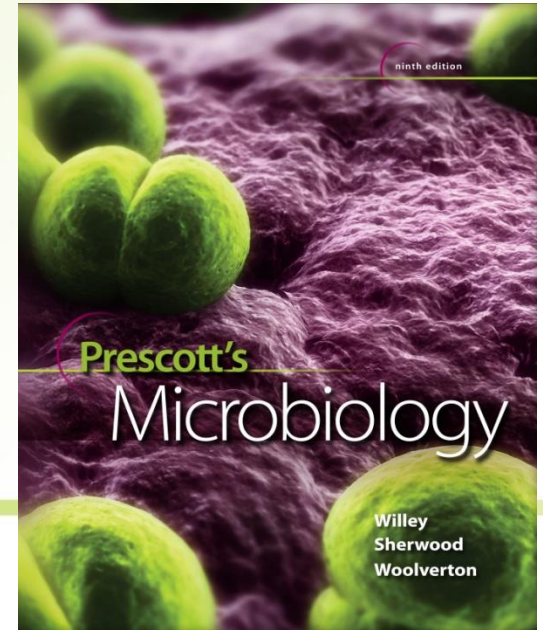


4

Archaeal Cell Structure





4.1 A typical archaeal cell

1. Describe a typical archaeal cell.

Archaea

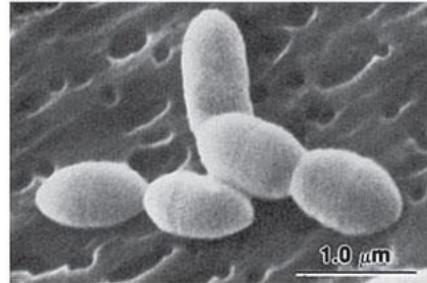
- Many features in common with *Eukarya*
 - genes encoding protein: replication, transcription, translation
- Features in common with *Bacteria*
 - genes for metabolism
- Other elements are unique to *Archaea*
 - unique rRNA gene structure
 - capable of methanogenesis

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

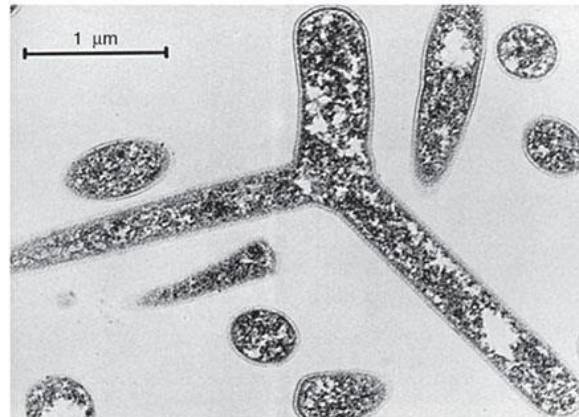
- Much like bacteria, cocci and rods are common shapes
- Other shapes can also exist
 - no spirochetes or mycelial forms yet
 - branched/flat shapes
- Sizes vary (typically 1-2 x 1-5 μm for rods, 1-5 μm in diameter for cocci)
- Smallest observed is 0.2 μm in diameter
- Largest is a multicellular form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



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



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



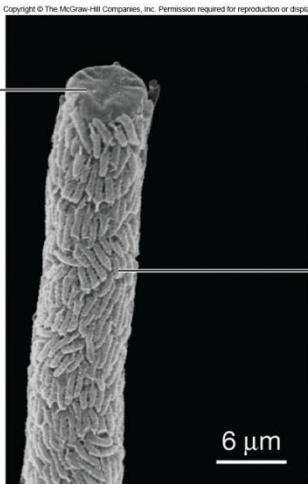
(c) *Thermoproteus tenax*—a branched archaeal cell



(d) *Haloquadratum walsbyi*—a square archaeon

a: © Friederich Widdell/Visuals Unlimited; b, c: From J.T. Staley, M.P. Bryant, N. Pfennig 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 Prokaryote

Filamentous archaeon



Bacterial biofilm

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

4.2 Archaeal cell envelopes

1. Draw an archaeal cell envelope and identify the component layers.
2. Compare and contrast archaeal and bacterial cell envelopes in terms of their structures, molecular makeup, and functions.
3. Compare and contrast nutrient uptake mechanisms observed in bacteria and archaea.

