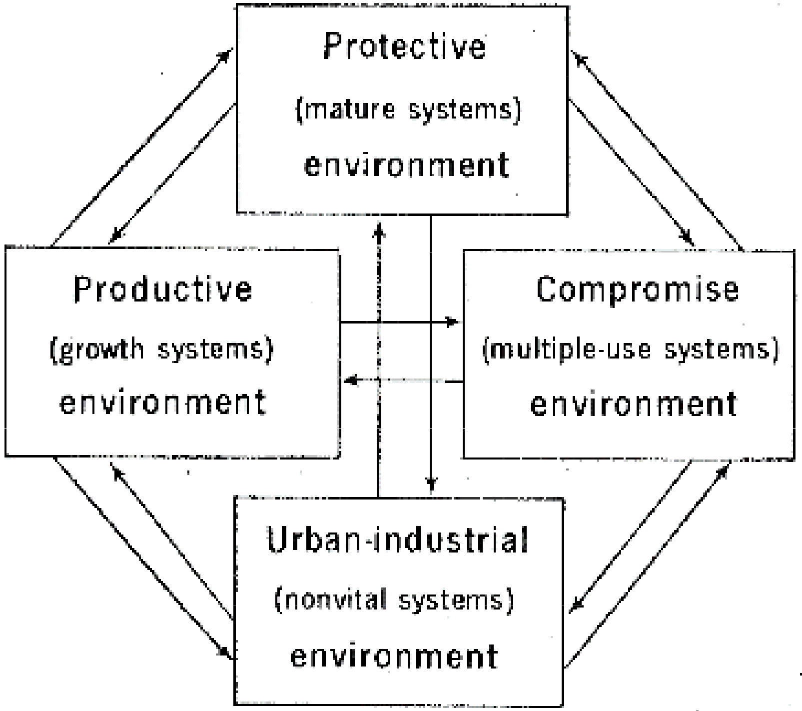
Logistic growth from early to late successional stages



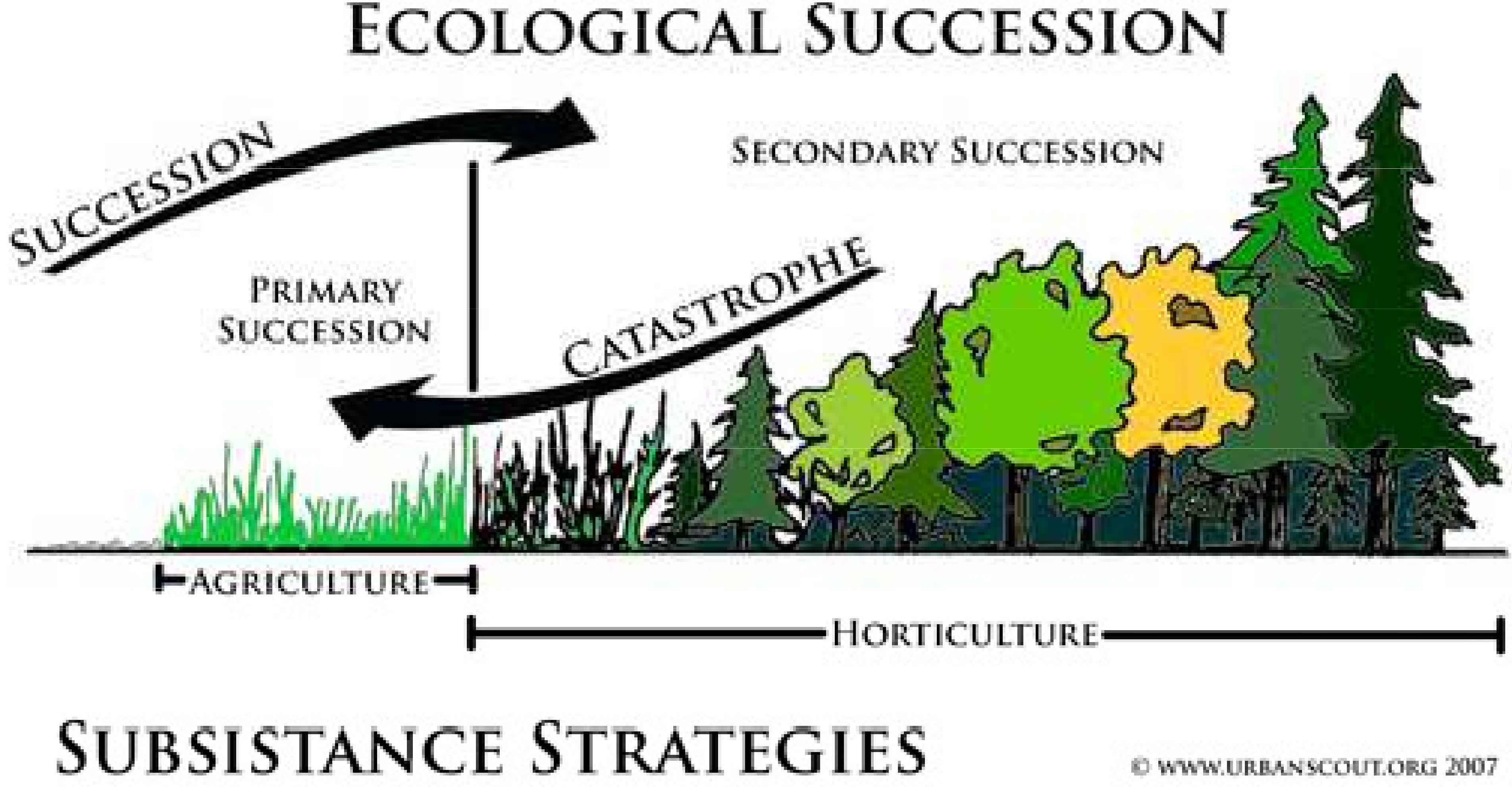
Ecosystem services are extracted to exploit growth phase

