"The Microbial Earth: More than 4,000,000,000,000,000,000,000,000,000,000 served"

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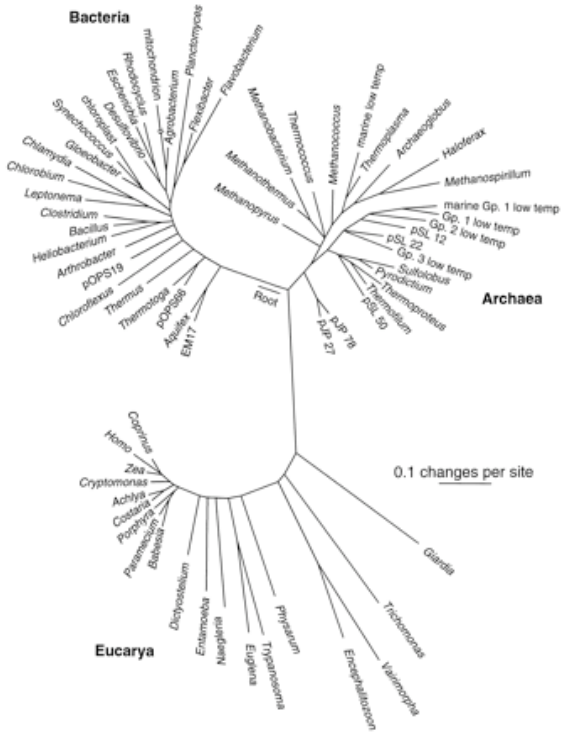
Microbial Abundance in the Biosphere

(*Whitman et al, 1998,* "Prokaryotes: The unseen majority", *PNAS, 95: 6578)*

- The Earth has 4 to 6 x 10^{30} prokaryotic cells (There are 3 x 10^{26} stars in the visible universe)
  - 350-550 x 1015 g Carbon (60-100% of C in plants)
  - 85-130 x 1015 g Nitrogen (>10x all plant N)
  - 9-14 x 1015 g Phosphate (>10x all plant P)
  -
- There are 2.6 x 1029 prokaryotic cells in the Earth's Soils

A Brief History of Microbial Biology

- Microscopic Observation
- Cultivation and Experiment
- Bulk Environmental Measurements
- Molecular Evolution Paradigm



Microbial Physiology

- **Animals and most Fungi:**
  (CH2O)n + O2 ® CO2 + H2O
  electron donor = (CH2O)n
  electron acceptor = O2

- **Plants and Algae:**
  H2O + CO2 + Light ® O2 + (CH2O)n
  electron donor = H2O
  electron acceptor = CO2

- **Microbes:**
  Compounds that can serve as electron donors and/or acceptors (a partial list):
  Carbon based: organic carbon, CH4, CO2, CO, methanol…
  Sulfur Based: sulfate, H2S, sulfuric acid, sulfur, thiosulfate, methyl sulfides…
  Nitrogen Based: NH4, NO3, NO2, N2O, NO
  Metal Based: iron, manganese, arsenic, chromium, gold, uranium. . .
  Non-metals: O2, H2

The Microbial Earth

- **5/6 of the history of life is microbial**

4.6 billion years	Earth formed
3.8 billion years	earliest evidence of life in form of stromatolites
2.8 billion years	earliest evidence for oxygenic photosynthesis
600 million years	oxygen reaching current levels
	appearance of multi-cellular animals
	start of Cambrian Explosion
400 million years	earliest evidence for land plants
100 million years	earliest mammals

- **Limits of Microbial Life:**

Temperature:	-1.5°C to 125°C
pH:	0 to 12
salt:	0 to >30% (seawater is 3%)

- **Methanogens**

- **Microbial Mats & Stromatolites**

  - **Cyanobacteria**

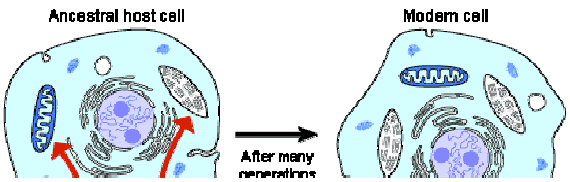
  - **Anoxygenic Phototrophs (Purple Sulfur and Green Sulfur Bacteria, Purple Non-sulfur and Green Non-sulfur Bacteria)**

  - **Sulfate Reducing Bacteria**

  - **Sulfide Oxidizing Bacteria**

- **Iron Oxidizing Bacteria**

- **Endosymbiosis and Evolution**



- Luminescent bacteria

(From Lynn Margulis, "The Origin of Eukaryotic Cells")

- Root nodules

- Hydrothermal vent systems
- Certain mollusks
- Many insects

Opportunities for Microbiology in the Classroom

Websites:
http://www.microbelibrary.org/
http://www.pbs.org/opb/intimatestrangers/
http://serc.carleton.edu/microbelife/index.html
http://www.microbeworld.org/home.htm
http://newton.physics.wwu.edu:8082/jstewart/scied/bio/microbio.html
http://www.science.siu.edu/microbiology/microforhighschoolteachers/index.html

Books:
"INTIMATE STRANGERS: UNSEEN LIFE ON EARTH"
By Cynthia A. Needham, PhD, Mahlon Hoaglan, PhD, Bert Dodson, Kenneth McPherson
ASM Press, ISBN 1-55581-163-9.
(A Companion Book to the PBS Series)

"Biodiversity of Microbial Life"
Edited by J. T. Staley and A-L Reysenbach
Wiley-Liss Inc, 2002, ISBN 0-471-25433-9

"Afield Guide to Bacteria"
Betsey Dexter Dyer
Cornell University Press, 2003, ISBN 0-8014-3902-7