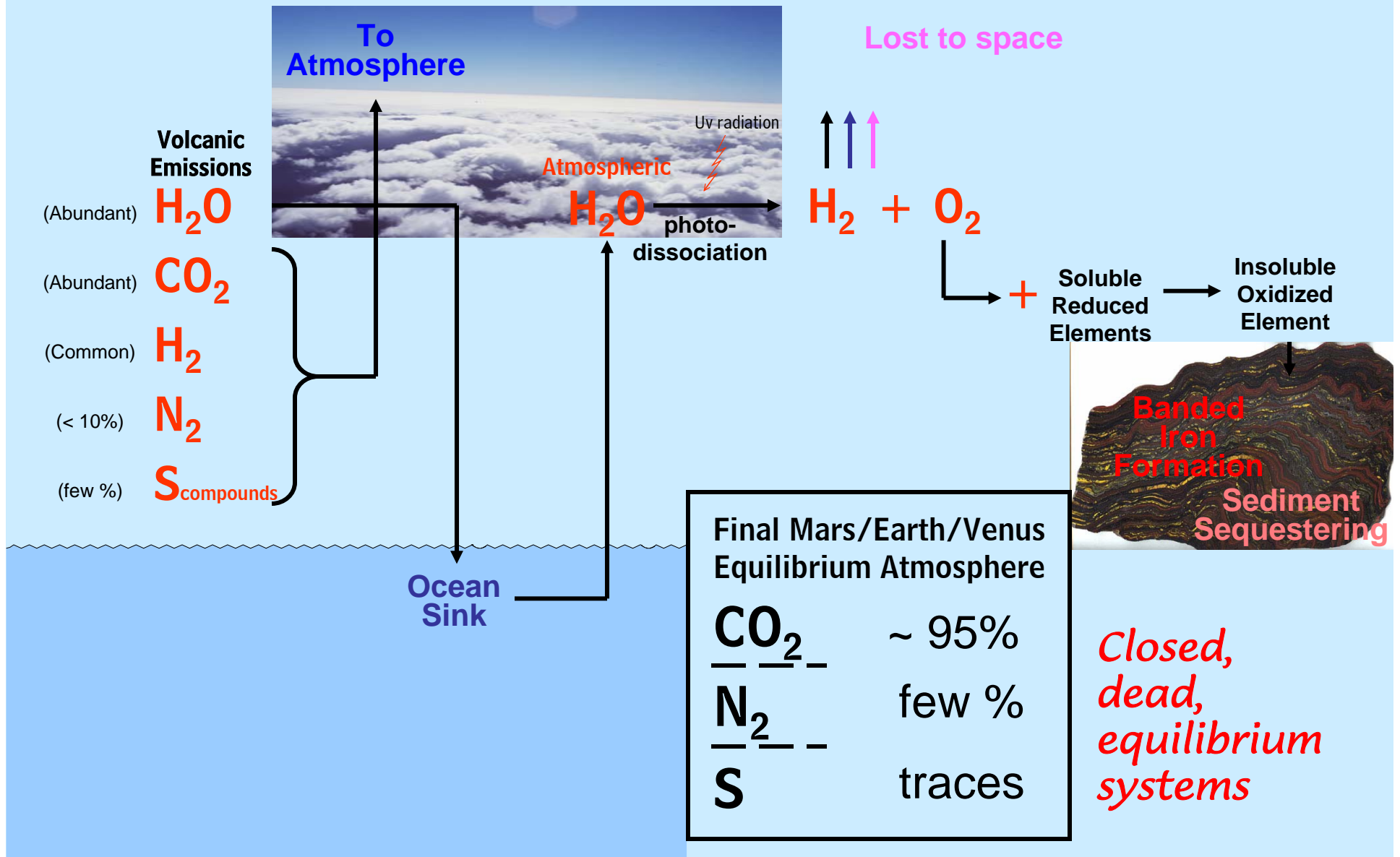


Evolution of Earth Environments

Bio-Geo-Chemical Cycling

EVOLUTION OF THE EARLIEST ATMOSPHERES OF MARS AND EARTH

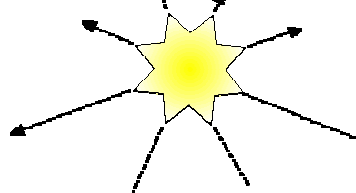
Volcanic Outgassing Evolving to Equilibrium Atmosphere



**The Earth Did Not Shut
Down Like Mars and
Venus . . .**

**Because It is Constructed
of Four Great Systems All
Mediated by Life**

EARTH SYSTEMS CYCLE



Unfortunately, these exist in different academic departments

HYDROSPHERE

Oceanography

ATMOSPHERE

Meteorology

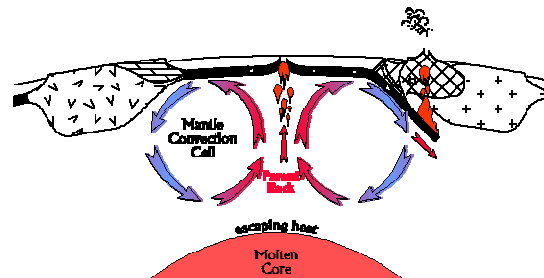
BIOSPHERE

Biology

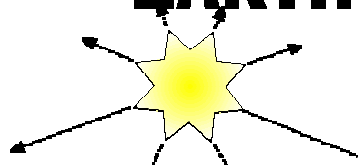
And because of that we know a great detail about each, subject, but very little about how they are all connected.

LITHOSPHERE

Geology/
EarthScience



EARTH SYSTEMS CYCLE



But, to understand Earth Environments the very thing we need to understand are the *connections* among these systems, all of