Human induced succession – deforestation, agriculture– moves the system back to earlier stage.



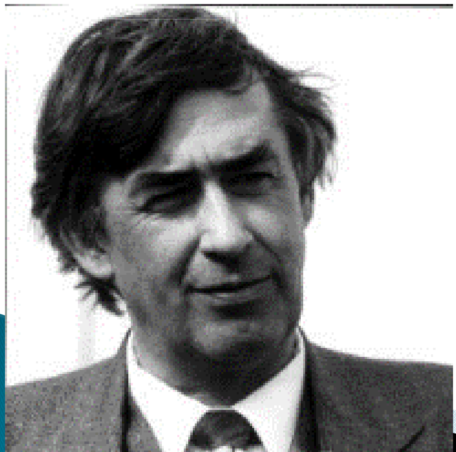


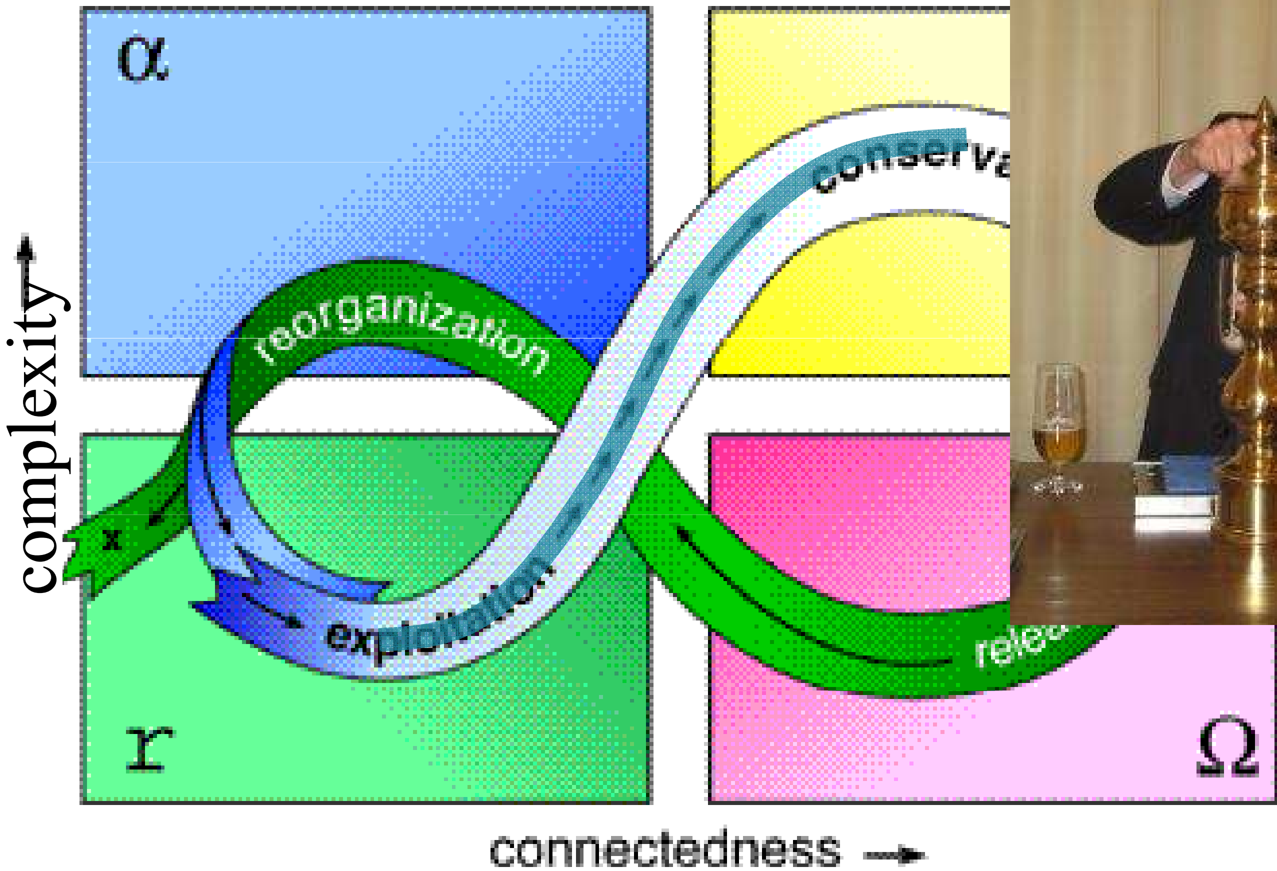
Compartment model of the basic kinds of environment required by humans partitioned according to ecosystem development

