Ecosystems are sustained systems; they flourish within their limits

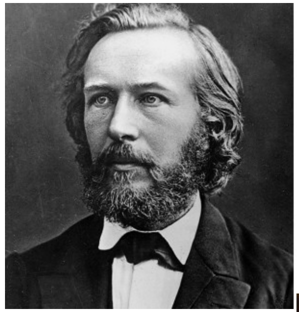
- Learning objectives
  - What is an ecosystem?
  - Understanding energy and its role in ecosystems
  - Food webs and trophic levels
  - How they change over time

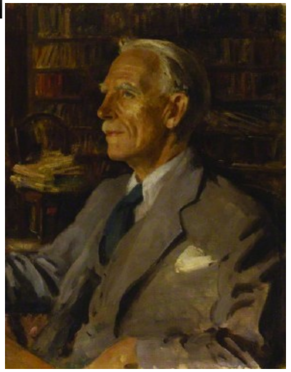
Definitions

- Biota – all living things within a given area
- Biosphere – the region of earth where life exists
- Ecosystems – community of organisms and its nonliving environment in which energy flows and matter cycles.

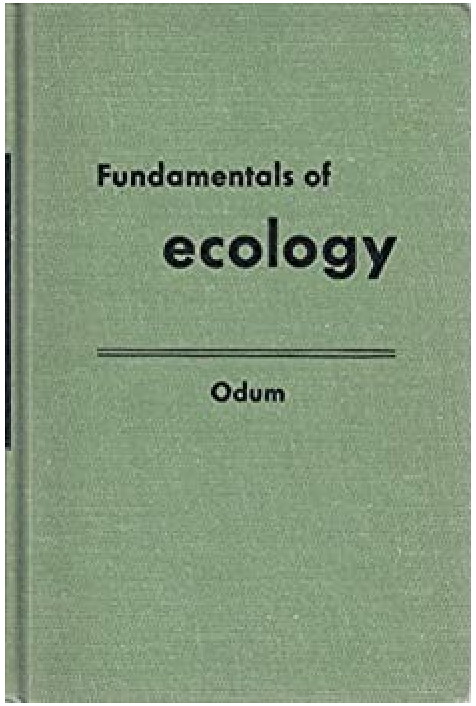
- What is needed to sustain life?
  - Sustained life on Earth is a characteristic of ecosystems. Earth as a system – no organism, population, or species can produce it own food and completely recycle it metabolic waste.

Ecology

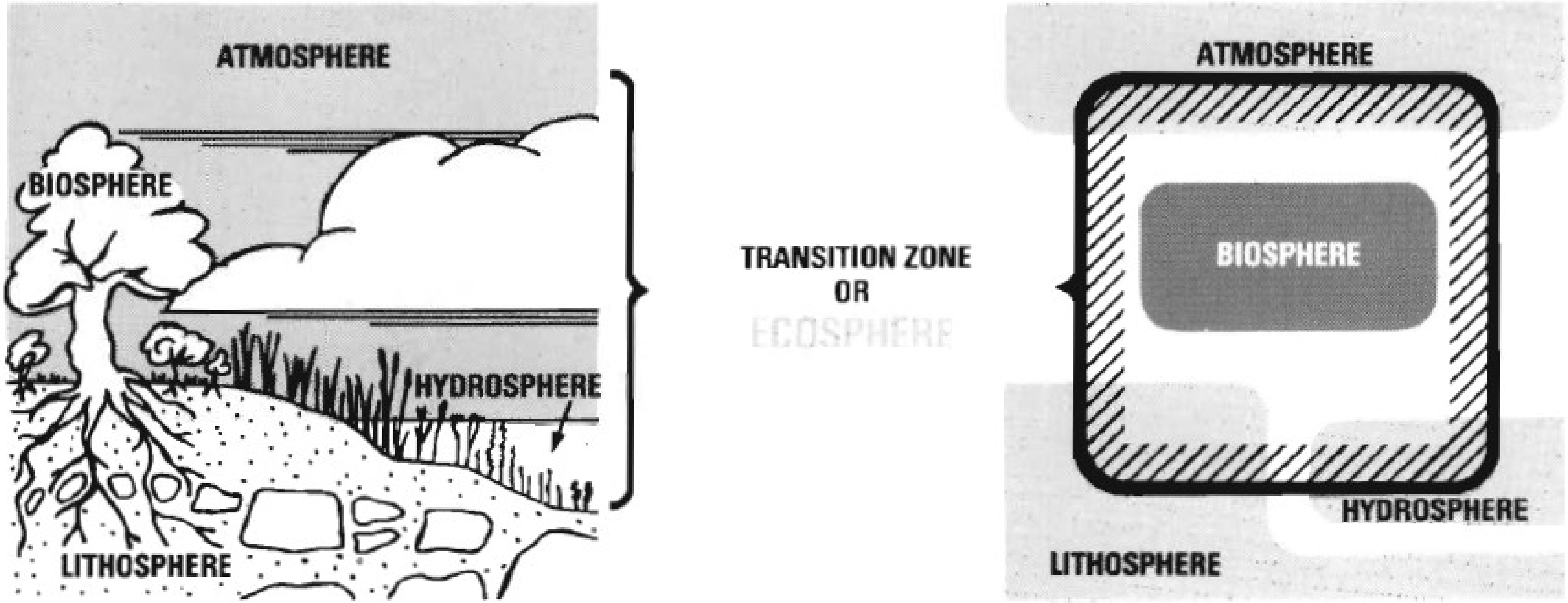




- Science of relations between living organisms and their environment (Ernst Haeckel – 1866, in German *oekologie*)
- Ecosystem is the basic system of ecology, “not only the organism-complex, but the also the whole complex of physical factors forming what we call the environment” (Tansley - 1935)
- *Fundamentals of Ecology* – EP Odum (1953)

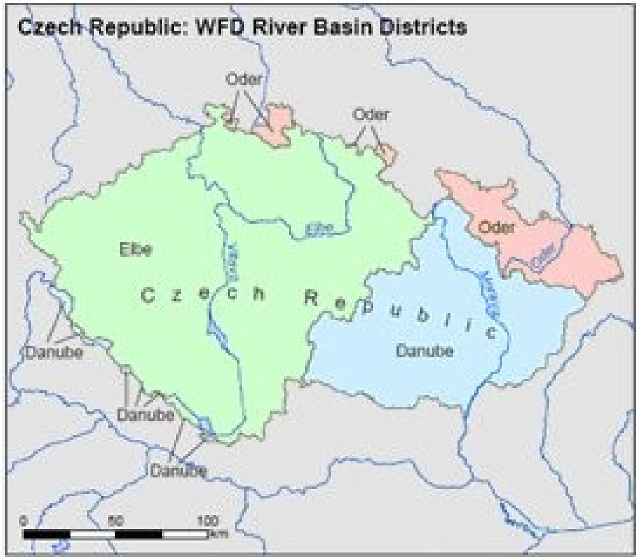


- Atmosphere, lithosphere, and hydrosphere all have functional links involving transfers of energy and matter with the living material of the biosphere



When do you have an ecosystem?

- Different size, different scale, different species
- Borders can be vague
- Natural (forest, field, wetland, stream, lake, etc.) or artificial (wastewater treatment ponds, agriculture, lawn)
- Watersheds –Political and natural boundaries not typically the same
- Common processes



Ecosystem has

- structure (parts) and
- function (processes)
  - Transfer/Exchange of energy
  - Cycling of material (particularly nutrients)
- and, is dynamic (orderly change called succession)

We live in a world full of life.

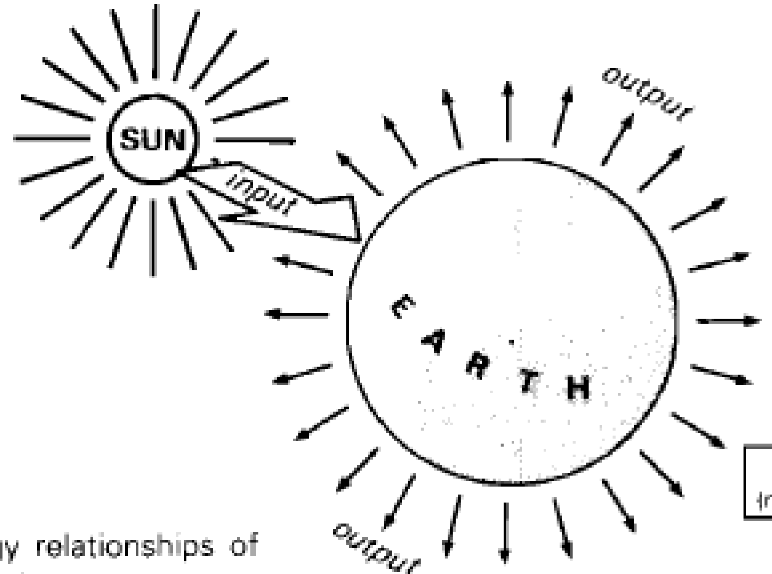
Nothing on Earth is entirely abiotic

Rather it is

With Life – **conbiotic**

Energy flow in ecosystems

Earth energy balance (1st law) as a closed system



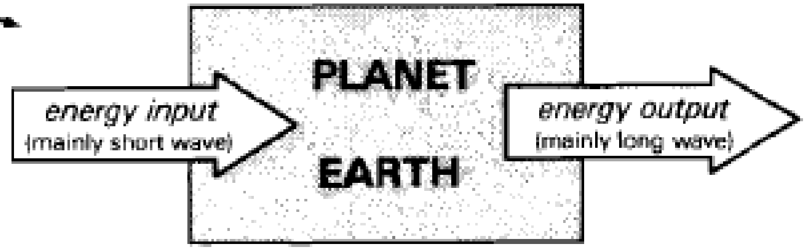
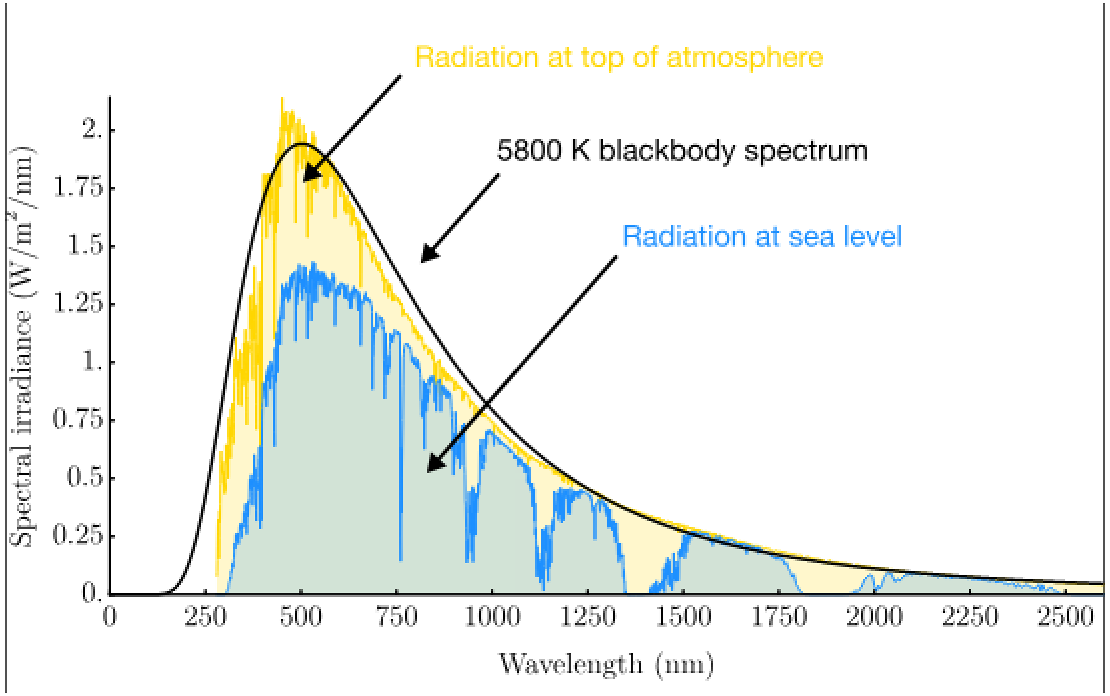
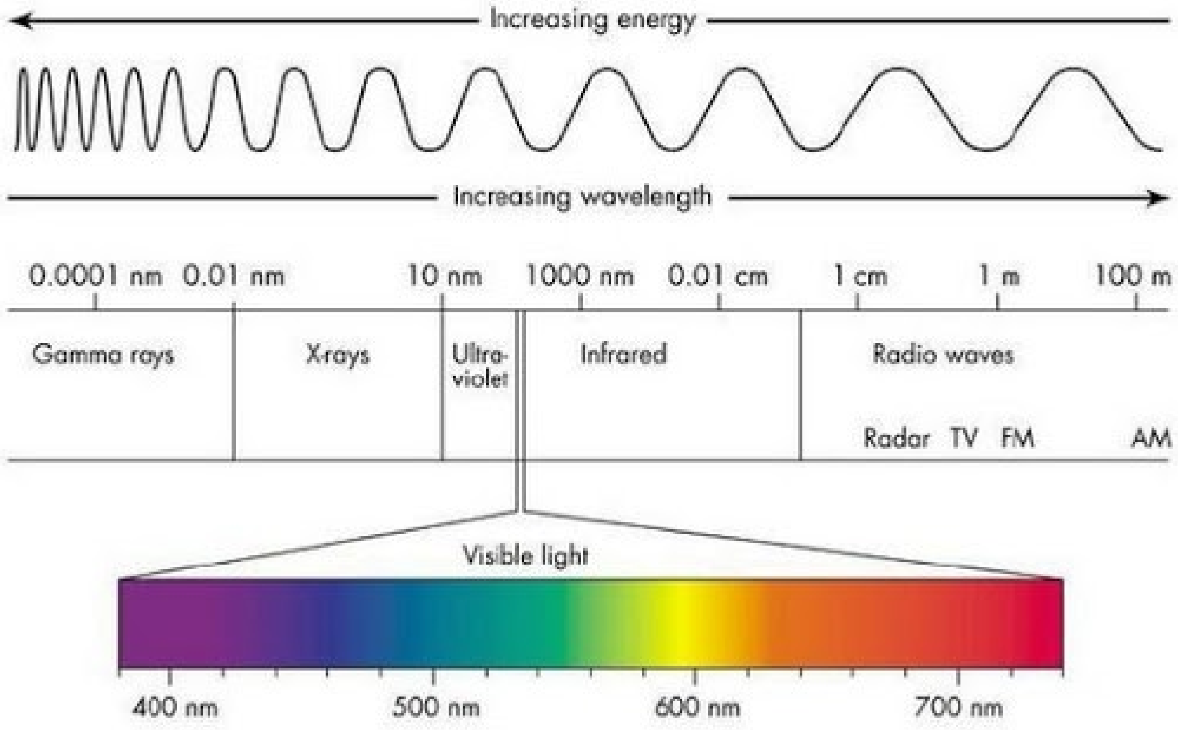


Fig. 3.1 The energy relationships of the Earth as a closed system.

