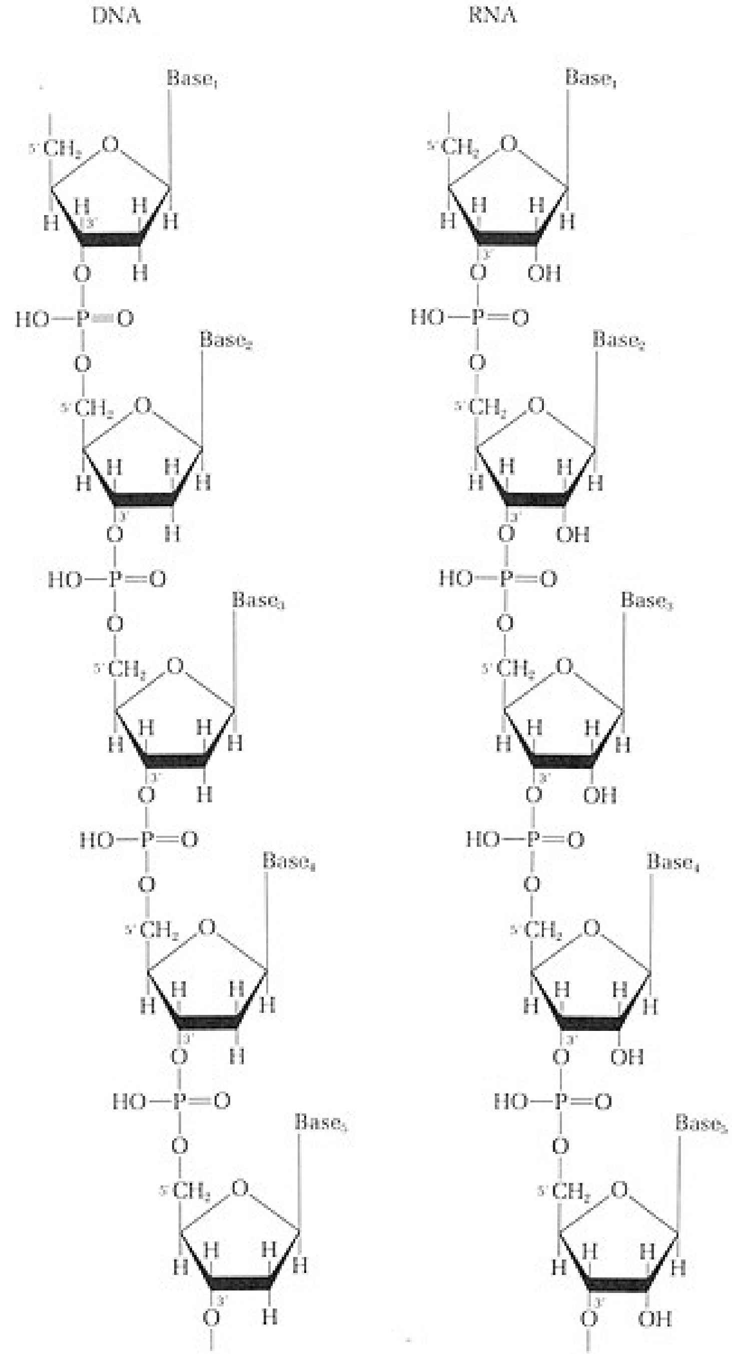
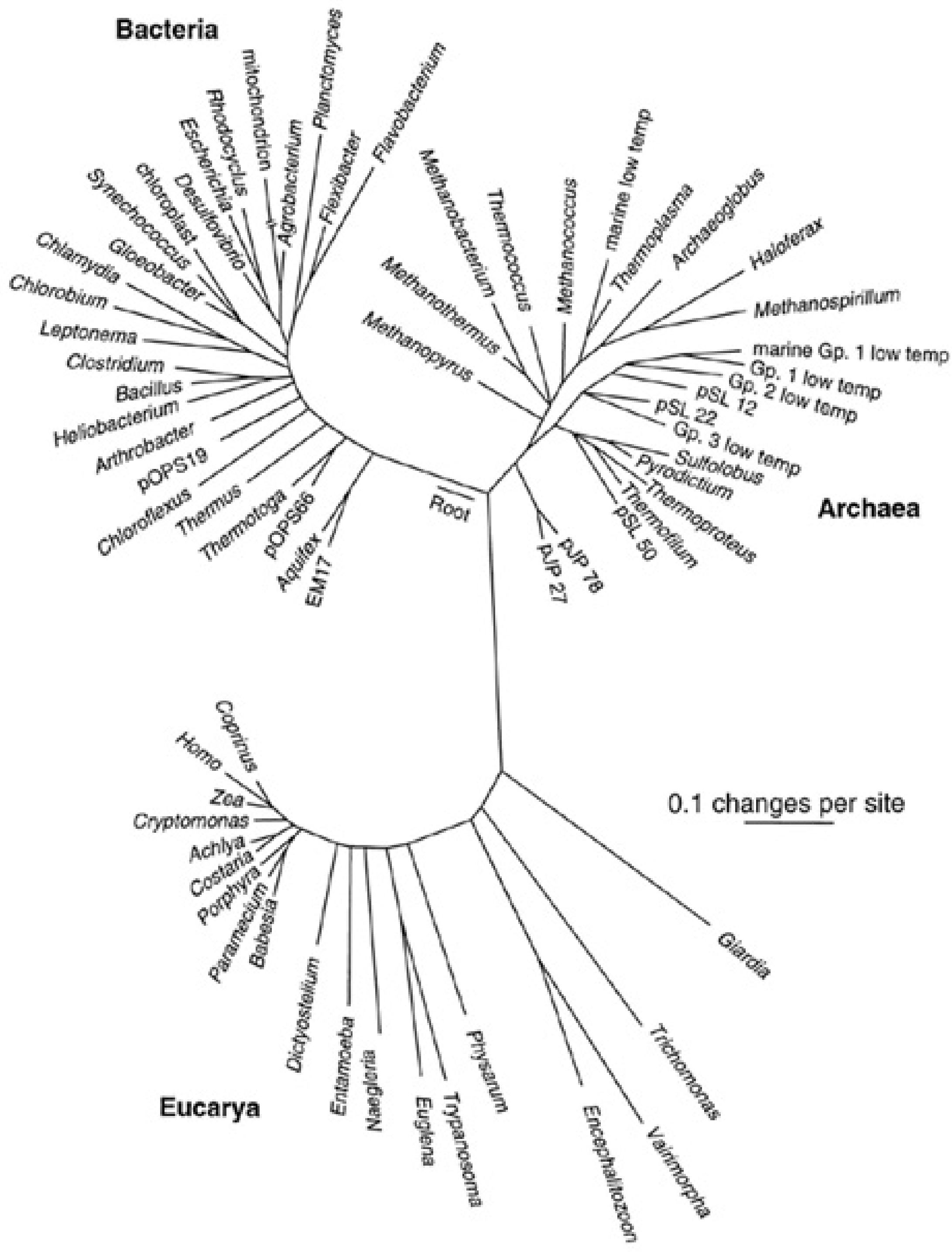
Polynucleotide structure. In DNA and RNA, the phosphodiester bridges link the 3'-hydroxyl of one nucleotide to the 5'-hydroxyl of the next.





