BIOL 4640 Mol Micro
Lecture 16 9/30/26
Cell Structures Part 2

- Assignment 10 due on 9/28/26
- Exam 1 on Monday, October 5
  - A study guide and an old exam is posted

- Assignment 11 – due on 10/7/26
- Assignment 12 due on 10/9/26

Unit 3. Features and Structures of Microbial Cells and Viruses B

A. Size and Shape of bacteria
B. Specialized External Structures of bacteria
C. Cell envelope of bacteria
D. Internal structures of bacteria
E. Cell Division in Bacteria
F. Viruses – Chapter 6
G. Atypical bacteria and viruses

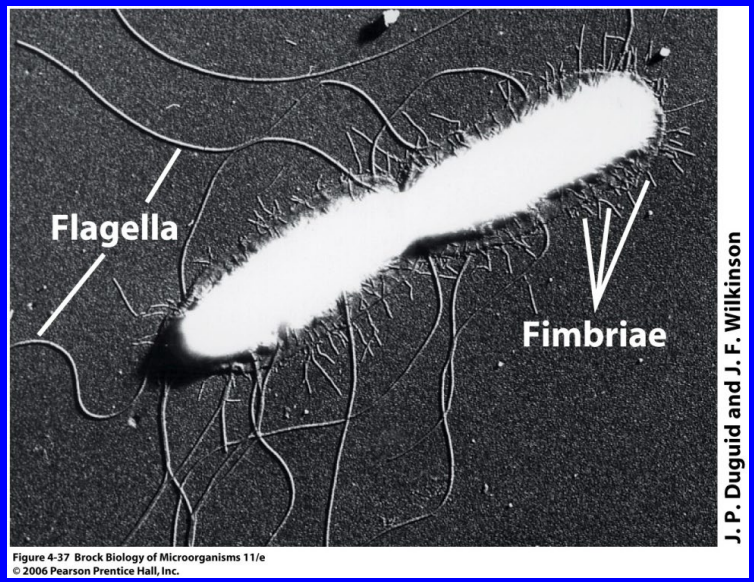
Mostly Chapter 3 in book

B. Specialized External Structures

- Protein filaments that project out from cell (Not enclosed by cell membrane or cell wall)
- Two main types
  1. Flagella – motility
     - Section 3.6 in
  2. Pili and fimbriae – adherence
     - Section 3.6 and 25.2 (6^{th} edition)
  3. Others
     - section 3.5 6^{th} edition

B. Specialized External Structures - 2

2. Pili and fimbriae
   - Protein filament tube that extend from cell
   - Thinner, shorter and more numerous than flagella
   - Several different types
   - Form 3 types of structures, each with a different role
   - More commonly observed in Gram negative bacteria



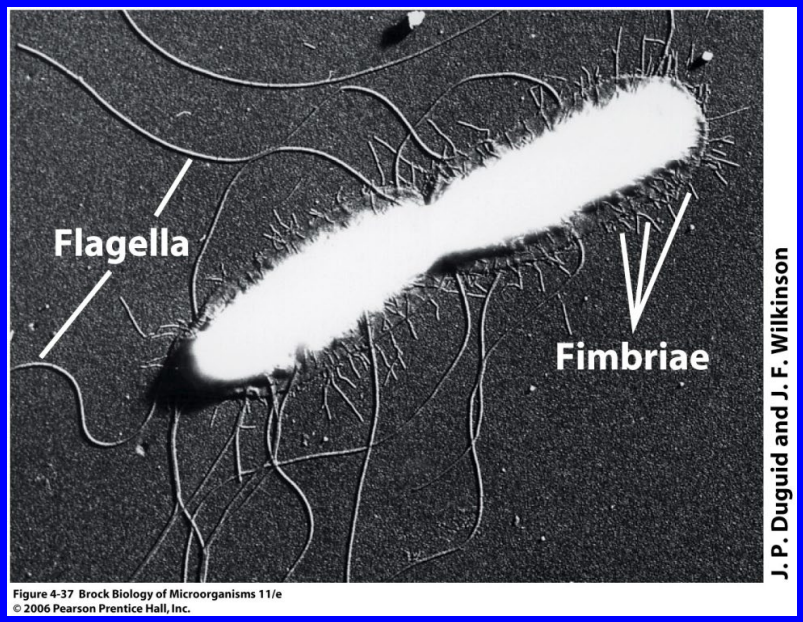
a. Types of pili

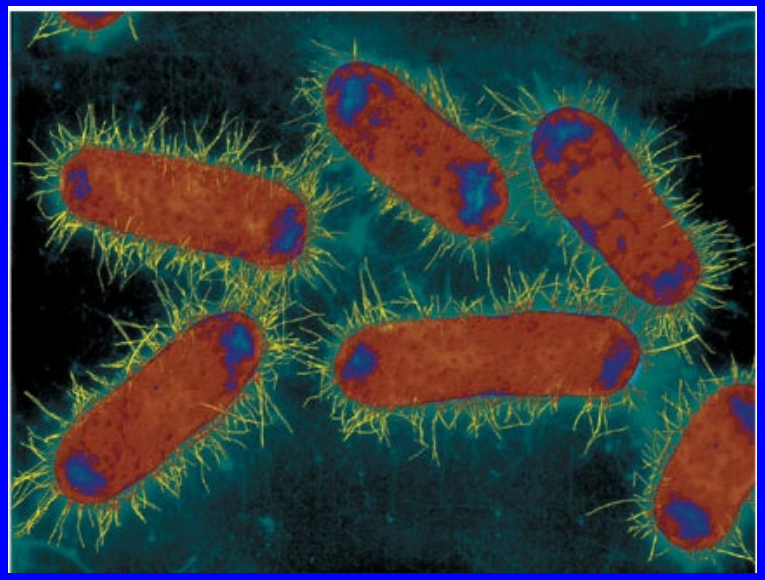
Type	Major functions	Important features / examples
Type I pili	Adhesion to host cells and surfaces; biofilms	Forms fimbriae. Chaperone–usher assembled; includes type 1 fimbriae of E. coli, which bind mannose-containing receptors
P pili	Adhesion, especially in urinary tract infections	Forms fimbriae; also called P fimbriae. Chaperone–usher assembled; E. coli P fimbriae bind receptors on urinary tract cells
Type IV pili	Twitching motility, adhesion, biofilm formation, DNA uptake	Generally called pili rather than fimbriae. Can rapidly extend and retract; important in Pseudomonas aeruginosa and Neisseria
Type V pili	Adhesion and aggregation	Often called Type V fimbriae. Typically form relatively short surface fibers involved in adhesion
Curli	Surface attachment, cell aggregation, biofilm formation	Often called curli fimbriae. Amyloid fibers produced by organisms such as E. coli and Salmonella
Conjugative (sex) pili	DNA transfer between bacterial cells	Not generally called fimbriae. Produced by conjugative plasmids; the F pilus of E. coli is the classic example
Type IV secretion pili	DNA/protein transfer; interaction with host cells	Generally called pili rather than fimbriae. Associated with some type IV secretion and conjugation systems
Competence pili	DNA uptake during transformation	Generally called pili rather than fimbriae. Often related to Type IV pili and facilitate uptake of extracellular DNA
Tad pili	Strong surface attachment and colonization	Can be called pili or fimbriae. “Tight adherence” structures important for persistent attachment
Type IV-like pili in Gram-positive bacteria	Adhesion, motility, DNA uptake	Generally called pili. Functionally and structurally related to Type IV pili

b. Pili Structures and Role

1) Common Pili or Fimbriae

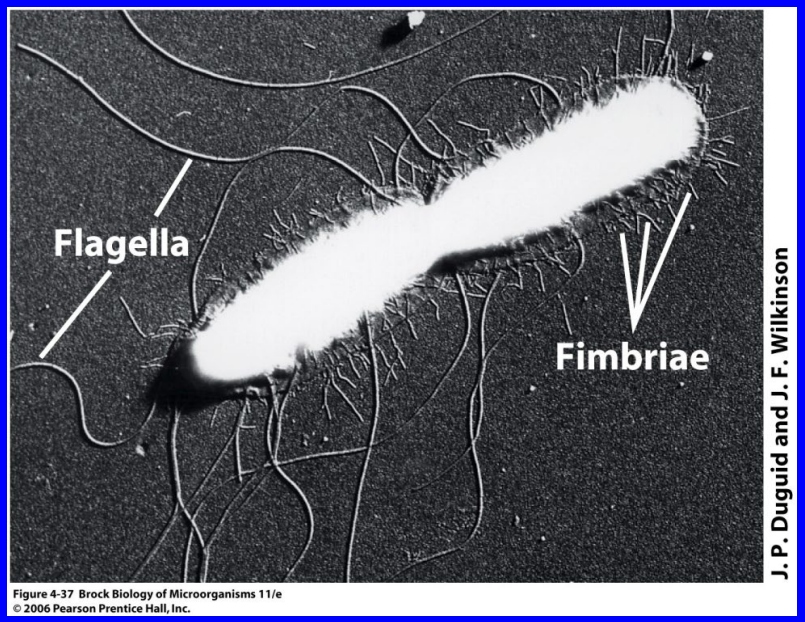
- Thinner and shorter than flagella (3-10 nm in diameter vs 14-20 nm for flagellum)
- Numerous (100s per cell)

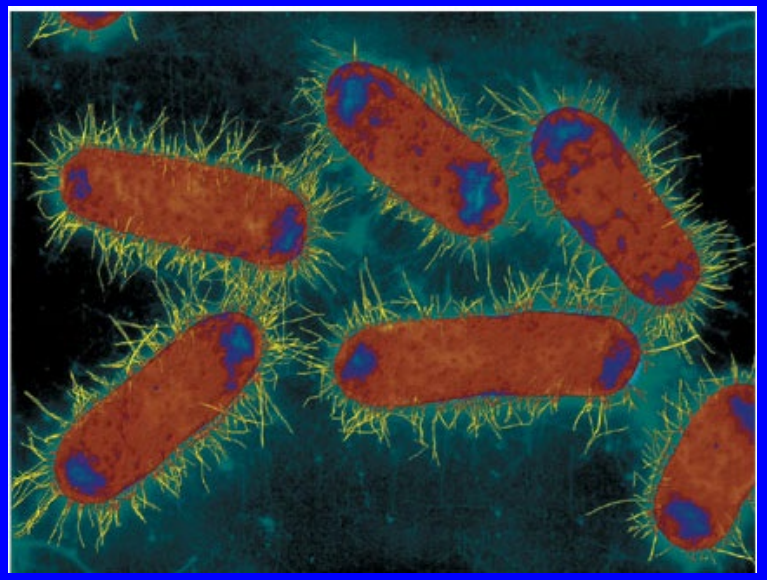




1) Common Pili or Fimbriae - 2

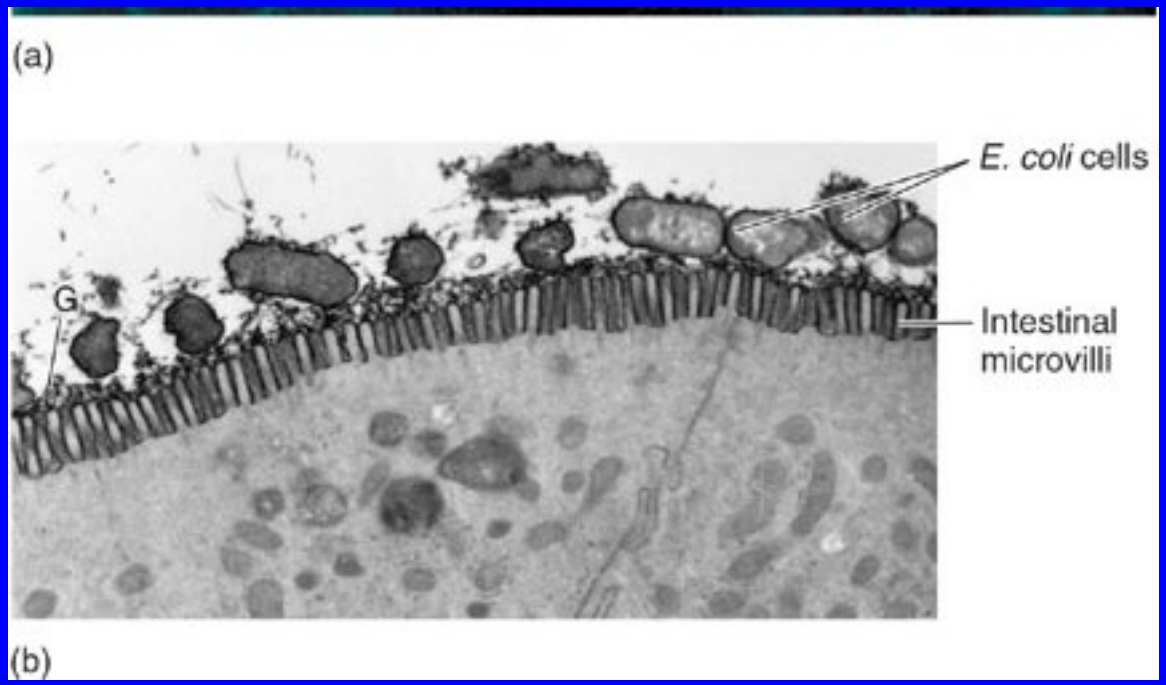
- Made from several types of pilin proteins
  - What types are used to form fimbriae structures?
  - Type I, P, V, curli, Tad





