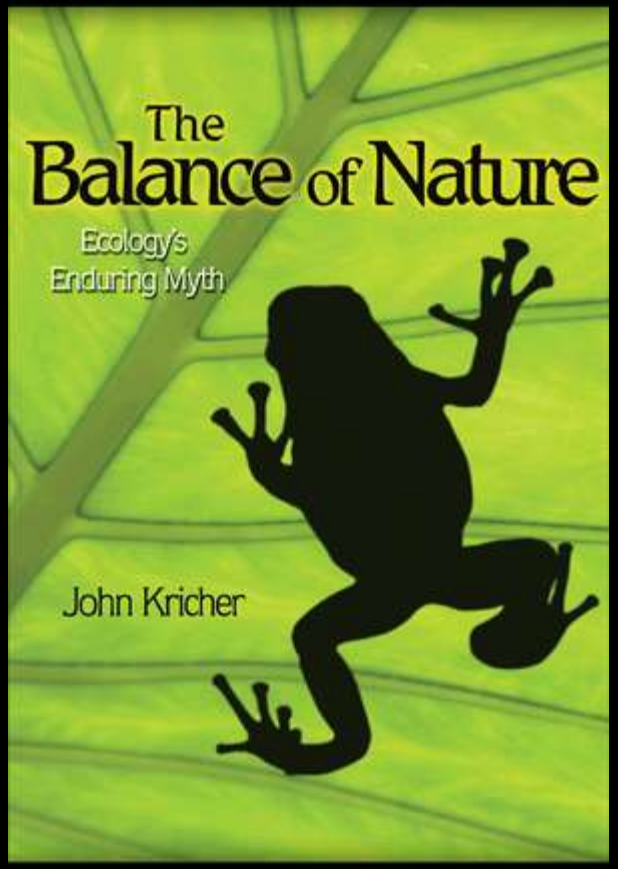
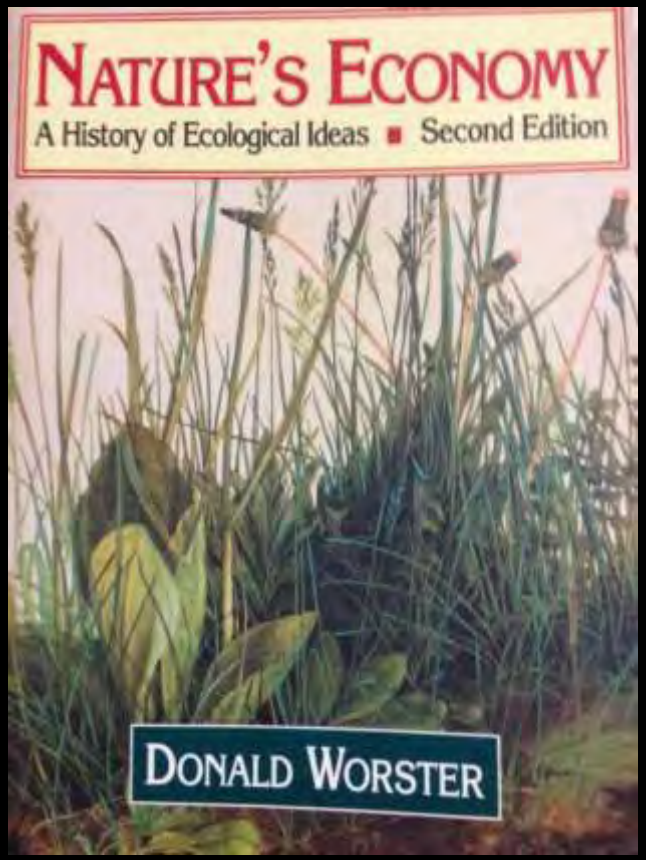
Ecology, Ecosystem Services, and the Balance of Nature

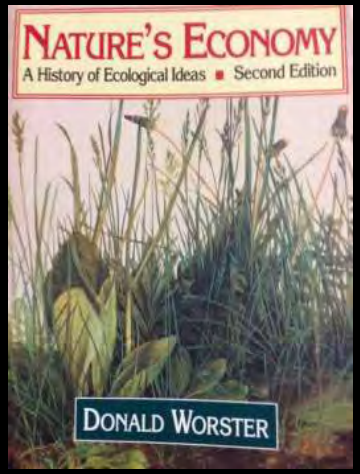
Kevin M. Anderson, Ph. D.
Austin Water Center for Environmental Research





Biology – the study of Life – biotic

Ecology – the study of Life Systems [ecosystems] – biotic and abiotic



- The word ecology was coined in 1866 by the German zoologist Ernst Haeckel, who applied the term oekologie to the "relation of the animal both to its organic as well as its inorganic environment."
- "the body of knowledge concerning the economy of nature (…) the study of all those complex interrelationships referred to by Darwin as the condition of the struggle for existence"
- The word comes from the Greek oikos, meaning "household," "home," or "place to live." Thus, ecology deals with the organism and its environment.
- "Every generation…writes its own description of the natural order, which generally reveals as much about human society and its changing concerns as it does about nature." Worster

Order and Change - Evolution

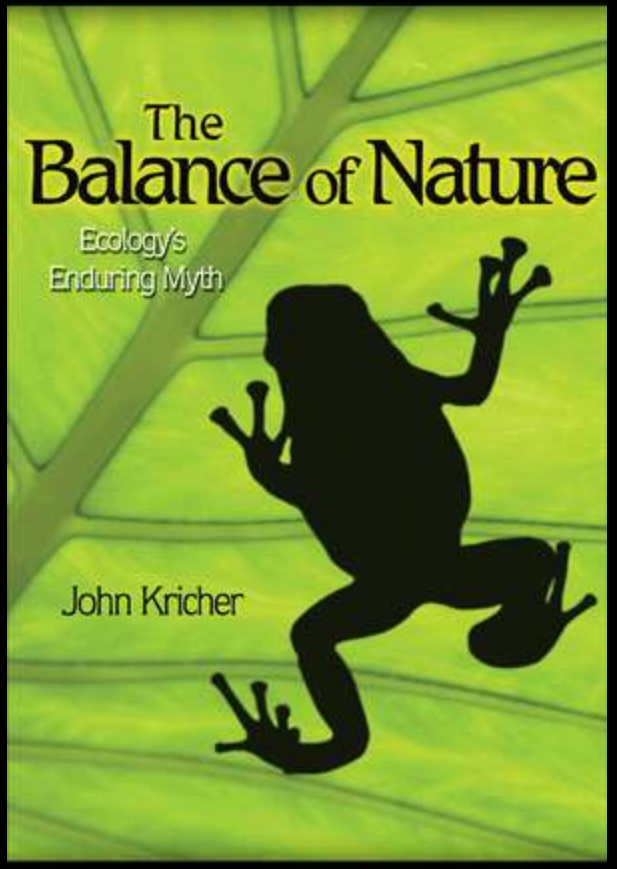
"The existence of a balance of nature has been a dominant part of Western philosophy since before Aristotle.