Bacteria
Archaea
Eucarya
Root
0.1 changes per site
Planctomyces
mitochondrion
Rhodocyclus
Escherichia
Agrobacterium
Flexibacter
Flavobacterium
Desulfovibrio
chloroplast
Synechococcus
Gloeobacter
Chlamydia
Chlorobium
Leptonema
Clostridium
Bacillus
Heliobacterium
Arthrobacter
pOPS19
Chloroflexus
Thermus
Thermotoga
pOPS66
Aquifex
EM17
Methanobacterium
Thermococcus
Methanococcus
marine low temp
Thermoplasma
Archaeoglobus
Haloferax
Methanospirillum
Methanothermus
Methanopyrus
marine Gp. 1 low temp
Gp. 1 low temp
Gp. 2 low temp
pSL 12
pSL 22
Gp. 3 low temp
Sulfolobus
Pyrodictium
Thermoproteus
Thermofilum
pSL 50
pJP 78
pJP 27
Coprinus
Homo
Zea
Cryptomonas
Achlya
Costaria
Porphyra
Paramecium
Babesia
Dictyostelium
Entamoeba
Naegleria
Euglena
Trypanosoma
Physarum
Encephalitozoon
Vairimorpha
Trichomonas
Giardia

What are we made of?

The “Big Six” elements

H, C, N, O, P, S

What are the forms of these elements in “organic” matter?

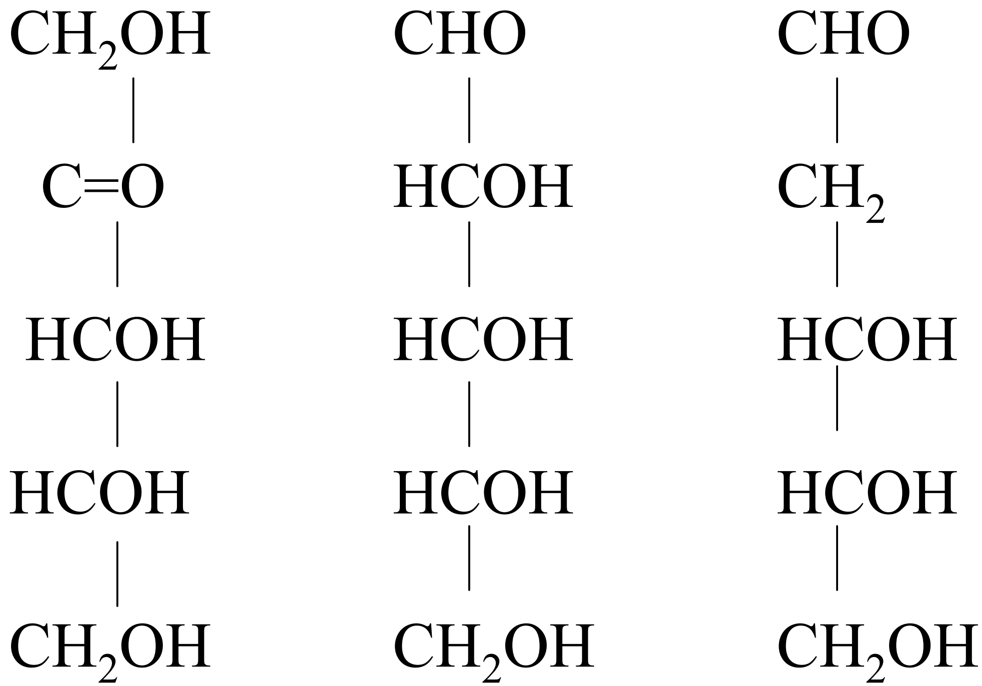
What makes a compound “organic”?

Are all organic molecules formed from biological processes?

What are early sources of organic matter on Earth?

What is “life”?

When did life begin?



D-ribulose D-ribose 2deoxy-D-ribose

The S C sugars

Table 9.1 Major Ion Composition of Seawater, Showing Relationships to Total Salinity and Mean Residence Times for the Elements with Respect to River Water Inputs

Constituent	Concentration in seawater[a] (mg/kg)	Chlorinity ratio[a]	Concentration in river water[b] (mg/kg)	Mean residence time (10^6 yr)
Sodium	10,760	0.5561	5.15	75
Magnesium	1,294	0.0668	3.35	14
Calcium	412	0.0213	13.4	1.1
Potassium	399	0.0206	1.3	11
Strontium	7.9	0.00041	0.03	12
Chloride	19,350	1.0000	5.75	120
Sulfate	2,712	0.1400	8.25	12
Bicarbonate	145	0.0075	52	0.10
Bromide	67	0.0035	.02	100
Boron	4.6	0.00024	0.01	10.0
Fluoride	1.3	0.000067	0.10	0.5
Water				0.034

[a] Holland (1978).
[b] Meybeck (1979) and Holland (1978).

