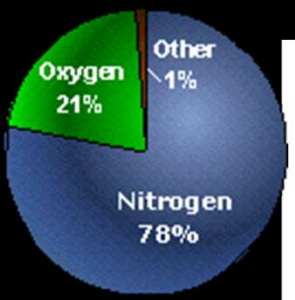
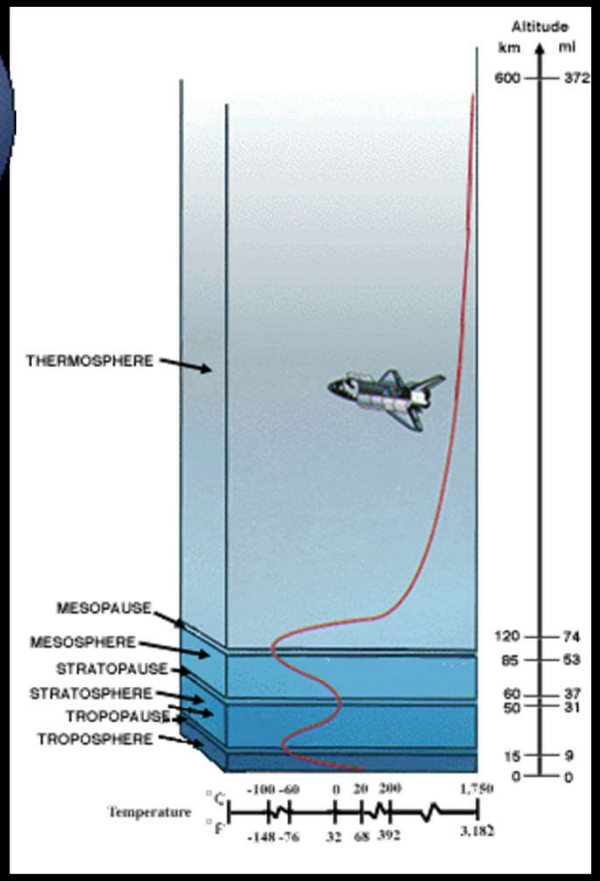
Class-6

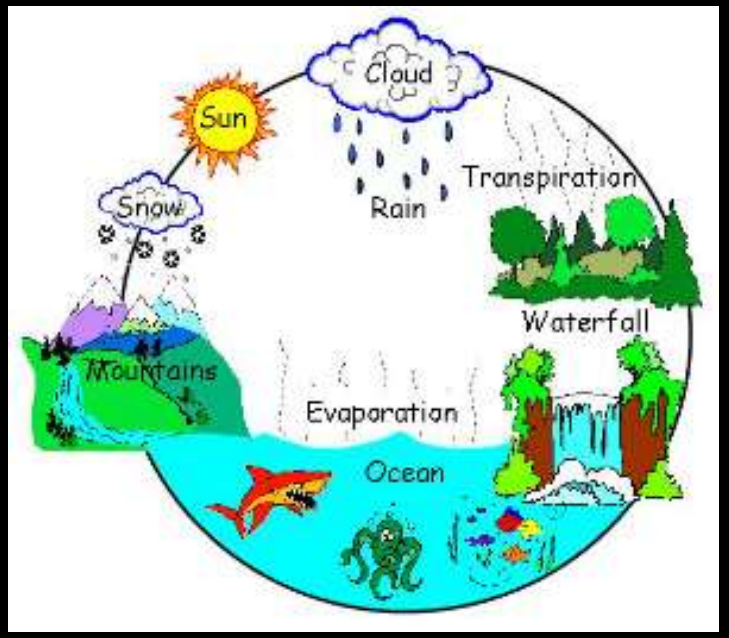
Earth System and its Components

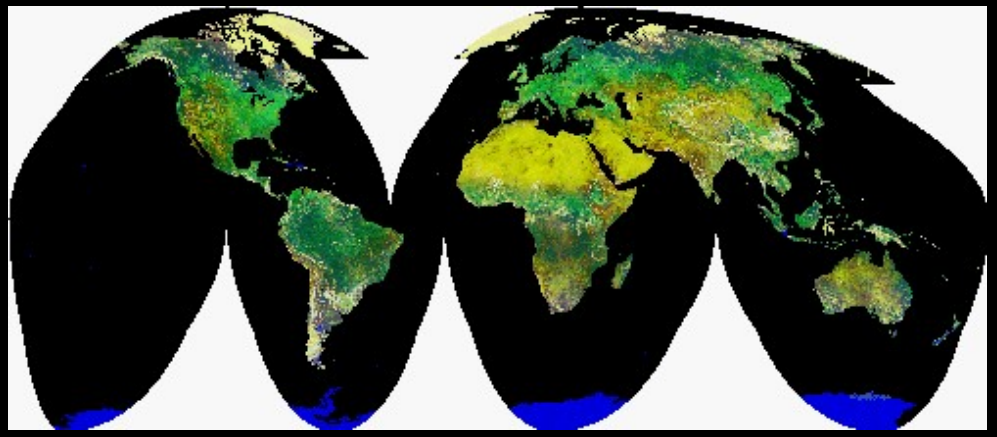
11th September 2023

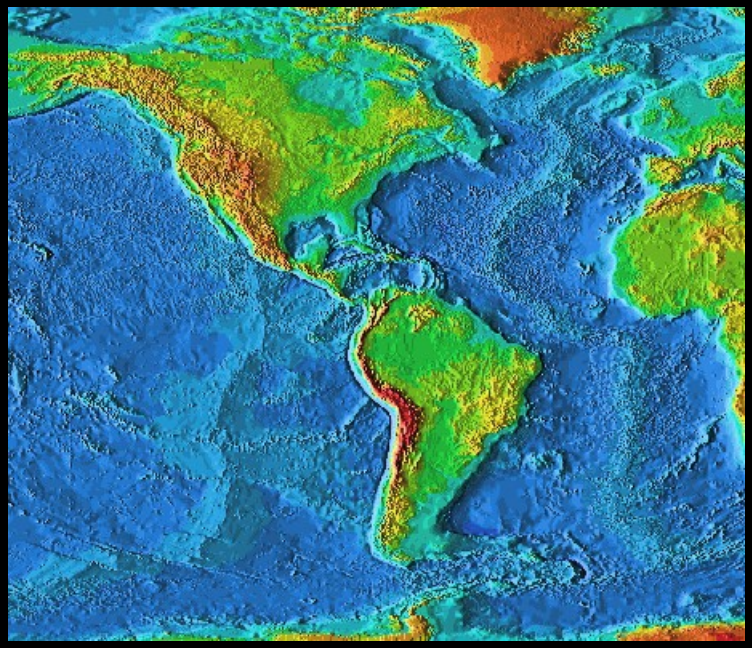
Earth Systems Overview





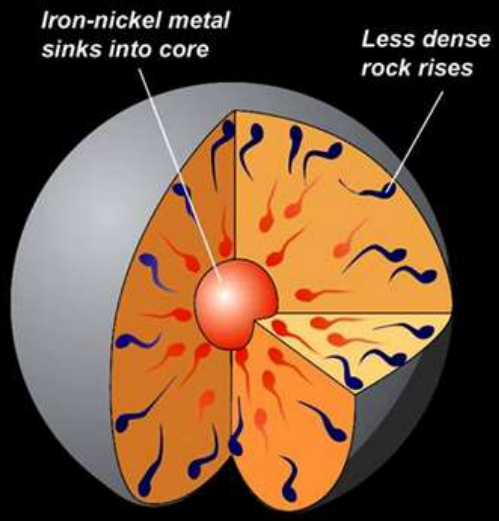


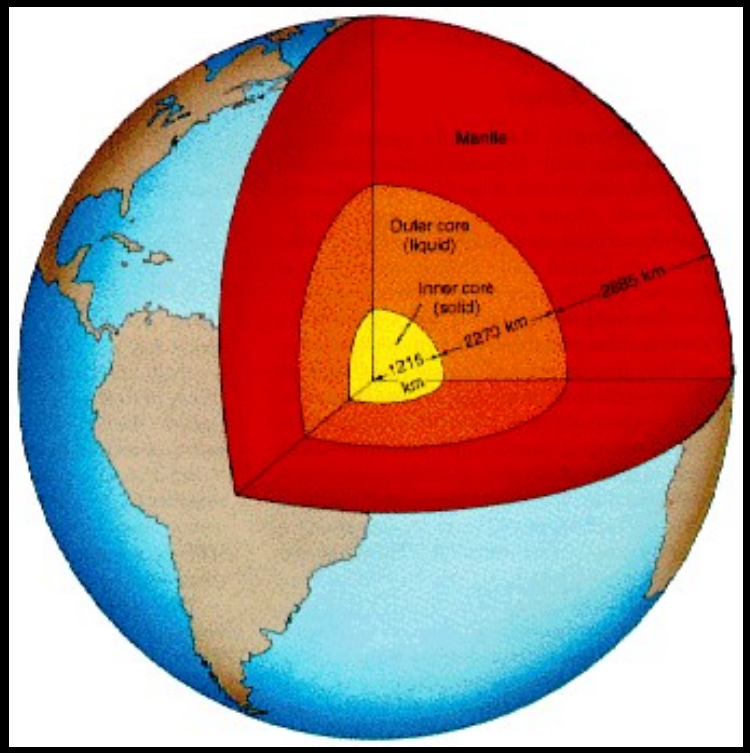




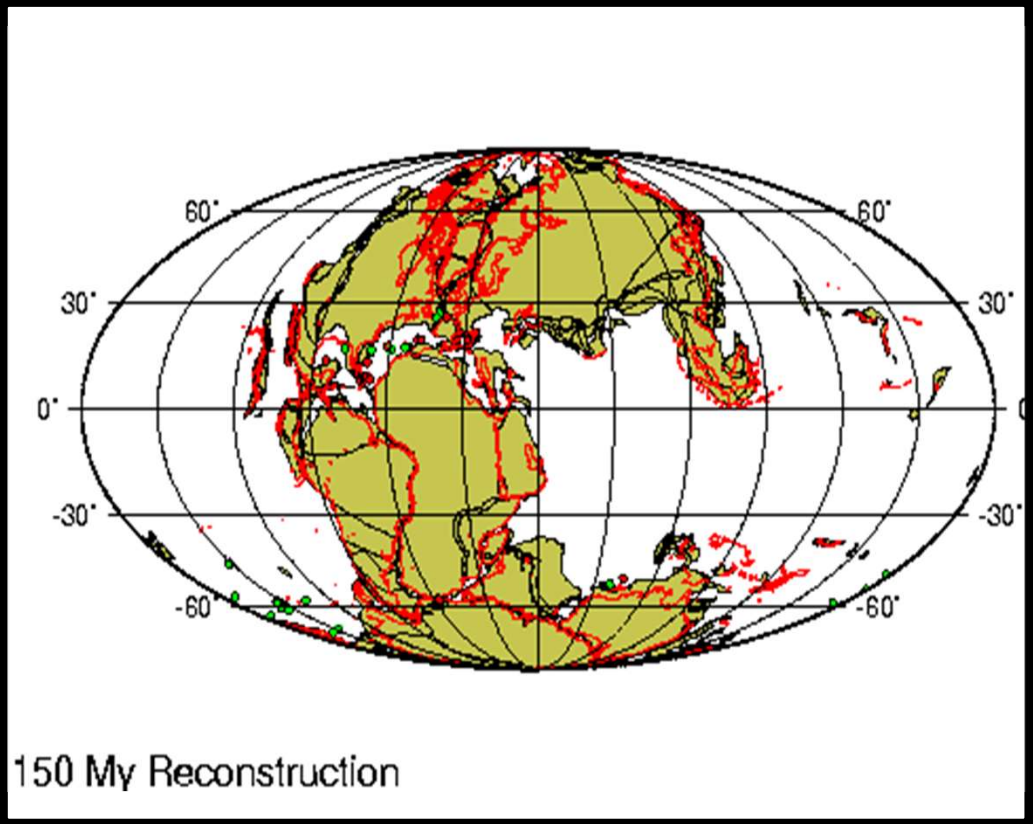
Layers of Earth

Core- center, mostly iron
Inner core- 1220 km thick, T & P cause iron to solidify
Outer core- 3480 km thick, liquid iron, creates magnetic field
Mantle- 70% of earth's interior, made of O, Si, Mg
Asthenospere- closest to core, gelatinous, where magma is formed
Upper mantle- cooler, more solid, brittle
Crust- outermost layer
Crust + upper mantle make up lithosphere

