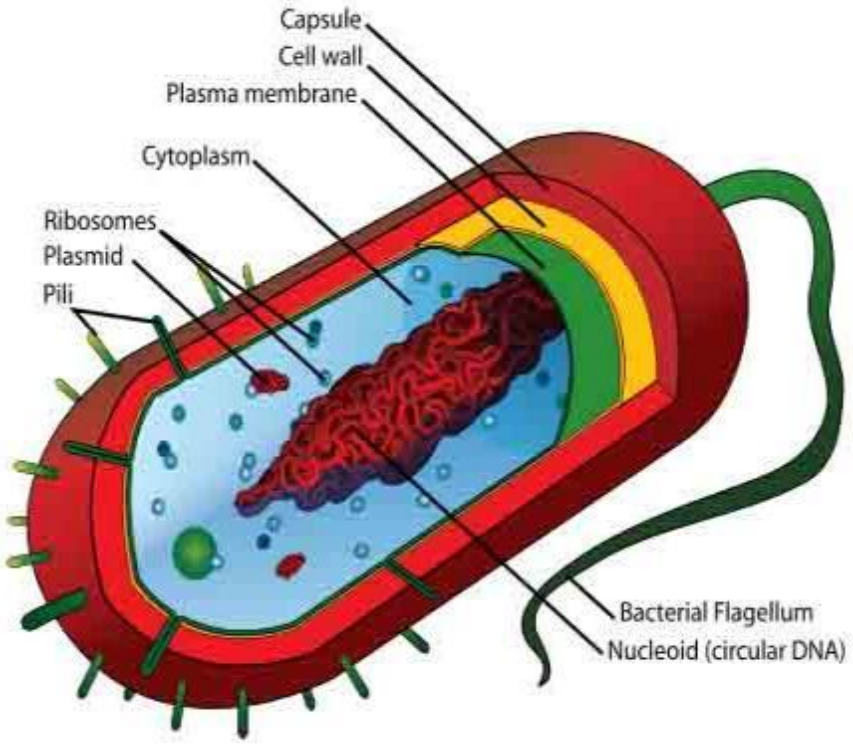
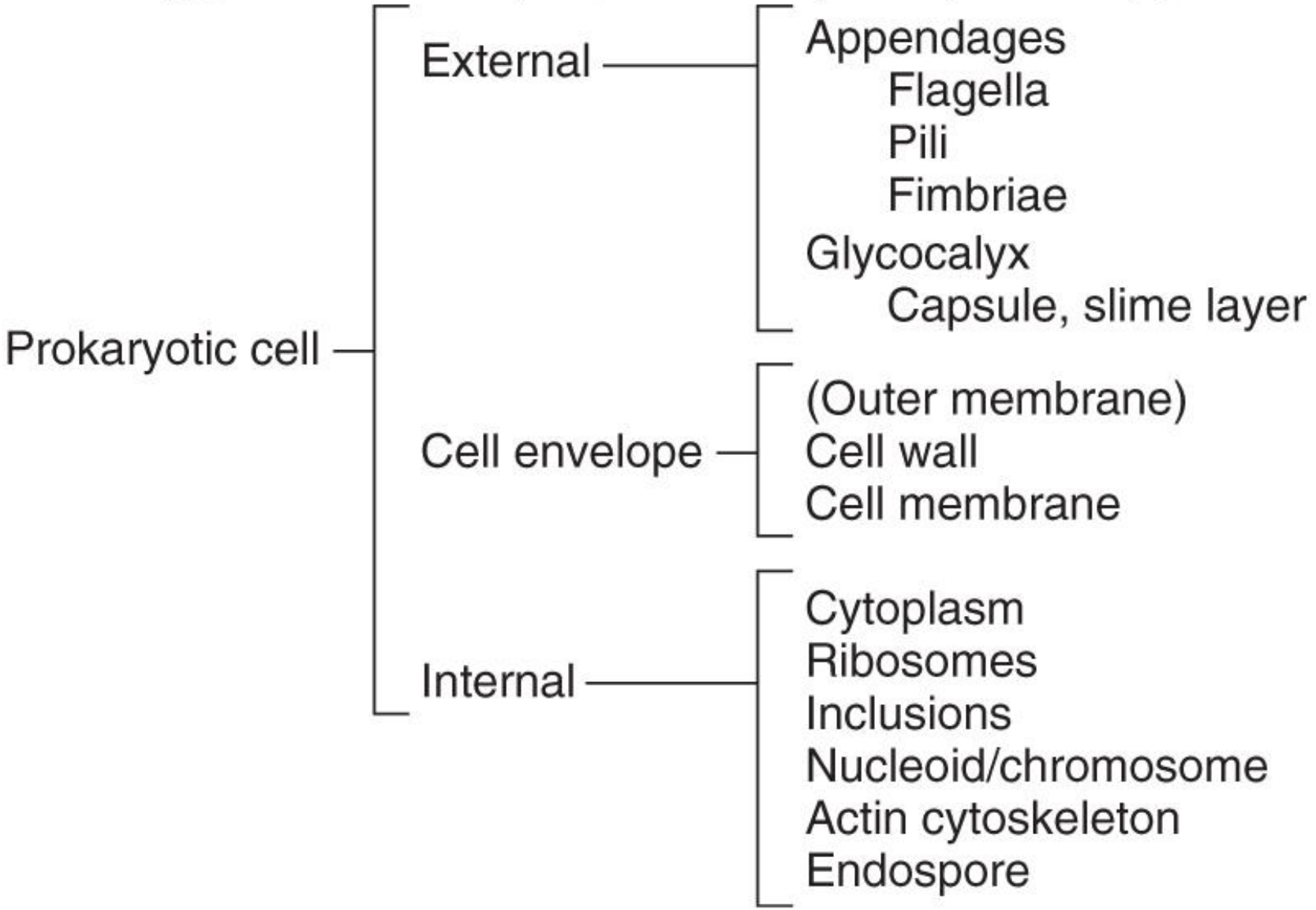


Prokaryotic Cell Structure & Function

How are Prokaryotes Different from Eukaryotes?

- The way their DNA is packaged
  - No nucleus
  - Not wrapped around **histones**
- The makeup of their cell wall
  - Bacteria- peptidoglycan
  - Archae- tough and made of other chemicals, distinct to them
- Their internal structures
  - No complex, membrane-bound organelles

4.1 Prokaryotic Form and Function



Structures in bacterial cells

Structures common to all bacterial cells

- Cell membrane
- Cytoplasm
- Ribosomes
- One (or a few) chromosomes

Structures found in most bacterial cells

- Cell wall
- Surface coating or glycocalyx

Structures found in some bacterial cells

- Flagella
- Pili
- Fimbriae
- Capsules
- Slime layers
- Inclusions
- Actin cytoskeleton
- Endospores