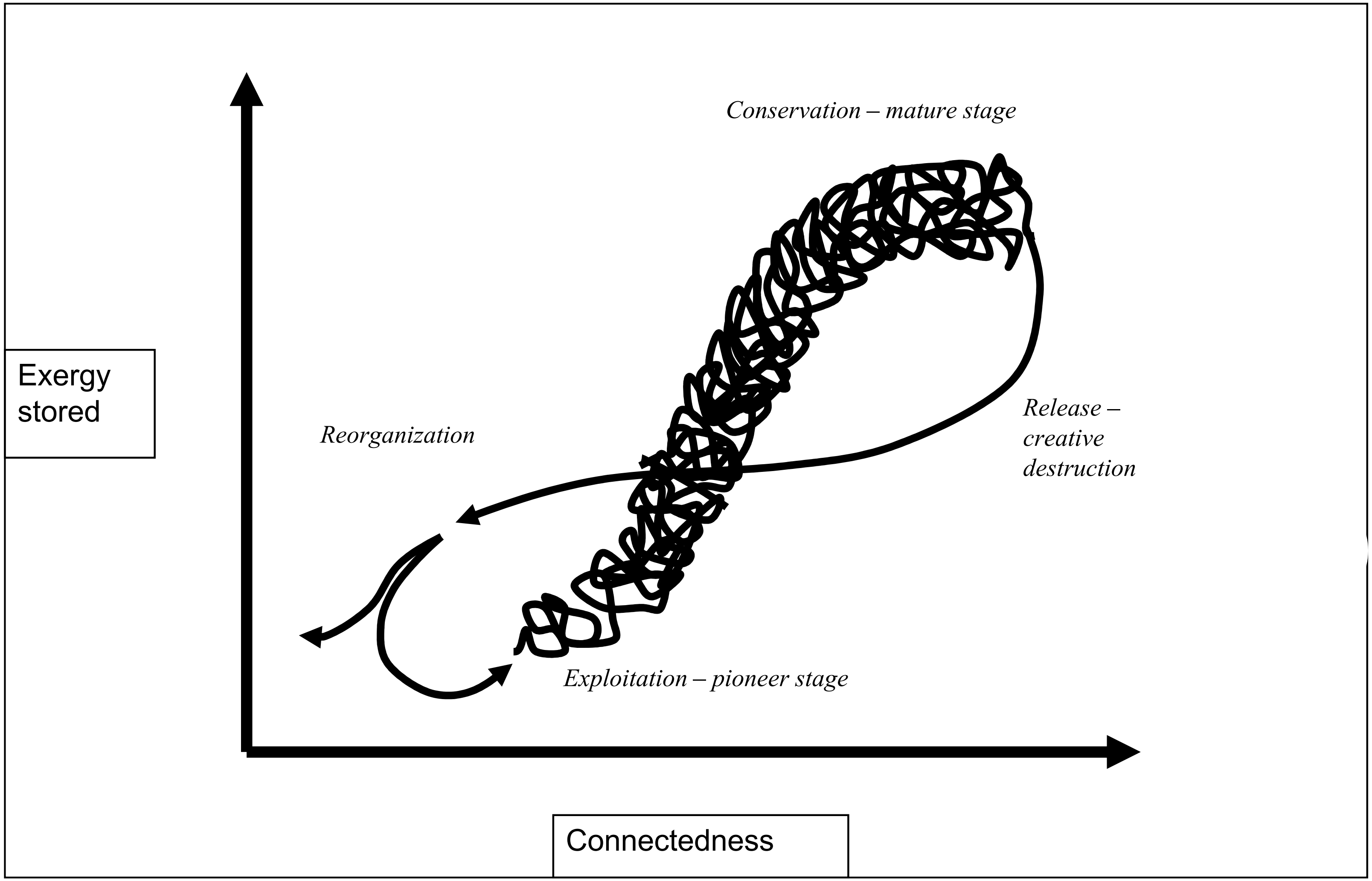

ECOLOGICAL SUCCESSION
SUCCESSION
SECONDARY SUCCESSION
PRIMARY SUCCESSION
CATASTROPHE
AGRICULTURE
HORTICULTURE
SUBSISTANCE STRATEGIES
© WWW.URBANSCOUT.ORG 2007

