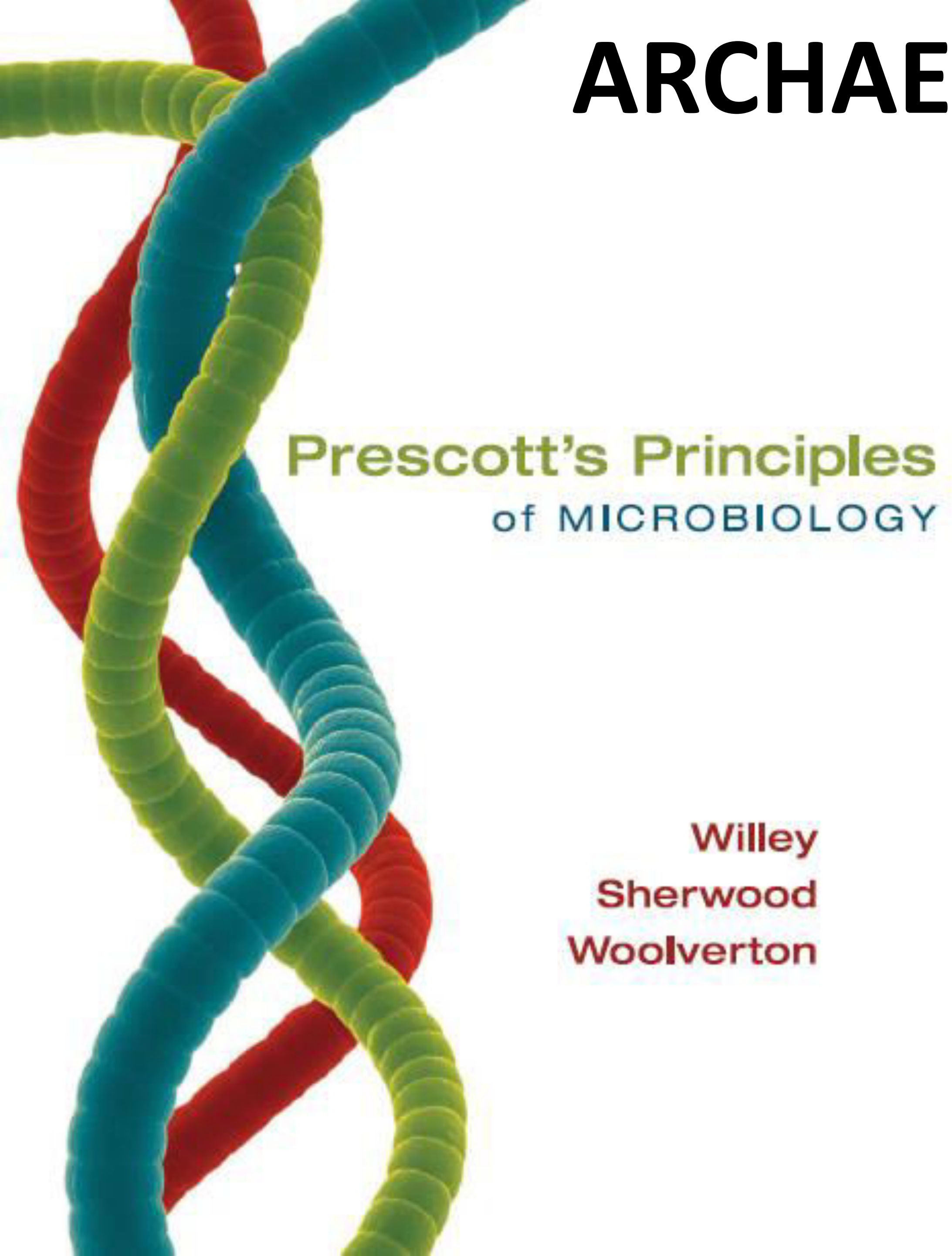
ARCHAEL CLASSIFICATION



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INTRODUCTION TO THE *ARCHAEA*