HYDROSPHERE

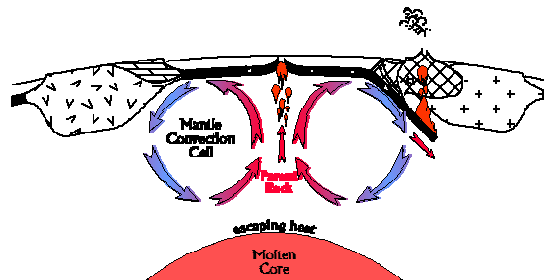
them

ATMOSPHERE

BIOSPHERE

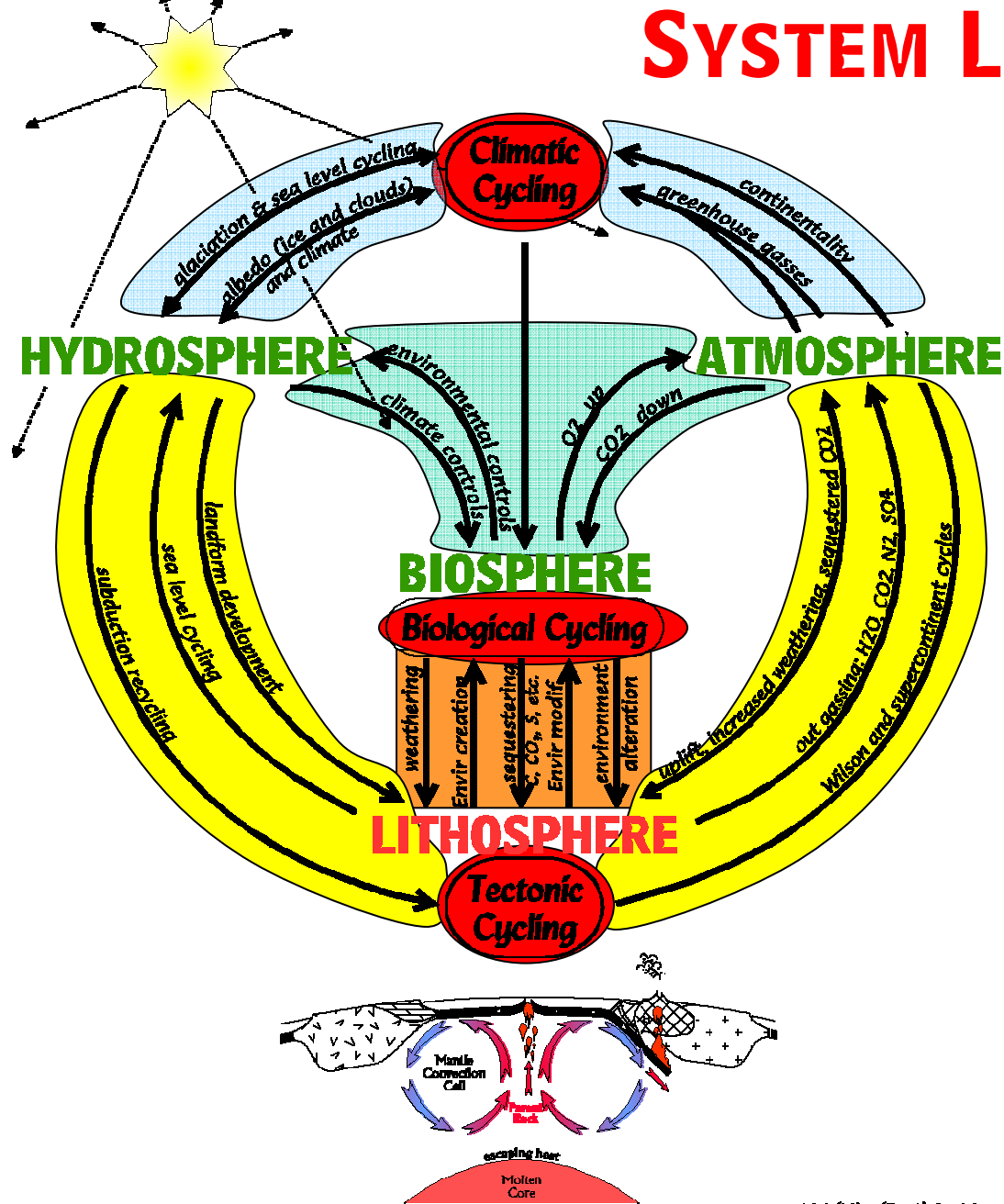
And that is often the very information we are missing, are not taught, and in fact until recently we did not even study.

LITHOSPHERE



EARTH SYSTEMS CYCLE

SYSTEM LINKAGES



An Example

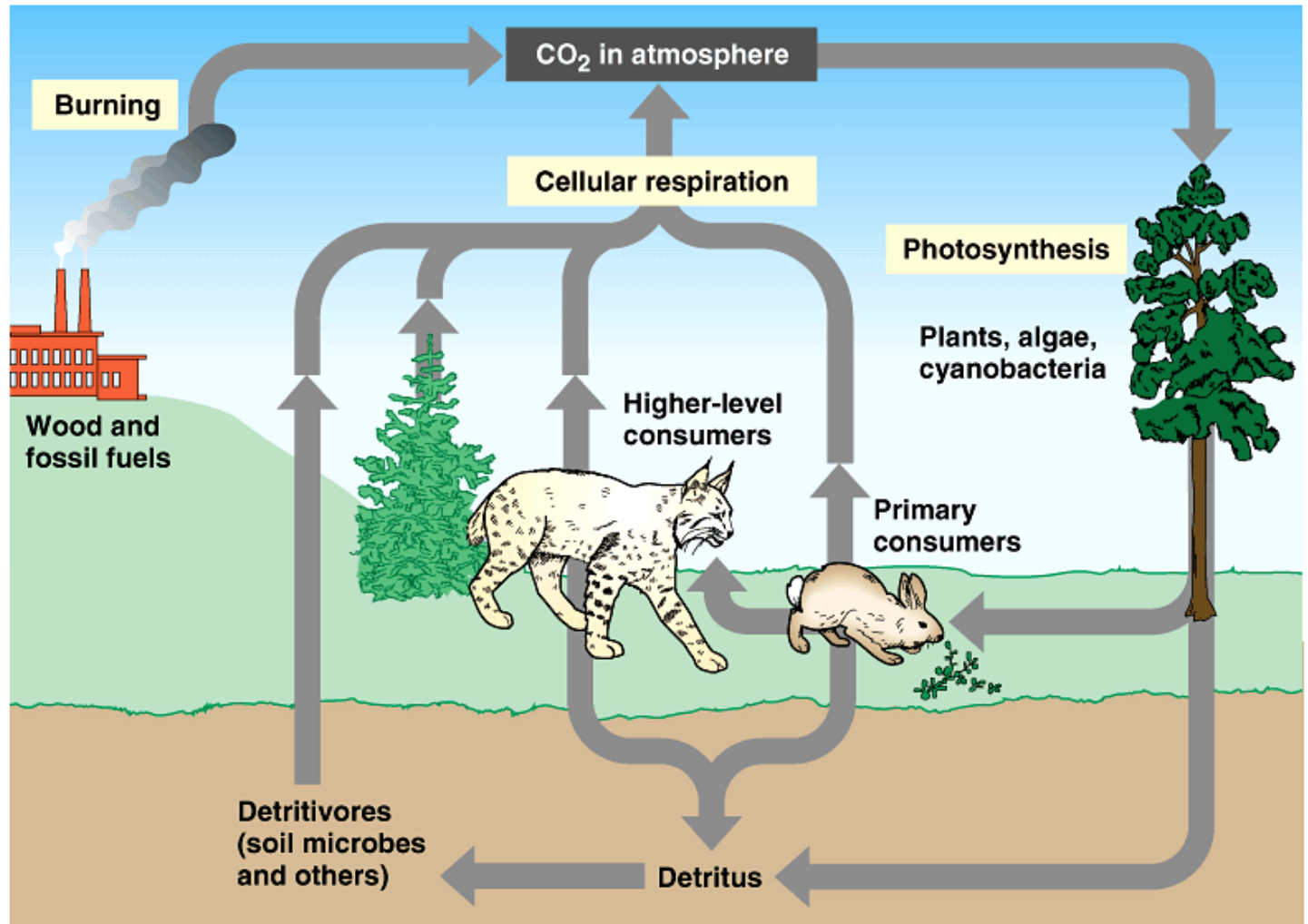
The Carbon

Cycle

Carbon Cycling

How are life and the earth related? Does the external environment and its alterations set the course of change, or does change arise from some independent and internal dynamic within organisms themselves?

Biosphere?
Atmosphere?
Hydrosphere?
Lithosphere?



