Prokaryota

Archaea

Methanogens

Halobacteria

Sulfolobus

Bacteria

Proteobacteria

Cyanobacteria

- Prokaryota are unicellular organisms (usually tiny < 10 μm) that divide rapidly, with no nuclear membrane, little DNA, no membrane-bound organelles.
- They feed by absorbing dissolved nutrients (large surface/volume ratio and permeable membranes), and grow rapidly
- They make a wide array of enzymes and can take advantage of biochemical opportunities (energy from a wide range of chemical (redox) reactions).
- Many produce highly resistant spores, and thermally stable enzymes, and some produce flagellated motile stage for dispersal.

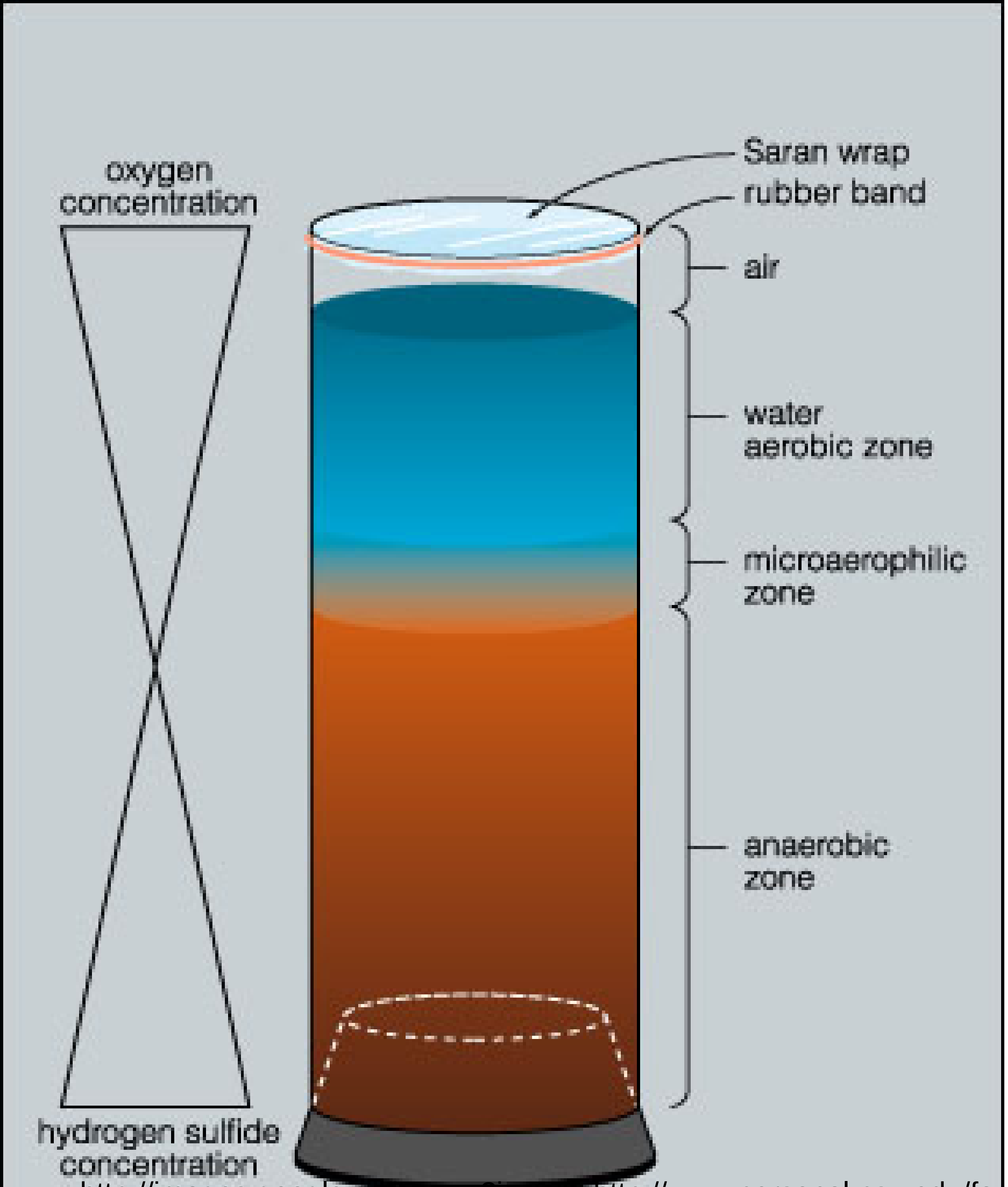
Nutrition and Metabolic Diversity

Four nutritional categories

Carbon Source

Energy Source	CO_2	Organic
Light	Photo-autotroph	Photo-heterotroph
Chemical	Chemo-autotroph	Chemo-heterotroph

Sergei Winogradsky
1856-1953, Kiev
•discovered chemoautotrophy



http://images.google.ca/imgres?imgurl=http://www.personal.psu.edu/faculty/j/e/jel5/biofilms/wgradsky.jpg&imgrefurl=http://www.personal.psu.edu/faculty/j/e/jel5/biofilms/winogradsky.html&h=1953&w=3000&sz=455&hl=en&start=8&tbnid=8gnGtagLSIrXPM:&tbnh=98&tbnw=150&prev=/images%3Fq%3Dpurple%2Bsulfur%2Bbacteria%26svnum%3D10%26hl%3Den%26lr%3D%26sa%3DG

