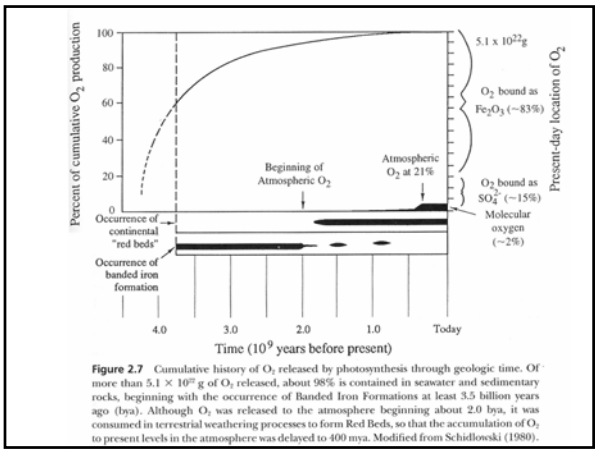
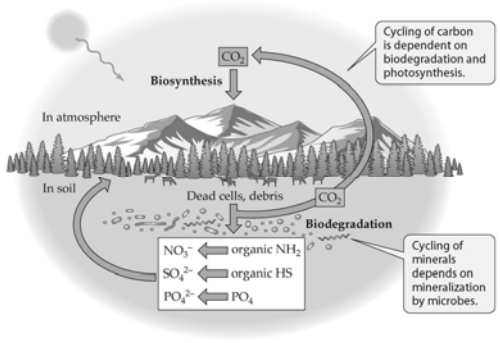


Figure 2.7 Cumulative history of O_2 released by photosynthesis through geologic time. Of more than 5.1×10^{22} g of O_2 released, about 98% is contained in seawater and sedimentary rocks, beginning with the occurrence of Banded Iron Formations at least 3.5 billion years ago (bya). Although O_2 was released 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).

● **Figure 11.7 Banded iron formations.** An exposed cliff about 10 m in height containing layers of iron oxides interspersed with layers containing iron silicates and other silica materials. Brockman Iron Formation, Hammersley Basin, Western Australia. The iron oxides contain iron in the ferric (Fe^{3+}) form produced from ferrous iron (Fe^{2+}) primarily by the oxygen released by cyanobacterial photosynthesis.

Balance between biosynthesis and biodegradation



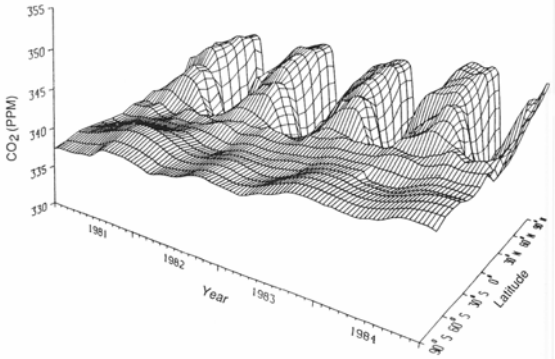
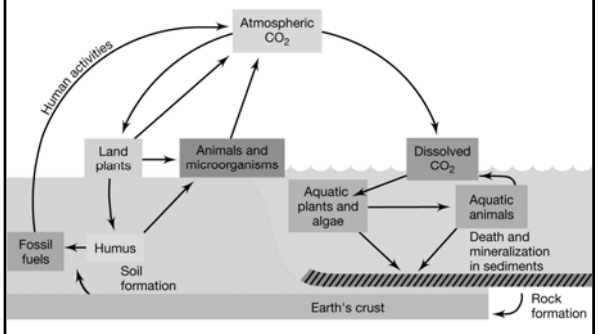
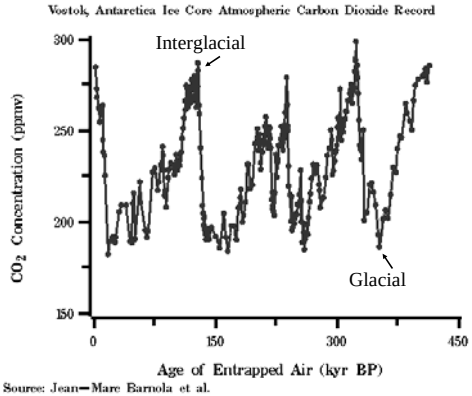