Carbon Cycling

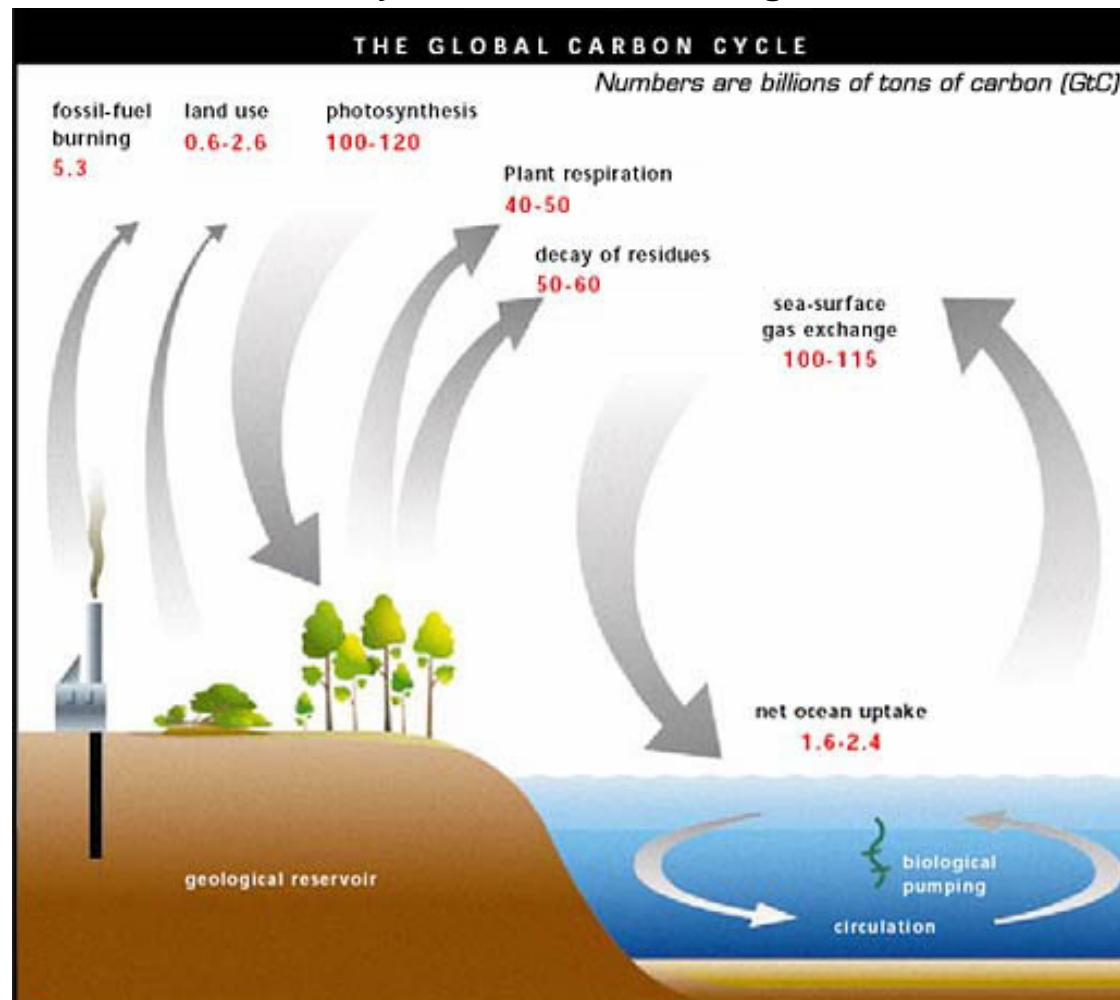
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Biosphere?

Atmosphere?

Hydrosphere?

Lithosphere?



Carbon Cycling

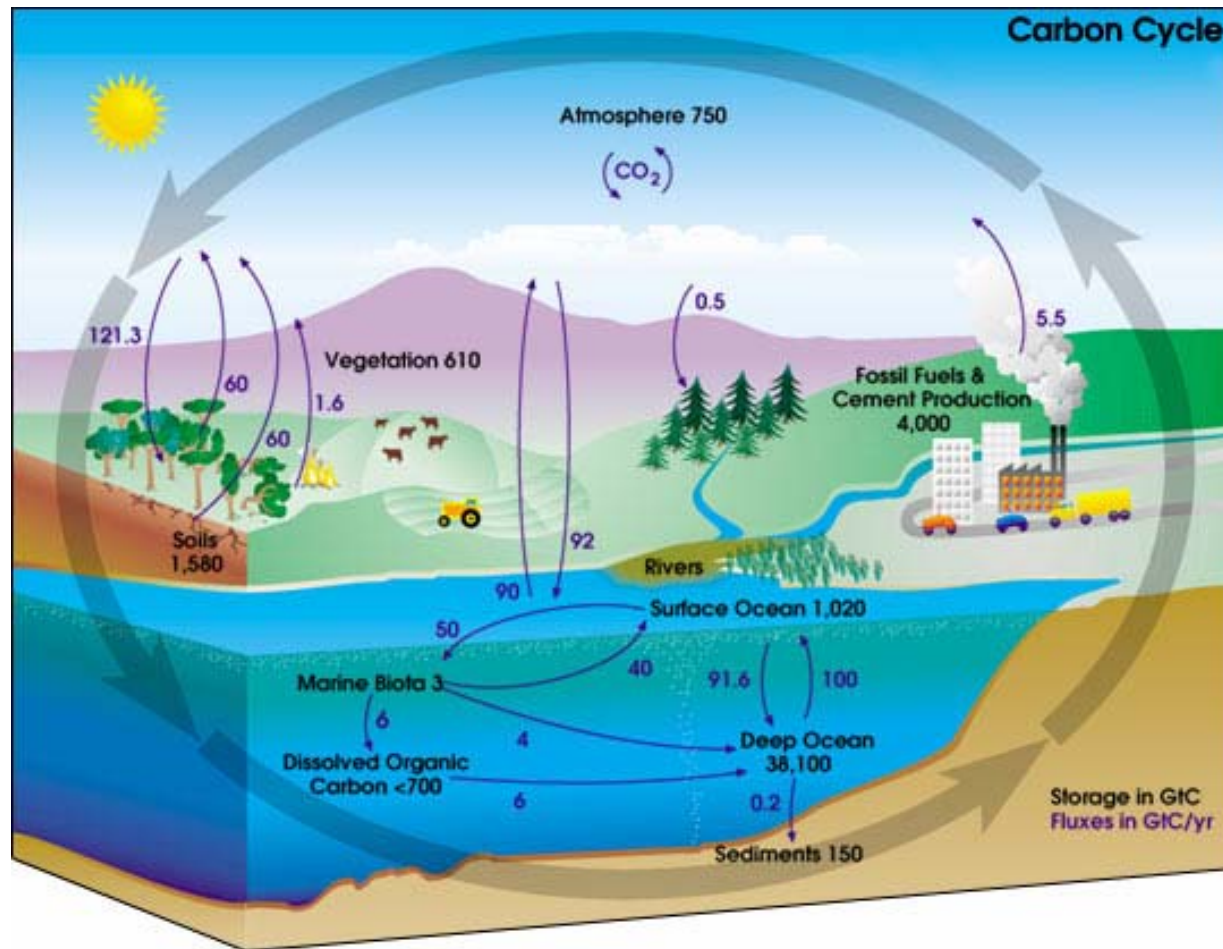
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Atmosphere?

Hydrosphere?

Lithosphere?



Carbon Cycling

How are life and the earth related? Does the external environment and its alterations set the course of change, or does change arise from some independent and internal dynamic within organisms themselves?

