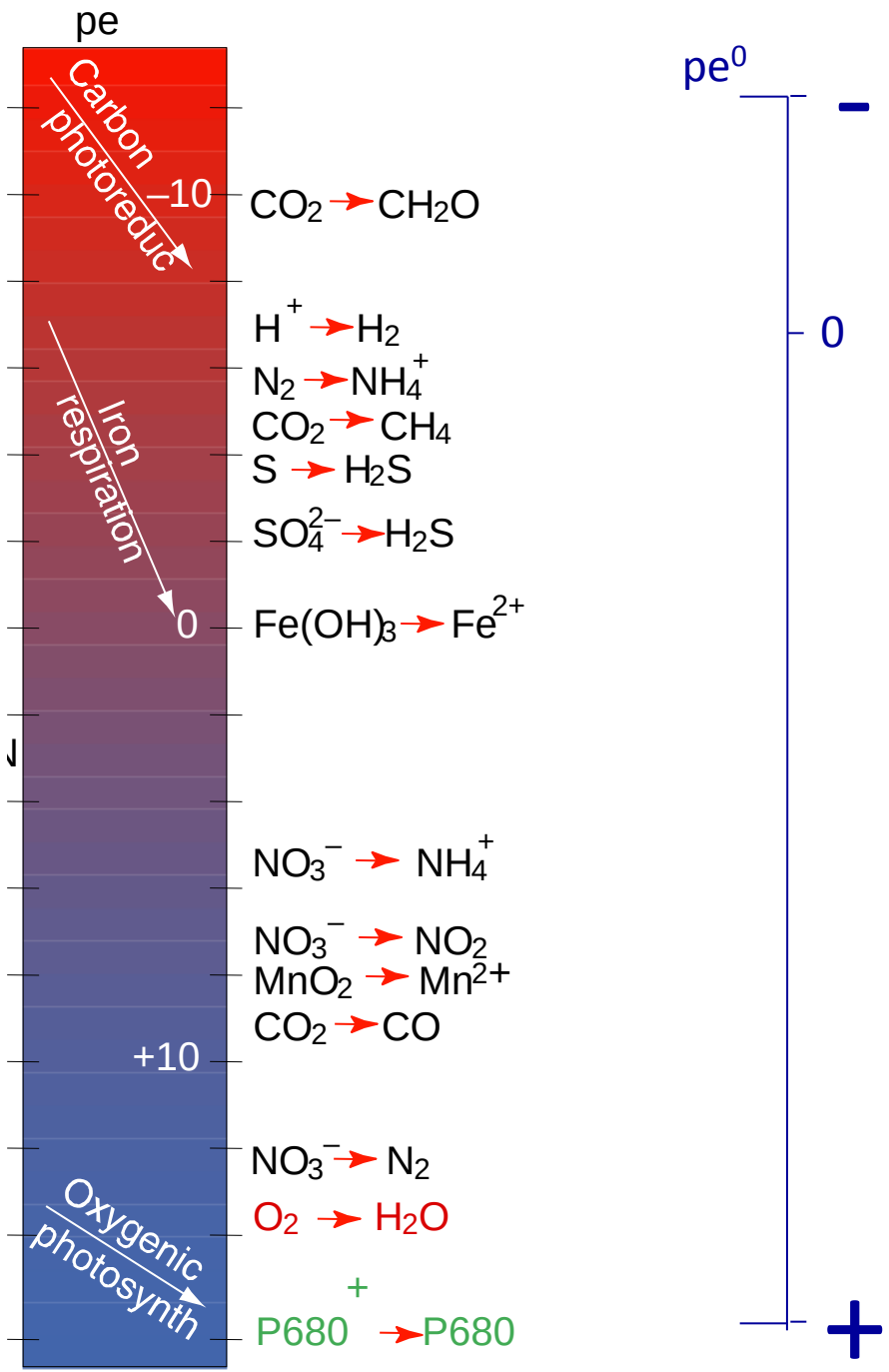
ENVIRONMENTAL REDOX AND PHOTOSYNTHESIS

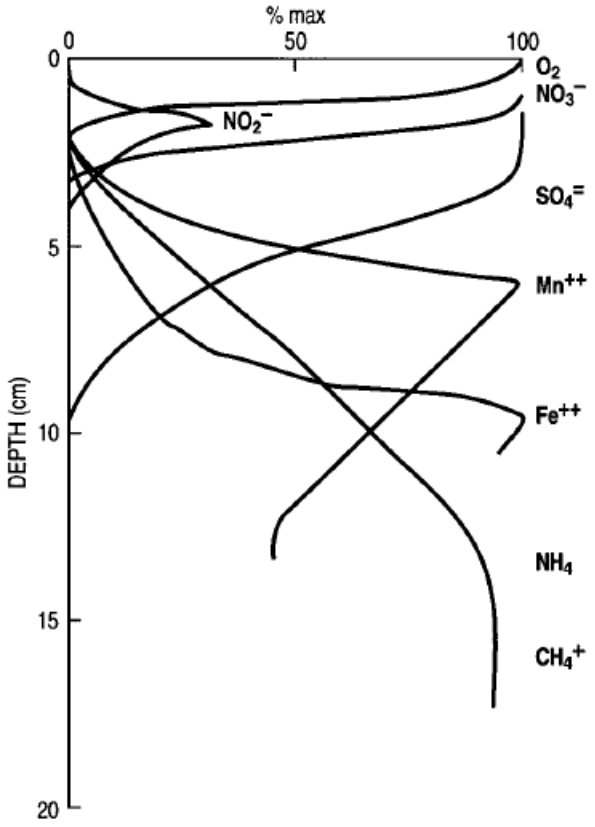
Concepts: Biogeochemical gradients according to the electron tower, redox calculations, anaerobic metabolisms, photosynthetic electron donors, anoxygenic and oxygenic photosynthesis, electron transport in photosynthetic organisms, photosynthetic pigments and reaction centers, geological record of oxygenic and anoxygenic photosynthesis.

Adapted from The
Carl Sagan Lecture
By Joe Kirschvink

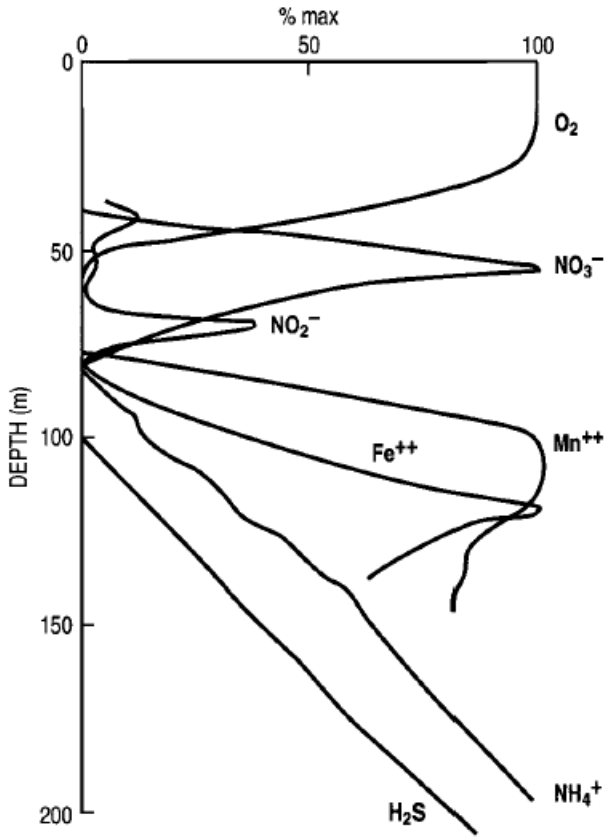


Courtesy of Joe Kirschvink. Used with permission.

