Chapter 4
Biogeochemical Cycles

ENERGY FLOW THROUGH ECOSYSTEMS

Nature's Building Blocks

- Matter
- Energy
- Laws of Nature
- Earth's Major Components

Ecosystems

- Ecology and biodiversity
- Organisms
- Components and structure
- Species interactions
- Biomes
- Change
- Human impacts

- According to the law of matter, emissions from stacks such as these do not simply disappear but end up somewhere else, often with undesirable consequences (i.e. acid deposition, global warming)

Earth's Components: Ecosphere

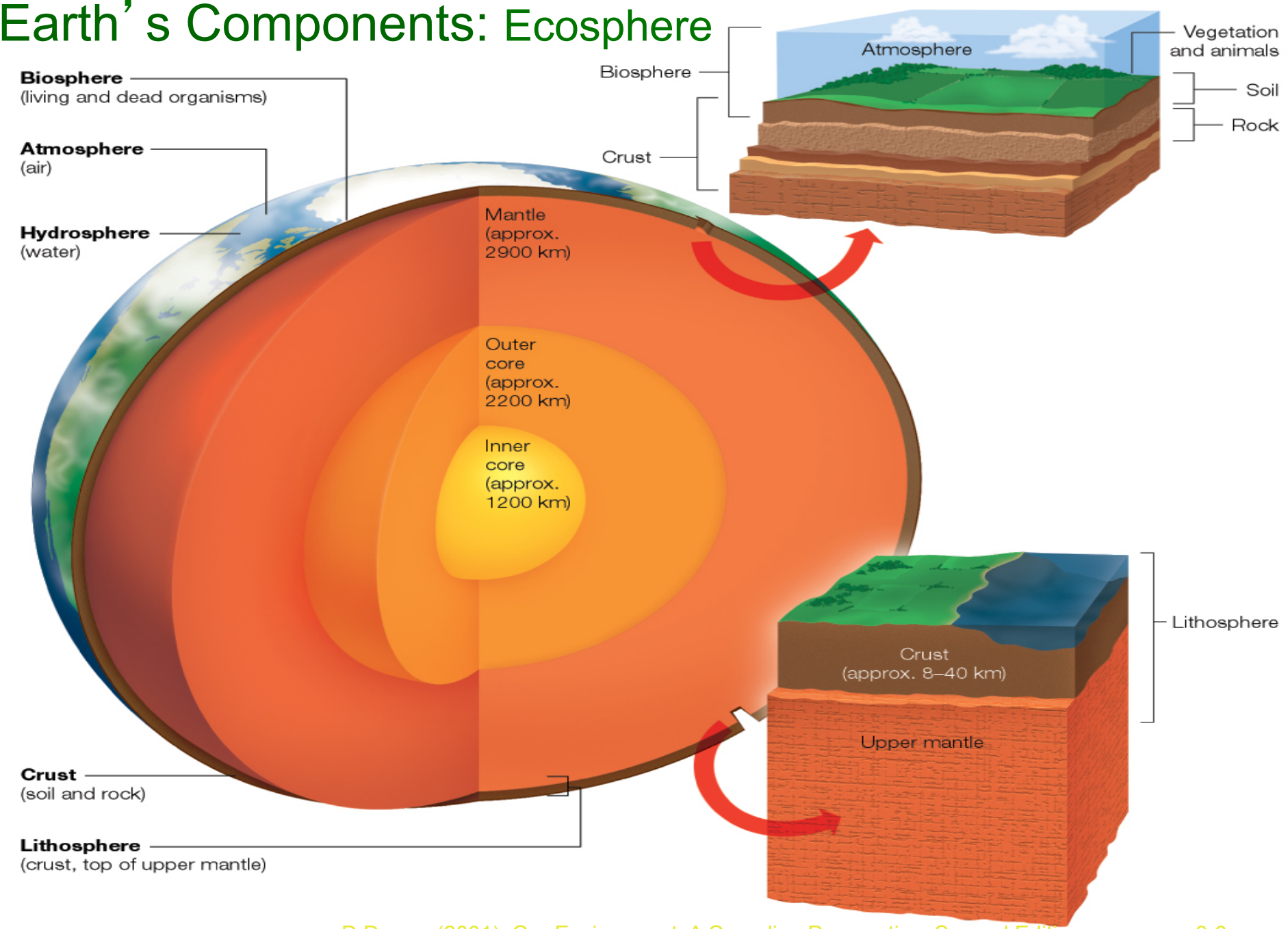


Figure 3–2
The general structure of the Earth

Quality of Energy and Energy Transformations

Energy – the capacity to do work

Low Quality – diffused and dispersed, low temperatures (Oceans)

High Quality–easy to use / energy disperses quickly (hot fire or gasoline)

Kinetic Energy – energy derived from an object's motion or mass

Potential Energy – stored energy that is available for later use

*It is important that we match the quality of the energy supplied to the task at hand

The relevance is for environmental studies and biophysical impacts is that many of the elements that circulate in biogeochemical cycles are required for life

Macro-Nutrient Scale

- Carbon - slow circulation in Trees, fast in Atmosphere
- Nitrogen – most plants/animals cannot use from atmosphere
- Phosphorous – Does not exist in a gaseous state
- Oxygen – Intimately linked with the carbon cycle
    - Hydrogen and sulphur

Law of Entropy – when energy is transformed from one form into another, there is always a decrease in the quality of useable energy

- Energy cannot be recycled, it flows through systems in a constantly degrading manner

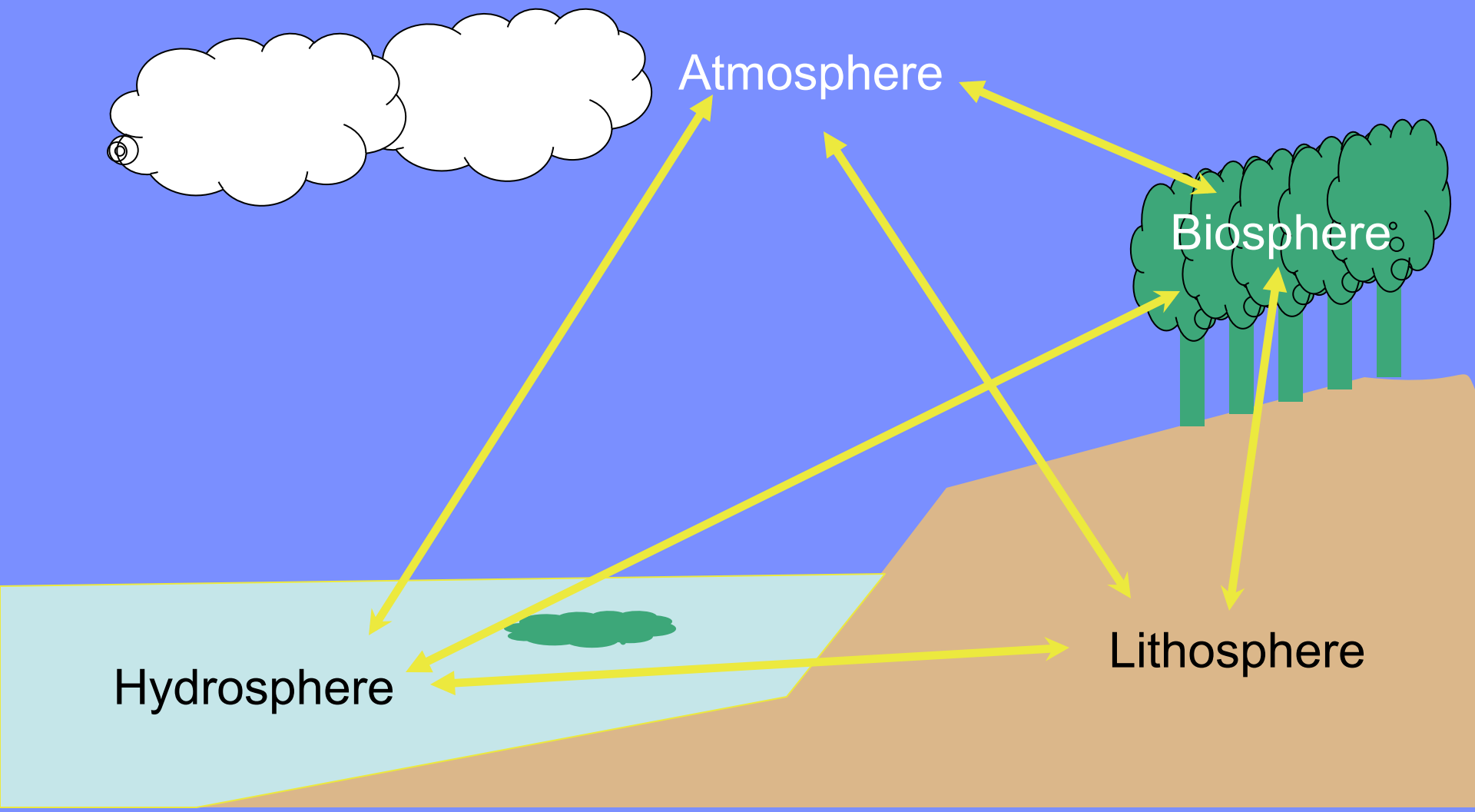
- The more energy that is transformed, the more it is dispersed into the atmosphere as entropy increases

- **Coal Fired Generating Facility converts 35% of coal's energy into electricity**
- **Only 10% of chemical energy in gas is converted into mechanical energy**

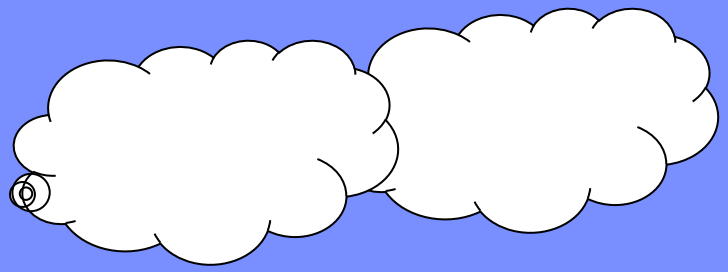
‘In geological terms we have released the energy input of millions of years in the blink of an eye – the last 250 years. Many problems are a result of this increase in entropy.

