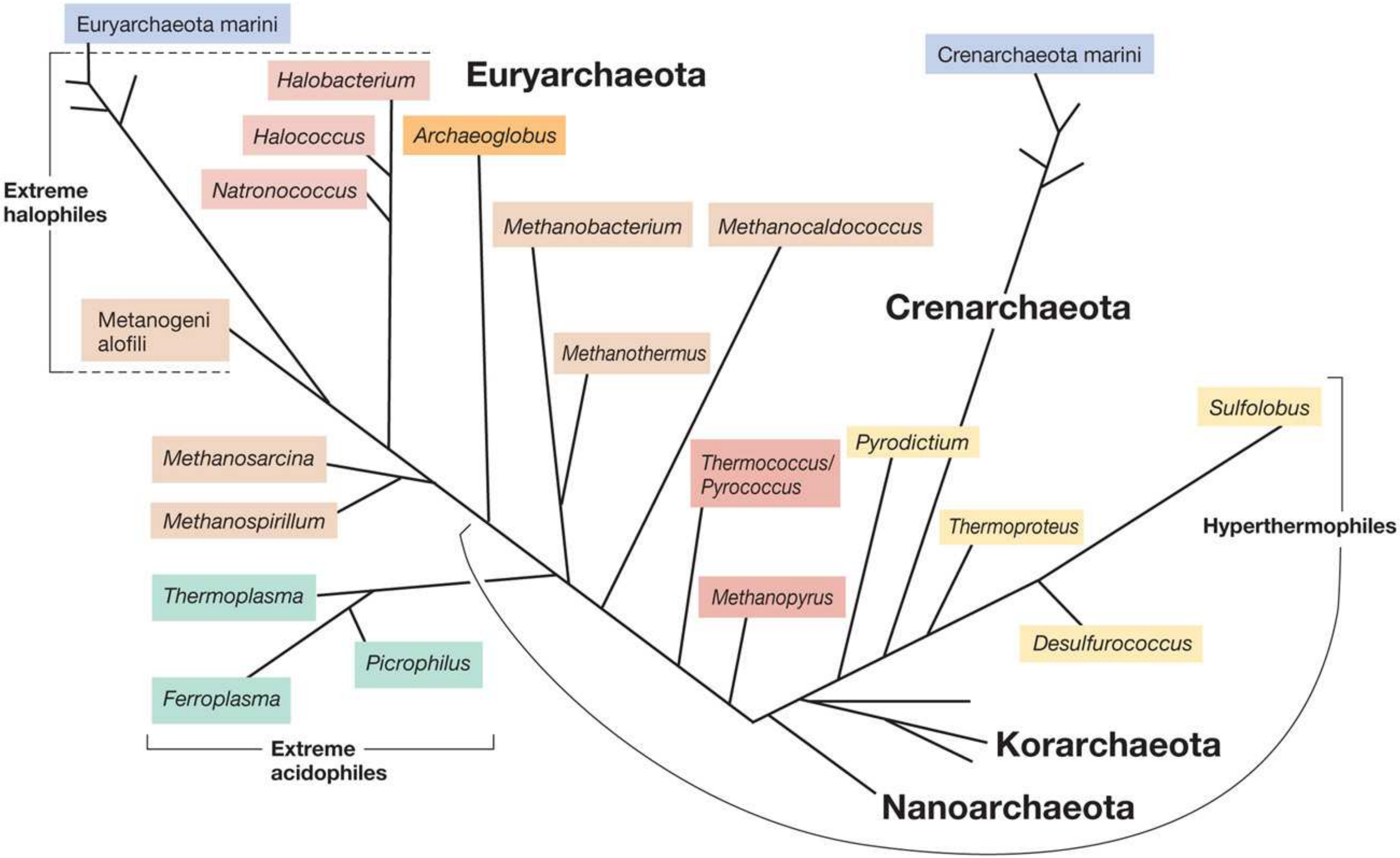
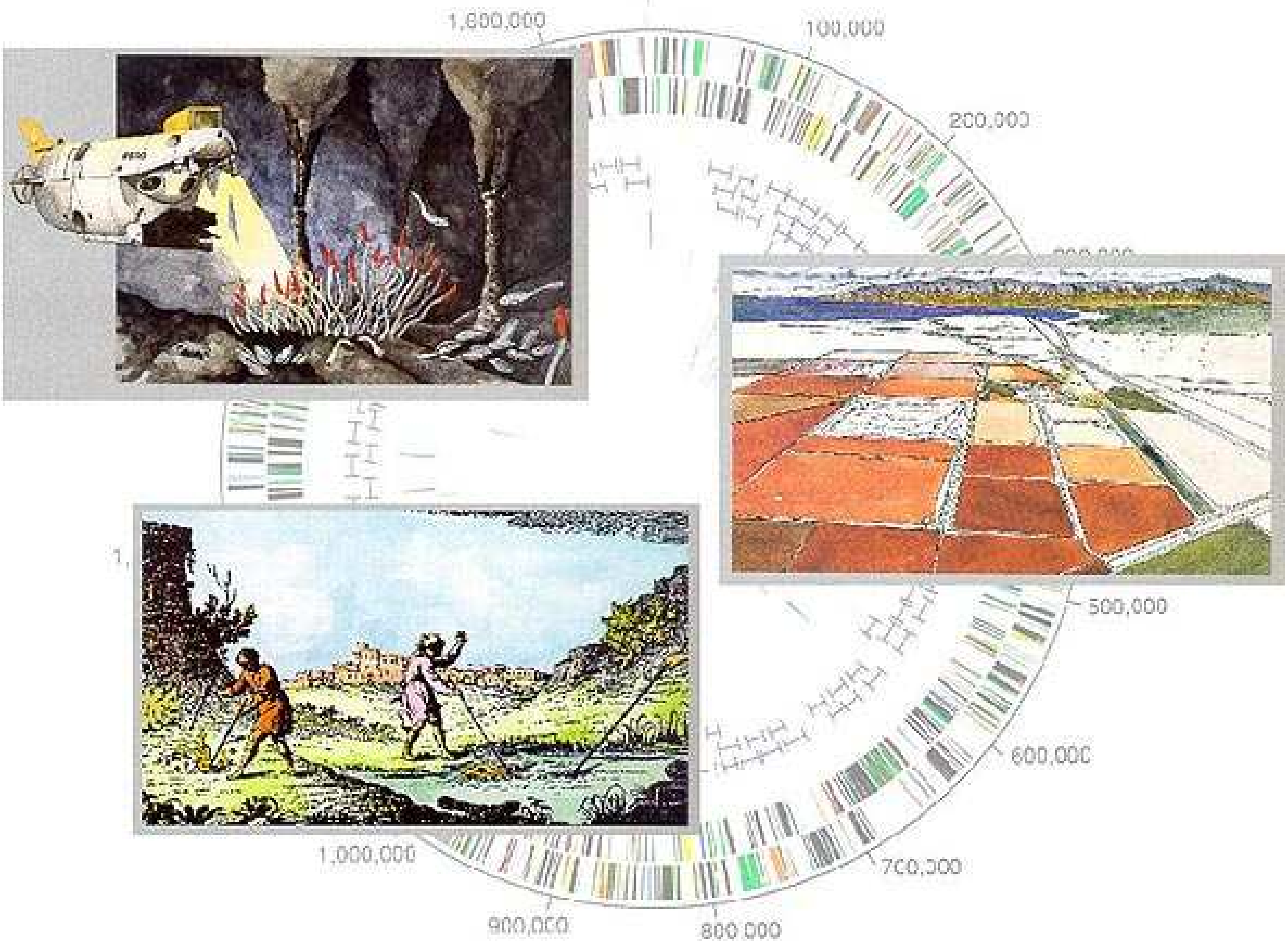
MICROBIOLOGIA GENERALE

The Archaea


Euryarchaeota marini
Euryarchaeota
Halobacterium
Halococcus
Archaeoglobus
Natronococcus
Extreme
halophiles
Methanobacterium
Methanocaldococcus
Crenarchaeota marini
Crenarchaeota
Metanogeni
alofili
Methanothermus
Sulfolobus
Methanosarcina
Thermococcus/
Pyrococcus
Pyrodictium
Methanospirillum
Thermoproteus
Hyperthermophiles
Thermoplasma
Methanopyrus
Desulfurococcus
Picrophilus
Ferroplasma
Extreme
acidophiles
Korarchaeota
Nanoarchaeota


1,600,000
100,000
200,000
500,000
600,000
700,000
800,000
900,000
1,000,000

The Archaea's traits

1. The cell wall of Archaea: pseudopeptidoglycan, polysaccharide, glycoprotein

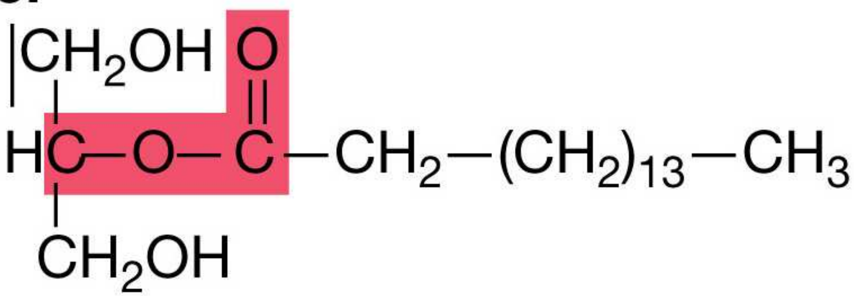
2. The cytoplasmic membrane of Archaea: ether linkage, glycerol diethers and tetraethers

3. Transcription and translation in Archaea

4. Energy metabolism and metabolic pathways in Archaea

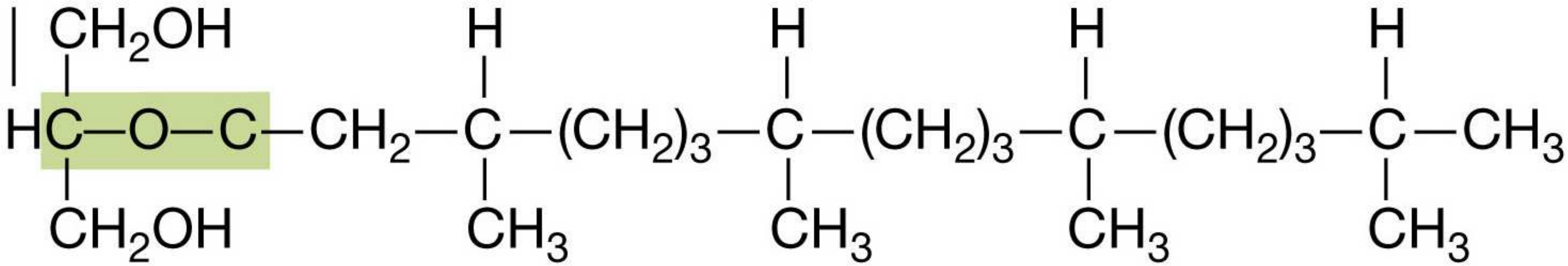
Lipids in Bacteria, Eukarya, and Archaea

Ester



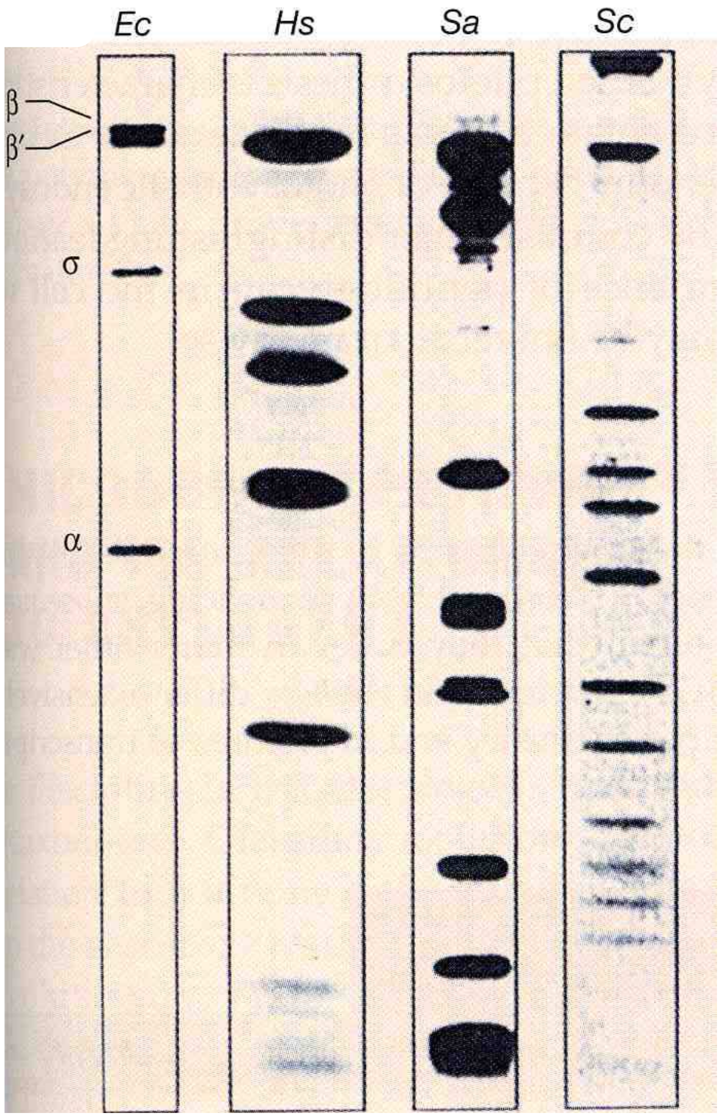
Bacteria, Eukarya

Ether



Archaea

RNA polymerases from Bacteria, Eukarya, and Archaea

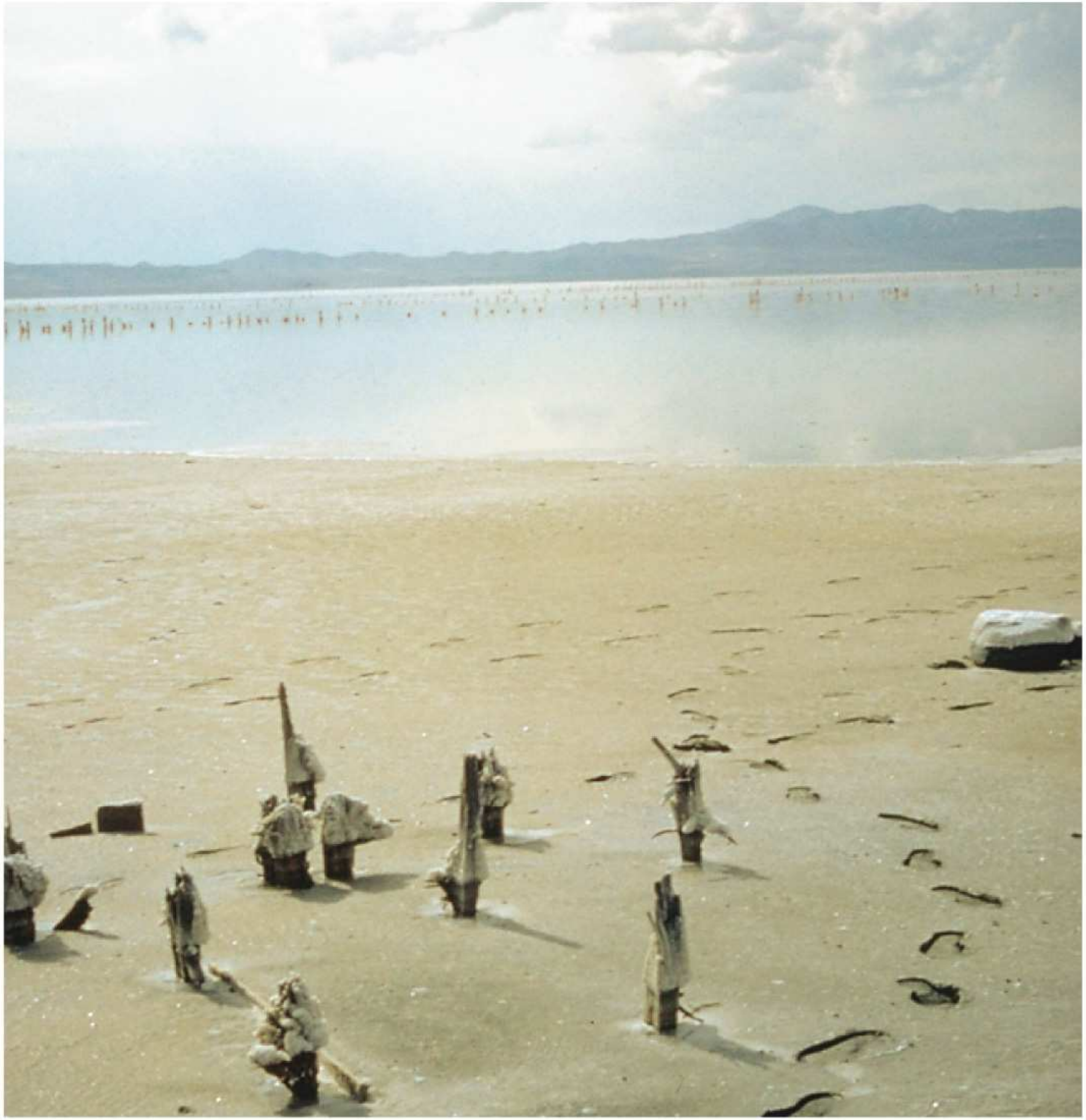


The Euryarchaeota:

extremely halophilic Archaea

Ionic composition of some highly saline environments

Ion	Concentration (g/l) Great Salt Lake	Dead Sea	Soda lake	Seawater
Na^+	105	401	142	10.6
K^+	6.7	7.7	2.3	0.38
Mg^{2+}	11	44	<0.1	1.27
Ca^{2+}	0.3	17.2	<0.1	0.40
Cl^-	181	225	155	18.9
SO_4^{2-}	27	0.5	23	2.65
$HCO3^-$	0.7	0.2	67	0.14
pH	7.7	6.1	11	8.1