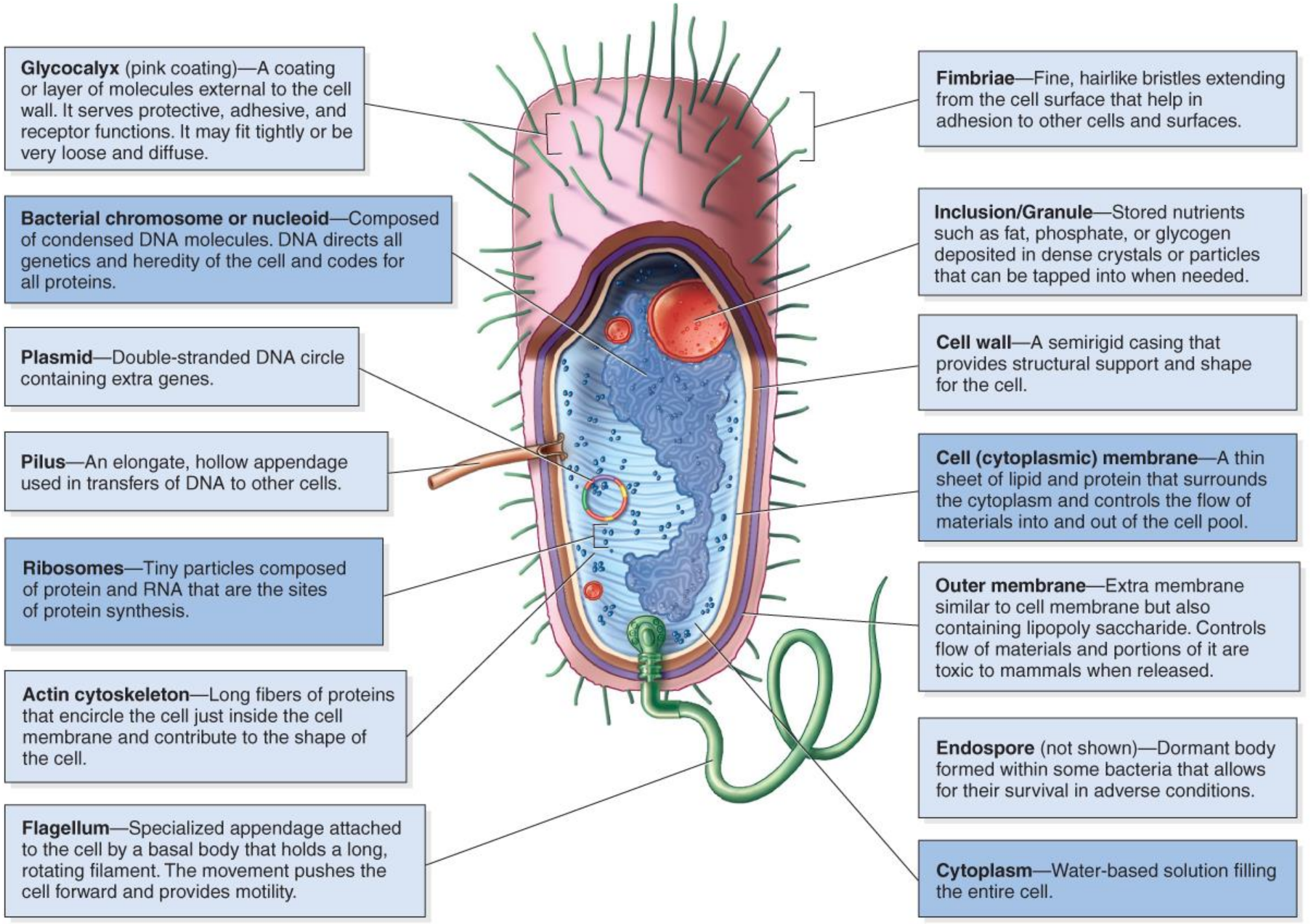


Figure 4.1

Bacterial Internal Structure

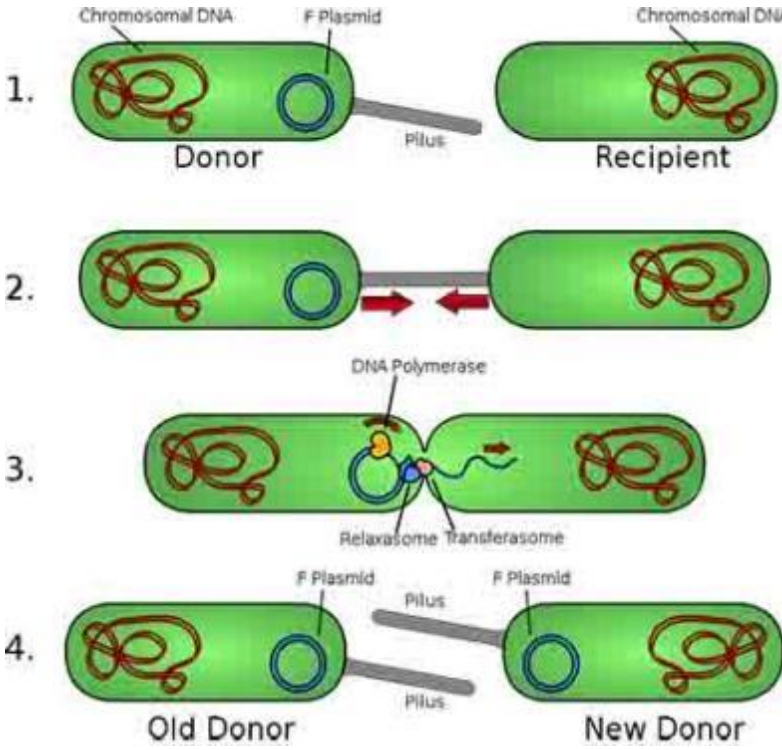
- Contents of the Cell **Cytoplasm**
  - Gelatinous solution
  - Site for many biochemical and synthetic activities
  - 70%-80% water
  - Also contains larger, discrete cell masses (chromatin body, ribosomes, granules, and actin strands)
  - Location of growth, metabolism, and replication

Bacterial Chromosome

- Single circular strand of DNA
- Aggregated in a dense area of the cell- the **nucleoid**

Plasmids

- Nonessential, circles of DNA (5-100 genes)
- Present in cytoplasm but may become incorporated into the chromosomal DNA
- Often confer protective traits such as drug resistance or the production of toxins and enzymes
- Pass on in conjugation



Inclusions

- Inclusions- also known as **inclusion bodies**
  - Some bacteria lay down nutrients in these inclusions during periods of nutrient abundance
  - Serve as a storehouse when nutrients become depleted
  - Some enclose condensed, energy-rich organic substances
  - Some aquatic bacterial inclusions include gas vesicles to provide buoyancy and flotation

Granules

- A type of inclusion body
- Contain crystals of inorganic compounds
- Are not enclosed by membranes
- Staining of some granules aids in identification.

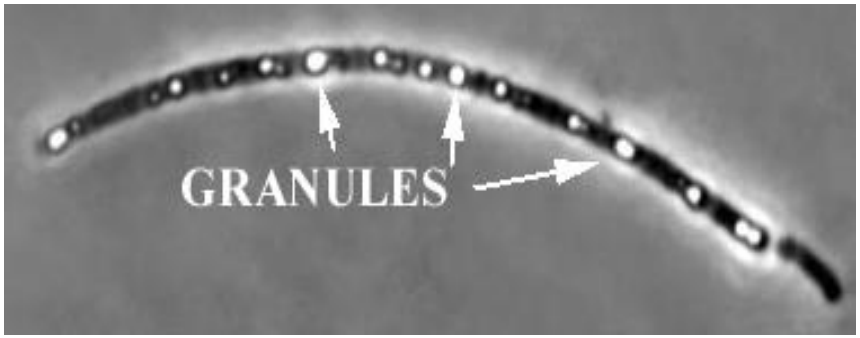
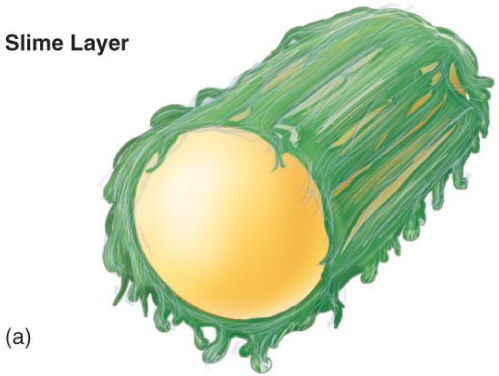
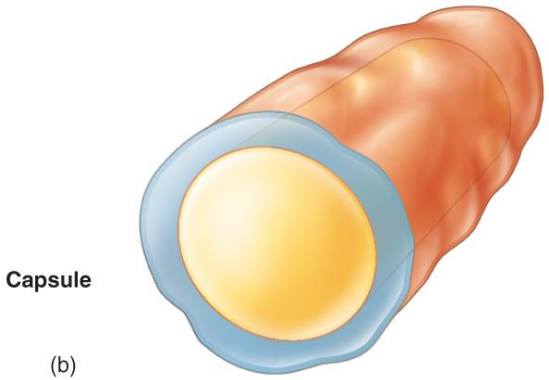


Figure 4.19

The **Glycocalyx**

- a coating of repeating polysaccharide, protein, or both
- Protects the cell
- Can help the cell adhere to the environment
- **Slime layer**- a loose shield that protects some bacteria from loss of water and nutrients
- **Capsule**- when the glycocalyx is bound more tightly to the cell and is denser and thicker





Functions of the Glycocalyx

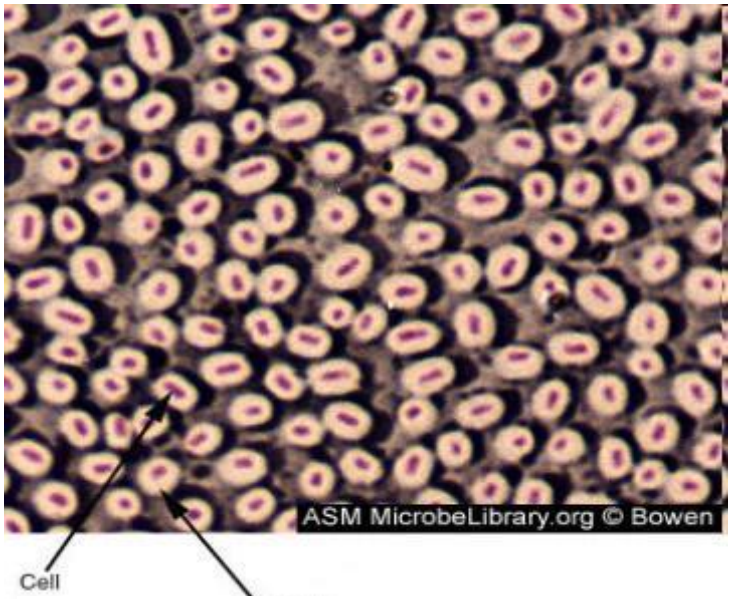
Many pathogenic bacteria have glycocalyces

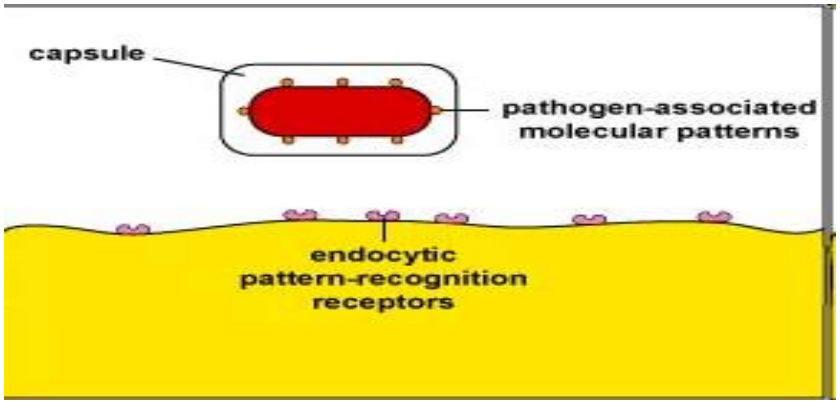
- Protect the bacteria against phagocytes
- Important in formation of biofilms
- *Streptococcus*
  - form a biofilm & eventually a buildup of plaque.
  - The slime layer of Gram+ *Streptococcus mutans* allows it to accumulate on tooth enamel (yuck mouth and one of the causes of cavities).
  - Other bacteria in the mouth become trapped in the slime

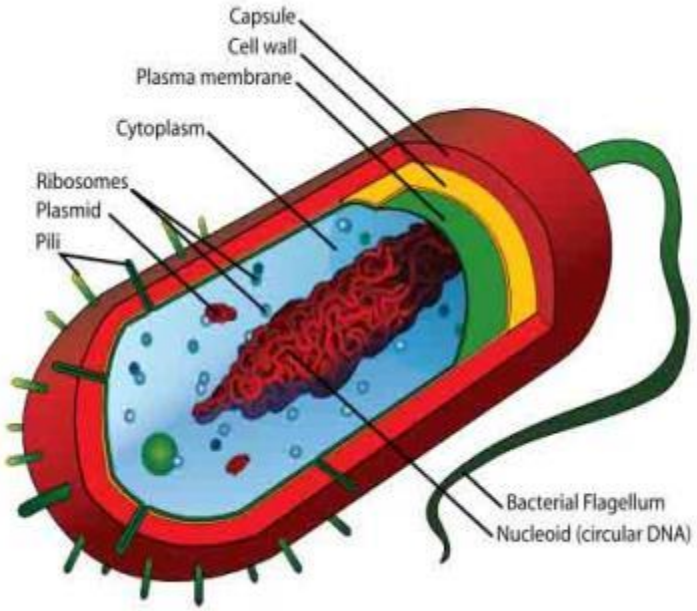
Prokaryotes - Glycocalyx

2. Capsule

- Polysaccharides firmly attached to the cell wall.
- Capsules adhere to solid surfaces and to nutrients in the environment.
- Adhesive power of capsules is a major factor in the initiation of some bacterial diseases.
- Capsule also protect bacteria from being phagocytized by cells of the hosts immune system.