- Dearden and Mitchell

Biogeochemical Cycles: Reservoirs & Pathways



Carbon Cycle



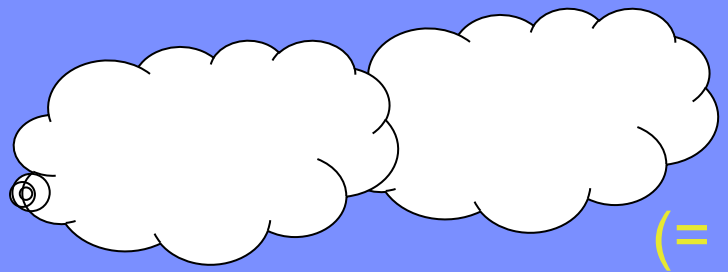
Atmosphere

Biosphere

Hydrosphere

Lithosphere

Carbon Cycle: Reservoirs



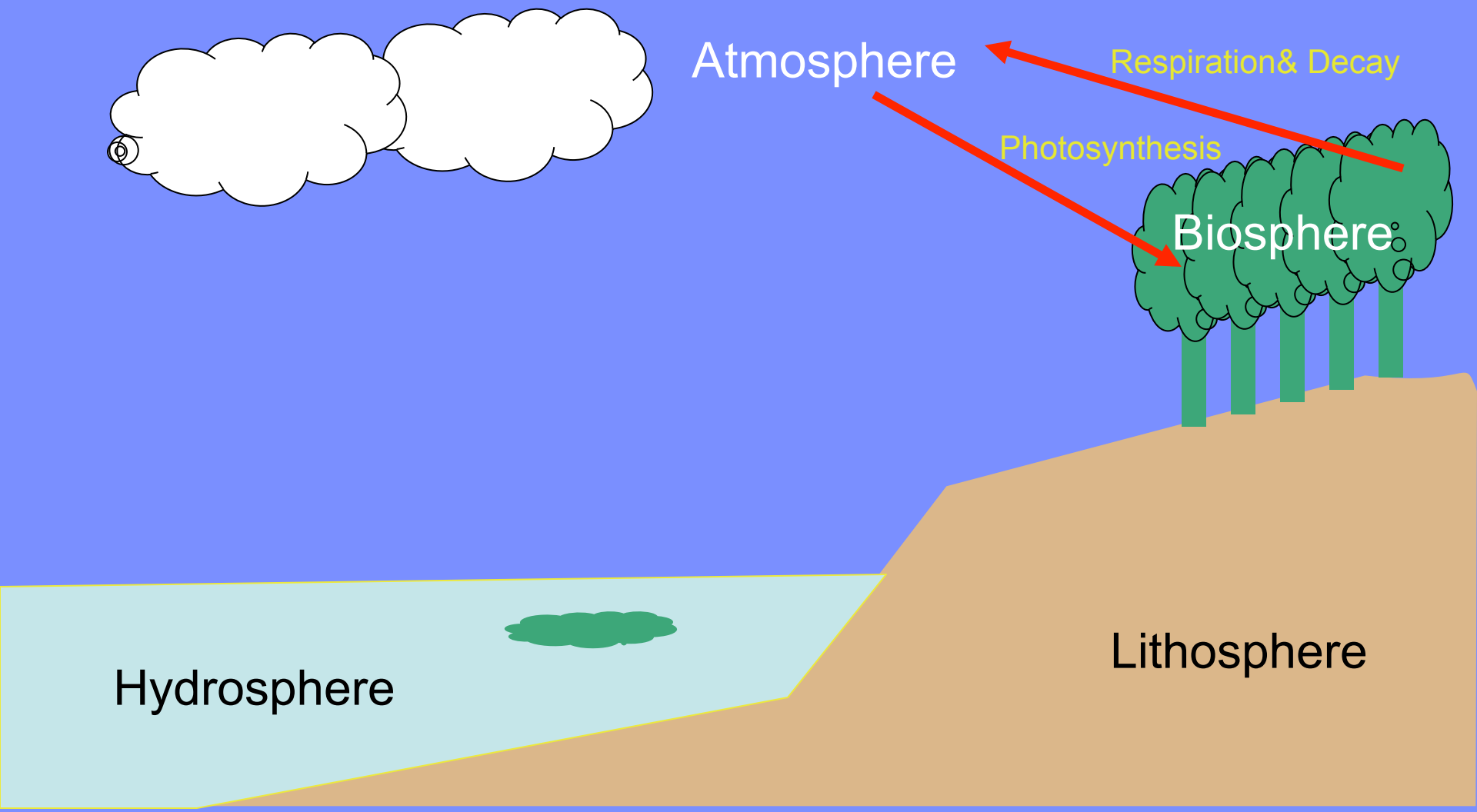
Atmosphere
1x
(= 7.3×10^{17} grams carbon)