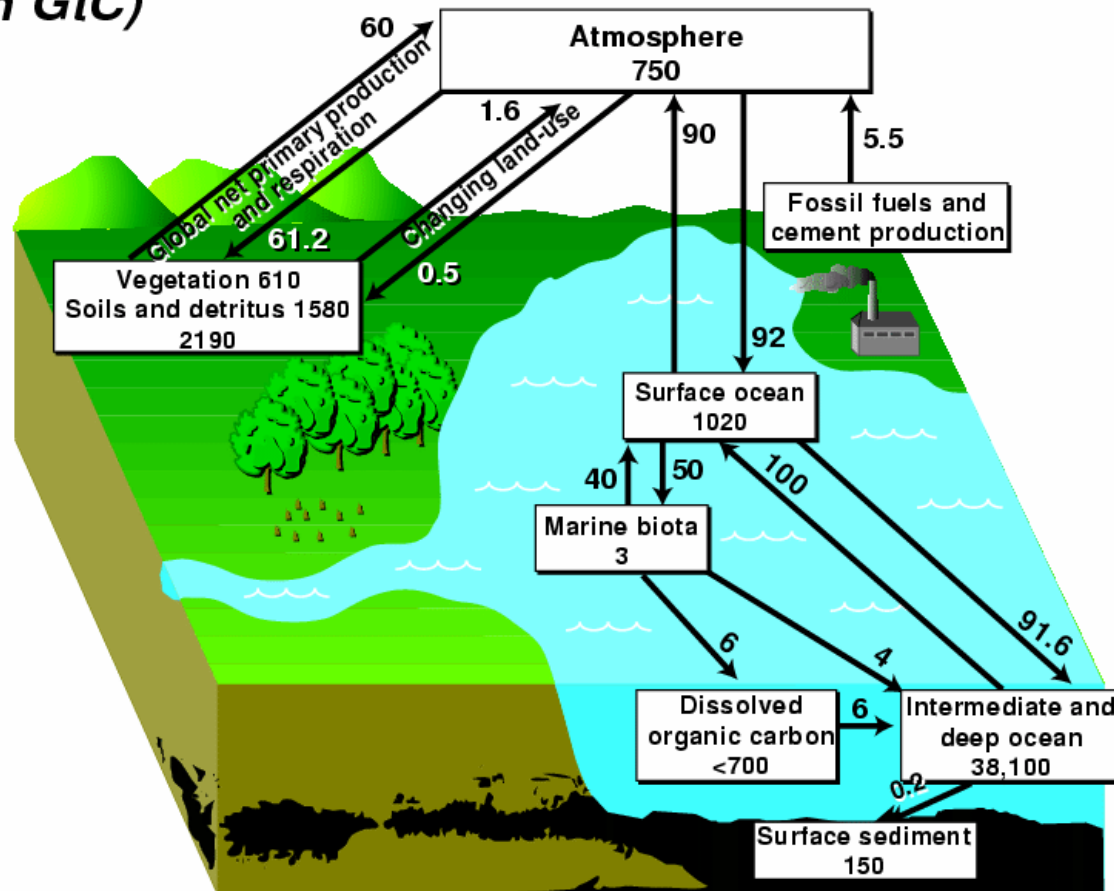
Biosphere?

Atmosphere?

Hydrosphere?

Lithosphere?

Global Carbon Cycle (in GtC)



Carbon Cycling

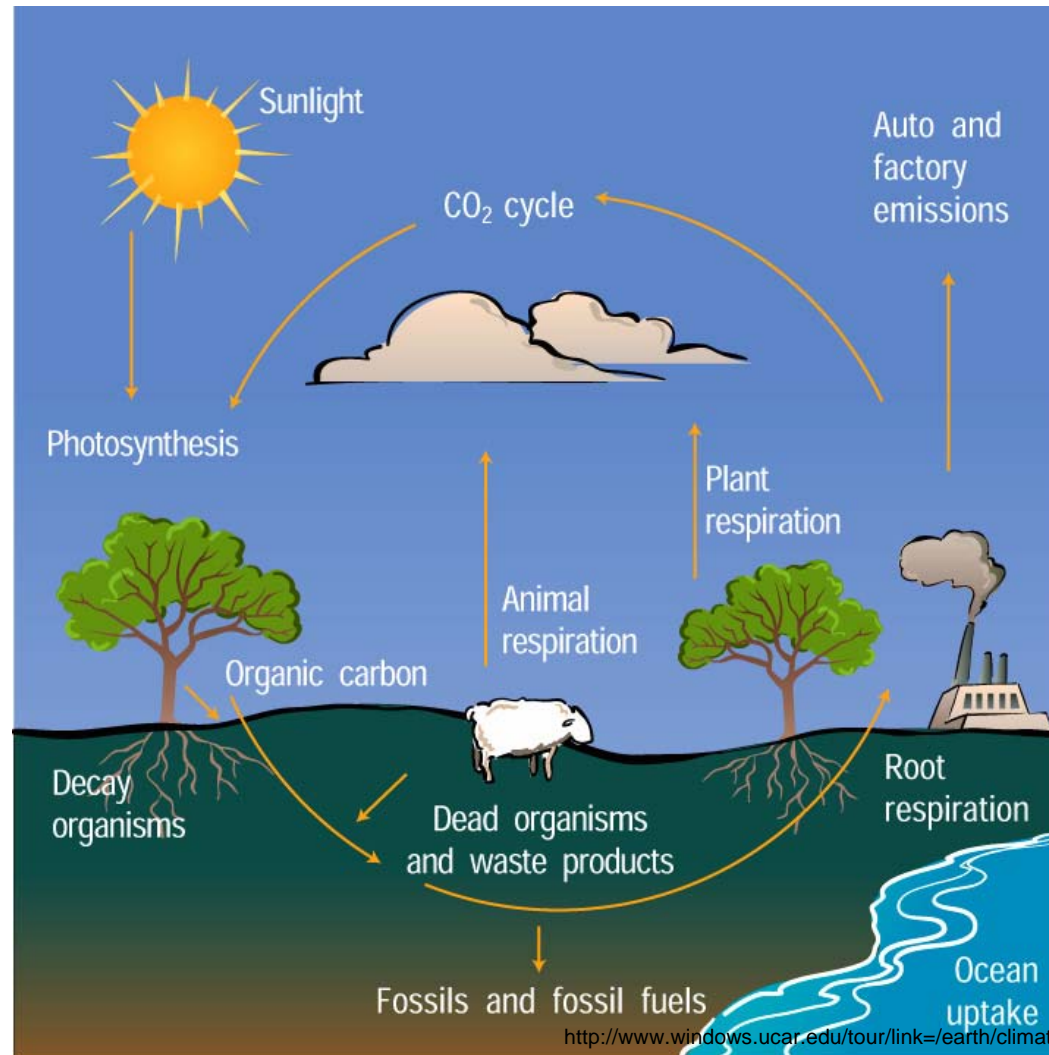
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Biosphere?

Atmosphere?

Hydrosphere?

Lithosphere?



Carbon Cycling

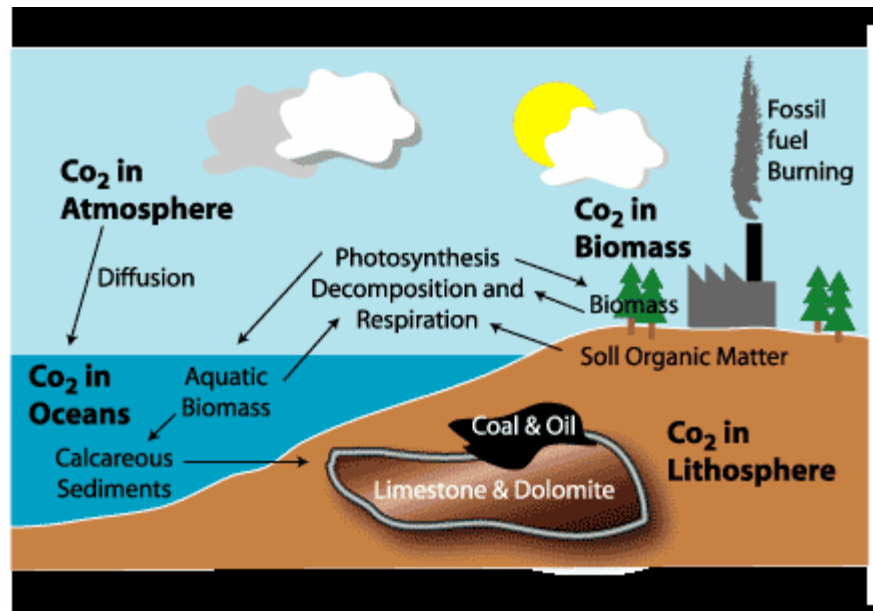
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Biosphere?

Atmosphere?

