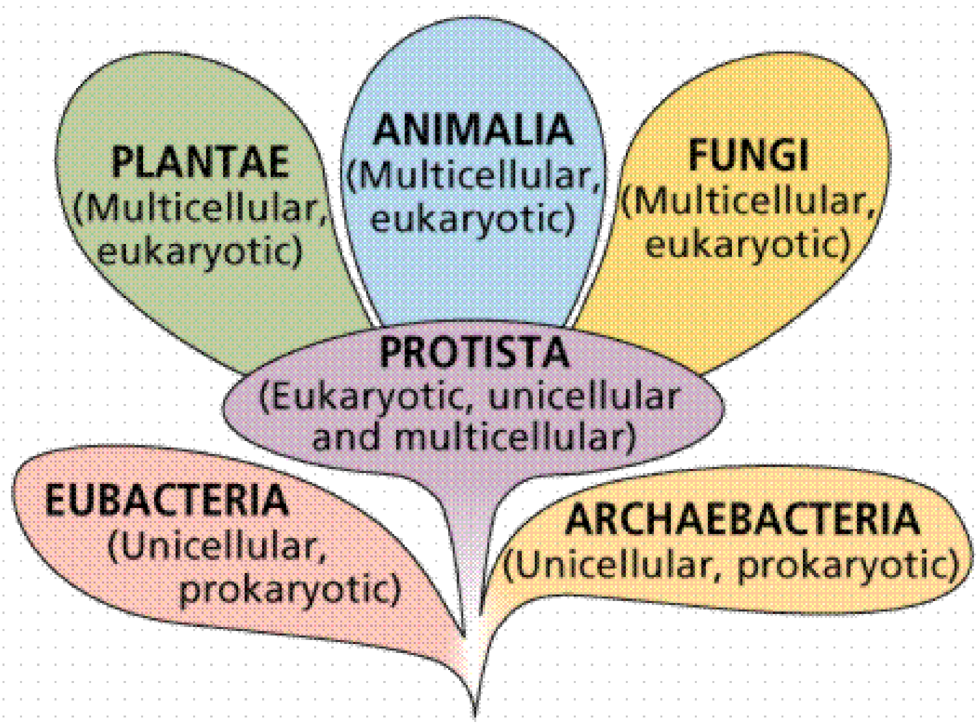
ARCHAEBACTERIA

Background

- Biologists have long organized living things into large groups called kingdoms.
- There are six of them:
  - Archaebacteria
  - Eubacteria
  - Protista
  - Fungi
  - Plantae
  - Animalia



5 common characteristics used for comparison among living organisms:

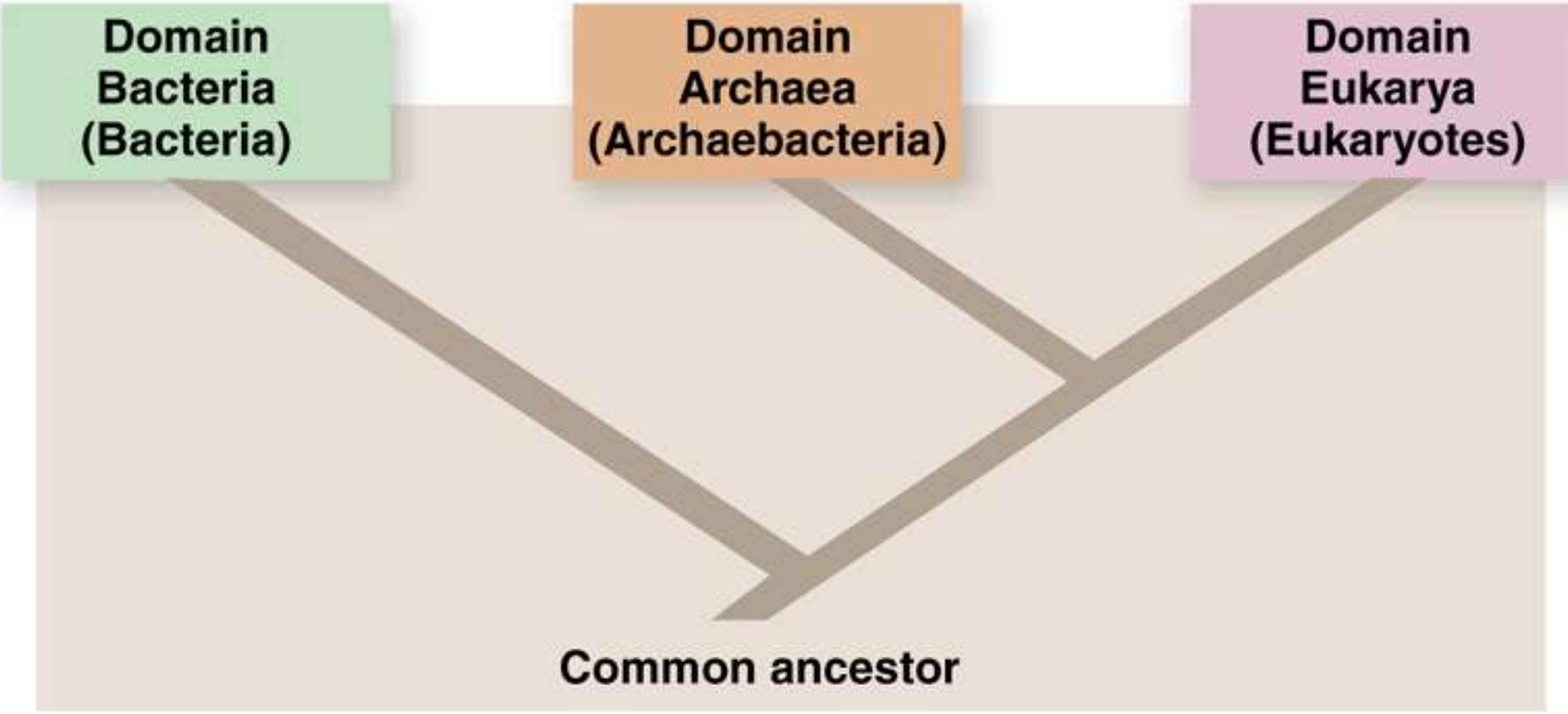
- Cell type – 2 kingdoms are prokaryotic; 4 kingdoms are eukaryotic
- Cell wall – 4 of the 6 kingdoms have a cell wall
- Body type – unicellular vs. multicellular
- Nutrition – autotrophic vs. heterotrophic
- Reproduction – sexual vs. asexual