Biosphere
3x

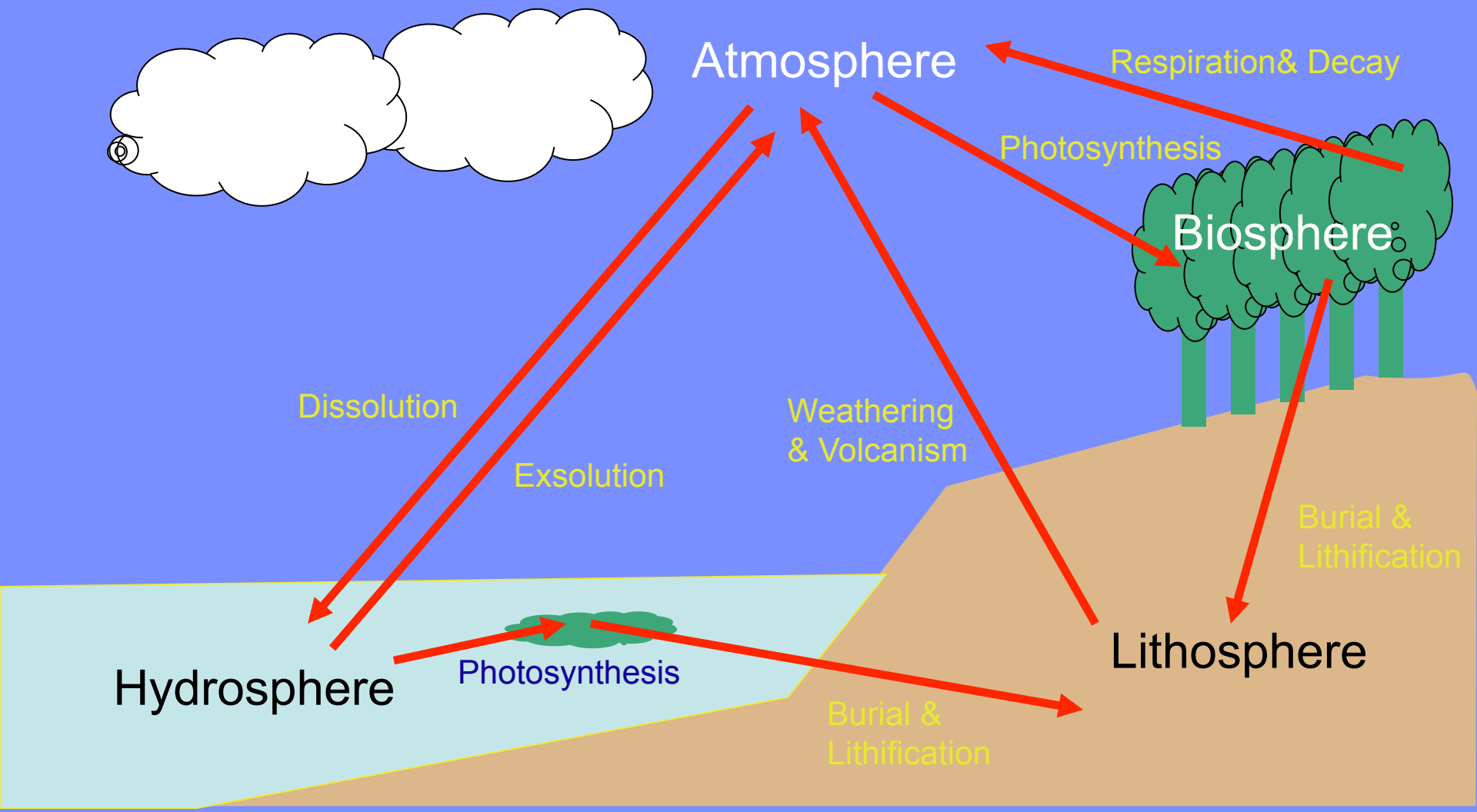
55x
Hydrosphere

35,000x
Lithosphere

Carbon Cycle



Carbon Cycle



Human Impacts

Carbon Cycle

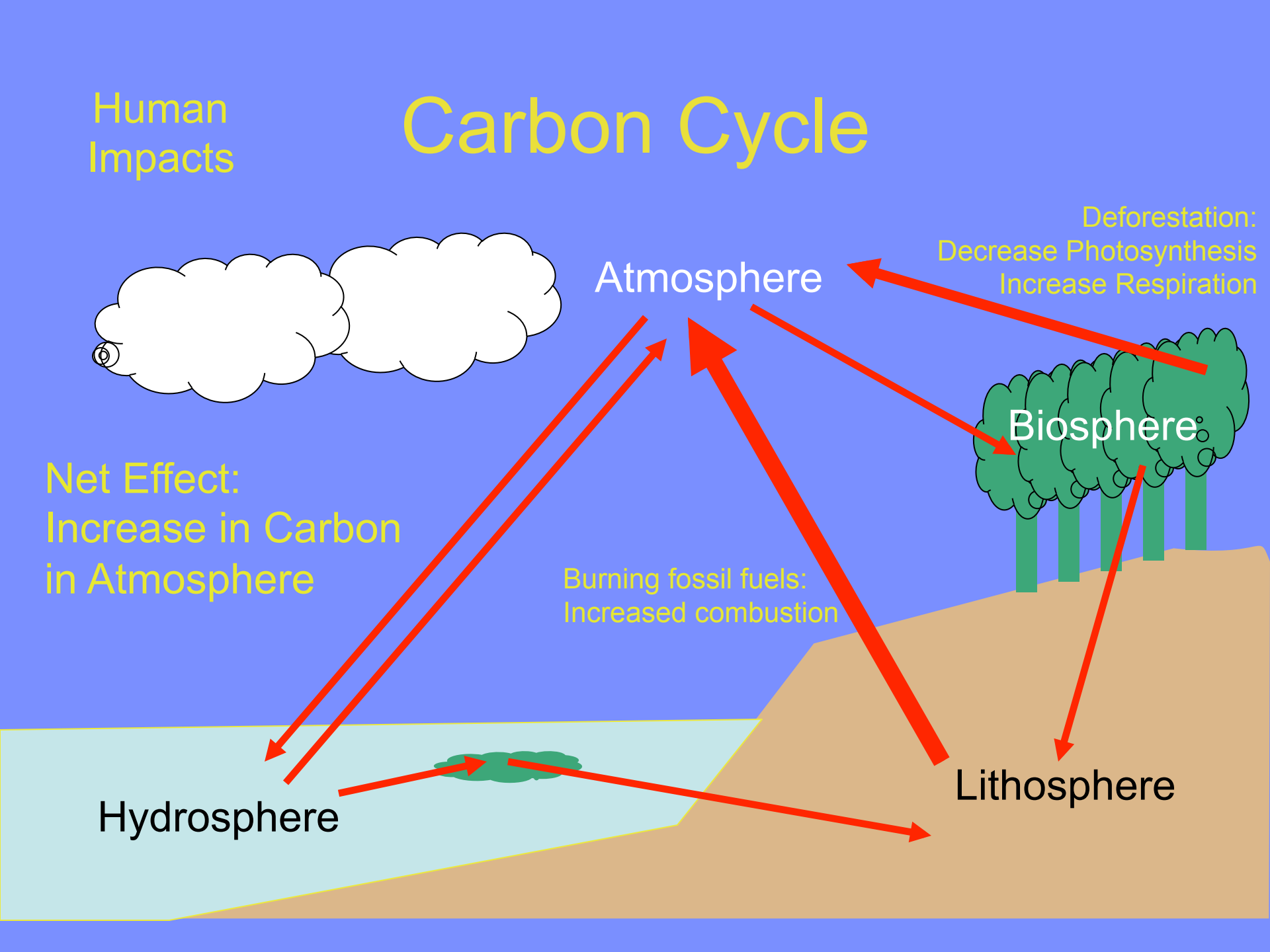
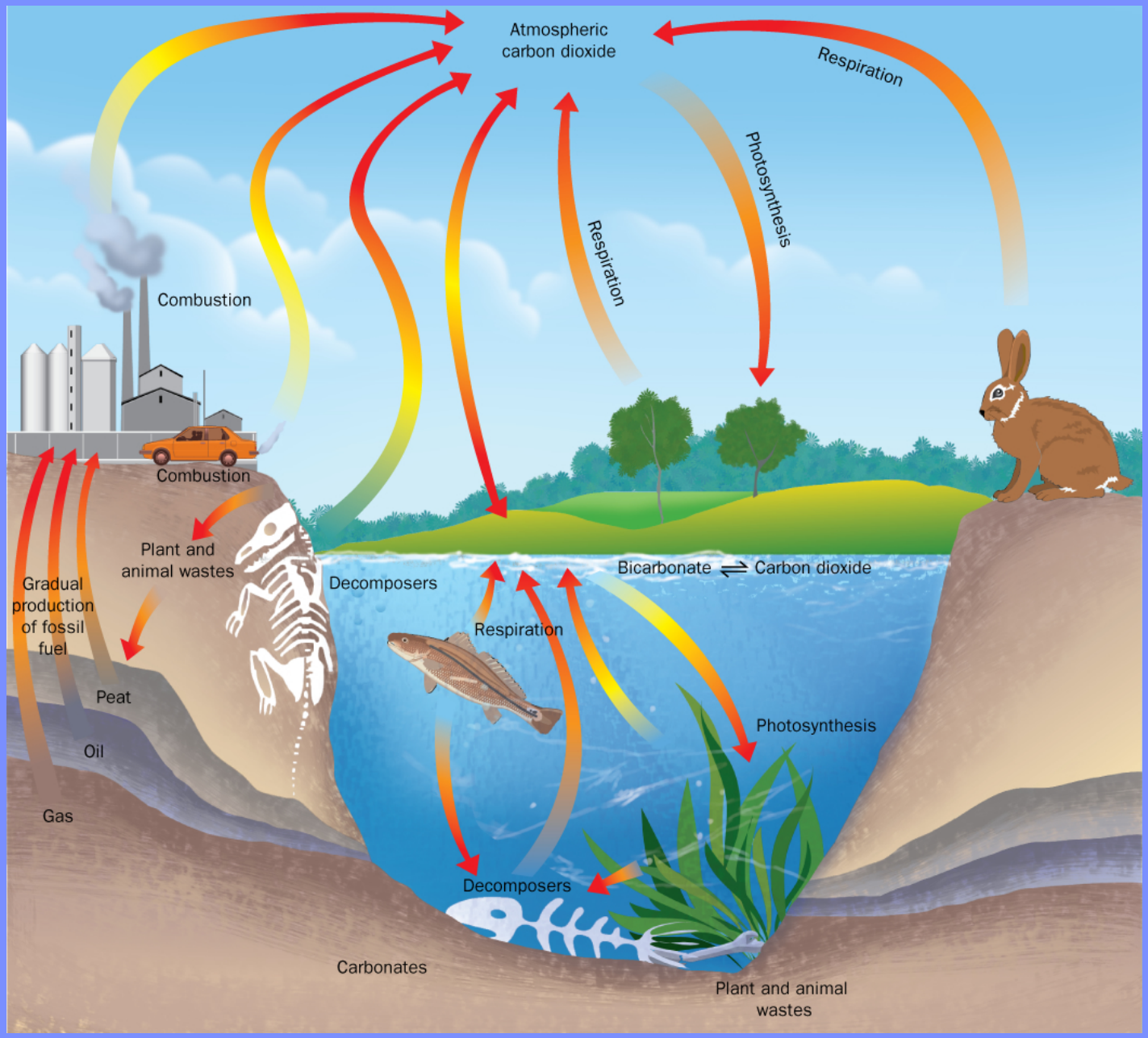
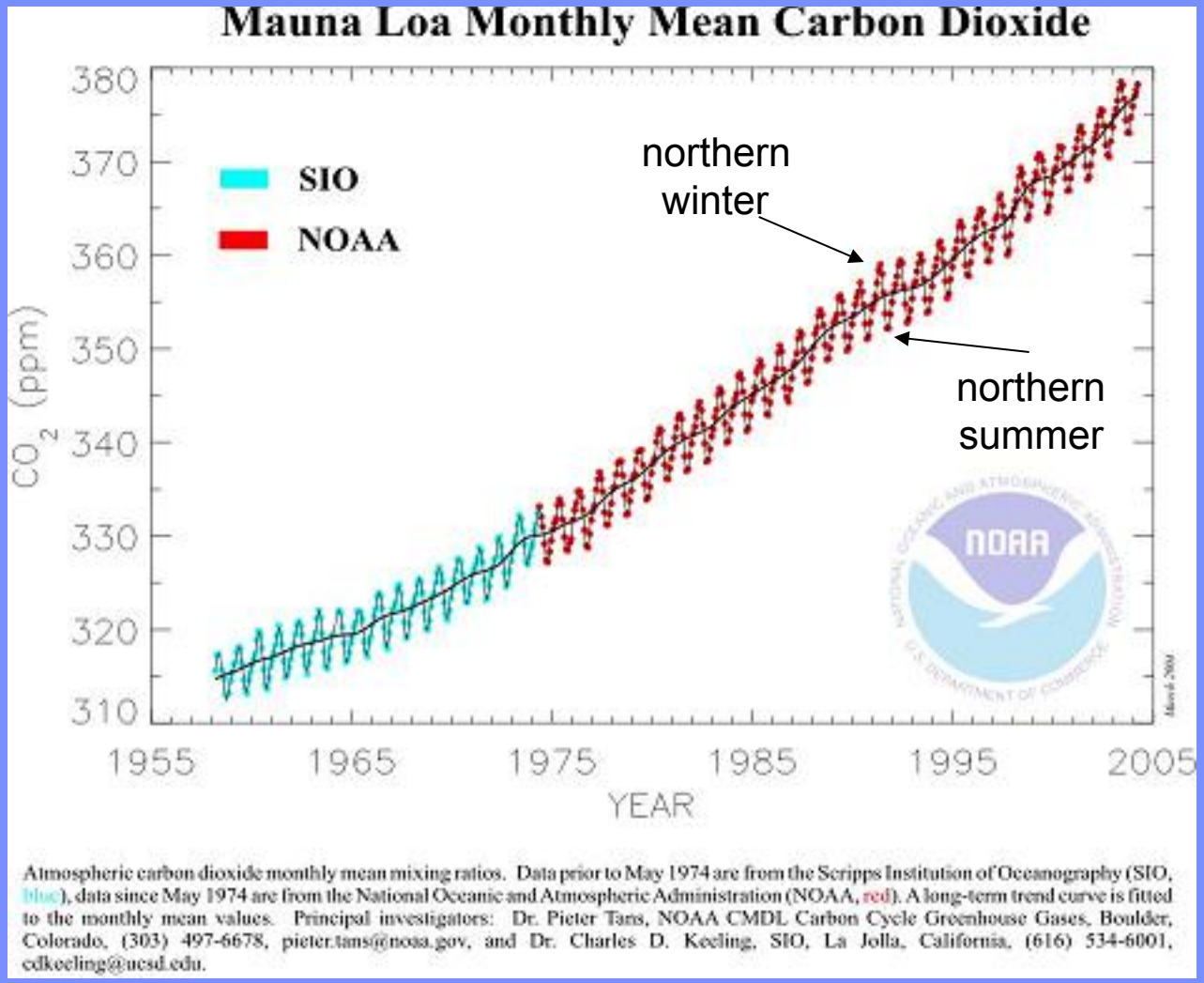