Table 2.1 Composition of Volcanic Gases Released from the Kudryavy and Other Volcanoes

Volcano	H_2O	H_2	CO_2	SO_2	H_2S	HCl	HF	N_2	NH_3	O_2	Ar	CH_4	Reference
Kudryavy, Russia	95.00	0.56	2.00	1.32	0.41	0.3700	0.030	0.21	—	0.03	0.002	0.002	Taran et al. (19
Nevado del Ruiz, Columbia	94.90		2.91	2.74	0.80	0.0052							Williams et al. (1
Kamchatka, Russia	78.60	3.01	4.87	0.03	0.16	0.5700	0.056	11.87	0.11	0.01	0.060	0.440	Dobrovolsky (19

The Initial Condition Problem

- Was the early Earth hot or cold?
- Was there NH_3 in Earth's atmosphere?
- What was the redox potential of the ocean?

The Amino Acid World

- Amino acids are stable for long periods even at relatively high temperatures. However, the abiodic formation of amino acids requires NH_3

- NH_3 was not stable in the Archean atmosphere

The RNA World

- Given a supply of ribose (a major caveat), RNA can self replicate. However, RNA stability is very much reduced at high temperature.

The Redox Reaction Hypothesis

• Oxidation/reduction reactions are catalyzed by transition metals independent of proteins.
• In a “Primordial Soup” with organic molecules, redox reactions can mediate “metabolic pathways” without organisms

Life is Electric

- All organisms derive energy for growth and maintenance by moving electrons from a substrate to a product.
- All substrates and products must ultimately be cycled.
- Biological processes are paired (e.g., photosynthesis and respiration)

Redox Reactions are Couple on a GLOBAL SCALE

Oxygenic Photosynthesis

$$2H_2O + CO_2 \longrightarrow (CH_2O)_n + O_2$$

Aerobic Respiration:

$$(CH_2O)_n + O_2 \longrightarrow 2H_2O + CO_2$$

Q. Are photosynthesis and respiration balanced on a global scale?

Redox Reactions Are Coupled On

General Reaction

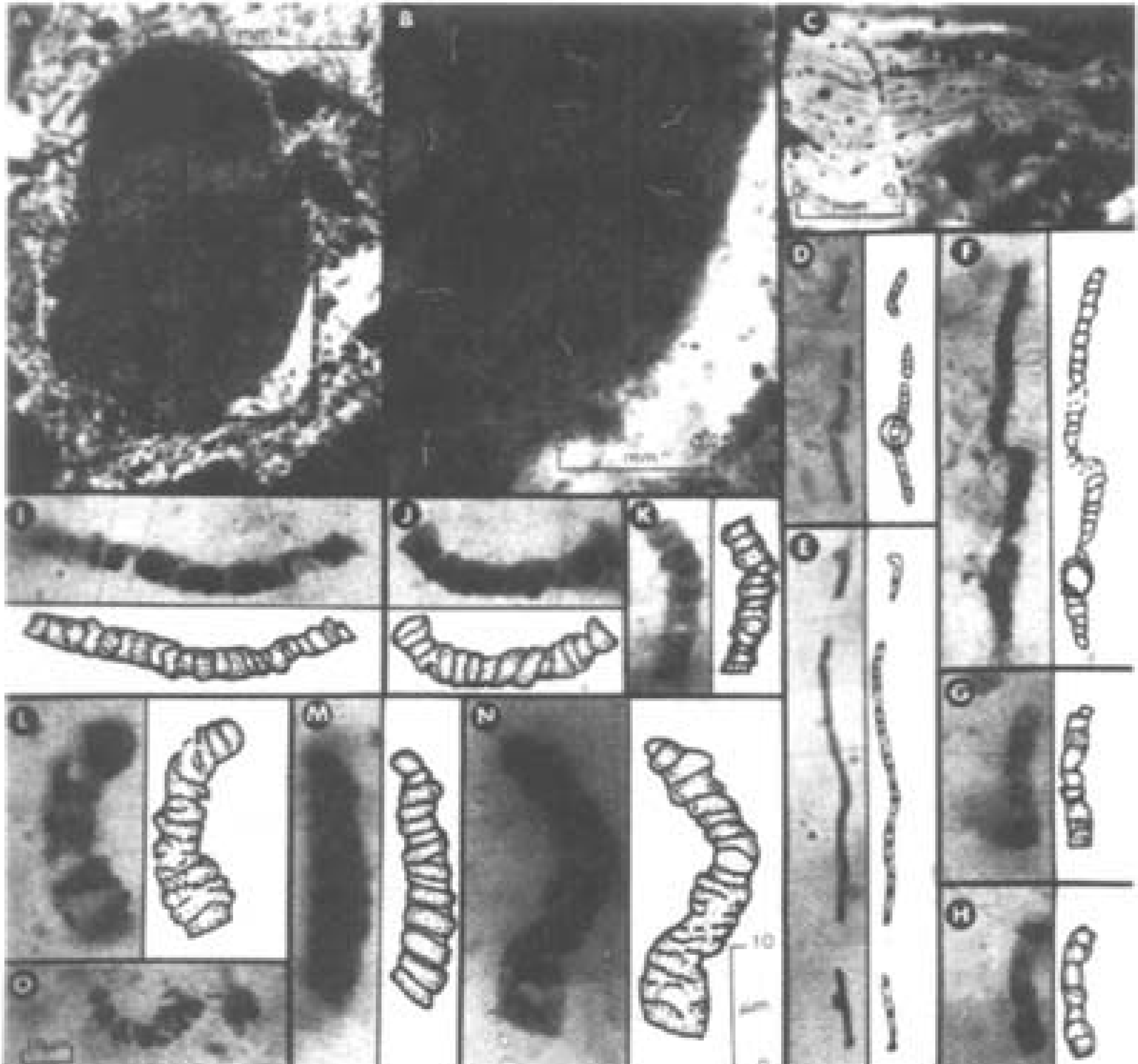
$$A(ox) + n(e^-) \longrightarrow A(red)$$