Complex Systems Cycle: Holling's 4-stage model of ecosystem dynamics

Logistic growth only captures part of the cycle

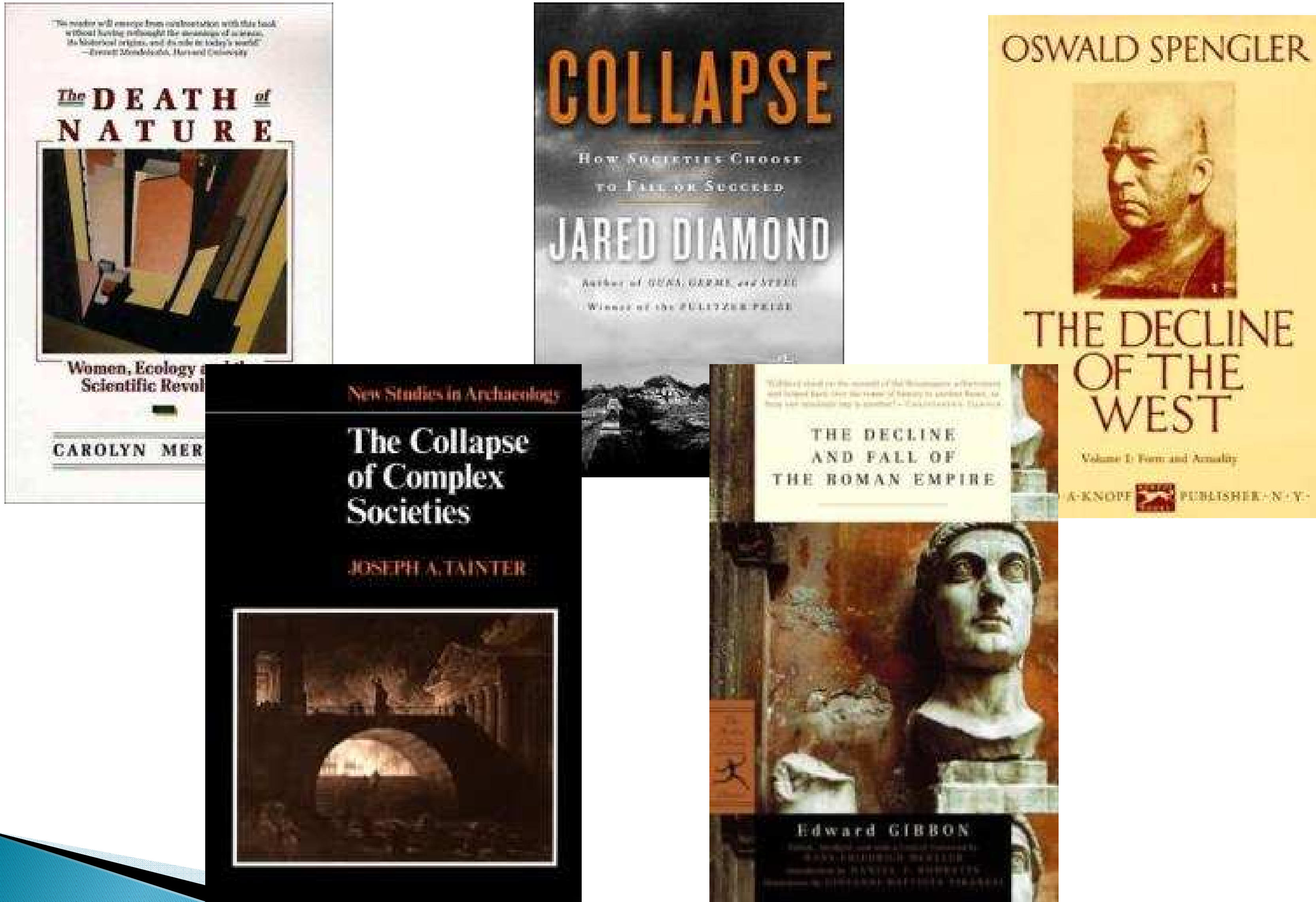






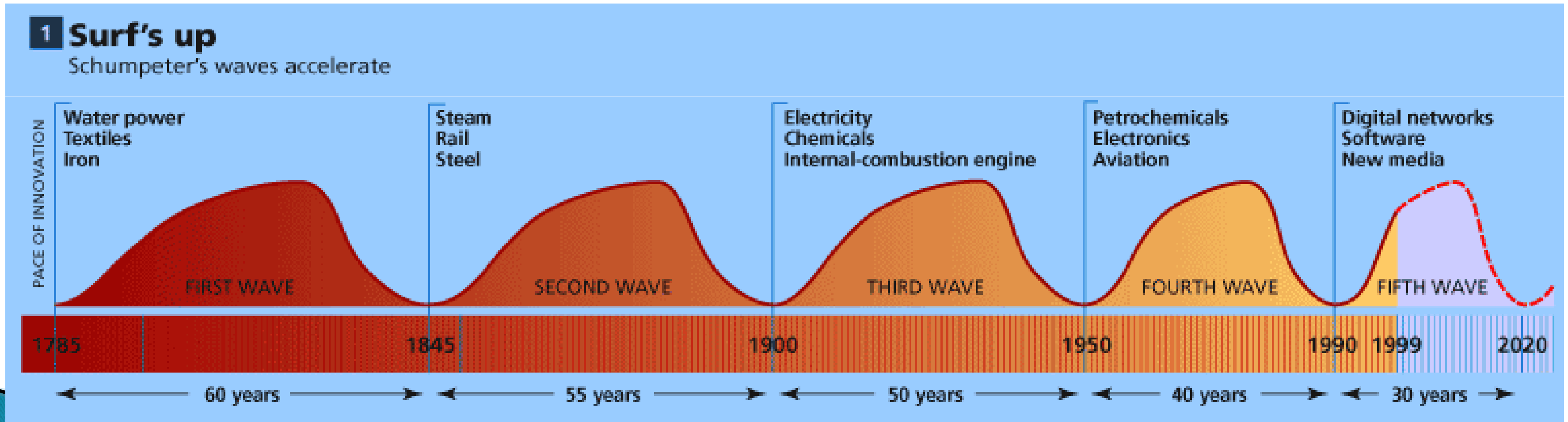
Ecosystem succession in the collapse dynamic

