Phylogenetic and metabolic diversity of The Archaea

Archaea constitute a significant component of life on Earth, **contributing to the microbiota of various organisms.**

- diverse **morphology, metabolism, and geographical distribution** enable them to fulfill **multiple ecological functions**, **including carbon fixation, nitrogen cycling, turnover of organic compounds, and the maintenance of microbial** **symbiotic and syntrophic communities**.

- there is a **lack of well-established examples of archaeal pathogens or parasites.**

- Instead, archaea commonly engage in **mutualistic or commensal relationships**.

  - methanogens, known for producing methane, inhabit the gastrointestinal tracts of both humans and ruminants, aiding in digestion.
  - **Methanogens also find applications in biogas production and sewage treatment.**

  - **biotechnology leverages enzymes** derived from extremophile archaea capable of withstanding high temperatures and organic solvents.

A- *Crenarchaeota*

1. **Hyper-thermophiles,**
2. **Thermophiles**
3. **Thermoacidophiles** involved in sulfur metabolism

B- *Euryarchaeota*

1. **Hyper-thermophiles,**
2. **Thermophiles**
3. **Thermoacidophiles involved in sulfur metabolism**
4. **Extreme halophiles**
5. **Methanogens**

C- Nanoarchaeota : Nanoarchaeum (parasitic species)

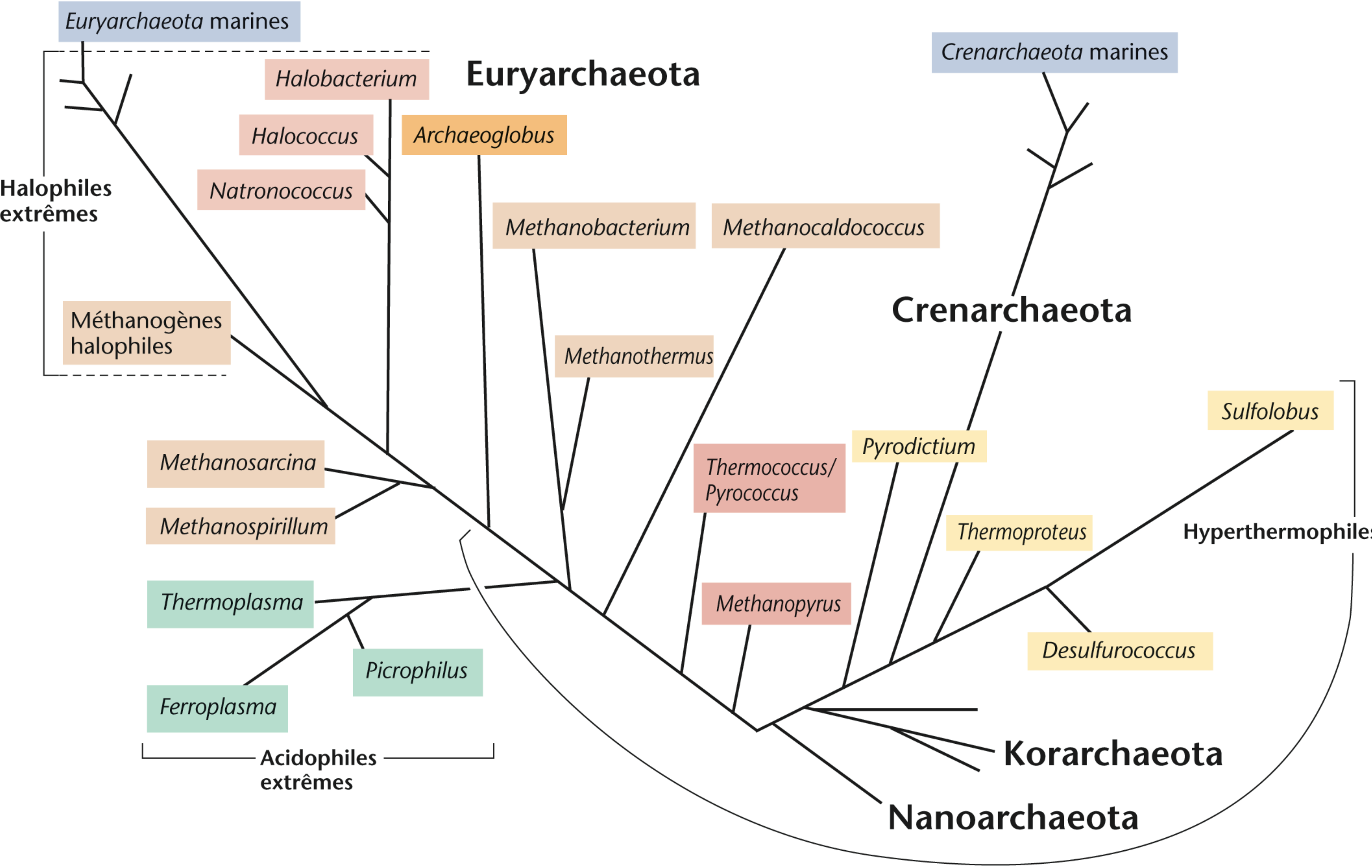
+ small genome known in a prokaryote

D- Thaumarchaeota

E- *Korarchaeota*

A- *Crenarchaeota*

1. **Hyper-thermophiles,**
2. **Thermophiles**
3. **Thermoacidophiles** involved in sulfur metabolism