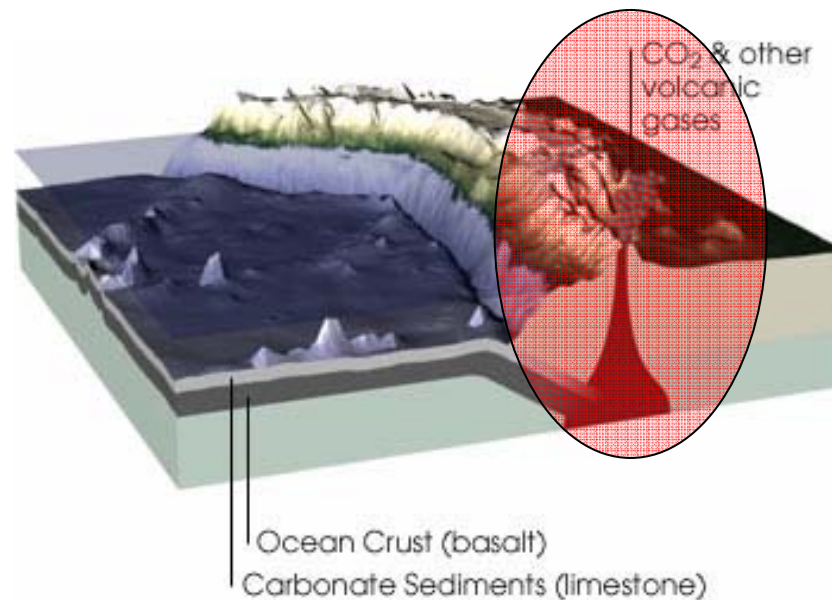
Hydrosphere?

Lithosphere?



Carbon Cycling

How are life and the earth related? Does the external environment and its alterations set the course of change, or does change arise from some independent and internal dynamic within organisms themselves?



Of all these carbon cycle diagrams this is the only one that acknowledges that volcanic activity and subduction zones might have something to do with carbon cycling on Earth.

Origin of Atmosphere and Oceans

But, we already know volcanic activity is an essential link in the presence of carbon, putting large quantities into the atmosphere.

Kilauea Volcanic Gasses

H_2O 67.7%

CO_2 12.7%

N_2 7.65%

SO_2 7.03%

SO_3 1.86%

S_2 1.04%

H_2 .75%

CO .67%

Cl_2 .41%

Ar .20%

Observe the following:

There is no free oxygen coming from the volcano, but oxygen is not rare. In fact, 90% of the gasses have oxygen in them.

Water must have been as common or more common in the past in volcanic outgassing (otherwise there would be no oceans.)

Carbon dioxide is very common.

Sulfur is very common, almost 10%.

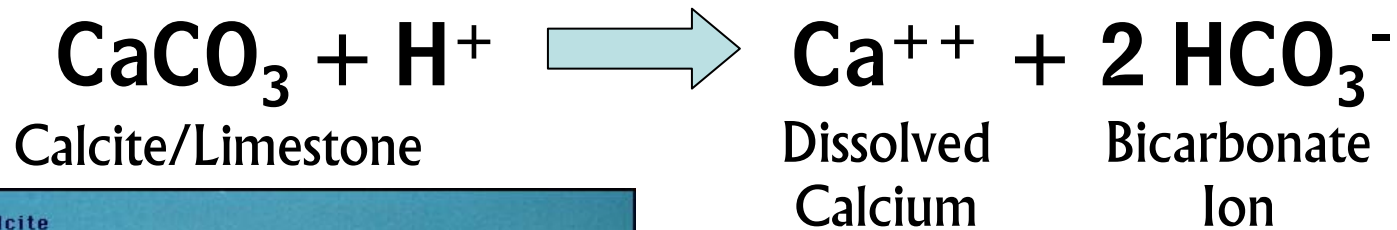
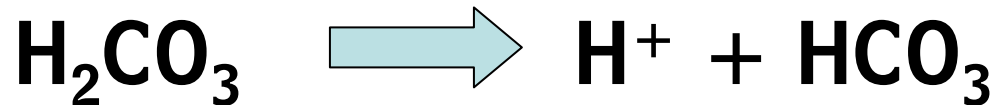
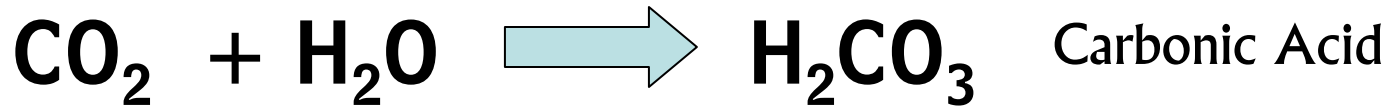
In addition:

Hydrogen must have been in much greater abundance in the past than today since hydrogen has been continuously lost to space over the past 4 billion years.

Chemical Weathering

P 129

And we know that weathering processes remove carbon from the atmosphere.



Origin of Atmosphere and Oceans By Fractionation

And we have good reason to believe that the Earth's original atmosphere was, like that of Mars and Venus, almost saturated with Carbon.

Original Composition of Earth's Atmosphere

<i>CO₂</i>	98.%
Nitrogen	1.9%
Oxygen	trace
Argon	0.1%

Atmospheric Pressure
60

Abundances of Gasses in Mar's Atmosphere

<i>CO₂</i>	95.3%	→
<i>Nitrogen</i>	2.7%	→
Argon	1.6%	
Oxygen	0.15%	
Water vapor	0.03%	

Atmospheric Pressure
0.064

Abundances of Gasses in Venus's Atmosphere

<i>CO₂</i>	96.5%
<i>Nitrogen</i>	3.5%
<i>SO₂</i>	150 ppm
Argon	70 ppm
Water vapor	20 ppm

Atmospheric Pressure
92
~1300 #/in²

Biogeochemical Carbon Cycling

Where is carbon stored on Earth?

Carbon Reservoirs on Earth

MASS IN BILLION METRIC TONS

Atmosphere	735
Carbonate rocks	10,000,000
Fossil Fuels	6000
Oceans	36,000
Plants (land and ocean)	560
Soils	1500

Biogeochemical Carbon Cycling

Carbon Reservoirs on Earth

MASS IN BILLION METRIC TONS

Carbonate rocks	10,000,000	LITHOSPHERE
Oceans	36,000	HYDROSPHERE
Fossil Fuels	6000	LITHOSPHERE
Soils	1500	LITHOSPHERE
Atmosphere	735	ATMOSPHERE
Plants (land and ocean)	560	BIOSPHERE

LITHOSPHERE = 10,750,000

HYDROSPHERE = 36,000

BIOSPHERE = 560

To understand the Evolution of Environments on Earth it is not enough to just study . . .

Geological cycling by itself . . .

Or, Biological cycling by itself. . .