All systems show signs of complex growth and **DECAY** dynamics

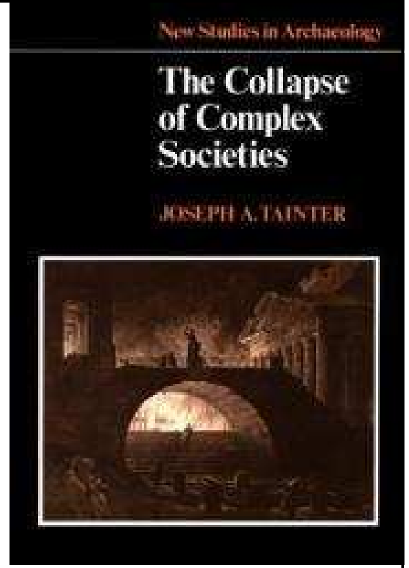


Benefits of collapse

- Schumpeter labeled the collapse, “creative destruction”, since it allowed for new configurations and innovation opportunities



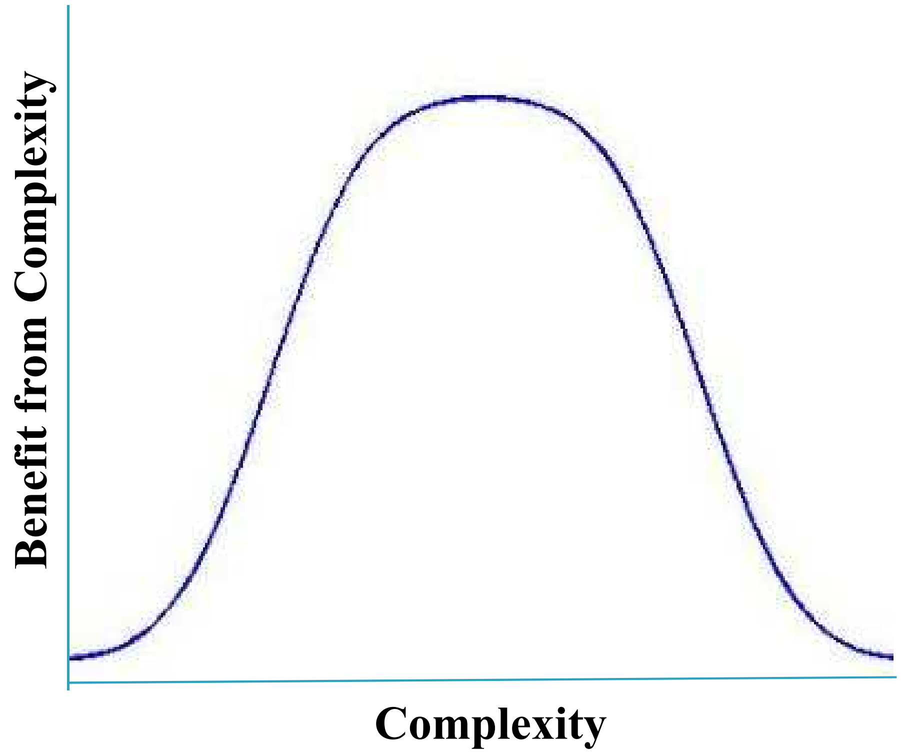
Collapse of Complex Societies (Tainter 1988)