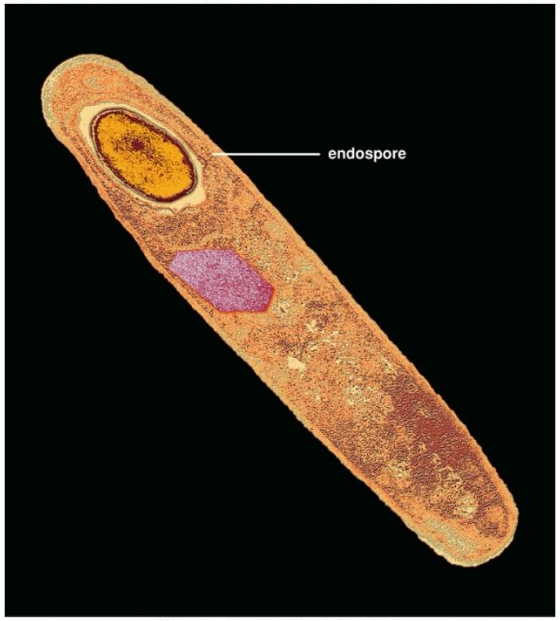


Bacterial **Endospores**: An Extremely Resistant Stage

- Dormant, tough, non-reproductive structure produced by small number of bacteria.

- Resistant to radiation, desiccation, lysozyme, temperature, starvation, and chemical disinfectants.

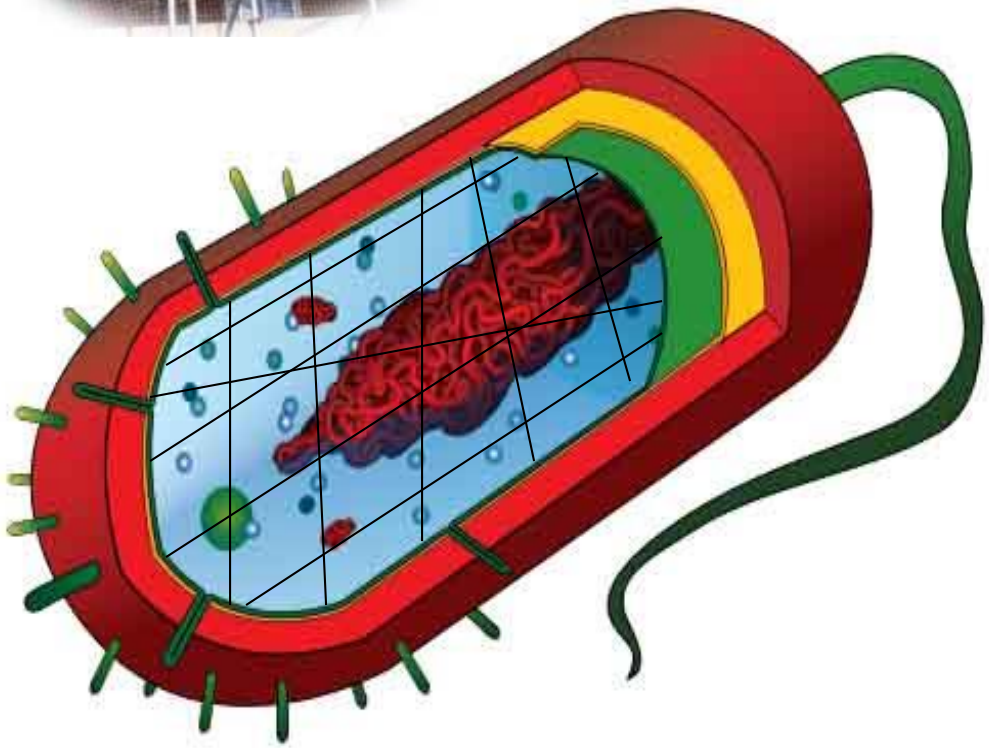
- Endospores are commonly found in soil and water, where they may survive for very long periods of time.



Prokaryotes

Cytoskeleton

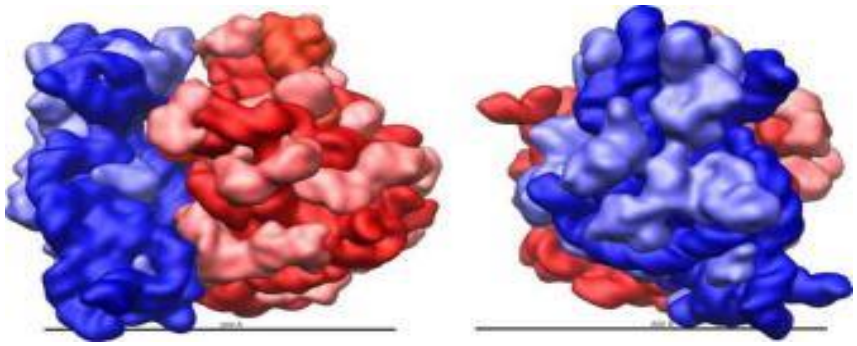
- Cellular "scaffolding" or "skeleton" within the cytoplasm.
- Major advance in prokaryotic cell biology in the last decade has been discovery of the prokaryotic cytoskeleton.
- Up until recently, thought to be a feature only of eukaryotic cells.



Prokaryotes

Ribosomes

- Found within cytoplasm or attached to plasma membrane.
- Made of protein & rRNA.
- Composed of two subunits.
- Cell may contain thousands
- Protein synthesis

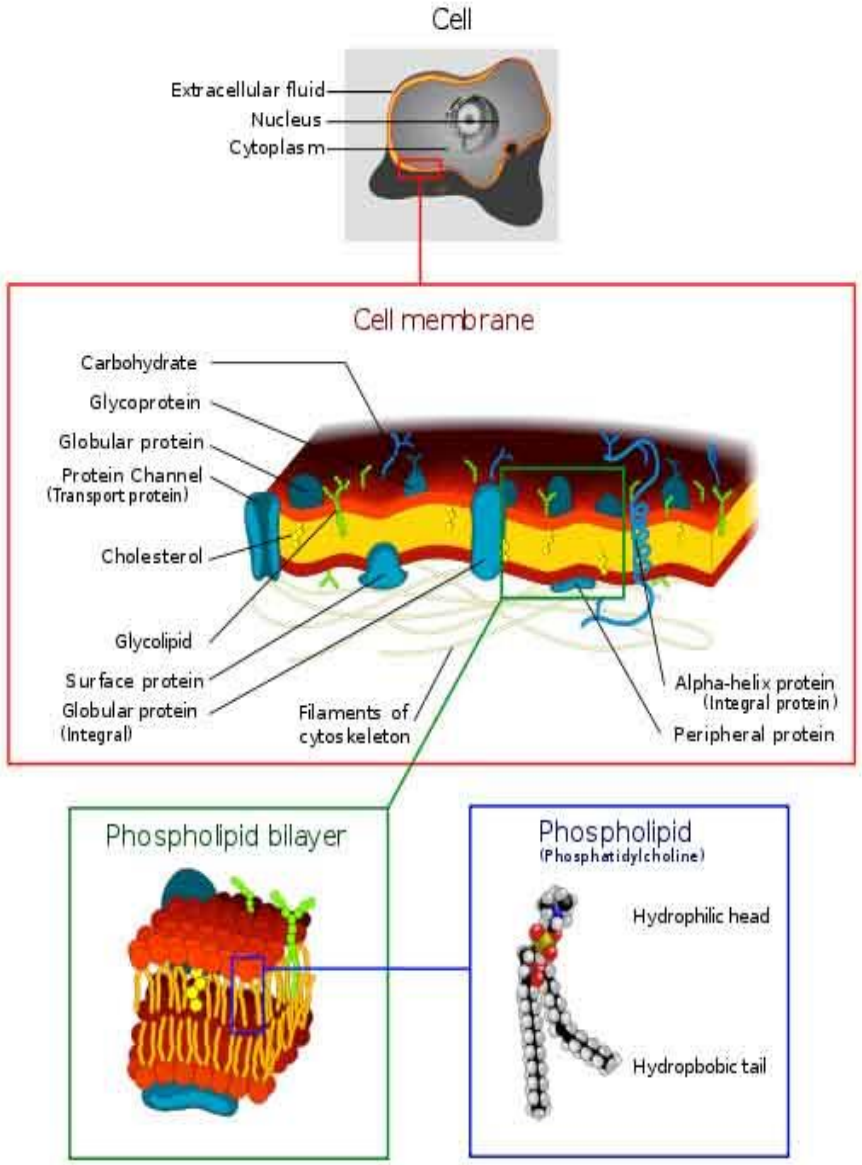


The Cell Envelope: The Boundary layer of Bacteria

- Majority of bacteria have a cell envelope
- Lies outside of the cytoplasm
- Composed of two or three basic layers
  - Cell membrane
  - Cell wall
  - In some bacteria, the outer membrane