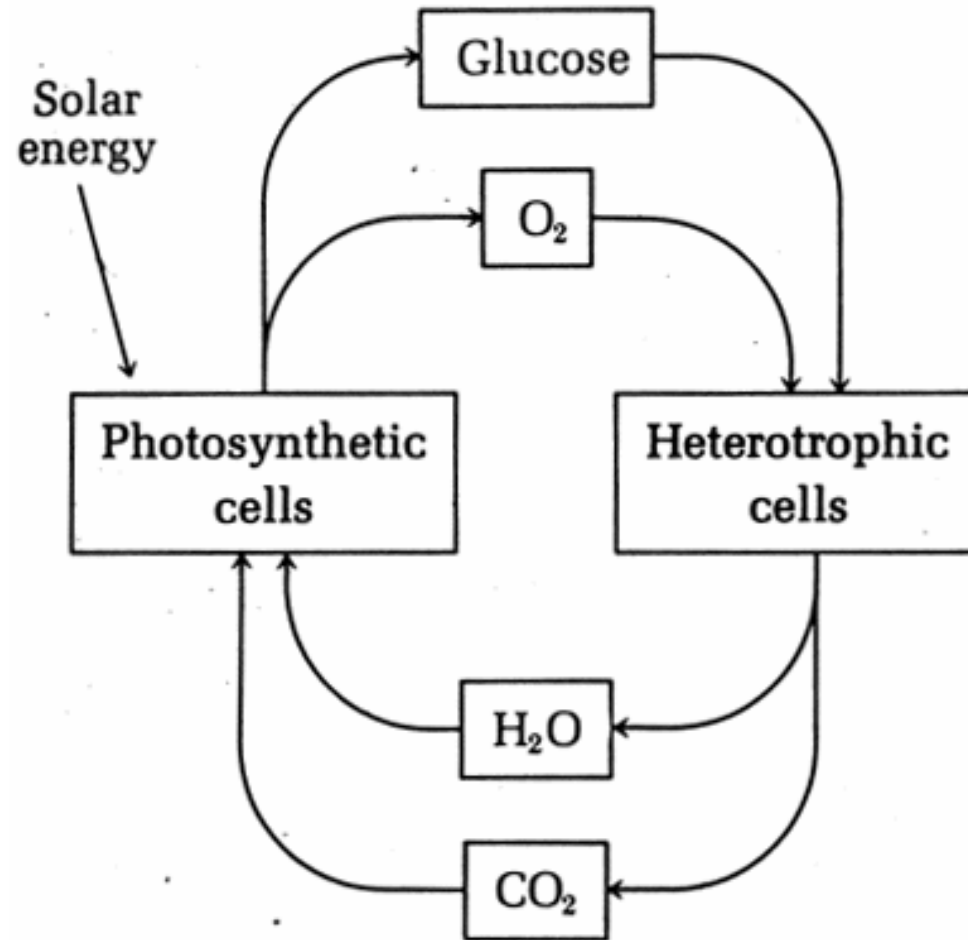
Or, Chemical cycling by itself.