Microbial environments

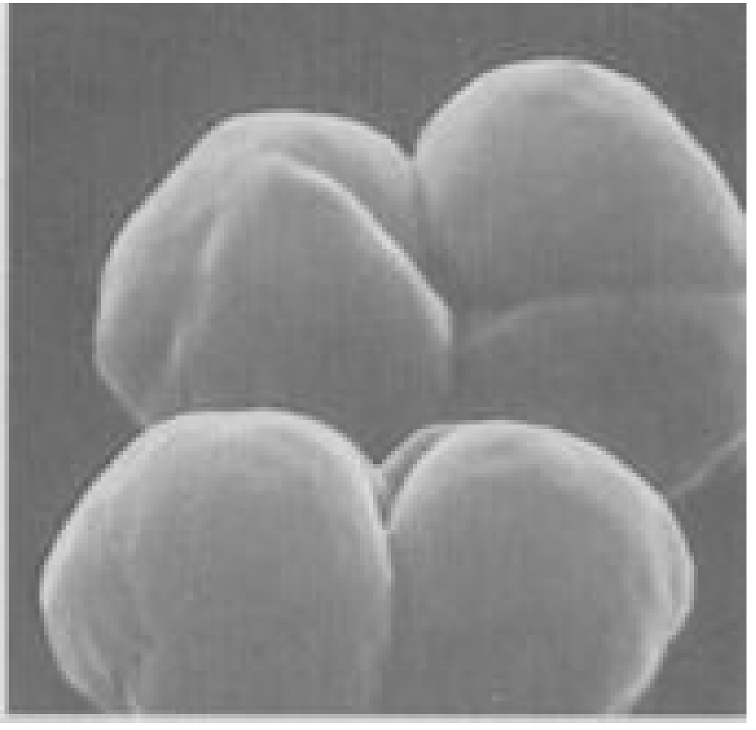
Winogradsky column

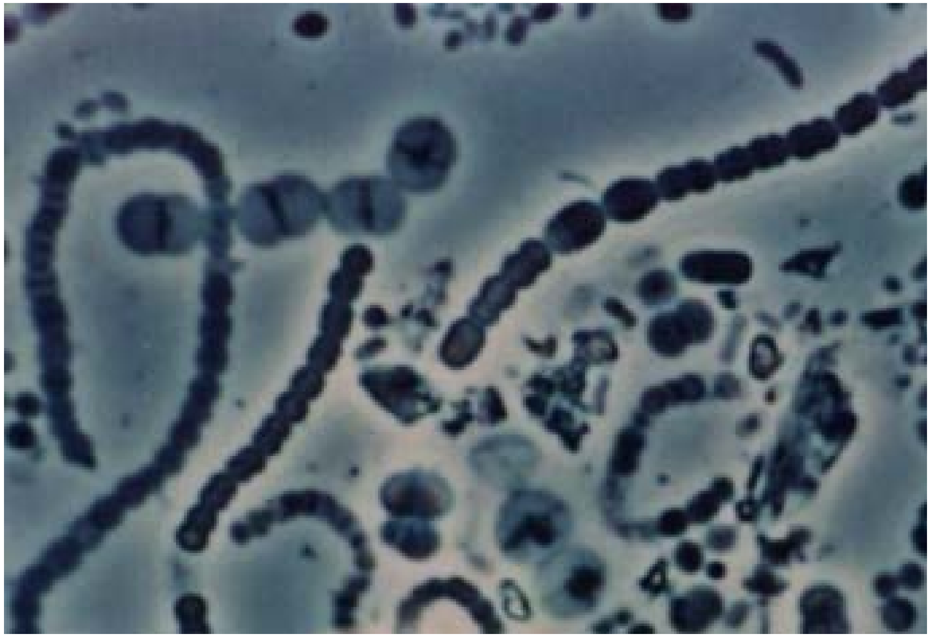
In which type of aquatic habitats would you expect to find a gradient like that in the column? Explain?

Explain why the anaerobic zone is rich in H_2S?

Where in the column would you expect find H_2? Why?

Where in the column would you expect to find methane (CH_4)? Why?





Methanogens are not true bacteria, they belong to the Archaea

Most methanogens can grow on CO_2 and H_2 as their energy & carbon source: Chemoautotrophs

Where in the Winogradsky column would you expect to find them?

http://faculty.plattsburgh.edu/jose.deondarza/images/Organisms/methanogen.jpg

Chemical equation for the reduction of CO_2 by H_2

$$CO_2 + H_2 \rightarrow CH_4 + \mathrm{E(energy)}$$

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

(+4) (0) (-4) (+1)

$8\,e^-$ are accepted per C

$1\,e^-$ is donated per H

How to assign Oxidation numbers

We keep track of the e^- transfer using Oxidation numbers *(Ox#)*

For each e^- transferred the *Ox#* changes by 1

$$2H_2 + O_2 \longrightarrow 2H_2O$$

$2H_2$	O_2	$2H_2O$	
0	**0**	**+1**	**-2**

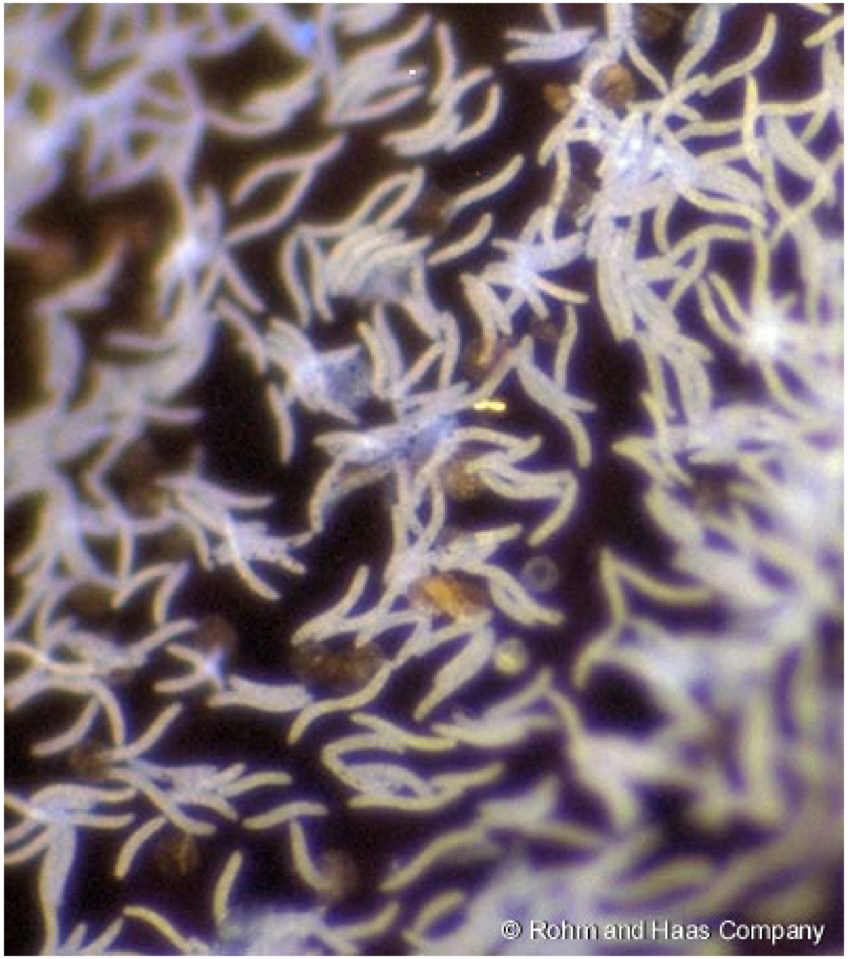
Some rules for Oxidation numbers

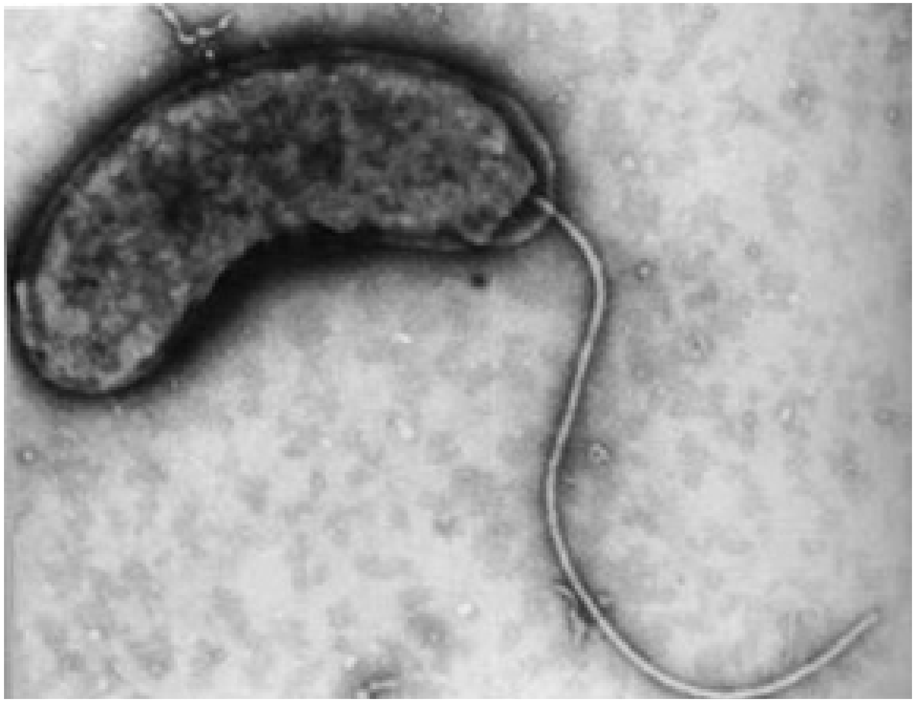
1. In free elements *Ox#* =0
2. For ions with one atom *Ox#* = charge. eg H^+ *Ox#* of H^+ = 1
3. Ox# of O in most compounds is -2,
4. Ox# of H in most compounds is +1,
5. For a complex ion like SO_4^{-2} , the net Ox# = charge (Thus S=+6)

Desulfovibrio : Sulfate reducing bacteria

commonly found in anaerobic aquatic environments with high levels of organic material, such as mud in lakes and ponds.