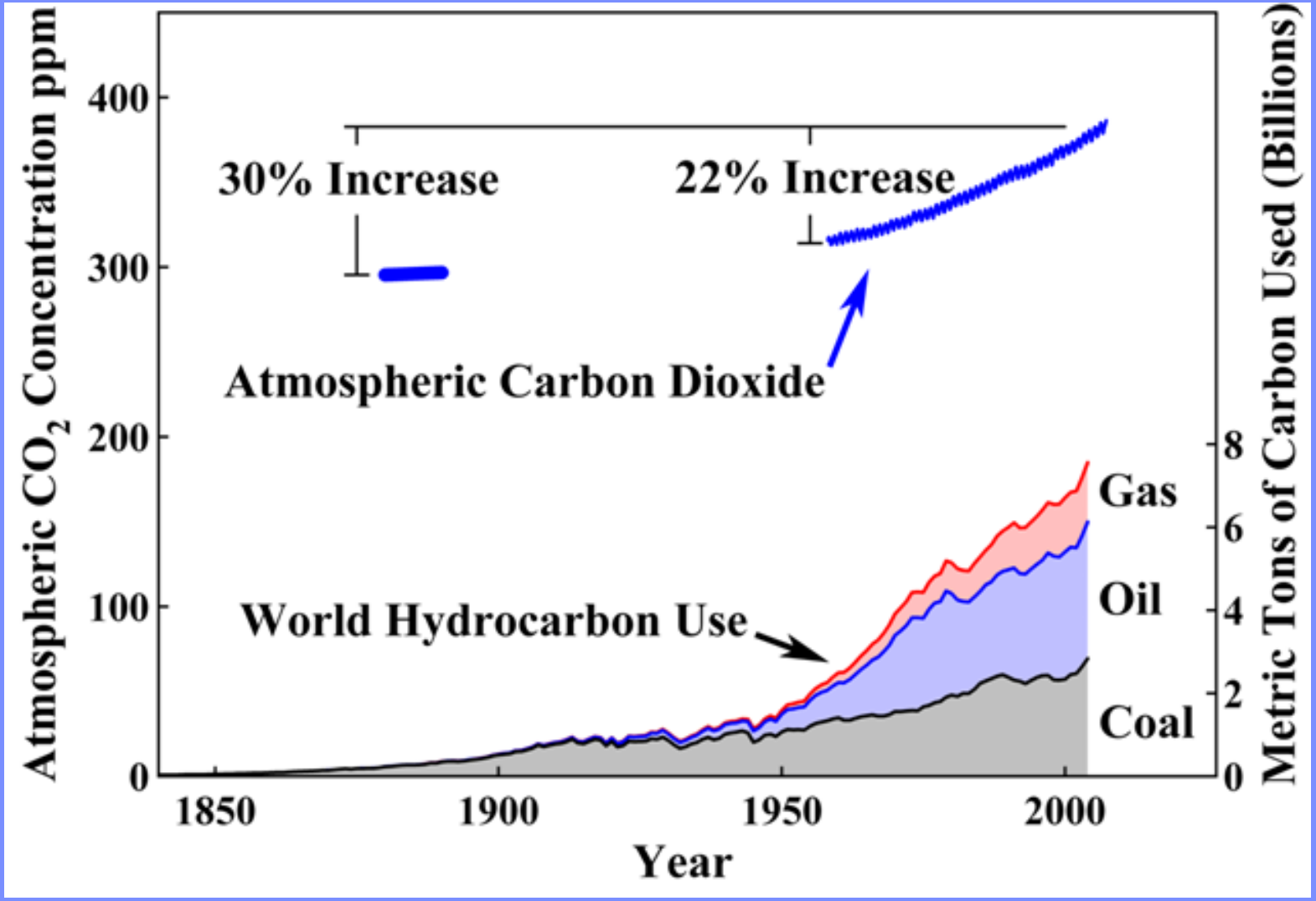
Figure 4.7 - The Carbon Cycle



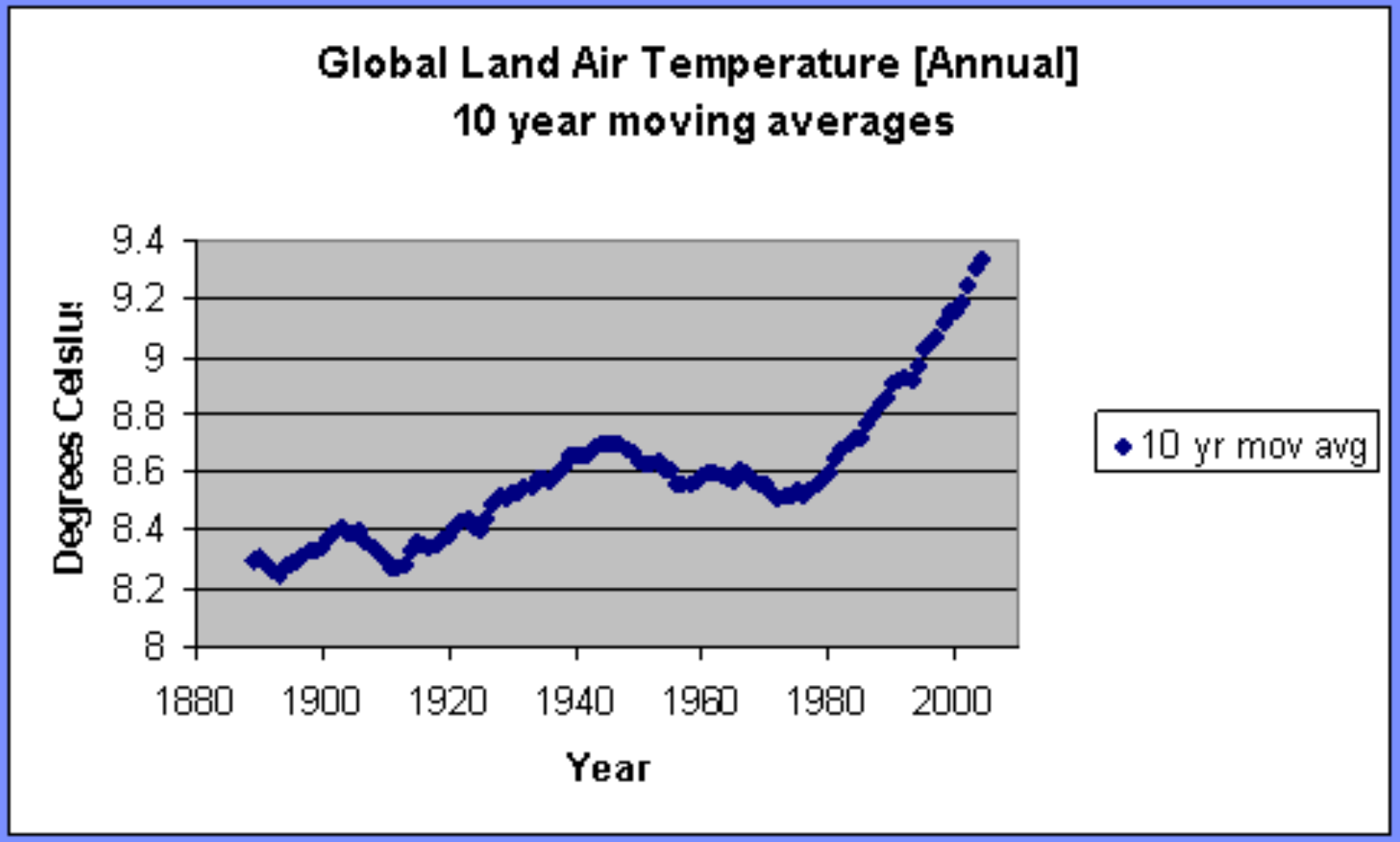
Atmospheric Carbon Dioxide



Atmospheric carbon dioxide monthly mean mixing ratios. Data prior to May 1974 are from the Scripps Institution of Oceanography (SIO, blue), data since May 1974 are from the National Oceanic and Atmospheric Administration (NOAA, red). A long-term trend curve is fitted to the monthly mean values. Principal investigators: Dr. Pieter Tans, NOAA CMDL Carbon Cycle Greenhouse Gases, Boulder, Colorado, (303) 497-6678, pieter.tans@noaa.gov, and Dr. Charles D. Keeling, SIO, La Jolla, California, (616) 534-6001, cdkeeling@ucsd.edu.


Atmospheric CO_2 Concentration ppm
400
300
200
100
0
30% Increase
22% Increase
Atmospheric Carbon Dioxide
World Hydrocarbon Use
Gas
Oil
Coal
8
6
4
2
0
Metric Tons of Carbon Used (Billions)
1850
1900
1950
2000
Year

Impact


Global Land Air Temperature [Annual]
10 year moving averages
Degrees Celsius
9.4
9.2
9
8.8
8.6
8.4
8.2
8
1880
1900
1920
1940
1960
1980
2000
Year
10 yr mov avg

Calgary team shows how to scrub CO2 from the air

Last Updated: Tuesday, September 30, 2008 | 5:58 PM ET Comments 103 Recommend 108
By Sharon Oosthoek CBC News

University of Calgary climate change scientist David Keith with his CO2 scrubber. (University of Calgary)

University of Calgary climate change researchers say they are close to figuring out how to commercialize the capture of carbon dioxide directly from the air with a simple system that could be set up anywhere in the world.

If they can make it work, it would allow greenhouse gas to be removed from ambient air and reduce the effect of emissions from transportation sources such as cars and airplanes.

"That's the excitement about it. It's a tool for dealing with diffuse CO2 emissions from transportation that account for roughly half of emissions," physicist and climate change scientist David Keith said Tuesday in a phone interview from his Calgary office.

That's important given how conventional systems for capturing CO2 work. Most involve installing "scrubbing" equipment at, for example, a coal-fired power plant to capture carbon dioxide produced during the burning of coal. But a system that can take CO2 out of ambient air is attractive because cars and airplanes aren't equipped with such scrubbers.