T. D. Brock

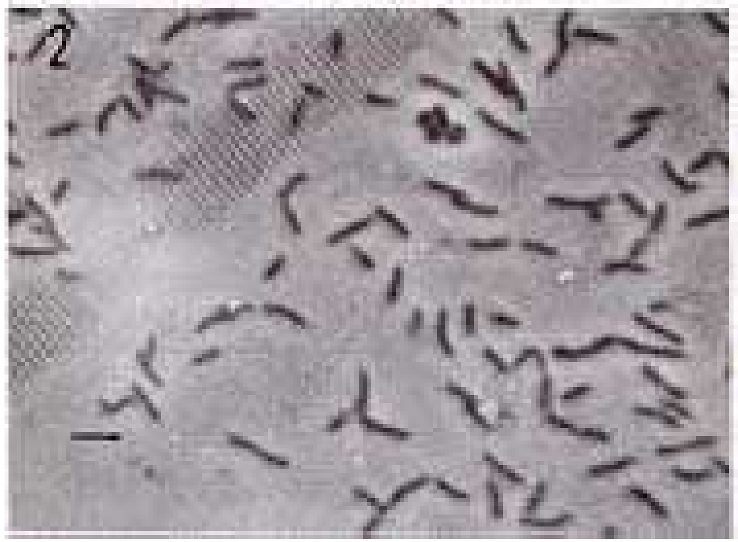
Hypersaline habitats for halophilic Archaea : the Great Salt Lake

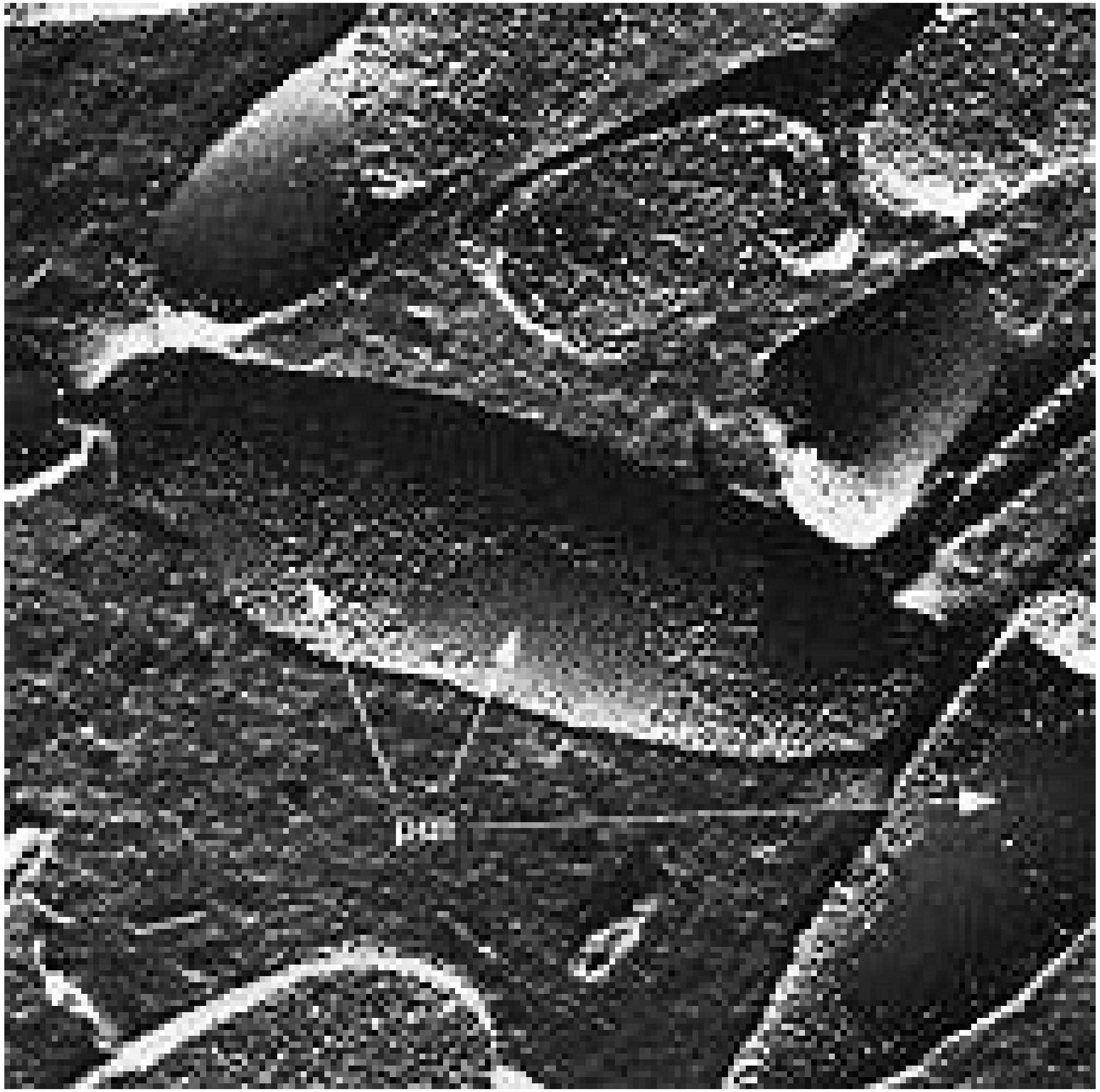
NASA

Hypersaline habitats for halophilic Archaea : the salter

Michael T. Madigan

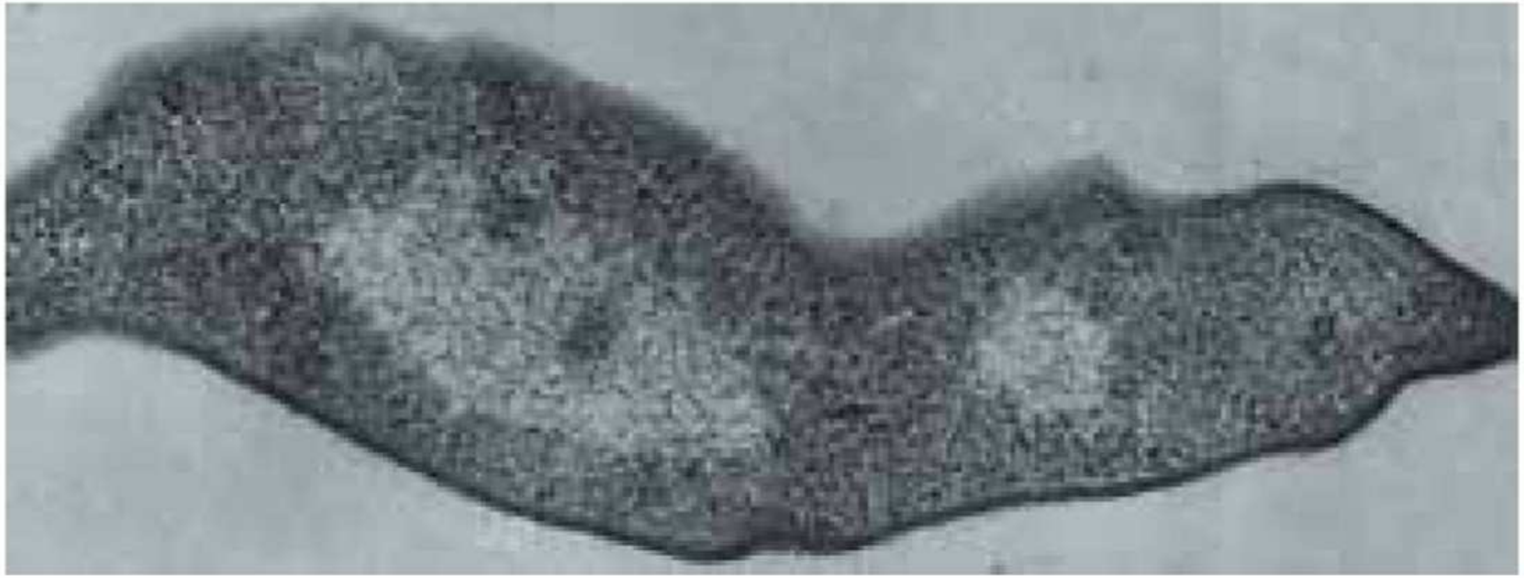
Hypersaline habitats for halophilic Archaea : Lake Hamara, Egypt





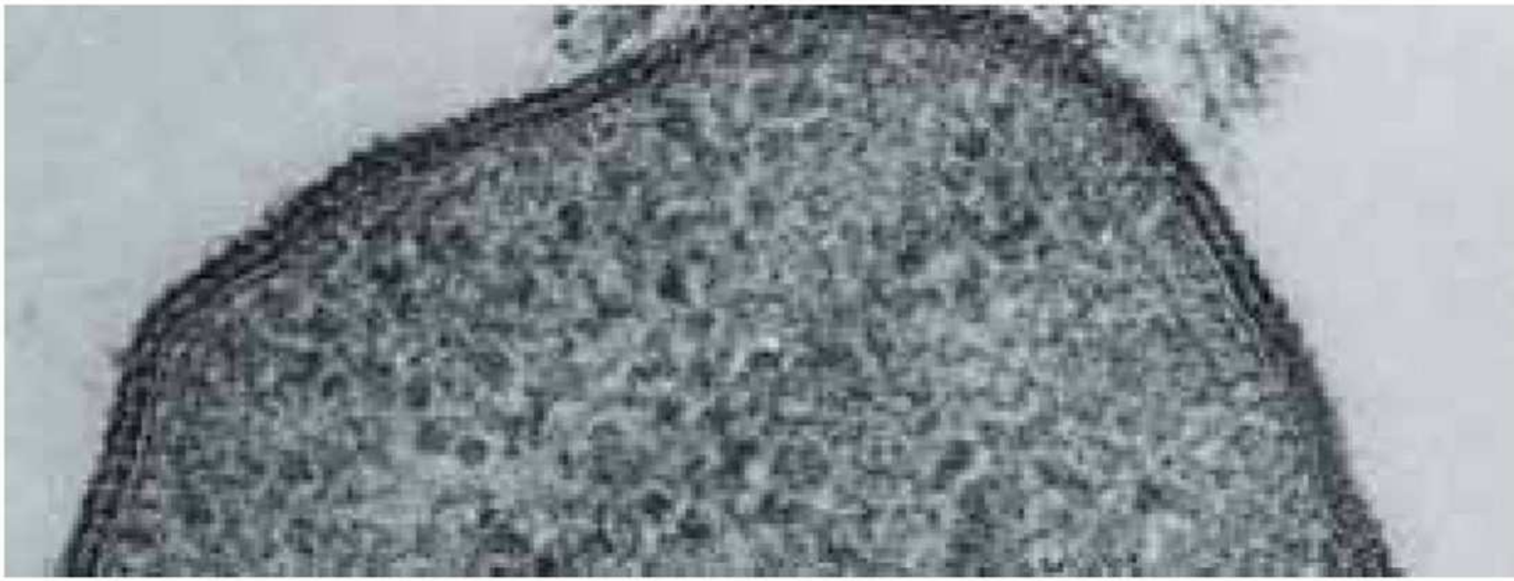
•*Halobacterium salinarium*is an extreme halophile that grows at 4 to 5 M NaCl.

•The freeze etched preparation shows the surface structure of the cell membrane and reveals smooth patches of"purple membrane" (bacteriorhodopsin).



Mary Reedy

(a)



Mary Reedy

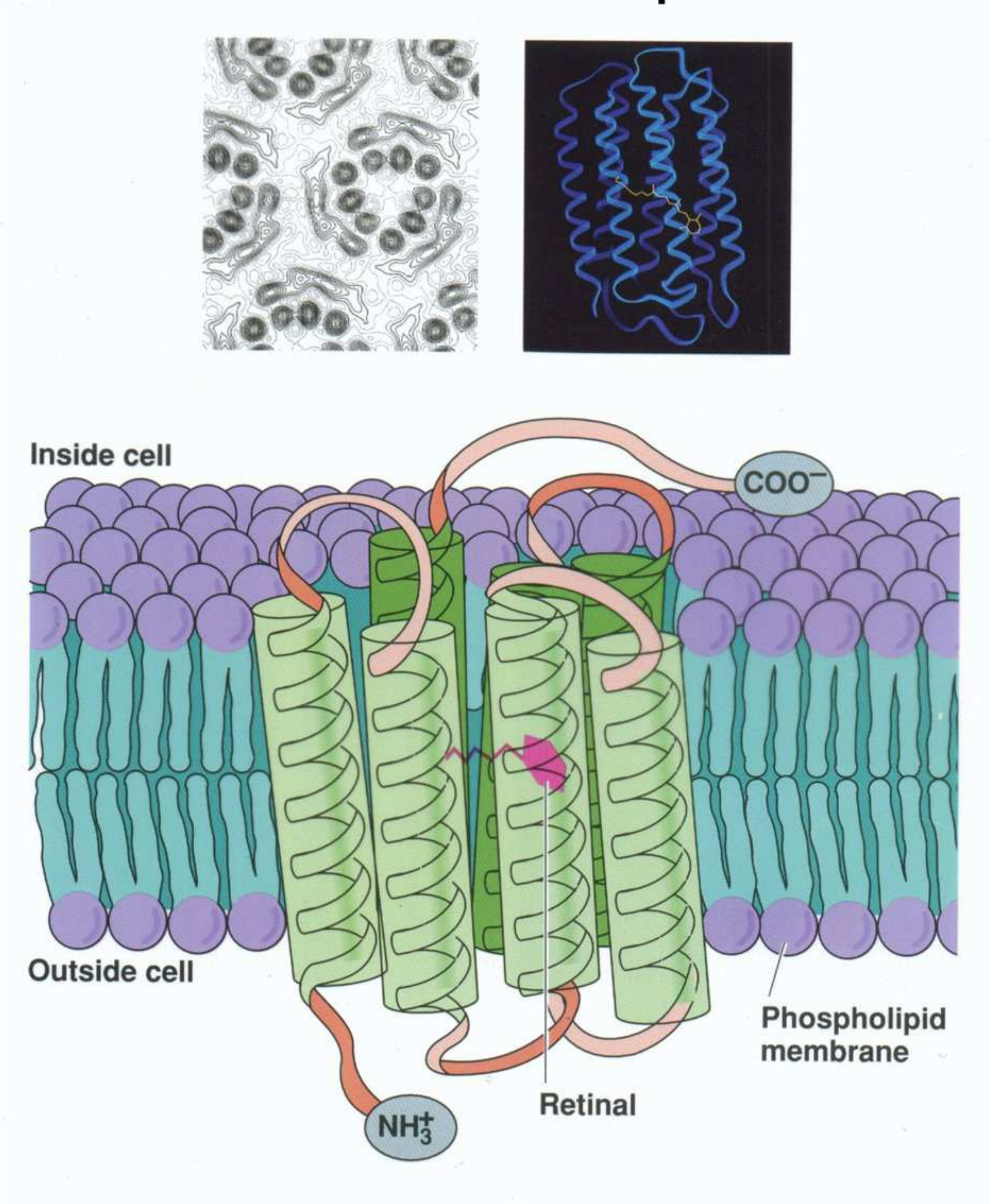
(b)