The electron tower generally explains porewater chemistry



Lake Michigan Sediment



Black Sea

Example of an anaerobic metabolism: Microbial growth in Mono Lake, CA

Image courtesy of USGS.

Image courtesy of State of California.

This table has been removed due to copyright restrictions. Please see Table 3B-2 on page http://www.monobasinresearch.org/images/mbeir/dchapter3/table3b-2.pdf.

Note: Concentrations have been adjusted to TDS of 100 g/l.

[a] Measured TDS concentrations.

Source: Based on LADWP measurements of lake and evaporation pond samples from 1974 to 1990. Russell (1984) and Mason (1967) analyses are given for comparison.

(Oremland et al., 2000)

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(Oremland et al., 2000)

$$Lactate^{-} + 2HAsO_4^{2-} + H^{+}$$

$$\longrightarrow Acetate^{-} + HCO_3^{-} + 2H_2AsO_3^{-}$$

$$(\Delta G'_0 = -156.8\ kJ\ mol^{-1}).$$

Image by MIT OpenCourseWare.

(Oremland et al., 2004)

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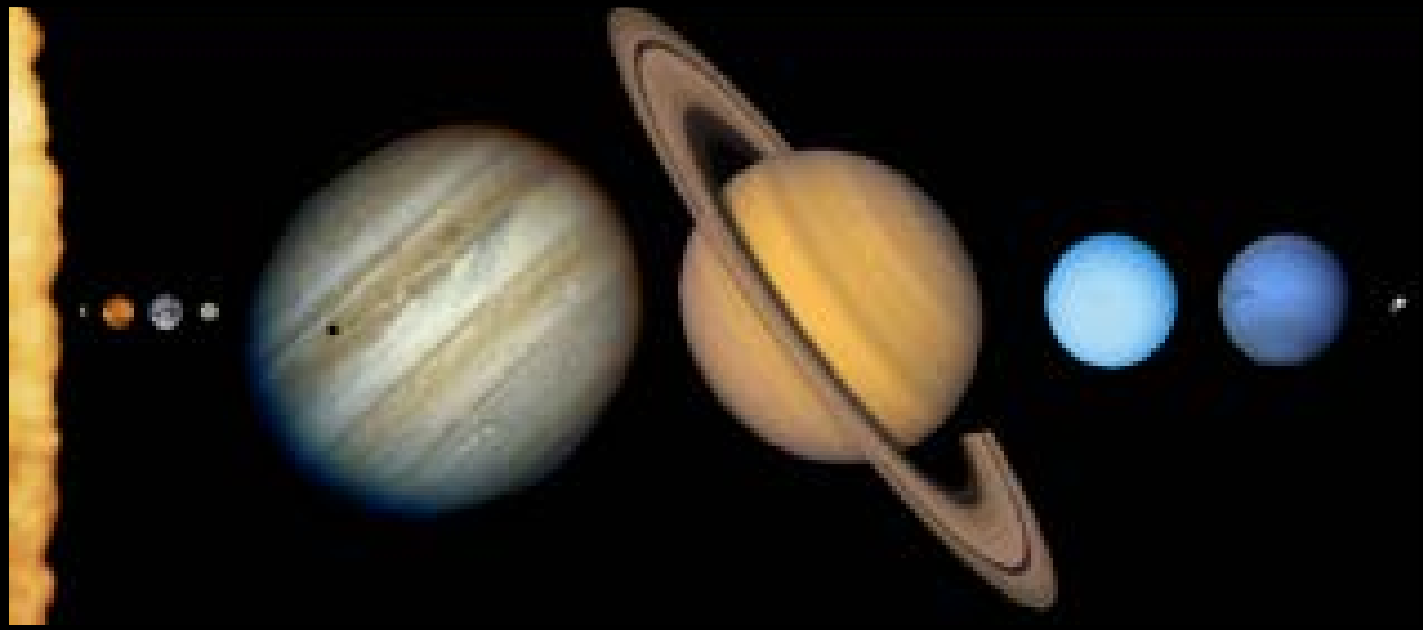
(Oremland et al., 2004)



THERE IS ~10,000 TIMES MORE SOLAR POWER THAN ALL OTHER SOURCES

Adapted from The
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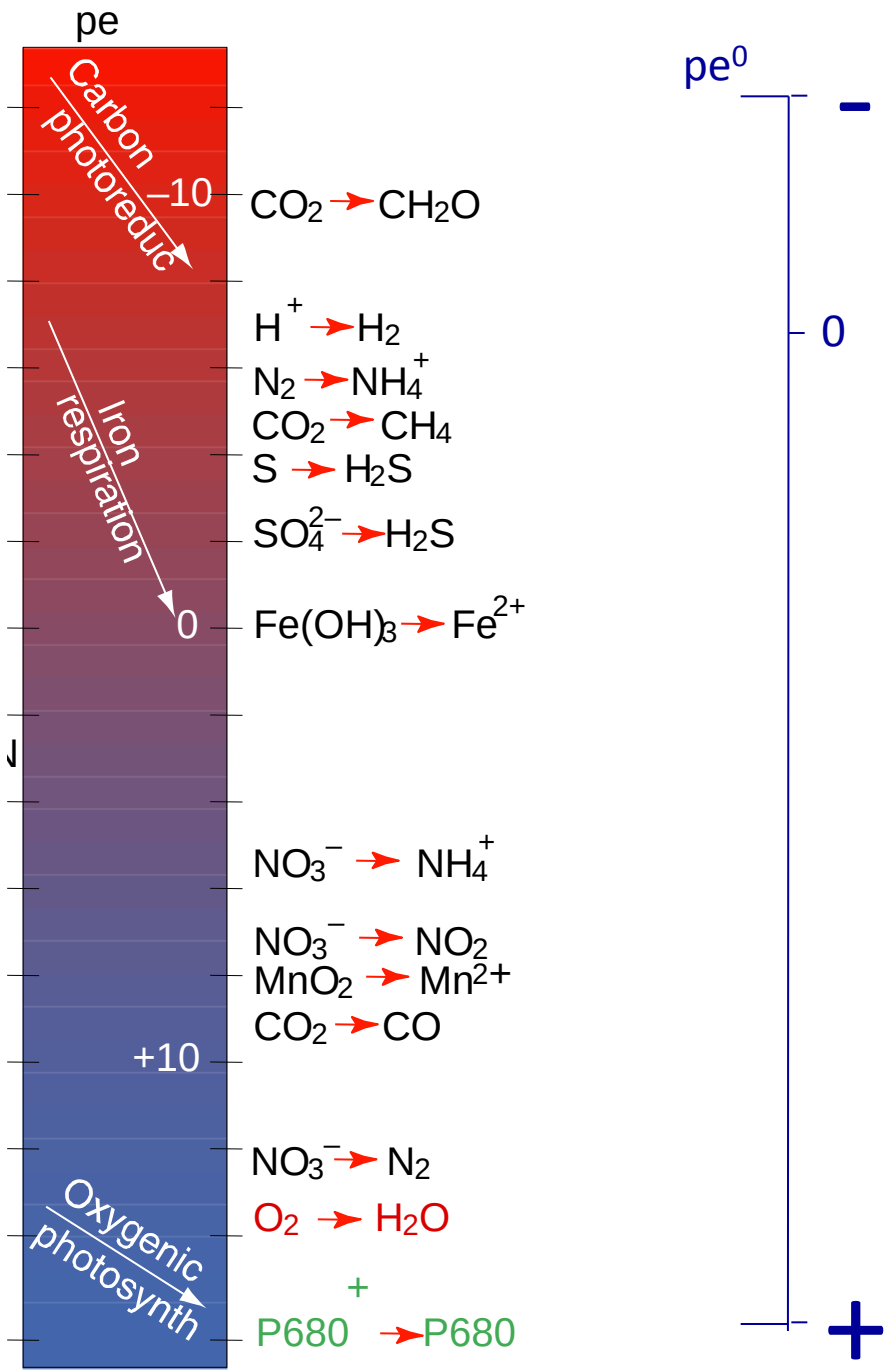
By Joe Kirschvink