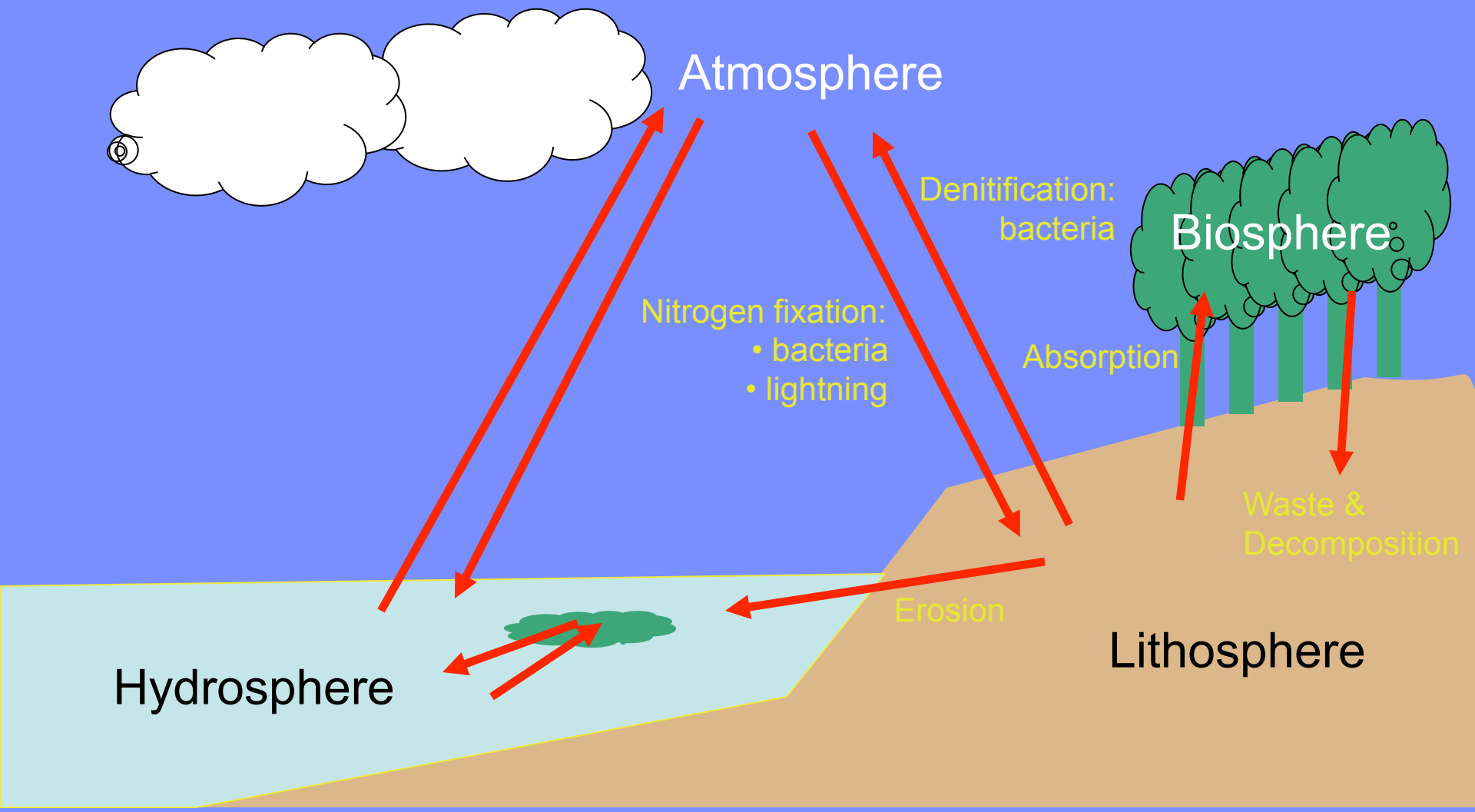
Some Major Cycles of Matter

- Water Cycle
- Rock Cycle
- Chemical Cycles
  - Carbon
  - Nitrogen
  - Phosphorous
  - Sulfur

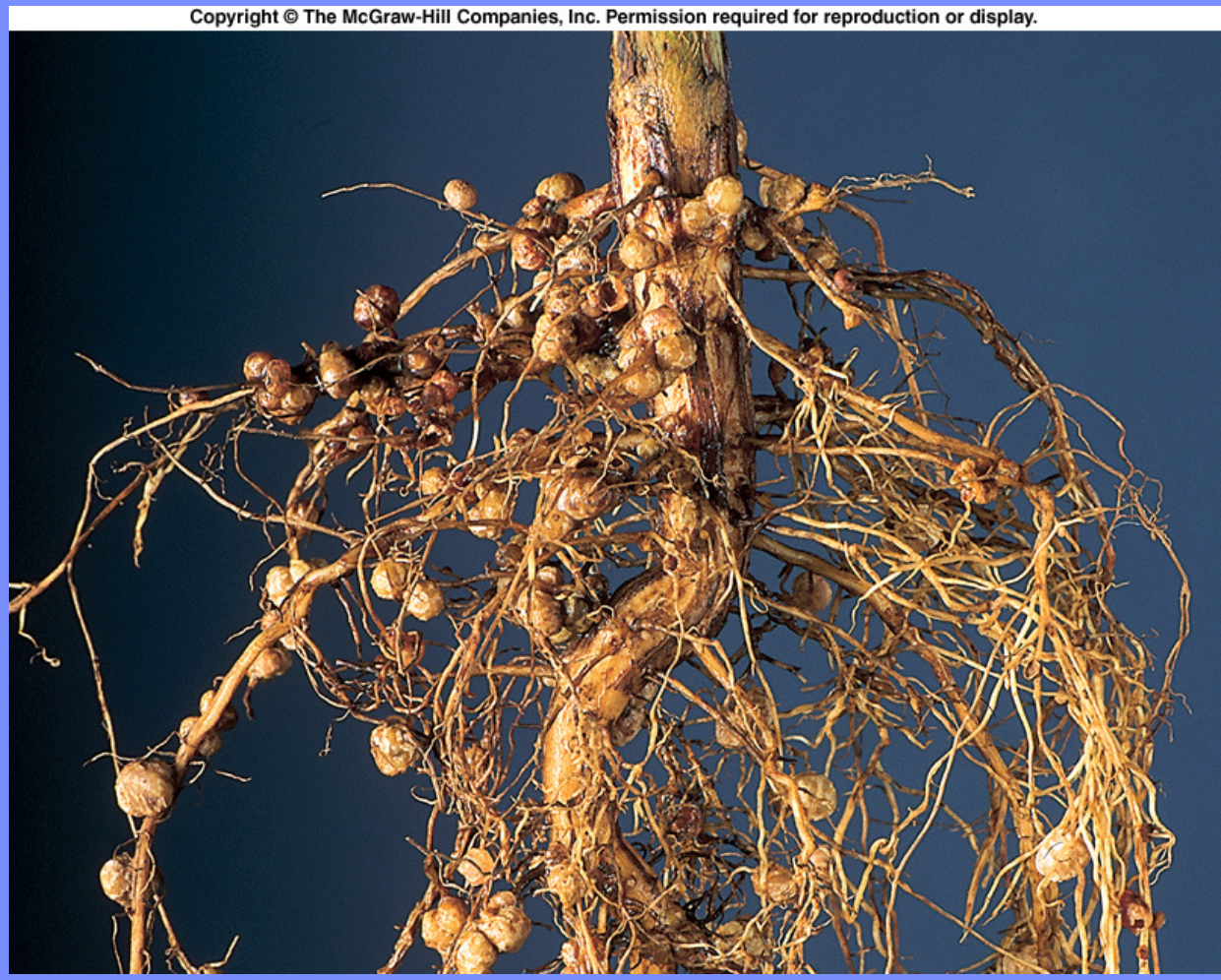
Nitrogen Cycle

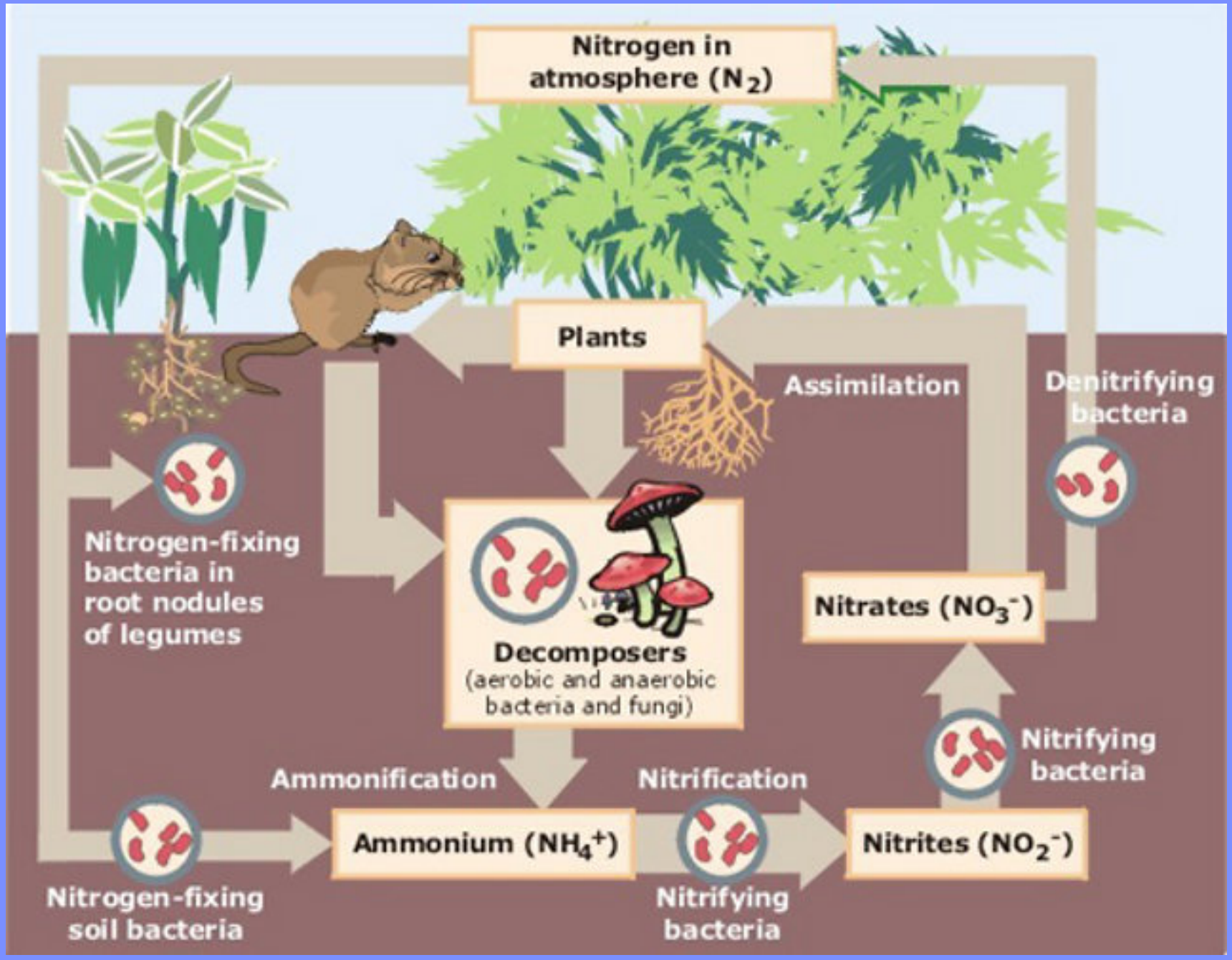
- Represents one of the most important nutrient cycles found in terrestrial ecosystems
- Used by living organisms to produce a number of complex organic molecules (amino acids, proteins)
- As a gas (N_2) the store of nitrogen in the atmosphere plays an important role for life (about 1 million x larger than in living organisms)
- Also exists in organic matter in soil and oceans

