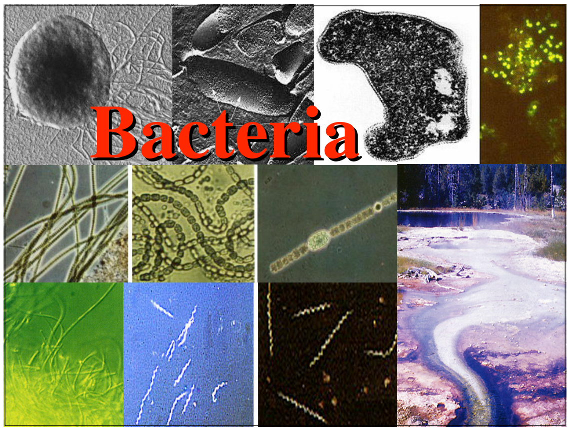


Bacteria are the most ancient life forms
- signs from ~3,500 m.y.a.

can tolerate great physical extremes

from ocean deeps to the stratosphere
to inside rocks & earth's crust

essentials = only H_20 + energy + matter

vast metabolic diversity, mostly unique;
- many sources of energy & matter

mostly **extremely tiny** - 0.1 - 10 x 10^{-6} m.

but extremely numerous:
1 spoon garden soil - 10^{10} cells
1 cm^2 gum scrape - 10^9 cells

total weight of all earth's bacteria
= $^1/_{10}$ all earth's mammals

cover all surfaces, interior & exterior;
mainly benign or beneficial

open genetic exchange; sex ≠ reproduction

bacterial metabolic activities exchange
all major reactive gases with atmosphere :

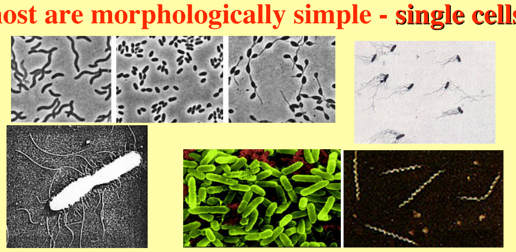
N_2, N_2O, O_2, CO_2, CO, H_2,
CH_4, NH_3, H_2S and many others

also central in cycling C, P, S

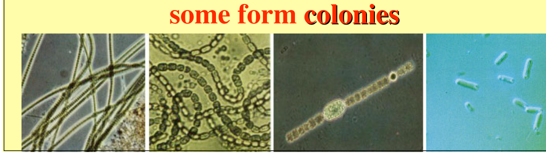
several of these re-cyclings are *restricted*
to bacteria - notably N_2

photosynthetic bacteria began the change
in character of earth's atmosphere ~3 b.y.a.

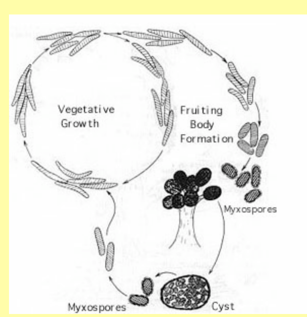
most are morphologically simple - **single cells**

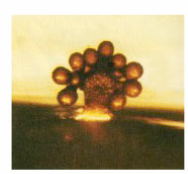


some form **colonies**

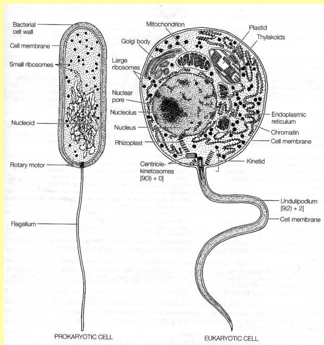


some generate temporary
multicellular structures





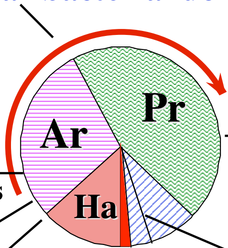
Prokaryote vs. Eukaryote structure



Prokaryotes vs. Eukaryotes

Prokaryotes	Eukaryotes
1-10 x 10^{-6}m	10 - 100 x 10^{-6}m
nucleoid, genophore	nucleus, chromosomes
no organelles	mitochondria, Golgi, E.R.
simple flagellum	tubulin cilia
highly diverse metabolism	uniform metabolism mostly aerobic

~2 x 10^9 year bacterial dominance



oldest stromatolites

oldest eukaryotes

oldest rocks

3.9

4.5 b.y.a.

