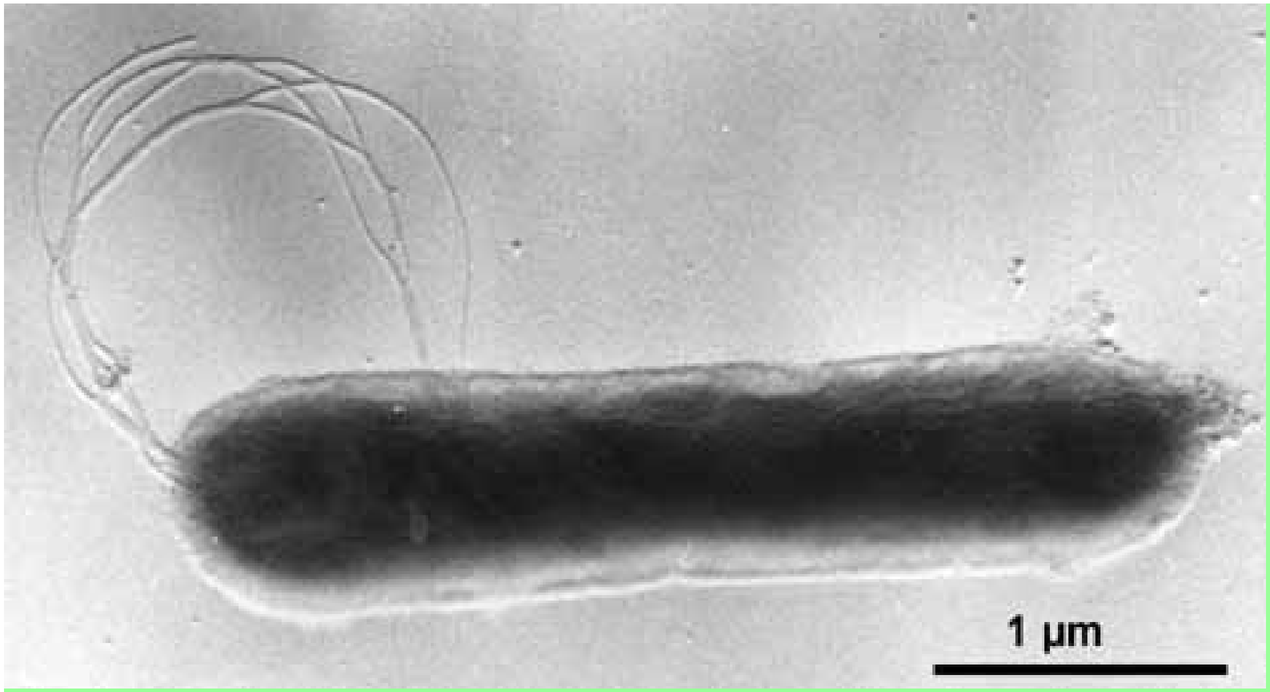
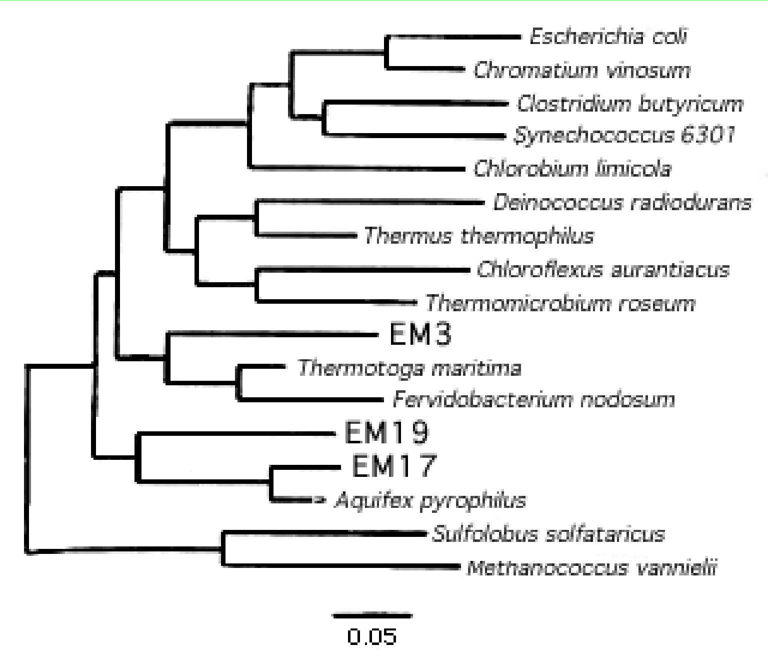
# More on
# Chemotrophic Potential

# Identification for the Octopus Spring Pink Filaments

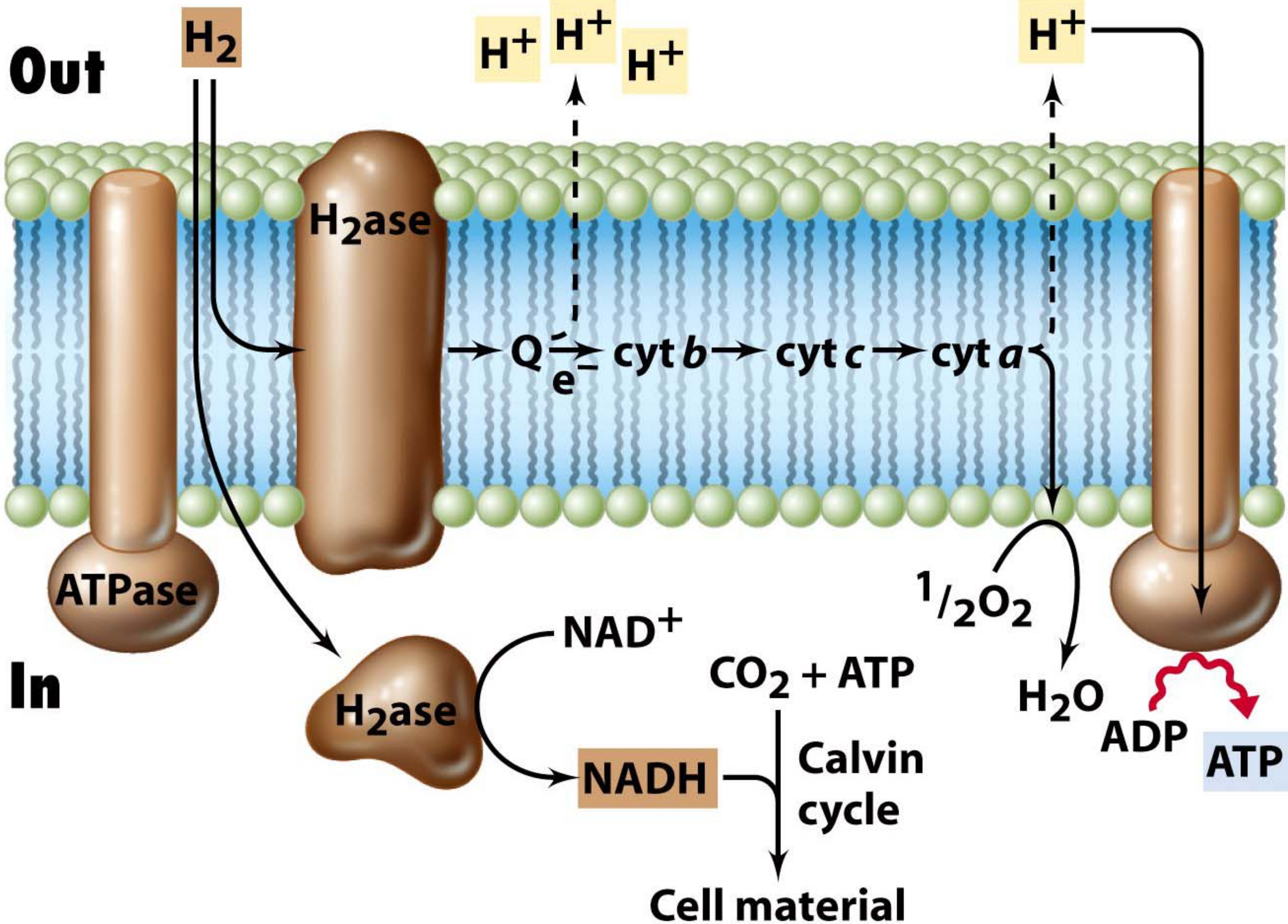



*Aquifex pyrophilus*




Yellowstone "Pink Filament" Isolates

# *Ralstonia eutropha*: An aerobic $H_2$ bacterium



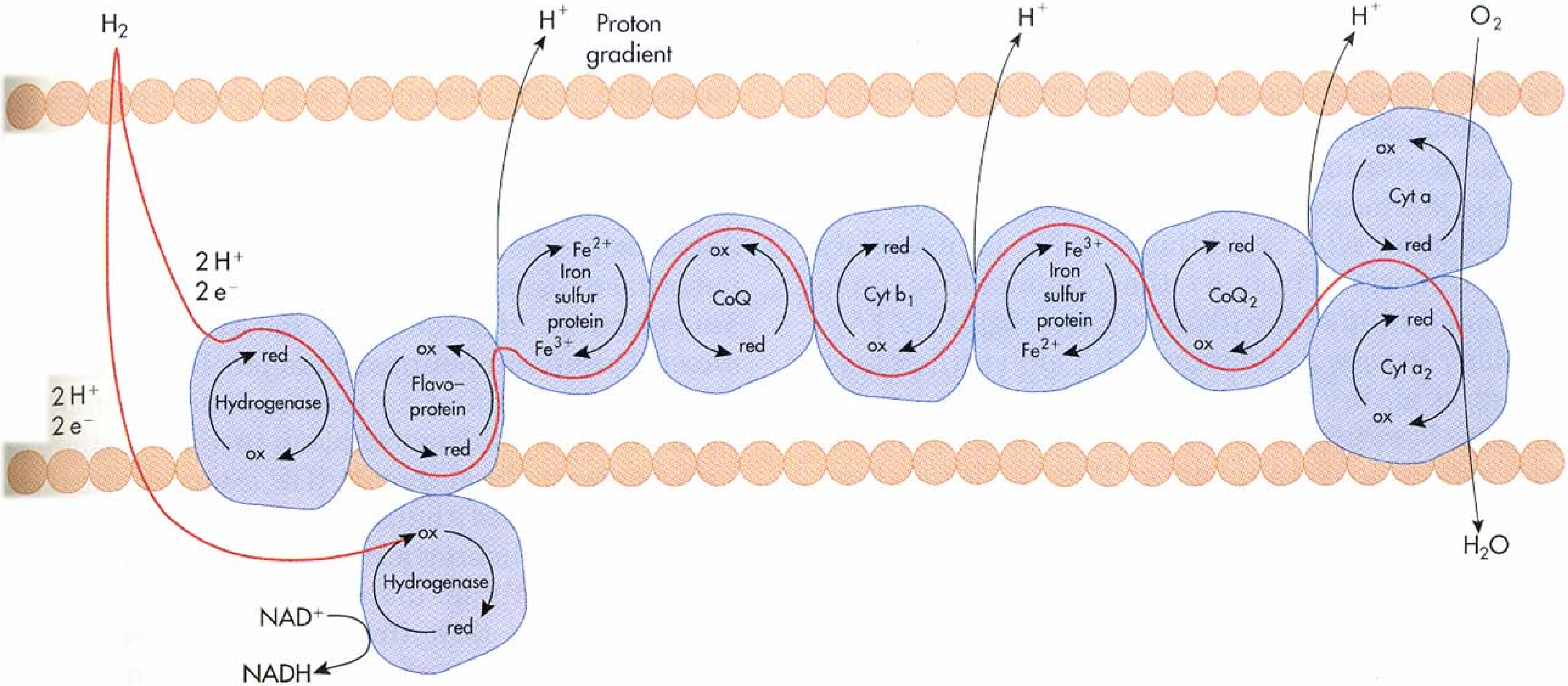



**Fig. 4-21 Hydrogenase and Chemolithotrophic Metabolism.** Hydrogenase splits hydrogen into protons and electrons that are transported via a membrane-bound electron transport system. This transport establishes a proton gradient.

