

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.

Electron transport in purple bacteria

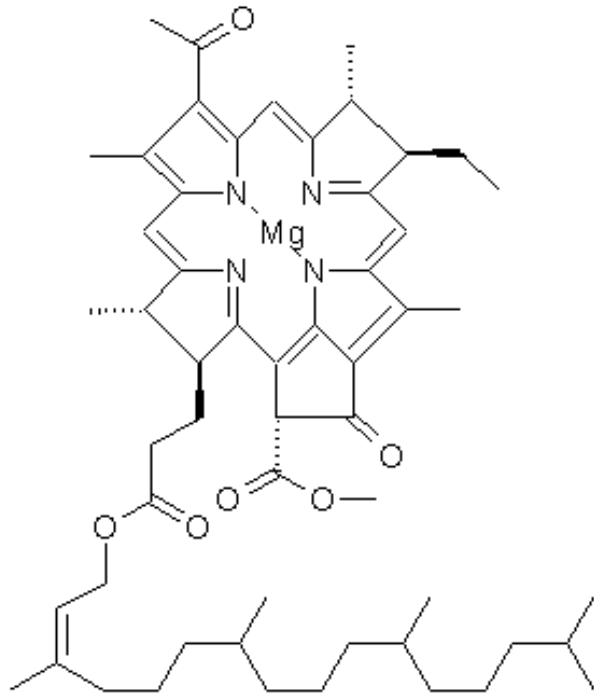
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Z- Scheme of electron transport in cyanobacteria and green plants

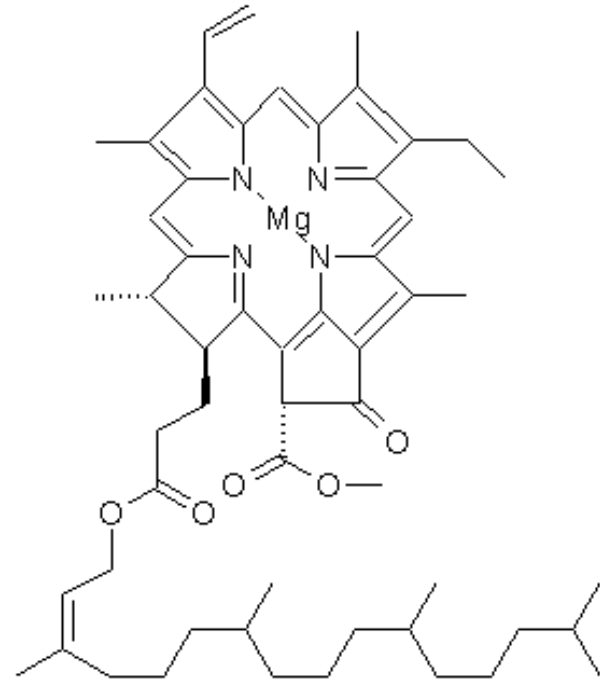
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<http://biochimej.univangers.fr/Page2/COURS/Zsuite/2Photosynthese/6SchemaZ/3Figures/2SchemaZHornton.gif>.

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MAJOR PHOTOSYNTHETIC PIGMENTS

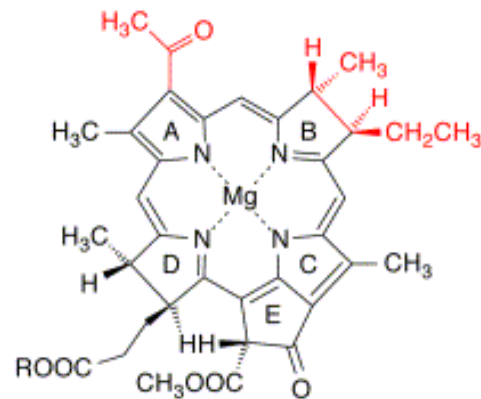


BACTERIOCHLOROPHYLL A
Anoxygenic

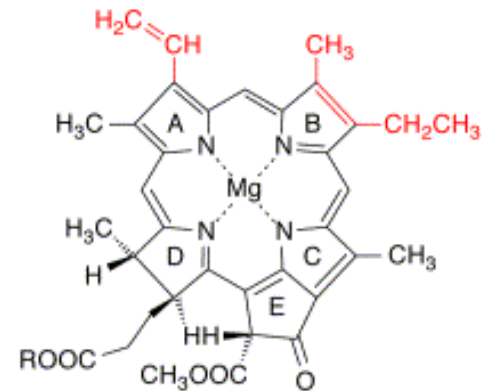


CHLOROPHYLL A
Oxygenic

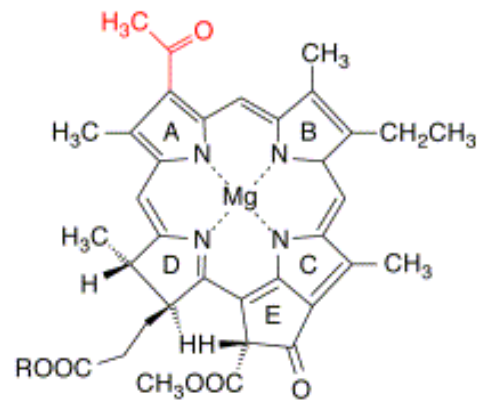
Progressive evolution of tetrapyrrole ring system for higher energy, lower λ excitation



