4

Archaeal Cell Structure

Archaea

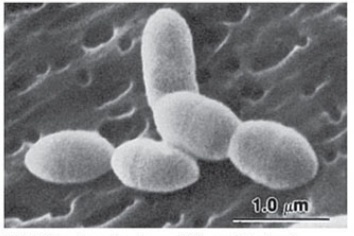
- Many features in common with *Eukarya*
  - genes encoding protein: replication, transcription, translation
- Features in common with *Bacteria*
  - genes for metabolism
- Other elements are unique to *Archaea*
  - unique rRNA gene structure
  - capable of methanogenesis → the production of methane.

Archaea

- Highly **diverse with respect to morphology, physiology, reproduction, and ecology**
- **Best known for growth in anaerobic, hypersaline, pH extremes, and high-temperature habitats**
- **Also found in marine arctic temperature and tropical waters**

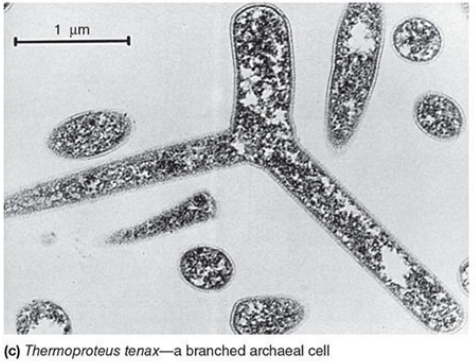
Archaeal size, shape, arrangement

- Much like bacteria, **cocci and rods** are common shapes
- Other shapes can also exist
  - no spirochetes or mycelial forms yet
  - branched/flat shapes
- Sizes vary (typically **1-2 x 1-5 µm** for rods, 1-5 µm in diameter for cocci)
- Smallest observed is **0.2 µm** in diameter
- Largest is a multicellular form that can reach **30 mm in length!**



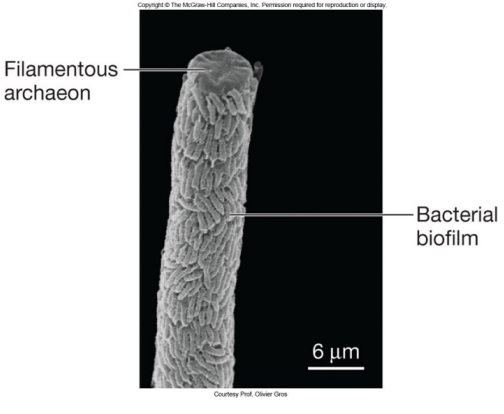
(a) *Methanobrevibacter smithii*—oval-to-short rod-shaped cells

(b) *Methanosarcina mazei*—a coccus that forms clusters



(c) *Thermoproteus tenax*—a branched archaeal cell

(d) *Haloquadratum walsbyi*—a square archaeon



Courtesy Prof. Olivier Gros

a: © Friederich Widdell/Visuals Unlimited; b,c: From J.T. Staley, M.P. Bryant, N. Pfenning and J.G. Holt (Eds), *Bergey's Manual of Systematic Bacteriology,* Vol. 3. © 1989 Williams and Wilkins Co., Baltimore; d: From Walther Stoeckenius: Walsby's Square Bacterium Fine Structures of an Orthogonal Procaryote

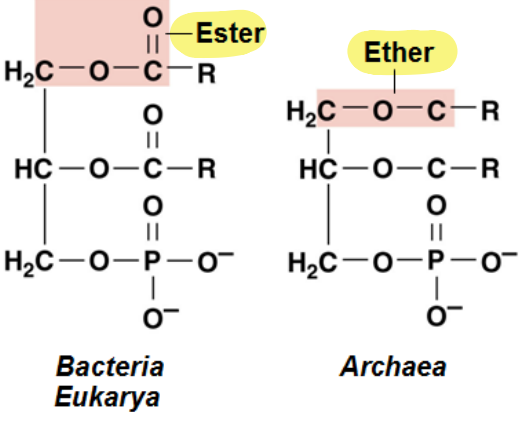
Table 4.1 Comparison of Bacterial and Archaeal Cells