- have metal reductases which can precipitate metal sulfides from the water
- Organic matter serves as both energy and carbon source





Sulfate reduction can absorb H+ and counteract acid rain

They also contribute to methylation of Mercury

Chemical equation for the oxidation of acetate by sulfate

$$CH_3COO^- + SO_4^{-2} \rightarrow S^{-2} + CO_2 + E$$

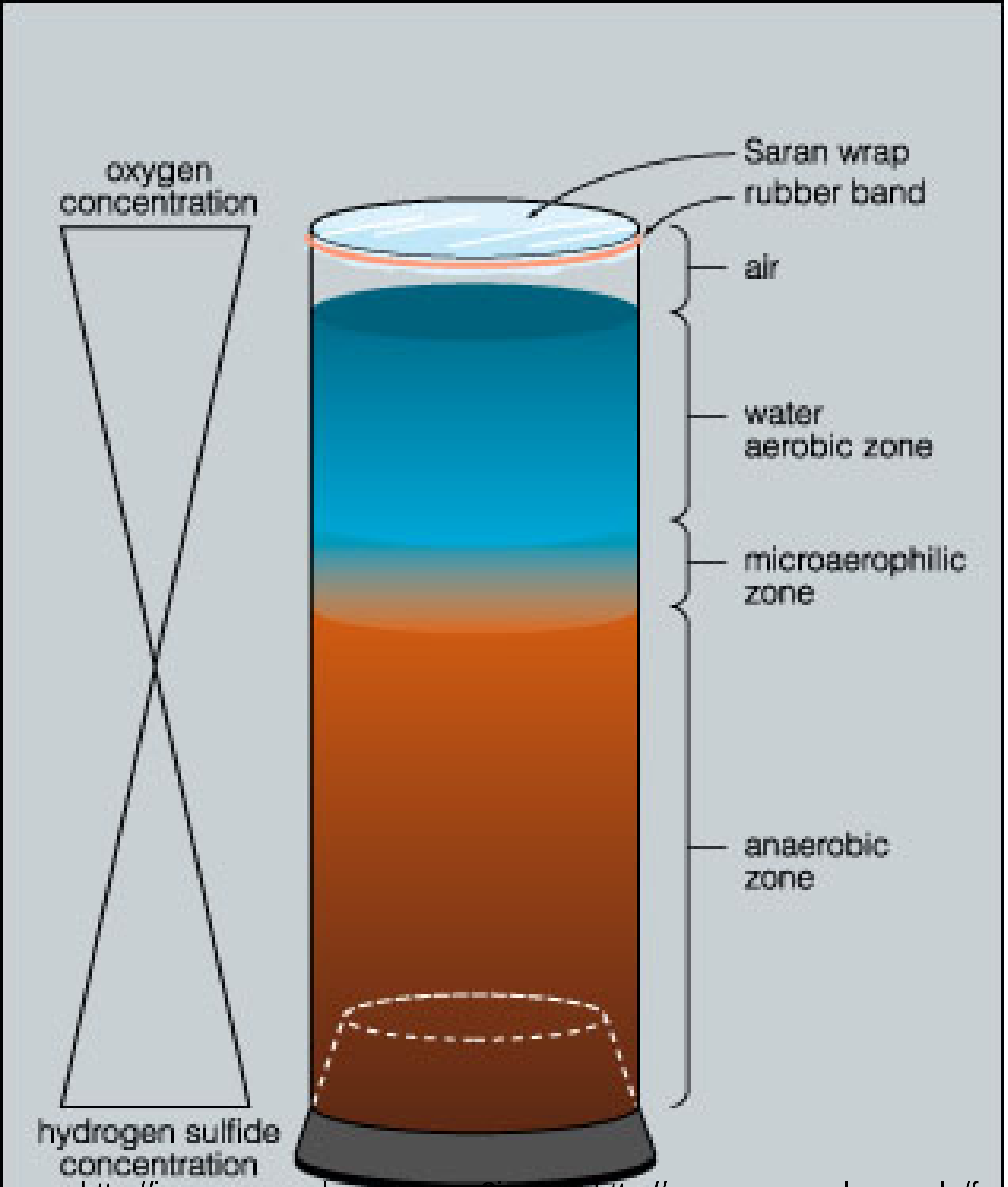
$$CH_3COO^- + SO_4^{-2} + H^+ \rightarrow S^{-2} + 2H_2O + 2CO_2$$

(0) (+6) (-2) (+4)

$8\,e^-$ are accepted per S

$4\,e^-$ are donated per C

Where do sulphate reducing bacteria fit in the functional classification?

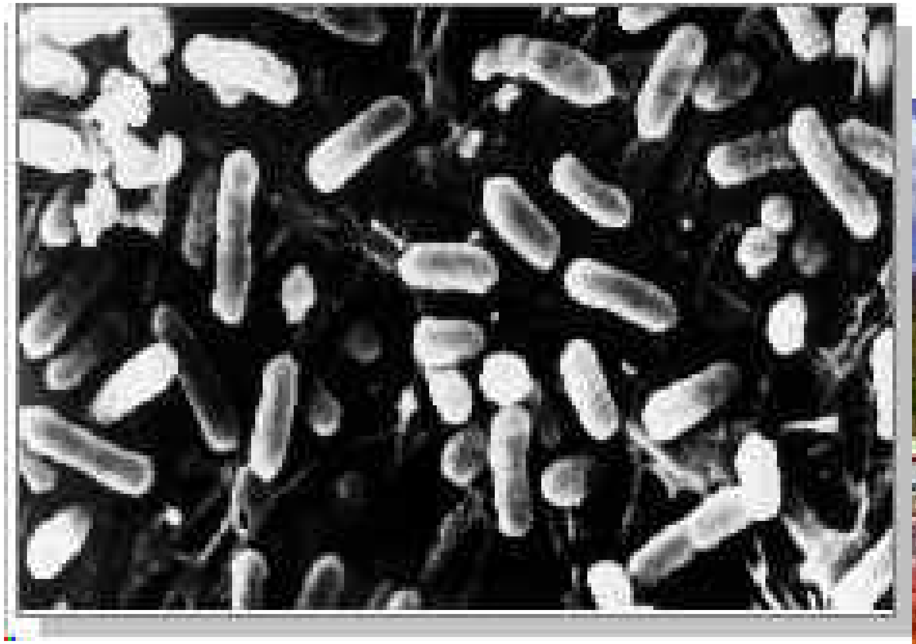


Microbial Ecology
Winogradsky column

Where in the column would you expect sulfate reducers to be most abundant? Explain.