Some recent findings…

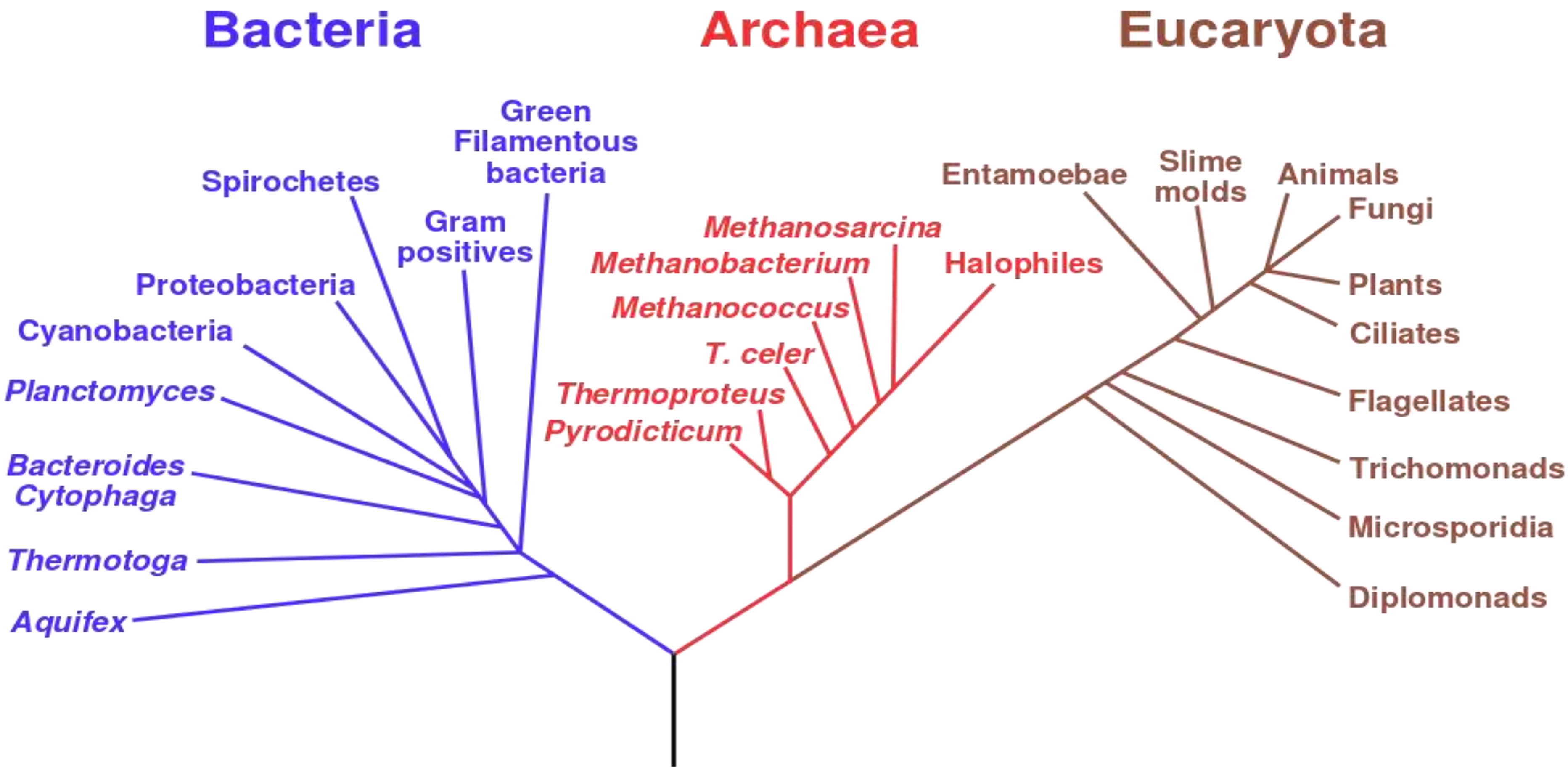
- In 1996, scientists decided to split Monera into two groups of bacteria:
  Archaebacteria and Eubacteria

- Because these two groups of bacteria were different in many ways scientists created a new level of classification called a DOMAIN.