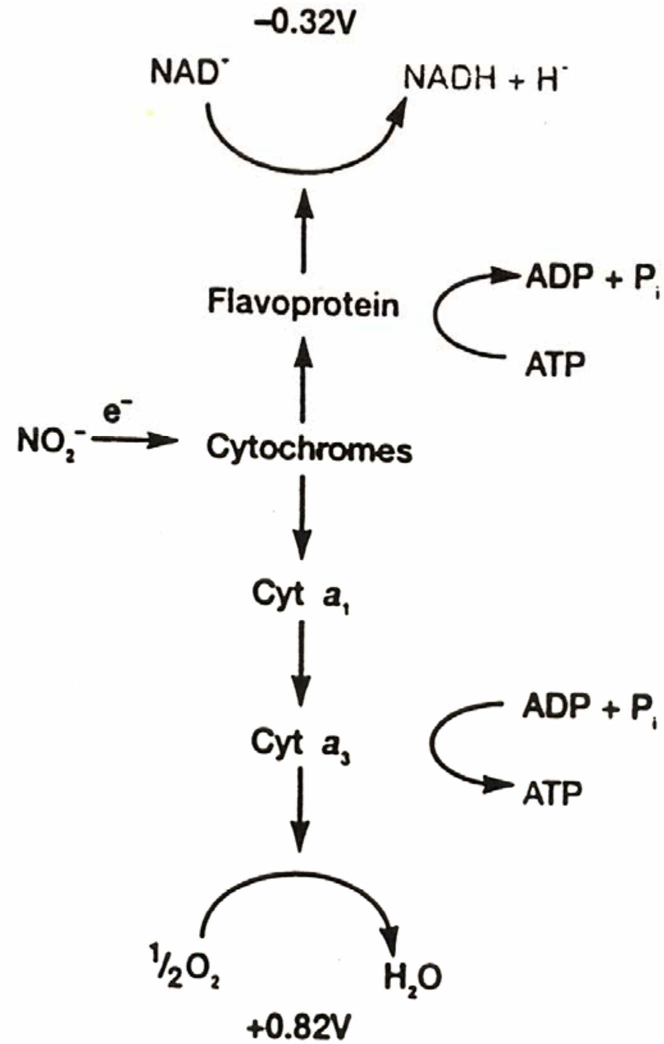
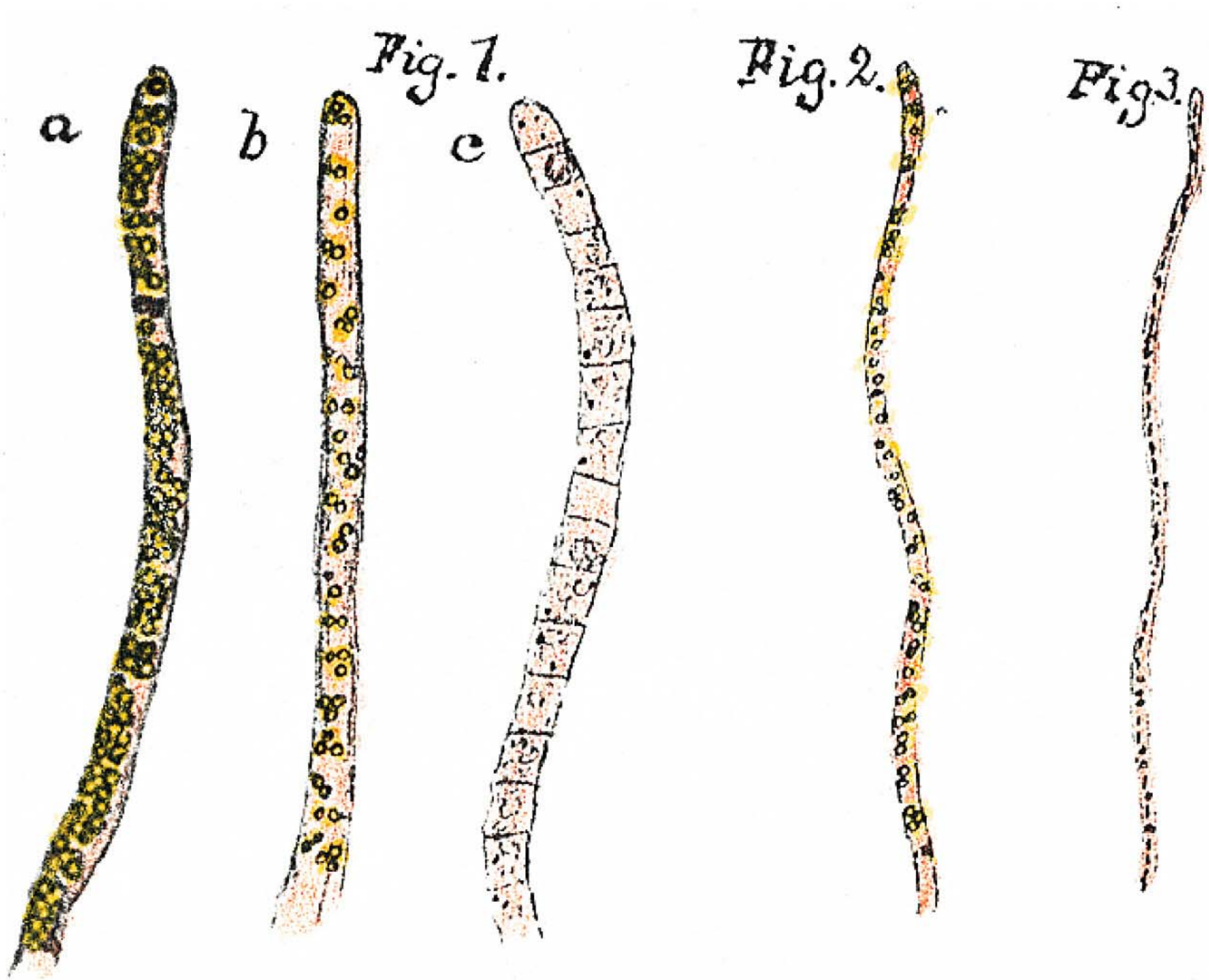
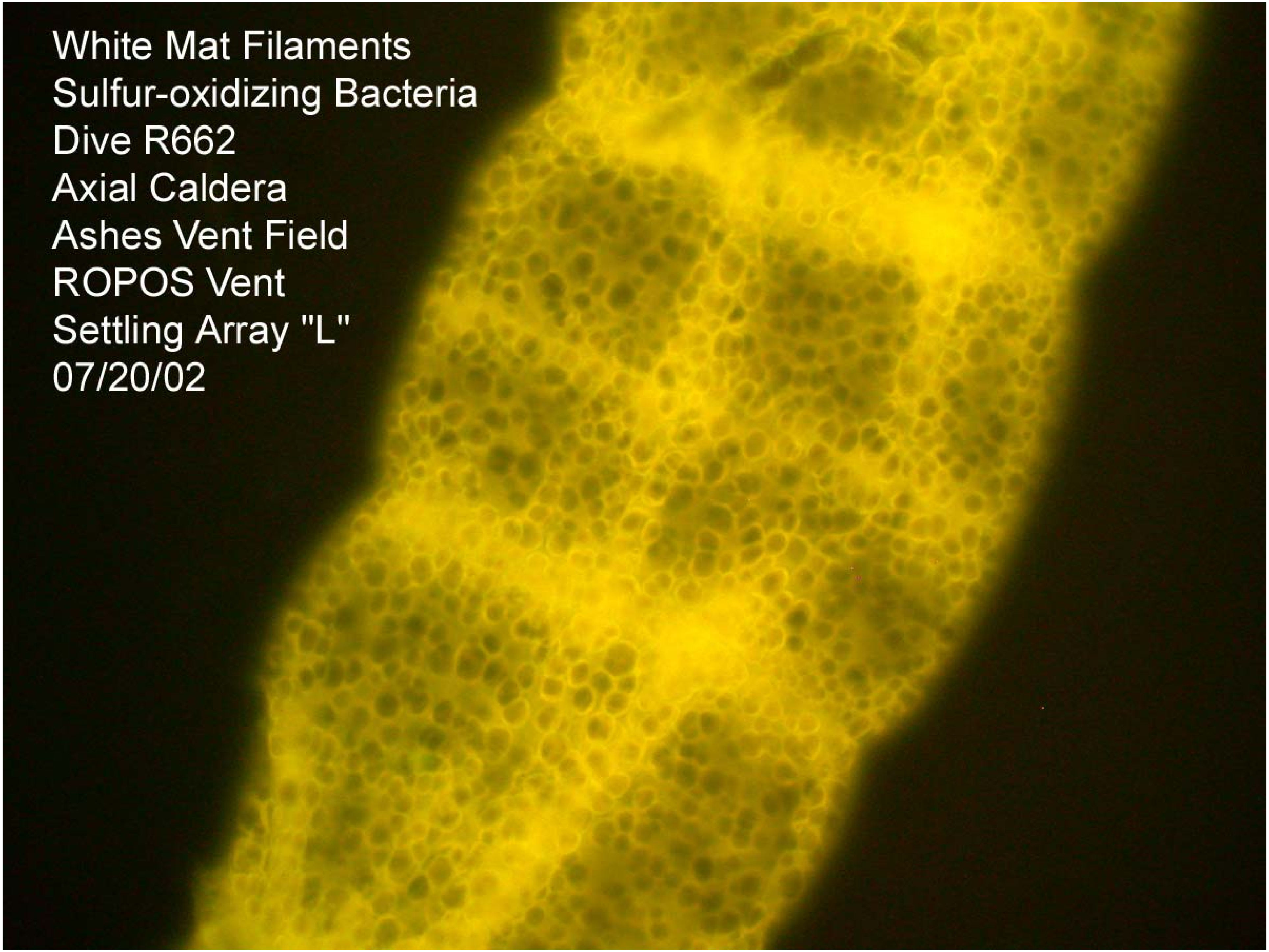