Energy input: solar radiation

- Electromagnetic radiation – travels at constant velocity – speed of light

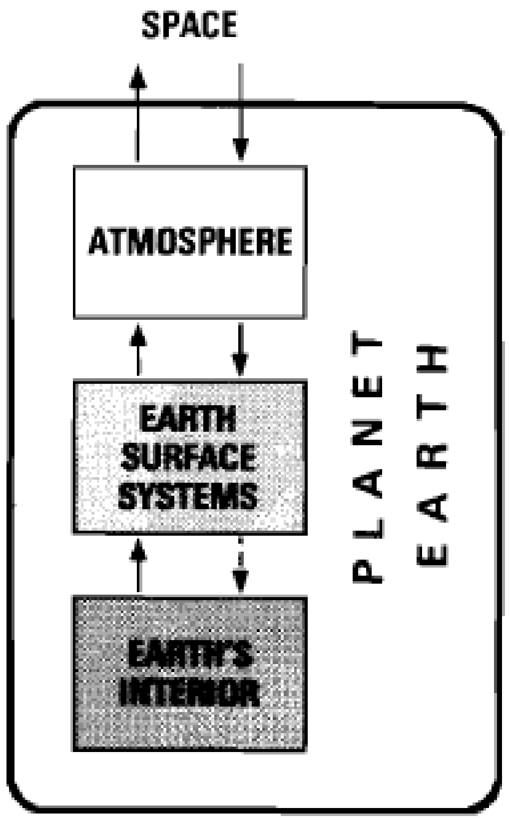




Energy output and the planetary radiation balance

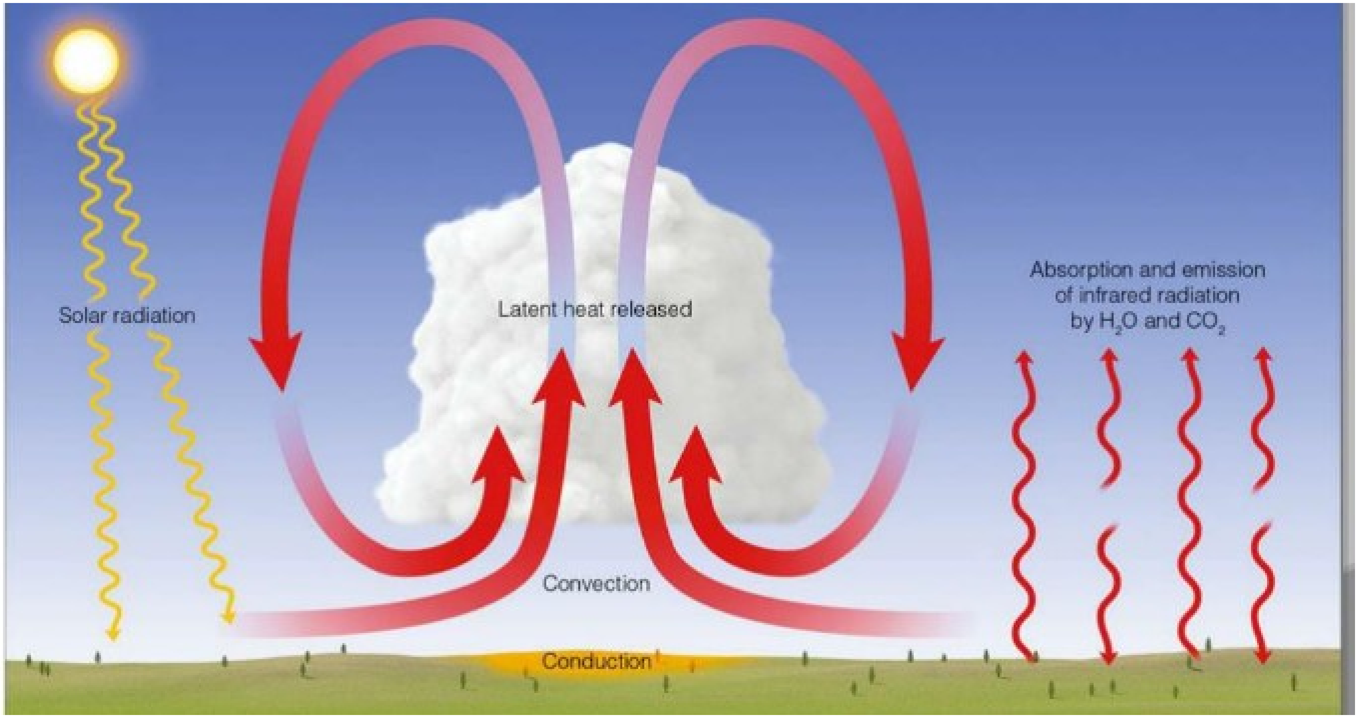
In absence of atmosphere, long term-balance:

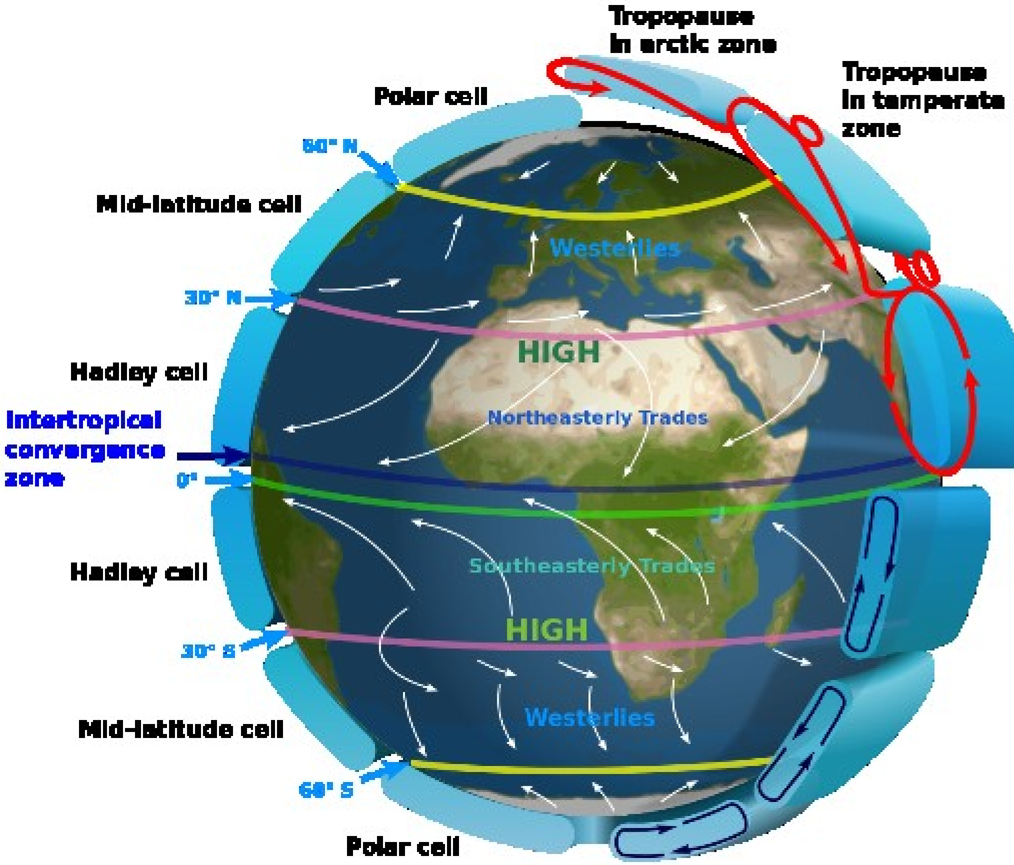
net radiation = incoming radiation (mainly shortwave visible light)
minus
outgoing radiation (mainly longwave heat)
= 0



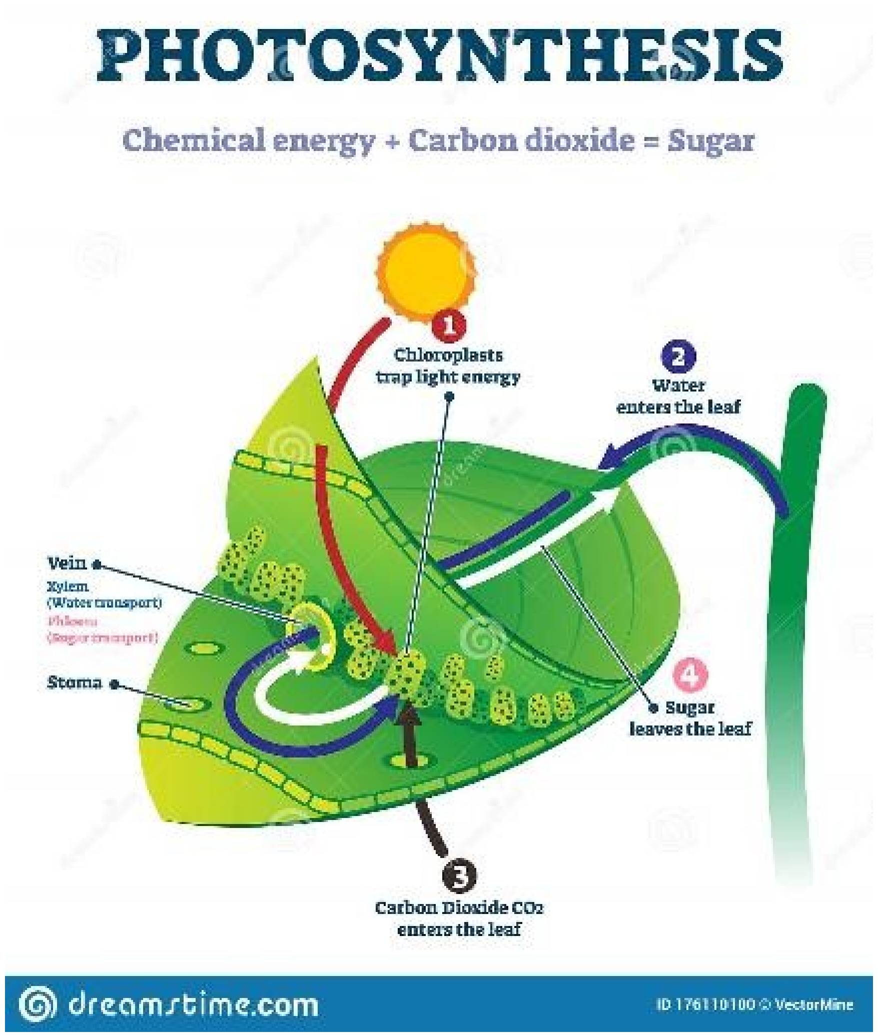
The increasing concentration of greenhouse gases retains Earth's energy from escaping to space, thus, warming the planet

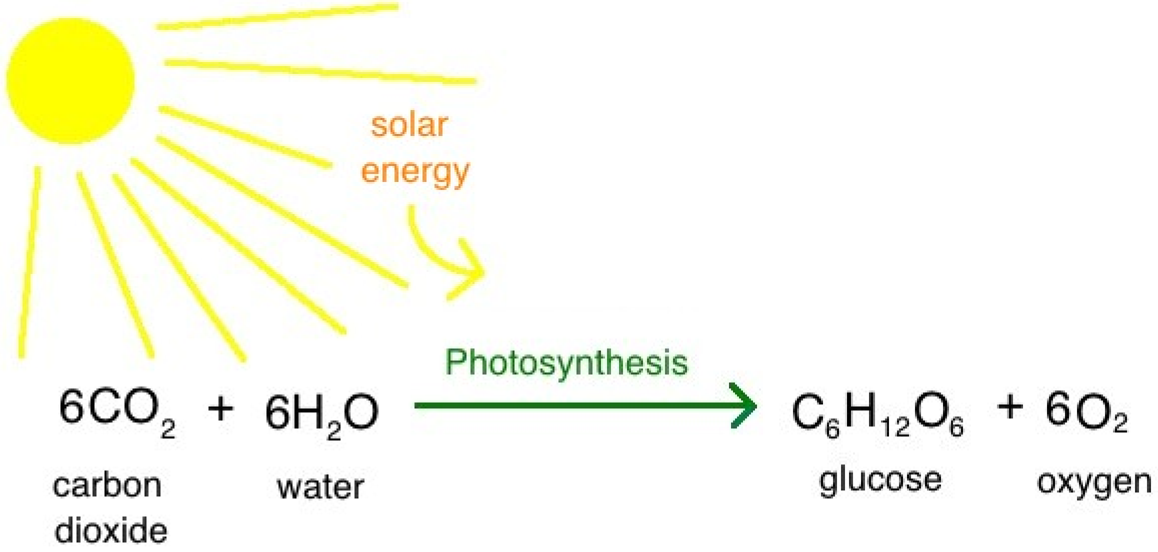
Sun’s energy drives global circulation



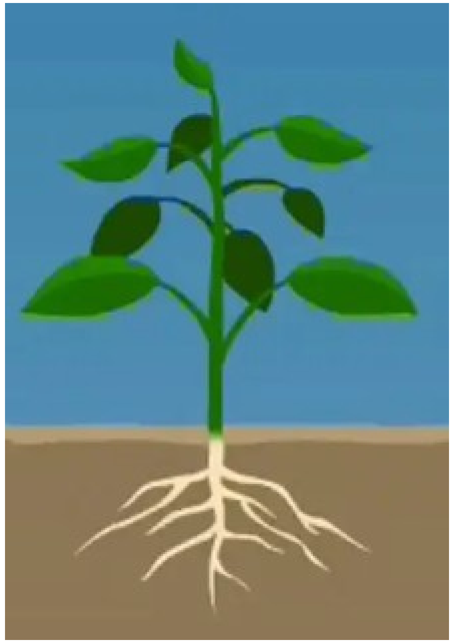


And, some used for photosynthesis to create organic, biological matter (biomass)