Molecular Classification



Phylogenetic Tree of Life



The Domain Archaea

- "ancient" bacteria
- Some of the first archaebacteria were discovered in Yellowstone National Park's hot springs and geysers.
- Prokaryotes are structurally simple, but biochemically complex

The Archaebacteria:

- Archaea are the smallest independently living single-celled organisms on earth.
- Typical cells range in size from 0.5 to1.0 µm in diameter.
- DNA lies free in the cell cytoplasm.
- A cell membrane comprised of phospholipids surrounds the cell.

The Archaebacteria also:

- The cell wall is usually made up of protein and carbohydrate and lipids.
- Most of the time they undergo asexual reproduction, mostly by dividing in half; some cells divide every 12–20 minutes, others take a lot longer.
- All organisms require carbon, which provides building blocks for cell materials

Archaea

- **Archaea** were originally thought to exist only in harsh environments .

- Were often described as ‚extremophiles' They are widely distributed and are found alongside bacteria in many environments including soil and water.

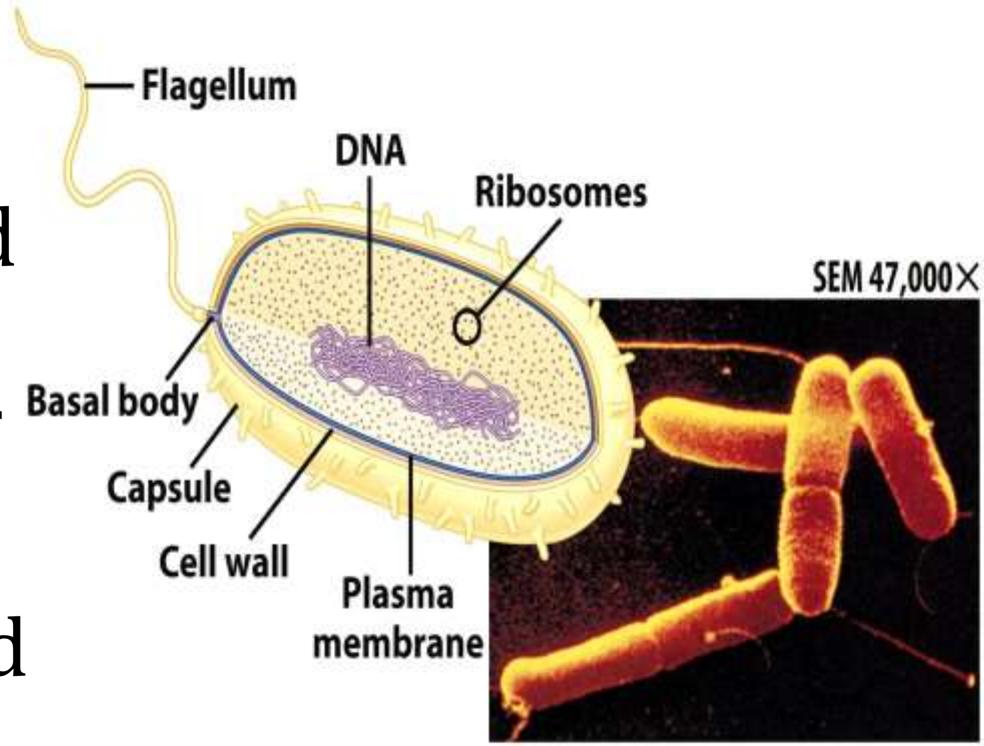
Archaea

- The best described groups of Archaea are the methanogens that produce methane, and the extremophiles that grow under high salt or extreme temperatures.

- *Pyrodictum*, for example, has an optimal growth temperature of 105°C.

Prokaryotic Cells

- First cell type on earth
- Cell type of Bacteria and Archaea
- No membrane bound nucleus
- Nucleoid = region of DNA concentration
- Organelles not bound by membranes



Some weird things about this kingdom…

- Most don't need oxygen to survive
- They can produce ATP (energy) from sunlight
- They can survive enormous temperature extremes
- They can survive high doses of radiation (radioactivity)
- They can survive under rocks and in ocean floor vents deep below the ocean's surface
- They can tolerate huge pressure differences

The archaebacteria have the following unique combination of traits:

Prokaryotic traits:

- They are about 1 micrometer (μm) in diameter, the size of typical prokaryotes.

- They lack membrane-bound organelles.