Plasma Membrane

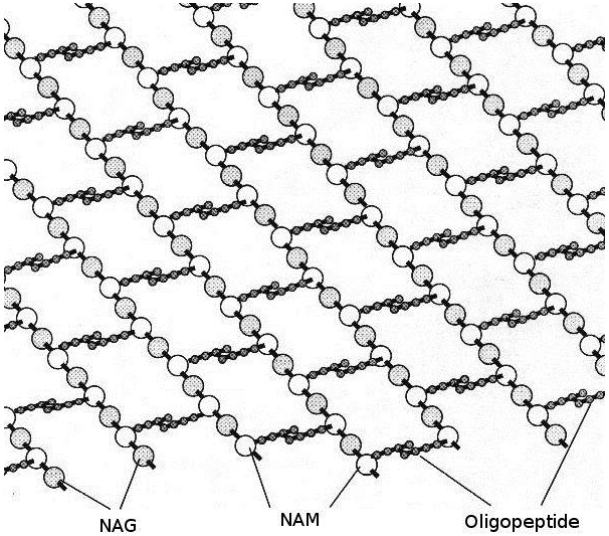
- Separates the cell from its environment
- Phospholipid bilayer with proteins embedded in two layers of lipids (lipid bilayer)
- Functions
  - Provides a site for functions such as energy reactions, nutrient processing, and synthesis
  - Regulates transport (selectively permeable membrane)
  - Secretion



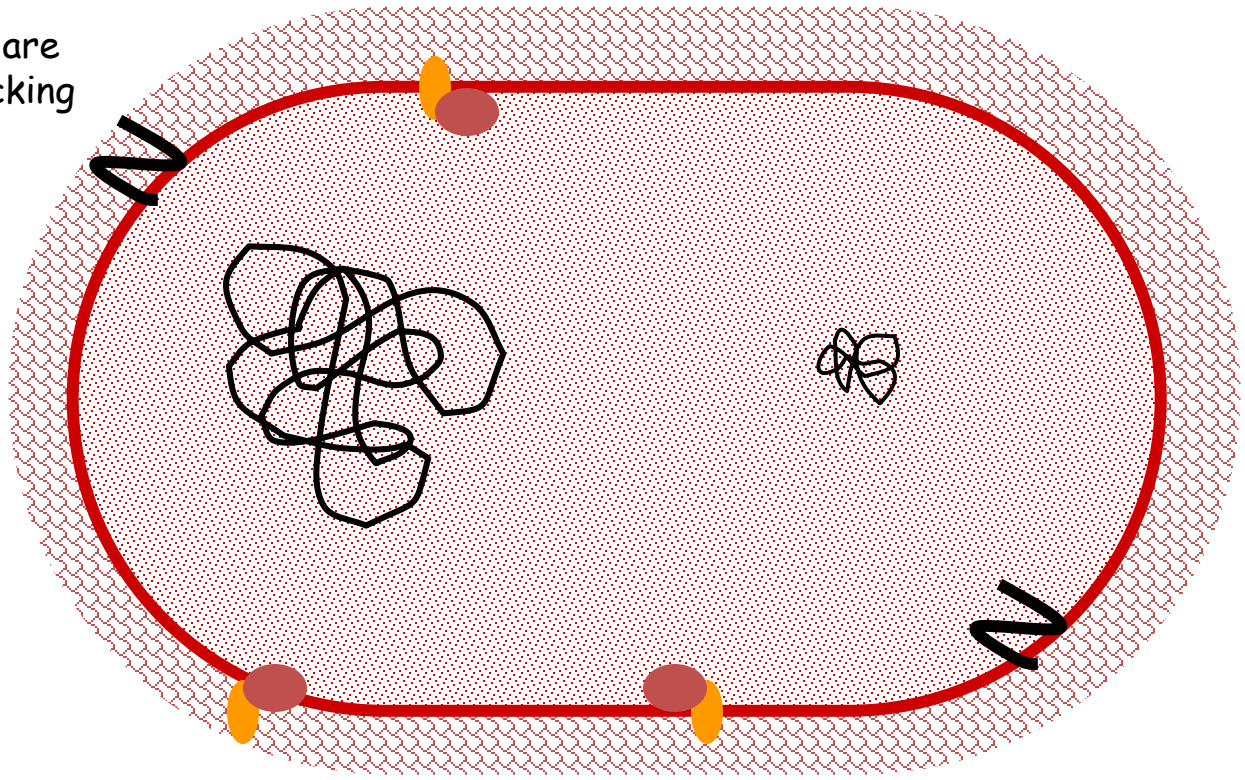
Differences in Cell Envelope Structure

- The differences between **gram-positive** and **gram-negative** bacteria lie in the cell envelope
- Gram-positive
  - Two layers
  - Cell wall and cytoplasmic membrane
- Gram-negative
  - Three layers
  - Outer membrane, cell wall, and cytoplasmic membrane

Bacterial Cell Wall



- **Peptidoglycan** is a huge polymer of interlocking chains of alternating monomers.
- Provides rigid support while freely permeable to solutes.
- Backbone of peptidoglycan molecule composed of two amino sugar derivatives of glucose. The "glycan" part of peptidoglycan:
  - N-acetylglucosamine (NAG)
  - N-acetlymuramic acid (NAM)
- NAG / NAM strands are connected by interlocking peptide bridges. The "peptid" part of peptidoglycan.



Structure of the **Cell Wall**

- Provides shape and strong structural support
- Most are rigid because of peptidoglycan content

- Target of many antibiotics- disrupt the cell wall, and cells have little protection from **lysis**
- Gram-positive cell (2 layers)
  - A thick (20 to 80 nm) petidoglycan cell wall and membrane

- Gram-Negative Cell (3 layers)
  - Outer membrane
  - Single, thin (1 to 3 nm) sheet of peptidoglycan (Periplasmic space surrounds the peptidoglycan)
  - Cell membrane