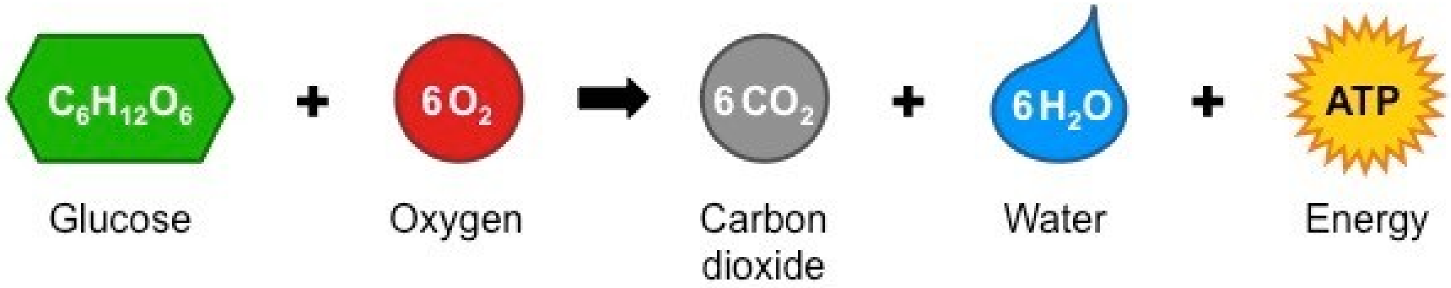




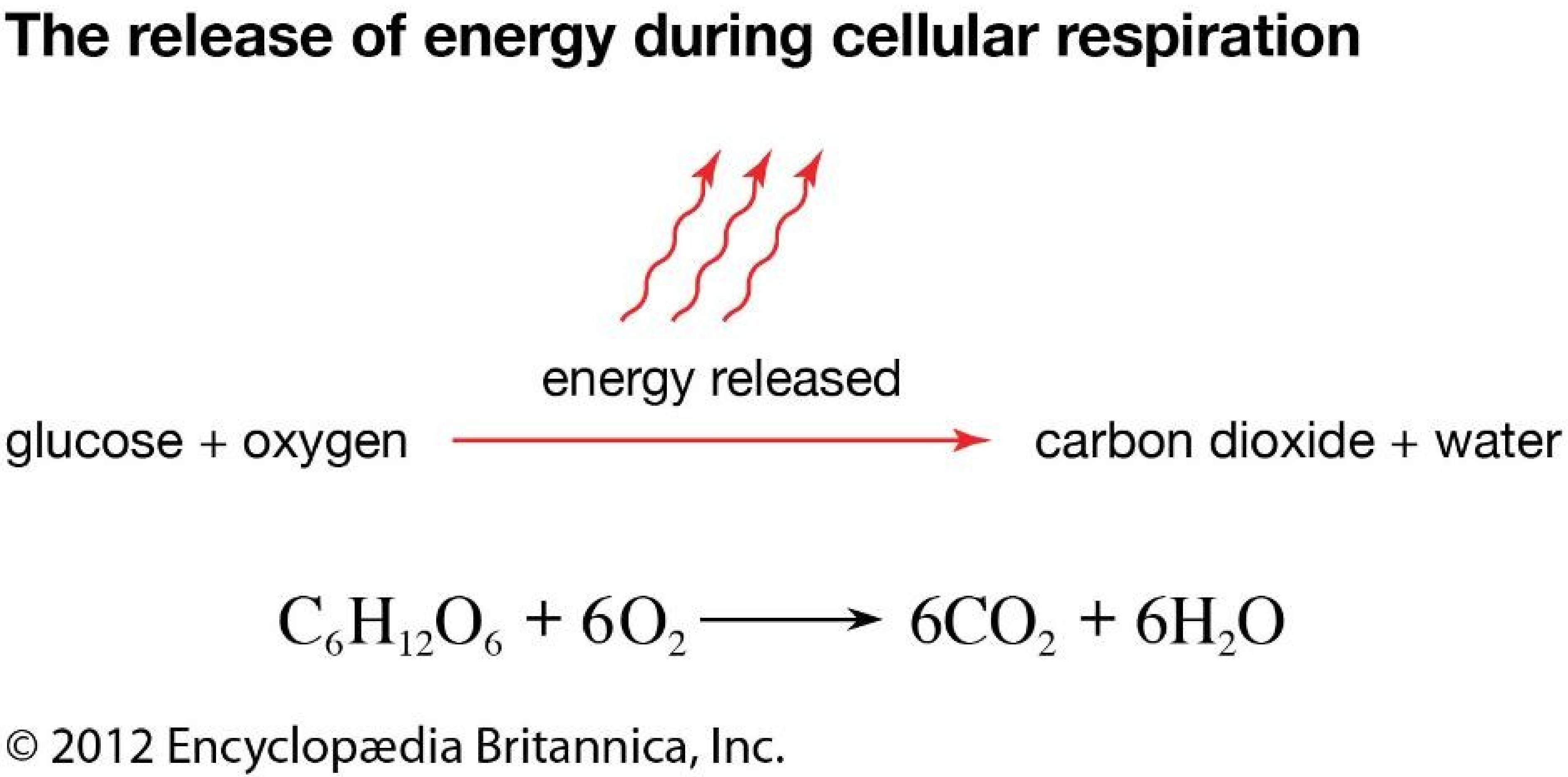
glucose



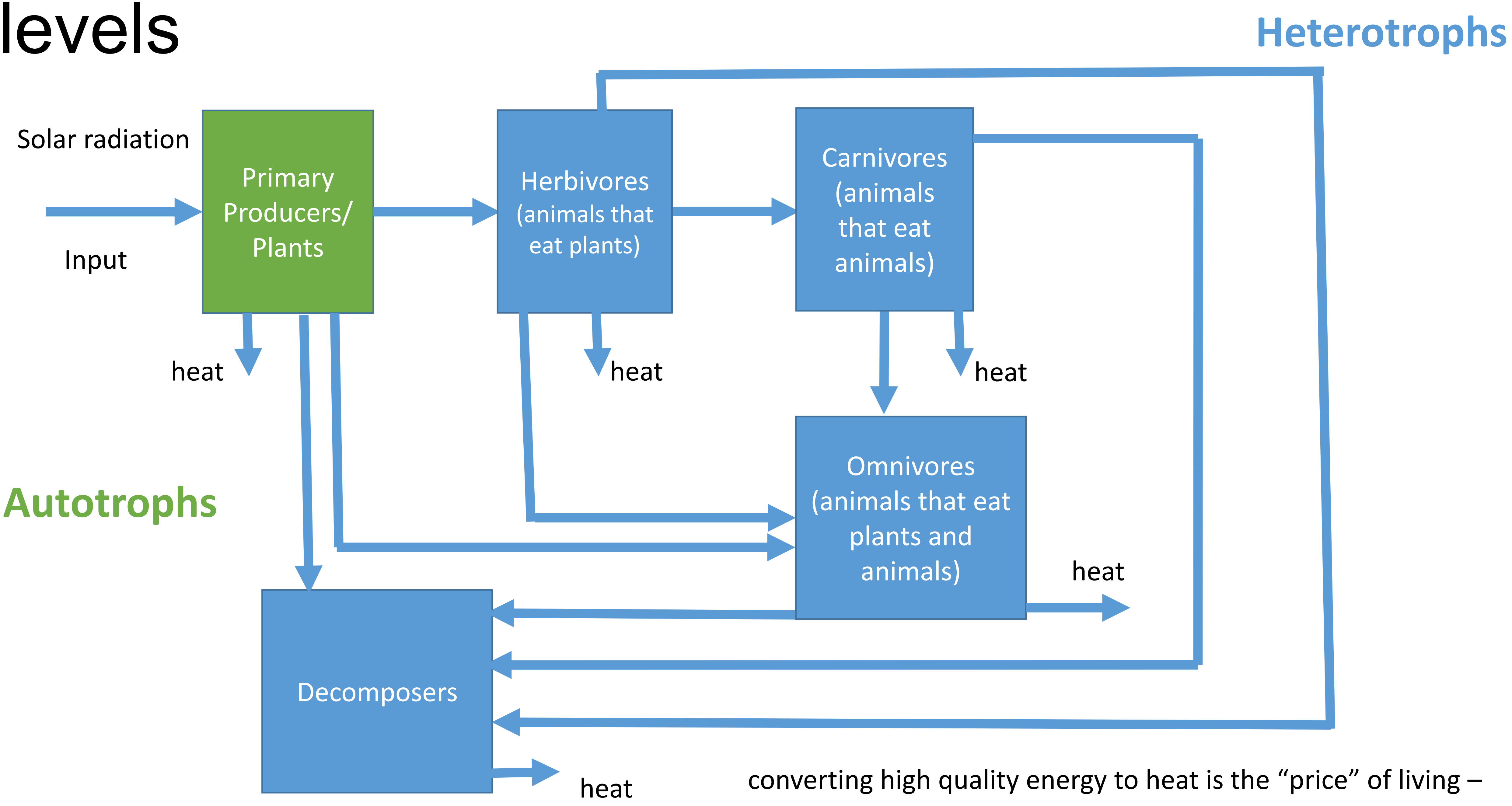
- Used as basic building block of living matter
- Energy stored in the chemical bond can be utilized later (in respiration) to do work



Respiration – complimentary process to photosynthesis

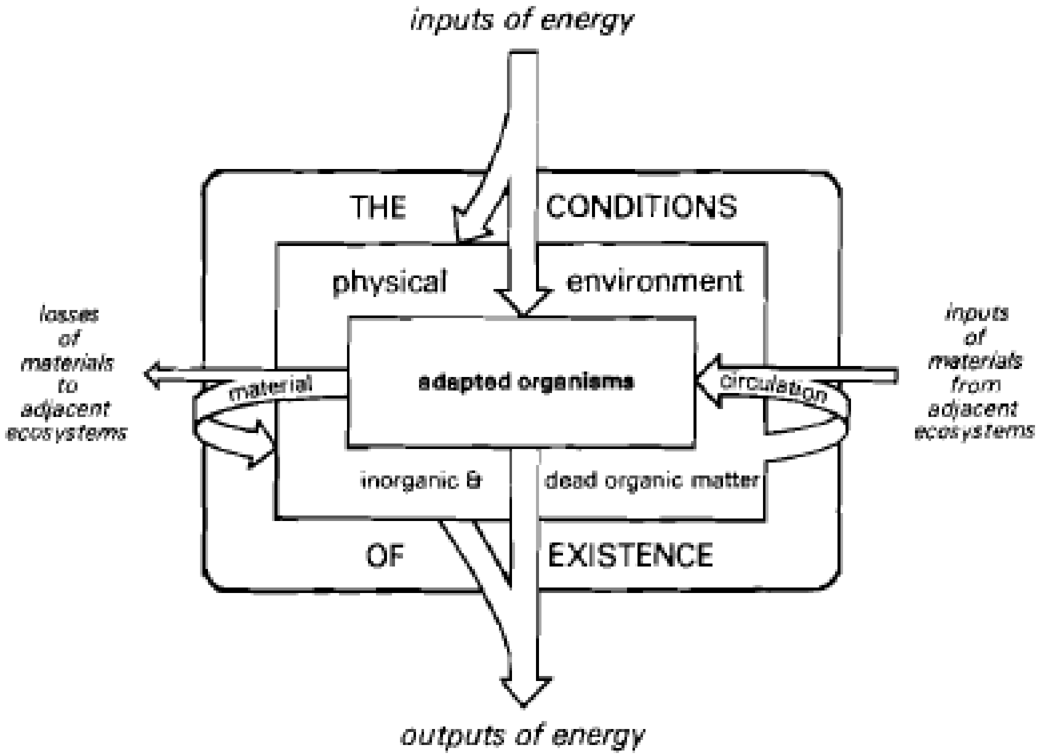


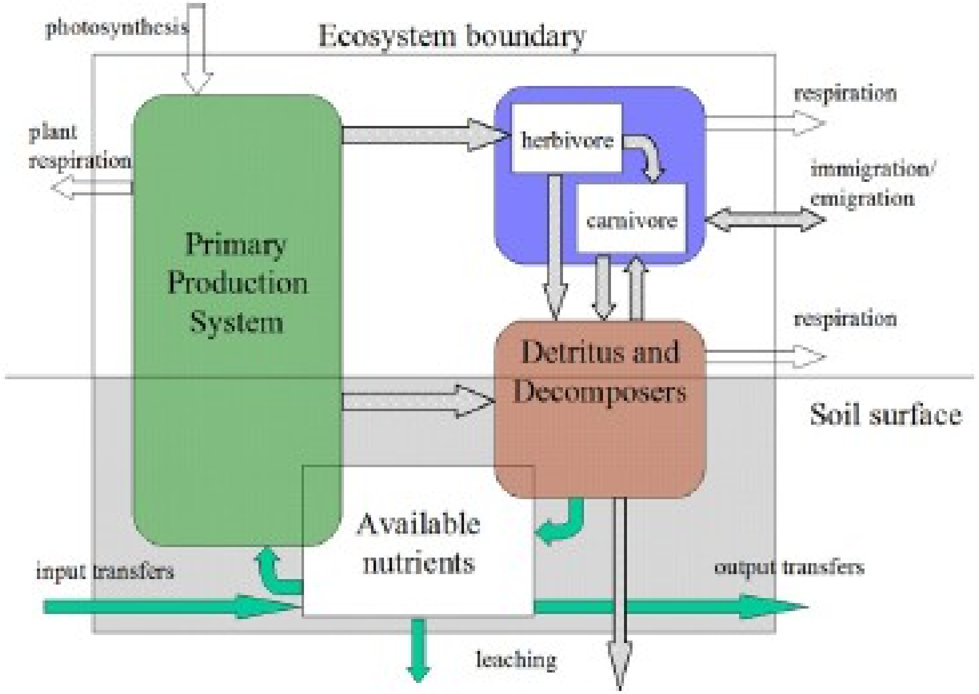
Energy flow in ecosystems – trophic levels