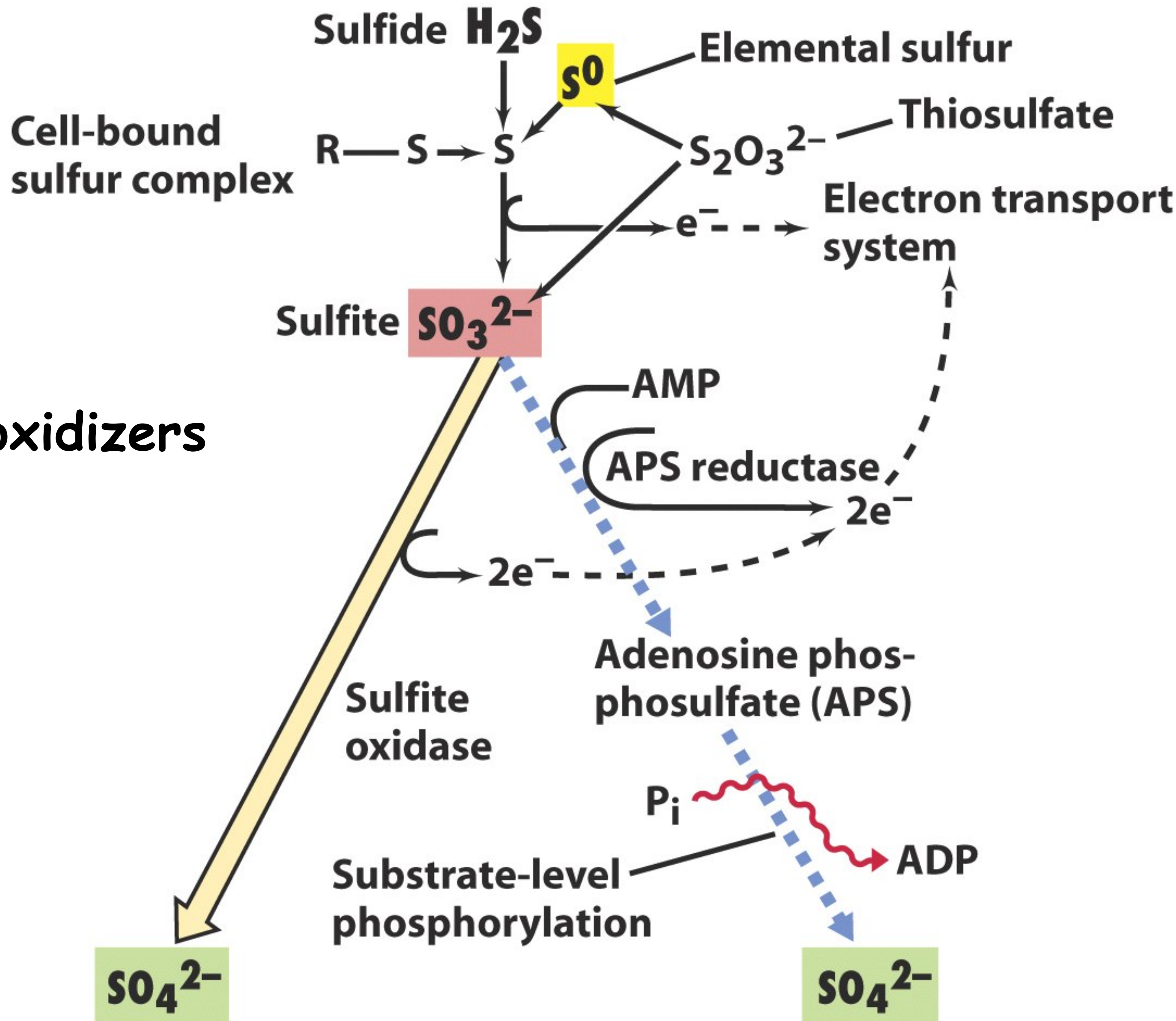

**Figure 9.20 Reversed Electron Flow.** The flow of electrons in the transport chain of *Nitrobacter*. Electrons flowing from nitrite to oxygen (down the reduction potential gradient) will release energy. It requires protonmotive force or ATP energy to force electrons to flow in the reverse direction from nitrite to $NAD^+$.



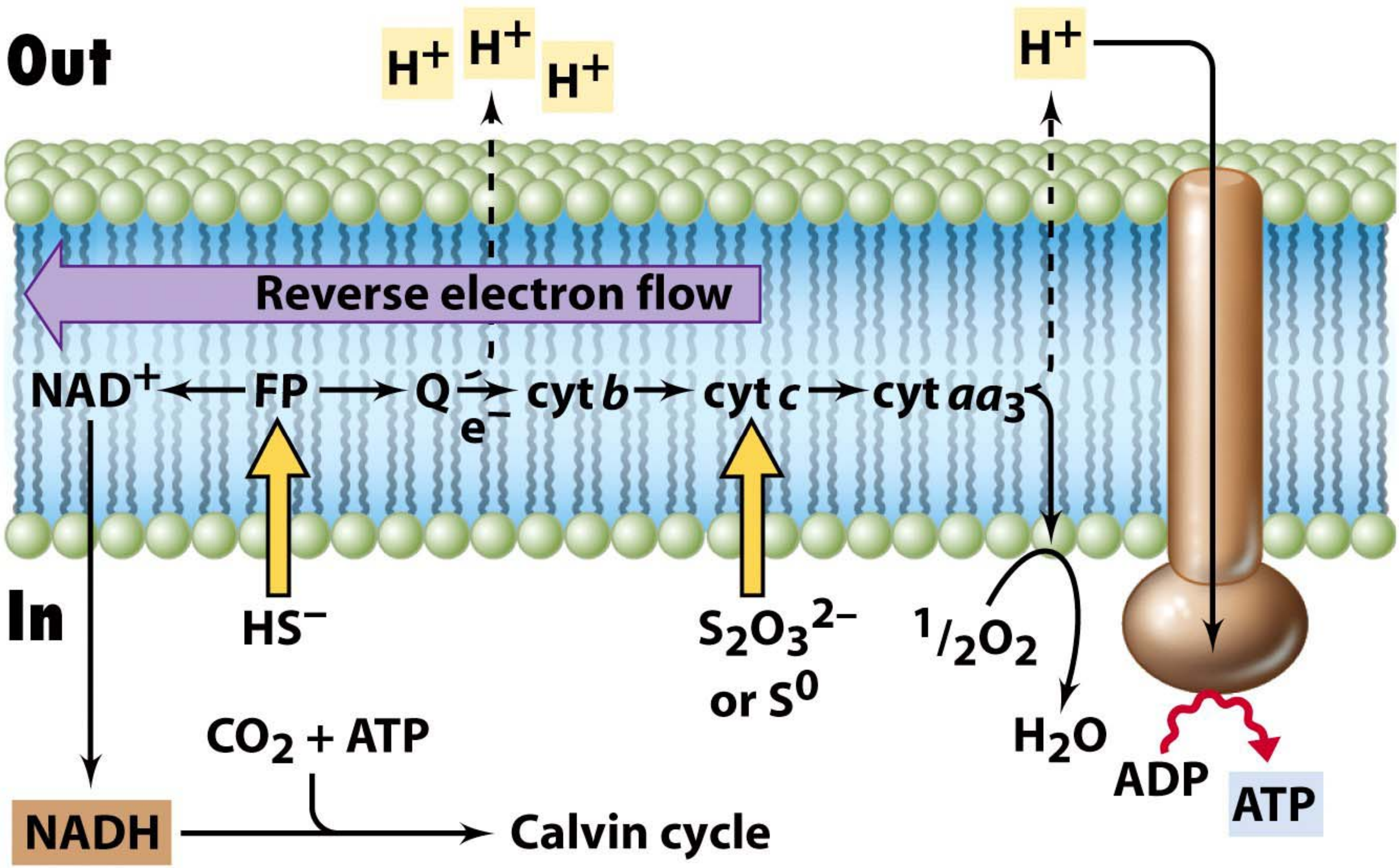

Winogradsky's drawings of *Beggiatoa*


White Mat Filaments
Sulfur-oxidizing Bacteria
Dive R662
Axial Caldera
Ashes Vent Field
ROPOS Vent
Settling Array "L"
07/20/02

S-oxidizers



Sulfide $H_2S$
$S^0$
Elemental sulfur
Thiosulfate
Cell-bound
sulfur complex
R—S → S
$S_2O_3^{2-}$
$e^-$
Electron transport
system
Sulfite $SO_3^{2-}$
AMP
APS reductase
$2e^-$
$2e^-$
Adenosine phos-
phosulfate (APS)
Sulfite
oxidase
$P_i$
ADP
Substrate-level
phosphorylation
$SO_4^{2-}$
$SO_4^{2-}$


Out
H+
H+
H+
H+
Reverse electron flow
NAD+
FP
Q
e−
cyt b
cyt c
cyt aa3
In
HS−
S2O3 2−
or S0
1/2O2
H2O
CO2 + ATP
NADH
Calvin cycle
ADP
ATP