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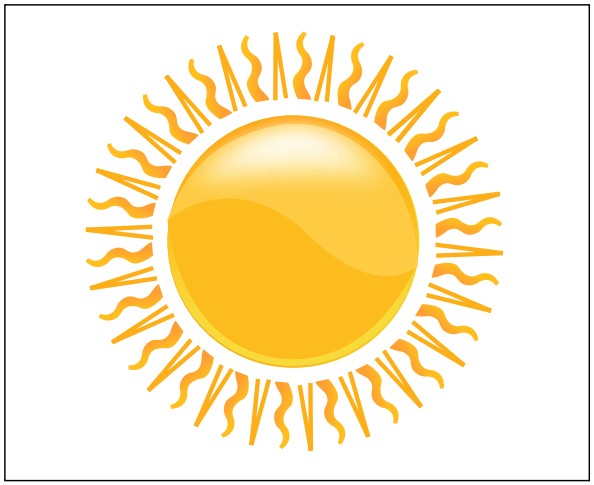

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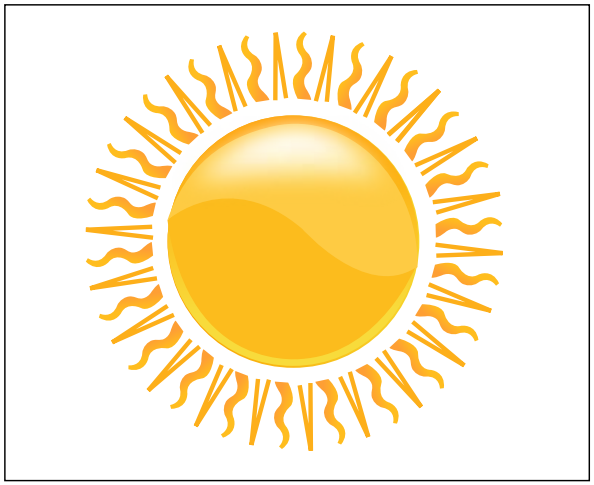
$$H_2O + CO_2 \rightarrow CH_2O + O_2$$



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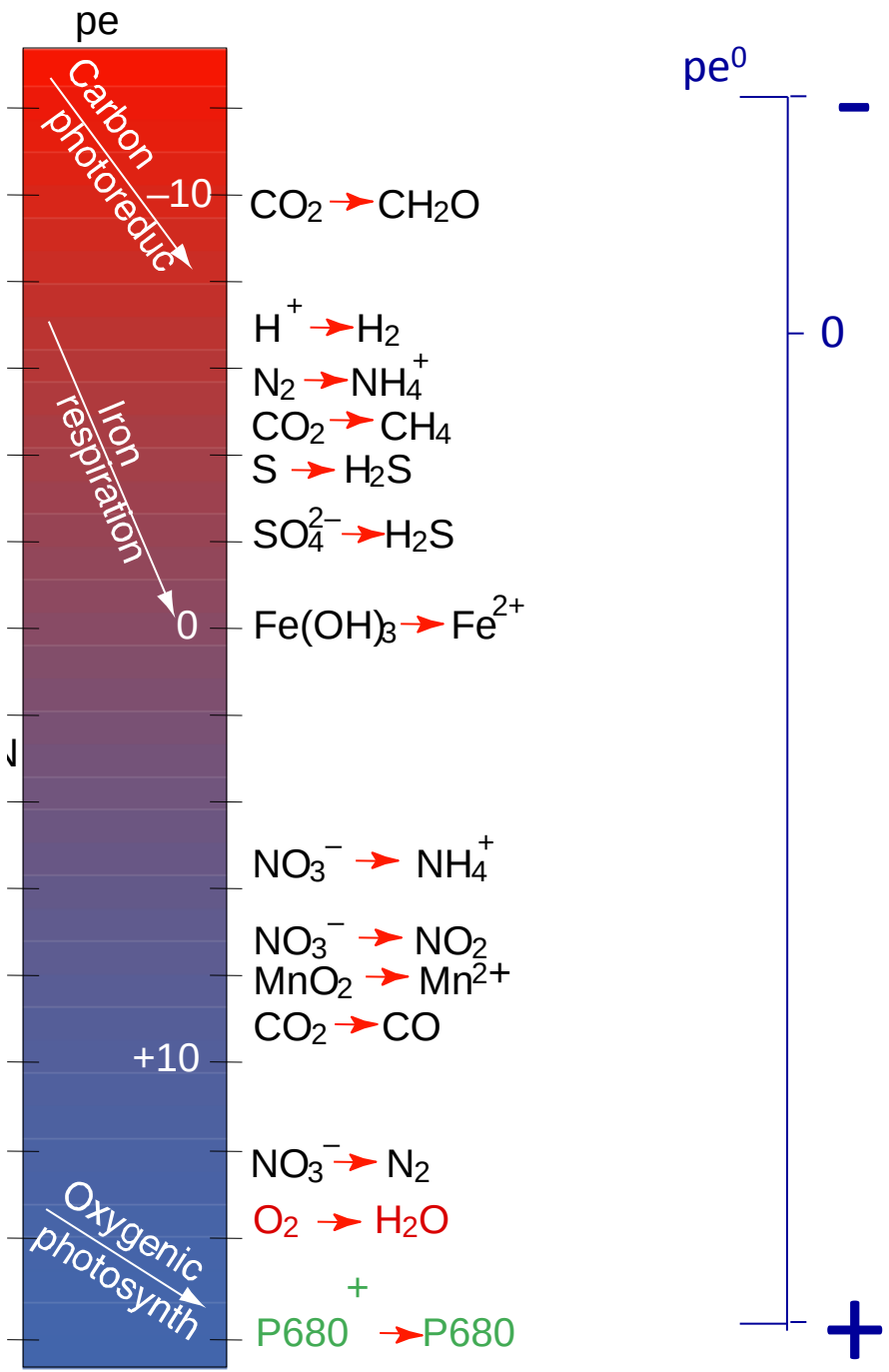
$$H_2A + CO_2 \rightarrow CH_2O + A$$

