Lecture 11

Earth's Biosphere

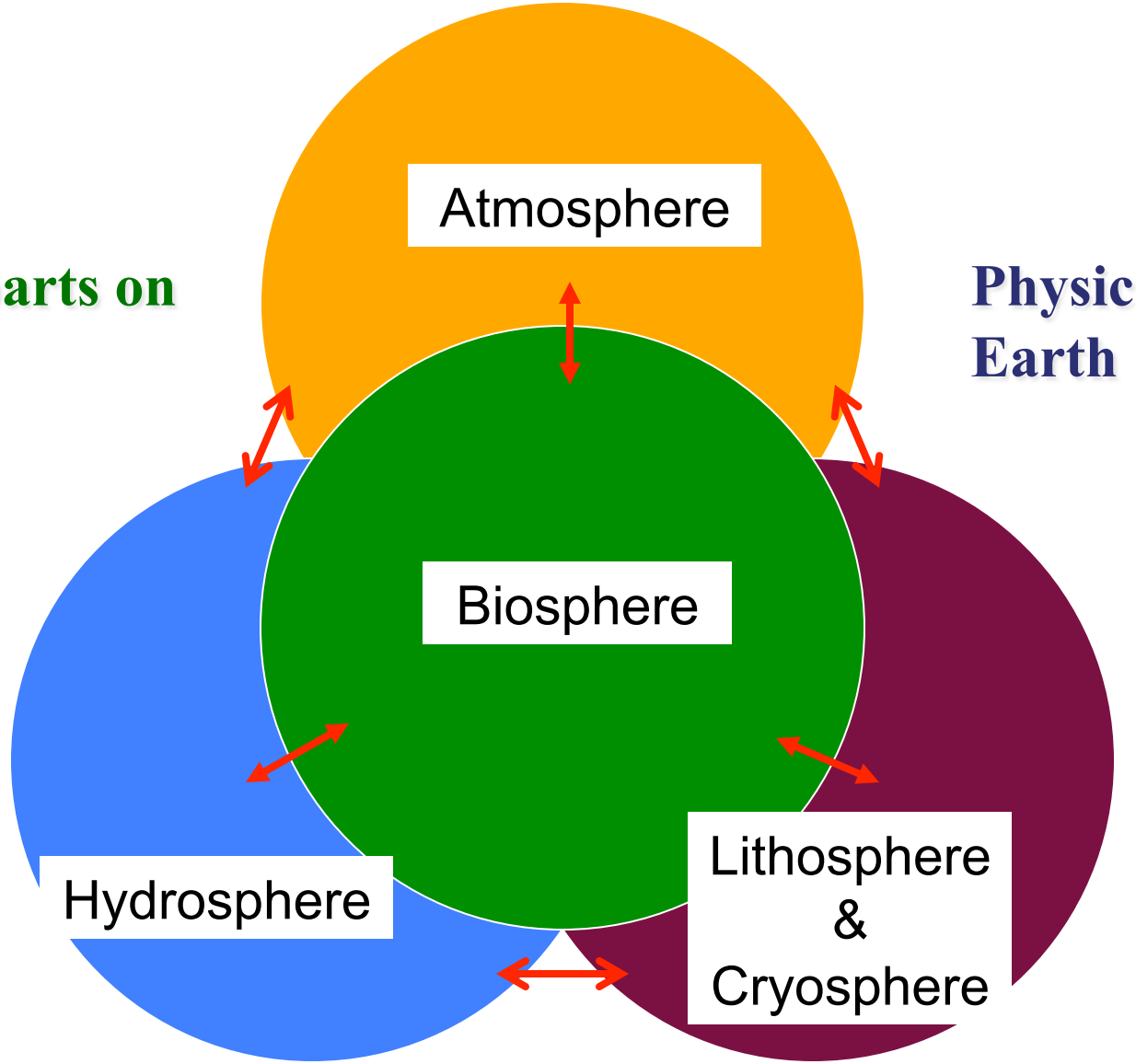
EarthsClimate_Web_Chapter.pdf, p. 30-35; Ch. 3, 46-47, 53-58