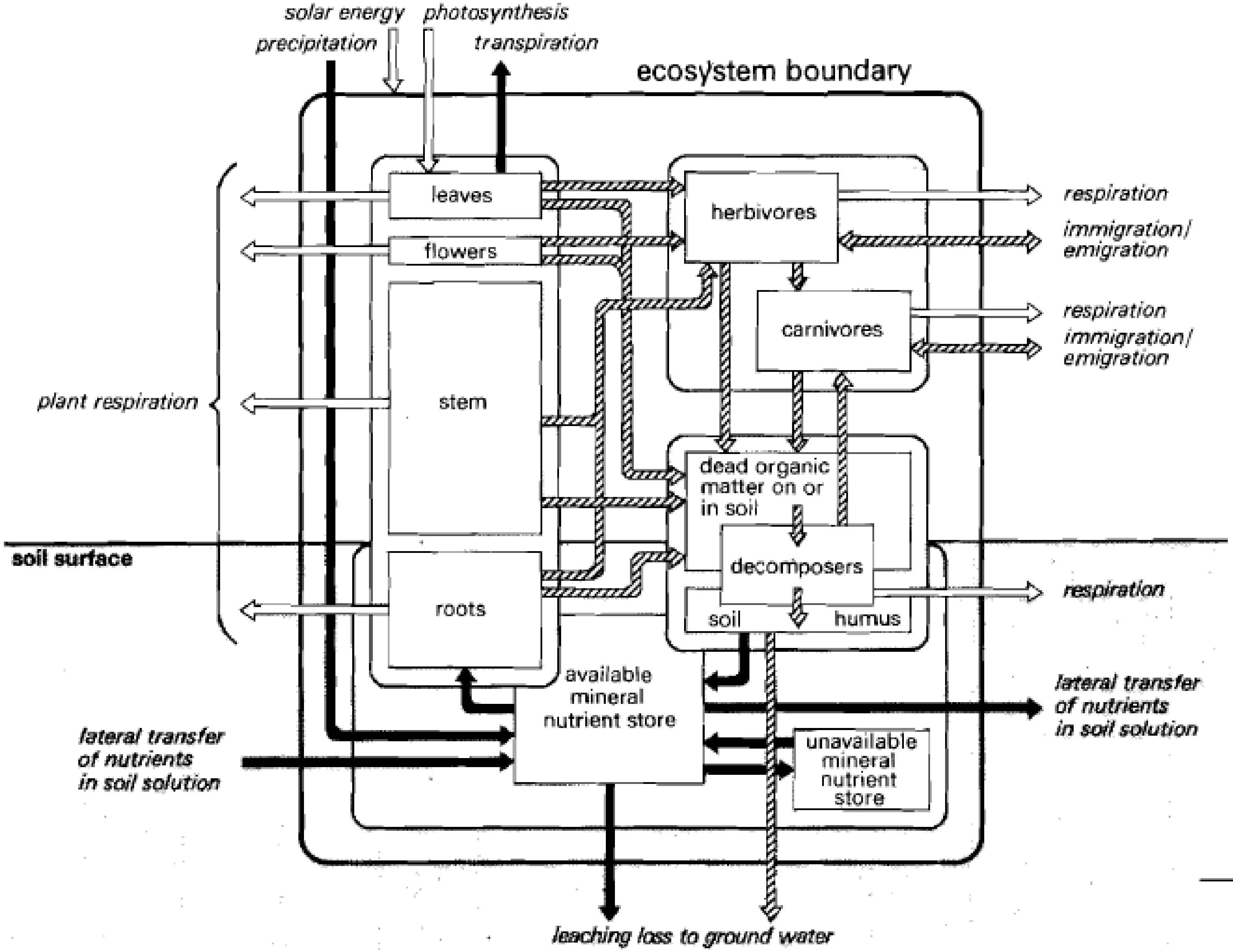
converting high quality energy to heat is the "price" of living –

Functional activity of the ecosystem: transfer of energy and matter

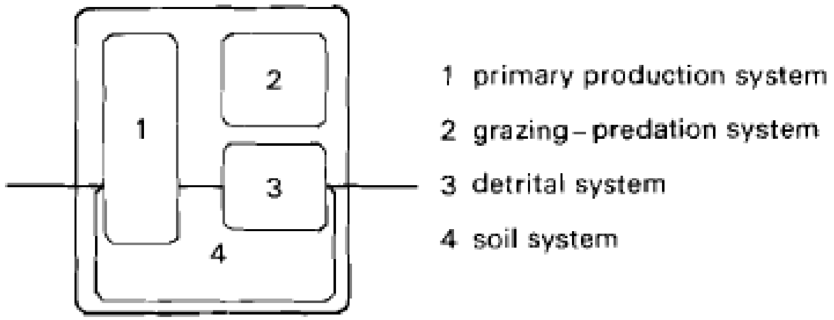




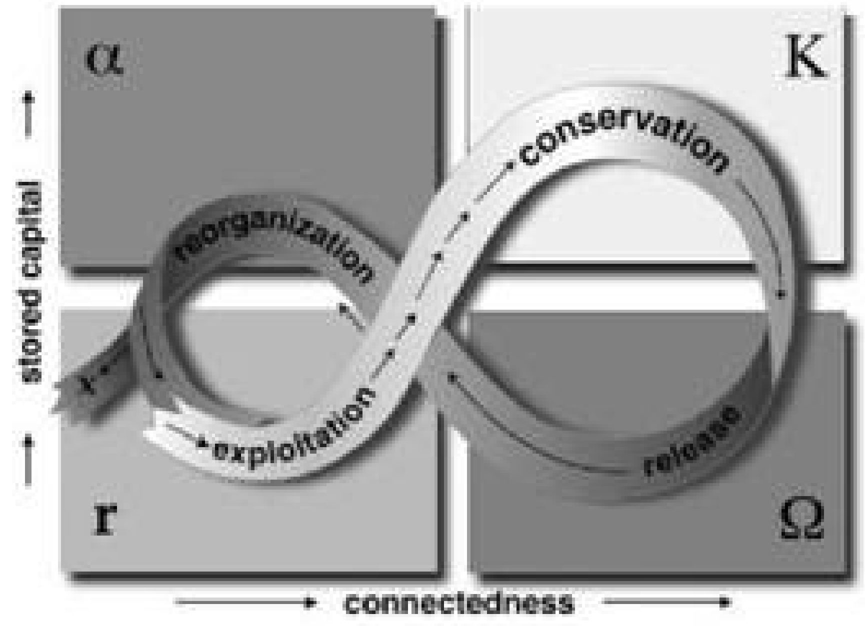
Fundamental functional activity – assimilation and utilization of energy and respiration



Inside the ecosystem boundary is a complex, flourishing system



Succession - Ecological dynamics



Adaptive Cycle

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Ecosystem growth and development

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Received 17 November 2003; received in revised form 14 June 2004; accepted 16 June 2004

Growth → *Quantitative* increase
Development → *Qualitative* increase

"We must realize that growth and development are two very different things. You can develop without growing and vice versa.“
Tibor Vasko, 2009, www.solon-line.de/interview-with-tibor-vasko.html

Ecosystems are dynamic

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

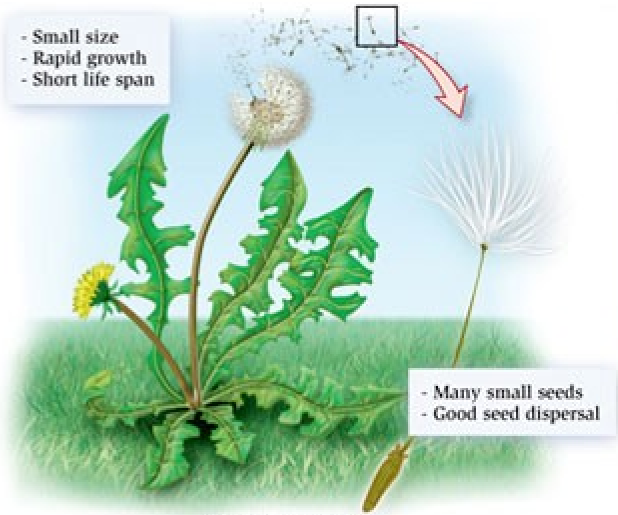
Succession – ordered pattern of growth and development

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

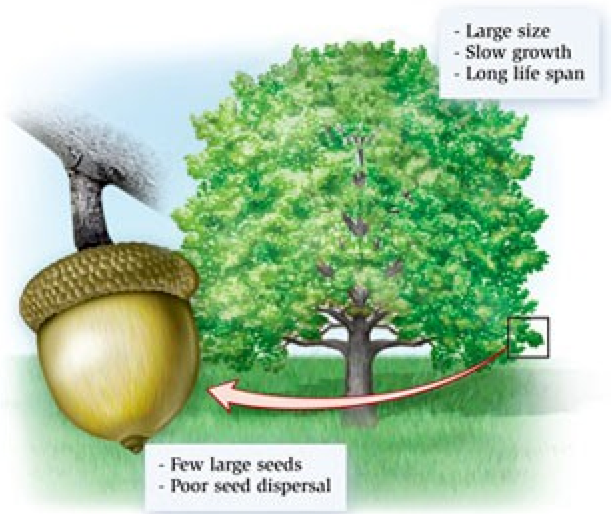
Community and Ecosystem Dynamics

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.