Nitrogen Cycle



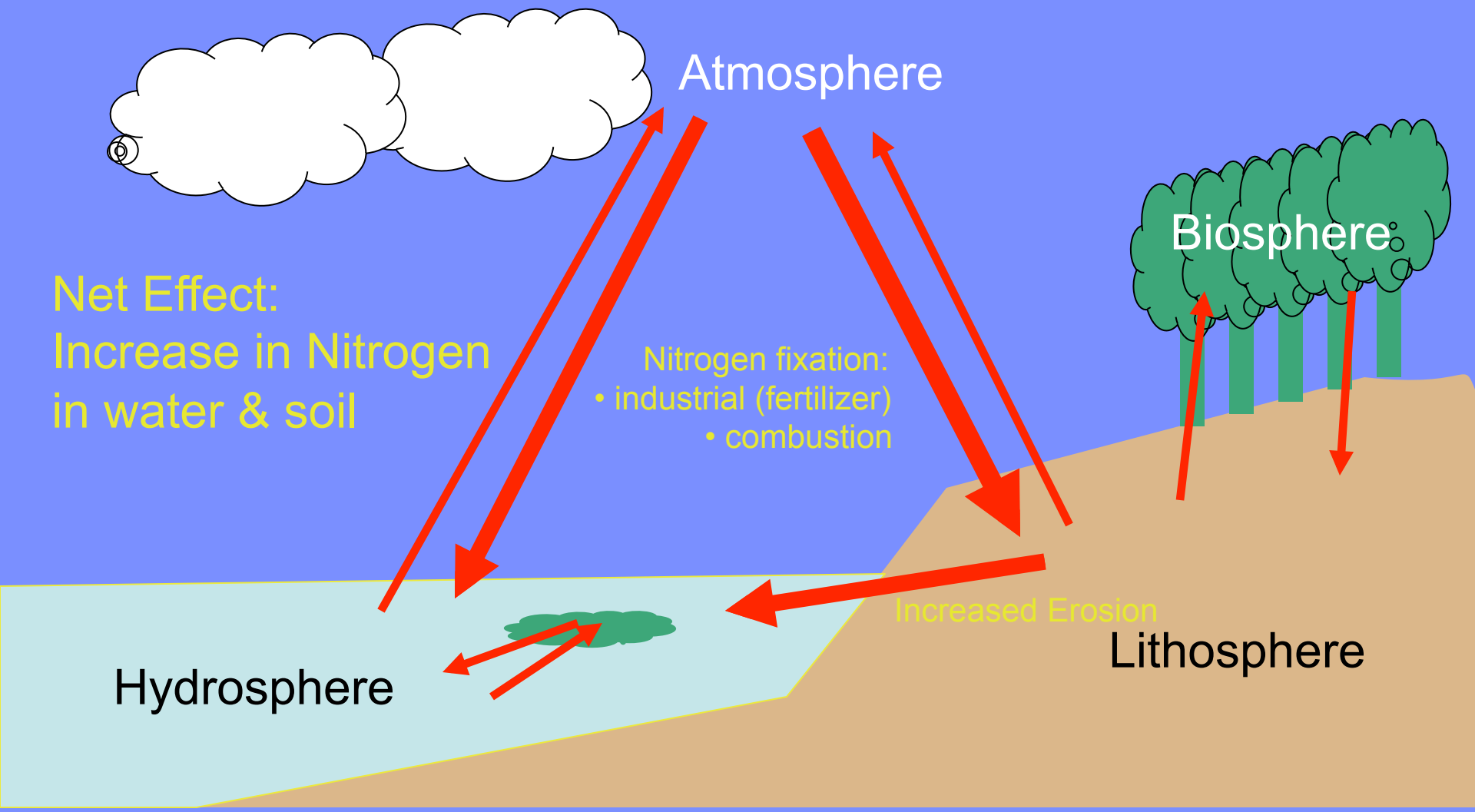
Nitrogen-Fixing Bacteria in Root Nodules




Nitrogen in atmosphere (N_2)
Plants
Assimilation
Denitrifying bacteria
Nitrogen-fixing bacteria in root nodules of legumes
Decomposers
(aerobic and anaerobic bacteria and fungi)
Nitrates (NO_3^-)
Nitrifying bacteria
Ammonification
Nitrification
Ammonium (NH_4^+)
Nitrites (NO_2^-)
Nitrogen-fixing soil bacteria
Nitrifying bacteria

Human Impacts

Nitrogen Cycle



Conclusions

Agricultural and industrial nitrogen (N) inputs to the environment currently exceed inputs from natural N fixation (Galloway 2003).

As a consequence of anthropogenic inputs, the global nitrogen cycle has been significantly altered over the past century.

Global atmospheric nitrous oxide (N_2O) concentrations have increased from a pre-industrial value of ~270 ppb to ~319 ppb in 2005 (Alley et al. 2007).

Some Major Cycles of Matter

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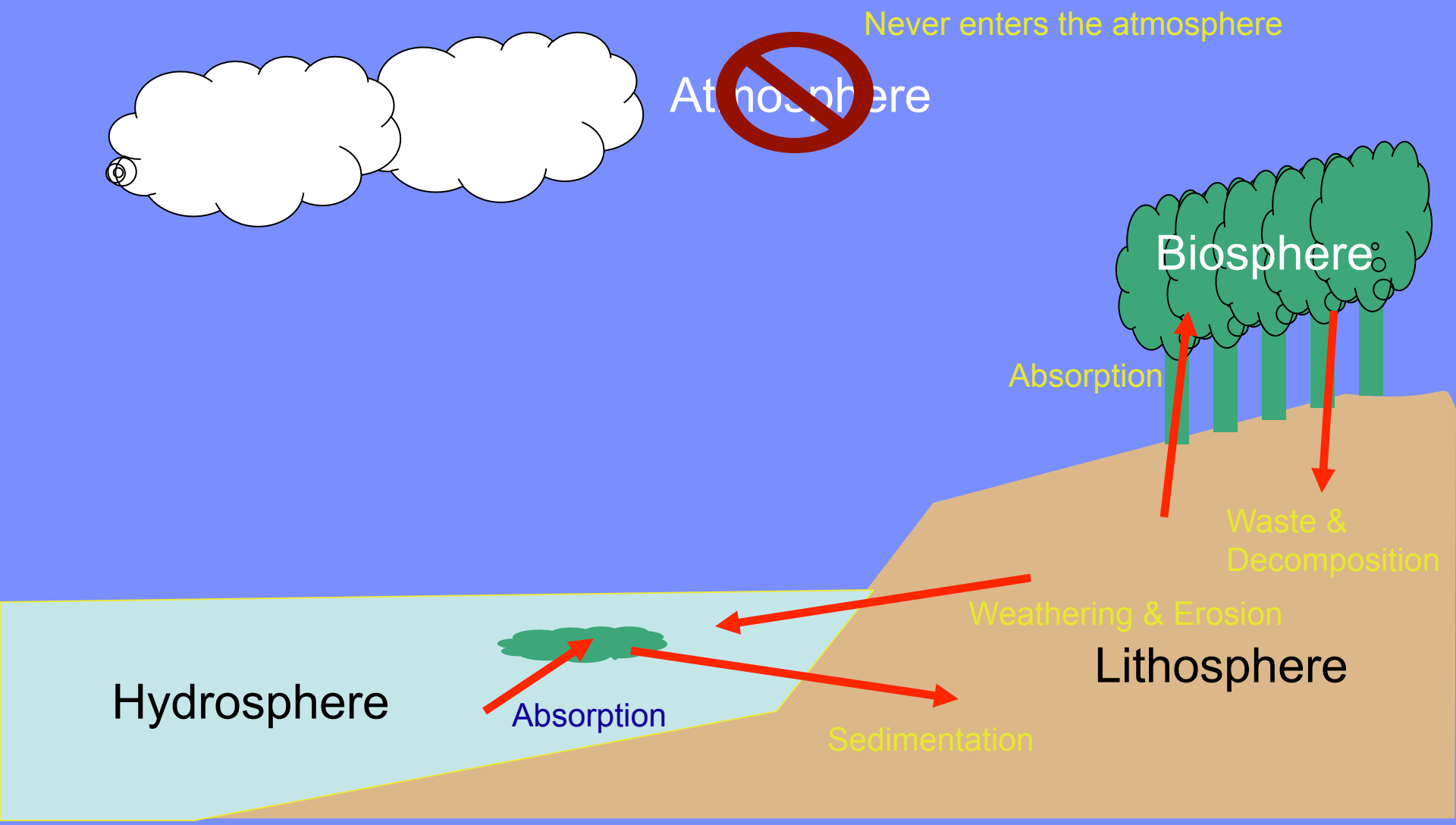
Phosphorous Cycle