I. Carbon Storage and Cycle
II. Climate → Biosphere
    a. Distribution of biomes
IV. Biosphere → Climate
    a. Natural processes
    b. Anthropogenic effects
Role of Biosphere in climate
    a. GAIA Hypothesis

Biosphere: Life Processes on Earth

Organic parts on Earth

Physical parts on Earth



Biosphere Dynamics

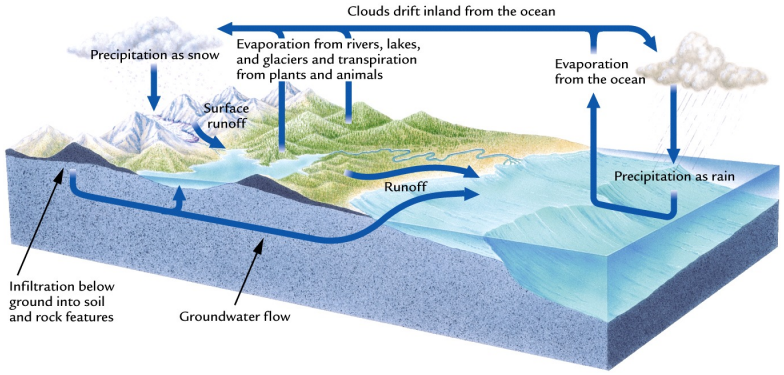
A. Ecosystems

1. *Habitat* - where an organism lives, its environment
2. *Niche* - interactions of an organism with its habitat
3. *Ecosystem* - habitat, niche and interactions between organisms

B. Energy

1. Sun → plants → animals
2. First Law of Thermodynamics → energy cannot be destroyed or created, just changes form

C. Water cycle



D. Nutrients and minerals recycled

1. Most plants require 17 elements

Composition of life (95%) is Carbon, Oxygen, Hydrogen, **Nitrogen, Phosphorous**, and Sulfur.

2. Elements and minerals necessary for animal functions

E. Food chain (phytoplankton → copepod → fish → squid → seal → *Orca*)

F. The biosphere pyramid (equilibrium balance / sustainable ecosystem)

Earth Biomes

A. Groups of ecosystems within a geographic region exposed to the same physical conditions with similar ecosystem structure.