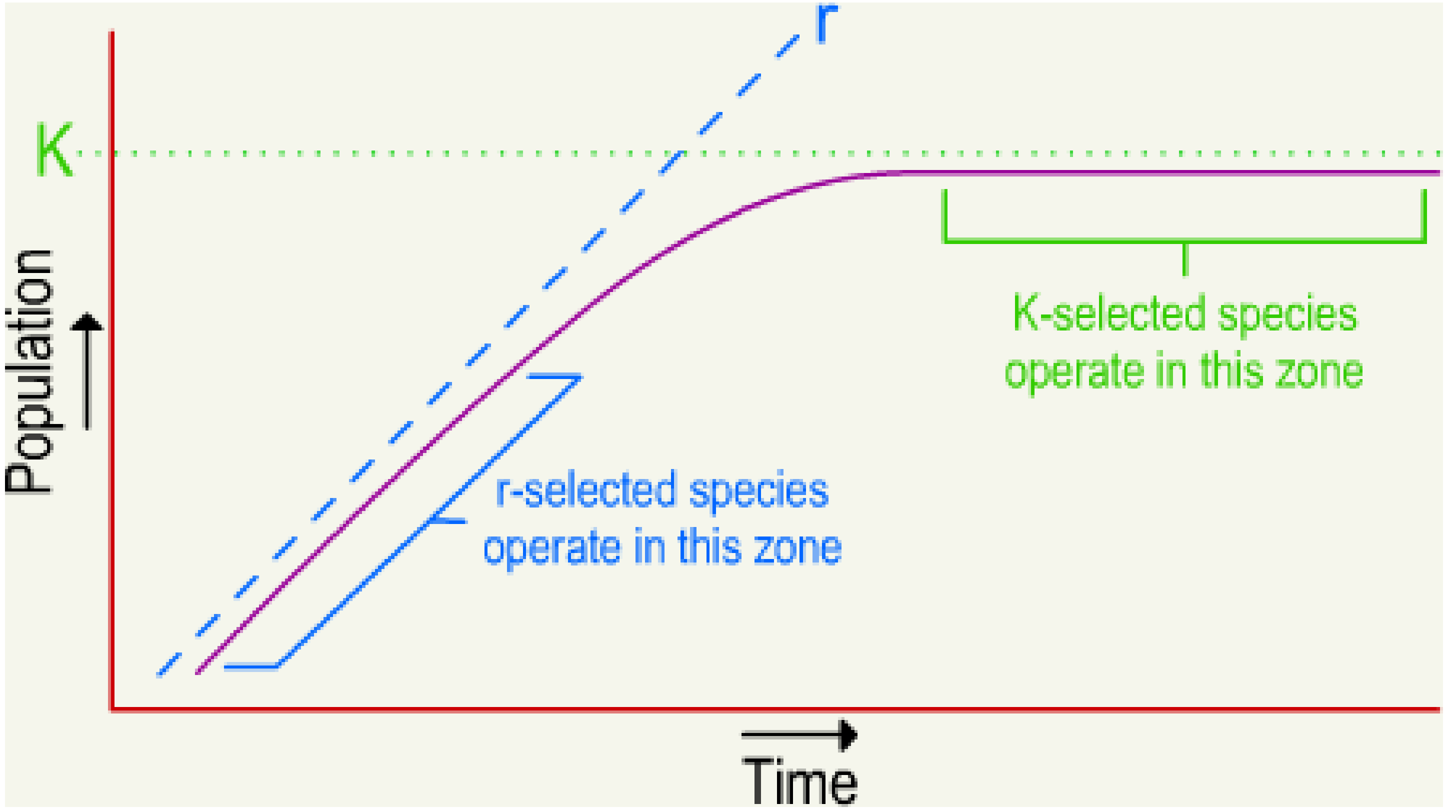


r-selected species



K-selected species

Succession



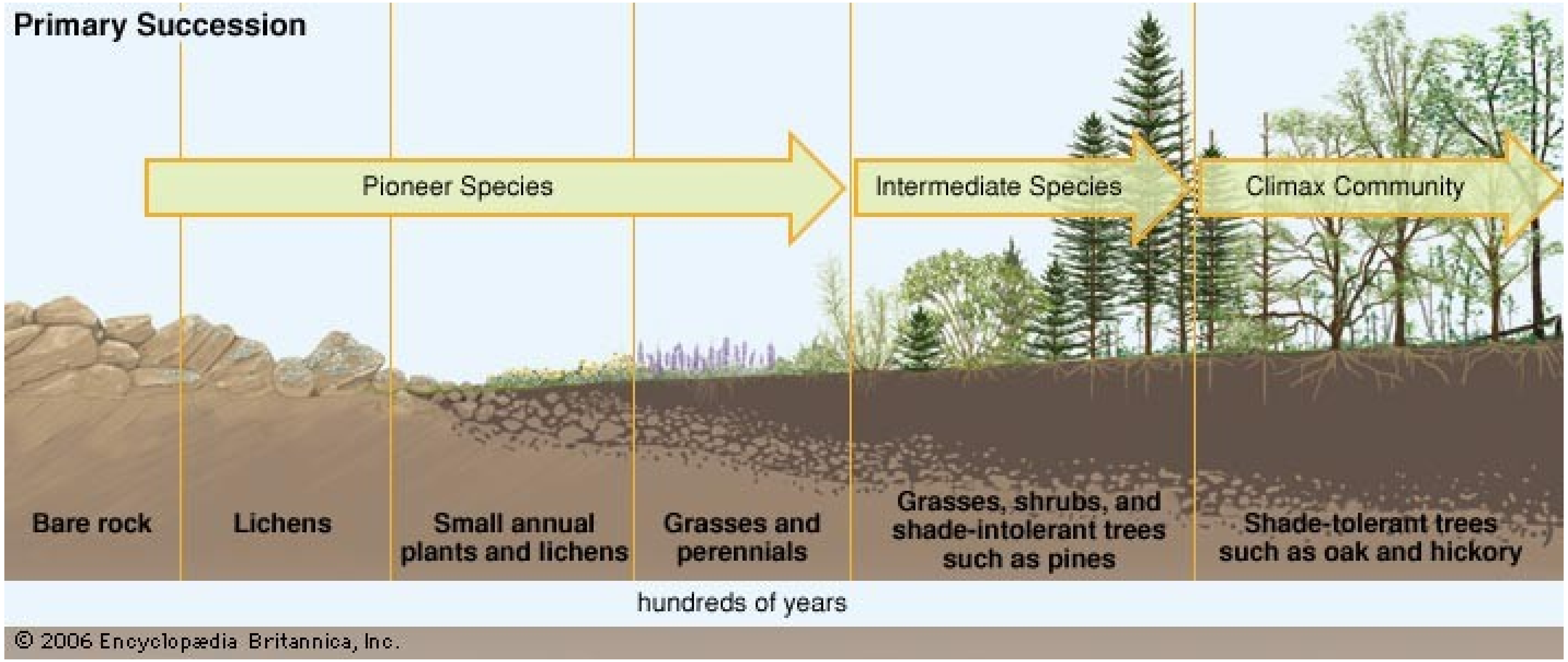
Early stage Late stage

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

Succession

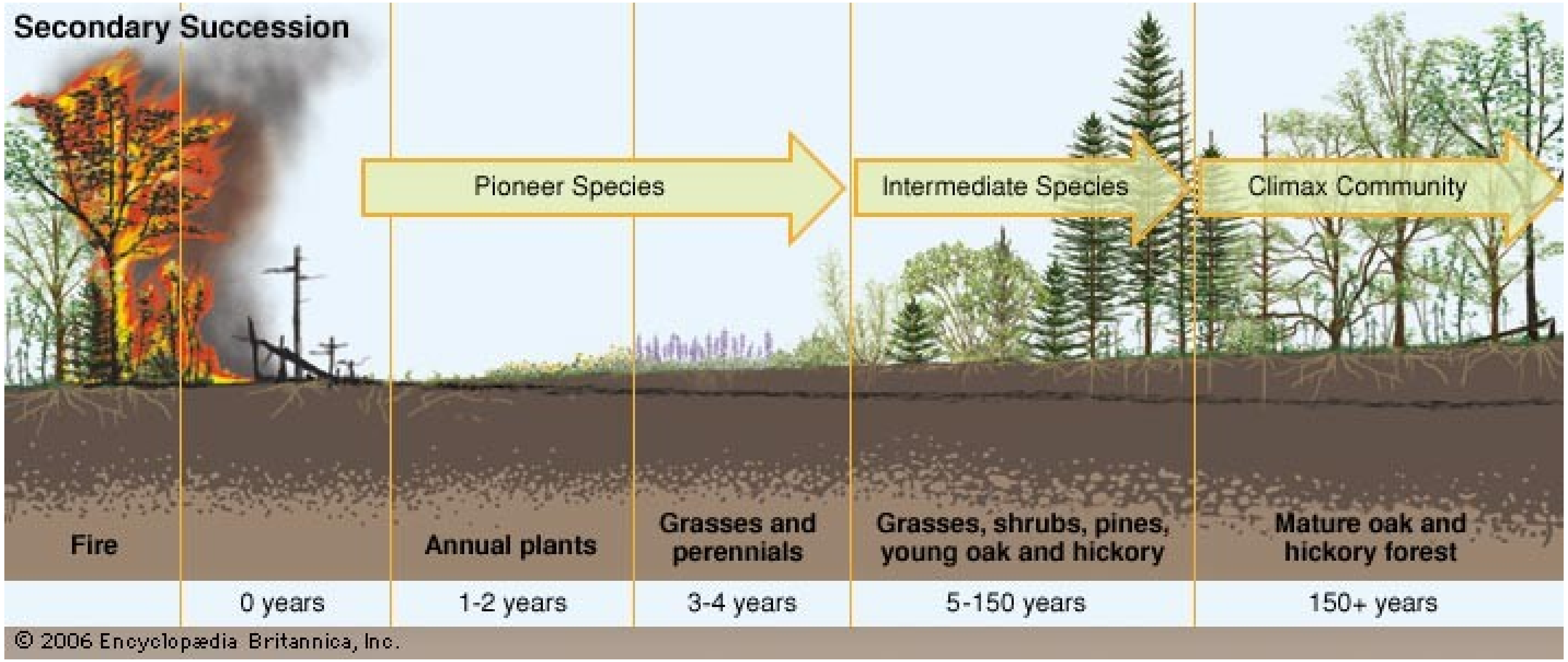
Mature communities with the highly developed interdependence of their constituent species and their complex network of interaction with the environment are the result of inherent processes of change – directional change akin to the growth and development of the organism.

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.



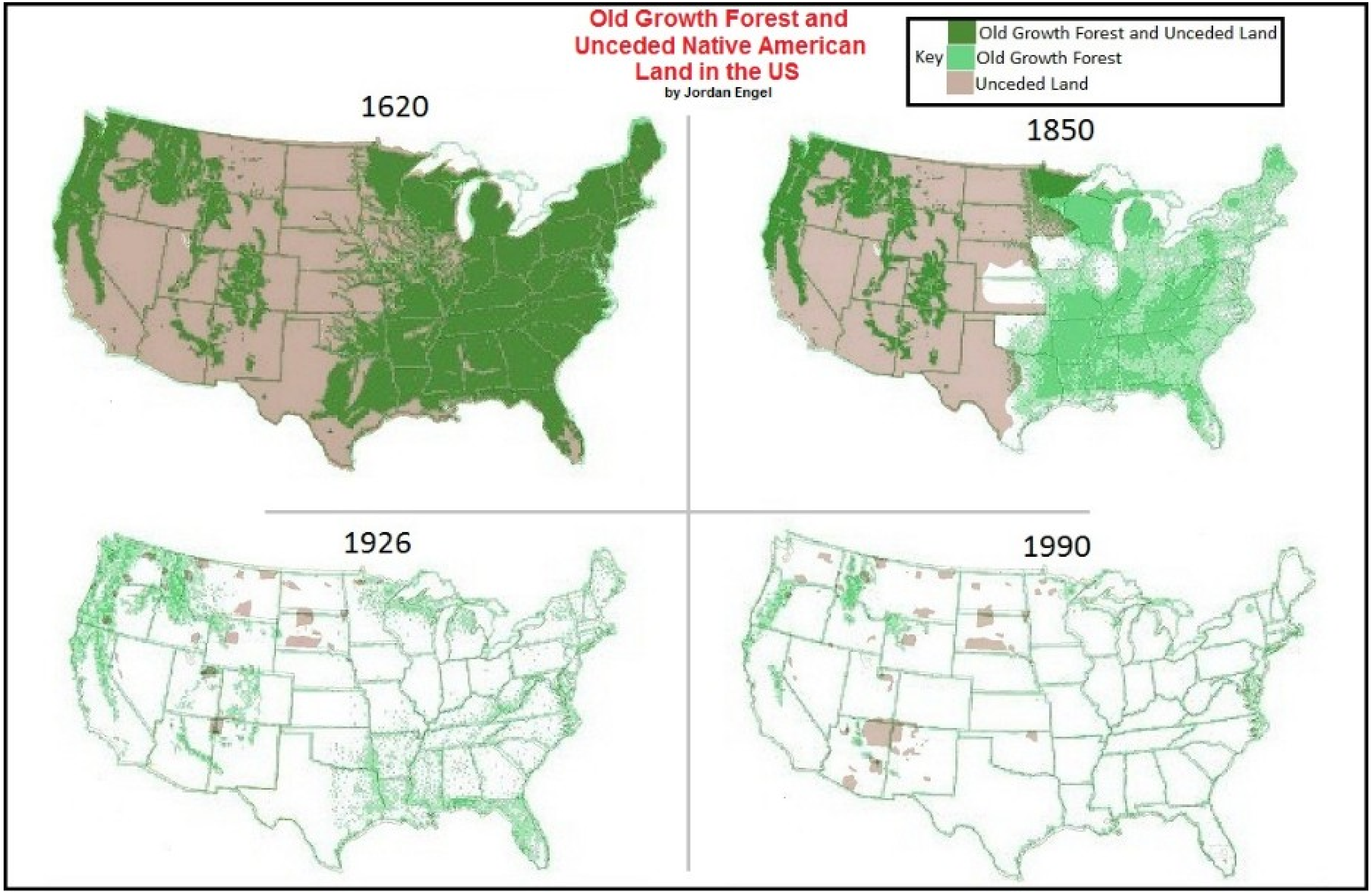
Primary succession – initial establishment and development of an ecosystem in an area devoid of an ecological community

Primary succession



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

By Hannu - Own work, Public Domain,
https://commons.wikimedia.org/w/index.php?curid=5190488

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.

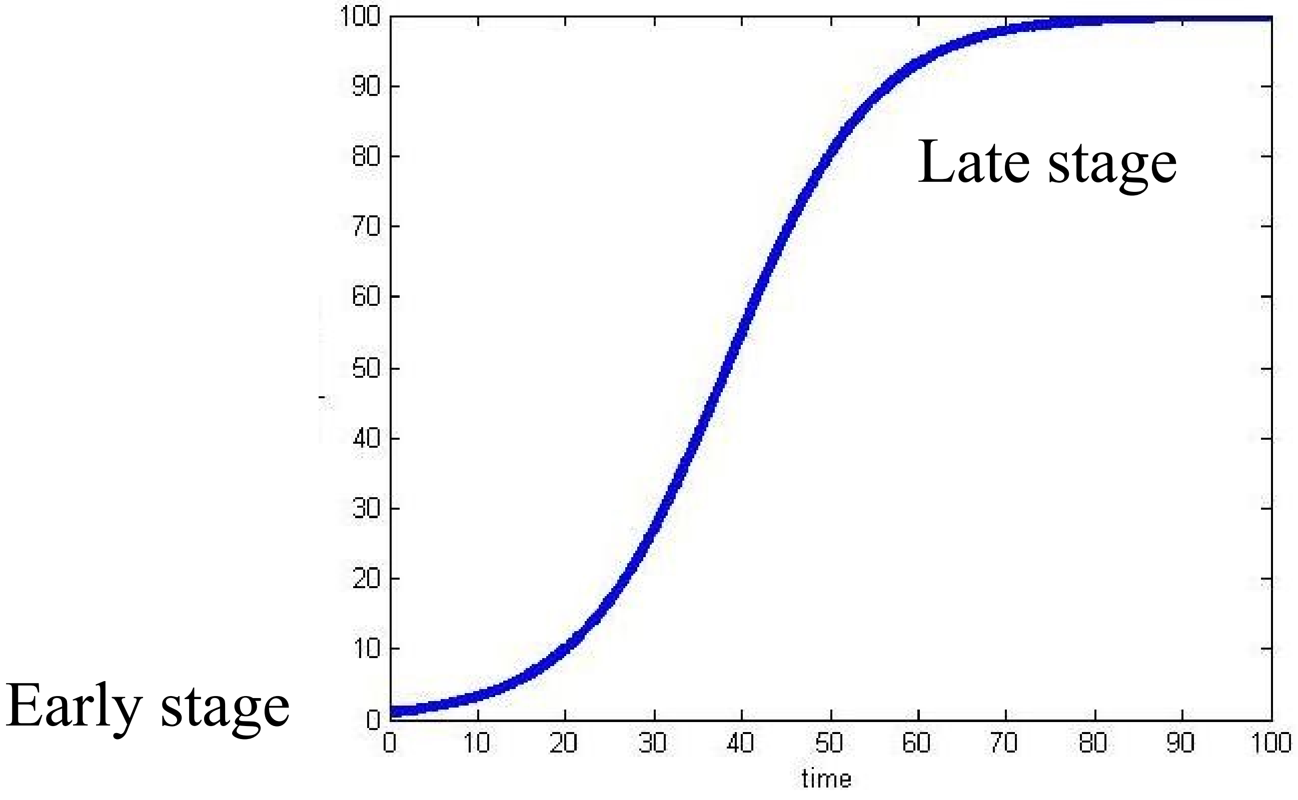
d. After twenty years, the juniper trees are mature, and there are also birch and maple trees in addition to the blackberry shrubs.

