Microbes and Mineral Cycling

Biogeochemical cycles on a global scale

Photosynthesis Is the Source of Atmospheric O_2

- Cyanobacteria, which evolved the ability to split water into hydrogen ions and O_2, created atmospheric O_2.
- Accumulation of free O_2 in the atmosphere made possible the evolution of aerobic metabolism.

Extant Microbial Mat Communities

Rust the Crust

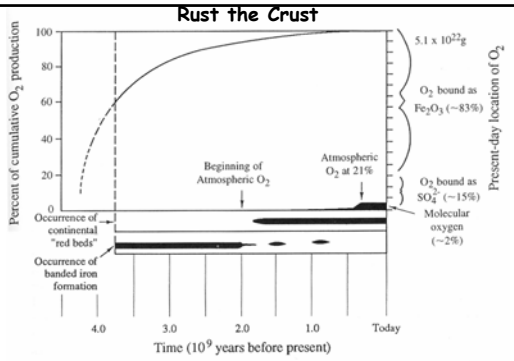
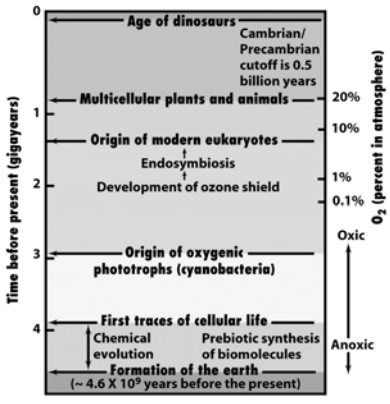
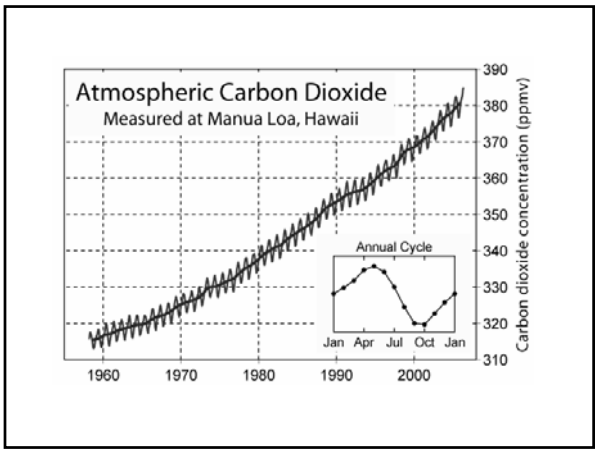


Figure 2.7 Cumulative history of O_2 released by photosynthesis through geologic time. Of more than 5.1×10^{22} g of O_2 released, about 98% is contained in seawater and sedimentary rocks, beginning with the occurrence of Banded Iron Formations at least 3.5 billion years ago (bya). Although O_2 was released to the atmosphere beginning about 2.0 bya, it was consumed in terrestrial weathering processes to form Red Beds, so that the accumulation of O_2 to present levels in the atmosphere was delayed to 400 mya. Modified from Schidlowski (1980).