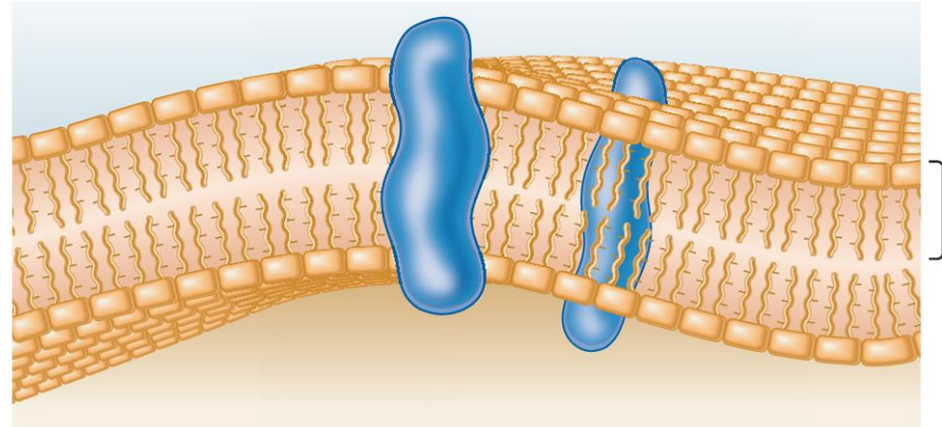
Archaeal Cell Envelopes

- 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

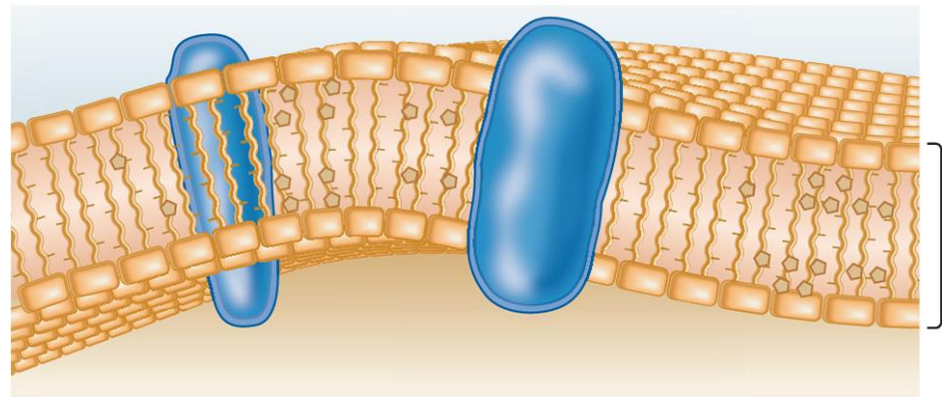
Archaeal Membranes

- 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

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(a) Bilayer of C₂₀ diethers



(b) Monolayer of C₄₀ 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

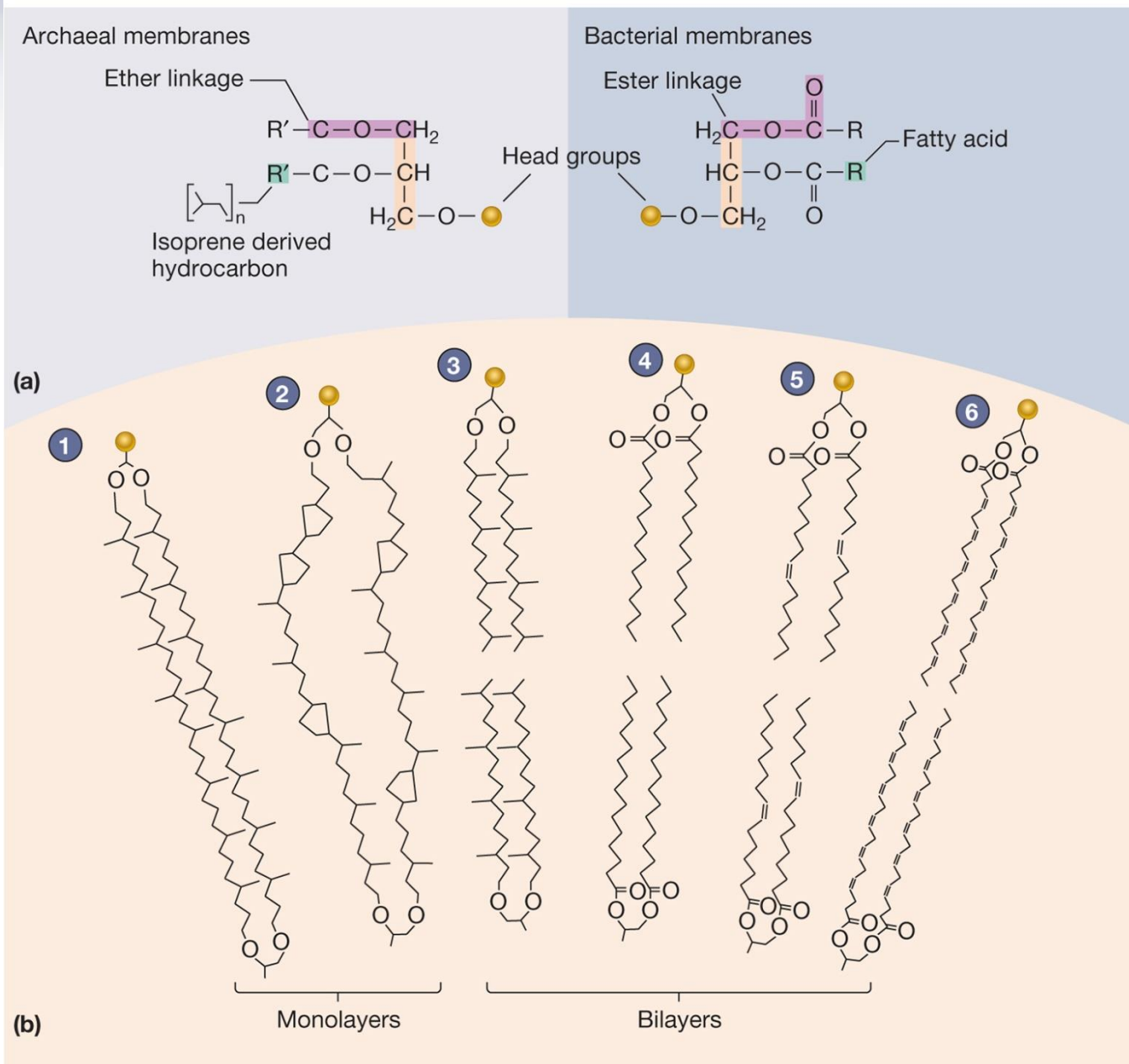