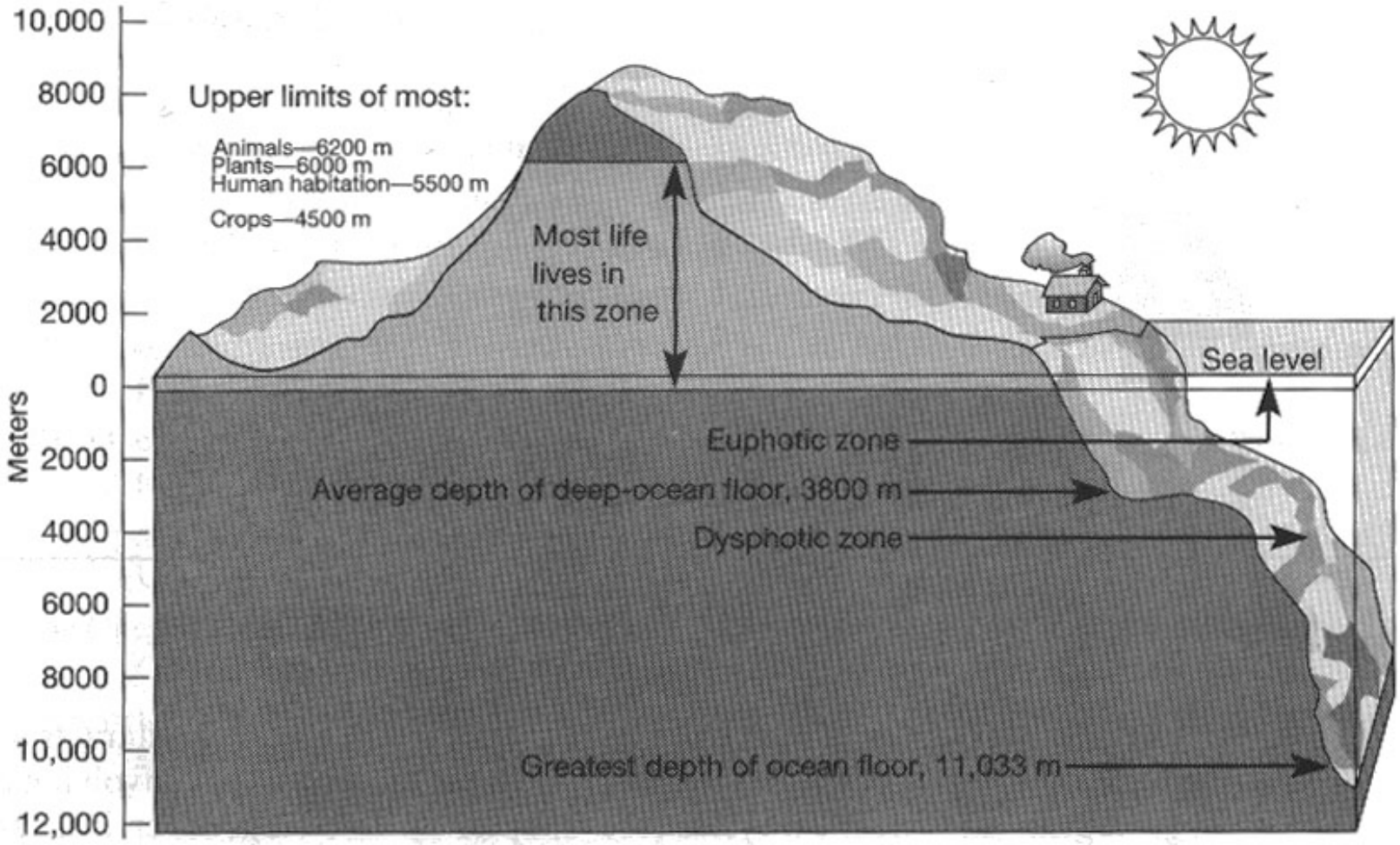
B. Terrestrial biomes

- polar ice
- tundra
- temperate (boreal, coniferous, deciduous) forests
- grasslands
- deserts
- savanna
- tropical rain forests

C. Aquatic biomes

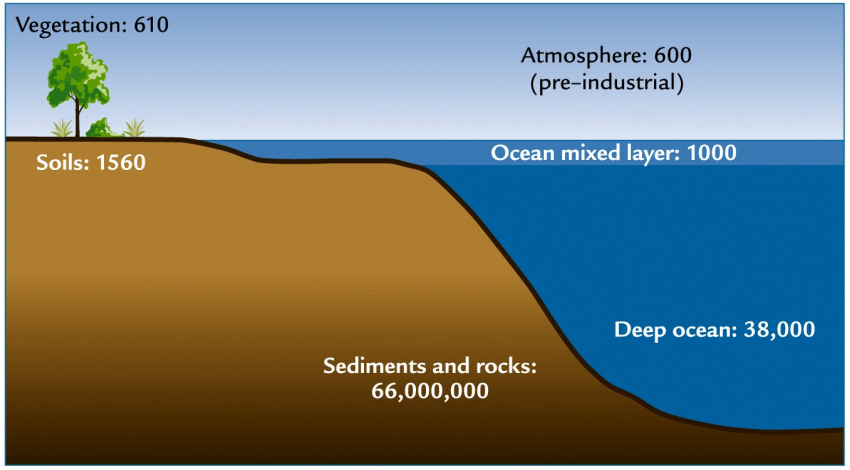
1. Freshwater (e.g., lakes, rivers, swamps)
2. Marine (e.g., oceans)
   - a. Coral reefs are the marine equivalent of the tropical rain forests
   - b. Continental shelves vs. open ocean
3. Estuaries (transitional between fresh and marine waters)

Vertical Dimension of Biosphere



Most life lives in the zone 200 meters below sea level and 6000 meters above sea level.