But the science of ecology and evolutionary biology together demonstrate that there is no balance of nature—not today and not at anytime in Earth's long history.

The paradigm is based on belief, not data; it has no scientific merit.

Nature is constantly in flux varying in scales of space and time, and most of that flux is due entirely to natural causes. At this time of extraordinary human influence on Earth's ecosystems and biota, I argue that it is essential for humanity to understand how evolution occurs and why ecology is far more dynamic than static."

Nothing Endures But Change
Heraclitus 540-480BC

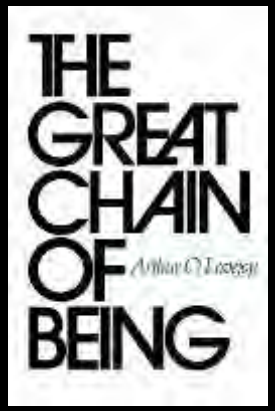


Order of Nature

Aristotle's *History of Animals* classified organisms in relation to a hierarchical "Ladder of Life" (scala naturae), placing them according to complexity of structure and function so that higher organisms showed greater vitality and ability to move

Aristotle believed that creatures were arranged in a graded scale of perfection rising from plants on up to man, the scala naturae or Great Chain of Being.

Arthur O. Lovejoy (1936), *The Great Chain of Being: A Study of the History of an Idea*



The Economy of Nature
Carl Linnaeus 1707 – 1778

Swedish botanist, physician, and zoologist, who laid the foundations for the modern scheme of binomial nomenclature (*Genus species*).

The first edition of *Systema Naturae* was printed in 1735. He then returned to Sweden, where he became professor of botany at Uppsala. In 1751 he publishes *The Economy of Nature*, [Transl. of *Oeconomia naturae*],

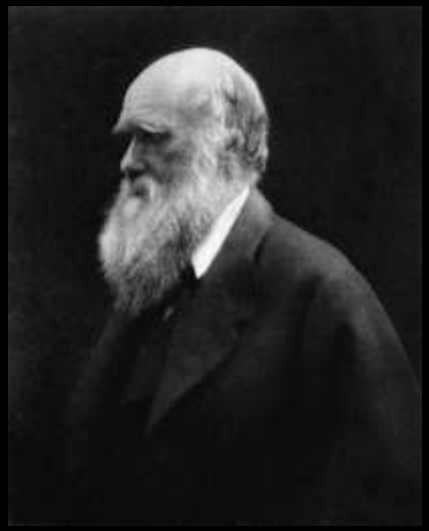
Linnaeus opened his *The Economy of Nature*, “We understand the all-wise disposition of the Creator in relation to natural things, by which they are fitted to produce general ends and reciprocal uses.“

"an order of nature, that some animals should be, as it were, created only to be miserably butchered by others, it seems that his Providence not only aimed at sustaining, but also keeping a just proportion amongst all the species; and so prevent any one of them increasing too much, to the detriment of men, and other animals.

For if it be true, as it is most assuredly, that the surface of the earth can support only a certain number of inhabitants, they must all perish, if the same number were doubled or tripled."

Evolution and the Economy of Nature

Charles Darwin 1809-1882



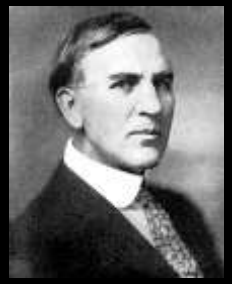
He established that all species of life have descended over time from common ancestry, and proposed the scientific theory that this branching pattern of evolution resulted from a process that he called natural selection in *On the Origin of the Species* (1859).

Darwin claims in the Origin that "all organic beings are striving, it may be said, to seize on each place in the economy of nature."

“The solution, as I believe, is that the modified offspring of all dominant and increasing forms tend to become adapted to many and highly diversified places in the economy of nature”

What was also new with Darwin is that the economy of nature began to be understood with conceptual tools borrowed from political economy. The division of labor, competition (“struggle” in Darwin’s words), trading, cost, the accumulation of innovations, the emergence of complex order from unintentional individual actions, the scarcity of resources and the geometric growth of populations are ideas borrowed from Adam Smith, Thomas Malthus, David Hume and other founders of modern economics.

Twentieth Century Development of Ecology – Equilibrium and Succession



Frederic Clements (1874-1945)
The Development and Structure of Vegetation (1904)
Plant Succession (1916)

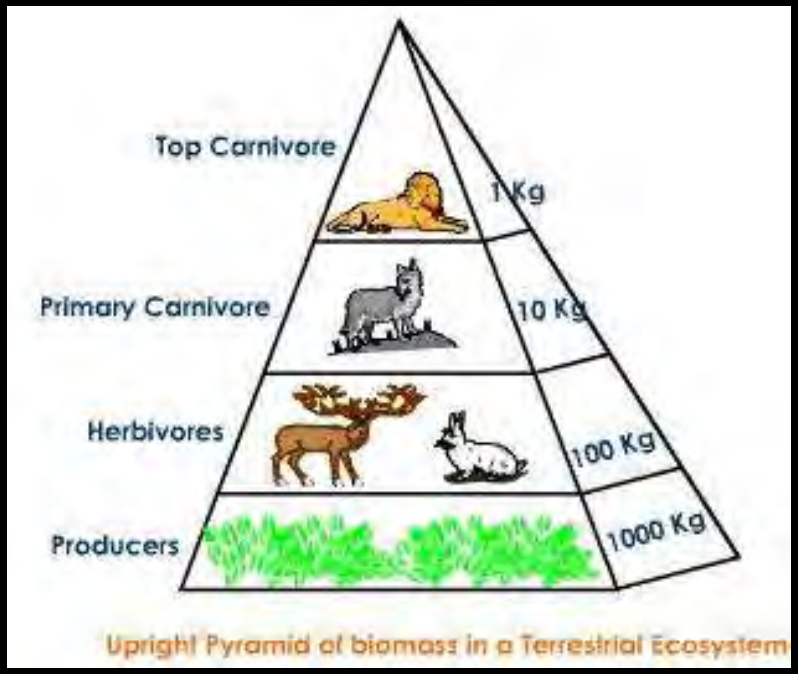
- Vegetation is dynamic
- Succession and climax stage
- Monoclimax – any region of Earth can have only one mature stage based on climate
- Assumes a natural state with no human interference – natural equilibrium
- "Nature's course, he contended, is not an aimless wandering to and fro but a steady flow toward stability that can be exactly plotted by the scientist." Worster

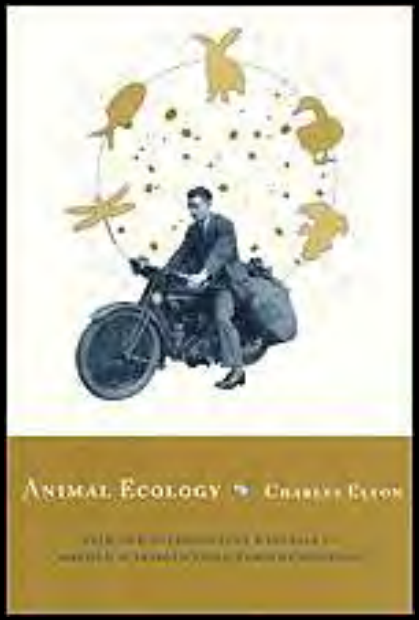
Twentieth Century Development of Ecology – Food Web and Energy