http://images.google.ca/imgres?imgurl=http://www.personal.psu.edu/faculty/j/e/jel5/biofilms/wgradsky.jpg&imgrefurl=http://www.personal.psu.edu/faculty/j/e/jel5/biofilms/winogradsky.html&h=1953&w=3000&sz=455&hl=en&start=8&tbnid=8gnGtagLSIrXPM:&tbnh=98&tbnw=150&prev=/images%3Fq%3Dpurple%2Bsulfur%2Bbacteria%26svnum%3D10%26hl%3Den%26lr%3D%26sa%3DG

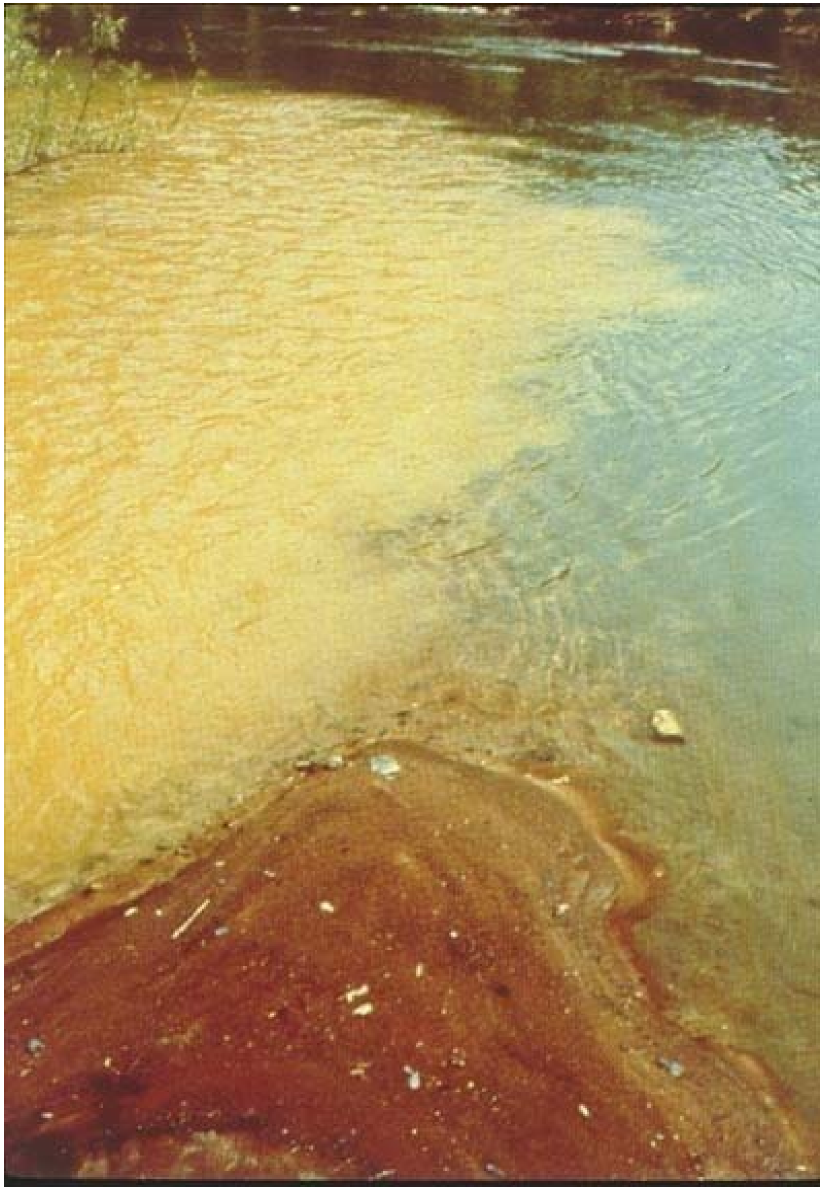
Thiobacillus. Oxidize reduced forms of S, Fe, and other metals using O_2 and live off the energy released—lithotrophs i.e. eat rocks



Where would they fit in the functional classification?
Where would you expect to find them in the Winogradsky column?

http://images.google.ca/imgres?imgurl=http://filebox.vt.edu/users/chagedor/biol_4684/Microbes/pipeimage.gif&imgrefurl=http://filebox.vt.edu/users/chagedor/biol_4684/Microbes/Thiobacillus.html&h=102&w=255&sz=18&hl=en&start=98&tbnid=bENjOh3kLwslM:&tbnh=44&tbnw=111&prev=/images%3Fq%3Dthiobacillus%26start%3D80%26ndsp%3D20%26svnum%3D10%26hl%3Den%26lr%3D%26sa%3DN

Oxidation of iron rich mine tailings by bacteria—microbial leaching.



Thiobacillus **mediates oxidation of iron pyrites (FeS_2) and obtains energy from this reaction.**

How can mine tailings stored so as to prevent this type of pollution?

Chemical equation for the oxidation of iron pyrites to sulfate and iron oxide

$$FeS_2 + O_2 \rightarrow SO_4^{-2} + Fe_2O_3 + E$$

$$4FeS_2 + 15O_2 + 8H_2O \rightarrow 8SO_4^{-2} + 2Fe_2O_3 + 16H^+$$

(+2)(-1) (0) (+6)(-2) (+3)(-2)