Phanerozoic

stromatolites

structures from bacterial mats plus mineral particles

fossil

living

traditionally, bacteria have been classified according to shape, chemistry & metabolism

now recognised that this is poor indication of true historical-genealogical relationships

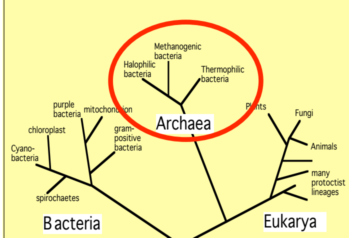
such similarities are ***mostly convergent***

true relationships becoming revealed by small-subunit ribosomal RNA (16S rRNA) sequences

16S rRNA shows two major groups

BACTERIA & ARCHAEA

(= Eubacteria & Archaebacteria)



Archaea tend to live in extreme environments

hot, acidic, salty, anoxic

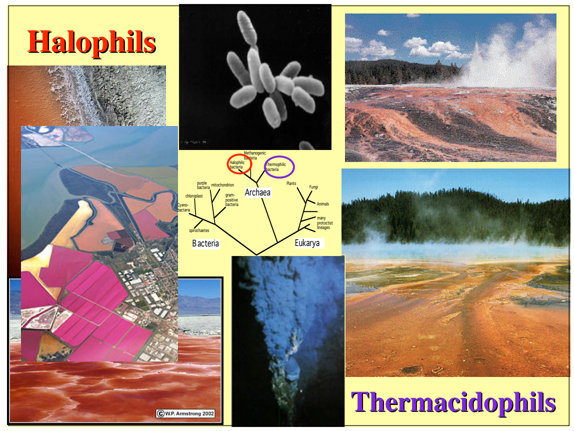
many Archaea live in environments typical of very early earth:

extremely hot (up to ~300°C), acidic and osmotically challenging conditions

hot springs; super-hot deep-sea vents

hypersaline seashores - 3-5 Molar NaCl

anoxic muds and soils, sewage, guts



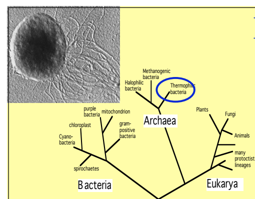
in early earth environment, physical processes (lightning, heat, UV) generated stew of organic molecules, rich in energy

anaerobic fermentation thought probably the **earliest global metabolism**

as life grew, organic supplies dwindled...

strong selection for autotrophic capability: energy and C from in**organic** sources

this is exactly what methanogens can do



Methanogenic bacteria

(O_2 intolerant)

reduce C with H_2 -> CH_4

C from CO_2, formate, methanol & acetate

H from H_2, formate, methanol & acetate

$[CO_2] + 4H_2 \rightarrow CH_4 + 2H_2O$

prevent accumulation of C in sediments by releasing it back to atmosphere

$2O_2 + CH_4 \rightarrow CO_2 + 2H_2O$

thus prevent accumulation of O_2 in air

NEXT CLASS

Other forms of autotrophic activity: changing the world's atmosphere

eventually, use of sunlight energy evolved

PHOTO-AUTOTROPHY

we think of photosynthesis as generating O_2

but first forms, probably still O_2-intolerant, used H_2, H_2S etc. as reducing agents for CO_2

$$2H_2X + CO_2 \rightarrow CH_2O + 2X + H_2O$$

use of **water + sunlight** a stunning technique

massive consequences for earth's atmosphere and its life......

oxygenic photosynthesis developed
~2.5 b.y.a. (end-Archaean)