Charles Elton (1900-1991) Nature as a competitive economy

Animal Ecology (1927) "the sociology and economics of animals"

- 'the balance of nature does not exist, and perhaps has never existed'
- Community Structure – an economy of nature
- Food chain, food web
- Plants = producers, Animals = consumers (reducers, decomposers)
- Niche – the status or occupation of an organism in a community
- One species to one niche (competition)





Twentieth Century Development of Ecology – Ecosystem and Stability

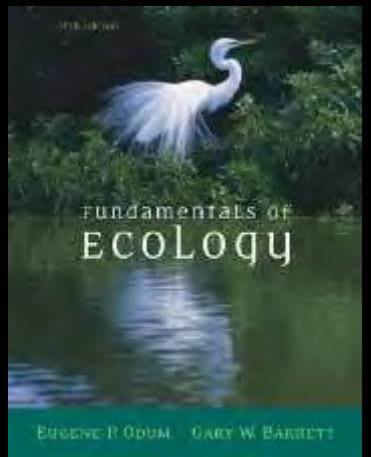
Ecology – systems and populations

Energy and Economic Model – Ecological Efficiency

Eugene Odum, *Fundamentals of Ecology* (1953)

- The law of organic nature is to bring order and harmony out of chaotic materials of existence
- Nature is a series of balanced ecosystems – the basic functional unit of ecology, and so a need for a unified theory of the ecosystem [a pond, a watershed, a meadow]
- A flow of energy leads to clearly defined trophic structure, biotic diversity, and material cycles within the system
- Rather than climax stage he used "mature ecosystem" – the ecosystem was often disturbed but fluctuated around a single homeostatic point – health = stability

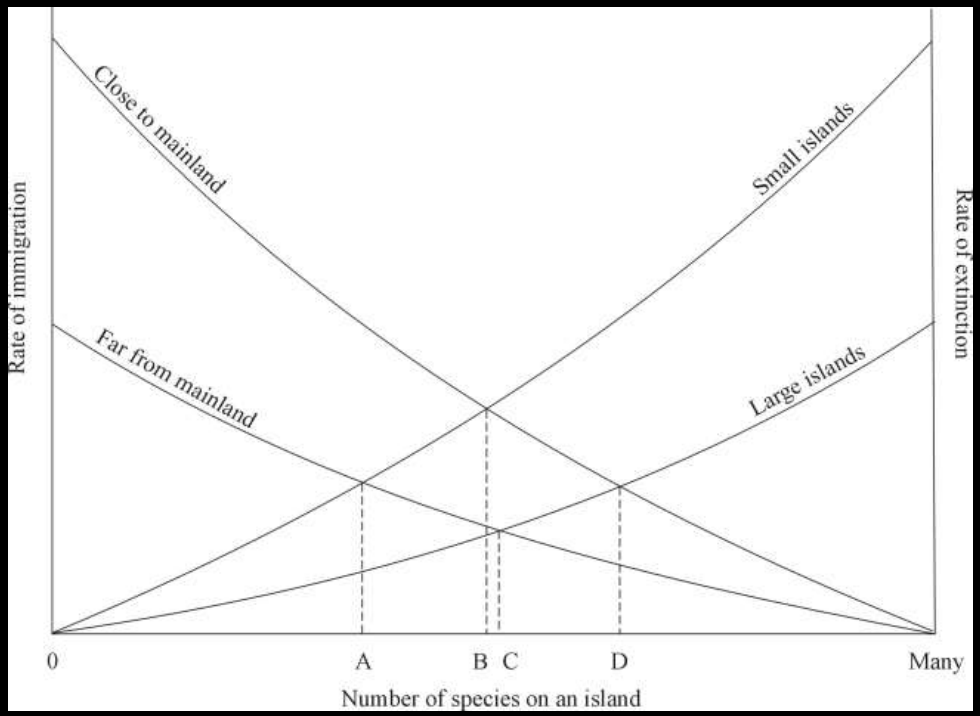
1. But is an ecosystem a reality or an abstraction?
2. Are ecosystems inherently stable?
3. How does disruption fit in?
4. How do the great disrupters – Humans - fit in?

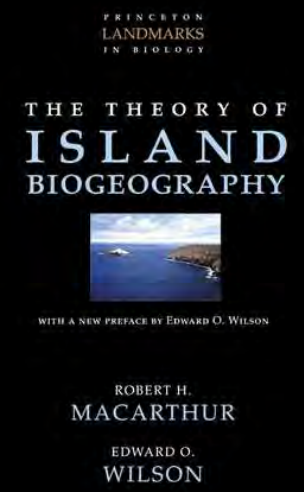


Development of Ecology – Equilibrium and Biodiversity

Robert MacArthur and Edward O. Wilson, *The Theory of Island Biogeography* (1967)

- An ecology that makes no testable predictions is not yet a science
- Mathematical modeling and islands
- The number of species represented on an island depends on size and location
- Number of species always reaches an equilibrium point – species diversity does not continue to develop indefinitely, new colonization must be matched by extinction – community structure focus rather than ecosystem



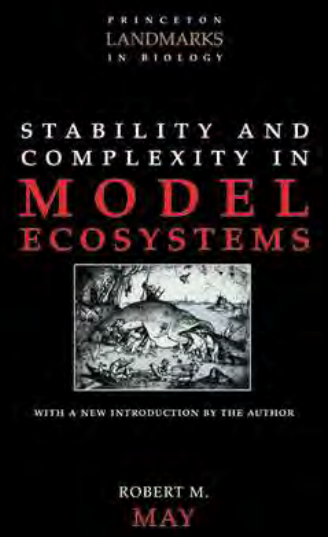


The “new ecology” post-Odum

No inherent stability

Robert May, *Stability and Complexity in Model Ecosystems* (1973)

- Mathematical models demonstrate that the more species there were, the more fragile was the system
- Chaos theory and complexity, “Confronted with disturbances beyond their normal experience” complex systems like rainforests tended to crumple.



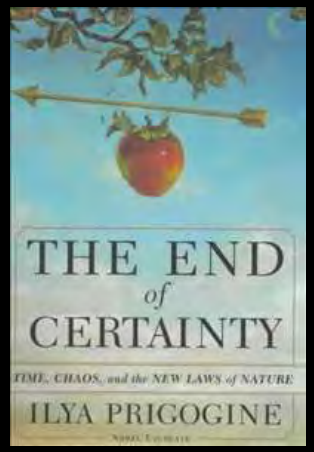
Instability of biodiversity and invasion biology

Daniel Botkin, *Discordant Harmonies: A New Ecology for the Twenty-first Century* (1990)

The new ecology emphasizes

- Disequilibria
- Instability
- Chaotic fluctuations

in ecosystems both “natural” and human impacted



If 20th-century ecology was marked by an infatuation with balance, then our era is one of disturbance, disruption, non-equilibrium, chaos, and randomness.