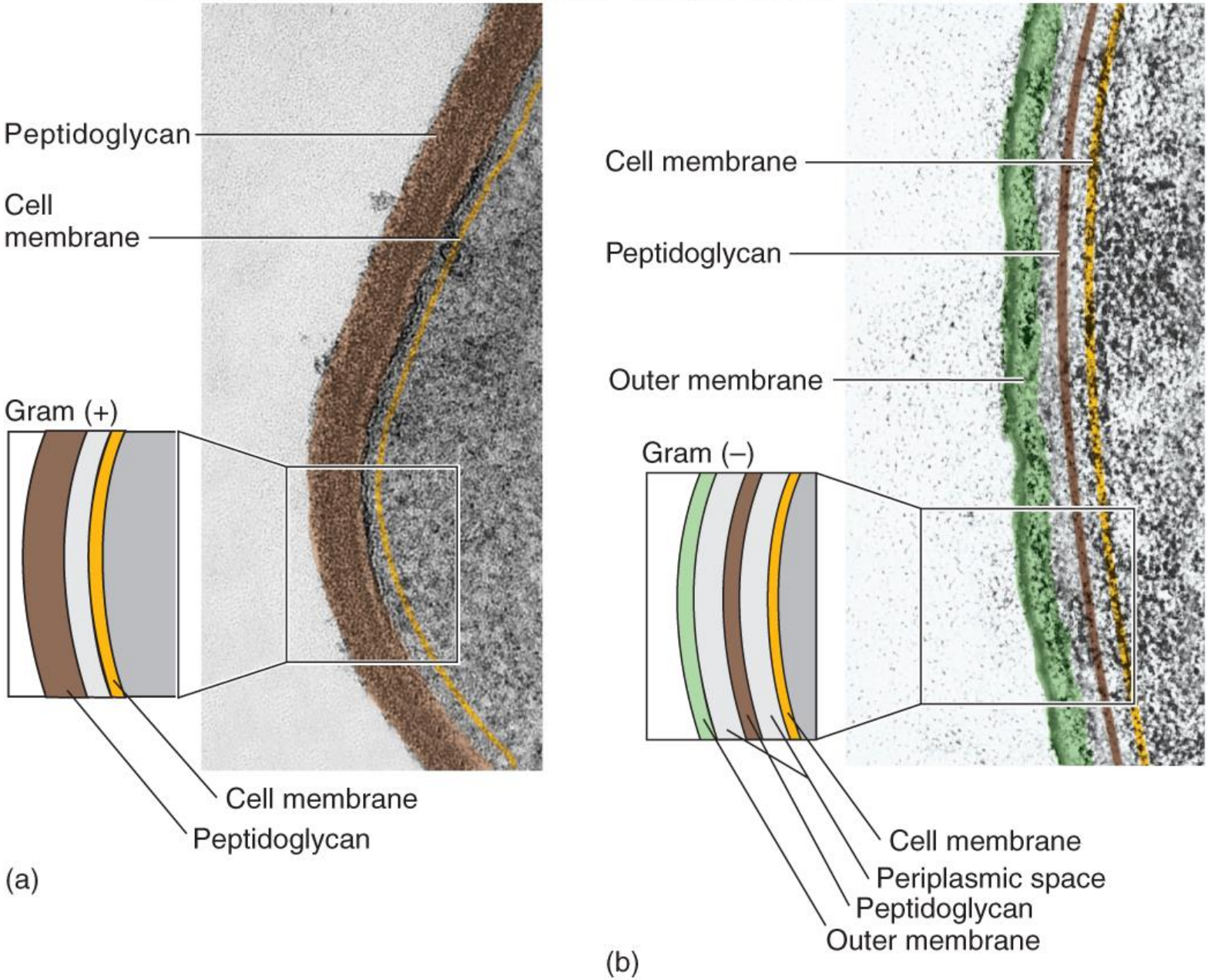


Figure 4.12

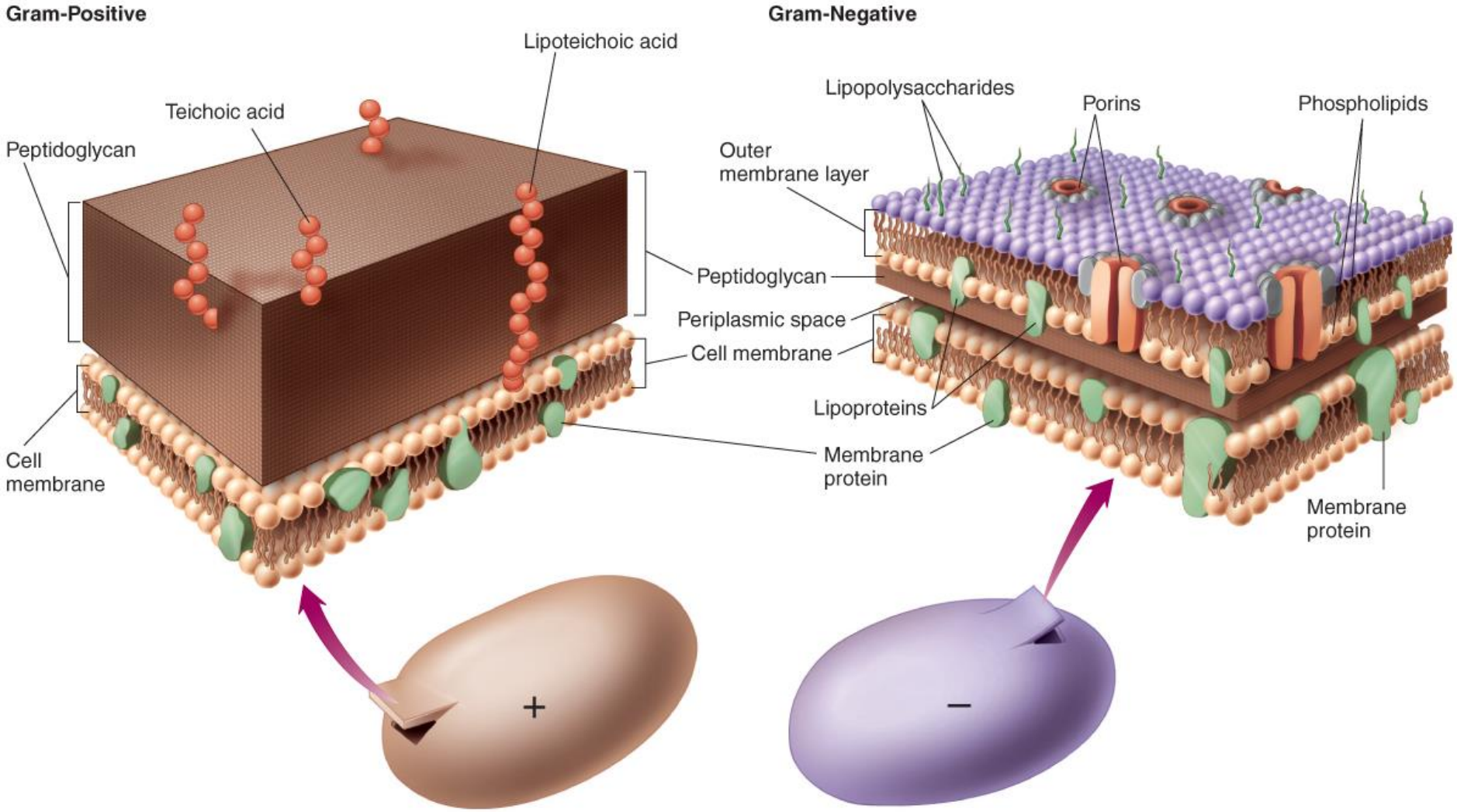


Figure 4.14

The Gram-Negative **Outer Membrane**

- Similar to the cell membrane, except it contains specialized polysaccharides and proteins
- Outermost layer- contains lipopolysaccharide (LPS)
- Innermost layer- phospholipid layer anchored by lipoproteins to the peptidoglycan layer below
- Outer membrane serves as a partial chemical sieve
  - Only relatively small molecules can penetrate
  - Access provided by special membrane channels formed by porin proteins

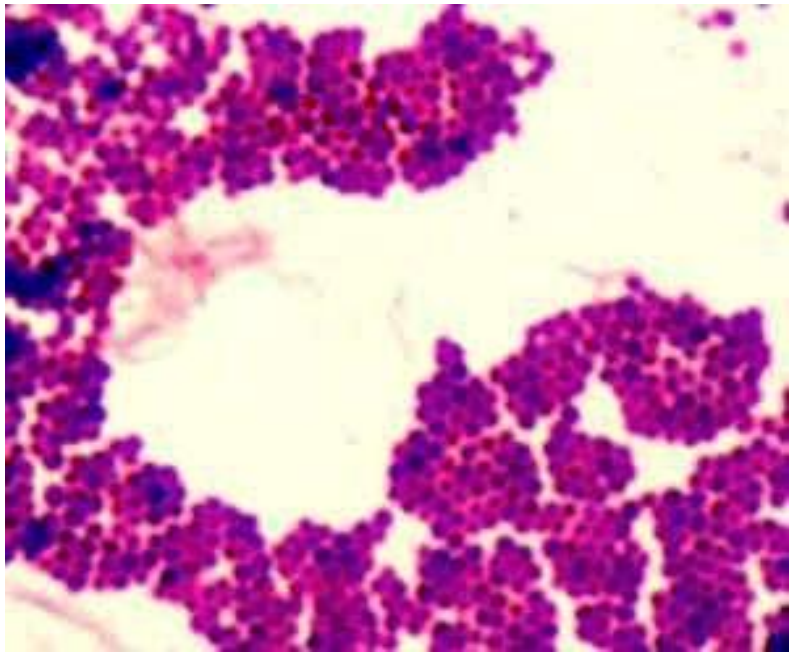
Practical Considerations of Differences in Cell Envelope Structure

- Outer membrane- an extra barrier in gram-negative bacteria
  - Makes them impervious to some antrimicrobial chemicals
  - Generally more difficult to inhibit or kill than gram-positive bacteria
- Cell envelope can interact with human tissues and cause disease
  - *Corynebacterium diphtheriae*
  - *Streptococcus pyogenes*

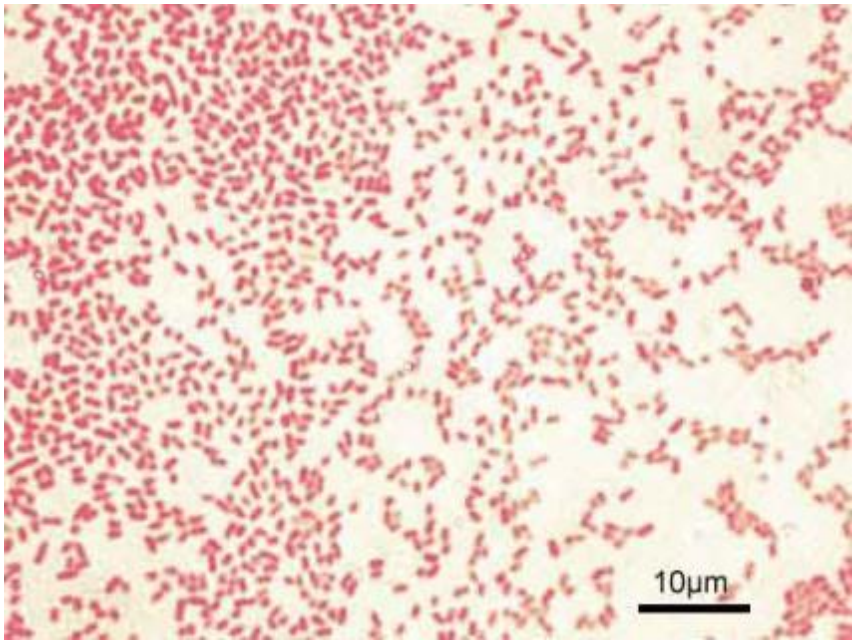
Prokaryotes - **Cell Wall**

From the peptidoglycan inwards all bacteria are very similar. Going further out, the bacterial world divides into two major classes (plus a couple of odd types). These are:

Gram-positive

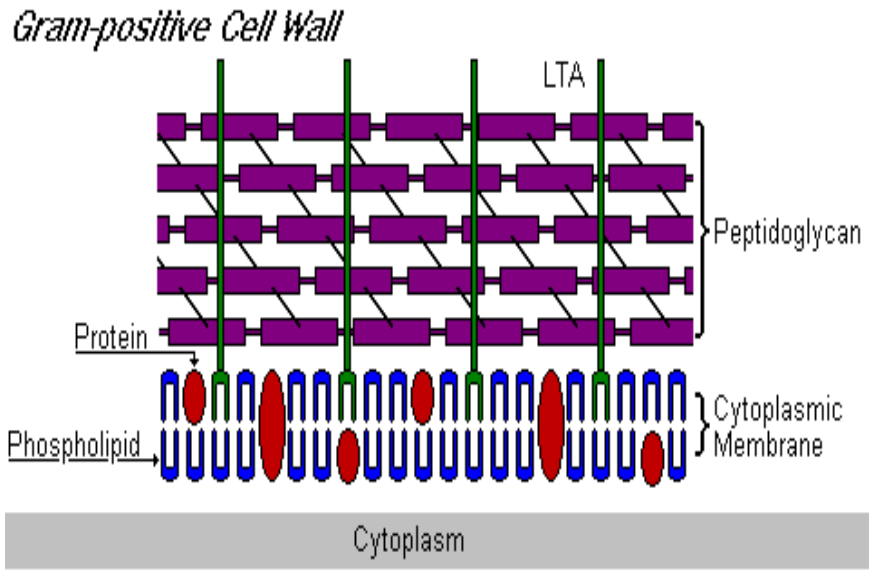


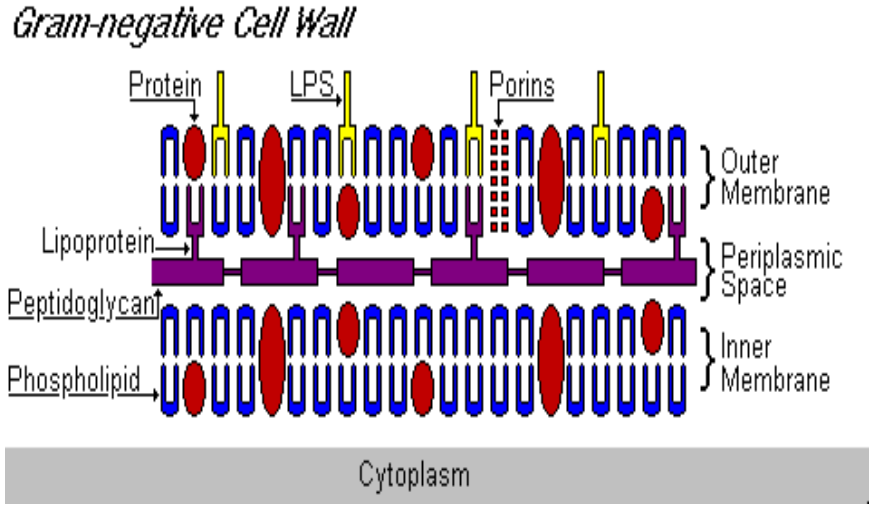
Gram-negative

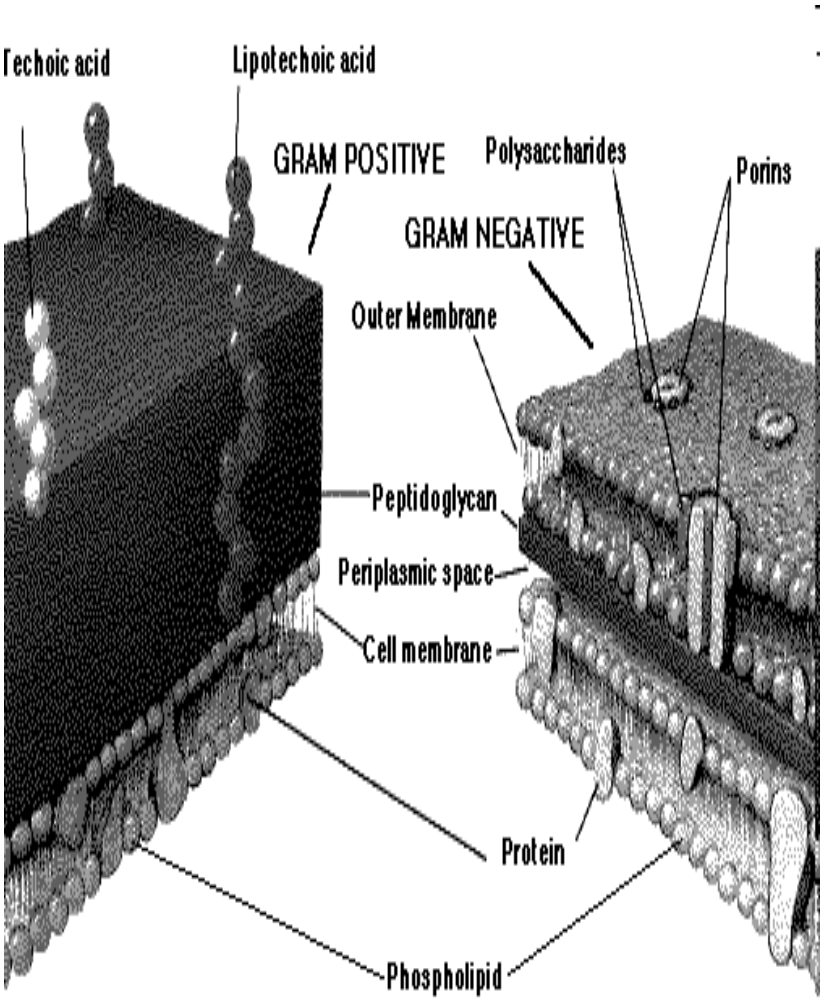


Prokaryotes - **Cell Wall**

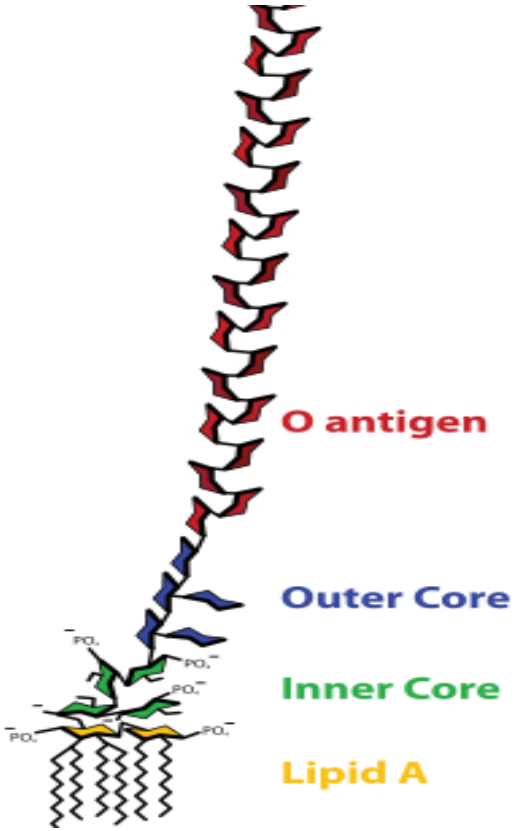
Gram-Positive & Gram-Negative

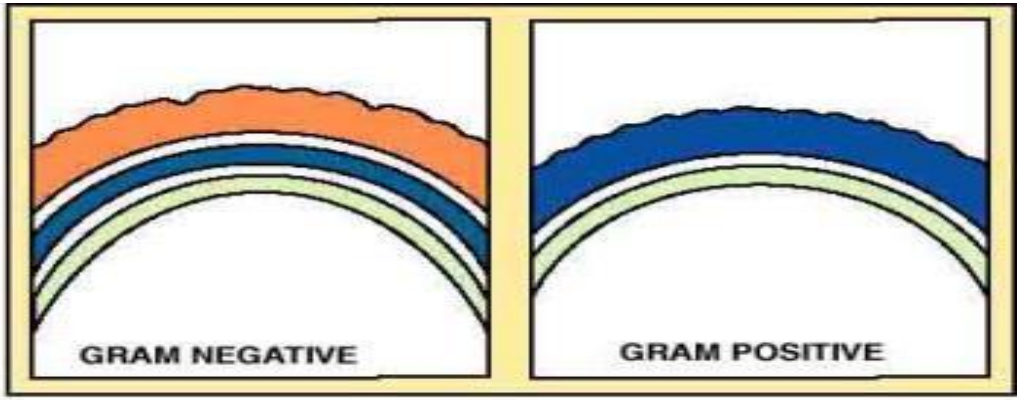


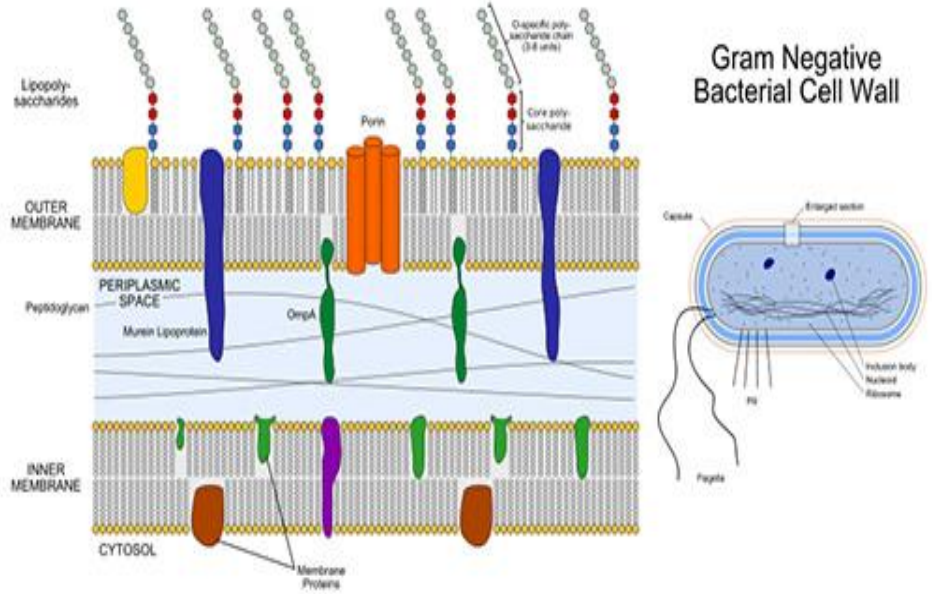




Q: Why are these differences in bacterial cell wall structure so important?