- They may be spherical, rod-shaped, spiral, lobed, cuboidal, triangular, or pleomorphic.
- They range in diameter from **0.1 to over 15 µm**, and some filaments can grow up to 200 µm.
- They can stain either gram positive or gram negative, but they have **unique cell wall**.
- Multiplication may be by binary fission, budding, fragmentation, or other mechanisms.
- They can be aerobic, facultatively anaerobic, or strictly anaerobic.
- Nutritionally, they range from **chemolitho-autotrophs** to **organotrophs**.
- They include psychrophiles, mesophiles, and hyperthermophiles that can grow above 100°C.
- Archaea have typically been considered microbes of "**extreme environments**," or "**extremophiles**".

Organism can be classified according to their source of Energy

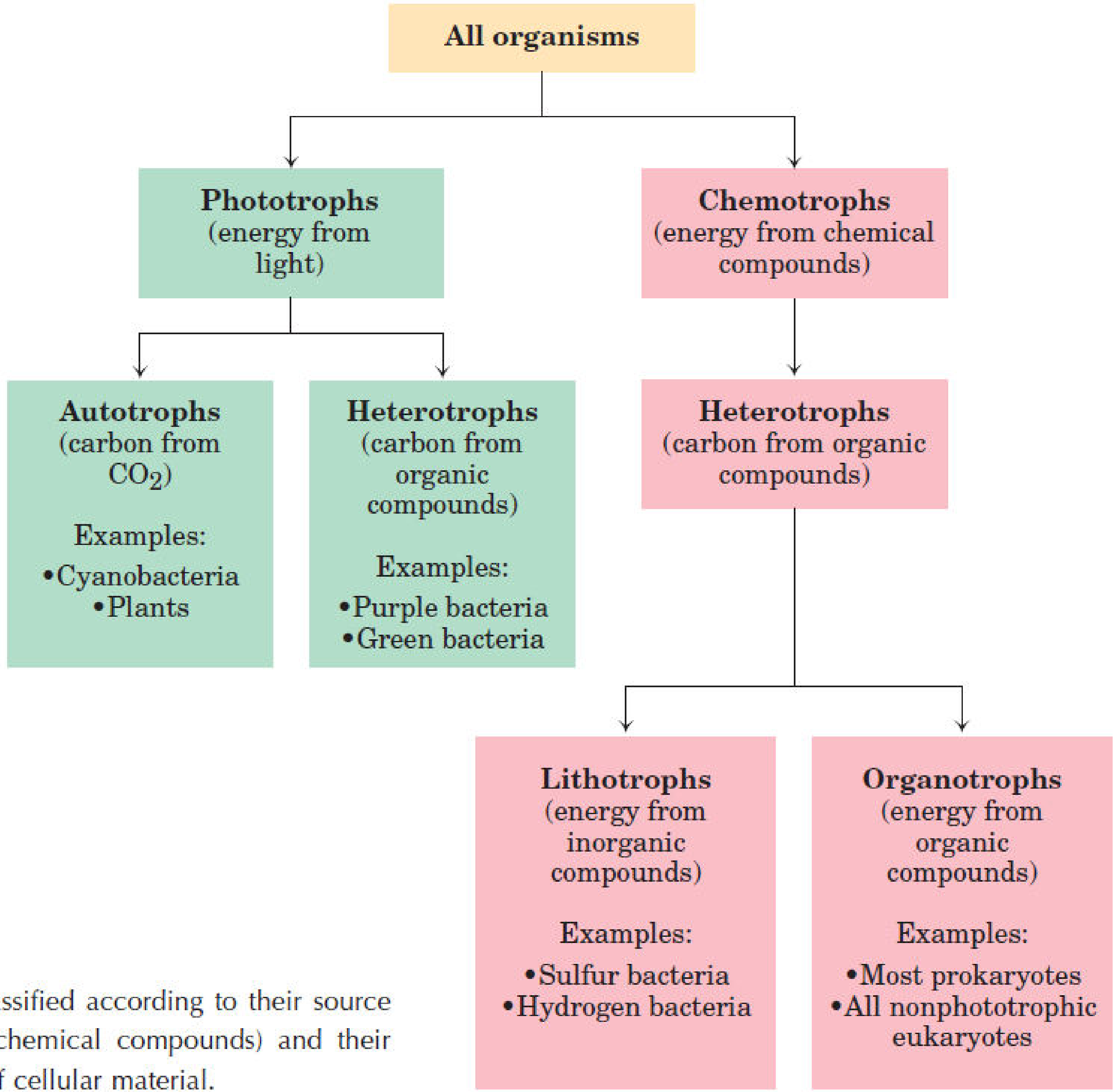


FIGURE 1–5 Organisms can be classified according to their source of energy (sunlight or oxidizable chemical compounds) and their source of carbon for the synthesis of cellular material.

Archaeal Taxonomy

Archaea can be divided into five major groups based on physiological and morphological differences.

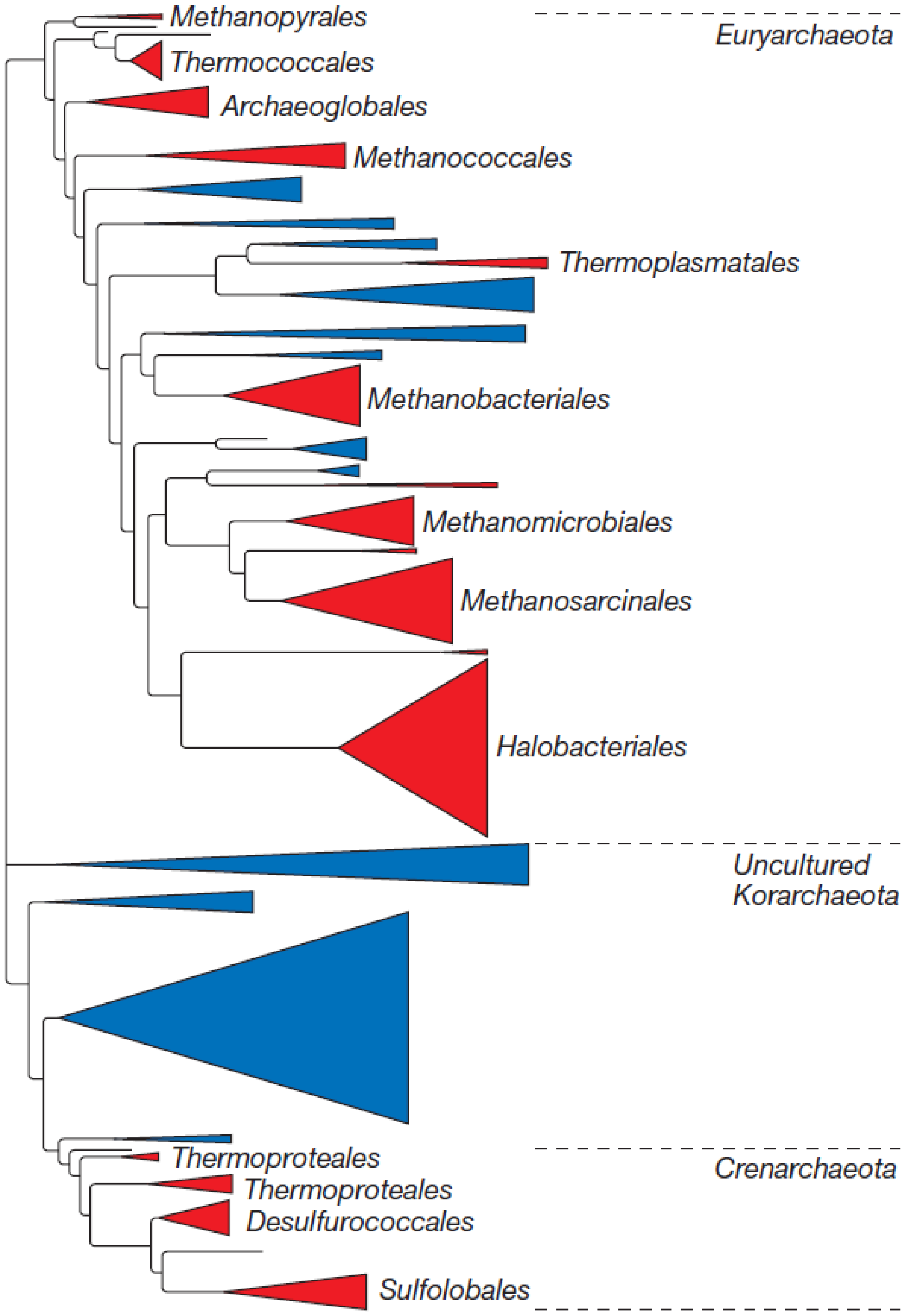
Table 18.1 Characteristics of the Major Archaeal Physiological Groups