$$A = Fe^{2+},\ H_2,\ S,\ H_2S,\ \ldots$$

Adapted from The
Carl Sagan Lecture
By Joe Kirschvink



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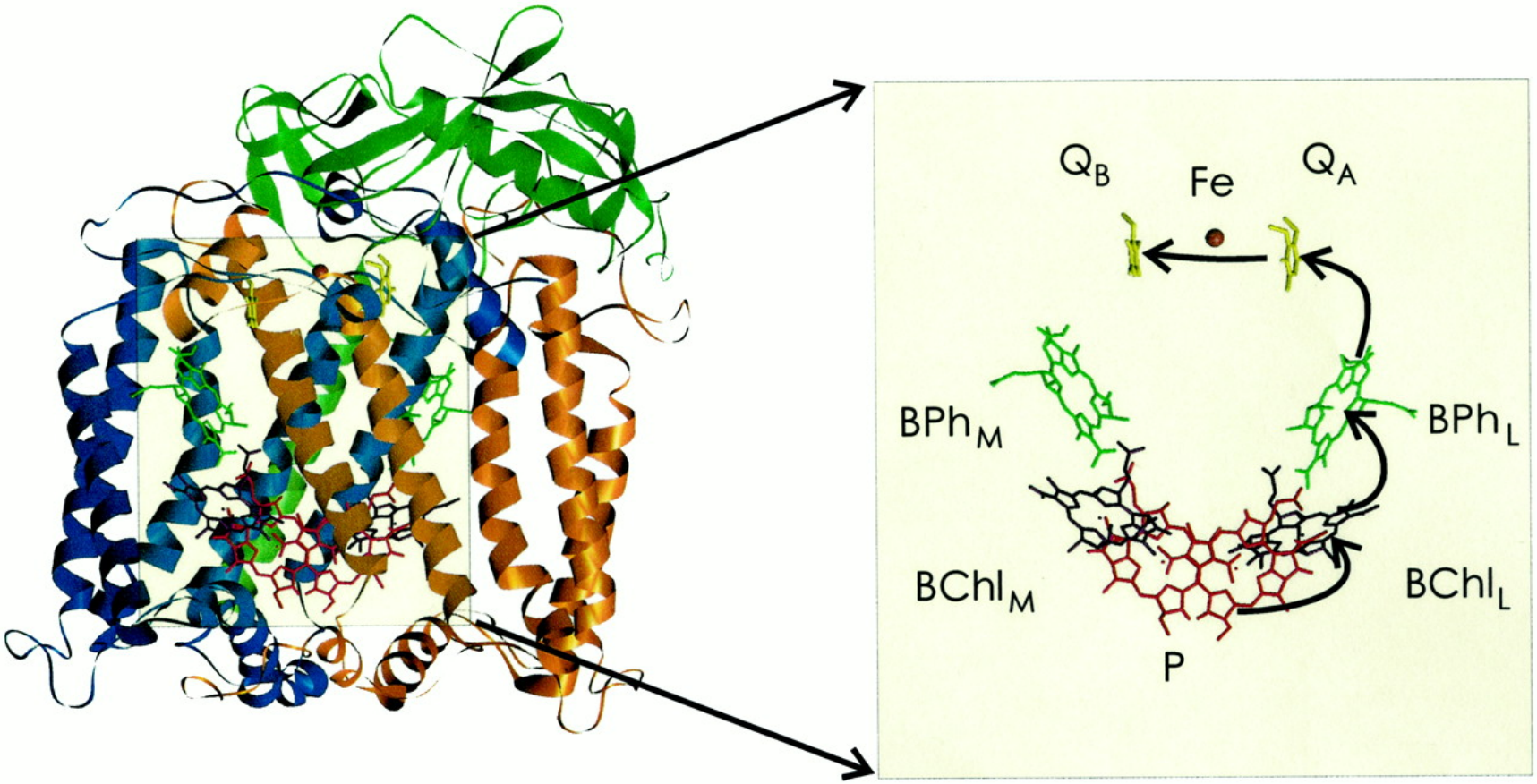
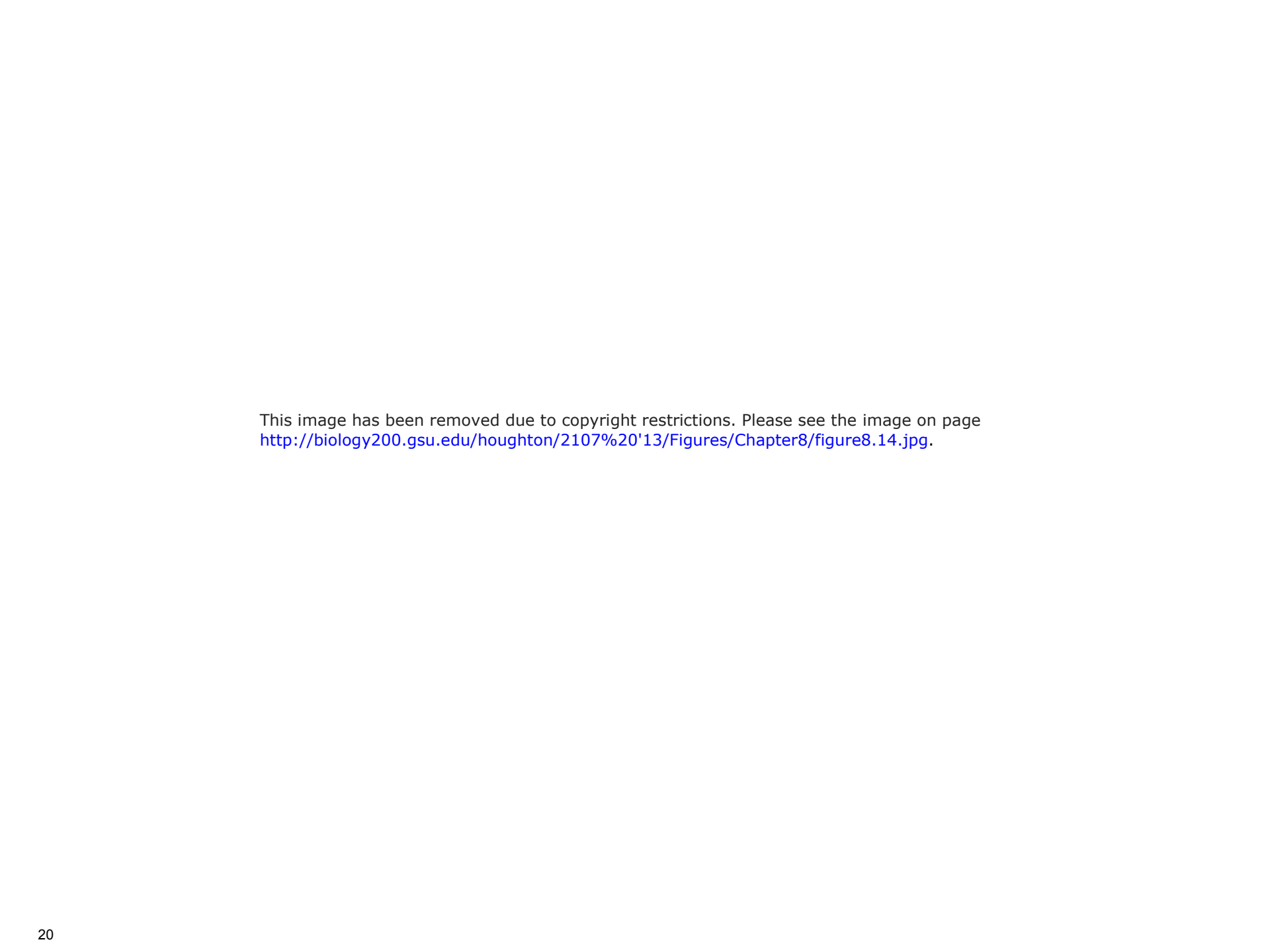
Electron transport in purple bacteria