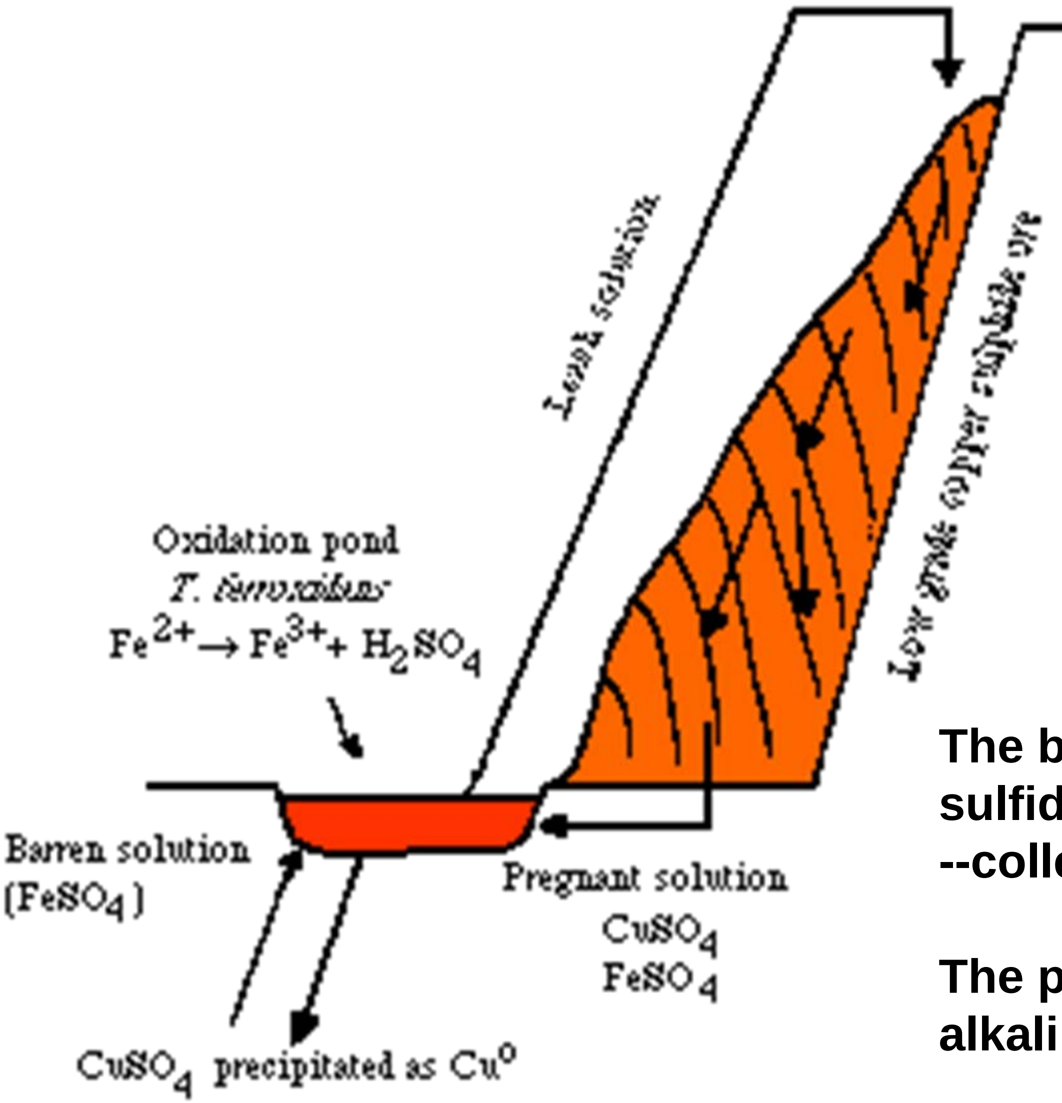
$15\,e^-$ are donated per mole of FeS_2

1 per mole of Fe, and 7 per mole of S

$2e^-$ accepted per mole of O

Mine tailings are a major source of acid pollution to aquatic environments? Explain.

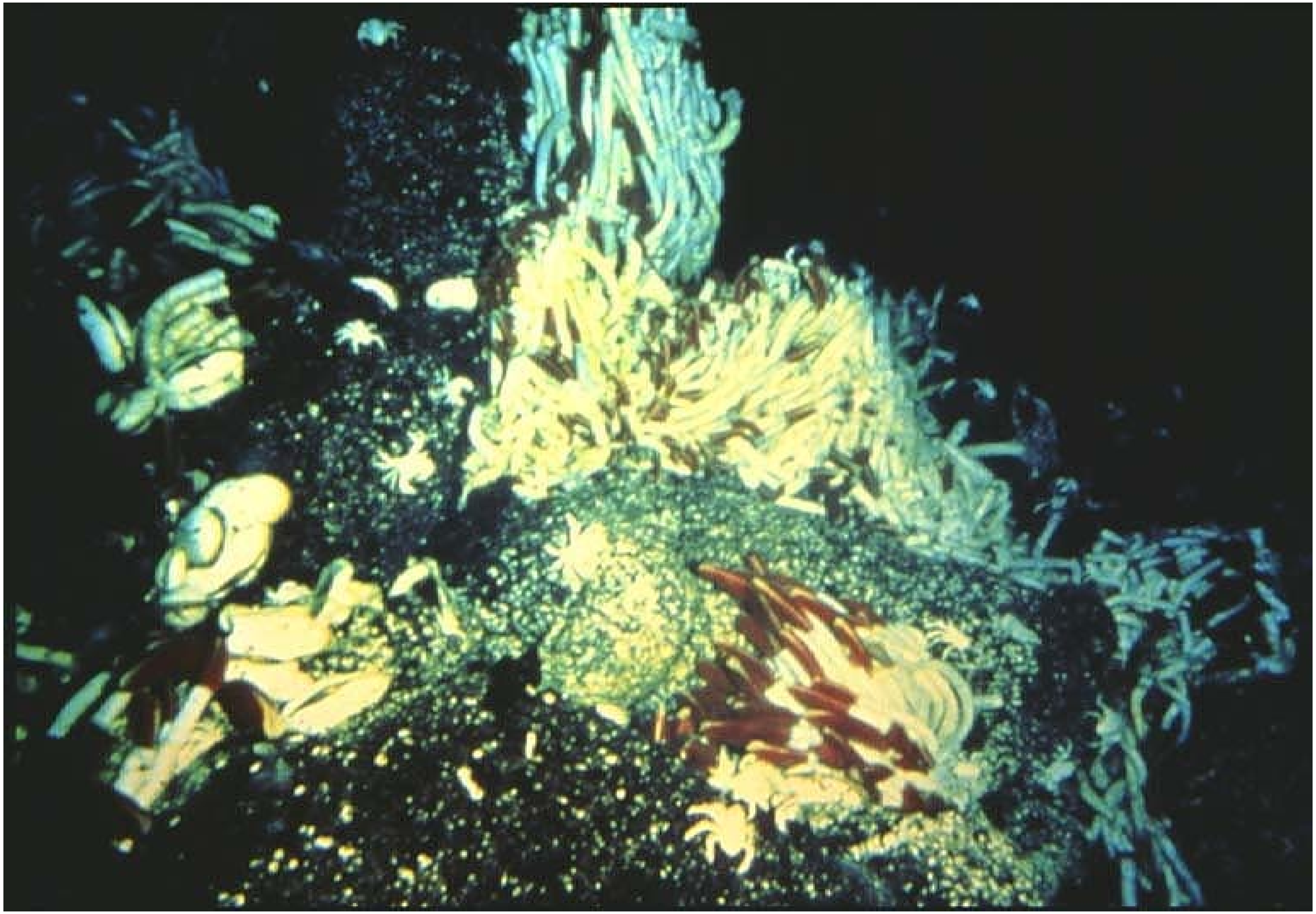
Microbial leaching can also be useful



The bacteria also oxidize the copper sulfide to copper sulfate which is soluble.
--collects in pond, “pregnant solution”

The pure copper is then precipitated with alkali (NaOH).

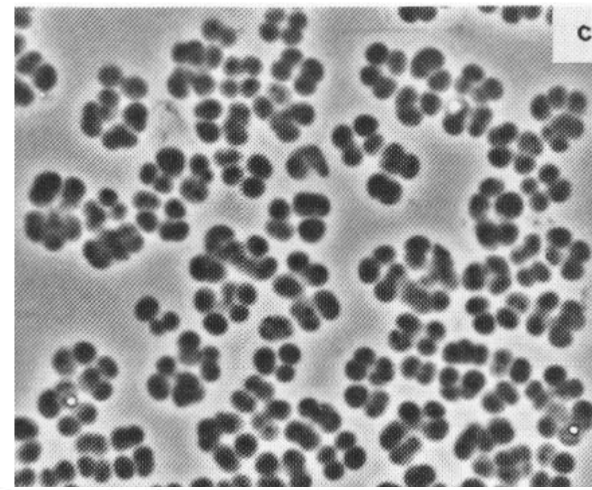
Refining of low grade copper ores using *Thiobacillus*



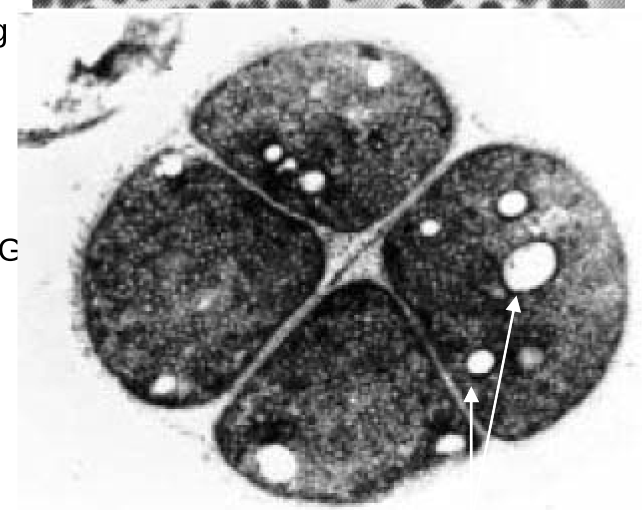
Thiobacillus bacteria also oxidize sulfide from groundwater spouts in the deep sea called hydrothermal vents, These bacteria support a rich community of animals deep in the ocean where no light reaches.

