Carbon

- Fourth most abundant element in the universe
- Basis for life
- 4 bonds
- Forms complex molecules
- Gaseous form

Buckminster Fullerene

Megaphone

Moronic Acid

Bastadin-5
The Global Carbon Cycle
pools $10^{15}$ gC, fluxes $10^{15}$ gC/year

- Land plants 560
- GPP 120
- $R_p$ 60
- $R_D$ 60
- Net destruction of vegetation 0.9
- Fossil fuels 6
- Atmospheric pool 750 + 3.2/year
- Rivers 0.4 DOC 0.4 DIC
- Soils 1500
- Oceans (38000)
  - 36 000 inorganic
  - 1 000 DOC
  - 3 POC
- Reactive marine sediments 3000
- Fossil fuels > 5000
- Burial 0.1
- > 10 000 000 sediments
- > 90 000 000 earth's crust
Photosynthesis

- Where does the mass of a tree come from?
- \( \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{CH}_2\text{O} + \text{O}_2 \)
Global Productivity
Respiration

- Mitochondria, bacteria, fires, combustion engines
- \( \text{O}_2 + \text{CH}_2\text{O} \rightarrow \text{CO}_2 + \text{H}_2\text{O} \)
- In earth system, the energy budget is balanced, chemical energy is temporary storage
- In ocean or land, 99.9% carbon is recycled
- Fossil Fuels burned at 20,000 times natural rates of oxidation
CO2 Emissions

- Combustion of Fossil Fuels
- Land Use Change

Annual Emissions to the Atmosphere (Pg C)

1850 1870 1890 1910 1930 1950 1970 1990
Atmospheric Measurements

Mauna Loa Monthly Mean 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, ptans@cmdl.noaa.gov, and Dr. Charles D. Keeling, SIO, La Jolla, California, (619) 534-6001, cdkoeling@ucsd.edu.
Global Distribution of Atmospheric Carbon Dioxide

NOAA CMDL Carbon Cycle Greenhouse Gases

Three dimensional representation of the latitudinal distribution of atmospheric carbon dioxide in the marine boundary layer. Data from the NOAA CMDL cooperative air sampling network were used. The surface represents data smoothed in time and latitude. Principal investigators: Pieter Tans and Thomas Conway, NOAA CMDL Carbon Cycle Greenhouse Gases, Boulder, Colorado. (303) 497-6678 (ptans@cmdl.noaa.gov, http://www.cmdl.noaa.gov/ccgg).
“Missing Sink” of Atmospheric CO2
(in Gigatons Carbon—$10^{15}$ gmC)

- Fossil Fuel Burning = 6.0 +/- 0.5
- Deforestation = 0.9 +/- 0.7
- Atmospheric Increase = 3.2 +/- 0.1
- Oceanic Uptake = 2.0 +/- 0.8
- “Missing Sink” = 1.7 +/- 1.2
Mass Balance

• Total mass is always conserved
• Each element is also conserved in a closed system
• Can you design a closed system that is sustainable indefinitely?
• Eco-sphere.com
Cycles are linked

- \( \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{CH}_2\text{O} + \text{O}_2 \)
Biosphere 2

- [http://www.b2science.org/about-mission.html](http://www.b2science.org/about-mission.html)
- 7 people, O2 began to drop
- Why?

![Graph showing O2 and CO2 levels](image)

Fig. 1. Oxygen and CO2 history in Biosphere 2. The same scale is used for O2 and CO2 with a 13% offset. Note that oxygen drop is much greater than CO2 increase, even taking into account the chemical scrubber. This requires the existence of a sink of O2 or CO2 other than respiration or photosynthesis.
Nitrogen Cycle

atmosphere \( \text{N} \)
primarily \( \text{N}_2 \) with traces
of \( \text{NH}_3, \text{NO}, \text{N}_2\text{O}, \text{NO}_2 \)

\( \text{N}_2, \text{N}_2\text{O}, \text{NO} \)

\( \text{N}_2\text{O}_3 \) Nitric Acid

Lightning

\( \text{NH}_3 \)
NH\(_3\) ammonia gas

Acid Rain

Fertilizer Production
\( \text{NH}_3, \text{NH}_4, \text{NO}_3 \)

\( \text{NO}_3^- \)
Nitrate

\( \text{NO}_2^- \)
Nitrite

Plant uptake

Nitrogen Fixation

Mineralization

Ammonification

Denitrification

Runoff

Erosion

Clay (Colloid)

Nitrogen Cycle

Nitrogen Cycle

Nitrogen Cycle
Needs

• Amino Acids \(\rightarrow\) proteins
• Nucleic Acids
• Chlorophyll
• Carbon to Nitrogen ratio
Sources

- Nitrogen Fixing bacteria
  - Legumes
  - Clover
  - Cyanobacteria
- Lightning
- Haber Process (factory fertilizer production)
- Internal combustion engines (cars)
- Mankind has doubled N-inputs to coastal areas → eutrophication
Fall Colors

- Chlorophyll-N recalled
- Accessory pigments shown
- Huge loss of C, but not N
Why do leaves turn colors?

- Nutrients
- Pigments
- Carotenoids, Xanthophylls
- Anthocyanins

![Chemical structures of B-Carotene, Crytoxanthin (Yellow), and Anthocyandin (purple).]
Lawn calculation

- If you add 1 pound of nitrogen fertilizer to your lawn, how many pounds of lawn clippings must you carry away?
- Water
- Carbon/Nitrogen ratio
Biogeochemistry

- Conservation of mass in a system
- Discover missing processes through box model budget
- Use tracers (biomarkers, elements, isotopes, radionuclides) to elucidate processes
- Variety of temporal and spatial scales