PHOTOSYNTHETIC REACTION CENTER



Z- Scheme of electron transport in cyanobacteria and green plants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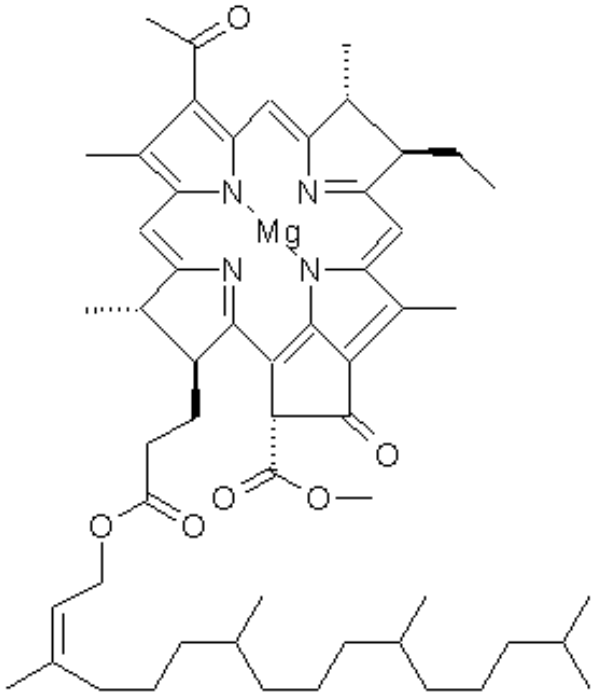
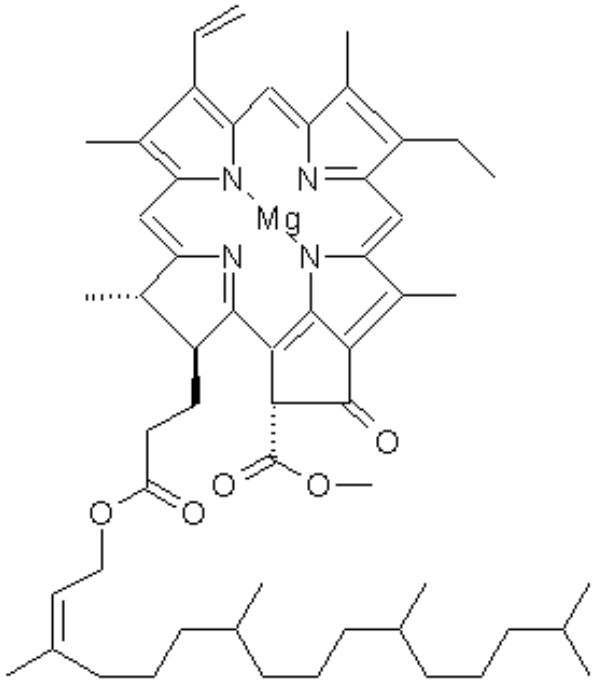
http://biology200.gsu.edu/houghton/2107%20'13/Figures/Chapter8/figure8.14.jpg.