Purple Photosynthetic sulfur bacteria (eg *Thiocapsa*)

http://www.esf.edu/efb/schulz/Limnology/Laboratory/PurpleBacteriafromGreenLake.JPG



http://biology.kenyon.edu/Microbial_Biorealm/bacteria/thiocapsa/thiocapsa_c.jpg



gas vacuoles. Why?

Thiocapsa are found most often in fresh water: lakes, sulfur springs, and waste water ponds. Requires anoxic conditions with light present. Under ideal conditions, *Thiocapsa* can form dense blooms.

•use reduced sulfur as an electron donor during photosynthesis. They are capable of oxidizing both sulfide and other reduced sulfur compounds.

Chemical equation for anoxygenic photosynthesis in purple sulfur bacteria

$$H_2S + CO_2 + light\ energy \rightarrow S + \text{glucose}$$

$$12H_2S + 6CO_2 \rightarrow 12S + C_6H_{12}O_6 + 6H_2O$$

(-2) (+4)(-2) (0) (0)

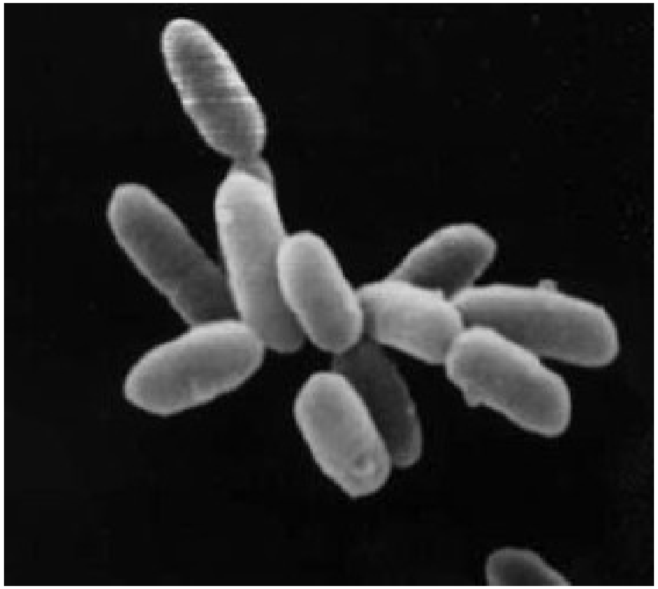
$2\,e^-$ are donated per S

$4\,e^-$ accepted per C

Where do these purple surfur bacteria fit in the functional classification scheme?

Where would we expect to find them in the water column of lakes and ponds?

Solar Saltern Plant: a typical habitat of *Halobacterium salinarium*



Functional classification?

- found in water saturated or nearly saturated with salt (Halophiles) and rich in organic matter.
- Large blooms appear reddish, from the pigment bacteriorhodopsin. This pigment is used to absorb light, which provides energy to create ATP.
- The process is unrelated to other forms of photosynthesis involving electron transport, and halobacteria are incapable of fixing carbon from carbon dioxide and must use organic carbon sources.

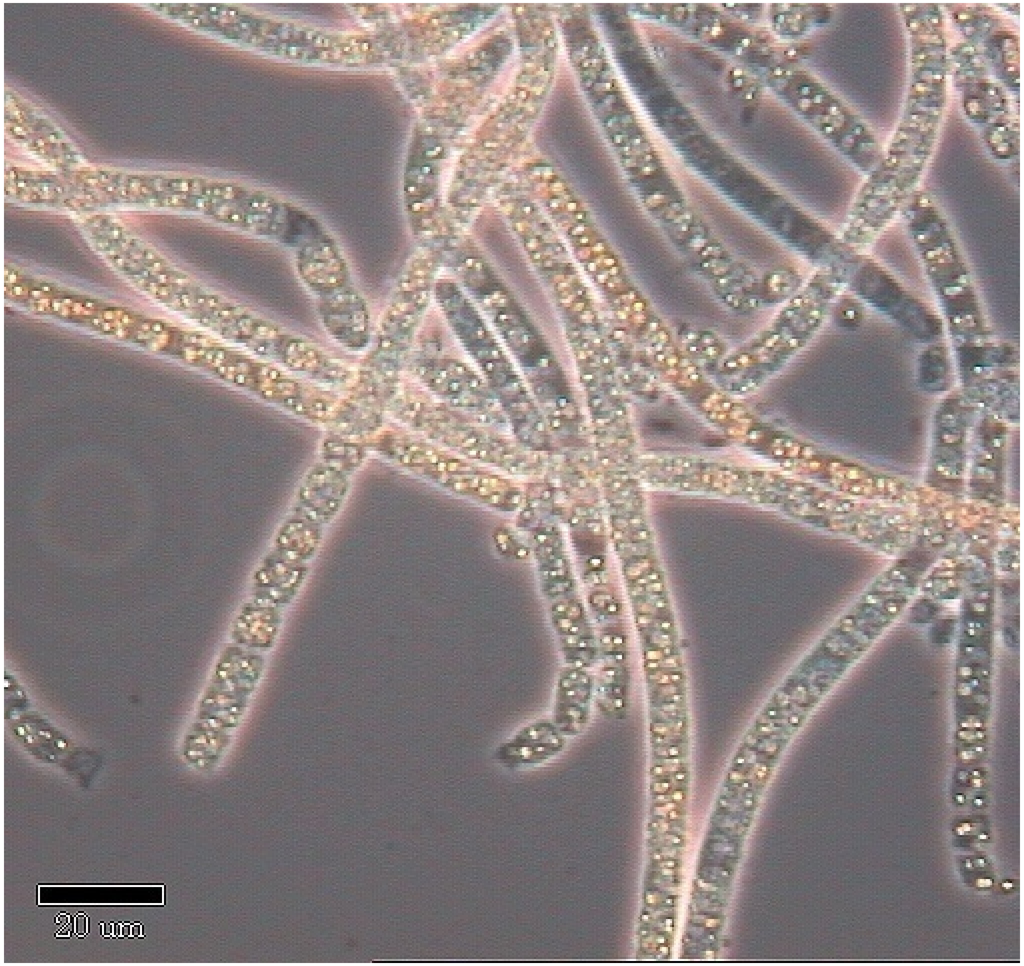
http://www.biochem.uni-luebeck.de/public/groups/metalloproteins/hubmacher/Hubmacher_Abb2.jpg