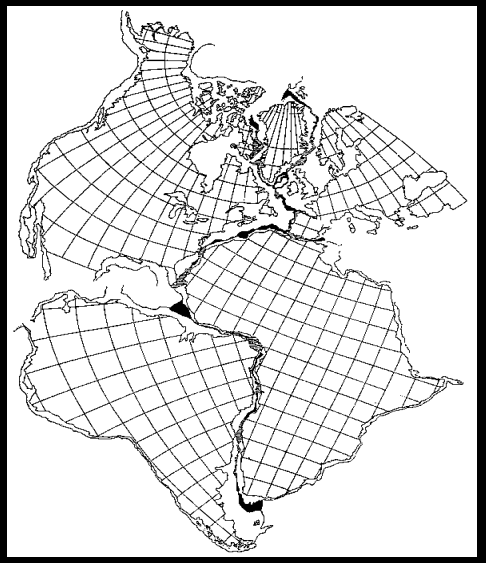


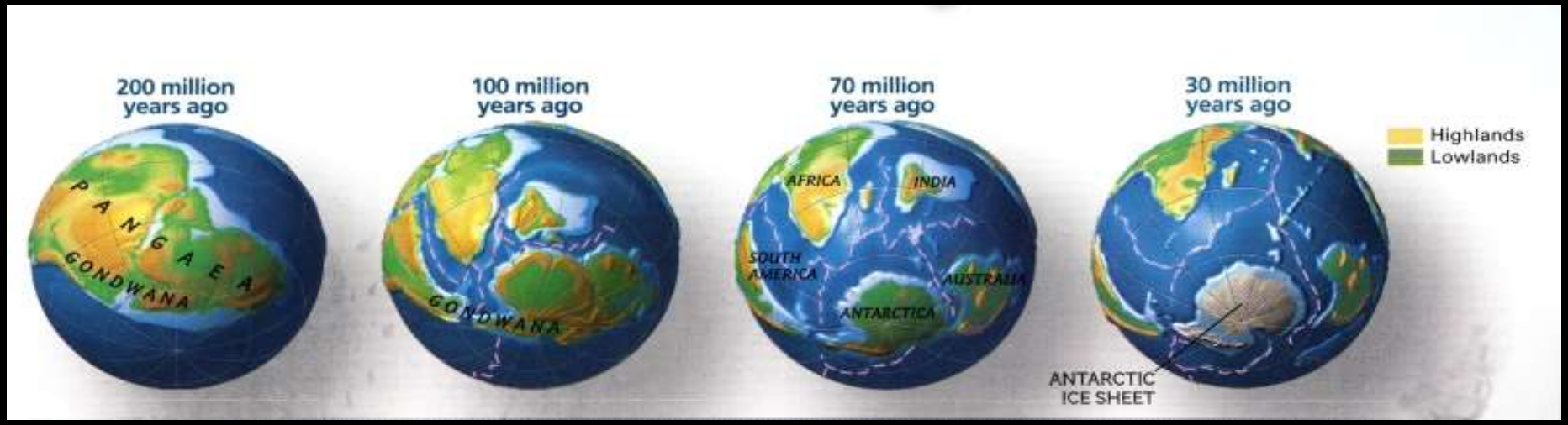


Continental drift theory

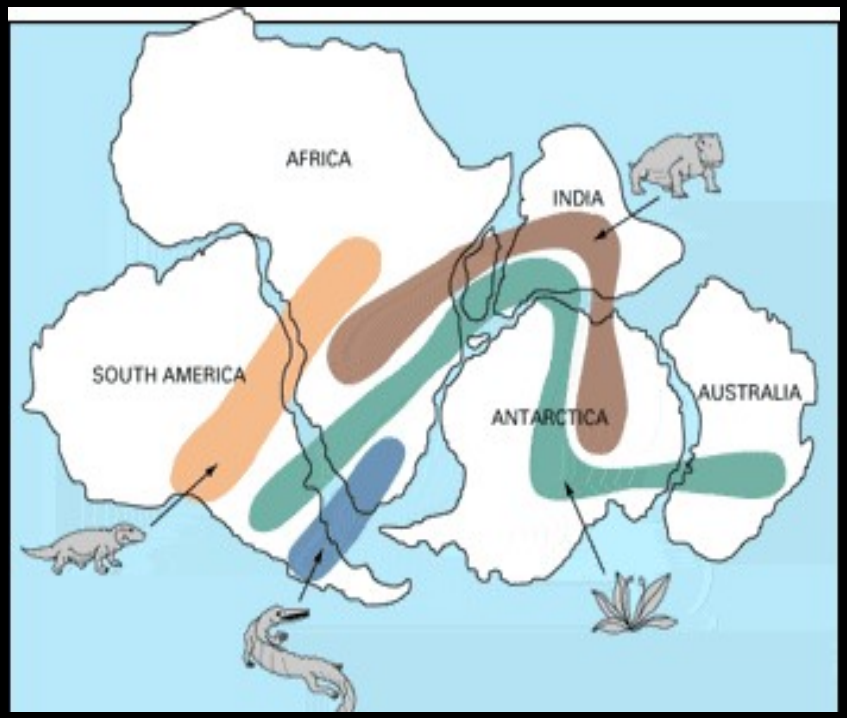


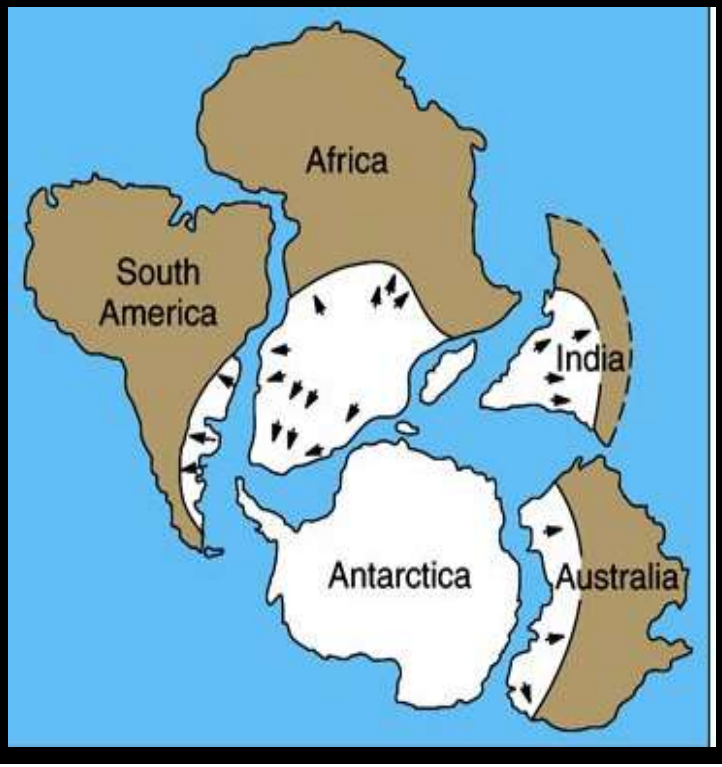
Evidence: Continents "fit together" like puzzle pieces



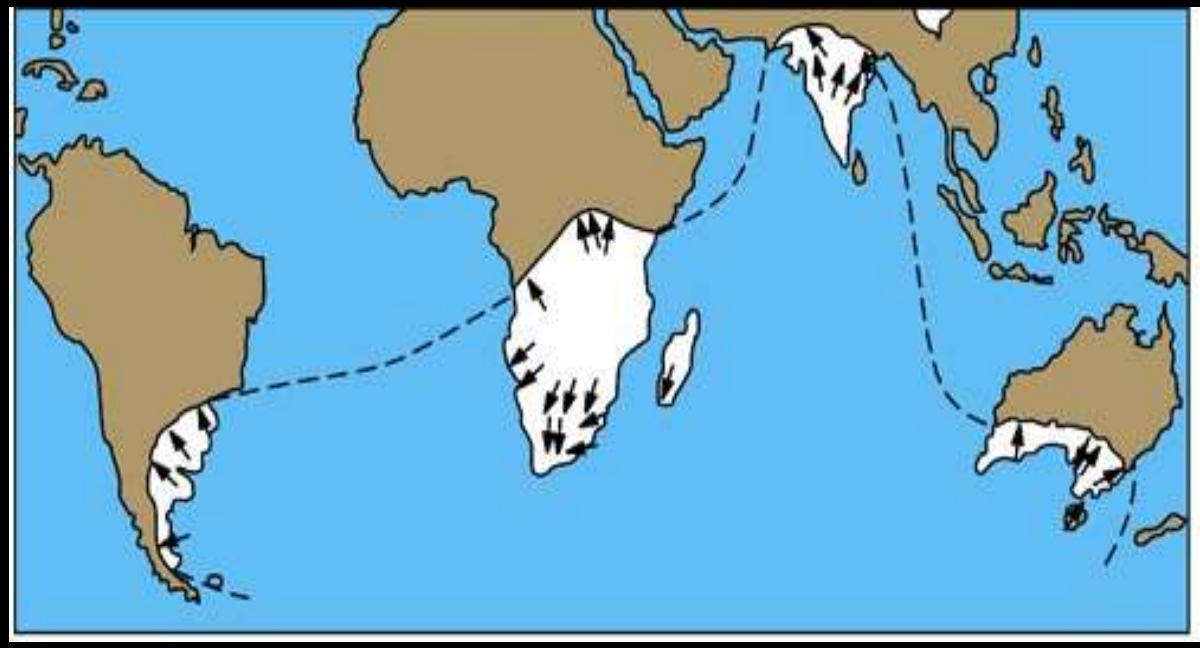


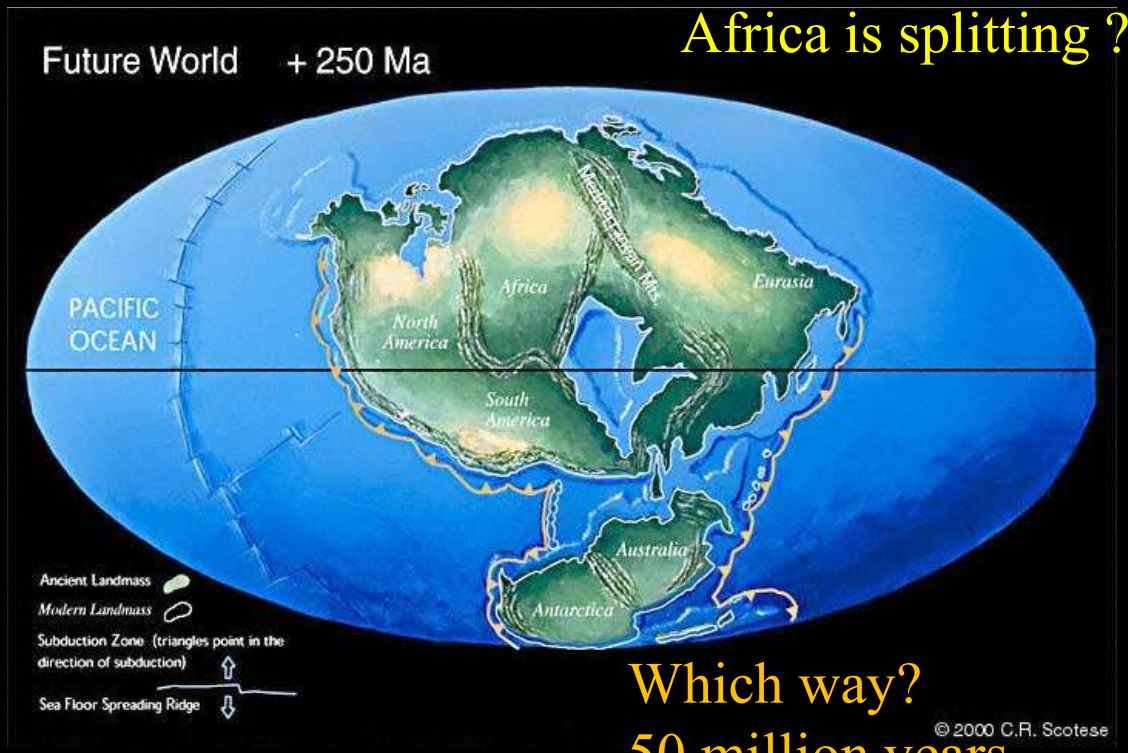
Fossil Evidence





Climate Evidence





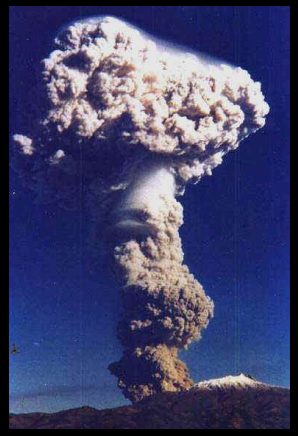
Africa is splitting ??

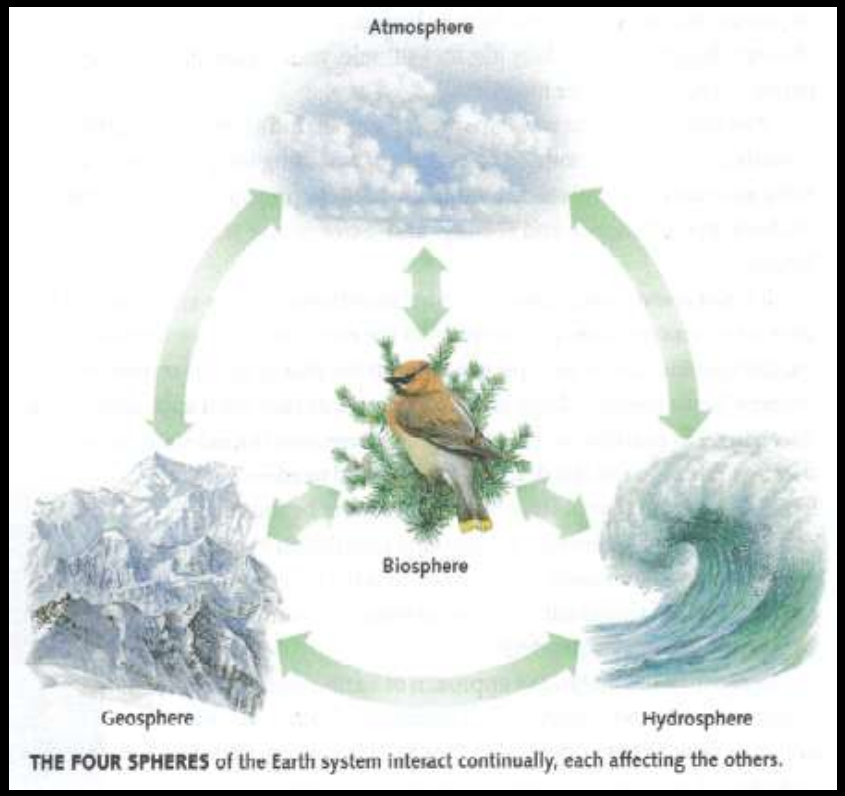
Which way?

50 million years

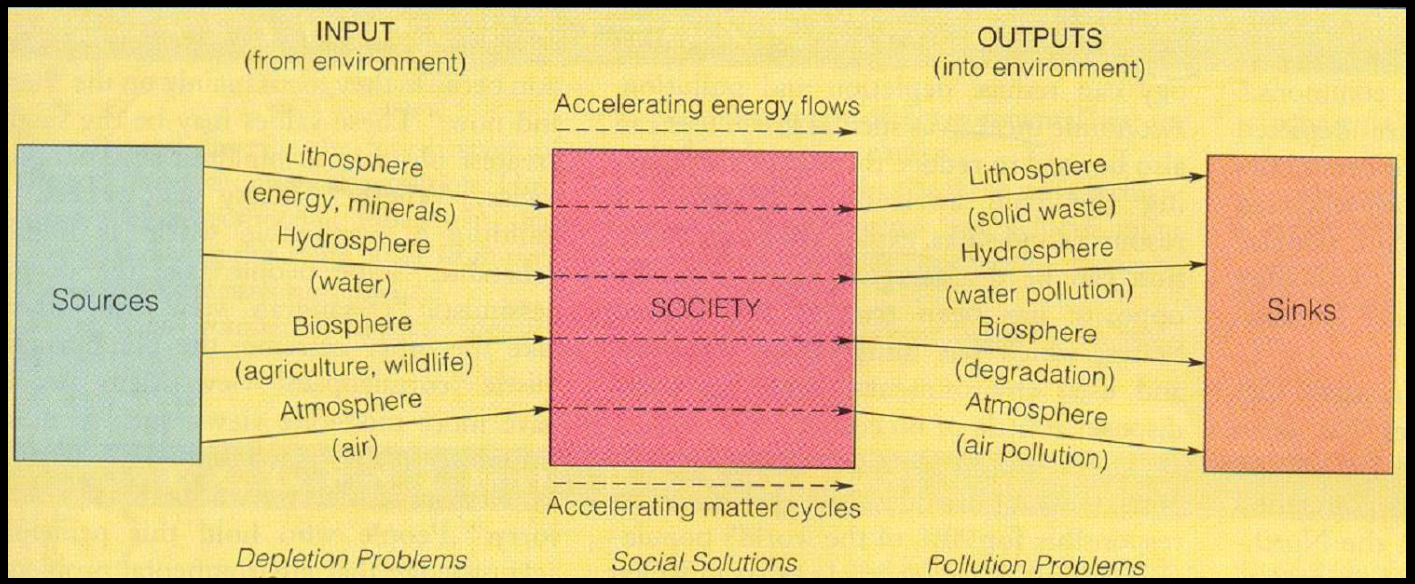
Earth System Science

Earth System Science is the study of how the four spheres of the Earth system interact continually, each affecting the others.