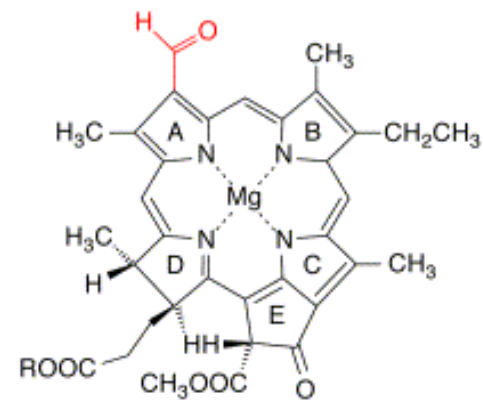
(a) Bacteriochlorophyll *a*



(b) Chlorophyll *a*



(c) 3-Acetyl-chlorophyll *a*

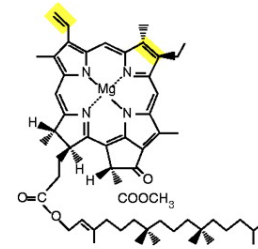
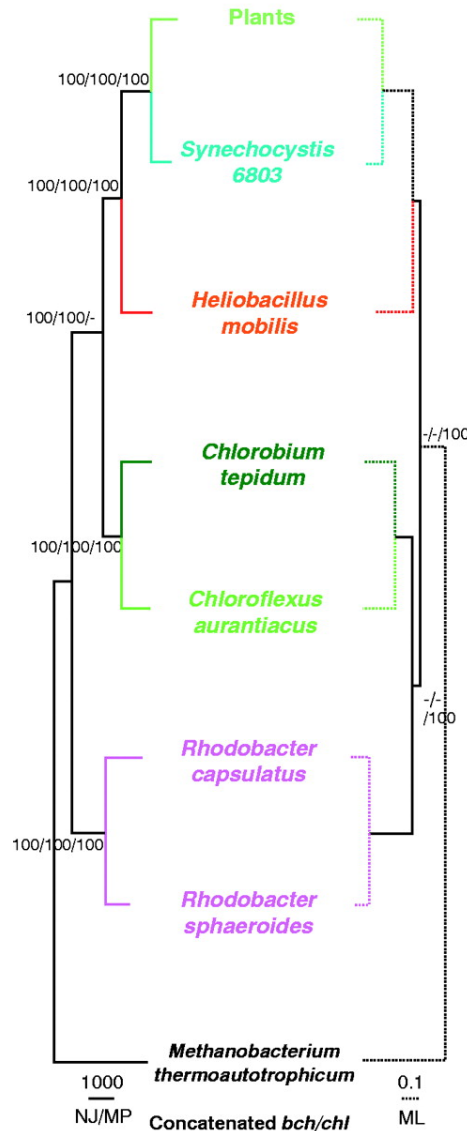


(d) Chlorophyll *d*

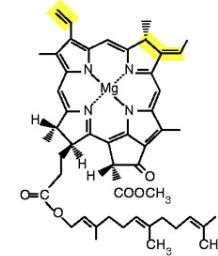
Chemical structures of (a) bacteriochlorophyll *a* and (b) chlorophyll *a*. Differences in the structures are shown in red. Chemical structures of (c) 3-acetyl-chlorophyll *a* and (d) chlorophyll *d*. R is the phytyl tail.

Phylogeny of bch and chl genes

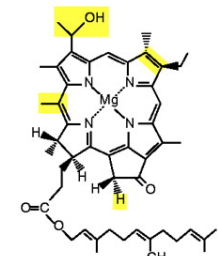
c



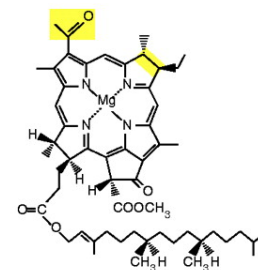
Chlorophyll a (Plants/Cyanobacteria)



Bacteriochlorophyll g (Heliobacteria)