O_2 accumulated, raising level from
0.01% of atmosphere then to 20% today
(~10% at ~0.5 b.y.a. - first vertebrates)

first O_2 photosynthesizers were probably just like today's Cyanobacteria
dominated 2.5 - 0.6 b.y.a. - stromatolites

global primary production

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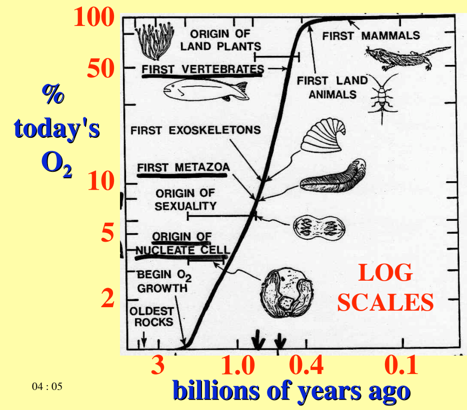

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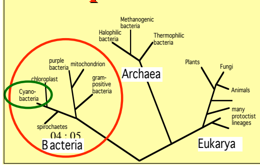
Cyanobacteria

O_2 production was a serious problem for O_2-intolerant forms



they had to **retreat** to O_2-free places or evolve tolerance

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OXYGEN AS A PROBLEM

highly reactive; oxidises organics to CO_2

O_2^-, OH^-, H_2O_2 seriously disruptive

O_2 -> O_3, which screens UV;
this further reduces production of organics

selection for new metabolic styles
and ways of dealing with free O_2

catalases, peroxidases to convert free radicals

USE O_2 to oxidise organics - respiration
fermenting - 1:18 - respiring

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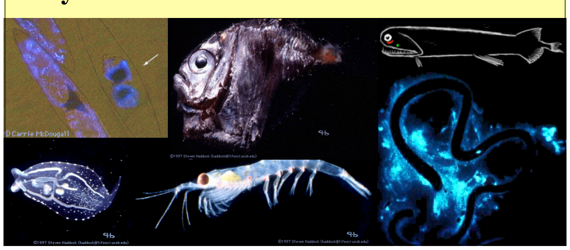
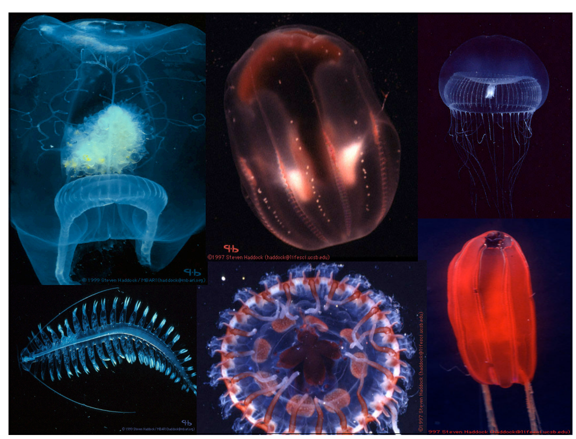
one way of dealing w/free radicals involves luciferin; light emitted with reaction
this is **bioluminescence**
most biotic light production involves symbiosis with bioluminescent bacteria





Bacterial Metabolic Diversity

huge diversity, even within "species"
can switch according to conditions found

in addition to eukaryote processes:
aerobic respiration and O_2 photosynthesis
and ethanol & lactate fermentation
(organoheterotrophy & photoautotrophy)
chem. energy   org. carbon   light energy   inorg. carbon (CO_2)

non-O_2 photoautotrophy - H_2S, H_2
lithoautotrophy - methanogenesis, N_2-fixation
lithoheterotrophy - metal oxidizers

thus bacteria perform a bewildering
diverse array of metabolic activities

most are different from those
of eukaryotes

for most bacterial metabolic by-products,
there are other bacteria who can use them as substrates for their own activities

entirely self-contained bacterial communities

can be independent of eukaryotes

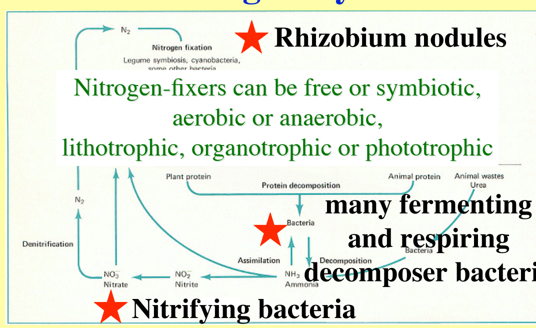
we shall sample bacterial activities
through looking at how they contribute
to the cycling of life's essential elements