1) Common Pili or Fimbriae - 3

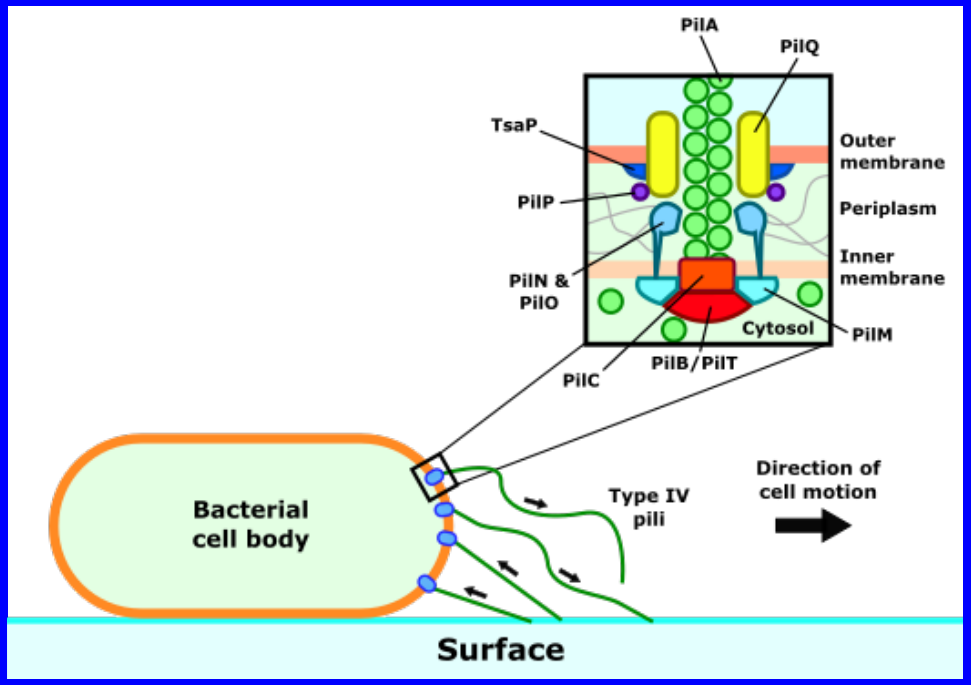
- Role: Adherence to surfaces
  - Adhesin protein at tip of filament binds to specific molecules (usually sugars)
  - Adhesins are important virulence factors
  - Also, can be important for formation of biofilm



b. Pili Structures and Roles - 2

2) Type IV Pili

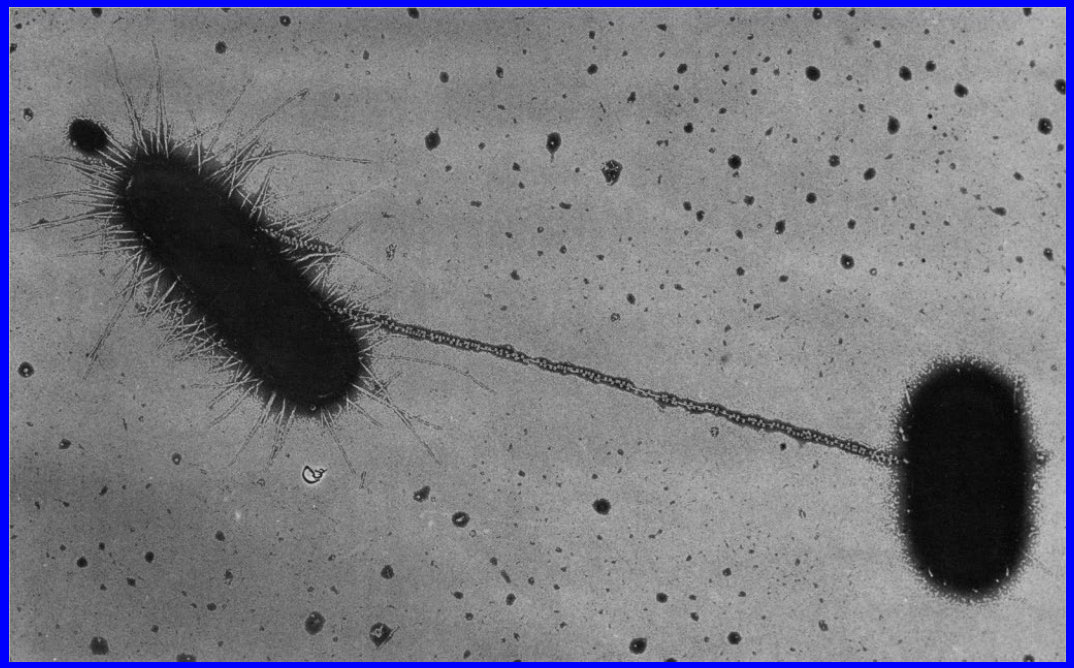
- Mediates twitching motility
- Several pili extend, attaches to surfaces and then shortens moving the bacterial cell in direction of attachment site



b. Pili Structures and Roles - 3

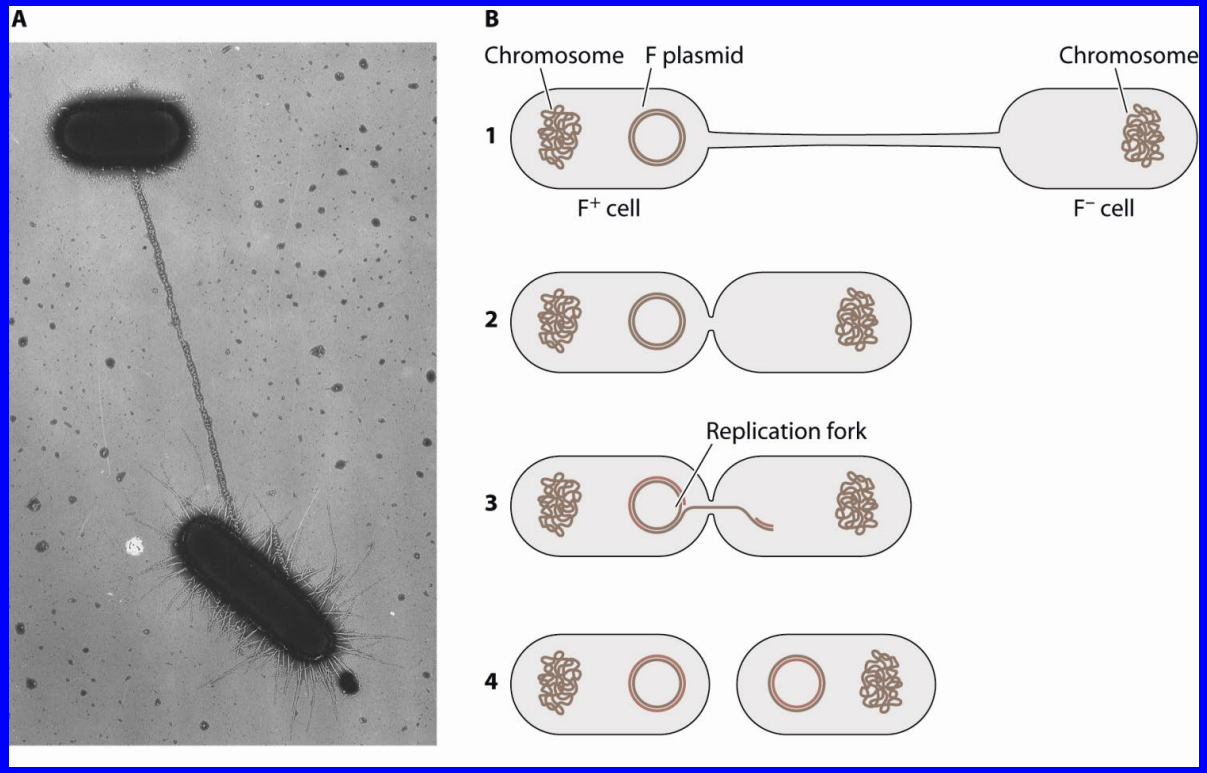
3) Conjugative, Sex or F pili
   - Longer and wider than common pili
   - Only a few per cell (<10)
   - Plays a role in DNA transfer via conjugation

Diameter:
- Sex pili:~7 nm
- Common Pili: 3-10 nm
- Flagellum: 14-20 nm



3) Conjugative, sex or F pili - 3

- Pili attaches to another bacterial cell and then shortens to bring cells close together
- DNA is then transferred to recipient cell



c. Pili Composition

Figure/Table shows components of different types of pili

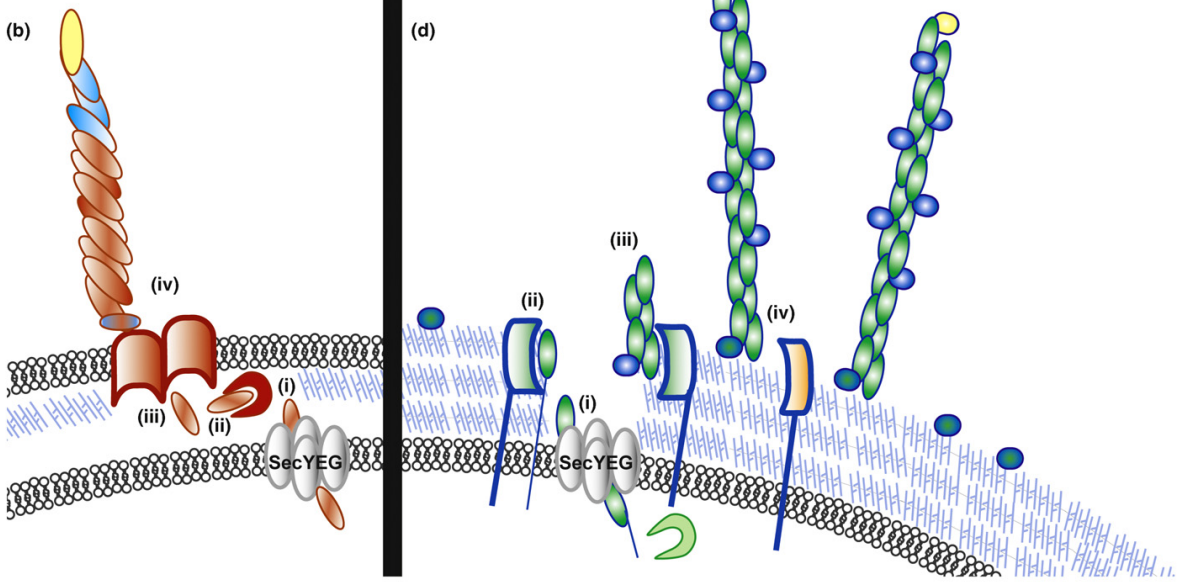
What conclusions would you make about the components of pilus?
How many different proteins form a pilus?