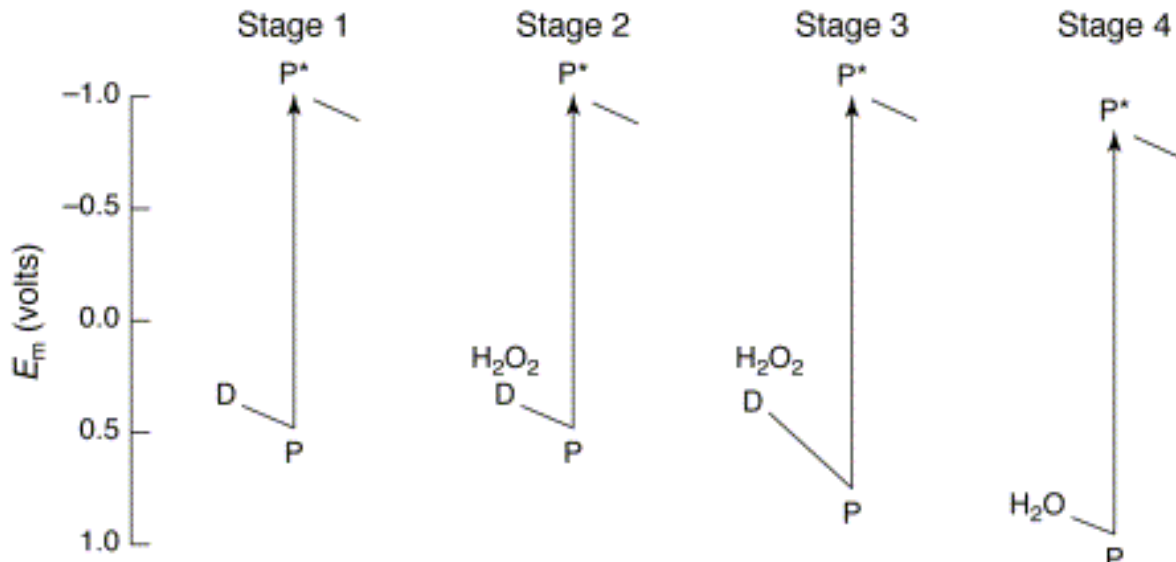


Bacteriochlorophyll c (Green bacteria)

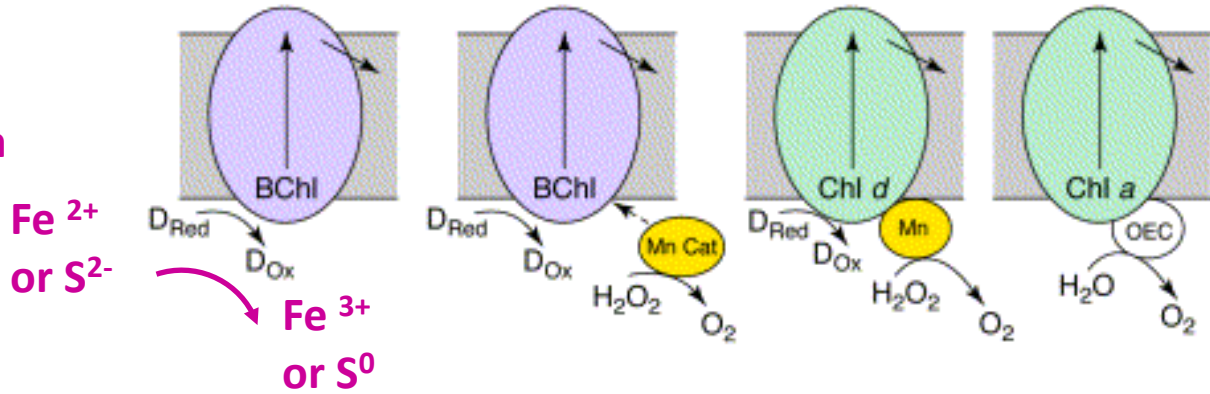


Bacteriochlorophyll a (Purple bacteria/green bacteria)

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Ancestral Purple Bacterium



Increasing excitation energy and yield

Incorporated from a Green S-Bacterium ??

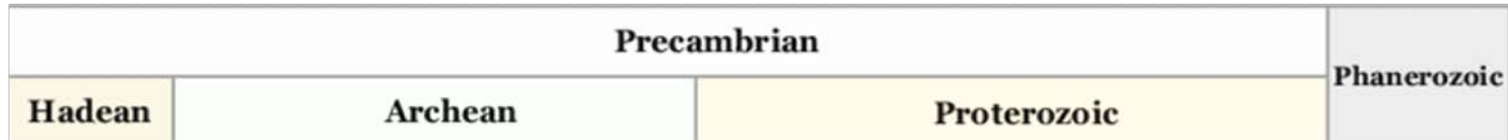
Evolving pigment and redox components



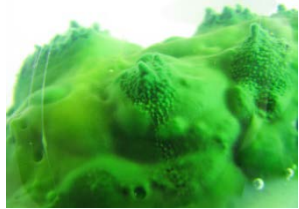
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Evolutionary stages of oxygen evolution capacity (OEC). Four stages are depicted, although additional intermediate stages undoubtedly also existed. For each stage, the upper diagram shows an energetic picture, and the lower diagram a schematic of the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

4500 4000 2500 500 million years



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O₂



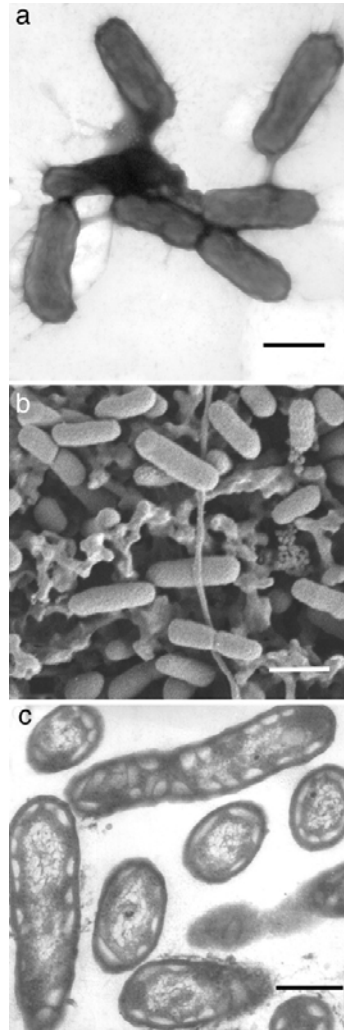
MODERN ANOXYGENIC PHOTOSYNTHETIC BACTERIA IN DEEPER LAYERS OF MICROBIAL MATS

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MODERN ANOXYGENIC PHOTOSYNTHETIC BACTERIA IN THE WATER COLUMNS OF MEROMICTIC LAKES