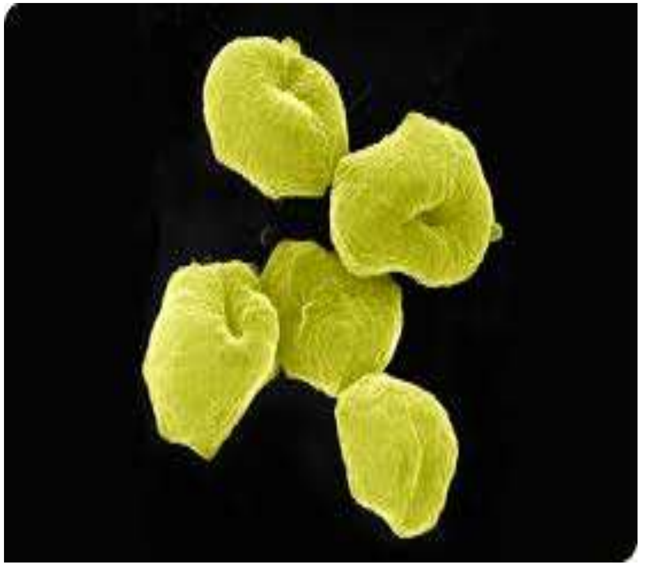
- They have nuclear bodies (nucleoids) rather than true, menbranee bound nuclei.

- Their ribosomes are 70 S, the size of those found in typical prokaryotes.

Eukaryotic traits:

- Their cell walls completely lack peptidoglycan.

- Their protein synthesis machinery is sensitive to inhibitors that typically affect only eukaryotes and is resistant to many inhibitors that affect prokaryotes.



- Some of their proteins, pigments, and biochemical processes closely resemble those found in eukaryotic cells.

Table 25.1 Features of the Domains of Life

Feature	Domain: Archaea	Domain: Bacteria	Domain: Eukarya
Amino acid that initiates protein synthesis	Methionine	Formyl-methionine	Methionine
Introns	Present in some genes	Absent	Present
Membrane-bounded organelles	Absent	Absent	Present
Membrane lipid structure	Branched	Unbranched	Unbranched
Nuclear envelope	Absent	Absent	Present
Number of different RNA polymerases	Several	One	Several
Peptidoglycan in cell wall	Absent	Present	Absent
Response to the antibiotics streptomycin and chloramphenicol	Growth not inhibited	Growth inhibited	Growth not inhibited

Archaea Vs. Eubacteria

- **Domain Archaea**
  - no membrane- bound organelles (prok.)
  - no peptidoglycan
  - do not respond to antibiotics
  - extremophiles
  - chemoautotrophs, heterotrophs
  - 3 main groups: methanogens, extreme halophiles, extreme thermophiles

- **Domain Eubacteria**
  - no membrane-bound organelles (prok.)
  - peptidoglycan in cell walls
  - growth inhibited by antibiotics
  - diverse metabolism
  - 5 main groups: spirochetes, actinobacteria, cyanobacteria, proteobacteria

3 Main Types

Methanogens

Thermoacidophiles

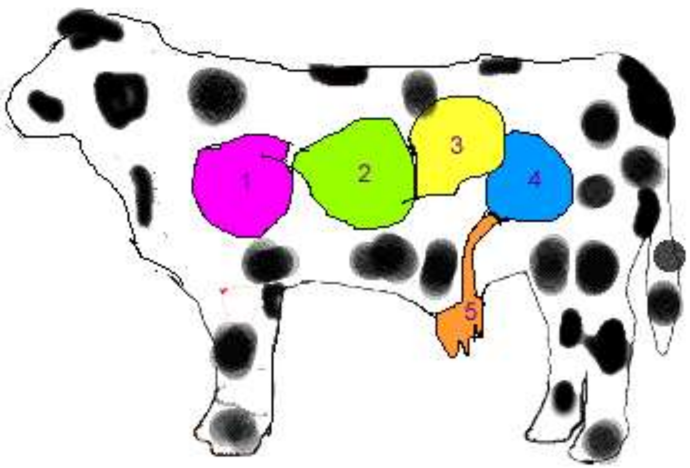
Halophiles

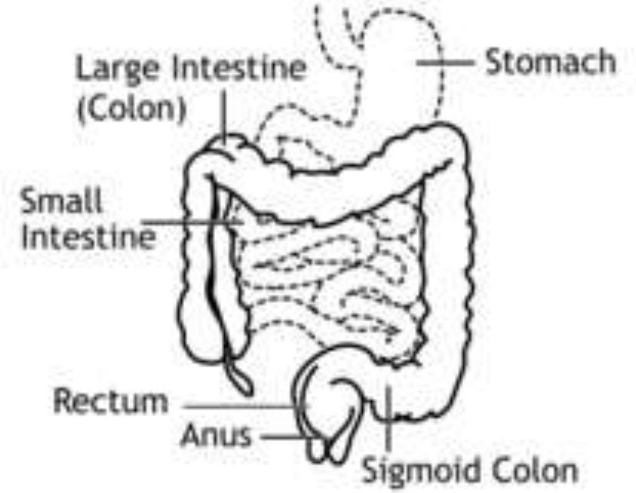
Methanogens

Phylum	Methanocreatices
Common Name	methanogens
Habitat	Sewage, swamps, cow stomachs
Nutrition	autotrophic/heterotrophic
Special Structures	Cocci, bacilli, spirilla; flagella or immobile
Reproduction	binary fission
Economic/Biological Importance	Decomposers, produces methane gas
Examples	*Methanobacillus melianski*