Halobacterium salinarum

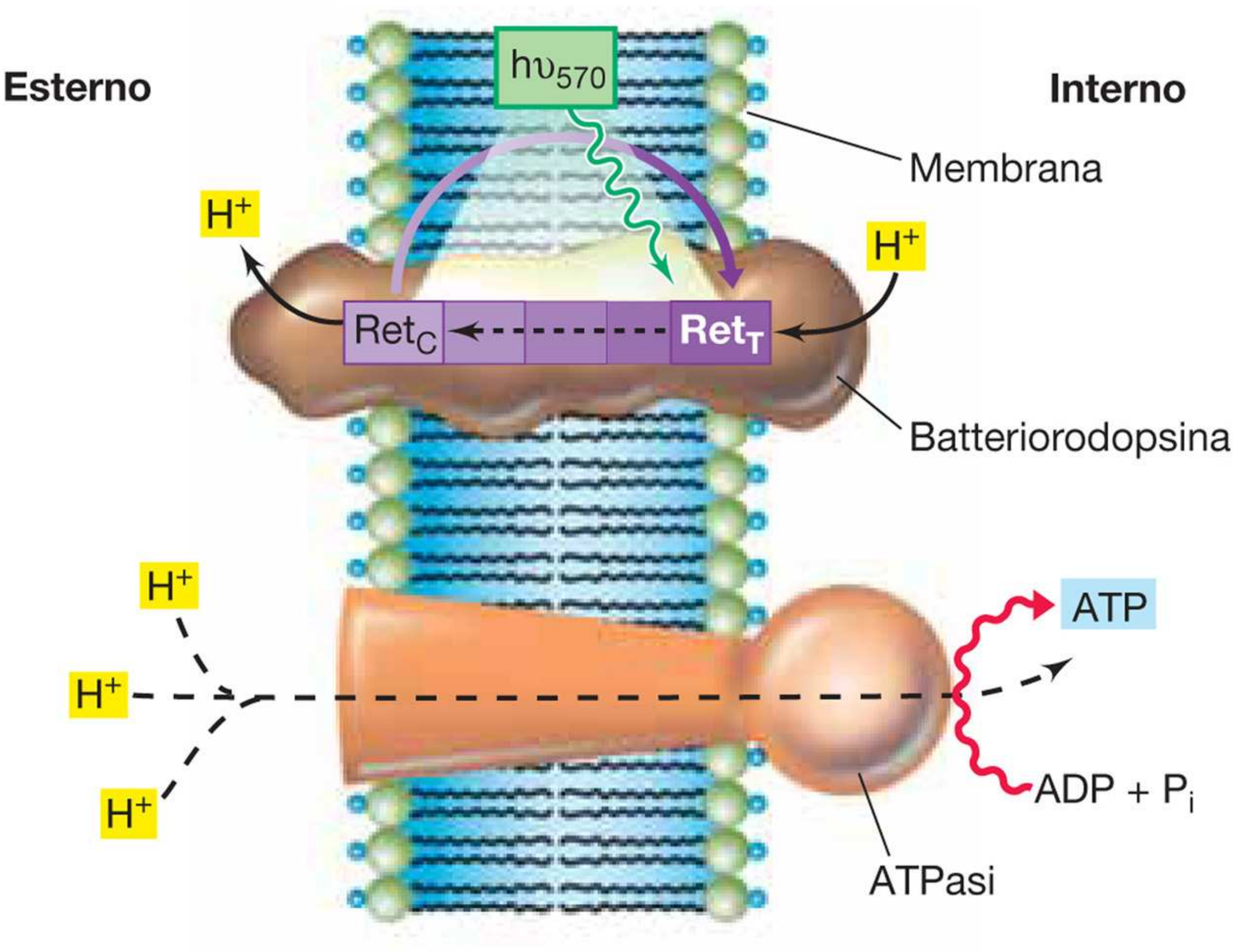
Concentration of ions in cells of *Halobacterium salinarum*

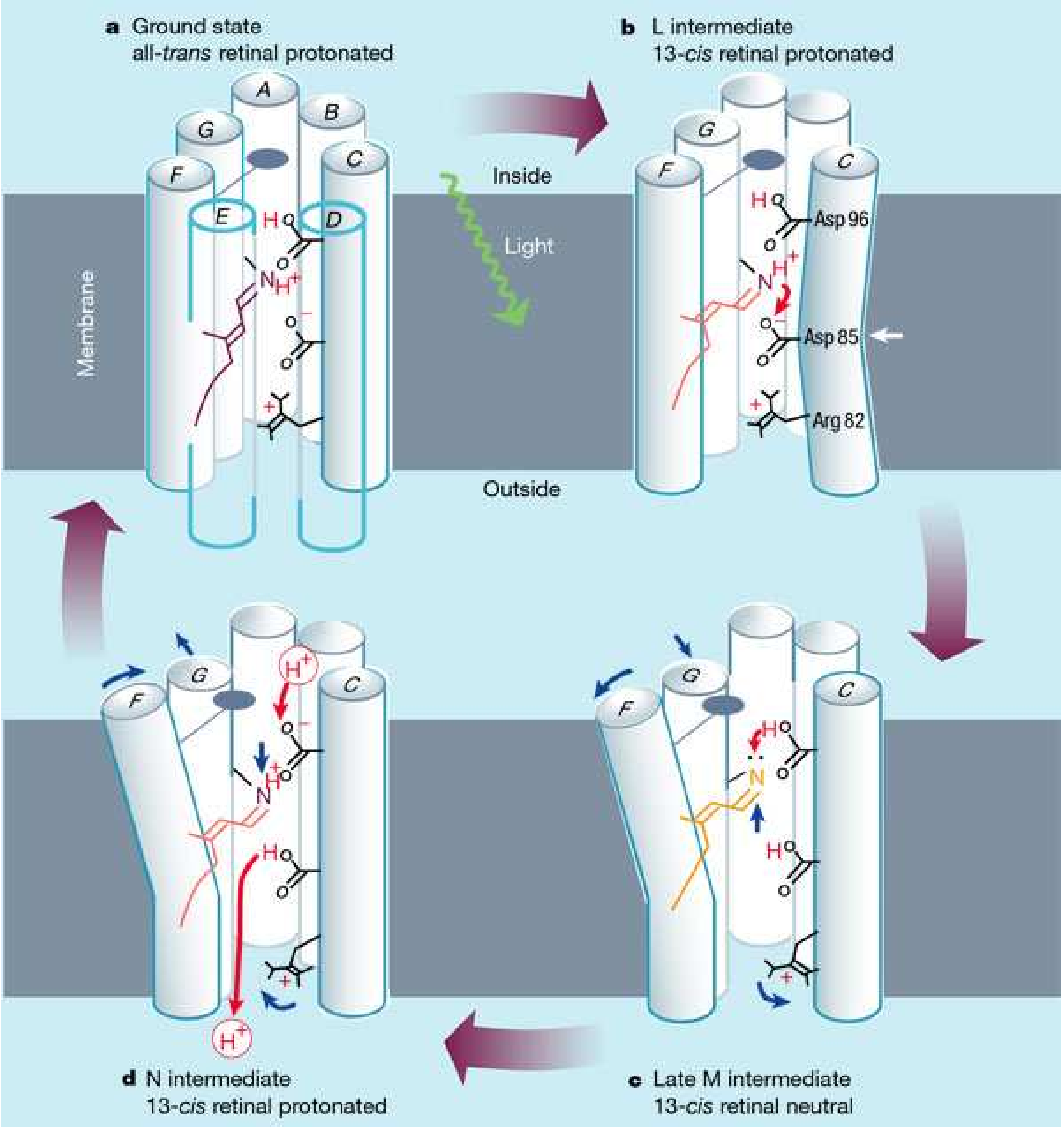
Ion	Concentration in medium (M)	Concentration in cells (M)
Na^{+}	3.3	0.8
K^{+}	0.05	5.3
Mg^{2+}	0.13	0.12
Cl^{-}	3.3	3.3

Bacteriorhodopsin



Mechanism of bacteriorhodopsin activity





a Ground state
all-trans retinal protonated
b L intermediate
13-cis retinal protonated
Inside
Light
Membrane
Outside
A
B
C
D
E
F
G
Asp 96
Asp 85
Arg 82
c Late M intermediate
13-cis retinal neutral
d N intermediate
13-cis retinal protonated

The Euryarchaeota:

methanogens

Habitats of Methanogens

1. Anoxic sediments: bogs, marshs, rice fields

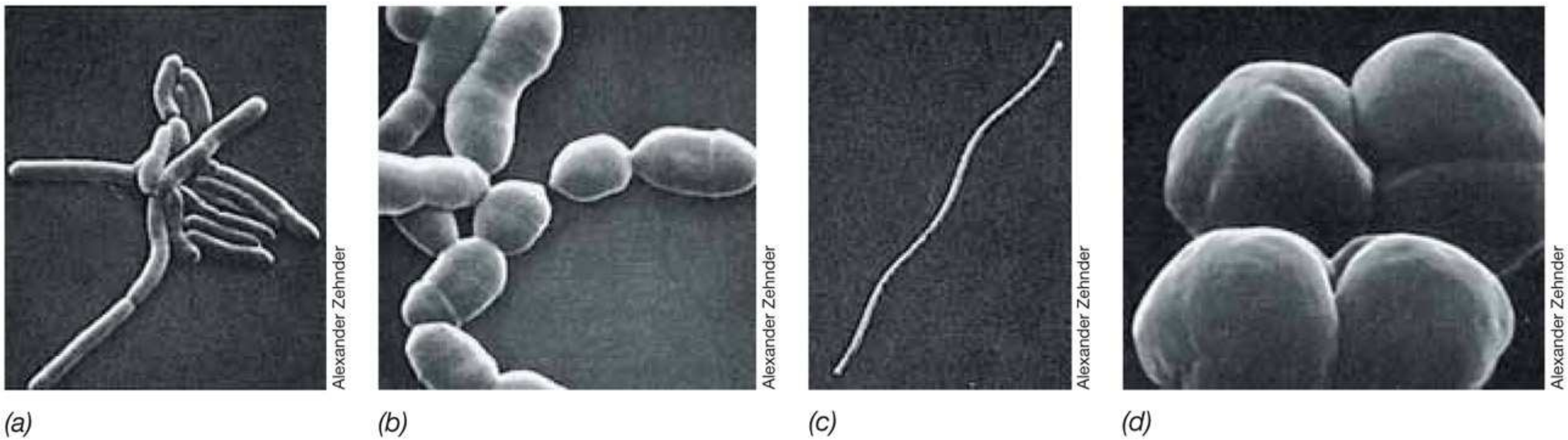
2. Animal digestive tracts: rumen of ruminants, cecum of cecal animals (horse, rabbits), large intestine of monogastric animals (humans), hindgut of cellolytic insects (termites)

3. Geothermal sources of H_2 +CO_2: hydrothermal vents

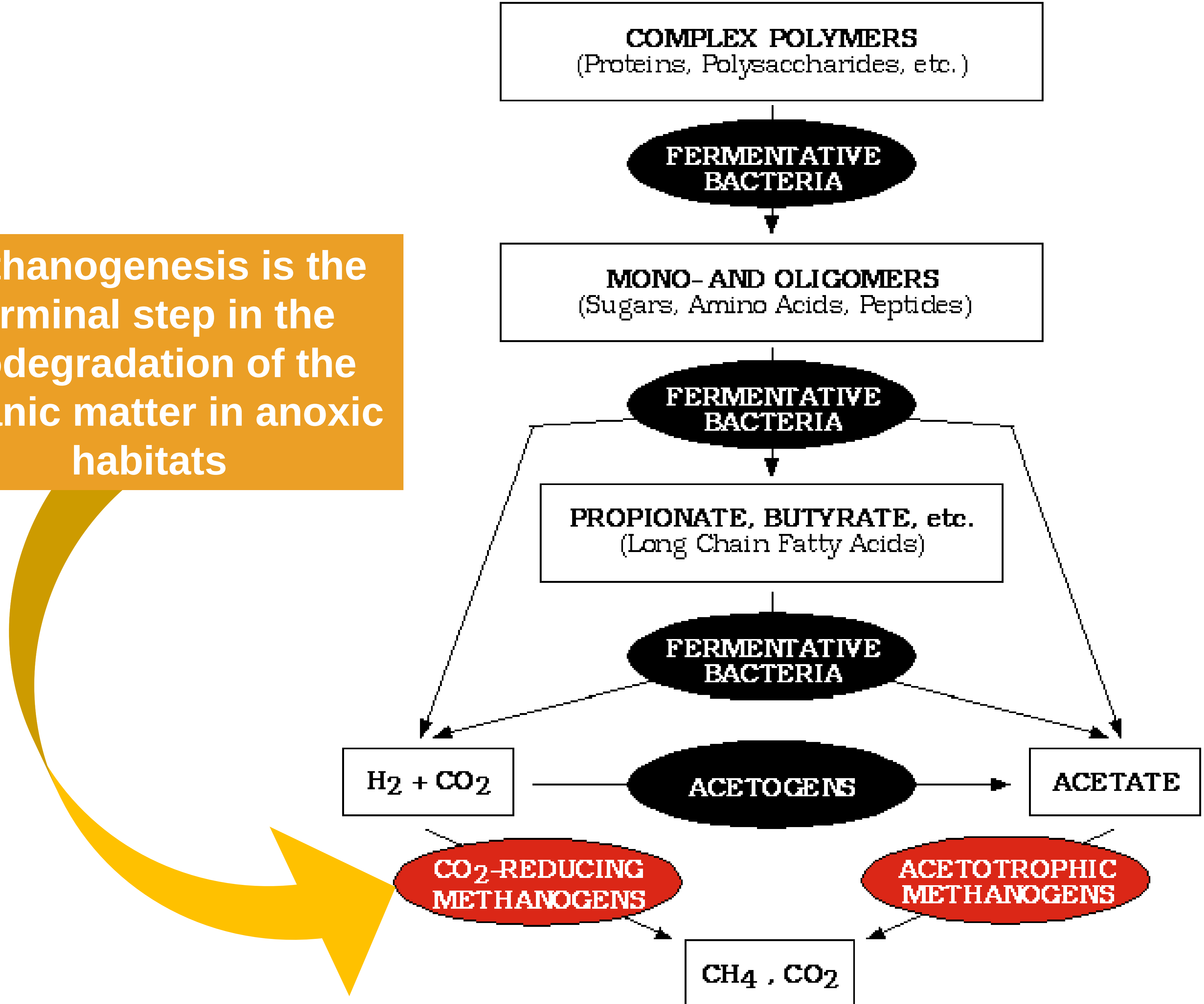
4. Artificial biodegradation facilities: sewage sludge digestors

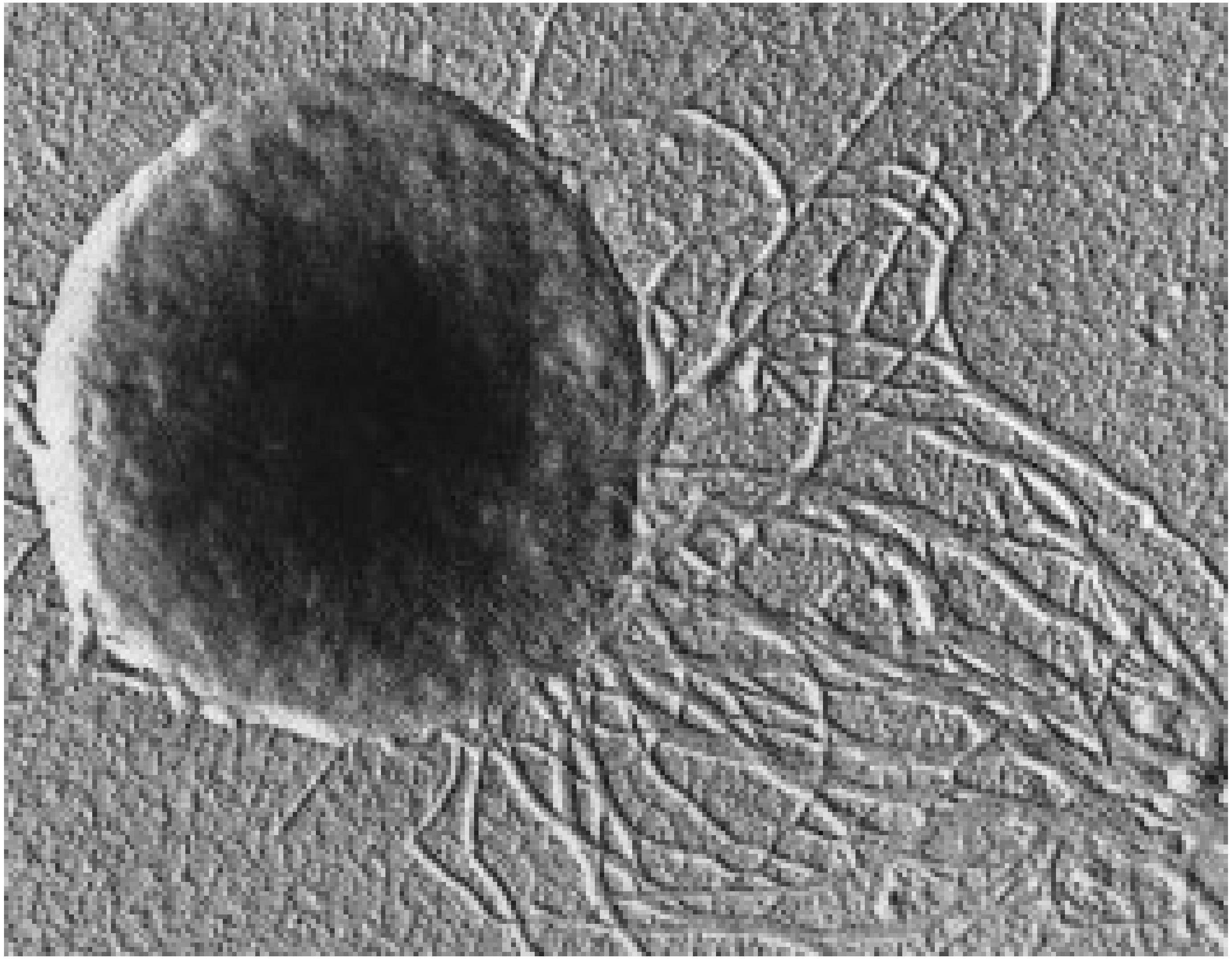
5. Endosymbionts of various anaerobic protozoa

Methanogens



Methanogenesis is the terminal step in the biodegradation of the organic matter in anoxic habitats





•*Methanococcus jannischii* was originally isolated from a "white smoker" chimney at an oceanic depth of 2,600 meters on the East Pacific Rise.