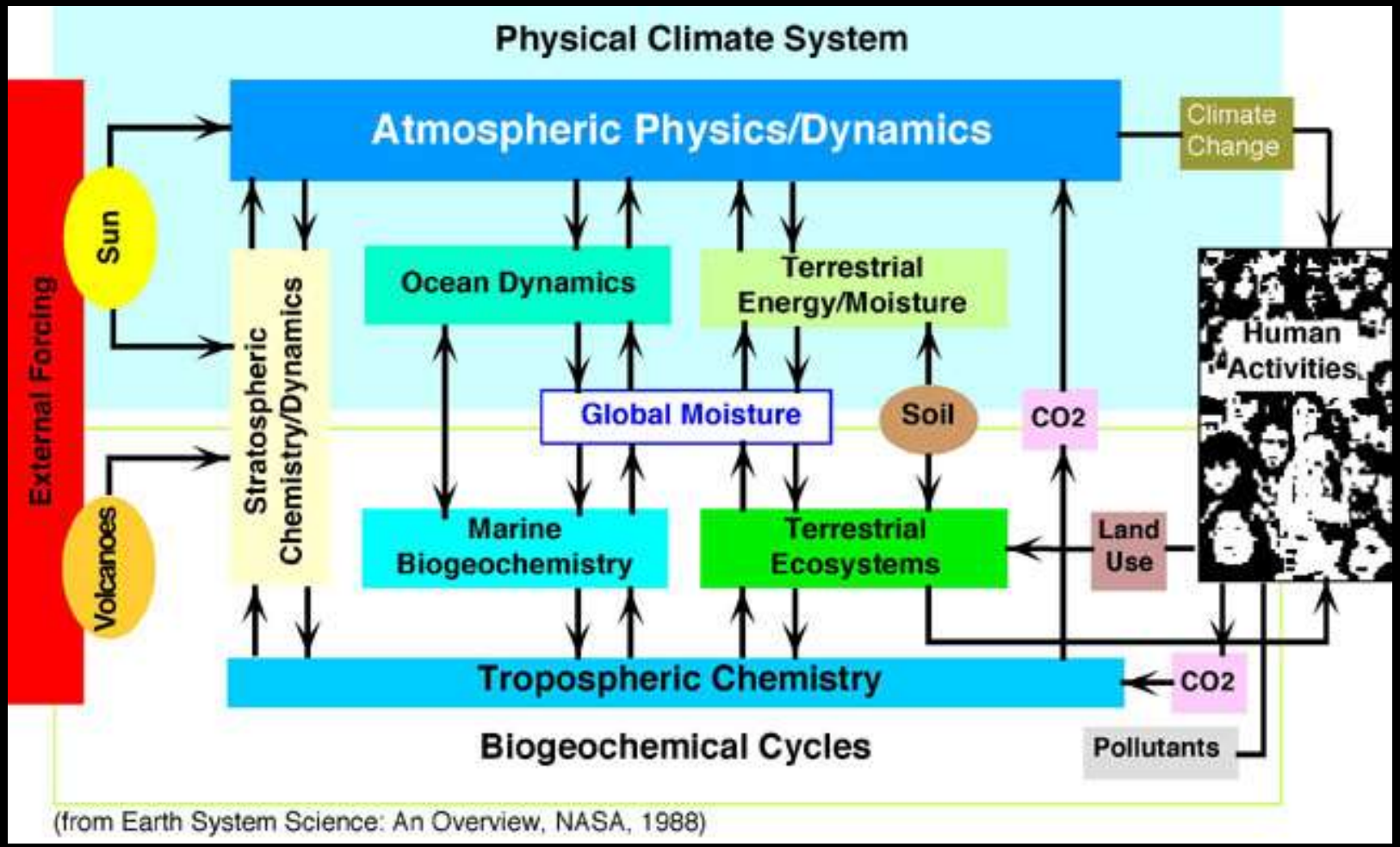


THE FOUR SPHERES of the Earth system interact continually, each affecting the others.



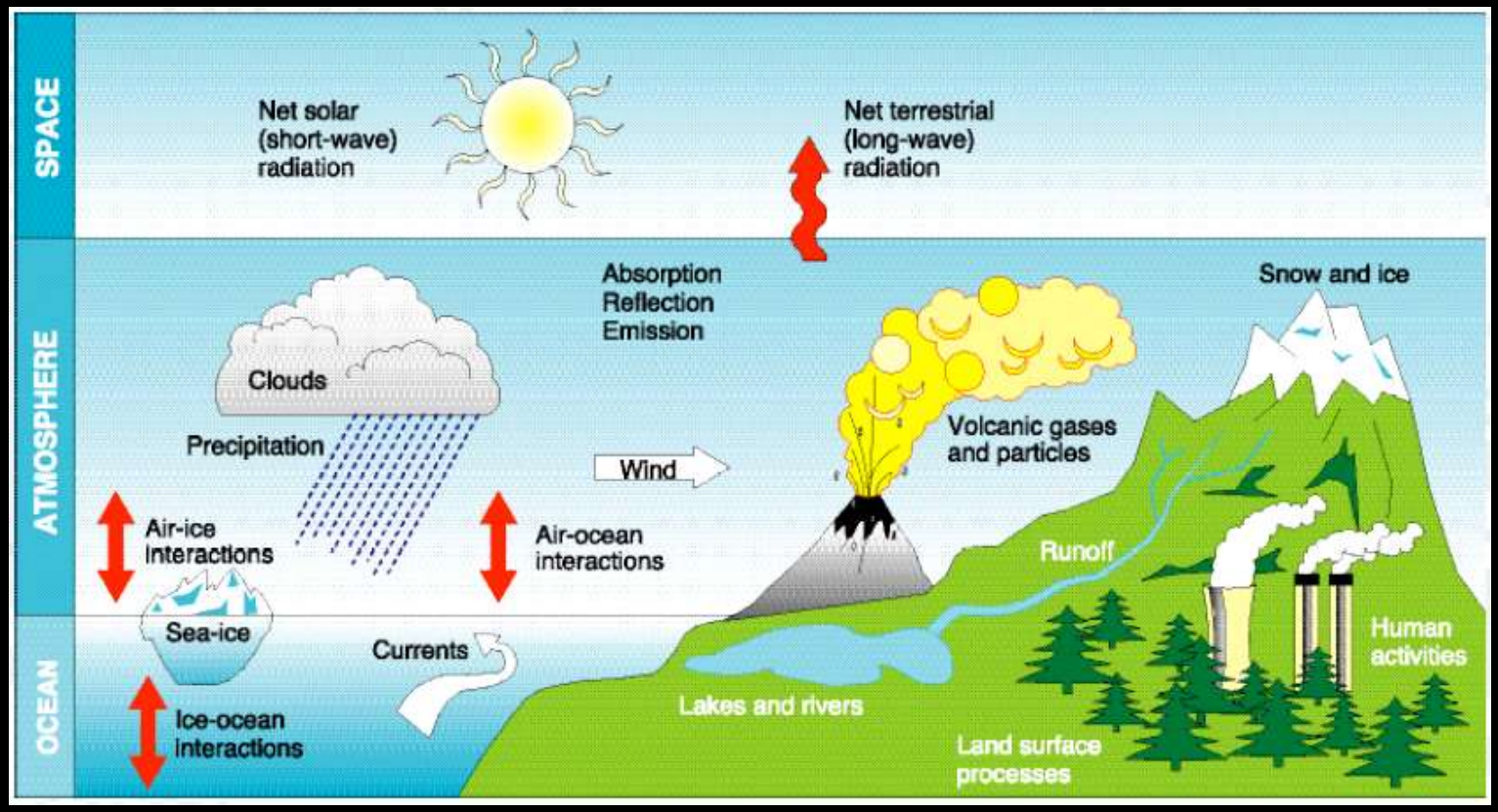
Earth System Science

- *... treats the entire Earth as a system*
- *this system evolves as a result of positive and negative feedbacks between many different systems*
- *gives scientists the ability to explain the past and possible future behaviour of the Earth system*



What is Earth System Modelling?

Interacting components on the environment are modeled in unison to understand how feedbacks between the components influence the properties of the whole system.



Gaia theories explain the behaviour of the Earth system in terms of the influence of the biosphere

Quelle: Max-Planck-Institut

The GAIA hypothesis:

Lovelock's "Discovery" of Gaia

Gas	Earth	Venus	Mars
CO_2	0.03%	96.5%	95%
O_2	21%	Trace	0.13%
N_2	79%	3.5%	2.7%

Interpretation?
Temperature regulation
Traditional evolutionary theory
Lovelock's theory
Bacteria: heavy lifters of Gaia - Margulis

What is GAIA HYPOTHESIS

James Lovelock

Lynn Margulis

GAIA HYPOTHESIS

Hypothesis: that the entire mass of living matter on Earth (the biosphere) functions as a single and vast superorganism that actively modifies its planet to produce the environment that suits its needs.
Life, or the biosphere, regulates or maintains the climate and the atmospheric composition at an optimum for itself.“

Lovelock states that our atmosphere can be considered to be “like the fur of a cat and shell of a snail, not living but made by living cells so as to protect them against the environment.
Inherent in this explanation is the idea that biosphere, the atmosphere, the lithosphere and the hydrosphere are in some kind of balance -- that they maintain a homeostatic condition.

This homeostasis is much like the internal maintenance of our own bodies; processes within our body insure a constant temperature, blood pH, electrochemical balance, etc.

The inner workings of Gaia, therefore, can be viewed as a study of the physiology of the Earth, where the oceans and rivers are the Earth's blood, the atmosphere is the Earth's lungs, the land is the Earth's bones, and the living organisms are the Earth's senses.

Lovelock calls this the science of geophysiology - the physiology of the Earth (or any other planet)

Genesis of name – GAIA

GAIAN ATTRIBUTES

Earth is a super-organism

Biota and physical environment are so tightly coupled they are considered a single organism.

The climate and chemical composition of Earth are kept in homeostasis at an optimum by and for the biosphere.

Recognizes emergent properties. (oxygen, temp, salinity, co_2)

What is Gaia?

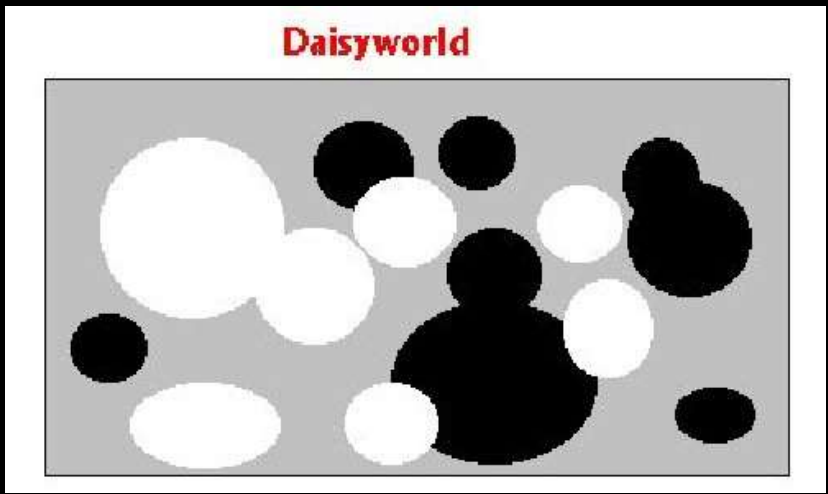
GAIA (if it exists!) is a collection of negative feedback loops
These loops stabilize the Earth's physical environment
The physical environment is maintained in a condition favorable to life.

In other words
Life itself is responsible for maintaining the stability of Earth's climate. The Earth has remained habitable because in some sense it is "alive" Biota manipulate their environment to optimize conditions for life

The criticism that developed the Daisy world model
Biota would need to possess the capacity for foresight if the Earth's system were to be self-regulated.
The Daisy world model demonstrates that a system can be self-regulating without the need of foresight. This is done through the simulation of a feedback control system

Daisy world

Lovelock used this computer simulation to demonstrate the hypothesis
Hypothetical world orbiting a sun whose temperature is slowly increasing in the simulation
Planet has two different species of daisy as its only life form: black daisies and white daisies



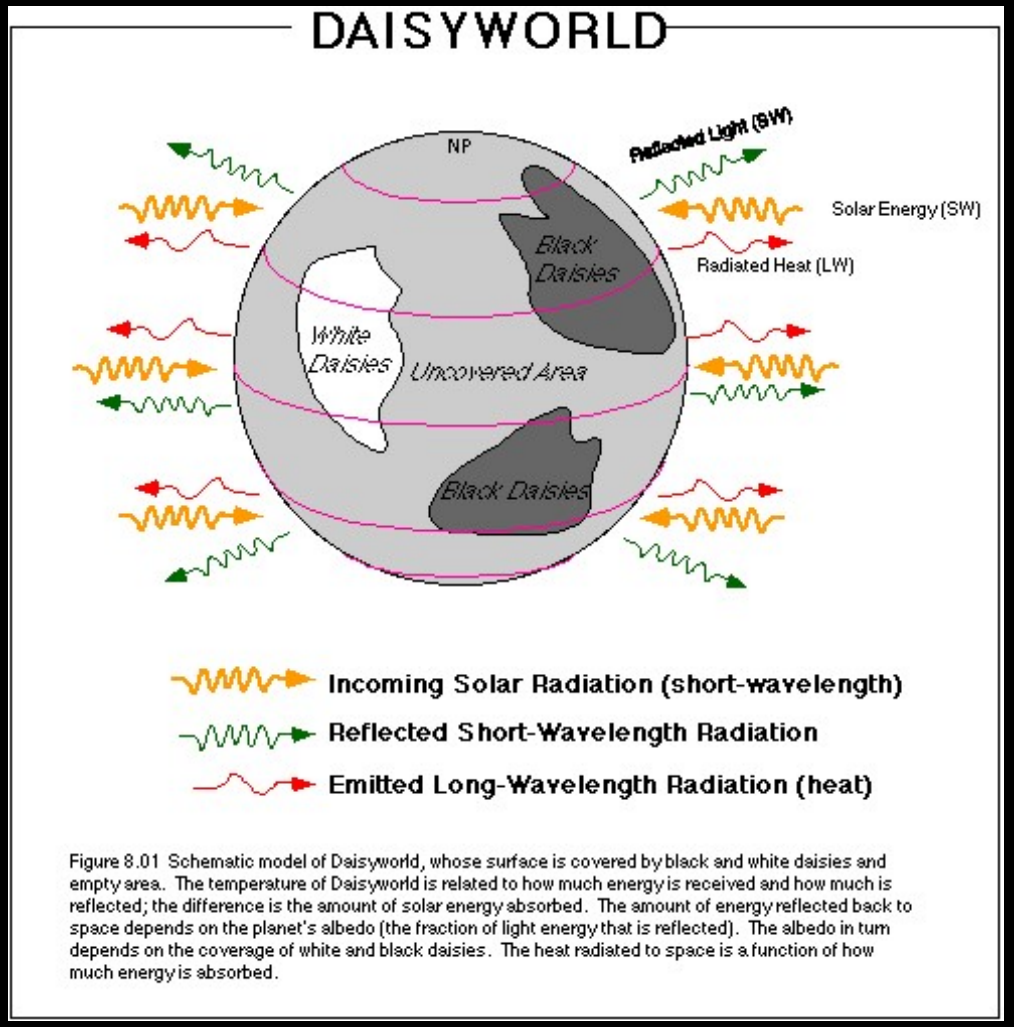
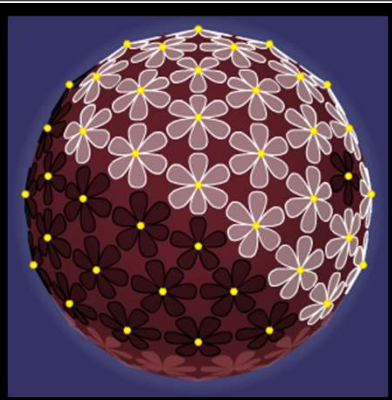


Figure 8.01 Schematic model of Daisyworld, whose surface is covered by black and white daisies and empty area. The temperature of Daisyworld is related to how much energy is received and how much is reflected; the difference is the amount of solar energy absorbed. The amount of energy reflected back to space depends on the planet's albedo (the fraction of light energy that is reflected). The albedo in turn depends on the coverage of white and black daisies. The heat radiated to space is a function of how much energy is absorbed.