(a)

	E. coli P pili	*E. coli* Type I pili
Major subunit	PapA [100]	FimA [92]
Minor tip adhesin	PapG [100]	FimH [96]
Minor tip fibrillum	PapFEK* [100]	FimGF [96]
Minor terminator	PapH* [21]	
Assembly factor/Usher	PapC [101]	FimD [97]
Chaperone	PapD [98]	FimC [95]

(c)

	C. diphtheriae	*S. pyogenes*	*S. agalactiae*	*S. pneumoniae*	*E. faecalis*	*B. cereus*
Major subunit	SpaA [46]	T3M3 [66] T6M6 [62]	GBS80PI-1 [61] GBS59PI-2a [63]	RrgB [91,94,99,]	EbpC [73]	BcpA [68]
Minor tip subunit	SpaC [46]	CpaM3 [66] CpaM6 [62]		RrgC [74,91]	EbpA [73]	BcpB [68]
Interspersed on fiber	SpaB [46]	Orf130M1 [62]	GBS104PI-1 [63] GBS67PI-2a [63]	RrgA [71,91,94,99] RrgC [91,94]	EbpA [73] EbpB [73]	
Surface associated		CpaM6 [62] Orf130M1 [62]	GBS104PI-1 [63] GBS67PI-2a [63]	RrgA [91]	EbpA [73]	BcpB [68]
Assembly factor	SrtA [46]	SrtC2M3 [65]		SrtB/C-1 [74,91,99] SrtC/C-2 [74,91,99] SrtC/C-3 [74,91,99]	SrtC/Bps [73]	SrtD [68]
Putatitve chaperone		SipA2M3 [66]				
Base associated terminator	SpaB [77]		GBS150PI-1 [78]			
Cell wall attachment	SrtF [76]		SrtA [93]			SrtA [68]



Kline *et al.* 2010 Trends Micro. 18:224

c. Pili Composition - 2

1) Filament
   - Mostly composed of multiple copies of a single type of protein called a pilin
   - May have a second minor protein
2) Tip
   - Composed of 1-2 proteins different from filament

c. Pili Composition - 3

- Cells may have multiple different pilin genes
- Can change which pili protein is made
- Tip protein mediates adhesion to surface
  - Tip or adhesion protein binds to specific molecules (sugars)
- Assembly varies (generally subunits added to base of filament causing tip to extend)

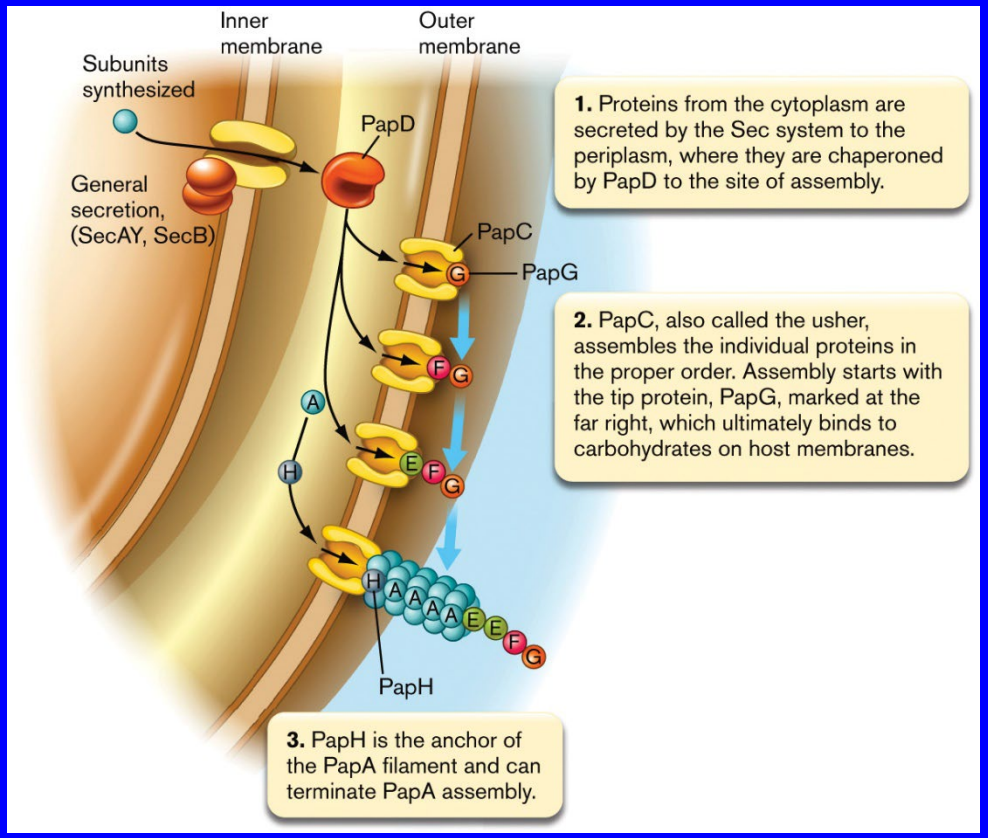
d. Pili Assembly

- Assembly varies by type
- Assembly of the pili filament differ from flagella. How? Look at the next two slides
- Pili subunits generally added to __

1) Assembly of Type I Pili

1. Proteins secreted into periplasm by Sec system
2. Bound by chaperone (PapD) and enters usher channel (PapC)
3. Pili is assembled on outer membrane
4. Starts with adhesions on tip and then adds pilin proteins to base of shaft to extend filament

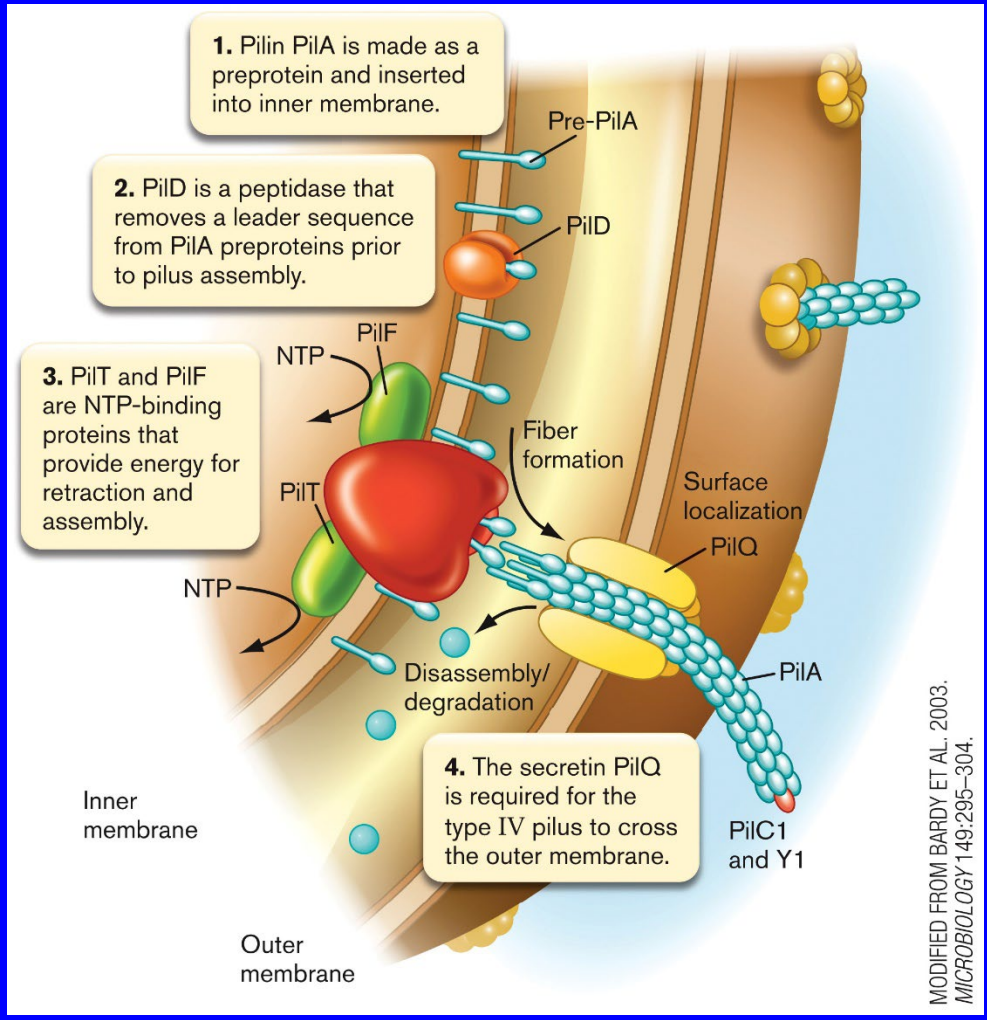
Figure 25.11B
6th edition



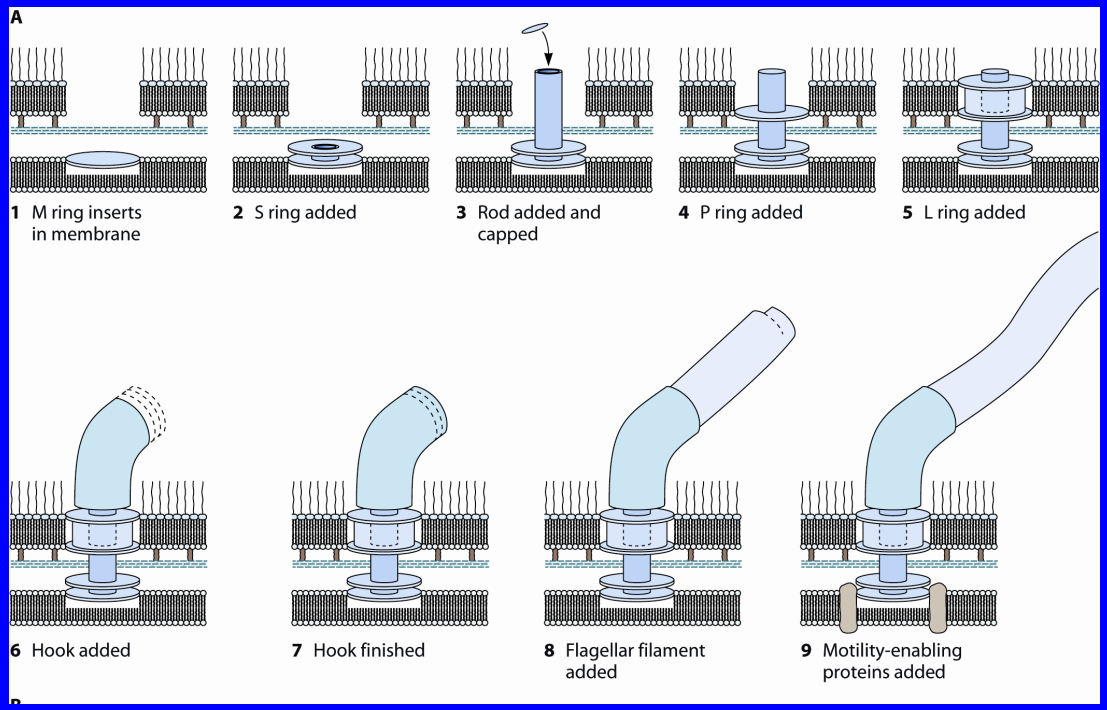
2) Assembly of Type IV pili

1. Pilin protein (PilA in figure) is assembled into a filament in inner membrane
2. _Assembled pilus is pushed through a channel in outer membrane
3. Shorten by disassembling pilin proteins from base

