Archaea Are Often Thought of as Extremophiles, but many are not

Pyrobolus—a thermophilic Archaeon that grow best above the bp of water!

Some archaea can live WITHIN granules of salt!

Similarities:

• Archaea have generally the same shape, size, and appearance as bacteria.
• Like bacteria, Archaea multiply by binary fission and move primarily by means of flagella.
• These morphological similarities can make it difficult to visually tell a bacterium and an archaean apart.
• Additionally, archaea are more phylogenetically similar to eukarya than bacteria is to either of them.

Differences

• Unlike bacteria, archaea cell walls do not contain peptidoglycan.

• Archaea have different membrane lipid bonding compared to Bacteria and Eucarya.
Archaea membrane lipids have ether bonds instead of ester bonds.

\[ \text{R-C-O-C-R = ETHER BOND = ARCHAEA} \]

Archaeal lipids lack the fatty acids found in Bacteria and Eukaryotes and instead have side chains composed of repeating units of isoprene.

\[ \text{CH}_3 \]
\[ \text{H}_2\text{C} = \text{C} - \text{C} = \text{CH}_2 \]

\[ \text{ISOPRENE} \]

Structure of the tetraether lipoglycan of the plasma membrane of *Thermoplasma acidophilum*. Note that this is not a lipid bilayer and the hydrophilic group is a polysaccharide rather than a phosphate group.

Membranes revisited

Lipid bilayer as seen in some Archaea and all Eucarya and Bacteria ---->

Lipid monolayer as found only in some Archaea - especially in extreme thermophiles ---->

Differences

- Unlike bacteria, archaea cell walls do not contain peptidoglycan.
- Archaea have different membrane lipid bonding from bacteria and eukaryya.
- There are genetic differences.

Other differences

- Like Bacteria, Archaea have 70S ribosomes, but they have a different shape.
- Archaea have more complex RNA polymerases than Bacteria, similar to Eucarya.
**Differences**

- Unlike bacteria, archaea cell walls do not contain peptidoglycan.
- Archaea have different membrane lipid bonding from bacteria and eukarya.
- There are genetic differences.
- Archaea have different metabolic pathways.

**Metabolic differences:**

- Archaea are very metabolically diverse, so they are hard to generalize.
- Archaea do not use glycolysis pathway to break down glucose (though they do use similar pathways).
- Many archaea do not have functional Kreb’s cycle pathways (but some do).

**The Taxonomy of Archaea**

The domain Archaea is divided into 2 main divisions (or kingdoms):

- Crenarchaeota
- Euryarchaeota

Archaea: major metabolic groups = methanogens, halophiles, and sulfur metabolizers

**Euryarchaeota**

- Occupy many different niches and have a diversity of metabolic patterns
- Include the methanogens, the extreme halophiles, the sulfate reducers, and many extreme thermophiles.

**The Euryarchaeaa - 5 major groups:**

1) Halophiles
2) Methanogens
3) Thermoplasms
4) Extreme Thermophilic S\(^0\) metabolizers
5) Sulfate - Reducers
Extremely Halophilic Archaea

• live in habitats that are highly saline (requires at least 9% NaCl for growth, may tolerate near saturation - 32%)
  > Dead Sea
  > Great Salt Lake
  > Heavily salted foods
• Most extreme halophiles are chemoheterotrophic

Some extreme halophiles are capable of light mediated synthesis of ATP that does NOT involve chlorophyll, i.e. a pathway that uses the sun's energy to make ATP.

Methanogens

• produce methane (CH$_4$) as part of energy metabolism.
• Occupy diverse habitats:
  > Marshes and swamps
  > Animal digestive tracts
  > Hydrothermal vents
  > Waste Management facilities

Methanogens are strictly anaerobic.

The basic chemical reaction most methanogens use:

$$\text{CO}_2 + 4\text{H}_2 \rightarrow \text{CH}_4 + 2\text{H}_2\text{O}$$

Other substrates may also be used such as formate ($\text{CO}_2 + \text{H}_2\text{O}$ in a combined form)
CO
Methyl substrates, e.g. methanol (CH$_3$OH)
Acetotrophic substrates, e.g. acetate (CH$_3$COO$^-$)

In any of those cases, the production of methane is an exergonic reaction, thus the energy can be used to synthesize ATP.