•It can be grown in a mineral medium containing only H2 and CO2 as sources of energy and carbon for growth

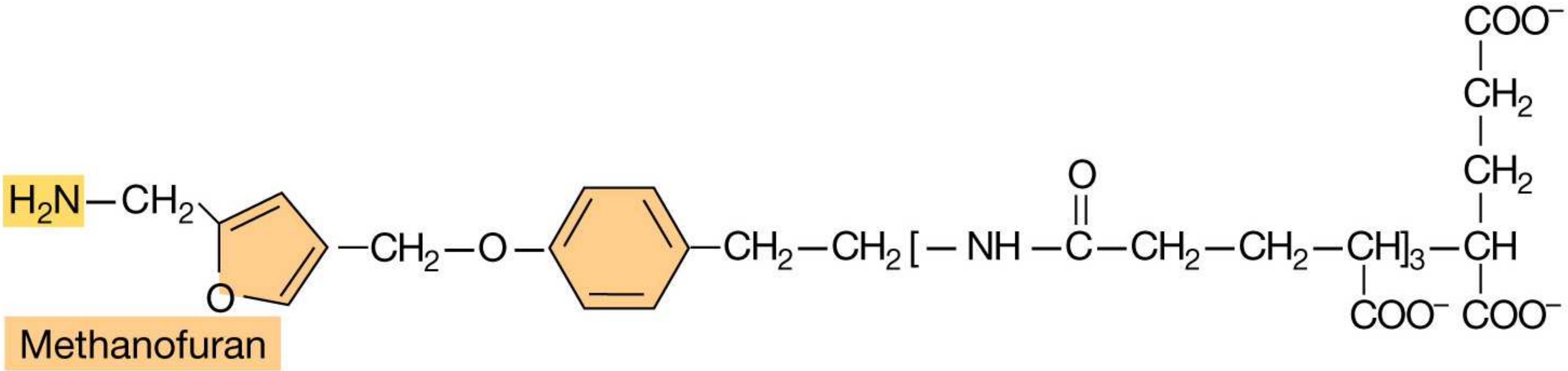
Substrates converted to methane by various methanogenic Archaea

1. CO_2-type substrates
   CO_2 (with electrons derived from H_2, alcohols or pyruvate)
   Formate, $HCOO^-$
   Carbon monoxide, CO

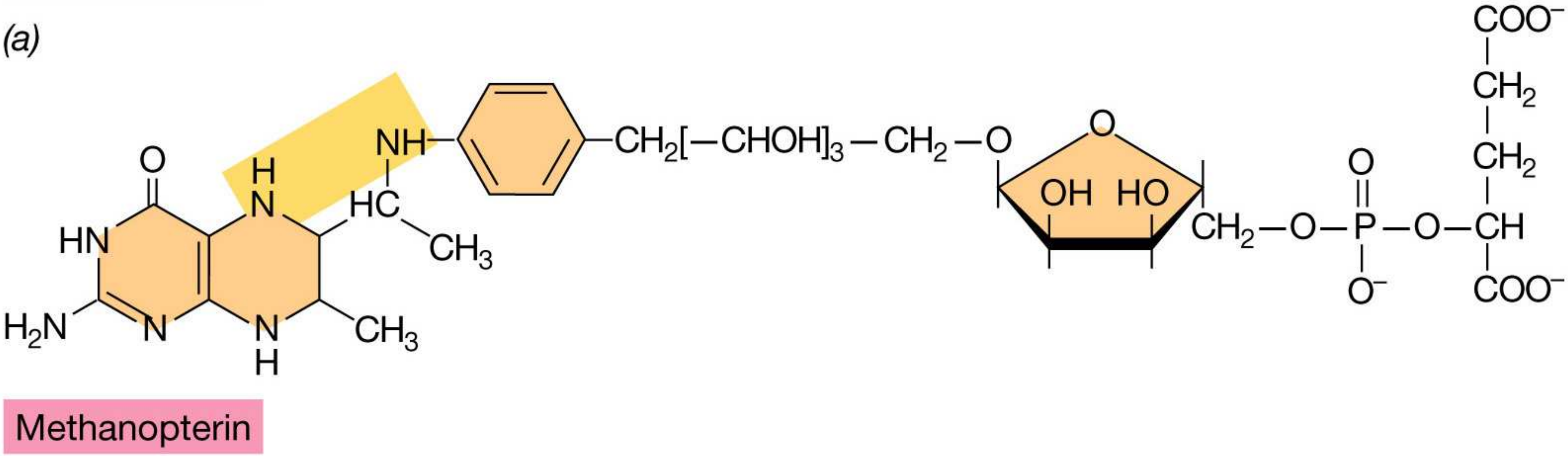
2. Methyl-substrates
   Methanol, CH_3OH
   Methylamine, $CH_3NH_3^+$
   Dimethylamine, $(CH_3)_2NH_2^+$
   Methylmercaptan, CH_3SH
   Dimethylsulfide, $(CH_3)_2S$

3. Acetotrophic substrates
   Acetate, CH_3COO^-
   Pyruvate, CH_3COCOO^-

Coenzymes of methanogenic Archaea: C1 carriers in methanogenesis

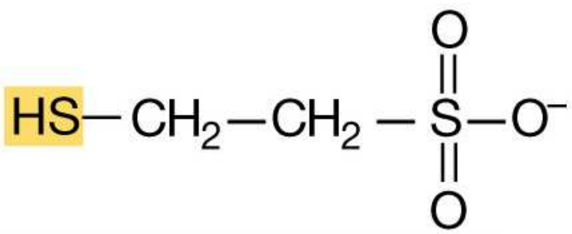


(a)



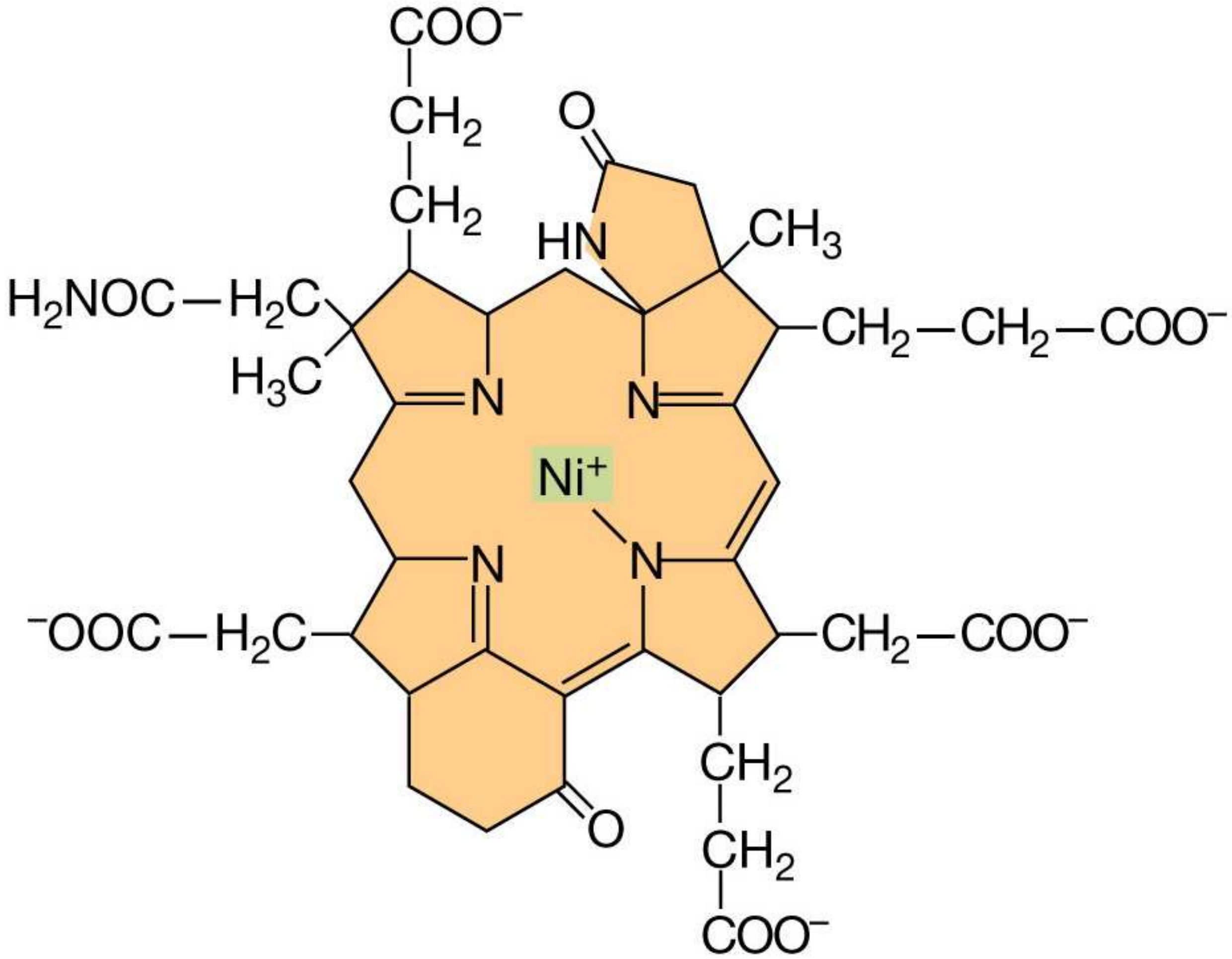
(b)

Coenzymes of methanogenic Archaea: C1 carriers in methanogenesis



Coenzyme M (CoM)

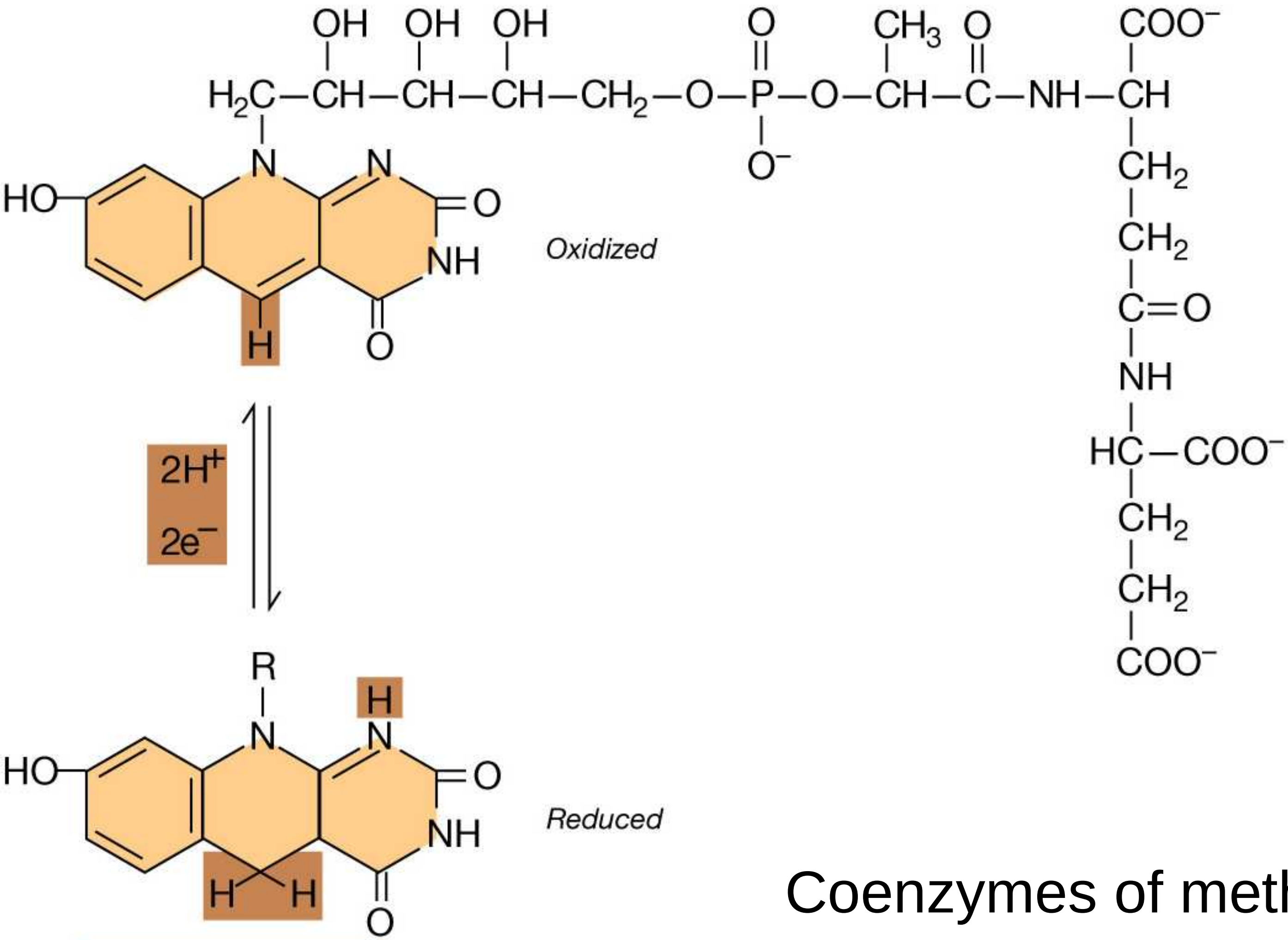
(c)



Coenzyme F_{430}

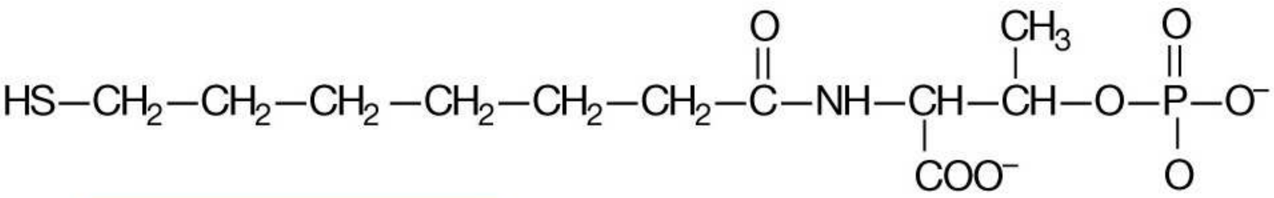
(d)