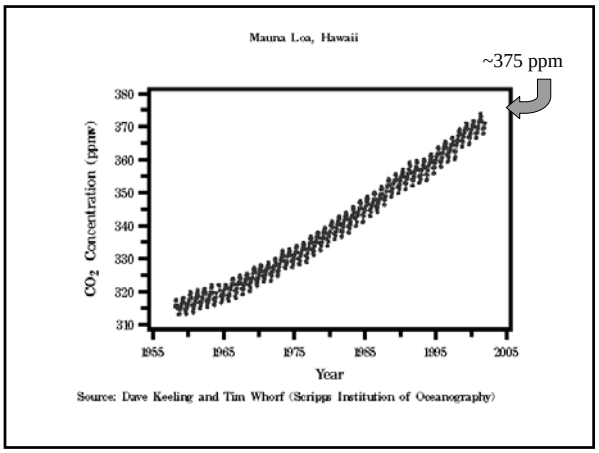
Figure 3.6 Seasonal fluctuations in the concentration of atmospheric CO_2 (1981–1984), shown as a function of 10° latitudinal belts (Conway et al. 1988). Note the smaller amplitude of the fluctuations in the southern hemisphere, reaching peak concentrations during northern hemisphere minima.

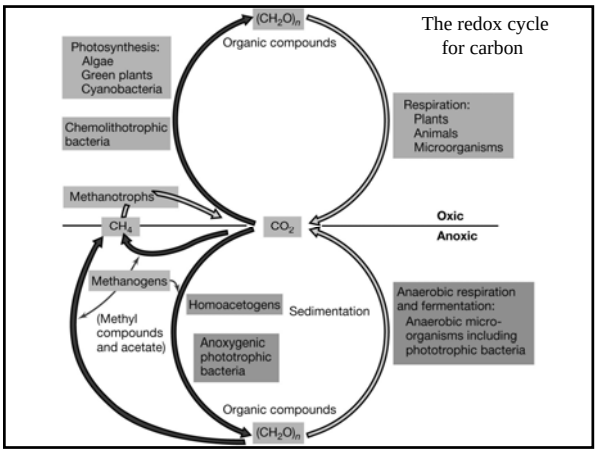
The carbon cycle, closely connected with oxygen cycle

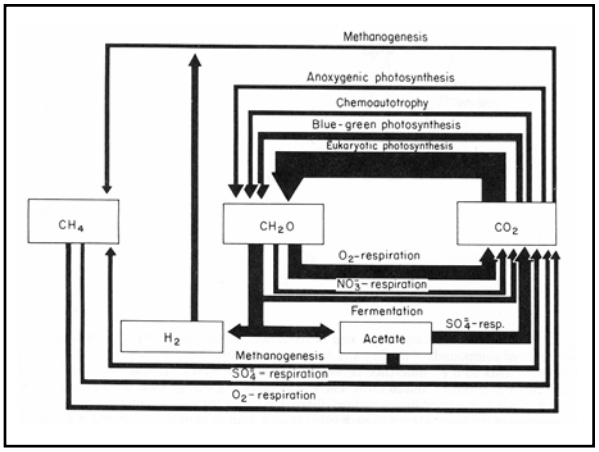


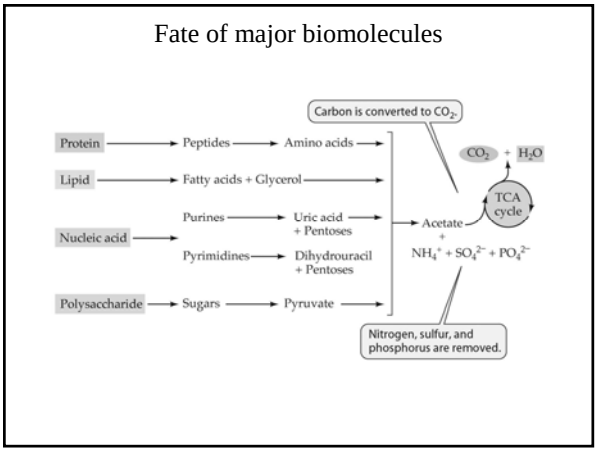
Most carbon in carbonate rocks & sediments