Methanogens

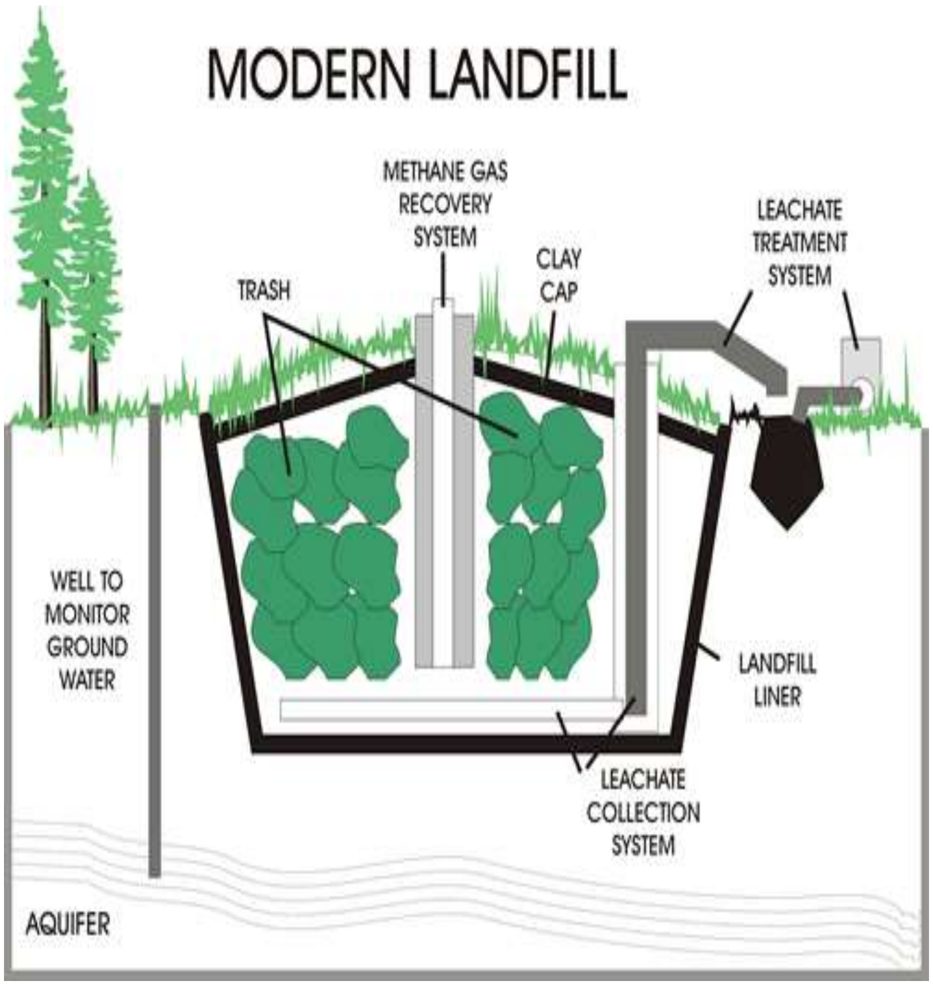
- They release methane (CH_4) as a waste product
- Many live in mud at the bottom of lakes and swamps because it lacks oxygen
- Some live in the intestinal tracts of animals to help break down food
- Others like to hang out in the stomach





Significance of methanogens

- They could play a role in garbage/sewage cleanup by having methanogens eat garbage.
  - The methane waste the bacteria produce after eating the garbage or sewage could be used as fuel to heat homes.
- Some landfills already employ this method—the only problem is that it's expensive.



THERMOACIDOPHILES

Phylum	Aphragmabacteria
Common Name	thermoacidophiles
Habitat	water (hot springs) & organisms
Nutrition	autotrophic/heterotrophic
Special Structures	Irregular shape or blobs
Reproduction	binary fission
Economic/Biological Importance	Pneumonia in domesticated animals, humans
Examples	*Mycoplasma pneumoniae, Thermoplasma acidophilum*

Thermoacidophiles

- Live in the dark
- Live without oxygen
- Like to live in superheated water with temperatures reaching 750 deg F
- Prefer environments that are very acidic (between pH of 1-3)
- Live in a chemical soup of hydrogen sulfide (H_2S) and other dissolved minerals (rotten egg smell)

Thermo = temperature

Acidophil = acid loving

Thermoacidophiles

- Like temperature and pH extremes
  - Hot = up to 110ºC
  - Cold = down to 1ºC
  - Acid = as low as pH 2
  - Alkali = as high as pH 9
- they are chemoautotrophs, using H_2S
- the first Extremophile was found about 30 years ago