Banded iron formations are evidence of oxygenic photosynthesis





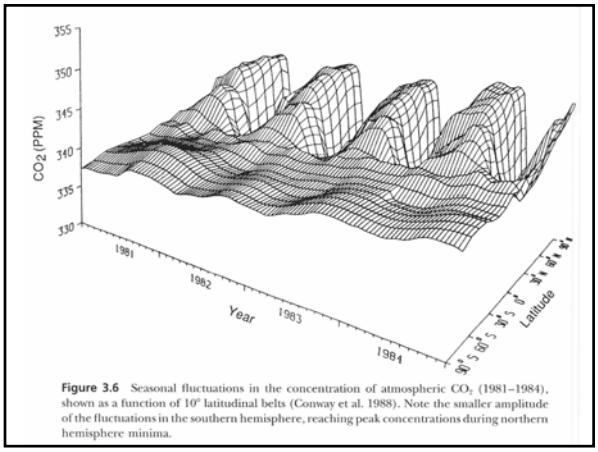
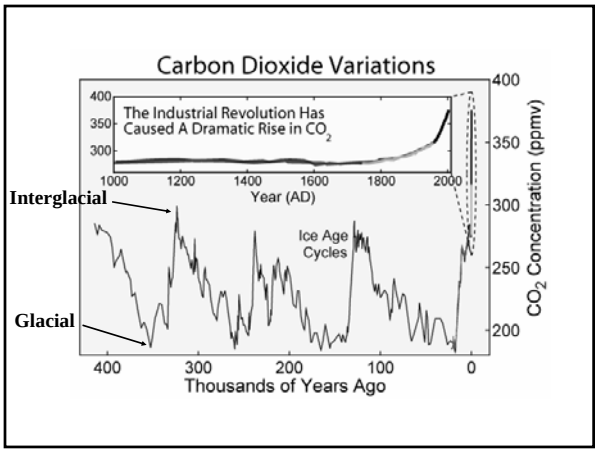
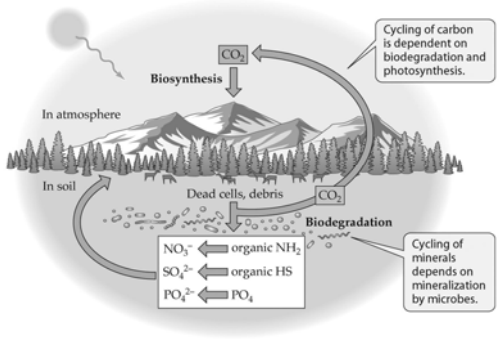


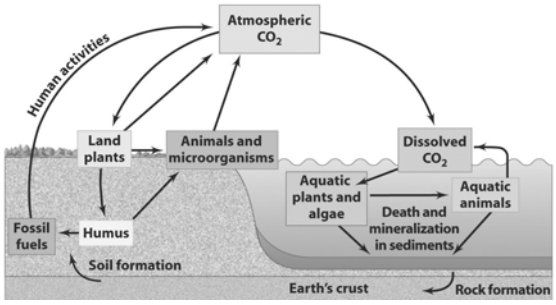
Figure 3.6 Seasonal fluctuations in the concentration of atmospheric CO_2 (1981–1984), shown as a function of 10° latitudinal belts (Conway et al. 1988). Note the smaller amplitude of the fluctuations in the southern hemisphere, reaching peak concentrations during northern hemisphere minima.



Balance between biosynthesis and biodegradation



The carbon cycle, closely connected with oxygen cycle



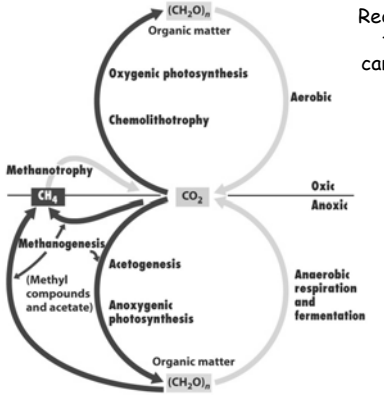
Most carbon in carbonate rocks & sediments

Table 19.3 Major carbon reservoirs on Earth

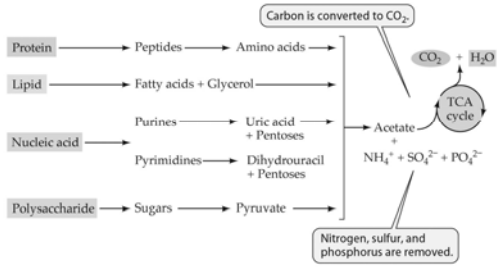
Reservoir	Carbon (gigatons)[a]	Percent of total carbon on Earth
Oceans	38×10^3 (>95% is inorganic C)	0.05
Rocks and sediments	75×10^6 (>80% is inorganic C)	>99.5[b]
Terrestrial biosphere	2×10^3	0.003
Aquatic biosphere	1–2	0.000002
Fossil fuels	4.2×10^3	0.006
Methane hydrates	10^4	0.014
Atmosphere	**720**	**0.005**

[a] One gigaton is 10^9 tons. Data adapted from *Science 290*:291–295 (2000).
[b] Much of the organic carbon is in prokaryotic cells.