Euryarchaeota marines
Halobacterium
Euryarchaeota
Crenarchaeota marines
Halococcus
Archaeoglobus
Halophiles extrêmes
Natronococcus
Methanobacterium
Methanocaldococcus
Crenarchaeota
Méthanogènes halophiles
Methanothermus
Sulfolobus
Pyrodictium
Methanosarcina
Thermococcus/ Pyrococcus
Methanospirillum
Thermoproteus
Hyperthermophiles
Thermoplasma
Methanopyrus
Picrophilus
Desulfurococcus
Ferroplasma
Acidophiles extrêmes
Korarchaeota
Nanoarchaeota

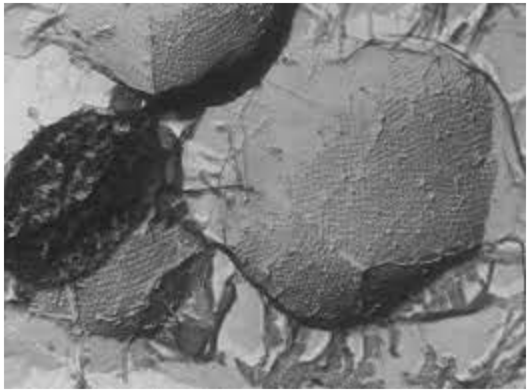
A. *The Crenarchaeota*

a. Underwater volcanic habitats

- ***Desulfurococcales* :** **Sulfo-reducers and fermenters**

  - **Strict anaerobes, hyperthermophilic, slightly acidophilic (pH: 5-6)**

    - **Nutrition :** Chemoorganotrophs
    - **Habitat :** Marine environments



b. Terrestrial volcanic habitats

- *Thermoproteales*

Hot acid sulfurous sources (pH 2 to 7; temperature 90°C to more than 100°C)

All these conditions are achieved in **the solfatara,** **a fumarole rich in sulfur gases** volcanic terrains where water vapor at a temperature of 100 to 300°C, and hot currents of gases such as **CO_2 , H_2 , H_2 are released through cracks. S , CO and CH_4** .

They are capable of oxidizing :

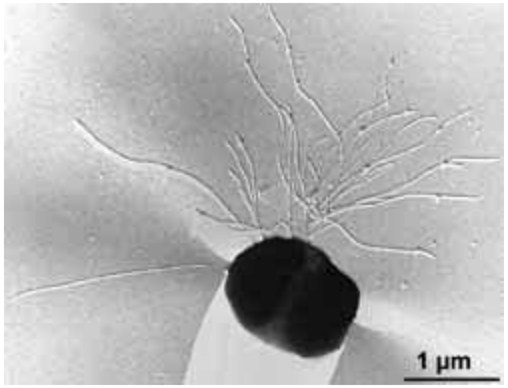
- ✓ **H2 and elemental sulfur** as energy **sources with CO2 as a carbon source (rTCA cycle)**
- ✓ **Organic matter by breathing elemental sulfur**

B- *Euryarchaeota*

1. Hyperthermophiles,
2. Thermophiles
3. Thermoacidophiles involved in sulfur metabolism
4. Extreme halophiles
5. Methanogens

B- Euryarchaeota

1- Hyperthermophiles



- ***Thermococci & Pyrococcus***

Marine sediments, particularly seabed hydrothermal vents,

Ex: Pyrococcus furiosus , isolated from geothermal marine sediments.

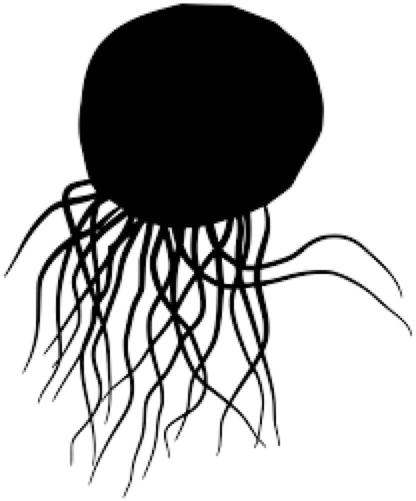
These microorganisms carry out anaerobic respiration

Electron donor : proteins, starch or maltose

M. organic + S --------> H_2S + CO_2

2- Thermophiles metabolizing sulfur at a phylogenetic position close to methanogens