MAJOR PHOTOSYNTHETIC PIGMENTS

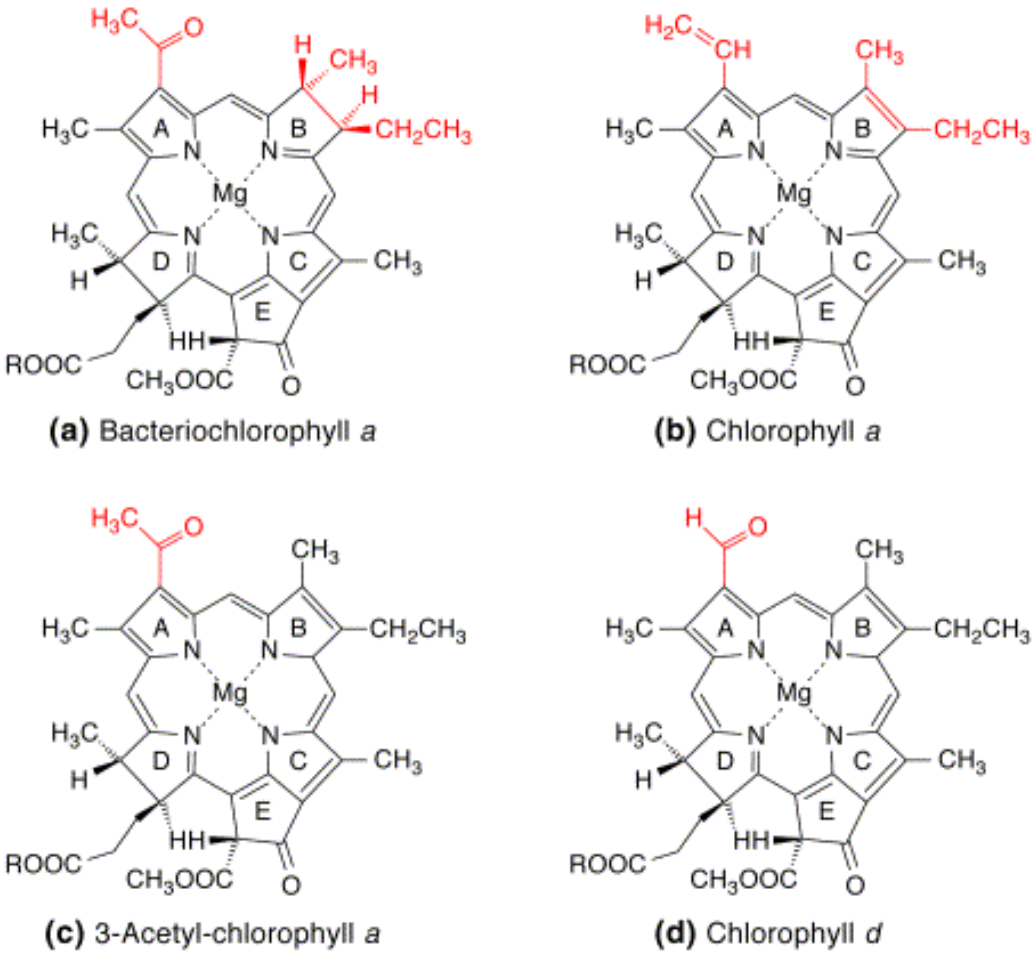


BACTERIOCHLOROPHYLL A
Anoxygenic



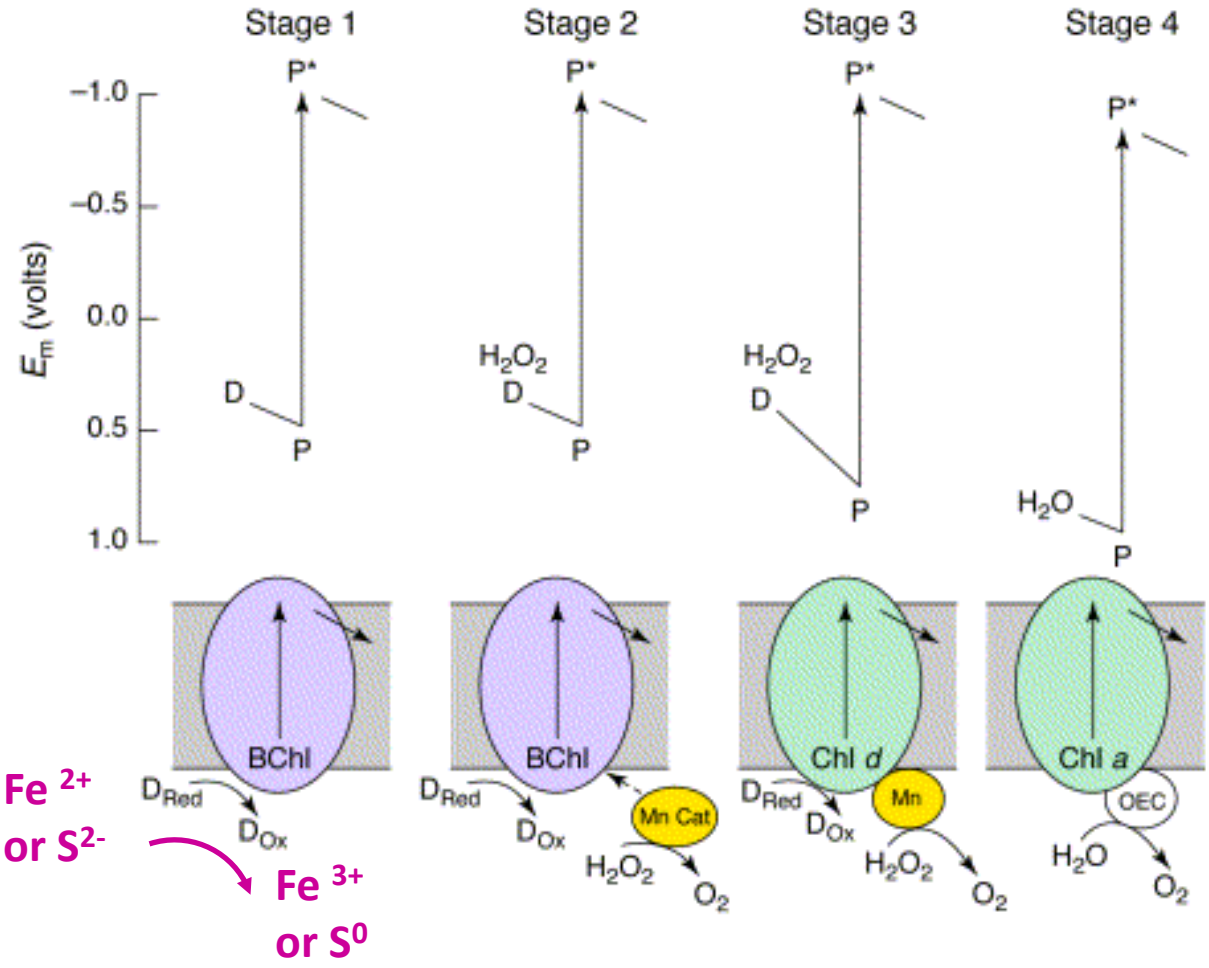
CHLOROPHYLL A
Oxygenic

Progressive evolution of tetrapyrole ring system for higher energy, lower λ excitation



Chemical structures of **(a)** bacteriochlorophyll *a* and **(b)** chlorophyll *a*. Differences in the structures are shown in red. Chemical structures of **(c)** 3-acetyl-chlorophyll *a* and **(d)** chlorophyll *d*. R is the phytyl tail.

Phylogeny of bch and chl genes



Ancestral Purple Bacterium

Fe $^{2+}$ or S^{2-}

Fe $^{3+}$ or S^0

Increasing excitation energy and yield

Incorporated from a Green S-Bacterium ??

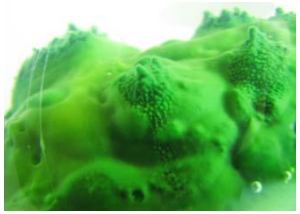
Evolving pigment and redox components

Evolutionary stages of oxygen evolution capacity (OEC). Four stages are depicted, although additional intermediate stages undoubtedly also existed. For each stage, the upper diagram shows an energetic picture, and the lower diagram a schematic of the reaction center protein in the photosynthetic membrane.