Both black and white daisies grow best at 22.5 C
Air is slightly warmer over black daisy patches
Air is slightly cooler over white daisy patches

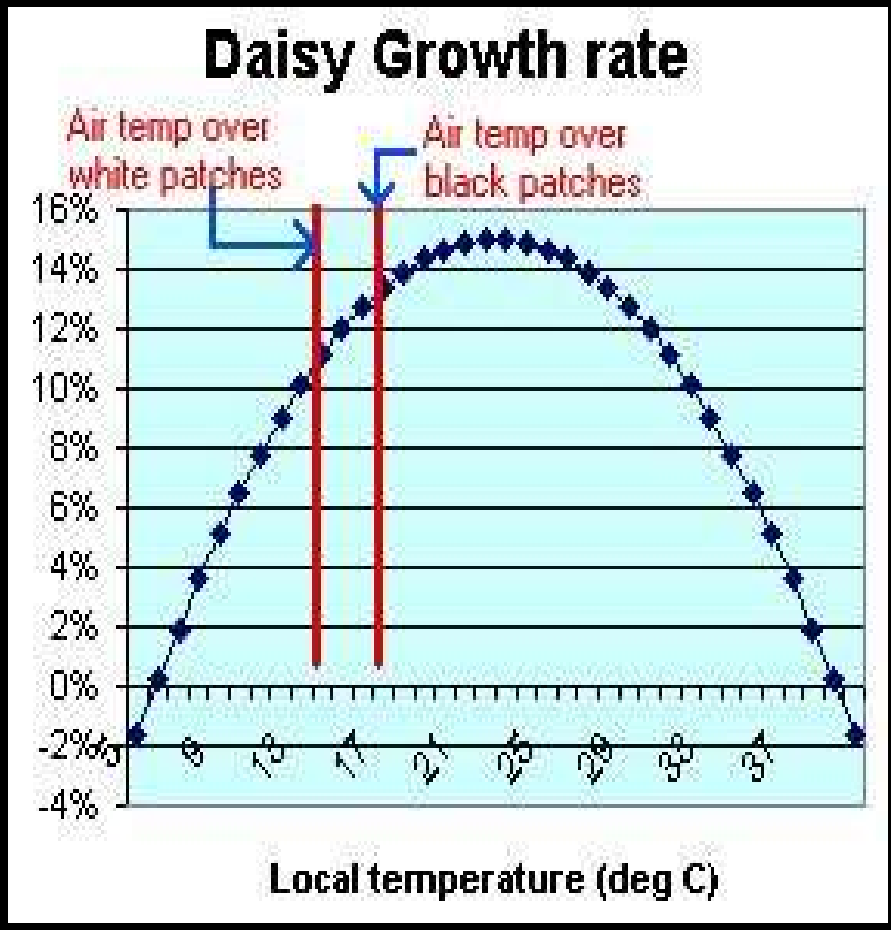


Daisy world simulation

First, run the model long enough for Daisy world temperature to reach equilibrium
Then, apply a sudden change in solar input
Observe how Daisy world reacts to restore its temperature

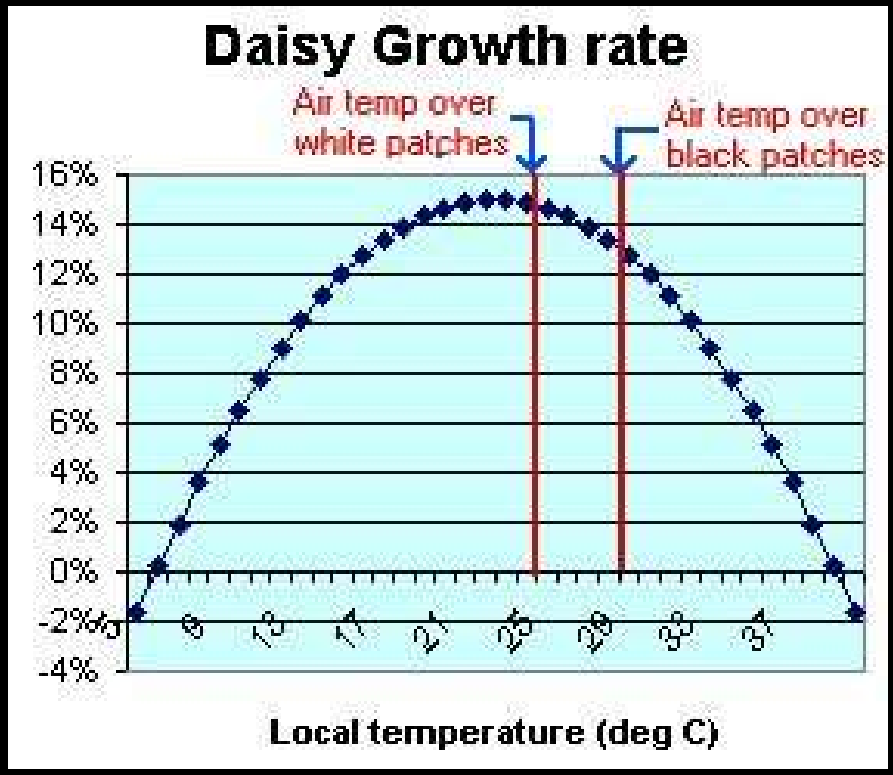
When Daisy world is cool…

Air temperature over the black patches is higher
Black patches grow more
Overall planet color becomes darker
Planet albedo decreases
Planet absorbs more sunlight and gets warmer
Daisies have altered the climate!
Daisy world temperature is closer to optimal temperature for daisies



When Daisy world is warm…

Air temperature over the black patches is higher
White patches grow more
Overall planet color becomes lighter
Planet albedo increases
Planet absorbs less sunlight and gets cooler
Daisies have altered the climate!
Daisy world temperature is closer to optimal temperature for daisies
Daisies have created a negative feedback loop!
This process is what might have created GAIA.



Hypothesis

One of the reasons that the Gaia Hypothesis sparked debate in scientific circles has to do with scientists' ability to test hypotheses. The traditional scientific method relies on refuting a hypothesis, proving it wrong, as the means for eliminating possible explanations.

No testable hypothesis

The single largest complaint lodged against the strong Gaia hypothesis is that experiments can't be designed to refute it (or test it at all, for that matter.)

The strong Gaia hypothesis states that life creates conditions on Earth to suit itself. Life created the planet Earth, not the other way around. As we explore the solar system and galaxies beyond, it may one day be possible to design an experiment to test whether life indeed manipulates planetary processes for its own purposes or whether life is just an evolutionary processes that occurs in response to changes in the non-living world.

At present, we cannot falsify the Gaia Hypothesis

Ecology
(in view of Gaia theory)

When the activity of an organism favors the environment as well as the organism itself, then its spread will be assisted;
eventually the organism and the environmental change associated with it will become global in extent.
The reverse is also true, and any species that adversely affects the environment is doomed; but life goes on.

Ecology

Ecology is the scientific study of the interactions between organisms and their environment.

a. Interactions determine distribution and abundance of organisms.

b. An organism's environment has both abiotic and biotic components.

An ecosystem consists of all abiotic factors plus all organisms that exist in a certain area à Ecosystem ecology.

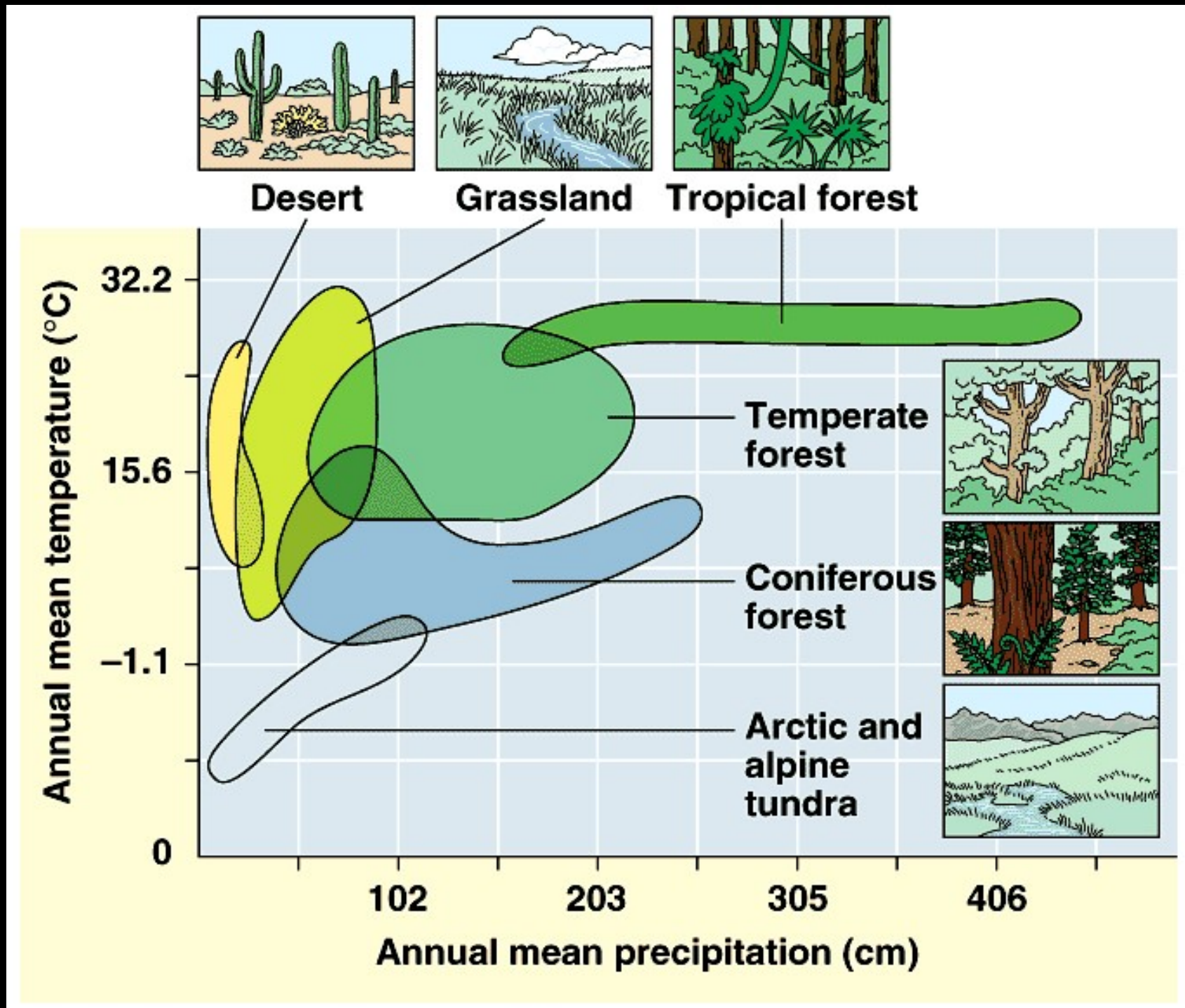
Landscape ecology- interactions among ecosystems.

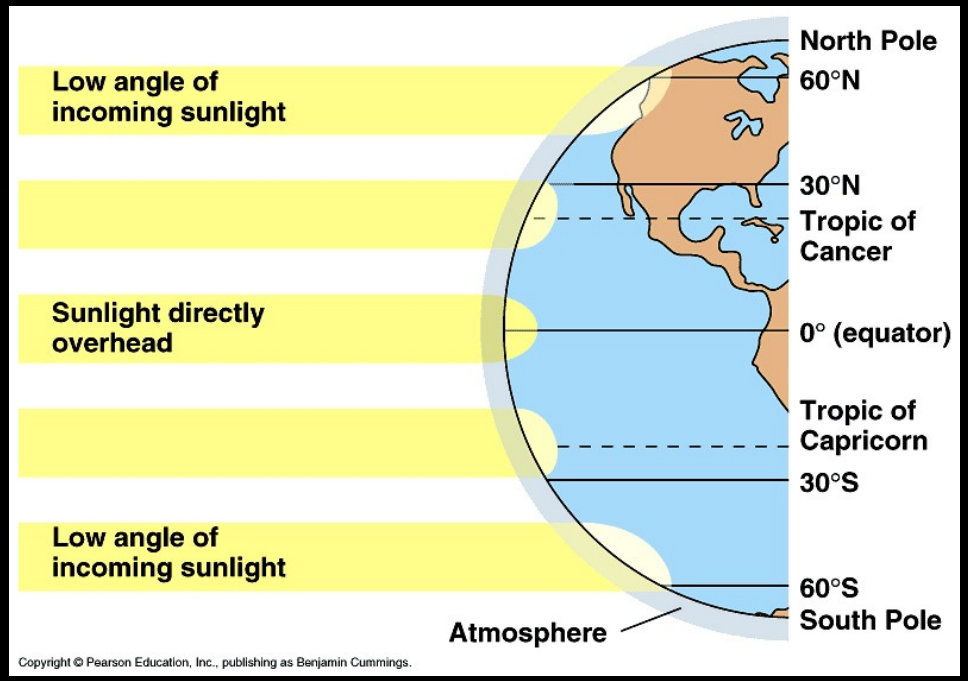
The biosphere is the global ecosystem. Global climate research is an example of ecology at the biosphere scale.