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An obligately photosynthetic bacterial anaerobe from a deep-sea hydrothermal vent



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Beatty J T et al. *PNAS* 2005;102:9306-9310

KARIJINI NATIONAL PARK –WESTERN AUSTRALIA



BANDED IRON



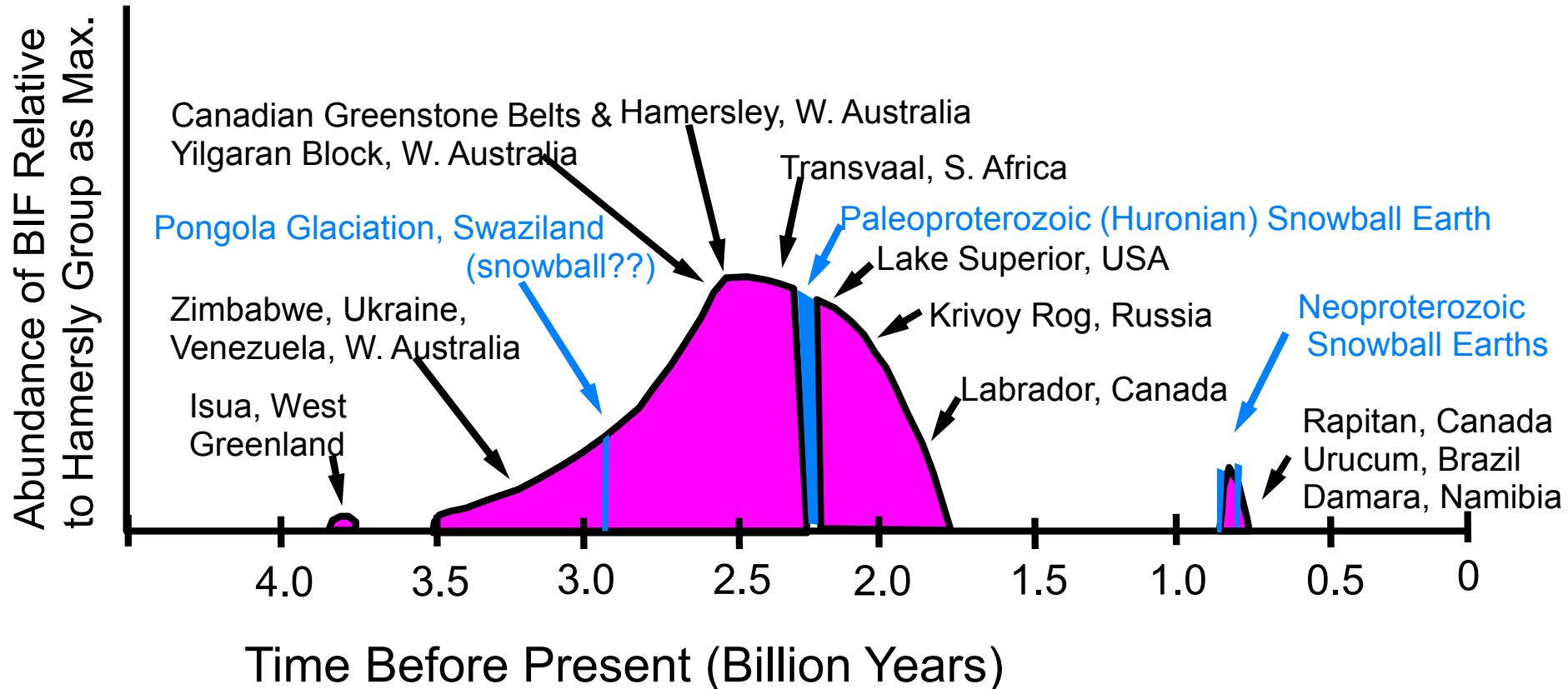
Evidence for life on Earth before 3,800 million years ago

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

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Precambrian Banded Iron Formations (BIFs)