Carbon Storage and Carbon Cycle



A Major carbon reservoirs (gigatons)

Major reservoirs:

Smallest: atmosphere, vegetation and the surface ocean

Slightly larger: soils

Much larger: deep ocean

Largest: rocks and sediments

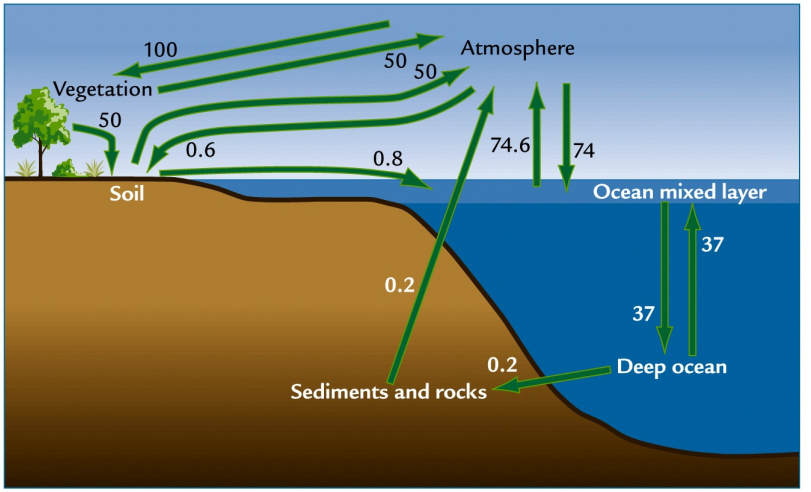
Exchange rates (inversely related to sizes):