Abiotic factors affect distribution

Temperature (range from 0 to 45 C),

Water, Sunlight ,Wind, Rocks and soil




Low angle of incoming sunlight
Sunlight directly overhead
Low angle of incoming sunlight
North Pole
60°N
30°N
Tropic of Cancer
0° (equator)
Tropic of Capricorn
30°S
60°S
South Pole
Atmosphere
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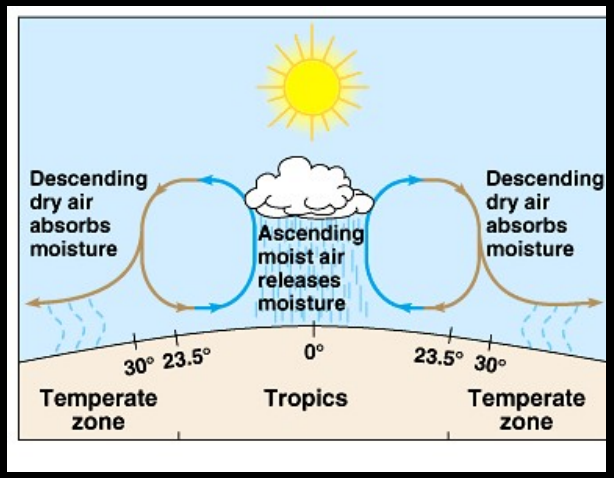
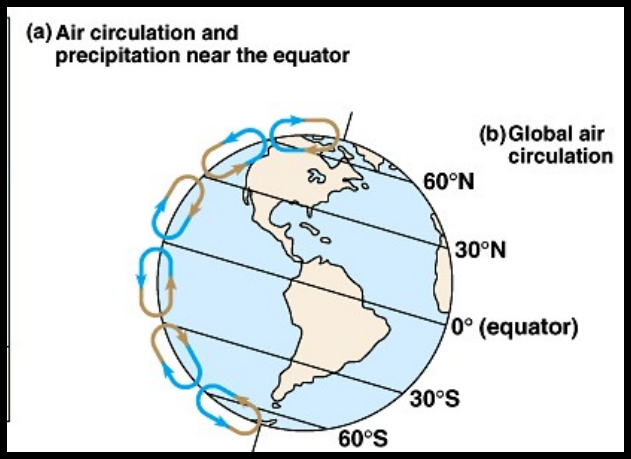
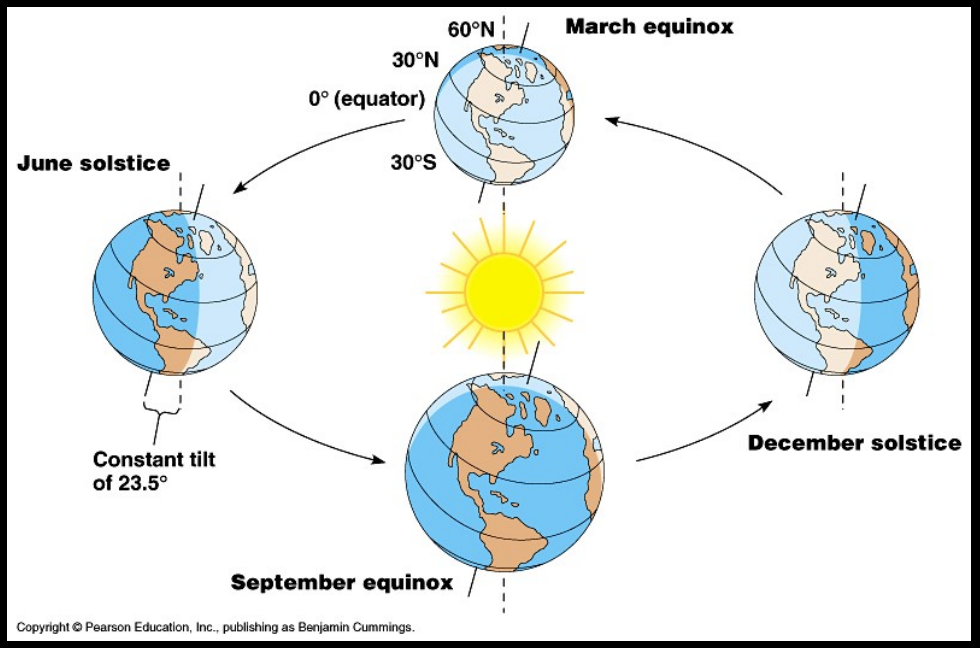

Descending dry air absorbs moisture
Ascending moist air releases moisture
Descending dry air absorbs moisture
30°
23.5°
0°
23.5°
30°
Temperate zone
Tropics
Temperate zone


(a) Air circulation and precipitation near the equator
(b) Global air circulation
60°N
30°N
0° (equator)
30°S
60°S


60°N
March equinox
30°N
0° (equator)
30°S
June solstice
Constant tilt of 23.5°
December solstice
September equinox
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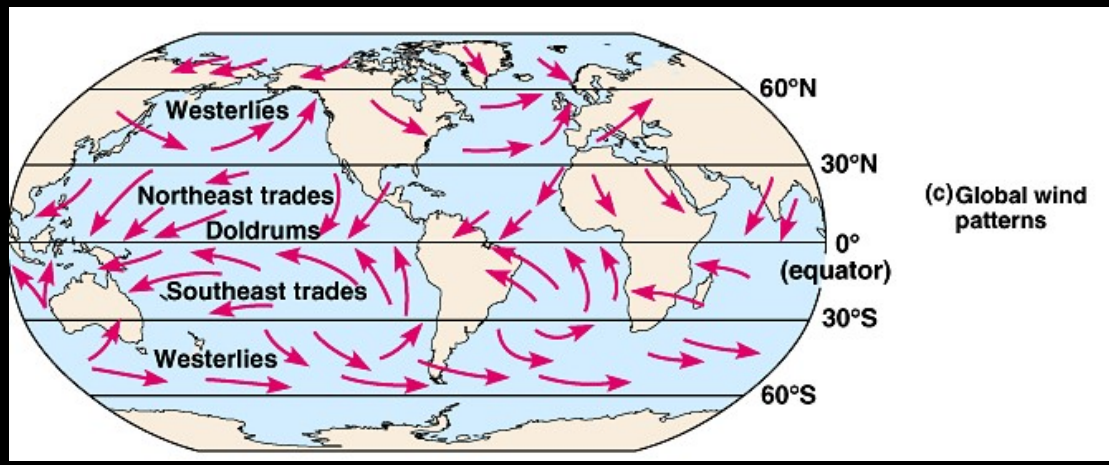
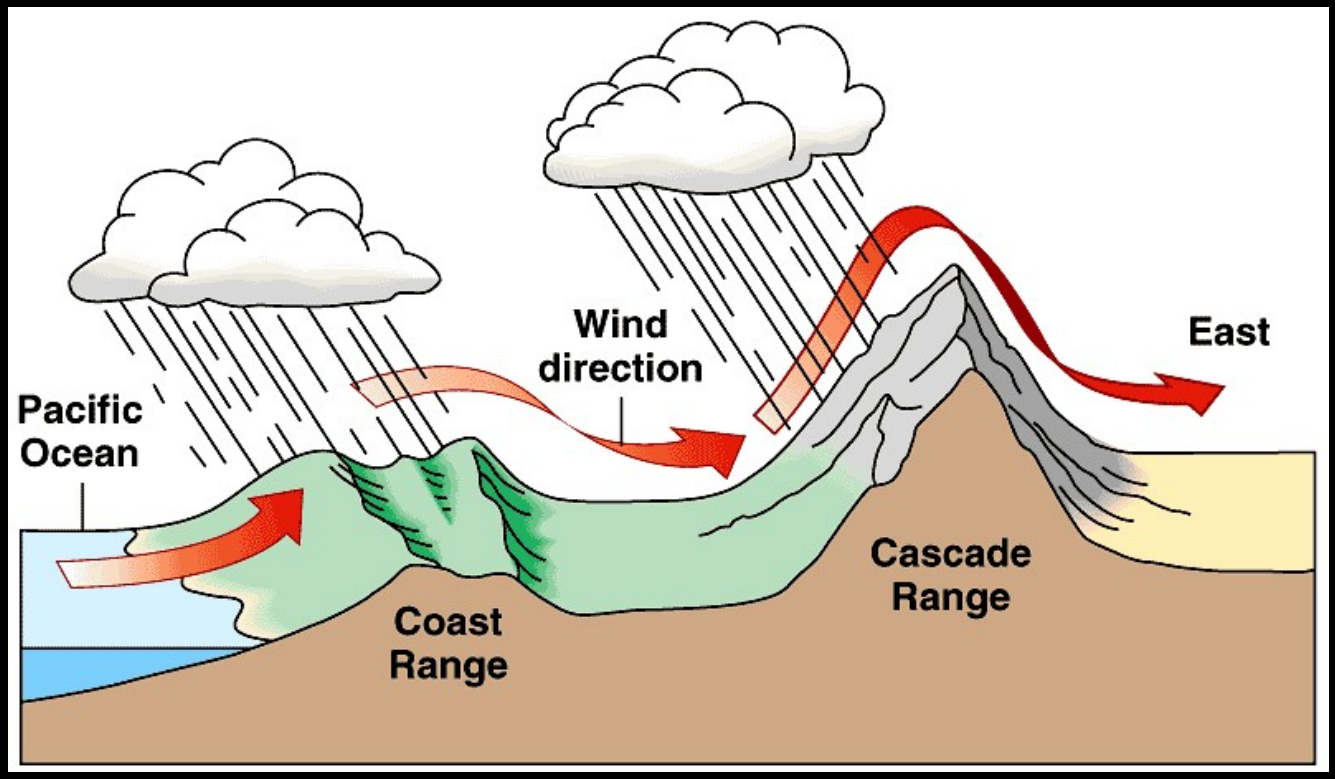

Westerlies
Northeast trades
Doldrums
Southeast trades
Westerlies
60°N
30°N
0° (equator)
30°S
60°S
(c) Global wind patterns

Local and seasonal effects on climate.
Bodies of water and topographic features such as mountain ranges can affect local climates.
Ocean currents can influence climate in coastal areas.
Mountains affect rainfall greatly.

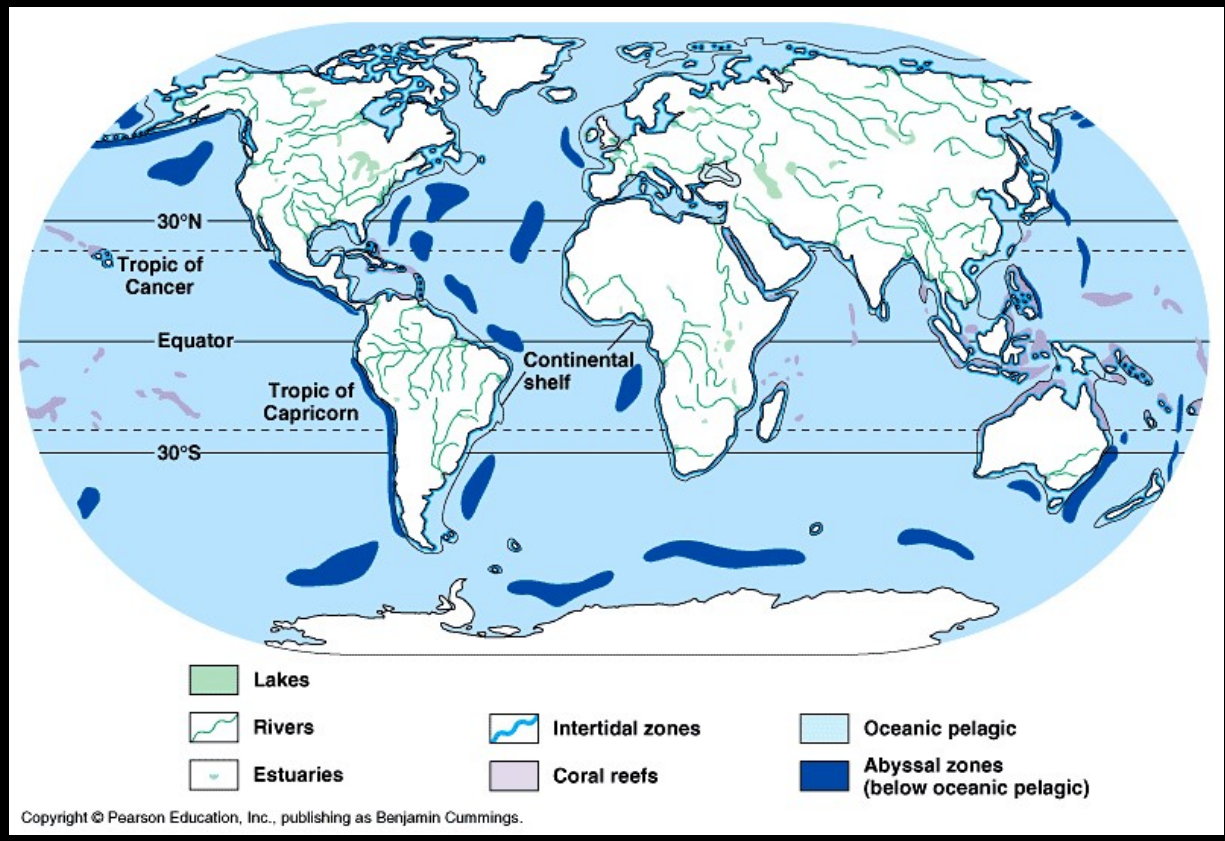


Aquatic and terrestrial biomes

(Biome = major ecosystem type)

A. Aquatic biomes cover about 75% of the earth's surface

- Wetlands
- Lakes
- Rivers, streams
- Intertidal zones
- Oceanic pelagic biome
- Coral reefs
- Benthos



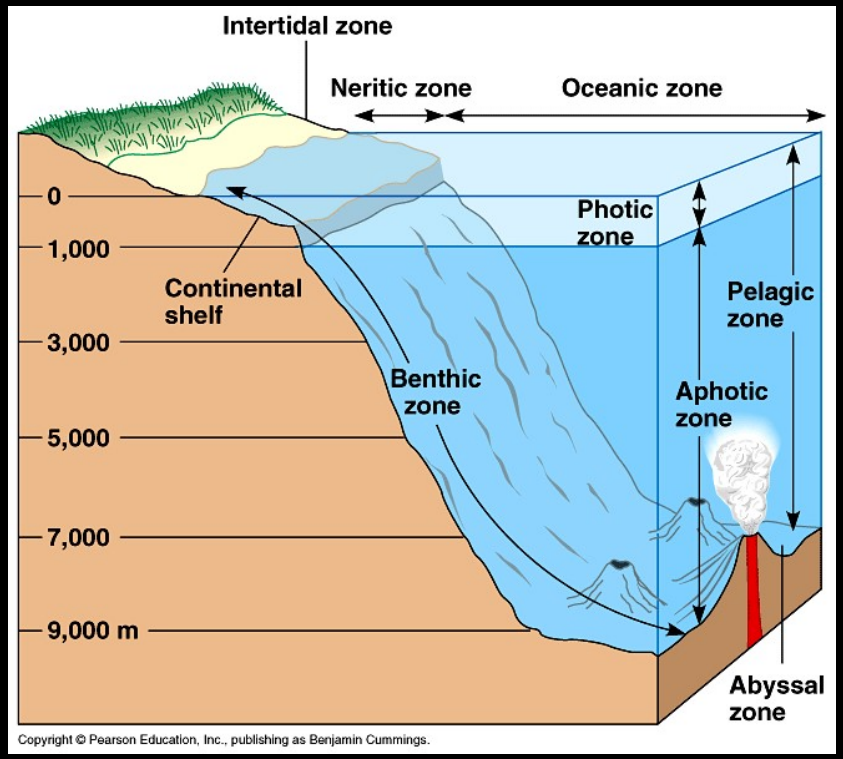
Oligotrophic Lake:

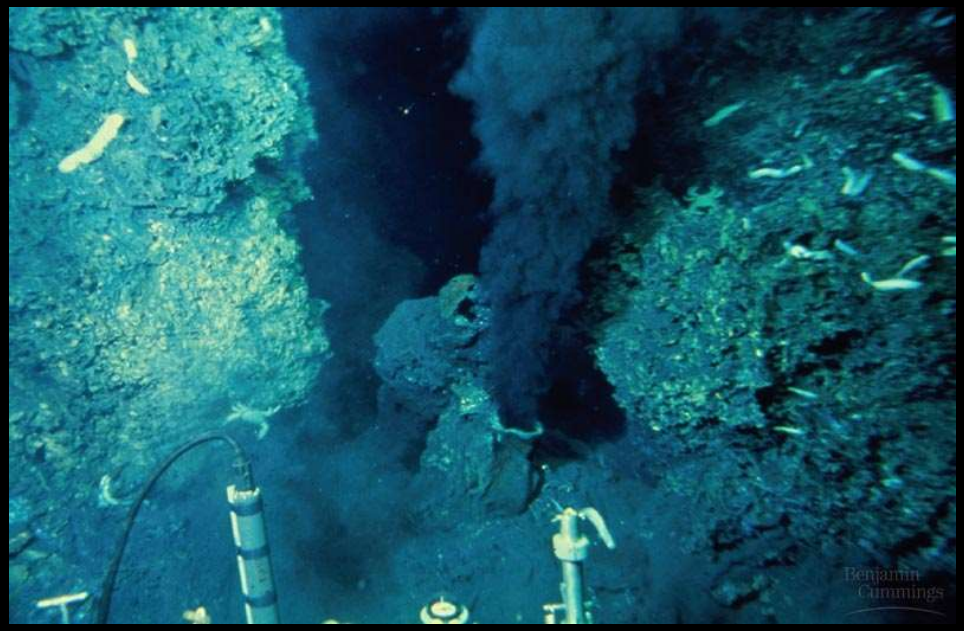
Eutrophic lake

Rivers and Streams:

Wetlands

Estuary:

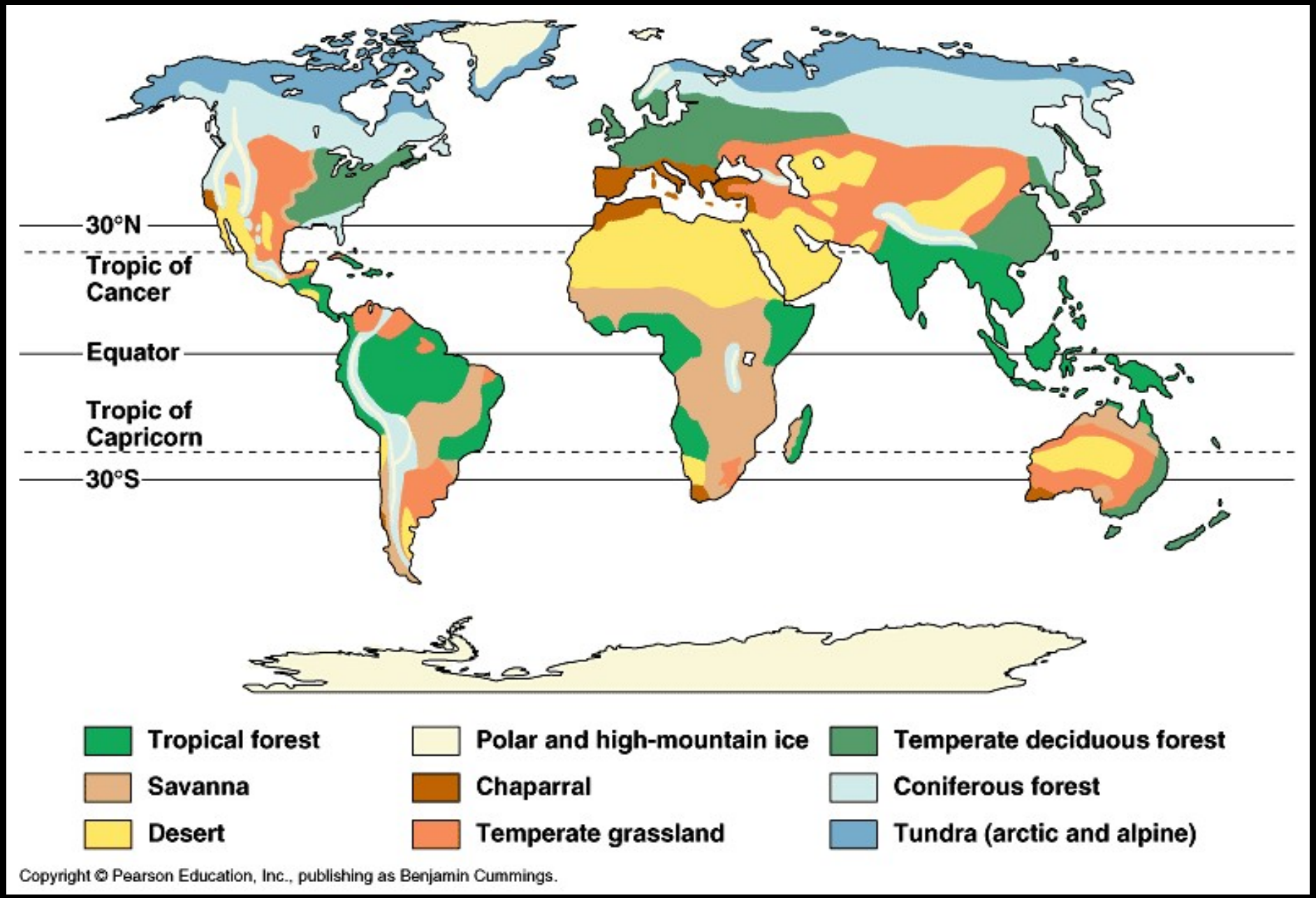




Marine environment with zonation.

B. Terrestrial biomes

-



Tropical Forest:

Tropical, Dry Forest

Desert: Sparse rainfall (< 30 cm per year), plants and animals adapted for water storage and conservation. Can be either very, very hot, or very cold (e.g. Antarctica)

Chaparral:

Temperate Grassland

Temperate Deciduous Forest

Tundra

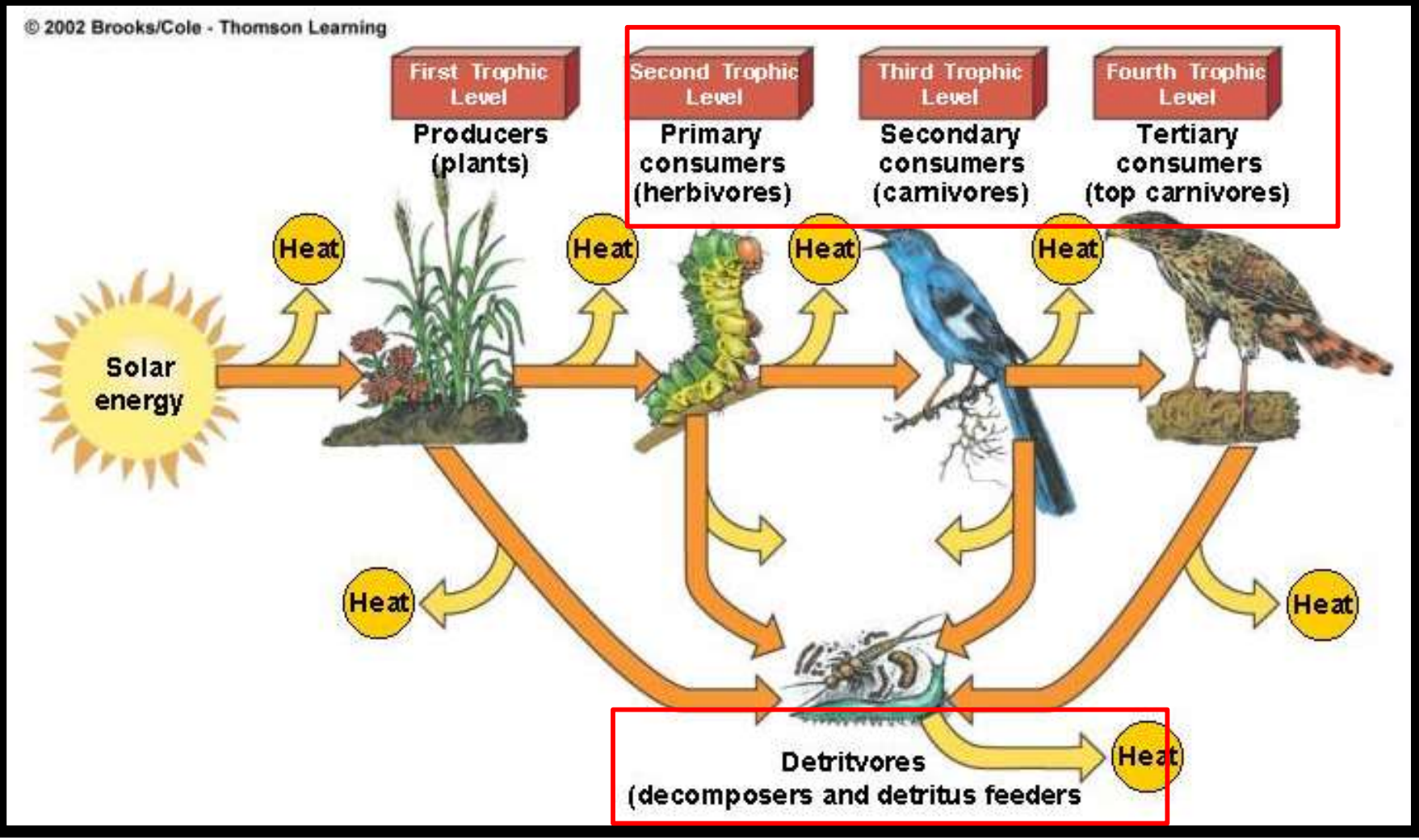
Coniferous forest: Largest terrestrial biome on earth, old growth forests rapidly disappearing, usually receives lots of moisture as rain or snow.


0 300 600 km
Scale
I N D I A
Tropic of Cancer
BAY OF BENGAL
ARABIAN SEA
Alpine Vegetation
Desert Vegetation
Littoral or Swamp
Montane Subtropical and Temperate
Tropical Dry Deciduous
Tropical Dry Evergreen
Tropical Evergreen
Tropical Moist Deciduous
Tropical Thorn
LAKSHADWEEP (INDIA)
LAKSHADWEEP SEA
ANDAMAN AND NICOBAR IS. (INDIA)
ANDAMAN SEA
INDIAN OCEAN

Food Chains

The concept of food chains was developed by Charles Elton based on his observations on Spitzbergen Island in the 1920s.