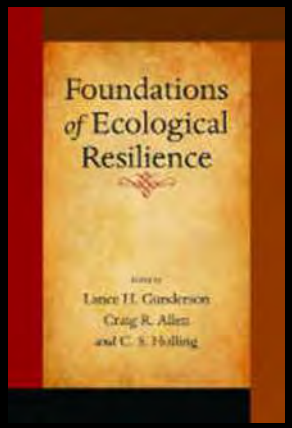
The New Ecology of Change - Ecological Resilience

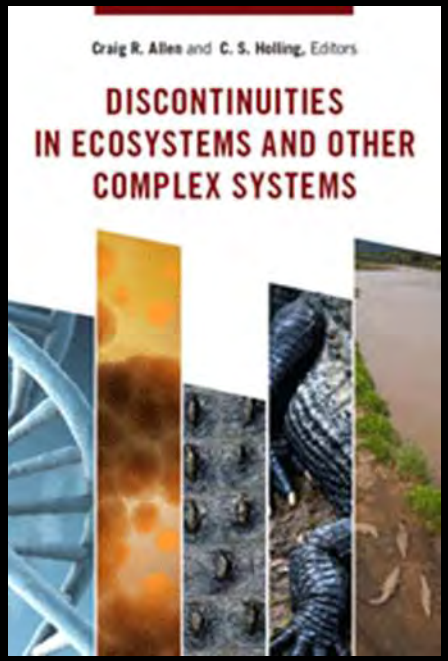
The general meaning of resilience, derived from its Latin roots 'to jump or leap back', is the ability to recover from or adjust easily to misfortune or change.

The concept of resilience in ecological systems was first introduced by the Canadian ecologist C.S. Holling in order to describe the persistence of natural systems in the face of changes in ecosystem variables due to natural or anthropogenic causes.

Holling argued that complex adaptive systems did not tend toward equilibria, but toward maximizing diversity over deeper evolutionary time.

Holling, C.S. (1973). "Resilience and stability of ecological systems". Annual Review of Ecology and Systematics 4: 1–23.





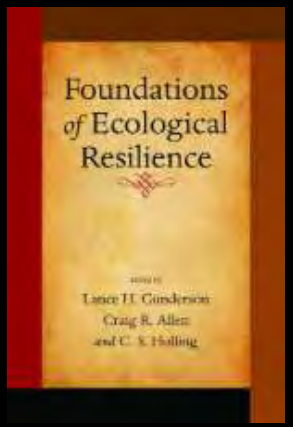
Resilience is...

…the ability to absorb disturbances, to be changed and then to reorganize and still have the same identity (retain the same basic structure and ways of functioning).

As resilience declines the magnitude of a shock from which an ecosystem cannot recover gets smaller and smaller.

Ecosystem resilience is the capacity of an ecosystem to tolerate disturbance without collapsing into a qualitatively different state that is controlled by a different set of processes.

A resilient ecosystem can withstand shocks and rebuild itself when necessary.



"Resilience" as applied to ecosystems has three defining characteristics:

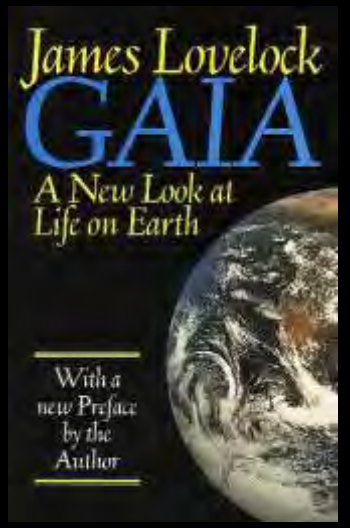
- The amount of change the system can undergo and still retain the same controls on function and structure
- The degree to which the system is capable of self-organization
- The ability to build and increase the capacity for learning and adaptation

Gaia Hypothesis and Symbiotic Nature

The hypothesis, which is named after the Greek goddess Gaia, was formulated by the scientist James Lovelock and co-developed by the microbiologist Lynn Margulis in the 1970s.

The Gaia hypothesis proposes that organisms interact with their inorganic surroundings on Earth to form a self-regulating, complex system that contributes to maintaining the conditions for life on the planet.

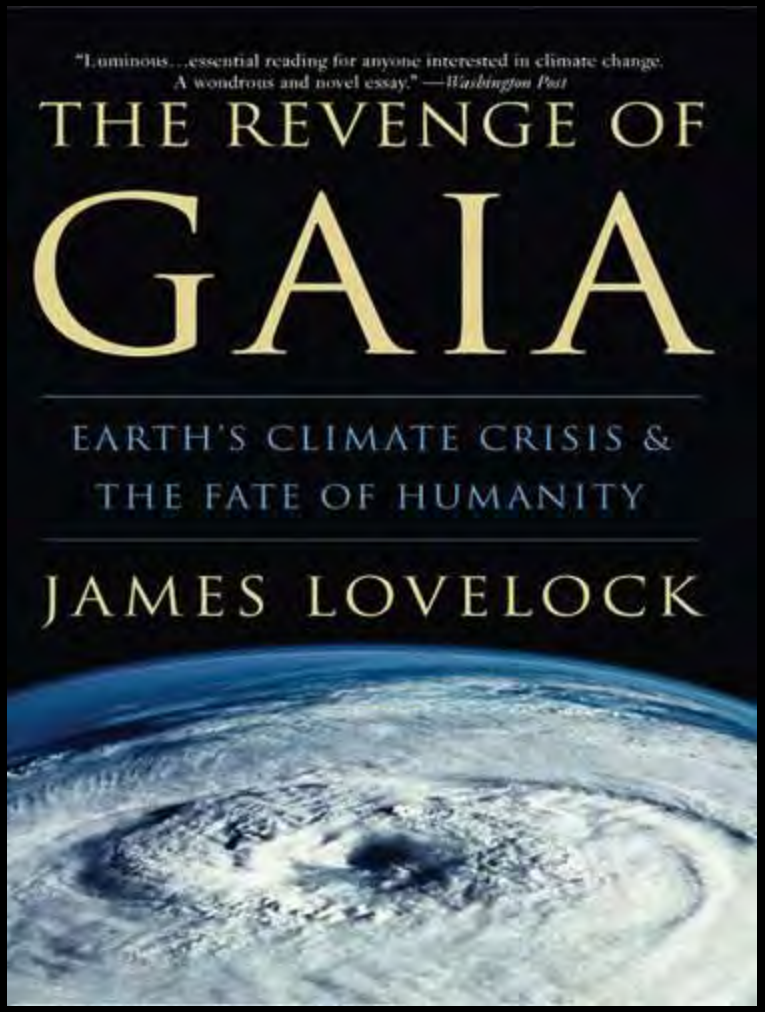
“the biota and its environment constitute a single homeostatic system that opposes changes unfavorable for life”