Archaeal Lipids and Membranes

Bacteria/Eukaryotes

- Fatty acids attached to glycerol by ester linkages

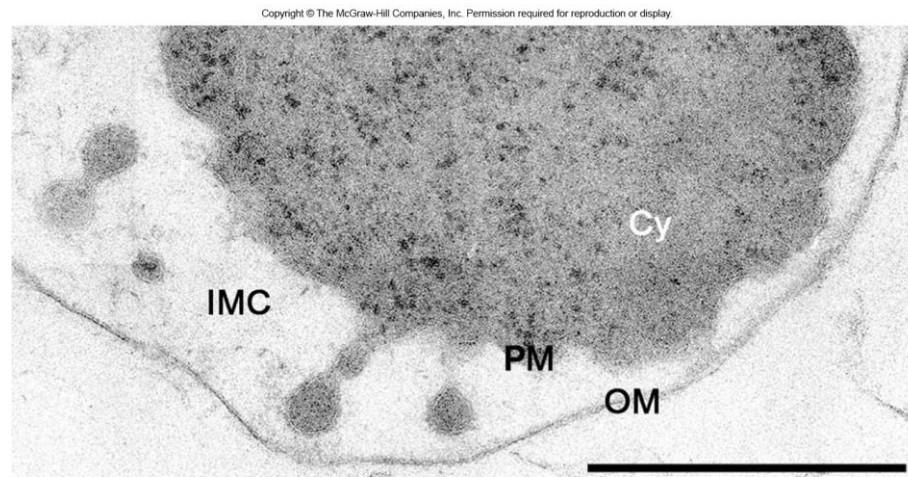
Archaea

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



Archaeal Cell Surfaces

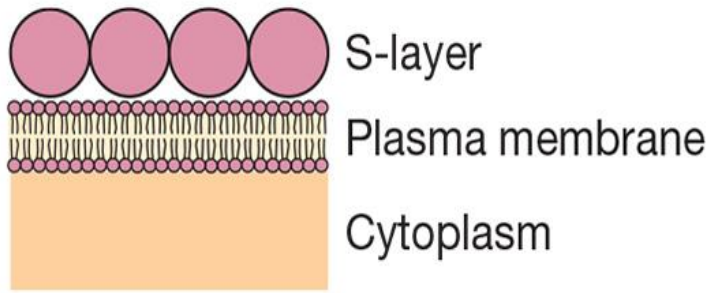
- Cell envelopes
 - varied S layers attached to plasma membrane
 - pseudomurein (peptidoglycan-like polymer)
 - complex polysaccharides, proteins, or glycoproteins found in some other species