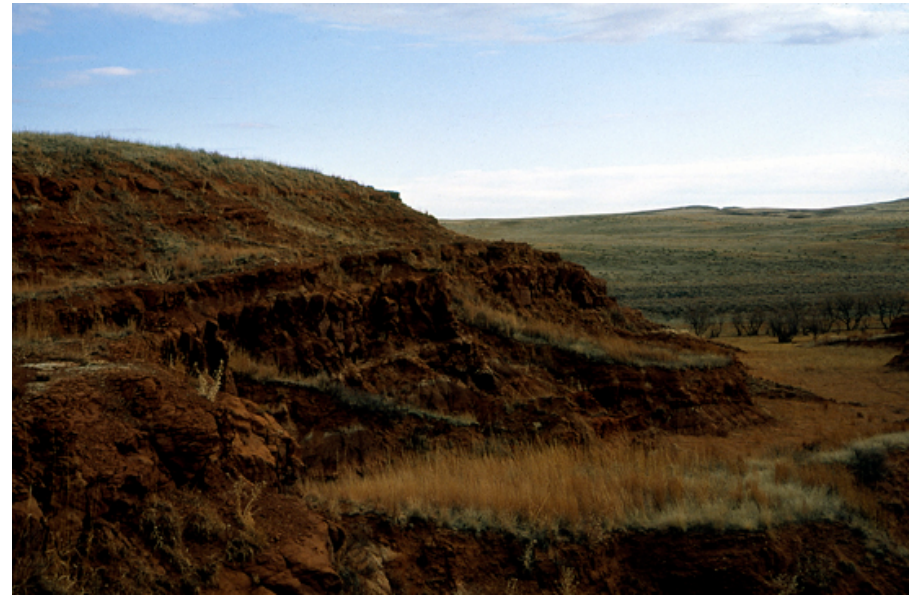
(Adapted from Klein & Beukes, 1992)



Courtesy of Joe Kirschvink. Used with permission.

Courtesy Joe Kirschvink, CalTech

Red beds



Photos: Kansas Geological Survey

Paleosols

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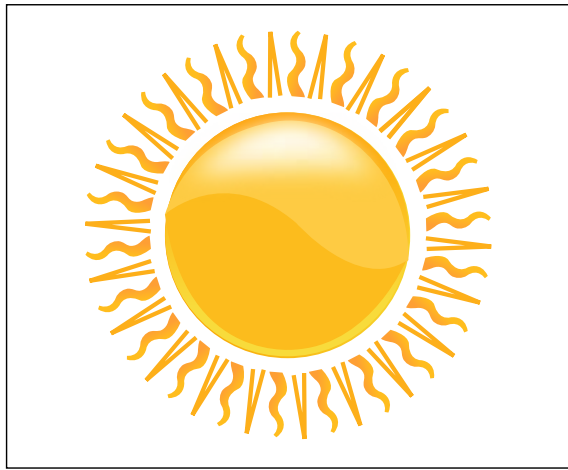
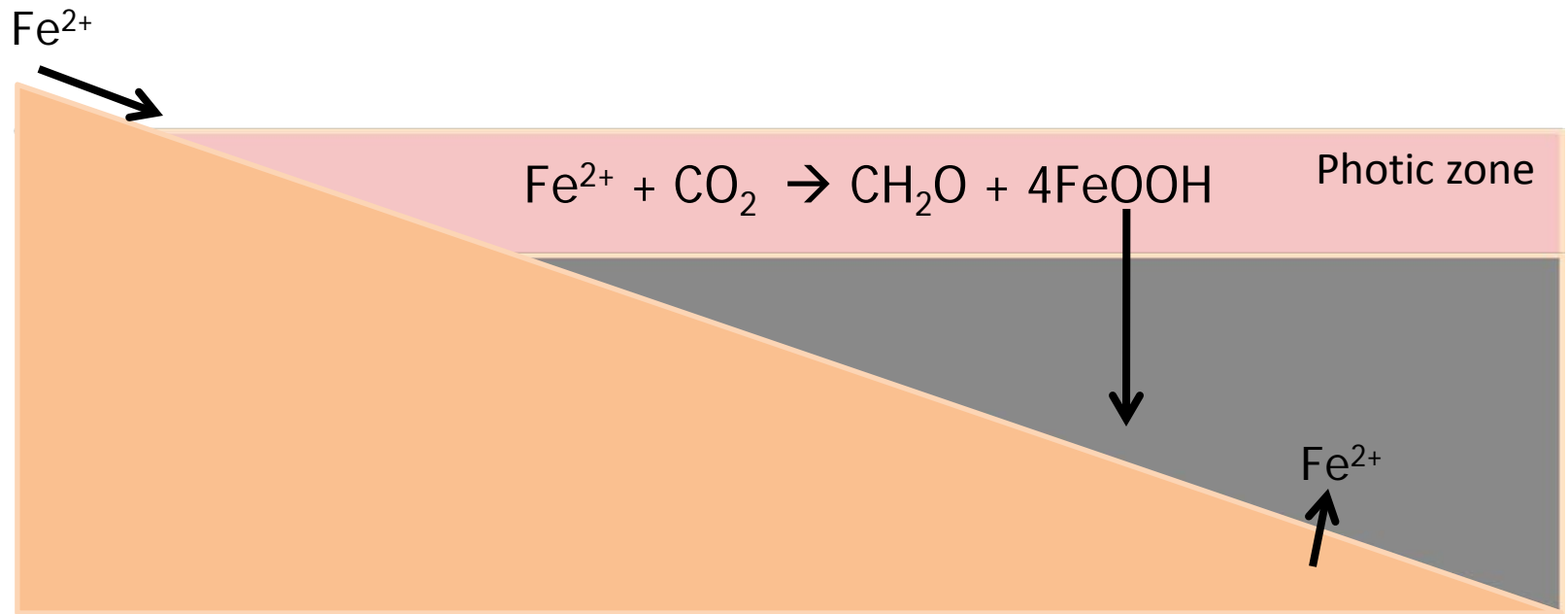