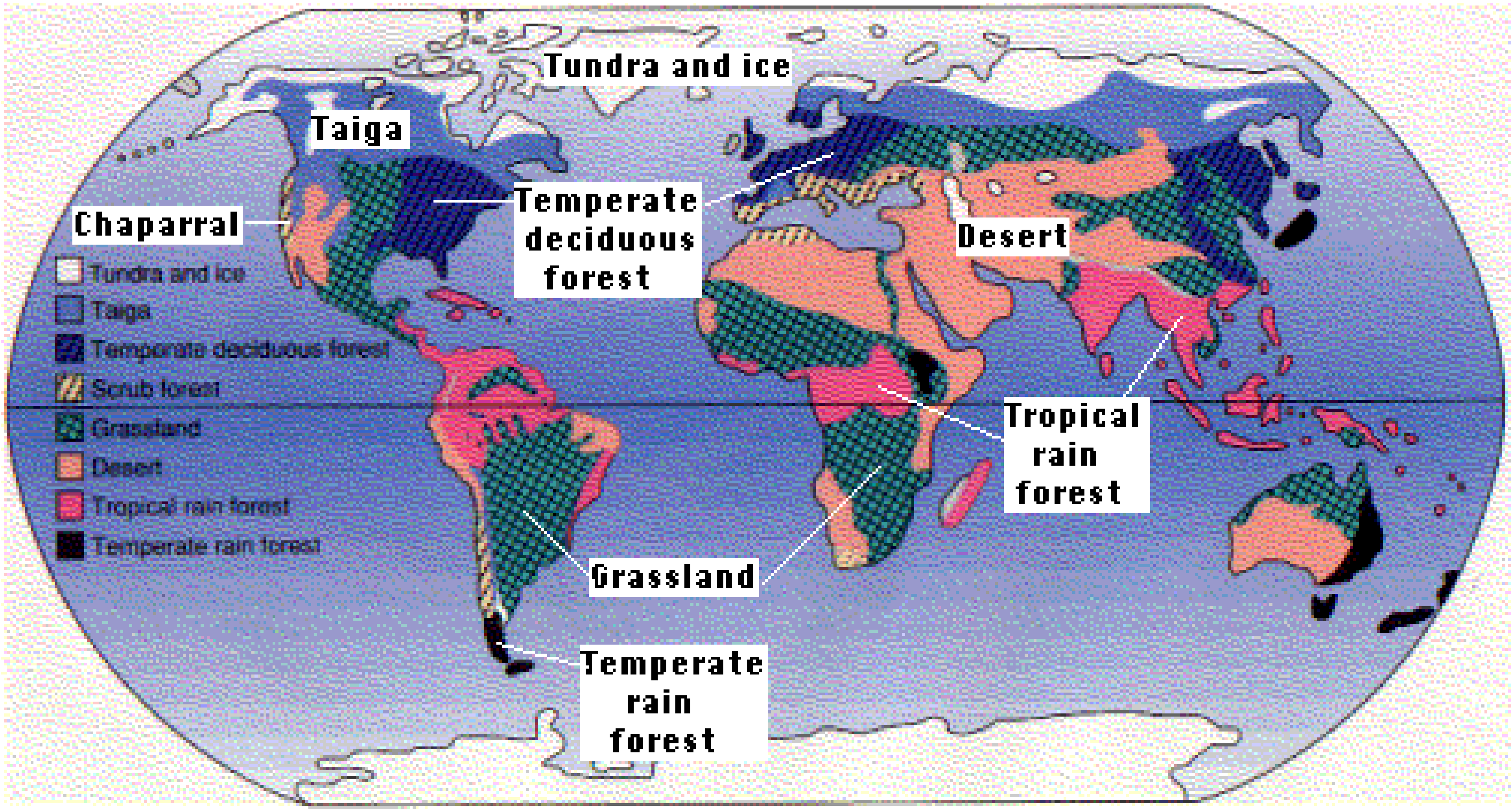
Secondary succession

Secondary succession

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

Logistic growth from early to late successional stages





Biomes of the world – nature flourishing within the climatic (temperature and precipitation) constraints

Bioenergetic model of succession

In early stages of succession, Pg>R and excess is channeled into growth and accumulation of biomass. Pn>0

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.

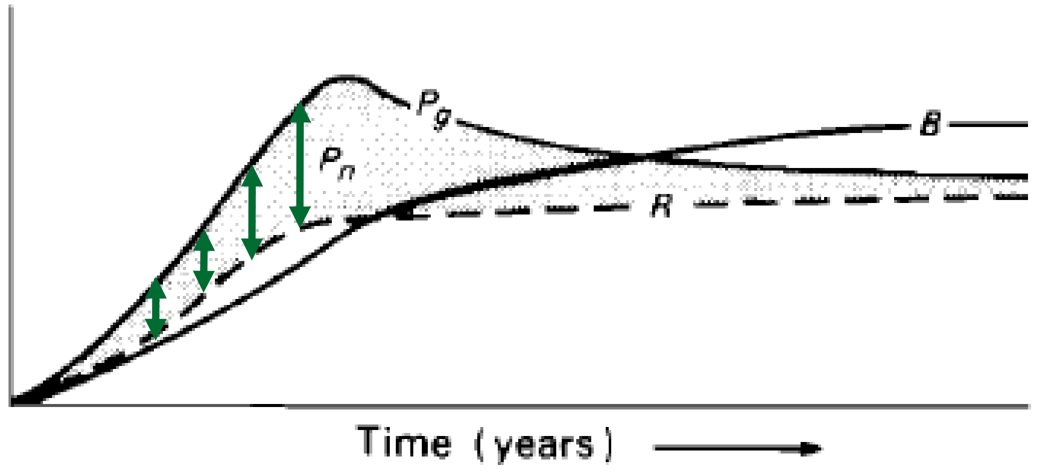


Fig. 25.17 Changes in gross (P_g) and net (P_n) production, respiration (R) and biomass (B) through succession.

Bioenergetic model of succession

In late stages of succession, Pg=R as maintenance costs increase respiration. Pn≈0

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

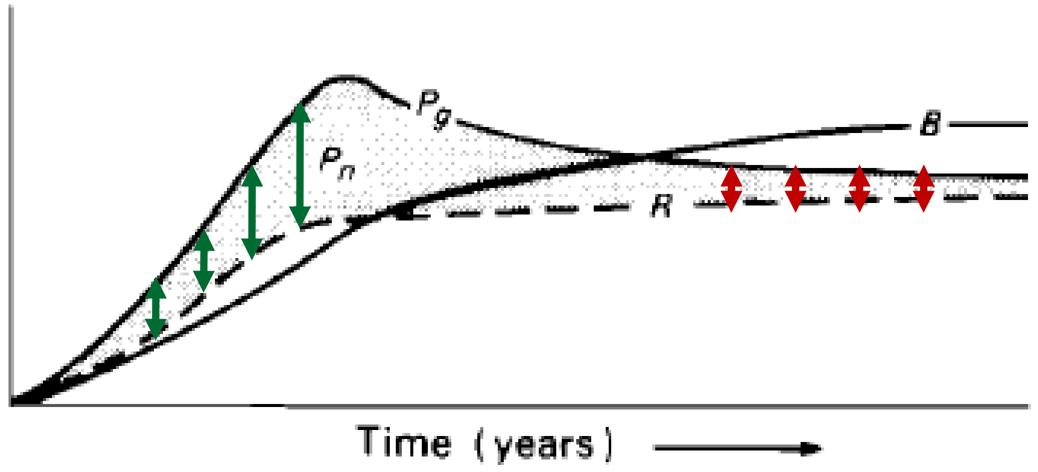
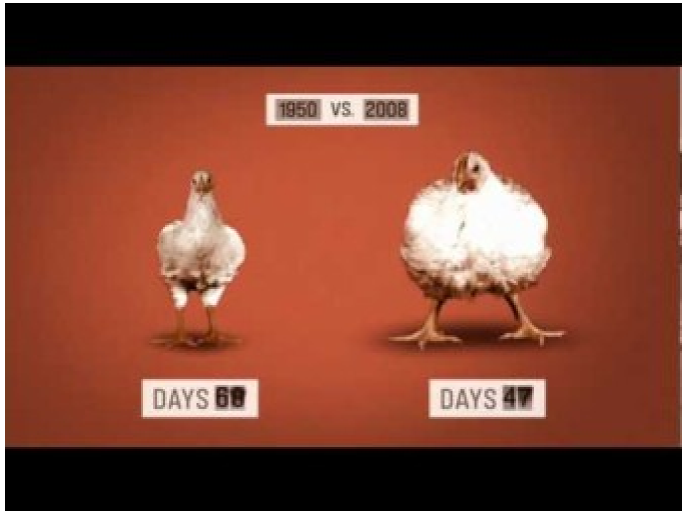


Fig. 25.17 Changes in gross (P_g) and net (P_n) production, respiration (R) and biomass (B) through succession.

Ecosystem services are extracted to exploit growth phase

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



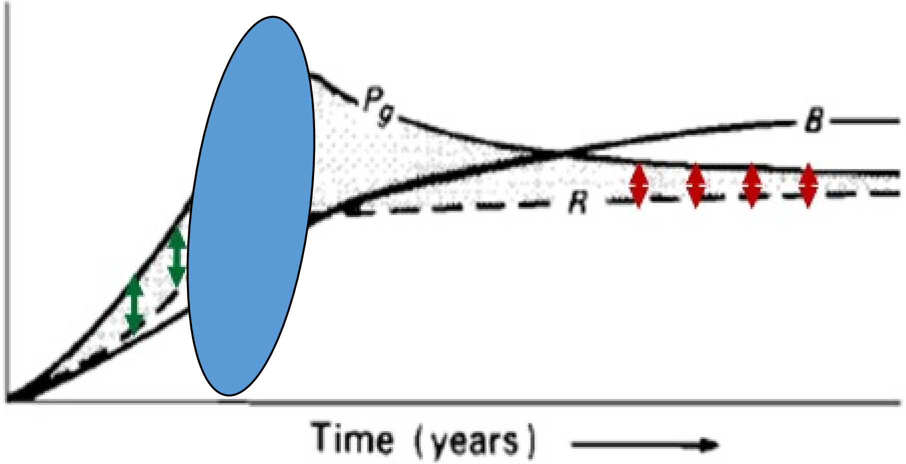


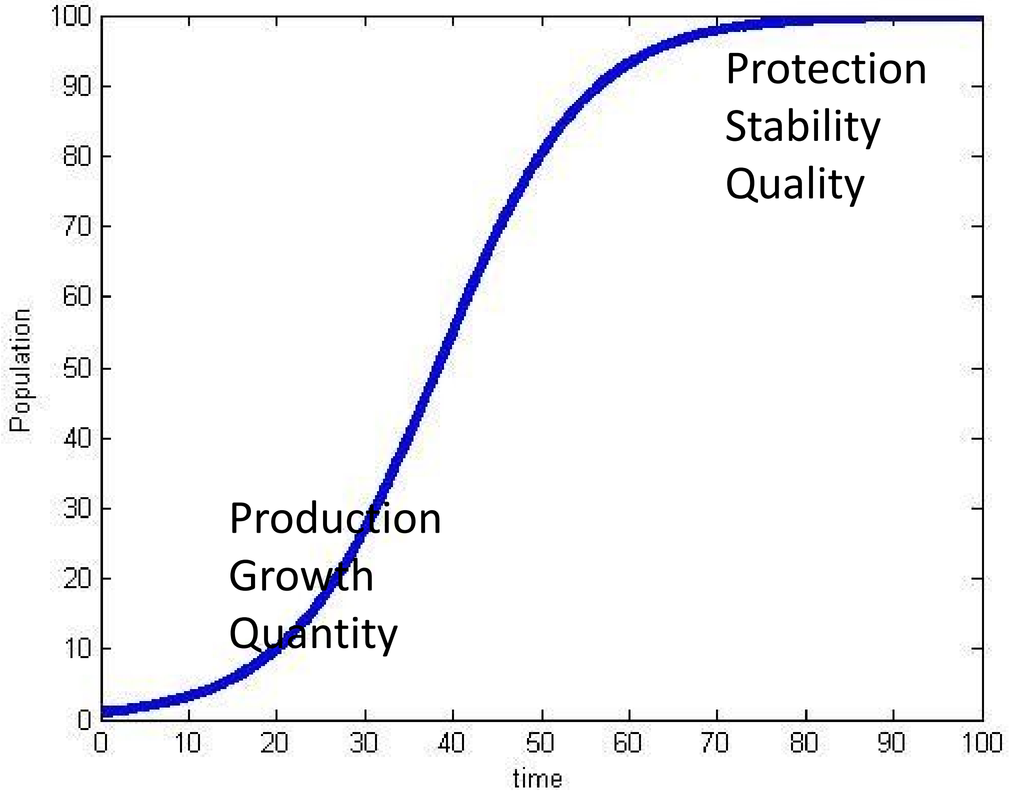
Fig. 25.17 Changes in gross (P_g) and net (P_n) production, respiration (R) and biomass (B) through succession.

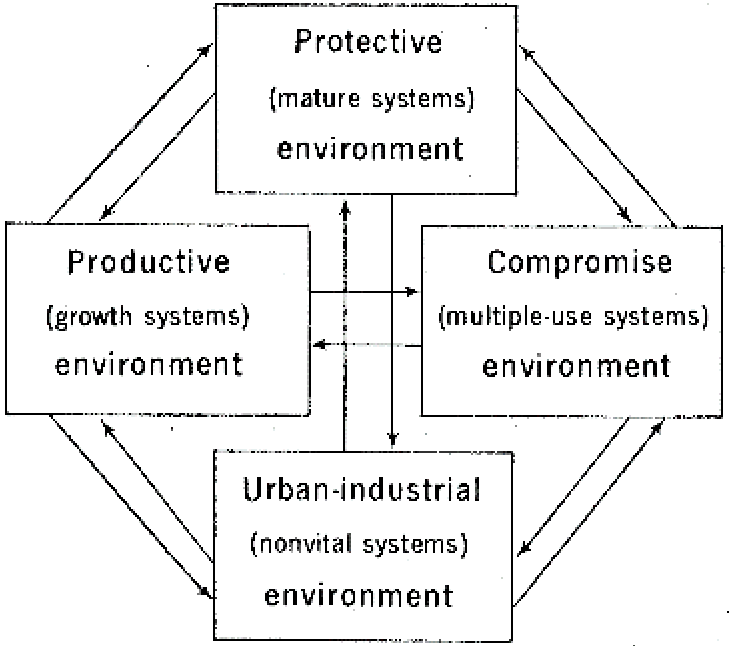
Odum, EP 1969
Strategy of Ecosystem Development