 - only *Ignicoccus* has outer membrane



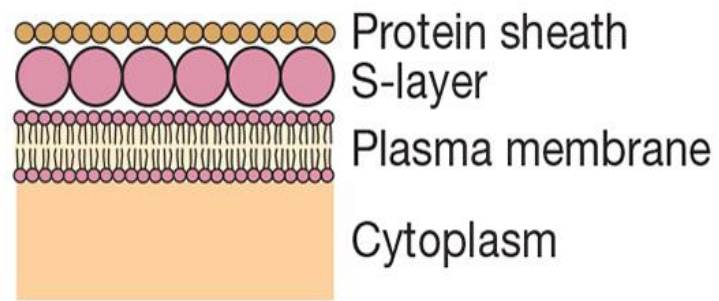
Courtesy Dr. Reinhard Rachel

Archaeal Cell Walls Differ from Bacterial Cell Walls

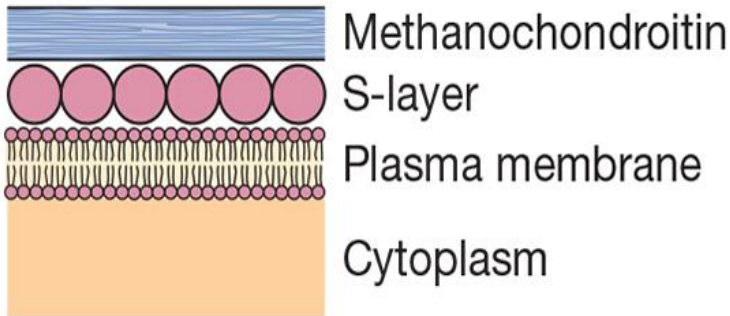
- Lack peptidoglycan
- Most common cell wall is S layer
- May have protein sheath external to S layer
- S layer may be outside membrane and separated by pseudomurein
- Pseudomurein may be outermost layer – similar to Gram-positive microorganisms