## Loihi Volcano

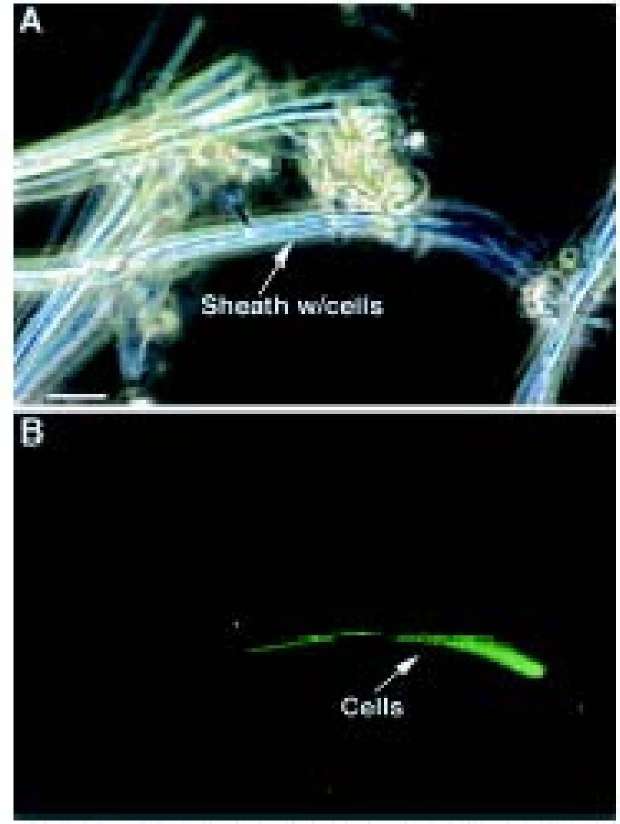
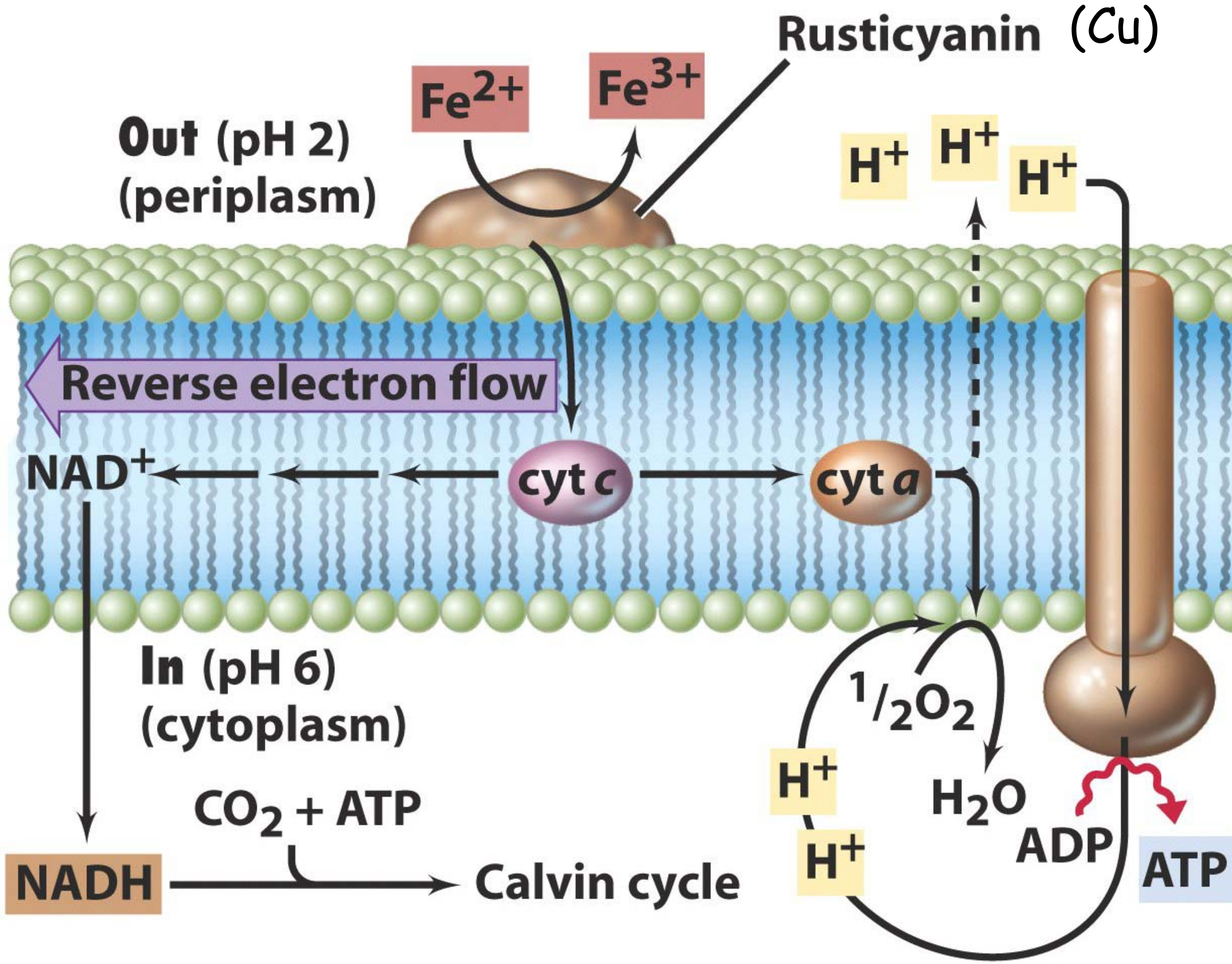


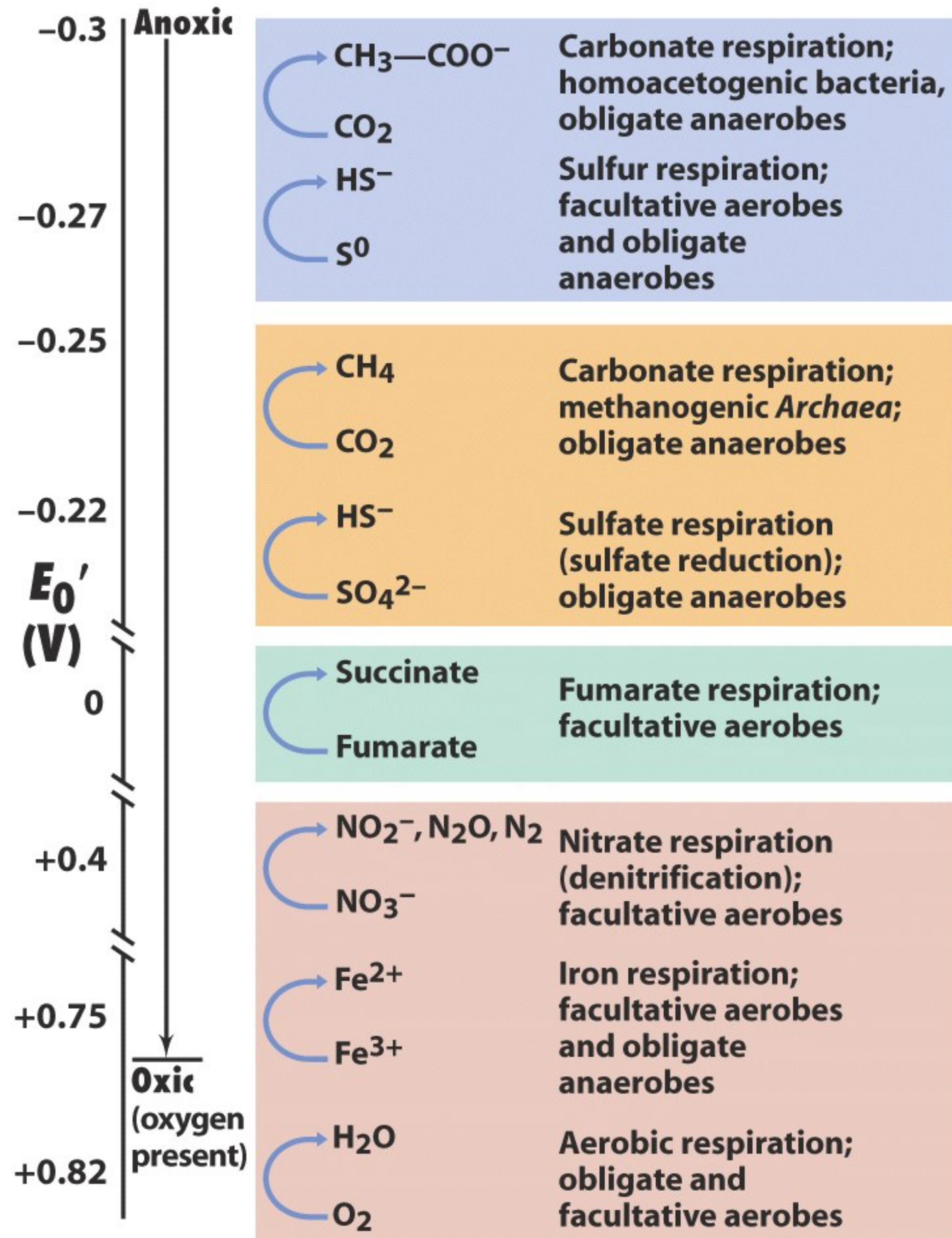

FIG. 3. *L. ochracea*-like sheaths collected at the Pohaku vents near marker 27. The sample has been stained with Syto. Panel B is the same image as in panel A but viewed by epifluorescence to reveal a filament of cells inside the iron-encrusted sheath. The cells are only visible when stained; most of the sheaths are empty. Bar, 5 μm.

Neutrophilic Fe-Oxidizing Bacteria
*zeta-Proteobacteria* (novel class)



Rusticyanin (Cu)
$Fe^{2+}$
$Fe^{3+}$
Out (pH 2)
(periplasm)
$H^+$
$H^+$
$H^+$
Reverse electron flow
$NAD^+$
cyt c
cyt a
In (pH 6)
(cytoplasm)
$1/2 O_2$
$H_2O$
$H^+$
$H^+$
ADP
ATP
$CO_2$ + ATP
NADH
Calvin cycle