Fastest: atmosphere, vegetation and the surface ocean

Slightly slower: soils

Much slower: deep ocean

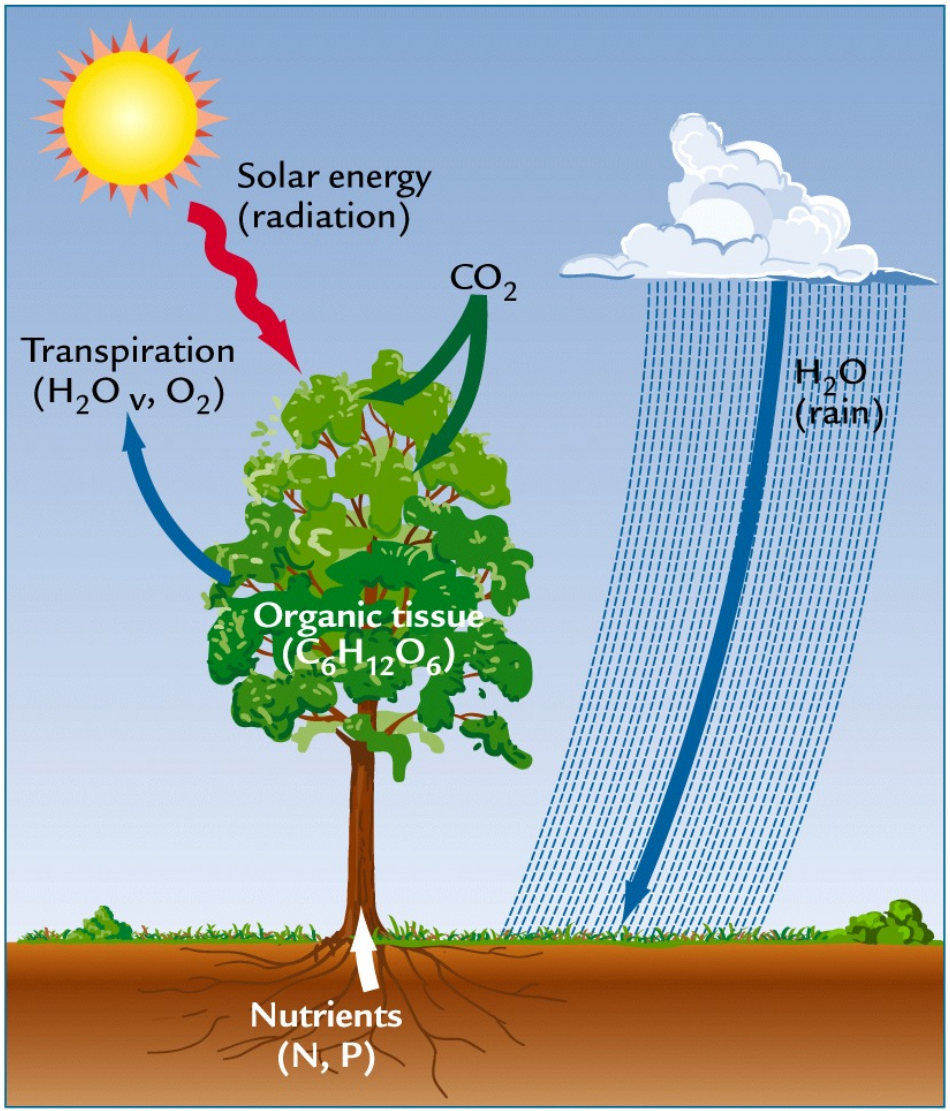