Figure 25.12A 6th edition



d. Assembly of Flagella - 2



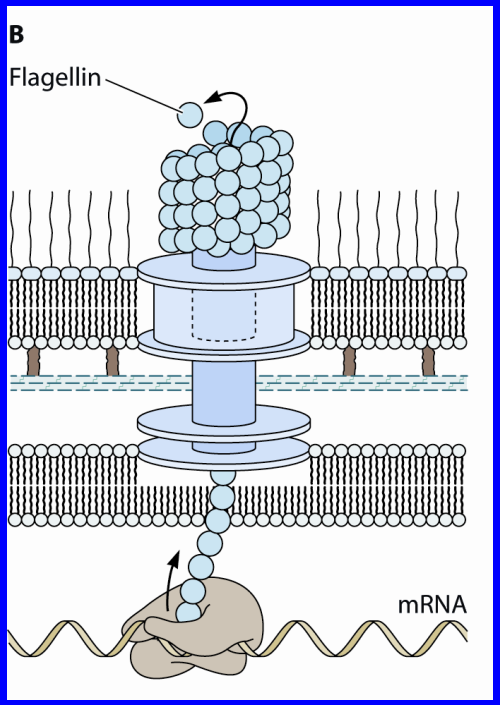


Figure 2.18 Microbe (A) The process begins with the insertion of rings of the basal body into the cell membrane (1 and 2). A rod is added (3), followed by two outer membrane rings (4 ad 5). The hook (6 and7) and the filament (8) are added. The last step is the addition of the motility proteins in the cell membrane (9). (B) Growth of the flagellar filament by extrusion of flagellin subunits through the core of the flagellum.

c. Pili Assembly - 2

- Assembly varies by type
- Assembly of the pili filament differ from flagella. How? Look at the next two slides
- Pili subunits generally added to __
  - __ base and cause filament to extend
  - Flagellum subunits are added to the tip

B. Specialized External Structures – 3a

3. Others
   a) Stalks seen in *Caulobauter* and other bacteria
   – Used for adhesion

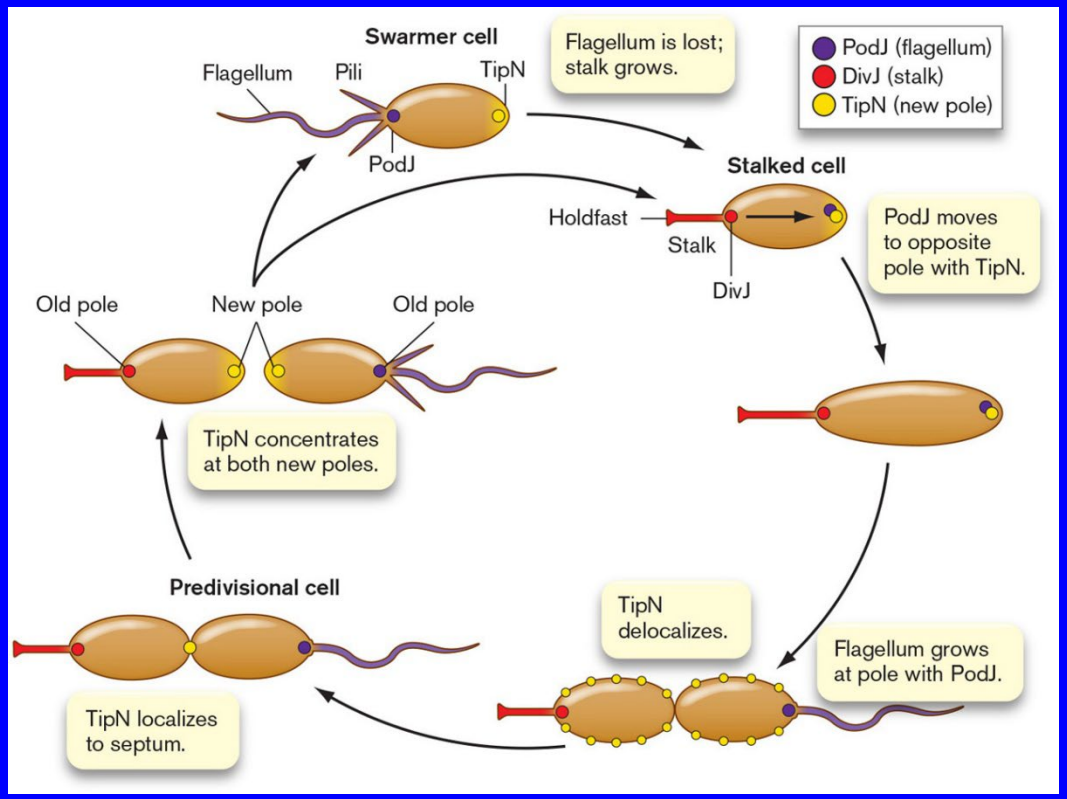
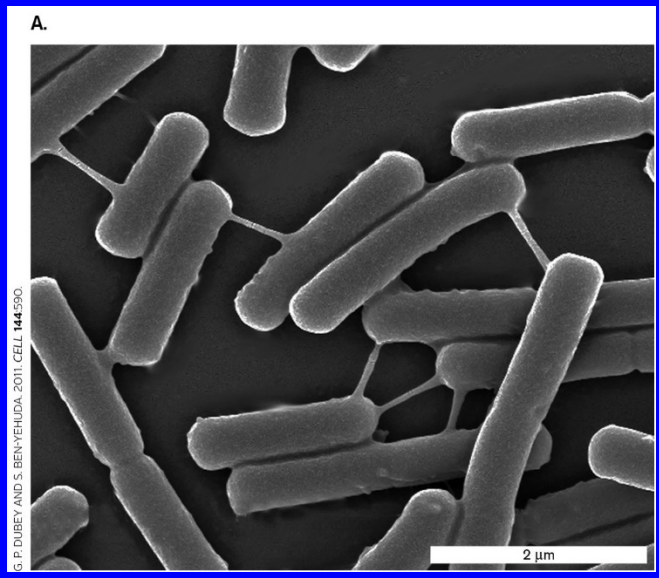


Figure 3.32
6th edition

B. Specialized External Structures – 3b

3. Others
   b) Nanotubes – (section 3.5 6th ed.)
      - Extension of cytoplasm or periplasm between 2 different cells
      - Can be between different species
      - What components are shared in Figure 3.35?



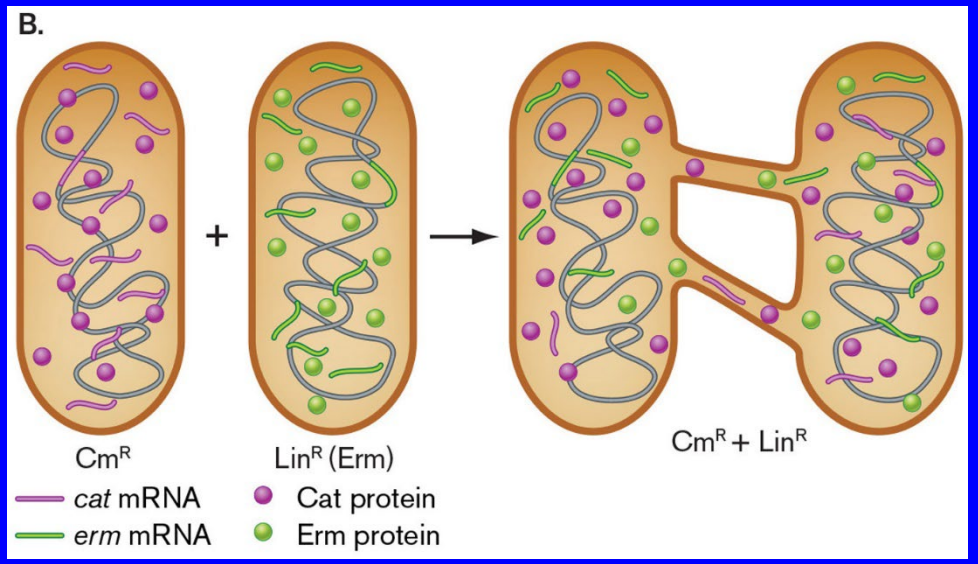
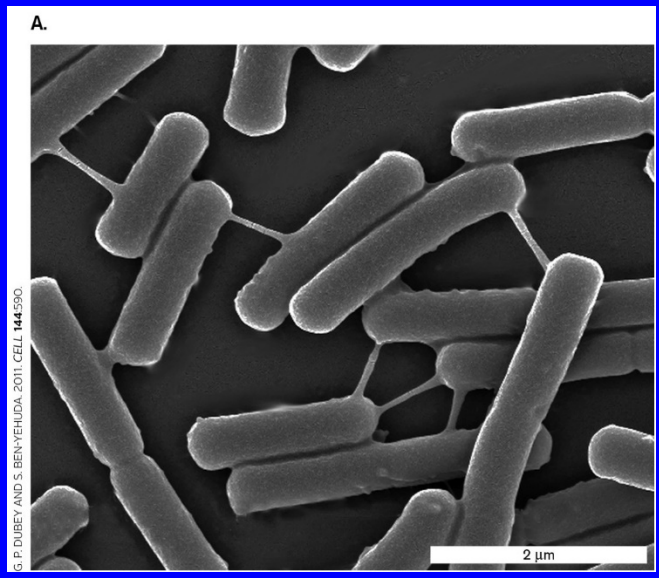


Figure 3.35
6th edition

B. Specialized External Structures – 3b2

3. Others
   b) Nanotubes – (section 3.5 6th ed.)
      - Extension of cytoplasm or periplasm between 2 different cells
      - Can be between different species
      - What components are shared in Figure 3.35?
        - Protein and nucleic acids