Coenzymes of methanogenic Archaea: electron donors in methanogenesis



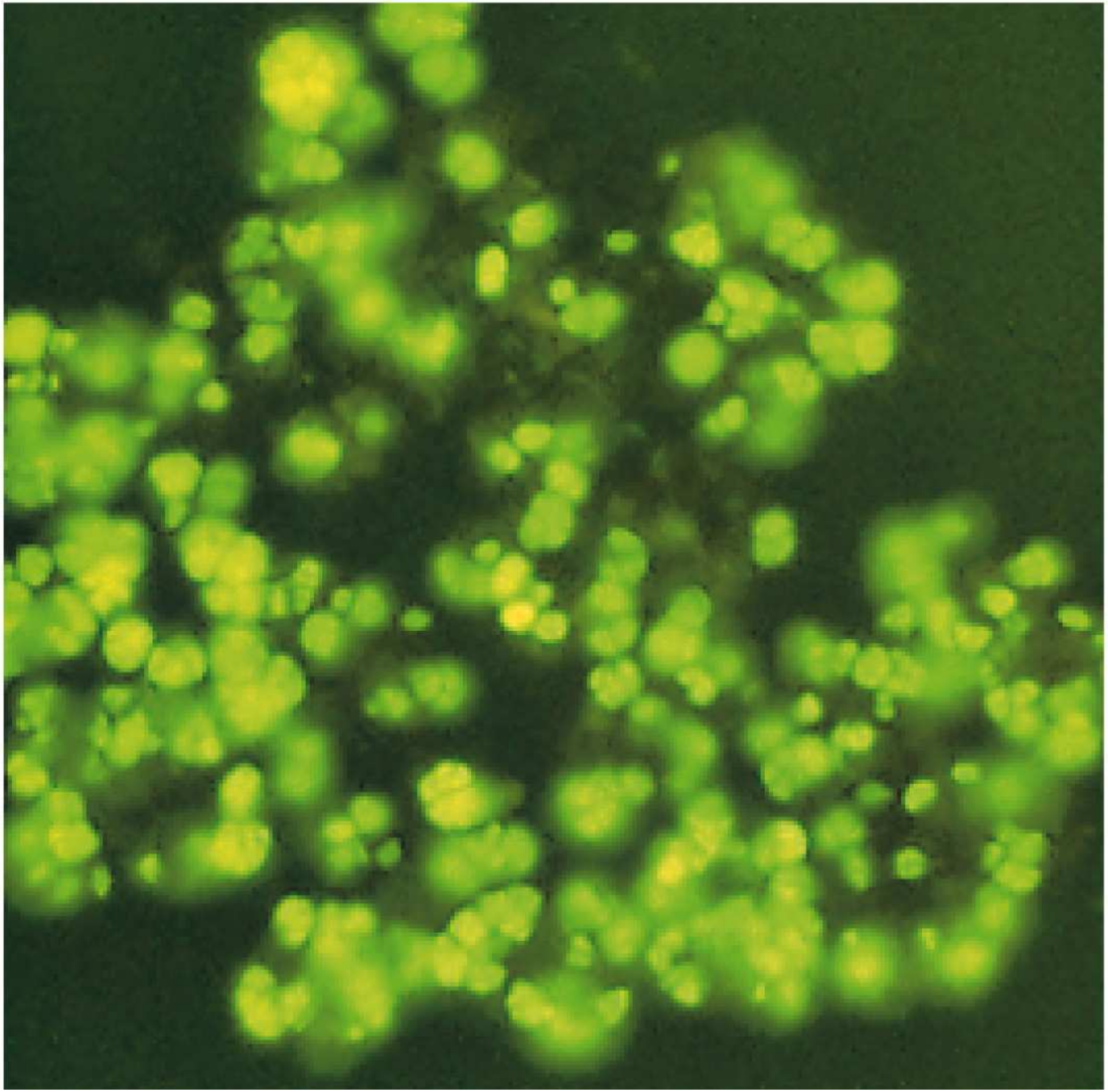
Coenzyme F_{420}

(e)

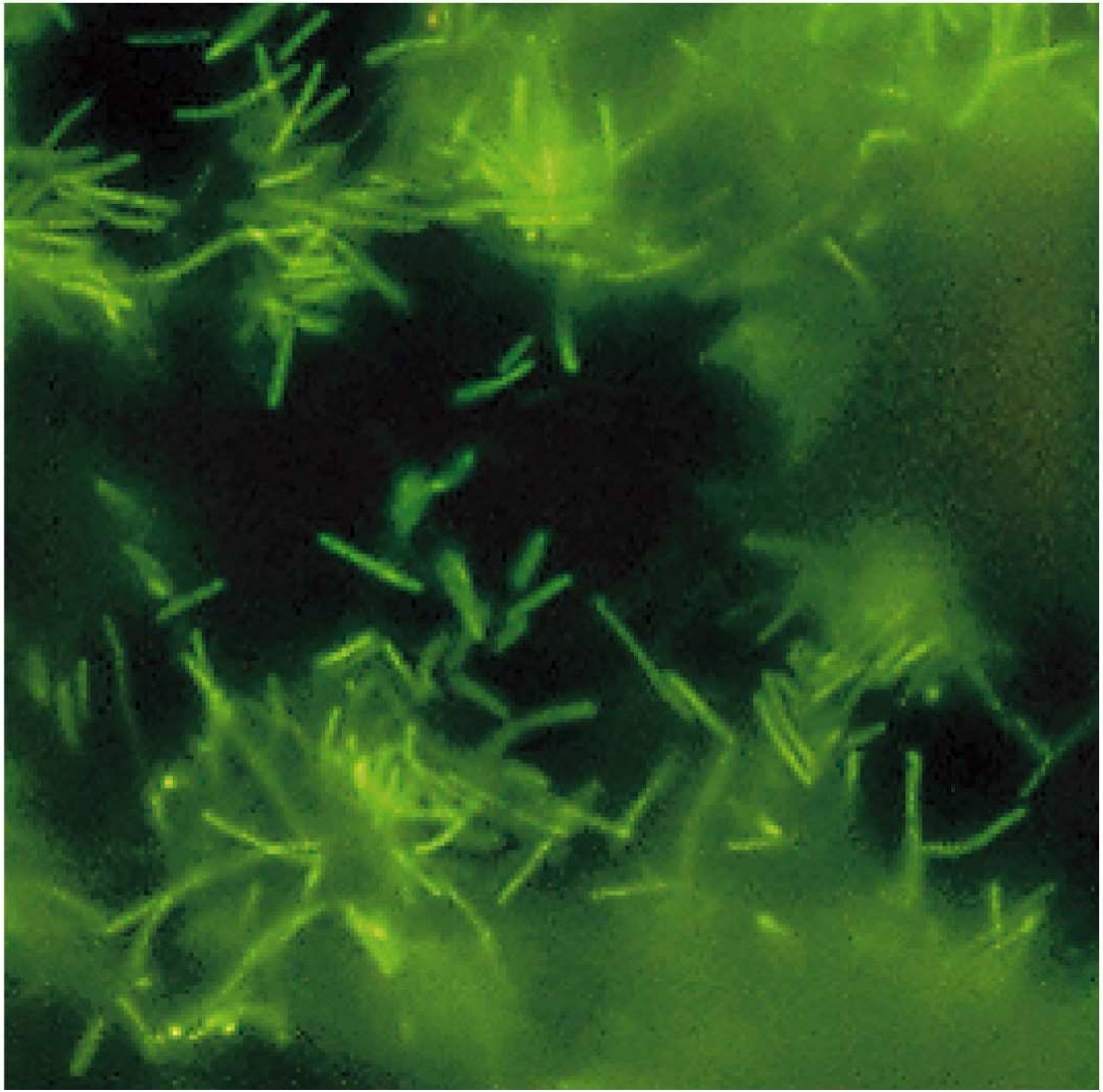


Coenzyme B (CoB)

(f)

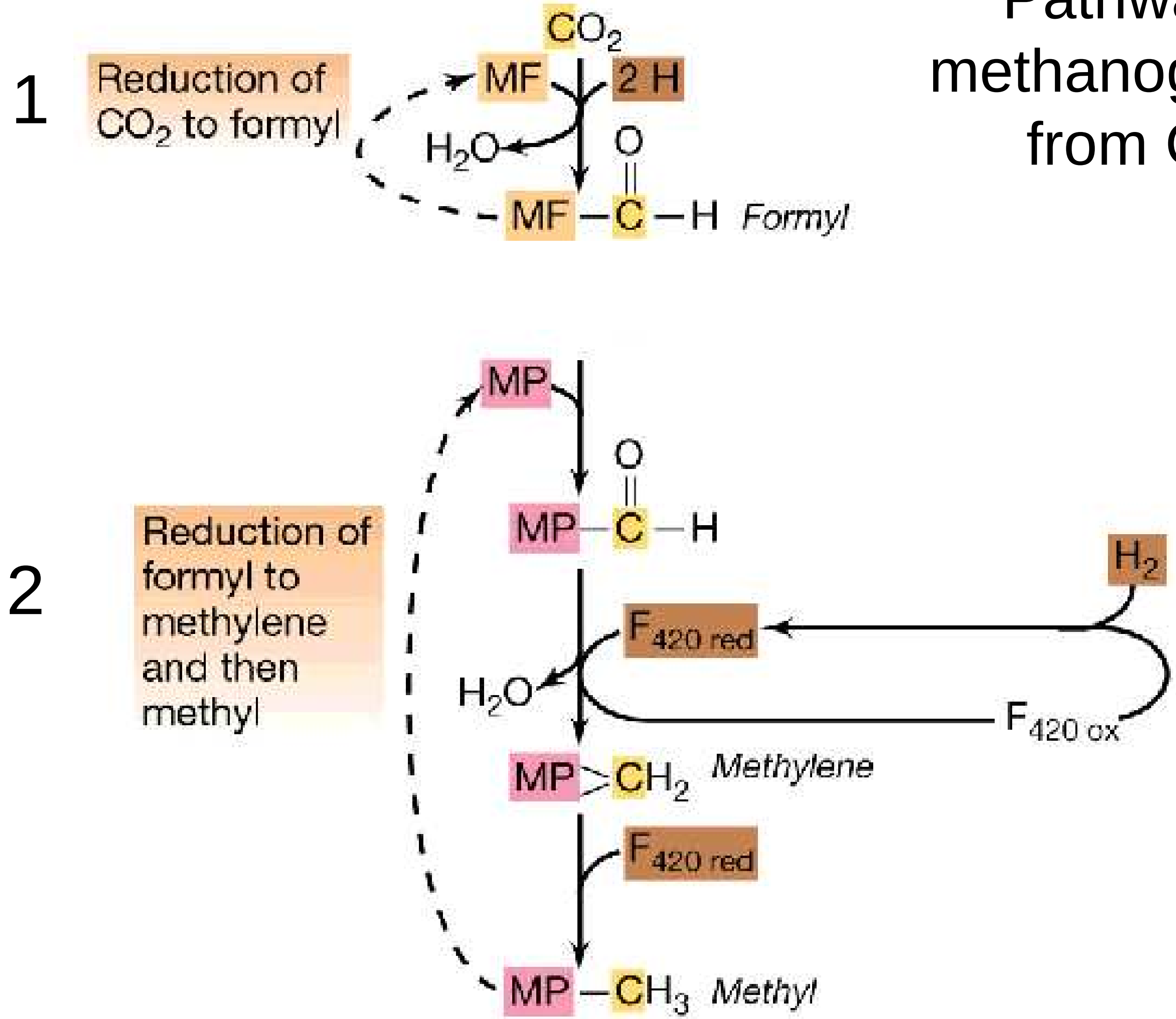


Autofluorescence in cells of the methanogen *Methanosarcina barkeri* due to the presence of the unique electron carrier F_{420}



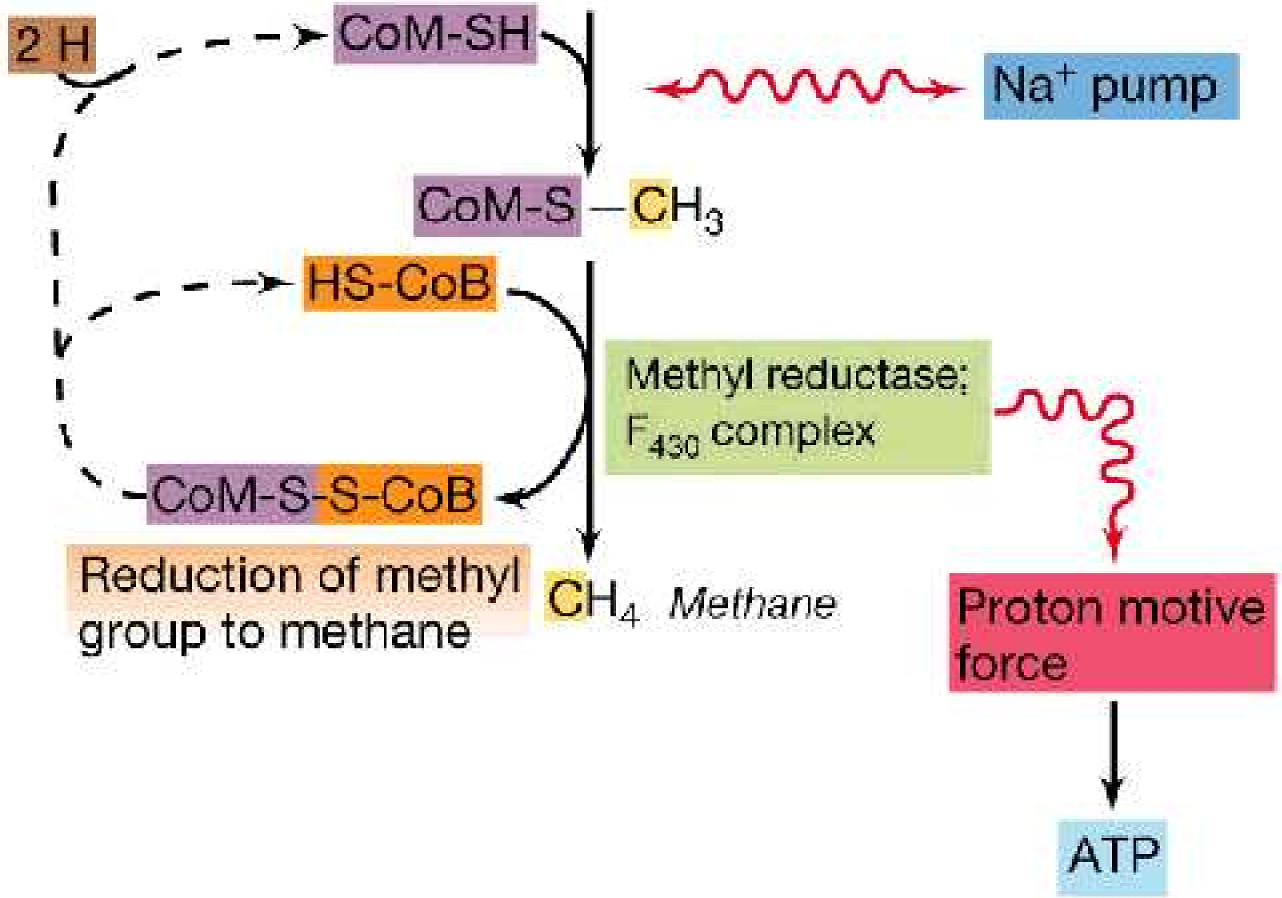
F_{420} fluorescence in cells of the methanogen
Methanobacterium formicum