Group	General Characteristics	Representative Genera
Methanogenic archaea	Strict anaerobes. Methane is the major metabolic end product. S^0 may be reduced to H_2S without yielding energy production. Cells possess coenzyme M, factors 420 and 430, and methanopterin.	*Methanobacterium* *Methanococcus* *Methanomicrobium* *Methanosarcina*
Archaeal sulfate reducers	Irregular gram-negative staining coccoid cells. H_2S formed from thiosulfate and sulfate. Autotrophic growth with thiosulfate and H_2. Can grow heterotrophically. Traces of methane also formed. Extremely thermophilic and strictly anaerobic. Possess factor 420 and methanopterin but not coenzyme M or factor 430.	*Archaeoglobus*
Extremely halophilic archaea	Rods, cocci, or irregular shaped cells, that may include pyramids or cubes. Stain gram negative or gram positive but like all archaea lack peptidoglycan. Primarily chemoorganoheterotrophs. Most species require sodium chloride ≥1.5 M, but some survive in as little as 0.5 M. Most produce characteristic bright-red colonies; some are unpigmented. Neutrophilic to alkalophilic. Generally mesophilic; however, at least one species is known to grow at 55°C. Possess either bacteriorhodopsin or halorhodopsin and can use light energy to produce ATP.	*Halobacterium* *Halococcus* *Natronobacterium*
Cell wall-less archaea	Pleomorphic cells lacking a cell wall. Thermoacidophilic and chemoorganotrophic. Facultatively anaerobic. Plasma membrane contains a mannose-rich glycoprotein and a lipoglycan.	*Thermoplasma*
Extremely thermophilic S^0-metabolizers	Gram-negative staining rods, filaments, or cocci. Obligately thermophilic (optimum growth temperature between 70–110°C). Usually strict anaerobes but may be aerobic or facultative. Acidophilic or neutrophilic. Autotrophic or heterotrophic. Most are sulfur metabolizers. S^0 reduced to H_2S anaerobically; H_2S or S^0 oxidized to H_2SO_4 aerobically.	*Desulfurococcus* *Pyrodictium* *Pyrococcus* *Sulfolobus* *Thermococcus* *Thermoproteus*

- **Bergey's Manual divides the Archaea** into the phyla ***Euryarchaeota*** (Greek: eurus, wide, and archaios, ancient or primitive) and ***Crenarchaeota*** (Greek crene, spring or fount, and archaios)

- The *Euryarchaeotes* are given this name because they occupy many **different ecological niches** and have a variety of metabolic patterns.

- The *Crenarchaeotes* are thought to resemble the ancestor of the Archaea, and almost all the well-characterized species are **thermophiles** or **hyperthermophiles**.



Cell Walls and Membranes

- Archaea can stain either gram positive or gram negative, even though they **lack** the **muramic acid** and **D-amino acids** that make up peptidoglycan.

- Without the constraints of the conserved molecule peptidoglycan, archaeal cell walls can be quite diverse.