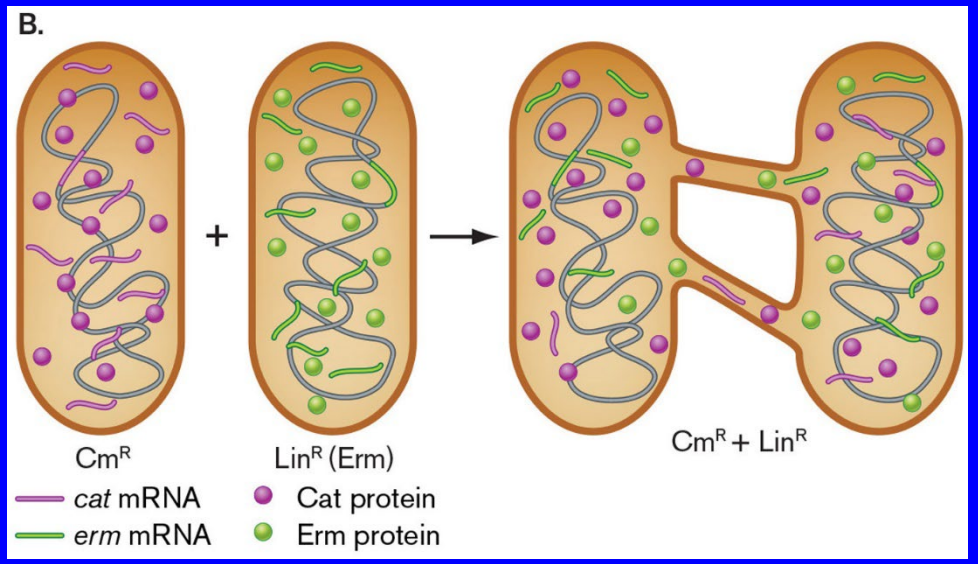


Figure 3.35
6th edition

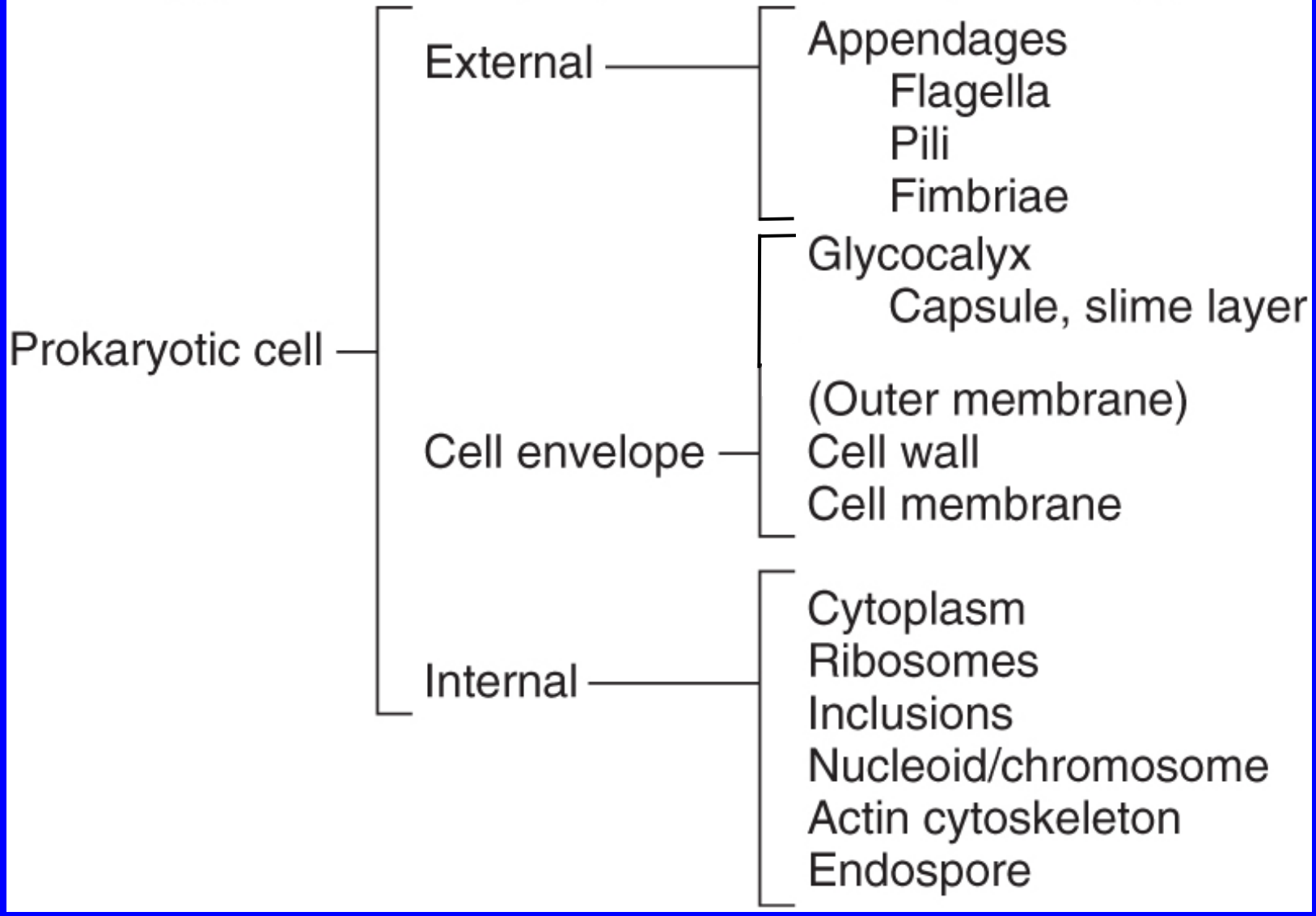
Unit 3. Features and Structures of Microbial Cells - C

A. Size and Shape of bacteria
B. Specialized External Structures of bacteria
C. Cell envelope of bacteria
D. Internal structures of bacteria
E. Cell Division in Bacteria
F. Viruses – Chapter 6
G. Atypical bacteria and viruses

Mostly Chapter 3 in book

Unit 3. Structures of Bacterial Cells

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C. Cell Envelope of Bacteria

- Includes cell membrane, cell wall, outer membrane and glycocalyx/capsule
- Different styles are observed in bacteria
  - Gram positive, Gram negative, Mycobacteria, etc
  - Each style has different layers and components
- Major way to group bacterial species
- Detectable by staining techniques and microscopy (Gram stain and acid fast)

Importance of Envelope Structure

- Major feature used to classify bacteria
  - Staining techniques detect differences
- Affects transport of material into cell
- Affects sensitivity of bacterium to antibiotics and disinfectants
  - Drug ands chemical will need to pass through it to enter the cell

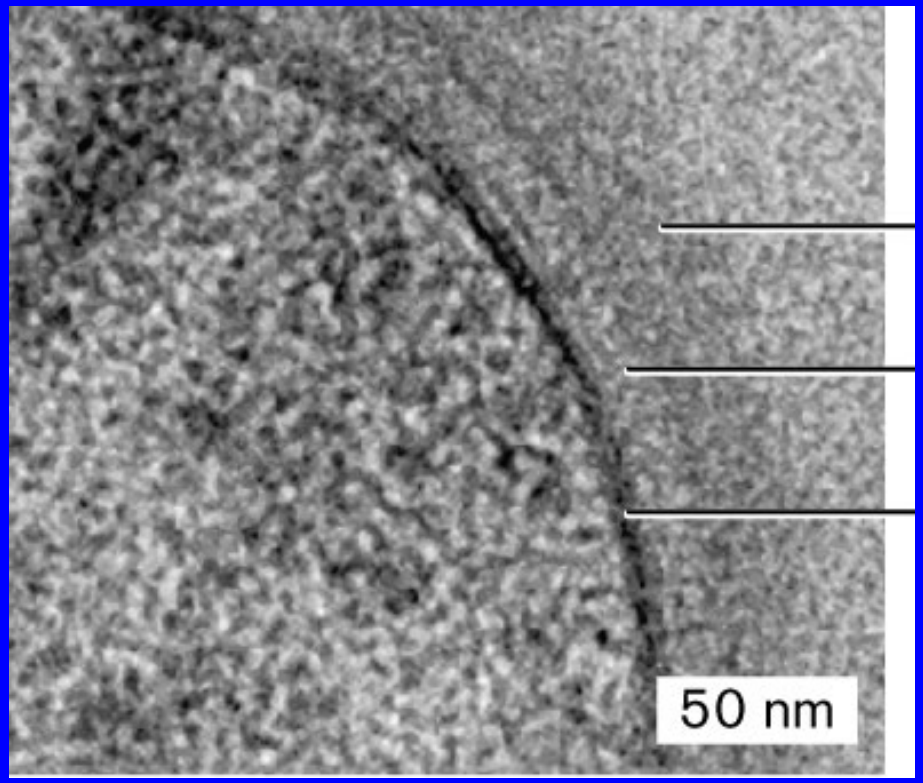
C. Cell Envelopes

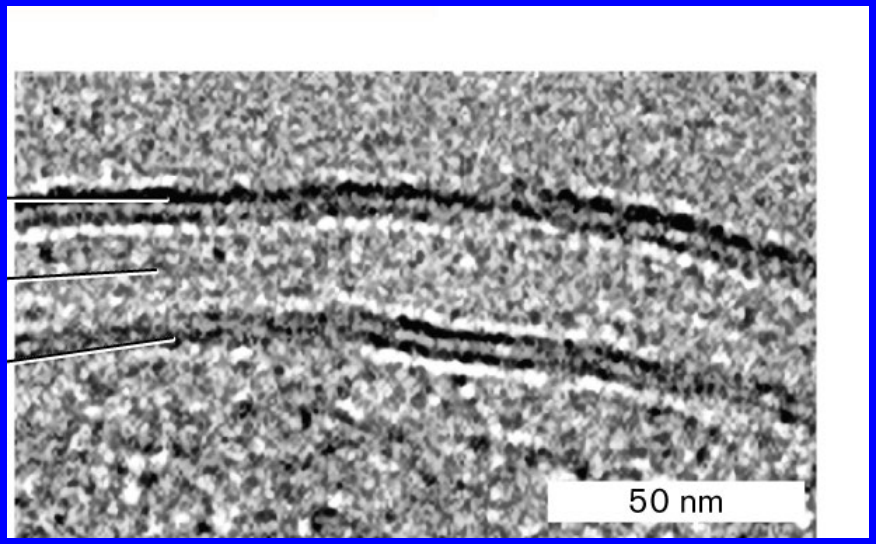
1. Major Styles/Configurations Observed
   a. Gram-positive (section 3.3)
   b. Mycobacterial (Gm+ actinomycete) - Acid-fast (section 3.3)
   c. Gram-negative (section 3.3)
   d. Mollicutes – *Mycoplasma* – no cell wall (pp. 734-735 6e)
   e. Archaeal (section 19.1)
2. Layers and Components
3. Antibacterial Chemicals and resistance

C. Cell Envelopes

a. Gram-positive

b. Gram-negative





Electron microscope images

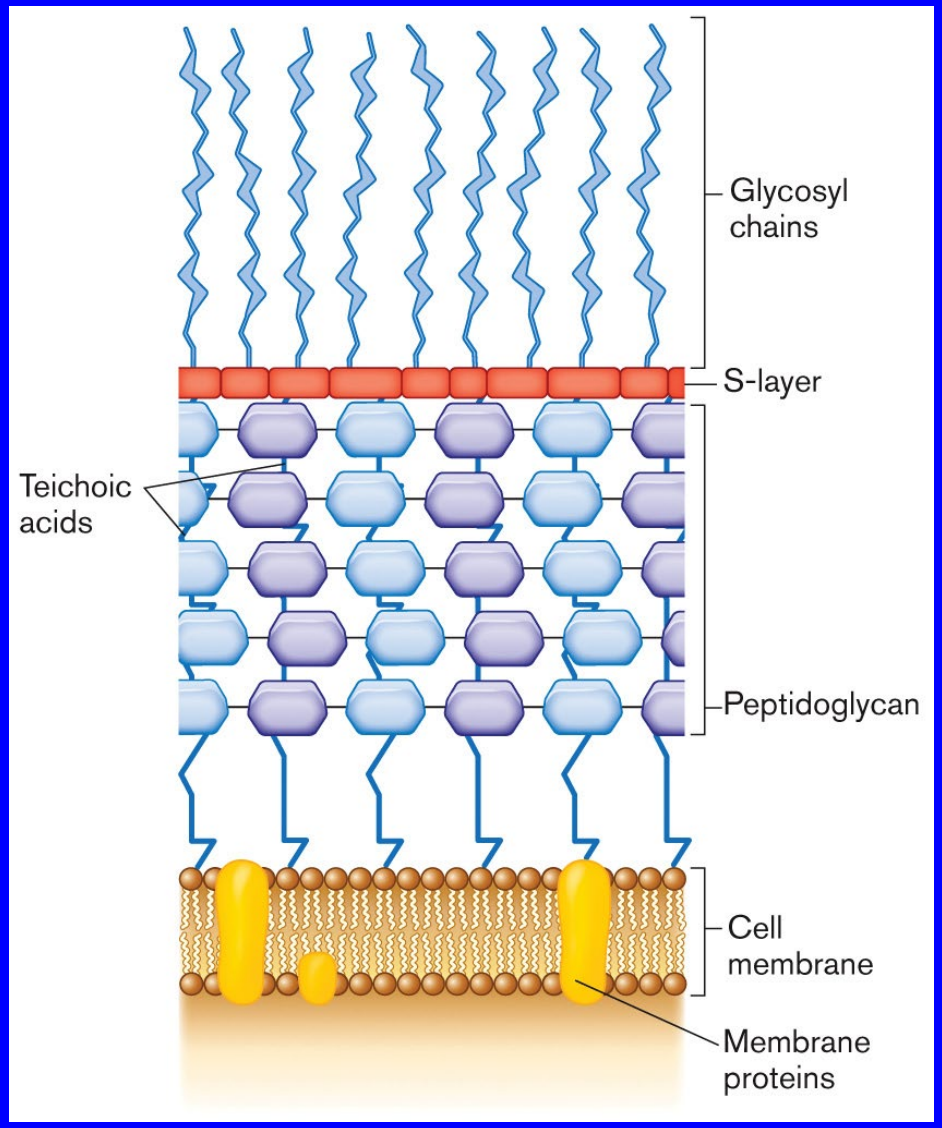
Assignment 12

1. What layers are found in envelope of each of the following types of bacteria?

   What type of molecules are found in each layer?