Bio-Geo-Chem-Cycling
Biogeochemistry

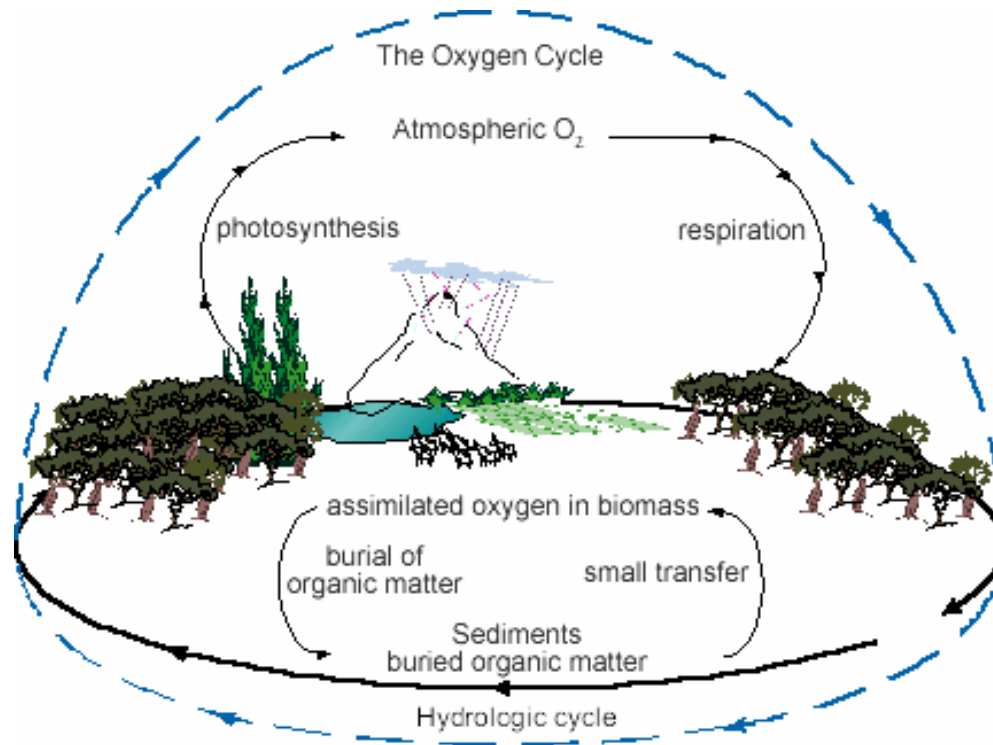
Biogeochemical Cycling

Oxygen Cycle

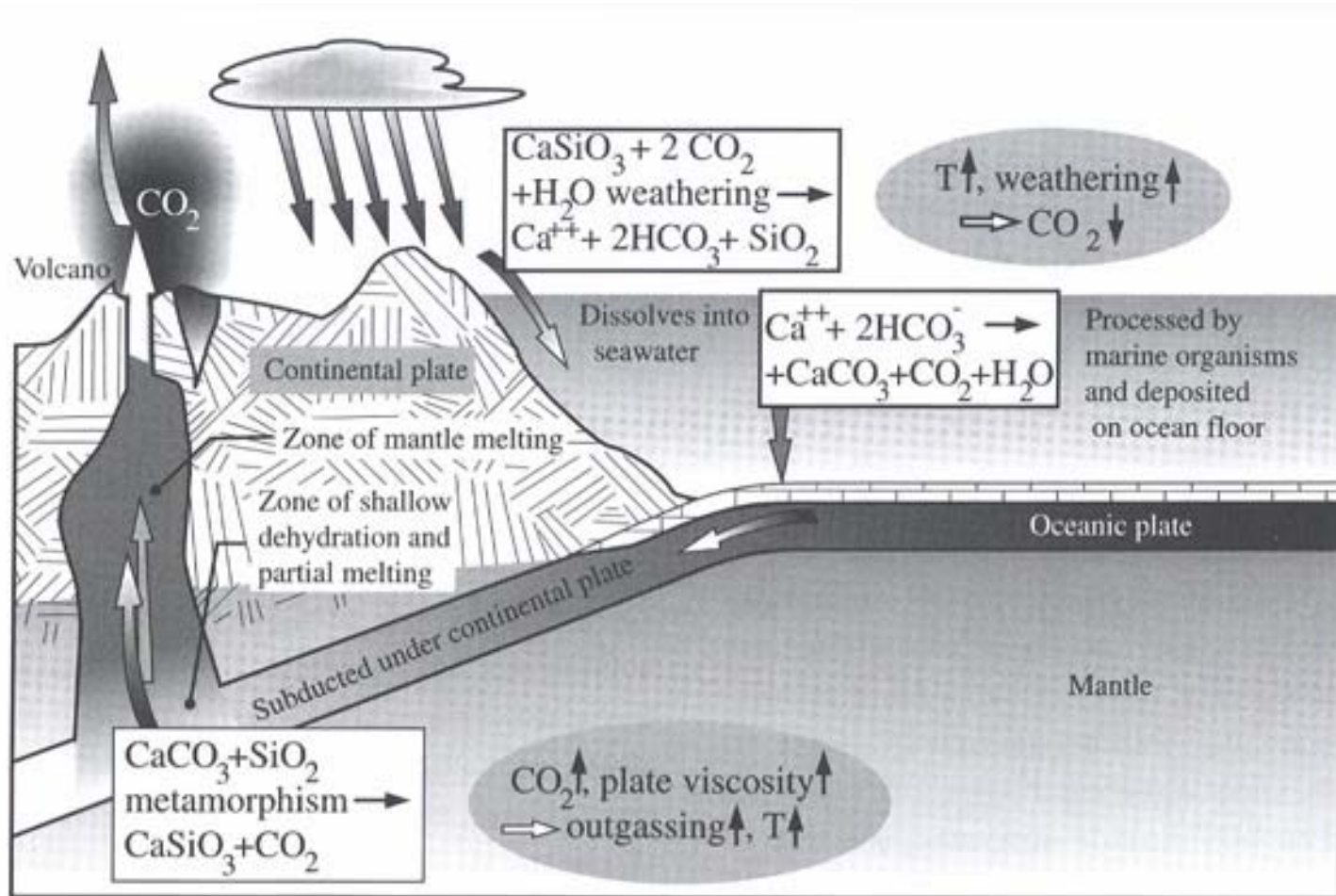
A purely biological oxygen cycle



A largely biological oxygen cycle



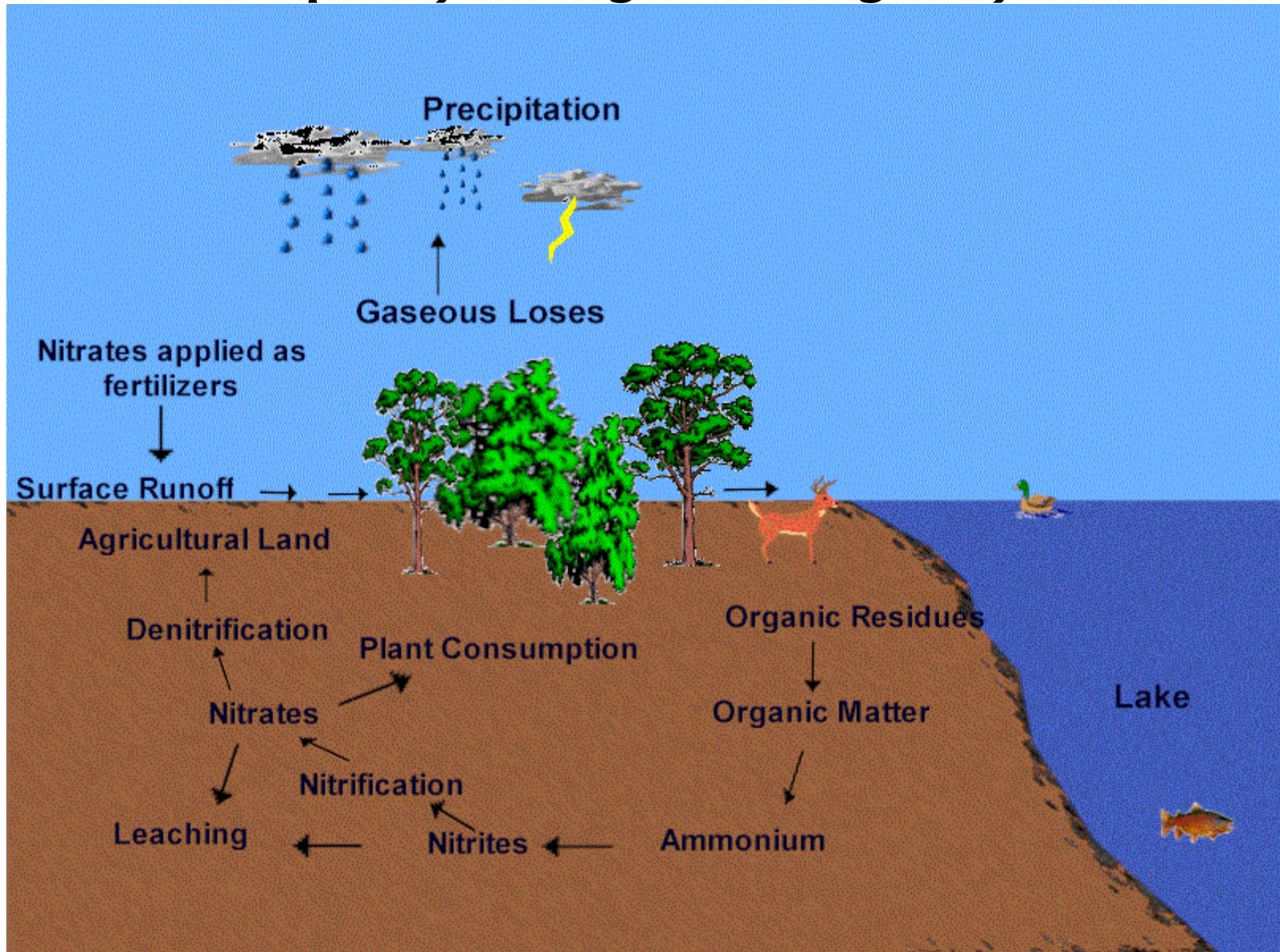
A mostly geological oxygen cycle



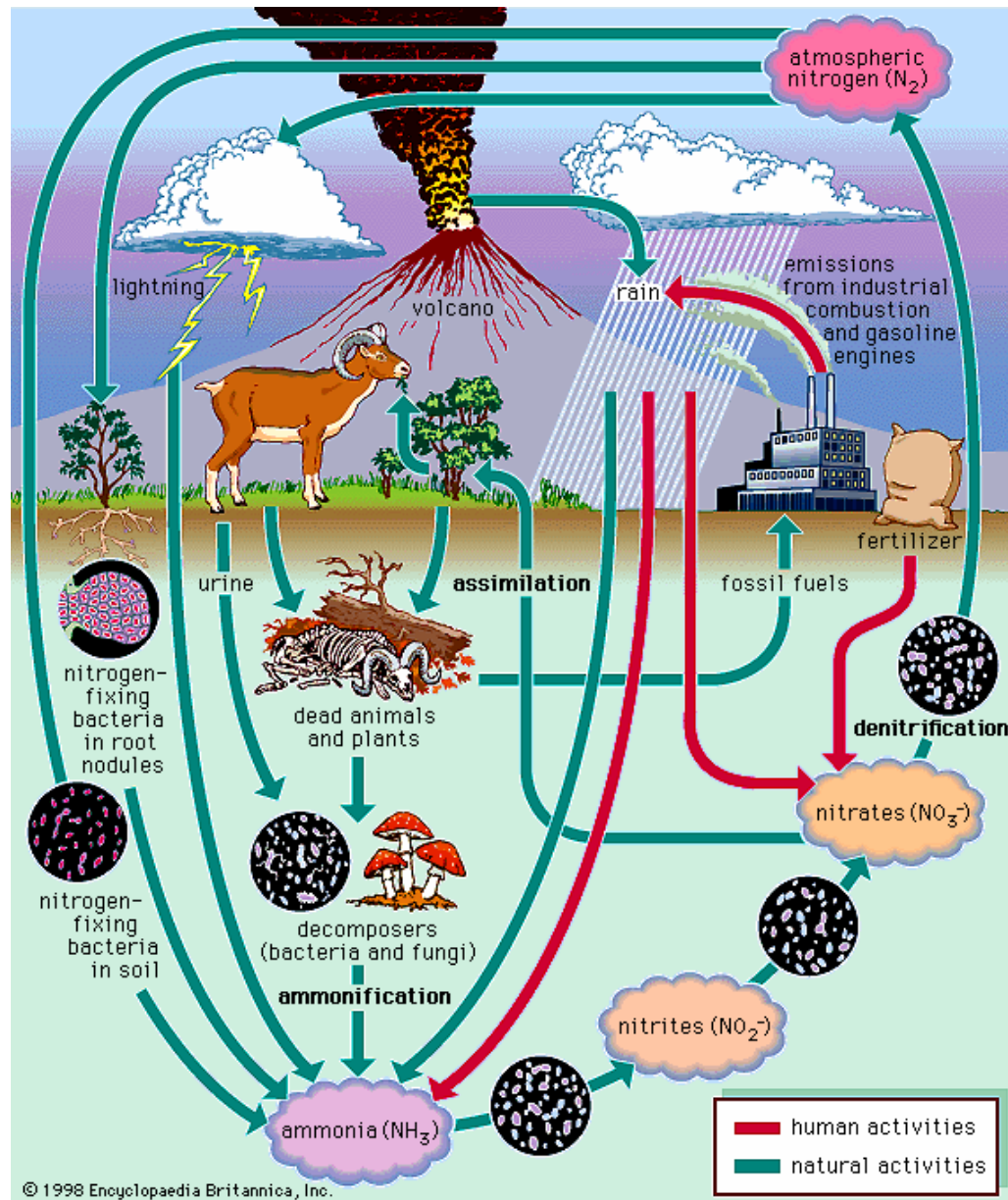
Biogeochemical Cycling

Nitrogen Cycle

A purely biological nitrogen cycle



A bio-geo-chemical nitrogen cycle



Sulfur Cycle

Kilauea Volcanic Gasses

H₂O 67.7%

CO₂ 12.7%

N₂ 7.65%

SO₂ 7.03%

SO₃ 1.86%

S₂ 1.04%