Property	Bacteria	Archaea
Plasma membrane lipids	Ester-linked phospholipids and hopanoids form a lipid bilayer; some have sterols	Glycerol diethers form lipid bilayers; glycerol tetraethers form lipid monolayers
Cell wall constituents	Peptidoglycan is present in nearly all; some lack cell walls	Very diverse but peptidoglycan is always absent: some consist of S-layer only, others combine S-layer with polysaccharides or proteins or both; some lack cell walls
Inclusions present	Yes, including gas vacuoles	Yes, including gas vacuoles
Ribosome size	70S	70S
Chromosome structure	Most are circular, double-stranded (ds) DNA; usually a single chromosome	All known are circular, dsDNA
Plasmids present	Yes; circular and linear dsDNA	Yes; circular dsDNA
External structures	Flagella, fimbriae (pili) common	Flagella, pili, and piluslike structures common
Capsules or slime layers	Common	Rare

Archaeal Cell Envelopes

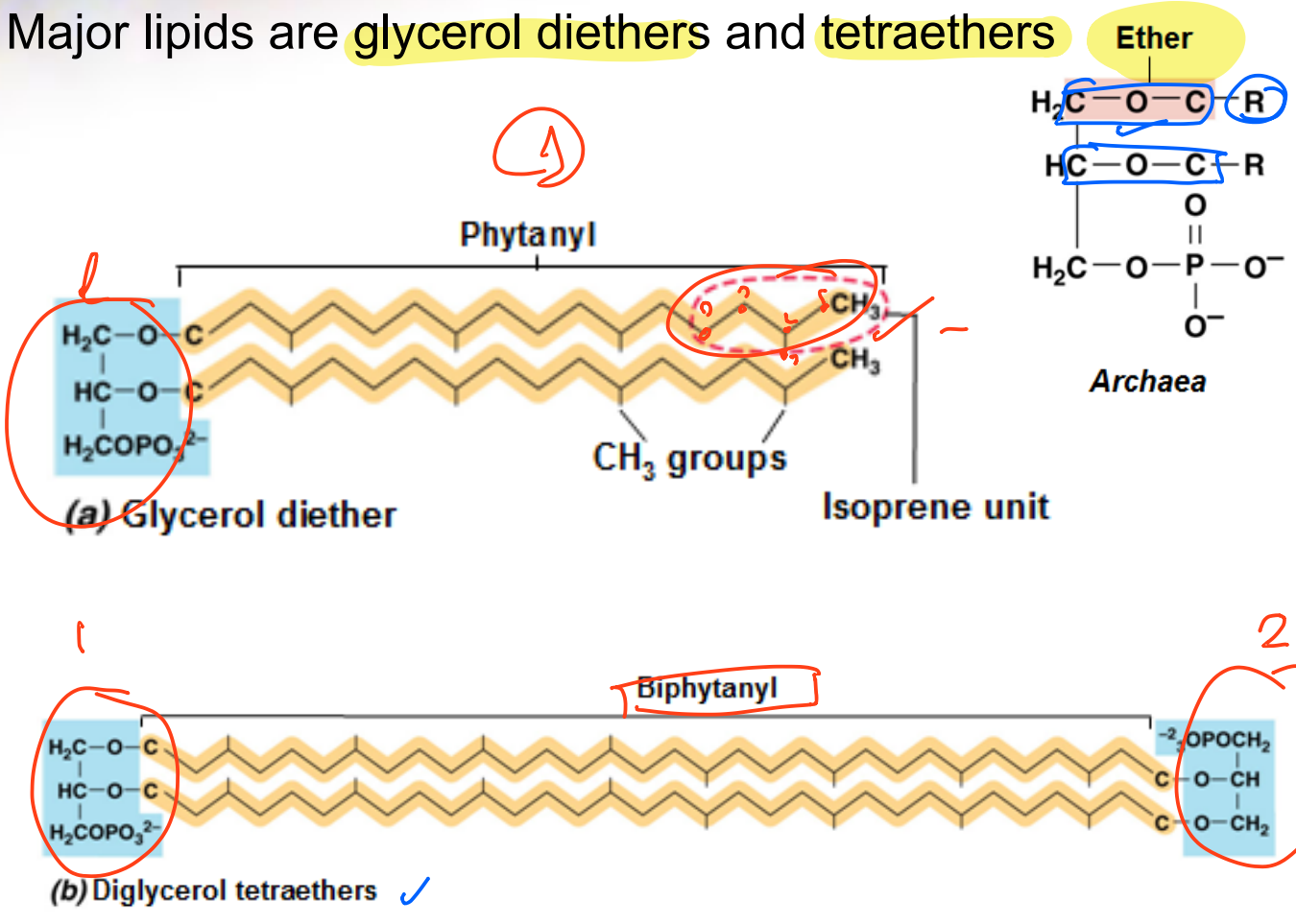
- Differ from bacterial envelopes in the molecular makeup and organization
  - S layer may be only component outside plasma membrane
  - some lack cell wall
  - capsules and slime layers are rare

instead of cell wall.