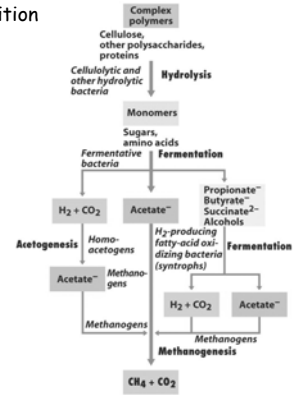
Redox states for the carbon cycle



Fate of major biomolecules



Anoxic decomposition



Take Home Message

- The oxygen and carbon cycles are interconnected through the complementary activities of autotrophic and heterotrophic organisms.
- Microbial decomposition is the single largest source of CO_2 released to the atmosphere.

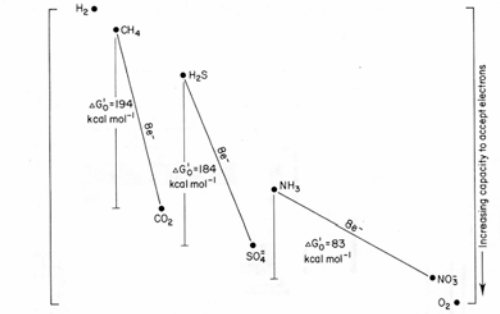
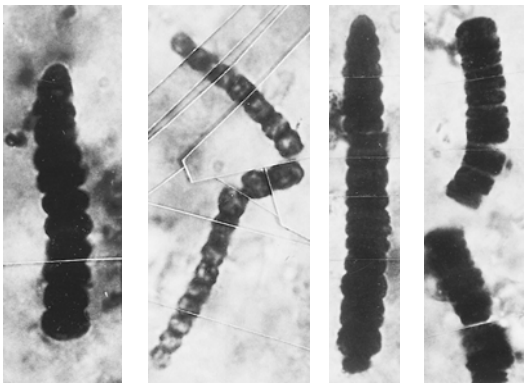


Fig. 22. A comparison between C, S and N oxidation/reductions. The most reduced and the most oxidized compounds of the C, S and N cycles are arranged in pairs, separated by a distance which represents an 8 e^- difference between the extremes. Given vertically are the G° for the oxidation, by O_2, of the reduced form. There is a decreasing energy yield through the series C, S to N which is represented by the vertical distance between the oxidized and the reduced forms. The location of the lines relative to each other is only approximately correct and is designed to illustrate the decrease in reducing potential through the series H_2, CH_4, H_2S to NH_3 and the increase in oxidizing potential through the series CO_2, SO_4^{2-}, NO_3^- to O_2.

Microbes and Origins of Life

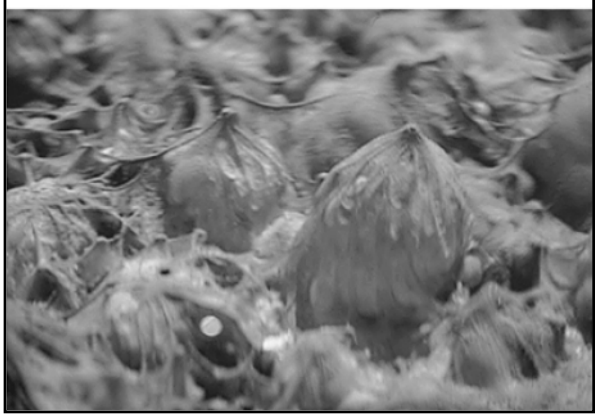
Evolution has occurred almost elusively in a microbial world !!!