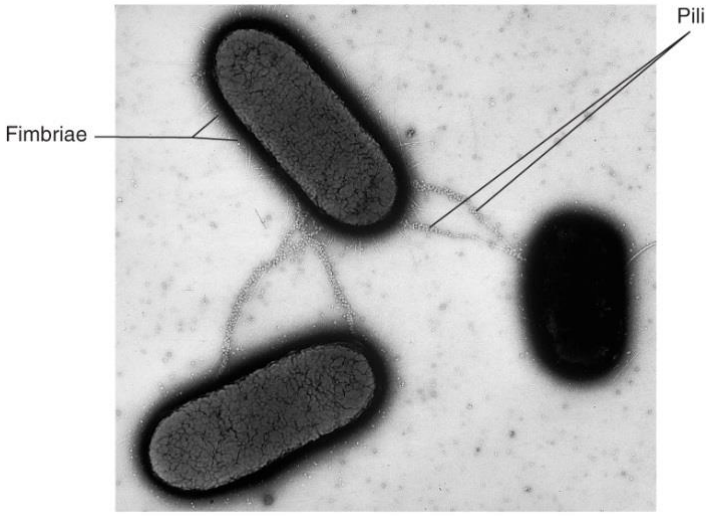


Nontypical Cell Walls

- Some aren't characterized as either gram-positive or gram-negative
- For example, *Mycobacterium* and *Nocardia*- unique types of lipids (acid-fast)
- Archaea – no peptidoglycan
- **Mycoplasmas**- lack cell wall entirely

External Structures

- **Appendages**: Cell extensions
  - Common but not present on all species
  - Can provide **motility** (**flagella** and axial filaments)
  - Can be used for attachment and mating (**pili** and **fimbriae**)



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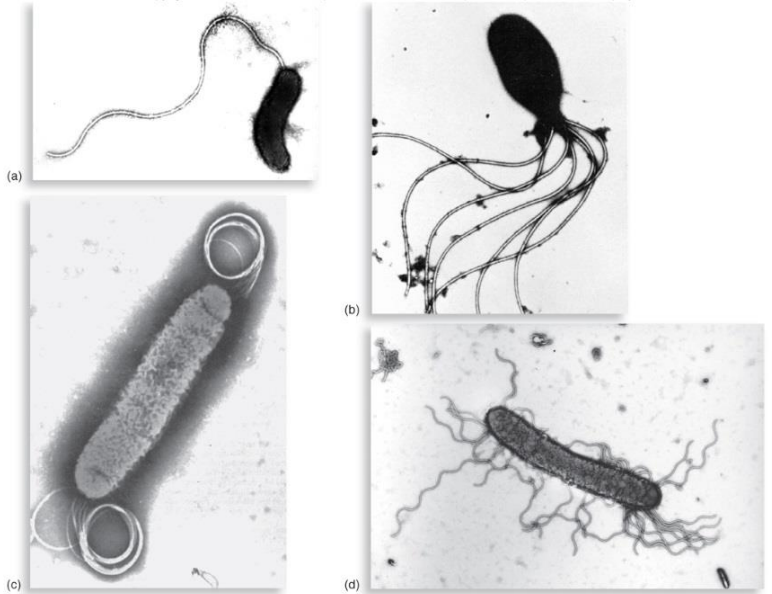

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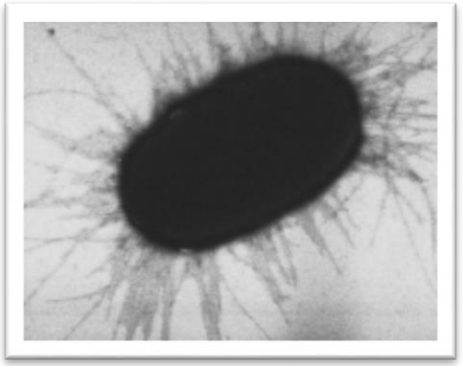
Prokaryotes – Surface Appendages

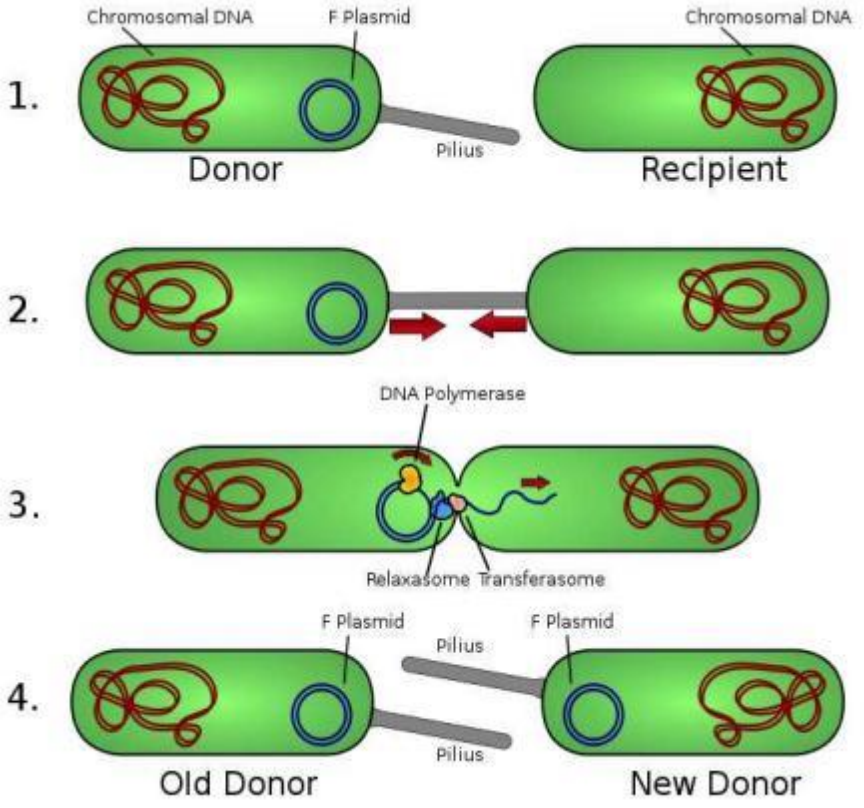


- **fimbriae**: Most Gram-negative bacteria have these short, fine appendages surrounding the cell. Gram+ bacteria don't have.

  No role in motility. Help bacteria adhere to solid surfaces. Major factor in virulence.
  (singular: fimbria)

- **pili**: Tubes that are longer than fimbriae, usually shorter than flagella.

  Use for movement, like grappling hooks, and also use conjugation pili to transfer plasmids. (singular = pilus)



Prokaryotes – Cell Shapes

Most bacteria are classifies according to shape:

1. **bacillus** *(pl. bacilli)* = rod-shaped
2. **coccus** *(pl. cocci … sounds like cox-eye)* = spherical
3. spiral shaped
    a. **spirillum** *(pl. spirilla)* = spiral with rigid cell wall, flagella
    b. **spirochete** *(pl. spirochetes)* = spiral with flexible cell wall, axial filament

Pleomorphism- when cells of a single species vary to some extent in shape and size

There are many more shapes beyond these basic ones. A few examples:

- Coccobacilli = elongated coccal form
- Filamentous = bacilli that occur in long threads
- Vibrios = short, slightly curved rods
- Fusiform = bacilli with tapered ends

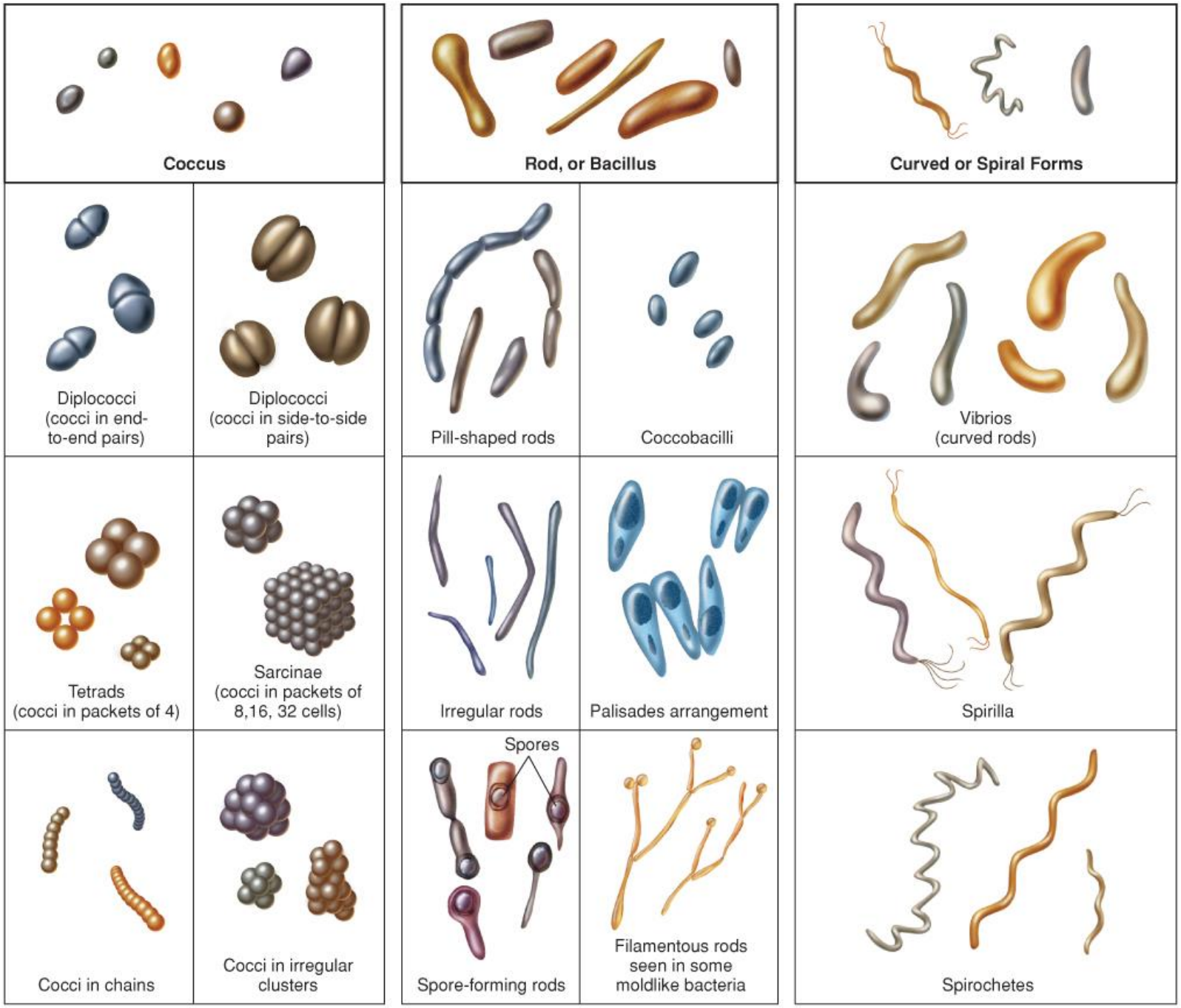


Figure 4.22

Arrangement, or Grouping

- Cocci- greatest variety in arrangement
  - Single
  - Pairs (diplococci)
  - Tetrads
  - Irregular clusters (staphylococci and micrococci)
  - Chains (streptococci)
  - Cubical packet (**sarcina**)
- Bacilli- less varied
  - Single
  - Pairs (diplobacilli)
  - Chain (streptobacilli)
  - Row of cells oriented side by side (**palisades**)
- Spirilla
  - Occasionally found in short chains