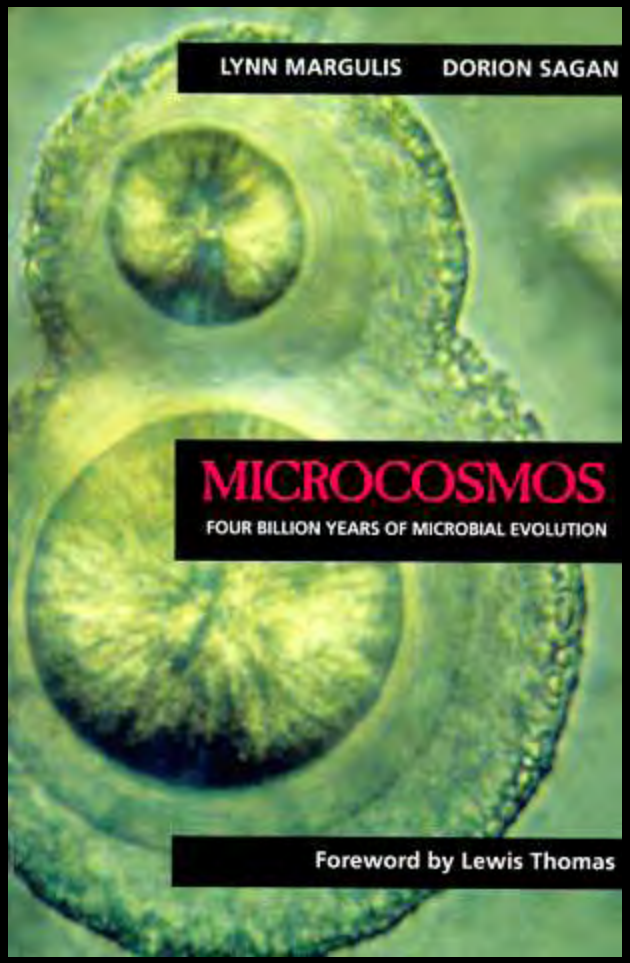


The scientifically accepted form of the hypothesis has been called "influential Gaia". It states the biota influence certain aspects of the abiotic world, e.g. temperature and atmosphere. They state the evolution of life and its environment may affect each other.

An example is how the activity of photosynthetic bacteria during Precambrian times have completely modified the Earth atmosphere to turn it aerobic, and as such supporting evolution of aerobic organisms (in particular eukaryotic life).

[But why did Gaia favor only the evolution of a particular branch of life?]


"Luminous…essential reading for anyone interested in climate change. A wondrous and novel essay." —Washington Post
THE REVENGE OF
GAIA
EARTH'S CLIMATE CRISIS &
THE FATE OF HUMANITY
JAMES LOVELOCK



Symbiotic Nature

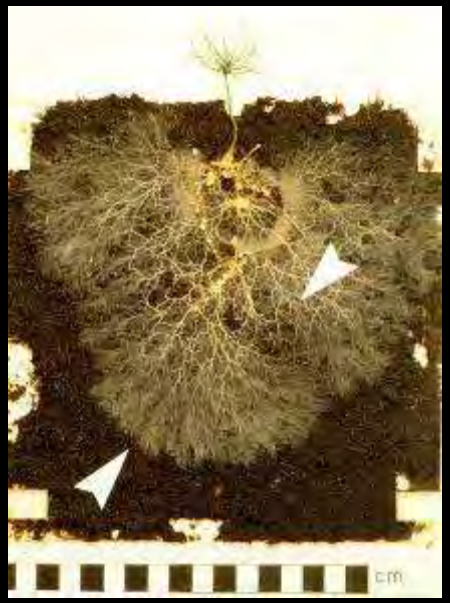
Symbiosis is a major driving force behind evolution. She considers Darwin's notion of evolution, driven by competition, as incomplete and claims that evolution is strongly based on cooperation, interaction, and mutual dependence among organisms.

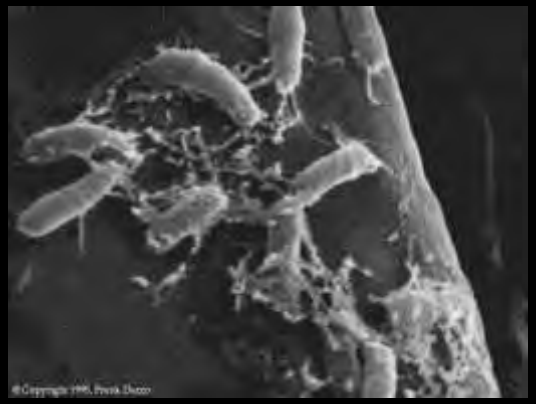
Endosymbiosis is any symbiotic relationship in which one symbiote lives within the tissues of the other, either in the intracellular space or extracellularly.

Examples are rhizobia, nitrogen-fixing bacteria that live in root nodules on legume roots; nitrogen-fixing bacteria called *Frankia*, which live in alder tree root nodules; single-celled algae inside reef-building corals; and bacterial endosymbionts that provide essential nutrients to about 10%–15% of insects.

Ectosymbiosis, also referred to as *exosymbiosis*, is any symbiotic relationship in which the symbiont lives on the body surface of the host, including the inner surface of the digestive tract