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(Canfield et al. 2006, Kharecha et al. 2005, Kappler et al. 2005)

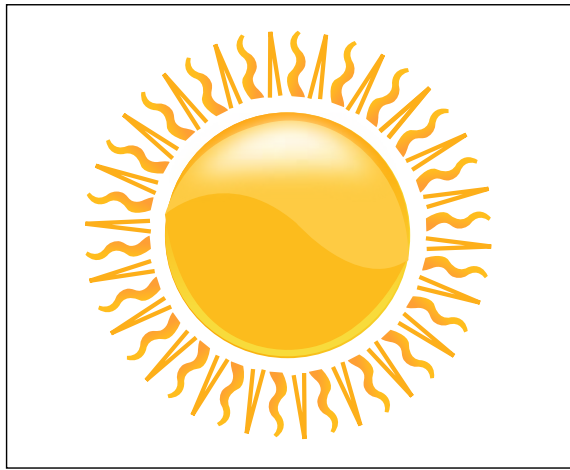
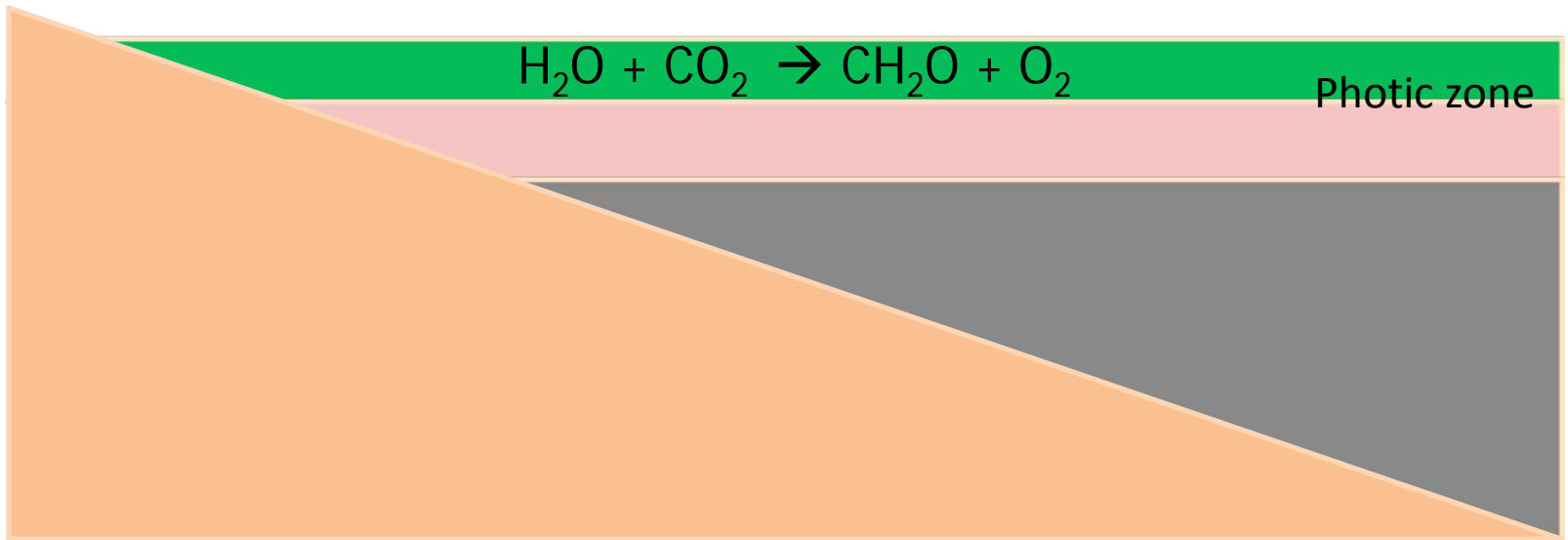


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STROMATOLITE RECORD OF MICROBIAL INTERACTIONS WITH SEDIMENTS

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<http://www.annualreviews.org/doi/full/10.1146/annurev-earth-042711-105327>.