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



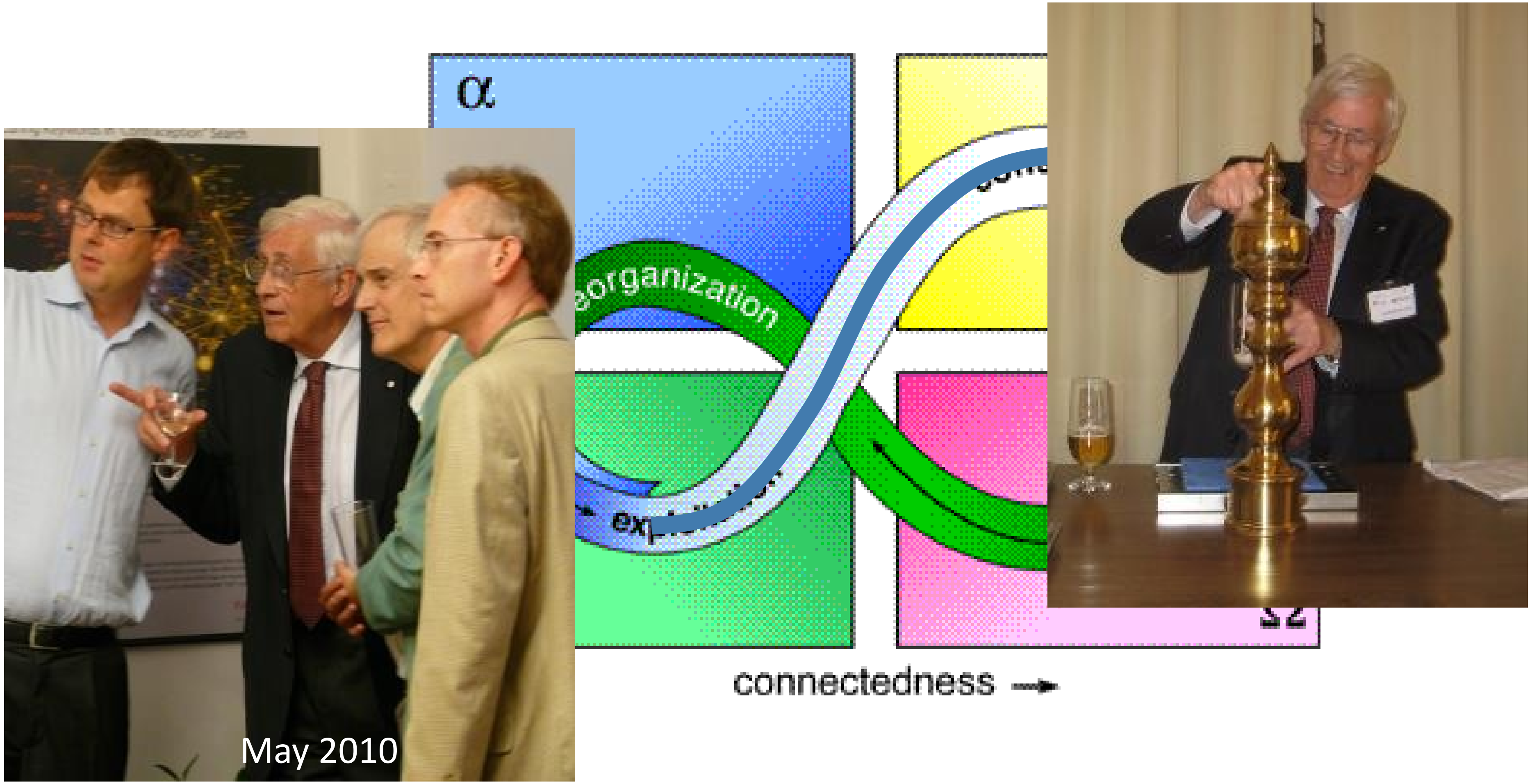


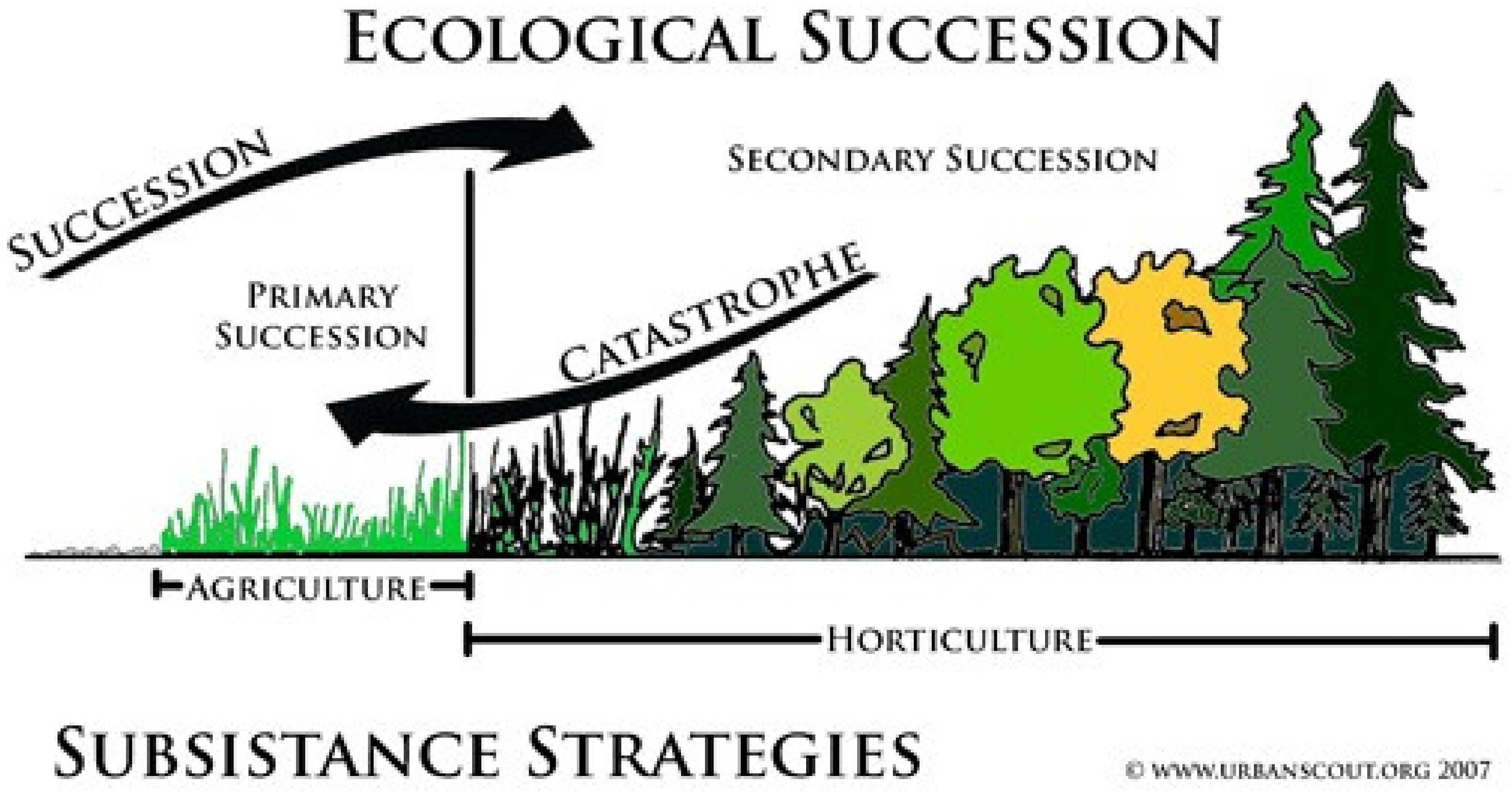
Compartment model of the basic kinds of environment required by humans

partitioned according to ecosystem development

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

Logistic growth only captures part of the cycle




ECOLOGICAL SUCCESSION
SUCCESSION
SECONDARY SUCCESSION
PRIMARY SUCCESSION
CATASTROPHE
AGRICULTURE
HORTICULTURE
SUBSISTANCE STRATEGIES
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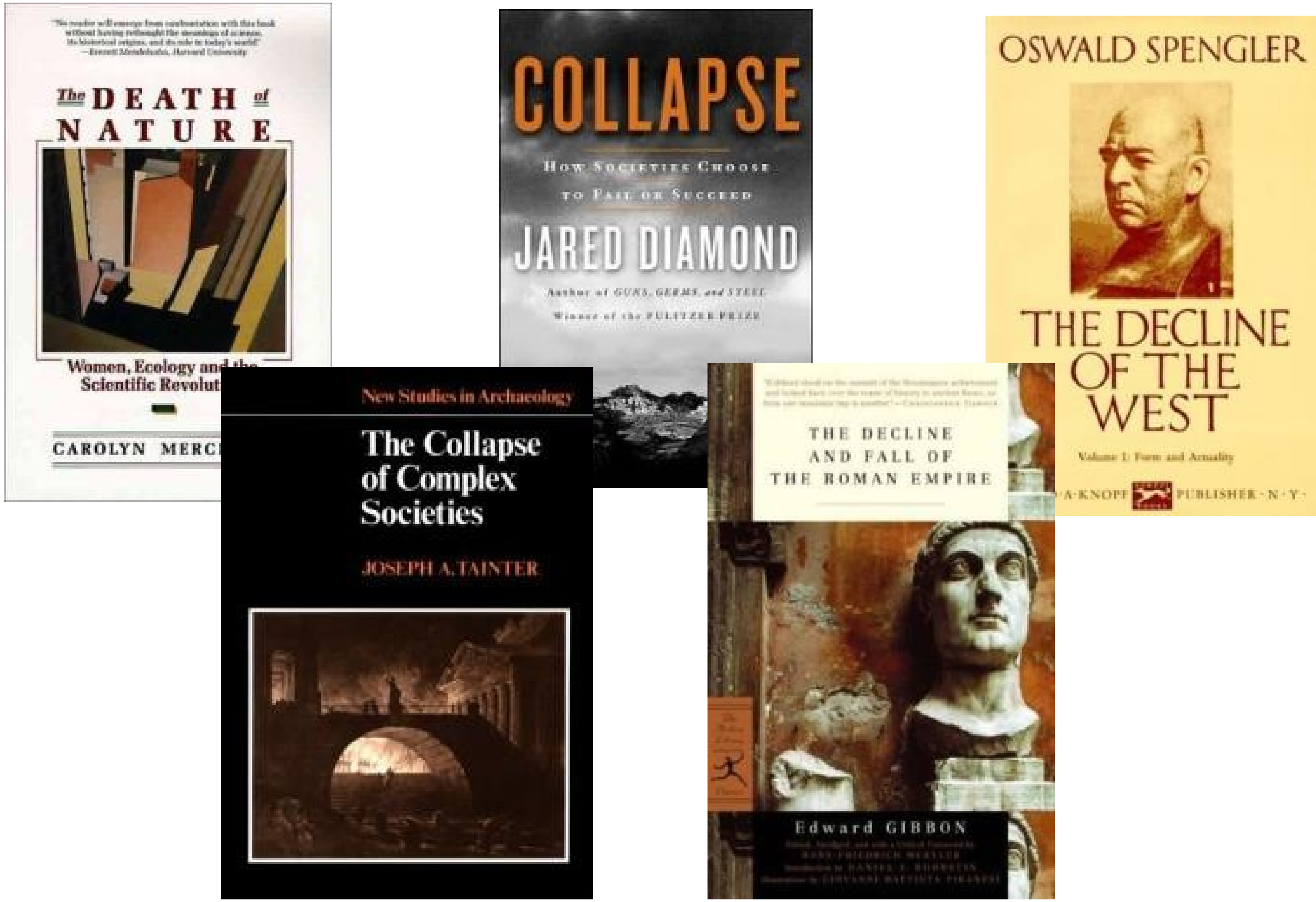
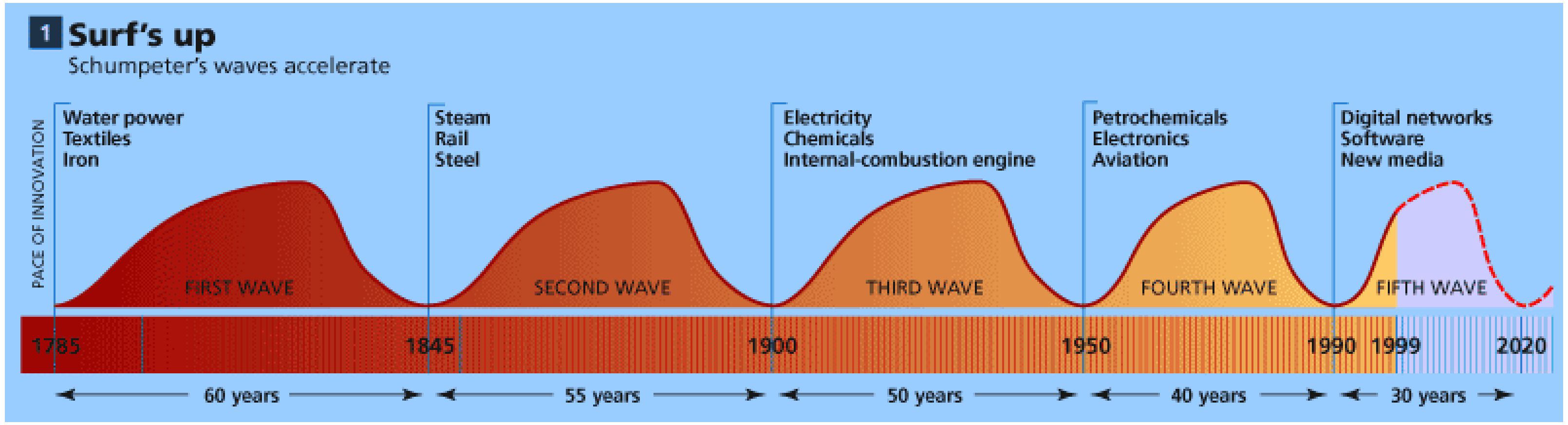
All systems show signs of complex growth and **DECAY** dynamics