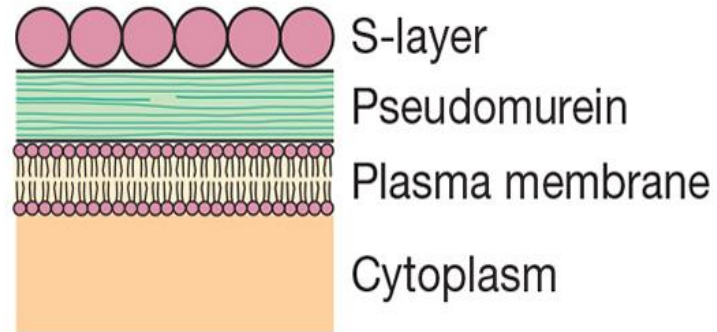
(a)



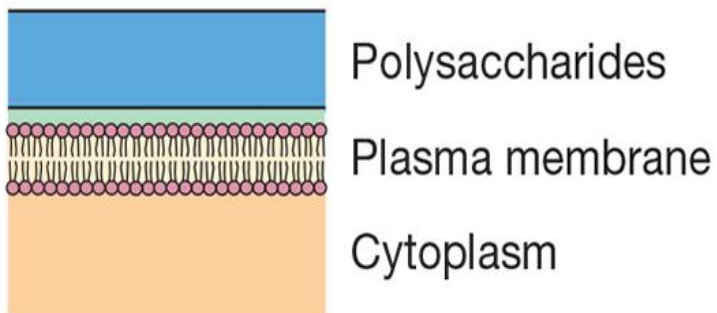
(b)



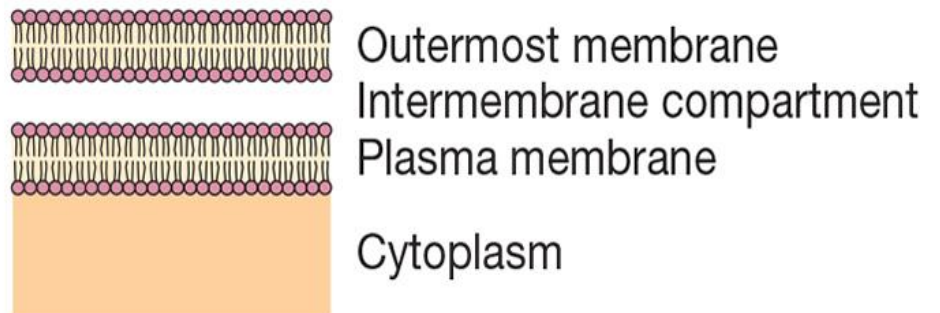
(c)



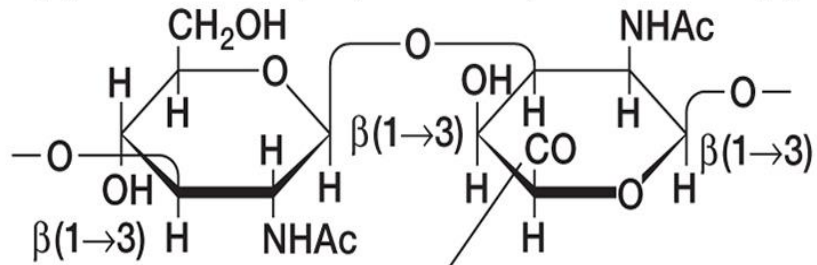
(d)



(e)



(f)



Glu — (NH₂)