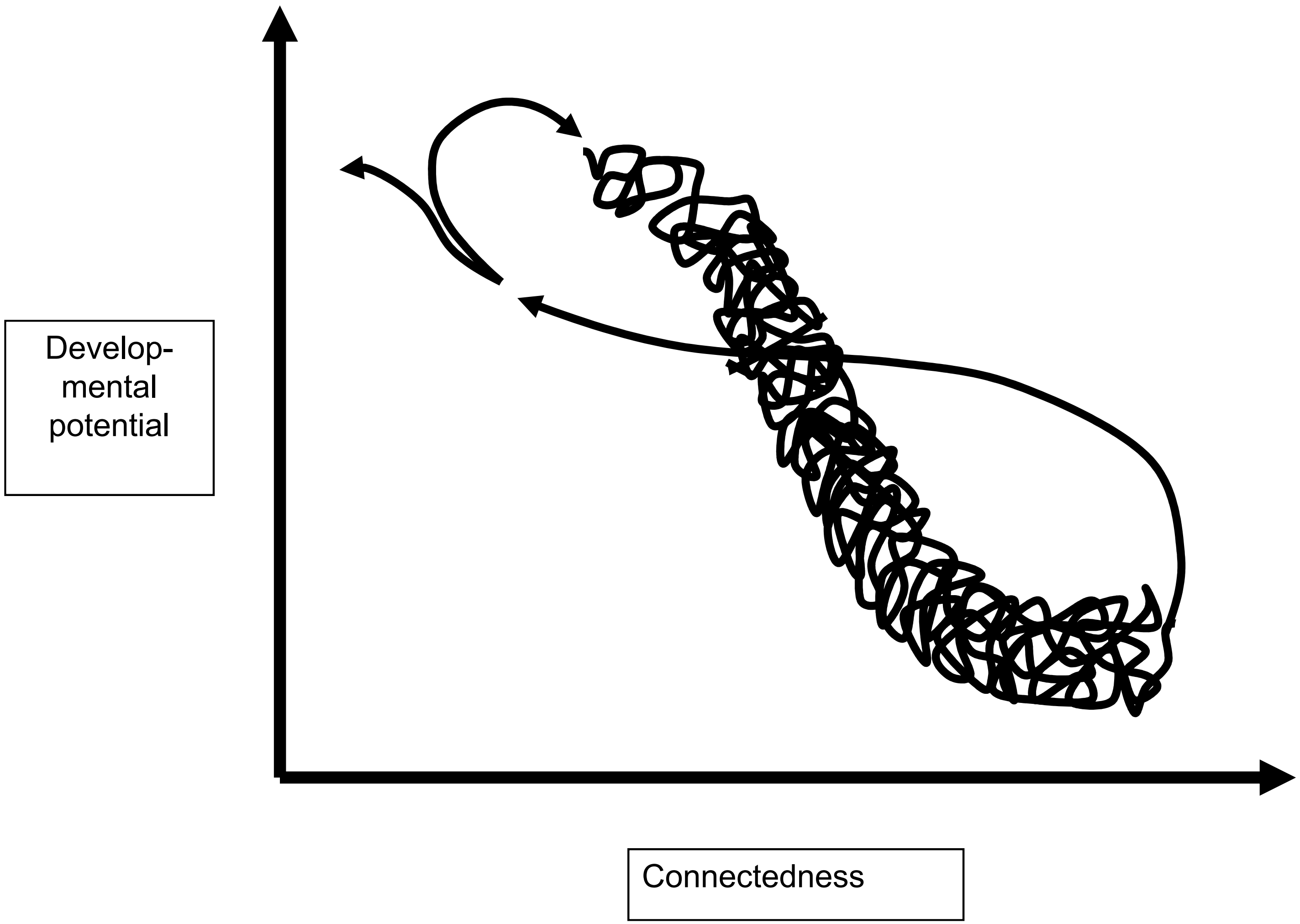


Complexification is limited as a problem solving strategy.

"More complex societies are more costly to maintain than simpler ones… as societies increase in complexity, more networks are created among individuals, more hierarchical controls are created to regulate these networks, more information is processed … increasing need to support specialists not directly involved in resource production, and the like" (Tainter 1988).