   a. Gram positive
   b. Mycobacterial
   c. Gram-negative
   d. Mollicutes - *Mycoplasma*
   e. Archaeal

a. Gram-Positive Cell Envelope



Layers and Components Present

•

Figure 3.15 6th edition

b. Mycobacterial Envelope

- Gram positive actinomycete

Layers and Components present

-

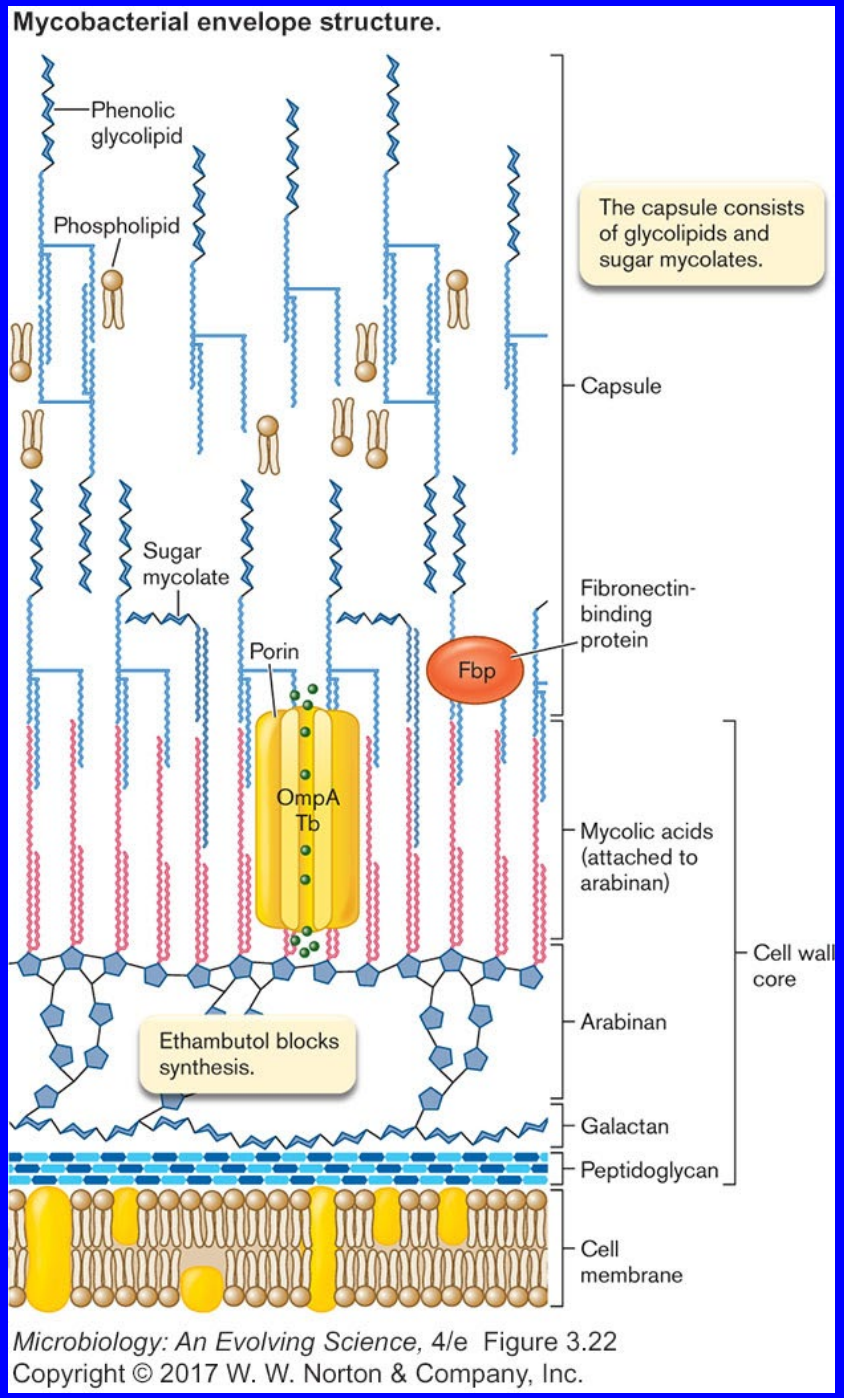
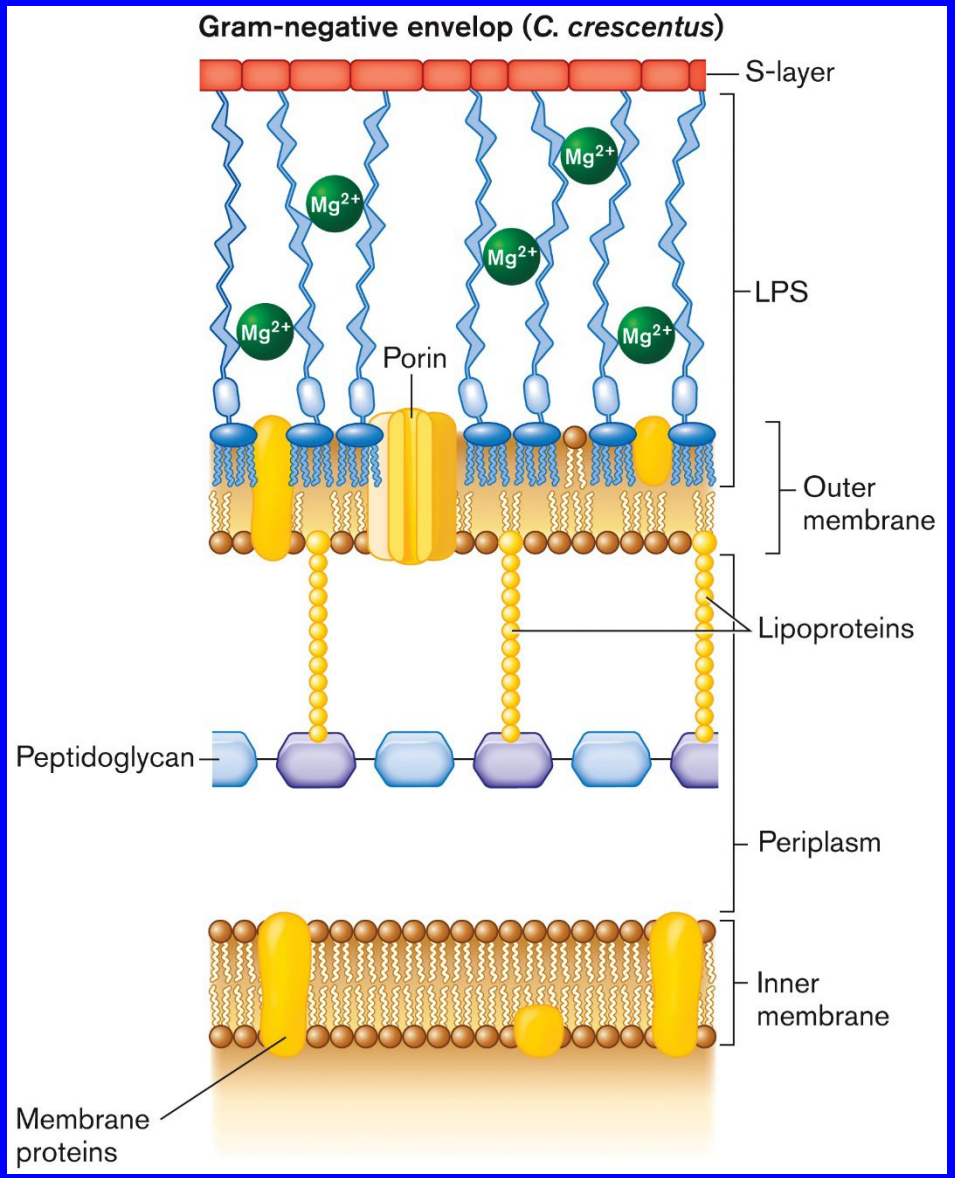