- For instance, some **methanogenic archaea** have **pseudomurein** (a peptidoglycan-like polymer that is cross-linked with L-amino acids) while others contain a complex polysaccharide similar to the **chondroitin sulfate** of animal connective tissue.

- Interestingly, some **hyperthermophilic archaea** and **methanogens** have **protein walls**.

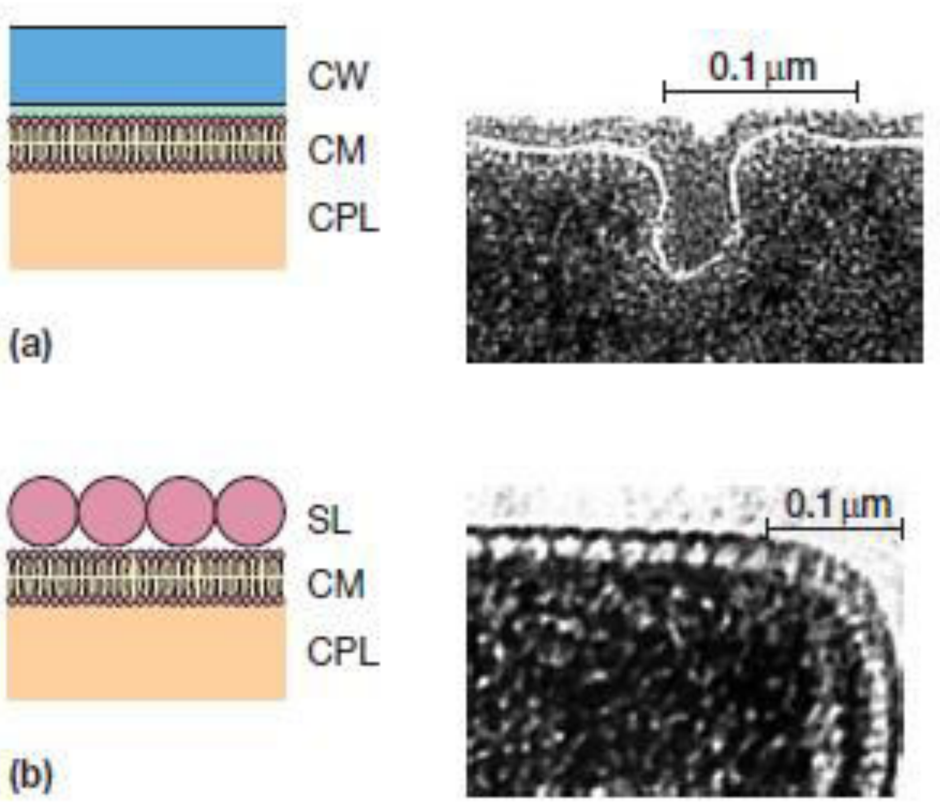
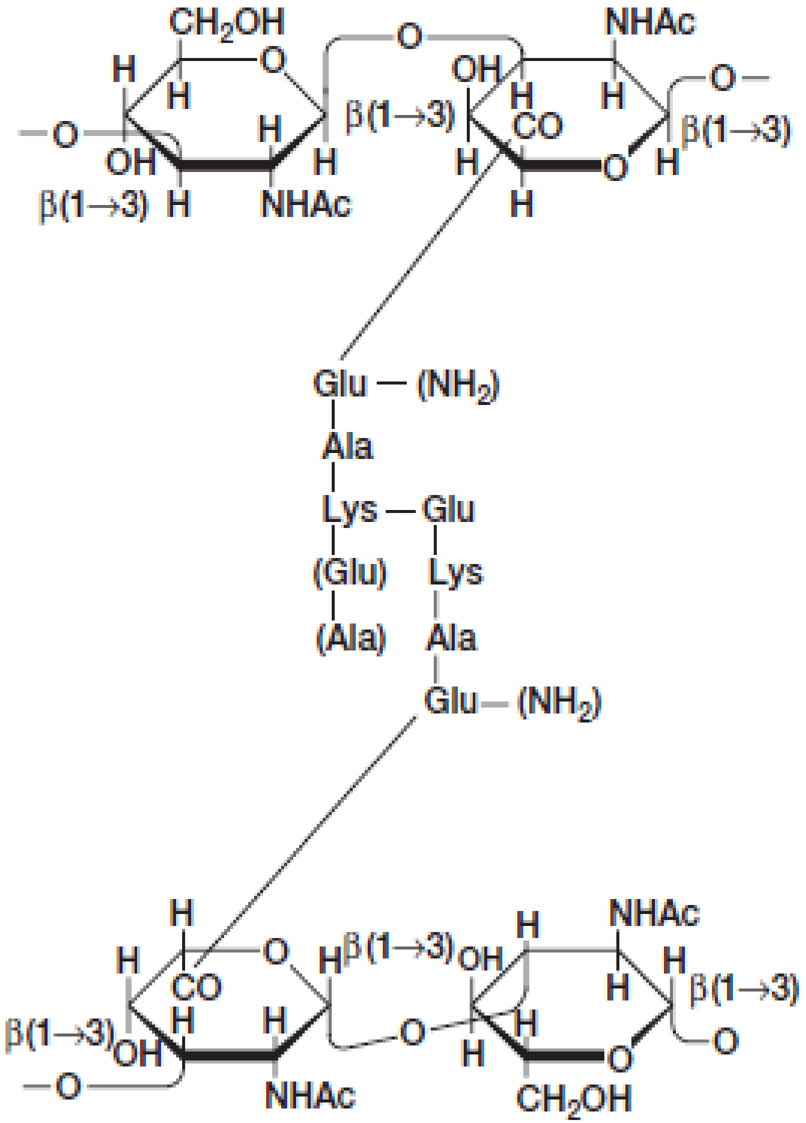