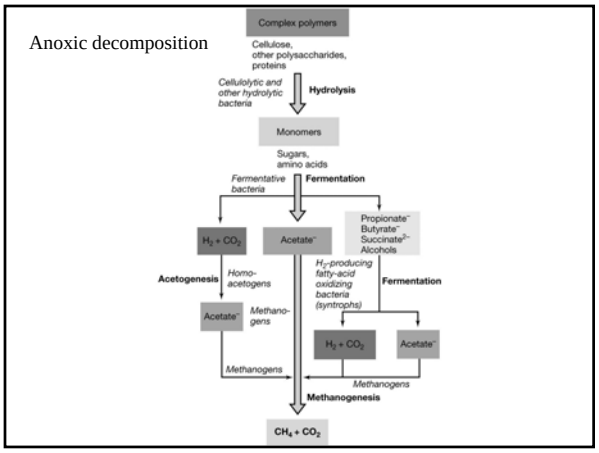


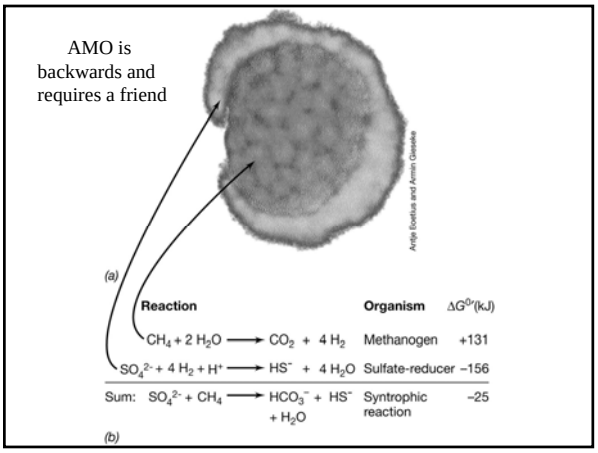

Mauna Loa, Hawaii
~375 ppm
CO_2 Concentration (ppmv)
380
370
360
350
340
330
320
310
1955
1965
1975
1985
1995
2005
Year
Source: Dave Keeling and Tim Whorf (Scripps Institution of Oceanography)


The redox cycle for carbon
$(CH_2O)_n$
Organic compounds
Photosynthesis:
Algae
Green plants
Cyanobacteria
Chemolithotrophic bacteria
Respiration:
Plants
Animals
Microorganisms
Methanotrophs
CH_4
CO_2
Oxic
Anoxic
Methanogens
(Methyl compounds and acetate)
Homoacetogens
Sedimentation
Anoxygenic phototrophic bacteria
Anaerobic respiration and fermentation:
Anaerobic micro-organisms including phototrophic bacteria
Organic compounds
$(CH_2O)_n$


Methanogenesis
Anoxygenic photosynthesis
Chemoautotrophy
Blue-green photosynthesis
Eukaryotic photosynthesis
CH_4
CH_2O
CO_2
O_2-respiration
NO_3^--respiration
Fermentation
SO_4^{2-}-resp.
H_2
Acetate
Methanogenesis
SO_4^{2-}-respiration
O_2-respiration


Fate of major biomolecules
Carbon is converted to CO_2.
Protein
Peptides
Amino acids
Lipid
Fatty acids + Glycerol
Nucleic acid
Purines
Uric acid + Pentoses
Pyrimidines
Dihydrouracil + Pentoses
Polysaccharide
Sugars
Pyruvate
Acetate + NH_4^+ + SO_4^{2-} + PO_4^{2-}
CO_2 + H_2O
TCA cycle
Nitrogen, sulfur, and phosphorus are removed.


Anoxic decomposition
Complex polymers
Cellulose, other polysaccharides, proteins
Cellulolytic and other hydrolytic bacteria
Hydrolysis
Monomers
Sugars, amino acids
Fermentative bacteria
Fermentation
$H_2 + CO_2$
Acetate⁻
Propionate⁻
Butyrate⁻
Succinate²⁻
Alcohols
Acetogenesis
Homo-acetogens
H_2-producing fatty-acid oxidizing bacteria (syntrophs)
Fermentation
Acetate⁻
Methano-gens
$H_2 + CO_2$
Acetate⁻
Methanogens
Methanogens
Methanogenesis
$CH_4 + CO_2$


AMO is backwards and requires a friend
(a)
Reaction
Organism
$\Delta G^{0\prime}$(kJ)
$CH_4 + 2\ H_2O \rightarrow CO_2 + 4\ H_2$
Methanogen
+131
$SO_4^{2-} + 4\ H_2 + H^+ \rightarrow HS^- + 4\ H_2O$
Sulfate-reducer
−156
Sum: $SO_4^{2-} + CH_4 \rightarrow HCO_3^- + HS^- + H_2O$
Syntrophic reaction
−25
(b)