Anaerobic Respirations

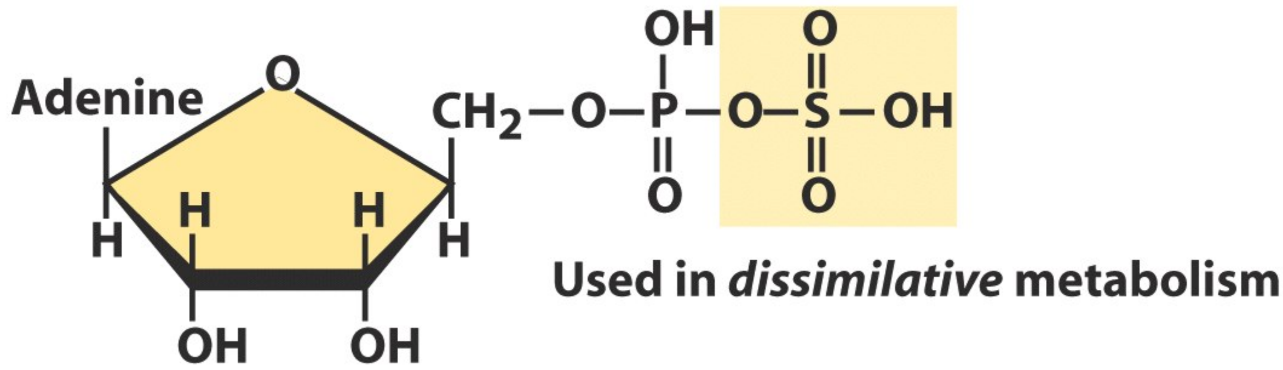



Assimilative vs. Dissimilative Metabolisms

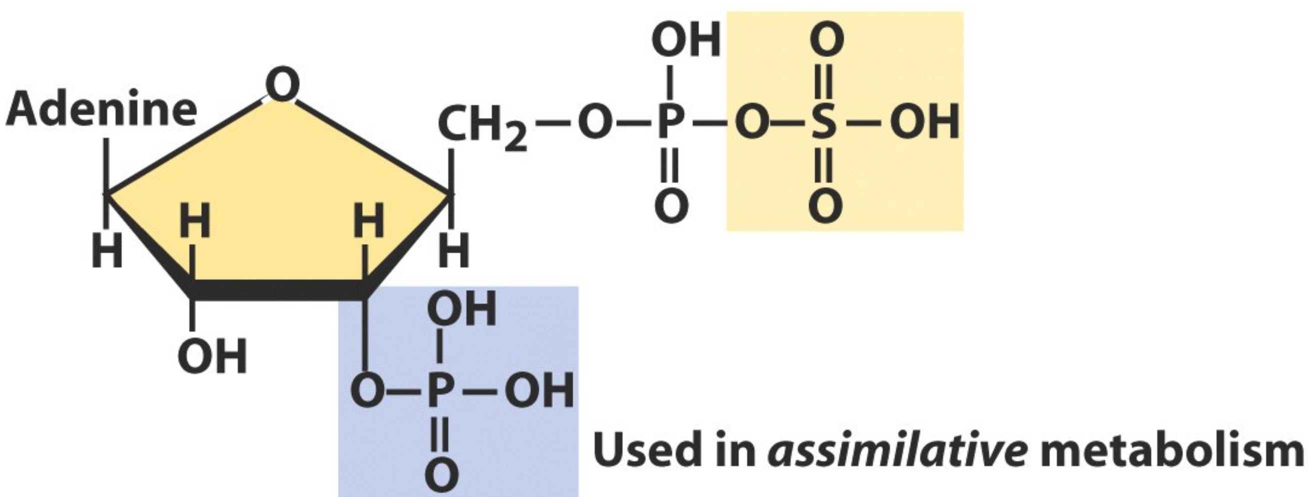
**Table 17.3 Sulfur compounds and electron donors for sulfate reduction**

| Compound | Oxidation state |
|---|---|
| **Oxidation states of key sulfur compounds** | |
| Organic S (R—SH) | −2 |
| Sulfide ($H_2S$) | −2 |
| Elemental sulfur ($S^0$) | 0 |
| Thiosulfate ($S_2O_3^{2-}$) | +2 (average per S) |
| Sulfur dioxide ($SO_2$) | +4 |
| Sulfite ($SO_3^{2-}$) | +4 |
| Sulfate ($SO_4^{2-}$) | +6 |
| **Some electron donors used for sulfate reduction** | |
| $H_2$ | Acetate |
| Lactate | Propionate |
| Pyruvate | Butyrate |
| Ethanol and other alcohols | Long-chain fatty acids |
| Fumarate | Benzoate |
| Malate | Indole |
| Choline | Hexadecane |