Figure 3.29 Cell Envelopes of *Archaea*. Schematic representations and electron micrographs of (a) *Methanobacterium formicicum* and (b) *Thermoproteus tenax*. CW, cell wall; SL, surface layer; CM, cell membrane or plasma membrane; CPL, cytoplasm.



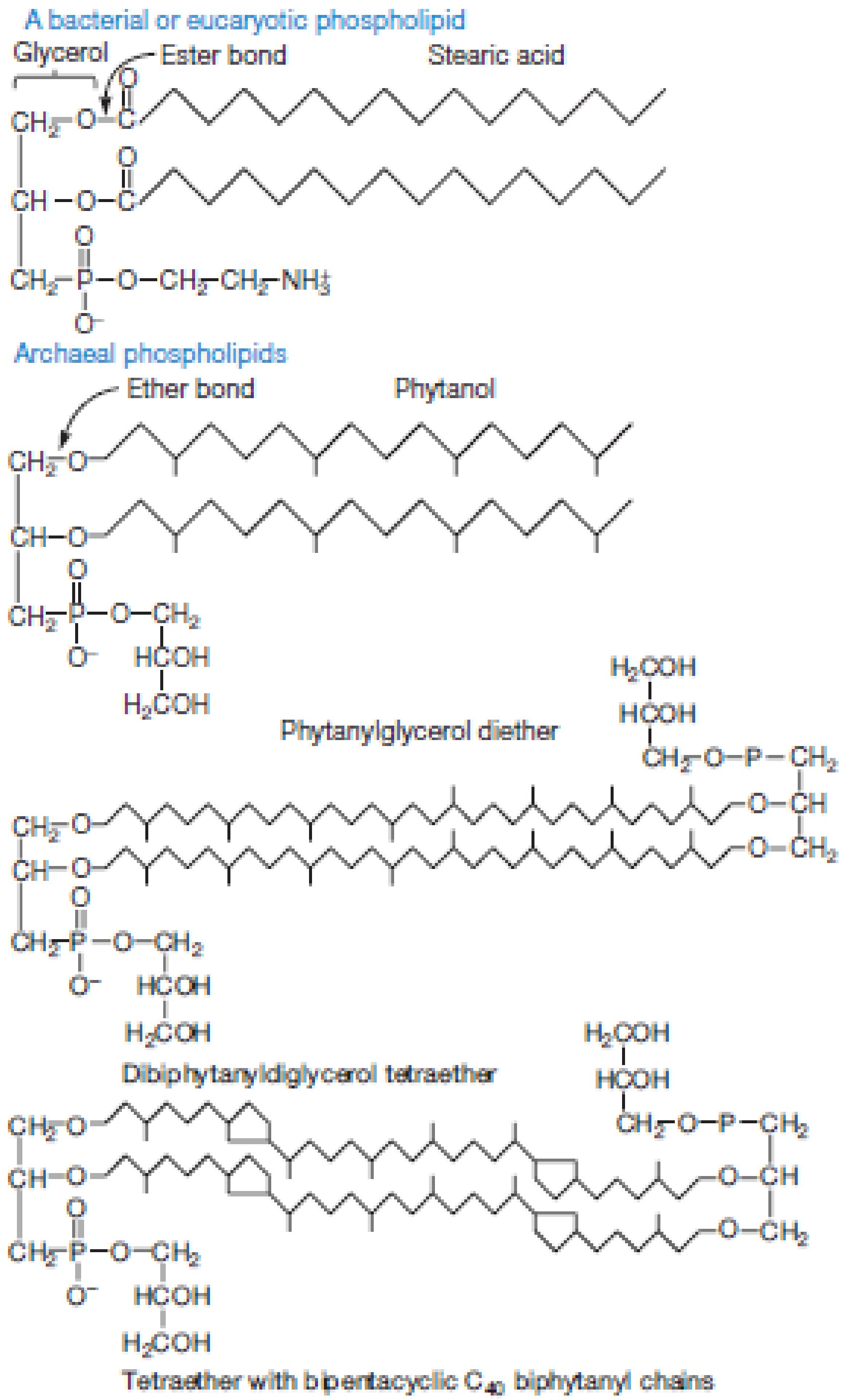