crucial in cycling of N_2, S and metals

major contributions to C, P cycling

substantial impact on O_2 balance

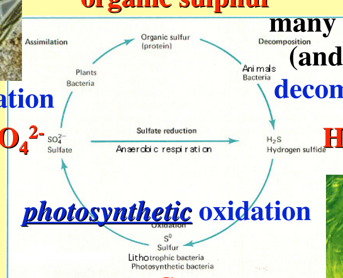
Nitrogen Cycle

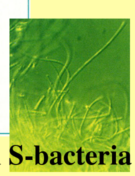


bacteria are <u>unique</u> in fixing N_2 gas

Sulphur Cycle

Cyanobacteria





purple and green S-bacteria

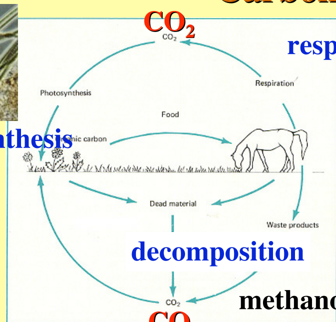
heavy metal cycling

Iron-Oxidizing (lithoautotroph) bacteria

several groups oxidize Fe^{2+} to Fe^{3+}
usually under acidic conditions

Cyanobacteria

Carbon Cycle



Bacterial Ecology

Terrestrial

generally live in H_2O films on soil particles

densest and most diverse communities
live near surface - most organic debris

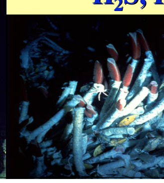
major contributions to cycling of C, N & O

live on all biological surfaces;
occasionally pathogenic

Aquatic Marine

bacteria generally poorly represented
except at shores and in great deeps

aphotic hydrothermal vents
vents produce 270-380°C
water w/highconcentrations of
H_2S, H_2, CO, Mn^{2+}



lithotrophic bacteria
provide base of
special communities,
independent of sun

Aquatic Freshwater

Most primary production is done by
bacteria and algae

bacteria dominate in anoxic, extreme parts

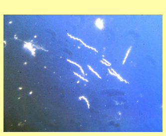
much primary production is respired by
the bacteria, consuming O_2

excess organics -> O_2 depletion

dynamics of both C and O closely linked
through bacterial activities

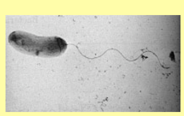
Treponema **- syphilis**

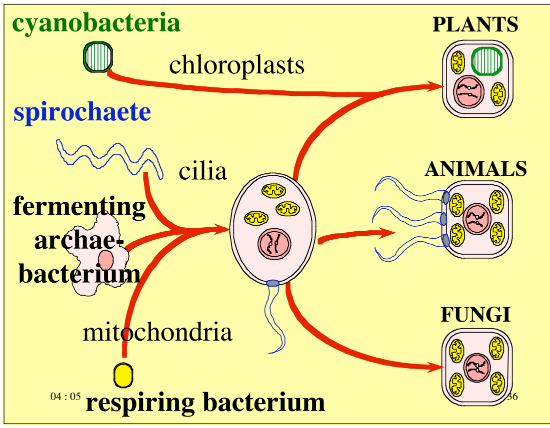
Neisseria **- gonorrhea, meningitis**



Borellia **- Lyme disease**

Vibrio **- cholera**





This SET view now broadly accepted

but long-resisted; symbiosis now recognised as being very common in life

Other symbioses

lichens
corals
vent-worm bacteria
root nodules
mycorrhizae

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NEXT CLASS:

The Protoctista - the simplest Eukaryote organisms

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thanks to the authors of the following sites

http://www.bact.wisc.edu/bact303/bact303mainpage

http://www.bact.wisc.edu/bact303/MajorGroupsOfProkaryotes

http://lifesci.ucsb.edu/~biolum/organism/photo.html

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