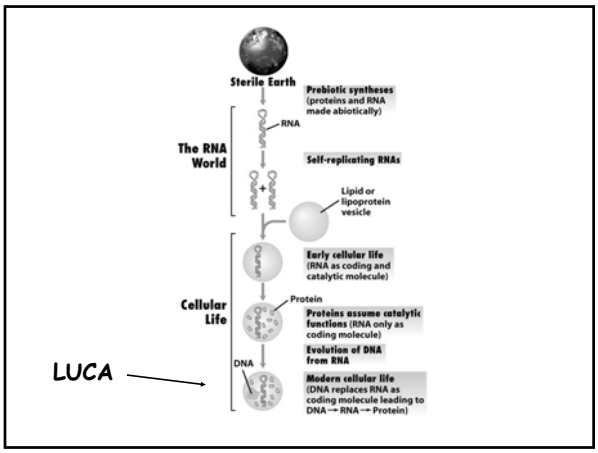
Oldest Known Fossils of Living Organisms (~3500 Mya)



Living Columnar Stromatolites, Shark Bay, Western Australia

Modern Stromatolites from Yellowstone Natl. Park





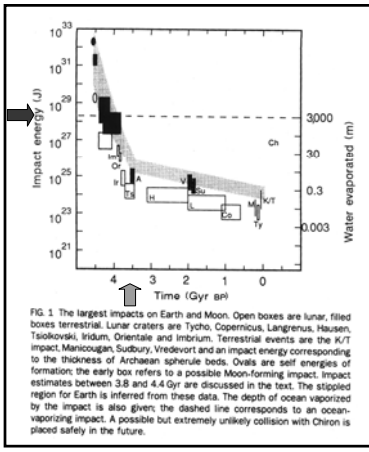
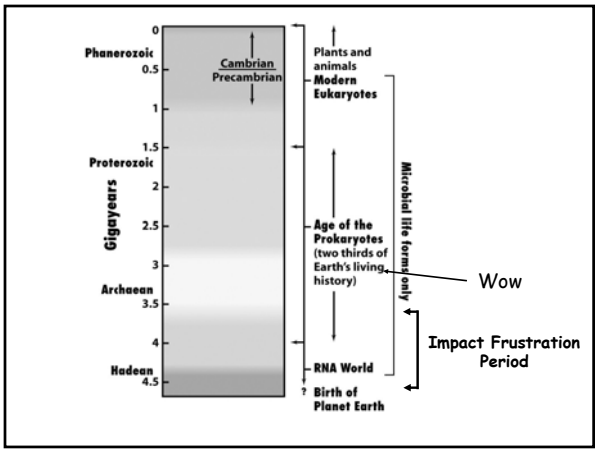
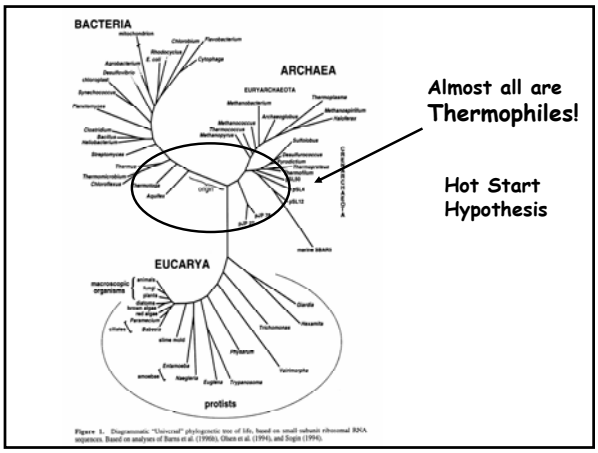