Sulfolobus—another Archaean, found in hotsprings or volcanic seeps

can grow either as a chemoautotroph by oxidizing sulfur, or as a chemoheterotroph using sulfate to oxidize simple organic carbon compounds

http://microbewiki.kenyon.edu/index.php/Sulfolobus

Beggiatoa: a filamentous sulfur bacterium



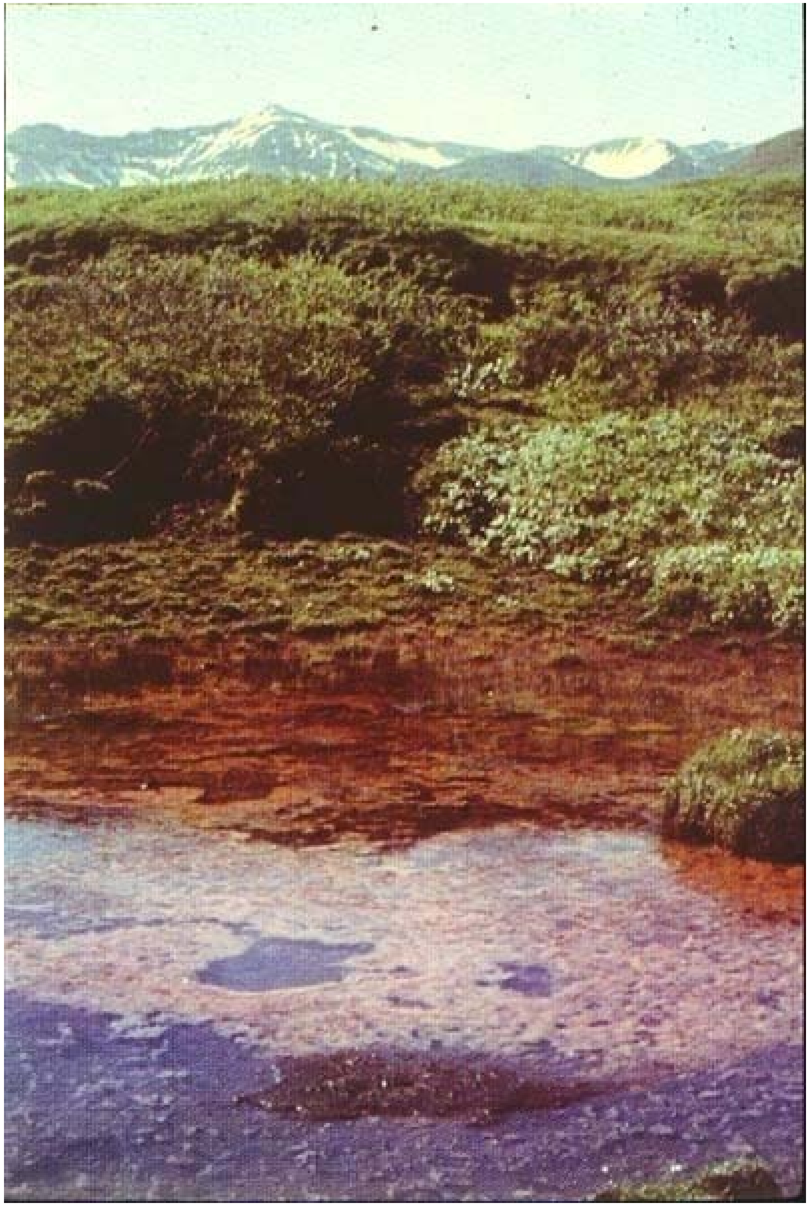
http://user.uni-frankfurt.de/~schauder/gradient/beggia06_bg.jpg

Beggiatoa is a genus of colorless, filamentous proteobacteria. With cells up to 200 microns in diameter, species of *Beggiatoa* are among the largest prokaryotes.

•can live as a chemoautotroph oxidizing reduced S compounds using either O_2 or other electron acceptors, or as a heterotroph using Sulfate to oxidize organic compounds.

•found in polluted environments, and can be seen by the naked eye as a white filamentous mat on top of the water.

Iron bacteria (*Leptothrix)* mediate the oxidation of iron in ground water seeps



+2, -2 0 +3,-2

$$4FeO + O_2 \rightarrow 2Fe_2O_3$$

While this reaction releases some energy, *Leptothrix* are believed to live mainly from the energy they obtain from aerobic decomposition of organic matter in water and mud.

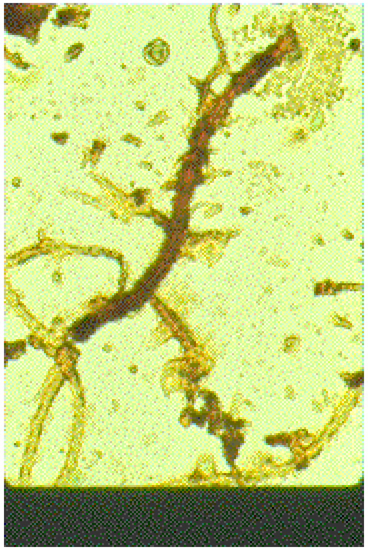
Functional classification?
Winogradsky column?

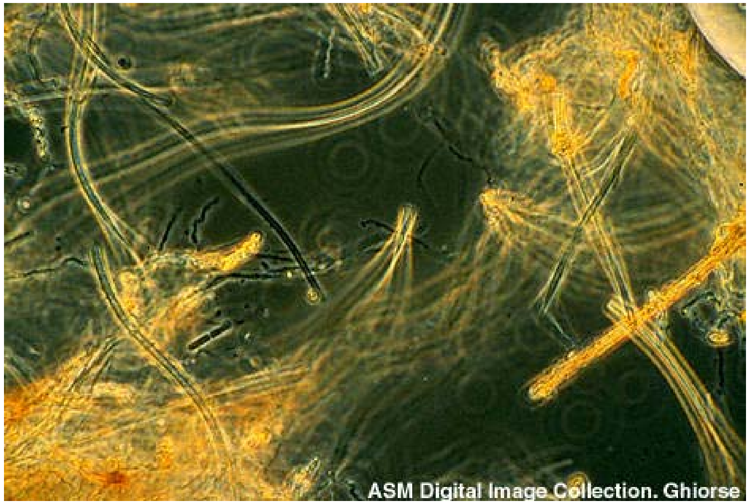
An “iron spring” at the base of a hill—the red colour is from the oxidized iron and other metals

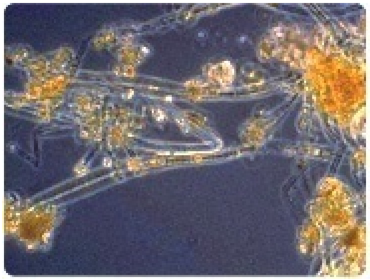
http://www.jcu.edu/philosophy/gensler/canyons/images/34.jpg

Leptothrix is a sheathed filamentous bacterium found in sediments rich in organic matter.

- *Leptothrix* bacteria are known to be capable of oxidizing both iron(II) and manganese(II)
- These metals often occur bound to organic material, so the metal oxidation may be a by-product of oxidizing the organic matter.