Collapse is the appropriate response of the system

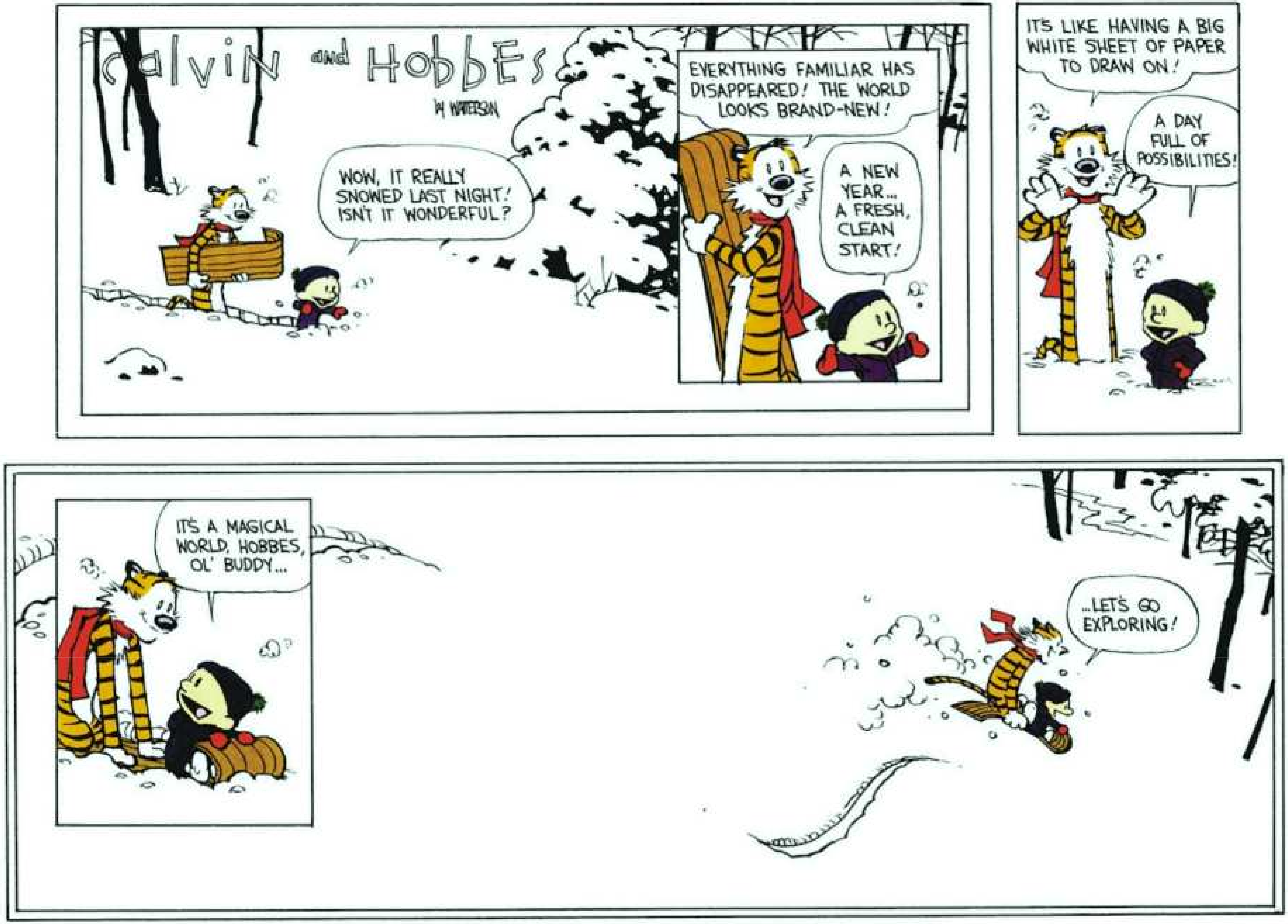




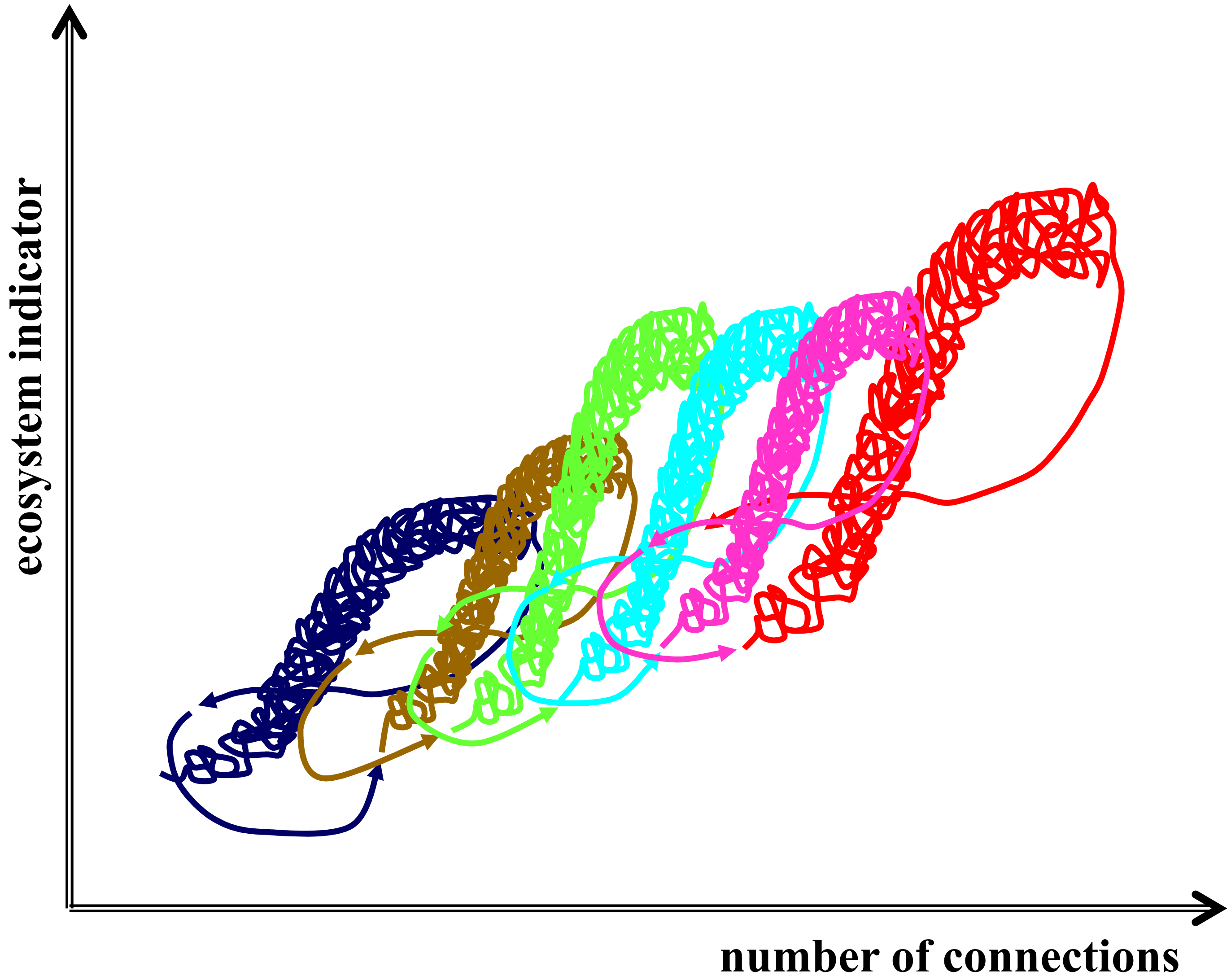
Developmental opportunities result from the collapse

Complex System Cycle – evidence from Late Bronze Age (~1177 BCE)