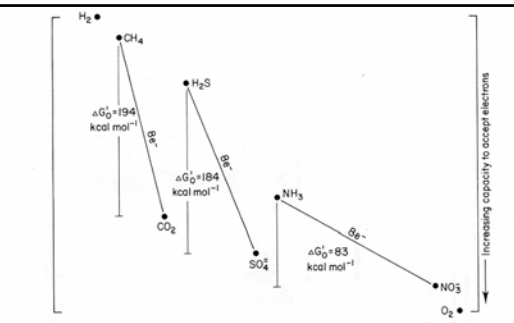
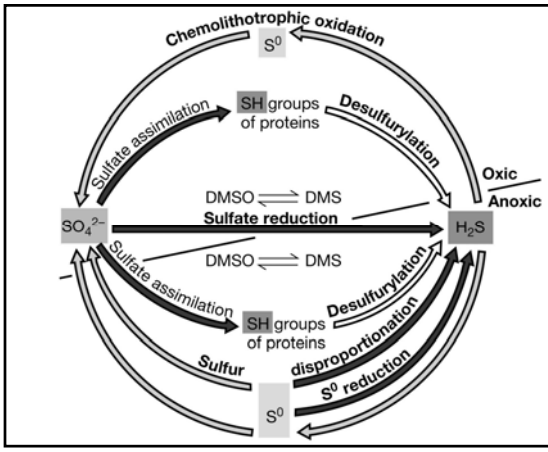
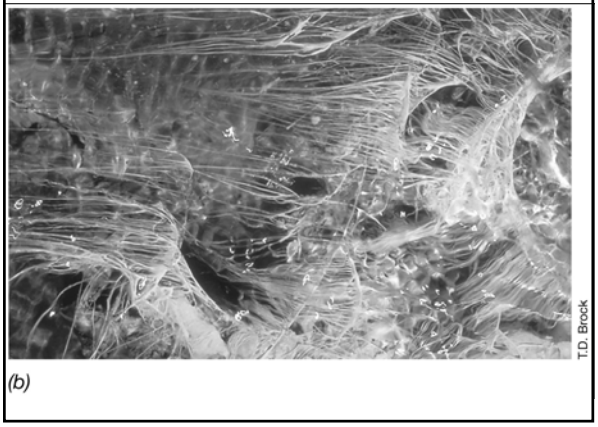


Fig. 22. A comparison between C, S and N oxidation/reductions. The most reduced and the most oxidized compounds of the C, S and N cycles are arranged in pairs, separated by a distance which represents an 8 e^- difference between the extremes. Given vertically are the G'_o for the oxidation, by O_2, of 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.

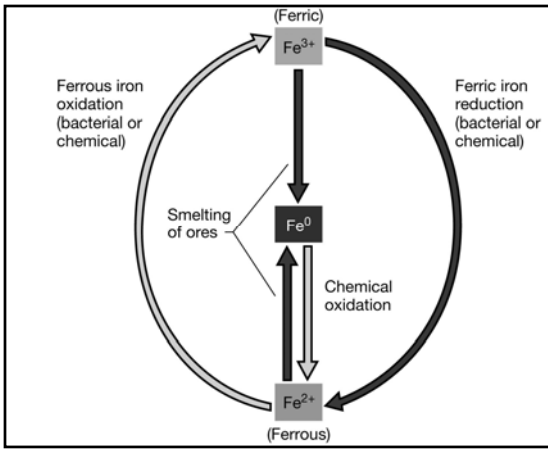
Key Processes and Prokaryotes in the Sulfur Cycle

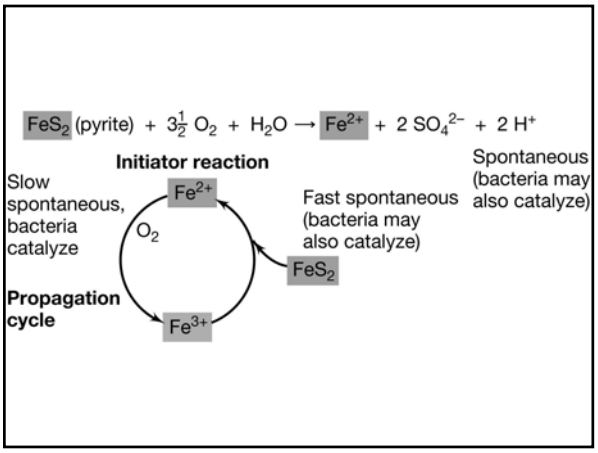
Process	Organisms
Sulfide/sulfur oxidation ($H_2S \rightarrow S^0 \rightarrow SO_4^{2-}$)	
Aerobic	Sulfur chemolithotrophs (*Thiobacillus*, *Beggiatoa*, many others)
Anaerobic	Purple and green phototrophic bacteria, some chemolithotrophs
Sulfate reduction (anaerobic) ($SO_4^{2-} \rightarrow H_2S$)	*Desulfovibrio*, *Desulfobacter*,
Sulfur reduction (anaerobic) ($S^0 \rightarrow H_2S$)	*Desulfuromonas*, many hyperthermophilic *Archaea*
Sulfur disproportionation ($S_2O_3^{2-} \rightarrow H_2S + SO_4^{2-}$)	*Desulfovibrio*, and others
Organic sulfur compound oxidation or reduction	($CH_3SH \rightarrow CO_2 + H_2S$) ($DMSO \rightarrow DMS$)
Desulfurylation (organic–S $\rightarrow H_2S$)	Many organisms can do this