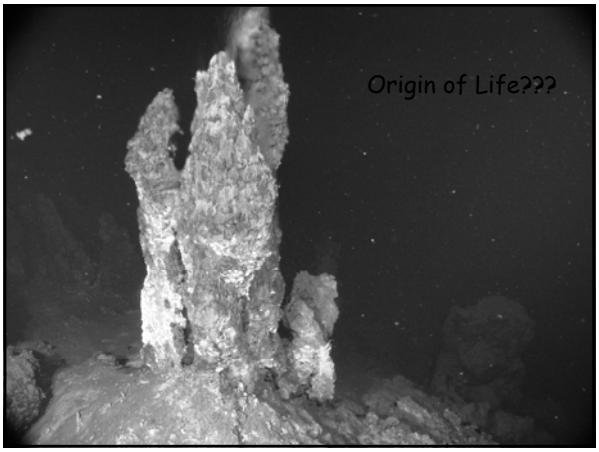
FIG. 1 The largest impacts on Earth and Moon. Open boxes are lunar, filled boxes terrestrial. Lunar craters are Tycho, Copernicus, Langrenus, Hausen, Tsiolkovski, Iridum, Orientale and Imbrium. Terrestrial events are the K/T impact, Manicougan, Sudbury, Vredevort and an impact energy corresponding to the thickness of Archaean spherule beds. Ovals are self energies of formation; the early box refers to a possible Moon-forming impact. Impact estimates between 3.8 and 4.4 Gyr are discussed in the text. The stippled region for Earth is inferred from these data. The depth of ocean vaporized by the impact is also given; the dashed line corresponds to an ocean-vaporizing impact. A possible but extremely unlikely collision with Chiron is placed safely in the future.

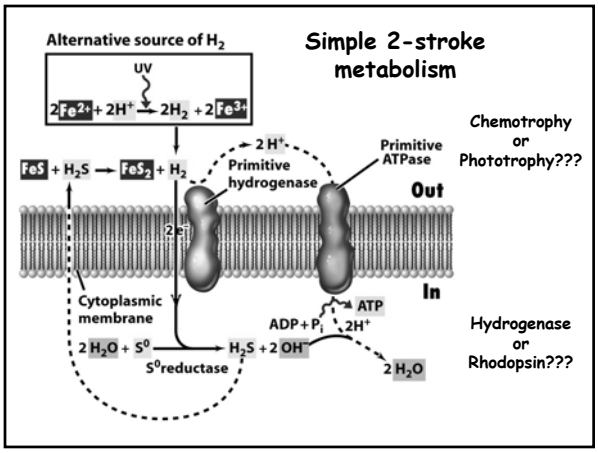
Impact Frustration period forces origins of life into a narrow time period to have gotten started!

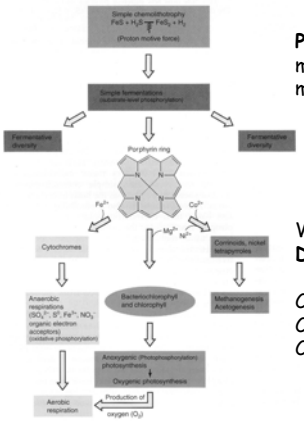
Hydrothermal vents may have served as zones of refuge.




BACTERIA
ARCHAEA
EUKARYA
protists
Almost all are Thermophiles!
Hot Start Hypothesis


Origin of Life???


Alternative source of H_2
Simple 2-stroke metabolism
UV
$2Fe^{2+} + 2H^+ \rightarrow 2H_2 + 2Fe^{3+}$
$FeS + H_2S \rightarrow FeS_2 + H_2$
$2H^+$
Primitive hydrogenase
Primitive ATPase
Out
In
$2e^-$
Cytoplasmic membrane
ATP
$ADP + P_i$
$2H^+$
$2H_2O + S^0 \rightarrow H_2S + 2OH^-$
S^0reductase
$2H_2O$
Chemotrophy or Phototrophy???
Hydrogenase or Rhodopsin???



Porphyrin Ring opens many possibilities for metabolic pathways!!!

Which ones are **Domain specific**?

Cytochromes: Bacteria…
Chlorophyll: Bacteria…
Corrinoids: Archaea only