Figure 3.21A
6th edition

c. Gram-Negative Envelope



Layers and Components present

•

Figure 3.15
6th edition

d. Envelopes of Mollicutes - *Mycoplasma*

Layers and Components

–

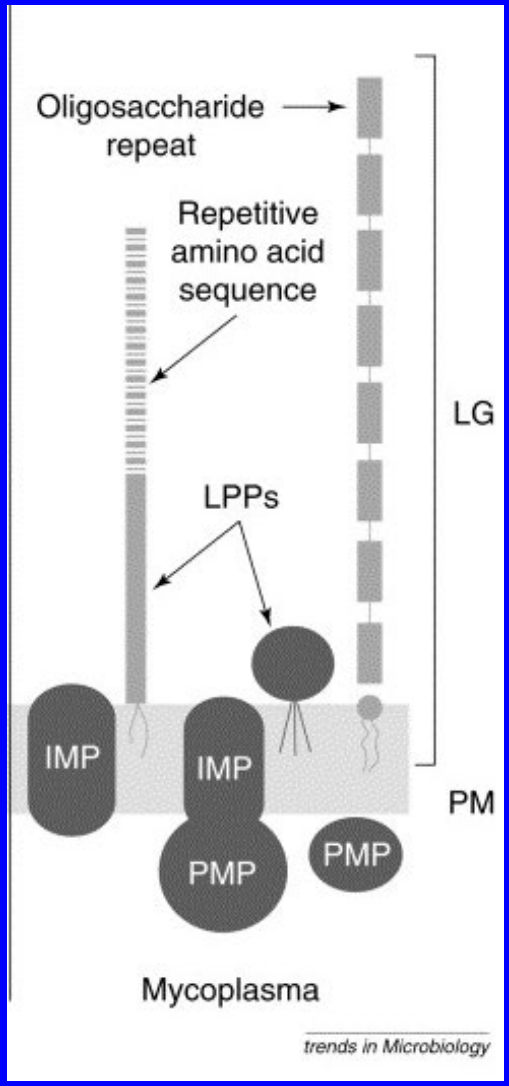


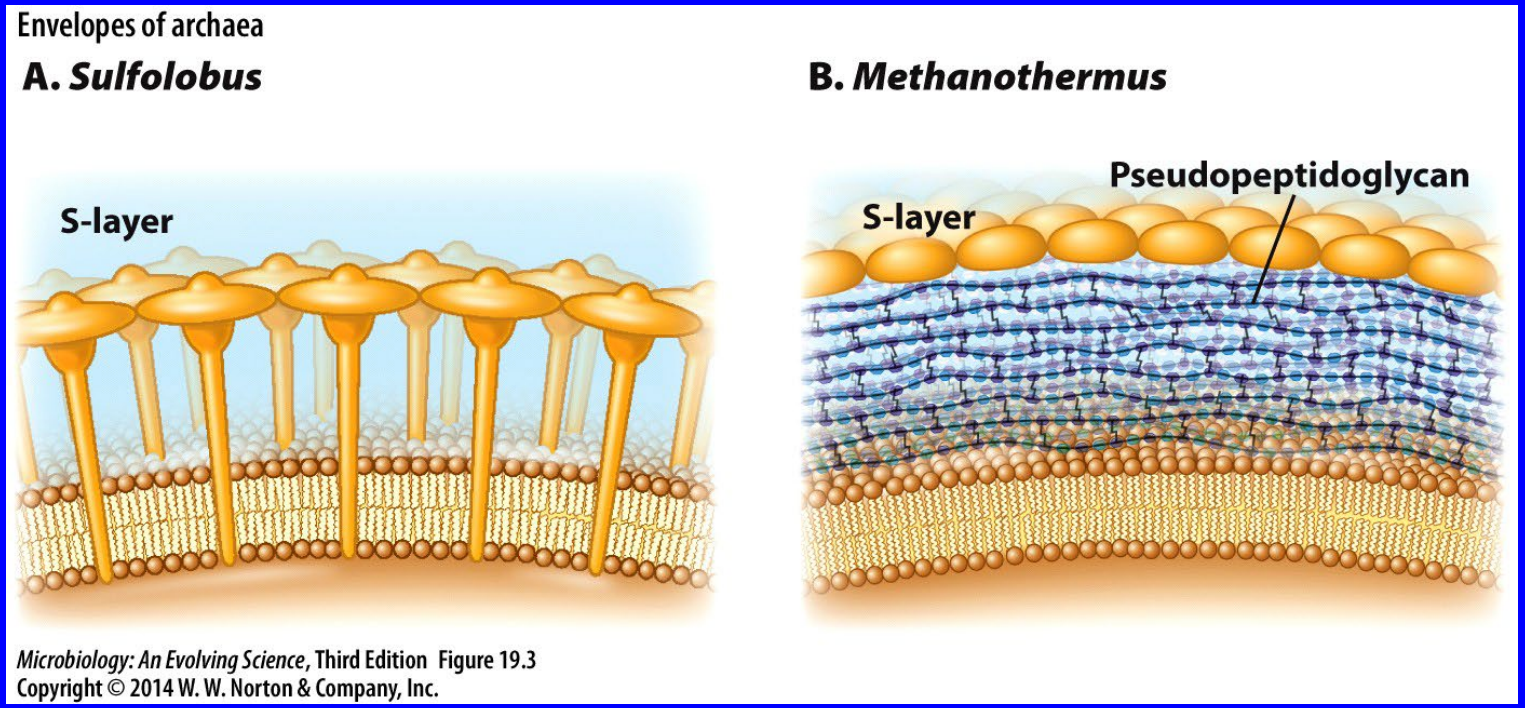
Figure Legend: LG = lipid-glycans?, LPPs = lipoproteins, PM = plasma membrane, IMP= intermembrane protein, PMP = peripheral membrane protein,

e. Envelopes of Archaea

Layers and Components Observed

–

Figure 19.3 3rd edition



Assignment 12 Question 2

2. The color observed in a Gram stained does not always match their actual envelope style. List two other methods one could use to determine or predict the nature of the envelope of a newly isolated bacterium.

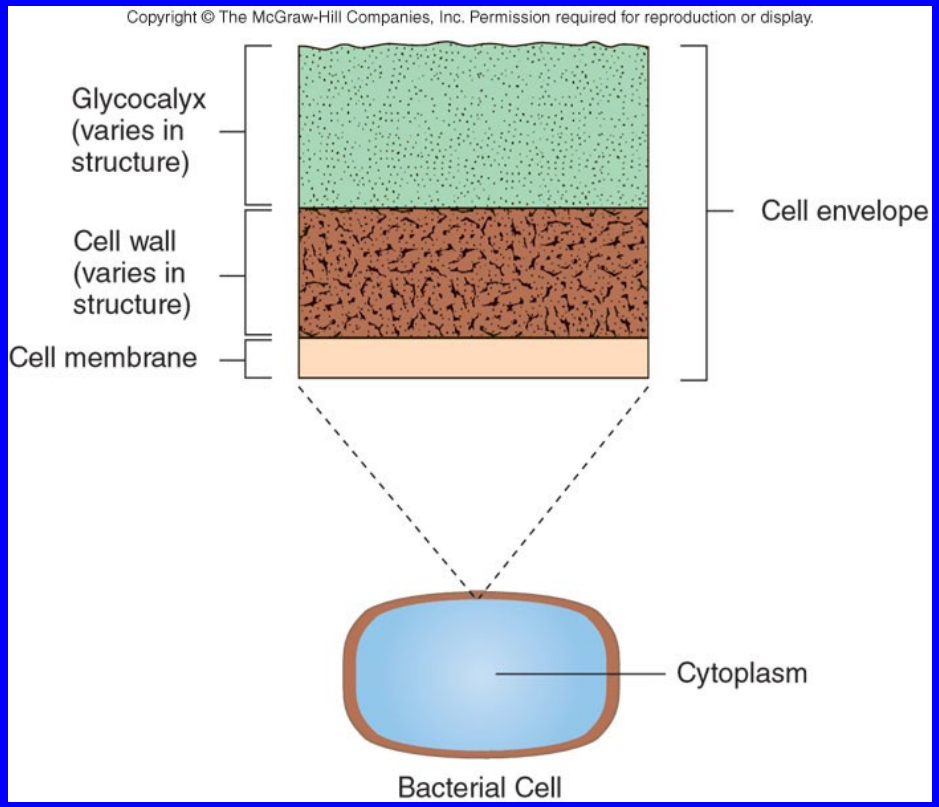
- Discuss with your neighbor

C. Cell Envelope of Bacteria - 2

2. Layers and Components
   a. Glycocalyx – capsule
   b. S layer -
   c. Outer membrane
      - LPS and phospholipids
   d. Cell wall -
      - Peptidoglycan, Pseudopeptidoglycan, Teichoic acid, Mycolic acids, Arabinogalactan, Periplasm
   e. Periplasm
   f. Cell membrane
      - Phospholipids, Isoprenoids and hopanoids

a. Glycocalyx or Capsule

1) Features
- Extracellular material beyond the cell wall
- Composition varies between different species



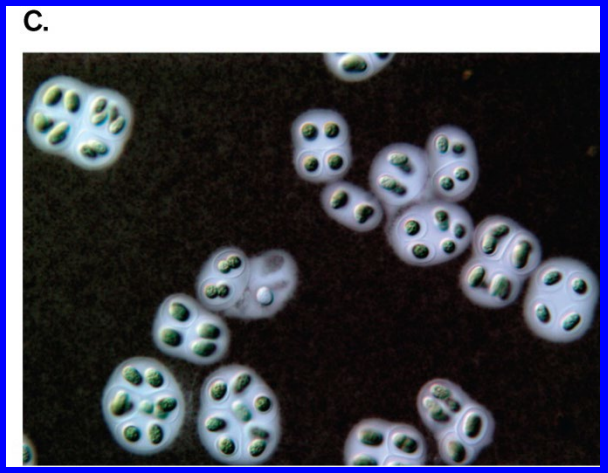
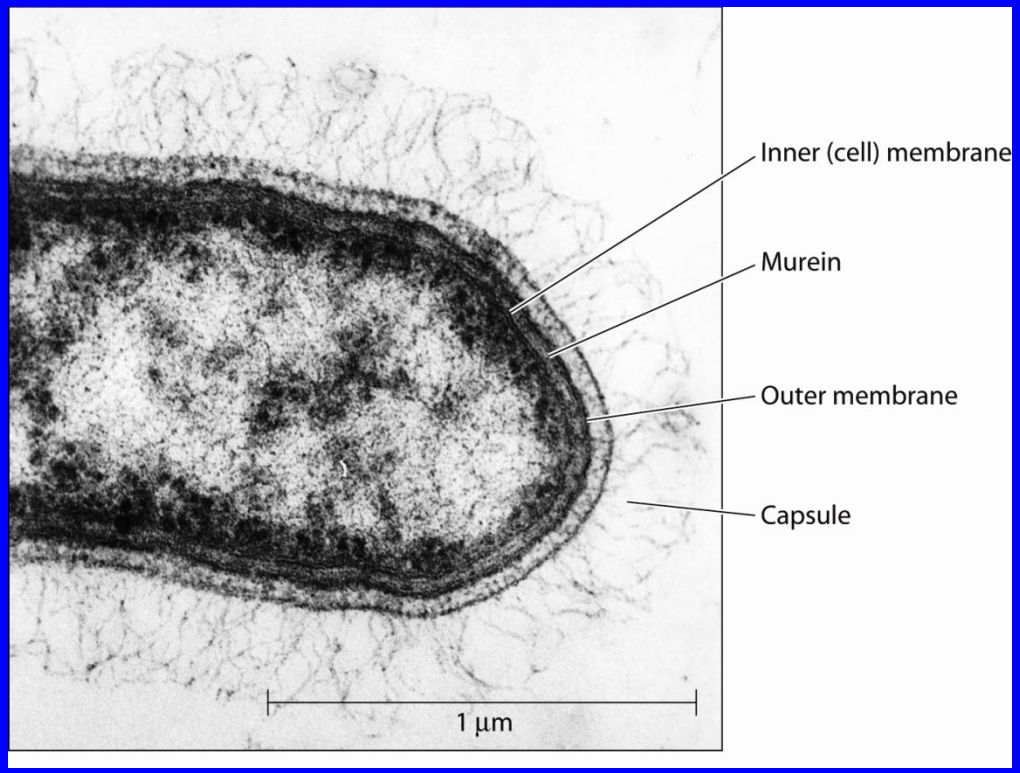
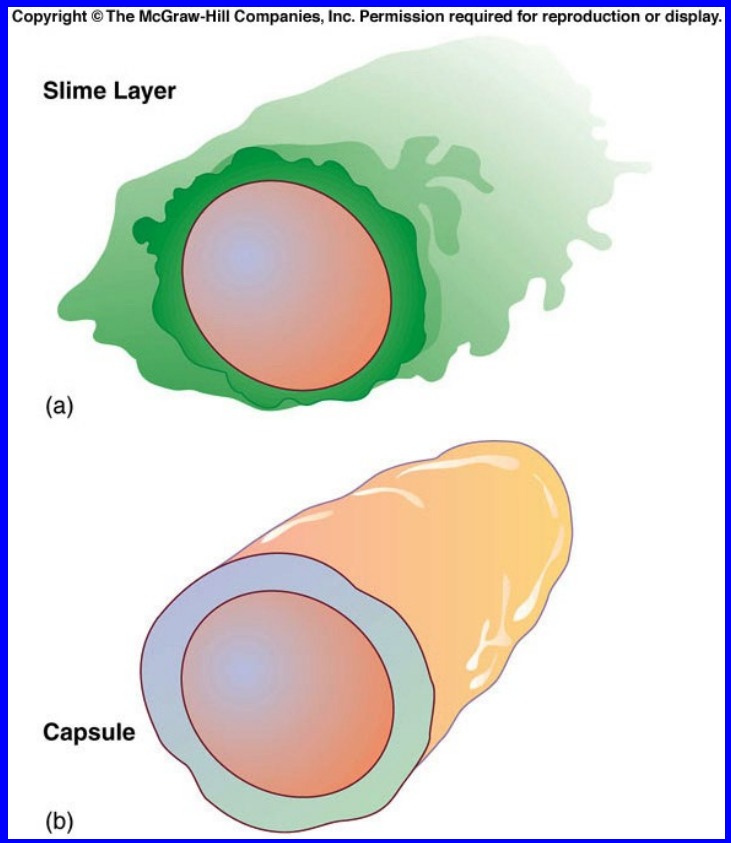


Figure 2.24C 4th edition
Darkfield microscopy image

a. Glycocalyx or capsule - 2

2) Types
   a) Slime layer – loosely attached
   b) Capsule – more firmly attached





3) Composition of Capsules

What conclusions would you draw about its composition? Frequency of each type observed?