Extreme Temperatures

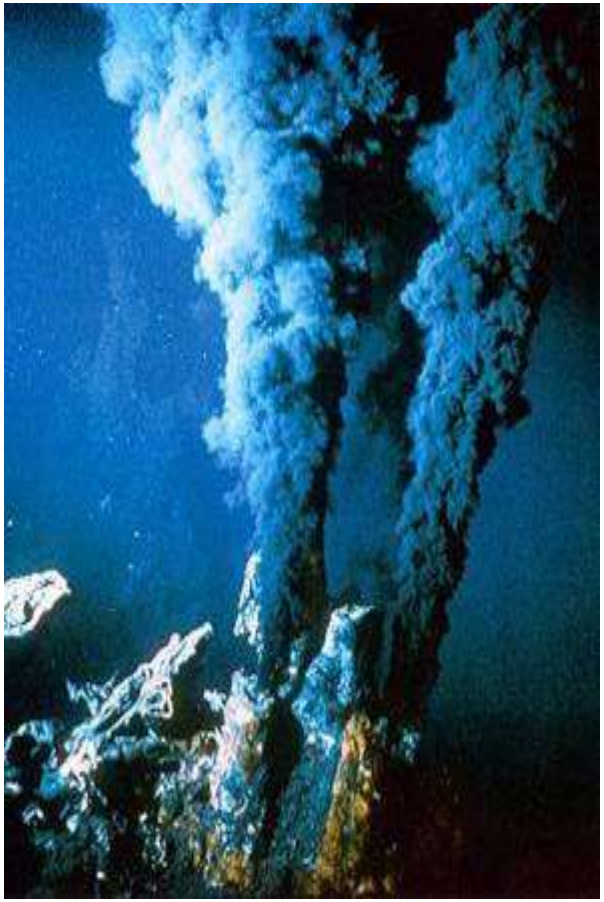
- **Thermophiles** - High temperature = 60-80°C
  - Thermal vents and hot springs
  - May go hand in hand with chemical extremes
- **Psychrophiles** - Low temperature
  - Arctic and Antarctic
    - 1/2 of Earth's surface is oceans between 1°C & 4°C
    - Deep sea –1°C to 4°C
    - Most rely on photosynthesis

Thermophile Applications

- Many industrial processes involve temperature extremes, which is a problem for most enzymes
  - Enzymes to work on foods that need to be refrigerated
  - Perfumes - most don’t tolerate high temperatures
  - Cold-wash detergents
  - PCR reactions

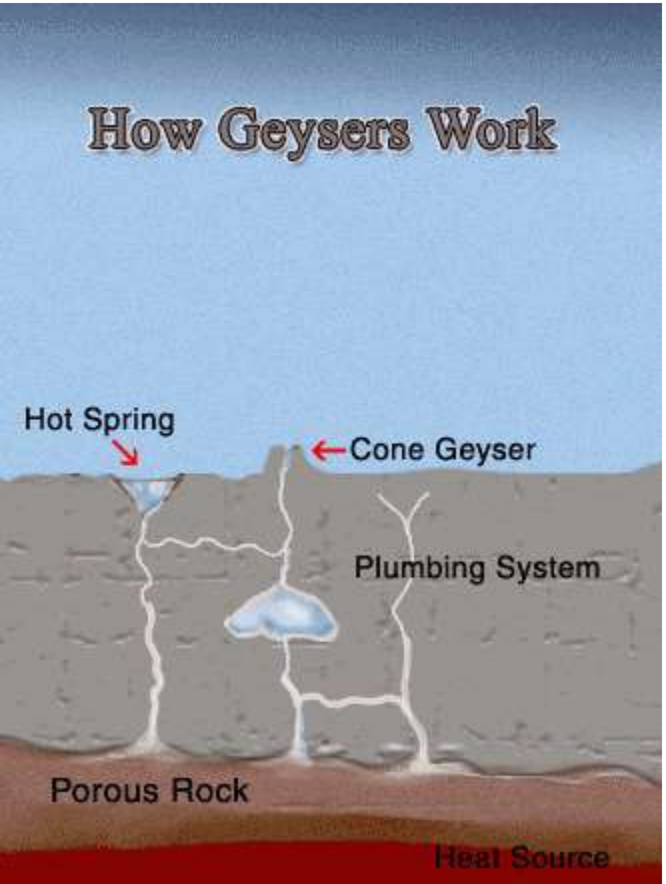
Black Smokers

The interior layers of the Earth are made up of many different types of metals (iron, copper). The black color is caused by a chemical reaction of the metals with the ocean water. In extreme temperatures and pressures, this is where some thermoacidophiles like to live.



Other thermoacidophiles like to live in hot springs or geysers. Hot springs are pools of hot water that have moved toward earth's surface. The source of their heat is the hot magma beneath and they can reach temperatures as high as 400 degrees Fahrenheit

http://www.nps.gov/archive/yell/oldfaithfulcam.htm



Old Faithful erupts more frequently than any of the other big geysers. Its average interval between eruptions is about 91 minutes. An eruption lasts 1 1/2 to 5 minutes, expels 3,700 - 8,400 gallons of boiling water, and reaches heights of 106 - 184 feet.