Slowest: rocks and sediments



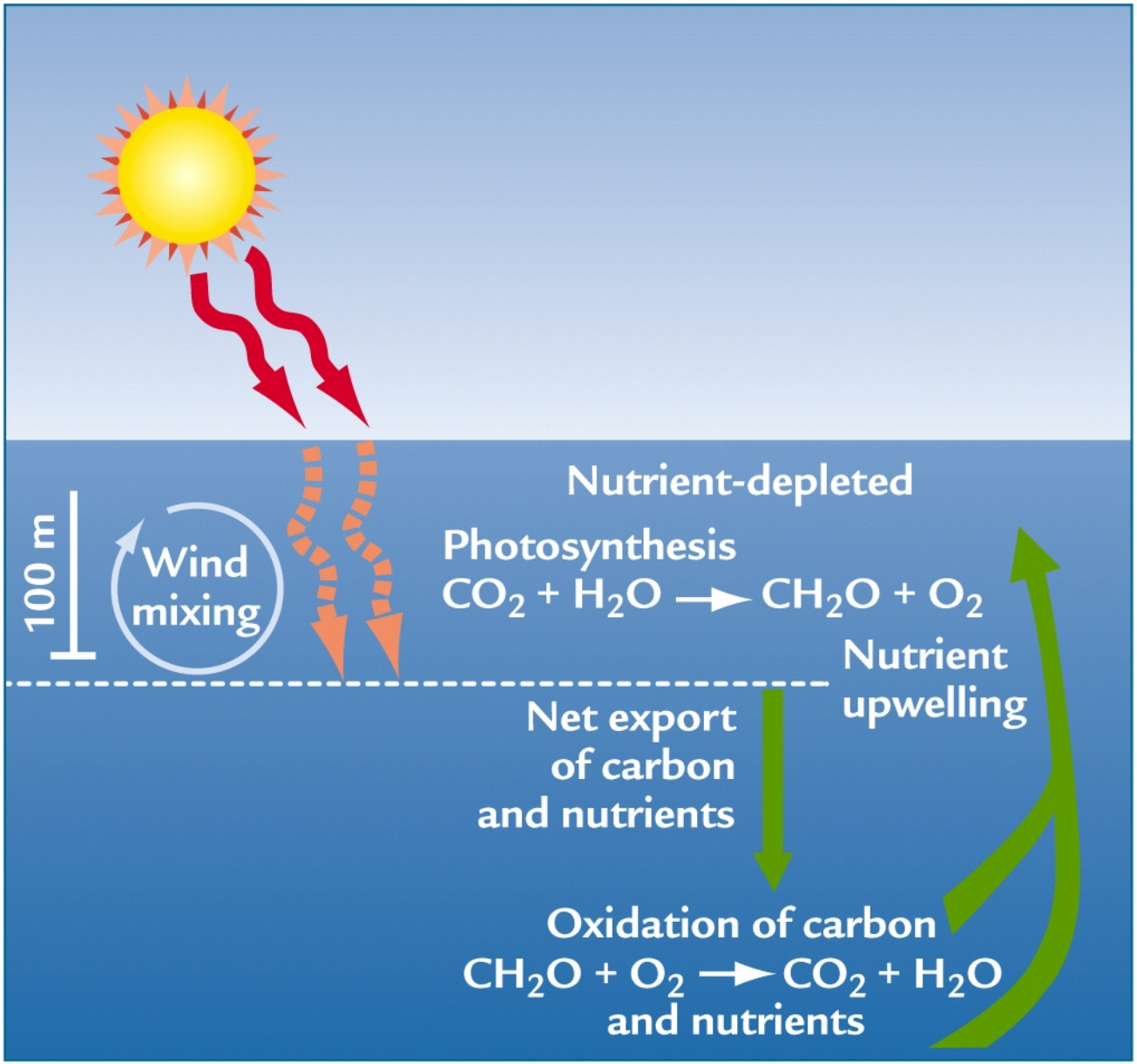
B Carbon exchange rates (gigatons/year)