# SRB's can make active sulfate compounds

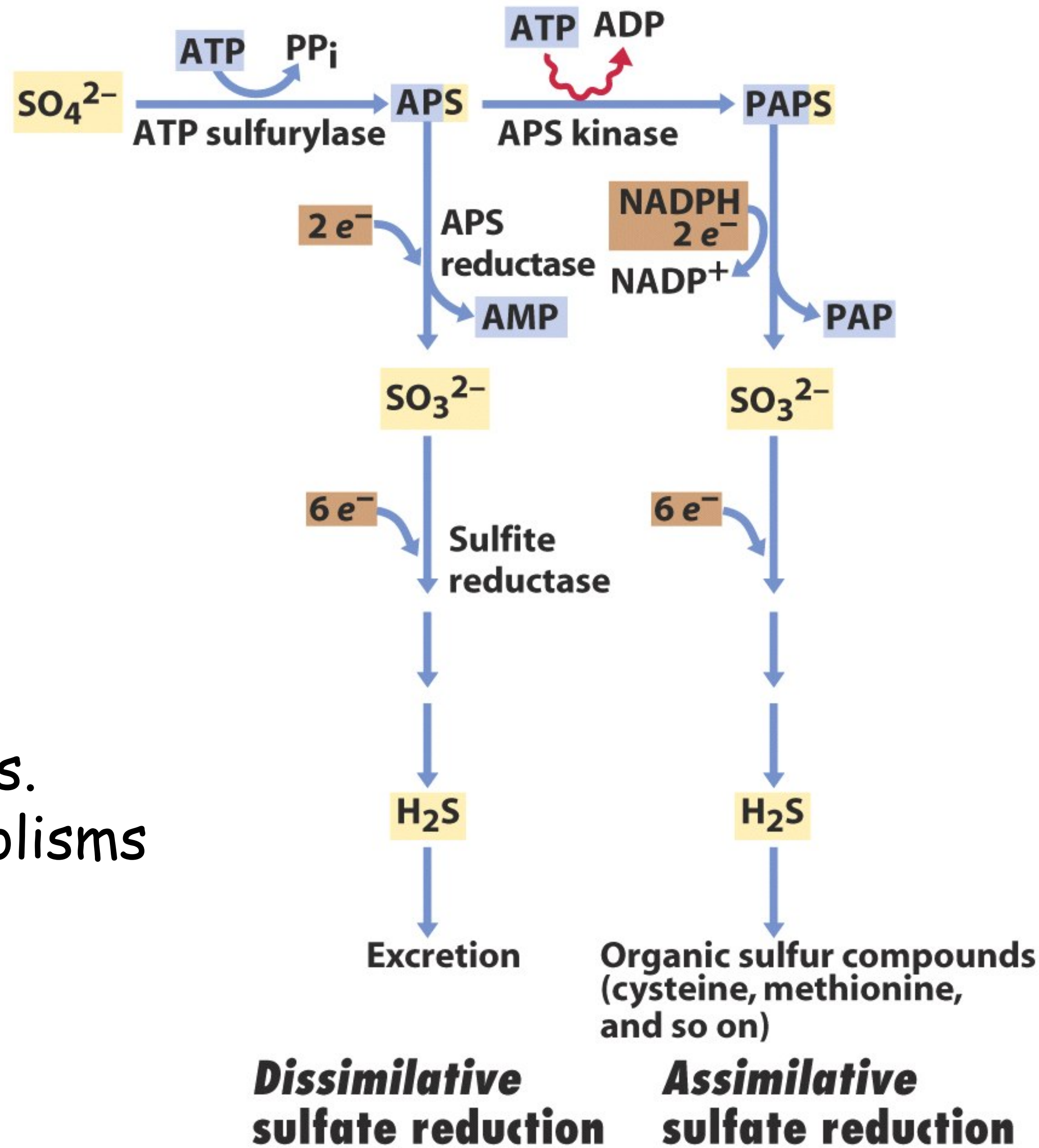



**APS** (Adenosine 5′-phosphosulfate)

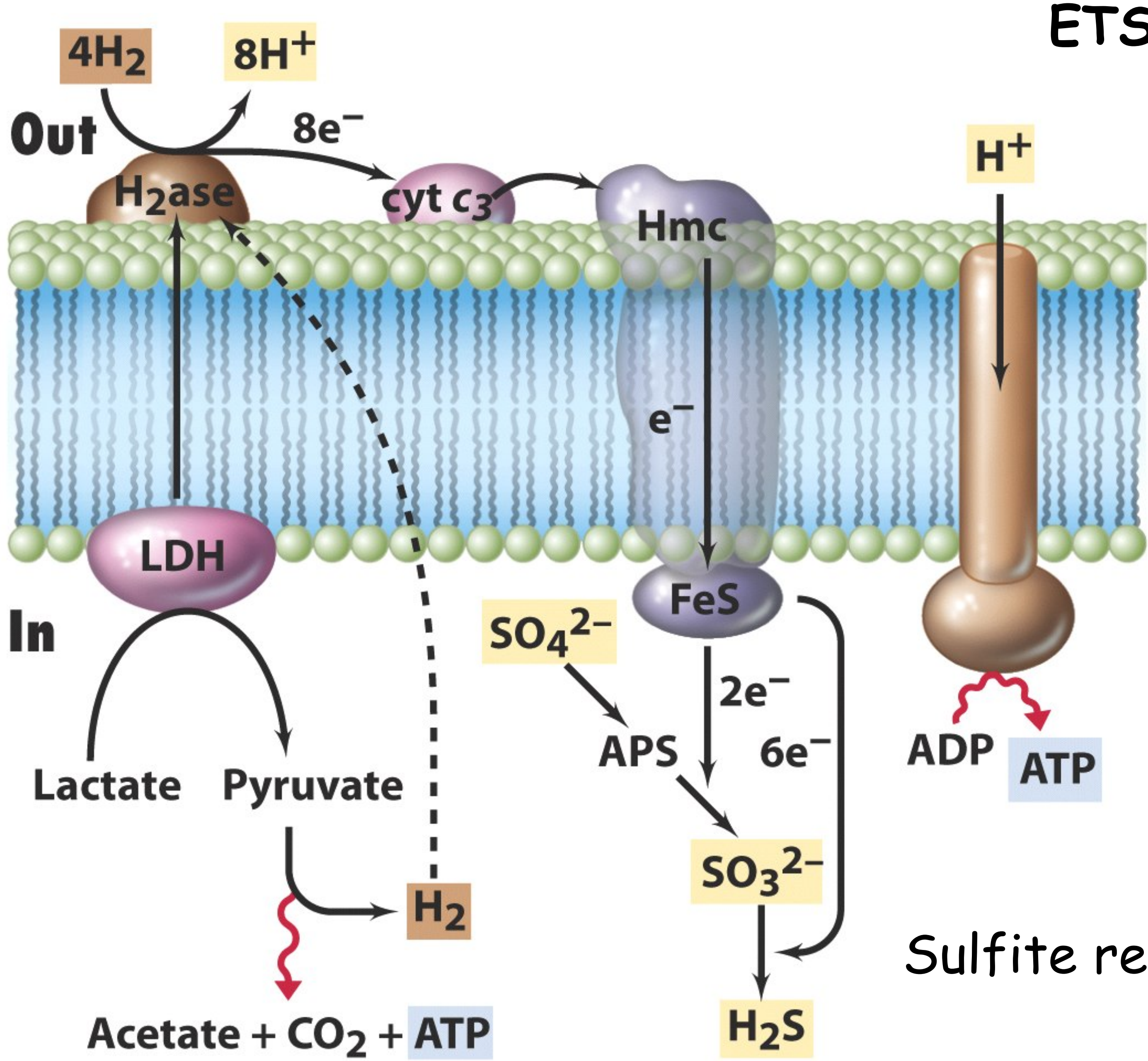



**PAPS** (Phosphoadenosine 5′-phosphosulfate)

SRB dissimilative vs. assimilative metabolisms



## ETS in SRBs




Sulfite reductase

# Sulfur Disproportionation

$S_2O_3^{2-} + H_2O \rightarrow SO_4^{2-} + H_2S$

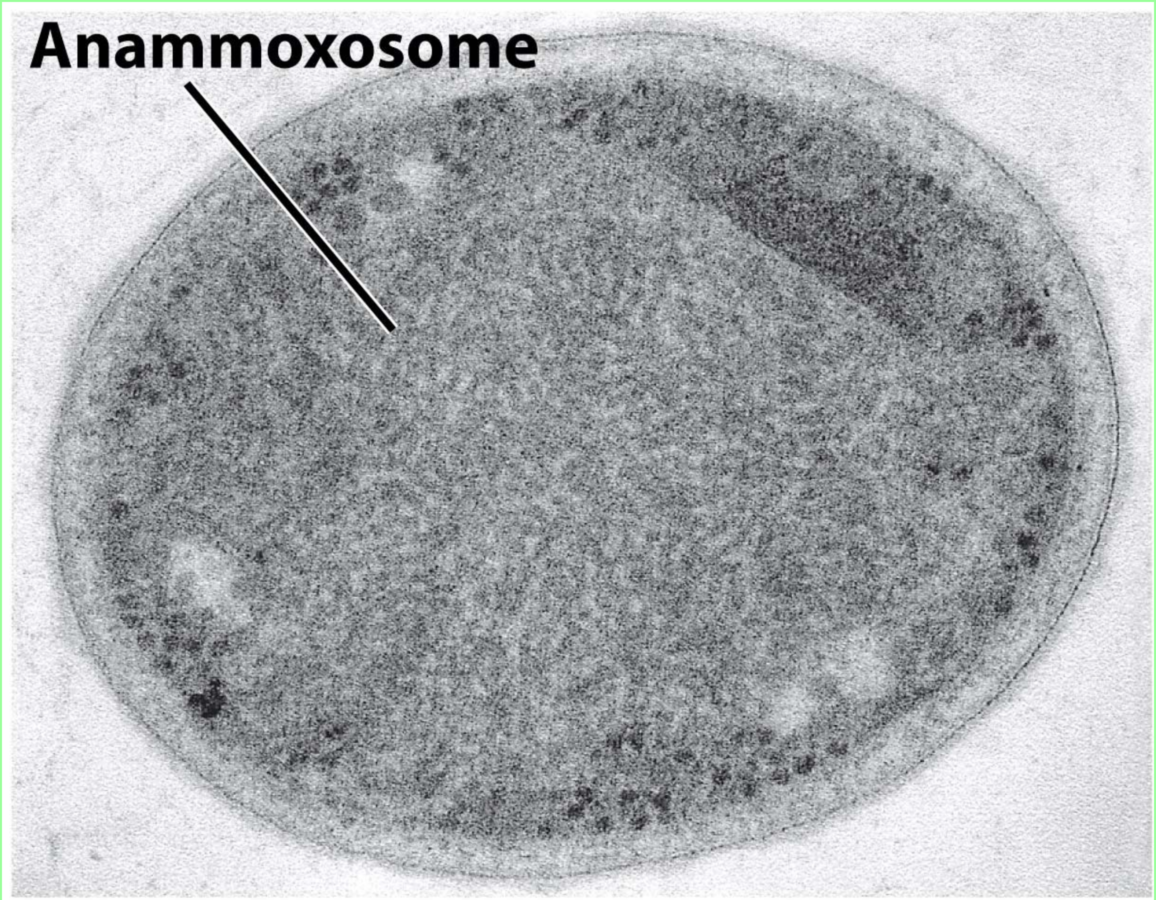
$\Delta G^{0'}$ = -21.9 kJ/rxn (not huge!)

Get your cake and eat it too!


Axial Volcano

# Anoxic ammonia oxidation: Anammox

A bizarre, toxin-filled microbe that could clean up sewage plants across the globe.



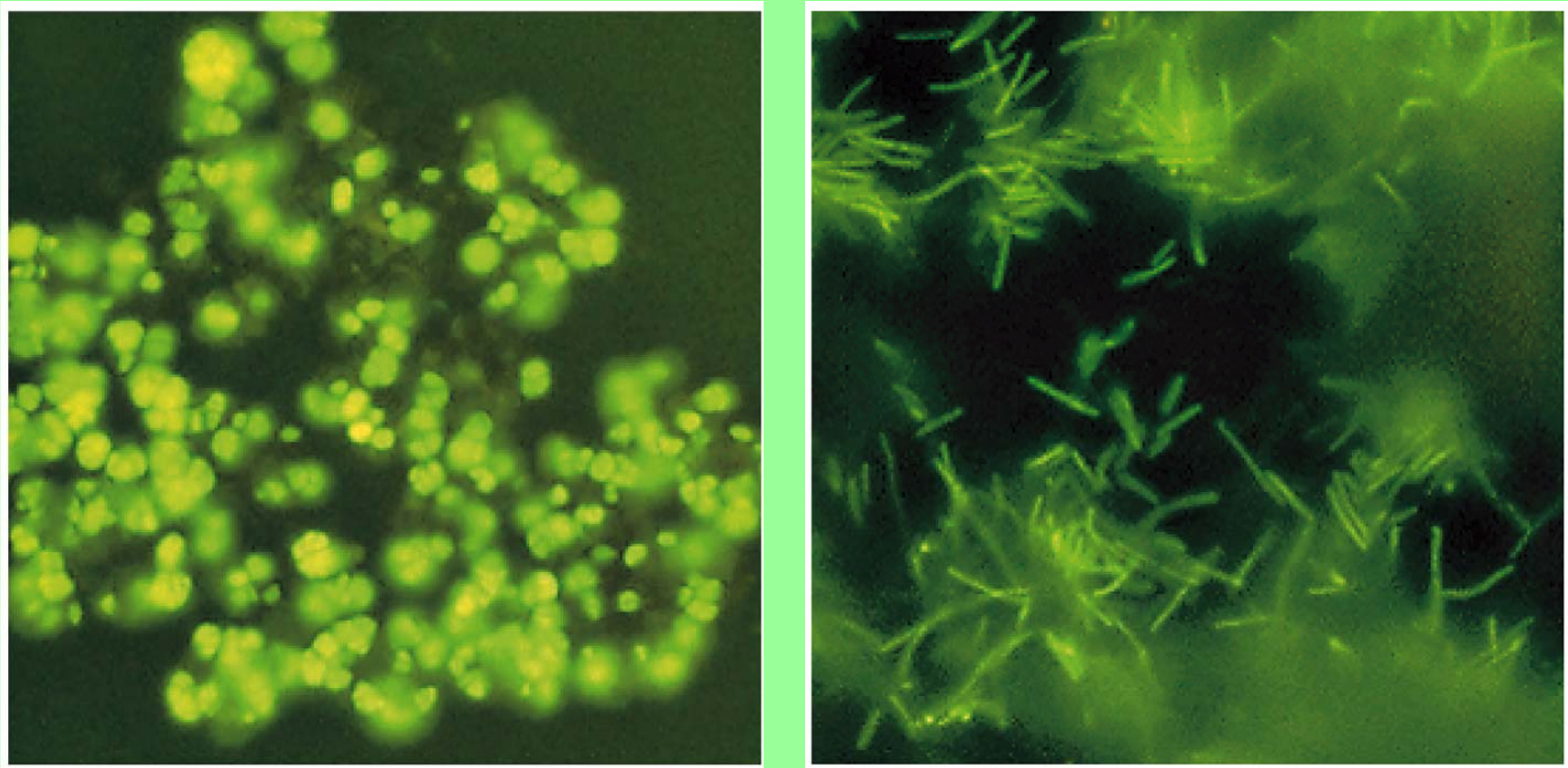

Contains: hydrazine

*Brocadia anammoxidans* (another *Planctomyces*)

**Table 17.2 Oxidation states of key nitrogen compounds**

| Compound | Oxidation state |
| --- | --- |
| Organic N (R—$NH_2$) | −3 |
| Ammonia ($NH_3$) | −3 |
| Nitrogen gas ($N_2$) | 0 |
| Nitrous oxide ($N_2O$) | +1 (average per N) |
| Nitrogen oxide (NO) | +2 |
| Nitrite ($NO_2^-$) | +3 |
| Nitrogen dioxide ($NO_2$) | +4 |
| Nitrate ($NO_3^-$) | +5 |

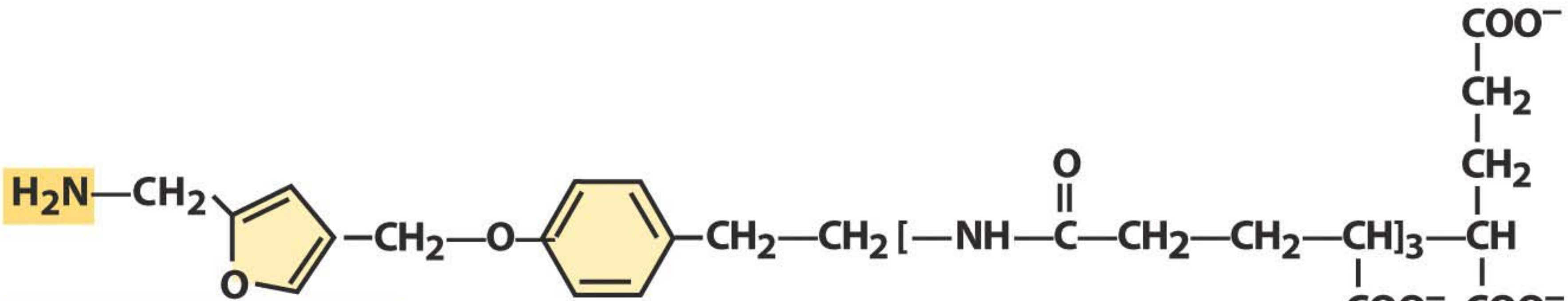
$$NH_4^+ + NO_2^- \rightarrow N_2 + H_2O$$



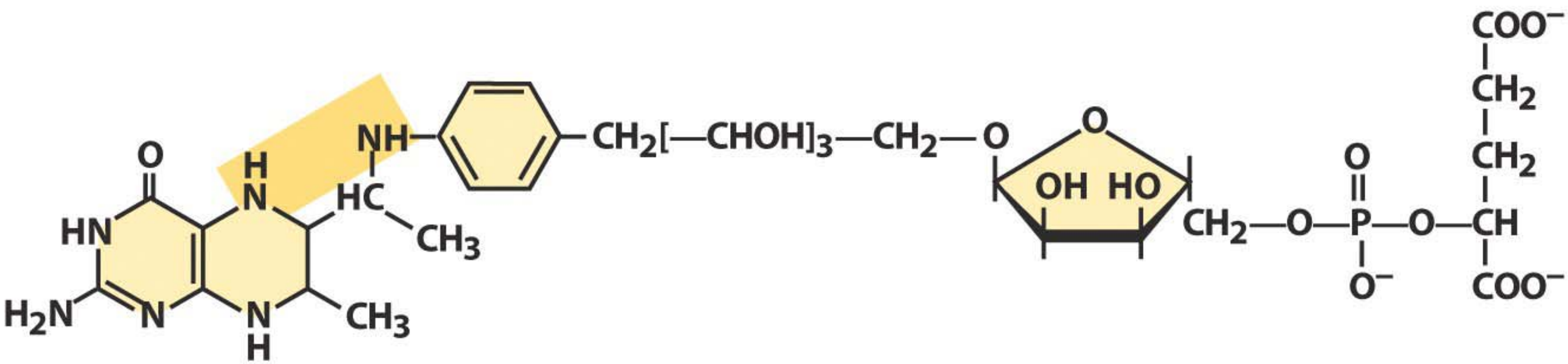
Autofluorescence in methanogen cells due to the presence of the unique electron carrier $F_{420}$