Pathway of methanogenesis from CO_2

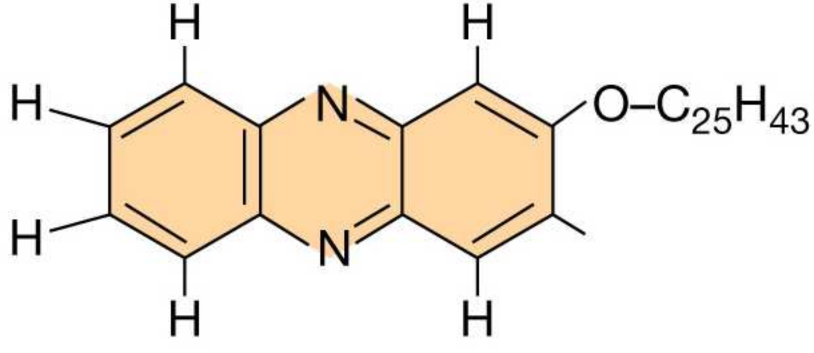


Pathway of methanogenesis from CO_2

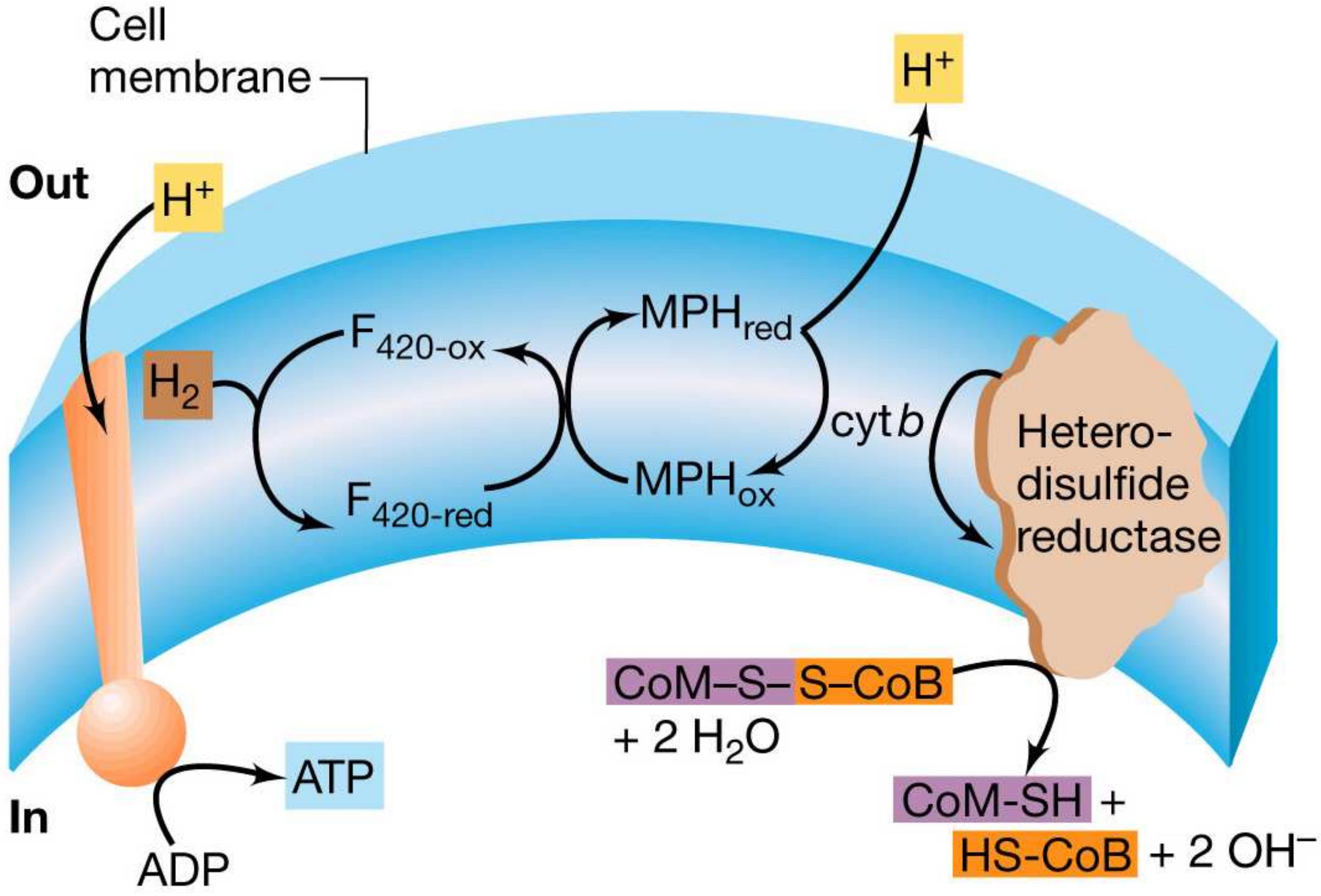
3



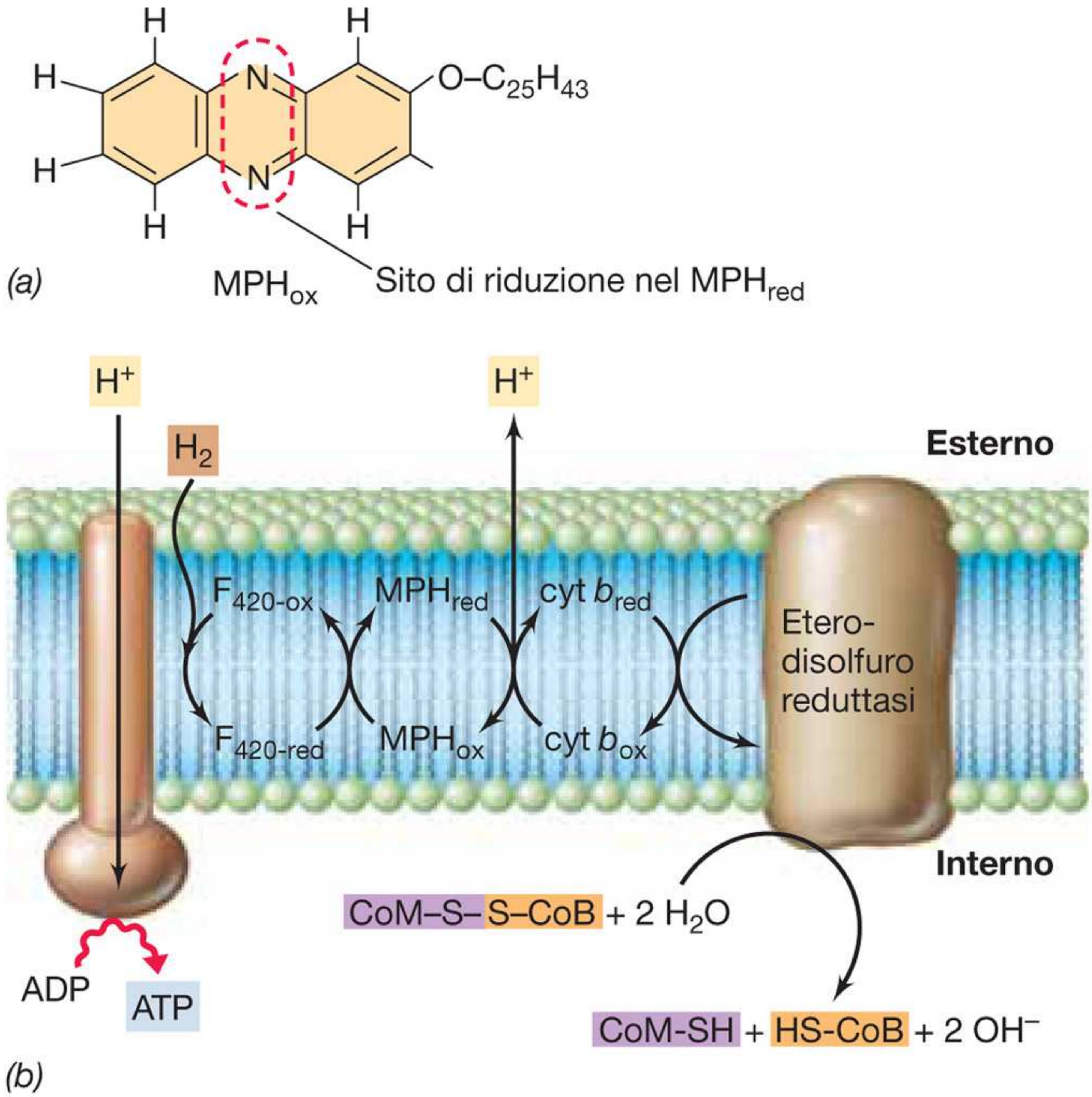
Energy conservation in methanogenesis



(a)

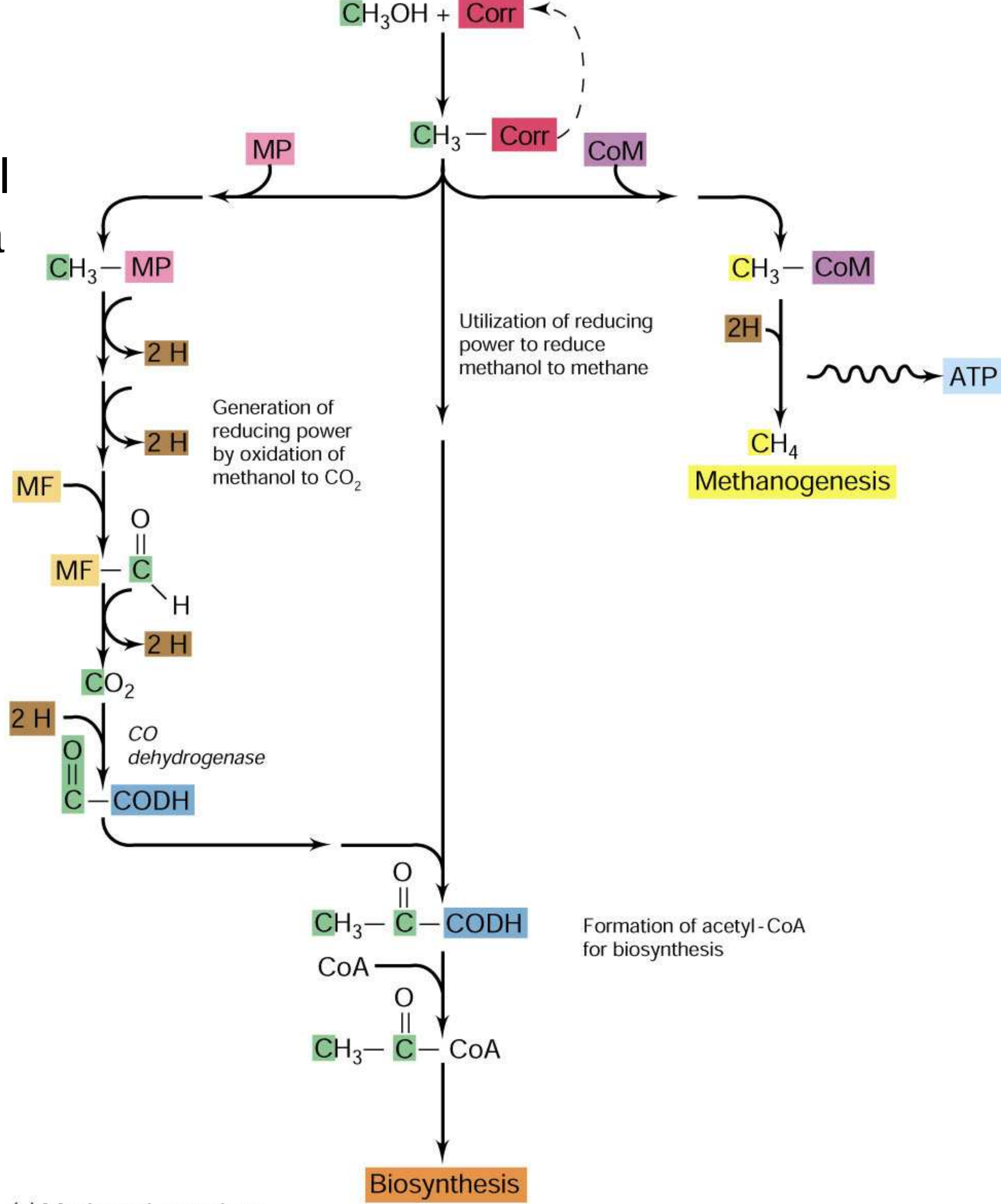


(b)



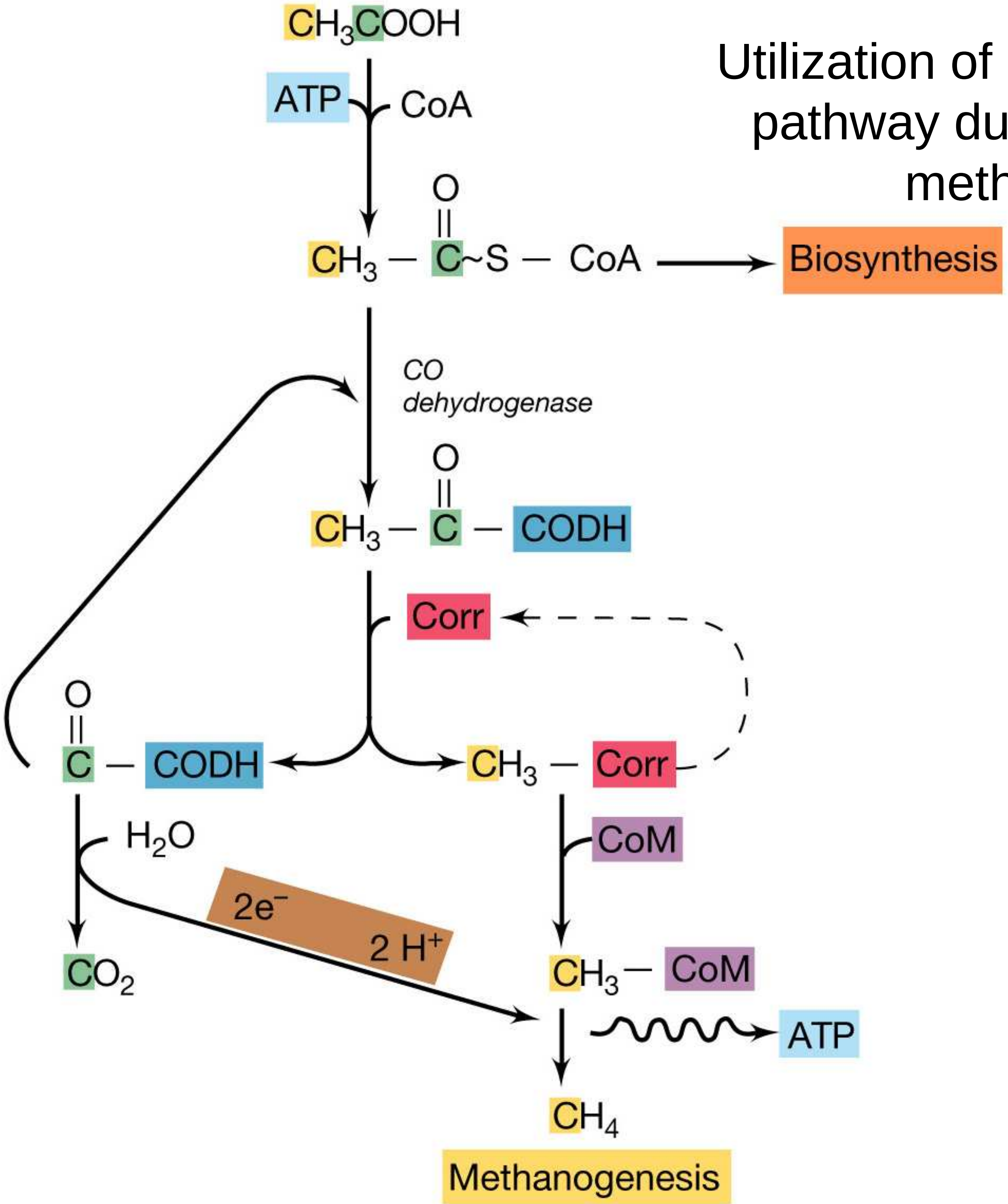
H
H
H
H
H
H
N
N
O–C25H43
(a)
MPHox
Sito di riduzione nel MPHred
H+
H2
H+
Esterno
F420-ox
MPHred
cyt bred
Etero-
disolfuro
reduttasi
F420-red
MPHox
cyt box
Interno
CoM–S–S–CoB + 2 H2O
ADP
ATP
CoM-SH + HS-CoB + 2 OH–
(b)

Utilization of reactions of the acetyl-CoA pathway during growth on methanol by methanogenic Archaea

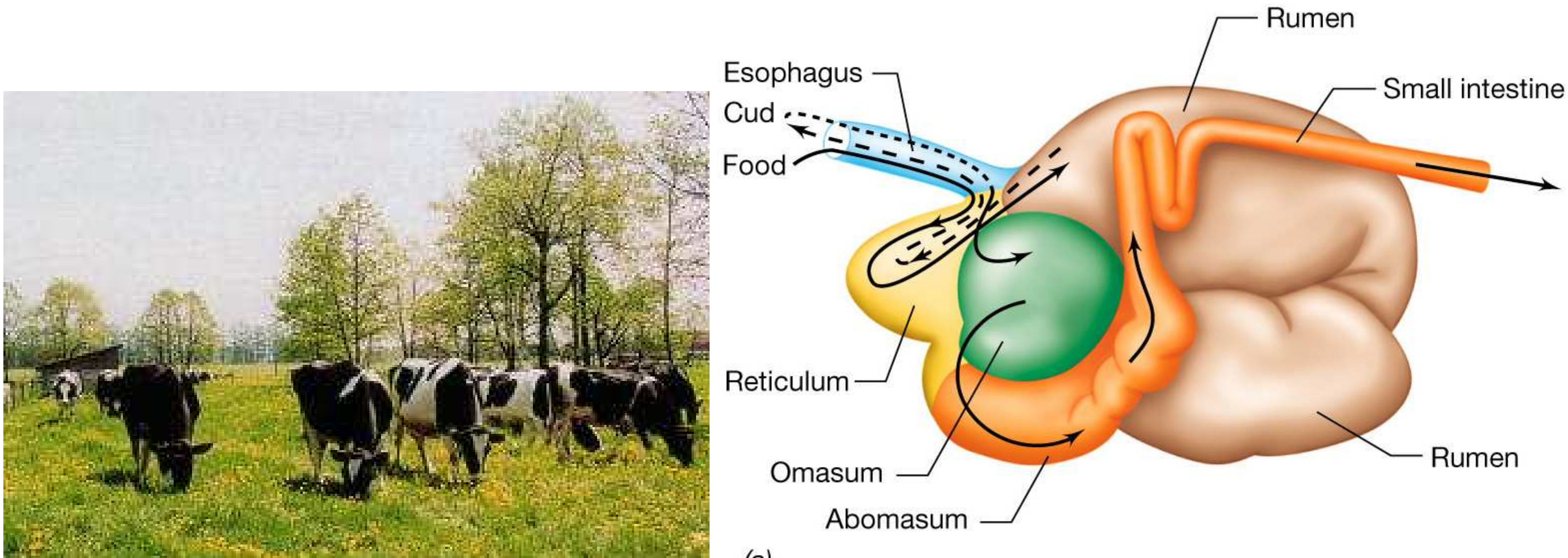


(a) Methanol reactions

Utilization of reactions of the acetyl-CoA pathway during growth on acetate by methanogenic Archaea