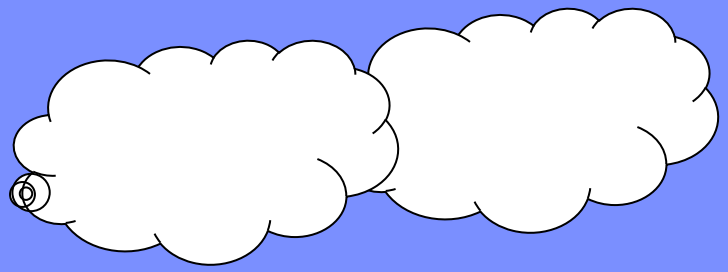


Guano Mining

Aerial view of the archipelago. Photo: Yann Arthus Bertrand

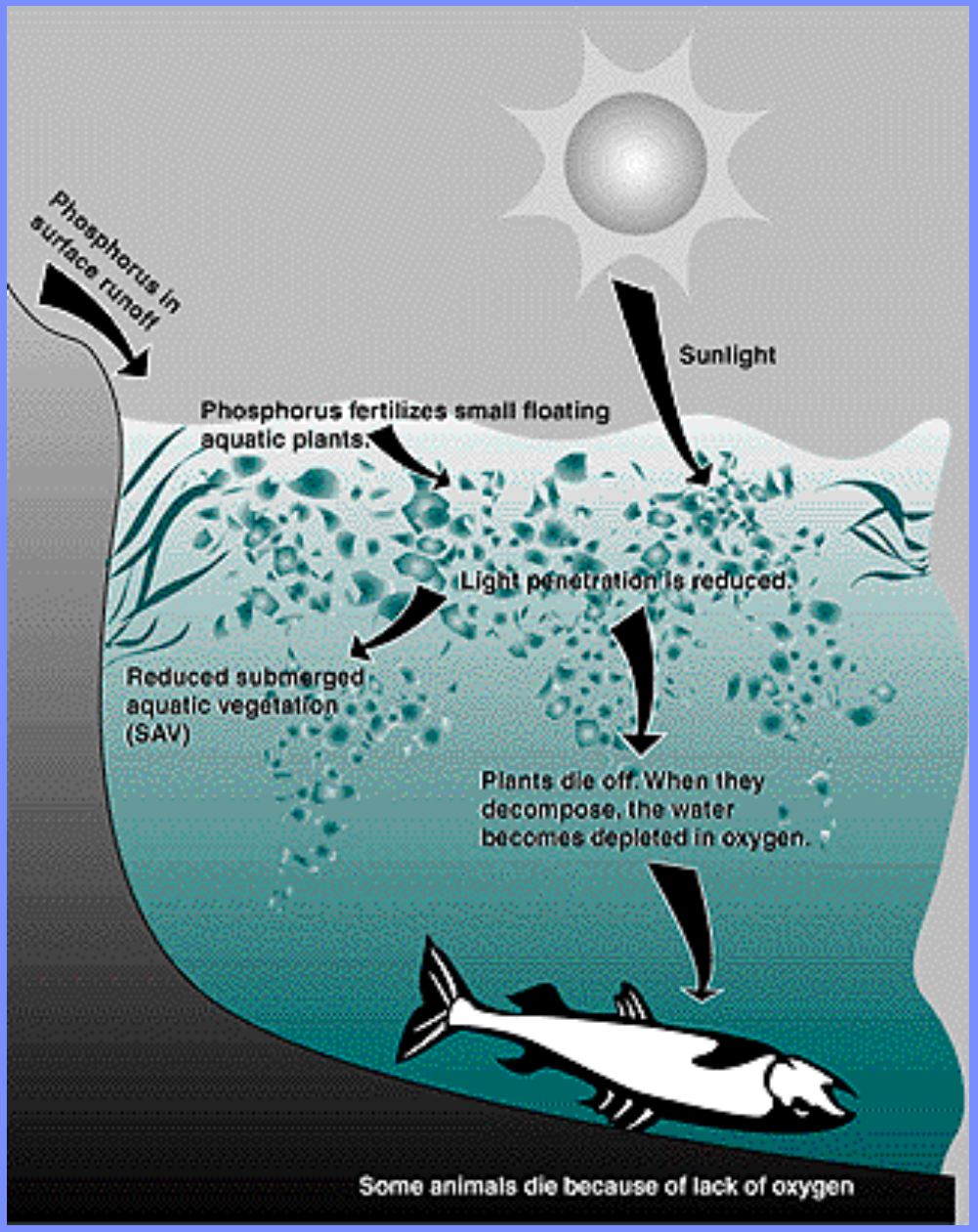
Human Impacts

Phosphorous Cycle



Net Effect:
Increase in phosphorous in water & "algal blooms"; Depletion in soils

Impact: Eutrophication



Impact: Red Tide

Eutrophication

Eutrophication results from the disruption in the phosphorous cycle

- process of damaging a lake ecosystem through excessive input of nutrients such as phosphorous

Among the Great Lakes, Lake Erie once suffered from major eutrophication

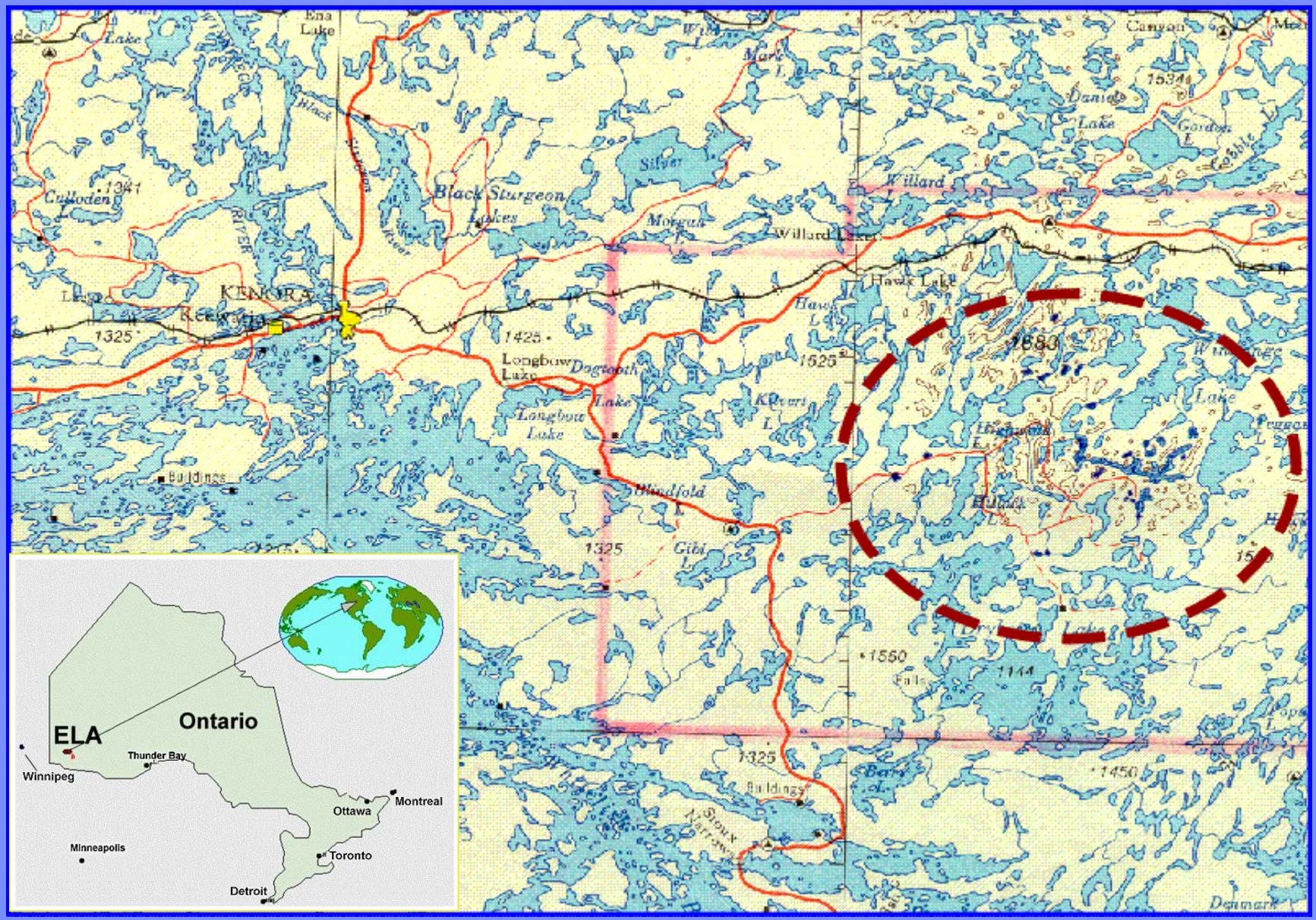
-1972 Great Lakes Water Quality agreement between Canada/ US

-controlling discharges of phosphorous in the lake

Lake superior has the least eutrophication problems (large, deep and relatively lower levels of industrialisation)

Lake of Fire!!