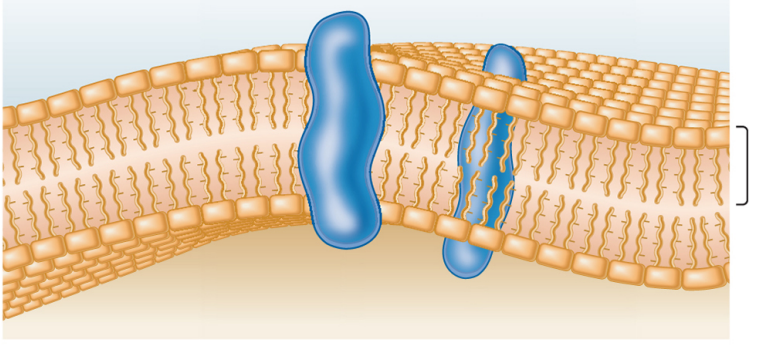
Diether and tetraether

Major lipids are glycerol diethers and tetraethers

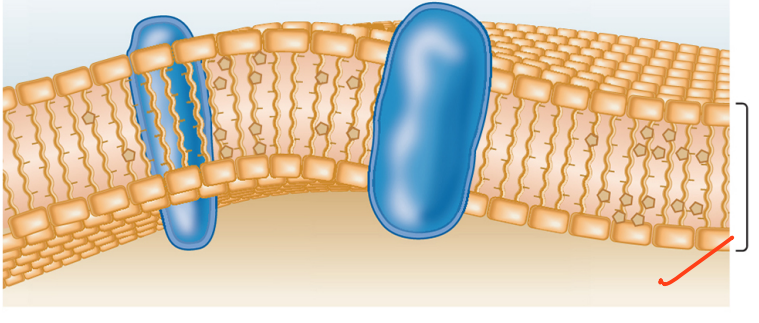


Archaeal Membranes

- Composed of unique lipids
  - isoprene units (five carbon, branched)
  - ether linkages rather than ester linkages to glycerol
- Some have a monolayer structure instead of a bilayer structure



(a) Bilayer of C_{20} diethers



(b) Monolayer of C_{40} tetraethers

Archaeal Membrane Lipids

- Differ from *Bacteria* and *Eukarya* **in having branched chain hydrocarbons attached to glycerol by ether linkages**
- Polar phospholipids, sulfolipids, glycolipids, and unique lipids are also found in archaeal membranes