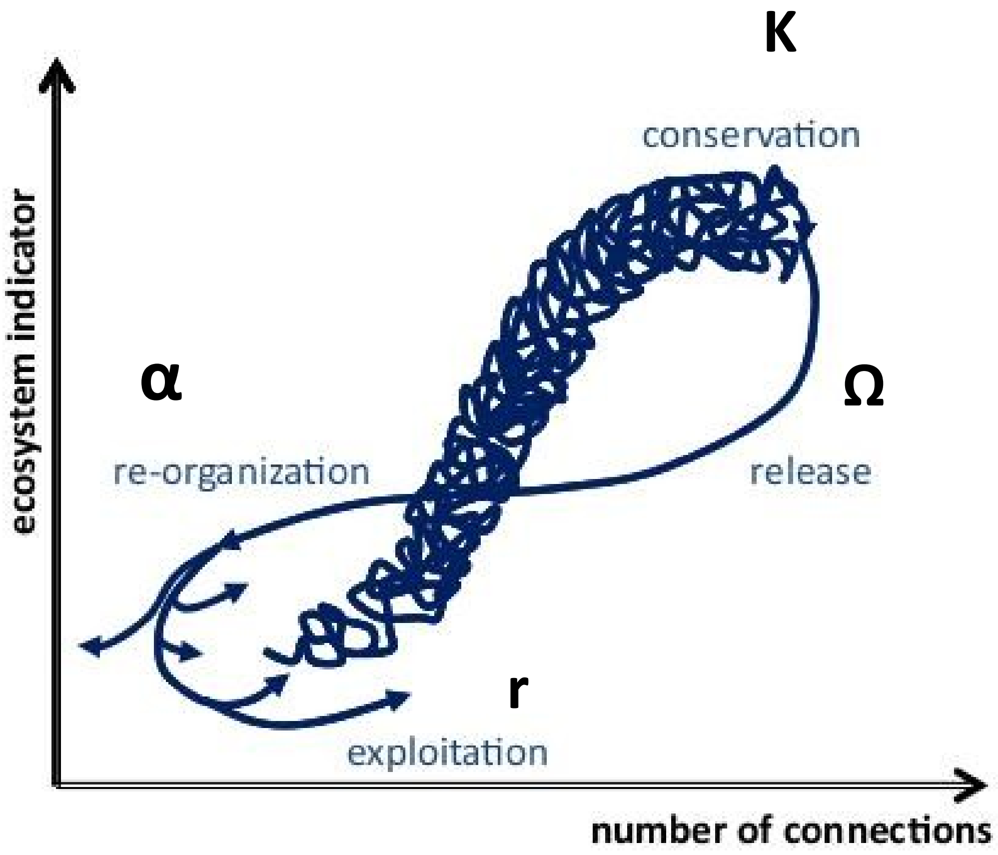


Benefits of collapse

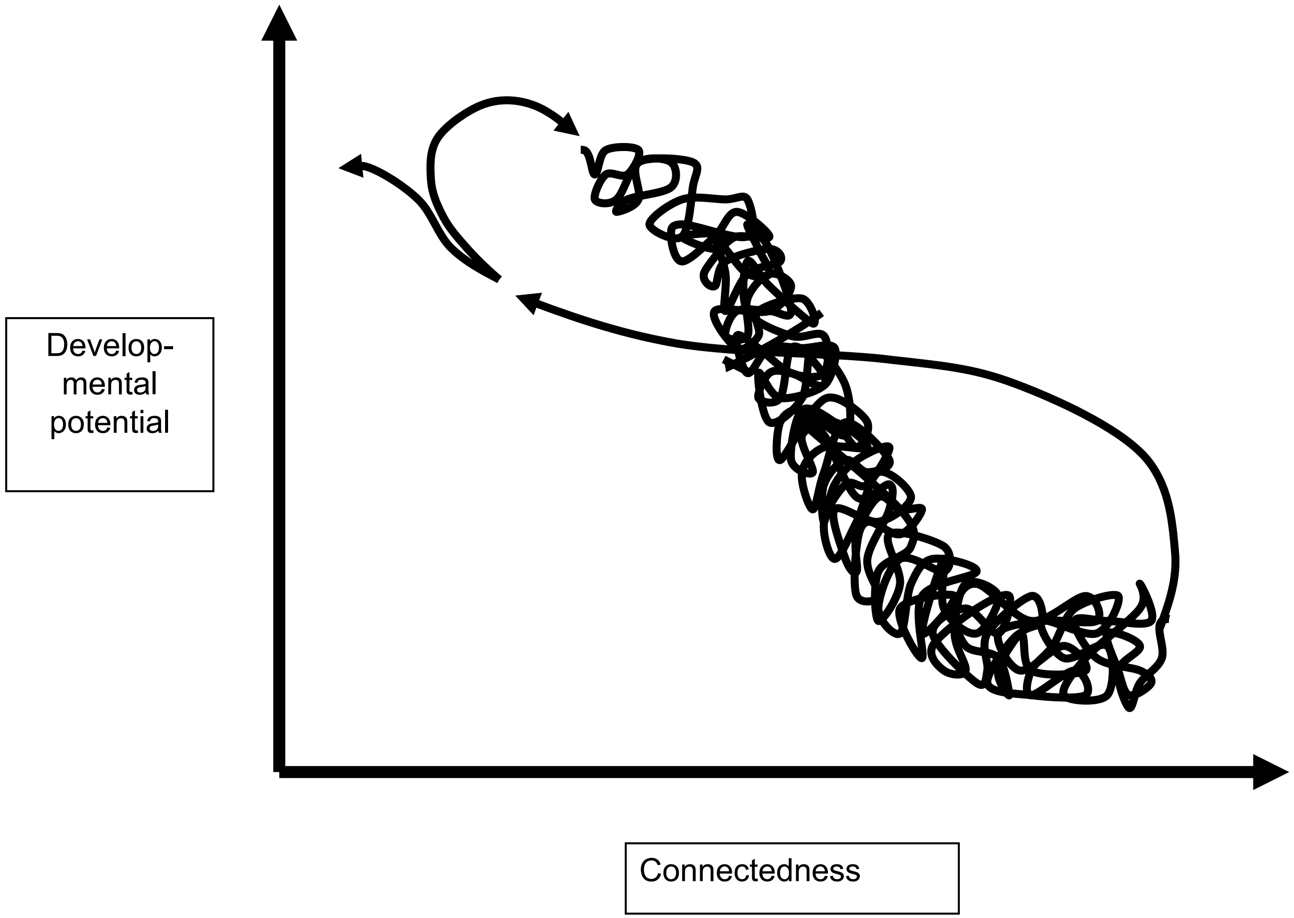
- Schumpeter labeled the collapse, “creative destruction”, since it allowed for new configurations and innovation opportunities



Adaptive Cycle - reoriented

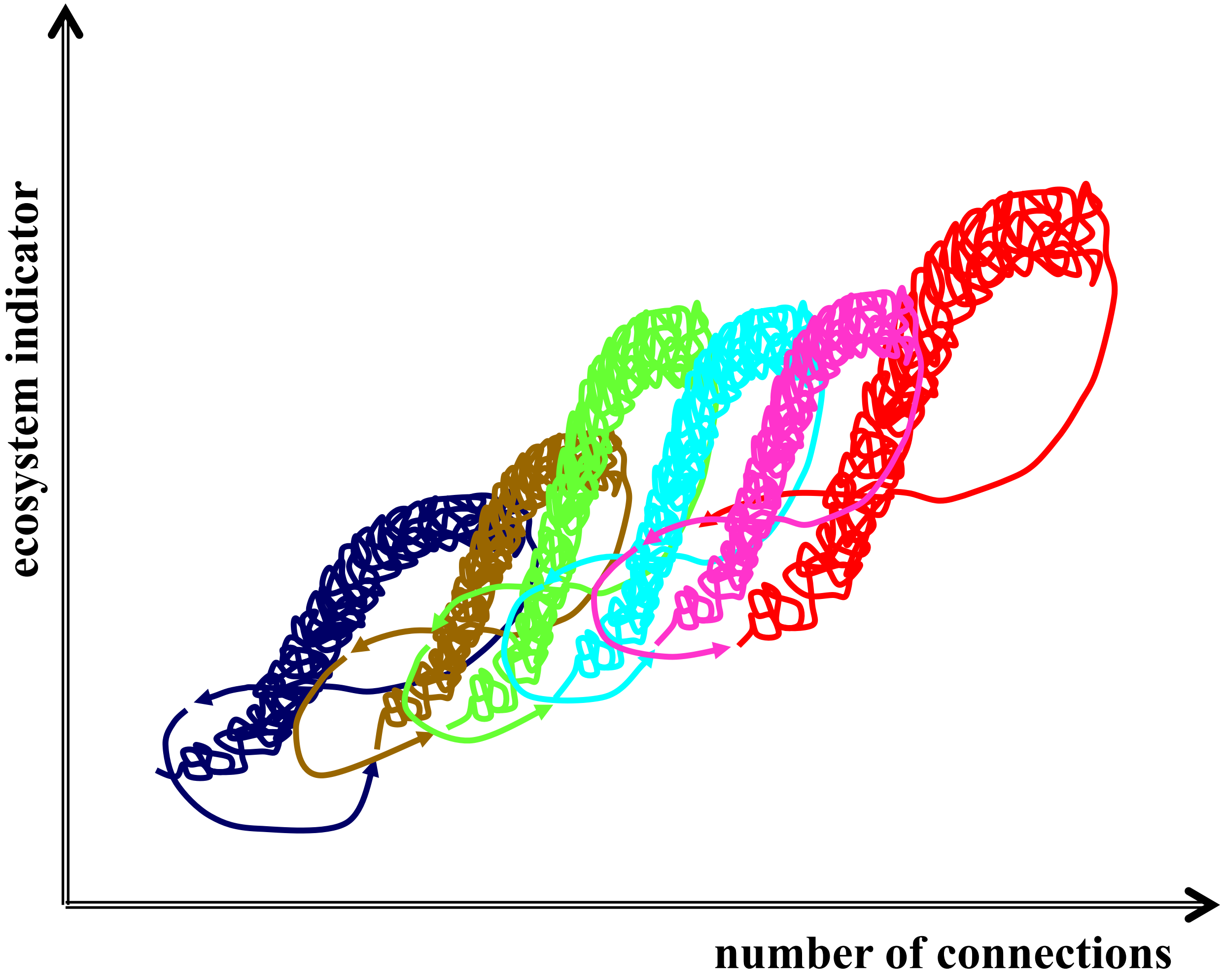


Burkhard et al. 2011

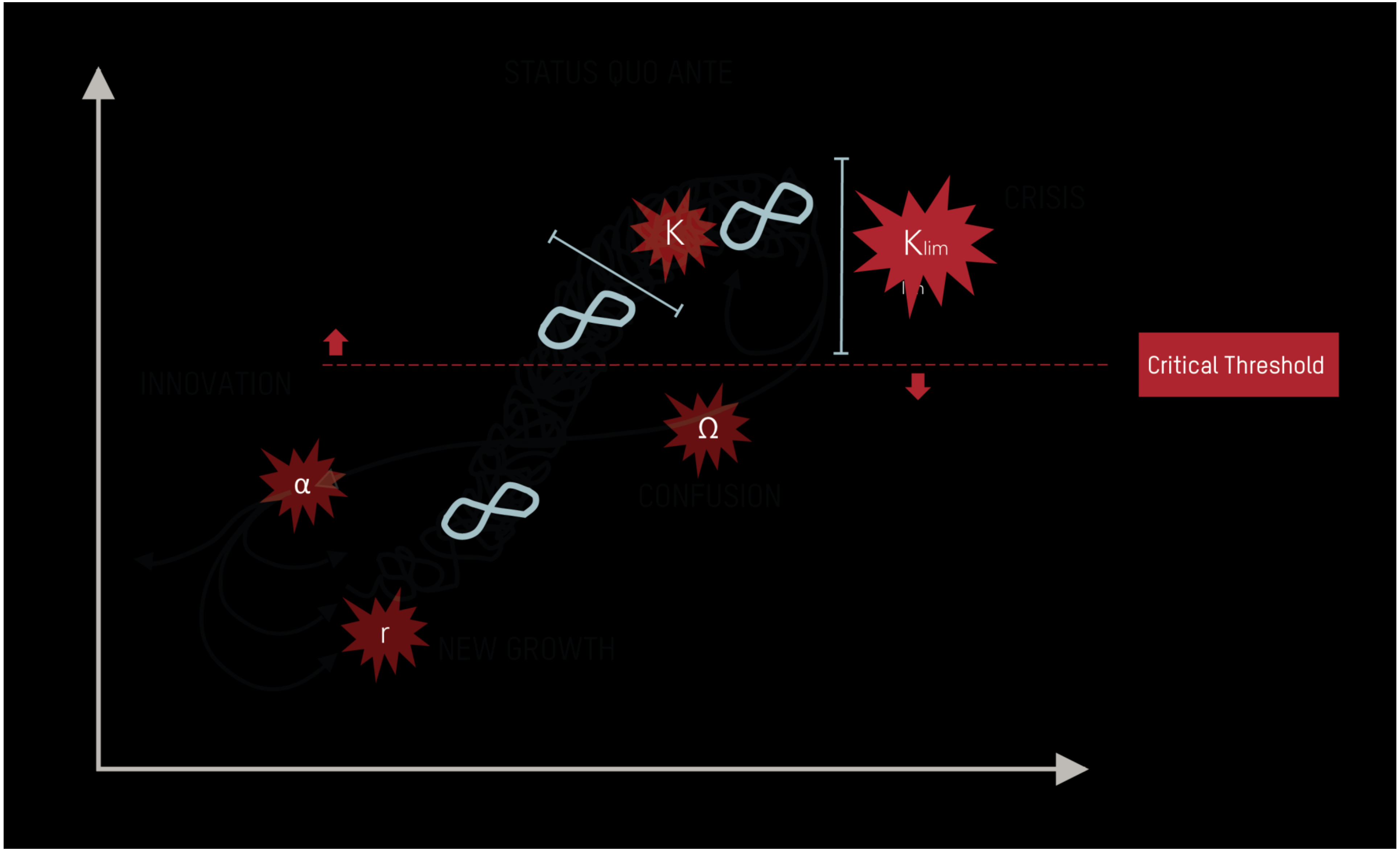


Developmental opportunities result from the collapse

December 31, 1995



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



Fath BD, Dean CA, Katzmair H. 2015. *Ecology and Society*. 20 (2), 24.

Summary

- Ecosystems are the minimum unit to sustain life
- Ecosystems and are dynamic, undergoing **patterned** growth and development
- Different stages emphasize different “priorities”
  - growth v. development
  - positive feedback v. negative feedback
  - change v. stasis
- Disturbance is a natural part of the complex systems cycle
- Resilience is the ability to navigate the entire adaptive cycle