N-acetyltalosaminuronic acid *N*-acetylglucosamine

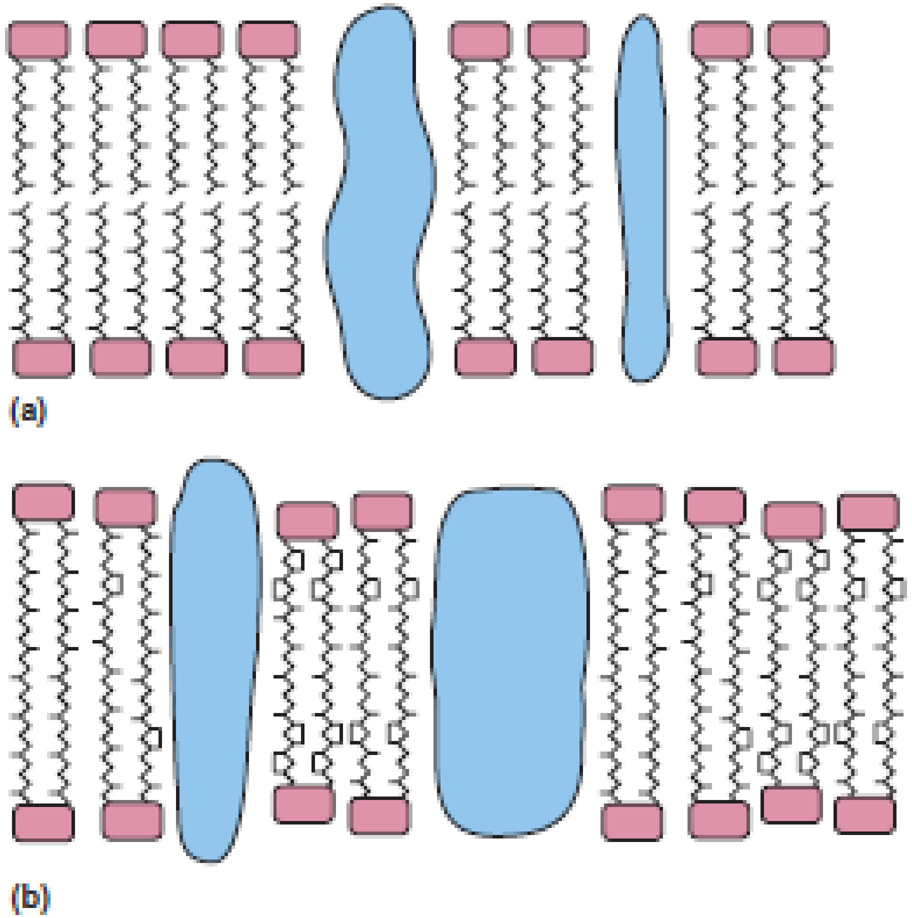
- The Archaea membrane lipids differ from both the Bacteria and the Eukarya in having branched chain hydrocarbons attached to glycerol **by ether** (rather than ester) **linkages**.