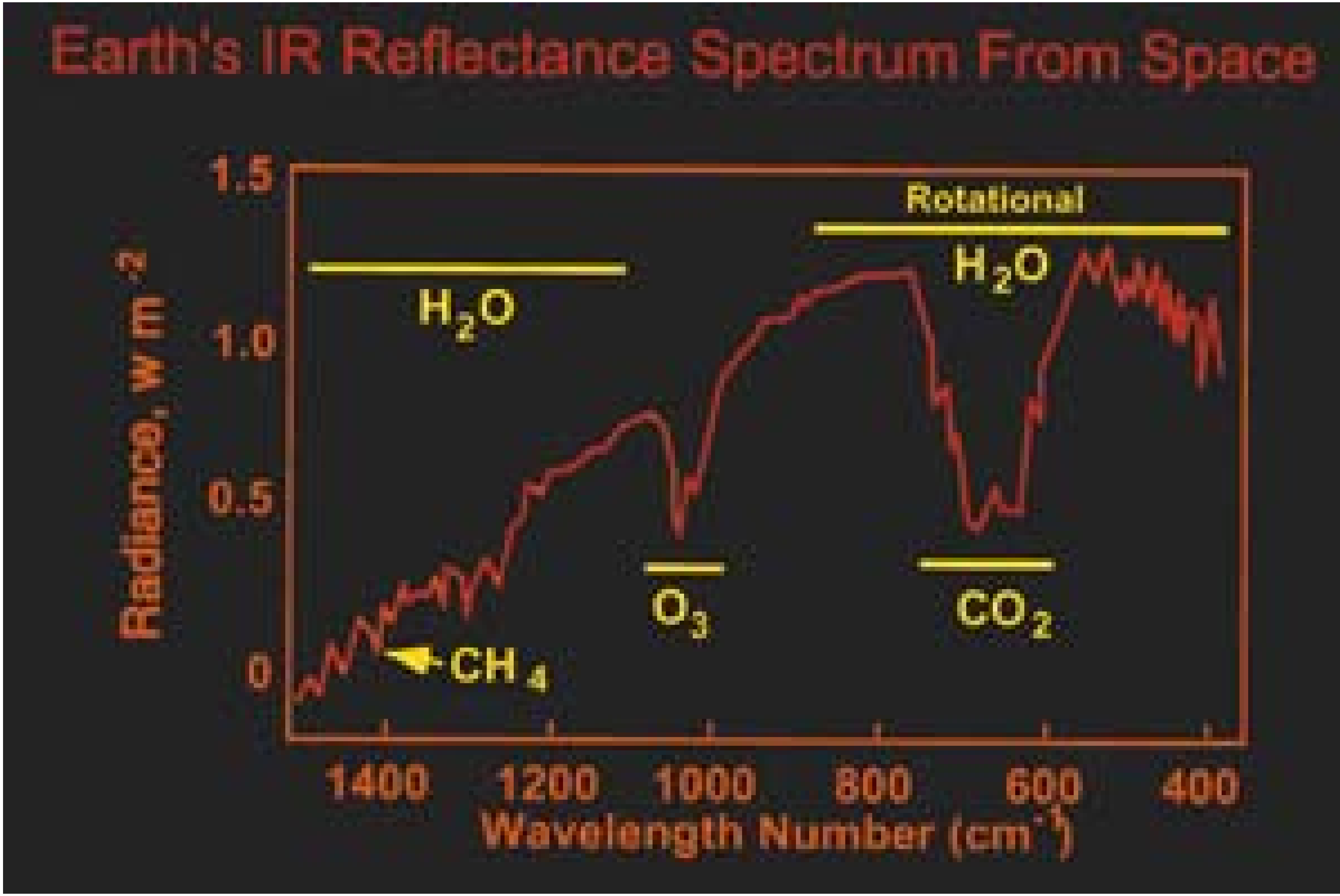
$$B(red) - n(e^-) \longrightarrow B(ox)$$

Photosynthesis

$$2H_2O + light \longrightarrow 4H^+ + 4e^- + O_2$$

$$CO_2 + 4H^+ + 4e^- \longrightarrow (CH_2O) + H_2O$$


A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
10
0


Earth's IR Reflectance Spectrum From Space
Rotational
H_2O
H_2O
O_3
CO_2
CH_4
1.5
1.0
0.5
0
Radiance, W m^{-2}
1400
1200
1000
800
600
400
Wavelength Number (cm^{-1})