H₂ .75%

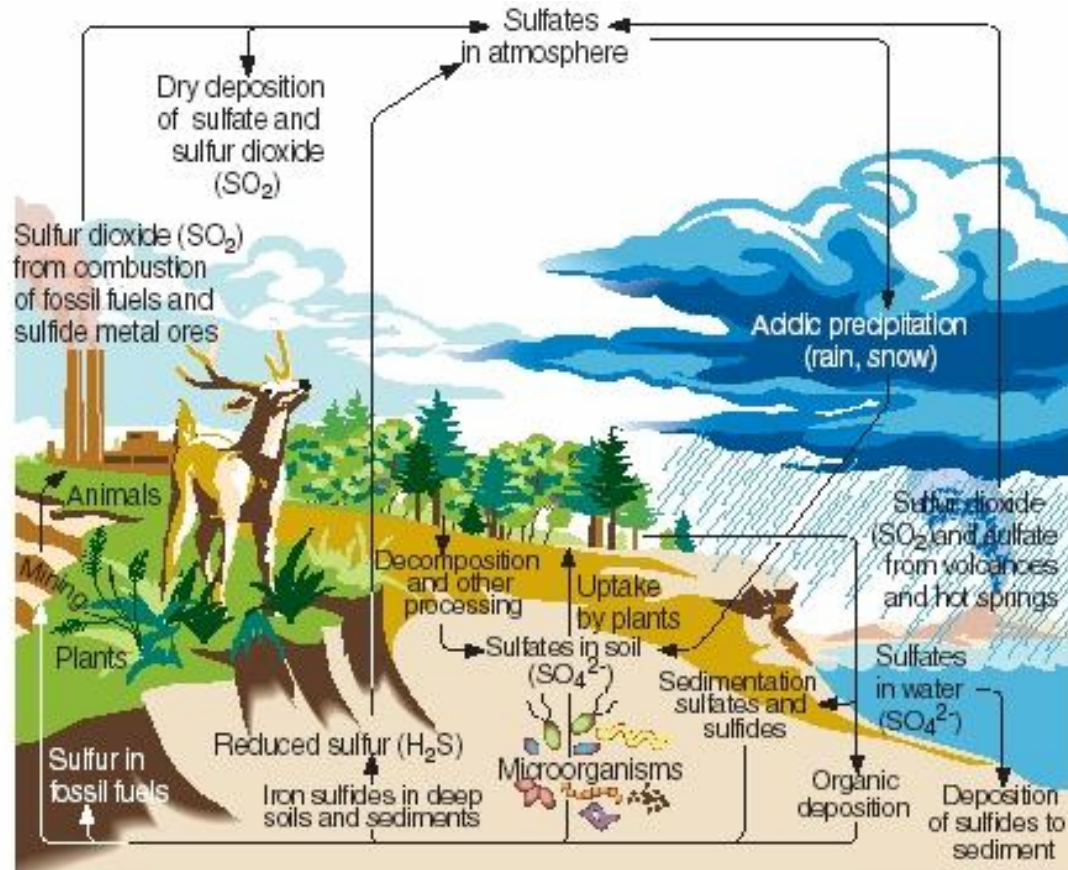
CO .67%

Cl₂ .41%

Ar .20%

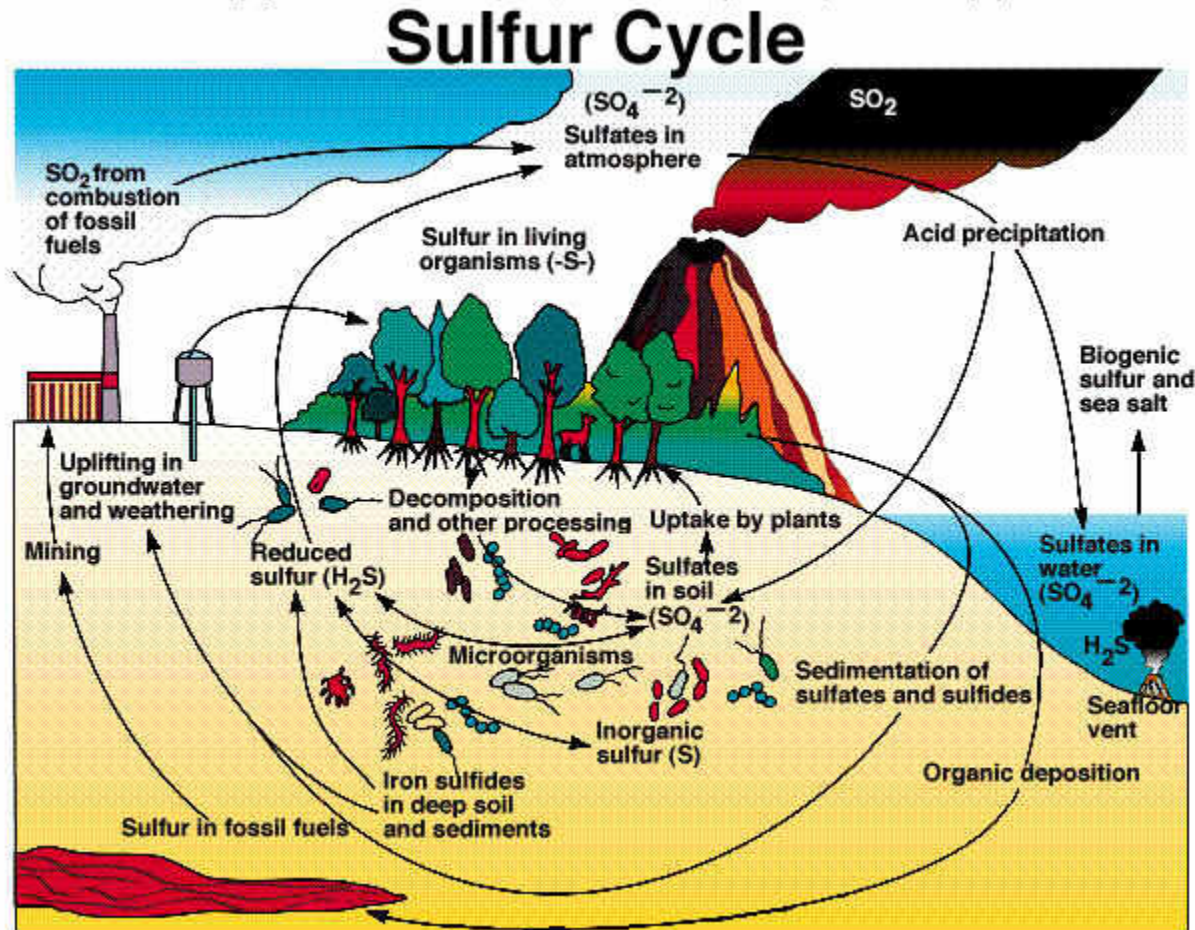


A mostly biological oxygen cycle



A well balanced bio-geo-chemical oxygen cycle

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What Happens on a Planet Without Life is that it closes down, dies, becomes a Dead Planet



Like the dead Norwegian Blue parrot

**What we are talking about here
is how these elements cycle
among the lithosphere,
atmosphere, hydrosphere and
biosphere.**

**That is, we are about the Earth
as a System . . .**