HALOPHILES

Phylum	Halobacteria
Common Name	halophiles
Habitat	Soil (salty), water (salty)
Nutrition	autotrophic
Special Structures	Rod-shaped or cocci-shaped, move by flagella
Reproduction	binary fission
Economic/Biological Importance	none
Examples	*Halobacterium halobium, Halobacterium salinarium*

Halophiles

- Can live in water with salt concentrations exceeding 15%
- The ocean's concentration is roughly 4%
- Halo = salt
  phil = loving

The Great Salt Lake in Utah

Halophiles

- are organisms that live in environments with extremely high salt concentrations
  - some extreme halophiles can live in solutions of 35 % salt. (seawater is only 3% salt!)
- most halophiles are aerobic and heterotrophic; others are anaerobic and photosynthetic, containing the pigment bacteriorhodopsin

Diversity of Halophilic Organisms

- Halophiles are found in salt lakes, salt marshes, subterranean salt deposits, dry soils, salted meats, hypersaline seas, and salt evaporation pools
- The Red Sea was named after the halobacterium that turns the water red during massive blooms.

The Great Salt Lake in Utah

- It is interesting to note that the Great Salt Lake is actually three to five times saltier than the ocean.
- Every year, members of the salt industry extract about 2.5 million tons of sodium chloride (salt, NaCl) from the lake.
- The Great Salt Lake has no fish. The largest aquatic critters in the Great Salt Lake are brine shrimp.
- Given that the salty water can be corrosive to metal, motorized boats are not very popular at Great Salt Lake State Park. Additionally, since the salt content of the Great Salt Lake increases the water's density, water skiing and jet skiing is not very common.

Chemical Extremes

- **Acidophiles** - Acidic
  - Again thermal vents and some hot springs
- **Alkaliphiles** - Alkaline
  - Soda lakes in Africa and western U.S.
- **Halophiles** - Highly Salty
  - Natural salt lakes and manmade pools
  - Sometimes occurs with extreme alkalinity

Acidophiles

- Enzymes used to increase efficiency of animal feeds
  - enzymes help animals extract nutrients from feed
    - more efficient and less expensive

Life at High Temperatures, Thomas M. Brock

Alkaliphiles

- "Stonewashed" pants
  - Alkaliphilic enzymes soften fabric and release some of the dyes, giving worn look and feel
- Detergents
  - Enzymes to dissolve proteins or fats
  - Alkaliphilic enzymes can work with detergents

Alkaliphile Environments

e.g. Mono Lake alkaline soda lake, pH 9, salinity 8%

Extremophiles as a source of novel enzymes for industrial application

- Extremophilic microorganisms are adapted to survive in ecological niches:
  - high temperatures,
  - extremes of pH,
  - high salt concentrations
  - high pressure.
- These microorganisms produce unique biocatalysts which operate under extreme conditions

Extremophiles as a source of novel enzymes for industrial application

- Selectedextracellular-polymer-degrading enzymes and other enzymes could be used in food, chemical and pharmaceutical industries and in environmental biotechnology.

  (amylases, pullulanases, cyclodextrin glycosyltransferases, cellulases, xylanases, chitinases, proteinases, esterases, glucose isomerases, alcohol dehydrogenases and DNA-modifying enzymes)

Biotechnological applications of archaeal biomasses

- Biological methanogenesis is applied to the anaerobic treatment of
  - sewage sludge,
  - agricultural, municipal and industrial wastes

- Methanogens are a group of microorganisms that obtain energy for growth from the reaction leading to methane production.

Biotechnological applications of archaeal biomasses

- Many bioreactor configurations have been exploited to increase the efficiency of anaerobic digestion, such as
  - the rotating biological contactor,
  - the anaerobic baffle reactor
  - the upflow anaerobic sludge blanket reactor,
  - several large-scale plants are in operation

Archaeal enzymes of biotechnological interest

- Natural and modified archaeal enzymes present huge possibilities for industrial applications
- Many archaeal enzymes involved in carbohydrate metabolism - special interest to the industrial biotechnology sector.
- The starch processing industry can profit from the exploitation of thermostable enzymes.
- Another promising application of hyperthermophilic archaeal enzymes is in trehalose production.

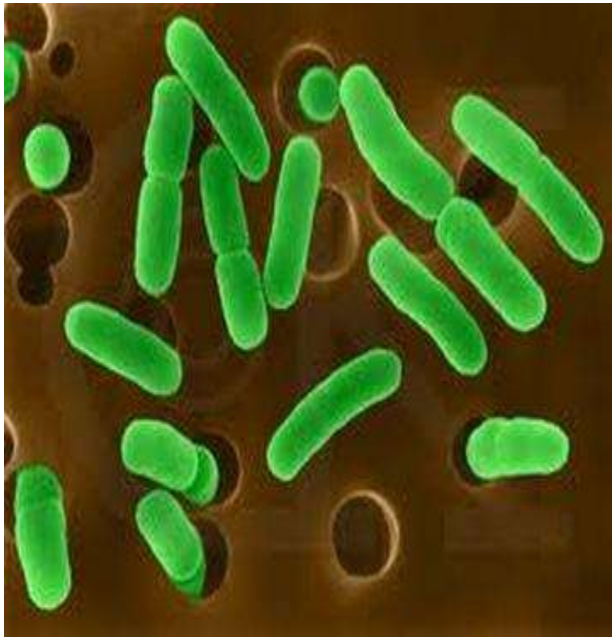
Archaeal enzymes of biotechnological interest