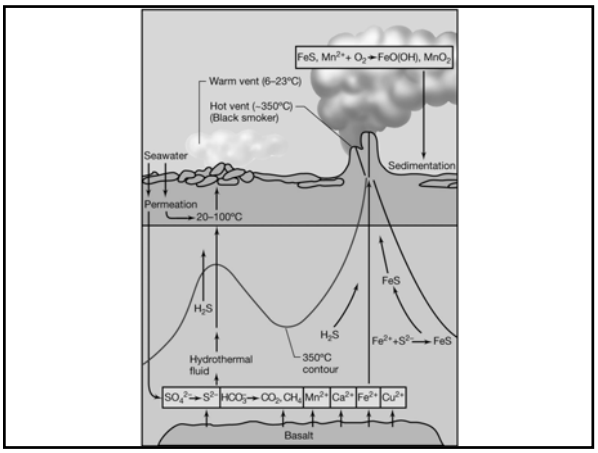


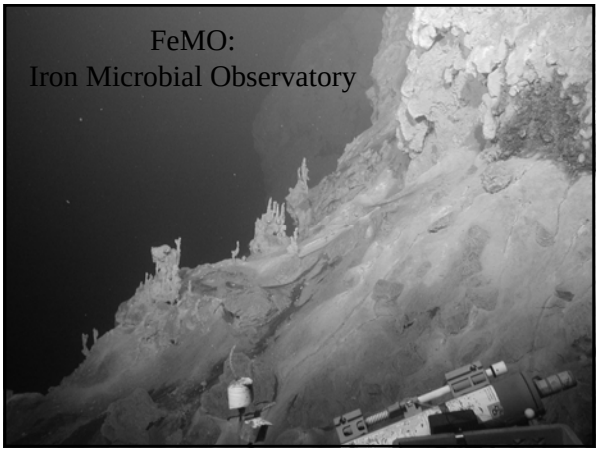


(b)









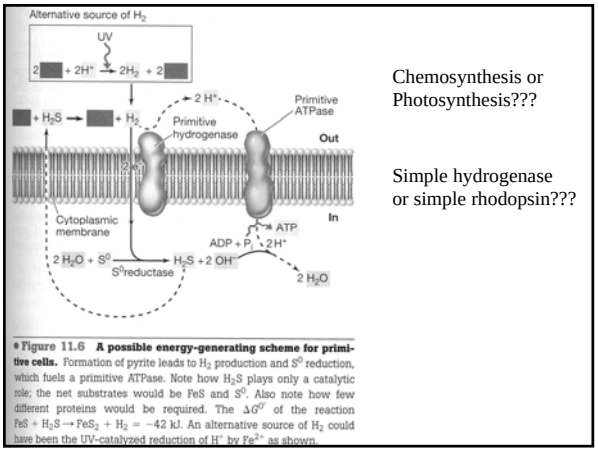


Figure 11.6 A possible energy-generating scheme for primitive cells. Formation of pyrite leads to H_2 production and S^0 reduction, which fuels a primitive ATPase. Note how H_2S plays only a catalytic role; the net substrates would be FeS and S^0. Also note how few different proteins would be required. The $\Delta G^{0\prime}$ of the reaction $FeS + H_2S \rightarrow FeS_2 + H_2 = -42$ kJ. An alternative source of H_2 could have been the UV-catalyzed reduction of H^+ by Fe^{2+} as shown.

Chemosynthesis or Photosynthesis???

Simple hydrogenase or simple rhodopsin???

Porphyrin ring opens many possibilities for metabolic diversity!!!

Which ones are Domain specific?

Cytochromes: Everyone
Chlorophyll: Bacteria only
Corrinoids: Archaea only