ELA Location

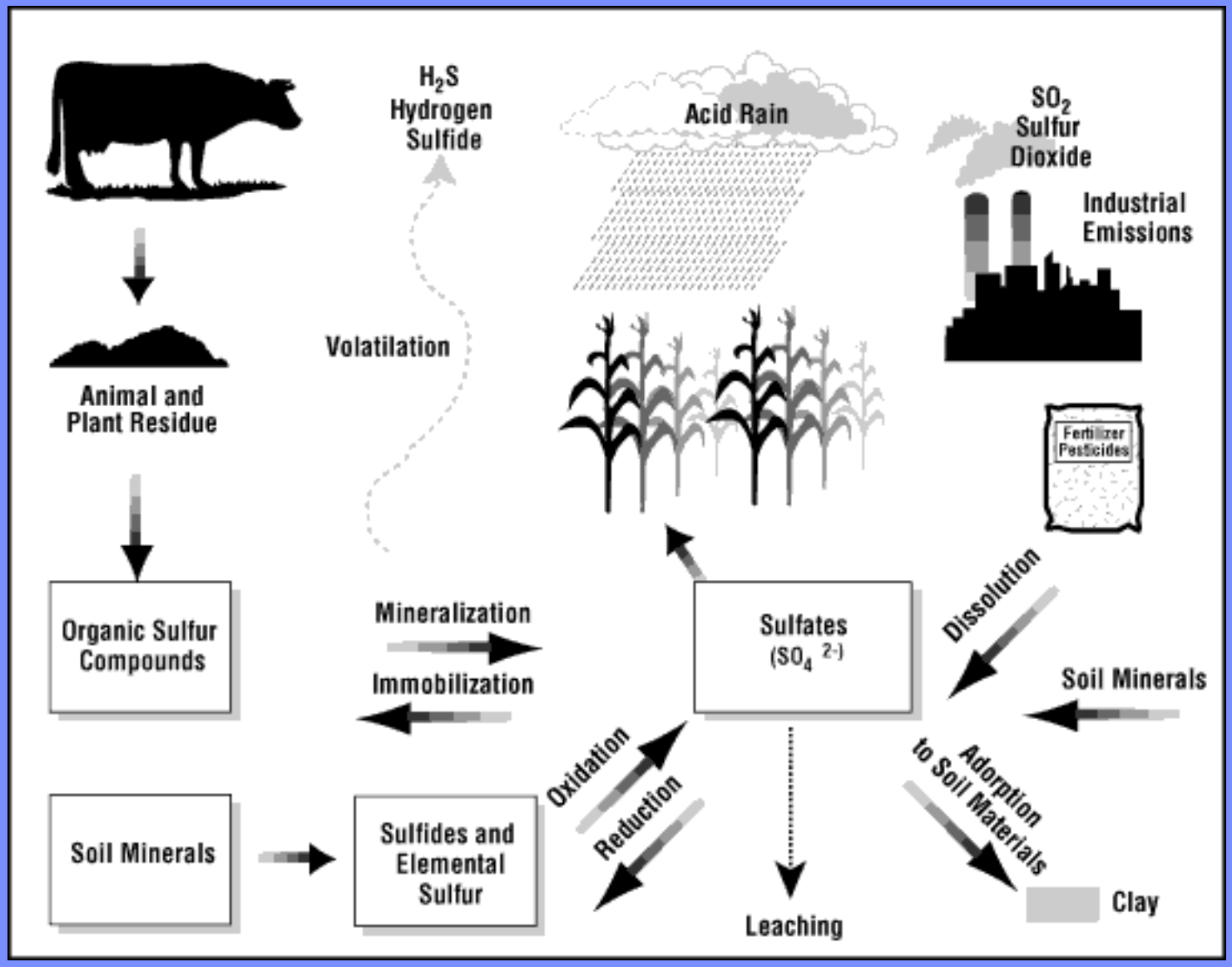


Lake 227 (1975) – Initial Loading

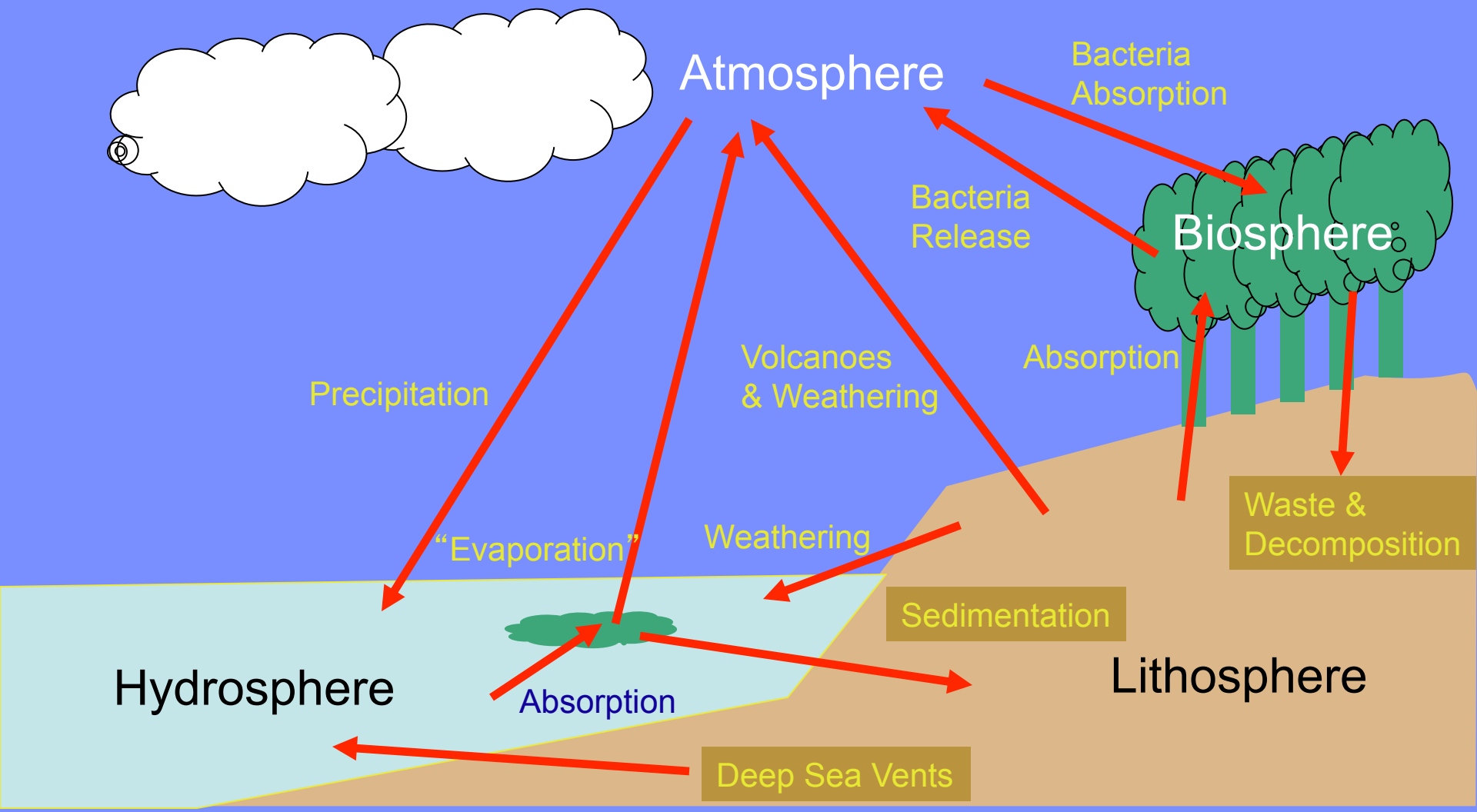
Lake 227 - Today

Lake 226

Sulfur Cycle

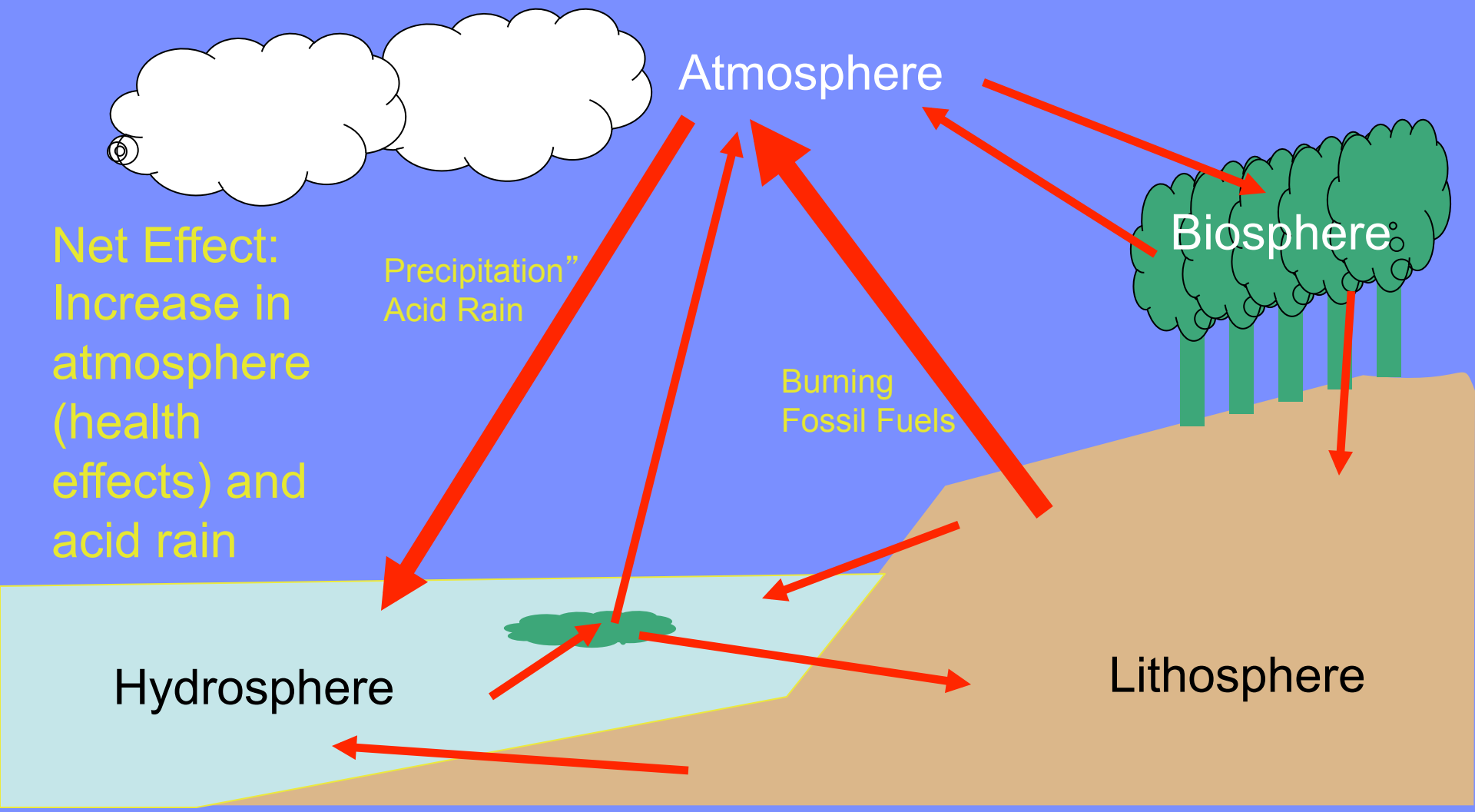


Sulfur Cycle



Human Impacts

Sulfur Cycle



Net Effect: Increase in atmosphere (health effects) and acid rain

Acid Deposition

any precipitation (rain, snow, fog, mist) that is more acidic than normal high because of the nature or the pH scale

Logarithmically, a decrease in value from pH 6 to pH 5 means that the solution has become ten times more acidic

If the number drops to pH 4 from pH 6, then the solution is 100 times more acidic

- The largest sources of increased acidity in lakes and other surface waters are through smelting of sulphur rich metal ores and the burning of fossil fuels
- presence of sulphuric acid (H_2SO_4) and nitric acid (HNO_3)
- most common acids that are discharged by industrial emissions
- roughly about two thirds of these emissions are sulphuric acid
- about one third are acid

The forest and soils of this landscape were killed and eroded through action of air pollution from smelters downwind in nearby Mt Lyell copper mines. Ironically this landscape is featured as a tourist attraction. Formerly temperate forest.