Prokaryotes – Arrangements of Cells

- Bacteria sometimes occur in groups, rather than singly.
- **bacilli** divide along a single axis, seen in pairs or chains.
- **cocci** divide on one or more planes, producing cells in:
  - pairs (diplococci)
  - chains (streptococci)
  - packets (sarcinae)
  - clusters (staphylococci).
- Size, shape and arrangement of cells often first clues in identification of a bacterium.
- Many "look-alikes", so shape and arrangement not enough for id of genus and species.

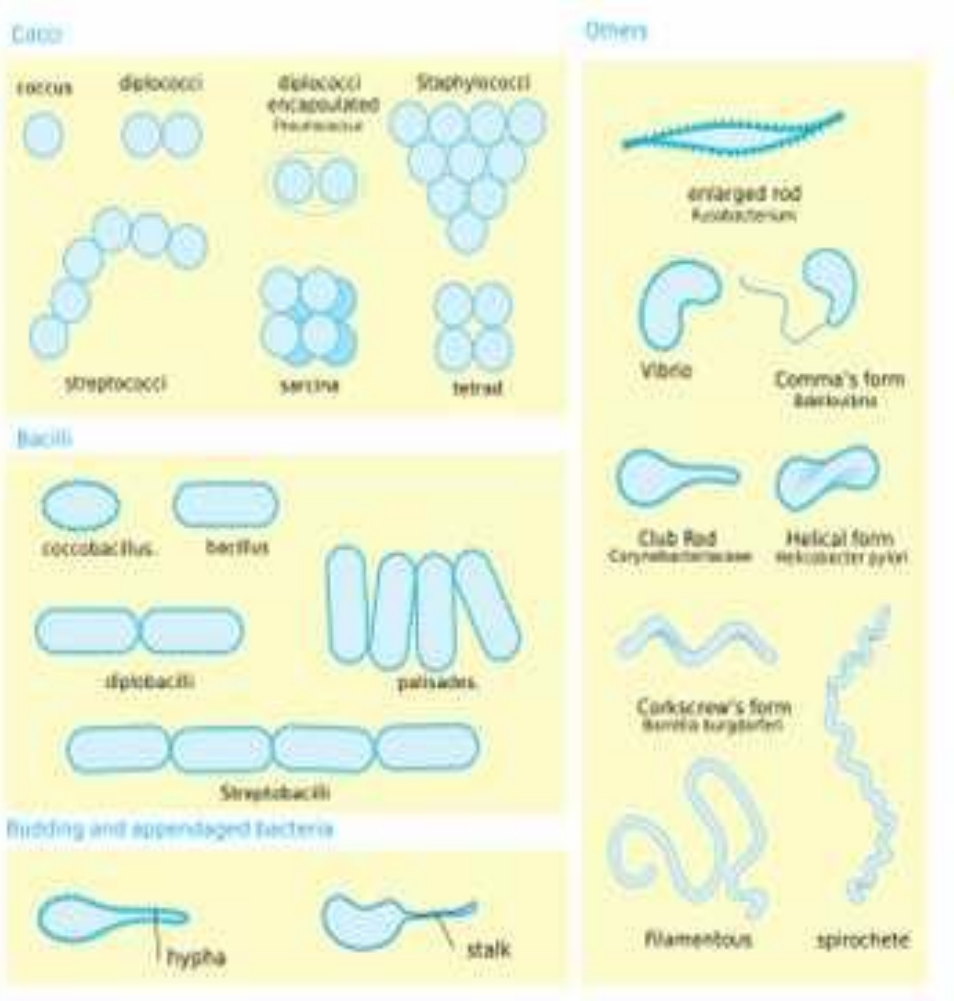
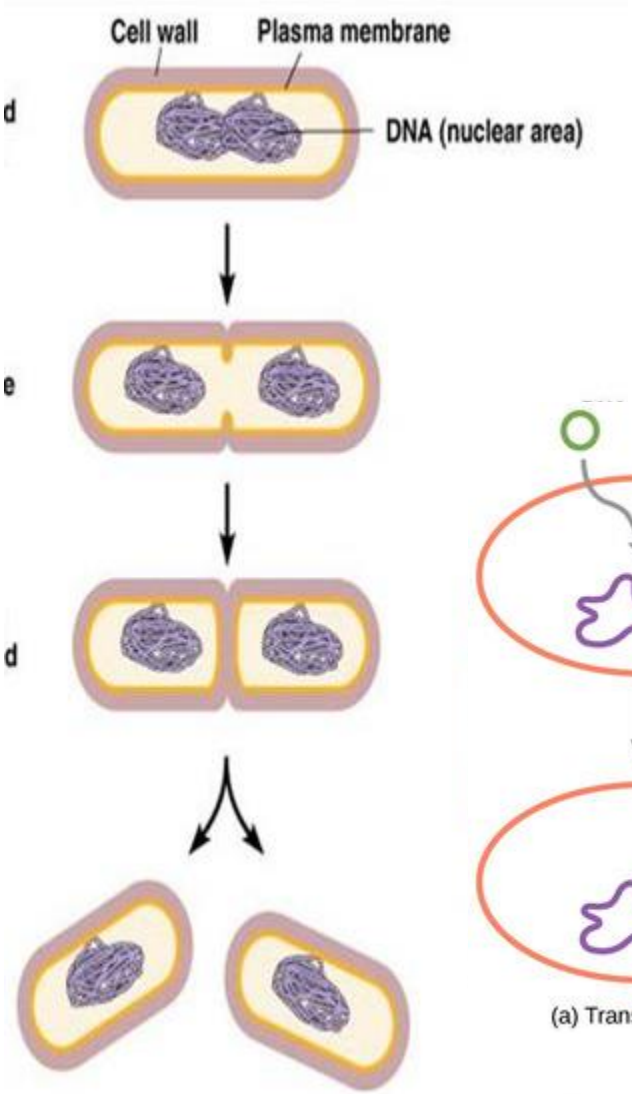
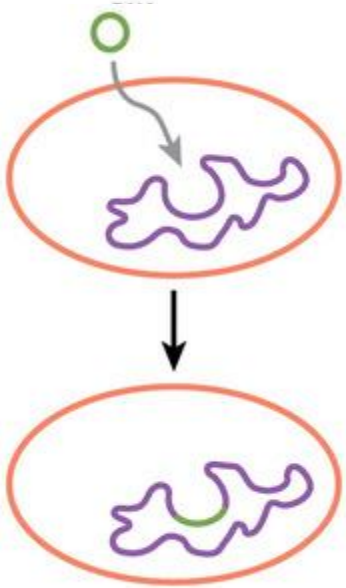


Image: Bacterial shapes and cell arrangements, Mariana Ruiz Villarreal

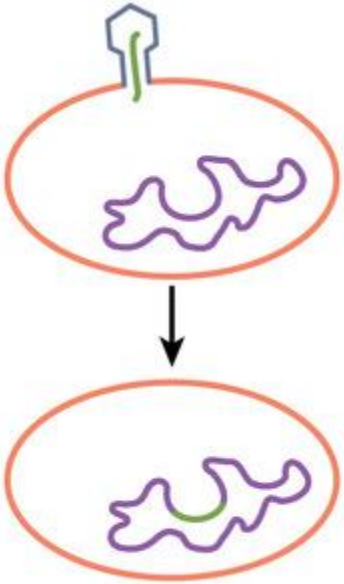
Prokaryotic reproduction

- **binary fission -** this process involves copying the chromosome and separating one cell into two
  - **asexual** form of reproduction
- Transformation - the prokaryote takes in DNA found in its environment that is shed by other prokaryotes.
- transduction - bacteriophages, the viruses that infect bacteria, sometimes also move short pieces of chromosomal DNA from one bacterium to another
- Conjugation - DNA is transferred from one prokaryote to another by means of a pilus

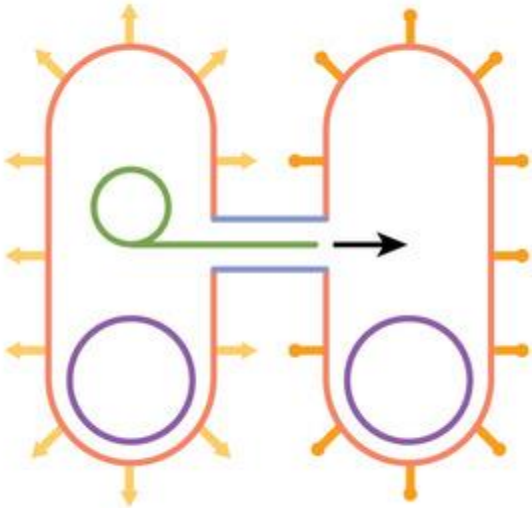




(a) Transformation



(b) Transduction



(c) Conjugation