The Microcosmos





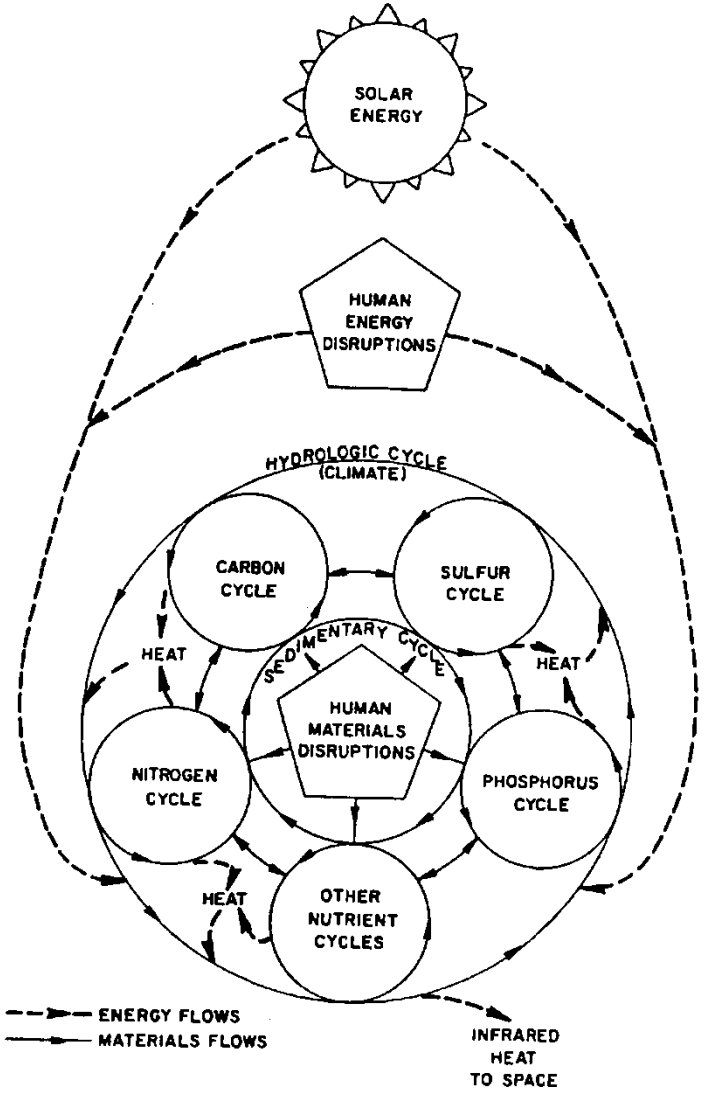


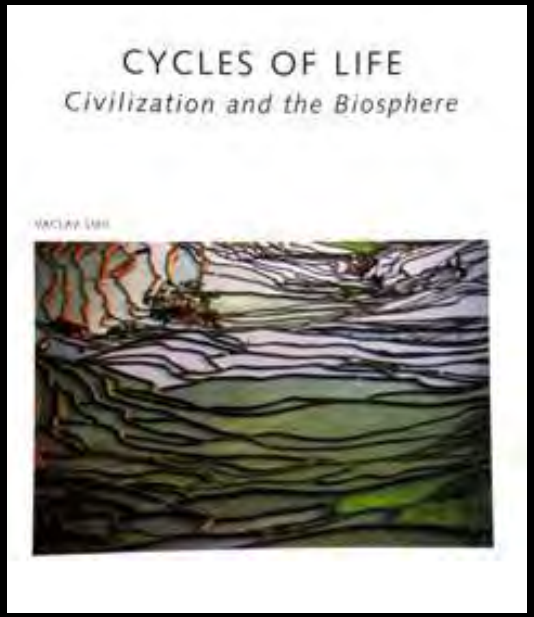
Figure 5.1. Climate and life are linked by a complex web of interconnected cycles. Life on earth depends on the cycling of nutrients through air, water, soil, and living things. The climate mediates the flow of materials through these global cycles. Solar energy degrades to heat at each stage of the cycling process and is eventually returned to space as infrared radiation. The composition of the earth's atmosphere regulates the radiative balance on earth between absorbed solar energy and emitted infrared energy, which, in turn, controls the climate.

Source: Schneider and Morton 1981.

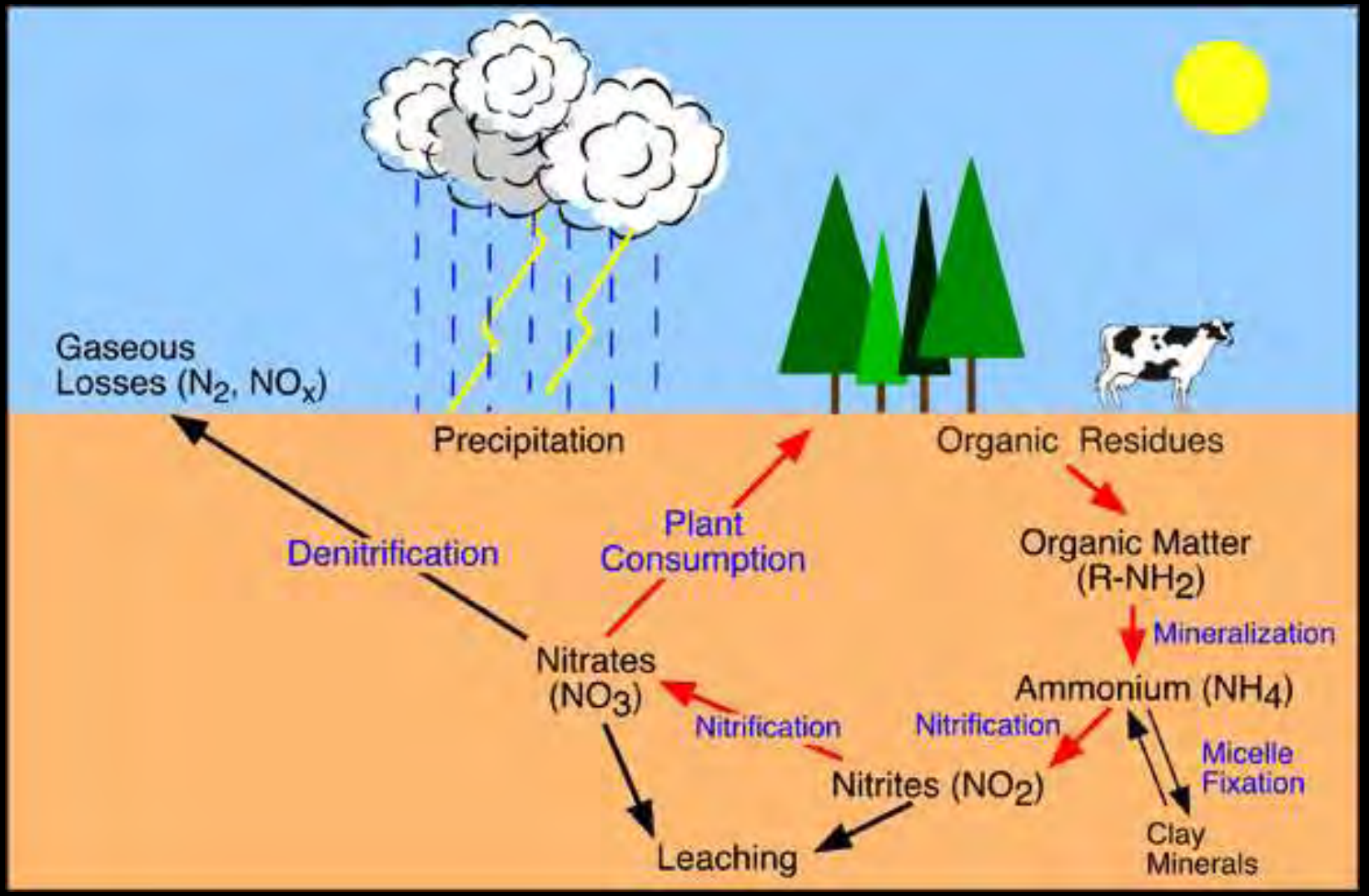
Ecosystem Cycles

[Biogeochemical Cycles]