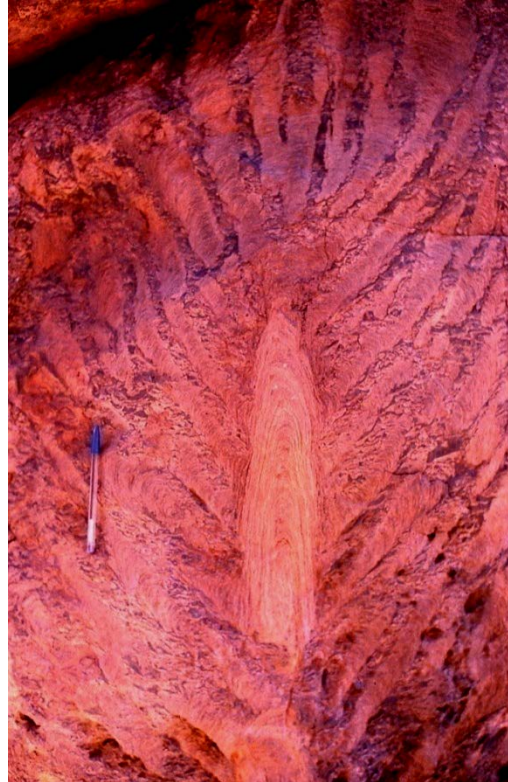
STROMATOLITES AS INDICATORS OF MICROBIAL PROCESSES

3.4 Ga



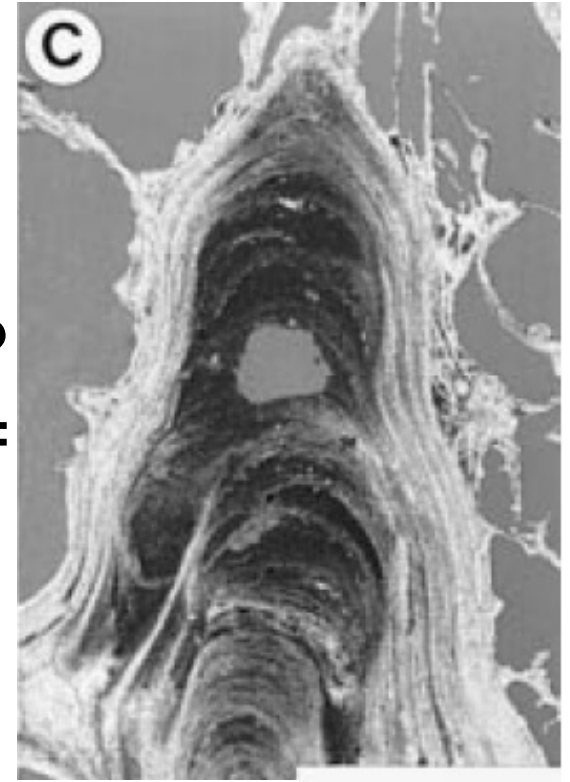
?
=

1.2 Ga



?
=

modern

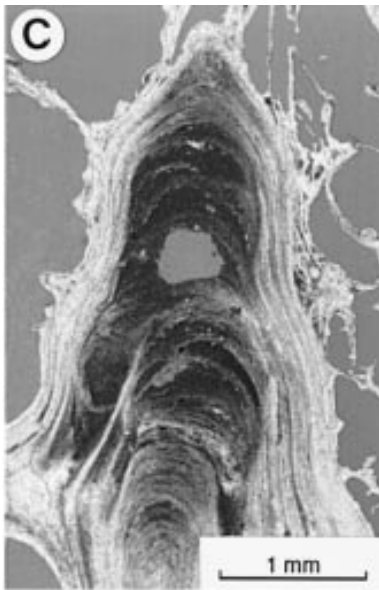


Allwood et al. 2007

Photo: P. Hoffman

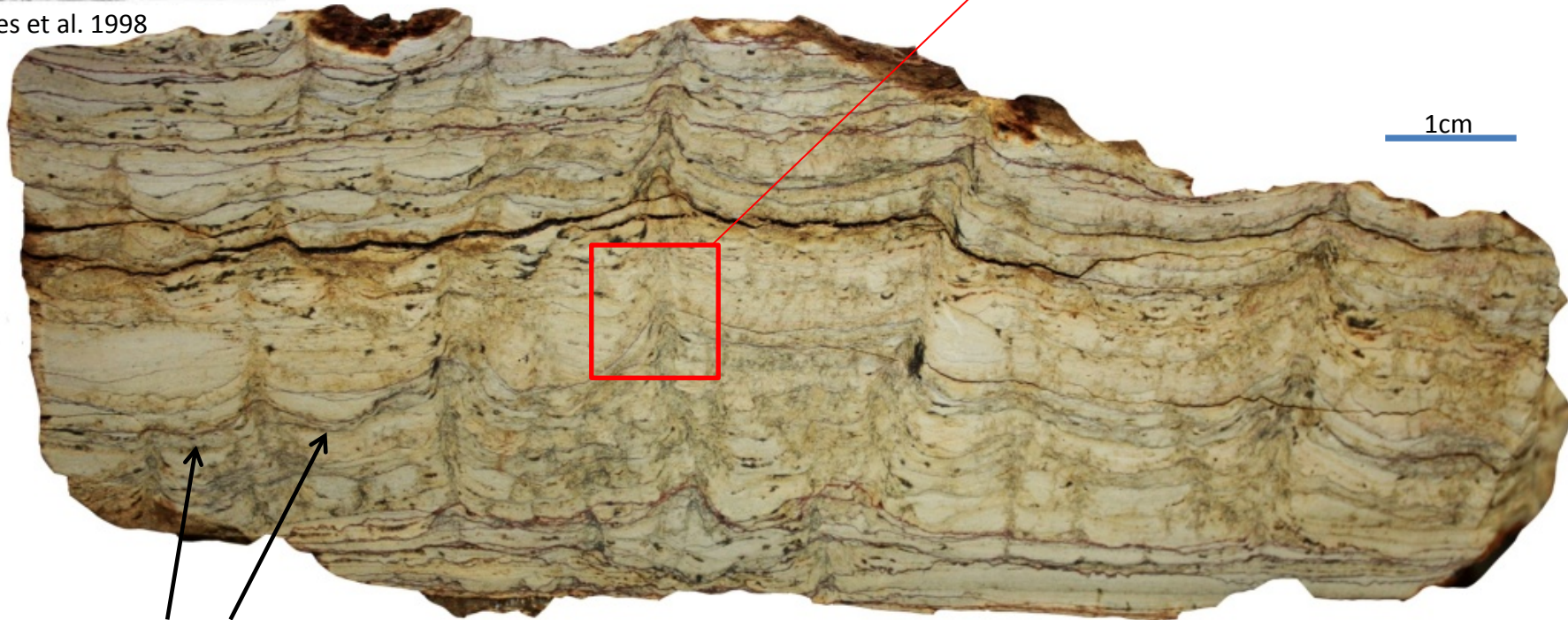
Jones et al. 1998 1 mm

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Jones et al. 1998

modern ← ancient (2.7Ga) →

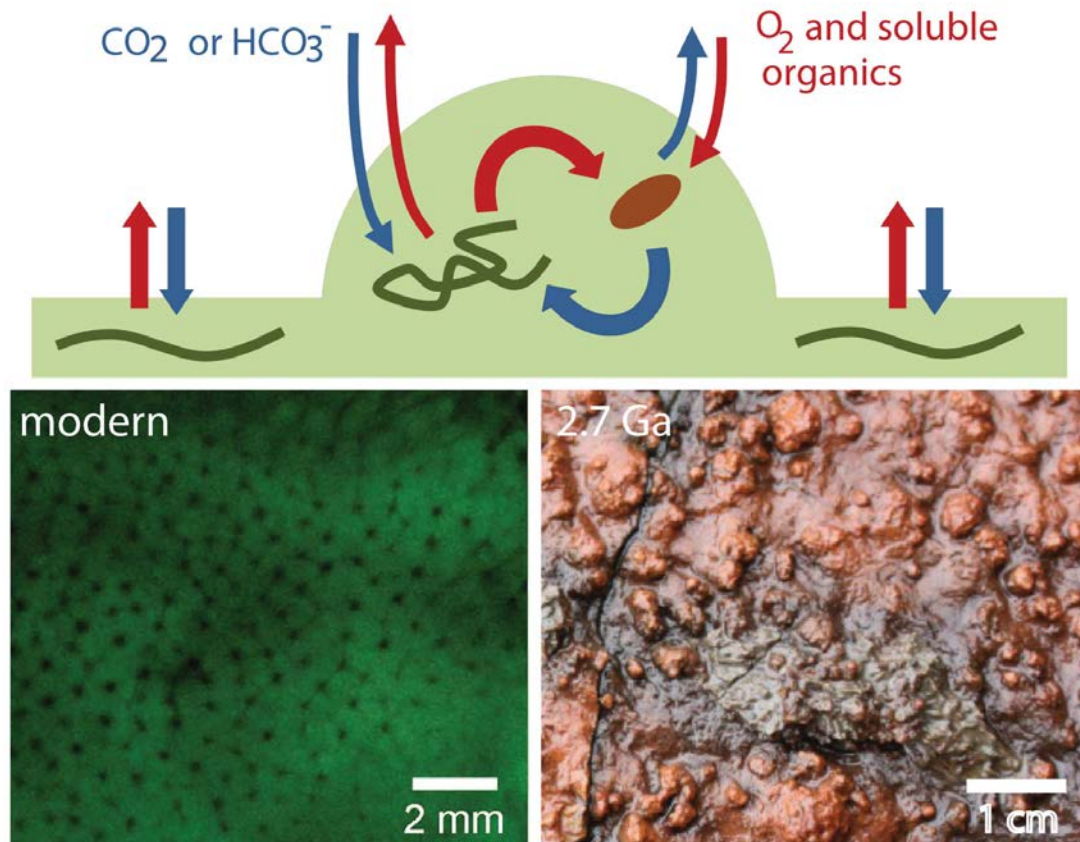


regularly occurring inter-column laminae

STROMATOLITE MORPHOLOGY AND OXYGENIC PHOTOSYNTHESIS AT 2.7 GA?