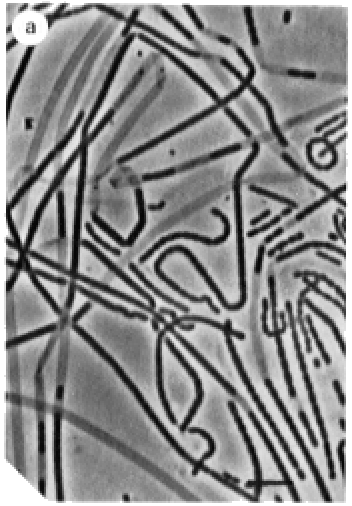


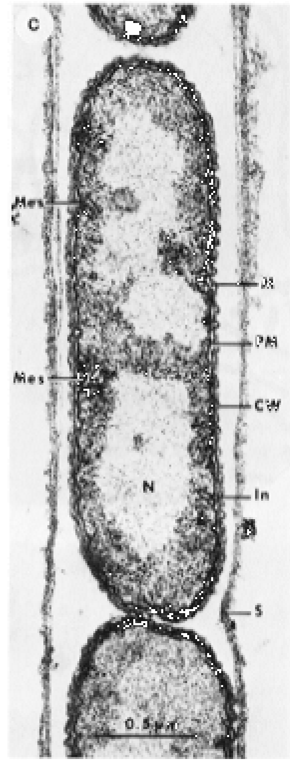




•The products of these oxidative reaction, ferric and manganese oxides/hydroxides coat the sheaths of the bacteria.
•The precipitate deposits on the sheath after the organic molecules are used by the cell.
•These bacteria can form nodules very rich in iron, manganese and other metals

http://microbewiki.kenyon.edu/index.php/Leptothrix



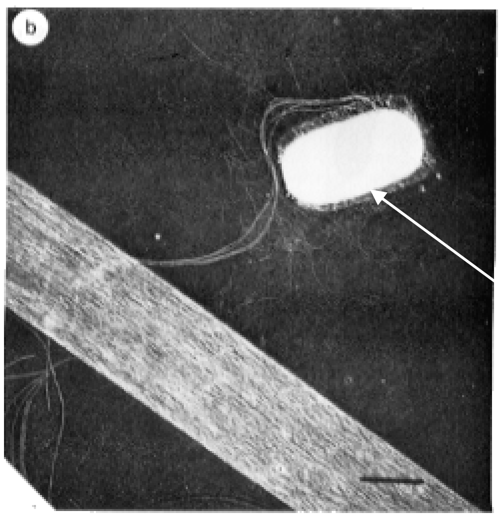


Sphaerotilus natans :an aerobic heterotroph

•filamentous bacterium that is covered in a tubular sheath and can be found in flowing water and in sewage and wastewater treatment plants.

•Also commonly found in thermal effluents or pulp mill effluents as a whitish scum trailing off the rocks

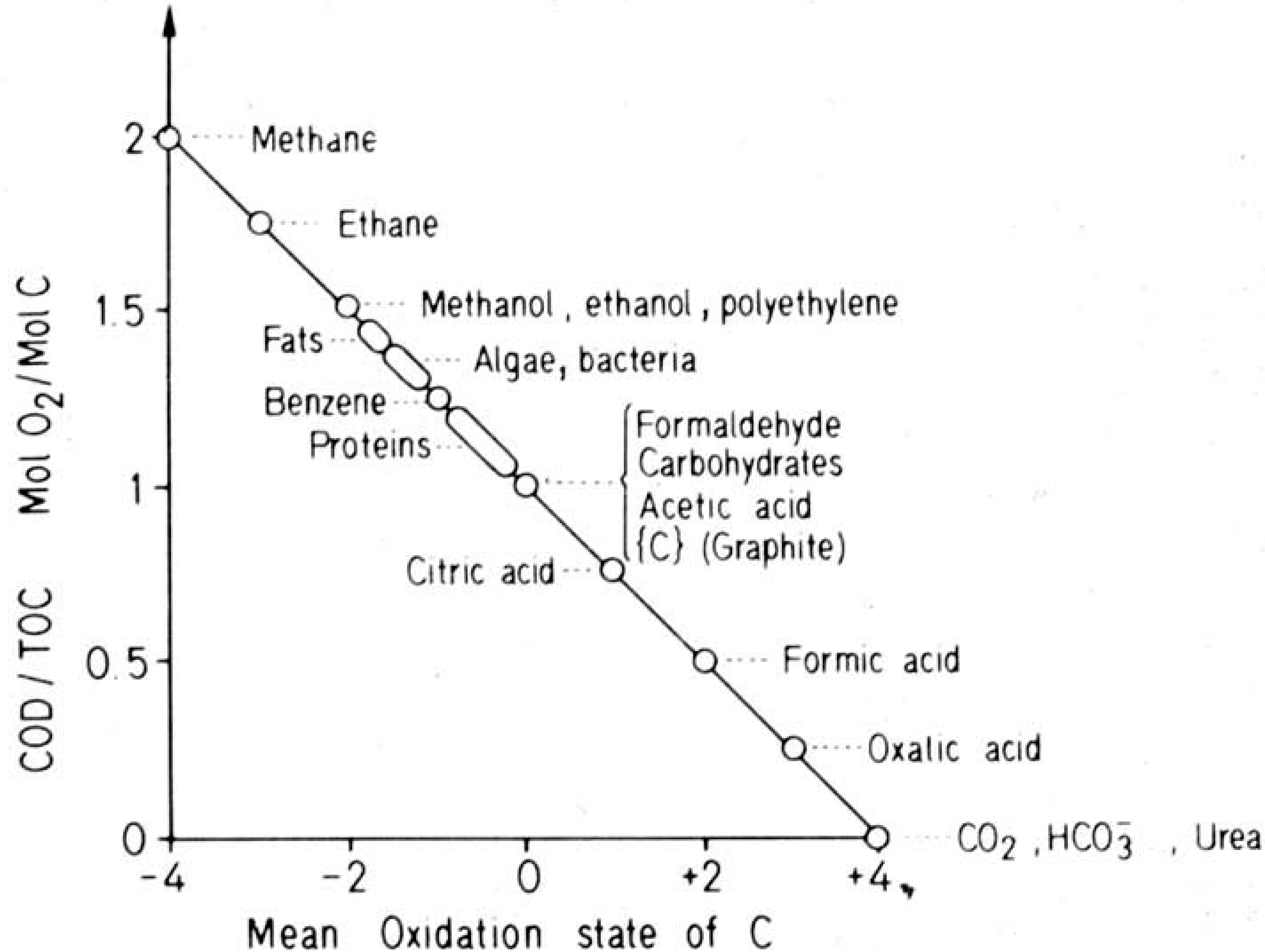
•sometimes clogs pipes and causes other similar problems, it does not cause major threat to wastewater treatment plants nor is it known to be pathogentic.



The swarmer (motile flagellated cell) stage of S.natans

http://images.google.ca/imgres?imgurl=http://141.150.157.117:8080/prokPUB/figures/normal/p345014.gif&imgrefurl=http://141.150.157.117:8080/prokPUB/chaphtm/345/COMPLETE.htm&h=518&w=401&sz=177&hl=en&start=6&tbnid=KwC7Xrr7jAWloM:&tbnh=131&tbnw=101&prev=/images%3Fq%3Dsphaerotilus%26svnum%3D10%26hl%3Den%26lr%3D%26sa%3DG

The Oxidation states of various organic compounds



Chemical equation for the oxidation of Hydrogen sulfide to elemental sulfur

$$H_2S + O_2 \rightarrow S + H_2O + E$$

$$2H_2S + O_2 \rightarrow S + 2H_2O$$

(-2) (0) (0) (-2)

$2\,e^{-}$ are donated per S

$2e^{-}$ accepted per O