4500 4000 2500 500 million years

Precambrian			Phanerozoic
Hadean	Archean	Proterozoic	

O_2



KARIJINI NATIONAL PARK –WESTERN AUSTRALIA

BANDED IRON

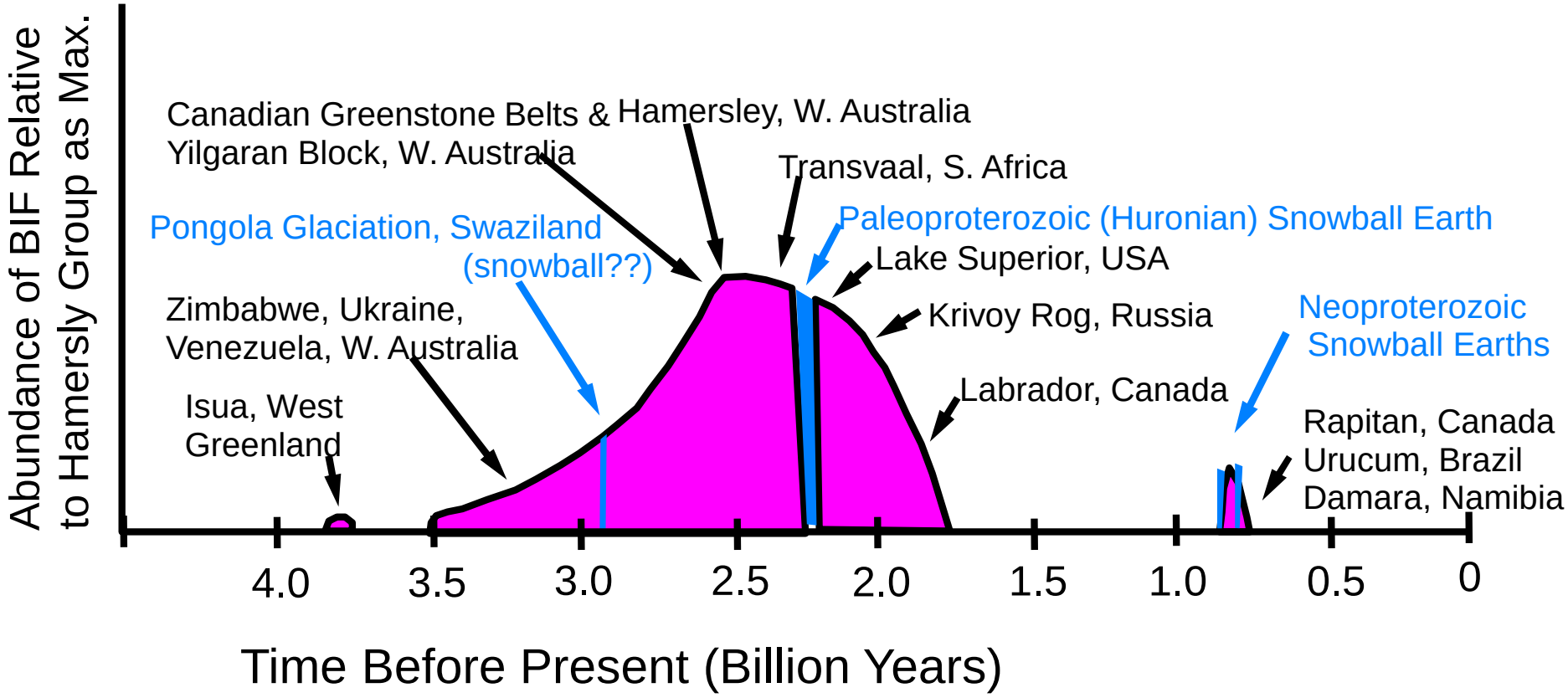
Evidence for life on Earth before 3,800 million years ago

S. J. Mojzsis*, G. Arrhenius*, K. D. McKeegan†,
T. M. Harrison†, A. P. Nutman‡ & C. R. L. Friend§

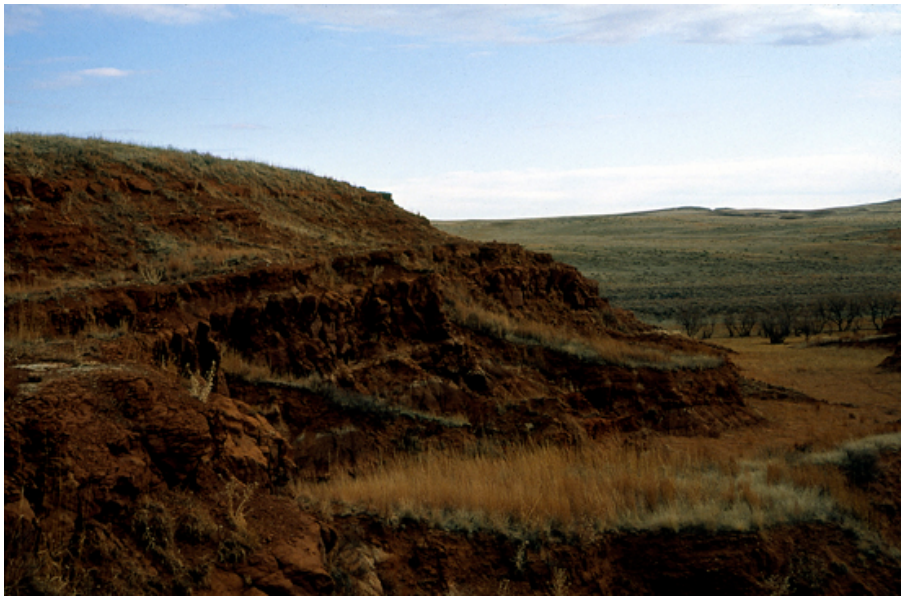
This image has been removed due to copyright restrictions. Please see the photo of rock in paper below.
Mojzsis, Stephen James, Gustaf Arrhenius, et al. "Evidence for Life on Earth Before 3,800 Million Years Ago." *Nature* 384, no. 6604 (1996): 55-9.

Precambrian Banded Iron Formations (BIFs)

(Adapted from Klein & Beukes, 1992)



Red beds



Photos: Kansas Geological Survey

Paleosols

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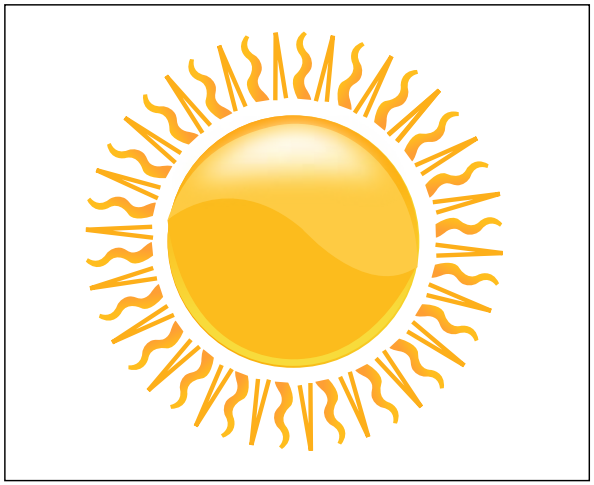