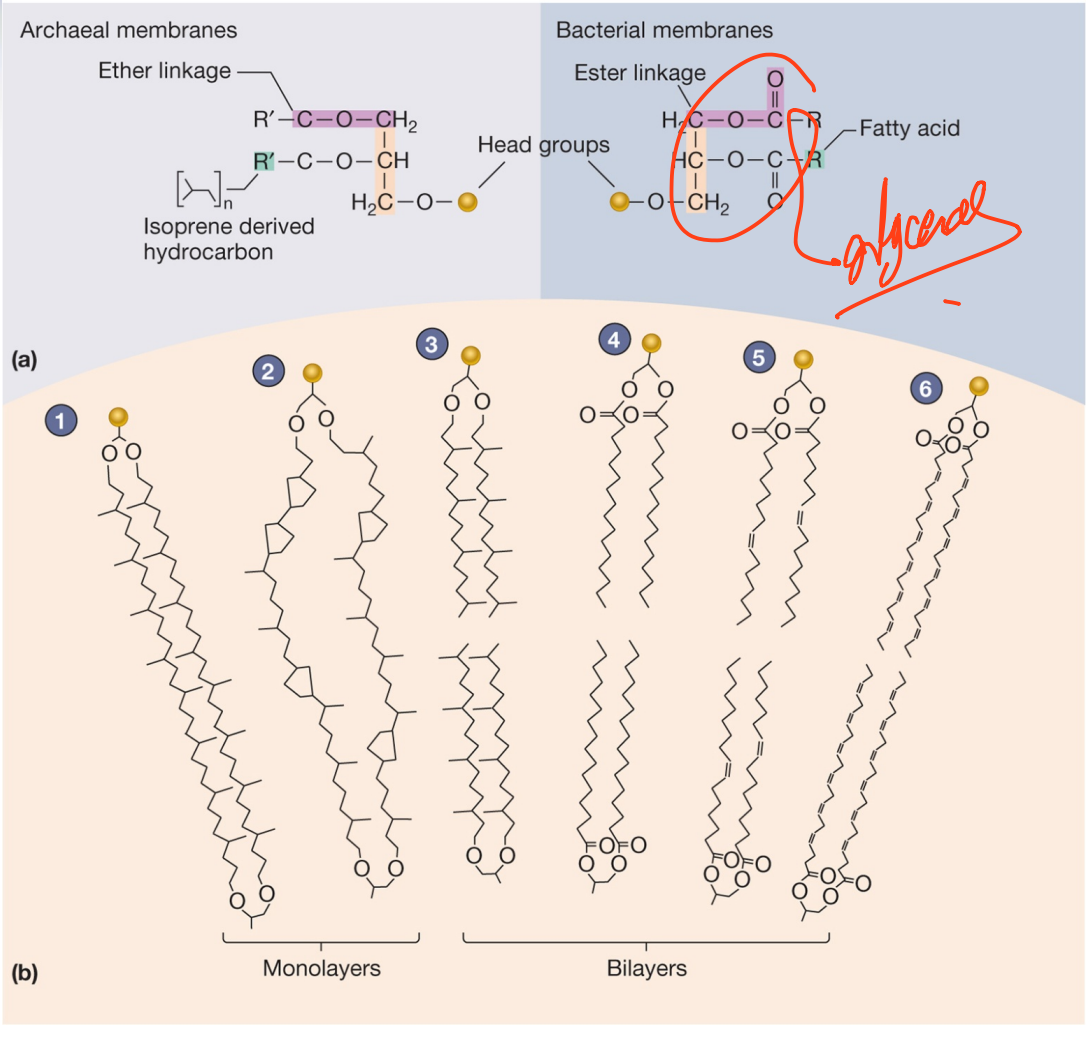
Archaeal Lipids and Membranes

Bacteria/Eukaryotes

- Fatty acids attached to glycerol by ester linkages

Archaea

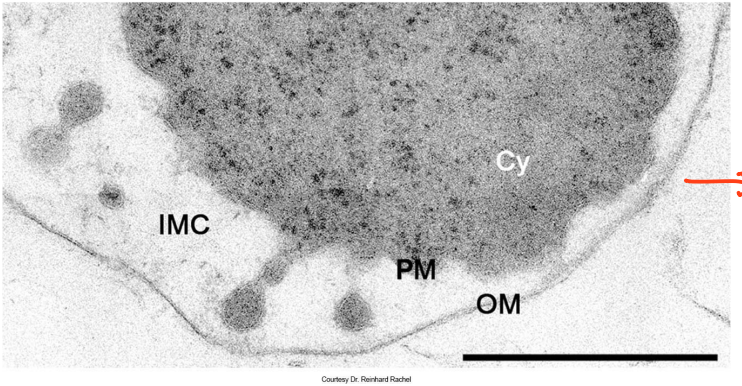
- branched chain hydrocarbons attached to glycerol by ether linkages
- some have diglycerol tetraethers



Archaeal Cell Surfaces

- **Cell envelopes**
  - varied S layers attached to plasma membrane
  - pseudomurein (peptidoglycan-like polymer)
  - complex polysaccharides, proteins, or glycoproteins found in some other species
  - only *Ignicoccus* has outer membrane

Looks like peptido glycan But not peptidoglycan.