- ***Archaeoglobus* : a sulfate reducer forming a distinct lineage within the Euryarchaeota**



Grows in 2 different ways:

✓ **Autotrophy by sulfate reduction**

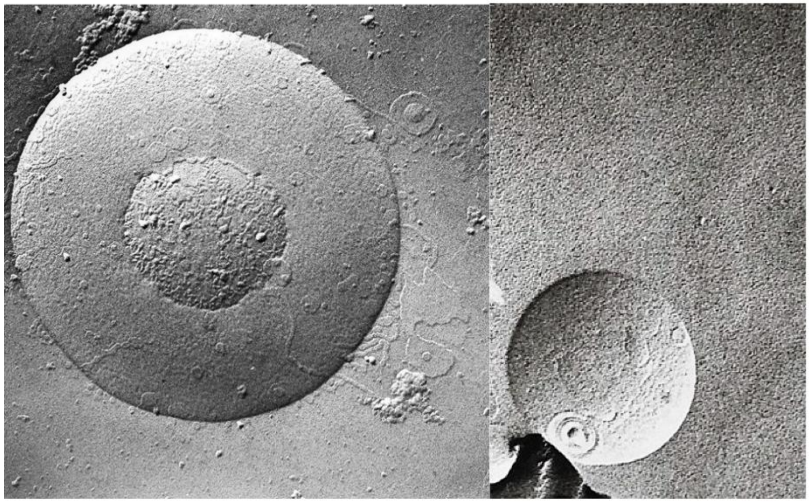
$4H_2$ + $SO_4^{=}$ + $2H^{+}$ ----------------> **H_2S** + 4 H_2O

✓ **Heterotrophy**

2 Lactates + $SO_4^{=}$ + H^{+} ---------> 2 acetates + HS^{-} + $2CO_2$ + $2H_2$

3- *Thermoacidophiles: Thermoplasma*

- ***Thermoplasma and Ferroplasma* are wallless cocci**



- **Grow at optimal pH of 2,**
- **some at pH 0.8! (>0.1M HCl),**
- **on complex medium at an optimum T°: 55°C**

***Thermoplasma* from piles of slow combustion of coal refuse**

Heterotrophic thermoacidophiles, facultative anaerobes

Terminal electron acceptor: O_2 **or sulfur**

4- Extreme halophiles

- **The halophiles require concentrations of 0.2 M of NaCl**

- **Extreme halophiles cannot grow below 2.5 M NaCl (150 g/l),**

Halococcus salinarium **requires 6.2M** (359 g/l)

Contain **red pigments,** the red sea gets its name because of the preponderance of these micro-organisms.

sea water (0.6M or 35 g/l)

5. Methanogens

These microorganisms form methane (CH_4) through a **unique metabolic pathway** , **having specific enzymes and cofactors**

- **All methanogens are obligate chemolithotrophs**

- **Produce energy only by methanogenesis, and fix CO_2 through the acteyl-COA pathway (CO_2 electron acceptor and carbon source for organic syntheses)**

Habitats:

- **Anoxic sediments** : Ponds, marshes, rice fields, lakes
- **Digestive tract of animals** : rumen, cecum , colon, rectal rumen of insects
- **Geothermal sources** of H_2 and CO_2
- **Wastewater treatment plants** : anaerobic sludge digesters
- **Endosymbionts** of various anaerobic protozoa

Fig 13.05 Brock

- Substrates that can be transformed into methane by methanogens:

- **2 types : HCOO-, CO, CO2**

- **Methylated substrates : methanol , methylamine $CH_3NH_3^+$, diMA , triMA , methylmercaptan (CH_3SH), Dimethylsulfide $(CH_3)_2S$**

- **Other substrates : Acetate , pyruvate**

4 major groups

Methanococcales , *Methanobacteriales* ,

Methanomicrobiales and *methanosarcinales* .

a. Methanococcales

- **In seaside salt marshes or in marine or estuarine sediments**
  - Some species are thermophilic, mesophiles
  - Grow mainly on

H_2 or format as an energy source

- Fix CO_2, synthesize their growth factors,

- Fix the N_2 and **the S from the H_2S**, etc.

- Very sensitive to O_2 and UV,

- they lack enzymes for repairing damage induced by exposure to UV (Photolyases)

b. Methanobacteriales

Use: **H_2 + CO_2** (in certain cases CO and/or formate)

vs. Methanomicrobiales

Use: **H_2 + CO_2 or format**

Require acetate for growth, used as a carbon source

d. Methanosarcinales

These microorganisms are very versatile

- (H_2 + CO_2, or CO)

- Acetate, methanol, or methylamines

- **Acetate ---> CH4 + CO2**
- **4 Methanols ---> 3CH4 + CO2 + 2H20**
- **Methylamines ---> CH4 + CO2 + NH3**

Reactions using mono-, di-, or trimethylamine generate methane, CO2, and **ammonia**