Early Proterozoic Ocean

circa 2000 Mybp

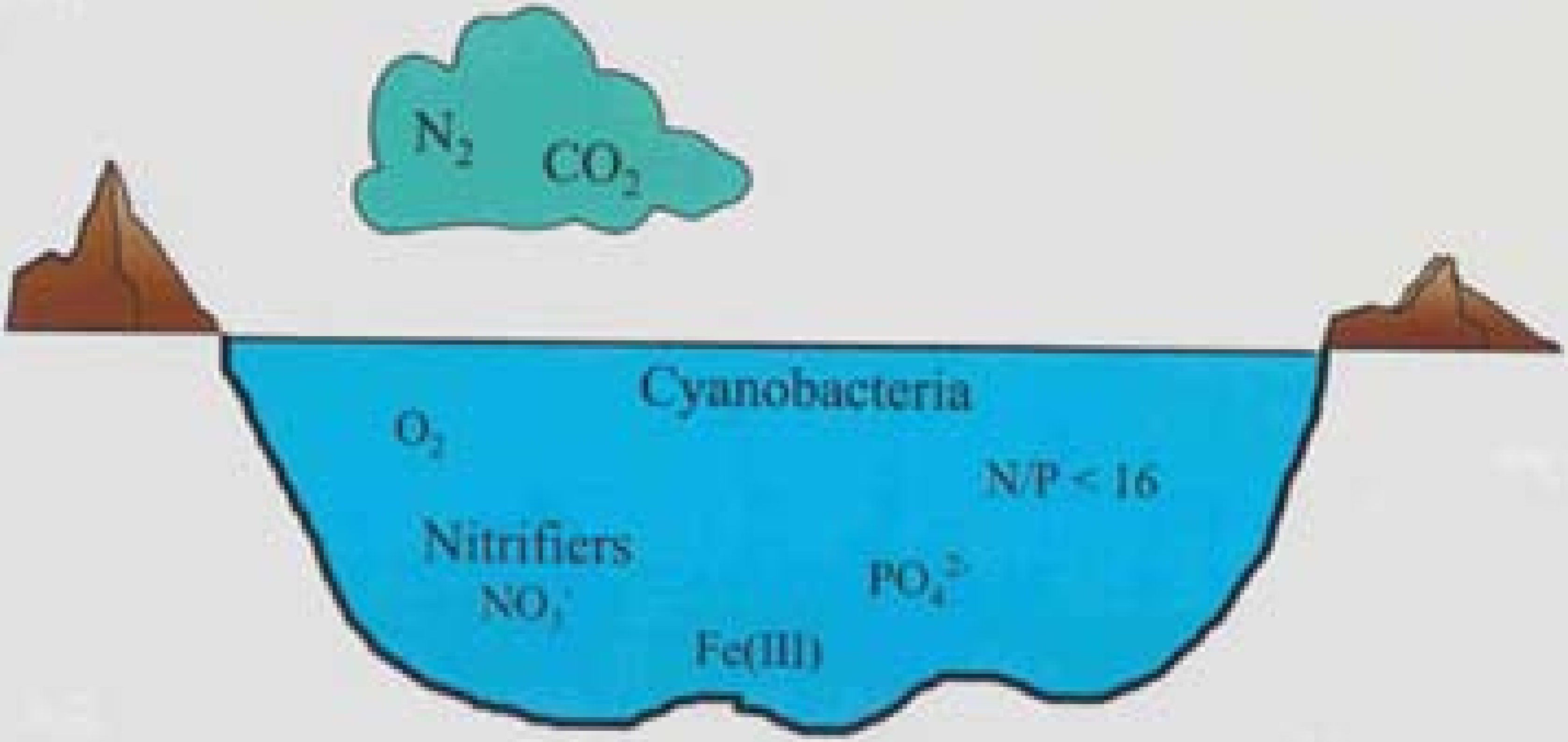


Table 8.5 Mean Composition of Dissolved Ions in River Waters of the World[a]

ontinent	HCO_3^-	SO_4^{2-}	Cl^-	NO_3^-	Ca^{2+}	Mg^{2+}	Na^+	K^+	Fe	SiO_2	Sum
h America	68	20	8	1	21	5	9	1.4	0.16	9	142
h America	31	4.8	4.9	0.7	7.2	1.5	4	2	1.4	11.9	69
pe	95	24	6.9	3.7	31.1	5.6	5.4	1.7	0.8	7.5	182
	79	8.4	8.7	0.7	18.4	5.6	9.3		0.01	11.7	142
	43	13.5	12.1	0.8	12.5	3.8	11		1.3	23.2	121
alia	31.6	2.6	10	0.05	3.9	2.7	2.9	1.4	0.3	3.9	59
	58.4	11.2	7.8	1	15	4.1	6.3	2.3	0.67	13.1	120
s[b]	0.958	0.233	0.220	0.017							1.428
s[b]					0.750	0.342	0.274	0.059			1.425

ingstone (1963); concentrations in mg/liter.

llequivalents of strongly ionized components.

Late Proterozoic Ocean

circa 800-500 Mybp