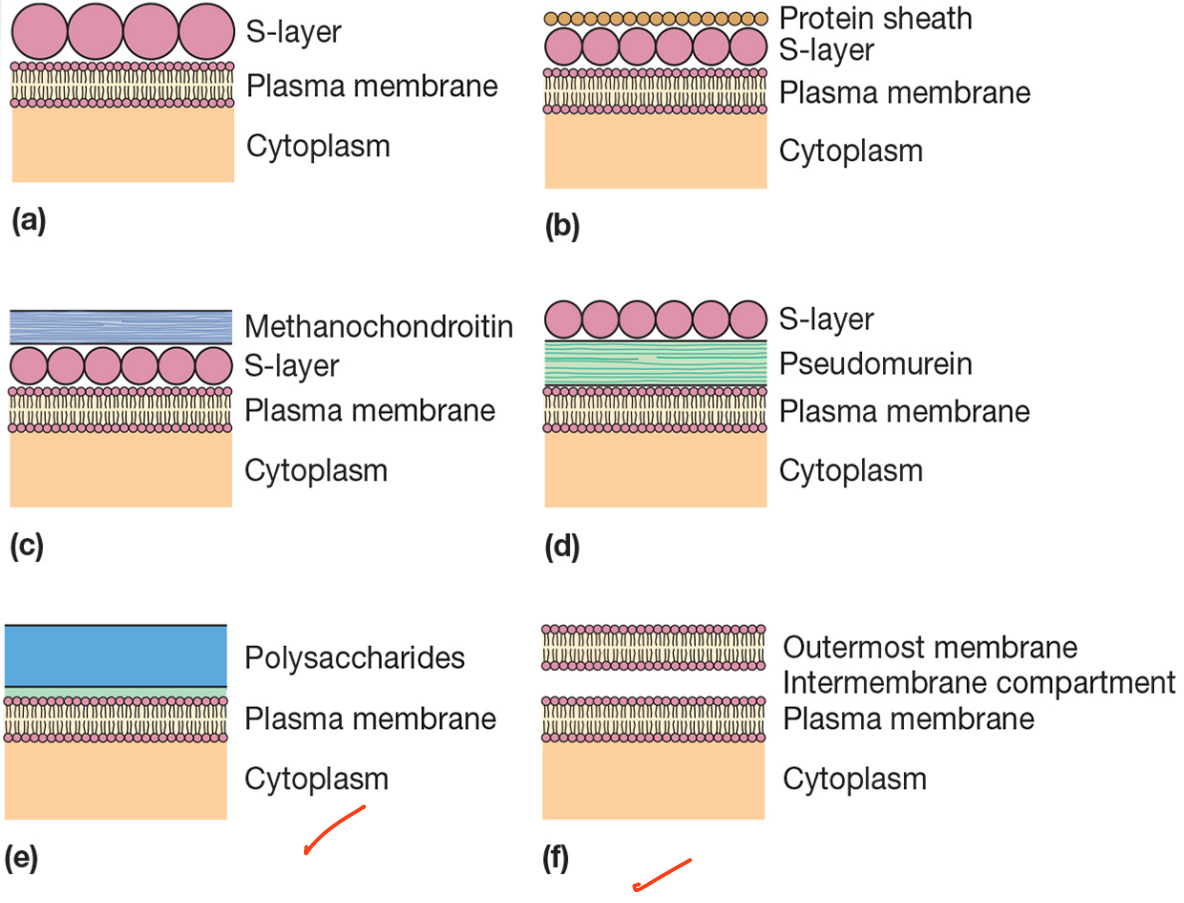


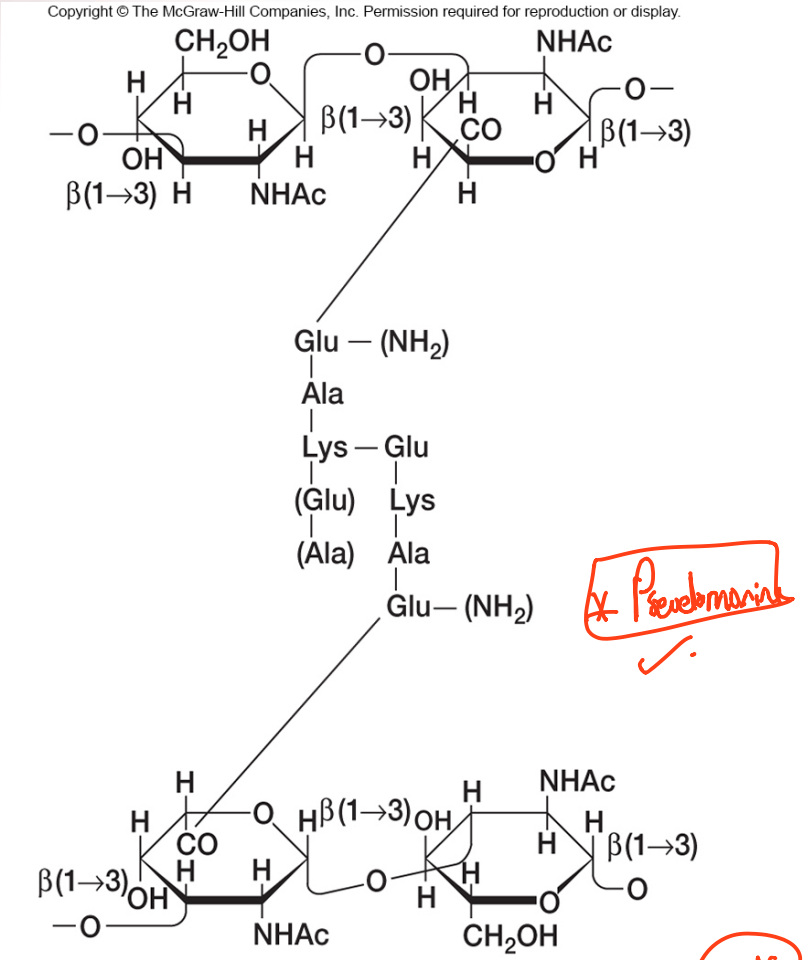
Courtesy Dr. Reinhard Rachel

Ignicoccus

Archaeal Cell Walls Differ from Bacterial Cell Walls

- **Lack peptidoglycan**
- **Most common cell wall is S layer**
- May have protein sheath external to S layer
- S layer may be outside membrane and separated by pseudomurein
- Pseudomurein may be outermost layer – similar to Gram-positive microorganisms





* Pseudomurein

N-acetyltalosaminuronic acid

N-acetylglucosamine

Archaeal vs. bacterial cytoplasm

- Very similar – **lack of membrane-enclosed organelles**
- May contain inclusion bodies (e.g. gas vesicles for buoyancy control)
- All the usual components
  - **ribosomes**
  - **nucleoid region**
  - **inclusion bodies**
- Some structures may be different, however…

