Archaea

When these microscopic organisms were first discovered (in 1977), they were considered bacteria. However, when their ribosomal RNA was sequenced, it became obvious that they bore no close relationship to the bacteria and were, in fact, more closely related to the eukaryotes (including ourselves!) For a time they were referred to as archaebacteria, but now to emphasize their distinctness, we call them Archaea.

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They have also been called **Extremophiles** in recognition of the extreme environments in which they have been found:

- **thermophiles**, which live at high temperatures;
- **hyperthermophiles**, which live at really high temperatures (present record is 121°C!);
- **psychrophiles**, which like it cold (one in the Antarctic grows best at 4°C);
- **halophiles**, which live in very saline environments (like the Dead Sea);
- **acidophiles**, which live at low pH (as low as pH 1 and who die at pH 7!);
- **alkaliphiles**, which thrive at a high pH.

Most of the >250 named species that have been discovered so far have been placed in two groups:

- Euryarchaeota
- Crenarchaeota

Euryarchaeota

There are three main groups:

- Methanogens
- Halophiles
- Thermoacidophiles

1. Methanogens

These are found living in such anaerobic environments as

- the muck of swamps and marshes;
- the rumen of cattle (where they live on the hydrogen and CO_2 produced by other microbes living along with them);
- our colon (large intestine);
- sewage sludge;
- the gut of termites.

They are chemoautotrophs; using hydrogen as a source of electrons for reducing carbon dioxide to food and giving off methane ("marsh gas", CH_4) as a byproduct.

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

Two methanogens that have had their complete genomes sequenced:

- ***Methanocaldococcus jannaschii*** and
- ***Methanothermobacter thermoautotrophicus***

[View the data]

2. Halophiles

These are found in extremely saline environments such as the Great Salt Lake in the U.S. and the Dead Sea. They maintain osmotic balance with their surroundings by building up the solute concentration within their cells.

3. Thermoacidophiles

As their name suggests, these like it hot and acid (but not as hot as some of the Crenarchaeota!). They are found in such places as acidic sulfur springs (e.g., in Yellowstone National Park) and undersea vents ("black smokers").

Crenarchaeota

The first members of this group to be discovered like it really hot and so are called **hyperthermophiles**. One can grow at 121°C (the same temperature in the autoclaves used to sterilize culture media, surgical instruments, etc.).

Many like it acid as well as hot and live in acidic sulfur springs at a pH as low as 1 (the equivalent of dilute sulfuric acid). These use hydrogen as a source of electrons to reduce sulfur in order to get the energy they need to synthesize their food (from CO_2).

Aeropyrum pernix is one member of the group that has had its genome completely sequenced [View].

Other members of this group seem to make up a large fraction of

- the plankton in cool, marine waters;
- the microbes in both soil and the ocean that convert ammonia into nitrites (nitrification).

Evolutionary Position of the Archaea

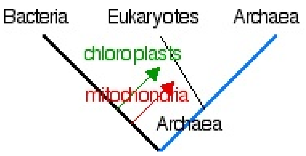
The archaea have a curious mix of traits characteristic of

- bacteria as well as traits found in
- eukaryotes

The table summarizes some of them.

Eukaryotic Traits	Bacterial Traits
• DNA replication machinery • histones • nucleosome-like structures • Transcription machinery ◦ RNA polymerase ◦ TFIIB ◦ TATA-binding protein (TBP) • Translation machinery ◦ initiation factors ◦ ribosomal proteins ◦ elongation factors ◦ poisoned by diphtheria toxin	• single, circular chromosome • operons • no introns • bacterial-type membrane transport channels • Many metabolic processes ◦ energy production ◦ nitrogen-fixation ◦ polysaccharide synthesis

What can we conclude from this collection of traits?



- Many traits found in the bacteria first appeared in the ancestors of all the present-day groups.
- The split leading to the archaea and the eukaryotes occurred after the bacteria had gone their own way.
- However, the acquisition by eukaryotes of
  - mitochondria (probably from an ancestor of today's rickettsias) and
  - chloroplasts (from cyanobacteria)

  occurred after their line had diverged from the archaea.

As more and more genes are sequenced, it appears that the line that eventually produced eukaryotes split off **after** the line leading to the euryarchaeota. If that is the case, Archaea is a paraphyletic group, and we shared a common ancestor with the other archaea more recently than they (and we) did with the euryarchaeota.

Economic Importance of the Archaea

Because they have enzymes that can function at high temperatures, considerable effort is being made to exploit the archaea for commercial processes such as providing

- enzymes to be added to detergents (maintain their activity at high temperatures and pH);
- an enzyme to covert corn starch into dextrins.

Archaea may also be enlisted to aid in cleaning up contaminated sites, e.g., petroleum spills.

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