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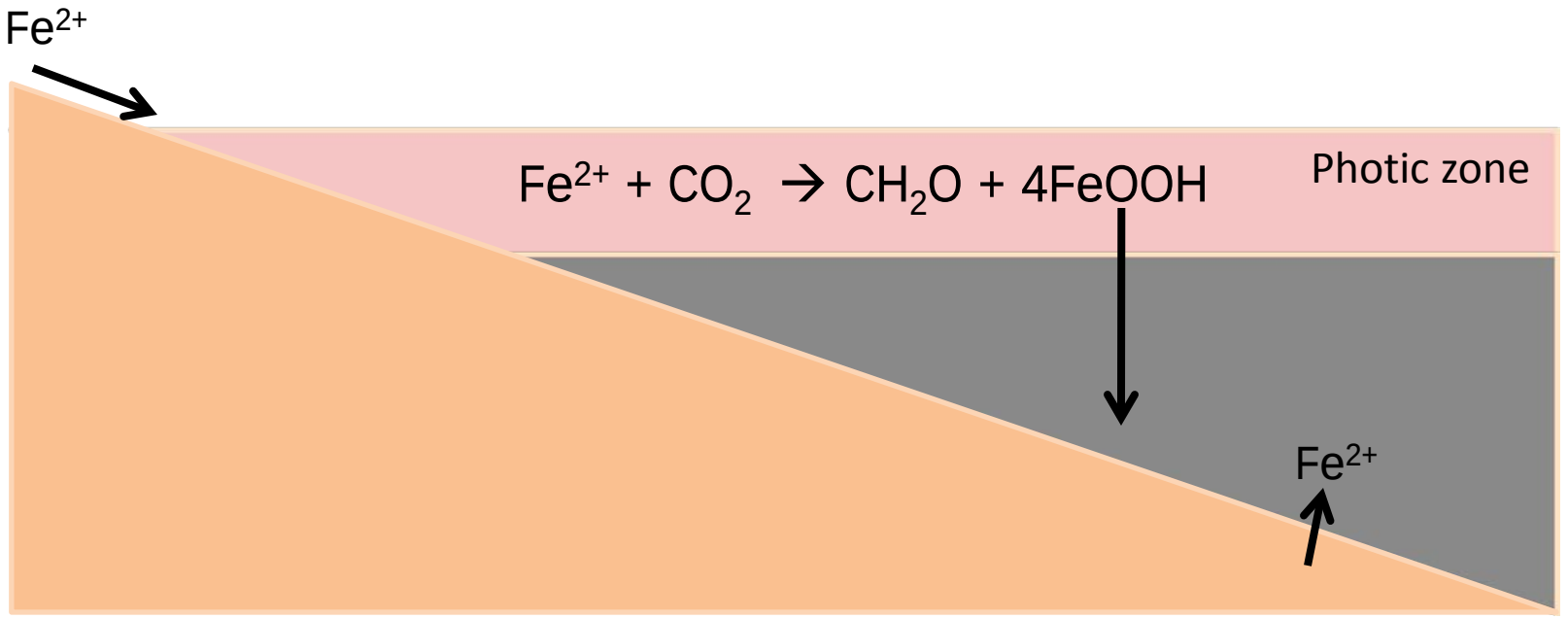
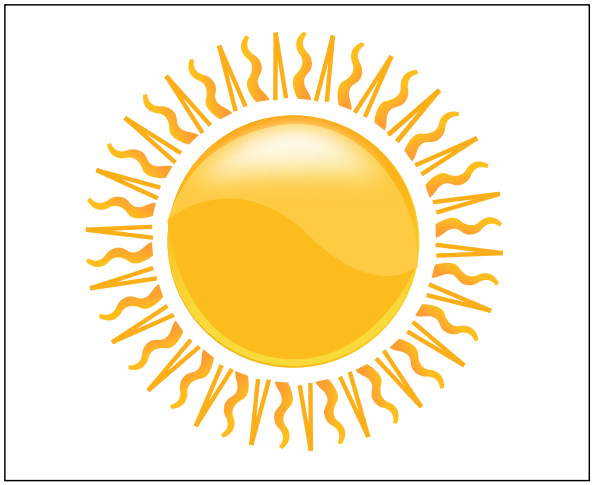


(Canfield et al. 2006, Kharecha et al. 2005, Kappler et al. 2005)



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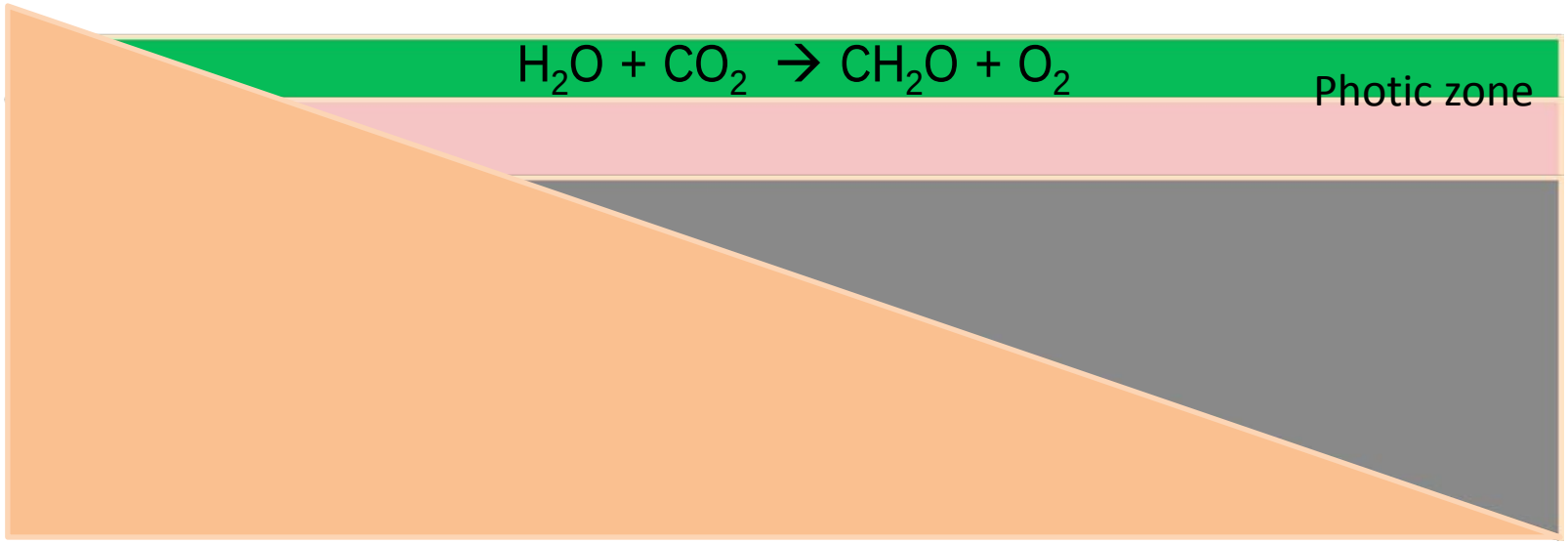
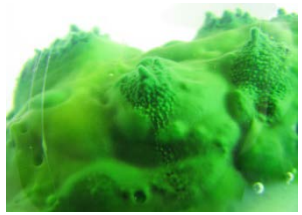


4500 4000 2500 500 million years

Precambrian			Phanerozoic
Hadean	Archean	Proterozoic	

O_2



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CHLOROPHYLL-C PLANKTON

DIATOMS


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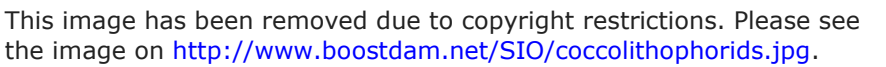
COCCOLITHOPHORIDS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12.007 Geobiology

Spring 2013