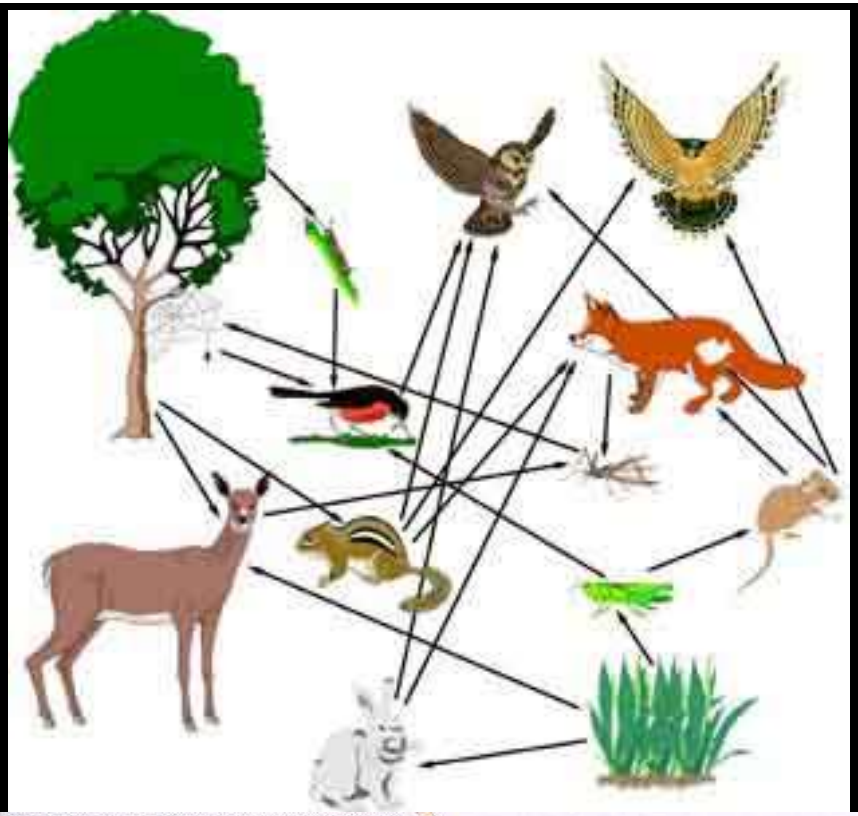
Trophic Levels

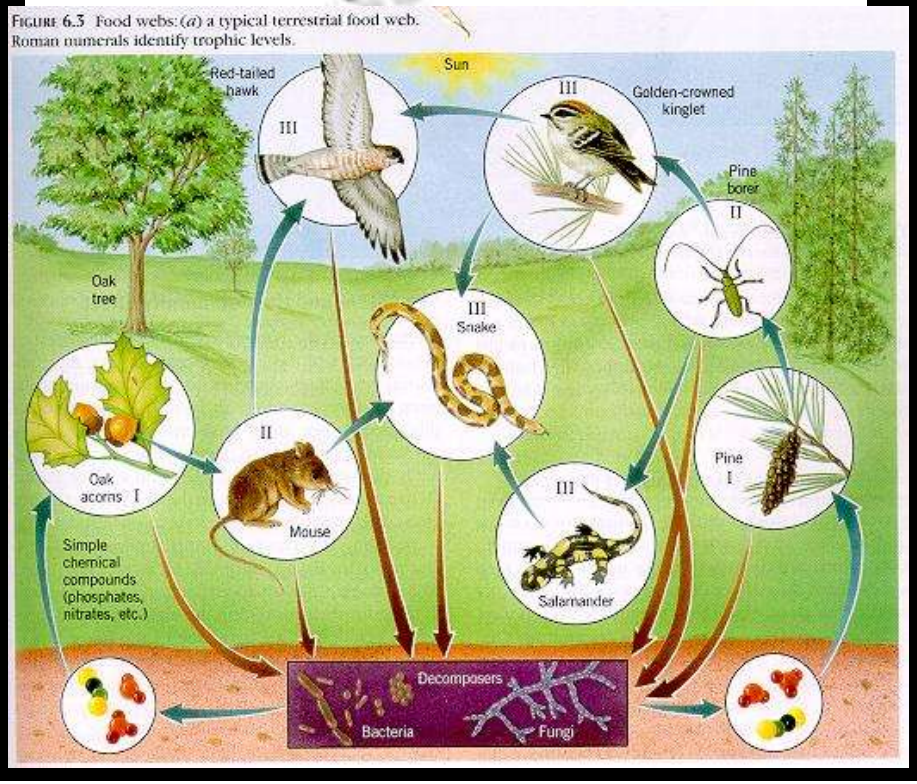


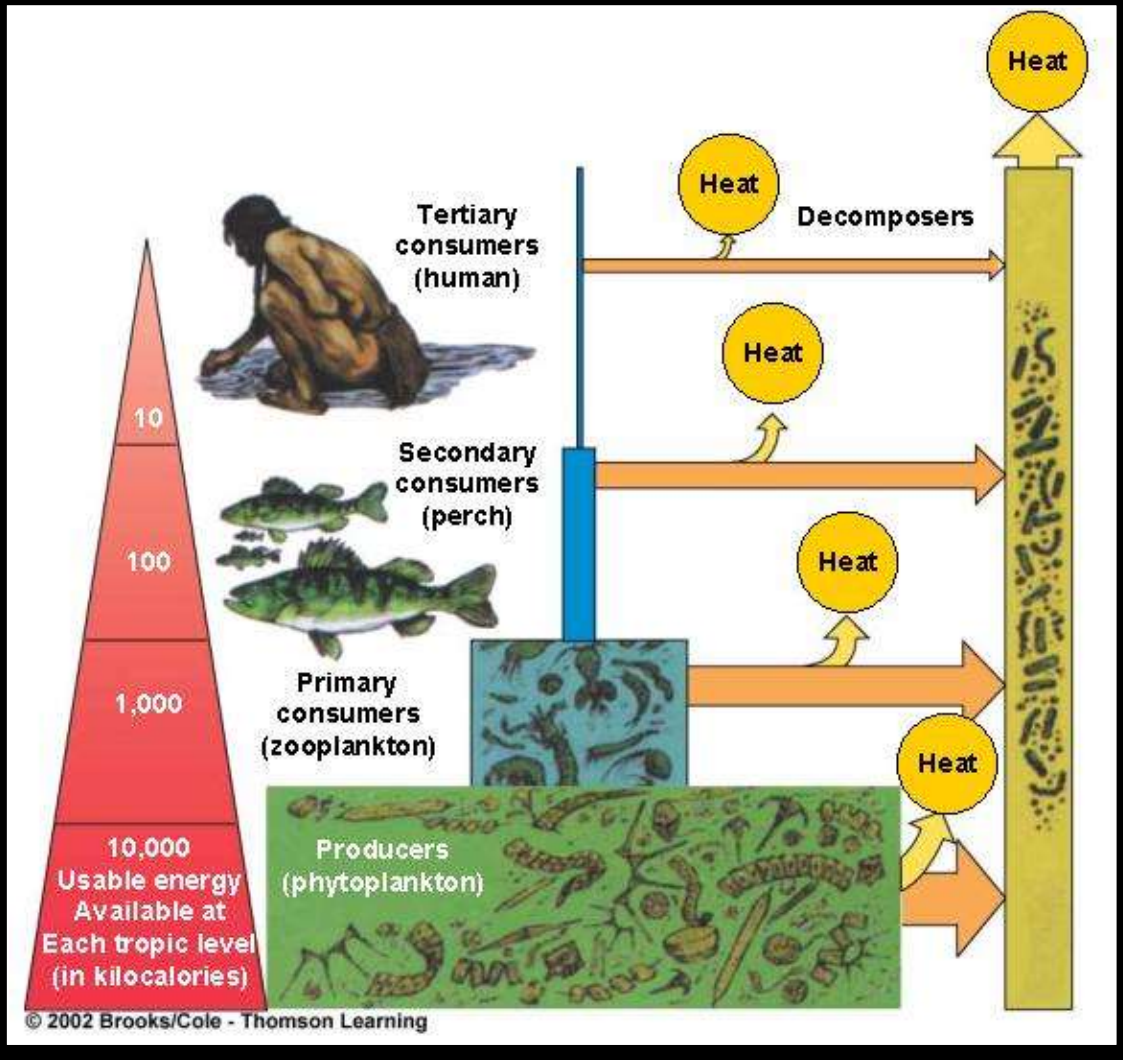
Ecological Pyramids

Pyramid of : biomass,
energy flow,
numbers

Trophic cascade?







Models of ecological energy flow

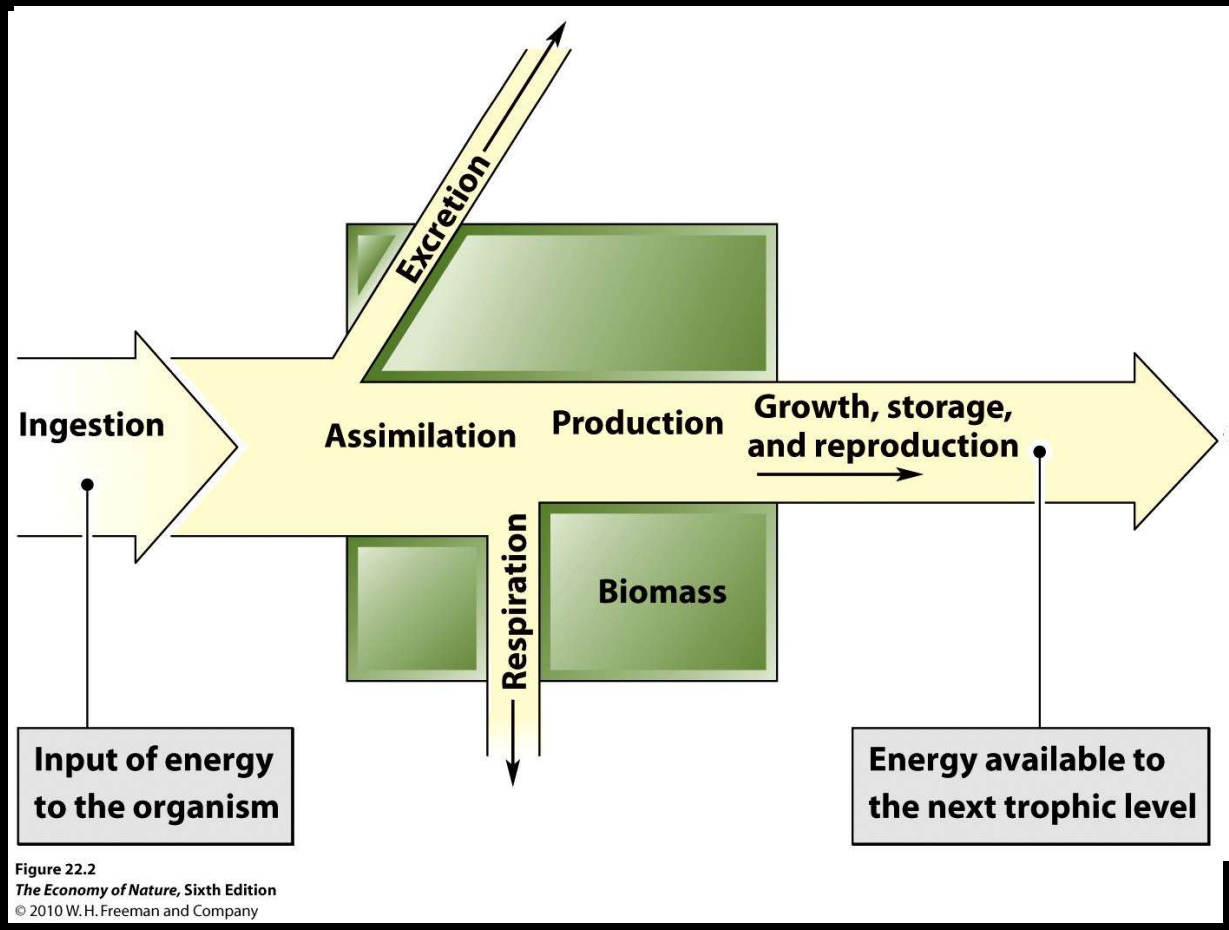
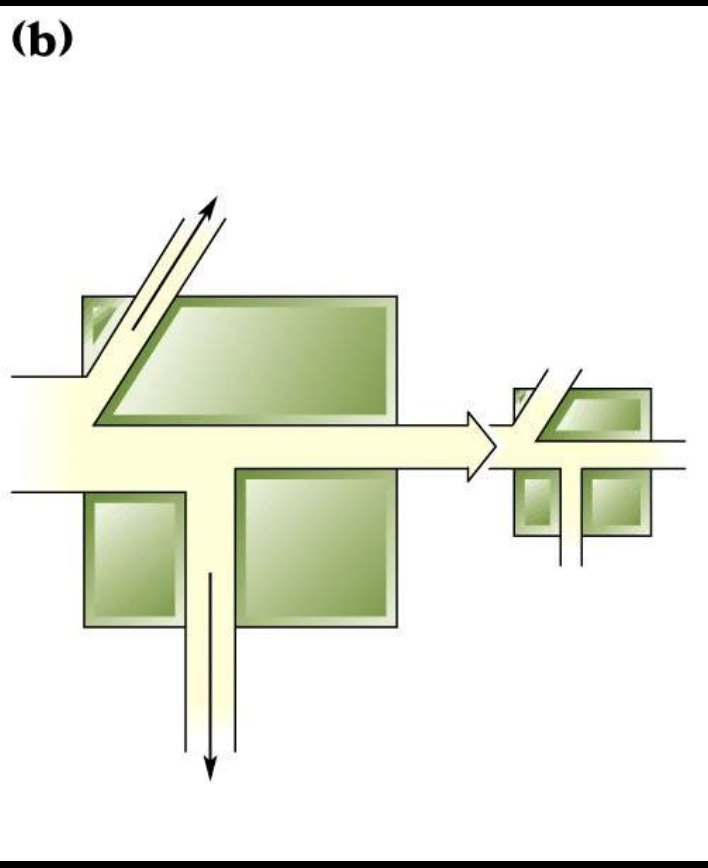