If the organisms use CO$_2$ as a carbon source, they are classified as autotrophs.

Many methanogens live symbiotically with fermenting bacteria.

Methanogens live in the guts of many organisms, from termites to humans.
Some even live endosymbiotically with anaerobic protozoans.

The methanogens use up the H₂ generated by a special organelle called the hydrogenosome.

Rumen Archaea

Animals that eat primarily cellulose, i.e. grazers, often use methanogenic archaea to help digestion.

Ruminants (cows, sheep, deer, camels) have compartmentalized stomachs that permit anaerobic archaea to thrive.

Cows can produce up to 600 liters of methane every day!

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This accounts for about 15% of global methane production and is a serious problem for global warming.

Thermoplasms

These organisms thrive at extreme temperatures and/or acidities.

ex.

• *Thermoplasma* - lives in refuse piles of coal mines. *Lacks a cell wall*

• *Picrophilus* - extreme acidophile - optimum growth at pH 0.7 and reported to grow at pH -0.67!

Crenarchaeota

Thought to resemble the ancestor of archaea

Almost all the best described ones are thermophiles or extreme thermophiles...

...though some mesophilic forms have recently been discovered in the ocean - dominant form of life below 300 meters in the oceans!
Crenarcheota

- most are strict anaerobes
- common in Yellowstone and deep sea volcanoes
- 2 important genera are *Sulfolobus* and *Thermoproteus*
- Can be chemoheterotrophic or chemoautotrophic

Korarcheota

- only recently discovered (1996) in Yellowstone hot spring - Obsidian Pool
- using environmental sampling of rDNA, 19 new taxa were discovered, including 2 that branched prior to the diversification of all other Archaea

How do these organisms survive at such high temperatures?

- Protein stability
- DNA stability
- Lipid stability
- covalent bonds in hydrophobic ends of lipids create a lipid monolayer instead of a lipid bilayer - less likely to be pulled apart.

DNA STABILITY

- Why don’t the two strands melt apart at these high temperatures?
  - Unique “reverse DNA gyrase” - makes positive supercoils that stabilize the DNA
  - Euryarchaea contain histones - like eukaryotes! Histones wind and compact the DNA to increase mp
  - Crenarchaea also have DNA binding proteins which bind to the DNA and increase the mp by 40°
  - the cytoplasm contains a solute which prevents chemical damage to DNA

PROTEIN STABILITY

- many proteins have similar amino acid composition as those of mesophilic bacteria, but are folded differently to make them more heat stable.
- the amino acids also tend to have very hydrophobic cores which lowers the tendency to unfold.
- they tend to have more chaperonins (= heat shock proteins) that refold denatured proteins.

Exam 1
mean = 75
High = 99
Low = 21
If we gave out grades right now....
A = 85 -100
B = 75 - 84
C = 66 - 74
Check your point total.
Q. 25. Last steps of the lactate fermentation = e-dumping, not substrate level phosphorylation.

![Diagram of lactate fermentation]

What's substrate-level phosphorylation???

![Diagram of substrate-level phosphorylation]

26. Match the process with the name of the process (use one letter per blank, letters can be used more than once) (8 pts.)

- __d__ denitrification
- __a__ nitrogen fixation
- __b__ anammox
- __c__ nitrification
- __c__ aerobic respiration
- __d__ anaerobic respiration by a chemoheterotroph
- __a__ an anabolic process
- __b__ anaerobic respiration by a chemoautotroph

Also filtered air through sterile cotton = caught lots of microbes

Q. 31. Longer runs, less frequent tumbles....

Lec. 3 and/or 4

![Diagram of tumble and swim]

a. No concentration gradient

b. Concentration of attractant is higher on the right

Q. 32. Koch's postulates (lec. 2):

1) The disease organism must be present in sick animals and not present in healthy ones.

2) The organism must be cultivated in pure culture.

3) This culture, when inoculated into a healthy animal should produce the disease.

4) The organism can be re-isolated from these animals.