Bacterium	Capsule composition	Structural subunits
Gram-positive Bacteria		
Bacillus anthracis	polypeptide (polyglutamic acid)	D-glutamic acid
Bacillus megaterium	polypeptide and polysaccharide	D-glutamic acid, amino sugars, sugars
Streptococcus mutans	polysaccharide	(dextran) glucose
Streptococcus pneumoniae	polysaccharides	sugars, amino sugars, uronic acids
Streptococcus pyogenes	polysaccharide (hyaluronic acid)	N-acetyl-glucosamine and glucuronic acid
Gram-negative Bacteria		
Acetobacter xylinum	polysaccharide	(cellulose) glucose
Escherichia coli	polysaccharide (colonic acid)	glucose, galactose, fucose glucuronic acid
Pseudomonas aeruginosa	polysaccharide	mannuronic acid
Azotobacter vinelandii	polysaccharide	glucuronic acid
Agrobacterium tumefaciens	polysaccharide	(glucan) glucose

Table 4
Online Textbook of Bacteriology

a. Glycocalyx – capsule - 3

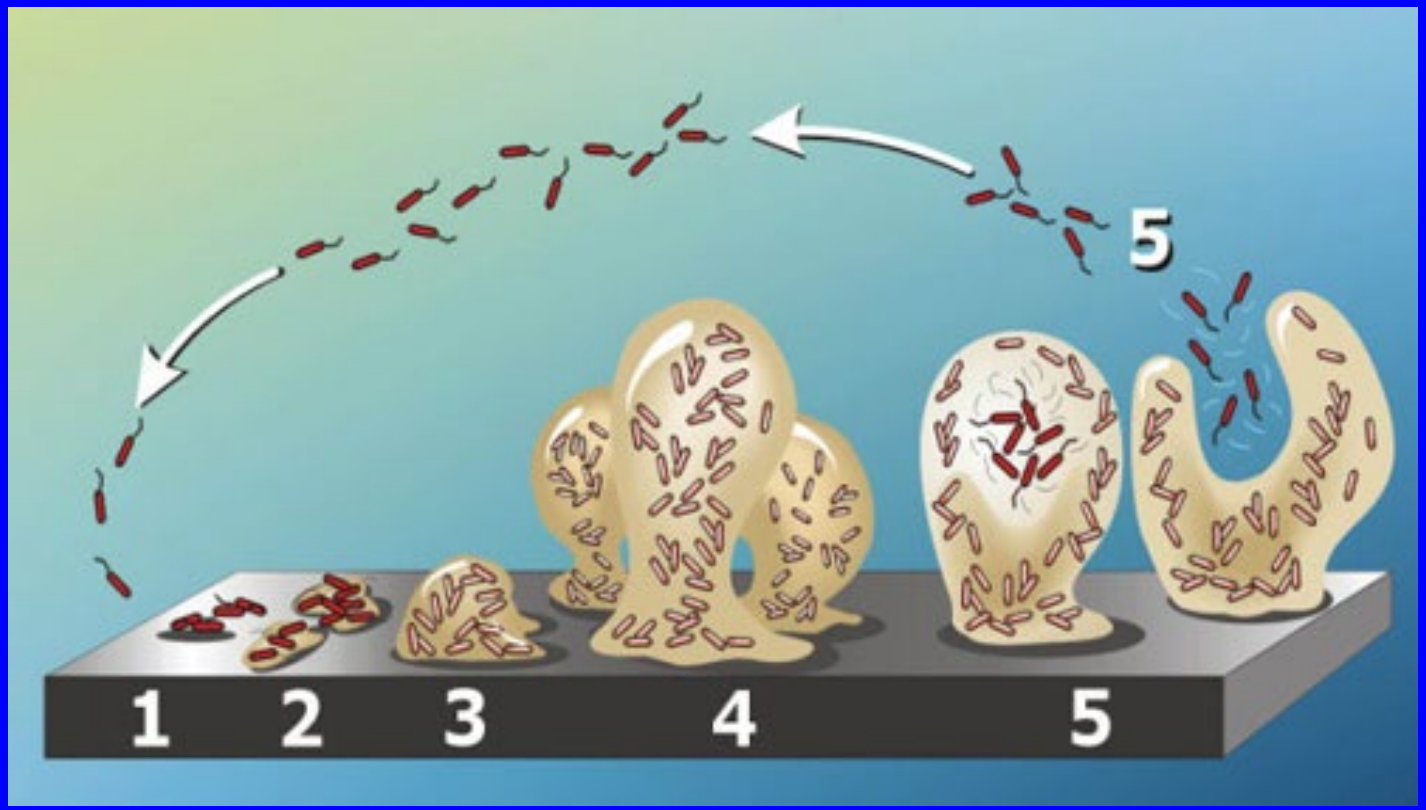
3) Composition

- Usually polysaccharides –
- May be peptides (more common in Gm+?)
- May also contain DNA
- Composition varies between species, strains of a species, and during the life of an organism
  - ~80 different capsular polysaccharides have been observed in *E. coli* (K antigen)
- Usually short chains of a homopolymer or heteropolymer of sugars and are called extracellular polysaccharide (EPS)
- Peptides are short chains of amino acids

a. Glycocalyx – capsule - 4

4) Role

- Attachment (biofilms) – Section 4.5 6th edition
- Protection from phagocytosis
- Protection from desiccation



b. S or surface Layer - 1

1) Features
   - Found on most (?) bacteria especially Archaea
     - Usually lost in lab cultured strains
   - On outside of cell wall or membrane
   - Layer of proteins or glycoproteins
   - Composed of a complex of a few proteins
   - Makes crystalline, porous matrix

Fig 3.17 3rd edition

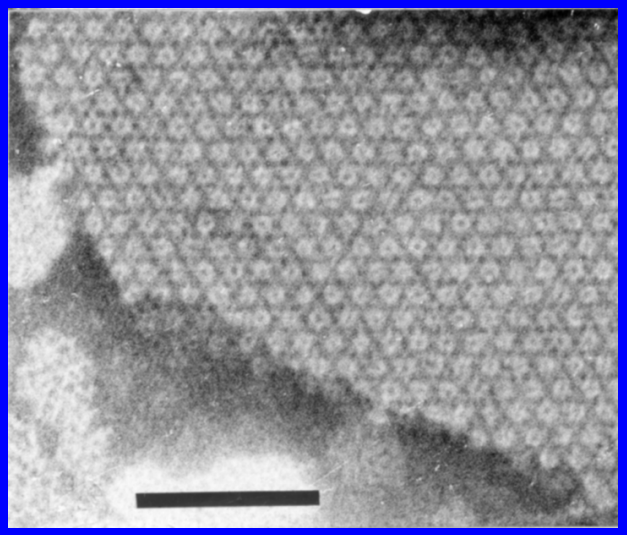
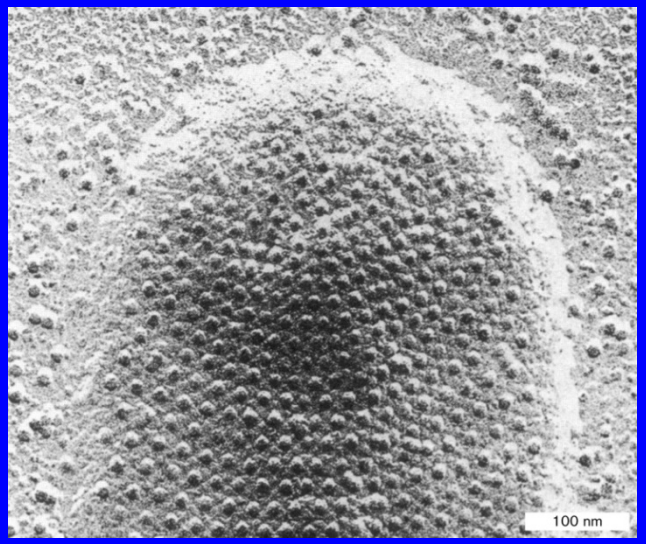
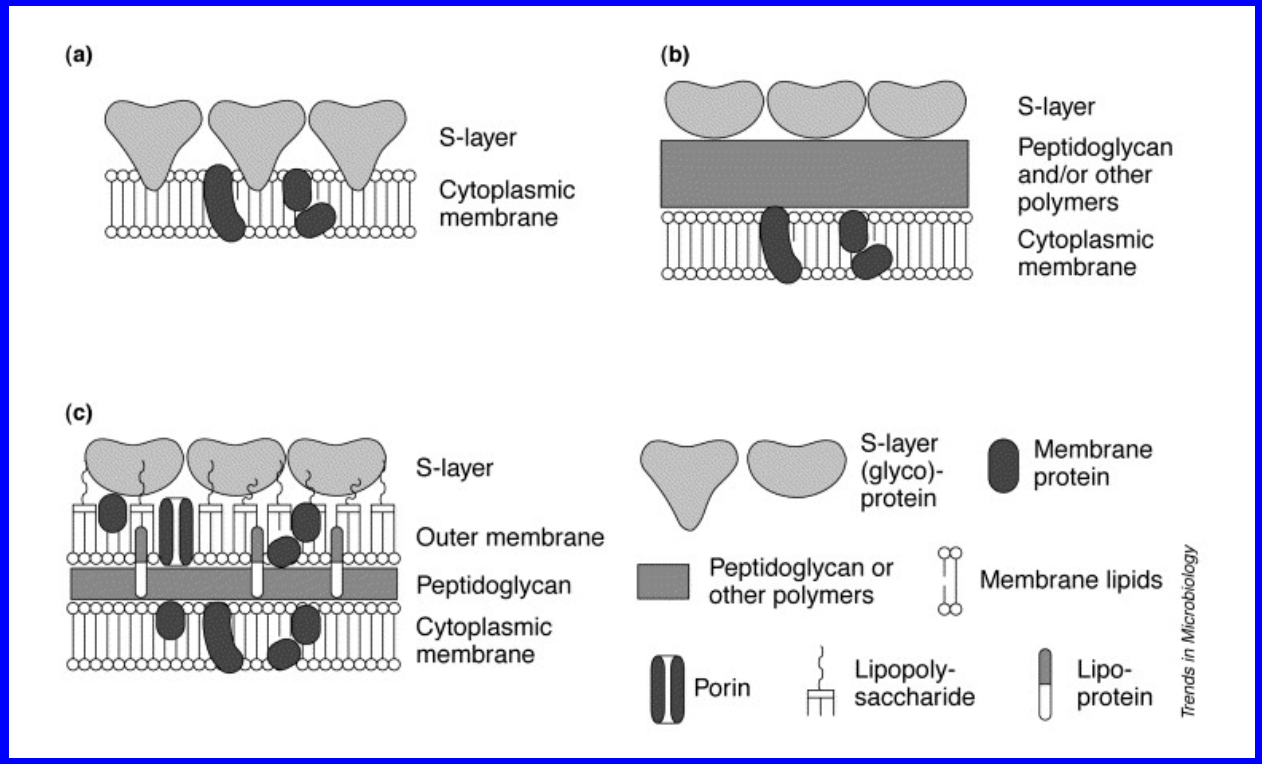


Figure 2.11
Microbe



b. S-layer - 2



Sleytr and Beveridge 1999 Trends in Microbiology

(a) Archaea with no cell wall just S-layer
(b) Gm pos with S-layer
(c) Gm neg. bacteria with S-layer

- Not found on all bacteria

b. S-layer - 3

2) Hypothesized Roles - not totally understood
   - Protection – osmotic stress
   - Structural – shape (Archaea)
   - Protection from viruses
   - Barrier to large molecules
   - Attachment to surfaces
   - Site for attachment of proteins