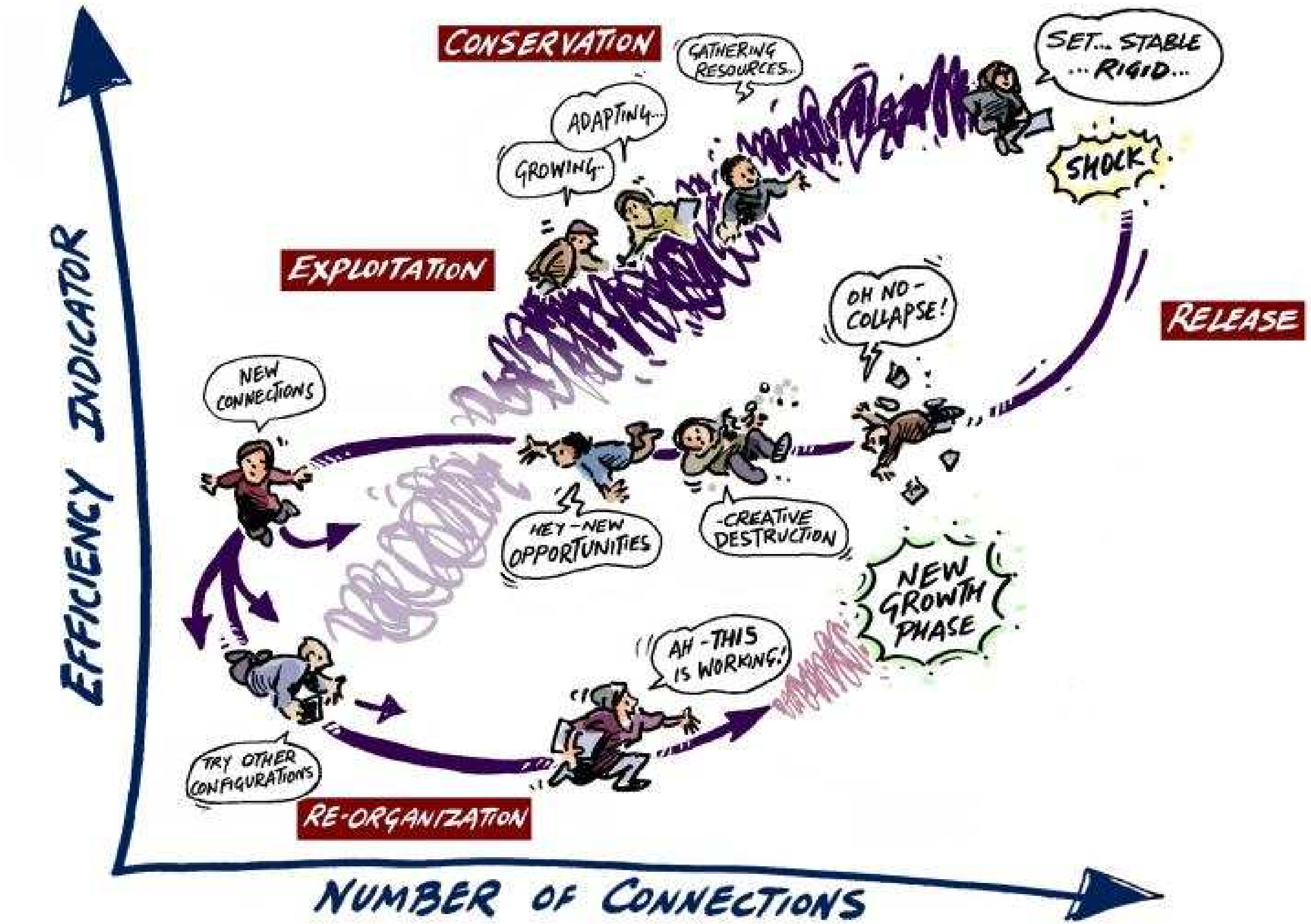
- Out of the ashes of the old world came inventions… It is a cycle that the world has seen time and again, and that many have come to believe is an inexorable process the rise and fall of empires, followed by the rise of new empires, which eventually fall and are replaced in turn by even newer empires, in a repeated cadence of birth, growth and evolution, decay or destruction, and ultimately renewal in a new form (Cline, 2014, p. 175)



DECEMBER 31, 1995



Long-term succession of ecosystems: small-scale disturbances may support the development of the overall system.


CONSERVATION
GATHERING RESOURCES...
SET... STABLE ...RIGID...
ADAPTING...
GROWING...
SHOCK
EXPLOITATION
OH NO-COLLAPSE!
RELEASE
NEW CONNECTIONS
HEY-NEW OPPORTUNITIES
-CREATIVE DESTRUCTION
NEW GROWTH PHASE
AH-THIS IS WORKING!
TRY OTHER CONFIGURATIONS
RE-ORGANIZATION
EFFICIENCY INDICATOR
NUMBER OF CONNECTIONS

Conclusions

- System dynamics include a collapse phase due to external perturbation or internal constraints
- Asymmetric relation between levels of organization give rise to functional hierarchies
- The new system that emerges is often able to build on the "seed bank" of the previous one
- How is this useful for understanding socio-ecological systems?