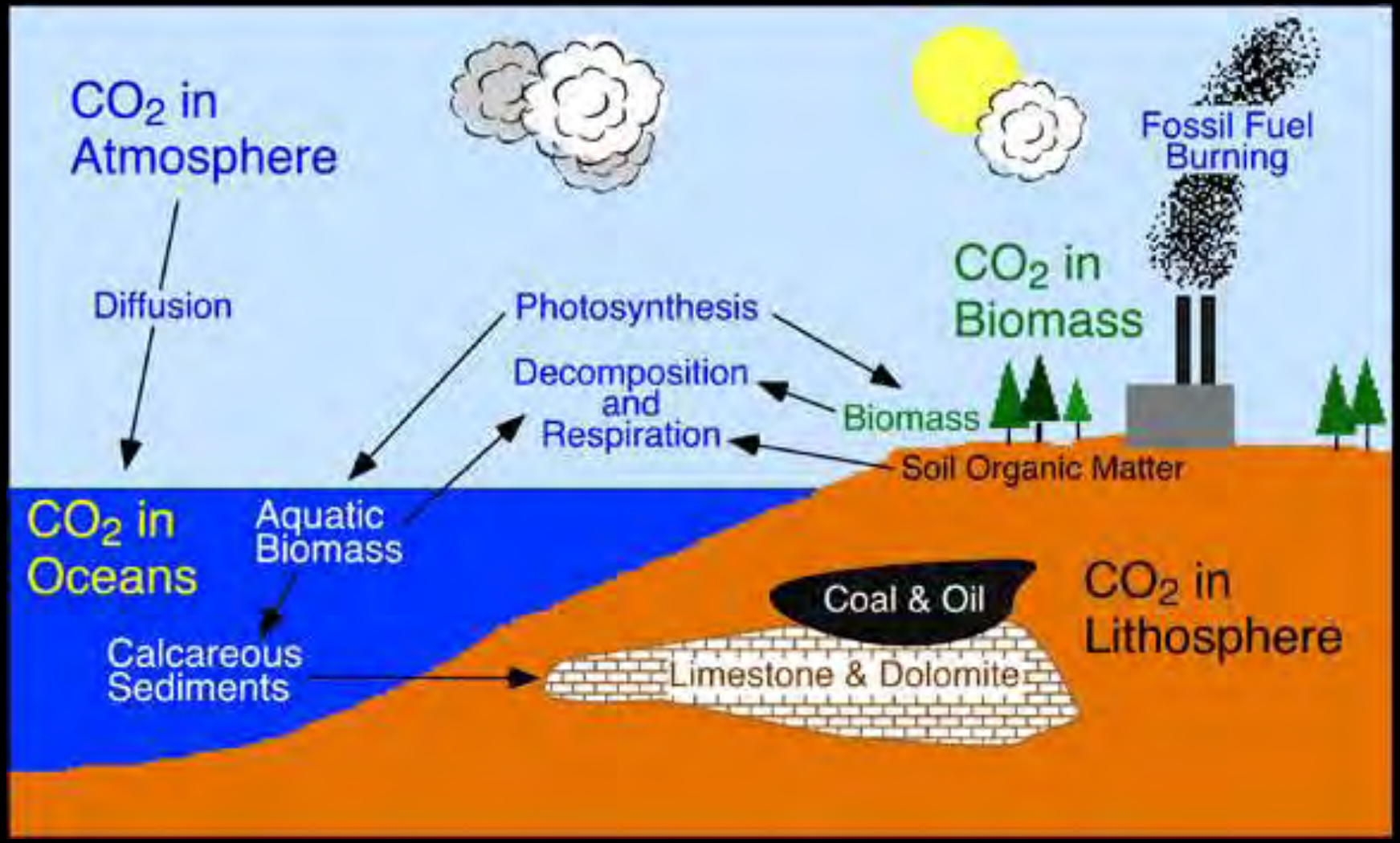
Short-circuiting Cycles



The Nitrogen Cycle



The Carbon Cycle



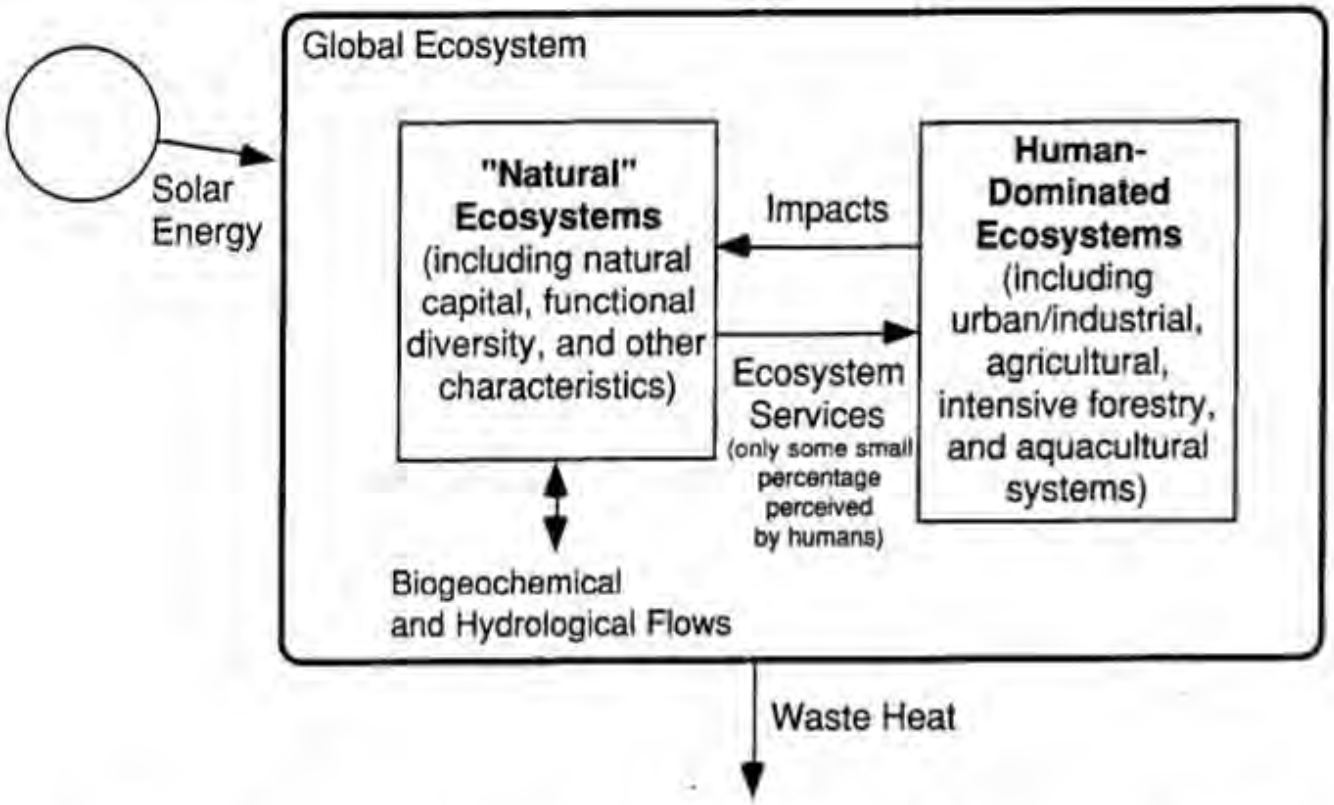
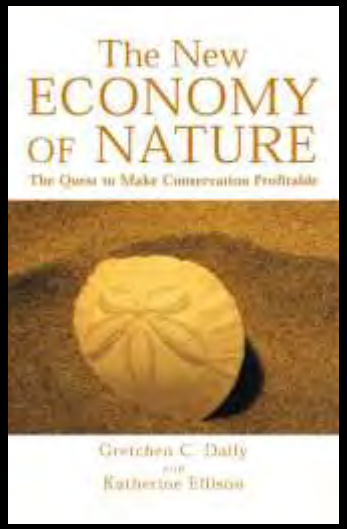