- Several other polymer-degrading enzymes isolated from archaea could play important roles in the chemical, pharmaceutical, paper, pulp or waste treatment industries. (xylanases and cellulases)
- Some archaeal metabolites have potential industrial applications.

  (proteins, osmotically active substances, exopolysaccharides and special lipids)
- Archaeal lipids have been proposed as monomers for bioelectronics

Utilization in the environment protection at the following emissioners:

- CO_2- bioconversion, real zero carbon emission and O_2 output – carbon quotas can be sold, valuable bioproduct production
- Cement industry
- Energy industry
- Chemical industry
- Vehicles
- Food industry
- Biofuels
- Lime-burners
- Biogas plants
- Pyrolysis plants
- Zero carbon emission of waste-fields



Bioenergetical utilization

- With the help of the climate-protecting processes, the system produces energy- and energy sources
- The increase of the energetical effectiveness of the biogas plant
- Production of biofuels
- Hidrothermal gasification
- Combined processes: trigen energy
- Bioenergetical and biotechnologigal utilization of thermal waters and the dissolved gases of thermal waters
- Biofuel production
- Landfill gas use without any kind of emission
- Energetical use of soiled gas wells
- Bio - batteries

Biotechnological – health protectional utilization

- Functional food producing
- Production of C5, C6 sugar with versatile utilization
- Animal feed, protected protein- and fat production for ruminant animals, fish- and crabfeed, hatcheries, increase of spawn- and caviar production
- Products with iodin content in case of nuclear radiation
- Propagation of tribe-yeasts
- Pharmaceutical groundmaterials, fine-biochemicals, vegetal stem-cells from archeas, medicinal fungus, herbs cells produced in closed/sterile system

Biotechnological – health protectional utilization

- Balneotherapy, wellness products
- Beauty-care, skin-care, biocosmetics
- Biotechnological care of the crop, pest control
- Complex utilization of carbon-dioxide stations for high-end biotechnological development
- Microalgaes, archaea for space-traveling and submarines
- Synthesis-gas-production, biomaterials, biopolymers, bio building blocks, bioresins

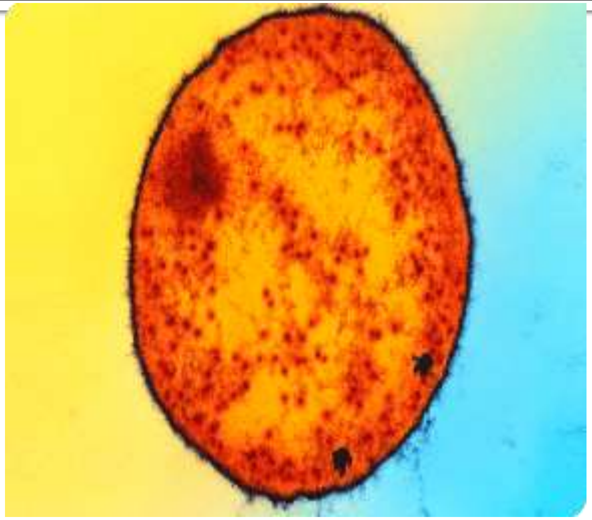
Environmental utilization

- Reduce of the salt content of thermal-, and seawater with use of halofil micro-organisms
- Intesification of waste water cleaning
- Nitrogen reduce of the fermentations fluid of the biogas plants, odour reducing/prevention
- Disposal of harmful wastes
- Elimination of radioactive pollution
- Regeneration of polluted soils (heavy metals, biological degradatible pollutions)
- Propagation of micro-organisms for soil- and pest control for seed-corn treatment.

Environmental utilization

- Enrichment of soils: biofertilizer
- Water-, and soil regeneration polluted with red-sludge
- Water protection, restoration of biodiversity
- Utilization of non-fermentable organic waste (pyrolysis)
- Environment rehabilitation
- Decrease of air pollution
- Waste management, utilization of organic wastes
- Air conditioning of closed areas, like spaceships, submarines

Biorefinery utilization



- biofuel diversification
- biochemicals
- biocharbohydtrates
- bioresins
- Biochemicals

- ➢ The projects are adoptable for any geographycal locations.
- ➢ The size and complexity of the system is variable,
- ➢ The product-range is broadable.

Biorefinery utilization

- size, the product-mix and the product volumes are changeable in connection with the market needs.

- From the container-form system to the bigggest giga-complexes is every form possible.

- It is posible to connect the system to polluting plants like heating plants, biogas plants, sewage farms, waste-fields etc.