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STROMATOLITE MORPHOLOGY AND OXYGENIC PHOTOSYNTHESIS AT 2.7 GA?



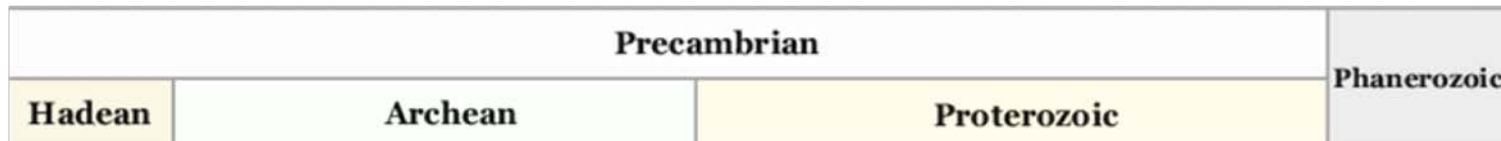
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Sim et al. 2012

STROMATOLITE MORPHOLOGY AND OXYGENIC PHOTOSYNTHESIS AT 2.7 GA?

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4500 4000 2500 500 million years



— — — — —
O₂



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CHLOROPHYLL-C PLANKTON

DIATOMS

COCCOLITHOPHORIDS

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12.007 Geobiology
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