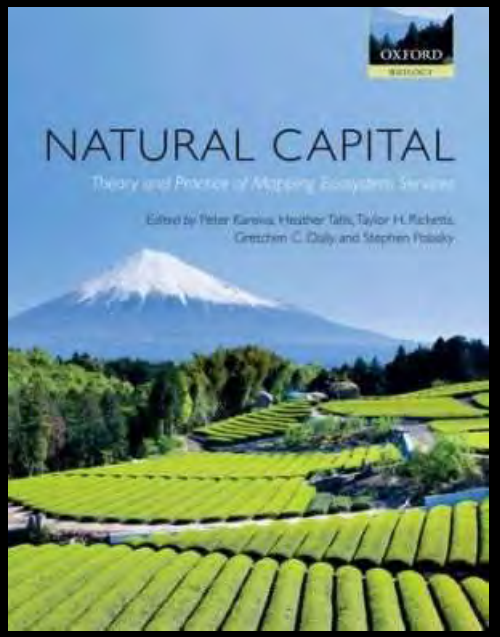
Figure 4.1. Human-dominated ecosystems are parts of the overall global system. Ecosystem services are essential for the development and well-being of human society, but only a fraction of this work is covered by market prices or perceived by humans.

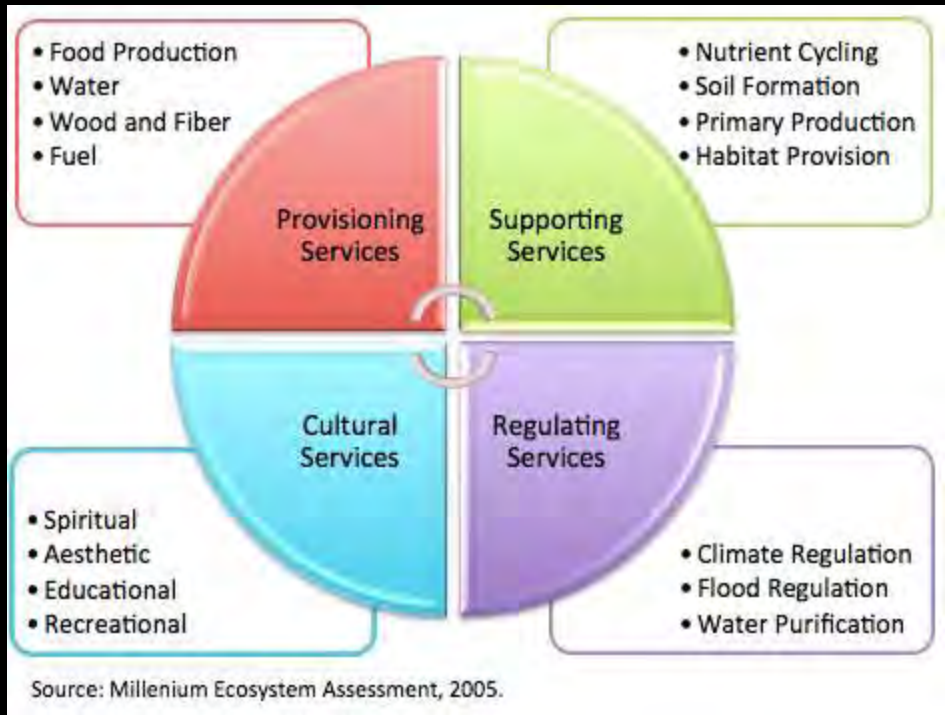
From Daily, *Nature's Services* 1997



Ecosystem Services

- Maintenance of atmosphere
- Protection from ultraviolet rays
- Regulation of climate
- Maintenance of genetic diversity
- Purification of air and water
- Detoxification and decomposition of wastes
- Generation of soil and renewal of soil fertility
- Pollination of vegetation
- Control of agricultural pests
- Dispersal of seeds
- Translocation of nutrients

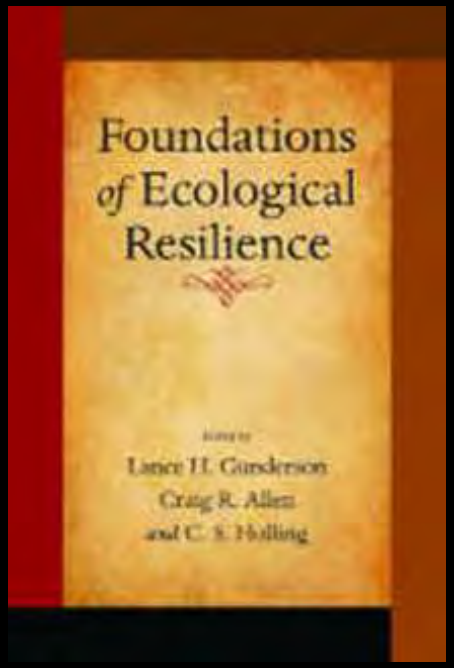




Source: Millenium Ecosystem Assessment, 2005.

Ecology – the study of Life Systems [ecosystems] – biotic and abiotic

The thing is, both balance and flux are undoubtedly aspects of nature. A new view of nature that combines them in a way that both scientists and the public find compelling is needed. We should bridge the present disparity between ecology as a science and ecology as a romantic idealism about nature, not only for intellectual reasons but for the sake of robust public policy.

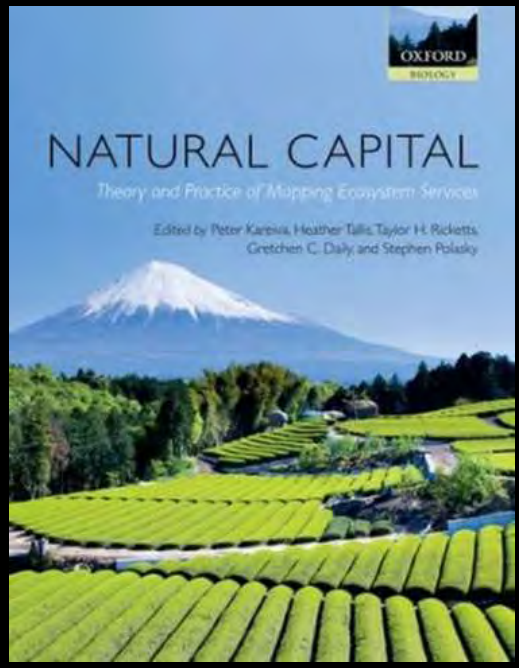


Order and Change – Evolution

Balance-> Stability-> Resilience

Nothing Endures But Change

Heraclitus 540-480BC



Ecology is an infant just learning to talk, and, like other infants, is engrossed with its own coinage of big words.

Its working days lie in the future.

Ecology is destined to become the lore of Round River, a belated attempt to convert our collective wisdom of biotic materials into a collective wisdom of biotic navigation.

This, in the last analysis, is conservation.