Ribosomes

- Complex structures, sites of protein synthesis
  - consisting of protein/RNA
- Entire ribosome
  - bacterial/archaeal ribosome = 70S
  - eukaryotic (80S) S = Svedburg unit
- Bacterial and archaeal ribosomal RNA
  - 16S small subunit
  - 23S and 5S in large subunit
  - archaea **have additional 5.8S (also seen in eukaryotic large subunit)**
- Proteins vary
  - archaea more similar to eukarya than to bacteria

The Nucleoid

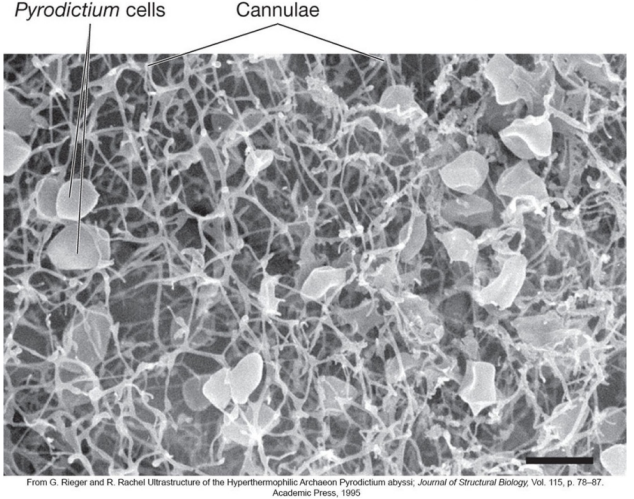
- Irregularly shaped region in bacteria and archaea
- ✓Usually not membrane bound (few exceptions)
- ✓ Location of chromosome and associated proteins
- **Usually 1** (some evidence for polyploidy in some archaeons)
- Supercoiling and nucleoid proteins (**histones, Alba, condensins**) aid in folding

Archaeal external structures:

- Pili
  - not well understood as of yet
  - **some composed of pilin protein and homologous to bacterial type IV pili proteins**
  - pili formed have a central lumen **similar to bacterial flagella, but not bacterial pili**
  - may be involved in archaeal adhesion mechanisms

Archaeal external structures:

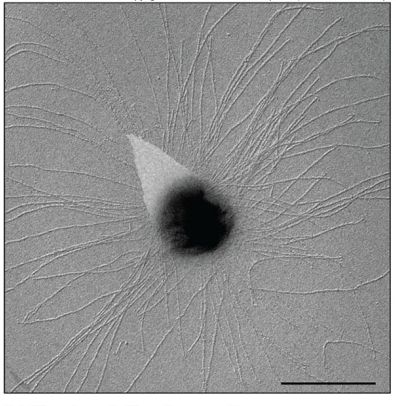
- Cannulae
  - hollow, **tubelike structures on the surface of thermophilic archae in** the genus *Pyrodictium*
  - function is unknown
  - may **be involved in formation of networks of multiple daughter cells**



From G. Rieger and R. Rachel Ultrastructure of the Hyperthermophilic Archaeon Pyrodictium abyssi, *Journal of Structural Biology,* Vol. 115, p. 78–87. Academic Press, 1995

Archaeal external structures:

- Hami
  - not well understood
  - ‘grappling hook’ appearance
  - involvement in cell adhesion mechanisms?

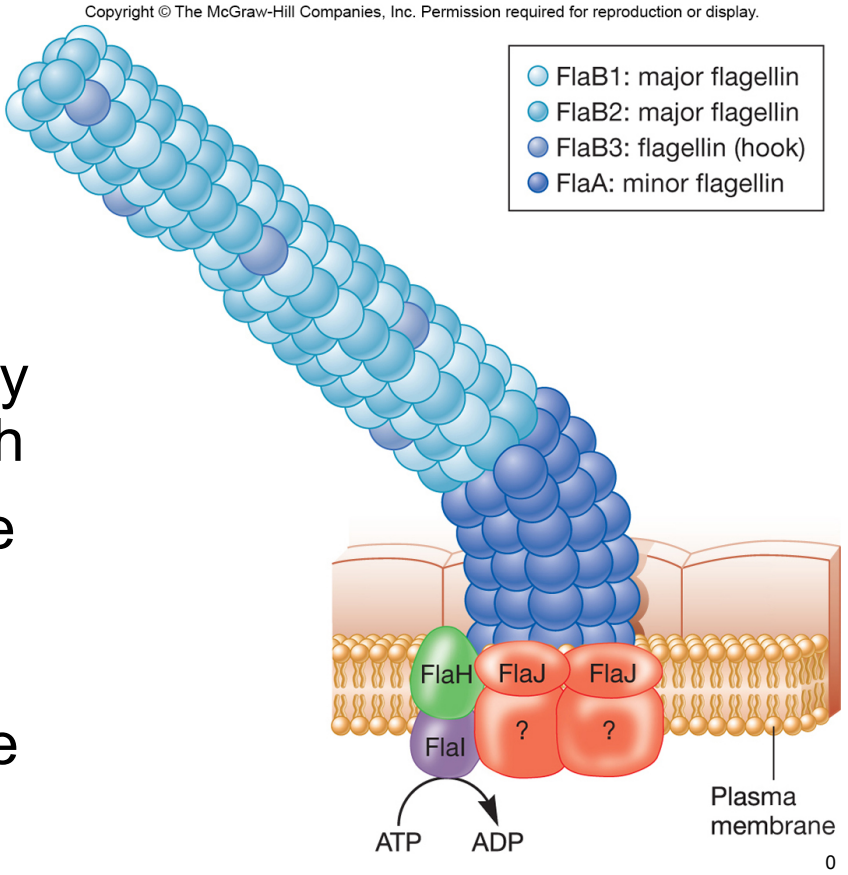


(a) Hami radiating from cell

(b) “Grappling hooks” at distal ends of hami

Differences of Archaeal Flagella

- Flagella thinner
- More than one type of flagellin protein
- Flagellum are not hollow
- Hook and basal body difficult to distinguish
- More related to Type IV secretions systems
- Growth occurs at the base, not the end



4.5 Comparison of *Bacteria* and *Archaea*

1. Compare and contrast bacterial and archaeal cells in terms of the structures observed and their chemical makeup.

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