- Thermophilic archaea sometimes link two glycerol groups to **form long tetraethers**.

- **Diether** side chains are usually 20 carbons long, and **tetraether** chains contain 40 carbon atoms.

- However, cells can adjust chain lengths by cyclizing the chains to form **cyclopentane rings**. These rings are more densely packed within the membrane, making them more stable at high temperatures.


A bacterial or eucaryotic phospholipid
Glycerol
Ester bond
Stearic acid
Archaeal phospholipids
Ether bond
Phytanol
Phytanylglycerol diether
Dibiphytanyldiglycerol tetraether
Tetraether with bipentacyclic C40 biphytanyl chains


(a)
(b)

- In fact, ***Thermophilic archaea*** **increase the number of cyclopentane rings** as growth temperature increases.

- **Cyclopentane ring-containing lipids** have also been discovered in **nonthermophilic Crenarchaeota**.

- These lipids, called **crenarchaeol**, are unique to these organisms so they are used as a **biomarker for the presence of crenarchaeotes** in natural environments such as marine plankton.

Genetics and Molecular Biology

- The **genomes** of some archaea are **significantly smaller** than those of many bacteria. A sign of archaeal diversity is the variation in **G+C content**, from about **21% to 68%.**

- Archaeal **DNA replication** appears to be a **complex mixture of eucaryotic and procaryotic** features. Like *Bacteria,* archaea have circular chromosomes and replication appears to be bidirectional.

- **Transcription** in the *Archaea* likewise **blends bacterial and eucaryotic features**. Archaeal **RNA polymerases** consist of at least **10 subunits** that are highly homologous to eucaryotic subunits. Also, like eucaryotic nuclear RNA polymerase, archaeal RNA polymerases **do not efficiently recognize promoter regions without the aid of additional proteins**.

- However, archaeal **mRNA appears to be similar to bacterial mRNA** in that it is **polycistronic** and there is **no evidence for mRNA splicing**.

- Finally, the **translational machinery** in the *Archaea* is **unique**. Unlike both *Bacteria* and eucaryotes, the TΨC arm of archaeal **tRNA lacks thymine and contains pseudouridine or 1-methylpseudouridine**.

- The archaeal **initiator tRNA carries methionine** as does the eucaryotic initiator tRNA.

- Although archaeal ribosomes are 70S, **similar to bacterial ribosomes**, electron microscopy studies show that **their shape is quite variable and sometimes differs from that of both bacterial and eucaryotic ribosomes**.

- They **resemble eucaryotic ribosomes** in their sensitivity to the antibiotic anisomycin and insensitivity to chloramphenicol and kanamycin.

- **Archaeal EF-2 reacts with diphtheria toxin** like the eucaryotic EF-2.

Q1: How do archaeal cell walls differ from those of the Bacteria? What is pseudomurein?

Q2: In what ways do archaeal membrane lipids differ from those of Bacteria and eucaryotes? How do these differences contribute to the survival of thermophilic and hyperthermophilic archaea?