Figure 22.2
The Economy of Nature, Sixth Edition

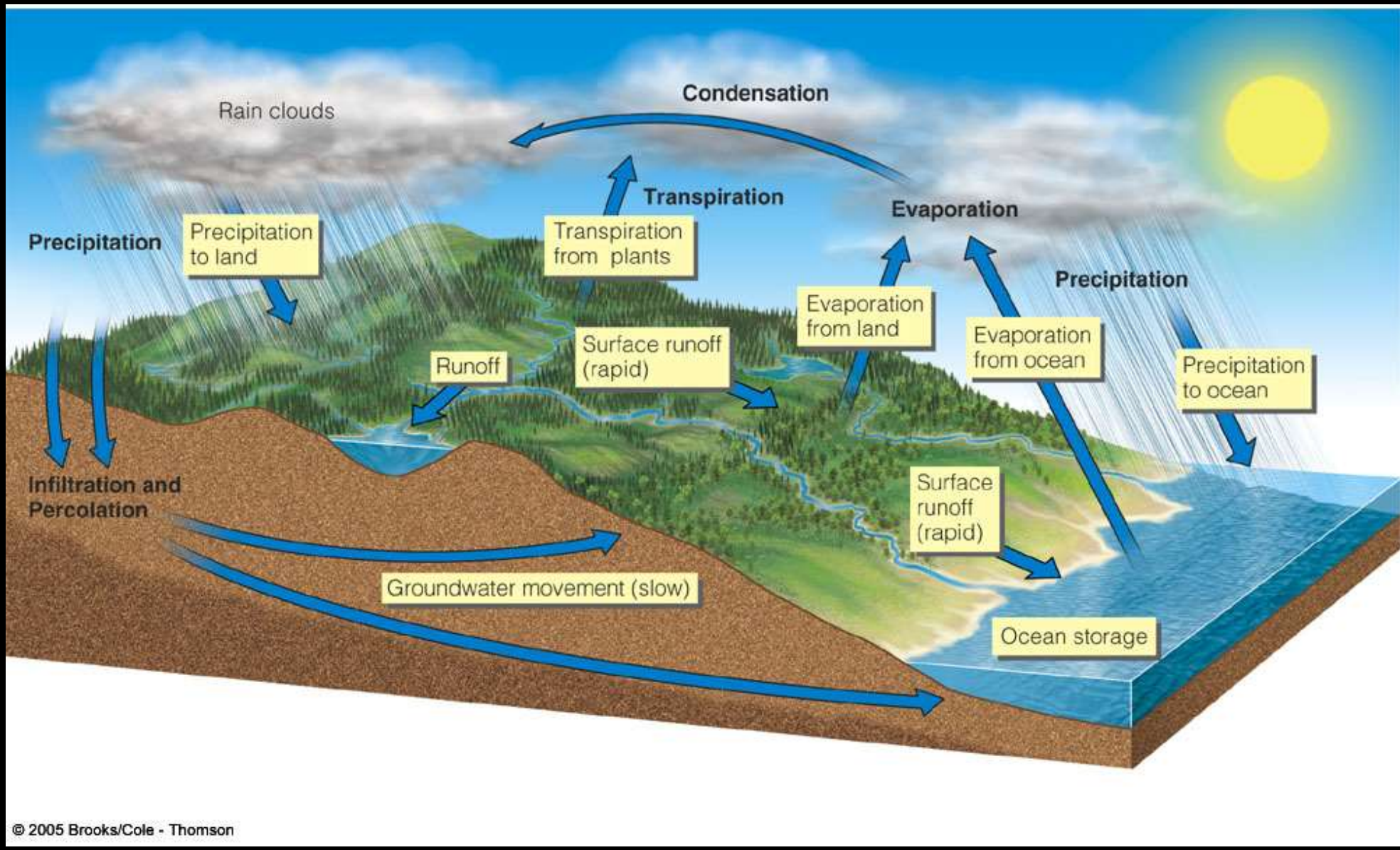
A single trophic level



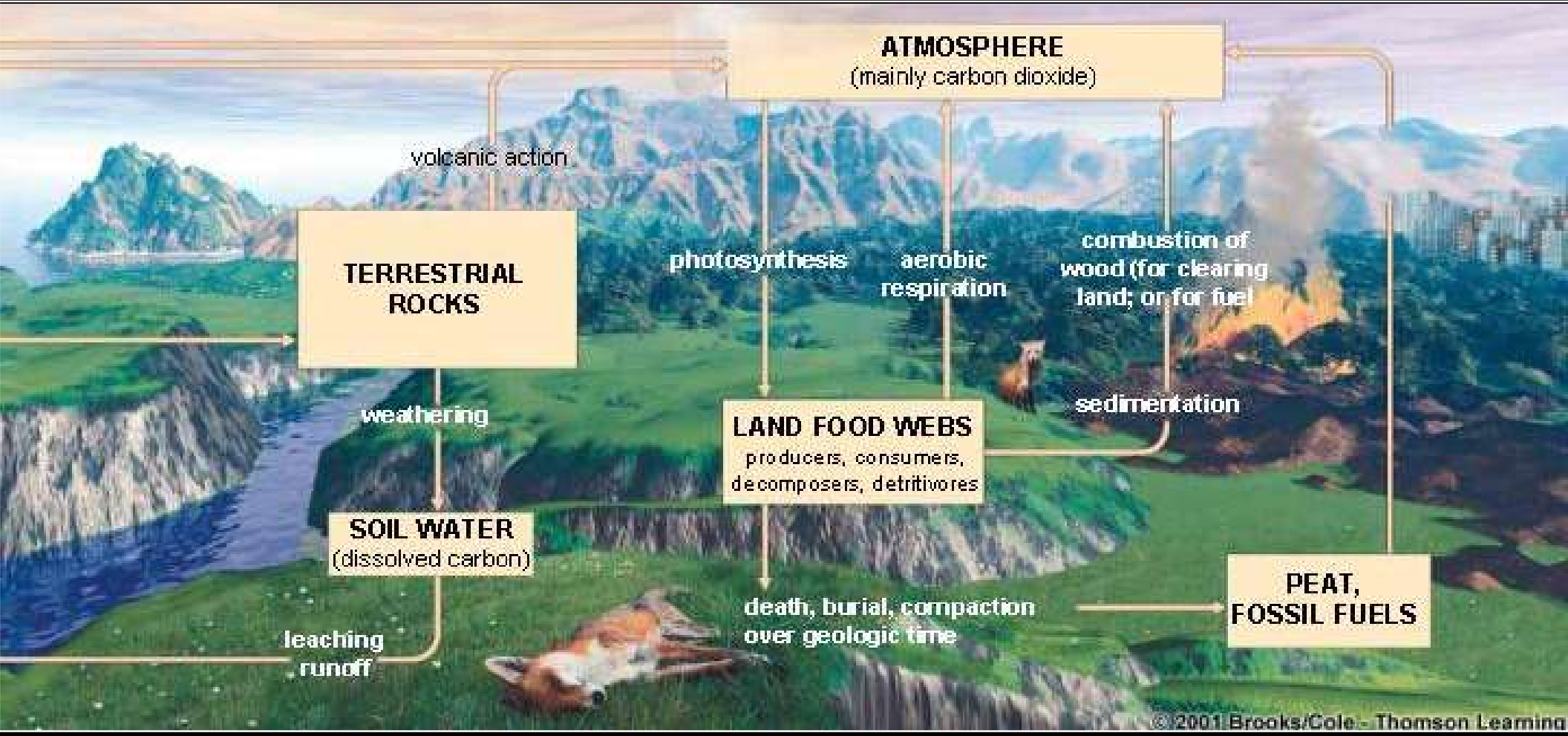
A food chain

Matter Cycling in Ecosystems : Biogeochemical cycles

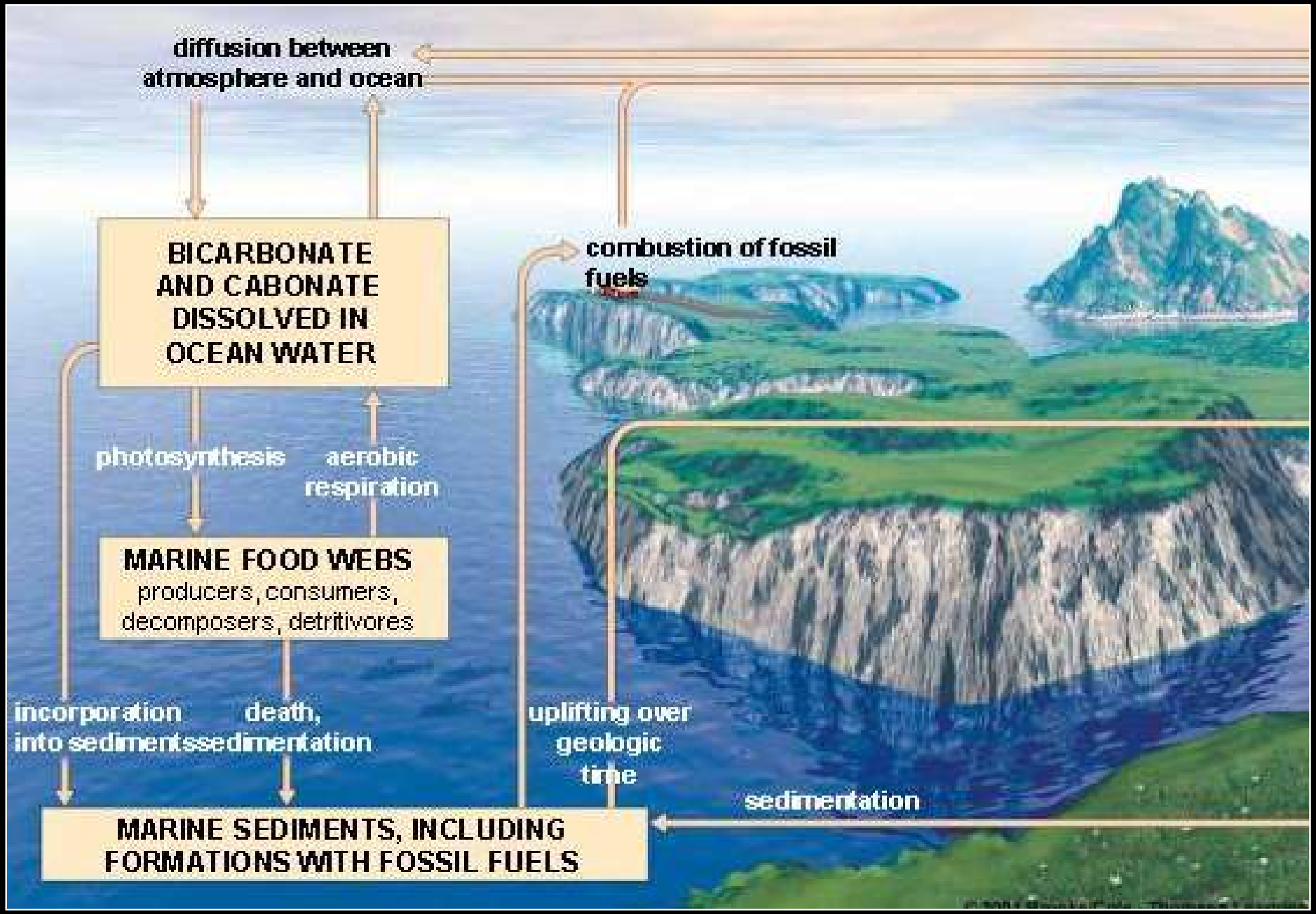
Hydrologic (Water) Cycle



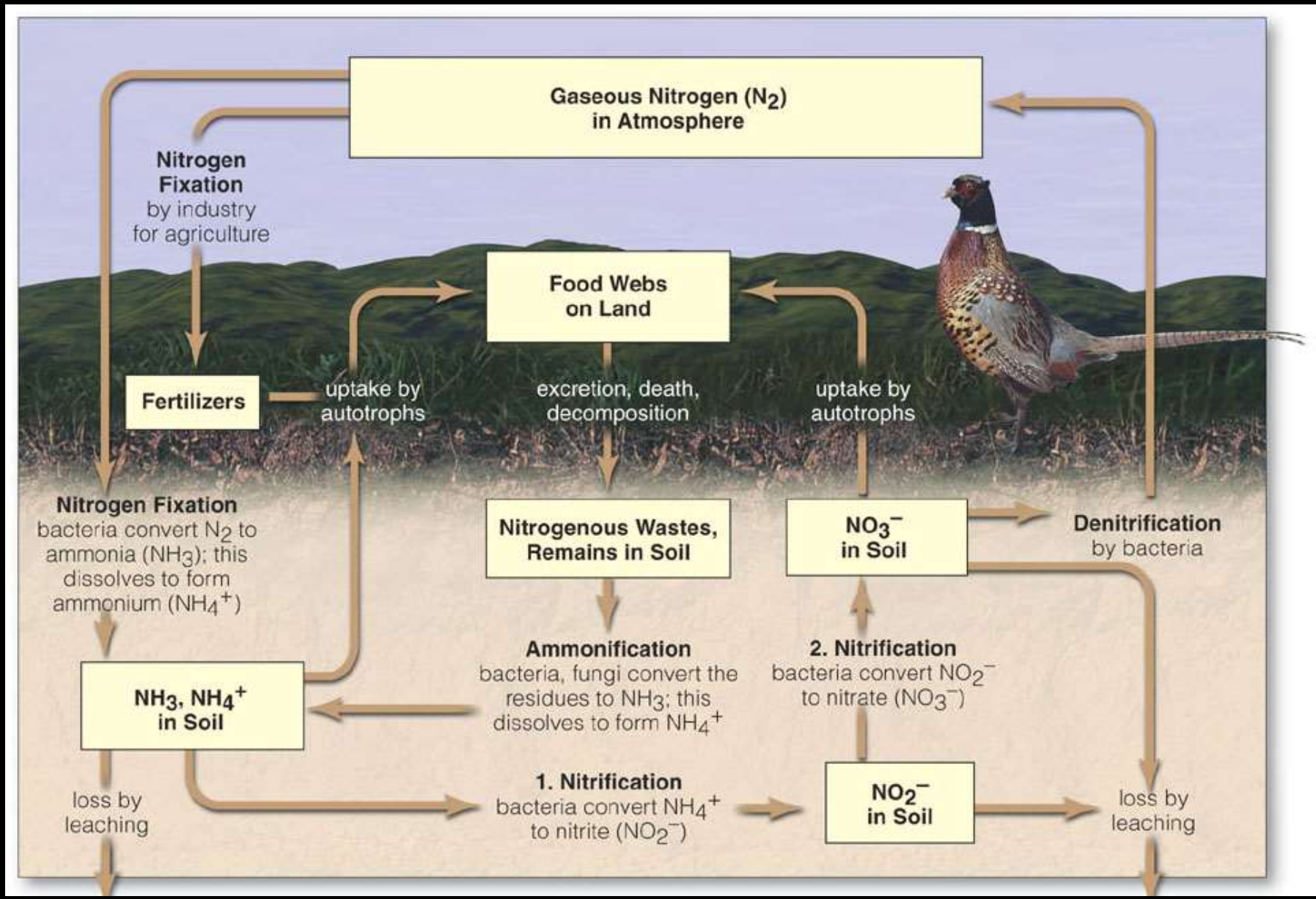
The Carbon Cycle (Terrestrial)



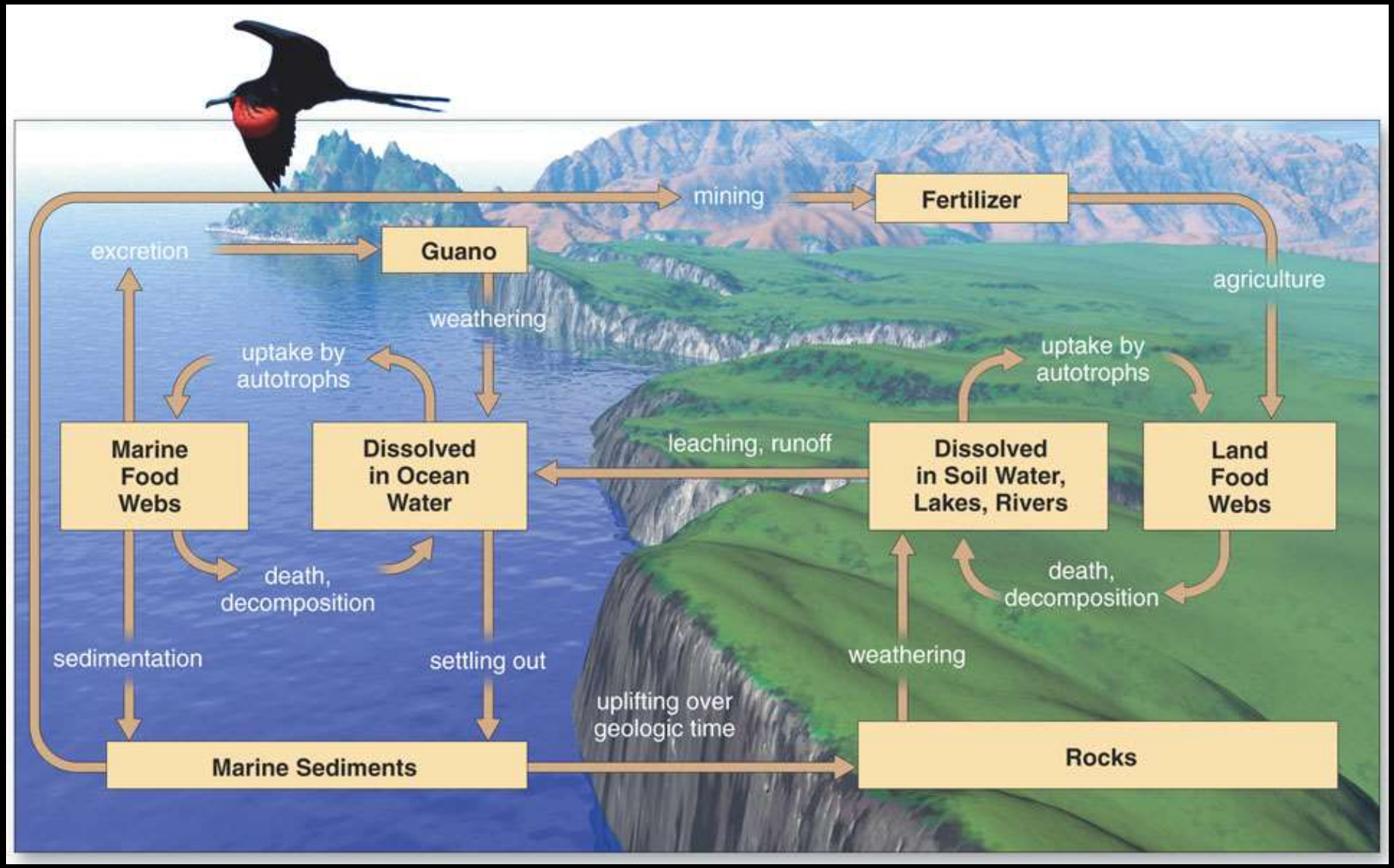
The Carbon Cycle (Marine): Group



The Nitrogen Cycle



The Phosphorus Cycle



https://missionwolf.org/trophic-cascade/
https://www.youtube.com/watch?v=yvqMamiu2b4
https://www.youtube.com/watch?v=I47vhzErOCE
https://www.youtube.com/watch?v=_Rxp3HQDUvY
https://www.youtube.com/watch?v=XVB2VNxRuHM