Photosynthesis on Land

$$6CO_2 + 6H_2O + \text{sunlight} \leftrightarrow C_6H_{12}O_6 + 6O_2$$

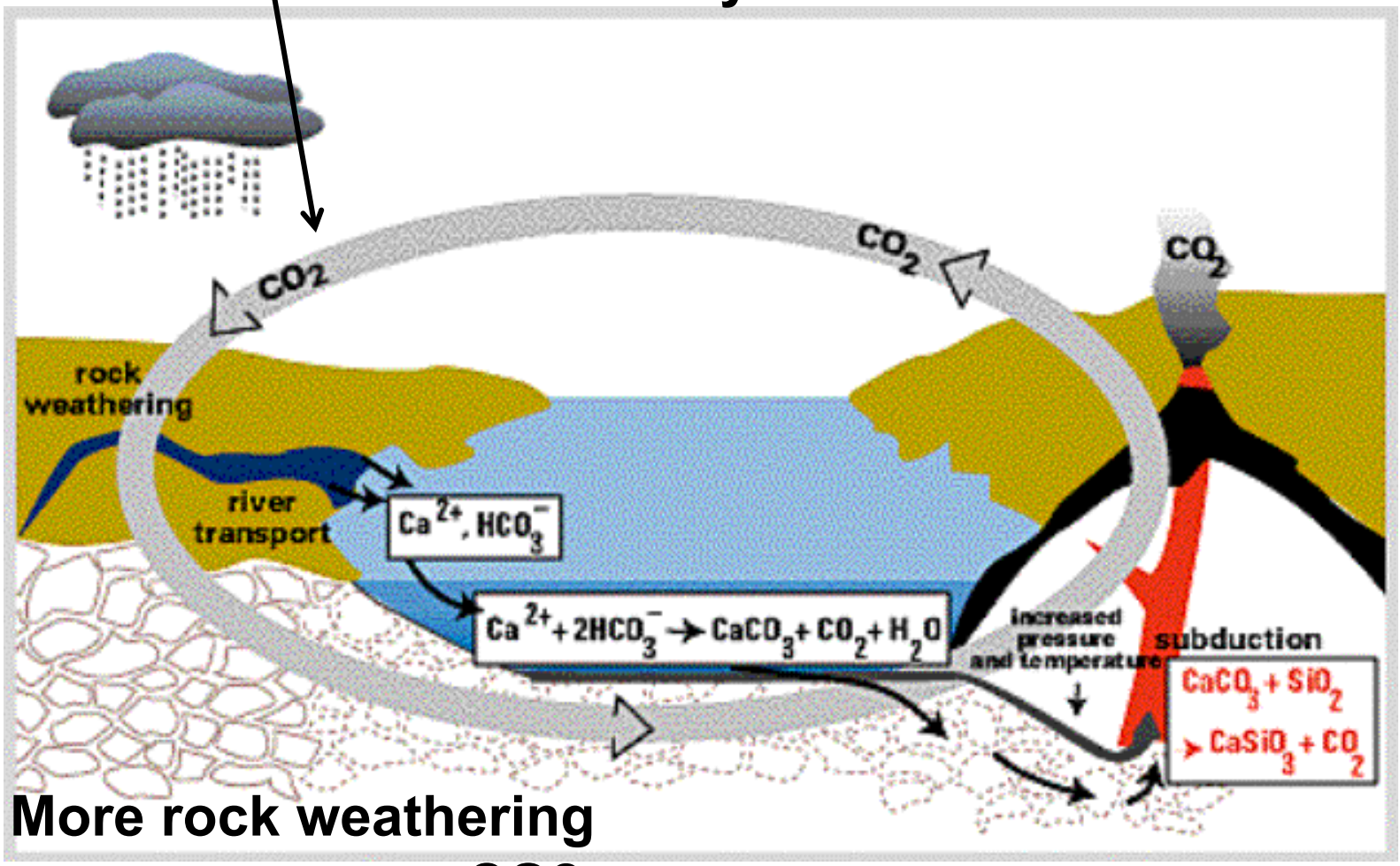


Photosynthesis in the Ocean



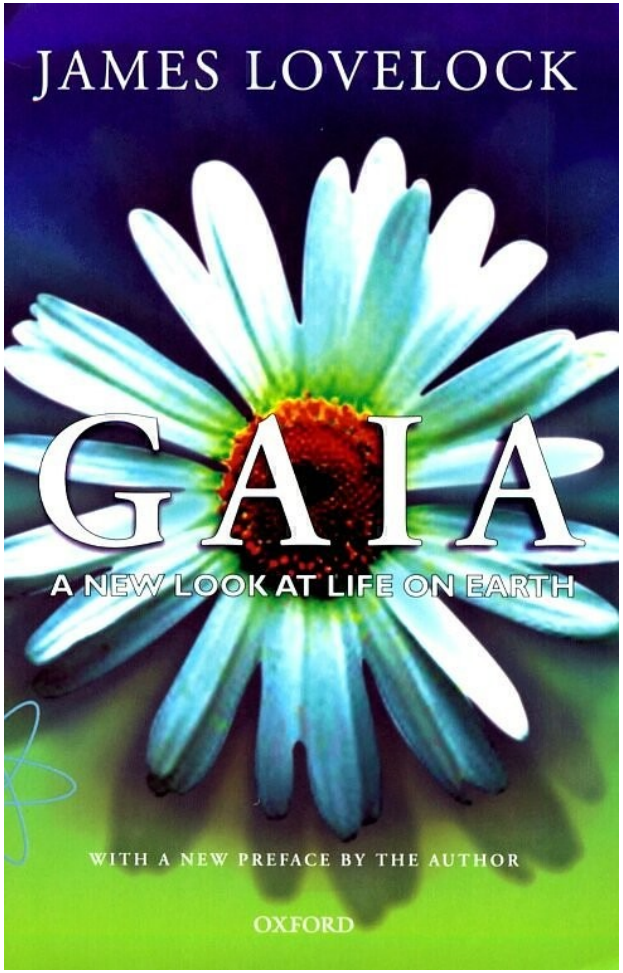
Warmer, more rainfall

Response of weathering rocks to climate regulate atmospheric CO2, in a way to stabilize climate