# Coenzymes of methanogenesis

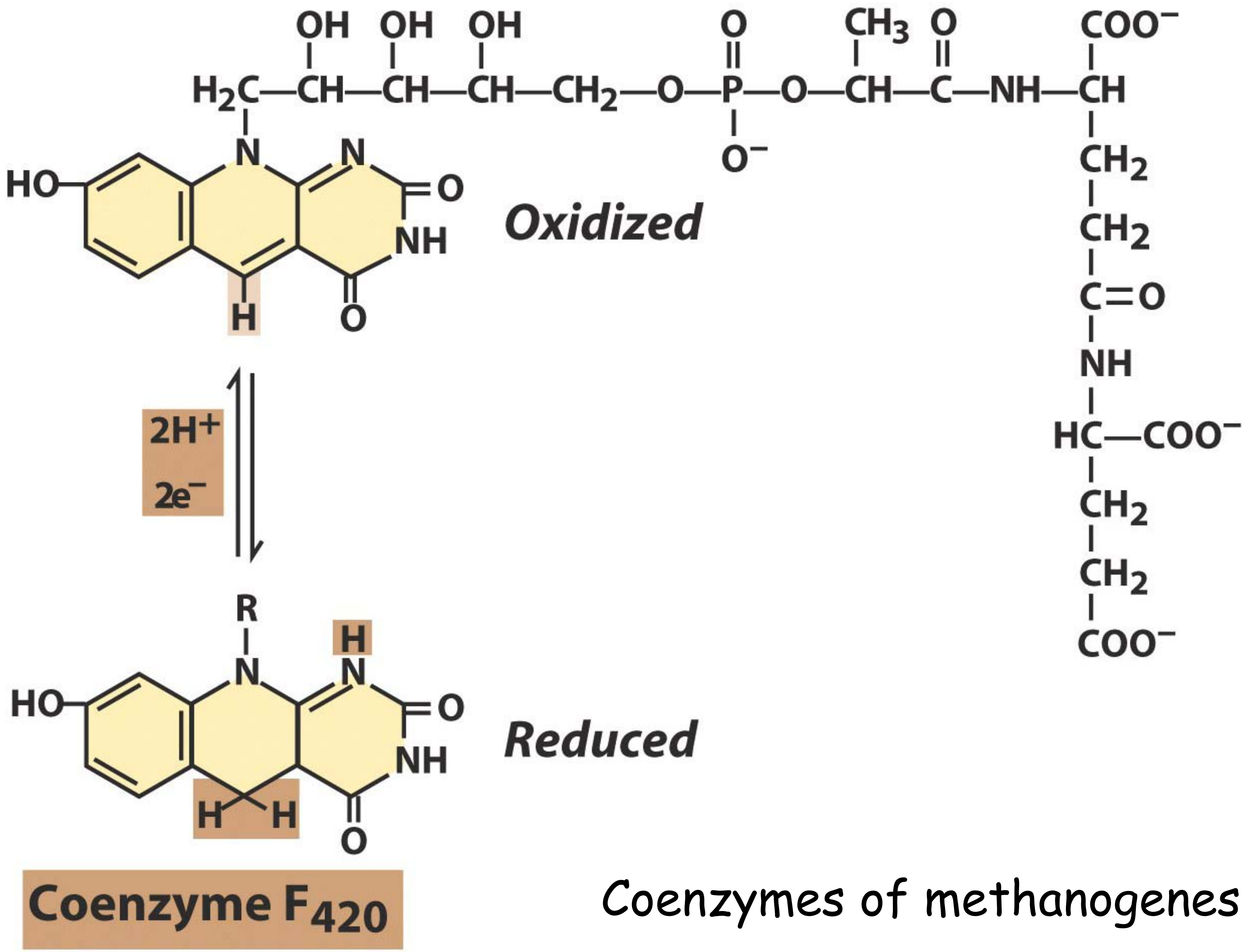
Two types: $C_1$ carriers or redox



Methanofuran

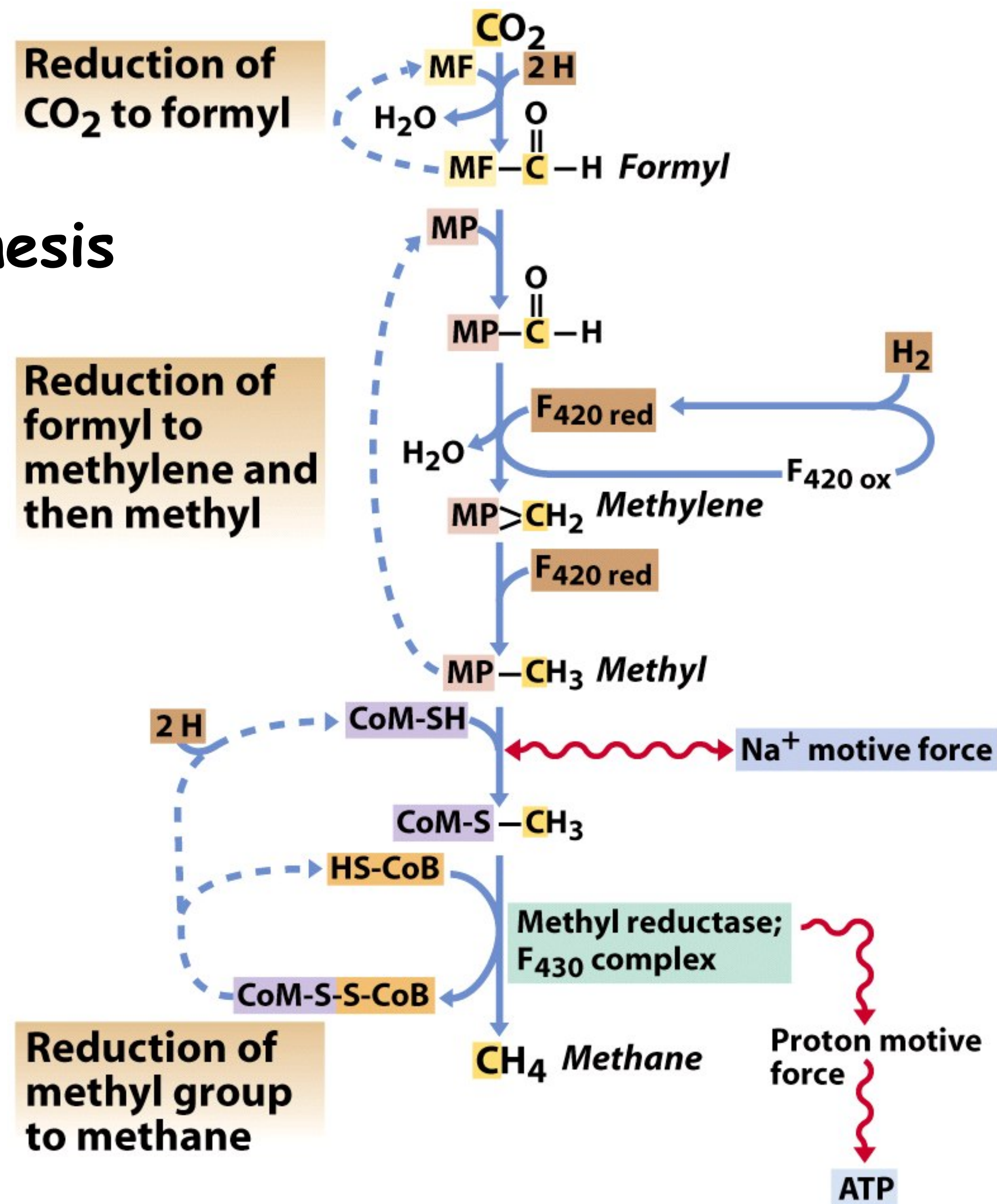


Methanopterin




Coenzymes of methanogenesis

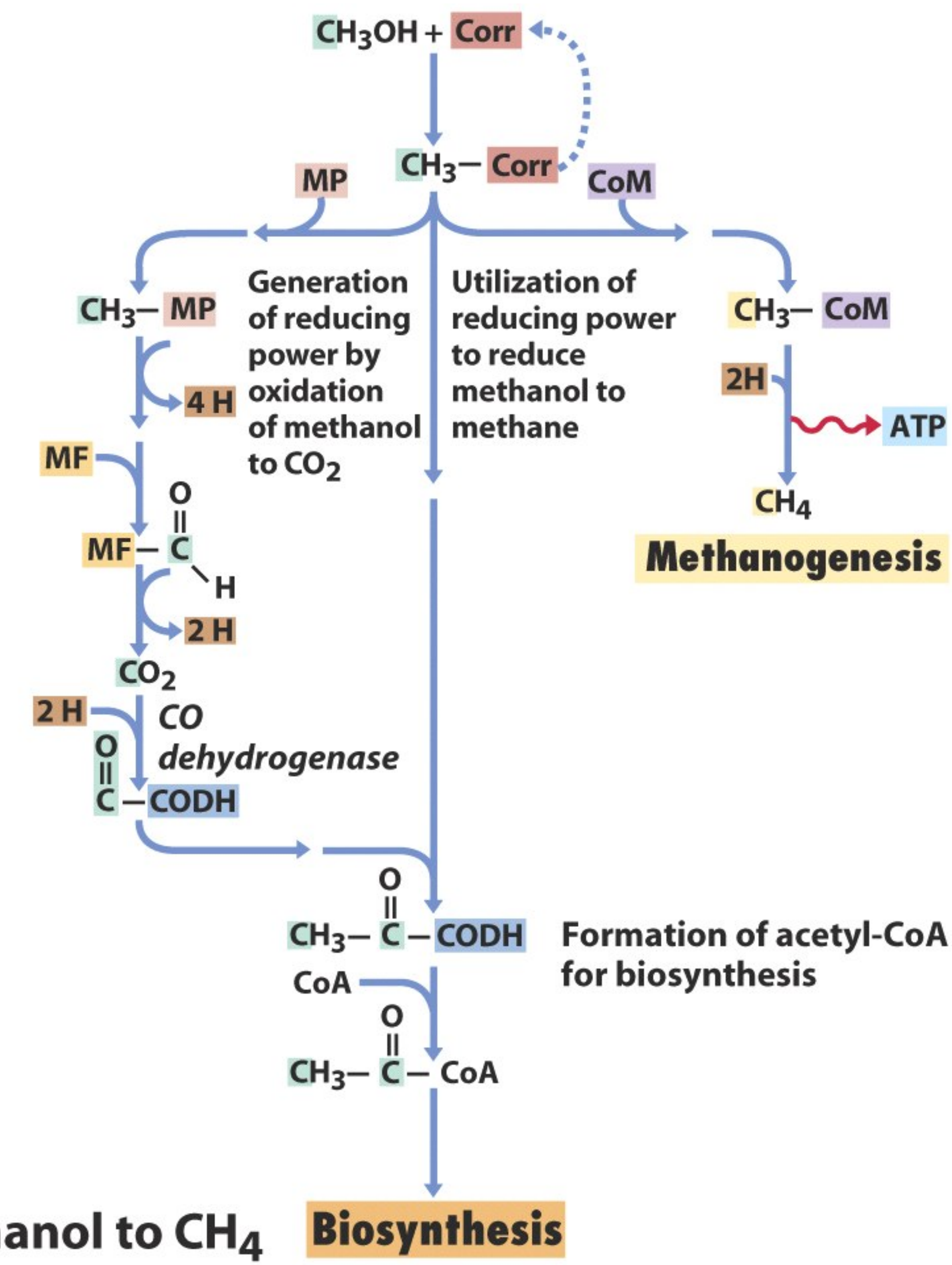
# Methanogenesis




$H_2 + CO_2$

↓

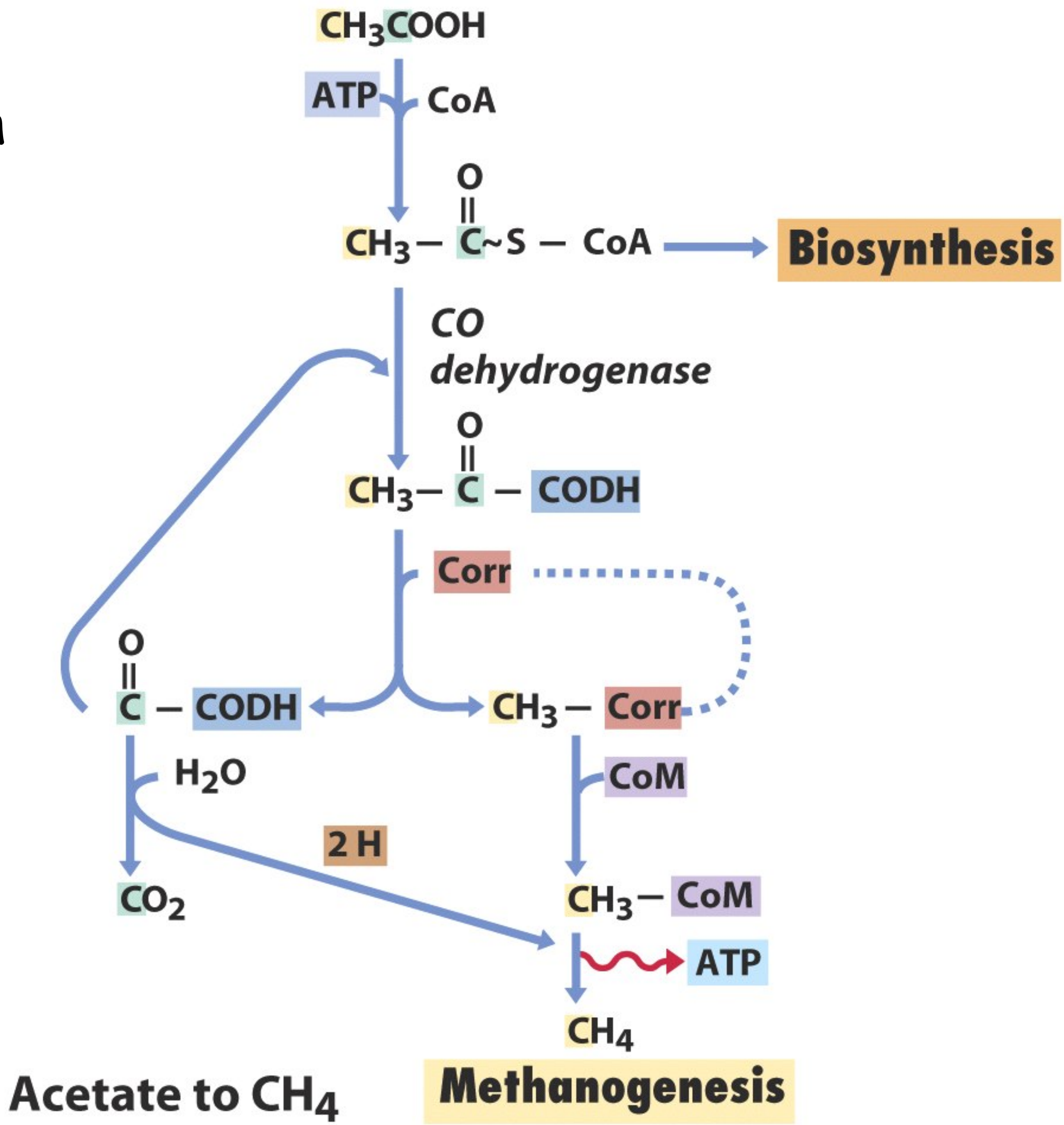
$CH_4$



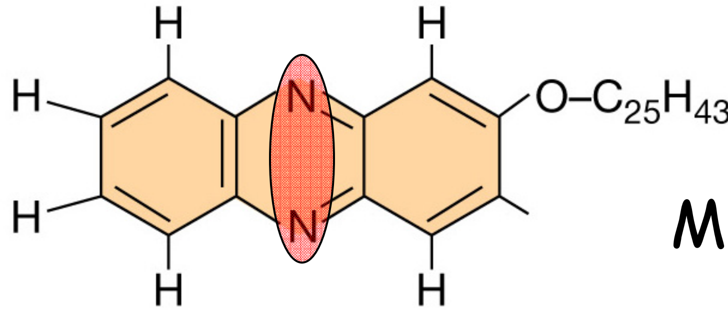

Methanol to $CH_4$

Autotrophy?
Corrinoids with Co centers!

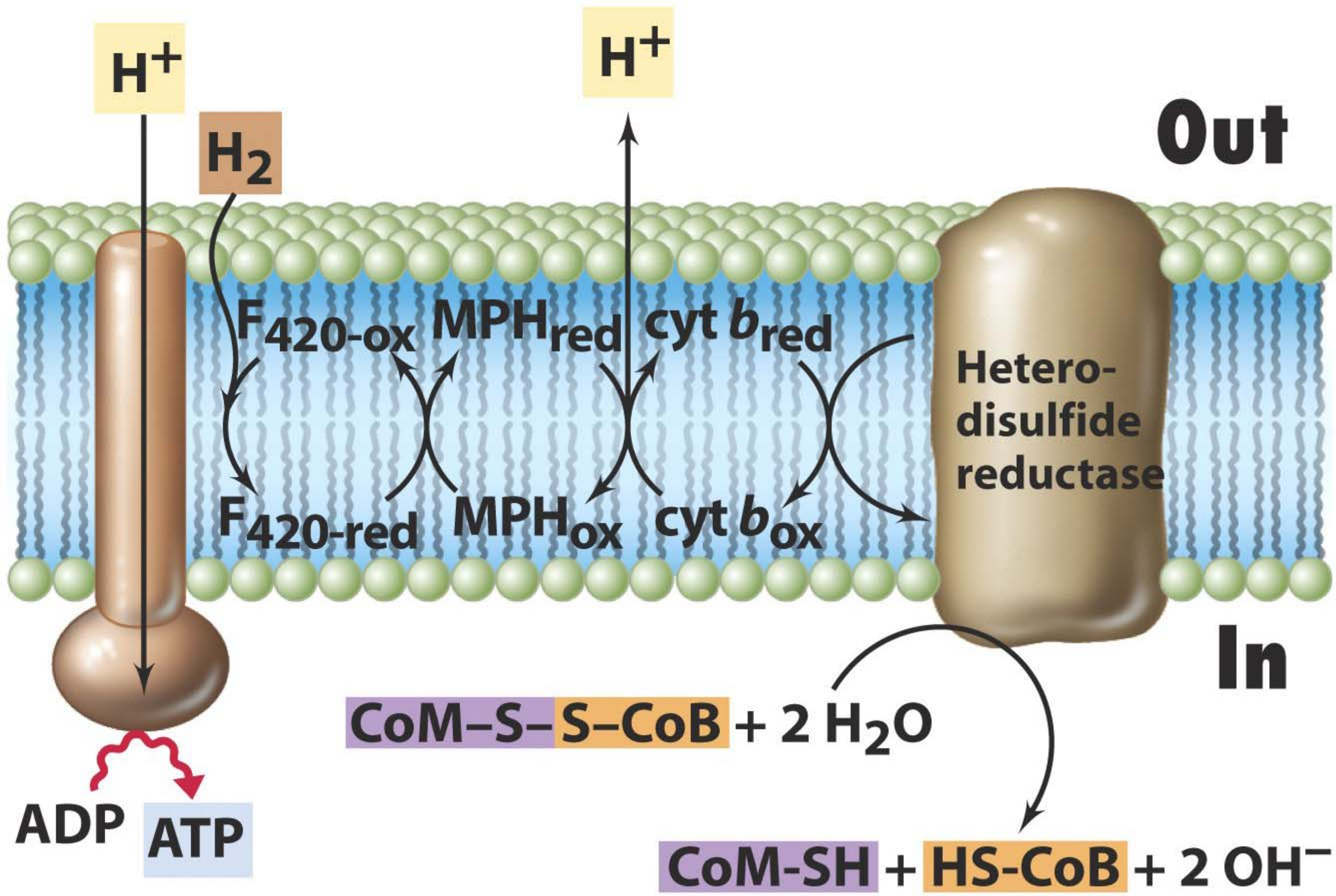
Autotrophy?
Corrinoids with
Co centers!



# Conservation of Energy




Methanophenazine



# Methanogenesis

Chemoautotrophs:
$CO_2 \rightarrow CH_4$ + Org. C
$H_2$ as electron donor

Chemoorganotrophs:
Acetate/MeOH $\rightarrow CH_4 + CO_2$
Org. C as electron donor

Global Biogenic Methane Production:
1/3 Chemoautotrophs
2/3 Chemoorganotrophs

# Take Home Message
# Methanogenesis

- Methanogenesis is the biological production of $CH_4$ from either $CO_2$ plus $H_2$ or from methylated compounds.

- A variety of unique coenzymes are involved in methanogenesis, and the process is strictly anaerobic.

- Energy conservation in methanogenesis involves both proton and sodium ion gradients.

- Only *Archaea* are able to pull this weird metabolism off.