(b) Acetate reactions

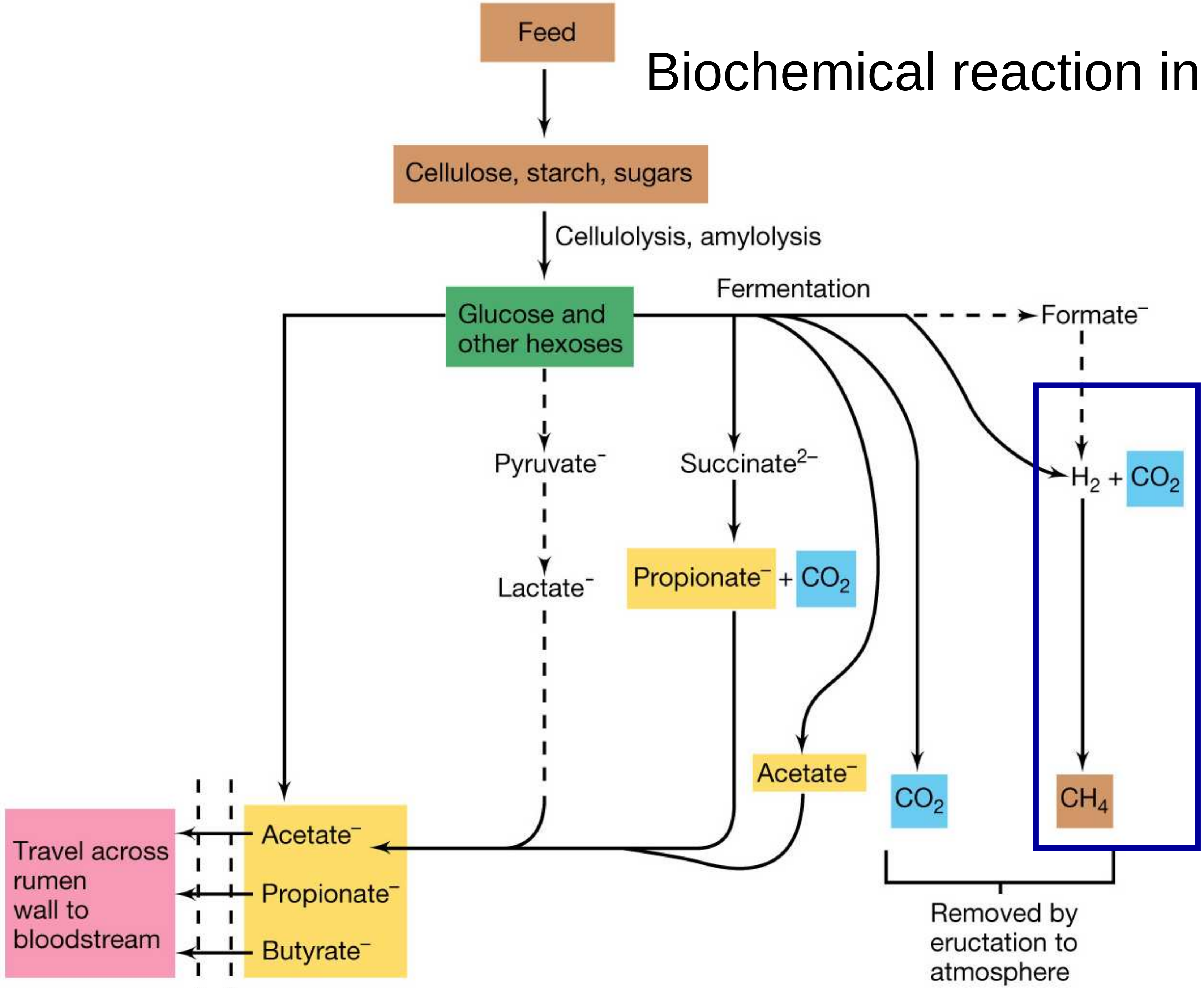


(a)

Sharisa D. Beek, Dept. Animal Science, Southern Illinois Univ.

(b)

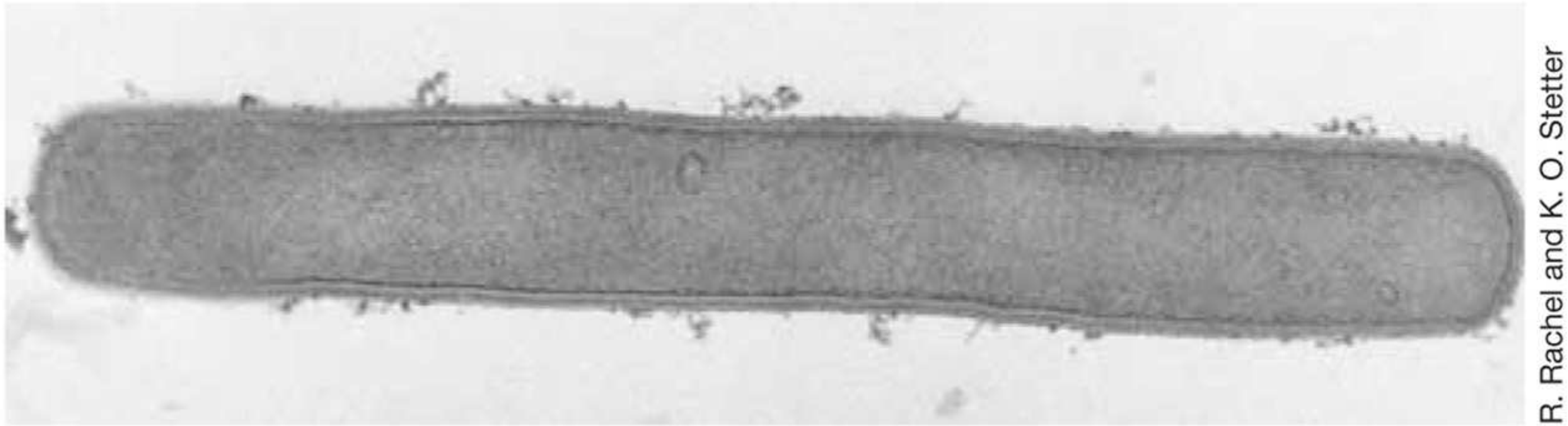
Biochemical reaction in the rumen



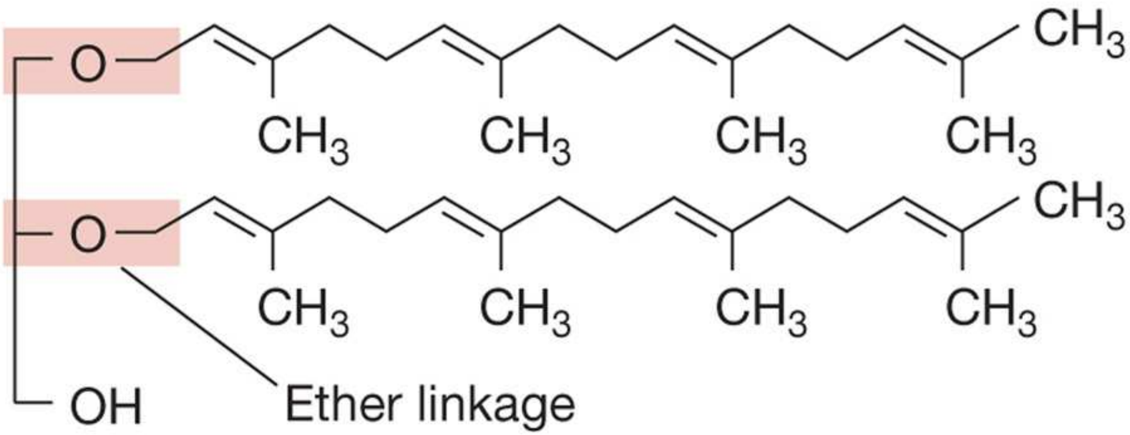
Overall stoichiometry of rumen fermentation:

57.5 glucose ⟶ 65 acetate⁻ + 20 propionate⁻ + 15 butyrate⁻ + 60 CO_2 + 35 CH_4 + 25 H_2O

Methanopyrus grows optimally at 100℃ and can make CH_4 only from CO_2 + H_2. Here is shown the structure of the lipid of M. kandleri.



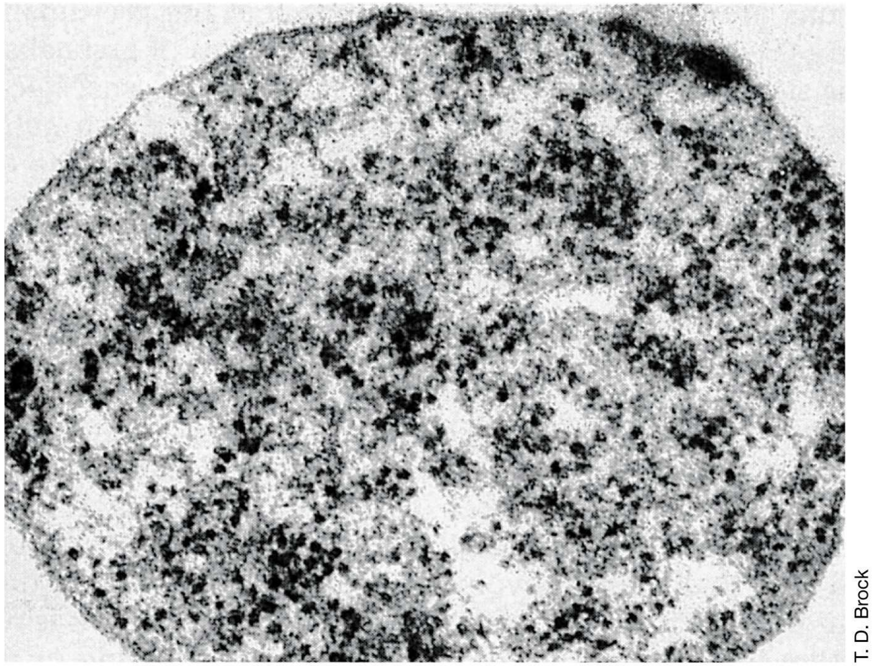
(a)



(b)

The Euryarchaeota:

Thermoplasma



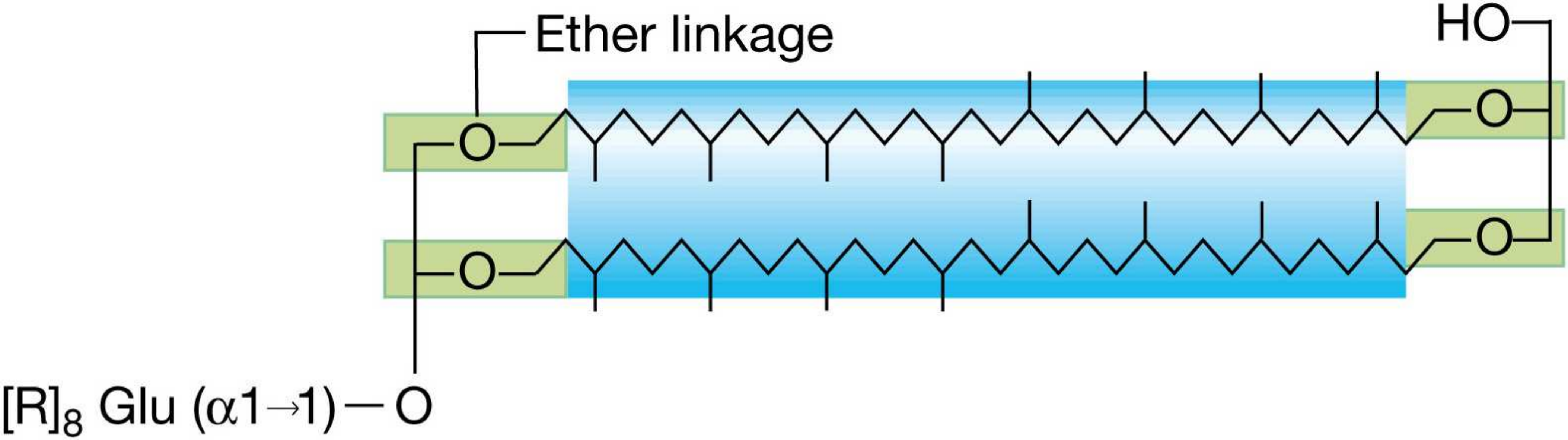
(a)

Thermoplasma acidophilum, an acidophilic, thermophilic **mycoplasma-like** archaeon

T. D. Brock

A typical self-heating coal refuse pile, habitat of *Thermoplasma*

Structure of the tetraether lipoglycan of *Thermoplasma acidophilum*



R = Man (α1 ⟶ 2) Man (α1 ⟶ 4) Man (α1 ⟶ 3)

The Crenarcaeota:

hyperthermophilic Archaea

Habitats of hyperthermophilic Archaea: A typical solfatara in Yellowstone National Park

Habitats of hyperthermophilic Archaea: A typical boiling spring of neutral pH in Yellowstone Park; Imperial Geyser

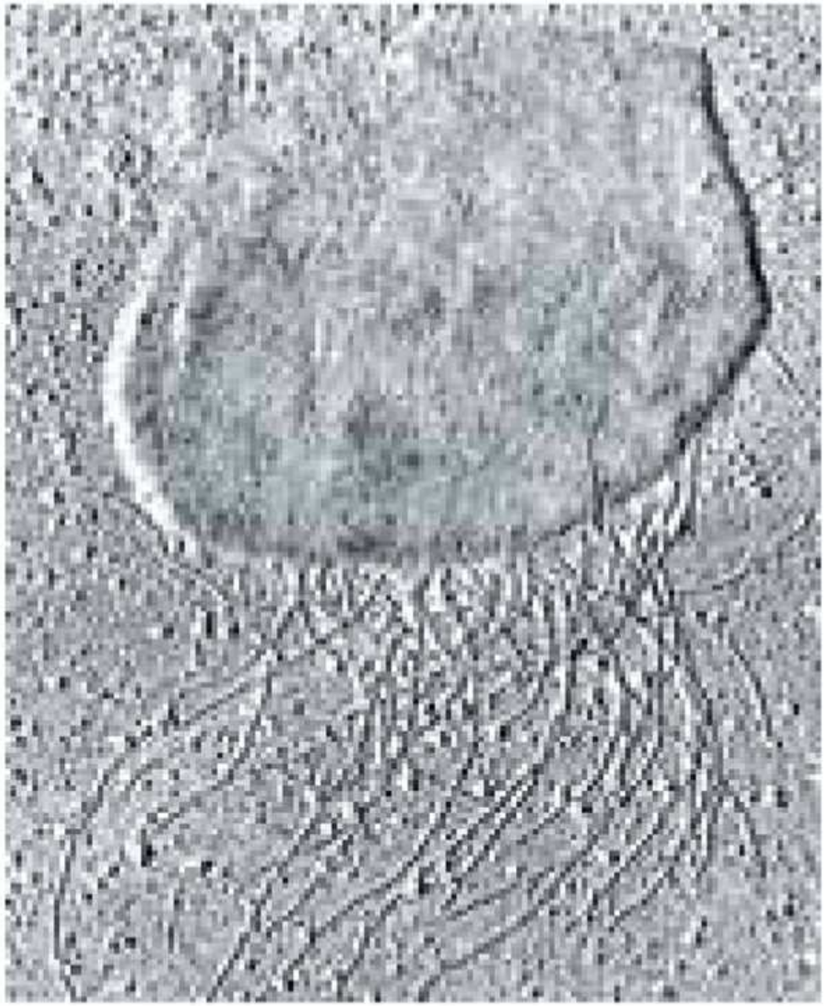
•Habitats of hyperthermophilic Archaea: Sulfur-rich hot spring, a habitat containing dense populations of *Sulfolobus.*

•The acidity in solfataras and sulfur springs comes from the oxidation of H_2S and S0 to H_2SO_4 by Sulfolobus and related prokaryotes