More rock weathering -> remove more CO2 from atmosphere

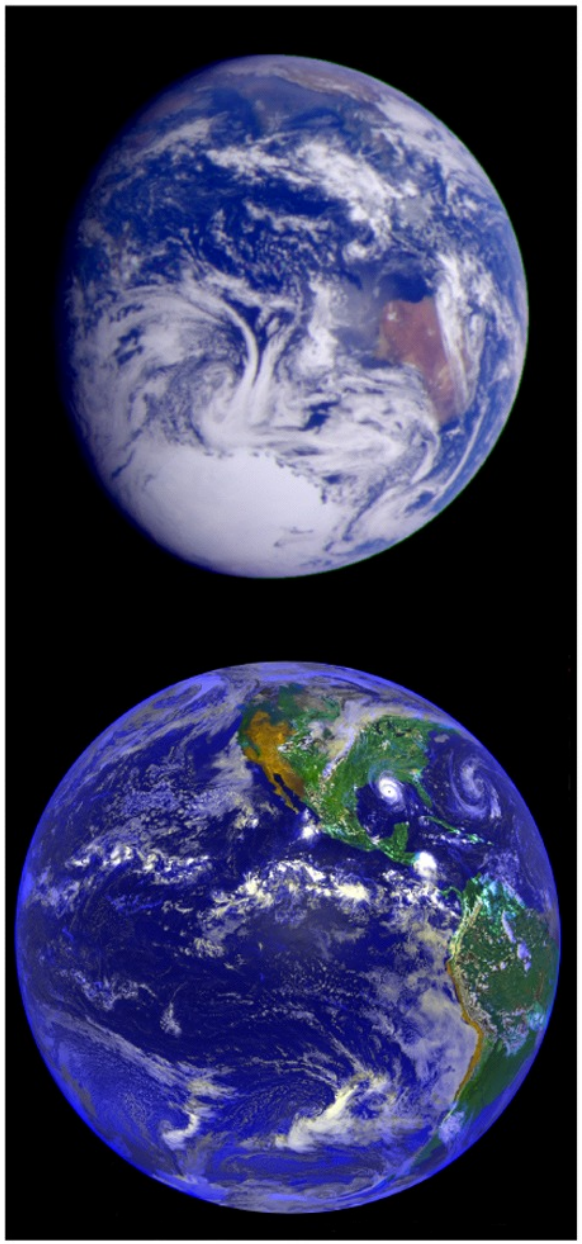
GAIA: A New Look at Life on Earth



". . . the physical and chemical condition of the surface of the Earth, of the atmosphere, and of the oceans has been and is actively made fit and comfortable by the presence of life itself. This is in contrast to the conventional wisdom which held that life adapted to the planetary conditions as it and they evolved their separate ways."

James Lovelock, 1979

GAIA – forming and regulating atmosphere?



"An awesome thought came to me. The Earth's atmosphere was an extraordinary and unstable mixture of gases, yet I knew that it was constant in composition over quite long periods of time. Could it be that life on Earth not only made the atmosphere, but also regulated it – keeping it at a constant composition, and at a level favorable for organisms?"

James Lovelock, 1991

Biosphere produces the succession of life-forms needed to keep the planet habitable.

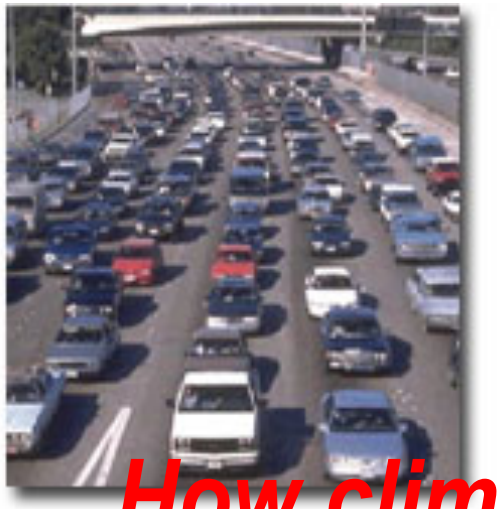
- Supporting evidences:
  - General path of biological evolution matches Earth's need for progressively greater chemical weathering. E.g., few but more primitive organisms existed in early history of the earth when it was to Earth's advantage to retain CO2 in its atmosphere to counter the weakness of the sun. As Solar radiation strengthened, more advanced organisms formed to accelerate the rate of weathering.
- Critics:
  - Life played little role in chemical weathering and carbon cycle in early earth's history (the first 4BY).

Lovelock's GAIA Contribution

Whether or not you accept the extreme versions of the GAIA hypothesis, the publication of "GAIA, A New Look at Life on Earth" (1979) has influenced the way in which scientists and the general public view the Earth. It is still being hotly debated 25 years later.

Raised consciousness! Holistic view of the Earth. Earth from space.

Focused attention on the role of the Biosphere in Atmospheric processes



How climate would change if we destroy most of biosphere on earth?

Summary:

- What role does biosphere play in determine the earth's climate?
- How do terrestrial and marine biosphere control global carbon cycle?
- What does the GAIA hypothesis tell us about the importance of biosphere in maintaining a habitable earth?