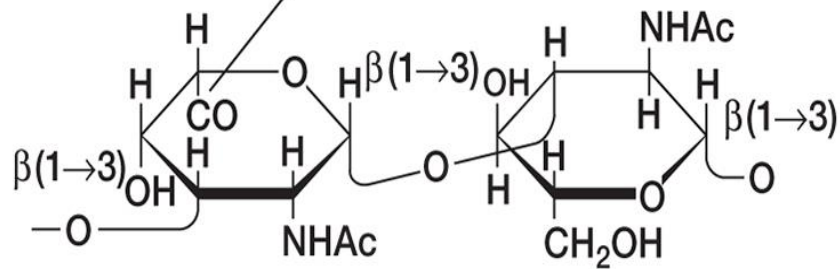
Ala

Lys — Glu

(Glu) Lys

(Ala) Ala

Glu — (NH₂)



N-acetyltalosaminuronic acid *N*-acetylglucosamine

Archaeal cells and nutrient uptake

- Archaeal cells use many of the same mechanisms for nutrient uptake exhibited in bacteria
 - facilitated diffusion
 - active transport (primary and secondary)
- No group translocation mechanisms have yet been discovered in archaea, however...



4.3 Archaeal cytoplasm

1. Compare and contrast the cytoplasm of bacterial and archaeal cells.

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



4.4 External structures

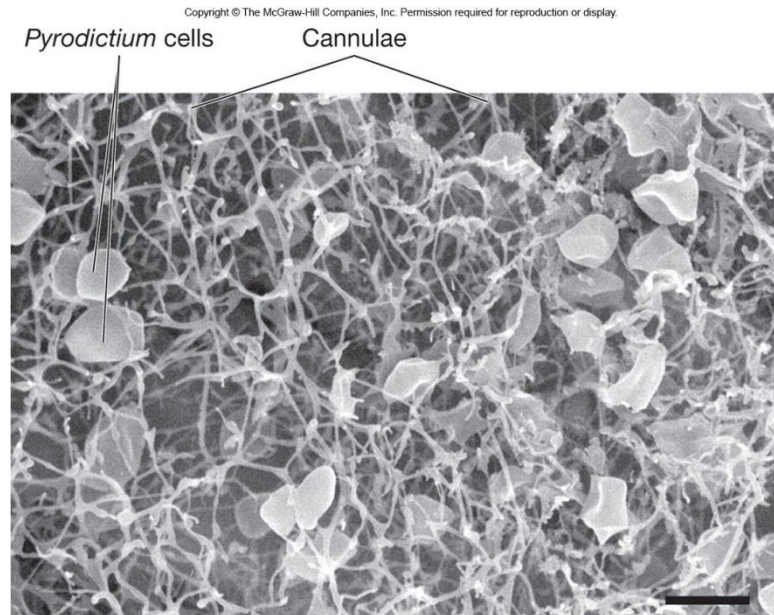
1. Describe cannulae and hami.
2. Compare and contrast bacterial and archaeal pili.
3. Compare and contrast bacterial and archaeal flagella in terms of their structure and function.

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 archaee in the genus *Pyrodictium*
 - function is unknown
 - may be involved in formation of networks of multiple daughter cells

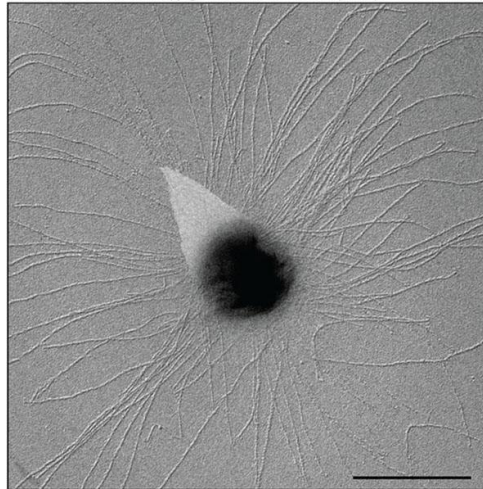


From G. Rieger and R. Rachel Ultrastructure of the Hyperthermophilic Archaeon *Pyrodictium abyssi*, *Journal of Structural Biology*, Vol. 115, p. 78–87. Academic Press, 1995

Archaeal external structures:

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

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(a) Hami radiating from cell

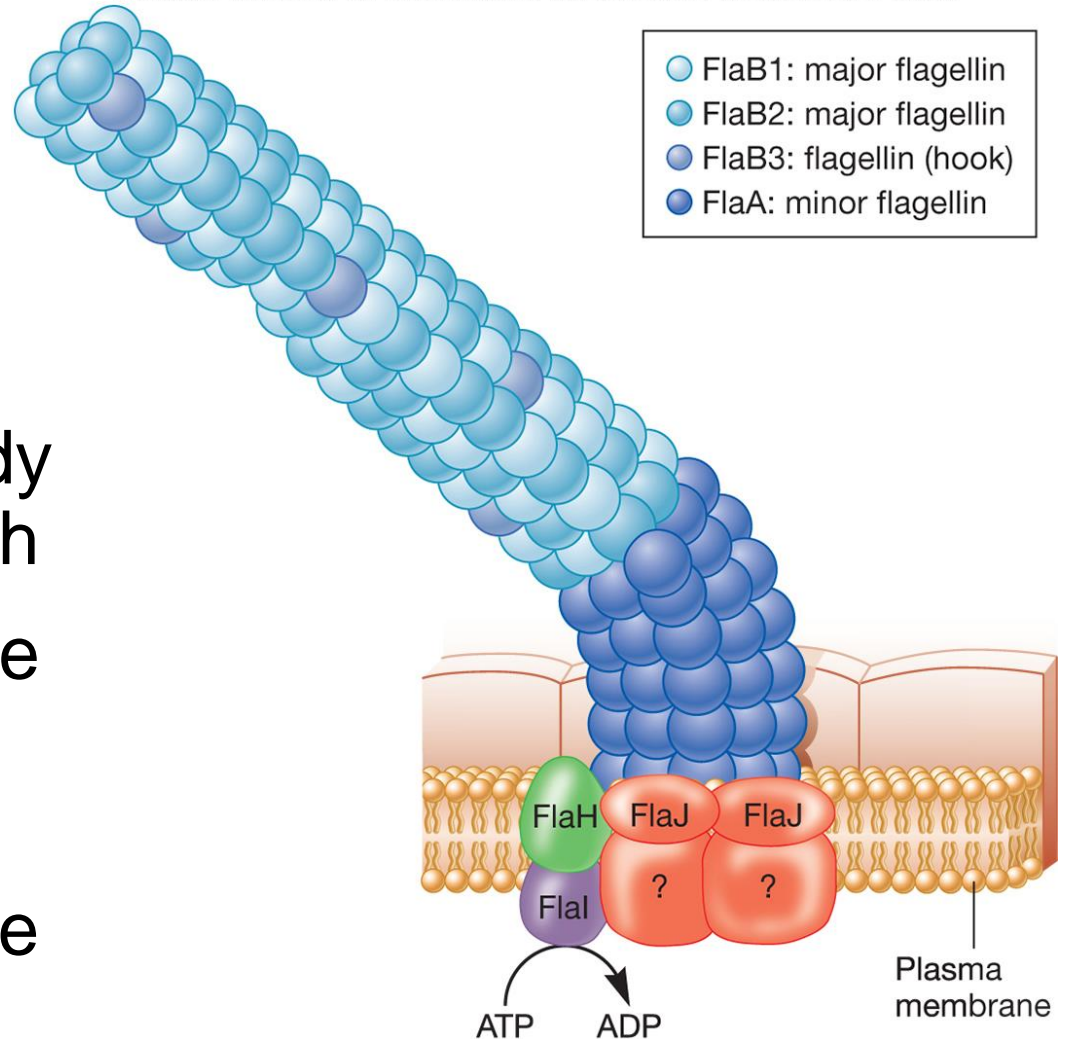


(b) “Grappling hooks” at distal ends of hami

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

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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.

Table 4.1 Comparison of Bacterial and Archaeal Cells

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