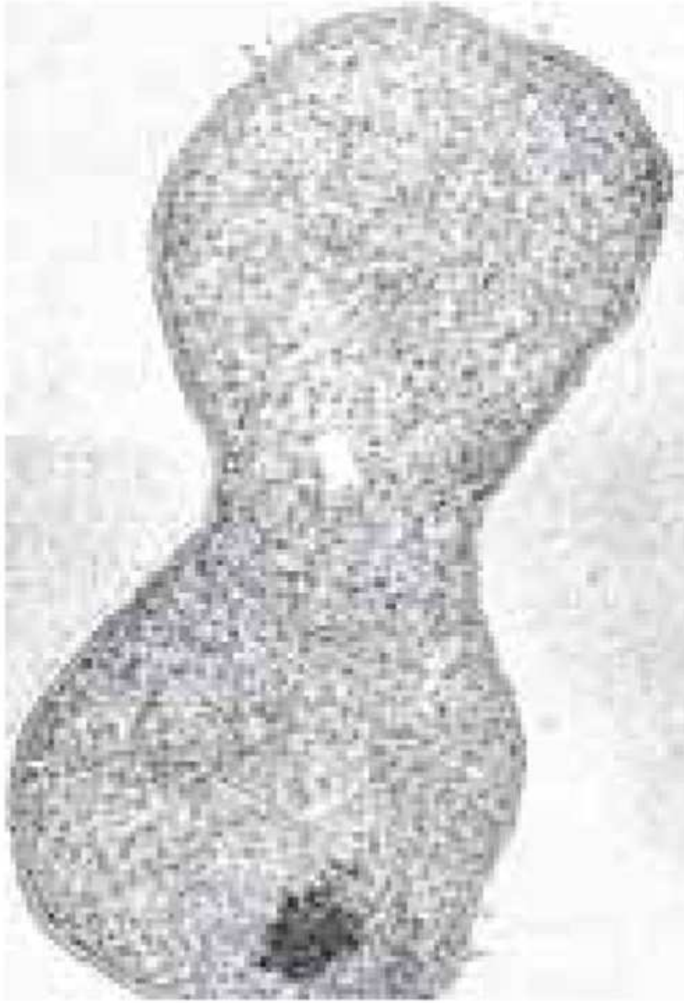
Habitats of hyperthermophilic Archaea: An acidic iron-rich geothermal spring, another *Sulfolobus* habitat

Energy yielding reactions of hyperthermophilic Archaea

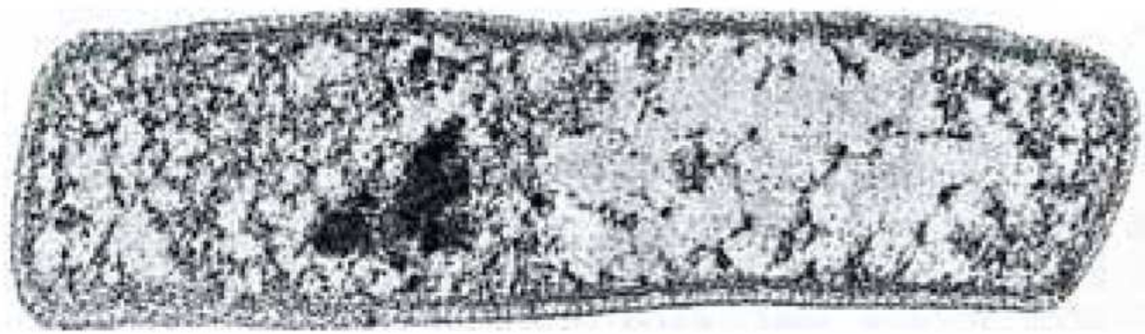
Nutritional class	Energy-yielding reaction	Metabolic type	Example
Chemoorganotrophic	Organic+ S^0= H_2S+CO_2	AnRespir	*Thermoproteus*
	Organic+SO_4^{2-}= H_2S+CO_2	AnRespir	*Archaeoglobus*
	Organic+O_2= H_2O+CO_2	AeRespir	*Sulfolobus*
	Pyruvate= CO_2+H_2+FA	Ferment	*Pyrococcus*
Chemolithotrophic	H_2+S^0= H_2S	AnRespir	*Pyrodyctium*
	H_2+2Fe^{3+}= 2Fe^{2+}+2H^+	AnRespir	*Pyrodyctium*
	2H_2+O_2= 2H_2O	AeRespir	*Sulfolobus*
	2S^0+3O_2+2H_2O= 2H_2SO_4	AeRespir	*Sulfolobus*


H. König and K. O. Stetter

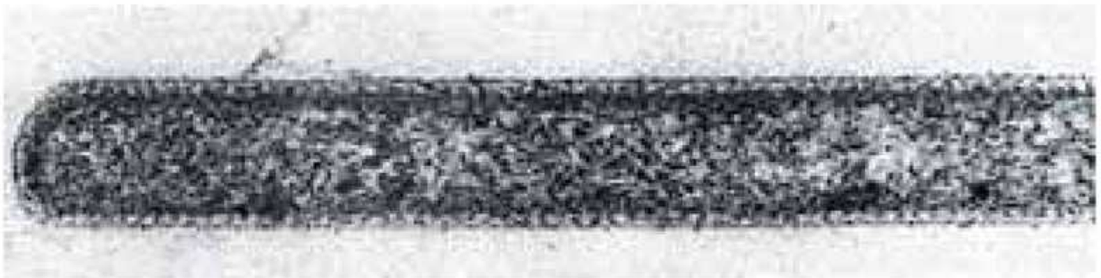
Thermococcus celer


G. Fiala and K. O. Stetter

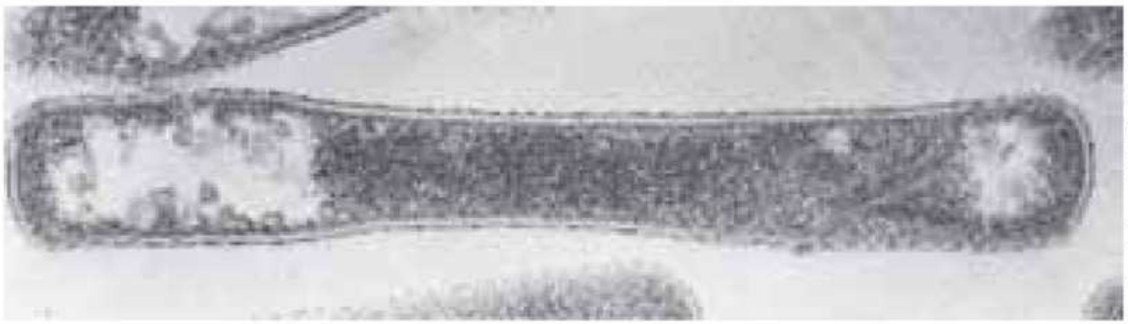
Pyrococcus furiosus


H. König and K. O. Stetter

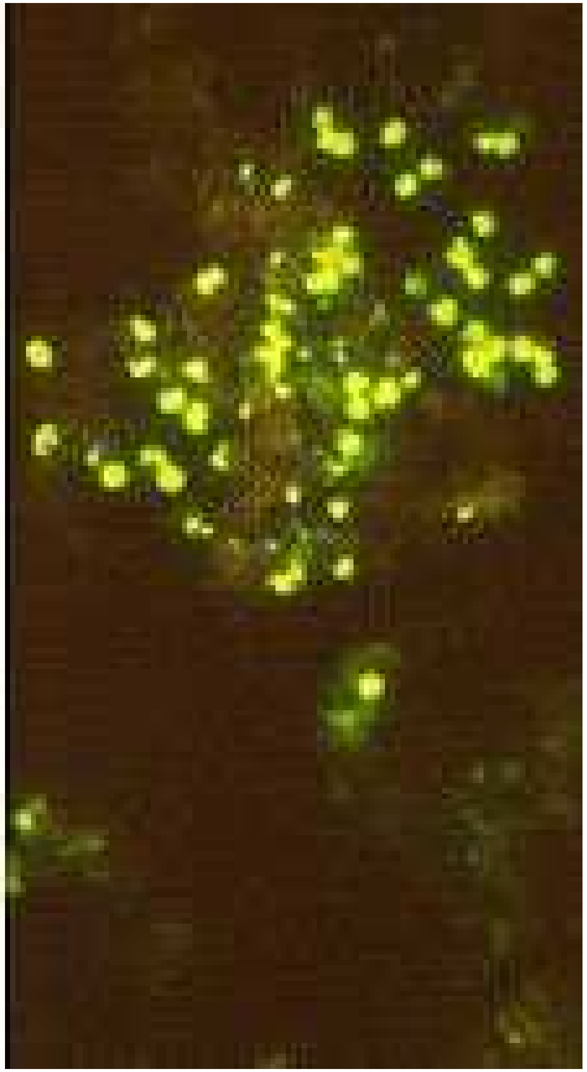
(a)


H. König and K. O. Stetter

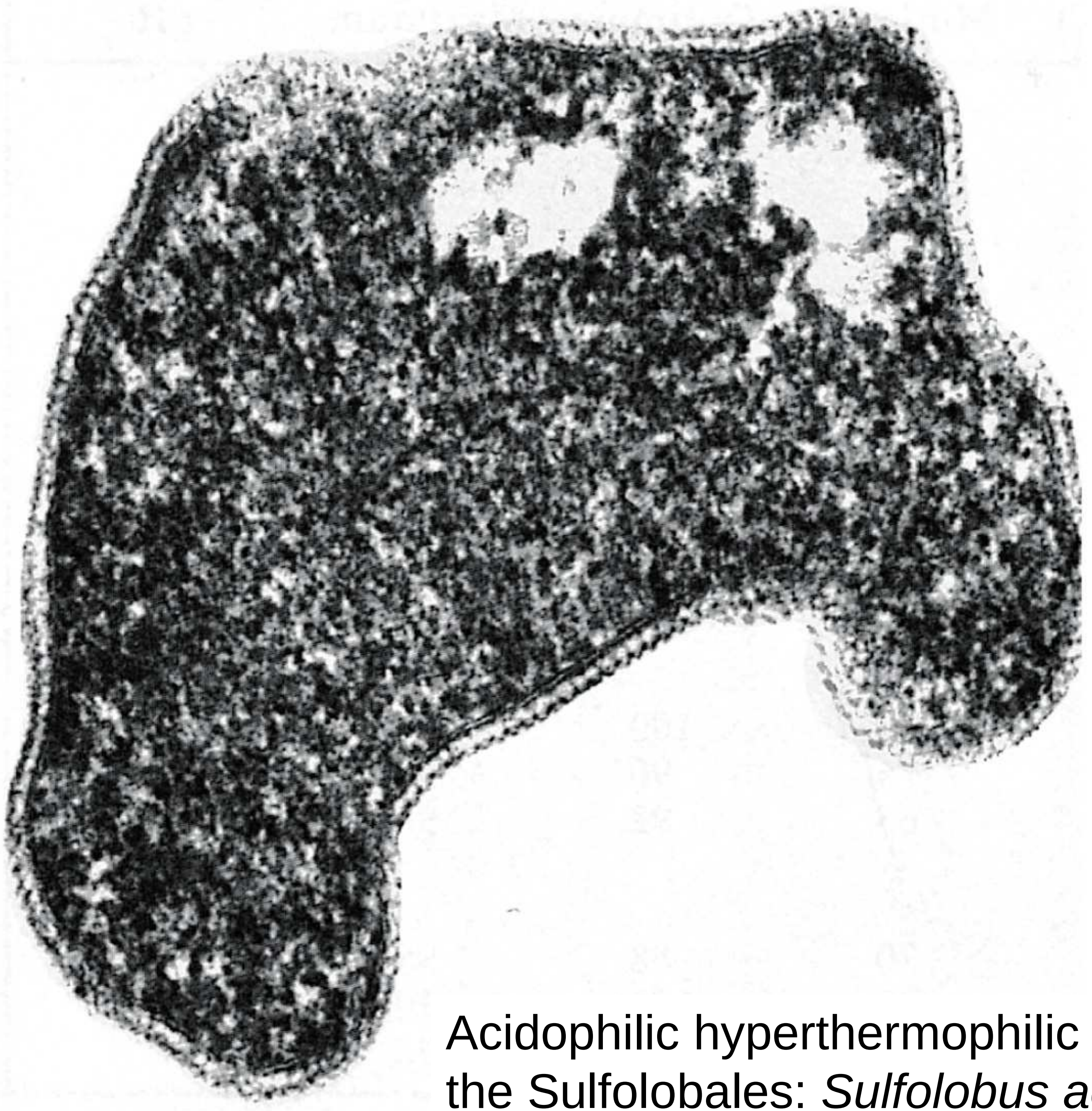
(b)


R. Rachel and K. O. Stetter

(c)

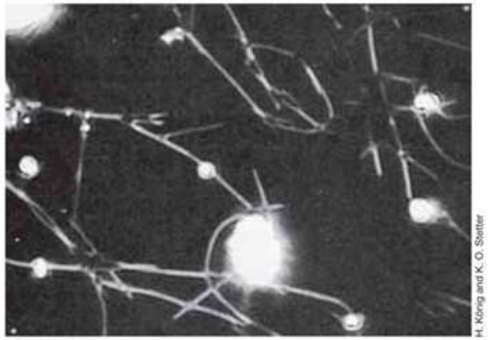


- *Sulfolobus acidocaldarius* is an extreme thermophile that has been found in geothermally-heated acid springs, mud pots and surface soils 60 to 95 degrees C, and a pH of 1 to 5.
- Fluorescent photomicrograph of cells attached to a sulfur crystal



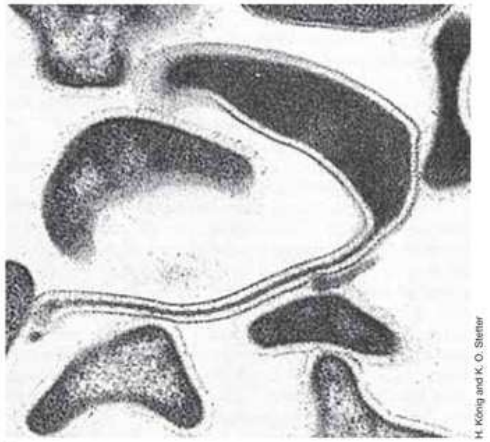
(a)

Acidophilic hyperthermophilic Archaea,
the Sulfolobales: *Sulfolobus acidocaldarius*



(a)

Pyrodictium occultum



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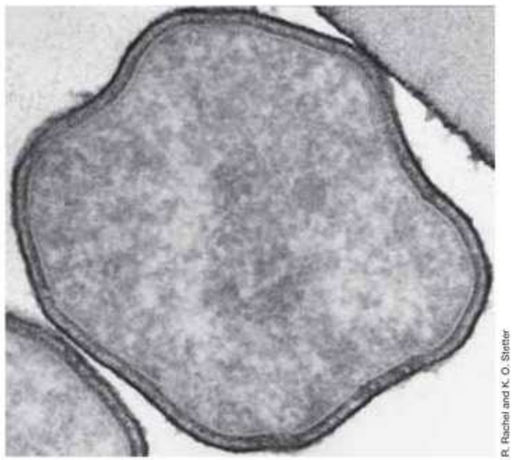
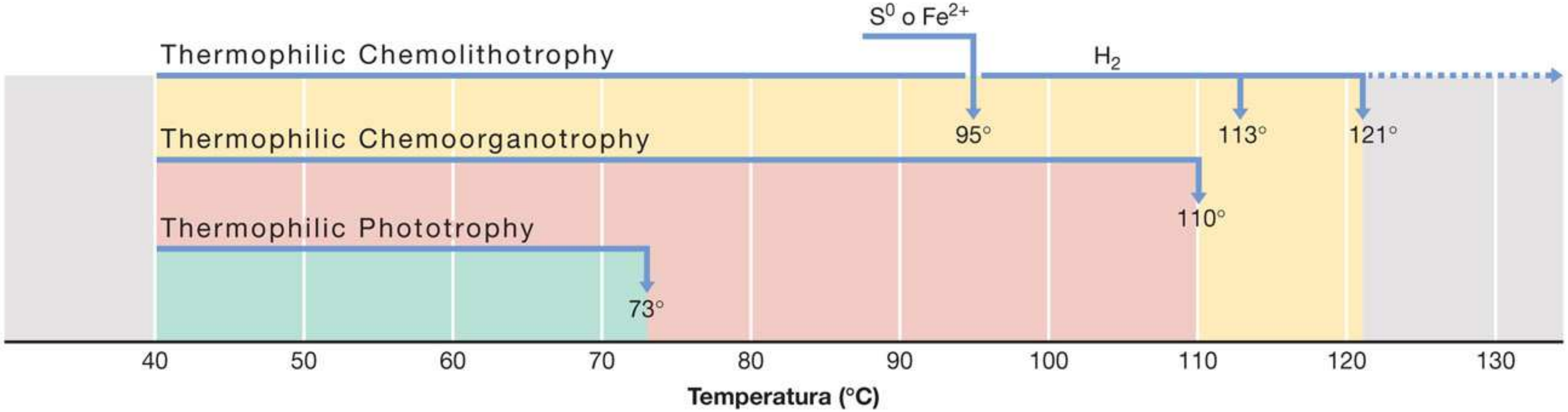


(c)

Pyrolobus fumarii



S^0 o Fe^{2+}
Thermophilic Chemolithotrophy
H_2
95°
113°
121°
Thermophilic Chemoorganotrophy
110°
Thermophilic Phototrophy
73°
40
50
60
70
80
90
100
110
120
130
Temperatura (°C)